Tailored Collaboration

Assessment of Single-Pass Ion Exchange and Adsorptive Media for Hexavalent Chromium Removal from Drinking Water

Submitted to:
Water Research Foundation

Submitted by: California Water Service Company

In association with

Originally Submitted August 29, 2011
Revised October 7, 2011

A. Cover Letter

August 29, 2011

Ms. Shonnie Cline
Senior Account Manager
Water Research Foundation
6666 West Quincy Avenue
Denver, CO 80235-3098

SUBJECT: Cal Water's Request for TC Funding to Study Additional Single-Pass Ion Exchange and Adsorptive Media for Cr(VI) Removal from Drinking Water

Dear Ms. Cline:

The California Water Service Company, in conjunction with the City of Glendale, propose additional research on at least four ion exchange medias and two iron based medias for chromium VI removal. This research builds on the work that Glendale has already done. Specifically, this study aims to test an additional source water that has different characteristics. Also, several newer technologies will be tested. This data is critical in developing national information on the cost to treat Cr(VI). Regulators will likely be using this data to determine an MCL. Utilities and municipalities will need this data to plan for future regulation. We believe that this is the top research need in the nation right now, and we are excited to contribute to the effort.

Our request is for $175,000, combined with $275,000 in matching funds from California Proposition 50 through the City of Glendale and an additional $100,000 from Cal Water, for a total of $550,000.

Chromium VI in drinking water supplies continues to be a great concern nationally, and particularly in the state of California. Most recently, the California Office of Environmental Health Hazard Assessment (OEHHA) has finalized a Public Health Goal (PHG) of 20 parts-per-trillion (ppt) for Cr(VI) as part of a California law to set a Maximum Contaminant Level (MCL).

While we know that WaterRF chooses the PAC, we have included a list of the long standing PAC for your information:

- Heather Collins, California Department of Public Health
- Sun Liang, Metropolitan Water District of Southern California
- Bruce Macler, U. S. Environmental Protection Agency
- Pankaj Parekh, Los Angeles Department of Water & Power
- Richard Sakaji, East Bay Municipal Utility District

The concerns with Cr(VI) in water supplies are ongoing. Our research effort will be closely followed by a number of researchers, regulators, and other water agencies that have this contaminant in their supplies and are seeking its removal.

Cal Water proposes to provide a $100,000 cash contribution towards this research effort and $100,000 as part of the City of Glendale's California Proposition 50 grant funds. To further this effort, a draft application package has been prepared by Dr. Nicole Blute, ARCADIS. ARCADIS has assembled an outstanding team to complete this effort.

WaterRF's involvement in this final phase will give this project the stature it deserves in the research community, and benefit the water community desiring to provide a better quality drinking water.

Cal Water appreciates your ongoing interest in this topic. Please contact Tarrah Henrie at (408) 318-3427 or thenrie@calwater.com, to discuss the application package and your participation in this project.

Sincerely,

Chet Auckly
Director of Water Quality

B. Co-Funding Support Form

TC CO-FUNDING SUPPORT FORM – California Water Service Company

Note: Each co-funding organization (including the sponsoring utility) must complete a separate Co-Funding Support Form and include it in the proposal.

Co-Funding Organization: California Water Service Company

Type of Organization: _x__water utility ____consulting firm ____ manufacturer ____other (describe)

Is your organization eligible to participate in one of The Foundation's subscription programs? __x_ Yes ____ No

Is your organization requesting that The Foundation match its funds? __x__ Yes ____No

Is your organization eligible for The Foundation matching funds? __x__ Yes ____No

Cash co-funding amount being provided by your organization (in USD) $ 100,000

Person responsible for contract matters for your organization:
Name: Michael Rossi
Address at which FedEx packages can be received: 1720 N. First Street, San Jose, CA 95112
Phone/Fax/e-mail: Phone: (408) 367-8245, Fax: (408) 367-8430, Email: mrossi@calwater.com

Person responsible for accounting matters for your organization:
Name: Calvin Breed
Address at which FedEx packages can be received: 1720 North First Street, San Jose, CA 95112
Phone/Fax/e-mail: Phone: (408) 367-8257, Fax: (408) 367-8425, Email: CBreed@calwater.com

What approvals will be required in order for your funds to be released to the Foundation? (e.g., City Council, Board of Commissioners)
Vice President of Engineering and Water Quality – Mike Rossi

Have these approvals been obtained? __x__ Yes ____ No

Can approvals be obtained and co-funding agreements be signed within 120 days of award? _x__Yes___No
(Note: 120 days after award notification the Foundation may cancel the award--see TC proposal guidelines for details.)

Are there any conditions of the Foundation Co-Funding Agreement that would prevent you from signing it as it is currently worded? __x___Yes _____No
If yes, please explain: (attach additional pages if required)
Because of the relationship between Glendale, Cal Water, and the State of California, there could be minor contract language revision.

The person signing below acknowledges they are authorized to commit their organization to the proposed work.

Signature________________________ Print Name Chet Auckly

Title Director of Water Quality Organization California Water Service Co.

Date ________________________ Phone (408) 367-8232

Mailing Address 1720 North First Street, San Jose, CA 95112

TC CO-FUNDING SUPPORT FORM – City of Glendale, California

Note: Each co-funding organization (including the sponsoring utility) must complete a separate Co-Funding Support Form and include it in the proposal.

Co-Funding Organization: City of Glendale, California

Type of Organization: _x__water utility ____consulting firm ____ manufacturer ____other (describe)

Is your organization eligible to participate in one of The Foundation's subscription programs? __x_ Yes ____ No

Is your organization requesting that The Foundation match its funds? __x__ Yes ____No

Is your organization eligible for The Foundation matching funds? __x__ Yes ____No

Cash co-funding amount being provided by your organization (in USD) $ 100,000

Person responsible for contract matters for your organization:

Name: Peter Kavounas
Address at which FedEx packages can be received: 141 N. Glendale Avenue, Level 4, Glendale, CA 91206
Phone/Fax/e-mail: Phone: (818) 548-2138, Fax: (818) 552-2852, Email: pkavounas@ci.glendale.ca.us

Person responsible for accounting matters for your organization:

Name: Leighton Fong
Address at which FedEx packages can be received: 141 N. Glendale Avenue, Level 4, Glendale, CA 91206
Phone/Fax/e-mail: Phone: (818) 548-3982, Fax: (818) 240-4754, Email: lfong@ci.glendale.ca.us

What approvals will be required in order for your funds to be released to the Foundation? (e.g., City Council, Board of Commissioners)
City Council

Have these approvals been obtained? __x__ Yes ____ No
Can approvals be obtained and co-funding agreements be signed within 120 days of award? _x__Yes___No
(Note: 120 days after award notification the Foundation may cancel the award--see TC proposal guidelines for details.)

Are there any conditions of the Foundation Co-Funding Agreement that would prevent you from signing it as it is currently worded? ___x__Yes _____No
If yes, please explain: (attach additional pages if required)
Because of the relationship between Glendale, Cal Water, and the State of California, there could be minor contract language revision.

The person signing below acknowledges they are authorized to commit their organization to the proposed work.

Signature____________________ Print Name James Starbird

Title City Manager Organization City of Glendale

Date ____________________ Phone (818) 548-4844

Mailing Address 141 N. Glendale Avenue, Level 4, Glendale, CA 91206

C. Proposal Cover Worksheet

TAILORED COLLABORATION PROPOSAL COVER WORKSHEET

Proposal Title:
Assessment of Single-Pass Ion Exchange and Adsorptive Media for Hexavalent Chromium Removal from Drinking Water

Sponsoring Utility (Foundation Subscriber submitting proposal):
California Water Service Company

Contact at Sponsoring Utility:
Name: Tarrah Henrie
Address: 1720 North First Street, San Jose, CA 95112
Phone: (408) 367-8376 Fax: (408) 367-8428 e-mail: thenrie@calwater.com

Co-Funding and In-kind Summary: (attach additional sheet if needed)

Organization Name	Cash Co-fund Amount	In-Kind Contribution Amount (sponsoring utilities)
1. California Water Service Company	$100,000	$0
2. City of Glendale, California	$100,000 (Proposition 50 funds)	$0
	Total Cash $200,000	**In-Kind** $0

<u>Project Personnel</u>
<u>Principal Investigator</u> (i.e., researcher responsible for conducting research)
Name: Peter Kavounas, Assistant General Manager
Organization: City of Glendale, California
Address: 141 N. Glendale Ave, Level 4, Glendale, California 91206
Phone: (818) 548-2137 Fax: (818) 552-2852 e-mail: PKavounas@ci.glendale.ca.us

<u>Person responsible for finalizing *Funding Agreement*</u> (i.e., research contract)
Name: Peter Kavounas, Assistant General Manager
Organization: City of Glendale, California
Address: 141 N. Glendale Ave, Level 4, Glendale, California 91206
Phone: (818) 548-2137 Fax: (818) 552-2852 e-mail: PKavounas@ci.glendale.ca.us

<u>Person responsible for accounting matters of contractor:</u>
Name: Leighton Fong, Civil Engineer
Address: 141 N. Glendale Ave, Level 4, Glendale, California 91206
Phone: (818) 548-3982 Fax: (818) 240-4754 e-mail: LFong@ci.glendale.ca.us

Foundation Funds Requested: $175,000 USD

Amount of Funds eligible for Foundation match: $200,000 USD

Amount of Funds not eligible for Foundation match: $175,000 USD

Total Cash Budget (Foundation Funds + All Co-Funding Cash): $550,000 USD

Total In-kind Contributions: $0 USD

Total Project Budget (Cash + In-kind): $550,000 USD

D. Project Abstract

California CDPH is mandated to set a Cr(VI) regulatory limit for Cr(VI) in drinking water, which is expected to be 2 to 3 years from now. The City of Glendale, California has been conducting nearly a decade-long research program on Cr(VI) removal options, yielding fruitful results to identify technologies.

Three primary technologies have been shown to achieve single-digit parts-per-billion levels: reduction/coagulation/filtration (RCF), weak-base anion exchange (WBA), and strong-base anion exchange (SBA). The RCF and regenerable SBA systems, while effective at achieving low parts-per-billion (ppb) levels, are too complex for many systems like many of those in the California Water Service Company (Cal Water) system. A regenerable SBA system may also not be sustainable due to the large volumes of brine waste that a utility might not be able to dispose. WBA offers the possibility of simple, once-through treatment but the one proven WBA resin has been shown to be problematic due to formaldehyde leaching (an identified human carcinogen) in demonstration testing. Although a temporary procedure was instituted to treat the WBA resin being tested at Glendale, the mechanism triggering formaldehyde release is unknown and studies are underway. Recently, several other potential media showing promising results in industrial settings have become available and are proposed for testing in this project.

The objectives of this study are to build upon existing research to identify and further test sustainable, cost-effective treatment options for removal of Cr(VI). This project will: (1) determine the effectiveness of potential single-pass technologies for removal of Cr(VI) and co-occurring contaminants on different water qualities, (2) assess the operational requirements of the treatment options, and (3) identify costs of treatment for these new approaches.

The research plan includes pilot-scale testing of ion exchange and adsorptive media. Two promising WBA ion exchange resins and up to three SBA ion exchange resins will be tested in two different water qualities to determine capacity and the impact of water quality differences on their capacity. The two WBA resins (Purolite S106 and ResinTech SIR-700) lack the formaldehyde backbone structure but may have a similar capacity to the formaldehyde-based Dow PWA7 resin based on industrial trials. These two WBA resins have epoxy polyamine backbones and the vendors state that no significant leaching of other parameters has been observed. In addition to the two WBA resins, up to three SBA resins that can be operated in single-pass mode (i.e., without brine regeneration) will be tested. The SBA resins offer a lower number of bed volumes treated but also a lower material cost and no pH adjustment, which may make them attractive for small wellhead treatment systems.

Pilot testing will also include evaluation of two adsorptive media for Cr(VI) removal efficacy. One of the adsorptive media (sulfur modified iron, or SMI) showed promise in Glendale's early bench-scale testing but was not ready for implementation due to operational issues. The media has reportedly evolved and is being implemented for nitrate removal. The other media (North American Höganäs Cleanit®) is a new approach using a permeable iron composite material. Entire system needs for all of the tested media will be assessed, including any pre- and post- treatment, residuals waste disposal, labor requirements, and costs.

This study is intended to provide water utilities with effective, simple treatment technologies for removal of Cr(VI), particularly for potential wellhead installations that require minimal operations. Cost curves for different influent concentrations and potential maximum contaminant levels (MCLs) will be developed for use by EPA and CDPH in setting an MCL for Cr(VI) to supplement the cost determinations in the Glendale

research. Results will be publicly disseminated in a final report, a peer-reviewed publication, and presentations intended for utilities, engineering firms, and the regulatory community.

The Principal Investigator on this study will be Mr. Peter Kavounas of the City of Glendale, California. Co-PIs will include Mr. Gary Witcher and Ms. Tarrah Henrie of California Water Service Company (Cal Water) and Dr. Nicole Blute of ARCADIS. Cal Water will be the sponsoring organization. The City of Glendale, led by Mr. Peter Kavounas, will be a participating utility in the study. Other utility partners and regulatory agencies have been involved in previous work that this study is based on, including the Cities of Los Angeles, Burbank, and San Fernando, USEPA, CDPH, ACWA, USBR, MWDSC, WaterRF, and industry.

In this project, Cal Water seeks $175,000 from WaterRF. Cal Water will provide $100,000 in cash. The City of Glendale will provide $275,000 in matching funds from California Proposition 50 funding through the City of Glendale, for a total project budget of $550,000.

E. Table of Contents

F. Project Description

REGULATORY HISTORY

Chromium is a naturally occurring element that is typically present in several valence states, with trivalent, Cr(III), and hexavalent, Cr(VI), chromium being the most common. While Cr(III) is an essential nutrient for humans, Cr(VI) compounds have been found to be carcinogenic by inhalation and ingestion. Although naturally occurring Cr(VI) can be reduced to Cr(III) by organic matter in the environment, Cr(VI) released by anthropogenic sources may persist in water and soils that contain low amount of organic matter (Johnson et al., 2006[1]; Loyaux-Lawniczak et al., 2001[2]; U.S. EPA, 1984[3]). Cr(VI) is considered to be more soluble in water than other types of chromium compounds (Loyaux-Lawniczak et al., 2001).

Cr(VI) is currently regulated under the federal limit for total chromium with an MCL of 100 µg/L. The current MCL was based on allergic dermatitis rather than cancer[4]. In the past few years, the toxicology of Cr(VI) was re-evaluated in a National Toxicology Program study. Based primarily on this study, the USEPA released its peer-review draft assessment of Cr(VI) toxicology for public comment in September 2010. The document identifies Cr(VI) as a carcinogen through ingestion, including from drinking water sources, and proposes a reference dose of 0.0009 mg/kg/day, which is much lower than the current reference dose of 0.003 mg/kg/day for total chromium. The reference dose serves as a predecessor to an MCL. If the proposed Cr(VI) reference dose is finalized, a separate MCL at a low parts-per-billion level is possible for Cr(VI).

The State of California currently has a lower MCL of 50 µg/L for total chromium. California State law requires CDPH to set a Cr(VI)-specific MCL. Adoption of this MCL depends on the CA Office of Environmental Health Hazard Assessment (OEHHA)'s publication of a Public Health Goal (PHG). OEHHA finalized the draft PHG at 0.02 µg/L on July 27, 2011, and now CDPH will perform cost-benefit analyses to set a Cr(VI) MCL. Utilities will be required to report exceedances of the PHG in the 2013 reporting cycle, contingent on the reporting level established for the Cr(VI) analytical method.

CHROMIUM(VI) OCCURRENCE

If the MCL is set at or below single-digit ppb levels, a significant number of sources in California would need treatment technologies for Cr(VI) removal. Throughout California, approximately 67% of sources tested for the Unregulated Chemical Monitoring Requirement (UCMR) had Cr(VI) at levels between 1 and 5 µg/L and 20% of sources had levels exceeding 5 µg/L. Further, California has a history of leading the charge in setting drinking water regulations that have been adopted nation-wide. The potential for a low Cr(VI) MCL, and changes in the federal standards as well based on National Toxicology Program (NTP) findings of Cr(VI) carcinogenicity in laboratory animals, are the principal motivations for drinking water utilities to better understand how to effectively remove Cr(VI) in their water supplies.

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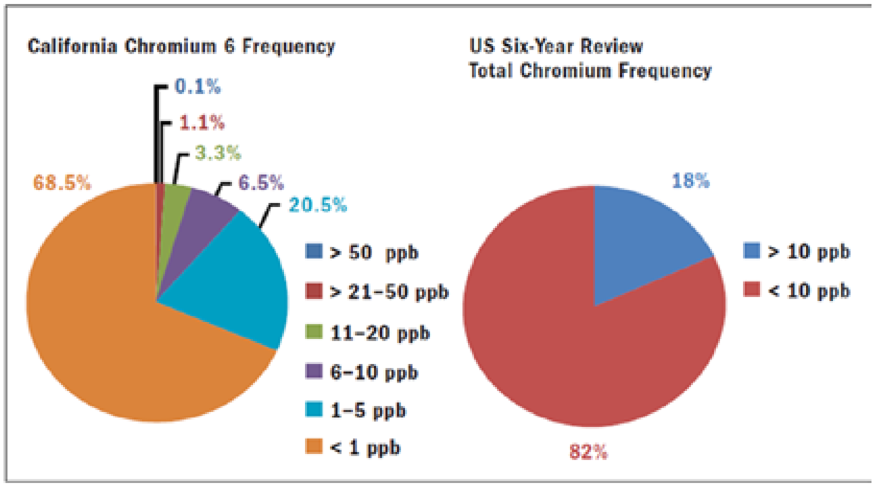
[1] Johnson, J; Schewel, L; Graedel, T.E. (2006). The contemporary anthropogenic chromium cycle. *Environ. Sci. Technol.* 40:7060-7069.

[2] Loyaux- Lawniczak, S; Lecomte, P; Ehrhardt, J.J. (2001). Behavior of hexavalent chromium in a polluted groundwater: Redox processes and immobilization in soils. *Environ. Sci. Technol.* 35:1350-1357.

[3] U.S. EPA (1984). *Health assessment document for chromium.* Final report. Cincinnati, OH: Environmental Criteria and Assessment Office. EPA 600883014F.

[4] U.S. EPA website: http://water.epa.gov/drink/contaminants/basicinformation/chromium.cfm

Figure 1. Chromium Occurrence in Drinking Water Supplies



Andrew Eaton, 2011. Hexavalent Chromium: It's DéJà Vu All Over Again. Opflow.

Cr(VI) in drinking water sources is expected to affect utilities nation-wide. Depending on the level at which a Cr(VI) MCL is set, a large amount of drinking water sources across the nation may need Cr(VI) treatment (Figure 1). However, treatment technologies for Cr(VI) removal have predominantly been developed for the treatment of industrial waste streams that contain Cr(VI) at levels significantly higher than that found in typical drinking water supplies (e.g. mg/L versus µg/L) and with treatment goals at the current MCL. The ability to remove Cr(VI) to low ppb levels was not certain before Glendale began their research campaign.

Previous Studies

Research to identify and test low level Cr(VI) treatment technologies for drinking water began in 2002 in Southern California. The City of Glendale has been leading the research program. The current demonstration testing builds upon prior bench and pilot studies (refer to Section H) to assess treatment technology feasibility and operational needs. Two technologies are being tested at the demonstration-scale based on the recommendations of Glendale's Project Advisory Committee (PAC): reduction/ coagulation/filtration (RCF) and weak-base anion exchange resin (WBA).

Each technology has advantages and disadvantages that must be weighed for a utility's specific needs. While the RCF process mechanism is fully understood and can adsorb influent concentration changes better than ion exchange, the WBA process is much simpler to operate. However, the tested WBA resin (Dow PWA7) was shown in demonstration testing to leach formaldehyde, which was recently announced by the NTP to be a human carcinogen. While procedures were instituted to reduce formaldehyde levels in treated water to below the California Notification Level of 100 ppb, Dow is returning to the laboratory to investigate the mechanism of release.

In demonstration-scale testing, the PWA7 resin was proven to operate to approximately 175,000 bed volumes before the effluent from the lead column reached 50% of the influent concentration (Figures 2 and 3). This number of bed volumes at a flow rate of 425 gallons per minute corresponds to a bed life of approximately one year.

Figure 2. Cr(VI) Removal with WBA Resin PWA7 in Demonstration Testing

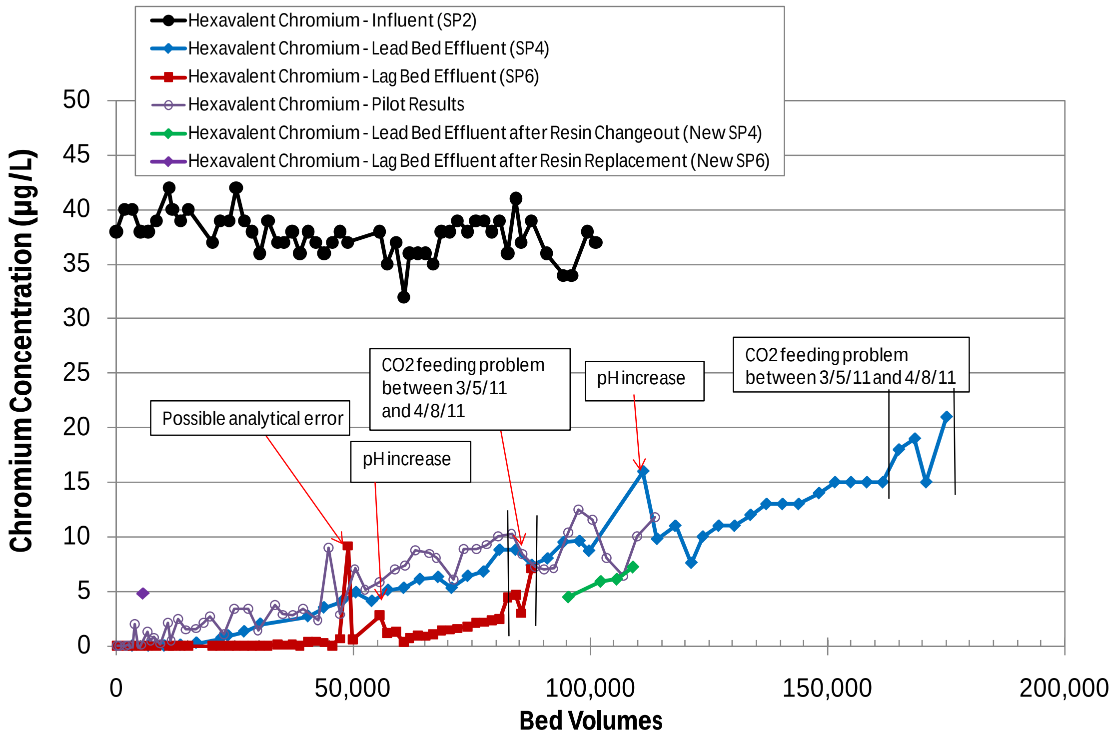
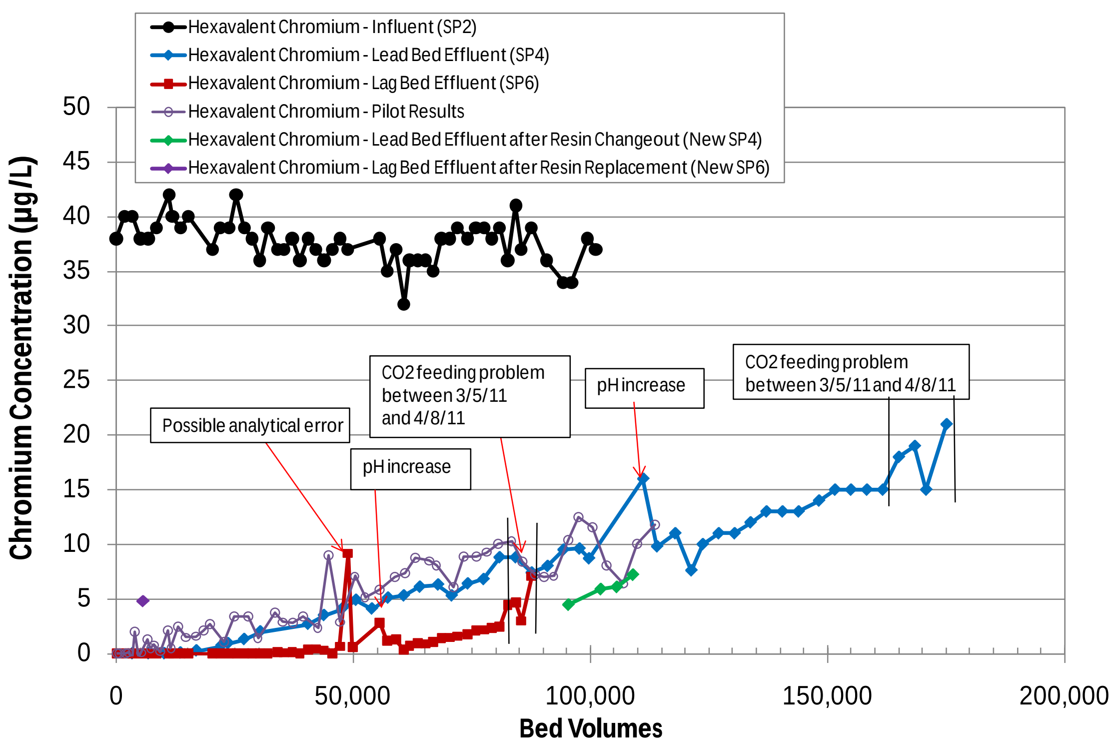


Figure 3. Total Cr Removal with WBA Resin PWA7 in Demonstration Testing



Research Approach

The objectives of this study are to build upon existing research to identify cost-effective treatment options for removal of Cr(VI) and potentially co-occurring contaminants (e.g., nitrate, arsenic, uranium). This project will accomplish the following objectives:

1. Determine the effectiveness of five single-pass media for removal of Cr(VI) in two different water qualities,
2. Assess the operational requirements of the treatment options, and
3. Identify costs of treatment (e.g., based on throughput and necessary water quality adjustments).

The proposed research will test a combination of single-pass media for removal of Cr(VI) as shown in Table 1, including three WBA resins, up to three SBA resins (which will be run sequentially; the total number tested will depend on the run lengths to remain within the 9 month window of testing), and two adsorptive media.

Table 1. Testing Matrix

Technology	Glendale (Well GS-3 water)	Cal Water Livermore (Well 12 water)
Ion Exchange		
WBA with pH adjustment - Purolite S106	Pilot at GS-3	Pilot at Well 12
WBA with pH adjustment – ResinTech SIR-700	Pilot at GS-3	Pilot at Well 12
WBA with pH adjustment – Dow PWA7	-	Pilot at Well 12*
SBA without pH adjustment – Dow SAR	Pilot at GS-3	Pilot at Well 12
SBA without pH adjustment – Purolite PFA6000	Pilot at GS-3	Pilot at Well 12
SBA without pH adjustment – TBD	Pilot at GS-3	Pilot at Well 12
Adsorptive Media		
Cleanit® by North American Höganäs	Pilot at GS-3	-≠
Sulfur Modified Iron (SMI-III)	Pilot at GS-3	Pilot at Well 12

* Dow PWA7 resin will be tested at the Livermore site as a control in case the results observed on the Livermore water quality varies significantly from Glendale.

≠ Note that North American Höganäs cannot commit to testing at both sites due to costs associated with supplying their pilot skid for more than 4 months.

ION EXCHANGE RESINS

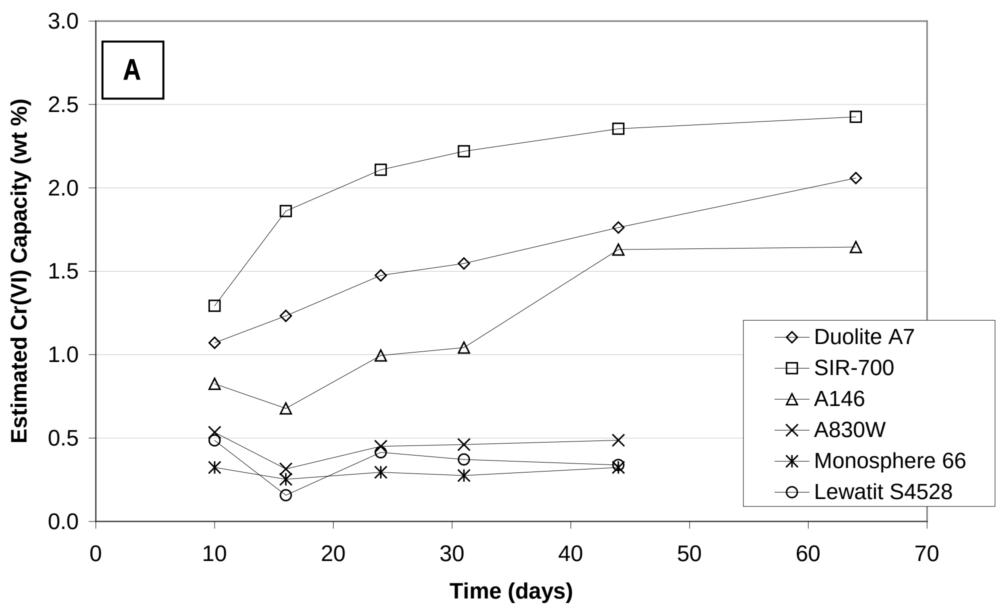
Three WBA resins will be tested at pilot-scale to assess resin capacity in Glendale and in the Cal Water Livermore system. Dow PWA7 will also be tested as a control in the Livermore system, but not for Glendale since pilot and demonstration testing have both been conducted on the Glendale GS-3 source already. Two additional WBA resins (Purolite S106 and ResinTech SIR-700) will be tested in this project. The mode of action for these resins involves reduction of Cr(VI) to Cr(III) and retention on the resins. For this reason, both Cr(VI) and total Cr will be monitored in conjunction during the testing to ensure that Cr(III), which can be reoxidized by chlorine or chloramines in a distribution system, is not reoxidized to Cr(VI). These two

WBA resins are considered epoxy polyamine resins, which differs from the phenol-formaldehyde (and secondary amine) structure of PWA7. The vendors of these two resins have stated that leaching of formaldehyde or other contaminants of concern is not expected.

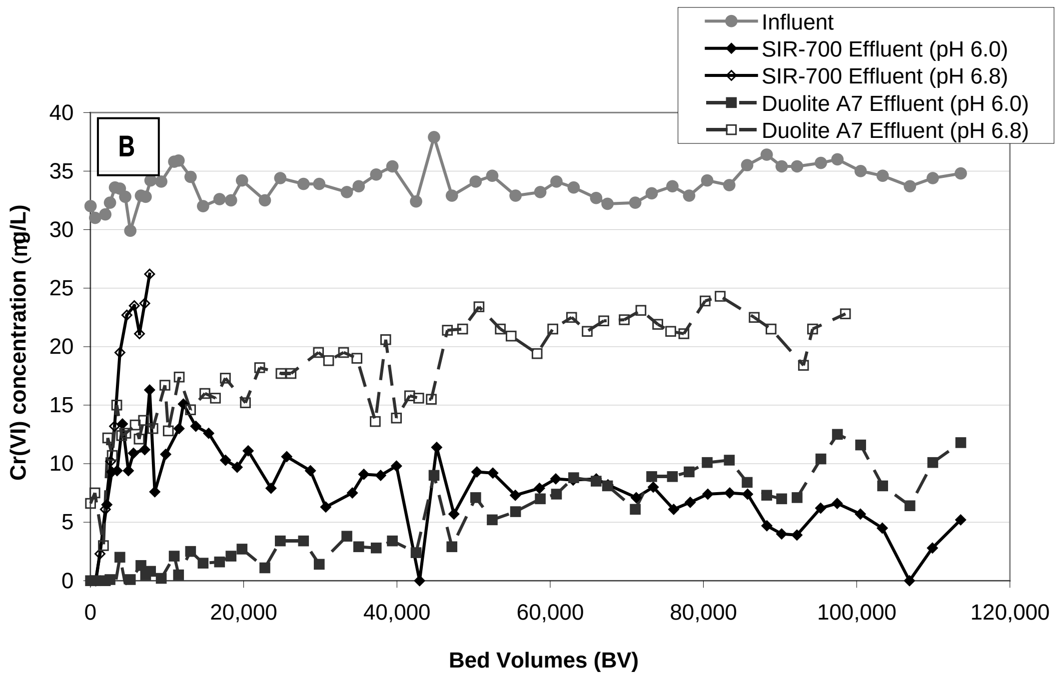
Testing will also reveal whether Cr(III) is removed by the WBA resins. The Cal Water Livermore site has a significant portion of Cr(III) in the groundwater (Table 2). By running the PWA7 as a control at the Cal Water Livermore site in conjunction with the other two WBA resins, the impact of water quality (including Cr speciation and other parameters) will be assessed.

Both of the new WBA resins have shown high Cr(VI) capacities, compared with SBA resins, in recent industrial applications using high influent Cr(VI) concentrations. ResinTech SIR-700 was tested in the Glendale Phase III Bridge Study, showing a high capacity in the isotherm tests exceeding that of the Dow PWA7 (Figure 4A) but an oddly shaped breakthrough curve (i.e., effluent concentration improving over time, as shown in Figure 4B). Subsequent ongoing studies at the Hanford Nuclear site in Washington have shown more than 40,000 bed volumes of water treated to less than 5 µg/L[5]. Testing at Argonne National Laboratories revealed that Cr(VI) reduction to Cr(III) and retention occurs by the resin, and that uranium retention is less than for the Dow PWA7 resin so that the SIR-700 resin may not become a mixed low-level radioactive waste during treatment.

Figure 4. Phase III Bridge Testing of WBA Resin SIR-700,
including Cr(VI) Capacity Determined in (A) Bench Testing and (B) Pilot Testing

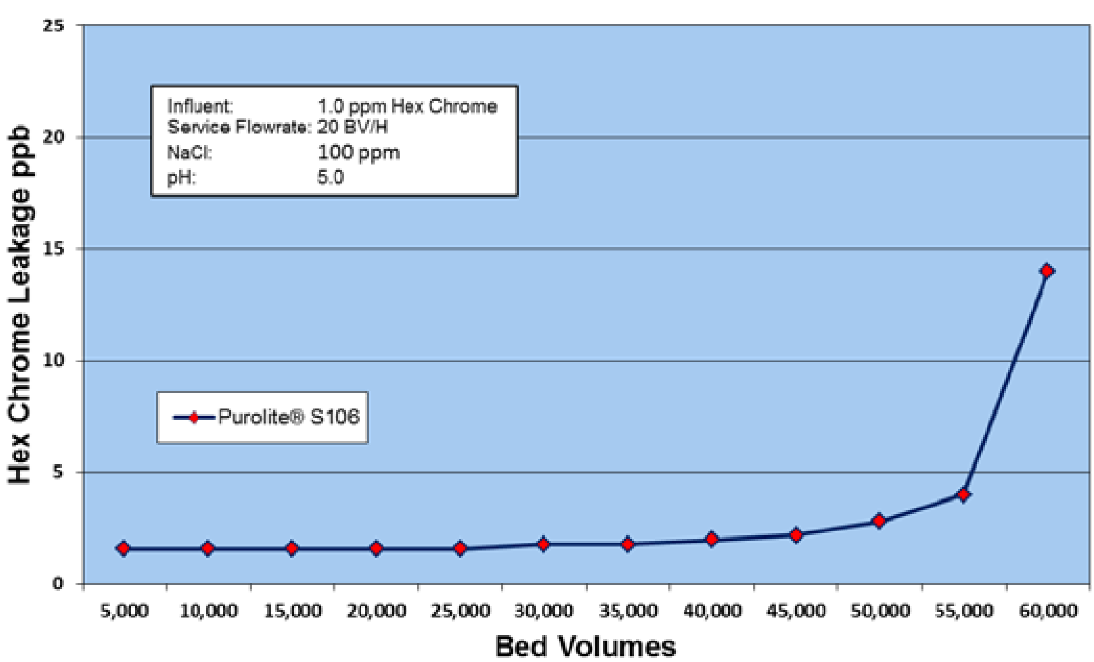


[5] Communications with Dean Neshem, Process Engineer at the Hanford Nuclear site, Washington, 27 July 2011.



Purolite S106 resin is also a WBA resin with an epoxy polyamine backbone similar to SIR-700. Both resins require pH adjustment to between 5 and 6 for effective Cr(VI) removal. Testing of S106 resin, as shown in Figure 5, revealed a capacity of 55,000 bed volumes to 5 µg/L for an influent Cr(VI) concentration of 1,000 µg/L. These preliminary results suggest that S106 may have a capacity on the order of PWA7 when operated at a lower influent concentration.

Figure 5. Purolite's Bench Testing of S106 WBA Resin for Cr(VI) Removal



Up to three additional single-pass ion exchange resins will also be tested. One column on each site's skid will be used for SBA resin testing. Since breakthrough is anticipated to occur for SBA resins well before the WBA resins, which will be operated at pilot scale for 9 months, we anticipate that up to 3 SBA resins can be tested during the 9 month testing duration.

The first resin to be tested, Dow SAR, is a Type II strong-base anion exchange resin with a styrene divinylbenzene gel matrix and dimethylethanol amine functional groups. The Dow SAR resin has a reportedly lower Cr(VI) capacity but a significantly lower cost and no need for pH adjustment so that it may become cost competitive with higher capacity WBA resins. Results of a full-scale, 615 gpm installation of Dow SAR for Cr(VI) treatment to a potable system in Colby, Kansas showed that approximately 9,000 bed volumes of water could be treated before the resin required replacement[6]. This system treats an average influent concentration of 125 μg/L with a Cr(VI) target effluent concentration of 17 μg/L. The resin is approximately half the cost of the PWA7 and may be cost-competitive with WBA resin the lack of pH adjustment for the Dow SAR resin is also considered.

Purolite has also indicated that they would recommend testing of an SBA resin called PFA6000/4740. This resin is anticipated to reach Cr(VI) saturation at approximately 10,000 bed volumes for Cal Water Livermore Well 12 water and 6,000 bed volumes for Glendale GS-3 water based on vendor modeling.

Other prominent resin vendors, including Calgon and ResinTech, will be invited to propose their best SBA resin for Cr(VI) removal and will be asked to estimate bed life to full breakthrough given Cal Water Livermore Well 12 and Glendale GS-3 water quality data. The top three SBA resins that are also NSF 61 certified and for which vendors provide actual breakthrough curves for Cr(VI) in groundwater will be prioritized for pilot testing. Up to three SBA resins will be tested in the pilot testing at each site.

ADSORPTIVE MEDIA

A couple of additional technology options have advanced in maturity that may also offer a simple operational approach to Cr(VI) removal. These adsorptive media may provide removal of other co-occurring contaminants and offer a simple option for treatment in small systems where an RCF process is untenable. This project will test Sulfur Modified Iron (SMI-III®) and Cleanit® technologies at pilot-scale for both Cal Water Livermore and Glendale water to determine their effectiveness and operational issues associated with the technologies.

SMI was shown in Phase I bench testing[7] to be effective for Cr(VI) removal but with drawbacks including iron leaching and increased headloss. SMI-III® is a later generation product also comprised of iron-based granular media that has recently been tested at the pilot scale for nitrate and arsenic removal[8]. Figure 6 shows the high capacity observed in Phase I bench testing of SMI resin at a pH of 7.0. Pilot-scale testing in Ripon, California showed removal of Cr(VI) from 4 μg/L to less than the detection limit used of 1 μg/L. In

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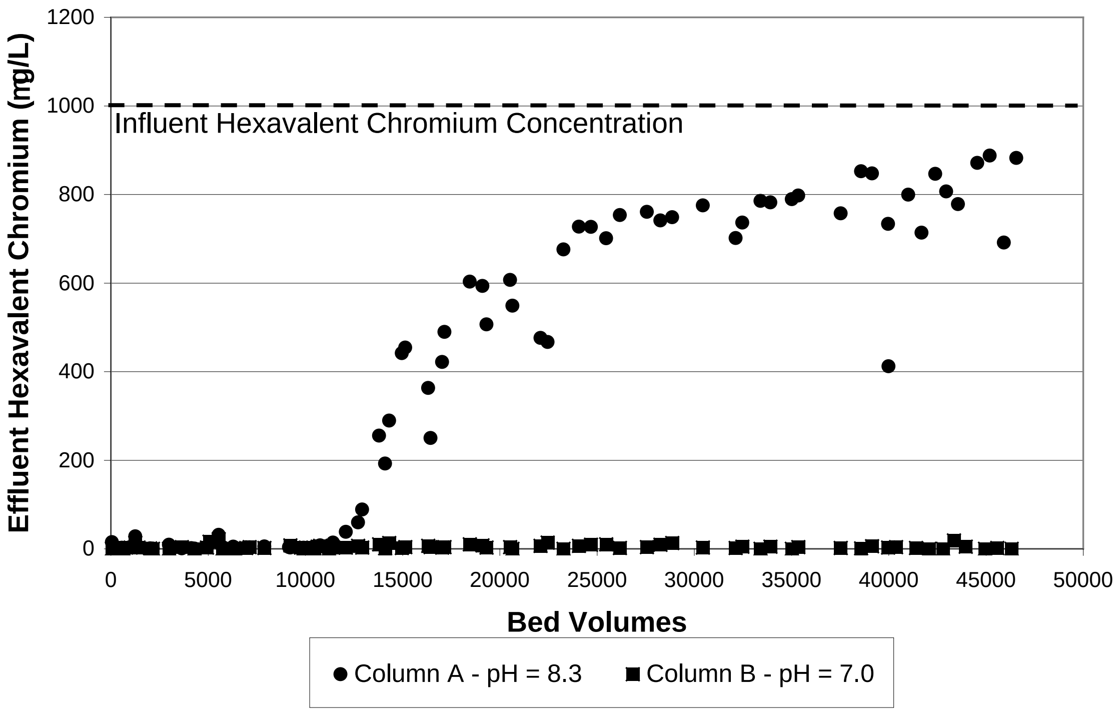
[6] USEPA, 2007. Remediation System Evaluation (RSE): ACE Services Superfund Site, Colby, Kansas. EPA 542-R-07-017, September.

[7] AwwaRF, 2004. Low-Level Hexavalent Chromium Treatment Options: Bench-Scale Evaluation. Authors: P.Brandhuber, M.Frey, M.McGuire, P.Chao, C.Seidel, G.Amy, J.Yoon, L.McNeill, and K.Banerjee.

[8] City of Ripon, California. 2010. Nitrate and Arsenic Treatment Demonstration. *Final Report to Proposition 50.* ID No. P50-3910007-055. http://www.cityofripon.org/EngineeringDepartment/Ripon-SMI-Pilot-Project-Final-Report_021010.pdf

systems requiring nitrate and/or arsenic treatment as well as Cr(VI), SMI-III® might offer an advantage since all three contaminants can be removed (albeit at potentially longer EBCTs, which requires testing), similar to regenerable SBA resin but without brine waste generation. SMI-III® is already NSF-61 certified for use in drinking water treatment.

Figure 6. Phase I Bench Testing of SMI Resin Cr(VI) Breakthrough
(Note that Total Cr data is not reported for this testing.)



A new NSF-61 certified porous iron composite media called Cleanit® LC (from North American Höganäs, Inc.) is also made from iron and reduces Cr(VI) to Cr(III) and co-precipitates and/or adsorbs the Cr(III). As shown in Figure 7, Cleanit® LC has been tested on the bench scale and has been shown to effectively reduce Cr(VI) from 500 µg/L to below the study MDL (7 µg/L) with empty bed contact times varying from 5 to 30 minutes, over several months of operation[9]. The manufacturer also reports that Cleanit® has demonstrated at the bench scale to convert up to 90% of nitrate to ammonia and nitrogen with a 30 minute EBCT. Cleanit® LC is viewed as an emerging but interesting technology at this point, requiring testing to determine the lower limits of Cr(VI) removal ability, operational issues, and costs of treatment.

[9] Communications with Sydney Luk, Vice President of Technology at North American Höganäs, 5 August 2011.

Figure 7. North American Höganäs Testing of Cleanit® Media for Cr(VI) Removal[10]

Hex-Cr Removal in Various Column Scales

Column	ϕ2-in	ϕ6-in	ϕ12-in
Media loading	100g	18 lbs	160 lbs
Test conditions			
flow rate	6 ml/min	135 ml/min	0.6 gpm
EBCT	10 min	30 min	30 min
operation time	63 days	72 days	39 days
treated water	141 gal.	4,211 gal.	33,700 gal.
Influent	groundwater	groundwater	tap water
spiked Cr6+, mg/L	0.51 (0.36~0.56)	0.49 (0.23~0.65)	0.094 (0.06~0.13)
Total Cr max limit, mg/L	0.05	0.05	0.05
Effluent			
Cr6+, mg/L (ave.)	0.007	0.007	0.007
(max)	0.025	0.032	0.027
total Cr, mg/L (ave.)	0.002	0.016	0.003
(max)	0.027	0.040	0.020

* MDL for total Cr: 0.007 mg/L

During operation, both of the iron-based adsorptive media have the potential to release iron into the water at levels above the secondary MCL of 300 µg/L. A second filter would likely be required downstream of the adsorptive filter to capture the released iron (e.g., granular media, ceramic, or microfilter) and will be tested in the pilot study. Depending on the adsorptive media and pH conditions, chlorine might be added to the water exiting the adsorptive filter to oxidize any residual iron to ferric iron, which then precipitates on the second filter.

IMPACT OF WATER QUALITY ON PERFORMANCE

Research to date has only proven one WBA resin to be effective for Cr(VI) removal, and that testing has only been conducted in one water quality (Glendale). A critical need exists to test treatment options in more than one water quality. Vast differences in treatment effectiveness were observed for arsenic treatment media in preparation for the Arsenic Rule; this research will add another dimension to our understanding of treatment technology effectiveness by testing Cr(VI) treatment by different resins in both Glendale water and water from Cal Water's Livermore system in Northern California.

Known parameters that can impact ion exchange and adsorptive media through competition for sites include silicate, phosphate, sulfate, and nitrate. The Cal Water Livermore water quality from Well 12 provides higher nitrate and silicate concentrations, as well as lower sulfate and chromium levels, as shown in Table 2. This pilot testing is intended to observe any potential variation in resin and adsorptive media capacity for two different water qualities, as well as to identify any operational differences. If results show that water quality can have a significant impact on Cr(VI) capacity, additional testing may be warranted to specifically identify parameters that impact the media performance.

[10] Hu, B. and Luk, S. 2011. Removal of Contaminants from Groundwater by a Porous Iron Composite Media with High Permeability. *Proceedings of the American Water Works Association Annual Conference and Exhibition.* Washington, D.C.

Table 2 – Comparison of Average Water Qualities for Two Systems

Raw Water Quality Parameter	Glendale (Well GS-3)	Cal Water Livermore (Well 12)
Cr(VI) (ppb)	40	10
Total Cr (ppb)	38	22
Uranium (ppb)	3.36	ND to 3.3
pH	6.8	7.4
Sulfate (mg/L as SO_4)	93	48
Nitrate (mg/L as N)	6.5	10
Phosphate (mg/L as PO_4)	0.28	NA
Arsenic (ppb)	0.5	1.5
Silica (mg/L as SiO_2)	34	46
Alkalinity (mg/L as $CaCO_3$)	191	309
Hardness (mg/L as $CaCO_3$)	350	424
Turbidity	0.29	0.5

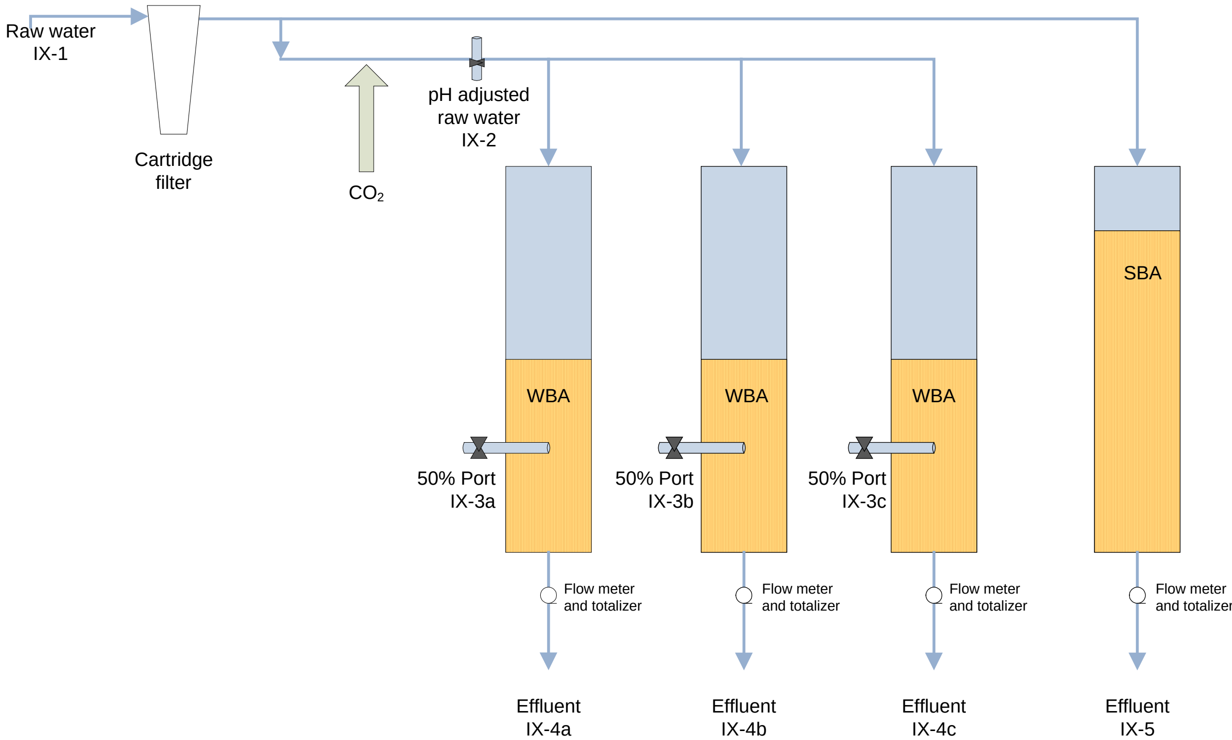
NA = Not Available

Ion Exchange Pilot Testing Treatment Systems. The ion exchange pilot testing systems will consist of one skid per site (Glendale GS-3 and Cal Water Livermore Well 12) for ion exchange. The skid will include coarse filtration to remove sand and minimize backwashing, pH adjustment, 2.5 inch diameter downflow resin columns with a screened sampling port at 50% bed depth and a total of 2 minute empty bed contact time (EBCT) for each resin, and a flow meter and totalizer on each column (Figure 8). WBA resin requires pH depression to protonate the functional group sites and allow for effective removal of contaminants. For pilot testing, influent water from the wells will be pH-adjusted for testing of the WBA resins by the addition of carbon dioxide from the initial pH of approximately 6.8-7.4 to a pH of 6.0 (with an acceptable range of 5.7 to 6.3). A WBA bed depth of 12.8 inches is anticipated, providing an aspect ratio (height to column width) of 5 (i.e., exceeding a recommendation of at least 4 according to Dow). An approximate resin bead to column diameter ratio of approximately 40 will be used, which is lower than the ratio of 100 recommended for filtration studies[11] but has been shown to be effective when previous Bridge Study pilot testing estimates of bed life using a 2.5 inch column were replicated at the demonstration-scale facility. In addition, Dow states that pilot columns greater than approximately 0.75 inches typically scale up linearly with respect to predicting bed life[12].

SBA resins will be tested consecutively in one column on the skid without pH adjustment. SBA will be tested with a larger bed depth and higher hydraulic loading rate (8 gpm/sf for SBA vs. 4 gpm/sf for WBA) as recommended by vendors. When the SBA column resin reaches the point of influent concentration equaling effluent concentration, the old SBA resin will be removed from the column and a new one added. Up to three SBA resins will be tested in this consecutive fashion.

[11] S. Kawamura. 2000. Integrated Design and Operations of Water Treatment Facilities. Wiley.
[12] Dow Tech Facts: Lab Guide.
http://msdssearch.dow.com/PublishedLiteratureDOWCOM/dh_003b/0901b8038003b90e.pdf?filepath=liquidseps/pdfs/noreg/016-00003.pdf&fromPage=GetDoc

Figure 8 – Schematic of Pilot Testing Skid for Ion Exchange



Adsorptive Media Pilot Testing Treatment Systems. Pilot-scale testing of adsorptive media will be conducted to assess capacities in the two water qualities shown in Table 9. Each of the adsorptive media vendors will provide a containerized pilot skid, as depicted in Figures 10 and 11. The SMI-III® pilot unit will be tested consecutively at Cal Water Livermore then the City of Glendale well sites. Due to costs associated with running their pilot unit, the Cleanit® pilot unit will only be available for 4 months of operation. We propose to test the SMI-III® system first at Cal Water Livermore due to the proximity to the vendor's headquarters and availability for troubleshooting assistance. Hence, the Cleanit® pilot unit would be tested only at the City of Glendale.

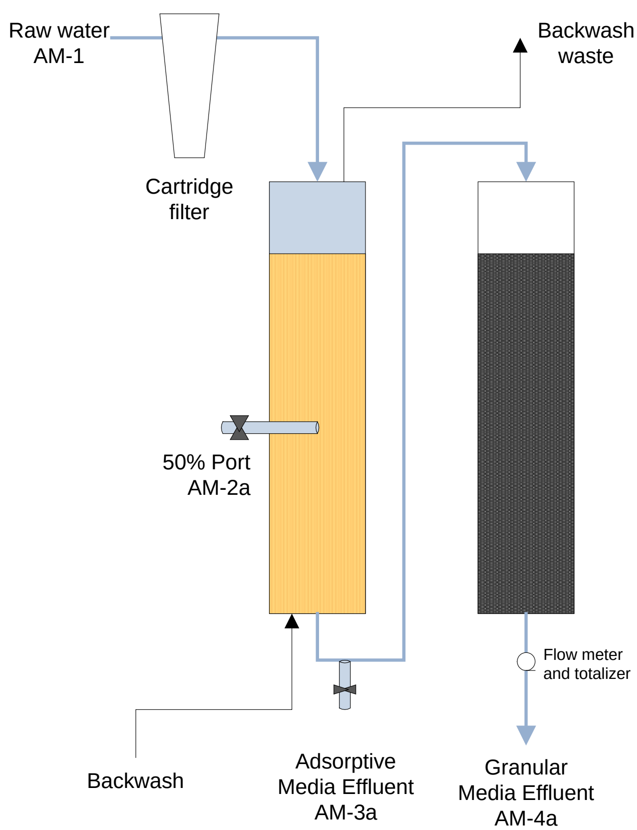
The North American Höganäs Cleanit® pilot skid will consist of one upflow 12" diameter, 32" bed depth column consisting of Cleanit® iron composite media. An effective particle size of 0.25 mm and a column diameter of 12" provide a ratio of column diameter to effective filter media size of approximate 1,200, exceeding the recommended value of 1,000 for minimizing sidewall effects during backwashing of granular filters[13]. An EBCT of approximately 3 minutes will be targeted in the column. A downflow polishing column consisting of sand or anthracite will be used to remove any particulate iron released from the Cleanit® media. North American Höganäs is planning to install a 50% bed depth sampling point to their column. The Cleanit® column is anticipated by the vendor to be backwashed approximately every 4 days and the polishing column about half as often. The skid will have the capability to adjust pH if necessary. Preliminary

[13] S. Kawamura. 2000. Integrated Design and Operations of Water Treatment Facilities. Wiley.

testing[14] has shown that an increased pH may be necessary to lessen dissolved iron leaching if influent pH is less than 6.5; at typical neutral values of 7 to 9, no pH adjustment is expected.

SMI has teamed up with Loprest Water Treatment to provide a containerized pilot unit. The SMI-III® pilot unit will consist of one upflow 12" diameter, 48" bed depth column consisting of SMI-III® iron media. The media is anticipated to be approximately the same mesh size or smaller than Cleanit®, based on prior testing[15]. An EBCT of approximately 3 minutes will be targeted in the column, and if effective, the vendor suggests decreasing the EBCT to 1 or 2 minutes. The adsorptive media column will be set up for upflow operation to prevent clogging if iron is released. A downflow polishing column consisting of sand or activated carbon will be used to remove any particulate iron released from the media. The SMI-III® column is anticipated by the vendor to be backwashed every day for 10 to 15 minutes and the polishing column about every 2 to 3 days. An automated pH adjustment system will be provided to decrease pH by between 1 to 1.5 pH units to counteract the natural increase in pH that is expected, and also to improve Cr(VI) removal.

Figure 9 –Schematic of Pilot Testing Skids for Adsorptive Media



[14] Communications with Tom Lavis, North American Höganäs, 16 August 2011.
[15] City of Ripon, California. 2010. Nitrate and Arsenic Treatment Demonstration. *Final Report to Proposition 50.* ID No. P50-3910007-055. http://www.cityofripon.org/EngineeringDepartment/Ripon-SMI-Pilot-Project-Final-Report_021010.pdf

Figure 10 –Photograph of Cleanit® Pilot Unit

Figure 11 –Photograph of SMI-III® Pilot Unit

Sampling and Analysis. Figure 8 shows the sampling locations on the ion exchange skid represented by "IX". Sampling locations for WBA resins include raw water (before pH adjustment, designated as IX-1), WBA influent (after pH adjustment, IX-2), test column 50 percent bed depth (IX-3a,b,c), test column effluent (IX-4a,b,c). SBA column testing locations will include test column effluent (IX-5).

Figure 9 shows the sampling for the pilot testing of adsorptive media represented by "AM". Sampling locations for adsorptive media resins include raw water (with pH adjustment, designated as AM-1), test column 50 percent bed depth (AM-2a,b), test column effluent (AM-3a,b), granular media filtration (AM-4a,b).

The monitoring locations and sampling frequencies for the water quality parameters in ion exchange testing are summarized in Tables 3 and 4. Critical water quality parameters that will be measured for the ion exchange resins include Cr(VI), total chromium, nitrate, sulfate, silicate, phosphate, uranium, and pH. Previous testing has highlighted the importance of pH depression and constant pH control for the effective operation of WBA resin. Other chemical and physical parameters, including temperature, conductivity, turbidity, and alkalinity will be routinely measured to fully characterize water quality. Arsenic will also be measured to identify if any arsenic removal is observed by the resins (noting that the influent concentrations are low at the two locations). Nitrosamines and formaldehyde, which have been found to leach from ion exchange resins, will be measured during startup and midpoint during operation after a start/stop procedure to assess any leaching. In addition, a broad scan for tentatively identified compounds (TICs) for both volatile organic compounds (VOCs) and synthetic volatile organic compounds (SVOCs) will be conducted initially and midpoint through operation to ensure that treatment does not introduce another contaminant of concern like the PWA7 resin leached formaldehyde.

Besides chemical and physical water quality analyses, process-related parameters will be recorded to evaluate operations. The process-related parameters include flow rate, backwash frequency (if necessary), EBCT, and numbers of bed volumes to breakthrough (> 5 ppb) at the 50% port.

Table 3. Sampling and Analysis Frequency for Ion Exchange Resins

Analytical Measurement	Monitoring IX-1 (Raw water)	IX-2 (Post-pH adjustment)	IX-3a,b,c,d (50% Port)	IX-4a,b,c,d (WBA Effluent)	IX-5 (SBA Effluent)	Residuals Spent Resin
Cr(VI)	–	W	W	W	3xW	–
Total Cr	–	W	W	W	3xW	–
Nitrate (NO_3^-)	–	M	M	M	W	–
Uranium	–	M	M	M	W	O
Arsenic (V)	–	M	M	M	W	–
Total Arsenic	–	M	M	M	W	–
pH	W	W	W	W	W	–
Sulfate (SO_4^{2-})	–	M	–	M	W	–
Phosphate (PO_4^{3-})	–	M	–	M	W	–
Silicate	–	M	–	M	W	–
Alkalinity	–	M	–	M	W	–
Conductivity	–	M	–	M	W	–
Nitrosamines	–	S*,MP	–	S*,MP	S*,MP	–
BNA SVOCs and TICs	–	S,MP	–	S,MP	S,MP	–
VOCs and TICs	–	S,MP	–	S,MP	S,MP	–
Formaldehyde	–	S,MP	–	S,MP	S,MP	–
Styrene	S, MP	–	–	S, MP	S, MP	–
TCLP, CWET	–	–	–	–	–	O

Notes:
Testing length expected is 9 months for WBA resins and 3-4 weeks for each SBA resin.
W: Weekly; M: Monthly; O: Once when spent; S: Start-up (first 2 days); MP – Midpoint through test period after a start/stop cycle.
* Nitrosamines sampling will be conducted at first flush, 1 hour, 4 hours, 24 hours, and midpoint through the test period.
BNA SVOC = base, neutral, acid semi-volatile organic compounds including phenol and tentatively identified compounds (TICs)
CWET = California Waste Extraction Test
TCLP = Toxicity Characteristic Leaching Procedure

A weekly sampling frequency for the WBA resin columns corresponds to approximately 5,000 bed volumes of water treated for the effluent sampling point. The 9 month testing duration will provide approximately 200,000 bed volumes to enable capture of a breakthrough curve for the two WBA resins consisting of about 40 data points. By comparison, a breakthrough curve for 200,000 bed volumes for the PWA7 resin would reach more than half the influent concentration for a 40 ppb influent Cr(VI) level. Since the Cal Water Livermore water quality is lower in Cr(VI) at approximately 22 ppb, a 9 month testing duration may not reach half the influent concentration unless other water quality parameters significantly impact Cr(VI) capacity. Overall, a nine month testing period is expected to capture the breakthrough to at least 5 ppb breakthrough and perhaps to a higher percentage.

SBA resins are expected to breakthrough much sooner than the WBA resins. Based on a mass balance calculation of resin capacity in a Colby, Kansas installation (assuming that water quality impacts are not significant), influent concentrations of 40 ppb Cr(VI) for Glendale and 22 ppb Cr(VI) for Cal Water Livermore might yield between 25,000 and 50,000 bed volumes. However, the Dow SAR resin is known to be impacted by sulfate and the Colby installation has low sulfate concentrations. By comparison, SBA resin PFA6000/4740 from Purolite is anticipated to reach Cr(VI) saturation at approximately 10,000 bed volumes for Cal Water Livermore Well 12 water and 6,000 bed volumes for Glendale GS-3 water based on vendor modeling. Thus, for the SBA testing, samples will be collected three times per week for the SBA resins to capture breakthrough curves at a frequency of every 2,000 bed volumes. Note that SBA testing is anticipated to occur for a two to three month period when analytical turnaround times and projected bed lives of three SBA resins are taken into consideration.

A weekly adsorptive media sampling frequency corresponds to approximately 500 to 750 bed volumes of water treated at the effluent point, and 1,000 to 1,500 bed volumes for the 50% port, depending on the unit. Over 4 months of operation, approximately 18,000 to 27,000 bed volumes will be captured.

Table 4. Sampling and Analysis Frequency for Adsorptive Media

	Monitoring Locations				
Analytical Measurement	AM-1a,b (Raw water)	AM-2a,b (50% Port)	AM-3a,b (Effluent)	AM-4a,b (Polishing Column Effluent)	Residuals Spent Resin
Cr(VI)	W	W	W	W	–
Total Cr	W	W	W	W	–
Nitrate (NO_3^-)	B	B	B	–	–
Ammonia (NH_3)	B	B	B	–	–
Nitrite (NO_2^-)	B	B	B	–	–
Uranium	B	B	B	–	O
Arsenic (V)	B	B	B	–	–
Total Arsenic	B	B	B	–	–
pH	W	W	W	–	–
Sulfate (SO_4^{2-})	B	–	M	–	–
Phosphate (PO_4^{3-})	M	–	M	–	–
Silicate	M	–	M	–	–
Total Iron	W	–	W	W	–
Fe(II)	W	–	W	W	–
Alkalinity	M	–	M	–	–
Conductivity	M	–	M	–	–
Nitrosamines	S*,MP	–	S,MP	–	–
BNA SVOCs and TICs	S,MP	–	S,MP	–	–
VOCs and TICs	S,MP	–	S,MP	–	–
Formaldehyde	S,MP	–	S,MP	–	–
TCLP, CWET	–	–	–	–	O

Notes:
Testing length expected is 6 months.
W: Weekly; B: Biweekly (every other week); M: Monthly; O: Once when spent; S: Start-up (first 2 days); MP – Midpoint through test period.
* Nitrosamines sampling will be conducted at first flush, 1 hour, 4 hours, 24 hours, and midpoint through the test period.
BNA SVOC = base, neutral, acid semi-volatile organic compounds including phenol and tentatively identified compounds (TICs)
CWET = California Waste Extraction Test
TCLP = Toxicity Characteristic Leaching Procedure

Descriptions of analytical methods for each water quality parameter are provided in Table 5.

Table 5. Analytical Methods

Analysis	Analytical Method	Analysis Location	Method Detection Limit (MDL)	Notes
Cr(VI)	EPA 218.6	ELAP-certified lab	0.010 µg/L	
Total Cr	EPA 200.8	ELAP-certified lab	0.088 µg/L	
Nitrate (NO_3^-)	EPA 300.0	ELAP-certified lab	0.009 mg/L	
Ammonia (NH_3)	Hach 8155	Field	0.05 mg/L as N	
Nitrite (NO_2^-)	EPA 300.0A	ELAP-certified lab	0.05 mg/L as N	
Uranium	EPA 200.8	ELAP-certified lab	0.001 mg/L	
Arsenic (V)	EPA 200.8	ELAP-certified lab	1 µg/L	
Total Arsenic	EPA 200.8	ELAP-certified lab	1 µg/L	
pH	SM 4500H+ B	Field	N/A	
Temperature	SM 2550	Field	N/A	
Sulfate (SO_4^{2-})	EPA 300.0A	ELAP-certified lab	0.5 mg/L	
Orthophosphate (PO_4^{3-})	SM 4500P-E	ELAP-certified lab	0.01 mg/L	
Silicate	EPA 200.7	ELAP-certified lab	0.2 mg/L	
Total Iron (Fe)	EPA 200.7	ELAP-certified lab	0.02 mg/L	
Fe(II)	Hach 8145	Field	0.02 mg/L	
Sulfide	Hach 8131	Field	0.005 mg/L	
Alkalinity	Hach 8203	Field	10 mg/L as $CaCO_3$	
Conductivity	SM 2510B	Field	N/A	
Turbidity	SM 2130 B	Field	0.02 NTU	
Nitrosamines (9)	EPA 521	ELAP-certified lab	1 ng/L	
BNA SVOCs and TICs	EPA 625	ELAP-certified lab	Varies by compound	
VOCs and TICs	EPA 524.2	ELAP-certified lab	Varies by compound	
Formaldehyde	EPA 556	ELAP-certified lab	0.005 µg/L	
Styrene	EPA 8260	ELAP-certified lab	0.0005 mg/L	
Residuals – TCLP	EPA 1311	ELAP-certified lab	Varies by element	
Residuals – CWET	CWET (Title 22)	ELAP-certified lab	Varies by element	
Residuals – Uranium	ASTM5174-91	ELAP-certified lab	0.004 mg/kg	

Notes:
ASTM = American Society of Testing and Materials
BNA SVOCs = base, neutral, acid semi-volatile organic compounds including phenol and tentatively identified compounds (TICs)
CWET = California Waste Extraction Test; TCLP = Toxicity Characteristic Leaching Procedure
ELAP = Environmental Laboratory Accreditation Program
USEPA = United States Environmental Protection Agency
SM = Standard Methods

Evaluation Criteria

The effectiveness of the different media (two WBA resins, up to three SBA resins to be operated in a single-pass approach, and two iron-based adsorptive media) will be tested in this project. Specific evaluation criteria to assess various project objectives are shown in Table 6. Treatment to detection limit levels will be assessed to identify the lower limits that can be achieved by the media and the costs associated with treatment to those levels.

Table 6. Project Objectives and Evaluation Criteria

Objectives	Evaluation Criteria
1. Determine the Cr(VI) capacity of promising single-pass media compared with WBA resins	· Cr(VI) and total Cr effluent concentrations as a function of throughput ·
2. Evaluate the impact of a different water quality on resin and adsorptive media performance	· Comparison of Cr(VI) capacity for Cal Water Livermore water compared with Glendale GS-3 water
3. Assess operational requirements of the resins	· Necessary flushing to remove compounds released by the resins and adsorptive media (e.g., VOCs, SVOCs, nitrosamines, aldehydes) · Backwashing requirements · Impact of a start-stop sequence on water quality (e.g., peaking of contaminants) · Effectiveness of SBA resin without pH adjustment · Disposal options, based on residuals testing
4. Test potential issues of concern for adsorptive media	· Iron leaching from iron-based media to assess necessary downstream filtration · Removal of co-occurring contaminants (nitrate, arsenate, phosphate) and generation of by-products (e.g., ammonia, nitrite, sulfide)
5. Identify costs of treatment	· Bed volumes of water treated to different effluent Cr(VI) and total Cr goals (tentatively, 0.5, 1, 2, 5, and 10 ppb) · Identification of pre- and post-treatment needs (e.g., pH adjustment, filtration)

Expected Results

The results of the pilot scale testing will provide information on the applicability of multiple single-pass ion exchange resins (two WBA resins and up to 3 SBA resins operated in single-pass mode) in two water qualities and one WBA resin known to be effective in Glendale but now tested in a second water quality that differs from Glendale's water quality. Throughput of the resin and hence costs will be established for the resins.

The adsorptive media pilot testing is intended to evaluate the effectiveness of two media, including one that held promise for Cr(VI) treatment in Phase I testing in a previous incarnation and another that presents a new approach (though based on the same principles as other reductive adsorption processes). The adsorptive media pilot testing will identify whether additional study is warranted for these two technologies or if operational challenges still hinder their application at full-scale.

Together, the pilot testing efforts are expected to identify additional Cr(VI) treatment options that will be of particular use to systems for which the RCF process is too complex. In a parallel but associated effort through the City of Glendale, cost information is being developed for WBA and RCF technologies at different potential MCLs and flow rates. A discussion about the impacts of the new treatment technologies may have on the costs will be included in the final report for this project, with an update to the cost information provided for the tested technologies.

G. Applications Potential

The primary product of this research will be a WaterRF report, publication in a peer-reviewed, mainstream journal like the *Journal of the American Water Works Association* and in conference presentations, which will be widely available to utilities interested in the research findings.

Finalization of the public health goal (PHG) for Cr(VI) at 0.020 ppb by the California Office of Environmental Health Hazard Assessment in July 2011, and the release of the draft Cr(VI) toxicology assessment (i.e., reference dose, RfD) by USEPA, indicate interest in regulating Cr(VI) at both the state and federal levels. Cr(VI) occurrence data in California and across the nation suggest widespread contamination in drinking water supplies, particularly at levels in the single ppb range, as shown in Figure 1. Based on the high occurrence and potentially low regulatory limits, the applications potential for this research is significant. The large number of utilities that would be impacted by an MCL even as low as 10 ppb highlights the importance of this project to the industry. In addition, California utilities with more than 10,000 service connections will need to report to consumers exceedances of the Cr(VI) PHG in 2013, along with information about best available technologies and costs (both aggregate and cost per consumer for use of the technology)[16].

Cr(VI) can originate from non-point sources, including from natural aquifer materials. Cal Water has 224 individual water sources that exceed 1 μg/L. Many of these sources are found in small systems, for which systems like RCF and regenerable SBA are too complex for operations staff. For comparison, the coagulation/filtration (CF) process for arsenic treatment is not considered a Best Available Technology (BAT) for systems with less than 500 service connections due to complexity. Consequently, alternatives are needed for small and large systems alike that are simple and cost-effective.

The project will be overseen by California Water Service Company with involvement by the City of Glendale, which provides utility involvement in the study. Glendale has gone to significant lengths to disseminate the information collected in this study through the years, both to the drinking water community and to the public, and both utilities will continue to do so in this project. Other utility partners and regulatory agencies have been involved at various stages, including the Cities of Los Angeles, Burbank, and San Fernando, USEPA, CDPH, ACWA, USBR, MWDSC, WaterRF, and industry. All testing conducted in the project so far, including the current demonstration-scale study, is based on assessing treatment technologies for utility application using potable water sources contaminated by Cr(VI). Findings of this project will be incorporated into the overall research program to ensure that utilities can access all of the information at one time.

[16] California Government Code Division 104 Chapter 4 Article 5 Section 116470(b) 4 and 5.

H. Summary of Related Research

The City of Glendale has been leading studies of Cr(VI) removal since 2002, comprised of a three-phase chromium research effort. Phase I included bench-scale studies to screen a wide range of potential technologies for Cr(VI) treatment[17]. Phase II built upon Phase I and pilot tested six technologies at the Glendale site[18,19]. Research findings in Phase II were used by the Project Advisory Committee to select technologies for demonstration testing in Phase III, including RCF and WBA technologies. During Phase III Demonstration testing, WBA was found to be advantageous over RCF due to its simplicity of operations, although formaldehyde leaching was observed from the resin and uranium accumulation occurred.

This project builds upon the prior work showing that WBA resin can have a very high capacity for Cr(VI). Since Phase III Bridge testing in which other WBA and SBA resins were investigated for Cr(VI) capacity[20], two WBA resins have shown a high degree of effectiveness in testing at industrial sites and both resins are currently in the NSF certification process (NSF/ANSI Standard 61) for use in drinking water applications, as described in Section F. At least one SBA resin has been used at full-scale in a single-pass approach for drinking water treatment (i.e. Dow SAR) and may be cost-competitive due to a lower cost than WBA resins despite a lower Cr(VI) capacity, and the lack of pH adjustment.

Two adsorptive media that have shown promise in other testing have either advanced in terms of process maturity since prior bench testing[21] (i.e., SMI) or represent a new potential approach based on a chemistry of iron reduction of Cr(VI) and retention by media (i.e., Cleanit®). SMI-III® media has been altered during manufacturing (i.e., with a smaller sieve size) and was recently shown to operate in pilot testing[22] without hydraulic issues observed in previous testing. This testing of SMI-III® focused on identifying optimal conditions for arsenic and nitrate removal, but removal of co-occurring contaminants, including Cr(VI), vanadium, and uranium was promising.

The Cleanit® technology has revealed effective removal of Cr(VI) in pilot testing conducted in Brazil for a period of 2 months[23]. No significant iron leaching was observed in the Brazilian pilot testing, with typical turbidities of 0.08 to 0.12 NTU coming from the Cleanit® column. Cr(VI) removals for this technology were discussed previously in Section F.

This project builds upon the findings of nearly a decade of research to test single-pass media at the pilot-scale that have been shown to hold promise, with the purpose of providing utilities with simple, effective treatment technologies for Cr(VI) removal.

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[17] AwwaRF, 2004. Low-Level Hexavalent Chromium Treatment Options: Bench-Scale Evaluation. Authors: P.Brandhuber, M.Frey, M.McGuire, P.Chao, C.Seidel, G.Amy, J.Yoon, L.McNeill, and K.Banerjee.

[18] McGuire, M.J., Blute, N.K., Seidel, C., Qin, G., and Fong, L. 2006. Pilot-scale studies of hexavalent chromium removal from drinking water. *Journal of the American Water Works Association*, v. 98 (2), p.134-143.

[19] Qin, G., McGuire, M.J., Blute, N.K., Seidel, C., and Fong, L. 2005. Pilot studies of hexavalent chromium removal in drinking water by ion exchange. *Environmental Science and Technology,* v. 39 (16), p.6321-6327.

[20] AwwaRF, 2007. Hexavalent Chromium Removal Using Anion Exchange and Reduction with Coagulation and Filtration. Authors: M.McGuire, N.Blute, G.Qin, P.Kavounas, D.Froelich, and L.Fong.

[21] City of Ripon, California. 2010. Nitrate and Arsenic Treatment Demonstration. *Final Report to Proposition 50.* ID No. P50-3910007-055. http://www.cityofripon.org/EngineeringDepartment/Ripon-SMI-Pilot-Project-Final-Report_021010.pdf

[22] *Ibid*.

[23] Communications with Tom Lavis, North American Höganäs, 16 August 2011.

I. Quality Assurance/Quality Control (QA/QC)

A detailed Quality Assurance Project Plan (QAPP) was prepared for the original Phase II pilot and Phase III demonstration projects in accordance with USEPA requirements. Many elements of the former QAPPs are similar to this effort. Specific, proposed QA/QC procedures to ensure project data quality in this project will be detailed in the test plan for this project, and are briefly described below.

All laboratory analysis will be performed using analytical methods which conform to EPA guidelines and recommended test methods, including those in *Standard Methods for the Examination of Water and Wastewater*. Standard Operating Procedures (SOPs) will be used for all measurements.
The effectiveness of media tested will depend largely on Cr(VI) and total Cr analyses of testing column effluent compared with influent.

Cr(VI) and total Cr will be analyzed using ion chromatography (EPA Method 218.6) and ICP-MS method (EPA Method 200.8), respectively, by an ELAP-certified laboratory (MWH Laboratories). MWH Labs is a laboratory specified as a CDPH "subgroup code 103.310" certified for Cr(VI) analysis using EPA Method 218.6. For Cr(VI), the method detection limit (MDL) is approximately 0.015 ppb, the method reporting limit (MRL) is 0.020 ppb, and the official detection limit for reporting (DLR) is 1 ppb. Cr(VI) can now be preserved and measured within a hold time of 5 days using either CDPH-preferred borate-carbonate buffer or an ammonium sulfate/hydroxide buffer[24]. For total Cr, the MDL is 0.088 ppb and the MRL is 1.0 ppb. Samples falling within the range of the MDL and the MRL will be flagged as "J values".

Laboratory analyses, including Cr(VI) and total Cr measurements, will be subjected to numerous procedures to assess quality assurance objectives. The ion chromatograph for Cr(VI) measurements will be calibrated each analysis day. Acceptance criteria include a correlation coefficient for the linear calibration curve of greater than 0.999. An external laboratory control sample (LCS) with a concentration of 2 ppb will be analyzed for every batch of 20 samples or less. The acceptance percent recovery range for the LCS sample is within 90-110%. A 20 ppb instrument performance check (IPC) sample will be run after the initial calibration and subsequently after every 10 samples, with an acceptable percent recovery range of 95 to 105%. A laboratory reagent blank (LRB) will also be measured after every 10 samples and should be below the MRL of 0.1 ppb each time.

The ICP-MS for total Cr will also be calibrated each analysis day. Acceptance criteria include a correlation coefficient for the linear calibration curve of greater than 0.999. An initial calibration verification standard (ICV) will be analyzed immediately after the calibration curve with an acceptance percent recovery range of 95 to 105%. A continuing calibration verification standard (CCV) will be run subsequently after every 10 samples, with an acceptable percent recovery range of 90 to 110%. A continuing calibration blank (CCB) will also be measured after every 10 samples and should be below one-half of the MRL of 1.0 ppb each time.

Accuracy in Cr(VI) and total Cr analyses will be evaluated by determining percent recoveries in laboratory-spiked samples. A matrix spike (MS) will be performed on 10% of samples (or at least one sample per run), chosen at random. MS recoveries should be between 90 and 110% of the expected value for Cr(VI) and between 70 to 130% for total Cr. National Institute of Standards and Technology (NIST) traceable

[24] CDPH, http://www.cdph.ca.gov/certlic/drinkingwater/pages/chromium6sampling.aspx. Last updated July 27, 2011.

Cr(VI) solutions and ICS total Cr standard solutions will be used for matrix spikes. Accuracy will also be tested throughout the runs and after every 10 samples by analyzing a mid-range IPC sample and a laboratory reagent blank (LRB). The acceptance criteria for the IPC sample are between 95 and 105%. The LRB should be below one-half the MRL. If concentrations are outside of these ranges, corrective actions will be performed.

Precision (random error) will be investigated by performing repeat analyses on the same analytical instruments. For every batch of twenty samples, a LCS and a MS will be run. The acceptable ranges for these sample results are between 90 and 110% for Method 218.6 and 70 to 130% for Method 200.8. Laboratory replicates and matrix spike duplicates (MSD) will be analyzed for every batch of twenty samples with an acceptance criterion of less than 20% relative percent difference (RPD).

As the critical parameters in evaluating the success of the project, Cr(VI) and total Cr concentration data will also be subjected to paired sample analyses (i.e., Cr(VI) and total Cr samples collected at the same time). Paired samples will be used to assess the chromium speciation and ensure full reduction in the RCF process.

For field-measured water quality parameters including iron and turbidity, accuracy and precision acceptance criteria will be based on manufacturer specifications, which will be tested using standards prepared in the water matrices. In general, acceptance criteria for these analytes will be less than 20% for field-collected duplicate samples. For the field methods, precision will be analyzed every 20 samples from repeat analyses on known-concentration accuracy check standards, with an acceptance criteria of 80 to 120%.

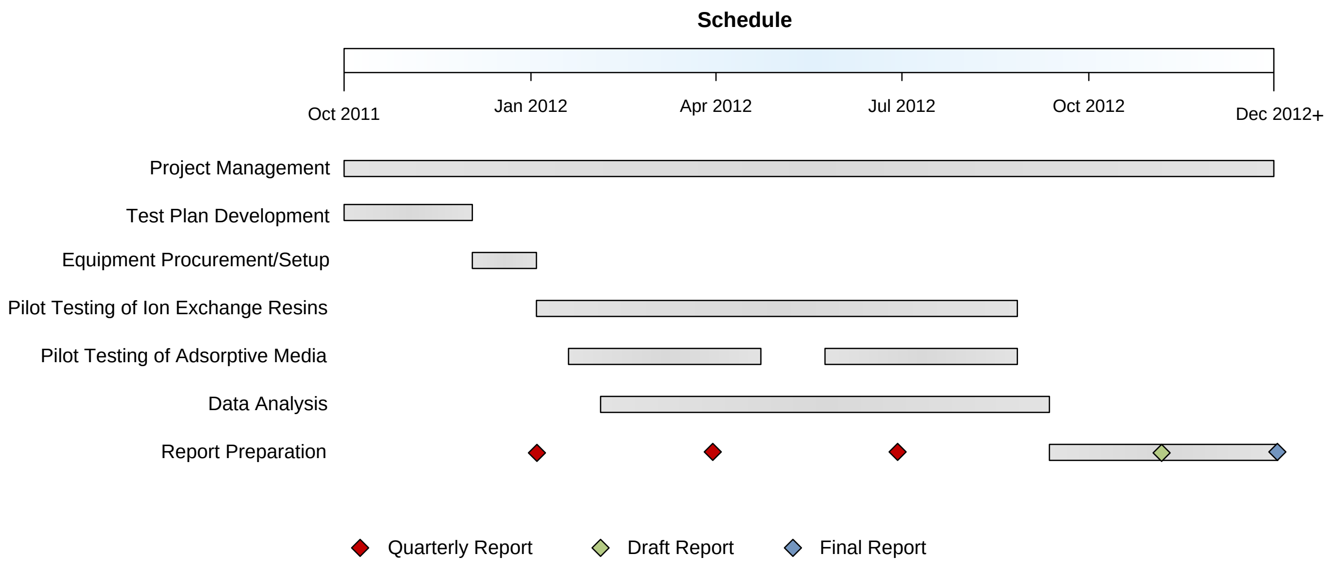
QA/QC sampling will include field-collected duplicate samples and field blanks. Field-collected duplicate samples will serve to ensure acquisition of representative samples, consistency of sampling, and precision of the analytical methods. Field-collected duplicate samples will be collected for at least 10% of all samples. These duplicates will not be identified as QA samples when sent to the laboratory. Field blanks will be prepared by filling metal-free distilled water in sample bottles provided by the laboratory. These samples will be sent to test any possible contamination during sample handling, transport and storage. At least one field blank sample will be prepared for each shipment. Blanks submitted to the laboratory for analysis will not be identified as QA samples. Sufficient sample volume will be collected for the required analysis. Samples will not be composited to amplify sample volume or average samples over time. Split samples will be used to verify analytical precision.

All field and process equipment will be calibrated. Field equipment calibration will be performed in accordance with manufacturer specifications for each instrument. Certified standard solutions will be used to test the functionality and accuracy of each instrument within the range of measurements and a frequency specified by the manufacturer, or at least once per month. In addition to online meters, portable meters for turbidity and pH will also be used to verify the online meter measurements. In case of instrument malfunction, a back-up instrument will be obtained and calibrated for interim use while the malfunctioning instrument is under repair. Process equipment, such as pumps and flow meters, will be calibrated before the MF pilot units are brought online, and at the conclusion of the test, to avoid disturbing the membrane operation during the test period unless unexpected results warrant recalibration.

J. Schedule

The project is anticipated to begin in October 2011 and will last through December 2012 as shown Figure 12. Quarterly progress reports will be produced for review by the PAC as shown in the schedule. The draft report will be submitted within three months of the last periodic report, and the final report by December 2012.

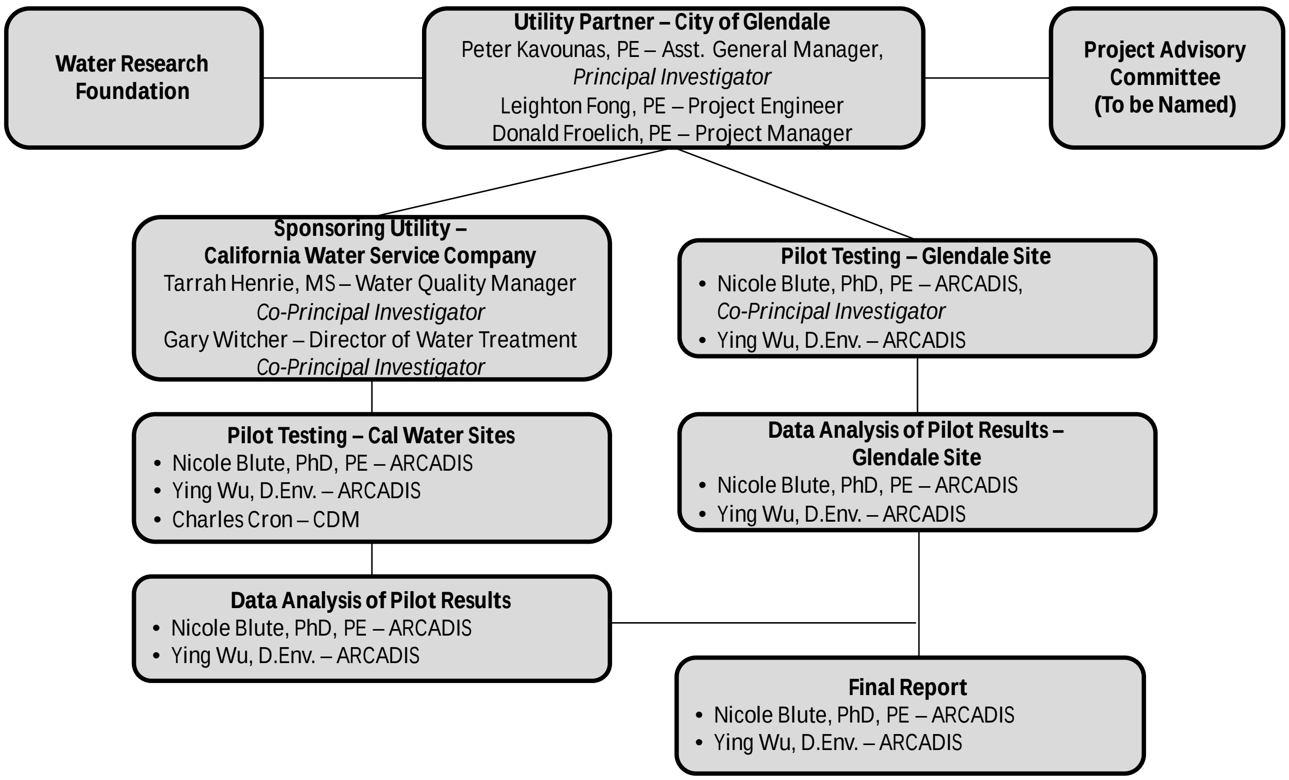
Figure 12. 2011-2 Project and Funding Schedule



K. Management Plan and Statement of Qualifications

The project team for the various entities in this project is shown in the organizational chart in Figure 13.

Figure 13. Project Team Organization Chart
Affiliations shown following individuals' names



Mr. Peter Kavounas will be the Principal Investigator, with Ms. Tarrah Henrie, Mr. Gary Witcher and Dr. Nicole Blute as co-Principal Investigators. This team will maintain accountability through frequent project meetings, weekly updates of data analysis, and clearly delineated tasks identified in the project work plan. Dr. Blute has been involved in Glendale research program for almost a decade and has a thorough understanding of all aspects of the program. Resumes for each of the key personnel listed below are appended to this proposal.

The teams working at each site are shown in Figure 13. At Cal Water's Livermore site, pilot testing will be set up by Dr. Blute and Dr. Wu with each week's sampling conducted by ARCADIS staff in Northern California that have been trained by Dr. Blute and Dr. Wu to ensure consistency in approach as at the Glendale site. Daily checks of the site will be performed by Cal Water operations staff and any issues will be brought to ARCADIS's attention and remedied by operations staff. Samples collected will be shipped to MWH Labs under Glendale's Tri-Cities laboratory rates but costs will be paid by Cal Water. Pilot testing at Glendale's GS-3 site, including set up and weekly sampling, will be conducted by Dr. Blute and Dr. Wu. Mr. Cron of CDM will visit the GS-3 site each day and assist in necessary troubleshooting.

Tarrah Henrie, MS, California Water Service Company. Ms. Henrie is the Water Quality Manager for California Water Service Company. She is responsible for meeting all state and federal water quality standards for 69 water systems, serving about 2,000,000 people in California. Cal Water has over 550 active groundwater wells and over 120 treatment units throughout the state. Ms. Henrie is a member of the AWWA inorganic committee, and is an active participate on the Cr(VI) sub-committee. She also has previous experience with iron based media for nitrate and arsenic treatment at the pilot scale, as well as full scale ion exchange treatment for perchlorate, nitrate and uranium. Ms. Henrie's educational background is in soil and water chemistry. Previous publications include a paper and presentation on Cr(VI) occurrence in Cal Waters groundwater wells.

Gary Witcher, California Water Service Company. Mr. Witcher is the Manager of Water Treatment for the California Water Service Company. He oversees two surface water treatment plants in Bakersfield, California. Mr. Witcher assists with construction and operation of all treatment facilities throughout the Cal Water service area. Mr Witcher has 17 years of experience in the water industry. He also oversees Cal Water's Pilot Testing Team and Treatment Process Evaluation Team.

Peter Kavounas, PE, City of Glendale. Mr. Kavounas is the Assistant General Manager - Water Services for the City of Glendale Department of Water and Power since 2004 and has 20 years of experience in the water industry. At Glendale, Mr. Kavounas is responsible for managing the operation, maintenance, and engineering activities of the water system serving the City's 200,000 residents. Mr. Kavounas will assure the City's commitment to providing the support and resources necessary to locate pilot facilities within the City's water system.

Donald Froelich, PE, City of Glendale. Mr. Froelich will act as the Glendale Project Manager for this research effort. Mr. Froelich, prior to his April 2004 retirement, was the Water Services Administrator for the City of Glendale with a long history of involvement in the EPA Superfund activities in Glendale, and the implementation of the four-phase Cr(VI) removal research program. Because of his long involvement in the Cr(VI) efforts, Mr. Froelich has been retained by Glendale to manage their portion of the research effort.

Leighton Fong, PE, City of Glendale. Mr. Fong will be the Glendale Project Engineer working with Mr. Froelich in managing the research effort. Mr. Fong has a long history in water quality activities, Superfund activities in the City of Burbank prior to being hired by the City of Glendale, managing water quality activities in Glendale, and participation in the pilot-testing program. He will manage the schedule and financial activities for this research project for Glendale.

Nicole K. Blute, PhD, PE, ARCADIS, Inc. Dr. Blute is a Principal Environmental Engineer at ARCADIS US, Inc. Dr. Blute has been working with Glendale on their Cr(VI) research effort since 2002 and brings an in-depth knowledge of all of the technical aspects of the technologies and research findings. For Glendale, she has prepared and presented study findings at more than a dozen forums. Dr. Blute will develop the test plan and ensure that the objectives of the testing and necessary project reporting requirements are met.

Ying Wu, DEnv, ARCADIS, Inc. Dr. Wu is a Staff Environmental Specialist at ARCADIS US, Inc. Dr. Wu has been actively involved in many projects focusing on drinking water treatment technology testing and implementation, including Glendale Cr(VI) research. She will assist Dr. Blute with test plan development, field sampling, data analysis, and report preparation.

Charles Cron, CDM. Mr. Cron is a Senior O&M Specialist for CDM and the Plant Manager for the Glendale Water Treatment Plant. He supported the Phase II pilot studies of Cr treatment and is currently overseeing the Phase III demonstration studies. Mr. Cron will provide support to ARCADIS in this project, including daily checks of the Glendale site.

L. Draft Communication Plan

The project team will coordinate and support the communication requirements of the Water Research Foundation for this project, including communications with WaterRF, PAC members, and the various contractors. Quarterly progress reports will be provided to all members of the project team, the WaterRF project manager, the PAC, and California DPH on a monthly basis to keep the team fully informed of activities in a timely manner. A draft report detailing research findings will be submitted to WaterRF within three months following the last progress report and a final report by the end of 2012.

A formal Draft Communication Plan will be developed in conjunction with WaterRF as part of this project. The Plan will contain the following components, with additional details to the preliminary details shown below.

I. Target Audience
    a. Water utility community
    b. Public
    c. Regulatory agencies (CDPH and USEPA; possibly other state health departments)

II. Deliverables
    a. Work plan
    b. Quarterly progress reports
    c. Draft and final project report

III. Communication Activities – each will include a description of level of detail, content, and focus
    a. Monthly project updates sent to a wide distribution list of interested parties
    b. Final project results presentation to the PAC, water industry, and community
    c. Webcast of project findings to WaterRF subscribers
    d. WaterRF final report in print
    e. PowerPoint presentations at national AWWA conferences (e.g., ACE and WQTC), ACWA and others

The eight-year research program that Glendale has been leading has a long history of a multi-platform communication approach. The project team intends to continue the various outreach activities intended to reach everyone from the concerned public to the water industry end-user of the technology to disseminate WaterRF project findings.

M. Licenses and Inventions (as required)

The project is unlikely to produce patentable technologies or products that can be developed.

N. Third Party Contribution Letters of Commitment (as required)

North American Höganäs

08/25/11

To: California Water Service Company

North American Höganäs, Inc. is committed to the site study for chromium (VI) removal in California as part of the California Water Service Company's proposal to the Water Research Foundation entitled "Assessment of Single-Pass Ion Exchange and Adsorptive Media for Hexavalent Chromium Removal from Drinking Water". North American Höganäs, Inc. will provide the containerized Cleanit® pilot unit free of charge for the 120 life of the study.

North American Höganäs will provide on-site support to assist in startup at the one site that will be tested (i.e., likely in Glendale, California) and at regular intervals as needed to ensure smooth operations (e.g., troubleshooting assistance, anticipated monthly).

Sincerely,

Thomas Lavis
General Manager
Environmental Segment/ Water

Postal address: North American Höganäs, Inc. | 111 Höganäs Way | Hollsopple | PA 1595-8416 | USA
Phone + 000 000-0000 | Fax + 000 000-0000 | www.nah.com

LOPREST
WATER TREATMENT CO.

August 24, 2011

Ms. Tarrah Henrie
Water Quality Manager
California Water Service Company
1720 North First Street
San Jose CA 95112

Re: Letter of Commitment to the California Water Service Company Water Research Foundation Cr(VI) Proposal

Dear Ms. Henrie:

Loprest Water Treatment, in conjunction with SMI, is pleased to offer our support of the California Water Service Company's proposal to the Water Research Foundation entitled "Assessment of Single-Pass Ion Exchange and Adsorptive Media for Hexavalent Chromium Removal from Drinking Water". Loprest together with SMI will provide a containerized pilot skid at no cost to the project.

Loprest will provide on-site support to assist in startup at each site (Cal Water Livermore and Glendale, California) and at regular intervals as needed to ensure smooth operations (e.g., troubleshooting assistance). Up to $10,000 at the Cal Water site and $10,000 at the Glendale site are available to compensate Loprest for time spent on site in troubleshooting.

Sincerely,

Randy Richey, PE
President
Loprest Water Treatment
Randy@Loprest.com

O. Participant Contribution Summary (PCS) Form

Project Sponsor: California Water Service Company

Project Title: Assessment of Single-Pass Ion Exchange and Adsorptive Media for Hexavalent Chromium Removal from Drinking Water

I. Project Participant Contribution Summary

THIS SECTION AUTOFILLS FROM THE INFORMATION ENTERED IN SECTIONS II AND III

A - Foundation Share	$ 375,000	This number is the sum total of all cash that will be managed by the Foundation and includes both Foundation and Co-Funder funds. *This amount should equal the Foundation Share share total in the completed Project Budget Form cost breakdown.*
B - Cost Share	$ 175,000	This number represents the dollar value of all contractor cost share that will be provided to the project. This amount should equal the Cost Share total in the completed Project Budget Form summary sheet cost breakdown.
C - Third Party Contributions	$ -	This number represents the sum of Third-Party cash contributions and the dollar value of all non-cash in-kind services provided by Co-Funders and Third-Party Contributors. *This amount should equal K - Third Party Contributions on the Project Budget Form.*
D - Total Project Budget	$ 550,000	This number represents the total of all cash and in-kind funding that will be provided by the Foundation, Co-Funders, Third-Party Contributors and Contractor Cost Share. The **Project Budget Total** on the Project Budet Form *must* equal this value.

I - Summary Sheet

Project Sponsor: California Water Service Company

Project Title: Assessment of Single-Pass Ion Exchange and Adsorptive Media for Hexavalent Chromium Removal

Co-Funder Contributions and Foundation Matching Guidelines:

- Organizations wishing to provide cash for a project **and have the Foundation manage the cash** should be listed below.
- Organizations who are providing cash to the project and are full paying subscribers wishing to have the Foundation match their cash contribution should indicate their request below.
- Organizations that wish to provide cash to the project but **will not be sending the funds to the Foundation** to be managed with other project funds should be listed on worksheet III under Third-Party Contributions
- All money managed by the Foundation, including co-funder cash, should be accounted for as Foundation Share on the main project budget form.
- Co-funders also contributing in-kind services should provide a dollar value for the services in the area indicated below.

SECTION II - Co-Funder Contribution and Requested Foundation Cash Match

Participant	Total	Co-Funder Cash	Foundation Cash Match	Co-Funder In-kind
California Water Service Company	$ 275,000	$ 100,000	$ 175,000	
City of Glendale, California	$ 100,000	$ 100,000	$ -	
	$ -			
	$ -			
	$ -			
	$ -			
	$ -			
	$ -			
	$ -			
	$ -			
	$ -			
	$ -			
	$ -			
	$ -			
	$ -			
	$ -			
	$ -			
	$ -			
	$ -			
	$ -			
	Total Carried to Section I.A ⇩		ERROR - Maximum Foundation Match Exceeded!	Total Carried to Section III.A ⇩
Totals		$ 200,000	$ 175,000	
Foundation Share = Co-Funder Cash + Foundation Cash Match (carries to Section I.A)	$ 375,000			$ -

II - Co-Funder and Foundation

Project Sponsor: California Water Service Company

Project Title: Assessment of Single-Pass Ion Exchange and Adsorptive Media for Hexavalent Chromium Removal from

Third Party Contributions and Contractor Cost Share Guidelines:

- Third party contributions can be made by any entity interested in either providing cash or in-kind services to the project.
- Organizations that wish to participate by providing in-kind services alone should be listed below along with the estimated value of the in-kind service.
- Organizations that wish to provide cash to the project but **will not be sending the funds to the Foundation** to be managed with other project funds should be listed below.
- Cash and in-kind services provided by project contractors should be indicated in Section III.B below.
- Cash provided by third parties must be accounted for on the main project budget form under the Cost Share column.

SECTION III.A Third-Party Contributions

Participant	Cash	In-Kind Services	Total In-Kind
			$ -
			$ -
			$ -
			$ -
			$ -
			$ -
			$ -
			$ -
			$ -
			$ -
			$ -
Totals	$0.00	$0.00	$0.00
Co-Funder In-Kind (Carried from Section II)			$ -
Total Third-Party In-Kind Services (carries to section I.C)			$0.00

SECTION III.B Contractor Cost Share

Participant	Total
City of Glendale, California from State Proposition 50	$ 175,000
Total Cost Share (Carries to Section I.B)	$ 175,000

P. Budget

ATTACHMENT 3

Water Research Foundation
Research Project Budget

Instructions for budgets are at http://www.waterrf.org/Research/Administration/ProposalGuidelines/Pages/default.aspx

*** Required fields are highlighted in yellow.**

*** Required fields are highlighted in yellow.**

Applicant: California Water Service Company
Project Title: Assessment of Single-Pass Ion Exchange and Adsorptive Media for Hexavalent Chromium
Preparation/Revision Date:
RFP # (if applicable):

Note: The information above will carry over to subsequent pages/worksheets.

Sources of Award, Cost Share, and Non-Cash In-Kind Contributions† (Insert rows to list more third parties.)	Award			Cost Share		Third-Party Non-Cash In Kind
	Foundation Funds	*Applicant*	*Third-Party Cash to Foundation*	*Applicant*	*Third-Party Cash to Applicant*	
Water Research Foundation	175,000	n/a	n/a	n/a	n/a	n/a
Applicant	n/a	200,000	n/a	175,000	n/a	n/a
Third Parties	n/a	n/a		n/a		
	n/a	n/a		n/a		
	n/a	n/a		n/a		
	n/a	n/a		n/a		
	n/a	n/a		n/a		
	n/a	n/a		n/a		
	n/a	n/a		n/a		
	n/a	n/a		n/a		
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	n/a	n/a		n/a		
	n/a	n/a		n/a		
	n/a	n/a		n/a		
	n/a	n/a		n/a		
Subtotal	*175,000*	*200,000*	*0*	*175,000*	*0*	*0*
Total	375,000			175,000		0
	Award			Cost Share		Third-Party Non-Cash In Kind

† List contributions from subcontractors in *Category F, Subcontracts*.

Water Research Foundation
Research Project Budget

Applicant: California Water Service Company
Project Title: Assessment of Single-Pass Ion Exchange and Adsorptive Media for Hexavalent Chromium Removal fr
RFP # (if applicable):

Note: All amounts below will be automatically populated from the following pages/worksheets.

		Total	Award	Cost Share
A	Key Personnel	0	0	0
B	Other Personnel	15,149	0	15,149
	Total Direct Labor and Fringe Benefits	*15,149*	*0*	*15,149*
C	Equipment Rental	0	0	0
	Special Equipment	0	0	0
D	Materials and Supplies	0	0	0
E	Travel	0	0	0
F	Subcontracts	520,000	375,000	145,000
G	Other Direct Costs	0	0	0
	Total Direct Costs	*535,149*	*375,000*	*160,149*
H	Indirect Costs	14,851	0	14,851
I	Fee	0	0	0
J	Surveys	0	0	0
	Total Direct and Indirect Costs	*550,000*	*375,000*	*175,000*
	Third-Party Non-Cash In Kind	**0**	n/a	n/a
	Total Project Value	**550,000**		

Water Research Foundation
Research Project Budget

*** Required fields are highlighted in yellow.**

Applicant: California Water Service Company
Project Title: Assessment of Single-Pass Ion Exchange and Adsorptive Media for Hexavalent Chromium Removal from Drinking Water
RFP # (if applicable):

A. Key Personnel *(PI and Co-PIs. Applicant's employees only.†)*

Name	Project Role	Number of Hours	Direct Hourly Rate	% Time Allocated to Project	Subtotal Direct Labor	Fringe Benefit % of Direct Labor	Subtotal Fringe Benefits	Total	Award	Cost Share
Peter Kavounas (overhead)	PI	40.00	0.00	1.0%	0	0.00%	0	0	0	0
Tarrah Henrie	Co-PI									
Gary Witcher	Co-PI									
		Total Key Personnel			**0**		**0**	**0**	**0**	**0**

B. Other Personnel *(Applicant's employees only.)*

Name/Position	Project Role	Number of Hours	Direct Hourly Rate	% Time Allocated to Project	Subtotal Direct Labor	Fringe Benefit % of Direct Labor	Subtotal Fringe Benefits	Total	Award	Cost Share
Donald Froelich	Glendale Project Manager	60.00	73.00	3.0%	4,380	40.00%	1,752.00	6,132		6,132
Leighton Fong	Glendale Project Engineer	113.00	57.00	7.0%	6,441	40.00%	2,576.40	9,017		9,017
		Total Other Personnel			**10,821**		**4,328.40**	**15,149**	**0**	**15,149**

† PI and co-PIs that are not Applicant's employees must **NOT** be listed here. Describe their project roles and responsibilities in the Budget Narrative under ***Category F, Subcontracts***.

Water Research Foundation
Research Project Budget

Applicant: California Water Service Company
Project Title: Assessment of Single-Pass Ion Exchange and Adsorptive Media for Hexavalent Chromium Removal from Drinking Water
RFP # (if applicable):

C. Equipment Rental and Special Equipment Purchase

Equipment Rental (*List items and dollar amount for each item exceeding $1,000*)	**Total**	**Award**	**Cost Share**
None			
Total Equipment Rental	0	0	0

Special Equipment Purchase (*List items and dollar amount for each item exceeding $5,000*)	**Total**	**Award**	**Cost Share**
None			
Total Special Equipment Purchase	0	0	0

Water Research Foundation
Research Project Budget

Applicant: California Water Service Company
Project Title: Assessment of Single-Pass Ion Exchange and Adsorptive Media for Hexavalent Chromium Removal from Drinking Water
RFP # (if applicable):

D. Materials and Supplies	**Total**	**Award**	**Cost Share**
None			
Total Materials and Supplies	0	0	0

E. Travel	**Total**	**Award**	**Cost Share**
None			
Total Travel	0	0	0

Water Research Foundation
Research Project Budget

Applicant: California Water Service Company
Project Title: Assessment of Single-Pass Ion Exchange and Adsorptive Media for Hexavalent Chromium Removal from Drinking Water
RFP # (if applicable):

F. Subcontracts	Total	Award	Cost Share
ARCADIS (includes Nicole Blute as co-Principal Investigator)	398,000	375,000	23,000
CDM Constructors	22,000	0	22,000
MWH Laboratories	100,000	0	100,000
Total Subcontracts	**520,000**	**375,000**	**145,000**

G. Other Direct Costs	Total	Award	Cost Share
Total Other Direct Costs	**0**	**0**	**0**

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Water Research Foundation
Research Project Budget

Applicant: California Water Service Company
Project Title: Assessment of Single-Pass Ion Exchange and Adsorptive Media for Hexavalent Chromium Removal from Drinking Water
RFP # (if applicable):

H. Indirect Costs ***(Attach copy of federally approved rates or detailed basis for rates)***

Cost Category	Rate %	Base $	Total	Award	Cost Share
City of Glendale Overhead only	98%	15,152	14,851	0	14,851
		Total Indirect Costs	**14,851**	**0**	**14,851**

I. Fee	%	Base $	Total	Award	Cost Share
		Total Fee	**0**	**0**	**0**

J. Survey	Total	Award	Cost Share
Total Survey Costs	**0**	**0**	**0**

IN-KIND SUPPORT FORM (FOR NON-CASH CONTRIBUTIONS)

Name of Organization	Name of Contact	Amount Specified in Letter of Commitment (USD$)
None		

Total Utility and other Organization In-kind ($)	

*Please note: Letters of commitment that specify dollar amount must be included with proposal for all in-kind included on this worksheet.

Q. Budget Narrative

The budget for this project is a total of $550,000 as detailed Tables 7 and 8. Major costs include test plan development, pilot skid and bench testing set up, labor for pilot and bench testing, sample analysis (laboratory) costs, data analysis, and project reporting.

The following assumptions form the basis of this budget:

- Glendale and Cal Water will provide project management and budgetary oversight for testing at their respective sites, with assistance from ARCADIS.
- ARCADIS will prepare the pilot testing plans for both the Cal Water and Glendale sites.
- ARCADIS will retrofit the ion exchange pilot testing skids and transport them to the Cal Water and Glendale sites. CDM will provide the connection between the GS-3 well water (raw and pH adjusted) to the pilot skids.
- Loprest Water Treatment will provide a self-contained trailer consisting of SMI-III® pilot columns and iron removal system for 4 months of testing at each site at no rental cost. Field support costs that will be incurred from Loprest of $10,000 for the Cal Water site and $10,000 for the Glendale site are included in the ARCADIS subcontract.
- North American Höganäs will provide a self-contained trailer consisting of Cleanit® LC pilot columns and iron removal system for 4 months of testing at one site for no rental cost.
- ARCADIS will provide onsite sample collection and troubleshooting approximately 2 days per week for the 9 month pilot studies at each of the two sites (i.e., Cal Water and Glendale).
- ARCADIS will analyze pilot testing data and prepare updates to the team twice per month.
- ARCADIS will write the draft and final reports and quarterly progress reports.
- Analytical costs reflect the frequency shown in Tables 3 and 4 consistent with Glendale's MWH Labs Tri-Cities rates. Cal Water will cover shipping costs of samples to MWH Labs from the Livermore site.

Table 7. Budget Breakdown by Task

Task	Task Description	Cal Water Site	Glendale Site	Joint	Total
1	**Project management**	$ -	$ -	$ 60,000	$ 60,000
2	**Test plan development**	$ 15,000	$ 15,000	$ -	$ 30,000
3	**Equipment procurement and setup**	$ 24,000	$ 17,000	$ -	$ 41,000
4	**Field testing of resins: Purolite S106**	$ 22,000	$ 31,000	$ -	$ 53,000
5	**Field testing of resins: ResinTech SIR-700**	$ 22,000	$ 31,000	$ -	$ 53,000
6	**Field testing of resins: SBA resins**	$ 22,000	$ 31,000	$ -	$ 53,000
7	**Field testing of resins: Dow PWA7**	$ 22,000	$ -	$ -	$ 22,000
8	**Field testing of media: SMI-III**	$ 58,000	$ 48,000	$ -	$ 106,000
9	**Field testing of media: Cleanit**	$ -	$ 48,000	$ -	$ 48,000
10	**Data analysis**	$ 17,000	$ 17,000	$ -	$ 34,000
11	**Report preparation**	$ -	$ -	$ 50,000	$ 50,000
Total		$ 202,000	$ 238,000	$ 110,000	$ 550,000

Cost Allocation			
	Joint Costs 50% / 50%	$ 55,000	$ 55,000
	Total for Each Utility	**$ 257,000**	**$ 293,000**
	Funding Source		
	• Proposition 50	$ -	$ 275,000
	• Water Research Foundation	$ 175,000	$ -
	• California Water Service Company	$ 100,000	$ -
	Total	**$ 275,000**	**$ 275,000**

Table 8. Budget Breakdown by Organization

Activity	Cal Water	Glendale	ARCADIS (Cal Water)	ARCADIS (Glendale)	CDM (Glendale)	MWH Labs (Cal Water)	MWH Labs (Glendale)	Total
Project management (Joint)	$ -	$ 30,000	$ 15,000	$ 15,000	$ -	$ -	$ -	$ 60,000
Test plan development	$ -	$ -	$ 15,000	$ 15,000	$ -	$ -	$ -	$ 30,000
Equipment procurement and setup	$ -	$ -	$ 24,000	$ 15,000	$ 2,000	$ -	$ -	$ 41,000
Field testing of resins	$ -	$ -	$ 51,000	$ 51,000	$ 10,000	$ 38,000	$ 32,000	$ 182,000
Pilot testing of adsorptive media	$ -	$ -	$ 48,000	$ 65,000	$ 10,000	$ 10,000	$ 20,000	$ 153,000
Data analysis	$ -	$ -	$ 17,000	$ 17,000	$ -	$ -	$ -	$ 34,000
Report preparation (Joint)	$ -	$ -	$ 25,000	$ 25,000	$ -	$ -	$ -	$ 50,000
Total	**$ -**	**$ 30,000**	**$ 195,000**	**$ 203,000**	**$ 22,000**	**$ 48,000**	**$ 52,000**	**$ 550,000**

SCHEDULE OF ONGOING PROJECT COSTS

Cal Water is proposing to complete this project within 15 months. Tasks 2 and 3 will be conducted in 2011 assuming a start date of October 1, and 20% of project management tasks will be performed in the three months of 2011. This results in approximately $81,000 of funding for the project spent in 2011 and the remainder in 2012.

PRIMARY CONTRACTOR BUDGET JUSTIFICATION – CALIFORNIA WATER SERVICE COMPANY

Salaries and Wages: Salaries and wages for Cal Water employees will not be charged to this project.
Fringe Benefits: Fringe benefits for Cal Water employees will not be charged to this project.
Equipment Rental: No equipment will be rented directly by Cal Water.

Materials and Supplies: No materials and supplies will be purchased directly by Cal Water.
Travel: Travel conducted by Cal Water employees will be paid by Cal Water and not the project.
Subcontract: California Water Service Company will enter into one subcontract with ARCADIS to perform work at the Cal Water site and sign a Memorandum of Understanding with the City of Glendale, California. Payment on the ARCADIS subcontract for the project will be routed through Glendale rather than Cal Water.
Other Direct Costs: Other direct costs are detailed in the Subcontractor budget narratives since they will be incurred by the Subcontractor rather than by Cal Water or Glendale directly.
Indirect Costs: No indirect costs will be incurred by the project.

PARTNERING UTILITY BUDGET JUSTIFICATION – CITY OF GLENDALE, CALIFORNIA

Salaries and Wages: Salary rates for City of Glendale employees (Donald Froelich and Leighton Fong) are established in conjunction with their employer, the City of Glendale Water and Power. No indirect/overhead costs are included in the hourly rates budget. Peter Kavounas will devote 1% of his time to planning and directing research activities, as well as monitoring the project budget and reviewing project reports. His costs are included in the overhead costs applied to the direct wages of Leighton Fong and Donald Froelich. Donald Froelich will devote 3% of his time to managing the project for the City of Glendale. Leighton Fong, as Project Engineer, will dedicate 7% of his time to coordination and execution of subcontracts and QA/QC of work.
Fringe Benefits: An estimate of 40% has been incorporated for Donald Froelich and Leighton Fong. Peter Kavounas' fringe benefits are included in the overhead costs.
Equipment Rental: No equipment will be rented directly by Glendale.
Materials and Supplies: No materials and supplies will be purchased directly by Glendale.
Travel: No travel is anticipated by Glendale.
Subcontract: The City of Glendale will sign a Memorandum of Understanding with California Water Service Company and enter into two subcontracts in this project with ARCADIS and CDM for work at the Glendale site. ARCADIS will be relied upon to develop the test plan, conduct the pilot testing, perform data analyses, and prepare the project report. CDM will be responsible for assisting with startup and providing daily site checks of the pilot systems.
Other Direct Costs: Other direct costs are detailed in the Subcontractor budget narratives since they will be incurred by the Subcontractor rather than by Glendale directly.
Indirect Costs: The contract mechanism to be used by the City of Glendale accounting for this project has no indirect costs associated with it.

SUBCONTRACTOR BUDGET JUSTIFICATION – ARCADIS

Salaries and Wages: The salary rates for ARCADIS are established by ARCADIS.
Co-PI Nicole Blute ($125,000 budgeted) will devote 22% of her time over the 15 month period to managing the project, developing the test plan, coordinating the equipment procurement and setup, analyzing data, and preparing the reports. She will oversee all project activities, data analysis and interpretation, and will be responsible for the reports.
A staff engineer, Ying Wu ($100,000 budgeted) will devote 28% of her time over the 15 month period to test plan development, equipment procurement and setup, on-site support at the Glendale site and periodic support at the Cal Water site, data compilation and trending, and support in project report preparation. Additional ARCADIS staff will assist with field sampling and system operations.
Fringe Benefits: Fringe benefits and overhead for ARCADIS are incorporated into the billing rates.

Materials and Supplies: Materials and supplies will be purchased by ARCADIS to enable skid construction, including supplies to retrofit the pilot testing equipment, a pH adjustment system for the Cal Water site, and field analytical supplies (i.e., consumables). A preliminary breakdown of the items contributing to a cost estimate of approximately $15,000 in materials and supplies is provided in Table 9.

Table 9. Estimate of Materials and Supplies

Component	Approximate Cost
pH adjustment system (assuming HCl) – Cal Water site	$12,000
Ion exchange skid retrofit, including new plastic columns, tubing, flow meters (total and instantaneous flow), cartridge filter) – includes both the Cal Water and Glendale sites	$10,000
Analytical supplies –includes both the Cal Water and Glendale sites	$2,000

Travel: Travel anticipated includes mileage to the Glendale site and travel (airfare/hotel/car rental) to the Livermore site. Travel costs incorporated in the pilot testing task budget include 10 trips to the Cal Water Livermore site for initial startup and monthly site visits at a rate of $1,000 each for airfare, hotel for two nights, and car rental (total of $10,000).
Other Direct Costs: Costs associated with on-site support by Loprest for the SMI media will be paid through ARCADIS and are anticipated to be approximately $20,000 (i.e., $10,000 per site). Other field analytical costs are not included in this budget because instruments were already purchased for prior testing and are available for use.
Indirect Costs: No significant indirect costs are expected.

SUBCONTRACTOR BUDGET JUSTIFICATION – CDM

Salaries and Wages: The salary rates for CDM are established by CDM.
Plant Manager Charles Cron ($22,000 budgeted) will devote 25% of his time to overseeing site installation and daily operations at the Glendale site.
Fringe Benefits: Fringe benefits and overhead for CDM are incorporated into the billing rates.
Materials and Supplies: No materials and supplies are anticipated for CDM.
Travel: No travel is anticipated by CDM.
Other Direct Costs: No other direct costs are expected for CDM.
Indirect Costs: No significant indirect costs are expected for CDM.

SUBCONTRACTOR BUDGET JUSTIFICATION – MWH Laboratories

Salaries and Wages: Salary rates for this subcontractor are not applicable. Fees will be charged based on a cost per sample analyzed.
Fringe Benefits: Fringe benefits for this subcontractor are not applicable.
Materials and Supplies: No materials and supplies will be charged by this subcontractor.

Travel: No travel costs will be charged by this subcontractor.
Other Direct Costs: Laboratory analytical costs will be paid through Glendale and are anticipated to be $100,000 including QA/QC samples.
Indirect Costs: No indirect costs are expected for this subcontractor.