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Michigan Geological Survey MGS Annual Report (2013)

The Michigan Geological Survey is pleased to present the 2013 Annual Report summarizing the activities and accomplishments to the State Geologist per Senate Bill No. 507.

OVERVIEW

The Michigan Geological Survey (MGS) was assigned to Western Michigan University (WMU) Geosciences by the state legislature in October 2011. The MGS at WMU has instituted a number of initiatives. Key goals are to re-introduce the Survey to the State of Michigan, to develop partnerships, to be recognized as the "go to" for geologic resources, and to seek funding to market Survey resources and skills to the State. To meet the objectives as the "Go to" for geologic and natural resource information for the State of Michigan, MGS has established nine Resource Centers in order to focus inquiries to the appropriate professional. The leaders of the Resource Centers are faculty and professional staff at Western Michigan University who are poised to support the State of Michigan in our new role as the re-invented Survey.

MGS has the largest and most comprehensive core repository and data storage facility in the State. The Michigan Geological Repository for Research and Education (MGRRE) has been in existence for over 30 years. The MGS has the technical background to support the hydrogeologic water initiatives of groundwater and the Great Lakes initiatives for Michigan. It has the strongest and longest functioning academic and applied groundwater program in the State and it has been at Western Michigan University for over 30 years. Lastly, WMU has been mapping the surface geology for over 18 years, both through contracts with the DEQ and now directly through the USGS. These three Resource Centers, plus the six others have provided support to the State this year through contract work, formal studies and technical assistance, and training sessions as summarized below.

MGS currently supports State water resource interests by sitting in on the Bi-monthly meetings of the Southwest Michigan Water Resource Council, and on the ex-officio seat of the Governor's mandated Water Use Advisory Council monthly meetings.

Michigan Technological University (MTU) and the MGS are considering the development of a Memorandum of Understanding (MOU) for a joint operating agreement. This will include the development and operation of a core and data resource center similar to MGRRE in the Upper Peninsula that will share the MGS website and data access functions. The UP facility will be affiliated with MTU and will have analytical and technical equipment to support industry, academic study, and research similar to MGRRE.

The MGS Director and Resource Center leaders have had nearly 30 meetings and/or made presentations to Michigan stakeholders during the past year, presenting the capabilities, strengths, and focus of the Re-invented Survey. MGS has prepared a number of proposals for continuing studies, and submitted them to the appropriate foundations and/or funding agencies. MGS also prepared unsolicited proposals where geologic and technical issues were identified and/or a problem is present that requires a solution that MGS can support and funding would be needed to meet the Re-invented State of Michigan economic and resource requirements. These can or will be submitted to the appropriate legislators and stakeholders in order to present a case to secure funding for the needed specific geologic programs in the State. These are outlined below and include, a strategic geologic mapping program, the mineral assessment program, airborne geophysical surveys, the atlas of geo-hazards, and core repositories to name those defined to date.

General Survey Activities and Accomplishments:

Staffing

Mr. John A. Yellich was hired as the permanent Director of the Survey on October 2, 2013. Mr. Yellich brings nearly 40 years of business and technical experience to the Survey and his functional responsibilities include generating and disseminating Michigan geologic information and raising operating funds. Dr. Alan Kehew was the interim Director and resumes his role as a Professor in the WMU Geosciences Department, and the head of the Mapping Resource Center.

Sita Karki was hired on August 5, 2013 as the GIS technician supporting geologic mapping, data compilation, data distribution functions, as well as the updates to the MGS Website through the GIS Data Management Resource Center.

Meetings/Presentations

The Michigan Geological Survey continues to make contact with the "client", and has conducted 30 meetings and presentations with key stakeholders to introduce the Re-Invented Survey and to present the benefits of the MGS as the "Go To" geologic resource for the State of Michigan. The following represents some of those key interactions:

1. January 8 – 10, 2013, Great Lakes Geological Mapping Coalition (GLGMC), Dr. Alan Kehew attended a working group meeting in Indianapolis, to review status of projects and Federal funding for mapping quadrangles in the State.
2. January 31 – Mining and Minerals Trade Association organizational meeting in Grand Rapids to discuss information acquisition and dissemination. Representatives in Houghton were linked to the meeting via computer. Dr. Joyashish Thakurta and Dr. Alan Kehew represented the Survey at this meeting.
3. February 11 – State Representative Aric Nesbitt visited several faculty members at MGRRE to consider available resources that might help stimulate economic development of Michigan's geological natural resources.
4. March 18 – Meeting at the MGRRE facility meeting with representatives of the Michigan Economic Development Council (MEDC), State Rep. Aric Nesbitt, Robert Mannes of Core Energy, Ted Pagano of Michigan Potash Corp., WMU VP for Legislative Affairs, Greg Rosine, and several Geosciences faculty members. The purpose of the meeting was to tour the MGRRE facility, to discuss potential economic development issues relating to geologic natural resources, and to demonstrate how MGS/MGRRE capabilities will contribute to Michigan economic development.
5. Feb 5-7 - Dr. Alan Kehew, GLGMC meetings in Washington, DC to brief legislators and staff, and to reinforce the need for funding for Michigan mapping projects through USGS.
6. April 1 – Dr. Alan Kehew addressed the Kalamazoo Rotary Club to present the new Michigan Geological Survey at WMU. The meeting was arranged by Rotarian Dr. Dan Lytinski who also attended the meeting. Drs. William Harrison and Mohamed Sultan of WMU Geosciences were also in attendance.
7. May 31 to June 9 – Dr. Joyashish Thakurta visited the UP and met with several public and private organizations related to mining and mineral resources in the UP Michigan, namely: (1) Joe Maki and Melanie Humphrey at the State core repository maintained by the DEQ in Harvey; (2) Bob Mahin, Chief Geologist, of the Eagle Mine at the core sheds in Gwinn and Negaunee; (3) Ross Grunwald of Keweenaw Copper Company at both their offices, and at their core shed in Calumet, (4) Helene Lukey of Cliffs Natural Resources in Ishpeming; (5) Wayne Pennington and other members of the Geological and Mining Engineering and Sciences at Michigan Tech University (MTU) in Houghton. The purpose of this trip was to explore the feasibility of research collaboration, and to collect a preliminary sample of rock units. The trip was funded by the Office of Vice President of Research at Western Michigan University.

8. May 29 and July 31 – Dr. Joyashish Thakurta went to meetings of the State of Michigan ICC Mining Team at Constitution Hall in Lansing to discuss improvements in mining policies and expected economic development outcomes.
9. June 9-13, - American Association of State Geologists Annual meeting, Deadwood, SD. Dr. Alan Kehew. Presentations and updates were made on state survey issues.
10. October 6 – Dr. Joyashish Thakurta met with Tom and Robin Quigley of Aquila Resources, Lois Ellis of MEDC, and Nancy Douglas of Menominee Business Development Corporation at the offices of Aquila Resources in Menominee to discuss mineral exploration projects in UP Michigan. A new research program on the geochemistry of the Back Forty deposit was initiated with Aquila Resources.
11. October 8 - Dan Wyant, DEQ Director-, Lansing (John Yellich and Greg Rosine) to introduce Yellich to Mr. Wyant, who outlined the important natural resource issues facing Michigan and Yellich then presented how MGS can assist to support those key issues such as groundwater resources and groundwater data management.
12. October 10 - Mining Association Exploratory Group – Fetzer Center and web cast with Michigan Tech in Houghton (John Yellich, Dr. Joyashish Thakurta, Dr. Alan Kehew) presentations by DEQ and stakeholders that included 25 attendees in Kalamazoo and 15 in Houghton at MTU. There were discussions concerning geologic data collection and management (MGS), and mineral development (DEQ) in the State.
13. October 11 - Geosciences Advisory Council – MGRRE (John Yellich) conducted a review of the MGS, its recent activities, and future functions.
14. October 16, PTTC, Traverse City, Meeting with Bill Stezler, Tim Blake, and Bob Mannes (Funding for Survey and MGRRE) to discuss geologic drill sample data capture for glacial geology, and water resource assessments in areas of oil well drilling.
15. Oct. 29- 30, - American Association of State Geologists, Dr. Alan Kehew semi Annual Update at the GSA meeting in Denver, presentations and updates on State survey issues.
16. October 30, Michigan Manufacturers Association – Mining Sub-Committee - Lansing (John Yellich) presentation and web cast to over 50 participants to review the functions of the Re-Invented Survey.
17. November 2, Michigan Teachers workshop to review MGRRE data for Earth Science education roles. Developed ideas and an initial framework for a MGRRE Online Education Portal that will allow teachers to use MGRRE Resources to supplement lesson plans. Dr. Peter Voice, Dr. Heather Petcovic, and Dr. William Harrison.
18. November 5, Members (8) of the Saudi Arabia Geological Survey – at MGRRE to review the functions of the MGRRE facility, and its contributions to the State by preserving real rock and core samples, and data for mineral, oil, and gas, and groundwater assessments.
19. November 7 - DEQ Drinking Water Division leader (Liane Shekter) and Dana DeBruyn - Chief Non Community and private drinking water supplies (Dr. Al Kehew and John Yellich). Discussed: water well data, Wellogic, funding for input of paper copies into the Wellogic data base, providing a training session for the drillers on input of relevant geologic data to Wellogic. Suggested coordinating with Michigan Groundwater Association.

20. November 11, Informal meetings with Wayne Wood, President Michigan Farm Bureau and Brian Eggers, Michigan Chamber of Commerce, to discuss MGS/WMU groundwater capabilities.
21. November 13, Joel Schultz, Director Central Upper Peninsula Planning and Development Regional Commission (CUPPAD) in Escanaba to discuss the MGS and a core repository in UP.
22. November 13, Thomas Quigley, Aquila Resources in Menominee to review UP core repository, exploration and development of Aquila's Back Forty project.
23. November 14, Wayne Pennington, MTU Interim Dean College of Engineering and Geology, discuss the MGS and its synergy with MGRRE, faculty and student programs and classes, and a UP core repository at MTU. Reviewed tentative repository sites in the area of MTU.
24. November 15, Meeting in Marquette with Carolee Swanberg, Lake Superior Community Partnership (LSCP) Business Development, to introduce and review MGS and its functions and those of a core repository. Ms. Swanberg was very receptive and knowledgeable of the need for a UP repository. MGS received invitation to present to the next LSCP meeting in December.
25. November 21, MGS Advisory Board (Member list attached) meeting at MGRRE. Items included a review of 2013 activities and plans for generating funds for the MGS in 2014 and beyond.
26. December 5, Dr. William Harrison presentation to American Institute of Professional Geologists (AIPG). A review of how a multi-billion dollar potash resource was re-discovered in Michigan, how the MGRRE core repository supported the re-discovery of this resource after a review and interpretation of the stored drill core and associated oil well logs.
27. December 9, Water Use Advisory Council meeting in Oakland County, Alan Kehew. The secondary purpose of attending the meeting was to introduce John Yellich, MGS Director, to the Council, and to discussions with key members of the Council (Jon Allan, Wayne Wood, Brian Eggers, George Carr) on the utilization of geologic information to assess water resources and, using the MGS as a technical resource.
28. December 12, Presentation in Marquette to the Lake Superior Community Partnership (LSCP) December member meeting, Amy Clickner, Director. Review the MGS, it's role in the UP, and the need for a functioning core repository in the UP as a collaborative project with MTU.
29. December 12, Meeting and webcast with UP stakeholders (John Yellich and Wayne Pennington). The purpose was to review the benefits of a functioning core repository at MTU, and to present how all of Michigan would benefit. There were 11 stakeholders in Marquette and 5 on line. Future meetings are planned.
30. December 13, Eagle Mine Tour for John Yellich and Wayne Pennington and some of the participants in the 12/12 meeting. Conducted by Robert Mahin, Chief Geologist for the Eagle Mine, Lundin Mining.

Publications based on recent mapping and survey projects

Linker, J.S. and Esch, J.M. 2013. Surficial Geology of the Marshall 7.5 Minute Quadrangle, Calhoun County, Michigan Map Series SGM-13-01. Scale 1:24,000

Esch, J.M. 2013. Surficial Geology of the Northwest Albion 7.5 Minute Quadrangle, Calhoun County, Michigan Surficial Geologic Map Series SGM-13-02 . Scale 1:24,000

Kehew, A.E. and Esch, J.M., 2013, Surficial Geology of the Climax 7.5 Minute Quadrangle, Calhoun and Kalamazoo Counties, Michigan, Surficial Geologic Map Series SGM-13-03, Scale 1:24000.

Esch, J.M., 2013, Surficial Geology of the Northeast Albion 7.5 Minute Quadrangle, Calhoun and Jackson Counties, Michigan, Surficial Geologic Map Series SGM-13-04, Scale 1:24,000.

Kehew, A.E., Ewald, S.K., Esch, J.M. and Kozlowski, A.L. 2013. On the origin of tunnel channels of the Saginaw Lobe, Laurentide Ice Sheet, Michigan USA. Boreas, Vol. 42, pp. 442–462.

Kehew, A.E., Kozlowski, A.L., Bird, B.C. and Esch, J.M. 2013. Contrasting terrains of the Lake Michigan and Saginaw lobes of the Laurentide Ice Sheet in southern Michigan, in, Gillespie, R., ed., Insights into the Michigan Basin, Geological Society of American, Field Guide 31, p. 15-36.

Resource Center Functions

MGRRE Subsurface Geology - Repository and data management- Dr. William Harrison III

The Michigan Geological Repository for Research and Education (MGRRE) at Western Michigan University is recognized nationally and internationally as the primary research facility for Michigan geology. Areas of strength and associated 2013 activities include:

a) Acquiring and preserving geological cores, samples and well records, bringing into existence a wealth of data that is easily accessible both on-site and on-line,
b) Developing new applied research technology relating to Michigan subsurface geology and geological natural resources including water resources occurring both at the surface and subsurface. This MGRRE research in conjunction with industry members' activities has positively impacted economic development through increased domestic energy from fossil fuel and geothermal sources, reduced greenhouse gas emissions, discovery of aggregate materials, and rediscovery of potash and other mineral deposits,
c) Establishing and maintaining academic and industry partnerships to promote economically sustainable and environmentally sound use of geological natural resources,

d) Implementing professional and public outreach programs to explain the science behind and the benefits of technological advances in energy recovery and CO2 capture and storage,
e) Providing hands-on training for students in the geosciences that was conducted in partnership with Michigan industries, producing highly trained graduates ready to assume responsible positions, and
f) Developing classroom programs with "backyard" geology modules to motivate and educate K-12 students.

Repository, data management and usage

Cores

Inventories have now been completed for 90 pallets of Michigan core obtained last year from the Bureau of Economic Geology in Texas. MGRRE selectively requested these cores because they represent the Glenwood, St. Peter, and Prairie Du Chien formations and were essential to producing reservoir property data for CO_2 sequestration research (see Research Activities below).

Inventoried a core collection donated to MGRRE by the Michigan Department of Transportation (MDOT). These shallow bedrock cores obtained during highway and bridge construction add new data to our collections and are particularly useful to bedrock aquifer research.

Obtained cores from three wells drilled by Dr. Alan Kehew, Department of Geosciences, as part of his regional mapping work. These cores are invaluable sources of information on aggregates and the glacial aquifers.

Leveraging labor by twelve work-study students, we were able to secure exact footages for thirty-one pallets of core that had previously been identified only by core and box numbers. Students compared the core analyses numbers on the cores to records held at MGRRE (donated by industry) and to publicly available records to secure these footages. Those cores can now be used in analytical work using Petra, a state-of-the-art software system for reservoir analysis and mapping which will be helpful to companies exploring for prospective locations for oil and gas production as well as for mineral resources.

We have also re-boxed more than 30 pallets of cores because their cardboard boxes had been damaged by water and poor storage conditions prior to coming to MGRRE. Well identifications were checked as well as core footages before inputting that data in our core inventory.

Library of journal articles, books and theses
Our staff and students also inventoried four pallets of journal articles and books about engineering geology that were bequeathed to MGRRE by a long-time Michigan petroleum engineer. These references are available to our researchers and students and provide another portal into geological investigation and resource development.

We have begun to search out all geologically related graduate theses conducted in Michigan. We are obtaining digital copies that can be archived at the MGS/MGRRE, data files and can be used in future research. Many of these were previously available in paper form only and very few have been available to the public.

Historic maps
We are also indexing sets of historic hand-drawn subsurface geology maps donated to us by geologists who worked in the Michigan Basin for decades. Their interpretations of subsurface geology were based on years of experience. We obtained map cabinets to properly store them for future use in resource review and identification.

Well records
MGRRE continues to sort through and catalogue paper well records donated to us by private individuals and industry. These records become part of our permanent collection and are reflected on our data sets at http://wsh060.westhills.wmich.edu/MGRRE/data/

Industry visits to MGRRE to examine cores, cuttings and well records
In addition to several members of the Michigan oil and gas industry, MGRRE welcomed visits by four major national companies to examine and sample cores, cuttings, and well records to help evaluate prospective oil and gas production areas. The major formations involved include areas of active exploration and development in the Trenton Black River, Dundee, Salina A1 Carbonate, Antrim, and Collingwood Formations.

Additionally, MGRRE welcomed several visits by two large mineral companies who are pursuing the development of potash deposits. Dr. Harrison worked with these companies in sampling and analyzing cores. MGRRE is the only source of these cores and they are critical to providing a first-hand visual hand specimen core for examination and description as well as obtaining assay data essential to assessing the nature and character of a major resource. Dr. Harrison and MGRRE staff also answered many inquiries about these deposits, following press

releases about this potential $65-billion-dollar asset. Because the US imports most of its potash from other countries, farmers pay a very high price for their fertilizer. Corn and soybeans require a great deal of the product. Michigan farmers alone use 300,000 tons/year. A local Michigan source could cut transportation costs for Midwest farmers significantly.

These industry visits, the resources at MGRRE, and the expertise of our researchers and staff are essential to future economic development from natural resources in Michigan.

Databases

We have begun to create a dataset of our cores listing the formations represented. This is a time-consuming process involving review of state records, private well records donated to MGRRE through drillers' reports, historic scout tickets, mudlogs, and wireline logs. More than sixty thousand oil and gas wells plus about thirty thousand mineral wells have been drilled in Michigan and the accompanying records represent very large data sets. We hope to have this work completed by the end of 2014. MGRRE has also received and catalogued cuttings samples and associated drillers' logs from more than 2000 public water supply wells.

We have reformatted and updated our core analysis dataset representing porosity and permeability data for more than 2100 wells in 65 Michigan counties. For quality control purposes, these data have been crossed with Michigan's DEQ Part 615 database and known anomalies and other notes have been commented with the dataset. Updated features for our data include direct links to driller's logs and scanned well files hosted by Michigan Office of Oil, Gas and Minerals, MDEQ's new website "GeoWebFace". We have made our core analyses dataset accessible on our website at
http://wsh060.westhills.wmich.edu/MGRRE/data/CoreAnalyses.xls

We continue to update our core inventory and will proceed to reformat that as well to include direct links to well data through "GeoWebFace".

Up scaling server speed and capacity to accommodate large amounts of data

After formatting all data for use in subsurface data analysis software (HIS Petra, a proprietary software), we found our existing server could not quickly process the enormous amount of data we have acquired. So, we designed a new server that could rapidly process user needs. We doubled data access speed, increased RAM four fold, and decreased potential data failure rate from 5% to 0.09%. We developed guidelines by which these data could be quantified and described, metadata were checked for accuracy, and now these large volumes can be used with analytical and geospatial software programs by students and industry/government members accessing the information at MGS/MGRRE.

Research Activities and MGRRE Proposals

Sample and Data Preservation

Dr. William Harrison and MGRRE staff completed work on this year's grant from the US Geological Survey's National Geological and Geophysical Data Preservation Program (NGGDPP) to inventory several recently received large collections of cores, cuttings, and well records, to secure all metadata, and enter that information in the appropriate format at the NGGDPP website. Additionally, historic paper records (core analyses from 800 wells, mudlogs from 600 wells and production from 500 wells) converted to digital format. These data represent cores, cuttings, mudlogs, and production history from several thousand oil and gas wells drilled throughout the state of Michigan in every prospective formation. MGRRE staff supervised a large group of students whose labor and attention to detail allowed us to meet or exceed all proposed goals.

Data from these wells are essential to preserving our geological legacy, and to addressing sustainable resource development and environmental issues. Completing this project meets several goals of the National Geological and Geophysical Data Preservation Program and mirrors the State's long-term goals of inventorying all geological collections and converting paper to digital data. The Michigan Geological Survey, now a part of Western Michigan University, will use these data in several research programs, in student training, and will make them available and accessible to all stakeholders.

Geothermal Energy

Dr. William Harrison is in the third and final year of his research, gathering data from Michigan wells relative to subsurface temperatures to evaluate Michigan's potential for geothermal energy. He has gathered data on deeper wells and will now focus data from shallower wells. These data from all over Michigan will be integrated into the National Geothermal Data System (NGDS) http://www.geothermaldata.org/ . This project will help understand the geothermal potential in Michigan to an extent never possible before.

In Michigan, Dr. Harrison is looking for geothermal energy found in naturally occurring hot brines in deep rock formations. For the first two years of the project, he amassed data from all subsurface rocks in Michigan, but especially those deeper than 10,000 feet deep. Data was found in two types of well tests originally conducted by oil and gas companies when they drilled deep wells: Drill Stem Tests (DST's) and Wireline Logs ("logs"). In this final year, Dr. Harrison will be searching for data from shallower wells.

In addition to building this database of temperature observations from Michigan's deep and shallow wells, data sets for formation brine chemistry, bottom hole pressure data, and formation lithology and thickness data have been compiled. Lithologies for individual deeper formations were recorded based on the dominant lithology as reported in drillers' logs or interpreted from cuttings and wireline lithology logs. Detailed lithology for shallow bedrock and glacial deposits was developed from a set drill cuttings from over 2000 wells from public

water supply wells. These data give more accurate lithology and thickness than the typical water well drillers' log. These data can now be used to plan the installation of shallow wells for domestic or commercial heat pump systems that pump water or other fluids into the shallow subsurface to exchange heat energy.

A database of nearly 1000 existing shallow heat pump well installations has also been compiled.

CO2 Sequestration and Enhanced Oil Recovery

Since 2005, MGS faculty and staff members have been collecting data and samples on a statewide basis about Michigan's geological formations relevant to CO2 storage, containment, and potential for enhanced oil recovery (EOR). Much of this work was conducted as a member of a research consortium, the Midwest Regional Carbon Sequestration Partnership (MRCSP). The MRCSP is one of seven regional partnerships established by the U.S. Department of Energy's National Energy Technology Laboratory (DOE/NETL). We are working with Battelle Memorial Institute, the project lead organization for the Michigan Project, and with Core Energy, LLC, of Traverse City, the industry partner and a long-time MGRRE supporter.

Here at MGRRE, Dr. Barnes leads the research team and works with Drs. Harrison and Hampton and several graduate students. On-going goals for this research include:

- Accumulating data with which to construct maps and tables of physical properties
- Implementing internal data shares (intranet) to facilitate compilation of information into a digital atlas
- Conducting basic and applied research to characterize Michigan saline reservoirs for CO_2 storage potential volume, injectivity and containment
- Integrating any new data from wells drilled primarily by the oil and gas industry.
- Compiling data for geological and fluid flow models
- Formulating models, integrating data, and running the models
- Applying models to specific predictive uses of CO_2 storage and enhanced oil recovery

This year significant work was accomplished on study of geological controls on reservoir properties in the Sylvania Sandstone-Bois Blanc (Middle Devonian) interval in the Michigan Basin:

The team continued to compile field data from several states for screening potential oil and gas fields as candidates for enhanced recovery using CO_2. The first criterion for selection of fields to be evaluated was depth to the top of the reservoir. A depth of 2,600 feet or greater was selected so that CO_2 would be kept in the supercritical phase and likely be miscible in most reservoir oils. Additionally, only oil fields that have already produced at least 250,000 barrels of oil were considered for this evaluation.

Data was acquired from Michigan sources and from the Geological Surveys of Kentucky, Ohio, Pennsylvania, and West Virginia. Michigan data was derived from records at MGRRE and the

Michigan Office of Oil Gas and Minerals (formerly the MDEQ [Michigan Geological Survey]). Data for all other states was taken from the TORIS database for the Appalachian Basin.

- The number of fields evaluated during this project includes: 3 from Kentucky, 95 from Michigan, 19 from Ohio, 2 from Pennsylvania, and 17 from West Virginia.
- In addition to the 95 Michigan fields that have undergone some secondary or enhanced recovery, we have selected approximately 400 additional fields that have produced over 250,000 barrels of oil and may be candidates for enhanced recovery.
- Data collected includes: *Field name, Field location, Discovery date, Number of producing wells, Number of dry holes within field area, Active wells, Abandoned wells, Producing formation(s), Lithology, Producing area, Pay thickness, Secondary or enhanced recovery efforts, Cumulative Total oil production, Cumulative primary oil production, Cumulative Total gas production, Cumulative primary gas production, Cumulative water production, Cumulative secondary or enhanced oil production, Cumulative secondary or enhanced gas production, Original oil in place, Original gas in place, Oil recovery factor, Formation volume factor, Initial reservoir pressure, Current reservoir pressure, Reservoir temperature, Initial water saturation, Oil viscosity, Oil API gravity, Average reservoir porosity, Average reservoir permeability.*
- Average recoveries from fields that have undergone some secondary recovery treatment can be evaluated from the data provided for Michigan, Ohio and West Virginia. Because there is very limited available field data in Kentucky and Pennsylvania, no interpretations about average performance of secondary recovery in reservoirs was made.
- Average primary recovery from oil reservoirs is: Michigan – 36.2%, Ohio – 17.0% and West Virginia – 17.9%.
- Average secondary recovery from the same reservoirs is: Michigan – 13.8%, Ohio – 5.25% and West Virginia – 14.9%

Drs. Harrison and Barnes continued to compile data about production and reservoir performance of water flood, gas reinjection and natural gas storage projects that produced oil recovery beyond the primary phase of oil production in the Niagaran Reefs of the Michigan Basin. The performance of these fields may be a useful analog for CO2 enhanced oil recovery. They also continued to compile reservoir properties data that can be used to evaluate candidate fields for CO_2 EOR development. Dr. Barnes and graduate students conducted high-resolution sedimentologic and petrologic investigations to prepare a detailed sedimentary facies model for the Sylvania Sandstone in Midland County. Data were acquired from studying conventional cores from 4 brine extraction wells.

Additional research using subsurface well log data for the construction of regional sequence stratigraphic cross sections was done to address regional stratigraphic relationships in the Sylvania-Bois Blanc interval. This work more confidently established the regional facies relationships of these units and the spatial distribution of reservoir facies in the Michigan basin.

The results indicate significant prospects for CO_2 sequestration in dolomitic facies of the Sylvania sandstone. Sandstone portions of the formation were found to be somewhat less prospective, but are now recognized to be a less volumetrically significant component of the Sylvania ”Sandstone” in areas of the Michigan basin most suitable for geological sequestration activities.

Dr. Hampton continued to focus on conceptual geologic model formulation, deployment of modeling software, and general guidance and coordination.

One task of the Arches Province Simulation Project is to simulate a specific site and determine what limits are necessary to be observed on injection pressures to avoid breaching the confining Eau Claire formation or otherwise inducing failure. For this geomechanical simulation a location near Holland, Ottawa County, Michigan, was chosen. In the analysis, multiple model scenarios were created and studied. All of our recent models assume dual permeability of the formation. This allows the models to have permeability values for the formation and for any fractures rather than the formation alone. Each simulation covered 15 years, with CO_2 injected during the first ten.

Various supercritical CO_2 injection rates, ranging from 10,000 ft^3/day to 2,000,000 ft^3/day, were modeled. Injection well perforation depths and lengths were varied. Perforations were located just below the cap rock layer, just below the upper Mount Simon and also at the bottom of the middle Mount Simon layer. Several rock strength parameters were tested for sensitivity as well. Variable cap rock thicknesses were simulated. The default boundary conditions that were applied to all models constrained both the bottom and sides of the grid leaving only the top to move freely in space.

The first model is a 3D model created using Schlumberger’s Petrel using permeability and porosity values obtained from the wells in Ottawa County. A second model was created in 2D also using permeability and porosity values obtained from the wells in Ottawa County. The third and fourth models were homogenous (or “layer cake”) models with single permeability and porosity values for each of three layers: Eau Claire, Upper Mount Simon and Lower Mount Simon. These models were 2D and 3D. These latter model studies included sensitivity analysis of permeability values in the Eau Claire.

MGRRE Research Proposals

Geologic Carbon Sequestration and Enhanced Oil Recovery—Dr. Barnes submitted a proposal for $600,000 for FY 2013-2017 to provide continuing funding for Phase III- Large Scale CO2 Injection and Enhanced Oil Recovery Project. This project consists of field studies of selected oil and gas fields, detailed analyses of core from target fields, and reservoir characterization for study fields. Target fields are in the Silurian Niagaran reefs of Otsego County, Michigan. Funding is by Battelle Memorial through the Midwest Regional Carbon Sequestration Partnership, with support from the U.S. Department of Energy.

The proposal has received partial funding and full funding is pending.

Data Preservation—Dr. Harrison submitted a proposal to the United States Geological Survey (USGS) National Geological and Geophysical and Data Preservation Program (NGGDPP) for $32,500 for FY 2013-2014 to (1) inventory and preserve two recently acquired core collections from 355 wells and create relative metadata for those collections, and to (2) scan a collection of 6,000 historic hand-written or typed sets of oil and gas well record and to create a spreadsheet listing these data along with newly created metadata.

This project was supported by the Michigan DEQ and will expand known subsurface core and well data, facilitating not only additional resource exploration, but also several on-going research projects at the MGS/MGRRE and student education at WMU. It will also result in adding useful data to the National Catalog from the MGS/MGRRE.

This proposal was fully funded.

Utica Shale Hydrocarbon potential—Dr. Harrison submitted a proposal to the Research Partnership to Secure Energy for America (RPSEA) for $338,000 funding for FY 2013-2015 to evaluate geological and geochemical characteristics of the Utica Shale for potential hydrocarbon development, and to assess prospective reservoirs that may be similar to those occurring elsewhere in the neighboring Appalachian Basin. Combining existing and new data, and developing new analytical procedures; we will produce maps of Utica Shale structure, lithofacies, mineralogy, thickness, organic content and thermal maturity that will define the potential commercial reservoirs and their spatial distribution.

This proposal is still pending.

This work would be completed in partnership with oil and gas companies. Results of this integrated project would lead to reduced exploration risk and potentially new production and development from an unconventional reservoir play by providing operators with viable models for predicting and interpreting the organic content and mineralogical, including mechanical properties of the Utica Shale throughout the Michigan Basin. Development of knowledge relating to the thermal maturity throughout different portions of the Michigan Basin would also allow operators to more closely define areas of exploration that best suit their target strategy for hydrocarbon phase of either natural gas or liquids. By drilling fewer, more productive wells, environmental risks are reduced. These analytical procedures and mapping techniques are relatively low cost, yield data that are potentially very profitable, and can be used in other unconventional resource plays.

Potash Resources—Dr. Harrison submitted a proposal for $217,000 to the Michigan Department of Agriculture and Rural Development Strategic Growth Initiative to study and evaluate potash deposits. The proposal was not selected for funding.

Outreach to members of Industry, Higher Education, and Government
As the Michigan leader of the Petroleum Technology Transfer Council (PTTC), Dr. William Harrison and staff member Linda Harrison organized two workshops with a total attendance of 230 people. At the annual one-day workshop in March, MGRRE faculty members Harrison, Barnes and Voice were among the 13 presenters who discussed recent oil-field experiences and research. In October we presented a 3-day workshop in Traverse City "How to find bypassed pay in old wells using DST data including selecting tight oil zones to re-drill with horizontal wells."

Dr. Harrison presented a lecture on Potash Resources in Michigan to the American Institute of Professional Geologists (AIPG) in East Lansing. He also participated in a WebEx presentation by U.S. Geological Survey on the National Geological and Geophysical Data Preservation Program (NGGDPP) to discuss funding for data preservation and the upcoming RFP.

Dr. Barnes presented a geological overview of CO2 sequestration research at MGRRE to a Battelle CO2 Sequestration GeoTeam meeting in Traverse City.

MGRRE hosted the annual all-day visit by a Central Michigan University professor and members of his Sedimentation and Stratigraphy class. They examined, described and interpreted cores archived at MGRRE.

Mapping Activities - Dr. Alan Kehew

The following items refer to mapping projects including USGS STATEMAP, EDMAP, and Great Lakes Geologic Mapping Coalition (GLGMC).

STATEMAP projects completed in 2013 were the Climax and NE Albion quadrangles. Proposals were submitted for 2014 projects for Duck Lake, Olivet and Vulcan Quadrangles.

Through the Great Lakes Geologic Mapping Coalition (GLSGMC), the Marshall and NE Albion quadrangles were submitted in provisional form. The East Leroy, Ellis Corners, Lyons Lake, SW Albion, SE Albion quadrangles remain in progress.

EDMAP
A proposal was submitted for Pictured Rocks National Lakeshore

K-12 Outreach – Dr. Peter Voice

MGS has expanded the Outreach program from the interaction with students and teachers to include all stakeholders in Michigan having an interest in the natural resources associated with

water, oil, gas, minerals, etc. in the State. The interactions and person contacts with Michigan stakeholders has increased geographically and numerically in the last calendar year to include a larger area of the Lower Peninsula.

One form of Outreach is a direct method of providing information, which is in-person contact with individuals. To increase these interactions, we have also established relationships and/or partnerships with associations in the public and private sectors, to include such entities as Michigan Aggregate Association, Michigan Manufacturing Association, Michigan Oil and Gas Association, Kalamazoo Geological and Mineral Society, Michigan Department of Environmental Quality, Michigan Basin Geological Society, Cranbrook Institute of Science, Central Michigan University, Saudi Arabian Geological Survey, Michigan Mineralogical Society, Kalamazoo Air Zoo, Michigan Science Teachers Association, the Michigan Earth Science Teachers Association, and just networking. The word of mouth contact with MGS and the Outreach leader, Dr. Voice is also effective where a stakeholder has an interest in either acquiring or providing information related to the geology and natural resources of the State to others.

A secondary method of providing the information is by a web site and tracking the interest in the MGS and the information distribution on Michigan geology and our natural resources. This can be indirectly measured by the number of unique MGS Web Site contacts that has increased by 38% in 2013 for a total of 29210 over the unique IP contacts in 2012. This interest generally will lead to a phone call or email request for more information.

Responding to the interest in natural resources and information is both direct and indirect. The direct person contacts have increased dramatically in the last year. We had approximately 3500 person contacts in 2012 and are at nearly 8,000 for 2013, over two times more. This has been accomplished by having 22 school visits and 19 formal scheduled events. These interactions and sessions have been primarily limited by the limited funding and manpower available to support the need and therefore have been focused in the southern portion of the State at this time.

The methods of general information transmittals is through some formal educational and hands on training or practical modules that can assist in answering questions by providing an education or information format. Much of this is tailored for the schools and classrooms, but all of these modules have a direct relationship to Michigan geology. These include Michigan Geologic History, Hydrogeology, Shale Energy, Natural Hazards and Michigan Fossils. All programs have been tested and used as training for students and adults at both schools and scheduled events.

To meet and respond to the high level of interest, MGS must continually submit proposals for funding of the Outreach programs. Support both monetary and verbally for these programs is needed from all areas of Michigan, including the State offices.

Mineral Assessments – Dr. Joyashish Thakurta

Multiple meetings were held in the Upper Peninsula with mineral and academic stakeholders to introduce the Mineral Assessments Resource Center and to assess how MGS can integrate academic and research programs with Michigan Tech and industry in the region. The meetings were very beneficial and future academic programs have been outlined and will be structured to include MTU and WMU faculty and MTU facilities as components of the UP geology field camps for MTU and WMU students are increasingly merged. The MGS relationships were also developed with industry and a geochemical assessment study of core samples was initiated for a research project on the Back Forty project north of Menominee.

An MEDC meeting was also attended by MGS staff in Lansing to gather information relevant to the mineral industry and assist in determining how MGS can support the exploration and development efforts in Michigan.

MGS website and Geostore - Sita Karki

The MGS website has been updated and is continually reviewed and updated. The website presents the nine resource center functions and the respective leaders. The website, “MGS Resource Centers” page allows users to find resources and services that peak their interest and can contact the person directly involved. The “Mapping” page provides information about available MGS map products and services and the MGS store has historical documents and maps available for purchase. The mapping products from our research activities are also made available through this store. There currently are surficial geology maps available for 43 USGS 7.5 minute quadrangles and three county summaries. The Hydrogeologic Atlas of Michigan is also available in the store. Informative imagery, photos and videos can be found in the "Multimedia" page and are being updated on a regular basis.

Information for the general public, a parent, teacher, or student who just wants to learn more about geology and related topics, can be found on the “Outreach and Education” page. Several teaching resources are available in “Teaching Resources” section. "Data" section provides information links from Michigan.gov and the US Geological Survey (USGS).

For researchers, or those who have some prior knowledge of the subject, the "Publications" and “Research” pages is the search location. Posted here are current and past research undertaken by faculty and staff published by the Michigan Geological Survey. The website is linked to all the oil well information documented at MGRRE, where there is a compilation of listings of Michigan cores, core analyses, drill cuttings, mudlogs, thin sections, and oil and gas data kept at MGRRE.

Proposals submitted and status

Research Proposals

Geologic Carbon Sequestration and Enhanced Oil Recovery—Dr. Dave Barnes, Partially funded, as noted above.
Data Preservation - Dr. Harrison, fully funded, as noted above.
Utica Shale Hydrocarbon potential - Dr. Harrison, still pending, as noted above.
Potash Resources - Dr. Harrison, unsuccessful, as noted above.

STATEMAP – Dr. Alan Kehew, Proposals were submitted for 2014 projects for Duck Lake, Olivet and Vulcan Quadrangles.

EDMAP – Dr. Alan Kehew, A proposal was submitted for Pictured Rocks National Lakeshore

MGRRE Education Portal - Dr. Heather Petcovic and Dr. Peter Voice, Engaging Students in Online Authentic Geologic Investigations. Submitted to the National Science Foundation Discovery Research K-12 Fund. Still pending.

Unsolicited Proposals to support the natural resources of Michigan

Michigan Geological Repositories - Dr. Harrison and MGRRE staff- This proposal was prepared to present the case to establish on-going funding for geological repositories in both the Lower and Upper Peninsula to preserve Michigan's geological samples and make them accessible to industry and government for the benefit of all its citizens. This proposal is being submitted to multiple entities in Michigan.

This initiative will positively impact Michigan's economy and quality of life for generations to come through careful management and responsible development of Michigan's geologic natural resources. In addition to the increasing use of geological cores and samples in exploration and development, these unique resources will also be used in addressing environmental health and groundwater supply issues. The need to map, monitor and manage our groundwater resources in an era of climate change may well become the greatest need of this century. Because 98% of the world's unfrozen freshwater is groundwater, the cores and geological data are critically important resources to industry, agriculture, and all our communities. Despite its importance, we know very little about Michigan's groundwater—how it flows, how quickly it is replenished, what is its quality and how has that changed over time. Using geological cores and samples and well records at the MGS/MGRRE, we can start to perform a comprehensive study of this crucial Michigan resource.

Proposal for an Economic Geology program – Dr. Joyashish Thakurta - The primary objective of the Economic Geology program of the Michigan Geological Survey is to evaluate the economic potential of the state of Michigan in terms of its mineral and energy resources and to partner with universities, private and government agencies to develop these resources. The program will lay down the foundations to re-invent the economic potential of the state of Michigan in terms of natural resources and that will most certainly lead to economic prosperity. In partnership with institutions of higher education and research, the program also aims to develop an active work- group of individuals dedicated to the cause of mineral exploration using environmentally friendly methods to evaluate the natural resources of the area. The program will emphasize through public outreach and in the education of the residents, with a focus on the mineral potential areas made up of rural residents of the state on the quantified scientific aspects of mining and development and maintaining the integrity of all of our natural resources in the area.

As an initial step in that direction, the program will highlight the occurrences of metallic sulfide mineral ore deposits in the Upper Peninsula of Michigan. The Upper Peninsula has been historically known to be a mining district for economic mineral deposits of iron, copper and nickel for over 150 years. Moreover, the mid-continent rift system in the upper mid-western United States is well known for its association with economic mineral deposits. In the recent times, the new discovery of the Eagle deposit, near Marquette by Rio Tinto Exploration, now Lundin Mining, has rejuvenated the economic potential of the area, and several new targets for sulfide mineralization of precious and base metals have been identified by private companies for prospecting and exploration. The Back Forty deposit (Aquila Resources) in Menominee County and the Copperwood deposit (Orvana) in Gogebic County have been studied and delineated by mining companies. The Michigan Geological survey aims to perform field and lab based research on these zones of prospective mineralization and assist in the discovery of new locations as targets for future exploration.

Airborne Geophysical Surveys – Dr. William Sauck - The MGS subscribes to the view that the geologic resources of a State are poorly known if the known geologic knowledge is limited to accessible outcrops and drill-hole information. With modern geophysical technology, the physical properties of the subsurface can readily be mapped to depths of more than 500 meters (1600 feet) in the case of electrical properties, and to several kilometers for the case of magnetic and density properties. Michigan is far behind adjacent states in that the current magnetic map is mostly low resolution and is a composite of more than 25 legacy airborne surveys dating between 1945 and 1999. These surveys had very different line spacings, flight altitudes, and data quality. Another important data set is the gravity map. The current gravity map is from land stations at nominal 3 mile spacing or greater, and dates from 1963, with small areas covered by more recent denser sampling. Modern technology allows for mapping of gravity gradients from an aircraft. There is no regional electrical conductivity (electromagnetic induction (E-M)) mapping, nor is there any systematic mapping of natural radioactivity. Both of these can also be done rapidly from aircraft.

To be able to make rational natural resource decisions regarding commercial and residential zoning and development, development of extraction industries (metallic minerals, non-metallic minerals, aggregates, and water), and the development of waste disposal sites, we must know far more about the subsurface of Michigan. This is a primary mission of the Michigan Geological Survey, and to this end we have embarked on preparing proposals to conduct these multi-method airborne surveys.

Evidence for the return on investment (ROI) of conducting such surveys in documented by the State of Minnesota Geology Survey contracting for and completing a detailed airborne magnetics survey more than 20 years ago. As a result of this State funded effort, multiple mineral deposits have been discovered and one, the Tamarac sulfide is on a path to see development and production in the next few years. Airborne geophysical surveys can be a compliment to surface mapping, water resource assessments and mineral prospecting in Michigan as well.

Dr. William Sauck has prepared an outline and received a contracting proposal, to assess the geology of the Upper Peninsula through a comprehensive airborne geophysical survey using multiple simultaneous airborne methods (Magnetic, Gravity, Electromagnetic, Radiometric, and LIDAR methods) which could be completed as a single survey or done in several annual phases. This would be contracted by the State and/or with stakeholders to be available for all potential companies to review and provide insights to the mineral potential of this geographic area, a marketing assessment.

Similarly, the same combination of airborne surveys could be applied to resource mapping in the lower peninsula of Michigan. Water resource assessment utilizing airborne geophysics was proposed for conducting a pilot airborne survey at the County scale to assist in the assessment of water resources in the State. A price quote for a 24 mile x 24 mile area was received. This would be done in an area of high demand for water resource development to determine the most effective airborne geophysical tools that could be used to evaluate the water potential, aggregate resources, and the deeper geologic structures in this and other areas of Michigan.

Geologic Mapping for resource assessments – Dr. Alan Kehew - An understanding of the near-surface geological materials is essential for the overwhelming majority of projects aimed at developing the State's resources, and enhancing its economic viability and prosperity. Examples of such projects and issues that require knowledge of surficial materials include the delineation of groundwater aquifers, the protection and management of groundwater resources, and the occurrence of non-metallic mineral resources such as sand and gravel aggregates, clay, limestone, gypsum, potash, and salt. Every Midwestern state, with the exception of Michigan, has had an active state-funded program to investigate its surficial materials and resources for decades. In Michigan, because of recurring funding issues and priorities, the Office of Oil, Gas and Minerals in the DEQ is limited to regulation of the oil and gas and mining industries. Because of its focus on regulatory activities, the OOGM had been unable to develop a comprehensive program for characterizing and mapping the State surficial

deposits and mineral resources, a situation that is hampering development in the State, and was leading to losses in revenues and investment opportunities until October 2011, when the MGS was transferred to Western Michigan University Geosciences.

The Re-invented Michigan Geological Survey will help to remedy this deficiency through the established Resource Centers. One of the basic functions of this center will be to develop a strategic program to map the surface geology of the state, particularly areas of high use and importance. There are several federal programs that fund this kind of work with matching funds from the investigator (State) and these include STATEMAP, and the Midwest Geologic Mapping Coalition. STATEMAP, a national program administered through the U.S. Geological Survey, provides a small amount of matching funds money to MGS to conduct this kind of work, however MGS is only matching funds with WMU salaries. If additional monies were provided by a State contribution, the mapping funds could be increased up to $300,000 in total annual funding.

The Midwest Geologic Mapping Coalition is composed of 8 states around the Great Lakes. It currently has a budget of approximately $750,000 annually for all 8 states plus the work of the US Geological Survey in the region. MGS receives approximately $70,000 per year or less for this effort in the Great Lakes Coalition, also requiring matching funds, which are WMU funded salaries only.

The Great Lakes emphasis reflects the fact that approximately 20% of the population of the U.S. resides around the Great Lakes and a huge part of our national economy is based in this region, which also contains the greatest surface freshwater resources in the world in a populated area. Future development in this water-rich area will accelerate as water resources in drier areas reach their limit and incremental climate change begins to negatively affect the human population in dry areas. Development will gravitate to areas that have the best knowledge and databases describing the surficial materials and groundwater resources. The mapping center will conduct studies to augment and accelerate existing federal programs (e.g., STATEMAP and the Midwest Geologic Mapping Coalition) to map the surface geology in Michigan's critical groundwater areas and will support and promote economic growth and development, that includes agriculture as well as industrial development. The development and growth will be predicated on the knowledge of the geological resources in the region and be based on sound plans to protect these resources for future generations. With this economic growth will come jobs that will restore Michigan to its position as a leader in business, manufacturing and agriculture.

Research involving the surficial geology of Michigan will complement the ongoing research in the Michigan Basin and its energy resources that is being conducted at the Michigan Geological Repository for Research and Education (MGRRE), which is also a Resource Center in the Michigan Geological Survey. MGRRE will partner with this Resource Mapping Center in projects designed to assess the potential for development of mineral resources such as potash,

that occur below the shallow subsurface sediments and glacial material and water resource zones that are the primary focus of this proposal.

One specific impetus of this geologic mapping effort is that Part 327, Great Lakes Preservation, of the Natural Resources and Environmental Protection Act requires the State of Michigan to develop and use a water withdrawal assessment tool (WWAT) that is dependent on the availability of defensible scientific information on groundwater, aquifer characteristics, surface water flows and the net gain or loss of water to the Great Lakes.. Michigan currently does not have adequate specific information on groundwater and aquifer characteristics to effectively utilize the WWAT tool and most important, there are those areas currently having groundwater withdrawal values that could impact the Great Lakes or current or future water users, an immediate problem. The geologic tool, 3-dimensional geologic mapping of the surface deposits, particularly in the problem areas of thick glacial deposits and a high priority of use, is necessary to complement the WWAT tool in those critical areas.

An Atlas of Geo-Hazards and Potential Landslide problems and areas in Michigan - Dr. Ronald Chase has proposed an atlas for assessing future land development in Michigan. The following is the rationale for such a document.

When a building project is planned, or an existing building is selected for purchase, four considerations come to the forefront: 1) finding an available and useful location; 2) establishing the financing to make the purchase and maintain the payments; 3) establishing reliable access; and 4) making sure the property exists on stable ground. Items 1 – 3 are dictated by business decisions. If considered at all, item 4 requires scientific expertise that the general public rarely consults, or places in proper perspective if it is considered. Guidelines for business decisions are universal and part of the training of any aspiring executive. The subject of the physical stability of land is contained in the subject of Geotechnical Engineering, which is not a part of a typical business curriculum.

In order to avoid bad decisions regarding property ownership and land use planning, a mechanism is needed to guide decisions regarding such planning to avoid future damage to real estate, structures, and lives. Any business venture that chooses to explore Michigan as a home must be able to systematically assess the stability aspects of the land upon which they wish to settle. Certainly a geotechnical engineer can be hired to assess land safety. However, the business executives or government planners must make decisions regarding where they want this land to be located and how expensive their financial commitments can be before the geotechnical engineer is hired.

To guide initial decisions, a guideline to regional stability of the land is needed. No such statewide guideline currently exists in Michigan. Not only can this map serve as a starting point for land-use discussions, it can serve to demonstrate to those business location decision makers that the land of their choice is stable over large areas and worthy of their investment.

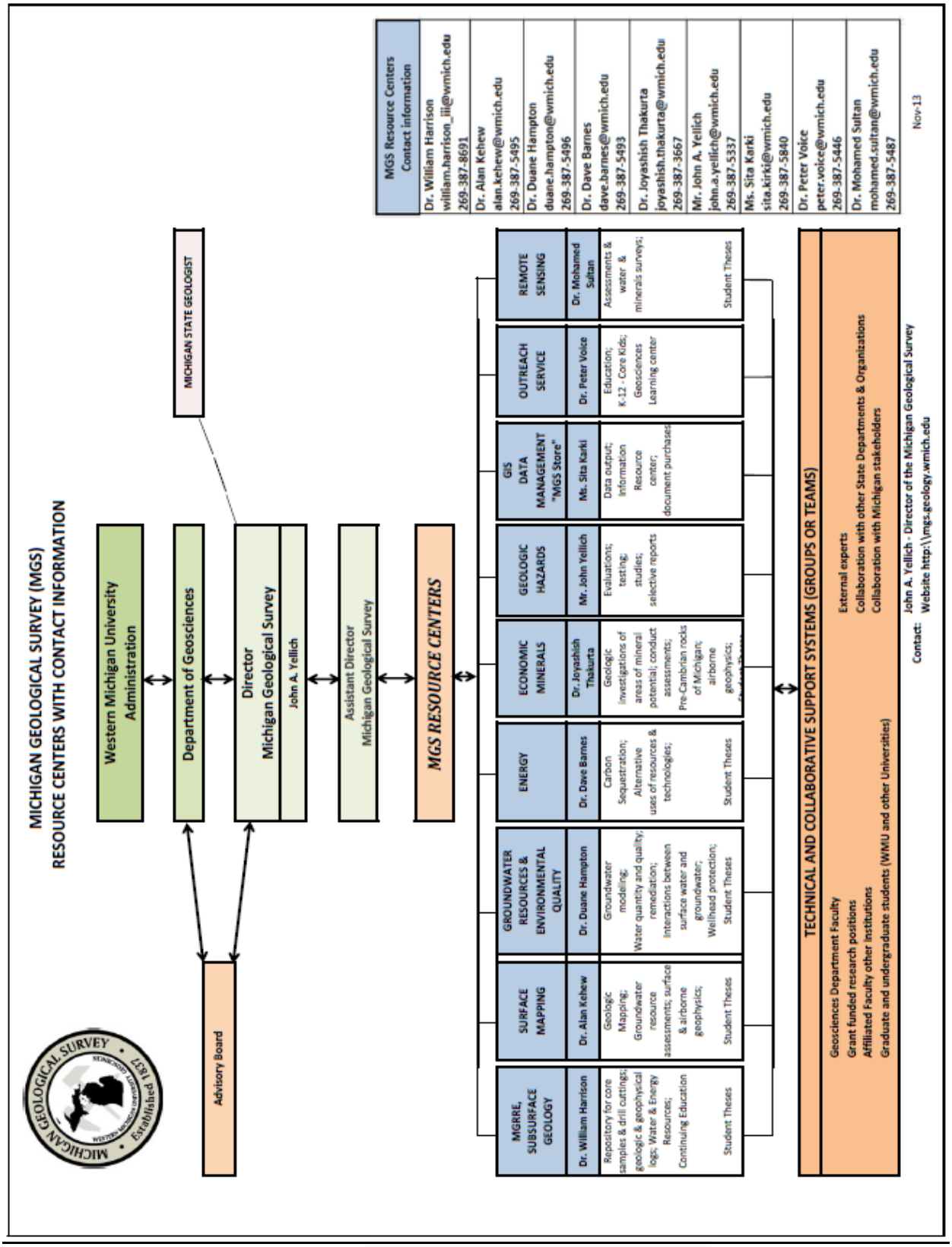
This proposal would apply to the expansion of the I-94 corridor, a critical mandate to expand development in Michigan.

Respectively Submitted,

John A. Yellich
Director

Attachments
Appendix 1, Resource Centers
Appendix 2, MGS Advisory Board

Appendix 1, Resource Centers



Appendix 2,. MGS Advisory Council

Michgan Geological Survey, Advisory Council

	NAME	AFFILIATION, PROFESSIONAL INTEREST AND (OTHER)	PRIMARY PHONE CONTACT	EMAIL	ADDRESS
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3	Mohamed Sultan	Department Chair, Geosciences Department, Western Michigan University Environmental Sciences & Remote Sensing	269-387-5451	mohamed.sultan@wmich.edu	1187 Rood Hall 1903 West Michigan Ave Kalamazoo, MI 49008-5421
4	William Harrison	MGRRE, Director of the MGS - MGRRE core repository at WMU, Emeritus Professor, WMU Geosciences Department	269-387-8691	william.harrisonIII@wmich.edu	1187 Rood Hall 1903 West Michigan Ave Kalamazoo, MI 49008-5421
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