STATE OF COLORADO
Colorado Water Conservation Board
Grant Agreement
with
Water Environment Research Foundation
Contract Number C150456

SCOPE OF PROFESSIONAL SERVICES

Demonstration of Membrane Zero Liquid Discharge Process for Drinking Water Systems

This project is administratively managed by the Water Environment Research Foundation (WERF), but the actual project work will be conducted through subcontractors.

WATER ACTIVITY NAME - Demonstration of Membrane Zero Liquid Discharge Process for Drinking Water Systems

GRANT RECIPIENT – Water Environment Research Foundation (WERF)

This project is administratively managed by the Grantee, the Water Environment Research Foundation, but the actual project work will be conducted by subcontractors (WERF will subcontract with HDR Engineering, and HDR will subcontract with MWH.)

FUNDING SOURCE[1] –
Water Supply Reserve Account (WSRA) grant funds, including:

- $700,000 from the WSRA Statewide fund,
- $50,000 from the Metro Basin WSRA fund,
- $25,000 from the South Platte Basin WSRA fund, and
- $25,000 from the Arkansas Basin WSRA fund.

I. Statement of Work (Scope of Work)

INTRODUCTION AND BACKGROUND

Increasing demands for potable water in Colorado have forced drinking water utilities to consider water supply from lower quality sources. These lower quality sources require the use of advanced treatment technologies such as reverse osmosis (RO) or nanofiltration (NF) membranes to treat the water to a level suitable for human consumption. At present, drinking water utilities have been reluctant to undertake RO or NF membrane projects due to the uncertainty surrounding the availability of feasible disposal options for the concentrate which may be of concern to wastewater treatment plants. Zero liquid discharge (ZLD) is a potentially sustainable disposal option that may represent a long-term solution to concentrate disposal for utilities that need membrane treatment to produce safe drinking water. The primary barrier to implementing ZLD is the lack of cost and performance data developed for drinking water systems under conditions unique to Colorado. A pilot test demonstrating ZLD

[1] This scope of services and budget also reflects WERF's match of $243,087[$88,000 in cash and $155,087 of in-kind (coming from partners)], of which $140,000 is required as the 20% match to the $700,000 from the WSRA Statewide Fund.

will help address the technical and financial uncertainties which currently hinder its implementation. With this knowledge, utilities will be more likely to undertake membrane projects that depend on lower quality water sources.

OBJECTIVES

Objectives of the pilot study include:

- Comparing the performance of two ZLD technologies;
- Developing capital, operating and maintenance costs for ZLD technologies;
- Determining the quantity and quality of the water recovered from the ZLD process;
- Characterizing the quantity and composition of brime/concentrate created by the process;
- Determining the handling, transportation and disposal requirements for brime/concentrate created by the process;
- Identifying potential marketable residuals from the ZLD process and summarizing applicable case studies;
- Disseminate information and results to the water quality community

TASKS

Task 0 – Project Review and Public Outreach Meetings

Description: The contractual Project Review portion of this task is comprised of Project Meetings held with the Project Subcommittee (PSC). This task also consists of project outreach to the Membrane Treatment Workgroup (MTWG) and the wider water community in Colorado. The purpose of the Project Subcommittee meetings is to solicit and obtain technical and programmatic guidance for the project from the Project Subcommittee formed by the Water Environment Research Foundation (see Task 9). The purpose of the public outreach meetings/workshops is to provide project status and technical transfer of information to interested parties represented in the MTWG and to provide technical transfer of information the wider Colorado water community. This task consists of three subtasks:

Task 0.1 - Participate in up to two meetings with the Project Subcommittee
Task 0.2 - Participate in up to four meetings with the Membrane Treatment Workgroup
Task 0.3 - Participate in up to two Outreach Workshops

Method/Procedure: Participate in meetings. Participation will include verbal presentation of relevant materials to the Project Subcommittee or MTWG.

Assumptions:

- Project Subcommittee and MTWG meetings will be held in Denver
- Duration of Project Subcommittee meeting is one and one half day
- Duration of MTWG meetings is one half day
- Workshops will be held in Denver, and one Colorado location outside the Denver area
- Duration of the Workshops is expected to be one half day

Deliverables:

- Attendance and briefings at meetings
- Briefing materials for the Project Subcommittee based on the Progress Reports
- Presentation at one national water quality community conference.

Task 1 – Perform Literature Review for Confirmation of Equipment/Processes Selected for Testing

Description: This contractual task is comprised of a review of the work completed by the State of Colorado Membrane Treatment Workgroup and the available literature on high-recovery reverse osmosis processes and zero liquid discharge technologies. Initially, a review of the previously completed MTWG report will be conducted to summarize all of the major conclusions of that report pertaining to the technologies to be tested. Once this step is completed, a review of the available literature will be conducted to update the conclusions of the MTWG report, and determine the most suitable technologies for the Brighton and La Junta pilot sites. The literature review will include high-recovery reverse osmosis as well as concentrate minimization, or zero liquid discharge technologies. The efforts of the literature review will be summarized in a Technical Memorandum (TM) and submitted in the first Periodic Progress Report. This task consists of two subtasks:

Task 1.1 – Perform Literature Review
Task 1.2 - Develop Technical Memo documenting results of Literature Review

Method/Procedure: Desk-top literature review documented in Technical Memo

Assumptions:

- Technical memo will be formatted for inclusion as a chapter in the project final report (Task 8.2)
- Technical memo will be reviewed prior to and approved by Project Subcommittee at the first Project Subcommittee meeting (Task 0.1). A failure by the Project Subcommittee to provide timely approval will require adjustment to project schedule and budget.

Deliverables and Due Dates:

- One (1) electronic copy of draft TM included in the First Periodic Progress Report (Task 8.1)
- One (1) electronic copy of final TM included in the Final Report (Task 8.2)

Task 2 - Develop Experimental and Sampling Plan

Description: This contractual Task is to develop the Experimental Plan for testing at the Brighton and La Junta sites. The Experimental Plan will contain the following: the objectives of the testing, equipment provided and site needs, success criteria of testing, breakdown of responsibilities, and the weekly or monthly test plan of major activities. Quality control procedures and any health and safety plans will be prepared, as required by the individual plant sites. The Experimental Plan will include a process flow diagram for each of the two sites showing major pieces of equipment, sampling locations and interface points for mechanical and electrical connections. The Experimental Plan will clearly define primary and secondary data types, and data acceptance criteria. It will also present data reporting and reduction and requirements and will be reviewed by the Project Subcommittee.

Develop the Sampling Plan for testing at the Brighton and La Junta sites. The Sampling Plan will address sampling and analytical requirements for both liquid and solid samples, generated from membrane concentrate. The Sampling Plan will contain at a minimum the following: sampling requirements, sampling locations, sampling frequency, analytical methods, chain of custody procedures and quality control procedures. The Sampling Plan will also coordinate the distribution of samples for analysis between utility laboratories providing in-kind laboratory services for the project.

This task consists of five subtasks:

Task 2.1 – Perform site visit (Brighton, La Junta)
Task 2.2 - Interface with equipment vendors
Task 2.3 – Identify permitting requirements
Task 2.4 - Develop and revise experimental plan
Task 2.5 – Develop and revise sampling plan

Method/Procedure: Identify experimental objectives and data requirements to evaluate if objectives have been met. Develop the plan in a logical order starting with the objective and outline the sequences necessary to produce the final delivery product for each site.

Assumptions:

- Experimental and Sampling Plans will be reviewed prior to and approved by the Project Subcommittee at the first Project Subcommittee meeting (Task 0.1)

Deliverables:

- One (1) electronic copy of the Draft Experimental Plan included in the First Periodic Progress Report (Task 8.1)
- One (1) electronic copy of the Draft Sampling Plan included in the First Periodic Progress Report (Task 8.1)
- One (1) electronic copy of the Final Experimental Plan included in the Second Periodic Progress Report (Task 8.1)
- One (1) electronic copy of the Final Sampling Plan included in the Second Periodic Progress Report (Task 8.1)

Task 3 – Design of Pilot Equipment and Site Coordination

Description: This contractual Task requires the preparation of the overall design for the pilot plants at each site. The design involves both the equipment design and the piping and electrical interconnections. Equipment lists, rough piping layouts, drainage requirements, equipment placement, and electrical connections/feeds will be designed. A schedule of activities will be prepared to outline the coordination and arrival of equipment and chemical feed systems. Pilot equipment rental contracts will be established and additional equipment procured during this phase. This task consists of five subtasks:

Task 3.1 – Site coordination (Brighton, La Junta)
Task 3.2 - Apply for permits (as required)
Task 3.3 – Vendor coordination
Task 3.4 - Develop site layouts
Task 3.5 – Develop equipment drawings

Method/Procedure: The Consultant will coordinate with each site and establish the location and coordination requirement for installation of the pilot equipment. Consultant will coordinate with vendors to integrate equipment onsite.

Assumptions:

- All electrical supply as well as connections to existing electrical feed sources will be provided by the Cities of Brighton and La Junta;
- Concentrate supply will be provided uninterrupted by the two cities;
- Sewer or other drains will be provided for any pilot plant discharge by the two cities.

Deliverables:

- None

Task 4 – Site Modifications/Installation of Pilot Equipment

Description: This contractual Task sets forth the necessary activities that the Consultant perform to oversee site modifications need to support the pilot test(s). Once the equipment arrives on site, the Consultant's pilot engineers shall arrive to oversee the installation. Pilot technicians and plumbers (as needed) will be required to install the mechanical elements of the pilot plant including tanks, pumps, and piping. Electrical connections to the pilot's central control panel will be provided by the site owner. Electrical connections from the pilot's central control panel to other pilot equipment will be made by the vendor under supervision of the Consultant. This task consists of four subtasks:

Task 4.1 – Oversee site modifications
Task 4.2 - Coordinate equipment shipping
Task 4.3 – Oversee equipment installation
Task 4.4 - Commission and start-up

Method/Procedure: Installation: In accordance with design drawings, local codes and National Electric Code (NECC).

Assumptions:

- Cities will provide labor for connections to any full-scale electrical and water connections.
- Cities will provide labor for disconnecting full-scale electrical and water connections upon completion of piloting.
- Consultant shall provide materials for connections to any full-scale electrical and water connections.
- Cities will provide level and accessible sites for installation of the pilot equipment.
- Consultant shall coordinate with selected vendors for delivery, unloading, handling, and placing pilot plant equipment.
- Consultant shall coordinate with selected vendors to handle, load, and remove equipment from each site upon completion of pilot testing.

Deliverables and Due Dates:

- Complete and operable pilot plant equipment at Brighton site.
- Complete and operable pilot plant equipment at La Junta site.

Task 5 – Operation of Pilot Plants

Description: This contractual Task requires the commissioning and start-up activities and operation of both pilot plants. During commissioning check-out of the hydraulics, electrical, and data and sampling collection methods will be established. Commissioning will include trouble shooting to minimize start-up activities.

Start-up of the pilot units involves determining the baseline conditions of each unit. Baseline conditions include the initial permeability or specific flux of RO membranes, cleaning procedures and frequencies and the feed flow rate. Establishing the baseline conditions is estimated to take between one and four weeks at each site depending on the equipment installed.

After the baseline conditions are established, the operation of the pilot plant will commence. Pilot equipment at each site will be operated for a minimum of three (3) months and a maximum of six (6) months. This will allow the testing of multiple conditions and firm establishment of operating conditions to determine costs.

This task consists of seven subtasks:

Task 5.1 – Operate pilot units - Brighton
Task 5.2 - Provide consumables
Task 5.3 – Decommission units – Brighton
Task 5.4 – Operate pilot units – La Junta
Task 5.5 - Provide consumables
Task 5.6 – Decommission units – La Junta
Task 5.7 – Provide rental equipment

Method/Procedure: Operations according to the "Experimental Plan" (Task 2.4) and "Sampling Plan" (Task 2.5)

***Assumptions*:**

- Consultant will provide "full-time" "technical/pilot support engineer(s)" at each of the two sites.
- It is not anticipated that both the Brighton and La Junta sites will be in start-up at the same time. It is anticipated that the second pilot plant will start up about three (3) months after the first site activity commences.
- While pilot plants may continue to operate over the weekends, operational changes and sampling is not expected to be conducted outside of the normal work week or normal working hours.
- Cities will provide:
    - Uninterrupted RO concentrate stream (except disruption for prescheduled maintenance and unexpected corrective or emergency repairs)
    - Once per day site checks of provided services (i.e. RO concentrate and electrical power) during normal work week hours
    - Any prescheduled amendments to WTP process for RO concentrate delivery during these once-per-day site checks.
    - Assistance with making unexpected repairs to pilot equipment and processes, if urgent and required.

Deliverables and Due Dates:

- Raw data from operating both plants under baseline and multiple conditions to establish operating conditions and determine capital and operating costs included in the third and fourth Periodic Progress Report (Task 8.1)

- Water and solid samples as described for analysis described in Task 6 included in the third Periodic Progress Report (Task 8.1)

Task 6 – Water Quality Sampling & Solids Analyses

Description: Sampling will be performed on the pilot equipment to monitor performance for real-time adjustments or optimization and to collect performance information for cost comparisons and capital and operational cost estimates. Some water quality sampling, such as pH, silt density index, and conductivity will be conducted on-site using handheld probes or test units. The remainder of the water quality will be collected with composite samplers or as otherwise defined by the sampling plan (Task 2.6).

Sampling will also be performed on solids slurry streams to collect performance information for cost comparisons and capital and operational cost estimates as well as for characterization of salt recovery options. These samples will be grab samples. In addition, the potential markets for recoverable salts will be identified for Colorado.

This task consists of three subtasks:

Task 6.1 – Liquid sample analysis
Task 6.2 - Solid sample analysis
Task 6.3 – Data reduction and analysis

Method/Procedure:

- Water analyses will be conducted in accordance with Standard Methods, latest edition. Modifications to this requirement will be allowed for analyzing high salinity samples and will be addressed in the Sampling Plan (Task 2.6)

***Assumptions*:**

- Samples will be 24 hour composites or as otherwise defined in the Sampling Plan (Task 2.6).
- Consultant shall collect samples and shall deliver or arrange for delivery of samples to laboratories.

- ***Deliverables and Due Dates:***
- Data analysis will be included in Period Progress Reports (Task 8.1), as pilot/sampling data becomes available.

Task 7 – Energy Evaluation and Support of Renewable Energy Study

Description: This task was designed to evaluate energy requirements and coordinate with a separate investigation and design project aimed at providing affordable renewable energy for ZLD.

Deleted – Renewable Energy Study has not been funded.

Task 8 –Reports

Description: Periodic progress reports will be prepared during the course of the project and a draft and final report will be prepared at the conclusion of the project. The progress reports will be provided by the Consultant to Water Environment Research Foundation for distribution, review, comment and approval by the Project Subcommittee. Copies of the progress reports will be provided to the Colorado Water Conservation Board (CWCB) by the Water Environment Research Foundation (see Task 9).

The draft final report will be provided by the Consultant to Water Environment Research Foundation for distribution, review, comment and approval by the Project Subcommittee. Copies of the draft final report and the final report will be provided to the Colorado Water Conservation Board (CWCB) by the Water Environment Research Foundation.

The periodic progress reports will provide the Water Environment Research Foundation and the Project Subcommittee information regarding the status and progress of the project. As noted above, deliverables under Tasks 1, 2, 3 and 6 will be included in the Progress Report.

The final report will contain information established for the experimental plan such as objectives, success criteria and the equipment descriptions. In addition, all of the water quality and operational data will be summarized and analyzed. The optimum operating parameters of each unit process will be established with capital and operating costs for the sizes of plants relevant to the needs of MTWG members. A mathematical relationship will be prepared with a graphical illustration that can be used to project costs for varying plant sizes. The accuracy of the equation and graph will be estimated by the Consultant and reviewed by the PSC.

The report is to include a section regarding "next best alternative" for utilities with impaired water quality as their source water.
This task consists of three subtasks:

Task 8.1 – Prepare Periodic Progress Reports
Task 8.2 - Develop draft final report
Task 8.3 – Revise and release final report to WERF

Method/Procedure: Use of the Experimental Plan and Sampling Plan as the basis and results from the pilot plant study to prepare the final report. Materials from the Periodic Progress Reports will be included in the final report as appropriate.

***Assumptions*:**

- Water Environment Research Foundation will provide copies of Periodic Progress Reports to CWCB
- Water Environment Research Foundation will provide copies of Draft Final Report and Final Report to CWCB
- Project Subcommittee will review the Draft Final Report and approve the Final Report, each within four weeks of submission.

Deliverables and Due Dates:

- Four (4) Periodic Reports during the course of the project.
    - One (1) electronic copy of each report will be provided of each Periodic Report
    - These reports will be due: 3 months after Project Start, 6 months after Project Start, 9 months after Project Start, and 12 months after Project Start
- One (1) electronic copy of the Draft Final Report due 14 months after Project Start
- One (1) electronic copy of the Final Report due 18 months after Project Start

Task 9 – Project Management by WERF

Description: WERF will oversee and manage the Research Project. WERF will enter into a research contract with HDR Engineering, Inc. to conduct the research and implement the tasks listed above in this Scope of Work. The research contract shall incorporate the objectives and details of the Research Project and the timetable for carrying out and completing the Research Project as well as the deliverables. WERF shall exercise its best efforts to enforce the principal investigator's performance under the Research Contract. The contractual portion of the project is expected to start somewhere between February 1st, 2011 and March 30th, 2011, and a projected end date of December 30th, 2012. WERF will implement its information dissemination activities and meet all other requirements of this Grant Agreement by June 30th, 2013. WERF will organize a Project Subcommittee (PSC) to provide technical review and advice on the Research Project progress. The PSC will provide feedback to the Research Team, advice on technical issues associated with the Research Project, and approval of the Final Report. The PSC will represent expertise from academia, technical professionals, water quality community (utilities) and regulatory agencies. WERF will also organize a Steering Committee to keep partners informed of the progress of the research. The Steering Committee will include one representative from each of the Contributing Partners (at Partner's discretion). WERF will publish the results of the Research Project ("Final Report") and make them available to the State of Colorado Water Conservation Board and the water quality community at large. WERF will apply its Peer Review procedures to provide technical review of the Research Project. WERF will manage the financial

aspects of the project paying invoices and submitting payment requests to the State of Colorado Water Conservation Board as set forth in this contract. WERF will coordinate the collection and documentation of the Partners' cash and in-kind contributions.

Method/Procedure:

- WERF will apply its Peer Review procedures to provide technical review of the Research Project implementing its EPA approved Quality Management Plan (QMP).

Deliverables and Due Dates:

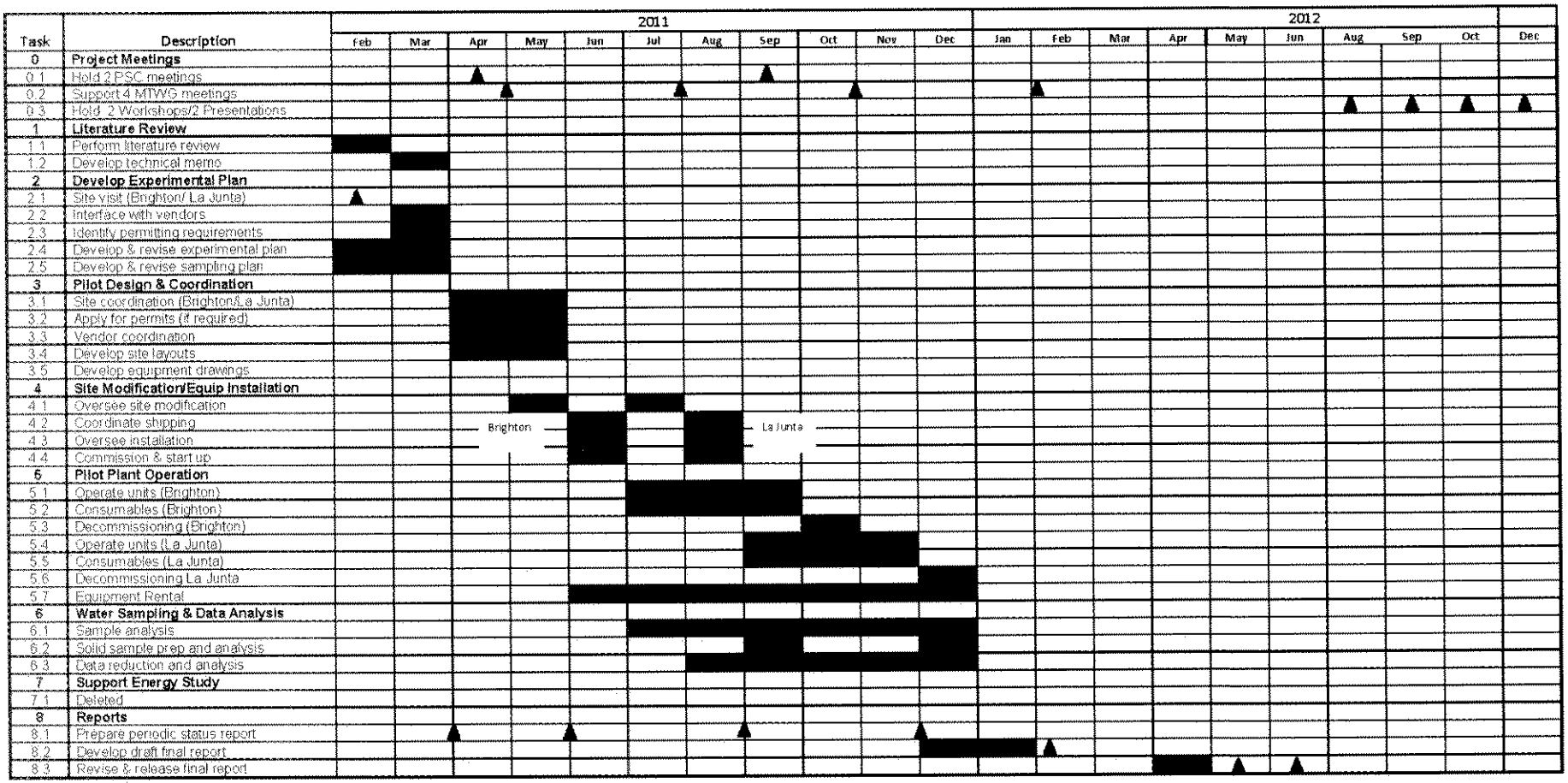
- Quarterly Reports (provided 30 days after the end of each Quarter) on the progress of the Research Project including a financial status of the activities;
- A Final Report on the project including all financial information (and close out materials) by no later than the last day of this agreement (June 30th, 2013);
- At least one Workshop in Denver, Colorado presenting the findings of the workshop to the water quality community of Colorado.

II. Personnel

Key personnel for the project are as follows:

Overall Project Manager –Jeff Moeller, PE: WERF
Support Project Management – Claudio Ternieden: Assistant Director of Research, WERF
Principal Investigator – Philip Brandhuber, PhD: HDR Engineering
Co-Principal Investigator – Karla Kinser, PE: MWH Americas
Project Engineers – Adriano Vieira, PhD: HDR Engineering,
Technical/Pilot Support Engineers – Stewart Bodtker: HDR Engineering, Engineer to be designated by MWH Americas

III. Schedule/Timetable for the Project Contractual Activities (Tasks 0-8)



IV. Budget

Water Environment Research Foundation			
Budget Detail - By Year			
Program: WERF Zero Liquid Discharge - Colorado TCR			
Program Period: February 1, 2011 - June 30, 2013			
Description	Total Budget	2011	2012/13
Personnel	$38,549	$28,629	$9,920
Fringe Benefits @ 26.37%	10,166	7,550	2,616
Travel	25,000	10,000	15,000
Equipment	0	0	0
Supplies	0	0	0
Contractual - HDR *	788,000	723,975	64,025
Other Expense **	14,952	4,008	10,944
Total Direct Costs	876,667	774,162	102,505
Indirect Costs @ 29.40%***	11,333	8,417	2,916
Total Costs	$888,000	$782,579	$105,421
In-Kind Costs Share	155,087	138,771	16,316
Total Value Including In-Kind Costs	$1,043,087	$921,350	$121,737
* HDR Contractual Project Budget (Attached)			
**Other Expense includes: Publications			
Rent allocation charges based on actual ratio of timesheet program charges.			
*** Indirect Costs @ 29.40% of Personnel (Salaries)			
Matching Funds: WERF's 20% (of Statewide Fund) required match is of $140,000.00 in cash and/or in-kind.			
This budget reflects the current contributions of $88,000 in cash and $155,087 of in-kind.			

HDR Contractual Project Budget WERF5T10

PERSONNEL (Applicant Organization Only)

Name	Project Role	% time	Salary Requested	Fringe Benefits	WERF Cost	In-Kind	Total Project Cost
Brandhuber	Principal		66142	31020	97162	45087	142249
Vieria	Project Engineer		37301	17494	54796		54796
Staff Engineer	Staff Engineer		31450	14750	46201		46201
Kwan	QA/QC		1748	820	2569		2569
Adminstrative	Clerical Support		835	391	1226		1226
Accounting	Admin Support		1658	778	2436		2436
				Subtotal	204389	45087	249476

OTHER DIRECT COSTS

EQUIPMENT (Use additional pages for itemization if necessary)				
Equipment Rental	30000			30000
Subtotal	30000	0		30000
SUPPLIES (Use additional sheets if necessary)				
Consumables	5000			5000
Subtotal	5000	0		5000
TRAVEL				
Domestic	22400	22400		22400
Foreign				
Subtotal	22400	0		22400
SUBCONTRACTS				
MWH	264000	264000		264000
Subtotal	264000	0		264000
DISADVANTAGED BUSINESSES (If none, steps taken by proposer must be described for justification to be accepted.)				
Subtotal	0	0		0
Other Costs (Itemize)				
Utility Lab Support	19957	45000		64957
Utility Site support		65000		65000
Subtotal	19957	110000		129957
TOTAL DIRECT COSTS:	545746	155087		700833
INDIRECT COSTS: 90.00 % (See instructions for calculation)	183950			183950
FEE (if applicable): % x (Personnel + Indirect Cost)	58305			58305
Total Cost	788000	155087		943088