



Restoration Funding Application Cover Sheet

APPLICANT INFORMATION

Name of Organization(s) Requesting Funding: Design, Community & Environment

Mailing Address: 1625 Shattuck Avenue, Suite 300

Berkeley, CA 94709

Federal Employee Identification Number: 94-3288331

Principal Investigator: Brian Fulfrost

Title: Associate Principal Institution: Design, Community & Environment

Telephone: (510) 848-3815 Email address: brian@dceplanning.com

Grant Administrator: Nancy Graham

Telephone: (510) 848-3815 Email address: nancy@dceplanning.com

PROJECT INFORMATION

RFP Study Topic # 1

Project Title Measuring Habitat Evolution Utilizing Satellite Imagery

Funding Request per year \$106,600 a year Number of years: 3

Confirmed in-kind or matching contributions: \$ 0


Source of in-kind or matching contributions: \$0


Purpose and Objectives:

The opening up of salt ponds to tidal action from San Francisco Bay is expected to enable native inter-tidal habitats and their vegetation communities to re-establish themselves. In order to understand and track the effectiveness of these restoration efforts with the adaptive management plan (Trulio et al. 2007), changes to mudflat extent and floral colonization will be mapped using a combination of satellite image analysis and field mapping. Datasets will be analyzed, stored and visualized using a range of Geographic Information Systems (GIS) tools. Our approach is focused on developing a "multi-method" plan that combines automated and manual interpretation of high resolution satellite imagery with expert ground truthing. The mapping protocols

and habitat classification scheme used for the study will conform to state and national standards. As an outcome of our imagery analyses and ground truthing we will develop a "habitat model" comprised of habitat image characteristics and mapping standards to allow for some automation and reduce costs of future mapping efforts. DC&E will develop and maintain a database for the South Bay Salt Pond Restoration Project (SBSP) and write an annual report articulating the change in frequency and diversity in the patchwork of habitats.

Proposed starting date: May 2009 Estimated completion date: February 2012

Signature :  Date: 12/05/08
Principal Investigator

Signature :  Date: 12/05/08
Grant Administrator

2. Proposal

(a) Abstract

The opening up of salt ponds to tidal action from San Francisco Bay is expected to enable native intertidal habitats and their vegetation communities to re-establish themselves. In order to understand and track the effectiveness of these restoration efforts with the adaptive management plan (Trulio et al. 2007), changes to mudflat extent and floral colonization will be mapped using a combination of satellite image analysis and field mapping. Datasets will be analyzed, stored and visualized using a range of Geographic Information Systems (GIS) tools. Our approach is focused on developing a “multi-method” plan that combines automated and manual interpretation of high resolution satellite imagery with expert ground truthing. The mapping protocols and habitat classification scheme used for the study will conform to state and national standards. As an outcome of our imagery analyses and ground truthing we will develop a “habitat model” comprised of habitat image characteristics and mapping standards to allow for some automation and reduce costs of future mapping efforts. DC&E will develop and maintain a database for the South Bay Salt Pond Restoration Project (SBSP) and write an annual report articulating the change in frequency and diversity in the patchwork of habitats.

(b) Background and Justification

The opening up of salt ponds to tidal action from San Francisco Bay will enable native intertidal habitats and their vegetation communities to re-establish themselves. After an initial period following the breaching of the ponds, increased tidal velocity and scour could impede sediment accretion, but with time, succession of special-status plants and animals and native species will occur as sediments accumulate outside of breached slat pond slough areas and sub-biome areas evolve into a mosaic of habitat types. The SBSP team will require empirical data to develop and test hypotheses for 1) the relationship between sediment accretion and floral colonization of tidal marsh ecosystems, 2) the effect of sediment redistribution on existing habitats and communities, 3) the evolutions of habitat supportive of endangered species and 4) the annual evolution of habitat types.

DC&E will utilize a combination of satellite image analysis and field mapping to track the changes to the extent of mud flats and floral colonization in restored tidal areas. We will apply a multi method approach to habitat mapping that will easily integrate with the SBSP’s other datasets so they can better understand the effectiveness of their restoration efforts. Satellite imagery is more efficient and costs less than high-resolution aerial imagery used in past SBSP monitoring projects (Ervin , Hayes and Keuren 2008). We propose to utilize high resolution multi spectral imagery from the IKONOS satellite at 1 meter resolution. The use of satellite imagery for detailed habitat classifications has been well documented (Mathieu, Aryal and Chong 2007, Duke, Boursier and Bourgeois 2007, Fuller, Morgan and Aichele 2005, Born-Phillips et al. 2005, Mumby and Edwards 2002) and our approach is informed by the methodological results of these studies. We will spend significant time ground truthing our habitat classifications in the field and perform supplementary field mapping of habitats.

(c) Study Objectives

Utilizing a combination of satellite image analysis, manual interpretation and ground truthing, we will map the spatial extent and distribution of sediment (i.e. mudflats) and vegetation yearly over a three year period in both restored tidal areas and existing habitats in the south bay. Habitat classifications used and generated from our analysis will be based on the *California Manual of Vegetation* (Sawyer and Keeler-Wolf 1995) naming system for comparison and integration into similar restoration projects in the San Francisco Bay region and elsewhere. The habitat data will be produced for visualization and analysis in a GIS (e.g. as an ESRI shape file). The habitat data produced from our mapping efforts can be used to inform other research projects.

DC&E proposes to also use the data and methodologies used as part of the project to develop, test and calibrate a multi-method “habitat mapping model”, based on habitat characteristics derived from satellite imagery and verified by ground truthing. The model will assist in automating part of the habitat mapping process.

During the first year, we will map the spatial extent and distribution of “changes areas” from the preexisting baseline (pre 2005). During the second and third years, we will identify these “changes areas” from previous study years as well as from the baseline. At the end of the study, we will also quantify and visualize how the mosaics of habitat types are changing in spatial and thematic terms.

These datasets will be instrumental in allowing the SBSP Restoration team to analyze and understand the relationships between natural sediment accretion in restored tidal areas and the evolution of emergent tidal marsh ecosystems. As vegetation cover develops in the restored areas and is mapped into a GIS format, the SBSP restoration team will be able to better understand how newly emergent habitats are enabling the recovery of endangered species. The SBSP Restoration team will also be able to explore the connection between the rate of sediment movement into restored tidal areas over time and existing habitat areas in the south bay.

(d) Study Area

The study area is located in the South San Francisco Bay and includes three South Bay Salt Pond (SBSP) Restoration Project Areas (Eden Landing, Ravenswood, Alviso) as well as the tidal marsh and mudflats adjacent to these Project Areas, seen in Figure 1. The Project Areas encompass approximately 15,100 acres, while the tidal marsh and mudflats outside of the project area cover approximately 14,300 acres. The entire study area encompasses the majority of ponds fronting the South San Francisco Bay.

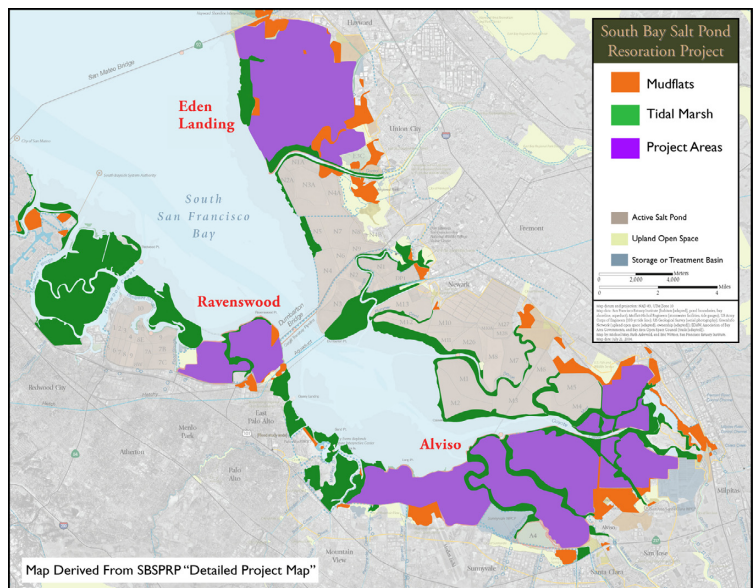


Figure 1: Study Area Locations

In the lab, we will map changes to mudflat extent and other habitats for the Project Areas and some or all of the remaining marsh habitat and mudflats as determined by SBSP staff and budget constraints. Each project year, we will ground truth a majority of the study area for each habitat using a GPS enabled tablet PC (see Section (d) – Task 6c below). At the beginning of the study, we will conduct preliminary field mapping to provide data for building our habitat classifications and for informing our image analyses.

(e) Approach

Detailed habitat maps are usually created by manual interpretation of high resolution aerial photos. This method has been applied to map habitats in the south bay for many years by the City of San Jose and other organizations (Duke, Boursier and Bourgeois 2007). The advent of high resolution satellite imagery (e.g. 1 meter Ikonos) makes it possible to map habitats with significant spatial and thematic variability. Satellite imagery can be more cost effective because it is cheaper allows for some automation. This has the potential to reduce labor costs associated with field mapping and manual image interpretation.

Our approach is focused on developing a “multi-method” plan that combines automated and manual interpretation of high resolution satellite imagery with expert ground truthing (Walker, Reigl and Dodge 2008). The spectral characteristics of the imagery should allow some level of automation in mapping habitat areas. We will document these and other image interpretation protocols in our “habitat model”. Our approach is designed to meet project goals in a flexible and cost effective manner. We will utilize ArcGIS 9.3 from ESRI for general mapping, image interpretation and model development. Spectral analyses will be conducted using the Leica ImageAnalysis extension for ArcGIS. All statistical analyses will be run using the R statistical software environment.

PHASE 1: HABITAT MAPPING PREPARATION

Task 1: Kickoff Meeting

We will hold an initial meeting with the SBSP Restoration team. The meeting will allow us to: clarify project objectives, review our multi method approach with SBSP staff, identify key project milestones and schedule and provide a forum for beginning a dialog between DC&E, and SBSP staff. After the meeting, the DC&E team will submit a technical appendix document describing the agreed-upon methodologies, mapping standards and data formats.

Task 2: Literature Review

Ikonos imagery has been used locally for habitat characterization at fine geographic scales (1:2400). This includes work conducted both by the City of San Jose (Duke, Boursier and Bourgeois 2007) and the San Francisco Estuary Institute (Collins and Stralberg 2004). In addition to these studies, we will conduct a comprehensive literature review in order to best inform the development of the “habitat model” developed in Phases 2 and 3. Our literature review will focus on methodological insights into habitat mapping.

Task 3: Data Acquisition and GIS Database Development

The geospatial data required for the proposed analyses falls into two broad categories: (1) preexisting conditions, basemap, and environmental data; and (2) Ikonos satellite imagery

Preexisting Conditions and Basemap Data

Data will be acquired from the SBSP Restoration project, SFEI, CDFG, City of San Jose Marsh Habitat data), Santa Clara Water District and other sources as needed. Key datasets to be acquired include (but are not limited to): land ownership boundaries, Ikonos (2002-04), water and hydrologic features, existing salt pond extents, habitat data, and LIDAR/topography.

Ikonos Imagery

We propose to utilize imagery from the Ikonos satellite since it meets the spatial and spectral requirements required to meet project objectives. We plan to acquire and purchase imagery in June of each project year. This enables us to maximize daylight hours, represents a time of year when there is a relatively repeatable low tide, there is a higher likelihood of clear skies (reduced atmospheric haze and cloud cover), vegetation is usually clearly visible and the weather for ground truthing of habitat polygons in the following months will be optimal. In the Table 1 below we have budgeted for 3 years of imagery acquisition using 1 meter pansharpened multispectral imagery from Ikonos. This imagery includes spectral information in 4 bands from 445 nm to 853 nm. These data will allow us to explore both the visible (RGB) and near infrared (NIR) properties of the habitats. We have also included costs for using the .4 meter multispectral imagery from the new GeoEye1 satellite which will begin delivering data in December 2008. Due to its increased spatial resolution, this imagery might make habitat mapping at the association level easier.

TABLE 1 IMAGERY ACQUISITION COST ALTERNATIVES

	Cost/km ²	km ²	Years	Total
IKONOS (1 meter)				
SBSP Restoration Areas	\$ 25	61	3	\$ 4,575
SBSP Restoration Areas plus existing Tidal Marsh and Mudflats	\$ 25	119	3	\$ 8,925
GeoEye1 (0.4 meter)				
SBSP Restoration Areas	\$ 30	61	3	\$ 5,490
SBSP Restoration Areas plus existing Tidal Marsh and Mudflats	\$ 30	119	3	\$ 10,710

GIS Database

Datasets acquired and produced as part of the project will be stored and organized into a series of ESRI file geodatabases and image libraries. Individual habitat datasets produced from the project will also be made available in standard GIS formats as requested by SBSP Restoration team (e.g. shapefiles). All geospatial datasets produced from this project will include FGDC compliant metadata. The database will be organized into four primary sections: basemap, preexisting conditions, imagery (organized by year) and habitat data. The habitat data will generated as a result of work completed on this project.

PHASE 2: MAPPING STANDARDS AND HABITAT CLASSIFICATIONS

Task4: Mapping Standards

Our mapping and change analyses will conform to strict Federal Geographic Data Committee (FGDC) and National Mapping Accuracy Standards (NMAS). All datasets will be accompanied by FGDC compliant metadata. Our Habitat Model will contain a set of mapping standards and an image interpretation guide. These products will allow for optimization of resources and ensure consistency in habitat mapping and

analyses. Our literature review will include an assessment of vegetation mapping standards outlined by the USGS, the National Park Service (NPS) and the California Department of Fish and Game (CDFG).

Spatial Accuracy

Spatial accuracy refers to the maximum planimetric distance that geographic features will be to their “true” location. For habitat mapping, assuming thematic accuracy is ~80% (see below), the spatial accuracy of our resulting habitat polygons will be a direct product of the positional accuracy of the imagery and GPS enabled ground truthing (~2-3 meters).

Image Resolution:	minimum of 1 meter
Digitizing Scale:	1:2400
Minimum Mapping Unit (MMU):	variable

Since we do not want to limit the identification of any change (no matter how big or small) occurring to mudflats and habitats, the MMU might vary according to each habitat type. The MMU will be a result of both the resolution of the imagery (1 meter) and the actual spatial extent and variability of changes occurring to habitats. We anticipate the MMU will range from 1/10 to 1/4 of a hectare.

Thematic Accuracy

The habitats most likely to occur within the study area will be categorized using the habitat alliances (and associations) found in the MCV and listed in the RFP. We will identify and map out intertidal mudflat, subtidal and marsh habitats at the spatial and thematic scale specified by the RFP (1:2400 for spatial scale) but most importantly at scales required to meet project goals and address key questions. This list of initial habitat classifications will be used to guide both our image analysis and ground truthing.

We will conduct a literature review and preliminary field mapping to further refine and clarify the initial list of habitats. Additional habitat types might also be added (or subtracted) from this list based on ground truthing in future years. The Ikonos imagery will enable us to map out at a minimum the vegetation alliances and a maximum the vegetation associations of the habitats within the study area. In the end, the MCV habitat classes assigned to the mapped areas will allow the SBSP Restoration team to understand the spatial and thematic variability of intertidal mudflats as well as subtidal and marsh habitats within the study area. We expect to achieve ~80% accuracy in thematic habitat classification which will be tested using stratified random sampling techniques outlined below.

Task 5: Habitat Classifications

Task 5a: Map Preexisting Conditions

We will first develop a GIS based model of the study area(s) that outlines the “(pre)existing condition” of the salt ponds before any pond underwent restoration. We will integrate existing LIDAR imagery, by developing a Digital Terrain Model (DTM) in ArcGIS of the study area (in a TIN format). We will also include Ikonos images of the study area, acquired by the City of San Jose in 2002 and 2004, into our GIS database. Although we assume that imagery is available for the entire study area, we have budgeted for some supplementary imagery at \$10 per square kilometer. We will “drape” the Ikonos images from 2002 and 2004 on top of the DTM to identify the extent (and height) of pre-existing mud flats and marsh habitat. Since part of the study was already mapped by the City of San Jose we will also include these data into the South

Bay Habitat GIS where available. We can then overlay the final derived mud flat extents and habitat polygons on top of this surface to track and measure changes from this “baseline” state.

Task 5b: Preliminary Ground Truthing

We propose to spend two weeks to identify and refine the habitat classes identified in the RFP and located in the MCV by conducting initial field mapping of similar habitats in the south bay. This will allow us to guide our satellite imagery analysis (it will guide our supervised classifications as well as our manual interpretation) based on confirmed locations of various habitat types. We will utilize the California Native Plant Society’s Rapid Assessment or Relevé mapping protocols (CNPS 2004), or a simplified version of them, for our preliminary mapping. We will relate what is visible on the satellite images with the characteristics of the habitat we acquire in the field.

Preliminary field mapping (and all subsequent ground truthing) will occur on GPS enabled pen tablet notebooks, running ArcGIS 9.x software, and using IKONOS imagery. The hardware, software, and imagery will conform to the mapping standards developed in Phase 2. All digitizing will occur at a standardized mapping scale, and follow any other guidelines provided by the SBSP management team.

Task 5c: Final Habitat Classifications

Working from the list of relevant MCV habitat classes taken from the RFP, our image analysis of preexisting conditions and our preliminary field mapping, we will generate a list of final habitat classifications. These habitat classifications will be modified and refined in Phase 3 (and to lesser extent Phases 4 and 5) as new flora and habitat evolve from restoration activities. The final list of habitat classifications will be assigned to habitat areas identified in our image analysis during Phases 3 to 5.

PHASE 3: HABITAT MAPPING – YEAR ONE

Task 6: Habitat Mapping and Habitat Model Development

Task 6a : Image Analysis

We will utilize the Leica ImageAnalysis extension for ArcGIS to automate the derivation of initial habitat polygons. This will include unsupervised, supervised and textural classifications. We will begin training the supervised classifications to differentiate between different habitat types based on preliminary ground truthing as well as published habitat information acquired from previous projects in the study area. We will assess the ability for these methods to improve efficiency, reduce labor time and enable consistency between project years. We propose to include a level of *semi-automation* to the habitat mapping process. Our habitat mapping will also include the necessary amount of manual interpretation and ground truthing to produce highly accurate results.

The outcome of out this step will be a set of initial “spectral and image characteristics” that will be further refined and developed using manual interpretation and ground truthing. Image characteristics can include: spectral signature(s), texture, color variation, shape, and pattern.

We will utilize the “spectral signatures” of geographic features like intertidal mudflats as well as subtidal and marsh habitats to identify changes occurring in the study area. Although Ikonos is available at relatively

high spatial resolutions (1 meter) compared to other satellite sensors, it has limited spectral range, limiting its potentially effectiveness for spectral classification. Although we are very aware of the limitations of identifying individual species or plant communities using imagery like Ikonos, we believe that spectral analysis will provide a baseline habitat classification that can be improved by other automated methods (texture analysis/object classification) and manual editing. The development of a “habitat model”, based on combination of semi-automated and manual classifications, will provide the SBSP Restoration team with consistent mapping standards and provide a mechanism for maximizing available resources. In addition to or as an alternative to spectral classification, we will assess using object classifications methods commonly used for aerial photos. These use the color, texture and shape of neighborhood pixels to group and classify parts of the image into “classes” or “objects”.

The results of our image analyses will be Areas of Interest (AOI) that form the foundation for conducting an iterative process of unsupervised and supervised classifications to “train” the software to identify and differentiate between the habitats of concern. Although some manual editing and verification is always suggested, we hope that these automated methods will reduce time required to map out the entire study area.

Task 6b: Manual Image Interpretation

Building on our knowledge of south bay habitat types and our expertise in satellite image interpretation, we will supplement and edit the results of our automated image analysis by manual interpreting CIR (and/or visible) composite images. The manual interpretation of the images is a key step in the process of deriving habitat areas from satellite imagery. All the habitat polygons produced during Step 1, will be systematically reviewed by both our image and habitat experts at a scale of 1:2400. The result of our manual interpretation will be both (a) improved habitat polygons (and thematic accuracy); and (b) a habitat model that is informed not only by the spectral characteristics of the imagery but also by the manually interpreted image characteristics (color, pattern, texture, etc.) of habitats within the study area.

Task 6c: Ground Truthing

Ground truthing remains a requirement for mapping features due to limitations imposed by the selected imagery and the variability of image characteristics among the habitats of concern. We will ground truth the habitat polygons generated in the lab by our satellite image analysis. Tidal marsh vegetation is best surveyed during the height of summer, so fieldwork will likely occur during July and August after the imagery has been acquired. Field mapping and ground truthing shall conform to the mapping standards developed in Phase(s) One and Two, as approved by the SBSP Restoration team

We will field verify a stratified random sample of a majority of the habitat polygons. This will enable us to calculate the level of statistical confidence in our habitat classifications in order to achieve the targeted 80 percent thematic accuracy. We anticipate ground truthing and field mapping 50 to 100 percent of the habitats each year – depending on habitat type, the amount of changes identified in habitats as well as logistical constraints. Although we hope that our automated habitat classification model will reduce fieldwork in subsequent year, we have budgeted for enough field time to guarantee the entire study area will be mapped.

We will load our initial habitat polygons into our two GPS enabled tablet PCs (using ArcView 9.3) for field verification and refinement. Crews will be sent to sampling locations and fill out digital survey forms used to assess habitat and floral characteristics of these locations (water, floral composition, mud/sediment).

Task 6d: Habitat Data Refinements

Data acquired during ground truthing will be uploaded into the GIS database and used to verify the habitat classification of polygons derived from our image analyses (Tasks 6a & 6b). Polygons that have been identified by field crews as having been assigned incorrect habitat classifications will be reassigned the correct classifications based on the composition of flora, water and sediment found at the sampling location. Field assessed habitat boundaries will also be used to edit habitat areas. These data will also be used to further refine our habitat model to improve the automated and manual classification of the satellite imagery.

The result of Tasks 6a-6d will be a GIS datasets that document the extent and distribution of mudflats and other habitat types within the study area during the current project year.

Task 6e: Data Analysis

Two types of analyses will be performed at the end of each project year. The first will be a statistical analysis to test the (thematic) accuracy of our habitat classifications of the satellite imagery based on our ground truthing efforts. We will assess the level of accuracy for each (and all) habitat class in two ways: (a) through descriptive statistics (i.e. what percentage of the field samples matched with the image based classifications) ;and, (b) calculate a Root Mean Square Error (RMSE) of the variance. We will utilize the R statistical software environment for this analysis.

We will also conduct a GIS based analysis to quantify the change in the extent and distribution of mudflats and other habitats from previous year(s). For the first year, we will overly new habitat polygons with our baseline. We will calculate the area of change through vector overlay procedures (e.g. intersection and distance between mudflat extents) of our final habitat data. We will also asses the feasibility of using raster processing techniques to identify habitat changes within the study area.

Task 6f: Progress Report and Presentation

At the end of each project year, we will present a short progress report to the SBSP Restoration team documenting the change in sediment and habitats as well as provide technical updates regarding the development of the automated multi-method habitat mapping model. A draft of the progress report will be presented to the group in a PowerPoint presentation, designed to stimulate productive discussion about the restoration progress (and the mapping model development). After each meeting, DC&E will receive one round of comments from the SBSP Restoration team, revise the report, and deliver the final draft.

PHASE 4: HABITAT MAPPING – YEAR TWO

Task 7a-7f: Tasks in year two will repeat the steps in year one.

PHASE 5: HABITAT MAPPING – YEAR THREE

Task 8a-8f: Tasks in year three will repeat the steps in year one.

PHASE 6: FINAL REPORT

Task 9: Final Data Analysis

After our third year of habitat mapping, we will conduct a final series of GIS based (vector and raster) change analyses for the entire project period. In addition to these yearly analyses, we will also utilize one or more spatial analysis techniques to quantify both the mosaic of habitat types and dispersion of specific flora. These analytical tools include: neighborhood analyses, standard deviational ellipse, and cluster analysis (Moran's I or Getis-Ord).

Task 10: Final Workshop for SBSP Restoration Team

We will hold final a final workshop for the SBSP Restoration team (and other project teams) to present the results of our final data analysis and provide an overview of changes identified to habitats for the entire project period. The workshop will include a power point presentation and a discussion of the habitat model and final data results. DC&E will take these comments from SBSP and make changes to the final report.

Task 11: Final Report (w/maps and GIS database)

The final hard copy report will include the following items: (a) summary of methodology, (b) final results, maps and analyses, (c) a "habitat model" and image interpretation guide for habitat mapping, and (d) habitat mapping standards and protocols. The report will include a clean and documented GIS database of digital geospatial data products on an external hard drive. A preliminary draft will be submitted to the SBSP Restoration team for comment. We will incorporate these comments into the final report.

(f) Data Archiving Procedures

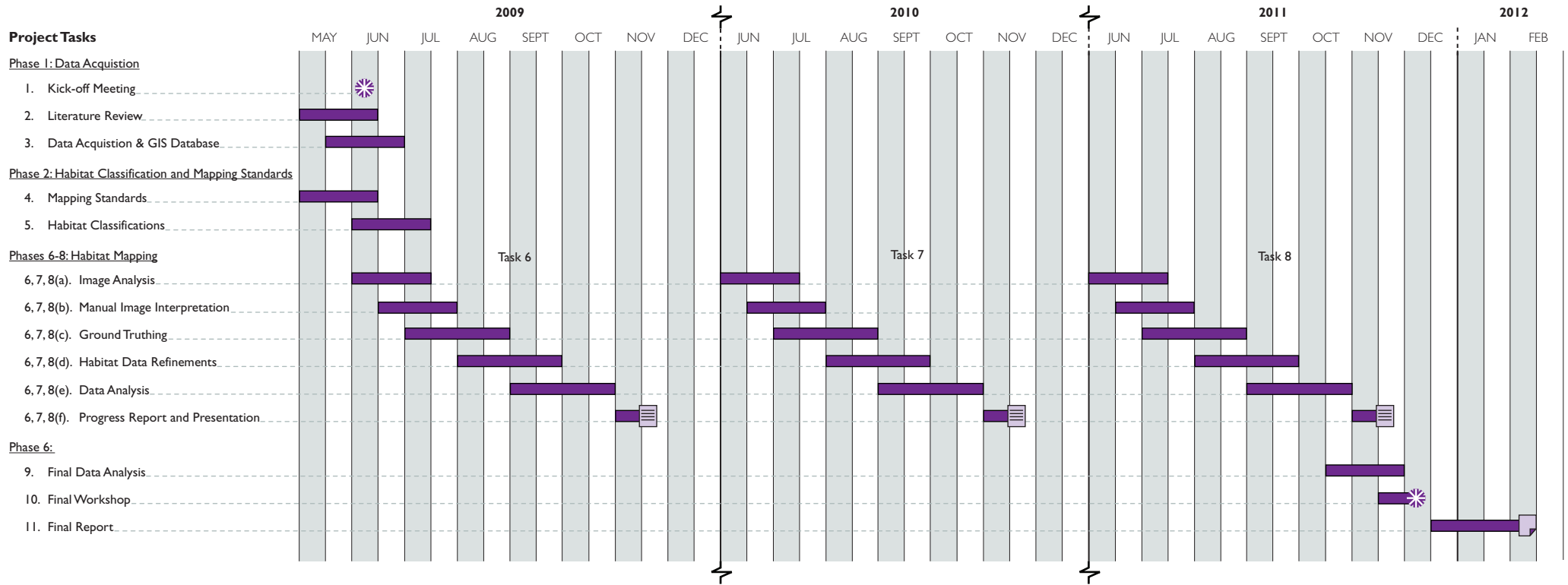
All GIS datasets, including satellite imagery, derived habitat datasets and secondary data, will be stored on a centralized server (Dell PowerVault MD100) with daily backups to tape (DLT Dell PowerVault 124T). During the project, the GIS database will consist of a series of ESRI file geodatabases and associated image library. As requested by the SBSP restoration team, habitat data will be exported to either an ESRI personal geodatabase or shapefile format. Both preliminary and final maps produced for annual progress presentations and the final report will be made available in web accessible formats (PDF or JPEG). The entire GIS database will be delivered to the SBSP Restoration team on an external hard drive.





(g) Work Schedule – See next page.

(h) Expected Products

A summary list of project deliverables is provided below.

- ◆ Kickoff Meeting
- ◆ Habitat Classification List (based on the Manual of California Vegetation)
- ◆ Three Annual Progress Reports with preliminary maps and data
- ◆ Three Annual Progress Report Presentations
- ◆ Final Report w/ methods, final maps, "habitat model", and mapping standards
- ◆ GIS database w/satellite imagery, final habitat data (for three years and final analysis) and basemap datasets on an external hard drive and CD/DVD (if requested)



-  Work Period
-  Presentation of Yearly reports
-  Final Report with maps and GIS Database
-  Meeting

3. Literature Cited

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Walker, Brian K., Bernhard Riegl and Richard E. Dodge, September 2008, *Mapping Coral Reef Habitats in Southeast Florida Using Combined Technique Approach*, Journal of Coastal Research, Volume 24, Issue 5, pages 1138 – 1150.

4. **Qualifications of investigators, partnerships, and cooperators** – *Please see following pages.*

5. **Budget and Staff Allocations** – *Please see page following resumes.*

6. **List of Potential Reviewers**

Dr. Eric Van Dyke: Elkhorn Slough National Estuarine Research Reserve
vandyke@elkhornslough.org
(831)728-2822 x309
1700 Elkhorn Rd., Watsonville, CA 95076

Dr. Grey Hayes: Elkhorn Slough National Estuarine Research Reserve
grey@elkhornslough.org
(831)728-2822 x306
1700 Elkhorn Rd., Watsonville, CA 95076

Dr. Todd Keeler-Wolf: California Dept of Fish and Game
tkfwolf@dfg.ca.gov
916-324-6857
Biogeographic Data Branch
1807 13th St. Room 202
Sacramento, CA 95814

Dr. Stu Weiss: Creekside Center for Earth Observation
650-854-9732
stu@creeksidescience.com
27 Bishop Lane
Menlo Park, CA 94025

Ingrid Hogle: Invasive Spartina Project
ibhogle@spartina.org
(510) 548-2461 (general)
2612-A 8th Street, Berkeley, CA 94710

BRIAN FULFROST M.S.
ASSOCIATE PRINCIPAL

Brian Fulfrost, Associate Principal, will serve as the Project Manager, as well as take the lead on the remote-sensing GIS elements of the project. Mr. Fulfrost has over 15 years of experience using GIS in a range of environmental science applications; including hydrologic modeling, vegetation mapping (field, aerial and satellite), habitat suitability, spatially enabled predictive analyses, and decision support systems for reserve design and management. Mr. Fulfrost has worked on several recent projects utilizing GIS in vegetation and habitat mapping. He has worked closely with the California Department of Fish and Game's (CDFG) VegCamp program to promote, utilize and improve vegetation mapping and data collection efforts. Mr. Fulfrost has also utilized the CDFG's Rapid Assessment protocol, combining aerial photo interpretation and efficient field studies, to map-out detailed vegetation communities for lands owned by the University of California, including parts of the UC Natural Reserve System. He currently is an advisor to the Santa Cruz Chapter of the California Native Plant Society, developing methods for prioritizing, identifying and mapping rare and endangered communities. Additionally, Mr. Fulfrost recently completed a multi-year effort funded by a USDA grant to map-out and classify vegetation around farms in the Monterey Bay region using high-resolution aerial photography.

Professional Experience

Design, Community and Environment, Berkeley, California. Associate Principal. 2008 through present. Responsible for maintaining and supporting DC&E's GIS services in support of environmental analysis, planning, landscape architecture and design projects.

University of California, Santa Cruz, Department of Environmental Studies, Santa Cruz, California. GIS Coordinator/Senior Lecturer.

Montgomery Watson Harza (MWH), Walnut Creek, California. Senior Environmental Scientist. 1999 to 2001.

Publications

Modeled Regional Climate Change and California Endemic Oak Ranges by Lara M. Kuempers, Mark A. Snyder, Lisa C. Sloan, Erika S. Zavaleta, and Brian Fulfrost. PNAS 2005 102: 16281-16286, 2005.

Regional Patterns of Recruitment Success and Failure in Two Endemic California Oaks by Erika Zavaleta, Kris Hulvey and Brian Fulfro. *Diversity and Distributions*, 13, 735–745 2007.

Integrating Field Surveys and High Resolution Remote Sensing Data for a Baseline Ecological Assessment of Ailinginae Atoll, Republic of the Marshall Islands by Daria Siciliano, Brian Fulfro, Karen Joyce, Jim Maragos and Karen Koltes. *Unpublished Manuscript*.

Exploring Climate Change Impacts to Elk Habitat Using NDVI from MODIS Satellite Imagery by Chris Wilmers, Brian Fulfro and Justin Woodjack. *Work in Progress*.

Presentations

What's the Goal? Using GIS to Evaluate the Advantages and Disadvantages of Various Weed Mapping Methods. 9th Annual War on Weeds Conference, CSUMB, Monterey, November 16th, 2007.

Ichneumonid Diversity in California's Agricultural Landscape Mosaics: What Supports the Wasps? Poster presented at the Ecological Society of America's Annual Meeting, San Francisco, California, December 2007.

Professional Affiliations

Imagery Sub-Committee, GIS Council, State of California.

Chair, Imagery Sub-Committee, Central Coast Joint Data Committee (2003-2005).

Co-Chair, Central Coast Joint Data Committee (2003-2005).

Advisor, Big Sur Land Trust.

Technical Advisor, Center for Integrated Marine Technologies.

Scientific Advisory Board Member, San Francisco Bay Bird Observatory.

Mapping Committee Member, California Invasive Species Council.

Advisory Committee Member, UCSC Arboretum.

Advisor, California Native Plant Society.

Reviewer, Environment, Development and Sustainability.

Reviewer, International Journal of Remote Sensing.

Member, Association of American Geographers.

Member, Society for Conservation Biology.

DAVID THOMSON M.S.
PROJECT MANAGER/LEAD SCIENTIST

David Thomson, Biologist, is a sole practitioner with significant experience in vegetation, wetland delineation and habitat mapping in the south bay. He will serve as the Lead Scientist and will be responsible for overseeing and conducting all ground-truthing and field mapping activities for the South Bay Salt Pond Habitat Evolution study. An expert in the habitat and ecology of the South Bay, Mr. Thomson will also assist with satellite image interpretation. Mr. Thomson has over 10 years of experience as a biologist and field scientist, and has worked on a wide variety of projects throughout the San Francisco Bay.

Professional Experience

San Francisco Bay Wildlife Society, Bay Ecotone Restoration Implementation. Project Manager and Lead Scientist. David is leading the demonstration research project to create plans and specifications for organizations seeking to restore ecotonal vegetation communities that are adjacent to and surrounding the tidal wetlands of San Francisco Bay. Helped develop this demonstration research project from a Vegetation Management Plan into an experiment, testing various treatments for controlling weeds and improving the performance of native vegetation both short- and long-term.

H.T. Harvey & Associates, California. Consulting Biologist. 2004 through 2008. Projects included researching and drafting biotic resources sections for Impact Analyses, Natural Environment Studies, Restoration and Monitoring Plans, Mitigation and Monitoring Plans, implementation PS&E packages, Monitoring Reports, as well as resource inventories and experimental studies. Also contributed to the biotic resources sections of Environmental Impact Reports and Environmental Impact Studies. Acted as technical lead or collaborated on over 30 successful projects, including contributing to proposal preparation.

Directed data collection, annual analyses, and report drafting, as well as conclusions for an experimental dredging project in the Alameda Flood Control Channel; mapped wetland and upland habitats throughout the San Francisco Bay Area including many parts of the baylands; and designed and collaborated upon many wetland and riparian restoration or creation projects such as planning Bair Island's restoration monitoring.

Annually mapped approximately 1,000 acres of intertidal marsh habitat in South San Francisco Bay to the level of dominant species. This work was performed using several types of equipment in the field, including sketching polygons onto "hard copy" plotted

aerial photographs mounted to poster board, aerial photographs in specialized field computers running custom mapping software, and IKONOS imagery loaded into ARCMAP 9.x on pen tablet computers.

Educational Experience

Graduate Assistant Southeastern Louisiana University. Research Assistant. Assisted the Edward G. Schleider Endowed Chair for Environmental Studies, the Turtle Cove Environmental Research Station's director and thesis adviser, Dr. Gary Shaffer, with K-12 educational classes, teacher educational workshops, and several research projects. Maintained equipment including automatic data recorders for weather and water quality, ferried passengers for official station business, and various office duties including data management. Traveled to remote field locations using a variety of small boats and other State of Louisiana vehicles.

Designed and implemented my thesis project to quantify the influence of altered hydrology on plant growth and marsh stability. Selected to implement a study of saltwater intrusion in support of a swampland mitigation project. Assisted in setting up and sampling a study of freshwater diversion effects using SETs. Lab instructor for Biostatistics and Introductory Biology.

Design, Community & Environment
Satellite Mapping of Habitat Evolution
Cost Estimate

Hours per Task	Design, Community & Environment				David Thomson
	Associate Principal (GIS Manager)	Project Planner (GIS Analyst)	Urban Designer (GIS technician)	Graphics Tech	
Phase 1: Habitat Mapping Preparation	24	52	112	10	6
1. Kickoff Meeting	8	16	20	10	6
2. Literature Review	8	12	32		
3. Data Acquisition & GIS Database	8	24	60		
Phase 2: Habitat Classification & Mapping Standards:	46	46	100	-	84
4. Mapping Standards	6	10	16		4
5. Habitat Classifications					
5a. Map Preexisting Conditions	16	16	32		
5b. Preliminary Ground Truthing	16	8	20		80
5c. Final Habitat Classifications	8	12	32		
Phase 3: Habitat Mapping - Year One	144	168	268	4	208
6a. Image Analysis	80	60	40		
6b. Manual Image Interpretation	24	40	120		8
6c. Ground Truthing	8	16			200
6d. Habitat Data Refinements	8	16	60		
6e. Data Analysis	16	16	24		
6f. Progress Report and Presentation	8	20	24	4	
Phase 4: Habitat Mapping - Year Two	144	168	268	4	208
7a. Image Analysis	80	60	40		
7b. Manual Image Interpretation	24	40	120		8
7c. Ground Truthing	8	16			200
7d. Habitat Data Refinements	8	16	60		
7e. Data Analysis	16	16	24		
7f. Progress Report and Presentation	8	20	24	4	
Phase 5: Habitat Mapping - Year Three	144	168	268	4	208
8a. Image Analysis	80	60	40		
8b. Manual Image Interpretation	24	40	120		8
8c. Ground Truthing	8	16			200
8d. Habitat Data Refinements	8	16	60		
8e. Data Analysis	16	16	24		
8f. Progress Report and Presentation	8	20	24	4	
Phase 6: Final Report	112	164	136	32	44
9. Final Data Analysis	60	80	24		
10. Final Workshop	12	24	32	16	12
11. Final Report	40	60	80	16	32
Total Hours	614	766	1,152	54	758
Hourly Rate	\$43.27	\$27.88	\$20.19	\$17.00	\$80
Labor Cost	\$26,568	\$21,356	\$23,259	\$918	\$60,640
Total Firm Labor Cost				\$72,101	\$60,640
Fringe Benefits			0.452	\$32,590	
Overhead			1.243	\$89,622	
Fixed Fee (Labor + Fringe + Overhead x 0.10)				\$19,431	
EXPENSES					
Ikonos Imagery (119km2 x 3 years at \$25/km2+ \$150 pansharpener):				9,075	
Ikonos Imagery - preexisting conditions (119km2 at \$10/km2)				1,190	
GPS enabled Tablet PC (\$5000 x 2)				10,000	
Leica ImageAnalysis extension for ArcGIS				4,000	
Mileage-Meetings (80 miles RT to meetings@ \$0.55 per mile X 5 meetings)				220	
Mileage- Ground Truthing (50 miles per day @ \$0.55 per mile X 25 days X 3 years)					2,062
Subconsultant Management (10%)				6,270	
Per diem for 5 meetings (\$10 lunch) for 3 people				150	
Mapping (4 E size maps per meeting @ \$90 X 5 meetings)				1,800	
Field Maps (\$50/year X 3 years)				150	
Deliveries (3 reports @ \$25)				75	
Report Production (5 reports @ \$50)				250	
Workshop Supplies & Refreshments (\$100 x 2 meetings -excluding presentations)				200	
Boat Rental for Field Survey (4 days @ \$ 900 /day x 3 years)				10,800	
Total Expenses				44,180	2,062
Total Each Firm				\$257,924	\$62,702
Grand Total				\$320,626	

7. Necessary Assessments, Certifications and Permits

Tidal marsh vegetation is best surveyed during the height of summer, so fieldwork will likely occur during July and/or August. However, this coincides with the California Clapper Rail nesting season, which is protected by Refuge regulations excluding anyone without an Endangered Species Permit (ESA Section 10(a)(1)(A)) for CLRA from entering tidal marshes between February 1st and August 31st. A Memorandum of Understanding (MoU) with the California Department of Fish and Game would also be required for full compliance with State and Federal regulations. During this period fieldwork will occur from adjacent levees and high points overlooking the marsh, as well as from a boat since some marshes are too broad to adequately survey from the levees. If any areas within marshes remain questionable they will be surveyed on foot in September after the CCRA nesting season protection ends.

We should also note that even outside of CCRA nesting season studies must request permission to enter the Refuge's tidal marshes. Access to any Refuge property for studies requires a Special Use Permit issued by the Refuge. If issued, a Special Use Permit would approve access for personnel stipulated on the permit and provide a key to Refuge gates for vehicles. This project would acquire a Refuge Special Use Permit and also request the stipulation that our field personnel be granted access into the marsh outside of the protected CCRA nesting season.

8. Animal Care and Use Certification

No animals will be used, collected, manipulated, nor experimented upon in the research required to complete the scope of work outlined in this proposal.

Fulfrost_Topic1

SPSR RFP Proposal questions and clarifications from the administrative review
Summary of e-mail below

Measuring Habitat Evolution Utilizing Satellite Imagery

Questions:

- 1. there appears to be 89,000\$ in overhead, can you clarify this line?**
- 2. what is included in the "fixed fee"?:**

Responses:

DC&E has used the standard government method of calculating our costs of actual costs plus overhead plus fixed fee.

DC&E's overhead rate is calculated by dividing our indirect expenses by our cost of direct labor. Similarly, the fringe benefit rate is calculated by dividing our indirect expenses by our cost of fringe benefits. An Excel spreadsheet is attached which shows the calculations and expenses which were disallowed for use in calculating the overhead rates.

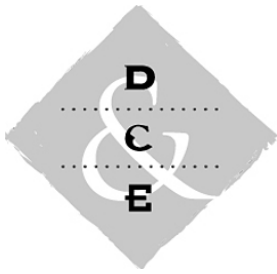
We are a for profit business. The "Fixed Fee" line is our profit percentage. The fee is calculated by adding together direct labor, fringe benefits and overhead, and then multiplying by the fixed fee.

Please feel free to contact me if you have any further questions about the budget or any technical questions regarding the proposal itself. We are excited to have been able to develop a proposal that can assist the south bay Salt Pond restoration project in meeting its goals. Thanks again.

Yes, there is that much in overhead. The reality is we lowered our rates somewhat significantly (~30%) for this project.

The hourly rate is what DC&E pays its employees (slightly discounted) without any overhead at all. We use this sheet to be extremely transparent - normally we would hide those costs.

Brian Fulfrost
Associate Principal
Design, Community & Environment
1625 Shattuck Avenue, Suite 300
Berkeley, CA 94709
Phone: 510.848.3815
Fax: 510.848.4315
Web: www.dceplanning.com



1625 SHATTUCK AVENUE
SUITE 300
BERKELEY, CA 94709
TEL: 510 848 3815
FAX: 510 848 4315
www.dceplanning.com

MEMORANDUM

DATE December 23, 2008
TO Cheryl Strong, US Fish and Wildlife Service
FROM Nancy Graham and David Early
RE **Overhead Rate Calculation**

This memo clarifies the overhead rate that DC&E used in its proposal for the *South Bay Salt Pond Restoration* project. We understand that there may be some confusion regarding this overhead rate, since various industries use the term “overhead rate” in different ways.

The overhead rate in our proposal is the same rate that we use in all government projects requiring us to invoice based on our labor costs plus overhead plus fixed fee. We have derived our overhead rate using rules promulgated by Caltrans and used throughout the engineering and planning professions.

DC&E's overhead rate is based solely on actual wages paid to individual workers. It is calculated by dividing our indirect expenses by our cost of direct labor. Similarly, the fringe benefit rate is calculated by dividing our indirect expenses by our cost of fringe benefits. Some expenses are disallowed in calculating the overhead rate, and those expenses were not used in our calculations.

DC&E can also bill its clients on a “loaded rate” basis, in which we bill for our employees' labor at “loaded” rates that cover all wages, benefits, and indirect costs. In this case, we do not charge any overhead separately. We would be happy to change our billing format to be based on these “loaded” rates, but our total cost for the project would be essentially the same.

Please do not hesitate to contact us if you have further questions.