SESSION 01 | Workforce Development Workshop

Owen Mills, Oklahoma Water Resources Board. A robust workforce is essential for water resources and the water resources industry will need to adapt to the changes in the workforce. The topical workshop is designed to invite an open dialog of different perspectives brought forward in the Workforce Panel regarding investment in Workforce strategies. The Workshop will briefly review takeaways from the earlier Workshop Panel session, covering the threat of an aging workforce and projecting few in line to replace them. And a workforce that holds new perspectives, desires, and expectations for job satisfaction.

The workshop is an extension of the Workforce Development Panel. The workshop will be a guided and open discussion of water resources workforce issues with the Workforce Development Panelists. Opinions will be strongly encouraged from students and new young professionals to garner new insights for everyone in the Workshop, from students to retirees. Information gathered will be reviewed to inform the development of an AWRA Water Resources Workforce Development Policy.

SESSION 02 | TOOL TIME! Water Data Improvements 1

Thomas Burley, US Geological Survey - USGS National Water Dashboard: Modern Water Data Delivery for the Next Decade. The USGS National Water Dashboard (NWD) is a mobile-friendly web tool that provides real-time information on water levels, weather, and flood forecasts in one interactive mapping application. Building on the USGS Texas Water Dashboard that was launched in early 2016, the NWD represents a progression for USGS water data delivery tools and serves an example of USGS data delivery for actionable intelligence. A national-scale web mapping application, the NWD serves decision makers, emergency managers, and the public with data and information for real-time streamflow, waterbody stage, precipitation, groundwater level, and water-quality data from more than 13,500 USGS observation sites across the country. This information is shown along with National Oceanic and Atmospheric Administration, National Weather Service weather data such as radar, watches and warnings, past precipitation totals, precipitation forecasts, and drought conditions from a variety of open water data sources. Hydrology layers such as rivers, watersheds, and aquifers can be displayed to add additional context to the map. To further enhance open water data delivery options, the NWD effort offers authoritative web services and tools to enable users to display USGS water data in their organization's applications and dashboards.

Allison Odell, US Bureau of Reclamation - RISE: A Data Portal for the Bureau of Reclamation's Water and Related Data. Since 2015, the Bureau of Reclamation has been working to make its water, hydropower, and related data available in open, machine-readable, standardized formats. In 2020 Reclamation launched the Reclamation Information Sharing Environment (RISE, https://data.usbr.gov), which provides open access to Reclamation datasets in a variety of formats. Data subjects include reservoir conditions, water delivery, hydropower generation, invasive species, threatened or endangered species, habitat conditions, water quality, and other mission-related topics. Data types include observed and modeled time series data, geographic information, reports, models and analytical products, and more. The RISE system consists of a data catalog, time-series query interface, map interface, public application programming interface (API), other public website components, an internal data and content administration interface, and underlying databases and APIs. RISE also provides public hosting for data visualization and analysis applications developed by Reclamation programs and offices. This presentation will highlight the features and data offerings of RISE, as well as describe some of the features that are under development, including improvements to time series plotting, improvements to web services, and location landing pages that include Geoconnex permanent identifiers and metadata for integration with the Internet of Water through references to the National Hydrography Dataset.

Adel Abdallah, Western States Water Council - Demo: The Western States Water Data Access and Analysis Tool (WestDAAT) Access to water rights data in a watershed spanning multiple western states is cumbersome due to different access protocols, structures, and terminology to describe data. Such regional data access and analysis are increasingly important due to the unprecedented drought and growth that the western U.S. is experiencing.

The Western States Water Council launched the Water Data Exchange (WaDE) Program ten years ago by working with its eighteen member states as a data hub to provide web services with streamlined access to water rights and water use data. The WaDE Data System is built using an agreed-upon data dictionary and schema that reconciles syntactic (e.g., structural) differences. It addresses semantic differences through a shared controlled vocabulary adopted by participating data providers.

This talk will demonstrate the new Western States Water Data Access and Analysis Tool (WestDAAT), which provides a wide range of interactive data queries and analyses for water rights across the Western U.S. The live demo will narrate how the tool is designed to

support a range of users, from a farmer, and river basin manager, to the governor level. The demo will also show how users can query upstream or downstream water rights and data from other national water data services such as the U.S. Geological Survey (USGS) stream gages and the Environmental Protection Agency's (EPA) water quality data services.

The western states have fully appropriated their water resources, and future demand shortages due to extended droughts and demand growth have the potential to expand water rights markets and transfers. Centralized and consistent access to water rights data in the west can facilitate this process and increase its transparency.

SESSION 03 | Stormwater

Scott Kindred, Kindred Hydro Inc. - Advances in Infiltration Testing for Stormwater Management. This presentation summarizes the results of an infiltration study to develop improved methods for measuring bulk hydraulic conductivity (Kb) in the vadose zone and using that information to estimate the capacity of stormwater infiltration facilities. Numerical simulations were conducted to evaluate falling-head and steady-state borehole permeameter methods. Fitting parameters were developed for both cased and uncased steady-state methods that provided accurate estimates of saturated hydraulic conductivity (Ks) for uniform, isotropic soils. The falling-head method assumes instantaneous filling of the test well, which is not feasible in the field. Given the limitations of actual field testing, the falling-head method was reasonably accurate for soils with Ks < 0.5 m/d (6 x 10-4 cm/s) and small test wells (borehole radius < 10 cm and sandpack length < 1 m).

Shallow infiltration testing was conducted at four sites, with two test pits and three shallow test wells at each site. This testing demonstrated a high degree of Kb variability over distances of 5 to 20 m. Estimates of Kb based on shallow well tests tend to be higher than estimates based on test pits, likely due to stratigraphic layering and differences in flow dynamics. Deep infiltration testing was conducted in eight deep test wells with total depths ranging from 6 to 27 m. This testing demonstrated the need for a drop casing that delivers the water below the water level to eliminate air entrainment during high flowrate borehole tests and in production drywells. In addition, test wells drilled using hollow stem auger methods are prone to clogging and may not provide accurate results.

Numerical simulations were conducted to determine the effects of stratigraphic layering and groundwater mounding and to evaluate the field testing results. These simulations demonstrate that six-hour steady state tests can effectively capture the effects of perching layers and shallow groundwater for most infiltration facilities and groundwater mounding analyses are only necessary for larger infiltration facilities. However, moving the test interval up or down in relationship to perching layers can dramatically affect the estimated Kb. Therefore, it is important that infiltration test intervals mimic the proposed infiltration facility to the extent feasible.

This study will produce an infiltration guide that may affect the recommended testing methods for Washington State.

Richard Martin, Richard Martin Groundwater LLC. - The Use of Mounding Analyses for Design of Infiltration Facilities. Mounding analyses are typically used to evaluate the rise in the water table as a result of infiltrating water from a stormwater facility. Often the mounding analysis is a regulatory requirement to confirm that the groundwater mound does not rise to the base of an infiltration facility and reduce facility performance. They can also be required to confirm that the groundwater mound does not impact other adjacent facilities or subsurface structures.

An alternative use of a mounding analysis is to support design of infiltration facilities. Three cases studies are presented to demonstrate the benefits of performing mounding analyses during design as opposed to being performed as a regulatory requirement to confirm facility performance. In two cases, the mounding analyses were used to size and locate infiltration facilities. For the third case, steep slopes are located downgradient of the proposed infiltration facilities and the mounding analysis was used to evaluate a "worst-case" scenario prior to determining the actual number and location of the facilities.

Kathryn Thomason, Old Castle Infrastructure - Using Drywells for Deep Infiltration. Many different solutions can and should be used to meet stormwater volume reduction goals, but have you considered deep infiltration? This presentation will focus on how deep infiltration can provide a solution for stormwater management and for public projects, reduce costly infrastructure upgrades. During the presentation I will:

- Identify where deep infiltration is a preferred solution based on WA geology, groundwater elevations, and Ecology's regulations.
- Evaluate the benefits of reducing stormwater volume using deep infiltration.
- Discuss deep infiltration construction methods and how deep drywells can be installed quickly in areas like existing roadways.
- Review several case studies where deep infiltration was used to manage stormwater in the Northwest.

Roy Jensen, Haley & Aldrich Inc. - Is Uncertainty Analysis Useful in Assessing Storm Water Infiltration Mounding Forecasts? Uncertainty analysis is considered good practice for evaluating the output of groundwater models. Groundwater flow models are used for mounding analysis to forecast the height and extent of the groundwater mound that will develop below a storm water infiltration facility from runoff generated during storm events. Because destructive flooding may occur if the mound intersects with the infiltration facility, it is important to understand the limitations of forecasts generated during mounding analysis. The utility of uncertainty analysis for evaluating groundwater model output during mounding analysis is illustrated with various case studies.

Mounding analysis can be performed using an analytical solution or numerical groundwater flow models. Using a numerical groundwater flow code, such as MODFLOW, is preferred because they are more versatile and allow the maximum flexibility in model construction consistent with the available data. The complexity of the model construction can vary from simple uncalibrate interpretive models to complex fully calibrated models. Because supporting field data is usually very limited, mounding analysis is most often performed using simple uncalibrated groundwater models.

Uncertainty analysis may not be useful for evaluating simple models with a limited number of parameters. Data available for model development maybe limited to a few parameters. Of these, some are potentially fixed or part of the system design, such as water table elevations, infiltration rates, and facility location, size, and storm water inflow hydrographs. Aquifer variables, such as hydraulic conductivity and storage value, are available for uncertainty analysis but are often inferred from limited field testing or from literature values. Model design parameters, such as layer thickness, number of layers, and boundary conditions are simplifications required in model construction and thus may not be suitable for uncertainty analysis. Because of the few options for parameterization, stochastic analysis may not be a useful assessment tool. In general, uncertainty analysis has limited utility in forecasting risk associated with mounding. If uncertainty analysis is undertaken, the benefits and limitations of uncertainty analysis should be clearly communicated in a way that stakeholders can understand.

SESSION 04 | Fish Passage Barrier Removal

Henry Hu, Washington State Department of Transportation - US 2/Sexton Creek Fish Barrier Removal and River Restoration – A Case Study & Washington State Department of Transportation Fish Passage Program. In 2013, a federal court injunction required Washington State to correct complete or partial fish barriers in Western Washington by removing state owned culverts that block access to spawning and rearing habitat for salmon and steelhead by 2030. As a result of the injunction, the Washington State Department of Transportation (WSDOT) is working to remove over 800 fish passage barriers at state highways by replacing existing culverts that act as barriers to fish passage with new crossings that restore access to habitat to aid in the protection and restoration of fish populations.

In this presentation, we use the US Highway 2 and Sexton Road crossings at Sexton Creek in Snohomish County, Washington as a case study to illustrate WSDOT's fish passage preliminary hydraulic design processes and methodology. The existing crossing at Sexton Road is listed as a partial barrier to fish passage due to the fishway constructed downstream of Sexton Road. We will present the multi-disciplinary, interagency approach used to design stream alignment, bed and structure openings, and channel complexity that allow fish passage and improve habitat. We will also present how the hydraulic design process addresses natural channel functions, constraints, opportunities, and risks associated with flood risk, potential channel aggradation or degradation, lateral migration, stream restoration, infrastructure safety, and climate resilience.

Tricia Gross, HNTB Corporation - Environmental Strategies for Successful Fish Passage Projects. Environmental review and permitting are critical to the success of any fish passage project. With multiple agencies, a variety of regulatory triggers, and diverse requirements, the environmental process can seem daunting. However, several key strategies can be used to ensure your fish passage project, whether stand-alone or part of a larger project, gets through the environmental review process smoothly and efficiently.

Including the environmental team during project planning and development sets the stage for interdisciplinary coordination, which is a key strategy for success. This allows the environmental team to review environmental information and get boots on the ground alongside the design team to evaluate site-specific conditions, identify sensitive resources, and consider potential permitting requirements. Such coordination helps to develop a shared understanding of design constraints and environmental considerations, leading to designs that minimize the risk of permitting delays or project redesign.

Designing fish passage projects that qualify for available streamlined permitting processes can help save time and permitting fees during a project. Washington Department of Fish and Wildlife's Fish Habitat Enhancement Program (FHEP) is one such process that may allow qualified fish passage projects designed with the sole purpose of fish habitat enhancement to bypass State Environmental

Policy Act (SEPA) processes, waive the need for local government permits and fees, and reduce timeframes for agency reviews.

Early, frequent, and clear communication with regulatory agencies, tribes, and other project partners helps to avoid costly and time-consuming surprises. Implementing a thorough communication strategy is of utmost importance in navigating environmental reviews, beginning during project planning and design, and continuing through construction. This coordination with permitting agencies lets them know what to expect from the project application which supports efficient reviews and timely permit issuance.

This presentation will expand upon the strategies described above and include additional environmental approaches for successful fish passage projects.

SESSION 05 | Policy, Planning & Legal 1

Adekunle Ojo, San Bernardino Valley Municipal Water District - Watershed Connect: Achieving Resilience Through Integrated Infrastructure. In Southern California, water issues and water supply reliability are top of mind for retail water providers, cities, and wholesale water providers, like the San Bernardino Valley Municipal Water District. In 2021, the San Bernardino Valley Municipal Water District (Valley District) took the bold step to develop WATERSHED CONNECT, a regional infrastructure program. WATERSHED CONNECT is a network of forward-looking projects designed to achieve water supply reliability, climate resilience, and long-term ecological health of the Upper Santa Ana River Watershed, in western San Bernardino County, California.

WATERSHED CONNECT is a multiphase program comprised of interconnected water capture, recharge, storage, treatment, and conveyance projects. This package of projects will collectively maximize the use and reuse of local water resources, while attaining a healthy, functional river ecosystem that supports 22 federally and state-protected species. WATERSHED CONNECT's innovative approach maximizes program value and offers synergistic benefits to the watershed and its people.

The Upper Santa Ana River Watershed Infrastructure Financing Authority was established as a Joint Powers Authority comprised of Valley District, San Bernardino Valley Water Conservation District, Western Municipal Water District, entities of Western Municipal Water District, City of Colton, City of San Bernardino Municipal Water Department, Big Bear Area Regional Wastewater Agency, and the Yucaipa Valley Water District. The participants, all of whom rely upon the highly connected tributaries, groundwater basins, and natural ecosystems of the Santa Ana River, have come together as stewards of the watershed to ensure funding is available to secure a reliable and sustainable water future for nearly 1 million people in San Bernardino and Riverside Counties.

The program reflects the region's long-standing commitment to integrated water resource management. Through multiple plans and efforts, water agencies in the Upper Santa Ana River Watershed continue to collaborate across traditional boundaries to build much needed water infrastructure, create and support jobs and the local economy, care for shared resources and accomplish a common goal; a secure, equitable, and reliable water supply for the region.

Salam Murtada, American Institute of Hydrology - Certifying the Practice of Hydrology in the US and Abroad. Our growing environmental challenges related to climate change, conservation efforts, flood management, water quality, urban growth and related impacts to natural resources underscores the need to adopt a national standard for practicing hydrology. As a result, the American Institute of Hydrology (AIH) was established in Minnesota on March 3, 1981, to promote hydrology scientifically and professionally and to protect it from non-professional and irresponsible practices. Forty years later, AIH includes more than 400 mostly fully certified professional hydrologist, hailing from the U.S., Canada, Mexico, and the U.K.In addition to establishing standards and procedures for certifying professional hydrologists in surface water, groundwater, and water quality, AIH certifies hydrologic technicians practicing in the field. AIH was also established to uphold ethical standards to protect the public, to deliver education and training, and to provide related advice and guidance to the public and government. However, there is more work to do and big challenges to meet. In this presentation, we will provide an overview of AIH: its mission, history and accomplishments. We will also discuss the results of our efforts to reach out to various professional organizations, academic institutions, and water resources professionals throughout the U.S. and beyond.

Caitlin Cavanagh, AECOM - Building Resiliency Beyond Borders: Leveraging Green Infrastructure Best Practices from Around the Country. The need to build climate resilient infrastructure grows each year as the intensity and frequency of extreme weather events increases. Government and regulatory agencies understand how crucial investments in stormwater management are to ensuring a future with healthy communities and functional local economies. However, planning large-scale improvements in complex geographies can be difficult and costly. Finding design approaches that work can also be a challenge when state regulations and even nomenclature differ from region to region. At the same time, engineers, scientists, and other technical professionals are always innovating and developing new solutions in stormwater management. Designers need to be able to pull industry knowledge from multiple sources to offer the most efficient solutions for their projects and clients. The Rebuild by Design Meadowlands (RBDM) project in northern New Jersey provided a unique opportunity for design teams, local residents, state agencies, and reviewers to collaborate to reduce flood risk, cultivate local ecologies, and energize communities impacted by Hurricane Sandy.

The RBDM Project Area is urban, low-lying, and built on top of a high groundwater table. Many typical best management practices (BMPs) in the state design manual would not be feasible. NJDEP officials were made aware of the standard BMP limitations and were open to accepting alternative designs that were in line with the project goals while still taking budget and local maintenance concerns into account. In researching cost-effective, technically feasible solutions, the team looked to different cities and states around the country. New Jersey, New York City, Philadelphia, Massachusetts, West Virginia, and even New Orleans green infrastructure and stormwater management design approaches were all evaluated. The collaborative nature of the project team was key in creating alternative design options for RBDM. Our communities may not be able to afford the "Do Nothing" approach as the climate continues to change.

SESSION 06 | Agriculture

Amr Safwat, APTIM/US-EPA - Comparing Agricultural BMP Effectiveness Simulations that Incorporate ACPF Results in the Upper East Fork Watershed SWAT Model. The Soil and Water Assessment Tool (SWAT) is a commonly used model for simulating nutrient fate and transport processes and the effects of agricultural BMPs (agBMPs) at larger spatial scales required for watershed management. In an existing SWAT model of the Upper East Fork of the Little Miami River Watershed (UEFW) in Southwestern Ohio, original simulations of agBMPs were modeled without consideration of their on-the-ground placement. These simulations used simplified assumptions such as assigning a wetland or other structural agBMPs to each subwatershed so that the location and size ensured runoff ran through all row crops area. The Agricultural Conservation Planning Framework (ACPF) tool provides an alternative to this simplifying approach. ACPF assesses agricultural landscapes for agBMP placement opportunities based on landscape geophysical properties. The results of ACPF analysis was applied and implemented in the SWAT model with the purpose of simulating more realistic agBMP placement scenarios. Five ACPF were configured, namely Nutrient Removal Wetlands (NRW), Grassed Waterways (GW), Contour Buffer Strips (CBS), Farm Ponds (Pond), and Water and Sediment Control Basins and Bioretention (WASCOB) and a combined scenario of all five practices. The reduction efficiencies at the watershed scale from the original simulation for each BMP type were 4.1, 2.4, and 4.3 times higher for Total Nitrogen (TN) and 6.6, 2.8, and 7.4 times higher for Total Phosphorus (TP) compared to the ACPF simulations for NRW, GW, and CBS, respectively. For the combined ACPF which included new BMP (WASCOB and Ponds) the TN and a TP median annual load reductions at the watershed scale were 3.3 lbs and 1 lbs per row crop acre, respectively. The median annual load reductions from the original simulations for CBS, GW and NRW at the watershed scale were 1.98, 2.05, 7.87 lbs and for TN and 1.26,1.31, 1.25 lbs for TN and TP, respectively. Overall, these results suggests that the original agBMP simulation was overly optimistic for the implementation of agBMPs to treat excess nutrients in runoff. The integration of the ACPF analysis with SWAT provides a more rational and spatially realistic means of estimating structural agBMP nutrient reduction opportunity in agricultural watersheds.

James Begley, Jupiter Environmental Research and Field Studies Academy - Quantification of Flunixin Meglumine and Nitrate Pollution In Cattle Ponds and Swales of South Florida. Anti-inflammatory drugs such as ibuprofen are known to be administered to cattle in the form of flunixin meglumine (FM). These NSAIDs do not completely metabolize and, if not housed in the muscle of the bovine (Zhao-Ying et al., 2014), they are excreted via urine and fecal matter (EMEA, 1999) to surface waters via run-off. Additionally, approximately 4% of all doses do not metabolize at all while other degradation products may potentially be toxic (Mulkiewicz et al., 2021). One pharmacological company acknowledges this toxicity as Merck (2021) states that, in excess, flunixin may cause bioaccumulation in fish as well as adverse effects in users: blood intoxication, damage to the kidney, the liver, and the gastrointestinal tract.

Florida houses 2.5 % of the country's cattle industry, boasting more than a million head of cattle and an additional 116 thousand dairy cows (USDA NASS, 2020). Okeechobee County is said to have 65% of its land dedicated to pastureland (USDA NASS, 2020) and is located in one of the largest watersheds in Florida, the KOE (Kissimmee River, Lake Okeechobee, Everglades). Downstream from the KOE, water sources in Okeechobee, Lee, and Palm Beach Counties have had dangerous algal effects from excess nutrient loading (Steinman & Conklin, 2003). Flunixin meglumine found in surface waters indicate that fecal matter from the cattle industry may also be affecting plumes.

Within the KOE watershed, surface water grab samples were collected using a Van Dorn water column sampler housed in 500 mL Nalgene bottles, placed in a cooler till it could be stored in a 4°C freezer and then transported to Florida Atlantic University Biochemistry BSL II Laboratory for analysis using a NeoGen Elisa Assay. Preliminary analysis for nitrates was determined using a Vernier nitrate probe. Once quantified that fecal matter was indeed present, said samples were used for flunixin determination. Results indicate there was indeed presence of FM. Aside from potential algal effects, Zhao-Ying (2014) concluded that even in trace amounts, the substance was toxic to the kidneys, the liver, the muscle, and the fat in animal tissues. Future investigations should involve testing local agricultural flora for FM systemic uptake.

Pierce McClendon, Auburn University - Irrigation Over the Internet: An Analysis of Three Irrigation Decision Support Systems in Alabama. In the United States, irrigation technologies are seeing consistent increases in adoption, with much of this growth occurring in the Southeast. With the implementation of these new practices, many farmers are seeking irrigation scheduling tools to

increase the efficacy of their irrigation systems. In order to build a greater understanding of the of commercially available irrigation decision support systems (IDSSs), several test plots were established throughout Alabama to assess the behavior and performance of three IDSSs – FieldNET Advisor, a crop evapotranspiration model, and a soil moisture sensor-based model. As these systems were monitored during the growing season, farmers were also encouraged to take part in the testing of each IDSS so that these finding may be shared with other local farmers on a peer-to-peer basis.

SESSION 07 | Yakima Basin 1

Wendy Christensen, United States Bureau of Reclamation; Tom Tebb, Washington State Department of Ecology Office of Columbia River; Phil Rigdon, Yakama Nation; Urban Eberhart, Kittitas Reclamation District; Mike Livingston, Washington Department of Fish and Wildlife; Lisa Pelly, Trout Unlimited - Yakima Basin Integrated Plan: Keeping our Stride through Implementation. A coalition of diverse interests came together in 2009 and created a nationally-recognized resource management framework around water management and aquatic habitat restoration for the Yakima River Basin. Now in implementation mode, the Yakima Basin Integrated Plan partners continue to engage challenges in delivering on their ambitious goals. A panel of YBIP partners will discuss how they work together through implementation-phase issues. Challenges include adaptive management as new urgent issues are learned and/or new projects identified, succession planning to keep the coalition strong, and funding and capacity acquisition to scale up work to meet the 30+ year implementation schedule. Partners must also remain focused and aligned to build the more controversial elements of YBIP. Collaborative watershed management is key to attaining vibrant, resilient watersheds, and YBIP partners want to share the essential knowledge and perspectives they have gained through being part of YBIP.

SESSION 08 | TOOL TIME! Water Data Improvements 2

Stacy Timmons, New Mexico Bureau of Geology and Mineral Resources - Water Data Tool Evaluation and Development Process for the Pecos Valley Region in New Mexico. The groundwater resources around Roswell, New Mexico, are largely used for irrigation. This region, with a dynamic artesian aquifer overlain by an alluvial aquifer, and traversed by the Pecos River – provides an opportunity to explore the usability of newly opened water datasets for water management and decision making. Working with local partners at the Pecos Valley Artesian Conservancy District (PVACD), a pilot project with the New Mexico Bureau of Geology is underway, as part of a U.S. Bureau of Reclamation WaterSMART grant. Following enactment of the New Mexico Water Data Act of 2019, state agencies and technical experts in the state are working to improve how water data is shared and integrated. While working on a statewide effort, this pilot project directs focus on one region to develop specific user tools. Stakeholder input suggests a dashboard platform is preferred with ability to evaluate water availability and groundwater-surface water interactions as top concerns. We conducted an initial dashboard demonstration in 2022, which provided invaluable feedback about the tools actually needed to address different end-user goals. Through in-person workshops, we discovered that the range of usability and data access preferences are highly dependent on the user's needs. Next steps for this project will include refining a dashboard for viewing long-term groundwater changes and trends, in addition to establishing a portal for streamlined access to new or real-time data for quick download. As water challenges and water shortages increase, having accessible water data can inform water management decisions. Through this project, we are working to build stakeholder engagement early and often and utilize open source data solutions where possible in hopes that this pilot project results can be reused in other regions of New Mexico or the western U.S.

Lauren Patterson, Nicholas Institute at Duke University - Water Supply Dashboard. The North Carolina General Statute 143-355 passed in 2005 following extreme drought conditions throughout much of the state and requires the state to maintain climatological and water resource records as a source of public information. The Statute also requires local community water systems (CWS) to report their conservation status and use on a weekly basis when their county is designated as Extreme or Exceptional drought conditions. The North Carolina Department of Environmental Quality (DEQ), North Carolina State Climate Office, and several local community water systems partnered with us to develop (1) a process for receiving local CWS demand and conservation status data and (2) a dashboard to view all climate and water supply data at a single location. The process for obtaining local data had to be flexible to allow for a variety of technical abilities and standardized to allow the data to be converted into a flexible API format to be pulled into the dashboard. The data in the dashboard are updated weekly, pulling together over a dozen datasets from six federal agencies, three state agencies, and participating utilities. The dashboard is designed to help the public identify their water provider, current conservation status, and allowed activities. Second, the dashboard is designed to allow utilities to quickly assess and display to their decision-makers (a) regional water supply conditions compared to normal for that time of year, (b) how demand is changing for interconnected utilities, and (c) short-term forecasts. The dashboard was developed in partnership with stakeholders and assessed with partners over several months to ensure the design is usable and meets their needs. The dashboard is currently in its final development at the State Climate Office, which is partnering with DEQ to maintain the dashboard over the long-term. Additionally, partners in Boerne, TX are adopting and adapting the dashboard for their municipality.

Nicholas Taylor, University of Florida - Using Data Analytics to Improve Water Conservation Efforts. H2OSAV: Water Savings, Analytics, & Verification is a University of Florida IFAS Extension program that works with utilities, government agencies and land development professionals to measurably reduce water use. This presentation will cover our data management approach, and the

suite of open-source software that we use to create and deliver our tools. We will discuss lessons learned, key takeaways and next steps in helping to advance water conservation in Florida.

Addie Navarro, Nicholas Institute at Duke University - Boundary Sync: A Service Boundary Digitization and Update Tool for Water Utilities. Boundary Sync is an open-source, free technology to enable water and wastewater utilities to create and maintain digital service area boundaries. The Water Policy Program at Duke University is piloting this tool in North Carolina through a collaborative project with the NC Rural Water Association, and funded by the Water Resources Research Institute at North Carolina State University. This presentation will include a demonstration of the Boundary Sync tool as well as information on tool development and stakeholder engagement. The presentation will also discuss next steps and potential uses for the Boundary Sync technologies for applications outside of water utilities.

SESSION 09 | Sewer and Stormwater 1

Chi Ho Sham, Eastern Research Group - AWWA Stormwater Management Standard: A Tool to Support Utility Operations. Water utilities strive to have a well-run water system that protects public health. With the ever-increasing complexity of water resources management and environmental protection issues, water utilities must tackle various challenges in the management and operation of their source water and infrastructure. As stormwater becomes more important for water professionals to understand and manage, in 2016, American Water Works Association (AWWA)'s Standards Council authorized the development of a new Utility Management Standard or G-series Standard, namely Stormwater Management for Water Utility. A committee was formed and has been working on the standard. The standard has recently been completed and approved by the Board of Directors of AWWA. This first edition of Stormwater Management Standard targets drinking water utilities and addresses the following issues: water quality, water quantity, design, operation and maintenance, emergency preparedness and response, and public outreach and communication. Because AWWA standards must undergo review and affirmation every five years per American National Standard Institute (ANSI) requirements, additional target audiences will be included in future editions of this standard. The purpose of this paper is to present the development process of AWWA Standards and the content of the new Stormwater Management Standard and open up discussions with conference participants regarding effective mechanisms to implement the Stormwater Management Standard for self-assessment, counsel, and assistance at the water utility level and beyond.

Zeda Yin & Arturo Leon, Florida International University - Towards Minimizing Sewer Overflows by Using Machine Learning. A combined sewer system (CSS) collects rainwater runoff, domestic sewage, and industrial wastewater in the same pipe. The volume of wastewater can sometimes exceed the system capacity during heavy rainfall events. When this occurs, untreated stormwater and wastewater discharge directly to nearby streams, rivers, and other water bodies (e.g., sewer overflows). This would threaten public health and the environment, contributing to drinking water contamination and other concerns. Minimizing sewer overflows require an optimization method that results in an optimal sequence of decision variables at control gates. Conventional strategies use classical optimization algorithms, such as Genetic algorithms and Pattern search, to find the optimal sequence of decision variables. However, these conventional frameworks are very time-consuming and it is almost impossible to achieve near real-time optimal control. This paper presents a new optimal decision tool using a two-stage fully deep learning strategy. In the first stage, we develop a surrogate time series forecasting deep learning model to predict water stage, overflow location, and volume for a fixed position of the controlled gates. The training dataset is hybdrid consisting of historical data and numerical simulations. In the second stage, we use reinforcement learning to create a sequence of input "policy" that is fed into the first stage model. The reward function is constructed based on the output of surrogated time series forecasting deep learning model. The process keeps minimizing the reward function to obtain the optimal flow release sequence at each control gate. The combined sewer system (CSS) of the Puritan-Fenkell 7-mile Facility in Detroit, MI, is chosen as the case study.

Pratik Mahyawansi, Florida International University - Numerical Modeling of Two Retrofitting Techniques to Mitigate Geysers in Sewer Systems. Geysers in stormsewer systems occur due to the uncontrolled release of trapped air at dropshaft locations. In this study, a transient three-dimensional (3D) computational fluid dynamics (CFD) model was used to evaluate the effectiveness of two potential retrofitting techniques to mitigate geysers. These strategies are: 1) adding a sloped bypass conduit adjacent to the dropshaft combined with an orifice plate, and 2) increasing the diameter of a section of the dropshaft. The objective of the proposed retrofitting techniques is to avoid initial water spills in dropshafts to preclude their rapid depressurization, which was found to be the initial mechanism for starting the geysering process. The CompressibleInterFoam (CIF) solver of OpenFOAM is used in the geyser simulations due to its suitability for modeling two compressible and immiscible fluids. The results show that the proposed methods allow smooth air release at the dropshaft and prevent rapid depressurization and geysering.

SESSION 10 | Research to Application

Richard Koehler, Visual Data Analytics LLC. - A Sequence-based Approach to Quantifying Streamflow Metrics – Part 1 and Theory & a Sequence-based Approach to Quantifying Streamflow Metrics – Part 2 Application. Presented is an innovative approach using autocorrelation lag (1) plots and sequence summations to quantify the streamflow properties of magnitude, frequency, duration, timing, and rate of change. The resulting products are a combination of visualizations and tables providing streamflow information

across all flow levels and address a fundamental hydrologic property – the temporal configuration of streamflow. A significant benefit is that the single change-in-flow graphic represents multiple streamflow attributes so a person can, at a glance, see patterns and trends within the data and easily make comparisons.

Regional case studies are presented to show the utility of this technique in different riverine environments and includes the following:

1. Merced River at Happy Isles Bridge, near Yosemite, CA
2. Colorado River at Lees Ferry, AZ
3. Red River of the North at Fargo, ND
4. Swift River at West Ware, MA

Jan Kwiatkowski, DHI - The Increasing Importance of Operational Decision Support Systems in Solving Water Management Challenges. As water shortages emerge in many parts of the globe, providing sufficient water resources for human consumption, agriculture and industry is becoming an increasingly difficult challenge. This challenge is exacerbated by changing climatic conditions as well as the inherent complexity of large river basins with controlled and uncontrolled flows, fluctuating water levels and inundation areas, interaction of surface water and groundwater systems, diversions, abstractions, and pollution. The latter, pronounced as increasing demand and anthropogenic pressure on water systems, is not making the challenge any easier. Some aid can however be offered to water managers thanks to the development of technology within monitoring, data transfer and processing, mathematical modeling, optimization techniques, model predictive controls, workflows and visualization. All these contribute to modern operational decision support systems for water efficiency optimization, which have been evolving over the last decades. Key learnings driven from several examples of such systems from Australia, Asia and Europe will be discussed with the emphasis on the practical advantages to water management outcomes, and potential near-future developments.

Nick Martin, Southwest Research Institute - 3D Visualization of Groundwater Model Hydrostratigraphy in (and beyond) GIS. Three-dimensional (3D) visualizations of subsurface conceptualizations and groundwater model simulation results provide an invaluable resource for interpretation and understanding of complex subsurface flow and transport environments. A mesh-based, groundwater computer model provides a readily available starting point for development of 3D visual objects that communicate the conceptual understanding of structurally and stratigraphically complex environments. The fundamental issue with visualization of 3D groundwater models is the large number of mesh cells or volumes needed to discretize subregions of a complex conceptual model to meet numerical stability and accuracy considerations. This issue can be circumvented for visualization by aggregating model cells, by structure or unit, into larger volumetric representations that are amenable to manipulation in a variety of open- and closed-source GIS, visualization , and animation tools. Several open-source tools and format specifications exist for implementing model grid aggregation. A conceptual workflow for visual model development from an existing groundwater model grid is presented and explained along with examples of the resulting visualization product. Advantages of this type of visualization for scientists, analysts, and stakeholders include: 1) development of intuition regarding control and influence of structures, preferential flow pathways, and heterogeneity; 2) explicit presentation of “depth-scale” provides for improved understanding of amounts of subsurface water and thickness/extent of contamination; and 3) provision of impactful and easy to understand depiction of hazards when uncertainty in water levels (or contaminate plume footprints) are included in the visualization.

SESSION 11 | MODELING (FLOOD MODELING & MAPPING)

Regina Buono, Aither - Fertile Ground: Law and Governance to Enable Nature-based Solutions in Cities. Nature-based solutions (NbS) present a valuable infrastructure tool to manage urban stormwater and an opportunity to create more liveable cities. Governance has been identified as an important part of capitalizing on the many benefits of nature-based solutions. This work seeks to offer municipal decision-makers a way to think practically about governance in their city and the legal structure embedded within. It can help them to identify and understand potential impediments to the wide-spread use of NbS and potential mechanisms for making governance more supportive and adaptive going forward. Using interviews and analysis of policy documents around NbS in Austin, Texas, and Valladolid, Spain, this research applies theoretical advancements in adaptive law and adaptive governance to examine the status of NbS in each city. It diagnoses implementation barriers within the legal and governance regimes of each city and identifies potential elements that may support the emergence of a more adaptive governance regime. Barriers may include strict water quality requirements, slow and opaque permitting regimes, historic preservation laws, and health and safety laws. To support the adoption and use of NbS, a legal framework must be adaptable and allow—or better, create—connection, collaboration and innovative thinking among decision-makers. This work proposes legal changes to support the use of NbS and analyses the implications for adaptive management of NbS and other innovative mechanisms. Rethinking the objectives and qualities of legal systems can ultimately increase social resilience by facilitating the use and acceptance of new technologies and innovations, in turn supporting adaptive governance.

Owen Kubit, Provost & Pritchard - Groundwater in California: Transition from Voluntary to Mandatory Management – The Next Chapter. Historically, groundwater pumping in California was largely unregulated causing some groundwater basins to become

heavily overdraft. The 1993 Groundwater Management Planning Act attempted to address this issue, but saw mixed results, largely because there was little to no enforcement. As a result, in 2014 a more robust series of laws, collectively called the Sustainable Groundwater Management Act, were passed to address overdrafted basins. California was effectively the last of the arid western States to require mandatory groundwater management. Several challenges have emerged as agencies completed and started implementing their Groundwater Sustainability Plans in 2020 including: 1) regulations for de minimus groundwater users; 2) management of displaced water; 3) implementing new taxes that must be approved by the groundwater pumpers; 4) developing sustainable management criteria acceptable to the State; 5) developing effective overdraft mitigation measures; 6) minimizing land subsidence; and 7) starting the new management era with a dry hydrologic cycle. This is the next chapter in the saga first presented at a 2015 AWRA conference.

Lauren Patterson & Martin Doyle, Nicholas Institute at Duke University - The Breadth and Depth of Water Affordability Challenges Across the U.S. The cost of providing water services (drinking water, wastewater, and stormwater) has been increasing faster than inflation for many years. The rise in costs is likely to continue as utilities seek to recover the full costs of providing water services and meet emerging challenges ranging from replacing aging infrastructure, to addressing lead lines and emerging contaminants (such as PFAS), to building in greater climate resiliency. The reliance of utilities on local rate payers to cover these costs places greater financial burden on households to the point that water services become unaffordable. We developed a database of water, wastewater, and stormwater rates for over 4,000 utilities in the United States. We obtained service area boundaries or created estimated boundaries using municipality data. We then combined estimated bills with census income data in each service area to calculate commonly used affordability metrics. In this presentation, we focus on understanding the depth of the financial burden low-income households (20th percentile income) are experiencing and the pervasiveness of unaffordability across all households (percent of households spending more than a day each month paying for water services) for large utilities across the U.S. Currently, we found at 6,000 gallons of water a month that low-income households have affordable services (less than a day of labor) in 62% of utilities, 33% spend 1-2 days paying for water, and 5% spend more than 2 days working to pay for water services. We found that on average, 16% of households in a service area spent more than a day paying for water services with large variability between states. We developed an interactive visualization tool to bring greater transparency to water affordability (https://nicholasinstitute.duke.edu/water-affordability/water-affordability-dashboard). Standardized data and clear communication about the breadth and depth of affordability challenges across states can gain national attention and catalyze action.

Erik Porse, Sacramento State and University of California at Los Angeles - Forecasting Future Urban Water Conservation and Wastewater Production in California with Climate, Technological, Economic, and Social Influences. Cities implement urban water conservation programs to manage water supply constraints, reduce costs, and promote environmental sustainability. Water use efficiency actions such as low-flow fixtures, reduced outdoor irrigation, and leak detection are tools used by urban water utilities. In California, statewide legislation established criteria for objectives of urban water use across over 400 retail water supply agencies. In this presentation, we discuss findings of a multi-year study to evaluate the environmental and economic impacts of urban water use efficiency regulations that apply to approximately 36 million people across California. We describe an integrated approach to forecast urban water demand in agencies, which includes factors for fixture efficiency improvements, population projections, and drought and climate change. The demand forecasting integrates statistical and end-use modeling approaches. We also developed risk indicators to quantify potential effects of efficiency and conservation on wastewater collection, treatment, and reuse systems. We conducted interviews with urban water supply and wastewater system management across California to understand likely adaptation actions for conservation. Economic modeling evaluated benefits and costs on potentially-affected sectors. The methods and findings are relevant to cities everywhere that undertake water use efficiency programs.

SESSION 12 | Coastal and Oceans

Amy Bainbridge, The Balmoral Group - Gone Fishing: A Citizen Science Framework to Monitoring Indian River Lagoon Health. The Indian River Lagoon (IRL) estuary, once a world class fishing destination for speckled trout, redfish, tarpon and snook, has faced a decline in water quality, loss of habitats, more frequent and extensive algal blooms and fish kills due to increased urbanization and other changing environmental factors. This project combines existing, publicly available environmental data (i.e. sea grass health, Nitrogen levels, HAB count, etc.) with citizen science reports from recreational anglers and fishing guides to construct an interactive, data visualization dashboard illustrating historical changes in fishing effort, water quality and habitat within the last few decades. This interface and resulting maps will allow researchers, politicians, and community members alike to observe interactions between water quality indicators to support coastal resource management strategies for future restoration projects.

***Pooyan Nikeghbali & *Rohan Benjankar, Southern Illinois University Edwardsville - The Rheology Model of Submerged Landslide with the SPH Method.** A landslide is the rapid movement of a mass of rock, sediment, or artificial fill on a slope, and it is most common in mountain and coastal regions. As the soil rheology is recognized as a separate area of soil mechanics and, research on soft soils, landslides, debris flows, and mudflow has been developed using Bingham-Plastic (B-P), Herschel-Bulkley (H-B) and μ(I) models to apply for the mass bodies in the deformable submerged landslide. In this study, the Smoothed Particle Hydrodynamics (SPH) method is used to simulate the rigid and deformable submerged landslide phenomenon. To apply the soil phase, the SPH code

is developed to two phases of water-soil and the yield stress point is calculated with the Mohr-Coulomb criteria in order to separate the quasi-static and gaseous components in the B-P and H-B models. The interface region between water and sediment is one of the most essential components of the developed code. The Navier-Stokes and continuity equations are improved to deal with the numerical instability at this interface. The rigid submerged landslide is modeled to verify the behavior of the water surface at the breaking area. The SPH simulated landslide process is compared with the Finite Element Method (FEM) simulation and the experimental models.

Xin Su, University of Arkansas - Quantitative Evaluation of Subterranean Coastal Barrier Performance at Marina Del Rey, California. Approximately 10% of the world's population lives in coastal areas, where the surface elevation is lower than 10 meters above sea level. In the United States, around 40% of the entire population lives in coastal counties . The increasing frequency and intensity of extreme events generate surface flooding that can threaten the safety of these populated coastal regions. Storms and sea-level rise can also influence subsurface hydrologic response, leading to groundwater emergence, which can exacerbate surface flooding, and seawater intrusion, which can weaken the subsurface soil strength, contaminate coastal fresh water, and undermine coastal subsurface infrastructure. Despite these concerns, the groundwater response to extreme events and sea-level rise has received less attention than surface processes, and inland groundwater level and flux responses typically are not considered in the development of shoreline flood protection strategies.

In this study, we investigate how surficial and subterranean barriers influence groundwater emergence in a coastal aquifer for storm events and sea level rise scenarios. We apply a transient 3D groundwater model for Marina Del Rey, CA. Short-term simulations of groundwater responses to storm events rely on coupling surface hydrodynamic model outputs to the groundwater flow domain, consisting of tides, waves, and various storm conditions. Each of these short-term analyses are performed for present-day conditions and with future sea-level rise. This framework allows us to test the importance of the long-term sea level and short-term marine forcing components of resulting groundwater flooding. Previous work simulating the relationship between barrier conditions and inland groundwater response has indicated that, 1) subterranean intrusion barriers can exacerbate groundwater emergence inland of the barrier, and 2) coastal topography determines groundwater emergence, groundwater seepage, and intrusion sensitivities for each barrier type. We extend this work by investigating a real-world site with more spatial complexity, advancing the understanding of how site-specific conditions influence groundwater response to shoreline adaptation strategies.

SESSION 13 | Citizen Volunteer Monitoring Program

Jule Schultz, Spokane Riverkeeper - Spokane River Community Science Turbidity Study: From Engagement to Policy. Community science projects represent a unique opportunity to educate and act on water pollution issues in local watersheds. Through training and sample collection, members of the public may become both advocates and scientists, contributing valuable information towards complex environmental issues.

The Spokane Riverkeeper, in partnership with Spokane Falls Trout Unlimited, leads a "Sediment Study" that documents the ongoing spring turbidity pollution that originates in Hangman (Latah) Creek and flows into the Spokane River, a recreational trout fishery. The study uses volunteers to sample, analyze, and record water samples for turbidity and water clarity. Samples are further analyzed by Spokane Riverkeeper Staff for turbidity and then entered in Washington State EIM database.

Volunteer engagement in the study remains high, with 26 volunteers collecting 554 samples over 135 sample events during the 2022's 180 day study season. In addition, 30 more volunteers were educated and trained that were not able to participate in the study.

The presenter will speak about the results and development of a community science project. This will include how the Spokane Riverkeeper engaged the community, taking the issue from concept to implementation to potential future actions. The presenter will discuss the need for next steps, such as cleanup plans and listings based on the data presented.

Results from the study show that sediment from Hangman Creek impacts turbidity in the Spokane River, causing violations of state water quality standards. Although water quality in Hangman Creek is improving, most likely due to a combination of improvements in the basin and reduced flows, it continues to cause impairments in the receiving waters of the Spokane River.

Stan Miller, Selkirk Conservation Alliance - Temperature Trends in Priest Lake, Idaho. In a recent report (see reference below) on indicators of climate change the US EPA reported on the temperature change in North American Lakes over a 25 year period (1985 – 2009). Of the 34 lakes monitored, 24 showed average temperature increases of greater than 1OC. Only two sites showed cooling (<1OC) and the remaining sites showed warming of less than 1OC.

This presentation examines data for Priest Lake, Idaho to assess temperature changes in Priest Lake as they compare to those in the EPA report. Examining the data base for Priest Lake, Idaho shows that there is a long term temperature record extending back to

1990 for one open water site and back to 1993 for many other sites. Between 1990 and 1995 data collection was conducted by the Idaho Department of Environmental Quality (IDEQ). Following a 13 year hiatus the Selkirk Conservation Alliance (SCA) began their Citizen Volunteer Monitoring Program on the lake. Temperature was determined by SCA using a YSI ProComm II Temperature / DO probe. Between 2008 and 2021 an open water site (PLNO) had temperature/DO profiles produced for 12 of the 13 years the group monitored the lake. Measurements for July, August, and September were made for 8 of those 12 years. Several other sites, located in bays, have long and complete enough data records to evaluate temperature trends.

The data for the PLNO site has been evaluated several ways: surface (top meter) temperature trends using the 3 month summer average, trends using the top meter temperature for monthly values and trends for the average temperature in the epilimnion. Using all these approaches Priest Lake open water temperature has increased over 1 degree C since 1990. Other open water sites show a similar trend but with many fewer years of data.

Temperatures in several shallower bays (~ 10 meters deep) were also examined. The bays, as expected showed greater temperature increases. Increases of over 2 degrees C were observed. (www.epa.gov/climate-indicators/climate-change-indicators-lake-temperature#tab-5)

Jim Ekins, PhD, University of Idaho Extension Water Outreach - Analysis of citizen science water monitoring volunteers: Contributing to community resiliency. Volunteer citizen science program managers can benefit from understanding participant activity patterns. I completed a mixed methods research project about cit-sci volunteer persistence. The study adapts Heckhausen & Gollwitzer's (1987) Rubicon Model of Action Phases, with help from Azjen's (1991) Theory of Planned Behavior, to better understand how someone becomes and persists as a volunteer citizen scientist. Survey research was triangulated with actual data upload patterns cross referenced with the list of all program participants.
Water quality monitoring has long-term benefits, but so too, does providing ongoing educational opportunities for lay community members. While consistent volunteers are valuable to a water quality monitoring program, attention to continually recruiting new volunteers, and assessing the correct action level for them, will also benefit water quality volunteer programs.

Beyond the volunteer experience, my larger research includes discovering how collective learning can lead to increased community resilience. This is based on this mental model: communities engaged in nonformal natural resources learning are encouraged to develop conservation-oriented social norms and increase social capitals. This can lead to improved ecosystem services management, which in turn can lead to increased adaptive capacity. Presentation link (via Prezi): https://prezi.com/view/GeVcRU9wkDJFAfCtKBPv/

SESSION 14 | Native American Values

Cynthia Carlstad, Northwest Hydraulic Consultants. Powerful treaty rights, federal law, and fisheries co-management authorities give Pacific Northwest Native American Tribes strong influence over water and natural resources management. Through their sovereign authorities and as part of watershed communities, many tribes choose to participate in collaborative watershed management efforts. Each tribe is unique, and the perspectives, governance structure, and decision-making process is nearly always different than standard operating norms for U.S. federal, state, regional, and local governments. The collaborative process can be challenging and frustrating for all, especially when these differences are not understood and respected. When collaborative groups seek to understand each other's underlying values, opportunities usually emerge. This panel discussion will focus on collaborative water and natural resource management from the perspectives of tribal representatives from tribes in Washington State, in the hopes that all participants will gain insights that lead to more productive relationships and outcomes.

SESSION 15 | Management & Tools 3

Carly Greyell, King County Department of Natural Resources and Parks - Overview of King County's Water Quality Benefits Evaluation. Local wastewater and stormwater utilities invest millions of dollars collected from ratepayers to protect water quality and meet regulatory requirements. Utilities consider many factors as they prioritize their work, including environmental outcomes. Utilities often compare the environmental benefits of potential projects by evaluating changes in pollutant loads or concentrations rather than looking at whether those projects will accomplish better environmental outcomes for people and wildlife.

In an effort to make better-informed decisions in King County, WA, we developed a framework (the Water Quality Benefits Evaluation [WQBE] toolkit) that connects potential management actions to projected environmental outcomes. The toolkit is an adaptable framework containing an integrated pollutant loading model, a pollutant reduction and cost optimization model, and a suite of causal models representing systems surrounding specified environmental outcomes. In this presentation, we provide an overview of each of these components of the WQBE toolkit and anticipated uses for regional planning efforts.

Timothy Clark, King County Department of Natural Resources and Parks- A Causal Model for Identifying Fecal Contamination Threats to Swimming Beaches. Local wastewater and stormwater utilities invest millions of dollars collected from ratepayers to protect water quality and meet regulatory requirements. Utilities consider many factors as they prioritize their work, including

environmental outcomes. In their prioritization and planning efforts, utilities consider many factors, including the benefit to environmental outcomes. The assessment of environmental outcomes, however, is often not direct nor transparent. It is obfuscated with simplifications, assumptions, and the black box of professional judgement.

We developed causal models for six environmental outcomes: (1) toxics in edible fish, (2) fecal contamination at shellfish beds, (3) fecal contamination at swimming beaches, (4) algal toxins at swimming beaches, (5) natural-origin Chinook salmon population health, and (6) Southern Resident Killer Whale population health. The causal models include Bayesian networks, narrative conceptual models, and fish bioaccumulation models. This holistic evaluation of environmental outcomes provides better information to decision-makers to consider alongside other factors such as costs to ratepayers and reversing environmental inequities.

This presentation will focus primarily on one of the causal models - fecal contamination at swimming beaches. We will provide a summary of the Bayesian network developing using expert elicitation and examples of how the model can be applied to support King County's utility planning decisions. The presentation will also provide insight on how the framework can be applied for other types of endpoints, such as equity and community health.

Jeff Burkey, King County Department of Natural Resources and Parks - Using an Optimized Cost-effectiveness Stormwater Model (SUSTAIN) at a Regional Scale. Stormwater runoff is the largest source of pollution in the Puget Sound region and disturbed and hardened landscapes increase this problem. The greater Seattle area, which resides within King County, contains the largest concentration of population within Washington State. As a result, most of the developable lands in King County have been developed with no or outdated and underperforming stormwater design standards.

The SUSTAIN modeling system was designed to evaluate cost-effective stormwater treatment solutions at a small scale. However, we needed to evaluate strategies that spanned over 1000 square miles with wide ranging intensities of development and rainfall. This situation in conjunction with different types of containments of concern (i.e., sediment, metals, organics), requires being able to evaluate the efficacy of any given BMP or treatment train (i.e., sequence) of BMPs
within the 1000 square miles.

This presentation will discuss how we scaled up the application of SUSTAIN while maintaining computational resolution at a parcel level evaluating the cost-effectiveness of potentially a unique strategy in every single catchment within the 1000 square miles—planning global, acting local.

Stephanie Truitt, King County Department of Natural Resources and Parks - Using the WQBE Toolkit to Support Stormwater Planning. Stormwater utilities often face difficult decisions in siting new projects and choosing when and where to update aging infrastructure. The WQBE Toolkit provides a suite of comprehensive modeling tools which allow utilities to make data-driven decisions on where to spend time and resources investing in stormwater infrastructure. This approach to comprehensive stormwater planning helps promote better outcomes for water quality in King County.

The WQBE Toolkit uses LSPC, a hydrology and pollutant loading model to determine where non-point source pollutants are entering water bodies in King County. Flow and pollutant concentration estimates from LSCP can be used in conjunction with existing spatial data sets to select catchments which would benefit most from stormwater projects.

Users of the WQBE Toolkit can select how they prioritize catchments based on a wide range of priorities, including reducing a specific contaminant such as copper, the application of equity and social justice metrics, or age of development, to name a few. This presentation will demonstrate how WQBE Toolkit products from LSPC, combined with other WQBE Toolkit components like the SUSTAIN model, can contribute to cleaner, healthier waters in King County.

SESSION 16 | Sewer & Stormwater 2

***Pratik Mahyawansi, Florida International University - Wire-Mesh Sensors in Sewer Geysers.** Wire-mesh sensors (WMS) are used to determine the phase fraction of gas-liquid flows in various applications. This paper reports the use of wire-mesh sensors to study the flow behavior in a stormwater pipe during violent geyser eruptions. The study focused on the transition from stratified to slug flow due to the development of a sudden large pressure gradient between the pipe and the dropshaft. Two 16×16 wire-mesh sensors were used to obtain the spatial/temporal variations of phase distributions at the two pipe cross-sections. A sequence of phase distribution and axially sliced images were used to investigate the void fraction profile and air-water two-phase flow interface. From the outcomes of this study, time series of void fraction, mean void fraction, and characteristic slug frequency are extracted and analyzed. Wire-mesh sensors, along with pressure sensors and high-speed cameras, were used to gain a fundamental understanding of the mechanisms that lead to violent geysers in stormsewer systems.

Marc Leisenring, Geosyntec Consultants- Balancing the Gray with the Green: Prioritization of the Urban Stormwater Infrastructure Retrofits. Integrated stormwater planning often seeks to achieve multiple objectives such as reducing flooding, reducing pipe failure risk, improving water quality, recharging aquifers, enhancing communities, and addressing social inequities, among many others. A common approach is to identify a suite of potential gray and green stormwater infrastructure improvement alternatives, assess the performance/benefits of each with respect to specific design criteria, and then select the most cost-effective alternative to move toward design. While this approach is often useful and appropriate, the number of alternatives (and combinations of alternatives) to evaluate can be extremely time consuming, especially for complex stormwater networks and many objectives. Also, the tools and approaches for evaluating benefits of conveyance improvements are often much different than the tools and approaches for evaluating the benefits of green infrastructure. This presentation will demonstrate the use of optimization, cloud-based computing, and hydrologic/hydraulic modeling to simultaneously ev aluate multiple objectives and improvement alternatives including both gray and green infrastructure. After providing a background on the theory and data input needs for setting up the optimization, case study examples will be presented. The case studies will demonstrate this novel approach to prioritizing cost-effective stormwater infrastructure projects including pipe upsizing and repair, downspout disconnections, and green street implementations to achieve desired levels of service, reduce flooding and failure risk, improve water quality, and reduce discharge volumes.

***Edward Brown, Morgan State University- Maximizing Stormwater Treatment Effectiveness in Best Management Practices.** Best management practices (BMP) are stormwater management technologies that were devised to address hydrology and water quality concerns in urban and rural environments. BMPs can encompass structural and non-structural practices and are designed to remediate a predetermined drainage area of impervious surface and/or treat a volumetric storm flow of stormwater runoff. These BMPs utilize several remediation techniques to treat stormwater runoff such as temporary or permanent water storage and either evapotranspiration or infiltration into the groundwater table of the stormwater. Several structural BMP types include plant-life that provide the water treatment by absorbing, sequestering, vaporizing, or metabolizing the pollutants out of the water. The purpose of this study is to explore methodology for maintaining the long-term effectiveness of a BMP structure. There are many factors to determine the long-term effectiveness of a BMP such as the maintenance performed on the structure, the health of the plant-life, the age of the structure, climate conditions, and public knowledge on the purpose of BMPs. Over the lifetime of the BMP the plant-life in the structure will eventually die off, weeds and other invasive plant species will propagate crowd out the native plants in the structure, sediment and refuse will clog physical structures, and the BMP will take structural damage. Part of the study is to determine how these and other factors impact performance and determine the critical threshold for addressing these problems. To establish a BMP performance index, it is n ecessary to first determine a benchmark for performance. The effectiveness of a BMP decreases over time and the amount of stormwater remediation decreases. The decrease in effectiveness over time can be charted and used to determine a maintenance schedule and important optimization milestones.

Joesph Brascher & Doug Beyerlein - Clear Creek Solutions, The Grand Unification of Stormwater Modeling. Water quality monitoring has long-term benefits, but so too, does providing ongoing educational opportunities for lay community members. While consistent volunteers are valuable to a water quality monitoring program, attention to continually recruiting new volunteers, and assessing the correct action level for them, will also benefit water quality volunteer programs.

SESSION 17 | Policy, Planning & Legal 3

***Amruta Sakalker, University of Texas - Environmental Planning, Community Stewardship, and Water: A Comparative Assessment of Green Infrastructure in Texas Cities.** Riparian lands, the interface between terrestrial & water ecologies, play a critical role in keeping ecosystems healthy. However, in Texas, rapidly sprawling metropolitan regions continue to urbanize environmentally vulnerable areas around streams to meet the housing demand or expand regional transportation infrastructure. Through land-use changes, land cover changes, multi-ownership, and multi-use, fragmentation further complicates urban riparian land planning. Within environmental plans, there is a growing trend of using environmental stewardship-based projects as tools to protect, restore & manage riparian lands. Scholars show that though these plans meet the environmental mitigation goals, they fail to address equity & justice, as economic growth is the driving force for creating such plans.

This research aims to describe, and categorize the relationship between environmental planning, environmental stewardship capacity, and equitable methods of preserving ecologically vulnerable urban riparian lands. My overarching research question is, how does urbanization affect the environmental stewardship capacity of communities? The supporting research questions are:

1. How do environmental plans enable or undermine the stewardship capacity of communities?
2. What is the relationship between neighborhood characteristics and riparian land quality?

A comparative case study of 2 rapidly urbanizing cities of Texas: Dallas and Houston were studied from the perspective of policies and practices of riparian protection and restoration. I analyzed greenbelt plans relevant to riparian lands and synthesize spatial data on the plans' environmental, ecological, and social context. I identified two broad grey & green epistemology trends influencing greenbelt planning policies and practices. I categorized community engagement processes into a spectrum informed by commoning theory. The spectrum helps capture the span of engagement: from public input to stewardship building. The spectrum presents

those geographic, policy-based, and social attributes that are important to make & sustain environmental stewardship practices, promoting equitable planning of riparian lands. As alternative & creative forms of riparian management become popular through greenbelt plans, I investigate if plans help to make environmental planning more equitable or further enhance the uneven urbanization of environmentally vulnerable areas.

Madeleine Hartley, WaterNSW - Drought is not an Emergency: Preparing Australian Water Resource Frameworks for the 'New Normal' Dry Conditions. Between 2017 and 2020, the Australian state of New South Wales (NSW) experienced a drought of record across several major rural catchments. The speed and intensity of the drought was historically unmatched and resulted in projections of 12 months' remaining water supply for towns of up to 60,000 people. This was the first time major inland communities in NSW had faced drought-induced 'day zero' projections.

Regardless of its intensity, drought is not considered an 'emergency' in NSW or Australian water resources frameworks. Rather, drought is a 'slow catastrophe' with the onset often difficult to identify and duration indeterminate. These features can make it difficult to deliver time-critical but unplanned water saving infrastructure. Consequently, and in recognition of the heightened frequency and intensity of drought conditions under Australia's climate projections, improved planning and legal frameworks are worthy of close consideration.

This paper shares the NSW experience of responding to severe drought from a legal and policy perspective. In many respects, the existing frameworks worked as intended operationally. The NSW Government lawfully reduced allocations and restricted water take in order to prioritise critical town supplies. This required water users to trade through the water market to secure additional supply. Conversely, the need for numerous legislative amendments and ultimately new legislation highlighted discrepancies and opportunities for improvement.

This paper also articulates the need for strong drought and climate policies to oversee water frameworks. Many drought response measures, including drought management plans, are now being developed in NSW in anticipation of the next drought. Improved water resource frameworks cannot just rely on historic climate data to guide water determinations and future planning, but must include real-time modelling and storage monitoring to better foreshadow the onset of drought. This approach will help governments make timely and well considered decisions regarding the most appropriate measures to extend community water supplies.

Many communities, including in the United States of America, now experience prolonged drought conditions as their 'new normal'. It is critical and timely to learn from international experiences and collaborate to create improved frameworks with jurisdictionally agnostic concepts.

Mali Karamigolbaghi, Stantec - Implementation of California's New Urban Water Use Efficiency Framework. The California State Legislature passed Senate Bill 606 and Assembly Bill 1668 including provisions for advancing urban water use efficiency through developing and implementing various water use efficiency standards, variances, and performance measures. The legislation asks for a new framework with a bottom-up estimate of efficient water use that should be allowed on a water supplier level for most of the urban water use based on four defined standards: indoor residential, outdoor residential, system water loss, and commercial, institutional, and industrial (CII) landscape irrigation with dedicated irrigation meters, plus additional justifiable variances for unique and significant water uses. The remaining CII water use is not subject to a quantitative limit but a set of performance measures. This new water conservation framework is the first in the nation with a forward-looking concept that fits for the 21st century, and a departure of the past approach focusing on closing the estimated water supply-demand imbalance. It requires a level of precision that is not present in current regulatory requirements or real-life practices by most urban retail water suppliers. Thus, it demands significant considerations of reasonableness of the requirements, implementation schedules, and long-term policy effects on drought resilience, quality of life and economy. Potential general and topic-specific assistances are likely required for implementation. California Department of Water Resources, in collaboration with the State Water Resources Control Board, led the development of recommendations for adoption with substantial stakeholder outreach. This presentation will outline the development process, recommendations for these various elements with annual reporting requirements, and potential implementation challenges and solutions.

SESSION 18 | Modeling Propeller Wash

Jeffrey Jung, DSI LLC, Paul Craig, DSI LLC, Wei-Cheng Wu, DSI LLC. Propeller wash is the high-velocity jet flow generated behind a rotating propeller. In areas of substantial vessel traffic, sediment bed materials can be resuspended and redistributed by the propeller wash, which may significantly impact aquatic ecosystems at contaminated sediment sites. The propeller wash has also been identified as the primary cause of scour around quay structures; such scour may result in structural instability or even failure. Modeling flow and sediment transport patterns induced by propeller wash will benefit researchers, engineers, and regulators in contaminant remediation planning, engineered channel designing, and long-term port management. Environmental Fluid Dynamics Code Plus (EFDC+) offers a dynamically-linked simulation of hydrodynamics, sediment transport, and propeller wash incorporating

vessel traffic data. This workshop will introduce theoretical and algorithmic concepts of the EFDC+ propeller wash module and provide step-by-step practice of propeller wash model development. Attendees are encouraged to bring their laptops with Windows 10 operating system, having administrative permissions to download and install the software. Following this workshop, the attendees will be able to: (1) obtain and process Automatic Identification System (AIS) vessel tracking data, (2) build and run a propeller wash model, and (3) analyze the model results using post-processing tools (e.g., map visualization, animation, time series plot).

SESSION 19 | Forecast-Informed Reservoir Operations (FIRO)

Duncan Axisa, CW3E Scripps Institution of Oceanography, Marty Ralph, Scripps Institution, Cary Talbot, US Army Corps of Engineers, Don Seymour, Sonoma Water. Forecast-Informed Reservoir Operations (FIRO) is a water management approach that uses atmosphere and watershed observations together with improved weather and hydrologic forecasts to support reservoir managers in more flexibly retaining or releasing water to manage weather extremes while retaining/improving water supply, flood-risk reduction, and environmental benefits. Operating rules for most US reservoirs were codified decades ago and the rules generally do not employ skillful hydrologic forecasts. With modern forecast improvements, and with reservoirs facing new resource demands and challenges from changing climates and watershed conditions, prospects for incorporating forecast information directly into operating rules and decision making are the focus of a growing number of scientific, engineering and water management studies.

Panelists will discuss:

A. Advances in Science and Technology: Existing and new FIRO concepts; the scientific findings that allow FIRO efficacy; and a framework that includes a collaborative vision and work plan development that fosters effective problem solving.
B. Applications and Transferability: Results of FIRO implementation to date, taking the lessons learned by applying FIRO at several pilot sites and transferring them to other locations, with the process and rationale used to select other pilots and the current status.
C. Adaptive Water Management: The application of FIRO research at a pair of reservoirs in the Yuba-Feather Rivers system in California, where adaptive water management strategies mitigate flood risk and strengthen the region's resilience to climate change.

SESSION 20 | Tribal Priorities in Water Resources

Phil Rigdon, Member, Yakama Nation; Starlivia Kaska, Member, Havasupai Tribe; Nikki Tulley, Member, Navajo Nation; and Valerisa Gaddy, Member, Navajo Nation. Presenters will discuss their perspectives on tribal water priorities and challenges. They will draw on personal and professional experiences related to water resources opportunities and obstacles in their communities. This conversation will contribute to raising awareness of water resources issues of Tribal Nations. It is hoped that the discussion provides 2022 AWRA Annual Conference attendees with information to help them to perform their water resources duties in a way that is in alignment with some of the initiatives mentioned below – and more.

1. White House Fact Sheet: Building A New Era of Nation-to-Nation Engagement (https://www.whitehouse.gov/briefing-room/statements-releases/2021/11/15/fact-sheet-building-a-new-era-of-nation-to-nation-engagement/)
2. Executive Order 14008: Tackling the Climate Crisis at Home and Abroad (https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/)
3. Executive Order 13985: Advancing Racial Equity and Support for Underserved Communities Through the Federal Government (https://www.federalregister.gov/d/2021-01753)
4. Executive Order 14049: White House Initiative on Advancing Educational Equity, Excellence, and Economic Opportunity for Native Americans and Strengthening Tribal Colleges and Universities (https://www.federalregister.gov/d/2021-22588)

SESSION 21 | Management & Tools 4

Jordy Wolfand, University of Portland - Oregon's Water Supply at Risk: Assessing Natural, Built, and Social Hazards to Inform Solutions. Water supply systems across the Western U.S. face multiple crises from changes to human and natural systems. Water supply challenges in the state of Oregon are typical of the Western U.S. As utilities within the state determine the best investments for promoting resilience in their supply systems, it is imperative to understand how these challenges vary across water agencies and regions. Furthermore, this understanding would help promote more efficient communication and collaboration between utilities facing similar stressors.

The goal of this work is to assess the vulnerability of water supplies in Oregon to multiple natural, social, and built infrastructure hazards and stressors. Specifically, the project aims to address the following research questions: (1) What are the risks to water supply source areas in Oregon, and which source areas are most vulnerable to each risk? and (2) How can water suppliers leverage collaboration to mitigate potential risk to water supplies? Data was collected for the 166 public water suppliers in Oregon that serve more than 500 people. Natural vulnerabilities include drought, flood risk, landslides, and water quality violations, while physical risks

relate to the resilience and robustness of grey and built infrastructure, including the diversity of supply sources. Socioeconomic stressors include projected population growth and the demographics of the population served. A network analysis was conducted to determine the interconnectedness of water suppliers in the state. Statistical clustering was used to identify groupings of public water supply systems that face similar challenges. Results provide an integrated assessment of Oregon's water supply at risk across multiple hazard categories and a deeper understanding of which public water supply systems are best suited for different state and local agency interventions.

Ava Saunders, Jupiter Environmental Research and Field Studies Academy - Demographics Effect on Willingness to Pay v. Accept Pertaining to Surface Waters in Wealthy Coastal Communities of Southeast Florida. Understanding the impact of demographics on volunteer motivations is essential to driving community-wide projects, especially those dealing with human health and water quality. A gated community in Southeast Florida, Jonathan's Landing (JL), has a golf course (15,000 sqft) and marina containing approximately 1,234 homes on or near the water (JL POA, 2021). The JL waterfront was developed by exposing the water table on or near the intracoastal. Additionally residential waters are affected by water traps on the golf course that have culverts spilling directly into waterways, residential lakefront lawn care that is year round, and manicured facilities lacking a riparian buffer. Concern grew as biodiversity decreased and algal blooms intensified. Residents contacted JERFSA (Jupiter Environmental Research and Field Studies Academy) and requested assistance in increasing resident involvement.

JERFSA students constructed and distributed a survey in the spring of 2021 regarding willingness to participate in volunteer activities. The survey was modified from the Green Mountain Conservation District (2021) and Ossipee Lake Alliance (2020) and was distributed by the POA via email. The survey was constructed through Survey Monkey and although the survey requested demographics, it was anonymous and voluntary. Inquiries included land use, financial and educational status, and overall understanding of the natural environment. The survey was distributed to 440 residents in three of the 27 villages that make up the neighborhood of JL. Of that population, 126 surveys were returned, resulting in a 28.6% return rate. Results indicated that according to the Norm-Activation Model (Onwezen, Antonides, Bartels 2013), which demonstrates pro-environmental behaviors will be enhanced by elevated levels of education, demographics of the JL population denote that they have a higher willingness to pay than accept. Limitations of the first survey included lack of inquiry regarding seasonal residency and vague explanation of physical commitment to volunteer projects. The survey also only reached a small percentage of the population, possibly altering results in favor of residents already involved in environmental preservation. A second survey was distributed spring of 2022, to a larger group of residents. Survey questions were made more specific to individual action. Data exemplified a connection between duration of residency and commitment to an environment.

Sayan Dey, Purdue University - RIMORPHIS: River Morphology Information System. Information on river shape, bed morphology and sediment load are critical to help inform research and management issues related to river channels. However, such information is not easily accessible and/or available in public domain. RIMORPHIS fills this information gap by providing a web platform for aggregating, storing, sharing and analyzing river related scientific data. Additionally, it will serve as a clearing house for river morphology data that will help improve our overall understanding of national rivers' health using scientifically-rendered datasets. This presentation will give an overview of RIMORPHIS, including its capabilities to: (i) store different types of data, (ii) process and visualize river morphology and hydrodynamics data; (iii) interact with other river data repositories; and (iv) support research related to river hydrodynamics, morphodynamics and sediment transport. Ongoing progress including summary from the first stakeholder workshop and prototype tool development will also be presented.

SESSION 22 | Groundwater 1

Dee Korich, City of Tucson/Tucson Water Department - Tucson's Use of Colorado River Water. The City of Tucson lies within the Sonoran Desert in the Santa Cruz River Valley of southern Arizona. Average annual rainfall is approximately 12 inches. Though the Santa Cruz River was once perennial, because of historic groundwater overdraft it now flows only for a short time following major storm events.

Today the population of the city of Tucson is just over half a million people, with another half million people residing within the Tucson metropolitan area. Until the mid-1980s when Tucson Water built a reclaimed water system, the growing city was completely dependent on groundwater. As a result, groundwater levels in central Tucson declined. By 2000 groundwater in central Tucson was declining at the rate of over four feet per year.

In November 1992, Tucson Water dedicated a new water treatment plant for the purpose of treating and then delivering to customers Colorado River water that arrived in Tucson via the Central Arizona Project (CAP) canal. However, this treatment plant was shut down by October 1993 following water quality complaints from customers.

Tucson Water was faced with a difficult challenge: how to make use of 144,191 AF/YR of Colorado River water that had just been rejected by the ratepayers. The answer was recharge and recovery. Under the umbrella of the new Clearwater Program, Tucson

Water built a recharge project in neighboring Avra Valley near the CAP canal, on former farmland that the City had purchased for the water rights.

Since then, the Clearwater Program was expanded to include two other recharge and recovery facilities capable of storing all of Tucson's annual allocation of Colorado River water as well as storing Colorado River water for partners.

Tucson's use of recharge and recovery allows for operational flexibility, regional partnerships, and storage for future use. Through 2021, Tucson has accumulated 550,000 AF of long-term storage credits through recharge of Colorado River water. At the current rate of potable usage (96,793 AF in 2021) that volume represents over 5 ½ years of annual potable usage in the Tucson Water Service Area.

***Connor Opton, Jupiter Environmental Research and Field Studies Academy - Quantification of Fecal Markers in Southeastern Florida 2013-2022.** Many residential areas in Southeastern Florida are prone to private well contamination due to frequent flooding, specifically, Jupiter Farms (JF). JF is a residential area with multiple acre lots, located approximately 5 miles from the Atlantic Ocean, surrounded by water management canals and a tidal river system fed by Lake Okeechobee, and is connected to more than 3000 acres of sloughs. This area is a private septic, private well location with a surface to open aquifer depth of 3 feet and an average depth from septic drain field base to water table being 2 feet. JF has also been known to flood an average of 60-90 inches annually. Since this area is divided into large lots of multiple acres, residents often house cattle, horses, sheep, and other large livestock on site. Additionally, JF contains many ornamental and vegetable farms.

For the past ten years JF has had measurable levels of nitrates often above the 10ppm MCL and for the past six years has recorded the presence of ibuprofen (human fecal marker) in sampled well waters (Delaney & Thornton, 2021). However, some of the highest nitrate levels came from wells where there was no ibuprofen. In order to examine the plethora of sources of fecal matter contamination, additional samples were taken from private well water during the wet season from 2021-2022 and initially measured for nitrogen. Wells identified with nitrogen will then be tested for markers such as copper (fertilizer), flunixin (large animal), and ibuprofen (human). Samples were analyzed for nitrates using a Vernier probe, for copper using a LaMotte 3 colorimeter, and an Elisa Assay was used for flunixin and ibuprofen. Results indicate that ibuprofen, and hence human waste, is indeed in private wells but that commercial horse barns used for polo tournaments were more likely to contain flunixin rather than small personal farms.

***Bu-Sheng Lee, National Yunlin University of Science and Technology - Three-dimensional Hydraulic Tomography Analysis of Invention Partitioning Well Pipe Operations: Studies with Synthetic Sandbox and Solute Transport Data.** The extent and complexity of pollution in underground aquifers depend on the properties of the porous medium, boundary conditions, and chemical, physical and biological processes. Hydraulic conductivity (K) and specific storage coefficient (Ss) are important geological parameters for the understanding of subsurface heterogeneous aquifers. In order to have a better understanding of the effect of soil structure on the contamination transport. The use of controlled laboratory methods is more persuasive than numerical or analytical solutions. A fairly reliable contribution to the ability to accurately predict groundwater flow, contaminant transport, and the design and operation of remediation systems.

Previous research has been used vsaft2 to synthesize the Numerical models combined with real geological information, then estimated the heterogeneous field in underground and simulate the results of subsurface pollutant concentration. However, the results ignore real transmission modes at subterranean environments. That only presented in a two-dimensional (2D) sandbox model which is not realistic. The 2D model can observe the existence of pollutants in the ground and their lateral flow but the location of depth has not been accurately estimated. Therefore, the prediction of pollutant transport in three-dimensional (3D) is worth to discussing. The purpose of this study is to design a multi-stage concentric well pipe, which can measure the water level at different depths in a single well pipe. Through various lateral positions and isolation depths Collecting data. Finally, analyzing horizontal and vertical distribution patterns of K and Ss at the same time to obtain detailed aquifer hydrogeological parameters by 3D transient hydraulic tomography (THT). Combining real 3D sandbox pumping experiments with quantitative tracer concentration tracking paths to validate the numerical model then predicted pollution transport flow. Therefore, in order to estimate the solute transport more precisely, this research focuses on (1) improving the collection of layered data (2) using 3DTHT combined with geological information to estimate the hydrogeological parameter field (3) using 3D sandbox model experiments to simultaneously predict (4) Use solute tracers to simulate the pollution situation (5) Verify the prediction of pollutant flow direction by monitoring concentration changes for a long time.

SESSION 23 | Community Engagement in Water Resources

Patrick Forbes, Louisiana Office of Community Development, Philip Moffatt, Washington State University. Citizen science enables regional-scale studies on water resources at otherwise unattainable frequencies. Understanding key drivers for the isotopic composition of precipitation in the Pacific Northwest requires just such a sampling scale and frequency. The objective of our work was to establish a daily observation program of precipitation and its isotopic content, for understanding key drivers of isotopic

composition and inputs to our watersheds. In collaboration with the Community Collaborative Rain Hail and Snow Network (CoCoRHaS), we collected daily precipitation samples from 19 locations dispersed across Washington and Oregon. The CoCoRHaS Network is responsible for collecting daily precipitation observations for NOAA and is well suited for the research objective. The collaboration with CoCoRHaS made this study possible. The daily observations comprise important covariates for statistical analyses underlying a new modeling framework and add valuable context to each sample. Samples are analyzed for deuterium and 18O and combined with data from HYSPLIT back-trajectories, PRISM, and GRIDMET. This novel dataset enables us to query the effects of trajectory, upwind meteorological conditions, and point weather data on isotope values. Regression of these data enables isoscape analysis and can inform the interpretation of paleoclimate records. Most of the volunteers have deep local knowledge of weather patterns, attention to detail, and intellectual curiosity; this improved the quality of research data and its impact. Finally, working with the CoCoRHaS Network, we co-created a robust and reproducible method for sampling and exchanging data and materials. Volunteer input, experience, and unique circumstances resulted in a quality process beneath sample analysis and model conclusions. The citizen science approach and the resulting data and modeling will be presented.

SESSION 24 | Ecosystems 1

Bill Norris, Parr Excellence, Eli Asher - Cowlitz Indian Tribe, Large Wood Treatments for Salmon Habitat Restoration: Is "Enough" Enough? A decade of intensively monitored habitat restoration work on Abernathy Creek ended in 2021. Ongoing out-migrating smolt monitoring is generating evidence that systematic, intensive replacement of wood in streams to influence stream processes can reverse salmonid population declines in forested watersheds where freshwater rearing habitat is a limiting factor. These results suggest that restoration professionals should strive to emulate historical conditions through extensive wood placements rather than providing just enough wood to improve conditions at the habitat unit scale.

Old growth trees dominated fluvial geomorphic processes as salmon evolved in forested Pacific Northwest streams. Downed trees spanned entire valley floors, creating grade control, and forcing channel engagement in multiple flow paths across floodplains. Living trees reinforced channel margins, created canopy heterogeneity, shaded channels, and provided nutrients. Coupled with beaver and fertilized with marine-derived nutrients from spawning salmon, old growth forests created a landscape the held water like a sponge, flattening flood peaks and buffering low summer flows. In the last two centuries we have systematically removed salmon, beaver, and old-growth wood from Pacific Northwest watersheds. This has reduced hydraulic complexity and increased stream power, resulting in incised streams inhospitable to salmon and incapable of maintaining functional, connected floodplains.

Many salmon habitat restoration projects focus on placing wood to create habitat units such as pools and overhead cover, but do not endeavor to reset channel planform to pre-contact conditions. To emulate historical conditions, we placed large volumes of wood to fundamentally alter hydraulics and drive geomorphic change through accretion, floodplain interaction, and floodplain channel formation. In project reaches where we placed large volumes of variably sized woody material, we achieved full floodplain engagement, multi-thread anastomosing channels, abundant summer and winter rearing habitat, and have observed increased beaver activity. Post-project smolt monitoring is ongoing, but preliminary results demonstrate a clear trend toward larger, more abundant out-migrating smolts than observed pre-project, and a dramatic increase compared with the adjacent control watershed.

Jason Doll, KCI - Embracing the Challenges of Urban Stream Restoration. By virtue of an aggressive program of Clean Water Act Section 401/404 Permitting, the State of North Carolina has driven the growth of an advanced stream and wetland mitigation industry. However, the vast bulk of that restoration work occurs in rural settings, often involving a single agricultural landowner, so there are very few constraints on the design of these stream channel and riparian corridor restoration projects, and designers are afforded full freedom to employ natural channel design principles to maximize the ecological uplift realized by the project, which is consistent with mitigation objectives.

Because the mitigation business is sensitive to the cost of delivering stream and wetland restoration credits, as it seeks to maximize profits for private mitigation firms and banks, it has proved to be unable to tackle the challenges of urban stream restoration. In the urban and suburban landscapes, continued land development and the associated increases in imperviousness, losses of riparian vegetation, and modification of streams to accommodate infrastructure continue to adversely impact stream channels. Local governments are continually confronted with unhealthy, typically incised and actively eroding stream channels, that load tons of harmful sediment pollution downstream and constantly threaten the integrity of adjacent anthropogenic infrastructure. Such streams are common on state lists of Impaired Waters as reported to the USEPA.

Fortunately, through the establishment of stormwater utilities, and growth of their dedicated funding streams, local governments have established the means to address these streams. However, the landscape and jurisdictional settings often present numerous challenges and constraints to the design and implementation process, requiring some level of creativity and adaptation on the part of designers. Over a near 30-year career in stormwater management and ecological restoration, the presenter, Jason Doll, has been a key team member and/or led several urban stream restoration projects for local governments. In the presentation he will provide real world examples of the challenges faced in these settings, the design solutions developed, and the lessons learned in their

implementation for recent urban stream restoration projects. He will also present the latest best practices he and his team have been employing in these settings.

Joanna Gibson, San Bernardino Valley Municipal Water District - Planning for Habitat Conservation Success in a Changing Climate. Beyond the volunteer experience, my larger research includes discovering how collective learning can lead to increased community resilience. This is based on this mental model: communities engaged in nonformal natural resources learning are encouraged to develop conservation-oriented social norms and increase social capitals. This can lead to improved ecosystem services management, which in turn can lead to increased adaptive capacity. Presentation link (via Prezi): https://prezi.com/view/GeVcRU9wkDJFAfCtKBPv/

SESSION 25 | Climate Change

Mariza Costa-Cabral, Northwest Hydraulic Consultants Inc. - Minimizing Uncertainty in Flood Risk Projections along the Pacific Coast of North America. There is a need for water resources professionals in private practice as well as academia to provide quantitative information on future flood risk, for purposes of flood protection and water resources planning. Future flood risk is estimated by combining the common tools of water resources professionals – hydrologic, hydraulic and coastal models, among others – with estimates of future temperatures and precipitation obtained by climate models and referred to as "climate projections". The main reason why projections are uncertain is that it is not known how global emissions of the main greenhouse gases (carbon dioxide, methane and nitrous oxide) will evolve in the future. This will depend on unpredictable future political, socio-economic and technological changes. Another source of uncertainty is that climate models, as all models, are imperfect and they don't always agree. Precipitation events of extreme intensity and duration are especially challenging to simulate accurately. Additional sources of uncertainty are the downscaling, in space and time, of projected climate variables, the use of extreme value analysis for time series that are only a few decades long, and the presence of decadal-scale natural variability.

What approaches are available to water resources professionals for mitigating uncertainty in flood risk projections? Northwest Hydraulic Consultants has been projecting future flood risk at Pacific Coast locations for over a decade. Examples will be drawn from NHC's projects to illustrate different types of approach we have used, including: identifying which aspects of climate projections are most reliable and increasing their influence in the analysis; considering an appropriately wide range of plausible projections; accounting for the capacity of decadal-scale climatic variability to mask or amplify a climatic change; using the watershed response to rare historical events to increase understanding of future responses to more frequent flooding; and leveraging our knowledge of how different techniques for "downscaling" climate projections may influence estimates of flood risk, and the appropriate use of extreme-value distributions in statistical downscaling. Examples of incorporating probabilistic sea level rise projections will be included. Projects used for illustration are located in California, Oregon, Washington, and British Columbia.

Shane Parson, AECOM - The Challenges of Modeling Climate Change Impacts to Riverine Flooding. Modeling climate change for riverine flooding has unique difficulties as compared with other major flooding types. Coastal flooding can be updated with sea level rise estimates. Upland, precipitation-driven pluvial or stormwater flooding can utilize updated IDF curves based directly on downscaled GCM daily precipitation data. Riverine or fluvial flooding, on the other hand, often does not have established procedures or site-specific modeling or equations that directly incorporate GCM outputs or derived indicators. This presentation will detail these challenges for fluvial flood modeling and a range of approaches for overcoming these limitations. A series of case studies will be profiled showing application of these approaches worldwide, including flooding influenced by snowmelt, natural and artificial lakes, and hurricanes.

***Jeongwoo Han, Texas A&M University - Hydrological Drought Forecasting using Machine Learning with Neural Ordinary Differential Equation.** Under global warming, extreme droughts have occurred more frequently, causing increasing economic and environmental losses. To be prepared for an anticipated drought, planning a proactive drought management based on long-lead drought forecasting is being needed. Therefore, this study developed a machine learning (ML) model with a neural ordinary differential equation (NODE) approach, hereafter called ML-NODE, to forecast hydrological drought at a long lead time across the continental U.S. (CONUS). ML-NODE fuses deep neural networks (DNNs) and mechanistic models internally so that the traceability/interpretability of the ML process increases due to the mechanistic model represented by the differential equation; the not-fully-represented nonlinear behavior by simplified conceptual or physical equations can be compensated for by data-driven methods, i.e., DNNs. The conceptual water balance model, which is comprised of the time derivative of the state variable (i.e., water storage) and mechanistic process variables (i.e., precipitation, evapotranspiration, and streamflow), was used to govern the hydrological process in the form of Euler's method that is equivalent to the formation of residual neural network (ResNet). However, solving the NODE is not limited to the application of ResNet. This study adopted the long short-term memory (LSTM) to construct ML-NODE, since LSTM can process the long-term dependency in time series. The loss function was to minimize the error in streamflow during training of ML-NODE, so that drought events were defined by applying the run-theory to the forecasted streamflow. The forecasting accuracies of ML-NODE were compared to those of LSTM and LSTM variants, such as wavelet-LSTM (W-LSTM) and wavelet-random forest-LSTM (W-RF-LSTM), at different lead times. ML-NODE outperformed LSTM and LSTM variants, since it learned both the knowledge contained in data and knowledge from the mechanistic laws addressing physical processes.

Besides the higher forecasting power, ML-NODE enables the interpretation of the interactions/dependencies among mechanistic process variables. Thus, this work seeks to develop a scientific ML that couples DNNs and physical governing equations for enhancing long-term drought forecasting.

Yung-Hsin Sun & Rebecca Guo, El Dorado Water Agency - Struggling through Caldor Fire Recovery Efforts – A Water Agency's Perspective on Misaligned State and Federal Policies and Practices. Wildfires in California and western states exposed the chilling fact that we have been managing our forest inappropriately and the continued encroachment of urbanization creates vulnerable urban-wildland interface that is susceptible to wildfire. Beyond the generality, every fire is unique and the consequently available resources for assisting impacted communities for emergency response and recovery from the State and federal assistances can be also very different. The presentation will examine the disconnects and inconsistency in funding authorities and practices for the on-the-ground needs through the experience of communities impacted by the Caldor Fire in 2019. Caldor Fire is the fifteenth largest fire in Californian history burning near 220,000 acres of private and federal lands in El Dorado County, which is mostly rural and with significant federal forest lands. It uniquely burned cross the Sierra Nevada ridge and impacted both west side foothill rural communities and the tourist attraction in South Lake Tahoe. The attention on and resources for the mildly affected South Lake Tahoe area muted the lack of attention and resources for the devastated rural foothill communities on the west side where the fire burned the most intensively. The one-time legislation couple years ago for sustaining a particular water district heavily impacted by fire is not available for a small water district experiencing a similar level of damage. Federal Emergency Management Agency (FEMA) denied Individual assistance program for impacted residents in an economic disadvantaged community in question of their intention to rebuild. A small water district serves a historical Gold-Rush town with its source of water in national forest, both damaged severely by the fire, faced great challenges in jurisdictional vacuum between state and federal agencies, and restrictions in funding or resource applicability. Creativities and great intention for collaboration were important to leverage what we have; however, substantial policy and practice reviews are necessary to align and maintain consistency between state and federal policies and funding authorities, and to correct FEMA's practices that are mostly built on flooding and other disasters but seemingly awkward in wildfire recovery efforts.

SESSION 26 | Yakima Basin 2 - CANCELED

SESSION 27 | Management & Tools 5

Noah Kaiser, Aither - Improved Water Governance and Strategy Through WaterGuide. It is well known that water scarcity is threatening the viability of societies, economies, and ecosystems across the planet, and particularly in the western United States. According to The Nature Conservancy, more than half of the continental US has regularly experienced drought conditions over the past two decades. Alongside broad recognition of the severity and risk associated with water scarcity, there is general recognition that solutions are known and available. The core challenge lies in the lack of effectiveness and efficiency of the management structures that are responsible for the delivery of these solutions; these barriers cause the continuous worsening of water scarcity in regions where water is already scarce and the proliferation of water scarcity into regions where it currently does not exist.

To address the challenge of water scarcity and assist governments and utilities to realise the long-term benefits of improved water management, the Australian Government, Australian Water Partnership, and Aither, a specialist water advisory firm, partnered to develop WaterGuide. First published in 2017 as a contribution to the UN and World Bank's High-Level Panel on Water, WaterGuide is an organising framework for improving use, management, and investment related to scarce water resources. It is not a prescription, nor a direct application of one model to other contexts. WaterGuide is a framework that recognises water reform is context-specific and must focus on practical action to stimulate progress. WaterGuide offers internationally proven guiding principles that support decision-makers, including large utilities, and state, county, and city governments, in the mitigation of commonly experienced challenges through targeted water strategy development.

Since 2017, WaterGuide has been used to promote dialogue among water sector decision-makers and facilitate sharing of knowledge and experience. Applications demonstrate that WaterGuide can be used by decision-makers to engage stakeholders, develop a vision for outcomes of water management, and diagnose strengths and weakness in water planning and allocation arrangements. Further, WaterGuide can support these agencies to identify the portfolio and sequence of policy interventions, management arrangements, and infrastructure investments that are most likely to deliver outcomes and to understand and communicate the benefits of water reforms.

Christopher Lupo, RESPEC - Improving Water Quality with the Scenario Application Manager (SAM). When water quality is impaired, watershed decision makers need to choose management practices that lead to the greatest improvements in water quality while balancing costs and practicality. The Scenario Application Manager (SAM) is a watershed-scale, decision-support tool. The SAM consists of a Geographic Information System (GIS) for site selection and evaluation, a Hydrologic Simulation Program – Fortran (HSPF) model application to simulate pollutant fate and transport, and the best management practice (BMP) database. An HSPF model application must first be developed and calibrated for SAM to become available to the decision makers. SAM assists in

developing custom strategies for protection, prioritization, and BMP implementation planning by combining individual and/or suites of scenarios to selected subwatersheds throughout a major basin. It simulates the expected instream water quality changes resulting from each simulated management practice. Land use changes for what-if scenarios and adjustments to point source time-series data for National Pollutant Discharge Elimination System (NPDES) permit development can also be represented. The combination of the graphical interface, a state-accepted watershed model, practical BMPs, flexible scenario development, and cost optimization bridges a gap between watershed characterization by water resource engineers and the water resource managers who ultimately develop implementation and pollutant reduction plans.

***Abhimanya Jha, Southern Illinois University Edwardsville - Numerical Study of Dam Break for The Pelican Rapids Dam.** The Pelican Rapids Dam in Minnesota was constructed in 1870 to provide waterpower to a sawmill. The Department of Natural Resources (DNR) considered this dam with a high risk of failure. To predict any potential risk and hazards due to the dam failure, we studied the dam break scenario using two-(2D) and three-dimensional (3D) hydraulic models. In order to understand the hydraulic behavior of dam break, 2D and 3D models are developed using HEC-RAS2D and Delft-3D numerical codes, respectively. In this study, the hydrodynamics of violent flow to the downstream and the morphology changes are analyzed, and the impact zones are delineated.

Casey Caldwell, Hazen and Sawyer, FIRO in the Desert: How the Salt River Project Uses Forecasts to Maintain a Reliable and Safe Water Supply for the Phoenix Metropolitan Area

SESSION 28 | Groundwater 2

Sara Sayed, Delaware River Basin Commission - Is Groundwater Being Used Sustainably in The Delaware River Basin? Spanning from the Catskill Mountains to Atlantic Ocean, the Delaware River Basin is the source of drinking water for 4% of the American population. While groundwater makes up only a small fraction (~5%) of overall water supply in the Delaware River Basin, it is an importance source for public water supply and self-supplied domestic uses. The Delaware River Basin Commission (DRBC) uses the drought of record (1961-1967) as the basis for determination and planning of dependable Basin water supply. Thus, it is critical to understand whether current and future groundwater use is sustainable especially during dry periods.

This study performed by the DRBC estimates the current and future availability of groundwater resources on two scales: the Delaware River Basin and the Southeastern Pennsylvania Groundwater Protected Area. Previous studies have developed methods to calculate annual groundwater baseflows to surface water s treams at 25- and 50-year recurrence intervals (representing dry and very dry years, respectively) for each of 147 subbasins within the Delaware River Basin; these baseflow values have been used to evaluate current groundwater availability but have never incorporated projections of future groundwater withdrawals. In this study, groundwater availability in each subbasin was evaluated between 2020 and 2060. Results indicate that the latest projections of Basin-wide groundwater withdrawals through 2060 are generally expected to be sustainable. Assessment on a finer spatial scale of the Southeastern Pennsylvania Groundwater Protected Area revealed two subbasins where groundwater withdrawals may exceed available baseflow at 25 and 50- year recurrence intervals; these two subbasins warrant further investigation to ensure sustainable groundwater use moving forward. While this assessment focused on annual groundwater availability, it is known that seasonal variations in withdrawals and baseflows exist and may impact groundwater availability (eg. the annual peak water demand often coincides with lower baseflows in late summer). The methods developed in this study serve as a framework for groundwater availability studies and future work will include a further exploration of sub-annual trends for the Delaware River Basin.

Todd Halihan, Oklahoma State University - Electrical Hydrogeology of NAPL Impacts: Two Decades of Surprises. Twenty years of electrically characterizing NAPL spills in subsurface environments has provided valuable lessons to promote more effective remediation. NAPL structure typically has 3D flow components, which must be evaluated to successfully delineate complex, on-site plume distribution and potential offsite migration. Additionally, naturally occurring bioactivity develops over time and interacts with the environment. This interaction can be ma pped and monitored to provide information on biodegradation, guiding remedial options. Examples from NAPL impacted porous media and hard rock environments will illustrate flowpath delineation, bioactivity assessment of these sites, and future directions for the technology.

Andrew Warner, CDM Smith- Water (In)Security: Health Impacts and Drinking Water Wells in Pennsylvania. Water insecurity includes a lack of access to water or water quality that is of sufficient quality, which can impact health, economic well-being, and household security. Water insecurity is a significant issue in Pennsylvania, particularly for the more than 2 million rural residents who rely on private water supplies. Pennsylvania is one of the only states in the U.S. with no statewide standards on private residential well drilling or construction. Several studies have revealed widespread water quality issues with private water supplies in Pennsylvania, with more than 40% failing health standards. While health impacts are suspected, linking water data with health impacts is a critical missing step, therefore this project evaluates existing groundwater quality datasets to better understand potential human health consequences. Building on existing research in Pennsylvania, this presentation will provide a summary of the project's progress to date including:

- The extent of individual/household water insecurity across Pennsylvania and those dependent on private water supplies in Pennsylvania;
- Statewide water quality trends in groundwater supplies;
- A brief summary of the current legal framework for private water supplies in Pennsylvania; and
- Efforts to engage a network of local and state stakeholders to increase groundwater education and reduce water insecurity issues.

This presentation will also explore how widespread water insecurity is for other states as well.

Claire Sheridan & Janet Clements, One Water Econ - Groundwater Trading in Madera County: Lessons Learned from a Pilot Program. Changes in the regulation of groundwater resources will dramatically impact our country's agricultural sector. California's 2014 Sustainable Groundwater Management Act (SGMA) identified critically overdrawn basins and delegated responsibility for management of groundwater sustainability to local agencies. Madera County, located in California's Central Valley, is one of the agencies charged with attaining sustainable yield in the overdrafted Chowchilla, Madera, and portions of the Delta-Mendota subbasins. The County will implement strategies and capital projects to decrease water use and generate new surface water supplies, but overall consumptive use of groundwater by agricultural growers will need to be dramatically reduced to achieve sustainable yield by 2040. These reductions will affect farmers, ranchers, and agricultural workers and have ripple effects throughout the economy.

A groundwater market can mitigate adverse economic effects associated with reductions in consumptive use by providing agricultural water users flexibility to manage groundwater allocations and remain profitable. With funding from the Bureau of Reclamation, Madera County set out to determine the feasibility of establishing a groundwater market to help farmers reduce consumption and meet sustainable withdrawal goals. Extensive stakeholder meetings and an economic impact evaluation informed the County of potential consequences associated with a groundwater market. From here, a market strategy framework was developed, and a simulation of a groundwater trading market was tested over the course of a 9-month pilot program. Volunteer pilot participants (most of whom were local agricultural growers) ultimately arrived at economically efficient outcomes. Participants fallowed water-intensive low-value crops and shifted their limited water supply to fewer acres of high-value crops. The qualitative results were surprisingly unequivocal: farmers do not want to stop farming. They will reduce profits and shift crops before idling acreage to sell water allocations in the short run, even though participants recognized the implications of long-term market equilibrium. Trading allocations was more readily accepted as a "necessary evil" than restrictions on use alone, allowing farmers more flexibility and control of their futures given legislated reductions in consumptive use. These outcomes suggest markets should be considered as a viable tool for supporting the agricultural sector in the future.

SESSION 29 | Flood Risk & Management 1

Robert Miller, University of Louisiana at Lafayette - Quantifying the Effects of Hydrologic Intensification on Flood Management in the Atchafalaya Basin, USA. A non-stationary increasing streamflow trend has been observed on the Mississippi River and other major river basins around the world. The current study analyzed the non-stationary streamflow effects (NSFEs) on flood management in backwater areas adjacent to the Atchafalaya Basin floodway in Louisiana, USA. A continuous simulation hydrology model coupled with a quasi-two-dimensional hydrodynamic model of the basin floodway and surrounding regions was used to develop over 180 simulation scenarios by superimposing local flood events (early summer 2014 and late summer 2016) against 90-years' worth of daily Atchafalaya River streamflow hydrographs. The NSFE on the Atchafalaya River induced substantial reductions in the performance of major flood regulating structures with seasonal effects based on the annual flood cycle. Capacity reductions at the structures were demonstrated to trigger a cascade of effects in ostensibly protected backwater areas including amplification of erosion potential near the levee and within tidal passes during early summer floods. Increases in mean and peak flood levels on the order of 15–20 cm during local storm events were shown to extend as far as 20 km away from the floodway protection levee during both early and late summer local flooding scenarios. Low-lying areas closest to the levee were adversely affected during both the high (early summer) and low flow (late summer) periods of the annual discharge cycle. The approach and findings of this study are relevant for risk management in river basins around the world affected by NSFEs.

Mohamed Askar, Southern Utah University - Flood Control Prediction and Analysis: Enoch and Cedar City - Utah Case Studies. Floods are becoming one of the most deadly natural disasters globally, claiming more lives than other natural disasters. Climate-related disasters have become more common in several parts of the world due to rapid changes in hydro-climatic conditions and other disturbances. According to Jha and Jessica (2020), floods harmed 178 million people in 2019, and overall financial damages in extreme years like 1998 and 2010 approached $40 billion. Many parts of Enoch and Cedar City, Utah, along with several other cities in the area, suffered significant flood damage due to the flood in the summer of 2021. This flooding should be controlled somehow, but more data is needed to find an economical solution. Hydraulic and hydrodynamic models are the major tools for flood mapping. They are primarily used to simulate flood events, estimate vulnerable areas, plan flood management, and determine relevant spatially distributed variables. The primary purpose of this study is to build a model of the watersheds around Enoch and Cedar City and analyze where flooding is most likely to occur within the city. This data could then will be used to create systems that reduce the

impact of potential flooding on the two cities. Secondary goals are to develop flood vulnerability hazard maps, give flood warnings, compute water surface profiles, map methodology of the flood level areas of different locations, and create emergency management plans for flood control. The study utilized HEC-RAS and Arc-Hydro software to generate flood inundation maps for precipitation events in both cities. The Flow-3D Hydro model results about the magnitude and timing of peak flows were considered for individual storm events. Hydraulic Engineering Center's Analysis System is the software used to control floods based on simulation of floods considering 100 years of past flood data. The results specified the number of damaged households for a specific percentage of occurrence floods. Finally, the study will be presented and discussed with Enoch and Cedar city for implementation.

Sayan Dey, Purdue University - Improving Surface-subsurface Process Characterization Through Efficient Bathymetric Incorporation in Large-scale Hydrologic and Hydraulic Models & Enhancing Feature Level Flood Forecasting in Near Real Time Through Efficient Integration of National Water Model and HEC-RAS. River channel geometry acts as a critical control for both fluvial and subsurface processes in the floodplains. While the effect of river bathymetry on channel routing is well known, its impact on surface-subsurface interactions requires further investigation. Specifically, there is a need for understanding the bathymetric properties of river network that influence surface-subsurface interactions especially at medium to large watershed scales. This study aims to analyze the effect of river bathymetry representation on characterizing physical processes such as infiltration, lateral seepage, and water table in tightly coupled hydrologic and hydrodynamic (H&H) models. The study develops four bathymetric configurations for three different watersheds of varying basin, groundwater and river network characteristics using an automated framework called System for Producing RIver Network Geometry (SPRING). These basins are simulated for multiple flood events using a physically based distributed model named Integrated Pond and Channel Routing (ICPR). A comparison of the simulation outputs provide insight into the role of bathymetric properties such as channel volume, surface area and sinuosity in controlling surface and subsurface fluxes. Results from this study are expected to guide the choice of efficient conceptual bathymetry incorporation across large river networks for accurate H&H modeling.

SESSION 30 | Ecosystems 2

Ge Sun, United States Department of Agriculture Forest Service SRS - Potential Effects of Longleaf Pine Restoration on Evapotranspiration and Water Yield in the Southeastern US. Longleaf pine (LLP) restoration has been identified as one of the principal goals in the southeastern U.S. due to its advantages in wildlife habitat, carbon sequestration, and water supply over loblolly pine (LOB) plantations. The goal of this study was to use a 'paired approach' to understand the contrasting water balances between the LLP and LOB ecosystems. We found significant differences ($p < 0.05$) in leaf area index (LAI), albedo, and land surface temperature (LST) between LLP and LOB. During the peak growing season (June to September), the average albedo (0.124) and LST (29.3 °C) of the LLP are significantly ($p < 0.05$) higher than those for the LOB stands (albedo = 0.119 and LST = 28.8 °C), while the average LAI of the LLP (5.12) was significantly ($p < 0.05$) lower than that for LOB stands (5.37). Moreover, we applied a daily scale Water Supply Stress Index Model (WaSSI) to a moderately well-drained loblolly pine dominated watershed, WS77, that is being restored to LLP at the Santee Experimental Forest. We found that the daily WaSSI performed well in predicting monthly water yield at WS77 for the 2012-2019 study period, with R2 of 0.98, Nash-Sutcliffe efficiency of 0.98, and Percen of Bias (PBIAS) of 1%. A hypothetical simulation suggests that clearcutting current watershed dominated by LOB plantations (albedo = 0.12 and average LAI = 3.7) in WS 77 (assuming the clear cut conditions for the whole watershed and whole period of simulation, with a higher albedo = 0.24 and lower LAI = 0.5) would result in a 240 mm (45%) increase of mean flow due to a sharp decrease in potential ET and actual ET. In contrast, a hypothetical moderate change in forest surface conditions (albedo = 0.16 and average LAI = 1.8) would result in a 77 mm or 18% increase in flow compared with the flow under the current watershed conditions (albedo = 0.12 and average LAI = 3.7). Our study suggests both albedo and LAI are critical land surface parameters for explaining the likely hydrological response of longleaf pine restoration on the lower coastal plain.

Daniel Brown, Oregon Department of Environmental Quality - The 2017 National Aquatic Resource Survey of Oregon Lakes. The National Lakes Assessment (NLA) is a collaborative effort between the Environmental Protection Agency and tribal/state/local partners to monitor and assess the status and trends of ecological conditions in the nation's lakes and reservoirs. The NLA is Oregon Department of Environmental Quality's (DEQ) regular program for monitoring lake conditions; however, in 2017, DEQ seized an opportunity to partner two water quality monitoring programs, maximize resources, boost our sample size, and complete the first statewide assessment of toxic compounds in Oregon's lakes and reservoirs. We modeled our objectives, sampling methods, and analyses to answer four key questions:

- What percent of lakes and reservoirs support healthy ecosystems and recreation?
- What are the most common water quality problems in lakes and reservoirs?
- Is water quality improving or getting worse?
- Are investments in improving water quality focused appropriately?

We assessed 49 of Oregon's 4,819 lakes meeting criteria for inclusion in the NLA. Lakes were randomly selected and weighted, which allowed for statistical inference to the population of Oregon lakes. We included nine groups of chemicals in the assessment of water and sediment samples. Key findings from the survey are:

- Biological conditions of Oregon's lakes were good overall.

- Eutrophication and lakeshore habitat indicators had the highest percentage of lakes in poor condition.
- All detected E. coli and microcystin concentrations were below recreational contact designations.
- Toxic compounds rarely exceeded human health or aquatic life criteria.
- Lake sediments contained mercury, DDT and PCBs above bioaccumulation screening levels.

SESSION 31 | Washington Water Storage Against Climate Change

Michael Scrafford, Aspect Consulting, Switzler Reservoir, Seth Defoe, Kennewick Irrigation District, KID Central Storage, Perrin Robinson, Jacobs, Walla Walla Storage, Mike Kaputa, Chelan County Natural Resource Department, Icicle Strategy. New water storage in Washington state continues to be an adaptive management tool to hedge against the hydrologic pressures of climate change. As warmer temperatures, higher spring runoff, and more frequent droughts create late season water challenges, water utilities in Washington are advancing storage projects to combat lost water supply. Storage projects being pursued in Washington are diverse, and are being planned for agricultural reliability, municipal use, and instream flow enhancement. Aspect Consulting and guests will lead a technical discussion and/or panel around a variety of new surface storage projects being developed in Washington State and discuss lessons learned, including:

1. Switzler Reservoir: A new 40,000+ acre-foot surface reservoir in south central Washington to meet agricultural reliability, agricultural expansion, and municipal water supply needs.
2. KID Central Storage: A new 12,000 acre-foot surface reservoir in central Washington to meet agricultural reliability.
3. Walla Walla Storage: Multiple new surface and underground storage projects being studied in the Walla Walla basin in southeast Washington.
4. Icicle Strategy: Storage reoperation and restoration projects in north central Washington to benefit instream flows and agricultural reliability.

These projects are in various stages of planning, design, and environmental review. Showcasing each project's vision will help identify how Washington water users are using storage to continue to provide reliable water supply to its users.

SESSION 32 | Management & Tools 6

***Fahad Alshehri, University of South Florida - An Innovative Technique to Characterize the Rating Curve for Alluvial Wetlands in Poorly Gaged Environment.** A depth discharge relationship or discharge rating is a relationship between the amount of water passing through a particular point in a channel of a lake, river, or stream and the water's depth at the channel. Hydrologic models simplify real-world hydrology and estimate hydrologic responses such as streamflow for managing water resources. The depth discharge relationship is essential in developing any surface water hydrologic model. To construct depth-discharge relations for each reach, intensive labor work is required. This is especially problematic when most stream reaches do not possess measured cross-section or flow behavior records; moreover, when hydrologic models are required for large areas with extensive streams, the required work becomes daunting. However, in most applications, the available data is GIS coverages and a few streamflow gaging stations. The available USGS gauging stations and GIS coverages were used to learn and implement a method to characterize the depth discharge relationship for hydrologic modeling of large and poorly gaged areas using commonly available data and non-dimensionalizing techniques previously developed by Mauses et al., (2007). The procedure is developed using drainage area, channel slope, and channel width. The rating curves for 74 USGS streamflow gages were reproduced using the procedure, then the produced and observed rating curves were compared to evaluate the accuracy. The Root Mean Squared Error and the Mean Error of the streamflow depth were 1.3 feet and 0.02 feet, respectively.

Gustavo Coraca & Matthew Davis, University of Alberta, Edmonton, Development of Water - Demand and Supply Footprints of Adoption of Novel Low-carbon Bitumen Extraction Technologies in a Net-zero Future. Bitumen recovery from the Canadian oil sands plays an important role in the country's economy and is expected to continuously increase due to expansions of in-situ oil sands projects. This sector is a major emitter of greenhouse gases (GHG); therefore, the advancement of low-carbon bitumen extraction technologies is key for a more sustainable recovery of crude oil. While many strategies to mitigate GHG emissions from the oil sands sector have been proposed, associated water-use impacts have not been assessed. This research focuses on development of a data-intensive and technology-specific model for in-situ bitumen extraction in Canada and utilization of this model to determine the long-term water footprint of novel low-carbon in-situ bitumen extraction technologies. Currently, steam-based bitumen extraction technology i.e., steam assisted gravity drainage (SAGD) is used. These low-carbon emerging technologies include hydrocarbon solvents instead of steam, hybrid steam-solvent processes, electromagnetic heating and in situ hydrocarbons combustion to heat the reservoir. The key results include total water consumption/withdrawal, the cost of saved water, and the water cost of abated GHG. These results will be further integrated with GHG emissions associated with these technologies over a long term planning horizon. The study horizon is from 2020 to 2050. Results will be informative to industry decision-makers and policymakers on the tradeoffs between GHG emission reduction and water-use implications from low-carbon technologies.

Chin Man Mok, GSI Environmental Inc. - Rainfall Simulations for Addressing Hydrologic Uncertainty in Water Resources Management. To support water management decision making, a calibrated application of the Integrated Hydrologic Model (IHM) was developed to simulate the hydrologic responses to rainfall and water supply operations in the Integrated Northern Tampa Bay

(INTB) region. Spatial and temporal distributions of rainfall significantly impact the hydrologic processes. However, the exact occurrence of future rainfall is unknown. This paper presents a probabilistic approach used to generate realizations of future 15-minute rainfall time series in 172 subbasins in the INTB region to represent rainfall uncertainty. The MC simulation of 25-year rainfall was conducted in four steps. In the first step, simulation was performed to generate 25-year realizations of monthly rainfall time series at 41 long-term rain gauge locations. The statistical model developed from historical data considers up to 8-year cyclical rainfall structure in the INTB region. In the second step, the realizations of monthly rainfall at the 41 long-term gauge locations were disaggregated to generate realizations of monthly rainfall in the 172 subbasins. The developed statistical model relates the monthly rainfall at the 41 long-term rain gauges and the monthly rainfall at the 172 subbasins based on the historical rainfall data at these long-term rain gauges and the rainfall in the 172 subbasins from 1995 to 2019. The 1995 to2019 subbasin rainfall was computed by integrating all available rain gauge and NEXRAD rainfall data for this period using a Bayesian statistical approach (Bayesian rainfall). In the third step, realizations of daily rainfall in the 172 subbasins were generated based on the Bayesian rainfall. The developed statistical model first considers the daily rainfall as a two-step sequential stochastic process: rain/no-rain occurrence in each subbasin each day and daily rain volume in the subbasins on the days of rain occurrence. The model accounts for inter-subbasin rainfall correlation. For both rain/no-rain occurrence and daily rain volume, the model assumes a 1-day Markovian process in time. The realizations of daily rainfall with the closest match of the monthly rainfall realizations in the second step were selected based on optimization. In the last step, the realizations of daily subbasin rainfall were disaggregated into 15-minute time steps based on random sampling the daily 15-min rainfall profiles from the Bayesian rainfall.

Gregory Guthrie, Geological Survey of Alabama - Delineation of Groundwater Recharge Areas for Water Management and Water Policy Development. Promoting sustainable water resources often requires the implementation of regulations and policies that identify and protect recharge areas. Managed aquifer recharge (MAR) policies can reduce demands on groundwater and surface water and provide sustainable water supplies for economic development and ecosystem management. Management of shallow groundwater sources is critical because of their susceptibility to both natural and anthropogenic stressors that affect the amount and quality of water available due to the unconfined or semi-confined character of water bearing units. A shallow aquifer recharge model (SARM) developed for Alabama allows for the identification of potential recharge areas. The model utilizes Multicriteria Decision Analysis in conjunction with the Analytical Hierarchy Process in a Geographic Information System environment to produce maps that can be modified for different climatic and land use scenarios to identify potential recharge areas. The model uses three intrinsic factors, soil permeability, slope, and aquifer conductivity, and three extrinsic factors, net recharge, land use/land cover, and depth to water table, to rank recharge potential across the state. The Huntsville (northern Alabama) and Baldwin County (southern Alabama) areas are experiencing high growth and concomitant land use conversion from agricultural lands to urban landscapes. Shallow aquifers are used extensively in these areas to provide groundwater for all applications. Fractured karstic carbonate rocks form aquifers in the Huntsville area and predominantly sandy strata form aquifers in Baldwin County. Depth to water tables in both areas fluctuates widely in response to changing climatic conditions, which affects water availability, and high permeabilities promote rapid infiltration of contaminants. SARM maps indicate that extensive recharge areas have been lost over the last few decades resulting from conversion of open agricultural lands to urban landscapes, promoting surface runoff and diminishing potential aquifer recharge. Shallow aquifer contamination potential has also increased due to expansion of urban and industrial potential contaminant sources. Implementation of MAR policies at the state and local levels can help address the loss of recharge areas by guiding management decisions that promote sustainable water resources for future growth and environmental health.

SESSION 33 | Flood & Risk Management 2

Sonja Michelsen, US Army Corps of Engineers - November 2021 Skagit River Flooding and the US Army Corps' Role in Flood Risk Reduction. An atmospheric river caused significant flooding in northwestern Washington and southwestern British Columbia in November 2021. During this flood, the US Army Corps of Engineers provided substantial flood risk reduction along the Skagit River through reservoir operations and emergency response. The reservoirs provided significant benefit by reducing the peak flow in the river by 40 percent, and the Skagit River still peaked within inches of the historical record at some locations. Sonja Michelsen will present on the hydrology of the November flood event and the Corps' role in flood risk reduction through reservoir regulation.

Felix Kristanovich, Windward Environmental LLC. - Success of Phase 1 and Phase 2 China Creek Water Storage and Fish Enhancement Projects, Centralia, Washington. The China Creek projects—developed, designed, permitted, and constructed between 2015 and 2022—were developed in two stages. Phase 1 added 9 acre-ft of storage in the event of a 100-year flood, added 10 acres of fish habitat, and almost tripled the existing habitat/wetland restoration area. Phase 2 provided additional flood storage in the event of any major flood and significantly enhanced the aquatic habitat. Project implementation for both phases included: a) a continuous monitoring program for China Creek; b) development of hydrologic and hydraulic models for China Creek; c) preparation of construction plans and specifications for the two water storage sites; d) preparation of required Washington State permits; and e) coordination of geotechnical, hydraulic, and structural engineering for the log stream outlet structure at the Phase 2 project site. Phase 2 also required a satisfactory Washington State Department of Ecology Dam Safety application that incorporated a 2-dimensional HEC-RAS hydraulic model to estimate flood inundations in the event of structural failure of the log stream outlet structure.

The 2-dimensional HEC-RAS model was used to assess channel capacity, sediment transport, and fish habitat enhancement features in the restored creek, and to develop flood inundation maps for the constructed project for different flood frequencies. The model was calibrated to the recorded water surface elevations along China Creek; calibration utilized data from a comprehensive creek monitoring program in 2014 and 2015 (e.g., flow, temperature, and sediment data) at select locations on China Creek. The monitoring stations were specifically installed for this project because there were no pre-existing stream gages on the creek. The primary purpose of the China Creek projects was to reduce peak flood flows in China Creek, thereby contributing to flood reduction in the Chehalis River. The secondary purpose was to improve fish habitat, create and enhance wetlands, and enhance of recreational opportunities.

This presentation will focus on chronological development of the two phases, flood inundation maps, and hurdles associated with the design and construction of the unique downstream log stream outlet structure.

Amir Kohanpur, University of Illinois at Urbana-Champaign- Physics-Informed Gaussian Process Regression for Urban Flood Forecasting. Integrated flood models are commonly used for urban infrastructure development planning and evaluating risk due to climate change and sea level rise. Real-time forecasting and uncertainty quantification are important components in flood prediction for efficient risk management in urban environments. However, integrated flood models rely on several parameters that are hard to measure directly and the resulting uncertainty in model prediction needs to be quantified. In this work, uncertainty quantification framework of model parameters and a physics-informed Gaussian process regression (PhI-GPR) method are presented and used for urban flood forecasting. As a case study, we use the Interconnected Channel and Pond Routing (ICPR) numerical model to simulate flooding in the city of Minneapolis in response to a range of storm events. We narrow down the number of uncertain parameters to Manning's roughness coefficient, vertical hydraulic conductivity of soil, and rainfall intensity. A joint distribution of parameters is propagated through the numerical model to obtain spatial variability of water depth. Uncertainty is described via the coefficient of variation and probability of flood is defined via the ratio of flooded realizations over total realizations. The output of flood simulations is used to identify highly uncertain locat ions and their temporal variability of water depth is used within the PhI-GPR to compute its prior statistics and real-time forecast. In standard data-driven Gaussian process regression (GPR), parameterized models for the prior statistics are fit by maximizing the marginal likelihood of observed data, whereas in PhI-GPR we compute the prior statistics off-line by solving stochastic differential equations (SDEs) governing the rain and storm water flow where certain properties such as Manning's roughness coefficients of surface water is treated as random variable. Our results demonstrate that urban flood models such as ICPR can be used to quantify parametric uncertainty and obtain sufficient data of flood prediction needed for real-time forecasting of flood through a PhI-GPR method. This study is part of the Urban Flooding Open Knowledge Network (UFOKN) project in which we incorporate flood model predictions in combination with machine learning, data and computer science, socioeconomics, and transportation to minimize economic and human losses from future urban flooding in the United States.

***Abhimanyu Jha, Southern Illinois University Edwardsville - Effectiveness of Snyder's Unit Hydrograph for Flow Estimation for a Small Himalayan Basin.** The necessity of flood hydrographs for hydraulic modelling cannot be overstated as hydrodynamic modelling requires unsteady flow for simulation. The development of storm induced flow is usually carried out with pre-existing synthetic unit hydrographs in basins with flow data scarcity. In this study we attempt to optimize the "peaking coefficient" and "basin lag time" parameters of Snyder's Hydrograph for a small basin in Himalayan regions of Nepal. Available storm and real-time flow data for specific events were used for parameters optimization ("peaking coefficient" and "basin lag time"). Lag Autocorrelation, RMSE (root mean square error), Peak Weighted RMSE and Percentage Error in Peak Discharge were estimated to analyze the performance or the approach. Furthermore, flows were simulated using hydrological model HEC-HMS to verify the results based on Snyder's Hydrograph. Our results indicated that Snyder's Hydrograph could be used to generate event specific flows, but additional factors are important when applying in an entirely different geographic range.

SESSION 34 | Session 34: Integrated Water Resources Management (IWRM)

Greg Gates, Hazen and Sawyer - Big Growth and Groundwater Constraints Drive an Innovative Integrated Water Management Approach: A Ft. Dodge (IA) Dtory. Ft. Dodge's Integrated Water Management (IWM) plan was driven by a planned growth strategy targets significant growth in their industrial sector over the next 20 years, potentially quadrupling current water demand. Currently, all demands are met through two groundwater sources: one with relatively limited hydrogeologic data and the other with regulatory limitations on drawdown. Likewise, recent drought conditions have stressed the capacity of the current infrastructure. Planning for future growth required an integrated approach to first assess current infrastructure limitations and then examine long-term groundwater supply. Historical well performance data were collected and compared to aquifer conditions and pump curves to assess current infrastructure. Groundwater modeling was completed with the state's regional model to examine potential maximum production given regulatory limits. This information was used along with a groundwater model developed for this project to arrive at overall groundwater production potential. This information was coupled in a dynamic simulation model with surface water, reservoir storage, reuse, and aquifer storage and recovery alternatives. Current and potential future supply sources simulated in the model to examine tradeoffs and assess reliability. For example, there is sufficient surface water to fully meet future demands, but backup

supply would be needed during drought and given water quality challenges surface water is a relatively expensive option. Groundwater peaking for 100% of future supply would stress the aquifers and would likely not provide full supply. A portfolio that includes groundwater, surface water, and reuse results in a balanced system that allows aquifers to recover, provides peaking capacity during drought, and results in a resilient system. This portfolio and others were considered in a tradeoff analysis that reflects the integrated nature of demand, wastewater production, and other available supplies. An integrated water management (IWM) approach was taken in the planning process to examine future supply gaps and assess alternative portfolios.

Jessica Seersma, Colorado State University, Venkatesh Merwade, Purdue University, & Siddharth Saksena, Virginia Tech University - Reshaping the Regulatory Framework: An Equitable Fully Distributed Integrated Water Resources Management Approach Applied to Optimal Green Infrastructure Selection. Though it has evolved over time the traditional regulatory framework that drives implementation of stormwater management practices and green infrastructure typically has just included volume and peak rate reduction, infiltration, and water quality requirements as metrics at the site scale or water/sewershed scale. There has been a shift to include economic, social, and environmental impacts, and environmental equity in the selection of optimal locations and types of green infrastructure practices. However, associated requirements are non-existent, may be loosely defined, and/or are accounted for after an optimal set has been chosen based on the aforementioned criteria. Therefore, there is a growing need to develop non-heuristic integrated water resources management decision support tools and associated modeling approaches to aid in the selection of green infrastructure that directly include all criteria and account for both site and system scale dynamics.

The USEPA Community-Enabled Life Cycle Analysis of Stormwater Infrastructure Costs (Clasic) tool was integrated along with the fully distributed model Inter-Connected Pond Routing (ICPR) as part of a multi-criteria decision support tool to determine the location and GI type ranking for five different types of GI for a 3,210 acre sewershed. A 1D/2D integrated ICPR model was used to assess the surface water, open channel, storm sewer pipe, and groundwater interactions, and to determine the severity and frequency of local flooding. A novel approach to evaluate environmental equity for each location was applied that accounted for racial minority, low income, and disabled community members.

The impacts of non-integrated and variably integrated approaches on optimal rankings were assessed through variations in the direct inclusion of various combinations of assessment criteria. Metrics were developed to assess the overall system impacts through determination of the cost associated with the attainment of target objectives for certain specified criteria for three different hydrologic scenarios and three different sets of antecedent moisture conditions through variation in the initial groundwater table elevation. The results are beneficial in determining how to structure metrics that can be used to reshape the regulatory framework.

Seongjoon Kim, Konkuk University - The Watershed Health, Vulnerability, and Resilience Analysis for Protection and Restoration Priorities of South Korea Watersheds. A good watershed management can be defined as the integrated and repetitive decision process to maintain the sustainability of resources through balanced use and conservation of water quantity, land, vegetation, and other natural resources within the watershed. With the watershed health assessment system, we can have more success in restoring impaired waters and get the many socio-economic benefits from the healthy watershed. Through the integrated assessment results, the local government can get the helpful information of curing weak component of watershed health among water supply, water quality, and natural ecosystem or their interactions. The main objective of this study is to suggest an application strategy for protection and restoration priorities at the watershed scale based on watershed health, vulnerability, and resilience assessments introduced by U.S. EPA (2012) of ”Identifying and Protecting Healthy Watersheds: Concepts, Assessments, and Management Approaches”. The watershed health was assessed using six components of landscape, stream geomorphology, aquatic habitat, biological condition, and SWAT simulated hydrology and stream water quality. The vulnerability was assessed using four components of impervious area change, climate change, recent land use change, and water use change. They were all normalized and indexed from 0 to 1 in each watershed of 850 standard watersheds in South Korea (100,210 km2). The resilience screening was conducted to assess the recovery potential of watershed using the results of integrated capacity, stressor exposure, and social context. The results of watershed health and vulnerability assessments can be used to set strategic management priorities at the watershed scale. Most of the regions in the upstream areas required protection or protection priority, and most regions in the downstream areas required restoration or restoration priority. The outputs of watershed health and vulnerability provide basic data that local communities can use to proactively plan for growth. We feel that further work on the management approaches to integrated watershed assessment will support decision making by national and local governments.

Sarah Dominick & Greg Gates, Hazen and Sawyer - One-sized Water Does Not Fit All. No matter what you call them, integrated planning, integrated water management, integrated water resource planning, or one water type projects have been rising in popularity since the late 1990s. As time has gone by the practice of planning for the urban water cycle has become more integrated and in doing so it has become more difficult to create a standard process for planning.

A key challenge for standardization is the fact that the drivers for integrated planning is dependent on the organization and the

central challenge the planning effort is designed to address. While there are a number of guides and frameworks that offer suggestions for creating an integrated planning effort, these documents often offer general information or are in service of a specific goal. Further complicating are the varied governmental structures organizations must navigate.
This presentation will offer practical, real-world advice on how to navigate an integrated planning effort focused on case studies from successful utilities. It will also breakdown the following widely available frameworks and provide suggestions for where to start on an integrated planning journey.

- Blueprint for One Water – The Water Research Foundation
- One Water Roadmap – US Water Alliance
- One Water for America Policy Framework – US Water Alliance
- Integrated Planning Framework – US EPA
- Progress on Integrated Water Resources Management – United Nations, UN Water

SESSION 35 | Geospatial Integrated System (GIS)

Daniel Philippus, Colorado School of Mines - Modeling the Temperature Response of Small Rivers to Land Cover Changes Using Satellite-based Spatial Data. The influence of urbanization and land cover alteration on water quality, including river temperatures, has important ecological implications. However, there is a dearth of information on temperature of rivers smaller than about 60 m wide (approximately fifth order and below), which constitute roughly 97% of total global stream length: collecting temperature field data for such rivers is logistically infeasible at large (e.g., regional or national) scales, while satellite-based temperature predictions are often inaccurate for smaller rivers. This lack of high-resolution spatial temperature data has hindered large scale assessment of river temperature patterns both spatially and temporally.

This study aims to model the temperature of small, especially urban, rivers across the contiguous United States without requiring field data. Building on a machine learning model for high-accuracy, satellite-based stream temperature estimation, we investigated the relationship between longitudinal changes in river temperatures and nearby land cover conditions, both along the riverbanks and in the general vicinity. The final model was developed to predict changes in temperature of small rivers anywhere in the contiguous United States based on publicly available land cover, climate, and regional data. Using two urban river reaches in the Western United States – the South Platte River in the Denver metro area, Colorado and the Los Angeles River in the Los Angeles metro area, California – we predict (1) temperature changes over time resulting from changes to land cover (i.e., urban development) and (2) the potential for in-stream and riparian restoration to mitigate these changes. Preliminary results indicate that satellite remote sensing-based modeling of river temperatures with high accuracy is feasible and can effectively support restoration efforts.

Mischa Hey, NV5 Geospatial - Remote Sensing Applications to Support Large-scale Riverine and Floodplain Assessment and Monitoring. Remote sensing and spatial analytics have substantial utility to support riverine and floodplain assessment and monitoring at extents not feasible with traditional field surveys. This presentation will provide an overview of relevant technologies such as topobathymetric lidar, sonar, and multiple imagery types, as well processes for integrating and analyzing these data. Broad-scale, objective, and reproducible analytics allow for geographic and temporal comparison across entire river systems to aid in inundation modeling, restoration prioritization, efficacy monitoring, and more. Quantification and mapping of geomorphic features, thermal refugia, floodplain connectivity, riparian vegetation, solar exposure, and water quality are some of the applications we will review. While this presentation is focused mainly on river systems, many of the concepts and data products can be applied similarly to other benthic systems such as ocean or lakes. The goal of this presentation is to provide managers and decision makers information on how remote sensing technologies, data fusion, and analytics can support their operations.

Amanda Lowe, United States Geological Survey - Introducing the 3D Hydrography Program: Data and Infostructure Overview. The 3D Hydrography Program (3DHP) is the hydrography component of the 3D National Topography Model (3DNTM), which will integrate USGS elevation and hydrography datasets. Hydrography features collected for 3DHP will include elevation values derived from the 3D Elevation Program (3DEP) data at each vertex, impose surface water characteristics such as downstream flow direction, and include features such as culverts and connectors to breach natural and manmade blockages to flow.

3DHP data will consist of hydrography and hydrologic units derived from 3DEP data: one-meter resolution digital elevation models (DEM) derived from lidar in CONUS and five-meter resolution DEMs derived from IfSAR in Alaska. The modernized 3DHP data model will also include topological rules for enforcing geometries, store the highest level of detail available for derived stream network features, and processes for generalization. 3DHP will be the geospatial framework underpinning a set of open and interoperable web-based tools, maps, and data catalogs including hydrographic addressing tools to enable users to link water data to 3DHP Datasets and create and share the information as authoritatively managed web-based maps.

SESSION 36 | Water Quality 1

Il Won Seo, Seoul National University - Regressive Prediction of Solute Transport in Rivers for Water Quality Protection. Pollutant spill accidents into rivers have been issued in water quality management because they lead to severe damage on fluvial ecosystem as well as the water supply system. Due to the difficulty of preventing such accidents, swift actions remain a key to minimize such damages. Accordingly, techniques of predicting spilt pollutant propagation along a river has been demanded. Due to computational cost, one-dimensional solute transport models are often used to predict a breakthrough curve of pollutants. In the one-dimensional models, the anomalous streamflow along natural rivers are simply characterized with several model parameters. However, the parameter determination of most studies using the one-dimensional models still relies on optimization techniques using pre-measured tracer breakthrough curves, which are not available in unpredictable spill accidents. Besides, managers of water intake facilities do not require a well-fitted breakthrough curve, but an arrival time of a pollutant cloud to the water intake station and any concentrations in excess of water quality standards.

This study presents a new method to predict a downstream breakthrough curve in an unmeasured river reach. From the tracer breakthrough curves obtained from the tracer tests in rivers in South Korea, we extracted 14 statistical features of each breakthrough curve relevant to river mixing mechanisms, and implemented the correlation analysis between the feature differences of 28 pairs of breakthrough curves and directly-measured flow properties such as flow discharge, flow depth and width, mean velocity, and travel distance (reach length). The results revealed the considerable reach-length dependency of significant features. Using this agreement, the simple regression equations for predicting important features were constructed and applied to breakthrough curve prediction. The prediction accuracy with the proposed method were compared with the tracer measurement and those with other conventional numerical models, 1D advection-dispersion equation and the transient storage model, and the results revealed that the proposed method produced the better accuracies than numerical models.

Kyle Duckett, Alta Science and Engineering, Inc. - Groundwater Collection and Treatment at the Bunker Hill Superfund Site to Improve Surface Water Quality. Groundwater at the Bunker Hill Superfund Site is contaminated with metals resulting from historical mine waste practices in the Coeur d'Alene Mining District. The Central Impoundment Area (CIA) in Operable Unit (OU) 2 is the historical Bunker Hill Company primary tailings impoundment, and groundwater flowing beneath the tailings has been identified as one of the largest sources of dissolved metals to the South Fork Coeur d'Alene River (SFCDR). A baseline groundwater quality dataset has been established, including data from 2002-2018 for groundwater monitoring sites in OU2. The Selected Remedial Alternative (RA) in the 2012 Record of Decision Amendment and subsequent decision documents was to install a Groundwater Collection System (GWCS) consisting of a soil-bentonite cutoff wall and a series of extraction wells downgradient of the CIA. Construction was completed in October 2020, and the GWCS began full operation by the State's contractor in October 2021. Water captured by the GWCS is treated at the recently upgraded Central Treatment Plant prior to being discharged directly to the SFCDR. The GWCS was designed to prevent contaminated groundwater from seeping into the river and to help minimize wetting and drying cycles in contaminated materials, thus eliminating a large contributor of the metal loading to the SFCDR. Groundwater quality sample locations were selected to provide data both spatially and among the hydrostratigraphic units, to establish post-RA performance in comparison with the baseline dataset. Groundwater quality results following GWCS operation will be presented relative to the baseline dataset.

Geoffrey Fouad, Monmouth University - Lake Water Quality Relative to Drainage Area Characteristics at Ten Coastal Lakes in Monmouth County, New Jersey. The water quality of lakes is threatened worldwide, yet the factors contributing to that are often unknown. It is reasonable to assume that the land area draining to a lake relates to its water quality. The size and land cover composition of a lake's drainage area can influence the quantity and quality of runoff carried to a lake. In Monmouth County, New Jersey, a series of ten coastal lakes are at the center of communities where each summer the water quality of these lakes can pose public health and ecological problems. For this reason, Monmouth University's Coastal Lakes Observing Network (CLONet) monitors a number of water quality parameters, such as chlorophyll a, nitrate, and total nitrogen, on a weekly basis in summer. The water quality parameters are averaged here in the summer of 2019, and compared to five drainage area characteristics of the lakes. The lake drainage areas are delineated using a geographic information system (GIS) analysis of a one square meter digital elevation model (DEM). The grid cells of the DEM flowing to a lake's perimeter are identified and grouped together to form the lake's drainage area. The drainage area of the lake then forms the unit of analysis for calculating (1) the area of land draining to the lake, (2) the ratio of the drainage area to the lake area, (3) percent coverage of urban areas, (4) percent coverage of wetlands, and (5) the area-weighted population density of the drainage area. Wetland coverage shows some of the strongest correlations to water quality parameters, with statistically significant positive (0.78) and negative (-0.64) correlations to nitrate and chlorophyll a, respectively. Population density also has correlations to the nutrient composition of lakes, with a significantly positive (0.64) correlation to total nitrogen. In a surprising turn, percent urban coverage has no significant correlations to water quality parameters, and overall, is least related to water quality in these ten lakes. This may be because the drainage areas are largely developed, and there is less variation in percent urban coverage. The results show that population and wetland coverage are related to lake water quality.

SESSION 37 | Streamflow Restoration Planning

Paul J. Pickett, Independent Water Resources Consultant, Tristan Weiss, Washington Department of Fish and Wildlife, Joel Purdy, Kitsap Public Utility District, Matthew Baerwalde, Snoqualmie Tribe. Washington State is seeing more frequent summer drought conditions and unprecedented heat waves. Recent controversies over "exempt wells" – small homeowner wells that don't require a water right – resulted in legislation that called for watershed plans to be developed in many key basins. Yet confusion and disagreement over the intent and language of the legislation resulted in a watershed planning process that was often fraught with discord and failed to reach consensus in multiple basins. Differing viewpoints clashed in the process. This panel will discuss the planning process from multiple perspectives: Tribal, local government, fish agency, water utility. What worked and what didn't? Were opportunities for better planning seized, or missed?

SESSION 38 | Management & Tools 7

Leah Bensching, Hazen and Sawyer - Application of a Water System Accounting Model to Meet Multiple Water Quality Targets and Maximize Cost-efficiency. Water utilities are under increasing pressure to use challenging water sources, particularly in water-stressed regions like Southern California. Recent droughts have limited the availability of surface supplies, and droughts are anticipated to become increasingly severe due to climate change. To reduce reliance on imported surface water supplies which are most susceptible to interruption during drought, utilities are increasing the use of existing and additional groundwater supplies.

Agricultural or industrial activities have been shown to impact groundwater supply water quality, leading to challenges incorporating these new supplies into an existing drinking water system. Because groundwater contaminants are commonly mobile within aquifers, the quality of water at each well can change over time. As a result, lower quality sources increase treatment costs, adding to the complexity of selecting sources to meet water demand while still meeting regulatory water quality requirements.

We present a case study of a water utility with a projected long-term supply deficit exacerbated by increasing system demands and detections of multiple groundwater contaminants. To model the potential sources of water for the utility, a water system accounting model was built to quickly analyze alternative supplies and capital improvement projects. The various sources available to meet the increasing demands over time were characterized in terms of their available maximum day supply (gpm), annual limits (acre-ft/year), anticipated water quality (TDS, PFAS, NO3, etc.), and total cost of water The water quality, cost, and maximum daily supply change over time as groundwater quality changes, new supplies are introduced, and infrastructure alternatives are implemented. The water system model optimizes the uses of supplies to meet demand based on cost after all water quality constraints are met.

This work shows a unique application of system modeling that has the potential to benefit utilities in water stressed regions to optimize local supply sources while limiting treatment and capital improvement costs.

Nick Olsen, United State Army Corps of Engineers Engineer Research and Development Center - The Use of Machine Learning for Calibration to Improve Continental-scale Streamflow Modeling. The Routing Application for Parallel computatIon of Discharge (RAPID) model uses a matrix version of the Muskingum method for the calculation of stream discharge from gridded runoff time series. RAPID can be used to produce hindcasts and forecasts of streamflow in dense river networks. The Muskingum method routes water in the reaches of a stream network based on two parameters: the travel time (k), and wave attenuation (x). In continental-scale hydrologic modelling, rigorous estimation of these parameters is difficult due to the abundance and breadth of reaches and their environs. Current operational models estimate a reach's k coefficient from its length and slope, and x is treated as a global constant. While length and slope play a large role in governing the travel time, other factors are expected to be involved as well, including vegetation, geology, and land use. To account for these remaining influences, this work attempts to calibrate the k and x values across approximately 1000 gaged streams in a routing model of North America that includes more than 2 million reaches. The adjustments made to the calibrated k and x values are submitted to several machine-learning algorithms alongside a quantitative description of the watershed physical environment. ML models tested in this work include Gaussian process regression, Gaussian mixture copula, Random Forest, XGBoost, and Convolutional Neural Network. These algorithms are then used to predict the adjustment factors for ungaged streams. At present, results indicate an average prediction skill R-squared value of 0.68.

Casey Ryan, Confederated Salish & Kootenai Tribes - CSKT Water Measurement Network - Tools for Real-time Instream Flow and Environmental Compliance. The Confederated Salish & Kootenai Tribes' (CSKT) Resources Department operates an expansive hydromet network comprised of stream, canal, reservoir, groundwater, snowpack, and miscellaneous hydrologic measurement efforts. The CSKT gage network has historically been used to ensure compliance for instream flows, ESA compliance for return flows, irrigation water management, and for various hydrologic analyses.

The majority of this water measurement occurs within the footprint of the Flathead Indian Irrigation Project (FIIP), the largest irrigation project in the state of Montana. The FIIP is located primarily within the boundaries of the Flathead Indian Reservation and supplies water to approximately 127,000 acres of agricultural land. The project consists of over 1,000 miles of canal and lateral

systems, and 14 primary irrigation reservoirs. The project is owned and operated by the Bureau of Indian Affairs with technical input from the Confederated Salish & Kootenai Tribes.

As part of the CSKT and the Compact Implementation Technical Team's (CITT) water rights compact implementation efforts, the CSKT have significantly expanded their measurement network. CSKT staff presently maintain over 80 stream, canal, and reservoir gages, and have updated each location to publish data to the internet in real-time.

This expansion of the CSKT measurement network will provide for the adaptive water management and regulatory compliance requirements which will phase in with the settlement. The CSKT and CITT are also planning future upgrades to the measurement network to provide real-time data on irrigation reservoir storage levels.

CSKT currently publishes their data to the internet in real-time utilizing the AQUARIUS WebPortal software. This has allowed for instantaneous checks of environmental compliance, and provides an important better decision support tool for system-wide irrigation water management.

We anticipate that these cumulative upgrades to the CSKT water measurement network will provide for better protection of instream flows, better streamflow management, allow for integrated water resource planning, and provide for more efficient and consistent irrigation water deliveries.

Sayan Dey, Purdue University - CyberTraining Modules for Findable, Accessible, Interoperable, and Reusable (FAIR) Science in Water and Climate. Addressing the grand challenges associated with growing population, food and water security, frequently occurring natural disasters, and changing climate require not only domain expertise, but also computational expertise to deal with big data analytics and simulations. However, formal training is lacking at most institutions to train students to handle big geoscience related data, develop computational workflows, use high performance computing (HPC) for scientific simulations and publish digital products, including data and models. Such training, referred here as cyber training, is critical for addressing the grand challenges such as in sustainability and resilience. Cyber training is also needed to make the science openly available and transparently reproducible by using the best practices in Findable, Accessible, Interoperable, and Reusable (FAIR) science as articulated by many scientific institutions. The overall goal of this work is to create a new generation of geoscientists to produce FAIR science using big data analytics, computational simulations and HPC. Specifically, we are developing a curriculum for cyber training that is driven by the need to acquire expertise in the following areas: data access, processing, visualization and publication. This presentation will discuss the overall water and climate FAIR cyber training curriculum, their implementation at Purdue University, summary of work by FAir CyberTraining (FACT) Fellows, and outcomes from the first cyber training workshop.

SESSION 39 | Flood Risk & Management 3

Zeda Yin & Arturo Leon, Florida International University - Improving Water Stage Prediction Using Several Deep Learning Models. Riverine floods, which often occur during heavy precipitation events, could cause substantial damage, including property and human life loss. Knowing ahead of time the maginitute of water stage at critical locations is critical for water managers to make decisions to mitigate floods. Conventionally, engineers have adopted physics-based numerical models (HEC-RAS, MIKE 9, Telemac, etc.) to forecast water stages in river systems during flood events. However, these numerical models are often not fast enough for near real-time flow optimization and issue flood warnings in a timely manner. Thus, an accurate ultrafast model to predict water stages is essential for real-time optimization. This paper presents several deep learning models to predict water stages, which will play the role of "environment" in the upcoming optimization phase. The downstream segments of the Miami river with two tributaries, Florida, is chosen as the case study in this paper. The training dataset consists of historical records (2010-2018) at several water stations, including water stages, flow rates, pixel rainfall intensities, gate positions, and pumping flow rates. The results of the deep learning model are compared to the test dataset (2019-2020). Comparing the various deep learning models with historical data and the physics-based HEC-RAS model shows a good agreement. The deep learning models provided the results with MAE (Mean Absolute Error) of [0.1, 0.2] feet, which is comparable to the performance of the HEC-RAS model. Different time intervals have also been tested to explore their influence on the models' performance.

Lilit Yeghiazarian, University of Cincinnati - The Urban Flooding Open Knowledge Network: Delivering Flood Information to Anyone, Anytime, Anywhere. This talk will introduce the Urban Flooding Open Knowledge Network (UFOKN) funded by the NSF Convergence Accelerator program. The goal of UFOKN is to increase urban resilience and minimize damage from future urban floods due to changing climate and changing land use patterns. It will allow queries that produce actionable information on what to do during storms and flooding, how to plan long-term, and how these decisions will contribute to urban sustainability and resilience

Floods impact a series of interconnected urban systems – the Urban Multiplex, that include the power grid and transportation network, surface water and groundwater, sewerage and drinking water systems, inland navigation and dams, all of which are intertwined with the socioeconomic and public health sectors. The real impact of flooding on the Urban Multiplex is currently very

difficult to quantify because many of its systems are independently designed and managed. Hence an open knowledge network that captures the interconnectedness of these systems and how they impact each other is critically needed. This project links the Urban Multiplex information, whose subsystems generate data that have traditionally been not interoperable, and enables meaningful queries on flood-related information relevant to urban sustainability.

The convergence research and development team supporting this effort has integrated researchers and methods from across disciplines including civil and environmental engineering, hydrology, geography, computer science, meteorology, public safety, emergency response, and economics. The partners engaged as advisors, potential users, and developers include more than a dozen municipalities and water management districts, federal agencies (NOAA, USDOT, NIST, USGS, EPA, FEMA), a national lab (PNNL), non-profits (Consortium of Ocean Leadership, Woods Hole Oceanographic Institution, Consortium of Universities for the Advancement of Hydrologic Science), for-profit organizations, consortia, and individuals.

Shirley Clark, Penn State Harrisburg - Cloudburst Storms and Urban Development: Impacts of Flooding on Residents and Infrastructure. Due to climate change, much of the eastern US is predicted to have more rain in shorter time periods, leading to series of flash floods and flash droughts. Middletown, PA is already seeing this with a flash flooding storm occurring approximately every two years – 4.71 inches of rain in 85 minutes, 2.22 in in 66 minutes, 0.85 in. in 20 minutes. In each of these incidents, road closures occurred and basements took on water. Cars got stuck in low-lying areas, resulting in totaled cars. For those residents whose property is ruined in these storms, there is limited assistance outside of insurance because these storms do not rise to the level of a state or federal disaster. And many residents are not insured because they do not live along a river; this flooding is occurring along the stream of storm sewer pipes whose capacity is being exceeded. This research project attempts to holistically address this issue. First the project is focusing on the characteristics of land development (compacted soils, trenching and filling in trenches, burying streams, types and hydraulic efficiency of the storm sewer system, etc.). Sensors are monitoring soil infiltration rates both horizontally and vertically in real time to better understand shallow subsurface flows that are entering the storm piping system. Level sensors are installed in the pipe run that contains the local stream named Bloody Run that was buried approximately a century ago. Field tests in this area show a compacted layer approximately 6 inches below the land surface in several areas, creating an impermeable barrier that drives infiltrating water horizontally towards the low-lying areas such as stormwater pipes and basements. The models that were developed several years ago are being calibrated using the data. However, this engineering/science data does not capture the impacts on residents. Storytelling, especially of long-term residents and those that live near the buried stream now, will be used to understand the impact of these floods financially and psychologically. Residents have records of when these floods occurred, what appliances had to be replaced, how deep the water was, and what the toll was in terms of stress and lost wages. This project is storytelling to give residents voice and so that we can glean information about their experiences and begin to help the borough frame solutions that will both work in an engineering sense and that meet the residents' goals

***Michael Bianchini, University of Illinois at Urbana-Champaign - Rapid Decision-support Tool for Issuance of Flood Evacuation Orders.** Emergency managers are challenged to make effective and timely evacuation decisions prior to impending floods to reduce consequences. Traditional tools, such as hydrologic models, provide detailed information to managers about forecasted flood characteristics but do not consider how humans might behave during an evacuation event. An integrated, agent-based modeling framework is introduced to resolve human decision and traffic dynamics during flood evacuation events. The agent-based opinion dynamics model and a large-scale agent-based transport model (MATSim) are coupled with an optimization model (SCIP) and flood inundation model (National Water Model) to develop the decision support framework. Tradeoffs between flood risks on the road and at home are minimized. The framework is applied using a machine learning-based algorithm to develop a city-specific rapid and easy-to-use decision support tool, which recommends evacuation order policies to emergency managers. Recommendations include when and where to issue suggested and/or mandatory flood evacuation orders based on the severity of a forecasted flood event and lead time to flood arrival. The tool will be installed in the platform of Urban-Flooding Open Knowledge Network (UFOKN), a project being supported by National Science Foundation (NSF). A demonstration of model development and tool application is presented for a forecasted flood event in the City of Wilmington, NC. Efforts to apply the tool to cities across the Contiguous United States (CONUS) are discussed.

SESSION 40 | Surface Water 1

***Mara Getachew Zenebe - System-wide Nexus Analyses: Water Management and Distribution Rules, Agricultural Productivity, and Livelihoods in Flood-based Livelihoods Systems.** Flood-based Livelihood Systems (FBLS) make productive use of floods that are inherently unpredictable in timing and volume. FBLS are substantial: they cover 25 million hectares across water stressed basins in Africa and Asia, potentially providing water and food security for 50 million farmers and pastoralists. They also deliver environmental benefits including recharging groundwater, reducing soil moisture and soil fertility depletion.

Water distribution rules in FBLS have a key role in enhancing system-wide productivity and livelihoods. While such potential has to a certain extent been harnessed in some FBLS in Asia such as the DG Khan in Pakistan; it has not yet been fulfilled in FBLS in Africa as

demonstrated in Tana River and Fogera in Kenya and Ethiopia respectively. Drawing from discussions with 153 Pakistani FBLS farmers, the paper establishes that a package of water distribution rules has significantly contributed to mitigating flood damage and excessive upstream floodwater use, reducing downstream water scarcity, and realising nearly 4 ton/ha of the major wheat crop across the upstream and downstream areas. This yield is 20% higher than the country-wide average, and two-third of the maximum achievable. Furthermore, 86% of the upstream and 76% of the downstream farmers fully covered their livelihood needs. On the other hand, the analyses based on discussions with 126 Ethiopian and 195 Kenyan FBLS farmers, uncovered the negative consequences of the absence of a comprehensive package of water distribution rules. In Kenya, the downstream small-scale farmers that account for two-third of the Tana River FBLS population frequently suffer from floodwater scarcity. They could not cultivate the high return rice crop and their staple maize yield was low at about 1.25 tons/ha, 20% of the maximum attainable. Four in five reported poor livelihoods. The upstream large-scale farmers however often diverted excessive floodwater; they usually grow rice as well as maize for home consumption. The situation in Fogera is similar. The water distribution rules prioritised the upstream rice cultivation introduced a decade back to boost economic growth. This caused downstream floodwater scarcity resulting in about 30% maize yield reduction and livelihood deterioration. These findings on the impacts of water distribution rules can contribute to formulating investments that better achieve the productivity and livelihood potentials of FBLS across Africa and globally.

Johnny Boggs, United States Department of Agriculture Forest Service - Converting Naturally Regenerated Mixed Pine-hardwood to Loblolly Pine Plantation Forest Reduces Streamflow in the Piedmont of North Carolina. There were almost no pine plantations in the southern United States in the 1950s. Now there are over 39 million acres of planted pine with most of that expansion occurring over the last twenty-five years to meet the rising demand for wood. Land management practices that include species conversion can have consequences to surface water availability by altering total forest transpiration. In 2010, two mixed-pine hardwood watersheds located in two different North Carolina Piedmont basins (i.e., Carolina Slate Belt, (CSB) and Triassic Basin, (TB)) were clearcut. In 2010, loblolly pine (Pinus taeda) was planted in the CSB watershed and shortleaf pine (Pinus echinata) was planted in the TB. Plot-level basal area measurements and continuous streamflow were monitored in each watershed to quantity how streamflow changed following the conversion from mixed-pine hardwood to pine. The CSB soils are thick, well-drained, and tend to function in a similar capacity across seasons. Conversely, the TB soils are thin, with a confining clay layer 30cm below ground surface, and are more prone to stormflow generation than CSB particularly in nongrowing seasons. We found that annual water yield increased by 260% in the CSB and 250% in the TB one year after the clearcut. However, yield decreased in subsequent years due to a rapid growth of the planted pines. By 2019, annual water yield was 8% less in the CSB than if the hardwood trees had not been cut. Despite the different soils, changes in basal and species are a more powerful regulator of annual hydrology in these ecosystems. This study is ongoing and the growth of the young pine trees will continue to be linked to streamflow, groundwater, and soil moisture measurements. Data from this project will help public and private landowners decide how to most effectively sustain forest and water resources together with silvicultural activities across the Piedmont region. Study results also have important implications to evaluate the role of vegetation in regulating storm runoff in the rapidly urbanizing Piedmont region in the southern U.S.

Anneliese Sytsma, Colorado School of Mines - Channel Restoration in Highly Urbanized Systems: Using Ecological Flow Targets to Optimize Channel Design Under Future Management Scenarios. The desire to restore urban rivers to improve habitat and provide social amenities can be complicated because flows are often highly altered and managed to accommodate water quality (e.g., stormwater capture), flood protection, wastewater discharge, and water reuse. Urban river restoration must account for unnatural flow regimes but should still be optimized to accommodate the needs of target species and habitats of management interest. This study evaluates design options for instream restoration in the Los Angeles River that can offset the effects of flow augmentation or depletion associated with water reuse and stormwater management. Ecological flow targets associated with species of management concern (Willow, Steelhead, and Santa Ana Sucker) were computed from hydraulic-ecology models. Anticipated changes to flow were simulated using the EPA Stormwater Management Model (SWMM). These flows were routed through a 1-D Hydrologic Engineering Center River Analysis System (HEC-RAS) model of the Los Angeles River, used to simulate hydraulics and iterate potential channel cross-section configurations across the changes to flow. The resulting hydraulic outputs (for each flow scenario) were then compared to the ecological flow targets. The results indicate that a range of channel restoration designs may satisfy ecological targets under managed flows, and also identify the trade-offs between water management goals and target species habitats. For example, we find that even with optimized/redesigned channels, high water reuse scenarios might not yield the best ecological outcomes for Steelhead and Santa Ana Sucker. Furthermore, we find that optimal channel design can vary across species targets and life stages, e.g., with deeper low flow channels meeting depth and shear stress targets needed for adult Willow survival, but shallow low flow channels providing more consistent inundation for Willow germination. Overall, this study illustrates the potential to use ecological flow targets combined with iterative hydraulic modeling to guide restoration design in highly modified urban systems and offers an approach to weighing the trade-offs between the future of sustainable water resource management and ecological conditions.

SESSION 41 | Water Supply 1

Richard Niswonger, United States Geological Survey - Development of National Water Use Models for Public Supply, Thermoelectric, and Irrigation. The USGS Water Availability and Use Program (WAUSP) is changing how national 5-year water use summaries are produced as compared to previous summaries that were produced during the last several decades. Previous 5-year summaries at a county resolution were prepared from water use data compiled by USGS water science centers in each state, often relying on furnished raw data and disparate approaches to produce country summaries in each state. The USGS is now developing water use models designed to provide nationally consistent water use estimates at a monthly, HUC12 resolution. Initially, the water use models will be used to produce a monthly reanalysis for the historical period 2000-2020 and to provide greater understanding about the trends and driving factors for public supply, thermoelectric, and irrigation water use that make up more than 90% of the total national water use. Subsequently, additional water use models will be developed representing other major water use sectors in the US. Water use reanalysis will provide a basis for developing seasonal to multi-decadal forecasts of water use to support decision making and to better understand water shortages and their associated environmental factors. The public supply, thermoelectric, and irrigation water use models consist of combined physics-based and data driven/machine learning modeling approaches and include many national data sets being developed by the USGS and grant partners.

Rebecca Guo, Stantec, Kyle Ericson, El Dorado Water Agency, & Stephen Pang, Stantec - Building Resiliency for Rural Foothill Small Water Systems. With California's ongoing drought, dwindling snowpacks, increasing wildfire threats, and aging infrastructure, the water supply reliability of small water systems in El Dorado County's rural Sierra Nevada foothills are under constant threat. Many of these small water systems rely on fractured rock groundwater or local springs that need sufficient annual winter precipitation which is becoming rarer with the realization of climate change. Furthermore, the remoteness and significant elevation changes between each system make it prohibitive to successfully consolidate, which is one of the often-recommended soutions to improve small water system reliability.

El Dorado Water Agency (Agency), whose mission is to ensure that El Dorado County has adequate water for today and in the future since its formation in 1959, recognizes these issues and identified strategies to improve small water system reliability in its 2019 Water Resources Development and Management Plan. They have been working in partnership with local governments, including the County of El Dorado, public water agencies, small water systems, the community, and others to improve small water system reliability. Consistent with the new Senate Bill 552 (Hertzberg, 2021), the Agency is the lead in facilitiating a county drought task force and developing countywide water shortage plan to improve preparedness and resiliency of small water systems. This includes working collaboratively to collect data, identify vulnerabilities, formulate mitigation and response actions, and support implementation.

This presentation will overview the challenges encountered associated with improving water supply reliability for small water systems in El Dorado County, and the instrumental collaboration role the Agency has and continues to fill to promote coordinated and successful steps towards improved reliability.

Phoebe Aron, Jeremy Hise, Josh Weiss, Hazen and Sawyer, Steve DeRidder - Berkeley County Public Service Water District, Resilience and Reliability at the Edge of Urban Sprawl: Long-term Water Supply Planning in Eastern West Virginia. The Berkeley County Public Service Water District (BCPSWD) operates the Bunker Hill Water Treatment Plant and produces up to 2.8 mgd for approximately 30,000 Berkeley County residents in eastern West Virginia. However, local population and regional water demand will soon exceed the current plant capacity because the County is located near Washington, DC and northern Virginia and is rapidly growing. To address these challenges, the plant is undergoing a major renovation that will improve water supply and increase the treatment capacity to 6.0 mgd. These upgrades will allow BCPSWD to effectively manage regional water resources and continue to supply safe and reliable drinking water to Berkeley County residents for decades to come.

This presentation will explore future water resource planning, supplemental and emergency water supply development, source water quality, and water treatability associated with long-term regional supply planning and the ongoing plant upgrade. In particular, the current raw water source, a groundwater spring located near the plant, cannot consistently supply 6.0 mgd or meet projected future water demands. As a result, BCPSWD is exploring a new active quarry source that could provide an additional 2.0 mgd of raw water. Quarry water was supplied to the plant in 2002 when drought conditions caused the primary groundwater spring to go dry, but this was only permitted on an emergency basis and quarry water is pumped directly into a nearby creek under normal operations. First, this presentation will explore the water resource considerations associated with the quarry supply, including flow-by requirements and aquatic impacts in the creek, local hydrogeology that supports groundwater flow, and drought operations that may limit the quarry supply. Second, the presentation will discuss source water protection plans and water quality monitoring programs to ensure long-term reliability of water supplies. Third, this presentation will outline the regulatory requirements and capital infrastructure needed to connect quarry water with the existing water supply and upgraded plant. Taken together, this presentation will provide insight and lessons about future water supply planning in a region that is experiencing rapid growth and increasing water demands.

Courtney O'Neill, AECOM, & Venus Price, Houston Water - Source Water Protection Planning: A Paint by Numbers Approach to Protect the City of Houston's Drinking Water Supply. Source water protection (SWP) planning is an important component of the multiple barrier approach to producing safe drinking water. However, when you are charged with managing one of the largest and most complex water systems in the nation and are resource constrained, the process can be complex and overwhelming. We worked closely with the Drinking Water Operations team for Houston Water to design a multi-phase source water protection program that helps break down a complicated process into a manageable approach – just like painting a landscape via paint by numbers- by focusing on one step at a time.

During the first phase, we focused on understanding the existing federal, state, and local regulations for SWP. We found over 250 regulations that govern the protection of Houston's water supply sources, which is significant to manage for a small team. To make things manageable, two spreadsheet tools were developed to evaluate and track compliance with regulations- one for surface water and one for groundwater. The spreadsheets allow the regulations to be searched, sorted, and reviewed to determine compliance at the regulation or system component level. It also notes which department or agency is responsible for management activities, which facilitates conversations across departments in a multi-jurisdictional system.

The next steps in the program will identify and prioritize water quality and related watershed problems and develop protection and/or remediation strategies based on the assessment of the sources and their susceptibility to contamination. The program will continue to roll out in phases, painting a clearer picture of source water protection with each step.

This presentation will talk about lessons learned during the development of the tools and focus on how this paint by numbers approach can be implemented in other systems with similar resource constraints so that managers can implement ambitious protection plans in realistic and manageable steps.

SESSION 42 | Water Quality 2

Jae Ryu, University of Idaho - Autonomous Unmanned Vehicle Platforms for Real-time Water Quality Monitoring. Urbanization, land use change, and economic development continue to affect water quality standards in the nation's open waterways, such as rivers, lakes, and reservoirs. Although conventional water quality monitoring exercise contributes to the water community, additional investigation is still needed to enhance real-time water quality monitoring for public safety. A couple of unmanned vehicle platforms, including unmanned aerial vehicle (UAV) and unmanned surface vehicle (USV) are used to advance real-time water quality monitoring along with the cloud-based data sharing platform via Long-term Evolution (LTE) communication protocols. During the presentation, we will discuss pros and cons of these systems and explore potential alternatives to leverage the existing citizen-science projects for broader impacts. Collectively, the proposed UAV and USV platform will contribute to environmental stewardship in water research ecosystems.

Il Won Seo & Siyoon Kwon, Seoul National University - Monitoring of Suspended Sediment Concentration Using Hyperspectral Remote Sensing in Shallow Waters. Suspended sediment is one of the crucial factors of the natural processes occurring in river systems, which changes the river morphology and has an enormous influence on the river water quality. However, monitoring suspended sediment concentration (SSC) in continuous way over a large space is very difficult and requiring a lot of cost and time since the measurement of the SSC has been depending on the direct measurement method using a traditional sampler. Therefore, to overcome the limitations of the existing monitoring system, this study proposed a hyperspectral imagery-based SSC monitoring method. In this study, we focused on SSC monitoring in shallow waters, which is challenging because of the increased spectral variability of the water arisen from various types of suspended matter in the water and the heterogeneous streambed properties. We dealt with this spectral variability problem by combining hyperspectral clustering and Random Forest Regressors (RFRs). The hyperspectral clustering separated the complex dataset into several homogeneous datasets according to spectral characteristics. Then, the RFR models corresponding to separated data sets were built to construct the relationship between spectrum in hyperspectral imagery and SSC. The model validation was carried out in two sites: the Hwang River; and the confluence of Nakdong River and Hwang River in South Korea. The streambed substrates of both rivers were dominantly fine sand; thus, morphological change and sediment transport also occurred in various ways. The validation results showed that the proposed method successfully retrieved the spatial distribution of SSC at both sites. Furthermore, it substantially improved the accuracy of SSC estimation and retrieved the SSC mixing pattern of river confluence in greater detail compared to the conventional measurement method.

***Vedant Janapaty, Silver Creek High School - A West Coast Estuarine Case Study: A Novel, Predictive Approach to Monitor Estuarine Eutrophication.** Estuaries are wetlands where freshwater from streams mixes with salt water from sea. Also known as "kidneys of our planet"- they are extremely productive environments that filter pollutants, absorb floods from sea level rise,and shelter a unique ecosystem. However, eutrophication and loss of native species are ailing our wetlands. There is a lack of uniform data collection and sparse research on correlations between satellite data and in situ measurements. Remote sensing (RS) has shown great promise in environmental monitoring.

This project attempts to use satellite data and correlate metrics with in situ observations, collected at estuaries. Images for satellite data were processed to calculate 7 bands (SIs) using Python. Average SI values were calculated per month for 23 years. Publicly available data from estuaries was used to obtain 10 parameters (OPs). Average OP values were calculated per month for 23 years. Linear correlations between the 7 SIs and 10 OPs were made and found to be inadequate (correlation = 0 to 44%). Fourier transform analysis on 7 SIs was performed. Dominant frequencies and amplitudes were extracted for 7 SIs and four machine learning(ML) model algorithms were trained, validated, and tested for 10 OPs. The OPs saw improved R2 values in the range of 96.1% to 99%.

This novel approach can be used to get periodic analysis of overall wetland health with satellite indices. It proves that remote sensing can be used to develop correlations with critical parameters that measure eutrophication in situ data and can be used by practitioners to easily monitor wetland health.

***Nathaniel Hess, University of Sydney - Linking Temporal and Spatial Changes in Estuarine Water to Oyster Aquaculture Using Novel Remote Sensing Approaches.** Destruction of oyster reefs has resulted in the loss of key ecosystem services provided by these structures in estuaries. However, questions remain as to whether the ecosystem services provided by oyster aquaculture can mitigate that loss. This project used a novel approach to study how large-scale temporal and spatial variations in estuarine conditions are related to oyster aquaculture intensity using remote sensing. Aquaculture infrastructure was mapped at 6 sites in 4 estuaries from 2010-2021. Landsat and Sentinel remote sensing data was extracted upstream and downstream of these sites, and at matched control sites. Two remote sensing algorithms (green:red and blue:red), shown to be related to Secchi Depth in NSW estuaries, were used to examine water color changes upstream and downstream of infrastructure and control sites over time. Results showed that aquaculture infrastructure has the capacity to stabilize water colour across all sites, but the effects on mean water colour was variable between sites. Two out of the six sites showed significant changes in water color upstream and downstream of infrastructure. This implies that aquaculture infrastructure can provide valuable outcomes for estuarine conditions, but that their effect depends on environmental context. This study also provides a framework for establishing relationships between in-situ and remote sensing data in coastal estuaries around the world.

SESSION 43 | Community Driven Relationship - CANCELED

SESSION 44 | Drought

Maritza Flores Marquez, Stantec - California Drought Planning for State Small Water Systems and Domestic Wells. California Senate Bill (SB) 552 is part of the implementation of the California 2018 Water Conservation and Drought Planning Legislation (Legislation). The 2018 Legislation provides a new approach to urban water conservation, additional requirements for agricultural water use, and a series of requirements to improve drought planning, including the vulnerable small water suppliers and rural communities that were struggling in the 2012-2016 drought in California. As the conditions for small water suppliers and rural communities are diverse, the 2018 Legislation directs the California Department of Water Resources (DWR), in coordination with the State Water Resources Control Board (State Water Board), to develop recommendations to the Legislature for actions to improve drought planning for small water suppliers and rural communities. The 2018 Legislation did not provide a definition for small water suppliers or rural communities, although it was implied by the definition of urban water suppliers who are subject to the requirements in a separate part of the legislation. SB 552 provides such definitions and refines the focused water systems with customized requirements. The 2018 Legislation makes specific references to counties regarding their potential role and responsibilities in land use planning, drought planning for small water suppliers and rural communities in line with counties' jurisdictions over certain small water systems and those under the Sustainable Groundwater Management Act of 2014. Since the passage of SB 552, DWR, in coordination with State Water Board, developed an approach for implementing SB 552 and meeting the specific requirements outlined for DWR. DWR has developed a guidebook for California counties to develop their corresponding drought plan to cover the emergency response needs of State Small Water Systems and domestic wells within a county to address drought vulnerability and potential water shortages.

This presentation will present the guidebook and approach for developing the guidebook for California counties to develop their drought plan for integration with existing county plans including but not limited to existing general plans, local hazard mitigation plans, and Groundwater Sustainability Plans. The developed guidebook provides California counties with the tools to better improve water supply reliability and better prepare for water shortage conditions.

***Ji Eun Kim, Jiyoung Yoo & Tae-Woong Kim, Hanyang University - Comprehensive Drought Risk Assessment Using PLS-Structural Equation Model and Bayesian Network.** Drought risk is not only a natural phenomenon but also an interaction with society and the environment. If a drought has already occurred, the damage is quite serious due to various drought characteristics. In particular, water supply and demand closely linked to the local community have a significant impact on the drought risk. Therefore, it is necessary to assess the drought risk in order to mitigate damage to the social economy by analyzing these interactions and identifying the impacts of drought in advance. The main purpose of this study is to comprehensively assess drought risk combining hazard, vulnerability, and response capacity considering regional water supply system. To do this, a structural equation model was

used to select the impact factors of drought risk so that the subjective opinions of the evaluators could be excluded and the relationships between factors of drought risk could be considered. In addition, various objective weighting methods such as Bayesian network were applied when estimating drought vulnerability and response capacity. As a result, the drought risk of Bucheon in Gyeonggi, which has the highest vulnerability, was the highest at 0.46, and that of Gumi in Gyeongsang, with poor hazard and response capacity, was the highest at 0.34. In Chungcheong, Daejeon with high hazard and vulnerability showed a high risk of 0.44, and in Jeolla, Goheung, where vulnerability and response capacity are poor, had the highest at 0.42. Finally, in Yeongwol, Gangwon, all three values are dangerous, so the risk is the highest at 0.45.

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Jason Lillywhite & Danyal Aziz, GoldSim Technology Group - Simulating Stochastic Precipitation Driven by Long-term Drought. Persistent droughts are the new normal in the Southwestern United States. Several states in the region are experiencing lower than average precipitation amounts, deficient soil moisture levels, and decreasing streamflow yields and water storage. The effects of persistent droughts have been more pronounced in recent years. There is a consensus among the sciences that climate change will exacerbate the magnitude, frequency, and duration of the droughts in the region, which is even more alarming. Droughts in general and persistent droughts specifically present a severe environment al and economic challenge, expected to result in more significant risks to society, agricultural and industrial sectors. These threats across the sectors from the expected increasing frequency of droughts, point to the need for simulation tools that can incorporate these risks as a function of the changing climate and long-term droughts. This study summarizes the results and performance of a stochastic weather generator with a new approach to modeling droughts based on historical drought observations in a case study region in the Southwestern US. The process has been applied and tested using the GoldSim dynamic simulation platform with an implementation of the US National Weather Service's Weather Generation tool, "WGEN." Initial results show that historical observations of precipitation can be used to build a robust simulation and forecasting tool to evaluate ranges of plausible drought scenarios using Monte Carlo simulation.

Lee Ellenburg, University of Alabama in Huntsville - Evaluation of the National Water Model During Low Flows Across the Southeastern US. Accurately simulating and predicting streamflow during low flow periods is critical to understanding water availability especially in terms of water use and water resources planning. This can be particularly acute in regions like the Southeastern US. where overall water availability is abundant, however, the ecosystem that has evolved in such an environment generates a rapid hydrologic cycle. Thus, the timing and variability of summer season streamflow is critical for water users and planners across all sectors. Towards that end, the National Water Model configuration of WRF-Hydro was run over the Alabama-Coosa-Talapoosa river basin in the Southeastern US and evaluated during low flow conditions. Two key processes were examined: (1) the parameterization of reservoirs and dams and (2) the land surface water balance and routing mechanisms. The results of this study will highlight areas where the model is performing satisfactory and provide clues towards where the model can be improved for low flow considerations.

SESSION 45 | Thermoelectric Water Use

Kenneth Skinner, United States Geological Survey, Melissa Harris, United States Geological Survey, Amy Galanter, United States Geological Survey, Melissa Lombard, United States Geological Survey. Humans impact water availability for a myriad of uses. Thermoelectric power plants are the largest users of water among water-use sectors due to the amount needed to cool and condensate steam used to generate electricity. Quantifying the amount of water use at spatial and temporal scales relevant for water-use managers is necessary for protecting the resource. Federal- and state-reported thermoelectric water-use data have differed historically. Additionally, USGS has provided 5-year snapshots of average annual thermoelectric water use at the county level, scales not conducive to water-resource management or availability studies. USGS has recently developed physics-based models that provide consistent methods to estimate thermoelectric water use across generation and cooling-system technologies at the plant level and monthly time scale. Furthermore, USGS is developing machine-learning techniques to estimate near-real time and forecasted thermoelectric water use. This session will present updated methods and estimates of thermoelectric water use across the United States.

SESSION 46 | Surface Water 2

Joseph Brascher & Doug Beyerlein, Clear Creek Solutions - Can Engineers Trust Modern Low Impact Development Designs? Can engineers trust their stormwater designs? There is a stark difference between designing stormwater elements on paper and how these elements act in the real world. Water resources engineers must be able to trust that their designs can be replicated in the field properly. Even as the use of bioretention and stormwater treatment increases in new and redevelopment in the Puget Sound region, surprisingly little assessment has been conducted of the hydrologic performance of constructed facilities. As population grows and developable space in the Puget Sound region is increasingly scarce, natural stream channel ecosystems remain vulnerable to stormwater runoff, pollution, and erosive flows. To confidently create effective stormwater designs, modelers need to be assured that the elements represented in stormwater software perform realistically. Low Impact Development (LID) facilities such as rain

gardens, planter boxes, and roadside embankments can be used to reduce stormwater runoff. These soil-based facilities filter stormwater for pollutants and provide storage to runoff. Infiltration and evapotranspiration from these facilities can reduce runoff volume and peak flows. Bioretention facilities have been the elements of interest for LID studies and research.Clear Creek Solutions has created a state-of-the-science continuous simulation hydrologic computer model of the movement of water through the soil for LID modeling. The continuous simulation computer model, WWHM2012, uses the modified Green Ampt equation to compute the surface infiltration into the top soil layer, and Darcy's and Van Genuchten's equations for the lower layers.The hydrologic performance of ten bioretention facilities in the Puget Sound region have been studied using WWHM2012. The research found that the range in performance in terms of ponding depths and well point elevations met or exceeded the expected WWHM2012 model graphical results comparison with the monitored data for many of the sites. This research also shows that WWHM2012 represented the performance of these elements in the field. The models of the ten bioretention sites reproduced the monitored hydrologic performance data with accurate results when viewing long-term trends. In the presentation, hydrologists and stormwater modelers will learn how WWHM2012 accurately models these bioretention facilities and specifics of the study's results and long-term ramifications.

John Clayton, Hazen and Sawyer- New Basin Modeling Approach for Georgia and its Application in Regional Water Use Planning. Georgia EPD has recently completed development of next-generation surface water supply models for all basins in their state. These models, termed Basin Environmental Assessment Models (BEAMs), utilize a Linear-Programming-based simulation approach (the OASIS platform) to incorporate high levels of spatial detail within stream network models. BEAMs explicitly represent the water use operations of every permitted surface water withdrawer, discharger, and supply reservoir in each basin, primary river, and tributary over an 80-year daily hydrologic period. Despite this temporal scale and spatial complexity, BEAMs are easily reconfigurable and have fast runtimes, supporting rapid and interactive evaluation of structural and operational water supply alternatives and their resulting basin-wide impacts. Over the second half of 2022, these models were paired with forecasts of water needs for permittees, thereby identifying potential future water availability challenges. These results were used by Regional Water Planning Councils throughout Georgia to understand those challenges and con template management practices to address them. This presentation will give an introduction to the BEAMs and their simulations of future conditions, describe various methods for translating flow and storage outputs to performance measures (i.e. indicators of environmental quality, supply reliability, economic suitability, etc.), then highlight some of the resource assessment results that successfully informed the Planning Councils in the planning process.

Lilit Yeghiazarian, University of Cincinnati - Impact of Nodal and Edge Dynamics on Controllability of Flooding Networks. Despite local and federal mitigation plans, damages due to inland flooding have been on the rise in the past few decades. In order to prepare for disastrous flooding events, it is essential to understand the control measures needed to contain or limit the extent of damages. From a systems analysis point of view, a system is called controllable if, with a proper choice of inputs, it can be driven from any initial state to any desired state. Viewing flooding networks as a system, controllability can then readily be interpreted as the ability to control flow levels – a major goal in flood mitigation and management.

Hydrologic networks are typically represented as a collection of nodes symbolizing junctions, inlets and outlets, and edges (links) symbolizing stream paths. Typically, controllability is measured through nodal dynamics. However, due to the importance of dynamical processes that occur along the flow conduits (i.e. edges), edge dynamics can highly affect our ability to control such networks.

In our earlier study (Riasi & Yeghiazarian, 2017), we studied controllability of hydrological networks by focusing on nodal dynamics where we proposed a set of four metrics (Full controllability, Target control efficiency, control Centrality, and control Profile – FTCP). These metrics collectively determine the structural boundaries of the system's control space and answer questions such as: How does the structure of a network affect its controllability? How to efficiently control a preselected subset of the network? Which nodes have the highest control power? What types of topological structures dominate controllability?

In this study we extend our analysis to edge-based controllability and conduct a side-by-side comparison of node- and edge-based controllability measures. The objective of this study is to i) understand the impact of networks structure on the overall controllability of the system; ii) understand the impact of individual nodes and edges on the overall controllability of the system; and iii) develop a framework to identify the best control approach based on the networks structure (node-based, edge-based or hybrid).

May Wu, Argonne National Laboratory - Measuring Environmental Benefits and Cost of Nitrogen Reduction by Riparian Buffers: Effects on Urban Water Production. Exceedingly high nitrogen concentrations (>10ppm) in the surface water became the cause of nitrate removal treatment for water production facilities. It is well-established that installing riparian buffer in agricultural land can improve quality of water resource (reduce nutrient and soil runoffs) and ecosystem service for the watershed. How the water industry and urban community can benefit from a decrease of nitrogen in the source water through conservation programs was rarely reported. This study investigates the water production cost-benefit and carbon emission implications of growing riparian buffer biomass feedstock in the Raccoon River watershed. The water production facility located in Des Moines, Iowa, U.S.A.,

downstream of the croplands in the Raccoon River watershed. We simulated a buffer scenario with a calibrated SWAT model and compared it with a historical baseline for nitrate loadings. A statistical model is developed to establish the relationships between water quantity and quality parameters and operation parameters in the waterworks based on 17 years operational data. The changes in nitrate treatment operation for the nitrate peak-months April through June under the buffer scenario were subject to cost and carbon intensity analyses.

Results show that the urban water production facility could reduce sodium chloride use by 425 metric tons, fresh water by 20.8 million liters, electricity by 147,810 kWh, and powder activated carbon by 253 metric tons when riparian buffers were installed in cropland. The material and energy savings translate to 86.9 metric tons (CO2eq) less GHG emissions. We found that over a half of the carbon reductions (58%) came from electricity generation. Carbon from sodium chloride production accounts for a third. Cost analysis showed that the riparian buffer would avoid $327,326 (range: $277,095 - $407,390) of the nitrate treatment in peak months. The most potential cost savings occur in May ($215,100), followed by April ($65,465), and June is the last of the three ($46,761). Results suggest there is an upper limit in the nutrient absorption capacity of the switchgrass buffer for the peak months. This study illustrates the substantial value of riparian buffer to urban communities.

SESSION 47 | Water Supply 2

Nathan Ivy & Simon Lester, Concrete Canvas - Using Concrete Canvas' Type II GCCM/B's to ASTM D8364 to Effectively Eliminate Seepage in Canals. There are more than 25,000 miles of canals in the US comprised of more than 18,000 individual canals. A common problem associated with canals is seepage. Seepage can result directly in water loss through the network or result in waterlogging of adjacent land. In the case of land used for cultivation, waterlogging can reduce crop yields or cause salinisation of the soils. This does not only occur in earthen canals, but also in concrete lined canals, particularly those that have experienced cracking, scour, panel separation or damage. It is also a common misconception that concrete lining of canals is an effective method of mitigating seepage losses.

The 25-year study performed by the USBR indicates that concrete over geomembrane has a 95% effectiveness at reducing seepage through canals1. This abstract introduces a revolutionary new class of materials called Geosynthetic Cementitious Composite Mats and Barriers (GCCM's and GCCB's), specifically Type II GCCB's to ASTM D8364 for lining of bulk water transportation canals. The Type II GCCB in question consists of concrete encapsulated between two geotextile layers with a 40 mil LLDPE geomembrane backing which can be thermally welded to produce a testable and highly impermeable joint, per ASTM D5820, with the air channel test to ensure a leak free installation. Because it is a composite of concrete and geomembrane in a single application, installation can occur as a one-step process imparting both cost and time savings to the project. The abrasion resistance of the concrete layer is 5 times that of typical 20MPa ST4 concrete typically used for canal applications. With a design life of more than 50 years, this new product will provide a cost-effective, long-term solution to help preserve and protect fresh, clean water, one of earth's most precious – and ever more scarce – natural resources.

Jeremy McDowell, United States Geological Survey - Estimating Recent and Future Water Use Associated with Hydraulic Fracturing Using Data-driven Models. Since 2015, the U.S. Geological Survey has been estimating water use in the United States associated with hydraulic fracturing, or more generally continuous oil and gas (COG) resources, including detailed studies in the Williston Basin in North Dakota and Montana in 2020 and the Permian Basin in Texas and New Mexico in 2021. These more recent studies estimated water use within the specified basins spatially at the county level, temporally on an annual basis, and categorically by use for direct, indirect, and ancillary (consequent to COG development) purposes. The results of these studies indicate that water use for COG development is not only increasing within the basins overall but is also increasing per oil and gas well within the studied basins. Understanding how much water is being used for COG development is particularly important in areas with meager available water because they receive minimal precipitation or contain minimally productive aquifers. In contrast to prior studies that used linear regression models with local input data to estimate water use, publicly available and nationally consistent datasets are being used to estimate recent (2010–21) and future COG water use across the United States. These estimates are generated using historical trends in a multivariate regression model, with covariates related to climatic and socioeconomic indicators. The analyses are being developed in a highly reproducible way using Python and R scripts to automate data compilation and model runs within open-source Git repositories, which will allow for collaborative engagement and streamlined adjustments to the model in the future. In the next phase of this study estimates of recent and future water use are being made for all types of mining activities, which, in addition to oil and gas, include both fuels (such as coal) and non-fuels (such as copper); refining these estimates may require a machine learning data-driven approach.

***Jen-Chieh Shih, Fu-Yuan Lin, Ming-Der Hong, Hong-Ru Lin & Jet-Chau Wen, National Yunlin University of Science and Technology - Optimization of the Water-Energy-Food Nexus for Micro-hydropower Generation in Agricultural Channels.** With the gradual development of science and technology and the continuous growth of the population, the demand for resources has also increased, making water-energy-food (WEF) closely linked with life, so such issues are widely discussed. attention. WEF describes the interaction between water, energy, and food (R. Lawford, et al., 2013). A set of synergies and management trade-offs are developed

within the relationship to achieve maximum economic benefit. The relationship between water-energy-food is a relatively new field, and it is committed to the management and integration of its comprehensive resources between urban and rural areas. Over the past decade, WEF has become a prominent topic, gaining recognition among different fields of research as it is a complete concept for achieving sustainable development. The introduction of this concept has attracted the attention of the general public, emphasizing the importance of exploring the interaction and synergy of resources to achieve sustainability (Hoff, 2011). According to its speculation, energy occupies a large proportion of the WEF, and hydropower occupies an important position in this relationship chain, accounting for about 19% of the total global power generation. It is undeniably the most efficient and reliable renewable energy source (Elbatran et al., 2015).

This study selects Linnei channel in the Zhuoshui River Basin in central Taiwan as the research site. Linnei channel is used as an agricultural irrigation system with a stable flow. In 2020, Linnei channel has installed two sets of stream-flow micro-hydropower systems. Therefore, this study will measure the stage, water velocity, discharge, and turbine speed, and analyze the potential power generation, profit, and cost of the micro-hydropower generation system. Then using the General Algebraic Modeling System (GAMS) software to solve the equation of the generator to find the best parameters to achieve the optimization, and apply it to the agricultural channel for hydropower generation.

Jason Zhang, University of Illinois at Urbana-Champaign - Characterize Water Use Intensity for Thermoelectric Power Plants in the Contiguous United States. Thermoelectric power generation plants depend primarily on water for cooling purposes, making them vulnerable to the availability of this finite resource. Thermoelectric power generation is the largest water use sector by water withdrawal in the U.S. Therefore, quantifying the relationship between water and energy becomes essential for both water and energy security. Water use intensity has been estimated in the United States based on cooling operations and generation records but there are often based on data of a single year. Nevertheless, these estimations do not consider the effect of regional and seasonal variability. The current study characterizes the water withdrawal intensity (WWI) and water consumption intensity (WCI), by analyzing ten years of data (2010-2019) provided by the Energy Information Administration (EIA). A total of 234 thermoelectric plants across the contiguous United States (CONUS) were evaluated, and 26 cooling-engine technology combinations were estimated. The results showed that WCI for thermoelectric facilities using cooling systems with ponds varied the most by region. On the other hand, recirculating cooling with natural draft systems is more variable by season.

SESSION 48 | Water Quality 3

Michael Schramm, Texas Water Resources Institute, Texas A&M AgriLife - Statistical Modeling and Trends in Freshwater Derived Nutrient Loads, Lavaca Bay, Texas. The Texas coastline includes seven major and five minor estuaries. Recent assessments have id entified some of these bays and estuaries as eutrophication “hot spots” that are particularly vulnerable to additional increases in nutrient loads. Although major bay and rivers that contribute flow and nutrients into these estuaries are typically well monitored, smaller secondary bays and inlets receive substantial freshwater inflows and nutrient fluxes from sparsely monitored coastal watersheds. This project uses statistical models to estimate annual nutrient fluxes and inform improved sampling design in these sparsely monitored watershed. Our case study uses Lavaca Bay, a secondary embayment on the Matagorda Bay system along the central Gulf of Mexico Coast in Texas. Lavaca Bay has been identified as having a moderate risk of eutrophication. Primary freshwater inflows are from the Lavaca-Navidad river system which is monitored for dissolved nutrient parameters between 4 and 12 times annually. The contributing watersheds are agriculturally dominated with primary land uses composed of pasture or crop fields. The routine monitoring program has been in place for only ten years making it less suitable for commonly used empirical load estimation methods. We evaluate the use of generalized additive models, which is a flexible data-driven semi-parametric regression approach, for predicting total loads and evaluating temporal trends in seasonal and annual nutrient loads in sparsely monitored watersheds.

***Dylan Barr, University of Florida - Research the Efficacy of Reclaimed Water Landscape Irrigation BMPs for Nutrient Load Reductions in Residential Areas.** Population growth and other anthropogenic and environmental factors put Florida’s freshwater resources under exceptional and persistently increasing demand. Expanding sustainable use practices to reduce the strain on the state’s groundwater stores is critical to protect environmental systems, ensure public health, and promote economic development. These practices should also not contribute to the many water quality issues plaguing freshwater and marine ecosystems around the state. This research aims to investigate the water quality impact of using treated municipal wastewater or reclaimed water for residential landscape irrigation. Study sites are located in the Indian River Lagoon watershed in Martin and St. Lucie Counties, Florida. Water samples collected from household sprinkler systems that utilize reclaimed water are used to quantify the concentration of nitrogen and phosphorus. Homeowner irrigation behaviors will be surveyed to aid in assessing possible over-irrigation. Additionally, we seek to quantify the amount of wasteful sprinkler overspray, or the amount of water being applied to impervious surfaces such as driveways, sidewalks, and roads. Combining those points allows us to determine the amount of possible nutrient reductions in the watershed if improper or unnecessary irrigation practices are reduced. The eventual goal of this research is to develop science based BMPs for using reclaimed water in residential irrigation settings and ultimately to reduce nutrient loads being received by the Indian River Lagoon and St. Lucie estuary.

***Elizabeth Flint, British Geological Survey - Leakage of Water from Public Supply Distribution Networks is Responsible for Significant Phosphorus Fluxes within Many Urban Counties Across the United States.** Phosphorus (P) is a fundamental element for global food production, however human activity has led to excess concentrations across many aquatic environments. Despite decades of policy aiming to reduce P inputs, high P concentrations (as phosphate) continue to contribute to eutrophication of coastal and freshwaters across the United States (US). Developing more effective nutrient management policies is imperative and will require improved understanding of P sources to the environment. Public water supply is widely treated with phosphate (PO4) across the US for controlling the corrosion and release of lead and copper within distribution pipes. Leakage of PO4 treated water from the distribution network has been shown to be a significant source of P to the environment in the United Kingdom. On average, 16% of water entering the US distribution network is lost due to leakage, thus we hypothesize leakage may also be a mechanism for P input across the US. We estimated that in 2015, PO4 treatment resulted in the addition of up to 13.6 kt PO4-P yr-1 into the distribution network. Nationally, up to 2.6 kt PO4-P yr-1 is estimated to be lost from the network as a result of mains water leakage, equivalent to 30% of P leached from non-agricultural fertilizer and 1% of point source P. Mains water leakage PO4-P fluxes are potentially a significant source of P to the environment across many urbanized and eastern US counties. This is due their dense populations and heightened presence of old lead service lines that create the need for PO4 dosing, as well as increased susceptibility to leakage. After losses from the distribution network, due to both leakage and outdoor irrigation using treated water, we estimate 8.7 kt PO4-P is returned to wastewater treatment plants - accounting for around 3% of the country's estimated total influent loading to WWTPs. Results presented here will aid the development of more effective P management strategies, particularly across urban and coastal areas, as well as help determine sustainable levels of leakage and inform corrosion control policies both in the US and other countries who undertake PO4 dosing.

SESSION 49 | Water Reuse in the Pacific Northwest

Jacque Klug, King County, Wendy Stephenson, LOTT Clean Water Alliance, Erica Marbet, Squaxin Island Tribe, Hannah McDonough, Project Manager, Washington Water Trust. Known for its ample rainfall, there is an impression that water is an abundant resource in Western Washington. However, climate change and population growth impacts are increasingly putting stress on our waterways and water resources. One potential tool to combat water shortages while meeting water demand is the use of recycled water (also known as reclaimed water). In WA State, recycled water is used to manage and improve water resources via streamflow augmentation, managed aquifer recharge, and source switch opportunities. It provides a sustainable and climate resilient water management option, yet is arguably underutilized in WA State when compared to states such as California. This panel session will cover how the use of recycled water for water resource projects is progressing in WA State, and how it could expand in the future.

SESSION 50 | Forest Management

Susan Dickerson-Lange, Natural Systems Design, Department of Civil and Environmental Engineering, University of Washington - Modeling the Potential of Forest Management Strategies to Buffer Climate Change Impacts to Summer Streamflow in the South Fork Nooksack River, Northwest Washington. Water quality and water quantity are impaired in the South Fork Nooksack River (SFNR), which is a tributary to the Salish Sea and is home to a federally listed population of threatened spring Chinook salmon. Current conditions result in degraded habitat conditions for salmonids and future summer streamflow is projected to be substantially lower and warmer by the end of the century. As such, instream, riparian, and upland strategies to decrease summer water temperatures and increase summer streamflow are being considered to support salmon recovery as well as increase climate resilience. We completed a pilot hydrologic modeling study to test the effects of hypothetical forest management scenarios on the magnitude of August streamflow. We applied and compared results between two models, DHSVM and VELMA, in order to use best available process representations of the effects of forest gaps on snow storage and the effects of timber harvest on transpiration rates and soil water storage. In particular, by implementing end-member scenarios to estimate the outer bounds of effects, we find that introducing 40 m forest gaps through the entire snow zone resulted in an average 25% increase in median August streamflow under historical climate conditions, and a 9% increase under end-of-century climate conditions. In an extreme scenario with no timber harvest as compared to approximate existing conditions, which includes a mosaic of harvested and unharvested forests, simulations indicate a 17% increase in median August streamflow under historical climate conditions and an 11% increase under end-of-century climate conditions, respectively, once a dynamic equilibrium of forest ages is reached. Given that the effects estimated by each model are the result of semi-independent influences on the water budget, specifically snow interception and storage in the forest gap scenarios and soil water usage and transpiration rates in the timber harvest scenarios, the effects may be additive and forest management strategies for climate resilience could consider both gap cuts and stand age management for an enhanced summer streamflow effect. Future work is planned to explore incremental strategies such as thinning, variable retention harvesting, and decreased harvest frequencies.

Emily Howe, The Nature Conservancy - Forest Management Effects on Snow Storage in the Transitional Climate Zone of the Eastern Slopes of the Cascade Range, Washington. Extensive forest thinning across the western US is being planned, funded, and implemented in order to reduce wildfire risk resulting from legacy fire suppression practices and warming climate conditions. Forest

thinning also affects the water storage and usage across the landscape, thereby influencing instream water availability and timing. In mountainous watersheds, the presence and characteristics of forest cover can influence the amount and duration of snow storage, which is projected to decline under a warming climate. However, in many areas throughout the western US, forest management practices designed to reduce wildfire risk do not examine associated hydrologic impacts. Previous work indicates that the net effect of forest management actions on extending or curtailing snow storage duration, as well as overall snow amount, varies with climate, topography, and forest characteristics. Considerable uncertainty exists in some climate zones where forest management for wildfire risk reduction is most active. The eastern Cascades in Washington State is one such zone that is particularly vulnerable to wildfire risk and water scarcity, yet there are no empirical data observing the relationship between forest canopy, snowpack, and topographic position. To fill this data gap, we collected 3 years of field observations of snow depth and duration across a range of forest and climate conditions, and across topographic positions. These observations indicate snow storage duration is similar across forest canopy densities, including continuous and thinned forests as well as forest gaps, but snow storage magnitude is greater where canopy cover is lower. Additionally, field observations and lidar-acquired snow depth data across a north to south facing topographic position indicate the forest effect on snow storage magnitude and duration shifts substantially with slope aspect – specifically, snow storage was almost 2x higher and snow duration was longer in north-facing gaps compared to continuous forest, whereas on the south side, snow depth and disappearance timing were similar between forest types. These data suggest that in this climate zone, forest thinning prescriptions intended to promote fire resiliency and forest health are unlikely to amplify climate impacts on snow storage, and that forest thinning can potentially increase snow storage on north-facing slope aspects.

Phillip North, Tulalip Tribes - Challenges and Results of Combining Ecohydrologic Models with the Forest Vegetation Simulator, the Wetlands Intrinsic Potential Tool and Climate Data to Test Water Retention Strategies in the Snohomish River Basin. We used the ecohydrologic models VELMA and DHSVM with forest management scenarios generated from the Forest Vegetation Simulator, Wetland Intrinsic Potential Tool and weather data from 1990 through 2099 at a 90-meter scale to test our ability to manage water conditions in uplands and stream channels in the Snohomish River Basin. Calibration of the models, such that predictions matched past flow measurements at gages, proved more complex when we moved from modeling the entire watershed at a single downstream gage at Monroe to modeling representative HUC 10 subwatersheds. The Forest Vegetation Simulator was used to generate a business-as-usual harvest management scenario to the end of this century, and a harvest management scenario that aims to favor water retention to the end of this century. Preliminary results have shown that these models can match observed results reasonably well and act as a basis for testing forest management scenarios over time. A key objective of this project is to make this approach portable to other basins in the Salish Sea. In this presentation we'll review objectives and methods, briefly discuss challenges encountered and results generated for mid- and end-of- century, and how we are documenting this work in an open knowledge network to make reproducing and porting this work easier.

SESSION 51 | Floodplain Restoration Case Study

Chris Collins, Lower Columbia Estuary Partnership - Lessons Learned from Nine Years of Managing a $31M Urban Floodplain Restoration Project. The dire prospects for many salmonid and lamprey species combined with the increasing need for climate resilient infrastructure necessitates increasing the scale and magnitude of floodplain restoration; however, these larger, more impactful projects inherently have greater social and technical risks and complexities. The Steigerwald Reconnection Project is a $32M effort spanning nine years and 1,000 acres of Columbia River floodplain that successfully navigated those complexities. The project involved eleven real estate acquisitions, one state highway, two federally regulated setback levees, and 1.7M cubic yards of earthwork. The purpose of this presentation is to briefly summarize the project, provide an overview of the project's risk management and stakeholder outreach strategies, and share keys to the project's success, such as its design approach and procurement strategy. This presentation provides context for the three other presentations in this session.

Jared McKee, United States Fish & Wildlife Service - Decarbonizing Stream Restoration and the Fuel Efficiency of the River Machine. The field of aquatic restoration has relied heavily on habitat construction via heavy machinery. Stream, river and wetland restoration designs are often developed under the assumption that heavy machinery is required to construct habitat. Common practices involve moving large quantities of materials that risk disturbance to soils and vegetation while disrupting existing ecological recovery processes and emitting large amounts of greenhouse gases. Such an approach discounts and misses opportunities to utilize natural forces such as flood energy and sediment transport to rebuild aquatic habitat. Restoration projects that default to and rely heavily on fossil fuel energy also risk becoming net carbon emitters which contribute to the degradation of habitats globally. Reducing greenhouse gas emissions early in the life of a stream restoration project can increase the certainty of net carbon storage and the pace at which carbon savings can be accomplished within the stream restoration sector. Reliance on fossil fuel energy to do the restoration work is in part attributed to uncertainty or unknown potential to work with fluvial process and perceived time required to achieve specific project goals. However, for most, if not all, projects, some emissions are inevitable. For example, The Steigerwald Reconnection Project required substantial emissions to reconstruct a levee system, thus reconnecting 965-acres of historic floodplain. Here the project team minimized emissions to the extent possible by minimizing habitat creation while focusing fossil fuel usage on the adaptation of legacy infrastructure to allow for a more dynamic stream-wetland corridor. Here we illustrate two approaches to responsible carbon usage and application of stream energy to achieve restoration goals, and use the Steigerwald

Project as a case study of how to responsibly incorporate carbon capture into the restoration design so that all carbon produced by the project will be sequestered within a reasonable timeframe. This restoration approach scales to meet scope of habitat degradation in specific locations while fighting against the causes and effects of climate change on a global level. Application of this analysis may reduce uncertainties regarding the harnessing of stream and biological energy for process-based restoration and increase implementation of ecologically sound restoration practices.

Wade Osborne, Cornforth Consultants Inc. - Design and Monitoring Considerations for Construction of Setback Levees on Soft Alluvial Soils. The construction of setback levees for the Steigerwald Restoration Project were an effective method to maintain flood protection for existing residents, commercial properties, and infrastructure, but presented significant challenges. This presentation will discuss the geotechnical aspects for design and construction of large levees on native, soft alluvial soils. The design considered the seepage, strength, and settlement properties of the foundation materials and potential borrow sources for levee fill materials. The project included construction of test fill embankments to confirm the design assumptions and included installation sensors to monitor settlement during construction. The project encountered several critical challenges related to construction staging and levee settlement during construction of the soft soils comprising the historical floodplain. This presentation will discuss how the design and construction teams resolved the issues to complete construction on time.

Curtis Loeb, Wolf Water Resources - Restoration Incorporating Living Shorelines, Stage 0 Alluvial Fans, and Other Design Measures for Climate Adaptability on a 1,000 Acre Floodplain of the Lower Columbia River. The Lower Columbia Estuary Partnership, Port of Camas-Washougal, U.S. Fish and Wildlife Service, Bonneville Power Administration, and others have partnered to reconnect 965 acres of historic Columbia River floodplain and reduce flood risks at the Steigerwald National Wildlife Refuge located southeast of Washougal in Clark County, Washington. Restoration and reconnection of the floodplain presented numerous technical challenges, including ensuring no adverse impacts to WA State Route 14 and designing a levee and floodwall to meet strict regulatory, flood risk reduction, and habitat objectives. Reconnection was particularly challenging given anticipated changes in climate (higher winter flows and higher summer stream temperatures) and future increases in watershed development. Three distinct measures were developed to improve resiliency to climate risk and uncertainty. (1) A vegetated wind-wave overbuild berm was designed in lieu of riprap to protect the levee from extreme winds and associated wave erosion that is anticipated to increase in the future. The berm also accommodates transitioning wetland and riparian habitats up the topographic slope due to changing river stages. (2) When analyzing site hydrology and hydraulics, the design also incorporated peak flows scaled to account for anticipated future development and higher intensity winter storms, as predicted by climate models. Consequently, site infrastructure including the west setback levee is designed for Gibbons Creek discharges that are 20% larger than current peaks. (3) Finally, the design targeted full floodplain connectivity (Stage Zero condition) in restoring Gibbons Creek's 80-acre alluvial fan while also ensuring functionality of instream habitat at the base of the alluvial fan. Maximizing hyporheic exchange to cool water temperatures along with wood structures for initial floodplain roughness and cover habitat for juvenile salmonids in turn maximizes thermal refuge for salmonids throughout the warm summer months. These three climate resiliency design measures were based on several simple yet often underestimated concepts including space, scale, imprecision, and redundancy, and the focus of the presentation will be on how these ideas can be applied even in constrained environments.

SESSION 52 | Walla Walla Basin - CANCELED

SESSION 53 | 3D National Topography Model

Steve Aichele, United States Geological Survey. The US Geological Survey (USGS) has developed a vision for the 3D National Topography Model (3DNTM), which will integrate USGS elevation and hydrography datasets to model the Nation's topography in 3D. The 3D Hydrography Program (3DHP) is the hydrography component of the 3DNTM and the next generation of national hydrography mapping that will include deriving a stream network from elevation data and building an information infrastructure to share water data within the context of the stream network. 3DHP will provide critical data for applications like flooding, contaminant spills, water quality and quantity, drought, climate change, and other, emerging applications. The presentations in this session will provide an overview of 3DHP plans including scope and timelines for the emerging program.

SESSION 54 | Water Quality 4

Michael Du Bose, Geosyntec Consultants - Modeling the Potential Impacts of a Catastrophic Liquid Fuel Spill in the Lower Willamette and Columbia Rivers. The Critical Energy Infrastructure (CEI) Hub in Northwest Portland, Oregon spans a six-mile stretch of the Lower Willamette River and stores 90% of Oregon's liquid fuel supply and 100% of the jet fuel for PDX in above ground storage tanks. The CEI Hub is also built entirely on liquefiable soils which are likely to fail during a Cascadia earthquake event. The purpose of this project was to model a liquid fuel spill in the Lower Willamette and Columbia Rivers using the CE-QUAL-W2 model. Several scenarios were developed to account for different environmental conditions (e.g., high and low discharge years) and varying spill durations (e.g., rapid or prolonged). Additionally, several novel approaches were used to approximate liquid fuel and oil buoyancy as there was no way to specify density for added constituents in the model. Settling velocities and initial fuel temperatures were modified for each of the added fuel constituents. Sensitivity analyses were used to determine whether numerical error was

introduced by these modifications. Fuel concentrations were analyzed near Portland and the downstream towns of St. Helens and Rainier to assess potential impacts of a liquid fuel spill on communities along the affected rivers. Comparisons of estimated concentrations to EPA standards were performed for Rainier since the town relies on Columbia River surface water as a drinking water source. This study found that downstream receiving waters and communities are vulnerable to significant water quality impacts from a catastrophic fuel spill event. Model limitations and potential refinements were identified for future fuel spill analysis on this river system.

Diane Roher & Alex Gerling, Hazen and Sawyer - Leveraging Source Water Quality Management Strategies for Navigating Future Uncertainty. Water resources planning and management begins at the watershed and ends at the tap. Reservoir water quality degradation is an increasing challenge for front-range water utilities. Understanding historical source water quality can provide a roadmap to refine source water management and water treatment strategies. Reservoir management plans are not universal approaches, but rather nuanced strategies to account for unique water quality, watershed conditions, reservoir usage, and treatment processes.

The presentation will focus on proactive source water monitoring and management to better understand baseline water quality conditions and establish strategies to reinforce ecosystem resiliency. Three main objectives of a source water monitoring plan will be emphasized: capturing seasonal trends (historical and present), understanding biological characteristics, and correlating to secondary metabolites. Strategies to meet these objectives will be discussed. Similarly, three key management objectives and strategies to achieve these goals will be examined: minimizing internal flux, stabilizing the phytoplankton community, and reducing external influences.

The presentation will highlight three case studies that have successfully implemented the discussed monitoring and/or management strategies. The firsts case study is focused on long-term monitoring to prioritize management needs. The second case study addresses unique taste and odor complaints. The third case study highlights early success of preventative management program. These case studies exemplify the value in leveraging source water management to inform data driven decisions as well correlating historical trends to better prepare for the future.