Award Number G11AP20174

Detailed Surficial Geological Mapping for the Creve Coeur and Kirkwood 7.5' Quadrangles as a Portion of the St. Louis Area Earthquake Hazard Mapping Project (SLAEHMP)

Collaborative Research with:
United States Geological Survey; Earthquake Hazards Program Office
and
Missouri Department of Natural Resources;
Division of Geology and Land Survey

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Abstract

The Missouri Department of Natural Resources' Division of Geology and Land Survey (MoDNR' DGLS) proposed and has produced detailed geologic maps of surficial materials for the Creve Coeur and Kirkwood 7.5-minute USGS quadrangles as part of the St. Louis Area Earthquake Hazard Mapping Project (SLAEHMP). Surficial materials mapping comprises the first phase of seismic hazard assessment by reducing the uncertainty in the three dimensional distribution of surficial material units and their related physical properties.

DGLS has compiled and correlated existing data from multiple databases to characterize the study area. The maps were produced in the Geographic Information System (GIS) geodatabase format to reduce file size and to improve the quality and functionality of the final product.

Introduction

The goal of the project for fiscal year 2011 (FY11) was to complete new detailed surficial geologic maps for the Creve Coeur and Kirkwood 7.5' quadrangles. Depth to ground water is currently being addressed by the SLAEHMP Technical Working Group (TWG) to rectify the true potentiometric surface.

Mapping for this project was completed using available subsurface data and stratigraphic profiles developed for the St. Louis Surficial Materials Database developed by Jim Palmer as part of the National Earthquake Reduction Program (NEHRP), the St. Louis Database under development by Missouri University of Science and Technology (MS&T), and correlated with published small-scale surficial material maps (Brill, 1991; Goodfield, 1965; Lutzen and Rockaway, 1971). Existing small-scale maps and reports indicate that these areas have surficial material units that vary from Paleozoic bedrock exposures and residuum to early Quaternary loess and alluvium with wide ranges in grain size. Boring data was incorporated to examine the three-dimensional spatial variation of the surficial material unit properties. This analysis will be used to assess the response of the alluvial column, the liquefaction potential, and the potential for site amplification in response to different magnitude earthquakes. The information will improve the accuracy of the earthquake hazard maps prepared by the SLAEHMP TWG.

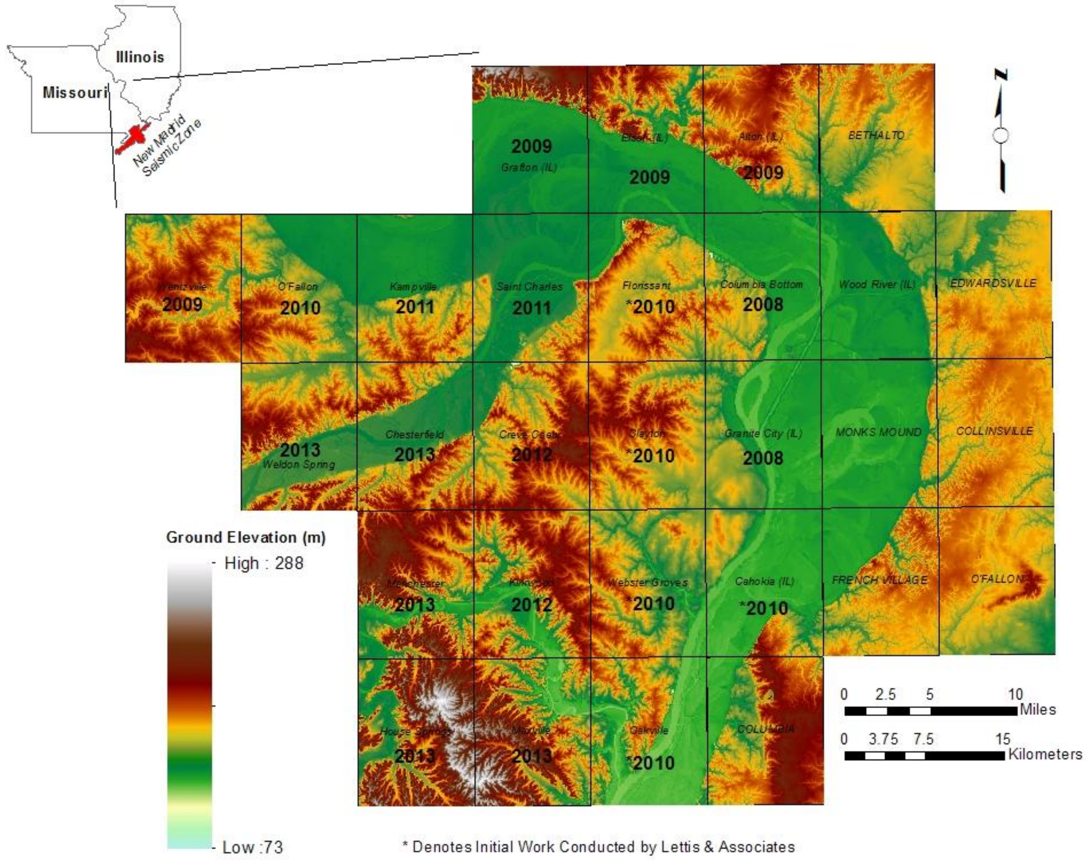

Figure 1. SLAEHMP AREA. The SLAEHMP study area and the proposed mapping priorities for the SLAEHMP TWG. Years listed on quadrangles denote the anticipated completion.

Methods

Borehole data derived from the division's St. Louis Surficial Materials Database developed by Jim Palmer as part of the National Earthquake Reduction Program (NEHRP) was supplemented by the St. Louis Database under development by MS&T. All of the geotechnical information was compiled and correlated with the divisions' water well databases to identify any inconsistencies in depth to bedrock measurements. The corrected data was then imported into the divisions' geodatabase created for each individual quadrangle.

The Geographic Information System (GIS) geodatabase format is preferred over the GIS shapefile format. This change in mapping methodology increases productivity and functionality while reducing file size. The structure of an individual geodatabase includes feature data sets of major layer groups which include feature classes of specified data. An example of this structure is depicted in Figure 2. The Creve Coeur and Kirkwood geodatabases contain seven feature data sets. One of them is transportation. Within the transportation feature data set are the feature classes associated with transportation such as roads, railroads, and various other transportation networks along with their associated buffers. Within the data point feature data set are five feature classes associated with the type of data point such as geotechnical borings, seismic cone penetrometer test, shallow seismic by method, and bedrock penetration.

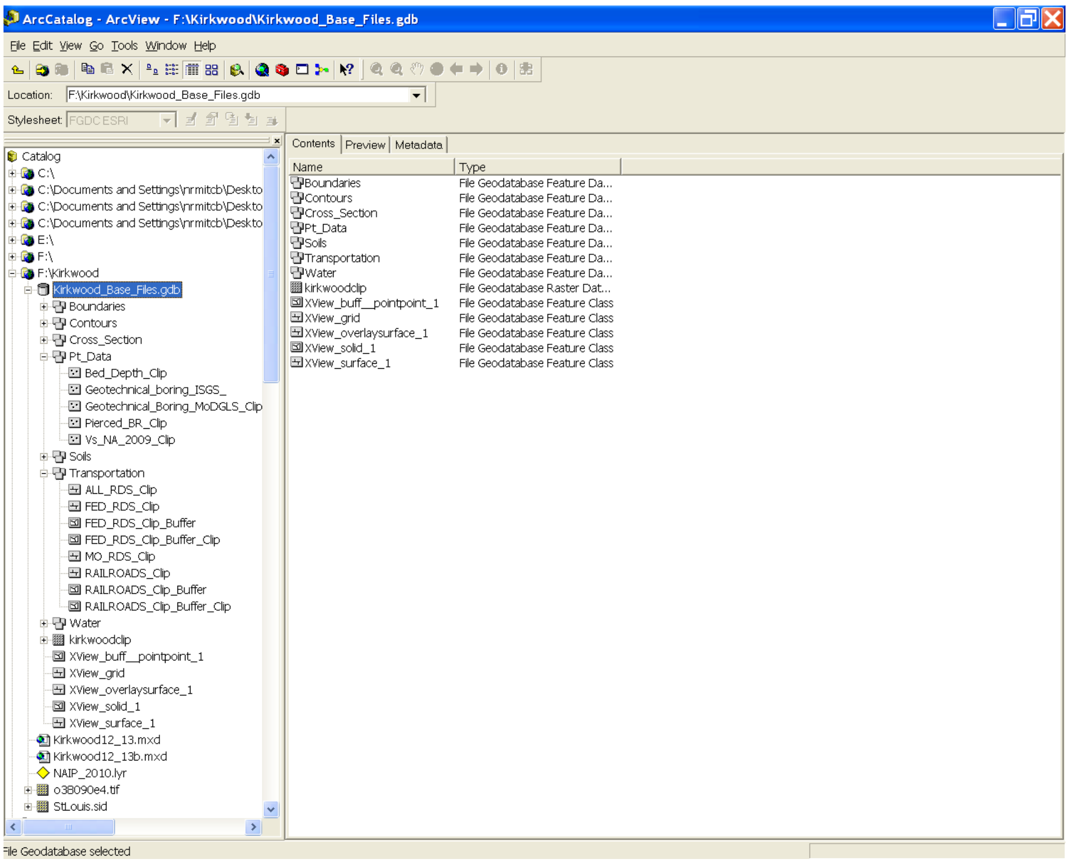

Figure 2. ARC CATOLOG. Screen shot of the structure of the Kirkwood geodatabase. The feature data sets are shown on the right while the feature classes contained in the feature data sets, point data and transportation, are shown on the left.

The map layout consists of a 1:24,000 scale surficial material geologic map, a 1:24,000 scale cross section, a 1:52,800 scale Surficial Material Thickness map with material thickness contours overlaying a USGS Digital Elevation Model (DEM), a 1:52,800 scale bedrock elevation map with bedrock elevation contours overlying a USGS DEM, and a 1:52,800 scale data point location map showing the spatial distribution and the types of data used in producing the maps including pertinent information for selected points. An example of the surficial material geologic maps is depicted in Figure 3.

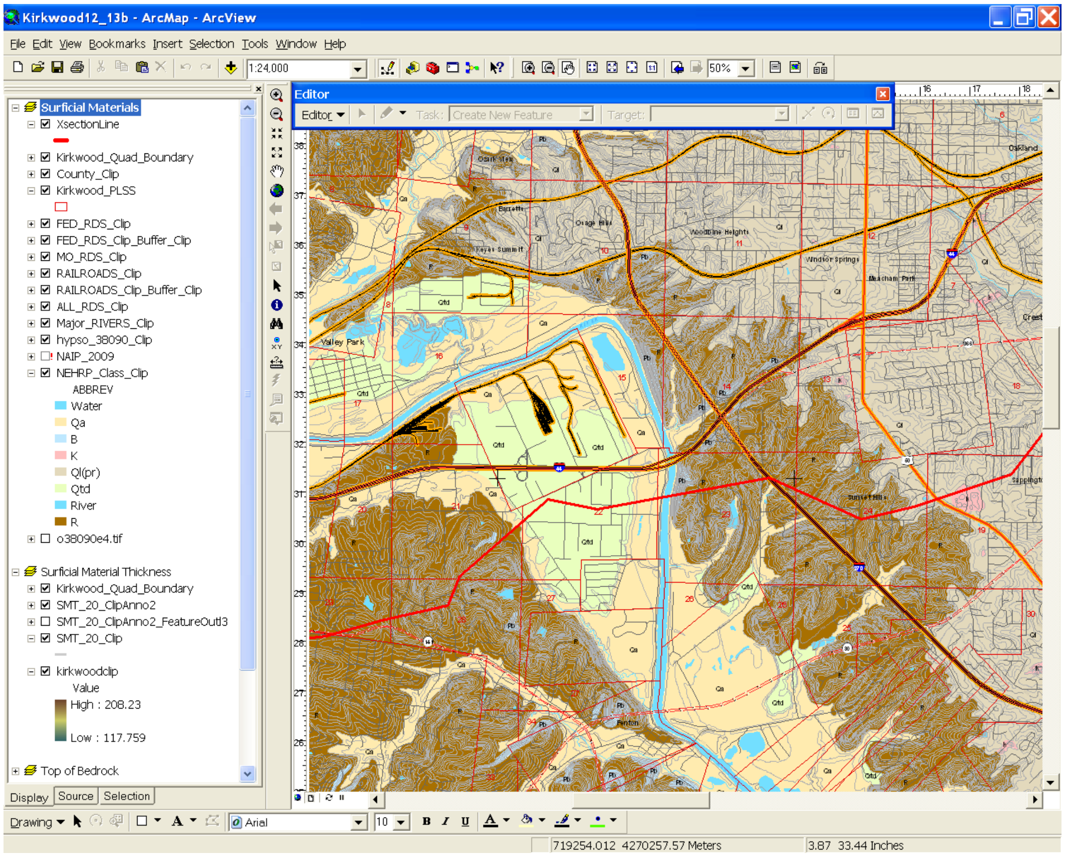

Figure 3. SURFICIAL GEOLOGY. The surficial material geologic map above displays the layered structure of the maps on the left. On the right is an example of the main map.

The surficial material geologic maps are in a layered format that includes all pertinent information for the base maps. The base mapping was created at DGLS by editing features from USGS 7.5' topographic maps and aerial photography from the National Agriculture Imagery Program (NAIP). NAIP 2007 and NAIP 2009 were used to determine annual surface water variations. NAIP 2008 was not considered an editing source because inconsistencies in the imagery were identified. Using multiple imagery sets for editing keep the maps current as surface changes become apparent. The surficial material geologic maps were field checked during production. The Creve Coeur quadrangle map was field checked in 2011 and the Kirkwood quadrangle map was field checked in 2012.

The associated information of surficial material types and characteristics are included in the attributes table as shown in Figure 4. The attributes table lists pertinent information for that feature class. The surficial material attribute table lists the type of feature: polygon, point or line, as well as the symbol, description, interpretation, geologic setting, state, size, and age of the surficial material if known. The project area contains approximately eighteen surficial material descriptions. The principle components of the thematic map contain attributes for the entire project area while periphery components are clipped to contain only the subject quadrangles. Characteristics of the surficial material are listed in the geotechnical data attributes table discussed later in this section.

Attributes of NEHRP_Class

OBJECTID_1 *	Shape *	OBJECTID	ABBREV	STATE	GEOLOGY	NAME	Site_Class
1	Polygon	1	af(dg)	Illionois	af(dg)(artificial fill or disturbed ground)	Af Missouri and Illinois	D (180~360 m/s)
2	Polygon	2	c(f)	Illionois	c(f)(Cahokia fan facies)	Cahokia fan	D to E
3	Polygon	3	c	Illionois	c(Cahokia Fm)	Cahokia	D (180~360 m/s)
4	Polygon	4	c(s)	Illionois	c(s)(Cahokia sandy facies)	Cahokia sandy	D (180~360 m/s)
5	Polygon	5	c(c)	Illionois	c(c)(Cahokia clayey facies)	Cahokia clayey	D (180~360 m/s)
6	Polygon	6	Qa	Missouri	Qa(alluvium)	Qa Floodplain	D (180~360 m/s)
7	Polygon	7	K	Missouri	K(karst)	karst St Louis County & City	C (360~760 m/s)
8	Polygon	8	Qa	Missouri	Qa(alluvium)	Qa in St. Charles	C (360~760 m/s)
9	Polygon	9	Ql(pr)	Illionois	Ql(pr)(Peoria and Roxana Silts(loess))	Ql Illinois	D (180~360 m/s)
10	Polygon	10	Ql(pr)	Missouri	Ql(pr)(Peoria and Roxana Silts(loess))	Ql St Charles	C (360~760 m/s)
11	Polygon	11	Ql(pr)	Missouri	Ql(pr)(Peoria and Roxana Silts(loess))	Ql St Louis County & City	C to D
12	Polygon	12	Qt	Missouri	Qt(till)	Qt St Charles County	C (360~760 m/s)
13	Polygon	13	Qt	Missouri	Qt(till)	Qt St Louis City	C to D
14	Polygon	14	Qtd	Missouri	Qtd(terrace or lake deposits)	Qtd in St. Louis	C to D
15	Polygon	15	R	Illionois	Residuum	Residuum	no data
16	Polygon	16	River			Mississippi River	River
17	Polygon	17	B	Illionois	B(bedrock)		Bedrock
18	Polygon	18	Qa	Missouri	Qa(alluvium)	Qa _St Louis upland	D (180~360 m/s)

Record: 15 Show: All Selected Records (0 out of 18 Selected) Options

Figure 4. SURFICIAL GEOLOGY ATTRIBUTES. The surficial geology attributes table provides information about the materials being mapped. Displayed are common material types for the study area.

The 1:24,000 scale cross section shown in Figure 5 and Figure 6 was constructed to display the same features as the surficial material geologic maps. The cross section lines were drawn from data point to data point across the subject quadrangles. The location of the cross section lines were selected to show the geomorphic characteristics of the mapped areas and to include intersecting bedrock borings that would allow better correlation of the bedrock surface. The topographic surface lines were generated from a DEM. The bedrock surfaces were interpreted from borings that intersect bedrock and at surface outcrops. Due to the changes in topography from the dissected uplands to the floodplain, a 20X vertical exaggeration was chosen so identification of low areas of relief could be recognized and mapped accordingly. Often, slight changes in topography within a floodplain can create higher or lower potentiometric surface values.

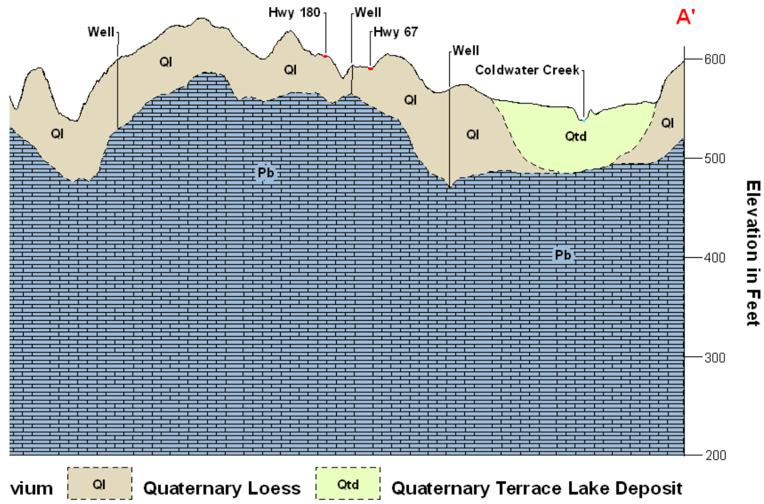

Figure 5. UPLAND CROSS SECTION. The 1:24,000 scale cross section provides a side view of the subject area. Above is the uplands portion of the depicted cross section. The cross section exhibits a 20X vertical exaggeration to highlight small variations in vertical change.

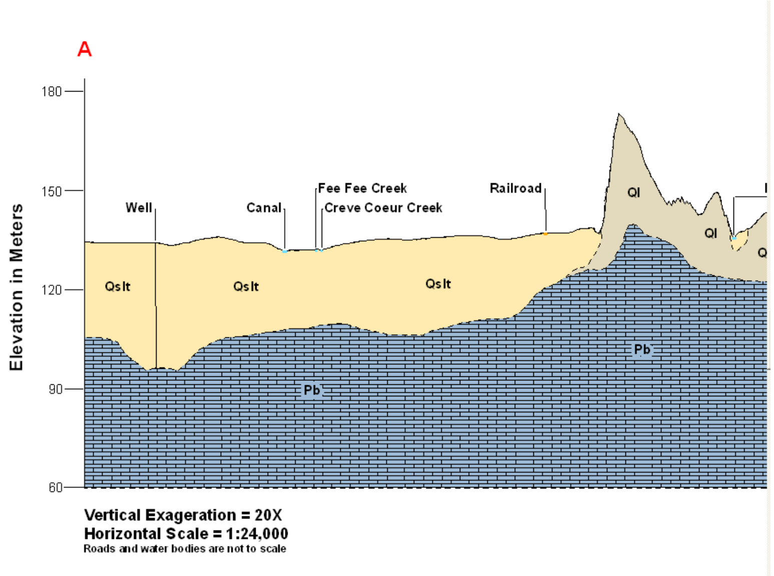

Figure 6. FLOODPLAIN CROSS SECTION. The 1:24,000 scale cross section provides a side view of the subject area. Above is the floodplain portion of the depicted cross section. The cross section exhibits a 20X vertical exaggeration to highlight small variations in vertical change.

The floodplain portion of the cross section is depicted in Figure 6. The depth to alluvium (cap thickness) is quite variable and not well identified in boring logs. Therefore, the descriptions depicted on the cross sections are the symbology of the sediment cap. Seismic Cone Penetration Tests (SCPT) were performed in both quadrangles. The SCPT logs show layered deposits of clay, silt, sand and gravels in various amounts. This will be discussed later in the results section of the report.

The map layouts each contain 3 large scale inset maps showing the surficial material thickness, bedrock surface, and data point locations. The inset maps are 1:52,800 scale maps, two of which use a DEM as a base layer while the third uses a surficial material geologic layer as a base layer. The inset maps are shown in Figures 7, 8, and 9.

SURFICIAL MATERIAL THICKNESS

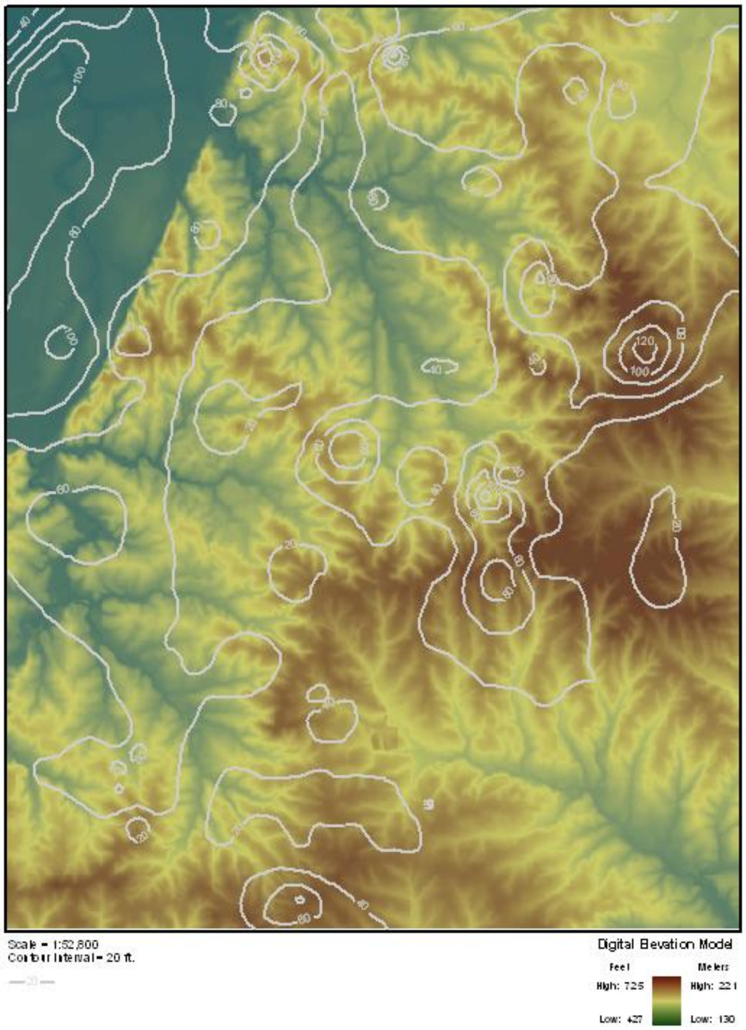

Figure 7. SURFICIAL MATERIAL THICKNESS. The 1:52,800 scale inset map displays the contoured thickness of the surficial material. The inset map has a 20 foot contour interval.

The surficial material thickness inset maps were constructed at a 1:52,800 scale and use a USGS DEM as the base layer. The types and characteristics of surficial material are listed in the surficial geology attribute table and in the geotechnical boring attribute table. Thickness of surficial material was derived from the difference between elevation and the depth to bedrock. Older large and small scale maps were also referenced along with the divisions' water well databases. The data was processed using contouring software to interpret surficial material thickness. The contours were generated using Inverse Distance Weighting (IDW) to interpolate thickness for the entire project area then manually edited to account for geomorphic and geologic influences.

TOP OF BEDROCK

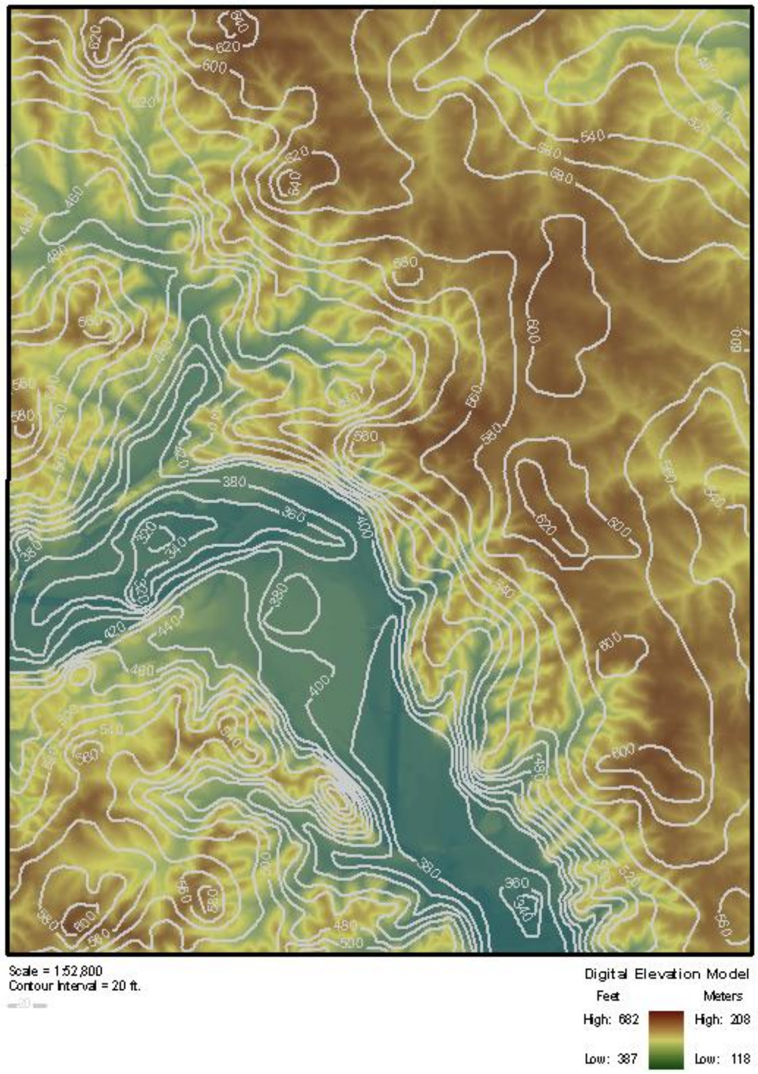

Figure 8. TOP OF BEDROCK. The 1:52,800 scale top of bedrock inset map displays the bedrock surface contours. The inset map has a 20 foot contour interval.

The top of bedrock inset maps were constructed at a 1:52,800 scale and use a USGS DEM as the base layer. The bedrock borings and lithological characteristics are listed in the bedrock borings attribute table. The top of bedrock determination was made by correlating drilling logs, shallow seismic surveys, and water well databases from DGLS. Older large and small scale maps were also referenced. The data was processed using contouring software to interpret the bedrock surface. The contours were generated using IDW to interpolate the elevation of the bedrock surface. They were then manually edited to account for geomorphic and geologic influences.

DATA POINT LOCATION

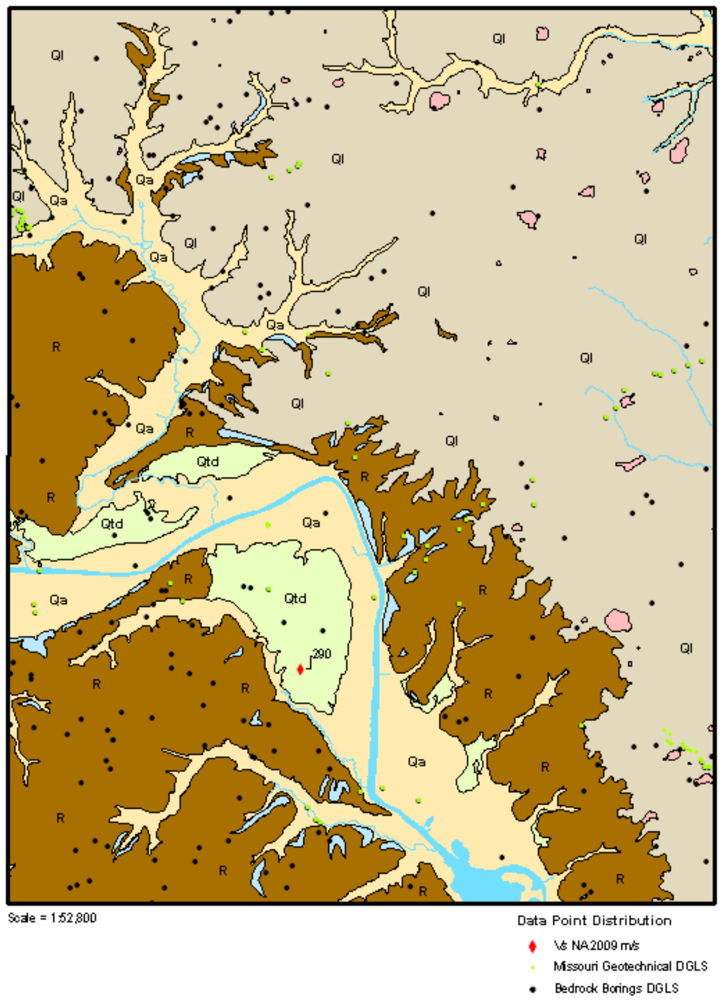

Figure 9. DATA POINT LOCATION. The 1:52,800 scale data point location inset map displays the spatial distribution and type of data points.

The data point location inset maps were constructed at a 1:52,800 scale and use a surficial geology layer as the base layer. These maps display the spatial distribution of the data points as well as the type of data point such as geotechnical boring, bedrock boring, or seismic survey methods.

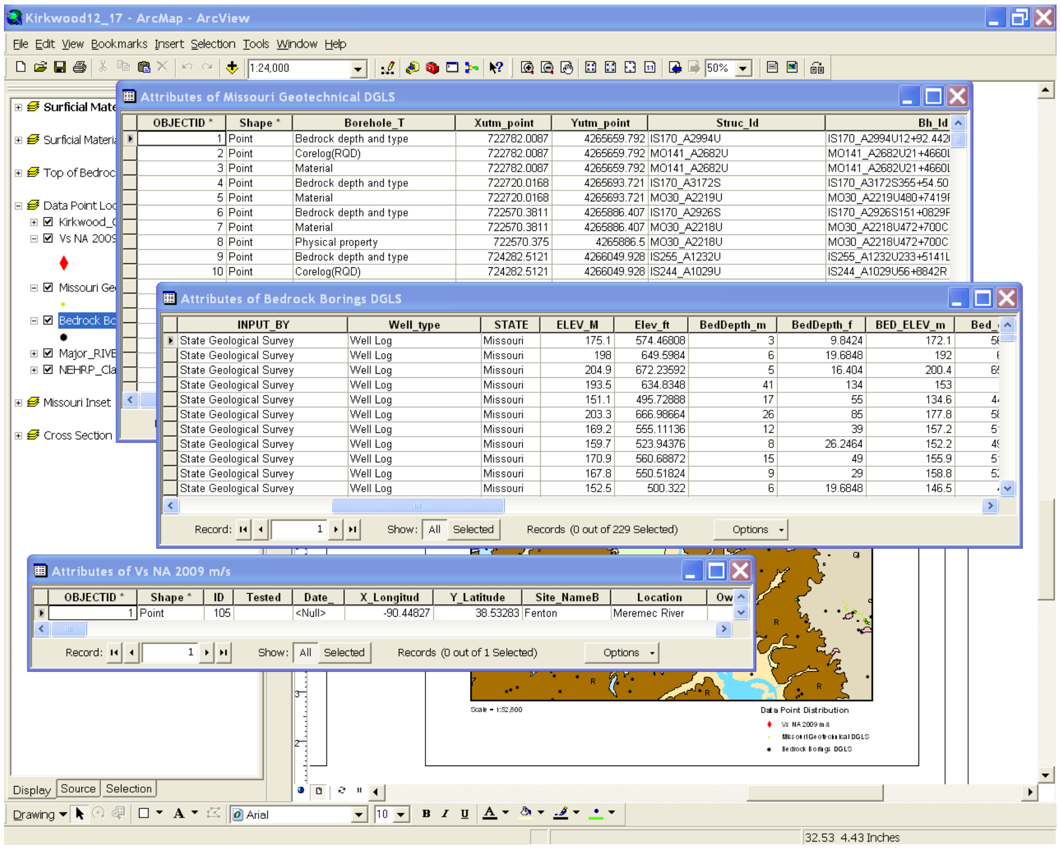

Figure 10. DATA POINT ATTRIBUTES. The screen shot displays the attribute tables of three of the five feature classes within the data point location feature data set. The attributes displayed are from the shear wave (v/s), geotechnical borings and the bedrock borings.

Each of the feature classes within a feature data set contains the information pertinent to that particular class. The "bed depth" feature class contains 12,189 lines of information. Each line is a data point within the project area. The attribute table lists the information in a table format and functions like other database tables. The desired fields are added and populated. The attributes for the feature classes bed depth, geotechnical borings, shear wave velocity (Vs) and surficial geology contain the data for the entire project area while others only contain information for the particular quadrangle. When a feature class is edited, the changes are also applied to all other feature classes within the feature data set. This allows greater continuity within the maps attribute tables and increases productivity.

SCPT were performed at three locations, two in the Creve Coeur quadrangle and one in the Kirkwood quadrangle. All were conducted under a cooperative agreement with the Missouri Department of Transportation (MoDOT). The SCPT sampling locations were selected based on accessibility and spatial gaps in shear wave velocity information, as well as the need to evaluate materials beneath transportation infrastructure. Subsurface data and stratigraphic profiles were reviewed and compared with published small scale surficial material maps and other previously developed genetic and lithostratigraphic surficial material models to facilitate mapping. These data points were used to verify the surficial material types and thicknesses not to generate the top of bedrock elevation contours. This analysis is necessary to assess seismic wave amplification and liquefaction potential of unconsolidated material. In addition, the accuracy and precision of earthquake hazard maps being produced by the SLAEHMP TWG will be improved through the application of this information.

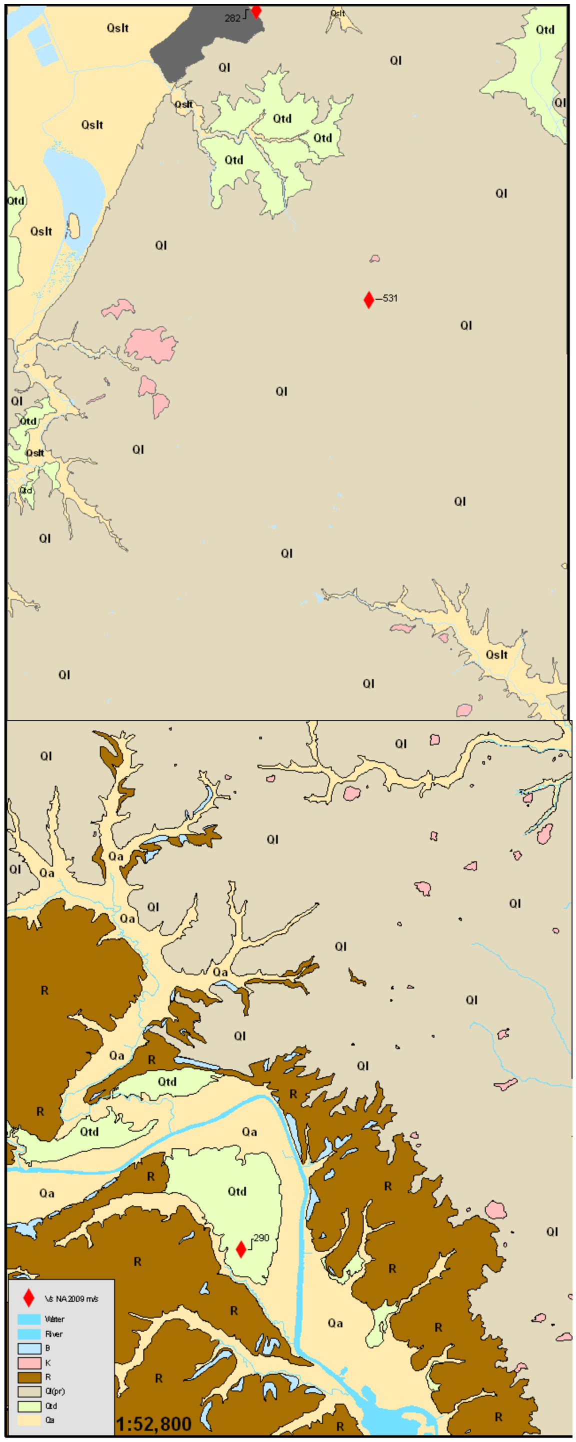

Figure 11. SCPT LOCATIONS. The SCPT test sites displayed above are the locations of the Creve Coeur and Kirkwood tests conducted in 2009 by the DGLS and the Missouri Department of Transportation.

Results

The area represented by the Creve Coeur quadrangle shown in figure 12 is covered by 2 to 120 feet thick deposits of primarily loess or alluvium. Loess coverage varies in thickness from 2 to 100 feet on the upland areas while deposits of alluvium greater than 100 feet fill some areas within the Missouri River floodplain. The bedrock surface in the upland area of the Creve Coeur quadrangle can reach elevations of 680 feet mean sea level (msl) but is more commonly between 540 feet msl and 580 feet msl. At the mouth of the tributaries the bedrock surface is consistently around 440 feet msl while the bedrock surface at the head of the tributaries varies between 480 feet msl and 520 feet msl. The floodplain bedrock surface elevation ranges from just over 320 feet msl in the interior of the floodplain to around 460 feet msl at the upland edge.

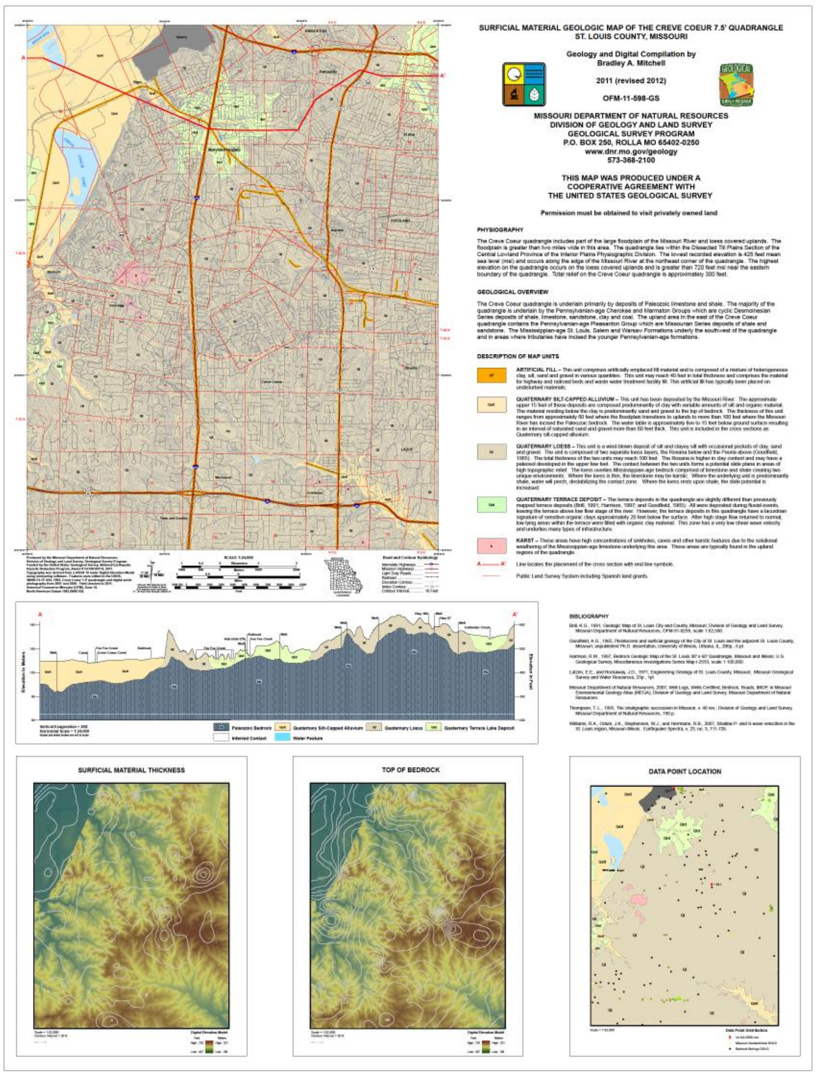

Figure 12. SURFICIAL MATERIAL GEOLOGICAL MAP OF THE CREVE COEUR QUADRANGLE.

The area represented by the Kirkwood quadrangle shown in figure 13 is covered by 5 to greater than 55 feet thick deposits of loess on the upland areas and alluvium greater than 100 feet thick in the floodplain. The floodplain is lined with thick terrace deposits. The slopes of high relief areas adjacent to the Meramec River floodplain are covered by 2 to 40 feet of residuum. The bedrock surface in the Kirkwood quadrangle upland areas is highly variable with elevation values ranging from approximately 420 feet msl to around 650 feet msl. Floodplain areas of the quadrangle have bedrock elevations that range from 300 feet msl to 400 feet msl. However, consistent measurements of 340 feet msl to 380 feet msl are most common within the Meramec River valley.

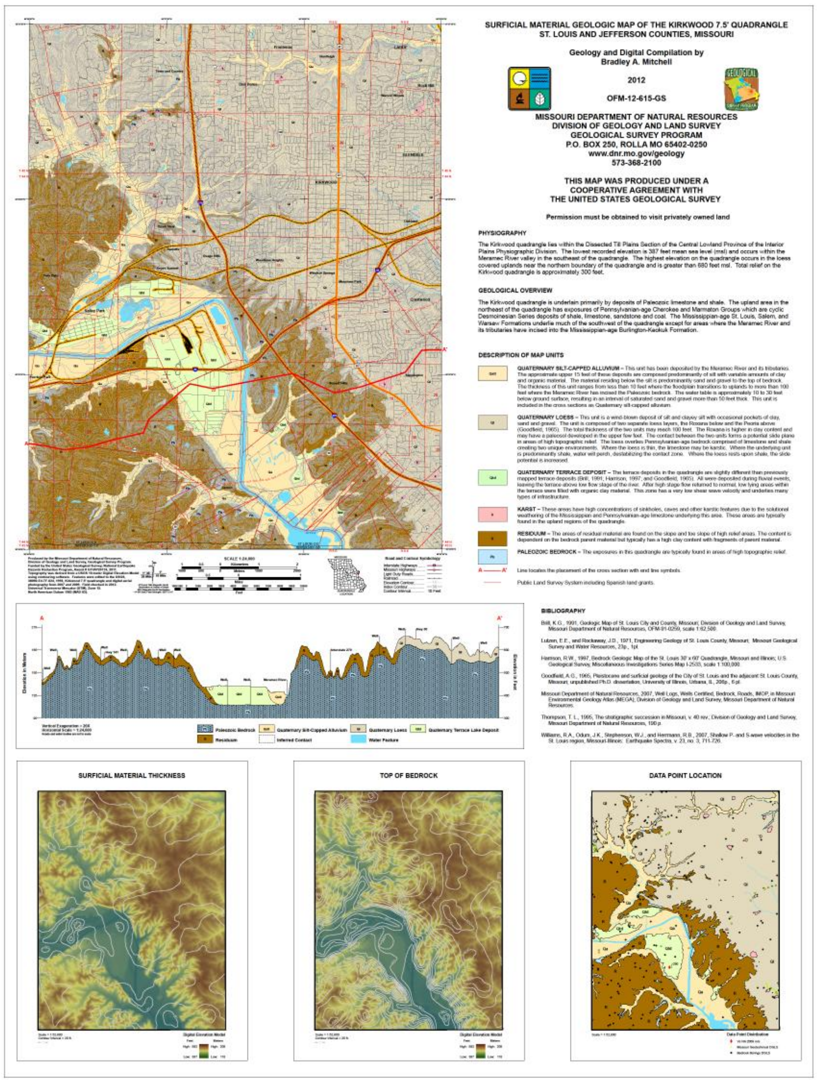

Figure 13. SURFICIAL MATERIAL GEOLOGICAL MAP OF THE KIRKWOOD QUADRANGLE. The Kirkwood quadrangle contains various surficial materials and displays the complex nature of the study area.

Conclusion

The surficial material geologic maps for the Creve Coeur and Kirkwood 7.5' quadrangles have been completed as deliverables in fulfillment of award number G11AP20174. These maps were compiled using new and existing data derived from the St. Louis Surficial Material Database (formerly compiled by DGLS), St. Louis Database, shallow seismic surveys, SCPT, and from various sources listed in the bibliography.

The maps were constructed in a GIS geodatabase format for improved quality of the finished product. Each 7.5' quadrangle in the project area is its own geodatabase to be easily seamed with the other quadrangles in the project area. This provides the base for the latest mapping techniques to be applied. Attribute tables are associated with each feature class in the geodatabase for ease of viewing data. While improving the quality of the product, the division was able to reduce the file size and increase the storage capacity to facilitate each maps ease of transfer.

The specific age of mapped units was not determined or depicted, only their age with respect to the other mapped units. Considerations were given to small scale maps of the region which were produced by former DGLS staff. Inset contour maps were developed using a 10m DEM and data points across the 22 quadrangle SLAEHMP project site to generate contours based on the surficial material thickness and elevation of the top of bedrock. The contour maps depict a 20 foot contour interval and were clipped to each specific quadrangle boundary. A surficial material vector map was utilized as a base map to display the spatial distribution of the point data. The inset maps were created and added to the final map product.

The geologic surficial material mapping is the first product developed for seismic hazard analysis. The data gathered in the mapping process is critical base information for seismic hazard analysis. The depth to bedrock, depth to water table, and the type of surficial material is the fundamental basis for seismic assessment. Analysis of this data is used to assess how the alluvial column will respond to different magnitude earthquakes with respect to liquefaction and site amplification potential. The data compiled for the SLAEHMP surficial material maps improves the accuracy and precision of the earthquake hazard maps being prepared by the SLAEHMP TWG.

Bibliography

Benham, K.E., 1979, Soil survey of St. Louis County and St. Louis City, Missouri; Soil Conservation Service, U.S. Department of Agriculture, 137 p, 17 pl.

Brill, K.G., 1991, Geologic Map of St. Louis City and County, Missouri; Division of Geology and Land Survey, Missouri Department of Natural Resources, OFM-91-0259, scale 1:62,500.

Goodfield, A.G., 1965, Pleistocene and surficial geology of the City of St. Louis and the adjacent St. Louis County, Missouri; unpublished Ph.D. dissertation, University of Illinois, Urbana, IL, 206 p, 6 pl.

Harrison, R.W., 1997, Bedrock Geologic Map of the St. Louis 30' x 60' Quadrangle, Missouri and Illinois; U.S. Geological Survey, Miscellaneous Investigations Series Map I-2533, scale 1:100,000.

Lutzen, E.E, and Rockaway J.D., 1971, Engineering geology of St. Louis County, Missouri; Missouri Geological Survey and Water Resources, 23 p, 1 pl.

Missouri Department of Natural Resources, 2007, well logs, wells certified, bedrock, roads, IMOP, in, Missouri Environmental Geology Atlas (MEGA); Division of Geology and Land Survey, Missouri Department of Natural Resources.

Pearce, J.T., and Baldwin J.N., 2005, Liquefaction susceptibility mapping, St. Louis, Missouri and Illinois; William Lettis and Associates, Inc., 42 p. 8 pl.

Thompson, Thomas L., 1995, The stratigraphic succession in Missouri, Volume 40- revised; Division of Geology and Land Survey, Missouri Department of Natural Resources, 190 p.

Williams R.A., Odum, J.K. Stephenson, W.J. and Herrmann, R.B., 2007, Shallow P- and S-wave velocities in the St. Louis region, Missouri-Illinois: Earthquake Spectra, v.23, no.3, 711-726.