Appendix 3 – CH2M Hill Reports

Big Canyon Wash Wetlands Restoration: Baseline Selenium Results

Prepared for

City of Newport Beach, California, and the Santa Ana Regional Water Quality Control Board

November 6, 2008

Prepared by

Earl Byron and Gary Santolo

CH2MHILL

2485 Natomas Park Drive, Suite 600
Sacramento, CA 95833

Background

The City of Newport Beach is considering various design elements related to the restoration of habitat in Big Canyon Wash (BCW), a small (2 square mile) tributary watershed draining to Upper Newport Bay. The 60-acre undeveloped area of the watershed being considered for restoration is known as Big Canyon Creek Nature Park and is the most downstream portion of the watershed.

Preliminary studies of the water quality and sediment in this drainage revealed water quality exceedances for selenium (over the 5 µg/L chronic criterion for protection of aquatic life [Weston, 2007]) and elevated selenium in sediment (over the 4 mg/kg dry weight ecological risk guideline [Sutula et al., 2008]). The purpose of the current study was to provide a more comprehensive baseline characterization of selenium in surface water, wetted sediments, and tissues of resident aquatic biota. The results will provide a record of the spatial distribution of selenium within the drainageway and the overall level of contamination during dry-weather flows. These findings can be used to assess possible impairment of beneficial uses due to selenium and to assist with the design of restoration alternatives. Additional samples (i.e., sediment or soil borings or samples from selected storm drains) may be necessary for further characterization of the site and as related to specific restoration alternatives.

Methods

The baseline sampling effort characterized waterborne selenium and selenium speciation throughout the lower drainage and on into Upper Newport Bay; it also included samples from three tributary stormdrains that contribute to the main flow of the creek along the northeast side of the drainage. Other stormdrains were dry at the time of sample collection during June 9 to 11, 2008. Water, sediment, and biota were sampled from the sites shown in Figure 1. Site-by-site collection details are provided in the results tables, as indicated below.

Water

All water was sampled as grab samples using standard clean handling techniques and transported on ice to the laboratory for filtration and processing within 24 hours of collection. The deep sample in the pond (LBCW-FWMP-D, see Figure 1) was collected using a Van Dorn sample bottle lowered into approximately 5 feet of water depth.

Field measurements were limited to temperature and salinity (from a refractometer) as water quality meters were otherwise unavailable at the time of sampling.

Sediment

Surface sediments (top 3 - 6 inches) were sampled using a clean stainless steel trowel as compiled from multiple scoops over a small area (4 – 5 square feet). Samples were kept chilled and dark and shipped to the laboratory within 24 hours of collection.

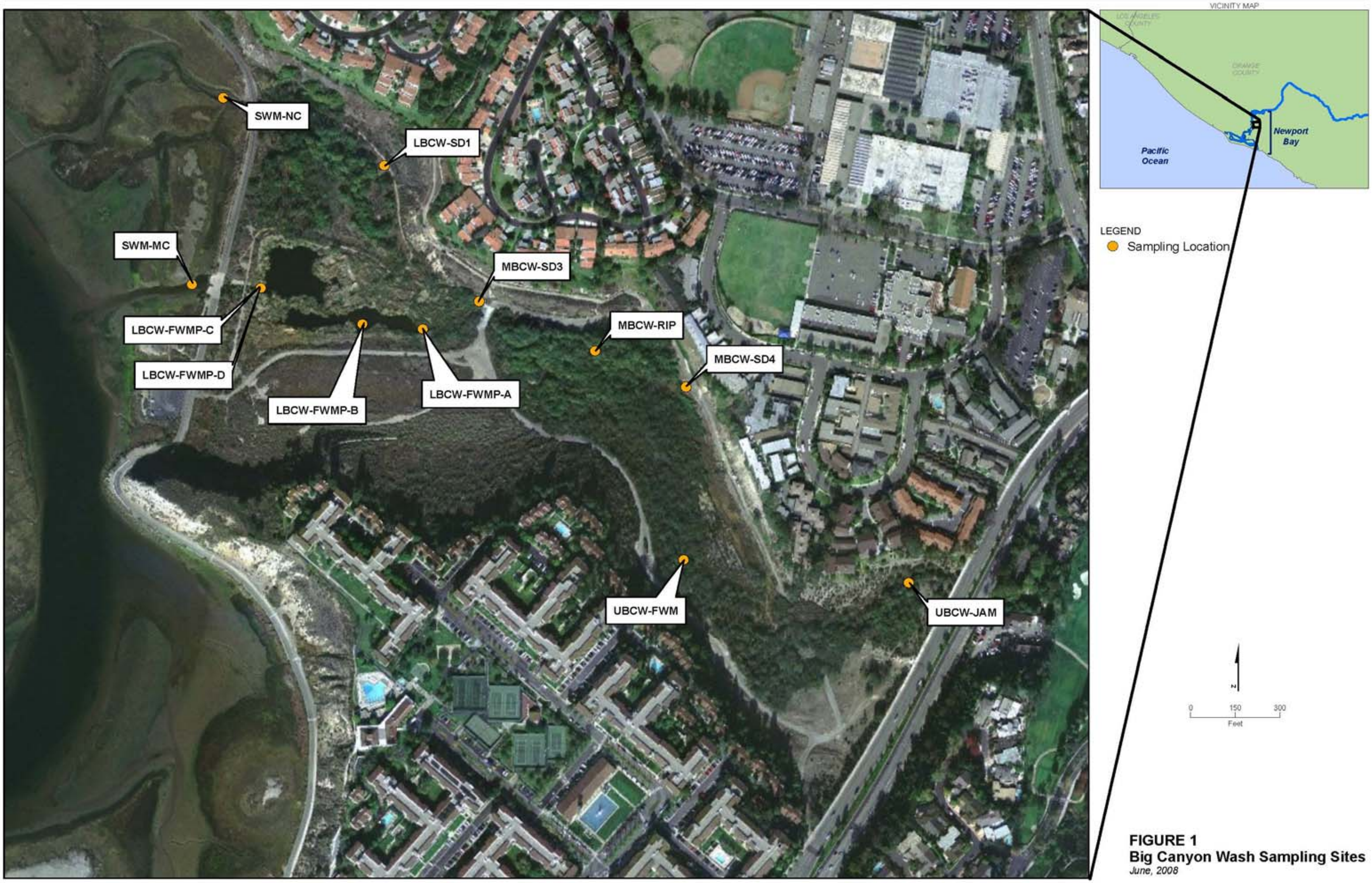


FIGURE 1
Big Canyon Wash Sampling Sites
June, 2008

Biota

All biota tissues were analyzed as whole-body composite samples of at least 4 or 5 individuals of similar taxa for any given sample. Samples were collected by hand (e.g., mussels, algae) or, most often, by kicknet or other net (e.g., insects, crayfish, frogs, fish). Composite samples were placed into clean Ziploc or Whirlpak bags for transport to the laboratory. Mussels were shelled by the laboratory before analysis of soft tissues. No bird eggs were found for collection.

Results and Discussion

Water

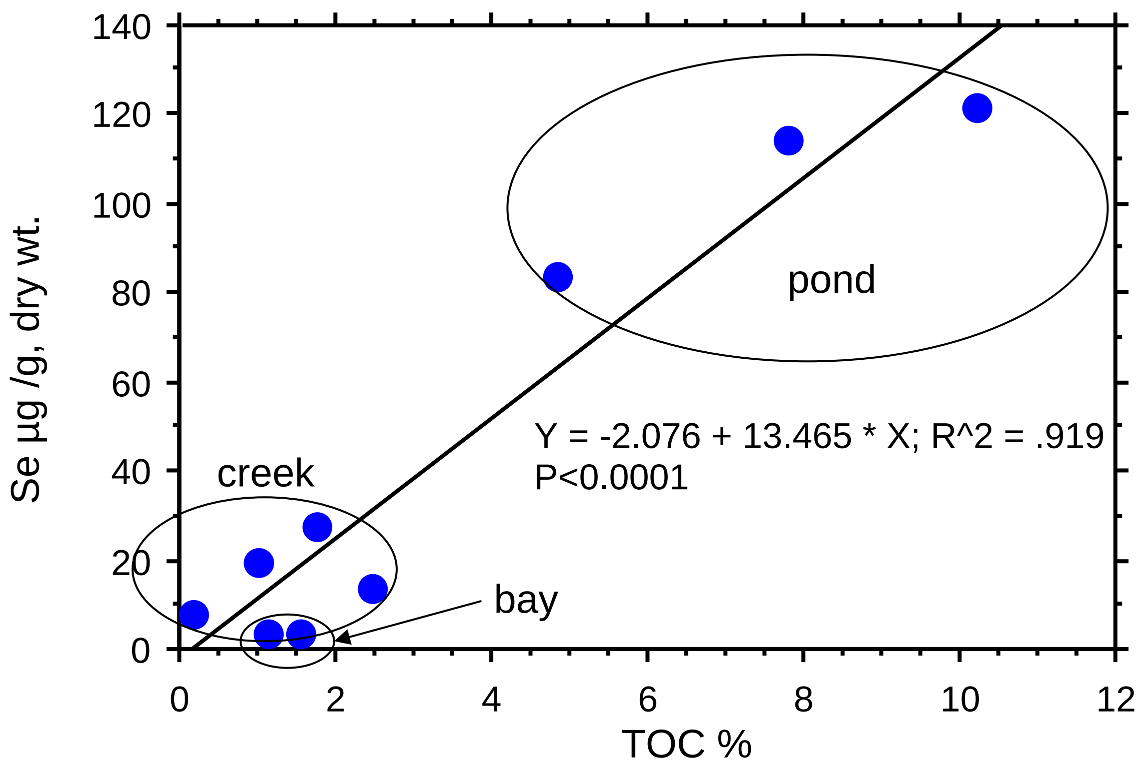
Surface water chemistry results are shown in Table 1, and sampling locations are shown in Figure 1. Selenium results are shown at the top of the table for ease of presentation, and location identifiers are abbreviated to simplify the “Site” columns of the table. Total selenium concentrations ranged from 8.23 to 23.6 µg/L. All freshwater BCW sites were in exceedance of the California and National water quality criterion value of 5 µg/L (as total recoverable selenium). In comparison to other water quality criteria, only copper in the bay showed exceedance of the criterion value for saltwater (Table 1).

There was a clear and logical pattern of waterborne selenium contamination throughout the wash. Elevated concentrations of selenium flow downstream from Jamboree Road as part of the main drainage flow. Concentrations were all about 20 – 25 µg Se/L running down the wash until entering the pond, where waterborne concentrations decreased, probably associated with biotic uptake, loss, and sedimentation processes. Water flowing into the pond (FWMP-A) entered at 23.6 µg Se/L but then decreased to 14.4 before exiting the pond at the lower end (FWMP-C) (Table 1). As the main flow entered the bay, it was immediately diluted with bay water to a concentration of 8.23 µg Se/L. The salinity at the bay location NC at the time of water collection was 10 parts per thousand (ppt), indicating estuarine conditions and significant dilution of freshwater flows with bay water. Stormdrains with minimal flow that enter the channel from the north side ranged from less than 2 to 13 µg Se/L. The main flow that crosses under Jamboree Road carries most of the selenium down the wash and into the pond during dry weather flows.

Sediment

Sediment concentration patterns support the concept of the pond as a sink for the particulate fractions of waterborne contaminants and for an area of biological uptake and sediment accumulation. Table 2 shows that the main drainage in the upper part of the wash contains variable concentrations of total selenium in surface sediments (7.8 to 27.6 µg Se/g). It is likely that the high variability is due to uneven deposition and association with organic fractions in a flowing, creek environment. In contrast, the pond showed very high concentrations of selenium associated with surface sediments, ranging from 84 to 122 µg Se/g. This pattern suggests that the pond functions as a sediment trap for selenium from the upper canyon sources and for settling pond biota that have taken up waterborne selenium. The pond sediments were enriched with soft, decomposing organic material, with total organic carbon and sulfide values significantly higher than all other sediment sampling locations (Table 2). There is a significant, positive relationship between sediment selenium and sediment organic carbon content across all freshwater BCW Sites (Figure 2). The data suggest that selenium is sequestered into the biotic fraction as it enters the pond and accumulates in the pond sediment. The elevated sulfide concentrations in the pond sediments (see Table 2) demonstrate that the organic enrichment contributes to anaerobic, reducing conditions that may help trap selenium and help explain the high sediment concentrations in the pond. Other constituents showing exceedances of sediment quality guidelines included arsenic, barium, cadmium, chromium, cobalt, copper, iron, manganese, nickel, tin, vanadium, and zinc (Table 2).

FIGURE 2
Selenium and total organic carbon relationship in BCW surface sediments.



As expected, the concentration of surface sediment selenium was immediately reduced as it entered the bay and the areas of tidal flux, with values in the bay at or less than 4 µg Se/g (Table 2). The single off-channel stormdrain (SD1) sampled for sediment selenium revealed a concentration approximating those found in the upper wash drainage (Table 2).

Biota

Selenium concentrations in biota showed surprisingly elevated values as compared to nearby San Diego Creek. Highest selenium concentrations in BCW were found in the main drainage pathway. The off-channel drainage (SD1) and bay samples (MC, NC), though higher than typical background, were all below 10 µg/g selenium except for one mussel sample of 11.9 (Table 3). In contrast, the main creek samples of invertebrates, fish, frogs, and algae all exceeded 25 µg Se/g and the pond fish exceeded 60 µg Se/g (Table 3). These levels are approximately 10 times background concentrations and well above biological toxic effect levels (DOI, 1998). It is likely that these levels of bioaccumulation are associated with the elevated bioavailability of the waterborne selenium, with significant selenite (SeIV) and organoselenium fractions (Table 1). In contrast, selenium in San Diego Creek, with similar waterborne total selenium concentrations to BCW (but dominated by the Se(VI) fraction), appears to be generally much less bioaccumulative.

No aquatic or semi-aquatic nesting birds (e.g., coots, grebes) were found for egg sampling. Several broods of ducklings were seen, indicating the possibility that the sampling might have been conducted too late in the year for most nesting activity. In addition, Orange County Mosquito Abatement was observed in the pond with motor boat and loud blower used to spray pellets for larvicide treatments. Their frequency of treatment of the pond (every 10 to 14 days) probably effectively disturbs and disperses any nesting birds attempting to use the pond (the ducks we observed nest away from the water and then return after the eggs hatch).

These concentrations found in water, sediment, and tissues are high enough to expect reduced reproductive success of sensitive species of birds or fish. It is possible that some sensitive fish species (such as bluegill) could have been extirpated from the stream and pond due to these levels of chronic selenium exposure. These concentrations are comparable to or higher than those found at Belews Lake, NC (Lemly, 1997), and some of the agricultural drainwater evaporation basins in the San Joaquin Valley where impacts have been observed (Saiki and Lowe, 1987; Ohlendorf, 1989).

Other chemicals showing toxicity guideline exceedances in tissue included boron, copper, mercury, and zinc (Table 3). Only selenium and copper showed toxicity guideline exceedances for all media.

The biota sampled included the alga *Enteromorpha* sp. and mussels *Ischadium demissum* (introduced, ribbed horse mussel) in the bay (as noted at this location by Kinnetics, 2004). Freshwater algae were probably *Cladophora* sp. Odonate samples were mixed species of dragonfly and damselfly larvae. Crayfish were probably *Procambarus* sp. The fish sampled were mosquitofish (*Gambusia affinis*) and fathead minnow (*Pimephales promelas*). The frogs were adult African clawed frogs (*Xenopus laevis*).

Conclusions and Recommendations

Conclusions

Although the June 2008 study results reported here represent a snapshot of time during seasonal low flows in BCW, the selenium accumulated in the sediments of the pond and bioaccumulated in biota tissue throughout the drainage indicates the chronic nature of the selenium contamination in this watershed. Selenium concentrations in water, sediment, algae, aquatic invertebrates, and fish all exceed established criteria or toxicity guidelines (i.e., Tables 1, 2, 3) and are comparable to key examples of selenium-polluted areas (DOI, 1998; Ohlendorf, 2003). In addition, many other metals show the pattern of trapping to problem levels in the pond sediments (Table 2).

It is expected that higher, stormwater flows in the wet season would produce lower waterborne selenium (and most other chemical) concentrations. The three stormdrains (SD1, 3, and 4, see Figure 1) all had much lower selenium concentrations than those found in the main drainage (Table 1) and stormwater flows are expected to dilute the selenium concentrations in BCW, as they do in nearby San Diego Creek.

The selenium in BCW is strongly associated with sediments and the organic fraction of those sediments (Figure 2). The highly organic, sulfide-rich sediments of the pond had the highest levels of selenium found in BCW (over 100 µg/g, see Table 2). The pond acts as an effective sink and trapping mechanism for the watershed but also exacerbates exposure and risk to birds and other wildlife through the production of reduced, bioaccumulative forms of selenium and metals (Table 1) and the high levels of bioaccumulation in the pond (over 60 µg Se/g in fish tissues, see Table 3).

Although the ponds might be designed to reduce selenium bioaccumulation somewhat, it is unlikely that they could be designed to provide “safe” habitat for pond turtles unless an alternative water supply is used or the inflow is treated before it enters the ponds. Some of the treatment technologies proposed in the NSMP may serve that purpose, but treatment would be expensive and would require further evaluation. Best management practices that might be implemented would need to reduce the volume of water generated upgradient where it is mobilizing selenium from soil or rocks before entering the lower portion of the watershed.

As noted in Table 2, selenium concentrations in surface sediment throughout much of BCW are far higher than the concentration that was associated with significant effects in fish and birds at various freshwater sites (4 mg Se/kg). The depth (through the soil/sediment profile) to which selenium concentrations are as high as those measured in surface sediment (or perhaps higher at depth?) is not known, but should be determined to assess the suitability of the site for beneficial wetland/pond habitat. It is possible that the entire area has selenium concentrations in soil/sediment so that it would be available through the food chain if ponds are created there, even if alternative water sources are used.

Ponds providing habitat for pond turtles also would be used by various waterbirds (e.g., grebes, waterfowl, shorebirds); selenium concentrations in the BCW water are well into the range of concern for ponds that are accessible to birds.

Recommendations

Restoration actions in BCW should consider the impact of elevated selenium and metals in the drainage and the need for further baseline characterization prior to design.

The following recommendations focus on the selenium problem at BCW:

1. Continue the baseline characterization of selenium contamination in the watershed during dry weather flows by further sampling to trace the waterborne selenium upstream to its source(s).

2. Get monthly and stormflow estimates of flow and selenium load at several points in the watershed to help characterize sources and loads within BCW and loads to Newport Bay. Include the analyses of flow and concentrations from flowing stormflows from as many stormdrains as possible during dry and wet periods.

3. Re-sample the sediment in the pond using cores based on a spatial array with analyses along the vertical gradient as needed to characterize the vertical extent and estimated total volume of contaminated sediment for all constituents of concern.
4. Sample biota in the watershed for tissue selenium concentrations next spring to expand the baseline characterization and to sample bird eggs of species using the marsh, if possible. Combine the egg sampling with bird surveys to document bird use of the BCW downstream of Jamboree, the pond, and the saltmarsh in immediate vicinity of the BCW drainage. Survey the pond and creek for possible use by western pond turtle and the saltmarsh immediately adjacent to BCW for use by California clapper rail.

References

DOI, 1998. *National Irrigation Water Quality Program, Guidelines for Interpretation of the Biological Effects of Selected Constituents in Biota, Water, and Sediment.* US Department of Interior, National Irrigation Water Quality Program, Information Report No. 3, November, 1998.

Kinnetics, 2004. Kinnetic Laboratories and EOA, Inc. *Final Report. Newport Bay Shellfish Harvesting Assessment.* Report to Orange County. August, 2004.

LANL, 2003. Los Alamos National Laboratory. *Ecorisk Database. Release 2.0a.* RRES-RS Project. November.

Lemly, A.D. 1997. Ecosystem recovery following selenium contamination in a freshwater reservoir. Ecotoxicol. Environ. Saf. 36: 275 – 281.

NOAA SQuiRT Tables. 2004 update. *NOAA Screening Quick Reference Tables.* M. Buchman, NOAA/ARD. Seattle, WA.

Ohlendorf, H.M. 1989. Bioaccumulation and effects of selenium in wildlife. Pages 133-172 in L.W. Jacobs, ed. *Selenium in Agriculture and the Environment.* Soil Science Society of America and American Society of Agronomy. SSSA Special Publication no. 23.

Ohlendorf, H.M. 2003. Chapter 17. Ecotoxicology of Selenium, in Hoffman, et al., (ed.) 2003. *Handbook of Ecotoxicology, 2nd Edition*. Lewis Publishers, Boca Raton.

Saiki, M. K. and T. P. Lowe. 1987. Selenium in aquatic organisms from subsurface agricultural drainage water, San Joaquin Valley, California. *Arch. Environ. Contam. Toxicol.* 16: 657 – 670.

Sutula, M., J. Brown, E. Fetscher, S. Madon, G. Santolo, E. Byron, and C. Stransky. 2008. Habitat Value of Urban Wetlands. *Final report to the Los Angeles Regional Water Quality Control Board for the "Assessment of Effectiveness of Treatment Wetlands for Stormwater BMPs and Compatibility with Wildlife Beneficial Uses".* Grant Agreement No. 04-090-554-0. SCCWRP Technical Report.

TNRCC, 2001 (Texas Natural Resource Conservation Commission). *Guidance for Conducting Ecological Risk Assessments at Corrective Action Sites in Texas.*

USEPA, 1996. *Assessment and Remediation of Contaminated Sediments Program. Calculation and Evaluation of Sediment Effect Concentrations for the Amphipod Hyalella azteca and the Midge Chironomus riparius.* Great Lakes National Program Office. EPA-905-R96-008. September.

USEPA, 2003. *Region 5 Ecological Screening Values for RCRA*. http://www.epa.gov/reg5rcra/ca/edql.htm

USEPA, 2006. *National Recommended Water Quality Criteria.* Office of Water, Office of Science and Technology.

Weston Solutions, Inc. 2007. *Big Canyon Flow and Water Quality Assessment. Report*. prepared for WRC Consulting Services.

Tables

TABLE 1
Water Quality Assessment of Big Canyon Wash and Upper Newport Bay Sites, June 9 - 11, 2008.

					Site												Water Quality Criteria	
					Freshwater Drainage										Newport Bay			
Sample type	ANALYTE	UNITS	MDL	RL	JAM	FWM	RIP	SD1	SD3	SD4	FWMP-A	FWMP-B	FWMP-C	FWMP-D	MC	NC	Freshwater	Marine
Selenium Speciation																		
Total	Selenium	µg/L	0.006	0.03	21.1	21.6	-	13.1	< 2*	< 2*	23.6	17.6	14.4	14.5	-	8.23	5	71
Dissolved	Selenium	µg/L	0.006	0.03	20.5	21.2	-	13	-	-	22.3	17.2	13.5	13.3	-	7.53	-	-
Dissolved	Selenite (SeIV)	µg/L	0.028	0.14	4.35	5.7	-	0.34	-	-	6.66	6.07	4.9	4.43	-	0.83	-	-
Dissolved	Selenate (SeVI)	µg/L	0.023	0.115	16	16.9	-	14.4	-	-	17.4	11	7.75	8.03	-	5.43	-	-
Dissolved	Organo-Selenium	µg/L	0.026	0.13	0.257	0.3	-	ND	-	-	0.279	0.35	0.367	0.264	-	ND	-	-
Other Constituents																		
Dissolved	Antimony	µg/L	0.04	0.5	0.6	0.6	0.6	ND	0.6	0.6	0.6	0.6	0.5	0.5	1.7	1.3	4300	-
Dissolved	Arsenic	µg/L	0.08	1.0	4.8	4.4	4.5	4.1	3.0	2.2	4.7	4.1	4.1	3.7	21	13	150	36
Dissolved	Beryllium	µg/L	0.1	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
Dissolved	Boron	µg/L	17	100	530	560	650	590	150	200	620	710	710	690	2000	1600	-	-
Dissolved	Cadmium	µg/L	0.01	0.25	1.5	1.2	0.94	ND	ND	ND	1.1	1.0	0.62	0.42	ND	ND	6.2	9.3
Dissolved	Calcium	mg/L	1.0	2.0	260	270	280	110	66	67	280	300	310	300	350	240	-	-
Dissolved	Copper	µg/L	0.04	0.5	13	12	12	8.7	5.6	7.5	13	13	12	12	280	93	29.3	3.1
Dissolved	DOC	mg/L	0.14	0.70	ND	7.7	7.9	4.6	6.6	8.3	7.8	8.5	9.0	8.9	6.3	6.4	-	-
Dissolved	Iron	µg/L	50	100	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1000	-
Dissolved	Lead	µg/L	0.03	0.5	220	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	10.9	8.1
Dissolved	Magnesium	mg/L	1.0	2.0	ND	210	220	59	16	18	220	230	230	230	680	340	-	-
Dissolved	Mercury	µg/L	0.12	0.20	12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.77	0.04
Dissolved	Nickel	µg/L	0.06	1.0	8.4	9.0	8.4	5.1	3.7	2.6	8.2	8.1	7.0	7.1	5.4	7.3	168	8.2
Dissolved	Potassium	mg/L	1.0	2.0	11	11	11	13	5.2	11	12	12	11	11	200	110	-	-
Dissolved	Silver	µg/L	0.03	0.25	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	37.4	1.9
Dissolved	Sodium	mg/L	1.0	2.0	510	470	500	300	85	110	500	540	530	530	5000	2600	-	-
Dissolved	Thallium	µg/L	0.02	1.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.47	-
Dissolved	Zinc	µg/L	0.3	1.0	5.8	4.9	5.2	8.2	3.0	17	4.3	5.6	3.9	6.3	8.2	4.9	382	81
Total	Ammonia-N	mg/L	0.059	0.10	0.25	0.22	0.20	ND	ND	0.15	0.20	0.23	0.21	0.22	1.1	0.48		
Total	Antimony	µg/L	0.04	0.5	0.7	0.6	0.6	ND	0.5	0.7	0.6	0.6	0.5	0.5	2.1	0.6		
Total	Arsenic	µg/L	0.08	1.0	4.0	3.4	3.5	4.1	3.0	2.2	3.5	3.7	3.4	3.3	22	10		
Total	Beryllium	µg/L	0.1	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
Total	Bicarbonate	mg/L	1.7	3.0	350	370	390	360	210	200	390	410	420	420	290	490		
Total	Boron	µg/L	17	100	550	610	620	660	150	220	650	740	730	700	2200	1500		
Total	Cadmium	µg/L	0.01	0.25	3.7	2.9	2.7	0.70	ND	ND	2.7	2.0	1.3	1.6	0.70	ND		
Total	Calcium	mg/L	0.50	1.0	260	290	280	120	70	79	290	330	320	310	350	240		
Total	Carbonate	mg/L	1.7	3.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
Total	Chloride	mg/L	0.17	1.0	760	740	770	300	83	130	760	850	860	760	9900	3000		
Total	Copper	µg/L	0.04	0.5	14	13	15	9.0	8.5	11	14	14	14	15	310	42	29.3	3.1
Total	Fluoride	mg/L	0.05	0.1	0.5	0.5	0.6	0.4	0.5	0.6	0.6	0.6	0.6	0.5	0.7	0.6		
Total	Hydroxide	mg/L	1.7	3.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
Total	Iron	µg/L	25	50	ND	ND	ND	520	210	140	ND	ND	ND	ND	ND	1800		
Total	Kjeldahl-N	mg/L	0.062	0.10	1.1	0.62	0.50	1.1	1.3	1.2	0.40	0.30	0.55	0.85	1.1	0.56		
Total	Lead	µg/L	0.03	0.5	ND	ND	1.4	ND	0.7	1.3	ND	ND	ND	ND	ND	0.9		
Total	Magnesium	mg/L	0.50	1.0	210	220	210	61	17	21	230	240	240	230	660	240		
Total	Mercury	µg/L	0.12	0.20	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
Total	Nickel	µg/L	0.06	1.0	14	11	8.0	6.0	3.4	2.6	8.3	7.8	6.9	7.1	5.9	9.9		
Total	Nitrate-N	mg/L	0.11	0.20	0.29	0.32	0.29	1.8	0.27	ND	0.29	ND	ND	ND	ND	0.50		
Total	Nitrite-N	mg/L	0.017	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
Total	pH	pH Units	1.0	1.0	7.7	7.6	7.7	7.7	7.8	7.3	7.9	7.6	7.4	7.4	7.6	7.8	6.5 - 8.5	
Total	Potassium	mg/L	0.50	1.0	11	11	10	15	6.2	14	11	12	11	11	190	63		
Total	Silver	µg/L	0.03	0.25	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
Total	Sodium	mg/L	0.50	1.0	490	490	470	320	86	130	510	550	540	520	4600	1500		
Total	EC	umhos/cr	1.0	1.0	4100	4200	4200	2300	870	1100	4200	4600	4600	4600	26000	11000		
Total	Sulfate	mg/L	0.17	0.50	1200	1300	1400	530	140	170	1400	1500	1500	1400	2000	1200		
Total	Thallium	µg/L	0.02	1.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
Total	Total Alkalinity	mg/L	1.7	3.0	290	310	320	290	170	160	320	340	340	340	240	400		
Total	TDS	mg/L	11	20	3200	3400	2200	1500	540	650	9500	3800	3800	3700	19000	7100		
Total	TOC	mg/L	0.33	1.4	8.8	7.8	7.8	5.6	8.0	9.7	7.9	9.0	9.5	9.6	6.5	6.6		
Total	Phosphorus	mg/L	0.01	0.05	0.21	0.18	0.18	0.46	0.75	0.41	0.19	0.21	0.23	0.25	0.21	0.05		
Total	Zinc	µg/L	0.3	1.0	10	6.7	9.3	19	14	38	6.2	8.9	6.5	10	15	10		

Notes:
*Selenium at sites SD3 and SD4 was characterized by another lab showing high bias for Se; these were both measured as less than 2 µg/L.
Highlighted values exceed water quality criteria
Hardness-dependent metals criteria estimated at 400 mg/L hardness (maximum)
MDL = detection limit
RL = reporting limit

TECHNICAL MEMORANDUM CH2MHILL

Supplemental Surface and Groundwater Sampling, June, 2009: Big Canyon Creek, Newport Beach.

PREPARED FOR:	Robin Hayes/VA Consulting Robert Stein/City of Newport Beach
PREPARED BY:	Earl Byron/CH2M HILL
COPIES:	Gary Santolo Richard Sturn CH2M HILL
DATE:	July 17, 2009

The purpose of this memorandum is to report the chemical analytical results for two surface water and two groundwater samples collected within the Big Canyon Creek watershed on June 29, 2009. The surface water samples are supplemental to a more extensive investigation of selenium sources in the watershed conducted on May 8, 2009 (CH2M HILL, 2009). The lakes were sampled as surface grab samples from the shore.

The surface water sampling locations of Lakes 1 and 6 are shown in Figure 1. The lakes were not sampled as part of the May, 2009 investigation because they are not part of the main surface water drainage constituting the inflows, drainages, and golf course lakes. The results as shown in Table 1 confirm that the surface waters of lakes 1 and 6 were found to be quite low in selenium concentration (i.e., less than 2 µg Se/L), in contrast to the other lakes and stream courses in the golf course, that ranged from 14 to 65 µg Se/L (CH2M HILL, 2009). Based on the selenium concentrations observed in these lakes, they are not part of the main drainage systems.

The two groundwater samples were collected as duplicates from the same boring in the Nature Park area and were in close agreement, ranging from 9.5 to 11.2 µg dissolved Se/L (Table 1). Note, however, that although they are slightly lower in concentration than most of the Big Canyon Creek surface water samples, they still exceed the National Recommended Water Quality Criterion of 5 µg Se/L for the protection of freshwater aquatic life.

The two lake samples, although much lower in concentration than other Big Canyon Creek surface water samples, have a proportion of total selenium as selenite (SeIV) near 50%. As is similar to the rest of the surface water system, the elevated percentage of selenium in the form of the more bioaccumulative species, selenite, is likely to favor selenium bioaccumulation in the watershed (e.g., CH2M HILL, 2009). Chemical and biological recycling within the lakes favors the formation of more chemically-reduced forms, such as selenite.

Reference:

CH2M HILL, 2009. DRAFT Big Canyon Creek Restoration: Selenium Source Tracking. Prepared for City of Newport Beach, California, June, 2009.

Table 1. Analytical Chemistry Results for Water Quality Samples Collected June 29, 2009. Big Canyon Wash, Newport Beach, California

Analyte	**Results (µg/L) unless otherwise noted.**			
	Lake 1	**Lake 6**	**Groundwater 1**	**Groundwater 2**
TSS (mg/L)	3.7	11.2	NR	NR
TDS (mg/L)	522	535	NR	NR
Hardness (mg/L)	203	229	NR	NR
Se (IV)	0.95	0.44	0.19	0.25
Se (VI)	0.224	0.215	6.86	7.90
SeCN	ND (<0.085)	ND (<0.085)	ND (<0.085)	ND (<0.085)
MeSe(IV)	ND (<0.11)	ND (<0.11)	ND (<0.11)	ND (<0.11)
SeMe	ND (<0.11)	ND (<0.11)	ND (<0.11)	ND (<0.11)
Diss Se	1.33	0.84	9.48	11.2
Total Se	1.77	0.986	NR	NR
Diss Cd	0.076	ND (<0.011)	NR	NR
Total Cd	0.188	0.166	NR	NR
Diss Cu	2.48	1.94	NR	NR
Total Cu	7.00	6.66	NR	NR
Diss Cr	0.122	0.074	NR	NR
Total Cr	0.293	1.45	NR	NR
Diss Ni	1.63	2.34	NR	NR
Total Ni	2.06	4.04	NR	NR
Diss Pb	ND (<0.032)	ND (<0.032)	NR	NR
Total Pb	ND (<0.080)	0.332	NR	NR
Diss Zn	1.71	0.96	NR	NR
Total Zn	2.84	4.34	NR	NR

ND = Not detected at the applied dilution
NR = Analyte not requested

Figure 1. Proposed Sampling Locations – Big Canyon Golf Course

Boring for groundwater sample

Sample Locations: Inflow Lake Riparian Outflow Blueline Stream Storm Drain

CH2M Hill 2009b

Final

Big Canyon Creek Restoration: Selenium Source Tracking

Prepared for

City of Newport Beach, California

June 2009

Prepared by:
Earl Byron and Gary Santolo

CH2MHILL
2485 Natomas Park Drive, Suite 600
Sacramento, CA 95833

Background

The City of Newport Beach, Orange County, CA is considering various design elements related to the restoration of habitat in Big Canyon Creek, a small (2 square mile) tributary watershed draining to Upper Newport Bay. The small watershed is characterized by several small drainages that join within the area of the Big Canyon Country Club golf course and contribute to some of the open water features (ponds, streams) within the body of the course. The single stream collects water from all combined upstream sources, exits the golf course, and continues downstream through an undeveloped portion of the watershed that includes the stream, a pond, and drainage into the tidal marsh channels of upper Newport Bay. This 60-acre undeveloped area of the lower watershed, known as Big Canyon Creek Nature Park, is being considered for restoration.

Preliminary studies of the water quality and sediment in this drainage revealed water quality exceedances for selenium (over the 5 µg/L chronic criterion for protection of aquatic life [Weston, 2007]) and elevated selenium in sediment (over the 4 mg/kg dry weight ecological risk guideline [Sutula et al., 2008]). A subsequent investigation in 2008 revealed elevated selenium concentrations in water, sediment, and biota throughout the lower watershed Nature Park (CH2M HILL, 2008). The purpose of the current study was to trace upstream selenium concentrations from multiple sources and to characterize the general level of selenium and other metals contamination and selenium speciation (a measure of biological risk and uptake potential) in the areas of the watershed upstream of the Nature Park. The results provide a record of the spatial distribution of selenium within the watershed, the overall level of contamination during dry-weather flows, and identify possible sources emanating from upstream or within the golf course. These findings can be used to assess possible impairment of beneficial uses due to selenium and to assist with the design of restoration alternatives. Flows and concentrations were estimated to produce a "snapshot" estimate of selenium mass balance loading throughout the system during a time of low, baseflow conditions.

Biota sampling in the downstream Nature Park pond was conducted to further characterize bioaccumulation of selenium and various metals in the eggs of aquatic-dependent birds and their potential food items. Unfortunately, no eggs were available for collection (see below).

Methods

Samples were collected on May 8, 2009 to characterize waterborne selenium, selenium speciation, and other metals throughout the upper drainage in the area of the golf course (Figure 1). Inflows 11 and 15 were not sampled because they were dry. Lakes 1 and 6 were not sampled because they were not part of the flow-through drainage that went through to Newport Bay. Inflows 4 and 5 were sampled after their confluence with the main, small drainage along the eastern half of the golf course (instead of as indicated on Figure 1). As a result, Riparian 3 was not separately sampled because it was redundant with these two new locations.

Figure 1. Proposed Sampling Locations – Big Canyon Golf Course

Sample Locations: Inflow Lake Riparian Outflow Blueline Stream Storm Drain

All water was sampled as grab samples using standard clean handling techniques and transported on ice to the laboratory for filtration and processing within 24 hours of collection. Water samples were analyzed by Applied Speciation and Consulting, LLC, using ion chromatography inductively coupled plasma mass spectrometry (IC-ICP-MS) for selenium speciation. Total metals, hardness, and metals on particulates were analyzed by ICP dynamic reaction cell methods (ICP-DRC-MS). Water field meter readings (pH, EC, temperature) were collected at each site at the time of water sampling using a calibrated, field multimeter.

Flow velocity was estimated at all flowing water locations using a PolySonics flow meter with direct readout in feet per second. Channel depths and widths were measured directly using a metal tape and averaged to estimate the cross sectional area of flow. The cross sectional area multiplied by velocity produced the estimates of instantaneous flow in cubic feet per second (cfs).

The pond in the Nature Park was searched extensively for nesting aquatic-dependent birds (e.g. shorebirds, waterfowl) for possible egg collection on May 7, 2009. Searches were conducted along the shoreline on foot and in the pond from a kayak. No nests were found. Instead, potential bird food items were collected at the pond inlet, mid-pond, and the pond outlet. The samples included filamentous algae, crayfish, mosquitofish, and fathead minnow. All were analyzed for total tissue selenium and other metals in composite, whole-body samples, except for the fathead minnow sample, which consisted of a single, whole-body fish. Biota were collected using a kicknet or by hand (algae) and sent on wet ice to the laboratory within 24 hours of collection. The tissue samples were analyzed by ICP-MS (EPA method 6020m) by CRG Marine Laboratories, Inc. All results, including QA/QC, are included in the Appendix.

1.1 Results and Discussion

1.1.1 Water

Surface water chemistry results are shown in Tables 1 and 2, and sampling locations are shown in Figure 1 with exceptions as noted in the Methods section, above. The sample results are grouped to show the two main drainages versus the outlet. The eastern drainage takes inflow from Inflows 3, 4 and 5, flows into Riparian 3 and then to the outflow at Jamboree Road. It does not include any lakes in line with the flows (Lake 6 is bypassed and was not sampled). The western drainage combines flows from Inflows 1 and 2, continues to Lake 1, Riparian 1, Lakes 3, 4, and 5 before merging flows with the eastern drainage (Site Inflow 5+) immediately upstream of the Outflow. Lake 1 was not sampled on the western drainage because it was not part of the flow-through system.

The waterborne selenium concentrations and loads of selenium (Table 1) are depicted in Figure 2 for the two flowpaths of the golf course. Note that the volume of Inflows 1-5 approximately equals to the Outflow volume indicating little gain or loss in flows over the area of the golf course.

As expected, selenium loads for both drainages were not found to be constant probably due to sedimentation losses and biotic uptake.

The relatively elevated selenium load from Inflow 3 (Figure 2) are due to extremely high total selenium concentrations (Table 1) coupled with low flows in the stormdrain. Because the shallow sheetflow in the drain, the flow meter could not be used; velocities were estimated by timing floating objects).

For the western drainage, Inflows 1 and 2 add together to form the Riparian 1 flows. The Riparian 2 and Inflow 5+ flows add together to match the measured Outflow.

The western and eastern drainage combined selenium loads add to match the estimated Outflow load (Figure 2, Table 1).

Although selenium loads increase moving downstream through the golf course (Figure 1) the total selenium concentrations general decrease over the course of both drainages

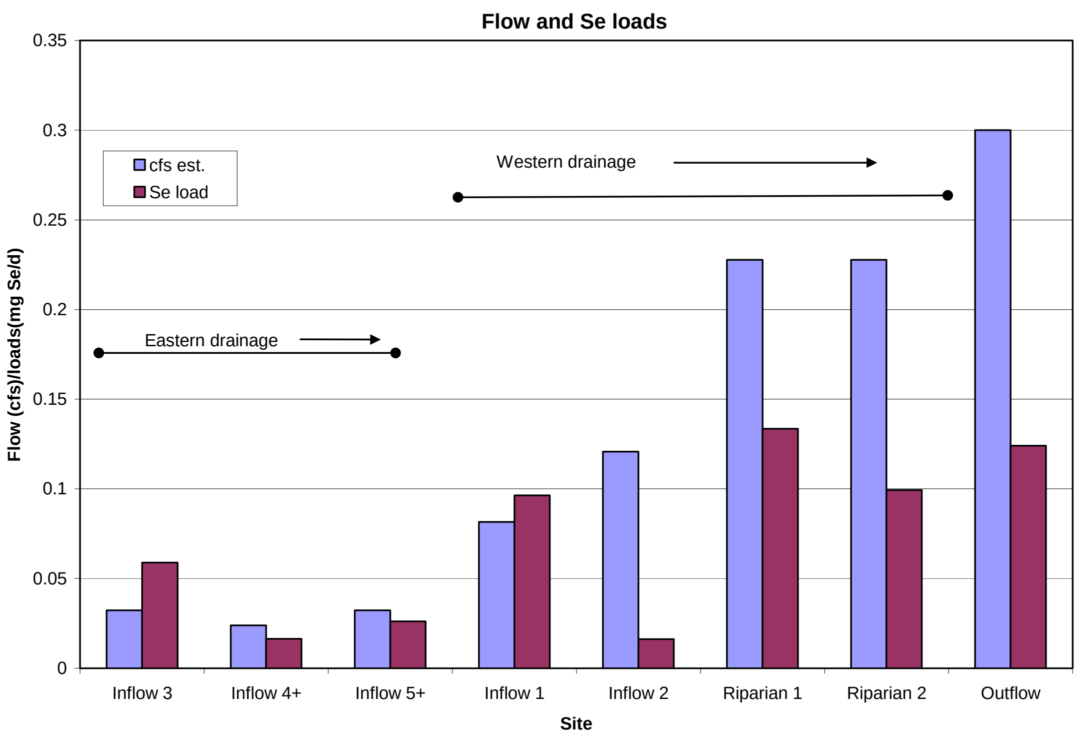


FIGURE 2
Surface water flow and associated selenium loading throughout the Big Canyon Country Club golf course area, May 8, 2009. Inflows 1 and 2 are independent additive drainages of the westernmost channel.

(Figure 2). This is particularly true for the western drainage as it passes through the three lakes, all likely sites of selenium sedimentation and biotic uptake and loss from the waterborne phase. The system of lakes acts to remove selenium through sequestration and sedimentation.

The system of lakes in the western drainage is linked to the production of organic and reduced forms of selenium. The biotic processes of the lakes are illustrated in Figure 3 by the stepwise increase in the proportion of total selenium as selenite (Se 4+), the more chemically-reduced form of selenium that is formed from biotic processes and reducing environments such as wetlands or lakes. Waterborne selenium enters the golf course in the

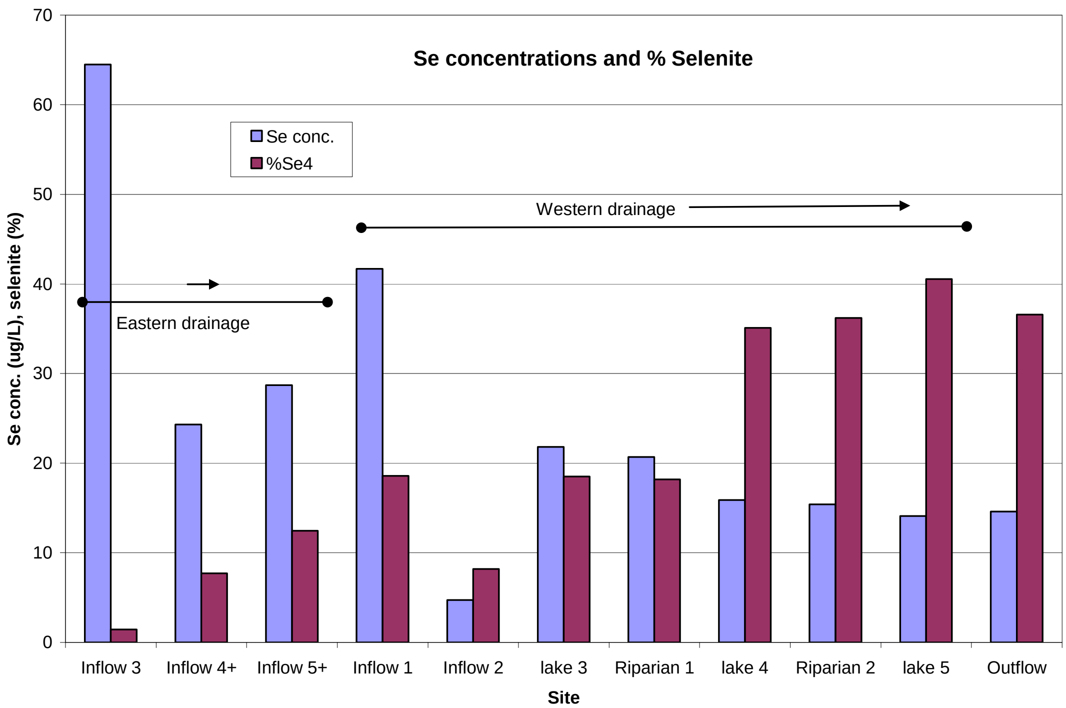


FIGURE 3
Total selenium concentrations and percent of total dissolved selenium as selenite (Se 4+). Inflows 1 and 2 are independent, additive drainages that go to Lake 3.

range of 1 to 19 percent selenite and exits at the Outflow at about 37 percent (Table 1, Figure 3). Selenite, and the organic selenium species as seen in the system of lakes on the western drainage (Table 1) are a concern because of the potential for greatly enhanced bioaccumulation rates in resident biota from these forms of selenium, as compared to selenate (Se 6+) (CH2M HILL, 2008, 2009; Presser and Luoma, 2009).

The concentrations of additional metals of possible concern and other constituents in water are presented in Table 2. Note that the water is basic in pH with relatively high total dissolved solids and hardness. As a result, the hardness-dependent water quality criteria as appropriate for most of the dissolved metal concentrations are elevated and none of the metal concentrations exceed criteria. In contrast, all selenium values from all samples exceed the current chronic freshwater criterion of 5 µg/L (Table 1).

1.1.2 Biota

Selenium concentrations in the biota of the Nature Park pond showed elevated values as compared to nearby San Diego Creek and comparable values to those observed in 2008 (CH2M HILL, 2008). Highest selenium tissue concentrations were found in the fish from the pond and pond outlet (Table 3). No bird eggs were found for analysis. It is likely that these levels of bioaccumulation are associated with the elevated bioavailability of the waterborne selenium, with significant selenite (Se 4+) and organoselenium fractions (Table 1). In contrast, San Diego Creek, with similar waterborne total selenium concentrations to the Big Canyon Creek pond and stream (but dominated by the selenate fraction) appear to be generally much less bioaccumulative.

Other chemicals showing toxicity guideline exceedances in tissue consisted of cadmium, copper, lead, nickel, and zinc (Table 3). Selenium, cadmium, and zinc showed toxicity guideline exceedances for all media.

Freshwater algae were probably *Cladophora* sp. Crayfish were probably *Procambarus* sp. The fish sampled were mosquitofish (*Gambusia affinis*) and fathead minnow (*Pimephales promelas*).

The pond and lower creek area were surveyed for nesting birds for the collection of bird eggs for tissue chemistry analysis on May 7, 2009. Bird species that would likely use the pond and lower creek for nesting include pied-billed grebe (*Podilymbus podiceps*), mallard (*Anas platyrhynchos*), and American coot (*Fulica Americana*). Coots were observed foraging at the outlet of Big Canyon Wash to the upper bay but no nests were found in the Nature Park. We attributed the lack of nesting in the Nature Park to the intensity of the vector control efforts. Orange County Mosquito Abatement was observed in the pond with motor boat and loud blower used to spray pellets for larvicide treatments during our 2008 sampling effort. Although Mosquito Abatement was not encountered during our 2009 sampling, evidence of their continued vector control program was observed in the pond. The frequency of treatment to the pond (every 10 to 14 days) probably effectively disturbs and disperses any nesting birds attempting to use the pond.

1.2 Conclusions

The waterborne selenium chemistry results provide a clear pattern of selenium loading and transformation and loss through the golf course portion of the BCW watershed as a snapshot for May 8, 2009, during a period of low, baseflows during the dry season. As shown in Table 1 and Figures 2 and 3, even though Inflow 3 was exceptionally elevated in total selenium concentration (64.5 µg/L) it had very little flow and load. Most of the selenium load in the system was in the western drainage, as supplied through Inflow 1 (at 41.7 µg/L). As the selenium travelled through the system of small lakes and interconnected streams it is greatly reduced in concentration (Figure 3) but slightly increased in total load (Figure 2). The drop in concentration can probably be attributed to biotic uptake and sedimentation. The total selenium concentration exiting the golf course was 14.6 µg/L.

The conversion of selenium to increasing proportion as selenite over the downstream course of the western drainage is evident in Figure 3. As was evident from previous samples in the Nature Park (CH2M HILL, 2008) and confirmed by the biota tissue results in Table 2, selenium bioaccumulation in fish and invertebrates is greatly enhanced in Big Canyon Creek as compared to nearby San Diego Creek locations where total waterborne selenium concentrations are comparable. The important difference between the sites is the elevated proportion of selenium as the more-bioaccumulative form, selenite, in Big Canyon Creek. It appears that the primary source of that selenite is the selenium rich flow emanating from Inflow 1 (entering at 19 percent selenite, Table 1) and subsequent selenite formation in the series of small lakes (doubling the selenite to 37 percent).

It is expected that stormwater flows will produce lower waterborne selenium (and most other chemical) concentrations due to dilution of selenium concentrations in Big Canyon Creek, as they do in San Diego Creek (CH2M HILL, 2009).

The selenium in Big Canyon Creek is strongly associated with sediments and the organic fraction of those sediments. The highly organic, sulfide-rich sediments of the Nature Park pond had the highest levels of selenium found in Big Canyon Creek (over 100 µg/g) (CH2M HILL, 2008). The pond acts as an effective sink and trapping mechanism for selenium, and as such, exacerbates exposure and risk to birds and other wildlife through the production of reduced, bioaccumulative forms of selenium and metals (almost 50 µg Se/g in fish tissues, see Table 3). Biota was not sampled within the golf course lakes and streams, but would be expected to be elevated in selenium concentration.

The uptake of selenium from dissolved waterborne fractions into organic particles, known as the partitioning coefficient (K_d), is the first step in the food chain and an important measure of selenium's bioaccumulation potential in any given environment. The K_d is simply calculated as the selenium concentrations in particulate form (algae, sediment, or suspended particles) divided by the dissolved waterborne fraction. Higher K_ds indicate a higher transfer of selenium from dissolved inorganic forms into the food chain. The K_ds in the golf course lakes (Table 1) are indicative of areas of elevated biotic uptake of selenium (Presser and Luoma, 2009). The high K_ds are undoubtedly caused by the elevated proportion of selenite in the drainage (as was seen in the downstream Nature Park pond, CH2M HILL, 2008).

Bird eggs were not collected from the vicinity of the Nature Park pond, although birds are likely foraging in the pond. The potential dietary items provide some measure of potential exposure and risk to aquatic dependent birds and mammals (Table 3). As was affirmed in 2008, biota tissues in this portion of the Big Canyon Creek watershed remain the highest measured in the Newport Bay watershed and well above current EPA guidelines and potential future tissue-based TMDL targets for the watershed of 5 µg/g and 8 µg/g for whole-body fish and bird egg tissue, respectively.

Recommendations

Restoration actions in Big Canyon Creek should consider the effect of elevated selenium and metals in the drainage and the need for further baseline characterization.

The following recommendations focus on the selenium problem at Big Canyon Creek:

1. Continue the baseline characterization of selenium contamination in the watershed during dry weather flows by sampling to trace the waterborne selenium upstream to its source(s).

2. Get monthly and stormflow estimates of flow and selenium load at several points in the watershed to help characterize sources and loads within Big Canyon Creek and loads to

Newport Bay. Include the analyses of flow and concentrations from stormflows from as many drains as possible.

3. Re-sample the sediment in the pond using cores based on a spatial array with analyses along the vertical gradient as needed to characterize the vertical extent and estimated total volume of contaminated sediment for all constituents of concern.
4. Sample biota, including bird eggs of species using the marsh, throughout the watershed for tissue selenium concentrations to expand the baseline characterization . Combine egg sampling with bird surveys to document bird use of Big Canyon Creek downstream of Jamboree, the pond, and the saltmarsh in immediate vicinity of the Big Canyon Creek drainage. Survey the pond and creek for possible use by western pond turtle and the saltmarsh immediately adjacent to Big Canyon Creek for use by California clapper rail.

References

CH2M HILL, 2008. *Big Canyon Wash Wetlands Restoration: Baseline Selenium Results.* Report prepared for the City of Newport Beach, California and the Santa Ana Regional Water Quality Control Board. Nov. 6, 2008.

CH2M HILL, 2009. *Sources and Loads for Selenium in the Newport Bay Watershed.* Final Report, for the Nitrogen and Selenium Management Program (NSMP) Working Group. June, 2009.

Hinck, J.E., C. J. Schmitt, K. A. Chojnacki, and D. E. Tillitt. 2009. Environmental contaminants in freshwater fish and their risk to piscivorous wildlife based on a national monitoring program. *Environ. Monit. Assess.* 152: 469 – 494.

Presser, T. S. and S. N. Luoma. 2009. *Modeling of Selenium for the San Diego Creek Watershed and Newport Bay, California*. USGS Open-File Report; In review.

Sutula, M., J. Brown, E. Fetscher, S. Madon, G. Santolo, E. Byron, and C. Stransky. 2008. Habitat Value of Urban Wetlands. *Final report to the Los Angeles Regional Water Quality Control Board for the "Assessment of Effectiveness of Treatment Wetlands for Stormwater BMPs and Compatibility with Wildlife Beneficial Uses".* Grant Agreement No. 04-090-554-0. SCCWRP Technical Report.

Weston Solutions, Inc. 2007. *Big Canyon Flow and Water Quality Assessment. Report*. prepared for WRC Consulting Services.

Tables

TABLE 1
Big Canyon Wash water sampling results for selenium.

May 8, 2009.

Site	Flow (cfs)	Total Se (µg/L)	Se load (mg/day)	Se 4+ (µg/L)	Se 4+ (%)	Organic Se (µg/L)	Organic Se (%)	Dissolved Se (µg/L)	Particulate Se (mg Se/kg dw)	Kd (part./diss)*1000
Inflow 3	0.032	64.5	0.059	0.91	0.014	ND	ND	62.9		
Inflow 4+	0.024	24.3	0.016	1.78	0.077	ND	ND	23.1		
Inflow 4 only*	ND									
Inflow 5+	0.032	28.7	0.026	3.58	0.125	ND	ND	28.7		
Inflow 5 only*	0.008	41.3	0.010							
Inflow 1	0.082	41.7	0.096	7.4	0.186	0.25	0.006	39.8		
Inflow 2	0.121	4.74	0.016	0.37	0.082	ND	ND	4.52		
lake 3		21.8		3.74	0.185	2.19	0.108	20.2	39.2	1941
Riparian 1	0.228	20.7	0.134	3.6	0.182	1.54	0.078	19.8		
lake 4		15.9		5.02	0.351	0.73	0.051	14.3	66.9	4678
Riparian 2	x	15.4	0.099	5.07	0.362	0.32	0.023	14		
lake 5		14.1		5.39	0.405	0.67	0.050	13.3	45.2	3398
Outflow	0.300	14.6	0.124	5.16	0.366	0.65	0.046	14.1		

* estimated by subtraction
* Inflow 4 yielded negative results, no estimates possible
Inflows 11 and 15, riparian 3, and lakes 1 and 6 not sampled.

TABLE 2
Big Canyon Wash, water quality sampling results other than selenium, May 8, 2009.

Site	pH	TSS (mg/L)	EC (mS/cm)	TDS (mg/L)	Hardness (mg/L)	Cadmium (µg/L)		Copper (µg/L)		Chromium (µg/L)		Nickel (µg/L)		Lead (µg/L)		Zinc (µg/L)	
						Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
Inflow 3	7	2.2	4.1	2180	868	1.2	2.11	4.27	6.61	0.367	0.501	4.08	4.34	0.062	<0.17	8.26	10.7
Inflow 4+	6.9	11.2	2.6	1310	563	0.42	1.70	6.21	33.30	0.239	4.010	2.87	10.90	0.048	2.61	18	118
Inflow 5+	8.3	6.2	3.2	2160	1030	9.05	10.20	4.84	7.09	0.159	0.321	8.94	9.63	0.034	1.90	27.7	31.2
Inflow 1	7.7	14.6	6.4	3250	1700	2.05	5.75	2.21	5.03	0.191	0.380	4.67	5.82	0.046	0.19	3.07	7.9
Inflow 2	7	4.4	3.9	1710	679	0.195	0.24	5.46	7.29	0.289	0.457	3.97	4.42	0.035	<0.17	10.3	15.5
lake 3	8.34	19.1	5.69	3220	1570	1.7	5.03	2.61	5.07	0.149	0.441	10.4	12.40	0.028	0.09	1.46	7.3
Riparian 1	8.33	12.6	5.1	3200	1490	1.45	3.62	2.04	4.49	0.134	0.323	9.43	11.40	0.025	<0.17	1.36	5.4
lake 4	7.54	25.7	5.9	3420	1740	0.431	1.85	1.45	3.22	0.119	0.411	8.62	12.20	0.037	0.30	0.64	4.8
Riparian 2	7.95	14	6.04	3640	1730	0.83	2.44	1.82	3.71	0.077	0.241	8.55	11.40	0.018	0.24	0.6	4.6
lake 5	7.7	3.9	6	3530	1750	0.483	1.03	1.99	2.65	0.094	0.146	8.21	9.20	0.022	<0.022	0.52	1.5
Outflow	8.1	7	5.7	3360	1580	0.61	1.19	1.9	3.35	0.089	0.202	7.58	8.83	0.018	<0.17	0.89	2.8
CTR chronic criteria					Mean 1247	14.3		77.4		11		440		33.4		1002	

TABLE 3
Big Canyon Bitoa tissue sampling results.

May 7, 2009 **Nature Park**

			Tissue chemistry (mg/kg dw)						
Site	**Biota**	**Type**	**Cd**	**Cr**	**Cu**	**Pb**	**Ni**	**Se**	**Zn**
Inflow to pond	Filamentous algae	Composite	6.22	6.043	7.952	3.786	9.489	6.847	22.76
	Filamentous algae	Composite	21.67	20.41	27.04	19.1	78.41	15.14	111.8
Mid-Pond	Mosquitofish	Composite	0.422	0.124	6.573	0.095	0.298	48.57	125.4
Pond outflow	Mosquitofish	Composite	0.291	0.129	8.61	0.077	0.536	37.44	98.41
	Fathead minnow	Individual	0.471	0.86	3.676	0.075	0.226	23.27	98.77
	Crayfish	Composite	10.95	1.69	161.4*	0.217	3.116	13.58	62.82
	Crayfish	Composite	4.652	1.153	115.7*	0.195	1.818	9.672	50.53
Tissue toxicity screening guidelines for fish and wildlife			(0.23 - 15.6)	1.0	(11.1 - 42)	(0.4 - 8.8)	58	7.91	(40 - 64)

Highlighted cells show screening exceedances
(Hinck et al., 2009, except for Se = 7.91, USEPA)
* Copper is a component of crustacean blood and therefore probably not a good measure of whole-body contamination.

2010 Selenium Monitoring Results: Fish and Bird Egg Tissue Chemistry, Newport Bay Watershed

PREPARED FOR: Amanda Carr/Orange County
Jian Peng/Orange County

PREPARED BY: Earl Byron/CH2M HILL
Gary Santolo/CH2M HILL

COPIES: Harry Ohlendorf/CH2M HILL
Karen Ashby/LWA
Daniel Apt/RBF

DATE: August 12, 2010

Background

The objective of this task was to conduct additional fish and bird egg tissue monitoring to provide additional baseline data and help inform the development of the Newport Bay Watershed Selenium Total Maximum Daily Load (TMDL). The task included the collection of as many biota tissue samples of target fish and bird eggs as practical from the freshwater drainage sites and bird eggs from the upper bay, including off-channel wetlands, with the exception that no biota samples were collected from the Santa Ana Delhi Channel. Each fish sample was a composite of up to 5 whole-body fish of the same species and similar size. Bird eggs were collected and analyzed as the contents of individual eggs. Twenty (20) fish and thirty (30) bird egg samples were collected for selenium analysis. Two separate trips to collect bird eggs were needed because of the timing of egg laying by different species and nest availability in the watershed. The biota sampling was coordinated to be concurrent with or immediately following a routine County water quality sampling event.

Methods

Sample locations for the fish and bird egg collections are indicated on **Figure 1** and collection methods are described below. Water and sediment were collected from the same or nearby locations and dates by Orange County staff; those collection and analysis methods and results are available from the County.

COPYRIGHT 2011 BY CH2M HILL, INC. • COMPANY CONFIDENTIAL

Figure 1. Newport Bay Watershed with the Five Sites Where Eggs Were Collected Circled in Red and the Five Sites where Fish Were Sampled in Yellow; from Top to Bottom: San Diego Creek, IRWD Marsh, UCI Marsh, Upper Newport Bay, and Big Canyon Golf Course.

COPYRIGHT 2011 BY CH2M HILL, INC. • COMPANY CONFIDENTIAL

Fish

Small, freshwater fish species were targeted for sampling to provide estimates of whole-body tissue selenium concentrations in support of the development of the Selenium TMDL for Newport Bay Watershed. Members of the sunfish and bass family (Centrarchidae) were targeted because of their widespread occurrence and the extensive body of selenium toxicity research for those species. In addition, the new USEPA selenium water quality criteria likely will recommend tissue-based selenium guidelines based on concentrations in fish eggs and ovaries (EPA, 2010). Therefore, a particular objective of this sampling event was to collect eggs and ovaries from bluegill and other centrarchid species to compare to whole-body tissue concentrations. The goal was to develop a site-specific egg/whole-body tissue selenium concentration relationship for the Newport Bay watershed TMDL to facilitate future compliance monitoring where fish egg concentrations may not always be available.

Fish were collected using a 50-foot by 4-foot, ¼-inch mesh beach seine, kicknet, or by electrofishing using a backpack shocker. The effectiveness of electrofishing was limited by high conductivity in lower San Diego Creek and IRWD pond 2, where all fish were captured by seine and kicknets. However, electrofishing proved to be a useful collection tool in the lower conductivity environment of Peters Canyon Wash. Seining and netting were used for mosquitofish collections in UCI Ponds and Big Canyon Wash creek and pond.

Two types of fish samples were prepared for analysis. Composite samples consisted of five or more whole-body fish of similar size submitted for chemical analysis. In two cases, fewer than five fish were available; one composite consisted of two small largemouth bass and another included four fathead minnows from Peters Canyon Wash. The second type of sample consisted of larger individual fish submitted for dissection of eggs and ovaries for analysis and separate analysis of all "remainder" tissues. Two bluegills and one largemouth bass were submitted for these dissections. However, the bass was male and was therefore analyzed as an individual, whole-body fish. The two female bluegills were processed for eggs/ovary and remainder analysis.

For the two female bluegills dissected for eggs/ovary analysis, the reconstructed whole-body fish tissue concentration was estimated as follows:

Whole-body conc. = ((Conc. A)*(weight A)) + ((Conc. B)*(weight B))/ (A+B weights)

Where A = egg/ovary and B = all remainder tissues.

Bird Eggs

Eggs were collected only from nests that contained two or more eggs, and they were considered "random" eggs as opposed to a biased sample (such as "failed-to-hatch" or salvaged eggs). The eggs were collected under California Scientific Collecting Permit 002407 and Federal Collecting Permit MB829185-0. Eggs were not collected from some nests for various reasons (e.g., chicks were pipping the shell or there were too few eggs in the nest for collection). To keep track of each egg and nest site, each egg was marked at collection with its unique nest code and the date it was removed from the nest. The data were recorded along with a location point using a hand-held global positioning system (GPS) unit. Eggs were placed in a container to avoid damage, and then kept on wet ice and then refrigerated until they were examined and processed for chemical analysis.

COPYRIGHT 2011 BY CH2M HILL, INC. • COMPANY CONFIDENTIAL

Eggs with embryos greater than Day 13 of development were considered to be "assessable" for abnormalities because at this stage of development and later, abnormalities can be observed by gross examination. Eggs collected from the Newport Bay watershed were examined to determine their fertility, stage of embryo development, the position of the embryo, embryo viability and normality in assessable eggs, and whether pipping had occurred (i.e., whether the embryo had begun to break out of the egg). Embryos were considered viable if the egg was fertile or an embryo could be observed during processing. Each embryo was examined for evidence of external deformities. The entire contents of the egg were then saved in chemically cleaned containers and stored at -20 degrees Celsius (°C) until they were shipped on wet ice to CRG Laboratories for chemical analyses.

Statistical Analyses

Descriptive statistics are provided for summary purposes. Statistical summaries and tests were performed using the program StatView; specific tests are addressed with the results. Means were considered significantly different if $p \leq 0.05$.

Results and Discussion

Fish

The following fish species were sampled or observed:

- Bluegill (*Lepomis macrochirus*) (Common in San Diego Creek; found in Peters Canyon Wash) [Sampled]
- Green sunfish (*Lepomis cyanellus*) (Found in San Diego Creek and IRWD wetland pond 2) [Sampled]
- Largemouth bass (*Micropterus salmoides*) (Found in San Diego Creek, IRWD wetland pond 2, and Peters Canyon Wash) [Sampled]
- Fathead minnow (*Pimephales promelas*) (Found in San Diego Creek and Peters Canyon Wash) [Sampled]
- Red shiner (*Notropis lutrensis*) (Abundant in Peters Canyon Wash and San Diego Creek) [Sampled]
- Mosquitofish (*Gambusia affinis*) (Abundant in Big Canyon Wash and UCI ponds) [Sampled]
- Common carp (*Cyprinus carpio*) (Abundant throughout San Diego Creek and Peters Canyon Wash) [Not sampled]
- Threadfin shad (*Dorosoma petenense*) (Found in IRWD wetland pond 2) [Not sampled]

Adult and larval African clawed frogs (*Xenopus laevis*) were observed in Big Canyon Wash and UCI wetlands and western pond turtle (*Actinemys marmorata*) were observed in UCI ponds but were not collected.

Fish tissue selenium results for all sites for 2010 are presented in **Table 1**. All fish species analyzed for selenium exhibited some instances of exceedances of TMDL targets for selenium in whole-body fish.

COPYRIGHT 2011 BY CH2M HILL, INC. • COMPANY CONFIDENTIAL

Table 1. Fish tissue selenium concentrations, Newport Bay watershed monitoring, 2010

Species, Location	Tissue Type	Sample Type	Sample	Selenium	Solids
-				(mg/kg dw)	(%)
Bluegill, SDC	Whole-body	Composite	BGASDC	16.7	25.8
	Whole-body	Composite	BGBSDC	14.8	26.9
	Whole-body	Composite	BGCSDC	16.3	24.5
	Whole-body	Composite	BGDSDC	17.3	23.4
	Whole-body	Composite	BGESDC	15.4	23.5
	Remainder	Individual	BGFSDC	15.2*	28.3
	Eggs and Ovary	Individual	BGFSDC	12.7*	32
	Whole-body, est.	Individual	BGFSDC	14.8	28.3
	Remainder	Individual	BGGSDC	13.0*	29.4
	Ovary	Individual	BGGSDC	4.0*	32
	Whole-body, est.	Individual	BGGSDC	12.9	29.4
	Whole-body	Composite	BGHSDC	17.4	26.3
	Whole-body	Composite	BGISDC	15.4	24.7
Red Shiner, PCW	Whole-body	Composite	RSHPCW	12.2	34.1
	Whole-body	Composite	RSH2PCW	11.6	32.6
Bluegill, PCW	Whole-body	Composite	BGPCW	4.2	23.5
Largemouth bass, PCW	Whole-body	Composite	LMBPCW	2.4	32.6
Fathead minnow, PCW	Whole-body	Composite	FHMPCW	9.6	33.35
Largemouth bass, IRWD	Whole-body	Individual	LMBIRWD2	16.5	32.6
Green sunfish, IRWD	Whole-body	Composite	GSFIRWD2	18.9	22.8
Mosquitofish, UCI	Whole-body	Composite	MFSHDUCI	5.4	26.4
Mosquitofish, BCW	Whole-body	Composite	MFSHABCW	57.4	28.4
	Whole-body	Composite	MFSHBBCW	63.4	27.6
	Whole-body	Composite	MFSHCBCW	63.3	28.1

Shaded values exceed TMDL tissue target of 5 mg Se/kg dw in whole-body fish.
*Remainder and eggs/ovaries measurements are not compared to TMDL targets

COPYRIGHT 2011 BY CH2M HILL, INC. • COMPANY CONFIDENTIAL

The elevated concentrations of selenium in mosquitofish from the Big Canyon Wash (BCW) restoration area pond at Back Bay Road are similar to tissue concentrations previously found at that location. In particular, the BCW fish results are consistent with the expected increase in bioaccumulation associated with the greater proportion of reduced forms of selenium (i.e., the more bioaccumulative selenite and organic) in that drainage (CH2M HILL, 2009a). Fish from BCW have the highest concentrations of selenium in fish tissues observed in the Newport Bay watershed.

For the main San Diego Creek drainage, note that the fish from Peters Canyon Wash (PCW) tended to be slightly lower in average tissue selenium concentration than those from farther downstream, in the San Diego Creek Basin 2 area (particularly for bluegill and largemouth bass), even though waterborne selenium concentrations tend to be higher in the more upstream PCW area (CH2M HILL, 2009b). This increased bioaccumulation in the lower watershed may be evidence for generally increased selenium bioavailability in the deeper, lower elevation environments with higher hydraulic residence times and increased organic substrates. However, previous water quality sampling results did not indicate more bioaccumulative forms of waterborne selenium in lower San Diego Creek as compared to Peters Canyon Wash (CH2M HILL, 2009b).

With only one gravid female bluegill collected (BGFBCW) and another from which separate ovary without eggs could be analyzed, no meaningful relationship can yet be established between whole-body and eggs/ovary selenium concentrations. However, for the two fish collected in 2010, note that egg and ovary tissues had lower selenium concentrations than the remainder tissues. Also, the ovary without eggs analysis (BGGSDC) was of very low sample weight and may not be as indicative of the egg and ovary concentrations measured for BGFBCW (Table 1). Future TMDL monitoring should take place earlier in the spring to better overlap with the centrarchid breeding period and to facilitate the collection and analysis of more bass and sunfish females and their eggs.

Bird eggs

Thirty eggs were collected from active pied-billed grebe (*Podilymbus podiceps*), American coot (*Fulica americana*), black-necked stilt (*Himantopus mexicanus*), American avocet (*Recurvirostra americana*), Forster's tern (*Sterna forsteri*), and black skimmer (*Rynchops niger*) nests in the Newport Bay watershed. The eggs were collected from five sites: Big Canyon Golf Course (BCGC; Figure 2), Upper Newport Bay, (UNB; Figures 3 and 4), UCI Marsh (UCI; Figure 5), Irvine Ranch Water District Marsh (IRWD; Figure 6), and San Diego Creek (SDC; Figure 7). Ten of the eggs came from the most downstream location, UNB, west of the Jamboree Drive bridge, 14 of the eggs came from two off-channel wetlands (8 from UCI and 6 from IRWD), four came from SDC just below the confluence with Peters Canyon Wash, and two came from BCGC ponds upstream from Newport Bay (Figure 1, Link 1). Note that the internet link provided at the bottom of Figure 7 will connect you to a file allowing navigation to all sites in the watershed.

COPYRIGHT 2011 BY CH2M HILL, INC. • COMPANY CONFIDENTIAL

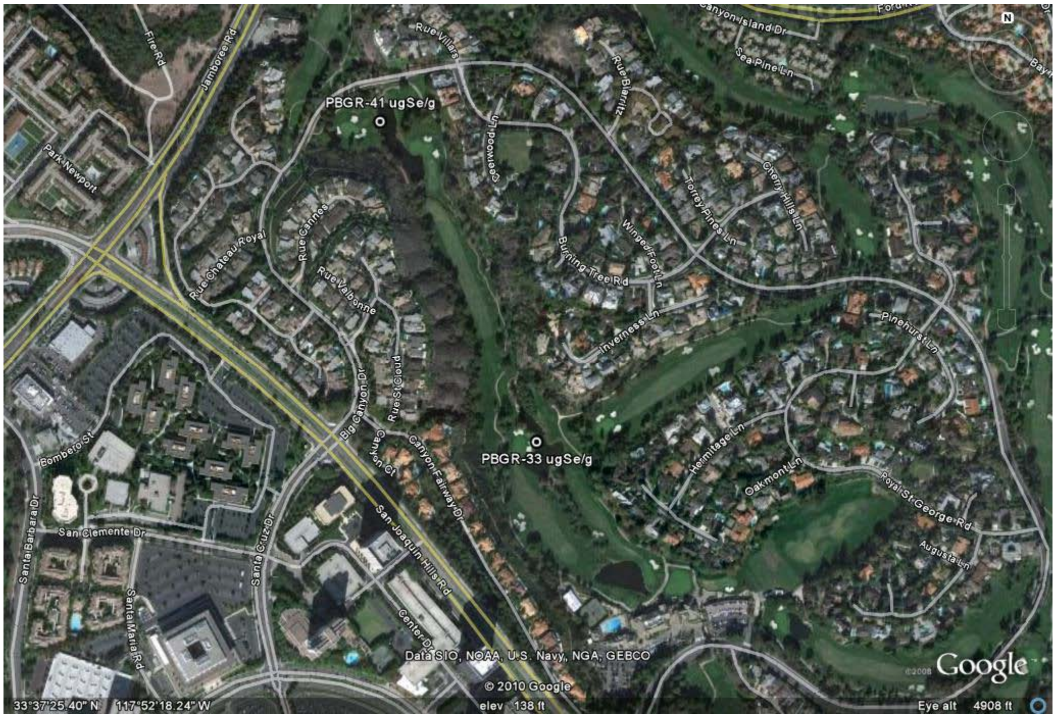


Figure 2. Nest locations and selenium concentrations (µg Se/g) of pied-billed grebes (PBGR) at Big Canyon Golf Course.

COPYRIGHT 2011 BY CH2M HILL, INC. • COMPANY CONFIDENTIAL

Figure 3. Nest locations and selenium concentrations (µg Se/g) of Forster's terns (FOTE) from Upper Newport Bay.

COPYRIGHT 2011 BY CH2M HILL, INC. • COMPANY CONFIDENTIAL

Figure 4. Nest locations and selenium concentrations (µg Se/g) of black skimmers (BLSK) from Upper Newport Bay.

Figure 5. Nest locations and selenium concentrations (µg Se/g) of pied-billed grebes (PBGR) and American coots (AMCO) at UCI Marsh.

COPYRIGHT 2011 BY CH2M HILL, INC. • COMPANY CONFIDENTIAL

Figure 6. Nest locations and selenium concentrations (µg Se/g) of black skimmers (BLSK) and American avocets (AMAV) at IRWD Pond 2.

COPYRIGHT 2011 BY CH2M HILL, INC. • COMPANY CONFIDENTIAL

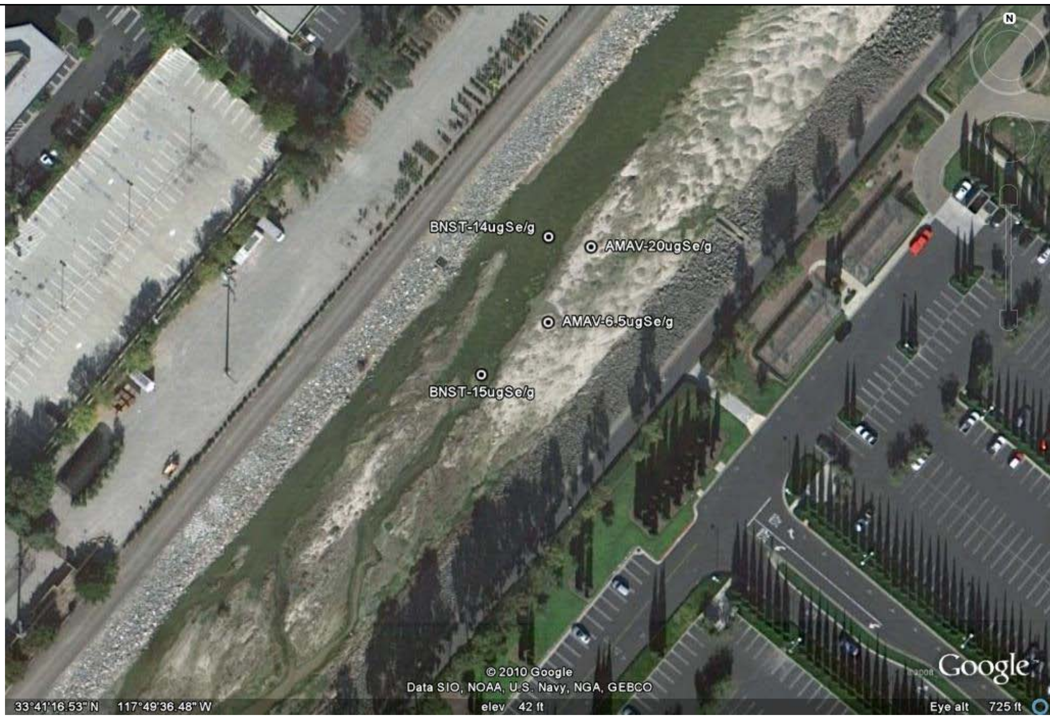


Figure 7. Nest locations and selenium concentrations (µg Se/g) of black-necked stilts (BNST) and American avocets (AMAV) at San Diego Creek below the confluence of San Diego Creek and Peters Canyon Wash.

Link 1. Double-click on the link to zoom in and out of the sites (your computer must be connected to the Internet): 

2010-NSMP_Monitoring.kmz

COPYRIGHT 2011 BY CH2M HILL, INC. • COMPANY CONFIDENTIAL

All eggs were fertile. Of the thirteen of the embryos that were assessable, no abnormalities were observed. However, elevated concentrations, above the 8 µg Se/g target suggested for selenium (RWQCB 2009), were found in bird eggs throughout the watershed (**Table 2**).

Table 2. Species, Species ID, Location, Selenium Concentration (µg/g dry weight [DW]), Percent Moisture, and Percent Lipids in Eggs Collected from the Newport Bay Watershed from May through June, 2010.

Species	Species ID	Location	Se (ug/g DW)	% Moisture	% Lipids
Pied-billed grebe	PBGR	Big Canyon Golf Course	41	75.9	8.83
Pied-billed grebe	PBGR	Big Canyon Golf Course	33	77.3	9.24
Black skimmer	BLSK	Upper Newport Bay	3.3	76.5	9.86
Black skimmer	BLSK	Upper Newport Bay	3.3	77.0	9.09
Black skimmer	BLSK	Upper Newport Bay	3.8	77.5	9.19
Black skimmer	BLSK	Upper Newport Bay	3.5	77.9	8.77
Black skimmer	BLSK	Upper Newport Bay	2.5	76.8	9.90
Forster's tern	FOTE	Upper Newport Bay	3.4	81.0	6.03
Forster's tern	FOTE	Upper Newport Bay	4.8	84.1	3.93
Forster's tern	FOTE	Upper Newport Bay	4.4	81.4	6.31
Forster's tern	FOTE	Upper Newport Bay	2.9	73.7	11.2
Forster's tern	FOTE	Upper Newport Bay	3.7	82.3	5.31
American coot	AMCO	UCI Marsh	3.9	79.6	8.38
American coot	AMCO	UCI Marsh	6.8	73.6	11.2
American coot	AMCO	UCI Marsh	6.0	74.8	9.74
American coot	AMCO	UCI Marsh	4.0	72.8	11.8
American coot	AMCO	UCI Marsh	18	74.4	9.97
Pied-billed grebe	PBGR	UCI Marsh	6.1	76.0	10.2
Pied-billed grebe	PBGR	UCI Marsh	11	85.4	3.39
Pied-billed grebe	PBGR	UCI Marsh	13	79.3	6.18
American avocet	AMAV	IRWD Marsh	6.8	73.5	12.0
American avocet	AMAV	IRWD Marsh	40	74.6	10.8
American avocet	AMAV	IRWD Marsh	7.8	74.2	11.6
American avocet	AMAV	IRWD Marsh	8.5	83.1	6.13
Black skimmer	BLSK	IRWD Marsh	3.4	77.4	9.29
Black skimmer	BLSK	IRWD Marsh	4.3	74.2	8.87
American avocet	AMAV	San Diego Creek	6.5	74.9	10.8

COPYRIGHT 2011 BY CH2M HILL, INC. • COMPANY CONFIDENTIAL

Table 2. Species, Species ID, Location, Selenium Concentration (µg/g dry weight [DW]), Percent Moisture, and Percent Lipids in Eggs Collected from the Newport Bay Watershed from May through June, 2010.

Species	Species ID	Location	Se (ug/g DW)	% Moisture	% Lipids
Black-necked stilt	BNST	San Diego Creek	15	74.0	12.3
Black-necked stilt	BNST	San Diego Creek	14	73.4	12.4
American avocet	AMAV	San Diego Creek	20	73.3	12.1

Shaded values exceed proposed TMDL tissue target of 8 µg Se/g dw in bird eggs.

There was a great deal of variability in selenium concentration in eggs collected in 2010. Individually, a pied-billed grebe egg from BCGC had the highest selenium concentration (41 µg Se/g), and an egg collected from an avocet nest in IRWD was nearly as high (40 µg Se/g). Eggs from the two piscivorous species, Forster's tern and black skimmer, generally had the lowest egg selenium concentrations. Overall selenium concentrations ranged from 2.5 to 41 µg Se/g.

Ten of the 30 eggs (33%) collected were above 8 µg Se/g. The numbers and percentages of eggs above 8 µg Se/g at each sample site were as follows: BCGC 2 (100%), UNB 0 (0%), UCI 3 (38%), IRWD 2 (33%), and SDC 3 (75%). Other than the eggs collected at BCGC, which both had high selenium concentrations, and from UNB, where all of the eggs had low selenium concentrations and the geometric mean egg selenium concentration was significantly lower than the other sites, selenium concentrations varied within the three sites but the geometric mean selenium concentrations were similar among the sites.

The elevated egg selenium concentrations in the BCGC grebes were expected based on the results of water, sediment, invertebrate, fish, and frog sampling in previous years. However, some of the higher concentrations observed in other parts of the watershed were surprising. Based on the two black skimmer eggs from IRWD and the ten tern and skimmer eggs collected from UNB, it seems that there is a lower exposure to piscivorous birds than to other birds using the watershed. The grebes, coots, and shorebirds had variable exposure, likely reflecting the variable concentrations of selenium in the sediments, plants, and invertebrates in the watershed.

References

CH2M HILL. 2009a. *Big Canyon Creek Restoration: Selenium Source Tracking*, Prepared for City of Newport Beach. June, 2009.

CH2M HILL. 2009b. *Sources and Loads for Selenium in the Newport Bay Watershed.* Prepared for the Nitrogen Selenium Management Program. Final Report. June 12, 2009.

EPA. 2010. Personal Communication, Eugenia McNaughton, EPA, May, 2010. San Francisco Regional Water Quality Board, Selenium TMDL, Technical Meeting.

RWQCB. 2009. *Draft TMDL Proposed Implementation Plan*. March 13.

COPYRIGHT 2011 BY CH2M HILL, INC. • COMPANY CONFIDENTIAL