



‘Ike Wai

*Securing Hawaii’s
Water Future*

YEAR 1 ANNUAL REPORT

REPORTING PERIOD JUNE 1, 2016 TO FEBRUARY 28, 2017



A Program Administered by the University of Hawai'i System



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I. 'Ike Wai Year 1 Annual Report Information

RII Track-1: 'Ike Wai: Securing Hawai'i's Water Future
NSF Award Number: OIA-1557349
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Principal Investigator: Gwen Jacobs
University of Hawai'i
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II. Overview

A. Vision, mission, and goals of the project

Vision: Water resource management in Hawai'i is sustainable, responsible and data-driven. Scientific, cultural and social dimensions to the problem of water security are integrated in a transparent, stakeholder-driven and rigorous water research enterprise in Hawai'i.

Mission: To ensure Hawai'i's future water security through an integrated program of research, education, community engagement and decision support.

The goals of the 'Ike Wai project are:

Goal 1: Collect new hydrological and geophysical data on the two study sites to address data gaps in our understanding of subsurface structure and flow.

Objective 1.1: Image subsurface geologic structures and/or the location of groundwater in 3 to 4 target areas of Hualālai and Pearl Harbor aquifers systems using geophysical techniques by the end of Year 3

Objective 1.2: Map groundwater flow paths and improve estimates of connectivity and flux in the Pearl Harbor and Hualālai aquifer systems using integrated isotope, biogeochemical, and submarine groundwater discharge data by the end Year 5

Objective 1.3: Produce datasets on physical and chemical parameters of groundwater by establishing novel sensor-based monitoring network in wells within targeted regions of the Pearl Harbor and Hualālai aquifer systems by the end of Yr. 3

Goal 2: Develop a new data and modeling platform for Hawai'i volcanic hydrogeology, economic modeling and decision support.

Objective 2.1: IKE Platform: Implement a fully featured data management, analysis, and visualization application based on the AGAVE software framework.

Objective 2.2: Data Store Population: Aggregate, annotate and store legacy, existing models and new scientific data.

‘Ike Wai has the potential to be a transformational project for the University of Hawai‘i, the state, and for organized research units such as the University’s Water Resources Research Center (WRRC). The project’s promise is to be transformative *scientifically* in terms of the knowledge base of a critical resource, to transform *capacity*, in terms of the human, physical and computational capital to perform cutting-edge water research, and *socially*, to threshold a new level of partnership between the academic community and stakeholders in Hawai‘i. Prior to proposal submission, and throughout the strategic planning process in Year 1, the ‘Ike Wai team acknowledged that each of these advances requires its own ‘auwai. Identifying the components of a collective strategy towards these goals, and targeted capacity building to address issues that have systematically weakened water research in Hawai‘i in the last two decades, has been a critical focus for Year 1. These activities position us at the beginning of Year 2 to operationalize our research and education plans and deliver preliminary project outputs to stakeholders.

B. Coordination and interdependencies of multi-disciplinary research and education program.

Overview of Administration and Leadership Structure and Approach. ‘Ike Wai is a complex project with multiple internal and external participants. Our goal is to approach this as one single integrated project. Entering the award period, the Project’s PIs and co-PIs identified a clear need to build both the coalition of researchers and educators who would implement the project, and a leadership structure that would guide the project, liaise with stakeholders and communicate project outputs to the wider community. Two campuses, UH Mānoa (UHM) and UH Hilo (UHH) form the key institutions. At UHM, the units include Water Resources Research Center (WRRC (for overarching water resource management), Hawai‘i Institute of Geophysics & Planetology (HIGP; for geophysics and geology), UH Economic Research Organization (UHERO; for water economics), Dept. Civil and Environmental Engineering (for groundwater modeling), Dept. Electrical Engineering for sensor development and deployment, and the College of Social Sciences (CSS) for stakeholder engagement. At the University of Hawaii System (UHS) level, Information Technology Services (ITS) provides, senior leadership (PI, Jacobs) and the backbone for the database and data visualization. At UHH, hiring four new tenure-track faculty will provide the basis of a new initiative in data science.

To coordinate all of the diverse activities with ‘Ike Wai, we have established a Leadership Team of 9 people, which includes the PI and 4 Co-Is. Additional members include Darren Lerner, the Director of WRRC, Greg Chun, leader for community engagement, the Aly El-Kadi - Science Team Leader, and Kevin Kelly, Managing Director. This Leadership Team meets twice per month (typically for 2 hours each meeting).

The Science Team comprises the individual faculty members (and their students and post-docs) who have research tasks funded under ‘Ike Wai. The three new UHM faculty hires will join the Science Team. The Science Team membership includes investigators in groundwater modeling, water chemistry, geophysics, microbial analyses, submarine groundwater discharge, Hawaiian studies, economics and sensor development. The Science Team has its own research meetings, typically once or twice per month to plan joint initiatives (e.g., water sampling, installation of rain gauges).

All-Hands Meetings are held monthly, and typically run for 2 hours. They provide both a mechanism for reporting on overall project goals as well as bring new individuals (students, post-docs, etc.) into the project. These meetings are held using our CyberCANOE, thereby showcasing the type of visual displays we wish to use to engage our stakeholders, while at the same time enabling our team members from UHH to join the discussion.

Identification of interdependencies in the research program. The 'Ike Wai research endeavor comprises the efforts of the Science Team (geophysics, biogeochemistry, hydrologic and economic modeling, sensor engineering, Hawaiian studies) and liaises closely with the Cyberinfrastructure and Visualization team as these efforts are intrinsically inter-dependent. For example, numerical models will be refined by better knowledge of the subsurface structure revealed by the geophysics measurements. Models will also be refined using water flow paths detected by microbial tracers and water chemistry, while historical data (derived from Hawaiian newspapers) will provide an independent test to fresh water sources and availability. Well data will set constraints on aquifer inter-connectivity. Submarine Groundwater Discharge (SGD) will both test the models, as well as provide constraints on the amount of water that is available for economic development models and/or consideration of environmental protection. Data archiving and data visualization are seen as major benefits to our stakeholders (e.g., USGS, Board of Water Supply, and Commission of Water Resource Management). The Data Science initiative at UHH will address some of these stakeholder needs, as well as support aspects of data collection and processing (such as SGD) led by UHM. Recognizing these interdependencies, the Leadership Team is operating an ongoing set of tabletop exercises to define a framework for project integration and allow us to articulate clear dependencies and deadlines that they generate into the strategic plan and project timeline.

C. Brief summary of key accomplishments achieved during the reporting period

Administration and Leadership: In Year 1 we established a management structure with accompanying project policies. The pre-award steering group has been replaced with a new Leadership Team (LT). Several members of the prior RII, including the Project Director (Jacobs) and Managing Director (Kelly), have been retained, supporting continuity and preserving the project's overall history and goals. The LT comprises representation from the UHM, UHH, USGS, UH Sea Grant and Water Resources Research Center, the 'Ike Wai project science, education, community engagement and cyberinfrastructure teams. Major activities of the LT in Year 1 are summarized as follows: (1) bi-weekly LT meetings and a program of all-hands meetings implemented, the latter including strategic planning and tabletop exercises in February-May 2017; (2) an external communications specialist facilitated community dissemination in Hawai'i and developed an external communications plan including website, social media, media and speaking engagement schedules has been developed and implemented; (3) a Team Science compact is under development, providing a set of 'rules of engagement' for the implementation and intra-team decision-making on topics such as data release, data sharing and authorships; (4) coordination of 3 faculty searches for UH Mānoa (in the areas of geophysics, hydro-engineering and the economics of water); (5) the LT liaises with the Hawai'i Statewide Science and Technology Committee (HSSTC), and in Year 1 provided informational briefings at the beginning and end of the award period; (6) an 'Ike Wai

External Advisory Board (EAB) has been convened and met for the first time in April 27 – 28, 2017. The EAB's mandate for the Year 1 meeting was delivered by PI Jacobs, and included the following focus areas: (1) Provide constructive feedback and advice on the four project areas and compliance with the terms of the cooperative agreement; (2) Provide a set of actionable recommendations to guide changes and adjustments to our strategic plan; (3) In Years 2 and 4 conduct a mock site visit, to prepare the team for NSF reverse and onsite reviews.

The EAB composition is as follows:

- *Economic modeling and Decision Support*: **Dr. Susan Capalbo** is Professor and Department Head for the Department of Applied Economics at Oregon State University;
- *Information Systems Research and Education*: **Dr. Paul Cronan** is Professor of Information Systems at the University of Arkansas and holds the M. D. Matthews Chair in Information Systems. He is currently Director of the Master of Information Systems degree program and Co-Director of the University of Arkansas Teaching and Faculty Support Center;
- *Computational Modeling and Data Science*: **Dr. Kimmen Sjölander** is Professor of Bioengineering in the Department of Plant & Molecular Biology at UC Berkeley. Her research focus is the development of novel computational methods for biological discovery;
- *Cyberinfrastructure*: **Dr. Dan Stanzione** is the Executive Director of the Texas Advanced Computing Center (TACC) at The University of Texas at Austin;
- *Hydrogeology*: **Dr. Clifford Voss** is Senior Scientist with the hydrological research program of the U.S. Geological Survey (USGS) in Menlo Park, CA. Dr. Voss fulfills the Jurisdictional Specific Terms and Conditions item 8.2: *The awardee will arrange for a representative from the US Geological Survey with knowledge of this agency's past and current hydrological modeling of Hawaiian aquifers to serve as a member of the project's External Advisory Committee.*

Research:

(a) Geophysics (Objective 1.1; Lautze - Hawai'i Institute of Geophysics & Planetary Sciences (HIGP) UH Mānoa lead). The geophysics effort for 'Ike Wai entered the award period with critical gaps in expertise and equipment which we sought to address in Year 1. Unfortunately in Year 1, even though this search was initiated within two months of the start of this project, we have not completed the search process for a faculty member in geophysics. Two candidates have been identified and will be visiting for interviews in June 2017 and a mitigation plan for geophysics was developed and implemented absent this Year 1 hire. We have hired a new postdoc in geophysics (Dr. Eric Attias) who will join the team in November 2017. In addition, team member Lautze (who will supervise Attias) has prior publications in geophysics and geochemistry and has a DOE funded project on magneto-telluric imaging of sub-surface geology on Lanai Island, and the Project Scientist Mougini-Mark is a volcanic geologist. In Year 1 using this extant project expertise we: (1) acquired new equipment for the geochemistry studies for rain catchment and water chemistry analyses, and (2) identified geophysical sites to be identified on the west side of Hualālai (where well heights are above sea level) as well as major structures (e.g., the extension of the S.E. Rift Zone of the volcano, where it might influence the westward flow of

groundwater from Mauna Loa). Planning for these geophysical measurements has been coordinated with sampling needs (for water chemistry, rain gauges and microbial studies), so that some discussions with landholders have been held. For the geophysics effort, study site selection and the specific geophysical techniques to be employed (e.g., magneto-tellurics, gravity, seismics) are needed to provide the most informative information on the subsurface structures in the two aquifers, which in turn provides constraints on the numerical models.

(b) Geochemistry, microbial analysis and SGD (Objective 1.2; Lautze, HIGP, Dulai - Geology & Geophysics (G&G) and Frank - Pacific Biomedical Research Center (PBRC) UH Mānoa lead). In Year 1 we identified ~50 - 60 target wells for sampling, and sensor and rain collector deployment are underway. We produced a listing of all wells, their geographic location, and ownership, and field work plan. Stakeholder and landowner engagement was also a priority in Year 1, including meetings and informational session in Kona to build relationships with the well owners, discuss our sampling plan with them so that they understand our techniques. We searched for and hired a graduate student, in Year 1 who will be full-time by June 2017. Our Submarine Groundwater Discharge (SGD) study has designed a new radon “sniffer” which meets local community requirements for deployment (40 vs. 200 lbs., 90% submerged vs. 30% submerged). Permits are currently pending on the deployment of two such sensors; one will be for continuous monitoring in Kiholo Bay, and the other will be used for periodic sampling at four other sites. For the microbial ecology research, where we plan to use microbial diversity as an innovative approach to mapping flow, we have purchased necessary equipment and have recruited a new post-doc (Dr. Sheree Watson from Oregon State University) who will start in September 2017. Plans have been made to examine and archive genomic DNA and microbial sequence data from > 200 wells over the next two years.

(c) Well Monitoring (Objective 1.3. Garmire - COE: Year 1 design and preliminary testing of sensors, HIGP: Year 1 selection of potential deployment sites for sensors via stakeholder engagement). Key isotopes (oxygen and carbon) and geochemical/geophysical data (salinity, temperature, pressure, organics) to be measured have been identified for down-hole measurement. In Year 1, using rapid prototyping technology and techniques including 3D printing, circuit board milling, and laser cutting, we were able to produce the first prototypes of sensors that will be capable of sampling salinity (<50 ppm up to a dynamic range of >30 ppt via a novel 4-point capacitive technique), temperature (thermistors capable of 0.1°C over a desired range of <5 - 30°C), and pressure (<10 mm resolution or < 100 Pa via accurate depth-to-surface measurement techniques). We designed novel flow rate sensors (<1 micron / second in each direction). We lab-tested the salinity, temperature, and pressure sensors and will test the flow rate sensors by June. In order to ensure minimal leaching, we employed water-proofing and environmental-friendly materials, and designed the prototype with a novel cabling system and cable to serve as a tether as well as a data and power connection. Low-cost embedded systems such as an raspberry pi zero w (RZW) were considered, and the RZW was selected for the processing component which will relay the data from the sensor modules to the wireless network (4G) and eventually deposited into the CI data platform using json for minimal data translation. Due to the low power consumption of the sensor technology, the power system was designed with a 10W panel and ~80Wh battery which should operate continuously through rainstorms (2-3 days of dim light). Due to the robust

materials employed and novel sensing approaches, the platform should be resistant to weathering, biofouling, and corrosion for up to 2 years; however, an outcome of this endeavor will be to measure and quantify sensing robustness. The ultimate goal of this effort would be to develop a Down-well Remote Operating Platform (DROP) that would allow multiple measurements types at different depths simultaneously within the well at a rate of a few hertz.

(d) Hydrological modeling (Objective 2.2.5 - El-Kadi (WRRC/G&G lead). In Year 1 we focused on the following major research questions in modeling the subsurface flow of water: (1) the identification of water flow path-lines, (2) the water budget, including aquifer storage, inter-aquifer flow, sustainable yield, SGD and the contributions of high level elevated water areas to the basal aquifers. In Year 1 we have developed a 3-Phase approach to modeling the Hualālai and Pearl Harbor sites. To test the modeling procedures, a simplified Phase 1 MODFLOW model of West Hawai'i was developed. The model assumed a sharp interface flow boundary and a steady state condition. This model includes three vertical layers, a simplified geology at depth (i.e., same as surface), fresh water only, and assumes that the bottom of the aquifer is based on a 40:1 ratio of fresh water height above MSL constrained to a maximum depth of -2,000 m (where void compaction should have occurred). We have also constructed "detailed" but generic cross-sectional models using FEFLOW to test capabilities of the software. In future years, Phase 2 will use an improved version of the West Hawai'i model to create a detailed model, by mainly including density dependent flow through the use of FEFLOW. Phase 3 will focus on detailed "local" models (FEFLOW), utilizing results from Phases 1 and 2 to set accurate boundaries. This Phase 3 model will permit the inclusion of transient conditions, preferential flow, and detailed historic information. Additional areas of progress this year have included team building, a new faculty hire underway, the integration and identification of interdependencies for modeling and field data collection (Objective 1.1), developing modeling protocols, and building expertise with new modeling software (FEFLOW). We have hired a new postdoc in Hydrological Modeling, (Dr. Ahmed Elshall) who will join the team June 1, 2017. Dr. Elshall brings significant expertise in groundwater modeling, including advanced techniques of multi-modal modeling techniques, such as model selection and model combination.

(e) Economic Modeling. (Objective 2.3 - Burnett – UHERO/SSRI – lead). In the proposal, we identified a critical lack of depth in our expertise in the economics of groundwater resources in Hawaii. A goal, therefore, was to hire a new tenure-track specialist with this skill set as a joint appointment between WRRC and UHERO. This goal has been met, with Dr. Leah Bremer starting at UHM on July 1, 2017. Dr. Bremer's faculty position is in SSRI/UHERO and WRRC. The focus of Year 1 activities was to engage with State and County water management agencies to identify their decision support needs regarding overall policy and management issues they are challenged by and as well as those with specific economic implications. Stakeholder needs emerged from these meetings, articulated mainly as an interest in improved methodology for calculating sustainable yield and ROI analyses on watershed conservation investment. Lower priority was placed on understanding pricing and cost-benefit implications of future planning scenarios. These stakeholder perspectives therefore sharpened our focus in Year 1.

(f) Hawaiian Studies. (Objective 2.2.4 - Nogelmeier, Aga - Hawaiiinuiakea School of Hawaiian Studies) A key component to the Institute of Hawaiian Language Research and Translation's (IHLRT) model is capacity building. All research work is contingent on the hiring of graduate student researchers, their

training and involvement in research and translation. In Year 1 gains were made in capacity in this area, comprising two graduate student researchers (hired in November 2016 and March 2017). Year 1 activities focused on: 1) place-based research for the two identified study sites and 2) term and concept research for a broader range of water resources and management practices, not limited to the particular study sites. Initial searches in Hawaiian language newspapers, archaeological surveys, and other printed texts have been done to determine the scope of material that is available. In regards to place-based research, the focus has been on the Keauhou Aquifer area. Research on the Pearl Harbor Aquifer in the 'Ewa moku (large land division) will start once a defined study site with boundaries has been selected for O'ahu. Term and concept research started with 40 terms, giving an initial range of thousands of potential articles to review. That list of search terms are being refined and then will be used to search within the Hawaiian language newspapers and other archival materials for content and relevance. IHLRT staff has also been providing Hawaiian language support responding to queries from individual researchers and providing the Kapunalu'u (lit. spring dived for) Hawaiian language series. Presentations have been made during the regular Science Team Meetings to familiarize the 'Ike Wai participants with the promise and potential of our aspect of the project.

(g) Ike Platform. (Objective 2.1 - Jacobs/Leigh - UH ITS). The criticality of data management, analytics and visualization was recognized in the proposal. During tabletop exercises, shared discussion between stakeholder engagement and the cyberinfrastructure team revolved around developing aspects of the platform as a decision support tool for non-academic audiences. The decision to integrate both the scientific and community outreach goals for the IKE platform from the earliest stages of the project was taken in Year 1. Significant progress was made on implementing the data management functions of the IKE platform to support the storage, annotation and sharing of both legacy and new data sets. This functionality is in place and in production as of the end of Year 1.

(h) Education and Workforce Development (Objectives 3.1 – 3.6 - Bruno UHM, Pelayo UHH.) The educational 'auwai (effort) consists of six pathways (objectives). Except for Pathway 6, which is scheduled to be rolled out during Year 2, significant accomplishments have been achieved in all areas. These accomplished are presented in detail in Section III Goal E (Education and Workforce Development) and are briefly summarized in Section C below. Importantly, all major milestones have been met for Year 1. The 'Ike Wai Scholars Program (3.1.) was modeled after the C-MORE Scholars program. This undergraduate research and professional development is an academic-year program that includes a closely mentored research experience and monthly professional development workshops. During Year 1, we set and accomplished the goal of training 20 diverse undergraduate scholars at UH Mānoa and UH Hilo. We also developed a series of monthly professional development workshops for undergraduates, to be implemented as scheduled during Year 2. The Summer Bridge Programs (3.2.) are offering summer bridge programs at UH Mānoa (May 2017) and UH Hilo (June-July 2017). Accomplishments to date include curriculum development and recruitment of teaching team. The Mānoa curriculum covers Hawaiian culture and community, geology, hydrology and careers. The Hilo curriculum focuses on mathematics and data science. For both programs, the teaching team has been recruited. The Individualized Professional Development and Mentoring Cascade (3.3) was implemented as designed in Year 1. We created an 'Ike Wai IDP template based on existing models, and delivered a professional

development workshop to train 'Ike Wai graduate students on creating their IDP. All five 'Ike Wai graduate students hired during Year 1 have created an IDP. We also developed a structure for the mentoring cascade (or layered mentoring network), based on best practices and existing models. During the reporting period, we piloted the mentoring cascade with 5 graduate student mentees and same number of faculty/staff mentors. The mentors supported the students as they created their IDPs. The cohorted Professional Development and EDventures mini-grant program (3.4.) were designed to provide education and professional development training to our cohort of 'Ike Wai graduate students, post-docs, faculty and staff, we developed a series of workshops in pedagogy, team science, mentoring, team building, leadership and negotiations. All workshops were delivered during Spring 2017 (February through May) and facilitated by expert external consultants. We also created EDventures, an internal proposal-funding mechanism aimed at providing proposal-writing training and encouraging leadership/new initiatives. EDventures will be rolled out on schedule during Year 2. Data Science capacity building at UH Hilo (3.5.) made significant progress in Year 1. Two faculty searches in data science are complete. at UHH. Recommendations for both positions have been made, and the selected candidates will start August 2017. A certificate and BA in data analytics are under development, and we anticipate they will be rolled out on schedule. Note that also Objective 3.6: Business and Community is scheduled to begin during Year 2, so there are no accomplishments to report to date.

D. How accomplishments address the NSF criteria of intellectual merit and broader impacts.

Intellectual Merit: The theme of the 'Ike Wai first year has been the development of 'auwai. In terms of intellectual merit, our focus on grand challenge level science in the field of Hawaiian hydrogeology remains at center. In some areas of the project, research and engineering challenges are already being addressed in libraries, laboratory and field (exemplified by early successes in the project's Hawaiian traditional knowledge, geochemistry and sensor engineering focus areas). In other areas, planning and capacity building have been the 'auwai activities for Year 1. These include advances in CI and sensor engineering and the new acquisition of sophisticated MT and molecular biology instrumentation that will transform the landscape for hydrogeological research in Hawai'i for the short and medium term future. Innovations include novel, and possibly exquisitely sensitive methods for discerning water flow paths through microbial ecology studies. Here, intellectual merit derives from the application of cutting edge sequencing and metagenomics techniques to an essentially physical problem, and new insights will emerge from this new approach. In addition, sensor innovation is an important outcome that is already bearing fruit in Year 1. The intellectual and technical challenge of focusing on robust low-power distributed sensing responds to the fact that most scientific field work -- especially in geology, hydrology, and oceanography -- is still performed using expensive sensor technology where the focus has been to improve single-point sensor resolution. This project addresses the considerable technical challenge inherent to the approach but holds the promise to advance the state-of-the-art in merging low-cost (but potentially less accurate) distributed sensor modules with numerical models to create real-time stakeholder tools for assessing water management policies.

Broader Impacts: Broader impacts of this project are starting to emerge and cluster around three themes. First, *diversity in participation*. Our project participants are diverse, including numerous women and minorities, including Native Hawaiian scientists and students. Our education program is linking water, land and culture for Native Hawaiian and Pacific Islander students, providing opportunities contextualized by indigenous culture and concerns rather than alienated from them. Second, *diversity of approach*. It seems almost trite to emphasize the inter- and trans-disciplinary nature of the Ike Wai project. However, particularly during all-hands meetings, synergies between diverse project areas are rapidly emerging. Just one example of this is a newly identified synergy between numerical hydrology modeling and our Hawaiian traditional knowledge project. Here, we are preparing to hold a desk-top simulation of the numerical models and visualization of model predictions so that our stakeholders might better understand groundwater resources. A key component of testing the validity of the models is to utilize the indigenous knowledge provided by the 19th century Hawaiian newspapers. Here we have the ability to test if our models correctly predict the locations of springs before any pumping took place, according to Native Hawaiian historical and traditional knowledge. Third, *diversity of view points*. Our participants distribute upon other axes of diversity that simple ethnicity or gender. Our strong outreach and community engagement commitment means that the public, agencies, and scientists have both input into and will benefit from Ike Wai activities. Our hope is that the level of community engagement we seek becomes eventually a role model for other large science project in the State of Hawai'i, particularly in our willingness to contextualize our science with community concerns and our indigenous host culture. Engaging with stakeholders and allowing the 'difficult conversations' has not been a hallmark of UH relationship with community in Hawai'i, and Ike Wai seeks to redress that imbalance with a concomitant positive impact on the perception of science, of its utility in decision support and of its service to community within the State.

E. Briefly describe any significant problems, novel opportunities, and/or changes in strategy during the reporting period.

Significant problems. There have been operational and planning challenges to be navigated during Year 1. Specific challenges included:

(1) Hiring delay. The 'Ike Wai Faculty Hiring Plan is presented graphically below in Table 1. The plan calls for 3 hires in Year 1 (2 faculty at UH Manoa, 1 professional staff member at UH System) and 3 hires in Year 2 (1 faculty at UH Manoa, 2 faculty at UH Hilo). The "4 new faculty hired" statement for Years 1-2 from Table 7 of the proposal is a typographical error and should read "5 new faculty hired" to match the stated distribution of 3 UHM, 2 UHH in the same table cell.

New Faculty Hires							
Campus	Discipline	Y1	Y2	Y3	Y4	Y5	Total
Hilo			2	1	1		4
	Computer Science	Search Completed	Start 8/1/17				
	Mathematics	Search Completed	Start 8/14/17				
	Genomics/Proteomics		Search Begins	Start 8/1/18			
	TBD		Search Begins		Start 8/1/19		
Manoa		2	1				3
	Geophysics	Candidates under Review					
	Hydro Engineer	Offer Imminent					
	Economics	Search Completed	Start 7/1/17				
Total Hires:		2	3	1	1	0	7

Table 1: New Faculty Hiring Plan for 'Ike Wai showing the status of UH Hilo hires in Years 2, 3 and 4 and UH Manoa hires in Years 1 and 2.

Of 2 hires required by PTC in Year 1, one is delayed. A faculty search had to be cancelled and restarted in September 2016, resulting in some delay to the hiring of the Geophysics position. The second UHM faculty search (the hydro-engineer) is nearing completion - a third candidate interviewed on May 11-12, 2017 and an offer is planned before the end of May 2017. **Mitigation plan for Geophysics hiring delay:** (a) The search remains open and we have one recent (April 28th, 2017) applicant for original position looks promising, and we are currently proceeding to obtain external letters. (b) We will leverage available Geophysics faculty expertise not originally part of the hiring plan. At the time of proposal submission geophysics expertise was to be filled by one faculty hire and one post-doc. The post-doc has been successfully hired. Team member (Lautze) is a critical component of our mitigation plan for the lack of a complete Geophysics hire in Year 1. She will work closely with the Project Scientist (Mouginis-Mark) to initially define targets for geophysical surveys, and she has the necessary expertise and experience with the EPSCoR project to do so. She has been directing initial surveys. Expertise from USGS that was not part of the original proposal is also now available in support of our Geophysics effort and we have hired a geophysics post-doc who will join the team in November 2017.

At UH Hilo, candidates for two positions to be hired for Year 2 have been interviewed and both candidates accepted the positions. Grady Weyenberg will join the UHH Mathematics Department and Travis Mandel will join UHH Computer Science starting in Fall 2017.

(2) Operations. We identify a need to increase team awareness about processes such as strategic planning, tabletop exercises and science planning that distinguish a program such as an RII Track I from a more conventional research grant with which they are familiar;

(3) Community Relationships. Emergent concerns from the indigenous Native Hawaiian community about the potential for data collection methods in the Hualālai aquifer to overlap with those used for geothermal prospecting, which is an extremely controversial technique in these areas and within our indigenous host culture (it should be noted that litigation is one potential outcome of these challenges). We also identified a need to maintain perceived independence and community perception that the project will provide unbiased analyses to the community for decision support;

(4) Responding to PTC re: the inclusion of a USGS partner. We are committed to bringing USGS in as major partners during Year 1, requiring both the initiation of new institutional collaborations and formalized partnering documents. USGS will be fully engaged in all of our table-top exercises and will be consulted on a regular basis on our science plan. Steve Anthony, Director of the USGS Pacific Islands Water Center is a member of the 'Ike Wai leadership team.

(5) Guarding against 'scope creep'. As more stakeholders have been engaged in the project, more questions emerge that are priorities for these groups but for which resources are not allocated in the current proposal

Novel opportunities. Several novel opportunities and directions have emerged since the original proposal was submitted and during Year 1. These include: (1) the opportunity for a deep and authentic level of partnership with USGS. This was a stipulation that emerged from peer review and in exploration of the potential for this partnership during Year 1, the strengths that it offers 'Ike Wai have become obvious and exciting. A strategic crosswalk between USGS and 'Ike Wai shared priorities identified USGS data sets and modeling foundations on which 'Ike Wai can build, and highlighted areas of need in data collection and modeling intense modeling that are outside USGS capacity but which can be provided by 'Ike Wai; (2) stakeholder engagement has exceeded expectations in Year 1 and relationships that were not predicted when the proposal was developed have emerged and become central to the future success of 'Ike Wai. These include the Hawai'i Community Foundation, Ulupono Initiative, Kona Water Roundtable, Waimea Water Roundtable, Kamehameha Schools, Palani Ranch, Queen Lili'uokalani Trust, Kohana'iki Resort, and the Natural Energy Lab of Hawaii (NELHA). In particular, opportunities for partnerships with organizations such as the Hawai'i Community Foundation Clean Water Initiative and the Ulupono Initiative lend strength to our project through clear alignment with statewide and community goals, leverage the capacity of these organizations in terms of community and stakeholder engagement, and provide a foundational layer for discussions about the sustainability of the project; (3) a prior Hawai'i EPSCoR partner Chaminade University (a Federally-designated Native Hawaiian serving institution) has recently funded an I-USE on undergraduate data science (and is exploring both Certificates and undergraduate degree programs in this area), initiated a CyberCANOE and VR program, and is also performing a major overhaul and development of its Environmental Science major around the Food-Water-Energy nexus. These efforts will leverage 'Ike Wai expertise and collaboration going forward; (4) as new information about priority projects outside the immediate scope of 'Ike Wai emerge from stakeholders and science team members, opportunities for grant proposals that leverage Ike 'Wai and extend the project's impact are being identified. Two examples of this leveraging activity are (1) Chaminade's indigenously-focused data science curriculum initiative is the subject of a 2017 NSF INCLUDES submission in collaboration with Ike 'Wai and the Texas Advanced Computing Center; and (2) a NASA technology development program that would enable the use of an unmanned aerial system (a.k.a. "drone") using advanced MEMS technology to build a new gravimeter to conduct high spatial-resolution gravity measurements to study the role of the SE Rift Zone of the volcano in controlling water flow from Mauna Loa to the east. The Step-1 proposal has already been submitted..

Changes in Strategy. No changes in scope have emerged from the planning and implementation activities in Year 1 but there have been areas in which tactical changes emerged from both Strategic

Planning and tabletop exercises. These include: (1) a decision to initially focus on the Hualālai aquifer, establish boundary conditions and detailed sampling plans for this area and then to recapitulate this process for the Pearl Harbor aquifer; (2) develop a Year 1-2 priority area in the acquisition of legacy data from multiple sources, and add the potential for reanalysis of some of these data (e.g., gravity imaging data) to our strategic plan and project capacity. In tabletop exercises, a data audit revealed rich veins of data from diverse sources that will contribute to the IKE. The number and diversity of these data sets were greater than originally planned for however, the raw nature of some of these data sets and their extensiveness required an adjustment in strategy to deploy resources to their acquisition, cleaning, and incorporation into the 'Ike Wai data platform; (3) technical alternatives and complementary techniques to magnetotelluric imaging in both study sites have been actively discussed and are likely to be components of the science plan going forward. The potential litigation issue alluded above may require changes in strategy in Year 2, and therefore we have devoted resources in Year 1 towards to developing a full understanding of the potential issues at all levels of the project and UH organization and a mitigation plan. *Issue summary:* Concerns from a group of residents in West Hawai'i have been presented to NSF and UH General Counsels regarding the implications of our research for future geothermal exploration in the region. This group previously stopped a UH/State of Hawai'i geothermal research project in the region through extended litigation that resulted in the State withdrawing funding that supported the project. They are threatening the same here. There are two issues they have raised: 1) Despite the focus of 'Ike Wai being groundwater the same data we collect can be used to identify geothermal resources. Their claim is that this project is a ruse for geothermal prospecting and that the UH knowingly pursued this EPSCoR award for this purpose. 2) The geophysical imaging techniques we propose to use (magnetotellurics) results in disturbances to the soil surface so should require an environmental assessment prior to proceeding. *Mitigation Efforts:* (i) *Review of field method for environmental assessment.* In reviewing the actual field method it is clear that this claim is unjustified. Under both NEPA and HEPA 'Ike Wai is exempt as a research study from having to do an environmental assessment. This requires the UH to conduct a formal internal review and declare a self-exemption, the process for which is under review by UH General Counsel. (ii) *Adaptation of field practices.* In the interest of good stewardship we are proposing to have archaeological and flora/fauna monitors in the field when the equipment is installed and removed. Discussions with the complainants will be pursued once the internal review is complete. Our goal is to avoid the risk of having to reduce the scope of the data collection originally proposed and/or change study sites that will require a major shift in focus for all components of the project.

Unobligated Funds & Faculty Hiring Update

The data for the Expenditures Including Obligations spreadsheet (Table F) was assembled using account data through January 2017 in anticipation of submitting our annual report in early March. The obligated funds data in the annual report was updated using the most recent data available from the end of March, 2017. All of the data presented here is current as of March 31, 2017.

Spreadsheet

The attached spreadsheet (Unobligated Funds-Year 1-Review.xlsx) shows the original NSF Year 1

approved budget in Column E. In Column F the actual expenditures through March 31, 2017 are shown. Column G shows the budget items included in the carry-forward request that was submitted with the annual report.

In assembling this spreadsheet we discovered an error in calculating total expenditures during Year 1 resulting in an increase of actual spending of \$140,052. As a result, through the end of March total spending was \$2,435,513 (60.9% of total budget) and funds available for carry-forward is \$1,564,487 (39.1% of total budget). As a result, this carry-forward request is based on the figures shown in Column H of the spreadsheet (Current Carry-forward Request).

The primary source of unobligated funds are accrued funds not paid to faculty, post doc and student hires in Year 1 due to extensive searches, delays in hiring and the soft roll-out of the 'Ike Wai Scholars program. These totals are approximately \$232,000 for faculty and professional staff, \$183,000 for post-docs, \$155,000 for grad students and \$58,000 for undergrads (\$628,000). Funds for these hires were encumbered per university policy requiring funds to be available for advertised positions. Salary support for these positions is already included in the Year 2 budget. As a result we wish to utilize these funds to address shortcomings in personnel identified during Year 1 by both the Leadership Team and our External Advisory Board by providing, in some instances, up to two years of support from carry-forward funds. Beyond Year 3 the project has much more flexibility in its budget with existing projects scheduled for completion and new, seed funded projects being initiated that will necessitate a redistribution of student, post-doc and professional staff effort.

We request the following expenditure of carry-forward funds based on the available amount of \$1,564,487:

1. We propose two (2) months of salary support for Dr. Peter Mouginis-Mark to serve as the project's Project Scientist in project Years 2 and 3. He is responsible for aligning the activities and workflow between the Research, Cyberinfrastructure and Community Outreach components of the project. Dr. Mouginis-Mark is a tenured faculty member in HIGP and a Co-PI of the 'Ike Wai award. Mouginis-Mark is a planetary geomorphologist with a deep understanding of Hawai'i volcanoes, is a past Director of HIGP, the former Associate Dean for Research (College of Engineering), and a former Chief Scientist, Pacific Disaster Center, Maui. (COST: \$104,586).
2. We request funds to accelerate the hiring of a software engineer currently scheduled to be hired in Year 3. Although on schedule, we are currently in need of additional support for the IKE platform development in anticipation of computational needs of our incoming faculty hires. We request one year of salary/benefits for this hire who is already included in the budget for Years 3-5. (COST: 148,990)
3. We propose adding one (1) additional post-doctoral researcher to bolster our expertise in geophysics and hydrology and accelerate the activities in Goal 1 that have been impacted by delays in faculty hiring and expanded community outreach. We request funds for this position for 9 months in Year 2 and the entirety of Year 3 (COST: \$159,047)
4. We propose the addition of a full-time Data Manager to the Cyberinfrastructure team to work directly with research faculty and software developers to insure timely and efficient acquisition, curation

and access to project data and data products. This position was not included in the original proposal however The Leadership Team's identification of the need for this position was confirmed in a recent visit of our External Advisory Board. We request funds for Years 2 and 3 for this hire (COST: \$225,705)

5. Four of our current graduate students are available to work full-time over the summer. We wish to take advantage of this opportunity and provide summer overload for these students. (COST: \$9,716)

6. The resources required to identify, translate and digitize native Hawaiian historical records were underestimated in our original budget request. We propose additional support for this component by providing two (2) months of salary support to Institute of Hawaiian Language Research and Translation Director Puakea Nogelmeier (\$28,800) and 30% salary support for one professional staff person (\$28,286) in Years 2 and 3. (COST: \$114,172)

7. We request permission to carry forward \$20,050 in travel funds in order to meet expected increases in field activity in Year 2. In addition we anticipate the need to provide some travel support for new faculty and post-docs that are coming onto the project.

8. Similarly, we request carrying forward \$55,000 in materials and supplies to support the activities described in item 7 above.

9. We have removed the \$35,000 request for support for a Data Management Workshop subsequent to the information provided at the May 2017 PD/PA meeting regarding workshop funding.

10. We expect Indirect Cost charges in the amount of \$347,465 as a result of the distribution of funds in items 1-9 above.

III. Research and Education Program

Here we describe the major accomplishments and research findings during the current reporting period organized by the major goals or focus areas of the project, as put forth in the original proposal and approved strategic plan.

A. Goal 1: Develop and validate improved conceptual models of subsurface water distribution and flow within and through Pearl Harbor and Hualālai aquifers systems (in order to develop a framework to sustainably manage groundwater resources in both regions).

Objective 1.1: Image subsurface geologic structures and/or the location of groundwater in 3 to 4 target areas of Hualālai and Pearl Harbor aquifers systems using geophysical techniques by the end of Year 3.

Proposed Year 1 Activities: Complete several identified synthetic simulations of aquifers, enlarged team working on synthetic simulations using geophysical techniques. Hire post-doc and tenure-track faculty member in geophysics. **Objective 1.1 Results:** Discussions held with USGS Hawaiian Volcano

Observatory (HVO) (March 2017) on optimal sites for geophysics surveys, as well as best techniques to use. Gravity and shallow seismics along SE Rift Zone of Hualālai, as well as boundary of high-to-low water level wells, were recommended to supplement future magneto-telluric measurements. Historic gravity data for Hualālai (across gravity low to the west of volcano summit) has been received from HVO.

Mitigation Plan: None needed, on track for Year 2.

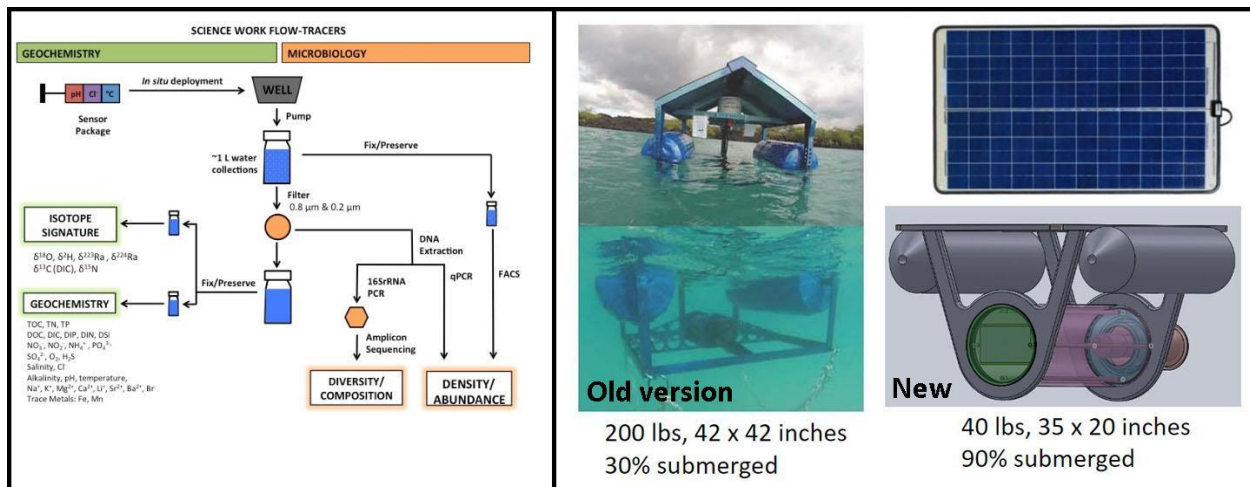


Figure 2 (Left): Schematic of sampling plan methodology for microbial investigations.

Figure 3 (Right): We have designed and built a new version of the SGD “sniffer”, which will first be used on Hawai’i Island. 4 rotating sites and a permanent “reference site” have been identified for the Kiholo Aquifer. At least 1 sniffer will also be deployed in Pearl Harbor.

Objective 1.3: Establish novel sensor-based monitoring network in wells by end of Year 3. **Proposed Year 1 Activities:** Preliminary design of sensor package, definition of parameters to be measured. Fabrication of complete sensing modules and testing. Preliminary sensor built and readied for field testing via pumping experiments. **Objective 1.3 Results.** Sensor package version 1.0 built. Work conducted on mechanism to lower package into well, power the package, and retrieve data stream also conducted so that tests can be conducted. First test in a well on Oahu planned for Fall 2017. We engaged in meeting with Kamehameha Schools and developers along the Hualālai Aquifer coastal region to ascertain initial wells for testing. We identified a number of wells that would be suitable for testing and we will be allowed to deploy our sensors there. We also examined possible deployment wells in Pearl Harbor. First prototypes of sensors were built (Fig. 4) with capability to sample salinity (<50 ppm up to a dynamic range of >30 ppt via a novel 4-point capacitive technique), temperature (thermistors capable of 0.1°C over a desired range of <5 - 30°C), and pressure (<10 mm resolution or <100 Pa via accurate depth-to-surface measurement techniques). Designed novel flow rate sensors (<1 micron/sec in each direction) to be tested in June 2017. Developed a novel tethering system and lightweight strong cable to handle signal transmission, power, and sensor retrieval. The down-well remote operating platform (DROP) is estimated to be <\$500 and potentially can also handle some of the submarine groundwater discharge measurements. At the same time, the sensor leverages 4G network (widely available on each island) to communicate data and allow continuous reprogramming in the field based on sensing requirements. We are in a good position to handle the next stage of assembly and packaging the sensor modules and deploying in wells for testing (summer and fall).

Mitigation Plan: None needed, on track for Year 2.

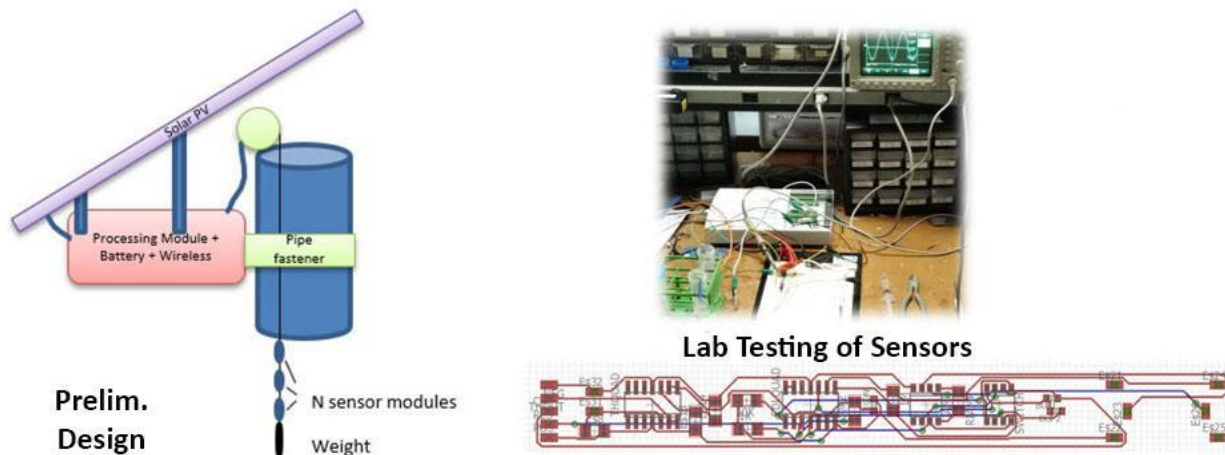


Figure 4: At left, the conceptual design of sensor package and at top right some of the breadboard sensors being tested in the lab. The final circuit layout is shown in the bottom right.

Goal 2: Develop a new data and modeling platform for Hawai'i volcanic hydrology, economic modeling and decision support

Objective 2.1: IKE Platform: Implement a fully featured data management, analysis, and visualization application based on the AGAVE software framework. **Mitigation Plan:** None needed, on track for Year 2.

Activity 2.1.1: Hire Professional Staff. In July of 2016 Jennifer Geis was hired as a software engineer to work on the development of the IKE platform.

Activity 2.1.2: Setup Computation and Storage platforms. **Infrastructure:** In order to support the 'Ike Wai project UH partnered with the Texas Advanced Computing Center (TACC) to setup a local Hawai'i Agave platform instance to provide a robust middleware layer to build a flexible and responsive science platform. A set of Development Agave infrastructure (Fig. 5) was deployed in June of 2016 enabling the newly hired software developer (Jennifer Geis) to work with Cleveland on developing a user interface for the Integrated Knowledge Environment (IKE) platform. The IKE infrastructure deployments for development and production environments currently require 8 virtual machines (VMs) to support the Agave middleware components. Two VMs are needed to host user interface web applications. Lastly, one VM is needed to provide access to storage and one VM for the forthcoming dissemination service.

The Agave authentication (Auth) and core science API services (Core) along with the 'Ike ToGo servers are hosted in the 10G science DMZ portion of the UH network to allow for fast data transfers and access response. The database VMs are hosted behind the UH firewall to protect the data and services. The central data repository is physically hosted on the UH Information Technology Services (ITS) enterprise grade network attached storage appliance located in the UH ITS data center. The storage volume being used is currently 10TB in size and is backed up to a second storage location in the UH data center nightly

as well as encrypted and backed up to a cloud storage location offsite for disaster recovery.

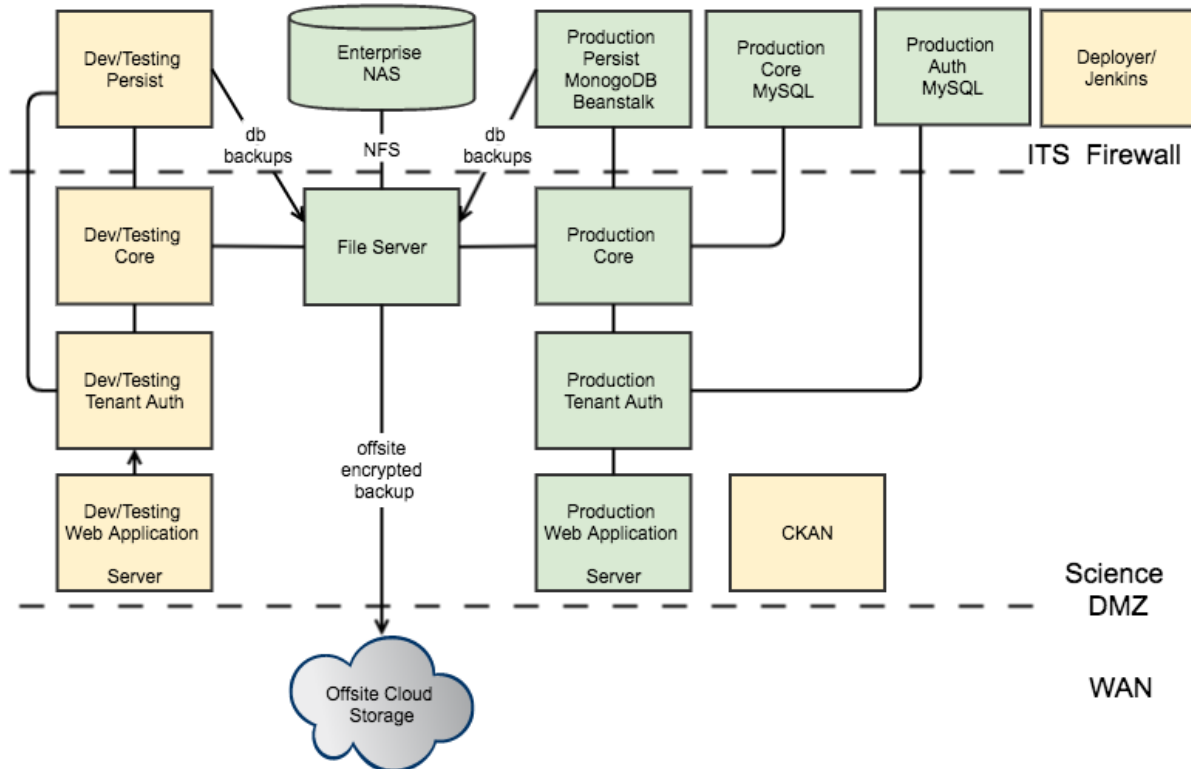


Figure 5. The IKE Platform infrastructure diagram. Yellow boxes denote development/testing virtual machine components. Green boxes denote production components.

User Interface: In the Fall of 2016 the initial graphical user interface (GUI) for the IKE platform’s science APIs began development. The GUI is a customized version of TACC’s Agave ToGo (<https://bitbucket.org/agaveapi/agave-togo>) web application. Agave ToGo is an Angularjs based web interface using the bootstrap framework built on top of the Agave Angularjs SDK. The IKE platform GUI is called IKE ToGo (Fig. 6) (<https://agaveauth.its.hawaii.edu> source: <https://github.com/UH-CI/ike-togo-app>) and currently supports the following features:

- Login with UH Credentials - Authentication is handled by the University of Hawai’i LDAP and Authorization leverages Agave’s managed permissions
- Data upload, download and browse within a user storage area
- File and folder manipulations (rename, copy, move, delete)
- Data sharing with limited use URLs
- Creation and management of metadata objects
- Annotation of files with metadata
- Search on annotated files and metadata

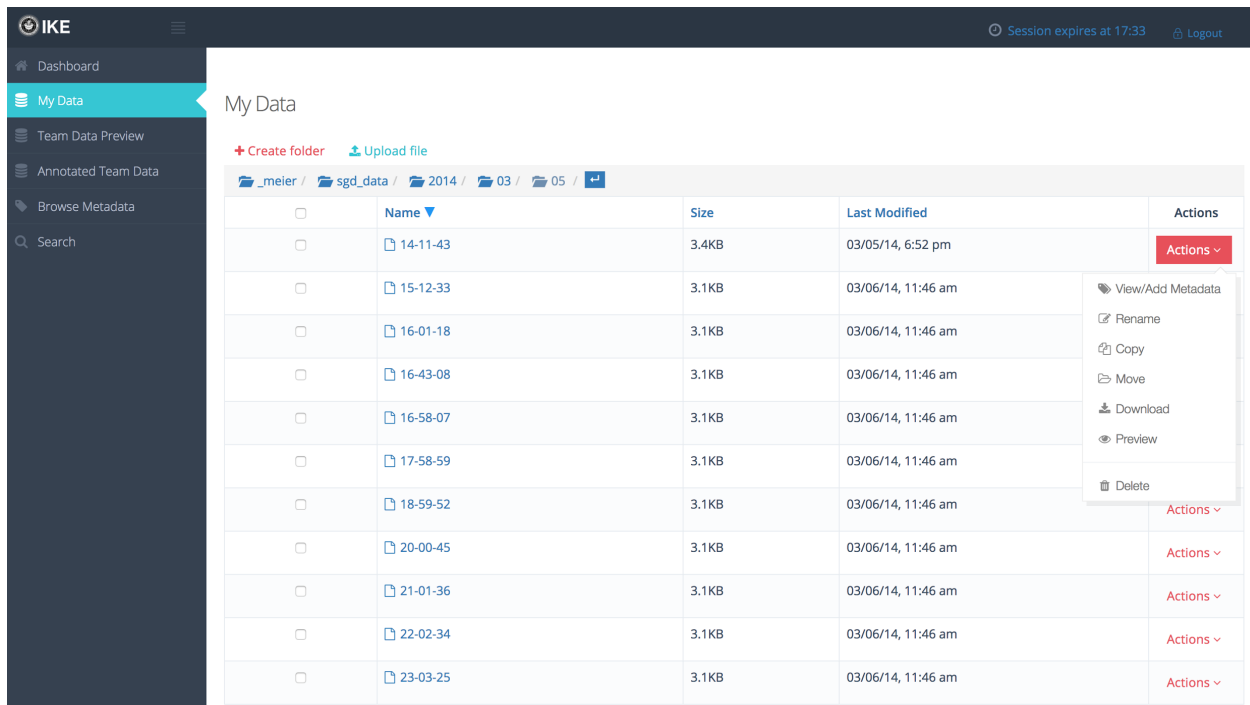


Figure 6: The My Data storage area in the IKE ToGo User Interface for the IKE platform.

The IKE platform currently has three areas that users can access storage: a PI/Group data area called My Data in the interface where users can upload data, download data and do other file manipulations as well as annotate data, the Team data preview area allows for sharing of preliminary data results amongst the 'Ike Wai researchers prior to the data being fully annotated - only data download is allowed from this storage area, the Annotated Team Data repository is where accepted annotated data is deposited and available to the 'Ike Wai researchers for discovery through browsing and search based on associated metadata (Fig. 7). The cyberinfrastructure team is completing the final rounds of testing of the IKE ToGo interface and plans to put the software into full production summer 2017.

Computation: The current IKE platform infrastructure via the Agave APIs currently supports running computations on the University of Hawaii High Performance Compute (HPC) cluster. Test applications with Mothur and Qiime related to Frank's analysis workflow have been developed and tested. The user interface to allow researchers to launch and manage computational jobs from IKE ToGo is under development as we customize the Agave ToGo general purpose computational interface to better fit with the 'Ike Wai project. Additionally, in an effort to begin testing and support for the modeling effort the MODFLOW software has been deployed on the UH HPC and integration with IKE ToGo is underway.

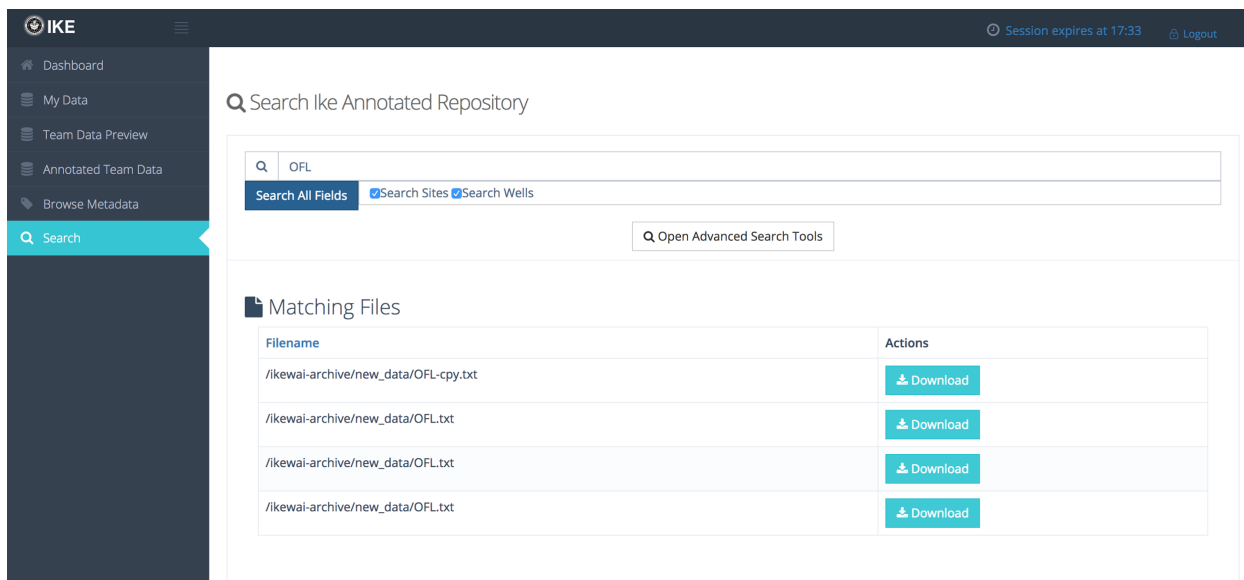


Figure 7: IKE ToGo Search interface.

Activity 2.1.3: Create training materials, documentation and train researchers on using the 'Ike Wai storage platform. No progress - work is slated to begin in Year 2.

Activity 2.1.3: Create/Deploy initial science computational workflow. The developers and data manager had meetings with all researchers on the project discussing data and computational workflows. Initial specifications of some of the workflows to support data processing and analysis for microbial and water chemistry data have been developed.

Objective 2.1.4: Visualization: Create tools and visualization environments for data exploration and collaboration using SAGE2 and CyberCANOE. **Mitigation Plan:** None needed, on track for Year 2.

The visualization team conducted training and provided additional technical assistance in the construction and installation of the CyberCANOE at the University of Hawai'i-Hilo (Fig. 8).



Figure 8: At left, a view of the newly built UH-Hilo Data Science classroom with CyberCANOE and student computer lab and (right) UH-Hilo staff and student team that assembled Data Science classroom.

The visualization team reviewed existing data and visualizations used by the science teams. Outcomes: Baseline increased from zero at start of the project to 6 after Year 1. Data sets and visualizations reviewed (Fig. 9) include: historical Hawaiian articles database, coastal water temperature data, submarine groundwater discharge & well data, water flow simulation data, rainwater collection site data, plume location data.

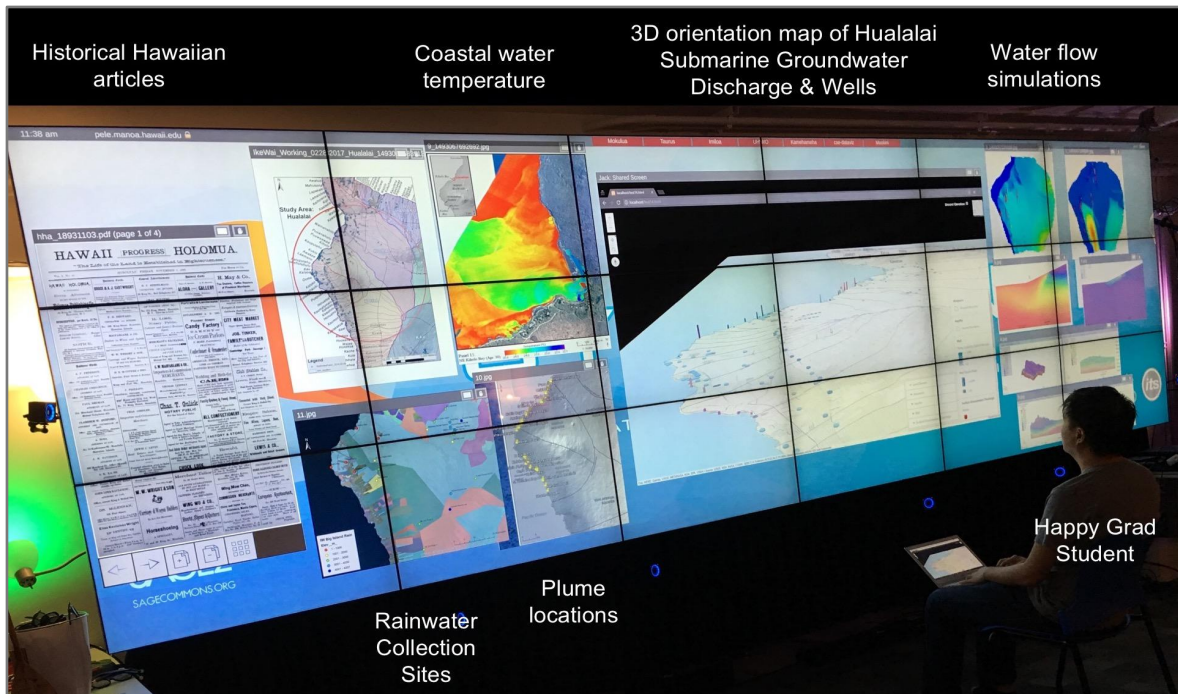


Figure 9: Student, Jack Lam, on the visualization team, learned to use the AGAVE data infrastructure so that in the future his visualizations can directly access data from the repository rather than an ad hoc repository.

Outcome: A prototype visualization (Fig. 10) was produced to provide an overview map of the project site areas including locations of Submarine Ground Water, wells, and Ahupua'a boundaries.

Objective 2.1.5: Dissemination and Decision Support: Create gateways for data access and dissemination, develop decision support tools with stakeholders. **Mitigation Plan:** None needed, on track for Year 2.

Activity 2.1.5: IKE Dissemination Platform. In Spring 2017 a testing instance of the Comprehensive Knowledge Archive Network (CKAN) was setup to explore its use as a dissemination platform and integration with the IKE platform. Evaluation and testing is currently underway to determine if this platform will successfully integrate and provide the necessary features for the 'Ike Wai project.

Objective 2.2: Data Store Population: Aggregate, annotate and store legacy, existing and new scientific data.

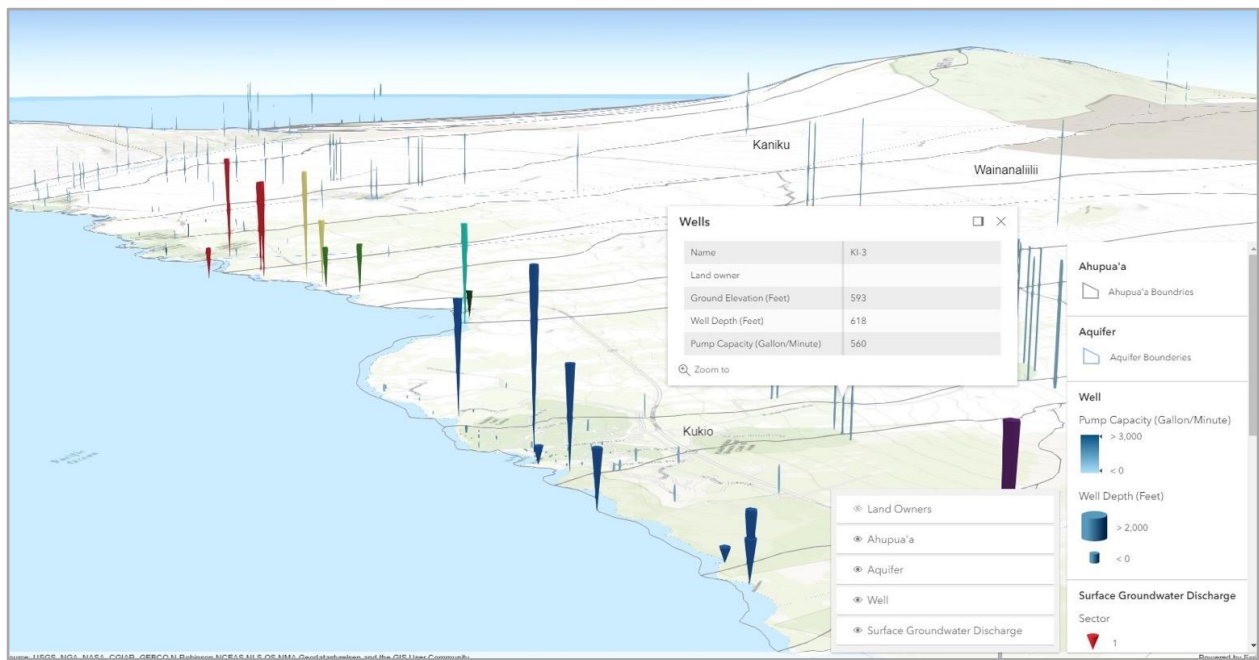


Figure 10: Prototype visualization of the distribution of wells on the west side of Hualālai, giving an impression of the spatial availability of pumped water.

Activity 2.2.1: Personnel & Training

Personnel: A data manager, Dr. Ouida Meier, was hired and started working on the project at the beginning of April 2017.

Training: The development team did training on the IKE Platform with Jack Lam, a graduate student working on the visualizations in Spring 2017. On April 12, 2017 the cyberinfrastructure team and TACC hosted a day-long bioinformatics genomics data workshop at UH Mānoa. John Fonner (TACC) and Sean Cleveland (UH) presented with Rion Dooley (TACC), Joe Stubbs (TACC), Ron Merrill (UH), David Schanzenbach (UH) and Jennifer Geis (UH) assisting the 32 participants (30 from UH and 2 from Chaminade University) that attended. The workshop covered metadata and data organization, using the command line, R, Jupyter notebooks, some basic genomics processing software, creating computational workflows, and using the Agave ToGo software instance that is hosted on the UH infrastructure. The goal of the workshop was to allow the attendees to manage and analyze data more effectively and be able to apply the tools and approaches directly to their ongoing research.

DataDescriptor – minimal metadata	
Title	[filename]
Format	[base on .ext then allow modify]
Location	[Well, Site dropdowns, LatLong]
Author	[names + fund.proj. + institution]
Variables	[Chem., Sensor, etc. dropdowns]
Rights	[sharing + license]
Subject	[sub-project/directory]
StartDate	[of work in data file]
EndDate	[if not StartDate]
Description	[open text]
Relations	[relev. IDs/files if any - open text]
Language	[Hawaiian or disciplin. vocab.]
OtherLocation	[if Loc. options above unsuited]
OtherVariables	[if Var. options above unsuited]

Figure 11: Data Descriptor fields - aggregating minimal metadata.

Activity 2.2.2: Data Store & Curation

In Spring 2017 the development team and data manager held 12 meetings with the research teams to identify the different data products being produced, and developed specifications for the minimal set of metadata required. Based on these meetings and using existing metadata standards the cyberinfrastructure team designed an initial set of minimal metadata that conforms to Dublin Core standards to capture the basic information about a file or dataset that works in the IKE platform (Fig. 11). The IKE platform is leveraging the Agave metadata APIs that support storage and management of metadata as JSON documents within the Agave mongoDB server. The initial minimal set of metadata objects or schema in the IKE platform consist of a Data Descriptor object, a Variable object, and location objects such as Wells and Sites. The Data Descriptor object contains fields that contain the Dublin Core minimal representative fields (i.e., title, author, source, publisher, rights, description, etc.). To enhance search and discovery of information in the IKE platform as well as reusability of information, the location information is separated out into other metadata objects such as wells and sites. The variable information is also expanded into metadata objects to ensure compatibility and standardization within the IKE platform. Within the IKE platform each file is designated a unique identifier, which can be associated with the various metadata objects in order to describe each file.

Metadata Workflow and Strategy

Assess needs, inputs, outputs

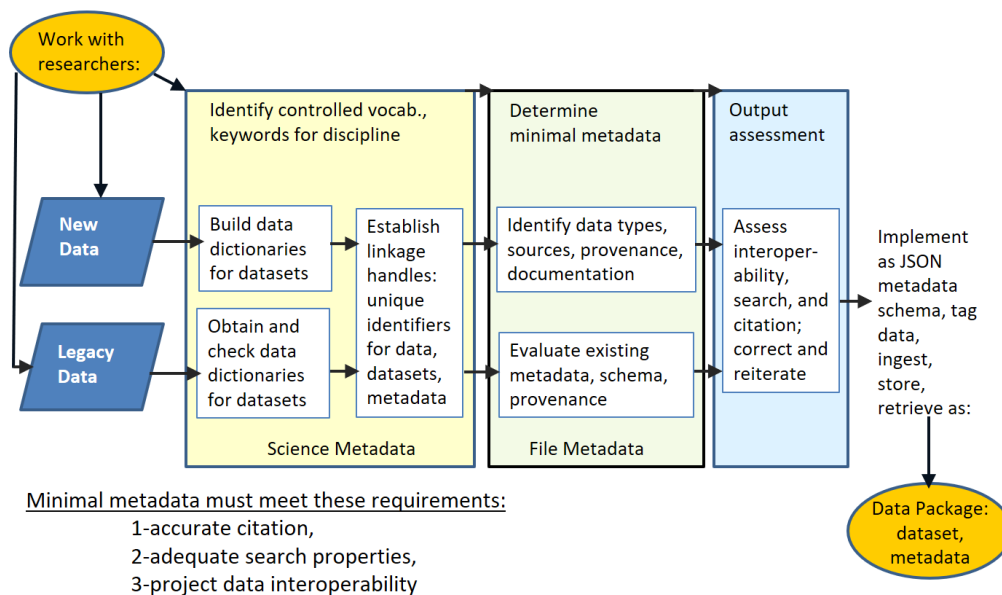


Figure 12: Metadata Workflow and Strategy

The following strategy for annotation of data was developed by the 'Ike Wai Data Manager. IKE ToGo supports an annotation workflow that allows users to manage their raw and pre-quality controlled data file to exist in their My Data storage solution and be annotated with metadata and submitted for review by the data manager. Once the data manager reviews the annotations the file can be approved and then migrated to the Annotate Ike Wai Team repository or rejected and sent back for further annotation (Fig. 13).

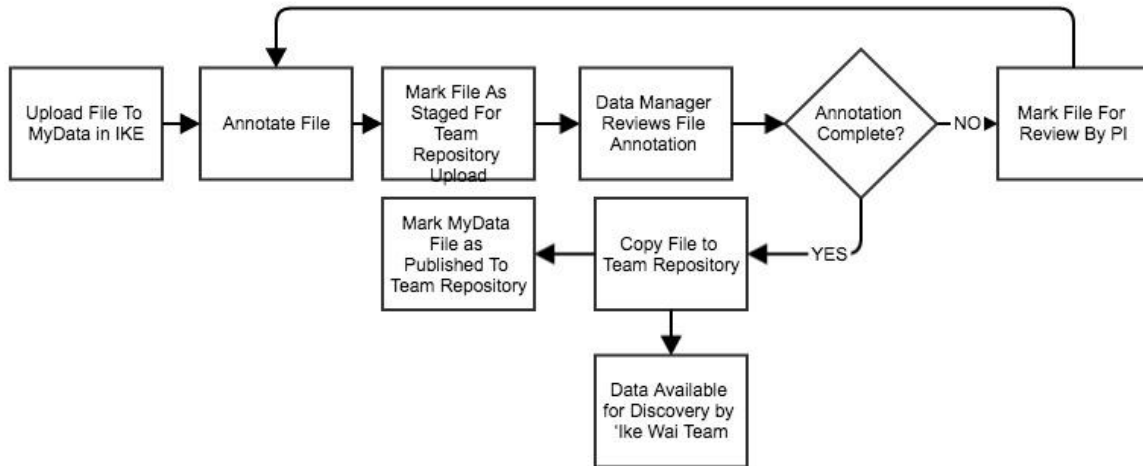


Figure 13: Data annotation strategy to be implemented in the IKE ToGo workflow

The cyberinfrastructure team loaded over 6,450 test legacy data files from the previous EPSCoR award including SGD sniffer and rainfall atlas (<http://rainfall.geography.hawaii.edu/>) data files and annotated them with minimal metadata. In addition metadata about the existing wells across the state of Hawaii were created, resulting in 4,761 well metadata objects in the IKE platform that can be used to describe future data collected in the 'Ike Wai project related to those well locations. The cyberinfrastructure team has been testing annotating these files with the base level of metadata to streamline the process. Eleven metadata schemas have been defined so far, and we will begin curating new project data files during the next reporting period.

Activity 2.2.3: Aggregate, annotate and store legacy and new data and models. **Proposed Year 1**

Activities: Determine number of data sets held by Federal and State agencies, hire graduate research assistants, build a spreadsheet of Hawaiian terms for water and provide summaries and translations, identify number of historic groundwater data sets, hire graduate student, present seminars on importance of historical documents, participants are more familiar with Hawaiian language. **Mitigation Plan:** None needed, on track for Year 2. **Activity 2.2.3 Results.** Three main historic data sets identified for future inclusion in IKE, Graduate student hired, preliminary list of 40 search terms developed to interrogate scanned Hawaiian newspapers. We have identified the following historical and current data sets, which are now under investigation. (1) The Historic Hawaii Rainfall Atlas maps and data, including

historic rainfall maps dating back to 1929. A set covering years 1978-2007 serves as a critical 30-year baseline to modern precipitation measurements, but as its current repository is unlikely to be sustained long-term, its migration to an actively curated repository is imperative. (2) Driller's logs from water well construction have valuable historic information about water level and chloride concentrations at the time of drilling. Most of this information is in image-only format, but could be digitized and converted to raw data. This would allow potentially sensitive location information to be used in modeling and analysis. (3) Hawaii Undersea Research Laboratory (HURL) submersible observations of conductivity, temperature and depth, ranging from 330-1500 meters below sea level during 1982-2012; hundreds of dives near Kona and near Hilo potentially allow construction of large-scale 3D distribution patterns of freshwater discharge along Hawaiian coastlines and their variability over time.

Activity 2.2.4. Obtain historical land use data from Indigenous knowledge contained in Hawaiian newspapers and other sources. We are working to obtain water data (location of 19th century springs and sites of SGD) from Hawaiian and Hawaiian language newspapers. Two graduate research assistants have begun research, focusing on: (1) Place-based historical information related to each study site, and term and concept research for a broader range of water resources and management practices, not limited to the particular study sites. Initial research in November and December focused on curating resources related to 'Ewa. The moku of 'Ewa is a large land division using a Hawaiian land division system that encompasses the entire Pearl Harbor Aquifer. Two large series/resources were identified for initial review and translations; *Lei Momi o Ewa* and *Wahi Pana o Ewa 1899* - from Ka Loea Kalaiaina Newspaper of about 100 pages of text. When the study site boundary for O'ahu was being reconsidered, place-based research shifted focus to Keauhou. With both graduate researchers on-board we have been able to identify collections of relevant articles. These articles have been assembled into a spreadsheet for analysis and prioritizing. A preliminary list of 40 search terms and concepts related to water resources and water management has been created.

Activity 2.2.5: Develop and parameterize coupled conceptual models. Proposed Year 1 Activities: Develop strategy between modeling, geophysics and geochemistry parts of project. Improve understanding of conceptual models. Identify spatial distribution of hydrogeologic parameters. Hire new tenure-track faculty member in hydro-engineering, hire post-doc in hydro-engineering. **Actual Year 1 Outcomes:** Fly-out interviews conducted for 2 candidates for tenure-track position but offers were declined. A post-doc (Dr. Ahmed Elshall) to start May 29th, 2017. **Mitigation Plan:** Third faculty candidate interviewing May 11/12, post-doc to start work on models using commercial software (FEFLOW) as soon as possible while awaiting new faculty member. **Activity 2.2.5 Results:** *Parameterize coupled models.* The Modeling, Geophysical, Geochemical, Microbiological, and Monitoring Teams have met twice specifically to address data gaps, which will help refine models. A general research framework was established including an approach for identifying data gaps and procedures for filling these gaps (Fig. 14).

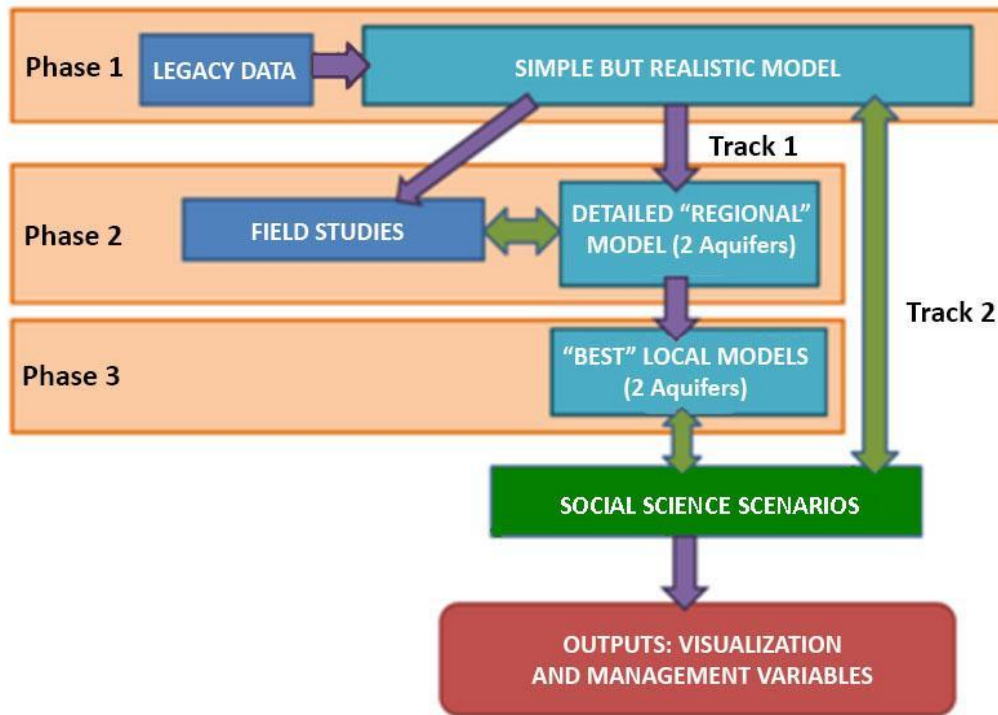


Figure 14. Conceptualization of the inter-relationships between data (dark blue boxes), groundwater models (light blue boxes), and social scenarios (green box), which all lead to the visualization of the groundwater variables by stakeholders (red box). Purple arrows indicate one-way flows of information, two-way information flow by green arrows. The complexity of the models can be broadly defined in three Phases, with the simplest model in Phase 1 and the most complex in Phase 3. Multiple paths (“Tracks”) between the models and social scenarios are possible.

Activity 2.2.6: Develop and apply suitable numerical models for comprehensive scheme. In addition to preliminary data and literature searches, a preliminary model was developed for the West Oahu area covering the Hualālai site. Gaps in hydrogeologic information include the boundary of the site in question. For example, all indications are that an area up to the Mauna Loa and Mauna Kea sites contributes subsurface water flow to the Hualālai site (Fig. 15). In such a case, a more accurate representation includes modeling such an area, which is labeled in the figure as the West Hawai’i area. Estimate model parameters. We have tested numerical capabilities of the density dependent model FEFLOW, which is suitable for modeling freshwater-saltwater interaction. Such a model is a comprehensive software package for groundwater and porous media modeling. In addition, to density dependent flow, the model can simulate fluid flow, groundwater age, contaminant and heat transport under fully or variably saturated conditions - from local to regional scale. The model is equipped to handle preferential flow due to heterogeneities as well as fractures. It can also allow high resolution modeling with unlimited number of elements.

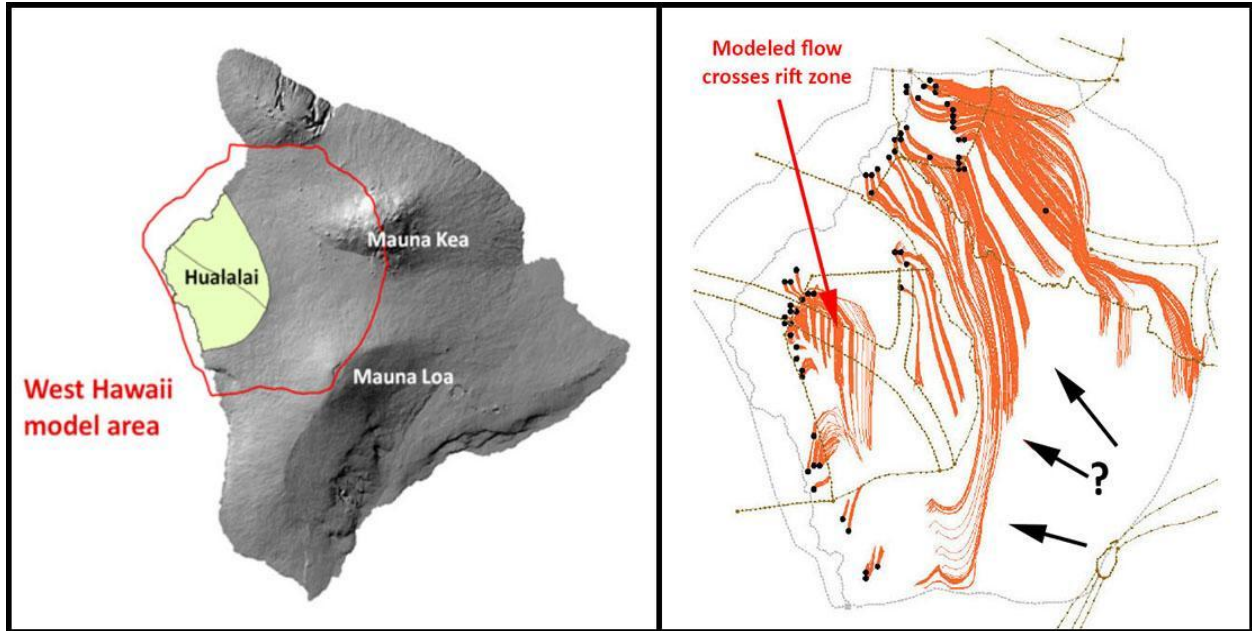


Figure 15 (Left): Recognition of the likely extended boundaries of the Hualālai aquifers (red boundary). As we strive to better understand the subsurface flow paths, it is likely that water that fell as rain on Mauna Kea and Mauna Loa contributes to the aquifers of interest. (Right): Simulated flow path-lines for a simplified groundwater model for West Hawai'i. Based on field observations at the wells (black dots), inaccuracies in the model regarding flow directions from Mauna Loa volcano (black arrows) and potential effects of the W. Rift Zone (parallel lines of brown dots, indicated by red arrow) are examples of identifying data gaps. The dotted line to the west of the coastline marks the location of the submerged reef at a depth of 150 m.

The model was tested for two cases involving density dependent flow due to saltwater-freshwater interaction, which represents an important factor in the two chosen modeling sites. The first case for testing addressed the flow was in an Oahu island-wide model. The island was divided into 30 vertical layers with 15,000 elements per layer of about 500 meter each, i.e., a total of 450,000 elements. The results regarding salinity are shown in Fig. 16. The spatial profile of salinity in this three-dimensional model displays the expected distribution under variable density flow conditions. The second case dealt with high-resolution simulation in a cross sectional model of 18 km length and up to 2 km depth. The area was divided into ~46,000 elements with an element size of about 30 meters. The model was successful in simulating the flow under this tortuous test. Figure 17 shows the results in a near shore portion of the modeled area.

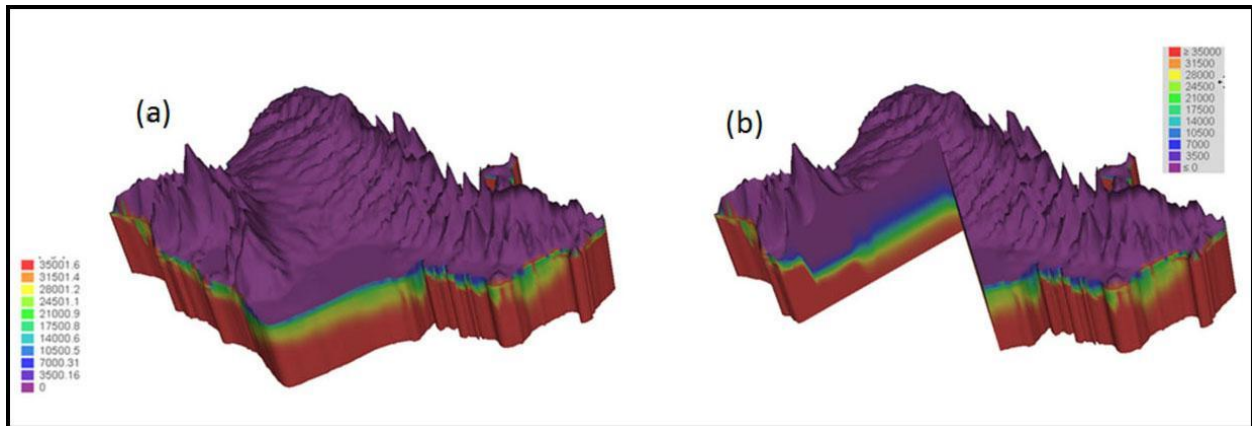


Figure 16: Uncalibrated three-dimensional island-wide model of Oahu showing salinity distribution using FEFLOW. This model allows us to investigate the spatial distribution of salinity as a function of various hydrologic conditions including recharge and pumping. Salinity is displayed in milligrams per liter: (a) full island, and (b) sliced section to show the interior of the island.

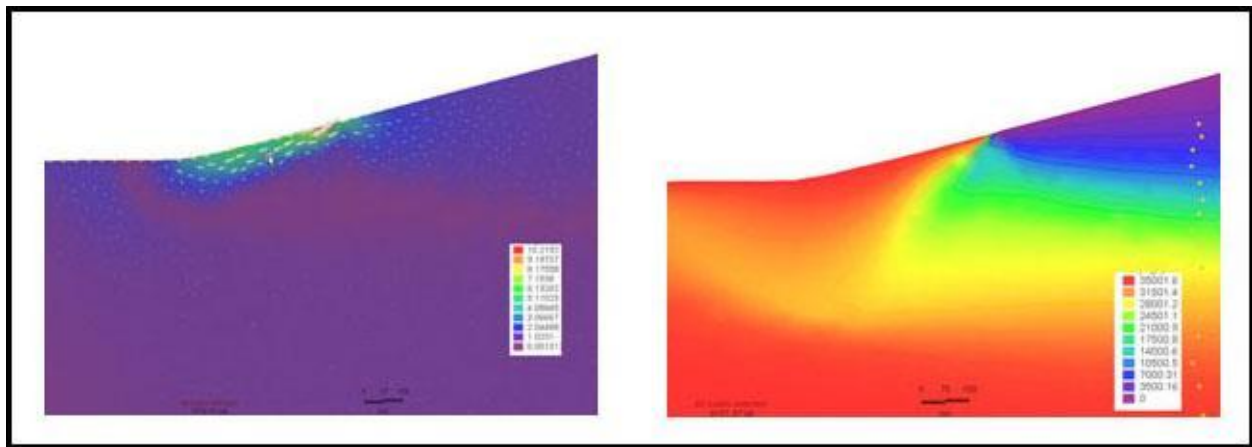


Figure 17: Two examples of our detailed FEFLOW simulations of the freshwater/seawater interface for Oahu. Left: Results of water fluxes (in meter per day) with white arrows depicting velocities. The arrow sizes are proportional to velocity magnitude. Right: Variations in salinity (milligram per liter). As should be expected, a freshwater lens floats on the top of the saltwater with brackish water separating the two zones.

Objective 2.3: Economic modeling. Proposed **Year 1 Activities:** Hire new tenure-track faculty member in water economics, develop stakeholder engagement plan and compete first round of stakeholder meetings, list of scenario implications in order to develop appropriate quantification of framework, engage numerous stakeholders to develop water management scenarios. **Mitigation Plan:** None needed, on track for Year 2. **Objective 2.3 Results.** New faculty member (Dr. Leah Bremer) hired and will start July 1, 2017. 5 stakeholder meetings held, reaching 8 key State organizations. Three key management concerns identified (link between pumping and freshwater discharge, areas for most cost-effective increase in groundwater recharge, and framework for revising SY estimates).

Activity 2.3.1: Stakeholder engagement. We have held five stakeholder meetings, including eight key State water stakeholders, namely the Commission on Water Resource Management, County of Hawai'i Department of Water Supply, Department of Health: Clean Water Branch, Department of Health: Safe Drinking Water Branch, Department of Health: Office of Environmental Quality Control, Department of Agriculture, Department of Hawaiian Homelands, and the Office of Hawaiian Affairs.

Activity 2.3.2: We have initiated the development of stakeholder-driven management scenarios to jointly consider with the hydrological model on Hawai'i Island. The process of scenario building is a recursive process that will be refined through further stakeholder meetings and increased collaboration with the 'Ike Wai groundwater modeling team. At this stage, we have identified three key management concerns that will likely inform the finalized scenarios: (i) understanding the link between pumping and freshwater discharge along the coast and implications for nearshore ecology, (ii) identifying areas where watershed management would be most cost-effective for increasing groundwater recharge, (iii) developing a framework for revising current estimates of sustainable yield to include additional factors (e.g. nearshore ecology, traditional/customary uses, seawater intrusion). The final scenarios will be constructed by varying the following: population-based groundwater pumping projections (aggregate low, base, high; also how pumping is allocated spatially across wells), watershed management decisions (how much and where), SGD constraint to protect nearshore resources (low, base, high; likely location-specific).

Activity 2.3.3: We have performed a spatial analysis of watershed restoration investments, with an increased understanding of stakeholder concerns around restoration and stakeholder engagement around analysis of spatial watershed restoration.

Objective 2.4. Community Engagement: *Establish collaborative relationships with key agency stakeholders.*

Activity 2.4.1: Agency Outreach. Agency outreach commenced immediately upon receiving the award. Relationships and collaborations have been established with the Commission and Water Resource Management (CWRM), United States Geological Survey (USGS), the Hawai'i County Department of Water Supply (DWS), and the Honolulu Board of Water Supply (HBWS) that include data sharing, technical consultation, and use of their wells as sampling sites. In addition, we have met with the following State departments all of whom regulate and/or monitor some aspect of water management in Hawai'i: Department of Health (Clean Water and Safe Drinking Water Branches), the Department of Hawaiian Homelands (DHHL), Office of Hawaiian Affairs (OHA), Department of Agriculture (DOA), Office of Environmental Quality Control (OEQC), and the Native Hawaiian Legal Corporation (NHLC). Inclusive of all State and County agencies, we have held in excess of 15 meetings with State agencies involved in water management during the Program Year 2016-17. **Mitigation Plan:** None needed, on track for Year 2.

Activity 2.4.2: Establish Water Resources Advisory Committee (WRAC). One of our community partners is the Hawai'i Community Foundation (HCF). Two years ago HCF initiated the Hawai'i Freshwater Initiative (HRWI), a major water resources initiative whose purpose is to increase the availability of fresh

water in the State by 100M gallons per day by 2030 through conservation, reuse, and recycling. As part of that initiative, HCF established the Fresh Water Advisory Council (FWAC) comprised of major public and private water stakeholders. Rather than reinventing the wheel, our strategy is to work closely with HCF and the FWAC as a forum for gathering the type of feedback and input we originally thought of seeking from the WRAC. In Program Year 2016-17 we conducted one presentation on 'Ike Wai to the FWAC and have met with the HCF Director on two separate occasions to develop this idea of "sharing" the advisory services of the FWAC. Discussions are currently on hold as the HCF Director was recently recruited to join the City and County of Honolulu's Administration as Director of Sustainability. Regardless of the actual formalizing of this group, our engagement activities thus far (See Activity 3.1.1) have yielded commitments for data-sharing from water managers across the State and information regarding their decision-support needs (Activity 3.2.1) that are informing and shaping our science focus and activities. **Mitigation Plan:** None needed, on track for Year 2.

Activity 2.4.3: Identify stakeholder decision-support needs. In October 2016 we were approached by The Ulupono Initiative (UI), a private social impact investment firm located in Hawai'i with interests in water sustainability, to collaborate on a study of the State's water management system. This study was beyond the scope of our planned work to identify the decision-support needs of water managers but with UI's additional funding we have been able to leverage our EPSCoR award to expand the scope of our interviews with no real increase in effort on our part. Our assessment is ongoing and is scheduled to be completed by November 2017. Preliminary findings, which are already being shared with the project team for consideration into their respective goals and objectives, indicate that the major water management decision-support needs are: 1) the development of a new methodology for determining sustainable yield; 2) creation of a State-wide water data repository, and 3) visualization tools for education and planning purposes. **Mitigation Plan:** None needed, on track for Year 2.

Activity 2.4.4: Establish interagency data committee. The need to formally establish an interagency data committee has been reconsidered in light of our successful agency outreach to date. With the hiring of the Data Manager, the more effective strategy to identify the specific needs to be considered in sharing data and developing a data depository is to have the Data Manager actively involved in our ongoing agency engagement and to schedule ad hoc meetings with subject matter experts (SME's) from the water agencies as needed. **Mitigation Plan:** None needed, on track for Year 2.

Activity 2.4.5. Negotiate, document, and manage landowner agreements. Priority for this activity during the Project Year has been in West Hawai'i (the Hualālai Aquifer). Fig. 18 is a map of the major land and well owners identified as desirable field sites. Working iteratively with the science team, outreach to the following land and well owners in the region whose lands and/or wells provide potentially suitable field sites for the geophysical and geochemical sampling we propose to conduct include:

- Kamehameha Schools (KS)
- Hawai'i County Department of Water Supply (HDWS)
- Natural Energy Lab of Hawai'i (NELHA)
- Kohnana'iki Resort (KR)

- Queen Lili'uokalani Trust (QLT)
- Palani Ranch (PaR)

Under development are:

- Kohala Coast Resorts (Various)
- Parker Ranch (PR)
- Waiki'i Ranch (WR)

Based on this initial outreach and work with the science team, six access and collaboration agreement proposals have been submitted to KS, NELHA, QLT, PaR, KR, and HWDS. Approvals are still pending. **Mitigation Plan:** None needed, on track for Year 2.

Activity 2.4.6: Develop Strategic Community Partnerships. Collaborations and/or partnerships with the following private sector, major NGO, and community groups have been established (bulleted below).

Mitigation Plan: None needed, on track for Year 2.

- The Ulupono Initiative - A private social impact investing firm who is providing additional funding to expand the scope of our agency outreach to include an assessment of the water management system in Hawai'i. This is an unanticipated opportunity that arose after our award was received.
- Hawai'i Community Foundation - Conveners of the Hawai'i Fresh Water Initiative (HFWI) with whom we are exploring the potential of sharing advisory committees. In addition, we were invited to submit proposals to a recently announced RFP focused on water advancing various water initiatives identified in their Blueprint plan and which they are underwriting. Thus, these are opportunities to develop an ongoing strategic partnership with HCF and not just funding opportunities. One proposal is for collecting existing water legacy data in the State not included in agency data and the second is to develop a methodology for determining ROI on watershed conservation. These are unanticipated opportunities arising post-award.
- Moanalua Gardens Foundation (MGF) - Land stewardship organization that conducts place-based education in the Moanalua Valley on O'ahu that abuts our Pearl Harbor Aquifer study site. We are in discussions regarding a mutual capacity building strategy that could include data sharing, study site access, and serving as a potential learning/teaching site to support our student and faculty development.
- Kona and Waimea Water Roundtables - Community forums on Hawai'i Island convened for the purpose of education and advocacy on water issues in their respective communities. Currently in discussions regarding their assistance in convening Roundtables as forums for ongoing education and consultation with the general community in West Hawai'i.

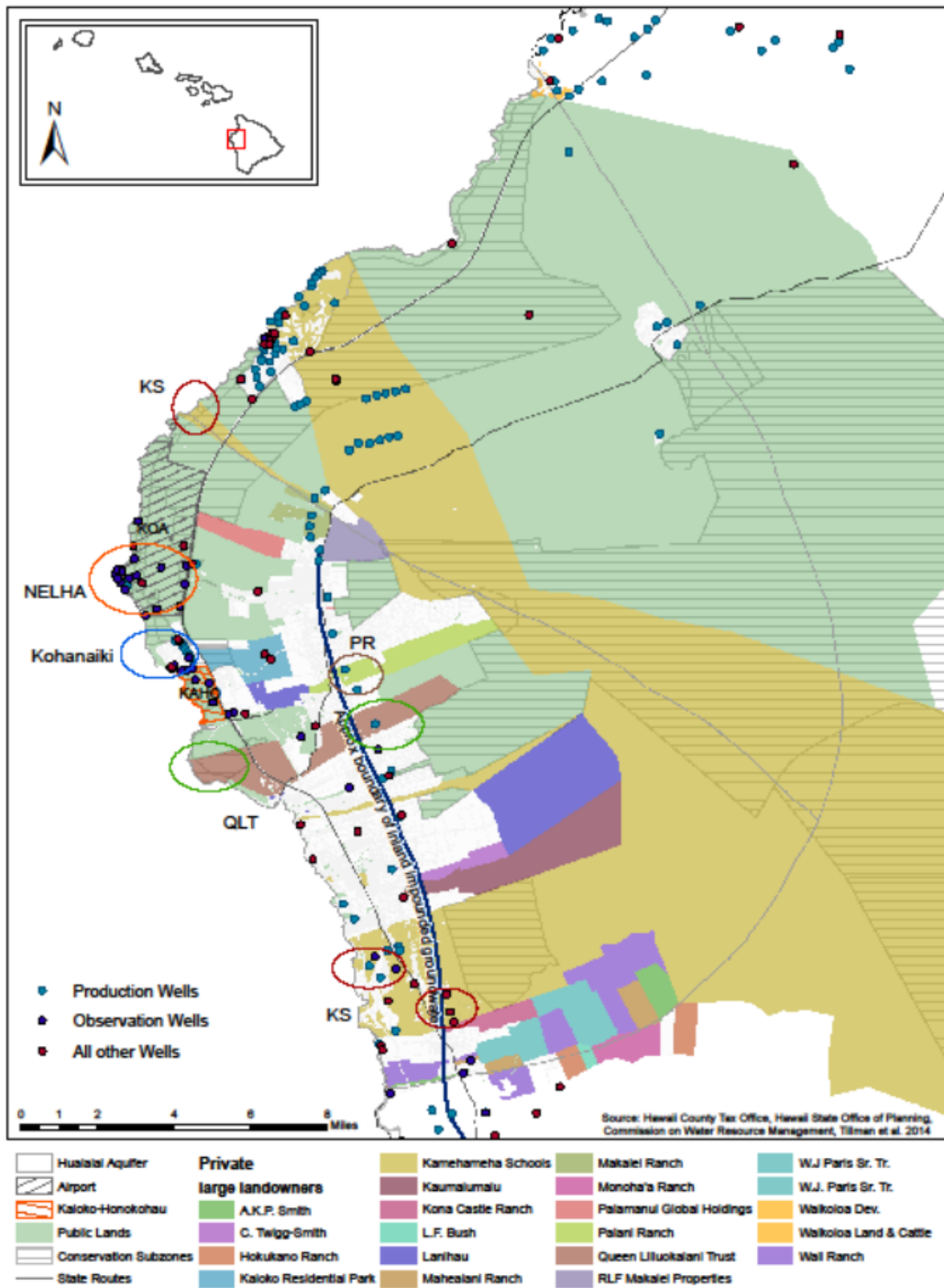


Figure 18: Map of the major land and well owners identified as desirable field sites

Activity 2.4.7. Conduct General Education and Disseminate Information. The following collateral material, educational presentations, and media productions have been developed and/or completed this Program Year. **Mitigation Plan:** None needed, on track for Year 2.

- ❑ Project Executive Summary (One-pager) - used for general project overviews and as a leave behind (see attached)
- ❑ Hawai'i Leeward Planning Conference - Project briefing. This is an organization of landowners, government agencies, and private sector professionals working in development and resource management. Immediate outcomes include pending data-sharing and access agreements with Kohana'iki Resort and Queen Lili'uokalani Trust.
- ❑ Honolulu and Kona Science Cafés - Project briefing. This is a monthly lecture series open to the general public dedicated to science and technology. Combined attendance= 141
- ❑ Mapping Freshwater in Hawai'i <https://youtu.be/4YB1kP1VFgA>
- ❑ Testing Freshwater <https://youtu.be/h6HNmZQP-l4>
- ❑ Translating Hawaiian Newspapers https://youtu.be/U2lv_M-cwjik
- ❑ ThinkTech Hawai'i - Likable Science. Weekly live-aired television program focused on making science understandable. Described the overall project and our team science efforts.
- ❑ <https://www.youtube.com/watch?v=Q1laVhHwCao>
- ❑ IT All Campus Workshop; 195 attendees
- ❑ EPSCoR Proposal workshop; 81 attendees from 5 UH campuses
- ❑ Hawaii County meetings reported 100 attendees

Goal 3: Education and Workforce Development Focus: Establish an integrated set of pathways to train and develop a diverse cohort of students, post-doctoral and faculty researchers at UHM and UHH to address Hawai'i's water challenges.

Objective 3.1: 'Ike Wai Undergraduate Scholars Program: Undergraduate research and professional development.

Activity 3.1.1: Undergraduate Research. During the reporting period, 20 undergraduate scholars were trained at UH Mānoa and UH Hilo. UH Mānoa projects focused on water science, whereas UH Hilo projects focused on data science. UH Hilo students presented their research results as poster presentations in April 2017. These students are highly diverse, as shown in Table 2 in section IV.B: Diversity. During the reporting period, recruiting partnerships were developed with several Native Hawaiian-serving and other minority-serving programs, and we anticipate student diversity will be further increased in our Year 2 cohort of undergraduate scholars. Website portals to accept Scholars applications have been developed and implemented at both UH Hilo and UH Mānoa, and we are currently accepting applications for Year 2. **Mitigation Plan:** None needed, on track for Year 2.

Activity 3.1.2: Undergraduate Professional Development (PD). In accordance with what was proposed, during Year 1, we did a soft roll out of the 'Ike Wai Undergraduate Scholars program, limited to research opportunities. During the reporting period, we developed a series of professional development workshops for undergraduates, and these will be implemented as planned during Year 2 at both UH

Mānoa and UH Hilo. Sample workshop topics include website design, data analysis, resume writing, cultural competency, networking, interviewing, time management and presentation skills. **Mitigation Plan:** None needed, on track for Year 2.

Objective 3.2: Summer Bridge Programs: Attract early undergraduates to 'Ike Wai-related STEM fields by developing and implementing summer bridges

Activity 3.2.1: O'ahu Summer Bridge for rising sophomores. A summer bridge program between Kapi'olani Community College (KCC) and UH Mānoa has been developed based on 'Ike Wai research covering four main content areas: (1) Hawaiian culture and community; (2) Geology; (3) Hydrology and (4) Careers. The teaching team has been recruited, and includes 'Ike Wai graduate students and faculty in science and Hawaiian language. Our partners at KCC have recruited 25 students, with diverse majors ranging from Hawaiian studies to various STEM disciplines, and 5 peer mentors who serve as teaching assistants. The program was implemented in May 2017, and interested summer bridge students will be recruited into the 'Ike Wai Undergraduate Scholars program and SOEST majors. **Mitigation Plan:** None needed, on track for Year 2.

Activity 3.2.2: Hilo Summer Bridge for rising freshmen & sophomores. In Spring 2017, Pelayo began the development of the 'Ike Wai Summer Bridge Program in Data Science. In addition to Pelayo, two computer scientists at UH-Hilo (Drs. Edwards and Peterson) were hired to develop an Introduction to *Data Science* module for the bridge experience. Also hired in Spring 2017 were a bridge coordinator, Math teaching assistant, and data science teaching assistant. In April 2017, applications for the summer bridge experience were advertised to local high school students (rising UH-Hilo Freshmen) and UH-Hilo students (rising sophomores). A curriculum that focuses on beginning a Mathematics pipelines (via a PreCalculus and Calculus 1 course) and an Introduction to Data Science course has been developed and will be implemented in June-July 2017 during the 5-week summer bridge experience. **Mitigation Plan:** None needed, on track for Year 2.

Objective 3.3: Individualized Professional Development: Create and implement individualized professional development plans for graduate students and postdocs, and Mentoring Cascade.

Activity 3.3.1: Individual Development Plan (IDP) for graduate students and post-docs. During the reporting period, the education team first conducted a review of best practices for developing and administering IDPs, and this led to the development of an 'Ike Wai IDP template. A presentation on the 'Ike Wai IDP and mentoring cascade was delivered at the Fall Meeting of the American Geophysical Union (AGU) in Dec 2016. Revisions were made based on feedback received. We then delivered a professional development workshop for 'Ike Wai graduate students to provide guidance on how to create an IDP using this template. The IDP template includes a student self-assessment of job-related skills/experience and career goals, and asks the student to reflect on the additional skills/experience needed to achieve their career goals. Five 'Ike Wai graduate students were hired during Year 1, and all five have created an IDP with the support of their mentor. A key outcome of the student self-assessment of job-related skills/experience and career goals is enhanced awareness of the additional skills and experience that must be obtained in order to achieve career goals. **Mitigation Plan:** None needed, on track for Year 2.

Activity 3.3.2: Mentoring Cascade. Create and implement a mentoring cascade for all 'Ike Wai participants. We developed a structure for the mentoring cascade (or layered mentoring network), based on best practices and existing models. All 'Ike Wai personnel will eventually participate, as mentors and/or mentees. During the reporting period, we piloted the mentoring cascade with five graduate student mentees and an equal number of faculty/staff mentors. These mentors are not the student's research advisors: they are in a different research field and their purpose is to provide holistic (non-research) support to help the student set and attain career-oriented professional development goals. A professional development workshop was delivered in February 2017 to train the mentors in effective ways of providing feedback and support to their mentees to assist them as they develop their IDP. An outcome of having mentors provide such feedback to their student was a more realistic self-assessment and IDP. The mentoring cascade was included in the Dec 2016 AGU Conference presentation noted above. **Mitigation Plan:** None needed, on track for Year 2.

Objective 3.4: Cohorted Professional Development: Develop and implement a series of education and training workshops for 'Ike Wai Graduate Students, Post-docs, Faculty and Staff, and establish an EDventures mini-grant program.

Activity 3.4.1: Provide Cohorted Professional Development (PD) Training for Graduate Students, Post-docs, Faculty and Staff. Two Ph.D. scientist-educators (each 50%) were hired to join the education team. Their duties include assisting with the development of a professional development plan for the 'Ike Wai cohort of students and scientists, and delivering professional development workshops. A pedagogy training plan was developed during the reporting period, and presented at two UH Mānoa departmental seminar series (Geology & Geophysics and Oceanography). Based on feedback received from instructional faculty at these seminars, the plan was subsequently revised. Several in-house pedagogy and other professional development trainings were delivered by members of the 'Ike Wai education team. In addition, six professional development training workshops were delivered by expert external consultants.

- *Active Learning*, by Sarah Sherman & Sara Harris (Feb 2017)
- *Team Science*, by Peter Adler (March 2017)
- *Mentoring*, by Becky Packard (April 2017)
- *Team Building through Communication*, by Jane Tucker and Nancy Houfek (May 2017)
- *Academic Leadership*, by Jane Tucker and Nancy Houfek (May 2017)
- *Strategic Persuasion through Negotiation & Problem-Solving*, by Jane Tucker and Nancy Houfek (May 2017)

Outcomes of these workshop include increased faculty awareness of tools for engaging students, and increased leadership and communication skills for faculty, students & post-docs. **Mitigation Plan:** None needed, on track for Year 2.

Activity 3.4.2: EDventures mini-grants. Create and Implement an internal proposal-funding mechanism to provide proposal-writing training and encourage leadership/new initiatives. Based on a model developed by the NSF-funded Center for Microbial Oceanography: Research and Education (C-MORE), *EDventures* (or Educational Venture Capital) is an internal proposal-funding mechanism that trains

students in proposal writing while simultaneously providing an opportunity for them to propose their ideas. Through a two-stage review cycle, proposals are peer-reviewed based on NSF merit review criteria, and proposers can revise and resubmit their proposals within a single review cycle. In Year 1 we started developing a semi-annual Request for Proposals (RFP), which will be uploaded to the 'Ike Wai website. This program will be rolled out during Year 2, as planned, during which time an *EDventures* Review Panel will be established. Training is obtained in three ways: (1) by writing an NSF-style proposal; (2) by conducting the proposed activities (if funded); and/or (3) by serving on the review panel. **Mitigation Plan:** None needed, on track for Year 2.

Objective 3.5: Data Science: Establish two academic programs at UH Hilo in Data Science, a certificate and a BA in data analytics.

Activity 3.5.1: Initiate Strategic Faculty Hires in Data Science. Beginning in September 2016, two advertisements for Assistant Professors (one in Mathematics and one in Computer Science at UH-Hilo) with emphases in Data Science curricular development were posted. Two search committees were created to manage the applications, conduct interviews, and ultimately make a recommendation for the new hires. In April 2017, the two search committees forwarded their recommendations to both positions to the Vice Chancellor for Academic Affairs at UH-Hilo. These two hires are expected to start on August 1, 2017. **Mitigation Plan:** None needed, on track for Year 2.

Activity 3.5.2: Develop a Data Science Pathway. Along with finalizing the search process for two Data Scientists that will help develop a Data Science curriculum. Pelayo has researched current Data Science curricula at other undergraduate universities. He attended the Park City Math Institute (PCMI) 2016 Summer Undergraduate Faculty Program for the purpose of composing guidelines for undergraduate programs in Data Science. The group consisted of 25 undergraduate faculty from a variety of institutions in the U.S., primarily from the disciplines of mathematics, statistics and computer science. The guidelines are meant to provide some structure for institutions planning for or revising a major in Data Science. The program resulted in a coauthored publication on undergraduate Data Science programs (called *Curriculum Guidelines for Undergraduate Programs in Data Science*). Using this and other models, a Data Science Education advisory board (chaired by Pelayo) consisting of UH-Hilo faculty members was developed to help shape the Data Science curriculum at UH-Hilo. **Mitigation Plan:** None needed, on track for Year 2.

Objective 3.6: Business and Community: Connect 'Ike Wai to business and community.

Activity 3.6.1: Engage with Stakeholders. This activity is scheduled to begin during Year 2, so there are no accomplishments to report to date.

IV. Solicitation-Specific Project Elements

A. Workforce Development

Workforce development during Year 1 has been accomplished through three integrated efforts: research-based education programs in water science, new academic programs in data science, and professional development training for all 'Ike Wai personnel (students, post-docs, staff and faculty). Our research-based education programs include closely mentored undergraduate, graduate and post-doctoral research. During Year 1, 20 undergraduate researchers and 5 graduate research assistants were employed, and 4 post-docs were hired who will start in Year 2. Two new academic programs in data science (a certificate and a BA degree) are under development, and a data science summer bridge will be offered during summer 2017. Two of four data science hires are nearing completion at UH Hilo. Those new faculty have anticipated start dates of August 1, and their offer letters include an assignment to develop and teach data science courses. Professional development trainings include pedagogy and mentoring training, to ensure faculty are aware of research-based methods and best practices to maximize student success, as well as non-academic professional skills, such as team science, team-building, communication, leadership, and negotiation.

B. Diversity

Broadening participation is integral to the 'Ike Wai research and education missions. We set ambitious demographic targets (both in terms of gender equity and ethnicity) and are fully committed to attaining them by the end of the project period. For undergraduates, we are striving for 75% women and 50% underrepresented minorities (URM), including 25% Native Hawaiians and Pacific Islanders (NHPI). We are making excellent progress toward these targets, as our Year 1 undergraduate cohort includes 55% women and 65% URM. We have established a recruiting partnership with the 'oiwi internship program to reach out to Native Hawaiian undergraduates to join our Year 2 cohort.

For graduate students and post-doctoral researchers, our targets are 50% women and 25% URM. For graduate students, we have exceeded this goal, as our Year 1 graduate cohort comprises 80% female and 40% URM (all Native Hawaiian). Our post-doc hires begin in Year 2, and we have broadly advertised these

Category	# of Individual Responses	% Female	% URM
Faculty	13	38%	8%
Staff	5	60%	20%
Post docs	0	n/a	n/a
Graduate students	5	80%	40%
Undergraduate students	20	55%	65%
RII Leadership Team	9	33%	33%
Advisory Boards	24	38%	8%

Table 2: Breakdown of gender and ethnicity of 'Ike Wai participants by project role.

positions through local and national minority-serving organizations, including the Institute of Broadening Participation, the Society for Advancement of Chicanos and Native Americans in Science (SACNAS), the American Indian Science and Engineering Society (AISES) and the NSF Science and Technology education and diversity listserv.

Our commitment to diversity is reflected in the demographic make-up of the leadership team, which is 33% female and 33% URM. Although we have not set formal targets for faculty and staff, we are actively recruiting for diversity as new positions become available.

C. Partnerships

We have developed strategic partnerships with ten different entities, including local foundations with missions focused on island sustainability, resiliency and land stewardship, state agencies and key land owners and community forums. These partnerships provide two important benefits to the project, 1) a direct and trusted connection between our project activities and the potential benefits and impacts on the community and 2) access to land for study sites and wells and to current and legacy data important to our work.

- The Ulupono Initiative - A private social impact investment firm who is providing additional funding to expand the scope of our agency outreach to include an assessment of the water management system in Hawai'i. This is an unanticipated opportunity that arose after our award was received.
- Hawai'i Community Foundation - Conveners of the HFWI with whom we are exploring the potential of sharing advisory committees. In addition, we were invited to submit proposals to a recently announced RFP focused on water advancing various water initiatives identified in their Blueprint plan and which they are underwriting. Thus, these are opportunities to develop an ongoing strategic partnership with HCF and not just funding opportunities. One proposal is for collecting existing water legacy data in the State not included in agency data and the second is to develop a methodology for determining ROI on watershed conservation. These are unanticipated opportunities arising post-award.
- Moanalua Gardens Foundation (MGF) - Land stewardship organization that conducts place-based education in the Moanalua Valley on O'ahu that abuts our Pearl Harbor Aquifer study site. We are in discussions regarding a mutual capacity building strategy that could include data sharing, study site access, and serving as a potential learning/teaching site to support our student and faculty development.
- Kona and Waimea Water Roundtables - Community forums on Hawai'i Island convened for the purpose of education and advocacy on water issues in their respective communities. Currently in discussions regarding their assistance in convening Roundtables as forums for ongoing education and consultation with the general community in West Hawai'i.
- Kamehameha Schools (KS) - Landowner; Study Site access.
- Hawai'i County Department of Water Supply (HDWS) - Well owner and operator; study site access and data sharing.
- Natural Energy Lab of Hawai'i (NELHA) - Land/well owner; study site access and data sharing.
- Kohnana'iki Resort (KR) - Land/well owner; study site access and data sharing.
- Queen Lili'uokalani Trust (QLT) - Land/well owner; study site access and data sharing.
- Palani Ranch (PaR) - Landowner; study site access and data sharing.

D. Collaborations

We engaged in two significant collaborations during the reporting period, one with the USGS Water Branch and the other with the Texas Advanced Computing Center. These collaborations will continue throughout the duration of the project. Our collaborators provide expertise, technical advice and deep knowledge of the respective subject areas

- US Geological Survey: Key members of the USGS Water Branch, listed below provide in depth advice on groundwater modeling in Hawai'i. Our teams met to engage in table top exercises on both study sites on 5 different occasions and Director Steve Anthony, serves on our 'Ike Wai leadership team. The USGS team is the lead science organization in the state focused on water issues and their input and advice has been extremely valuable to our project. Team members are listed below.
 - Steve Anthony, Director USGS Water Branch
 - Delwyn Oki, Lead Scientist
 - Bill Souza, Hydrological Modeling
 - Kolja Rotzoll, Hydrological Modeling
 - Joseph Kennedy, Hydrological Modeling
 - Travis Hylton, Deputy Director USGS Water Branch

- Texas Advanced Computing Center (TACC): The CI team of 'Ike Wai collaborates with members of TACC on the development of the AGAVE software platform that will be used to support data storage, management and sharing. Our teams met monthly via teleconference to collaboration on the design, architecture and implementation of the 'Ike Wai platform. The TACC team (Stubbs, Fonner and Dooley) visited for a week in April to co-lead a workshop for the UH community and for a week long face-to-face working session on the platform. Dan Stanzione, Director of TACC serves on our external advisory board.
 - Dan Stanzione, Executive Director, TACC
 - Joe Stubbs, Software Engineer
 - John Fonner, Software Engineer
 - Rion Dooley, Software Architect

E. Sustainability

Continued funding beyond the five-year duration of this award is essential for our continued engagement with the community. Thus we have already started to prepare new research proposals for Federal and local opportunities. Garmire and Mougini-Mark are preparing a proposal to NASA's Earth Science Division for the development of a MEMS-based gravimeter that can fly on an unmanned aerial system. We are also developing a proposal to the Hawai'i Community Foundation (HCF), which seeks to build capacity for freshwater security in the Hawaiian Islands. In this proposal, we will identify and collect key water legacy data sets, curate them and make them available to the public through our 'Ike Wai data platform. We are also considering submitting a proposal to NSF's Data Spokes opportunity, focusing on the visualization of our numerical simulations of groundwater flow.

As a result of 'Ike Wai, the Ulupono Initiative (UI) has indicated interest in exploring an expanded relationship with the UH to develop knowledge and practice in the area of systems change as it relates to water, energy, and food security in Hawai'i. The UH was invited to submit a concept paper to the UI Board of Directors in March 2017 on how this work might be approached with additional funding from them with initial conversations in the \$1M range. The concept presented included expanding on our cyberinfrastructure, decision-support, and workforce development activities that are part of 'Ike Wai to improve policy and decision-making in the areas of water, energy, and food security. The concept paper was received positively. If successful, this could become a key component of our long-term sustainability strategy.

V. Tabular/Graphic Representation of Progress to Date

The table below is a graphic representation of progress to date of all of the goals and objectives as stated in the strategic plan. The progress of each objective is tracked using a color-coded system where:

Blue: Future Activities or Activities not Addressed in this Annual Report
Green: Completed Activity or Activity is Ahead of Schedule
Yellow: Activity In Progress or On Schedule
Red: Activity Not Started or Behind Schedule

Project Year Semester	Year 1			Year 2			Year 3			Year 4			Year 5		
	Sm16	F16	Sp17	Sm17	F17	Sp18	Sm18	F18	Sp19	Sm19	F19	Sp20	Sm20	F20	Sp21
GOAL 1: Collect new hydrological and geophysical data on the two study sites to address data gaps in our understanding of subsurface structure and flow.															
Objective 1.1															
Activity 1.1.1															
Activity 1.1.2															
Activity 1.1.3	no work planned														
Activity 1.1.4	no work planned														
Objective 1.2															
Activity 1.2.1															
Activity 1.2.2															
Activity 1.2.3															
Activity 1.2.4															
Objective 1.3															
Activity 1.3.1															
Activity 1.3.2															

Project Year Semester	Year 1			Year 2			Year 3			Year 4			Year 5		
	Sm16	F16	Sp17	Sm17	F17	Sp18	Sm18	F18	Sp19	Sm19	F19	Sp20	Sm20	F20	Sp21
Goal 2: Develop a new data and modeling platform for Hawai'i volcanic hydrogeology, economic modeling and decision support.															
Objective 2.1															
Activity 2.1.1	█						█								
Activity 2.1.2	█			█			█								
Activity 2.1.3	no work planned						█			█					
Activity 2.1.4.	█						█							█	
Activity 2.1.5	█						█							█	
Objective 2.2															
Activity 2.2.1			█				█			█			█		
Activity 2.2.2	█						█			█			█		
Activity 2.2.3	█						█			█			█		
Activity 2.2.4	█						█			█			█		
Activity 2.2.5	█						█			█			█		
Activity 2.2.6	█						█			█			█		
Activity 2.2.7	█						█			█			█		
Activity 2.2.8	█						█			█			█		
Objective 2.3															
Activity 2.3.1		█			█			█			█			█	
Activity 2.3.2		█			█			█			█			█	
Activity 2.3.3		█			█			█			█			█	
Objective 2.4															
Activity 2.4.1	█						█			█			█		
Activity 2.4.2			█				█			█			█		
Activity 2.4.3	█						█			█			█		
Activity 2.4.4			█				█			█			█		
Activity 2.4.5	█						█			█			█		
Activity 2.4.6	█						█			█			█		
Activity 2.4.7	█						█			█			█		
Goal 3: Education and Workforce Development: Establish an integrated set of pathways to train and develop a diverse cohort of students, post-doctoral and faculty researchers at UHM and UHH to address Hawai'i's water challenges.															
Objective 3.1															
Activity 3.1.1		█			█			█			█			█	
Activity 3.1.2		█			█			█			█			█	
Objective 3.2															
Activity 3.2.1			█		█			█			█			█	
Activity 3.2.2			█		█			█			█			█	
Objective 3.3															
Activity 3.3.1		█			█			█			█			█	
Activity 3.3.2		█			█			█			█			█	
Objective 3.4															
Activity 3.4.1		█			█			█			█			█	
Activity 5.4.2			█		█			█			█			█	
Objective 3.5															
Activity 3.5.1			█		█			█			█			█	
Activity 3.5.2			█		█			█			█			█	
Objective 3.6															

VI. Special Conditions

Two Programmatic Terms & Conditions were specified:

1. *Place a USGS expert on our EAB.* Response: Dr. Cliff Voss (see above) is appointed to our EAB. In addition, Dr. Steve Anthony (USGS, Hawaii) is now appointed to our leadership team. USGS is well-represented therefore at the advisory and leadership levels and USGS personnel are present at all all-hands meetings.
2. *Move the hydrological modeling hire from the proposed Year 2 to Year 1.* Response: the search for this hire was initiated as recommended at the beginning of Year 1 and is close to conclusion.

VII. Response to External Evaluation Recommendations

Recommendation 1: Establish Intentional Systems of Internal Project Communications.

Recommendation: Incorporate dependencies and deadlines into project timelines. *Response:* This process has been initiated for both the strategic plan and project management timeline and is ongoing. Identification of dependencies occur throughout current strategic plan. The evaluation report was written based on an earlier version of the strategic plan (Oct. 31, 2016), so these dependencies have been addressed. *Recommendation:* Schedule a variety of means for internal communications:

Responses: (i) All-hands meetings bi-weekly started in March 2017. In Year 2 we have scheduled monthly All-Hands meetings and bi-weekly Leadership Team meetings. (ii) Project newsletter will start in Fall 2017 and is being planned by Communications Manager and Leadership team over summer 2017; (iii) social media and website efforts to bolster internal communications are ongoing, in particular an 'EPSCoR calendar' is being added to the website so that all hands are aware of upcoming deadlines and opportunities; (iv) meeting minutes/notes (Leadership Team, Science Team and Education Team meetings) will be summarized in a bi-weekly digest to all-hands starting in Fall 2017. On the alternate weeks, and ad hoc as needed, the PI/PD is sending out regular team updates by email to all-hands.

Recommendation 2: Develop a tactical plan for community communication and engagement.

Recommendation. Develop a Community Engagement Plan (CEP) with goals, timeline and training for 'Ike Wai participants. *Response:* An intentional CEP has been implemented throughout Year 1. The goals of the CEP are clearly stated in our strategic plan (Objective 2.4), and were reviewed and presented to the team in two of the all-hands meetings held in Spring 2017. The Year 1 timeline for CE has been incorporated into the project timeline and is regularly reviewed at Leadership Team meetings. CE activities include over two dozen community engagement meetings with high priority organizations partners across 22 agencies/organizations on multiple islands. 'Ike Wai participants included variously the CE lead (Chun), the PI Jacobs, science team members (e.g., Lautze, Burnett, Mougini-Mark), and USGS partners, reflecting the CE operating principle that the whole 'Ike Wai endeavor needs to be involved in stakeholder conversations. Training and exposure for 'Ike Wai participants in community engagement goals and processes is ongoing. Examples of these activities include:

- 15 team members accompanying CE lead Chun to Hawaii Island for a community engagement workshop on May 30-31 at the UH Palamanui campus in Kailua-Kona with 36 people representing 9 key

partners and community groups;

- Liaison activities between education and CE teams, incorporating stakeholder perspectives and engagement techniques into undergraduate, graduate and post-doc training activities in Year 2;
- All-hands meetings are a vehicle for candid discussions of stakeholder perspectives, allowing team members at all career stages to be exposed to the processes and complexities of CE in Hawaii, particularly with reference to water politics and Hawaiian community viewpoints.

Recommendation 3: More intentional planning to ensure diversity and inclusiveness.

Recommendation: Implement pro-diversity practices in recruitment process for 'Ike Wai positions.

Response: Diversity efforts cross-cut the entire 'Ike Wai project. Diversity efforts in Year 1 yielded the following metrics:

- 50% of project participants reporting gender are women
- 35.2% of project participants are URM
- 33% of the leadership team are women
- 33% of the leadership team are URM
- Of the Year 1 faculty and professional staff hires, both are women
- 80% of graduate trainees are women
- 40% of graduate trainees are URM

In addition, pro-diversity hiring practices are indeed in place as suggested by the evaluation finding. These comprise: (i) Diversity and inclusiveness language included in each position description and job advertisement per UH practices as an indigenous- and Hawaiian-serving institution of higher education. (ii) Diversity on hiring committees is monitored and achieved within the limitations of the tenured faculty representation in the various departments, all hiring committees include women. (iv) Advertising for both positions (faculty and trainees) and opportunities (e.g., undergraduate research experiences) leverage diversity channels as much as possible. These include choices in advertising venue, leveraging of national professional networks and use of local chapters e.g. of AAGGU, AISES, relevant listservers, and SACNAS for recruitment of diverse students. (v) Training for interviewers and recruiters at the faculty level is mandatory for search committee members and is run by the UH Office of Human Resources. All 'Ike Wai committee members completed this process. Individual search committees have been charged with establishing candidate's rankings and inclusion of interview questions concerning awareness of the UH indigenous- and Hawaiian-serving context. Attention to these issues has been assured by having a Leadership Team member (Mouginis-Mark) serve as a common Chair across all 4 active searches in Year 1. At least one committee member on each of the three search committees was a woman and one (Engineering) included a Native Hawaiian.

Recommendation 4: More intentional integration of core values.

Recommendation: Include norms or protocols for meetings that formally call out and embody core values. *Responses:* Core values were identified for the 'Ike Wai project at the beginning of Year 1 and incorporated into our strategic plan. Intentional reference to core values is component of each 'Ike Wai activity and examples of these references are as follows: (i) *Team Science Compact development*. A team

science agreement for signing by all-hands is under development and will be completed by the end of summer 2017. A workshop was held to develop a first draft of this compact with all 'Ike Wai participants. Following established models (e.g., NIH Ombudsman Office, NSF) for team science agreements this document addresses operational (data release, authorships, etc.) and philosophical (project ethics, core values, sense of place and relationship to host culture, conflict resolution) underpinnings of the 'Ike Wai project. (ii) *Practices relating to core values in meetings*. First, starting in Spring 2017, each all-hands meeting starts with a reflection by a team member designed to center the team on the effort at hand and to reflect core values, host culture or personal experience of the project. Second, all-hands meetings incorporate *place*. In each meeting, especially where sampling sites or fieldwork are being discussed, time is allotted for the Hawaiian Studies team to discuss those places under review from the standpoint of historical and cultural significance. Third, the project incorporates *language*, the Hawaiian language *olelo-Hawaii* is used interchangeably with English when discussing project activities (e.g., use of the common terms such *huakai* to discuss field trips, naming of activities, use of *olelo noeau* (Hawaiian wisdom saying) in team materials). In addition Hawaiian language expert Puakea Nogelmeier provides guidance on pronunciation and dual (functional, poetic) translations of Hawaiian concepts and words that are relevant to the project and during the academic year all project personnel are invited to participate in Kapunalu'u, a lunchtime Hawaiian Language gathering. Fourth, the project has incorporated aspects of both Western and Hawaiian thought into the proposed conflict management plan currently discussed by the Leadership Team in the context of the Team Science agreement. *Hooponopono* ('to put to rights') is a Hawaiian conflict resolution system founded on a process of reflection, acknowledgement, cooperation and release from obligation. There are some elements of *hooponopono* that might be of utility in the Team Science agreement under which 'Ike Wai will operate, as a supplement to Western methods. These efforts and discussions are ongoing as the Team Science agreement approaches finalization.

More detailed contingency plans.

Recommendation: Develop clear contingency plans for events such as unsuccessful hiring searches of land use permission issues. *Response:* Attention to possible roadblocks is reflected in the fact that the status of issues such as searches, permits for land access and potential litigation, searches and permitting are standing agenda items for Leadership Team meetings. Over the course of Year 1 as potential barriers to progress have emerged, they have been discussed, alternate paths of action developed and mitigation plans stated and incorporated into strategic planning. The two specific issues mentioned (hires and permits) here were at the forefront of leadership minds when the external evaluation interviews were carried out in early 2017. However in the intervening time period some concerns have regressed somewhat. For example, Community Engagement efforts have been broadly successful in either identifying landowner partners where permitting is not a significant issue or engaging with landowners successfully to secure cooperation. The CE team has also worked to foster understanding within the science team of how field teams can design sampling schedule in a manner that is responsive to and considerate of landowner time and the land itself. Regarding hires, 1 of 3 hires have been successful in Year 1 and following the rejection of our first offer in March 2017, an offer on a second position is imminent. The third search is underway, with 14 applications received so far. An early

focus on mitigation of potential hiring issues has meant that the effect of pending searches on project goals has been greatly minimized. Overall, the push to focus on contingency planning is well-taken guidance and it has prompted a renewed focus on these efforts and mitigation plans as reflected in our Strategic Plan.

Appendix A: Abbreviations and Hawaiian Language Terms

AGU	American Geophysical Union
CI	Cyberinfrastructure
CKAN	Comprehensive Knowledge Archive Network
COACH	Council of Academic Chemists
COE	College of Engineering
CSS	College of Social Sciences
CWRM	Commission on Water Resource Management
CWSEI	Carl Wieman Science Education Initiative
DLNR	Department of Land and Natural Resources
DROP	Down-well Remote Operating Platform
EPA	Environmental Protection Agency
FWAC	Fresh Water Advisory Council
G&G	Geology and Geophysics
HBWS	Honolulu Board of Water Supply
HCF	Hawai'i Community Foundation
HDOA	Hawaii Department of Agriculture
HDOH	Hawai'i Department of Health
HDWS	Hawai'i County Department of Water Supply
HFWI	Hawai'i Fresh Water Initiative
HIGP	Hawai'i Institute of Geophysics & Planetology
HLPC	Hawai'i Leeward Planning Commission
HPC	High Performance Computing
HSSTC	Hawai'i Science & Technology Committee
HVO	Hawai'i Volcano Observatory
ICS	Information and Computer Sciences
IDC	Interagency Data Committee
IDP	Individual Development Plan
IHLRT	Institute of Hawaiian Language Research and Translation
IKE	Integrated Knowledge Environment
ITS	Information Technology Services
KCC	Kapiolani Community College
KS	Kamehameha Schools
KR	Kohnana'iki Resort
LT	Leadership Team
NELHA	Natural Energy Laboratory of Hawai'i Authority
NPV	Net Present Value
PaR	Palani Ranch
PBRC	Pacific Biomedical Research Center
PIWSC	USGS Pacific Islands Water Sciences Center
PR	Parker Ranch

QLT	Queen Lili'uokalani Trust
RHBFSF	Red Hill Bunker Fuel Storage Facility
S&T	Science and Technology
SG	UH Sea Grant
SGD	Submarine Groundwater Discharge
SOEST	UH Mānoa School of Ocean and Earth Science and Technology
SST	Science & Technology Thrusts
ST	Sustainable Yield
TACC	Texas Advanced Computing Center
USGS	US Geological Survey
UH	University of Hawai'i
UHERO	UH Economic Research Organization
UHH	University of Hawaii Hilo
UHM	University of Hawaii Mānoa
UHS	University of Hawai'i System
UI	Ulupono Initiative
WFD	Workforce Development
WMP	Water Master Plan
WR	Waiki'i Ranch
WRAC	Water Resources Advisory Council
WRRC	UH-Water Resources Research Center

Hawaiian Language Terms

'auwai	Path water flow
'ike wai	'Ike, meaning knowledge, wai, meaning water
kapunalu'u	Spring dived for
moku	Large district land division
mo'olelo	Stories or history
'oiwi	Native son
Pono	What is right
po'e	People
'āina	Land
wai	Water