USGS Digital Base Map Data - Where to Get It, How to Use It

Note: use as reference in regards to major categories of map components: digital elevation models (DEM's), scanned USGS topo maps (DRG's) digital raster graphs, and digital orthophotography (DOQQ's). Also know what is a DLG or digital line graph. Sean Booth - GEOG 85

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Abstract:

Psomas is a mid-sized Survey and Engineering firm providing GIS and Environmental services to a diverse spectrum of private and municipal clients. Obtaining low cost, spatially accurate digital base map data is often a critical first step in the development of GIS services and applications. Although a variety of low cost data sources exist, USGS digital sources have proven to be unparalleled in their level of accuracy, detail, and accessibility. This paper introduces the vector and raster base map data available from the USGS, and discusses their potential uses and applications.

INTRODUCTION

Throughout the history of the United States, maps have played a pivotal role in the development of our nation. There is virtually no aspect of commerce, environment, or politics that is not in some integral way related to its physical location, or does not derive its essential nature from the geospatial context of its surroundings. The USGS 7.5 minute quad sheet, usually referred to simply as a USGS "quad" or "topo map", has become the workhorse of most common mapping applications. On any given day thousands of quads lie spread out on the desks of planners, engineers, biologists, economists, historians, politicians, recreational enthusiasts, and of course geographers, playing an integral role in whatever task is at hand. They have become so common and easily accessible that we run the risk of taking them for granted, and lose sight of the technical, logistic and monetary effort that was needed to produce them in the first place.

Today, the base mapping of the United States and its territories at 1:24000 scale is completed—a total of over 53,000 individual quad sheets delineating transportation (roads, railroads, utility features, and pipelines); hydrography (lakes, rivers, reservoirs, dams, wells and springs); hypsography (elevation contours and spot heights); boundaries (of counties, cities, national parks, national forests, reservations and other municipalities); public lands (the public land survey system depicting section, range and township locations); vegetation (forests, shrubland, wetlands, and agriculture); man-made features (buildings, airports, stadiums etc.); non-man-made features (sand dunes, glaciers); survey control (horizontal and vertical control of the National Geodetic Network); geographic names (of all of the features above, including cities, rivers, mountains, canyons, etc.) and coordinate grids, in Latitude/Longitude, Stateplane and UTM projections. The private-sector cost of creating today a single 24K quad depicting the same information, and produced to meet National Map Accuracy Standards, has been estimated at approximately half a million dollars. Yet anyone can buy such a map, in full-color 24 x 36 inch format, for four dollars and fifty cents. It would be difficult to find any product in the public or private sector of comparable cost and benefit. The foresight, productivity and public service of this agency is probably without peer in the government sector. We owe to them an incalculable debt.

Several decades ago the USGS embarked on the journey of developing a model to convert its hard copy maps into digital format. Based on the simple concept of cartesian coordinate systems, and extended to include concepts of topology, the "Digital Line Graph" was born. These vector based mapping data represented the first mass produced GIS data for public use in the world. As both funding and need grew, so did the extent of the digital data program. The program was extended to include production of digital elevation models (DEM's), scanned USGS topo maps (DRG's), and digital orthophotography (DOQQ's). Taken as a whole, these core datasets of the so-called "National Framework" probably represents the lowest cost, highest quality, and most underutilized digital GIS basemapping data currently available.

There is a reason why USGS digital data is not used as much as it could be: it is notoriously difficult and time consuming to process. In fact in the absence of platform specific programs (e.g., aml's) developed specifically for the purpose of processing the data, the routine use of the data for GIS basemapping applications is for most intents and purposes impractical. This is an impediment in its own right but has led to another, perhaps more serious problem in terms of public awareness--the average GIS user has probably only a passing familiarity with the benefits of using the full suite of data available from the USGS precisely because it is so difficult to process. And while any of the data sets taken individually can be useful, their true power is realized when they are routinely used as a total basemapping "package".

This paper is not intended to be a data processing handbook. The intent is to introduce, or perhaps re-introduce, the various commonly available USGS datasets. The sections that follow will outline some of their advantages, in the hope that readers will become interested in their use. The following two tables describe the datasets discussed in this paper, where to get them, and how much they cost.

Available Products

PRODUCT	NAME	DATA TYPE	DESCRIPTION	SCALE
USGS DLG	"Digital Line Graph"	Vector	Polygon, line, and point layers depicting features of hard-copy USGS topo maps.	1:24,000 1:100,000 1:2,000,000
USGS DEM	"Digital Elevation Model"	Raster grid	Elevation x,y,z values used for 3 dimensional display and topographic analysis.	1:24,000 1:100,000 1:2,000,000
USGS DOQQ	"Digital Orthophoto Quarter Quad"	Raster TIFF	Georeferenced digital orthorectified aerial photography	1:12,000
USGS DRG	"Digital Raster Graphic"	Raster TIFF	Georeferenced digital scans of USGS topo sheets.	1:24,000

Where to Get Them

PRODUCT	OBTAIN FROM	WEB ADDRESS / COST
USGS DLG	US Geodata Homepage	http://edcwww.cr.usgs.gov/doc/edchome/ndcdb/ndcdb.html Free
USGS DEM	US Geodata Homepage	http://edcwww.cr.usgs.gov/doc/edchome/ndcdb/ndcdb.html Free
USGS DOQQ	Geographic Land Information System (GLIS)	http://edcwww.cr.usgs.gov/webglis/ Base charge $30.00 for FTP, or $45.00 for CD, plus $7.50 each B&W, $15.00 each CIR
USGS DRG	Geographic Land Information System (GLIS)	http://edcwww.cr.usgs.gov/webglis/ Base charge $30.00 for FTP, or $45.00 for CD, plus $1.00 each DRG

USGS Digital Line Graphs – 1:100,000

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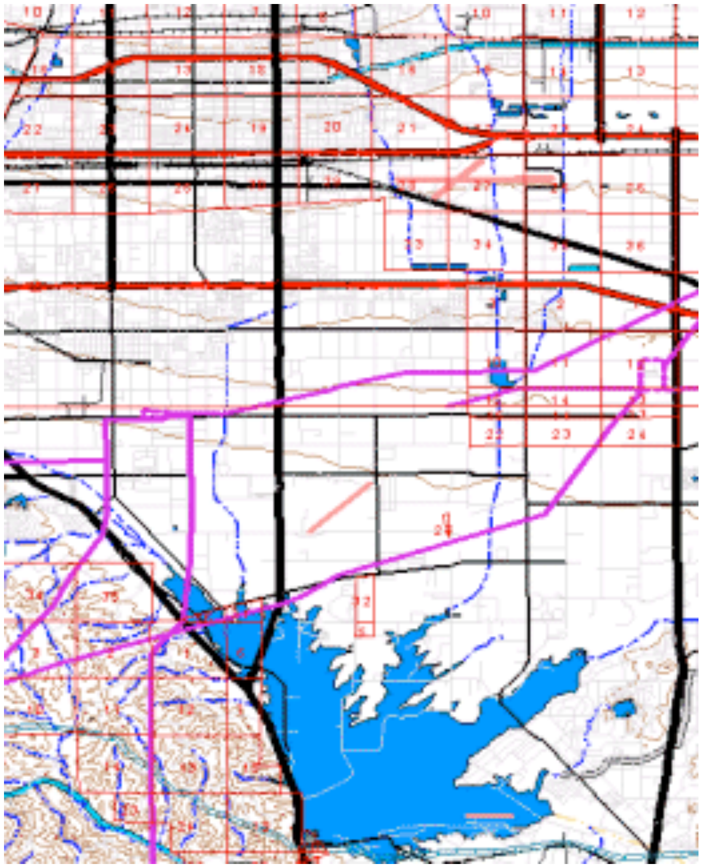

Digital Line Graphs (commonly known as "DLG’s) are a digital vector representation of the features typically seen on a standard USGS topographic map. Unlike a scanned quad sheet, which is simply a graphic image, these vector data sets can be converted into actual ArcInfo coverages. Each layer can be edited and cartographically manipulated, for example to update the alignment of a road or to change its display characteristics. DLG's are available three different scales: 1:24,000 (24K), 1:100,000 (100K), and 1:2,000,000 (2M). This section focuses on the 100K DLG product because of its wide availability. 100K DLG’s come in 5 separate data sets representing a total of 10 different data layers as listed in the table below.

DATA SET	**LAYER**	**DESCRIPTION**
USGS DLG – Transportation	Roads	Freeways, major roads, residential streets, trails
	Railroads	Railroads, turn-arounds
	Miscellaneous Transportation	Pipelines, powerlines, sub-stations

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USGS DLG – Hydrography	Lakes	Lakes, dry lakes, dams, reservoirs
	Rivers	Rivers, streams, coastlines, shorelines
	Springs	Springs and wells
USGS DLG – Hypsography	Contours	Contours
	Spot	Spot elevations
USGS DLG – Public Land Survey System	Plss	Section, Range and Township grid
USGS DLG - Boundaries	Boundaries	Boundaries of public owned/ administered lands

Coverage layers for USGS DLG 100K data.

The principle advantage of DLG's is that they are the only seamless vector basemap data in the United States produced to meet National Map Accuracy Standards. This means that on a regional scale, adjoining map sheets will meet at their edges, and features will have uniform accuracy at scale. This is an important consideration in regional mapping applications, where uniform basemap data is needed to cover tens or hundreds of miles. DLG data also tends to have a higher resolution than comparable data sets of national scope. For example, coastlines and lake shorelines show a great deal of detail when compared to other more generalized data sets. In fact the term "100K" scale is somewhat misleading. 100K DLG data sets were originally compiled from 1:24,000 (24K) topo source sheets, and although certain feature classes were weeded out—for example vegetation and man-made features—others were retatined at virtually full resolution. For example in the DLG Transportation layer, road detail is retained to the level of residential streets.

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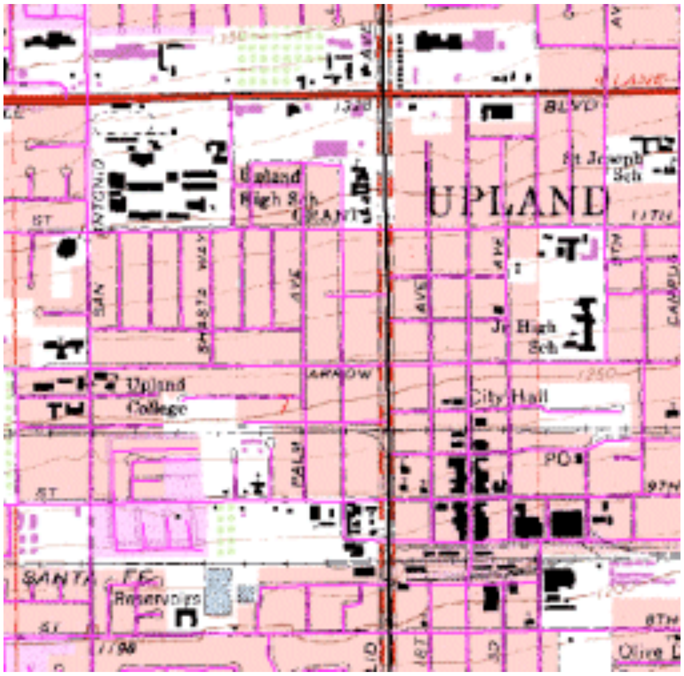


"100K" DLG residential roads layer (in magenta) overlayed on 24K DRG

DLG data can also be described as "feature rich". There is no other data set of national scope produced to meet NMAS that contains the unique combination of basic base mappping layers as listed in the table above. And although most applications will probably never need to know the locations of duck ponds, railroad sidings, or meander corners, there many types of data contained in DLGs which can be found nowhere else. The sections that follow include an outline of the major feature types included in each of the 100K DLG data sets. The most commonly sited drawback to DLGs is their vintage. Most DLG 100K is more than a decade old, and a lack of funding has held back systematic updating and revision of the data. This is less of a problem in rural areas or in urban areas which have been "built out", where major features may change little. But it is an issue in developing areas where many new features-- particularly transportation features and municipal boundaries-- may not be current. Even in such situations it's usually better to start with an existing digital map that can revised than to start with nothing at all, and features can be revised by referring to other reference information such as current aerial photography. The USGS DOQQs are particularly useful for this purpose since they are both digital and fully orthorectified. DLG's are also notoriously poor in some types of attributing. For example, attributes will exist to distinguish a major road from a trail, or a river from a shoreline, but the proper names of features are rarely attributed. This can be a major issue for themes such as roads or hydrography, where feature names can be vital to the purpose of the map; the manual addition of correct attributing from alternative reference maps can be extremely costly and time consuming. Not all DLG data layers are subject to these limitations. For example, the

Public Land Survey System layer is fully attributed with section, range and township information. The Miscellaneous Transportation layer, although not fully attributed, may be less of an issue since features such as power lines, pipelines and railroads are relatively few and relatively easy to attribute manually.

The sections below list the feature attributes present in each data layer along with some sample graphics intented to give the reader some feeling for the degree of feature richness present in DLG datasets.

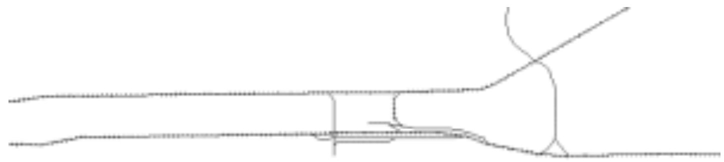
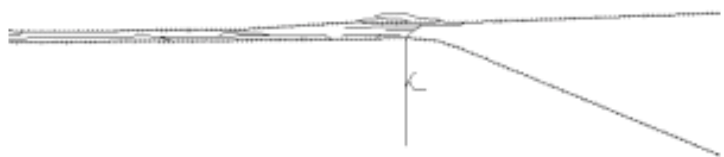
Transportation

Roads and Trails

1700001	Bridge abutment
1700002	Tunnel portal
1700004	Gate
1700005	Cul-de-sac
1700006	Dead end
1700007	Drawbridge
1700201	Class 1, undivided
1700202	Class 1, divided by centerline
1700203	Class 1, divided, lanes separated
1700204	Class 1, one way
1700205	Class 2, undivided
1700206	Class 2, divided by centerline
1700207	Class 2, divided, lanes separated
1700208	Class 2, one way
1700209	Class 3

1700210	Class 4	
1700211	Trail, other than 4WD	
1700212	Trail, 4WD	
1700213	Footbridge	
1700214	Road ferry crossing	
1700215	Perimeter of parking area	
1700217	Class 3, divided by centerline	
1700218	Class 3, divided, lanes separated	
1700219	Class 4, one way	
1700220	Closure line	
1700221	Class 3, one way	
1700222	Road in transition	
1700299	Processing line	
1700401	Traffic circle	
1700402	Cloverleaf or interchange	
1700403	Tollgate	
1700404	Weight station	
1700405	Nonstandard section of road	
1700406	Covered bridge	
1700613	In service facility, rest area	

Railroads

1800001	Bridge abutment	 
1800002	Tunnel portal	
1800003	Crossover	
1800007	Drawbridge	
1800201	Railroad	
1800202	Railroad in street or road	
1800204	Carline	
1800205	Cog railroad, incline railway, logging tram	
1800207	Railroad ferry crossing	
1800208	Railroad siding or spur	
1800209	Perimeter or limit of yard	
1800211	Closure line	
1800299	Processing line	
1800400	Railroad station, perimeter of station	
1800401	Turntable	
1800402	Roundhouse	

Miscelaneous Transportation

1900001	End of transmission line	
1900002	End of pipeline at oil or gas field	
1900003	End of pipeline at refinery, depot, ...	

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1900004	Steel or concrete tower on transmission line	
1900201	Pipeline	
1900202	Power transmission line	
1900203	Telephone or telegraph line	
1900204	Aerial tramway, monorail, or ski lift	
1900206	Closure line	
1900299	Processing line	
1900300	Seaplane anchorage	
1900400	Power station	
1900401	Substation	
1900402	Hydroelectric plant	
1900403	Landing strip, airport, perimeter of airport	
1900404	Heliport, perimeter of heliport	
1900405	Launch complex, perimeter of launch complex	
1900406	Pumping station or compressor station	
1900407	Seaplane ramp or landing area	
1900408	Measuring station, or valve station	

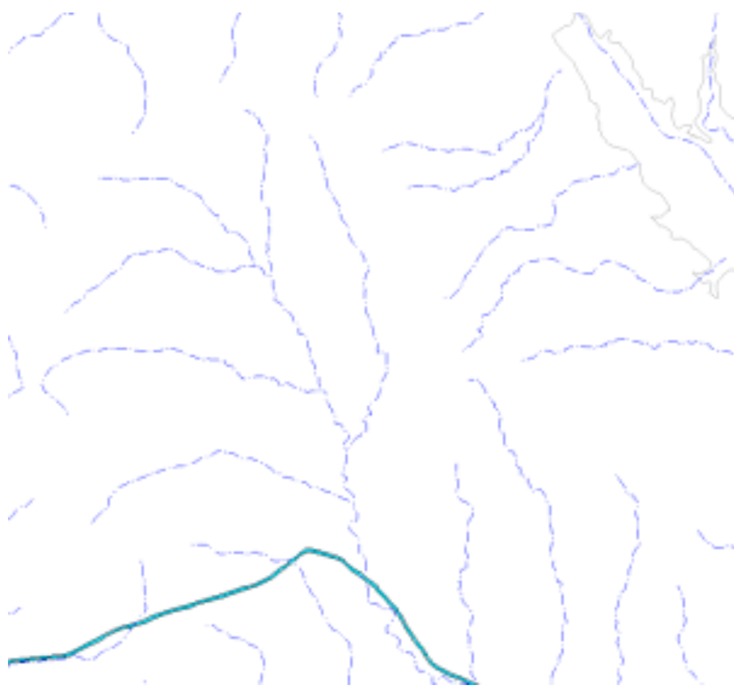
Hydrography

Lakes

Streams

Springs and Wells

500001	Upper origin of stream
500002	Upper origin of stream at water body
500003	Sink, channel no longer evident
500004	Stream entering water body
500005	Stream exiting water body
500100	Alkali flat
500101	Reservoir
500102	Covered reservoir
500103	Glacier or permanent snow field
500104	Salt evaporator
500105	Inundation area
500106	Fish hatchery or farm
500107	Industrial water impoundment
500108	Area to be submerged
500109	Sewage disposal pond or settling basin
500110	Tailings pond or settling basin



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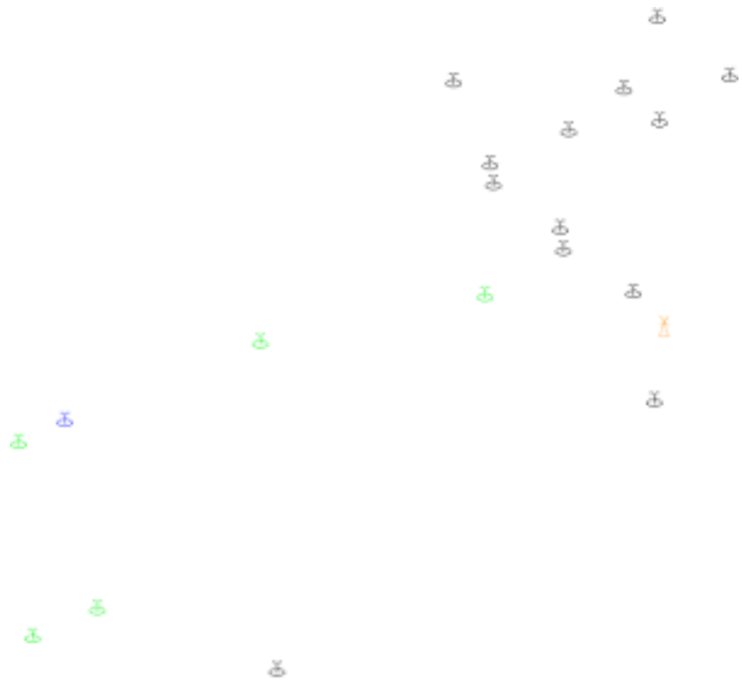
500111	Marsh, wetland, swamp, or bog
500112	Mangrove area
500113	Rice field
500114	Cranberry bog
500115	Flats (tidal, mud, sand, or gravel)
500116	Bays, estuaries, gulfs, oceans, or seas
500117	Shoal
500118	Soda evaporator
500119	Duck evaporator
500121	Obstruction area in water area
500200	Shoreline
500201	Manmade shoreline
500202	Closure line
500203	Indefinite shoreline
500204	Apparent limit
500205	Outline of a Carolina bay
500206	Danger curve
500207	Apparent shoreline
500208	Sounding datum
500209	Low-water line
500299	Processing line



500300	Spring
500301	Non-flowing well
500302	Flowing well
500303	Riser
500304	Geyser
500305	Windmill
500306	Cistern
500400	Rapids
500401	Falls
500402	Gravel pit or quarry filled with water
500403	Gaging station
500404	Pumping station
500405	Water intake
500406	Dam or weir
500407	Canal lock or sluice gate
500408	Spillway
500409	Gate (flood, tidal, head, or check)
500410	Rock
500411	Crevasse
500412	Stream
500413	Braided stream
500414	Ditch or canal

500415	Aqueduct
500416	Flume
500417	Penstock
500418	Siphon
500419	Channel in water area
500420	Wash or ephemeral drain
500421	Lake or pond
500422	Coral reef
500423	Sand in open water
500424	Spoil area, dredge area, or dump area
500425	Fish ladders
500426	Holiday area

Hypsography

Contours

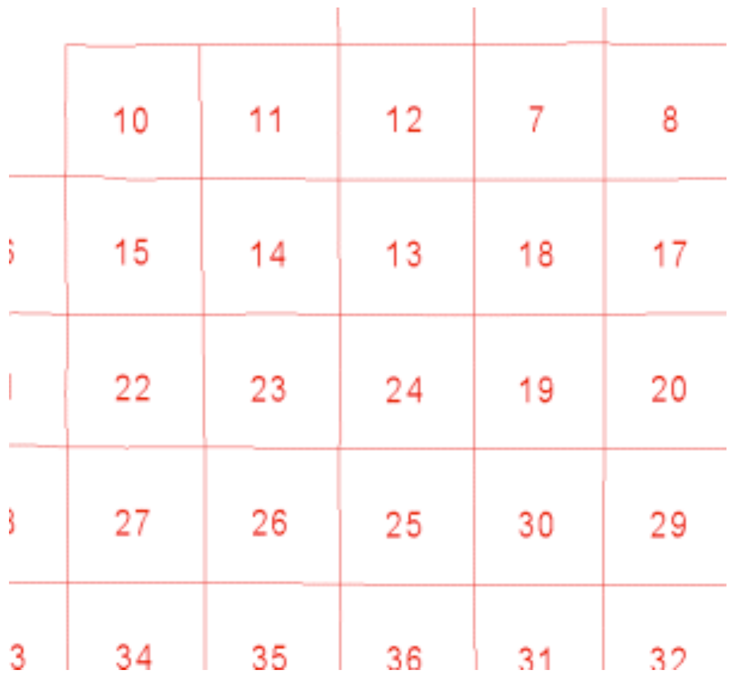
Spot Elevations

200200	Contour
200201	Carrying contour
200203	Continuation contour
200205	Bathymetric contour
200206	Depth curve
200207	Watershed divide
200208	Closure line

200299	Processing line
200300	Spot elevation, less than third order
200301	Spot elevation, less than third order, not at ground level

Public Land Survey System (PLSS)

3000001	PLSS section corner
3000002	Point on section line
3000003	Closing corner
3000004	Meander corner
3000005	Auxiliary meander corner
3000006	Special meander corner
3000007	Witness corner
3000008	Witness point
3000009	Angle point
3000010	Location monument
3000011	Reference monument
3000012	Quarter-section corner
3000013	Tract corner
3000014	Land grant or donation land claim corner
3000015	Arbitrary section corner
3000100	Indian lands
3000101	Homestead entries



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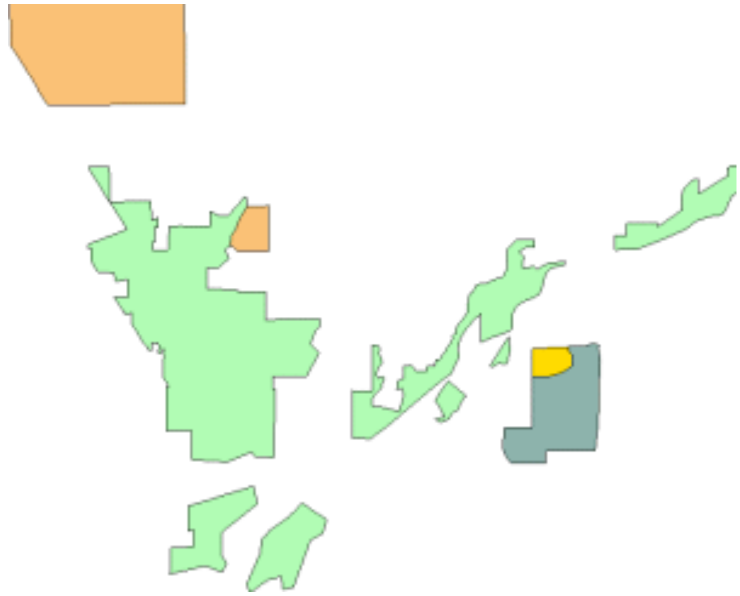
3000102	Donation land claims	
3000103	Land grants or civil colonies	
3000104	Private extension of PLSS	
3000105	Area of public and private survey overlap	
3000106	Overlapping land grants	
3000107	Military reservation	
3000108	Private survey	
3000109	Other reservation	
3000198	Water	
3000199	Unsurveyed area	
3000203	Arbitrary closure line	
3000204	Base line	
3000205	Claim line, grant line	
3000299	Processing line	
3000300	Location monument	
3000301	Isolated found section corner	
3000302	Witness corner (off surveyed line)	

Boundaries

900001	Monumented point on a boundary	

900002	Boundary turning point
900103	National park
900105	National wildlife refuge
900107	Indian reservation
900108	Military reservation
900109	Nonmilitary government reservation
900110	Federal prison
900111	Miscellaneous Federal reservation
900113	Land grant
900129	Miscellaneous State reservation
900130	State park
900131	State wildlife refuge
900132	State forest
900133	State prison
900134	County game preserve
900150	Large park
900151	Small park
900197	Canada
900198	Mexico
900199	Open water
900200	Approximate boundary
900201	Indefinite boundary



900202	Disputed boundary	
900203	Historical line	
900204	Boundary closure line	
900299	Processing line	
900301	Reference monuments	

USGS Digital Elevation Models—24K DEM

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Digital Elevation Models (commonly referred to as DEMs) are a raster-based grid of numeric elevation values. They are used in a GIS to produce three-dimensional terrain models. Because they are based on a raster data model, some products produced from DEMs can appear similar to simple graphic images. For example, DEMs are commonly used to produce striking shaded-relief images, which in addition to their visual appeal, are extremely useful for visualizing local and regional terrain features. But DEMs are more than simple graphic images. They are fully georeferenced coverages and can be used to produce numerous spatial and analytical products. For example, DEMs can be used to produce maps of slope and aspect, and can be used to generate vector elevation contour lines. They are also the foundational data set used in many terrain-based GIS modeling applications such as watershed modeling, visibility analysis, flood susceptibility, landslide potential, and wildlife corridor determinations.

Viewshed derived from DEM data.

Contours derived from DEM data.

DEMs are distributed in two common scales. 24K DEMs (also known as 7.5 minute or 1:24,000 DEMs) cover the extent of a standard 7.5 minute, 1:24,000 USGS quad sheet. The nominal grid cell sampling resolution can be either 10 or 30 meters. 250K DEMs (also known as 3' – "three second" or "three arc second" DEMs) cover the extent of a standard 1^o, 1:250,000 USGS quad sheet. The nominal grid cell sampling resolution is three arc seconds, a distance of about 90 meters. The use of one product versus the other depends on the application. 24K DEMs cover a smaller area of the earth's surface, and have a correspondingly higher degree of accuracy and resolution than the 250K DEMs. As such, they are generally the preferred product for modeling and analytical applications on a local or semi-regional scale. If the study area is larger than a single

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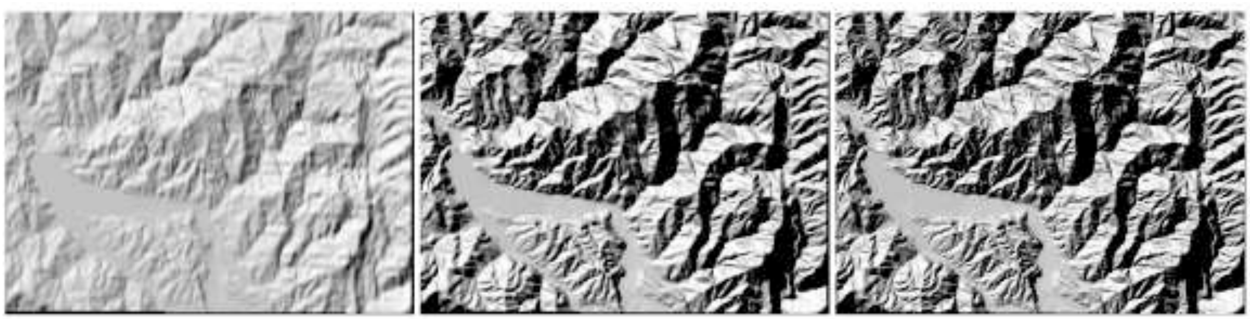
quad sheet, adjoining DEMs are usually mosaiced together into a single, larger DEM. The larger the study area, the more DEMs that must be mosaiced, and the larger the output DEM becomes. For example, a single 24K DEM (floating point) has a size of roughly 10 Megs; mosaicing 10 DEMs together will produce an output DEM of about 100 Megs. At some point, the output DEM becomes too large to be practical, and the use of the 250K DEM product may be preferred. The 250K DEM has lower accuracy and resolution than the 24K DEM, but it covers a much larger area without incurring the larger file size. They are useful for regional modeling applications, and they are excellent cartographic tools for producing three -dimensional vicinity maps to show local study areas within their broader, regional context. They can also be useful as an overlay tool for producing perspective photographic drapes.

24K DEMs are produced in 3 different levels of accuracy and resolution: 30 meter, level 1; 30 meter, level 2; and 10 meter, level 2. Level 2 data is collected with different methods than level 1 and is generally both more accurate and of higher visual resolution on-screen than level 1. 30 meter coverage is available for the coterminous US. 10 meter 24K DEM coverage is relatively rare, but if you can find it where you need it is of exceptional quality. The graphic below shows a comparasion between 30 meter, level 1; 30 meter, level 2; and 10 meter, level 2 data for the same quad.



There are several caveats worth mentioning in the processing of DEM data. There is no standard vertical unit in the production of DEMs. Native horizontal units are meters, but vertical units can be either meters or feet, depending on the extent of the local terrain relief. As a consequence, a neighborhood of adjacent DEM's are frequently of mixed vertical units and must be converted to a standard vertical unit during processing. The USGS also uses two different integer values to represent areas of "no data". Null data areas are coded with the value -32,766 while void data areas are coded with the value -32,767. If these values are not replaced with valid ArcInfo "no data" values they will be interpreted as elevations, and corrupt the DEM during conversion. Lastly is the issue of vertical datum. Just as vector coverages must always specify a horizontal datum as an integral part of the projection parameters, the vertical datum is equally critical when dealing with DEM elevation data. Unfortunately, ArcInfo does not currently support reporting of the vertical datum as part of the conversion process. The standard vertical datum for 24K DEMs is the North American Vertical Datum of 1929 (NAVD29). Native elevations can be converted to the more current North American Vertical Datum of 1988 using a quad specific conversion factor obtained from the USGS.

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With the advent and proliferation of GPS data, which commonly uses NAVD88 as its datum, conformance to a common datum is critical.

USGS Digital Raster Graphics

USGS Digital Raster Graphics (commonly known as DRGs) are scanned, geo-referenced images of standard 7.5 minute USGS quad sheets. They are not vector coverages—they are simply images—but they differ from a simple graphic picture in that they are geo-referenced. When correctly projected, DRGs will "overlay" with all other GIS data layers in correct geographic space. The images are in full color and high resolution. In fact, plots of DRGs from an HP 2500 plotter are virtually indistinguishable from the original paper product.

DRGs have a variety of uses. The most obvious is that, in digital form, color copies can plotted and distributed at will. Derivative products, such as project specific features overlaid onto the DRG and replotted, are easily produced. This is extremely useful for field personell such as surveyors, biologist, geologists, and so on who routinely use topo maps in the course of their work. Since most people are already familiar with the "look"

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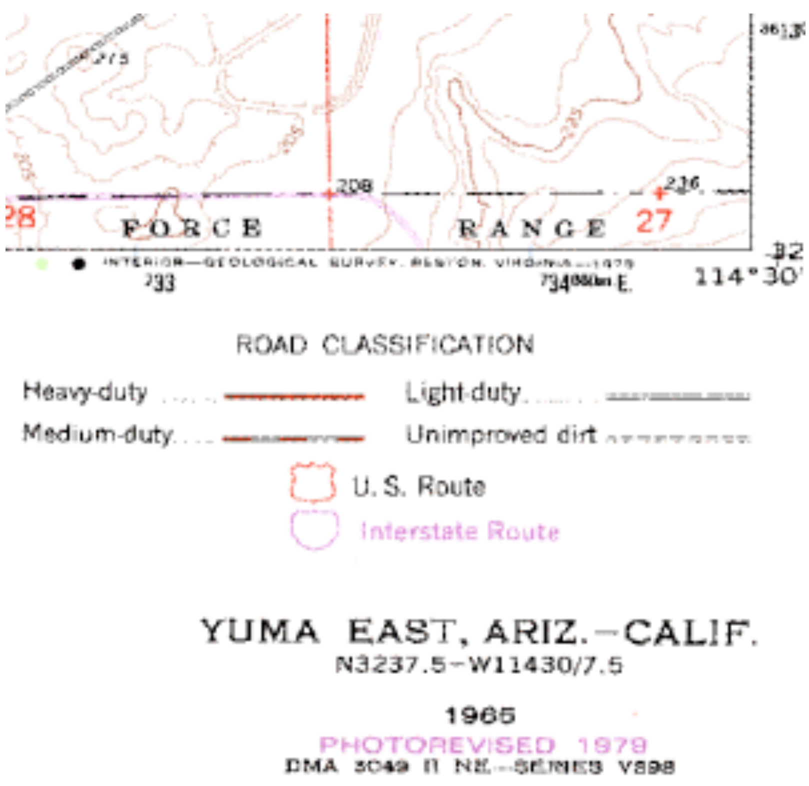
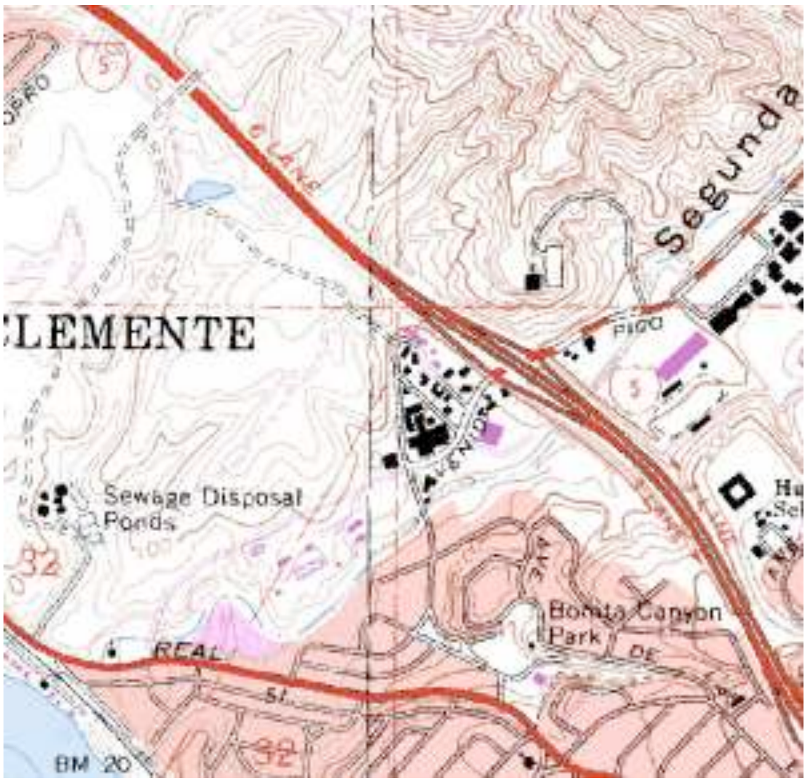
of a standard USGS 7.5 minute quad sheet, DRGs are also useful as background images upon which specific GIS data layers can be overlaid. Using DRGs in this way is often a cost-effective solution to creating quick exhibits, since the overhead of creating all of the background detail—roads, streams, major buildings, etc.—is avoided.

Native DRGs are "collared"; the product looks identical to a standard USGS topo map and includes the white paper margin surrounding all USGS quad sheets. The collar contains a variety of standard USGS information such as the title block, the scale bar and north arrow, the names of the four surrounding quad sheets, the coordinate system grids for Latitude and Longitude, State Plane, and UTM projections, and so on. This information is often vital to a user, and its inclusion makes it possible to reproduce a USGS quad sheet in full fidelity.



Metadata contained in the margin or "collar" of a native DRG.

For the purpose of screen display or GIS overlay mapping however, the collar often gets in the way. For example, if a user wants to display two adjacent DRGs on-screen at the same time, the white collar of one DRG will overlap, and effectively cover up, the mapping data on the adjoining DRG. To solve this problem, the collar can be clipped to form a "collarless" DRG. This makes it possible to load multiple DRG simultaneously with no loss of information. It is also an effective solution for producing overlay exhibits across multiple quad sheets—adjoining quad sheets will appear "seamed" together into one consistent map.



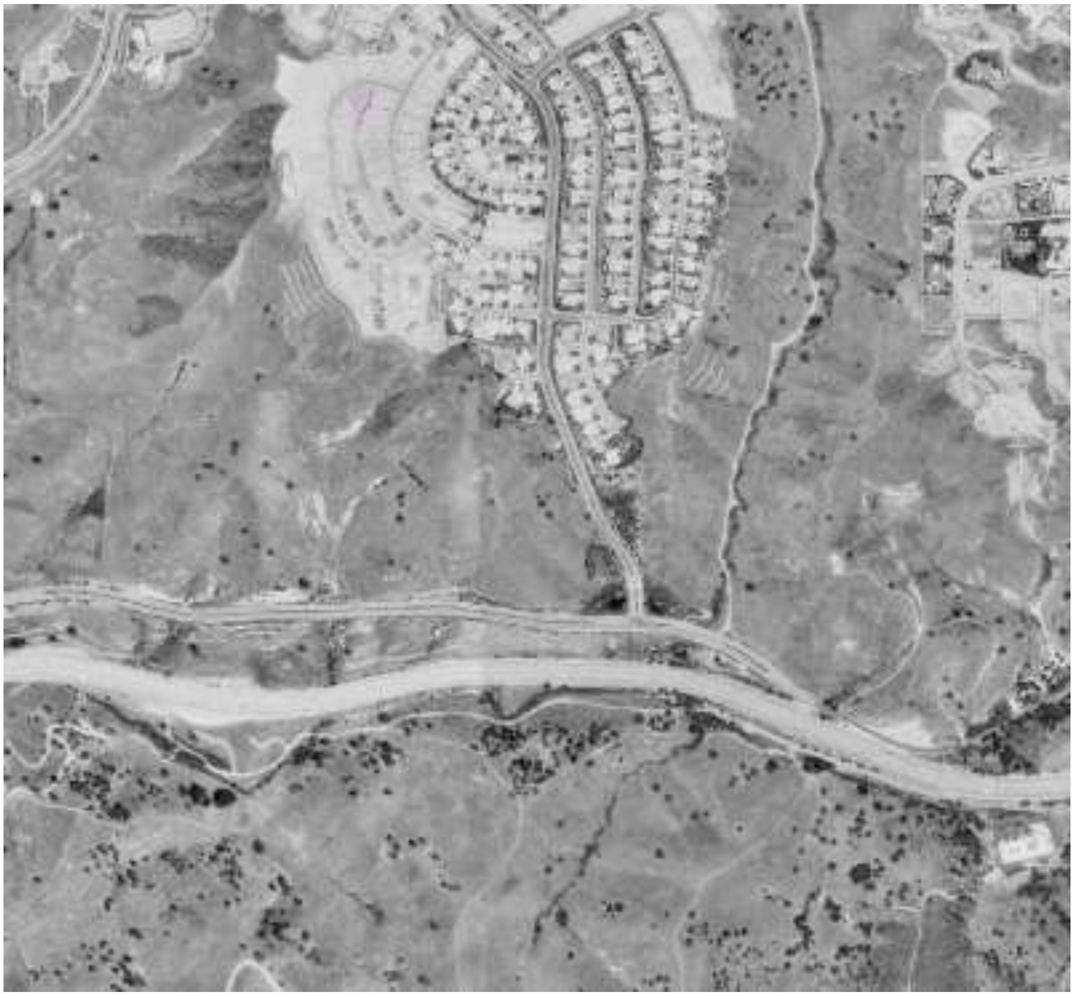
Collarless DRGs displayed as a single mosaic.

USGS Digital Orthophoto Quarter Quads

USGS Digital Orthophoto Quarter Quads (typically called "DOQQs") are georeferenced, fully orthorectified, digital aerial photography. Because the effects of rotation, tilt and terrain relief have been removed they can be used directly for feature digitization and GIS data layer updating. They are extremely useful as an overlay for verifying, revising, and supplementing the information content of DLGs, DRGs, and DEMs. They are also an invaluable tool in the field as an aid to regional and urban planning efforts and environmental mapping projects. The imagery has a native resolution of 1m and will support plots to scales of 1:3,000 (1"=250'). Because file sizes are large (typically 50 megs for black and white and 150 megs for CIR), they are distributed as quarter sections (NW,NE,SW,SE) of a 7.5 minute quad sheet.

Unlike DRGs, DOQQs have no collar and are intentionally produced with a good degree of overlap between adjacent images. Native DOQQs are generally not color balanced, so the "seam" between images may visible as a discrepency in tone and contratst even though the geometry is solid. Image processing software can be used to feather and color balance adjacent images if necessarry.

http://proceedings.esri.com/library/userconf/proc00/professional/papers/PAP691/p691.htm



Adjacent DOQQs showing slight differences in tone and contrast.

DOQQs are generally flown on a five year cycle. More current orthophotography can be obtained on the open market but would typically cost several thousands of dollars for comparable "custom flown" orthophotography. The fact that DOQQs can be purchased for a base charge of $30.00 at $7.50 each makes them a remarkable resource.

CONCLUSION

In summary, the core National Framework datasets—DLGs,DEMs,DOQQs and DRGs—constitute a powerful and versatile suite of GIS basemapping and analytical tools that would not otherwise be available, except at enormous cost. Their underutilization by the general GIS community is undoubtedly related to the difficulty, time and effort associated with processing the data into a useful product, but more people might make that effort if it were clear what the benefits are. In our experience, there is rarely a project that is not benefited by the use of these datasets, frequently for the performance of value added services which budgetary constraints would not otherwise have allowed. With each dataset georeferenced and produced to consistent National Map Accuracy Standards, they represent the most consistently accurate, lowest cost and readily available data of its kind.

Authors Note: Readers interested in exlploring this data further can request a full set of USGS DLG, DEM, DRG and DOQQ sample data in ArcInfo format by contacting the author at the e-mail address below, or by visiting the Digital Map Products web site at http://www.digmap.com

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