# ERP Proposal Application Form

| For DFG use only | |
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| Proposal No. | Region |
| | |

(Pages A13-A18)

## *Section 1: Summary Information*

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|---|---|
| **1. Project title:** | Delta Online Water Quality Index |
| **2. Applicant name:** | The Regents of the University of California |
| **3. Contact person:** | David Miller |
| **4. Address:** | 1850 Research Park Drive, Suite 300 |
| **5. City, State, Zip:** | Davis, CA 95618-6153 |
| **6. Telephone #:** | 530-754-7700 |
| **7. Fax #:** | 530-754-8229 |
| **8. Email address:** | davmiller@ucdavis.edu |
| **9. Agency Type:** | Federal Agency ☐ State Agency ☐ Local Agency ☐ Nonprofit Organization ☐ University (CSU/UC) ☒ Native American Indian Tribe ☐ |
| **10. Certified nonprofit organization:** | Yes ☒ No ☐ |
| **11. New grantee:** | Yes ☒ No ☐ |
| **12. Amount requested:** | $455,240 |
| **13. Total project cost:** | $455,240 |
| **14. Topic Area(s):** | Primary: Ecosystem water and sediment quality; Secondary: Estuary foodweb productivity; Hydrodynamics, sediment transport and flow regimes; X2 |
| **15. ERP Project type:** | Primary: Monitoring; Secondary: Research |
| **16. Ecosystem Element:** | Primary: Bay-Delta aquatic foodweb; Secondary: Bay-Delta hydrodynamics; Central Valley stream temperatures; Delta sloughs; Essential fish habitats; Contaminants |
| **17. Water Quality Constituent:** | Primary: Nutrients and oxygen-depleting substances; Secondary: Temperature, Turbidity and sedimentation, Organic carbon;Salinity |
| **18. At-Risk species benefited:** | Central Valley winter-, spring- and fall/late fall-run chinook salmon ESUs, Central Valley steelhead ESU, delta smelt, longfin smelt, Sacramento splittail, green sturgeon |
| **19. Project objectives:** | Provide real-time and historical index of water quality to understand instantaneous threats to at-risk species and effectiveness of ecosystem restoration |
| **20. Time frame:** | January 1, 2012 to December 31, 2013 |

## *Section 2: Location Information*

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|---|---|
| **1. Township, Range, Section: and the 7.5 USGS Quad map name.** | **Entire Statutory Delta** |
| **2. Latitude, Longitude (in decimal degrees, Geographic, NAD83):** | Entire Statutory Delta (approx 38.58N, -122.12W, 37.66S, -121.2E) |
| **3. Location description:** | Entire Statutory Delta |
| **4. County(ies):** | San Joaquin, Solano, Yolo, Contra Costa |
| **5. Directions:** | N/A |
| **6. Ecological Management Region:** | Sacramento-San Joaquin Delta |
| **7. Ecological Management Zone(s):** | Sacramento-San Joaquin Delta |
| **8. Ecological Management Unit(s):** | North, East, South, and Central & West EMUs |
| **9. Watershed Plan(s):** | |
| **10. Project area:** | Statutory Delta |
| **11. Land use statement:** | |
| **12. Project area ownership:** | % Private_______ % State________ % Federal________<br>*Enter ownership percentages by type of ownership.* |
| **13. Project area with landowners support of proposal:** | |

## *Section 3: Landowners, Access and Permits*

| | |
|---|---|
| **1. Landowners Granting Access for Project:** (Please attach provisional access agreement[s])<br>None required for project | |
| **2. Owner Interest:** | |
| **3. Permits:** | |
| **4. Lead CEQA agency:** | |
| **5. Required mitigation:** | Yes ☐ No X |

## *Section 4: Project Objectives Outline*

**1. List task information:**

The proposed project would address two research priorities identified in the PSP: "Better understanding of the Delta system and impact of management actions" and "Better understanding of linkages – restoration, species, and water quality". The project will also address the following ERP Goals and Objectives:

Goal 1, Endangered and Other At-Risk Species and Native Biotic Communities, Objective 1: Chinook salmon, delta smelt
Objective 3: native resident estuarine and freshwater fish, estuarine plankton assemblages

Goal 2, Ecological Processes, Objective 2: Increase estuarine productivity and rehabilitate estuarine food web processes to support the recovery and restoration of native estuarine species and biotic communities. Objective 4, Create and/or maintain flow and temperature regimes in rivers that support the recovery and restoration of native aquatic species.

Goal 6, Water and Sediment Quality, Objective 2: Reduce loadings of oxygen-depleting substances from human activities into aquatic ecosystems in the Bay-Delta estuary and watershed to levels that do not cause adverse ecological effects. Objective 3: Reduce fine sediment loadings from human activities into rivers and streams to levels that do not cause adverse ecological effects.

**2. Additional objectives:**

**3. Source(s) of above information:**

ERP Strategic Goals and Objectives, 2010

## *Section 5: Conflict of Interest*

Persons listed in the proposal, who wrote the proposal, will be performing the tasks listed in the proposal, or who will benefit financially if the proposal is funded:
**Primary Contact for Proposal:**
**Primary Investigator: Fraser Shilling**
**Co-Primary Investigators: James Quinn and Robert Hijmans**
**Supporting Staff: David Waetjen**
Subcontractors listed in the proposal, who will perform tasks listed in the proposal, or will benefit financially if the proposal is funded.
**Subcontractor: ESSA Technologies Inc.**
Provide the list of names and organizations of all individuals not listed in the proposal who helped with proposal development along with any comments. NONE

## *Section 6: Project Tasks and Results Outline*

**1. Detailed Project Description**

At a recent special symposium organized by the Environmental Water Resources Institute (Feb 15, 2011), a critical thread among presenters was that feedback mechanisms are needed between a highly dynamic natural system like the Delta and responsive management systems. Responses at multiple time-frames are needed to changing conditions in components of the Delta that protect individual attributes (e.g., Delta smelt populations) and integrated systems. Feedback systems are needed to evaluate restoration effectiveness and to understand current threats to species of management concern. We propose an online water quality index that will permit instantaneous and long-term understanding of water conditions, their potential effects on valued species and ecosystems, and the effectiveness of management actions to restore ecosystem attributes and processes. The index will be developed during a transparent stakeholder process where various interests and experts contribute to the rules that convert water parameter data to ecological meaning. Our project team has successfully developed monitoring and modeling tools in stakeholder processes, advanced the use of multi-parametric indices in California, and developed online tools for environmental data visualization and analysis.

## 2. Background and Conceptual Models

### *A. Stakeholder Process*

The Delta has myriad stakeholders with competing interests and many different ideas about how the system should function. Although there are occasional disagreements about data collected in the Delta, generally these data are not contested. Similarly, past and current studies describing Delta ecology have fairly broad buy-in as to their meaning. For example, the role of a sudden winter-rains induced increase in turbidity in triggering Delta smelt migration to spawn has been studied by USGS under the IEP and during the 2010 IEP meeting seemed to be uncontroversial. The exact role of nitrogen-based nutrients in Delta ecology enjoys less consensus, with academic studies (Gilbert et al., 2010) and local agency studies (SRCSD, 2010) reaching dissimilar policy conclusions with similar data. The value of certain flow regimes through the Delta have been even more encumbered by contention, including recent rulings for and against water agencies and environmental organizations by the same judge in a case known simply as “Consolidated Salmonid Cases” filed against the San Luis & Delta-Mendota Water Authority. What has not been in question in most of these contests over resources and policies is the underlying data. The value of the stakeholder process for contentious issues is in finding some agreement about what is known, what is occurring at a given moment in natural systems, and what actions may reduce conflict. In the case of the Delta Smelt Working Group, joint regulatory agency and water agency meetings allow communication about the meaning of particular findings for Delta conditions and the numbers of Delta smelt recovered in trawls.

Stakeholder engagement in this project is important for several reasons (modified from Korff et al. 2010):

- improved relevance and legitimacy of the index and for decision-makers using it, because the index design and development process will take into account stakeholder interests and values and thereby cultivate trust;
- higher quality of the index, because stakeholders add otherwise unavailable vital information, reframe problems, and contribute new ideas;
- greater acceptance and use of the index, because people are less likely to oppose – and more likely to use – a decision support tool that they have helped shape; and
- increased civic competency and social capital because of the learning that will occur through participant interaction.

### *B. Index Development*

Environmental, economic, and social indicators are used world-wide to report on the condition of human, natural, and combined human-natural systems. Indicator frameworks vary depending on what is being measured and on the intended reporting audience. The National Research Council (NRC, 2000) identified two types of frameworks: those that measure the status or condition of the system, and those that seek to identify cause and effect relationships. Many contemporary indicator frameworks incorporate both condition indicators and indicators of pressures or influences. This combination allows for a condition assessment and an evaluation of what may be driving condition. This reflects a common aspect of these frameworks – that they are practical and intended to support decision-making, usually in support of restoration, regulatory, or sustainability goals. This combination allows for evaluation and reporting on system attributes that are important for watershed and regional residents and stakeholders, as reflected in regional and local goals. For the proposed project, selection of indicators to be used in the index, rules for interpreting data, and methods of reporting would conducted in an open, transparent process, which provides an opportunity for all involved to influence this proposed decision-support tool. Choosing indicators that reflect conditions and understanding how they might change in response to various influences facilitates a better understanding of how actions in a specific region can affect watershed and waterway function and processes.

Indicators can be used to tell us about status and trends for a variety of attributes of different systems. Individually or collectively (in an index) they help us understand system condition and can inform decisions affecting management and restoration of valued attributes and processes. To be effective, they are usually organized into structures that help users clearly understand their meaning. For example, water characteristics such as temperature, dissolved oxygen, pH, and turbidity are not necessarily intuitively-understood by a non-technical audience but can be combined into a more user-friendly index of water quality to help regulators and the public understand water quality status and trends and whether there might be a need for particular regulations or investments in infrastructure. When based in contemporary ecological studies, this type of index and its constituent indicators can also inform expert users about day-to-day or longer timeframe performance of waterways.

Canada uses a national water quality index that combines measures of (i) scope – the extent of water quality guideline non-compliance, (ii) frequency – the percentage of water quality tests that do not meet water quality objectives, and (iii) amplitude – the amount by which water quality tests do not meet water quality objectives (CCME 2001). This national index was modeled after that developed in the province of British Columbia, which was the only province in Canada to incorporate the percentage of water quality guidelines exceeded into its index, although Manitoba and Ontario have since adopted the same approach. The national water quality index is used to report on the status of freshwater quality for protection of aquatic life [1], and British Columbia uses its provincial index to report on water quality status and trends [2]. While it may be desirable to use more biologically meaningful benchmarks than water quality objectives in the Bay-Delta, the methodology used in Canada may be informative and will be further examined to see what aspects may be applicable.

The critical defining conditions of our proposed index are that it is transparent, easy-to-understand, based on stakeholder input on the system, and based in contemporary scientific studies of the Delta. For example, we will use recent and current studies of Delta smelt habitat requirements (Kimmerer, 2002; Bennett, 2005; various presenters, IEP-2010 meeting) in order to propose indicators and interpretation of the indicators that would help with online, instantaneous reporting of Delta smelt habitat conditions. These will include: water temperature, salinity, turbidity, flows and flow reversals, and nutrients. The use of the individual indicators and their interpretation may vary seasonally as ecological needs of different important species and other factors change seasonally. These could be included retrospectively into a model index exclusively for Delta smelt, or combined using a Generalized Additive Model in online applications that show both the historical change in the model index and its current state. Our use of historic data from the network of Delta monitoring stations, using the indicator and index approach as described, would also provide an integrated (but dis-aggregatable) measure of condition over time, which could be compared with past events and ecological declines that have resulted in effects on water delivery and ecosystem health.

1 http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=En&n=68DE8F72-1
2 http://www.env.gov.bc.ca/soe/indicators/freshwater/docs/freshwater.pdf

*B.i. Indicators*

There are several existing indicators of water quality collected in real-time in the Delta at 10 – 20 stations (depending on the parameter): Flow, turbidity, temperature, salinity, chl-a, nitrogen species. Although these indicators are not ecologically independent from one another, they each serve an important function in management decision-making in the Delta and are thus independently important. Data for other water quality indicators are collected at other time-scales and recorded in the Surface Water Ambient Monitoring Program's database tool (California Environmental Data Exchange Network), the California Data Exchange Center, and the US Geological Survey's National Water Information System. Although a real-time index would be constrained by the available parameters with real-time sampling, the rate of data reporting is accelerating on systems like NWIS, making recent index reporting (previous month) feasible.

*B.ii. Distance to indicator threshold or target*

Comparing indicator condition against a fixed/reference value is a critical requirement for turning parameter data into decision-support information. This fixed value could be an historical condition, a desired future condition, a legal threshold, or some other reference value. It provides the context for interpreting data – it is a number against which current status and trends can be compared. For instance, a high water temperature or an increasing trend in water temperature only tells us something useful for decision-making if the information is in the context of ecological or other (e.g., economic) meaning of water temperature. High water temperatures are meaningful conditions to fish if we know at what temperature fish will be adversely affected, and whether the current trend is moving toward or further away from temperatures that may affect growth, disease, or mortality.

To put this idea in context, in situ, water temperatures $<20^{o}$C in the late winter and spring will indicate when Delta smelt may spawn in that water-body, or in receiving waters of that waterbody. The longer the time period when spawning is possible, between early winter in-migration and $20^{o}$C, the more spawning is likely to take place (Moyle, 2002). Figure 1 shows that in late March, the San Joaquin River at Stockton approached $20^{o}$C at short intervals and in mid-April, exceeded $20^{o}$C for several days. Instantaneous interpretation of the real-time temperatures in situ are important for understanding when ecological conditions are suitable and unsuitable for protection of listed species and critical ecological processes. On the same graph, the approximate timing of salmon smolt out-migration is indicated (April and May) as well as the temperatures ranges when these smolt are likely to do well (survive and grow, Brett et al., 1982; Cavallo et al., 2007). In April, water temperatures in the lower San Joaquin River were already in the growth-inhibition range and by late May were potentially causing thermal-based mortality.

A reference value is a quantity/value of an indicator that reflects some threshold, desired goal or target, or historic and/or pristine condition, according to what is most meaningful for the assessment and reporting purpose, and supported by science. The selection of reference values is as important as the selection of the indicator itself because, without this baseline, it is difficult to assess the magnitude of change objectively, whether the magnitude of change is important, or if any efforts at improving conditions are succeeding (National Research Council, 2000).

Essentially this means that the use of water quality parameters in support of decision-making must be accompanied by the development and use of reference or threshold values/conditions. The term reference condition also may have multiple meanings. Stoddard et al. (2006) suggest that the term ''reference condition'' is reserved for referring to the ''naturalness'' of the biota (structure and function) and that naturalness implies the absence of significant human disturbance or alteration. They further propose specific terms to characterize the expected condition to which current conditions are compared: ''minimally disturbed condition'', ''historical condition'', ''least disturbed condition'', and ''best attainable condition''. A similar concept of reference

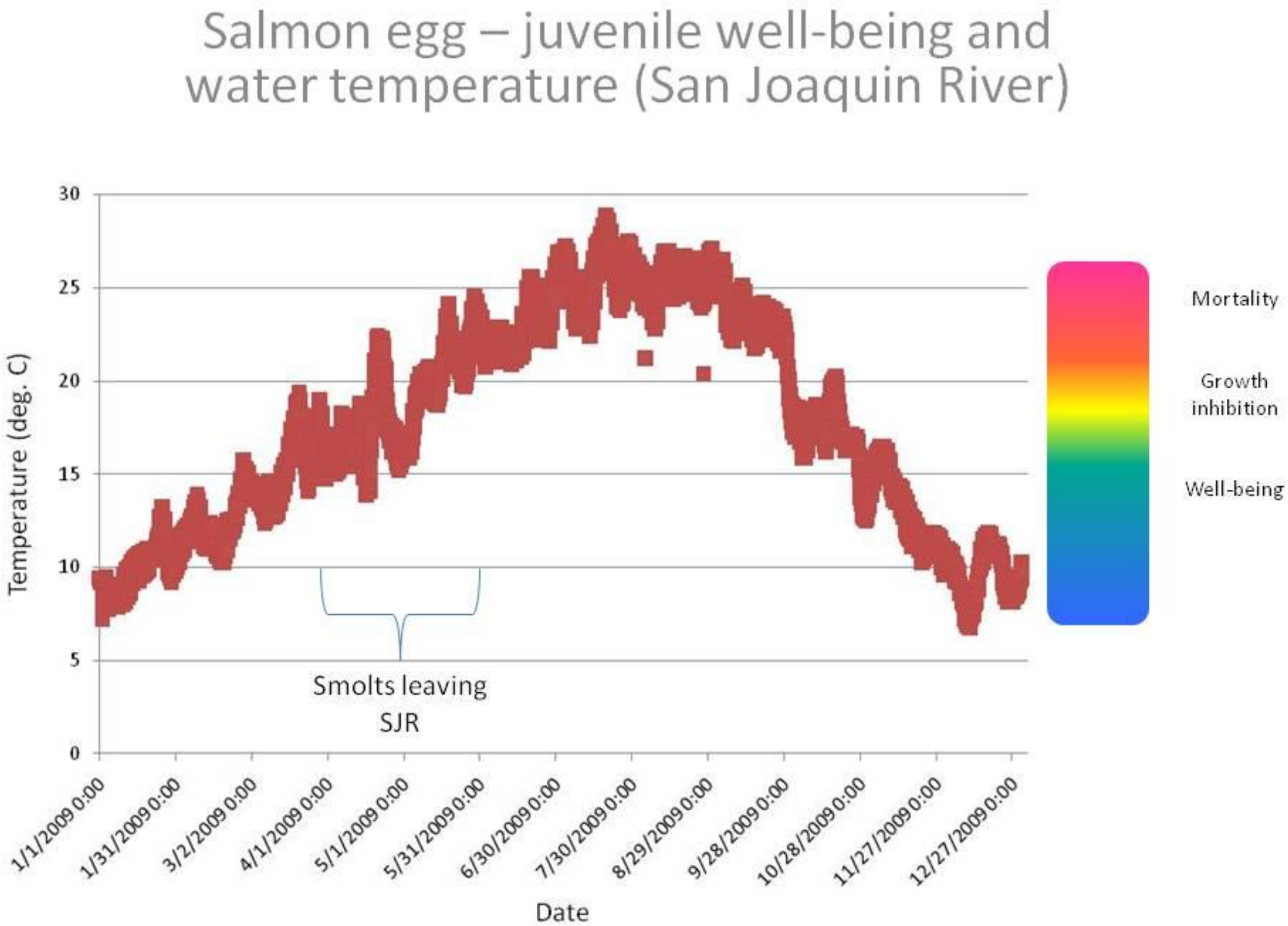


*Figure 1: Surface water temperature reported in real-time from SJL monitoring station and salmon well-being.*

conditions is considered in the EPA-Science Advisory Board indicator reporting framework (Young and Sanzone, 2002): “Reference conditions that attempt to define a ‘healthy’ ecological system are often derived from either the conditions that existed prior to anthropogenic disturbance or conditions in a relatively undisturbed but comparable system in the ecoregion. Alternatively, reference conditions can be inferred from a combination of historical data, a composite of best remaining regional conditions, and professional judgment.”

A useful definition in the case of the proposed Delta Online Water quality index is that reference condition is the state that provides baseline information about the system against which comparisons can be made for decision-support, for example, for water operations scenarios. This is essentially the same definition used in the review of OCAP by the CALFED science review panel in 2009. A critical and important feature of reference states is that they can be changed as a user sees fit, as long as the reference state is transparently shown.

***C. A Web-based (Real-time) Online Index***

While an online index can be thought of as a simplified expression of a real-world condition, the data transformations and statistical models run to produce the value can be fairly complicated. The algorithms used (e.g., based upon DRERIP conceptual models), expert system rules applied, and the intermediate processing steps from the mathematical models all provide the provenance for a particular index, and details on these discrete steps must be available to those utilizing the service. Additionally, the lineage of these data must be preserved so that if certain conditions are met which cause the system to raise an alarm notification (for example), the calculation can easily be reproduced. These essential methods provide additional confidence in the index which are vital for any decision support system.

To provide access to these online indexes to the broader community of partners, regulators, and researchers, it is important to support machine-readable standardized data formats, such as the emerging Water Quality Exchange (WQX)[3] used by the EPA, and WaterML, an NSF-supported schema to exchange hydrologic data. The CUAHSI-Hydrologic Information System[4] has developed tools and web services to support WaterML and the conversion between WQX and WaterML. These services are being used to report Texas water quality data to the EPA, and the California Water Resources Control Board and the Department of Water Resources (DWR) are beginning to develop WaterML applications, suggesting that this approach may also directly facilitate data exchange among the California water agencies.

A web-based model for data access and sharing of the indexes will be developed based on the Representational State Transfer (REST) web-service architecture. REST architectures allow clients to receive data--often in a standards based XML format such as WaterML--from a server which provides these transformed data at a particular web address. The architecture identifies resources based on their website address, and accessing that address will provide the data needed to display the online index (for example, an index based on a particular sensor in the Delta). The figure above (Figure 2) shows how various online sensors are utilized by the stakeholders to provide meaningful information that will aid in decision support processing.

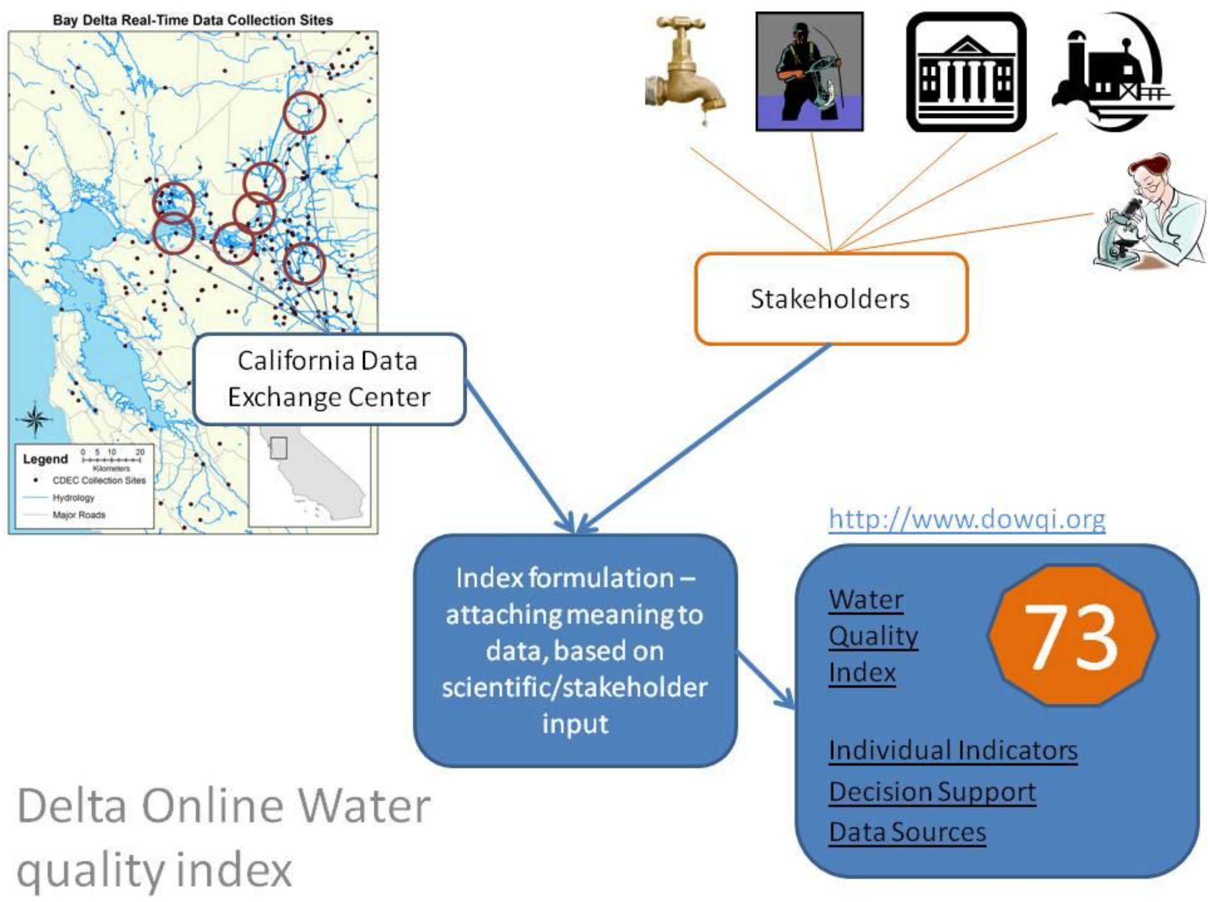


*Figure 2: Stakeholders will benefit from meaningful real-time data though the water quality index and the data provenance that shows precisely how the value was calculated and achieved.*

3 http://www.epa.gov/storet/wqx/
4 http://his.cuahsi.org/

A sensor network is one or more data collection devices that capture *events*–data parameters– about the environment. These devices can range from small, single parameter collectors, such as the Tidbit sensors which collect temperature only, to larger weather stations collecting a broad range of parameters. Video surveillance systems, satellite imagery, and even human data collection–sensors do not need to be electronic devices–can all be collection instruments on the sensor network. Data is transported via a wrapper or transportation mechanism to a data repository or warehouse where these data it can be utilized. Data from these sensors are essential to calculate the online index. The California Data Exchange Center (CDEC) and the US Geological Survey (USGS) National Water Information System (NWIS) provide data from their sensor network in "real-time." The frequency that a sensor collects its data varies from fifteen minutes to longer intervals, such as hourly or sometime daily. These real-time (and historic) data will be collected and assembled in a local database where we can apply various statistical models and data transformations which provide the metrics for the index.

# 3. Approach and Scope of Work

### *A. Stakeholder Process*

We have used formal and informal stakeholder input processes for social, economic, and environmental indicator system development in the Sacramento River watershed, North San Francisco Bay, and for both indicator and/or decision support tool development at various scales in Canada, Australia, and Southeast Asia. The Sacramento River watershed and North San Francisco Bay studies were conducted with CALFED Watershed Program funds, administered through the Department of Water Resources and finished in 2/2011 and 6/2010, respectively. In partnership with The Nature Conservancy of California we have also worked for over 9 years on stakeholder driven decision support tools for ecological flow management, through the Ecological Flows Tool projects for the Sacramento River and the Bay-Delta (in progress). Through these experiences we have learned the importance of ensuring a strong and clear linkage between the chosen indicators and the *interests* of stakeholders (i.e. that the indicators will be *meaningful* for the intended audience), that these linkages *are ecologically important* (i.e., tied to survival or productivity of key focal species), and ensuring a strong and clear linkage to *actions or decisions* (i.e. that the results will be *useful*).

In the proposed project, we would use a formal stakeholder process to:

- Both gage and encourage common understanding about the meaning of particular realtime data in the network of Delta monitoring stations,
- Select the indicators to be included in the index,
- Determine how the index will be calculated, and
- Derive rules for interpreting real-time data as part of a water quality index*, and
- Design the online user interface for the index.

*(For example, surface water temperature is continuously measured at X sites around the Delta. Water temperature can have significant impacts on Delta ecosystems, responds to water and to some extent land-management, and is a parameter that can be used to adaptively manage water conditions. Previous scientific studies have demonstrated the sensitivity of fish to water temperatures, affecting growth and survival.) We will employ our experience in “knowledge engineering” for expert systems to help compile the necessary “if-then” rules to help us with both indicator scoring and interpretation within the index.

We anticipate the engagement of the following stakeholders, although this list is preliminary and will be refined in the first part of our stakeholder engagement process (see approach #1 below)

- Government: CALFED, US Bureau of Reclamation, US Fish and Wildlife Service, US Geological

Service, CA Department of Water Resources, CA Water Resources Control Board, CA Department of Fish and Game, CA Natural Resources Agency (Bay Delta Conservation Plan), Delta Stewardship Council, Delta Conservancy Board,

- Academia: UC Santa Barbara, UC Davis faculty not affiliated with the project), San Francisco State University, California State Universities.
- NGOs and other independent entities: Delta Independent Science Board, Sonoma Ecology Center, The Bay Institute, The Nature Conservancy, watershed councils/programs (e.g. Sacramento River Watershed Program)

We propose to use the following sequence of approaches to accomplish this:

1. Situational assessment and stakeholder analysis. We will identify the groups currently using water quality data in the Delta for decision-making (e.g. State water operators who control flows at Shasta, Keswick, Delta pumping plants, etc. who already have other real-time instruments that they employ in the management of the State and Central Valley Projects), how they currently access such data, what decisions or actions this information informs, and what other decision support tools they use. We will also identify other stakeholders with potential interests in the index who may not have direct power or authority over management decisions, and map all of these stakeholders against an interest/influence grid, a common template for which is shown in Figure 1. We anticipate drafting this from readily-available information, following up with telephone interviews if/as needed to complete the analysis. This will help ensure that when we invite engagement in next steps from stakeholder groups, we work hardest to include participation from stakeholders in the three outer quadrants of the analysis grid.

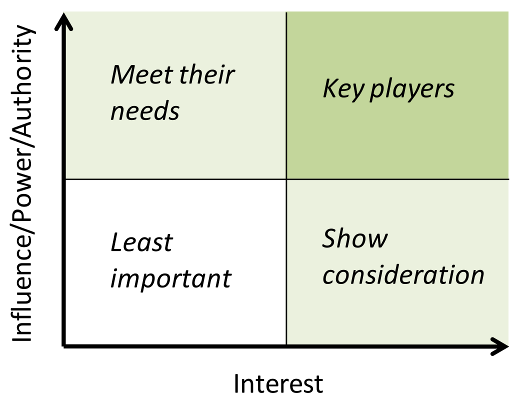


**Figure 1. Typical stakeholder analysis grid.**

2. Design workshops. We plan to break this down into two separate events:
   a. First, we will hold an *Information Session and Scoping Workshop* for the interested stakeholders, to (i) build common understanding about the index (its intended purpose, and the meaning of particular real-time data in the network of Delta monitoring stations), explain our design and development process and the various opportunities for stakeholder engagement, and answer any questions, (ii) identify the questions they would like the index to answer and/or the decisions or actions they would like it to inform, and (iii) begin preliminary discussions of what parameters the index might include. This information will help drive the technical development and keep it on track. We will invite all stakeholders to self-select participants to attend this workshop (whomever they think can best contribute according to the agenda topics), up to a specified limit (to be determined based on the number of stakeholder groups). We anticipate this to be a full-day workshop, held in Sacramento, similar in concept to the recent and successful California Sustainability Indicators Symposia, co-organized by Fraser Shilling (project lead).

b. We will then hold a *Technical Design Workshop*. This workshop will focus on two tasks. The first will be identification of indicators for the stakeholder interests (questions, decisions and actions) identified at the Info Session and Scoping Workshop, clearly mapping the linkages between these indicators and stakeholder interests as well as their ecological importance. If an unexpectedly large number of indicators are identified, will also ask participants to help us develop a list of ranking criteria that we would then apply to the list. The second workshop task will be to begin discussions of how these indicators will be combined into an index. We will invite stakeholders to identify potential participants, who should be scientists with expertise in water quality issues and measurement in the Delta, or expertise in focal systems and species vulnerable to changes in water quality. We anticipate this to be an up to two-day workshop, held in Sacramento.

3. <u>Development workshops.</u> Building this type of decision support tool is an iterative process. We anticipate several *Technical Development Workshops* to further advance the design, once our team has a chance to build a straw index based on inputs during the Technical Design Workshop. We anticipate the same technical-level participant group, and will focus on presenting, evaluating and building on progressive iterations of the index through the development phase. These workshops will address index calculation and index interpretation and will help maintain credibility and relevance of the index through the development process. We envision an initial two-day workshop, followed by 2-3 full-day follow-up workshops to focus on specific issues towards index refinement, depending on the degree of divergence or convergence of comments/views among the technical participants on the emerging index.

4. <u>Review workshop.</u> Towards the end of the development process we will hold a one-day review workshop with the target users of the index, to test the relevance for those whose decisions or actions the index intends to inform. We expect the participants for this workshop to comprise decision-makers from the stakeholder groups.

5. <u>Focus group.</u> We will engage a *User Interface Focus Group* (a volunteer subset of the stakeholders) to help design and review the user interface for the index as it will appear online. This will be done remotely for the most part, through emailed links to an index testing site and emailed comments, with focus group conference calls to discuss and resolve issues where their respective comments may conflict.

Objectives and expected outputs will be clearly articulated prior to all of the stakeholder engagement events described under approaches 2-5 above.

***B. Index Development***

We will develop the first water quality index for the Delta based on Delta stakeholder input, Delta scientist recommendations, and the needs of the Delta Science Program. We will work closely with the California Water Quality monitoring Council and the Surface Water Ambient Monitoring Program of the State Water Resources Control Board as they develop criteria and guidelines for reporting on stream health through their "Stream Health Partnership" web portals. This index will be implemented online for several time-frames. It will include a real-time index that takes advantage of the >20 real-time monitoring site throughout the Delta, a number that is growing and featuring at least 6 regularly sampled parameters. The index will be an aggregate of indicators and will allow user-disaggregation into component indicators to examine indicator specific conditions and trends. Both status and trend will be reported using contemporary techniques for attaching meaning to environmental data that we have perfected over the last 2 years during 3 bond-funded projects administered by the Department of Water Resources and advanced statistical tools. Although the goal is to provide a simplified report of conditions for the widest possible audience of public and decision-makers, provenance information will be provided to allow people to investigate the data used, rules used to interpret data, and stakeholder and scientific process used to generate the rules. Finally, this decision-support tool will be tested for its actual utility with Delta technical and non-technical audiences and the tool modified to make it more useful.

*B.i. Indicators*

We will develop the index based upon indicators of water quality that are either direct measurements of ecological condition or ecosystem service, or proxies for those conditions. For example, a direct measurement of water quality for human health is nitrate concentrations because of the potential health impacts of this constituent. Water temperature is a critical physical habitat indicator that provides indirect or proxy information about in-stream conditions important for ecosystem health.

We select indicators that tell us the most about system health, that are the most understandable and useful in decision-making, and for which there are contemporary and historic data collection. We will use approaches for indicator selection similar to those used in the recent Sacramento River Watershed Health Indicator Project [5] and Delta Ecological Flows Tool Project [6]. In both cases, indicators were related to their direct or proxy function in representing system condition and their relevance to stakeholder-expressed or likely value of the indicator in decision-making.

*B.ii. Target and reference condition selection*

For each indicator in the proposed water quality index, target or reference conditions will be described. These range from an estimate of a "good" or healthy condition, to a description of an unacceptable or worst condition. Targets set for good reference condition will receive a score of 100, and for the poor reference condition will receive a score 0. Each indicator in the index will be evaluated in real-time on this range from poor to good reference conditions. Each indicator status value (or trend) will be compared to a reference or standard value, and the comparison used to generate a score. Although it is important to pick a reference value that is meaningful for decision-making, it is just as important to make the choice transparent so that the reference value can be changed in the future if warranted by changes in knowledge, goals or assumptions. We will choose reference or target conditions specific to the indicator using best available science and input from stakeholders. These are all mutable choices and can be regarded as proposals for how indicators can be evaluated (Shilling, et al., 2010).

In the case of the Delta Ecological Flows Tool project, TNC and ESSA Technologies proposed a multi-focal species approach to identifying flow, temperature target and salinity conditions that would inform managers about how those conditions might change under future climate, conveyance, and water operations in the future. These focal species and habitat indicators are used inside scenario modeling of flows and hydrodynamics to evaluate outcomes for Delta smelt, salmonids, sturgeon, invasive species, and other valued ecological features. Indicator target setting was an important element of the DeltaEFT methodology for determining relative changes in the performance of alternate flow regimes.

A very important benefit of taking the step of comparing instantaneous or historic conditions to targets/references is that scores can be combined into an index across very different indicators (e.g., water temperature, nitrogen species, and turbidity), whereas otherwise this would not be possible. Because all indicator conditions will be quantitatively compared to a target, they can all be normalized to the same scale – distance to target. Once the normalization takes place, the new values, ranging from 0 to 100, mean the same thing and can therefore be combined into an index. Because environmental processes and conditions rarely

5 http://www.sacriver.org/monitoring/reportcard.php
6 http://www.essa.com/tools/SacDeltaEFT/

respond to influences in a linear fashion, evaluating indicators relative to reference conditions must take into account these non-linear responses. For example, evaluation of water temperature would probably use a non-linear function, such as the relationship between fish growth or mortality and temperature.

Indicator metrics will be quantified in their raw or native units (e.g., degrees C or tons carbon sequestered), and evaluated on the basis of their separation from the target condition. This target or reference condition is sometimes called the “ideal point” (Malczewski, 1999). The ideal point method was first introduced in the late 1950s and expanded by Milan Zeleny in the 1970s (Pomerol and Barba- Romero 2000). Zeleny (1982) operationalized the measurement of closeness with:

$$d_i = f_i* - f_i (x_{ji})$$

Where *di* is the distance of attribute state *xji* to the ideal value *fi*, *i* indicates the attribute and *j* indicates the objective. For the DOWqi, indicator distances from target will be calculated in their native units and converted to a common scale (0-100) to be aggregated with other indicators into composite indices. The common scale conversion will be relative to a threshold or objective specific to each indicator and will be based on the appropriate linear or non-linear rate of change relationship.

*B.iii. Online and multi-timeframe statistical operations*

Contemporary investigations of environmental quality necessarily involve the employment of data-cleaning/checking tools, spatial statistics, trends analysis, and statistical significance tests. These are usually done on data collected and assembled into a desktop flat-tile (e.g., Excel spreadsheet) or relational database. One challenge of online reporting systems is the necessity of carrying out statistical and data checking operations “on the fly” in order to provide accurate indicator information in a timely fashion for decision-support. We will use tools in the open source statistical package R to implement statistical operations in user real-time for a constrained set of *ad hoc* queries. R has a very active global following and developer audience among scientists from many disciplines and provides a stable and consistent platform for the deployment of statistical operations in the online index proposed.

**Data Cleaning**

Real-time data online has distinct advantages over archived data in that conditions in the system are instantaneously reflected by the data. One potential disadvantage is that mechanical/software problems with sensors, data transmission, and data serving may result in anomalous values. For this reason, it would be important to have automated protocols for data checking and cleaning that are independent of expert data censoring. We will develop several data checking and alert protocols over distinct real-time and short timeframe reporting in order to censor potentially anomalous data from use in indicator reporting, but not from later retrieval and reporting if an event turns out to not be anomalous. For each indicator, rules will be developed for interpretation of corresponding data.

**Statistical Significance**

Environmental conditions normally vary around some central tendency condition over daily and other time-frames. A user may want an instantaneous or longer timeframe comparison with a standard/threshold or useful for decision-making (e.g., a certain turbidity NTU value or water temperature). This comparison is best made while taking into account normal measurement error and natural variation. We will design protocols that assess variation in parameter data over user-defined time-frames, from near-instantaneous (last 2 hours of 15 minute sampling intervals) to daily, weekly, or longer, in order to use the variation as a source of information in interpreting the indicator and index score. We have found that measuring and reflecting uncertainty in index development and reporting is a critical piece of information for stakeholder users.

**Trends Analysis**

Changes in ecosystem characteristics over time are an important type of analysis and one of the most valuable types of information conveyed with indicators. Somewhat counter-intuitively, they are also rarely conducted using appropriate statistical techniques. Analysis of trend in time series data is necessary to determine if conditions in a waterway are improving or deteriorating. One of the most common techniques for determining trend is linear regression. However, linear regression requires certain data characteristics, such as normal distribution of values, which are not easy to assess in small data sets. Distribution-free trend analysis is ideal due to the unknown nature of the data, so non-parametric tests are preferred. Of the various commonly used options, the Mann-Kendall rank correlation trend test is the strongest (Berryman et al. 1988). It is appropriate for data that are not normally-distributed, tolerates missing values, and is relatively unaffected by extreme values or skewed data. The output of the Mann-Kendall analysis is an assessment of the trend slope (Sen's slope estimate) and its statistical significance. To adjust for seasonality, the Seasonal-Kendall test can be used to determine whether or not significant changes have occurred over time, while taking into account variation due to seasonal effects (Hirsch et al., 1982; Hirsch and Slack 1984; Esterby 1996). When assessing trend within a broad region with multiple sampling sites, the same principle applies as with seasonal data: it is better to compare trends across sites than to combine them into a single time series. The Regional Mann-Kendall is analogous to the Seasonal-Kendall, but compares individual locations rather than seasons (Helsel & Frans. 2006). Because it is statistically identical, it has all the advantages of the Seasonal-Kendall.

We will deploy Mann-Kendall, Regional Mann-Kendall, and Seasonal Mann-Kendall tests in R online as part of the water quality index package, when appropriate and feasible. The user will be able to set certain temporal and spatial boundaries on queries, then run customized Kendall scripts that we have developed in the DWR-funded whole-system indicator projects in the Sacramento River watershed and North Bay regions (Shilling et al., 2010 a,b). At a recent National Water Quality Monitoring Council meeting (April, 2010), Robert Hirsch (US Geological Survey demonstrated using nitrate and nitrite data for the Mississippi River that flow correction was a critical part of a trends analysis, with trend significance changing from significant to not significant for nitrogen parameters depending on whether or not corrections were made for flow (Hirsch et al., 2010). We will test its applicability to the water quality index in the online tool and deploy flow correction as needed.

***C. Building an online real-time water quality index***

In order to report water quality condition in real-time a sensor array or network is needed to spatially represent waterway specific and regional conditions. This network is available through the CDEC, which retrieves and serves data from USGS and DWR stations and sensors (see Map below). These sensors function as a network because of their distribution throughout the system. Also, because of their distribution, they provide system redundancy in that multiple measures of the same waterway can be made in similar time-frames. This allows users to understand and control for spatial homogeneity or heterogeneity, accuracy, and sub-regional status and trends for individual stations or collections of stations.

*C.i. Sensor Networks*

Sensors capture distinct *events* – data parameters – about the environment. Once an event is captured, the data becomes part of a pipeline to the data repository and in a position to be used by a user of the Delta Online Water quality index. Sensors capture data but not until the data reaches users does it become useful. Data quality is an important consideration when building an index. The system will include rudimentary detection protocols that will flag data that might be incorrect, but there will be a strong reliance on the data providers (CDEC and NWIS) to produce high quality data (see Figure 3). To look at data quality, we propose using the spatial context of the sensor to help identify problems with the data. Grouped sensors often have a spatial autocorrelation to their data, and this fact can be used to help test data quality and to develop accurate, spatially-explicit models of environmental quality.

**Homogeneous vs. Heterogeneous Sensor Nodes**

Within a homogeneous sensor network, all the nodes share the same data organization, which eases the management of the underlying storage system and the overall maintenance of nodes. Although this may be the ideal case (i.e. having nodes of all the same type), generally sensor networks have heterogeneous nodes. Heterogeneous nodes come in two flavors. First, they collect different parameters, e.g. some to monitor temperature and others to measure flow and turbidity. Secondly, even for the nodes collecting the same parameters, a different data organization may be present, e.g. one device collects temperature and dissolved oxygen, and the newer device collects temperature, dissolved oxygen, and turbidity. In sensor database systems, besides computing results with the present data, some source information related to the data or results has to be provided as well for users, i.e. data lineage. An important lineage problem, relating to how a researcher utilizes the data for various statistical analyses, is having a fixed dataset after a query so that if an analysis is rerun, the same results are guaranteed. When a scientist requests data from the system, a text file is generated with a timestamp. These request files are stored for a period of time and the researcher can identify files for longer term storage. Keeping a compressed copy of the original result will preserve the data provenance (or history of that data usage) for some fixed length of time if there is need for data verification. We will keep compressed records of all data used in the construction of the water quality index.

*C.ii. Data Storage and Management*

Data from the sensor nodes is stored in the data repository. It is the storage mechanism of the data, in terms of both logical and physical storage. Potentially, some of the data is summarized or aggregated, creating a data warehouse which can speed up query processing and serve a larger number of requests. We will rely on CDEC and NWIS as the primary data providers and store these data (as well as their historic data) in a local data repository. If a new monitoring station comes online during the project, adding a new collection node to the web-reporting will be done via an administrative interface. The procedure will be slightly different if the new data node has the same type of data that is already being stored or if the new data to be added is unique. If the new data feed is of the same type that the database already stored (knows about), adding this node will be very straightforward and easy. The addition of a new node is as simple as adding a record to the database and writing a line to a correspondence file.

*C.iii. Website Services*

A successful website shows off an intuitive designed that is deceptively simple. Design is often an iterative process and should be considered the norm. When the design is assumed to be iterative, initially less emphasis can be made on a particular interface and more concentration can be given to the content and functionality. As new areas develop, those areas can be reexamined as far as user-usability is concerned. The website should provide a range of content to please the diverse set of visitors to the site. This not only includes the data, but other educational material. This can include information on the data collection devices, full descriptions about the sites where the data is being collected, sample data sets with examples on how analysis can be done.

The proposed web-reporting tool intends to provide an index of water quality condition, supported by a concise reference on remote historical data collection, real-time data, analysis techniques, and stakeholder and scientific rules used to give meaning to the data. From the academic researcher from to the high school student, all should find something useful on the site. The target audience of this site is purposefully diverse. The general public should immediately see the usefulness of this site, even if utilizing the raw-data is not possible. A water or ecosystem manager should be able to learn more about immediate conditions, the dynamics of their ecosystem, and possible types of analysis that can be done with these data using tools on the site itself. The academic researcher could download the data and incorporate it into a research project.

A webserver is required to service all website visitors. The webserver hosts the website which communicates with the database for the required information, providing the index, the disaggregated indicators, and the all of the data and information provenance pathways needed (e.g., where the data came from, what interpretation rules were used, who developed the rules). The website will have a clean interface, clear navigation, and maintain flexibility and expandability as a project like this requires. We can consider building the application on an existing framework, such as Mambo or another CMS.

***D. Evaluating the usefulness of the index in decision-support***

**Stakeholder Feedback**

A stakeholder process will be used after the development of the water quality index and the online real-time tool to evaluate its usefulness in education, science, and decision-support. Input from this feedback will then be used to modify the tool. Focus groups will be the primary mechanism for this, targeting the main stakeholder groups involved in the development of the index as well as representatives from the intended audience groups for the index including

**Website Logs: Measuring Success**

The website logs will track the number of visitors per day to the site. From the IP address of the visitor, one can establish from which country, agency, and/or organization type this person is visiting from. Site use, including residence time, pages used, and actions performed can all be tracked. This provides an important test of the utility of the system – if staff from critical agencies are using the site, the independent confirmation of decision-support utility is provided beyond people's stated use of the site. The success of the website will become an indicator for the success of the project. This measurement is not only based on the number of visitors, or unique visitors, but rather what the visitors do with the information received from this site.

# 4. Deliverables

<u>Stakeholder Process (# workshops)</u>
Stakeholder situation assessment report
Stakeholder scoping and technical design workshops (2)
Stakeholder technical development and refinement workshops (4)
Stakeholder review workshop (post-index deployment)
Focus group meeting
Report describing stakeholder process

<u>Web-based index creation</u>
Report describing: 1) draft and final indicators for index, 2) description of data sources, including monitoring station, 3) description of rules for index creation and operation, 4) description of statistical approaches to analyze indicator data for post-hoc analysis and real-time analysis, 5) description of contemporary and historical index output
Web location with real-time and historic index values
"Widget" (device that can be included on any website) reporting the index values, link to provenance pathways
Web-site describing full provenance for data, rules for developing index, related scientific literature, description

of stakeholder process

Database management
Archived data store for historical data indexing
Continuous data archiving over time
Data management for real-time index construction

Reporting
Final report describing process and outcomes

## 5. Feasibility

The likelihood of success of the project is high for several reasons: We have developed and used all of the component procedures in previous projects in the region or nearby. For example, we have led or been intimately involved in 3 large geographic regions in California in the development of a combined social, economic, and environmental indicator system based on stakeholder input and the scientific literature and scientific input. The combined cost of these projects was ~$1 million, over 2 years, and involved multiple universities, agencies, and nongovernmental organizations. The unprecedented investment in indicator system development provides a secure foundation for the proposed project, which focuses more narrowly on one environmental index. At the Information Center for Environment, we have developed computational tools that allow ad hoc reporting and queries, in several programming languages. We are dependent on several environmental data reporting platforms staying online – for example, NWIS and CDEC, but don't anticipate this changing. We are not dependent on any unfunded program, or program that has a near-term or discernible funding horizon. We have working relationships with all agencies that provide online data in real-time or archival form and agencies that are currently providing value-added services with data (e.g., the water quality portal under development by SWAMP under the aegis of the California Water Quality Monitoring Council). Because stakeholder processes can affect project outcomes, our contingency plan is to develop 2 separate indices, based upon majority stakeholder opinion and the technical literature, then vett these indices with the stakeholder process.

## 6. Relevance to the CALFED ERP

**The project and index meets ERP Conservation Strategy – III.C Water quality stressors, Water temp, DO, contaminants, ammonia, mercury (DOC),** in that the decision-support tool "Delta Online Water quality index" will provide an historical and contemporary reflection of conditions, be based on state-of the- science understanding of the system, based upon conceptual models (e.g., from DRERIP), and stakeholder input on how such an index should "look", and be useful for resource managers operating at different time-scales. This decision-support tool will operate in desk-top mode through a web-service and will integrate disparate aspects of the aquatic system to promote more rational, transparent, and real-time decision-making. By working directly with the stakeholders who will use the tool, we will ensure the relevance of the tool to scientific, policy, and management needs. We will also measure use of the tool in a time-frame that allows feedback-based modification of the tool itself.

**The project also meets the need of ERP Conservation Strategy IV. Species, Delta smelt (turbidity, salinity, temperature determine distribution)** in that the project includes consideration of the physiological tolerances of fish to key environmental stressors in a changing estuary (most of the water quality indicators within the index will be built on our evolving understanding of these relationships, making the index immediately useful).

The proposed project addresses the more general effects of variable and changing water quality from contaminants, sediments, and nutrient inputs by developing a system to index these changes. Of emerging concern are climate change effects on water temperature, salinity, and other water quality parameters that may affect aquatic food webs within the Bay-Delta (the index will report on variable and changing water quality conditions in a way that attaches meaning to the parameter data; it will also provide an historical and changing record that can show climate change effects on Delta aquatic conditions). The project address the hydrodynamic conditions, water quality, primary and secondary production, and food web dynamics linked within aquatic ecosystems of the Delta and its tributaries and floodplains? (The index will be based upon combined hydrodynamic and water quality condition indicators that have relevance to the aquatic ecosystems.) The project is inter-disciplinary and collaborative, drawing upon broad expertise within the team, as well as with Delta stakeholders. We will initially take advantage of the extensive historical data to provide a back-casting of the water quality index up until "now", at which point the real-time index will be operational, providing access to historical information as well as ever-changing conditions from this point forward.

## 7. Expected quantitative results (project summary):

Using a stakeholder process, we will develop the first online water quality index for a California ecosystem that is home to billions of dollars in restoration action and water transactions, endangered fish and wildlife, and considerable controversy. Maintaining clear provenance pathways and transparency, we will use both the social interactions in a stakeholder process and contemporary web and statistical tools to reveal long-term and instantaneous conditions in Delta waterways. The tool will provide both clear summary values, for example the hourly DOW-qI value, and clear pathways to retrieve as much information as the user wishes to gain about both the process of developing and numeric inputs and outputs of the index. This stakeholder process and transparency will address many fears about water quality in the Delta ecosystem and build trust in this important ecosystem attribute. We expect that people will turn to the DOW-qI values as an objective source of information about conditions in order to measure effects and effectiveness of various actions, potential risks to listed species and water quality, and potential source types of stressors for ecosystem functioning (e.g., water column primary productivity) and components (e.g., fish populations).

## 8. Other products and results:

There have now been several decades of contention over Delta ecosystem conditions and California water conveyance through the Delta. It is likely that decision-making and ecosystem conditions are suffering from almost continuous arguing over whether or not species are at risk, how much they are threatened, whether or not management and restoration actions have been or are likely to be effective, and even what parameter data mean. We do not intend to resolve all arguments in the Delta over aquatic ecosystem condition. However, we do intend that the DOW-qI contributes to the neutral decision spaces that are critical in restoring ecosystem function through both the inherent transparency of the process and tool, and the transparency of the daily and long-term output of the index. Because the system is naturally scalable, data from a networked system of monitoring stations can contribute to both an overall understanding of water quality in the system and a fine-scale understanding on individual waterways. This will allow for both the easy-to-communicate values that managers and decision-makers need and the ability to discover fine-scale relationships important in daily and waterway-specific decision-making and effects-monitoring.

## 9. Qualifications

Dr. Fraser Shilling (Project Lead) has developed indicator and index systems at multiple scales and for multiple institutional purposes and is a researcher at the UC Davis Information Center for the Environment (ICE, http://ice.ucdavis.edu). His projects most related to the proposed project includes lead or partner involvement in developing indicator systems for the Sacramento River watershed, North Bay, and Southern California regions. These 2-year projects, mentioned earlier in the proposal, employed the same stakeholder process, scientific basis, and theoretic foundation as proposed here (Shilling et al., 2010 a,b). In addition, Dr. Shilling developed an Urban Roads Ecological Performance Index for the Korean Ministry of Transportation (2009) and is co-developing (for CDFG/CALFED-ERP, agreement # P0620021) a riparian restoration effectiveness reporting system based on the same theoretic principles as the proposed index. He also is the lead author of the California Watershed Assessment Manual (2007), which includes basing integrative assessments on an indicator framework and the distance to target method. Dr. Shilling will manage and lead the theoretical and scientific components of the project. He will manage staff and sub-contractors.

David Waetjen (Programmer-Analyst) is a 5th year graduate student in his last year of an environmental informatics Ph.D., primarily working at ICE. Mr. Waetjen has developed environmental data web sites that allow ad hoc queries and show data provenance and other relevant information to expert and non-expert users. He will be the primary programmer and web site developer and will stay on the project after graduation as a programming analyst and post-doctoral fellow.

Dr. James Quinn (Principal Investigator) is the director of ICE and has a long history as one of California's premier ecologists and of developing environmental data and informatics systems. Under his leadership, ICE has become a node of one of the US' primary environmental informatics networks, the National Biological Information Infrastructure, a collaboration of the US Geological Survey, the National Science Foundation, and other agencies. He is Mr. Waetjen's graduate advisor and employs a staff of over two-dozen graduate students, undergraduate students, technicians, and doctoral scientists.

Carol Murray (Stakeholder process consultant) is a senior environmental scientist at ESSA Technologies in Canada and a key partner in the development of the Sacramento River watershed indicator system. [*ESSA Technologies was selected as a consultant because of their extensive corporate experience with large-scale environmental index construction, their professional expertise in contentious settings (e.g., effects on salmon of Columbia River hydro-power management), and their experience in the Central Valley and Delta in particular developing useful flow-management decision-support tools – namely the multi-component "Ecological Flows Tool".*] Over the past 17 years Ms. Murray has been involved in environmental indicator system development and reporting projects at various scales in Canada, including co-authoring British Columbia's first State of Environment Report. She will bring other ESSA staff to the project who were instrumental in developing the Ecological Flows Tool (EFT) in collaboration with The Nature Conservancy. The Sacramento and Delta EFT projects involved considerable background literature reviews and multiple expert workshops and review cycles on how physical habitat variables (flow, water temperature, salinity, flooded areas, turbidity, etc.) affect key focal species life-history events.

Katherine Wieckowski, a Systems Ecologist with ESSA, is an analyst with six years of experience in resource management. Her primary area of focus is fisheries, freshwater, and marine management. Ms. Wieckowski has been involved in a range of research projects at ESSA involving monitoring program design, indicator development and aggregation, data synthesis and analysis, literature review, simulation modelling, program evaluation, and policy implementation. She has worked on a number of indicator related projects, the most recent of which include: 1) indicator selection, monitoring/sampling designs, and developing protocols for status and trends reporting for Fisheries Sensitive Watersheds in British Columbia; 2) indicator selection and design for an ecological flow decision support tool for the Sacramento – San Joaquin Delta and the Sacramento River in California (two separate projects); and 3) indicator selection and analysis for the Sacramento Watershed Report Card.

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## *Section 7: Project Budget*

1. **Detailed Project Budget** ***(Excel spreadsheets can be used)***

| | | | |
|---|---|---|---|
| **Budget** | | | |
| **Delta Online Water Quality Index** | | | |
| | | | **Totals** |
| **PERSONAL SERVICES** | | | |
| **Staff Level** | **Number of Hours** | **Hourly Rate** | |
| Fraser Shilling, Project manager | 1417 | 31 | $43,949 |
| Analyst | 2050 | 22.5 | $46,125 |
| Administrative Assistant | 1023 | 17 | $17,392 |
| Graduate student researcher | 1788 | 18 | $32,177 |
| Subtotal | | | $139,643 |
| Staff Benefits @ 40% Student 1.3% | | | $45,822 |
| **TOTAL PERSONAL SERVICES** | | | **$185,465** |
| **OPERATING EXPENSES** | | | |
| **Description** | | | |
| Subcontractor Costs (ESSA Technologies) | | | $186,870 |
| Materials | | | |
| Photographic Supplies | | | |
| Printing and Duplicating | | | $1,000 |
| Office Supplies | | | $2,400 |
| General Expense | | | |
| Travel and Per Diem | | | $2,000 |
| Graduate student fees | | | $23,539 |
| *Add/delete line items above for work to be performed by the contractor* | | | |
| | | | |
| **Total Operating Expenses** | | | $215,865 |
| | | | |
| **EQUIPMENT** | | | |
| | | | |
| SUBTOTAL | | | $401,274 |
| OVERHEAD @ 25% (Less Equipment, fees, 75% subcontractor cost) | | | $53,966 |
| **GRAND TOTAL** | | | **$455,240** |

**2. Budget justification:**

### General comments on the budget:

**Fringe Benefits-** University-required fringe benefits are included at a rate of 40% for Shilling, the Analyst II, and the administrative assistant; 1.3% for graduate students in academic quarters.

**Inflation Adjustments-** Salaries, have been adjusted at a rate of approximately 5% per year.

### Senior/Key Personnel

**Fraser Shilling, Ph.D.** (Primary Investigator, 8 Calendar Months Effort over 24 month project)
We request 8 months of salary for PI Fraser Shilling, a staff researcher with salary paid through grants. Fraser Shilling is an environmental scientist with expertise in a variety of different areas, including multiple-parameter indicator system development, policy vehicles to deal with environmental pollution, and complex system

analysis in partnership with non-academic partners.

Role: As lead-investigator, Dr. Shilling will be in charge of managing the project and will be involved in all substantive and scientific aspects of the project. He will develop reports to the Department of Fish and Game/ERP and lead the publication of the WQI in a nationally-recognized journal.

**James Quinn, Ph.D.** (Co-Investigator, 1 Calendar Months Effort as match)
Role: As co-investigator, Dr. Quinn will serve an advisory role on all elements of the project. He will review research materials and results to insure the highest scientific quality.

**Robert Hijmans, Ph.D.** (Co-Investigator)
Role: As co-investigator, Dr. Hijmans will serve an advisory role on all elements of the project. He will review research materials and results to insure the highest scientific quality.

**Other Personnel**

**David Waetjen** (Analyst II, 12 Calendar Months Effort)
We request 12 months of salary for analyst and post-doctoral fellow David Waetjen. David is a finishing graduate student with Dr. Quinn, specializing in development of informatics and web applications for serving complex environmental information with ad hoc querying and analytical capacities.
Role: Mr. Waetjen will be responsible for web programming for the project. He has years of graduate student and professional experience in programming in multiple languages and formats. He is capable of writing novel routines in web environments to serve environmental data to support multi-stakeholder decision-making.

**TBN Administrative Assistant** (6 Calendar Months effort)
We request 6 months salary support for an assistant to aid in the stakeholder process and other printing, information-sharing, and office duties associated with the project.

**TBN Graduates Student Researcher** (1 Graduate Student Researcher, 9 Calendar Months Effort at 50%, per year)
Role: One graduate student researcher will be assigned to aid in index development, including data collection and analysis in the construction of the historic WQI. The student will have advanced statistical skills in at least trends analysis and spatial analysis using environmental data.

**Travel**

***Annual Meeting-***
Funding is included to pay for registration for up to 4 UCD personnel to attend the CALFED Science Conference and similar regional conferences and workshops where either relevant issues will be discussed (e.g., IEP Workshops) or presentations on the DOW-qi can be made.

***Field Work***
Funds are budgeted for the PIs and other UCD personnel to travel to meet with stakeholders and expert-stakeholder groups throughout the Delta. Cost estimates are based on current mileage and per diem. We estimate the trips will use personal cars, for a maximum distance of 120 miles round trip, at the federally approved rate of $0.50/mile.

**Other Direct Costs**

***Materials and Supplies: Data Storage and Mobile Computing***

We will use $700 to purchase upgraded data backup storage for existing server infrastructure at UC Davis. We also request partial funding for one laptop computer for investigator Shilling, at $1000.

***Materials and Supplies: Office and Printing***
Materials and supplies funds are requested to purchase printing supplies and services, telephone services (conference calls), and other office supplies ($1,700).

***Consultant Costs: Expert Process and Index Development***
We request $186,870 total support for the involvement of Carol Murray, Katherine Wieckowski and other staff from ESSA Technologies Inc. in the development of the index. ESSA has been involved internationally in the development of complex indices of environmental condition and modeling of flows and other environmental conditions in the Delta and tributaries. Their role will be to lead the stakeholder process, aid in development of the index, and lead evaluating the utility of the index. See "Qualifications" for additional information.

***Graduate Student Researcher Fee Remission-***
Graduate student fee remission is a required cost for employing a graduate student on a research project. The cost for the 11/12 academic year is projected to be $13,257, inclusive of a 25% reduction applied by the institution. Therefore, $27,840 has been budgeted in years 1-2 for the graduate student to be employed on the project, which includes a possible 10% increase in fees for year 2 (2013).

## Indirect costs

### 3. Administrative overhead:

Indirect costs are required by UC-Davis at 25% for contracts with state agencies, based upon total direct costs, minus equipment and graduate student fees.