

# **GEOGRAPHIC INFORMATION SYSTEM APPROACH FOR PLAY PORTFOLIOS TO IMPROVE OIL PRODUCTION IN THE ILLINOIS BASIN**

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## Abstract

Oil and gas have been commercially produced in Illinois for over 100 years. Existing commercial production is from more than fifty-two named pay horizons in Paleozoic rocks ranging in age from Middle Ordovician to Pennsylvanian. Over 3.2 billion barrels of oil have been produced. Recent calculations indicate that remaining mobile resources in the Illinois Basin may be on the order of several billion barrels. Thus, large quantities of oil, potentially recoverable using current technology, remain in Illinois oil fields despite a century of development. Many opportunities for increased production may have been missed due to complex development histories, multiple stacked pays, and commingled production which makes thorough exploitation of pays and the application of secondary or improved/enhanced recovery strategies difficult. Access to data, and the techniques required to evaluate and manage large amounts of diverse data are major barriers to increased production of critical reserves in the Illinois Basin. These constraints will be alleviated by developing database access using a Geographic Information System (GIS) approach for evaluation and identification of underdeveloped pays.

The Illinois State Geological Survey has developed a methodology that is being used by industry to identify underdeveloped areas (UDAs) in and around petroleum reservoirs in Illinois using a GIS approach. This project utilizes a statewide oil and gas Oracle® database to develop a series of Oil and Gas Base Maps with well location symbols that are color-coded by producing horizon. These maps are presented in scalable format on an Arc/IMS website at <http://meltwater.isgs.uiuc.edu/website/iloil>. Individual producing horizons are displayed as layers and can be selected as separate or combined layers that can be turned on and off. Map views can be customized to serve individual needs and page size maps can be printed. Transfer of this technology has taken place at the Illinois Oil and Gas Association meeting in March 2003, the Kentucky Oil and Gas Association meeting in Louisville, Kentucky, June 23-June 25, 2003, and at the Independent Oil Producers Association Tri-State, Inc. annual meeting in Evansville, Indiana, June 27, 2003.

Core analysis data with over 200,000 entries have been compiled and assembled into an Access® database. Preliminary maps of wells with core data have been generated. Data from over 1,200 Illinois waterflood units have been entered into another Access® database. Formation depths for the Beech Creek and Ste. Genevieve Limestones in over 80 percent of the oil producing region of Illinois have been calculated and entered into a digital database. Digital contoured structure maps will be constructed and added to the website when data collection is completed.

GIS layers showing cored wells, structure maps and waterflood units will be added to the ArcIMS website when they are completed. This technology/methodology will address the long-standing constraints related to information access and data management in Illinois by significantly

simplifying the laborious process that industry presently must use to identify underdeveloped pay zones in Illinois.

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## List of Graphical Materials

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## Introduction

An interactive map prototype website was activated for this contract in February 2003. The public can access the website at <http://meltwater.isgs.uiuc.edu/website/iloil> using their Web browser. Color-coded producing formation maps are available on the website. Maps can be customized for individual needs by activating needed layers. Maps can be scaled using the zoom tool on the menu and can be printed by users. Users are able to label and print customized maps. An upgrade for the website with a front page and tutorial is planned and will be implemented when the newest version of ESRI ArcIMS is installed on the new map server purchased for this contract.

New layers providing additional information will be added as they are completed. Layers showing current and historical waterflood units are being prepared for inclusion as layers on the website. Data from over 1,200 waterflood units have been entered into an Access database. Structure maps contoured on the Beech Creek and Ste. Genevieve formations are also being prepared. Formation depths for these formations have been calculated for over half the oil producing region in Illinois with over 20,000 formation depths entered into a digital database.

An upgrade of the ILOIL website to be implemented in October 2003, will offer well status information as well as producing horizon data and allow users to customize maps at desired scales with desired layers and features.

Transfer of this technology has taken place in several venues including the Illinois Oil and Gas Association meeting in March 2003, the Kentucky Oil and Gas Association meeting in Louisville, Kentucky, June 23-June 25, 2003, and at the Independent Oil Producers Association Tri-State, Inc. annual meeting in Evansville, Indiana, June 27, 2003. Meeting attendees provided positive reviews for the website. ISGS staff have offered guidance on the use of website features on an individual basis to answer user questions on an on-going basis. Website use has increased as operators become aware of site and become familiar with its features.

## Executive Summary

An interactive map website was activated in February 2003 and can be accessed at <http://meltwater.isgs.uiuc.edu/website/iloil>. The current ILOIL Interactive Map application was implemented with ESRI ArcIMS #4.0, ArcSDE and Oracle database applications. The purpose of the ILOIL website is to enable the public, via their web browser, to access pertinent petroleum exploration and development information and to interactively search and display this information through a GIS layering format. GIS data layers used on this website were generated by completion of tasks outlined in this contract and include the following producing horizons: Pennsylvanian Spoon and Caseyville horizons, Mississippian Waltersburg, Tar Springs, Cypress, Ridenhower, Yankeetown, Aux Vases, Ste. Genevieve, St. Louis, Salem, and Ullin horizons, Devonian Lingle and Grand Tower horizons, Silurian Niagaran reef horizons, Ordovician Galena and Trenton horizons and a layer for gas storage wells in Cambrian formations. Other interactive layers include: oil wells, oil fields, townships, sections, municipalities, US highways, State highways, Interstate highways, counties, USGS 7.5 Minute Quadrangles and Oil and Gas Development Map overlays. Other layers will be added as contract subtasks are completed. Layers to be added at a later date include contoured structure maps, waterflood unit coverages and waterflood injection and production data, core analysis data and play portfolio data. ArcIMS#4.0 software was an essential component for distributing GIS data and applications on the new website. This software (on the server side) works with client-side Web browsers to distribute mapping data through the World Wide Web (WWW).

Connecting to the IMS website is easy and only requires an Internet Web browser (Internet Explorer 5.0 or Netscape 6.0) and typing the following URL into the address window: <http://meltwater.isgs.uiuc.edu/website/iloil>.

Transfer of this technology has taken place at the Illinois Oil and Gas Association Meeting in March 2003, the Kentucky Oil and Gas Association Meeting in Louisville, Kentucky, June 23-June 25, 2003, and at the Independent Oil Producers Association Tri-State, Inc. annual meeting in Evansville, Indiana. Demonstrations on data distributed through the website and instruction on how to access and use the map layers on the website were given at each presentation.

Manipulation of layers available on the website permits users to customize maps for development and exploration purposes. Maps of single producing horizons can be viewed at any scale or color-coded maps of all producing formations can be created by turning pertinent layers on or off. Tools in the menu bar are easily manipulated to produce custom maps which can be printed on a printer connected to a user's computer. Map titles and labels can be added to maps prior to printing, adding to the ability to create customized products from the website. Maps can be printed at any scale.

Map details such as township and section lines and well spot locations become visible as map magnification increases. Features are displayed as the scale becomes appropriate for added detail.

Additional layers will be incorporated onto the website as contract tasks are completed. Waterflood unit maps and injection and production data will be added when data from the over 2,000 waterflood units in Illinois are computerized. To date, information from 1,200 waterflood units has been entered into a digital format. An Access<sup>®</sup> database consisting of entries for over 200,000 core analyses has been completed. Preliminary maps of formations and wells in the database have been compiled. Hand drawn color-coded producing formation maps created by Richard Howard and updated through 1985 have been scanned and made available on CD. Geologic play portfolio models are in the process of being generated as the development of the website progresses.

## Experimental

A new interactive map website was activated in February 2003 and can be accessed at <http://meltwater.isgs.uiuc.edu/website/iloil>. This website was designed as a prototype for a project to enable the public to have access via their web browsers to interactively search and display GIS map layers pertinent to identifying underdeveloped areas (UDAs) in existing oil fields in Illinois. These maps are scalable and can be customized for individual petroleum development purposes. The current website was implemented with ESRI software and utilizes the ArcIMS#4.0 and ArcSDE applications to query and display data residing in the Illinois State Geological Survey's basic well data file, on Oracle® databases.

## Results and Discussion of last six Months

This results and discussion section summarizes the progress on the tasks and deliverables outlined in the contract. Some of this material is best shown in its graphic or display presentation format.

### Task 1. New Evaluation Tools for Identifying UDAs Task for Identifying UDAs: Computerized color-coded pay maps

The following tasks, designed to computerize and display oil production from individual horizons using the ISGS Oil and Gas Development Maps Series (a series of separate maps that covers the entire oil producing region in Illinois), have been completed. 1) A series of color coded pay maps have been completed and are available on the new website at <http://meltwater.isgs.uiuc.edu/website/iloil>. 2) The integration and computerization of the databases required to generate the colored coded pay maps have been completed. 3) Digital production of the series of Oil and Gas Development Maps for Illinois has been completed. Updated plots of these maps are now available. 4) Computerization of maps using a GIS format has been completed. This format facilitates the separation and layering of each pay zone. These maps can now be used to identify individual pay zone trends and identify potential UDAs.

The subtasks completed in order to generate the color-coded pay map series are outlined as follows: 1) editing and updating producing formation data (approximately 83,000 wells) (completed), 2) formatting and translating producing formation data into GIS system (completed), 3) designing color-coded pay maps with GIS software (electronic copies) (completed), 4) serving maps on Internet in searchable and scalable format (completed).

An overview of the new website is outlined below. The overview includes: 1) an example of the preliminary introduction to the website that is being presented to the public and is followed by 2) an example of the

interactive display format that is being designed for the front page of the website (figure 1).

## About ILOIL GIS Interactive Maps

The current ILOIL Interactive Map application was implemented in February 2003 with ESRI ArcIMS#4.0, ArcSDE and Oracle database applications. The purpose of ILOIL is to enable public access via their Web browser to interactively search and display various GIS layers. GIS data layers used on this website are generated by ISGS for DOE Contract No. DE-FC26-02NT15132.

ArcIMS#4.0 software is the foundation for distributing GIS data and applications on the Internet. This software (on the server side) works with your (client side) Web browser to distribute mapping data through the World Wide Web (WWW).

Connecting to the IMS is easy. Using an Internet Web browser (Internet Explorer 5.0) type the following URL into the address window:  
<http://meltwater.isgs.uiuc.edu/website/iloil>.

### Screen Overview

**HTML Viewer Architecture**

The screenshot shows a web browser window displaying a GIS map. The interface is annotated with callouts for various components:

- Tool Bar (ToolFrame) toolbar.htm**: Located on the left side of the map.
- Text Display (TextFrame) text.htm**: Located below the tool bar.
- Mode Display (ModeFrame) ModeFrame.htm**: Located at the bottom left.
- Overview Map Display (Style Sheet/Layer)**: The main map area.
- Map Display (MapFrame) MapFrame.htm**: Located on the right side of the map.
- Layer List & Legend (TOCFrame) toc.htm**: Located on the right side, below the map display.
- Hidden Post Form (PostFrame) jsForm.htm**: Located at the bottom right.

The map shows a geographical area with various layers. A table is visible at the bottom of the map area:

STATE	COUNTRY	POPULATION	CAPITAL	ACRES	ACRES
Alabama	USA	3,000,000	Montgomery	57	57
Arkansas	USA	2,000,000	Fayetteville	36	36
California	USA	30,000,000	Sacramento	37	37
Colorado	USA	4,000,000	Denver	10	10
Connecticut	USA	3,500,000	Hartford	5	5
Delaware	USA	700,000	Dover	2	2
Florida	USA	15,000,000	Tallahassee	9	9
Georgia	USA	7,000,000	Atlanta	5	5
Hawaii	USA	1,000,000	Honolulu	1	1
Idaho	USA	1,500,000	Boise	14	14
Illinois	USA	12,000,000	Springfield	14	14
Indiana	USA	6,000,000	Indianapolis	3	3
Iowa	USA	3,000,000	Des Moines	19	19
Kansas	USA	3,500,000	Topeka	35	35
Kentucky	USA	4,000,000	Frankfort	20	20
Louisiana	USA	4,500,000	Baton Rouge	52	52
Maine	USA	1,300,000	Oxford	9	9
Maryland	USA	5,500,000	Annapolis	8	8
Massachusetts	USA	6,500,000	Boston	4	4
Michigan	USA	10,000,000	Lansing	16	16
Minnesota	USA	5,000,000	St. Paul	23	23
Mississippi	USA	3,000,000	Jackson	47	47
Missouri	USA	4,000,000	Jefferson City	20	20
Montana	USA	1,000,000	Helena	10	10
Nebraska	USA	2,000,000	Lincoln	33	33
Nevada	USA	2,500,000	Carson City	11	11
New Hampshire	USA	1,300,000	Manchester	3	3
New Jersey	USA	8,500,000	Trenton	8	8
New Mexico	USA	2,000,000	Santa Fe	31	31
New York	USA	19,000,000	Albany	4	4
North Carolina	USA	7,500,000	Raleigh	10	10
North Dakota	USA	1,000,000	Bismarck	18	18
Ohio	USA	11,500,000	Columbus	15	15
Oklahoma	USA	3,500,000	Oklahoma City	37	37
Oregon	USA	3,500,000	Salem	24	24
Pennsylvania	USA	12,500,000	Harrisburg	3	3
Rhode Island	USA	1,000,000	Providence	1	1
South Carolina	USA	4,000,000	Columbia	16	16
South Dakota	USA	1,000,000	Sioux Falls	17	17
Tennessee	USA	5,500,000	Nashville	6	6
Texas	USA	20,000,000	Austin	69	69
Utah	USA	2,500,000	Salt Lake City	20	20
Vermont	USA	600,000	Montpelier	2	2
Virginia	USA	6,500,000	Richmond	20	20
Washington	USA	5,500,000	Olympia	5	5
West Virginia	USA	1,800,000	Charleston	6	6
Wisconsin	USA	5,500,000	Madison	16	16
Wyoming	USA	1,000,000	Cheyenne	7	7

Figure 1. Example of the interactive display format being designed for the front page of the website.

General Instructions for the website show browser requirements for using the interactive map site. Instructions for operating the website are included.

## **General Instructions**

### Recommended Minimal Configurations

The following is a list of the minimum computer requirements needed to run the ILOIL GIS Interactive Maps application:

1. Internet Browser--Internet Explorer 5.0 or higher and Netscape 6.0 or higher
2. Modem connection--56K or higher speed connection
3. Color and Screen Resolution--The colors should be set to 32,000 (16-bit) with a resolution of 800 x 600. See "Windows Help" for more information on this topic.

Note: This application will run on lesser configurations, but performance will be slow. This application is not supported on Macintosh computers.

### **Viewing Map Layers**

The layer list is grouped by layer similarity.

1. To view a map layer, click on the View Layer check box to the left of the layer title.
2. To refresh the map, click the Refresh Map button above the Layer/Legend tabs.
3. Some layers do not have boxes to the left of the layer title at the full state map view. To view these layers, you must click the icon to the right of the layer name which will automatically zoom you to the view scale of the layer or you may zoom in using the Zoom In tool .

### **Making Map Layers Active**

The Active Layer function allows you to Identify, Query, Search or Select a feature or features in a layer, or to Hyperlink to the Oracle business application data for that feature.

1. Only one layer can be made active at a time. Click on the layer name to make the layer active.
2. The layer name will be highlighted in white and displayed at the top of the map window in yellow text.

### **Displaying Feature Labels**

Most of the map features are labeled on the map, but the labels may not be visible at the same level that the feature becomes visible. If a feature is not labeled, zoom in until the label is displayed. You may also use the Zoom to Scale function at the bottom left of the screen. Look up the Zoom to Scale value for a feature's label in Layer Information. Enter that value in the box and click the adjacent Zoom button.

The following is a list of the layers that can be displayed on the Website either separately or in combination.

**PENNSYLVANIAN PRODUCERS**

Spoon

Caseyville

**MISSISSIPPIAN PRODUCERS**

Waltersburg

Tar Springs

Cypress

Ridenhower

Yankeetown

Aux Vases

Ste. Genevieve

St. Louis

Salem

Ullin

**DEVONIAN PRODUCERS**

Lingle

Grand Tower

**SILURIAN PRODUCERS**

Niagran Reef

**ORDOVICIAN PRODUCERS**

Galena - Trenton

**CAMBRIAN PRODUCERS**

Oil Wells

Oil Fields

Overlay

Townships

Sections

Municipalities

US Highways

State Highways

Interstates

Counties

7.5 Minute Quads

Oil & Gas Development

The following is a description of the menu bar functions that are displayed on the Website. Note the menu bar shown in figure 2.

## Menu bar Tool Descriptions



Legend Tab – Used to Toggle Between Legend and Layers List



Overview Map-- Turns Overview Map On/Off



Zoom In – Zooms to an Area of Interest



Zooms Out – Zooms out so the Map Displays a Larger Area



Pan – Moves Map In Any Direction



Zoom To Full Extent – Zooms Out to the Full State Map



Zoom to Last Extent



Back To Last Extent – Returns to the Previous Map View



Identify – Identifies a Feature in the *Active Layer*



Measure – Measures the Distance between Points and Area of a Polygon



Set Units – Sets the Units of Measurement for the Measure tool



Clear Selection – Clears All Selected Items



Print – Prints Your View

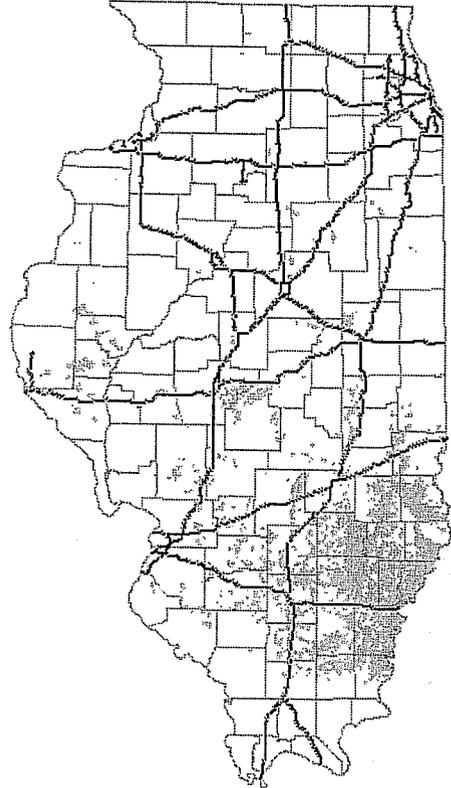
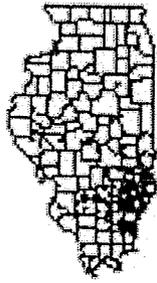


Figure 2. Screen capture of the initial display of the Interactive Map and menu bar for the website at <http://meltwater.isgs.uiuc.edu/website/iloil>.

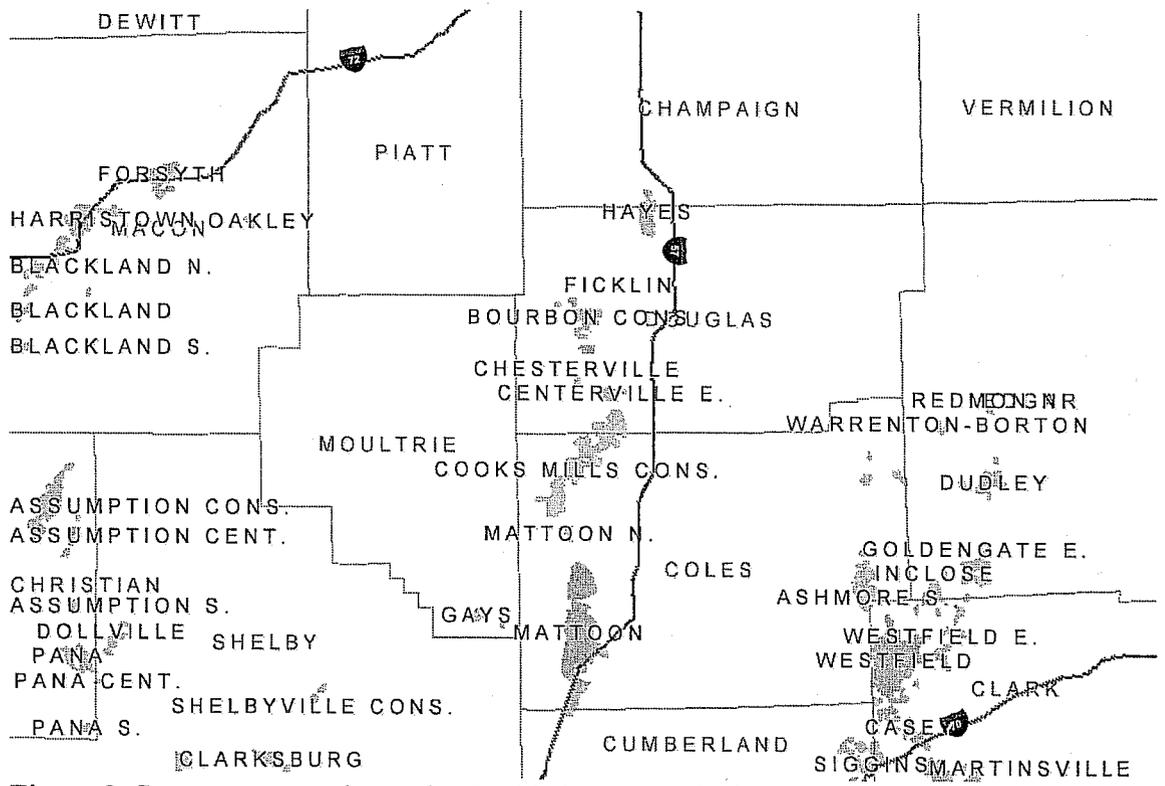


Figure 3. Screen capture shows detail added as zoom in feature is used on state map.

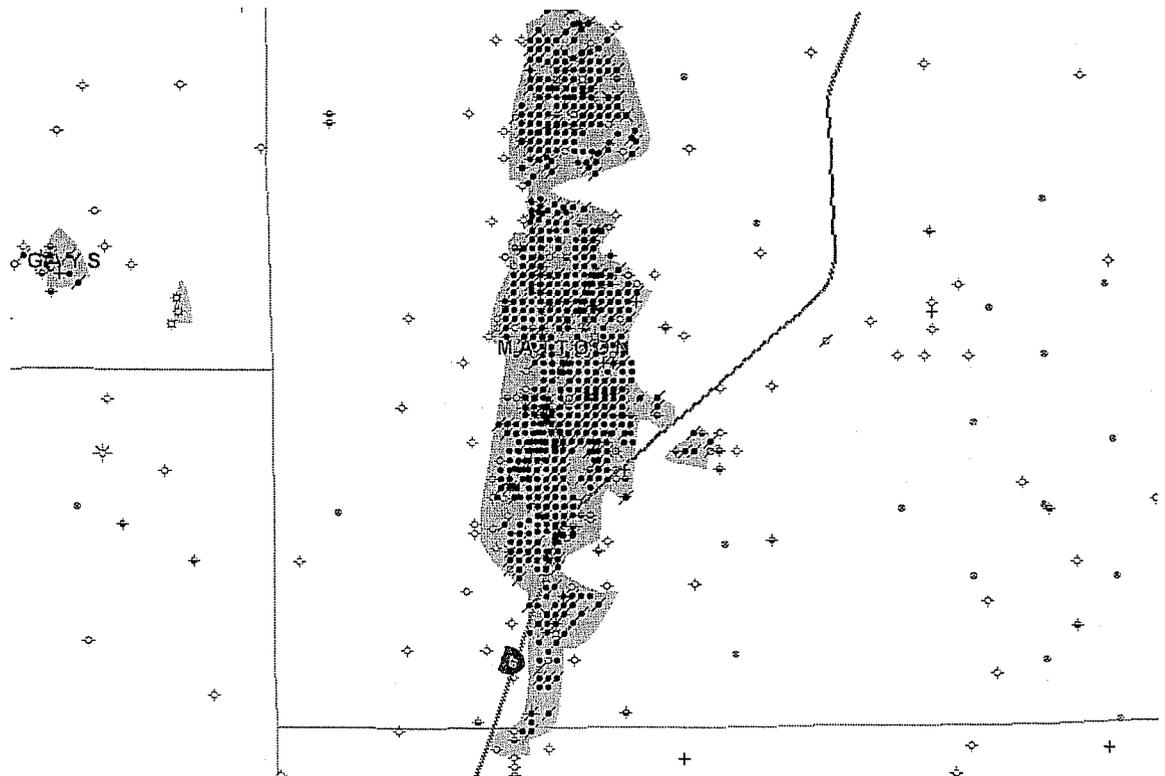


Figure 4. Screen capture of added detail as zoom in feature is used on an oil field.

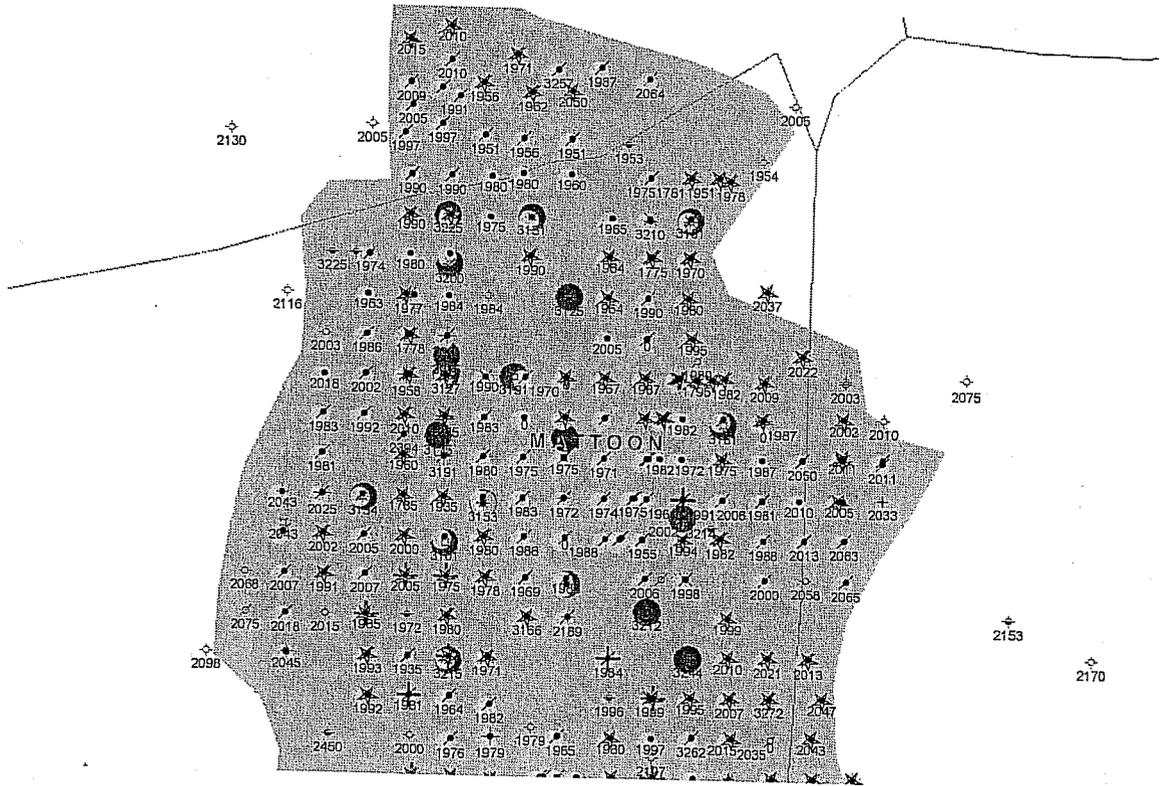


Figure 5. Screen capture close-up (Zoom In) of an area from the interactive statewide map. This display illustrates the individual color coded producing wells. Details such as township and section boundaries and well locations are shown as map area decreases (as Zoom In is activated).



This is a screen capture of the legend that accompanies the map displayed in figure 3 showing the color code key with all horizons and layers in the "visible" mode.

The following tasks have been initiated with subtasks in varying stages of progress:

Task 2. New Evaluation Technique for identifying UDAs: Automate Historic Injection Wells

The Basic Well Data File contains a substantial amount of data relevant to the exploration and development of reservoirs in the Illinois Basin. Among the data most useful in the identification of UDAs are records that identify historic injection wells that are no longer posted as injection wells on Oil and Gas Development Maps because their status has changed. Mapping of all injection wells (historic and current) on a base of the color-coded pay maps can be used to eliminate possible resource-depleted areas and add further utility and refinement to this new

screening methodology. The subtasks associated with adding historical injection wells to the color-coded map series are outlined below:

- 1) extract from basic well datafile records, all current and historic injection wells (completed)
- 2) generate maps of all injection wells with area of influence buffers and overlay onto color-coded pay maps (all injection wells are shown on maps)
- 3) create new maps showing proven pay areas that have not been waterflooded nor influenced by waterflood activities (to be completed)
- 4) design and develop CDs with potential waterflood target maps for manual distribution (1,200 historic water flood units have been digitized)
- 5) serve maps on Internet and offer online demand for computer plots at cost (current injection wells now available on line and on Oil and Gas Development Maps historic injection well information to be added in future upgrades)

### Task 3. New Evaluation Technique for identifying UDAs: Computerization of waterflood records

The ISGS has collected data regarding injected and produced fluids from over 2000 water flood units in Illinois, data from over 600 of these waterflood units has been entered into a digital database. A digital database of current waterflood units in Illinois has been incorporated into the digital Oil and Gas Development Map series. Current waterfloods are now displayed on Oil and Gas Development Maps. Waterflood unit maps have been digitized for incorporation into a GIS layer on the website. The ability to graphically display and visualize the combination of particular pay zones from the color-coded pay maps with injection well locations, coupled with waterflood volumetrics will comprise a formidable system for the identification of UDAs. The stage of completion for subtasks is as follows:

- 1) input data from historic waterflood reports (data entry is 33% completed);  
make waterflood record data available in digital format on the internet and on CD (data entry is 70% complete)
- 2) generate acreage maps for waterflood units by producing formation (digital waterflood unit maps for current waterflood units in Illinois are available, over 1,200 historic waterflood units have been digitized)
- 3) generate maps delineating acreage by formation with waterflood opportunities (not yet completed)
- 4) serve maps on Internet and make available on CD (current waterflood units available)

### Task 4. Identifying UDAs: Evaluation of Core Analysis Reports

Grouping of reservoirs with similar petrophysical characteristics has been initiated by extracting and analyzing porosity and permeability data from the ISGS core analysis database. A large database containing over 200,000 entries of porosity, permeability, water saturation and oil saturation measures from approximately 30,000 wells has been compiled from several smaller databases. Initial GIS maps of core analysis data identified by formation have been compiled in preparation for adding these layers to the website. Additional analytical and statistical analyzes will be conducted using these data. A student intern has been hired to continue work on this data in the Fall 2003 semester. This data will be used to identify highly porous and permeable zones as well as areas with lesser porosity and permeability. This information can be used to recognize areas with additional waterflood potential. Subtasks include:

- 1) compile and edit core analysis data (databases have been compiled)
- 2) create and edit maps showing wells with core analysis data (preliminary maps have been generated)
- 3) serve database on internet
- 4) extract porosity and permeability data from core analysis database by formation

## **Conclusion**

ESRI software has been used to extract and compile data from the ISGS Oracle database and to serve it in interactive map layers on a new website. The interactive maps are available to anyone with a web browser. Technology transfer workshops on how data were compiled for the website and on how to use the website were conducted in February 2003. Response to the website has been very positive. Map layers can be manipulated to produce customized maps that meet individual user needs. Interactive maps and map layers that will be added as contract tasks are completed will enhance development and exploration capabilities in Illinois. These tools have revolutionized display and access of petroleum related data in Illinois. The combination of ArcGIS generated maps, upgrade of the ISGS Oracle database, implementation of ArcSDE 4.0 and ArcIMS has vastly improved the institutional capability at the ISGS to query our database, create interactive map layers and serve map and data layers over the internet. The following layers are available on the website:

PENNSYLVANIAN PRODUCERS in the Spoon and Caseyville formations; MISSISSIPPIAN PRODUCERS in the Waltersburg, Tar Springs, Cypress, Ridenhower, Yankeetown, Aux Vases, Ste. Genevieve, St. Louis, Salem, and Ullin formations, DEVONIAN PRODUCERS in the Lingle and Grand Tower formations SILURIAN PRODUCERS in Niagaran Reefs and ORDOVICIAN PRODUCERS in the Galena – Trenton formation, 7.5 Minute Quads, Oil Fields, Oil & Gas Development Overlay, Oil Wells, Counties, Townships, Sections, Municipalities, US Highways, State

Highways, and Interstates. This software permits the ISGS to add scale appropriate details such as township and section lines as map magnification increases. Users need only a web browser to gain access to map and data layers. Users can turn layers on or off to create custom maps for development and exploration purposes. Map labels and titles can be added by users and page size maps can be printed off the internet if a user has a printer.

Transfer of this technology has taken place at the Illinois Oil and Gas Association Meeting in March 2003, the Kentucky Oil and Gas Association Meeting in Louisville, Kentucky, June 23-June 25, 2003, and at the Independent Oil Producers Association Tri-State, Inc. annual meeting in Evansville, Indiana on June 27, 2003. Participants were shown how to use the website menu bar and other website features were introduced. The website was well received and has been a popular exploration and development tool.

User feedback shows that users find the website to be helpful to their work in petroleum exploration and development in Illinois. We are paying close attention to user suggestions for upgrades to the website. The up-graded version will be available in September 2003 and will have county names, township and section numbers, and well status symbols. Other website upgrades will include a front page and tutorial section. Additional data layers will also be available.

**References**  
No citations

## List of Acronyms and Abbreviations

Arc/GIS	Geographic Information System mapping software
ArcInfo	Geographic Mapping Software
ArcView	PC based geographic mapping software
CDs	Compact Discs
bpd	barrels per day
DOE	U. S. Department of Energy
GIS	Geographic Information System
IMS	Internet Mapping Server software
IOGA	Illinois Oil and Gas Association
ISGS	Illinois State Geological Survey
OOIP	Original Oil in Place
PMP	Preferred Management Practices
PTTC	Petroleum Technology Transfer Council
SDE	Spatial design engine for ArcInfo and ArcView products
UDA	Underdeveloped Area (with potential for increased production)
USGS	United States Geological Survey