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8:30 am to 9:45 am Gulf Coast

Applications of the Louisiana Coastal Geohazards Atlas in groundwater management

Chris McLindon, New Orleans Geological Society,
chris.mclindon@upstreamexp.com

The Louisiana Coastal Geohazards Atlas Project is being jointly developed by the Louisiana Geological Survey and the New Orleans Geological Society. The focus of the atlas will be to map faults and salt domes across south Louisiana. There is a substantial body of research on the role of faults as both conduits and barriers to subsurface fluid migration including fresh and brackish groundwater. Salt domes in south Louisiana have also been shown to generate plumes of hypersaline fluid in groundwater aquifers caused by dissolution of the salt.

A review of the mechanics of the compilation of the atlas and some examples where detailed interpretation exists will demonstrate the application of a completed atlas to groundwater management. The atlas could be used to better understand the relationships between faults and fluid movement in drinking water aquifers and to better guide the planning and permitting of wastewater injection wells.

Keywords: groundwater, faults, and salt dome

Bayou Lafourche Sewage Project

Jesse Means, Louisiana Department of Environmental Quality, jesselmeans3@gmail.com

Bayou Lafourche, a major drinking water source serving over 200,000 people, is listed as an impaired water body due to the levels of fecal coliform in it. Because Bayou Lafourche is a source of drinking water and because a total maximum daily pollutant load has been developed for it which requires a reduction of the amount of fecal coliform, the Drinking Water Protection Program has worked to address the fecal coliform issue with the bayou. This effort has included work to pinpoint the sources of fecal coliform in the bayou and to identify ways to address them.

Many areas along Bayou Lafourche don't have community sewage service. It has been suggested by several local citizens and officials that improper treatment of sewage from individual homes is the most likely source of fecal coliform levels in the bayou. To begin addressing the fecal coliform in the bayou, DEQ's surveillance staff inspected all sewage systems along Bayou Lafourche that DEQ regulates (anything other than a home) to eliminate them as a potential source of fecal coliform. DEQ then contracted with Nicholls State University to locate areas that contribute human sewage to the bayou. The Nicholls study identified eleven locations as "hot spots" that contribute human sewage to it.

The results of the study were explained to the DEQ surveillance staff, LDH, and local officials. DEQ's Bayou Lafourche Regional Office followed up in areas around the hot spots for any sewage systems DEQ regulates. Several other options have been identified that should be implemented to address the sewage coming from the areas that drain to these hot spots, some of which require the active participation of the local government, especially the Lafourche Parish Council. These solutions include utilizing existing LDH regulations, utilizing a local parish ordinance to provide more local oversight, connecting individual sewage systems to existing community sewage systems, forming new community systems, repairing and/or replacing malfunctioning individual sewage treatment systems, and educating the public on proper individual sewage system maintenance.

Some of the above solutions have been implemented but it will take a combination of all the solutions, depending on various factors particular to each location, in order to provide for better environmental conditions in Bayou Lafourche. This will benefit fish and wildlife and human health, it will benefit the public water systems that must treat the water for public consumption, and it will better the quality of life in the communities affected. If no action is taken elevated fecal coliform levels in the bayou will persist and an increase in construction of new homes and businesses in unsewered areas along Bayou Lafourche along with the aging of existing individual sewage treatment systems could result in an increase of these levels.

Keywords: Bayou Lafourche, sewage, and water

Distribution and recovery trajectory of Macondo oil: shelf and wetlands

R. Eugene Turner, Louisiana State University, euturne@lsu.edu; Nancy Rabalais, Louisiana State University, nrabalais@lumcon.edu; and Edward Overton, Louisiana State University,

The temporal and spatial trajectory of oiling from the April, 2010 Deepwater Horizon oil spill is documented in water from Louisiana's continental shelf, the estuarine waters of Barataria Bay, and in coastal marsh sediment. The concentration of 28 target alkanes and 43 total target polycyclic aromatic hydrocarbons was determined in water samples collected on 10 offshore cruises. The concentration of target aromatics peaked in late summer, 2010, at 100 times above the May, 2010 values, which were already slightly contaminated. There were no differences in samples in surface or bottom water samples. The concentration of targeted aromatics declined at a rate of 73% y-1 to 1/1000th of the May 2010 values by summer 2016. The concentrations in 19 water samples collected monthly one km offshore, and at 13 inshore stations in 2010 and 2013, were 10-30% lower inshore compared to near shore. The differences in oil concentrations were initially different at 1 and 10 m distance into the marsh, but became equal after 2 years. Thus, the distinction between oiled and unoiled sites became blurred, if not non-existent then, and oiling had spread over an area wider than was visible initially. The alkane and aromatic concentrations from 2010 to 2018 were determined in 16 to 60 surficial marsh sediment samples collected on each of 26 trips. The concentrations were 100 to 1000 times above the May 2010 values, and dropped to 10 times higher after 8 years, thereafter, demonstrating a long-term contamination by oil or oil residues that will remain for decades. The chemical signature of oil residues offshore compared to in the marsh reflects the more aerobic offshore conditions and water-soluble tendencies of the dissolved components, whereas the anaerobic marsh soils will retain the heavier molecular components for a long time, and have a consequential effect on the ecosystems.

Keywords: oil residues, alkanes, aromatics, Louisiana continental shelf, estuaries, and salt marsh

8:30 am to 11:15 am State Wide Water Issues & Management

Update on work towards a Comprehensive Water Code for Louisiana

Christopher Dalbom, Tulane Institute on Water Resources Law & Policy, cdalbom@tulane.edu

As work under the authority of SR 171 (2014) continues, the Water Code Committee of the Louisiana State Law Institute plans to synthesize the wide array of research on comparative water law and water administration that the Tulane Institute on Water Resources Law & Policy

("WaLPo") has gathered. One result of this research is a better understanding of the important role played by data monitoring and modeling. Put simply, effective water resource management or administration by a local, state, regional, or national authority is simply impossible without adequate data. This presentation will update the findings of the Water Code Committee and the WaLPo, share a roadmap for the work going forward, and make an appeal to the scientific community to be partners in this work that, to be effective, will need to be rooted in the geosciences.

Keywords: Policy, administration, and law

Clean Water is our Life Blood

General Russell Honore', General Honoré, LLC, ftctsai@gmail.com

With a few slides about State and Global water issues, will give our GreenARMY assessment of Louisiana Small Rural Systems Challenges with recommendation to fix, 400 of our 1245 systems are at risk, ten have been declared emergency and state has taken control. Will also talk about improving water testing and training for operators, the later two are in Legislative bills being submitted this year

Keywords: Clean water, Louisana, and Rural Systems

What in the World are we Doing About our Fresh Water Resources?

George Losonsky, Losonsky & Associates Inc., glosonsky@gmail.com; and William Schramm, Losonsky & Associates Inc., 1billschramm@gmail.com

Almost daily the news draws our attention to serious concerns about the need for clean drinking water in our own communities, throughout the United States, and worldwide. Remote populations, rural communities, cities, and even entire countries and subcontinents are experiencing extreme drought conditions with no ability to provide their citizens with the resources necessary for survival.

In the United States, we assume there is no need to worry about fresh, clean drinking water when in fact, our expanding population has a growing demand for water, with rising expectations of water quality, to sustain our national way of life. Yet this fundamental resource is rapidly becoming scarce and costly to produce and distribute, causing economic and political strains.

A brief review of water policy and water resources planning by states indicates a general state of concern, but little in the way of effective water management and planning for future needs. Most states are dealing with immediate demands or shortages rather than reducing use, seeking alternate sources, or shifting use to less precious second water resources.

This presentation will touch on examples of state efforts in apportioning diminishing water resources; use minimization techniques; alternate sources; and the conundrum of shared resources.

Keywords**:** Water Resources, Second Water, Water Quality, Drinking Water, and Drought Conditions

Analysis of Public Supply Water Use in Louisiana

Pierre Sargent, U.S. Geological Survey, psargent@usgs.gov

The U.S. Geological Survey (USGS), in cooperation with the Louisiana Department of Transportation and Development, has collected and published water-withdrawal and water-use information on a 5-year basis since 1960. Although water data is collected quarterly from approximately 80 public suppliers that withdraw over one million gallons per day, the five-year time span between data collection for the other approximately 700 public suppliers does not provide for continuity in data collection. Estimates of water withdrawals are made when a water-supply facility does not have meters or when water-use data is not reported. A method is needed to check the validity of all withdrawal data. This study was initiated to (1) develop an improved method to estimate pumpage from public suppliers, and (2) provide a means to evaluate the validity of withdrawal data provided by all public water suppliers.

Data used for this study resulted from the mining of information collected as part of the 2015 Louisiana water-use compilation. Data from the compilation included: (1) percentage of water divided among public supply, commercial, industrial, and unknown uses; (2) number of residential connections; (3) population served; (4) data collection method; (5) meter location; and withdrawals in million gallons per day on an annual basis. Additional data was available from the Louisiana Department of Health and Hospitals and the United States Department of Homeland Security.

Assumptions made as part of this study include: (1) that withdrawal data from water-supply facilities with meters approximates ‘true’ residential water use, (2) meters used to obtain pumpage data have been calibrated, read, and reported correctly, and (3) estimated public supply water use can be improved with a new algorithm based on data analysis. The expected improved public water supply data as a result of this study will aid in the appraisal of Louisiana’s water resources based on present land use and the planning of future use.

Keywords: Water resources, Louisiana, public water supply and water use

The Louisiana Watershed Initiative Predisaster Planning & Water Management

William Wicker, Louisiana Watershed Initiative, william.b.wicker@gmail.com; and Alexandra Carter, Louisiana Watershed Initiative, alexandra.carter@la.gov

Louisiana is no stranger to flooding. From the Great Mississippi Flood of 1927 to Hurricane Katrina in 2005, the state's history is filled with destructive and catastrophic flooding events. With each new challenge, the State has risen smarter, stronger, and more resilient; and—as a result—become known for its expertise in flood recovery, disaster response and coastal management. The Louisiana Watershed Initiative, established in 2018 by Gov. John Bel Edwards, represents the state's response to its latest disaster: the Great Floods of August and March 2016.

The Great Floods of 2016 made it clear that the way we manage water in Louisiana needs to evolve to reflect the increased level of risk we face. Ten billion in damages and floodwaters that impacted more than 145,000 homes—many of which were NOT in a special flood hazard area—from a historic rainfall event—NOT associated with a hurricane—became a lightning rod for change. State leadership responded, emphasizing the importance of understanding why this disaster happened in the first place and the need to take immediate steps to reduce future impacts associated with a similar event. This Initiative boldly proposes to shift away from recovery and response and towards a more sustainable, proactive, holistic, watershed approach that can reduce the likelihood that we'd be buying out and elevating our communities of tomorrow (that are being built today) by setting new standards grounded in science-based pre-disaster flood planning and water management.

This approach requires acknowledging the importance of: (1) understanding how water naturally moves throughout the state, (2) implementing the systems to monitor, refine and update this knowledge, and (3) sharing responsibility with local, regional, and state-level decision-makers to coordinate and support the adoption of policies informed by these information systems – policies that would make a lasting, positive, change for citizens throughout the State of Louisiana.

The State is currently building the foundation to inform this process: gathering data and building dynamic models necessary to fully understand how water moves within and across the state, establishing the framework to support more coordinated decision-making across all levels of government, and working across all its agencies and programs to empower local jurisdictions and communities with the capacity, capability and resources to implement corresponding solutions. With more than $1.2 billion in federal funds on the horizon, pre-disaster flood planning, science-driven decision making and smart, holistic investments grounded in a watershed approach; Louisiana's communities can become more resilient and sustainable.

In line with LAWater 2019's aim of disseminating the latest water-related research and activities within and around Louisiana, Louisiana Watershed Initiative representatives will share more about how this Initiative represents the next-steps in a natural progression of the state's

efforts to reduce statewide flooding, what the Initiative has accomplished to-date and where it is headed, and explore key themes such as: regional coalition building, partnering with key market sectors to reduce risk, building trust and understanding between government agencies and external stakeholders, and how to empower all Louisiana residents to work together to counter rising flood risk.

Keywords: Louisiana Watershed Initiative, Flood Recovery Water Management, Disaster Recovery, and Flood Risk

Louisiana Watershed Initiative: Designing a Monitoring and Modeling Approach in Support of Statewide Comprehensive Watershed Management

William Wicker, Louisiana Watershed Initiative, william.b.wicker@gmail.com; Patrick Forbes, Louisiana Watershed Initiative, lori.dupont@la.gov; Ehab Meselhe, Louisiana Watershed Initiative, emeselhe@tulane.edu; and Emad Habib, Louisiana Watershed Initiative, ehhabib@gmail.com

The 'Great Floods' of August 2016 heightened an urgent and strenuous need for comprehensive watershed management plans in the State of Louisiana. Similarly, Texas endured devastating damages as a result of Hurricane Harvey in 2017. In addition to these extreme events, Gulf Coastal communities continue to be subjected to nuisance flooding from more frequent (and smaller) rain storms.

Designing data collection programs and developing predictive models to address the needs of communities experiencing combined chronic (small frequent storms) and acute (hurricanes and major storms) stressors has proven challenging. The Louisiana Watershed Initiative, established by Governor John Bel Edwards by Executive Order in May 2018, is seeking a holistic approach to collect static (topographic, bathymetric, land use, etc.) and dynamic (rain, stage, flows, wind, etc.) data in support of developing predictive models to provide high-quality information to support planning and decision-making processes statewide.

The models will be utilized to support flood mitigation feasibility studies, no adverse impact assessments, consequence assessment, risk assessment, and to continuously manage future developments and community growth. Another key component of the Initiative is to develop a long-term sustainability program to provide effective maintenance and access to the comprehensive monitoring program and its associated predictive tools. This sustainability program will ensure an effective utilization of resources in support of regional and local watershed management activities.

The presentation will provide an overview of the Initiative, describe the data collection and modeling approaches, and how they will be used to support holistic watershed management and project evaluation tools.

Keywords: Watershed, Floodplain Modeling, Monitoring Statewide, Great Floods, and Executive Order

10:00 am to 11:15 am Mississippi River

Contrasting diel dissolved carbon dynamics in the Mississippi and Yangtze Rivers

Jeremy Reiman, Louisiana State University - Department of Renewable Natural Resources, jreima1@lsu.edu; Lei Gao, East China Normal University - State Key Laboratory of Estuarine and Coastal Research, lgao@sklec.ecnu.edu.cn; Weiguo Zhang, East China Normal University - State Key Laboratory of Estuarine and Coastal Research, wgzhang@sklec.ecnu.edu.cn; and Y. Jun Xu, Louisiana State University - Department of Renewable Natural Resources, yjxu@lsu.edu

Rivers play an integral role in the exchange of dissolved carbon species between land, oceans, and atmosphere. Functioning primarily as a conduit for the delivery of terrigenous derived inorganic and organic carbon to the ocean, rivers are the back-bone of coastal food-webs. Though rivers can also emit a significant amount of carbon into the atmosphere through a process known as carbon dioxide (CO2) outgassing, which is attributed to an over-saturation of CO2 in the water column compared to concentrations in the atmosphere. Recent research has found many of the world's largest rivers function as a source of CO2 to the atmosphere, making outgassing a significant component of the global carbon cycle. However, accurately quantifying rivers' contribution to atmospheric CO2 emissions and carbon fluxes to coastal systems is very challenging, as several biotic and abiotic processes regulating carbon in river systems can greatly vary on the diel scale.

The overarching goal of this study is to determine the mechanisms influencing CO2 outgassing and dissolved riverine carbon dynamics over the span of a day in the lower reaches of large river systems. The study's specific objectives were to (1) analyze diel partial pressure of carbon dioxide (pCO2), dissolved organic carbon (DOC), and dissolved inorganic carbon (DIC) variability in the lowermost Mississippi River and the lowermost Yangtze River; (2) estimate diel changes in CO2 outgassing and DIC/DOC loading rates and; and (3) identify environmental factors influencing diel variation. To achieve the above objectives, water samples of DOC and DIC concentrations and in-situ measurements of pCO2 were collected at 3-hour intervals across multiple days in the Mississippi River in Baton Rouge, LA and freshwater inner estuary of the Yangtze River, China, in the summer and fall of 2018. Ambient water chemistry and meteorological parameters were also gathered to assist in identifying processes influencing diel variation.

Our data reveal a significant diel variation in CO2 outgassing in Mississippi River due to in-situ biological processes driven by solar radiation. In the inner estuary of the Yangtze River, analysis of ambient water data revealed a significant influence of ebb/flow tidal patterns on water chemistry, pCO2, and DOC. Incorporating diurnal variation into daily outgassing and loading

rates resulted in significantly higher rates in both rivers, indicating the importance of considering time of day into field-sample collection schedules and including diel carbon dynamics into future carbon export estimates.

Keywords: carbon dioxide outgassing, dissolved organic carbon, dissolved inorganic carbon, hydrology, Mississippi River, and Yangtze River

Morganza Control Structure & the Mississippi River Flood Fight

Tzenge-Huey Shih, U.S. Army Corp of Engineers New Orleans District, tzenge-huey.shih@usace.army.mil; David Vossen, U.S. Army Corp of Engineers New Orleans District, david.j.vossen@usace.army.mil; and Amena Henville, U.S. Army Corp of Engineers New Orleans District, amena.m.henville@usace.army.mil

Authorized by the Flood Control Act, adopted under Public Act No. 391, 70th Congress, approved 15 May 1928, the construction of Morganza Control Structure (MCS) was completed in 1954. Across the head of the Morganza Floodway, MCS is facing an approximate 4,500 acre forebay, which has a low elevation potato ridge to the northeast so that the Mississippi River can overtop during a high flow event. The MCS is a pile supported reinforced concrete gated structure, which shares its foundation with Louisiana Highway 1 and a railroad bridge. It is 3,906 feet long, with 125 active opening gate bays. The MCS is capable of diverting 600,000 cubic feet per second (cfs) of Mississippi River floodwater at a specific design stage to the Gulf of Mexico.

The design limitations for operating the Mississippi River and Tributaries (MR&T) structures is based on a hypothetical "maximum probable" flood called “Project Flood”. The operation of the MCS is based on a U.S. Army Corps of Engineers (USACE) Mississippi River Division approved Water Control Manual. The MCS operation is to prevent riverine flood stages from (1) exceeding the approved flow line, i.e. encroachment on freeboard requirements, (2) limiting flows to design discharge of 1,500,000 cfs between MCS and Bonnet Carre Spillway, and (3) limiting flow below the Bonnet Carre Spillway to the design flow of 1,250,000 cfs.

Since 1954, the MCS has only been operated twice, in 1973 and 2011. Both operations caused severe scour damage immediately downstream of the MCS. To meet the primary project goal of having the MCS fully repaired by the 2014 flood season, the construction phase of the repair work was executed by the USACE New Orleans District (MVN) in three consecutive phases, each occurring upon completion of its respective physical model experiment performed by the USACE Engineer Research and Development Center (ERDC). MVN began the rehab construction on September 19, 2012. The contractor completed all repair work on March 19, 2014. After 18 months of repair and construction, the MCS is ready and capable of passing the project flood. Based on ERDC’s recommendation and lessons learned from operation in the 2011 flood, MVN has refined the MCS Water Control Manual to ensure that the Corps can safely operate the flood control structure in the future.

The authors wish to use this conference to introduce the 2014 completed MCS tailbay scour protection feature and how MVN uses it to fight for the Mississippi River high flow event.

Keywords: Flood Control Act, Morganza Control Structure, MCS, Mississippi River and Tributaries, MR&T, and Mississippi River Flood Fight

Decadal changes in river discharge from the continental United States to the Gulf of Mexico

Y. Jun Xu, Louisiana State University, yjxu@lsu.edu; and Yan Qi, Louisiana State University, yqi5@lsu.edu

The impact of river freshwater flowing into estuaries on biological processes and ecosystem development has long been recognized. The magnitude, timing, and duration of freshwater can affect fluctuations in estuarine physical and chemical properties including temperature, salinity, turbidity, and concentrations of nutrients, sediment, and dissolved oxygen. This study analyzed discharge of 24 major rivers entering the Gulf of Mexico from the continental United States. Geographically, these rivers span from Florida in the east to Texas in the west. Quantitatively, they drain land surface areas ranging from approximately 500 square kilometers to over 3 million square kilometers. The discharge data covered a period from 2016 back to the early 20th century, allowing an assessment of their long-term variability and trends. The study found several interesting outcomes: 1) All eight rivers east of the Pearl River on the state borderline between Louisiana and Mississippi showed a significantly declining trend of discharge over the past century, with the Hillsborough River in Florida having the largest decline (nearly 40%) in the past 30 years; 2) Most rivers (twelve) west of the Pearl River showed an increasing trend of discharge, with the San Antonio River in Texas having the highest increase rate (>30%) in the past 30 years; 3) On average, the Mississippi-Atchafalaya River System (MARS) contributed nearly 83% of the total river flow (i.e., 809 cubic square kilometers) from the U.S. continent into the Gulf of Mexico, playing a dominant role affecting coastal and marine environments of the world's ninth largest ocean; and 4) the MARS had a clear increase in discharge over the past century, both in extreme lows and in extreme highs. The findings indicate the effects of both climate change and human impact on freshwater resources across the large region.

Keywords: rivers, freshwater resource, Mississippi-Atchafalaya, and Gulf of Mexico

Monday April 15, 2019 afternoon oral secessions

1:00 pm to 3:05 pm Ethics & Techniques

Evaluating Shallow Groundwater Resources Using Smart Tools

Scott Bergeron, Professional Technical Support Services, Inc., smbergeron@envirodepot.com; and George Losonsky, Losonsky & Associates, Inc., glosonsky@gmail.com

Keywords: Geoprobe, Hydraulic Profiling Tool, Pneumatic Slug Testing, and Optical Imaging Profiler

Estimating groundwater availability and land-surface subsidence in the Coastal Lowlands Aquifer System using a MODFLOW 6 model and uncertainty analysis

Linzy Foster, U.S. Geological Survey Texas Water Science Center, lfoster@usgs.gov; Leslie Duncan, U.S. Geological Survey Lower Mississippi Gulf Water Science Center, lduncan@usgs.gov; and Brian Clark, U.S. Geological Survey Water Mission Area, brclark@usgs.gov

The vast Coastal Lowlands Aquifer System (CLAS), one of the principal aquifers of the United States, underlies the coastal regions of Texas, Louisiana, Mississippi, Alabama, and the panhandle region of Florida. In 2016, the U.S. Geological Survey began a 5-year study focused on understanding groundwater availability, water budgets, land-surface subsidence, and the value of the existing monitoring-well network in the CLAS. A new MODFLOW 6 groundwater model is in development to gain a better understanding of this aquifer system and enable predictions of quantities of interest (QoIs) such as water levels, land-surface subsidence, and base flow in streams. These QoIs will be estimated using uncertainty quantification (UQ). First-Order Second-Moment analysis (also known as linear analysis) capabilities built into the USGS PEST++ and pyEMU suite of software will be used to develop an initial posterior ensemble of model parameters and predictions of QoIs. The UQ is being used to guide next steps in development by quantifying changes in predictive uncertainty resulting from a specific model update. UQ estimates will be improved with the use of the new iterative ensemble smoother algorithm in PEST++. QoIs will be evaluated for baseline conditions as well as different combinations of anthropogenic and climate scenarios.

Several models of the CLAS have been developed in the past few decades on both regional and local scales. Model parameter and groundwater withdrawal information from these models are being used to inform the prior information for the UQ of the new MODFLOW 6 model and to provide water-use information for the model. The new model is based on current (2019) understanding of the hydrostratigraphic units of the Chicot, Evangeline, and Jasper

aquifers in the study area. The model incorporates information obtained from work done in 2017 by Intera Geoscience and Engineering Solutions in Texas, USGS datasets in Louisiana, and other datasets for the aquifer system published since the previous Regional Aquifer System Analysis (RASA) investigations of the 1990s. Information on the current conceptualization of the model, datasets used in development of the model, and next steps of model development and UQ will be discussed in this presentation.

Keywords: Mississippi Alluvial Plain, Airborne Electromagnetic, and Mississippi River Valley alluvial aquifer

Professional Ethics for Geologists and Engineers

John Johnston, Louisiana Geological Survey, hammer@lsu.edu

The ethical obligations of professional geologists and professional engineers are addressed. Topics covered include possessing the required education, keeping current in your professional field(s), never misrepresenting yourself, the need to have a license (and possibly a certification), avoiding professional wrongdoing, obeying your professions' own professional code of ethics, avoiding conflicts of interest, approaching every professional task with logic and caution, and never making false, misleading, or sensationalist professional statements.

Keywords: Ethics, Geologists, and Engineers

Hidden complexity of the Mississippi River Alluvial Valley aquifer illuminated like never before using regional-scale airborne geophysics

Wade Kress, U.S. Geological Survey, wkress@usgs.gov; Burke Minsley, U.S. Geological Survey, bminsley@usgs.gov; and James Rigby, U.S. Department of Agriculture, JR.Rigby@ars.usda.gov

In 2018, the U.S. Geological Survey began a multi-year airborne geophysical mapping initiative, incorporating both regional and high-resolution airborne electromagnetic (AEM) surveys as part of the Mississippi Alluvial Plain water availability project. The initial high-resolution survey in March 2018 comprised approximately 2,500 line-km of airborne geophysical data over a 1000 sq. km survey block near Shellmound, MS, using the CGG Resolve1 helicopter system. Later that year, the first phase of the regional AEM survey began (also with the Resolve AEM instrument) and acquired nearly 17,000 line-km of data mainly along west-east flight lines at 12 km intervals in the northern and southern portions of the study area, and 6 km intervals in the central portion of the study area. Additionally, approximately 2,000 line-km were acquired along several rivers to better characterize the connectivity between surface water and groundwater. Additional flight lines will be flown each year to increase the resolution of the regional hydrogeologic framework to the targeted 3 km-spaced flight lines.

Comparison of preliminary resistivity data to previously-published Mississippi River Valley alluvial (MRVA) aquifer base maps and borehole data indicate that the EM sensor was able to fully penetrate the Quaternary alluvium. Resistivity data below the MRVA aquifer base show the spatial extent of several subcropping aquifer (high resistivity) and confining (low resistivity) units from the Mississippi Embayment sequence. Resistivity data also show that the Quaternary-Tertiary contact may have more topographic relief than previously interpreted from borehole data.

We will illustrate the tradeoffs between the high-resolution survey (sub-1 km spacing) with the regional survey grid (3+ km spacing). Interpretations of the resistivity models will be used to refine interpreted surfaces of the base of the MRVA aquifer, subcropping units, and shallow confining layers that can be incorporated into groundwater models. By better quantifying and reducing uncertainty about the geologic framework, we hope to improve estimates of hydrologic uncertainty to better aid and inform management decisions.

Keywords: Mississippi Alluvial Plain, Airborne Electromagnetic, and Mississippi River Valley alluvial aquifer

1:00 pm to 3:05 pm Louisiana and Beyond

Trends for Hydraulic Fracturing for Unconventional Plays compared to Haynesville

Douglas Carlson, Louisiana Geological Survey, dcarlson@lsu.edu

In the last 20 years directional drilling and hydraulic fracturing (HF) been improved so as to have a major impact on oil and gas field development. The result is wells with horizontal laterals and pay zones of a mile or two compared to 100s of feet for vertical wells. The resulting volumes of water used have increased tremendously. For example, the average water used for a single Haynesville shale in Louisiana in 2018 was approximately 20 million gallons (20 MG). The question are the values and trends for HF the Haynesville similar to other major unconventional plays?

This study's analysis on FracFocus data included approximately 120,000 hydraulic fracturing jobs primarily between 2012 and 2018 throughout the United States. Between 2013 and 2018 were base fluid was noted water was used for over 99.6% of HFs and other non-water fluids were used for 14% of HFs.

Past studies have noted that there has been a general increase in water used for HF in the United States. For this study, the median volume used for fracturing a well in the United States has increased by approximately 350% between 2012 and 2018, while share of wells fractured with 10 MG or 20 MG has increased, 1.55% to 50.5% and 0.12% to 13.9% respectively.

Usually past studies considered HF for single fields. This study noted increases of average water use for 18 of 19 shales between 2012 and 2018, and tripled for 9 shales. Haynesville is 10 th among fields with increase of water volume of approximately 200%. Largest

rates of increase were for fields in semi-arid and arid areas in Colorado, southwest Texas, Utah and Wyoming. Average volumes of water use for re-HF a well increase by 100% for the Haynesville. Results are similar for the Bakken, Eagle Ford and Wolfbone Shale.

Keywords: hydraulic fracturing, water use, non-water use as base fluid, and refracturing of wells

Investigation of the geochemical and geophysical evolution of groundwater in a Neogen basin: kert aquifer NE of Morocco

Mohammed Elgettafi, Mohamed first University, m.elgettafi@ump.ac.ma; and Juan Lorenzo, Louisiana State University, gllore@lsu.edu

Groundwater's studies at Kert aquifer in northeast of Morocco are very important because of its semi-arid character and geological history. The region was affected by the Messinian salinity crisis 5.6 Ma. Freshwater with total dissolved solids 740 mg/l in Tafersite district is chemically distinct from saline water with total dissolved solids of 9803 mg/l in the south. The Kert River contains water characterized by S04-Cl-Ca facies influenced by groundwater and surface water flow from highlands in south.

This study reveals that weathering of evaporated rocks is the process that is responsible for high Na+, Ca2+, Mg2+, Cl- and SO42- concentrations. Also, hydro chemical data displays that freshwater observed in the northwest part reflect the influence of freshwaters coming from metamorphic massive of Temsamane. Environmental isotopes data of Oxygen and hydrogen isotopes in ground water and sulphur and oxygen content of dissolved sulphate as well as characteristics of d-excess are used to illustrate the origin of the salinity. The isotope compositions in these waters range from −5.74 to −4.51 ‰ for oxygen and from −40.8 to −34.1 ‰ for hydrogen. In the Kert River the values are −6.47 ‰ for oxygen and −47.56 ‰ for hydrogen. All sample plots with a slope <8 do not fall on the meteoric water line indicating a light evaporation. Water has low and different d-excess values (ranging from +1.37 to +9.82 ‰), and reflects different climatic conditions. The isotope compositions range from −2.2 to +16 ‰ for sulphur and from +5.02 to +13.86 ‰ for oxygen. In Kert River these values are −4.6 and +5.3 ‰ for sulphur and oxygen respectively.

There are fairly constant differences between oxygen isotope of water and the oxygen isotope of sulphate suggesting a dominant control of this latter in sulphate sources. At least three major sulphate sources were identified by the isotope data from sulphate in these waters: (1) dissolved marine sulphate from the underlying upper Miocene unit; (2) dissolved sulphate from Kert River; (3) sulphate derived from oxidation of sulphur compounds in the metamorphic massif of Temsamane. The latter has a dilution role. The isotopic variations of these waters and sulphate concentration therein reflect mixing of these sources in the aquifer.

Kert aquifer has been characterized by electrical resistivity tomography method. A relationship has been outlined between resistivity values obtained from geophysical method and groundwater salinity. The electrical resistivity values vary laterally from the north to the south and East. High resistivity values ($20<\rho<430$ Ω.m) are located in the northwest part of the plain,

while resistivity values decrease gradually eastward ($6<\rho<100$ Ω.m), as well as to the south ($2<\rho<170$ Ω.m). This variation is in accordance with groundwater salinity measured in wells which is relatively low in the northwestern (TDS 600mg/l) and that become saline in the rest of the plain (TDS 12 000 mg/l). From the inverted geoelectrical cross-sections two origins of groundwater salinity have been identified. The first is represented by the contact with Miocene Marls and the second by saline water flowing through the Kert River.

Keywords: Groundwater salinization, Geochemistry, Electrical tomography, and Morocco

Assessment of trace metal levels along an estuary of petrochemical industrial areas in Southwest Louisiana

Songjie He, Louisiana State University, she5@lsu.edu; and Y. Jun Xu, Louisiana State University, yjxu@lsu.edu

To better understand the potential for metal pollution in an estuary heavily concentrated with petrochemical industries, we measured concentrations of metals and metalloids in the Calcasieu River estuary entering the northern Gulf of Mexico in the United States. We sampled six sites along the last 88-km reach of the river monthly between May 2013 and November 2015, during which salinity ranged from 0.02 to 29.5 from upstream to downstream. Surface water of a tributary, Bayou d'Inde - an EPA superfund site, was also sampled during this study period. Surface water samples were analyzed for total recoverable aluminum (Al), arsenic (As), boron (B), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), lithium (Li), manganese (Mn), nickel (Ni), titanium (Ti), vanadium (V), zinc (Zn), and total suspended sediments (TSS). Additionally, in-stream measurements of temperature, salinity, pH, and dissolved oxygen concentration were made at the time of water sample collections. Over the 31-month study period, Cd, Co, Cr, Cu, Ni, and V were detected in less than 30% of the surface water samples and were therefore excluded from the temporal and spatial trend analysis. The Bayou d'Inde site had much higher Ba and Mn concentrations than the six main stream sites. There were no metal pollution concerns except for Al and Fe. The total recoverable concentrations of B and Li increased significantly with increasing salinity, but the concentrations of other elements showed no trends with respect to salinity. Fluxes of these trace elements from Calcasieu River's freshwater to its estuary were also calculated.

Keywords: Trace elements, Metal pollution, Spatiotemporal, Calcasieu River, and Gulf of Mexico

Recent Morphological Evolution of the Channel Bar in the Middle Yangtze River During 1985-2015 Influence of Sediment Decline by Anthropogenic Interference

Hui Li, China University of Geosciences, 33230398@qq.com; Jun Xu, School of Renewable Natural Resources, Louisiana State University, yjxu@lsu.edu; and Zhaoyang Wang, China University of Geosciences, zhaoywang@cug.edu.cn

Channel bar is a highly dynamic depositional feature in the channel and has significance for navigation, flood control, and river ecosystem. It evolves as a result of combined effects of both natural process and human interferences. In the past several decades the human-induced riverine sediment decline is a common phenomenon observed in many river systems around the world. This is especially the case with the world's largest hydropower dam, the Three Gorges Dam (TGD).However, relatively little is known about the impact of such human interferences on the long-term evolution of channel bar in the MYR. Such information can be helpful for the design of engineering projects in advance to reduce possible hazards in bank collapse and navigation safety in the MYR.

The purpose of this study is to investigate morphological changes of the Wugui bar 400 km downstream of the TGD during 1986–2015, and to delineate the effects of upstream dam and channel dikes on the morphology of channel bars.

Our results showed that the deposition and erosion pattern exhibited strong temporal and spatial variations, leading to the bar area variations. The evolution of the bar can be divided into four stages, including stable extension stage (1986–1997), quick shrink stage (1998-2001), stable shrink stage (2002-2008) and stable extension stage (2009-2015), with the corresponding area change rates of 0.31 km2/a, -0.60 km2/a, -0.13 km2/a, and 0.09 km2/a.

The preliminary analysis shows that there was a close positive relationship between bar areas and sediment concentrations. The first stable extension stage reflects the nature development of the bar. The second quick shrink and third stable shrink stages reveals the human interferences as the TGD was constructed and closed during these stages. The fourth stable extension stage suggests the bar protection measures take effects as the V-dikes were installed at the bar head shortly before this stage. A detailed relationship between human interference and bar evolution will be carried out in the next step. Our results indicated that the evolution of bar morphology of the studied Wugui bar is directly affected by the dramatic reduction of sediment load, which is much close related to anthropogenic interferences in the MYR in recent decades.

Keywords: Channel bar, Yangtze River, Three Gorges Dam, Landsat images, sediment concentrations, and anthropogenic interferences

Assessing Louisiana public supply water wells in terms of Ground Water under Direct Influence of Surface Water (GWUDISW)

Yuanda Zhu, Louisiana Department of Health, yuanda.zhu@yahoo.com; and Johan Forsman, Louisiana Department of Health, Johan.Forsman@la.gov

The Interim Enhanced Surface Water Treatment Rule (SWTR) requires public water systems (PWSs) to install disinfection and filtration treatment, if the systems obtain their water from surface water or from groundwater that is under direct influence of surface water. The EPA further requires states with drinking water primacy to develop a program to determine which PWS ground water sources may be under the direct influence of surface water.

The Louisiana Department of Health (LDH) Safe Drinking Water Program (SDWP) completed the first assessment of GWUDISW for community water systems between 1994 and 1995 and for non-community water systems in 2000. No ground water sources in the SDWP inventory were found to be GWUDISW. Since the first assessment completed, new water systems and new wells have been added to the SDWP inventory, necessitating a new assessment.

In total, 2,689 active wells, belonging to 1,209 active PWSs, were evaluated. By applying a series of exclusion criteria, 21 wells were selected for Microscopic Particulate Analysis (MPA) testing to determine whether the wells are at risk of GWUDISW. Two rounds of sampling have been completed, October/November 2018 and January /March 2019, with the final round scheduled for May/June 2019. The results thus far indicate that all wells are at low risk of GWUDISW, except for one sample with moderate risk reported.

Keyword: Groundwater, public supply water well, direct influence of surface water, and safe drinking water

3:20 pm to 5:00 pm Southern Louisiana

The Springs of Denham Springs, Louisiana their history, chemistry and source of water

Douglas Carlson, Louisiana Geological Survey, dcarlson@lsu.edu

Approximately 100 to 150 years ago a series of hotel were built for tourist that considered the springs' water to be therapeutic. Currently Spring Park includes some of these springs. This study included a search for springs within the park. Water samples from the springs analyzed to see if spring water is different from city groundwater and interpretation of what is the source of the spring water.

On April 21, five additional seeps/springs found within a couple hundred feet of the spring the city marked off by a cement cistern. Springs sampled in, April, June and October. Water collected from each seep/spring and the current spring with a cement cistern around it. One unpreserved 50 ml sample later analyzed using an ion chromatography system for a series of

anions. Another preserved with nitric acid 50 ml sample later analyzed using an inductively coupled plasma-optical emission spectrometer for mainly a series of metals and other cations.

Except for ions that have non-detection concentrations, concentrations of ions in seep water exceed that in city water from deep aquifer by often up to a factor of 60. Seep water has higher concentrations of aluminum, calcium, iron, magnesium, and manganese than city water that is to be expected. In addition, seep water has concentrations of most ions far over those for any of the other more shallow aquifers in the Denham Springs area. This in particular true for chloride concentrations, which eliminates the possibility that seep water source, is the underlying aquifers that make up the Southern Hills Aquifer System. This means surface water source is the likely for the high chloride concentrations observed in the seep water. The likely source of surface water is Lake Maurepas water mixed in with more dilute Amite River, nearby groundwater and infiltrated rainwater

Keyword: history, water chemistry, water source

Structured Decision Making to Support Long-Term Water Resource Planning

Alyssa Dausman, The Water Institute, adausman@thewaterinstitute.org; Ryan Clark, The Water Institute , rclark@thewaterinstitute.org; Michael C. Runge. U.S. Geological Survey, mrunge@usgs.gov; and Ellen Bean, beanellen@gmail.com

The Capital Area Ground Water Conservation District was created by the Louisiana Legislature in 1974 because of groundwater-level declines in the Southern Hills Aquifer System, saltwater encroachment in several local aquifers, land subsidence caused by over-pumping, and other concerns. The District's governing Commission began work in 1975 with a mission to provide for the efficient administration, conservation, orderly development, and supplementation of groundwater resources in the Greater Baton Rouge Area. The Commission consists of eighteen members appointed by the Governor and confirmed by the Senate. The job of the Commission is to develop, promote, and implement management strategies to provide for the conservation, protection, and sustainable use of local groundwater resources. Although the Commission has invested in monitoring, modeling, and science to inform decision making in setting groundwater use priorities and production limits, saltwater encroachment continues to be an issue in the aquifer. There remain questions as to whether the state of the science informing Commission decisions is sufficient, and whether other strategies, such as expanding surface water use, need to be considered as the Greater Baton Rouge Area grows and water resource needs increase. Further, among the stakeholders within the District, there is not yet consensus on a path forward for long-term water resource development. Therefore, there is a need for a long-term strategic plan for water resources.

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such as expanding surface water use, need to be considered as the Greater Baton Rouge Area grows and water resource needs increase. Further, among the stakeholders within the District, there is not yet consensus on a path forward for long-term water resource development. Therefore, there is a need for a long-term strategic plan for water resources.

The Water Institute of the Gulf (Institute) and the U.S. Geological Survey (USGS) is initiating the first phase of a project with the Commission to support a long-term strategic planning process for water resources. The project objectives are to:

• Work with the Commission and other technical stakeholders to identify and evaluate feasible, realistic, and cost-effective science-based alternatives which meet long-term water resource needs.

• Evaluate the state of the science related to groundwater use and aquifer conservation needed to evaluate alternatives and inform decisions.

• Work with the Commission to identify management alternatives that are economically feasible and acceptable to support the development of a strategic plan for long-term water supply sustainability for the District.

The Institute and USGS are using formal methods of decision analysis to meet project objectives, following the PrOACT framework for structuring decisions. This includes:

• Defining the Problem

• Determining the Objectives

• Identifying Alternatives

• Evaluating alternatives and forecasting the Consequences

• Evaluating the Trade-offs

• Making the decision and taking action

In the first phase of this project, the Institute and USGS are taking this structured, facilitated approach with the Commission to articulate and identify: (1) the potential problems based on the mandates, laws, preferences, and scope of current decisions of the Commission; (2) the specific long-term fundamental objectives of the Commission; and (3) the potential management alternatives the Commission would consider. It is anticipated that subsequent phases of the project will lead to development of a long-term strategic plan for water supply and management in the District.

Keywords: Structured Decision Making, Groundwater, Saltwater Intrusion

Approaches to Minimization of Saltwater Intrusion in the Baton Rouge Area

Anthony Duplechin, Capital Area Groundwater Conservation District, tony@cagwcc.com

Due to heavy pumping of certain aquifers within the Capital area, saltwater from the south has moved across the Baton Rouge Fault into some of the fresh water aquifers in East Baton Rouge Parish. The Capital Area Groundwater Conservation District is empowered to take all necessary steps to prevent intrusion of salt water or any other form of pollutant into any aquifer or aquifers, including the powers to operate withdrawal wells for the extraction of salt water or water affected by any pollutant and to dispose of such water by injection or otherwise; to operate injection wells to create freshwater barriers against salt water intrusion or the intrusion of any other pollutant; and to control pumping rates by users in any area threatened by intrusion of saltwater or other form of pollutant.

The District has explored options to address saltwater intrusion in the "2,000-ft" sand, which is used by both industry and public supply. Installation of a saltwater scavenger well system is the preferred course of action. A suitable site for the first exploratory well has been selected and work on this well should be completed before the end of 2019.

Keywords: Groundwater, Saltwater Intrusion, and Remediation

Chicot aquifer water-level increases correspond with a reduction in groundwater withdrawals in the Lake Charles area

Vincent White, United States Geological Survey, vwhite@usgs.gov

The "200-foot," 500-foot," and "700-foot" sands of the Chicot aquifer system are an important source of groundwater that is used for various purposes including public supply, agriculture, industry, and power generation in the Lake Charles area. Since the 1940s, large groundwater withdrawals have caused water-level surface declines in these sands. Recent analysis shows that from 1995 to 2012, water levels have risen by as much as about 30 ft in the "500-foot" sand, 19 ft in the "700-foot" sand, and 7 ft in the "200-foot" sand in the Lake Charles area. In comparison, groundwater withdrawals from these sands in the Lake Charles area decreased by 25 million gallons per day (Mgal/d), from 109 Mgal/d in 1995 to 84 Mgal/d in 2012. These are the results of analysis of water levels measured in ninety wells to prepare 2011–12 potentiometric surfaces of the "200-foot," 500-foot," and "700-foot" sands of the Chicot aquifer system underlying Calcasieu and Cameron Parishes of southwestern Louisiana. These levels were compared to 1995 data to create water-level change maps of selected wells screened in these sands. Further comparison was made with water use data collected by the USGS Water Resources Cooperative Program: Louisiana Water Use Program.

This analysis used existing datasets to make inferences about the relationship between water-levels and groundwater withdrawals and provides scientific knowledge needed by water-

resource managers to plan for future development. Higher groundwater levels can reduce the costs of pumping water from wells and reduce the potential for saltwater intrusion into freshwater aquifers. This work was completed by the U.S. Geological Survey in cooperation with the Louisiana Department of Transportation and Development to assist in developing and evaluating groundwater-resource management strategies and as a service to the public.

Keywords: Chicot aquifer, Lake Charles, potentiometric surface, 200-foot" sand, "500-foot" sand, and"700-foot" sand

3:20 pm to 4:35 pm Northern Louisiana

Mapping the Variability of Specific Conductance in Groundwater of the Mississippi River Valley Alluvial Aquifer

Ashley Bussell, U.S. Geological Survey, Lower Mississippi-Gulf Water Science Center, abussell@usgs.gov; Courntey Killian, U.S. Geological Survey, Lower Mississippi-Gulf Water Science Center, ckillian@usgs.gov; Katherine Knierim, U.S. Geological Survey, Lower Mississippi-Gulf Water Science Center, kknierim@usgs.gov; James Kingsbury, U.S. Geological Survey, Lower Mississippi-Gulf Water Science Center, jakingsb@usgs.gov; Samantha Wacaster, U.S. Geological Survey, Lower Mississippi-Gulf Water Science Center, srwacaster@usgs.gov; and Wade Kress, U.S. Geological Survey, Lower Mississippi-Gulf Water Science Center, wkress@usgs.gov

The Mississippi River Valley alluvial (MRVA) aquifer is the uppermost aquifer underlying the Mississippi Alluvial Plain (MAP) and spans portions of eight states within the Mississippi Embayment. The MRVA aquifer supplies most of the groundwater used for irrigation throughout the MAP. Water-quality conditions in parts of the aquifer may limit the availability of groundwater for irrigation, public supply, and domestic use. To better understand and map the water resources of the MAP, the U.S. Geological Survey (USGS) designed an Airborne Electromagnetic (AEM) survey to map resistivity of hydrologic units at the regional scale. Mapping resistivity changes of hydrologic units will help identify the primary drivers that influence groundwater quality in the MRVA aquifer. To accurately interpret the AEM survey data and the changes in resistivity, the spatial and vertical distribution of groundwater specific conductance throughout the aquifer needed to be delineated. This study compared newly collected and existing historical specific conductance and chloride data from over 1,500 existing wells and cooperatively funded water-quality monitoring sites screened in the MRVA aquifer to changes in geomorphology, recharge rates, and well depth. The results from this study will support three-dimensional machine-learning models of specific conductance and recharge-rate estimates as a part of characterizing the water-budget components in the MAP. Results will also help to predict aquifer salinity across the region and help to characterize areas where possible upwelling from deeper saline units may impact the availability of fresh water in shallower aquifers.

Keywords: Specific Conductance, Mississippi River Valley alluvial, aquifer salinity, groundwater, Mississippi Embayment, Mississippi Alluvial Plain, and fresh water availability

Water quality index in the assessment of the Red Bayou water quality for crop irrigation

Changyoon Jeong, Louisiana State University, she5@lsu.edu; and Se-Won Kang, Louisiana State University, yjxu@lsu.edu

Water availability is one of the major limitations to crop production and sustainability in many regions. Utilizing diverted water or tailwater recovery systems as an alternative irrigation method is increasingly being used to supplement groundwater. Recently, Louisiana has seasonally experienced severe drought, emphasizing the need for farmers to develop dependable sources of irrigation water to meet crop needs during critical stages of growth. Water diversion and tailwater recovery systems conserve irrigation water supplies through capture and reuse for agriculture. Water diversion project was completed at the Red Bayou watershed in June 2014 to support a local community mainly for agricultural irrigation in the northwest of Louisiana. The Red Bayou project was funded by the American Recovery and Reinvestment Act (ARRA) and partially supported by the plan of the Obama Administration to improve the nation's infrastructure and to enhance a local economy. Although irrigation efficiency and water quantity were enhanced after completion of the water diversion project, the evaluation of water quality for irrigation has not yet been fully assessed. The specific objective of this study was to monitor water quality parameters of seasonal variation and develop the Water Quality Index (WQI) for the evaluation. In-stream water samples were collected bi-weekly based on regular and rain events. Water samples were analyzed for the concentration of total suspended solids (TSS, mg/L), total P (TP, mg/L), soluble reactive (SRP, mg/L), total N (TN, mg/L), and nitrate ($NO3^-$, mg/L) using Lachat Quickchem Flow Injection analysis system (Hach, Loveland, CO) at the Red River Research Station, LSU AgCenter. Besides, the smarTROLL multi-probes instrument (In-Situ Inc.) was used to measure in-situ dissolved oxygen (DO, mg/L), pH, temperature (◦C), conductivity (µS/cm), and depth (m). Results of four years study showed a strong seasonal and spatial variation on surface water quality across the Red Bayou watershed. The value of water quality index (WQI) was calculated to evaluate water quality along the bayou and seasonal water quality changes.

Keywords: Water quality index (WQI), Irrigation, and Red Bayou

Challenges with Salt Water Disposal in the Haynesville Shale Play

Corey Shircliff, Louisiana Department of Natural Resources, ceshircliff@gmail.com

In Louisiana Haynesville Shale play and the surrounding area in northwest Louisiana, there are upwards of 750 active injection wells, including several high-volume commercial injection wells. While these injection wells inject into subsurface zones of varying thickness and

lithology, all inject the same substances: produced water and flow-back water from the hydraulic fracturing operations.

Unlike the thick sands with ample porosity and permeability found across most of Louisiana, the injection zones in northwest Louisiana are typically sparse and thinner, with lower porosity and permeability, and commonly pinch out or change character quickly across horizontal distances. Over time, the reservoir pressure in these zones has increased as a function of the geological characteristics of the formation and the volumes of fluid injected.

Louisiana permits a maximum injection pressure for each salt water disposal well that is based on a percentage of the pressure needed to fracture the injection formation. Across the state line in Texas, this maximum injection pressure calculation is different, allowing injection at significantly higher pressures with correspondingly higher volumes of produced water. In 2017, increased injection formation pressures were noted within Louisiana near the Texas border in areas without any active injection wells.

Ultimately, northwest Louisiana faces the challenges of diminishing usable injection zones due to formation pressuring from historic disposal operations, increased volumes of produced water from new wells with more and larger hydraulic fracture operations, and pressures within injection formations potentially migrating eastward from our neighbor to the west. With compromise solutions between regulators and operators tough to find, new regulations and possible understandings between neighboring states are likely.

Keywords: Haynesville Shale, Injection Wells, Salt Water Disposal, Hydraulic Fracturing, Fracking, and Water Resources

Monday April 15, 2019 poster secessions

Levees and Rivers

Characterization of sedimentology and infill rates for borrow areas in coastal Louisiana

Matthew Barley, Louisiana State University, mbarle1@Lsu.edu; Carol Wilson, Louisiana State University, carolw@lsu.edu; Kehui Xu, Louisiana State University, kxu@lsu.edu; and Sam Bentley, Louisiana State University, sjb@lsu.edu

Over the past century, Louisiana has experienced some of the highest rates of coastal land loss within the United States. More recently, the State of Louisiana has addressed this issue by relocating sand from borrow areas to replenish coastal barrier islands. Introducing new sand from borrow areas helps to slow coastal wetland loss. However, little is known on how sediment dredging impacts water quality and biogeochemistry within borrow areas. Furthermore, changes to seafloor topography within borrow areas has potential to affect oil and gas infrastructure in close proximity. Our research is focused on comparing effects of sand excavation in sandy

versus muddy environments in coastal Louisiana. Previous work within the area shows silty sediments (finer than ~30 μm) are filling in the borrow area at high (~0.1-0.3 cm/day) rates following deposition associated with winter months and at low rates (0.01-0.02 cm/day) for summer months. Although many studies have been conducted within borrow areas, there is a lack of data that could possibly link sediment infill in borrow areas to duration and intensity of hypoxia in the northern Gulf of Mexico. As of September 2018, 5 multicores were taken at Caminada borrow area, a sandy energetic site approximately 25 km off the coast of central Louisiana. Of the cores taken, half were prepared for x-ray analysis to understand the sedimentary characteristics within the pit. The other half were extruded in 2 cm intervals for analysis of water saturation, grain size, radionuclide (7Be), and organic matter accumulation. The latter will be important to discern if muddy, organic-rich sediment is increasing the length and duration of hypoxia within borrow areas by absorbing oxygen during decomposition. Preliminary results of x-ray core images show a lack of bioturbation within recently deposited sediment (top ~4cm) which is indicative of hypoxic environments.

Keywords: Borrow Areas, Coastal Restoration, Sedimentology, Infill Rates, and Hypoxia

Evaluation of Relief Wells along Levees of Inner Harbor Navigation Canal, New Orleans, Louisiana

Ye-Hong Chen, Department of Civil & Environmental Engineering, Louisiana State University, yche122@lsu.edu; and Frank T.-C. Tsai, Department of Civil & Environmental Engineering, Louisiana State University, ftsai@lsu.edu

The Inner Harbor Navigation Canal (IHNC) is a 5.5-mile industrial waterway connecting Lake Pontchartrain and the Mississippi River in New Orleans, Louisiana. The levee at the sides of the IHNC experiences excess underseepage during hurricane events or high canal stages. To control seepage and prevent internal erosion (e.g., piping, uplifting) beneath the IHNC levee, U.S. Army Corps Engineers designed 186 relief wells at the landside of west and east bank along the IHNC to release excess hydrostatic pressures in the aquifer. However, the efficiency of relief wells could be decreased as years pass due to various factors (e.g., clogging, chemical incrustation). This study developed a three-dimensional groundwater model by using USGS MODFLOW-USG to evaluate the performance of the relief wells and predict the factor of safety (FS) at the relief wells. The hydrostratigraphy for the model was built with drillers' logs and borings by using indicator kriging method to interpolate subsurface heterogeneity. A combination of a Connected Linear Network (CLN) with a Drain package was used to simulate relief well flow. The IHNC model was calibrated with specific capacity test data and piezometer data provided by mainly tuning aquifer hydraulic conductivity, constant-head boundary and skin factor of relief well. The IHNC model predicted the distribution of total head, discharge and FS at the relief wells during a hurricane event. The prediction reveals that the most relief wells produce discharges less than 20 gallons per minute and FS is lower than 1.5 which might bring out concern of uplifting.

Keywords: Seepage, Relief well, IHNC, Levee, and MODFLOW-USG

A quantitative analysis of the organic and mineral content of Mississippi River suspended sediment in the falling hydrograph

Abigail Eckland, The Water Institute of the Gulf, Tulane University, aeckland@thewaterinstitute.org; Mead Allison, Tulane University, meadallison@tulane.edu; and Thomas Bianchi, University of Florida, tbianchi@ufl.edu

This study examines the composition of the suspended sediment load of the lower Mississippi River at New Orleans, LA during the falling to low discharge period. The high discharge period of the lower Mississippi River hydrograph typically occurs in spring through summer followed by a low discharge period in fall through winter. Mississippi River suspended sediment concentrations are directly related to the water discharge hydrograph. Thus, suspended sediment loads are greatest during the rising limb of discharge when hysteresis and watershed-controlled sediment transport are most influential and smallest during the low discharge phase. However, peaks in turbidity, a proxy for suspended sediment concentration, during past low discharge events indicate that an important, and unconstrained, control on sediment is being supplied to or generated within the river over this time period. In order for the State of Louisiana to move forward with the effective operation of river diversions to help restore its rapidly disappearing coast, the seasonal character of the river's suspended load must be better understood and predicted. Through the evaluation of the mineral and organic fractions of the suspended sediment load and grain size measurements, this study found a significant portion of the suspended load is organic rather than mineral matter, with the proportion of the organic matter fraction increasing throughout the low discharge study period. This study also determined that the composition of the organic matter fraction fluctuates significantly over short (weekly) timescales as was determined through a detailed pigment analysis, which may be a function of nutrient availability, light penetration into the water column, the grain size character of the suspended sediment load, and other controls. This study aims to improve the operation of lower Mississippi River sediment diversions, which are currently in the design and engineering phases, and to minimize their potential harmful impact on the ecology of the estuarine-receiving basin by maximizing the sediment:water ratio that they emit.

Keywords: lower Mississippi River, suspended sediment, loss on ignition, low discharge period, pigment analysis, and sediment diversion

Shear Wave and Resistivity Surveys to Evaluate Seepage Flow Under A Levee in the Lower Mississippi River Valley

Daniel E. Locci Lopez, Louisiana State University, danilocci@live.com; Juan M. Lorenzo, Louisiana State University, gllore@lsu.edu; Frank T.-C. Tsai, Louisiana State University, ftsai@lsu.edu; and Mohammed Elgettafi, Université, m.elgettafi@ump.ac.ma

Standard practice to prevent dangerous seepage beneath flood-protection levees during high stages of the Mississippi River includes the use of pressure relief wells. In particular, the School of Veterinary Medicine Building at Louisiana State University (LSU) continues to experience flooding from seepage despite five actively flowing relief wells.

Current groundwater flow models assume that seepage flow travels horizontally in a homogeneous isotropic confined aquifer, not allowing any upward leakage from the flow medium (Ozkan et al., 2008). However, ancient preserved fluvial successions are often represented by significant crevasse-splay and sandy point bar deposits (Farrel, 1987), both of which can be highly heterogeneous both laterally and vertically (Burns et al., 2017; Nanson, 1980). Seepage flow increase and high permeability could be attributed to the existence of crevasse splays, point bars which are associated with coarse bedload (Farrel, 1987; Jackson, 1978).

We aim to understand the mechanisms of groundwater flow at the landside of a flood-protecting levee using geophysical techniques such as time-lapse Electrical Resistivity Tomography (ERT) and surface-wave dispersion inversion over an extended period of time that captures river stage fluctuations. Resistivity and surface wave analyses have proven useful in determining lithology, grain size, and water saturation (e.g. Burton and Cannia, 2011; Dunbar et al., 2007). Because electrical resistivity is sensitive to sediment composition, the ERT method is employed to produce ground models that provide detailed insights into the heterogeneity of sedimentary deposits (Parsekian et al., 2015; Van Dam, 2012).

Typical soils under the levees for the Lower Mississippi River Valley consist of a semi-permeable horizontal top-stratum with a permeable substratum on the riverside and landside of the levee sediments (USACE, 2000; Ozkan et al., 2008) suggesting finer grains overlaying coarser grains. Preliminary ERT results along the east side of the LSU Veterinary School building (Fig. 1a) suggest a wedge-shaped layer of more-resistive material over less-resistive material (Fig. 1b). Because this first survey was conducted at a high-river stage, we assume that the whole section is saturated. For this case, the differences in resistivity may be caused by grain composition, e.g., a sandy wedge over more-clay rich material. Furthermore, the upper 5 meters of the section is a laterally heterogeneous comprising alternating zones relatively high and low resistivity. New relationships between soil type, resistivity, and shear wave velocity (Goff et al., 2015) may help identify soil types adjacent to the levees on the Lower Mississippi River Valley.

Keywords: Lower Mississippi River Valley, Levee, flooding from seepage, ERT(Electrical Resistivity Tomography), Surface-wave dispersion inversion, time-lapse, and Point bars

Effect of Land Use Change on River Network and Channel Morphology of Four Tributaries in the Vermilion Watershed in South Louisiana

Courtney Poirier, University of Louisiana at Lafayette, courtney.poirier07@gmail.com; and Katie Costigan, University of Louisiana at Lafayette, costigan@louisiana.edu

Land use change has altered the hydrology and morphology of many rivers. Current and historical imagery were used to detect impacts of land use changes in four watersheds located near Lafayette, Louisiana: Coulee Mine, Coulee Ile Des Cannes, Anselm/Isaac Verot, and Bayou Tortue. Supervised classification-Maximum Likelihood in ArcGIS was used to classify the land use based on three information classes: agriculture/grassland, forest/wetland, and urban. In each of the watersheds, the agriculture/grassland information class decreases while urban classes increased. The extent of the river network did not change significantly between the 1970s and 2017. However, some channel sections have been buried to better control and direct flow via culvert or pipe installation. Channel width and sinuosity were measured at ten points and eight points, respectively, along the main channel of the tributary to see if there were any changes seen in the geometry of the channel. Overall, the channel width increased from the 1970s to 2017 along each of the main channels of the tributaries. Furthermore, the sinuosity of the channels was found to be either straight (sinuosity < 1.05) or sinuous (sinuosity 1.05 – 1.5) except for Bayou Tortue, which ranged from sinuous to meandering (sinuosity > 1.5). In order to determine if channel width and sinuosity are related, a correlation analysis was performed, which showed no strong correlations (p-value > 0.05) except for in Coulee Mine watershed in 2017 (p-value = 0.05). The results suggest that the channel had to adjust itself by widening to compensate for more surface water runoff due to land use modifications but may not always lead to the channel becoming more sinuous. The importance of this study is to understand the effect land use change has on the river network and channel morphology and to provide information that can be used in the future.

Keywords: Land use change, Supervised classification, Vermilion watershed, Channel characteristics, and River network

Changes in riverbed morphology in the upper lowermost Yangtze River from 1998 to 2013

Wei Xu, East China Normal University, xuwei930608@163.com; Y. Jun Xu. Louisiana State University, yjxu@lsu.edu; and Heqin Cheng, hqch@sklec.ecnu.edu.cn

It has been reported that the Three Gorges Dam spanning over the Yangtze East China Normal University River in China has affected sediment fluxes downstream. A recent study has documented considerable sediment reduction, riverbed deformation, and channel erosion in the

final 565 kilometers of the Yangtze River, also termed as the Lowermost Yangtze River (LmYR). In this study, we took a further look at recent channel dynamics in the upper reach of the LmYR to assess longer-term and possible future trend of this development. Specifically, we analyzed the navigational charts of 1998, 2008 and 2013 to quantify sediment entrainment and transport in the 95 km long Nanjing reach. We found that the riverbed eroded in all water depth intervals (0 m to -2 m, -2 m to -5 m, -5 m to -10 m and below -10 m) during 1998-2008, and that the total net erosion volume amounted to 1.17×108 m3. In the following five years from 2009 to 2013, however, we found sediment entrainment in all water depth intervals, making a total net deposition of 1.99×108 m3. This erosion – deposition development over the last 15 years resulted in a net deposition of 0.82 ×108 m3, indicating the highly dynamic nature of sediment transport and riverbed morphology in a large alluvial river.

Keywords: the upper lowermost Yangtze River, riverbed morphology, sediment entrainment, and erosion and deposition

Water modeling, supply, and use

Developing statewide hydrostratigraphy model for Louisiana State

Hamid Vahdat Aboueshagh. Louisiana State University, hvahda1@lsu.edu; and Frank Tsai, Louisiana State University, ftsai@lsu.edu

Developing large scale geological models has always been a challenge for both geologists and engineers. This issue arises due to both mismanaging the available data and lack of a robust framework to construct the model. This study aims to propose a new approach where a large amount of geological data can be utilized for building geological model. The framework consists of data management, defining geological characteristic based tiles, creating geological structure for each tile, and combining the structures to achieve the final model. To examine the validity of the method, the hydrostratagraphy model of Louisiana state was developed employing around 115000 well log data as well as geological information on dip direction and angles in different parts of the study area. The state model has been discretized into 376 tiles with more than 123000 2-D grid cells. The Baton Rouge area faults and major alluvial formations of Red River and Mississippi River were considered in model settings. The computational time for running the geological model code written in FORTRAN environment is approximately 13 hrs on Supermike machine at Louisiana State University high performance computing center (LSU HPC). The results demonstrate the suggested method fully is successful in reflecting the geological characteristics such as faults, dip formations and transitions, and identifying the outcrop zones in the study domain. The computational efficiency, having the capability of tracking errors, power to perform numerical analysis, and simplicity are some striking features of this method. The results of this study will be used for building statewide groundwater model.

Keywords: Geological modeling, Large-scale hydrostratigraphy, and Groundwater modeling

2015 Water Use in Louisiana

Angela Collier, U. S. Geological Survey, acollier@usgs.gov

In 2015, approximately 8,720 million gallons per day (Mgal/d) of water was withdrawn from groundwater and surface-water sources in Louisiana, a 2.6 percent increase from 2010. Total groundwater withdrawals were about 1,750 Mgal/d, an increase of 12 percent from 2010, and total surface-water withdrawals were about 6,970 Mgal/d, an increase of 0.44 percent from 2010 to 2015.

Total water withdrawals, in Mgal/d, in 2015 for the various categories of use were as follows: public supply—715, industry—2,155, power generation—4,265, rural domestic—39, livestock—6, rice irrigation—825, general irrigation—225, and aquaculture—490. From 2010 to 2015, Louisiana's total withdrawals for public supply decreased by 3.4 percent, industry increased by 5.7 percent, power generation decreased by 3.9 percent, rural domestic decreased by 4.1 percent, livestock decreased by 21 percent, rice irrigation increased by 20 percent, general irrigation decreased by 6.0 percent, and aquaculture increased by 58 percent.

About 48 percent (approximately 850 Mgal/d) of all groundwater withdrawn was from the Chicot aquifer system and 22 percent (approximately 385 Mgal/d) was withdrawn from the Mississippi River Valley alluvial aquifer. Since 2010, withdrawals from the Chicot aquifer system increased by 30 percent and withdrawals from the Mississippi River Valley alluvial aquifer decreased by 2.9 percent.

About 70 percent (4,905 Mgal/d) of all surface water withdrawn was from the Mississippi River mainstem. This value represents a 1.1-percent decrease in withdrawals from 2010 to 2015.

Keywords: Water Use, Louisiana, Groundwater, Surface Water, and Public Supply

Emergency preparedness and recovery lessons after the Great Louisiana Flood of 2016 among domestic well owners

Aubrey Gilliland, LSUHSC-New Orleans, agill4@lsuhsc.edu; Kelsey Pieper, Virginia Tech, kpeiper@vt.edu; Susanne Straif-Bourgeois, LSUHSC-New Orleans, sstra1@lsuhsc.edu; William Rhoads, Virginia Tech, wroads@vt.edu; Marc Edwards, Virginia Tech, edwardsm@vt.edu; Kari Brisolara, LSUHSC-New Orleans, kbriso@lsuhsc.edu; and Adrienne Katner, LSUHSC-New Orleans, akatn1@lsuhsc.edu

In August 2016, a historic flood affected over 100,000 homes in southeast Louisiana. Private domestic well water safety is the responsibility of the well owner in Louisiana, but researchers observed little outreach to well owners in the impacted areas. To evaluate well user preparedness and recovery, a convenience sample of flood-impacted well owners was surveyed and offered free well water testing, nine to ten weeks after flood waters subsided (n=106). Well users were surveyed to characterize behaviors, risk perceptions, and resource needs; and well

water was tested for indicator bacteria. Surveyed well owners indicated a need for information on well testing labs (90%), water contamination (77%), and water treatment (78%). Of the well users who flooded (n=75), one-third resided in low flood risk zones, indicating a need for a more current assessment of areas at risk for floods. After the flood, over half (57%) of flood-impacted well users (n=75) continued consuming well water after the flood; yet, 26% had water which tested positive for total coliform, indicating the possible risk of waterborne disease. Of flood-impacted well users who resumed well water consumption (n=43), 69% disinfected their water, but microbial testing results suggest that even after disinfection, microbes can regrow or re-enter wells. Thus, disinfection methods are either insufficient, conducted incorrectly, or will not work due to well system failures. When asked about well depth, over one-third of flooded well-reliant participants did not know their well depth, a necessary component of proper well water disinfection. After the flood, the major barrier to well stewardship was knowledge gaps. Overall, the study results suggest well owners lack the knowledge, means, resources, or motivation to protect well water and treat water adequately after floods. Recommendations are made to enhance emergency response communications, and improve well water surveillance. Given the likelihood that more frequent and severe inland flooding events will occur in the future, government officials need to update and enhance existing resources, and provide well user training to facilitate well owner preparedness, self-reliance, and resilience in the face of more frequent natural disasters.

Keywords: Emergency Response, Water Security, and Domestic wells

Introduce Sediment Module into WRF-Hydro

Dongxiao Yin, Louisiana State University, dyin2@lsu.edu; and Zuo Xue, Louisiana State University, zxue@lsu.edu

A sediment model is developed by adapting CASC2D-SED and introducing it into WRF-Hydro. The model mainly contains two components: (1) sediment erosion and transport from overland to channel, and (2) sediment transport through the channel to the watershed outlet. Based on USLE formula, sediment is eroded by overland flow with consideration of soil type, vegetation type as well as bed slope. Following through the direction of steepest slope, the eroded sediment is transported grid by grid all the way to the channel, meanwhile deposition process is simulated according to settling velocity, time step and water depth. Once sediment gets into channel, it will be carried by the stream flow all the way to the watershed outlet. Using the high temporal resolution observation data of stream and sediment discharge, the model has been tested on the watershed of Goodwin Creek, Mississippi, USA. Overall the model yields good estimate of sediment discharge at the outlet.

Keywords: WRF-Hydro, CASC2D-SED, and Goodwin Creek Watershed

Bi-objective saltwater intrusion risk assessment using Bayesian set pair analysis and machine learning based ensemble surrogates

Jina Yin, Louisiana State University, jyin3@lsu.edu; and Frank Tsai, Louisiana State University, ftsai@lsu.edu

Surrogate models are effective to substitute computationally intensive groundwater simulation models. However, solutions of single-surrogate-based optimization are not reliable mainly due to unstable performance as well as large prediction uncertainty by using only one surrogate model. In this regard, we present an ensemble-surrogate-assisted bi-objective optimization method for deriving Pareto-optimal strategies to mitigate saltwater encroachment in a multi-aquifer system. Machine learning based ensemble groundwater surrogates are developed to replace a high-fidelity solute transport model for predicting saltwater intrusion. In this study, three surrogate models (response surface regression model, artificial neural network and support vector machine) are developed. Optimal Latin hypercube design is employed to generate training and testing datasets. Bayesian set pair analysis is conducted to construct an ensemble surrogate that addresses prediction uncertainty persisting in individual surrogate models. Then, a nonlinear optimization model of two conflicting objectives is established to obtain a set of Pareto-optimal pumping schedules. The two conflicting objectives are minimizing total extraction from a horizontal scavenger well and maximizing the minimum difference between chloride concentration at the monitoring location. The proposed methodology is applied to the saltwater intrusion problem in the Baton Rouge area, southeast Louisiana. Pareto fronts can be obtained through Non-dominated Sorting Genetic Algorithm II (NSGA-II). The ensemble-surrogate-assisted optimal solutions are verified through the physically based numerical simulation model and compared against the solutions obtained using single-surrogate-based modeling. The ensemble-based optimization modeling approach is found to provide more stable and reliable solutions for saltwater scavenging design while retaining the advantage of considerably reducing computational burden. Bayesian set pair analysis is robust to build highly accurate ensemble surrogate models while accounting for model prediction uncertainty.

Keywords: Saltwater scavenging, multi-objective optimization, ensemble surrogate, Bayesian set pair analysis, Uncertainty, and machine learning

Groundwater-surface water interactions in the Lower Mississippi River Delta Plain

An Li, Louisiana State University, ali7@lsu.edu and Frank Tsai, Louisiana State University, ftsai@lsu.edu

The Lower Mississippi River Delta Plain (LMRDP) is shaped by fluvial, deltaic and coastal processes, which form a complex subsurface system that consists of interdependent stratigraphic and hydrogeologic components. However, the LMRDP subsurface system is largely ignored and the interdependencies of these subsurface components are not well understood. Lacking subsurface studies hinders people from understanding interactions between water bodies

(river, estuary, and groundwater) in the river-deltaic environment, and how the interactions affect natural process (e.g. land subsidence and land loss) and engineered process (e.g. river diversion and marsh creation). In this study, an integrated modeling approach was adapted to model stratigraphy and groundwater flow in the LMRDP. A subsurface stratigraphy model was constructed using a multiple indicator method along with geotechnical boring data. A groundwater flow model was then developed by incorporating hydrogeological parameters (hydraulic conductivity, specific storage, and specific yield) and hydrologic forcing (river loading and tides). The integrated model covers about 1,800 km2 along the Mississippi River main channel from the Jesuits Bend to the Head of Passes, and extends from 4 m to -65 m in elevation. The modeling results show strong river-estuary-groundwater interaction through sandy deposits, and seasonal and abrupt fluctuation of pore water pressure associated with flooding and hurricane events. The integrated model gives insights into interdependencies of the stratigraphically-hydraulically coupled coastal subsurface system, and will be useful to Louisiana's coastal protection and restoration efforts.

Keywords: groundwater, surface water, interaction, and modeling

Tuesday April 16, 2019 morning oral secessions

8:00 am to 9:40 am Surface Water

Hydraulic responses to frontal passage in a microtidal environment

Sara Ates, Louisiana State University, sates001@lsu.edu; and Matthew Hiatt, Louisiana State University, mhiatt1@lsu.edu

Keywords: Water Level, Cold Front, and Coast

Current and future depositions of nitrogen and sulfate in Southeastern U.S.

Jessica Nguyen, Louisiana State University, jnguy76@lsu.edu; and Hao Guo, Louisiana State University, hguo8@lsu.edu

Nitrogen and sulfur are essential plant nutrients, but excess quantities can stress ecosystems. Atmospheric nitrogen and sulfur deposition lead to changes in water and soil chemistry causing acidification of surface water bodies and ensuing detriment to aquatic and terrestrial ecosystems. This affects a wide variety of water plants and animals such as trees, insects, and fish. Louisiana has copious natural water resources; thus, it is essential to safeguard water resources from excessive atmospheric deposition of sulfur and nitrogen. However, information for understanding nitrogen and sulfur deposition and unfavorable effects in Louisiana as well as the Southeastern U.S. is limited. In this research investigation, Community Multi-scale Air Quality (CMAQ) model was employed to simulate emission, formation, transport, and deposition of sulfur and nitrogen species in Southeastern U.S. for the present and

future to understand the forms of sulfur and nitrogen deposition due to wet and dry processes, to show the spatial and temporal variations of deposition fluxes, and to quantify the contributions of different sources to sulfur and nitrogen deposition. Furthermore, Weather Research and Forecasting (WRF) model was utilized to predict future variations in climate and the subsequent fluctuations of deposition due to climate change.

Keywords: Community Multi-scale Air Quality (CMAQ) model, Weather Research and Forecasting (WRF) model, and sulfur and nitrogen deposition

Water-sediment diversion rate at the Old River Control Structures

Bo Wang, Louisiana State University, bwang13@lsu.edu; and Y. Jun Xu, Louisiana State University, yjxu@lsu.edu

Bed material transport at river bifurcations is crucial for channel stability and downstream geomorphic dynamics. However, quantitative estimation of bed material transport at bifurcations of large alluvial rivers is scarce. In this study, we applied one-dimensional sediment transport equations to investigate bed material transport near the engineering-controlled Mississippi- Atchafalaya River diversion, which is of great importance to sediment distribution and delivery of the rivers to Louisiana's coast. Yang's 1973 sediment transport equation was selected as the best to calculate the bed-material loads upstream, downstream, and through the diversion over the period from 2004 through 2013. Results show that there were in total 215 million metric tons (MT) of bed material load transported upstream of the diversion. Among of them, ~47 MT (i.e., 22%) bed materials were diverted through the bifurcation channel. The findings from this study reveal that, proportionally, more bed materials were carried downstream in the Mississippi mainstem channel under the current flow diversion. Severe bed scouring occurred in the controlled outflow channel, while riverbed aggradation progressed in the mainstream downstream of the diversion structure.

Keywords: Sediment transport, Old River Control Structures, and Water diversion

Elements geochemistry across the waterscape: A case study in the lower Little River Basin, Louisiana

Zhen Xu, Louisiana State University, zxu3@lsu.edu; and Y. Jun Xu, Louisiana State University, yjxu@lsu.edu

Studying the biogeochemical connectivity between rivers and lakes is important in understanding their ecological and environmental impacts. However, there is a gap in our knowledge of the connectivity of metal chemistry of water across a river-lake continuum. In this study, we analyzed total recoverable metal concentrations from water samples collected monthly at four locations along the Little River-Catahoula Lake in the low-gradient subtropical Louisiana, United States during February 2015 - January 2016 to assess metal biogeochemistry in such a river-lake continuum. Results show that six major metals (Al, Ca, Fe, K, Mg and Na) constituted

more that 98% portion of the pool based on average monthly metal concentrations, while five others (B, Ba, Mn, Sr and Ti) were amounted to the rest 1-2%. Significant decreases in average monthly concentrations of all metals were observed from river upstream to lake inflow, indicating that the river functioned as a sink for metal transport which could be attributed to sedimentation and biological removal. In contrast, significant increases in average monthly concentrations of Al, Mg, K and Ti were found between lake inflow and outflow. The fall turnover and the stronger weathering intensity of the lake were considered mainly responsible for the source functionality. In addition, the backwater to the lake also contributed to the lake source effect as it contained a significantly higher Mg. Since the role of the lake within the fluvial network for metals in this study is mainly determined by the lake hydrology, future investigations for in-network lakes with different depths and at different climate regions would be beneficial for a further understanding of metal transport in a river-lake continuum.

Keywords: Total recoverable metal, Biogeochemistry, River-lake continuum, Backwater, and Ouachita River Basin

10:00 am to 11:40 am Groundwater

Groundwater Use in the Agricultural Sector in Louisiana, 2004-2017

Dependra Bhatt, Louisiana State University, dbhatt6@lsu.edu; Krishna Paudel, Louisiana State University, kpaude1@lsu.edu; Frank Tsai, Louisiana State University, ftsai@lsu.edu; and Huizhen Niu, Louisiana State University, hniu@agcenter.lsu.edu

During the last few years, Louisiana producers have invested heavily on irrigation technologies. As a result, some of the aquifers in agricultural dependent parishes have shown water level decline that could potentially compromise the viability of agricultural production in the state. The combination of the perceived abundance of groundwater resources, profitability from adding irrigation capabilities, lack of groundwater regulations, and lack of irrigation research have a long term impact on the sustainability of groundwater across the state. The objective of this research is to quantify the amount of water extracted for agricultural activities in Louisiana from 2004 to 2017. We calculated groundwater use for three different agricultural sectors: aquaculture, livestock, and row crop production. We used information from a survey conducted in 2017, active well information data obtained from SONRIS, and a GIS-based approach to derive the total irrigated crop acreage for corn, cotton, rice, soybean, and wheat. We compiled total livestock number and area under aquaculture from LSU AgSummary, Louisiana State University. In 2004, the total water extraction was 163,094 million gallons per year which increased almost by double to 291,439 million gallons in 2017. Among the three sectors, aquaculture always had the highest water demand. Interestingly, groundwater withdrawal for corn and soybean increased by 99% and 266%, respectively and for cotton, it decreased by 85% from 2004-2017. The crop acreage allocation from cotton to soybean and corn could have been due to the biofuel policy act after 2007. In any case, our calculation showed that aquifer level has

been decreasing in Louisiana and a policy to curtail continuous decline may be needed if the long term sustainability and profitability of farmers are to be ensured in future.

Keywords: aquifer , livestock, agriculture, and water use

Safe Water For Disinfection: Using Disinfectant Water for the 2014 Eboa Outbreak

Lee Gary, Strategic Management Services-USA / Tulane University, pgary@Tulane.edu; Robert Reimers, Tulane University, Rreimers@Tulane.edu; and Kari Brisolora, Louisiana State University School of Public Health, Kbriso@lsuhsc.edu

Ubiquitous safe water is convenient to differentiate between a developed country and a developing country. Such safe water, elevated to be a disinfectant solution, has risen to significant status for protecting individuals – in developing nations – from the deadly threat of a pathogenic outbreak. A recent, devasting example is the Ebola Outbreak in West Africa, brutally erupting in 2014, and was ultimately halted by unlimited use of disinfectant water with sodium hypochlorite (NaClO).

The challenge of preparing a disinfectant solution in a developing country using suspect water from surface and ground sources is detailed as "lesson learned" for conference participants. Vivid operational and morbidity data are included for an Ebola Treatment Center in Sierra Leone, managed by International Medical Corps.

Safe, unlimited disinfectant water is the essential precursor for mitigating a viral epidemic. It is the ultimate defensive agent. Everything and everyone – victims and responders – must be washed or whipped with aqueous disinfectant to halt the spread of the killer pathogen. No exceptions any time.

The challenge to stop an epidemic, such a flu or Ebola outbreak, is complex in a developing country, where disinfectant water is imperative but scarce.

Keywords: safe water, disinfectant, Ebola Virus, and disinfectant water

Managed Aquifer Storage and Recovery Feasibility Study

Olivia LaHaye, University of Louisiana at Lafayette, olahaye24@gmail.com; Emad Habib, University of Louisiana at Lafayette, ehhabib@gmail.com; Hamid Aboueshagh, Louisiana State University, hvahda1@lsu.edu; Frank Tsai, Louisiana State University, ftsai@lsu.edu; and David Borrok, Missouri University of Science & Technology, borrokd@mst.edu

Increasing demands in the agricultural, industrial, and public sectors have exhausted natural resources, especially fresh water. Sustainable water management solutions are no longer

just appealing, but now crucial for the protection of dwindling resources. Over-drafting freshwater aquifers has¬ resulted in land subsidence, saltwater intrusion, and groundwater deficit. This problem is apparent in many regions in the United States and is becoming more pressing in coastal Louisiana. Aquifer Storage and Recovery (ASR) is a viable water management technology that exploits the available space within the aquifer as a storage space for excess water from other potential sources (e.g. surface water runoff). Excess surface water can be captured when available, injected into the aquifer, and made available for times of drought or peak demands. This present study is to assess the feasibility of implementing ASR technology in southwest Louisiana, in conjunction with surface reservoirs and water treatment facilities, through the applications of a regional site selection suitability analysis and local groundwater and surface water modeling analysis. The regional feasibility analysis introduces a site suitability index using a cumulative distribution function rating method and multi-criteria decision support technique. Thirteen feasibility criteria are chosen within the focus regions—water availability, model-based aquifer characteristics, water quality, and land use—and applied across a 12-digit Hydrological Unit Code (HUC) boundary resolution. Each HUC12 unit area is rated from 0 to 1 based on each criterion's potential to affect ASR feasibility. Each criterion is also assigned a weight based on its importance in affecting ASR feasibility, and the weights are integrated into a multiplicative and additive hybrid function resulting in a combined ASR feasibility index. The combined index ranks the regional ASR feasibility of each location from 0 to 1 based on the combination of all criteria. This study is applied to the Chicot Aquifer in southwest Louisiana, and the results indicate a region in the eastern central "sink" of the aquifer that is most suited for ASR and is also a region of substantial groundwater withdrawal for agriculture and aquaculture activities. The selection of one or few ideal watersheds will initiate the next phase of assessing ASR feasibility, where localized-scale analyses will be conducted using hydrologic and hydrogeologic model simulations and optimization.

Keywords: Aquifer Storage and Recovery, Site Suitability, Feasibility, Index, Chicot Aquifer, Subsidence, Saltwater intrusion, Surface Hydrology, and Groundwater Hydrogeology

The impact of unconventional energy development using hydraulic fracturing on Louisiana water resources availability

Hanz Unruh, University of Louisiana at Lafayette, hgu2853@louisiana.edu; Emad Habib, University of Louisiana at Lafayette, habib@louisiana.edu; and David Borrok, Missouri University of Science & Technology, borrokd@mst.edu

In the United States, unconventional oil and gas extraction has been deployed significantly in the recent years. The current study focuses on the impact of Hydraulic Fracturing (HF) on the sustainability of Louisiana's water resources. This impact is measured by quantifying the water stress due to several HF water use scenarios. Current and future HF water use scenarios are examined over the two main shale plays Louisiana, Haynesville and Tuscaloosa. A Water stress analysis assessment is conducted at the HUC-12 catchment spatial scale. Initially, sectoral-based stress metrics were calculated for surface and groundwater, without including HF water use. Several demand sectors were included in this first stress

estimation (i.e. power generation, public supply, and industrial). Based on the 2010 reported water uses in Louisiana, three scenarios for surface and groundwater resources were evaluated. In the first scenario, a peak year (2011) of HF water use was added as a new category into the stress analysis. The results indicate a significant impact on groundwater water stress metric due to HF activities. In contrast, the surface water stress does not seem to be affected by the HF water use. Despite the abundant surface water in the region, the location of the wells is not always adjacent to the body of water, which makes trucking or piping of water required. For this reason, availability of groundwater in situ is a relevant factor in terms of production cost. Second and third tested scenarios consisted of increasing the number of wells in the Haynesville and Tuscaloosa shale plays. The second scenario calculates the stress including the water use of the total number of wells that currently exists in both shale plays in one year. The third tested scenario addressed the full unconventional extraction of the whole shale plays capacity in a short time period (one year). This full extraction scenario is conceived by increasing the number of the currently existing wells at each shale play. The results of the additional scenarios implementation show further impacts on the Louisiana groundwater resources due to the HF activities. The results of this study point out to the water management authorities the need to investigate the alternative use of non-traditional water resources (i.e. recycled flow back water, treated wastewater, and brackish water) in HF activities as a possible stress reliever. Additionally, a cost analysis can be developed in a future study analyzing the economic feasibility of treating and reusing the HF waste water as a source of water stress relief.

Keywords: water resources, hydraulic fracturing, water stress, groundwater stress, and surface water stress