State of Kansas

Geographic Information Systems
Business Plan

Improved Elevation Data for Statewide Applications

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Table of Contents

1. EXECUTIVE SUMMARY

This plan is intended to facilitate the acquisition of high-resolution digital elevation data for the State of Kansas, which is a programmatic goal identified in the new Kansas GIS Strategic Plan. Improved elevation data is needed to strengthen the state's preparedness for flood events, to protect the health and safety of Kansans, and to mitigate damages from flooding. Elevation data is a multi-purpose resource, however, and benefits will extend beyond flood map modernization to other applications as varied as dam safety assessment, transportation modeling, precision agriculture and soil mapping, correction of aerial photography, and urban planning.

There exist several cost-effective technology options to capture improved digital elevation data for the entire state, which is essential to modernize elevation models and contours that are decades old and too coarse (i.e., 10-foot interval) for most of the abovementioned applications. For example, experience in other states has shown that financial return on investment is high from applying modern technology such as LiDAR and related methods to develop high resolution contours (i.e., two-foot interval or better), which are significantly more useful and accurate than currently available statewide elevation data.

In Kansas, no single department is currently responsible for statewide acquisition of elevation data, but many would benefit. Therefore, the State GIS Coordinator under the Chief Information Officer (CIO) has led the collaborative effort to plan for this program initiative, for the benefit of all GIS stakeholders in Kansas. Participants in the planning process are acknowledged in Appendix D of this document.

The acquisition of improved elevation data is a multi-year effort. A phased approach is described in this plan, spanning a three-year period for program development activities and milestones, and a seven-year budget cycle to fully cover the State with improved elevation data and related product deliveries. For budgeting purposes, the essential base data assumes a cost of $90 per square mile for LiDAR acquisition, or over $7 million for the entire state (rough order of magnitude). Additional data products can be derived from the base data, adding to the total investment. For example, improving from the current 10-foot elevation contours to the two-foot contours needed for flood map modernization would add another $95 per square mile, which can be invested on a prioritized, task order basis to spread costs over time.

2. GOALS FOR THE PROGRAM

This Business Plan is a follow-on action to the Kansas GIS Strategic Plan, and is focused on one of five programmatic goals. The Strategic Plan enumerated the full set of goals, as follows:

- Develop improved statewide elevation data that will support two-foot contours to support detailed topographic mapping necessary for a multitude of critical applications and risk determination
- Development of a long-term, sustainable funding strategy that will enable Kansas to better sustain its spatial data infrastructure
- Explicit outreach to the Kansas Department of Revenue to pursue the goal of a statewide parcel data layer
- Develop a coordinated approach for statewide critical infrastructure mapping
- Develop a program for electronically managing and disseminating existing geodetic control points to the public

Several factors influenced the selection of improved elevation data as the focus for a Business Plan. The urgency of need for improved elevation data, in light of flooding and other risks to public health and safety, is high. At the same time, the effectiveness of new data acquisition methods, such as LiDAR, is achieving widespread success and acceptance across the nation. Notably, LiDAR has been applied inside the state on the Kansas River Corridor project, and on the national 133 Urban Areas Program in the City of Wichita (see Section 4, Program Requirements). Acquisition of improved elevation data is especially important, since, according to the National Research Council (NRC), *"The principal factor impacting the reliability of the floodplain boundary delineation is the quality of the input digital elevation information"* (National Research Council Committee on Floodplain Mapping Technologies 2007).

Programmatic Goal and Objectives

Programmatic Goal	Develop improved statewide elevation data that will support two-foot contours to support detailed topographic mapping necessary for a multitude of critical applications and risk determination
Objective 1:	Identify elevation program management team who will champion the project forward
Objective 2:	Gather core requirements and expectations for stakeholder community
Objective 3:	Analyze current and near future high resolution elevation data collection efforts to determine the necessary geographic extent of the program
Objective 4:	Evaluate available technologic options and approaches for suitability
Objective 5:	Determine data storage and other management strategies, including mechanisms for promoting the availability of the data and its applicability, and distribution details
Objective 6:	Request program cost estimates from qualified solution/data providers based on a scope of work

Objective 7:	Identify and pursue program funding source(s); encumber funds
Objective 8:	Develop technical specifications, determine acquisition criteria, and procure services according to scope of work
Objective 9:	Advertise and make available project deliverables to stakeholders
Objective 10:	Conduct post-project assessment, including scoring of success factors and lessons learned

3. PROGRAM JUSTIFICATION AND BENEFITS

Applications

Acquisition of improved elevation data is justified through immediate, tangible benefits of statewide relevance. One of the desired products – elevation contour lines at two-foot intervals – is a considerable improvement over existing statewide USGS data (i.e., contour lines at 10-foot intervals). The following table summarizes the breadth and variety of beneficial applications, with six specific application areas highlighted in greater detail.

Discipline	Application(s)
Flood Prediction and Mitigation	• Floodplain delineation • Flood prone properties • Risk determination and insurance assessment • Flood flow characterization (e.g., direction, velocity, and depth) • Flood preparedness • Evacuation planning • Reverse E-911 proactive notification
Dam Safety Assessment	• Dam hazard rating • Site selection • Dam flood stage rating and structural analyses • Dam flood prediction • Levee integrity and capacity • Emergency management plans
Precision Agriculture and Soil Mapping	• Heavy equipment routing and fuel savings • Optimization of fertilizer application • Irrigation optimization • Contaminant runoff • Landform verification • Topographic exposure to wind and wind

Discipline	Application(s)
	erosion modeling • Water erosion • Downstream soil deposition modeling
Orthorectification of Aerial Imagery	• Correction of aerial photos with digital elevation models • Topographic feature identification (e.g., spot heights and breaklines)
Transportation	• Transportation corridor planning • Volumetric calculations: critical cut and fill operations • Landslide risk • Ecological impacts of projects • Slope determination to support site suitability studies • Highway drainage analysis • Bridge safety, scour analysis • Aviation terminal procedure evaluation • Subsidence monitoring
Habitat Characterization	• Arbovirus vector habitats (mosquitoes) • Landscape-level ecologic studies (e.g. stream bank habitats) • Stream channel change • Vegetation classification
Urban Planning	• Steep slope/hazard overlay • Hillside development • Facility permitting • Characterization of structures • Impervious surface studies • Site suitability studies • Change detection • Construction planning • Subsidence detection • Stormwater Management
Watershed Analysis	• Flood pool analysis of federal reservoirs for water supply protections • Total Maximum Daily Load (TMDL) best practices • Spill containment flows • Run-off coefficients
Emergency Response	• Vulnerability assessments of critical infrastructure • Staging area siting

Discipline	Application(s)
	• Animal burial siting • Public safety tower siting and deadsite identification • Hazardous material spill containment • Identification of vulnerable populations for response and planning prior to floods • Search and rescue in waterways • Line of sight analysis

Descriptive Use Cases: Benefits for Kansans

Benefits of improved elevation data have been demonstrated through many specific use cases. Below is a representative sample of the breadth of ways improved elevation data can be used, or is already being put to use, in the State of Kansas.

Flood Prediction and Mitigation

Kansas is prone to regional flooding. Conditions that may precede a flood include unusually hard rain over several hours or steady substantial rain over several days. Spring floods in Kansas may occur with rains that coincide with spring thaw. In Kansas, the flood season runs from mid-March into the summer (July), but the state can see autumn floods after periods of substantial rain. Flooding poses risks to people and property; business and government operations; and cultural, historic, and natural resources, as well.

Floods in Kansas can result from natural and man-made causes. Melting of winter snow and spring rain can cause river flooding, when water from a river basin fills up overflows into the neighboring areas. Over long timescales, 50 years or 100 years for example, most rivers have some risk of flooding. A flash flood is distinguished by onset of six hours or less. Like a river flood, a flash flood may occur after substantial rainfall. In a flash flood, the saturated ground cannot absorb the fallen water, and the runoff quickly collects and pools in low-lying areas. Man-made surfaces that are impervious, such as pavement, increase the speed of runoff. Another type of flash flood follows the failure of a water barrier such as an ice dam or a man-made dam.

Accurate floodplain characterization relies on high quality elevation information to map the shape of the land surface in three dimensions, which is critical in determining the likely direction, velocity, and depth of flood flows. To reduce the risk of damage to private property, communities develop floodplain management programs that consider both preventative and corrective measures. Early, accurate identification of flood-prone properties inform flood preparedness measures such as elevating structure or construction of levees. During emergencies, floodplain maps allow public safety organizations to establish warning and evacuation priorities. Requiring homeowners to obtain flood insurance through the National Flood Insurance Program (NFIP) for properties within the floodplain offsets a portion of the cost resulting from flooding.

To support the NFIP, the Federal Emergency Management Agency (FEMA) coordinates flood hazard mapping efforts. Nationwide, FEMA floodmaps are an average of 35 years old. In 2003 FEMA instituted the national Map Modernization Program to answer the nationwide call for better quality, newer flood hazard maps. Kansas is currently using LiDAR to update Digital Flood Insurance Rate Maps (DFIRMS) for the following six counties: Jefferson, Shawnee, Douglas, Riley, Pottawatomie, and Johnson. However, Kansas does not have a consistent, statewide dataset that meets FEMA's flood mapping requirements for detailed study areas, which are:

- Two-foot contour accuracy in flat areas
- One-foot contour accuracy in extremely flat areas
- Data acquisition should be within the last seven years to account for the effects of land development on flood elevations
- Flood depth at structures should be known for detailed study areas when flood insurance is obtained; the flood insurance rate for detailed study areas is based on the height of the first finished floor with respect to Base Flood Elevation (BFE), or the elevation to which floodwater is anticipated to rise during a flood; in other words, a modern flood map view should be three-dimensional, rather than just planar extent of a flood plain on a flat map

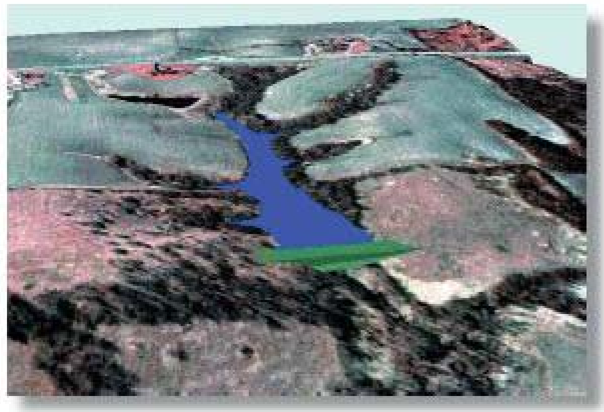
The National Flood Insurance Program is seriously undermined without accurate, current flood maps. Homeowners may be required to purchase flood insurance for properties incorrectly identified as within the flood zone, whereas at-risk homes remain uninsured and unprotected. Benefits of improved elevation for floodplain mapping include:

- Cost savings to homeowners, including accurate insurance assessments and reduction in expenses incurred from land surveys normally required for map revisions
- Improved siting of flood protection measures such as dams, levees, and bypass channels
- Improved floodplain regulation efficiency

<u>Dam Safety Assessment</u>

Models for dam breach inundation include, but are not limited to the following elevation parameters: reservoir capacity, including height and volume, and an accurate three-dimensional characterization of the downstream flood channel. Accurate cross-sectional analysis of reservoirs aids in dam site selection and structural analyses.

Dam breach inundation mapping with current and accurate elevation information is critical in lending credibility and confidence to county planning and zoning boards who will ultimately be making zoning decisions based on this type of information. The Natural Resources Conservation Services conservatively estimates an average cost between $500,000 and $1,000,000 to upgrade a dam that moves from a low hazard classification to a high hazard classification based on downstream development.



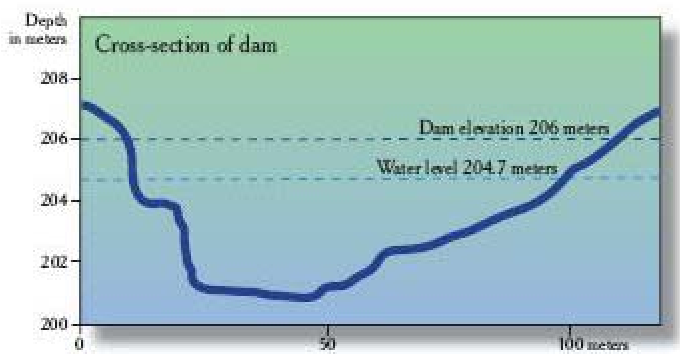


Image source: Iowa Geologic Survey. Resource Information Fact Sheet 2006-1.

Precision Agriculture and Soil Mapping

The environmental spatial variability exists within agricultural fields can have a direct impact on the quality of agricultural output. The application of remote sensing and mapping systems to provide spatially related data on crop, soil and environmental factors is increasing in the field of precision agriculture. Terrain and soil characteristics are highly linked; therefore having accurate terrain models at the local agricultural scale will help precision farmers better optimize their inputs with respect to existing nutrient resources. Furthermore, tractors, harvesters, chemical applicators and other precision agriculture equipment are now outfitted with Global Positioning Systems (GPS) devices that record not only latitude and longitude, but also elevation data which can feed into and refine precision agriculture models.

Orthorectification of Aerial Imagery

Orthorectification is the process by which the geometric distortions in an aerial image are removed, resulting in feature representation that is correct in two-dimensions. Ortho-rectified images can then be used as highly-accurate basemaps in a Geographic Information System (GIS). Usually, orthorectification involves removal of distortion caused by elevation. The resultant quality of the orthorectification is directly related to the accuracy of the input elevation model. Currently, the State of Kansas does not have an elevation model to support high-resolution orthoimagery acquisition.

Furthermore, having a statewide high-resolution DEM (e.g. produced from LiDAR) would provide cost-savings, particularly for transportation and engineering applications, that usually require the creation of survey DEMs on a project-by-project basis.

Transportation

Aviation:
The Kansas Department of Transportation Aviation Division conducts safety inspections of all 143 public use airports. These inspections are primarily concerned with obstacles that penetrate the approach surfaces to runways. LiDAR data could establish base maps for the airports. The creation of an overlay on that base map would permit the inspector to determine if obstructions were in critical areas. At present, the inspector attempts to calculate the distance of an object from a runway threshold. The inspector then calculates the height of the distant obstruction. Critical safety areas vary based on the type of airport that is being inspected whether or not an instrument approach is available for the airport. A safe glide slope may be 1:20 for a visual runway, 1:34 for a non-precision instrument approach or 1:50 for a precision approach. There are also safety areas to the side of the runway at a 1:7 ratio. Frequently, the controlling obstruction is a tree or other natural object. Local communities often express frustration that when a tree is removed, the tree behind it becomes the controlling obstruction. LiDAR could give a definitive answer to which trees must be cut to remove all obstructions. LiDAR would not replace the inspector. It would, however, provide a great deal of accuracy to the process and provide a very powerful tool for aviation safety.

Furthermore, the continuity of vital all-weather services at airports, such as air ambulance evacuation, is dependent upon instrument approach procedures. An instrument approach procedure is established by evaluating the terminal area or the area within 10 square miles of the landing surface. The procedure permits the pilot to safely traverse an area in low visibility conditions with absolute confidence that nothing is obstructing the aircraft's route to the airport. The height of all objects within the terminal area and the height of the landing surface determine the type of procedure that may be initiated through a Terminal Area Procedure (Terps) evaluation. LiDAR data could be used to quickly and easily identify potential obstacles to the creation of an instrument procedure prior to initiating an expensive survey. At present, the determination of a potential obstacle is done by sight inspection. Following a sight inspection, a review of the National Aeronautical Charting Office (NACO) Digital Obstacle File is conducted. The current method has two major weaknesses: 1) terrain may inhibit the ability to visually locate potential obstacles, and 2) natural obstacles are not contained in NACO Digital Obstacle File. The Digital Obstacle file itself also contains phantom obstructions that were placed in the file using estimated coordinates. LiDAR would verify existing obstructions and assist in the removal of phantom obstructions.

Highways:
The K-18 Corridor Study in Riley County studied options to upgrade K-18 to a freeway from Ogden to Manhattan. The Kansas Department of Transportation (KDOT) imported the KS-MO LiDAR elevation data into design software and used it as an existing ground surface where mapping or survey data were not available. This included many roadway alignments (until survey was finalized) and all drainage areas. The highway project included two major drainage studies adjacent to K-18 and the majority of drainage area and outfall were covered by LiDAR elevation data alone. These drainage studies, along with the preliminary roadway alignments, had a higher level of accuracy in existing surface with minimal cost than other methods available. Although the LIDAR elevation data used for K-18 does not appear to be accurate enough for final design, it could be used to reduce the area covered by aerial mapping or ground survey. If a new project was started today where LiDAR elevation data are available, the information would be accurate enough to carry the project through the study phase and possibly into preliminary design without significant ground survey, producing both a cost and schedule savings to the project.

<u>Urban Planning</u>

Accurate digital elevation models (DEM) of urban environments are required for a variety of urban planning applications related to engineering, construction, and utilities. Detailed Surface Elevation Models can be extracted from LIDAR data and enhanced using 3-D visualization software to create virtual-reality environments for modeling and analysis. Engineers and planners can design and visualize proposed structures. The DEM can also be used in conjunction with GIS and CAD software to enable planners and engineers to model various scenarios in choosing the best route or location for future construction. Engineering surveys of road and other construction projects use digital elevation models created from LIDAR data to estimate cut and fill quantities during the planning stages.

<u>Local Government</u>

Johnson County:
Johnson County has used LiDAR for a variety of projects. The LiDAR has replaced the pre-existing DTM and has served as the basis of newly derived contour data. The LiDAR data has also been used to get an average, minimum, and maximum height on buildings and an elevation on parcel centroids. The Planning Department has used the contour data to address floodplain-related inquiries including the amount of fill that would be needed for new construction in floodplains. The LiDAR data is available in a website viewer, and anyone with internet access can hover on the map and read elevations off visible LiDAR points. Recently a citizen was able to determine the elevations in an area and suggest alternative higher locations for a proposed cell tower.

Jefferson County:
Jefferson County regularly supplies elevation maps to internal departments and public citizens. The Road and Bridge Department requests maps with contour data during the planning stages of bridge and culvert repair. Depiction of slope and drainage areas is particularly helpful for these applications. Citizens have requested elevation maps for

water/sewer repairs, and an architect generated a 3D model of a forty-acre land parcel from LiDAR data in order to site a house for maximum energy efficiency.

City of Lawrence and Douglas County:
Kansas LIDAR data is being used by the City of Lawrence for watershed delineation and storm water flow calculations. The LIDAR data was also used to create an inundation map for the Kansas River if the Bowersock Dam were raised one foot. Lawrence and Douglas County had the LIDAR data processed into Digital Terrain Models (DTMs) that incorporate hydrography features and breaklines. The DTMs provide a quick reference of the terrain when viewing the city or county. The DTMs are also used to make a surface for cutting profiles and cross section to help get answers for preliminary design. Lawrence and Douglas County have also generated one-foot and two-foot contours from the LIDAR data.

City of Junction City:
Junction City is a smaller city of covering 11 sq miles with a population of approximately 23,000, but it has recently been dealing with growth issues stemming from its proximity to Fort Riley Military Reservation. Junction City used the LIDAR data to generate one and two foot contours over the entire city area. These contours were used in urban development designs and plans for new housing developments and golf courses, and highway, city sewer system, and storm water drainage improvement projects. A TIN layer was created to visualize some areas of the city in 3D view. These 3D views were used to demonstrate the geographic setting of the city for various purposes. A DEM was created to cover the area of the city. With these DEM many important decisions were made. In newly developed areas Emergency Alarm System were established with the help of the highest land elevations identified by this DEM. Also several elevation profiles were created to determine the flow of sanitary and storm sewer from some places of the city to other places. 3D modeling was done for engineering projects in specific locations of the city. One such was the boat landing site at the Republican River convergence with the Smoky Hill River.

<u>Military Reservations</u>

Fort Riley:
LiDAR has been used for .25 meter contour development to assist contractors and land managers in new range and facility construction planning. The data has also been used to update the streams and associated hydrography map layers which were originally created using 30-meter data. Quality elevation data also facilitates line-of-sight analysis and 3D presentation of landforms.

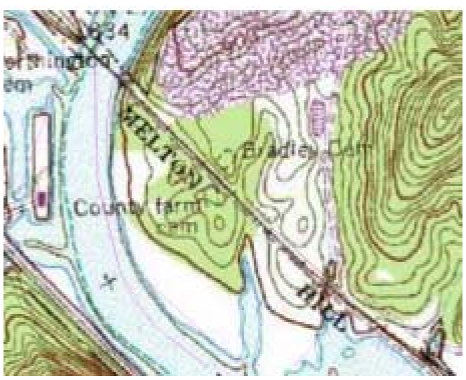
4. PROGRAM REQUIREMENTS AND COSTS

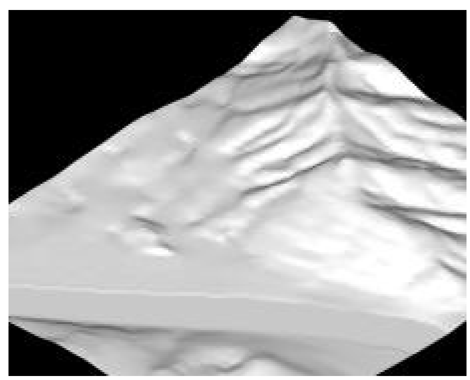
Inventory of Existing Infrastructure and Suitability Assessment

<u>Existing Elevation Contour Data</u>

The USGS Topographic Map Series is the most detailed statewide elevation dataset for Kansas. The nationwide map series shows contours and other natural and civic features. An additional product from USGS is the digitized contours from a topographic map, which are known as a hypsography Digital Line Graph (DLG). A derivative by-product from USGS digital elevation model (DEM) production is known as Tagged Vector Contour (TVC). The USGS has provided to the Kansas Data Access and Support Center (DASC) with TVCs from the 7.5 minute topographic quadrangle maps series for Kansas. The contour interval varies according to the particular quad, but most of the maps have 10-foot contours. Some contours may be absent, particularly where text labels obscured features in the original paper map version. This dataset has not been cleaned of other aberrations that may have been introduced into the digitization process.

Most of the contours in this map series were captured using photogrammetric techniques in the 1950's-1980's when the Topographic Map Series project was initiated. Features of many topographic quadrangles have been updated, but due to expense and complexity, the contours are not typically maintained. Therefore, derivative elevation products such as a DLG or TVC are typically outdated by many decades.





Left: Example USGS Topographic map with contours; Right: Shaded Relief from 10-meter DEM. Image Source: Topodepot.com

<u>USGS National Elevation Dataset (NED)</u>

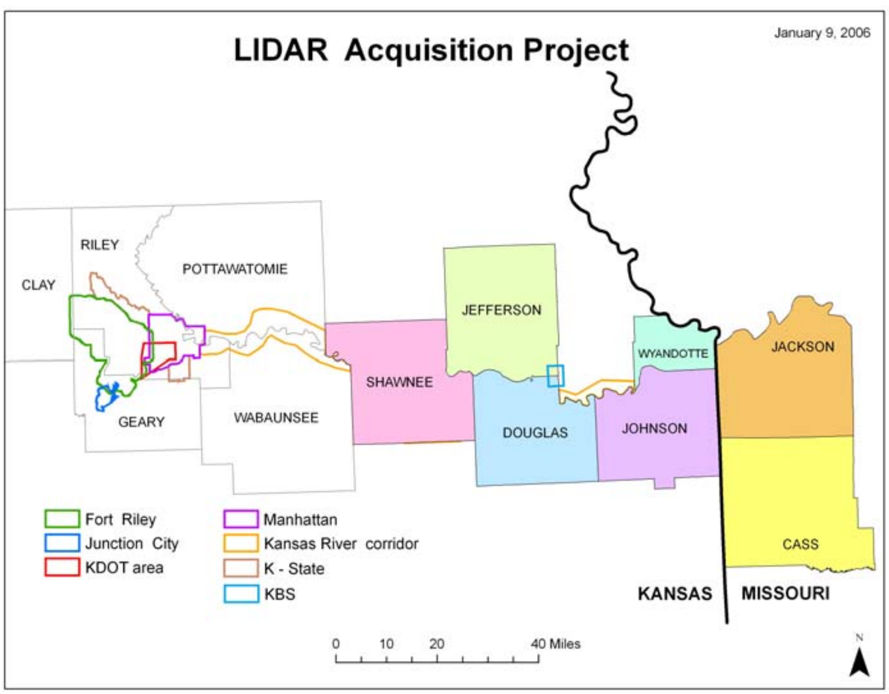
The USGS maintains nationwide elevation data known as the National Elevation Dataset (NED). These datasets are available publicly for free download from the USGS Seamless Data Distribution System. NED 1/3 Arc-Second products are available for 70% of the country, including complete coverage for Kansas.

Like the DLG and TVC, the NED is a derived product from the 7.5 minute topographic map series. Through a process of complex linear interpolation, the contour elevation information is resampled onto 10-m interval postings so that elevation is represented as a continuous coverage. The NED is sometimes referred to as a "high resolution" Digital Elevation Model (DEM), but it is not truly suitable for detailed studies at the large-scale (i.e. local) level.

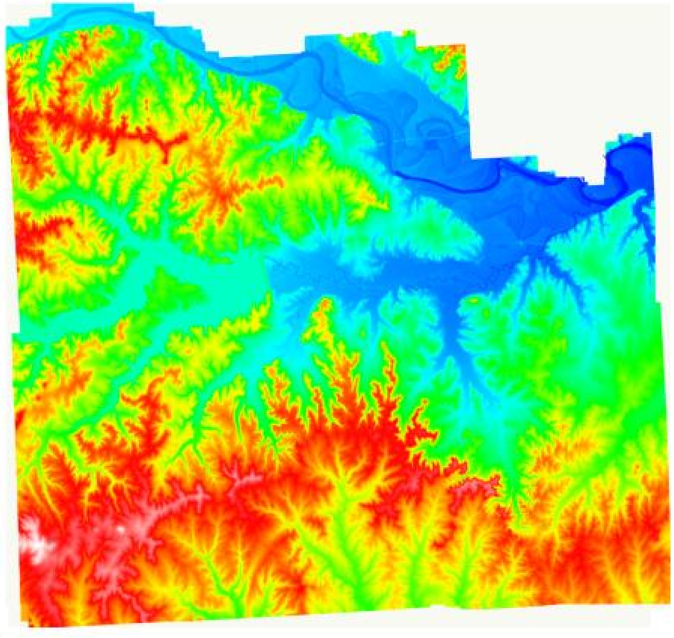
Kansas-Missouri LiDAR Project

In 2006 the USGS and 15 other partners, including five counties in Kansas and two in Missouri, conducted a Light Detection and Ranging (LiDAR) project in the Kansas River Corridor. LiDAR is a relatively new elevation acquisition technology whereby laser reflections are measured off distant objects. LiDAR can detect “bare earth” characteristics, which supports the creation of DEMs for the earth’s surface, minus man-made structures and vegetation. LiDAR bare earth DEMs are comparable to NED DEMs, but they are much higher accuracy and can be used at a larger geographic scale (e.g. small area studies). They have a wide range of uses for analytical studies and projects, from roadway and pipeline engineering to floodplain and wetlands mapping.

In the Kansas-Missouri LiDAR project, approximately 4000 square miles of terrain was captured in the total acquisition. Elevation points had a vertical accuracy of 15-18.5 centimeters on bare earth surfaces allowing two-foot contours to be generated by the partners. LiDAR product deliverables included filtered elevation points for the bare earth surface, elevation points of all the returns, triangulated irregular networks (TINs) surface of the bare earth, images of the intensity values of each return, and two-meter digital elevation models.



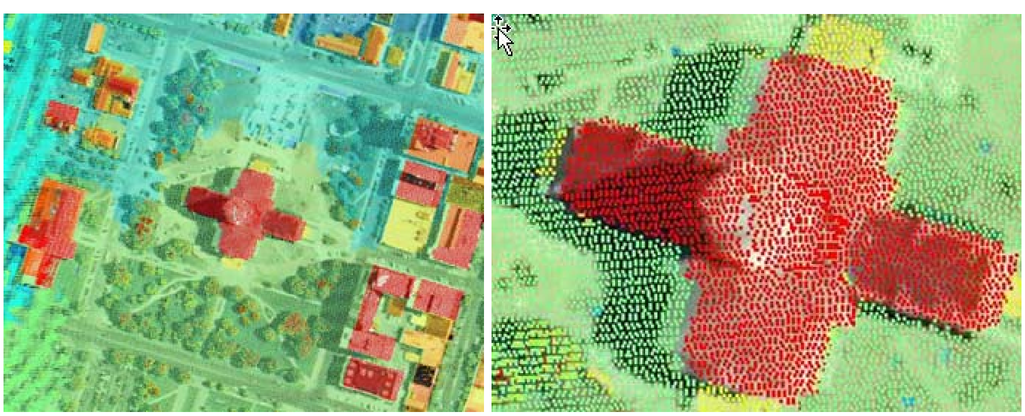
Extent of Kansas-Missouri LiDAR Acquisition. Image source: http://igskmncngs506.cr.usgs.gov/website/lidar/BB/index.php?act=attach&type=post&id=15



Douglas County digital elevation model of the bare earth surface derived from generalized LIDAR data. Image source: Douglas County GIS Department

<u>133 Urban Areas Program</u>

Through a partnership with USGS, the National Geospatial-Intelligence Agency (NGA) administers the 133 Urban Areas Program, which seeks to acquire high quality orthoimagery and high-resolution elevation data for 133 of the most populated metropolitan areas in the United States to meet critical Homeland Security and Emergency Services requirements. The flyovers are coordinated on a two-to-three year cycle. LiDAR data for Kansas City, Kansas and Topeka are publicly available at the DASC. The City of Wichita and Sedgwick County are both acquiring LiDAR in 2008.



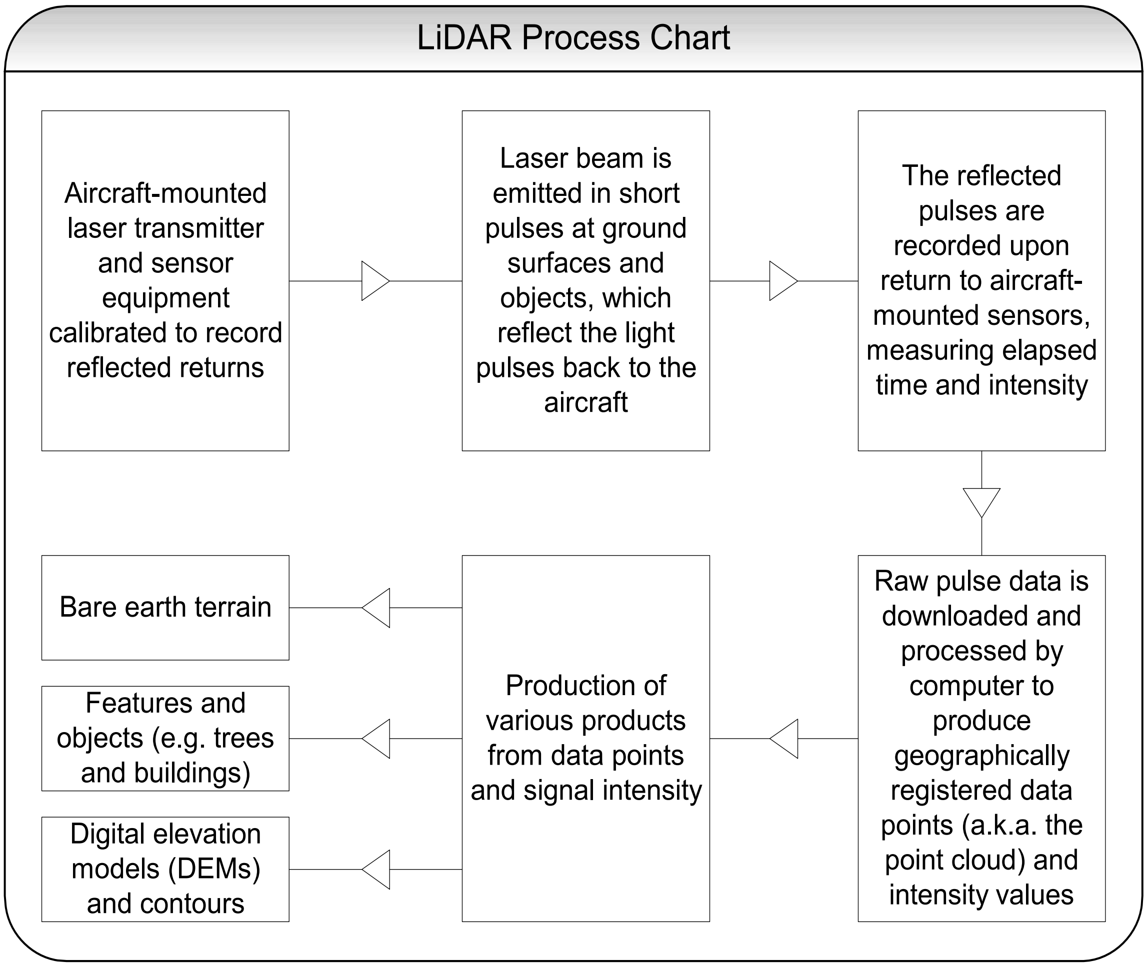
Raw LIDAR points of State Capitol Building in Topeka, KS. Image Source: Kansas State University

Technology Overview

This section is an examination of several popular technology options for high-resolution elevation data acquisition. Because technology rapidly evolves, this discussion is provided for background only. The appropriate selection of a technology would be conducted in the context of carefully articulated user requirements.

Acquisition Approach	Technology Framework	Strength and Benefits	Caveats and Limitations
Photogrammetry	Uses several views (from multiple images) of the same point on the ground from two perspectives to create a three-dimensional image (i.e. stereoscopy)	Mature, perfected technology, well-established best practices Compromised by leaf-on conditions and cloud cover	Most expensive and time-consuming option; usually cost prohibitive for large geographic areas
Airborne Light Detection and Ranging (LiDAR)	Airborne laser scans a target and returns a cloud of points	Significantly reduces cost for two-foot contours over traditional photogrammetric techniques Ideal for large areas Can be conducted day or night or in cloud cover Can capture bare-earth and built features	Accuracy tied to precise calibration of sensor equipment More echoes required to hit a hole in canopy of densely-vegetated areas Millions of returns can lead to production of large file sizes.
Interferometric Synthetic Aperture Radar (IFSAR)	Using sophisticated antennae, airborne Radar sensor measures echo from a target	Suitable for global-scale missions.	Accuracy depends on precise instrument calibration, quality of reflective surface model Generally less accurate than photogrammetry or LiDAR Requires sophisticated image post-processing, photo interpretation
Lidargrammetry	Hybrid approach between LiDAR & photogrammetry techniques	Cost-efficiencies gained by blending image and elevation acquisition into one flyover mission	Relatively new approach, best practices not established. Planimetric accuracies not well-documented
Terrestrial LiDAR (a.k.a Industrial LiDAR)	Scanning laser mounted on a tripod, vehicle, or other ground-based elevated platform collected 3-D points from oblique (side) reflections	3-D capture method, ideal for volumetric data that may not be detected in an aerial flight survey	Logistically impractical for large survey areas Must be georeferenced using high-accuracy control points, usually GPS Quality of data also relies on precise laser leveling

The following figure illustrates the process of capturing improved elevation data using LiDAR for data acquisition. LiDAR employs an aircraft-mounted laser beam to collect many millions of signal reflections returned from objects and surfaces below the flight path. These returns are recorded by aircraft-mounted sensors and are referred to as point "clouds" because they are recorded in three dimensions. These 3D point clouds can be used to effectively produce high resolution elevation models and contours.



By comparison, orthoimagery uses an airborne digital camera to capture images, not points, which are then post-processed using an elevation model to correct for geometric distortions in the raw imagery. A DEM derived from LiDAR can be used to help produce orthoimagery. Both LiDAR and orthoimagery are important for statewide applications, and programs for each should be synchronized for maximum synergy.

Data Requirements and Standards

During the State of Kansas Strategic Planning effort, stakeholders articulated the specific need for a two-foot or better contour product to advance the aforementioned applications (see Section 3), which would be a five-fold increase in the spatial accuracy of the current available data. A significant improvement in the elevation data acquisition is needed to support the creation of these contours. A high-resolution digital elevation model (DEM) is also needed, which might be enhanced by including breaklines and independent control points known as “spot elevations.” Lastly, the elevation products must support FEMA guidelines for modern floodplain mapping.

National Digital Elevation Program Guidelines

A treatment of all the standards related to digital elevation data is beyond the scope of this document. Elevation data acquisition is a highly technical subject, and available technologies are evolving quite rapidly. The National Digital Elevation Program has published comprehensive guidance and recommendations for acquiring high resolution digital elevation data in any of its various forms (see National Digital Elevation Program, 2004). Content in this work includes discussion of surface models, data sources, derived products and file formats in the context of specific application areas.

National Standards for Spatial Data Accuracy (NSSDA)

In 1998, the Federal Geographic Data Committee (FGDC) published the National Standard for Spatial Data Accuracy (NSSDA), which is a statistical approach for characterizing positional accuracy that is appropriate for digital map products (FGDC 1998). The NSSDA is defined such that:

- Removal of systematic error will leave error that is normally-distributed
- Study dataset should be compared to a reference dataset that is three times more accurate
- Root mean square error (RMSE) between study and reference reported at an established confidence level.
- Accuracy may be reported as “equivalent contour interval accuracy.” For example, for two-foot contours, 90 percent of tested points will fall within one foot of the reference, or one-half the contour interval.

In other words, the proposed elevation project must achieve one-foot equivalent contour interval accuracy for two-foot contours (Association of State Floodplain Managers Mapping & Engineering Standards Committee, 2004).

Technology-Specific Guidelines

Essentially, the State of Kansas should expect that elevation data acquisition proposals to adhere to existing standards relevant to the proposed technology and mapping application (e.g. floodmaps). For example, FEMA has published specifications for LiDAR data collection for flood hazard mapping (see Federal Emergency Management Agency, 2002 and Appendix C).

Budget Requirements

Elements

Regardless of choice of technology, the elevation data project would have the following general line items that must be considered in a detailed cost proposal:

- Acquisition activity
- Infrastructure to store and distribute data
- Data management and handling, including quality control
- Project administration
- Derived products, including a digital elevation model, terrain model, and contours

Range of Costs

Elevation data costs vary considerably according to technologic approach, geographic extent of coverage, and requirements for deliverables. On the least expensive end of the spectrum, base LiDAR for the entire state of Kansas may be acquired for approximately $90 per square mile for FEMA grade 1.4 meter post spacing, or approximately $7.2 million. On the opposite end of the cost spectrum, a traditional photogrammetric approach from aerial imagery could increase costs significantly for two-foot contours. Deriving contours from aerial imagery using photogrammetry is many times more costly than using LiDAR.

The addition of two-foot contours would increase the per-square mile costs to $185 per square mile, or $14.8 million for both base LiDAR and two-foot contours, statewide. Breaklines, which would prevent contours from crossing lakes, could also be added for an additional $140 per square mile (total cost of $26 million), however LiDAR contours have very high definition of roads and other features and breaklines are arguably not necessary. The state can use the base LiDAR intensity to generate breaklines in the future if they are needed.

Generally, there exist economies of scale with respect to statewide digital elevation data capture; in other words, the per-area cost decreases with increasing geographic coverage extent. Therefore, it is desirable to establish a program of capital investment in a statewide base layer, repeated at a regular interval (e.g. repeated every seven years as advised by FEMA elevation guidelines for detailed study areas).

The reader will find a detailed Implementation Plan in Section 6 of this document, including a “Budget Plan and Schedule” which suggests a project schedule with estimated costs split-out by year, based on a phased approach. A potential approach for phasing is to divide the state into project areas, as suggested in Section 6, “Consideration of Project Areas.”

Lessons Learned in Other States

Kansas can benefit from the experience of other states that have already moved ahead with statewide programs for improved elevation data. Lessons learned in the states of North Carolina and Iowa are provided in this section, to illustrate some of the challenges as well as the benefits of their efforts.

State of North Carolina Case Study

The State of North Carolina is prone to flooding because of frequent hurricane activity, with annual flood damages of $56 million (Smith 2002). A devastatingly large hurricane, such as Hurricane Floyd that swept through the state in 1999, can cause damage on the order of billions of dollars.

To address the State's human toll and financial burden from flooding, North Carolina initiated a statewide digital elevation data project, a comprehensive floodplain map modernization program, and a real-time flood warning and inundation prediction system (North Carolina Floodplain Mapping Program 2003). FEMA agreed to let the state assume responsibility for floodplain map modernization through it Cooperative Technical Partners Program, and the Program received appropriated funding from the governor and state legislature for statewide LiDAR data. The total geography of 48,000 square miles was broken down into three flyover areas based on dominant topography, and the collection was conducted sequentially in phases.

Now, local government agencies have current, high accurate maps with which to make better administrative decisions; the map update process has been streamlined due to all-digital map products known as FEMA Digital Flood Insurance Rate Map (DFIRM); and the analysis of the LiDAR dataset has also been widely adopted into the business processes of numerous state agencies, from Transportation to Forestry.

State of Iowa Case Study

With funding from the State's Department of Transportation (DOT), Department of Natural Resources (DNR), Department of Agriculture, and the Natural Resources Conservation Service (NRCS), the State of Iowa has been conducting LiDAR data acquisition for the entire state because improved elevation data would improve government efficiency and achieve significant cost savings. For example, the DNR identified $390K annual cost savings for planning level surveys. The NRCS estimated that they might achieve $3-5 million annually in their efforts to conduct Water Quality Best Management Practices (BMPs) activities, and the DOT estimated that with LiDAR data they could shave 1-3% off their billion dollar budget for applications such as cut and fill, preliminary design, road grading, new roads, and line of site studies for passing lanes. Similar to North Carolina, Iowa broke down the acquisition project into three distinct phases. As of November 2007, approximately 28% of the entire state (56,343 square miles) has been collected in part or in full (Iowa Department of Natural Resources 2007).

State of Louisiana Case Study

The state of Louisiana initiated a statewide LiDAR project in 2000 to offset the severe costs due to repeated coastal flooding (Cunningham 2004). FEMA has provided funding and the State of Louisiana has provided matching funds The original project sponsor was the Louisiana Oil Spill Coordinators Office (LOSCO), with subsequent administration conducted by the Louisiana Office of Emergency Preparedness. The project has been conducted in phases over an eight-year project schedule. The first phase was focused on acquiring LiDAR-based elevation data in wetlands, forested, agriculture, and developed terrain; however, subsequent phases prioritized acquisition of data in areas where flood insurance maps needed modernization (Stoker et al 2007).

Currently, the LiDAR data are downloadable via web from Louisiana State University. As of February 2007, approximately 35,000 square miles of LiDAR data were available. The information aided the emergency response immediately after Hurricane Katrina and providing models to enhance the understanding of the storm's impact and stresses on the city levees.

5. ORGANIZATIONAL APPROACH

Program Management Concept

Digital elevation data require technical expertise to procure and apply. No single department is currently responsible for statewide acquisition of elevation data, but many would benefit. Therefore, it is fitting for the State GIS Coordinator who serves as the GIS Director under the Chief Information Officer (CIO) to lead the program initiative, for the benefit of all departments.

Specific steps have been defined elsewhere in this plan on what needs to be done. This section describes who will be responsible. The overall organizational approach will be coordinated by the State GIS Coordinator, and executed by the GIS Manager of DASC, with support from major departmental stakeholders in the program.

The State GIS Coordinator will be responsible for procurement and funding coordination, and the DASC GIS Manager will be responsible for acceptance of product deliverables, data management and dissemination. Individual departments and representatives on the GIS Technical Advisory Committee will provide support to the program effort, including consultation and input on technical specifications.

Program Participants

The following is a list of participants and their general role in the program to acquire improved elevation data for statewide applications. The purpose of this section is to establish accountability for implementation of the program.

Program Executive Sponsor: Tracy Streeter, Chair, GIS Policy Board

Program Director: Ivan Weichert, GIS Director, Department of Administration, Division of Information Systems and Communications (DISC)

Program Technical Advice: GIS Technical Advisory Committee (TAC)

Program Technical Manager: Ken Nelson, Manager, Data Access and Support Center (DASC)

Stakeholder Support: Kansas Department of Transportation (KDOT); Kansas Water Office (KWO); Kansas Department of Agriculture (KDA); Kansas Geological Survey (KGS); and others to be named by GIS Policy Board as appropriate

Federal Program Liaisons: Ingrid Landgraf, United States Geological Survey (USGS); Travis Rome, Natural Resources Conservation Service (NRCS)

6. IMPLEMENTATION PLAN

Consideration of Project Areas

The State of Kansas could adopt an incremental approach for developing the data products (e.g. two-foot or better contours) from the base LiDAR data. This approach would entail prioritizing areas of the state and, for example, defining project areas based on geographic criteria, such as according to watershed, along major streams, or perhaps according to expansions of metropolitan areas, with cost-sharing by project or area sponsors.

Activities and Milestones

Objectives for achieving the programmatic goal of improved elevation data were defined in Section 2 of this Business Plan. These objectives are further broken down into activities and milestones on a tentative schedule in the following section, by Fiscal Year (see chart, below):

Activities and Milestones	FY 2009	FY 2010	FY 2011
Objective 1: Identify elevation program management team who will champion the project forward			
1.1 Develop short, medium, and long term coordination and planning objectives	✓		
1.2 Assign priorities and develop oversight and management protocols	✓		
1.3 Obtain GIS Policy Board approval	✓		

Activities and Milestones	FY 2009	FY 2010	FY 2011
Objective 2: Gather core requirements and expectations for stakeholder community			
2.1 Meet with all appropriate agency representatives to develop a state-of-the-state elevation use and needs picture	✓		
Objective 3: Analyze current and near future high resolution elevation data collection efforts to determine the necessary geographic extent of the program			
3.1 Conduct spatial analyses to determine data gaps with respect to spatial and temporal coverage in current and near future data holdings.	✓	✓	
3.2 Finalize flyover coverage area	✓		
Objective 4: Evaluate available technologic options and approaches for suitability			
4.1 Conduct cost-benefit analyses of data acquisition approaches for study area	✓		
4.2 Evaluate technologic options against user requirements and expectations	✓		
Objective 5: Determine data storage and other management strategies, including mechanisms for promoting the availability of the data and its applicability, and distribution details			
5.1 Establish and maintain Internet website for the sharing of elevation-related news and information	✓	✓	✓
5.2 Create and maintain data download portal	✓	✓	✓
5.3 Locate hardware and purchase software	✓		
Objective 6: Request program cost estimates from qualified solution/data providers based on a scope of work			
6.1 Communicate expectation and requirements	✓		
Objective 7: Identify and pursue program funding source(s); encumber funds			
7.1 Identify multiple potential funding streams Produce and circulate project fact sheet	✓		
7.2 Obtain legislative support	✓		
7.3 Identify key partner agencies	✓		
7.4 Secure funding	✓		
Objective 8: Develop technical specifications, determine acquisition criteria, and procure services according to scope of work			
8.1 Coordinate procurement for base LiDAR project	✓	✓	
8.2 Develop technical specifications	✓		
8.3 Determine acquisition criteria	✓		
8.4 Select service provider(s)	✓		
8.5 Schedule and conduct flyover	✓		
8.6 Review/QC pilot deliverables		✓	
8.7 Review/QC final deliverables		✓	
8.8 Coordinate procurement for for production of product deliverables (e.g., contours)		✓	

Activities and Milestones	FY 2009	FY 2010	FY 2011
8.9 Develop technical specifications		✓	
8.10 Determine acquisition criteria		✓	
8.11 Select service provider(s)		✓	
8.12 Schedule and conduct Pilot Test		✓	
8.13 Review/QC pilot deliverables		✓	
8.14 Review/QC final deliverables			✓
Objective 9: Advertise and make available project deliverables to stakeholders			
9.1 Load data inventory content and extended metadata			✓
9.2 Hold Data User Workshops to promote the data products			✓
Objective 10: Conduct post-project assessment, including scoring of success factors and lessons learned			
10.1 Identify success stories			✓
10.2 Analyze project with respect to scope and budget			✓
10.3 Document lessons learned			✓
10.4 Communicate findings to stakeholders and peer community.			✓

Budget Plan and Schedule

The State GIS Coordinator, working with the Program Team, will develop a budget based on this plan and will determine appropriate methods of funding. Rough Order of Magnitude (ROM) numbers are provided in Section 4, earlier in this document. Decisions need to be made on the most viable approach to funding, which may include breaking the project into phases, and setting-up cost-shares for the program amongst major stakeholders. The following is an outline of some of the important considerations to the budget plan.

<u>Legislative Appropriation</u>

- Synchronize timing with state budget cycle and Fiscal Year
- Identify political champion

<u>Agency Cost-Share</u>

- Cost-sharing breakdown
- Lead agency identification
- Need agency contract agreements

<u>County Cost-Share</u>

- County buy-in and/or buy-up program
- Counties by watershed cost-sharing

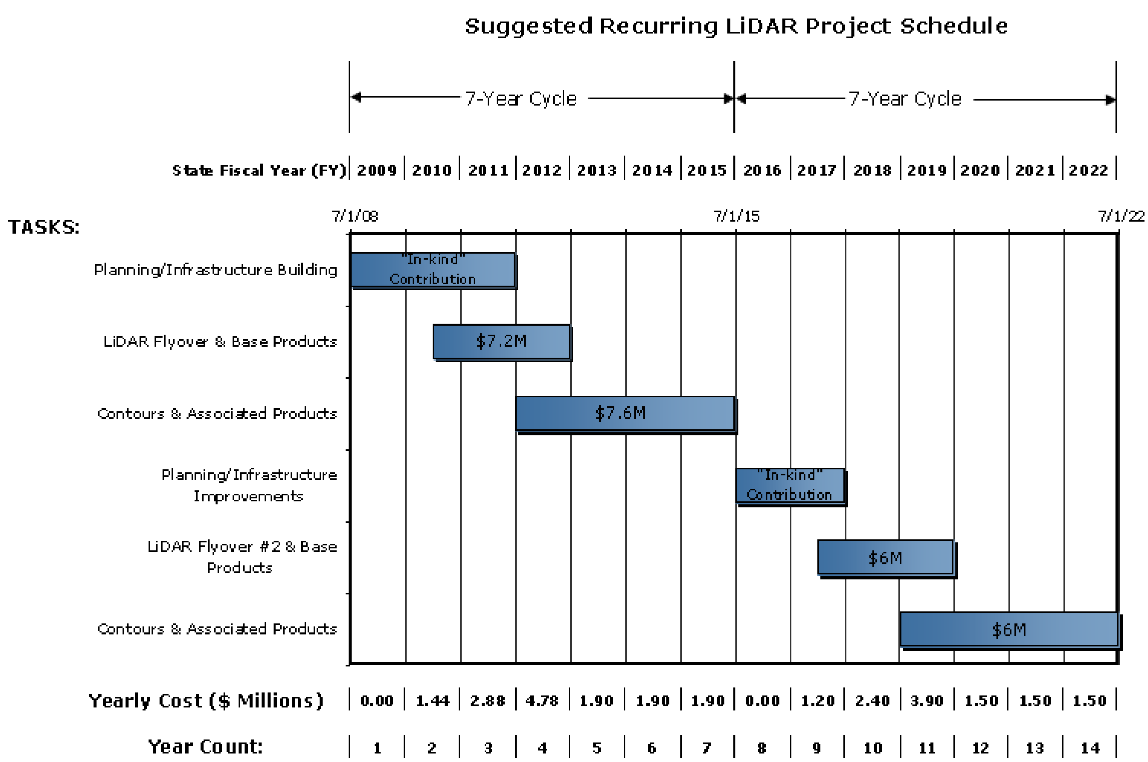
Federal Funding Sources

- FEMA Map Modernization funds
- Geodetic control modernization
- USGS Cost Sharing

Funding Requirements Across Time

The long-term funding requirements account for two 7-year cycles, which is the frequency recommended by FEMA for updating contour data. Costs and project tasks are broken down by year. It can reasonably be assumed that technology will continue to improve, and costs will continue to come down, so estimates for the second 7-year cycle should certainly be revisited during the project cycle. The rough order of magnitude estimates herein are for budgetary purposes only.

After a project planning period starting in FY09 (July 2008-June 2009), the LiDAR flyover is scheduled to start mid fiscal year 2009, which is the first quarter of calendar year 2009. The flyover can be done incrementally by targeting different areas of the state on a sequential basis (see “Consideration of Project Areas” at the beginning of this section). Separate from the flyover, the production of products is a follow-on activity, and can be staggered to begin after initial coverage is obtained for each geographic project area. The following diagram illustrates a conservative and incremental data acquisition and budget schedule.



Year Count: 1 2 3 4 5 6 7 / 8 9 10 11 12 13 14

Product production could begin sooner than FY11 based on completion of specific areas of base coverage on a prioritized basis. A test area can be designated as a "pilot project" to validate product specifications and quality control. Also, depending on participants in cost-sharing arrangements, some areas may choose to produce products on their own, using the base data and DEM provided by the State. There is precedent for this, on the Kansas River Project, for example.

Marketing Outreach

Improved elevation data may not sound very exciting by itself, but in the context of the seriousness of flooding and destructive storms, its importance becomes elevated on the stage of public opinion. Because it also involves newer but proven technologies, Kansas has an opportunity to show national leadership on adopting best practices for the benefit of its citizens. Positioning this project in such a manner will enhance its probability of success, by raising its visibility and building support for its purpose. The following is a sample list of actionable items, which could be articulated in a Marketing Plan outside the scope of this Business Plan, by the Program Team.

- One-page flyer on the benefits
- Project portal and website
- Stakeholder workshop on the program details
- Presentation for department heads
- Presentation for legislative committees

Measuring Success, Feedback, and Recalibration

The programmatic scorecard provides a quantitative mechanism for determining what level of progress has been achieved over time. Assessing progress against proposed 'targets' provides a ready means to determine the current success level. If necessary, adjustments to the implementation plan can then be made.

Below is a preliminary scorecard for the defined programmatic goal and associated objectives. These can be modified and extended as appropriate. On a predefined schedule, it is recommended that the set of tasks be reviewed and the checklist updated to reflect task completion. Totaling the number of checklist points enables a percentage estimate to be made against the target total, for checking status.

Programmatic Goal: Develop improved statewide elevation data that will support two-foot contours to support detailed topographic mapping necessary for a multitude of critical applications and risk determination			
OBJECTIVES	**Total Points**	**Current Score**	**CHECKLIST OF SUCCESS FACTORS**
Objective 1: Identify elevation program management team who will champion the project forward	10		☐ Develop short, medium, and long term coordination and planning objectives **(2 points)** ☐ Assign priorities and develop oversight and management protocols **(2 points)** ☐ Obtain GIS Policy Board approval **(6 point)**
Objective 2: Gather core requirements and expectations for stakeholder community	7		☐ Meet with all appropriate agency representatives to develop a state-of-the-state elevation use and needs picture **(7 points)**
Objective 3: Analyze current and near future high resolution elevation data collection efforts to determine the necessary geographic extent of the program	6		☐ Conduct spatial analyses to determine data gaps with respect to spatial and temporal coverage in current and near future data holdings. **(3 points)** ☐ Finalize flyover coverage area **(3 points)**
Objective 4: Evaluate available technologic options and approaches for suitability	6		☐ Conduct cost-benefit analyses of data acquisition approaches for study area **(3 points)** ☐ Evaluate technologic options against user requirements and expectations **(3 points)**
Objective 5: Determine data storage and other management strategies, including mechanisms for promoting the availability of the data and its applicability, and distribution details	10		☐ Establish Intranet based website for the sharing of elevation-related news and information **(3 points)** ☐ Create data download portal **(3 points)** ☐ Locate hardware and purchase **(4 points)** software
Objective 6: Request program cost estimates from qualified solution/data providers based on a scope of work	3		☐ Communicate expectation and requirements **(3 points)**
Objective 7: Identify and pursue program funding source(s); encumber funds	21		☐ Identify multiple potential funding streams **(4 points)** ☐ Produce and circulate project fact sheet **(2 point)** ☐ Obtain legislative support **(4 points)**

Programmatic Goal: Develop improved statewide elevation data that will support two-foot contours to support detailed topographic mapping necessary for a multitude of critical applications and risk determination			
OBJECTIVES	**Total Points**	**Current Score**	**CHECKLIST OF SUCCESS FACTORS**
			□ Identify key partner agencies **(4 points)** □ Secure funding **(7 points)**
Objective 8: Develop tech specs, determine acquisition criteria, and procure services according to scope of work	26		□ Develop tech specs for project **(1 point)** □ Determine acquisition criteria **(1 point)** □ Identify qualified service providers **(1 point)** □ Interview service provider candidates **(1 point)** □ Select service provider(s) **(1 point)** □ Achieve flyover **(5 points)** □ Review/QC pilot deliverables **(8 points)** □ Review/QC final deliverables **(8 points)**
Objective 9: Advertise and make available project deliverables to stakeholders	6		□ Load data inventory content and extended metadata **(3 points)** □ Hold Data User Workshops to promote the data products **(3 points)**
Objective 10: Conduct post-project assessment, including scoring of success factors and lessons learned	6		□ Identify success stories **(1 point)** □ Analyze project with respect to scope and budget **(1 point)** □ Document lessons learned **(2 point)** □ Communicate findings to stakeholders and peer community **(2 point)**
TOTAL POINTS	100		

Use the following summary table to score your overall progress. Partial progress on a particular checklist item can get partial points. When a success factor is complete, full points can be counted. This will give some indication of the current level of success, on an ongoing basis. A quarterly reporting schedule is shown in the table, below, and should be accompanied by a narrative report.

		Year 1				Year 2				Year 3			
Progress Matrix	**Total Points**	June 2009	Sept. 2009	Dec. 2009	March 2010	June 2010	Sept. 2010	Dec. 2010	March 2011	June 2011	Sept 2011	Dec 2011	March 2012
Programmatic Goal: Improve elevation data to support statewide applications.	100												
Running Totals	0												

APPENDIX A. SOURCE DOCUMENTS

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APPENDIX B. GLOSSARY OF TERMS

Breaklines: linear features in a data model that describe a change in the smoothness or continuity of the surface. Hard breaklines define interruptions in surface smoothness such as streams, shorelines, dams, ridges, and building footprints. Soft breaklines are used to ensure that known "Z" (elevation) values along a linear feature (such as a roadway) are maintained in a TIN.

Digital Elevation Model (DEM): a digital representation of ground surface topography or terrain.

Digital Flood Insurance Rate Map (DFIRM) Database: a digital version of the FEMA flood insurance rate map that is designed for use with digital mapping and analysis software.

Interoferometric Synthetic Aperture Radar (InSAR or IfSAR): technique for topographic map generation using two or more synthetic aperture radar (SAR) images.

Light Detection and Ranging (LiDAR), also known as lasar altimetry: Remote sensing technologies whereby properties laser echoes are measured off a distant object. For topographic mapping, the distance to an object, or *range*, is determined by measuring the time delay between transmission of a pulse and detection of the reflected signal. The range is then compared to a geodetic earth model to determine absolute elevation.

Orthoimagery: digital or film earth imagery with an orthogonal (straight-down) ground view. Features are displayed in their true correct position, and geographic distances, angles, directions, and areas are preserved.

Orthorectification: image processing technique to remove geometric and displacement errors in an aerial or satellite image.

Photogrammetry: remote sensing technique whereby geometric features are read from photographs. Measurements made in two or more photographic images taken from different positions can be compared to derive three-dimensional coordinates (see stereoscopy).

Planimetric: two-dimensional (planar) representation of geographic features in three dimensions. In Geographic Information Systems (GIS), the term also refers to geographic features interpreted from imagery.

Radio Detection and Ranging (RADAR): remote sensing technology that uses the echo of radio electromagnetic waves (backscatter) to identify the range, altitude, direction, or speed of targets. This is especially suited to detection of metal objects, which create distinctive radar backscatter patterns.

Resample: to alter the size of a digital image by changing the pixel size. Information in the pixels from the original image is then remapped to pixels in the resized image using computer algorithms.

Spot Elevations, also known as Spot Heights: point data features that represent locations on the ground in three dimensions, typically created individually through photogrammetric or survey methods and placed at specific locations in a digital elevation model that may not be accurately represented by mass points.

Stereoscopy: an optical technique by which two images of the same object are blended into one, giving a three-dimensional appearance to the single image.

Synthetic Aperture Radar (SAR): type of radar technology distinguished by a relatively narrow effective beam, achieved through sophisticated data processing methods.

Triangular Irregular Network (TIN): line-based representation of the physical land surface or sea bottom, made up of irregularly distributed points and lines with three dimensional coordinates (x,y, and z) that are arranged in a network of nonoverlapping triangles.

APPENDIX C: SPECIFICATIONS FOR FEMA FLOOD MAPPPING – DELIVERABLES AND ACCURACIES

LIDAR – Light Detection and Ranging - Airborne LiDAR is an instrument, flown aboard rotary or fixed-wing aircraft that measures the elevation of objects including buildings, vegetation and other features, as well as bare earth for topographic and engineering applications. The LiDAR sensor measures the distance to a reflecting object by emitting timed pulses of laser light and measuring the time between emission and reception of reflected pulses. The measured time interval is converted to distance. The first-return LIDAR pulses are used to map the top surfaces of terrain feature. Last-return LIDAR pulses are used to map the bottom, bare-earth terrain features.

FEMA Default Deliverable

1. **Bare Earth Surface (NFIP default)**
    a. Bare earth terrain, devoid of vegetation and man-made structures.

Additional Deliverables that may be required by FEMA lead

Hydraulic analyses require high accuracy contours, mass points and breaklines of floodplain only.

1. **Mass points**
    a. Irregularly spaced LIDAR elevation points
    b. Can be first (canopy), last (bare earth), intermediate (vegetation) returns or all returns (multiple return data)
2. **Breaklines**
    a. Linear features that describe a change in the slope, smoothness or continuity of a surface.
    b. Water features and ridgelines most important (tops and bottoms of stream banks, stream centerlines, levees, road/hwy embankments.)
3. **Contours**
    a. Depict breakline features of interest.
    b. Typically 2-foot contours for urban areas and 4-foot contours for rural areas.
4. **TIN's (hydro enforced TIN)**
    a. A set of adjacent, non-overlapping triangles, computed from irregularly spaced points with x/y coordinates and z-values. The TIN is based on irregularly spaced point, line, and polygon data interpreted as mass points and breaklines.
    b. Hydro enforced TIN incorporates the breaklines with the bare earth surface so breaklines do not "jump" across a flooding source.
5. **DEM's**
    a. Model the elevation of the land (z-values) at regularly spaced intervals in x and y directions. DEM's are usually displayed as uniformly spaced grids, thus they can "jump over" breaklines without identifying ditches, stream banks or other important features. These are simple data models,

easy to store, and suitable for automated hydrologic analyses and modeling where breakline information is not important.

6. **Color or CIR Ortho Imagery**
   a. Typically 1-foot resolution, 1”=200’ accuracy.

LIDAR ACCURACY

All products associated with contract deliverables shall meet or exceed relevant NSSDA standards per FEMA Guidelines

Guidelines and Specifications for Flood Hazard Mapping Partners [April 2003]

Table A-2. Comparison of Vertical Accuracy Standards

NMAS Contour Interval	NMAS VMAS 90% confidence level	NSSDA $Accuracy_z$ 95% confidence level	NSSDA $RMSE_z$	ASPRS 1990 Class 1/2/3 Limiting $RMSE_z$
2 feet	1 foot	1.2 feet	0.6 foot 18.5 centimeters	0.7 foot (Class 1) 1.3 feet (Class 2) 2.0 feet (Class 3)
4 feet	2 feet	2.4 feet	1.2 feet 37.0 centimeters	1.3 feet (Class 1) 2.7 feet (Class 2) 4.0 feet (Class 3)

Required accuracy for LIDAR suitable for 2-foot contours

FEMA Guidelines and Specifications Appendix A, Section A.4.3.2 Vertical Accuracy as a Function of Horizontal Resolution

1. **Standard 2-foot equivalent contour interval accuracy appropriate for flat terrain**
   a. DEM post spacing of 2 meters or better
   b. Vertical accuracy must meet 18.5 cm RMSEz (1.2 ft ACCURACYz)
   c. Two-foot equivalent contour interval for flat terrain (Accuracy(z) = 1.2 foot at the 95-percent confidence level – RMSEz x 1.9600). This means that 95 percent of the elevations in the dataset will have an error with respect to true ground elevation that is equal to or smaller than 1.2 feet. (Assuming data follows a normal distribution)

2. **Standard 4-foot equivalent contour interval accuracy appropriate for rolling to hilly terrain**
   a. DEM post spacing of 4 meters or better
   b. Vertical accuracy must meet 37 cm RMSEz (2.4 ft ACCURACYz)
   c. Four-foot equivalent contour interval for rolling to hilly terrain (Accuracy(z) = 2.4 ft at the 95 percent confidence level- RMSEz x 1.9600.) This means that 95 percent of the elevations in the dataset will have an error with respect to true ground elevation that is equal to or smaller than 2.4 feet. (Assuming data follows a normal distribution)

NSSDA Vertical and Horizontal Accuracy Tables

The tables below show the accuracy for 2 foot contours highlighted in yellow. These tables found in the ASPRS vertical accuracy guidelines are similar to the tables in FEMA Guidelines and Specifications for Flood Hazard Mapping.

NSSDA Vertical Accuracy Table

Table 2: Comparison of NMAS/NSSDA Vertical Accuracy (ASPRS guidelines Vertical Accuracy Reporting for LiDAR Data, Version 1.0)

NMAS Equivalent Contour Interval	NSSDA RMSE(z)	NSSDA Accuracy(z) 95% Confidence	Required QC Accuracy for "Tested to Meet"
0.5	0.15 ft or 4.6 cm	0.30 ft or 9.1 cm	0.10 ft
1	0.30 ft or 9.25 cm	0.60 ft or 18.2 cm	0.20 ft
2	0.61 ft or 18.5 cm	1.19 ft or 36.3 cm	0.40 ft
4	1.22 ft or 37.0 cm	2.38 ft or 72.6 cm	0.79 ft
5	1.52 ft or 46.3 cm	2.98 ft or 90.8 cm	0.99 ft
10	3.04 ft or 92.7 cm	5.96 ft or 181.6 cm	1.98 ft

NSSDA Horizontal Accuracy Table

Table 3 Comparison of NMAS/NSSDA Horizontal Accuracy (ASPRS guidelines Vertical Accuracy Reporting for LiDAR Data, Version 1.0)

NMAS Map Scale	**NMAS** CMAS 90%	**NSSDA** RMSE(r)	**NSSDA** Accuracy(r) 95% confidence level
1" = 100' or 1:1,200	3.33 ft	2.20 ft or 67.0 cm	3.80 ft or 1.159 m
1" = 200' or 1:2,400	6.67 ft	4.39 ft or 1.339 m	7.60 ft or 2.318 m
1" = 400' or 1:4,800	13.33 ft	8.79 ft or 2.678 m	15.21 ft or 4.635 m
1" = 500' or 1:6,000	16.67 ft	10.98 ft or 3.348 m	19.01 ft or 5.794 m
1" = 1000' or 1:12,000	33.33 ft	21.97 ft or 6.695 m	38.02 ft or 11.588 m
1" = 2000' or 1:24,000	40.00 ft	26.36 ft or 8.035 m	45.62 ft or 13.906 m

Quality Control and Quality Assurance / Check Point Survey

FEMA states a minimum of 20 test points for each major vegetation category. A minimum of 3 major land categories will be used. (Minimum of 60 checkpoints). Confidence in the calculated RMSE value increases with the number of checkpoints and is a function of sample size. It is important to have a check point survey to assure data validity.

Major Land Cover Categories:

1. Bare Earth and low grass
2. High grass, weeds, and crops
3. Brush lands and low trees
4. Forested, fully covered by trees
5. Urban

6. Sawgrass
7. Mangrove

NSSDA states a minimum of 20 checkpoints for the entire project area. Typically this is used when the project area is smaller than 50 sq miles.

For All Check Points (FEMA and NSSDA)

- Check points to follow FGDC-STD-007.1, FGDC-STD-007.2 and NGS-58 (NOAA 1997)
- Points will be located in terrain that is flat or uniformly sloped within 5 meters in all directions.
- The slope must not exceed 20 percent.
- Test points must not be located near to breaklines, such as bridges or embankments.
- All points must be 3x's as accurate as the surface being tested
  - i.e.) 15 cm LiDAR data set needs control to be accurate to 5cm

REPORTING

Pre Flight Report

Prior to collection vendors must provide a map showing the study area boundaries and flight path. Must document altitude, airspeed, scan angle, scan rate, LIDAR pulse rates, and other flight and equipment settings and parameters as well as a chart of PDOP values.

Post Flight Report

After completion of acquisition, vendors must provide comprehensive account detailing: LIDAR system report, flight report, ground control report, ellipsoid model used, data processing procedures, system calibration report and accuracy analysis using check point survey.

Accuracy Labeling

If data set was collected to be suitable for 2 foot contour mapping and is tested to a vertical RMSE of 0.6 ft (18.5 cm) and recognizing that Accuracy(z) = 1.9600 x RMSEz when errors have a normal distribution, the metadata would read as follows:

Tested 1.2 foot vertical accuracy at 95-percent confidence level

References:

- FEMA Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix A: Guidance for Aerial Mapping and Surveying www.fema.gov/fhm/dl_cgs.shtm

- NDEP Guidelines for Digital Elevation Data http://www.ndep.gov/NDEP_Elevation_Guidelines_Ver1_10May2004.pdf

- ASPRS Guidelines Vertical Accuracy Reporting for Lidar Data V1.0 http://www.asprs.org/society/committees/lidar/Downloads/Vertical_Accuracy_Reporting_for_Lidar_Data.pdf

(Information on FEMA Specifications courtesy of MJ Harden Company)

APPENDIX D. ACKNOWLEDGEMENTS

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  - Douglas County