PA Geospatial Coordinating Board

SERVICES DELIVERY TASK FORCE

PA BaseMap 2030 & 3D PA Report

Introduction

As geospatial data sharing has expanded, so has demand for 3D-enabled data and services to enable users to visualize aspects of the state. The potential for 3D data to reveal new insights and understanding is almost limitless – on everything from buildings to bridges to habitats to floods.

In response to this emerging trend, the Pennsylvania Geospatial Coordinating Board (GeoBoard) directed its Services Delivery Task Force (STF) to gather more detailed information about 3D data needs and how it might be used to support efforts across the state.

Throughout late 2022 and early 2023, the STF explored how the PA BaseMap 2030 initiative could expand and enhance our ability as a Commonwealth to enable 3D data development and access (3D PA). In addition, the task force examined strengths, challenges, and opportunities for building PA BaseMap and 3D PA data services. The following report is based on the findings of the STF and outlines the process for its research.

3D render of Philadelphia

About PA BaseMap 2030 and 3D PA

The PA BaseMap 2030 initiative is focused on developing a complete and updated set of base data layers for Pennsylvania. The base layers include transportation, hydrography, imagery, elevation, land parcels, geodetic control, addresses, and boundaries. PA BaseMap 2030 will help guide interagency and intergovernmental efforts on data development, ownership, funding, and sharing. The result will be authoritative data that users can depend on to be current and reliable, and for which ongoing process improvement is fundamental (PA GeoBoard).

The PA BaseMap 2030 data layers are based on the National Spatial Data Infrastructure (NSDI) Framework. The NSDI Framework is a collaborative initiative to develop geographic datasets that are compatible based upon spatial location and content. The framework approach allows data collected for a variety of reasons and by a variety of agencies to work together seamlessly, which can ultimately reduce project costs and increase interagency cooperation (FGDC).

Key objectives of the PA BaseMap 2030 initiative are to:

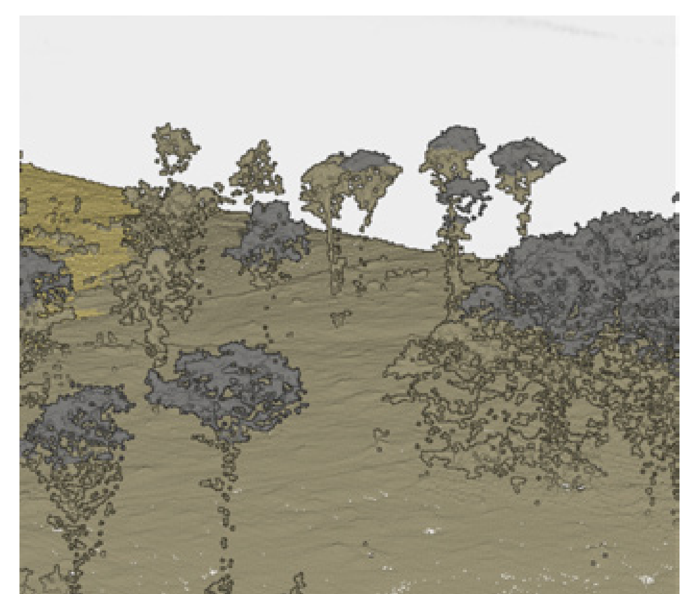
- Coordinate data collection and development efforts to ensure efficient use of resources
- Provide open, standards-driven, authoritative data that is free to access and easy to find and use
- Deliver a common map that can be used by all levels of government for decision making
- Establish a single version of base map data layers where applicable (i.e., roads, streams, civic boundaries)
- Continue to evolve to support computations and display in a stable 3D framework

3D PA is a natural extension of PA BaseMap 2030. The three-dimensional data environment is growing and expanding across all levels of government, business, academia, and everyday life. 3D PA relies on the development and use of 3D-enabled geospatial data.

3D geospatial data represents the shape, position, and features of objects and landscapes. Examples of 3D data include elevation in the form of LiDAR; imagery; buildings including footprints, heights, and internal features; and objects such as vehicles, trees, plants, roads, bridges, and geologic features. Almost any spatial data can be captured and used in a 3D environment.

3D data allows for the creation of what is called a "Digital Twin," a virtual representation of a physical object like a building, a mountain, a tree, or even a person.

3D PA is particularly relevant now that the creation and use of real-time information, drones, and artificial intelligence (AI) are rapidly expanding.



QL1 LiDAR Point Cloud. Source: PA Department of Conservation and Natural Resources

AI Generated Digital Twin of Pittsburgh PA

Imagining the Potential for 3D PA

STANDING AT THE TOP OF HYNER VIEW STATE PARK…

You and your hang glider are ready to soar along the mountains above the river. You can see the tree canopy as you float along the ridge, observing the different foliage and the rise and fall of elevation as you slowly descend to your landing place.

Hyner View State Park.

AN EMERGENCY RESPONDER…

You are responding to a train derailment that has released toxic chemicals next to a small community. You can easily view the evacuation routes as you determine the best way to help residents move to safety. You can view weather patterns, wind, rain, and streams to determine where the dangerous chemicals might flow.

A MINING ENGINEER…

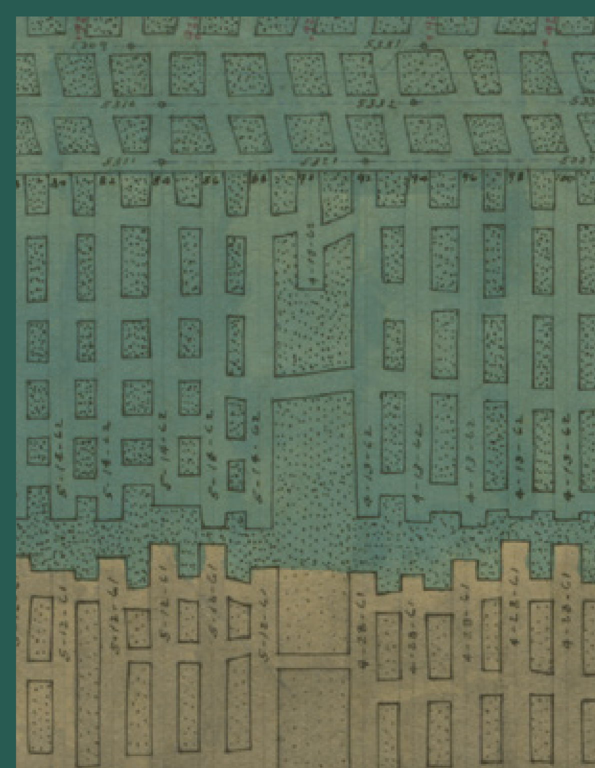
You are examining the structures of an underground mine. You move through a vast network of rooms and past support pillars. You can feel the cramped spaces and see the vast extent of the mine laid out before you.

A CITY PLANNER…

You are trying to understand the potential impact of extensive flooding on your community. You can see where water levels of one, two, three, etc. feet above flood stage would submerge specific homes and businesses and develop plans to mitigate the risks.

A SOFTWARE DEVELOPER…

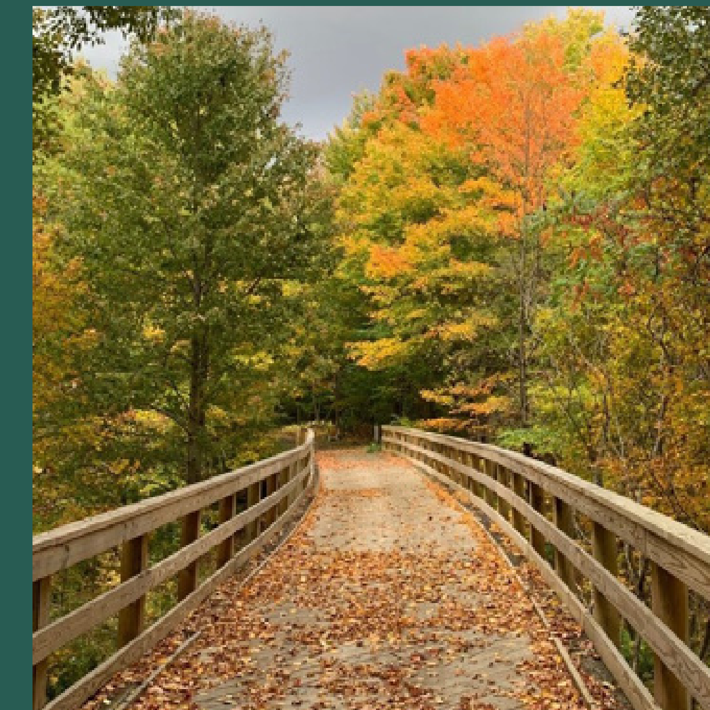
You are working with an automotive company on their autonomous vehicle (AV) development team. Your job is to help AVs interpret the landscape and how to navigate around objects and obstructions.



Underground Mine Map.
Source: PA Department of Environmental Protection

A HIKER…

You are exploring one of Pennsylvania's many hiking trails. You want to know as much about the trail before you go. What is the elevation? Is it rocky or smooth? Is there a path? Is it accessible to those with disabilities? What flora and fauna will you see along the way? You find out all you need to know to plan your trip.



Knox to Kane Trail. Source: PA Department of Conservation and Natural Resources

A BIOLOGIST…

You are studying the habitat of the Box Turtle. You are looking for specific types of plants, changes to riparian areas, and assessing water quality and availability.

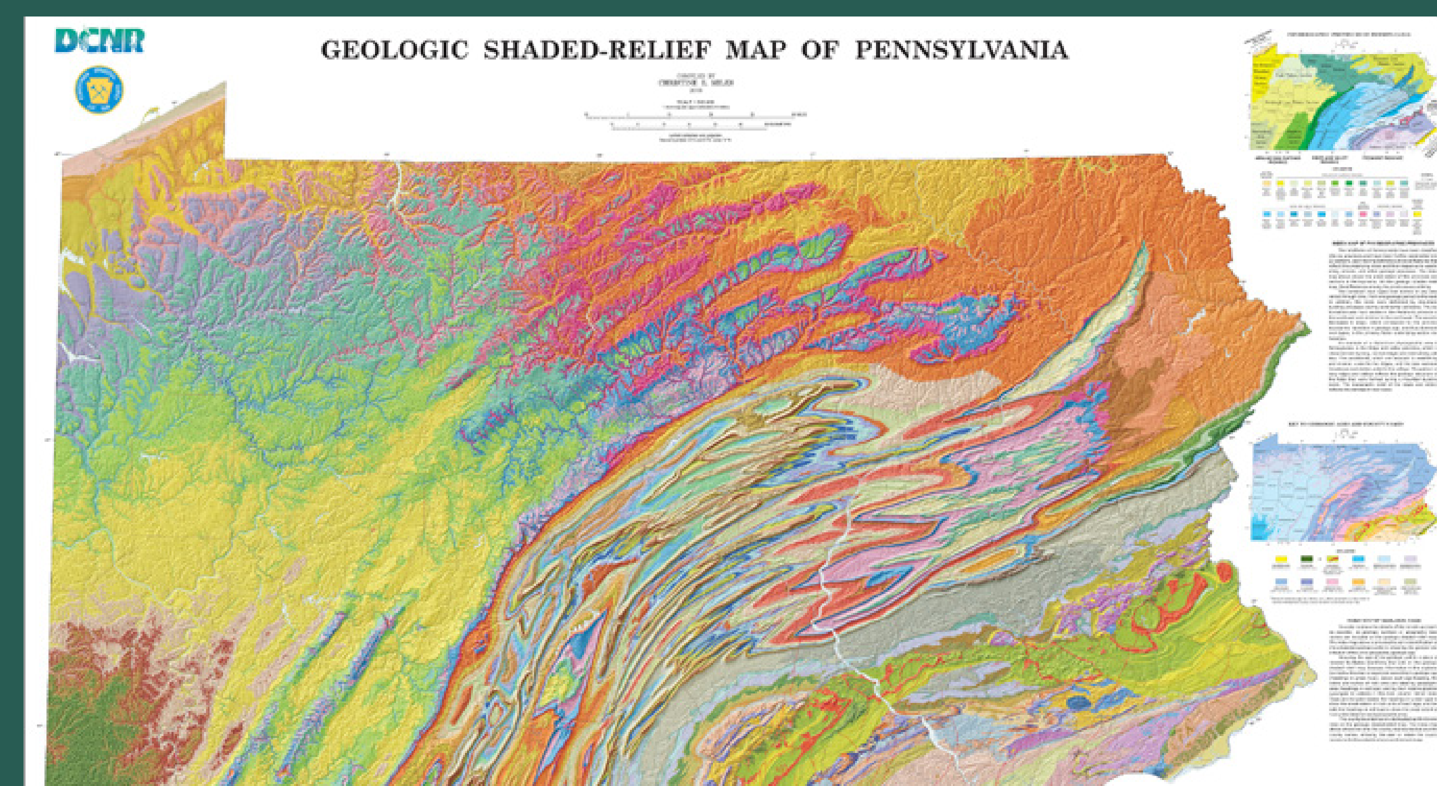
A TEACHER…

You are showing your students historic places and structures across the state. You want your students to experience what it was like to walk through historic Philadelphia buildings and see the shapes, colors, and structures of the past.

A GEOLOGIST…

You are exploring areas of significant geologic interest. You are looking for critical minerals that may be hidden in sediments and formations. You look at rock formations, former mining locations, and reclaimed lands for the ideal places where these vital minerals might be present.

Now, imagine you are doing all of this on your desktop, laptop, mobile device, and/or virtual reality headset. That is the power of the PA BaseMap 2030 and 3D PA data initiatives.



Bedrock Geology of Pennsylvania. Source: PA Department of Conservation and Natural Resources, PA Geological Survey

What is 3D Data?

3D data essentially adds what is called a Z value to data, allowing it to have a three-dimensional shape (height, width, and depth). Rather than depicting an object in a flat, two-dimensional manner, the object can resemble its form in real life. Much of the data that is potentially 3D is developed by using a remote sensing technology called Light Detection and Ranging (LiDAR). LiDAR uses light that is emitted from a laser to measure things on the ground. This light travels to the ground and reflects off things like buildings and tree branches. The reflected light energy then returns to the LiDAR sensor which then measures the time it takes for emitted light to travel to the ground and back. By measuring the time it takes to come back to the sensor, the LiDAR system then calculates the elevation of the object(s) (NEON).

There are different kinds of 3D data. Two of the most common types are:

3D MESH

A 3D mesh is not the same as draping imagery. It is a data format itself. Overlapping photos from multiple angles and directions are analyzed using computer algorithms to detect common points among the overlapping photos generating a 3D model, point cloud, and surface. This process is commonly referred to as structure from motion. Satellites, airplanes, helicopters, drones, street level imagery, phones, and web cams are all capable of capturing photos and videos that can then produce a 3D Mesh.

A 3D mesh, specifically in the vision of 3DPA, is a full surface model made possible by generating an independent 3D product using photogrammetric processes. This process recreates a digital model of the physical world.

This image shows flood level analysis across both a 3D mesh on the left compared to traditional image draping on the right.

3D POINT CLOUD

Point clouds are a set of points that allow us to create 3D objects at higher resolution. These points are used to show information in 3D format. As shown in the picture, to create a 3D image of a human face, we would place points at intervals along the surface of the face (Ladimo). These points could then be used to render an image of the face in 3D. This technology is used all the time in movies, video games, architecture, and engineering.

The same approach is used for geographic features as well. The points are placed closely together to accurately capture the shape of an object like a building, mountain, or tree at high 3D resolution. The Pennsylvania Geological Survey (PAGS) notes that "from this data, scientists construct detailed models of the earth's surface as well as objects on the surface, such as:

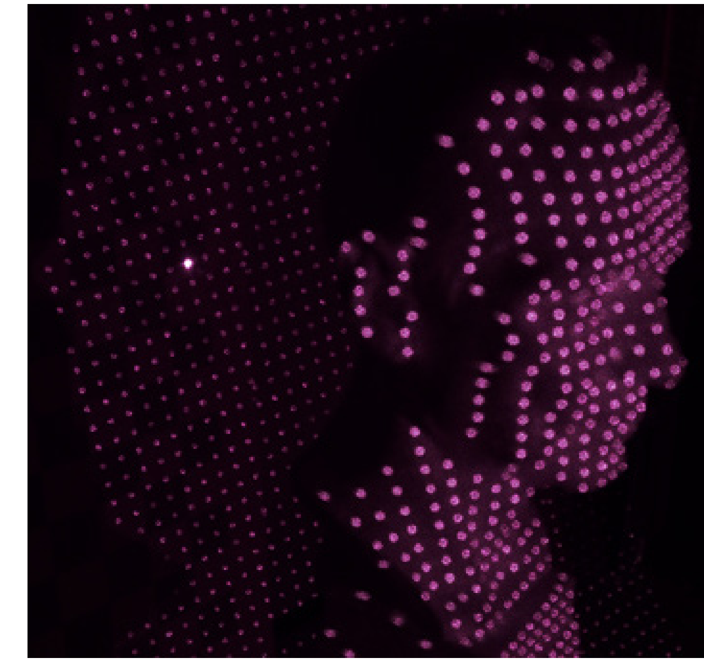
- Buildings
- Trees
- Low-level vegetation
- Utility lines

Lidar data can be processed to produce a variety of layers, including:

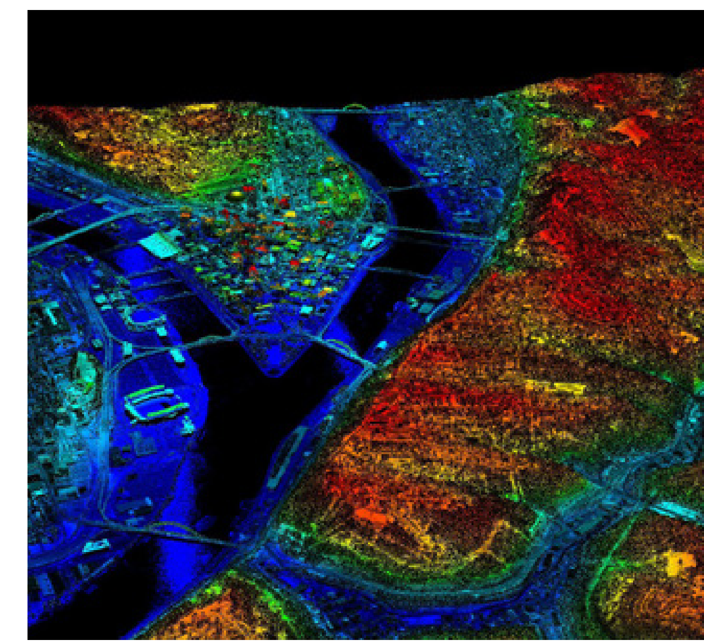
- Height of tree canopies
- Building locations and height
- Bare-earth digital elevation models
- Topographic contours

The US Geological Survey created a point cloud of downtown Pittsburgh. This point cloud can be used to see building heights and shapes, 3D trees and vegetation, and infrastructure such as bridges.

According to the PA Geological Survey, when vegetation and other raised objects are stripped away through data processing, digital elevation models can reveal "hidden" features such as landslide scars and archaeological sites.



3D Point Cloud of a Face. Source: Jorma Palmén, Wikimedia Commons



Point Cloud of Downtown Pittsburgh. Source: US Geological Survey

GeoBoard Services Delivery Task Force PA BaseMap 2030 and 3D PA

3D PA evolved as a concept over the last several years due to the increasing need for 3D and 3D-enabled data. As data sharing has expanded, so too has the need for data that will allow users to visualize aspects of the state. The potential uses for 3D data are almost limitless, for everything from buildings to bridges to habitats to floods. The GeoBoard directed its Services Delivery Task Force (STF) to gather information from stakeholders about their needs for 3D data and how it might be used to support efforts across the state. Throughout late 2022 and early 2023, the STF explored how the PA BaseMap 2030 initiative could expand and enhance our ability as a Commonwealth to enable 3D data development and access. In addition, the task force examined strengths, challenges, and opportunities for building PA BaseMap and 3D data services.

The STF approached the assignment in three phases. The first phase of the effort was to establish a working group. The second phase was to create a survey to gather input from the broader community. The last phase was to hold in-person meetings to explore what 3D capabilities exist and what efforts we can undertake as pilot projects to demonstrate the value of 3D data.

Phase 1: PA BaseMap 2030 & 3D PA Working Group

In July and August of 2022, the STF convened a working group to explore the data and services needs related to the PA BaseMap 2030 initiative.

The STF brought together a diverse group of individuals from different sectors of the geospatial community (see full list in Appendix B). Three virtual meetings were held over the course of a month.

The initial meeting focused on introducing the participants to the PA BaseMap 2030 concept and vision and providing an opportunity for the group to discuss the business case for such an initiative. The participants were separated into two virtual breakout rooms to brainstorm ideas and discuss the challenges and opportunities related to the PA BaseMap 2030 initiative.

The second meeting focused on the business drivers of the initiative. It was clear the group recognized how important data is to drive the development of apps and tools, that data is developed as the result of business needs and practices, and that other parties may enhance or add to the data locally. Other issues discussed included data currency and how every provider has different update intervals and how users feel about the currency of data. There are also data sets that do not change frequently including hydro, rail, parks, etc., while others change more frequently. The group also explored the data sets that are most used on services like Pennsylvania Spatial Data Access (PASDA).These included data from the PA Department of Environmental Protection and PennDOT, as well as imagery, LiDAR, historic imagery, and parcels.. Data is both downloaded and pulled as services. In addition, knowing what date a feature changed is critical for keeping historical information. A dataset can be current, presenting the features that are up to date and synced, but we also need to keep the changes in a historic way and not overwrite or delete old features.

Finally, the group discussed the term “Ready to Use Data” which it felt could be defined as:

- Data that is normalized and aggregated across the state
- Data that is ready to use (clipped and projected) so there is less processing on the user side
- Data that can be made available in different formats
- Data that is available through an application programming interface (API)
- Data that has been crowdsourced, as long as quality and accuracy are apparent and controlled
- Data that is 3D-ready, such as meshes and point clouds

The final meeting of the working group continued with some general discussion of what users want and what are the current trends. The answers to these questions informed the development of the survey. It was clear to the STF members that the PA BaseMap 2030 would serve as the basis for a number of key developments, including 3D-enabled data and services.

STF WORKING GROUP FINDINGS

Challenges

The group first discussed challenges, including how the effort will be funded and how the PA GeoBoard can support users in accessing and using 3D data services. In addition, questions were posed about software availability, coordinating data providers, reducing competing data sets, NG 911, county needs to complete this initiative, the lack of statewide data for many key layers, and editing and updating the base map layers.

Surface Model of Harrisburg using 2016 LiDAR. Source: PA GeoBoard Elevation Working Group

Opportunities

The opportunities discussed included the value of having seamless 3D data and the value of regularly updated data such as LiDAR. The working group agreed that a coordinated series of data sets that work seamlessly together and require minimal processing would be extremely beneficial to ensuring everyone is referencing the same data.

Throughout the three meetings and email exchanges in the group, the question of what users want came up time and again. The group’s thoughts in the third meeting included:

- Anything that can make it easier to distribute 3D data
- Connection to an API endpoint to bring digital elevation models (DEMS) into browser
- Downloads will always need to be an option for users
- A consistent updated background layer
- More accurate stream data

Current trends identified in the third meeting included:

- Data from companies such as Cesium and their respective data tiling
- Flood inundation mapping for Pennsylvania
- Processing data online, such as for an entire watershed to calculate flow lines
- Software changing to online versus desktop
- In-browser processing capabilities, such as developing a tree canopy data set, should be an option
- Data on-demand to allow users to draw areas of interest and get all data and descriptions for that area, as seen in PAGeode and the Natural Resources Conservation Service (NRCS) sites
- Allowing users to attribute streaming data locally
- Different data format availability
- Bulk point query service, as is available in the National Map application

Additionally, the group discussed what future generations might be looking for from geospatial data and services and what their needs and expectations might be. They also contemplated how people will use the data. Discussions included how business and industry, local governments, permitting agencies, and others would benefit greatly from easier access to 3D data to make processes quicker and build apps and tools. The group also noted that it would be beneficial if PA BaseMap 2030 was enabled with Augmented Reality (AR). Data gaps and needs identified by this group include impervious surface data, 3D Elevation Program (3 DEP) Elevation-Derived Hydrography (EDH), and a regularly updated cycle of topographic quality level 2 (QL2) LiDAR. The group also recognized that traditional vector data will still be needed for some time. However, the opportunities exist to use data that is currently being developed. County and local GIS data creation and enhancement are a considerable return on investment (ROI) built upon regular funding and updates of the elevation and imagery data. In addition, the establishment of regularly funded and updated elevation and imagery data pays forward directly through Hazard Mitigation Planning (HMP) GIS. With this one priority project, many, many other applications and projects are made possible when 3DPA becomes a reality.

Phase 2: STF Survey on PA BaseMap 2030 & 3D PA

The second phase was to create a survey to gather input from the broader geospatial user community.

The survey was created and reviewed by members of the working group. It was launched at the end of August and remained open for input until December

2022. Over the four-month period, 270 individuals responded to the survey (see full survey results in Appendix C). The respondents represented a broad cross section of the community and included individuals from federal, state, local, and regional governments, nonprofit organizations, utilities, academic institutions, business and industry, and the surveying community. Most of the respondents had more than 10 years of experience in GIS.

The highlights of the survey include:

Software

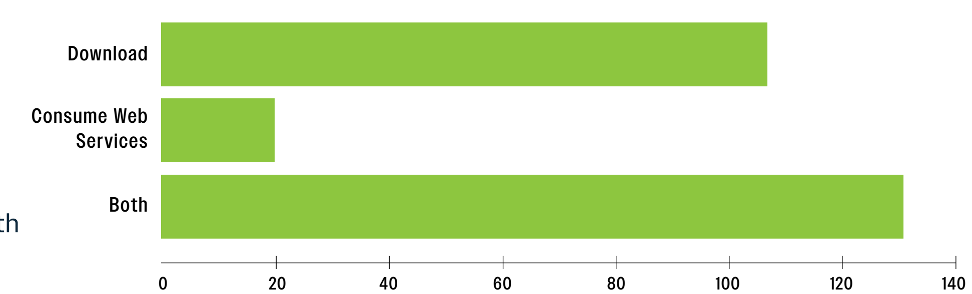
The respondents noted a wide range of software use including esri products, AutoCAD, GeoMedia, Microstation, and some open-source GIS software programs like QGIS.

How Users Access Data

Common questions in GeoBoard discussions are how users are accessing data and if downloading data still an important option. Based on the responses to the survey, users want both streaming data (map services) and a download option.

The majority of respondents wanted both and there was a heavy preference for downloading data when asked to select between map services and downloading.

When accessing data, do you most often...

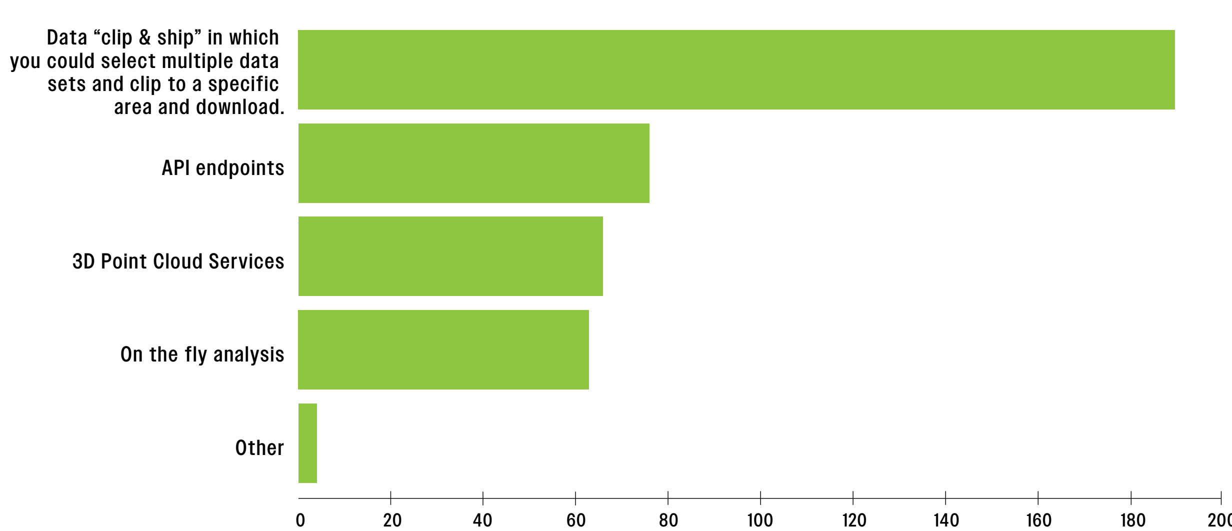


Data and Functionality

Respondents shared a number of ideas about what they want to see in terms of PA BaseMap data accessibility and capabilities. These ranged from clipping data and zipping it for download to API end points and on-the-fly analysis. About a third of respondents also wanted 3D point cloud data services, which demonstrates that 3D PA will be an important part of the overall PA BaseMap effort.

Additional suggestions included having access to both real-time data and historic data that is time stamped, 3D-enabled imagery, annual updated aerial photography, 3D data that is compatible with gaming engines, new data structures, underground 3D, and the development of statewide parcel data.

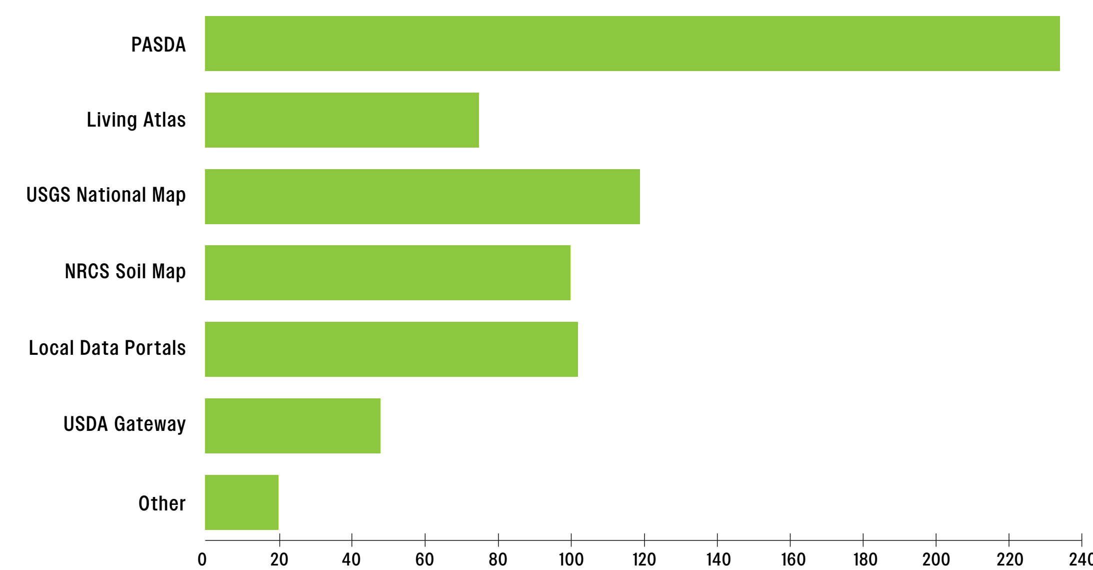
Which of the following would be useful to you? Select all that apply.



Data Access Sites

The respondents overwhelmingly identified PASDA as the most often used source for accessing data. Other sites included the USGS National Map, NRCS Soil Map, and local data portals.

Where do you go to find data and services



Overall, the survey results provided STF and the GeoBoard with solid information on what the community wants from the PA BaseMap and 3D PA initiatives. The final step was to explore what capabilities were available to build out 3D data and serve the PA BaseMap data layers.

Phase 3: STF Meetings with Penn State Center for Immersive Experiences (CIE)

The STF held in-person meetings at the Penn State Center for Immersive Experiences (CIE) to explore what 3D capabilities exist and what efforts we can undertake as pilot projects to demonstrate the value of 3D data. The participants were the Pennsylvania Office of Administration, the GeoBoard executive director, Pennsylvania Emergency Management Agency, Pennsylvania Department of Military and Veterans Affairs, Pennsylvania Geological Survey, Mifflin County, Cambria County, and U.S. Geological Survey.

In April 2023, the CIE was included as a tour in the Pennsylvania GIS Conference.

The attendees had an opportunity to brainstorm on how the technology could be used and offer ideas for pilot projects that would help move development of the data and adoption of the technology. These included discussions of using 3D PA data for training disaster and emergency responders and police, supporting the effective conservation of natural resources, supporting military operations and training, providing access to detailed subsurface information for mines, geologic features, oil and gas, and critical minerals, supporting and promoting tourism and recreation, and educational support for teachers and researchers who are studying Pennsylvania.

The STF also explored software options for serving data and 3D data in particular. PASDA reviewed options for software and purchased, through Penn State, a license for Skyline software. PASDA, CIE, and Cambria County are working together on a pilot project to create and provide access to 3D PA BaseMap data with the expected launch of this data in summer 2024.

CONCLUSION

Pennsylvania has a vast amount of data and a strong history of sharing data to build upon in the creation of PA BaseMap 2030 and 3D data and capabilities. The existing PA BaseMap layers are already available on PASDA and accessible to the public. The next steps will be to build more data, ensure more complete data, and create more 3D data to take the Commonwealth to the next level of data availability.

References

1. PA GeoBoard, PA BaseMap 20230: https://www.oa.pa.gov/Programs/Information%20Technology/Pages/BaseMap-2030.aspx
2. Federal Geographic Data Committee (FGDC), NSDI Framework, https://www.fgdc.gov/training/nsdi-training-program/materials/framework-training-base.pdf
3. NEON: The Basics of LiDAR, https://www.neonscience.org/resources/learning-hub/tutorials/lidar-basics
4. Ladimo, P. 3D point cloud statue.
5. Pennsylvania Geological Survey (PAGS), https://www.dcnr.pa.gov/Geology/DigitalBaseMaps/Pages/default.aspx
6. USGS LiDAR Point Cloud Pittsburgh PA: https://www.usgs.gov/media/images/LiDAR-point-cloud-pittsburgh-pa-0
7. PA GeoBoard Elevation Working Group. Image Credit: https://www.srbc.gov/pennsylvania-elevation-working-group/docs/pennsylvania-lidar-information-sheet.pdf
8. 3D Philadelphia image. Morakot Pilouk, create realistic perspectives with 3D, 2012.

Appendix A: Case Study—Cambria County

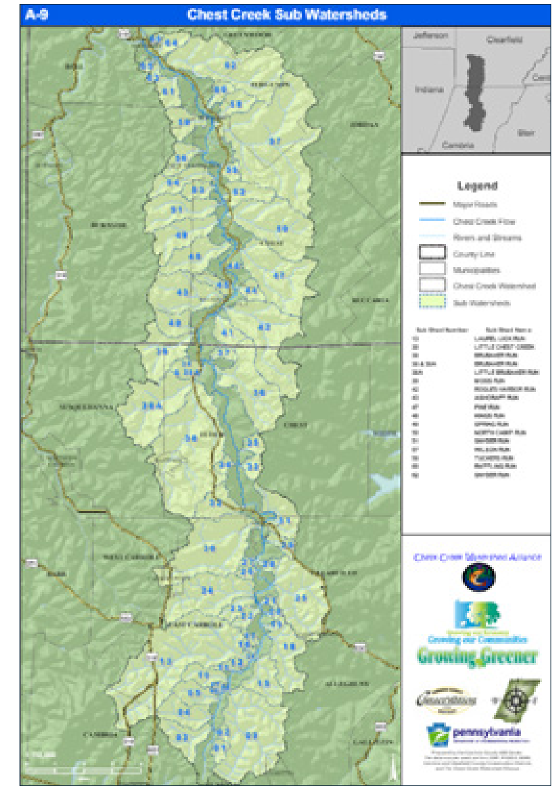
3D INITIATIVE CASE STUDY: CAMBRIA COUNTY

Cambria County is at the forefront of 3D technology in Pennsylvania. A history of developing GIS in 3D originated in the early 2000s coinciding with the PAMAP program and the development of LiDAR data for the state. Early efforts in Cambria focused on creating 3D representations of buildings from lidar and imagery. At the time, the LiDAR point density (the number of lidar points recorded per unit area) was not adequate for well-defined building footprint generation. However, it was clear that as lidar data improved, so would the value-added products like building data. In addition, existing building footprint polygons could be enhanced to make basic 3D buildings using heights from LiDAR. Additionally, 3D roads were interpolated from Digital Elevation Models (DEMs) from the PAMAP program. LiDAR was used to help identify and break road/bridge segments at terrain changes making true 3D bridge sections.

Testing PAMAP 2006 Lidar point cloud with tools to enhance existing building footprints and create tree features. Showing results with a line of site indicating sightline looking from southeast to northwest.

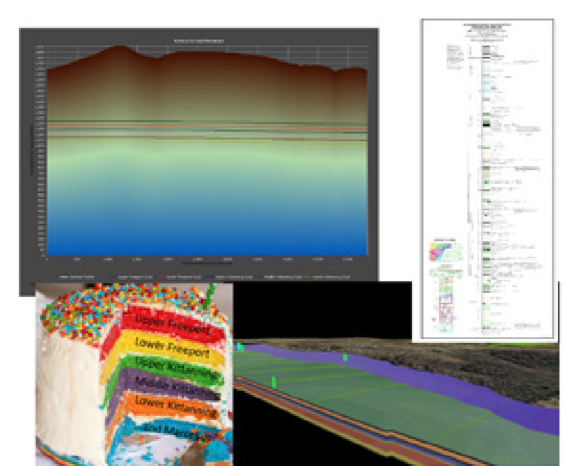
3D watershed generation was another early product in which Cambria County applied PAMAP DEMs. Using watershed analysis tools for the Chest Creek Watershed Alliance resulted in a detailed map series and small watershed delineation for each of the 66 tributaries that feed the main stream. The Chest Creek watershed spans Cambria and Clearfield counties.

In 2009 the county acquired new orthophotos and oblique imagery which then provided a new visual tool to assist with 3D interpretation. Oblique imagery is aerial photography that is taken at an angle, usually between 40° and 50° downward from the ground. This is different from traditional orthophotos, which are taken straight down. The angle of oblique imagery allows viewers to see and measure the sides of objects in addition to the top. High resolution orthophotos were draped on PAMAP DEMs to help display basic 3D. Obliques helped with visual verifications of features and measurements. Using oblique images and measuring tools were quickly proven a complementary asset and software to traditional GIS.



Newly modeled Chest Creek Watershed with 66 tributary sub watersheds analyzed using PAMAP 2006 DEM source.

Cambria County Obliques 2009: A new view to support 3D measurements.

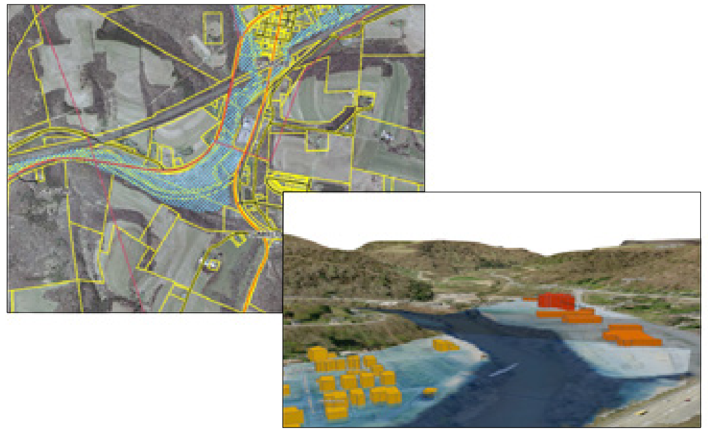


Building a subsurface layer cake complete with well points and aquifer making DEP 3D

Between 2011 and 2012 the county built a subsurface coal seam dataset based on PA Geologic Survey coal studies. The surface and subsurface combined to add 3D visualization of five bituminous coal seams, Marcellus and Utica deposits and wells, and DEP well water and aquifer source data. Subsequently, Cambria County provided one of the earliest and largest collections of mine maps that had been digitized by Pennsylvania Department of Environmental Protection's California District Mining Office. As a result of Cambria County's GIS and 3D coal seams the digitized mine maps can be placed in 3D space.

In 2012 the Federal Emergency Management Agency (FEMA) updated the Digital Flood Rate Insurance Maps (DFIRM) for the county. Cambria County realized that this new flood hazard data was naturally 3D and it was integrated into outreach to municipalities regarding the new flood hazard areas identifying properties and structures impacted. The new DFIRMSs and depth grids found way into another 3D project. GIS data preparation began in 2016 for the Cambria County Hazard Mitigation Plan (HMP) update in 2017. By combining FEMA flood hazard data, with local address, road/bridge/transportation, and property records, the result was a full 3D analysis of flood impact interpretation. The benefit of this effort for local data hazard mitigation planning allowed for the creation of more detailed and accurate data.

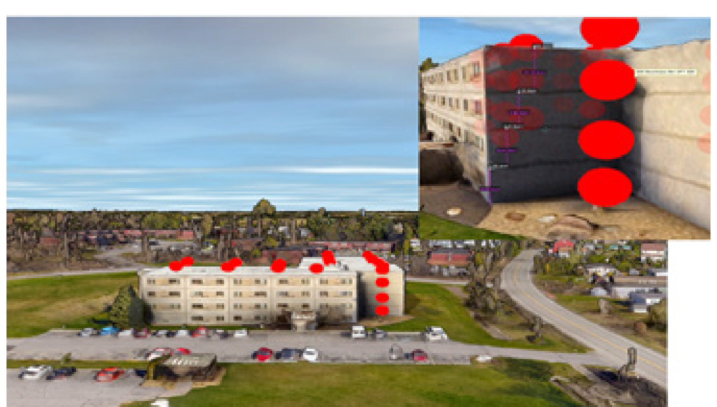
In 2017 Cambria County received funding to update long outdated ortho and oblique imagery. The surprising, and unexpected gem of the imagery update request for proposals was a delivered ASPRS accurate true ortho, countywide obliques, and full 3D photo mesh—all within the expected budget. Spending smart for an updated imagery project was the beginning of a new era in 3D at Cambria County. Flights began in the fall of 2017 and concluded in the spring of 2018. In less than a year from the first captures to full 3D photo mesh deliverables this project demonstrated the foundation and reality of photo realistic 3D for the county. Once the new imagery was implemented, old LiDAR and 3D projects were added to compare and validate accuracy. The ability to integrate many 3D sources, old and new, proved that a project of this magnitude was indeed spending smart.



Making meaningful flood analysis and results with better 3D input and results

2017 Photomesh (photo generated 3D model) showing 2006 LiDAR enhanced building frames layer to compare accuracy and results

UAV planning surface model and LiDAR to operations and production yield 3D GIS from beginning to end, full circle integration.



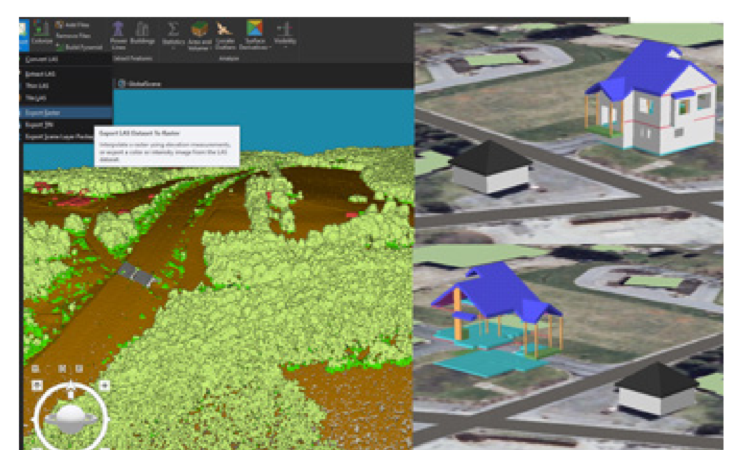
Building NG911 3D addressing accuracy and intelligence from 3D integrated photomesh and data management

In 2019 the Western PA Lidar collection was coincident with the USGS 3DEP program. Then in 2019 Cambria County received a grant to implement a UAV (unmanned aerial vehicle) program. The county's 3D foundation, PAMAP/USGS/NRCS/FEMA LiDAR, and PEMA imagery contribute to successful and safe UAV operations. When planning for UAV missions the 3D photo mesh LiDAR, and UAV flight plan is evaluated and adjusted before a crew is sent to the field. In 2021 during Tropical Storm Ida damage assessment the county highlighted one of the many UAV program applications. A total time of less than 3 hours from capture to products yielded results to which flood level reach and models could be evaluated. Cambria County has demonstrated a full circle approach to UAV production beginning with 3D planning and ending with 3D products being integrated back into the system. 3D has proven itself a critical component in modern GIS.

Supporting public safety and 911 emergency dispatching is taking a step forward with NG911 address points and call information. Delivering a caller's 3D locations as mandated by FCC and NENA has placed 3D addressing on the timeline. In preparation for this level of expectation, Cambria County has continued to build upon a 3D foundation helping PEMA as a case study in 3D for NG911. A full update of high resolution ortho, oblique, and 3D photo mesh was conducted in the spring of 2022. With this new update, countywide building footprint generation, new road centerline alignment, and 911 CAD (computer aided dispatch) 3D integration has begun. The UAV program has continued to show how local updates assist with 3D addressing and will continue to serve as a GIS tool for 3D. Cambria County envisions a multi-level approach to indoor mapping for addressable units like schools, apartment complexes, shopping malls, or hotels. Basic 3D address points can be created from floorplans and general level above ground calculations. High resolution 3D and oblique imagery enable address managers to verify correct heights above ground, especially for complex buildings with multiple entrance points. Adding indoor 360 photos and/or video help provide an enhanced experience for NG911 addressing and other building information by providing a visual complement to 3D GIS construction much like obliques help visualize the outside of a building. A full complement of point clouds, 360 photos/video, 3D GIS assets, and 3D photo mesh is a top level, fully immersive and integrated 3D GIS.

The 3D foundation continues immersive applications from outside to inside (Richland Area High School).

LiDAR, 3D Photomesh, FAA Airspace, 911 call analysis bringing life saving response with drone services.



LiDAR points being classified for surface model properties and integrating building models (BIM) into GIS. Fig. 22,23 IFC model project with Greater Altoona Career and Technology Center 2010

Another recent Cambria County 3D integration project has been collecting mobile LiDAR and 360 photos to demonstrate a fully immersive outdoor to indoor realistic 3D environment. Software for the mobile LiDAR uses the 360 photos and LiDAR to produce colorized, very dense point clouds and spatially accurate 3D/360 virtual tours. Within this software users can now generate 3D points of interest which can be enhanced with a multitude of customer specific information. Using that same dataset as a property manager information tool enables users to create 3D point locations for assets. Examples like fire extinguishers, defibrillators, electric panels and HVAC infrastructure can all have a place in 3D. The inclusion and development of immersive 3D has taken another leap forward as game engines and Virtual/Mixed/Augmented Reality all now integrate geospatial datasets. Preparing and producing 3D GIS will pay forward as many user experiences become mainstream.

In March of 2024 Cambria County received a US Department of Transportation SMART grant to implement UAV emergency medical deliveries. It is no surprise that planning for this advanced aviation infrastructure can only be served best by 3D compositions and analysis. Further proof that 3D GIS is a foundation for planning and technology implementation of the future.

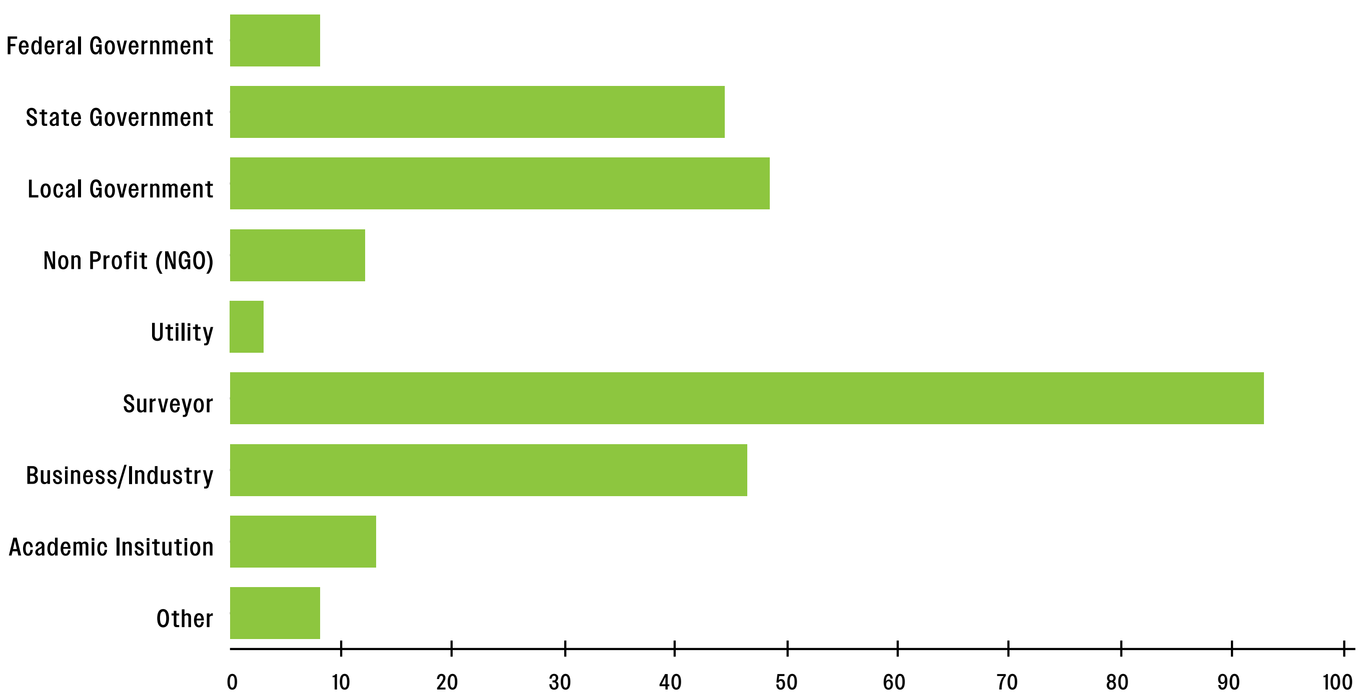
With a wealth of 3D sources available in Pennsylvania every GIS task and endeavor has potential to be 3D.

Appendix B: Working Group Participants

Jim Querry (Philadelphia University), Laura Lettiere (Mifflin County), Steve Kocsis (Cambria County), Keith Previc (PA DEP), Patrick Jaquay (PA DEP), Matt Cavanaugh (PA DEP), Emily Mercurio (CivicMapper), Eliza Gross (USGS), Matt McCullough (FEMA), Mike Anderson (SpatialIT), Scott Dane (Penn State), Rachel Ralls (The Nature Conservancy), Robin Wallace (PA State Police), Maurie Kelly (Penn State), Al Guiseppe (PA Geologic Survey), Patrick McKinney (PA Department of Health), Jeff Zimmerman (Susquehanna River Basin Commission), Megan Birch (Dauphin County), Mark Leitzell (PennDOT), Christian Przybylek (PEMA), Tom Mueller (PennWest University), Charles Ross (NOAA/NWS).

Appendix C: Survey Results

What type of organization do you represent?

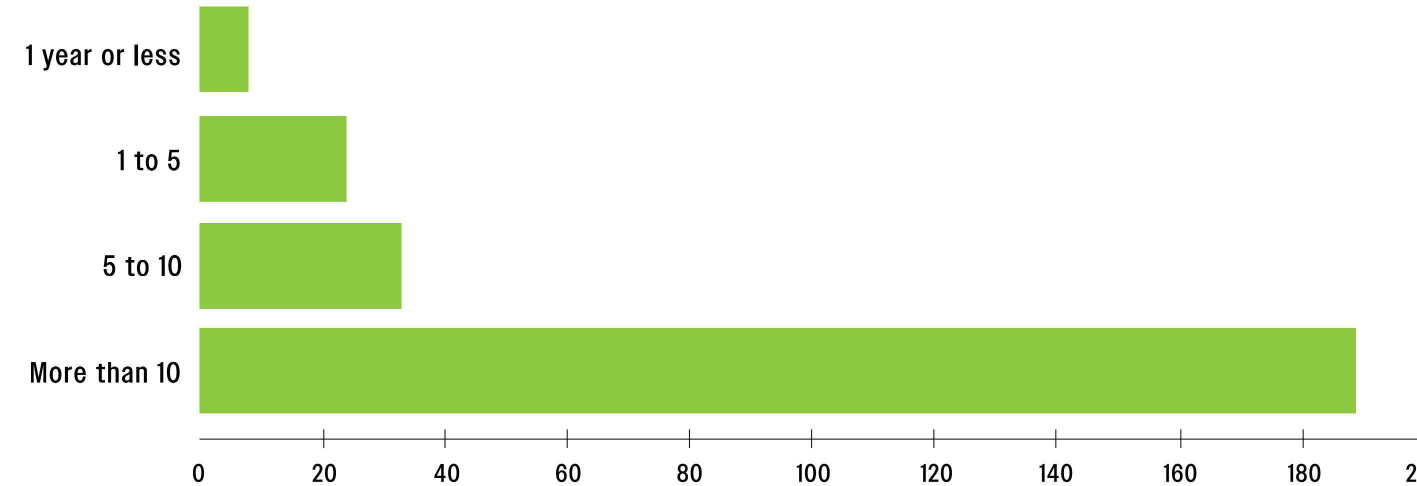


Answer	%	Count
Federal Government	2.92	8
State Government	16.06	44
Local Government	17.52	48
Non Profit (NGO)	4.38	12
Utility	1.09	3
Surveyor	33.58	92
Business/Industry	16.79	46
Academic Insitution	4.74	13
Other	2.92	8
Total	100	274

Responses to “Other”:

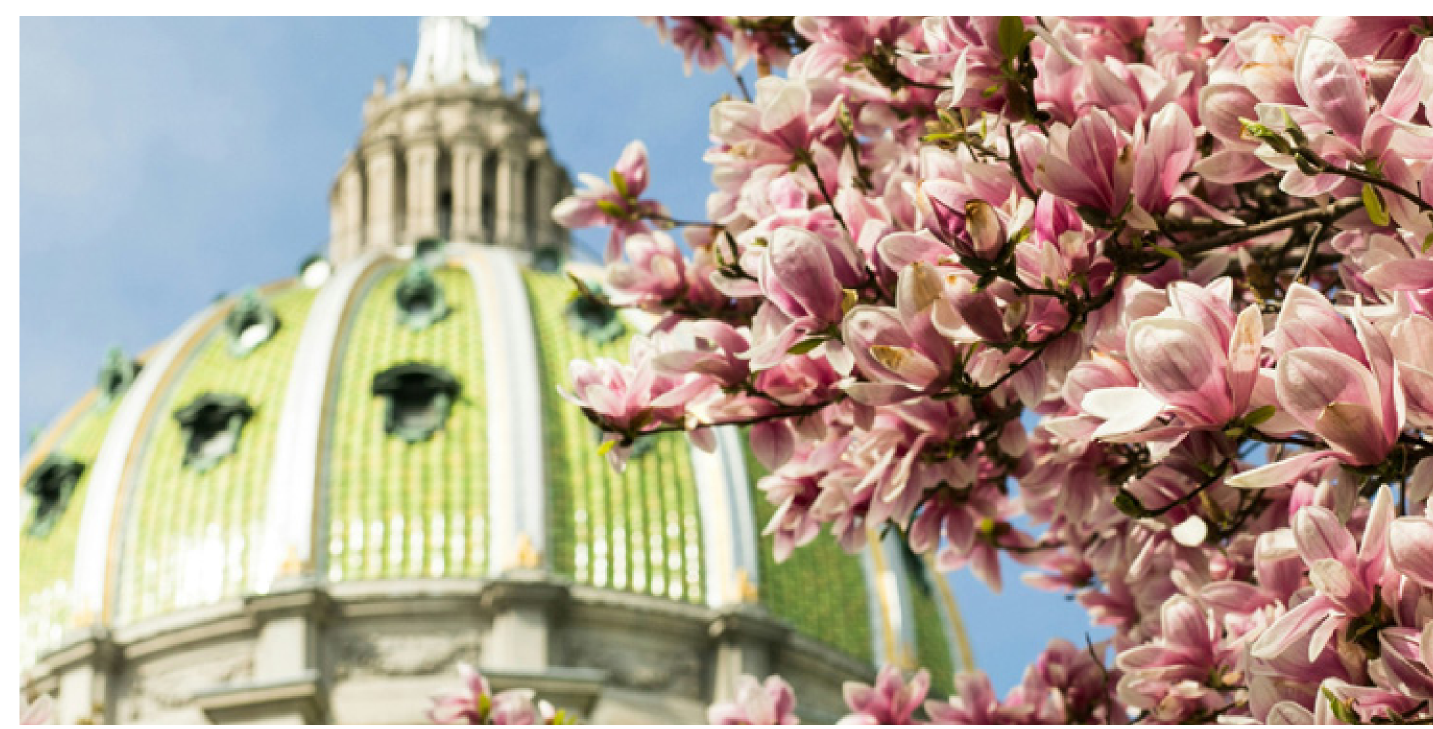
- Metropolitan Planning Commission (regional government)
- Landscape Architecture - Land Planning
- engineering consulting
- Geotechnical engineering
- Rwdy construction
- Engineering / Surveying Company

How long have you worked in the field?



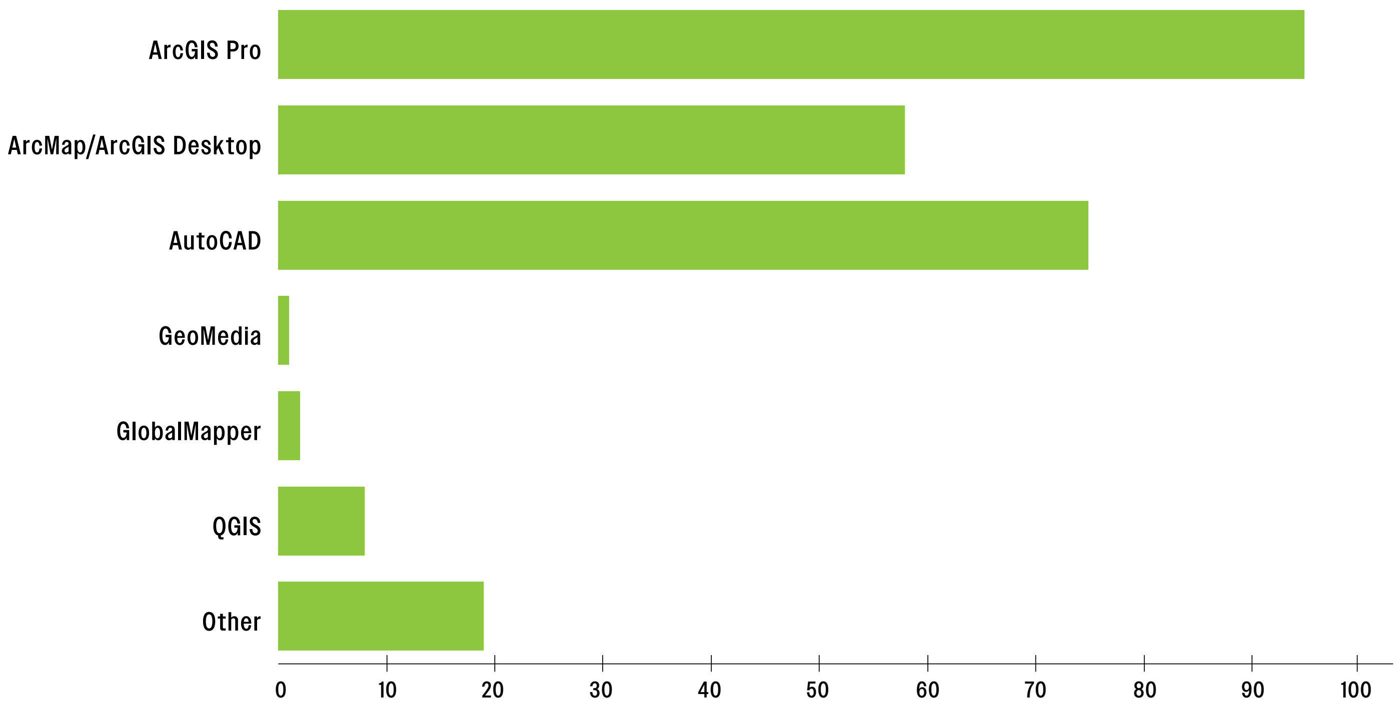
Field	Minimum	Maximum	Mean	Std. Deviation	Variance	Count
How long have you worked in the field	1.00	4.00	3.59	0.79	0.62	254

Answer	%	Count
1 year or less	3.15	8
1-5	9.45	24
5-10	12.99	33
More than 10	74.41	189
Total	100%	254



Magnolia blooms at the Pennsylvania Capitol Building

What software do you most commonly use with GIS data?



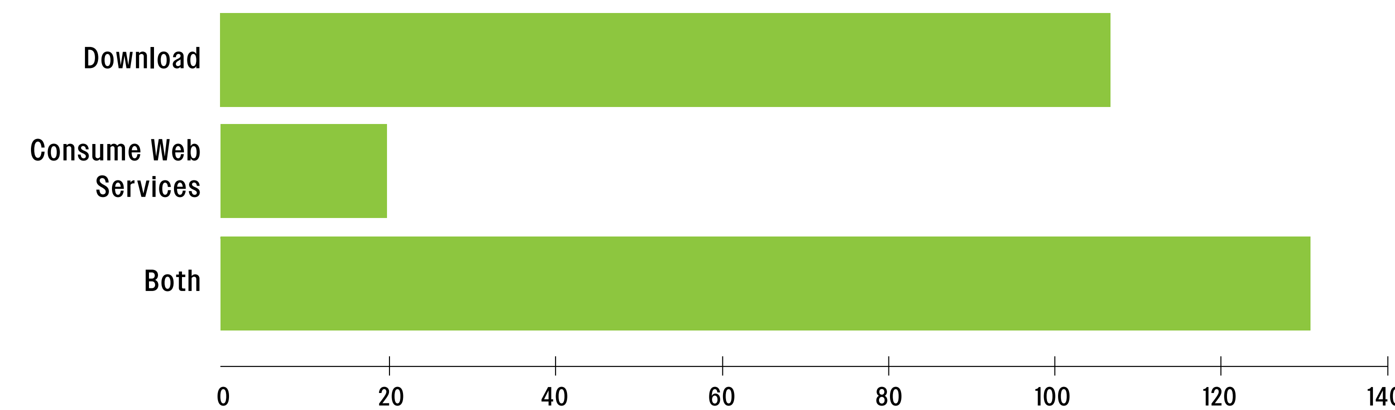
Field	Minimum	Maximum	Mean	Std. Deviation	Variance	Count
What software do you most commonly use with GIS data? - Selected Choice	1.00	7.00	2.45	1.70	2.88	258

Answer	%	Count
ArcGIS Pro	36.82	95
ArcMap/ArcGIS Desktop	22.48	58
AutoCAD	29.07	75
GeoMedia	0.39	1
GlobalMapper	0.78	2
QGIS	3.10	8
Other	7.36	19
Total	100	258

Responses to "Other":

- Traverse PC
- ESRI products and R or Python
- Desktop and Pro equally
- Bentley Microstation
- Carlson
- MapInfo
- We haven't been using GIS data in that sense
- ArcGIS Enterprise Portal
- Carlson
- Autodesk Civil 3D & Map
- CARLSON
- Bentley
- Bentley MicroStation
- AGOL
- ArcGIS Server

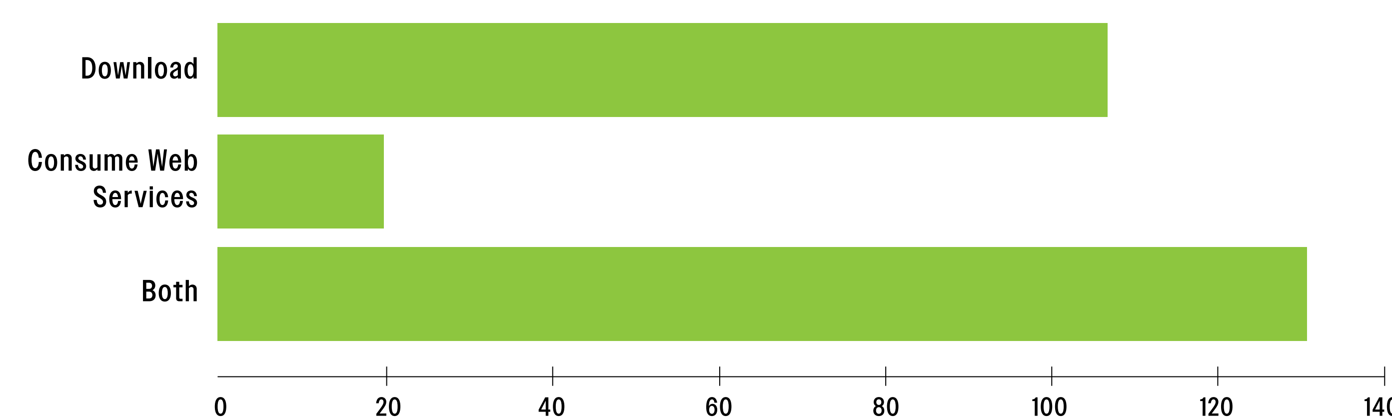
When accessing data, do you most often…



Field	Minimum	Maximum	Mean	Std. Deviation	Variance	Count
When accessing data, do you most often…	1.00	3.00	2.09	0.96	0.91	258

Answer	%	Count
Download	41.47	107
Consume Web Services	7.75	20
Both	50.78	131
Total	100	258

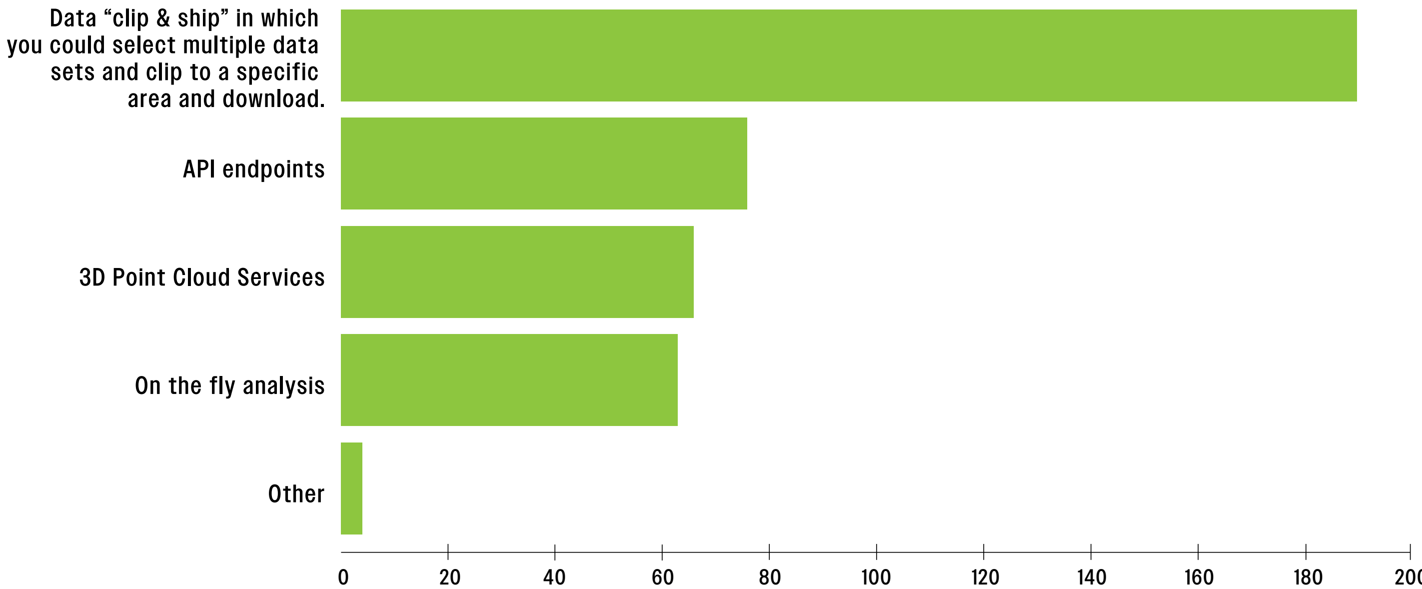
If you consume services, which would you prefer?



Field	Minimum	Maximum	Mean	Std. Deviation	Variance	Count
If you consume services, which would you prefer? (SELECTED CHOICE)	1.00	5.00	3.10	1.31	1.72	234

Answer	%	Count
OGC web services	11.97	28
esri endpoint	20.94	49
Both	36.75	86
Other	5.56	13
N/A-I DO NOT CONSUME SERVICES	24.79	58
Total	100	234

Which of the following would be useful to you? Select all that apply.

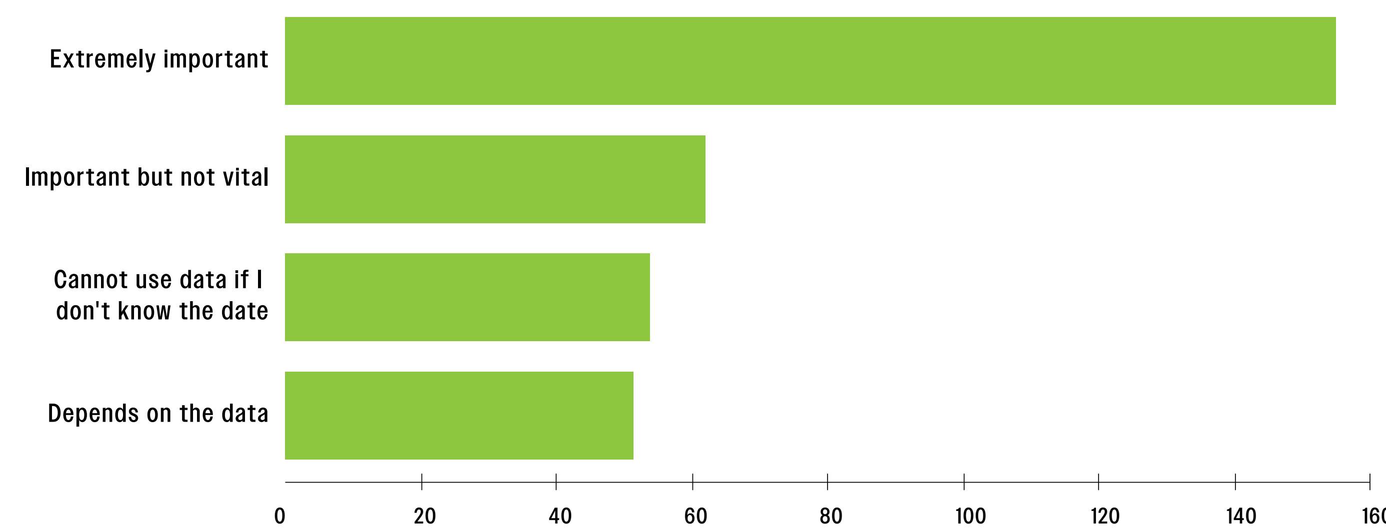


Answer	%	Count
Data "clip & ship" in which you could select multiple data sets and clip to a specific area and download.	47.62	190
API endpoints	19.05	76
3D Point Cloud Service	16.54	66
On the fly analysis	15.79	63
Other	1.00	4
Total	100	399

Are there other data, formats, or services that you would like to have that are not mentioned above?

- no
- N/A
- n/a
- none that I can think of now
- Shape files of contours, road maps, subdivision plans.
- no
- No
- no
- na
- not that i can think of
- No
- USGS 3DEP Integration/ extraction
- UP TO DATE, YEARLY, AERIAL PHOTOGRAPHY
- Aerial Images
- Streaming real time aggregated data in addition to archived and time stamped historical data
- No
- statewide parcel data
- no
- dgn format for Bentley Cad
- Carlson
- terramodel
- Updated aerial photographs and classified LIDAR
- .tin surface files
- use geopackages not geodatabased
- Geocoding
- .dwg files
- Hydrologically correct Surface model
- no
- No
- Imagery available for offline export use
- imagery is almost always the most desirable and 3D is even better
- Imagery
- Still a big fan of simple shapefiles
- Not really
- No
- LiDAR breaklines
- dxw
- None that I can think of
- NA
- No
- n/a
- .DWG, .DXF
- no
- LAStools
- Building footprints, benchmarks, streams and wetlands,
- ?
- Breaklines
- Not that I am aware of.
- No
- newest LiDAR data available via seamless DEM and hillshade map service.
- PASDA's imagery viewer/ download tool would be great in theory, but frequently it doesn't work / the images don't resolve / it doesn't show all the data available for download.
- LAS Datasets (compilations of *.las files)
- STAC and COPC would be neat!
- Boundary markers, Land Survey Markers, Survey Network Markers (PDOT, etc.)
- No
- None
- n/a
- We should be prepared for formats and approaches we do not yet envision - gaming engines, riffs on medical imagng comapisons , virtual reality scenes, 3D underground, new data structures
- No

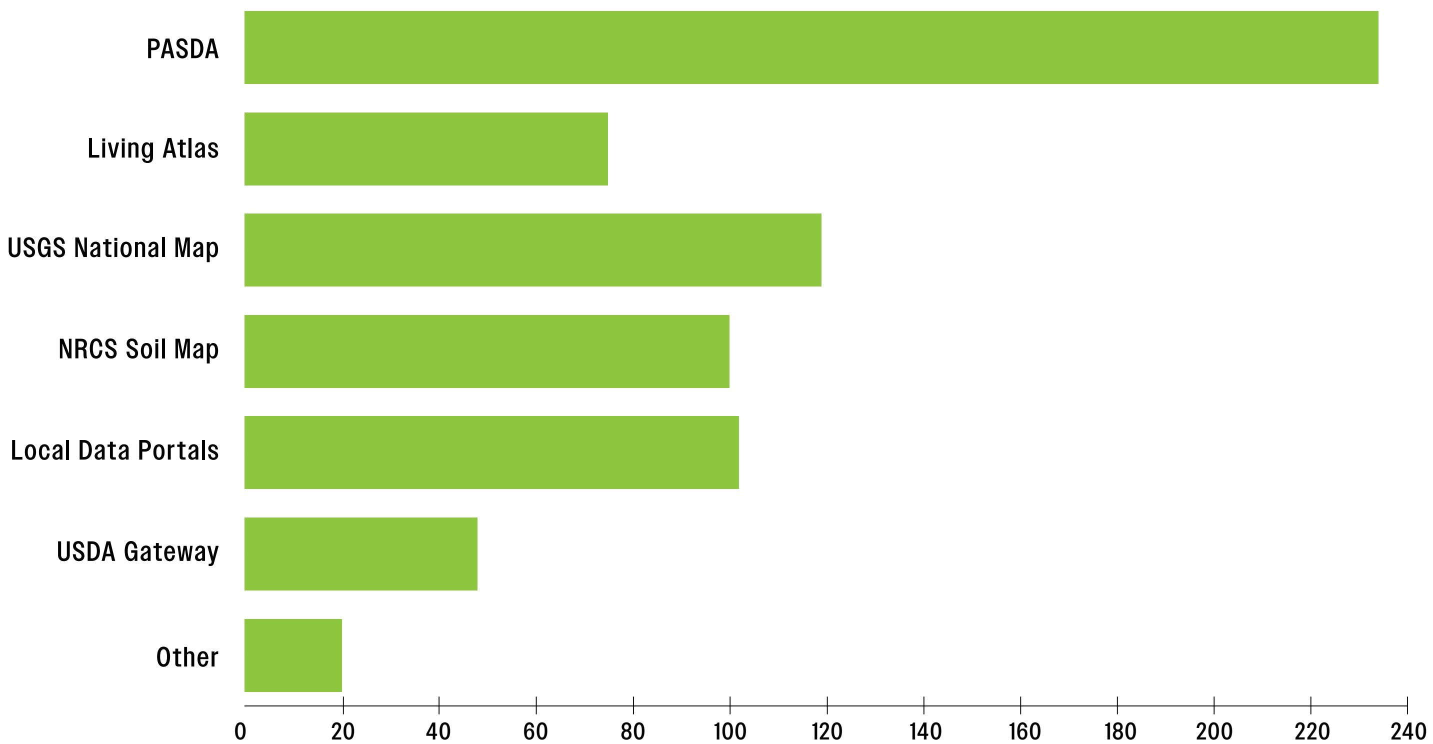
HOW IMPORTANT IS IT TO KNOW THE DATE THAT DATA WAS PRODUCED OR AT LEAST CHANGED?



Field	Minimum	Maximum	Mean	Std. Deviation	Variance	Count
How important is it to know the date that data was produced or at least changed? (SELECTED CHOICE)	1.00	4.00	1.64	0.99	0.97	253

Answer	%	Count
Extremely important	61.26	155
Important but not vital	25.30	64
Cannot use data if I don't know the date	1.58	4
Depends on the data	11.86	30
Total	100	253

WHERE DO YOU GO TO FIND DATA AND SERVICES

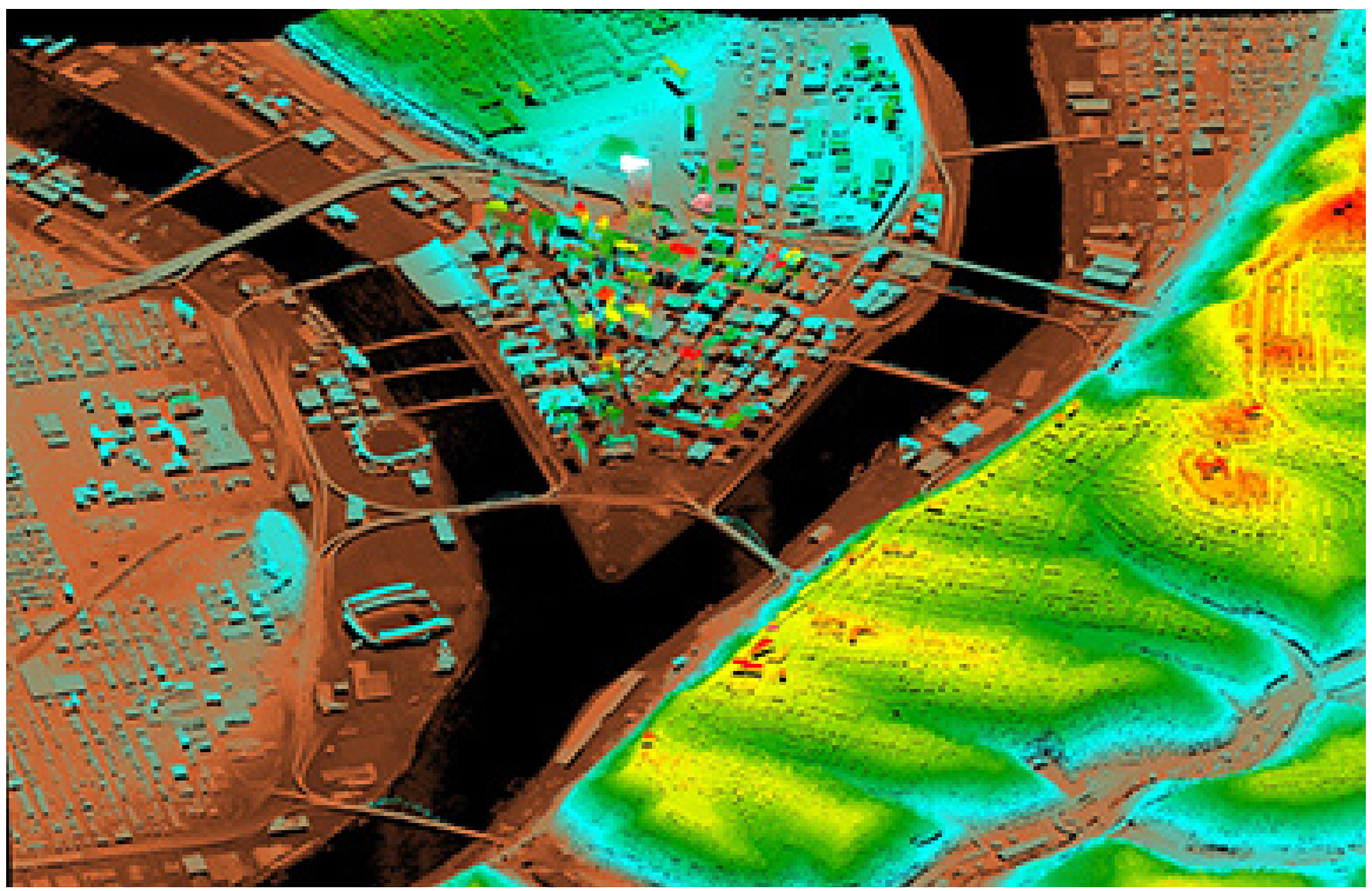


Answer	%	Count
PASDA	33.52	234
Living Atlas	10.74	75
USGS National Map	17.05	119
NRCS Soil Map	14.33	100
Local Data Portals	14.61	102
USDA Gateway	6.88	48
Other	2.87	20
Total	100	698

IF A POINT CLOUD AND/OR CONTOUR SERVICE WAS AVAILABLE, WHAT SOFTWARE WOULD YOU USE TO CONSUME THESE SERVICES?

- CAD
- ArcGIS Pro, Bentley MicroStation
- AutoCAD or Bentley
- Civil 3D
- pro
- pro
- arcgispro
- Trimble Business Center
- autocad
- Traverse PC
- ESRI
- Civil 3D - AutoCAD
- ArcMap or ArcPro
- arcgis pro
- esri some qgis
- arcmap esri
- Pro
- AutoCAD
- ESRI, Autodesk, Bentley products
- AutoCAD
- ESRI Software
- Autocad Civil3d
- AutoCAD
- ArcGIS Pro
- ESRI GIS products or R and Python
- Carlson/IntelliCAD
- Trimble Buisiness Center_ AutoDesk/Carlson_ArcGIS Pro
- Civil 3d
- ArcGIS and custom apps
- Autocad
- Autocad
- Autocad
- autocad
- Carlson
- ArcGIS Pro
- Autocad
- LASTools, AutoCAD
- Trimble business center
- ArcGIS Online, ArcGIS Pro
- yes
- CAD
- autocad civil3d
- ArcGIS Pro and/or ArcGIS Online
- ArcPro
- Arcgis Pro
- CAD
- autocad
- Carlson
- AutoCAD
- Autodesk
- leica infinity
- ArcGIS Pro
- ArcGIS Pro/AGOL/Portal
- OpenRoads Designer or Civil 3D
- ArcGIS Pro
- Autocad
- ArcMap
- qgis
- ArcGIS Pro
- ArcPro
- ArcGIS
- ArcGIS Pro
- Carlson Civil Suite
- ArcPro
- Pro at least
- no
- ArcMap/ArcGIS Desktop
- pro
- ArcGIS Pro, Online, and/or Enterprise
- Esri ArcPro
- ArcGIS Pro
- ArcGIS Pro
- ArcPro
- Arc Pro
- AutoCAD
- Autocad Civil 3D
- ArcGIS Online
- ArcGIS Pro
- ESRI ArcMap/ArcPro. Possibly AGOL
- ArcPro
- ArcPro
- Not sure
- Open source or ArcGIS pro pending the analysis need
- ArcGIS Pro
- Arc Pro
- AutoCAD Civil 3D
- esri arcmap
- ArcGIS Pro or a web app developed using ArcGIS Online or custom javascript
- arcmap
- OpenRoads Designer
- Arc Pro
- ArcMap
- QGIS
- Pro
- Arc GIS Pro
- ArcGIS Pro
- Civil3D
- Leica
- Civil3D
- carlson
- Civil 3D
- Carlson
- I don't use this kind of data
- ArcGIS Desktop
- Autocad
- AutoCAD
- Autocad; more importantly what serves the purpose for the task.
- Autodesk
- Carlson
- Autodesk Civil 3D
- auto-cad
- Civil3D; ArcMap; Trimble Business Center
- carlson
- AutoCAD Civil 3D
- CARLSON
- AUTODESK CIVIL3D
- Bentley
- AutoCAD
- Autocad
- Cadd
- civil 3d
- AUTOCAD CIVIL 3D
- civil 3d
- Trimble Business Center, Civil 3D, Carlson Survey and ArcGIS
- ArcGIS Pro
- AutoCAD, ReCap, Civil 3D, Infraworks, Pix4D, SketchUp, LumenRT, Twinmotion
- latest microsoft
- MicroStation InRoads
- AutoCAD

- AutoCadd/SURVCadd
- AutoCAD
- Autocadd
- autodesk
- carlson
- ArcGIS Desktop
- ArcGIS Pro Or AutoCAD Civil 3D
- QT Modeler
- Arc Pro
- Arc Pro
- ArcPro
- ArcGIS Pro
- ArcGIS Pro, ArcMap, QGIS
- esri toolset primarily. Custom web apps using current web focused languages.
- ArcGIS Pro, QGIS
- Arc Products
- I have no idea what I should use
- ArcGIS Pro
- ArcGIS Pro
- ArcGIS Pro and ArcGIS Online
- ArcGIS Pro
- ArcGIS
- Soon, in the future I will be using ArcGIS Pro.
- ArcGIS Pro
- ArcGIS Pro
- ArcGIS Pro
- ESRI
- esri products
- ArcGIS Pro
- ArcGIS Pro and ArcGIS Online
- ArcPro
- ArcGIS Pro and Vectorworks
- ESRI - ArcPro
- ESRI
- ArcGIS Pro and ArcGIS Enterprise Portal
- ESRI
- Arc Pro LP 360
- ESRI Arc Products
- Esri



3DEP, lidar point cloud, Pittsburgh

Dequesne Incline, Pittsburg