

KENTUCKY RESEARCH CONSORTIUM for ENERGY and ENVIRONMENT



PADUCAH GASEOUS DIFFUSION PLANT A CHALLENGE IN PROGRESS

The U.S. Department of Energy's (DOE) Paducah Gaseous Diffusion Plant (PGDP), located in far Western Kentucky, was the last operating government-owned [uranium enrichment](#) facility in the country. Plant enrichment operations began in the early 1950s as the initial uranium enrichment step for Cold-War weapons development and a growing nuclear power industry.

The now-antiquated gaseous diffusion process was used to produce low-enriched uranium at the PGDP and required extensive water, power, and cooling infrastructure. Site process operations utilized up to 32 million gallons of water per day and reportedly consumed as much electricity as the cities of St. Louis or New York City. The byproduct of the enrichment process, depleted uranium feedstock, is stored at the PGDP for re-enrichment, recycling or disposal and comprises the largest stockpile of mined uranium in the world.

PGDP operations, maintenance, and process upgrades generated waste materials disposed in site landfills and burial grounds as well as waste fluids released to site waste & water systems, treatment lagoons and surface waterways. Leaching of disposed materials contaminated site soil and groundwater resulting in the largest documented trichloroethene (TCE) and technetium-99 groundwater plumes in the DOE complex among the largest TCE plume systems in the world.

The number of source areas contributing to soil, surface water and groundwater contamination

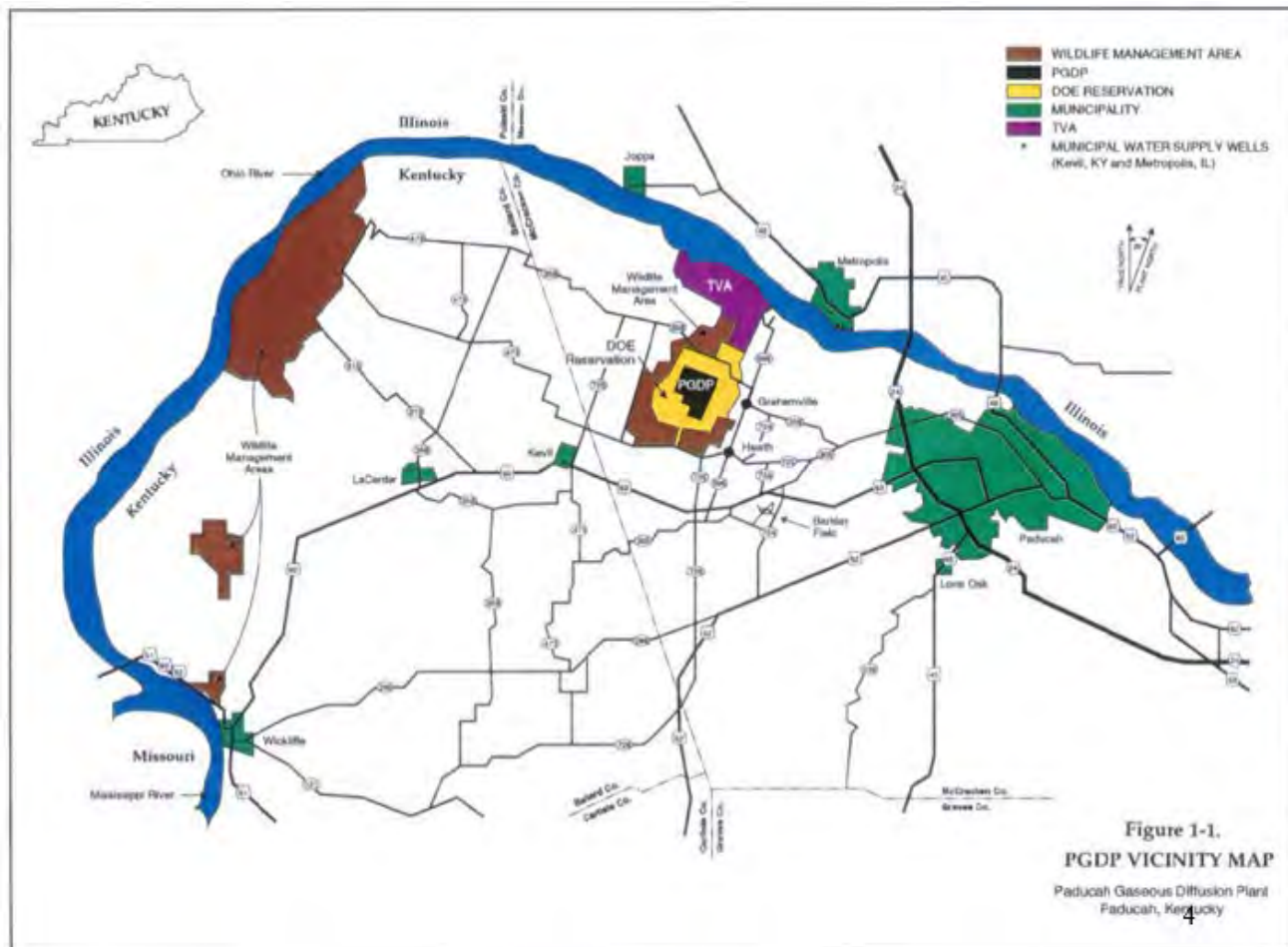
along with the depth, contaminants and site groundwater geochemistry of the plumes pose world-class technical and regulatory challenges for compliance, oversight and cleanup.

During 6 decades of enrichment operations, the PGDP contributed billions of dollars to the local economy through employment and local business. During the 1950s, 29,000 construction workers and tradesmen were employed in the construction of the PGDP and two nearby power plants required to supply electricity for PGDP operations. During enrichment operations, PGDP employed an average of 1,700 skilled workers and scientists to operate the enrichment process and maintain plant infrastructure.

When industrial enrichment operations ceased in May 2014, the PGDP continued to employ more than 1,400 skilled workers and scientists to address the complex tasks of de-activating plant facilities, implementing plant decontamination and decommissioning, and continuing environmental restoration activities.



Rotating Picture Array TBD



The PGDP uranium enrichment facility (black) is located on a U.S. Department of Energy Reservation (Yellow) approximately 3 miles south of the Ohio River and 13 miles west of Paducah, Kentucky. The PGDP and DOE Reservation are surrounded by the West Kentucky Wildlife Management Area, rural farm and residential properties and the Tennessee Valley Authority (TVA) Shawnee Steam Plant.

KRCEE

The Kentucky Research Consortium for Energy and Environment (KRCEE) was created in 2003 through the efforts of Senator Mitch McConnell and the Kentucky Congressional Delegation to offer innovative & technically sound solutions to problems facing the environmental restoration and continued economic use of the PGDP and its surrounding areas ([About KRCEE](#)). KRCEE is administered by the University of Kentucky Center for Applied Energy Research (CAER) and managed by professional staff and faculty at the University of Kentucky.

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ECOLOGICAL SCIENCE

BACKGROUND

Did releases from historical industrial operations impact local ecosystems, flora and fauna in the vicinity of the PGDP? What has been studied? What hasn't been studied? Has ecological monitoring been conducted on the appropriate terrestrial and aquatic populations in the watersheds and related habitats of the PGDP industrial site, reservation, and West Kentucky Wildlife Management Area? What species might be monitored as indicators of ecological health and impacts for specific trophic groups within the vicinity of the PGDP impacts?

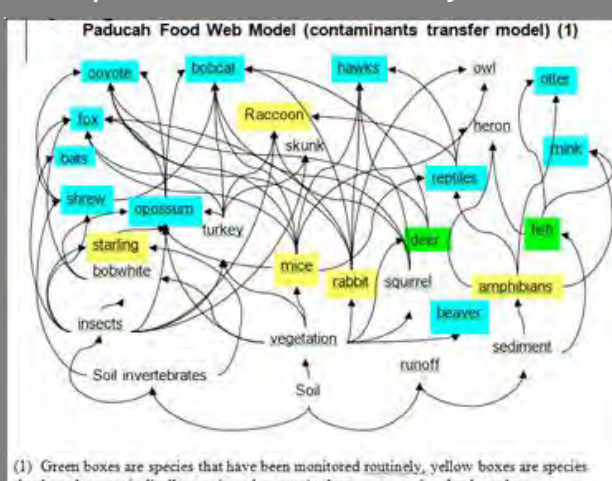
ECOLOGICAL PROJECTS 1

KRCEE's initial PGDP ecological science project was implemented to compile ecological studies, data, and reports into an accessible repository. Once historical studies were compiled, a team of subject

matter experts reviewed the status of PGDP ecological studies to develop recommendations for future ecological monitoring.

The development of trophic web/contaminant transfer models and trophic position models for species found in the habitats surrounding PGDP was a key component of project work.

A summary of published ecological studies, trophic web and trophic position models along with future monitoring recommendations are provided in the project report.



(1) Green boxes are species that have been monitored routinely, yellow boxes are species that have been periodically monitored, turquoise boxes are species that have been opportunistically monitored.

Food Web/Contaminant Transfer Model

Project Team

- Dr. Richard S. Halbrook, Emeritus, Southern Illinois University Carbondale (PI)
- Dr. Howard Whiteman, Murray State University, Biological Sciences
- Dr. Steve Alexander, U.S. Department of Fish and Wildlife, Cookeville, TN
- Lenn Roberts, KY Environmental Protection Cabinet
- Dr. John Volpe, KRCEE
- Steve Hampson, KRCEE

Project Documents

Report	Halbrook, R., Whiteman, H.H., Roberts, L., Ecological Monitoring at the Paducah Gaseous Diffusion Plant: Historical Evaluation and Guidelines for Future Monitoring, UK/KRCEE doc #19.1, May 2007.
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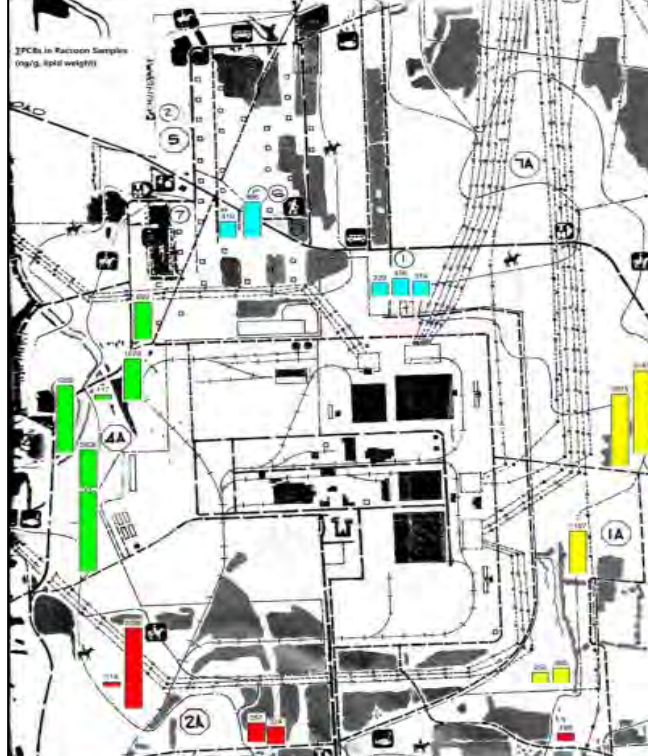
ECOLOGICAL PROJECTS 2

A field study of polychlorinated biphenyls (PCBs) in PGDP & vicinity raccoon populations was completed. The follow-on study was based on indicator species monitoring recommendations in the report

"Ecological Monitoring at the Paducah Gaseous Diffusion Plant: Historical Evaluation and Guidelines for Future Monitoring" (above Ecological Projects 1).

The study was accompanied by two summary evaluations: 1) A compilation of PCB distribution (maps) in soil, sediment, surface water and groundwater; and 2) A Summary of University of Kentucky PCB/Metals Data Collection Efforts at the Paducah Gaseous Diffusion Plant, 1997-2007.

The report "Summary of University of Kentucky PCB/Metals Data Collection Efforts at PGDP" provides an overview of extensive soil, surface water and sediment monitoring efforts conducted by Dr. Wes Birge and D.J. Price of the UK Department of Biological Sciences under the auspices of the Kentucky Agreement in Principle Program and Kentucky Department of Environmental Protection.



Raccoon sampling locations in the vicinity of the PGDP (colored bars indicate ng/g total PCB's lipid weight)

Project Team

- Dr. Richard Halbrook, Emeritus, Southern Illinois University (PI)
- Dr. Lindell Ormsbee, PE, UK-Civil Engineering, Director Ky. Water Resources Research Institute, Director Superfund Basic Research Program Translation Core, Director Ky. Research Consortium for Energy & Environment
- Steve Hampson, KRCEE

Project Documents

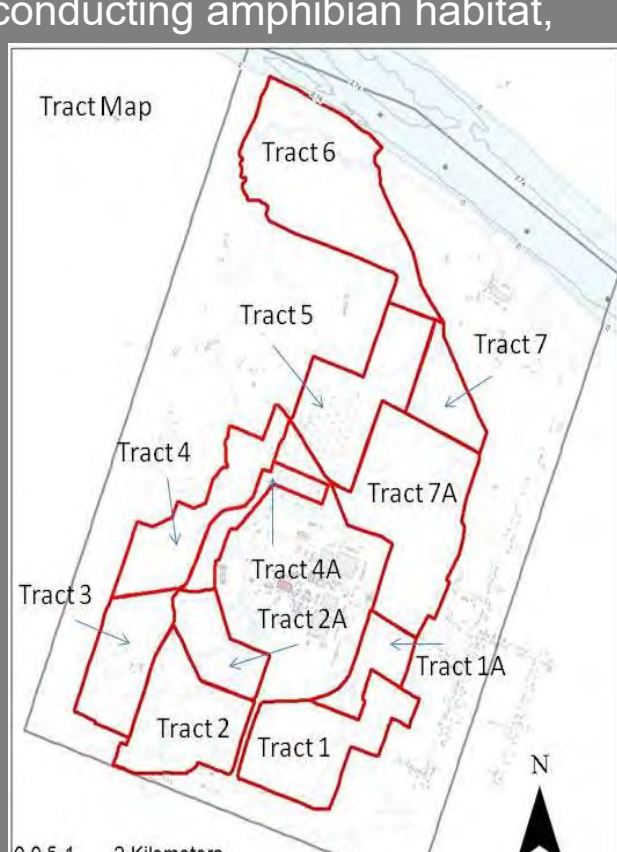
Report	Halbrook, R., Preliminary Study of PCBs in Raccoons Living on or near the Paducah Gaseous Diffusion Plant, Kentucky, UK/KRCEE Doc#. P19.5 2015, January 2016.
Report	Summary of University of Kentucky PCB/Metals Data Collection Efforts at the Paducah Gaseous Diffusion Plant 1997-2007.
Report	Polychlorinated Biphenyl - Arochlor Monitoring in Paducah Gaseous Diffusion Plant Surface Soil, Sediment, Surface Water, Groundwater 1988 - 2006 (Data Summary Figures)
Link	UK Biology PGDP Monitoring Reports 1987-2008 (58 Links)

ECOLOGICAL PROJECTS 3

University of Kentucky and West Kentucky Wildlife Management Area (WKWMA) researchers are actively conducting amphibian habitat,

distribution, and population abundance studies in natural and artificial wetlands that occupy watersheds surrounding the PGDP. An initial characterization of PGDP & vicinity wetland habitats relative to amphibians was completed in 2015 (Price, 2015).

As part of ongoing field research, University and WKWMA ecologists mentor Marshall County (Kentucky) high school students during "hands-on" data collection field trips to the WKWMA. Data collected during the annual field trips is incorporated into published, peer-reviewed species distribution and diversity journal articles published by the UK College of Agriculture – Department of Forestry. Two recent articles based upon data collected in the vicinity of the PGDP and WKWMA were published in peer-reviewed journals: (Drayer, A.N. et.al., & Davis, A.G., et.al.)



Tracts evaluated for the evaluation of amphibian wetlands

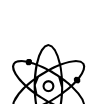
Project Team

- Dr. Steve Price, Associate Professor, Department of Forestry and Natural Resources, College of Agriculture, University of Kentucky (Principal Investigator)
- Andrea Drayer, Senior Researcher, Department of Forestry and Natural Resources, College of Agriculture, University of Kentucky
- Tim Kreher, Manager, West Kentucky Wildlife Management Area
- Tina Marshall, Environmental Science Instructor, Marshall County High School
- Steve Hampson, KRCEE

Project Documents

Report	Price, S.J., Kreher, T., Amphibian Habitat Assessment at the Paducah Gaseous Diffusion Plant and the West Kentucky State Wildlife Management Area. UK/KRCEE Doc#. P27.16. 2015.
Journal Article	Drayer, A.N., Guzy, R.C., and Price, S.J. Created wetlands managed for hydroperiod provide habitat for amphibians in Western Kentucky, USA. Wetlands Ecology and Management, Volume 28, pp. 543–558 (2020).
Journal Article	Davis, A.G., Leuenberger, W., Drayer, A.N., and Price, S.J. Activity, Movements, and Microenvironment Associations of Siren intermedia (Lesser Siren) in a Western Kentucky Wetland Complex. Northeastern Naturalist, Volume 28(2): 114-126, 2021.

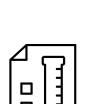
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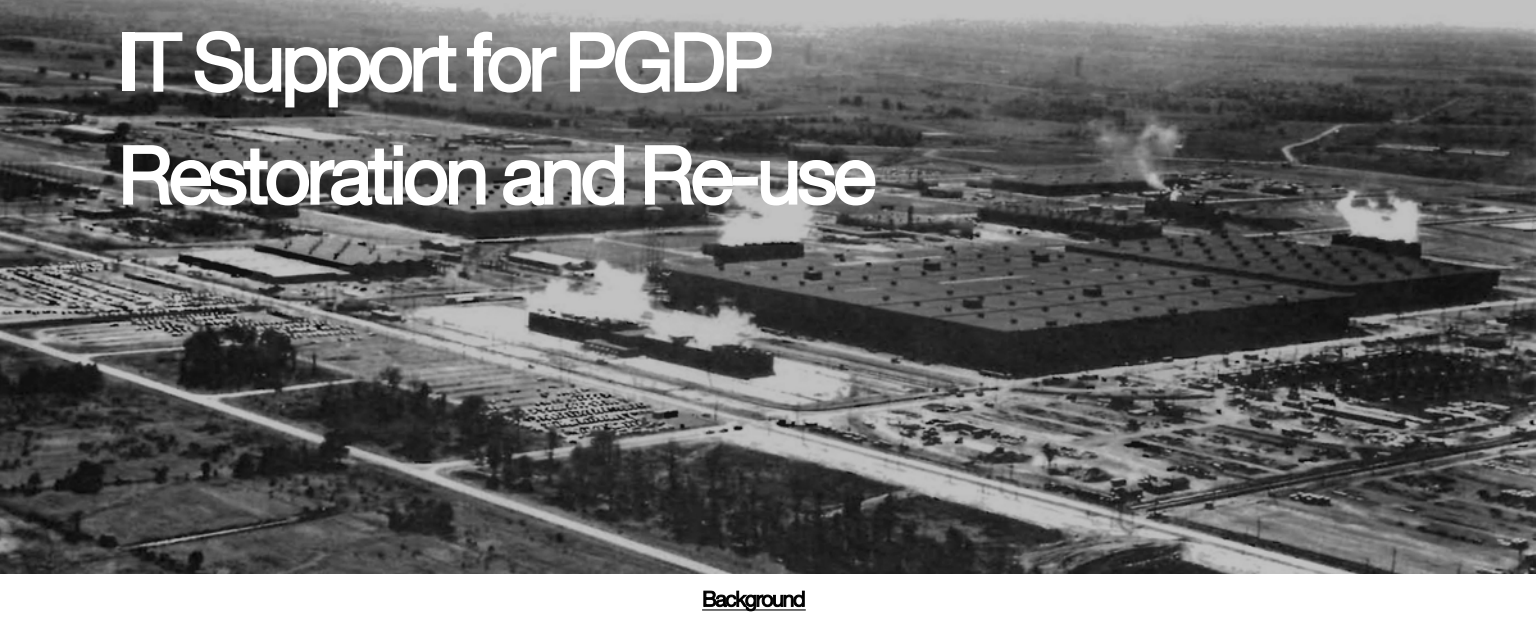
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IT Support for PGDP Restoration and Re-use

Background

Environmental activities at large industrial facilities, such as the PGDP, generate vast amounts of physical, chemical, spatial, and temporal data from operations, environmental management, health and safety actions, and regulatory compliance. Once collected data must be housed, managed, related, retrieved and distributed in a variety of formats which serve the needs of end-users practicing many disciplines.

By 2005 the PGDP had accumulated over 2.1 million environmental monitoring data records, millions of attributes related to those records, and an immense collection of related physical and geotechnical data kept as paper records. KRCEE and the DOE Portsmouth-Paducah Project Office evaluated existing web-based data storage and retrieval

systems that linked environmental data to GIS and geospatial data. A decision was made to adopt and enhance an existing "Data Warehouse –GIS" System developed for managers and contractors internal use at the Portsmouth Gaseous Diffusion Plant.

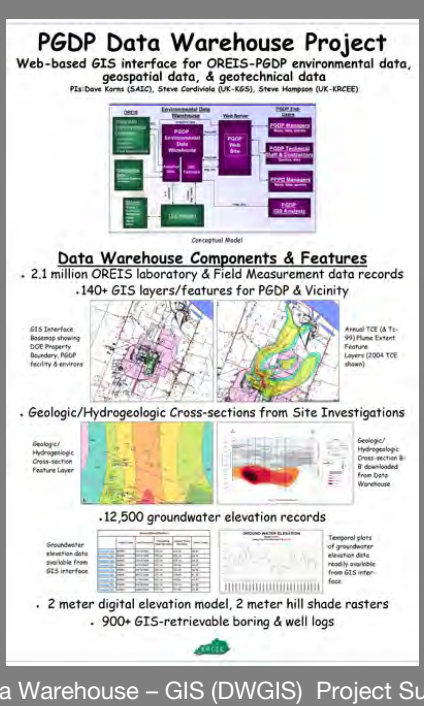
DATA ACCESS, ASSESSMENT, AND VISUALIZATION

The Paducah Data Warehouse and GIS System (DWGIS) Project began in 2005. Technical, regulatory and public uses of PGDP spatial and environmental data were identified through collaborative efforts of KRCEE, Scientific Applications International Corporation (SAIC), DOE-PPO & PGDP staff, DOE-contractor personnel and the Kentucky Geological Survey.

During DWGIS development, user's data needs were translated into basic tools and system capabilities that allowed web-based geospatial data access and database access to PGDP environmental data. Recommendations for DWGIS tools and architecture were developed and delivered to DOE-PPPO as part of DWGIS Project Team development activities.

In 2006, KRCEE submitted the beta-tested PGDP-DWGIS and the original DWGIS User's Manual to the DOE-PPPO.

In 2011, DOE and its site contractors, LATA KY and SWIFT & STALEY, released the Paducah Environmental Geographic Analytical Spatial Information System (PEGASIS) and provided internal and public access to the former Paducah DWGIS. PEGASIS can be accessed at <https://pegasis.nrc.gov/>.



Data Warehouse – GIS (DWGIS) Project Summary Poster Kentucky Water Resources Research Institute Annual Symposium, (March 2007)

Project Team

- David Korns (Principal Investigator), Scientific Applications International Corporation
- David Taylor, U.S. Department of Energy, Portsmouth Paducah Project Office
- Dr. John Volpe, KRCEE
- Dr. Rich Bonczek, U.S. Department of Energy, Portsmouth Paducah Project Office
- Tracey Bugg, Scientific Applications International Corporation
- Bruce Phillips, Navarro Research and Engineering
- Steve Hampson, KRCEE

Project Documents

Link	Paducah Environmental Geographic Analytical Spatial Information System (PEGASIS)
Report	Paducah DWGIS White Paper
Presentation	Korns, D., DWGIS Pre-Development Status Presentation, May 2006
Report	DWGIS ARCHITECTURE RECOMMENDATIONS PROPOSAL
Professional Meeting Poster	Kentucky Water Resources Research Institute Annual Symposium, (March 2007) Data Warehouse – GIS (DWGIS) Project Summary Poster.
Project Document	Original DWGIS Users Manual (2006)
Professional Meeting Presentation	Korns, D.E., Cordiviola, S., Hampson, S., Ormsbee, L., Volpe, J.A., & Phillips, B., E., Using an Environmental Data Warehouse to Integrate Analytical Data, GIS, and the Web, Geological Society of America, Southeastern Section 55th Annual Meeting, March 2006. (Abstract)
Professional Meeting Presentation	Korns, D.E., Cordiviola, S., Hampson, S., Ormsbee, L., Volpe, J.A., & Phillips, B., E., Using an Environmental Data Warehouse to Integrate Analytical Data, GIS, and the Web, Geological Society of America, Southeastern Section 55th Annual Meeting, March 2006

DEVELOPMENT AND MAINTENANCE OF THE KRCEE WEBSITE

KRCEE, KWRI and CAER staff developed and have been maintaining a KRCEE website since 2004. The current KRCEE website is the 5th website update and 3rd major website redesign. This project will be updated when the contents of this document are finalized and posted to the world wide web.

SUPPORT FOR PADUCAH DWGIS

From calendar years 2011 to 2021, KRCEE staff and contractors routinely participated in Paducah DWGIS Workgroup activities. The workgroup meets monthly to address database technical, development and upgrade issues related to the PEGASIS deployment.

During calendar years 2018 - 2020, KRCEE and the Kentucky Radiation Environmental Monitoring Laboratory (REML) developed and delivered a comprehensive SQL query. The Query automates assignment of Detect/Non-Detect (DETECT column) and radiation data quality assessment (DATA_ASSESSMENT column) attributes to 400,000 radioactive material analytical data Re-cords

accessible in the PEGASIS environmental database.

As part of ongoing participation in the PGDP 'Data Warehouse Project', comprehensive SQL queries are currently being developed automate the assignment of DETECT attributes (Detect, Non-detect, and Rejected) for VOA, SVOA and METALS analytical data.

Project Participants

- Bruce Meadows, PGDP-FRNP
- Stephanie Brock, KY Radiation Environmental Monitoring Laboratory
- Eric Scott, KRCEE
- Steve Hampson, KRCEE (PI)

Project Documents

Project Document	Available upon request through Webmaster
Project Document	Hampson, S., Brock, S., Scott, E., Meadows, B., UPDATED PEGASIS DATA ASSESSMENT CODES OUT 030520 (DIST)
Project Document	Hampson, S., Brock, S., Scott, E., Meadows, B., RAD QUERY KYRHB CODES HIERARCHY OUT 030520 (DIST)
Project Document	Hampson, S., Brock, S., Scott, E., Meadows, B., KYRHB DATA EVALUATION CODES DEFINITIONS 2020 OUT_030520 (DIST)
Project Document	RADSdbf_June2021.xls - Manual_Query_Spreadsheet 405,000 Records (Request from Webmaster)

DEVELOPMENT OF THE PGDP VIRTUAL MUSEUM

The PGDP Virtual Museum (VM) is an ongoing project that involves development of an interactive website detailing the history of the PGDP from 'The Need for Uranium' through Site Construction, Enrichment Operations, Site Missions, and Remediation of Environmental Impacts.

VM project activities began with a team of graduate and upper-class College of Design (CoD) students researching the PGDP, recording its history, operations and impacts. The team compiled that information as an interactive digital "Museum". The CoD 'Project Team' presented the beta 'Virtual Museum' to DOE-PPPO managers in August 2016.



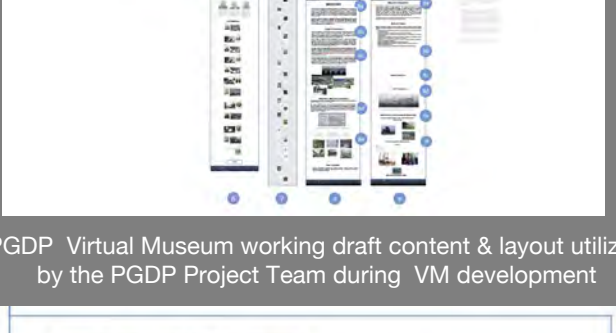
PGDP Virtual Museum Logo Designed by CoD Beta Virtual Museum Project Team

In late 2016 KRCEE organized a PGDP VM Project Team comprised of DOE, DOE Contractors, PPPO Contractors, UK-CoD PI's, UK-CoD Graduate Students. The PGDP VM Project Team was tasked to augment information on the beta Virtual Museum website with information released from the PGDP 'Vault' and 'hands on' information from a retired PGDP site historian.



PGDP Virtual Museum working draft content & layout utilized by the PGDP Project Team during VM development

The PGDP VM Project Team supplemented the beta VM content with several additional museum displays including a beta highlighting Site 'Missions' and an expanded page timeline that focused on four timeline themes: 1) History of Paducah and the Jackson Purchase; 2) History of Nuclear Science Leading to Nuclear Energy; 3) PGDP Site History; and 4) History of Environmental Regulations and PGDP Environmental Accomplishments.



Interactive Timelines developed for the final PGDP Virtual Museum

The VM Project Team submitted and posted a Draft Final Virtual Museum in 2018. The PGDP Virtual Museum was released in September 2021 following completion of a formal DOE security review.

*CoD Project Team cited in Public Outreach: Education, History & Future Use Projects

Project Participants

- Anne Filson, Professor, College of Design, University of Kentucky (Co-PI)
- Gary Rohrbacher, Associate Professor, College of Design, University of Kentucky (Co-PI)
- Brad Mitzfeldt, Public Relations, DOE-PPPO Contractor
- Tracey Taylor, Engineer, DOE-PPPO Contractor
- Eddie Spraggs, Public Relations, DOE-PPPO Contractor
- Thomas Pinkerton, Media Specialist/Webmaster, Center for Applied Research, University of Kentucky
- Steve Hampson, KRCEE

Project Documents

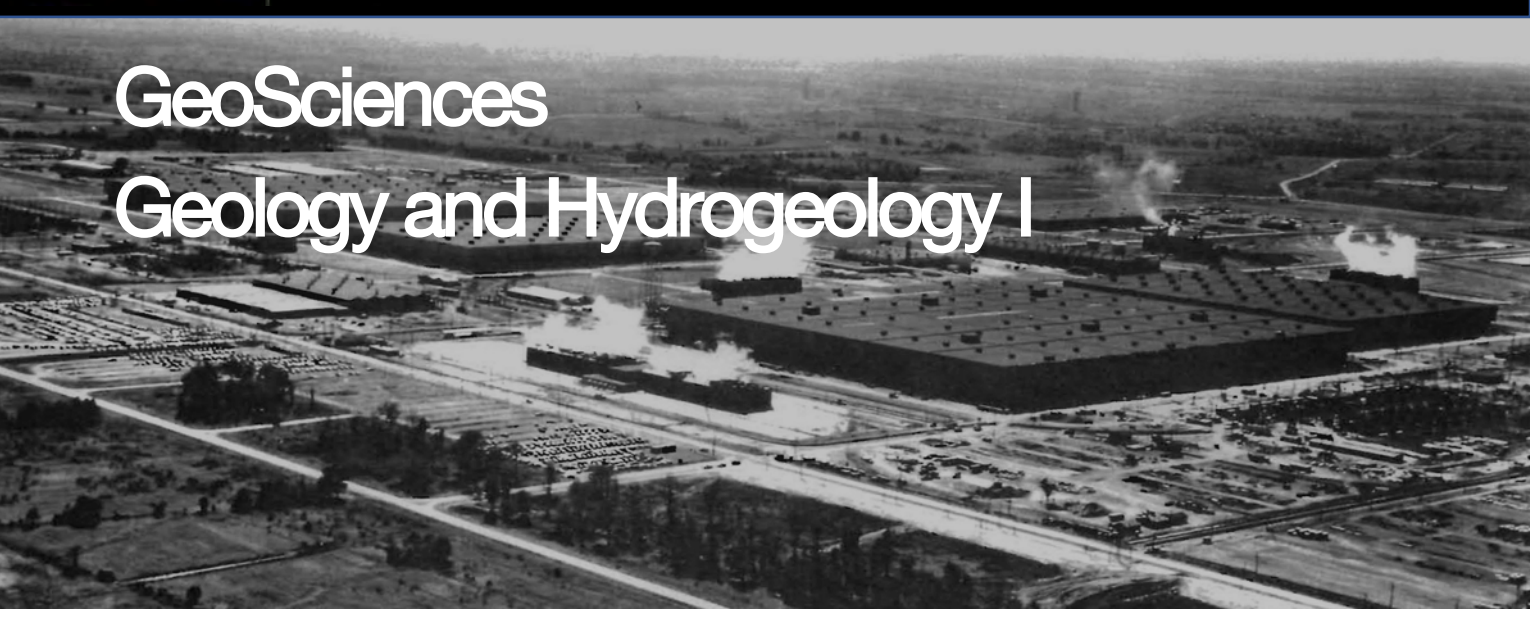
Link	http://pgdpvirtualmuseum.org/
Report	Hampson, S., PGDP Virtual Museum Development Summary Report

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GeoSciences Geology and Hydrogeology I

GEOSCIENCES BACKGROUND

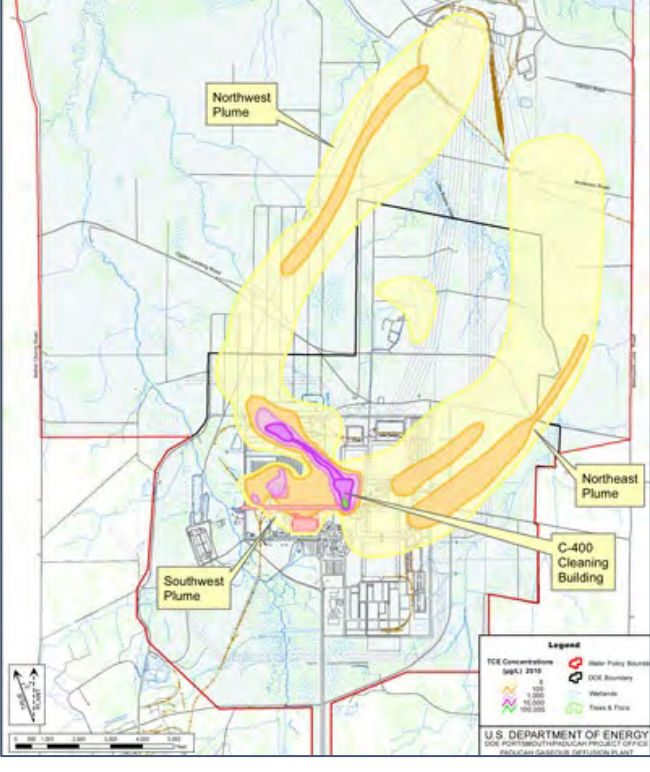
Uranium was enriched at the Paducah Gaseous Diffusion Plant (PGDP) from 1952 through 2014. Trichloroethene (TCE), a manufactured volatile organic compound (VOC), was used extensively to degrease enrichment process equipment and & routinely clean more than 400 miles of enrichment process piping. From 1953 until 1993, rail tank cars unloaded TCE at the southeast corner of the C-400 Cleaning Facility where it

was stored, transferred and used for degreasing in heated liquid baths, high-pressure sprayers and vapor degreasing units.



TCE Baths in the Southeast Corner of the C-400 Building

Losses of TCE DNAPL to the shallow subsurface included: 1) Leakage along TCE transfer system piping; 2) Discharge through process wastewater; 3) spills; and 4) Cleaning process vapor releases. TCE-laden water from the C-400 cleaning baths was discharged through wastewater piping for transfer to the PGDP wastewater treatment facility. The discharged TCE dissolved the oakum joints used to seal the pipes of the wastewater transfer system and allowed TCE-laden water to enter the subsurface directly.

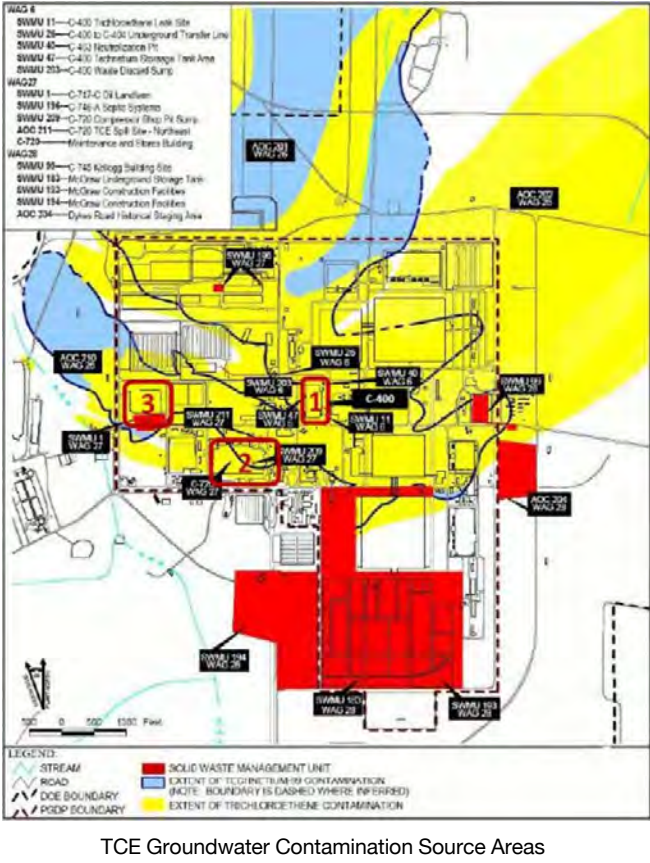


TCE Groundwater Plumes Calendar Year 2010

TCE is a dense non-aqueous phase liquid (DNAPL) and is denser than water. TCE's density causes it to sink through porous soil, aquifer materials, and groundwater. As TCE sinks through soil and aquifer media it leaves TCE DNAPL in the interstitial pore spaces where it remains as it is slowly dissolved. When sufficient quantities of DNAPL are released, their downward movement will continue until they encounter impermeable materials such as clay. When impermeable material is encountered TCE DNAPL will pool. Once pooled, the DNAPL will remain a long-term source to groundwater contamination.

From 1953 to 1976, the PGDP feed plant reprocessed spent nuclear fuel rods containing uranium. Re-processing resulted in the introduction of a man-made fission radioisotope tech-netium-99 (⁹⁹Tc or Tc-99), and other radioactive materials not associated with naturally occurring uranium. Deposition in process equipment, piping and transfer equipment as well as transfer and storage of ⁹⁹Tc-bearing liquids introduced ⁹⁹Tc to PGDP waste and wastewater streams.

Technetium-99 is a unique radionuclide in environmental settings because it easily dissolves in water where it forms the pertechnetate ion, TcO⁴⁻. The pertechnetate ion is relatively unreactive with aquifer materials and very mobile in groundwater.



TCE Groundwater Contamination Source Areas

The southeast and northwest corners of the C-400 Cleaning Building have been identified as major groundwater contamination sources related to the PGDP Northwest Plume which contains TCE and ⁹⁹Tc. Sources of the Southwest Plume (TCE and ⁹⁹Tc) include uranium burial grounds, a RCRA closure drummed uranium above-ground burial facility, an oil land-farm, and the C-720 maintenance facility. The Southwest Plume is limited to DOE property. On-site sources for the Northeast Plume have not been clearly defined.

The Northeast and Northwest TCE Plumes and the Northwest ⁹⁹Tc Plume are the largest in the DOE complex and amongst the largest documented groundwater plumes of their kind in the world. The depth of the contaminated aquifer, the geochemistry of the aquifer and contaminants, and aquifer materials that range from flowing fine sands to cobble all pose challenges to geoscientists and engineers in their efforts to characterize and remediate PGDP groundwater contamination.

Lithostratigraphy 1 Stratigraphic Model Development

KRCEE's initial lithostratigraphy efforts began as an M.S. Thesis project to independently develop a stratigraphic model and compile historical lithologic logs collected during PGDP and vicinity

environmental investigations. Initial project activities included extensive field reconnaissance in the vicinity of the PGDP, consultation with Kentucky and Illinois Geological Surveys to correlate the distribution of geologic units in southern Illinois with geologic units in the vicinity of the PGDP, and carbon dating analysis of (Upper) Continental Deposit material overlying the Regional Gravel Aquifer. Approximately 400 lithologic logs were gathered, compiled in ROCKWARE[®] software and used to produce stratigraphic and hydro-stratigraphic surfaces and cross-sections for the PGDP and vicinity.



Field reconnaissance: A gravel exposure in a lower reach of Little Bayou Creek (Sexton, 2006)

Project Participants

- Josh Sexton, M.S. Student, Department of Geological Sciences, University of Kentucky
- Dr. Alan Fryar, Department of Geological Sciences, University of Kentucky (PI)
- Dr. Stephen Greb, Kentucky Geological Survey, University of Kentucky
- Dr. Steve Cordivola, Kentucky Geological Survey, University of Kentucky
- Steve Hampson, KRCEE

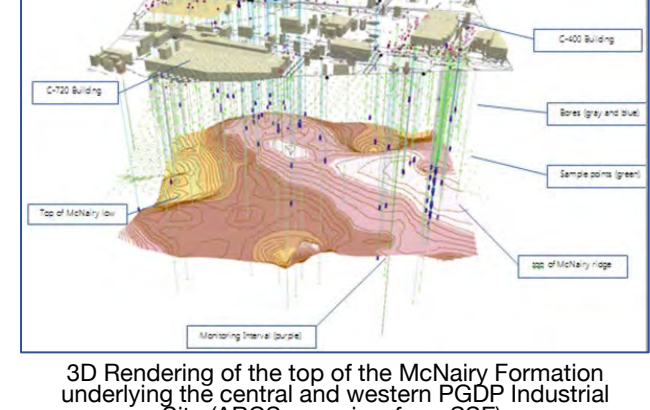
Project Documents

Thesis	Sexton, Joshua L., "Lithologic and Stratigraphic Compilation of Near-Surface Sediments for the Paducah Gaseous Diffusion Plant, McCracken County, Ky." (2006). University of Kentucky Master's Theses. 295. https://uknowledge.uky.edu/gradschool_theses/295 (KRCEE Doc #4.1, 2006)
Presentation	Sexton, J.L., Fryar, A., Greb, S., "Geologic Mapping of Near-Surface Sediments in the Northern Mississippi Embayment, Geological Society of America Meeting, Poster Presentation, Paper 33-6, April 2005." (KRCEE Doc #4.2, 2005)
Digital Data	Sexton, J.L., Cordivola, S., Digitally Scanned PGDP Lithologic Logs (original lithologic logs to populate 'Well and Borehole Data' on the PGDP PEGASIS website). (PEGASIS LITHOLOGIC LOGS)

Lithostratigraphic Database Project

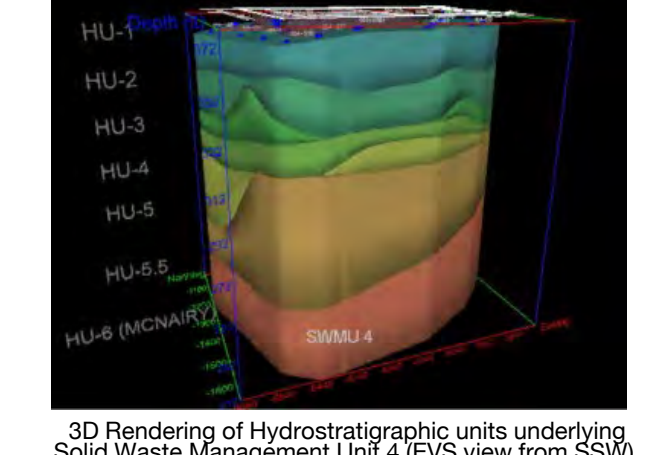
The Lithostratigraphic Database Development Project encompasses ongoing lithologic data compilation, classification, and development/updating of a hydrogeologic and lithostratigraphic database for the PGDP and its environs. Database development began in 2004

with a focus on identification of the top and bottom of the Regional Gravel Aquifer (RGA), boring interval depths, elevations, and descriptions. Aquifer surfaces interpolated from database records were utilized in the 2008 PGDP Groundwater Flow Model Update, 2010/2012 PGDP pump and treat optimization activities, and the 2016 PGDP Flow Model Update. Newly acquired lithologic log data is included in semi-annual updates to the database. In CY 2020 a 28,000-record 10th update to the database was submitted to the PGDP.



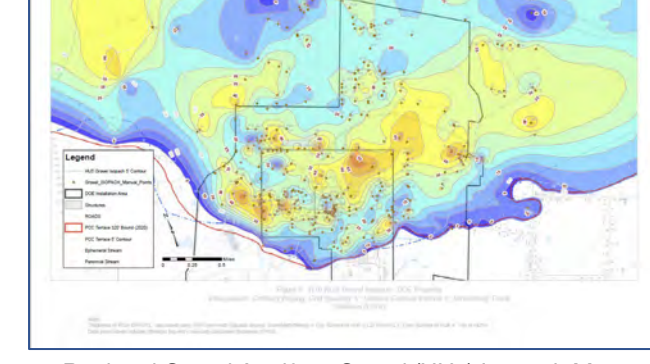
3D Rendering of the top of the McNairy Formation underlying the central and western PGDP Industrial Site (ARCSense view from SSE).

Lithologic log data has been acquired from PGDP site & CERCLA project documents, the Kentucky Geological Survey water well data repository, U.S. Army Corps of Engineers, TVA Shawnee Steam Plant engineering documents, geologic quadrangle maps and the Illinois Geological Survey. Approximately 1700 digital lithologic log files were transferred from KRCEE to PEGASIS in 2014.



3D Rendering of Hydrostratigraphic units underlying Solid Waste Management Unit 4 (EVS view from SSW).

Stratigraphic surface and hydrogeologic unit surface maps, isopach maps and 3D renderings have been produced from Lithostratigraphic Database records utilizing a variety of geotechnical software packages including Surfer, ARCMAP, ArcScene, Earth Visioning Software (EVS), Leapfrog, Groundwater Modeling System (GMS) and Rockware.



Regional Gravel Aquifer - Gravel (HU5) Isopach Map Underlying PGDP & Vicinity (Surfer & ARCMAP).

Lithostratigraphic Database Project Team participants included PGDP personnel, University of Kentucky faculty & staff, contractor subject matter experts and Earth and Environmental Science graduate students. The Kentucky Geological Survey enlisted geological sciences graduate students to conduct a significant data input during the summer of 2009. Approximately 1,000 lithologic logs were digitized or digitally entered by Agricultural and Biosystems engineering summer student support during 2012.

Project Team

- Adam Locke, Engineer/GIS Specialist, CDM Inc., Pittsburgh
- Bruce Phillips, Sr. Environmental Scientist, Navarro Engineering & Strata-G
- Dr. Alan Fryar, Professor, Department of Earth and Environmental Sciences, University of Kentucky
- Dr. William Andrews, Kentucky Geological Survey, University of Kentucky
- Emily Eastridge, M.S. Student, Earth and Environmental Sciences, University of Kentucky
- Estifanos Haile, M.S. Student, Earth and Environmental Sciences, University of Kentucky
- Dr. Ganesh Nath Tripathi, Ph.D. Student, Earth and Environmental Science, University of Kentucky
- Dr. Abhijit Mukherjee, Earth and Environmental Sciences, University of Kentucky
- David Cross, M.S., Earth & Environmental Sciences, University of Kentucky
- JoAnna Foresman, Research Assistant, Biosystems and Agricultural Engineering, College of Engineering
- Ken Davis, Geologist, Paducah Remediation Services & Four Rivers Nuclear Partnership (Paducah Site)
- Mark Cross, M.S. Student, Earth & Environmental Sciences, University of Kentucky
- Steve Hampson, KRCEE (PI)

Project Documents

Database	R10 HydroLitho Dbase posted 121620 (.xlsx DOWNLOAD ONLY)
Document	R10 Characterization Model
Document	R10 Database Column ID
Document	R10 GLY Column Details Notes
Rendered Data	Figure 2. R10 121020 Top HU6 DOE Property
Rendered Data	Figure 3. R10 Porters Creek Clay Terrace - DOE Property
Rendered Data	Figure 4. R10 Top of RGA DOE-TVA
Rendered Data	Figure 5. R10 HU5 Gravel Isopach -DOE Property
Rendered Data	Figure 5a. R10 HU5 Gravel Isopach - DOE-TVA 0
Rendered Data	Figure 5b. R10 HU5 Gravel Isopach - StudyArea-GWM
Rendered Data	Figure 5c. R10 HU5 Gravel Isopach - C-400
Rendered Data	Figure 6. R10 Top of HU3 - Industrial Site
Rendered Data	Figure 7. R10 HU3 Isopach (Manual) - Industrial Site
Rendered Data	Plate 1. R9 Hydrolithostratigraphy Dbase Locations
Rendered Data	Plate 1a. R9 Hydrolithostratigraphy Dbase N NWPlume & TVA
Rendered Data	Plate 1b. R9 Hydrolithostratigraphy Dbase Eastern Industrial Site Locations
Rendered Data	Plate 1c. R9 Hydrolithostratigraphy Dbase N Industrial Site ULF
Rendered Data	Plate 1d. R9 Hydrolithostratigraphy Dbase Western Industrial Site Locations
Rendered Data	Plate 1e. R9 Hydrolithostratigraphy Dbase C-400 Locations

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GeoSciences

Geology and Hydrogeology II

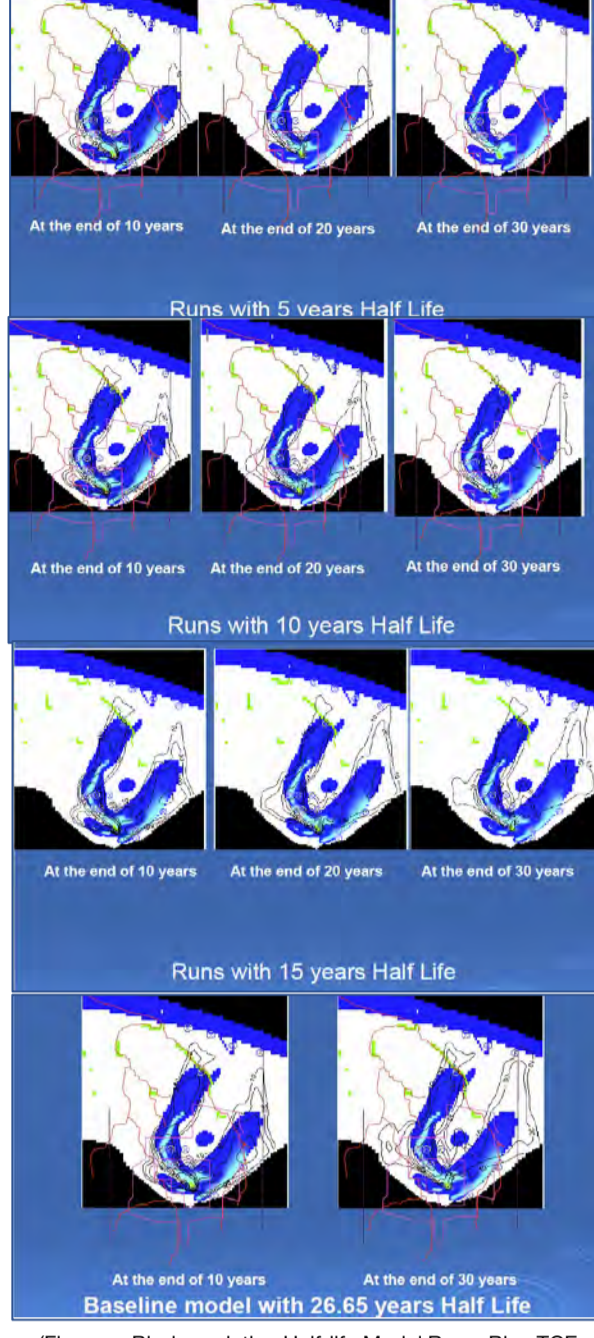
Groundwater Modeling 1

KRCEE participation in PGDP groundwater modeling efforts began in 2004 as a carryover of UK-Kentucky Radiation Health groundwater modeling evaluation efforts conducted as part of the Agreement in Principle Program.

The first Project Team task undertaken by Department of Civil Engineering faculty and post-doctoral staff was an independent review of historical PGDP modeling efforts. The review encompassed the initial 1994 PGDP Groundwater Flow Model (MODFLOW) and model updates through calendar year 2000 which included development and implementation of a flow and transport model (MODFLOWT). (1998 PGDP Groundwater Flow Model)

Next, the Project Team ran the 1998 MODFLOW and MODFLOWT model simulations and evaluated results. Sensitivity analyses were then conducted on key model parameters including hydraulic conductivity and TCE degradation rates. Sensitivity analysis of TCE plume extents over a range of TCE intrinsic biodegradation half-lives, from 5 years to 26.5 years are shown in accompanying figures.

A summary of Project Team findings is provided in the *GW Modeling Efforts FFA Summary Presentation* below.



(Figures: Biodegradation Half-life Model Runs: Blue TCE plume extents are the baseline model at time zero, black line is the TCE plume extent after specified model run duration. Half Life is specified on each slide)

Effect of Biodegradation Half Life Period

- Biodegradation of TCE in the PGDP Regional Ground water model is handled using Half Life Period. (26.65 years : 9729.04 days)
- Trials were made with 5 years, 10 years, 15 years, with varying half Life period in two zones and with varying half Life period in Four zones. Varying half life period in different zones are experimented to simulate lesser biodegradation near DNAPL sources.
- Far-field TCE concentrations do not agree with calibrated model/field measurements under "no half-life" scenario

(Above: Description of biodegradation half life sensitivity analyses.)

Project Team

- Dr. Srinivasa Lingireddy, Associate Professor, UK-Civil Engineering (Co-PI)
- Dr. Chandramouli Viswanathan, Adjunct Faculty, UK-Civil Engineering (Co-PI)
- Dr. Alaudin Kahn, SAIC, Knoxville, TN
- Dr. Lindell Ormsbee, PE, UK-Civil Engineering, Director Ky. Water Resources Research Institute, Director Superfund Basic Research Program Translation Core, Director Ky. Research Consortium for Energy & Environment
- Dr. Alan Fryar, Professor, UK-Earth and Environmental Sciences
- James Kipp, Associate Director, UK-KWRI
- Steve Hampson, KRCEE

Project Documents

FFA Meeting Presentation	Ormsbee, L., GW Modeling Efforts FFA Summary Presentation, KRCEE 3.2, 2006
KRCEE Symposium Summary Presentation	Viswanathan, C., Lingireddy, S., Ormsbee, L., Hampson, S., KRCEE SYMPOSIUM Groundwater Modeling Efforts Summary, October, 2007.

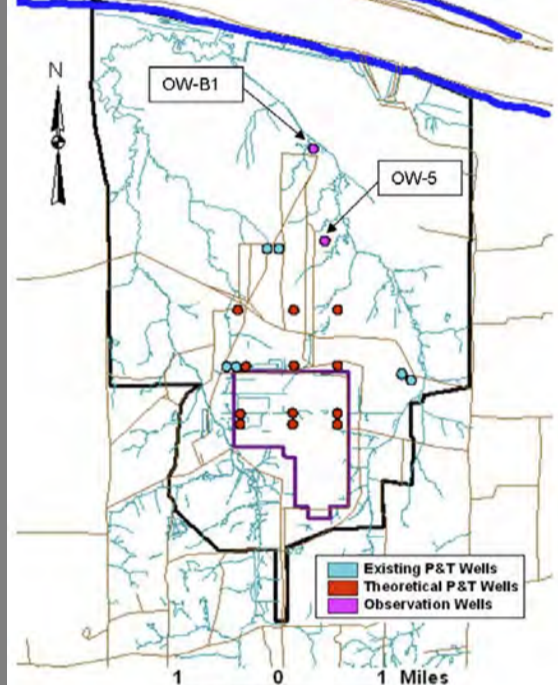
Groundwater Modeling Alternative Groundwater Model Development

Faculty, staff and graduate student modelers at the Kentucky Water Resources Research Institute (KWRI) and UK College of Engineering developed an Artificial Neural Network (ANN) model to supplement the use of MODFLOW groundwater flow and MODFLOWT transport models at the PGDP site.

"The purpose of an ANN model for the PGDP is to forecast TCE concentrations as accurately as the MODFLOW model so that it can be incorporated with an optimization technique and integrated into a management model.

An optimization model requires numerous evaluations of the objective function, and this is not feasible with a MODFLOWT model that can take hours (to days) for one simulation. A properly trained ANN model could give results of the objective function in seconds."

Three distinct groundwater modeling tasks were accomplished for the Project. Results are discussed in the reports below.



Locations of existing and simulated pumping wells used in ANN model simulations.

Project Team

- Joshua Kopp, Graduate Student, UK-Civil Engineering
- Dr. Lindell Ormsbee, PE, UK-Civil Engineering, Director Ky. Water Resources Research Institute, Director Superfund Basic Research Program Translation Core, Director Ky. Research Consortium for Energy & Environment
- Dr. Chandramouli Viswanathan, Adjunct Faculty, UK-Civil Engineering

Project Documents

Project Report	Kopp, J., Sensitivity Analysis on the Half-Life of Trichloroethylene (ANN), KRCEE 12.1 2007.
Project Report	Kopp, J., Using Artificial Neural Networks to Forecast Trichloroethylene KRCEE 12.2 2007.
Project Report	Kopp, J., Using the Box Complex Method to Optimize PGDP Pumping Strategies KRCEE 12.3 2007.

Groundwater Modeling Property Acquisition Report (Land Study) Groundwater Modeling

The PGDP Property Acquisition Study (Land Study) was conducted in accordance with a Congressional Directive to DOE in the *Energy and Water Development Appropriation Bill, 2006 (Senate Report 109-084)*.

"Within the funds provided the Department shall undertake a study of the potential purchase of property or options to purchase property that is located above the plume of contaminated groundwater near the facility

site. The study shall evaluate the adequate protection of human health and environment from exposure to contaminated groundwater and consider whether such purchase, when taking into account the cost of remediation, long-term surveillance, and maintenance, is in the best interest of taxpayers."

The Land Study required a groundwater modeling evaluation for a complete range of groundwater remedial alternatives identified in PGDP decision (regulatory program) documents. Five alternatives were identified, No Action and four remedial scenarios (Table 3.4.1 below). For each alternative, the temporal as well as maximum extent of plume impacts was modeled over a 100-year period.

A KWRI and UK-Civil Engineering Project team applied existing in-site groundwater modeling (see Groundwater Modeling 1) to conduct MODFLOW and MODFLOWT simulations of each remedial action scenario using the 1998 PGDP Flow and Transport Models (Bechtel-Jacobs, DOE, 1998*).

Further project groundwater modeling information is available in the text and Appendix A of the [Property Acquisition Study Final Report.](#)**



Modeled maximum TCE Plume Contours at 500 µg/L over time assuming Source Reductions at C400, C720, SWMU1 and SWMU4 (including dissolved phase treatment of Southwest Plume and PTZ at facility fence) (Scenario 4)

*DOE (U.S. Department of Energy) 1998. Ground Water Flow Model Recalibration and Transport Model Construction at the PGDP, Paducah, Kentucky, DOE/OR/07-1742&DO, United States Department of Energy, Paducah, KY, June 1998.

**The findings of the PGDP Property Acquisition Study are presented in greater detail with [PGDP Future Use, Public Outreach & Education Projects](#)

Table 3.4.1 Potential Response Action Scenarios

Scenario	ID	Description
1	P&T	Continuation of existing pump and treat action
2	C400	Source reduction of contamination at C-400 building using direct heating technology
3	URD	Source reduction of UCRS and RGA sources using direct heating technology, and treatment of Southwest Plume using ozonation (i.e. C-Sparge) technology
4	URD-PTZ	Source reduction for all sources, treatment of Southwest Plume, and PTZ technology at the PGDP security fence.

Project Team (Land Study GIS)

- Dr. Srinivasa Lingireddy - UK-Civil Engineering (Co-PI)
- Dr. Lindell Ormsbee, PE, UK-Civil Engineering, Director Ky. Water Resources Research Institute, Director Superfund Basic Research Program Translation Core, Director Ky. Research Consortium for Energy & Environment (PI)
- Dr. Chandramouli Viswanathan, Adjunct Faculty, UK-Civil Engineering (Co-PI)
- Terri Dowdie, GIS Specialist, Agriculture and Biosystems Engineering, University of Kentucky

Project Documents

Report	Ormsbee, L., Property Acquisition Study Final Report, OSTI KRCEE 24.1 2007
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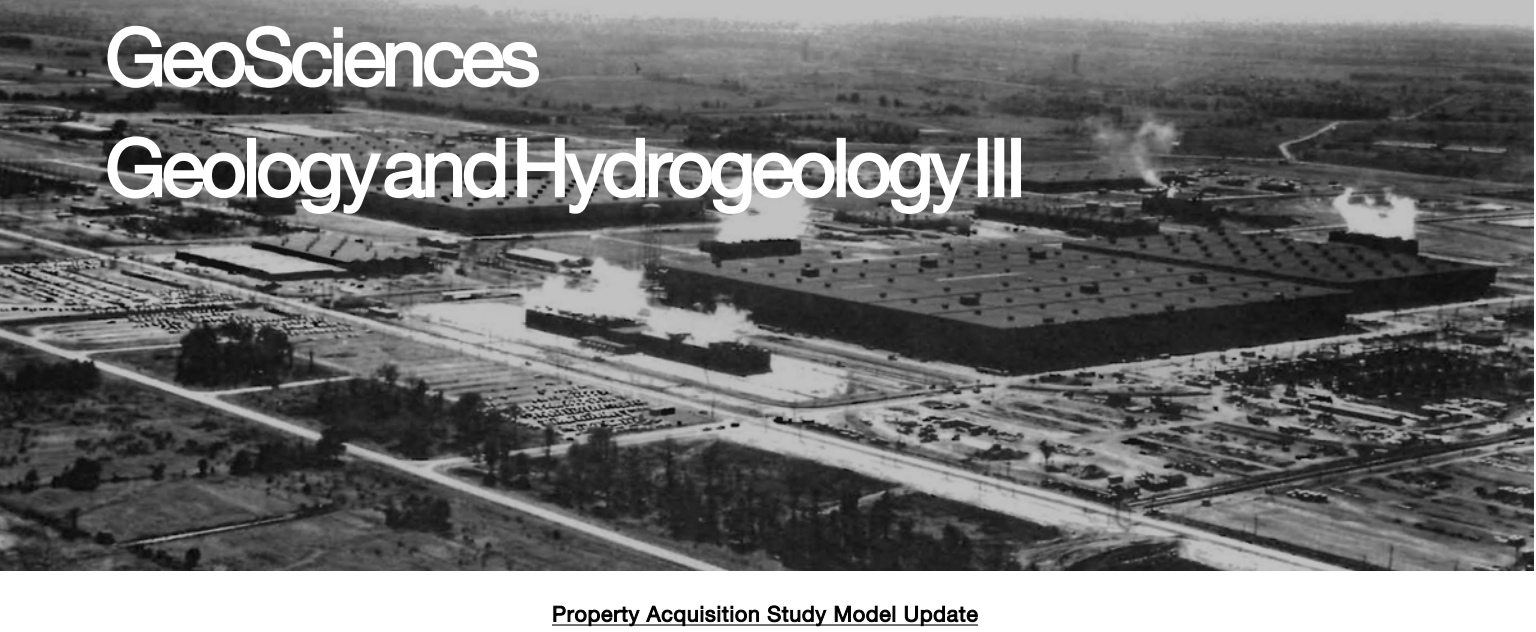
PROJECT DOCUMENTS



PGDP MULTIMEDIA



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GeoSciences Geology and Hydrogeology III

Property Acquisition Study Model Update

A faculty and staff Project Team from the Kentucky Water Resources Research Institute (KWRI), the Kentucky Geological Survey (KGS), KRCEE and the UK College of Engineering utilized the updated 2008 PGDP Groundwater Model to re-evaluate the Property Acquisition Scenarios GW modeling responses to remedial actions.

Project Participants

- Dr. Junfeng Zhu, Hydrogeologist, UK-KGS (Co-PI)
- Dr. Lindell Ormsbee, PE, UK-Civil Engineering, Director Ky. Water Resources Research Institute, Director Superfund Basic Research Program Translation Core, Director Ky. Research Consortium for Energy & Environment
- Dr. Kelly Pennell, PE, UK-Civil Engineering
- Dr. Alan Fryar, Professor, UK-Earth and Environmental Sciences
- Steve Hampson, UK-KRCEE

Project Documents

Meeting Presentation	Zhu, J., Updated Land Study Groundwater Modeling, KRCEE Quarterly Meeting Presentation, October 2012.
Poster	Zhu, J., Updated Land Study Groundwater Modeling, Poster Presentation, Midwest Groundwater Association Meeting, 2012
Report	Zhu, J., Reassessment of PGDP Land Study Plume Extents Utilizing PGDP 2008 GW Flow and Transport Models, 2014.

PGDP Groundwater Model Support Independent Model Reviews

A groundwater modeling Project Team from the Kentucky Water Resources Research Institute, Kentucky Geological Survey, UK Earth and Environmental Sciences and the UK College of Engineering executed and evaluated the 2008 and 2016 PGDP Groundwater Model Updates.

The Project Team reviewed project documents and model inputs for each updated model. Following execution of the MODFLOW models for each update,

the Project Team provided an independent review of model results and recommendations for future model improvements.

Project Team

- Dr. Lindell Ormsbee, PE, UK-Civil Engineering, Director Ky. Water Resources Research Institute, Director Superfund Basic Research Program Translation Core, Director Ky. Research Consortium for Energy & Environment
- Dr. James S. Dinger, Head, UK-KGS Water Section
- Dr. Junfeng Zhu, Hydrogeologist, UK-KGS (Co-PI)
- Dr. Kelly Pennell, PE, UK-Civil Engineering
- Dr. Alan Fryar, Professor, UK-Earth and Environmental Sciences
- Estifanos Haile, Graduate Student, UK-Earth and Environmental Sciences

Project Documents

Report	Zhu, J., Ormsbee, L., Pennell, K., Fryar, A., PGDP GW Modeling Support Activities Phase1: Updated 2008 PGDP Model Evaluation & Recommendations, KRCEE P30 1, 2011
Report	Zhu, J., Ormsbee, L., Pennell, K., Fryar, A., PGDP GW Modeling Support Activities Phase1: Updated 2016 PGDP Groundwater Flow Model Evaluation & Recommendations, KRCEE P30 1, 2011

Groundwater-Surface Water Interaction

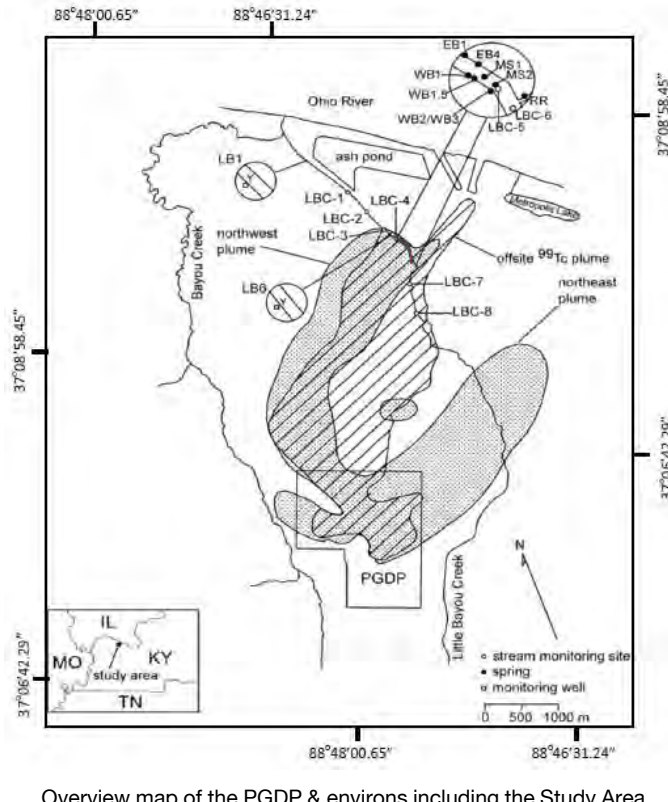
UK Earth and Environmental Science PGDP projects conducted from 2000 – 2013 evaluated the extent, concentrations, and trends associated with groundwater seeps that discharge TCE and technetium-99 contaminated groundwater to Little Bayou Creek approximately 3 miles down-gradient of contamination sources on the PGDP industrial site. The projects have included research for and authorship of independent journal articles as well as in-depth thesis and dissertation work.

Preliminary site and seep characterization and assessment work was conducted independently (Mukherjee, 2003) and as part of thesis (Mukherjee, 2003) and dissertation work (LaSage, 2004, Unpublished Doctoral Dissertation) with funding from the University of Kentucky Water Resources Research Institute (KWRI) Federal Facilities Oversight Unit (FFOU).

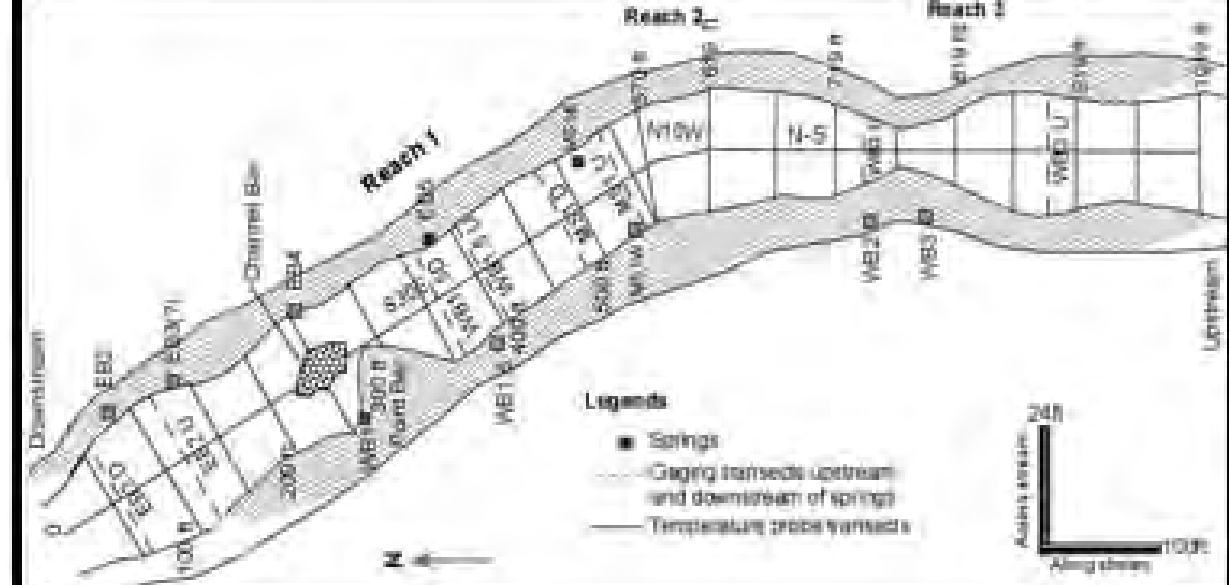
Subsequent publications, thesis and dissertation work built upon earlier works.



Newly emerged spring along Study Area Reach 2 in Calendar Year 2012



Overview map of the PGDP & environs including the Study Area where offsite TCE groundwater plumes discharge through seeps to Little Bayou Creek.



LBC Seeps Study Area Detail (Tripathi, 2011)

Projects Participants

- Dr. Alan Fryar, Professor, UK Earth and Environmental Sciences (PI)
- Josh Sexton, M.S. Student, Department of Geological Sciences, University of Kentucky
- Ganesh Nath Tripathi, Ph.D. Student – UK Earth & Environmental Science
- Darita LaSage, Ph.D. Student – UK Earth & Environmental Science
- Dr. Steve Greb, Kentucky Geological Survey, University of Kentucky

Project Documents

Journal Article	Fryar, A.E., Wallin, E.J., Brown, D.L., 2000. Spatial and temporal variability in seepage between a contaminated aquifer and tributaries to the Ohio River. Ground Water Monitoring & Remediation 20, 129–146.
Thesis	Mukherjee, Abhijit, "Identification of Natural Attenuation of Trichloroethene and Technetium-99 Along Little Bayou Creek, McCracken County, Kentucky" (2003). University of Kentucky Master's Theses. 293. https://uknowledge.uky.edu/gradschool_theses/293_2003.
Meeting Presentation and Poster	Mukherjee, A., Fryar, A.E., Evaluating Natural Attenuation of Contaminants Along a First Order Coastal Plain Stream, Presentation to Geological Society of America, Paper 152-4.
Dissertation	LaSage, D.M., 2004. Natural attenuation along a first-order stream recharged by contaminated groundwater. Ph.D. Thesis, University of Kentucky, USA, 238p. (unpublished)
Journal Article	Mukherjee, A., Fryar, A.E., LaSage, D.M., 2005. Using tracer tests to assess natural attenuation of contaminants along a channelized Coastal Plain stream, 2005 Environmental & Engineering Geoscience 11 (4), 371–382.
Meeting Poster	Sexton, J., Geologic Mapping of Near-Surface Sediments in the Northern Mississippi Embayment, Poster Session, Geological Society of America, Knoxville, TN. April 2005.
Thesis	Sexton, J., Lithologic and Stratigraphic Compilation of Near Surface Sediment, 2006. (Sexton MS Thesis)
Journal Article	LaSage, D.M., Sexton, J.L., Mukherjee, A., Fryar, A.E., Greb, S.F., 2008. Groundwater discharge along a channelized Coastal Plain stream. Journal of Hydrology 360 (1-4), 252–264.
Journal Article	LaSage, D.M., Fryar, A.E., Mukherjee, A., Sturchio, N.C., Heraty, L.J., 2008a. Groundwater-derived contaminant fluxes along a channelized Coastal Plain stream. J. Hydrology. 360, 265-280. (KRCEE 4.5 2008d)
Meeting Presentation	Tripathi, G.N., Fryar, A.E., Spatio-temporal variability in groundwater discharge and contaminant fluxes along Little Bayou Creek, KRCEE Quarterly Meeting Presentation, June 2011.
Meeting Presentation	Tripathi, G.N., Fryar, A.E., Thermal profiling of focused groundwater discharge along a channelized stream in western Kentucky. Presentation, October 2011.
Dissertation	Tripathi, G.N., 2013, Spatio-temporal variability in groundwater discharge and contaminant fluxes along a channelized stream in western Kentucky, Ph.D. dissertation, University of Kentucky, Lexington, Kentucky, 127 p. https://uknowledge.uky.edu/ees_etds/13/.
Meeting Poster	Hampson, S., Little Bayou Creek Seep Studies, PGDP GW Modeling Team Poster & Discussion, February 2015.
Meeting Poster	Tripathi, G.N., Fryar, A.E., Spatial and seasonal variability in groundwater discharge and contaminant fluxes along a channelized stream in western Kentucky, September 2020.
Journal Article	Tripathi, G.N., Fryar, A.E., Hampson, S.K., Mukherjee, A., Seasonal to Decadal Variability in Focused Groundwater and Contaminant Discharge along a Channelized Stream. Groundwater Monitoring and Remediation, January 2021.

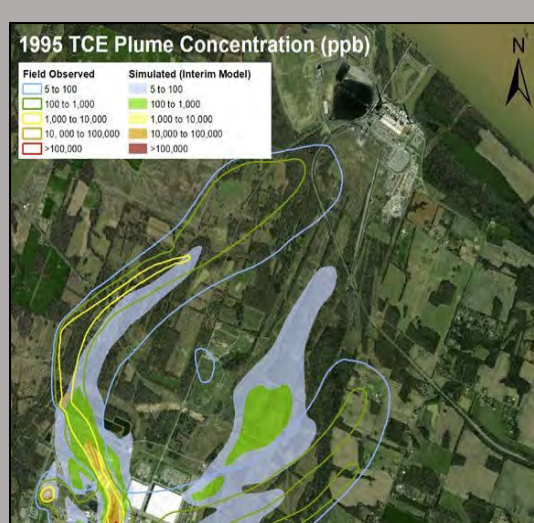
PGDP Groundwater Model Interim Transport Model Evaluation

The ITM activity consisted of the development of an Interim (Groundwater) Transport Model utilizing flow parameters from the 2016 Update of the Paducah Gaseous Diffusion Plant Site-wide Groundwater Flow Model (DOE, 2017) and transport parameters from the 2008 Update of the Paducah Gaseous

Diffusion Plant Site-wide Groundwater Flow Model (DOE, 2010). ITM outputs for several time frames through CY 2018 were compared to 1) transport outputs from the 2008 Update of PGDP Groundwater Flow Model and 2) published interpretations of PGDP trichloroethene (TCE) plume extents based on field measurements. Recommendations regarding the development and refinement of a transport model to supplement the 2016 Update of the Paducah Gaseous Diffusion Plant Site-wide Groundwater Flow Model are included in the Report and Presentation below.

Project Team

- Dr. Junfeng Zhu, Hydrogeologist, UK-KGS (PI)
- Steve Hampson, KRCEE



1995 Interim Transport Model TCE plume results (shaded) plotted against 1995 TCE field monitoring results (lines)

Project Documents

Report	Zhu, J., Interim TCE Transport Model for the Paducah Gaseous Diffusion Plant Site, February 2020.
Report Presentation	Zhu, J., PGDP Interim Transport Model Presentation
Professional Meeting Presentation	Hampson, S., Zhu, J., KRCEE PGDP GW Model Activities: Independent Reviews, Applications, and Recommendations. Project Presentation to PGDP GW Model Project Team, January 2022.

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GeoSciences Soil & Sediment Characterization & Remediation I

"Real-Time" Soil Characterization and Remediation Demonstration Project

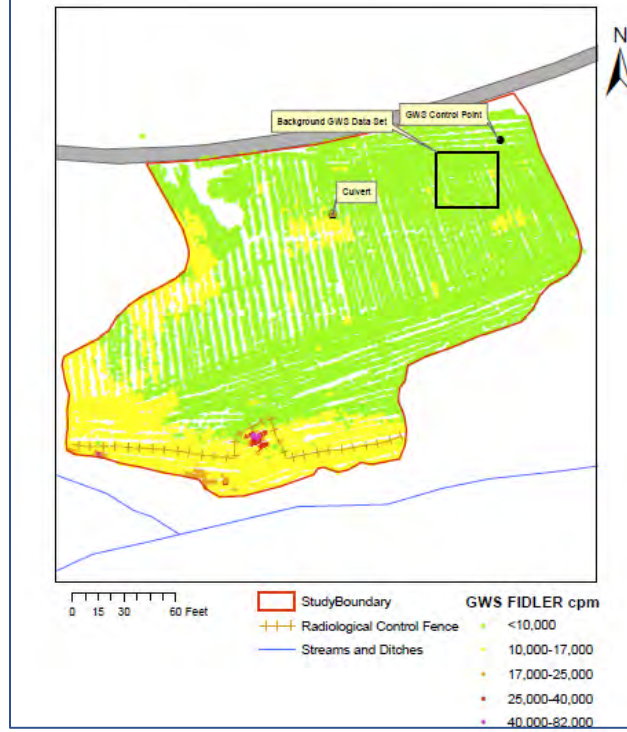
Argonne National Laboratory, UK, Industry and PGDP scientists developed and demonstrated a tailored, site-specific approach to utilize state-of-the-art field instrumentation to conduct a PGDP soil/sediment project from characterization through remediation and verification of clean-up. The 'Real Time' Demonstration Project (RTD) accomplished characterization and cleanup of PCB, metal, and radionuclide contamination on the 16-acre AOC-492 site (Figure 1) in a 3-week field mobilization versus the typical 3-4 years necessary for completing existing iterative field project life cycles.

The Project integrated key conceptual approaches from Argonne National Laboratory, the Adaptive Sampling and Analysis Plan (ASAP) approach, and the Environmental Protection Agency TRIAD approach. Following Project completion TRIAD and ASAP training was provided to PGDP DOE staff, PGDP Contractor Staff, University Staff, EPA Staff, Kentucky regulators and the public.

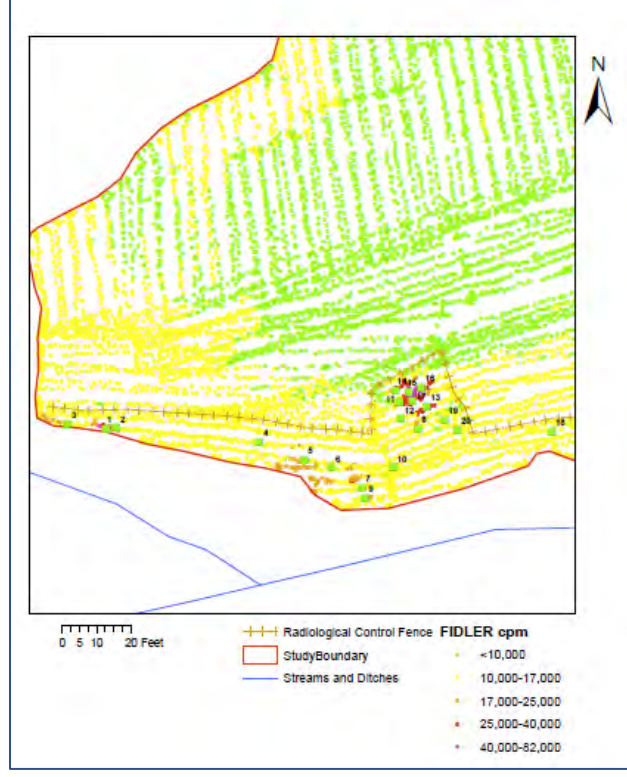
Preliminary RTD project efforts included rigorous testing to verify performance and project suitability for XRF metal quantification field instruments and PCB field test kits. XRF performance verification was conducted with the assistance of private industry and PCB field test kit performance verification was conducted cooperatively with USEPA's Technology Innovation Field Services Division (Las Vegas).

The RTD Project technology suite (Figure 2) included: 1) Logged GWS surveys (GWS) for gamma-emitting radionuclides; 2) Discrete in-situ gamma measurements (Figures 3-6); 3) In-situ High Purity Germanium (HPGe) gamma spectroscopy for radionuclides; 4) In-situ and ex-situ X-Ray Fluorescence (XRF) for metals including total uranium; and 5) field test kits for polychlorinated biphenyls (PCBs). Multi-increment sampling and adaptive compositing techniques were included in the dynamic work strategy applied to the study area. In addition to in-situ and ex-situ measurements accomplished in the field, composite samples were analyzed by fixed laboratory to support the real-time technologies.

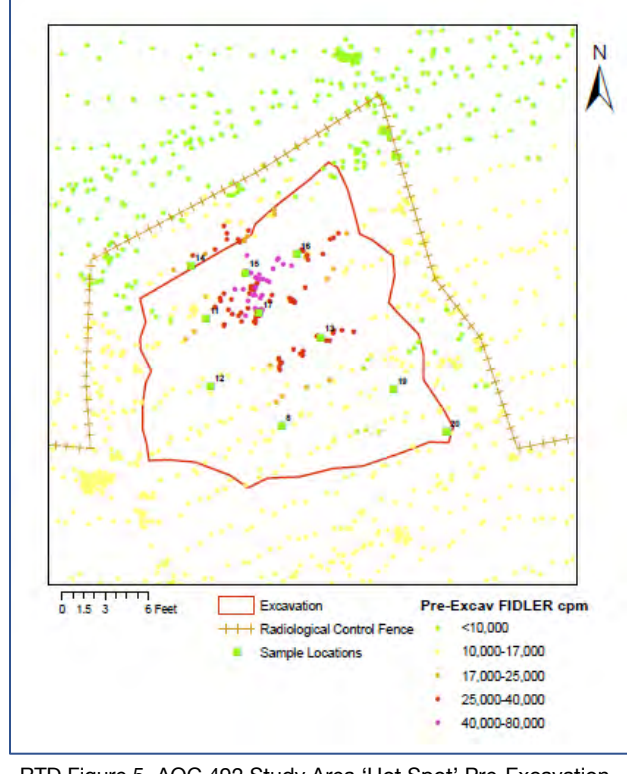
The [Real Time Technology Application Demonstration Project Final Report](#) and Project Concept Presentations discuss the Project approach and the application of field and laboratory methods.



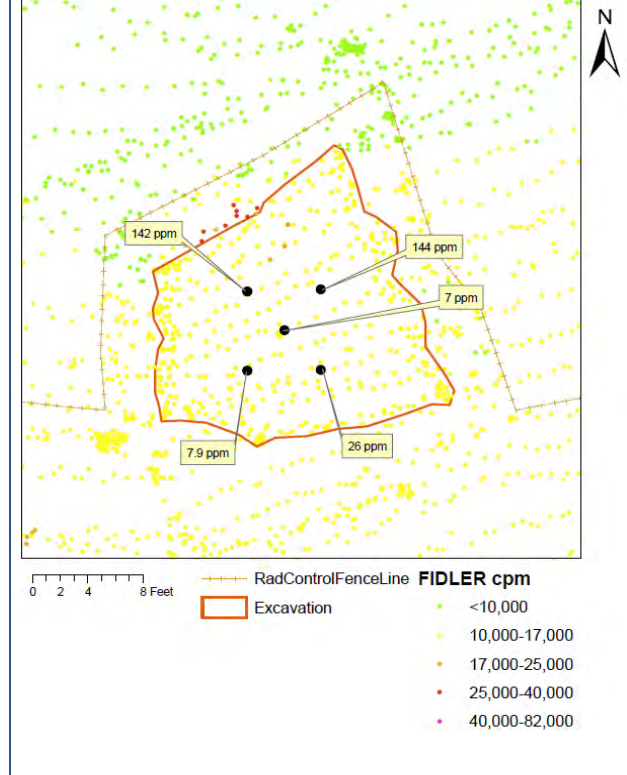
RTD Figure 3. AOC 492 Study Area Gamma Walkover Survey



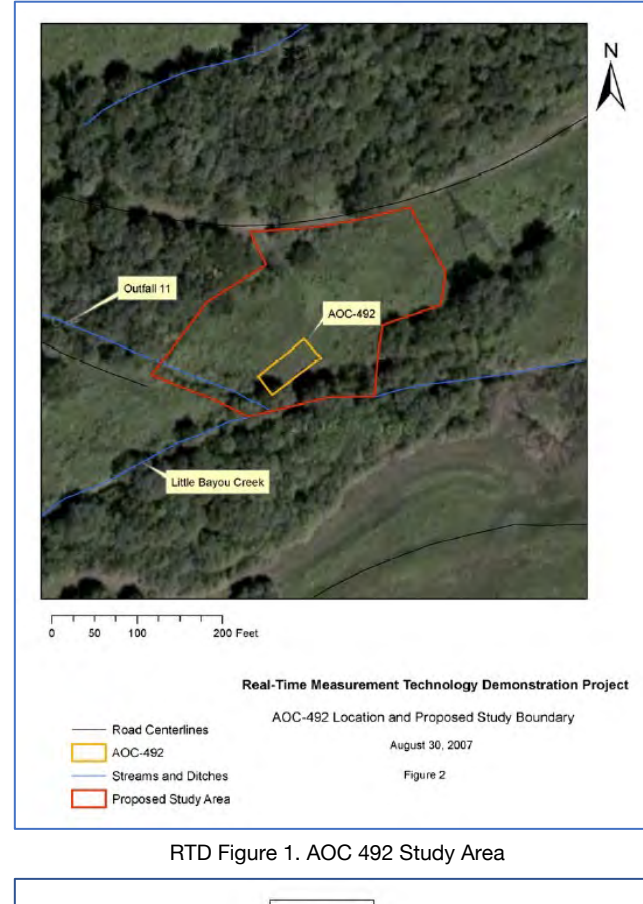
RTD Figure 4. AOC 492 Study Area Gamma Walkover Survey With Sampling Locations



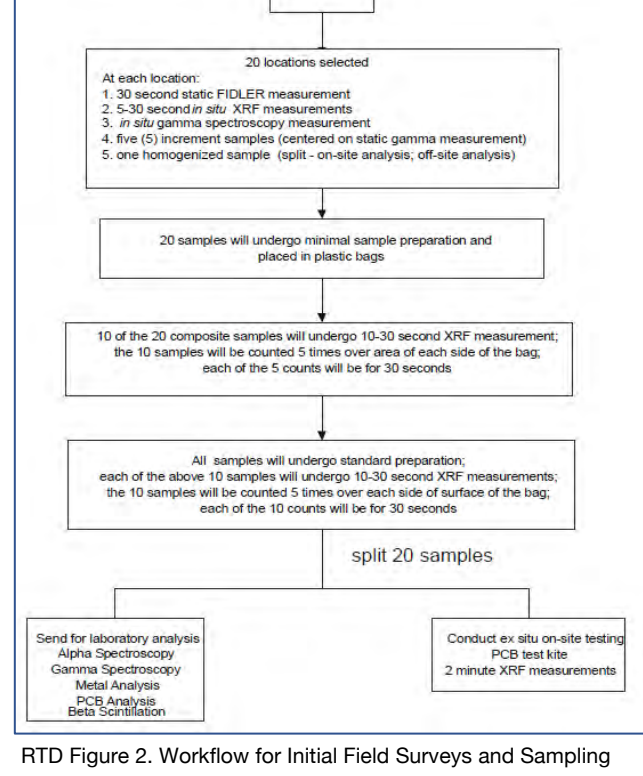
RTD Figure 5. AOC 492 Study Area 'Hot Spot' Pre-Excavation Sample Locations



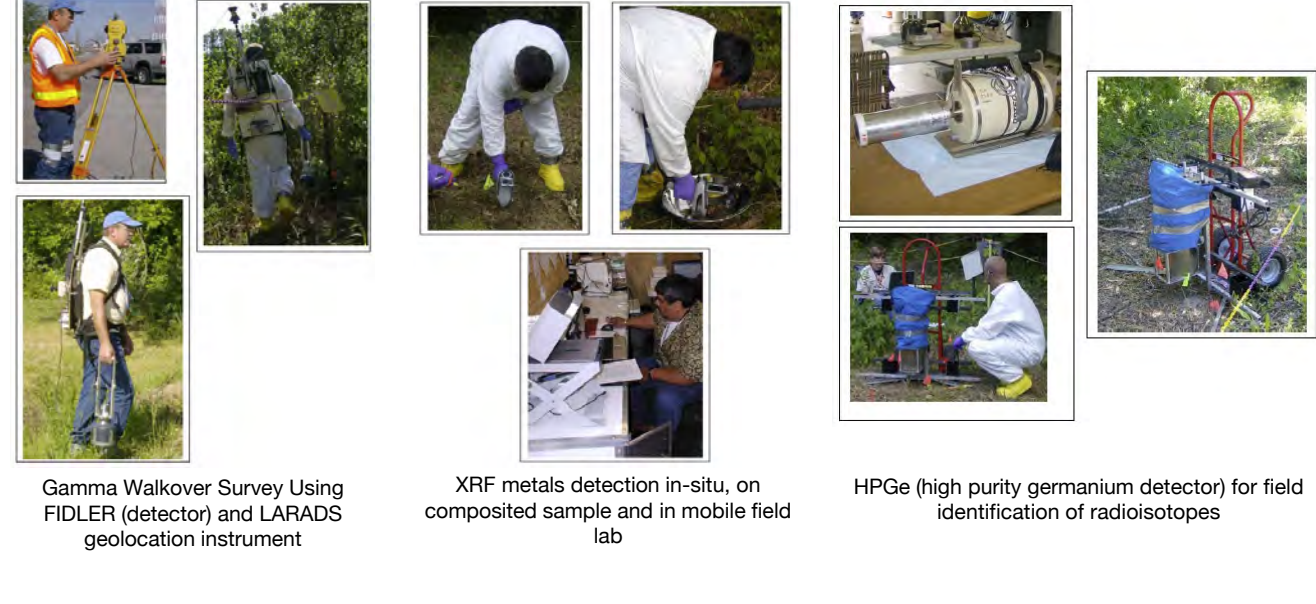
RTD Figure 6. AOC 492 Study Area FIDLER Survey after Hot Spot Removal



RTD Figure 1. AOC 492 Study Area



RTD Figure 2. Workflow for Initial Field Surveys and Sampling



Project Participants

- Robert Johnson, Ph.D., Argonne National Laboratory, University of Chicago (Co-PI)
- John A. Volpe, Ph.D., KRCEE (Co-PI)
- Rich Bonczek, Ph.D., DOE Portsmouth Paducah Project Office
- Jon Richards, Health Physicist, USEPA Region IV
- Steve Meiners, Health Physicist, Tricord, Inc.
- Deanna Crumbling, USEPA TIFSD
- Mike Dillon, Eberline Services
- Dave Lawrence, Eberline Services
- Dave Lasher, Eberline Services
- Larry Payne, Tricord, Inc.
- Jason Boulton, Geo Consultants
- Windy Gregory, Tricord, Inc.
- Hipolito Hernandez, Eberline Services
- Chris Higgins, Eberline Services
- Jim Craig, Eberline Services
- Frazier Krnstone, Paducah Remediation Services
- Jim Kipp, KRCEE
- Stephanie Jenkins, KRCEE
- Steve Hampson, KRCEE

Project Documents

Project Concept Presentation	Johnson, R.L., Case Study: ASAP Techniques in Support of Precision Excavation
Project Concept Presentation	Johnson, R.L., PGDP Case Study Improving Volume w Dynamic Work Strategies
Project Concept Presentation	Johnson, R.L., Strategies and Tools for Improved Management of Uncertainties at Contaminated Sites
Project Concept Presentation	Johnson, R.L., An Introduction to the Triad Approach
Project Final Report	Volpe, J.A., Johnson, R.L. & Hampson, S., Real Time Technology Application Demonstration Project Final Report, KRCEE Doc# P18.32, 2008
Project Supporting Study Document	Crumbling, D., USEPA TIFSD Soil PCB Pilot Study Experimental Design Plan, 2008
Project Supporting Study Report	Johnson, R.L., Real Time Demonstration Project XRF Performance Evaluation Report for Paducah Gaseous Diffusion Plant AOC 492, April 2008.
USEPA Newsletter	Bonczek, R., Johnson, R.L., Hampson, S., 'Single Field Mobilization Completes Site Investigation and Removal Actions', in USEPA Technology News and Trends, Issue 40, January 2009, pp. 3-4.
USEPA Quick Reference Fact Sheet	Bonczek, R., Johnson, R.L., Hampson, S., "Profile: Paducah Gaseous Diffusion Plant, Paducah, KY," in Green Remediation: Best Management Practices for Excavation and Surface Restoration. United States Environmental Protection Agency Office of Solid Waste and Emergency Response, EPA 542-F-08-012, December 2008.
Project Supporting Document	Argonne National Laboratory, Field Sampling Plan for AOC 492, Real Time Measurement Demonstration Project, KRCEE 18.11 2008d, December 2007.
Supporting Professional Presentation	Richards, J. (USEPA Region IV), Real-Time Demonstration Project: Dynamic, Real-Time Characterization, Remediation, and Verification of Cleanup for PCBs and Radionuclides in Soil/Sediment at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, USEPA Radiation Superfund Meeting, April 2008. (not linked)
Supporting Professional Presentation	Volpe, J.A., Real-Time Demonstration Project: Dynamic, Real-Time Characterization, Remediation, and Verification of Cleanup for PCBs and Radionuclides in Soil/Sediment at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Conference of Radiation Control Program Directors Annual Meeting, Columbus, Ohio, February 2009. (not linked)
Supporting Professional Presentation	Johnson, R.A., Real-Time Demonstration Project: Dynamic, Real-Time Characterization, Remediation, and Verification of Cleanup for PCBs and Radionuclides in Soil/Sediment at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Interstate Technology and Regulatory Council (ITRC) National Meeting: Presentation and Discussion, Louisville, Kentucky, December 2009. (not linked)
Supporting Presentation	Hampson, S., Real Time Remedial Demonstration Project Introduction, PGDP Citizens Advisory Board (CAB) Presentation, Paducah, Kentucky, May 2006.
Supporting Presentation	Hampson, S., Real Time Demonstration Project Introduction, PGDP Site Managers Meeting Presentation, Kevill, Kentucky, May 2006. (above)
Supporting Presentation	Hampson, S., Real Time Demonstration Project Introduction, KRCEE Quarterly Meeting Presentation, Lexington, Kentucky, May 2006. (above)

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GeoSciences Soil & Sediment Characterization & Remediation II

Design of Cost-Effective, Real-Time Implementable, Sediment and Contaminant Release Controls

UK Biosystems and Agricultural Engineering Department and KWRRRI developed alternative, readily implementable, design options for integrated storm water and sediment control systems for PGDP Outfalls

008, 011 and 015. The project's remedial options design process utilized the SEDCAD surface water and sediment release model with historical PGDP watershed flow and sediment concentrations. Outfall watershed discharge and sediment loading were modeled.

objectives, be cost effective, readily implementable, and require minimal excavation disturbance for placement.

Project remedial options and recommendations for future watershed monitoring are provided in the project final report.

Remedial options were required to meet performance

Project Team

- Dr. Richard Warner**, Professor, UK Agriculture and Biosystems Engineering (PI)
- Dr. Lindell Ormsbee**, PE, UK-Civil Engineering, Director Ky. Water Resources Research Institute, Director Superfund Basic Research Program Translation Core, Director Ky. Research Consortium for Energy & Environment
- Dr. John A. Volpe**, KRCEE
- Steve Hampson**, KRCEE

Project Documents

Meeting Presentation	Warner, R., Development and Design of Cost-Effective, Real-Time Implementable Sediment and Contaminant Release Controls, KRCEE Quarterly Meeting Presentation, May 2005.
Meeting Presentation	Warner, R., Preliminary Design of Sediment Release Controls for Outfalls 011, 015, & 008 KRCEE Qly Mtg Presentation, September 2006
Report	Warner, R. & Ormsbee, L., Development and Design of Cost-Effective Real Time Implementable Sediment and Contaminant Release Controls, KRCEE Doc #: P5.1 2007
Meeting Presentation	Design of Sediment Release Controls for Outfalls 011, 010, & 08 Project Final Presentation, 2008

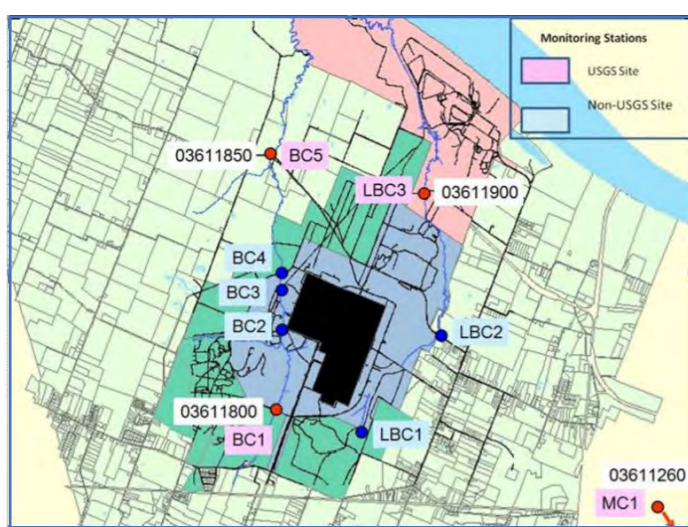
Surface Water Total Maximum Daily Load (TMDL) Development

The Kentucky Water Resources Research Institute (KWRRRI), Murray State University, and UK Civil Engineering conducted an extensive hydrologic and water quality evaluation of the PGDP and associated watersheds.

TMDL Development Project Phase 1 compiled and assessed available surface water flow and water quality data to develop TMDL criteria for surface water associated with the PGDP.

Based on TMDL Phase 1 data assessment it was determined that additional field data was needed to complete evaluation and recommendations for Cu, Fe, Pb, and Hg in Bayou and Little Bayou Creeks. During 2009 the TMDL Phase 2 Project collected supplemental metal-of-interest data from Bayou Creek, Little Bayou Creek, and reference locations.

The project final report discusses the evaluation of supplemental data and provides TMDL recommendations.



Field data locations for the collection of metals data for Phase II of the TMDL project.

Project Team

- Dr. Lindell Ormsbee**, PE, UK-Civil Engineering, Director Ky. Water Resources Research Institute, Director Superfund Basic Research Program Translation Core, Director Ky. Research Consortium for Energy & Environment
- Dr. Chandramouli Viswanathan**, Adjunct Faculty, Kentucky Water Resources Research Institute/College of Engineering, University of Kentucky
- Dr. Andrew Charles Kellie**, Professor, Industrial Engineering & Technology, Murray State University
- Dr. Michael Kemp**, Professor, Industrial Engineering & Technology, Murray State University
- Jane Benson**, Professor, Industrial Engineering & Technology, Murray State University
- Michael Matthews**, Industrial Engineering & Technology, Murray State University
- Matthew Phillip**, Industrial Engineering & Technology, Murray State University
- Ben Albritton**, Scientist, Kentucky Water Resources Research Institute, University of Kentucky
- Clay Johnson**, Research Assistant, Kentucky Water Resources Research Institute (KWRRRI), University of Kentucky
- Steve Meiners**, Health Physicist, Tricord Inc.

Project Documents

Report	Ormsbee, L., Kemp, M., Kellie, A., Benson, J., Matthews, M., Phillip, M., Total Maximum Daily Load Development Paducah Gaseous Diffusion Plant: Background and Hydrology, UK/KRCEE Doc. # 6.1, February 2006
Report	Ormsbee, L., Kemp, M., Kellie, A., Benson, J., Matthews, M., Phillip, M., Total Maximum Daily Load Development Paducah Gaseous Diffusion Plant: Water Budget, UK/KRCEE Doc. # 6.2, February 2006
Report	Ormsbee, L., Kemp, M., Kellie, A., Benson, J., Matthews, M., Phillip, M., Total Maximum Daily Load Development Paducah Gaseous Diffusion Plant: Existing Data Review, UK/KRCEE Doc. # 6.3, February 2006
Report	Ormsbee, L., Kemp, M., Kellie, A., Benson, J., Matthews, M., Phillip, M., Total Maximum Daily Load Development Paducah Gaseous Diffusion Plant: Data Supplemental Review, UK/KRCEE Doc. # 6.4, February 2006
Report	Ormsbee, L., Albritton, B., Johnson, C., Summary of University of Kentucky Surface Water Metal Data Collection Efforts Relating to Total Maximum Daily Load Development for Little Bayou and Bayou Creeks at the Paducah Gaseous Diffusion Plant 2007-2008, UK/KRCEE Doc. # 14.1, June 2010

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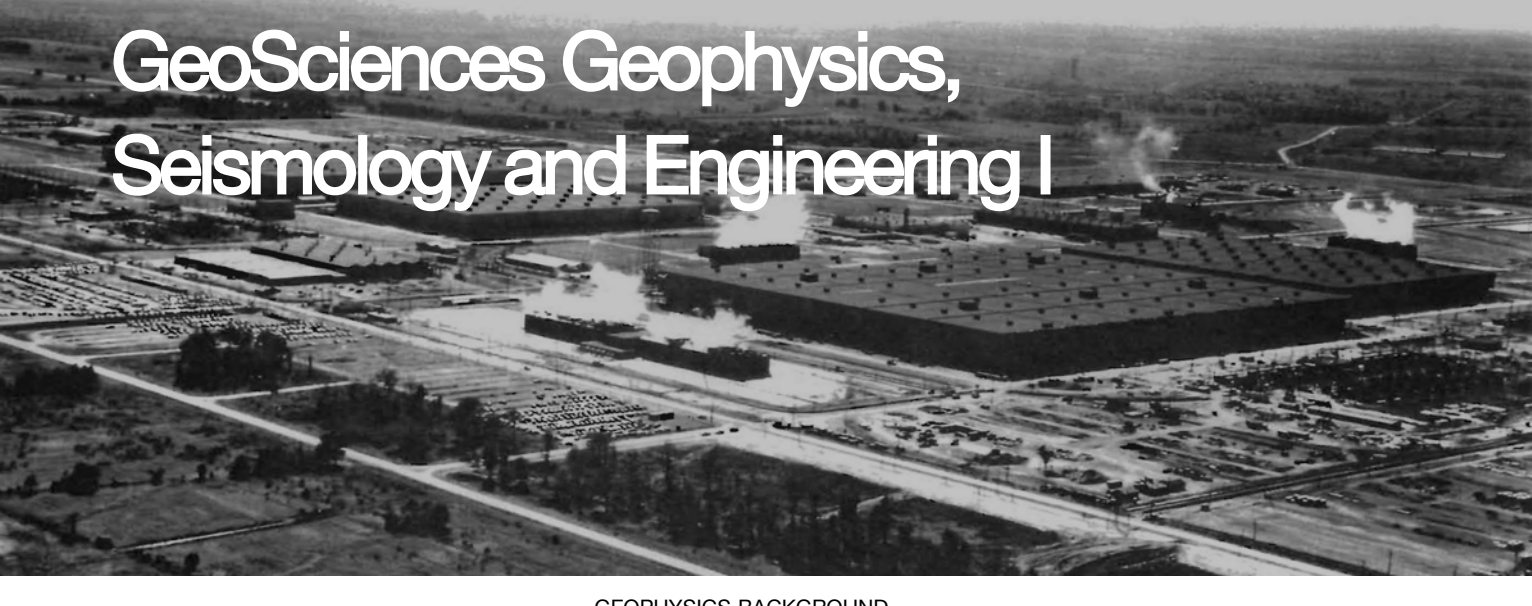
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GeoSciences Geophysics, Seismology and Engineering I

GEOPHYSICS BACKGROUND

The University of Kentucky – Department of Earth and Environmental Sciences – Geophysical Sciences Program has been conducting extensive geophysical characterizations of the PGDP and vicinity since 1992.

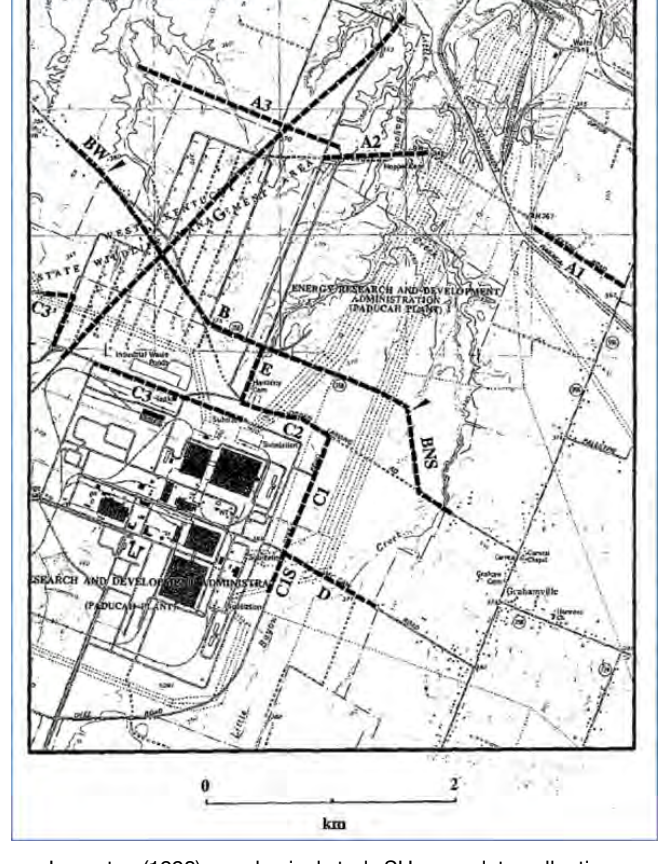
Dr. Ron Street, Ph.D. students Christina Langston & J.B. Harris evaluated historical geophysical data collected at the PGDP. Subsequently, they collected more than 17 km of shear wave (SH-wave) reflection data in the immediate vicinity of the PGDP in an area encompassing the TCE and 99Tc groundwater contaminant plumes (Langston, 1998).

The Department of Earth and Environmental Sciences (formerly Geological Sciences) began recent geophysical investigations at the PGDP in 2005. One M.S. thesis project, 'Structural Features Related to PGDP Groundwater and Plumes' has been completed and a follow-up Ph.D. dissertation study has been completed 'SH-Wave Imaging of Near Surface Controls on Contaminant Plume Migration.'

The eventual 1998 release of the report "ACQUISITION OF SH-WAVE SEISMIC REFLECTION AND REFRACTION DATA IN THE AREA OF THE NORTHEASTWARD TRENDING CONTAMINANT PLUME AT THE PGDP" remains the single largest geophysical investigation conducted at the PGDP.

The "Langston" report identified the major structural features in bedrock underlying the PGDP along the collection lines. Data processing and filtering capabilities of the time allowed the bedrock displacement features to be tracked upward through overlying (younger) and more recent unconsolidated materials to the approximate surface of the Region Gravel Aquifer (RGA).

Rapid advances in geophysical data collection and interpolation capabilities began in the late 1990's and continue today. Pre- and post-processing, filtering, new algorithms and rapid improvement of public and proprietary software allowed researchers to re-process "old" data. Data collected during the 1998 study has been re-processed over the course of two recent geophysical investigations to provide targets for additional field data collection.



Langston (1998) geophysical study SH wave data collection lines

Project Team

- Dr. Ron Street, Geological Sciences-Geophysics, University of Kentucky
- Christina Langston, Ph.D. Student, Geological Sciences-Geophysics, University of Kentucky
- J.B. Harris, Geological Sciences-Geophysics, University of Kentucky
- Dr. Edward Woolery, Earth and Environmental Sciences- Geophysics, University of Kentucky

Project Documents

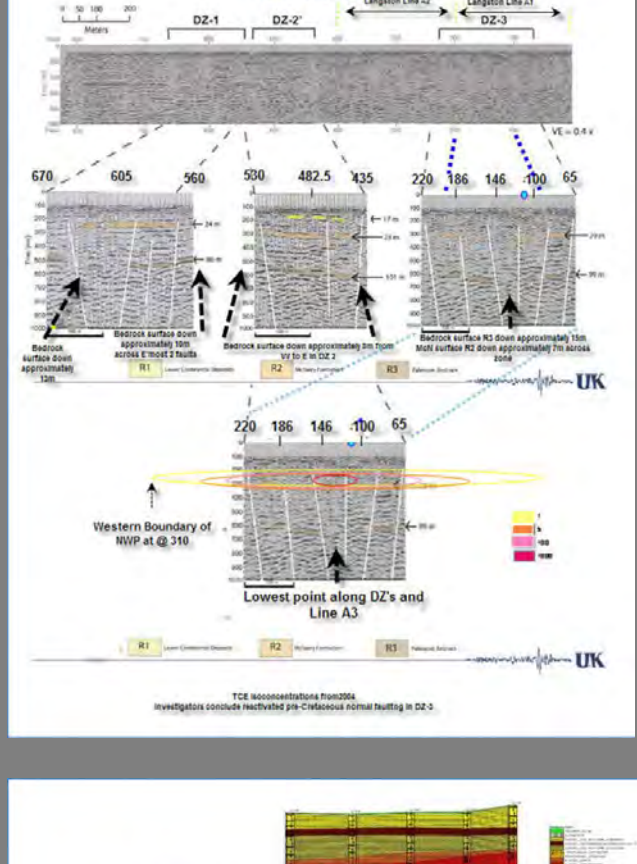
Dissertation & Report	Langston, C., 1998, Acquisition of SH-Wave Seismic Reflection and Refraction Data in the Area of the Northeastward Trending Contaminant Plume at the PGDP, Ph.D. Dissertation, University of Kentucky.
Professional Meeting Presentation	Langston, C., McIntyre, J., Street, R., and Harris, J., 1998, Investigation of the shallow subsurface near the Paducah Gaseous Diffusion Plant using SH-wave seismic methods, SEG Technical Program Expanded Abstracts 1998. https://library.seg.org/doi/abs/10.1190/1.1820628
Journal Article	Woolery, E.W., Street, R., Quaternary Fault Reactivation in the Fluorspar Area Fault Complex of Western Kentucky: Evidence from Shallow SH-wave Reflection Profiles. Seismological Research Letters 73(5):628-639., September 2002.

Geophysical Methods Application to Support Site Activities

University of Kentucky Earth and Environmental Science (EES) geophysical data collection and assessment thesis and dissertation projects have been instrumental in the development and application of SH-wave methods in the shallow sub-surface. From 2003 to 2014, the

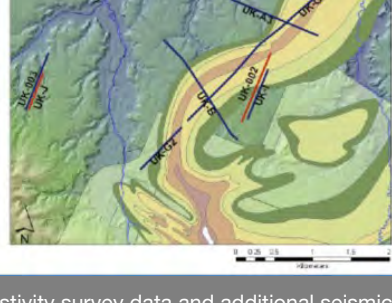
projects expanded PGDP & vicinity geophysical data coverage and successfully applied two iterations of state-of-the-art data processing methods to define the upper and lower surfaces of the Lower Continental Deposits comprising the Regional Groundwater Aquifer (RGA). Both projects re-processed data collected by Langston (1998) and collected additional data on focused targets.

- Through the additional data collection and use of two iterations of improved analytical software the Projects:
- 1) correlated shallow subsurface displacement features with the lateral extent of PGDP's off-site Northwest and Northeast Plumes in the Regional Gravel Aquifer;
 - 2) Utilized electrical resistivity along seismic lines to identify areas of decreased resistivity that correlate with structural features
 - 3) Utilized electrical resistivity to identify a very shallow area of lower resistivity coincident with contaminated groundwater seep discharges in Little Bayou Creek; and
 - 4) Applied a birefringence approach to identify 'fast' and 'slow' flow directions in the RGA material (see Al-Mayahi, 2013).



Methodology

- 1) SH-wave seismic reflection surveys
- 2) Dipole-dipole electrical resistivity arrays



Locations of electrical resistivity survey data and additional seismic reflection survey data collected in the vicinity of the PGDP. (Blits, 2008)

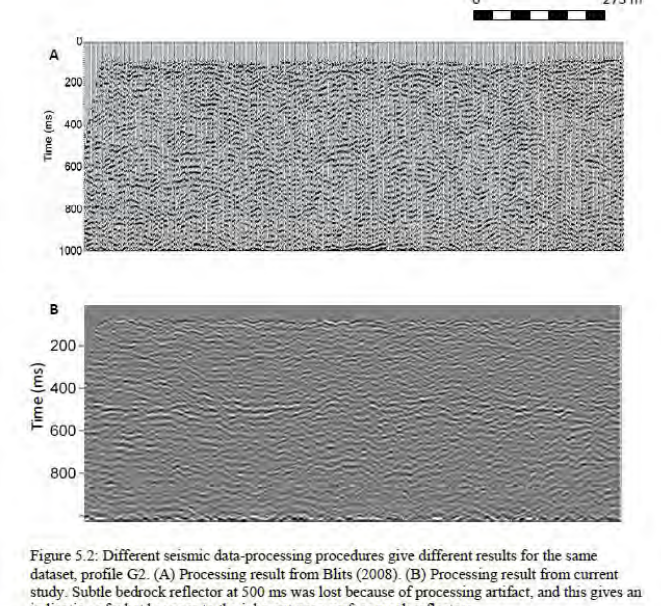


Figure 5.2: Different seismic data-processing procedures give different results for the same dataset, profile G2. (A) Processing result from Blits (2008). (B) Processing result from current study. (C) Processing result from current study. Subtle bedrock reflector at 500 ms was lost because of processing artifact, and this gives an indication of what happens to the inherent near-surface weak reflectors.

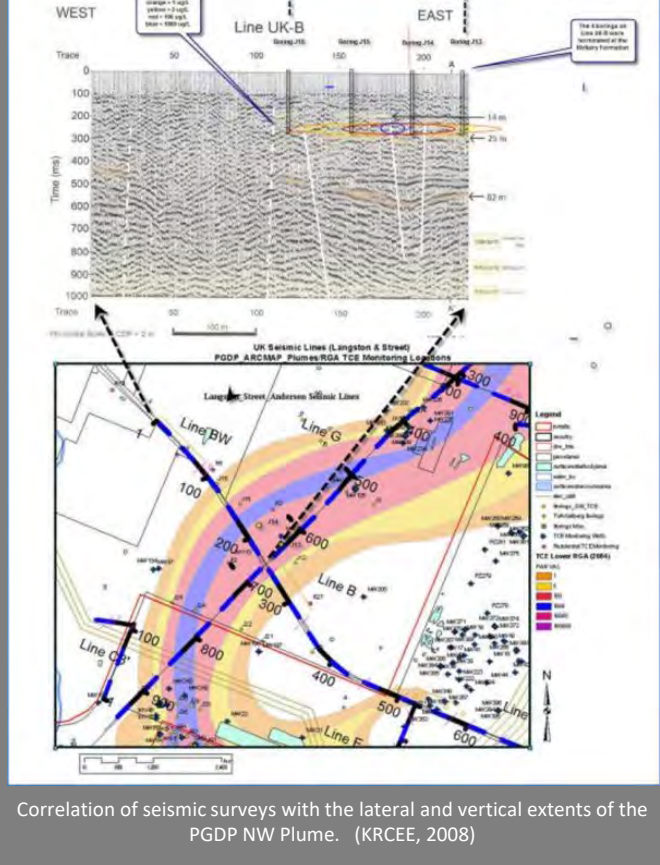
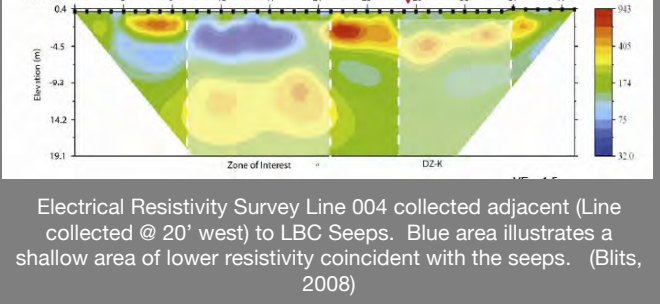
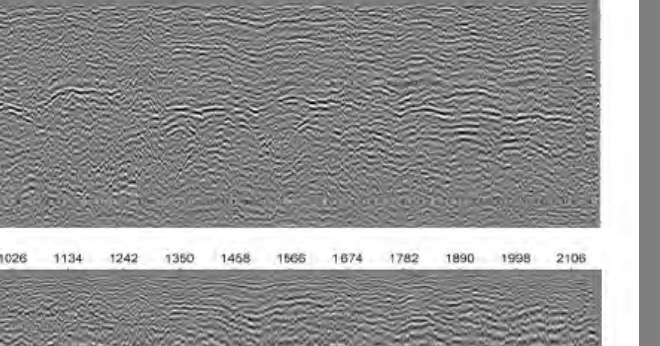


Figure 4.5: SH-wave seismic-reflection profile B. (A) Unmigrated. (B) Depth-migrated uninterpreted. (C) Depth-migrated interpreted.



Correlation of seismic surveys with the lateral and vertical extents of the PGDP NW Plume. (KRCEE, 2008)



Electrical Resistivity Survey Line 004 collected adjacent (Line collected @ 20' west) to LBC Seeps. Blue area illustrates a shallow area of lower resistivity coincident with the seeps. (Blits, 2008)

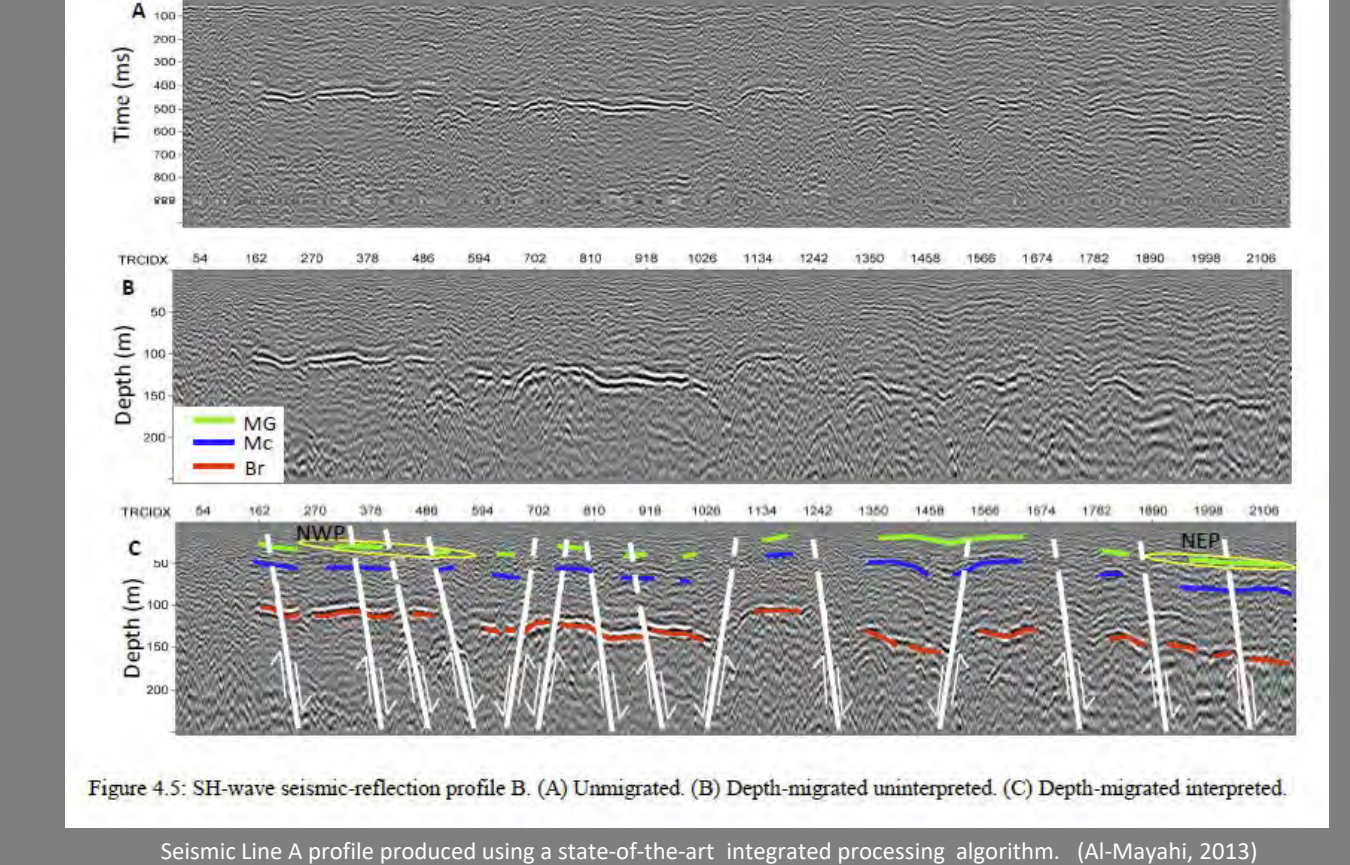


Figure 4.5: SH-wave seismic-reflection profile B. (A) Unmigrated. (B) Depth-migrated uninterpreted. (C) Depth-migrated interpreted.

Seismic Line A profile produced using a state-of-the-art integrated processing algorithm. (Al-Mayahi, 2013)

Project Team

- Dr. Edward Woolery, Geophysics Professor, UK-Earth and Environmental Sciences (PI)
- Cora Blits, Graduate Student, UK-Earth and Environmental Sciences - Geophysics
- Ali Al-Mayahi, Ph.D. Student, UK-Earth and Environmental Sciences - Geophysics

Project Documents

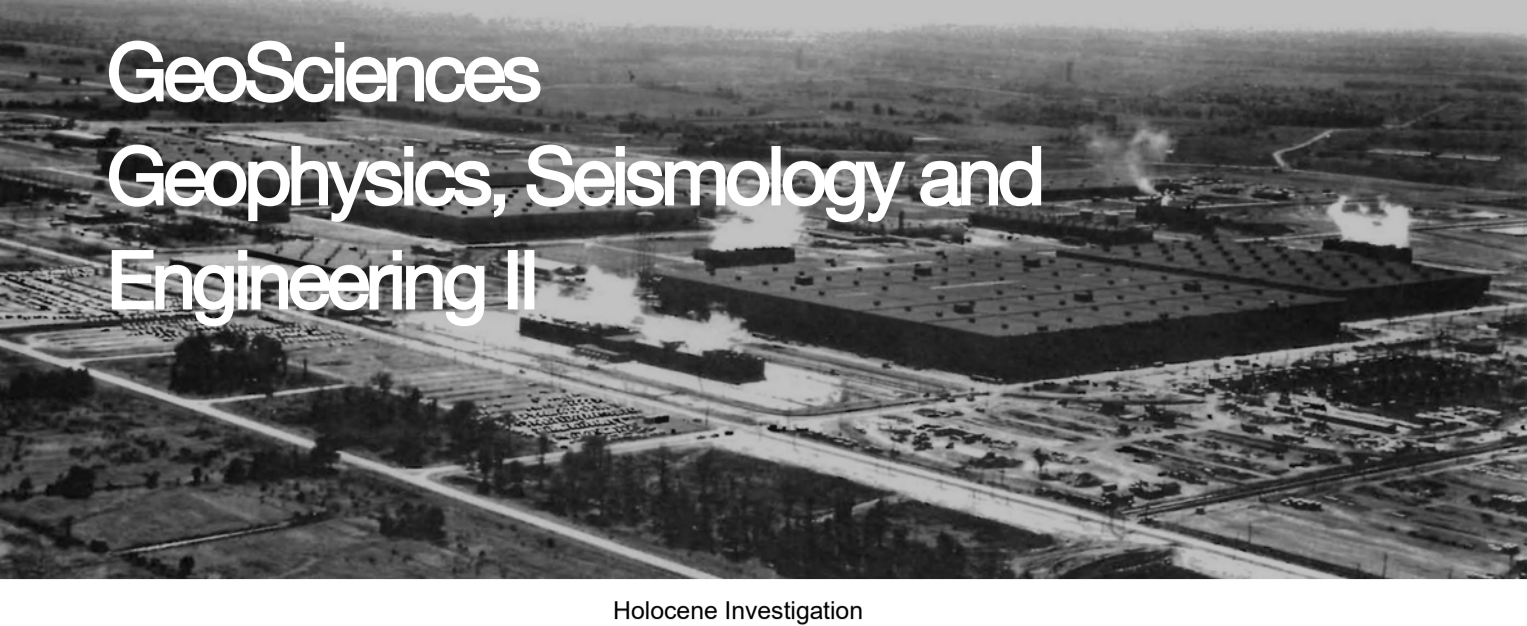
M.S. Thesis	Blits, Cora A., "INTEGRATED GEOPHYSICAL IMAGING OF SUBSURFACE GEOLOGIC CONDITIONS ACROSS A CONTAMINANT PLUME, MCCracken COUNTY, KENTUCKY" (2008). University of Kentucky Master's Theses. 560. https://uknowledge.uky.edu/gradschool_theses/560
Meeting Presentation	Blits, C.A., et al., Integrated Geophysical Imaging Techniques for Detecting Neotectonic Deformation in the Fluorspar Area Fault Complex of Western Kentucky, April 2008, 42nd Annual Meeting of the North Central Section of the Geological Society of America
Meeting Presentation	(KRCEE, 2008) Hampson, S.K., Blits, C.A., & Woolery, E.W., Correlation of Recently Updated SH-Wave Seismic Line Interpretations to an Offsite Transect of the PGDP Northwest Plume (TCE). KRCEE Quarterly Meeting Presentation, 2008.
Meeting Presentation	Hampson, S.K., & Woolery, E.W., The Future of PGDP Geophysical & Stratigraphic Modeling. KRCEE Quarterly Meeting Presentation, 2009.
Meeting Poster	SH-Wave Imaging of Potential Near-Surface Geologic Controls on Contaminant Plume Migration — Fluorspar Area Fault Complex, Western Kentucky, Seismologic Society of America Annual Meeting(2011), University of Texas.
Dissertation	Al-Mayahi, Ali Z., "SHEAR-WAVE IMAGING AND BIREFRINGENCE IN A COMPLEX NEAR-SURFACE GEOLOGICAL ENVIRONMENT" (2013). Theses and Dissertations—Earth and Environmental Sciences. 12. https://uknowledge.uky.edu/ees_etds/12
Journal Article	Woolery, E.W. and Al-Mayahi, A. Shear-Wave Birefringence Measurements in Faulted Near-Surface Sediment (Fluorspar Area Fault Complex, Central United States). Bulletin of the Seismological Society of America (2014). 104(3):1540
Journal Article	Ali Al-Mayahi, Edward W. Woolery, Fault-controlled contaminant plume migration: Inferences from SH-wave reflection and electrical resistivity experiments, Journal of Applied Geophysics, Volume 158, 2018, Pages 57-64.
Journal Article	Woolery, Edward W. and Al-Mayahi, Ali, "Northeast-Oriented Transpression Structure in the Northern New Madrid Seismic Zone: Extension of a Shear Zone across the Reeffoot Fault Stepover Arm" (2014). Earth and Environmental Sciences Faculty Publications. 2. https://uknowledge.uky.edu/ees_facpub/2 (MOVE TO CUSSO)

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GeoSciences Geophysics, Seismology and Engineering II

Holocene Investigation

This Holocene Investigation was an in-depth [Paleoseismic](#) fault hazard investigation for a proposed expansion of the C-746-U landfill located at the Paducah Gaseous Diffusion Plant (PGDP), in Paducah, Kentucky. The purpose of the fault hazard investigation was to determine if Holocene-active fault displacement is present beneath the footprint of the proposed landfill expansion.

The Code of Federal Regulations (CFR), Subtitle D, Title 40, Part 258, subpart B (258.13) requires that disposal facilities (such as the C-746-U landfill and possible expansions) be located more than 200 feet from a fault that has had surface displacement within [Holocene time](#) (i.e., the past 11,000 years).

The planned expansion is located directly north of the present-day C-746-U landfill. Previous geophysical studies (Blackhawk 2003) within the PGDP site and vicinity identified possible northeast-striking faults beneath the proposed landfill expansion (Below). Prior to this investigation the existence, locations, and ages of these inferred faults have not been confirmed through independent subsurface exploration.

The Holocene Investigation geologic assessment included (a) review of relevant geologic and geotechnical data from the site vicinity, (b) analysis of detailed aerial photography, (c) field reconnaissance of the site vicinity and other important sites of previous investigations, (d) collection and stratigraphic analysis of 86 subsurface sediment cores, (e) laboratory chronological (age-dating) analyses, and (f) preparation of this report. These activities were completed at or above the accepted standard-of-practice for geologic investigations in the mid-continent region; overall this investigation represents an effort that exceeds previous levels of investigation for site-specific fault-rupture assessments in the mid-continent.

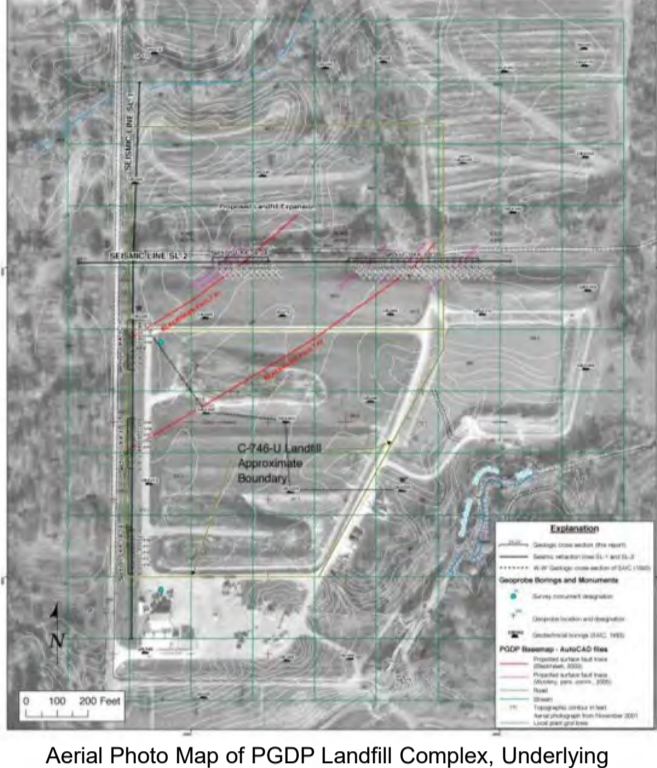
The investigation was completed as a collaborative effort involving local, regional, and national paleoseismology subject-matter experts; William Lettis & Associates, Inc., Earth and Environmental Sciences (Geology) Department of the University of Kentucky, and the University of Chicago.

Technical peer review of the approach, methods, preliminary results and final conclusions of this study have been provided by geoscientists and paleoseismic technical experts with the Kentucky Geological Survey, the Illinois Geological Survey,

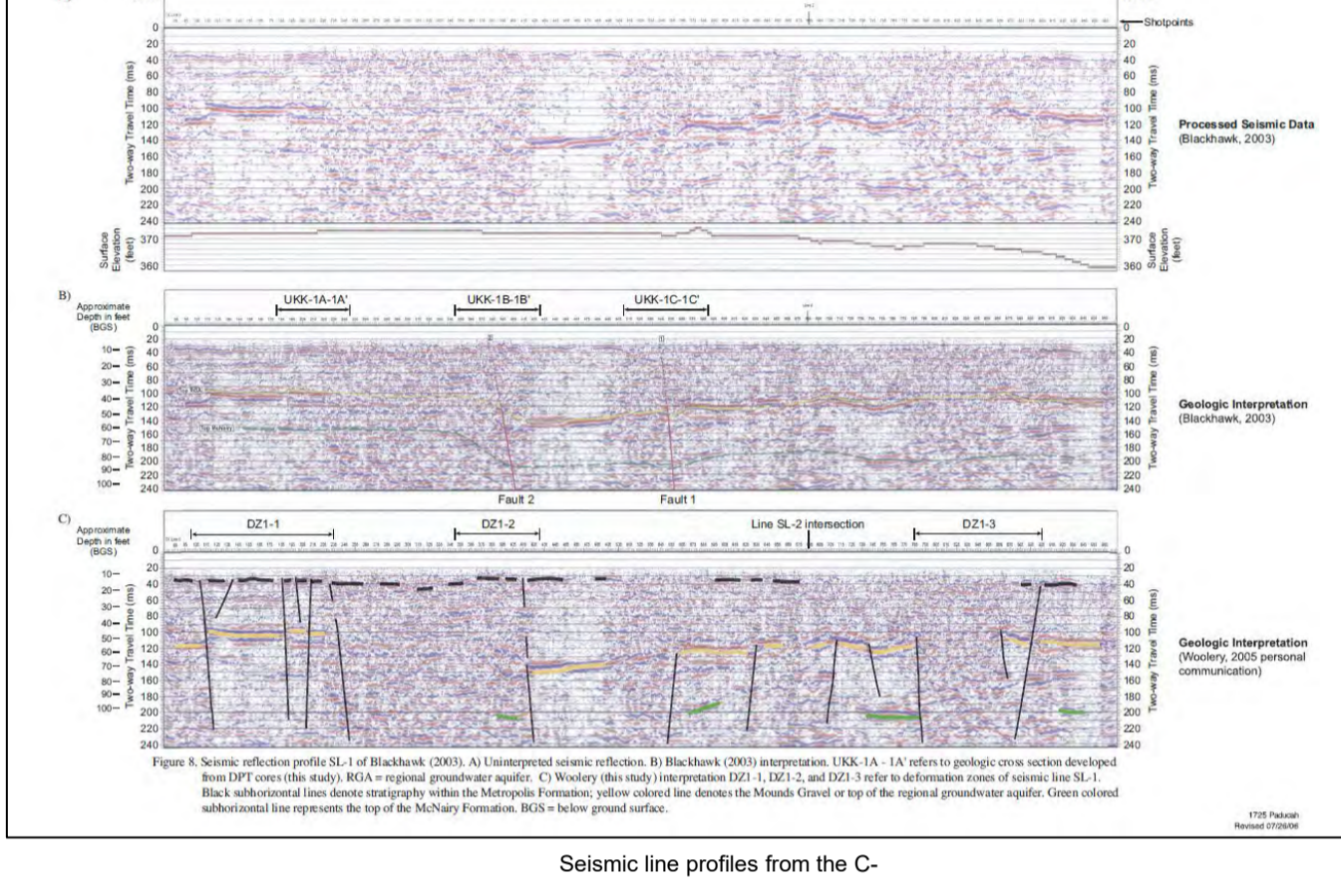
the University of Memphis, the University of Illinois – Champaign, Science Applications International Corporation (SAIC), and M. Tuttle & Associates.

Based on extensive data collection and analysis followed by paleoseismic subject-matter-expert review there is NOT evidence of Holocene Displacement in the study area, i.e. displacement of materials within the last 11,000 years. If late Quaternary displacement has occurred beneath the site, the most-recent displacement occurred following deposition of the Unnamed Intermediate Silt between approximately 53,600 and 75,500 years ago.

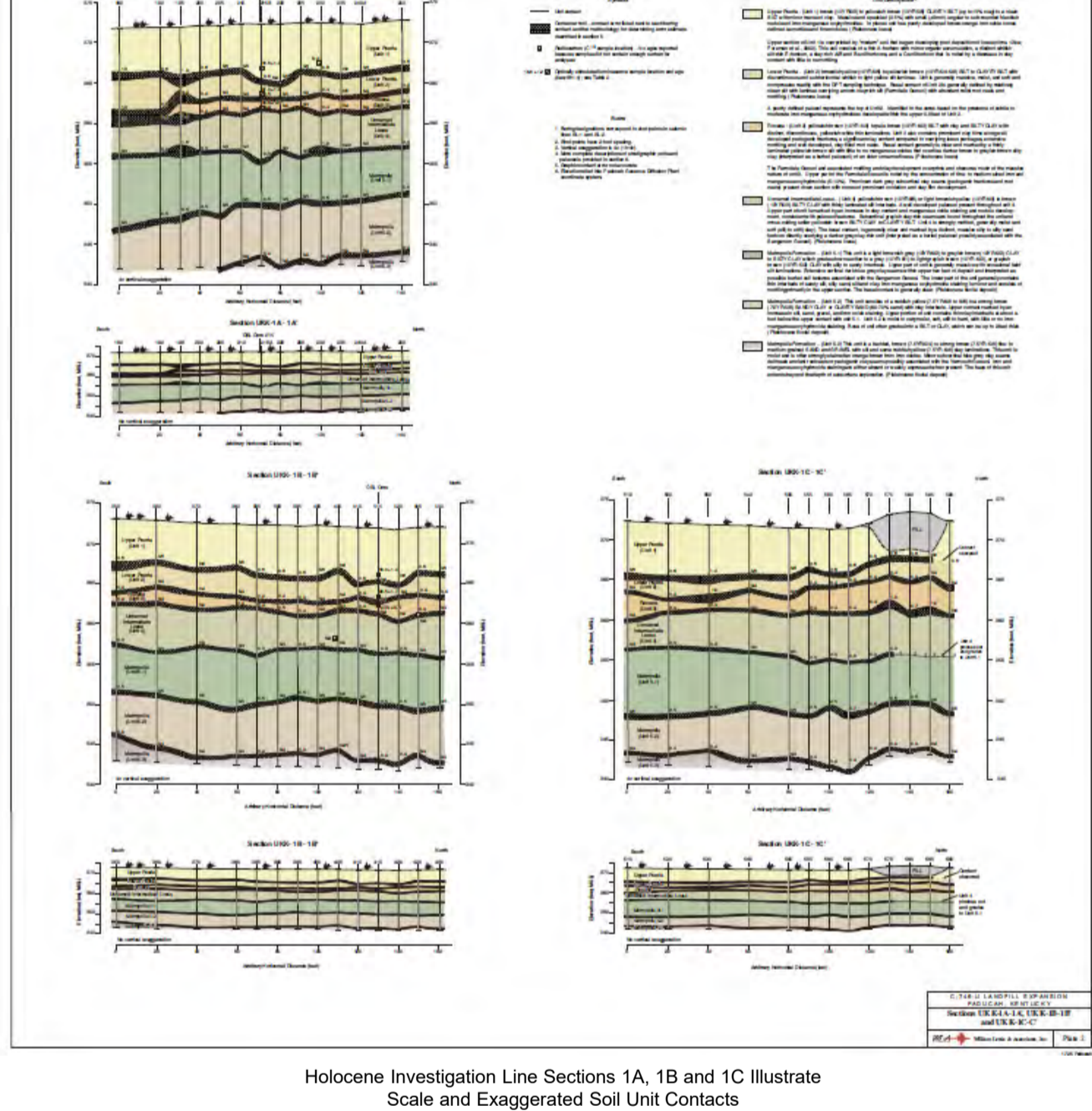
The Holocene Investigation Report presents the findings of a fault hazard investigation for a proposed expansion of the C-746-U landfill located at the Paducah Gaseous Diffusion Plant (PGDP), in Paducah, Kentucky.



Aerial Photo Map of PGDP Landfill Complex, Underlying Interpreted Faults (Blackhawk 2003), and Holocene Project Data Collection Points.



Seismic line profiles from the C-



Holocene Investigation Line Sections 1A, 1B and 1C Illustrate Scale and Exaggerated Soil Unit Contacts

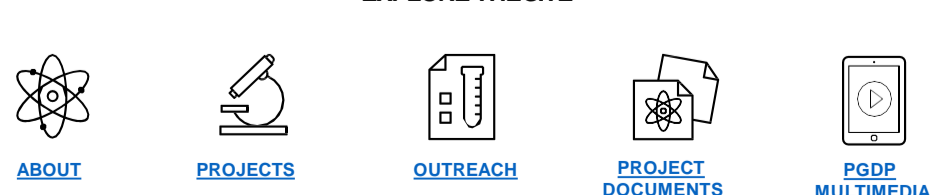
Project Team

- Dr. Edward Woolery**, Geophysics Professor, Earth and Environmental Sciences, University of Kentucky (PI)
- Dr. Zhenming Wang**, Seismologist and Section Head (Geological Hazards), Kentucky Geological Survey, University of Kentucky
- Dr. Martitia (Tish) Tuttle** – Tuttle and Associates (formerly Univ of Maryland)
- Dr. Roy Van Arsdale** – University of Memphis
- Dr. John Nelson** – Illinois Geological Survey
- Dr. Leon Follmer** – Illinois Geological Survey
- Dr. Bill Lettis**, Lettis & Assoc. / Walnut Grove, CA
- Dr. John Baldwin**, Lettis & Assoc. / Walnut Grove, CA
- Dr. Keith Kelson**, Lettis & Assoc. / Walnut Grove, CA
- Robert Givler**, Lettis & Assoc. / Walnut Grove, CA
- Sean Sundermann**, Lettis & Assoc. / Walnut Grove, CA
- Ken Davis**, Paducah Remediation Services
- Dr. Dave Amick**, Scientific Applications International Corporation, Augusta
- Mr. Marshall Davenport** – Jacobs Engineering, Oak Ridge
- Steve Hampson** - KRCEE

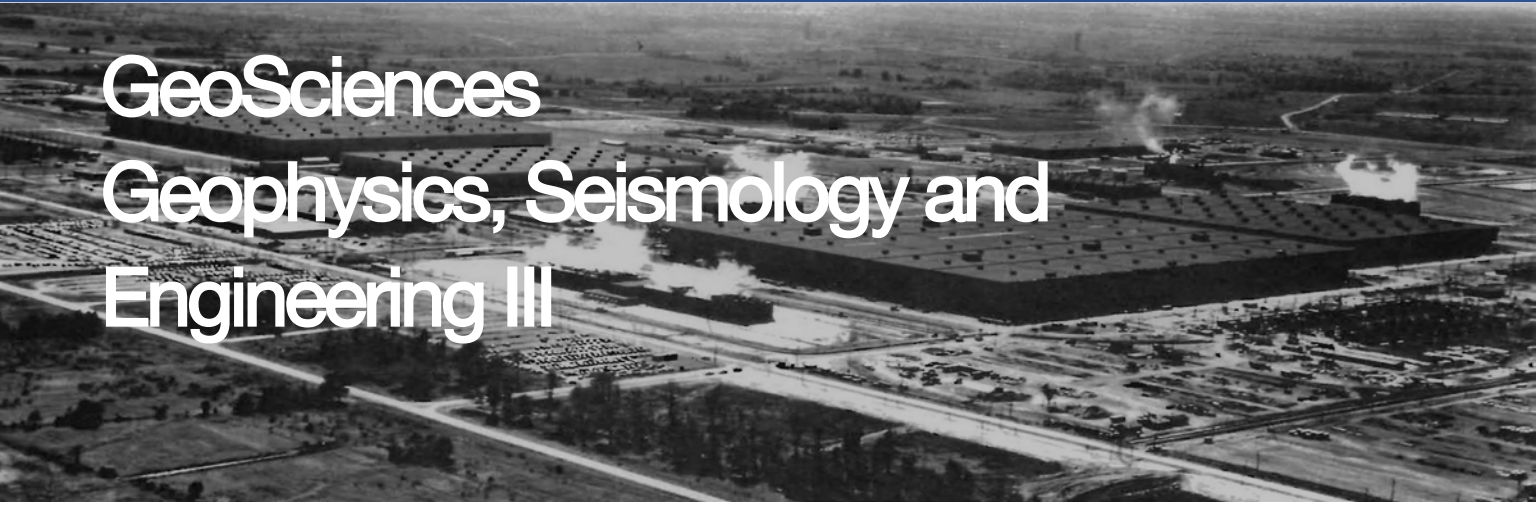
Project Documents

U Landfill Project Review to PPPO	Review ULF Project: Further Seismic Investigation Recommendation, April 2004
SME Supporting Report	Follmer, L., Soil Stratigraphy of the C-740-U Landfill Site, October 2005
SME Supporting Report	Nelson, J., Tuttle, M., and Van Arsdale, R., Determination of Holocene Displacement at the C-746-U Landfill – Project Independent Technical Review (ITR), September 2005.
Report	INVESTIGATION OF HOLOCENE FAULTING, Proposed U-Landfill Expansion Paducah Gaseous Diffusion Plant, Paducah, Kentucky. William Lettis & Associates, Walnut California, July 2006.
Report Plates and Figures	INVESTIGATION OF HOLOCENE FAULTING, 2006, Project Report Figures and Plates
Symposium Poster	Field Investigation of Holocene Faulting at the Proposed C-746-U Landfill, KWRRRI Technical Symposium, Poster Presentation, 2007
Meeting Presentation	Tuttle, M., The NMSZ & Evidence of Holocene Displacement in the Jackson Purchase Proceedings of KRCEE Technical Symposium, 2007
Meeting Presentation	Baldwin, John, Kelson, K., Sundermann, S., Woolery, E.W., Hampson, S., Field Investigation of Holocene Displacement at the Proposed C-746-U Landfill Expansion, Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Proceedings of the 2007 KRCEE Technical Symposium.
Meeting Poster	Woolery, E., Kelson, K., Baldwin, J., Givler, R., Hampson, S., Site-Specific Fault Rupture Hazard Assessment – Fluorspar Area Fault Complex, Western Kentucky (PGDP), American Geophysical Union (AGU) Fall Meeting, 2008
Journal Article	Woolery, E., Baldwin, J., Kelson, K., Hampson, S., Givler, R., Sundermann, S., Site-specific Fault Rupture Hazard Assessment—Fluorspar Area Fault Complex, Western Kentucky, Seismological Research Letters (2009) 80 (6): 1035–1044.

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GeoSciences Geophysics, Seismology and Engineering III

Seismic Sciences: Background and Issues

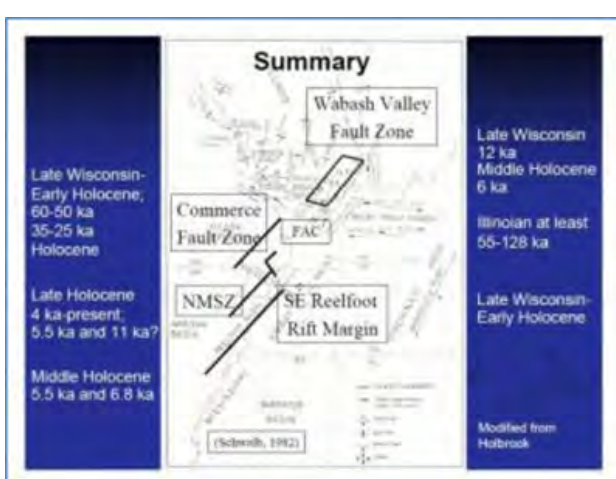
Far western Kentucky lies within the northeastern extent of the New Madrid Seismic Zone (NMSZ), an area that holds intrigue for historians, geologists, geophysicists, engineers, seismologists and paleoseismologists. New Madrid, Missouri sits astride one of the notable great bends in the Mississippi River, Kentucky Bend. New

Madrid also marks the epicenter of the Great New Madrid Earthquakes of 1811-12. More than 1,000 earthquakes occurred during those 2 years with the strongest up to magnitude 8. The ground liquefied, sand boiled to the surface, the mighty Mississippi flowed backwards and the bootheel of Kentucky, across the river from New Madrid, raised and fell depending upon where you were standing. The largest earthquakes of 1811-12 remain the strongest earthquakes to have occurred in the continental U.S. away from plate margin subduction zones.

The PGDP and the city of Paducah are located 55+ miles northeast of New Madrid, Mo. and straddle 3 known seismic zones: the Wabash Valley Seismic Zone (WVSZ), Fluorspar Area Fault Complex (FAC or FAFC) and the NMSZ.

The FAC, which is the zone in closest proximity to the PGDP, has not been active in the last 55,000 years. Portions of the WVSZ have been active in the last 6,000 years and the NMSZ remains active today. PGDP's location relative to known seismic zones prompted the 1988 installation of seismic joints in enrichment process piping to ensure system integrity in the event of modern seismic events in the region.

For public officials, engineers, seismic scientists, and local folk, intrigue may be replaced by the challenges of defining and understanding the history and occurrence of earthquakes in the region, their likelihood of recurrence, and the bedrock to surface response at given locations. Defensible and actionable characterization of the seismic hazards and resultant risks inherent to specific locations remain a challenge for all, especially the technical and regulatory community.



Seismic features in the vicinity of the PGDP.



Seismic joints added to Enrichment Process piping in 1998 as part of seismic engineering safety measures.

Project Participants

- Dr. Edward Woolery** - Geophysics Professor, Earth & Environmental Sciences, University of Kentucky (Co-PI)
- Dr. Zhenming Wang** - Seismologist and Section Head (Geological Hazards), Kentucky Geological Survey (Co-PI)
- Alice Orton** - Graduate Student, Earth and Environmental Sciences, University of Kentucky
- Jonathan McIntyre** - Kentucky Geological Survey, University of Kentucky
- Cora Blits** - Graduate Student, UK-Earth and Environmental Sciences - Geophysics
- Steve Hampson** - KRCEE

Project Documents

Public Meeting Presentation	Overview of Report "Seismic Issues for Consideration in Site Selection and Design of a Potential On-Site CERCLA Waste Disposal Facility at the Paducah Gaseous Diffusion Plant", Presentation to PGDP Site Specific Advisory Board (SAAB), 2001.
Professional Publication	Wang, Z. (compiler), 2003, Proceedings of The Kentucky NEHRP Seismic Hazards and Design Maps Workshop, November 18, 2002, Lexington, Kentucky, Kentucky Geological Survey, ser. 12, Special Publication 5, 38p.
Symposium Presentation	Anderson, Cora, Observed Seismicity in the Jackson Purchase Region of Western Kentucky Between January 2003 and June 2005, Proceedings of the 2007 KRCEE Technical Symposium.
Symposium Presentation	Woolery, E.W., Western Kentucky Seismicity and Neotectonics: Integrated Geophysical and Geological Solutions, Proceedings of the 2007 KRCEE Technical Symposium.
Project Brief	List of Kentucky Geological Survey and UK Department of Earth and Environmental Sciences Activities Related to the Seismic Hazard Assessment at PGDP, KRCEE p21.8 2007d.
Congressional Briefing	Cobb, J.C., Seismic Policy and Regulation in Western Kentucky, Kentucky Congressional Office Briefing, July 2009.
Journal Article	Wang, Z., 2011, Seismic Hazard Assessment: Issues and Alternatives, Pure and Applied Geophysics, 168: 11–25.
Book Chapter	Wang, Z., 2014, Seismic Design in Western Kentucky: Issues and Alternatives. Seismic Hazard Design Issues in the Central United States, in Beavers, J., and Uddin, N., eds, Seismic Hazard Design Issues in the Central United States, Chapter 9, p 111-141, doi: 10.1061/9780784413203.ch09.
Professional Meeting Presentation	Wang, Z., 2014, Comparison of Design Ground Motion between Coastal California and the Central United States, Proceedings of the Tenth U.S. National Conference on Earthquake Engineering Frontiers of Earthquake Engineering, July 21-25, 2014, Anchorage, Alaska (DOI: 10.4231/D3NP1WJ9K), p. 8020–8030.
Thesis	Orton, A., SCIENCE AND PUBLIC POLICY OF EARTHQUAKE HAZARD MITIGATION IN THE NMSZ, M.S. Thesis, 2014 (http://uknowledge.uky.edu/ees_etds/19)
Professional Publication	Orton, A., Woolery, E., and Wang, Z.W., Earthquake hazard mitigation the NMSZ (Report of Investigations 32, Series XII, Kentucky Geological Survey (KGS) Publication, 2016.
Journal Article	Wang, Z., Orton, A., Wang, L., and Woolery, E.W., 2016, Seismic hazard mapping and mitigation policy development in the central United States and western China, Natural Hazards, 81: 387–404, doi:10.1007/s11069-015-2086-y.

Kentucky Strong Motion Seismic Monitoring Network

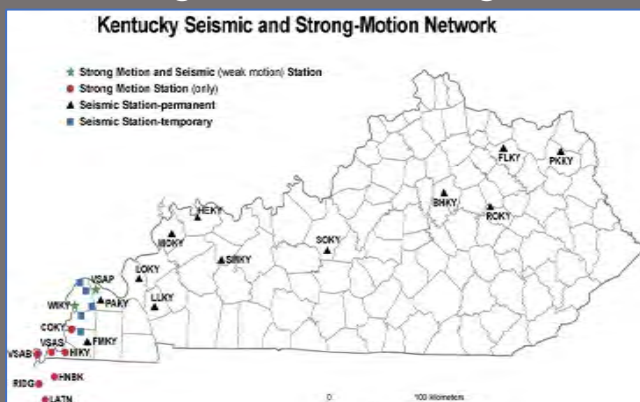
The Kentucky Seismic and Strong Motion Monitoring Network (KSSMN) is a series of 26 monitoring stations across the Commonwealth. KSSMN can monitor any earthquake with a magnitude 2.0 or larger within

Kentucky and includes monitoring of significant blasts, mine collapses, and explosions.

Data from 12 seismic stations are continuously recorded as part of the "near" real-time monitoring system. The system "triggers" to record events of note to be reviewed. The real-time network utilizes the Kentucky Early Warning System (KEWS) for data transmission.

Data from remaining stations are downloaded weekly via modem (weekly) or are downloaded manually on a quarterly basis and reviewed.

KSSMN recorded numerous earthquakes since January 1, 2006. Instruments available to rapidly begin aftershock studies for large events.



Kentucky Seismic and Strong Motion Network (KSSMN) Installation Locations. Location VSAP is in the West Kentucky Wildlife Management Area adjacent to the PGDP.

Project Participants

- Dr. Edward Woolery** - Geophysics Professor, Earth & Environmental Sciences, University of Kentucky (Co-PI)
- Dr. Zhenming Wang** - Seismologist/Section Head (Geological Hazards), Kentucky Geological Survey, University of Kentucky (Co-PI)
- Dr. Seth Carpenter** - Seismologist, Kentucky Geological Survey, University of Kentucky
- Dr. Ron Street** - Geophysics Professor (Emeritus), Earth and Environmental Sciences, University of Kentucky
- Jonathan McIntyre** - Kentucky Geological Survey, University of Kentucky
- Cora Blits** - Graduate Student, UK-Earth and Environmental Sciences - Geophysics
- Steve Hampson** - KRCEE

Project Documents

Professional Publication	Wang, Z., E.W. Woolery, and B. Shi, 2003, Observed Seismicity (Earthquake Activity) in the Jackson Purchase Region of Western Kentucky: January through June 2003, Kentucky Geological Survey, ser. 12, Special Publication 6, 16p.
Project Report	Woolery, E.W., Wang, Z., Seismic Velocity Measurements at Expanded Seismic Network Sites, 2008, OSTI KRCEE8.3 2005.
Project Report	Woolery, E., Wang, Z., FINAL TECHNICAL REPORT: SEISMIC VELOCITY MEASUREMENTS AT EXPANDED SEISMIC NETWORK SITES, January 2005
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Symposium Presentation	McIntyre, J., Wang, Z., Woolery, E.W., Kentucky Seismic and Strong Motion Network - Including the Central United States Seismology Observatory (CUSSO), 2007 KRCEE-PGDP Technical Symposium, 30 October 2007.
Project Report	Wang, Z. and Woolery, E.W., Operation and Maintenance of the Seismic Network in the Vicinity of the Paducah Gaseous Diffusion Plant April 2009–September 2012, Final Report, Kentucky Geological Survey Contract Report 5, Series XII, 2013.
Professional Publication	Wang, Z., and Woolery, E., 2013, Operation and Maintenance of the Seismic Network in the Vicinity of the Paducah Gaseous Diffusion Plant: April 2009–September 2012, Kentucky Geological Survey, ser. 12, Contract Report 5, 11 p.
Professional Publication	Wang, Z., Woolery, E.W., and Carpenter, N.S., 2019, An update of seismic monitoring and research in the vicinity of the Paducah Gaseous Diffusion Plant: January 2013–December 2017, Kentucky Geological Survey, ser. 13, Report of Investigations 6, 19 p.
Professional Publication	Wang, Z., Carpenter, N.S., and Woolery, E.W., 2020, An update of seismic monitoring and research in the vicinity of the Paducah Gaseous Diffusion Plant: January 2018–December 2019, Kentucky Geological Survey, ser. 13, Report of Investigations 12, 21 p., doi.org/10.13023/kgs.ri12.13.
Professional Publication	Street, R.L., Wang, Z., Carpenter, N.S., and Woolery, E.W., 2021, The Kentucky Seismic and Strong Motion Network: History, Service, and Research, Kentucky Geological Survey, ser. 13, Special Publication 1, 18p.

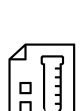
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PGDP MULTIMEDIA

GeoSciences Geophysics, Seismology and Engineering IV

Central United States Seismic Observatory (CUSO)

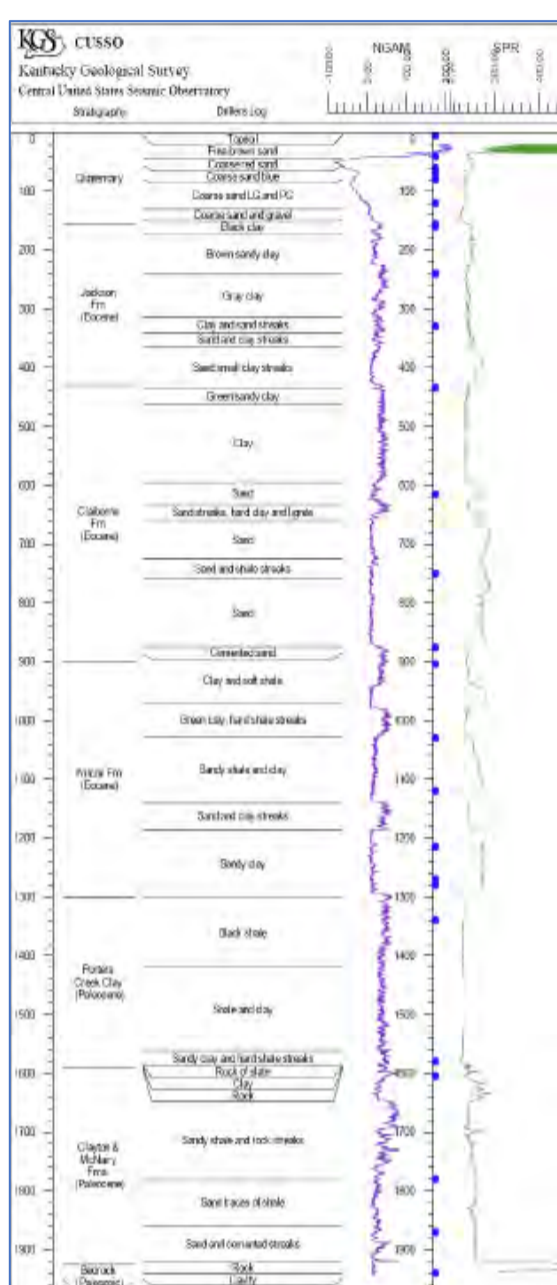
The Central United States Seismic Observatory (CUSO) was installed and is monitored in collaboration with DOE, USGS, and KGS to characterize seismicity and soil column response from bedrock to ground surface in the centroid of the New Madrid Seismic Zone. The

1900-foot deep CUSO installation located at Sassafras Ridge, near the “bootheel” of Kentucky, is instrumented to monitor three (3) subsurface horizons. Data collected from CUSO will be used to refine models used by architects and engineers to design ground-motion safety features.

After 15 years of operation, CUSO received maintenance upgrades in CY’s 2020 and 2021. The KGS Hazards Section publishes semi-annual reports summarizing CUSO and network data collection efforts and research findings.



CUSO Installation at Sassafras Ridge, Kentucky.



CUSO Stratigraphic and geophysical well log interpretations. Stratigraphic interpretation from cuttings at the well head.

Project Participants

- Dr. Edward Woolery** - Geophysics Professor, Earth & Environmental Sciences, University of Kentucky (Co-PI)
- Dr. Zhenming Wang** - Seismologist and Section Head (Geological Hazards), Kentucky (Co-PI)
- Dr. Ron Street** - Geophysics Professor (Emeritus), Geological Sciences, University of Kentucky
- Dr. Seth Carpenter** – Seismologist, Kentucky Geological Survey
- Jonathan McIntyre** – Seismologist, Kentucky Geological Survey
- Steve Hampson** - KRCEE

Project Documents

Project Brief	CUSO_Deep_Hole_Proposal_Letter_DOE
Project Brief	CUSO Deep Hole Proposal Research Objectives, KRCEE 21.5 2005d.
Press Release	Deep Hole Project (CUSO) Press Release, KRCEE 21.2 2006.
Journal Article	Wang, Z. and Woolery, E.W., Recordings from the Deepest Borehole in the New Madrid Seismic Zone, <i>Seismological Research Letters</i>, Volume 77, No. 2, March/April 2006.
Professional Meeting Presentation	Wang, Z. and Woolery, E.W., THE CENTRAL U.S. SEISMIC OBSERVATORY: SOME PRELIMINARY RESULTS.
Professional Meeting Poster	KRCEE 21.7 2006d Poster CUSO and Network.
Press Release	“Researchers complete seismic borehole in Kentucky”, <i>American Association for the Advancement of Science, Eureka Alert</i>, December 13, 2006.
Project Report	Final Technical Report, Central United States Seismic Observatory: Phase 1 Borehole Installation, March 2008 (KRCEE 21.4 2008d).
Professional Meeting Poster	Wang, Z., Woolery, E.W. and McIntyre, J., The Central United States Seismic Observatory (Overview), October 2009.
Journal Article	Wang, Z., and E.W. Woolery, 2006, Recordings from the Deepest Borehole in the New Madrid Seismic Zone, <i>Seismological Research Letters</i>, 77: 131-136.
Professional Meeting Abstract	McIntyre, J., Wang, Z., Woolery, E.W., THE CENTRAL U.S. SEISMIC OBSERVATORY (CUSO), <i>Seismological Society of America Meeting 2010</i> (Abstract)
KRCEE Meeting Presentation	Al Mayahi, A., Woolery, E.W., Wang, Z., CUSO Seismic Modeling Presentation, July 2010.
Professional Meeting Presentation	Wang, Z., Woolery, E.W., and Hu, C., 2012, The Central United States Seismic Observatory: Site Characterization, <i>Proceedings of the 5th International Conference on Environmental and Engineering Geophysics</i>, June 15-18, 2012, Changsha, China, p. 223–227.
Project Report	Woolery, E.W., Wang, Z., Operation and Maintenance of the Kentucky Seismic Network in the Vicinity of PGDP February 2013. Final Report, February 2013.
Journal Article	Woolery, E.W., Wang, Z., Carpenter, N. Seth, Street, R., Brengman, C., The Central United States Seismic Observatory: Site Characterization, Instrumentation, and Recordings, <i>Seismological Research Letters</i>, Volume 87, No. 1, January/February 2016.
Journal Article	Carpenter, N.S., Wang, Z., Woolery, E.W., and Rong, M., Estimating Site Response with Recordings from Deep Boreholes and HVSR: Examples from the Mississippi Embayment of the Central United States, <i>Bulletin of the Seismological Society of America</i>, Vol. 108, No. 3A, pp. 1199–1209, June 2018.
Current/Ongoing Project Proposal	PROPOSAL to DOE - Integrated Geophysical Surveying of Seismotectonic Structure in the New Madrid Seismic Zone, Central United States, 2018.
Journal Article	Wang, Z., Carpenter, N.S., and Woolery, E.W., 2019, Horizontal-to-vertical spectral ratio of S-waves and SH-wave transfer functions at the vertical seismic and strong-motion arrays in the central United States, <i>Journal of Applied Geophysics</i>, 160: 64–71, doi:10.1016/j.jappgeo.2018.10.017.
Professional Meeting Poster	Burford, Jr., D.D., et.al., INTEGRATED SEISMIC-REFLECTION AND MICROGRAVITY IMAGING ACROSS THE SOUTHERN BOUNDARY OF THE CHARLESTON UPLIFT, NEW MADRID SEISMIC ZONE, USA, 68th Annual Meeting of the Southeastern Section of the Geological Society of America. Abstract and Poster, March 2019.

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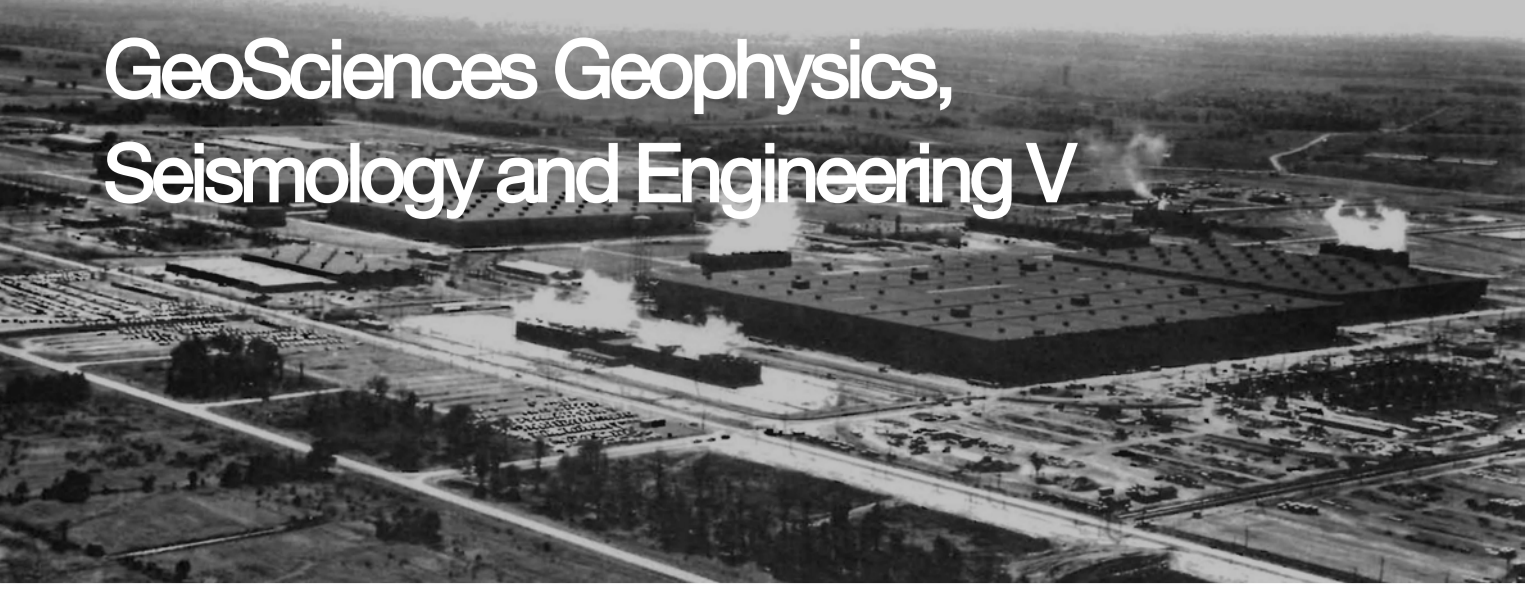
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[PGDP MULTIMEDIA](#)



Seismic Hazard and Risk Assessment

Seismic Hazard and Risk Assessment projects included research into, development of, and recommendations for the application of seismic hazard assessment methods for the Jackson Purchase Region of western Kentucky.

Project Participants

- Dr. Zhenming Wang - Seismologist and Section Head (Geological Hazards), Kentucky (Co-PI)
- Dr. Edward Woolery - Geophysics Professor, Earth and Environmental Sciences, University of Kentucky (Co-PI)
- Dr. Seth Carpenter - Seismologist, Kentucky Geological Survey, University of Kentucky
- Dr. Baoping Shi, Postdoctoral Researcher, Kentucky Geological Survey, University of Kentucky
- Alice Orton - Geophysics Graduate Student, Earth and Environmental Sciences, University of Kentucky
- Steve Hampson - KRCEE

Project Documents

Workshop Presentation	Woolery, E.W., SEISMIC INVESTIGATION: Earthquake Input Parameters for the PGDP Region, Workshop Presentation, JULY 2004.
Professional Meeting Poster	Wang, Z., Woolery, E.W., Shi, B., The Vertical Strong-Motion Stations of the Kentucky Strong Motion Network, Seismological Society of America, 2004 Eastern Section Annual Meeting, Poster Presentation, 2004 (KRCEE p11.8, 2004d).
Professional Meeting Presentation	Wang, Z., E.W. Woolery, B. Shi, and J. D. Kiefer, 2004, What is the Maximum Considered Earthquake Ground Motion (MCE)?, the 2004 EERI Annual Meeting, February 4-7, 2004, Los Angeles, CA.
Professional Meeting Presentation	Wang, Z., E.W. Woolery, B. Shi., and J.D. Kiefer, 2004, IBC and IRC 2000 and Seismic Hazard Assessment in the Central United States: An Example of Miscommunication between the Policy-Makers and Seismologists, the 76th Annual Meeting of the Eastern Section of the Seismological Society of America, Blacksburg, Virginia, October 31-November 2, 2004.
Professional Meeting Presentation	Wang, Z., E.W. Woolery, B. Shi, and J. D. Kiefer, 2004, Some Issues with Probabilistic Seismic Hazard Analysis in the Central and Eastern United States, the 2004 Seismological Society of America, Palm Spring, California, April 14-16, 2004.
Professional Meeting Presentation	Wang, Z., 2005, Role of the Kentucky Geological Survey in Implementing IBC-2000 and IRC-2000 in Kentucky: Better Communication of Seismic Hazard and Risk, AGU 2005 Fall Meeting, San Francisco, CA., December 5-9, 2005 (invited).
Professional Meeting Presentation	Wang, Z., 2005, A Clear Definition of Seismic Hazard and Risk: A Basis for Hazard and Risk Assessment, Communication, and Management, AGU 2005 Fall Meeting, San Francisco, CA., December 5-9, 2005.
Journal Article	Wang, Z. and L. Ormsbee, 2005, Comparison between probabilistic seismic hazard analysis and flood frequency analysis, EOS, Trans., AGU, 86: 45, 51-52.
Professional Meeting Presentation	Anderson, C., Z. Wang, and E. Woolery, Observed Seismicity in the Jackson Purchase Region of Western Kentucky between January 2003 and June 2005, The 77th Annual Meeting of the Eastern Section of the Seismological Society of America, Memphis, Tennessee, October 3-4, 2005.
Professional Meeting Presentation	Wang, Z., 2005, Seismic Hazard and Risk Assessment and Communication in the Central and Eastern United States, The 77th Annual Meeting of the Eastern Section of the Seismological Society of America, Memphis, Tennessee, October 3-4, 2005.
Professional Meeting Presentation	Wang, Z., E.W. Woolery, D. Yuan, and L. Wang, 2005, Comparison between the Active Faults in the New Madrid Seismic Zone of the Central United States and Gansu Province in Northwestern China, the 77th Annual Meeting of the Eastern Section of the Seismological Society of America, Memphis, Tennessee, October 3-4, 2005.
Professional Meeting Presentation	Wang, Z., E.W. Woolery, D. Yuan, and L. Wang, 2005, Comparison between the Active Faults in the New Madrid Seismic Zone of the Central United States and Gansu Province in Northwestern China, the 77th Annual Meeting of the Eastern Section of the Seismological Society of America, Memphis, Tennessee, October 3-4, 2005.
Journal Article	Wang, Z., 2005, Reply to "Comment on 'Comparison between probabilistic seismic hazard analysis and flood frequency analysis' by Zhenming Wang and Lindell Ormsbee" by R. M. W. Musson, EOS, Trans., AGU, 86: 354.
Journal Article	Wang, Z., 2005, Reply to "Comment on 'Comparison between probabilistic seismic hazard analysis and flood frequency analysis' by Zhenming Wang and Lindell Ormsbee" by Thomas L Holzer, EOS, Trans., AGU, 86: 303.
Journal Article	Wang, Z., B. Shi, and J. Kiefer, 2005, Comment on "How Can Seismic Hazard around the New Madrid Seismic Zone Be Similar to that in California?" by Arthur Frankel, Seismological Research Letters, 76: 472-477.
Professional Meeting Paper	Wang, Z., 2006, Understanding Seismic Hazard and Risk Assessments: An Example in the New Madrid Seismic Zone of the Central United States, Proceedings of the 8th National Conference on Earthquake Engineering, April 18-22, 2006, San Francisco, CA. (KRCEE p11.1, 2006).
Journal Article	Wang, Z., 2006, Probabilistic Seismic Hazard Analysis: A New Approach (submitted to the Bulletin of Seismological Society of America)
Professional Meeting Presentation	Wang, Z., 2006, Seismic Safety Regulations in Western Kentucky: The Role of Geology in Public Policy, Geologic Society of America - Southeastern Section, 55th Annual Meeting, March 23-24, 2006, Nashville, TN. (KRCEE p11.7, 2006d)
Journal Article	Wang, Z., 2006, Understanding Seismic Hazard and Risk Assessments: An Example in the New Madrid Seismic Zone of the Central United States, Proceedings of the 8th National Conference on Earthquake Engineering, April 18-22, 2006, San Francisco, CA.
Project Report	Wang, Z., E.W. Woolery, Preliminary Report on Seismic Hazard Assessment at Paducah Gaseous, KRCEE 11.5 2006.
Professional Meeting Presentation	Cobb, J. and Z. Wang, Kentucky Seismic Hazard Mapping Issues, the USGS national seismic hazard maps, the CEUS workshop, May 9-10, 2006, Cambridge, MA.
Presentation Abstract	Wang, Z., Seismic Safety Regulations in Western Kentucky: The Role of Geology in Public Policy (Presentation Abstract), Southeastern Section of the Geological Society of America, Paper No. 26-7, March 2006
Professional Meeting Presentation	Wang, Z., "Seismic Hazard and Risk in Kentucky", Kentucky Geotechnical Engineering Group, Frankfurt, Kentucky, January 10, 2006.
Book Chapter	Wang, Z., 2006, Seismic Hazard and Risk Assessment in the Intraplate Environment: The New Madrid Seismic Zone of the Central United States, GSA Book, Continental Intraplate Earthquakes: Science, Hazard, and Policy Issues. (KRCEE p11.4, 2007)
Symposium Presentation	KRCEE-ZW02 Probabilistic and Deterministic Seismic Hazard Assessment, KRCEE TECHNICAL SYMPOSIUM, 2007
Project Report	Final Report Seismic Hazard Assessment at the PGDP, KRCEE p11.6 2007
Professional Meeting Presentation	Wang, Z., Woolery E.W., Challenges in Seismic Hazard Assessment for the PGDP KRCEE Symposium, October 2007
Project Brief	Wang, Z., A Short Note on Probabilistic Seismic Hazard Analysis, KRCEE p.11.2, 2007
Activities Summary (2007)	Wang, Z., Woolery, E.W., KGS - Earth and Environmental Sciences Activities Related to the Seismic Hazard Assessment, KRCEE 21.8 2007d
Journal Article	Wang, Z., 2008, A technical Note on Seismic Microzonation in the Central United States, Journal of Earth System Science, 117(S2): 749-756.
Professional Meeting Presentation	Wang, Z., 2008, Understanding seismic hazard and risk: A gap between engineers and seismologists, Proceedings of the 14th World Conference on Earthquake Engineering, October 12-17, 2008, Beijing, China, Paper No. S27-001,11 p.
Special Publication	Wang, Z., and E.W. Woolery, 2008, Seismic Hazard Assessment of the Paducah Gaseous Diffusion Plant, Kentucky Geological Survey, ser. 12, Special Publication 9, 37p. Above Project Report KRCEE p11.5, 2007.
Meeting Poster	Wang, Z., Extreme Ground Motion at Yucca Mountain A Statistical Result, KRCEE p11.9 2008d.
Journal Article	Wang, Z., 2009, Seismic Hazard vs. Seismic Risk, Seismological Research Letters, 80: 673-674.
Journal Article	Macpherson, K.A., Woolery, E.W., Wang, Z., and Liu, P., 2010, Three-Dimensional Long Period Ground Motion Simulations in the Upper Mississippi Embayment, Seismological Research Letters, 81: 391-405.
Journal Article	Wang, Z., 2010, Ground Motion for the Maximum Credible Earthquake in Kentucky, Kentucky Geological Survey, ser. 12, Report of Investigations 22, 9 p.
Professional Meeting Presentation	Wang, Z., 2011, Seismic Risk Assessment and Application in the Central United States, Proceedings of the GeoRisk 2011 Conference, June 26 - 28, 2011, Atlanta, GA, p. 1020-1027.
Journal Article	Wang, Z., 2011, Seismic Hazard Assessment: Issues and Alternatives, Pure and Applied Geophysics, 168: 11-25.
Journal Article	Wang, Z., and Cobb, J.C., 2012, A critique of probabilistic versus deterministic seismic hazard analysis with special reference to the New Madrid seismic zone, in Cox, R.T., Tuttle, M.P., Boyd, O.S., and Locat, J., eds., Recent Advances in North American Paleoseismology and Neotectonics East of the Rockies: Geological Society of America Special Paper 493, p. 259-275, doi:10.1130/2012.2493(13).
M.S. Thesis	Orton, A.M., Science and Public Policy of Hazard Mitigation in the New Madrid Seismic Zone, M.S. Thesis, University of Kentucky, 2014.
Journal Article	Wang, Z., 2015, Predicting or Forecasting of Earthquake and the Resulting Ground Motion Hazards: A Dilemma for Earth Scientists, Seismological Research Letters, 86: 1-5.
Professional Meeting Presentation	Wang, Z., 2015, the USGS National Seismic Hazard Mapping Project: Issues and Improvements, Proceedings of the ATC/USGS Seismic Hazard User-Needs Workshop, September 21-22, 2015, Menlo Park, California.
Project Report (KGS)	Orton, A., Wang, Z., Woolery, E.W., Seismic Hazard Mitigation in the New Madrid Seismic Zone - Science and Public Policy, Kentucky Geological Survey Report of Investigations 32, Series XII, 2016.
Journal Article	Carpenter, N.S., Wang, Z., Woolery, E.W., and Rong, M., 2018, Estimating site response with recordings from deep boreholes and HVSR: Examples from the central United States, Bulletin of Seismological Society of America, 108: 1199-1209, doi:10.1785/0120170156
Journal Article	Zhu, Y., Wang, Z., Carpenter, N.S., Woolery, E.W., and Haneberg, W.C., 2021, Mapping fundamental-mode site response and amplifications from thick sediments: An example from the Jackson Purchase Region of western Kentucky, central United States, Bulletin of the Seismological Society of America, 111, 1868-1884, doi:10.1785/0120200300.
Book Chapter	Wang, Z., Carpenter, N.S., and Woolery, E.W., 2022, Chapter 17 - Scenario-based seismic hazard and its application in the central United States, in P. G., Laor, E. and De Vivo B., eds, Earthquake and Sustainable Infrastructure, p. 349-371, doi:10.1016/B978-0-12-823503-4.00035-X (Elsevier).

Seismic Update Reports

Seismic update reporting is an ongoing annual to semi-annual project. Reports update the status of seismic monitoring and data collection related to the PGDP, the New Madrid Seismic

Zone and the Jackson Purchase Region. In general, the reports focus on seismic monitoring and data collection conducted at CUSSO & the Kentucky Seismic and Strong Motion Monitoring Network (KSSMN) including station VSAP located adjacent to the PGDP in the West

Kentucky Wildlife Management Area. Developments and recommendations for the application of seismic hazard assessment methods for the Jackson Purchase Region of western Kentucky are also included in the Update Reports.

Project Participants

- Dr. Zhenming Wang - Seismologist and Section Head (Geological Hazards), Kentucky (Co-PI)
- Dr. Edward Woolery - Geophysics Professor, Earth and Environmental Sciences, University of Kentucky (Co-PI)
- Dr. Seth Carpenter - Seismologist, Kentucky Geological Survey, University of Kentucky (Co-PI)
- Steve Hampson - KRCEE

Project Documents

Project Report	Wang, Z., Woolery, E.W., Operation and Maintenance of the Seismic Network in the Vicinity of the Paducah Gaseous Diffusion Plant April 2009-September 2012, Final Report, KGS Contract Report 5, Series XII, 2013.
Symposium Presentation	Wang, Z., Woolery, E.W., Seismicity and Monitoring in the Vicinity of the Paducah Gaseous Diffusion Plant - Phase II (2009-2012), Phase I & II Seismic Projects Status Presentation for the KRCEE Virtual Symposium
Project Report	Wang, Z., Woolery, E.W., Carpenter, S., An Update of Seismic Monitoring and Research in the Vicinity of the Paducah Gaseous Diffusion Plant: January 2013-December 2017, KGS Contract Report 6, Series XIII, 2019.
Project Report	Wang, Z., Woolery, E.W., Carpenter, S., An Update of Seismic Monitoring and Research in the Vicinity of the Paducah Gaseous Diffusion Plant: January 2018-December 2019, KGS Report

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Chemical and Materials Engineering: Remedial Technology Development I

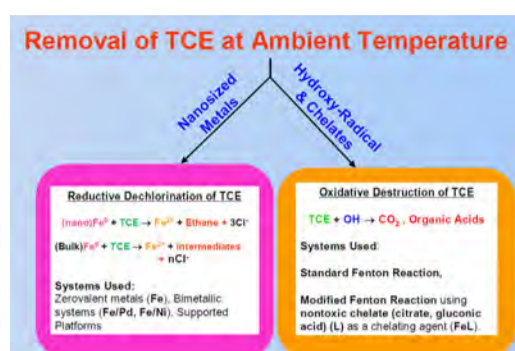
Nano-Structured Particles for In-Situ TCE DESTRUCTION

A project team of UK and UC Berkeley faculty, post-doctoral students, graduate students and researchers completed bench-scale development and evaluation of oxidative TCE destruction utilizing a chelate-modified Fenton reaction and reductive destruction using bi-metallic (Fe/Ni and Fe/Pd) nanoparticles to dechlorinate trichloro-ethylene (TCE) in situ.

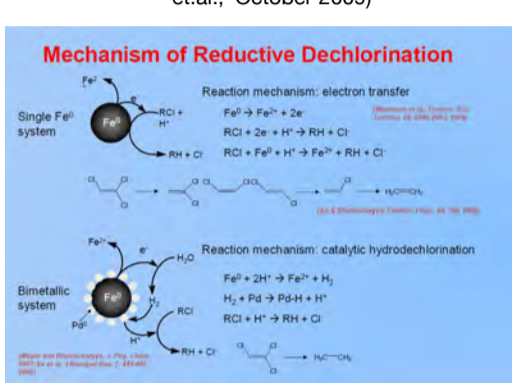
The Project was jointly supported by KRCEE and UK NIEH Superfund Basic Research Program through the Kentucky Water Resources Research Institute.

Project Goals Included:

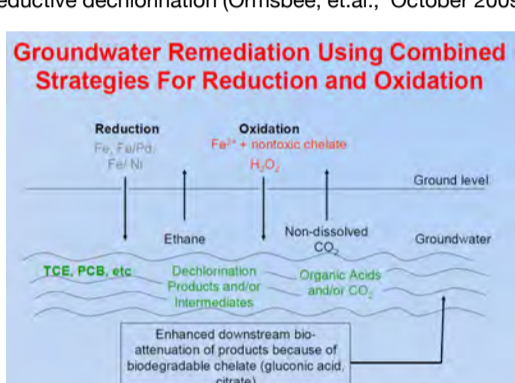
- ▶ Development of effective methods for the dechlorination of toxic organics at ambient temperatures
- ▶ Determine role of **dopant metal** in bimetallic nanoparticle reactivity
- ▶ Study potential for **on-site generation** of chemicals needed for chelate-modified Fenton reaction
- ▶ Determine effectiveness of both **reductive and oxidative dechlorination** in column studies to simulate groundwater flow
- ▶ Development of a Treatability Study Work Plan for preliminary ex-situ and in-situ testing of oxidative and reductive TCE dechlorination at the PGDP.



Mechanisms evaluated for destruction and dechlorination of trichloroethylene (Ormsbee, et.al., October 2009)



Reductive dechlorination (Ormsbee, et.al., October 2009)



Combined groundwater application of reductive and oxidative TCE removal mechanisms. Yields organic acids as a food (Carbon) source for indigenous microbes (Ormsbee, et.al., October 2009)

Column tests utilizing PGDP vicinity regional gravel aquifer groundwater and media were part of the nanoparticle (nanoaggregate) and modified Fenton reaction laboratory testing protocols.

Circulating batch-column experiments were used to study dechlorination under flow conditions and demonstrate the ability of non-stabilized Fe/Pd nano-aggregates to remove significant amounts of TCE (80–90%) over a broad range of groundwater velocities (12.9–83 ft per day) using moderate metal loadings (0.23–0.5 g L⁻¹).

Project experimentation proved the non-toxic chelate modified Fenton reaction effectively dechlorinated TCE in both the aqueous and organic phases at pH 6–7 using low H₂O₂:Fe(II) molar ratios (4:1 to 8:1).

Detailed information on the Project's methods and outcomes are summarized in the Project reports, presentations and journal articles below.

Project Participants

- Dr. Dibakar Bhattacharyya**, Chemical and Materials Engineering, University of Kentucky (Co-PI)
- Dr. Lindell Ormsbee**, PE, UK-Civil Engineering, Director Ky. Water Resources Research Institute, Director Superfund Basic Research Program Translation Core, Director Ky. Research Consortium for Energy & Environment (Co-PI)
- Dr. Rodney Andrews**, Center for Applied Energy Research, University of Kentucky
- Dr. David Sedlak**, University of California Berkeley
- Dr. David Meyer**, Chemical and Materials Engineering, University of Kentucky
- Dr. Vasile Smuleac**, Chemical and Materials Engineering, University of Kentucky
- Dr. Leonidas Bachas**, Department of Chemistry, University of Kentucky
- Scott Lewis**, Chemical and Materials Engineering, University of Kentucky
- Noah Meeks**, Chemical and Materials Engineering, University of Kentucky
- Andrew Lynch**, Chemical and Materials Engineering, University of Kentucky
- Jim Kipp**, Kentucky Water Resources Research Institute, University of Kentucky
- Y. Li**, Ph.D. Student, Chemical and Materials Engineering, University of Kentucky
- J. Xu**, Ph.D. Student, Chemical and Materials Engineering, University of Kentucky
- Y. Tee**, Ph.D. Student, Chemical and Materials Engineering, University of Kentucky
- Steve Hampson** - KRCEE

Project Documents

Research Brief	Bhattacharyya, D., Meyer, D., Lewis, S., Li, Y., Xu, J., Tee, Y., Lynch, A., Destruction of TCE Using Oxidative and Reductive Pathways as Potential In-Situ Treatments for the Contaminated Paducah Groundwater, UK/KRCEE Doc #: P13.1, 2007.
Meeting Proceedings	Ormsbee, L., Bhattacharyya, D., Nano Particles SITEWIDE Project Team KICKOFF Presentation, October 2009
Journal Article	Meyer, D.A., Hampson, S., Ormsbee, L., and Bhattacharyya, D., 2008, A Study of Groundwater Matrix Effects for the Destruction of Trichloroethylene using Fe-Pd NanoAggregates, Environmental Progress and Sustainable Energy, American Institute of Chemical Engineers, November 10, 2009.
Report	Ormsbee, L., Bhattacharyya, D., Hampson, S., Development of a Treatability Study Work Plan for Testing Nanoparticles at a USDOE Superfund Site ASCE EWRI Nano Paper Final, 1-15-10.
Meeting Proceedings	Bhattacharyya, D., UK Chemical Engineering - EPA Meeting, September 2009
Journal Article	Lewis, S., Lynch, A., Bachas, L., Hampson, S., Ormsbee, L., Bhattacharyya, D., Chelate-Modified Fenton Reaction for the Degradation of Trichloroethylene in Aqueous and Two-Phase Systems, Environmental Engineering Science, Volume 26, Number 4, 2009.
Professional Meeting Poster	Lewis, S., Li, Y.C., Smuleac, J., Bachas, L., Bhattacharyya, D., Toxic Organic Degradation by Immobilized Nanoparticles and Free Radicals, NARPM Poster Presentation, 2009.
KRCEE Quarterly Meeting Presentation	Lewis, S., Bhattacharyya, D., Iron-Based Remediation Oxidative Platform, KRCEE Quarterly Meeting Presentation, July 8, 2010.
KRCEE Quarterly Meeting Presentation	Bhattacharyya, D., Smuleac, J., Fe and Fe-Pd Nanoparticle Synthesis in Membrane Domain Using Green Synthesis, KRCEE Meeting Presentation, July 8, 2010.
KRCEE Quarterly Meeting Presentation	Bhattacharyya, D., Destruction of TCE Using Oxidative and Reductive Pathways, KRCEE Quarterly Meeting Presentation, February 2007.
KRCEE Quarterly Meeting Presentation	Ormsbee, L., Nano Technology Project Status, KRCEE Quarterly Meeting Presentation, August 2009

TCE Bioaccumulation by Microalgae

TCE is common xenobiotic contaminant that is recalcitrant to degradation. Widespread and prolonged use of this volatile solvent in industrial applications has led to extensive contamination of soils, groundwater, and surface water. *In situ* remediation technologies, such

as natural attenuation, phytoremediation, and biodegradation are typically for the removal of TCE from contaminated sites. However, these techniques may require several decades to achieve acceptable treatment goals. Thus, there is a need to develop more efficient, cost-effective, and low maintenance methods for remediation (O'Neill et al, 1999).

Ponds contaminated with TCE have been known to support the growth of microalgae. The utilization of microalgae to take up TCE from the ponds, also referred to as bio-concentration, may be an effective path for TCE removal from the ponds. In order for microalgae to be used for TCE removal, the microalgae must be able to grow in the presence of TCE, which was shown by Biggs and co-workers (1979). Second, the microalgae must be able to bio-accumulate TCE, which was shown to be the case with *Chlorella vulgaris* and *Scenedesmus quadricauda* (Smets and Rittman,

1990). Third, the system needs to be tested in a laboratory setting to determine the effectiveness and possible optimization of the process, which is the focus of this scope of work.

Project work included three tasks:

1. Literature review of the previous work with TCE accumulation in microalgae and of the previous work on bio-accumulation of 99Tc.
2. Flask experiments (300 mL working volume) to determine rate of uptake, effects of TCE on algae growth, and to gather TCE-rich algae cells to determine what the TCE-uptake & well-established chlorine clean-up needs are. Flask experiments will focus on the two strains identified previously as TCE bio accumulators, which are both also currently being cultured in our labs.
3. Employment of the bio fence to a larger scale TCE scrubbing demonstration.

Project Participants

- Dr. Czarena Crofcheck** – UK Agriculture and Biosystems Engineering (PI) Dr.
- Rodney Andrews**, UK-Center for Applied Energy
- Dr. Mark Crocker**, UK-Center for Applied Energy Research
- Steve Hampson** – KRCEE

Project Documents

Professional Meeting Poster	Vance, Z., Crofcheck, C., Montross, M., Shea, A. Crocker, M., Andrews, R., Utilization of algae for TCE Remediation
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Chemical and Materials Engineering: Recycling and ReUse II

Disposition of Paducah Gaseous Diffusion Plant Nickel

University of Kentucky Extended Campus Engineering Paducah Program faculty completed research into the release, sale and reuse of nickel from the Paducah Gaseous Diffusion Plant. There are an estimated 9,000 tons

of radioactively contaminated nickel in the form of ingots stored at the current and former uranium enrichment plants in Paducah, Kentucky, Portsmouth, Ohio and Oak Ridge, Tennessee.

Nickel has a particularly high scrap value, but a lack of U.S. standard for release of volumetrically contaminated material and a moratorium by the DOE on commercial reuse of any radioactively contaminated metals prevents sale or re-use of

volumetrically contaminated material - even within the nuclear complex.

Project research identified the regulatory framework and roadblocks which impact release of volumetrically contaminated material. Project recommendations include the establishment and validation of a process whereby the contaminated nickel can be made as clean as or cleaner than conventional commercially available nickel.

Project Participants

Dr. David Silverstein, Assistant Professor, Paducah Engineering Program, University of Kentucky (Co-PI)
 Dr. Lindell Ormsbee, PE, UK-Civil Engineering, Director Ky. Water Resources Research Institute, Director Superfund Basic Research Program Translation Core, Director Ky. Research Consortium for Energy & Environment (Co-PI)

Project Documents

Project Report	Silverstein, D.L., Disposition of Paducah Gaseous Diffusion Plant Nickel, UK/KRCEE Doc #: P1.1 2007
Project Briefing Presentation	Silverstein, D.L., Economic Analysis of Nickel Release, KRCEE Quarterly Meeting, September 2006

Nickel Release Support

University of Kentucky Paducah Extended Campus Engineering Program faculty provided support to the Paducah Area Community Re-use

Organization (PACRO) for the organizations efforts to initiate a cleanup and sale of nickel stockpiled at the Paducah plant. A preliminary

recommendation to utilize a modified chemical vapor deposition (CVD) process to was provided to PACRO.

Project Participants

Dr. Jim Smart, Assistant Professor, Paducah Engineering Program, University of Kentucky
 Dr. Fuqian Yang, Chemical and Materials Engineering, University of Kentucky

Project Documents

Project Report	Volpe, J.A., et al., Market Available Virgin Nickel Analysis Data Summary, KRCEE 9.1, 2004
Project Briefing Presentation	PACRO Commercial Nickel Sampling and Analysis Plan (Revision 1) KRCEE 9.2, 2003

Uranium Re-Use – Battery Development

University of Kentucky Paducah Campus Engineering Program faculty and a project team of industry subject matter experts completed research into the potential use of PGDP's depleted uranium as battery material in lithium-ion batteries. There are currently more than 5 billion pounds of depleted uranium hexafluoride stored at the PGDP.

Project Participants

Dr. Paul D. Dunbar, Assistant Professor, University of Kentucky, Paducah Engineering Program (Co-PI)
 Dr. Rhonda Lee DeSautels, Assistant Professor, University of Kentucky, Paducah Engineering Program (Co-PI)
 Dr. Lindell Ormsbee, PE, UK-Civil Engineering, Director Ky. Water Resources Research Institute, Director Superfund Basic Research Program Translation Core, Director Ky. Research Consortium for Energy & Environment (Co-PI)
 Walter Tracinski, Applied Power Inc.,
 Dr. Stephen Lipka, Center for Applied Energy Research, University of Kentucky
 Dr. Richard Howard, Boeing Company
 Dr. Chris Johnson, Boeing Company

Project Documents

Project Report	Dunbar, P.D., DeSautels, R.L., Uranium Battery Development Project Final Report, KRCEE p2.1, 2007
Project Status Presentation	Dunbar, P.D., Uranium Battery Project Introduction, KRCEE Quarterly Meeting Presentation, April 2004.
Project Status Presentation	Dunbar, P.D., Uranium Battery Project Update, KRCEE Quarterly Meeting Presentation, February 2005.
Project Status Presentation	Dunbar, P.D., Uranium Battery Project Update, KRCEE Quarterly Meeting Presentation, April 2006.
Project Status Presentation	Dunbar, P.D., Uranium Battery Project Update, KRCEE Quarterly Meeting Presentation, September 2006.

Separation of Radionuclides from PGDP Nickel

The decontamination and radiation decommissioning of the gaseous diffusion process at the PGDP has generated and will generate vast quantities of nickel and other metals volumetrically contaminated with detectable levels of radioactive materials. The most frequently identified contaminant in the PGDP nickel is technetium-99 (⁹⁹Tc).

Available refining technologies were proven incapable of removing ⁹⁹Tc to less than detectable levels.

A moratorium on the release of any volumetrically contaminated material containing detectable

radiation precludes the release of the PGDP nickel stockpile.

This project's research identified properties of ⁹⁹Tc and nickel and pursued development of a bench-scale separation process.

Project Participants

Dr. Eric Grulke - Director, Chemical and Materials Engineering, University of Kentucky (PI)
 Dr. Lindell Ormsbee, PE, UK-Civil Engineering, Director Ky. Water Resources Research Institute, Director Superfund Basic Research Program Translation Core, Director Ky. Research Consortium for Energy & Environment (Co-PI)
 Dr. Tony Zhai, Chemical and Materials Engineering, University of Kentucky
 Dr. Louie El-Azzami, Ph.D. Researcher, Chemical and Materials Engineering, University of Kentucky
 Dr. Burt Lynn, Chemical and Materials Engineering, University of Kentucky
 Steve Hampson - KRCEE

Project Documents

Project Briefing Presentation	Grulke, E.A., Recovery of purified nickel from material contaminated with ⁹⁹Tc, KRCEE Quarterly Meeting Presentation, September 2006
Project Briefing Presentation	Grulke, E.A., Nickel-Technetium Separation by Metal Distillation and Vapor Deposition PACRO Presentation, KRCEE p9.4, 2004.
Project Research Review and Proposal	Grulke, E.A., Zhai, T., El-Azzami, L., Separation of Nickel from Technetium-Contaminated Scrap, UK/KRCEE Doc #: P9.5 2007
Project Professional Meeting Presentation	Grulke, E.A., Nickel-Technetium Separation by Metal Distillation and Vapor Deposition PACRO Presentation, UK/KRCEE Doc #: P9.4, August 2004

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Public Outreach: Education, History & Future Use

Background

The Paducah Gaseous Diffusion Plant operated under the shroud of Cold War secrecy from the early 1950' through the late 1980's. Plant operators and workers functioned under the provisions of security clearances that prohibited discussion of the PGDP's mission of enriching uranium for Cold War weapons and nuclear power generation. Several generations of residents and workers grew up only quietly acknowledging the PGDP's presence. Outside of the Jackson Purchase Region and Paducah, little was known about the existence, no less, the importance of the PGDP's missions.

Generations worldwide were taught to "duck and cover", fallout shelters were constructed in backyards, and silent fear was instilled with the mention of the words "nuclear", "radiation" & "atomic". Public awareness and media coverage of gross industrial age environmental impacts and resulting health threats grew exponentially during the late 1960's and continued into the 1970' & 1980's. The Environmental Protection Agency started in the 1970's and with it, the cleanup of the Industrial Age's legacies.

In the 1980's the "veil of secrecy" was lifted and information about the government & DOE's Cold War industrial and science efforts entered the public conversation. Stories of clandestine secret projects occurring on the government's nuclear sites remained more common in the public forum than data disclosing the nature and extent of Cold War facilities environmental and health impacts. Data to identify environmental and health impacts was slowly being collected, assessed and selectively released. Environmental activism proliferated, allegations of the governments mishandling of materials with disregard for health & safety found its way into the court of public opinion, lawsuits, and regulations.

Fast forward to the late 1990's - 2000's, a new era of digital information and a new era of public

awareness and participation in government activities. Public discussion about the retirement, dismantling, and cleanup of government facilities evolved to include future use: futures of communities, economies, employment, environmental impacts & cleanups. The onset of PUBLIC participation in government and government projects had occurred along with acute challenges to inform, interact with and educate government officials, stakeholders and the local community.

Since 2003, KRCEE Public Outreach and Education projects have evolved in response to the needs of local citizens, government and public officials, and the DOE. Initial public outreach activities focused on informing community representatives, management, regulators, and site contractors with focused technical information regarding contemporary and alternative approaches to addressing clean-up and re-use problems. Technical meeting presentations have evolved into public interaction projects that gather and assess community perceptions and needs along with providing information and tools that foster understanding and the ability to address the challenges faced in the cleanup and re-use of the PGDP.

Annual Site Environmental Report (ASER) Project

Each Department of Energy (DOE) site prepares an Annual Site Environmental Report (ASER) documenting its environmental activities during a calendar year. The PGDP ASER document is a technical document relating the Site's environmental activities and data to an extensive list of regulatory requirements.

KRCEE personnel, PGDP personnel, UK and industry subject matter experts (SMEs) assist Marshall County High School (MCHS) environmental science students with a STEM (science, technology, engineering & math) program focused on the preparation of an annual 'PGDP ASER: High School Summary Report'.

The PGDP ASER: High School Summary Report provides streamlined information on "what the public should know" about PGDP's environmental activities. Students review the most recent published copy of the PGDP ASER, answer study questions and summarize content prior to publication and widespread distribution.

In addition to production of the ASER High School Summary Report, students are provided introductory PGDP presentations from the DOE site office and tour the PGDP site industrial facilities and

environmental projects.

The students utilize the PGDP Virtual Museum to conduct research on PGDP's history. Subject matter experts provide several classroom presentations that range from the recent history of the PGDP to radioactive materials and ecosystem primers.

Students participate in 'hands on' fieldwork assessing habitats and biota that occupy the DOE reservation and West Kentucky Wildlife Management Area (WKWMA) which surrounds the PGDP site.

The ASER project is an ongoing project that began in 2013 with 17 MCHS environmental science students. In 2021, 130+ students were participating in the ASER Project through their enrollment in MCHS environmental science classes.



Jennifer Woodard, PGDP Site Manager, providing an Introduction Briefing to MCHS Students.



Dr. Price engaging MCHS field trip class amphibian and reptile habitat lecture at the WKWMA lodge.



MCHS field trip during an on-site watershed discussion at Bayou Creek .



WKWMA-PGDP habitat lecture includes 'hands on' reptile and amphibian instruction.

Project Participants

Thomas Pinkerton, Multimedia Specialist, Center for Applied Energy Research, University of Kentucky Dr. Steve Price, Associate Professor, Department of Forestry and Natural Resources, College of Agriculture, University of Kentucky Andrea Drayer, Senior Researcher, Department of Forestry and Natural Resources, College of Agriculture, University of Kentucky

Tim Kreher, Manager, West Kentucky Wildlife Management Area Tina Marshall, Environmental Science Instructor, Marshall County High School Dr. Richard S. Halbrook, Professor Emeritus, Cooperative Wildlife Research Laboratory, Department of Zoology, Southern Illinois University Carbondale

Stephanie Brock, Manager, KY Radiation and Environmental Monitoring Laboratory, Cabinet for Health Services, Commonwealth of KY

Robert 'Buz' Smith, Public Relations, Paducah Site Office, Department of Energy

Jennifer Woodard, PGDP Site Manager, United States Department of Energy

Tracey Duncan, PGDP Site, United States Department of Energy

Dr. Richard Bonczek, Technical Project Manager & Risk Assessor, Portsmouth-Paducah Project Office, U.S. Department of Energy

Tracy Taylor, Engineer, ETAS Paducah Site Contractor

Dr. Martin Clauberg, ETAS Paducah Site Contractor

Eddie Spraggs, Paducah Site Contractor

Steve Christmas, Public Relations, Four Rivers Nuclear Partnership

Darrell Taulbee, Ph.D., Center for Applied Energy Research, University of Kentucky

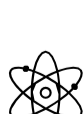
Jean Hartinger, Media Specialist, Center for Applied Energy Research, University of Kentucky

Steve Hampson, KRCEE

Project Documents

Project Report	MCHS Student ASER 2012 FINAL (December 2015)
Project Report	PGDP ASER CY 2013: MCHS Student Summary Report. (2014 15 School Year)
Project Report	PGDP ASER CY 2014: MCHS Student Summary Report. (2016-17 School Year)
Project Report	PGDP ASER CY 2016: MCHS Student Summary Report. (2018-19 School Year)
Project Report	PGDP ASER CY 2017: MCHS Student Summary Report. (2019-20 School Year)
Project Report	PGDP ASER CY 2018: MCHS Student Summary Report. (2020-21 School Year)
MCHS Media Release	MCHS Media Release, February 2017
DOE Media Release	PGDP Media Press Release (2015 ASER Project), 2016
DOE Site Tour Video	CY 2020 ASER High School Site Introduction Video Presentation (2020-21 & 2021-2022 School Years)
DOE Site Tour Presentation	DOE PGDP Overview for High School Briefing 092917
Class Presentation	ASER rad-2017r1
Class Presentation	ASER MCHS Class PGDP INTRO Sept29 2017 FINAL
Class Presentation	ASER MCHS Ecosystem/Watershed/Habitat Presentation (April 1, 2021)
Field Demo Video	ASER Field Instruction Video (Spring 2021)
Project Report	ASER Student Summary Study Guide (2016) Chapters 0 - 7 Questions & Outlines, 2018.

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Public Outreach: Education, History & Future Use II

PGDP Future Vision Project

Subject Matter Experts from the Kentucky Water Resources Research Institute (KWRI), the Kentucky Transportation Center (KTC), College of Engineering, College of Communications, and KRCEE assisted the local community in their efforts to identify a future use vision for the PGDP.

The PGDP Future Vision Project (a.k.a Public End State Project) was an extensive public outreach and community involvement project. The project was conducted to engage public participation in order to identify community preferences for the future use of the PGDP industrial site and DOE reservation.

The project integrated several applied public engagement theoretical approaches in order to garner the public's participation. Lessons learned from past DOE public participation projects which are published in the DOE document 'The Politics of Cleanup' were also integrated into the project methodology.

The project involved educating the public about site history, economic impacts, the history and status of ongoing environmental activities. An extensive project website, paducahvision.org, was deployed to support community participants as they explored PGDP's past and potential future activities.

An extensive list of stakeholder representatives participated in early phases of project work in order to identify 12 possible future use scenarios (below). The future use scenarios presented to community participants for discussion and identification of preferred future use(s).

Public preferences regarding the future of the PGDP are discussed in the project final report '[Community Visions for the Paducah Gaseous Diffusion Plant Site](#)' and project documents below.

Public and stakeholder participation for this project far exceeded all previous DOE and UK site-related projects involving public participation.

Future PGDP Use Scenarios Evaluated for PGDP Future Vision Project

PES Scenario	Scenario Description	Scenario Page Link (Map & Video)
Scenario 1	Scenario 1 Description: Nuclear Plant on Plant Site; Wildlife Management Area (WMA) Remains; All Plant Decommissioning Waste kept onsite in Waste Disposal Alternative (WDA); Existing Burial Grounds excavated and moved to managed landfills	http://paducahvision.org/scenario-1.html
Scenario 2	Scenario 2 Description: Nuclear Plant on Plant Site; Wildlife Management Area (WMA) Remains; Part of Plant Decommissioning Waste kept onsite in Waste Disposal Alternative (WDA); Existing Burial Grounds sealed and left in place	http://paducahvision.org/scenario-2.html
Scenario 3	Scenario 3 Description: Heavy Industry on Plant Site; Recreational Facilities added to Wildlife Management Area (WMA); All Plant Decommissioning Waste Removed from Site; Existing Burial Grounds excavated and moved to managed landfills; Heavy Industry on Plant Site	http://paducahvision.org/scenario-3.html
Scenario 4	Scenario 4 Description: Heavy Industry on Plant Site; Wildlife Management Area (WMA) Remains; All Plant Decommissioning Waste kept onsite in Waste Disposal Alternative (WDA); Existing Burial Grounds sealed and left in place	http://paducahvision.org/scenario-4.html
Scenario 5	Scenario 5 Description Light Industry on Plant Site; Recreational Facilities added to Wildlife Management Area (WMA); Some Plant Decommissioning Waste kept onsite in Waste Disposal Alternative (WDA); Existing Burial Grounds excavated and moved to managed landfills	http://paducahvision.org/scenario-5.html
Scenario 6	Scenario 6 : Light Industry on Plant Site Wildlife Management Area (WMA) Remains; All Plant Decommissioning Waste Removed from Site; Existing Burial Grounds sealed and left in place	http://paducahvision.org/scenario-6.html
Scenario 7	Scenario 7 Description: Recreational Facilities on Plant Site; Wildlife Management Remains; Some Plant Decommissioning Waste kept onsite in Waste Disposal Alternative (WDA); Existing Burial Grounds sealed and left in place	http://paducahvision.org/scenario-7.html
Scenario 8	Scenario 8 Description: Recreational Facilities on Plant Site; Recreational Facilities added to Wildlife Management Area (WMA); All Plant Decommissioning Waste kept onsite in Waste Disposal Alternative (WDA); Existing Burial Grounds excavated and moved to managed landfills	http://paducahvision.org/scenario-8.html
Scenario 9	Scenario 9 Description: Nature Preserve on Plant Site; Recreational Facilities added to Wildlife Management Area (WMA); All Plant Decommissioning Waste Removed from Site; Existing Burial Grounds sealed and left in place	http://paducahvision.org/scenario-9.html
Scenario 10	Scenario 10 Description: Nature Preserve on Plant Site Wildlife Management Area (WMA) remains Some Plant Decommissioning Waste kept onsite in Waste Disposal Alternative (WDA) Existing Burial Grounds excavated and moved to managed landfills	http://paducahvision.org/scenario-10.html
Scenario 11	Scenario 11 Description: Plant Site sealed, fenced, access restricted Wildlife Management Area (WMA) remains; All Plant Decommissioning Waste Removed from Site; Existing Burial Grounds excavated and moved to managed landfills	http://paducahvision.org/scenario-11.html
Scenario 12	Scenario 12 Description: Plant Site sealed, fenced, access restricted; Recreational Facilities added to Wildlife Management Area (WMA); All Plant Decommissioning Waste kept onsite in Waste Disposal Alternative (WDA); Existing Burial Grounds sealed and left in place	http://paducahvision.org/scenario-12.html

Project Participants

- Dr. Lindell Ormsbee, PE, UK-Civil Engineering, Director Ky. Water Resources Research Institute, Director Superfund Basic Research Program Translation Core, Director Ky. Research Consortium for Energy & Environment (PI)
- Dr. Chike Anyaegbunam, College of Communications, University of Kentucky (Community Based Participatory Communication)
- Dr. Ted Grossardt, Kentucky Transportation Center, University of Kentucky (Structured Public Involvement)
- Dr. Keiron Bailey, University of Arizona (Casewise Evaluation)
- John Ripey, Kentucky Transportation Center, University of Kentucky (Scenario Visualization)
- Ben Blandford, Kentucky Transportation Center, University of Kentucky (Scenario Visualization)
- Dr. Anna Hoover, KWRI (Technical Support/Facilitator)
- Mitchael Schwartz, College of Communications, University of Kentucky (Technical Support/Facilitator)
- Dr. Richard Bonczek, Portsmouth-Paducah Project Office, U.S. Department of Energy (Technical Liaison)
- Steve Hampson, KRCEE, University of Kentucky (Technical Liaison)

Project Documents

Project Web Site	http://paducahvision.org
Project Report	Ormsbee, L., Grossardt, T., Anyaegbunam, C., Bailey, K. Community Visions for the Paducah Gaseous Diffusion Plant Site, September 2011. (UK/KRCEE Doc#: P25.1 2011)
Project Presentation	Ormsbee, L., Grossardt, T., Anyaegbunam, C., Project Results Presentation to DOE, February 7, 2011.
Public Meeting Presentation	Ormsbee, L., Grossardt, T., Anyaegbunam, C., PGDP Overview Presentation for Public Meeting, Part 1, 2009.
Public Meeting Presentation	Ormsbee, L., Grossardt, T., Anyaegbunam, C., PGDP Overview Presentation for Public Meeting, Part 2, 2009.
Public Meeting Presentation	Ormsbee, L., Grossardt, T., Anyaegbunam, C., PGDP Overview Presentation for Public Meeting, Part 3, 2009.
Public Meeting Presentation	Grossardt, T., PGDP Future Vision Project - A presentation to the PGDP CAB, May 21, 2009
Project Results Presentation	Ormsbee, L., PGDP Future Vision Project, Final Project Presentation to DOE, February 27, 2011.
Project Results Presentation	PGDP Community Visions Scenario Links (Table to Web Postings for Scenario Description, Maps, and Video Fly Throughs).
Project Presentation	Ormsbee, L., Paducah Chamber of Commerce Paducahvision Web Presentation, 2009
Project Presentation	Hoover, A., Public End State Vision Briefing for Communications Students Supporting Project, 2009.
Professional Meeting Presentation	Ormsbee, L., Public End State Revised Focus Group Presentation, KRCEE Quarterly Technical Meeting, April 2009.
Project Presentation	Ormsbee, L., Public End State Presentation to Heath Middle School Students, April 2010.
Project Presentation	Grossardt, T., Public End State Project Public Participation Preference Summary Presentation, July 2011.

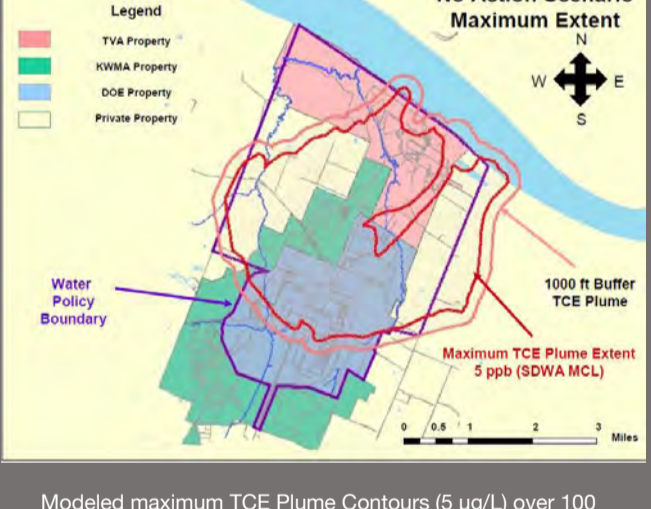
Property Acquisition (Land Study) Study Report

The PGDP Property Acquisition Study (Land Study) was conducted in accordance with a Congressional Directive to DOE in the *Energy and Water Development Appropriation Bill, 2006 (Senate Report 109-084)*. "Within the funds provided the Department shall undertake a study of the potential purchase of property or options to purchase property that is located above the plume of contaminated groundwater near the facility site.

The study shall evaluate the adequate protection of human health and environment from exposure to contaminated groundwater and consider whether such purchase, when considering the cost of remediation, long-term surveillance, and maintenance, is in the best interest of taxpayers."

Scenario	ID	Description
1	PA-E	Continuation of existing pump and treat action
2	C-#00	Source reduction of contaminants at C-400 building using direct heating technology
3	URD	Source reduction of UCERS and RGA sources using direct heating technology, and treatment of Southwest Plume using oxidation (i.e. C-Springs) technology
4	URD-PTZ	Source reduction for all sources, treatment of Southwest Plume, and PTZ technology at the PGDP security fence.

Table 3.4.1 Identification of four (4) potential response action scenarios. A fifth "No Action" scenario was also evaluated for the Project.



Modeled maximum TCE Plume Contours (5 µg/L) over 100 years assuming no action and illustrating a 1000' buffer zone around Modeled TCE maximum extent.

The Land Study required a groundwater modeling evaluation for a complete range of groundwater remedial alternatives identified in PGDP decision (regulatory program) documents. Five alternatives were identified, No Action and four potential Response Action scenarios (Table 3.4.1). For each alternative, the temporal as well as maximum extent of plume impacts was modeled over a 100-year period.

A KWRI & UK-Civil Engineering Project Team applied experience in site groundwater modeling (see Groundwater Modeling 1) to conduct MODFLOW and MODFLOWT simulations of each remedial action scenario using the 1998-99 PGDP Flow and Transport Models (Bechtel-Jacobs, DOE, 1998*).

Faculty and staff of KRCEE, the University of Kentucky College of Law, College of Agriculture, Department of Agriculture and Biosystems Engineering, and College of Engineering provided their relevant expertise for subject matter in the report, and it's use in report evaluations:

1. Legal framework for applicable property acquisition and access options
2. Rural residential and agricultural property valuation
3. Groundwater modeling to identify temporal and spatial contaminant extents relative to application of a variety of potential remedial actions
4. GIS
5. Marketing and Public Relations

Costs to purchase potentially impacted properties and costs to implement the five (5) possible remedial action assemblages are discussed in the Property Acquisition Study Final Report.

*DOE (U.S. Department of Energy) 1998. Ground Water Flow Model Recalibration and Transport Model Construction at the PGDP, Paducah, Kentucky. DOE/OR/07-1742&DO. United States Department of Energy, KY, June 1998.

Project Team

- Dr. Srinivasa Lingireddy - UK-Civil Engineering (Co-PI)
- Dr. Lindell Ormsbee, PE, UK-Civil Engineering, Director Ky. Water Resources Research Institute, Director Superfund Basic Research Program Translation Core, Director Ky. Research Consortium for Energy & Environment (Co-PI)
- Dr. Chandramouli Viswanathan, Adjunct Faculty, UK-Civil Engineering (Co-PI)
- Jim Kipp, Associate Director, KY Water Resources Research Institute
- Terri Dowdie, GIS Specialist, Agriculture and Biosystems Engineering, University of Kentucky
- Steve Hampson, Associate Director, KRCEE

Project Documents

Congressional Report	Ormsbee, L., Property Acquisition Study Final Report OSTI KRCEE_p24.1_2007
Meeting Presentation	Ormsbee, L., Land Study Citizens Advisory Board (CAB) Project Background & Startup Presentation, KRCEE 24.4 2006d (June 15, 2006)
Meeting Presentation	Land Study Model Impacted Properties Poster KRCEE 24.7 2006d
Public Meeting Presentation	Land PGDP Public Informational Meeting KRCEE 24.3 2006d (June 29)
Public Meeting Presentation	Land Study CAB Prelim Results Presentation KRCEE 24.5 2007d (September 2006)
Public Meeting Presentation	Land Study Final Public Mtg Presentation Heath HS KRCEE 24.6 2007d (March 2011)
Media Release	LOUISVILLE COURIER JOURNAL ARTICLE JULY 10 2006 Media Releases Property Acquisition Study KRCEE 24.1 2007d (April)
Professional Meeting Presentation	Land Study Sr Mgr Presentation KRCEE DOE PRS 061409
Media Release	Media Releases Property Acquisition Study Public Meeting Results KRCEE 24.1 2010 (October 7)
Media Release	Paducah Sun Article Property Acquisition Study KRCEE 24.1 2007d (April)
Media Release	Paducah Sun Media Release Property Acquisition Study June 30 2006
Media Release	Paducah Sun Media Release Property Acquisition Study July 2006
Media Release	Media Releases Property Acquisition Study WKY News & Paducah Sun KRCEE 24.1 2007d (March 15)
Public Meeting Presentation	Land Study PGDP Public Informational Meeting KRCEE 24.3 2006d (June 29)
Media Release	DOE Public Meeting for Land Study Public Notice
Media Release	DOE Press Release Public Meeting for Land Study Announcement June 2006
Public Meeting Presentation	Land Study Presentation KRCEE DOE CAB-09-21-2006_rev11_final

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Public Outreach: Education, History & Future Use III

PGDP History Project

The PGDP History Project was initiated to create documentary resources (print, video and online) detailing the history of the site. The Project encompassed several components including a history

book, a web-based video oral history focused on the experiences of plant employees, and a PGDP history documentary.

The Project Team's initial activity was the development of a draft 220-page history documentary storyboard which was submitted to the PGDP Citizens Advisory Board (CAB) for review. Following the review and discussions with the DOE Portsmouth Paducah Project Office, the CAB compiled and published a must-read PGDP pictorial history book, '[Megatons to Megawatts](#)'.

The Story of the Paducah Gaseous Diffusion Plant

Megatons to Megawatts



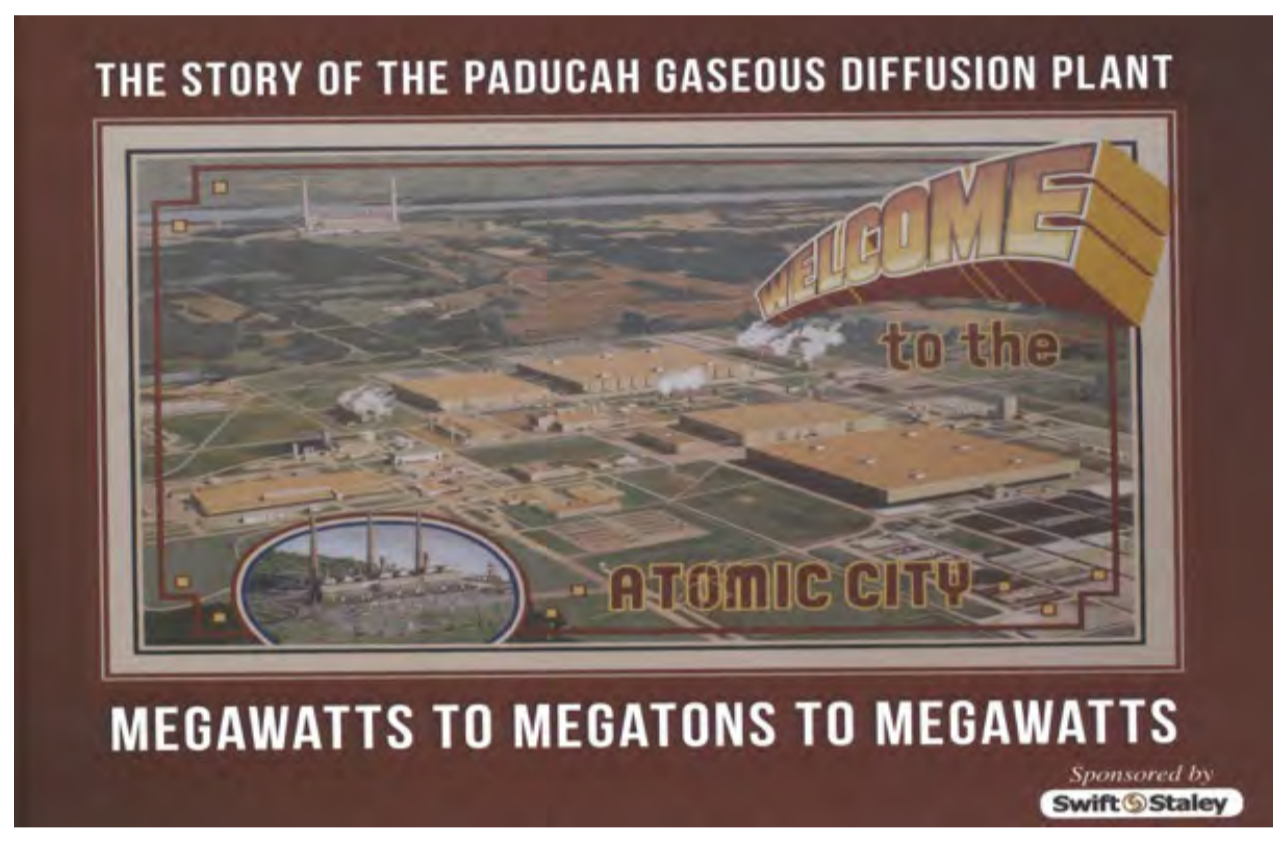
PGDP History Storyboard Cover Page

Project Participants

Dr. Lindell Ormsbee, PE, UK-Civil Engineering, Director Ky. Water Resources Research Institute, Director Superfund Basic Research Program Translation Core, Director Ky. Research Consortium for Energy & Environment (Co-PI)
John Robertson, Historian, Paducah, Kentucky
Fiona Young-Brown, Writer/Author/Editor
Carol Butler, Editor, Butler Books
History Committee, Paducah Gaseous Diffusion Plant Citizens Advisory Board

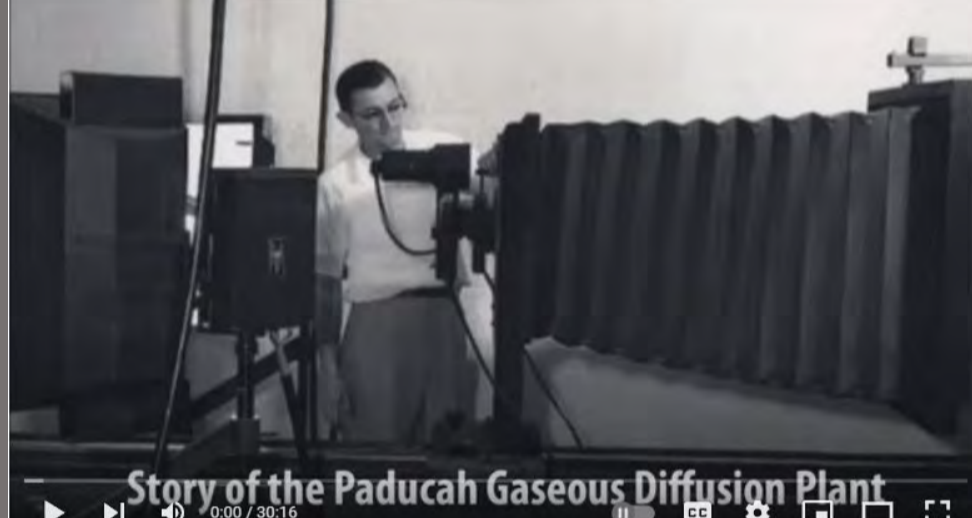
Project Documents

Project Document	Ormsbee, L., Brown, F., Robertson, J., Butler, C., Draft PGDP History Documentary Storyboard, October 2011.
Meeting Presentation	Ormsbee, L., History Project Overview, Public Meeting Presentation, July 2011



History Project: PGDP Video Oral History

West Kentucky Community and Technical College (WKCTC) Paducah Visual Communication and Multimedia Program arranged and video-taped interviews with former PGDP workers, local citizens, and community leaders to document the "A Story of the Paducah Gaseous Diffusion Plant".



Project Participants

Dr. Lindell Ormsbee, PE, UK-KWRRI & UK-Civil Engineering, Director KWRRI & KRCEE (PI)
Andrew Evitts, Instructor, West Kentucky Community and Technical College (Co-PI & Director)
Christopher Bower, West Kentucky Community and Technical College (Narrator)
Dan Tanner, Editor, West Kentucky Community and Technical College
Chris Gilbert, Editor, West Kentucky Community and Technical College
Grace Baldrige, Student, West Kentucky Community and Technical College (Interviewer)
Moki Blanding, Student, West Kentucky Community and Technical College (Interviewer)
Josh Brown, Student, West Kentucky Community and Technical College (Interviewer)
Meghan Doyle, Student, West Kentucky Community and Technical College (Interviewer)
McKenzy Mangrum, Student, West Kentucky Community and Technical College (Interviewer)
Kayce Prescott, Student, West Kentucky Community and Technical College (Interviewer)
Crys Terrell, Student, West Kentucky Community and Technical College (Interviewer)
JR Roper, Student, West Kentucky Community and Technical College (Interviewer)
Robby Ballard, Student, West Kentucky Community and Technical College (Interviewer)
Kristen Johnson, Student, West Kentucky Community and Technical College (Interviewer)
Mitchell Dunaway, Student, West Kentucky Community and Technical College (Interviewer)
Beverly Quimby, Student, West Kentucky Community and Technical College (Interviewer)
Randall Barnes, Student, West Kentucky Community and Technical College (Interviewer)
Lauren Barclay, Student, West Kentucky Community and Technical College (Camera/Audio/Lighting)
Andrew Cummins, Student, West Kentucky Community and Technical College (Camera/Audio/Lighting)
Jared Parish, Student, West Kentucky Community and Technical College (Camera/Audio/Lighting)
Wil Woods, Student, West Kentucky Community and Technical College (Camera/Audio/Lighting)
Dan Tanner, Student, West Kentucky Community and Technical College (Camera/Audio/Lighting)
Vanessa Kaiser, Student, West Kentucky Community and Technical College (Camera/Audio/Lighting)
Donald Shaw, Student, West Kentucky Community and Technical College (Camera/Audio/Lighting)
Alan Simpson, Student, West Kentucky Community and Technical College (Camera/Audio/Lighting)
Drew Johnson, Student, West Kentucky Community and Technical College (Camera/Audio/Lighting)

Project Documents

Project Video	Evitts, A., et al., The Story of the Paducah Gaseous Diffusion Plant, https://youtu.be/ZSbvx1vO3sA
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History Project: History of the Paducah Gaseous Diffusion Plant

The Kentucky Water Resources Research Institute (KWRRI), West Kentucky Community and Technical College (WKCTC) Visual Communication and Multimedia Program and the PGDP Citizens Advisory Board developed the video documentary "The History of the Paducah Gaseous Diffusion Plant".



Project Participants

Dr. Lindell Ormsbee, PE, UK-Civil Engineering, Director Ky. Water Resources Research Institute, Director Superfund Basic Research Program Translation Core, Director Ky. Research Consortium for Energy & Environment (PI)
John Robertson, Historian, Paducah, Kentucky
Fiona Young-Brown, Writer/Author/Editor
Carol Butler, Editor, Butler Books
History Committee, Paducah Gaseous Diffusion Plant Citizens Advisory Board

Project Documents

Project Document	A History of the Paducah Gaseous Diffusion Plant, https://www.youtube.com/watch?v=ZSbvx1vO3sA
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Public Outreach: Education, History & Future Use IV

UK CoD ATOMIC CITY STUDIOS
SUSTAINABLE DEVELOPMENT & PGDP PHYSICAL MODEL DEVELOPMENT

During calendar years 2010 and 2011, the UK College of Design, through its state-wide River Cities Project, was actively addressing social, economic, environmental and future sustainability challenges faced by Kentucky's 'River Cities' as their historical river-based industrial economies were left behind by emerging technology.

Concurrently, the DOE Site Office, DOE Portsmouth-Paducah Project Office (PPPO) and University of Kentucky (UK) discussed needs to provide interactive tools for the Paducah Gaseous Diffusion Plant (PGDP) to support discussions about industrial site cleanup, facilities demolition, waste disposal, groundwater remediation, future use, and other issues.

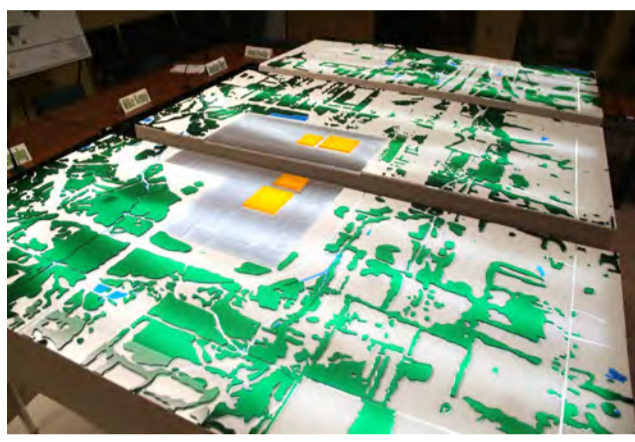
Based on their experience developing sustainable economic strategies and creating communications tools to convey those strategies to stakeholders and the public, the UK-College of Design was recruited to take a 'deep dive' into the PGDP, independently

evaluate the future of the Site and create communications tools to convey current Site status and future use recommendations. Plans to build an initial physical model of the PGDP site and environs were drafted, rendered and put in place.

An initial model of the PGDP and vicinity was constructed for the PGDP Citizens Advisory Board at a scale of 1:350. The design of the PGDP model was generated via interactive Design Industry methods which became the charge of the UK-College of Design (CoD) Spring 2011 Graduate Design Studio: Manhattan Redux: Paducah PGDP Futures

Manhattan Redux: Paducah PGDP Futures UK COLLEGE OF DESIGN, GRADUATE ARCHITECTURE STUDIO X/XII SPRING 2011

The studio proposed an economy generated by the serious undertaking of PGDP environmental cleanup and built a first-ever 1:350 scale model of the site and plume highlighting PGDP groundwater plumes. The model was intended to provoke conversation and debate among scientists and communicate issues to the public, all with the hope of stimulating progress toward resolution of groundwater and soil contamination, enabling regeneration of the site and region.



Site 1:350 Model on display at a PGDP CAB meeting.

"Over time, as plants close down and environmental damage is assessed, jobs disappear and cleanup estimates skyrocket, communities are becoming overwhelmed by the question of what to do. From evaluating several of these communities across the country and the world, the Atomic Cities Research Group made the observation that Energy, Economy, Education and Environment are inextricably related."

Excerpt from the CoD 'Atomic Cities' document identifying the four factors used to evaluate sustainable development in cities impacted by loss of industry and legacy environmental impacts.

Atomic Cities: Paducah + UK COLLEGE OF DESIGN, GRADUATE ARCHITECTURE STUDIO X/XII FALL 2011

The Paducah + group considered Paducah's particular issues through an analysis of nine global cities, each with resident industrial contamination like PGDP's plumes. The group considered the four E's as parameters essential to the health and growth of any community; Economy, Environment, Energy and Education. They proposed a methodology for the regeneration of the impacted towns through alignment and equilibration of the four E's.

The Radical Remediation team researched remediation methods and proposed a demonstration of the remediation program at the site. The proposed clean industry is informed by a local knowledge infrastructure, dependent upon local labor, focused on a local problem, but also generates intellectual capital and technical innovations exportable to the world. The Radical Remediation group is proposing remediation techniques at the nexus of biotech and robotics - interrelating freely across humans, things, technology and nature.

Atomic Cities: The STORY UK COLLEGE OF DESIGN, GRADUATE ARCHITECTURE STUDIO X/XII SPRING 2012

The Spring 2012 semester's task was to gather all the materials developed in the first two semesters and coalesce them into a thoughtful, concise, provocative and hopeful STORY.



Site 1:150 PGDP Industrial Site Model on display at the IABR, National CAB Managers Meeting & WKCTC

The STORY was presented in several venues simultaneously: 1) the National Citizens Advisory Board meeting in Paducah attended by representatives from all two hundred plus DOE legacy contaminated sites, 2) UK's CAER, with campus, State and local officials in attendance, and 3) as an invited exhibition at the (re) Making City International Architecture Biennale Rotterdam (IABR) attended by over one hundred thousand planners and designers from every country in the world. The PGDP IABR exhibit was part of UK CoD's River Cities Project.

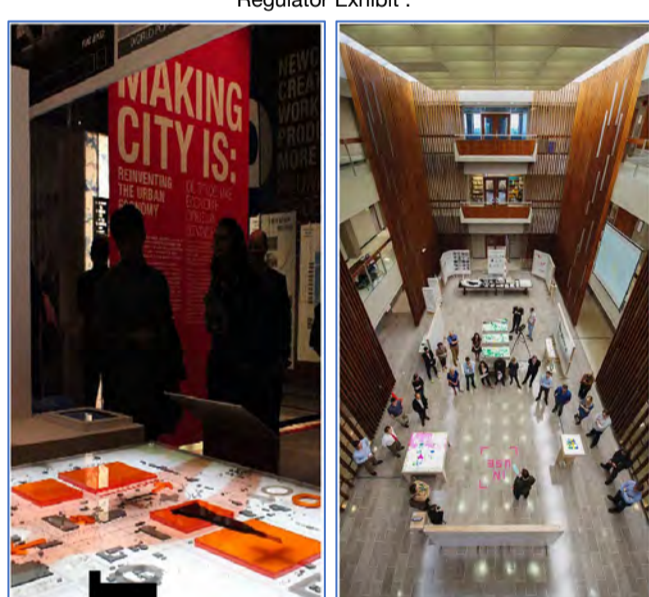
Spring 2012 Studio Exhibit: DOE National CAB Meeting, Paducah, Kentucky



Site 1:150 PGDP Future Use Model on display at the CAER Campus Public, Academic and Regulator Exhibit.

Spring 2012 Studio Invited Exhibit: 10th International Architecture Biennale, Rotterdam, Netherlands

Spring 2012 Studio Campus Public, Academic and Regulator Exhibit: Center for Applied Energy Research, Lexington, Kentucky



1:150 PGDP Industrial Site Model on display at the IABR (left) & comprehensive display of models and information posters at the UK's CAER (right).

Winter - Spring 2013 PGDP GW Accomplishments Exhibit: Western Kentucky Community and Technical College, Paducah, Kentucky

Atomic City Museum UK COLLEGE OF DESIGN, GRADUATE ARCHITECTURE STUDIO X/XII SPRING 2014

Atomic City Museum

Radical Remediation: Cut and Fill UK COLLEGE OF DESIGN, GRADUATE ARCHITECTURE STUDIO X/XII FALL 2015

Cut and Fill Studio 1



Site Future Use Model exhibition at the National CAB Managers Meeting in Paducah.

The Problem is the Solution: Oxeye Remediation UK COLLEGE OF DESIGN, GRADUATE ARCHITECTURE STUDIO X/XII SPRING 2016



The logo created to represent the remote technology envisioned for remediation deployment and future use development at the PGDP.

Project Participants

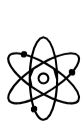
Project Participants list includes faculty, students and contractors that participated in CoD semester studios

Project Documents

Project Documents includes studio presentation videos models and studio products

Report	Rohrbacher, G., Atomic Cities Studios, Models & Exhibitions Chronology
Video	Fall 2015 Studio, Cut and Fill, 'Cut/Fill'
Video	Fall 2015 Studio, Cut and Fill, 'Milling the Site'
Video	Hawkins, J., Fall 2015 Studio, Cut and Fill, "Drone Mining" Video
Video	Fall 2015 Studio, Cut and Fill, 'Site Uncovering'
Media Release	Spring 2012 Studio, Paducah National Citizens Advisory Board Meeting Exhibit Photos, DOE Current Events Flickr (http://www.flickr.com/photos/departmentofenergy/sets/72157630196512180/)
Report	Spring 2016 Studio, Cut and Fill Compendium Final: (re) Mediating Paducah, Oxeye Remediation
Video	Spring 2016 Studio: Cut and Fill 11 Final Video, Oxeye Remediation

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[PGDP MULTIMEDIA](#)

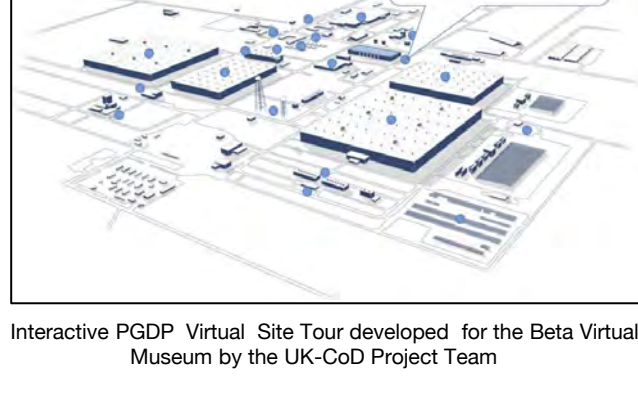


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DEVELOPMENT OF THE BETA PGDP VIRTUAL MUSEUM

The PGDP Virtual Museum Project began with a team of graduate and upper-class College of Design (CoD) students researching the PGDP, recording available information about the site's history, operations and impacts. The team compiled that information as an interactive digital "Museum". The CoD Project Team presented the beta 'Virtual Museum' to DOE-PPPO managers in August 2016.



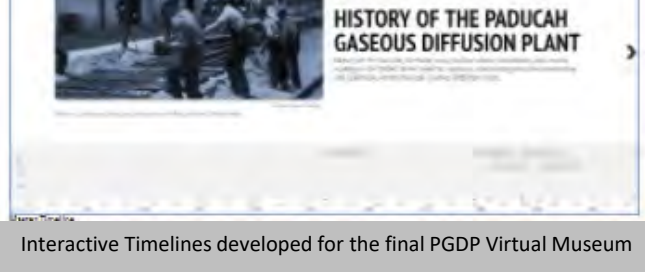
Project Participants

- Anne Filson, Professor, College of Design, University of Kentucky (Co-PI)
- Gary Rohrbacher, Associate Professor, College of Design, University of Kentucky (Co-PI)
- Brad Mitzefeldt, Public Relations, DOE-PPPO Contractor
- Dr. Bobette Nourse, DOE-PPPO Support Contractor, Knoxville, Tennessee
- Chris Westfall, Graduate Student, College of Design, University of Kentucky
- Steven Schwab, Graduate Student, College of Design, University of Kentucky
- Sydney Kidd, Graduate Research Assistant, College of Design, University of Kentucky
- Steve Hampson, KRCEE

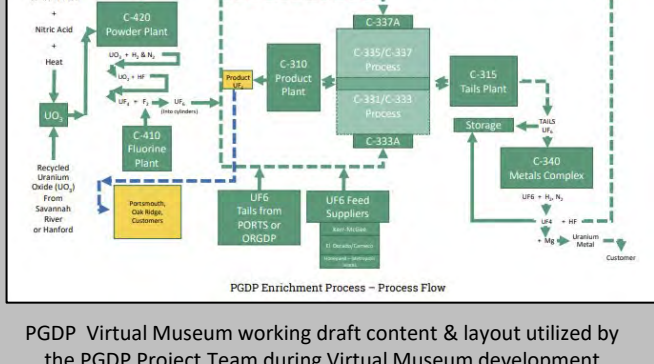
DEVELOPMENT OF THE PGDP VIRTUAL MUSEUM

The PGDP Virtual Museum (VM) is an ongoing project that involves development of an interactive website detailing the history of the PGDP from 'The Need for Uranium' through Site Construction, Enrichment Operations, Site Missions, and Remediation of Environmental Impacts.

In late 2016 KRCEE organized a PGDP VM Project Team comprised of DOE, DOE Contractors, PPPO Contractors, UK-CoD PI's, UK-CoD Graduate Students. The PGDP VM Project Team was tasked to augment information on the beta Virtual Museum website with information released from the PGDP 'Vault' and 'hands on' information from a retired PGDP site historian.



The PGDP VM Project Team supplemented the Beta VM content with several additional museum displays including a page highlighting Site 'Missions' and an expanded timeline that focused on four timeline themes: 1) History of Paducah and the Jackson Purchase; 2) History of Nuclear Science Leading to Nuclear Energy; 3) PGDP Site History; and 4) History of Environmental Regulations and PGDP Environmental Accomplishments.



PGDP Virtual Museum working draft content & layout utilized by the PGDP Project Team during Virtual Museum development

The VM Project Team submitted and posted a Draft Final Virtual Museum in 2018. The PGDP Virtual Museum was released in September 2021 following completion of a formal DOE security review.

Project Participants

- Anne Filson, Professor, College of Design, University of Kentucky (Co-PI)
- Gary Rohrbacher, Associate Professor, College of Design, University of Kentucky (Co-PI)
- Brad Mitzefeldt, Public Relations, DOE-PPPO Contractor
- Tracey Taylor, Engineer, DOE-PPPO Contractor
- Eddie Spraggs, Public Relations, DOE-PPPO Contractor
- Dr. Bobette Nourse, DOE-PPPO Support Contractor, Knoxville, Tennessee
- Thomas Pinkerton, Media Specialist/Webmaster, Center for Applied Research, University of Kentucky
- Steve Hampson, KRCEE

Project Documents

Link	http://pgdpvirtualmuseum.org/
Report	Hampson, S., PGDP Virtual Museum Development Summary Report

VIRTUAL SYMPOSIUM

KRCEE and Ohio University collaborated to deploy a website featuring video summaries of their respective projects at the Paducah Gaseous Diffusion Plant and the Portsmouth Gaseous Diffusion Plant.

Virtual Symposium Home Page (try 'Click Here')

Dr. Lindell Ormsbee (UK-KWRRI, KRCEE, CE)

Dr. Alan Fryar (UK EES)

Dr. Zhenming Wang, (UK-KGS, Hazards Section)

Dr. Lindell Ormsbee (UK-KWRRI, KRCEE, CE)

UK-CAER, UK-KRCEE, UK-KWRRI, UK-CoD

WKCTC & PGDP CAB

Dr. Lindell Ormsbee (UK-KWRRI, KRCEE, CE)

Project Participants

- Alicia Gregory, Director, Research & Graduate Studies Communications, University of Kentucky (Co-PI)
- Chad Rumsford, Director, Research & Graduate Studies Videography, University of Kentucky (Co-PI)
- Dr. Rodney Andrews, Director, Center for Applied Energy Research & KRCEE
- Dr. Lindell Ormsbee, Director, Kentucky Water Resources Research Institute & past Director KRCEE
- Anne Filson, Professor, College of Design, University of Kentucky
- Gary Rohrbacher, Associate Professor, College of Design, University of Kentucky
- Dr. D. Bhattacharyya, Professor, Chemical and Materials Engineering, University of Kentucky
- Dr. Zhenming Wang, Seismologist, Kentucky Geological Survey Hazards Section, University of Kentucky
- Dr. Edward W. Woolery, Associate Professor, Earth and Environmental Sciences (Geophysics), University of Kentucky
- Dr. Alan Fryar, Associate Professor, Earth and Environmental Sciences, University of Kentucky
- Andrew Evitts, Instructor, West Kentucky Community and Technical College
- Jeanne Hartinger, Media Specialist, Center for Applied Energy Research, University of Kentucky
- Steve Hampson, KRCEE

Project Documents

Link	Virtual Symposium Home Page: https://www.portsfuture.com/virtual-symposium-2/
Link	KRCEE PGDP Symposium Pages: http://www.ukrcee.org/symposia/index.html
Link	Ohio University PORTS Symposium Pages: https://www.portsfuture.com/virtual-symposium/
Video	Ormsbee, L., Bhattacharyya, D., Chloro Organic Detoxification by Membrane Supported Iron/Iron Oxide System, KRCEE Virtual Symposium, 2015
Video	Fryar, A., Tripathi, G., Spatio-temporal variability in groundwater discharge and contaminant fluxes along Little Bayou Creek, KRCEE Virtual Symposium, 2015
Video	Wang, Z., Woolery, E.W., Seismicity and Monitoring in the Vicinity of the Paducah Gaseous Diffusion Plant, KRCEE Virtual Symposium, 2015
Video	Ormsbee, L., et al., Stakeholder Future Vision Process for the Paducah Gaseous Diffusion Plant, KRCEE Virtual Symposium, 2015
Video	Evitts, A., WKCTC, Paducah Citizens Advisory Board, Video Oral History: Story of the Paducah Gaseous Diffusion Plant, 2011
Video	Ormsbee, L., et al., A History of the Paducah Gaseous Diffusion Plant, 2012
Video	Gregory, A., Rumsford, C., et al., The Problem Is the Solution, 2015

KRCEE TECHNICAL SYMPOSIUM

In late October 2007 KRCEE held a technical symposium in Lexington, Kentucky. The symposium was attended by 60+ University, PGDP Site, National Laboratory, Industry and Federal & State Regulatory personnel. The Symposium fostered discussion about PGDP technical issues ranging from seismology & TCE remediation, to decontamination & release of contaminated nickel stockpiles.

October 30-31, 2007

Presentations

[Welcome and Overview of KRCEE](#) (Lindell Ormsbee and Chuck Staben, University of Kentucky; Bill Murphie, Department of Energy)

Session 1: Data Management Issues

- Development and Implementation of Data and Geographical Information System Tools for PORTS and PAD "DWIS" (David Korns, SAIC)
- [History of Nickel Recovery Efforts](#) (David Silverstein, University of Kentucky)
- [PGDP Land Acquisition Study](#) (Lindell Ormsbee, University of Kentucky)

Session 2: New Technologies

- [Nanotechnology and Oxidative Techniques for Remediation](#) (D. Bhattacharyya, D. Meyer, J. Xu, S. Lewis, Y. Li, and L. Bachas, University of Kentucky)
- Evaluation of Biotic and Abiotic Processes on TCE Fate & Transport for the PGDP Northwest Plume (S. Hampson, KRCEE; Bruce Phillips, Portage; Bryan Clayton, PRS)

Session 3: Historical and Seismic Activity

- [Neo-Tectonics and Historical Seismicity](#) (Ed Woolery and Cora Anderson, University of Kentucky)
- Post Cretaceous Faulting in the Mississippi Embayment in Southern Illinois (John Nelson, Illinois Geological Survey)
- [The New Madrid Seismic Zone: Evidence of Holocene Displacement in the Jackson Purchase, SE Missouri, and Tennessee](#) (Martitia Tuttle, Tuttle & Associates)
- Field Investigation of Holocene Faulting and the PGDP (John Baldwin and Keith Kelson, William Lettis and Associates; Ed Woolery, University of Kentucky)

Session 4: Current Seismic Assessment

- [Challenges in Seismic Hazard Assessment for PGDP](#) (Zhenming Wang, Kentucky Geological Survey)
- [Kentucky Seismic and Strong Motion Network Including the Deep Hole Observatory](#) (Jonathan McIntyre, Kentucky Geological Survey)
- [PGDP Probabilistic and Deterministic Seismic Hazard Analysis](#) (Zhenming Wang, Kentucky Geological Survey)

Session 5: Surface Water and Ecological Issues

- [Surface Water Flow Model Development of the PGDP](#) (Mike Kemp and Andy Kellie, Murray State University)
- [Innovative Runoff/Sediment Control Facilities](#) (Richard Warner, University of Kentucky)
- [Summary of Past Ecological Investigation & Future Ecological Investigation Recommendations of the PGDP: What to Monitor and Why?](#) (Richard Halbrook, Southern Illinois University; Howard Whiteman, Murray State University)

Session 6: New Technologies II

- [Real-Time Adaptive Sampling and Analysis Approaches to Clean-up: Challenges, Benefits, Technical & Cost Successes](#) (Robert Johnson, Argonne National Laboratory)
- [Sensing Superfund Chemicals with Recombinant Systems](#) (Sylvia Daunert and Patrizia Pasini, University of Kentucky)
- [Application of Enzyme Activity Probes to Characterize Aerobic Microorganisms in Groundwater at INEEL, PGDP & elsewhere](#) (Hope Lee, Northwind INC)
- Nickel Purification via Distillation (Eric Grulke and Tony Zhai, University of Kentucky)

Session 7: Groundwater Modeling

- Surface and Subsurface Lithostratigraphic Characterization of the PGDP and Vicinity (Josh Sexton, Sexton and Son; Alan Fryar, University of Kentucky; Steven Greb, Kentucky Geological Survey; Steve Hampson, KRCEE)
- [Lithostratigraphic and GMS Modeling](#) (Bruce Phillips, Portage; Bryan Clayton and Ken Davis, PRS LLC; Steve Hampson, KRCEE)
- [Sensitivity Analysis of PGDP Groundwater](#) (Chandramouli Viswanathan, University of Kentucky)
- Future Research Directions (Lindell Ormsbee, University of Kentucky)

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Public Outreach: Education, History & Future Use VI

TRIAD + ADAPTIVE SAMPLING & ANALYSIS (ASAP) TRAINING

A total of 26 Attendees from U.S. DOE – PPPO, U.S. DOE – PGDP, U.S. EPA – Region IV, Paducah Remediation Services, Inc. – PGDP, the KY. Environmental Protection Cabinet-Federal Facilities Unit, Performance Results Corporation -Paducah, the KY. Cabinet for

Health Services – Radiation Environmental Monitoring Lab, UK-Kentucky Transportation Center, and UK-Kentucky Geological Survey attended two-day hands-on TRIAD and ASAP training course at the UK – KY Geological Survey Core Barn.

and Analysis Plan program. Each participant conducted an evaluation, development of sampling methods, sampling plans, remediation and remedial verification strategies based on a multi-contaminant site utilizing “real-time” field instrumentation to accomplish attainment of project clean-up goals.

Course instructors had been long-time collaborators in the development of the USEPA Technology Innovation Office’s TRIAD program and the DOE Argonne National Laboratory’s Adaptive Sampling

TRIAD Resource Center website:

<http://www.triadcentral.org/>

INSTRUCTORS

Dr. Robert Johnson, Argonne National Laboratory
Deana Crumbling, USEPA, Technology Innovation Program

VISUAL SAMPLING AND ANALYSIS PLAN TRAINING

A total of 21 Attendees from U.S. DOE PPPO, Homeland Security, DOE-PGDP, PGDP contractors, Industry contractors (Atlanta), University of Kentucky, the KY. Radiation and Environmental

Monitoring Lab and U.S. EPA Region IV braved an early February snowstorm to travel to Lexington and attend Visual Sample Plan (VSP) training. Visual Sample Plan (VSP) is a software tool that supports the development of a defensible sampling plan based on statistical sampling theory and the

statistical analysis of sample results to support confident decision making. VSP couples site, building, and sample location visualization capabilities with optimal sampling design and statistical analysis strategies.

Visual Sampling Plan Resource Website:

<https://www.pnnl.gov/projects/visual-sample-plan>

INSTRUCTOR

Brent Pulsipher, Pacific Northwest National Laboratory

SPATIAL ANALYSIS AND DATA ASSISTANCE (SADA) TRAINING

There were approximately 30 attendees for Spatial Analysis and Decision Assistance (SADA) software training. SADA incorporates tools from environmental assessment fields into an effective problem-solving environment. Tools include integrated modules for visualization,

geospatial analysis, statistical analysis, human health risk assessment, ecological risk assessment, cost/benefit analysis, sampling design, and decision analysis. The capabilities of SADA can be used independently or collectively to address site specific

concerns when characterizing a contaminated site, assessing risk, determining the location of future samples, and when designing remedial action.

SADA Resource Website:

<https://www.sadaproject.net/index.html>

INSTRUCTOR

Dr. Robert Stewart, Geographic Information Science and Technology group, Oak Ridge National Laboratory

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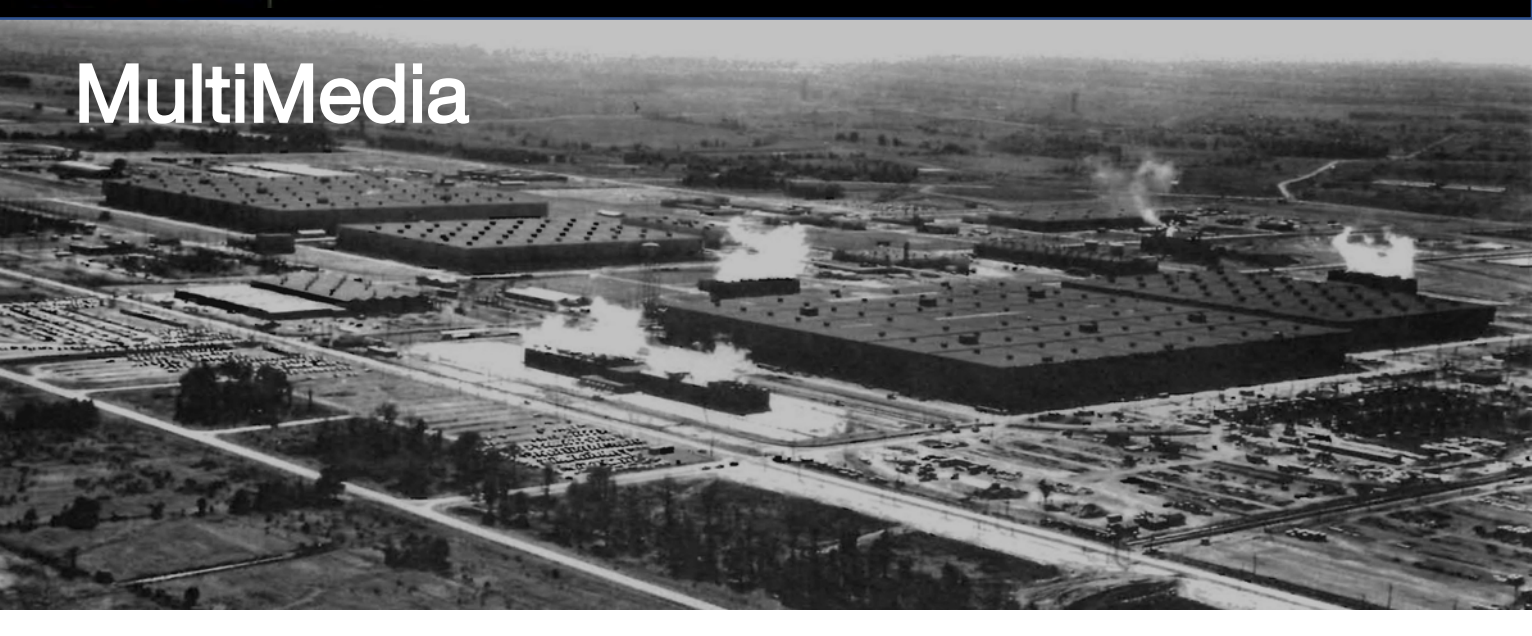
[OUTREACH](#)



[PROJECT DOCUMENTS](#)



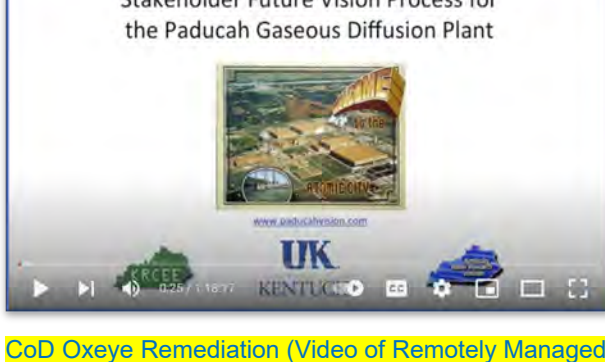
[PGDP MULTIMEDIA](#)



MultiMedia

Project Videos

1. [PGDP Future Vision Stakeholder Involvement Process](#)
Dr. Lindell Ormsbee (UK KWRR/UK KTC/UK Journalism) - (Email: lindell.ormsbee@uky.edu)



2. [CoD Oxeye Remediation \(Video of Remotely Managed Radical Remediation ~ The Problem Is the Solution\)](#)



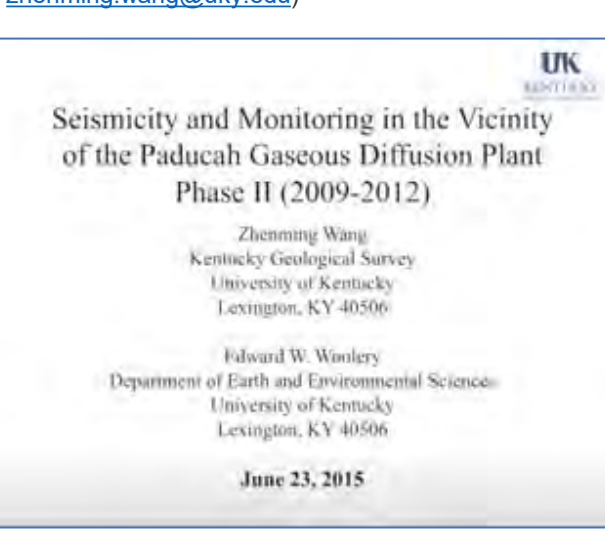
3. [Advanced Material and Membrane Technology Development for Remediation of TCE and PCBs](#)
Dr. Lindell Ormsbee (UK KWRR/UK ChemE) – (Email: lindell.ormsbee@uky.edu)



4. [Paducah Physical Model Development - \(UK CAER/UK KWRR/UK KRCEE/UK CoD\) – \(Email: \[steve.hampson@uky.edu\]\(mailto:steve.hampson@uky.edu\)\)](#)



5. [Seismicity and Seismic Monitoring of the Paducah Gaseous Diffusion Plant and Vicinity](#)
Dr. Zhenming Wang (UK KGS/UK EES) – (Email: zhenming.wang@uky.edu) -



6. [PGDP Little Bayou Creek Groundwater Plume Discharge Characterizations: 1999 – Present](#)
Dr. Alan Fryar (UK EES) -



7. [Public End State Scenario Video Fly-Throughs \(12\)](#)

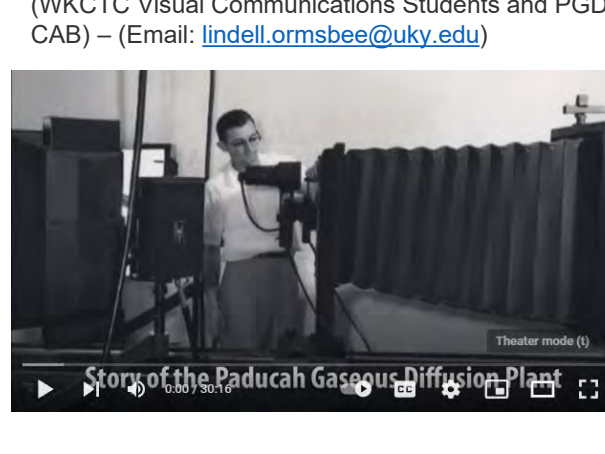


History Videos

1. [A History of the Paducah Gaseous Diffusion Plant \(KRCEE\) – \(Email: \[lindell.ormsbee@uky.edu\]\(mailto:lindell.ormsbee@uky.edu\)\)](#)



2. [Paducah Video Oral History - Story of the Paducah Gaseous Diffusion Plant: Video Oral History: \(WKTC\) \(WKTC Visual Communications Students and PGDP CAB\) – \(Email: \[lindell.ormsbee@uky.edu\]\(mailto:lindell.ormsbee@uky.edu\)\)](#)



Virtual Symposium

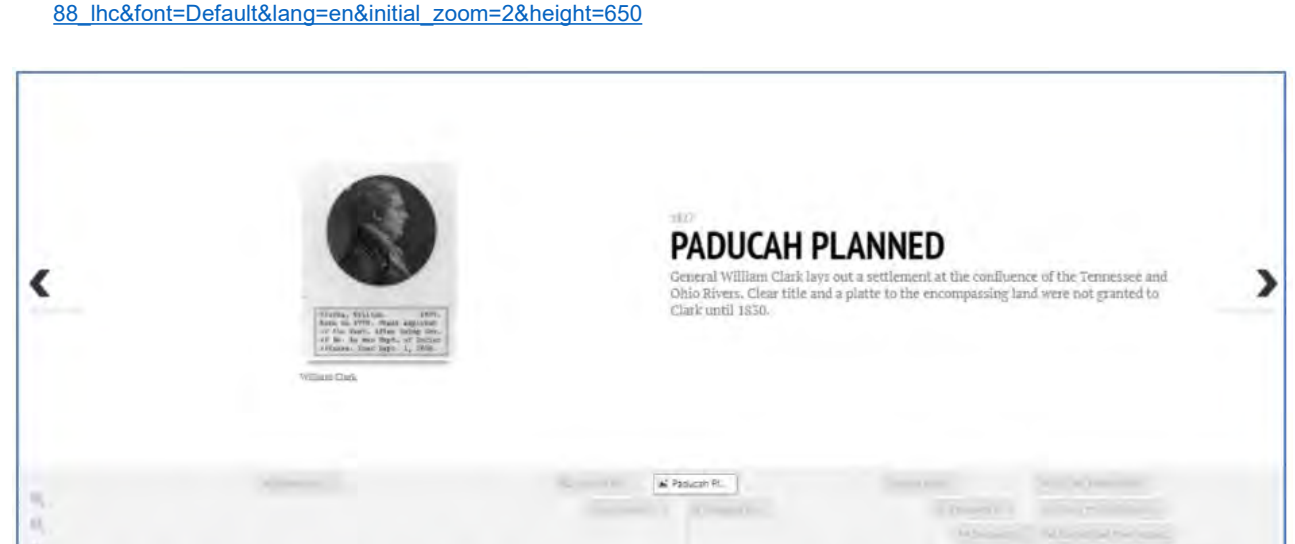


Interactive PGDP Timelines

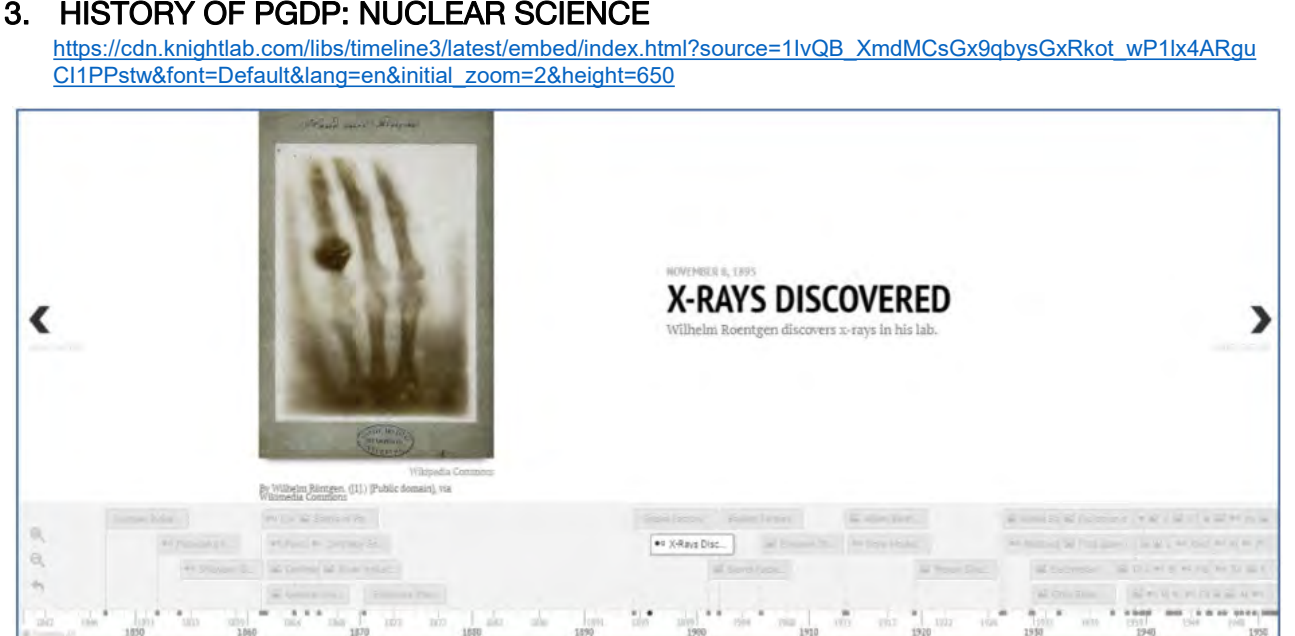
1. **HISTORY OF THE PGDP (COMPREHENSIVE)**
https://cdn.knightlab.com/libs/timeline3/latest/embed/index.html?source=1Bci06K0XKqEKohQ7GTS1w8z40KypS8Sh5WkL5yb9sXI&font=Default&lang=en&initial_zoom=2&height=650



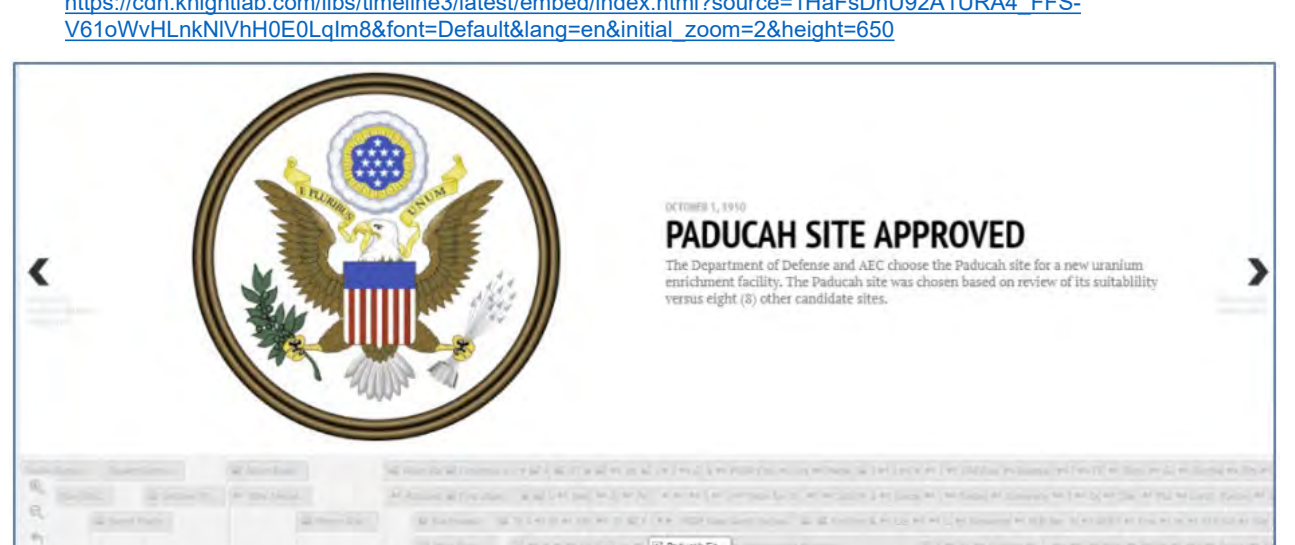
2. **HISTORY OF PGDP: THE JACKSON PURCHASE AND PADUCAH**
https://cdn.knightlab.com/libs/timeline3/latest/embed/index.html?source=1ioNXPfC4oO3qXm0Hvq_jV89cSiM2la39DxNoa88_lhc&font=Default&lang=en&initial_zoom=2&height=650



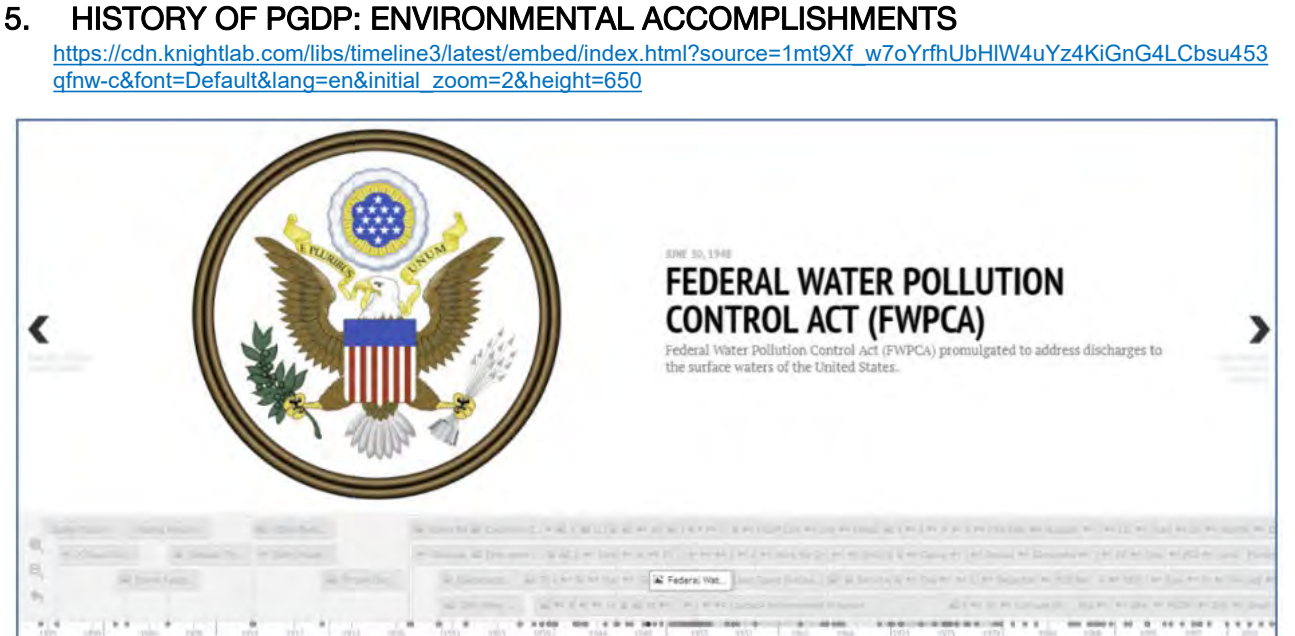
3. **HISTORY OF PGDP: NUCLEAR SCIENCE**
https://cdn.knightlab.com/libs/timeline3/latest/embed/index.html?source=1vQb_XmdMCsGx9qbysGxRkot_wp1lx4ARqC11PPstw&font=Default&lang=en&initial_zoom=2&height=650



4. **HISTORY OF PGDP: CONSTRUCTION AND OPERATIONS**
https://cdn.knightlab.com/libs/timeline3/latest/embed/index.html?source=1HaFsDhU92A1UR4_FFS-V61oVwHLNkNIVhHOE0LqIm8&font=Default&lang=en&initial_zoom=2&height=650



5. **HISTORY OF PGDP: ENVIRONMENTAL ACCOMPLISHMENTS**
https://cdn.knightlab.com/libs/timeline3/latest/embed/index.html?source=1mt9XF_w7oYrRhUbHIW4uYz4KiGnG4LCbsu453qfw-c&font=Default&lang=en&initial_zoom=2&height=650



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About

KRCEE

KRCEE was created in 2003 through the efforts of Senator Mitch McConnell and the Kentucky Congressional Delegation to offer innovative and technically sound solutions to problems facing the environmental restoration and continued economic use of the Paducah Gaseous Diffusion Plant (PGDP) and its surrounding areas (Map).

KRCEE is administered by the [University of Kentucky Center for Applied Energy Research \(CAER\)](#) and managed by professional staff and faculty at the University of Kentucky. KRCEE operations, tasks and projects are developed in collaboration with the Department of Energy (DOE) and executed in collaboration with academia, industry, subject-matter experts,

stakeholders and the regulatory community (See: [Collaborators](#) & [Investigators](#)).

KRCEE's tasks and projects offer independent considerations and recommendations to problems facing the environmental restoration and re-use of the PGDP that are not addressed by existing contracts or regulatory requirements.

KRCEE History

On September 15, 2003 the Kentucky Research Consortium for Energy and Environment (KRCEE) was established at the University of Kentucky for the purpose of supporting expeditious, cost effective, and technically effective environmental clean-up activities at the PGDP. The KRCEE was initially funded with a 4-year, \$5 million dollar Department

of Energy Congressional earmark obtained through the efforts of Senator Mitch McConnell and the Kentucky Congressional Delegation.

collaborating partners of the KRCEE.

Dr. Lindell Ormsbee wrote the original proposal for the Consortium and served as the initial director of the KRCEE from 2003 to 2009. Mr. Steve Hampson has served as the associate director of the KRCEE and the site activities coordinator since its inception. In 2009, Dr. Ormsbee, stepped down as director of the KRCEE to devote more time to the activities of the Kentucky Water Resources Research Institute and the University of Kentucky Superfund Research Center, both of which continue to serve as

During the first phase of funding, Ormsbee and Hampson developed an initial portfolio of over 30 projects that focused on a range of issues including: data assessment and visualization, ecological science, surface water and sediment, geoscience and engineering, and scrap and contaminated metals recycling. From 2003 through 2009, administrative support for the KRCEE was provided by the Kentucky Water Resources Research Institute. In 2009, administrative support for the KRCEE was transferred to the CAER and Dr. Rodney Andrews became the KRCEE director.

Collaborators

Since CY 2002, academic and governmental agencies, offices, industrial entities, and subject-matter-expert individuals collaborated with the KRCEE for the shared goals of environmental restoration and future use of the Paducah Gaseous Diffusion Plant (PGDP).

Industry

- Miller Drilling, Lawrenceburg, TN (Holocene Project Drilling Contractor)
- [Tricord, Inc.](#) (Holocene and Real Time Demonstration Projects Health and Safety Contractor)
- [Fugro William Lettis and Associates](#) (PI's Holocene Displacement Project at the U Landfill)
- [M. Tuttle and Associates, Georgetown ME](#) (ITR Holocene Displacement Project Team)
- [Scientific Applications International Corporation \(SAIC\) – Cleveland OH](#) (Phase 11 DWGIS IT)
- [Scientific Applications International Corporation \(SAIC\) – Arlington Va.](#) (Phase 11 DWGIS IT)
- [Eberline Services, Hanford WA](#) (SME's, Technical Field Personnel and Instruments Real Time Demonstration Project)
- [CDM, Inc., State College PA](#) (SME Lithostratigraphy & DWGIS IT)
- [StrataG, Inc., Oak Ridge TN](#) (Lithostratigraphy)
- Jacobs Engineering, Oak Ridge TN
- Monster Color, Lexington, KY (Public Outreach)
- Photo Science, Lexington, KY (GW-SW Interaction – IR Aerial Photography)
- Performance Results Corporation, Paducah, KY

Government

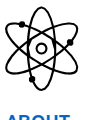
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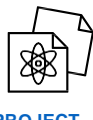
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