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Scoping the Utilization of Acoustic Sensors to Detect Streambed Mobilization

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14. ABSTRACT
A scoping proposal sought to evaluate the use of underwater acoustic sensors, or hydrophones, for detecting incipient motion in the Wild and Scenic Rio Chama. This river reach experiences fine sediment inflows that smother the gravel streambed and negatively impact brown trout habitat. Using hydrophones, incipient motion can be detected, and that data correlated to a range of flow rates. These flow rates can be used by water managers in planning environmental flows that remove fine sediments from the coarse, gravel bed of the Chama. A conducting proposal for an in-river study has been prepared in collaboration with the USGS and submitted to the Science and Technology Program.

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brown trout, acoustic sensor, hydrophone, incipient motion, sediment transport, streambed mobilization, Rio Chama, Wild and Scenic Rio Chama

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Scoping the Utilization of Acoustic Sensors to Detect Streambed Mobilization

Final Report No. ST-2020-20070-1

prepared by

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Peer Review

Bureau of Reclamation
Research and Development Office
Science and Technology Program

(Final) Report ST-2020-20070-1

Scoping the Utilization of Acoustic Sensors to Detect Streambed Mobilization

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Executive Summary

The stretch of the Rio Chama between El Vado Dam and Abiquiu Dam was designated a Wild and Scenic River in 1988 and is a high-sediment system with a significant amount of fine sand, silt, and clay sediments deposited by inflows from arroyos and bank erosion onto gravel-cobble (coarse) bed material. The fine sediment fills the interstitial spaces within the gravel streambed and restricts oxygen transport. This reduces food sources and impacts spawning habitat of the brown trout, a key species in the designation of the Wild and Scenic reach.

Bureau of Reclamation (Reclamation) periodically releases high flow pulses from El Vado Dam for environmental enhancement purposes, including to clear fine sediment from the streambed to maintain habitat for brown trout and their macroinvertebrate food base. Fine sediments are mobilized, along with coarser sediment, in a threshold event called incipient motion. Incipient motion is said to begin when a flow has enough energy to pick up the median grain size in the streambed (Gregory, 2013). Mobilization of the streambed is necessary to not only remove fine sediments on top of the gravels but also the fines in the interstitial spaces.

The Rio Chama receives a combination of native water and inter-basin transfer water from the San Juan-Chama Project. Because of climate change, the Rio Chama is projected to see native water flows decrease by one-third and inter-basin transfer flows by one-quarter over the next century (Reclamation, 2013). With less water available in the future for high flow pulses, it is necessary to better understand what flow rates are needed to trigger incipient motion. This knowledge would assist water managers in planning the most effective high flow pulses.

A conducting proposal was developed and submitted for the FY21 S&T Program call for proposals (Appendix A). The conducting proposal seeks to expand the applicability of underwater acoustic sensors, or hydrophones, to the Wild and Scenic Rio Chama to test its capabilities there and potentially develop a long-term sediment mobilization monitoring methodology. Previous research has shown hydrophones to be a viable low-cost and passive method to monitor sediment transport. Mathieu Marineau, a research hydrologist from USGS who worked on a similar study on the Upper Colorado River, has agreed to collaborate on this project and will bring his experience using hydrophones and processing the recorded data.

Recent research efforts on incipient motion in the Rio Chama conducted by researchers at the University of New Mexico collected pebble count data and topographic surveys to develop an SRH-2D numerical hydrodynamic model. The study found that flows at 56 m^3/s (~1,980 cfs) would mobilize fine sediments and flows above 100 m^3/s (~3,530 cfs) would cause "extensive" flushing of fine sediments (Gregory et al., 2018). One of the test sites used in this study, the "Archuleta" site, was chosen as the test site for the conducting proposal. This site was selected for the conducting proposal because it has road access to each side of the river to facilitate data retrieval even during high flows. Also, the SRH-2D model would provide a verification method for the results of the hydrophone study.

Background

The Rio Chama is a tributary of the Rio Grande in northwestern New Mexico. The stretch of the Rio Chama between El Vado Dam and Abiquiu Dam was designated a Wild and Scenic River in 1988 (Figure 1). The Wild and Scenic Rio Chama is a high-sediment system with a significant amount of fine sand, silt and clay sediments deposited by inflows from arroyos and bank erosion onto coarse bed material consisting of gravels and cobbles. The fine sediment fills the interstitial spaces within the gravel streambed and restricts oxygen transport. This reduces food sources and impacts spawning habitat of the brown trout, a key species in the designation of the Wild and Scenic reach.

Bureau of Reclamation (Reclamation) periodically releases high flow pulses from El Vado Dam for environmental enhancement purposes, including to clear fine sediment from the streambed to maintain habitat for brown trout and their macroinvertebrate food base. Fine sediments are mobilized, along with coarser sediment, in a threshold event called incipient motion. Incipient motion is said to begin when a flow has enough energy to pick up the median grain size in the streambed (Gregory, 2013). Mobilization of the streambed is necessary to not only remove fine sediments on top of the gravels but also the fines in the interstitial spaces.

The Rio Chama receives a combination of native water and inter-basin transfer water from the San Juan-Chama Project. Because of climate change, the Rio Chama is projected to see native water flows decrease by one-third and inter-basin transfer flows by one-quarter over the next century (Reclamation, 2013). With less water available in the future for high flow pulses, it is necessary to better understand what flow rates are needed to trigger incipient motion. This knowledge would assist water managers in planning the most effective high flow pulses possible.

Scoping Proposal

A scoping proposal was submitted during the FY20 Science and Technology (S&T) Program's call for proposals to evaluate the suitability of underwater acoustic sensors, or hydrophones, for detecting streambed mobilization in the Rio Chama. The proposal included tasks for literature review of existing sensor technologies and current applications and a flume study to characterize the relevant hydrophone data. The end product of this work would be a conducting proposal for an in-river study.

When the literature review began, it quickly became apparent that the use of hydrophones for detecting incipient motion is a more developed method than was thought when the scoping proposal was developed. The work of characterizing hydrophone data and establishing methods for processing the data has already been done by previous researchers and does not need duplication. Furthermore, the COVID-19 pandemic restricted access to the University of New Mexico's (UNM) hydraulics lab, which is where the flume study would have been conducted. For these reasons, the

flume study was omitted. Instead, more effort was placed into consulting with researchers who have worked on hydrophone/sediment transport projects.

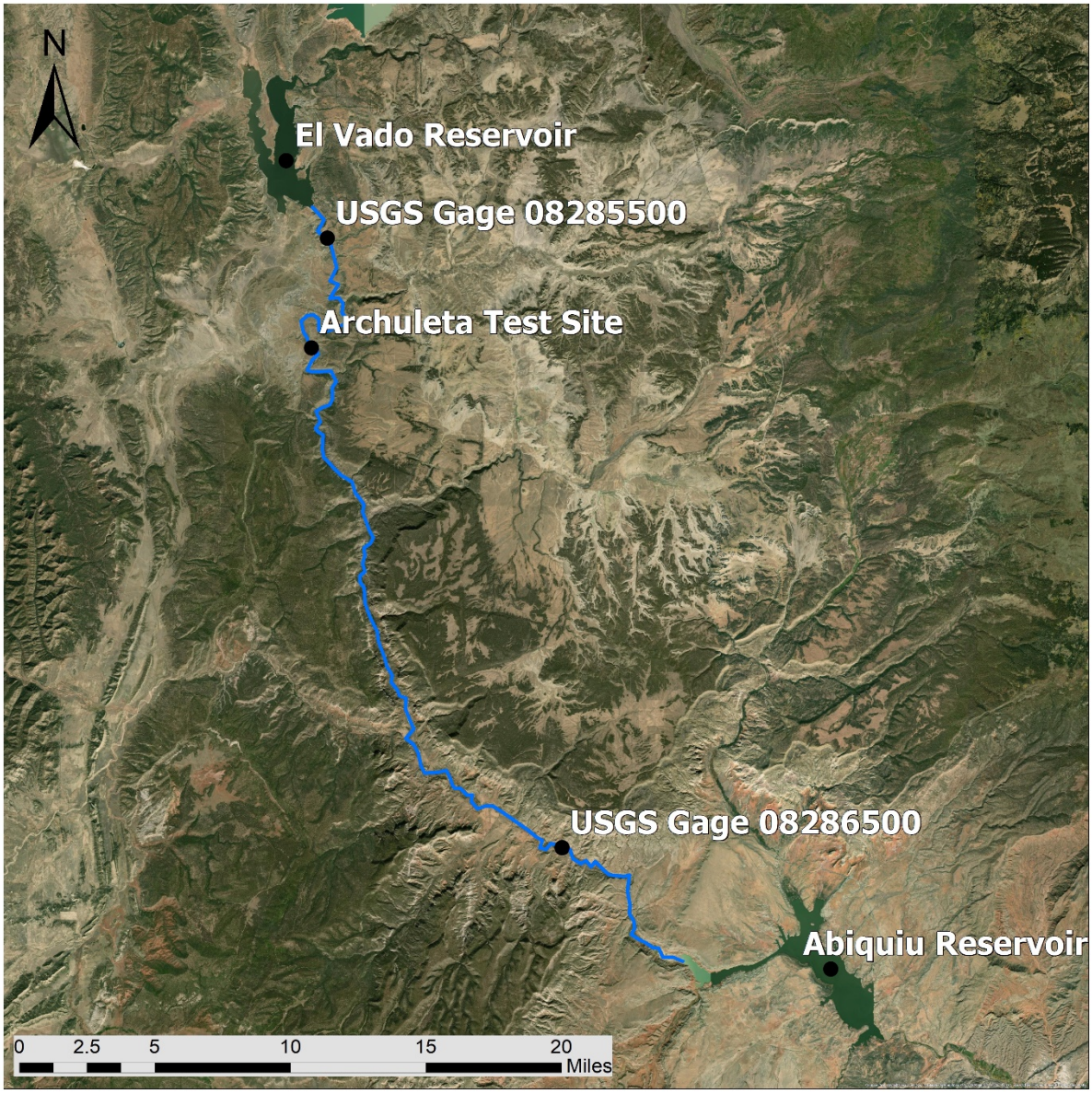

Figure 1. Wild and Scenic Rio Chama with USGS streamflow gages and selected test site labeled.

Literature Review Findings

There were three key findings of the literature review. The first was identification of a recent research effort on incipient motion in the Rio Chama conducted by researchers at UNM. For this study, pebble counts and topographic surveys were performed. The data was used to develop an SRH-2D numerical hydrodynamic model, the output from which was used to quantify bed material

mobilization. Two reports were published about the study, one in 2013 following the initial data collection of model work and another in 2018 following updates to the model. Overall, the study found that flows at 56 m^3/s (~1,980 cfs) would mobilize fine sediments and flows above 100 m^3/s (~3,530 cfs) would cause "extensive" flushing of fine sediments (Gregory et al., 2018). Efforts to analyze incipient motion for the benefit of the brown trout on the Wild and Scenic Rio Chama date back to the 1992 Rio Chama Instream Flow Assessment. The assessment found that a 2,000 cfs flow did not cause a significant change in the fine sediment percentage of the streambed composition (BLM, 1992).

The second finding is the selection of a test site for the conducting proposal. One of the sites included in the UNM study is referred to as "Archuleta" and is located approximately 7.3 miles downstream of El Vado Dam (at approximately 36°32'N, 106°44'W). This site was selected for the conducting proposal because it has road access to each side of the river to facilitate data retrieval even during high flows. Also, the SRH-2D model that was developed for this site would provide a verification method for the results of the hydrophone study.

The third finding is that, while still a developing application for the technology, previous research has shown underwater acoustic sensors, or hydrophones, to be a viable low-cost and passive method to monitor sediment transport. Hydrophones were used in studies conducted by the U.S. Geological Survey (USGS) as well as an S&T project to estimate rates of bedload transport as part of Reclamation's Trinity River Restoration Program (Marineau et al., 2017; Hilldale et al., 2017). During the literature review process, researchers who had worked on such projects were contacted to learn more about their projects. The researchers contacted included Ari Posner, a physical scientist from Reclamation, and Ron Griffiths and Jeb Brown, both hydrologists from the USGS, who are all involved in an S&T project related to suspended sediment monitoring of acoustic sensors.

Through contacting the above researchers, it was discovered that a hydrophone project with the same purpose and intent of this Rio Chama project had been conducted by USGS researchers. A 2019 USGS study used stationery and boat-mounted hydrophones to estimate incipient motion and flushing flows on the Upper Colorado River (Kohn et al., 2020). Like the Rio Chama, the Upper Colorado River uses flushing flows to restore and maintain aquatic habitat for trout. The study was conducted in cooperation with the Upper Colorado River Wild and Scenic Stakeholder Group and sought to "better understand sediment transport and its relation to flow regimes of the river".

Mathieu Marineau, a research hydrologist who co-authored the study, was also contacted and agreed to be a co-principal investigator on the Rio Chama conducting proposal's work. Michael Kohn, a civil engineer and the principal investigator on the USGS study, and Mathieu Marineau have graciously agreed to lend four of the stationary hydrophone setups they built for their 2019 study to the Rio Chama study, should it be approved.

Summary of Conducting Proposal

Following the literature review and speaking with several researchers that have worked with hydrophones, a conducting proposal was developed and submitted for the FY21 S&T Program call for proposals (Appendix A). The conducting proposal seeks to expand the applicability of

hydrophones to a new river location, the Wild and Scenic Rio Chama, to test its capabilities there and potentially develop a long-term sediment mobilization monitoring methodology. Mathieu Marineau, a research hydrologist who worked on the Upper Colorado River study, has agreed to collaborate on this project and will bring his experience using hydrophones and processing the recorded data.

The research method for the Rio Chama study would follow the same methods used in the Upper Colorado River study (Kohn et al., 2020). Installation of the four stationary hydrophones would occur at locations throughout the Archuleta site, most likely in pools/runs downstream of riffles where trout spawning habitat is located and bed mobilization is most desired. The installation points would also depend on their proximity to a safe place on the riverbank where the data logger and power source can be placed in a weatherproof case and secured. The installation points would be determined during an initial site visit.

The hydrophones would be mounted to rebar that is driven into the streambed at a sufficient depth that it does not move during high flows. The hydrophones would be connected to a data logger and would record data continuously from April to December. This is historically when higher flows that could initiate mobilization are experienced on the Rio Chama, based on data from the USGS gauge below El Vado Dam (USGS 08285500), the streamflow gauge closest to the study site. Data would be retrieved from the logger every four weeks.

The signal processing and data analysis/interpretation would follow a similar procedure to that used in the USGS Upper Colorado study. The audio signals are processed in MATLAB using a Fourier transform to obtain the power spectral density. A spectrogram would then be created displaying time versus frequency and the sound level for each frequency. The spectrogram would be used to estimate the sediment generated noise. If debris or another disturbance were to cause undesirable background noise in the data, a manual aural review of audio files selected at an interval would be conducted. The data would be sorted into one of four transport categories: no transport, very low transport, low transport, and moderate transport. The time stamps from the hydrophone data would be correlated to the nearest corresponding time stamp of the streamflow gauge at El Vado to determine the discharge at that time (Kohn et al., 2020).

Another signal analysis technique, one that was not used in the USGS study, was suggested by Mathieu Marineau to be tested in the proposed Rio Chama project. This technique would count the number of bedload particle collisions over a threshold level to qualitatively determine when bedload mobilization starts, as well as obtaining a crude quantitative estimate of the transport rate at low levels. The estimated transport rate can be compared to the current understanding of transport rates for incipient motion, such as the dimensionless transport parameter W* which is equal to 0.002 when incipient motion is beginning (M. Marineau, personal communication, June 8, 2020).

Sediment sampling of the streambed materials, preferably using freeze-core sampling and/or Quorer method, before and after the data collection period would provide a method of verifying that mobilization/fine sediment flushing occurred. The SRH-2D numerical model (Gregory, 2013; Gregory et al., 2018) that has been developed at the project site can provide another method of verifying the conclusions drawn from the hydrophone data. Additionally, a turbidity monitor installed at the study site would record when fine sediment is mobilized and identify when tributary flow events that contribute fine sediment to the site have occurred and compare this to when the

hydrophones detect gravel mobilization. Turbidity monitors were not used in the Upper Colorado study but were recommended by Mathieu Marineau to provide a more robust understanding of what is occurring at the test sites during high flows.

Through the collection and analysis of this data, it is the intention of the conducting proposal to better understand the range of flows that will initiate and most effectively mobilize streambed sediments for the benefit of brown trout in the Rio Chama and to advance the research of using hydrophones for this purpose.

Conclusion

Hydrophones are an economical and passive method to detect incipient motion and determine what range of flow rates are needed for streambed mobilization. A better understanding of the interaction between flow rates and mobilization would assist water managers in planning more effective high-flow pulses for environmental enhancement where only the minimal, required flow is released. As less water is available in the Rio Chama due to climate change and its impacts on water supply, using only the required flow will become more important.

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Glossary

Freeze-core sampling. Sampling technique which allows for "undisturbed sampling of cohesionless sediments by freezing the sediment [using liquid nitrogen] whilst preserving its original sediment structure" (Strasser et al., 2015).

Incipient motion. "…the transition from a stationary state to a state of initial…motion of the sediment particles in response to an increase in hydrodynamic forces acting on a bed of loose sediment" (Simões, 2014).

Power spectral density. "…shows the strength of variations [in a time series data set] as a function of frequency". "PSD is a very useful tool if you want to [identify] frequencies and amplitudes of oscillatory signals…" (CRI, n.d.).

Quorer method. Provides a measure of the suspendible fine sediments on the surface and within the subsurface of gravel-bed rivers (Clapcott et al., 2011).

Sedimentation and River Hydraulics – Two-Dimension (SRH-2D). "…two-dimensional (2D) flow hydraulic and mobile-bed sediment transport model for river systems." The software was developed by Reclamation in collaboration with the Federal Highway Administration and Taiwan's Water Resources Agency (Reclamation, 2020).

Appendix A – Conducting Proposal (Project 21092)

Utilizing Hydrophones to Detect Streambed Mobilization in the Wild and Scenic Reach of the Rio Chama

Project: 21092

Rebecca Dias Braz, rbraz@usbr.gov

Bureau of Reclamation
Research and Development Office
Science and Technology Program

Bookmarks

SECTION I - Proposal Summary Information

Proposal Type
ST Internally Solicited

Performance Period
2021 - 2022

Proposal Description

The Rio Chama is a tributary of the Rio Grande in northwestern New Mexico. The Chama receives a combination of native water and inter-basin transfer water from the San Juan-Chama Project. Because of climate change, native water flows in the Rio Chama are expected to decrease by one-third and inter-basin transfer flows by one-quarter over the next century.

The stretch of the Rio Chama between El Vado Dam and Abiquiu Dam was designated Wild and Scenic in 1988. This stretch of the Rio Chama is a high-sediment system with a significant amount of fine sand, silt and clay (mud) deposited on gravel-cobble (coarse) bed material. This mud restricts oxygen transport in the gravel streambed, reducing food sources and affecting spawning habitat of the brown trout, a key species in the designation of the Wild and Scenic reach. The Bureau of Reclamation periodically releases high-flow pulses from El Vado Dam for environmental enhancement purposes, including to clear mud from the streambed to maintain habitat for the brown trout and their macroinvertebrate food base.

Previous research has shown that fine sediment is mobilized, along with coarser sediment, in a threshold event that occurs when flows have enough energy to pick up the median grain size in the bed. With less water available in the future for these high flow pulses, it is necessary to better understand what range of flow rates are needed for bed mobilization to help water managers plan more effective high-flow pulses.

Hydrophones have been shown to be a viable low-cost and passive method to monitor sediment transport. A 2019 study conducted by the USGS used stationery and boat-mounted hydrophones to estimate incipient motion and flushing flows on the Upper Colorado River (Kohn et al., 2019). This proposal seeks to expand the applicability of hydrophones to a new river location, the Rio Chama, to test its capabilities there and potentially develop a long-term monitoring methodology. Mathieu Marineau, a research hydrologist at the USGS California Water Science Center who worked on the Upper Colorado River study, has agreed to collaborate on this project and lend his experience using hydrophones and processing its data.

The area for this research would be a site referred to as “Archuleta” located approximately 7.3 miles downstream of El Vado Dam. A recent incipient motion study conducted by the University of New Mexico included this site. In this study, pebble counts and topographic surveys were performed. The data was used to develop an SRH-2D numerical hydrodynamic model, the output from which was used to quantify bed material mobilization (Gregory et al., 2018). The mud content of the bed materials at this site was also quantified (Hobbs in prep.) using the Quorer method, but the effects of mud on bed material mobilization have yet to be investigated. The numerical model could be used as a method of validating the reasonableness of the results of this proposed hydrophone study.

Hydrophone systems would be placed in various locations within the Archuleta site. Continuous data collection would occur from April to December, which is historically when higher flows are experienced on the Chama based on the USGS gauge below El Vado Dam (USGS 08285500). Sediment samples would be taken at each hydrophone site at the beginning and end of the data collection period to provide another means of evaluating if and what changes occurred in the streambed during higher flows. A turbidity monitor would also be installed at the Archuleta site to give insight into fine sediment transport; this would be compared to the coarse sediment transport information recorded by the hydrophones.

Through the collection and analysis of this data, it is the intention of this proposal to better understand the range of flows that will initiate and most effectively mobilize streambed sediments for the benefit of brown trout in the Rio Chama and to advance the research of using hydrophones for this purpose.

Tags

brown trout, hydrophone, incipient motion, sediment transport, streambed mobilization

Benefiting Regions

Interior Region 5 & 6: Missouri Basin & Arkansas-Rio Grande-Texas-Gulf	Interior Region 7: Upper Colorado Basin	Interior Region 8: Lower Colorado Basin	Interior Region 9: Columbia-Pacific Northwest	Interior Region 10: California-Great Basin	Denver Office
Y	Y	Y	Y	Y	Y

Field-Based Research Location

Wild and Scenic reach of the Rio Chama (Archuleta site located at approximately 36°32’N, 106°44’W)

Project Type

Conducting

Technology Readiness Level (TRL)

TRL-8 Actual system completed and qualified through test and demonstration

Technology Transfer/ Intellectual Property

Proposal discloses IP that should be or is protected through it's narration (unlikely)	No
Principal Investigator intends to use IP provided by partner that should be or is protected	No
Principal Investigator intends to develop IP (with or without partner) that they anticipate will need protection	No

Security Sensitive Information

No

Regional Director Need

No

Research Area - Research Category - Research Need

Research Area: Environmental Issues for Water Delivery and Management

Research Category: Water Delivery Reliability

Research Need: 1. Operations strategies for flow hydrographs to improve ecological resiliencies (e.g. ecosystems, groundwater recharge, bioc

Need Description: Native and inter-basin transfer water in the Rio Chama is expected to decrease over the next century because of climate ch the flow rates that flush fine sediment and mobilize the gravel streambed to maintain brown trout habitat and the supporting aquatic ecosyster passive coarse sediment monitoring tool that could be utilized in the Chama and any gravel-bed river in all of regions of Reclamation.

Prize Competition

Prize Title: None

Prize Solution: N/A-Not Applicable

Prize Competition Comment: None

SECTION II - Research Strategy - Task Description

Need, Benefit and Urgency

Native and inter-basin transfer water in the Rio Chama is expected to decrease over the next century because of climate change. The Wild and Scenic stretch of the Rio Chama relies on high-flow dam releases for environmental enhancement purposes, including to flush fine sediment and mobilize the gravel streambed, which is a necessary part of maintaining brown trout habitat and the supporting aquatic ecosystem in the Chama. An SRH-2D numerical hydrodynamic model was developed for two sites on the Wild and Scenic stretch by researchers at the University of New Mexico to study incipient motion and quantify bed material mobilization. While this model can be used to predict sediment mobilization, the outputs of this model still require verification. The results of this project would provide a physical means of doing that.

Hydrophone technology has been successfully used to quantify magnitude of bedload transport and to produce near continuous records of transport. There has been some research using hydrophones to detect incipient motion, the recent USGS study on the Upper Colorado River for example. The proposed project on the Rio Chama would aid the refinement of this methodology by adding to its research base and testing the technology in a new river location. The components of a hydrophone system are relatively low-cost which makes it desirable as an economical and passive method for monitoring flushing flows that could benefit rivers in all regions of Reclamation.

The coarse sediment transport detected by the hydrophones can be correlated to a range of flow rates. The results would be a “range” of flow rates because different magnitude flows are needed to initiate mobilization in different places within the reach. This information could be used by water managers to increase the effectiveness of high flow pulses on the Rio Chama that are released for environmental enhancement. Also, hydrophones deployed long-term in different rivers could allow water managers in all regions of Reclamation to monitor the effectiveness of environmental flows as climate change decreases water supply. It is important to study these methods of monitoring and increasing the effectiveness of environmental flows while our water supply is still adequate to do so.

Previous Work

Hydrophones have been used by the USGS on many rivers in the United States to detect bedload sediment transport, including the Trinity River, at part of the USBR Trinity River Restoration Program and most recently on the Upper Colorado River to detect incipient motion and estimate flushing flows. This Upper Colorado River study used stationery and boat-mounted hydrophones to analyze where bedload transport was occurring during various flow rates for the benefit of brown trout spawning. Mathieu Marineau, who co-authored that study, is a co-PI on this proposal’s work. Citations below.

Kohn, M.S., Marineau, M.D., Hempel, L.A., and McDonald, R.R., 2020, Incipient Bed Movement and Flood-Frequency Analysis using Hydrophones to estimate Flushing Flows on the Upper Colorado River, 2019: U.S. Geological Survey Scientific Investigations Report 2020-XXXX, XX p., https://doi.org/10.3133/sir2020xxxx.

Marineau, M.D., Wright, S.A., Gaeuman, D., Curran, C.A., Stark, K., Siemion, J., Schenk, E.R., 2019, “Overview of Five Recent Acoustic Bedload Monitoring Field Experiments Using Hydrophones”, Proceedings to SEDHYD, Reno, NV, 14p.

Marineau, M.D., Wright, S.A., Gaeuman, D., 2017, Estimating bedload transport along the gravel-bedded Trinity River using in-situ and boat-mounted hydrophones: Proceedings of the 2017 Hydraulic Measurements and Experimental Methods Conference, Durham, New Hampshire, July, 10-12, 2017, 6 p.

Research on incipient motion in the Rio Chama has been conducted by researchers at the University of New Mexico with two reports on the study having been published in 2013 and 2018 (citations below). One of the sites included in the study was the Archuleta site. Pebble counts and topographic data were collected at Archuleta and used to develop an SRH-2D model. This analysis found that flows at 56m3/s (~1980cfs) would mobilize fine sediments and flows above 100m3/s (~3530cfs) would cause “extensive” flushing of fine sediments. The SRH-2D model could be used a method of testing the reasonableness of the results of this hydrophone study.

Gregory, Angela. "Incipient motion of mixed sediment load on the Rio Chama." (2013). https://digitalrepository.unm.edu/ce_etds/83

Gregory, Angela & Morrison, Ryan & Stone, Mark. (2018). Assessing the Hydrogeomorphic Effects of Environmental Flows using Hydrodynamic Modeling. Environmental Management. 62.10.1007/s00267-018-1041-6.

Research Question

The Wild and Scenic Rio Chama receives a significant supply of fine sediments from its tributaries and from bank erosion. These fine sediments smother and fill the interstitial spaces within the gravel streambed and restrict oxygen transport in the bed which negatively affects brown trout habitat. Mobilization of the streambed is necessary to not only remove fines on top of the gravels but also the fines in the interstitial spaces. Environmental flows released from El Vado Dam are used to initiate streambed mobilization in the Rio Chama. This research seeks to utilize hydrophone technology to detect when streambed mobilization occurs and correlate this occurrence to a range of flow rates. The flow rates would be used by water managers to plan more effective environmental flows. This project also seeks to further the refinement of hydrophones as an incipient motion monitoring methodology as it would be an economical and passive (i.e., desirable) method for doing so.

Research Methodology

This proposal seeks to use hydrophone technology to detect streambed mobilization. Michael Kohn, the principal investigator on the USGS Upper Colorado River study, and Mathieu Marineau have graciously agreed to lend the four stationary hydrophone setups used in their 2019 study. Installation of the stationary hydrophones would occur at four locations throughout the Archuleta site, most likely in pools/runs downstream of riffles where bed mobilization would occur first. The installation points will also depend on their proximity to a safe and secure place on the riverbank where the data logger and power source (placed in a weatherproof case) can be placed. The hydrophones will be mounted to rebar that is driven into the streambed at a sufficient depth so it will not move during the high flows. The hydrophones would be connected to a data logger that will record data continuously from April to December which is historically when higher flows that could initiate mobilization are experienced on the Chama, based on data from the USGS gauge below El Vado Dam (USGS 08285500) which is the gauge closest to the study site. Data will be retrieved from the logger every four weeks.

The signal processing and data analysis/interpretation will follow a similar procedure to that used in the USGS Upper Colorado study (Kohn et al., 2019). The audio signals will be processed in MATLAB using a Fourier transform to obtain the power spectral density. A spectrogram is then created displaying time vs frequency and the sound level for each frequency and is used to estimate the sediment generated noise. If debris or another disturbance were to cause undesirable background noise in the data, a manual aural review of audio files selected at an interval would be conducted. The data will be sorted into one of four transport categories: no transport, very low transport, low transport, and moderate transport. The time stamps from the hydrophone data will be correlated to the nearest corresponding time stamp of the streamflow gauge at El Vado to determine the discharge at that time.

Another signal analysis technique not used in the USGS study will be tested in this proposed project. This technique would effectively count the number of bedload particle collisions over a threshold level and assume the detection area. With this method it can be qualitatively determined when bedload mobilization starts as well as obtaining a crude quantitative estimate of the transport rate at low levels. The estimate of the transport rate can be compared to the current understanding of transport rates for incipient motion.

Sediment sampling of the streambed materials, preferably using the freeze-core sampling and/or Quorer method, before and after the data collection period would provide a method of verifying that mobilization/fine sediment flushing occurred. The SRH-2D numerical model that has been developed at the project site can provide another method of verifying the conclusions drawn from the hydrophone data. Additionally, a turbidity monitor installed at the study site would record when fine sediment is mobilized and identify when tributary events that contribute fine sediment to the site have occurred and compare this to when the hydrophones detect gravel mobilization.

Research Strategy Tasks

Task Number	Task Name	FYB	FYE	Task Description
Task-0	Project Management	2021	2022	- Tracking project funding and progress - Responding to quarterly reports - Providing updates to collaborators - Entering requisitions
Task-1	Prepare Interagency Agreement with USGS	2021	2021	- Once project funds are released, prepare the PR package for the interagency agreement. - Coordinate with Mary Maestas, Contracting Officer at Reclamation's Albuquerque Area Office and Vicki Wu, the Budget Analyst at USGS California Water Science Center to put the agreement in place so that Mathieu Marineau receives funding. Rebecca will act as the COR for this agreement. - This proposal's timeline is adaptable to the expected four to six month time period to get this agreement in place
Task-2	Site Investigation	2021	2021	- Before high flows start in April, the Chama's stream height is such that the streambed can be safely accessed. During this low flow period, a site investigation trip will be conducted to choose specific points at the Archuleta site where hydrophones will be placed. - Place stakes so the specific sites can easily be relocated for installation. - Inspection by Environment and Lands Division of Reclamation's Albuquerque Area Office for NEPA compliance; expected to be a simple Categorical Exclusion.
Task-3	Acquire Equipment & Installation Preparation	2021	2021	- Purchase all equipment needed for installation (turbidity monitors, materials for freeze-core sampling, rebar, possibly PPE, etc.). - Complete any preparation that can be done prior to field work (wiring to power source, placing equipment in weather-proof storage, etc.)
Task-4	Equipment Installation	2021	2021	- During the low flow period when the streambed can be safely accessed, install the hydrophone systems (hydrophones, data logger, power source, rebar for deflecting debris, etc.) and turbidity monitors - Collect sediment samples at each monitoring site. Perform sieve analysis of sediment samples when returned to the office.

Research Strategy Tasks

Task Number	Task Name	FYB	FYE	Task Description
Task-5	Data Collection	2021	2022	- Hydrophones and turbidity monitors will be connected to a logger that will record data continuously; will retrieve data from the logger every four weeks during the collection period from April to December - Two, weekly visits when high flows first begin in FY21 to check the stability of the hydrophone installation - Switch out power source at each monthly visit - Upload, store, and backup data when back in the office after each visit - Because this task takes place on the riverbank in a remote location, this task will be completed in pairs and wearing proper PPE (e.g., lifejackets) - Last collection visit, or when flows are low enough again to safely access the streambed, collect another set of sediment samples at each installation site. Perform the sieve analysis once returned to the office.
Task-6	Signal Processing, Analysis, and Interpretation	2021	2022	- Signal processing using MATLAB script - Create spectrogram and interpret results to identify transport regime, may need to manually review audio files - Counts of bedload particle collisions to identify when transport is initiated and to obtain a crude estimate of transport rate - Manual, aural review of data audio data files if necessary and/or for quality control - Correlating data time-series to the stream gauge readings; will use data from USGS gauge 08285500 Rio Chama Below El Vado Dam, NM
Task-7	Final Report & Closeout Process	2021	2022	- Develop final report and bulletin of findings - Peer review process - Complete closeout process - Ensuring the audio time-series data and report are posted online

SECTION III - Research Strategy - Key Persons

Key Person	Task Number	E-Mail	Expertise	Responsibilities	Organization	Region
Rebecca Dias Braz	0, 1, 2, 3, 4, 5, 6, 7	rbraz@usbr.gov	Academic experience with geotechnical engineering, geology, and hydrology; river geomorphology training with USGS; completed a literature review for the S&T scoping project (ID 20070) that led to the completion of this conducting proposal	Co-Principal Investigator; COR	Interior Region 7: Upper Colorado Basin	UC
Dagmar K. Llewellyn	2, 4, 5	dllewellyn@usbr.gov	Experience with water management of high flow pulses for benefit of trout habitat in the Rio Chama	Co-researcher	Interior Region 7: Upper Colorado Basin	UC
Mary Beth Maestas	1	mmaestas@usbr.gov	Contracting Officer at Reclamation's Albuquerque Area Office	Assist with the interagency agreement	Interior Region 7: Upper Colorado Basin	UC
Mathieu D. Marineau	1, 2, 3, 4, 6, 7	mmarineau@usgs.gov	Experience utilizing hydrophones to monitor bedload transport and interpreting the data collected; recently completed a study with the same objective as this proposal	Co-Principal Investigator	USGS California Water Science Center	
Victoria Wu	1	vwu@usgs.gov	Budget Analyst at the USGS California Water Science Center	Assist with the interagency agreement	USGS California Water Science Center	

SECTION IV - Proposal Budget Detail

Fiscal Year	Fiscal Year Total Budget
2021	$94,000.00
2022	$53,000.00

2021

Interior Region 7: Upper Colorado Basin

Labor	Travel	Contracts	Contract Type	Non Labor	Total
$50,000.00	$1,500.00	$0.00		$6,500.00	$58,000.00

USGS California Water Science Center

Labor	Travel	Contracts	Contract Type	Non Labor	Total
$0.00	$0.00	$36,000.00	Interagency Agreement	$0.00	$36,000.00

Total For Fiscal Year: $94,000.00

2022

Interior Region 7: Upper Colorado Basin

Labor	Travel	Contracts	Contract Type	Non Labor	Total
$25,000.00	$0.00	$0.00		$1,000.00	$26,000.00

USGS California Water Science Center

Labor	Travel	Contracts	Contract Type	Non Labor	Total
$0.00	$0.00	$27,000.00	Interagency Agreement	$0.00	$27,000.00

Total For Fiscal Year: $53,000.00

SECTION V - Partnership

Fiscal Year	BOR	Federal Government	Non Federal Government
2021	$10,000.00	$10,000.00	$0.00
2022	$0.00	$0.00	$0.00

2021

Partner Name	E-Mail	Organization Type	Description	Contribution Type	Amount
Jennifer A. Faler	jfaler@usbr.gov	BOR	A request for local funding has been submitted to the Area Office Manager of Reclamation's Albuquerque Area Office	Cash - Not Firm	$10,000.00

2021

Partner Name	E-Mail	Organization Type	Description	Contribution Type	Amount
Michael Kohn	mkohn@usgs.gov	Federal Government	Michael Kohn has agreed to contribute the four hydrophone setups that have been successfully deployed in a recent study with the same purpose at this proposed study. The setups include the data loggers (which were put together by Mathieu Marineau). Between the raw components (hydrophones, pre-amplifiers, data loggers, wiring, etc.) and labor for assembly, programming, and testing, the contribution is estimated at approximately $10,000. These costs would have been incurred in the first year of the project and so are noted as a contribution in FY21 although the equipment will be used in FY22 also.	In Kind - Firm	$10,000.00
				Total For Fiscal Year:	$20,000.00

2022

Partner Name	E-Mail	Organization Type	Description	Contribution Type	Amount
Jennifer A. Faler	jfaler@usbr.gov	BOR	N/A	Cash - Firm	$0.00
Michael Kohn	mkohn@usgs.gov	Federal Government	N/A	Cash - Firm	$0.00
				Total For Fiscal Year:	$0.00

SECTION VI - Proposal Details

Quality Control

Mathieu Marineau's prior experience using hydrophone technology to acquire streambed mobilization data will benefit quality control greatly. A peer review of the final report and bulletin will be completed prior to submission and will follow the Project Closeout Requirements.

Risk Management

If flows that are inadequate to mobilize the streambed are forecasted to be released from El Vado Dam during the data collection period, then usable data may not be attainable. If this were to occur, the data collection period may need to be pushed back or extended.

A potential source of risk is damage to the hydrophones or poor data quality caused by debris. This risk can be mitigated by placing rebar a short distance upstream of the hydrophone installations to deflect or catch debris and by servicing the hydrophone equipment on a regular basis when debris can potentially be cleared.

If the rebar that the hydrophones are mounted on were to be dislodged during the high flow releases, the hydrophones are still connected by wiring to the data logger on the riverbanks, which could save the hydrophone from being lost totally. By servicing the hydrophones regularly, we will know if the rebar has become dislodged and can address the issue.

There is some potential risk of vandalism because the equipment will be in the field continuously. The remote location of the test site both helps and hinders this potential problem. The weatherproof casing that houses the power source and data logger will be padlocked, secured, and concealed to the highest degree possible.

Other Comments

N/A

SECTION VII - Communicating Results

Communication Plan

The final report and bulletin will be prepared following all Project Closeout Requirements. The final report and bulletin will include a summary of the methods used for data collection, the equipment used, analysis of the data collected, and conclusions drawn from the analysis. The final report will be shared with water managers who can use the findings in planning more efficient environmental flows in the Wild and Scenic Rio Chama. The report will also highlight how well the hydrophones performed in this new river location and discuss the advancements to the research of this monitoring method that could benefit all regions of Reclamation. The raw audio data collected, estimated to be between 20GB and 30GB, will be backed up on internal servers and a reduced-size version may be released online.

Optional Deliverables

Infographics	Journal Article	Conference	Powerpoint Presentation	Targeted E-Mail	Software	Video	Webcast	Workshop
N	N	N	N	N	N	N	N	N

Talking Points - Bottom Line

The Wild and Scenic Rio Chama receives a significant supply of fine sediments from its tributaries and from bank erosion. These fine sediments smother and fill the interstitial spaces within the gravel streambed and restrict oxygen transport in the bed which negatively affects brown trout spawning habitat and its macroinvertebrate food source. Mobilization of the streambed is necessary to not only remove fines on top of the gravels but also the fines in the interstitial spaces. Environmental flows released from El Vado Dam, at the upstream-most point of the Wild and Scenic stretch, are used to initiate streambed mobilization for environmental enhancement purposes. This research seeks to utilize hydrophone technology to detect when streambed mobilization occurs and correlate this occurrence to a range of flow rates that can be used by water managers to plan more effective environmental flows on the Rio Chama. This project also seeks to further the refinement of hydrophones as a coarse sediment transport monitoring methodology as it would be an economical and passive (i.e., desirable) method for doing so that could be used in all regions of Reclamation.

Talking Points - Better, Faster, Cheaper

Hydrophones are an economical and passive method for detecting streambed sediment mobilization that could potentially be used in all regions of Reclamation. This research would focus on the occurrence of mobilization in the Wild and Scenic Rio Chama where mobilization is necessary to promote oxygen transport in the streambed to support brown trout habitat. The occurrence of mobilization could be correlated to a range of flow rates lending to better management of high-flow pulses in the Chama.

SECTION VIII - Implementation of Results

Application Potential

Hydrophones can be used to determine when streambed mobilization occurs in any river with a coarse sediment streambed. In this proposed study, the hydrophones will record mobilization in the Wild and Scenic Rio Chama, which can then be correlated to a flow rate. The resulting data would increase the efficiency of high flow pulses that are released from El Vado Dam for environmental enhancement purposes, including mobilizing sediment to support oxygen transport in the stream bed. Using hydrophones is a low-cost and passive method for determining the effectiveness of environmental flows' ability to initiate bed mobilization.

Application Desciption

This application of hydrophones could be used in all locations where gravel and fine sediment riverbeds exist and wherever it would be beneficial to better understand streambed/sediment movement. Downstream of dams especially, where the change in sediment supply and transport has varied effects, it would be beneficial to have a passive method to acquire continuous sediment transport data to evaluate how certain flows are affecting the sediments in the streambed.

Facilitated Adoption

The results of this research project would be a better understanding of what flows will initiate streambed mobilization in the Wild and Scenic Rio Chama, which is desirable from an environmental enhancement perspective. The hydrophones detect when bed mobilization has occurred, and this moment of mobilization can be correlated to a range of flow rates. Water managers at Reclamation can use this information to increase the efficiency of environmental flows released from El Vado Dam. This research will also widen the research base of using hydrophones for this purpose and potentially promote their use in all regions of Reclamation.

Impact Description

This proposal seeks to widen the applicability of hydrophones to a new river location, the Wild and Scenic Rio Chama, and test its capabilities there. Hydrophones are an economical and passive method to detect streambed mobilization and determine what range of flow rates are needed. This heightened understanding would result in more effective environmental flows (high-flow pulses) where only the required flow is released. The effectiveness of these flows will become more important as less water becomes available in the Chama because of climate change. Previous S&T-funded research has shown that acoustic sensors are suitable for detecting movement of coarse sediments (Robert Hilldale from TSC's work with hydrophones as an example). Research conducted by the USGS, as discussed in the Previous Work section, has shown that hydrophones are suitable for detecting bedload movement.

SECTION IX - Approvals

Manager: Anthony Michael Lampert