

Proposal Summary

Title:

Co-Designing Earth-Observation Water-Quality Intelligence for Greater Houston's Drinking-Water Reservoirs

Project Need and Significance:

Urban water-supply reservoirs are increasingly threatened by pollution, harmful algal blooms, shifting hydrology, climate variability, and land-use transitions. Greater Houston depends predominantly on surface-water supplies associated with Lake Livingston, Lake Conroe, and Lake Houston [3]. Lake Conroe and Lake Houston are critical drinking-water sources for the region and are managed within a complex network of reservoir operators, water utilities, watershed organizations, and regulatory agencies.

The water quality of these reservoirs is monitored through valuable field sampling, laboratory analysis, and continuous-observation programs [3–5]. However, fixed monitoring stations and discrete samples cannot continuously characterize spatially heterogeneous conditions across entire reservoirs and their contributing source waters. Stormwater runoff, sediment and nutrient pulses, drought, harmful algal blooms, wastewater-treatment or conveyance failures, and land-use changes can alter source-water conditions between routine sampling events or outside sampling locations. There are needs and an opportunity to determine how Earth observations could add actionable spatial context, improve event awareness, and support more informed sampling, source-water management, and treatment-preparedness decisions.

NASA Earth observations can complement—but not replace—in-situ monitoring programs by providing estimates of optically active indicators such as turbidity, water elevation, and chlorophyll-related conditions [7–14]. When combined with locally collected measurements and appropriate models, Earth observations may also help evaluate indirect, site-specific relationships with non-optically active parameters such as suspended solids, nutrients, dissolved oxygen, algal blooms, and fecal-indicator bacteria. Such relationships cannot be assumed to represent direct satellite retrievals and must be locally calibrated, independently validated, and the uncertainty determined. The project will also document limitations associated with clouds, atmospheric correction, mixed land-water pixels, inland-water optical complexity, satellite revisit intervals, spatial resolution, and constituents that lack a direct optical signal [7–14].

Based on successful remote-sensing applications on other inland water bodies, and with the collaboration of key end users, this project will investigate how NASA Earth observations and commercial satellite data available through NASA's Commercial Satellite Data Acquisition program can be combined with existing and ongoing in-situ data collection [4–14]. The central question is whether these integrated data can provide water-quality information at the spatial

resolution, frequency, latency, accuracy, and confidence required to improve end-user decisions concerning Lake Houston and Lake Conroe drinking-water sources for the Greater Houston region.

This one-year **Needs and Opportunities** project will answer that question through structured end-user engagement, partnership building, decision-workflow mapping, Earth-observation screening, historical event replay, limited artificial intelligence and machine learning feasibility testing, and the co-design of potential information products. The project begins at Application Readiness Level (ARL) 2 and targets ARL 3: specific applications will be formulated, user requirements documented, candidate data streams screened, feasibility and viability tested, and development and adoption risks identified [1,2].

Goals and objectives

Goal: Determine the desirability, technical feasibility, decision value, and organizational viability of a NASA Earth-observation-enabled framework that augments existing in-situ water-quality monitoring for Greater Houston drinking-water reservoirs.

• **Objective 1 – Build partnerships, and identify and define needs:**

Build Partnerships:

Develop a comprehensive project and engagement plan that identifies relevant end-user organizations, decision-makers, monitoring partners, and professional networks. Using this plan, build a cross-agency collaborative representing reservoir operations, source-water monitoring, drinking-water treatment, watershed management, and regulatory assessment.

Facilitated workshops will establish organizational roles, decision authority, opportunities for coordination, expectations for participation, and shared priorities. The engagement process will ensure that potential solution concepts are driven by end-user needs rather than by the availability of particular technologies or data products.

Identify and Define Needs:

Document current monitoring, data-management, and communication practices; identify decision-making challenges and the authority of end users to act on new information; characterize existing information gaps and unmet data needs; and determine the spatial resolution, temporal frequency, latency, accuracy, uncertainty, accessibility, and communication requirements associated with priority decisions.

Decision-workflow mapping will evaluate where additional spatial or event-based information could improve activities such as:

- Targeting or prioritizing field sampling;

- Detecting and characterizing sediment or algal events;
- Evaluating conditions near source-water intakes;
- Supporting treatment preparedness;
- Investigating possible upstream sources or watershed disturbances;
- Assessing conditions following storms, droughts, or infrastructure failures; and
- Sharing information among agencies and organizations.

The assessment will distinguish between information that is desirable and information that can feasibly and sustainably influence an operational or management decision.

• Objective 2 – Introduce Earth science data and explore organizational capacity to adopt new solutions

Evaluate the Potential Value of NASA and Complementary Observations

Evaluate how NASA and complementary Earth observations could add value to the cross-agency collaborative and to its existing in-situ monitoring programs. Candidate data sources will include Landsat and Harmonized Landsat–Sentinel-2 observations [6], as well as potentially relevant measurements from PACE, NISAR, and SWOT. Other publicly available satellite observations and commercial data accessible through the NASA Commercial Satellite Data Acquisition program will also be screened where appropriate [1,2].

Each candidate observation will be assessed against user-defined requirements for spatial resolution, revisit frequency, latency, historical availability, cloud sensitivity, data accessibility, processing requirements, uncertainty, and operational sustainability. The project will not presume that every candidate NASA mission is suitable for these reservoirs or decisions. Instead, it will document where each observation provides useful information, where it does not, and whether combinations of observations could overcome individual limitations.

Introduce Potential Products and Assess Adoption Capacity

Provide end users with examples of relevant solutions and information products developed for comparable studies and water bodies [7–14]. These examples may include turbidity or suspended-sediment maps, chlorophyll-related indicators, surface bloom assessments, change-detection products, event alerts, sampling-prioritization maps, historical condition summaries, and confidence or uncertainty layers.

Through workshops and structured assessment, evaluate how potential solution concepts could be interpreted, adopted, maintained, and used by participating end-user organizations. This assessment will examine:

- End-user familiarity with Earth science and remote-sensing data;
- Existing technical infrastructure and staff capacity;
- Data-access and processing constraints;
- Requirements for quality assurance and regulatory acceptance;

- Preferred formats, visualization approaches, and communication channels;
- Organizational responsibilities for maintaining a potential capability;
- Interagency data-governance requirements; and
- Financial and institutional barriers to sustained use.

The purpose is to identify not only technically promising concepts but also concepts that are understandable, trustworthy, maintainable, sustainable, and compatible with existing organizational practices.

• **Objective 3 – Summarize feasibility and viability of potential a solution concept**

Co-Conceptualize and Test Potential Solution Concepts

Co-conceptualize one or more potential solution concepts that address clearly defined decision-making needs. Candidate concepts will be evaluated through data screening, historical event replay, integration of satellite and in-situ observations, transparent baseline fusion models, limited AI/ML feasibility testing, blocked validation, and explicit uncertainty analysis.

Historical event replay will examine whether candidate observations and products would have provided useful information during selected past events, such as major runoff and sediment episodes, algal conditions, drought periods, or other documented changes in source-water quality. Testing will evaluate whether candidate information could have been available at a relevant time, place, spatial scale, and level of confidence to affect a specific decision.

Where sufficient paired satellite and in-situ data exist, baseline statistical models will be compared with limited AI/ML approaches. Evaluation will address generalization across locations, seasons, and events and will guard against temporal or spatial data leakage through blocked validation. Non-optically active parameters—including nutrients, dissolved oxygen, and fecal-indicator bacteria—will be treated as exploratory, indirect modeling targets requiring local calibration rather than as directly observable satellite products. Negative, uncertain, or non-transferable results will be documented as important feasibility findings.

Co-Design a Solution-Development Blueprint

Working with the end-user collaborative, co-design a solution-development blueprint that outlines the next steps, resources, project team, data sources and needs, validation activities, and governance required for subsequent solution development and implementation.

The blueprint will identify:

- Priority decision workflow or workflows;
- Candidate Earth-observation and in-situ data streams;
- Proposed information products and user interfaces;

- User-defined performance and uncertainty requirements;
- Additional calibration and validation data needed;
- Roles and responsibilities of participating organizations;
- Requirements for operation, maintenance, and sustained use;
- Opportunities for transfer or scaling to other U.S. drinking-water reservoirs; and
- Potential funding opportunities for solution development and implementation.

The blueprint will not represent deployment of a predetermined operational system. Rather, it will provide an evidence-based and user-informed roadmap for deciding whether and how to proceed to a future Solutions Development project.

Expected Outcomes and Deliverables

The project will produce the required A.13 Needs and Opportunities deliverables: a comprehensive project and engagement plan, a midpoint report, stakeholder communications materials, and a final report [1,2]. The final report will summarize:

- End-user organizations, networks, decision authority, and engagement outcomes;
- Current monitoring and decision-making workflows;
- Priority information gaps and user-defined requirements;
- End-user familiarity with Earth science data and organizational adoption capacity;
- Candidate NASA, complementary public, commercial, and in-situ data streams;
- Historical event-replay and limited feasibility-testing results;
- Initial accuracy, uncertainty, latency, and data-availability limitations;
- The desirability, feasibility, viability, and potential decision value of candidate concepts; and
- A co-designed blueprint for subsequent solution development and implementation.

Useful data, software, methods, and project documentation resulting from the work will be made publicly available by the end of the award period, consistent with NASA's Science Information Policy and applicable commercial-data licensing requirements [1].

Relevance to A.13 and Earth Science to Action

The project directly addresses A.13 priorities concerning U.S. resilience, natural resources, public health, water security, infrastructure, AI/ML, cross-thematic challenges, and increased use of NASA Earth observations [1,2]. It addresses the solicitation's interest in integrated terrestrial and coastal water-system assessments, improved monitoring and management, multi-sensor observability, and the combination of NASA observations with other public and commercial satellite data.

The project advances NASA's Earth Science to Action strategy by using societal needs to inform the co-design of potential applications and by assessing how trusted Earth science information could be integrated into sustained end-user decision frameworks. This user-centered approach will build bridges among Earth observations, applied research, source-water monitoring,

reservoir management, drinking-water treatment, and public-health protection. If feasibility and viability are demonstrated, the resulting framework could provide a scalable model for drinking-water reservoirs elsewhere in the United States.

References:

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