Joint Technology Transfer Initiative

Improving Hydrologic Observing Capabilities with Stream Radars

Research to Operations Transition Plan

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Approval page

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The below parties, by providing signatures, are satisfied with and approve of the transition plan outlined in this document, which may be reviewed on an annual basis and updated as needed.

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1. Purpose/Objective

The purpose of this Research to Operations (R2O) Transition Plan is to describe an approach for transitioning unique hydrologic observations using Stream Radars from a research project to real-time data transmission to the National Weather Service (NWS), with the potential for long-term sustained operational capability. Stream Radars provide a cost-effective, low-maintenance observing platform to complement the conventional streamgage network, allowing water monitoring where otherwise impractical.

The new National Water Model has dramatically increased the resolution of water forecasting, and advances in river monitoring must follow suit. The United States Geological Survey (USGS) operates approximately 7800 real-time streamgages in the conterminous United States. However, still more watersheds at the HUC 10 scale remain ungaged, largely because access or cost makes conventional gaging uneconomical. It is estimated that the annual operations and maintenance (O&M) cost of a conventional streamgage is on par with the initial deployment cost of ~$15,000. One of the major O&M cost drivers is the need to continually update stage-discharge ratings through repeated, labor-intensive, manual measurements.

Stream Radars address this problem by measuring both stage and velocity, enabling direct discharge calculation provided that the streambed is surveyed and is reasonably stable. The resultant savings in O&M, combined with very minimal infrastructure requirements, make Stream Radars a viable option for monitoring smaller or less accessible watersheds. In the future, a network of Stream Radars may complement the existing USGS gage network, providing high-quality data for the National Water Model in areas currently unmonitored. This project will accelerate that future by installing 14 Stream Radars for operational use and providing a template for future expansion.

2. Research background

The USGS began exploring the possibility of noncontact streamflow measurements in the late 1990s, using radar sensors for measuring surface velocity and depth.[1] While that demonstration showed promise, it was shelved in the early 2000s. Collaborator John Fulton (USGS) revisited the concept a decade later, taking advantage of a growing market of commercially available radar sensors for hydrologic measurement. In April 2014, Mr. Fulton installed a radar stage sensor over the Rio Grande at Embudo, NM, collocated with a conventional streamgage for intercomparison. Over the 17-month evaluation period, the radar stage sensor showed excellent agreement with the conventional gage in a wide variety of flow conditions (7-94 cubic meters per second). In 2015, a team led by Mr. Fulton, with support from collaborator Jonathan Gourley and PI Daniel Wasielewski, installed three stage-velocity Stream Radars in Waldo Canyon, CO, to serve as an early alert to the Colorado

[1] Costa, J. E., et al. "Use of radars to monitor stream discharge by noncontact methods." *Water Resources Research* 42.7 (2006).

Department of Transportation of impending flash floods and debris flow events. The Waldo Canyon installations were very successful and serve as the template for the 14 Stream Radars that will be installed in the course of this project.

3. Capabilities and Functions

3.1 Current capability

The present readiness level of the system is estimated at a 6 (System/subsystem model or prototyping demonstration in a relevant end-to-end environment). Members of the project team were involved in the deployment of the Stream Radars in Waldo Canyon, CO. These Stream Radars were successfully demonstrated for data collection with low-latency transmission to local stakeholders and the Pueblo NWS office, typically completing scheduled transmissions within 2 minutes of the scheduled time and providing unscheduled emergency notifications within 10 minutes of a flood event.

3.2 Operational capability

This two-year project will raise the readiness to an 8 (Actual system completed and "mission qualified" through test and demo in operational environment). At the conclusion of the project, it is intended that Stream Radars are fielded in 14 locations chosen to (a) address the peculiarities of installations with varied accessibility, infrastructure, and hydrologic conditions, (b) highlight advantages of the Stream Radar system and/or (c) facilitate comparison with conventional gages or other instruments. Additionally, the data from these installations will be transmitted from the site and included in the USGS National Water Information System (NWIS). The National Water Model already ingests conventional gage data from NWIS, so there is no need to establish an independent pipeline for these data.

The JTTI project entails the support of the Stream Radar platforms and transmission of their data for potential operational use for a period of two years. The investigators will seek partners during this demonstration from potential beneficiaries such as state Mesonets, the Chickasaw and Choctaw tribes, the Oklahoma and Colorado Departments of Transportation, Texas State University, and other local academic or industry entities depending on the siting of the systems. It is envisioned that these local stakeholders will cover or share the responsibility of the O&M costs to continue the data platforms. Should the technology prove beneficial, the OWP and NWC would engage with NWS Observation Portfolio or other Federal Agencies to explore options of permanent installation and long-term O&M.

A second aspect of this R2O project is to provide a template for future installations. The Stream Radar concept may be proliferated as a complementary network to the existing USGS streamgage network. This project will generate manuals and documentation detailing a baseline system and any site-specific features or deviations. The NWS or

other partners may use these manuals and documents if this demonstration generates further investment in the concept.

3.3 Acceptance criteria for transition

- Successful installation of the Stream Radars and transmission of data with latency less than 10 minutes (this specification is for transmission only; actual time between event and data availability in NWIS will vary from several minutes to several hours depending on configurable adaptive logging and telemetry intervals).
- Data available in NWIS in a format backward-compatible with existing USGS gage data for seamless integration into the National Water Model
- Agreement within 15% (or as deemed acceptable by the receiving office) with independent measurements at Stream Radar "control sites" located at an instrumented watershed or near an existing gage

4. Transition Activities

The primary deliverable of the project is providing real-time stage height and velocity data to compute streamflow at 14 sites throughout the U.S. These data will be used to evaluate National Water Model forecasts, setting the stage for the assimilation of the data into the model. Another activity related to the transition of the technology is the provision of the real-time data to local stakeholders including but not limited to River Forecast Centers and NWS forecast offices. These offices are presently being consulted in order to find "hot spots" in need of additional gaging. After installation of the Stream Radars, their feedbacks will be used to assess and improve the utility of the data to their operations. These feedbacks include data latency, adequacy of thresholds for communicating alerts, data quality, and utility of the alerts in their operational monitoring of streams in their operational domains.

The intention of this transition plan is to transition this project to operations if the project is completed successfully satisfying NWS metrics for success and operational constraints. The ultimate decision to transition this project to operations resides with the director of the NWS receiving office or center.

5. Milestones and deliverables

The timeline for the stream radar installations and maintenance/repair revisits as well as key milestones are presented in Table 1.

Table 1. Timeline for key milestones for the Stream Radar project

Milestone	Oct-Dec 2016	Jan-Mar 2017	Apr-Jun 2017	Jul-Sep 2017	Oct-Dec 2017	Jan-Mar 2018	Apr-Jun 2018	Jul-Sep 2018
Visit personnel at the National Water Center to identify high-priority sites	■							
Install Group A stream radars	■	■	■					
Install Group B stream radars			■	■	■			
Meet with NWS and OAR management to discuss path to operations					■			
Revisit Group A stream radars for maintenance and repairs				■	■	■		
Revisit Group B stream radars for maintenance and repairs						■	■	■
Present results at a scientific conference						■		
Publish results								■

The project deliverables are:

1. Real-time data from the Stream Radar systems available for ingest by the National Water Model
2. Installation and maintenance manuals for the baseline system, with addenda for site-specific deviations

6. Roles and Responsibilities

6.1 Project Team Role

The project team is responsible for siting, installation, and configuration of the 14 Stream Radar systems. This includes ensuring logging and transmission of data with low latency and incorporation of this data into the USGS NWIS database for the duration of the funded project period. Furthermore, the project team is responsible to create manuals and technical documentation detailing how to install, maintain, and use these systems.

6.2 NWS Role

The primary receiving NWS office is the Office of Water Prediction (OWP) and the National Water Center (NWC) in Tuscaloosa, Alabama. Collaborator Edward Clark (NWS, also the receiving office point-of-contact) will provide input on site selection for

the benefit of the National Water Model. Stream Radar data will be available in the existing formats and protocols established for transmission of conventional USGS gage data; however, the decision whether to use, and how to use, this data within the National Water Model is the responsibility of the receiving office. The NWC will be responsible to coordinate transition of the data into research projects related to additional testbed activities such as the NWC Innovators Program. One potential application is to reserve a Stream Radar sensor for temporary deployment during the Innovators Program Summer Institute hosted at the NWC.

6.3 OAR Role

Subject to availability of funds, the Office of Weather and Air Quality (OWAQ)/OAR, will fund this project under NOAA cooperative agreement No. NA16OAR4590234, which describes the terms and conditions of this project, for a period of two years starting in October 2016. OWAQ will also provide the management oversight of the project for the above funding duration.

7. Budget Overview

7.1 Cost of current system

Subject to availability of appropriated funds, the demonstration part of this project is funded by the NOAA/Office of Oceanic and Atmospheric Research/Office of Weather and Air Quality/Joint Technology Transfer Initiative Program at a cost of $591,902 over two years starting in October 2016 (see Table 2).

7.2 Cost of transition

Given that this project entails installation of hardware (covered by costs in 7.1) and delivery of data to support research and operations at the National Water Center, there are no additional transition costs that go beyond the budget requirements outlined in 7.3.

7.3 Cost of operational system maintenance including computational resources needed

The cost provided in this section is contingent upon local stakeholders' engagement and commitments as well as the NWS's decision regarding operational implementation of this project and, as such, is subject to availability of appropriated funds.

The transition plan utilizes existing infrastructure to transmit Stream Radar data to the National Water Model. The National Water Model already ingests and uses data from approximately 7800 streamgages. The additional computational resource cost associated with long-term use of the 14 stream radar sites is negligible.

Long-term sustained operation of the hardware itself, however, incurs O&M cost beyond the scope of the two-year project. It is envisioned that local stakeholders will cover or share O&M. The project team estimates the per-site annual O&M costs associated with a single Stream Radar site at approximately $4000 (see Table 3). This cost includes data transmission and hosting as well as parts and labor for maintenance. It should be considered a rough order-of-magnitude estimate as the largest cost driver (travel and labor) will vary considerably based on location/accessibility of each site and whether an unstable streambed requires updating of the cross-section. Based on this estimate, total annual O&M cost for all 14 sites is estimated at $56,000.

Table 3. Per-site annual Operations and Maintenance costs

Item	Annual Cost
Cellular/satellite data service	$300
Data hosting service	$200
Miscellaneous hardware for maintenance/repair	$500
Travel/labor for maintenance and cross-section updates (where needed)	$3000
Total	**$4000**

8. Risks and Mitigation

Identify potential risks of the project transition to operations and your risk mitigation plan.

Risk 1: Schedule and staffing

- **Risk:** The project schedule is very aggressive for the deployment of 14 systems. If spread over a geographically large area, revisiting the installations for improvements or maintenance may prove impractical for the project team.
- **Mitigations:**
    - Of candidate sites that meet the siting criteria (e.g. need for monitoring, vulnerability to runoff, potential for impact in the National Water Model, etc.), prefer locations accessible to the project team and locations where bridge mounting is possible.
    - Engage with local stakeholders (emergency managers, NWS offices, property owners, water resource boards) willing to support the project with staff-hours.

Risk 2: Incorporation of data into NWIS

- **Risk:** The National Water Information System is an automated system managed by the USGS. Successful incorporation of our data into NWIS depends on technological feasibility and USGS cooperation.
- **Mitigations:**

- For the demonstration phase of this project, the project team has contracted HyQuest Solutions for data hosting. HyQuest Solutions staff have developed a system to export data in a format ingestible by the NWIS. Collaborator John Fulton (USGS) has begun working on establishing NWIS sites designated as R&D for Stream Radar data.
- If the conduit to NWIS via HyQuest Solutions proves impractical, the project team may consider GOES-based telemetry, consistent with conventional USGS streamgage sites.

Risk 3: Site surveys

- **Risk:** The project does not presently include costs to conduct surveys at each site. These surveys are necessary in order to establish a datum for the measurements and to provide a measured cross-section of the channel bathymetry. USGS personnel routinely make these surveys for all conventional gauges.
- **Mitigations:**
  - The project team has discussed the possibility of a separate contract to include support for USGS collaborator John Fulton to lead and assist with the surveys at the sites proposed in Colorado (approximately 4). If NWS management determines that additional surveys are needed at the remaining sites, additional support will be needed to engage USGS hydrologic technicians to contribute their instruments and labor for surveying. This will involve costs for their travel and labor.