Rationale for Proposed Revisions to Selenium Criterion for Ambient Water Quality

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RATIONALE FOR PROPOSED REVISIONS TO THE WATER QUALITY CRITERIA FOR SELENIUM

Introduction

The Clean Water Act requires that the U.S. Environmental Protection Agency (EPA) periodically update ambient water quality criteria to accurately reflect the latest scientific knowledge. In June 2016, EPA published the final report updating the criterion to protect aquatic life from the toxic effects of selenium, as "***Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater 2016*** (EPA 2016). This criterion contains multiple components, with numeric criteria based on data for both fish-tissue and water samples. The EPA stressed that fish-tissue data have primacy over the water-column data in most cases.[1] EPA last finalized the criteria for selenium in 1987, although a number of draft revisions to the criteria have been released between 1987 and 2016 (Table 1).

Section 303 of the Clean Water Act and other Federal regulations (40 Code of Federal Regulations [CFR] Part 131) require that States and authorized tribes routinely review and, as appropriate, modify water quality standards that protect the designated uses of surface waters. Such standards also provide a basis for controlling discharges or releases of pollutants into a waterbody. The EPA has, through Section 303 of the Clean Water Act, delegated authority to Nevada to establish water quality standards for all waterbodies or segments of waterbodies within the state. Additionally, Nevada state law (Nevada Revised Statutes [NRS] 445A.520) requires the state to establish water quality standards to protect beneficial uses of surface waters of the state.

In preparation for adopting the EPA's recommended criterion, this rationale prepared by the Nevada Division of Environmental Protection (NDEP), Bureau of Water Quality Planning (BWQP) reviews and discusses the revisions proposed to update Nevada's water quality standards for selenium. It is not until the adoption, as part of the State water quality standards, that the criterion values become regulatory.

Background on Water Quality Criteria for Selenium

Water quality standards establish numeric criteria for selenium to protect aquatic life from harmful effects of exposure to selenium. These criteria represent the concentrations of selenium that should not be exceeded in a waterbody, and are based on the results of toxicity testing on aquatic organisms. Selenium toxicity is primarily manifested as reproductive impairment due to maternal transfer, resulting in embryotoxicity and teratogenicity in egg-laying vertebrates. Early studies (pre-1980) focused mainly on exposure of organisms to varying concentrations of selenium in the water column,

[1] Fish-tissue data have primacy when the waterbody is at a steady-state condition. Water-column data should be used if steady-state conditions have not yet been achieved for a waterbody. See EPA (2016) for more details.

and adult and juvenile mortality of different species of fish and invertebrates. Other studies also evaluated the relative toxicity of selenite (+4) and selenate (+6) oxidation states, which occur as selenite (SeO_3^{2-}) and selenate (SeO_4^{2-}) ions in most natural waters. Results of standard toxicity tests based on survival of adults and juveniles found species-related differences in the chronic and acute toxicities of selenite and selenate, but the general lack of data collected for these ions made their use impractical as numeric criteria.

1980 Draft Ambient Water Quality Criteria for Selenium (EPA 1980)

In 1980, EPA first published numeric criteria to protect aquatic life from selenium in freshwater and saltwater systems. Freshwater criteria were **35 micrograms per liter (µg/L)** for chronic exposure and **260 µg/L** for acute exposure. These criteria were based on water-only exposure (no dietary exposure) and did not consider bioaccumulation. The 1980 document established numeric criteria for total recoverable selenite and selenate in freshwater aquatic systems, and total recoverable selenite in saltwater aquatic systems. There was a lack of data on toxicity of selenate in saltwater systems, so no numeric criterion was provided for selenate in saltwater systems. Bioaccumulation via the food chain was not assessed in developing the numeric criteria presented in the 1980 document; however, the importance of dietary intake was suggested by some researchers (e.g., Adams 1976).

1987 Final Ambient Water Quality Criteria for Selenium (EPA 1987)

By 1987, researchers recognized that the behavior and toxicity of selenium in aquatic systems are highly dependent upon site-specific factors, including food-web structure and hydrology. Because selenium poses risk to aquatic organisms mainly through dietary intake, traditional methods for predicting toxicity solely on the basis of exposure to dissolved (i.e., water-column) concentrations needed to be modified for assessing exposure to selenium in aquatic systems. EPA noted that "substantial quantities of selenium enter surface waters from both natural and anthropogenic sources."

In 1987, EPA promulgated national criteria for selenium (Table 2) that sought to address dietary intake (*Ambient Water Quality Criteria for Selenium – 1987*). The new criteria were issued after toxicity was observed in aquatic ecosystems where selenium was present in the water column at concentrations less the values for the 1980 criteria. The numeric criteria issued in 1987 (**5 µg/L** chronic, **20 µg/L** acute) were based on toxic effects observed at Belews Lake, North Carolina. This site hosted a cooling-water reservoir where water quality and fish communities had been affected by selenium loads from a coal-fired power plant. The 1987 update also provided an acute criterion of 20 µg/L, using an acute/chronic ratio derived from toxicity tests and based on dietary and water-column exposure in Belews Lake. These concentration limits were assumed to be protective of bioaccumulation via dietary intake of all forms of selenium.

The 1987 criteria recognized that "selenium is unique among pollutants" because of its chemistry and because it is an essential nutrient in trace amounts. Selenium is a metalloid rather than a metal, with chemical and physical property that are similar to sulfur. Selenium can replace sulfur in some minerals and biologically important compounds, and it forms organo-metallic compounds, such as selenomethionine, dimethyl selenide and dimethyl diselenide. The 1987 criteria speculated that the mode of toxicity may be related to reaction with or substitution for sulfur in biologically active compounds such as sulfur-containing amino acids. The complex geochemistry of selenium required significant research to refine the criteria to better account for bioaccumulation in aquatic vertebrates.

Research and Draft Documents: 1998-2014

In May **1998**, EPA sponsored a workshop on the bioaccumulation and toxicity of selenium in aquatic systems. The ability of selenium to convert between different inorganic and organic forms, along with its propensity to bioaccumulate in aquatic food webs, was found to complicate the derivation of suitably protective numeric criteria for aquatic systems. As noted in the workshop report:

> "*…selenium can exist in several different oxidation states in water, each with varying toxicities, and can undergo biotransformations between inorganic and organic forms. The biotransformation of selenium can significantly alter its bioavailability and toxicity to aquatic organisms. Selenium also has been shown to bioaccumulate in aquatic food webs, which makes dietary exposures to selenium a significant exposure pathway for aquatic organisms*."

In **1998-1999**, EPA published a revised acute criterion for selenium, using a formula that recognized that the two oxidation states (selenite and selenate) appeared to have "substantially different acute toxicities" (EPA 1998). That same year, EPA concluded that concentrations of selenium in fish tissue better represent the chronic adverse effects of selenium, which are based on food-chain bioaccumulation rather than water exposures.

In **2002**, EPA again recommended that the water quality criterion for acute exposure of aquatic life to selenium take into account the different oxidation states, which appeared to have different acute toxicities. The formula provided in the table of "National Recommended Water Quality Criteria for Priority Toxic Pollutants" (EPA 2002) was as follows:

> *"The criteria maximum concentration (CMC) = $1/[(f1/CMC_1) + (f2/CMC_2)]$ where f1 and f2 are the fractions of total selenium that are treated as selenite and selenate, respectively, and CMC_1 and CMC_2 are 185.9 µg/l and 12.82 µg/l, respectively*."

EPA (**2004**) considered diet as the primary route of exposure that controls chronic toxicity to fish, and published a draft document (EPA 2004). The 2004 draft criterion recommended a whole-body fish-tissue value of no more than 7.91 mg/kg, and attempted to account for different toxicities of selenite and selenate in the water column. The proposed values were 258 µg/L for selenite and a calculated value for selenate, based on sulfate concentrations, as shown below:

Selenite (Fresh Water)

Final Acute Value = 514.9 µg /L

CMC = (514 .9 µg/L) ÷ 2 = 257 µg/L

Selenate (Fresh Water)

Final Acute Value = 834.4 µg/L (calculated at a sulfate concentration of 100 mg/L)

CMC = (834.4 µg/L) ÷ 2 = 417 µg/L (at 100 mg/L sulfate)

Pooled Slope = 0.5812 (see Appendix A)

ln(CMC) = ln(417.2) - [slope x ln(100)]

= 6.0335 - (0.5812 x 4.605) = 3.357

CMC for Selenate (at 100 mg/L sulfate) = $e^{(0.5812[\ln(\text{sulfate})]+3.357)}$

Although accounting for the different toxicities of selenite and selenate forms may be the most technically correct approach for assessing selenium, most states do not collect data for these selenium ions. It appears that this general lack of analytical data for these selenium ions in water samples presented a significant obstacle to acceptance of the criteria proposed in 2004.

Since the 2004 publication, additional scientific evidence has been compiled; reaffirming that diet is the primary pathway for selenium exposure for both invertebrates and vertebrates. In 2009, the use of fish-tissue data to monitor selenium toxicity in aquatic systems was refined based on findings of a Pellston scientific workshop (Chapman and others, 2009, 2010). These studies confirmed that selenium toxicity manifests primarily as reproductive effects and causes embryotoxicity and teratogencity in egg-laying vertebrates.

In **2014**, the EPA released an external peer-review draft of an updated selenium criterion, consisting of criteria values for two fish-tissue and two water-column components. This draft criterion specified that the values of the fish-tissue criterion values were not to be exceeded more than once in three years, on average. The values proposed for the tissue and water components were as follows:

Fish-tissue elements (2014 draft):

- Egg-ovary tissue 15.2 mg/kg
- Fish whole body 8.1 mg/kg
- Fish muscle (skinless, boneless fillet) 11.8 mg/kg

Water-column elements (2014 draft):

- Chronic water column 1.3 µg/L (lentic system)
- Chronic water column 4.8 µg/L (lotic system)
- Intermittent water column = $[(WQC_{30\text{-}day} - C_{bkgd}(1\text{-}f_{int})]/f_{int}$[2]

Selenium in the water column was no longer given as specific selenium ions in the 2014 draft. This is perhaps due to stakeholder concerns over the analytical challenges and resources needed to collect selenium ion data, as well as the lack of selenium ion data in state databases. In the 2015 draft of the criterion, the values of the tissue and water components were modified slightly, as follows:

Fish-tissue elements (2015 draft):

- Egg/ovary tissue 15.8 mg/kg
- Fish whole body 8.0 mg/kg
- Fish muscle (skinless, boneless fillet) 11.3 mg/kg

Water-column elements (2015 draft):

- Chronic water column 1.2 µg/L (lentic system)
- Chronic water column 3.1 µg/L (lotic system)
- Intermittent water column = $[(WQC_{30\text{-}day} - C_{bkgd}(1\text{-}f_{int})]/f_{int}$[1]

<u>2016 Final Ambient Water Quality Criterion for Selenium – Freshwater. (EPA 2016)</u>

In 2016, EPA published the final selenium criterion for freshwater aquatic life (*Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater 2016*) (Table 3). This final version considered all ecological studies published since the draft criterion was issued in 2004, in addition to all previous toxicity studies, and was refined by expert peer reviews of the drafts released in 2014 and 2015. EPA's final 2016 criterion reflects the latest scientific consensus on the effects of selenium on aquatic life and supersedes all previous aquatic-life water quality criteria for selenium. The assessment endpoint used was effects concentration (EC) where 10 percent of test organisms exhibited effects (EC_{10}). Genus mean chronic values (GMCV) were established based on concentrations in the egg-ovary tissue and ranked by sensitivity of the taxa.

EPA worked with the U.S. Geological Survey (USGS) to derive a translation equation to estimate the site-specific concentration of selenium in the water column that corresponded to the concentration of selenium in egg-ovary tissue. The final water quality criterion (EPA 2016) promulgated the following values:

[2] *Where: $WQC_{30\text{-}day}$ = 1.9 µg/L for lentic waters and 3.9 µg/L for lotic waters*
C_{bkgd} = the average daily ambient (background) concentration, integrated over 30 days
f_{int} = the fraction of any 30-day period during which there are elevated concentrations of selenium

Fish-tissue elements:

- Egg-ovary tissue 15.1 mg/kg
- Fish whole body 8.5 mg/kg
- Fish muscle (skinless, boneless fillet) 11.3 mg/kg

Water-column elements:

- Chronic water column 1.5 µg/L (lentic system)
- Chronic water column 3.1 µg/L (lotic system)
- Intermittent water column, $WQC_{int} = [(WQC_{30\text{-}day} - C_{bkgd}(1 - f_{int})]/f_{int}$[3]

Selenium bioaccumulates in fish and other aquatic organisms, with the potential to transfer up the food chain. The toxicity of selenium manifests as reproductive effects in fish, which are the most-sensitive organisms, and other egg-laying vertebrates. These new standards will better protect aquatic life by accounting for bioaccumulation. The 2016 criterion specifies that data for dissolved selenium (i.e., field-filtered water samples) should be used in the assessment of waterbodies; however, absent such data, data for total recoverable selenium should be used, without modification. EPA recommends that states adopt all components of the 2016 criterion into their water quality standards.

Nevada's Water Quality Standards for Selenium

Selenium is grouped into the category of "toxics," which have statewide values (or formulas) established to be protective of aquatic life (i.e., aquatic-life beneficial use). Nevada's current water quality standards for exposure of aquatic life to selenium were based on EPA's previously promulgated criteria (EPA 1987). The current water quality standards for selenium (20 µg/L, acute and 5 µg/L, chronic) were accepted into NAC 445A.1236 in 1990[4] and were approved by the EPA in a letter received by the NDEP on January 22, 1991.

Research conducted since 1987 has concluded that dietary intake, rather than exposure to selenium in the water column, is the primary mode by which aquatic life is exposed to selenium. The fate and transport of selenium in aquatic systems is affected by the distribution of selenium species and the species transformations in water, sediment, and biota. To capture some of this complexity, a more complex criterion was needed; however, this means there is not a direct comparison of the 2016 and 1987 criteria. The previous criteria from 1987 applied only to water-column data and provided one value for chronic exposures (5 µg/L) and one value for acute exposures (20 µg/L). The 2016 criterion contains two types of media, each with several components, some of which have multiple values.

[3] *Where: $WQC_{30\text{-}day}$ = 1.9 µg/L for lentic waters and 3.9 µg/L for lotic waters*
C_{bkgd} = the average daily ambient (background) concentration, integrated over 30 days
f_{int} = the fraction of any 30-day period during which there are elevated concentrations of selenium

[4] In 1990, the toxic materials table was located under NAC 445A.1339

As described in the following paragraphs, this petition seeks to adopt statewide numeric values of the EPA's updated criterion for aquatic-life exposures to selenium (EPA 2016) into the NAC. The multiple components of the updated criterion include numeric values for several type of fish tissue (egg-ovary, whole-body, and muscle [i.e., skinless boneless fillet]), as well as numeric values for chronic exposure in water, with separate values for lentic (still) and lotic (flowing) waters. The 2016 criterion does not include a value for acute exposure to selenium in the water column, but there is a formula to calculate values for "intermittent" exposures to higher concentrations of selenium in the water column. The intermittent value is intended to address short-term exposures that contribute to chronic effects through bioaccumulation. All the water-column values were modeled from egg-ovary tissue data, using bioaccumulation factors obtained from analysis of field study data, and assume a steady-state relationship between all environmental compartments at a site.

The EPA evaluated data from a series of field studies that provided quantitative estimates of the bioaccumulation of selenium in particulate material from selenium in the water column. Field and laboratory data were used to quantify and model the trophic transfer of selenium up the food chain. EPA validated this approach using selenium measurements from aquatic systems with a range of bioaccumulation potentials. Fish accumulate selenium as a result of ingesting selenium-contaminated prey, such as macroinvertebrates. The main effects of selenium toxicity are reproductive, due to maternal transfer of selenium in the yolks of eggs. Hatchlings are exposed via the yolk and manifest minor to gross (lethal) deformities and other effects that can diminish survival.

EPA's calculation of criterion concentrations for all elements of the 2016 selenium criterion used data from the four most-sensitive taxa identified from results of toxicity tests. Fish were determined to be the most-sensitive group and white sturgeon was determined to be the most-sensitive fish. Specifically, "*the egg-ovary Final Chronic Value (FCV) was calculated from regression analysis of the four most sensitive GMCVs, in this case extrapolating to the 5th percentile of the distribution represented by the tested genera*" (EPA 2016).

The Nevada Department of Wildlife (NDOW) has confirmed that there are no sturgeon in Nevada's waterbodies. Accordingly, EPA allows for a "species deletion procedure" wherein criteria concentrations may be recalculated by "deleting" a nonresident sensitive species and using data from the four most-sensitive taxa that do occur at a site or within a state (see EPA 2013). As stated in EPA 2013:

> *"The Recalculation Procedure involves editing the composition of a Species Sensitivity Distribution of tested species used to derive a site-specific aquatic life criterion in order to allow it to better reflect the taxonomy of species that reside at the site*."

The EPA-recommended species-deletion process was used to identify whether White Sturgeon is a surrogate for any other species occurring in Nevada. White Sturgeon is not a surrogate for other resident species because no other species in the same genus (*Acipenser*), family (Acipenseridae), or order (Acipenseriformes) occurs in the State. Other species listed in Table 3.2 of EPA's 2016 selenium criterion, which shows the ranked GMCVs for each genus or species, were confirmed to occur in Nevada. Species found in Nevada that are also listed in Table 3.2 (EPA 2016) include brown trout, rainbow trout, bluegill sunfish, green sunfish, and smallmouth and largemouth bass.

Absent the sturgeon, data from the four most-sensitive taxa were obtained from EPA (2016). These taxa include the following genera: *Micropterus* (largemouth bass), *Oncorynchus* (rainbow trout or cutthroat trout), *Salmo* (brown trout) and *Lepomis* (bluegill or green sunfish). The GMCVs for these four taxa were 20.6 mg/kg (*Lepomis*), 21.0 mg/kg (*Salmo*), 25.3 mg/kg (*Oncorynchus*) and 26.3 mg/kg (*Micropterus*); all tissue values reported here are for dry weight. Nevada applied the recalculation procedure (EPA 2013) to the data provided in EPA's 2016 selenium criterion to develop the following statewide criteria concentrations: Deleting the sturgeon from the calculations yields an egg-ovary value of 19.0 mg/kg, a muscle value of 9.5 mg/kg and a whole-body value of 13.1 mg/kg selenium (all tissue values given as dry weight). Tables 4 through 6 provide the calculations showing derivation of Nevada's statewide criterion concentrations for selenium in the three types of fish tissue (egg-ovary, whole-body and muscle).

Nevada's BWQP developed the criterion concentrations for the water-column elements following one of the approaches described in EPA's 2016 selenium criterion. Empirical bioaccumulation factors (BAFs) are typically calculated using site-specific data. However, Nevada used a BAF calculated from the values of EPA's national criterion (EPA 2016) to derive a baseline BAF that would be protective of the most sensitive fish and all other aquatic life. The BAF values for lentic and lotic waters were calculated using the EPA's national tissue criterion value divided by EPA's national water criterion value. The egg-ovary criterion value of 15.1 µg/g was divided by the lotic water-column criterion value of 3.1 µg/L to derive a BAF of 4.87 L/g for lotic waters; the egg-ovary criterion value of 15.1 µg/g was divided by the lentic water-column criterion value of 1.5 to derive a BAF of 10.07 L/g for lentic waters (Table 7).

The BAF values derived from the concentrations of the national criteria were applied to the Nevada-specific concentrations of the tissue elements that were calculated using EPA 2016 data minus the sturgeon. This is appropriate because there are no sturgeon in Nevada. Using the calculated BAFs and the revised criterion values for fish egg-ovary tissues, the criterion value for selenium in the water column of lentic waters is 1.9 µg/L. The criterion value for selenium in the water column of lotic waters is 3.9 µg/L, using the egg-ovary tissue value to calculate the BAF values. This is appropriate because egg-ovary tissue has primacy over all other tissue types (EPA 2016). The values for the water-column elements were calculated using the BAF for egg-ovary tissue to obtain statewide values of 1.9 µg/L for lentic waters and 3.9 µg/L for lotic waters. Table 8 shows a side-by-side comparison of the national and proposed statewide criterion values for selenium in tissue and water.

Additional Options for Developing Site-Specific Criterion Values for Selenium

EPA's updated criterion for selenium also allows for derivation of site-specific values. Such values derived for water-column criteria are based on dissolved selenium in water and are derived from fish tissue data using a performance-based approach. These site-specific values for lotic and lentic waters may be derived using mechanistic modeling or a bioaccumulation factor approach, as described in Appendix K of the updated criterion document (EPA 2016). In addition, one may apply the Recalculation Procedure (EPA 2013) for a specific site.

Summary

EPA's water quality regulations at 40 CFR 131.11(a)(1) require states to adopt protective criteria that are based on scientifically defensible rationale. Such criteria must contain sufficient parameters or constituents to protect the designated use. Nevada's existing selenium criteria for the protection of aquatic life as a beneficial use are based on EPA criteria published in 1987. In 2016, EPA published an updated selenium criterion, which reflects results of significant research and peer review that have taken place since the 1987 criteria were promulgated. These new criteria to protect aquatic life from exposure to selenium have undergone extensive peer review, comment and revision since initially proposed by EPA in a 2004 draft. The 2016 selenium criterion for protection of aquatic life represents a balance of the most technically rigorous science, with practical implementation of protective concentrations for a bioaccumulative chemical.

The NDEP is proposing to amend Nevada Administration Code (NAC) 445A.070 – 445A.2234, Standards for Water Quality, to align with the most-current numeric criteria recommended by the EPA for selenium to protect the aquatic-life beneficial use of waterbodies in Nevada. The proposed revisions to the NAC include changes to NAC 445A.1236, and addition of NAC 445A.1237, as follows:

- In the Table provided under **NAC 445A.1236**, the current listing for selenium provides values for municipal supply, irrigation, and livestock, in addition to acute (1-hour average) and chronic (96-hour average) criteria values for protection of aquatic life.

Chemical	Municipal or Domestic Supply (µg/l)	Aquatic Life[1,2] (µg/l)	Irrigation (µg/l)	Watering of Livestock (µg/l)
INORGANIC CHEMICALS[3]		-		
Selenium	50[b]		20[d]	50[d]
1-hour average	-	20[a]	-	-
96-hour average	-	5.0[e]	-	-

- The NDEP is proposing to amend NAC 445A.1236 as below, retaining selenium criteria for other beneficial uses and inserting a reference into the toxics table under NAC 445A.1236 , as follows:

Chemical	Municipal or Domestic Supply (µg/l)	Aquatic Life (µg/l)	Irrigation (µg/l)	Watering of Livestock (µg/l)
INORGANIC CHEMICALS[3]		-		
Selenium	50[b]		20[d]	50[d]
30-day average	-	See NAC 445A.1237	-	-
>once every 3 years	-	See NAC 445A.1237	-	-

- The revised NAC 445A.1236 directs the reader to the new values for aquatic-life beneficial use under the newly created NAC 445A.1237, which would describe the following:

NAC 445A.1237 Water Quality Criterion for Selenium (Aquatic-Life Beneficial Use). There are multiple components to the new water quality criterion (WQC) for selenium, with numeric criterion values for concentrations of selenium in three types of fish tissue tissue (egg-ovary, whole body, and muscle) and two criterion values for chronic exposures in two types of waterbodies (lotic, which includes all flowing waters, and lentic, which includes lakes and reservoirs). The selenium criterion also includes a formula for calculating numeric values for intermittent exposures to higher concentrations of selenium in the water column, for lotic and lentic waterbodies. All numeric values for Nevada were derived for "non-sturgeon waters" because there are no sturgeon or related species in Nevada.

1. The criterion values for fish tissue are instantaneous values that are not to be exceeded. Each criterion value depends on the type of tissue sample analyzed, as follows:
   (a) Egg or ovary fish tissue is 19.0 milligrams per kilogram, dry weight
   (b) Muscle (skinless, boneless fillet) fish tissue is 13.1 milligrams per kilogram, dry weight
   (c) Whole-body fish tissue is 9.5 milligrams per kilogram, dry weight.

Guidance for sampling of fish tissue is provided in USEPA 2016a and 2016b. In general, a composite sample of five fish or individual samples of five fish are recommended. See implementation guidance (USEPA 2016b) for specific details on sampling for fish tissue.

2. The chronic criterion values for the concentration of dissolved selenium in the water column are values not to be exceeded more than once every three years, on average. These values are specific to waterbody type, as follows:
   (a) The 30-day average for lotic (i.e., flowing) waters is 3.9 micrograms per liter
   (b) The 30-day average for lentic (i.e., still) waters is 1.9 micrograms per liter

3. The criterion value for intermittent exposure is a calculated value, which is not to be exceeded more than once every three years, on average. The formula is as follows:

$$WQC_{int} = (WQC_{30\text{-}day} - C_{bkgd}(1 - f_{int}))/f_{int}$$

Where: the $WQC_{30\text{-}day}$ is 1.9 micrograms per liter for lentic waters and 3.9 micrograms per liter for lotic waters

4. Site-specific criterion values for selenium in fish tissue and the water column may also be derived, based on data collected following submittal and approval of a sampling and analysis plan for the collection and analysis of fish tissue. See implementation guidance (USEPA 2016b) for specific details on sampling, analysis and derivation of site-specific values.

USEPA (2016a). *Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater*. EPA 822-R-16-006. June.
USEPA (2016b). *Draft Technical Support for Fish Tissue Monitoring for Implementation of EPA's 2016 Selenium Criterion*. EPA 820-F-16-007. September.

TYPE OF STANDARD/CRITERION	2019 Proposed for Nevada, Statewide	UNITS
FISH TISSUE (FRESHWATER)		
Fish egg/ovary tissue	**19.0**	mg/kg
Fish whole body	**9.5**	mg/kg
Fish muscle (skinless, boneless fillet)	**13.1**	mg/kg
WATER COLUMN		
30-day average, lentic systems	**1.9**	µg/L
30-day average, lotic systems	**3.9**	µg/L
Intermittent (>1 every 3 yrs), lentic	**$(1.9 - C_{bkgd}(1 - f_{int})/f_{int}$**	µg/L
Intermittent (>1 every 3 yrs), lotic	**$(3.9 - C_{bkgd}(1 - f_{int})/f_{int}$**	µg/L

µg/L = micrograms per liter
mg/kg = milligrams per kilogram

The following equation is used for calculating the "average background" for a 30-day period (see Equation 20, EPA 2016):

$$C_{30\text{-day}} = C_{int} * f_{int} + C_{bkgd}(1 - f_{int})$$

C_{int} = the intermittent spike concentration, in µg/L
f_{int} = the fraction of any 30-day period during which there are elevated concentrations of selenium
C_{bkgd} = the average daily ambient (background) concentration , integrated over 30 days

Using the Method Detection Limit to Censor Analytical Data

To assess the possible impact of adopting the new criterion values, the ranges of selenium concentrations (by basin) in Nevada, were compared to the 1987 criteria value of 5 µg/L, EPA's updated 2016 criterion values for dissolved selenium in water (EPA 2016) and Nevada's proposed values for dissolved selenium recalculated for "sturgeon-free" waters (Figure 1). The current data show that analytical results for selenium need to be censored at the value of the method detection limit (MDL), as required in NAC 445A.1236(1)(c) for toxic constituents. Censoring of selenium data at a quantitation limit, the values of which may be 10 times greater than the MDL, leads to "less than" values that exceed the criterion values. Not only does censoring results at a quantitation limit obscure concentrations of detectable selenium, it is contrary to the requirement in NAC 445A.1236(1)(c), which states:

> *If a criterion is less than the **detection limit of a method** that is acceptable to the Division, laboratory results which show that the substance was not detected shall be deemed to show compliance with the standard unless other information indicates that the substance may be present.*

Because the criterion values for water (1.9 and 3.9 µg/L) are **not** less than the MDLs typically achieved using common analytical methods for selenium, the Division will **not** accept "less than" values censored at the higher values of quantitation limits. That is, a "<5 µg/L" value is not acceptable as evidence that the concentrations of selenium are in compliance with the standard. Entities who are sampling surface waters for dissolved selenium and other toxic constituents must request that their laboratory report both MDLs and quantitation limits for the analytical results. Concentrations that exceed the MDL but are less than the quantitation limit must be reported as detected and qualified as "estimated" (i.e., lower precision and accuracy) results. Only those results that are less than the MDL will be considered as "nondetects."

Because all laboratories must calculate MDLs as part of certification requirements, there is no additional cost. Dischargers must request that their laboratories report the value of the MDL, and that they censor and qualify data appropriately in all laboratory reports of analytical data. This requirement to censor data at the MDL rather than a quantitation limit holds true for all parameters in the "toxics table" under NAC 445A.1236

Conclusions

Adoption of EPA's 2016 recommendations by the State of Nevada will ensure that the most appropriate level of protection from exposure to selenium is provided for aquatic life in Nevada's surface waters. There will likely be an impact to dischargers upon implementing the new standards, and additional waterbodies or waterbody segments may become listed as impaired for aquatic life. Impaired waters (i.e., 303 d list) are listed in the Integrated Report submitted biennially to the EPA.

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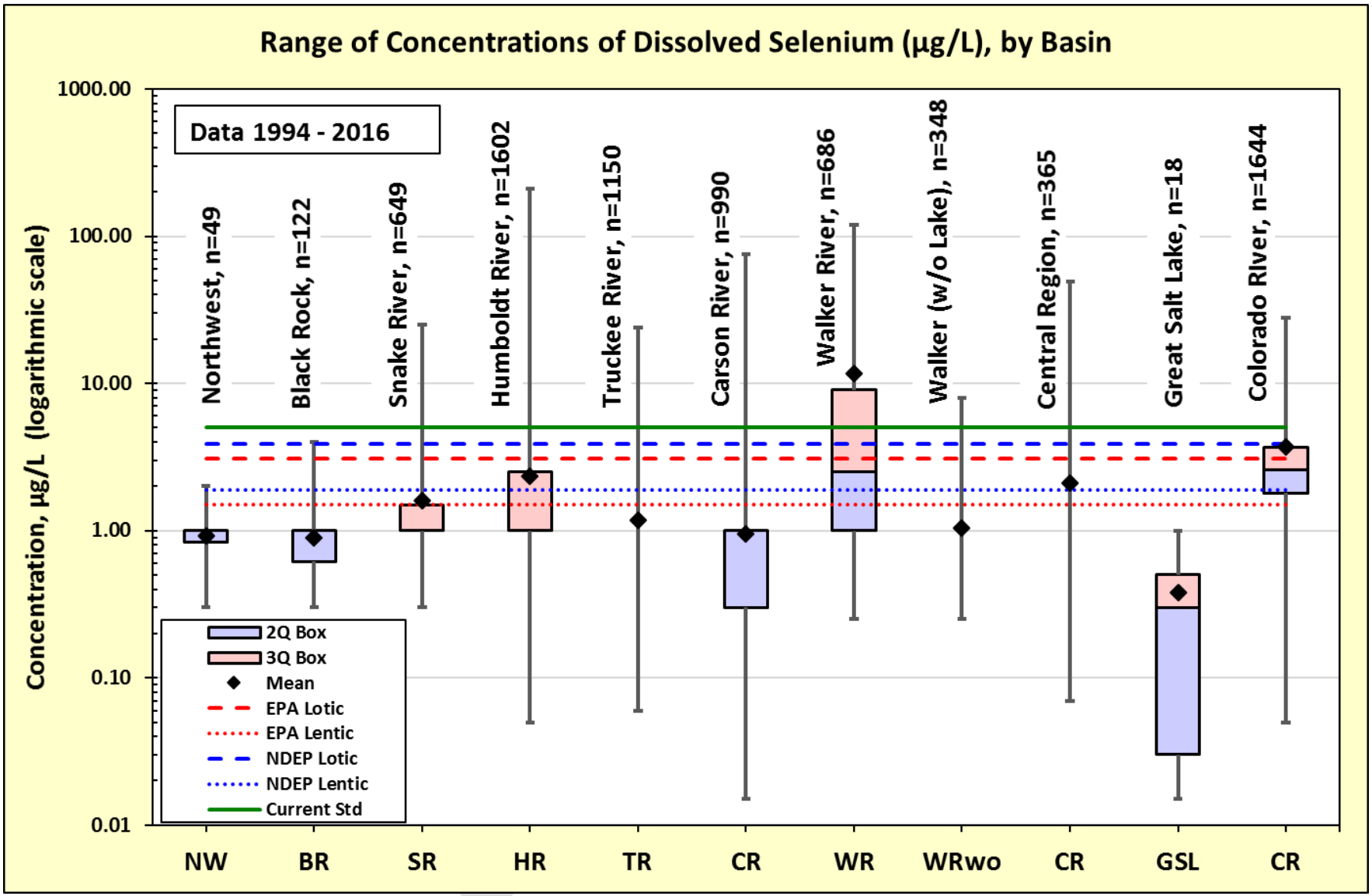

Figure 1. Box and Whisker Plot Showing the Range of Selenium Concentrations, by Basin, Along with Criteria Values Shown as Horizontal Lines. (Note: 2Q refers to the second quartile, 25 to 50%; 3Q refers to the third quartile, 50 to 75%; whiskers extend to the minimum and maximum concentrations. "WRwo" indicates data for the Walker River Basin without data for Walker Lake, which has unusual chemistry. All data depicted here for dissolved selenium were extracted from BWQP's data warehouse on October 13, 2018.)

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Table 1. History of EPA's Aquatic-Life Criteria for Selenium

(Does not Include Values Recalculated for Sturgeon-free Waters*)

TYPE OF STANDARD/CRITERION	1980	1987 Final	1991/1992	2004 Draft	2014 Draft	2015 Draft	2016 Final	UNITS
HUMAN HEALTH								
Drinking water standard (MCL)	**10**		**50**					µg/L
WATER COLUMN								
24-hr avg - chronic (freshwater)	35	**5**			5			µg/L
1-hr - acute (freshwater)	260	**20**			1/[selenite/185.9)] + (selenate/12.82)			µg/L
24-hr avg - chronic (saltwater)	54							µg/L
1-hr -acute - (saltwater)	410							µg/L
4-day average (saltwater)		**71**						µg/L
1-hr - acute (saltwater)		**300**						µg/L
Acute exposure - selenite				258				µg/L
Acute exposure - selenate				$e^{(05812[\ln(\text{sulfate})]+3.357}$				µg/L
Monthly avg, lentic systems						1.2	**1.5**	µg/L
Monthly avg, lotic systems						3.1	**3.1**	µg/L
Intermittent (>1 every 3 yrs), lentic						$(1.2 - C_{bkgd}(1 - f_{int})/f_{int}$	$\mathbf{(1.5 - C_{bkgd}(1 - f_{int})/f_{int}}$	µg/L
Intermittent (>1 every 3 yrs), lotic						$(3.1 - C_{bkgd}(1 - f_{int})/f_{int}$	$\mathbf{(3.1 - C_{bkgd}(1 - f_{int})/f_{int}}$	µg/L
FISH TISSUE (FRESHWATER)								
Chronic exposure - freshwater fish				7.91				mg/kg
Monitor stage - freshwater fish				5.85				mg/kg
Fish egg/ovary tissue					15.2	15.8	**15.1**	mg/kg
Fish whole body					8.1	8	**8.5**	mg/kg
Fish muscle (skinless, boneless fillet)					11.2	11.3	**11.3**	mg/kg

Where: f_{int} = no. days selenium exceeds criterion/30 days, where one day = 0.033

C_{bkgd} = background concentration of selenium

Note: 2016 "Background" (bkgd) must be defined numerically; text implies it is the arithmetic mean and is the "ambient" concentration rather than "naturally occurring background" Page 95 of EPA, 2016 gives the following equation (Equation 20) for calculating the "average background" for a 30-day period:

$$C_{30\text{-day}} = C_{int} * f_{int} + C_{bkgd}(1 - f_{int})$$

Where:

C_{int} = the intermittent spike concentration, in µg/L

f_{int} = the fraction of any 30-day period during which there are elevated concentrations of selenium

C_{bkgd} = the average daily ambient concentration , integrated over 30 days

Note: Once listed, the finalized standard/criterion stands until a new standard/criterion is finalized.

*Nevada BWQP recalculated criterion values for "sturgeon-free" waters, using EPA's revised "Recalculation Procedure" (EPA 2013).

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Table 2. EPA's 1987 Ambient Water Quality Criteria for Selenium (EPA 1987)

Criteria:	Chronic Exposures	Acute Exposures
Numeric Value[1]:	**5 µg/L**	**20 µg/L**
Duration:	4-day average	1-hour average
Frequency:	Not more than once every 3 years, on average	Not more than once every 3 years, on average

1. Concentrations as measured for acid-soluble selenium dissolved in freshwater. Acid-soluble selenium values are for samples that are acidified without field-filtering, but are filtered in the laboratory prior to analysis.

Table 3. EPA's Recommended Ambient Water Quality Criterion for Protection of Freshwater Aquatic Life from Exposure to Selenium (EPA 2016).

Medium:	Fish Tissue[1]		Water Column[4]	
Criterion Elements:	**Egg-Ovary[2]**	**Whole Body or Muscle[3]**	**Monthly Average**	**Intermittent[5]**
Numeric Value:	**15.1 mg/kg dw**	**8.5 mg/kg dw**, whole body or **11.3 mg/kg dw**, muscle (fillet)	**1.5 µg/L** - lentic systems and **3.1 µg/L** - lotic systems	$WQC_{int} = \frac{WQC_{30-day} - C_{bkgrnd}(1 - f_{int})}{f_{int}}$
Duration:	Instantaneous[6]	Instantaneous[6]	30-day average	Number of days per month elevated
Frequency:	Not to be exceeded	Not to be exceeded	Not more than once every 3 years, on average	Not more than once every 3 years, on average

1. Fish tissue values are expressed as steady-state
2. Egg-ovary criterion values have precedence over all other tissue and water criterion values
3. Fish whole-body and muscle criterion values have precedence over water-column criterion values
4. Water-column values are based on dissolved selenium; these values are the applicable criteria when there are no data for fish tissue. Dissolved form is taken to mean results from analysis of a sample that has been field-filtered prior to acidification.
5. $WQC_{30\text{-day}}$ is the monthly value for lotic or lentic waters; C_{bkgrnd} is the average ambient concentration of selenium established prior to the intermittent release; and F_{int} is the fraction of any 30-day period during which elevated concentrations of selenium are present, with f_{int} assigned a value of 0.033 (1 day out of 30 days).
6. Fish-tissue data are instantaneous measurements that reflect integrative accumulation of selenium over time and space in fish populations at a given site.

Table 4. Using EPA's "Recalculation Procedure" to Calculate Nevada's Statewide Criterion Concentrations for Fish Egg-Ovary Tissue.

Genus	Rank	GMCV[a]	ln(GMCV)	ln(GMCV)^2	P=R/(N+1)[b]	sqrt(P)
Micropterus	4	26.3	3.27	10.69	0.27	0.52
Oncorhynchus	3	25.3	3.23	10.44	0.20	0.45
Salmo	2	21	3.04	9.27	0.13	0.37
Lepomis	1	20.6	3.03	9.15	0.07	0.26
		sum	12.57	39.55	0.67	1.59
					N[c]	14
					S^{2}[d]	1.28
					S	1.13
					L[e]	2.69
					A[f]	2.95
					FCV[g]	19.0

Notes:

[a] Selenium concentration in mg/kg dw

[b] Cumulative probability

[c] Total number of GMCVs in dataset

[d] $S^2 = \frac{\Sigma((\ln GMCV)^2)-((\Sigma\, lnGMAV))^2/4}{\Sigma(F)-((\Sigma(\sqrt{P}))^2/4)}$

[e] $L = (\Sigma(\text{lnGMAV}) - S\left(\Sigma\left(\sqrt{P}\right)\right))/4$

[f] $A = S(\sqrt{0.05}) + L$

[g] Final chronic value (FCV) in mg/kg dw

Table 5. Using EPA's "Recalculation Procedure" to Calculate Nevada's Statewide Criterion Concentrations for Fish Whole-Body Tissue.

Genus	Rank	GMCV[a]	ln(GMCV)	ln(GMCV)^2	P=R/(N+1)[b]	sqrt(P)
Esox	4	14.2	2.65	7.04	0.27	0.52
Salmo	3	13.2	2.58	6.66	0.20	0.45
Oncorhynchus	2	11.6	2.45	6.01	0.13	0.37
Lepomis	1	9.9	2.29	5.26	0.07	0.26
		sum	9.98	24.96	0.67	1.59
					N[c]	14
					S^{2}[d]	2.03
					S	1.42
					L[e]	1.93
					A[f]	2.25
					FCV[g]	9.5

Notes:

[a] Selenium concentration in mg/kg dw

[b] Cumulative probability

[c] Total number of GMCVs in dataset

[d] $S^2 = \frac{\Sigma((\ln GMCV)^2)-((\sum lnGMAV))^2/4}{\Sigma(F)-((\Sigma(\sqrt{P}))^2/4)}$

[e] $L = (\Sigma(\text{lnGMAV}) - S\left(\Sigma\left(\sqrt{P}\right)\right))/4$

[f] $A = S(\sqrt{0.05}) + L$

[g] Final chronic value (FCV) in mg/kg dw

Table 6. Using EPA's "Recalculation Procedure" to Calculate Nevada's Statewide Criterion Concentrations for Fish Muscle Tissue.

Genus	Rank	GMCV[a]	ln(GMCV)	ln(GMCV)^2	P=R/(N+1)[b]	sqrt(P)
Esox	4	21.7	3.08	9.47	0.27	0.52
Salmo	3	18.5	2.92	8.51	0.20	0.45
Lepomis	2	15.9	2.77	7.65	0.13	0.37
Oncorhynchus	1	14.3	2.66	7.08	0.07	0.26
		sum	11.42	32.71	0.67	1.59
					N[c]	14
					S^{2d}	2.68
					S	1.64
					L[e]	2.21
					A[f]	2.57
					FCV[g]	13.1

Notes:

[a] Selenium concentration in mg/kg dw

[b] Cumulative probability

[c] Total number of GMCVs in dataset

[d] $S^2 = \frac{\Sigma((\ln GMCV)^2)-((\sum lnGMAV))^2/4}{\Sigma(F)-((\Sigma(\sqrt{P}))^2/4)}$

[e] $L = (\Sigma(\text{lnGMAV}) - S\left(\Sigma\left(\sqrt{P}\right)\right))/4$

[f] $A = S(\sqrt{0.05}) + L$

[g] Final chronic value (FCV) in mg/kg dw

Table 7. Calculation of Bioaccumulation Factors for Egg-Ovary Tissue in Lotic and Lentic Waters Using EPA's National Dataset for Selenium Toxicity, Minus the Data for *Acipenser Species*, Calculated for "Sturgeon-Free" Waters.

Medium	National Values			Nevada Values		Calculations
	Egg-Ovary Tissue	Lotic water	BAF, Egg-Ovary/Lotic	Egg-Ovary Tissue	Lotic Water	
Egg-ovary tissue has primacy over all tissue types and water-column values	15.1	3.1	4.87	19.0	**3.9**	$BAF_{lotic} = \frac{15.1\ \mu g/g}{3.1\ \mu g/L} = 4.87\ L/g$ $C_{lotic} = \frac{19.0\ \mu g/g}{4.87\ L/g} = 3.9\ \mu g/L$
Medium	**Egg-Ovary Tissue**	**Lentic water**	**BAF, Egg-Ovary/Lentic**	**Egg-Ovary Tissue**	**Lentic Water**	$BAF_{lentic} = \frac{15.1\ \mu g/g}{1.5\ \mu g/L} = 10.07\ L/g$ $C_{lentic} = \frac{19.0\ \mu g/g}{10.07\ L/g} = 1.9\ \mu g/L$
Egg-ovary tissue has primacy over all tissue types and water-column values	15.1	1.5	10.07	19.0	**1.9**	

Where:
BAF = Bioaccumulation factor, calculated using EPA's national criterion value for egg-ovary tissue divided by EPA's national criterion values for lotic or lentic waters
C = Criterion concentration for lotic and lentic waters, using the statewide egg-ovary tissue value derived for "sturgeon-free" waters and the national BAF values for lotic and lentic waters.

Table 8. Comparison of EPA National Criteria Concentrations and Proposed Nevada Statewide Concentrations, Calculated Minus Sturgeon Data, for the Selenium Criterion Elements.

Criterion Element	EPA National Values	Proposed Statewide Values for Nevada	Units
Fish Egg-Ovary Tissue	15.1	**19**	mg/kg, µg/g
Fish Muscle Tissue	11.3	**13.1**	mg/kg, µg/g
Fish Whole-Body Tissue	8.5	**9.5**	mg/kg, µg/g
30-day Lentic Water	1.5	**1.9**	µg/L
30-day Lotic Water	3.1	**3.9**	µg/L

Where:
mg/kg = milligrams per kilogram, which is equivalent to micrograms per gram (µg/g)
µg/L = micrograms per liter
Proposed Statewide Values use the recalculated numbers for egg-ovary tissue (minus Acipenser) and BAF values for the national dataset as presented in EPA's updated Selenium Criterion (2016), for lotic and lentic waters.