Proposed Site-Specific Selenium Criterion, Sage and Crow Creeks, Idaho

January 2012

Prepared for:

J.R. Simplot Company

Prepared by:

Formation Environmental, LLC
2500 55th Street, Suite 200
Boulder, Colorado 80301

and

HabiTech, Inc.
401 Grand Ave., # 301
Laramie, WY 82073

TABLE OF CONTENTS

Page

LIST OF FIGURES ii

LIST OF ACRONYMS iii

1.0 INTRODUCTION 1

2.0 SITE SETTING AND SCOPE OF APPLICABILITY 3

3.0 LITERATURE REVIEW 5

4.0 FIELD MONITORING 6

5.0 LABORATORY STUDIES 9

6.0 INTEGRATING LINES OF EVIDENCE 14

7.0 PROPOSED CRITERION IMPLEMENTATION 16

8.0 REFERENCES 17

LIST OF FIGURES

Figure	Title
1	Location of the Smoky Canyon Mine
2	Relationship of Lines of Evidence to Developing a Site-Specific Selenium Criterion
3	Overview Location Map
4	Trout Density Estimates at Sage Creek (LSV-4) based on Historical Estimates, SSSC Monitoring Data (2006), and Panels F and G Monitoring (2010)
5	Logistic Regression of Brown Trout Egg Selenium Concentrations Versus Survival Percentage (Hatch to Test End) Focused on Effect Region for Derivation of EC_x Values
6	Species Sensitivity Distribution for Cold Water Species Effects Data Derived from Maternal Transfer Studies
7	Species Sensitivity Distribution of a Representative Cold Water Aquatic Community to Selenium
8	Flow Diagram for Implementing the Site-Specific Selenium Criterion for the Site

LIST OF ACRONYMS

CFR	Code of Federal Regulations
CWA	Clean Water Act
EC/EC_x	Effect Concentration
ELS	Early Life Stage
EPA	United States Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera, Trichoptera
HS	Hoopes Spring
IDAPA	Idaho Administrative Code
IDEQ	Idaho Department of Environmental Quality
IDFG	Idaho Department of Fish and Game
ODA	Overburden Disposal Area
SFSC	South Fork Sage Creek
SMI	Stream Macroinvertebrate Index
SSSC	Site-Specific Selenium Criterion
TRAP	Toxicity Relationship Analysis Program
TSD	Technical Support Document
USFS	United States Forest Service
WDEQ	Wyoming Department of Environmental Quality
YCT	Yellowstone Cutthroat Trout

1.0 INTRODUCTION

Presented herein is the J.R. Simplot Company's (Simplot) proposal for a chronic site-specific selenium criterion (SSSC) for Sage Creek and Crow Creek, Idaho; streams nearby Simplot's Smoky Canyon Phosphate Mine (Figure 1). This proposal document prefaces the *Technical Support Document: Proposed Site-Specific Selenium Criterion, Sage and Crow Creeks and appendices*.[1] Simplot, as a part of the ecological investigation associated with the releases of selenium from historical phosphate mining in southeastern Idaho, began in 2006 a series of scientific studies into the effects of selenium on trout in local streams. These studies have become the basis for a proposed SSSC for streams near Simplot's Smoky Canyon Mine. To develop such a proposal requires following the regulations developed by the State of Idaho and approved by the U.S. Environmental Protection Agency (EPA).

The Clean Water Act (CWA) found in the Code of Federal Regulations (CFR) includes a provision (i.e., 40 CFR 131.11(b)) that allows for establishing site-specific water quality criteria. EPA has delegated enforcement of the CWA to the State of Idaho, including decision making related to development of site-specific criteria. The State of Idaho has very specific requirements to be followed to develop site-specific criterion (Idaho Administrative Code, IDAPA 58.01.02.275). These EPA-approved rules include the following:

> **275.01.b.** Any person may develop site-specific criteria in accordance with these rules. To insure that the approach to be used in developing site-specific criteria is scientifically valid, the Department shall be involved early in the planning of any site-specific analyses so that an agreement can be reached concerning the availability of existing data, additional data needs, methods to be used in generating new data, testing procedures to be used, schedules to be followed and quality control and assurance provisions to be used. (8-24-94)

To fulfill the rule identified above, the Idaho Department of Environmental Quality (IDEQ) facilitated a series of meetings in which various state and federal environmental and resource agency scientists met and reviewed study plans and study results compiled over a period of approximately three years. Representatives from IDEQ, Idaho Department of Fish and Game (IDFG), EPA, United States Forest Service (USFS), Wyoming Department of Environmental Quality (WDEQ), and Simplot participated in this multi-year technical Workgroup effort.

The intent of this multi-faceted study is to develop the science to support a proposed chronic SSSC. Site-specific species and their responses to ambient exposure levels, and the physical

[1] The Technical Support Document (TSD) is the revised Draft Interpretive Findings for Field and Laboratory Studies and Literature Review in Support of a Site-Specific Selenium Criterion (Interpretive Report). Revisions to the Interpretive Report were made to incorporate comments provided by a SSSC technical Workgroup.

and chemical characteristics of the streams monitored provide the basis for a criterion that is protective of the aquatic community. The approach relies on the relationship between three primary lines of evidence (Figure 2): a comprehensive literature review, field studies, and laboratory studies. Available literature has been continually reviewed to guide the design for and augment the findings of the field and laboratory studies. Data collected through field monitoring studies have been used to characterize the exposure environment, the condition of the aquatic community, and the physical habitat. Laboratory studies have been utilized to characterize reproductive and developmental effects in two trout species. Collectively, these three lines of evidence have been brought together to support the proposed SSSC.

The geographic range that the proposed criterion would cover includes Sage Creek and tributaries and Crow Creek from Sage Creek to the Idaho and Wyoming state line. A more specific scope of applicability is described below in Section 2.0.

2.0 SITE SETTING AND SCOPE OF APPLICABILITY

Simplot's Smoky Canyon Mine is located in Caribou County, in the southeast corner of Idaho, approximately 10 miles west of Afton, Wyoming and 23 miles east of Soda Springs, Idaho. The mine is situated on the eastern edge of the Webster Range overlooking Sage Valley to the east. Hoopes Spring is located in the foothills transitioning into Sage Valley east of the Smoky Canyon Mine (Figure 3). Hoopes Spring, and to a lesser extent South Fork Sage Creek (SFSC) Springs are the primary surface water discharges of selenium to Sage Creek whose headwaters originate in Sage Valley and the Webster Range (Figure 3). Sage Creek flows into Crow Creek which flows north, northeast and crosses the Idaho-Wyoming state line and discharges to the Salt River. Site streams are cold water streams that are east trending or north to northeast trending, ranging from moderately high to low gradients.

2.1 Site Setting

Investigations to date, at the nearby Smoky Canyon Mine, have identified elevated concentrations of selenium in surface water being discharged via Hoopes Spring and SFSC Springs. The selenium is released from historical operating areas (known as overburden disposal areas [ODAs]) at the mine. The primary areas potentially affected by discharge of Hoopes Spring and the SFSC springs include: Sage Creek from its confluence with the Hoopes Spring discharge channel to its confluence with Crow Creek, South Fork Sage Creek below the springs complex, and Crow Creek from its confluence with Sage Creek to the Idaho and Wyoming state line.

Ambient conditions were characterized though field monitoring at a number of locations. Three Crow Creek locations and a single location on Deer Creek, each upstream of Sage Creek, were monitored and were considered to represent natural background conditions. Two locations on Hoopes Spring, two locations on Sage Creek, and two locations on Crow Creek downstream of Sage Creek were also monitored. These locations are influenced by the Hoopes Spring discharge. Collectively, these background and downstream locations represent the Site conditions. A single reference location outside of the Crow Creek drainage and outside of the phosphate patch at South Fork Tincup Creek was also monitored.

2.2 Scope of Applicability

A proposal for a SSSC must define the geographic scope or area to which the criterion would apply. IDEQ's (2011) Integrated Report identifies specific stream segments as being limited by one or more parameters that affect use attainment. These stream segments are identified using an alpha numeric coding system. The stream segment numbers pertinent to this Site are

presented below and should aid in providing definition to narratives that describe stream segments to which the SSSC is applicable. The proposed SSSC is applicable to all or portions of the stream segments identified. Sage Creek and its tributaries would include the following stream segments:

- ID17040105SK009_02 North Fork Sage Creek (12.41 miles);
- ID17040105SK009_02c Sage Creek (1.81 miles);
- ID17040105SK009_02d Pole Canyon Creek (3.6 miles);
- ID17040105SK009_02e South Fork Sage Creek (7.93 miles); and
- ID17040105SK009_03 Sage Creek - confluence with North Fork Sage Creek to mouth (3.22 miles).

For Crow Creek, only one stream segment is applicable. For this segment, the reach defined would extend from Sage Creek to the Idaho and Wyoming state line. The applicable stream segment falls within the larger segment identified as:

- ID17040105SK008_04 Crow Creek - Deer Creek to border (10.42 miles).

Monitoring locations characterized as part of these site-specific studies are representative of streams in the area; therefore, while some specific streams were not characterized, the proposed SSSC is still applicable and appropriate given the common sources, water quality, and proximity within the basin.

3.0 LITERATURE REVIEW

Review of published and unpublished gray literature has been conducted at several periods during the time span of this project. The Literature review has been and continues to be a very important part of the overall process. Most notably, the fairly consistent input of new science is increasing the overall knowledge of selenium toxicity to aquatic organisms. The literature has guided the development of the approach and design for this study. Initially, the literature was reviewed to examine the various approaches that have been used to evaluate selenium toxicity to aquatic life. Information from the literature has also been used to identify sensitive species of aquatic life, sensitive life stages, the most relevant pathways for evaluating potential effects, and effective measurement endpoints for evaluating toxicity. In the analysis phase of the evaluation, the literature continues to be reviewed to assess how results from this study compare to those of others. This step provides an important “reality” check in making determinations about data applicability, accuracy, and representativeness.

Review of the available literature indicates a wide range of species sensitivities. Among studies focused on maternal transfer and egg development, where young fish are evaluated relative to ovary or egg tissue selenium concentration, the threshold for effects ranges from 20 to 54 mg/kg dw egg or ovary tissue (Deforest et al. 2011). Effects for several trout species, suckers, largemouth bass, northern pike, and fathead minnows ranged from 20 to 26 mg/kg dw egg or ovary and comprised a fairly narrow range of effects. Dolly Varden char and razorback sucker, however, ranged from 41.9 to 54 mg/kg dw egg or ovary. Brook trout, brown trout and northern pike were the most sensitive fish species tested. Maternal transfer is the key mechanism for selenium toxicity to young developing fish where the level of selenium bioaccumulation by the maternal parent and subsequently compartmentalized into eggs is a determining factor in the level of effects experienced in developing fish. For most studies reviewed, deformities and/or mortality were common endpoints. In almost all the studies reviewed, the dose response was steep, and the effects were best correlated to egg selenium concentrations.

No studies were found that provided effects data for cool or cold water cyprinid species or for sculpin. Overall, the literature suggests that reproductive endpoints in fish tend to be a sensitive indicator of excessive selenium and that invertebrates are less sensitive to selenium effects than fish. Studies by deBruyn and Chapman (2007) and Conley et al. (2009) presented evidence suggesting that the difference between thresholds for toxicity in fish and invertebrates is not as great as some had previously suggested. Section 6 of the TSD evaluates species sensitivity to assure that the proposed criterion is adequately protective.

4.0 FIELD MONITORING

Seasonal monitoring was conducted to characterize the selenium exposure conditions and productivity (or health) of the aquatic community within the study area. During each monitoring event, locations were sampled for a range of chemical, biological, and physical characteristics. Activities conducted to document and evaluate existing conditions included collection of water, sediment, periphyton, benthic invertebrate, and fish tissues for chemical analyses of selenium concentrations. Benthic community, fish population and community, and physical habitat quality assessments were conducted. Fish communities were sampled to characterize their density and diversity. Physical habitat attributes were measured to document the qualities of habitat conditions that exist at each location. The primary data for these evaluations were those collected during 2006 to 2008. Data from 2009 and 2010 collected to meet other project objectives were also utilized for some analyses.

Selenium exposure conditions across exposure media (surface water, sediment, prey) and resultant receptor concentrations are described in a spatial context (TSD Appendix A). In particular, changes in concentrations in these media with distance from source and by relationships to receptor concentrations are described. Receptor population/community data and their relationship to exposure conditions and selenium tissue concentrations are examined (TSD Appendix B). Finally, the physical setting/habitat is evaluated at the locations where population/community data were collected to account for the differences between selenium concentrations and the role of habitat (TSD Appendix C). These steps were performed to generally evaluate whether there were obvious impacts to the aquatic biological system due to selenium and correspondingly, to provide a "reality check" on the laboratory data (TSD Appendix D through Appendix F) and literature lines of evidence.

Exposure media show a consistent spatial trend of selenium concentrations. Exposure media have the highest concentrations nearest to the source area at Hoopes Spring, and concentrations decrease at distance downstream from the source area. Sage Creek exposure media concentrations are elevated but are typically lower than those observed at Hoopes Spring. In Crow Creek downstream of Sage Creek, periphyton and benthic tissue concentrations as well as surface water concentrations typically are slightly higher, but within the range of variability of those concentrations measured in Crow Creek and Deer Creek locations upstream of Sage Creek.

The fish communities at the monitoring locations vary, and are influenced by a number of factors including the quality and quantity of water, food, and habitat. Fish in Hoopes Spring and Sage Creek are exposed to elevated levels of selenium in water and prey items (benthic tissues, periphyton, prey fish) above those levels observed at background locations and the reference location. If selenium is having a toxic effect, even on a chronic basis, monitoring over a period would be expected to indicate some relative reduction in fishery potential, when other factors are considered. For example, differences in the quality of the physical habitat and water temperature would ultimately need to be considered when comparing population data between locations. These relationships are discussed further in Section 4.3 and Appendix B of the TSD. Given the diversity of physical habitats (stream gradients, channel sizes, and stream temperatures, among others), variations in the fish community composition is to be expected.

Benthic macroinvertebrate community characteristics were evaluated by examining various functional and structure metrics versus selenium concentrations in water and other media (TSD Appendix B). Community samples were collected during each fall monitoring event. Several individual structural and functional metrics were evaluated graphically for locations across the three fall periods. Numbers of benthic taxa and abundance per square meter, along with numbers of species in different benthic families as well as their abundance were evaluated. Five benthic invertebrate composition metrics were evaluated, including the number of ephemeroptera taxa, plecoptera taxa, trichoptera taxa, dipteran taxa, and the number of ephemeroptera, plecoptera, and trichoptera (EPT) taxa. Functional feeding groups, including predators, shredders, filterers, scrapers, omnivores, and collector-gatherers, were evaluated (see TSD Appendix B figures). The length of a benthic organism's life cycles (i.e., voltinism) was independently assessed. Finally, a composite metric used by the State of Idaho to assess beneficial use attainment, the Stream Macroinvertebrate Index (SMI), was evaluated relative to aqueous selenium concentrations for the 2006 to 2008 data.

Because of the influence of physical habitat quality and quantity on the quality of the aquatic community, trout populations were evaluated relative to habitat quality. Habitat is a strong determinant in fish abundance and diversity; therefore, it is incumbent on investigations evaluating effects of contaminants to also consider the habitat effects. Analysis of trout populations and habitat quality data overall indicates that trout populations from downstream areas affected by Hoopes Spring discharge are not substantially reduced when compared to background trout populations. Trout populations are highest where elevated selenium concentrations are found. Favorable habitat conditions are likely present that allow for functional and reproducing trout populations, such that population estimates derived at locations where selenium is elevated do not differ from those where selenium is not elevated. Sculpin population density and age class structure suggests that there is no difference in sculpin populations between high and low selenium locations; rather, sculpin population density is more likely dictated by habitat conditions. While some specific habitat features are limiting the full potential of the fishery, the quality is not diminished substantially enough to negatively alter trout populations.

Characterization of the exposure environment and ecological receptors indicates the following:

- Selenium exposure in aqueous and dietary media is occurring downstream of Hoopes Spring.

- Fish population, abundance, density, community and biomass data do not exhibit negative impacts due to exposures that are not accounted for by habitat quality.

- Analysis of benthic invertebrate data (including the 2009 and 2010 data) indicates that taxa abundance metrics (i.e., number of taxa or number of EPT taxa) are significantly lower at downstream locations versus upstream locations. Relationships between these metrics and selenium in aqueous media exist as do relationships to percent fines. The strength of the relationship of benthic metrics to percent fines as compared to selenium concentrations suggests that percent fines may be a stronger determining factor in observed differences than selenium exposure.

- When differences in habitat are considered, the trout population data do not indicate negative impacts due to selenium exposure conditions.

- Habitat quality data suggests overall, that good quality habitat is available, but external land uses (i.e., grazing) exist that may limit the full range of the fishery potential.

- Comparisons of Site trout population data to ecoregional and more localized trout population and growth data indicates that Site population and growth data are well within the range of other trout populations in the region and often exceed upper percentile ranking when compared to these other ecoregional populations.

- Qualitative comparisons of select Site trout population estimates to Site historical fish population estimates suggest that trout populations have remained relatively stable.

- Long-term trout density estimates from a single location downstream of Hoopes Spring, including pre-mining time frames, suggests trout abundance fluctuates, but a long-term decline in abundance has not been observed (Figure 4).

5.0 LABORATORY STUDIES

Three laboratory studies were conducted to assess effects of selenium in trout species present in the Crow Creek watershed. Two reproduction studies focused on maternal transfer of selenium and its effects on developing young. A third study, early life stage (ELS), focused on the effects of selenium from aqueous and dietary exposure to developing young Yellowstone Cutthroat Trout (YCT) that had no maternal selenium transfer. Collectively, these three studies examined two different pathways: (1) maternal transfer of accumulated selenium; and (2) dietary and aqueous exposure of young with no maternal transfer.

The maternal transfer studies evaluated reproduction of adult wild trout from the Site in a controlled laboratory setting. These studies were conducted independently, with one study using brown trout *(Salmo trutta)* and the second study using YCT *(Oncorhynchus clarki)*. Trout were collected from different areas of the Site, covering a range of exposure conditions. Eggs from females were fertilized in the field and transported to the laboratory for rearing. Method controls for the study were hatchery-raised fish.

5.1 Brown Trout Studies

The effects of maternal selenium transfer in wild brown trout were evaluated by collecting eggs from wild female brown trout from different locations with varying selenium exposure levels. Effects analyses evaluated egg selenium concentration versus growth, survival, and deformity endpoints. Logistic regression analyses were used to develop dose-response relationships and predict effect concentrations (EC_x) of egg selenium for a measured effect endpoint. USEPA's Toxicity Relationship Analysis Program (TRAP) (Version 1.2; Erickson 2008) software was used to derive dose response models. The predicted post-hatch survival EC_{20} was 21.63 mg/kg dw egg selenium, while the EC_{10} for this endpoint was 17.68 mg/kg dw egg selenium. For deformities, the sum fraction normal endpoint EC_{20} was 21.7 mg/kg dw egg selenium, while the EC_{10} for this endpoint was 19.33 mg/kg dw egg selenium.

The brown trout data presented in the *Final Brown Trout Laboratory Reproduction Studies Conducted in Support of Development of a Site-Specific Selenium Criterion* (Formation Environmental 2011 – Appendix D TSD) were submitted to USEPA for use in their derivation of the National Criterion. Their subsequent review of these data, submitted as part of formal comments (December 21, 2010) on the Draft Interpretive Report, suggested some alternative evaluations may be practical. USEPA's review of these data indicates agreement with the selection of the endpoint for survival (hatch to test end). In addition to the logistic model available as part of TRAP, two additional non-linear models are also available including the threshold sigmoidal and piecewise linear models. USEPA's comment letter illustrated an investigation of each of these models relative to the logistic model used as part of the brown

trout studies, and found that the projected EC_x values are likely conservative. As part of the USEPA's evaluation, another alternative examined exclusion of data points that exceeded 30 mg/kg dw in eggs, due to the fact that effects were already occurring between 15 and 30 mg/kg dw. This approach was investigated as a means of optimizing the model output. By eliminating the three highest data points, the logistic model is able to focus on the region of interest (i.e., between 15 and 30 mg/kg dw egg selenium). Using this approach, the logistic model run using log-transformed exposure data (egg selenium concentrations) versus survival (hatch to test end) resulted in a model with a $R^2 = 0.99$ (Figure 5). Confidence intervals derived for the estimated EC_x values are also tight about the estimates and the standard error of the model is low. This improved model results in an EC_{20} equal to 23.1 mg/kg dw egg selenium and an EC_{10} equal to 20.8 mg/kg dw.

5.2 Yellowstone Cutthroat Trout Studies

Adult YCT females, collected from the wild, bioaccumulated selenium in whole body and eggs based on their exposure to ambient diet and aqueous concentrations of selenium (Appendix E – TSD). Endpoints for YCT were variable and not always consistent with those observations for brown trout. Eggs from one particular female had high egg selenium (47.6 mg/kg dw) and high survival (88%). Removal of that single data point for the survival data (hatch to test end) allowed for a data distribution that more closely resembled observations found for brown trout. Growth data for YCT did not show enough differences between low and high egg selenium concentrations to distinguish a dose response. Deformity observations were also variable, with most fish ranked as having no deformities or only slight deformities. Considering all of the deformity data, and using the fraction normal as a total endpoint for this measure did produce a viable dose response relationship, however, the percent survival (hatch to test end) endpoint proved to be a stronger relationship, similar to the response observed for brown trout, albeit at a higher egg selenium concentration.

Of the relationships evaluated for YCT, percent survival (hatch to test end) provided the best relationship to egg selenium exposure. Relying solely on the model output, EC_{10} and EC_{20} values are greater than 35 mg/kg dw egg selenium. Additional analyses were also conducted using piecewise linear and sigmoidal dose response models. Despite the use of multiple approaches and data transformations, clear dose response models using these effects endpoints were few. YCT data showed highly variable responses to egg selenium concentrations. Examination of the data distribution, however, did suggest differences in responses between 22.3 and 27.9 mg/kg dw egg selenium. A decreased response was noted at egg selenium concentrations greater than 27.9 mg/kg dw for survival and growth. Averaging the observed no effect and potential effect concentrations resulted in a value of 25.1 mg/kg dw, which is expected to be lower than a derived EC_{10}. Without a true EC_x value derived from the dose response modeling, effects for egg selenium exposure on survival and deformities are at some concentration greater than 25 mg/kg dw in eggs.

These analyses indicate that brown trout and YCT responses to selenium exposure are different. Brown trout are more sensitive in their response to maternally-accumulated selenium and its effects on reproduction than are YCT. This finding is consistent with studies that have utilized several different cutthroat trout species (e.g., Hardy 2005, Hardy et al. 2010, Rudolph et al. 2008, Nautilus Environmental 2011) and that indicate sensitivity differences among similar species.

Based on the results from testing of wild-collected maternal brown trout, several conclusions were drawn from the study and are presented below:

- Significant breaks between no and/or low ranges of effects and high ranges of effects were observed based on visual inspection of the data between 20 and 25 mg/kg dw egg selenium concentration for several endpoints.

- Post-hatch survival and total deformity frequency (fraction normal) were found to be the most biologically relevant endpoints exhibiting dose response relationships and concurrence of observed data to predicted values for brown trout. The predicted post-hatch survival EC_{20} was 21.63 mg/kg dw egg selenium, while the EC_{10} for this endpoint was 17.68 mg/kg dw egg selenium. For deformities, the sum fraction normal endpoint EC_{20} was 21.7 mg/kg dw egg selenium, while the EC_{10} for this endpoint was 19.33 mg/kg dw egg selenium.

- Model data for survival were re-evaluated focusing on the data range where effects occur. This improved model results in an EC_{20} of 23.1 mg/kg dw egg selenium and an EC_{10} of 20.8 mg/kg dw.

- Effects thresholds defined for brown trout from this study are consistent with reported effects found for other species in the literature.

Results and analyses of the YCT adult reproduction study data yield the following conclusions:

- Egg selenium concentrations were strongly related to whole body selenium concentrations.

- Maternal transfer studies yielded evidence of decreasing growth, survival, and fraction normal fish relative to egg selenium concentrations. However, these relationships were weak due to variability of each response to egg selenium concentrations. Removal of a single data point that had high egg selenium and high survival substantially improved the relationships.

- The test endpoint percent survival (hatch to test end) for YCT was evaluated using the TRAP software regression routines to evaluate the potential for a dose response relationship. The best model produced using a piecewise linear regression resulted in EC_{20} and EC_{10} values of 36.3 and 35.8 mg/kg dw egg selenium, respectively.

- The test endpoint fraction normal evaluated for YCT deformities yielded a dose response relationship using logistic regression models similar to that developed for brown trout. The EC_{20} for the mean fraction normal fish was 37.6 mg/kg dw egg selenium while the EC_{10} was 32.7 mg/kg dw egg selenium.

- YCT data showed highly variable responses to egg selenium concentrations. The dose response models derived did not provide the best fit due to data variability. An alternative examination of these data and their distribution, however, did suggest differences in responses between 22.3 and 27.9 mg/kg dw egg selenium. A decreased response was noted at egg selenium concentrations greater than 27.9 mg/kg dw for survival and growth. Averaging the observed no effect and potential effect concentrations resulted in a value of 25.1 mg/kg dw. For YCT survival, the EC_{10} is expected to be between 25 and 35.8 mg/kg dw in eggs.

5.3 Early Life Stage Studies (YCT)

ELS studies conducted with naïve (i.e., no pre-parental exposure) fry utilized newly hatched YCT from the Henry's Lake Fish Hatchery, Henry's Lake, Idaho. Results and analyses of the YCT ELS study data yield the following conclusions:

- The post-hatch survival rate at test termination was significantly different from controls (One way ANOVA, $p = 0.009$) at the nominal treatment of 20 mg/kg diet and 20 µg/L aqueous selenium. At the nominal treatment of 40 mg/kg diet and 40 µg/L aqueous selenium, no difference from control was found. No dose response was observed for dietary treatments[2].

- Growth and deformities in treatments were not significantly different from controls.

[2] As noted in the TSD, the lack of a dose-response for survival, although a significant difference was observed at one treatment level, may be due to complications encountered during testing ELS YCT where young trout were found to be gorging themselves to death. Competition in the treatment tanks also complicated exposure.

- Despite selenium tissue residues up to 34.5 mg/kg dw in young fish with no pre-parental exposure, resulting from dietary and aqueous treatment exposures, no relationships were observed for survival, growth, or fraction normal fish that suggested effects with increasing exposure.

- The lack of maternal exposure may preclude detrimental effects even if the adult spawns in a stream with elevated selenium, since the maternal pathway is the primary route of exposure to induce chronic effects.

6.0 INTEGRATING LINES OF EVIDENCE

The draft Interpretive Report proposed an EC_{20} as the SSSC for this project. The USEPA has indicated that they intend to propose an EC_{10} in their Draft National Criterion, which includes the brown trout data developed as part of this study. In comments received from USEPA on the Draft Interpretive Report, EPA stated that for developing a SSSC for this site, the EC_{10} is a more appropriate endpoint than the proposed EC_{20}. Their primary rationale was that as a bioaccumulative pollutant that accumulates in fish tissue, selenium concentrations in fish tissue are more stable over time than aqueous selenium concentrations. This stability may lead to tissue selenium concentrations that are just below the criterion for extended periods of time. A number of strong arguments were presented as to why an EC_{20} was appropriate for this site. However, to accommodate USEPA policy and to provide an additional margin of safety, the proposed SSSC is based on the EC_{10}.

The brown trout EC_{10} (20.8 mg/kg dw egg selenium) for survival (hatch to test end) is proposed as the SSSC. The proposed value is supported by the three primary lines of evidence evaluated for the study: review of the literature on selenium toxicity to cold-water fish, field studies of aquatic communities and populations, and site-specific laboratory studies. Rationale for selection of this value is provided below.

1. The life stage for the criterion is appropriate. Embryo-larval effects resulting from maternal transfer of selenium from the parent fish have been shown to be the most sensitive life stage, as opposed to juvenile or adult life stages.

2. A tissue-based criterion is consistent with the state of the science. Early on, investigators pursued and actively researched relationships of a variety of different fish tissues from different life stages of fish. The mounting body of evidence supports the tissue threshold approach. Whole body tissues were initially advocated as a basis for USEPA's 2004 national criterion. USEPA has since revised its position. Based on new research, its current position is that the best predictor of selenium toxicity is the egg/ovary tissue.

3. The species tested is sensitive. Based on the current Site-specific studies and literature for similarly conducted maternal transfer studies, brown trout young are sensitive to the effects of selenium. Of the cold-water species tested, brown trout are one of the more sensitive species, with EC_xs falling below those for most other trout species (Figure 6). Compared to benthic invertebrates, brown trout also tend to be more sensitive relative to effects of selenium (Figure 7). The brown trout is an appropriately sensitive species protective of the larger aquatic community assemblage.

4. The endpoint is biologically relevant. Survival directly affects individuals and populations. Selenium literature has focused on larval deformities as a sensitive endpoint, rationalizing that individuals with severe enough deformities ultimately do not survive, affecting population dynamics. In the brown trout studies, the survival endpoint, measured from hatch to test termination, was slightly more sensitive in terms of predicted effects levels than the deformity endpoint.

5. Site and species specificity requires no extrapolation. Effects levels and criteria are often based on species and conditions that may not represent site conditions (e.g., laboratory studies of surrogate species, warm- versus cold-water environments and species, non-representative exposure pathways). The Site and species specificity of this study eliminates many, if not all, of these variables.

6. Field observations of abundance, population structure, and diversity over the same range of exposure conditions utilized for the laboratory studies indicate that the EC_{10} derived for individual brown trout survival is conservative with regard to population effects and is protective of other aquatic species.

7. The EC_{10} provides a margin of safety for aquatic communities present at this Site. Consideration of the effects data generated for both brown trout and YCT, as well as the population and community data for these species and other species present at the Site, indicates that the EC_{10} is a protective threshold for the aquatic community. The brown trout EC_{10} is lower than the EC_{10} for YCT derived from Site studies.

In combination, the three primary lines of evidence considered for this Site-specific study provide a very large and detailed body of information upon which to select a criterion. Importantly, the three lines of evidence converge to support the proposed criterion. The information comprising these lines of evidence provides the appropriate level of scientific assurance that the proposed criterion is conservative and thereby provides an adequate margin of safety for the aquatic community.

7.0 PROPOSED CRITERION IMPLEMENTATION

The criterion proposed herein is based on the survival of young developing brown trout relative to the egg tissue selenium concentration (20.8 mg/kg dw). To implement the proposed egg criterion, a tiered approach is described that provides clear targets by which to assess compliance, and will provide regulated entities with clear requirements for monitoring. Because of the level of effort required to monitor egg selenium concentrations, two relationships will be useful to the implementation process, including: (1) a process to derive an aqueous selenium concentration or trigger value from the egg criterion value; and (2) translation from egg selenium concentrations to whole body selenium concentrations. An aqueous trigger value is proposed for selenium (based on the egg effect criterion) as a measure by which rapid evaluations can be made to assess whether more in-depth monitoring is needed. The proposed aqueous trigger value is 11 µg/L selenium (see Section 6.4.8 of the TSD). An egg to whole body translation relationship is also provided if more in-depth monitoring is needed. The translated egg to whole body value at an egg selenium concentration of 20.8 mg/kg dw is 12.9 mg/kg dw selenium whole body (see TSD Section 5.5). Subsequent steps are included in a decision tree procedure should the aqueous trigger value be exceeded (Section 7 of the TSD). Figure 8 graphically illustrates this decision tree. Consideration of location, the frequency of sampling, number of samples, and how the data are integrated all affect how the data are used to gauge compliance and ultimately protect downstream uses.

8.0 REFERENCES

Conley, J.M., D.H. Funk, and D.B. Buchwalter. 2009. Selenium Bioaccumulation and Maternal Transfer in the Mayfly *Centroptilum triangulifer* in a Life-Cycle, Periphyton-Biofilm Trophic Assay. Environ. Sci. Technol. 2009, 43, 7952–7957.

deBruyn, A.M.H. and P.M. Chapman. 2007. Selenium Toxicity to Invertebrates: Will Proposed Thresholds for Toxicity to Fish and Birds Also Protect Their Prey? 1;41(5): 1766-70 / Environ. Sci. & Technol. Published on the Web 02/02/2007.

DeForest, D.K., G. Gilron, S.A. Armstrong, and E.L. Robertson. Species Sensitivity Distribution Evaluation for Selenium in Fish Eggs: Considerations for Development of a Canadian Tissue-Based Guideline. Integrated Environmental Assessment and Management. DOI: 10.1002/iem.245

Erickson, R. 2008. Toxicity relationship analysis program (TRAP v.1.20). U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Midcontinent Ecology Division, Duluth, Minnesota, USA.

Hardy, R.W. 2005. Final Report: Effects of dietary selenium on cutthroat trout *(Oncorhynchus clarki)* growth and reproductive performance. Prepared for Montgomery Watson Harza, Bellvue, Washington.

Hardy, R., W, Libbie, L. Oram, and G. Moeller. 2010. Effects of Dietary Selenomethionine on Cutthroat Trout *(Oncorhynchus clarki bouvieri)* Growth and Reproductive Performance Over a Life Cycle. Archives of Environmental Contamination and Toxicology, 58(1): 237-245.

Idaho Department of Environmental Quality. 2011. Idaho Department of Environmental Quality Final 2010 Integrated Report. Boise, ID: Idaho Department of Environmental Quality.

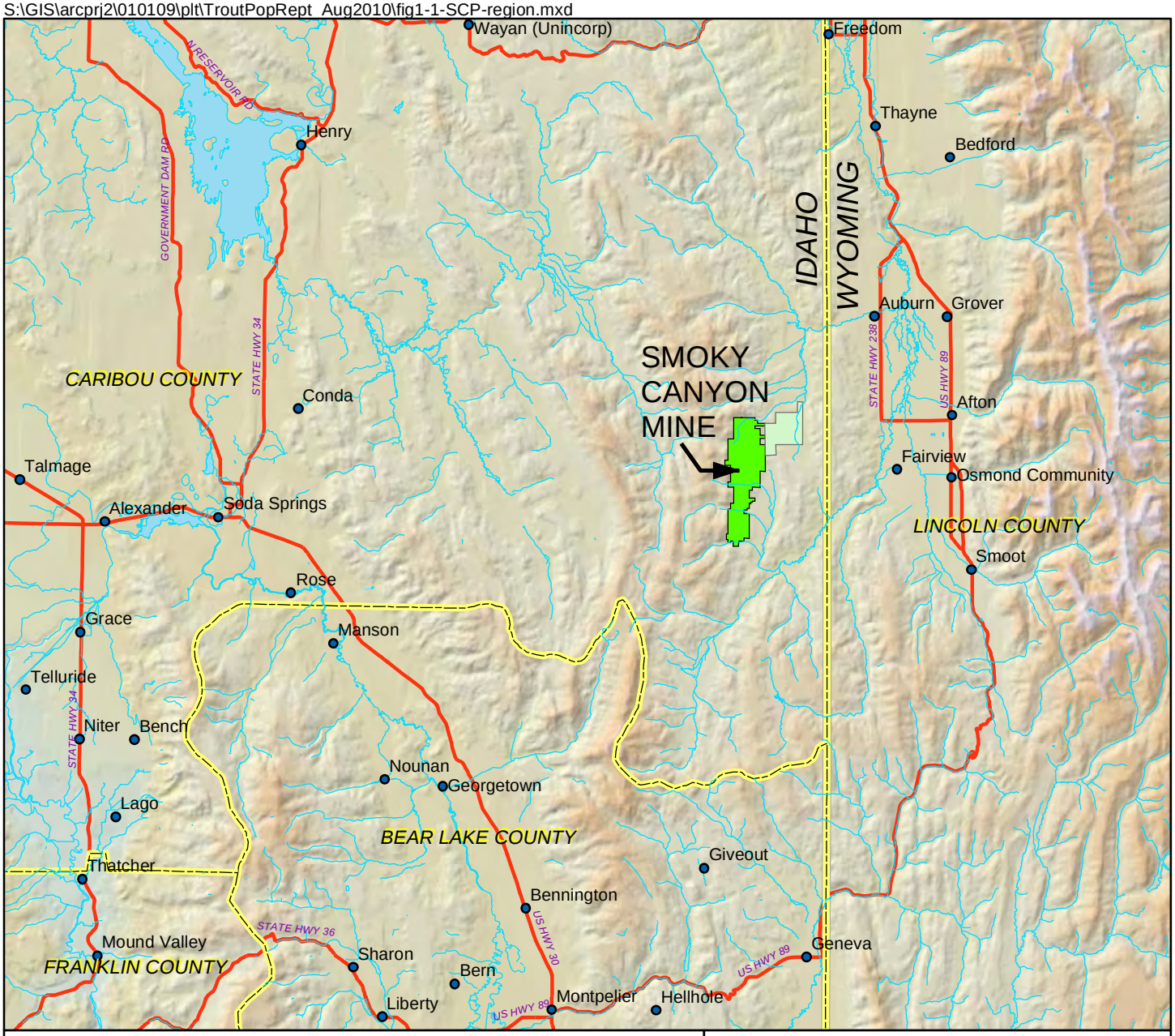
Nautilus Environmental. 2011. Evaluation of the effects of selenium on early life stage development of Westslope cutthroat trout in the Elk Valley, BC. Draft Revised Report, Prepared for the Elk Valley Selenium Task Force, Sparwood, BC, Canada.

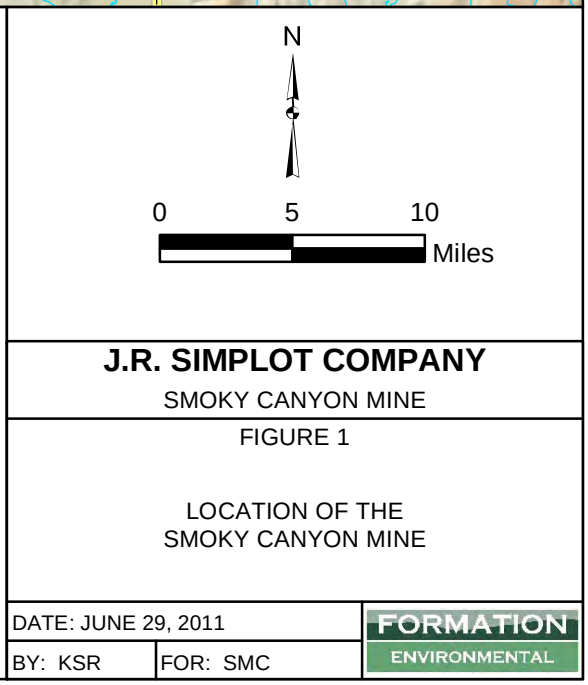
Formation Environmental. 2011. Final Brown Trout Laboratory Reproduction Studies Conducted in Support of Development of a Site-Specific Selenium Criterion. Prepared for J.R. Simplot Company. June.

Rudolph, B.L., I. Andreller, and C. Kennedy. 2008. Reproductive Success, Early Life Stage Development, and Survival of Westslope Cutthroat Trout (*Oncorhynchus clarki lewisi*) Exposed to Elevated Selenium in an Area of Active Coal Mining. Environ. Sci. Technol. 2008, 42, 3109-3114.

FIGURES

S:\GIS\arcprj2\010109\plt\TroutPopRept_Aug2010\fig1-1-SCP-region.mxd





J.R. SIMPLOT COMPANY

SMOKY CANYON MINE

FIGURE 1

LOCATION OF THE
SMOKY CANYON MINE

DATE: JUNE 29, 2011		FORMATION ENVIRONMENTAL
BY: KSR	FOR: SMC	

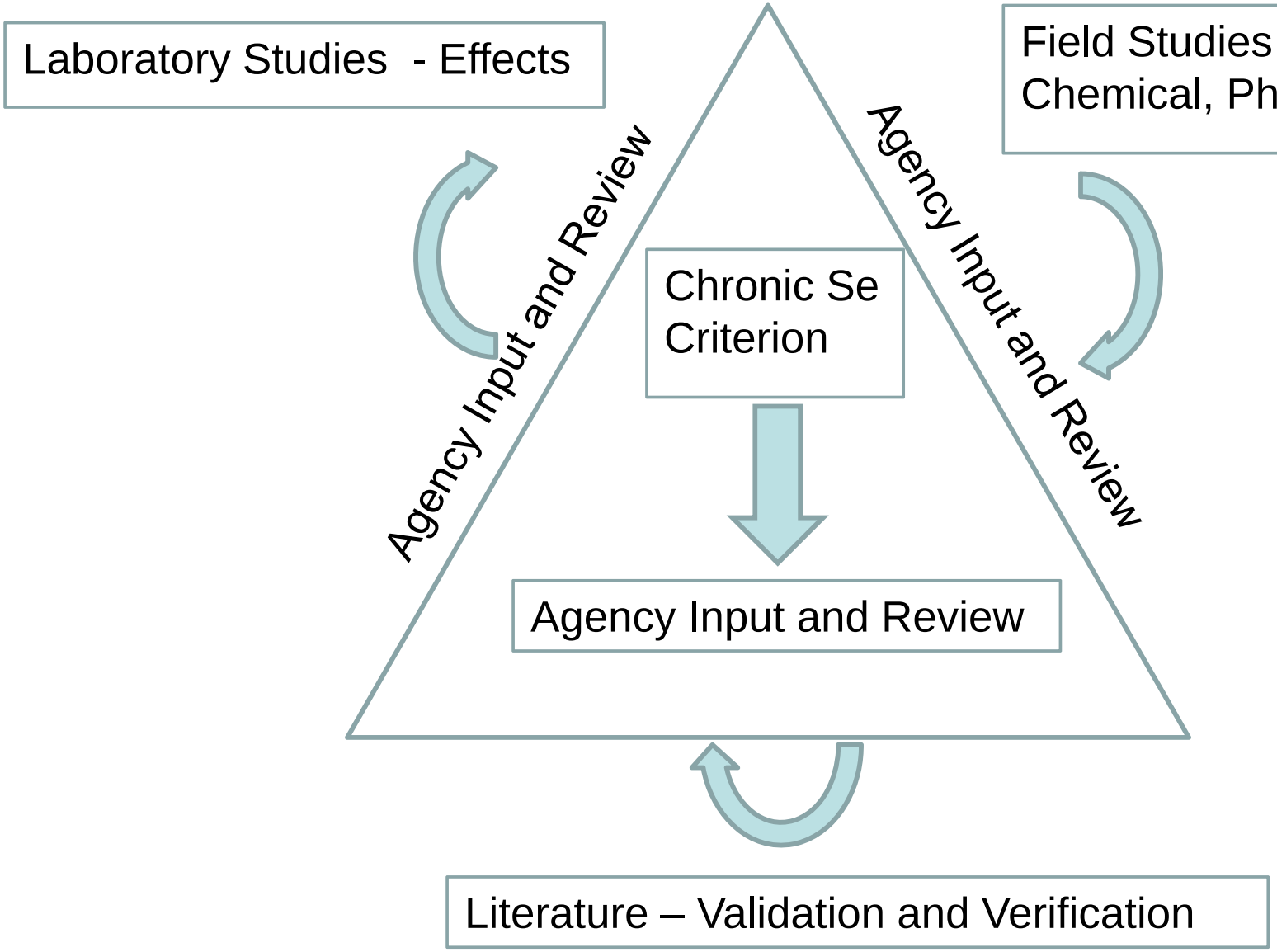


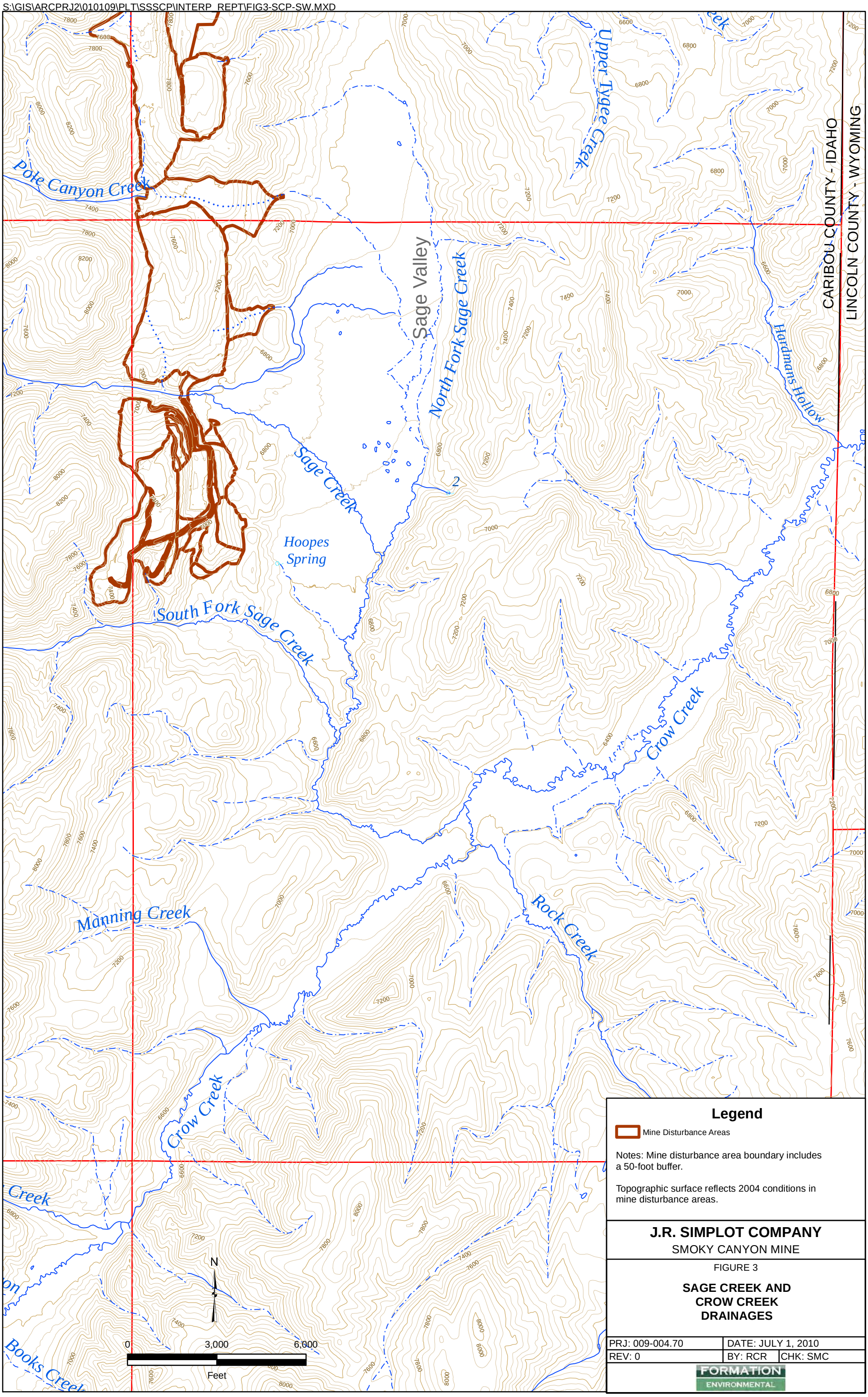
Figure 2
Relationship of Lines of Evidence to Developing a Site-Specific Selenium Criterion

J.R. Simplot Company
Site-Specific Selenium Criterion

PRJ: 0442-004-900.70	DATE: January 2012	
REV: 1	BY: SMC	CHK: SMC

FORMATION ENVIRONMENTAL

S:\GIS\ARCPRJ2\010109\PLT\SSSCP\INTERP_REPT\FIG3-SCP-SW.MXD



Legend

Mine Disturbance Areas

Notes: Mine disturbance area boundary includes a 50-foot buffer.

Topographic surface reflects 2004 conditions in mine disturbance areas.

J.R. SIMPLOT COMPANY

SMOKY CANYON MINE

FIGURE 3

SAGE CREEK AND CROW CREEK DRAINAGES

PRJ: 009-004.70	DATE: JULY 1, 2010	
REV: 0	BY: RCR	CHK: SMC

FORMATION ENVIRONMENTAL

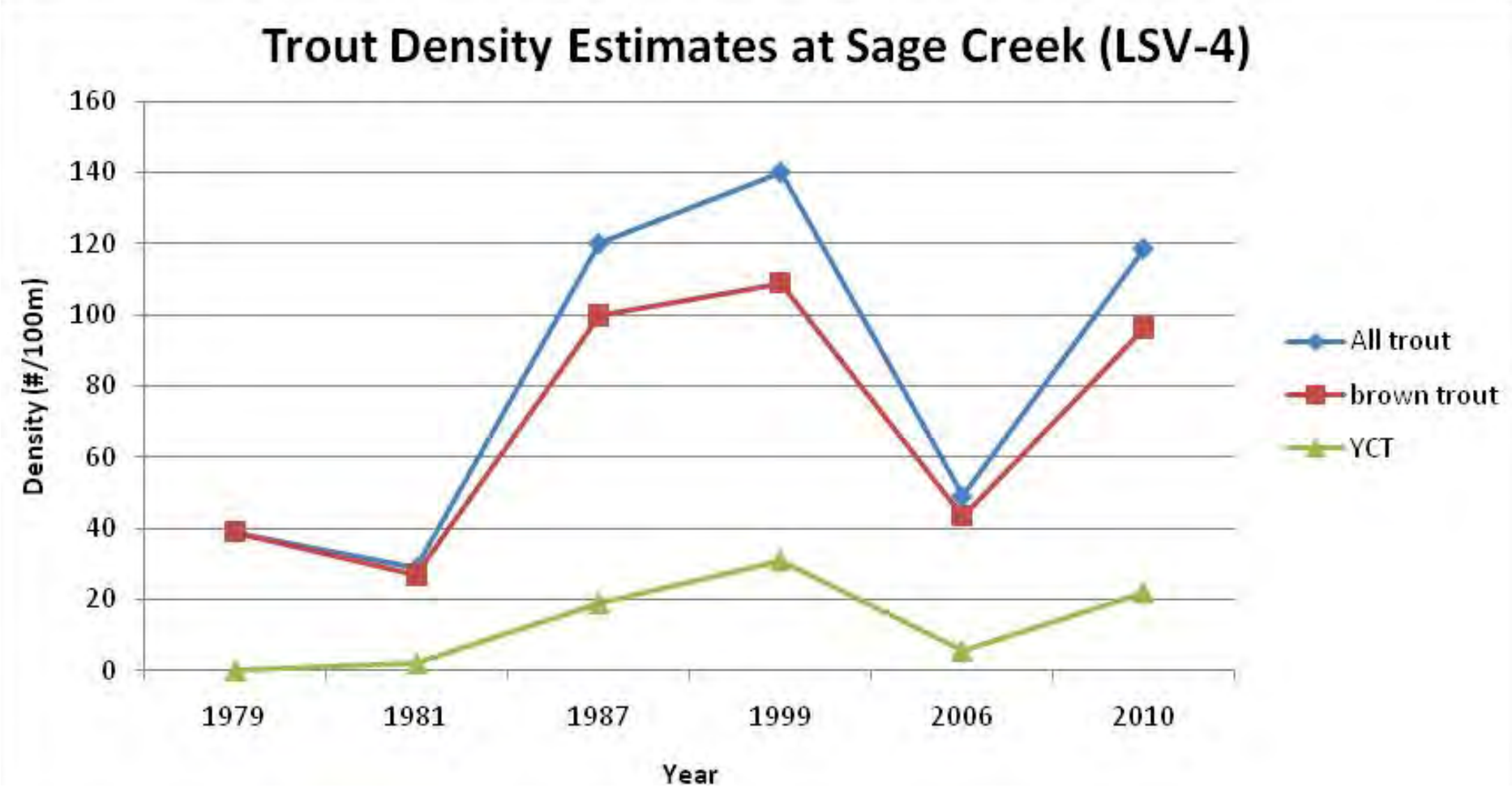


Figure 4
Trout Density Estimates at Sage Creek (LSV-4)
Based on Historical Estimates, SSSC Monitoring Data (2006), and Panels F and G Monitoring (2010)

J.R. Simplot Company
Site-Specific Selenium Criterion

PRJ: 0442-004-900.70	DATE: January 2012	
REV: 0	BY: SMC	CHK: SMC

FORMATION ENVIRONMENTAL

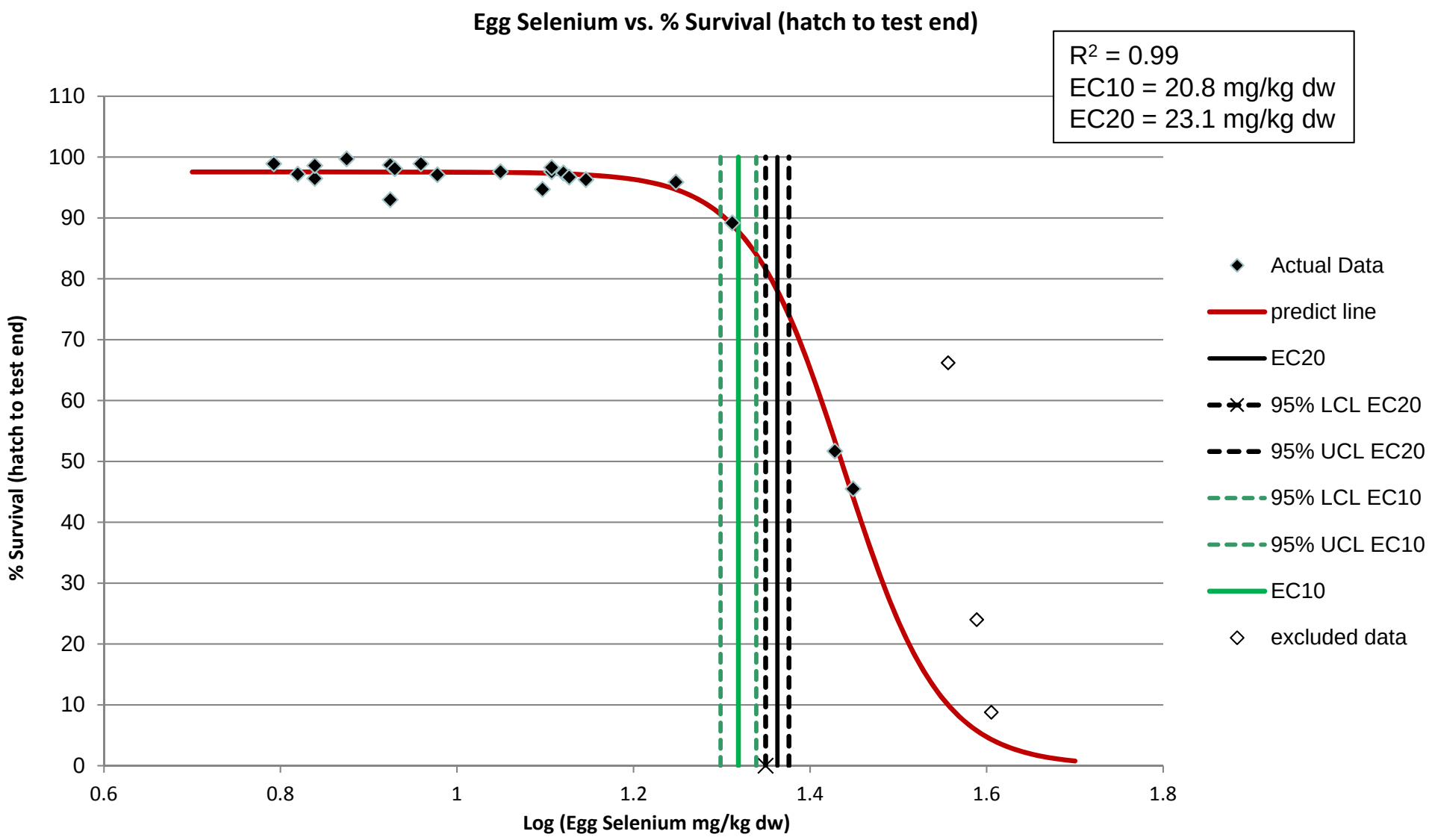


Figure 5
Logistic Regression of Brown Trout Egg Selenium Concentrations Versus Survival Percentage (Hatch to Test End) Focused on Effect Region for Derivation of EC_x Values

J.R. Simplot Company
Site-Specific Selenium Criterion

PRJ: 0442-004-900.70	DATE: January 2012	
REV: 1	BY: SMC	CHK: SMC

FORMATION ENVIRONMENTAL

Figure 6
Species Sensitivity Distribution for Cold and Cool Water Species Effects Data Derived from Maternal Transfer Studies

J.R. Simplot Company
Site-Specific Selenium Criterion

PRJ: 0442-004-900.70	DATE: January 2012	
REV: 1	BY: SMC	CHK: SMC

FORMATION ENVIRONMENTAL

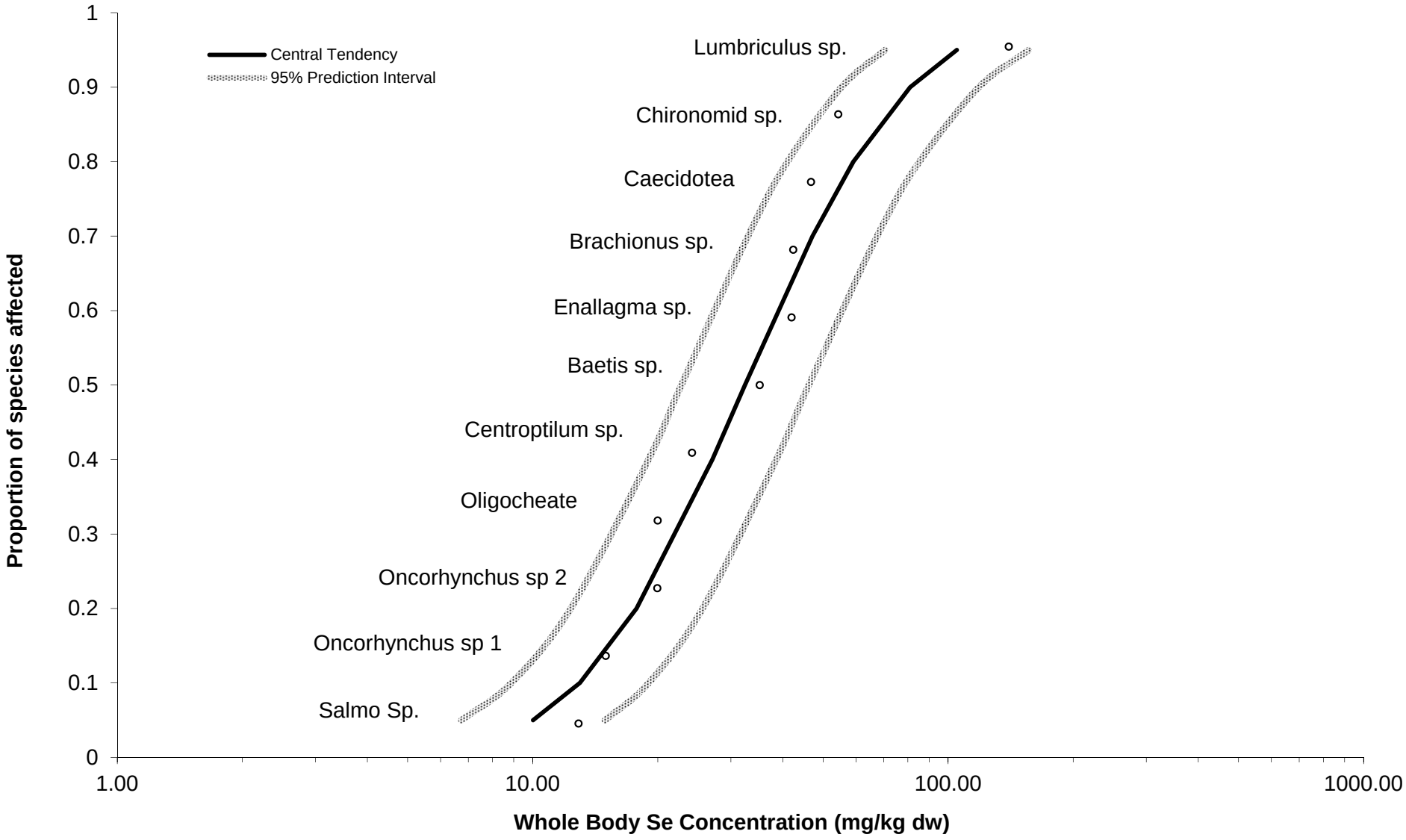


Figure 7
Species Sensitivity Distribution of a Representative Cold Water Aquatic Community to Selenium

J.R. Simplot Company
Site-Specific Selenium Criterion

PRJ: 0442-004-900.70	DATE: January 2012	
REV: 1	BY: SMC	CHK: SMC

FORMATION ENVIRONMENTAL

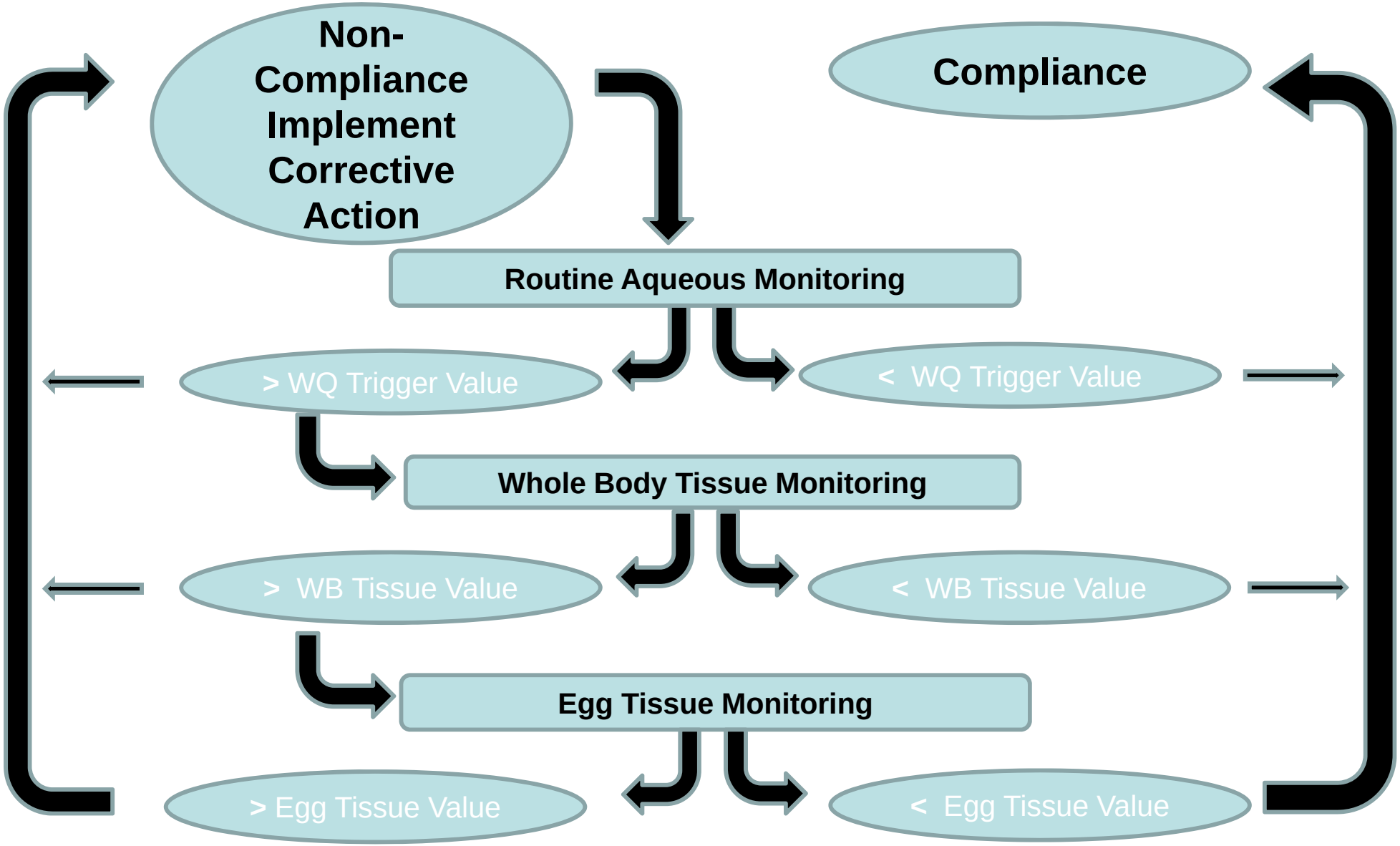


Figure 8
Flow Diagram for Implementing the Site-Specific Selenium Criterion for the Site

J.R. Simplot Company
Site-Specific Selenium Criterion

PRJ: 0442-004-900.70	DATE: January 2012	
REV: 1	BY: SMC	CHK: SMC

FORMATION ENVIRONMENTAL