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Determination of MASW Shear-Wave Velocities at Various Sites in SE Missouri

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16. Abstract

In order to demonstrate the utility of shear-wave velocity data, a suite of 3-D maps depicting spatial variations in thickness, stratigraphy and shear-wave velocity of soils in the Poplar Bluff area were prepared. A 3-D shallow subsurface materials map, complete with shear-wave velocity test data (suitable for preparation of an earthquake soil amplification map) was also generated.

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MODIFIED GEOLOGIC AND EARTHQUAKE HAZARDS MAPS BASED SHEAR-WAVE VELOCITY CONTROL FROM VARIOUS SITES IN SE MISSOURI

Overview

In order to demonstrate the utility of shear-wave velocity data, a suite of 3-D maps depicting spatial variations in thickness, stratigraphy and shear-wave velocity of soils in the Poplar Bluff area were prepared. A 3-D shallow subsurface materials map, complete with shear-wave velocity test data (suitable for preparation of an earthquake soil amplification map) was also generated.

The generation of the suite of maps for the Poplar Bluff study area involved the following:

- Collection of readily available existing and newly generated digital data, databases and maps with information on soil stratigraphy, and shear-wave velocity from the following sources.
    - Missouri Department of Natural Resources (MoDNR), Geological Survey and Resource Assessment Division
        - LOGMAIN stratigraphic well log database
        - WIMS water well drillers well log database
        - Public water supply well log database
        - Digital surficial materials maps of the study area
        - Shear-wave velocity database for study area
    - Missouri Department of Transportation, Geotechnical Section
        - MoDOT geotechnical database
        - New SCPT shear-wave velocity data from this study
    - University of Missouri – Rolla
        - New MASW shear-wave velocity data from this study
        - New CH shear-wave velocity data from this study
        - New borings stratigraphic data from this study
        - New laboratory UPV shear-wave velocity data from this study
    - Other public and commercial sources
        - Digital Raster Graphic (DRG) topographic map images
        - Digital Orthophoto Quarter Quadrangle (DOQQ) airphoto images
        - Digital Elevation Model (DEM) elevation data
        - Highway data
        - Topographic map boundaries
        - Urban boundaries

- Evaluation of these data for problems and determination of usefulness (re: planned mapping).

- Sorting, converting, formating and, where necessary, modifying the digital data used to make the maps. This involved entering some new data into tables or databases.

- Using a geographic information system (GIS), specifically ArcView with the 3-D Analyst's Extension, to manipulate the digital data and make the suite of maps.

Inherent problems in the various data sources limited their usefulness. Most of these problems were in one of the following categories.

- Inadequate location coordinates
- Limited stratigraphic information
- Limited depth penetration
- Inadequate elevation information

Some data did not include adequate or usable location coordinate information and therefore could not be used in the GIS environment. This was a problem with some of the WIMS well log information provided by water well drillers. Most of the LOGMAIN, WIMS and public water supply well logs had little stratigraphic information on the soils or non-bedrock materials. Often this interval was lumped into one entry with a generic description that could not be used to map separate layers. MoDOT borings had relatively detailed soil stratigraphy but they frequently did not penetrate very deep and therefore did not sample the entire thickness of surficial material. In the Mississippi Embayment portion of the study area, wells and borings seldom penetrated to bedrock for two reasons. For water wells, an abundant water supply is available in the shallow alluvial aquifer so there is no need to drill deeper into bedrock. For MoDOT borings, the deeper portion of the surficial materials is not explored as that stratigraphic information is not usually needed for traditional geotechnical foundation design. Therefore, surficial materials thickness data is very sparse for the Mississippi Embayment area and the thickness maps produced for that area show only a minimum thickness based on available data. In most cases, the bedrock surface is deeper than shown. In the Ozarks uplands the surficial materials are often quite thick and therefore some wells and borings do not penetrate the entire thickness. At some locations in the Ozarks the surficial materials thickness maps show only a minimum thickness based on available data. The public water supply well database only contained 28 wells for the study area and this database included no surficial materials stratigraphy data. Therefore, this database was not used during this study. Most of the wells in the public water supply database are also in the LOGMAIN database which was used. Some data, the WIMS well logs, had no elevation information and therefore could not be used to generate elevation contours and surfaces for their stratigraphic data.

Other problems in the various data sources were related to their format. It was necessary in many cases to individually review the records or fields for each log and reformat them or make new fields in a table that could be used in the GIS environment. The new data fields could then be used to map the desired characteristics.

Basic Maps

A general location map of the four quadrangle study area was assembled in the GIS. The map (Figure 1) shows the DRG images of the four USGS 7.5' quadrangles, Poplar Bluff, Rombauer, Harviell and Hanleyville. It also highlights with other GIS data the City of Poplar Bluff, the major highways and the physiographic provinces in the study area. The map, Figure 1, prepared for this report was done at a scale of 1:150,000 in order to fit the 8.5 by 11-inch page format of this report (some change in scale probably has occurred during publication – please refer to the scale bar on the map).

Much of the detail in the original DGR data for the general location map is lost at the small 1:150,000 scale. The original detail is preserved in the GIS environment and may be viewed on the computer screen at any desired scale. Larger versions of the printed map which show more detail may also be made using large format plotters. All maps presented in this report are similar small scale maps formatted to fit the report page but they may be viewed on the computer screen at any desired scale or printed at any larger scale subject to the limitations of the printer/plotter used for printing.

To better render the topography of the study area at the small scale of the report maps, the USGS DEM data for the study area were input into the GIS and mapped as a topographic surface using color shades related to 25-foot elevation zones (Figure 2). That data was also contoured using a 25-foot contour interval (Figure 3). The elevation zones and contours could have been made using a smaller (or larger) contour interval but for display on a page size map the contour lines would become too numerous and close together so as to make the map unreadable. At larger scales the smaller contour interval is desirable as it more faithfully reproduces the contour lines shown on the DRG or printed topographic map and has fewer anomalies shown.

Stratigraphic Maps

The surficial materials units in the study area have been mapped in digital GIS format by the MoDNR Geological Survey (MGS). The four individual quadrangles were assembled in the GIS to make a surficial materials map for the study area (Figure 4). The map units indicate the location and the generalized stratigraphic makeup of all the soil material above the bedrock surface. The 3-dimensional information for these stratigraphic units is shown on the accompanying maps.

The 3-dimensional information was derived from the well log databases. This consists of the thickness information using the LOGMAIN and WIMS well log databases. The distribution of those data points is shown in Figures 5 and 6. The MoDOT geotechnical database (Figure 7) was not used for mapping in this study due to the sparse data coverage and shallow depth of penetration. However, the sometimes intense data coverage and detailed stratigraphic information of MoDOT data at a local site makes it suitable for larger scale, more detailed mapping of a local site using the same GIS techniques. If database compatibility was not an issue the LOGMAIN, WIMS and MoDOT databases could be combined and much better mapping could be accomplished due to the better aerial distribution of data. Figure 8 illustrates the combined data point distributions.

The LOGMAIN database was modified and used to determine surficial materials (or soil) thickness. Using the GIS a 2-D soil thickness map was made from this data (Figure 9). The 2-D map is a simplified method of showing the 3-D characteristic of the surficial materials. The 2-D map shows thickness by color zones that are 25 ft thick. The same data was contoured using 25-foot contour intervals. The contours were labeled with numeric values and overlaid on the color zones. Despite some local anomalies in the map due to data limitations a general trend can be seen. A northeast-southwest trend of thinner surficial materials is associated with the physiographic boundary between the Mississippi Embayment and the Ozarks with thicker deposits in both directions away from the boundary. This band of thinner surficial materials is probably due to the topographic escarpment at this boundary that enhances erosion of surficial materials at the edge of the uplands and due to the lesser depth to bedrock at the margin of the lowlands alluvial valley. The lack of data points that penetrate the full thickness of the alluvial soils undoubtedly causes the thickness of the lowlands surficial materials to be considerably underestimated on the map.

Using the WIMS database and a similar process, a 2-D surficial materials thickness map of WIMS data was made (Figure 10). The WIMS soil thickness map shows the same general pattern as the LOGMAIN soil thickness map except in the Mississippi Embayment area. Despite the greater number of Mississippi Embayment data points in the WIMS data, the WIMS map shows a smaller thickness of lowlands soil with a much subdued variation in thickness. This is primarily due to a limitation of the data and how it was used. Not one of the WIMS data points in the Embayment penetrated to bedrock. The total depth drilled was used to represent the thickness of the surficial materials even though that was a known underestimate.

Ground surface elevation data was available for the LOGMAIN database but not for the WIMS database. Using the ground surface elevation data in the LOGMAIN database, the elevation of the base of the surficial materials, or the top of bedrock elevation, could be calculated by subtracting the surficial materials thickness in the GIS data base. The resulting bedrock surface elevation was then used in the GIS to 2-D map the bedrock surface topography (Figure 11). This map shows the expected general trend of the top of the bedrock becoming deeper toward the southeast, from the uplands to the lowlands.

Using the 3-D capability of the GIS (ArcView 3-D Analysts Extension) the LOGMAIN data was used to create a 3-D model of the study area.   The well location, ground surface elevation, top of bedrock elevation (base of surficial materials), map boundaries, city boundary, physiographic boundary and major roads were input into the 3-D model and converted to 3-D surfaces or lines. On the computer screen the 3-D model can be manipulated to view it from any angle. It can be rotated 360 degrees in the horizontal direction and plus or minus 90 degrees in the vertical direction. It can also be zoomed in or out and panned in any direction. The visibility of the displayed layers can be varied continuously to make them anything from opaque to transparent. A screen snap shot of the 3-D model can be exported and/or printed at any time during the manipulation of the model. A series of screen snap shot illustrations to show the 3-D model are included as Figures 12 to 20.

Shear-wave Velocity Map

Shear-wave velocity data was collected at 40 sites in the study area. A total of 167 shear-wave velocity test measurements were conducted, including old and new measurements. Some sites had only one test measurement at them while other sites had as many as 28 tests. The multiple test data for individual sites seemed to cluster nicely with only a small amount of scatter in the results. The shear-wave velocity data is summarized on Figure 21 which shows the distribution of test sites and the average results at those sites. (Velocities were averaged over 100 ft in accordance with NEHRP guidelines.) The shear-wave velocity values correlate very nicely with the surficial materials map units (Figure 22). The alluvial lowland soils have lower shear-wave velocities than the upland residual soils.

Earthquake Soil Amplification Map

Using the shear-wave velocity data and the NEHRP (National Earthquake Hazard Reduction Program) soil class definitions based on shear-wave velocity, an earthquake soil shaking amplification map was made (Figure 23). The Mississippi Embayment lowland soils and the Ozarks alluvial valley soils have shear-wave velocity values in the 600 to 1200 ft/s range which puts them into the NEHRP soil class of D. The Ozark upland residual soils have shear-wave velocity values in the 1200 to 2500 range which puts them into the NEHRP soil class of C. The soils with the lower shear-wave velocity values, or the NEHRP soil class letter further from A, will experience more earthquake ground shaking than the bedrock due to the wave amplifying properties of the soil.

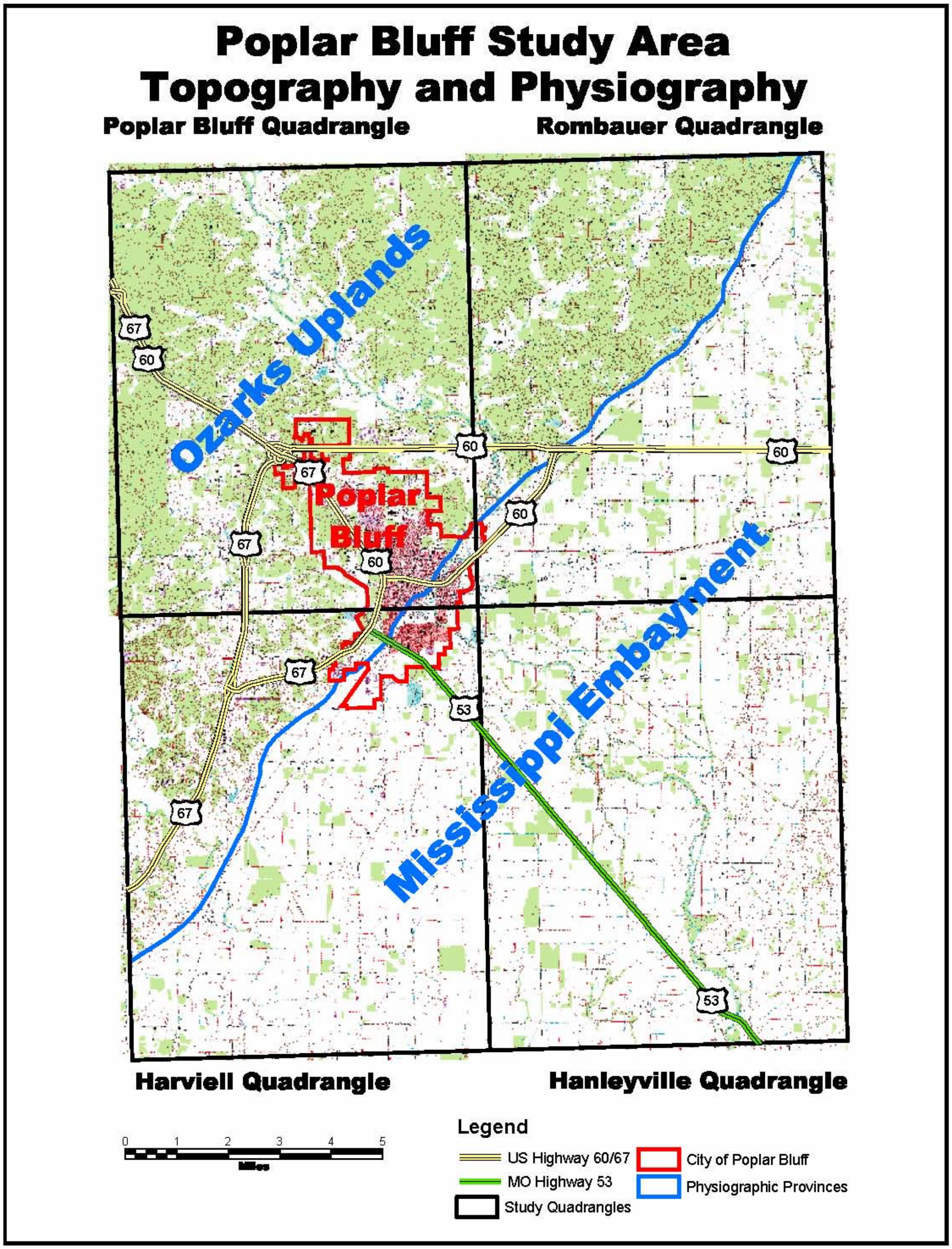

Figure 1: Poplar Bluff study area topography and physiography map.

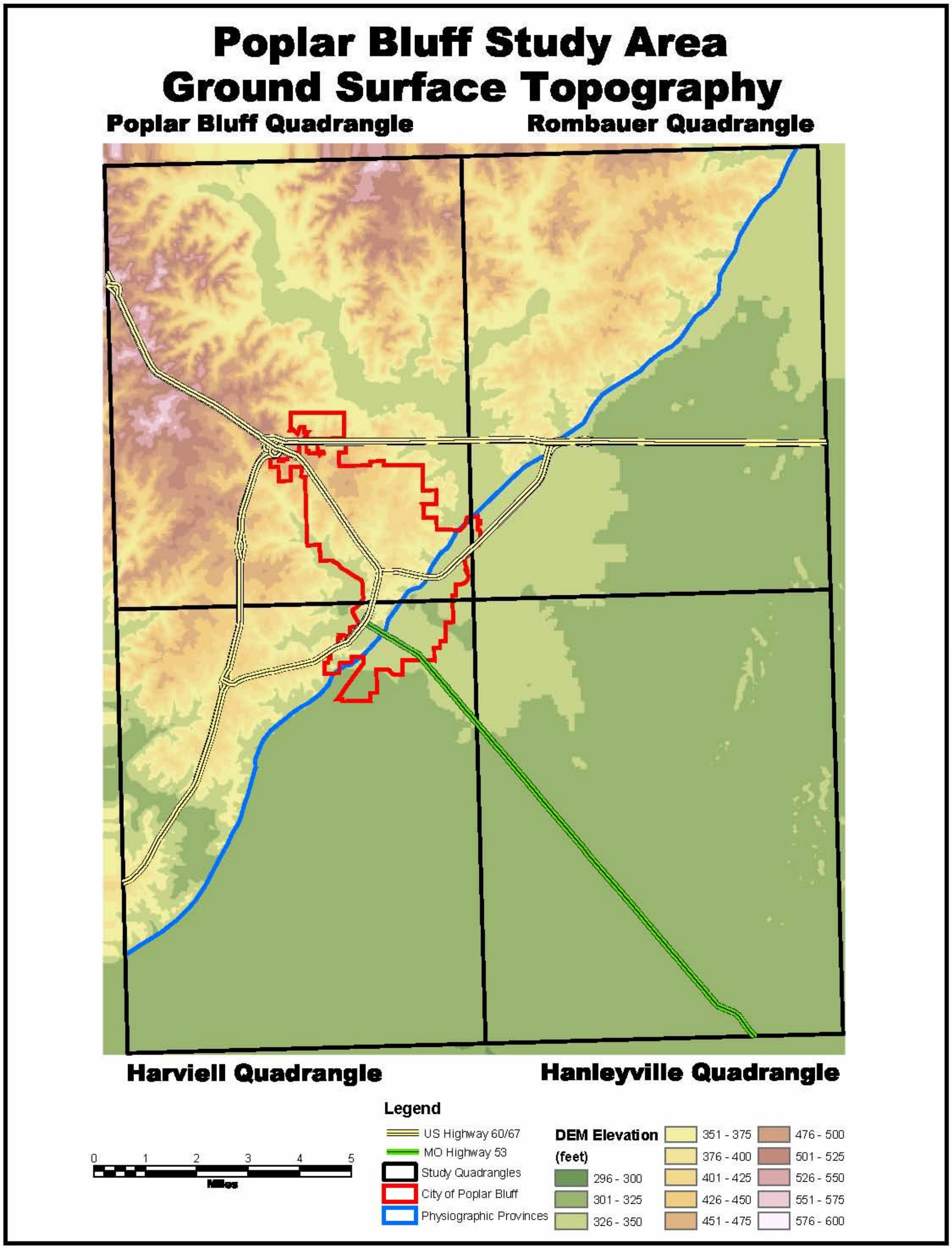

Figure 2: Poplar Bluff study area ground surface topography map.

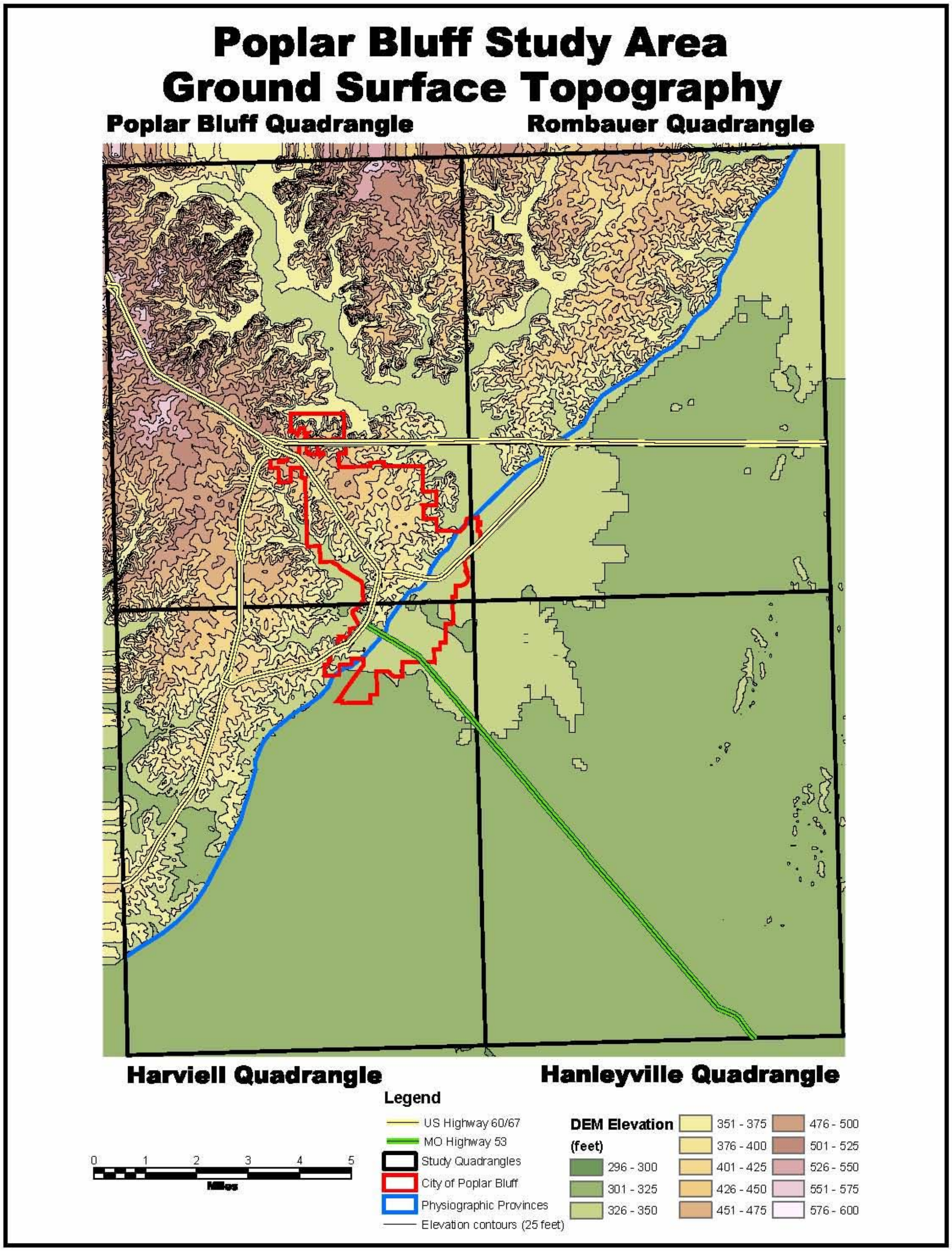

Figure 3: Poplar Bluff study area ground surface topography map with contours.

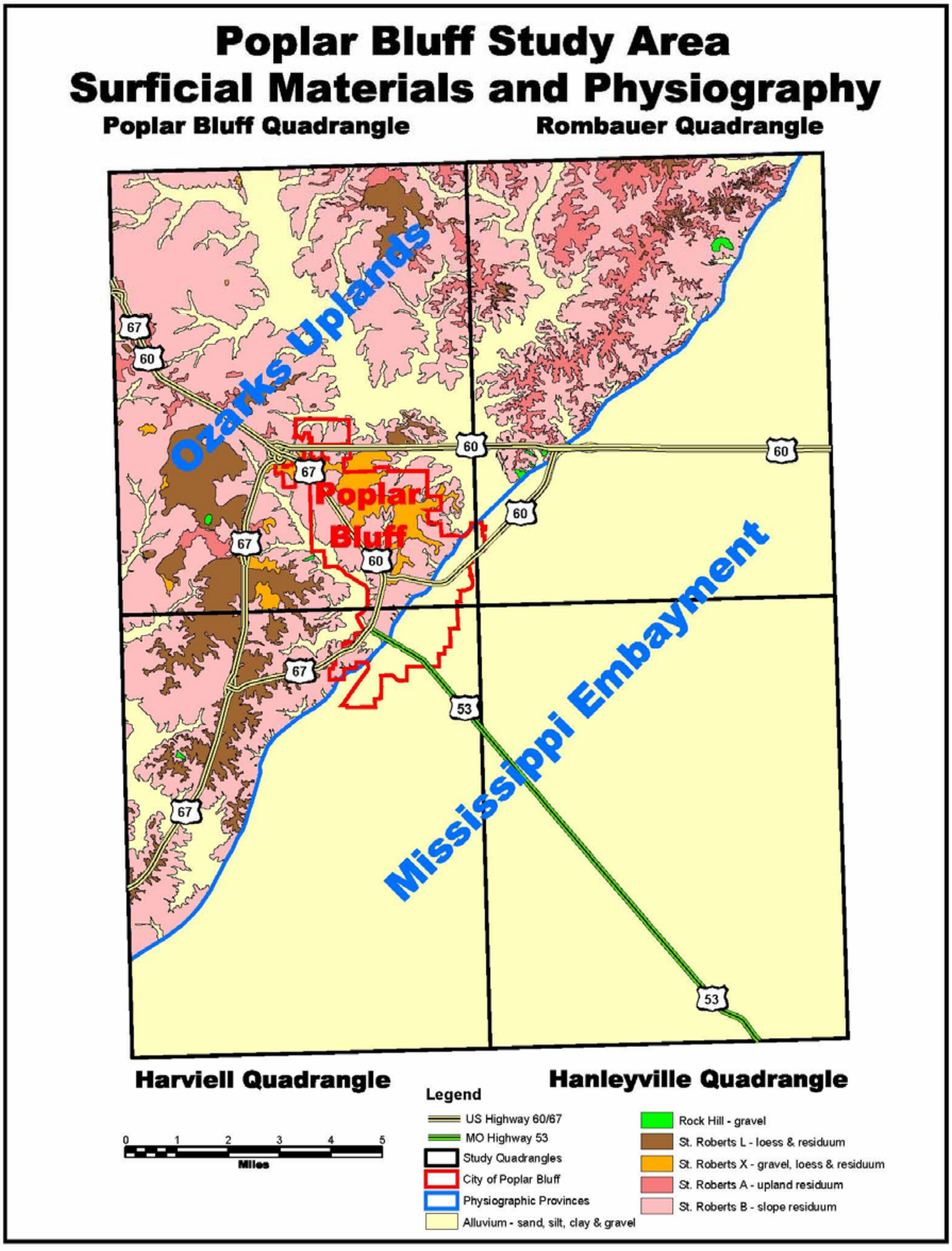

Figure 4: Poplar Bluff study area surficial materials and physiography map.

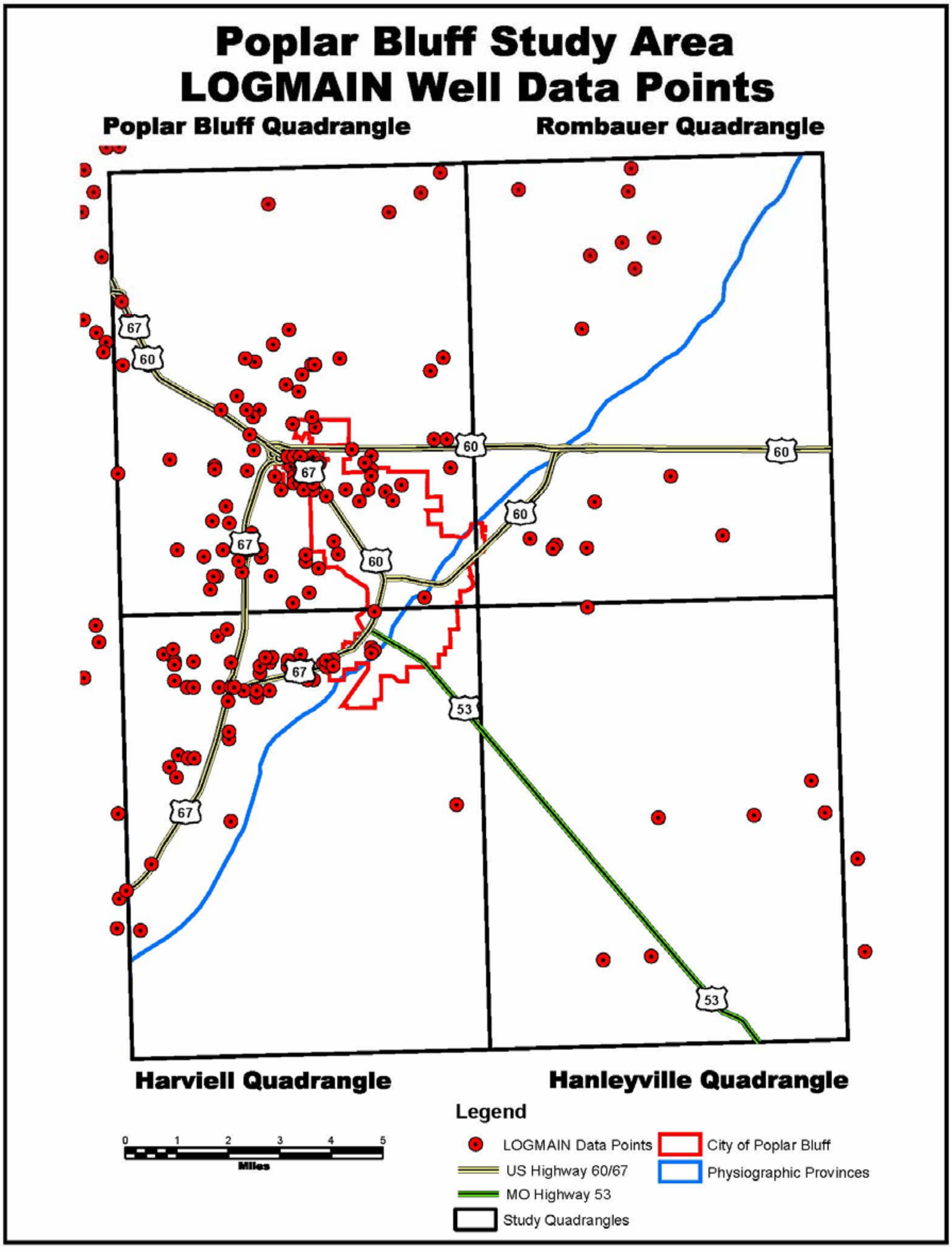

Figure 5: Poplar Bluff study area LOGMAIN well data points map.

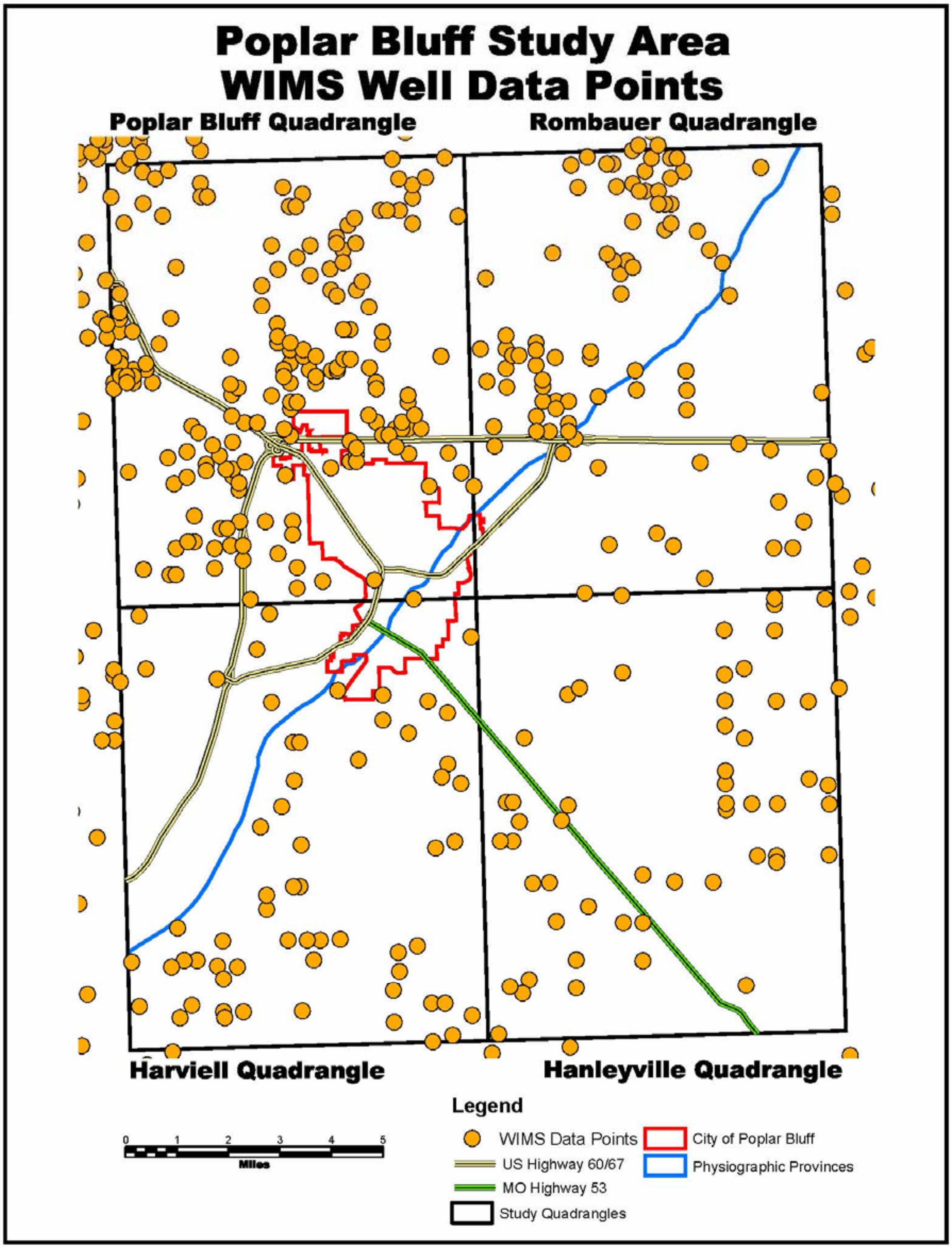

Figure 6: Poplar Bluff study area WIMS well data points map.

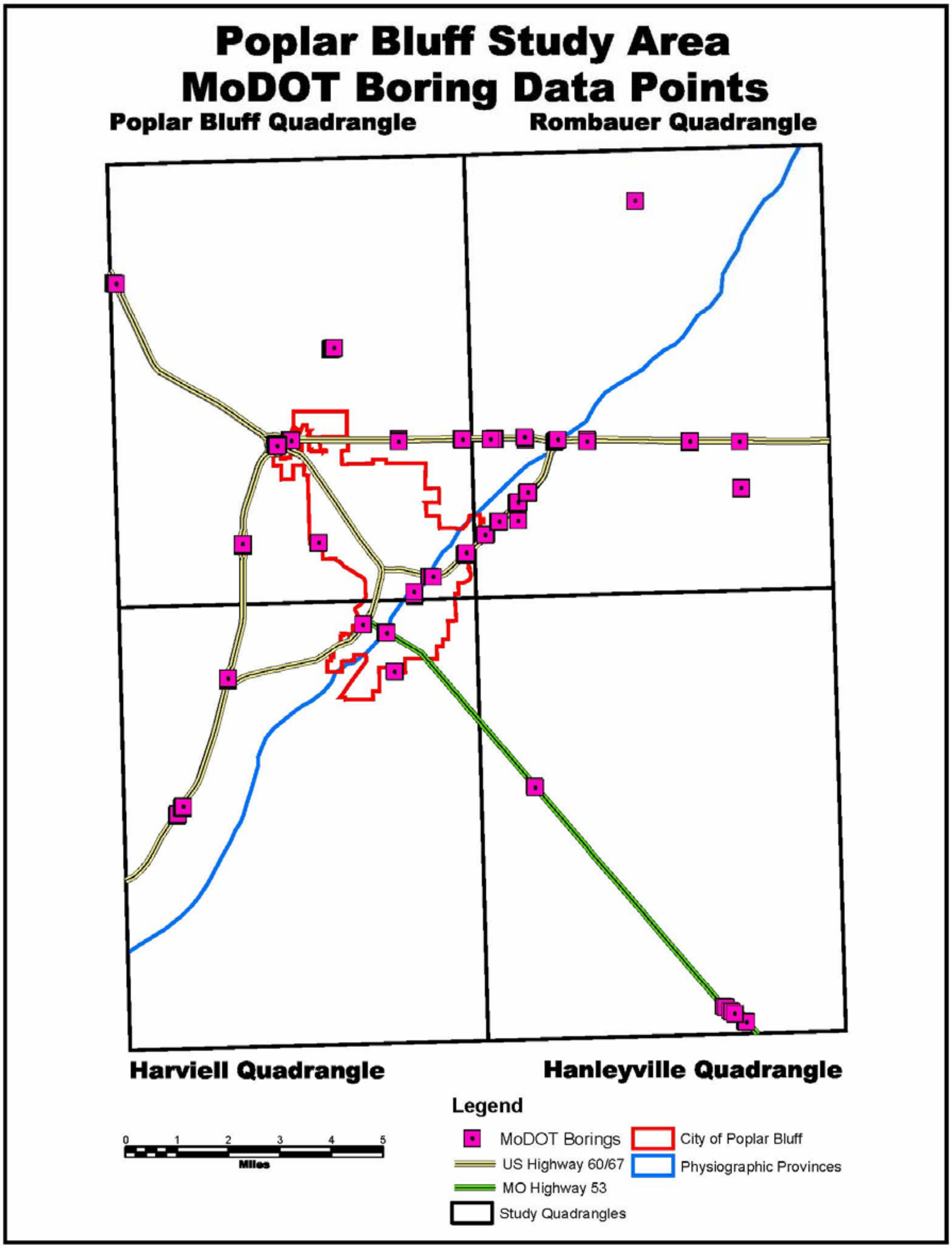

Figure 7: Poplar Bluff study area MoDOT boring data points map.

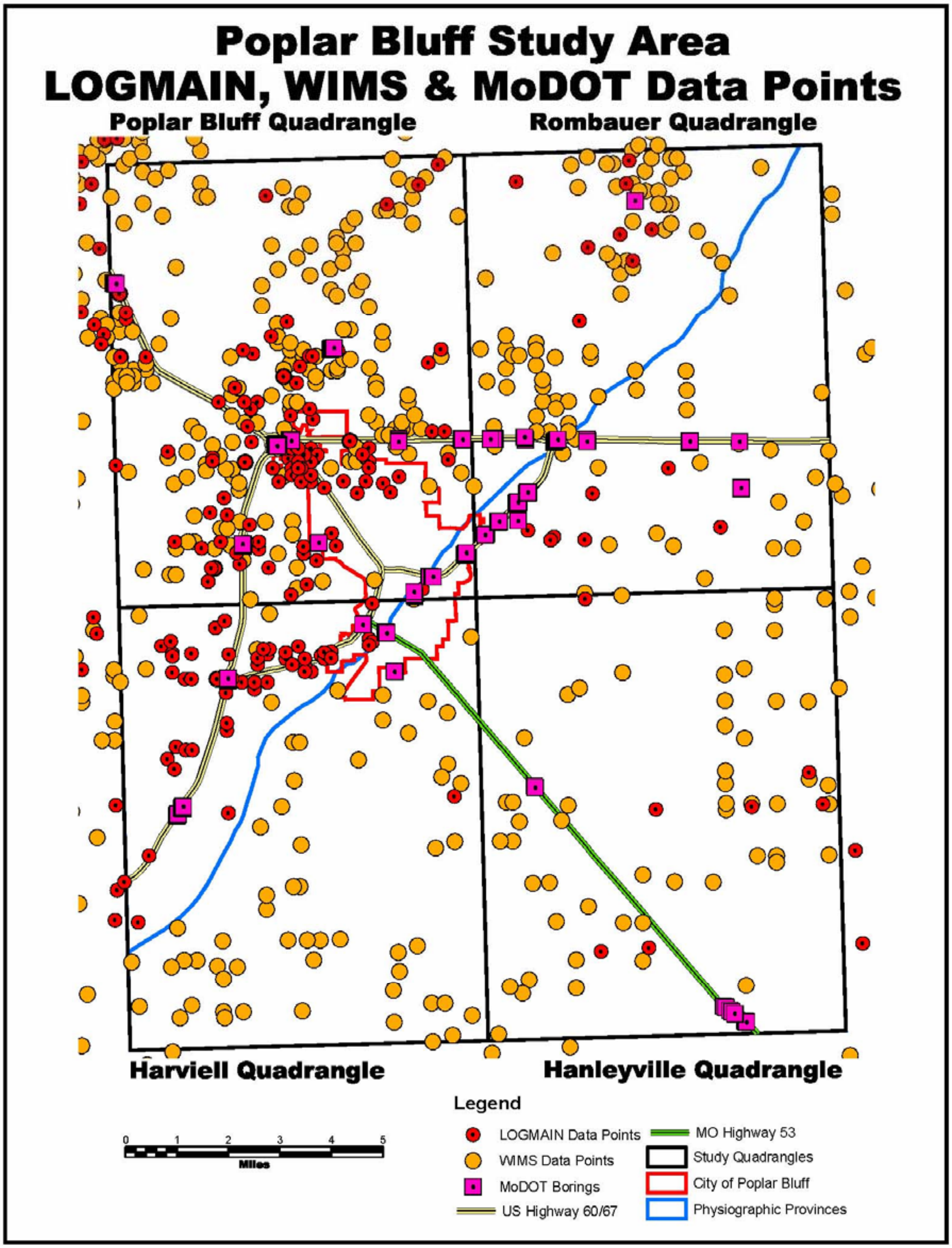

Figure 8: Poplar Bluff study area LOGMAIN, WIMS & MoDOT data points map.

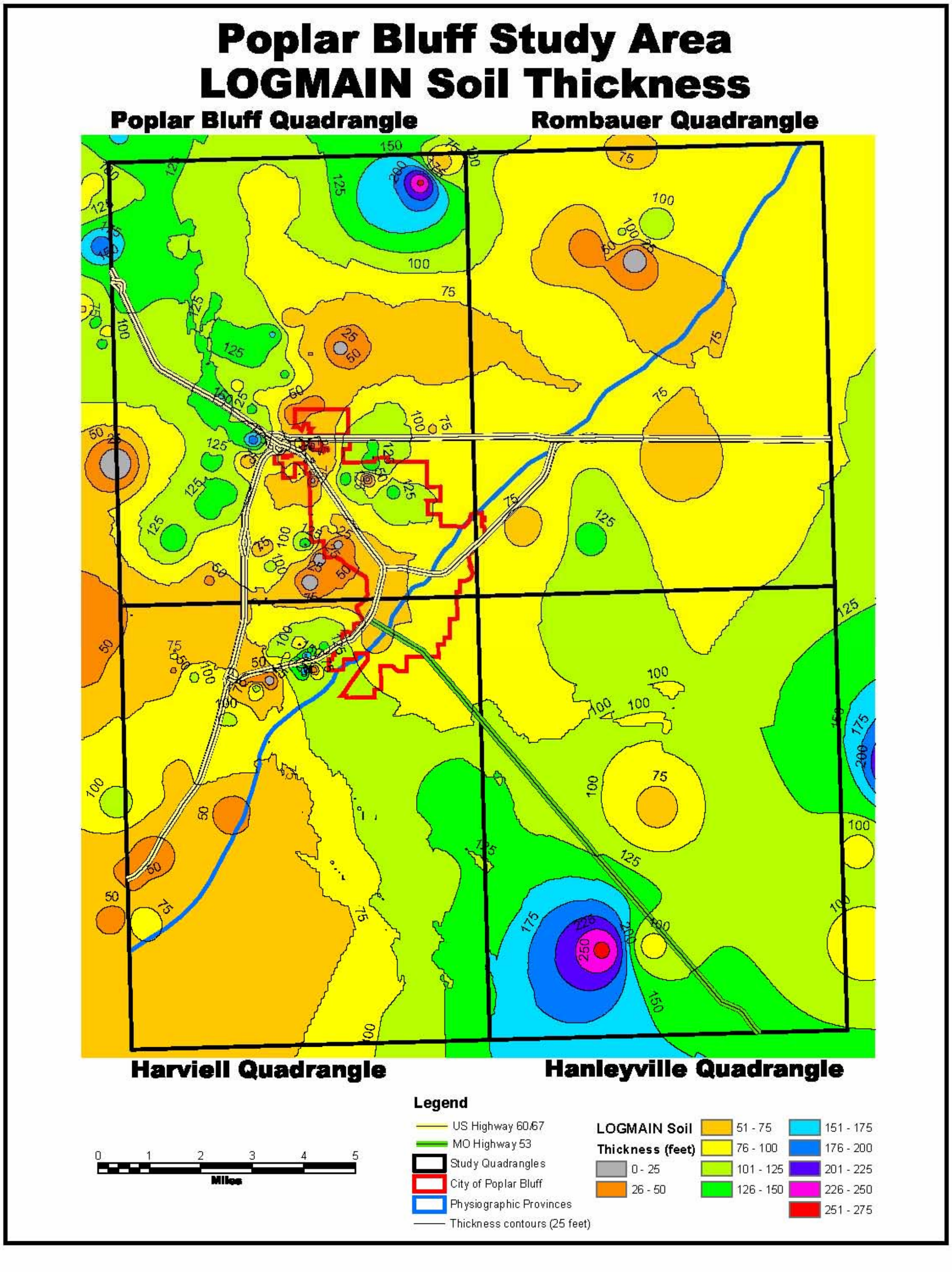

Figure 9: Poplar Bluff study area LOGMAIN soil thickness map.

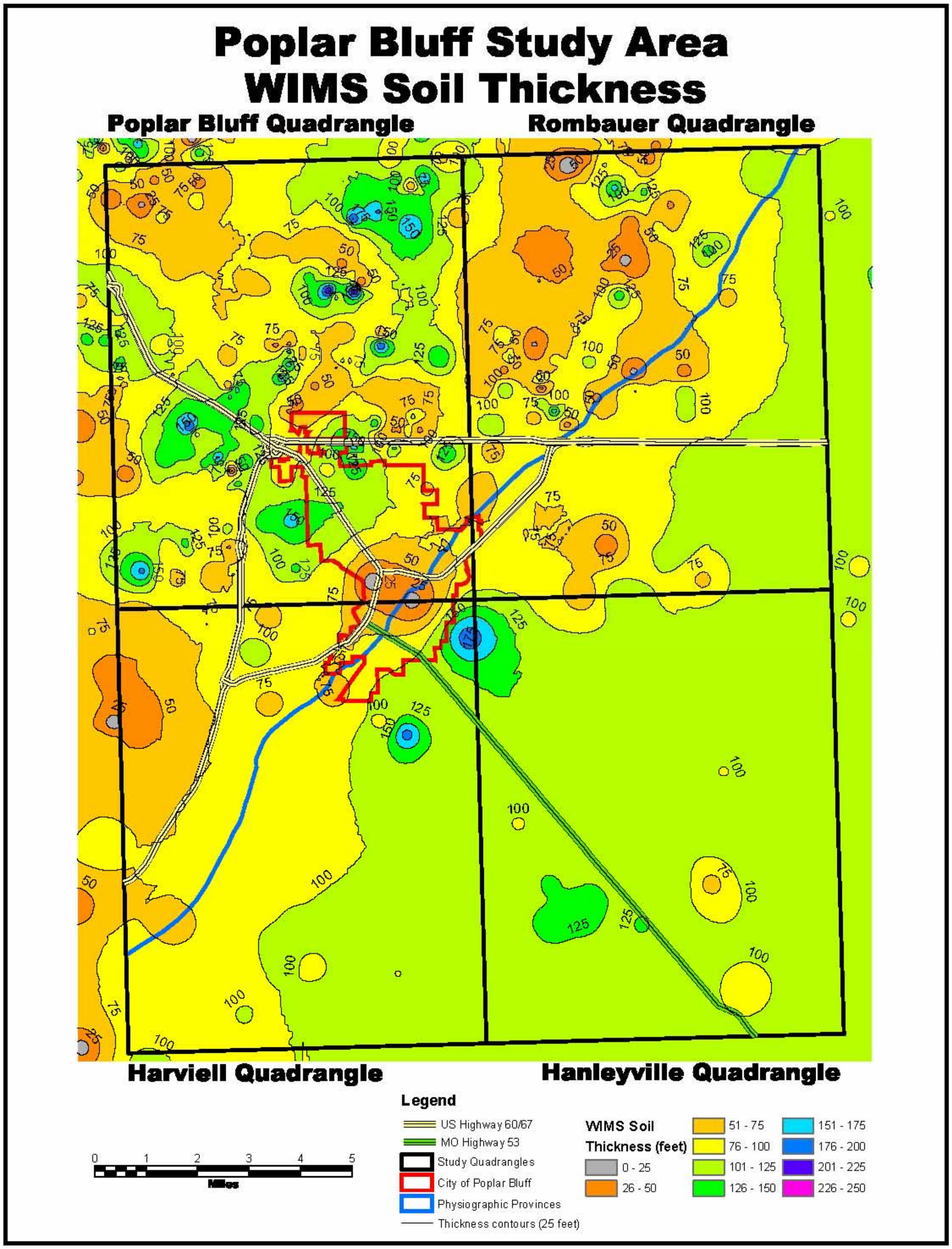

Figure 10: Poplar Bluff study area WIMS soil thickness map.

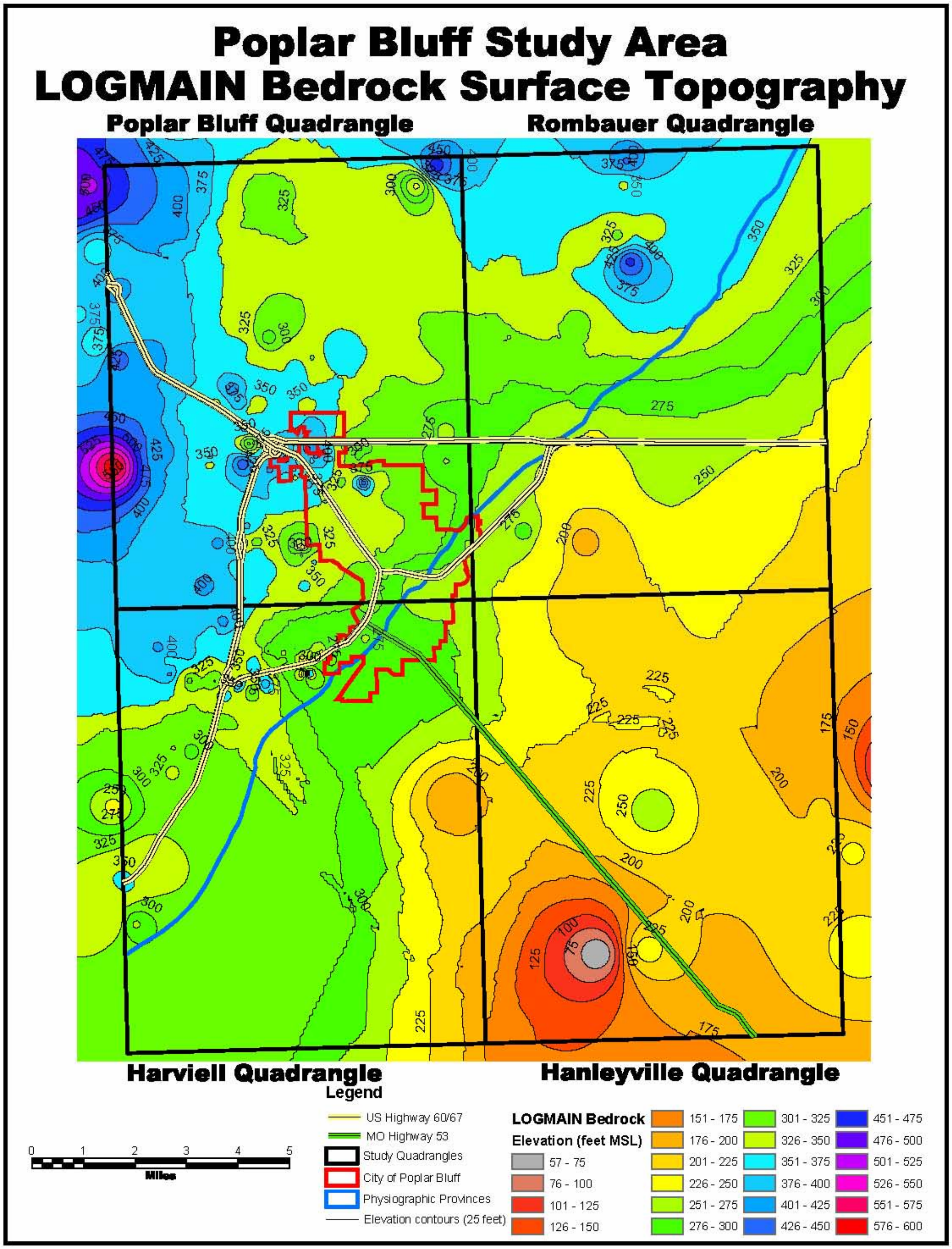

Figure 11: Poplar Bluff study area LOGMAIN bedrock surface topography map.

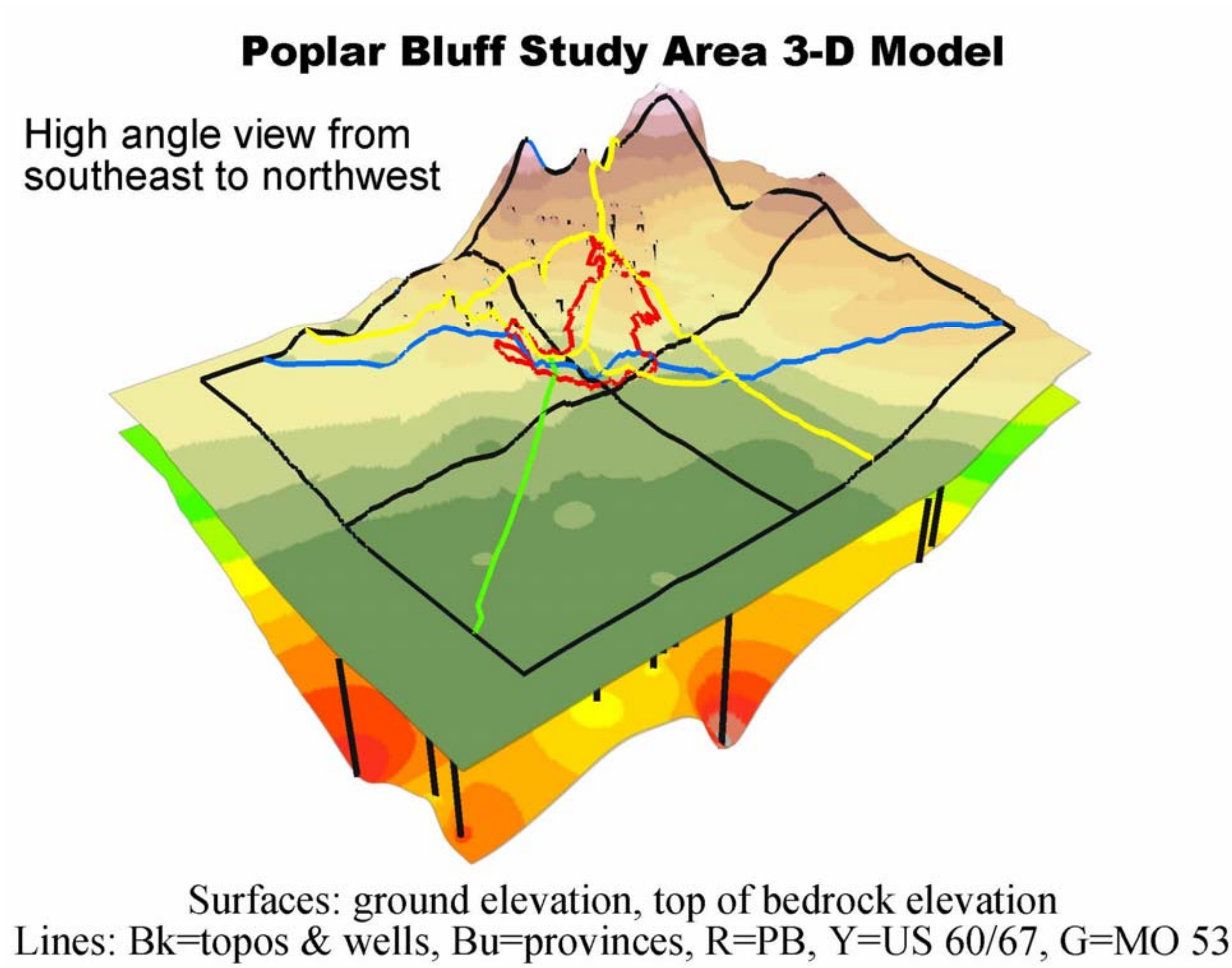

Figure 12: Poplar Bluff 3-D model, high angle view from southeast to northwest.

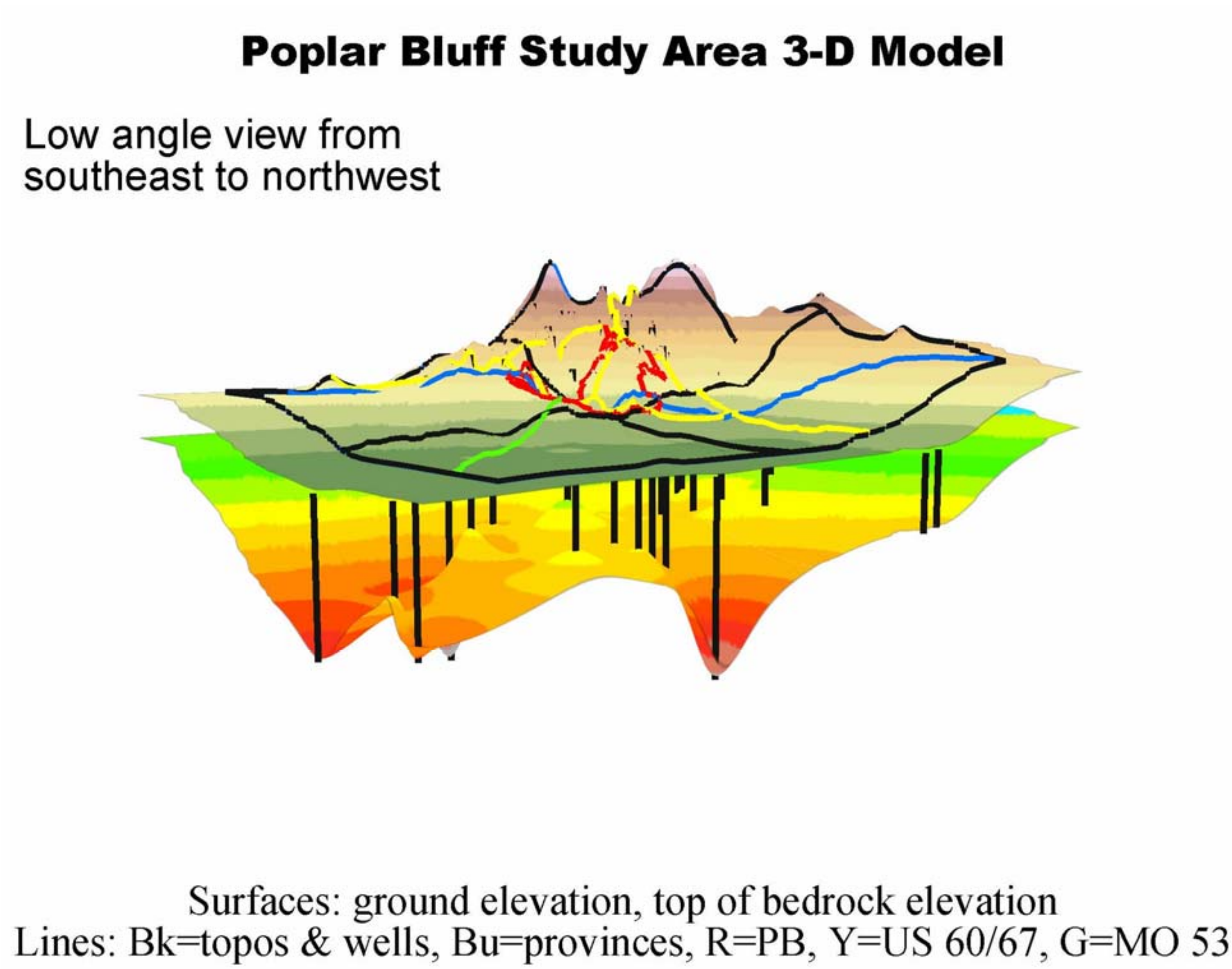

Figure 13: Poplar Bluff 3-D model, low angle view from southeast to northwest.

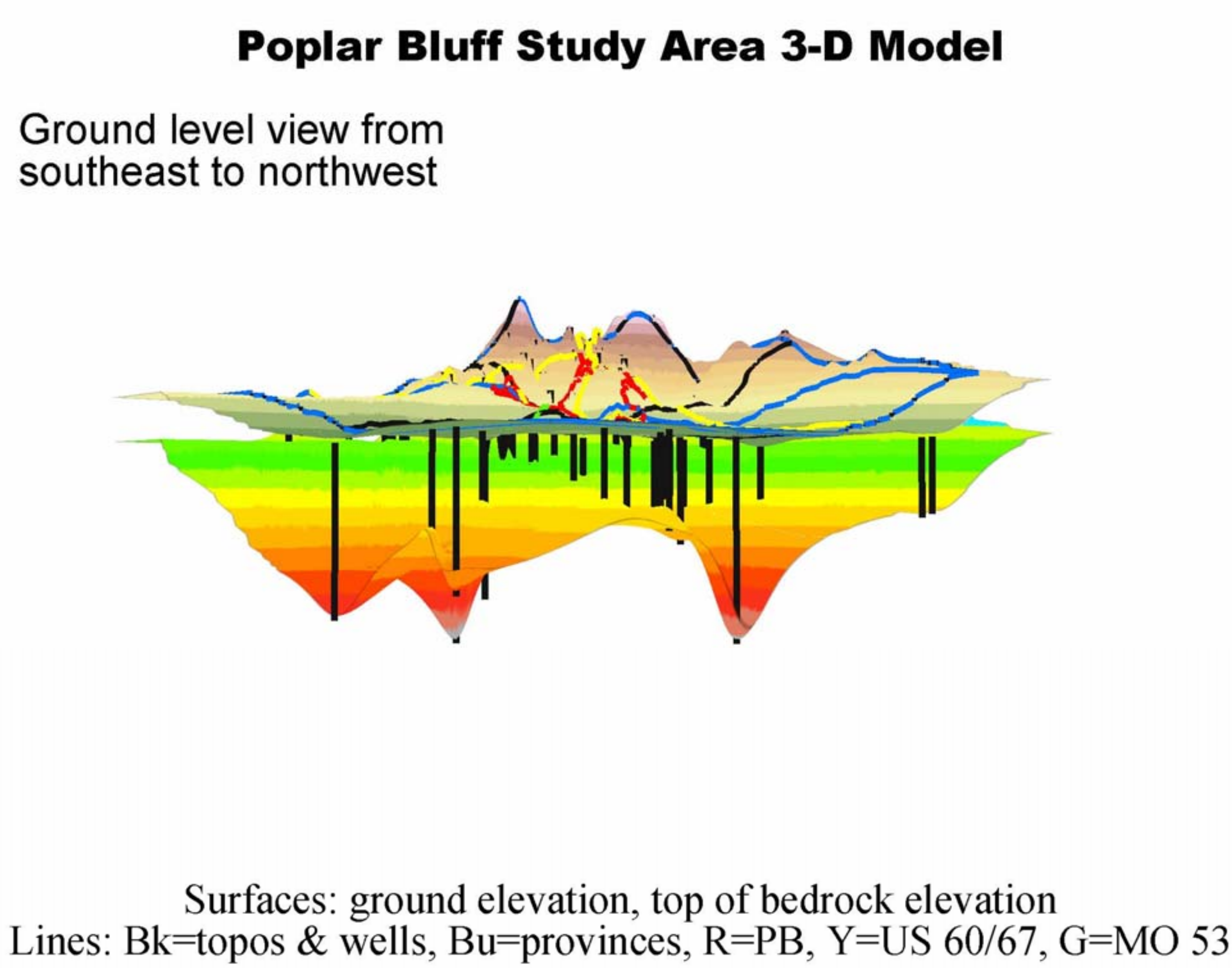

Figure 14: Poplar Bluff 3-D model, ground level view from southeast to northwest.

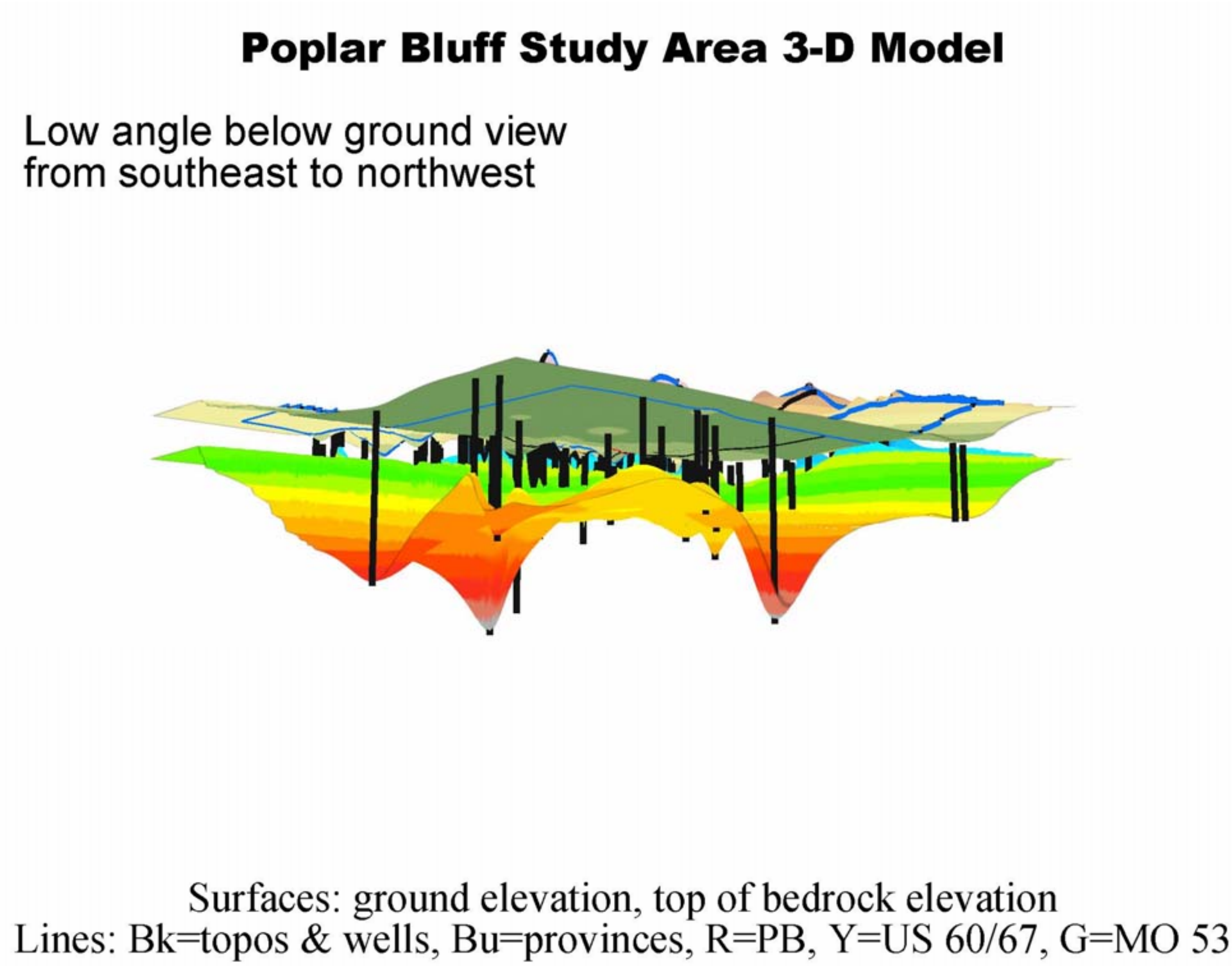

Figure 15: Poplar Bluff 3-D model, low angle below ground view from southeast to northwest.

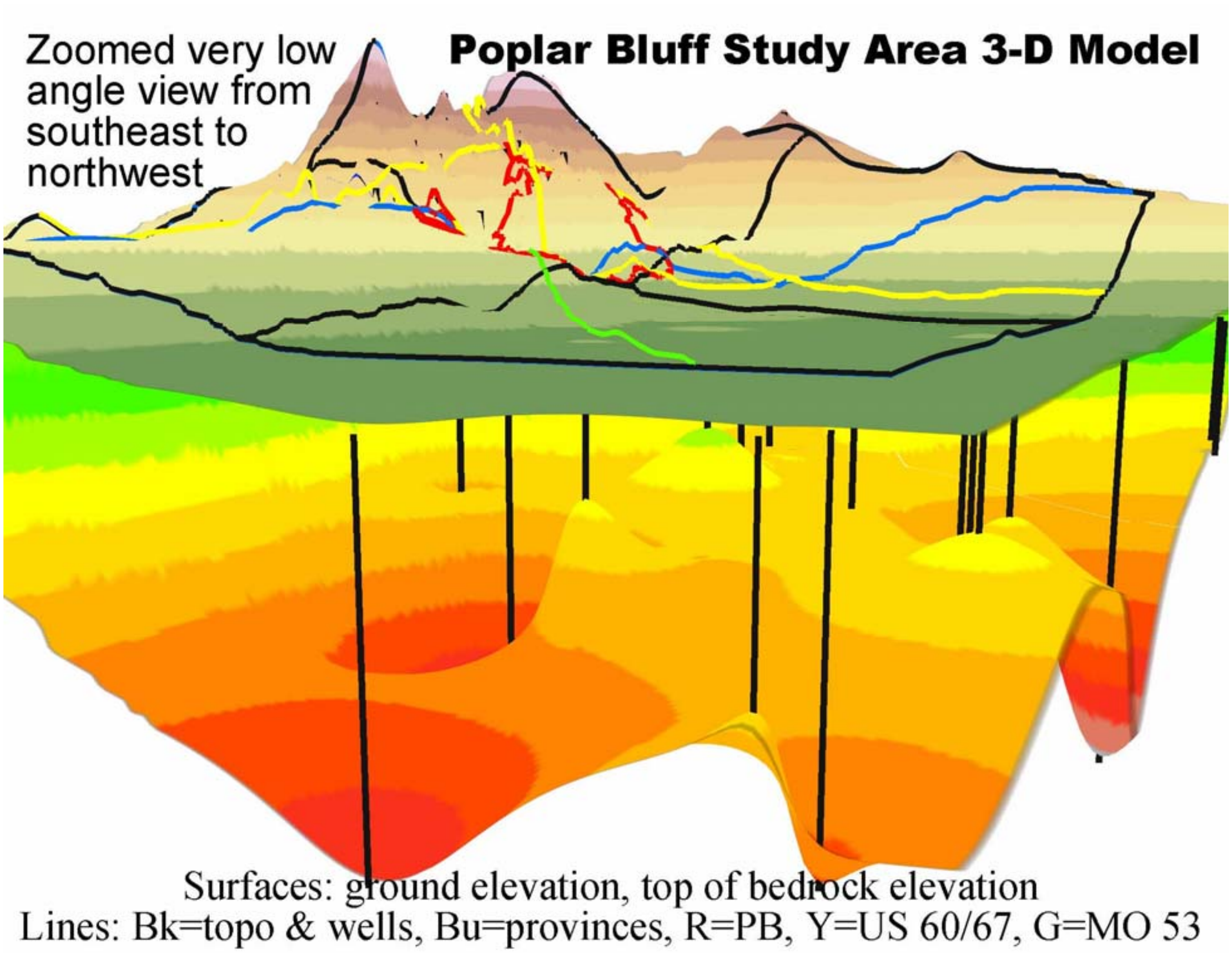

Figure 16: Poplar Bluff 3-D model, zoomed very low angle view from southeast to northwest.

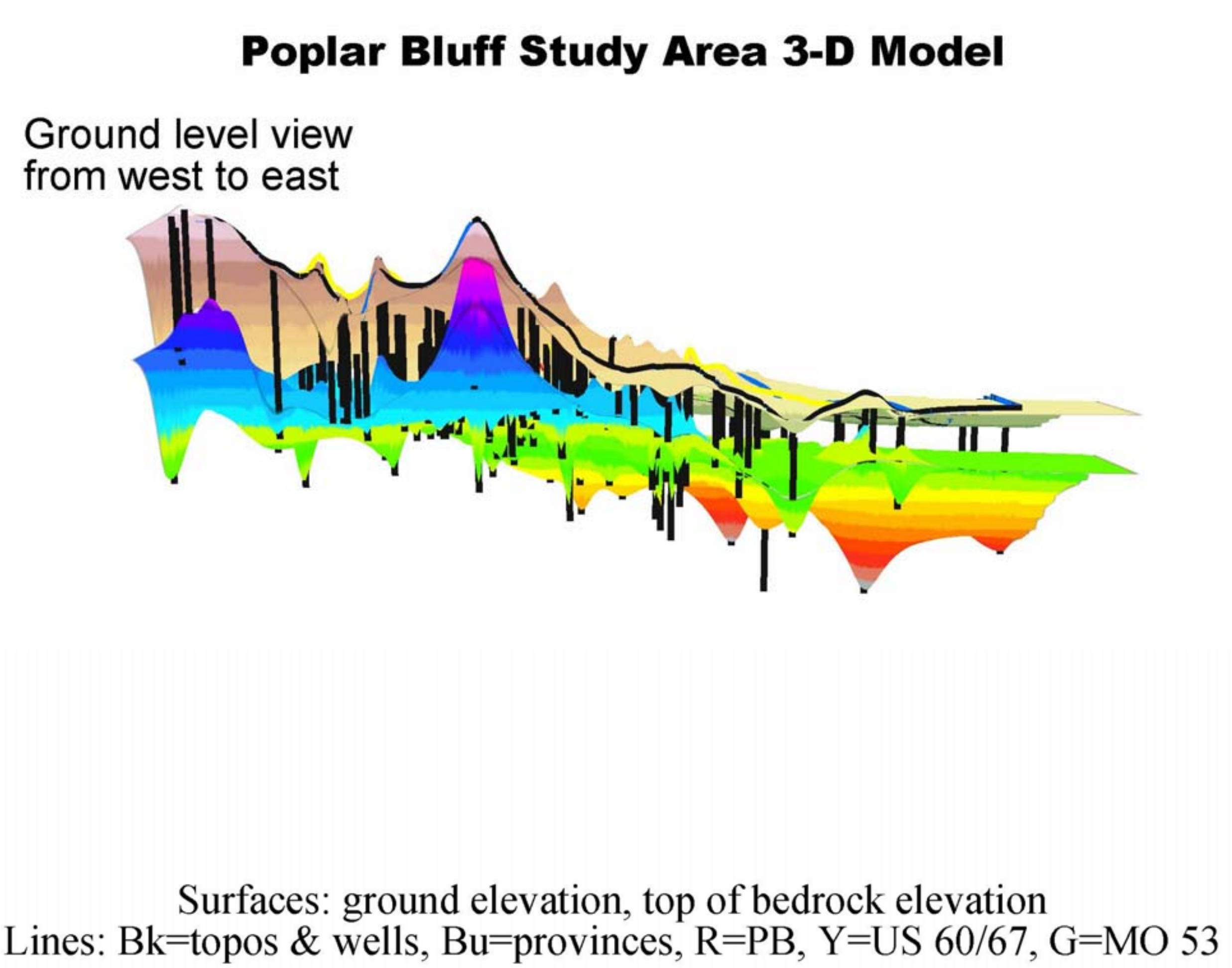

Figure 17: Poplar Bluff 3-D model, ground level view from west to east.

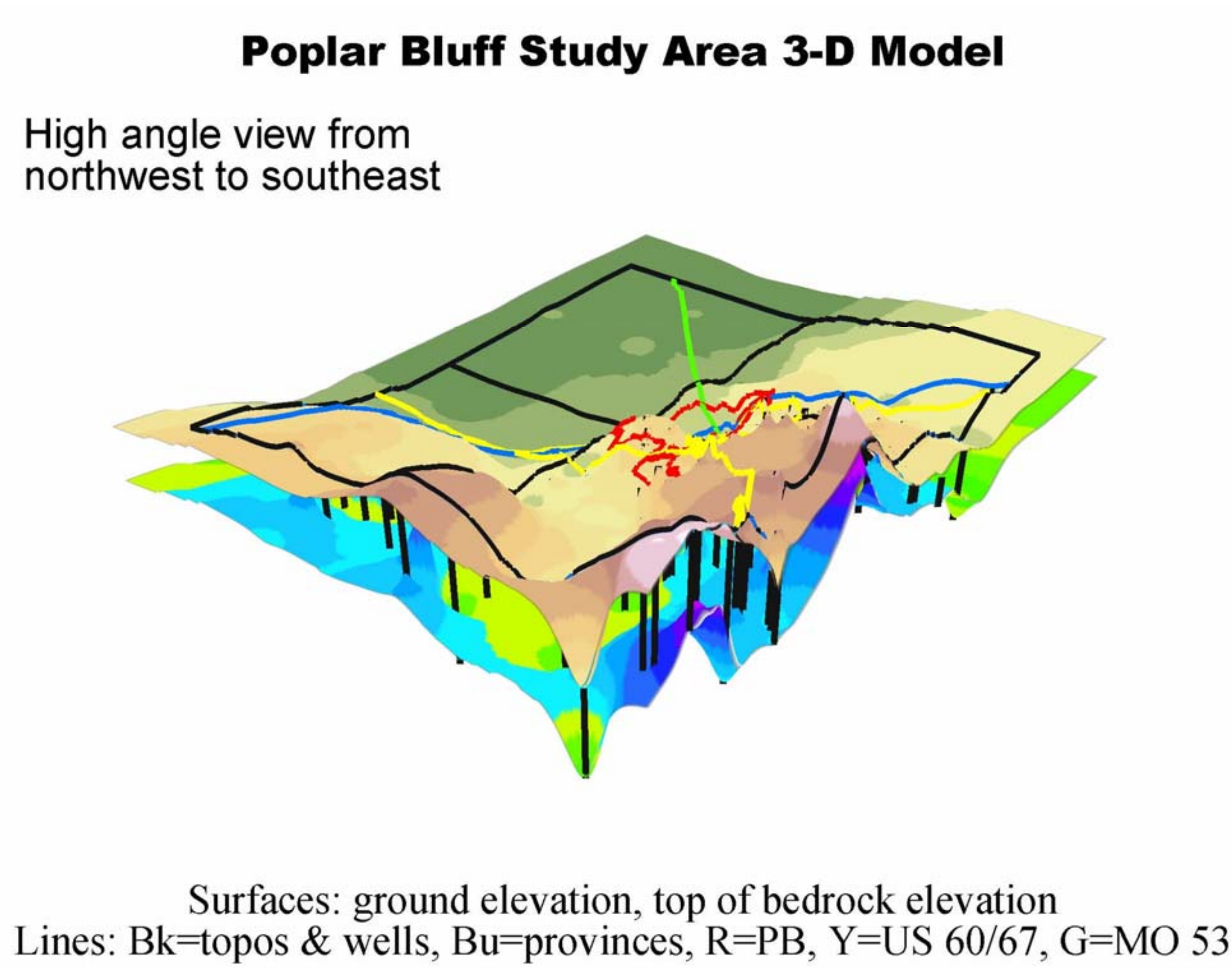

Figure 18: Poplar Bluff 3-D model, high angle view from northwest to southeast.

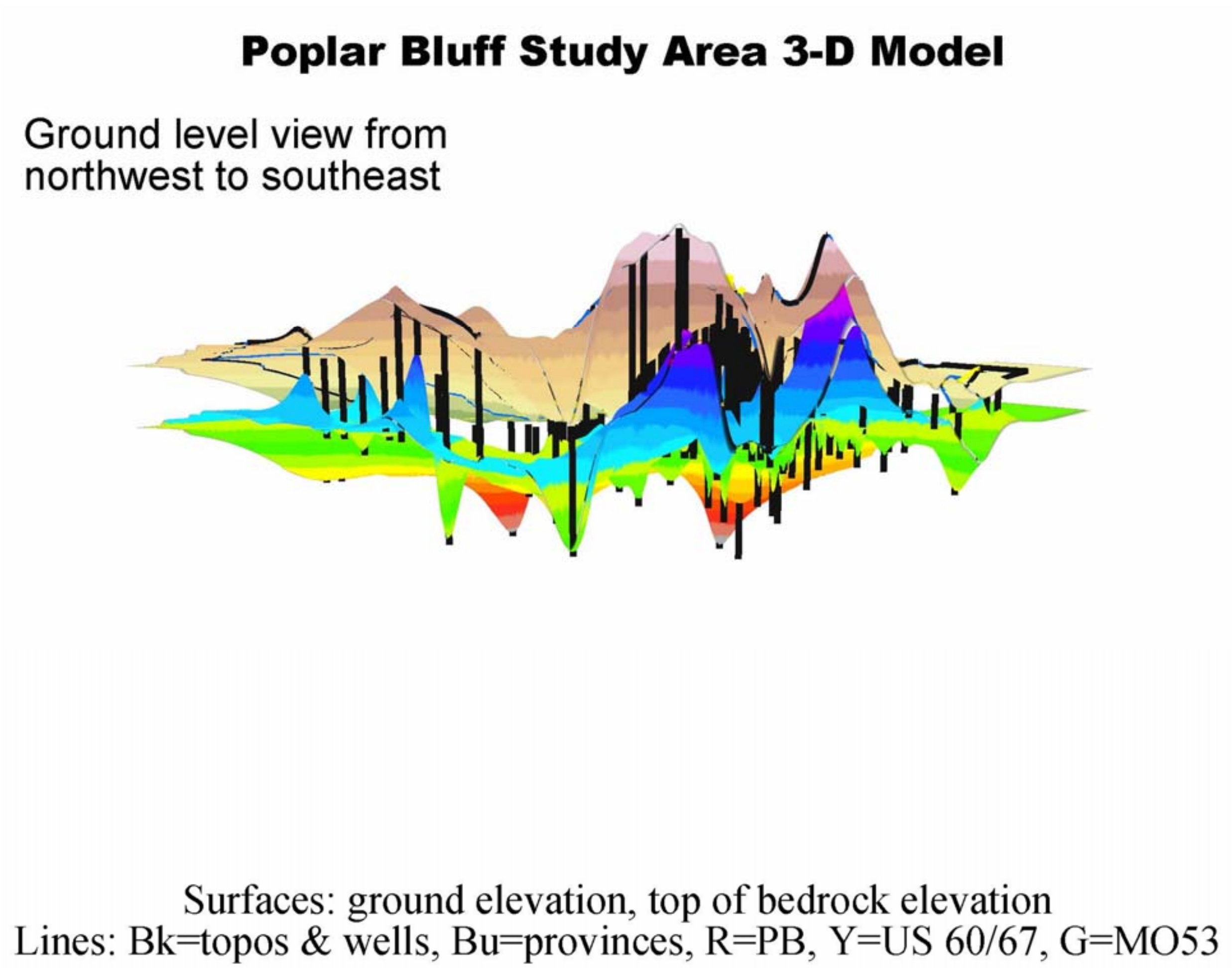

Figure 19: Poplar Bluff 3-D model, ground level view from northwest to southeast.

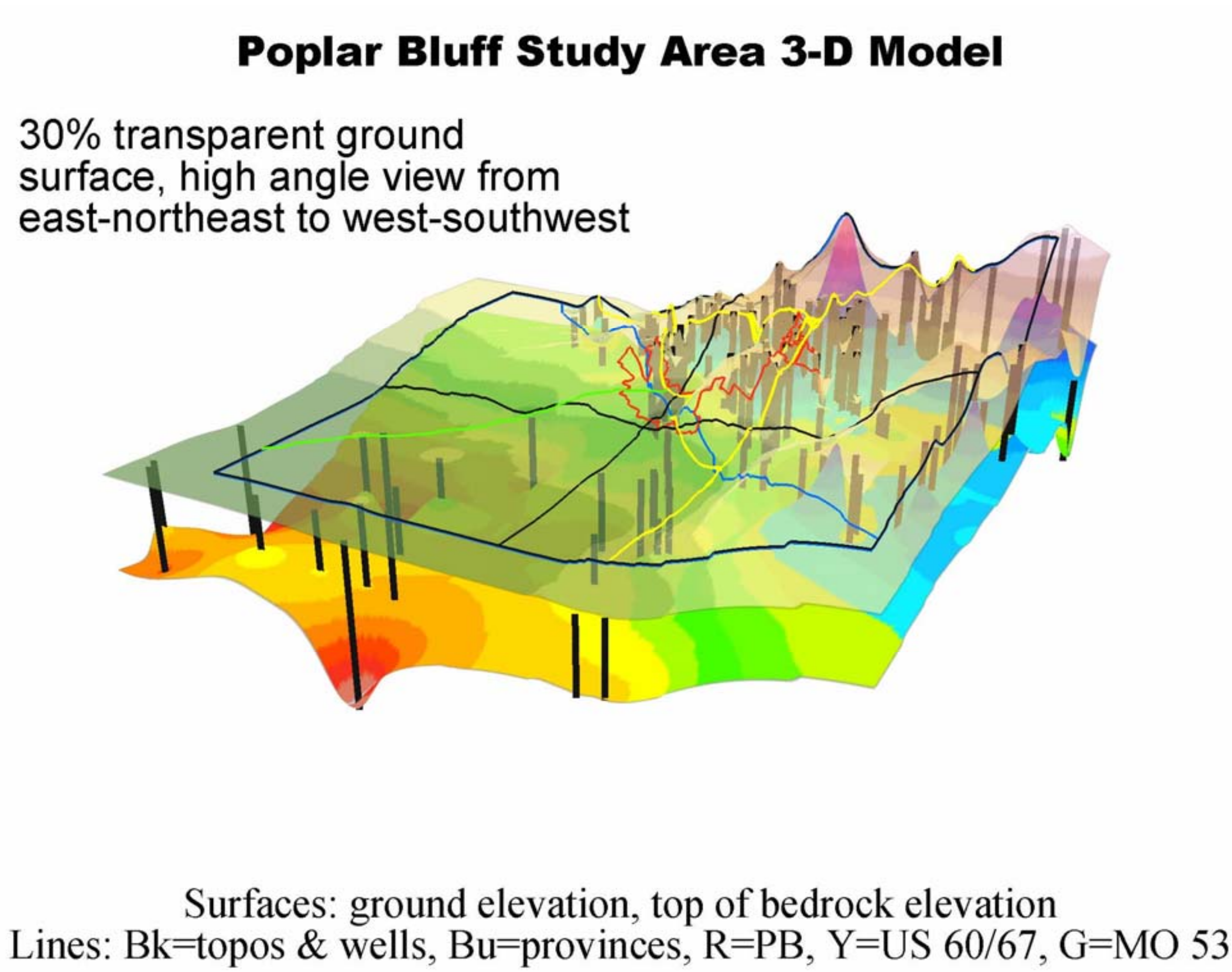

Figure 20: Poplar Bluff 3-D model, 30% transparent ground surface, high angle view from east-northeast to west-southwest.

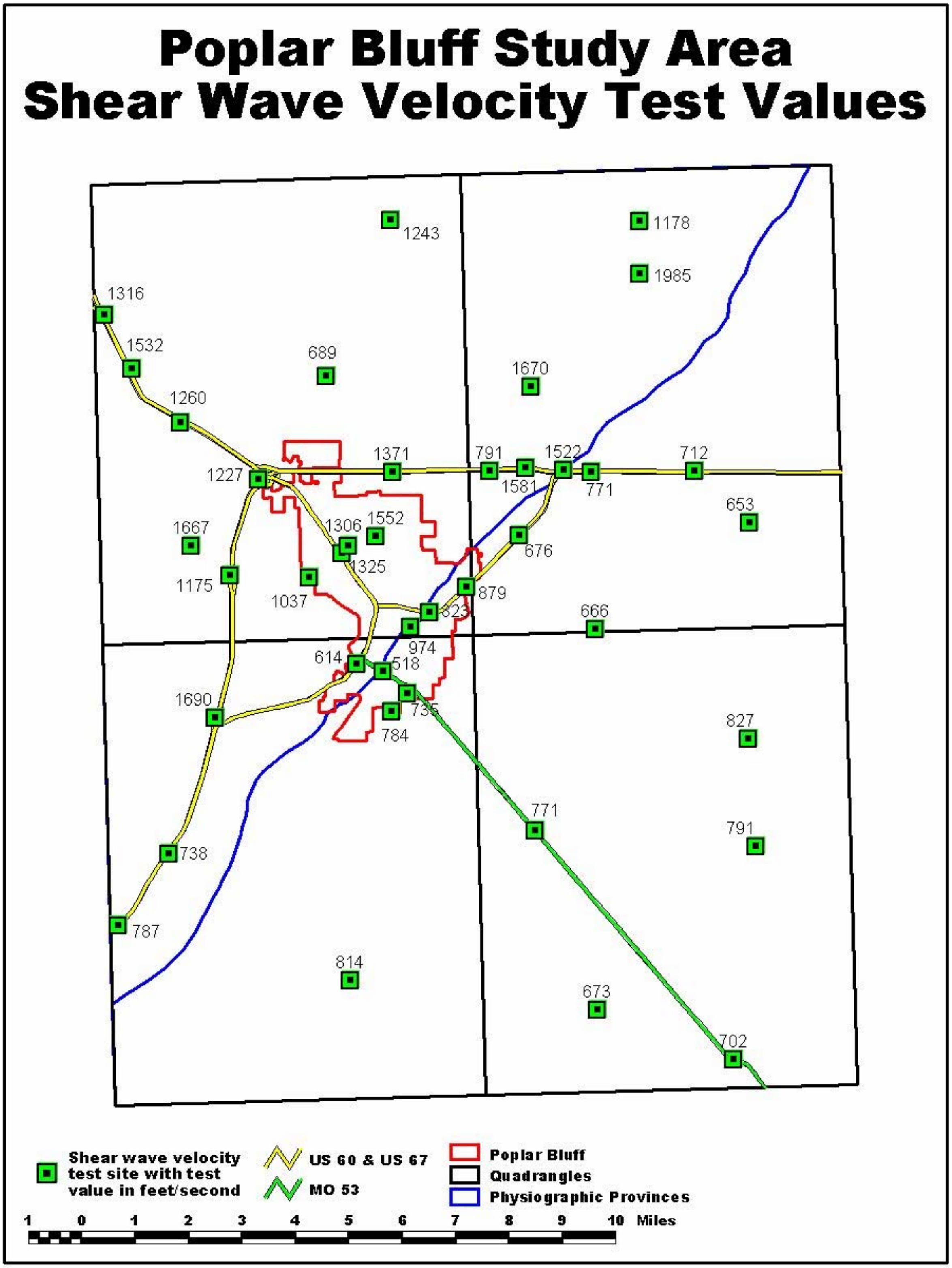

Figure 21: Poplar Bluff study area shear-wave velocity test values.

Poplar Bluff Study Area
Shear Wave Velocity Test Values

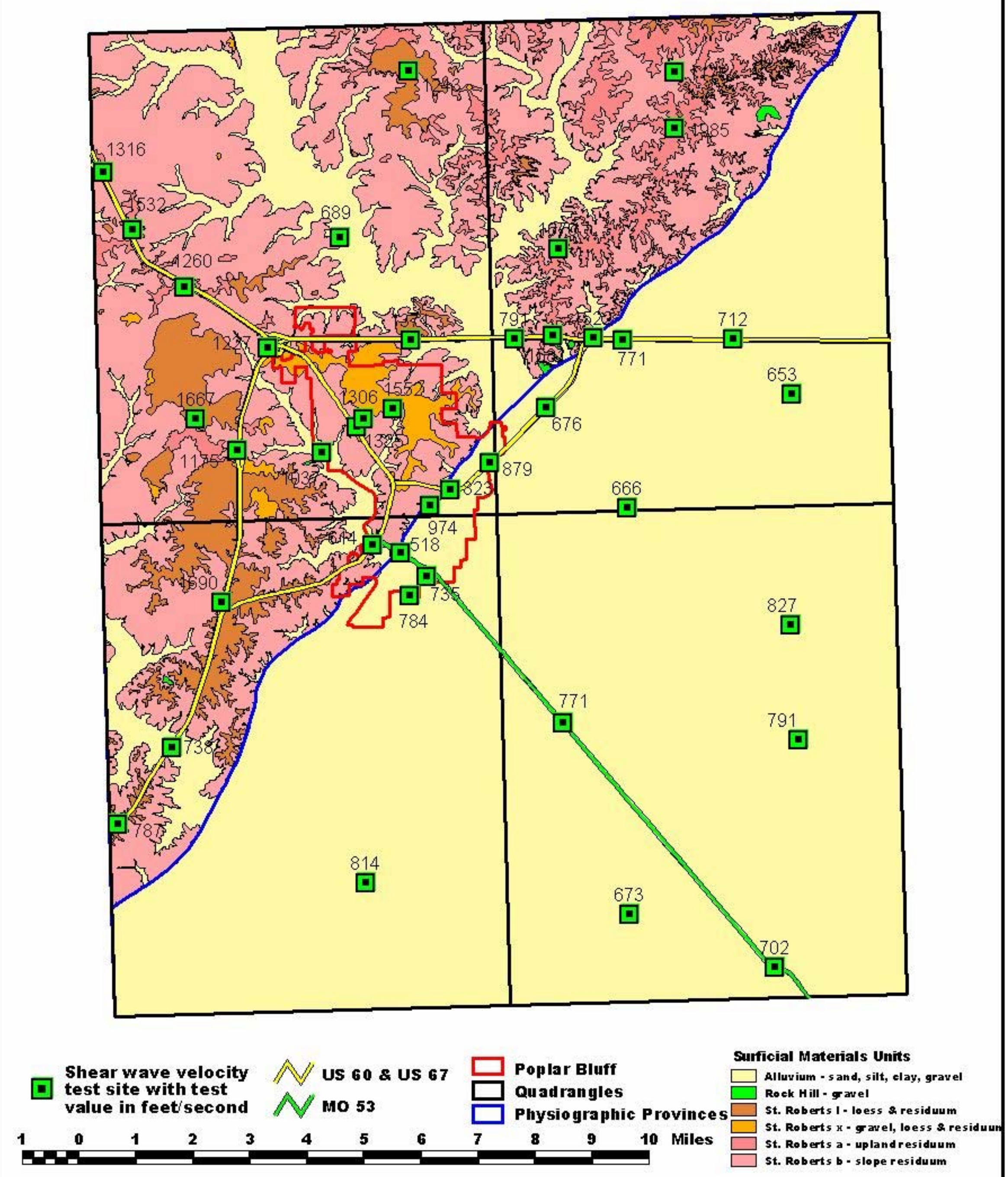

Figure 22: Poplar Bluff study area shear-wave velocity test values and surficial materials units.

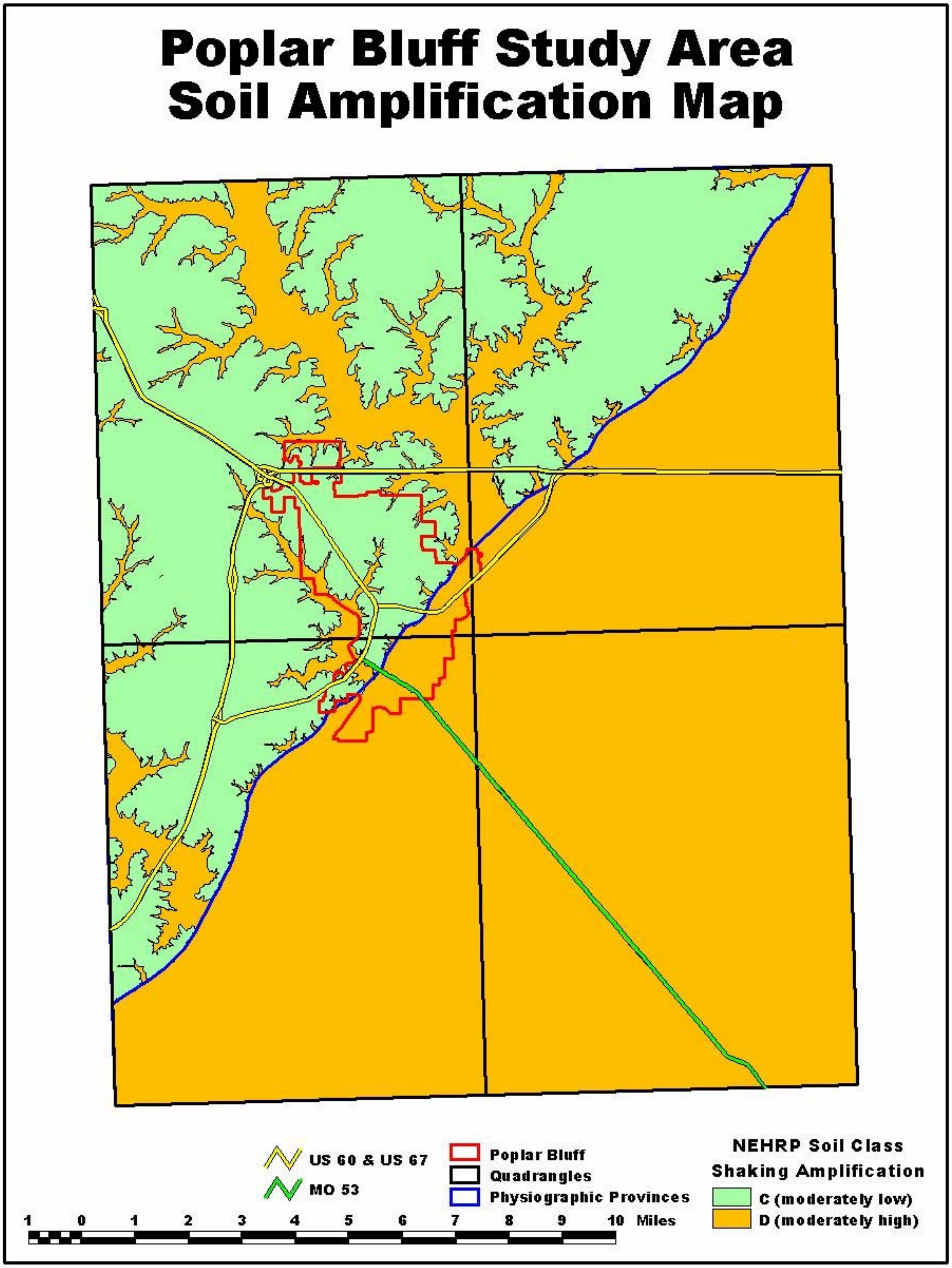

Figure 23: Poplar Bluff study area soil amplification map.