5501 Hobart St.
Pittsburgh, PA 15217
June 2, 2008

Bandon Woodlands Community Association
PO Box 592
Bandon, OR 97411

Dear Bandon Woodlands Community Association,

Please find attached a report entitled, "Geochemical Risk and Chromite Mining Activity on the Bandon Coast," outlining my professional opinions about potential risks arising from the mining activity proposed by the Oregon Resources Corporation and proposed monitoring activities to gather necessary information for characterization and management of these risks. I have drafted this document relying upon my experience with the subject matter, including my dissertation research on historical chromite mining wastes in the Baltimore, MD region, my post-doctoral laboratory research on Cr oxidation/reduction with the US Geological Survey in Menlo Park, CA, and the research program I am developing at the University of Pittsburgh. (I have attached my c.v. for your reference). Based on these experiences and as outlined in the report, I believe there is uncertainty about how the hydrologic and geochemical systems will respond to potential mining disturbance and therefore believe the system should be monitored to protect the health of both humans and local in-stream biota.

Please feel free to contact me with questions about the report as they may arise.

Respectfully submitted,

Daniel J. Bain, PhD

Attachment 1: Geochemical Risk and Chromite Mining Activity on the Bandon Coast
Attachment 2: Bain c.v.

Geochemical Risk and Chromite Mining Activity on the Bandon Coast

The Oregon Resource Corporation recently began the process of applying for permits to allow the mining of chromite sands from the Bandon, OR area. The Bandon Woodlands Community Association has solicited this document to characterize potential risks posed by mining activities and the associated disruptions to local hydrologic systems. This document outlines recent findings regarding the environmental geochemistry of chromium that raise concerns about consequences arising from the mining activity. Based on the literature summarized herein, I suggest monitoring and testing should be implemented as part of the planned mining activity, to protect both the citizens of the Bandon Coast and the Oregon Resource Corporation.

Chromium Aqueous Chemistry

Chromium (Cr) is a trace, transition metal (atomic number 24, average US soil concentrations 53 ppm [*Shacklette et al.*, 1971]). Chromium's behavior in environmental aquatic systems is dictated by the valance or oxidation state (essentially the electrostatic charge on the atom). Cr atoms can have charges (or valence states) ranging from −2 to +6, though under Earth's atmosphere and in environmental conditions, Cr generally carries a charge of +3 or +6. These electrostatic charges correspond to the common names for chromium species, "trivalent" Cr (Cr^{III}) and "hexavalent" Cr (Cr^{VI}), respectively. While Cr is the same core material in each state, the valance state controls the number of oxygen atoms bonded with the Cr atom. This difference in oxygen atoms results in strongly contrasting environmental behavior. Table 1 summarizes these contrasts.

Table 1 Summary of Cr species characteristics and behavior

Cr Species	*Cr^{III} (trivalent)*	*Cr^{VI} (hexavlent)*
Common Species	$Cr_2^{III}O_3$(s), $Cr(OH)_3^0$(aq), $Cr(OH)_2^{+1}$(sorbed)	$Cr_2O_7^{2-}$(aq), CrO_4^{2-}
Solubility	Low in non-acidic waters (pH>4.5)	Very soluble, can pass through cell membrane
Interaction with soils	Bonds strongly with iron oxide surfaces, making Cr^{III} relatively immobile in soil.	Very mobile in soil due to the negative charge of anionic form and the negative charge of the soil materials (clays, etc.). If there is sufficient organic material or ferrous iron in the soil, Cr^{VI} will rapidly reduce.
Interaction with biota	Essential micronutrient important in the metabolism of sugars.	Can pass through soil membranes and oxidize intercellular material, including genetic material

Understanding the risks associate with Cr requires an understanding of the environmental transitions between these two oxidation states. For many years, based on the pioneering work of Bartlett and James [e.g.,*Bartlett and James*, 1988], Cr was thought to exist predominantly in the Cr^{III} state in environmental conditions without direct inputs of Cr^{VI} from human activities. Hexavalent Cr will rapidly reduce (i.e., transform) to Cr^{III} when it encounters organic material, reduced iron, reduced sulfur, and other common environmental materials. In addition, until

Fendorf and Zasoski [1992] demonstrated the ability of manganese oxides to oxidize Cr^{III} to Cr^{VI} in laboratory experiments, there were assumed to be few or no non-human influenced processes that produced hexavalent Cr in environmental conditions. Therefore, before recent research results emerged [*Ball and Izbicki*, 2004; *Chung et al.*, 2001; *Gonzalez et al.*, 2005; *Oze et al.*, 2007; *Robles-Camacho and Armienta*, 2000], it was assumed that very little hexavalent Cr was created naturally, and if it were, the Cr would be rapidly transformed back to the much more benign form.

It should be stressed that much of the environmental reduction and oxidation of Cr has focused on the behavior of Cr in soil systems. Groundwater systems are fundamentally different, particularly in terms of potential reductants. In general, organic material diminishes exponentially with depth in the soil column. Therefore, at the water table and deeper, unless there is close connection between the soil surface and groundwater (e.g., a wetland), there is limited organic material in groundwater. Further, if hexavalent Cr does reach groundwater, there is potential for transport of some distance via the groundwater system, particularly if the system is oxic. In addition, if chromium is oxidized and therefore created in or near the groundwater system by manganese oxides, there are limited opportunities to reduce the resulting hexavalent Cr. In this case there is also the potential for transport of Cr to relatively distant areas, including local receiving waters.

All assumptions underlying chromium risk analysis chromium must be correct to ensure the safety of residents in areas surrounding the proposed ORC mines and aquatic species downstream of these sites. That is, all of the following must be true:

1. Hexavalent Cr is not generated in the black sands of the southern Oregon Coast.
2. Alterations to local hydrology and stratigraphy caused by the mining activity do not change environmental conditions to enhance or create processes oxidizing Cr to the hexavalent state.
3. There is sufficient organic material and other Cr-reducing materials in the soils and sediments between the mine sites and drinking water wells/surface waters to transform any oxidized Cr to the benign, immobile trivalent state.

However, as discussed in the remainder of this document, these assumptions cannot be validated with currently available data. As a result, there is the potential for unforeseen consequences arising from mining activities that could increase risks to local residents and environmental systems.

Bandon Chromite Sands Mineralogy and Geochemistry

According to Griggs [*Griggs*, 1945], the "black sands" of the Southern Oregon Coast originate from serpentinized bedrock in the Oregon Coast Range and Klamath Mountains. During deposition in Tertiary sandstones and in contemporary beach deposits, these materials have been concentrated by density sorting. Samples of sand taken from several of the mines open in 1945 have mineralogies as described in Table 2:

Table 2 Mineralogy of Southern Oregon Coast Black Sands from Griggs [1945].

			Mine & Sample			
Mineral	Chemical Formula	Specific Gravity	Pioneer BS-1-G	Shepard BS-2-G	Shepard BS-3-G	Eagle BS-4-G
Quartz	SiO_2	2.55-2.66	3	5.1	10.6	4.3
Olivine	$(Mg,Fe)_2.Si0_4$	3.18-3.57	6	21.6	20.1	5.6
Pyroxene	Ca,Mg,Al,Fe,silicate	2.8 -3.7	2.8	23	13.6	5.3
Ilmenite	$FeTiO_3$	4.44-4.90	2.8	8.3	6.4	6.4
Rutile	TiO_2	4 18-5.13	0.3	0.5	0.2	0.1
Zircon	$ZrSiO_4$	4.02-4.86	2.5	1.9	1.5	3
Garnet (% indicates sum of Almandite and Spessartite)			28.8	10.2	25.7	27.6
-- Almandite	$Fe_3Al_2Si_3O_{12}$	3.69-4.33				
-- Spessartite	$Mn_3Al_2Si_3O_{12}$	3.8 -4.3				
Chromite	(Mg,Fe)O·(Fe,Al,Cr)2O3	4.32-4.57	48.8	20.7	18.4	43.1
Magnetite	$FeFe_2O_4$	4.97-5.18	4.7	7	2.7	4.4
Epidote.	$Ca(Al,Fe)_3(OH)(SiO_4)_3$	3.07-3.50		0.2		
All others..			0.4	1.4	0.4	0.3
Total			100.1	99.9	99.6	100.1

These deposits contain substantial amounts of both chromium and manganese, creating the potential for interaction between manganese and chromium to generate hexavalent chromium. Moreover, the mixing of sediments and changes in hydrology associated with the proposed mining activity could enhance such oxidation and mobilization. However, as our understanding of the chemical mechanisms and environmental processes are limited, we cannot predict the consequences with much certainty. This uncertainty, coupled with the toxic nature of hexavalent Cr, dictates that a cautious approach to large scale disruption of hydrologic flow paths in the region should be followed.

Recent Recognition of Hexavalent Chromium in Groundwaters

The first to recognize the presence of natural hexavalent chromium was Frederick Robertson in his 1975 Masters thesis work at Arizona State University. Since, natural hexavalent Cr has been detected in a variety of groundwater systems. This report will focus on data from California, as the southern Oregon Coast shares California's strong seasonal climate and similar, and in many cases richer, Cr-source rocks. More important, California, in conjunction with the USGS, has begun state-wide monitoring of hexavalent chromium in groundwater [*Bennett et al.*, 2006; *Fram and Belitz*, 2007; *Kulongoski et al.*, 2006; *Kulongoski and Belitz*, 2007; *Milby Dawson et al.*, 2008; *Wright et al.*, 2005], following the discovery of natural hexavalent Cr in several California aquifers and the potential for generation of hexavalent Cr in California soils [*Ball and Izbicki*, 2004; *Chung et al.*, 2001; *Gonzalez et al.*, 2005]. It is assumed that the hexavalent Cr encountered in these groundwater systems results from the oxidation of trivalent Cr to hexavalent Cr by manganese oxides.

The California Groundwater Ambient Monitoring and Assessment Program (GAMA, see the citations above) results are important to consider when evaluating the risks associated with the mining of the chromite sands on the Bandon Coast. Table 3 summarizes the data from all published GAMA results. It includes the number of wells with measurable hexavalent Cr, the

total number of wells sampled, and the range of total and hexavalent Cr concentrations observed. There seems to be a loose affiliation between Cr rich source rock and groundwater concentrations (e.g., the Sacramento River drains Cr source rocks (part of the Klamath formations) and the Southern Sierra is poor in Cr source rock). Unfortunately, the Klamath region, the region most relevant to the Bandon Coast question (due to similarities in source rock composition), will not be evaluated until 2010. However, it is clear that hexavalent Cr occurs in groundwater throughout California and therefore it is likely that Cr^{VI} exists in Oregon ground waters as well.

Table 3 Summary of to-date Cr results from the California Groundwater Ambient Monitoring and Assessment Program.

GAMA Region	*Number of wells sampled*	*Wells with detectable Cr^{VI}*	*Cr^{VI} concentration range (ppb)*	*Total Cr concentration range (ppb)*
San Diego (DS 129)	40	27	0.1 – 5.6	0.1 – 5.7
North San Francisco Bay (DS 167)	97	79	0.1 – 15.6	0.1 – 17.1
Northern San Joaquin (DS 196)	39	32	1 – 14 (estimated)	1 – 15 (estimated)
Monterey Bay/Salinas Valley (DS 258)	97	86	1 – 33	1 -33
Southern Sacramento Valley (DS 285)	47	24	8 – 70	8 - 67
Southern Sierra (DS 301)	28	17	1 – 9	1 - 11

In most cases, the concentrations of Cr^{VI} detected by the GAMA studies are well below drinking water regulatory levels (the drinking water total Cr MCL is 100 ppb). However, the studies demonstrate that the assumption that hexavalent Cr is not produced naturally is clearly incorrect. Moreover, as we are only beginning to discover natural hexavalent Cr in our groundwater systems, we have limited geochemical theory available to predict levels of hexavalent Cr in groundwater. Ultimately, we have no basis to understand the consequences of landscape disruption associated with mining activity to hexavalent Cr concentrations in groundwater systems.

Transfer of Chromium in Groundwater to Surface Water

While groundwater contamination is a concern to human health, the potential discharge of hexavalent Cr enriched groundwaters to local surface waters also raises concerns about impacts to instream biota. For example, we know rivers discharging to the San Francisco Bay have hexavalent Cr concentrations in the parts per billion range, particularly during the wet winters [*Abu Saba and Flegal*, 1997]. These concentrations do not seem to correspond with human inputs [*Abu Saba and Flegal*, 1997] and therefore likely result from the processes discussed above. While values at the Bay itself are below concentrations of concern for in stream biota (i.e., USEPA surface water quality criteria of 11 ppb), these are measurements from the mouths of large river systems and are likely lower than concentrations in drainages upstream due significant dilution and in-stream reduction. Therefore, groundwater discharges directly to streams should be more concentrated and potentially higher than 11 ppb. This potential exposure raises concern as hexavalent chromium concentrations of 200 ppb are reported to be acutely toxic to salmon fingerlings and concentrations of 16-21 ppb inhibit growth in trout and salmon fingerlings [*Eisler*, 1986]. In-stream biota may have been exposed to very small quantities of hexavalent Cr in local waters for years. The question remains, will mining activities alter

hydrologic processes to increase or prolong these exposures? As with hexavalent Cr in groundwaters, we do not have sufficient information to confidently answer this question.

Chromium Toxicology

Chromium is a substance of concern primarily due to the strongly toxic behavior of hexavalent chromium. In terms of human exposures generated by mining activity, there are two pathways of particular concern, respiratory (via dust generated by earth movement, etc.) and orally (via drinking water). In terms of larger ecosystem effects, any discharge of hexavalent Cr enriched groundwaters to surface waters will expose all biota living in those waters to this toxic material. Risk associated with Cr exposures tends to be minimized in the toxicological literature due to the assumptions made about Cr environmental behavior. First, it is assumed that Cr is predominantly in the trivalent form in soil environments, minimizing the mobility of Cr. The ATSDR Toxicological Profile (pg. 295, [*Agency for Toxic Substances and Disease Registry (ATSDR)*, 2000]) states in the Environmental Fate section, "In most soils, chromium will be present predominantly in the chromium(III) state. This form has very low solubility and low reactivity resulting in low mobility in the environment and low toxicity in living organisms." Second, it is further assumed that most exposures to hexavalent Cr result from releases of human generated Cr. In the Public Health Relevance section of the ATSDR Toxicological Profile [2000, pg. 171], it states, "chromium(VI) in the environment is almost always related to anthropogenic activity." However, as is outlined above, the recent environmental chemical research points to mobilization of Cr from environmental pools to groundwater and therefore the potential for unexpected mobility of and exposure to hexavalent chromium in environmental systems. Moreover, this potential transformation has led to the recent examination of how particulate Cr behaves once it enters the lung tissue [e.g., *Goldhaber et al.*, 2006]. It is important to carefully evaluate the potential risks associated with mining activity in the Bandon, OR area in order to ensure that proper monitoring and, if necessary, abatement occurs.

Inhalation Exposures Standards

The link between inhalation of Cr, particularly hexavalent Cr, and human health effects is well established. Federal agencies including EPA, OSHA, and NIOSH all regulate ambient air Cr standards. Oregon has measured airborne Cr in variety of forms in at least 37 locations (see Figure 1). However, most of these locations are located inland from coastal areas and are concentrated in relatively urban areas. Ultimately, airborne Cr concentrations (regardless of valence state) in the Bandon area are uncertain. While most of the Cr disturbed during mining will likely be in the trivalent form, there remains the potential to significantly increase dust levels and therefore airborne exposures to total Cr in the area, particularly in the dry summers. As a result, this exposure should be quantified, particularly as emerging work suggests that simulated human lung leaches (i.e., simulations of the liquids encountered in the human lung) can leach up to 1 ppm Cr from ultramafic soils, even when the Cr is in the trivalent state [*Goldhaber et al.*, 2006].

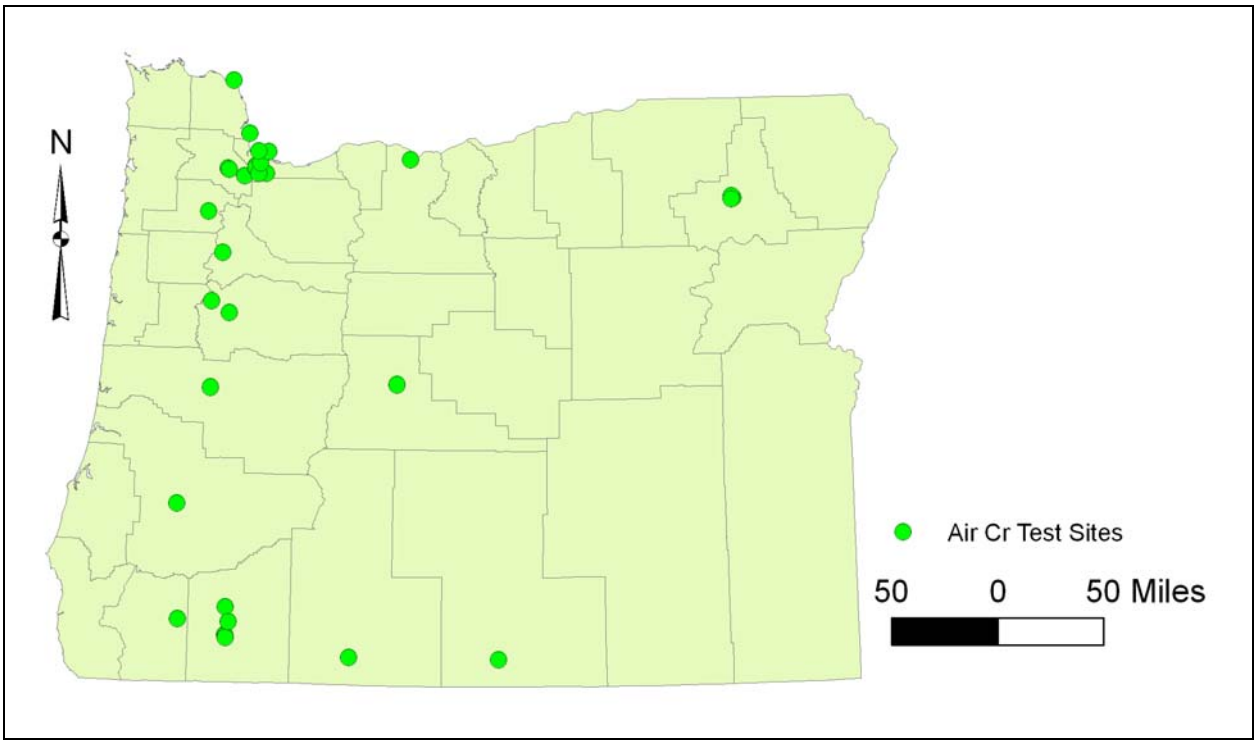

Figure 1 Map of locations tested for airborne chromium in Oregon according to the Department of Environmental Quality's Laboratory Analytical Storage and Retrieval (LASAR) system [*Oregon Department of Environmental Quality*, 2008].

Drinking Water and Surface Water Quality Standards

The risks associated with chronic oral exposure to hexavalent Cr have led to the regulation of Cr concentrations in drinking water (the USEPA total chromium drinking water standard is 100 ppb. Some states, including California, have a total Cr standard of 50 ppb, in line with World Health Organization recommendations). Further, due to potential impacts to in stream biota, USEPA and Oregon Cr surface water criteria indicate Cr^{VI} should be below 11 ppb. Groundwater Cr levels observed in California sometimes exceed the California drinking water standard and approach the USEPA drinking water standard. These groundwater Cr concentrations are routinely above surface water quality criteria. We do not have a baseline Cr concentration characterization of waters in the Bandon area, making the origin of any future Cr^{VI} detected during monitoring uncertain.

Summary and Recommendations

Based on the evidence presented in this document, it is my professional opinion that:

1. The geochemistry of the sand includes significant amounts of both chromium and manganese. This sand and the hydrogeologic flowpaths through this sand will be disrupted by the mining process. This disruption will include mixing of formerly separated sediments, large changes in local hydrogeology due to dewatering and disposal of the resulting water, etc.
2. Recent research results demonstrate that the benign trivalent chromium can be oxidized to the toxic hexavalent form by manganese oxides in environmental conditions.

3. Field studies in the United States, and particularly in California, have identified substantial concentrations of hexavalent Cr in groundwater systems. These concentrations can exceed the California total Cr drinking water standard and the USEPA surface water quality criteria. Further, this hexavalent Cr can reach surface waters, particularly during the wet Oregon winters.
4. We cannot accurately predict the impacts of disrupting the sediments and hydrogeology on the concentrations of hexavalent Cr in local drinking water wells or in groundwater discharges to local surface waters. Nor can we say how these activities will alter air quality.

Therefore, it is my professional opinion that the following monitoring should occur as part of the mining operation:

1. A baseline measurement of both total and hexavalent Cr in all potentially impacted drinking water wells and springs discharging to local streams should be made at least twice (in both winter and summer conditions) prior to the onset of mining activity. This will not only protect the consumers of drinking water and in-stream biota, it will also protect ORC if hexavalent Cr is measured in these wells after mining, as post-mining results can be compared with unambiguous pre-mining concentrations.
2. Groundwater monitoring wells should be installed downgradient of all mining locations to monitor total and hexavalent Cr concentrations in groundwater systems downstream of the operations. These wells, when regularly monitored (an appropriate sampling frequency should be developed based on local hydrogeologic conditions, particularly groundwater velocities), should provide early warning of any changes in dissolved Cr arising from mining activity. Again, these wells should be installed, developed, and sampled multiple times before mining activity begins to ensure proper pre-mining concentrations are characterized.
3. Once mining operations begin, potentially impacted wells and springs should be sampled and measured for total and hexavalent Cr at least annually, and more frequently if hexavalent Cr concentrations increase in these wells.
4. Following cessation of mining operations, monitoring wells should be sampled and Cr measured regularly over a time period several times the expected time period necessary for groundwater to move from the mine sites to the monitoring well. In addition, total and hexavalent Cr should be measured in potentially impacted domestic wells and local springs annually for a similar period (springs should be sampled in the wet season).
5. Dust monitoring. As inhalation exposures to chromium have documented human health impacts, baseline monitoring of ambient air quality, particularly in the summer dry season should be conducted during periods when mining operations are ongoing. The concentrations of both total Cr and hexavalent Cr should be measured during this period and the results assessed to determine the necessity of continued monitoring.

References

Abu Saba, K. E., and A. R. Flegal (1997), Temporally variable freshwater sources of dissolved chromium to the San Francisco Bay estuary, *Environmental Science & Technology*, *31*(12), 3455-3460.

Agency for Toxic Substances and Disease Registry (ATSDR) (2000), Toxicological profile for Chromium, edited, U.S. Department of Health and Human Services, Public Health Service, Atlanta, GA.

Ball, J. W., and J. A. Izbicki (2004), Occurrence of hexavalent chromium in ground water in the western Mojave Desert, California, *Applied Geochemistry*, *19*(7), 1123-1135.

Bartlett, R. J., and B. R. James (1988), Mobility and Bioavailability of Chromium in Soils, in *Chromium in the Natural and Human Environments*, edited by J. O. Nriagu and E. Nieboer, Wiley-Interscience, New York.

Bennett, G. L., et al. (2006), California GAMA Program: Ground-Water Quality Data in the Northern San Joaquin Basin Study Unit, 2005, in *Data Series 196*, edited, p. 122, US Geologic Survey, Washington, DC.

Chung, J. B., et al. (2001), Chromate generation by chromate depleted subsurface materials, *Water Air and Soil Pollution*, *128*(3-4), 407-417.

Eisler, R. (1986), Chromium Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review, Biological Report 85, 38 pp, USFWS Patuxent Wildlife Research Center, Laurel, MD.

Fendorf, S. E., and R. J. Zasoski (1992), Chromium(III) Oxidation by Delta-MNO2: 1. CHARACTERIZATION, *Environmental Science & Technology*, *26*(1), 79-85.

Fram, M. S., and K. Belitz (2007), Ground-Water Quality Data in the Southern Sierra Study Unit, 2006 - Results from the California GAMA Program, in *Data Series 301*, edited, p. 78, US Geological Survey, Washington, DC.

Goldhaber, M. B., et al. (2006), A soil geochemical transect in northern California: Links to human health, *Geochimica Et Cosmochimica Acta*, *70*(18), A207-A207.

Gonzalez, A. R., et al. (2005), Natural occurrence of hexavalent chromium in the aromas red sands aquifer, California, *Environmental Science & Technology*, *39*(15), 5505-5511.

Griggs, A. B. (1945), Chromite-bearing sands of the southern part of the coast of Oregon, in *USGS Bulletin 945-E*, edited, pp. 113-150, US Geological Survey, Washington, DC.

Kulongoski, J. T., et al. (2006), Ground-water quality data in the north San Francisco Bay hydrologic provinces, California, 2004: Results from the California Ground-water Ambient Monitoring and Assessment (GAMA) program, in *Data Series 167*, edited, p. 100, US Geologic Survey, Washington, DC.

Kulongoski, J. T., and K. Belitz (2007), Ground-Water Quality Data in the Monterey Bay and Salinas Valley Basins, California, 2005 - Results from the California GAMA Program, in *Data Series 258*, edited, p. 84, US Geological Survey, Washington, DC.

Milby Dawson, B. J., et al. (2008), Ground-Water Quality Data in the Southern Sacramento Valley, California, 2005 - Results from the California GAMA Program, in *Data Series 285*, edited, p. 93, US Geological Survey, Washington, DC.

Oregon Department of Environmental Quality (2008), Laboratory Analytical Storage and Retrieval (LASAR), edited, Oregon Department of Environmental Quality.

Oze, C., et al. (2007), Genesis of hexavalent chromium from natural sources in soil and groundwater, *Proceedings of the National Academy of Sciences of the United States of America*, *104*(16), 6544-6549.

Robles-Camacho, J., and M. A. Armienta (2000), Natural chromium contamination of groundwater at Leon Valley, Mexico, *Journal of Geochemical Exploration*, *68*(3), 167-181.

Shacklette, H. T., et al. (1971), Elemental Composition of Surficial Materials in the Conterminous United States, 71 pp, US Geological Survey, Washington DC.

Wright, M. T., et al. (2005), California GAMA program: ground-water quality data in the San Diego drainages hydrogeologic province, California, 2004, in *Data Series 129*, edited, US Geologic Survey, Washington, DC.

DANIEL J. BAIN

Department of Geology and Planetary Science
200 SRCC Building
4107 O'Hara Street
University of Pittsburgh
Pittsburgh, PA 15260

Email: dbain@pitt.edu
Phone: 412 624 8766
Fax: 412 624 3914

PROFESSIONAL & RESEARCH EXPERIENCE

Jan 2007-	**Assistant Professor**: University of Pittsburgh, Department of Geology and Planetary Science, Pittsburgh, PA
Jan 2004- Sept 2006	**National Research Council Post-Doctoral Fellow:** USGS Water Resources Division Menlo Park, CA (research advisors: Thomas Bullen and Suzanne Anderson)
Sept 1998- Oct 2003	**National Science Foundation Graduate Research Fellow:** Johns Hopkins University Department of Geography and Environmental Engineering, Baltimore, MD
Oct 1996- July 1998	**Environmental Scientist I**: North Dakota State Department of Health, Groundwater Protection Program, Bismarck, ND
Professional Affiliations:	American Geophysical Union, Association of American Geographers, Geochemical Society, Geological Society of America, U.S. International Association of Landscape Ecologists

EDUCATION

May 2004	**Ph.D. in Geography and Environmental Engineering** Department of Geography and Environmental Engineering Johns Hopkins University (JHU), Baltimore, Maryland Dissertation: *400 Years of Land Use Impacts on Landscape Structure and Riparian Sediment Dynamics: Investigations using Chromite Mining Waste and Property Mosaics* (Advisor: Dr. Grace S. Brush)
May 2000	**Masters of Science in Environmental Science**, JHU, Baltimore, Maryland Department of Geography and Environmental Engineering
May 1996	**Bachelor of Arts** *Cum Laude*, Macalester College, St. Paul, Minnesota Majors: Chemistry and Geography Minor: Mathematics
Awards & Recognition	CUAHSI Early Career Fellow, UNH CUAHSI Synthesis Center (2007-present) 2006 Summer Institute at Duke University's Center on Global Change -- Uncertainty and Variability in Ecological Inference, Forecasting, and Decision Making 2006 SEEK Early Career Faculty and Post Doctoral Workshop on Ecoinformatics 2004-2006 NRC Research Associate Fellowship 2003 NASA-MSU Professional Enhancement Award 2002 Johns Hopkins University Graduate Representative Organization Service Award 2001-2002 William R. Kenan, Jr. Fellowship 2001-2002 JHU Center for Educational Resources Technology Fellowship 1999 ESRI User Conference Student Assistant

1998-2003 NSF Graduate Research Fellowship
1998-99 American Meteorological Society Ind./Gov. Graduate Fellowship (declined)
1998 (April) ND Health Dept. "Going the Extra Mile" Award
1996 Phi Beta Kappa
1996 Chester Shiflett Endowed Prize in Chemistry
1996 AAG/NCGE Award for Excellence of Scholarship
1995 Hildegard Binder Johnson Award
1995 ACS Undergraduate Award in Analytical Chemistry
1991 Eagle Scout

PUBLICATIONS (PEER REVIEWED)

Williams, J., C. ReVelle and **D. J. Bain**, (2003), "A Decision Model For Selecting Protected Habitat Areas Within Migratory Flyways," *SocioEconomic Planning Sciences*. **37**(4), 239-268.

Groffman, P. M., **D. J. Bain**, L. E. Band, K. T. Belt, G. S. Brush, J. M. Grove, R. V. Pouyat, I. C. Yesilonis and W. C. Zipperer (2003), "Urban Riparian Ecology," *Frontiers in Ecology and Environment.* **1**(6), 315-321.

Bain, D. J. and G. S. Brush (2004) "Placing the Pieces: Reconstructing The Original Property Mosaic in a Metes and Bounds Watershed", *Landscape Ecology*. **19**(8), 843-856.

Bain, D. J. and G. S. Brush (2005) "Early Chromite Mining and Agricultural Clearance: Opportunities for the Investigation of Agricultural Sediment Dynamics in the Eastern Piedmont (USA)", *American Journal of Science*. **305**, 957-981.

Elliott, E.M., C. Kendall, S. D. Wankel, D. A. Burns, E. W. Boyer, K. Harlin, **D. J. Bain,** and T. J. Butler, (2007) "Nitrogen isotopes as indicators of NOx source contributions to atmospheric nitrate deposition across the Midwestern and Northeastern United States", *Environmental Science and Technology*. **41**(22), 7661-7667

Bain, D. J. and G. S. Brush (2008) "Gradients, Property Templates, and Land Use Change", *Professional Geographer*. **60**(2)

Bain, D. J., S. M. Smith, and G.N. Nagle (submitted) "Extrapolation and Implications of Mill Dam Findings", *Science*

Bain, D. J., S. P. Anderson, T. D. Bullen, J. Fitzpatrick, M. S. Schulz, D.V. Vivit, and A.F. White (in preparation) "Using Lithogenic and Biogenic Water Chemistries to follow Solute Flushing", *Water Resources Research*.

INVITED & RECENT PRESENTATIONS

Oral

(invited) *Buried Floodplains and Old Mines: Understanding Legacy Agricultural Sediments in Maryland Valleys*, Maryland Department of Natural Resources Marine and Non-Tidal Assessment (MANTA) Noon Seminar, Annapolis, MD, April 12, 2007

Metals in Baltimore riparian sediments: Chemical legacies in urban streams, 2006 American Geophysical Union Spring Joint Assembly, Baltimore, MD, May 24, 2006

(invited) *Urban Ecology: Understanding and Managing our Cities*, North Carolina State Department of Forestry and Environmental Resources, Raleigh, NC, May 1,2006

(invited) *Impacts of Urbanization and Land Use History on Chemical and Sediment Cycling*, University of Illinois at Urbana-Champaign Department of Natural Resources and Environmental Sciences, Urbana, IL, April 13, 2006

(invited) *Human Decisions and Trace Metal Cycling: Coupling Social and Natural Science in Urban Systems*, Yale School of Forestry, New Haven, CT, March 29, 2006

(invited) *Trace Metal Cycling in Watersheds & Landscapes*, Wright State University Department of Geological Sciences, Dayton, OH, March 13, 2006

(invited) *Trace Metal Cycling in Watersheds & Landscapes*, University of Pittsburgh Department of Geologic and Planetary Sciences, Pittsburgh, PA, February 28, 2006

Lithogenic vs Biogenic Stream Water Chemistry: Following the Solute Flush, 2005 American Geophysical Union Fall Meeting, San Francisco, CA, December 6, 2005

(invited) *Chromium Isotope Fractionation During Oxidation of Cr(III) by Manganese Oxides,* 2005 Goldschmidt Conference, Moscow, ID, May 25, 2005

(invited) *Trace Metal Cycling in Dynamic Landscapes*, SUNY-Albany Department of Geography and Planning, Albany, NY, April 11, 2005

Experimental Determination of Isotopic Fractionation of Chromium(III) During Oxidation by Manganese Oxides, 2004 American Geophysical Union Fall Meeting, San Francisco, CA, December 16, 2004

(invited) *Chromite mining signature in Baltimore riparian sediments*. Information Exchange: Sediment and the Chesapeake Bay Watershed From Top to Bottom. Baltimore, MD, January 22, 2002.

BOOK REVIEWS

Wetlands and Sustainable Water Systems. Review of M. M. Holland, E. R. Blood, and L. R. Shaffer (eds.), 2003. Achieving Sustainable Freshwater Systems: A Web of Connections. Island Press, Washington, DC. 312 pgs. *Landscape Ecology*. **19**(7), 815-816.

Glaciers and Riverboats: Landscape History of the Upper Mississippi Corridor. Review of C. E. Fremling, 2005. Immortal River: The Upper Mississippi in Ancient and Modern Times. The University of Wisconsin Press, Madison, WI, USA. 429 pp. *Landscape Ecology* **21**(2), 307-308.

Review of Warren R. Hofstra, 2004. The Planting of New Virginia: Settlement and Landscape in the Shenandoah Valley. The Johns Hopkins University Press, Baltimore, MD. 410 pgs. *Material Culture* (accepted).

Review of Robert L. France, 2006. Introduction to Watershed Development: Understanding and Managing the Impacts of Sprawl. Rowan and Littlefield Publishers, Lanham, MD. 221 pgs. *Journal of Urban Affairs* **28**(5), 535-536.

PUBLICATIONS (NON-PEER REVIEWED)

Bain, D. J. and E. R. Broich, Powdermill Run Historic Stream Courses, University of Pittsburgh Department of Geology and Planetary Science, Pittsburgh, PA

Bain, D. J., 1997, Wellhead Protection Area Delineation for the City of Strasburg, Emmons County, North Dakota, North Dakota Department of Health, Bismarck, ND.

Bain, D. J., 1997, Wellhead Protection Area Delineation for the City of Glen Ullin, Morton County, North Dakota, North Dakota Department of Health, Bismarck, ND.

Bain, D. J., 1997, Wellhead Protection Area Delineation for the City of Hebron, Morton County, North Dakota, North Dakota Department of Health, Bismarck, ND.