



WESTERN RESOURCE
ADVOCATES

February 1, 2011

Walt Baker, Executive Secretary
Utah Water Quality Board
P.O. Box 144870
Salt Lake City, UT 84114-4870

*RE: Draft UPDES Permit UT0025836; Jordan Valley Water Conservancy District
Southwest Groundwater Treatment Plant*

Dear Walt:

Thank you for the opportunity to comment on the draft UPDES permit for the Jordan Valley Water Conservancy District Southwest Groundwater Treatment Plant (Jordan Valley), UT0025836. These comments are submitted on behalf of FRIENDS of Great Salt Lake, Utah Waterfowl Association, Western Wildlife Conservancy, Utah Airboat Association, Utah Mud Motor Association, Utah Chapter of the Sierra Club, League of Women Voters of Salt Lake, League of Women Voters of Utah, Great Salt Lake Audubon, Utah Rivers Council and the Great Salt Lake Yacht Club (Collectively FRIENDS).

As you know, the Jordan Valley discharge has been a matter of special interest for FRIENDS for some time now because of the possible detrimental impacts of the discharge on Great Salt Lake. Members of the conservation groups listed above extensively use and enjoy the transitional wetlands and the Gilbert Bay portion of Great Salt Lake that would be impacted by this discharge for, among other purposes, wildlife viewing, boating, hunting, photography, scientific study, and solitude. Beyond the specific concerns outlined below related to the Jordan Valley discharge, FRIENDS is also concerned about the cumulative impacts of this proposed discharge along with the existing Kennecott Utah Copper Corporation (KUCC) discharge. The Jordan Valley discharge is located approximately 50 feet from the existing KUCC discharge at Outfall 012 and will flow to the open waters of the Lake within the same delta as the KUCC discharge. Neither the KUCC permit nor the Jordan Valley permit evaluates the possible cumulative impacts of this joint discharge.

FRIENDS submits the following comments because of its concern that the Division of Water Quality (DWQ) has not adequately assessed the potential impacts from the proposed discharge prior to issuing this draft permit.

Introduction

The Jordan Valley discharge is the byproduct of remediation efforts necessary to clean up groundwater contaminated by KUCC mining operations for use in the local communities as culinary water. The project will pump contaminated groundwater from deep aquifer wells and subject that water to reverse osmosis (RO) treatment in a facility owned by the Jordan Valley Water Conservancy District. The project will also pump groundwater from shallow aquifer wells that have not been contaminated by mining operations for use in the RO process. The RO byproduct will be discharged into Great Salt Lake via a 21-mile pipeline to Gilbert Bay. While initially slated to discharge up to 1.5 million gallons per day (MGD) at build out, the facility will generate and discharge up to 3 MGD of byproduct into the Lake. In addition, discharges from a number of shallow groundwater wells will flow into the Jordan River under certain conditions outlined in the permit.

While FRIENDS has a number of concerns with the proposed discharges, these comments will focus on very specific areas of concern related to the Gilbert Bay outfall area of this discharge (Outfall 001). We also hereby incorporate by reference the comments submitted by the Great Sale Lake Alliance in this matter (Appendix A, attached).

I. DWQ Erroneously Assumes that a Mixing Zone Exists Contiguous to this Discharge.

A key premise to the proposed permitted concentration of selenium within the discharge – 54 µg/L – is the supposition that the concentration of selenium will be diluted to a “safe” concentration of 27 µg/L within a mixing zone located contiguous to Outfall 001. This premise is based on the following assumptions: a) that there is, in fact, an actual mixing zone at the discharge; b) that the proposed permitted concentration of 54 µg/L will be diluted to 27 µg/L within that theoretical mixing zone; and, c) that 27µg/L is a safe concentration of selenium that will not cause harm to the ecosystem. In the first two cases, there is no actual mixing zone and the concentration of selenium is therefore not diluted, and in the third case, there is no confirmation that 27µg/L is a safe level of selenium concentration.

- A. R317-2-5 limits mixing zones to 200’; however, current conditions do not provide for mixing within at least the first 4,000’.

Utah Administrative Code R317-2-5 states that the “chronic mixing zone in lakes and reservoirs shall not exceed 200 feet” and must be “contiguous to a discharge.” However, the proposed Jordan Valley discharge remains in a confined channel and does not “mix” with the open waters of the Lake for at least the first 4,000 feet of flow. As a result, the actual mixing zone is not contiguous to the discharge, and it is not within 200 feet of the discharge point. Additionally, the only other water source for that channel is the KUCC discharge, which also has a permit limit of 54 µg/L for selenium. Therefore, under present circumstances, DWQ has erroneously applied the concept of a mixing zone

to conclude that the permitted concentration of selenium in this discharge will be diluted to a concentration of 27 µg/L.

Indeed, that a discharge in the location of the Jordan Valley outfall does not mix has been demonstrated by water quality samples collected by Professor John Cavitt as part of the analysis that led to the adoption of the tissue-based standard for selenium applied to Gilbert Bay. As stated in that study, water samples collected a considerable distance from the KUCC discharge showed no mixing or dilution of the mining company's discharge. KUCC typically discharges at a concentration of 35 µg/L¹ and the relevant water quality samples showed a concentration of 33.7 µg/L at the same location that he collected bird eggs showing tissue concentrations as high as 9.2 µg/g dw.²

Therefore, it is almost certain that the Jordan Valley discharge will make conditions in the transitional wetlands associated with the current KUCC outfall more dangerous to humans and wildlife. This is because the concentration of selenium in the Jordan Valley discharge will be substantially higher (by approximately 1/3) than the current KUCC discharge (35 µg/L). Additionally, while the current KUCC discharge is seasonal, the Jordan Valley discharge is year-round. As a result, there will be times of the year when the Jordan Valley discharge will effectively displace the KUCC discharge resulting in higher total concentrations of selenium in the transitional wetlands downstream of Outfall 001 than currently exist.

- B. Because there is no mixing zone, the Jordan Valley discharge will be almost double the "safe" level of 27 µg/L.

In addition to the fact that no mixing zone exists contiguous to the Jordan Valley discharge at Outfall 001, Jordan Valley has informed DWQ that the selenium concentrations in its discharge will be very close to the proposed permitted limit of 54 µg/L. This concentration is almost double the 27 µg/L "safe" level cited by DWQ. Statement of Basis (SOB) at 3; *see also* Brix et al., Exhibit C, attached. Even assuming DWQ's assertion that 27 µg/L is a "safe" level of selenium is proper, Jordan Valley's discharge to the transitional mudflats leading to the open waters of the Lake will be far in excess – almost double – that acknowledged "safe" level. In order to correct this error, DWQ must either: 1) not allow this discharge to occur until it formulates a numeric water-based concentration for selenium applicable to Great Salt Lake that correlates to the current tissue-based standard, and ensures that this discharge conforms to this standard; or 2) require Jordan Valley not to exceed a concentration of 27 µg/L in its discharge.

¹ *See* Exhibit B attached, Statement of Basis, KUCC Major Permit Modification (UPDES Permit No. UT 0000051).

² *Concentration and Effects of Selenium on Shorebirds at Great Salt Lake, Utah, Final Report: Development of a Selenium Standard for the Open Waters of the Great Salt Lake*, (Final Report), Appendix C at 21 (http://www.deq.utah.gov/Issues/GSL_WQSC/docs/GLS_Selenium_Standards/index.htm). *See* page 18 of Appendix C for a map showing location of collection site vis-à-vis the KUCC discharge.

- C. DWQ has not confirmed the assertion in the 2001 Brix study that a 27 µg/L concentration will not be detrimental to the designated uses of the Lake and will not lead to a violation of the tissue-based standard for selenium.

While DWQ asserts for the purposes of this permit that a selenium concentration of 27 µg/L is sufficiently protective of the designated uses of the transitional mudflats and the open waters of the Lake, the agency also admits that “the currently available data is [*sic*] inadequate to accurately predict the correlation between selenium water and bird egg concentration.” Draft SOB at 3. Given this admission and DWQ’s statement that “some uncertainty remains” about the potential effects of selenium on the biota of the Lake, SOB at 4, the agency cannot assume that the 27 µg/L concentration cited by Brix is a sufficiently protective standard. SOB at 3-4. This is true for three reasons.

First, as DWQ admits, a sufficient correlation has not been established between any specific concentration and the tissue-based standard. Second, the “safe” standard is based on a level in eggs in which “reproductive impairment is much more likely to occur.” Heinz GH, Hoffman DJ, Gold LG, 1989. Impaired reproduction was noted in mallards fed an organic form of selenium. *J. Wildl Manag* 53:418–428. Third, the SOB focuses heavily on Lake-wide loading, but this is unlikely to address the local concentration levels – an issue of primary concern. While it is possible or even probable that a correlation exists between localized loading levels and Lake-wide concentration levels, as discussed below, the focus on Lake-wide loading limits misses the mark. It is the localized concentration levels that would cause localized elevated concentrations of selenium both at the transitional mudflat area associated with this discharge, and where the discharge channel meets the open waters of the Lake. Within this localized area, the 27 µg/L may not be protective of the Lake’s beneficial uses.

- D. DWQ must remove the statement in the Draft SOB that “[l]oading increases of up to 300% (4,500 kg/yr to 9,000 kg/yr) are predicted to remain protective of the tissue-based standard.”

For reasons identified above, the DWQ is in error to assume extreme increases in the selenium load will have no effect on the Lake. Therefore, DWQ must remove the statement in the Draft SOB that “[l]oading increases of up to 300% (4,500 kg/yr to 9,000 kg/yr) are predicted to remain protective of the tissue-based standard.” In making this statement, DWQ failed to recognize that bird eggs collected in the area of the proposed discharge in 1996, 1997 and 2006 show tissue concentrations much higher than those collected elsewhere on the Lake.

Indeed, the avocet eggs collected by Professor John Cavitt in and around the area of the KUCC discharge showed tissue concentrations of: 8.2, 9.2, 6.8, 5.3, 3.2, 3.6, 5.4 and 2.9 µg/g dw with a median Se concentration of 5.4 µg/g dw.³ At the same time, the dissolved Se concentrations within water samples taken at the KUCC site (median = 33.7

³ Final Report, Appendix C at 20, 33.

µg/L) were much higher than reported background levels.⁴ This demonstrates conclusively that suggestions that an increase of loading of 300% would protect the tissue-based standard are without a basis in record and indeed conflict with existing analysis.⁵

E. DWQ must include a selenium effluent limitation in the Jordan Valley permit

It has been suggested that the permit effluent limit⁶ for selenium could be removed from the Jordan Valley permit and DWQ could rely exclusively on the egg tissue standard to regulate the Jordan Valley discharge. This would violate the law. According to federal regulations which apply to Utah's UPDES program, every UPDES permit must include requirements necessary to achieve water quality standards. 40 C.F.R. § 122.44(d)(1); 40 C.F.R. § 123.25 (applying 40 C.F.R. § 122.44 to states). Pursuant to this requirement, permit "[l]imitations must control all pollutants" which have the "reasonable potential to cause, or contribute to an excursion above any water quality standard, including State narrative criteria for water quality." 40 C.F.R. § 122.44(d)(1)(i). Plainly, the concentration of the toxic pollutant selenium in the Jordan Valley discharge of 51 to 52 µg/L has the reasonable potential to cause or contribute to a violation of the numeric and narrative standard applicable to selenium. Moreover, the data and analysis cited in these comments confirms this point.

Where this potential exists and where the state has developed numeric criteria for a particular pollutant in order to protect water quality, "the permit must contain effluent limits for that pollutant." 40 C.F.R. § 122.44(d)(1)(iii). Because Utah has numeric selenium standard for Gilbert Bay in the form of a tissue-based standard, DWQ must include an effluent limitation for selenium in the Jordan Valley permit. Section 122.44 also requires that, where a state relies on a narrative standard to protect water quality, as Utah does for the transitional wetlands, the permitting authority is still required to "establish effluent limits using one or more of the" options spelled out in the rule. 40 C.F.R. § 122.44(d)(1)(vi). In any case, the permit must include an effluent standard. Therefore, the Jordan Valley permit must contain an effluent limit for selenium.

⁴ *Id.* at 21.

⁵ According to the conclusions of the Final Report "A selenium water quality standard that prevents impairment for aquatic wildlife of Great Salt Lake lies within the range of 6.4 to 16 mg Se/kg for bird eggs." Moreover, the selenium standard for Great Salt Lake requires particular steps by DWQ in the face of tissue concentrations of 5.0 and 6.4 µg/g dw. This means that tissue concentrations in three eggs of eight eggs collected in the area of the KUCC discharge exceed or threaten to exceed the selenium standard and that the medium concentration of these eggs already requires corrective responses by DWQ.

⁶ "Effluent limitation means any restriction . . . quantities, discharge rates, and concentrations of 'pollutants' which are 'discharged' from 'point sources[.]'" 40 C.F.R. § 122.2.

II. The Final Permit Should not be Issued Before the Completion of the Public Comment Process on the Comprehensive Sampling and Analysis Plan.

With the notable exception explained below, the outline of the proposed sampling and analysis model contained within the permit appears to be sufficient to determine whether the biota in the area of Outfall 001 is being harmed by the discharge. However, because the actual monitoring plan has not been submitted to DWQ by Jordan Valley, and because the plan will not be available for public review and comment until after the close of the public comment period for this permit, DWQ should not issue the final permit until the public review process of the proposed plan is complete. The specific parameters of how Jordan Valley proposes to accomplish its sampling and analysis model are an integral part of this UPDES permit. It is imperative that the public have the opportunity to review and comment on those parameters, and that Jordan Valley submit a final revised plan based on feedback received during the public process before the permit is issued.

III. DWQ Admits that it does not have a Backup Plan for Determining Impairment if it Cannot Achieve the Statistically Required 8-Egg Sample.

DWQ has stated that it will not have a statistically sufficient sample unless it is able to obtain a full 8-egg sample annually from the area of the outfall near Gilbert Bay. At this point, however, DWQ is unable to confirm whether a sufficient quantity of eggs will be available to accomplish this. Without this, the agency has stated that it will not be able to get a statistically meaningful sample, and thus will not be able to determine whether any possible impairment to the eggs is occurring. This is a significant shortfall in the premise that the monitoring plan will provide sufficient oversight of any possible impacts of this discharge. DWQ has also stated that it does not have an alternative means of achieving monitoring. In effect, the inability to obtain the full 8-egg sample set would fundamentally undermine the monitoring plan, with nothing to take its place. Because of this, DWQ must formulate a contingency plan for monitoring the impacts of this discharge if there are not sufficient eggs available in the outfall area.

IV. It is Possible that a Hot Zone of Selenium Exists in the Lake at the End of the Discharge Channel.

There is evidence to suggest that there could be a localized “hot zone” of selenium in the area of the Lake where the discharge channel meets the open waters of the Lake. Such a hot zone would consist of significantly higher levels of selenium loading than are found in other areas of the Lake. Because there is a correlation between increased loading and an increased level of concentration of selenium within a given area, it is possible that this hot zone is causing increased concentrations of selenium in that area. At this point, the suggested monitoring plan does not provide for any water or sediment sampling in that area. Additional sampling would be required to confirm or deny the existence of such a zone and DWQ should request that it be added to the monitoring plan.

V. The Level of Permitted Methyl Mercury in the Discharge is not Quantified.

The permit only cites a total load of mercury from the discharge at 0.38 kg/yr and does not distinguish between elemental mercury, and methyl mercury. Therefore, it appears that DWQ's position is that a 0.38 kg/yr discharge of methyl mercury would not be detrimental to the designated uses of the outfall area of the Lake. More specificity regarding the breakout of the types of mercury permitted is needed to inform the public as to the potential impacts to water quality from the proposed discharge.

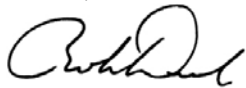
VI. WET Testing

The permit should include WET testing to analyze the toxicity of the whole effluent. It is crucial to determine if the *combination* of the pollutants in the effluent is toxic. This is particularly true because the KUCC discharge will be mixing with the Jordan Valley discharge. We urge DWQ to find a suitable test organism. Because the effluent is composed of fresh water that does not mix with the saline waters of Great Salt Lake for a consider distance and over a significant time frame, it may be appropriate to use a freshwater species as a test organism. Without an appropriate test organism, the proper conclusion may well be that nothing can survive in the effluent and the effluent is toxic. If so, the permit would have to be adjusted accordingly.

Conclusion

Thank you for the opportunity to comment on this Draft Permit. As always, we very much appreciate your willingness to consider our input and to work with us towards improving the water quality of Great Salt Lake.

Yours,



ROB DUBUC

JORO WALKER

Attorneys for FRIENDS

GREAT SALT LAKE ALLIANCE
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COMMENTS ON JORDAN VALLEY UPDES PERMITS TO DISCHARGE
INTO GREAT SALT LAKE and JORDAN RIVER

Kim Shelley
Utah Division of Water Quality
PO Box 144870
Salt Lake City, UT 84114-4870
Dear Ms Shelley,

Thank you for giving us the opportunity to discuss the Jordan Valley Water Conservancy District UPDES permit. The Great Salt Lake Alliance is composed of a large and diverse group of organizations and individuals representing primarily environmental interests. Individual members served as members of the GSL Water Quality Standard Steering Committee during creation of the GSL selenium standard, attended Science Panel meetings, are familiar with the ecological resources of the Lake and have done research on the Lake.

These comments are based on the experience described above and review of the Fact Sheet/Statement of Basis (SOB) and the Draft Authorization to Jordan Valley Water Conservancy District (JVWCD) to Discharge under UPDES as well as discussions with members of the Division of Water Quality October 21, 2010. Thank you for your responses to our initial written comments in November.

Individuals and organizations participating in these comments are: The Nature Conservancy in Utah; National Audubon Society; League of Women Voters of Utah; League of Women Voters of Salt Lake City; Bruce Waddell U.S.F.W.S. retired; Jason Kershaw. President, Lake Front Gun, Fur and Reclamation Club; Richard West, President, South Shore Wetlands and Wildlife Management Inc. ; Maunsel Pearce, Chair Great Salt Lake Alliance.

Elements of Concern:

In general, although other contaminants are present in the discharges to Great Salt Lake and Jordan River, our major concerns are with selenium and mercury because they are bioaccumulative and can be toxic to inhabitants of the GSL ecosystem (in particular waterfowl, shorebirds, and the organisms in their food chain).

Selenium Standard for the Open Water:

The selenium numeric water quality standard process was undertaken during 2004-2008 to provide a means of protecting the Great Salt Lake ecosystem of Gilbert Bay. At the time, only one major discharge permit existed but Jordan Valley needed a disposal process for waste from the proposed reverse osmosis process used to recover drinking water from an aquifer contaminated by historic mining. Scientific projects were devised and supervised by a Science Panel to understand the best way to measure selenium and its movement up the food chain organisms to waterfowl and shorebirds.

Selenium bioaccumulates in food chain organisms and bird toxicity occurs most noticeably at the egg/embryo level, but direct toxicity and sublethal effects also occur. High levels of selenium in blood and livers of GSL water birds were not investigated further in this study.

Members of the Steering Committee representing environmental interests and wildlife agency representatives all favored a selenium standard which produced no embryo mortality. Consensus could not be reached by the Steering committee about how protective to be of the ecosystem. A small majority favored a Se standard of 12.5 mg/kg. dry weight, allowing a 10% egg/embryo mortality before impairment is reached and reduction of discharges into GSL is required. Because this 10% mortality seems to violate the International Migratory Bird Treaty Act, the EPA has not yet approved the standard although it is now in Utah Law.

The Jordan Valley Permit Fact Sheet states that the present maximum discharge from Kennecott is 843 kg/yr. and that “loading increases of up to 300%...remain protective of the tissue-based standard”. We believe there are enough uncertainties in the model and baseline data that this conclusion is unwarranted and appears more protective of the discharge than the resource. Selenium concentrations increased almost 100% in GSL during the project (2006-2007) and yet no more recent data for the discharge site or GSL are available. This implies a huge margin of safety in allocating the proposed discharge of an estimated 224 kg/yr selenium. No citation was provided to indicate how the conclusion was arrived at.

Please include the calculation and assure numbers are correct especially where changing between pounds and kilograms.

- We recommend immediately resampling the Lakewide sampling sites developed earlier during the Standard Setting Process prior to commencement of new discharges to establish current conditions. We also recommend continuation of monitoring all surface water sites entering Gilbert Bay to accurately characterize at least surface water sources.
- Because of the uncertainties in the model, and uncertainties in the baseline we recommend that new discharges be awarded using an adaptive management approach using small volumes and including an adequate time to monitor GSL changes associated with these controlled releases, perhaps 3 years or a statistical analysis estimating equilibrium has been reached.

Studies by USGS, USFWS, the State and other researchers have already found elevated concentrations of selenium and mercury in birds using the Great Salt Lake. Effects studies of these concentrations on non-nesting birds have not been completed.

- Studies should be initiated to evaluate the sublethal effects of selenium (and mercury) on these birds. Studies should be initiated to determine off-site effects such as lowered winter survival, nesting effects, disease prone, etc.

Mercury in the Jordan Valley Discharge:

No numeric mercury standard for GSL exists and a process to develop one has not been initiated. Very little mercury data was collected concurrent with developing the selenium standard. During the project we repeatedly asked Jordan Valley for reports on the concentrations of mercury in the Zone B contaminated aquifer. The data has never been reported and will not be available for a year (Fact Sheet Compliance schedule, page 4). GSL is a mercury hot spot containing some of the highest mercury levels in the nation. Data collected by USGS has estimated loads entering via atmosphere and surface waters. Consumption advisories are in effect for 3 GSL waterfowl species due to the presence of mercury in tissues exceeding thresholds for human consumption. Yet DWQ is permitting a mercury discharge from an unknown concentration in the aquifer that has an arbitrary limit based on an estimated total mercury load to GSL.

Under these conditions, adding a new mercury discharge to GSL is a risky experiment. The form and fate of mercury must be measured from the RO plant to the mixing zone in the Lake.

Selenium and Mercury Standards for the Transitional Wetlands:

Since 2007 the Lake has dropped over 3 feet in elevation to 4193.7 The discharge sites for Kennecott and Jordan Valley will be at about 4208 feet. Jordan Valley's new discharge site (Outfall 001) will join Kennecott's Outfall 012 to flow for a mile as a vegetation lined stream before reaching the open GSL water in Gilbert Bay. Because no water column selenium limit has been established, compliance with the tissue-based standard in egg/embryo of 12.5 mg/kg will be required. Annual sampling of eggs in this outfall nesting area is critical for monitoring these combined discharges. Sampling activities may result in the decline of bird nesting and thus eggs available for assessment. It is also a concern that certain species are more sensitive, e.g. snowy plover, and should be protected.

Because the combined discharges have no mixing zone for the better part of a mile, DWQ should apply existing freshwater numeric standards for selenium and mercury. This would ensure that the Transitional Wetlands do not constitute an attractive nuisance to waterbirds where Se and Hg have become concentrated in food items resulting in a toxic wetland or nesting site. The open channel discharge area is clearly expected to be closer in quality to freshwater than the Great Salt Lake. Where does the brine layer underlay the freshwater, e.g. where does the mixing zone actually start?

In December of 2009, the tissue-based standard for selenium of 12.5 mg/kg in bird egg/embryo was included as part of the Utah Administrative Code and became Utah Law as R317-2-14. Specifically, footnote 14 requires collection of a minimum of 5 egg samples for selenium from Gilbert Bay sites during the nesting season. That data will not be available for the approval of this permit. Data collected during the Se Standard Project show that the eggs at KUCC discharge site are at the threshold that should trigger modification of the monitoring plan. *See* Draft Permit, page 9. Three of 8 eggs collected during the Se standard process exceeded the 6.4 ppm dw. We are not comfortable with DWQ's unequivocal position that mutations associated with Se and Hg do not exist. Flooding that occurred at KUCC nest site in 2006 prevented adequate investigation.

- Assume that discharging at concentrations 10 times the freshwater standard for selenium and unknown for mercury will expedite the appearance of high concentrations in embryos.
- Assume dead embryos and deformities would occur as predicted, e.g. none at 5.0 ppm dw and 10% at 12.5 ppm dw.

We understand that monitoring the selenium standard for open water of GSL will not be part of this permit. DWQ must include, and allow the public to comment on, the sampling and analysis plan associated with the Jordan Valley discharge as part of the permitting process. Given that monitoring of bird eggs is scheduled to occur in less than five months, there is no practical reason for delaying creation and approval of this plan. The details of this plan are a critical component of the monitoring program and DWQ should not ask the public to sign off on the plan sight unseen.

- We recommend that the public be provided an opportunity to comment on the monitoring plan.
- We recommend that concurrence be obtained on the plan from USFWS, Utah Office and UDWR State office on methodology and species.
- We recommend that contingency decisions be identified when bird eggs are unavailable or nesting pairs reach a certain minimum density.

Cumulative Discharge Evaluation

There is no time limit for this permit. Although the Groundwater Cleanup Project was described as a 40-year process, and although the permit renews every 5 years, it is for all practical purposes an indefinite permit. Because of that, the loadings/concentrations over time will have additional significant impacts to wetlands and the GSL where processes retain and recycle certain elements such as Se and Hg.

The time limits for these discharges should be clearly stated in the permit, and an attempt at quantifying the long-term cumulative impacts should be made. It is our understanding that DWQ has no plans to do this.

The impact of lost Jordan River flow into GSL wetlands from the net loss of 3 million gallons/day of shallow wells pumping will be significant but has not been calculated. As

more wells along the Jordan River are added, greater impacts to Jordan River flows into the wetlands will have major impacts to beneficial uses. Comments are needed from the Division of Water Resources on this issue.

The impact of replacing geologically slow seepage of shallow groundwater into the Jordan River compared to pumping, treating, and discharge of contaminant concentrate to the Jordan River have not been explained or fully evaluated.

- Evaluate the change in concentration and water supply to the Jordan River and down stream wetlands.

In addition, some of Jordan Valley's effluent will periodically flow into the Jordan River and downstream wetlands of Great Salt Lake. Cumulative effects on essentially terminal wetlands should be evaluated for selenium and mercury.

- Establish baseline conditions in wetlands. Determine cumulative effect of selenium and mercury concentrations.

We recommend evaluation of the cumulative discharges known or expected. For instance, if it is known or reasonably expected that Kennecott will be asking for an increase in their discharge permit, this should be the basis of discussion of impacts, in addition to the permit under consideration.

When DWQ determined that Se (and presumably Hg) were lost by volatilization from the terminal GSL into the atmosphere, it was welcomed as a partial solution to the selenium question. However, what goes up as volatile compounds of Se and Hg could be just coming down and spreading/recycling within the basin. Once Se is released from the soils/rocks sequestering it, it is almost impossible to put it back in secure form. Ideally Se and Hg should not be released into the environment by industry and prevention should simply be a cost of doing business. This was the original intent of the Clean Water Act.

Again, we appreciate this opportunity for public input and we appreciate DWQ's lead in establishing the first numeric water quality standard for Great Salt Lake. We anticipate ongoing assurance by DWQ of ecosystem protection in the face of new discharges.

Sincerely,

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Maunsel B. Pearce

**STATEMENT OF BASIS
FACT SHEET
KENNECOTT UTAH COPPER CORPORATION
MAJOR PERMIT MODIFICATION
UPDES PERMIT NO. UT0000051**

FACILITY CONTACT

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Position:	Superintendent of Water Resources	Position:	Principal Advisor, Env.
Number:	(801) 569-7915	Number:	(801) 569-7427

Facility Name:	Kennecott Utah Copper Corporation
Mailing Address:	PO BOX 6001 Magna, Utah 84044-6001
Actual Address:	8315 West 3595 South

REASON FOR MAJOR PERMIT MODIFICATION

Kennecott's permit has been modified to incorporate conditions implemented in the new selenium standard for Gilbert Bay as given by the Division of Water Quality's Fact Sheet, *Recommended Guidelines for a Water Quality Standard for Selenium in Great Salt Lake*. The changes also further clarify monitoring requirements to ensure compliance with standard applicable to the mudflat area. The changes include sampling of bird eggs (if permits are available from Fish and Wildlife Services), co-located sampling of macroinvertebrate and water column, bird surveys, a load-based limit for selenium, and modified selenium sampling frequency for Kennecott's discharges to the Great Salt Lake (GSL).

SPECIFIC LIMITATIONS AND SELF-MONITORING REQUIREMENTS

Kennecott is required to annually sample eight (8) bird eggs, if available, but not to exceed 20% of available eggs, during the nesting season, May 1 through June 15, for the current permit cycle. The eggs will be collected from bird nests in the "Kennecott 012 outfall area".

Kennecott is required to annually collect co-located macroinvertebrate and water samples once during each year eggs are sampled and as close in time as practical to the bird egg collection. Kennecott will be required to annually collect a minimum of 6 samples taken at distances from the waters edge from where Outfall 012 enters standing waters of the GSL determined at the time of sampling to be biologically significant.

Kennecott will conduct annual bird surveys approximately every two weeks between May 1 and June 15 (four times per season) to document bird abundance, diversity, and use of the Outfall 012 mud flat habitat, particularly for evidence of feeding and nesting (use methodology recently recommended by CH2M Hill for Kennecott wetlands).

The permit limit for an annual load for selenium to GSL will be 3,730 pounds per year. Since there is no current impairment to the GSL, the load limit was calculated based upon a concentration of 35 ug/L with a flow of 35 million gallons a day. If future information indicates an increase of selenium in bird eggs and/or water column data, near the Kennecott outfalls, the permit may be reopened and modified. The loading includes all Kennecott outfalls to the GSL which are Outfall 002, Outfall 004, Outfall 007, Outfall 008, Outfall 011 and Outfall 012.

Due to concerns of selenium in the GSL, Kennecott will be required to sample Outfall 012 for selenium, when the valve is open for discharge to the GSL. If the duration of the discharge is less than 6 hours then a grab sample will be required to be analyzed and meet the permit limits for selenium.

At the end of this permit cycle all information stated in this section will be re-evaluated and changed, if needed.

PERMIT DURATION

The permit modification will be effective until midnight on the January 31st 2012.

Permit Modified by
Jennifer Robinson, Environmental Engineer
August 11, 2008

Running Head: Site-Specific Water Quality Standard for Selenium

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Word count: 5,335

1 **DERIVATION OF A SITE-SPECIFIC WATER QUALITY STANDARD FOR**
2 **SELENIUM IN THE GREAT SALT LAKE, UTAH**

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25 **ABSTRACT**

26 The purpose of this study was to develop a site-specific water quality standard for
27 selenium in the Great Salt Lake, Utah. The study examined the direct bioavailability and
28 toxicity of selenium, as selenate, to biota resident to the Great Salt Lake and the potential
29 for dietary selenium exposure to aquatic dependent birds that might consume resident
30 biota. Because of its high salinity, the lake has limited biological diversity with bacteria,
31 algae, diatoms, brine shrimp and brine flies being the only organisms present in the main
32 (hypersaline) portions of the Lake. To evaluate their sensitivity to selenium, a series of
33 acute and chronic toxicity studies were conducted on brine shrimp, *Artemia franciscana*,
34 brine fly, *Ephydra cinerea*, and a hypersaline alga, *Dunaliella viridis*. The resulting
35 acute and chronic toxicity values indicated that resident species are more selenium
36 tolerant than many freshwater species. This is thought to result in part to the lake's high
37 ambient sulfate concentrations (>5,800 mg/L), as sulfate is known to reduce selenate
38 bioavailability. The acute and chronic test results were compared to selenium
39 concentrations expected to occur in a mining effluent discharge located at the south end
40 of the lake. Based on these comparisons, no appreciable risks to resident aquatic biota
41 were projected. Field and laboratory data collected on selenium bioaccumulation in brine
42 shrimp demonstrated a linear relationship between water and tissue selenium
43 concentrations. Applying a dietary selenium threshold of 5 mg/kg dw for aquatic birds to
44 this relationship resulted in an estimate of 27 µg/L Se in water as a safe concentration for
45 this exposure pathway and an appropriate site-specific water quality standard.

46 **Key Words: Selenium Site Specific Water Quality Standard Great Salt Lake**

INTRODUCTION

47

48

49 The Great Salt Lake (GSL) is the fourth largest terminal lake in the world [1] and
50 the largest hypersaline lake in North America [2]. In 1957, the Southern Pacific Railroad
51 Company constructed a rock-filled causeway across the lake, dividing it into two arms.
52 Although culverts link the two arms, they are insufficient to maintain mixing between
53 them. Consequently, the GSL essentially consists of two lakes, each with varying salinity
54 and dominant organisms. Approximately 92 percent of freshwater inputs enter the
55 southern arm [3], resulting in the northern arm being more saline (approximate salinity
56 330 g/L) than the southern arm (approximate salinity 100 g/L).

57 The food web of the southern arm of the GSL is relatively simple because few
58 organisms can tolerate its high salinity and low oxygen solubility [4, 5]. The aquatic food
59 web consists of at least four species of bacteria (mainly *Halobacterium* and *Halococcus*), up
60 to 20 species of algae (mainly *Dunaliella viridis* and *D. salina*), at least 17 diatom species,
61 brine shrimp (*Artemia franciscana*), and seven species of brine flies (*Ephydra* spp.).
62 Additionally, in areas near significant freshwater inputs where the salinity is less than <75
63 g/L, corixids (*Trichocorixa verticalis*), rotifers (*Brachionus* sp.) and two species of
64 copepods (*Cletocampus albuquerqueensis* and *Diaptomus connexus*) have been observed [2,
65 5-8]. The abundance of these taxa fluctuates with season and salinity [1].

66 Because of the high salinity, no fish occur in the lake except in freshwater
67 estuaries near the Bear, Jordan and Weber Rivers. This lack of aquatic predators, in turn,
68 can lead to extraordinarily high densities of brine shrimp and brine flies, which are an
69 important food source for resident and migratory birds. The lake and its surrounding

70 wetlands is an important stop-over point for migratory shorebirds and waterfowl. Greater
71 than 75% of the West's population of tundra swans (*Cygnus columbianus*), 50% of the
72 continent's Wilson's phalaropes (*Phalaropus tricolor*), 25% of the continent's northern
73 pintails (*Anas acuta*), the world's largest nesting population of California gulls (*Larus*
74 *californicus*), and millions of other waterfowl use the lake during their annual migration
75 periods.

76 The eastern and southeastern shorelines of the lake's southern arm are bordered by
77 the Salt Lake City metropolitan area. Among the industries bordering the lake are the
78 smelting and refining facilities for a copper mine. The major constituent of this facility's
79 wastewater discharge is selenium, with concentrations as high as 300 µg/L Se having
80 been measured historically. Current selenium discharge levels are approximately 20-50
81 µg/L before dilution. The majority (>95%) of this Se is in the form of selenate and
82 unless otherwise noted, all discussion of Se in this paper is referring to selenate. The
83 effluent is considerably less saline (5 g/L) than the lake creating creating a small
84 estuarine zone in the immediate area of the discharge.

85 The outfall discharge has cut a channel 2-4 feet deep in the lake sediments
86 immediately offshore. Water depth surrounding the channeled area averages
87 approximately 8-18 inches. Lake sediments consist of well-compacted silty, sandy clays.
88 Sediments in the channeled area are less compacted and composed of finer material.
89 Dense stands of *Phragmites* sp. have established along the banks of the channel,
90 stabilizing it. Over time, deposition of fine sediments and organic material and continued
91 colonization by *Phragmites* has effectively extended the channel approximately 1,500
92 feet out into the lake (Figure 1). The water depth and velocity, along with the dense

93 *Phragmites*, effectively limits shorebird use in the channel proper, but they are routinely
94 observed to feed along the shorelines on either side of the channel.

95 Because of its unique water quality characteristics and biota, generic water quality
96 criteria do not apply to the GSL [9], and historically very little toxicity data has been
97 generated for the lake's resident species. Hence, the appropriate water quality standard
98 for Se in the GSL is unclear. Additionally, unlike most other metals and metalloids, the
99 diet typically represents the most important exposure pathway for Se, with top trophic
100 level consumers (e.g., fish and aquatic-dependent birds) being the most sensitive
101 environmental receptors in an aquatic system [10, 11]. Consequently, any site-specific
102 water quality standard for selenium must consider exposure via both water and dietary
103 pathways. This study was designed to evaluate potential exposure and effects from Se
104 discharges to the lake via both pathways through a series of laboratory and field studies
105 on resident species. Study results were then used to develop an appropriate site-specific
106 water quality discharge limit.

107

108

METHODS AND MATERIALS

109

110 Given that Se may cause either direct effects on aquatic biota resident to the lake
111 or the resident biota may accumulate Se to deleterious levels for organisms that consume
112 them, both pathways needed evaluation in order to propose an appropriate site-specific
113 water quality standard (Figure 2).

114

115 To evaluate the potential for direct effects on resident aquatic biota, we conducted
116 toxicity tests on brine shrimp, larvae of the brine fly, *Ephydra cinerea*, and the most

116 common alga in the southern arm of the lake, *Dunaliella viridis*. This species is a
117 principal food source for brine shrimp. Acute testing was conducted using brine shrimp
118 and brine fly larvae and chronic testing was conducted using *Dunaliella viridis* and brine
119 shrimp. The chronic sensitivity of brine flies was not investigated because of their
120 extreme insensitivity when tested acutely.

121 To evaluate the potential for avian toxicity arising from the dietary pathway, Se
122 concentrations in brine shrimp were measured in specimens collected within and adjacent
123 to the mine discharge, as well as at background Se concentrations in the lake. These data
124 were then compared to appropriate dietary thresholds for aquatic dependent birds.

125

126 **Toxicity Testing**

127

128 *Acute Testing*

129

130 The methods used for conducting the acute tests were consistent with those
131 described in U.S. EPA [12], although parameters such as dilution water and test volume
132 were modified to meet species-specific requirements. Tests were static non-renewal
133 studies conducted at 25 ± 1 °C with five test concentrations and a control. Dilution water
134 for the acute tests was GSL water collected from the shoreline on the north side of
135 Antelope Island, a location well removed from anthropogenic inputs to the lake.
136 Conventional water quality parameters were measured in the dilution water prior to
137 testing (Table 1).

138 Reagent grade sodium selenate (CAS #13410-01-0) obtained from Sigma
139 Chemical Company, St. Louis, Missouri was used to create stock solutions. For the brine
140 shrimp study, a 10 g/L stock solution was prepared by adding 23.9 g of sodium selenate
141 to 1 L of deionized water. The extreme insensitivity of brine fly larvae prevented
142 preparation of a single stock solution. Instead, the sodium selenate was added directly to
143 5 L batches of dilution water in order to achieve the desired nominal test concentrations.

144 The brine shrimp test was initiated with nauplii <24 hours old that were hatched
145 overnight at 25 °C in 25 g/L artificial seawater. Nauplii were not acclimated to the
146 dilution water salinity (82 g/L) prior to testing. This treatment reflects natural conditions
147 where cysts hatch in the relatively low salinity lens of water on the lake surface and then
148 drop down in the more saline water column. Nauplii were randomly introduced to
149 exposure chambers (600 mL beakers with 400 mL of test solution) for each of the five
150 treatments and control. Four replicates were conducted with each treatment. Preliminary
151 testing indicated brine shrimp required daily feeding to achieve acceptable control
152 survival and so were fed daily 2 mL of a 500,000 cells/mL stock of the marine algae
153 *Platymonas* sp.

154 Brine fly larvae were collected for testing from White Rock Bay on the north
155 shore of Antelope Island. Larvae were identified to species by Chadwick and Associates
156 in Littleton, Colorado. Test organisms were held in GSL water in 40 L aquaria at 12 °C
157 for eight weeks prior to testing. During holding 40 mL of 3.5×10^6 cells/mL solution of
158 *Dunaliella viridis* were added weekly to the aquaria. Forty-eight hours prior to testing,
159 larvae were acclimated to the test temperature of 25 °C. Four replicate 1 L beakers with

160 800 mL of test solution were tested at each Se concentration. Test organisms were not
161 fed during testing.

162

163 *Chronic Testing*

164

165 The methods for conducting the chronic brine shrimp life-cycle test were
166 previously described in Brix et al. [13]. Briefly, this 28-day test measured survival,
167 growth and reproduction of the parental generation, and survival and growth of the F₁
168 generation. The test was conducted under intermittent flow-through conditions beginning
169 with brine shrimp nauplii <24 hours old. After 11 days, brine shrimp matured sexually
170 and began pairing for mating. At this time, they were thinned by collecting and weighing
171 (dry) a random subsample from each test concentration. Six adult pairs for each test
172 concentration were then monitored for reproduction until day 28 when surviving shrimp
173 were measured for dry weight. For each test concentration, randomly selected nauplii (F₁
174 generation) from the pairs were subjected to the same conditions as the parental
175 generation for 11 days, with survival and dry weight being monitored for comparison
176 with the parental generation.

177 The experimental design for the algae toxicity test followed U.S. EPA [14] and
178 EU [15], except for the dilution media, which was GSL water passed through a 1 µm
179 filter. In this test, 1 x 10⁴ cells of *D. viridis* from a culture in log-phase growth were
180 inoculated into 125 mL test flasks with 50 mL of test solution. Test flasks were placed
181 on a shaker table rotated at 100 cpm. Each test concentration consisted of 16 replicates
182 and every 24 hours, four of the replicates were terminated, whereupon water quality was

183 monitored and cell densities measured using a Hach 300 spectrophotometer. The
184 spectrophotometer was calibrated against known cell density stocks of *D. viridis*.

185

186 *Analytical Chemistry*

187

188 For all tests, water quality parameters (temperature, salinity, pH and dissolved
189 oxygen) were measured daily in one replicate of each treatment and control. Samples
190 from each concentration were collected for Se analysis at test initiation and termination
191 using the hydride generation method of Cutter [16]. The exception to this sampling
192 regime was the chronic brine shrimp study where samples were collected on a weekly
193 basis.

194

195 *Data Analysis*

196

197 For the acute brine fly and brine shrimp tests, statistical analyses were conducted
198 using the statistical computer package Toxis[®] [17] to estimate the LC50 and its 95%
199 confidence interval, as well as the no observed effect concentration (NOEC) and lowest
200 observed effect concentration (LOEC). The NOEC and LOEC were determined by
201 Steel's many-one rank test and the LC50 was estimated by probit analysis.

202 The statistical evaluation of the chronic brine shrimp results included testing for
203 differences between the treatments and controls at reproductive pairing (Day 11), Day 21
204 and Day 28 by parametric or non-parametric methods depending on whether data met
205 normality and homogeneity assumptions. If the data met the assumptions of normality

206 and homogeneity, an ANOVA was computed to determine whether any differences
207 existed among levels (concentrations or generations). If either of the assumptions could
208 not be met, the non-parametric Kruskal-Wallis test was used to test for differences. The
209 statistics were calculated using Statgraphics [18].

210 For the chronic algae tests, statistical analyses for the NOEC and LOEC were
211 conducted using SPSS [19] in accordance with procedures described in EU [15]. Specific
212 growth rate and cumulative area under the curve were calculated for each replicate, as were
213 summary statistics for each time period. The statistical computer package Toxis[®] [17] was
214 used to estimate the EC50 value and the 95% confidence interval based on results from
215 specific growth rate and cumulative area under the growth curve calculations.

216

217 **Field Bioaccumulation Study**

218

219 In order to evaluate the potential for Se in the mining effluent to bioaccumulate in
220 aquatic organisms that might be fed upon by migratory shorebirds, a field program was
221 implemented to sample water and co-located brine shrimp at various locations relative to
222 the mining effluent discharge (Figure 1). Two sampling events (June and August) were
223 undertaken to characterize Se concentrations in water and biota. However, because brine
224 shrimp were not found at most stations in the discharge channel during the August
225 sampling event, only results for the June sampling event and a single sampling station
226 (station 7) with brine shrimp present during the August sampling event are presented.

227 Surface samples were collected because preliminary sampling efforts indicated
228 the majority of brine shrimp occurred in the upper water column. Water depth along the

229 sampling transect varied from 0.5 to 1.5 meters. Water samples were collected using a
230 battery-powered peristaltic pump using methods consistent with U.S. EPA [20]. Samples
231 were collected within the channel midway between the banks wherever possible.

232 When present, brine shrimp were collected at the same time and place as water
233 samples to evaluate the relationship between water and tissue Se concentrations. Brine
234 shrimp were collected using a dip net with a 15 x 30 cm basket constructed of 500 μm
235 Nitex™ screen. The dip net was slowly trawled through the water column approximately
236 15 cm below the water surface until the net contained sufficient specimens (5 g wet
237 weight) for analysis.

238 Total recoverable and dissolved Se were measured in water samples at the
239 Kennecott Environmental Laboratory using the hydride generation method of Cutter [16]
240 with an analytical detection limit of 2 $\mu\text{g/L}$ Se. Total selenium was determined on the
241 tissue digestate by hydride generation – atomic fluorescence spectrometry. A total
242 reduction/oxidation digestion, converting all forms to selenium (IV) was accomplished
243 by boiling the digested sample in 4M HCl with potassium persulfate. The analytical
244 detection limit in tissues was 0.5 mg/kg dw.

245

246

RESULTS

247

248 Toxicity Testing

249

250 Well defined concentration-response relationships were observed for all of the
251 studies. For the acute brine fly study, an LC50 of 495 mg/L Se was estimated. The brine

252 shrimp LC50 of 78 mg/L indicated it was substantially more sensitive than the brine fly
253 (Table 3). In the chronic *D. viridis* study, EC50s of 45 and 32 mg/L were observed for
254 the specific growth and area under the curve endpoints (Table 4). The NOEC was 11
255 mg/L for both endpoints. A number of different endpoints were evaluated in the chronic
256 brine shrimp study. Day 11 growth of the parental generation and Day 21 reproduction
257 were comparable and the most sensitive endpoints evaluated. For both, the NOEC was 3
258 mg/L Se and the LOEC 8 mg/L Se (Table 5). Overall, these two endpoints for the brine
259 shrimp were also the most sensitive of any endpoint and species evaluated.

260 Water quality parameters were within expected ranges for all studies (Table1).
261 Measured dissolved oxygen concentrations (1.8-6.0) mg/L require a brief discussion, as
262 the values are lower than what is typically considered acceptable in toxicity tests. The
263 low dissolved oxygen values measured during testing are a result of the hypersalinity of
264 the test solutions, which limits oxygen solubility. Dissolved oxygen saturation at these
265 salinities ranges from 3.6 to 5.0 mg/L depending on salinity and test temperature
266 (supersaturated values were measured in the study with *D. viridis* as will typically occur
267 in algal assays). Hence, the measured values in the tests were typically >60% saturation,
268 as is customary for toxicity tests. For comparison, the southern arm of the GSL has a
269 dissolved oxygen saturation of 2.0 mg/L, which is lower than noted above because the
270 lake is at an elevation of 4,200 feet [8], whereas the tests were performed in a laboratory
271 at sea level. Hence, the dissolved oxygen concentrations in these tests are characteristic
272 of what these organisms normally encounter in the environment. Selenium test
273 concentrations stayed relatively constant for all tests with coefficients of variation in test
274 concentrations $\leq 20\%$ for all treatments in all studies.

275

276 Field Bioaccumulation Study

277

278 In the June sampling event, surface water Se concentrations generally decreased
279 with distance from the outfall. Near the mouth of the outfall (Station 1) concentrations
280 were as high as 120 $\mu\text{g/L}$ Se, but declined relatively rapidly to background concentrations
281 (2 $\mu\text{g/L}$ Se) at Station 5 and beyond. Total recoverable and dissolved Se were essentially
282 equivalent at all stations. This is expected for Se discharges in the form of selenate, as it
283 does not readily adsorb to suspended solids [21, 22].

284 Consistent with water concentrations, Se in brine shrimp from the June sampling
285 event was highest near the outfall mouth, with concentrations as high as 15 mg/kg dw
286 (Table 6). Also consistent with waterborne Se data, brine shrimp tissue concentrations
287 dropped relatively rapidly to background (2-3 mg/kg dw) beginning at Station 4. The
288 single station (station 7) sampled in August also resulted in background Se concentrations
289 in brine shrimp tissue.

290

291

DISCUSSION

292

293 Toxicity Studies

294

295 The current U.S. EPA acute and chronic water quality criteria for Se in freshwater
296 systems are 20 and 5 $\mu\text{g/L}$ [23]. However, U.S. EPA has recently proposed a revised
297 criterion in which the acute criterion for selenate is 185 $\mu\text{g/L}$ and the chronic criterion is

298 based on a tissue residue concentration in fish [24]. In comparison, the lowest acute and
299 chronic toxicity values measured for biota resident to the GSL were one to two orders of
300 magnitude higher than the proposed acute criterion. However, as discussed below, a
301 close examination of the data indicates resident biota are actually average in sensitivity
302 relative to other freshwater species that have been tested. We make these comparisons
303 not as an argument that the freshwater water quality criteria is appropriate for the GSL,
304 but simply to understand why biota resident to the GSL may appear to be relatively
305 insensitive to Se.

306 The primary factor causing GSL biota to appear relatively insensitive is the effect
307 of ambient sulfate concentrations on selenate bioavailability. It is well recognized that
308 sulfate reduces selenate bioavailability to a variety of organisms, including algae,
309 bacteria, midges, daphnids and brine shrimp [25-30]. Brix et al. [31] quantified this
310 relationship by summarizing available data and conducting additional studies with
311 amphipods, daphnids and fish. They then developed a log-linear relationship similar to
312 that derived for hardness and divalent cationic metals to normalize for selenate
313 bioavailability as a function of ambient sulfate concentrations. This relationship is
314 important when evaluating the toxicity data in this study because the ambient sulfate
315 concentration in the GSL is 5,800 mg/L, high enough to significantly reduce selenate
316 bioavailability.

317 When the high ambient sulfate concentration of the GSL is considered, the
318 relative acute sensitivity of brine shrimp and brine flies is comparable to many freshwater
319 species. When the acute data from this study are plotted with available acute data and all
320 data normalized for ambient sulfate concentrations, brine shrimp and brine flies rank at

321 the 29th and 63rd percentiles of the species sensitivity distribution (Figure 3). The acute
322 brine shrimp data derived in this study are largely consistent with a previous study by
323 Forsythe et al. [25], who estimated 96hour LC50s of 1.4 and 82 mg/L Se at ambient
324 sulfate concentrations of 50 and 14,000 mg/L, respectively.

325 Similar to results for the acute studies, the effect levels from the chronic *D. viridis*
326 study are considerably higher than observed for other algal species that have been tested
327 with selenate, although the amount of data available are relatively limited. For example,
328 selenate chronic values for the freshwater green algae *Selenastrum capricornutum* and
329 *Scenedesmus obliquus* are in the range of 0.1-0.3 mg/L Se [32], compared with 14 mg/L
330 Se obtained for *D. viridis* in this study. While selenate toxicity to algae is also sulfate
331 dependent [30], the *D. viridis* study was conducted in an artificial media with a sulfate
332 concentration of only 195 mg/L. Normalizing this value to 50 mg/L sulfate (generally
333 comparable to standard freshwater algal test media) only lowers the estimated chronic
334 value for *D. viridis* to 6.3 mg/L. Hence, *D. viridis* appears to be substantially less
335 sensitive than freshwater green algae that have been previously tested.

336 In the chronic brine shrimp study, growth of the parental generation on Day 11
337 and reproduction on Day 21 were the two most sensitive endpoints, with both endpoints
338 having a NOEC of 3 mg/L and LOEC of 8 mg/L Se. Hence, the chronic value for this
339 study is the geometric mean of the NOEC and LOEC, 5 mg/L. Published data on the
340 chronic sensitivity of other invertebrate species to selenate are limited to an LOEC of
341 >0.7 mg/L for the amphipod *Hyaella azteca* [33].

342 Overall, the sensitivity of resident biota was relatively well characterized by the
343 studies performed. One shortcoming was the lack of testing of the corixid, *Trichocorixa*

344 *verticalis*, which has sporadically been observed in the discharge channel perimeter.
345 Although no standard toxicity testing with this species has been conducted, Thomas et al.
346 [34] did assess the short-term (48 hours) bioaccumulation of Se in *T. verticalis* by
347 exposing organisms to Se concentrations as high as 1 mg/L with no effect on survival.
348 Hence, the 48-hour LC50 for this species is >1 mg/L Se.

349 An overall assessment of the selenium toxicity data generated in this study
350 indicates brine shrimp is the GSL's most sensitive species resident, with a chronic value
351 of 5 mg/L Se. In comparison, selenium concentrations in the mine effluent typically
352 range from 20-50 µg/L Se, approximately two orders of magnitude lower than those
353 predicted to cause chronic effects. Accordingly, the direct effects of Se on resident biota
354 are not the critical exposure pathway in deriving a site-specific water quality discharge
355 limit for the GSL.

356

357 **Bioaccumulation Study**

358

359 When tissue Se in brine shrimp is plotted as a function of co-located waterborne
360 Se concentrations, a relatively strong relationship is observed ($r^2 = 0.92$) (Figure 4).
361 These data demonstrate an inverse relationship between waterborne exposure
362 concentration and corresponding bioaccumulation factor that is frequently observed for
363 metals [35, 36]. Using this relationship, the site-specific waterborne Se concentration
364 that results in the dietary threshold for aquatic dependent birds can be estimated. For this
365 assessment, we used a conservative avian dietary Se threshold of 5 mg/kg dw [37, 38]. A
366 dietary threshold for birds was used because they are considered to be more sensitive than

367 other wildlife species. Using the equation for the linear regression model in Figure 3, the
368 water Se concentration resulting in a brine shrimp selenium concentration of 5 mg/kg dw
369 can be back-calculated using the following equation:

$$370 \quad \text{Site - Specific Water Quality Standard} = \frac{\text{Dietary Threshold} - \text{Intercept}}{\text{Slope}} \quad (3)$$

371 Where: Dietary Threshold = 5 mg/kg dw

372 Intercept = 2.2802

373 Slope = 0.1002

374 Using this equation, a waterborne Se concentration of 27 $\mu\text{g/L}$ is the maximum
375 concentration that will not result in brine shrimp Se concentrations equal to or greater
376 than the avian dietary threshold of 5 mg/kg dw. Given that this value is more than two
377 orders of magnitude lower than the lowest effect level observed for direct Se toxicity to
378 resident aquatic biota, Se bioaccumulation in brine shrimp and subsequent dietary
379 toxicity to aquatic birds clearly represents the most critical exposure pathway.
380 Consequently, a site-specific water quality discharge limit of 27 $\mu\text{g/L}$ Se appears
381 protective for aquatic species and sensitive wildlife for this site.

382

383

CONCLUSION

384

385 The GSL is a unique ecosystem in the United States for which there are no water
386 quality criteria and existing freshwater or marine national water quality criteria are
387 inappropriate due to the unique water quality characteristics and biota of the Lake. Using
388 a risk-based approach, we evaluated critical exposure pathways for Se released into this
389 environment with the objective of setting a site-specific water quality discharge limit.

390 Resident aquatic biota were found to be comparable in sensitivity to other species that
391 have been tested, but naturally high ambient sulfate concentrations significantly reduce
392 Se bioavailability in this environment. Field bioaccumulation data collected from the
393 study site indicate that waterborne Se concentrations as high as 27 µg/L will not result in
394 an exceedance of the Se dietary threshold for aquatic birds that feed on resident biota.
395 Therefore, 27 µg/L Se appears to be an appropriate site-specific water quality discharge
396 limit for the protection of all exposure pathways at this site.

397

398

REFERENCES

399

- 400 1. Stephens DE. 1990. Changes in lake levels, salinity and the biological community
401 of Great Salt Lake (Utah, USA), 1847-1987. *Hydrobiol.*, 197:139-146.
402
- 403 2. Felix EA ,Rushforth SR. 1979. The algal flora of the Great Salt Lake, Utah,
404 U.S.A. *Nova Hedwigia*, 31:163-195.
405
- 406 3. Arnow T.1980. *Water budget and water-surface fluctuations in the Great Salt*
407 *Lake*, In Gwynn JW, Editor *Great Salt Lake: A Scientific, Historical, and*
408 *Economic Overview*. Utah Geological and Mineral Survey: Salt Lake City, Utah.
409 p. 255-264.
410
- 411 4. Post FJ. 1980. Biology of the North Arm. *Utah Geo. Min. Sur. Bull.*, 116:313-
412 321.
413
- 414 5. Wurtsbaugh WA ,Berry TS. 1990. Cascading effects of decreased salinity on the
415 plankton, chemistry, and physics of the Great Salt Lake (Utah). *Can. J. Fish.*
416 *Aquat. Sci.*, 47:100-109.
417
- 418 6. Felix EA ,Rushforth SR.1980. *Biology of the south arm of the Great Salt Lake*, In
419 Gwynn JW, Editor *Great Salt Lake: A Scientific, Historical, and Economic*
420 *Overview*. Utah Geological and Mineral Survey: Salt Lake City, Utah. p. pp. 305-
421 312.
422
- 423 7. Jorgenson EC. 1956. Ephydra of Utah. 1956, University of Utah: Salt Lake City,
424 Utah.
425

- 426 8. Post FJ. 1977. The microbial ecology of the Great Salt Lake. *Microb. Ecol.*,
427 3:143-165.
428
- 429 9. Stephan CE, Mount DI, Hansen DJ, Gentile JH, Chapman GA, Brungs WA. 1985.
430 Guidelines for deriving numerical national water quality criteria for the protection
431 of aquatic organisms and their uses. 1985, U.S. Environmental Protection
432 Agency, Environmental Research Laboratory: Duluth. p. 98 pp.
433
- 434 10. DeForest DK, Brix KV, Adams WJ. 1999. Critical review of proposed residue-
435 based selenium toxicity thresholds for freshwater fish. *Hum. Ecol. Risk Assess.*,
436 5:1187-1228.
437
- 438 11. Fairbrother A, Brix KV, Toll JE, McKay S, Adams WJ. 1999. Egg selenium
439 concentrations as predictors of avian toxicity. *Hum. Ecol. Risk Assess.*, 5:1229-
440 1253.
441
- 442 12. USEPA. 1993. Methods for measuring the acute toxicity of effluents and
443 receiving waters to freshwater organisms. 1993, U.S. Environmental Protection
444 Agency: Cincinnati, Ohio.
445
- 446 13. Brix KV, Cardwell RD, Adams WJ. 2002. Chronic toxicity of arsenic to the Great
447 Salt Lake brine shrimp, *Artemia franciscana*. *Ecotoxicol. Environ. Saf.*:In
448 Review.
449
- 450 14. USEPA. 1994. Short-term methods for estimating the chronic toxicity of effluents
451 and receiving waters to freshwater organisms. 1994, U.S. Environmental
452 Protection Agency: Cincinnati, Ohio.
453
- 454 15. EU. 1992. European Union Protocol C.3. *Official Journal of the European*
455 *Communities*, L383A:179-186.
456
- 457 16. Cutter GA. 1986. Speciation of selenium and arsenic in natural waters and
458 sediments. Vol. 1: selenium speciation. 1986, Electric Power Research Institute:
459 Palo Alto, California.
460
- 461 17. EcoAnalysis. 1994. TOXIS. 1994: Ojai, California.
462
- 463 18. STSC I. 1991. Statgraphics. 1991: Rockville, Maryland.
464
- 465 19. Norusis MJ. 1994. SPSS for Windows. 1994: Chicago, Illinois.
466
- 467 20. USEPA. 1995. Method 1669: Sampling ambient water for trace metals at EPA
468 water quality criteria levels. 1995, U.S. Environmental Protection Agency, Office
469 of Water: Washington, D.C.
470

- 471 21. Measures CI ,Burton JD. 1978. Behaviour and speciation of dissolved selenium in
472 estuarine waters. *Nature*, 273:293-295.
473
- 474 22. Neal RH ,Sposito G. 1989. Selenate adsorption on alluvial soils. *Soil Sci. Soc. Am.*
475 *J.*, 53:70-74.
476
- 477 23. USEPA. 1987. Ambient water quality criteria for selenium - 1987. 1987, U.S.
478 Environmental Protection Agency, Office of Water: Washington, D.C. p. 121 pp.
479
- 480 24. USEPA. 2002. Draft aquatic life water quality criteria for selenium. 2002, U.S.
481 Environmental Protection Agency: Washington, D.C. p. 159 pp. + appendices.
482
- 483 25. Forsythe BL ,Klaine SJ. 1994. The interaction of sulfate and selenate (Se⁶⁺)
484 effects on brine shrimp, *Artemia* spp. *Chemosphere*, 29:789-800.
485
- 486 26. Hansen LD, Maier KJ, Knight AW. 1993. The effect of sulfate on the
487 bioconcentration of selenate by *Chironomus decorus* and *Daphnia magna*. *Arch.*
488 *Environ. Contam. Toxicol.*, 25:72-78.
489
- 490 27. Maier KJ ,Knight AW. 1993. Comparative acute toxicity and bioconcentration of
491 selenium by the midge *Chironomus decorus* exposed to selenate, selenite, and
492 seleno-DL-methionine. *Arch. Environ. Contam. Toxicol.*, 25:365-370.
493
- 494 28. Kumar HD ,Prakash G. 1971. Toxicity of selenium to the blue-green algae,
495 *Anacystis nidulans* and *Anabaena variabilis*. *Ann. Bot.*, 35:697-705.
496
- 497 29. Ogle RS ,Knight AW. 1996. Selenium bioaccumulation in aquatic systems: 1.
498 Effects of sulfate on the uptake and toxicity of selenate in *Daphnia magna*. *Arch.*
499 *Environ. Contam. Toxicol.*, 30:274-279.
500
- 501 30. Williams MJ, Ogle RS, Knight AW, Bureau RG. 1994. Effects of sulfate on
502 selenate uptake and toxicity in the green alga *Selenastrum capricornutum*. *Arch.*
503 *Environ. Contam. Toxicol.*, 27:449-453.
504
- 505 31. Brix KV, Volosin JS, Adams WJ, Reash RJ, Carlton RG, McIntyre DO. 2001.
506 Effects of sulfate on the acute toxicity of selenate to freshwater organisms.
507 *Environ. Toxicol. Chem.*, 20:1037-1045.
508
- 509 32. Vocke RW, Sears KL, O'Toole JJ, Wildman RB. 1980. Growth response of
510 selected freshwater algae to trace elements and scrubber ash slurry generated by
511 coal-fired power plants. *Wat. Res.*, 14:141-150.
512
- 513 33. Brasher AM ,Ogle RS. 1993. Comparative toxicity of selenite and selenate to the
514 amphipod *Hyaella azteca*. *Arch. Environ. Contam. Toxicol.*, 24:182-186.
515

- 516 34. Thomas BV, Knight AW, Maier KJ. 1999. Selenium bioaccumulation by the
517 water boatman *Trichocorixa reticulata* (Guerin-Meneville). *Arch. Environ.*
518 *Contam. Toxicol.*, 36:295-300.
519
- 520 35. Adams WJ, Conard B, Ethier G, Brix KV, Paquin PR, DiToro DM. 2000. The
521 challenges of hazard identification and classification of insoluble metals and
522 metal substances for the aquatic environment. *Hum. Ecol. Risk Assess.*, 6:1019-
523 1038.
524
- 525 36. McGeer JC, Brix KV, Skeaff JM, DeForest DK, Brigham SI, Adams WJ, Green
526 AS. 2002. The inverse relationship between bioconcentration factor and exposure
527 concentration for metals: implications for hazard assessment of metals in the
528 aquatic environment. *Environ. Toxicol. Chem.*, *Submitted*.
529
- 530 37. Heinz GH, Hoffman DJ, Gold LG. 1989. Impaired reproduction of mallards fed
531 an organic form of selenium. *J. Wildl. Manage.*, 53:418-428.
532
- 533 38. Skorupa JP, Morman SP, Sefchick-Edwards JS. 1996. Guidelines for interpreting
534 selenium exposure of biota associated with nonmarine aquatic habitats. 1996, U.S.
535 Fish and Wildlife Service, National Irrigation Water Quality Program:
536 Sacramento, California. p. 74 pp.
537

538 **Table 1. Dilution water quality during the acute and chronic toxicity tests.**

Parameter	Range
Temperature (°C)	25 ±1
pH	7.9 – 8.4
Dissolved Oxygen (mg/L)	1.8 – 6.0
Salinity (g/L)	80 – 102
Total Organic Carbon (mg/L)	35 – 49
Dissolved Organic Carbon (mg/L)	34.8 – 40
Total Suspended Solids (mg/L)	5-18
Sulfate (mg/L)	5,800

539

540 **Table 2. Composition of artificial water used for testing *Dunaliella viridis*.**

<i>Salt</i>	Concentration (mg/L)
NaCl	100,000
MgCl ₂ 6 H ₂ O	1,500
MgSO ₄ 7 H ₂ O	500
KCl	200
CaCl ₂ 2 H ₂ O	400
KNO ₃	1,000
NaHCO ₃	43
H ₃ BO ₃	2.86
MnCl ₂ 4 H ₂ O	1.81
ZnSO ₄ 7 H ₂ O	0.222
Na ₂ MoO ₄ 2 H ₂ O	0.39
CuSO ₄ 5 H ₂ O	0.079
Co(NO ₃) ₂ 6 H ₂ O	0.049
FeCl ₃ 6 H ₂ O	2.44
KH ₂ PO ₄	35

541 **Table 3. Summary of acute toxicity test results (all values are mg/L Se).**

Species	Se Form	LC50 (95% C.L.)	NOEC	LOEC
<i>Artemia franciscana</i>	Selenate	78 (71-86)	51	71
<i>Ephydra cinerea</i>	Selenate	490 (445-542)	369	691

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544

545 **Table 4. Summary of chronic *Dunaliella viridis* toxicity test (all values are mg/L Se).**

Evaluation	Specific Growth	Cumulative Area Under Growth Curve
EC50 (95% C.I.)	45 (36-71)	32 (28-36)
NOEC	11	11
LOEC	18	18
Chronic Value	14	14

546

547 **Table 5. Summary of chronic *A. franciscana* toxicity test results.**

Endpoint	Evaluation	mg/L Se
Survival – parental Day 11	NOEC	38
	LOEC	74
Survival – parental Day 21	NOEC	74
	LOEC	>74
Survival – parental Day 28	NOEC	74
	LOEC	>74
Growth – parental Day 11	NOEC	3
	LOEC	8
Growth – parental Day 28	NOEC	15
	LOEC	38
Reproduction - parental Day 21	NOEC	3
	LOEC	8
Reproduction - parental Day 28	NOEC	15
	LOEC	38
Survival - F ₁	NOEC	15
	LOEC	38
Growth - F ₁	NOEC	15
	LOEC	38
Final Chronic Value		5

549 **Table 6. Summary of Co-located Selenium Data in Surface Water and Brine Shrimp.**

Sample Date	Station	Total Se ($\mu\text{g/L}$)	Dissolved Se ($\mu\text{g/L}$)	Tissue Se (mg/kg dw)	BAF
6/21/98	1	120	121	15.5	129
6/21/98	2	117	116	15.4	132
6/21/98	3	85	81	7.82	92
6/21/98	4	30	30	3.36	112
6/21/98	5	2	2	2.75	1375
6/21/98	6	2	2	2.86	1430
6/21/98	7	2	2	3.14	1570
8/27/98	7	1	1	3.38	3380

Figure 1 - Map of Study Area and Sampling Locations.

Figure 2 – Conceptual Model.

Figure 3 - Species Sensitivity Distribution for Selenate (Sulfate-Normalized).

Figure 4 - Relationship Between Water and Brine Shrimp Selenium Concentrations.



