NM WRRI Student Water Research Grant Progress Report Form

Draft Final Report due Wednesday, November 15, 2023
Final Report Due Thursday, December 14, 2023

1. Student Researcher: Asmita Kaphle

2. Faculty Advisor: Dr. Ricardo Gonzalez Pinzon

3. Project title: Rapid Response Monitoring of the Propagation of Wildfire Disturbances from the Hermit's Peak - Calf Canyon Fire along Gallinas Creek

4. Description of the research problem and research objectives.

   The Hermit's Peak-Calf Canyon Fire, the largest fire in recorded history in New Mexico, burned around 341,700 acres. The fire affected a significant portion, about 85%, of the Gallinas watershed upstream of Las Vegas's water treatment plant. Gallinas Creek, which serves as the primary source of drinking water for Las Vegas, became contaminated with ash, sediment, and debris from the burned areas following precipitation in June 2022. The deterioration in water quality along Gallinas Creek prompted local municipalities to stop using it as their primary water supply and look for alternative drinking water supplies. After a wildfire, precipitation events can mobilize contaminants like nutrients and metals from the burned areas into streams and along entire fluvial networks. These contaminants pose risks to both human health and the river ecosystem. While the immediate impacts on water quality in the local area are evident, it remains unclear how far downstream the wildfire disturbances can propagate and their consequences on ecosystem services, environmental processes, and water quality.

   Metals can occur naturally in the soil in low quantities due to geological processes, commonly due to the weathering of geological formations. But metals can be concentrated in the ash in elevated amounts after a wildfire in the soil. The ash containing trace metals deposited on the soil after a wildfire can be washed away to the stream during rainfall runoff. The trace metals released by ash inside the burn area could be transported to the fluvial networks downstream, outside the burn area. Some post-fire investigations and research have reported elevated concentrations of metals such as, As, Al, Cd, Cr, Fe, Pb, Hg, Ca, Mg, Mn, Ba, and K in sediments and streams on fire-affected watersheds for several months after the occurrence of the fire event[i]. A study conducted on the 2009 Station Fire in Southern California showed that the filtered concentration of Mn, Fe, and Hg and the total concentration of most trace elements were elevated in the storm samples collected post-fire because of the Station Fire[ii]. The study also showed that the filtered concentrations of Cu, Pb, Ni, and Se and total concentrations of Cu have increased mainly because of the storm and not the Station Fire. However, the total concentrations of Se and Zn increased due to the storm and the Station Fire. The main objective of this study is to investigate the longitudinal propagation of some trace metals (Al, Cr, Ca, Mg, Mn, Pb, Se, Sr, Zn) along fluvial networks and their impact on water quality and aquatic ecosystem services.

5. Description of the methodology employed.

   The Hermits Peak Calf Canyon Fire, which started on April 6th, 2022, severely impacted Gallinas Creek. We collected water samples at different locations along Gallinas Creek from April 2022, to study the impact of the fire on water quality. The sampling took place before the monsoon season, during the monsoon season, and after the monsoon season till December 2022 for metal analysis. These water samples were immediately frozen at a temperature of 0°C in

the Ecohydrology Lab at the University of New Mexico for further analysis. The samples were already filtered during collection in the field using a 0.45 μm filter. Before analyzing the sample in ICP-OES, samples were acidified to keep the analytes of interest in the solution. 2% of Trace Metals Grade Nitric acid (70% w/w) was used to acidify the aqueous samples since, for many cations such as Ca, Mg, and Na, Nitric acid is known to work well. Trace metal grade acid was used since the lower grade acid could result in metal contamination. The acidified samples were poured into borosilicate glass vials before the ICP-OES analysis. Once the samples were prepared, they underwent analysis for various metals using ICP-OES (Inductively Coupled Plasma-Optical Emission Spectroscopy). ICP-OES is an instrumental technique for elemental analysis that utilizes the emission spectra of elements excited in a high-temperature plasma to generate analytical data. Firstly, the instrument was calibrated where three standards having known concentrations of each element of interest and calibration blank were measured. This data was then used to generate a calibration curve which serves as a reference to quantitatively analyze the concentrations of trace metals in the tested water samples. After instrument calibration, initial calibration verification (ICV) was performed to verify the calibration standards' accuracy and the instrument calibration's adequacy. Then, continuing calibration verification (CCV) was performed after every 20 samples. After the sample analysis, the results were extracted from the ICP-OES software for further data analysis.

The results obtained from the analysis were further evaluated to check if values were below detection limits. For statistical analysis, such values were treated as the limit of detection (LOD) values divided by 2, which provides a reasonable estimate for statistical calculations and ensures that these values are included in the analysis rather than being eliminated entirely or treated as zero. Then, the concentrations of trace metals were compared with the National Recommended Water Quality Criteria - Aquatic Life Criteria Table recommended by the United States Environmental Protection Agency (US EPA). These criteria were established to determine the maximum allowable concentrations of specific contaminants in water that are not expected to have a negative impact on most aquatic species. Criteria for some trace metals like Al, Cd, Pb, etc., require specific water quality parameters such as total hardness, pH, and dissolved organic carbon (DOC). YSI EXO2 multiparameter water quality sondes were installed at five sampling sites from which pH values were obtained. The total hardness was calculated from the following equation as the concentration of Ca and Mg of water samples are also measured.

$$\text{Hardness} = 2.497\,(\text{Ca}) + 4.118\,(\text{Mg})$$

DOC, pH, and Water Hardness Interpolation Maps (v1.0) – map application is used to obtain the DOC values of Gallinas Creek.

To understand the longitudinal propagation of the disturbances, it is important to study the export regime of the metals. Concentration-discharge (C-Q) relationships are one of the useful metrics for gaining quantitative insights into the mobilization and export of solutes and sediment from watersheds[iii]. There are three primary export patterns, namely mobilization, chemostatic, and dilution. Mobilization and dilution represent contrasting conditions where solute concentrations increase and decrease with discharge, respectively. Chemostatic represents a state when the concentration of solutes has no significant variation with discharge. Mathematical representations of concentration-discharge relationships, denoted as C-Q relationships, utilize power-law models, as shown in equation (1):

$$C = aQ^b \quad (1),$$

where C is the concentration of solutes, Q is the discharge, and a and b represent the intercept and slope of the power-law model. A positive slope (b) denotes mobilization, also referred to

as enrichment. A negative slope (b) denotes source limitation leading to dilution. Near-zero slopes (b) denote chemostatic behavior. Four sites along Gallinas and Pecos rivers (Table 1) were considered for the C-Q analysis as the sites are collocated with the USGS stream gages from where the discharge data can be extracted.

Table 1 Description of monitoring sites along Gallinas and Pecos Rivers

Site Names	Location	River Distance (km)
GHW	Gallinas Headwaters	0.0
GMZ	Gallinas near Montezuma (USGS Station)	29.0
GL	Gallinas near Lourdes	56.3
PSR	Pecos upstream of Santa Rosa Lake	169.8
PBS	Pecos downstream of Santa Rosa Lake	190.0
Note: All river distances are calculated from the headwaters of the Gallinas River.		

6. Description of results; include findings, conclusions, and recommendations for further research.

Water Quality Criteria:

The mean concentration of metals during the pre-monsoon, monsoon, and post-monsoon periods was compared with the US EPA's National Recommended Aquatic Life Criteria table. MATLAB's "ischange" function was utilized to determine points of significant change in a time series mean trend to define a pre-monsoon period from the beginning of our monitoring on April 25th, 2022, to June 26th, 2022; a monsoon period from June 26th, 2022, to September 13th, 2022; and a post-monsoon period from September 13th, 2022, to December 1st, 2022. The aquatic life criteria table provides ambient water quality criteria for Al, Cr, Pb, Se, and Zn.

The US EPA's Aluminum Criteria Calculator V2.0 was used to calculate the Criterion Maximum Concentration (CMC) and Criterion Continuous Concentration (CCC). CMC refers to the maximum allowable concentration of contaminants for short-term exposure without causing significant harm to aquatic organisms, whereas CCC refers to the maximum allowable concentration of contaminants for long-term or continuous exposure without causing substantial harm to aquatic life. The concentrations of Cr and Zn were below detection limits for more than 70% of the water samples, while the concentrations of Pb were below detection limits for all samples. The values above the detection limit for Al, Cr, and Zn did not exceed the US EPA's aquatic life criteria, indicating that the measured concentrations of Al, Cr, and Zn did not pose a significant risk to aquatic species. Figure 1 shows that, for

Al, the concentrations at all phases (pre-monsoon, monsoon, and post-monsoon) are much lower than the CMC and CCC values.

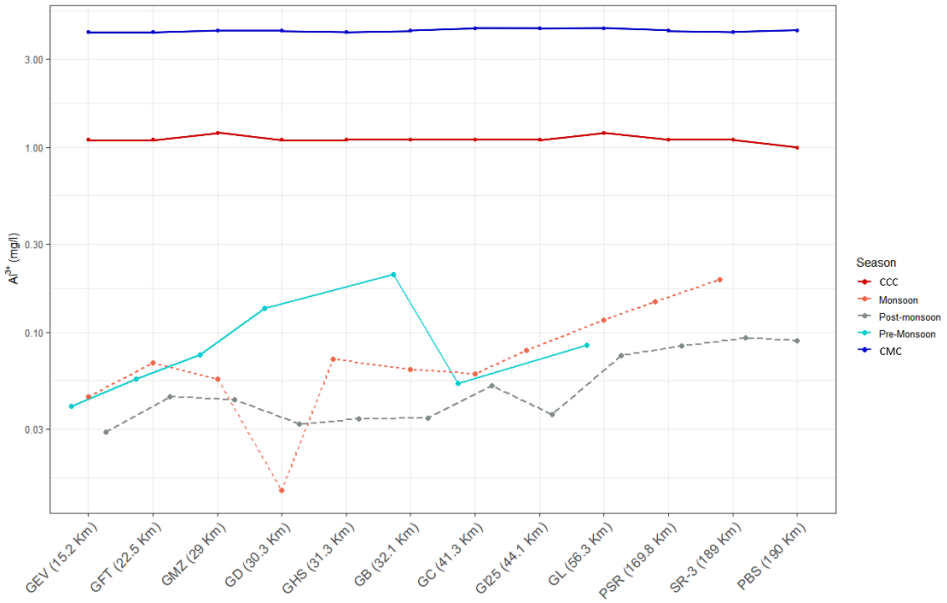

Figure 1 Concentration of Aluminum (Al) at sites located in the Gallinas Creek-Pecos River- Santa Rosa Lake fluvial network.

For Selenium, the US EPA has recommended CCC values of 1.5 µg/L for lentic systems and 3.1 µg/L for lotic systems. The US EPA does not recommend a separate acute criterion for selenium because it is bio-accumulative, and its toxicity primarily occurs through dietary exposure rather than short-term water-only exposure. During the pre-monsoon phase, selenium concentrations at three sampling sites exceeded the CCC. In the monsoon phase, most sampling sites show selenium concentrations surpassing the CCC, while post-monsoon, selenium is not detected at most sites except for four downstream locations located outside the burn perimeter. The result (Figure-2) indicates that selenium concentrations at most sites are higher during the monsoon period, possibly due to the release of contaminants containing selenium into streams through stormwater runoff.

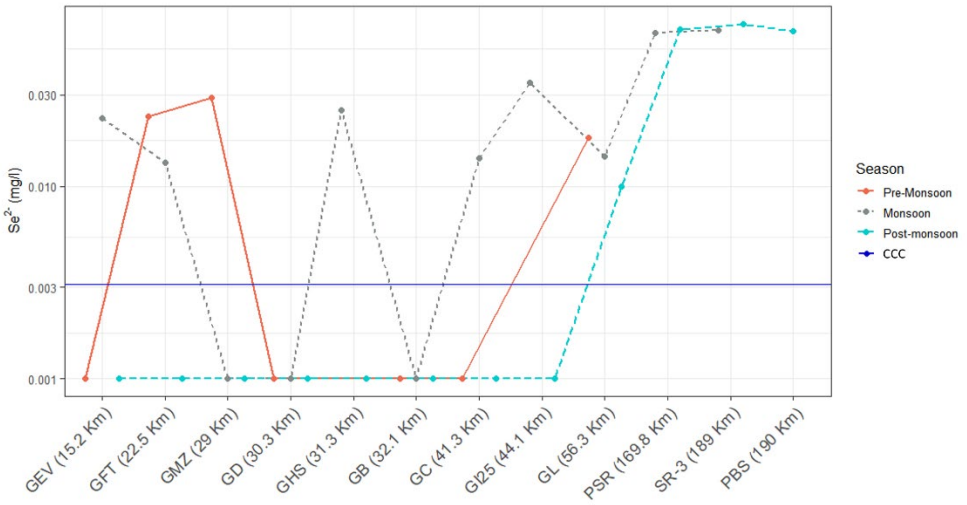

Figure 2 Concentration of Selenium (Se) at sites located in the Gallinas Creek-Pecos River- Santa Rosa Lake fluvial network.

C-Q analysis:

For metals, more than 50% of the concentration data for chromium (Cr^{3+}), lead (Pb^{2+}), selenium (Se^{2-}), strontium (Sr^{2+}), and zinc (Zn^{2+}) were below detection limits, and only 7 out of 36 C-Q regressions were statistically significant (p-value<0.05). The weak correlation observed between

metal concentrations and discharge was not effective in distinguishing mobilization and dilution trends.

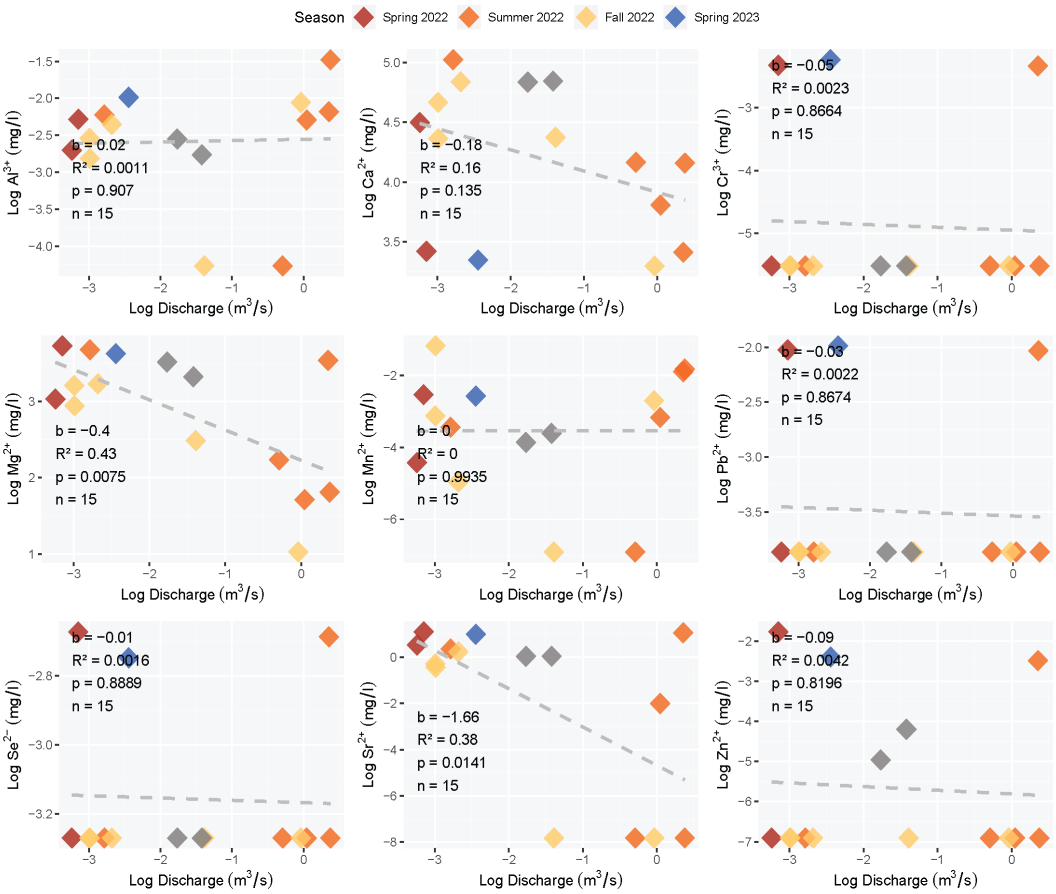

Figure 3 C-Q relationships of metals at GL.

7. Provide a paragraph on who will benefit from your research results. Include any water agency that could use your results.

The study on the impact of wildfire disturbances on water quality is expected to benefit several stakeholders and agencies. Firstly, the community of Las Vegas, New Mexico, which is planning to upgrade its water filtration system, can benefit from the study by gaining insights into the spatial and temporal impacts of wildfires on water quality. This knowledge can help the city make informed decisions and take necessary actions to protect its drinking water sources from the impacts of wildfires. Furthermore, regulatory agencies responsible for water management and environmental protection can also benefit from the study. The information gathered through monitoring water quality can provide them with valuable insights to assess the extent of wildfire impacts on hydrologic processes, environmental conditions, and aquatic ecosystem services. The data from the study can aid in formulating effective strategies and plans to mitigate the effects of wildfires on water resources in the future.

8. Describe how you have spent your grant funds. Also, provide your budget balance and how you will use any remaining funds. If you anticipate any funds remaining after December 14, 2023, please contact Carolina Mijares immediately. (575-646-7991; mijares@nmsu.edu)

   A total amount of $3,375 has been expended to pay the Geo/Analytical Laboratory at the Department of Earth and Planetary Sciences, UNM, for analyzing approximately 300 water

samples and buying sampling apparatus, tubing, Argon Dewar, and chemicals for sample analysis. A total amount of $1250.84 was spent on Aquarius Timeseries 21.1 and ArcGIS software. The Aquarius Timeseries software is used for applying quality assurance and quality control for water quality data. ArcGIS software is used for assessing the watershed characteristics and creating contributing catchment maps of each site. A total amount of $453.50 was spent on supplies such as a water rescue throw bag for field safety, waders, wading rod, and safety helmet. The amount of $1900 was spent on buying dissolved oxygen sensor for the water quality sonde.

Table 2 Grant Details

Description	Adjusted Budget	Expenses	Available balance
Ga Ta Ra Salaries Gen	$0	$0	$0
Other Staff Benefits Gen	$0	$0	$0
Computer software Gen	$0	$1,250.84	$0
Lab Supplies Gen	$2,724	$2353.5	$520.66
In state travel Gen	$250	$0	$0
Technical Services Gen	$4,526	$3,375	$0
Total	$7,500	$6,979.34	$520.66

9. List presentations you have made related to the project.

    - Presentation entitled "Water quality monitoring after the largest wildfire recorded in New Mexico" in 14th International Conference "Connection and Collaboration for Innovation and Transformation" at New Mexico State University, Las Cruces, NM on 18th March 2023.
    - MS Thesis Defense Presentation entitled “Post-wildfire export regime of solutes along the Gallinas-Pecos River-Santa Rosa Fluvial Network” on 6th November 2023.
    - Poster Presentation at 68th Annual New Mexico Water Conference entitled “Post-wildfire export regime of solutes along the Gallinas-Pecos River-Santa Rosa Fluvial Network” on 8th November 2023.

10. List publications or reports, if any, that you are preparing. For all publications/reports and posters resulting from this award, please attribute the funding to NM WRRI and the New Mexico State Legislature by including the account number: NMWRRI-SG-FALL2022.

    - Final Report submission to NM WRRI in December 2023.

11. List any other students or faculty members who have assisted you with your project.

    - Dr. Ricardo Gonzalez Pinzon
    - Katelin Fisher
    - Justin Nichols
    - Paige Tunby
    - Aashish Khandelwal

12. Provide special recognition awards or notable achievements as a result of the research, including any publicity such as newspaper articles or similar.

    - None

13. Provide information on degree completion and future career plans. Funding for student grants comes from the New Mexico Legislature and legislators are interested in whether recipients of these grants go on to complete academic degrees and work in a water-related field in New Mexico or elsewhere.

I plan to complete my master's degree and graduate in December 2023. My future goal is to advance knowledge in water resources engineering by pursuing a Ph.D. and contribute to developing effective strategies to mitigate the impact of climate change on water quality. Additionally, I aim to collaborate with government agencies, research institutions, and local communities to implement sustainable practices and policies that protect our water resources from the impacts of climate change.

You are encouraged to include graphics and/or photos in your draft and final report.
Final reports will be posted on the NM WRRI website and should be verified by the student's advisor.

References:

[i] Asifur Rahman, "Metal Reactivity in Laboratory Burned Wood from a Watershed Affected by Wildfires" (2018).

[ii] Carmen A. Burton et al., "Trace Elements in Stormflow, Ash, and Burned Soil Following the 2009 Station Fire in Southern California," *PLOS ONE* 11, no. 5 (May 4, 2016): e0153372, https://doi.org/10.1371/journal.pone.0153372.

[iii] Jon Chorover, Louis A. Derry, and William H. McDowell, "Concentration-Discharge Relations in the Critical Zone: Implications for Resolving Critical Zone Structure, Function, and Evolution," *Water Resources Research* 53, no. 11 (2017): 8654–59, https://doi.org/10.1002/2017WR021111; Adam S. Wymore et al., "Hysteretic Response of Solutes and Turbidity at the Event Scale Across Forested Tropical Montane Watersheds," *Frontiers in Earth Science* 7 (2019), https://www.frontiersin.org/articles/10.3389/feart.2019.00126.