GRDA
Grand River Dam Authority

A publication of the Ecosystems & Watershed Management and Scenic Rivers Operations Departments.

2020 Annual Review

ECOSYSTEMS EXPLORATIONS

Research, Conservation, and Protection

Grand River Dam Authority

GRDA's 5E's of Excellence

Electricity: We will produce low-cost, reliable electricity for our customers.

Environmental Stewardship: We will practice environmental awareness and promote conservation and reclamation of the natural resources under our control.

Economic Development: We will support economic growth and quality of life enhancement in Oklahoma.

Employees: We will be a diverse and energetic workforce, working together in a safe environment and treating each other with dignity and respect.

Efficiency: We will operate in the most efficient manner possible, to benefit our ratepayers and the people of Oklahoma.

Mission Statement

We deliver affordable, reliable ELECTRICITY, with a focus on EFFICIENCY and a commitment to ENVIRONMENTAL STEWARDSHIP.

We are dedicated to ECONOMIC DEVELOPMENT, providing resources and supporting economic growth.

Our EMPLOYEES are our greatest asset in meeting our mission to be an Oklahoma Agency of Excellence.

GRDA Grand River Dam Authority

-ELECTRICITY -EFFICIENCY -EMPLOYEES
-ENVIRONMENTAL STEWARDSHIP
-ECONOMIC DEVELOPMENT

If you are interested in learning more about the Grand River Dam Authority, please visit our website at www.grda.com or scan the QR code with your smartphone camera.

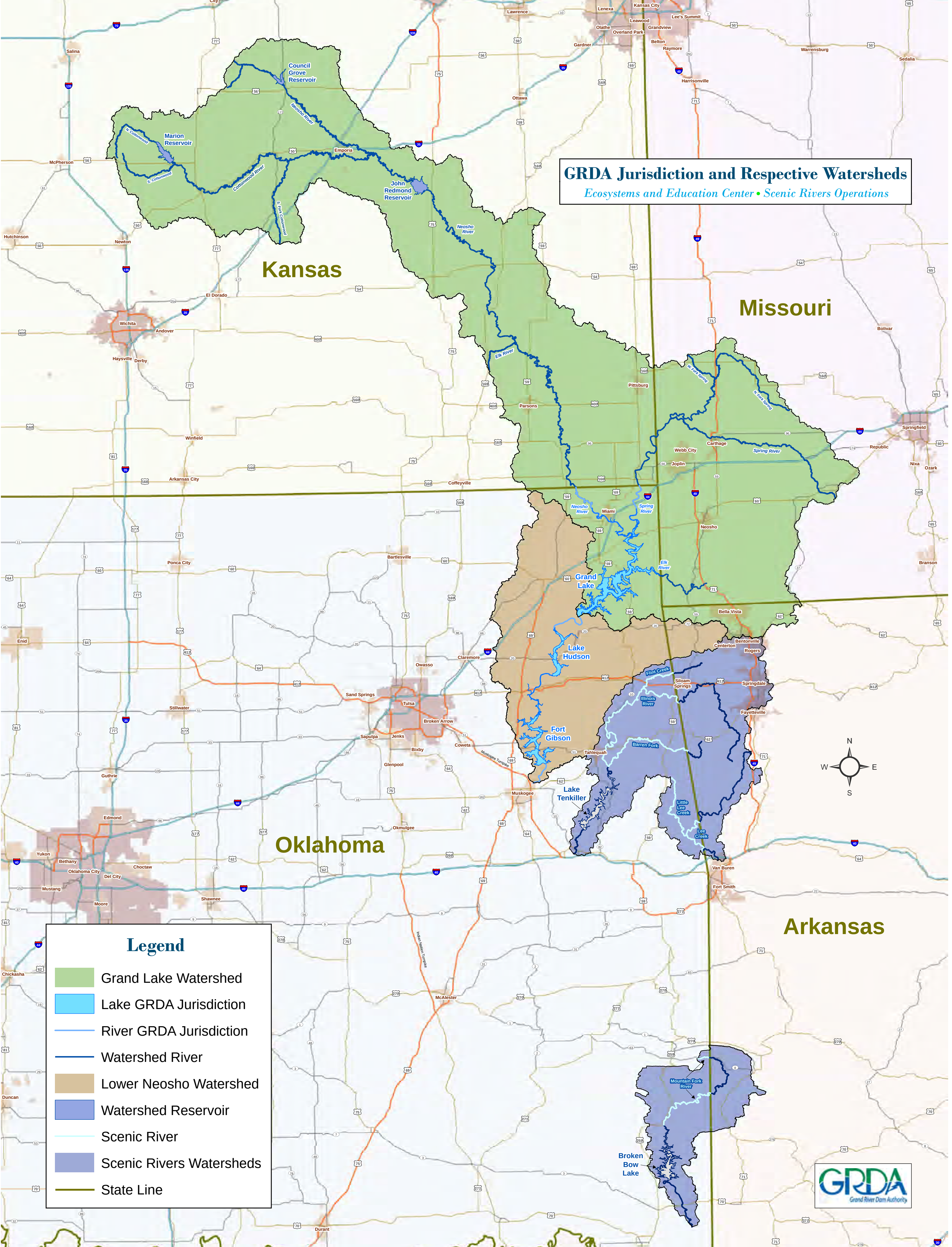
ECOSYSTEMS EXPLORATIONS - 2020 Annual Review

Table of Contents

The following is a compilation of programs, projects, and research performed and supported by the Ecosystems and Watershed Management and Scenic Rivers Operations Departments of the Grand River Dam Authority (GRDA). Even though COVID-19 presented challenges during 2020, both departments rose above to accomplish goals throughout the year. The work that is displayed in the following pages represent the continued commitment that GRDA has made to be good stewards of the natural resources under our control.

If you are interested in learning more about GRDA's research over the last 10 years, scan the QR Code with your smartphone camera.

Floaters enjoying the Illinois River in Tahlequah Oklahoma



GRDA Controlled Watersheds

What is a Watershed?

A watershed is defined as an area that drains all of its rivers, streams, creeks, and runoff to a common outlet. This outlet may be the outflow of a reservoir, or the mouth of a bay, depending on your geographic location. A watershed consists of all of the surface water - lakes, rivers, reservoirs, and wetlands as well as subsurface groundwater.

The Grand River Watershed

The Grand River watershed is a collection of rivers, streams, creeks, and runoff that stretches across a roughly 10,300 square mile area and eventually flows into the Grand River in Oklahoma's northeast corner. It rests in four states, straddles two EPA regions and impacts the lives of hundreds of thousands of people.

Most of the watershed lies in the state of Kansas, with the water eventually making its way to Oklahoma by way of the Neosho River. In Missouri, another large portion of the watershed drains into our state mostly through the Spring River. The confluence of the Neosho and Spring rivers, near the heart of Ottawa County, is the beginning of the Grand River. Impounded by three separate dams, this river then gives us Grand Lake (Pensacola Dam), Lake Hudson (Robert S. Kerr Dam) and the Fort Gibson Lake (Fort Gibson Dam). Together, these lakes provide not only the "fuel" for hydroelectric generation and a valuable water supply across a large region, but also serve as a foundation for economic development tied to multiple industries, including manufacturing, tourism, recreation and more.

GRDA's Scenic Rivers Watersheds

Currently, Oklahoma has six scenic rivers that collectively extend 161 miles through six counties. The scenic river designation affords these valuable resources the highest protection and priority available through Oklahoma's environmental agencies. Specific requirements of this designation include a strict prohibition on additional pollutants, dams, and wastewater treatment plants, and a close monitoring of construction activities alongside the river.

The GRDA Scenic Rivers Operations department is invested with the power to establish minimum standards for planning and other ordinances affecting scenic rivers. As the Oklahoma Scenic Rivers Commission had done since its establishment in 1977, GRDA continues to work with communities, businesses and individuals to mitigate their impact on scenic rivers. We strive to educate the public about scenic rivers and also to provide everyone the opportunity to enjoy the features that make these water resources so special.

The partnership with Northeastern State University to create the GRDA-NSU Scenic Rivers and Watershed Research Lab is meant to help protect and better understand the Illinois River and its watershed, as well as the rest of the scenic rivers. Together, the Ecosystems & Watershed Management department and the Scenic Rivers Operations department are ready to carry out the provisions of the Scenic Rivers Act through protection, preservation, and education.

Ecosystems and Watershed Management

When the Grand River Dam Authority established its Office of Ecosystems Management in 2004, it did so knowing there was much work ahead. After all, the Grand Lake watershed spans four states including Kansas, Missouri, Arkansas and Oklahoma and culminates into one of the most popular recreation destinations in the region: Grand Lake.

Because Oklahoma only encompasses approximately nine percent of the watershed and the majority of Grand Lake's water supply originates from neighboring states, GRDA realized it could not face the natural resource challenges alone. Thus, the underlying theme for the department has been to build cooperative relationships to facilitate communication and efficient utilization of resources necessary to accomplish GRDA's conservation and restoration goals.

If you are interested in learning more about GRDA's Ecosystems and Watershed Management department scan the QR Code with your smartphone camera.

Ecosystems & Watershed Mgmt.
420 Highway 28
PO BOX 70
Langley, OK 74350

Scenic Rivers Operations

On July 1, 2016, the Grand River Dam Authority (GRDA) absorbed the mission and responsibilities of the Oklahoma Scenic Rivers Commission (OSRC). That mission is to protect, enhance, and preserve the outstanding aesthetic, historic, archaeological and scientific features of the Illinois River and its tributaries (Lee Creek, Little Lee Creek, Barren Fork Creek, Flint Creek, and the Upper Mountain Fork River).

If you are interested in learning more about GRDA's Scenic Rivers Operations department scan the QR Code with your smartphone camera.

Scenic Rivers Operations
15971 N. Highway 10
PO Box 292
Tahlequah, Oklahoma
74464 (Physical) , 74465 (PO Box)

GRDA's Ecosystems and Education Center in Langley, OK

Neosho Bottoms

NEO A&M Partnership

In the summer of 2016, GRDA and NEO A&M formally announced a partnership agreement for pecan orchards and livestock grazing. The original plan was for GRDA to lease 1,600 acres in Ottawa County to NEO A&M for $1 per year. Since then, the original 1,600 acres has turned into around 3,000 acres available for the school's use. GRDA plays an active role in helping manage these lands by performing controlled burns and applying various best management practices.

The partnership allows NEO A&M to sublease the pecan orchards to local pecan producers and allows it to become a revenue stream for the school. These types of private-public partnerships help universities deal with massive reductions to public education budgets.

Controlled Hunts

In addition to the NEO A&M partnership, GRDA has opened around 2000 acres of this area along the Neosho River for controlled hunts, managed by GRDA. The public can register for these hunts online. Winners are selected at random with special consideration being given to those who are residents of municipal customers or public power communities. The different types of hunts include deer, waterfowl and turkey. There are also hunting areas that have been designated for use by the Mid-America Chapter of the Paralyzed Veterans of America (PVA). In fact, around 1,000 acres has been designated for PVA hunts since 2014. This partnership with PVA has given hunting opportunities to people with impaired mobility, who would otherwise have very limited access to public hunting lands.

Although the numbers were reduced in 2020 due to COVID-19, GRDA was still able to contribute to the cause and host hunters for controlled hunts, along with PVA hunters.

A hunter with his harvested buck from Neosho Bottoms

The Neosho Bottoms team conducting a controlled burn

Water Quality

The GRDA Ecosystems & Watershed Management Department opened the doors on its state-of-the-art water quality laboratory in 2010, and has been expanding and developing its capabilities and water monitoring efforts ever since. In fact, the installation of several floating water quality profilers in Grand and Hudson lakes in years past has allowed the department to make real-time water quality data readily available to interested lake stakeholders.

Currently, the department consists of two separate laboratories. The WQRL in Langley has 15 established sampling sites on Grand Lake, along with six on Lake Hudson and one on the W.R. Holway Reservoir. While the SRWRL in Tahlequah has 13 sites along Oklahoma's Scenic Rivers and their tributaries.

These monitoring locations are visited twice monthly during the recreation season, and once monthly during the off-season. Samples are taken more frequently and at non-established locations in the case of problem events such as blue green algae (BGA) blooms, bacteria outbreaks, and any public call out.

One goal of GRDA's water quality laboratories is to implement and conduct a long-term water quality monitoring program on GRDA's project lakes and rivers. These programs and the data that are produced when paired with agency and university partnerships will allow water professionals to make more informed and scientifically supported decisions on watershed management techniques in GRDA's watersheds. This goal of conducting long-term water quality monitoring programs ties hand in hand with supporting collaborative projects with other agencies and universities.

Both laboratories are responsible for responding to any call outs from the public concerning water quality. These can include BGA blooms, bacteria outbreaks, fish kills, and general concerns for health and public safety. These are areas that the Ecosystems & Watershed Management team take very seriously, and typically respond on the same business day.

If you are interested in learning more about GRDA's water quality efforts, please visit our website at www.grda.com/environmental-stewardship or scan the QR Code with your smartphone camera.

GRDA's sampling vessel

GRDA's mobile lab van

Water Quality Projects

Heavy Use Coves Monitoring - A Federal Regulatory Commission Project

As a condition of the current hydropower license for Pensacola Dam, the Federal Energy Regulatory Commission (FERC) required a project that began in the summers of 2016-2107 to be continued in 2020. Once again, GRDA will collect water samples to measure the impact, if any, that recreational boating has on water quality. The intent of the project is to determine if human activities in heavy use coves cause negative impacts on water quality. GRDA will strive to determine the impacts on water quality, and if any are identified that rise above the regulatory limits determined by the state of Oklahoma, these impacts would subsequently require GRDA to determine a strategy to mitigate the impacts and protect public health and safety. Over the years GRDA has identified heavy use areas during aerial boat counts and shoreline surveys. The areas that GRDA chose to monitor on Grand Lake included popular local destinations such as Dripping Springs, Summerfield Hollow, Duck Creek, and Woodard Hollow.

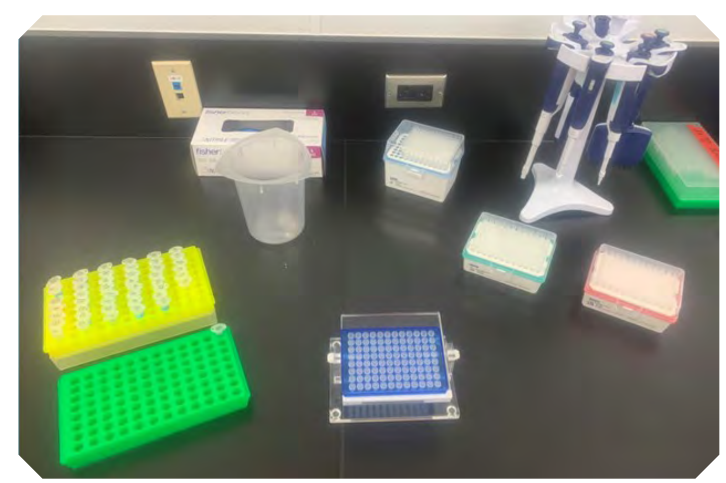
With respect to boating use, Woodard Hollow, Dripping Springs, and Summerfield Hollow become very busy on heavy use/holiday weekends. In general, the Independence Day Holiday on Grand Lake is the most popular. On this day in 2016 and 2017, Woodard Hollow held 301 and 322 boats, respectively, along with 152 boats in 2020 on a day with inclement weather. Overall, we found that between the coves there was a significant difference in the amount of boat traffic between holiday and non-holiday weekends which gave us a broad range of use to investigate. However, GRDA did not find any impacts of heavy recreation on water quality. This study is ongoing and will continue into 2021.

303d List Bacteria Project

In the summers of 2019 and 2020 GRDA set out on a project to look at some 303d streams in Northeast Oklahoma. 303d waterbodies are waters that are listed as "impaired" for some parameter, for our study we chose to focus on those waterbodies that are listed for bacteria, more specifically enterococcus. It is well known that bacteria is one of the leading causes of impairment in the United States, however less is known about the sources of these impairments.

We used digital PCR (dPCR) and Microbial Source Tracking (MST) technologies to look for these sources of impairments. MST markers were used to test our streams for fecal DNA from Humans, Cows, Birds, and Pigs. We used GIS to look at land cover and soil types to see if those influence bacterial communities.

Early results show that bacterial communities can be linked to land use and also show the importance of using best management practices that are tailored to your specific streams. BMPs should be site specific and be based on MST results.



DNA plate preparation

Shoreline Cleanup and Enforcement

The Adopt-the-Shoreline program (ATS) is designed to remove trash and debris from the shorelines of the Grand River, to safeguard the ecosystem and enhance the quality of life for all who use it. The program enables participants to organize cleanups through a process of shoreline adoption. GRDA provides resources and assistance for the cleanups. Grand Lake has been divided into 10 zones to allow participants to choose an area of the lake they wish to focus their preservation efforts on.

In addition to the ATS program, the shoreline team also conducts organized cleanups with local communities and organizations. Two cleanup events were held in 2020 one with the Seneca-Cayuga Tribe, and one with local FFA chapters. Although COVID-19 slowed down these efforts in 2020, the shoreline team still managed to cleanup around 38 tons of trash and debris around GRDA's lakes.

The shoreline team is also responsible for the permitting of docks, shoreline management permitting, and the installation and maintenance of navigation buoys.

The shoreline teams works to anchor a buoy

Shane Johnston works to install a navigation buoy

Guard the Grand

Participants in the Guard the Grand program with their yard signs

Educational Outreach Programs

Guard the Grand (Continued)

The Guard the Grand program is a watershed education program designed to involve the public in improving water quality throughout the Grand Lake watershed. Currently, the program is funded through an Environmental Protection Agency Environmental Education Grant. The grant targets three audiences; residents/lake users, educators and businesses. Each audience receives information specific to them and ways they can easily implement some best practices.

Residents/Lake Users:
We held six virtual workshops beginning in May 2020 on five topics. On average, we had 29 people register for each workshop, with the one on landscaping received over 50 registrations and about 30 people in attendance. The workshop topics included the Grand Lake Watershed, the Adopt-the-Shoreline Program and Boat and Dock Maintenance, Landscaping for Water Quality and Conservation, Septic System Maintenance and Shoreline Erosion and Vegetation. Each of the workshops was recorded and have been posted to the GRDA YouTube page. As a result of the workshops, 26 rain barrels and soil test kits were distributed to attendees along with yard signs signaling they are Guardians of the Grand. A mailing list was developed based on workshop registrations and currently has 111 subscribers. Emails are sent to announce new events, when videos become available and to provide information on simple things, like how they manage yard waste and leaves can have an impact on water quality.

Two community presentations were made in 2020, one to the Lakeside Garden Club and one to the Neosho River Advisory Panel.

Educators:
To help educate students about the watershed they live in, GRDA again partnered with the Oklahoma Water Survey at the University of Oklahoma to develop science curriculum for 4th grade students that includes specific information about Grand Lake and the surrounding watershed. To help familiarize the teachers with the curriculum two one-day in person workshops were held in July 2020. Seventeen teachers, one local resident and one representative from the Kansas Water Office participated in the workshops, giving them the opportunity to apply for a grant to help implement the curriculum in their classroom.

Additionally, a demonstration of the Enviroscape was given to about 30 high school FFA students who also participated in a cleanup event as part of the Adopt-the-Shoreline program.

Other Accomplishments:
GRDA staff have developed a Guard the Grand app that should be released in 2021. The app provides watershed information, lake information and how bugs and fish are used to help determine water quality. All workshop videos and pamphlets are available for download on the app and interested users can join the email list.

If you are interested in learning more about GRDA's Guard the Grand program, please visit our website at www.grda.com/guard-the-grand or scan the QR Code with your smartphone camera.

Conservation Easements and BMPs

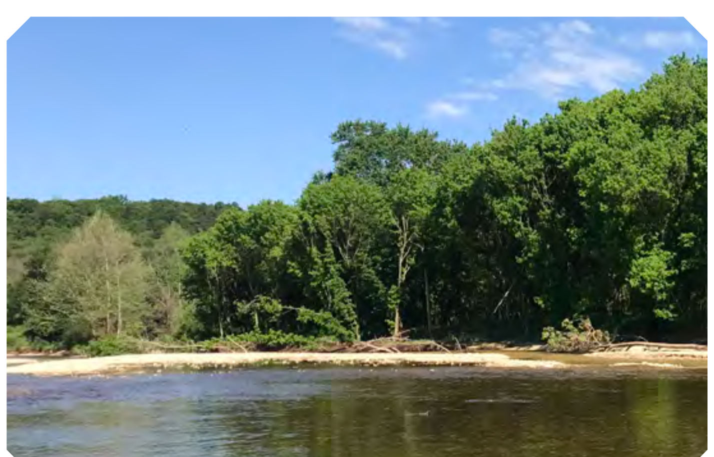
Conservation Easements

One of the Grand River Dam Authority's founding objectives was to create a conservation and reclamation district. Thus, good stewardship of the natural resources under our control has always been at the core of the GRDA mission. In recent years, GRDA has began to place extra emphasis on obtaining conservation easements along sensitive waterways. These conservation easements are legally binding although voluntary agreements, between GRDA and landowners, to restrict usage of land within the easements.

Once an easement is agreed upon, the property is designated as a protected riparian area. The landowner then works with GRDA staff and program resources to implement various conservation practices, stabilize streambanks, and manage the easement in ways that will benefit water quality in the adjacent water-bodies. These agreements include best management practices (BMPs), which are things such as stopping new construction, keeping livestock out, and optimizing agricultural production.

Having naturalized riparian areas can help to filter as much as 80 percent of pollutants such as bacteria, nutrients, and sediments before they enter streams, and are one of our best and least expensive tools to help protect water resources in these important watersheds. Since GRDA's absorption of the Oklahoma Scenic Rivers Commission in 2016, 1,480 acres have been added to the conservation easement inventory, including 800 acres in 2020.

The ultimate goal of these conservation easements and BMPs are to keep the land surrounding our precious water-bodies as close to its natural state as possible. If we are able to do this, the water quality in these areas will be better off for it.



A section of shoreline along Barren Fork Creek

The Fritts family enrolling in GRDA's easement program

Corporate Environmental Compliance

The role of Corporate Environmental Compliance

The Corporate Environmental Compliance division ensures that GRDA meets the requirements of laws, regulations, and codes designed to protect the environment. This means the CEC Division is responsible for managing environmental compliance throughout all of GRDA's property locations on air, land and water to comply with regulations set forth by the Environmental Protection Agency, Oklahoma Department of Environmental Quality, Oklahoma Corporation Commission, and other Federal, State and Tribal entities.

The CEC division works with all departments within GRDA to oversee, administer and regulate programs such as Recycling, Waste Disposal, Spill Prevention Control & Response, Above Ground Storage Tanks, Storm Water, Asbestos, Emergency Response, Remediation/Restoration and Environmental Training/Education.

The footprint of the CEC Division expands throughout the State of Oklahoma and Arkansas with GRDA's properties and resource management. The team offers a wide portfolio of Environmental resource knowledge and experience that include but are not limited to: Environmental Management, Conservation, Biology, Fisheries and Wildlife, Natural Resources, Limnology, Hydrology, Chemistry, Forestry and Toxicology.

GRDA's Mission statement, "The 5 E's" resonate with Efficiency, Economic Development, Employees, Electricity and Environmental Stewardship. GRDA's CEC Division's role and mission in Environmental Stewardship is to practice environmental awareness and promote conservation and reclamation of the natural resources under our control.

Performing a substation inspection

W.R. Holway and GRDA's Salina Pumped Storage Project

Photos from 2020

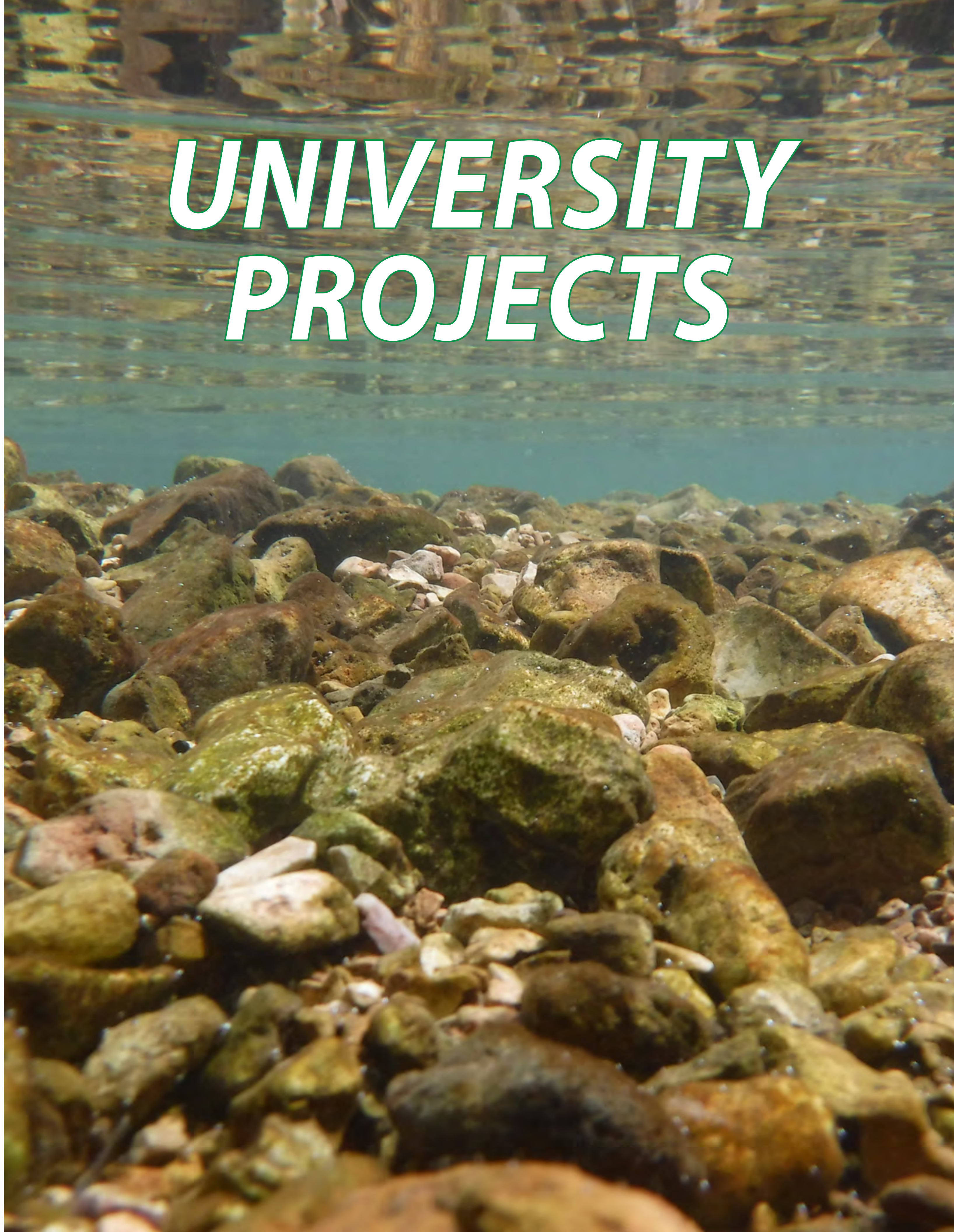

Katie Easter works to collect some rivercane


Steve Nikolai works to set an EAB trap


Courtney Stookey gives a demonstration of the enviroscape


Travis Hinshaw and Dalton Wortham on the Illinois

The shoreline team working a cleanup at W.R. Holway



Northeastern State University

Physiological Responses of *Arundinaria gigantea* (Rivercane) to Flooding Disturbance in the Cherokee Nation Reservation

Katie Easter and Elizabeth F. Waring*
**GRDA-NSU Undergraduate Fellow 2020-2021*
Northeastern State University

In the past 10 years the Illinois River has experienced record flooding disturbances with the top 10 historic crests occurring within these past 10 years of recorded history. *Arundinarea gigantea*, commonly referred to as Rivercane, occurs in a variety of soils and is commonly found along floodplains and hardwood bottom forests of the Illinois River waterbody and within the Cherokee Nation Reservation in Oklahoma. Less than 2% of original canebrake coverage remains in the United States. Many southern plains tribes relied on this plant for food shelter and a way of life before colonization. Many tribes still rely on this plant to pass down important cultural information and traditions made complete only by using this plant. Restoration and mapping efforts put forth by the Cherokee Nation and Cherokee Nation citizens report that the cane they can locate and map within the reservation are dying. Restoration efforts of Rivercane are failing in Northeastern Oklahoma. Rivercane rarely flowers to produce to new seeds, resulting in very low genetic diversity among canebrakes. Rivercane relies on vast networks of rhizomes to asexually reproduce. The new plants grow from the underground rhizomes to form culms. The intense rhizome systems are desired by many trying to restore not only canebrakes but riparian zones. Mature canebrakes work very well as riparian buffers and is a first choice by many of those whose efforts focus on fighting erosion of streams and rivers. Rivercane is also able to significant slowdown agricultural water runoff and filter nutrients efficiently making it ecologically important.

A thriving, mature canebrake (~30 years old) located in the flood plain of the Illinois River has been located and selected for this study to explore its physiological responses to flooding disturbance by measuring the alcohol dehydrogenase (ADH) activity levels in the roots. When flooding occurs, conditions among the roots become anerobic, affecting cellular respiration. Wetland plants are required to come up with a way to combat this in order to survive and thrive. Higher activity levels of ADH in the roots of the clones taken from the mature, well established, canebrake may have a physiological advantage over clones grown from a nursery and used for increasing restoration effects. Additionally, the morphology of the roots of Rivercane may change by aerenchyma cells which can aid in internal oxygen transport. This study will be a mesocosm study using clones from Rivercane from the well-established canebrake and clones ordered from a nursery will be grown in a greenhouse. Mesocosms will be filled up with water and flooded for 28 days at low, medium or deep flooding. Different amounts of phosphorus fertilizer will also be applied to the mesocosms to exam how excess phosphorus impacts flooding stress in Rivercane.

These results may be beneficial for restoration in terms of where the clones are sourced and also selection of site with frequent flooding.


Katie learning about Rivercane

Northeastern State University

Comparison of Seasonal Effects on Detritivore Breakdown of *Ailanthus altissima* and *Quercus stellata* Leaf Litter

Hunter Hodson and Elizabeth F. Waring
Northeastern State University

Ailanthus altissima, commonly known as Tree of Heaven (TOH), is an invasive tree species, originating from Southeast Asia, that is incredibly hardy and successful at displacing native species in Europe in the United States. TOH is able to invade due to rapid growth, regeneration, and seed production also allow this species to be incredibly successful in establishing itself in disturbed areas and outcompeting co-occurring species. Because TOH grows so quickly it has thin, non-fibrous leaves that can decompose rapidly. This is sharp contrast to native Quercus stellate (Post Oak) a common tree species in Oklahoma. Post Oak leaves tend to be thick and leathery and are more resistant to decomposition. As these two species are two of the most common sources of leaf litter in the Tahlequah area, we devised a project that could look that the potential impact of invasive TOH leaf litter and water temperature on freshwater detritivore communities in northeastern Oklahoma. This project will answer two questions. First, is there a difference species diversity of aquatic detritivorous invertebrates found in Ailanthus altissima leaf litter and Quercus stellata leaf litter. Second, what effect will seasonal changes in water temperature will have on species diversity of aquatic detritivorous invertebrates found in *Ailanthus altissima* leaf litter and Quercus stellata leaf litter. To do this, a research project that would investigate the breakdown of invasive TOH leaf litter compared to native Quercus stellata leaf litter, as well as the composition of detritivore communities found within each species of leaf litter over the span of almost one year was proposed. Leaf litter packs of each species will be placed in various locations in Tahlequah Creek for one week. During the week water temperature will be monitored continually. After collection the remaining litter and all other contents of the pack will be taken back to the GRDA laboratory at Northeastern State University to collect and identify any macroinvertebrates to determine species diversity of each leaf pack. The remaining rinsed leaf litter will be dried and weighted to determine how much leaf breakdown and decomposition took place. These methods would be repeated monthly from March through November of the year 2021 to observe seasonal effects on leaf litter breakdown of both plant species and detritivore community composition. At the conclusion of this project we will have a greater understanding of how water temperature will affect the decomposition of TOH and Post Oak as well as how both plant species impact the detritivore communities.


Underwater image of leaf litter


Collecting leaves for analysis

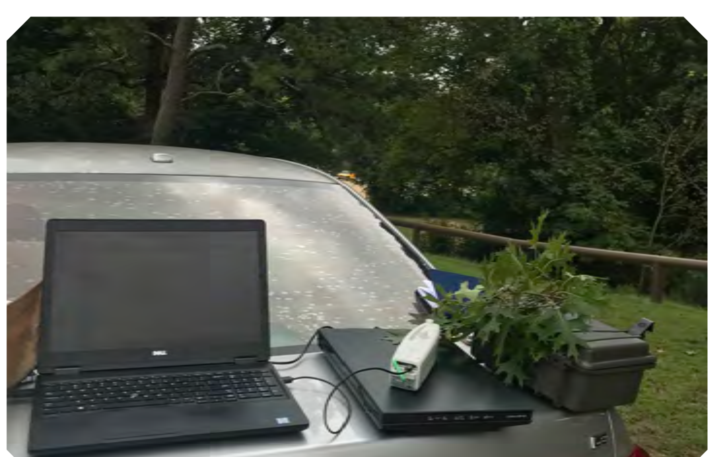
Northeastern State University

Proximity to Illinois River impacts photosynthetic leaf traits in Oaks

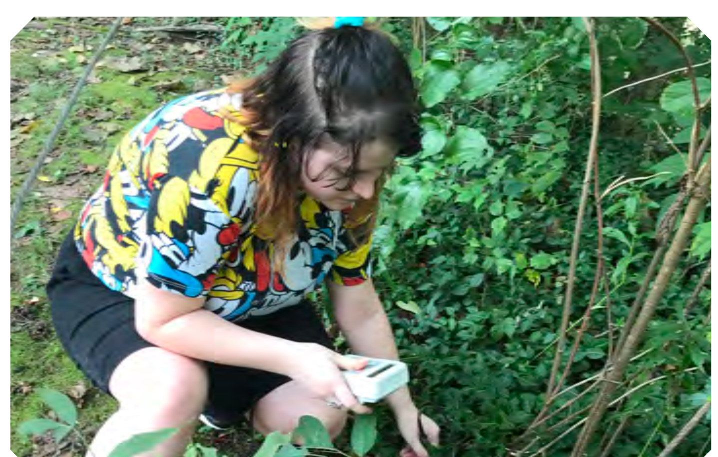
Katie Worden and Elizabeth F. Waring*
**GRDA-NSU Undergraduate Fellow 2020-2021*
Northeastern State University

One way to learn about the health of the photosynthetic systems in oaks (*Quercus spp.*) is to measure chlorophyll fluorescence to get detailed information on the light reactions of photosystem II. The purpose of this study is to analyze and compare how tree leaf traits vary across a riparian and upland gradient as well as between species of Quercus to (i) observe changes in leaf photosynthetic machinery, (ii) quantify changes in leaf shape and nutrient content, and (iii) measure soil moisture at a gradient of ten sites along the Upper Illinois River (riparian areas) to the more upland Northeastern State University's campus in Tahlequah, Oklahoma. By measuring plant and environmental parameters, I was able to assess how proximity to the river affects photosynthetic traits as well as leaf traits. Soil moisture was measured under each tree using a Dynamax TL3 Thetaprobe and leaves that were in full sunlight were measured using a Photosynq MultispeQ 2.0 to assess photosynthetic machinery function and chlorophyll content. Leaves were then measured for leaf area and taken to the lab to be dried and weighed for leaf specific area (SLA). While there was no effect of species of oak on photosynthetic traits, as distance from the river increases, nonphotochemical quenching and photosynthetic rates were measured as linear electron flow increased ($p<0.01$ for both measurements). The SLA of the oaks increased with proximity to the river ($p<0.0001$) indicating that leaves closer to the river are broader and thinner to allow for greater light capture. However, soil moisture was not affected by proximity to the river ($p>0.05$).

This indicates that due to the nature of the sites, riparian environments were denser than their upland counterparts and thus explains why riparian leaves were broader and possessed lower photosynthetic rates despite proximity to the river because of light competition.



Katie's mobile workspace



Collecting field data

Oklahoma State University

Testing the effects of relative supplies of N, P and Fe on harmful algal blooms in Grand Lake

Yetkin Ipek and Puni Jeyasingh
Department of Integrative Biology
Oklahoma State University

Harmful algal blooms are a constant environmental problem that affect water quality worldwide. During blooms, harmful algae increase in abundance in lake systems; greatly affecting the water quality. The toxins they release in water are directly harmful to humans and pets, as these toxins contaminate drinking water and reduce its availability for everyone. Harmful algae also directly impact economies as they negatively affect lake tourism and the health/abundance of fish in lakes. The Environmental Protection Agency (EPA)'s 2015 report has estimated the total management costs of algal blooms to be up to $2 billion every year. The most common environmental variable that triggers harmful algal blooms is the increased loading of nutrients (such as phosphorus, nitrogen, etc.) to freshwater systems. The runoff off these elements increases significantly by anthropogenic activities such as fertilizer use and sewage runoff.

The main reason that these elements are correlated to increased growth is given by the Growth Rate Hypothesis. As an increase in algal growth would demand a higher rate of protein production; nitrogen (N) is required as the building blocks of proteins and phosphorus (P) is required in the structure of rRNA to support increased rates of protein synthesis. As a result of increased N and P loading, protein production rate and algal growth are faster, leading to blooms. However, we are still unable to make strong predictions based on N and P alone. While it takes N and P (as rRNA) to generate proteins, protein function also requires other elements like metals. Cyanobacteria, as N-fixing species, have high demands for trace metals to support nitrogen fixation. So far, we have found that in N-limited systems, the supply of iron (Fe) as a trace metal greatly increases cyanobacterial growth, as it allows for higher rates of N fixation. We have also seen that changes in relative supplies of N, P and Fe caused changes in demands of all cellular elements, further supporting the idea of Fe impacts on algal blooms. We know Fe availability is quite variable across lakes, but it could also be variable between different locations of the same lake. During Summer 2021, we plan to study the elemental conditions as well as algal abundance in Duck Creek, Drowning Creek, Horse Creek, Honey Creek sites of Grand Lake to test for links between Fe and algal blooms (standardized for P or N).

With potentially increased runoff of P, cyanobacteria can fix atmospheric N to supply their growth. In such cases, Fe as a rate-determining element for cyanobacterial N fixation, could be crucial in predicting cyanobacterial blooms in lake systems. The findings from this study have a potential to help develop strategies against algal blooms in various relative supplies of N, P and Fe.

The experimental lab setup

Oklahoma State University

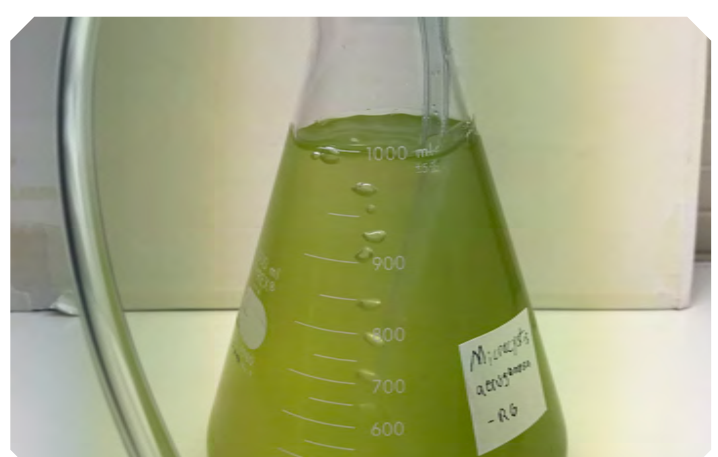
Methods for Integrative Passive Sampling and GC/MS Analysis of Total Microcystins

Ryan Grewe and Jason Beldon
Department of Integrative Biology
Oklahoma State University

Harmful algal blooms (HABs) can occur in water bodies receiving excess nutrients, and sometimes lead to the production of cyanotoxins, which present a risk to both aquatic and terrestrial life. Production of cyanotoxins by cyanobacteria fluctuates heavily with environmental parameters, especially temperature. Therefore, depending on the frequency of sampling, traditional grab sampling methods can fail to catch the full extent of cyanotoxin production in a water body. Passive sampling is a method of sampling in which a sorbent receptive to the analyte of interest (cyanotoxins) is placed in the water body to collect that analyte for a given period of time. As passive samplers continuously collect the analyte while deployed, they offer the possibility to determine the time weighted average concentration of the analyte, and to detect smaller concentrations than grab sampling. Solid phase adsorption toxin tracking (SPATT) and polar organic compound integrative samplers (POCIS) are the two most common passive sampling methods for detecting cyanotoxins, including microcystins, the most common freshwater cyanotoxin. Typically, however, the analytical methods associated with passives sampling of microcystins either fail to detect total microcystins (using LC-MS) or include time-consuming extraction procedures (using GC-MS).

In this study, microcystin contaminated water will be harvested from cyanobacteria grown in a controlled environment and used to replicate cyanotoxin contaminated water bodies for sampler testing. Hybrid SPATT and POCIS samplers will be designed and tested using the configuration of a POCIS sampler with the sorbents and membranes of a SPATT sampler to determine the best design for sampling of cyanotoxins. Two sorbents (Oasis HLB and HP20) and two configurations (nylon mesh and polymer membrane) will be tested to determine the best design for sampling microcystin. Additionally, a new analytical method will be tested where the ADDA moiety of microcystin is cleaved directly from the passive sampler for GC-MS analysis, thus simplifying the extraction process. Should these new methods of passive sampling of microcystin prove effective, they will allow for a more simplified and comprehensive analysis of total microcystins in contaminated water bodies.

A Polar Organic Chemical Integrative Sampler



A flask of cultured Microcystis

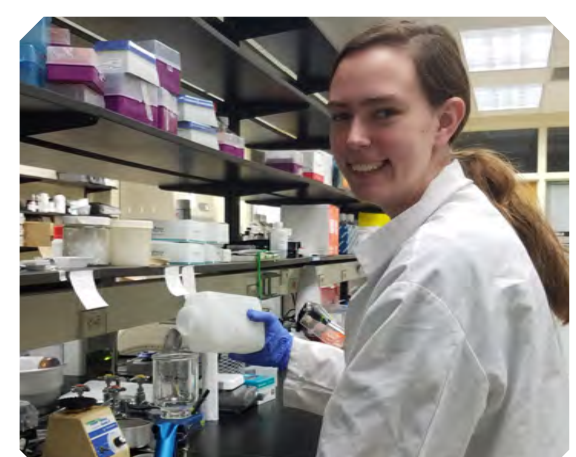
Oklahoma State University

Shifting Community: can changes in the lake microbiome predict algal blooms?

Chelsea Murphy and Noha Youssef
Department of Microbiology and Molecular Genetics
Oklahoma State University

Virtually every surface and environment in the world is teeming with tiny life-forms called microbes. While they may be invisible to the naked eye, these microscopic bacteria, archaea, fungi, algae, and single-celled animals have a big impact on our world. Just like any other organism, they eat and produce waste products as they grow, multiply, and fight for survival. Although a single microbe on its own might not have the ability to affect our macro-sized world, the overall microbial community comprised of billions of microbes belonging to thousands of species is mighty enough to create a tangible impact. In lake environments like at Grand Lake, this microbial community can help to cycle different elements to help fuel the growth and health of larger plants and animals. Some, such as the bacterial phylum Firmicutes, may help to break down organic material, helping to recycle the nutrients back into the environment and preventing buildups of waste. Others, like the green algae class Chlorophyceae, can capture the energy of sunlight and transform it into a form that other organisms can use. Still others, such as the bacterial genus Nitrospira, can make use of a variety of different nutrients like nitrogen and phosphorus, turning the elements in runoff and even the air itself into something plants can use. A sudden influx of nutrients, when combined with other factors such as temperature, can cause blooms, or abrupt population explosions, of algae. Of particular interest is the blooming of Cyanobacteria, also known as blue-green algae. While Cyanobacteria normally helps within a balanced community by capturing sunlight and nitrogen for others, a bloom can quickly be dangerous. The blooming of Cyanobacteria can deplete the oxygen in the water that other organisms, like fish, need to survive, as well as cover the surface enough to blot out the light aquatic plants rely on. In addition, Cyanobacteria can produce cyanotoxins that are harmful to humans and other animals. Although we have an idea of what some of the factors that can trigger these blooms are, the blooms can be difficult to predict in real-time, making it difficult to keep the lake healthy and safe to enjoy.

We are seeking to characterize the microbial community of Grand Lake and observe how it changes during the time leading to a harmful algal bloom. Through repeated sampling in different locations over time, we aim to collect data on both what microbes are present as well as how much of the community they make up. We aim to sequence both specific marker genes that can be linked to microbes' identities, as well as whole microbial genomes that can help identify what types of metabolism are enriched. With this data, we ultimately hope to be able to predict when blooms will occur based on the changes of the microbial community, as they should provide signals that the nutrition profile of the lake is changing. We hypothesize that complex community trends precede a bloom, and that these trends can be predicted. We aim to use the data we collect in machine-learning algorithms with the hope of creating an artificial intelligence program that can find the patterns leading to a harmful toxic blue-green algae bloom. Ideally, this would allow for advanced warning of a bloom or even a window to try and correct the lake's balance and prevent a bloom through measuring the concentrations of target lineages identified as important signals by the algorithm.



Chelsea filtering cells from lake water

University of Oklahoma

IS BIGGER ALWAYS BETTER? ANALYSIS OF MODELS DEVELOPED FROM SMALL UNOCCUPIED AERIAL SYSTEM IMAGERY COMPARED TO SATELLITE REMOTE SENSING OF OPTICAL AND NON-OPTICAL WATER QUALITY PARAMETERS

Juan G. Arango and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

Continuous global expansion of agricultural, industrial, and commercial practices has resulted in ubiquitous discharges of elevated concentrations of phosphorous and nitrogen into surface waters. Due to nutrient over-enrichment and resulting water quality degradation, effective monitoring of water bodies has become a necessity yet a major challenge. Modern remote sensing tools (multispectral sensors onboard satellites) can accurately and reliably estimate water quality information and expand the discrete sampling point coverage associated with traditional labor-intensive in-situ sampling but are subject to certain environmental limitations. However, the recent emergence of compact multispectral sensors and small Unoccupied Aerial Systems (sUAS) has opened the possibility of collecting high-resolution multispectral imagery without some of the constraints of satellite data collection. The purpose of this study was to compare multispectral imagery from two satellite-based remote sensing tools (Landsat 8 and Sentinel-2) and a sUAS. Optical and non-optical water quality parameters were able to be predicted in both low nutrient and high nutrient bodies of water by multiple linear regression. Algorithms for optical water quality parameters were developed with imagery collected with all platforms. However, for the non-optical data, reliable models were obtained only from the imagery collected with the sUAS.

GENERATION OF GEOLOCATED AND RADIOMETRICALLY CORRECTED TRUE REFLECTANCE SURFACES IN THE VISIBLE PORTION OF THE ELECTROMAGNETIC SPECTRUM OVER LARGE BODIES OF WATER USING IMAGES FROM AN sUAS

Juan G. Arango, Brandon Holzbauer-Schweitzer, Robert W. Nairn and Robert C. Knox
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

The focus of this study was to develop true reflectance surfaces in the visible portion of the electromagnetic spectrum from small Unoccupied Aerial System (sUAS) images obtained over large bodies of water when no ground control points were available. The goal of the research was to produce true reflectance surfaces from which reflectance values could be extracted and used to estimate optical water quality parameters utilizing limited in-situ water quality analyses. Multispectral imagery was collected using a sUAS equipped with a multispectral sensor, capable of obtaining information in the blue (0.475 µm), green (0.560 µm), red (0.668 µm), red edge (0.717 µm) and near infrared (0.840 µm) portions of the electromagnetic spectrum. In order to develop a reliable and repeatable protocol, a five-step methodology was implemented: (1) image and water quality data collection, (2) image processing, (3) reflectance extraction, (4) statistical interpolation and (5) data validation. Results indicate that the created protocol generates geolocated and radiometrically corrected true reflectance surfaces from sUAS missions flown over large bodies of water. Subsequently, relationships between true reflectance values and in-situ water quality parameters were developed.

University of Oklahoma

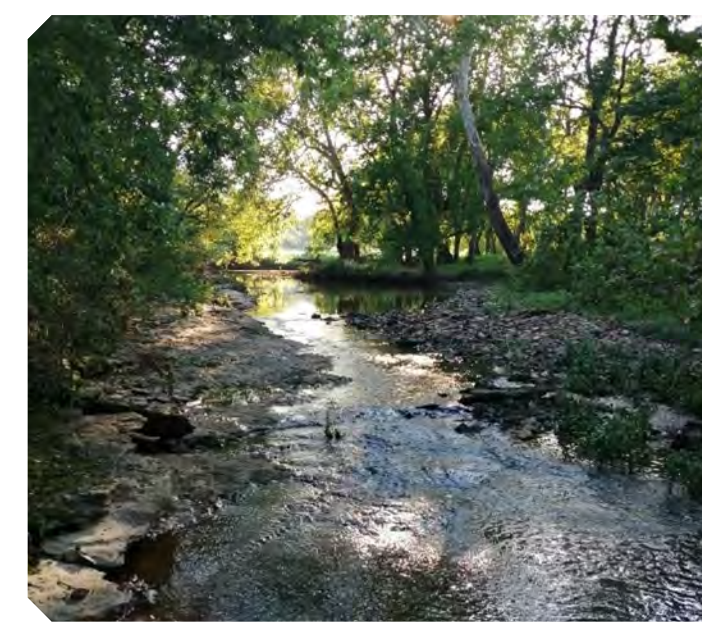
UNDERSTANDING THE PAST IN ORDER TO ACT IN THE FUTURE – PARTNERSHIP EFFORTS TO DECREASE NUTRIENT CONCENTRATIONS IN AN AGRICULTURAL WATERSHED

Juan G. Arango and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

Land use/land cover (LULC) influences the water quality of a watershed. Understanding the relationships between the activities that take place within a watershed and its water quality has become a must when it comes to addressing water quality concerns. More importantly, understanding these relationships provides knowledge that helps to properly design and implement restoration strategies that aim to improve water quality. As part of this study, a series of riparian conservation easements have been implemented on Horse Creek and its tributaries to improve water quality. Horse Creek directly discharges into Grand Lake o' the Cherokees, Oklahoma and has been the site of several harmful algae blooms (HABs). The purposes of this study were to: (1) determine the relationship between land use patterns and historical and present water quality, (2) calculate nutrient loads that are being discharged from Horse Creek into Grand Lake, (3) capture the current status of the riparian conservation easements and (4) provide initial baseline data to document potential changes in water quality as a result of the implementation of the riparian conservation areas.

Results indicate that: (1) Water quality in HC and LHC has been relatively stable for the past two decades, (2) LULC inside the Upper Horse Creek watershed has seen minimal changes, (3) 99% of the watershed is dominated by pasture/hay (62%), cultivated crops (28%), urban development (that includes low, medium and high-intensity development) (7%) and deciduous forest (2%) (4) it can be suggested that historical water quality for the watershed has been influenced by pasture/hay and cultivated crops and (5) one of the sources of elevated concentrations of nutrients could be attributed to NPS pollution that comes from actively managing pasture/hay and agricultural land.

Pre-Flight Setup of the sUAS



Upstream view of Horse Creek Easement

University of Oklahoma

UNDERSTANDING THE EFFECT OF IRON OXIDE MINEROLOGY ON SORPTION CAPACITY TO PROMOTE THE ENVIRONMENTALLY AND ECONOMICALLY SUSTAINABLE REUSE OF MINE DRAINAGE TREAMTENT SOLIDS

Dayton M'Kenzie Dorman and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

Sustainable reclamation must consider the full life cycle impacts and costs of a selected remedy. In the case of passive mine water treatment, that includes the ultimate disposal or reuse of accumulated solids, most notably iron oxide solids. The chemical composition of iron oxide solids is based on the untreated mine water chemistry and the specific treatment mechanisms employed resulting in solids retention. The resulting chemical composition, along with environmental conditions (pH and redox conditions) and time, drives the mineralogy of these solids. It is well-established that iron oxides have substantial surface area per unit mass and therefore considerable sorption capacity. By properly understanding iron oxide mineralogy, how it changes over time and its effect on sorption capacity, sustainable reuse of mine drainage treatment solids may present an opportunity to offset solids disposal costs and improve the sustainability of mine water treatment activities.

The overall goal of the proposed project is to develop a thorough understanding of the relationships between mineralogy and sorption capacity in mine-drainage derived iron oxides, in order to further advance sustainable environmental and economic reuse of mine drainage treatment solids. Beneficial reuse of mine water iron oxide solids not only decreases the environmental footprint of mine drainage treatment, but also alleviates the financial burdens of storing, treating, and disposing of such solids.

This project will 1) evaluate how water chemical composition affects the mineralogy of iron oxide mine drainage treatment solids and their sorption properties, 2) comprehensively evaluate iron mineralogical changes over time and the resulting effects on ratios of adsorption/desorption using collected depth samples in the field and performing a laboratory aging study and 3) estimate the economic benefit provided by using mine drainage treatment solids as sorbents.

This study will be performed using samples collected from two passive treatment systems located in the Tar Creek Superfund Site treating naturally net-alkaline hard-rock mine drainage and two abandoned coal mining locations: one passive treatment system where net acidic mine waters have been rendered alkaline and one untreated net acidic mine drainage discharge.

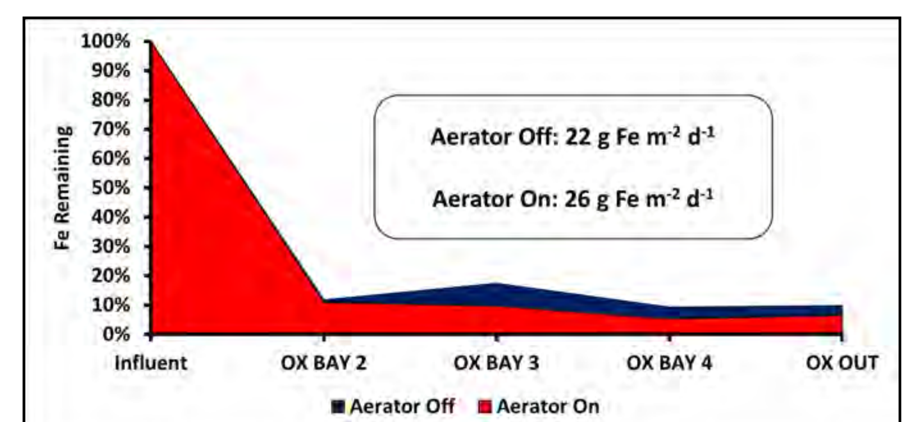
A float-mix aerator in a passive treatment pond

University of Oklahoma

THE ROLE OF SOLAR-POWERED FLOAT-MIX AERATORS ON IRON RETENTION IN PASSIVE TREATMENT OXIDATION PONDS

Dayton M'Kenzie Dorman and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

Aeration is a common water quality treatment option utilized in a variety of applications including reservoir management, water and wastewater treatment, and aquaculture. Aeration is also a critical step in the treatment of mine drainage. In passive treatment of mine drainage, aeration is commonly achieved by dissipation of energy from hydraulic head. However, this is not feasible for sites located in regions with limited topographic relief. This study investigated the effectiveness of custom-designed float-mix aerators (FMA, Figure 1) deployed at the Southeast Commerce Passive Treatment System in the Tar Creek Superfund Site to increase dissolved oxygen (DO) concentrations, degas carbon dioxide (CO2), and promote iron (Fe) retention from multiple perspectives: (1) with respect to depth in the water column, (2) spatially with respect to the aerator, and (3) spatially within the oxidation pond to examine overall effect of aeration on the performance of the oxidation pond. The study found: (1) The FMAs statistically increased DO saturation and raised pH at depths of 0.4 meters below the surface and shallower. The increase in DO and pH promoted Fe oxidation. When the aerators were on, lower total Fe concentrations were found in the shallower reaches of the water column and higher total Fe concentrations were found at depth compared to the FMAs off. Similarly, a larger fraction of the Fe present was in the particulate form indicating that more Fe was oxidized and precipitated and began to settle at increasing depths. (2) The FMAs were able to increase DO saturation up to 9 m downstream compared to solely passive aeration. The FMAs, however, had a limited radius of influence degassing CO2 and raising pH at approximately 3 m from the FMAs. The increased DO and pH provided by the FMAs allowed for more Fe to be oxidized and lower total Fe concentrations downstream of the FMAs compared to when the FMAs were off. (3) A comparison of oxidation pond influent and effluent water quality data showed that when the FMAs were on DO saturation increased over 100%, CO2 was degassed effectively and on average 93% of the Fe loading was removed before the water entered the next treatment unit. The study found the active aeration provided by the FMAs increased the Fe removal rate of the oxidation pond by 17% from 22 g m-2 d-1 without the FMAs to 26 g m-2 d-1 as shown in Figure 2. This study shows that FMAs are a viable aeration technology for sites where gravitational energy driven aeration is not feasible due to topographic limitations.



Percent of total influent iron remaining within the oxidation pond compared with aerators off and on, and iron retention rates with aerators off and on.

University of Oklahoma

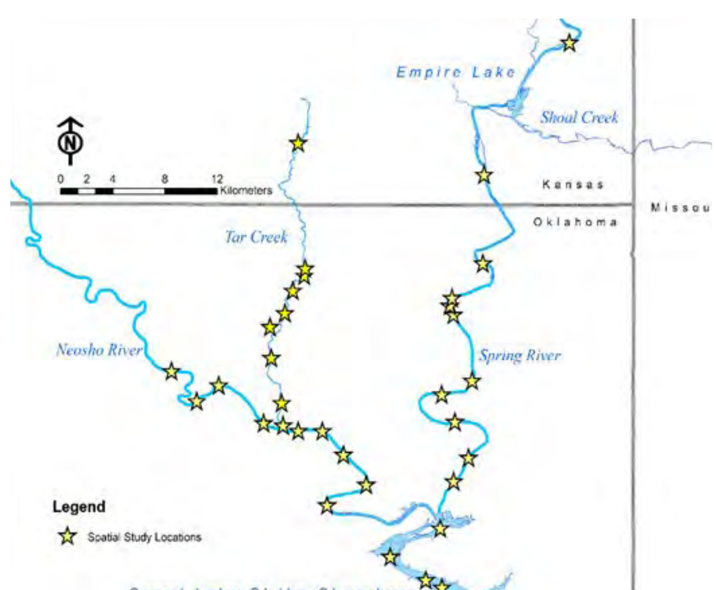
TEMPORAL CHANGES IN TRACE METAL CONCENTRATIONS IN TAR CREEK SEDIMENTS

Carlton A. Folz and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

In the Tar Creek watershed, mine drainage, elevated in dissolved metals, started flowing freely at the surface in 1979 near Commerce, OK. During the mid-1980s the United States Geological Survey (USGS) examined trace metal concentrations in the stream sediments of Tar Creek. The purpose of this study is to evaluate trace metal contamination in sediments over 35 years after the initial sampling event. The area has been undergoing remedial efforts including two passive treatment systems addressing several artesian discharges before the contaminated water enters an unnamed tributary and eventually Tar Creek. Sample collection was conducted to revisit the same locations as the previous USGS report.

While this study is still ongoing, initial results show a wide range of changes in trace metal concentration and organic matter content. Results from this study indicate a significant decrease in Fe and Pb concentrations and an increase in Zn and Cd concentrations ($p<0.05$). There was also a significant increase in organic carbon content. There are various factors influencing these changes on a macro- and micro-scale. Macro-scale changes include remedial efforts to clean and contain chat piles as well as the previously mentioned passive treatment systems. This extended time period also allows for the accumulation of organic matter into the sediments through natural processes. On the micro-scale, the dissolved and particulate trace metals in Tar Creek are interacting with high surface area particles such as iron hydroxides and organic carbon that have an affinity to sequester trace metals. This presents a scenario where stream sediments can act as a sink for trace metals, but if environmental or physiochemical conditions change, sediments can become a source and release the trace metals back into the stream. Due to the potential toxicity of Zn, Pb, and Cd, it is imperative to understand changes in Tar Creek sediments to protect human health and the environment. This research project will be completed in the spring of 2021.

Collecting sediment samples in a cattail marsh



Sampling locations

University of Oklahoma

SPATIAL EVALUATION OF SURFACE SEDIMENTS CONTAMINATION BY TRACE METALS IN NORTHEASTERN OKLAHOMA

Carlton A. Folz and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

Trace metals such as lead (Pb), zinc (Zn), and cadmium (Cd) are of great environmental concern due to their potential toxicity to humans and the environment. The purpose of this study is to i) determine the spatial distribution of trace metal contamination and ii) determine the concentration of bioavailable trace metals in surface sediments from Tar Creek, Neosho River, Spring River, and the upper reaches of Grand Lake O' the Cherokees. These sediments have been impaired from the historic lead-zinc mining in the Tri-State Mining District. Sediment samples were collected in October of 2020. The bioavailable concentrations will be determined through an ammonium-bicarbonate diethylenetriaminepentaacetic acid (AB-DTPA) extract. Samples are currently undergoing chemical analyses at the University of Oklahoma CREW laboratory. The concentrations of total metals will be compared to the Tri-State Mining District sediment quality guidelines to determine if concentrations exceed the probable effect concentration (PEC) for sediment-dwelling organisms. The concentrations will also be compared to the regional background concentrations to determine the magnitude of contamination.

It is hypothesized that the magnitude of contamination from trace metals will decrease with increasing distance from the mine drainage impacted streams (e.g., Tar Creek and Beaver Creek). The mining impacted streams, while smaller than the Neosho and Spring Rivers, contain elevated trace metals in the water and sediments, and have been flowing that way for decades. This allows for downstream transport and accumulation over time. The work will assist in the understanding mobility of trace metals as well as factors that may be influencing the accumulation and availability. This research is ongoing and will be completed in the spring of 2021.

A photo of historic Pensacola Dam

University of Oklahoma

SPECTRAL MONITORING TECHNIQUES FOR OPTICALLY DEEP MINE WATERS: MODEL CALIBRATION AND VERIFICATION

Brandon Holzbauer-Schweitzer and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

The remote estimation of water quality is of increasing interest in environmental monitoring. Unfortunately, environmental and technical limitations inhibit widespread application. Therefore, by considering a water body that is shallow in terms of physical depth (water surface to substrate surface), yet optically deep (highly turbid) like many mine water systems, examinations may be made of relationships between physical and optical depth, water clarity, water chemical composition, and spectral reflectance. The purpose of this study was to demonstrate spectral monitoring techniques for surface waters utilizing spectral data from two different platforms.

First, the feasibility of utilizing small Unoccupied Aerial System (sUAS)-derived multispectral imagery (e.g., tens of spectral measurements) to estimate in-situ metal concentrations in ferruginous lead-zinc mine drainage was examined. Collection of water quality samples and multispectral imagery to evaluate the relationships occurred within a one-hour time window. Results describe strong linear relationships between remotely collected multispectral reflectance and in-situ metal concentrations. Spatial regression techniques produced a model capable of predicting particulate iron concentrations with moderate confidence ($R2_{adj}$ = 0.83) and reasonable error (SSR = 69.80). Furthermore, strong positive correlations between untransformed reflected red electromagnetic (EM) energy and in-situ concentrations of total and particulate iron and total cadmium were found with correlation coefficients (R) of 0.86, 0.88, and 0.88, respectively.

Additionally, the untransformed reflected green EM energy displayed moderately strong inverse relationships with total calcium, cobalt, potassium, lithium, magnesium, manganese, sodium, nickel, lead, sulfur, and silica with R values of -0.68, -0.68, -0.71, -0.71, -0.69, -0.65, -0.71, -0.67, -0.75, -0.69, and -0.60, respectively. The observed statistical relationships with the optically inactive constituents were likely due to the iron precipitates' surface properties (e.g., high sorption affinity). The correlation between constituents has been used in traditional environmental remote sensing studies to estimate concentrations of constituents that are otherwise not optically active (e.g., phosphorus).

Overall, utilizing cost-effective sUAS-derived multispectral imagery to estimate mine water quality may represent a new and exciting tool and pave the way for the next generation of environmental monitoring. Adopting this technology will advance the efficiency and effectiveness of monitoring, alter traditional environmental remote sensing strategies, and provide a glimpse into the ever-advancing future of environmental restoration.

Brandon piloting OU's sUAS

University of Oklahoma

EXAMINING THE EFFECT OF AQUATIC OPTICAL DEPTH ON REFLECTED ELECTROMAGNETIC ENERGY: A MESOCOSM WATER QUALITY STUDY

Brandon Holzbauer-Schweitzer and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

To address the continued widespread degradation of the natural environment, particularly the quality of surface water resources, novel monitoring tools and technologies are required. Humans have already developed observation and analysis tools to remotely collect environmental information from large areal extents (e.g., remote sensing). However, collecting remote sensing data over water bodies is not without challenges. Relative to optically deep waters (ODWs), optically shallow waters (OSWs) have lower concentrations of various optically active constituents (OACs) (e.g., chlorophyll-a, total suspended solids (TSS), and undissolved metals). Also, OSWs tend to appear colorless (Figure 1A) and have greater Secchi disk depths (SDD) (e.g., lower turbidity). In this study, if SDD equaled or exceeded the physical water depth, the waters were considered optically shallow. Visible and near-infrared (NIR) spectral energy reflected from OSWs not only represents what is within the water column (e.g., OACs) but also the physical, chemical, and bathymetric properties of the substrate.

Therefore, the purpose of this study was to examine waters of different optical depths (Figure 1A and 1B) to quantify what effects interactions with substrate have on reflected spectral energy, and thus, the accurate development of in-situ water quality models. Four sets (e.g., Control (C), Biomass (B), Mine Drainage Residuals (M), Biomass + M (BM)) of experimental mesocosms (five-gallon PVC buckets) setup with similar substrate masses and filled with surface from a nearby pond served as the study vessels. In-situ water quality (e.g., chlorophyll-a, TSS, color, turbidity, SDD, and total and dissolved metals) and spectral data (multispectral and hyperspectral) were collected from the buckets before (unmixed) and after (mixed) mixing to isolate the effect of optical depth. Conversion of OSWs to ODWs (e.g., increase turbidity) was completed by mixing with a battery-powered drill for approximately 15 seconds or until the substrate was no longer visible. Overall, mixing significantly (p-values < 0.001) increased chlorophyll-a, TSS, turbidity, color, and some metals by over 100 percent. The mixed buckets displayed significantly higher (p-value < 0.05) overall reflectance than their unmixed counterparts (Figure 2). Mixing also decreased SDD to values smaller than the physical water depth, converting them from OSWs to ODWs.

Preliminary regression results examining the ability of hyperspectral reflectance to estimate in-situ water quality support the primary hypothesis. In OSWs, the relationships with hyperspectral reflectance and OACs were low to moderate (e.g., R = 0.12 – 0.42), while in ODWs the relationships were much stronger (e.g., R = 0.72 – 0.91). By simply altering the aquatic depth of mesocosm water bodies, this study's results demonstrated the impact remotely sensing substrate in OSWs has on collecting spectral data and the subsequent development of accurate water quality models. Future efforts should examine the role of scale (e.g., spatial and spectral resolutions) in developing models, particularly the ability for small Unoccupied Aerial Systems (sUAS) to be used as the spectral tool for environmental remote sensing studies.

University of Oklahoma

BIOLOGICAL SULFATE REMOVAL USING WASTE ORGANIC SUBSTRATES IN CONTINUOUS FLOW-THROUGH COLUMNS SIMULATING MINE WATER VERTICAL FLOW BIOREACTORS

J.D. Ingendorf and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

In mine water passive treatment systems, biological SO42- reduction in vertical flow bioreactors (VFBRs) is often utilized to precipitate trace metals as metal sulfides and to generate alkalinity. SO42- removal is not typically targeted and is trivial in bioreactors compared to the removal of targeted metals. However, utilizing biological sulfate reduction in VFBRs to specifically remove sulfate can be an effective strategy to decrease elevated SO42- concentration from mine drainage. In this study, a laboratory bench-scale continuous flow-through column study simulating mine water VFBRs was conducted over 370 days evaluating the effectiveness of three locally available waste organic substrates (Norman Aged Compost (NAC), Murphy Compost (MC), and Spent Mushroom Compost (SMC)) on biological sulfate (SO42-) removal by sulfate reducing bacteria (SRB). The substrates were tested in triplicate columns, constructed in opaque PVC pipes (0.19 m3), filled with a 2:1 mixture by volume of the substrate to washed river rock, and fed with a solution containing 1000 mg SO42- L-1 + 10%. Conditions at the start and at termination of the study were optimal for SO42- reduction: anaerobic conditions with circumneutral pH, reducing ORP, and moderate temperatures. During the first 305 days, SO42- removal rates and percent removal of SO42- decreased significantly in all treatments ($p < 0.01$). On Day 306, the hydraulic retention time (HRT) was decreased from eight days to four for 30 days and then again to two days on Day 336 for 30 days in order to observe changes in SO42- removal rates. At an HRT = 8 days, the SMC treatment consistently produced the lowest effluent SO42- concentrations (median = 221 mg L-1), and the greatest SO42- removal rates (mean = 548 mmol m-3 day-1), percent removal of SO42- (median = 77.3%), and effluent sulfide concentrations (median = 123.6 mg L-1) ($p < 0.01$). The SMC and MC treatments did not show significant differences in SO42- removal across all HRTs, however the NAC treatment had significantly lower SO42- removal with shorter HRTs ($p < 0.05$). Sulfide production decreased significantly with shorter HRTs in all treatments ($p < 0.05$). The substrates showed similar SO42- removal capabilities within a range of organic carbon contents in the substrates and in effluents.

Laboratory Flow-Through Column Study Benchtop Setup

University of Oklahoma

ASSESSING TOXICITY, RISK, AND FATE OF MINE DRAINAGE PASSIVE TREATMENT RESIDUAL SOLIDS

Justine Inez McCann and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

Ecological engineering has proved to be an effective manner for treating mine water containing elevated levels of trace metals. The biogeochemical processes used in these treatment systems work to sequester metals in both oxidizing and reducing conditions. Although these systems are cost-effective and require minimal energy input and maintenance, passive treatment systems have a finite lifetime that may be extended by removing metal-rich solids and replacing spent organic matter. Removal of these solids, however, creates a large amount of potentially hazardous material which may be reused if it is appropriately characterized and managed. In this study, the capacity for leaching of trace metals will be evaluated in the accumulated residual solids in the oxidation ponds and vertical flow bioreactors from two passive treatment systems located within the Tar Creek Superfund Site. A review of the literature has been conducted and indicates that leaching from mine drainage residuals can be appropriately characterized using the synthetic precipitation leaching procedure (SPLP) and the field leach test (FLT) due to the standard practice of disposing of mine wastes in situ. Using the toxicity characteristic leaching procedure (TCLP) is also recommended as it is required by law for disposal of potentially hazardous materials in landfills, but there are shortcomings of this method that should be considered. Several organic and inorganic amendments to increase sorption have been used in previous research to treat soils contaminated with trace metals but using these amendments to treat mine drainage residuals has not yet been attempted. First, unamended samples from the oxidation ponds and the vertical flow bioreactors of the two passive treatment systems will be tested for leachability using SPLP, FLT, and TCLP. Spatial variability will be determined during this step by collecting the statistically appropriate number of samples according to Environmental Protection Agency sampling guidelines. Amendments will be added to composited samples to determine the efficacy of treating the solids with sorbents. The study will conclude with comparing trace metal concentrations in the solids to consensus-based benchmarks for sediment and soil to quantify risks associated with adding these solids as a remedial substance to ecosystems in northeastern Oklahoma. This study should produce a clear picture of the feasibility of beneficial reuse for the solids in the oxidation ponds and vertical flow bioreactors of the passive treatment systems currently in place at Tar Creek Superfund Site.

Sampling substrates from one of the vertical flow bioreactors at the Mayer Ranch passive treatments system near Tar Creek.

University of Oklahoma

ASSESSING THE POTENTIAL FOR BENEFICIAL REUSE OF PASSIVELY-TREATED MINE WATERS FOR CROP IRRIGATION

Harper T. Stanfield and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

Passive treatment of mine drainage provides demonstrated water quality improvements and substantial removal of ecotoxic metals via biogeochemical, microbiological, and physical mechanisms. When mine drainage is treated to a quality that satisfies the pertinent ambient water quality criteria, it is often discharged into a receiving water body. If sufficiently treated mine water could be safely reused in crop irrigation, available surface and groundwater reserves could be freed up for other beneficial uses.

Three common Oklahoma crops – field corn (Zea mays indentata), sorghum (Sorghum bicolor spp. bicolor), and Bermuda grass (Cynodon dactylon) – were irrigated in potting mix from seed with either local central Oklahoma groundwater or treated lead-zinc mine water from the effluent of the Mayer Ranch Passive Treatment System (Tar Creek Superfund Site, Commerce, OK). Crop growth and chemical composition were monitored through regular measurements of above-ground height and growth stage as well as final determinations of biomass production and trace metals concentrations. Mine water irrigation did not have a significant effect on seedling emergence, plant growth, or biomass production for corn or Bermuda grass, whereas sorghum exhibited a temporary reduction in growth and a decrease in biomass production under mine water irrigation.

The crops were exposed to metals in irrigation waters, fertilizer, and commercial potting mix; irrigation was the smallest vector for many of the metal species. Cd, Na, and S accumulated in mine water-irrigated substrate. Mine water irrigation did not significantly increase concentrations of Fe, Mn, Zn, K, Ni, or Pb in any of the three plant species, had mixed effects on Ca concentrations, and increased concentrations of Cd in roots and Mg in belowground and aboveground biomass of some structures. Na and S concentrations in some corn and sorghum root structures and in all Bermuda grass biomass were elevated by mine water irrigation.

This study found that hard-rock, net-alkaline mine drainage can be treated in ecologically engineered systems and reused for the irrigation of some plant species without detriment to emergence patterns, growth, or biomass production relative to irrigation with groundwater. Treated mine water increased concentrations of certain elements in plants and soil, particularly Cd, Na, and S, but these metals were largely sequestered in the belowground biomass.

Harvesting crops for analysis

University of Oklahoma

MODELING LIVESTOCK CONSUMPTION OF PASSIVELY-TREATED MINE WATER IN OTTAWA COUNTY, OK

Harper T. Stanfield and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

The potential for beneficial reuse of passively-treated mine drainage for livestock watering was assessed through spreadsheet modeling and a comprehensive literature review. Livestock reuse of treated mine water is a complex hypothetical informed by science, economics, ethics, and regulatory guidance; this theoretical review focused primarily on the scientific component. Treated mine water flow rates at the Mayer Ranch Passive Treatment System (MRPTS) were compared to the water demands of Ottawa County cattle populations. Water quality data were used to determine the contaminant concentrations to which cattle populations would be exposed and to investigate how cattle have responded to similar concentrations documented in the literature. The water quality constituents of interest included salinity, hardness, trace metals, and nutrients. Calves and milk cows were excluded from consideration due to their heightened sensitivities to elevated sulfate concentrations. The quantity of interest was the mean total of Ottawa County beef cows, steers, heifers, and bulls across 2017, 2018 and 2019 – estimated at 44386 head. Collective water demand of the chosen cattle population was estimated by month from an assumed average cattle shrunk bodyweight (479 kg) and a variety of environmental parameters. The MRPTS discharges treated mine water at a rate of approximately 1000 L/min; this flow exceeded daily water intake (WI) of Ottawa County beef cows, steers, heifers, and bulls from December through February, was approximately 400000 L less than average monthly WI, and represented 40% of peak WI in July.

The MRPTS treats most influent mine water constituents to well below the maximum contaminant levels (MCLs) for cattle drinking water. Ca, Mg, F- and Mn concentrations could pose direct toxicity risks in combination with high dietary intake (Ca, Mg), cause chronic fluorosis after long-term, low-dose exposure (F), or discourage drinking due to taste and odor (Mn). However, sulfate was the most concerning water quality constituent; the 2000 mg/L SO42- typically measured in MRPTS outflow could negatively impact livestock consumption patterns, productivity, metabolic processes, and neurological health. The livestock study determined that although the volume of mine water treated by MRPTS could satisfy a substantial portion of livestock drinking water demand in Ottawa County, sulfate levels in the discharge render the passively-treated mine water unsuitable for cattle consumption – particularly calves and pregnant cows. Unless tertiary treatment for sulfate removal was implemented, it is unlikely that ranchers in Ottawa County would consider transporting treated mine water from MRPTS to livestock operations when existing water sources presumably meet current demands.

If you are interested in learning more about the University of Oklahoma's Center for Restoration of Ecosystems and Watersheds (CREW), scan the QR code with your smartphone camera.

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THE ROLE OF ALGAL BIOMASS ON NUTRIENT AND METAL INTERACTIONS AT THE SEDIMENT-WATER INTERFACE

Zepei Tang and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

The objective of this research was to understand how algal blooms impact the nutrient and trace metal cycling processes at the sediment layer-water column interface in a large terminal reservoir, the Grand Lake o' the Cherokees, Oklahoma. The study site has elevated metals concentrations in the sediments from the upstream Tri-State Lead-Zinc Mining District and elevated nutrient concentrations in the water column from agricultural and urban run-off, resulting in eutrophication and substantial algal blooms. It was hypothesized that trace metal release from contaminated sediments to the water column would be driven by increased algal biomass growth.

A greenhouse microcosm study was designed with three different biomass treatments: control (no algae addition), low biomass (40 µg L-1 chlorophyll a) and high biomass (80 µg L-1) using lake sediment groundwater (as a control) and laboratory-incubated Microcystis aeruginosa, one of the dominant blue-green algae in this lake. After 30 days, each of the treatments showed changes in planktonic, attached and benthic chlorophyll-a concentrations, and dominant algal species, and species richness. Soluble reactive phosphorus (SRP) and nitrate nitrogen (NO3-N) in the water column showed decreasing trends over time, indicating nutrient uptake by biomass. Iron (Fe), nickel (Ni) and cadmium (Cd) concentrations in all water column samples were below the practical quantitation limit (PQL), while lead (Pb) and zinc (Zn) concentrations ranged from 0.015 to 0.05 mg L-1, due to residual contamination from the sediments. Compared to US EPA National Recommended Water Quality Criteria (NRWQC), Pb concentrations were below the Criteria Maximum Concentration (CMC) but above the Criterion Continuous Concentration (CCC), while Zn concentrations were below both CMC and CCC. At the end of the study, Pb, Zn and Cd concentrations in the sediment showed no significant changes in any treatment, but all treatments had trace metal concentrations above the freshwater sediment quality guideline (SQG) thresholds. However, concentrations were below the Tri-State Mining District (TSMD)-specific SQG thresholds.

The results showed that biomass changed nutrient balances between the water column and sediment layer but did not impact trace metal concentrations in the system. It is not likely that increased algal blooms in the lake would result in trace metal release from the contaminated sediments into the water column.

Collecting samples for analysis

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RECOVERED MINE DRAINAGE PASSIVE TREATMENT RESIDUALS ADDRESS RESERVOIR SEDIMENT NUTRIENT AND TRACE METAL POLLUTION: A FIELD MESOCOSM STUDY AT GRAND LAKE O' THE CHEROKEES, OKLAHOMA

Zepei Tang and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

Grand Lake o' the Cherokees, Oklahoma is a large multipurpose reservoir that receives both elevated metals concentrations from the upstream Tri-State Lead-Zinc Mining District (TSMD) and excess nutrients from its agricultural watershed along with significant internal phosphorus (P) legacy loads. Mine drainage residuals (MDRs), amorphous iron oxyhydroxides recovered from passive treatment systems, may serve as phosphorus sinks.

To evaluate the role of MDRs on reservoir sediment dynamics, a field mesocosm study (20-L vessels) was designed with four different mine drainage residuals (MDR) treatments: sediment control (no addition), mixed (MDR mixed with sediment), layered (MDR on top of sediment, no mixing) and bagged (MDR inside a fine mesh bag on top of sediment, no mixing) with phosphorus-spiked water. Soluble reactive P (SRP) and total P (TP) concentrations demonstrated decreasing trends and the control treatment showed greater concentrations than all MDR treatments. P adsorption capacity (PAC) was determined to be approximately 0.7 mg/g and >30 mg/g for sediments and MDR, respectively. At Day 135, both SRP and TP reached >99% removal for all four treatments. Aqueous lead and cadmium concentrations were below detection limits and zinc concentrations were below the National Recommended Water Quality Criteria. Sediment lead, zinc and cadmium concentrations were below the TSMD-specific sediment quality guidelines, except for final Mixed MDR treatment sediment with 16.7% of samples exceeding both Cd and Pb criteria.

Overall, in this study, MDR addition was shown to accelerate P removal from the water column and enhance the P sink in the sediment. Compared to control sediment, which had its original P adsorption capacity, MDR addition amendments increased the maximum P adsorption potential due to greater PAC of MDR materials. There was no detectable trace metal contamination in the water column throughout the four-month study time for all three different MDR addition treatments, and only limited sediment trace metal contamination in the mixed MDR treatment. The Bagged MDR addition treatment seemed to be the most effective option for future practice, due to its P-removal performance from the water column, lack of exceedances of the NRWQCs and TSMD-SQGs, and its clear separation from the sediment layer which allowed easy extraction from the system and least leakage potential to cause further contamination. Future studies are needed to examine performance of engineering designs for large-scale MDR amendments to eutrophic reservoirs, which could identify the most appropriate MDR to sediment ratio and amendment time to achieve greatest P removal. Other examinations could target the recycle and reuse of the P sorbed to the MDR as fertilizers for local pastures and farms to help establish a closed and renewable P cycling process between pasture and farm/run-off to reservoir water/P sink. In this way, best management practices suggestions could be provided for local authorities to improve the water quality of reservoirs and achieve the most efficient use of P in the watersheds.

University of Oklahoma

Zepei Tang and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

SEDIMENT DISTURBANCE EFFECTS ON NUTRIENTS AND METALS IN A RESERVOIR RECEIVING BOTH AGRICULTURAL RUNOFF AND HARD ROCK MINE DRAINAGE

A greenhouse microcosm study was completed to simulate nutrient/metal interactions at the sediment layer-water column interface in a large Oklahoma reservoir that receives untreated lead-zinc mine waters and agricultural runoff. To evaluate sediment disturbance influences, three different mixing treatments were established in nine 25-L vessels containing lake sediments and water: control (no mixing), low mixing (200 rpm) and high mixing (500 rpm), using overhead blade-stirrers. A two-hour mixing period produced significant ($p<0.05$) increases in total suspended solids, total phosphorus (P), iron (Fe), nickel (Ni) and zinc (Zn) in the water column, indicating nutrient and trace metal release due to mixing disturbance. During the subsequent 7-day settling period, water column total P, Fe, Ni and Zn concentrations decreased 54.8%, 98.9%, 57.7% and 89.4%, respectively, for the low mixing treatment and 96.7%, 98.7%, 92.1% and 99.0%, respectively for the high mixing treatment, indicating sediment redeposition, metal precipitation, and/or nutrient sorption. After 7 days, sediments showed decreased P and increased metal (Fe, Zn, Cd and Pb) concentrations compared to initial conditions. The growth of algal biomass may have affected P-metal binding, turning bioavailable P into non-bioavailable P and promoting metal sequestration to the sediments with biomass. All aqueous metal concentrations, when compared to US EPA National Recommended Water Quality Criteria, were below both Criteria Maximum Concentration and Criteria Continuous Concentration guidelines. Sediment metal concentrations were below the site-specific sediment quality guidelines (SQGs) both before and after mixing. Overall, resuspension caused by mixing and subsequent settling helps to release sediment P into the water column and precipitate aqueous trace metals to the sediment layer.

THE ROLE OF MINE DRAINAGE RESIDUAL ADDITION ON NUTRIENT AND TRACE METAL RELEASE IN MICROCOSMS WITH BIOMASS GROWTH AND DECAY

A greenhouse microcosm study investigated the impacts of recovered iron oxyhydroxide mine drainage residuals (MDRs) on phosphorous (P) and trace metal distribution at the sediment layer and water column interface. Each mesocosm included 5 kg of lake sediment and 20 L on-site groundwater. Three treatments were examined with triplicate: Control (C) with no addition; Low MDR (LM) with 0.3 kg MDR; High MDR (HM) with 0.9 kg MDR. During the first 10 days, soluble reactive phosphorous (SRP) and total phosphorous (TP) showed decreasing trends due to uptake by biomass with no significant differences among three treatments. After 75 days, biomass died in all three treatments, P concentrations went down in LM and HM treatments due to MDR sorption, while C treatments showed a P release from dead biomass death and decay. Therefore, MDR additions appeared to serve as a long-term internal P loading control method to prevent labile P release back into water column after algal bloom decay which could enhance potential future blooms. Comparing trace metal concentrations in the water column to the USEPA National Recommended Water Quality Criteria and National Secondary Drinking Water Standards, all samples were below both the hardness-adjusted acute and chronic criteria, except for Pb with regard to the chronic criterion, which showed limited concerns for trace metal release from MDR additions. Compared to site-specific Sediment Quality Guidelines (SQGs), all sediment samples were below Tri-State Mining District (TSMD) specific SQGs, indicating that there was no significant toxicity introduced to the sediment layer after MDR addition. Metal concentrations in MDRs, however, exceeded TSMD site-specific SQGs. Future studies may be conducted to look at designs for practical MDR addition practices.

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HORSE CREEK WATERSHED CHARACTERIZATION USING A PAIRED HABITAT ASSESSMENT AND REMOTE SENSING APPROACH

David M. Wilcox and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

Riparian habitat protection agreements along Horse Creek in the Grand Lake o' the Cherokees watershed have incorporated continuous monitoring efforts to document changes in water quality, water quantity, and habitat and vegetation changes. In agriculturally dominated watersheds such as the Horse Creek watershed, loss of riparian habitat has been identified as a major contributor to water quality degradation. A paired habitat assessment and remote sensing study is proposed, in accordance with current efforts, to supplement ongoing monitoring efforts within riparian easements.

Previous studies have monitored physicochemical water quality data on a monthly basis. However, no studies of in-stream or riparian biota have been conducted to determine if conservation efforts have had an impact on aquatic life. Evaluating the presence and quality of habitat is necessary to assess the ecological stability of stream systems. In-stream and riparian zone assessments are traditionally conducted by performing habitat assessments (HAs) and rapid bioassessment protocols (RBPs), which incorporate periphyton, benthic macroinvertebrate, and fish assemblage data. HAs and RBPs will be completed following the Oklahoma Conservation Commission standard operating procedures, which are based on the US EPA's "Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates, and Fish" (Barbour et al. 1999).

Completion of these assessments alongside the collection of biotic community assemblage data will occur in late spring and early fall 2021 to quantify the impact of riparian protection and compare results across time and to other reference streams. Riparian vegetation function classification is necessary because these ecosystems provide ecotones between terrestrial and aquatic ecosystems. Functional classification traditionally describes biota at the reach scale by conducting in-situ field surveys according to the "National Riparian Core Protocol: A Riparian Vegetation Monitoring Protocol for Wadeable Streams of the Coterminous United States" (United States Forest Service 2017) standard operating procedures. Remote sensing using a small Unoccupied Aerial System (sUAS) will be conducted by surveying stream reaches with high-definition multispectral imagery. Combining aerial imagery and in-situ field surveys will generate data useful for calculating vegetation recovery and extent.

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EVALUATING PASSIVE TREATMENT FEASIBILITY FOR MINE DRAINAGE DISCHARGES LOCATED WITHIN THE TAR CREEK SUPERFUND SITE

Nicholas L. Shepherd and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

Lead and zinc mining in the Picher Mining Field began in the early 1900s and ceased by the 1970s, resulting in hydraulically connected mine workings in two states (OK and KS) with a total void volume of approximately 9.9x107 m3 (80,000 ac-ft or 26,153,028,000 gallons). When the pumps which dewatered the underground workings were finally shut off, surface and ground waters slowly refilled the voids, and eventually discharged at numerous locations across the Picher Field. The underground water contains elevated concentrations of Cd, Fe, Pb, and Zn and is referred to as a mine pool. When the contaminated water from the mine pool discharges to the surface, it is referred to as mine drainage.

This study focused on discharges located near Douthat, OK, where the piezometric surface of the mine pool and the land surface topography have similar elevations, resulting in numerous seasonally variable and rainfall driven discharges from abandoned mine shafts and boreholes. The goal of this research is to better understand the hydraulics of the mine pool in order to design a treatment system to remove metals from the mine drainage. One treatment option is passive treatment. Passive treatment does not require the continuous addition of chemicals and high energy inputs like traditional treatment systems. Rather, passive treatment uses natural process and non-grid energy to remove the majority of the target metals in the mine drainage. Water quality and quantity data from these artesian discharges were analyzed in order to evaluate the passive treatment design feasibility to remediate contaminated mine drainage before it enters Tar Creek. Water quality data have been regularly collected since 2018, and v-notch weirs with pressure sensors were installed in early 2019 to collect near-continuous flow data at five locations (Figure 1).

The five sampled discharges at this site have variable yet elevated metals concentrations, with the metals of interest being Cd, Fe, Pb, and Zn. Similarly, flow rates greatly fluctuate at each of the discharges based on the water elevation of the mine pool, with combined measured flow rates ranging from approximately 600 to over 4,000 gallons per minute in 2019. In 2019, the average flow rate of these discharges was 2,300 gallons per minute, resulting in an annual metals loading of 72 kg Cd, 254 kg Pb, 25,400 kg Zn, and 108,000 kg Fe.

Understanding and managing these highly variable conditions and sealing open mine shafts that allow water to enter the mine workings (Figure 2) is imperative to designing and implementing any successful treatment system.

Water flowing into the mine workings through an abandoned mine shaft

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CONTINUED EVALUATION OF FULL-SCALE MINE WATER PASSIVE TREATMENT SYSTEMS IN THE TAR CREEK WATERSHED

Robert W. Nairn and CREW
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

Since the early 2000s, OU CREW faculty and staff have focused on development, implementation, and assessment of ecologically engineered passive treatment systems to address degraded water quality in the historic and derelict Tri-State Lead-Zinc Mining District (TSMD), which is wholly located with the Grand Lake o' the Cherokees watershed. Artesian flowing mine pool discharges are major contributors to elevated ecotoxic metals concentrations in local streams, specifically Tar Creek and its tributaries. In the mid-1980s, surface water impacts at the Tar Creek Superfund Site were deemed due to "irreversible man-made damages". With funding from state and federal sources, and in cooperation with local partners, two full-scale, multi-process unit, mine water passive treatment systems (PTS) were installed by OU CREW to address some of these waters, contaminated by elevated concentrations of iron (138-192 mg/L), zinc (6-11 mg/L), lead (60-81 µg/L), cadmium (17-20 µg/L) and arsenic (40-64 µg/L).

The Mayer Ranch PTS (since 2008) and Southeast Commerce PTS (since 2017) produce circumneutral pH, net alkaline effluents containing ecotoxic metals concentrations meeting in-stream water quality criteria. Each PTS includes multiple process units designed for specific biogeochemical functions. Iron is primarily retained via oxidative mechanisms in aerobic ponds and wetlands. Resulting iron oxyhydroxide solids retain trace metals (especially arsenic) via sorption. Primary lead, zinc and cadmium removal occurs in sulfate-reducing vertical flow bioreactors. Given the relatively flat landscape of the region, off-the-grid (solar- and wind-powered) aeration technologies increase oxidative iron removal rates and address nuisance constituents (biogenic sulfide and oxygen demand) produced by the bioreactors. Annually, MRPTS and SECPTS retain approximately 57,000 and 27,000 kg of iron, 3,300 and 2,200 kg of zinc, 18 and 12 kg of lead, 19 and 8 kg of arsenic, and 5 and 7 kg of cadmium, respectively. The receiving stream has demonstrated substantial water chemical composition improvement and ecological recovery, with documented increases in both fish species richness and abundance, as well as the return of other fauna. The continued evaluation of these projects is supported by the OU CREW/GRDA EEC partnership.

Aerial photo of Meyer Ranch in Commerce, OK. Captured by the OU-CREW sUAS.

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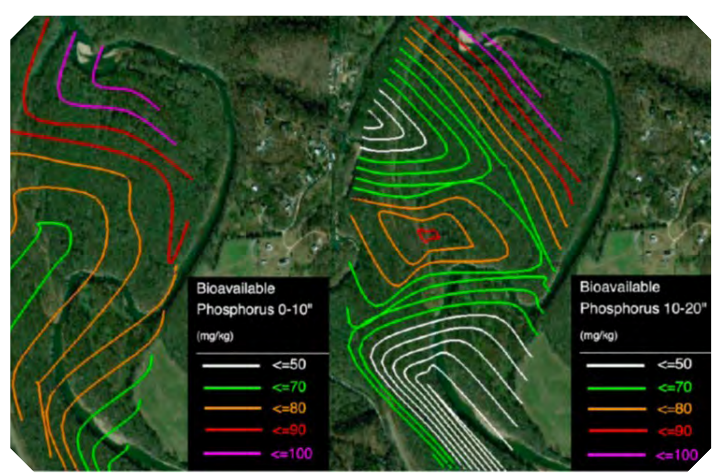
ASSESSMENT OF LAKE FRANCES WATER AND SEDIMENT QUALITY RELATED TO THE GRAND RIVER DAM AUTHORITY (GRDA) SCENIC RIVERS OPERATIONS RIPARIAN PROTECTION CONSERVATION EASEMENT PROGRAM

2019-2020 OU Environmental Science and Environmental Engineering Capstone Class
School of Civil Engineering and Environmental Science, University of Oklahoma

Students enrolled in the University of Oklahoma's Environmental Science and Environmental Engineering Senior Capstone Class conduct comprehensive analyses of open-ended, real-world environmental problems. In academic year 2019-2020, three student teams worked cooperatively with the staff of GRDA Scenic Rivers Operations (SRO) and Ecosystems and Education Center (EEC) to examine water and sediment quality near Lake Frances, an impoundment on the Illinois River near West Siloam Springs, Oklahoma. Teams completed Phase I and Phase II Environmental Site Assessments of an approximately 260-acre land parcel being considered for enrollment in GRDA's Riparian Protection Conservation Easement Program. The land was part of the former lakebed, on which the accumulated sediments have been naturally recolonized since partial failure of the lake dam 30 years ago. Student teams sampled water at six locations on the Illinois River and one location on Ballard Creek. Comprehensive aqueous analyses were conducted with an emphasis on nutrient, dissolved oxygen and bacteria concentrations. Student teams also sampled sediments at 12 locations in the Lake Francis former lakebed. These samples were thoroughly analyzed for physical and chemical parameters.

Overall, phosphorus concentrations in the aqueous phase were found to be elevated (exceeding the State Scenic Rivers criterion of 37 g/L) and correlated with suspended solids concentrations, indicating a possible link to erosion. Other nutrients and bacteria levels were found to be acceptable. In the sediments, phosphorus concentrations were found to be elevated and may serve as a source to the river. Concentrations of select metals indicate the need for further evaluation, although leachable metals concentrations were found to be well below regulatory criteria. The final written reports generated by the teams were substantial – 233, 269 and 485 pages in length, respectively. Due to COVID-19 pandemic restrictions, the teams orally presented to the project-specific Environmental Engineering and Science Advisory Board (EESAB) via videoconference. The EESAB included stakeholders from GRDA, the private sector, and local interests.

2020 OU Capstone Class



Bio-available Phosphorus

University of Oklahoma

TARGETED RESTORATION OF THE HORSE CREEK AND FLY CREEK WATERSHEDS OF GRAND LAKE O' THE CHEROKEES, OKLAHOMA

Fall 2020 OU Watershed Management and Restoration Class
School of Civil Engineering and Environmental Science, University of Oklahoma

This graduate-level class provides a comprehensive interdisciplinary examination of watershed assessment, management, planning, protection, and restoration. Processes governing drainage-basin scale physiography, hydrology, hydrogeomorphology, and ecology are examined, emphasizing water quality-driven approaches to watershed management and restoration, including development of watershed-based plans. Watershed restoration, incorporating terrestrial, riparian, and aquatic ecosystem approaches, is examined from a transdisciplinary perspective, including provision of ecosystem services and meeting of societal social and economic objectives. In fall semester 2020, two teams holistically examined the Horse Creek watershed, including the Little Horse Creek and Fly Creek sub-basins, following the U.S. Environmental Protection Agency (USEPA) watershed planning approach. Teams were asked to specifically focus on drivers of watershed water quality degradation. Generalized conclusions were reached regarding the relative importance of point source and nonpoint contributions, and teams were asked to specifically identify particular locations (pollution source areas, stream reaches, etc.) where interventions would provide the greatest benefit and specific watershed restoration interventions for these locations.

Both teams identified elevated nutrient concentrations as the primary drivers of harmful algae blooms in the Horse Creek arm of Grand Lake o' the Cherokees. Specific sources identified included the Afton wastewater treatment facility, poultry production operations (and associated litter management), cattle production operations (including direct stream access) and row crop agricultural encroachment on the streams. Structural and non-structural interventions to address water quality degradation included wetland restoration and preservation, water and sediment control basins, cattle exclusion fencing, eutrophic pond reclamation, riparian buffer restoration and management, in-stream rock riffles, improved wastewater treatment, increased soil testing, comprehensive hydrologic modeling, habitat assessments and agricultural and septic system outreach and education. Teams provided written reports and, due to COVID-19 pandemic restrictions, orally presented final recommendations via videoconference to GRDA staff.

Extremes of riparian condition along Little Horse Creek near E220 Road showing relatively intact riparian forest (right) and agricultural degraded riparian zones (left).

Employee Directory

Name:	Title:	Email:
Darrell Townsend	Vice President - Ecosystems	darrell.townsend@grda.com
Ed Fite	Vice President - SRO	edward.fite@grda.com
Jacklyn Jaggars	Director of Hydro Projects	jacklyn.jaggars@grda.com
Bob Harshaw	Historical Properties Manager	robert.harshaw@grda.com
Steve Nikolai	Water Quality Director	steve.nikolai@grda.com
William (Bill) Mausbach	Limnologist	william.mausbach@grda.com
Dustin Browning	Biologist II	dustin.browning@grda.com
Katherine Wollman	SRWRL Manager	katherine.wollman@grda.com
Courtney Stookey	Biologist I	courtney.stookey@grda.com
Scott Horton	Shoreline Enforcement	phillip.horton@grda.com
Kenny Baker	Compliance Officer	kenny.baker@grda.com
Janet Dellisanti	Permitting Official	janet.dellisanti@grda.com
Derrick Bidleman	Police Officer	derrick.bidleman@grda.com
Jacob Graham	Police Officer	jacob.graham@grda.com
Shane Johnston	Shoreline Technician II	shane.johnston@grda.com
Ira Gaylord	Shoreline Technician I	ira.gaylord@grda.com
Cory Bogle	Shoreline Technician I	cory.bogle@grda.com
Joel Barrow	GIS Specialist	joel.barrow@grda.com
Aaron Roper	Neosho Bottoms Director	aaron.roper@grda.com
Wyatt Speer	Natural Resources Technician I	wyatt.speer@grda.com
Jared Griffith	Natural Resources Technician I	jared.griffith@grda.com
Mike Bednar	Environmental Compliance Manager	mike.bednar@grda.com
Matt Conrad	Environmental Compliance Specialist	matthew.conrad@grda.com
Travis Hinshaw	Environmental Compliance Specialist	travis.hinshaw@grda.com
Nancy Sanchez	Senior Admin. Assistant	nancy.sanchez@grda.com
Suzi Allen-Daniels	Admin. Assistant	suzanna.allen@grda.com
Jeri Fleming	Outreach Contractor	jeri.r.fleming@gmail.com

Jeri Fleming, Bill Mausbach, Steve Nikolai, Kate Wollman, Dustin Browning, and Ed Fite surveying the Illinois river

Closing Thoughts

Although 2020 was a challenging year due to COVID-19, both the Ecosystems and Watershed Managment and Scenic Rivers Operations departments met the challenge head on with great **Efficiency**. Our water resources face challenges that do not stop due to a pandemic, which means we must be relentless in our **Environmental Stewardship** and research efforts even in the face of a global pandemic. These efforts have also allowed GRDA to continue to provide clean, low cost **Electricity** to its customers while also supporting sustainable **Economic Development** in the region of Northeast Oklahoma.

The research and projects that you have seen in the pages throughout this 2020 annual review demonstrate the commitment that **Employees** from both departments have made to continue to meet our water resource challenges head on. As we look back on the year 2020, we can see our many accomplishments, and continue to pursue environmental excellence as we move forward in the year 2021. Our water resources will continue to become one of our state and nations most valuable assets moving forward. It is our hope that through our work, and the work of our university partners, that many generations of future Oklahomans can continue to enjoy our water resources.

The team at GRDA will always remain committed to be good stewards of the natural resources under our control, and will continue to push the science forward with the help of the collaborations you see here.

Dr. Darrell Townsend
Vice President - ECO

Ed Fite
Vice President - SRO

If you have any questions about the ongoing cooperative research programs, visit our link on the GRDA website at www.grda.com or contact our offices at (918) 256-0723.

Sincerely,

Darrell Townsend and Ed Fite.

Ecosystems Explorations: 2020 Annual Review

EDITORS:
Justin Alberty
Dustin Browning

GRAPHIC DESIGN:
Page Layouts: Dustin Browning
Logos: GRDA Corporate Comms.

COVER CONCEPT:
Dustin Browning
Joel Barrow

REVIEWERS:
Melanie Earl
Jeri Fleming
Courtney Stookey

This publication was produced with input from the entire Ecosystems and Watershed Management and Scenic Rivers Operations teams. All maps are property of the GRDA GIS Department. All photos and student summaries have been submitted to GRDA via project updates, and are now authorized for use by GRDA.

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Ecosystems and Watershed Management
420 Highway 28
PO Box 70
Langley, Oklahoma
74350

Scenic Rivers Operations
15971 N. Highway 10
PO Box 292
Tahlequah, Oklahoma
74464 (Physical) , 74465 (PO Box)