AGIC

ARIZONA GEOGRAPHIC INFORMATION COUNCIL

ARIZONA LIDAR ACQUISITION PLAN

A PLAN FOR STATEWIDE LIDAR COVERAGE IN ARIZONA

2019-2023

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EXECUTIVE SUMMARY

This document provides the framework and intent for Arizona stakeholders to work together to better communicate individual acquisition plans, leverage available funds, and consolidate and serve lidar data across the state. Geographic areas of acquisition and a general timeline have been identified to facilitate coordination between stakeholders and plan out potential funding sources. This plan is not a commitment of resources, rather it is intended to provide a platform for stakeholders work together for a common goal of acquiring seamless data coverage across the state.

Why is lidar important?

Statewide lidar data is essential for public safety as its critical for emergency response, wildfires, floods and other natural disasters. Accessible lidar data for these uses and for daily business needs across disciplines has an estimated $12.56 million-dollar benefit to the state.

Use case examples

- Wildfire risk assessment and modeling; post wildfire analysis
- Geologic hazards mapping and assessments
- Transportation planning, management and mitigation
- Flood control mapping and mitigation
- Natural resource assessments
- Change detection

What are the challenges to Lidar acquisition?

- Funding
- Stakeholder identification and coordination
- Education: pathway to acquisition, understanding technical specifications, and applications of lidar and data derivatives
- Land ownership distribution (federal, state, tribal and private)
- Data storage and distribution

Next steps?

A statewide planning effort to facilitate the coordination of stakeholders, specifically targeting Arizona's large land-owner agencies and provide funding coordination to acquire lidar over the next five years utilizing the USGS 3D Elevation Program (3DEP). The AGIC Lidar Work Group will continue to work to support this planning effort through regular meetings, an annual symposium, educational outreach, resource development and stakeholder coordination.

INTRODUCTION

This document is part of the AGIC Lidar Work Group's mission to facilitate statewide lidar acquisition. It provides a plan for Arizona stakeholders to work together to acquire lidar data.

Plan Goal

To acquire quality level 2 (QL2) lidar data or better, seamlessly across Arizona by 2023 through partnerships of Federal, State, Local governments, Non-profit and for-profit entities, and Universities primarily by utilizing the USGS 3D Elevation Program (3DEP).

Plan Objectives

- To provide a framework for stakeholders to collaborate for lidar acquisition
- To provide guidance about funding opportunities and the USGS Broad Agency Announcement (BAA) grant process
- To divide Arizona into various acquisition blocks
- To provide a temporal acquisition plan to guide coordination
- To develop a data redistribution and management plan utilizing Arizona's State Geospatial Clearinghouse, AZGeo

Value and Benefit of Lidar to the State

It has been found that mid to high-quality elevation data is essential for flood mitigation, conservation management, emergency response, geologic resource assessment, infrastructure development, agriculture and water supply, and water quality. (USGS 3DEP) In addition, having this data freely available would create an expected annual benefit of $12.56 million dollars. (see table 1.) Enhanced elevation data could enable Federal, State, regional, and local governments to more effectively implement natural resources conservation practices such as grade stabilization, dam safety, habitat easements, pipelines, terracing, and wetland restoration while providing additional cost savings to the public. Statewide lidar data would allow public and private organizations to expand their use of lidar for planning and site-level engineering and reduce field work for conservation projects. Lidar data provides high-quality terrain information as input for more accurate and less expensive hydrologic and hydraulic modeling for flood studies. Lidar data can also aid the identification of vulnerable properties within a floodplain, facilitating better floodplain-management decisions and education of the public on true flood risks. The benefits of including lidar data in wildfire planning, management, and response may increase significantly. Lidar data can be used to prioritize areas in the State where tactical analysis, community interaction and education, or mitigation treatments might be necessary to reduce risk from wildfires and post-fire debris flows. High-resolution elevation data informs fire behavior modeling, fire response, vegetation loads, and post-fire assessment for slope instability, leading to improved public safety. (USGS Arizona Lidar Factsheet)

Rank	Business use	Annual benefits (millions)
1	Infrastructure and construction management	$6.11
2	Natural resources conservation	3.23
3	Flood risk management	1.75
4	Geologic resource assessment and hazard mitigation	0.49
5	Agriculture and precision farming	0.33
6	Forest resources management	0.31
7	Renewable energy resources	0.11
8	Aviation navigation and safety	0.10
9	Water supply and quality	0.06
10	River and stream resource management	0.05
	Other	0.02
	Total	12.56

Table 1. Conservative benefits estimate for the top 10 business uses of the proposed 3DEP data identified in the National Enhanced Elevation Assessment for Arizona (Dewberry, 2011)

CURRENT STATUS OF LIDAR IN ARIZONA

At the end of 2020, only about 26% of the state will have lidar at QL2 or better. The distribution of land ownership in Arizona has been a challenge to statewide lidar acquisition. Approximate breakdown of land ownership is 42% Federal land, 27% Tribal land, 13% State land and 17% Private land. Figure 1 compares total acres owned by agency or organization (red) to acres of lidar collected for the same entity (blue). There has been very little acquisition on Tribal lands even though it is 27.6% of the state.

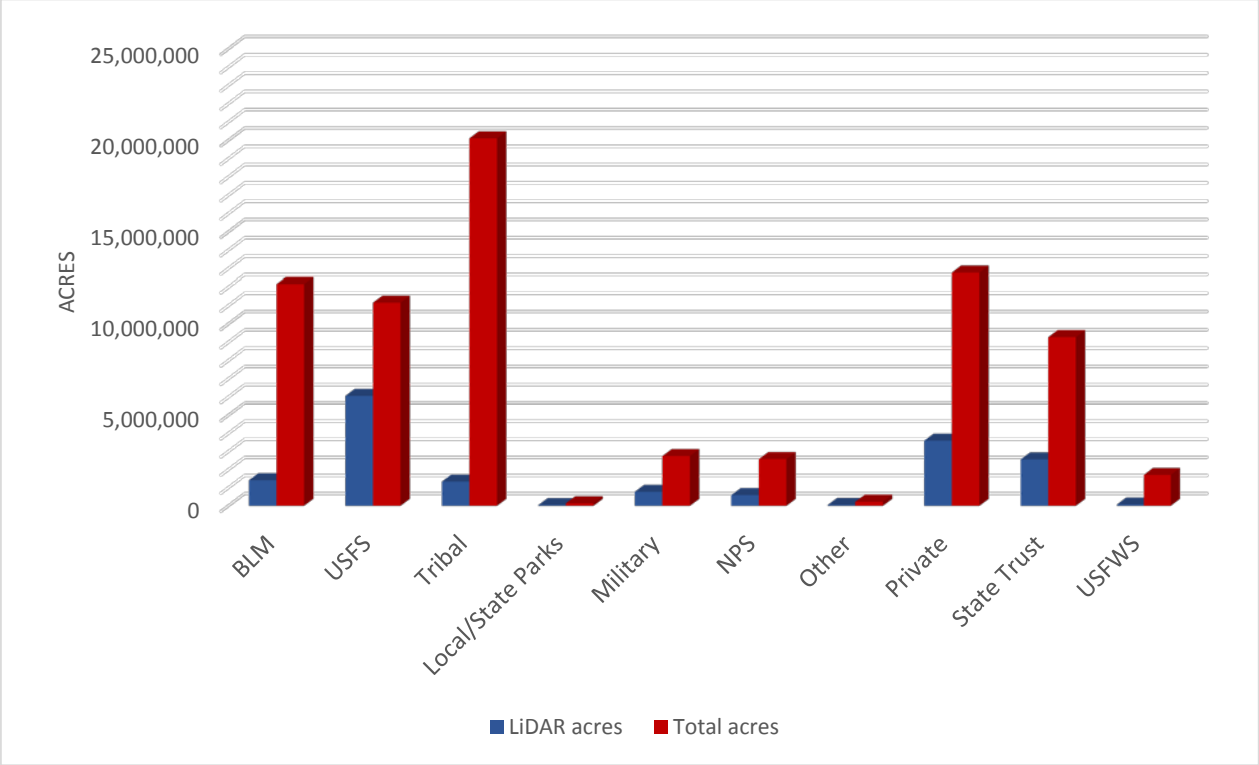
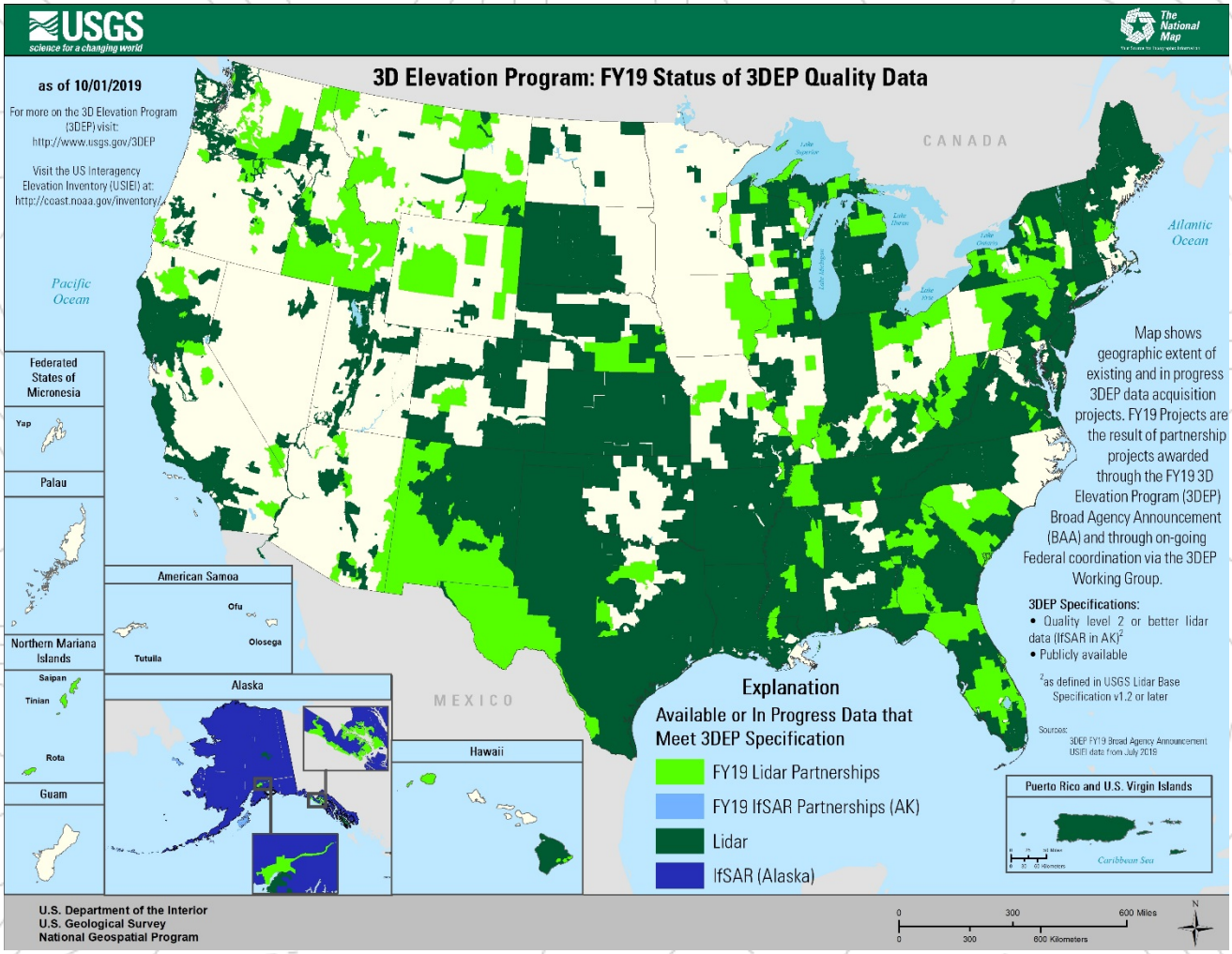
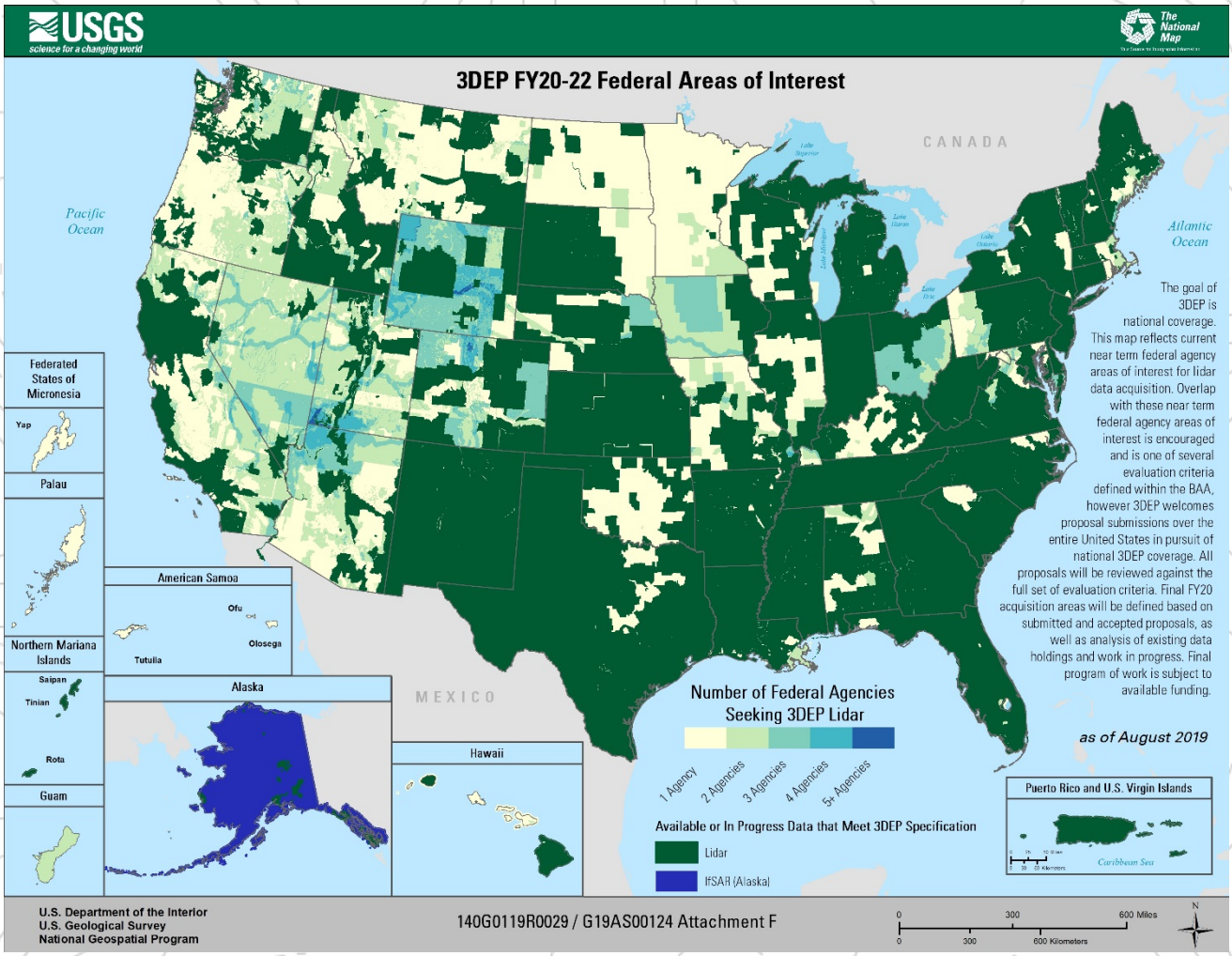


Figure 1. Comparison of total land acres and total existing lidar acres by entity

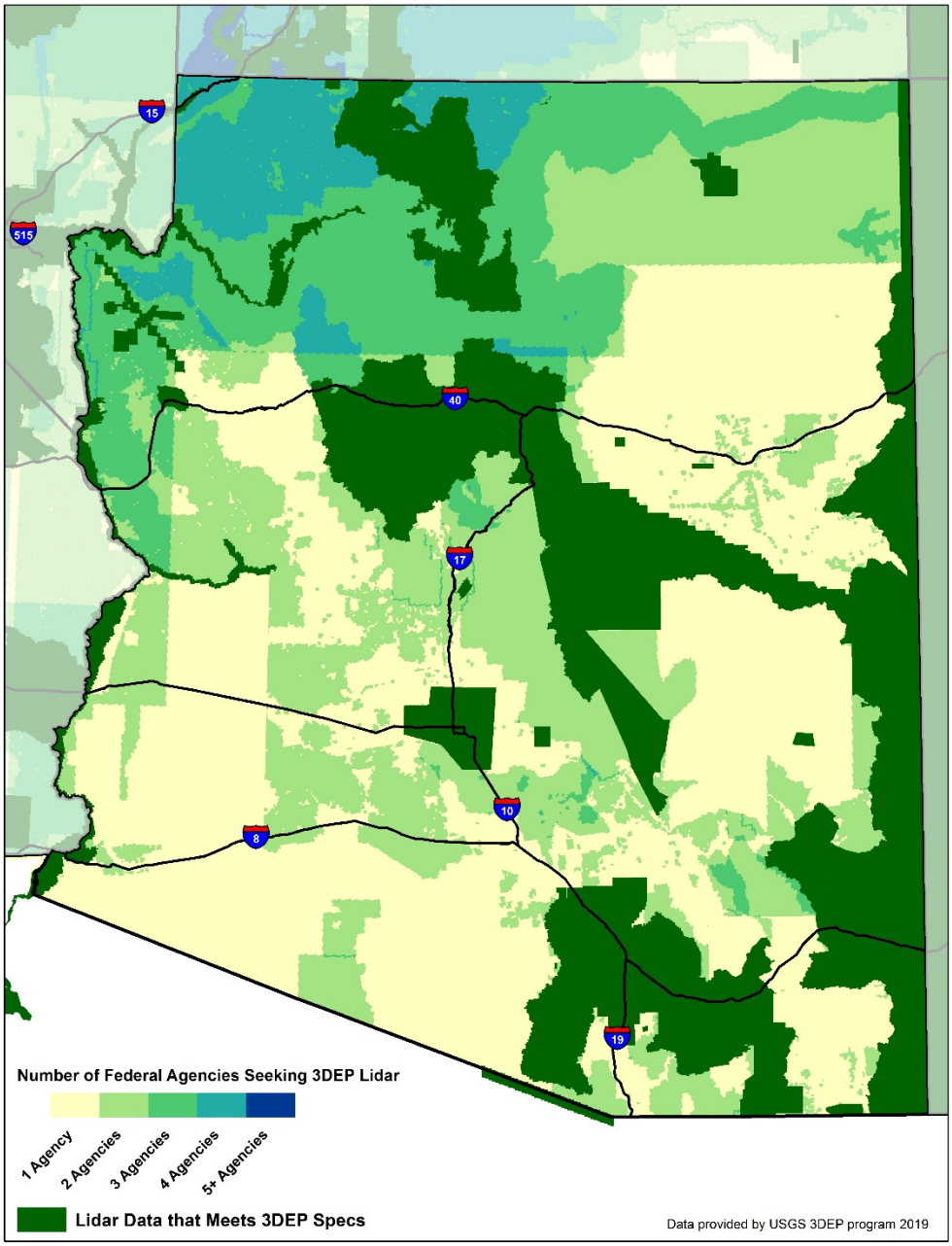
When comparing Arizona to the rest of the country, there is a large discrepancy of existing lidar, especially when compared to New Mexico where there is statewide coverage.



However, when looking at Arizona from a federal interest level, there is a statewide interest in acquiring lidar. We hope to look at different federal agencies to help fill in the gaps.

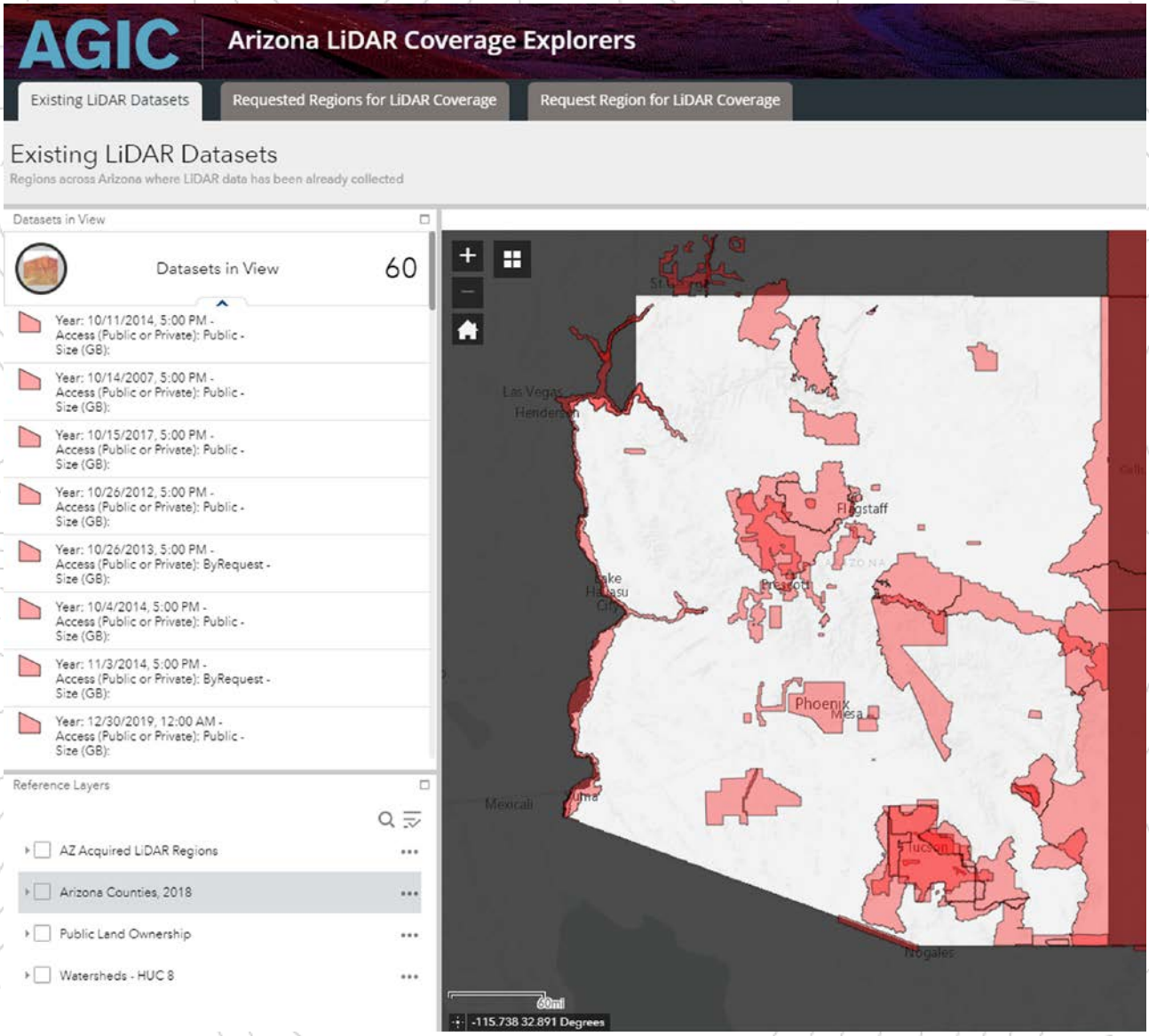


The map below displays the same data as the previous map, focused on Arizona. The data was downloaded from USGS and the colors matched to the USGS map for clarity. The dark green areas show where lidar has been collected that meets or exceeds the USGS specifications. The other colors of the map show the number of federal agencies interested in acquiring lidar for a location.



LIDAR PLANNING WEBPAGE AND MAP

The AGIC Lidar Work Group has a page on the AGIC website dedicated to lidar education, work group activities, and information for stakeholder coordination in Arizona. To support planning among stakeholders, the page includes a link to an interactive web application.



This application provides information on existing lidar data and areas of interest for future collection. The existing lidar dataset map shows where lidar is currently available in Arizona, what the quality level is, and where to obtain it. This map also provides reference overlays to assist in planning, like the watershed boundaries and land ownership. A second map shows stakeholder areas of interest for future lidar acquisition. This map is intended as a tool for facilitating coordination among partners where interests overlap.

It is our hope that groups within Arizona that currently have lidar data but are unsure how to share it may utilize this tool to post information about their data and make it publicly available. A geodatabase has been developed for the submission of a spatial footprint and information about their data (Quality Level, Products, etc.). If hosting of the data is desired, AGIC can assist through the AZGeo platform. For more information, submitting an area of interest, or existing lidar footprint, please email agic_info@azland.gov.

TECHNICAL SPECIFICATIONS AND STANDARDS

At a minimum, all lidar acquisitions facilitated through this plan will comply with the most current version of the USGS Lidar Base Specification v2.1 (current version as of publication) for quality levels one and two (QL1 and QL2, respectively). There is an opportunity for parties to customize their lidar request through the 3DEP process at an additional cost. For example, the US Forest Service often requests a 50% overlap in the data collection resulting in a 100% overlap that is useful in mapping the trees using QL1 data. Vendors can add point cloud classifications, contours, multispectral imagery or additional products to the end deliverables. The USGS documentation includes a list of common data upgrades.

DERIVED ELEVATION PRODUCTS

With all USGS lidar acquisitions, there are several standard products delivered. Many of these products are outlined in the deliverables section of USGS Lidar Base Specifications V2.1

- Lidar point cloud
- Digital Elevation Model (Hydro-flattened)
- Hillshade

In addition, the AGIC Lidar Work Group has been collaborating with the US Forest Service and Arizona Universities (ASU, UA, and NAU) to further develop products for the larger community. These are often referred to as second and third-order products. They are typically developed using regression modeling based on field data. For example, one suite of products developed by the US Forest Service creates 20-meter pixels showing basal area, crown bulk density, and tallest tree height in each pixel. Research continues to explore new techniques such as Individual Tree Segmentation to provide more robust models at higher resolutions. The products developed are a function of the quality level of the base lidar data and corresponding field verification. QL1 allows for more project specific models and products. *(See Appendix I for lidar examples)*

FUNDING

Cost Sharing

It should be noted that not all lidar projects are created equally. There are several variables that can play a significant role when defining a price per square mile estimate. Examples of these variables are as follows:

- the terrain and type of feature characteristics above the ground (i.e. excessive vegetation with extreme terrain relief vs. desert areas with minimal relief)
- defined derivative products
- quality levels requirements (QL1 vs. QL2)

While these factors certainly influence the overall costs, it should not discourage collaborative planning efforts amongst stakeholders. Most of the costs for any lidar project/program are the activities associated with the collection of the data itself (i.e. field work; survey operations and airborne acquisition). These costs can be diffused across a larger project area and/or multiple project areas resulting in a lower per square mile cost and thus, an increased return on investment. As stated before, taking advantage of the economies of scale is one way to inherent cost-savings (+/- 25 percent reduced costs for larger areas), ultimately increasing the incentive of planning project priority areas that are either contiguous or relatively close. Parties can obtain higher quality data at a lower cost for a greater area.

USGS 3D Elevation Program

The US Geologic Survey (USGS) has a mission of acquiring QL2 data across the entire lower 48 states through the 3D Elevation Program (3DEP). The 3DEP program is designed to facilitate the acquisition of lidar data through a grant program (the Broad Agency Announcement or BAA) that helps coordinate partnerships among stakeholders. The program facilitates easy access to vetted high-quality vendors and provides a mechanism for multiple parties to acquire lidar data under one contract. They ensure quality control of the data and produce a standard set of minimum deliverables. During the fiscal year 2019 broad agency announcement (BAA) public webinar, the 3DEP team noted that over the last three years the average BAA award has covered approximately 35% of the total project cost. USGS commonly reviews applications on a case by case basis to determine the funding match. Please review the 3DEP qualifications for fund matching.

The 3DEP guidance is updated often several times a year, please refer to the 3DEP website or contact the Arizona USGS Geospatial Liaison for the most current information.

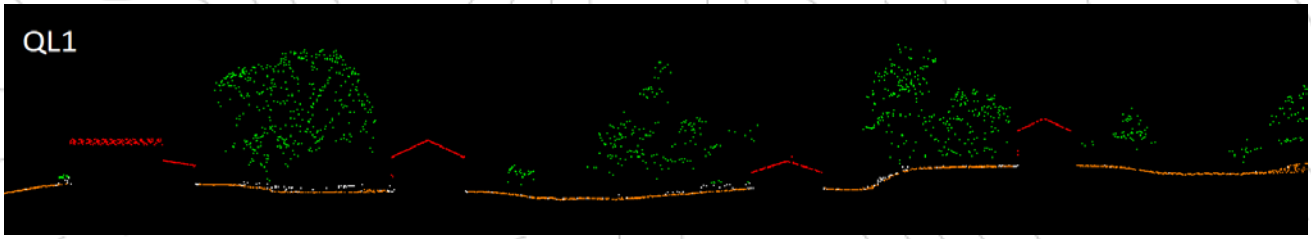
STRATEGY AND SCHEDULE

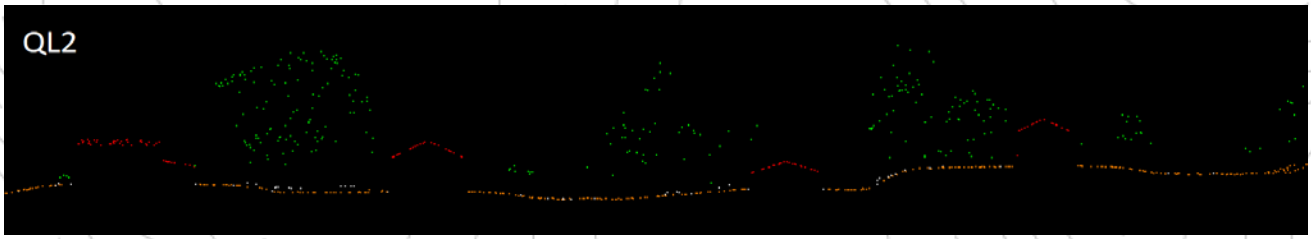
Lidar Quality Levels

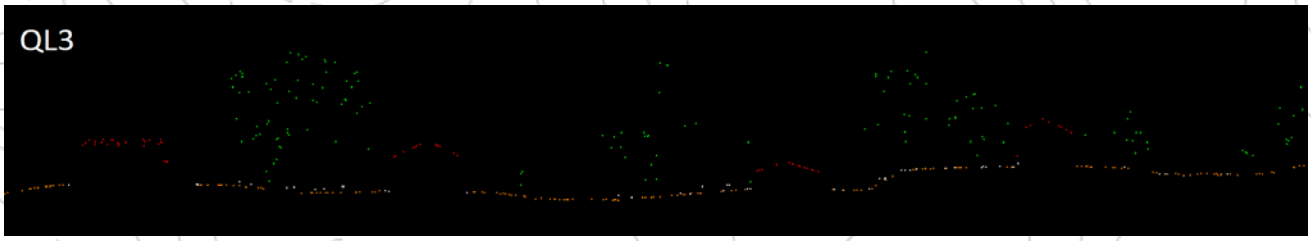
At the first AGIC Lidar Symposium held in 2018, Arizona lidar stakeholders determined that for most governmental agencies (Federal, State and Local) Quality Level 2 (2 pulses per square meter) was sufficient to meet many business requirements, however, several noted a need for Quality Level 1 (8 pulses per square meter). One of the benefits of utilizing the 3DEP program is scalability. Stakeholders can participate at the quality level that meets their requirements while still contributing to the statewide effort.

The following shaded relief images have been captured by the USGS to demonstrate the detail difference between Quality Level 1 and Quality Level 2 lidar. The detail in the structure rooftops demonstrates the ability to see a more distinct roofline within the Quality Level; 1 data due to the higher density of lidar point data in comparison to Quality Level two examples which has a lower lidar point density.

The following images are a cross section of a lidar point cloud at Quality Level 1, 2 and 3. The points have been classified into three categories, brown represents the ground, green represents the vegetation and red represents buildings. The images demonstrate the connection between quality level, point density and level of detail.







Images courtesy of Sanborn Map Company

The tables below outline the nominal pulse spacing, the minimum digital elevation model cell size created, the relative vertical accuracy for swath data, and absolute vertical accuracy for lidar and digital elevation models at each quality level.

Quality level	Aggregate nominal pulse space (m)	Aggregate nominal pulse density (pls/m^2)
QL0	≤0.35	≥8.0
QL1	≤0.35	≥8.0
QL2	≤0.71	≥2.0
QL3	≤1.41	≥0.5

Table 2. Aggregate nominal pulse spacing and density Source: USGS LBS v2.1

Quality level	Minimum cell size (m)	Minimum cell size (ft)
QL0	0.5	1
QL1	0.5	1
QL2	1	2
QL3	2	5

Table 3. Minimum digital elevation model cell size Source: USGS LBS v2.1

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$ (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

Table 4. Relative vertical accuracy for lidar swath data Source: USGS LBS v2.1

Quality level	$RMSE_z$ (nonvegetated)(m)	NVA at 95% confidence level (m)	VVA at 95th percentile (m)
QL0	≤0.050	≤0.098	≤0.15
QL1	≤0.100	≤0.196	≤0.30
QL2	≤0.100	≤0.196	≤0.30
QL3	≤0.200	≤0.392	≤0.60

Table 5. Absolute vertical accuracy for lidar and DEMs Source: USGS LBS v2.1

Timing

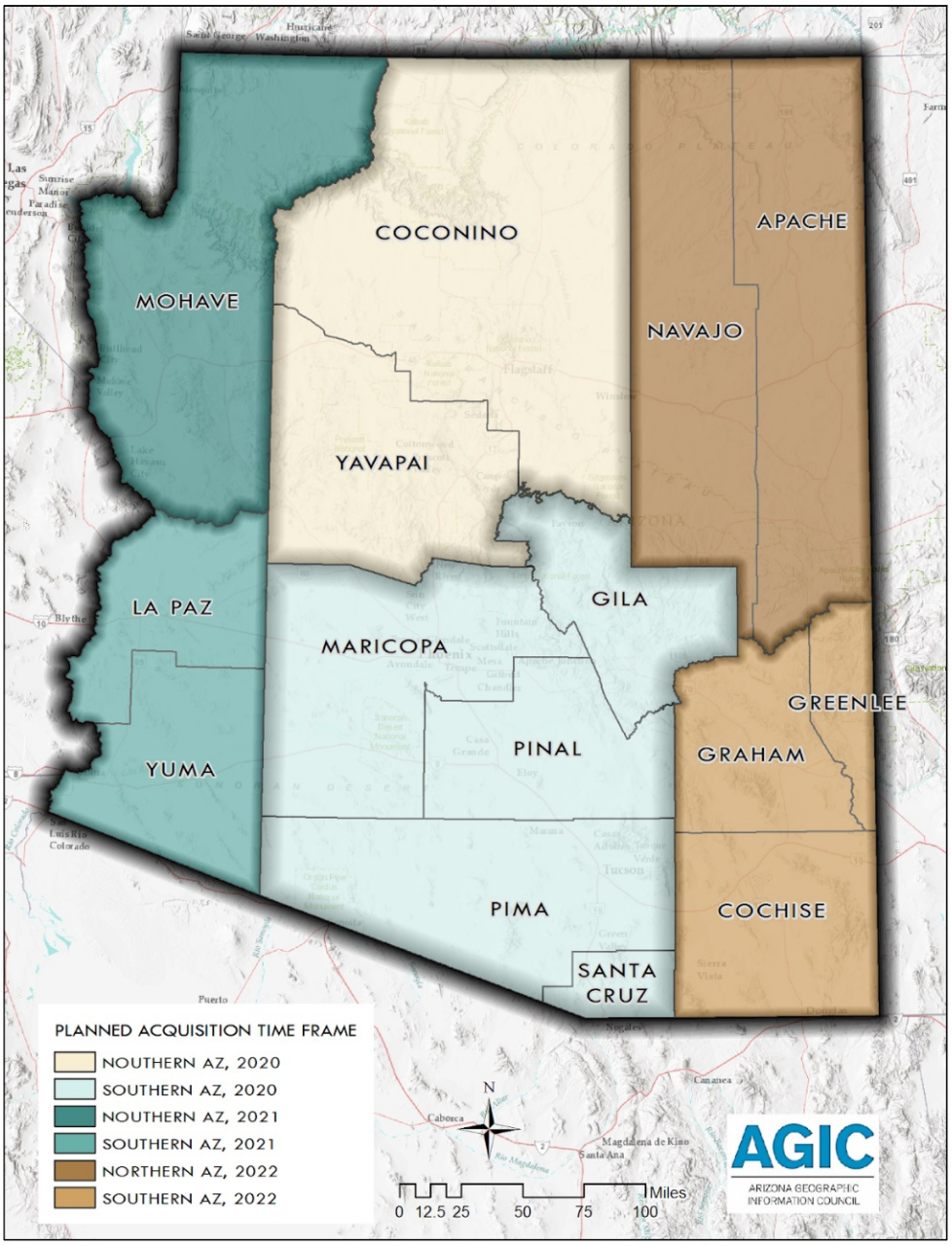
The 3DEP program is currently scheduled to end in 2023. To take advantage of the program, we have developed a three-phase approach dividing the state into Central, West and East zones. The central zone is scheduled for the 2019 application cycle and intended to be collected in 2020. The west zone is scheduled for the 2020 application cycle and intended to be collected in 2021. The east zone is scheduled for the 2021 application cycle and intended to be collected in 2022. This proposed schedule is flexible, but we believe it provides a framework for interested parties to discover partners with complementary areas of interest and encourages planning for funding coordination and collaboration to take advantage of the 3DEP program.

Lidar Acquisition Areas of Interest

The state of Arizona has been divided into six areas based on county lines. Three in the north and three in the south spread across three years. Map 1 shows the geographic extents. These are not hardened lines, but general guides to allow stakeholders to plan out Lidar acquisition.

Northern/Southern Divide

Due to the topography of Arizona, the state has been divided into Northern and Southern acquisition areas. The dividing line is the Colorado Plateau. The drastic difference in elevation between the two areas represents several different considerations when planning LiDAR acquisition. First, the two zones have very different ecosystems, the northern zone contains large contiguous areas of dense ponderosa pine and mixed conifer forests and the southern contains large areas dominated by woodlands and deserts. Also, flying a plane across the different areas with such a large elevation change would be cost prohibitive. It's more financially feasible to divide these two areas because flights could occur in the northern section during the summer months and in the winter in the southern portion of Arizona.



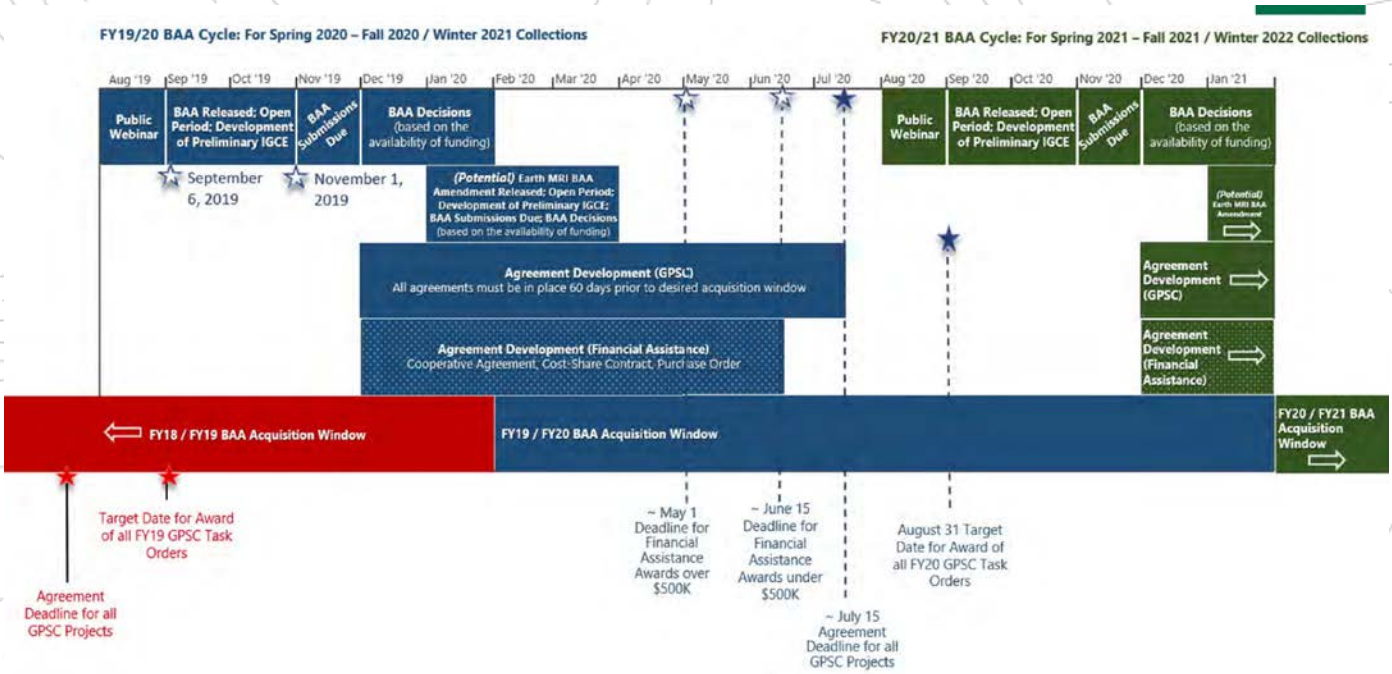
Map 1. This map shows both the timeframe of acquisition and the northern and southern acquisition areas

Opportunistic Acquisition

This report offers a general timeline for acquisition for the state. However, it's important to take advantage of lidar acquisition opportunities as they arise. Various Federal partners like the NPS, BLM and USFS often acquire lidar based on their own internal funding. Stakeholders should contact the AGIC Lidar Work Group Chairs to find out what lidar acquisitions have been planned and work together through the BAA process to optimize acquisition. Large acquisitions by federal partners can lead to substantial cost savings.

Broad Agency Announcement 3DEP Timeline

The USGS Broad Agency Announcement (BAA) for 3DEP includes a deadline for proposal submissions correlated to a specific fiscal year as referenced below. If partner funding is available, it is advisable to submit a proposal within the confines of the submission deadline specified by the USGS. However, there may be cases where partner funding does not become available until after the deadline set by the BAA. In the past, the USGS has allowed for proposal submissions after the BAA deadline has expired. USGS will accept proposals until all funding has been consumed for the fiscal year. For this reason, coordination with state representatives and USGS liaisons prior to developing a late response to the BAA is recommended to ensure matching funds are still available and that the proposal will be evaluated.



Timeline is an excerpt from the [USGS 3DEP FY19/20 BAA Instructional Webinar]

Data Management and Distribution

Arizona plans to use AZGeo, the state geospatial data clearinghouse, to serve publicly available lidar data. Discussions are underway with Arizona's public universities (ASU, UA and NAU) to collaborate with AGIC to serve and manage the collected data. Our goal is to store all raw lidar data and the first, second, and third-order products. With planning and collaboration, we believe we will develop a successful platform that is able to store and process the acquired data.

Standard Products

Lidar in a LAS file format is difficult for the public to use. As such, it is a goal to serve not just the point cloud but several derivatives. The products available from lidar vary based on the quality level.

QL1 Products:

Point Cloud, Bare Earth DEM, Bare Earth Hillshade, Highest Hit Hillshade, Canopy Height Model, Contours

QL2 Products:

Point Cloud, Bare Earth DEM, Bare Earth Hillshade, Contours

As more products are developed and made available to the public, AZGeo will be the distribution platform.

Acquisition Plan Maintenance

This plan will be reviewed annually by the AGIC Data Committee Lidar Work Group to ensure that it's up to date with the latest information and links. Additional topics identified for inclusion in the 2020 review are software options for visualizing and processing LAS data, benefits of old vs new lidar acquisitions (accuracy and control), and sensor differences and options for data collection.

APPENDIX I – LIDAR USE CASE EXAMPLES

Wildfire Management

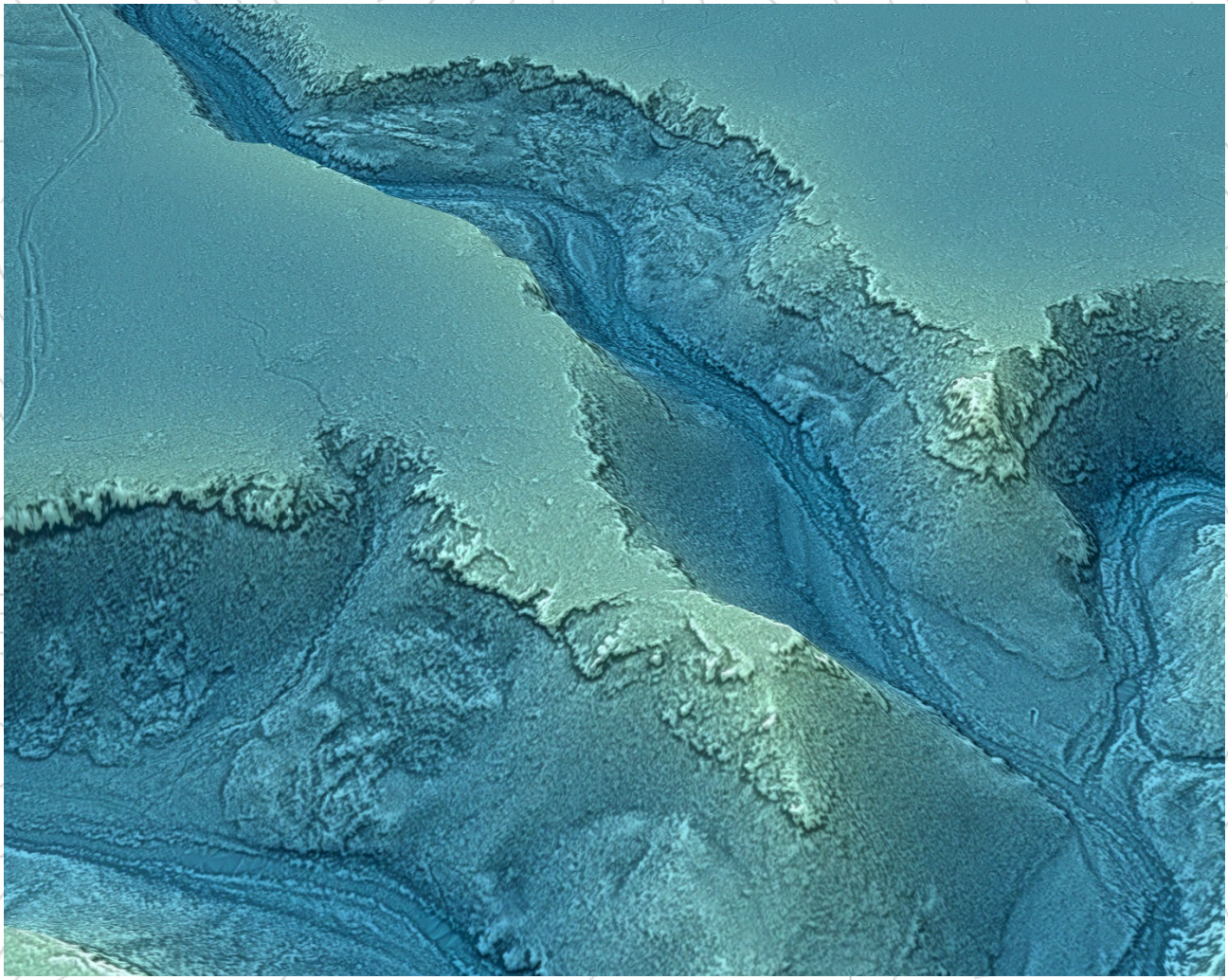
Lidar data is used to identify areas with increased risk of wildfires and to prepare for post-fire hazards such as debris flow and flooding.

- Forest Biomass
- Fire Behavior
- Emergency Response
- Remediation
- Erosion/Debris Flows
- Post-fire Flood Risk
- Risk Mitigation

Warm Fire (2006) scar; Kaibab National Forest; QL1 Lidar 2012
Image credit: Mark Christiano, USFS Region 3

Hazard Mitigation

The risks and impacts of fires, floods, landslides, earthquakes, and volcanoes can be better understood when the underlying topography is exposed in high resolution.

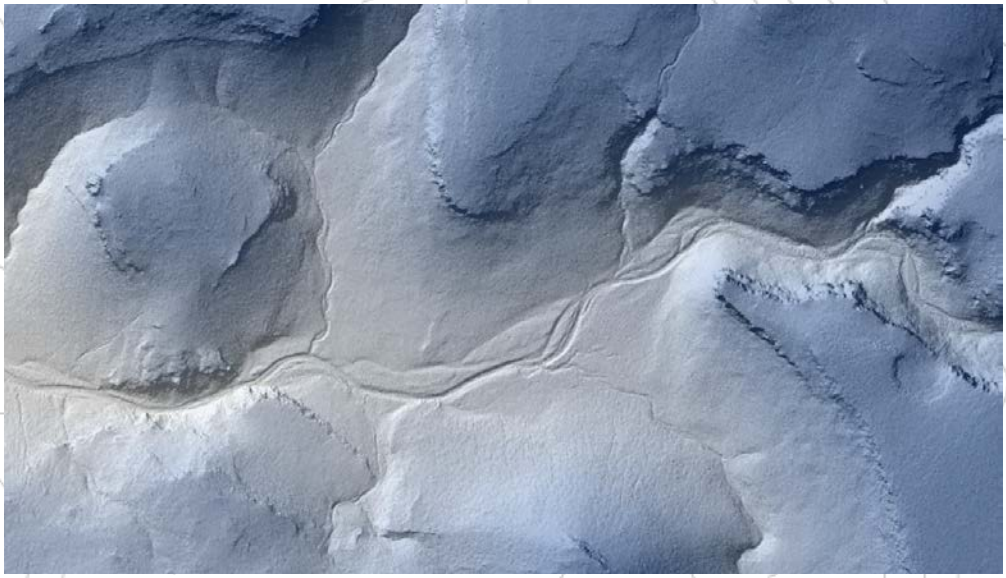


The Black River, Apache-Sitgreaves National Forest, QL1 Lidar 2014
Image courtesy of USFS Region 3

Hydrologic mapping

A comparison of lidar to NAIP imagery for hydrologic mapping.

Lidar collection utilizes an active sensor rather than a passive sensor which is what is traditionally used to collect imagery like the National Agriculture Imagery Program (NAIP) data. This functionality allows the sensor to penetrate the canopy and revel the underlying hydrology of an area. In this example, not only can you see the stream that is obscured on the imagery by the trees, you can see the different stream channels as the stream has meandered over time. The ability to penetrate the canopy improves stream datasets and hydrologic modeling.

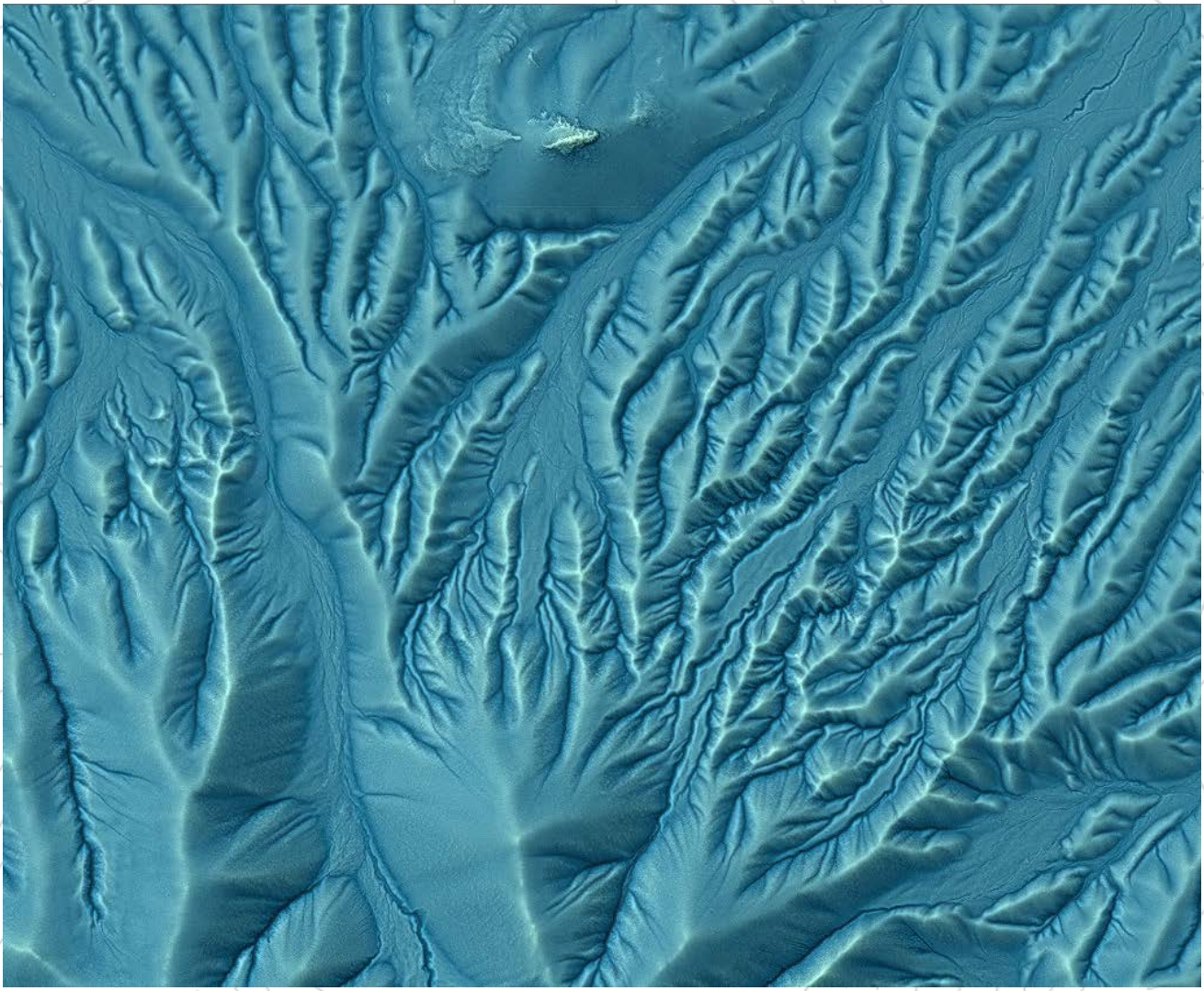


Kaibab South Zone, QL1 lidar 2018. Image courtesy of USFS Region 3

NAIP 2017

Highlighting Curvature, a raster function tool

The output of the Curvature function can be used to describe the physical characteristics of a drainage basin in an effort to understand erosion and runoff processes. The curvature value can be used to find soil erosion patterns as well as the distribution of water on land. The profile curvature affects the acceleration and deceleration of flow and, therefore, influences erosion and deposition. The planform curvature influences convergence and divergence of flow. This image has been colorized and pan sharpened for clarity.



Kaibab National Forest, North side of Sitgreaves Mountain, QL1 Lidar 2018.
Image courtesy of USFS Region 3

Infrastructure and Transportation/Construction Management

The second leading business use of lidar data is infrastructure. A broad range of infrastructure applications depend on the availability of an accurate elevation baseline. These lidar point cloud images show the main campus area of a university. The lidar data can be utilized for urban tree canopy studies, site planning for new developments (i.e. parking lots, new buildings / expansion programs, etc.), energy analysis of infrastructure, construction planning, impervious surface calculations, stormwater management, etc.

The following isometric image shows 3D lidar points of urban structures. A color ramp has been applied to the lidar points to demonstrate elevation difference between lower elevation data and higher elevation data. The blue in the image signifies a lower elevation area and the ramp up to red signifies a higher elevation area. This image demonstrates that a lidar point cloud contains millions of discrete 3D point measurements.

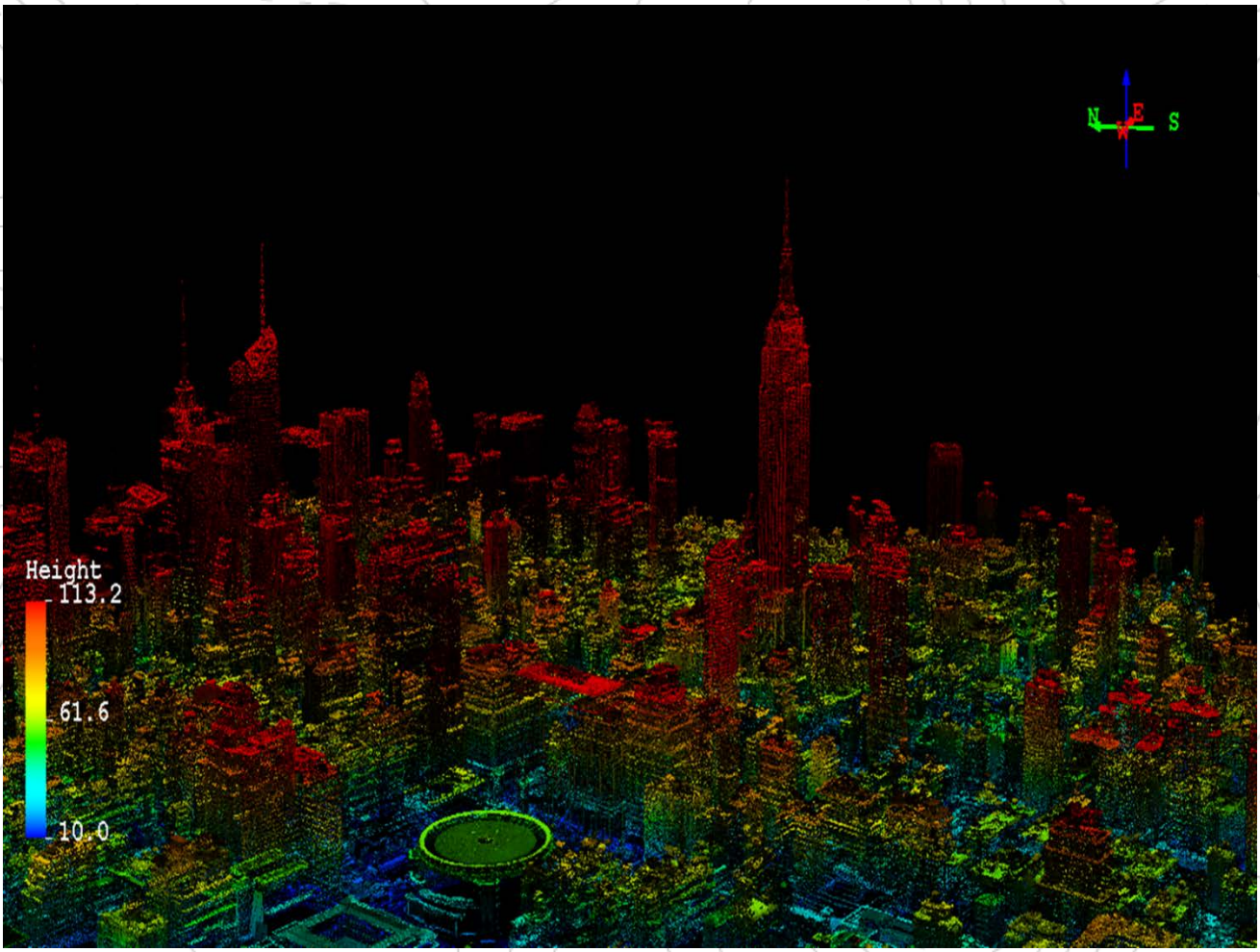
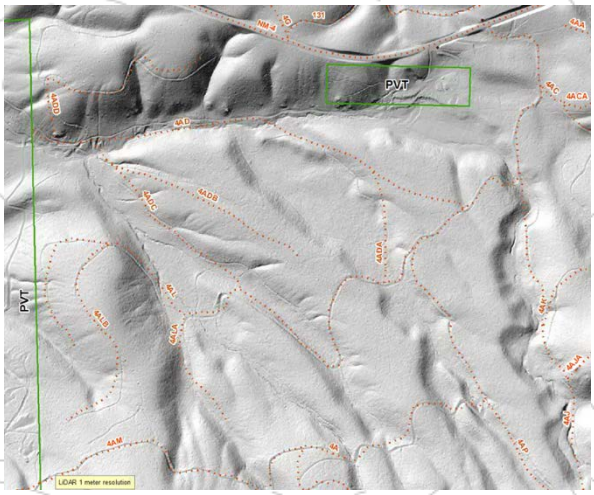


Image courtesy of Sanborn Map Company

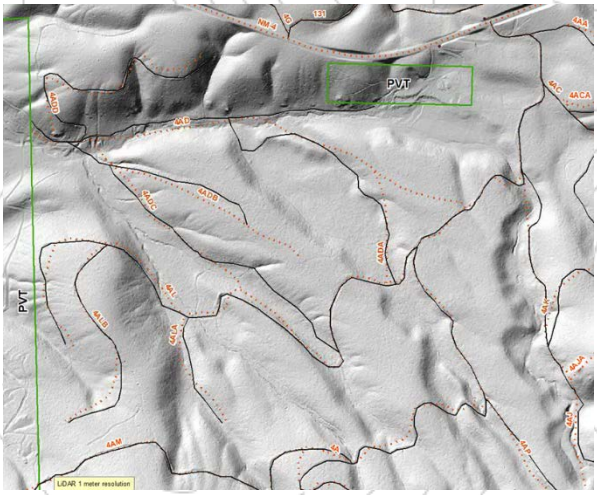
Rural Road Mapping

Mapping the roads when they are easily seen on imagery like NAIP is not an issue. However, roads in more rural locations, often under the canopy can prove problematic. Lidar can see through the trees and allow for quality mapping of the roads. Quality road information is critical during fires, search and rescue and general navigation by the public for recreation. The below example shows Forest Service Roads in dots prior to the lidar and after the lidar. The roads appear clearly on the bare earth hillshade.

Before



After

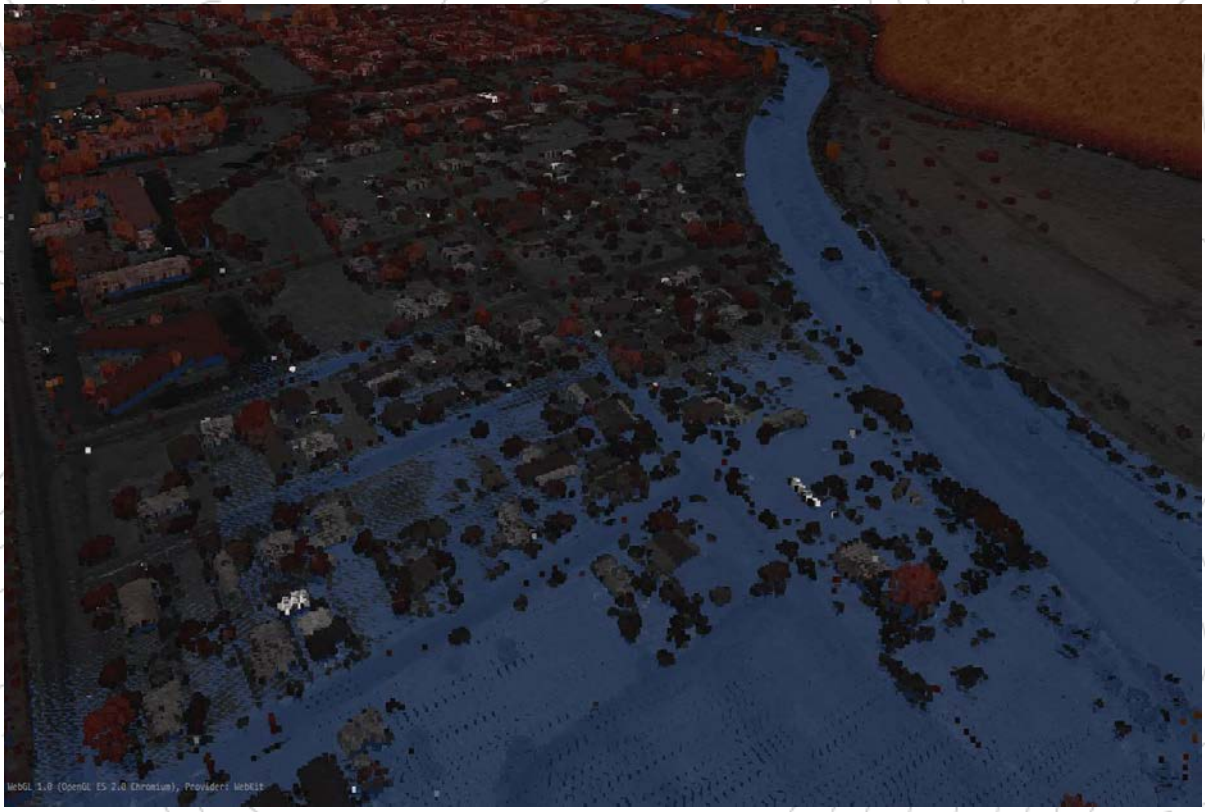


Santa Fe National Forest, QL1 Lidar 2012
Image credit: Julie Luetzelschwab, USFS Region 3

Land-Use Planning & Floodplain Management

Lidar data is becoming more common in land-use planning to better protect lives, property and infrastructure from the impacts of floods and other hazards. In fact, the top business use of 3DEP / lidar data is flood risk management because detailed topographic information is absolutely critical to accurately predicting where flooding will occur. Lidar data are invaluable for mapping the bare earth surface under vegetation. Additional applications include:

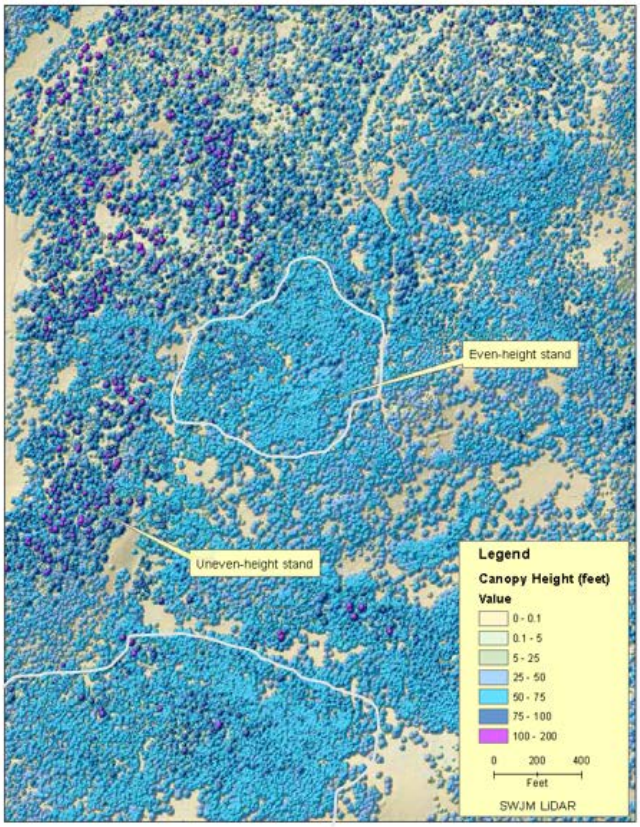
- Drainage Issues
- Development Impacts
- High-risk Structures
- Repetitive Loss Areas
- 3D Building Database



Eastern Pima County flood inundation, QL2 Lidar 2015
Image credit Ben Hickson, Pima Association of Governments

Vegetation Height

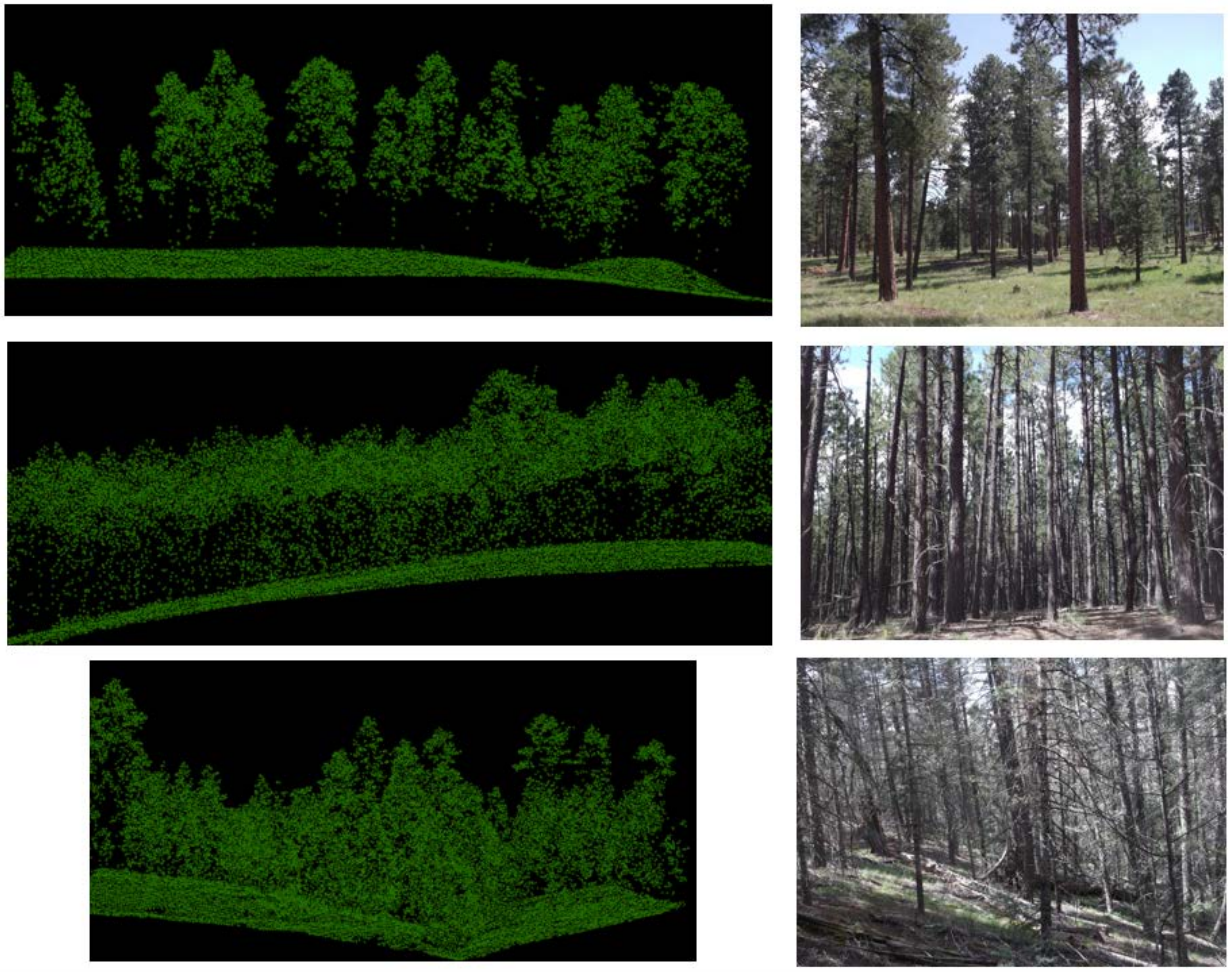
Determining the height of vegetation, like trees, is very difficult using standard aerial imagery products like NAIP (Left). Lidar allows the user to see the difference in tree height stands, allowing foresters to target restoration projects.



Santa Fe National Forest, QL1 Lidar 2012
Image credit: Julie Luetzelschwab, USFS Region 3

Stand Density

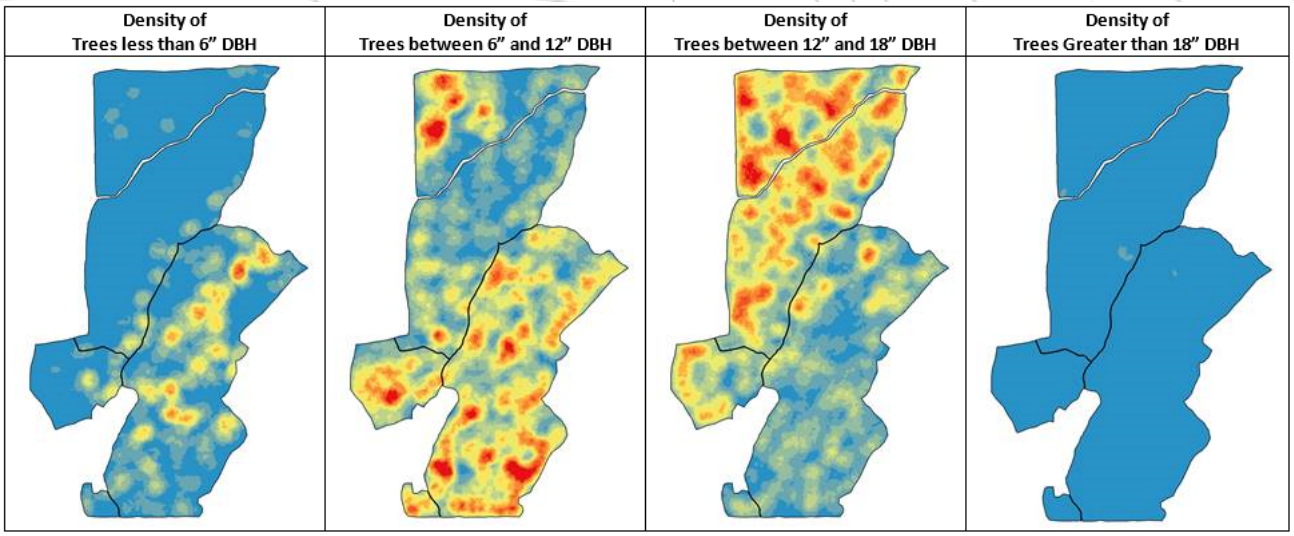
The point cloud allows users to “see” the forest, not just from above, but from the side, creating a digital forest. Helping people to evaluate the understory. This can help foresters calculate biomass or evaluate ladder fuels in remote locations. The images on the left show a vertical slide of the forest and the photos on the right show the forest condition.



Santa Fe National Forest, QL1 Lidar 2012
Image credit: Julie Luetzelschwab, USFS Region 3

Forest Structure

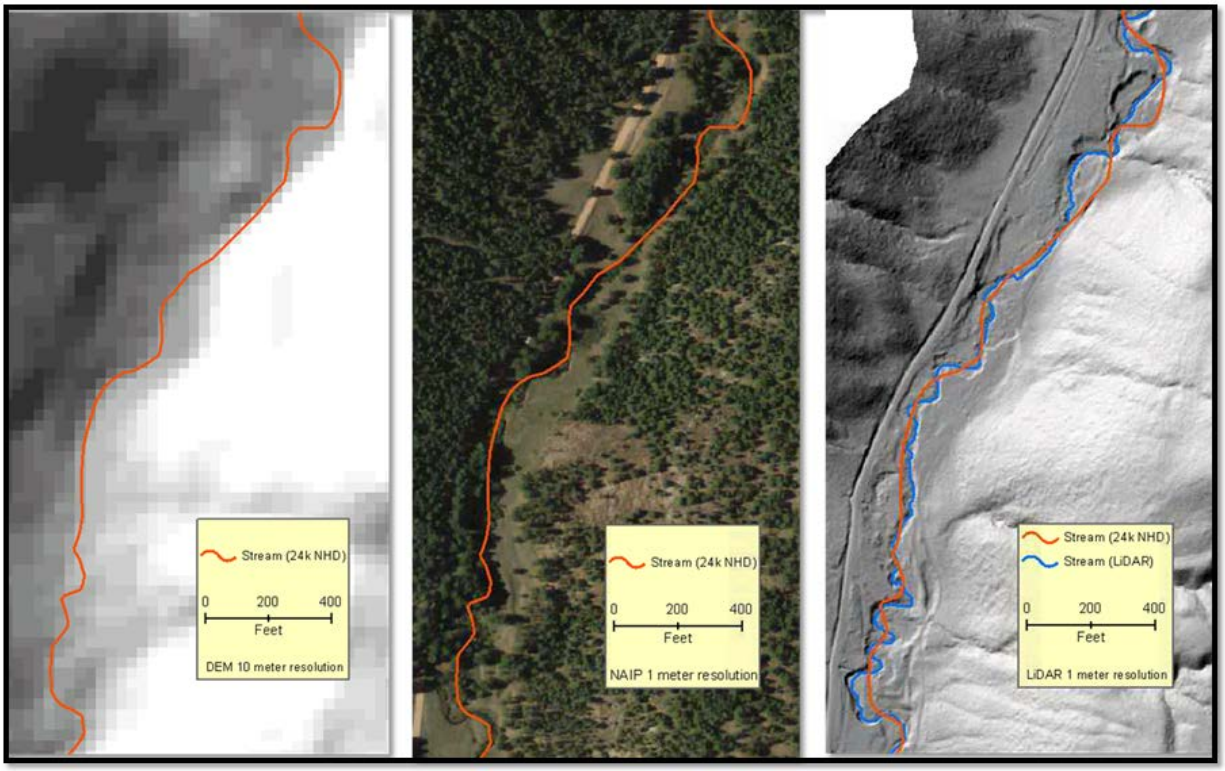
The lidar point cloud can be used to identify individual trees and tree heights. From that information tree size information can be modeled and summarized. Knowing the density and spatial distribution of trees of different sizes can help forest and land managers make better decisions. The image below displays a series of heat maps showing densities of trees of different sizes within a forest restoration project.

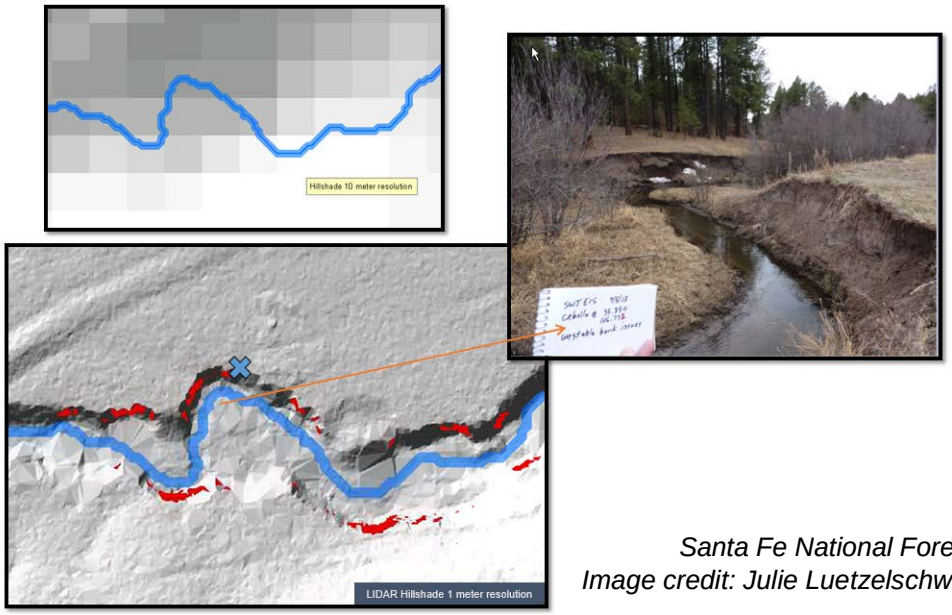


Coconino National Forest, QL1 Lidar 2017
Image courtesy of USFS Region 3

Stream Mapping

Mapping of stream and water channels using 10m DEM or NAIP can be difficult. Ten-meter DEM do not offer high enough quality and trees can obscure critical information. LiDAR ability to “see” through the trees leads to high quality stream data. This information is critical in flood modeling and post fire damage assessment and mitigation.

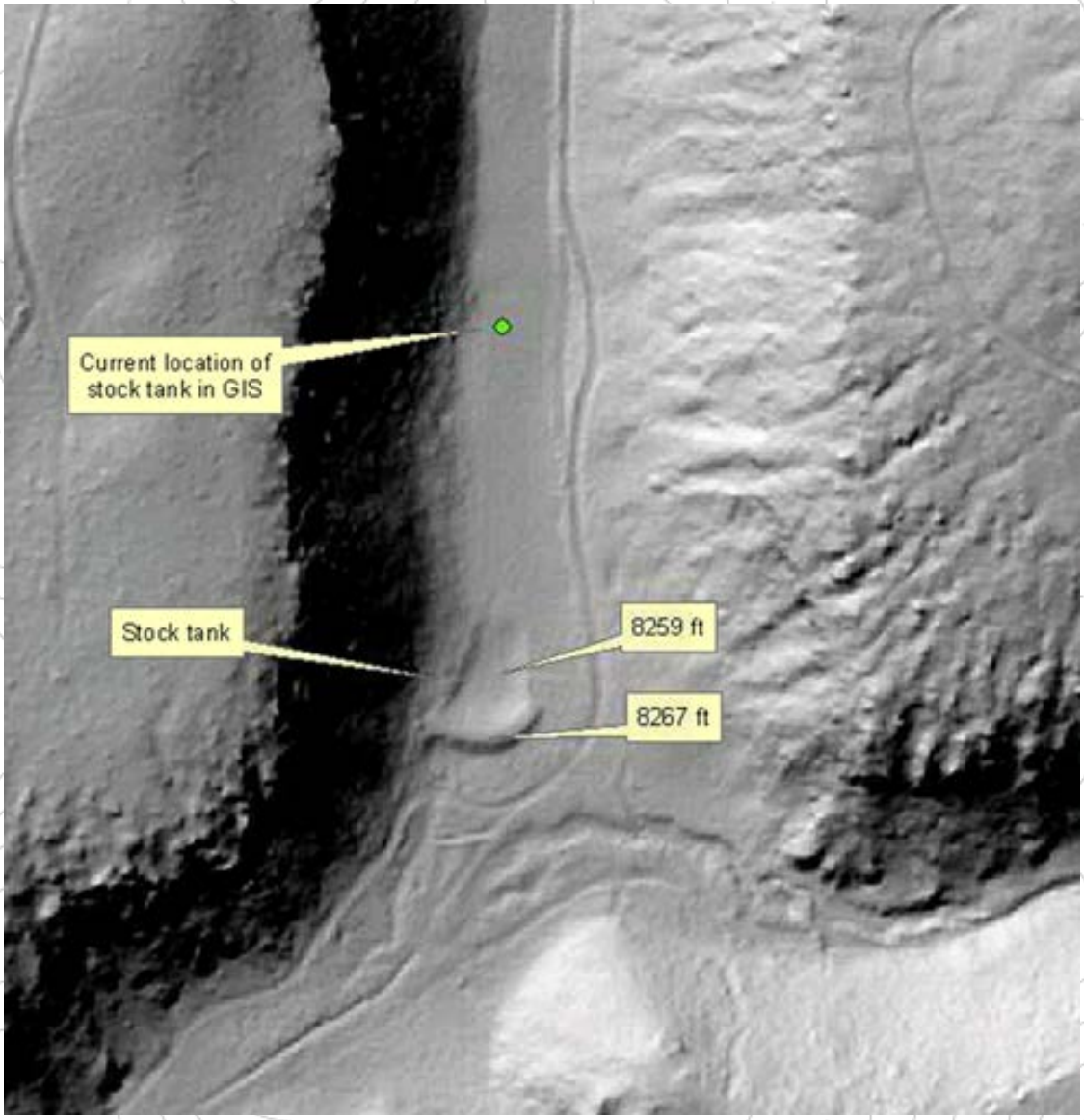




Santa Fe National Forest, QL1 Lidar 2012
Image credit: Julie Luetzelschwab USFS Region 3

Feature Mapping

Lidar can provide detailed information about man-made structures. Below is an example of a stock tank. The GIS information has a point in the wrong location. The point can be fixed and the amount of water the tank can hold all can be determined more accurately and with less cost than going into the field.



Santa Fe National Forest, QL1 Lidar 2012
Image credit: Julie Luetzelschwab USFS Region 3