The National Map

Topographic Mapping for the 21st Century

Final Report

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Preface

The report *The National Map* describes the vision by which the U.S. Geological Survey (USGS), working with partners, will provide the Nation with current, accurate, and nationally consistent basic spatial data, including digital data and derived topographic maps, and deliver spatial information that is current. Issues discussed include the form USGS maps and spatial data will take, ways that lag time between changes on the ground and corresponding updates in data and on maps can be reduced, and means by which the USGS can create and maintain these data and maps.

To develop the report, the USGS interviewed key individuals familiar with the development and use of spatial data. The individuals were from the USGS; associations of professionals and organizations, Federal, State, and regional agencies, and private companies. USGS personnel also reviewed the documents listed in the Selected References section. From this information, the USGS drafted a vision statement and released it for public review during the spring of 2001. On the basis of the 130 comments received from across the spatial data community, the USGS revised the report. Scientists from other USGS disciplines and representatives of selected professional organizations and interest groups validated the revisions.

The report recommended the development of *The National Map* to meet needs and take advantage of technological and other developments. *The National Map* is proposed as a database of basic spatial data that will provide a starting point for users to extend and enhance and to which users can tie additional data to meet their individual needs. *The National Map* concept is the unifying construct that incorporates all geography programs of the USGS: Cooperative Topographic Mapping, Land Remote Sensing, and Geographic Analysis and Monitoring. The USGS will provide the leadership needed to develop and continuously maintain *The National Map* through partnerships linking Federal, State, local, and tribal governments, the private sector, other organizations, and the general public.

USGS invites partners, customers, and the public to contribute to achieving the goals of *The National Map*. Suggestions can be sent by electronic mail to: nationalmap@usgs.gov.

Contents

Executive Summary: *The National Map*

This report defines a vision for *The National Map*, a database of continuously maintained base geographic information for the United States and its territories that will serve as the Nation's topographic map for the 21st century. Improvements will include greatly increased attention to keeping the information current, seamless national digital data coverage to avoid problems now caused by map boundaries, higher resolution and positional accuracy to better support user requirements, thorough data integration to improve the internal consistency of the data, and dramatically increased reliance on partnerships and commercially available data.

Governments depend on a common set of base information that locates and describes the Earth's surface and features as a tool for land and natural resource management, economic and community development, and health and security services. Federal functions ranging from land management to emergency management and defense to environmental protection require this information. Private industry, nongovernmental organizations, and the general public also create and use these geographic data. Spatial information underpins an increasingly large part of the Nation's economy.

The National Map will serve as a foundation for integrating, sharing, and using spatial data easily and consistently and will provide a new approach to provide more current information while retaining and improving other valued characteristics, such as positional accuracy and content completeness.

Under the leadership of the U.S. Geological Survey (USGS), and through partnerships with other Federal agencies, State and local governments, the private sector, academia, libraries, and the public, *The National Map* will provide data and operational capabilities that include the following:

- High-resolution digital orthorectified imagery. Imagery will provide some of the feature information content now symbolized on topographic maps.
- High-resolution surface elevation data, including bathymetry.
- Vector feature data for hydrography, transportation (such as roads, railways, and waterways), structures, and boundaries of government units and publicly owned lands.
- Geographic names, such as those for physical and cultural features.
- Land cover data classifying the land surface.

The USGS will continue to provide a standard set of digital data products and high-quality paper topographic maps derived from *The National Map*. Customers also will be able to create their own maps by defining a geographic area of interest, selecting unique combinations of data, and printing their maps at home or at kiosks.

Changes to *The National Map* will be captured in near real-time, rather than during cyclical inspection and revision. Currentness will be measured in days and months. The ultimate goal is that changes will be recorded within 7 days of a change on the landscape. Near-term expectations are for significant currentness improvements for most data themes compared with data now available from the USGS. Features will be represented in their entirety and consistently classified. This will enable users to extract data for geographic areas such as counties or watersheds and will allow improved computer analysis of the information. Data resolution and completeness will vary depending on geographic area and need. Positional accuracy will be sufficient to align features from different data themes.

The initial version of *The National Map* will be based primarily on existing available data. As the initial version is improved, emphasis will shift to maintaining data currentness through continuous updating. Potential data sources include State and local governments, private industry, and trained and certified local volunteers.

The National Map will be accessible continuously through the Internet. The vision calls for data to be in the public domain, which will require the negotiation of unlimited distribution and use rights for data from commercial sources.

Users will be able to combine data from *The National Map* with spatial information available from other organizations, such as cadastral information from the Bureau of Land Management and demographic data from the Bureau of the Census. *The National Map* will be the foundation of a USGS enterprisewide geographic information system to which other organizations can add or reference their information, such as land use data, school district boundaries, or wildlife census information.

The success of *The National Map* will depend heavily on sustainable partnerships. The USGS will lead the development and maintenance of *The National Map* by being the (1) guarantor of national data completeness, consistency, and accuracy, (2) organizer responsible for awareness, availability, and utility of *The National Map,* (3) catalyst and collaborator for creating and stimulating partnerships, (4) integrator and certifier of data from participants, (5) owner and data producer when no other sources for needed data exist, and (6) leader in the development of geospatial data standards.

The USGS will seek partnerships and business arrangements with other organizations to develop and operate *The National Map*. USGS staff will be located across the Nation to work directly with partner Federal, State, or other public organizations, private industry, and universities. Federal agencies would identify needs and develop and execute plans for collaborative data development and maintenance. The role of the USGS in these

relationships could range form being the organizer of consortia to working with other agencies to support the inclusion of their data in *The National Map*. State, regional, and local partners would coordinate or undertake area-specific geographic data development to meet their needs and, where interests align, to maintain and operate *The National Map* for their areas. Private organizations would provide analysis and visualization tools, develop standards-based, open technology and processing standards, and provide data under contract or license. The USGS will work with university faculty on relevant research topics. Libraries will support public access to *The National Map*. The USGS will encourage volunteers to help detect and report changes to maintain *The National Map*.

The USGS will maintain a 5-year plan for the Cooperative Topographic Mapping Program to implement *The National Map*. This plan will define objectives, data architecture, business methods, and an annual program of work goals necessary to establish the program structure and to measure progress toward full realization of *The National Map* vision.

Choices About the Future – Being Made Today

The National Map will underpin the mission activities of Federal agencies, as well as other public and private organizations. The proposed continuously maintained, nationally consistent set of basic spatial data will provide a starting point and organized means for integrating, sharing, and using spatial data easily, consistently, and quickly.

The following vignettes, set in the year 2010, offer ideas of the consequences of no action, and of how *The National Map* could benefit the Nation.

Vignette 1: Status Quo

FAIRVIEW, August 15, 2010 – It had been a long fire season, and it wasn't going to let up soon. Local, State, and Federal firefighting crews were being augmented by military units.

The commander of a newly arrived unit entered the command post. "Where do you want us?" he asked the Ops Chief.

"Come here and I'll show you," replied the Ops Chief. On a table were maps updated and annotated by hand using a rainbow of colored pencils. Stacked around these maps were USGS and other maps, aerial and satellite photos, and plots from computer files. Even a few tourist maps peeked from the pile, and the commander swore one looked like the map on the placemat from a local diner. "What's this?" he asked.

"We use the maps to plan fire lines," the Planning Section Chief said half-apologetically. "We get whatever base maps are available. They're often not current, and we update them with whatever information we can get. This probably is the first time most of this information has been pulled together. The information often doesn't fit well, but we do the best we can in the time we have."

"Isn't there anything better available?" asked the commander. The Planning Section Chief noted that, as a result of local interest and resources, there were good integrated digital base maps available for limited areas. "They're great to use, but they're often not available or don't contain the topographic information we need" he noted. "And where they are available, they usually stop at a county or forest boundary. Unfortunately, fires aren't too picky about crossing boundaries. There are less detailed satellite and other data that cover larger areas. They're great for getting an overall view, but they don't help much in the field. As for base maps for tactical firefighting, USGS topographic maps are available, but they're often out of date. No one pulls existing data together, fills in the gaps, and keeps the information current, so we make do."

The Ops Chief pointed to an area on the map. "We need your people to establish a fire break here. We're trying to protect some homes further up the mountain." "Where are the buildings?" the commander asked. "I don't see them on the map." "They're out there," the Planning Section Chief replied. "But we don't know exactly where, and so we can't plot them on the map."

"Hell of a way to fight a fire," the commander muttered as he left the command post.

Vignette 2: Common Action Enabled Through a Common Set of Basic Spatial Data

MIDWAY, July 4, 2010 – After years of cleanup efforts, the river was open to swimmers. On a hot, muggy Fourth of July, people were drawn to the river–swimming, tubing, boating, and fishing. They had no idea of how exciting their vacations were about to become.

Upriver, a containment pond had given way, and thousands of gallons of caustic sediment were pouring into the river. The skeleton staff at the plant alerted the emergency spill center, which swung into action.

Their first priority was public safety and health. Using *The National Map* developed and maintained by the USGS and other organizations, they located on recent digital aerial photos and river and lake data the place where the spill entered the river, and they identified the area and facilities downstream that the spill was most likely to affect. Water utilities with intakes in the area were ordered to stop pumping. The media broadcast warnings to stay clear of the contaminated water; however, officials were concerned that people on the river

might not receive the warning in time. In a flash of inspiration, they remembered that personal electronic devices had been equipped with Global Positioning System receivers for years. Using *The National Map* to outline an area that included the river and land within 100 yards of the shore, they identified all the devices in the area and sent them a simple message – "HAZARDOUS SPILL – LEAVE THE RIVER NOW." People headed for shore as the river came alive with the chirping of cell phones, pagers, and personal digital assistants.

The center also warned Federal and State natural resource and environmental agencies of the spill. The agencies, with partners from industry and non-governmental organizations, had been linking information about water quantity and quality, the shape and makeup of the riverbed, and aquatic plants and animals to *The National Map* for years. The agencies used these spatially referenced data to plan actions to minimize damage and start cleanup operations. "At least it won't get much worse," said one chemist after using the data to determine that the spill was unlikely to interact with other naturally occurring chemicals in the river. Using *The National Map*, scientists pinpointed wetlands and alerted field personnel to place barriers to protect this productive habitat.

Having issued the warning, the center concentrated on predicting the likely extent of the spill. By analyzing real-time river flow information, elevation and land cover data, and weather forecasts, they estimated the rate of the spread of the spill and produced maps showing impacted areas and access routes for remediation teams. "How about that," one official exclaimed, "we might get ahead of the spill before it reaches the Mississippi."

The National Map

The Needs of the Federal Government, and the Nation, for a Common Set of Basic Spatial Data

Governments are inherently geographic. All governments need spatial data that locate and classify lands and waters, describe the distribution of peoples, economic activities, infrastructure, and natural resources, and document the products of their domains. The National Academy of Public Administration (1998) identified 12 broad Federal functions, ranging from economic and community development to emergency management and defense to environmental protection, that require spatial data. The report summarized the Federal Government's role in spatial data functions as "one in which Government is expected to help ensure public safety, manage the public lands for multiple uses, preserve the Nation's resources for future generations, and help meet the basic needs of an expanding economy."

Spatial data required by the Federal Government are also created and used by State, regional, local, and tribal governments, private industry, nongovernmental organizations, and individual citizens. Paper maps and digital forms of spatial data underpin an increasingly large segment of the Nation's economy. The economic multiplier of freely available public domain geographic data is substantial. Entire industries are built around these data. Base geographic data should be considered and supported as part of the Nation's infrastructure. A 1997 National Research Council report concluded that:

> Spatial data have helped form a foundation for commercial enterprises, such as delivery services, and have also led to enhanced market analyses. At the same time, the use of spatial data has reduced costs and increased efficiencies in a wide variety of areas where it is necessary to manage large networks of geographically dispersed facilities, most notably in the utility industries, transportation, and local governments. Policies and practices of open and affordable access to spatial data have contributed to U.S. leadership in the world markets of spatial data technologies and applications.

The USGS's Role in Meeting These Needs

A common set of current, accurate, and consistent basic information that describes the Earth's surface and locates features is the starting point for most geographic activities. *The National Map* will be a composite of continuously maintained basic spatial data for the United States and its territories and will serve as the Nation's topographic map for the

21st century. It will be a data foundation that could be extended and enhanced, and to which additional data, both public and private, could be tied. It will contain sufficient detail to support national, regional, and local activities. Guaranteed availability of *The National Map* will allow Federal agencies to concentrate on data unique to their mission needs and to avoid expending resources to find, develop, and integrate basic spatial data each time they are needed. Within the U.S. Geological Survey (USGS), *The National Map* will be one of many data sets accessible through the USGS Gateway portal and will be the organizing mechanism for spatially referenced scientific information, as the foundation data of an enterprisewide geographic information system.

The USGS has a mandate to provide base topographic information to the Nation, including the needs of its own scientific programs and those of other Federal agencies. This mission is consistent with the Office of Management and Budget Circular A-16, "Coordination of Surveying, Mapping, and Related Spatial Data Activities."

The most widely known form of topographic information is the USGS primary series of topographic maps,[1] which gives a complete and consistent picture of our Nation's lands. The maps, complemented by digital forms of the mapped information and aerial and satellite imagery, support numerous government activities, including saving lives and property in natural disasters, aiding other bureaus of the Department of the Interior in carrying out their stewardship and regulatory responsibilities, and providing a cornerstone for other USGS science programs. These spatial data also have been used widely by State, regional, and local governments, the private sector, and other organizations. Citizens use the maps in educational, recreational, environmental, and conservation activities, and to explore and understand natural resource issues. The maps help people connect with the Earth through the power of place and geography.

Developing and maintaining basic, standardized spatial data for the Nation have required and will continue to require a significant national commitment and engineering effort. To give a sense of the scope of the effort, the USGS primary topographic map series includes more than 55,000 unique map sheet, and 220,000 digital orthorectified images[2] to cover the United States. Although one form of these spatial data, the paper map, once was sufficient, other needs evolved over the last 20 years with developments in computer technology. The USGS responded to these changing needs by providing basic spatial data in a number of digital forms in addition to the paper map form. While these maps and related digital data are considered by many to be a national treasure, they are rapidly becoming less valuable as they age. For example, the average age of the primary

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[1] The primary topographic map series subdivides the United States into four-sided figures called quadrangles, which are bounded by lines of latitude and longitude. Topographic maps present the horizontal and vertical positions of represented features. The maps show relief (elevations and depressions), water features, roads and railroads, structures, boundaries, names, and other information. The most widely known maps in the series are the 7½-minute quadrangles, most of which are published at a map scale of 1:24,000 (1 inch on the map represents 2,000 feet (24,000 inches) on the ground). For Alaska, most quadrangles are 15 minutes in latitude and from 20 to 36 minutes in longitude and are published at a scale of 1:63,360 (1 inch on the map represents 1 mile (63,360 inches) on the ground).

[2] An orthorectified image is an aerial photograph or satellite image from which displacements caused by terrain and other factors have been removed. The resulting image has the image characteristics of a photograph and the geometric qualities of a map.

topographic series maps is 23 years. Although historical base geographic information is vital for many governmental, commercial, and academic purposes, showing where changes have occurred on the landscape, the maps no longer portray conditions accurately. Complementary digital images often are more current; however, maintaining the currentness of the data provided by the USGS, while retaining other valued characteristics, such as positional accuracy and completeness, is a challenge, especially for areas of rapid development.

As the Nation's largest civilian mapping agency, the USGS has the responsibility to organize and lead partnerships and activities that provide basic spatial data needed by all national sectors. Clearly a new approach is needed to keep up with rapid changes on the landscape and to provide current, accurate, consistent, and useful basic spatial data.

Changing Needs for Spatial Data, and Opportunities for Meeting These Needs

The rapid pace of improvements in digital technologies and plunging unit costs for these technologies are changing the way information is made available and used. The use of spatial data has been affected radically by these trends. Computerized systems to use spatial data, such as geographic information systems, and to acquire the position of features and events, such as the Global Positioning System, are changing the spatial data needs of organizations and individuals and are providing new opportunities to meet those needs.

Major current and developing spatial data needs, and the implications of new capabilities, include the following:

- *Data:* There continues to be an unmet need for a common set of nationally consistent, basic spatial data. For some places, considerable data are available; for others, there is very little data. These data must be current and useful for any arbitrarily defined geographic area. Both digital and paper forms of basic spatial data are needed.
- *Technology:* Technology will continue to evolve and will provide new ways to collect, maintain, access, and use basic spatial data. For example, the convergence of personal digital devices, Global Positioning System capabilities, and wireless communications is stimulating numerous location-based services that provide access to geospatial data by users at remote sites and will make possible the real-time collection and updating of data by those same users.
- *Partnerships:* Common needs and interests offer opportunities for partnerships to collect, maintain, access, and use basic spatial data among Federal agencies and with other public organizations, notably State and regional organizations. Private sector investments in the collection, maintenance, access, and use of basic spatial data provide opportunities to meet national needs. Volunteers may be an untapped source of information needed to maintain basic spatial data.

- *Federal leadership:* Federal leadership and commitment are needed to ensure that nationally consistent, basic spatial data are available to support Federal agencies in accomplishing their missions. The USGS has the mission to lead in the development and maintenance of a common set of basic spatial data, although a new approach is needed. USGS leadership and participation in current interagency data development programs, as well as in activities of the Federal Geographic Data Committee, provide starting points and contexts for developing and maintaining basic spatial data.

Appendix 1 contains a summary of these changing needs and opportunities.

The National Map

The proposal for *The National Map* sketches the initial concept and way of moving forward to meet national needs for basic spatial data. The goal of *The National Map* is to provide a nationally consistent set of integrated, current topographic information that supports those needs. The resolution of the data will vary depending on geographic area and availability (for example, more detailed and accurate elevation data for flood plain or coastal areas). In no case will the resolution of the best available data in *The National Map* be lower than that associated with USGS primary series topographic maps for an area.

Information Content

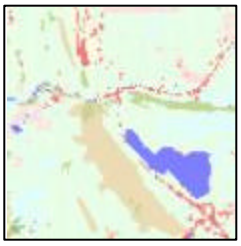
The National Map will consist of several themes of spatial data; this is the initial set:

High-resolution digital orthorectified imagery. An orthorectified image is an aerial photograph or satellite image from which most displacements caused by terrain relief and sensor geometry have been removed. The result combines the image characteristics of a photograph with the geometric qualities of a map. Images will be collected using the most efficient and effective combination of aircraft- and satellite-based remote sensing capabilities. In addition to providing the high-resolution imagery, *The National Map* will also serve seamless Landsat satellite imagery to provide intermediate-resolution national coverage.

High-resolution elevation data, including offshore bathymetric data maintained by the National Oceanic and Atmospheric Administration. At a minimum, these data will have sufficient detail to yield contours for primary series topographic maps, to support the geometric correction of imagery, to support three-dimensional perspective views and fly-throughs, and, in areas of subtle relief variation such as flood plains and coastal areas, to support hydrologic and other modeling. *(Data courtesy of Intermap Technologies, Inc.)*

Vector feature data for the themes of hydrography, transportation (especially roads, but also including railroads and waterways), structures, boundaries of governmental units, and administrative boundaries of publicly owned lands. These data will have unique feature identifiers and minimal associated descriptive information. In most cases, the information content will include simple classification information (for example, "stream/river" and "lake/pond") and a geographic name. Feature-based linear referencing systems required to link other data to *The National Map* will also be included. Examples include reach codes for hydrography data that support operations of the U.S. Environmental Protection Agency, U.S. Forest Service, and USGS, and street addresses that support operations of the Bureau of the Census.

Geographic names. These names include those for physical and cultural geographic features needed to support the U.S. Board on Geographic Names, and other names, such as for highways and streets. Names will be associated with their corresponding features, and the locational accuracy of names not associated with a feature specifically represented in *The National Map*, such as a locale or a ridgeline, will be improved.



Land cover information. These data classify the land surface into categories, such as open water, perennial ice/snow, evergreen forest, and high-density residential. The data satisfy the need for nationally consistent content for topographic mapping applications. Land cover data are developed from a combination of aircraft- and satellite-based remote sensing sources, supplemented by ground-truth information.

Data Characteristics

The National Map data will have the following characteristics:

- Currentness. Content will be updated on the basis of changes in the landscape instead of the cyclical inspection and revision cycles now in use. Currentness will be measured in days and months, not years. The ultimate goal is that new content be incorporated within 7 days of a change in the landscape. Currentness will vary depending on the data theme, local characteristics (for example, rate of change), user requirements, source availability, technology, and resources. Data expected to be significantly more current in the near future include imagery, elevation (depending on the applicability of new remote sensing technologies), and features for which surrogate indicators of change are available (such as construction or occupancy permits).
- Seamlessness. Features will be represented in their entirety and not interrupted by arbitrary edges, such as 7.5-minute map boundaries.

- Consistent classification. The type of feature, such as "road" and "lake/pond," will be identified the same way throughout the Nation.
- Variable resolution. Data resolution, or pixel size, may vary among imagery of urban, rural, and wilderness areas. The resolution of elevation data may be finer for flood plain, coastal, and other areas of low relief than for areas of high relief. A tool will be provided to generalize data of varying resolution within a specified geographic area. Reduced-resolution, internally consistent representations may be precomputed and stored or generated on the fly, depending on the complexity of the data and size of area selected.
- Completeness. Data content will include all mappable features (as defined by the applicable content standards for each data theme and source). Content will not be generalized (for example, features deleted or aggregated) as may be required for graphic representation. Tools will be provided to support data generalization and symbolization for graphic display.
- Consistency and integration. Content will be delineated geographically (that is, in its true ground position within the applicable accuracy limit) to ensure logical consistency between related features. For example, the terrain surface will be accurately depicted by the combined elevation and hydrography data, such that streams and rivers consistently flow downhill; each structure will be located correctly in relation to other local features, such as roads and other buildings.
- Variable positional accuracy. Positions will be based on locations on the ground and will not have offsets, generalizations, or other adjustments that are made to improve legibility on paper maps. The minimum positional accuracy will be that of the current primary topographic map series for an area. Actual positional accuracy will be reported in conformance with the Federal Geographic Data Committee's "Geospatial Positioning Accuracy Standard." Relative accuracy will be achieved through attention to logical consistency and data integration.
- Spatial reference systems. The coordinates for spatial data in *The National Map* will be based on defined horizontal and vertical datums and will be encoded in a defined coordinate system. Tools will be provided to integrate data that are mapped using different datums and referenced to different coordinate systems, and to reproject data to meet user requirements.
- Standardized content. The content of *The National Map* will conform to appropriate Federal Geographic Data Committee, other national, and/or international standards.
- Metadata. At a minimum, metadata will meet Federal Geographic Data Committee standards to document the content and characteristics of *The National Map* data, such as lineage, positional and attribute accuracy, completeness, and consistency. Metadata will be maintained at the feature level when applicable. The metadata will be published over the Internet, using standard Web protocols, such as the National Spatial Data Infrastructure Clearinghouse, to enable users to find and evaluate the reliability and usefulness of data for their unique applications.

- Temporal dimension. To facilitate the tracking of changes over time, the USGS will ensure that *The National Map* content is permanently archived by retaining versions of data sets or feature-based transactional information. Existing paper topographic map archives will also be preserved.

For many areas, *The National Map* will contain data that surpass standards for the current primary topographic map series and related digital spatial data.

Figure 1 illustrates the importance of the proposed data characteristics. Seamless and consistently classified data allow similar views to be generated for any area. Consistent and integrated data ensure that, when combined, data from the various themes register well. Currentness ensures that the data accurately represent the ground. These qualities are important for maps and other displays of data. They are also essential to ensure accurate results from automated analyses of the data.

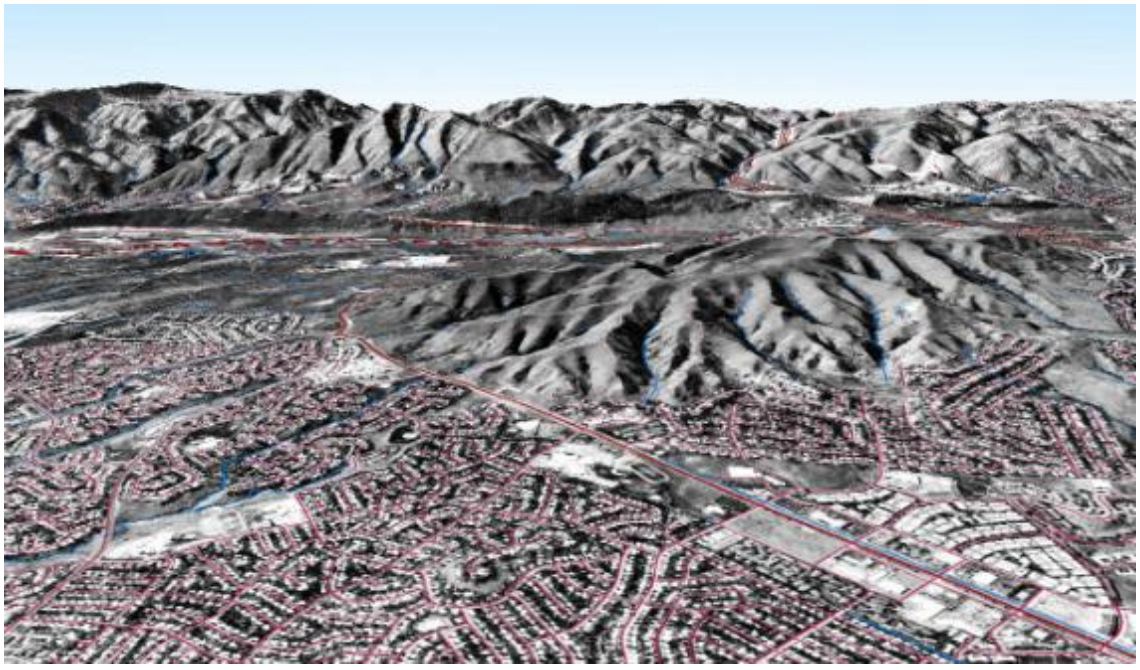


Figure 1. Computer-generated image for an area west of Denver from data such as those proposed for *The National Map*. A shaded, three-dimensional perspective view has been generated from elevation data; orthorectified image, transportation (roads in red), and hydrography (in blue) data are draped over the view.

Development, Maintenance, and Operations

The initial version of *The National Map* will largely be based on available data. Sources of data will include current holdings of the USGS and other participating organizations. When needed, new data will be obtained primarily through contracts with the private sector and purchases of data available in the marketplace. The initial version will not achieve all the characteristics described in the previous section, but data will be improved and replaced over the next decade as the emphasis shifts to maintaining data currentness through continual updating.

When a change on the landscape occurs, database updates will be made through transactions in which only the needed changes to the data will be processed. These updated data will be made available immediately. The processing of transactions will require ensuring the integrity of the resulting change with similar data for surrounding areas (for example, making sure new roads fit into the existing road network) and with related data from other themes in the same area (for example, making sure changes in hydrography data match the elevation data). The USGS will develop an archive strategy for *The National Map* that will include time-specific versions and feature-based change information, as appropriate.

Critical to success is a robust means of knowing about changes when they occur and of receiving spatial data that faithfully represent those changes for inclusion in *The National Map*. The ideal sources for information about a change and for new data that represent the change are those close to the change, such as local governments, local offices of other public and private organizations, or trained and certified local volunteers. The preferred approach would be for these organizations or persons to "push" updates to *The National Map* when changes occur on the landscape. Another approach is for public and private sector organizations that have reporting relationships with local organizations or individuals to act as intermediaries for providing updates. A third approach would be for the USGS to detect changes from imagery or from notifications of changes provided by others, and so directly acquire the data needed to update *The National Map*. The approach used for an area will depend on the commitment of partners and the relative costs of available approaches.

Computing and telecommunications technologies will allow numerous options for sharing responsibilities. *The National Map* may develop as a networked, distributed collection of databases, operated by public or private sector organizations that, as data stewards, agree to provide basic spatial data that meet common standards and levels of service. Although the data archive may be distributed among many sites, the data in *The National Map* will appear seamless to users. *The National Map* will follow relevant national and international standards that are supported by industry.

To continue to be relevant, it is important that *The National Map* be developed and improved in response to users' needs, as well as to changing technical and organizational requirements. There must be a means to obtain feedback from users and to respond to reported deficiencies and changing needs.

Access and Use

The National Map will provide around-the-clock access through the Internet to basic spatial data; access will be based on user-specified combinations of data and geographic area of coverage. Views of the data and transfers of reasonable amounts of data through the Internet will be provided at no cost. Access to large volumes of data may require a fee to pay for media and other distribution costs. The USGS will review data distribution charges periodically to ensure compliance with Federal pricing policy.

The USGS is committed to ensuring that *The National Map* content remains in the public domain and is made accessible over the World Wide Web through multiple Web-based services, including an image service (Web mapping), feature services (data streaming in support of location-based services and metadata browsing), and data extract (feature access and spatial data transfer). All services will use industry-supported, open, standards-based protocols, as appropriate, to allow these data to be accessed easily and readily, for maximum utility to all users. Unrestricted and immediate access to *The National Map* is of vital importance to public and private organizations for emergency and disaster response. To ensure access for these and other critical needs, *The National Map* will be designed with redundant servers, sufficient bandwidth, and around-the-clock operational support. In cases where rights to data are held by private organizations, the negotiation of appropriate distribution and use rights will be required.

The National Map will also provide means of accessing and using other data from Federal agencies and other organizations, using open, standards-based technology and processing methods, such as those being developed through the Open GIS Consortium and the Federal Geographic Data Committee. One method will be use of *The National Map* as a reference base to link to additional attribute information, such as detailed USGS scientific data. Another method will be the combination of displays of *The National Map* data with themes available from other organizations, such as geodetic control data from the National Oceanic and Atmospheric Administration, cadastral information from the Bureau of Land Management and State agencies, soils data from the Natural Resources Conservation Service, or demographic data from the Bureau of the Census. Similarly, data from local agencies, such as zoning, school, or watershed protection data, could be displayed in combination with data from *The National Map*. In addition, *The National Map* could provide access to more detailed data or value-added services available for a fee from public or private organizations.

The USGS will also provide a standardized set of high-quality paper topographic maps and digital data created from *The National Map*. This view of *The National Map* will be a continuation of the USGS primary topographic map series and complementary digital data.

Imagery may carry some of the information content now encoded with map symbols; for example, an image might substitute for symbols used to portray structures. Customers will have the flexibility to define map boundaries and to select different combinations of data to produce maps that best suit their needs. In addition, USGS business partners may develop kiosks that provide customized maps on demand through a distributed retail network (for

example, at gas stations, convenience stores, coffee shops, recreational stores, State or local government offices, bookstores, libraries, and post offices).

Organizational Issues and Strategies

The success of *The National Map* will depend on the participation and support of many organizations. To ensure success, the USGS must lead, develop, and sustain mutually beneficial relationships with other organizations. These issues will be among the most challenging to be addressed in developing and maintaining *The National Map*.

Roles of the USGS

The USGS will provide the national leadership to develop and maintain *The National Map*. This leadership includes being the (1) guarantor of national data completeness, consistency, and accuracy, (2) organizer responsible for awareness, availability, and utility of *The National Map*, (3) catalyst and collaborator for creating and stimulating partnerships, (4) integrator and certifier of data from other participants, (5) owner and data producer of content for *The National Map* when no other suitable and verifiable source for those data exist, and (6) leader in the development and implementation of national geospatial data standards. The USGS will also ensure the quality of *The National Map* data through standards development, by devising and implementing quality assurance procedures, and by promoting process certification criteria for content providers.

Within the USGS, the responsibility for *The National Map* is vested in the Associate Director for Geography. Program priorities and commitments are being aligned with financial and personnel resources to accomplish this responsibility. Priorities for the development and operation of *The National Map* will be reviewed and endorsed annually to update the long-term strategy, to define intermediate goals, and to establish an annual operating plan. Standards for currentness and strategies for maintenance and operations will be reviewed annually to consider new geographic, societal, and programmatic priorities (for example, regional patterns of wildland fire, coastal erosion activity, disease diffusion trends, and other requirements, including national security). Because the USGS will depend on partners to develop and operate *The National Map*, program staff will concentrate on the agreements needed to meet the goals of the program.

Because the ability to meet Federal needs is central to the success of *The National Map*, the USGS will provide liaison staff to Federal agencies to help understand their evolving needs and to identify opportunities to work with agencies that produce spatial data that could contribute to *National Map* maintenance. For similar reasons, substantial numbers of employees will be located in area maintenance offices to work with other USGS offices, partner organizations, and a volunteer workforce. These offices will analyze requirements, develop partnerships, and identify data for *The National Map*. They will provide data acquisition, evaluation, integration, and applications expertise to partners and users. When fully implemented, these offices will be responsible for ensuring that *The National Map* meets user needs in their areas. The USGS will also encourage

rotational assignments of staff among USGS offices and in university and private industry settings.

In addition to having area maintenance offices, the USGS will have field centers with responsibilities for *The National Map* to provide primary management, technical, and administrative support, including the following:

- Providing leadership by monitoring and responding to national trends in spatial data development and use, developing and managing standards, and providing independent technical expertise in the application of spatial technologies and data.
- Providing a core production workforce to maintain subject matter proficiency and to provide the technical underpinning to *The National Map*.
- For times when a surge capability is needed, such as during hazards and disaster response and recovery operations, supporting data "swat teams" to meet immediate needs for geographic information and applications.
- Addressing needs for cartographic and geographic information and general information science research.
- Staffing systems development, administration, and support activities.
- Providing product-generation operations, including those needed for standard USGS digital and paper map products.

To date, the USGS has organized, led, and participated in interagency data development activities to pool resources and make needed data available to Federal agencies and others. For example, *The National Atlas of the United States* ® is a partnership between government and business that delivers small-scale maps and data. A component of *The National Map*, the National Atlas is led by a network of Federal collaborators. It adheres to existing and emerging standards and uses the latest technologies. Its products are offered online. Integrated National Atlas data provide a reliable framework for regional, national, and global studies.

There are other examples. The USGS leveraged Federal and State resources over the last decade to provide coverage of digital orthorectified imagery through the National Digital Orthophoto Program. First-time coverage is nearly complete for 49 States. Similarly, the USGS worked with the U.S. Environmental Protection Agency to provide initial national coverage of the National Hydrography Dataset and is working with Department of the Interior Bureaus, the U.S. Forest Service, the U.S. Environmental Protection Agency, and States to develop more detailed data. Through the National Digital Elevation Program, the USGS leads a consortium of Federal and State organizations that require elevation data. Partnerships also exist for land cover data and for geographic names. The USGS participates on State geographic information development activities and provides leadership for themes of data in the Federal Geographic Data Committee. This experience will guide new partnerships needed to develop *The National Map*.

To realize the full potential of *The National Map*, the USGS will investigate a legislative initiative, patterned on the National Cooperative Geologic Mapping Act. Such legislation would clarify Federal responsibilities and support partnerships with State, regional, and

local governments, academic organizations, and the private sector. Advice and concurrence on this issue will be sought as *The National Map* implementation progresses.

Roles of Partners

Partnerships are the key to the success of *The National Map*. Among the roles of partners are identifying needs; budgeting, developing, and executing plans for collaborative data development and maintenance; organizing consortia; providing access to data; and conducting research.

To provide overall guidance, a proposed Federal advisory committee, consisting of representatives from the USGS and other Federal organizations, participating State and regional organizations, the private sector, and academia, would make recommendations on evolving requirements, approaches to data maintenance and processing, systems and technology development and implementation, and skill enhancements that contribute to *The National Map*.

Federal partners. The USGS will work with other Federal agencies to identify needs and to develop and execute plans for collaborative data development and maintenance to ensure that *The National Map* meets these needs. The role of the USGS in these relationships could range from being the organizer of collaboration to working with Federal agencies to support the inclusion of their data in *The National Map*. In addition to strengthened cooperation within the USGS for hydrography and elevation data, examples of potential partners among Federal agencies include Bureaus in the Department of the Interior and the Forest Service (basic data needed to manage Federal lands), Bureau of the Census (roads and boundaries), Environmental Protection Agency (hydrography and land cover), Federal Emergency Management Agency (elevation), the Department of Agriculture (imagery), the National Oceanic and Atmospheric Administration (bathymetry and links to the Nation's geodetic control data network), and the National Imagery and Mapping Agency (data required for national defense). Other potential partners include the National Aeronautics and Space Administration, Department of Housing and Urban Development, Federal Communications Commission, Federal Aviation Administration, and Centers for Disease Control and Prevention.

State, regional, and local partners. The USGS will strengthen its coordination with State and regional consortia to develop partnerships with State, county, city, and other local organizations for high-resolution data for *The National Map*. When partnership arrangements can contribute to *The National Map* and meet Federal needs, the USGS will participate in and support State and regional consortia, such as State geological surveys, State GIS councils, or Implementation Teams, which coordinate area-specific spatial data development to respond to local issues. When data held at State and local levels can contribute to *The National Map*, partnerships may be formed to develop methods and business relationships to extract data for *The National Map* from more detailed local holdings.

USGS participation will include providing national and multistate program perspectives, coordinating leadership as appropriate, and offering guidance and expertise on data development and maintenance strategies. Participation may include developing strategies for data collection and maintenance, and pooling funding, expertise, and other resources.

Area maintenance offices will develop business relationships needed to receive public reports of events (for example, building permits and road construction) that identify changes and trigger data maintenance efforts. Building on successes such as that of the Texas Natural Resources Information System, the USGS will encourage similar comprehensive State mapping capabilities. Where State and regional organizations share the goals of *The National Map*, they may develop, maintain, and operate *The National Map*, including distributing data and products, for their geographic areas. In these cases, the USGS will support their activities through cooperative agreements.

Private industry partners. The USGS will partner with private organizations that develop and supply geographic information analysis and visualization tools for broad public access, for research on cartographic technologies and issues, and for open technology and processing standards needed to take advantage of new computing and telecommunications technologies. The USGS will also procure data for *The National Map* from the private sector when the data and related licensing provisions support broad access to and use of the data. These procurements could be single purchases or subscriptions to updating services. When data are not available for an area, the USGS will contract with the private sector for data production and processing. For the derivation of products from *The National Map* beyond standard Internet-based displays and paper topographic maps, the USGS will rely on the private sector to provide value-added output capabilities for public access, including meeting the demands for customized paper maps.

Academic and library partners. On cartographic, geographic, and general information science topics relevant to *The National Map*, the USGS will work with universities by supporting research and by rotating assignments of staff. The USGS will continue to rely on the Federal Depository Library Program as a vehicle for ensuring public access to *The National Map* and for providing feedback about geospatial information needs. The USGS also will work with the library community on issues relating to information archival and distribution of *The National Map*.

Partnerships with the public. Taking advantage of the anticipated widespread availability of Global Positioning System capabilities in personal electronic devices, the USGS will certify and encourage the participation of groups (such as the Appalachian Trail Club), scouting organizations, and private citizens to serve as a volunteer force for maintaining and validating *The National Map*. These persons will be trained through a virtual "volunteer academy." Area Maintenance Offices will interact routinely with volunteers to ensure adequate training and data quality. The USGS will partner with private industry to support this large, semi-public activity and to ensure the widespread availability of low-cost techniques that integrate the Global Positioning System, wireless and broadband communications, high-resolution displays, and mass data storage technology.

Needed Research and Development

The near-term technical functions needed to accomplish this vision will be met using commercially available capabilities. Development will be required to integrate these

capabilities and to configure them to aid in the development and maintenance of *The National Map*.

To satisfy mid- and long-term goals, work is needed in applied topics in cartography, geographic information science, remote sensing, and general information science. In addition, issues such as new models for partnership relationships, the value of and business processes for sharing base geospatial information, and the relationship between intellectual property rights and public domain information needs must be investigated. These investigations will be focused first on needs that must be met in the next 5 years and will be pursued with partners from government, academia (including consortia such as the University Consortium for Geographic Information Science), and private industry. Appendix 2 contains a partial list of topics that require investigation.

Next Steps

The USGS plans to conduct the following activities to refine and implement *The National Map*:

- Conduct an ongoing review of the concept to evolve the vision.
    - Support a review of *The National Map* concept by the Mapping Sciences Committee of the National Research Council. This study will review the goals for *The National Map* and evaluate the approaches described for meeting those goals, the potential benefits of *The National Map* to the Nation, and the role of the USGS as the proposed leader for this effort.
    - Identify topics that require more formal study and support investigations in these areas.
    - Revise and add clarity to the concept on the basis of comments and the results of pilot projects, implementation activities, and research.
- Align USGS activities with the vision.
    - Complete a 5-year plan for the USGS Cooperative Topographic Mapping Program that identifies the goals for the Program and the steps necessary to achieve *The National Map* vision. The 5-year plan will include details about data architecture, operations concept, and annual goals and timelines. The goal for full implementation of *The National Map* by 2010 is part of the vision. However, significant accomplishments must be programmed for the fiscal year 2002-06 timeframe and defined in the 5-year plan. Implementation of *The National Map* will be accomplished in phases, and timeframes will differ for various data components and capabilities.
    - Develop a business model and funding mechanisms for implementing *The National Map*.
    - Identify and make needed changes in business practices.

- Identify characteristics of the workforce required to implement the concept and address deficiencies.
- Evaluate existing USGS and partner data holdings to understand their currentness and other characteristics in light of *The National Map* vision and to identify in more detail the information content to be captured in *The National Map*.
- On a pilot basis, expand selected current State liaison activities to assess the potential contributions of area maintenance offices.
- Identify needs for a legislative initiative as implementation progresses.

- Forge relationships with organizations interested in *The National Map* vision.
  - Identify organizations that use an approach similar to that proposed and work with them to identify key steps required to implement the concept.
  - Evaluate the characteristics of other organizations' holdings of basic spatial data and techniques for collecting and maintaining these data to understand what their value may be to *The National Map*.
  - Work with key Federal agencies to understand their needs for spatial data and how their plans will coincide with implementation activities for *The National Map*.
  - Work with interested State, regional, and local agencies to test and demonstrate aspects of the concept and to assess their interest in participating in *The National Map*.
  - Implement data stewardship agreements that define ownership and responsibilities for *The National Map* components, and develop other business and cooperative data partnerships.
  - Work with all sectors to identify the role of commercially provided data in *The National Map* and to resolve licensing issues such that the national interests for public domain data are served.
  - Seek and secure funding to encourage and sustain State, local, and private sector data maintenance and dissemination activities.
  - Identify priority research topics and opportunities for working with the academic and private sectors to undertake these investigations.
  - Identify priority technology developments needed to implement *The National Map* and opportunities to work with standards and other organizations to understand and influence these developments.
  - Assess how volunteers can best aid the development and maintenance of *The National Map* and identify and work with interested volunteer groups.

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Glossary

accuracy – the closeness of observations to true values or values accepted to be true. Accuracy relates to the quality of a result and is distinguished from precision, which relates to the quality of the operation by which the result is obtained.

area – a generic term for a bounded, continuous, two-dimensional object that may or may not include its boundary.

attribute – a defined characteristic of a feature. For example, "name" is an attribute for a feature "road."

attribute value – a specific quality or quantity assigned to an attribute for an occurrence of a feature. For example, "Spring Street" is the attribute value for the attribute "name" for an occurrence of the feature "road."

bathymetry – the science of determining depths of oceanic or other deep waters.

cadastral information – the geographic extent of the past, current, and future rights and interests in real property, including the spatial data needed to describe that geographic extent.

completeness – the relationship between the objects represented and the abstract universe of all such objects; in particular, the exhaustiveness of a set of features.

contour – an imaginary line on the ground, all points of which are at the same elevation.

coordinates – a set of numeric quantities that describe the location of a point in a geographic reference system.

database – a collection of information related by a common fact or purpose.

datum – any quantity, or set of such quantities, that may serve as a reference or basis for calculation of other quantities; especially a set of quantities that serve as a reference for the calculation of positions. A horizontal datum is the set of constants specifying the coordinate system to which horizontal coordinates are referred. A vertical datum is a set of constants specifying the coordinate system to which elevations are referred. In a linear referencing system, the datum serves as the basis for locating the linear referencing system in the real world and consists of a connected set of anchor sections that have anchor points at their junctions and termini.

digital – a description of data that are stored or transmitted as a sequence of discrete symbols from a finite set; most commonly this means binary data that are processed by computers.

digital orthorectified image – a digital representation of an orthorectified image. The digital image is composed of pixels whose dimensions define the minimum unit of resolution (expressed in distance on the ground).

elevation – the vertical distance from a datum to a point or object on the Earth's surface.

feature – a real world phenomenon of a given type, such as a "road."

Federal Geographic Data Committee – an interagency committee established by Office of Management and Budget Circular A-16 to promote the

coordinated development, use, sharing, and dissemination of spatial data, and to coordinate the development of the National Spatial Data Infrastructure.

generalization – reduction in detail in geographic data representation; for example, resampling elevation or image data to a larger spacing or reducing the number of points in a line.

geodetic control – a network of geodetic control points, or a set of known reference positions, used as a basis for obtaining positions of other features.

geographic information system (GIS) – a computer system for the input, editing, storage, maintenance, management, retrieval, analysis, synthesis, and output of spatial information. In the most restrictive usage, the term refers only to hardware and software. In common usage, it also includes data, and sometimes the people and procedures involved in operations.

Global Positioning System (GPS) – a satellite-based navigation system deployed by the Department of Defense and used to determine locations on the Earth's surface.

governmental units – the geographic extent of units of government, including the Nation, States, counties, incorporated places and consolidated cities, functioning and legal minor civil divisions, such as towns and townships, Federal- or State-recognized American Indian reservations and trustlands, and Alaskan Native regional corporations.

hydrography – surface water features, such as streams and rivers, lakes and ponds, canals and ditches, and oceans.

Implementation Team (I-Team) – a collaborative group organized to build portions of the National Spatial Data Infrastructure for a geographic area, such as a State or region. Participants may include local, State, Federal, and tribal organizations, private sector companies, and other organizations. A team prepares a comprehensive plan for compiling, maintaining, and financing a spatial data infrastructure for a geographic area. The planning includes alignment of participants' needs and resources, identification of participants' responsibilities, and development of milestones. Planned activities must adhere to National Spatial Data Infrastructure principles and include the development, testing, and use of standards.

integration – the processes required to compile a consistent set of data from different sources of data. In *horizontal* integration, sets of data of the same theme for adjoining areas are processed to remove gaps, overlaps, spurs, and other inconsistencies along their common edge. In *vertical* integration, sets of data of different themes for the same area are processed to ensure that, where features have the same alignments on the ground, the data that encode the features also have the same alignments. In *semantic* integration, sets of data that express a common theme or meaning in different ways are processed to express the theme or meaning in a consistent way.

line – a one-dimensional directed and nonbranching sequence of nonintersecting line segments.

linear referencing method – a mechanism for finding and stating the location of any point along a network by referencing it to a known point. Linear

referencing methods consist of traversals and associated traversal reference points that together provide a set of known points, a metric, and a direction for referencing the locations of unknown points.

linear referencing system – a set of datums, networks, and linear referencing methods, whereby each point along a network can be identified uniquely by specifying the direction and distance from any known point on the network.

metadata – data about data; data about the content, quality, condition, and other characteristics of data.

National Spatial Data Infrastructure (NSDI) – the technology, policies, standards, and human resources necessary to acquire, process, store, distribute, and improve the use of spatial data. The NSDI is an umbrella under which organizations and technology interact to foster activities for using, managing, and producing geographic data. Federal responsibilities for the NSDI are coordinated through Office of Management and Budget Circular A-16 and Executive Order 12906.

orthorectified image – an aerial photograph or satellite image from which most displacements caused by terrain relief and sensor geometry have been removed. The result combines the image characteristics of a photograph with the geometric qualities of a map.

pixel – a two-dimensional picture element that is the smallest nondivisible element of a digital image.

point – a zero-dimensional object that specifies a location.

raster data – spatial data in which locations are represented using an array of cells, pixels, or points that hold values for attributes.

reach – a continuous unbroken stretch or expanse of surface water.

reach code – a numeric code that uniquely identifies a reach.

referencing system – a set of datums and rules by which the location of points can be identified uniquely.

relief – elevations and depressions of the land or sea bottom.

resolution – the measurement of the finest detail distinguishable.

spatial data – information that identifies the geographic location and characteristics of natural or constructed features and boundaries on the Earth. The information may be derived from, among other things, remote sensing, mapping, and surveying technologies.

structure – something, such as a building, that is constructed.

theme – a topic or subject.

topographic map – a map that presents the horizontal and vertical positions of represented features, such as elevations and depressions of the land surface (relief), water features, roads and railroads, structures, boundaries, names, and other themes.

topography – the configuration (relief) of the land service; a representation or portrayal of that configuration.

transaction – a unit of processing activity that accomplishes a specific purpose, such as a retrieval, an update, a modification, or a deletion of one or more data elements.

transportation – features used to move people and goods from place to place, such as roads, trails, railroads, ports, airports, and waterways, and related features such as bridges and tunnels.

vector data – spatial data in which locations of features are represented using points, lines, and areas.

Appendix 1. The Changing Needs for Spatial Data, and Opportunities for Meeting These Needs

During the development of the concept, the USGS interviewed key individuals familiar with the development and use of spatial data from Federal, State, and regional government agencies, the private sector, the academic community, and professional organizations. In addition to doing the interviews, the USGS reviewed a number of documents listed in the Selected References section.

The following are current and developing spatial data needs and the implications of new capabilities identified during the development of the report:

- *There continues to be an unmet need for a common set of basic spatial data.* The Federal Government, other public and private organizations, and individuals need a common set of basic spatial data that they can expand and enhance to meet their mission, business, or individual needs. Not only must these data be developed, but they must also be maintained. These data would provide an enterprise level of spatial data for the Federal Government.
- *For some places, large amounts of data are available; for others, very little.* For areas for which spatial data exist, the data developed by different jurisdictions are not consistent. For other areas, little data, or data of unknown or poor quality, exist. Existing data should be used as a starting point for areas for which they are available. Investment is needed where data are lacking.
- *A standing collection of basic spatial data is needed*. There is a need to develop and maintain a standing inventory of these data. In spite of improvements in remote sensing and other technologies, a capability to develop all basic spatial data "just in time" is unlikely. The need to analyze changes in the landscape through time also requires an inventory of data.
- *These data must have the following characteristics*:
    - *Currentness*. Natural and human processes change even the most "timeless" features, such as elevations, and some features, such as a network of roads, can change very quickly. Data must accurately reflect the current state of the landscape. Reasons to maintain currentness range from ensuring correct results from analyses to gaining the confidence of those using the data. Continual maintenance is needed to ensure that the data typically are current in terms of days or months, not years.
    - *Usefulness for any arbitrarily defined geographic area*. Public and private organizations use spatial data to meet mission and business needs, and these needs often have different "footprints" on the landscape. For example, census data concern the geographies of census and political units, work on water resource problems often concerns watersheds, and responses to natural disaster concern the area affected. For the Federal Government, these areas may be as small as individual farms or fields, or as large as ecosystems (and sometimes the entire Nation). The data must have a consistent classification and minimum criteria for completeness

and positional accuracy. Inconsistencies must be resolved among data collected over different areas or by different jurisdictions, as must inconsistencies among different themes of data.

- *Both digital and paper forms of basic spatial data are needed; paper maps should be derived from a master set of digital data.* Much as word processing and other office productivity software have not eliminated paper documents, basic spatial information in the forms of both digital data and paper maps will continue to be needed. Data portrayed on maps must be consistent with those provided in digital form and should be derived from those digital data.

- *Technology will continue to evolve and will provide new ways to collect, maintain, access, and use basic spatial data.* There will be few technical limitations to meeting needs for spatial data; indeed, the future promises an expanding number of possibilities for spatial data collection, maintenance, access, and use. Advances in computing hardware and broadband and wireless communications will provide the basic ability needed to store, process, and communicate data. The trend of including Global Positioning System and "locationally aware" technologies in cell phones and other personal electronic devices promises increased use of spatial data and intriguing new ways of collecting and maintaining these data. Standards, including those for open geographic information technology and processing methods, will be key to capitalizing on these technologies. For the foreseeable future, it appears likely that human intervention will be required to interpret features such as roads and buildings from remotely sensed data.

- *The Internet will continue to provide new ways for disseminating and using spatial data.* The Internet will be the enabling technology that will increase the public and private sectors' and individuals' use and awareness of spatial data. Evolving from a means to view content and purchase products, the Internet will encourage the development of more holistic spatial services, stand-alone devices, specialized applications, customized spatial queries, and interactive capabilities. The result of these changes will be a proliferation of specialized devices that require spatial data accessed over the Internet to operate. The business models for providing these services will result in a number of new funding models.

- *Common needs and interests offer opportunities for partnerships to collect, maintain, access, and use basic spatial data among Federal agencies, and with other public organizations, notably State and regional organizations.* Although the missions of Federal agencies vary, and often are different from those of State, regional, local, and tribal governments, there are overlapping needs and interests in a common set of basic spatial data. Common needs can be met more quickly by pooling resources. The challenge of organizing these resources is substantial.

- *Private sector investments in capabilities to collect, maintain, access, and use basic spatial data, and in the development and maintenance of data, provide opportunities to meet Federal needs.* The private sector currently collects, under contract, basic spatial data that meet Federal specifications. Moreover, some privately held data developed and maintained for other markets could meet

Federal needs. It is worth noting, however, that some private sector business models are new and evolving and it is too early to predict the long-term success of these approaches.

- *Volunteers may be an untapped means of maintaining basic spatial data.* With the advent of "locationally aware" capabilities in cell phones and other personal electronic devices, volunteers knowledgeable about changes in their locales could be a useful source of information needed to maintain basic spatial data.

- *The National Spatial Data Infrastructure provides the context for developing and maintaining basic spatial data.* The National Spatial Data Infrastructure is the technologies, policies, and people necessary to promote sharing of geospatial data throughout all levels of government, the private and nonprofit sectors, and the academic community. The goals of the National Spatial Data Infrastructure are to (1) reduce duplication of effort among agencies, (2) improve quality and reduce costs related to geographic information, (3) make geographic data more accessible to the public, (4) increase the benefits of using available data, and (5) establish key partnerships with States, counties, cities, tribal nations, academia, and the private sector to increase data availability. Under Executive Order 12906, the Federal Geographic Data Committee coordinates the Federal Government's development of the National Spatial Data Infrastructure. The National Spatial Data Infrastructure encompasses policies, standards, and procedures for organizations to cooperatively produce and share geographic data. The 17 Federal agencies that are members of the committee cooperate with organizations from State, local, and tribal governments, the private sector, and the academic community to develop the National Spatial Data Infrastructure. The USGS participates in the committee and leads several of its activities. *The National Map* concept aligns with the goals of, and is one of several USGS activities that contribute to, the National Spatial Data Infrastructure.

- *Policies and other rules for accessing and sharing basic spatial data, such as licenses, must allow the data to flow as needed to meet Federal mission needs*. The Federal Government needs basic spatial data only as much as these data help meet mission needs. The trend for the Federal Government to carry out programs and evaluate results by working with State and other public entities, the private sector, nongovernmental organizations, and the public will continue to grow. Basic spatial data must be available for use by those carrying out programs and for reuse by different combinations of organizations for follow-on work and long-term understanding of change. The ability to share data widely also increases the opportunities for partnerships to fund data collection and maintenance. Therefore, licenses and other policies for basic spatial data use must allow for data sharing among partners that carry out, monitor, or evaluate Federal activities.

- *Federal leadership and commitment are needed to ensure that basic spatial data are available to support Federal agencies in accomplishing their missions.* Without leadership, agencies are likely to expend funds in areas outside their mission responsibilities to obtain these data. A coordinated approach to developing and maintaining these data would reduce duplication and expense.

- *As the Nation's largest civilian mapping agency, the USGS mission is to lead in the development and maintenance of this common set of basic spatial data. A new approach is needed.* The current approach of irregular cycles of updates and independent lines of digital data and paper maps will not meet the needs of the Federal Government. USGS leadership and participation, such as that demonstrated in interagency data development efforts for orthorectified imagery, elevation, hydrography, land cover, and geographic names data, are needed to foster partnerships and approaches to provide needed basic spatial data.

Appendix 2. Research and Development Needed to Support The National Map

Applied cartographic, geographic, and general information science research and development will be required to implement *The National Map*. Using mechanisms such as cooperative research and development agreements with the private sector, grants to universities, and interdisciplinary collaborative teams, the USGS will conduct applied research and development in the following representative areas:

Database Design

- Evaluation of alternative representation models, with the goal of selecting for each theme a single optimal model that will support a small, defined set of applications and product requirements.
- Design of seamless data organization methods that support incremental and transactional updates.
- Exploration of variable (not multiple) resolution models.
- Understanding of how to represent and propagate uncertainty.

Database Population Strategies

- Development of data conflation techniques (similarity indicators, multimode approaches).
- Identification of surrogates for permanent feature identifiers, and methods for using them.
- Identification of strategies for data integration (registration, constraints to logical intertheme relationships).

Data Maintenance Approaches

- Development of practical transaction-based update strategies.
- Development of means for providing temporal updates.
- Development of methods to improve the resolution and accuracy with which a feature is represented.
- Development of Internet-based change notification capabilities to take advantage of a citizenry empowered with Global Positioning System and other "locationally aware" technology.
- Development of new techniques for detecting change.

Product Generation

- Development of user-defined product generation options, including variable footprint, time-slice, resolution, reference system, feature/theme content, and representation models.

- Deployment of techniques for generalization, symbolization, name placement, overlay and transparency levels, and collar generation.
- Exploration of new format and media options, including those that support print-on-demand.
- Development of predefined product templates, especially those needed to support on-the-fly generation of traditional products, such as the maps of the primary topographic series.

Accessibility

- Development of interactive data access methods that comply with open geographic information technology and processing standards, as well as other Internet standards.
- Understanding of the technical aspects of data access licensing arrangements proposed by the private sector.

Related longer-term research needs include the following:

- Investigations of multidimensional data models to support the integration and application of other USGS scientific data holdings with *The National Map*.
- Understanding of the application of sensor technologies now being developed, including new techniques for sensing the landscape remotely and on the ground.
- Exploration of synchronization approaches for distributed data holdings and architectures.
- Exploiting of wireless devices and technology linked to the Global Positioning System for updating data.
- Understanding of mappings and transforms among different data models
- Investigations of cognition and visualization of spatial data.
- Investigations of topics related to models of institutional arrangements, the value of sharing data, and intellectual property.