Appendix 2.2
GSL Assessment Plan

Introduction

In Utah's 2006 Integrated Report, Great Salt Lake (GSL) is not included in any assessment category. Public comment on the Integrated Report raised concerns related to the condition of the GSL and cited evidence of potential nutrient enrichment in Farmington Bay, elevated water-column mercury concentrations, and findings of mercury accumulation in the avian species frequenting GSL. In response to the public comments received on the Integrated Report (IR), the Utah Division of Water Quality (UDWQ) and the Environmental Protection Agency (EPA) formed a collaborative workgroup. The purpose of the workgroup was to develop a process to assess the ability of GSL to support its beneficial uses as designated under the Clean Water Act. Because of the unique characteristics of GSL and the lack of assigned numeric criteria, the State's Assessment Methodology does not currently address GSL. The decision making approach described in this appendix serves as a guide to development of an assessment methodology for the GSL.

This appendix describes the proposed approach developed by the UDWQ / EPA workgroup for assessing whether GSL is supporting its designated uses. This process provides a structured methodology that can be used to determine whether GSL should be considered impaired and included in category 5 (303(d) section) of the Integrated Report (IR). Also presented is a description of the GSL ecosystem, a summary of the beneficial uses and applicable water quality standards. This appendix details the proposed decision making approach proposed for making a listing determination for GSL.

The decision making approach focuses on the open waters of GSL defined by DWQ as all open waters at or below the 4,208-foot lake elevation. The lake has been further divided into subclasses based on hydrologic boundaries and are as follows; 5A-Gilbert Bay, 5B-Gunnison Bay, 5C–Bear River Bay, 5D-Farmington Bay. A preliminary decision making framework for the GSL transitional wetlands is currently under development by the workgroup but is not discussed here.

The decision making approach outlined in this document represents the first step in the assessment process, which is to determine whether the GSL supports its beneficial uses or if it does not support its beneficial use and should be considered as impaired. This process may be iterative and conclusions may change as additional data become available.

1. GSL Ecology and Conditions

The GSL is a terminal waterbody with highly variable chemical and biological conditions. Salinities in the GSL range from about 2% salinity in Farmington and Bear River bays to about 30% salinity in Gunnison Bay. Gilbert Bay is intermediate at 12-14% salinity. Gilbert Bay and Farmington Bay often develop density stratification resulting from hypersaline water from Gunnison Bay underflowing the less saline water of Gilbert Bay and in turn the hypersaline water from Gilbert Bay underflowing the less saline water of Farmington Bay. This strong stratification can last months or even years. As a result, dissolved oxygen concentrations range from saturation (circa 4 mg L^{-1}) in the shallow brine layer to anoxia and strongly reducing conditions in the deep brine layers. Reduced forms of sulfur and metal ions have been described in the deep brine layer. Due to the extreme and variable conditions, the ecosystems of the various bays are dominated by different types of biota. Gilbert Bay is recognized for its prolific populations of brine shrimp and brine flies while Bear River and Farmington bays are generally too low in salinity to support significant brine shrimp populations. Rather, Bear River and Farmington bays are dominated by corixids and, to a lesser extent, by brine flies and midges. Algal and bacterial populations are also vastly different among the bays. Fish are absent from the open waters of the GSL except when a combination of low lake levels and high spring runoff contributes to a "freshening" of Farmington and Bear River bays. During these times bluegill, carp and other minnows have been observed and numerous pelicans, herons, egrets and cormorants have been observed actively feeding in these bays.

Abundant brine shrimp populations exist in the open water of Gilbert Bay. These brine shrimp have an interesting life cycle which includes a dormant overwintering stage known as cysts. Depending on temperature and freshwater inflow, these eggs begin hatching in April or early May. Several molting cycles result in various instar stages until mature adults begin appearing in early June. Brine shrimp densities may reach 3-5 individuals per liter that presents heavy grazing pressure on their preferred algal species, *Dunaliella viridis*. This simple food chain dependence results in two–five cycles of population spikes and crashes that are caused by a periods of overgrazing and depletion of Dunaliella followed by a crash in brine shrimp numbers, followed by exponential growth of Dunaliella which in turn, provides for exponential growth of brine shrimp. This cycling continues until late October or early November. Massive production of countless cysts occurs during the last few growth cycles of brine shrimp-providing the eggs for the next season's production. Cyst densities are so numerous that 20 to 30 million pounds of cysts are commercially harvested each winter and sold to food shrimp growers throughout the world. This harvest is carefully monitored by the Utah Division of Wildlife Resources in order to ensure sufficient cyst densities remain so that this brine shrimp population is sustained from year to year.

2. Applicable Beneficial Uses and Narrative Water Quality Criteria for GSL

The State of Utah's Rule R317-2 for Standards of Quality for Waters of the State lists GSL as a category 5 waterbody that is protected for "*primary and secondary contact recreation, waterfowl, shore birds and other water-oriented wildlife including their necessary aquatic organisms in their food chain, and mineral extraction*." Except for mineral extraction, these are the GSL's beneficial uses that must be protected under the Clean Water Act.

The lack of unimpacted reference sites with which to compare GSL and its unique ecosystem make it difficult to establish expected conditions for this water body. At present, numeric water quality criteria have not been established for GSL, rather the State's narrative criterion applies and states:

> *"it shall be unlawful, and a violation of these regulations, for any person to discharge or place any waste or other substance in such a way as will be or may become offensive such as unnatural deposits, floating debris, oil, scum or other nuisances such as color, odor or taste; or cause conditions which produce undesirable aquatic life or which*

produce objectionable tastes in edible aquatic organisms; or result in concentrations or combinations of substances which produce undesirable physiological responses in desirable resident fish, or other desirable aquatic life, or undesirable human health effects, as determined by bioassay or other tests performed in accordance with standard procedures."

3. Background on Beneficial Use Support Impairment Determinations Using Indicators

Assessing whether GSL supports its beneficial uses requires a methodology for interpreting Utah's narrative water quality standards. The methodology need not prove a particular contaminant is the cause of impairment to a beneficial use but should outline the procedures to be used to determine if a beneficial use is at risk.

For the assessment plan described in this appendix, we propose to identify both *direct* and *indirect* indicators of GSL ecosystem health. Thereby, quantitative measures of multiple lines of evidence will be used to determine whether the beneficial uses are at risk.

<u>Direct Indicators of Beneficial Use Support:</u> The most direct evidence for determining whether a waterbody is supporting its beneficial uses is to measure the use itself. Examples of direct indicators include:

- *Contact Recreation Use Support*: Quantifiable measures of amount of contact recreational use in the waterbody and documented illnesses related to recreational use of the waterbody;
- *Waterfowl/ Shorebird Use Support*: Quantifiable measures of the shorebird or waterfowl population and documented deaths occurring in the waterbody attributed to the waterbody; and
- *Aquatic Life Use Support*: Brine shrimp densities; zooplankton abundance and diversity, algal abundance and diversity.

Direct indicators are often difficult to develop due to the amount of data required, the influence of multiple stressors, and the need for "reference" sites for the development of thresholds or benchmarks. Because GSL is such a unique ecosystem, biological indices for macroinvertebrates, zooplankton, and algal species are not readily available in the literature or are not applicable to GSL.

Therefore, the use of direct indicators as the best measure of beneficial use support will require additional study and time to develop

<u>Indirect Indicators of Beneficial Use Support:</u> When it is difficult to gather or interpret data for direct indicators, *indirect indicators* can serve as surrogates to evaluate whether environmental conditions support an associated beneficial use. Examples of indirect indicators include the following types of measurements:

- *Contact Recreation Use Support*: E. coli or pathogen indicator densities have been correlated with human health impacts in fresh water environments. In marine environments Enterococci is used;

- *Waterfowl/ Shorebird Use Support*: Mercury concentrations in avian dietary items and in the livers, eggs and other tissues of birds have shown a link between mercury bioaccumulation and affects on avian reproduction and health; and
- *Aquatic Life Use Support*: Metals concentrations in the water column are linked with impacts to aquatic life (macroinvertebrates), waterfowl or shorebirds) based on toxicity studies.

4. Weight of Evidence Decision Making Approach

Using a weight of evidence approach, one would identify the important direct and indirect indicators needed to assess beneficial use attainment, identify thresholds for those indicators, and use the preponderance of evidence to make a conclusion regarding impairment. Using the weight of evidence approach, it is not necessary to prove that a particular contaminant is impacting a beneficial use but rather to demonstrate, using multiple lines of evidence that the beneficial use is at risk. Additional work would then be necessary to identify the causative factor/constituent.

Possible outcomes of an assessment include:

a) A determination that the waterbody is not impaired and placement of the waterbody into the appropriate IR category;
b) A determination that the condition of the waterbody is unknown and further study or action is warranted;
c) A determination that the waterbody is impaired with placement into IR category 5.

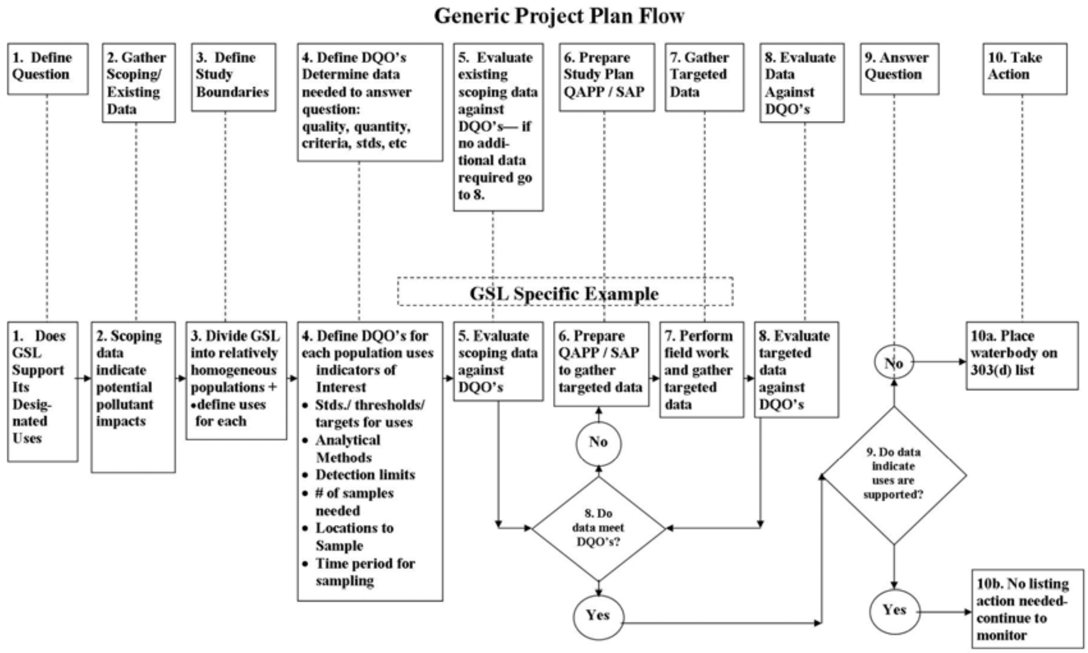
If the waterbody is impaired and 303(d)-listed, further efforts may be needed to establish numeric criteria or targets in the Total Maximum Daily Load (TMDL) process.

5. Logic Diagram for Weight of Evidence Decision Making Approach

The Decision Making Approach is an iterative process where large complicated issues are broken down into manageable study units. A series of questions, answers, and decisions are made in each unit so that incremental progress is made towards solving the larger issue of whether or not GSL supports its beneficial uses.

Figure 5-1 illustrates the systematic process by which data are gathered and evaluated in each unit. The UDWQ/EPA work group followed the steps outlined in this process to develop the draft GSL assessment plan presented in this document for mercury and nutrient impacts as raised by the 2006 Integrated Report public comments.

Figure 5-1. Generalized Flow Diagram



a. Step 1: Define the Question.

The first step in the assessment plan is to clearly identify the study question of interest. This focuses the effort so that efficient progress toward decision making can occur.

b. Step 2: Evaluate Existing/Scoping Data

The second step in the assessment plan is to evaluate existing/scoping data to determine if further study is warranted and clearly define the areas requiring evaluation.

c. Step 3: Define Study Boundaries

In Step 3, existing/scoping data are used to help define relatively homogeneous study boundaries. Study boundaries may be defined by physical, chemical, contaminant, or biological characteristics within an area. The goal is to narrow the study area so that the fewest number of samples may be collected to generate representative data. This step focuses the study so that defensible conclusions may be drawn.

Currently, the narrative criteria are applied to the GSL as one waterbody. However, because different bays of GSL have different salinities and hydrology, DWQ is proposing to segment the GSL into relatively homogenous areas for individual evaluation. These boundaries are defined as follows:

Class 5A - Gilbert Bay (south arm)

Geographical boundary includes the open water at or below surface elevation 4208 ft located south of the railroad causeway and north of the Syracuse (Antelope Island) causeway.

Beneficial Uses include protection for primary and secondary contact recreation, waterfowl, shore birds and other water-oriented wildlife including the necessary aquatic life in their food chain

Class 5B - Gunnison Bay (north arm)

Geographical boundary includes the open water at or below surface elevation 4208 ft north of the Union Pacific Railroad causeway and west of the Promontory Peninsula, excluding existing salt evaporation ponds;

Beneficial Uses include protection for primary and secondary contact recreation, waterfowl, shore birds and other water-oriented wildlife including the necessary aquatic life in their food chain.

Class 5C (Bear River Bay)

Geographical boundary includes open waters at or below surface elevation 4208 ft elevation north of the Union Pacific Railroad causeway and east of the Promontory Peninsula excluding existing salt evaporation ponds.

Beneficial Uses ─ Protected for secondary contact recreation, waterfowl, shore birds and other water-oriented wildlife including the necessary aquatic life in their food chain.

Class 5D (Farmington Bay)

Geographical boundary includes the open waters at or below elevation 4208 ft elevation south of the Syracuse (Antelope Island) causeway and east of Antelope Island;

Beneficial Uses ─ Protected for secondary contact recreation, waterfowl, shore birds and other water-oriented wildlife including the necessary aquatic life in their food chain.

Class 5E Natural Wetlands along the Great Salt Lake Shoreline (transitional wetlands)

Geographical boundary includes the exposed mudflat and vegetated areas below elevation 4208 and extended to the current edge of the open waters of Great Salt Lake the receive their source water from naturally occurring springs, streams, discharges or impounded wetlands.

Beneficial Uses ─ Protected for secondary contact recreation, waterfowl, shore birds and other water-oriented wildlife including the necessary aquatic life in their food chain.

Step 4: Define Data Quality Objectives (DQOs)

In Step 4, the information needed to answer the question in Step 1 is identified. Establishing data quality objectives and assessment methods requires that the following types of information be defined prior to additional data collection or analysis:

- Important indictors of impairment for which data has been or needs to be gathered (examples include nutrient concentrations, dissolved oxygen values, measures of biological diversity, toxic chemical concentrations, etc.);
- An assessment framework in which threshold values or contaminant benchmarks (water quality standards, contaminant limits) are identified for each indicator that may be used to distinguish between fully supporting and impaired conditions (see Tables SS-1 through TL-5 for examples). The assessment framework serves as a precursor to development of an assessment methodology for GSL. The State's Assessment Methodology currently describes the process for making impairment determinations for lakes/reservoirs and streams/rivers. This approach will be reviewed for its applicability to GSL.
- Physical locations and biological communities that need to be sampled and how sampling sites will be selected (random vs. targeted sampling.);
- The amount of data of each type needed to make an assessment;
- Statistics that will be applied in evaluating the data;
- Temporal requirements for sampling (daily impacts, seasonal impacts, annual impacts, etc.);
- Special sampling protocols that need to be followed to ensure a representative sample is available for laboratory analysis;
- Analytical methods and detection limits required to produce data that may be compared with thresholds/benchmarks for decision making;
- Field and laboratory quality control procedures needed to demonstrate adequate precision and accuracy of sample collection and measurements; and
- Defined decision rules that predetermine the actions that will be taken based on the results of the data interpretation. (A decision rule is a statement that describes the actions to be taken based on the data assessment outcome.)

d. Steps 5 Through 8: Analysis of Existing Data Against DQOs and Additional Targeted Data Gathering to Fill Data Gaps

In Steps 5 through 8, data are evaluated against the DQOs developed in Step 4 to ensure that the quality and quantity of data meets the study needs. In addition, the assessment frameworks are used to interpret the data. If additional data must be gathered to answer the question from Step 1, a thorough quality assurance project plan (QAPP) is devised and executed.

e. <u>Step 9: Answering the Question Posed in Step 1.</u>

Using the DQO's and assessment framework, the data is interpreted and the question in Step 1 is answered.

f. <u>Step 10: Taking Action Based on Data Analysis</u>

Once the question from Step 1 is answered, the decision rules identified in step 4 during the DQO process are implemented and the appropriate predefined action is taken.

The initial assessment of GSL will apply this weight of evidence decision making approach in evaluating the potential impacts of nutrient and mercury risks to waterfowl, shorebirds and aquatic-dependant life. If this approach is found to be useful, other beneficial use assessments for human health and recreational use will follow.

6. Mercury and Nutrient Specific Assessment Logic Diagrams and Assessment Frameworks

Given the concerns raised about possible impacts to GSL from mercury and nutrients, the UDWQ/EPA workgroup concentrated its efforts on developing a decision making approach that could be used to evaluate risks from these pollutants. The work group prepared decision making logic diagrams for both assessments of mercury and nutrient impacts to the aquatic life beneficial use of the GSL. In addition, the work group drafted study flow diagrams and assessment frameworks to be applied to each GSL segment. The following sections provide a brief description of the activities associated with each step in the diagrams, proposed actions, and schedule for an assessment determination. The actual proposed assessment parameters and metrics for each Great Salt Lake subclass are listed in the appendix (Table SS-1 for mercury and Tables TL-1 - TL-5 for nutrients). These assessment frameworks are in draft form for public review and comment. It is recognized that these frameworks will continue to be refined and updated with additional information and improved science.

6.1. Mercury Assessment Decision Making Approach

Figure 6.1-1 shows the logic or program flow diagram for performing the mercury assessment. Figure 6.1-2 illustrates the draft decision rules that accompany the Data Quality Objectives that are to be used for determining if mercury poses a significant health risk to avian species within the GSL ecosystem. These steps are briefly outlined as follows:

a. <u>Step One: Define Study Question</u> – *Are avian species (water fowl and shorebirds) at risk from mercury exposure associated with GSL*?

For this first step, the question is whether mercury associated with the GSL ecosystem (water, sediment, and aquatic life) poses a health risk to avian species that use GSL. Risk in this case is the potential for significant impacts to waterfowl and shorebird species composition and abundance (mercury impacts to health, survival, and reproduction).

b. Step 2: Gather and Evaluate Existing or Scoping Data to Determine if Further Study is Warranted.

Existing GSL data indicate elevated concentrations of mercury in the water column, duck muscle, liver and blood, and in eared grebe livers and breast muscle. Mean concentrations of mercury in brine shrimp during 2006 were nearly three times higher than those in 1996 and may be approaching avian dietary effects thresholds. Further evaluation of mercury risk to aquatic-dependant life is warranted.

c. Step 3: Establish Study Boundaries.

The DWQ has proposed to divide GSL into five sub-areas or subclasses based on specific physical, chemical and geographical characteristics. Each proposed GSL sub-area will be evaluated individually because some sub-areas of GSL may pose a greater risk to avian populations than others. Interactions between sub-areas may also be studied. Sensitive avian species as well as species in which the contribution of mercury from GSL is distinguished from mercury contributions from other locations during the birds' life cycle will be included in future studies. Input from experts will be sought to identify the most appropriate avian species and critical time periods for study if additional data are required. The existing eared grebe and migratory duck data will also be evaluated.

d. Step 4: Define Data Quality Objectives and Assessment Methodologies Against Which Existing and Future Data Will be Evaluated and Interpreted.

Indicator identification – Table SS-1 provides the Assessment Framework and examples of direct and indirect indictors chosen for further consideration in this study. It is likely that total mercury and methyl mercury in the diet, livers, muscle and eggs of targeted avian species will be the indicators of choice for this decision-making process. Experts will be consulted to assist in the choice of the most valuable indicators of avian risk. Water column and sediment concentrations may be evaluated if suitable benchmarks can be identified.

- Identification of threshold values (contaminant tissue limits or ambient biological or constituent thresholds) – Table SS-1 provides the Assessment Framework with threshold values and benchmarks for various indicators of interest based on literature values. Expert opinion will be sought to assist in the application of the most appropriate benchmarks for risk assessment.

- Choice of media and locations to be sampled –

- Dietary source samples - The primary dietary items of shorebirds and waterfowl will be evaluated. Existing brine shrimp, brine fly, brine fly larvae, midge larvae and corixid data will be evaluated. Additional data will be gathered on dietary contribution if required and may include sediment data since some species ingest sediment while foraging. The major feeding areas for these food sources will be targeted across GSL.
- Avian tissue samples - Existing tissue data (liver and muscle data) available for eared grebes and other birds will be evaluated against the DQO's and benchmarks. Archived tissue samples that were collected as part of the Great Salt Lake Selenium Study will be assessed for suitability for mercury analysis to supplement the database. Efforts will be made to ensure that additional tissue sampling planned by UDEQ, UDNR, and USFWS will be a coordinated to fill the data gaps identified through this process.
- Water column and sediment samples - Existing water column and sediment data will be evaluated as well as data that are soon to be available as part of the 2007 Regional Geographic Initiative (RGI) grant to UDEQ from the EPA.

- Choice of avian species to be studied – Eared grebe, and migratory duck data are available and will be evaluated against DQO's and benchmarks. In addition, expert opinion will be sought to determine the best target species to ensure that sensitive species and those species representing GSL exposures are included.
- Amount of each type of data required for assessment –Either, 30 to 50 samples from a relatively homogeneous population that produces reasonable estimates of population statistics such as mean values, standard deviations, etc. will be used or a power analysis will be performed to optimize the number of samples required for future sampling efforts.
- Statistics to be applied – Expert opinion will be sought to determine the proper statistic to use to evaluate against the threshold values. It is anticipated that means, ranges, variances, standard deviation, and tests for significance of difference will be employed in data analysis for data that are collected randomly and are normally distributed If the contaminant data are not normally distributed (ex. non-detects, species migration) the data could be analyzed using non-parametric tests
- Temporal requirements for sampling – Ideally, dietary samples and tissues samples would be collected upon arrival of a species at the lake and then again just before migratory departure from the lake. In this way, changes in the birds' body burden as a result of GSL use could be determined. For non-migratory species, collection of tissue samples should coincide with maximum use of the lake eco-system or most sensitive life stage. Expert input will be sought to determine the most appropriate sampling schedule.
- Field protocol requirements – Clean techniques should be employed for collection of mercury samples. Laboratory requirements for holding time and temperature must be followed.

- Laboratory analytical methods – Comparable laboratory methods used in previous studies will be employed. Detection limits for total mercury and methyl mercury must be below the thresholds/benchmarks for decision making.
- Field and laboratory quality control procedures – All required laboratory quality control requirements must be adhered to as specified in the Laboratory's Quality Management Plan or as described in Standard Operating Procedures. This should include at a minimum requirements for initial demonstration of capabilities for analysts, use of standard curves, internal standards, matrix spikes, duplicates, and blanks. Field quality control procedures should include preparation of field blanks and field duplicates (when appropriate) at a frequency of 10%.
- Decision rules – Data evaluation and potential outcomes and conclusions are presented in Figure 6.1-2. The predetermined actions that will be taken based on the results of the data interpretation are identified.

e. Steps 5 Through 9: Collection of Additional Data, Evaluation against DQO's, and Data Interpretation

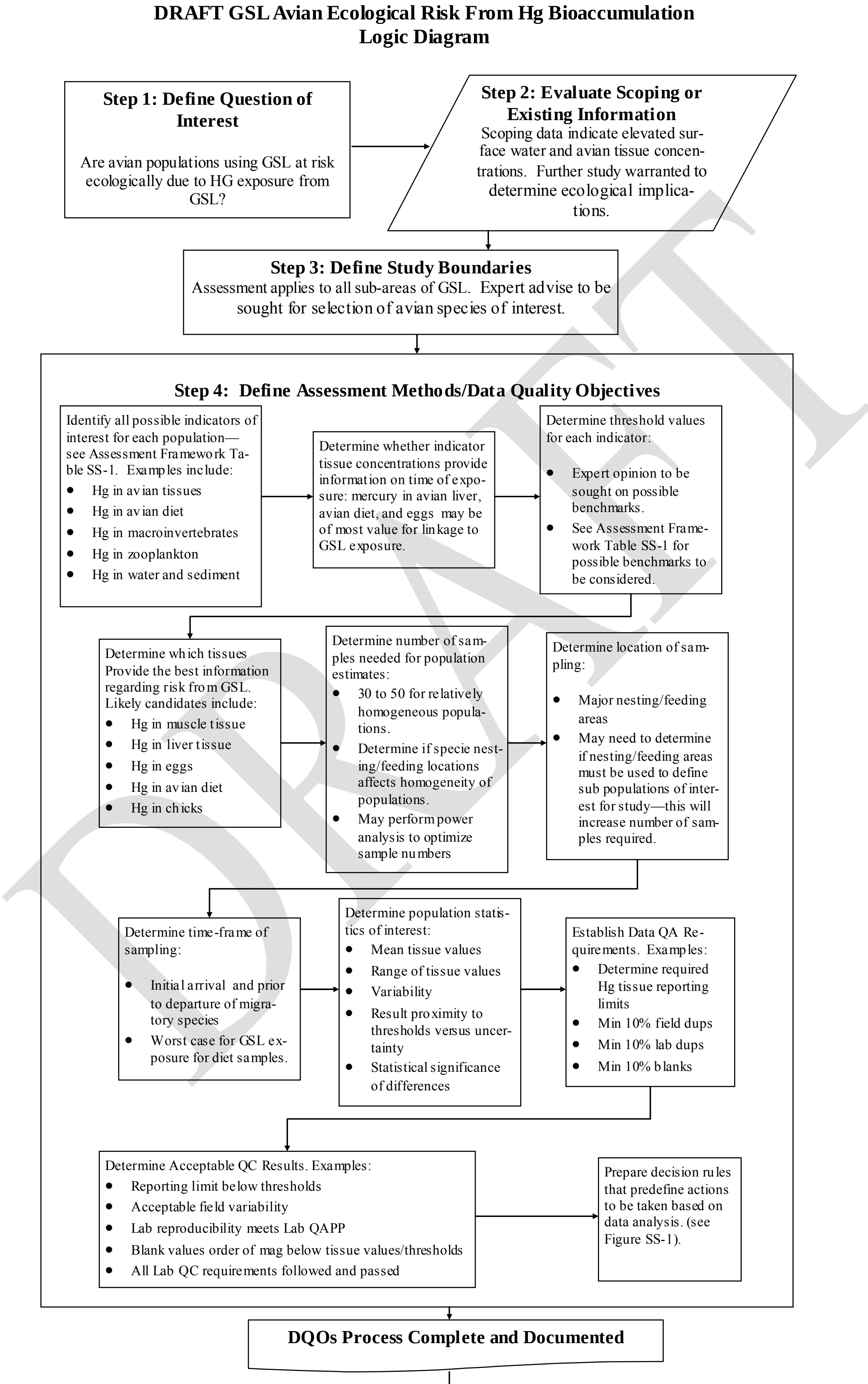
The next step is to compare the available scoping data against the draft DQOs and thresholds captured in the Assessment Framework (see Table SS-1). Available data for the recommended indicators will be summarized and compared to the thresholds identified in the Assessment Frameworks. The workgroup plans to review these data in 2008 to determine if the original questions concerning risks to the beneficial use can be answered.

If sufficient data exist, the questions identified in Step 1 (related to impairment determinations) will be made using the weight-of-evidence approach. If there are data gaps or the results are inconclusive, the workgroup will develop a monitoring plan designed to collect the necessary information to make a decision. If additional studies are necessary to better understand certain dynamics of the GSL ecosystem, the decision making process will be repeated, starting with Step 1 and based on a link to the original question of interest. For example, of paramount interest is the rate of methylation and proportion of mercury exposure from GSL sources vs sources elsewhere in the flyway and nesting grounds.

f. <u>Step 10: Decision Rule and Planned Actions</u>

A decision rule is a statement that describes the actions to be taken based on the data assessment outcome. Figure 6.1-2 provides the possible conclusions that could arise from data analysis and provides the decision rule to be followed. The decision rule for this decision making process is as follows: if it is concluded through this weight-of-evidence approach that waterfowl or shorebirds or other waterbirds are at risk due to mercury exposure associated with the open waters of GSL, the segments of the waterbody for which this risk applies will be placed into category 5 - list of impaired waters. Otherwise, the segments will be placed into the appropriate IR category and routine monitoring will continue.

Figure 6.1-1. Draft Mercury Logic Diagram



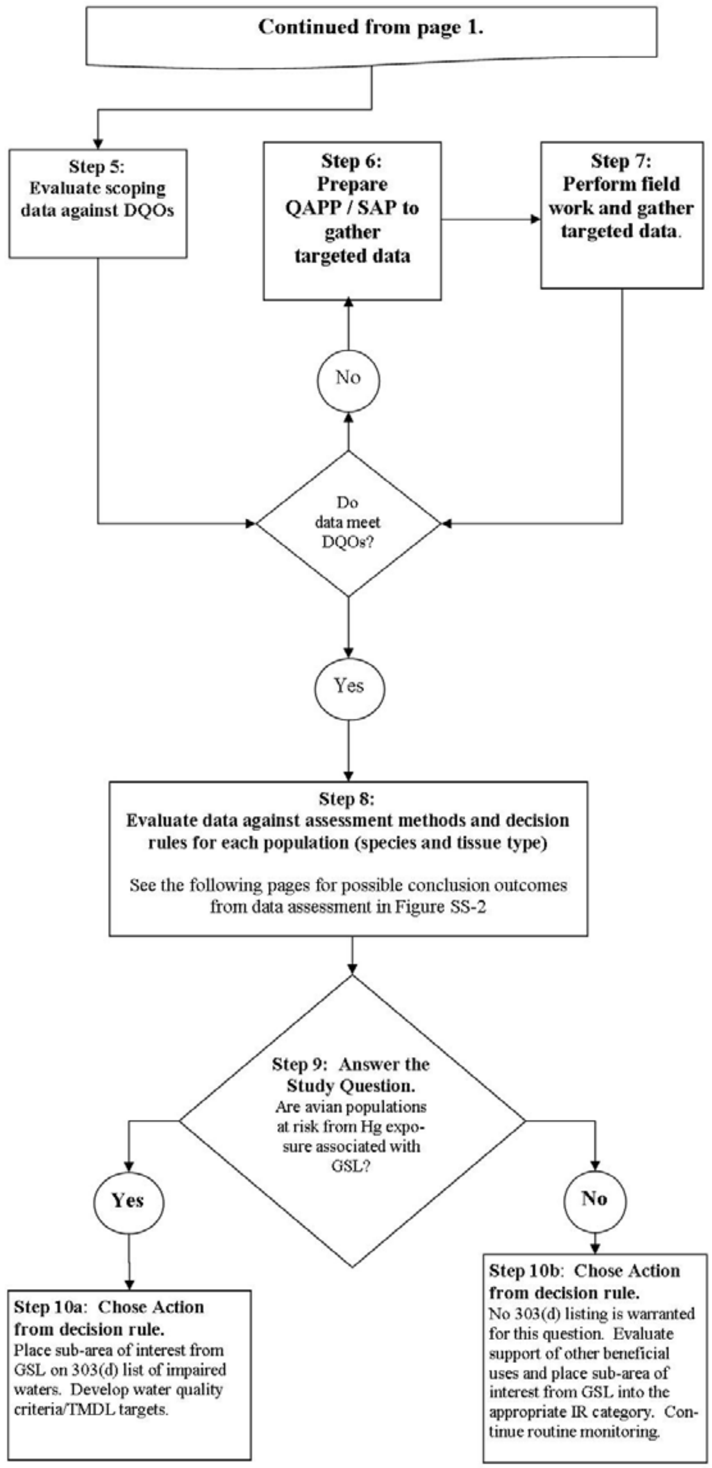

Continued from page 1.
Step 5: Evaluate scoping data against DQOs
Step 6: Prepare QAPP / SAP to gather targeted data
Step 7: Perform field work and gather targeted data.
No
Do data meet DQOs?
Yes
Step 8: Evaluate data against assessment methods and decision rules for each population (species and tissue type)
See the following pages for possible conclusion outcomes from data assessment in Figure SS-2
Step 9: Answer the Study Question. Are avian populations at risk from Hg exposure associated with GSL?
Yes
No
Step 10a: Chose Action from decision rule. Place sub-area of interest from GSL on 303(d) list of impaired waters. Develop water quality criteria/TMDL targets.
Step 10b: Chose Action from decision rule. No 303(d) listing is warranted for this question. Evaluate support of other beneficial uses and place sub-area of interest from GSL into the appropriate IR category. Continue routine monitoring.

Figure 6.1-2: Mercury Draft Decision Rules (Step 4: Data Quality Objectives)

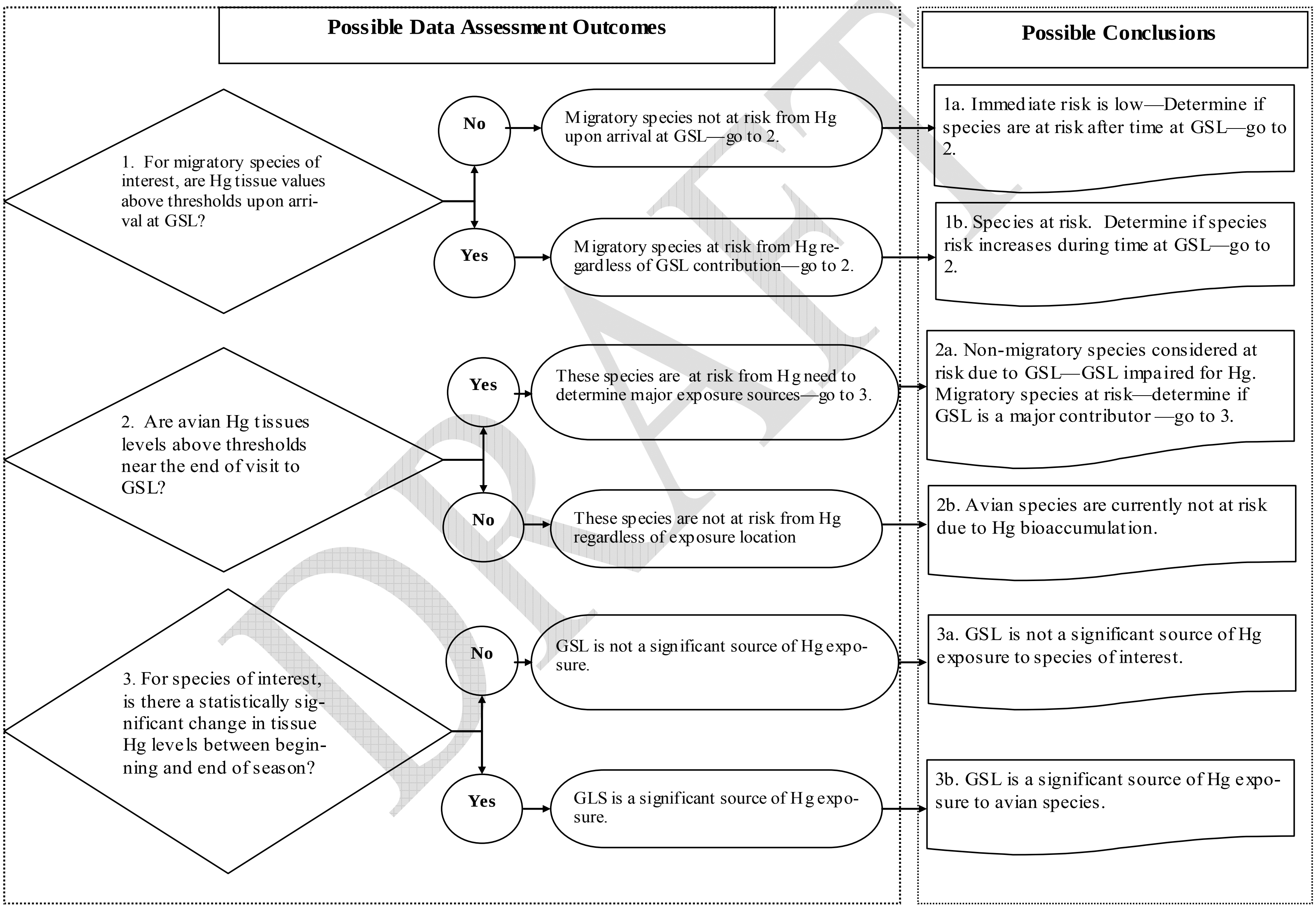


Figure 6.1-2: Mercury Draft Decision Rules (Step 4: Data Quality Objectives) (cont'd)

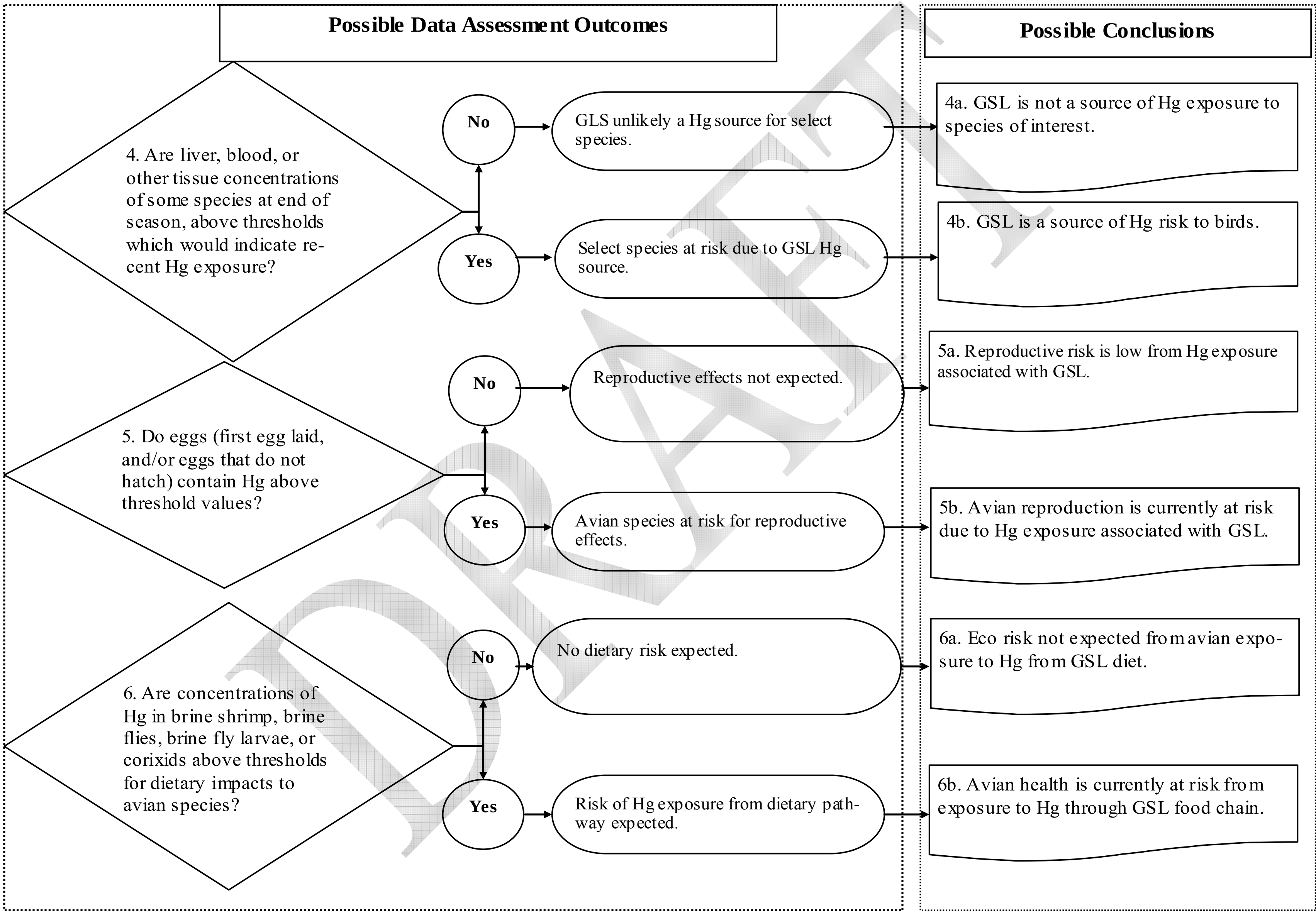
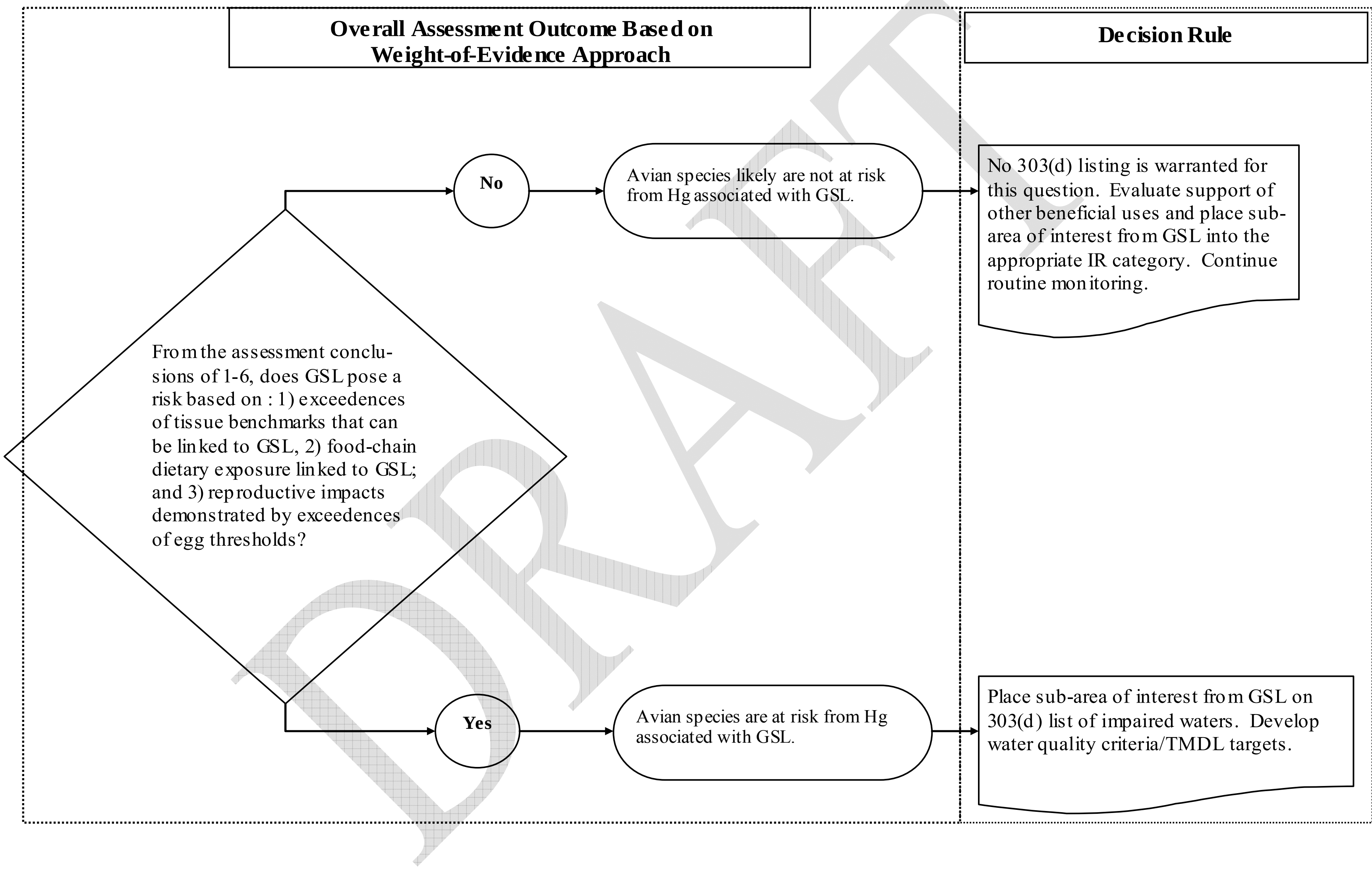


Figure 6.1-2: Mercury Draft Decision Rules (Step 4: Data Quality Objectives) (cont'd)



6.2. Nutrient Decision Making Approach

Figure 6.2-1 shows the generalized logic or program flow diagram for the GSL nutrient assessment program. Figure 6.2-2 includes a draft of the decision rules to be used in evaluating whether nutrient enrichment is impacting aquatic-dependant life in GSL. The nutrient assessment framework for each subclass is expressed in Tables TL-1 – TL-5.

a. Step 1: Define Study Question: *Are aquatic-dependant life in GSL at risk due to elevated nutrient concentrations*?

For nutrients and GSL, the question of interest is whether aquatic-dependant life in GSL are at risk due to elevated nutrient concentrations. Aquatic life use support refers to environmental conditions which support the following biological assemblages: macroinvertebrates, zooplankton and algal communities that comprise the GSL foodweb. Macroinvertebrates are animals lacking a backbone but large enough to be seen without the use of a microscope. Examples of the types of macroinvertebrates found in GSL ecosystems include corixids (water boatmen),and brine flies. Zooplankton are small animals that drift in open water including amphipods, copepods, cladocera and isopods. Copepods, cladocera and brine shrimp are the dominant zooplankton in GSL, however, their relative abundance and ecological importance varies with the salinity among the four bays. Given the economic importance that brine shrimp play in GSL, they are considered separately from zooplankton in the evaluation of whether GSL supports aquatic-dependant life.

b. Step 2: Scoping or Existing Information:

A cursory review of existing data for the GSL raised concerns about the possible impacts of nutrient enrichment on the GSL ecosystem.

c. Step 3: Define Study Boundaries:

The evaluation of risk from nutrient enrichment focuses on the entire GSL open water ecosystems with consideration for different salinity concentrations found in the four bays or subclasses. Since the aquatic life found in these subclasses is influenced by salinity, the indicators and subsequent data quality objectives reflect differences in the ecosystem which occur below and above 6% salinity. For example, dominance of blue-green algae as an indicator is assigned to all of GSL, however, data indicate limited likelihood of experiencing blue-green algal blooms which exceed the proposed thresholds in the highly saline areas of Gilbert and Gunnison bays. In addition, the aquatic life community found in certain areas of GSL varies with increases or decreases in salinity. For example, many freshwater zooplankton species are commonly found when the salinity is less than 6% compared to a brine shrimp-dominated community in areas containing greater than 6% salinity. (See Tables TL-1 through TL-5)

d. Step 4: Define Data Quality Objectives (DQOs) and Assessment Methodologies Against Which Existing and Future Data Will be Evaluated and Interpreted:

As stated previously, the risk of nutrient enrichment to GSL focuses on potential impacts to aquatic life. Nutrients affect aquatic life in a variety of direct and indirect pathways. Increased nutrient concentrations can result in increased phytoplankton growth as measured with chlorophyll a concentrations. These changes may result in increasing numbers of algal blooms covering areas of GSL (evaluated with chlorophyll a concentrations, Trophic State Index values, or aerial imagery). As algae die, bacteria consuming the decaying algae reduce the dissolved oxygen available in the water column, resulting in oxygen depletion. These various linkages support the evaluation of multiple direct and indirect indicators when considering nutrient enrichment.

The Assessment Frameworks (Tables TL-1 through TL-5) detail the direct and indirect indicators that may be used to evaluate possible impacts to the aquatic life beneficial use. Direct indicators of zooplankton composition or macroinvertebrate composition are mentioned as possible direct measures of aquatic life use support. However, developing the tools and thresholds to interpret the health of those communities may require additional studies.

In the interim, several indirect indicators have been identified as useful tools to evaluate possible nutrient impacts on the aquatic life in the GSL.

The list of primary indirect indicators includes:

- Algal biomass (measured by chlorophyll a concentrations)
- Trophic State Index Values
- Dominance of Blue-green algae
- Number, extent and duration of algal blooms as evaluated by aerial imagery
- Increasing nutrient concentrations
- Deviation from expected Redfield ratios
- Dissolved oxygen concentrations (less than 2 mg/L)

The different indicators each allow the evaluation of aspects of potential risk to the aquatic life from nutrient impacts. By describing the different questions that can be answered with each indicator, or a suite of indicators analyzed in combination, decisions can be reached about risk to the resource. Used in concert, these indicators will be evaluated as multiple lines of evidence following a weight-of-evidence approach to answer the question of risk to aquatic life use. Figure X describes the general decision making process that will be followed to reach impairment decisions. Clear indication of risk of nutrient enrichment is evidenced if GSL concentrations were well above the thresholds for multiple indicators.

In some cases, the answer to the question is not straight-forward and may generate additional questions that need to be answered. Additional questions that extend beyond the scope of the original question are captured as Phase II (future) studies. These studies may help clarify associations between different parameters and the impacts to aquatic life.

e. Steps 5 Through 9: Collection of Additional Data, Evaluation against DQO's, and Data Interpretation

The next step is to compare the available scoping data against the draft DQOs and thresholds captured in the assessment frameworks (see Tables TL-1 through TL-5). Available data for the recommended indicators will be summarized and compared to the thresholds identified in the assessment frameworks. The workgroup plans to review these data in spring 2008 to determine if the original questions concerning risks to the beneficial use can be answered.

If sufficient data exist the questions identified in Step 1 (related to impairment determinations) will be made using a weight-of-evidence approach. If there are data gaps or the results are inconclusive, the workgroup will develop a monitoring plan designed to collect the necessary information to make a decision. If additional studies are necessary to better understand certain dynamics of the GSL ecosystem, the decision making process will be repeated, starting with Step 1 and based on a link to the original question of interest.

f. Step 10: Decision Rule and Planned Actions

A decision rule is a statement that describes the actions to be taken based on the data assessment outcome. Figure SS-2 provides the possible conclusions that could arise from data analysis and provides the decision rule to be followed. The decision rule for this decision-making process is as follows: if it is concluded through this weight-of-evidence approach that waterfowl or shorebirds or other waterbirds are at risk due to nutrient enrichment associated with the GSL, the segments of the waterbody for which this risk applies will be placed into category 5, the list of impaired waters. Otherwise, the segments will be placed into the appropriate IR category and routine monitoring will continue.

Figure 6.2-1. Draft Nutrient Logic Diagram

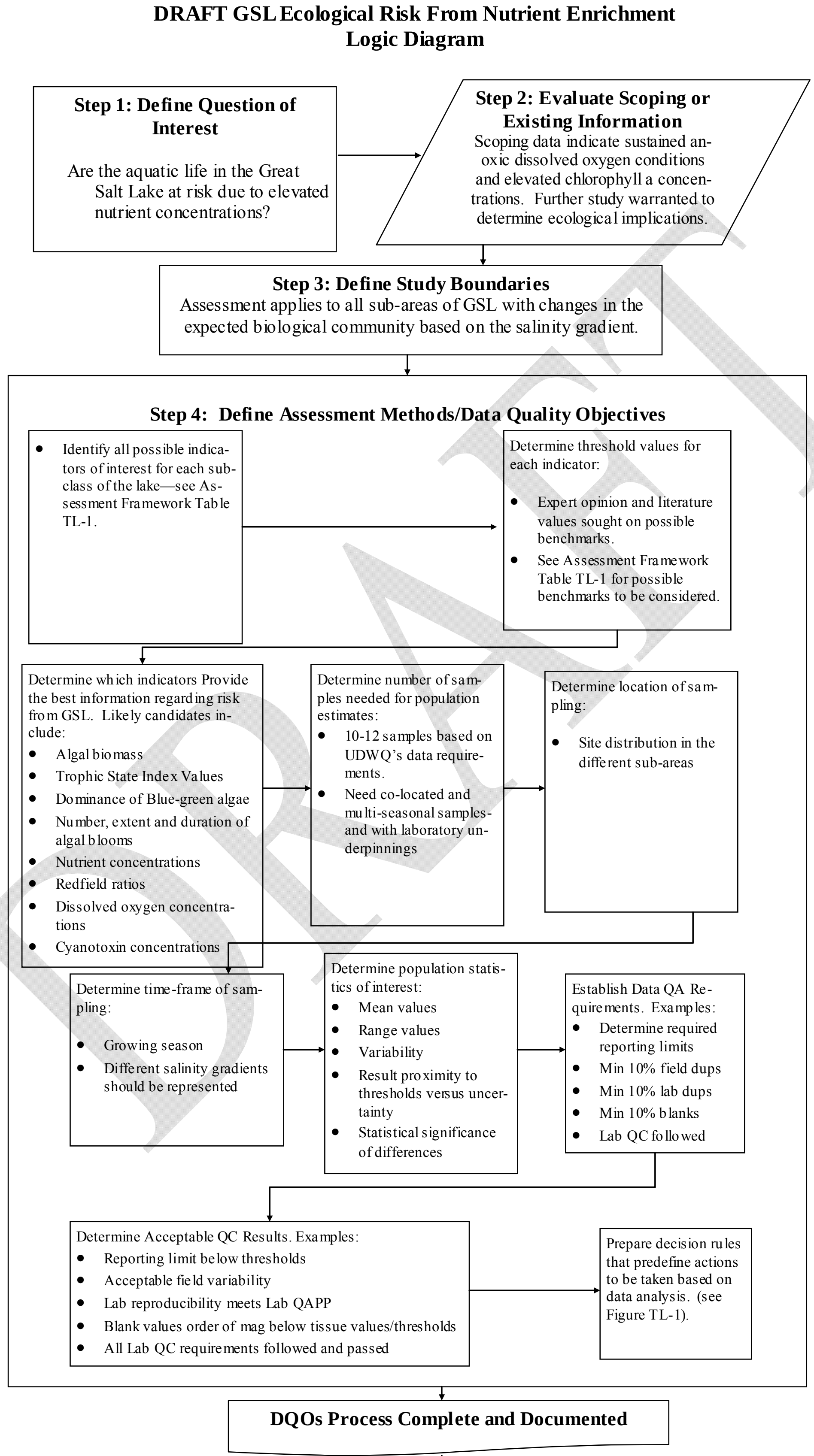


Figure 6.2-1. Draft Nutrient Logic Diagram (con't)

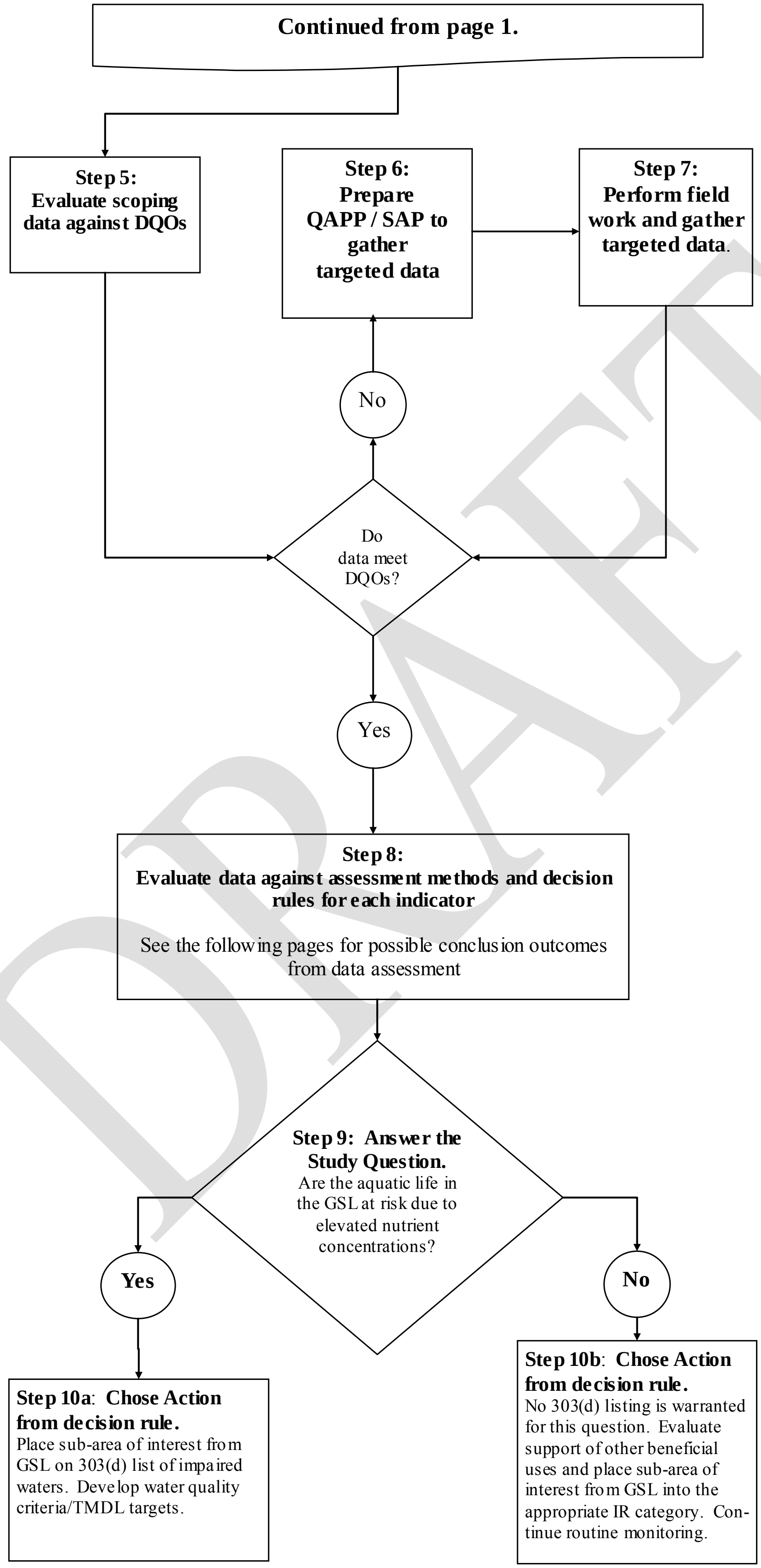


Figure 6.2- 2: Nutrient Draft Decision Rules (Step 4: Data Quality Objectives)

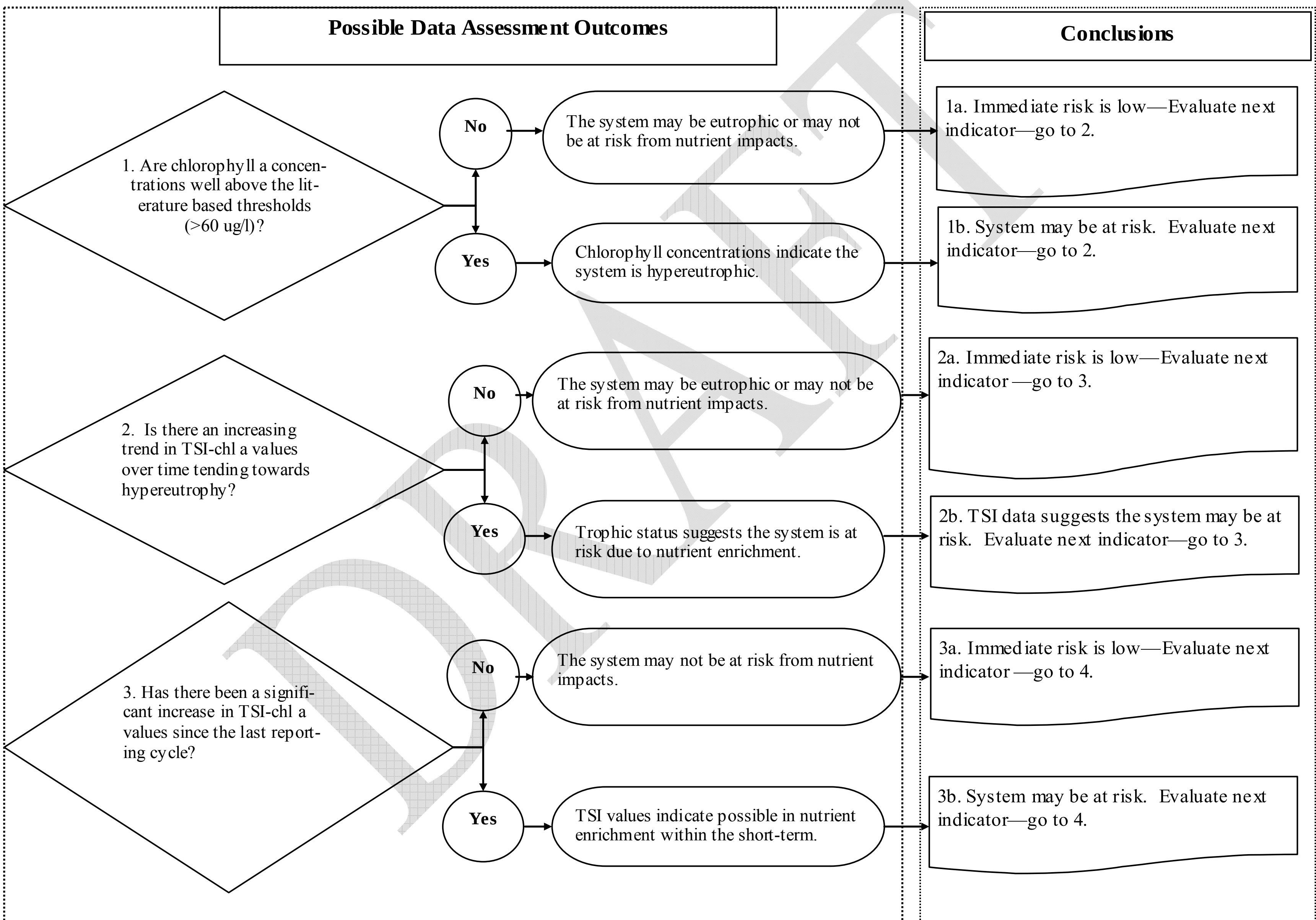


Figure 6.2- 2: Nutrient Draft Decision Rules (Step 4: Data Quality Objectives) (cont'd.)

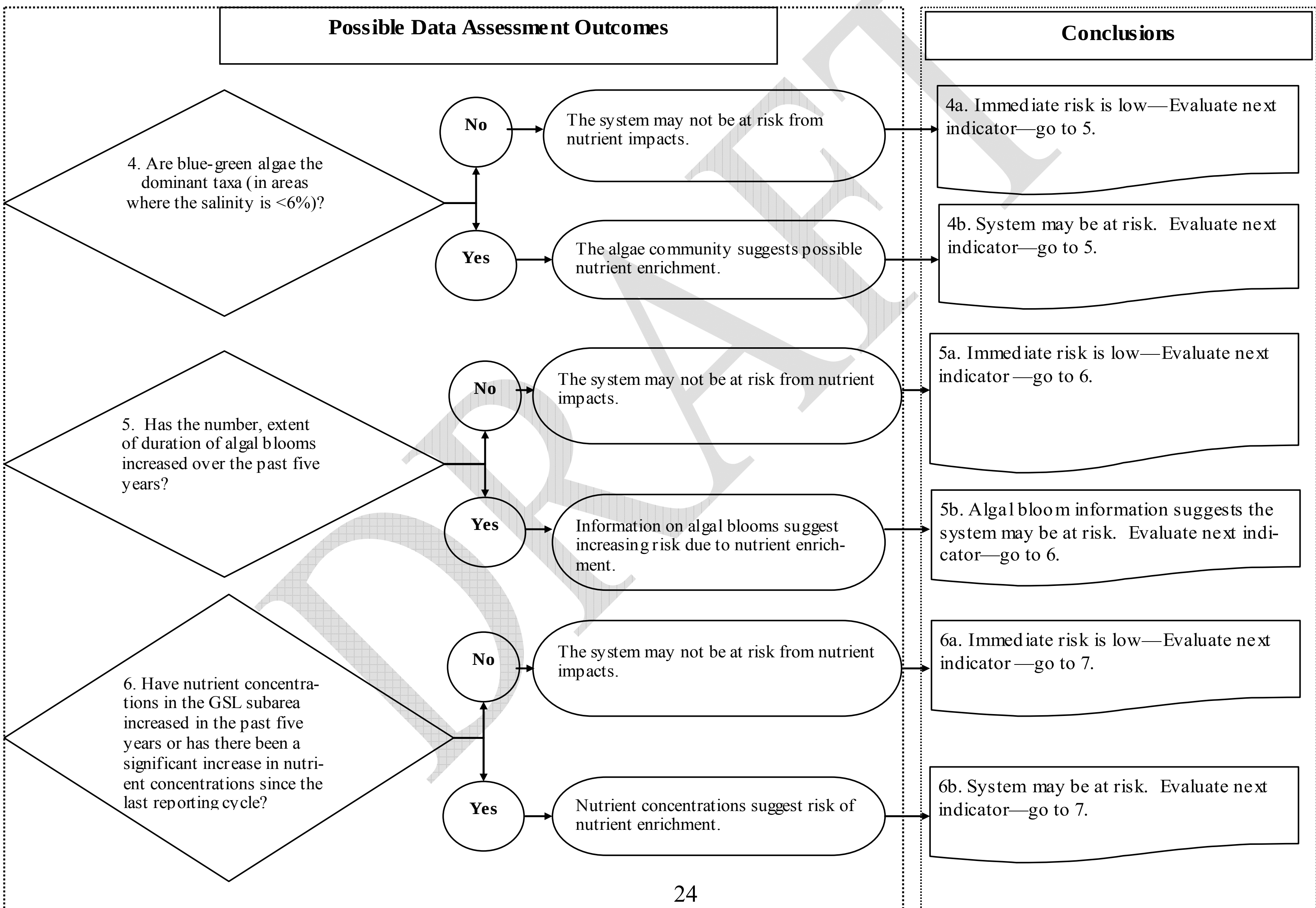


Figure 6.2- 2: Nutrient Draft Decision Rules (Step 4: Data Quality Objectives) (cont'd.)

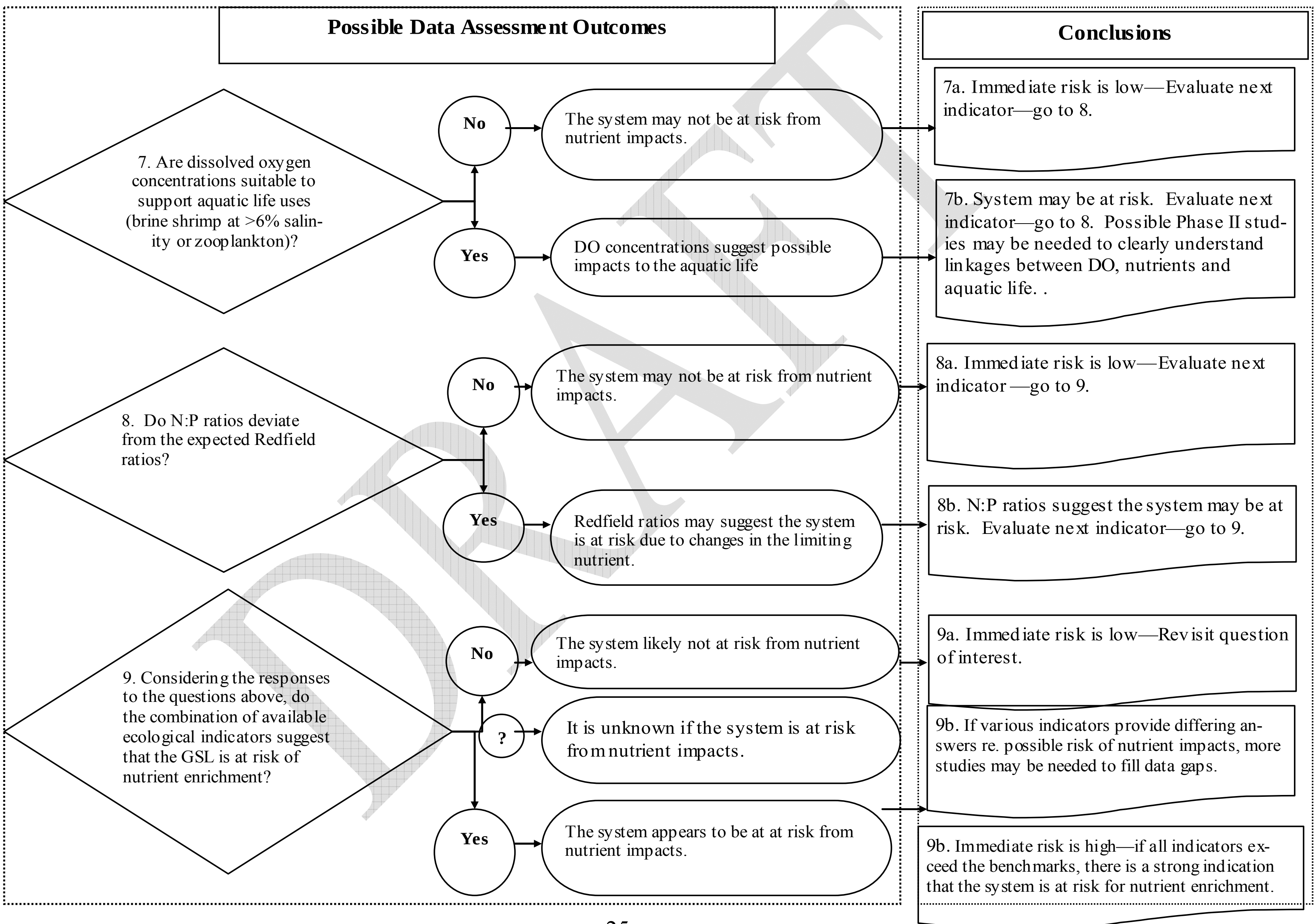


Table SS-1. Draft Mercury Assessment Framework

GSL All areas with waterfowl/ shorebird use						
Biological (biological assemblages), Chemical and Physical Integrity	**Direct Indicators**	**Indirect Indicators**	**Utility (applicability) of the Indicator (1-3 with 3 as highest)**	**Confidence in the Indicator**	**Threshold Value Available (Y/N) + Value**	**Exposure Location/Timeframe Represented by Indicator**
Waterfowl and Shorebirds	Waterfowl and/or shorebird health	total Hg in diet	3	3	total-Hg: Acute poisoning effects at 20 mg/kg (USEPA 1997). 10 mg/Kg (RAIS); 0.5 ppm (64 ug/kg bw/day) LOAEL for mallard ducks (Rfd = 21 ug/kg bw/d) (Heinz 1975); 0.3 ppm in fish caused reproductive effects in loons (Barr 1986). Effects levels of forage fish on avian species lies in the range of 0.077 to 0.3 ppm (Mercury Study Report to Congress). 0.3 to 0.4 ppm in prey resulted in reduced egg laying in loon (Schuehammer 1991 MRTC). Common dietary effect level 0.50 ug/g dw (USGS 2006). Free-living common loons show negative impacts when mercury in prey fish reaches 0.2 to 0.4 mg/kg wet weights (Barr 1986, Nocera and Taylor 1998, Scheuhammer 1995).	GSL linked exposure
		total Hg in kidney	3	2	total-Hg: Acute poisoning effects at 20 mg/kg (USEPA 1997). 20 mg/Kg (RAIS). 30 ug/g fresh weight in liver and kidney showed neurological effects (Scheuhammer 1991).	Not determined
		total Hg in liver	3	3	total-Hg: Acute poisoning effects at 20 mg/kg (USEPA 1997). 20 mg/Kg (RAIS); 23 ppm in liver of black ducks showed reproductive effects (Findley and Stendell, 1978 Mercury Report to Congress). total-Hg> 20 ug/g fresh weight of soft tissues extremely hazardous to avian species (Findley et al. 1979). 30 ug/g fresh weight in liver and kidney showed neurological effects (Scheuhammer 1991). Liver concentrations in adult pheasants and mallard ducks of 2 to 12 ug/g fresh weight linked to decreased hatchability of eggs (Scheuhammer 1991). Diagnosis of Hg poisoning with 20 ppm Hg in liver and presence of microscopic lesions.	Fairly recent exposure
		total Hg in blood	3	3	High risk associated with values >3.0 ug/g ww (USGS 2006).	Fairly recent exposure
		total Hg or methyl-Hg in feathers	3	2	Effects occur at 5 to 65 mg/kg dry weight (Burger and Gochfeld 1997).	Historic exposure record

		total Hg in brain	3	3	total-Hg: 15 ug/g fresh weight brain tissue showed neurological impacts (Scheuhammer 1991). Adult loons with 2 ppm fresh weight in brain showed aberrations in reproductive behavior (Barr 1986). 2 to 3 ppm in loon brain correlated with reduced eggs laying and nest and territorial fidelity in loon (Schuehammer 1991).	Not determined
		total Hg or methyl-Hg in muscle	3	3	None identified	Not determined
		total Hg or methyl-Hg concentrations in water column	3	3	methyl-Hg: OSWER Tier II Secondary Surface Water screening benchmark 3 ng/L. Tier II SAV Surface Water Screening Benchmark 99 ng/L. Tier II SCV Surface Water Screening Benchmark 2.8 ng/L. total-Hg: OSWER Ambient Water Quality Criteria 1,300 ng/L; EPA wildlife criteria for methyl-Hg 50 pg/L and t-Hg 641 pg/L (Mercury Report to Congress).	GSL linked exposure
		total Hg concentrations in sediments	3	3	total-Hg: OSWER Ecotox Thresholds sediment screening benchmark 0.15 mg/Kg	GSL linked exposure
	Waterfowl and/or shorebird reproductive success (hatching, fledgling)	total Hg in eggs (first egg or unhatched eggs are best)	3	3	total-Hg: 0.5 mg/Kg (RAIS); 2 to 3 ppm total-Hg in loon eggs correlated with reduced eggs laying and nest and territorial fidelity in loon (Schuehammer, 1991 MRTC). Values of 0.5 to 2.0 ug/g total-Hg in eggs sufficient to reduce viability, hatchability, embryo survival and chick survival in nonmarine birds (Thompson 1996). Embryo deformities occur in eggs with 1 ug/L total-Hg with sensitive embryos experiencing mortality with Hg as low as 0.74 ug/g (Heinz and Hoffman 2003). Often used reproductive effect endpoint for total-Hg in eggs is 0.80 ug/g (Heinz 1979, Henny et al. 2002). Adverse effects on reproduction occur at egg concentrations of 0.05 to 2.0 mg/kg total-Hg wet weight. (Global Mercury Assessment). Bird effects in general occur at egg concentrations of 0.05 to 5.5 mg/kg wet weight for total-Hg with majority around 0.5 to 1.0 mg/kg (Global Mercury Assessment). LOEC for avian egg = 0.5 ppm fresh weight (AEHHIM)	Represents recent exposure or mobilization from other tissues - local conditions and/or migratory conditions. Walsh 1990 suggested that eggs provide good indicator of mercury exposure in vicinity of nesting site in for immediate pre-laying season. (AEHHIM)

		total Hg in diet	3	3	total-Hg: 10 mg/Kg (RAIS); 0.5 ppm (64 ug/kg bw/day) LOAEL for mallard ducks (Rfd = 21 ug/kg bw/d) (Heinz 1975); 0.3 ppm in fish caused reproductive effects in loons (Barr 1986). Effects levels in forage fish lies in the range of 0.077 to 0.3 ppm (Mercury Study Report to Congress). 0.3 to 0.4 ppm in prey resulted in reduced egg laying in loon (Schuehammer, 1991 MRTC).	GSL linked exposure
		total Hg or methyl-Hg in down feathers	3		None identified	GSL linked exposure
		total Hg in liver	3	3	total-Hg: Liver concentrations in adult pheasants and mallard ducks of 2 to 12 ug/g fresh weight for total-Hg linked to decreased hatchability of eggs (Scheuhammer 1991 (MRTC)).	Fairly recent exposure
		total Hg in brain	3	3	total-Hg: Adult loons with 2 ppm fresh weight for total-Hg in brain showed aberrations in reproductive behavior (Barr 1986). 2 to 3 ppm in loon brain correlated with reduced eggs laying and nest and territorial fidelity in loon (Schuehammer 1991).	Not determined
		total Hg or methyl-Hg in dead chicks vs. live chicks	3	3	None identified	GSL linked exposure
Algae	Algae composition and abundance	total Hg or methyl-Hg concentration in algae cells	2	2	None identified	GSL linked exposure
		total Hg or methyl-Hg surface water concentrations	2	2	None identified	GSL linked exposure
Microorganisms	Composition and abundance	total Hg or methyl-Hg in surface water concentrations	2	2	Inorganic mercury effects reported at 5 ug/L in algal cultures. Organic mercury effects noted at 10 times lower concentrations (WHO/IPCS 1991)	GSL linked exposure
Macroinvertebrates (corixids in 5C, 5D and 5E), brine shrimp and brine fly larvae and adults)	Macroinvertebrate abundance	total Hg or methyl-Hg concentration in macros	2	2	None identified	GSL linked exposure

		total Hg surface water concentrations	3	3	total-Hg: Aquatic invertebrates vary in susceptibility with larval stages being more sensitive than adults. 48 hour exposure LC50's around 10 ug/L which are typically 100 times higher than those for adults. GMA.)	GSL linked exposure
		total Hg or methyl-Hg sediment concentrations	3	3	None identified	GSL linked exposure
Zooplankton/brine shrimp	Zooplankton composition and abundance	total Hg or methyl-Hg concentrations in zooplankton/brine shrimp	2	2	None identified	GSL linked exposure
		total Hg surface water concentrations	3	3	total-Hg: Daphnids EC20 870 ng/L; Daphnids LCV 40 ng/L	GSL linked exposure
Aquatic plants5E)	Composition and abundance	total Hg or methyl-Hg in surface water concentrations	2	1	Aquatic plants affected by mercury in water at concentration approaching 1 mg/L for inorganic mercury but at much lower concentrations of organic mercury (WHO/IPCS 1991).	GSL linked exposure
Chemistry	total Hg or methyl-Hg concentrations in water column		3	2	methyl-Hg: OSWER Tier II Secondary Surface Water screening benchmark 3 ng/L. Tier II SAV Surface Water Screening Benchmark 99 ng/L. Tier II SCV Surface Water Screening Benchmark 2.8 ng/L. total-Hg: OSWER Ambient Water Quality Criteria 1,300 ng/L; EPA wildlife criteria for m-Hg 50 pg/L and t-Hg 641 pg/L (Mercury Report to Congress). Minnesota Statewide TMDL Lake Superior Basin wildlife-based standards 1.3 ng/L. EPA Wildlife for m-hg US EPA 1997 - kingfisher - 33 pg/L, Loon 82 pg/L, Osprey 82 pg/L, Bald eagle 100 pg/L.	GSL linked exposure
	total Hg concentrations in sediments		3	2	total-Hg: OSWER Ecotox Thresholds sediment screening benchmark 0.15 mg/Kg	GSL linked exposure

Table TL-1. Gilbert Bay Draft Assessment Framework

5A Gilbert Bay (South Arm) - Hypersaline							
GSL Assessment Unit	**Designated Use**	**Salinity (correlates approximately to water level of 4202 Ft.)**	**Direct Indicators**	**Indirect Indicator**	**Utility or applicability of the Indicator (1-3 with 3 as highest)**	**Confidence in the Indicator (1-3 with 3 as highest)**	**Threshold Value Available (Y/N) + Value**
Gilbert Bay	Primary Contact Recreation	>6%	Health Advisories; Reports of Rashes or Illness			1	Yes; thresholds associated with human health
Gilbert Bay	Primary Contact Recreation	>6%		Cyanotoxins			order of magnitude above the WHO Human Health criteria (20 ug/l); 3 x times in a growing season (frequency) and duration should be considered; geometric mean of several samples
Gilbert Bay	Primary Contact Recreation	>6%	Cyanotoxins	Large surface mats of algae; aerial observation of color, density, etc.	3/1	3	significant increase in the # of blooms or in the frequency, extent,and duration of bloom;requires adequate historic aerial imagery or development of a baseline from 2007
Gilbert Bay	Primary Contact Recreation	>6%		Enterococci			geometric mean of 35 col/100 ml; mean Enterococci density (single sample max value) of: 104 col/100 mL; Need to evaluate if Enterococci fate and survival align with pathogen fate in higher salinity environments.
Gilbert Bay	Secondary Contact Recreation	>6%	Health Advisories; Reports of Rashes or Illness		3/1	1	threshold and the utility is currently under evaluation: anedoctal information indicates human health impacts
Gilbert Bay	Secondary Contact Recreation	>6%		Cyanotoxins			order of magnitude above the WHO Human Health criteria (20 ug/l); 3 x times in a growing season (frequency) and duration should be considered; geometric mean of several samples
Gilbert Bay	Secondary Contact	>6%	Cyanotoxins	Large surface mats of algae; aerial	3/1	3	significant increase in the # of blooms or in the frequency, extent,and

5A Gilbert Bay (South Arm) - Hypersaline							
GSL Assessment Unit	**Designated Use**	**Salinity (correlates approximately to water level of 4202 Ft.)**	**Direct Indicators**	**Indirect Indicator**	**Utility or applicability of the Indicator (1-3 with 3 as highest)**	**Confidence in the Indicator (1-3 with 3 as highest)**	**Threshold Value Available (Y/N) + Value**
	Recreation			observation of color, density, etc.			duration of bloom;requires adequate historic aerial imagery or development of a baseline from 2007
Gilbert Bay	Secondary Contact Recreation	>6%		Enterococci			geometric mean of 35 col/100 ml; mean Enterococci density (single sample max value) of: 501 col/100 mL. Need to evaluate if Enterococci fate and survival align with pathogen fate in higher salinity environments.
Gilbert Bay	Aquatic Life	>6%	Algae composition	Chlorophyll a	3/3 direct/indirect	3	Chl a literature thresholds: >60 ug/l (NEEA) for 3x in the growing season; TSI thresholds links to DO depletion
Gilbert Bay	Aquatic Life	>6%	Algae composition	TSI Values	2/3		increasing trend in TSI values over time tending towards hypereutrophy
Gilbert Bay	Aquatic Life	>6%	Algae composition	TSI Values	2		significant increase in TSI values between listing cycles
Gilbert Bay	Aquatic Life	>6%	Algae composition	% Blue-Green Dominance	1		blue-green algae as dominant taxa for 3x in the growing season – similar to current UDWQ lakes approach
Gilbert Bay	Aquatic Life	>6%	Algae composition	Paleolimnology	2/2		Comparison of historic diatom composition to present day
Gilbert Bay	Aquatic Life	>6%	Algae composition	Cyanotoxins	1/1	1	need to review existing literature to evaluate possible link to aquatic life; future studies may be needed
Gilbert Bay	Aquatic Life	>6%	Algae composition	Large surface mats of algae; aerial observation of color, density, etc.	3/1	1	Measure the # of blooms per year; significant increase in the # of blooms, extent, or the duration of bloom; requires adequate historic aerial imagery or development of a baseline from 2007; need more information
Gilbert Bay	Aquatic Life	>6%	Algae composition	Excess nutrients (N&P)	3/2	3	Nutrient concentrations shows increasing trend over time or a significant increase between reporting cycles; future research needed to develop site-specific numbers
Gilbert Bay	Aquatic Life	>6%	Algae composition	Redfield Ratio			Increasing trend in deviation from the expected Redfield ratio
Gilbert Bay	Aquatic Life	>6%	Brine shrimp		3	3	evaluate use of DWR's brine shrimp

5A Gilbert Bay (South Arm) - Hypersaline							
GSL Assessment Unit	**Designated Use**	**Salinity (correlates approximately to water level of 4202 Ft.)**	**Direct Indicators**	**Indirect Indicator**	**Utility or applicability of the Indicator (1-3 with 3 as highest)**	**Confidence in the Indicator (1-3 with 3 as highest)**	**Threshold Value Available (Y/N) + Value**
			density				data and relate to FB populations
Gilbert Bay	Aquatic Life	>6%	Brine shrimp density	DO	3/1	2	DO concentrations < 2mg/l for (24 hr average) or frequency (3x/ growing season) a specified duration or frequency days
Gilbert Bay	Aquatic Life	>6%	Brine shrimp density	Sulfides	3/1	3	review literature for possible thresholds
Gilbert Bay	Aquatic Life	>6%	Brine shrimp density	pH	3/1	3	review literature for possible thresholds
Gilbert Bay	Aquatic Life	>6%	Brine shrimp density	Salinity	3/1	3	existing literature values (Wurtsbaugh, Belovsky)
Gilbert Bay	Waterfowl	>6%	Population Counts of indicator bird species		1	1	
Gilbert Bay	Waterfowl	>6%	Hg Tissue Conc. in Birds (see Hg assessment framework)		3		

Table TL-2. Gunnison Bay Draft Assessment Framework

5B Gunnison Bay (North Arm) - Hypersaline							
GSL Assessment Unit	**Designated Use**	**Salinity (correlates approximately to water level of 4202 ft)**	**Direct Indicators**	**Indirect Indicator**	**Utility or applicability of the Indicator (1-3 with 3 as highest)**	**Confidence in the Indicator (1-3 with 3 as highest)**	**Threshold Value Available (Y/N) + Value**
Gunnison Bay	Primary Contact Recreation	>6%	Health Advisories; Reports of Rashes or Illness			1	Yes; thresholds associated with human health
Gunnison Bay	Primary Contact Recreation	>6%		Cyanotoxins	? (establish whether present)	3 (establish whether present)	order of magnitude above the WHO Human Health criteria (20 ug/l); 3 x times in a growing season (frequency) and duration should be considered; geometric mean of several samples
Gunnison Bay	Primary Contact Recreation	>6%	Cyanotoxins	Large surface mats of algae; aerial observation of color, density, etc.	3/1 (establish whether present)	3 (establish whether present)	significant increase in the # of blooms or in the frequency, extent, and duration of bloom; requires adequate historic aerial imagery or development of a baseline from 2007
Gunnison Bay	Primary Contact Recreation	>6%		Enterococci			geometric mean of 35 col/100 ml; mean Enterococci density (single sample max value) of: 104 col/100 mL; Need to evaluate if Enterococci fate and survival align with pathogen fate in higher salinity environments.
Gunnison Bay	Secondary Contact Recreation	>6%	Health Advisories; Reports of Rashes or Illness		3	1	threshold and the utility is currently under evaluation: anedoctal information indicates human health impacts
Gunnison Bay	Secondary Contact Recreation	>6%		Cyanotoxins	? (establish whether present)	? (establish whether present)	order of magnitude above the WHO Human Health criteria (20 ug/l); 3 x times in a growing season (frequency) and duration should be considered; geometric mean of several samples
Gunnison Bay	Secondary Contact Recreation	>6%	Cyanotoxins	Large surface mats of algae; aerial observation of color, density, etc.	3/1 (establish whether present)	3 (establish whether present)	significant increase in the # of blooms or extent and duration of bloom; requires adequate historic aerial imagery or development of a

5B Gunnison Bay (North Arm) - Hypersaline							
GSL Assessment Unit	**Designated Use**	**Salinity (correlates approximately to water level of 4202 ft)**	**Direct Indicators**	**Indirect Indicator**	**Utility or applicability of the Indicator (1-3 with 3 as highest)**	**Confidence in the Indicator (1-3 with 3 as highest)**	**Threshold Value Available (Y/N) + Value**
							baseline from 2007
Gunnison Bay	Secondary Contact Recreation	>6%		Enterococci			geometric mean of 35 col/100 ml; mean Enterococci density (single sample max value) of: 501 col/100 mL. Need to evaluate if Enterococci fate and survival align with pathogen fate in higher salinity environments.
Gunnison Bay	Aquatic Life	>6%	Algae composition	Chlorophyll a	3/3 direct/indirect	3	Chl a literature thresholds: >60 ug/l (NEEA) for 3x in the growing season; TSI thresholds links to DO depletion
Gunnison Bay	Aquatic Life	>6%	Algae composition	TSI Values	2/3		increasing trend in TSI values over time tending towards hypereutrophy
Gunnison Bay	Aquatic Life	>6%	Algae composition	TSI Values	3		significant increase in TSI values between listing cycles
Gunnison Bay	Aquatic Life	>6%	Algae composition	% Blue-Green Dominance	2		blue-green algae as dominant taxa for 3x in the growing season - current UDWQ lakes approach
Gunnison Bay	Aquatic Life	>6%	Algae composition	Paleoliminology	2/2		Comparison of historic diatom composition to present day
Gunnison Bay	Aquatic Life	>6%	Algae composition	Cyanotoxins	3/1	1	need to review existing literature to evaluate possible link to aquatic life; future studies may be needed
Gunnison Bay	Aquatic Life	>6%	Algae composition	Large surface mats of algae; aerial observation of color, density, etc.	3/1	1	Measure the # of blooms per year; significant increase in the # of blooms, extent, or the duration of bloom; requires adequate historic aerial imagery or development of a baseline from 2007; need more information
Gunnison Bay	Aquatic Life	>6%	Algae composition	Excess nutrients (N&P)	3/2	3	Nutrient concentrations shows increasing trend over time or a significant increase between reporting cycles; future research needed to develop site-specific numbers
Gunnison Bay	Aquatic Life	>6%	Algae composition	Redfield Ratio			Increasing trend in deviation from the expected Redfield ratio
Gunnison Bay	Aquatic Life	>6%	Brine shrimp density		3	3	evaluate use of DWR's brine shrimp data and relate to FB populations
Gunnison Bay	Aquatic Life	>6%	Brine shrimp	DO	3/1	2	DO concentrations < 2mg/l for (24 hr

5B Gunnison Bay (North Arm) - Hypersaline							
GSL Assessment Unit	**Designated Use**	**Salinity (correlates approximately to water level of 4202 ft)**	**Direct Indicators**	**Indirect Indicator**	**Utility or applicability of the Indicator (1-3 with 3 as highest)**	**Confidence in the Indicator (1-3 with 3 as highest)**	**Threshold Value Available (Y/N) + Value**
			density				average) or frequency (3x/ growing season) a specified duration or frequency days
Gunnison Bay	Aquatic Life	>6%	Brine shrimp density	Sulfides	3/1	3	review literature for possible thresholds
Gunnison Bay	Aquatic Life	>6%	Brine shrimp density	pH	3/1	3	review literature for possible thresholds
Gunnison Bay	Aquatic Life	>6%	Brine shrimp density	Salinity	3/1	3	existing literature values (Wurtsbaugh, Belovsky)
Gunnison Bay	Waterfowl	>6%	Population Counts of indicator bird species		3	3	Based upon long term (multi-year) trends in population counts
Gunnison Bay	Waterfowl	>6%	Hg Tissue Conc. in Birds (see Hg assessment framework)		3		

Table TL-3. Bear River Bay Draft Assessment Framework

5C Bear River Bay Open Water							
GSL Assessment Unit	**Designated Use**	**Salinity (correlates approximately to water level of 4198 ft)**	**Direct Indicators**	**Indirect Indicator**	**Utility or applicability of the Indicator (1-3 with 3 as highest)**	**Confidence in the Indicator (1-3 with 3 as highest)**	**Threshold Value Available (Y/N) + Value**
Bear River Bay	Secondary Contact Recreation			Health Advisories; Reports of Rashes or Illness	3	1	threshold and the utility is currently under evaluation: anedoctal information indicates human health impacts
Bear River Bay	Secondary Contact Recreation	<6%		Cyanotoxins			order of magnitude above the WHO Human Health criteria (20 ug/l); 3 x times in a growing season (frequency) and duration should be considered; geometric mean of several samples
Bear River Bay	Secondary Contact Recreation	<6%	Cyanotoxins	Large surface mats of algae; aerial observation of color, density, etc.	3/1	3	significant increase in the # of blooms or in the frequency, extent,and duration of bloom;requires adequate historic aerial imagery or development of a baseline from 2007
Bear River Bay	Secondary Contact Recreation	<6%		Enterococci			mean Enterococci density (single sample max value) of: 501 col/100 mL. Need to evaluate if Enterococci fate and survival align with pathogen fate in higher salinity environments.
Bear River Bay	Aquatic Life	<6%	Algae composition	Chlorophyll a	3/3 direct/indirect	3	Chl a literature thresholds: >60 ug/l (NEEA) for 3x in the growing season; TSI thresholds links to DO depletion
Bear River Bay	Aquatic Life	<6%	Algae composition	TSI Values	2/3		increasing trend in TSI values over time tending towards hypereutrophy
Bear River Bay	Aquatic Life	<6%	Algae composition	TSI Values	3		significant increase in TSI values between listing cycles
Bear River Bay	Aquatic Life	<6%	Algae composition	% Blue-Green Dominance	2		blue-green algae as dominant taxa for 3x in the growing season – similar to current UDWQ lakes approach
Bear River Bay	Aquatic Life	<6%	Algae composition	Paleoliminology	2/2		Comparison of historic diatom composition to present day
Bear River Bay	Aquatic Life	<6%	Algae composition	Cyanotoxins	3/3	1	need to review existing literature to evaluate possible link to aquatic life; future studies may be needed
Bear River Bay	Aquatic Life	<6%	Algae composition	Large surface	3/1	1	Measure the # of blooms per year; significant

5C Bear River Bay Open Water							
GSL Assessment Unit	**Designated Use**	**Salinity (correlates approximately to water level of 4198 ft)**	**Direct Indicators**	**Indirect Indicator**	**Utility or applicability of the Indicator (1-3 with 3 as highest)**	**Confidence in the Indicator (1-3 with 3 as highest)**	**Threshold Value Available (Y/N) + Value**
				mats of algae; aerial observation of color, density, etc.			increase in the # of blooms, extent, or the duration of bloom; requires adequate historic aerial imagery or development of a baseline from 2007; need more information
Bear River Bay	Aquatic Life	<6%	Algae composition	Excess nutrients (N&P)	3/2	3	Nutrient concentrations shows increasing trend over time or a significant increase between reporting cycles; future research needed to develop site-specific numbers
Bear River Bay	Aquatic Life	<6%	Algae composition	Redfield Ratio			Increasing trend in deviation from the expected Redfield ratio
Bear River Bay	Aquatic Life	<6%	Macroinvertebrate composition and abundance		2	1	No current thresholds - may not be worth exploring as a threshold - may relate to Phase II studies with links to brine flies/shrimp populations
Bear River Bay	Aquatic Life	<6%	Zooplankton composition and abundance		2	3	no current thresholds; review marine literature for possible thresholds; future research needed to develop thresholds
Bear River Bay	Aquatic Life	<6%	Zooplankton composition and abundance	DO	2/2		DO concentrations < DO tolerances of zooplankton for a specified duration (24 hr average) or frequency (3x/ growing season)
Bear River Bay	Aquatic Life	<6%	Zooplankton composition and abundance	pH	2/2		no current thresholds; review marine literature for possible thresholds
Bear River Bay	Aquatic Life	<6%	Zooplankton composition and abundance	Sulfides			review literature for possible thresholds
Bear River Bay	Aquatic Life	<6%	Zooplankton composition and abundance	Ammonia Concentrations			EPA WQ criteria
Bear River Bay	Aquatic Life	>6%	Brine shrimp density		3	3	evaluate use of DWR's brine shrimp data and relate to FB populations
Bear River Bay	Aquatic Life	>6%	Brine shrimp density	DO	3/1	2	DO concentrations < 2mg/l for (24 hr average) or frequency (3x/ growing season) a specified duration or frequency days
Bear River Bay	Aquatic Life	>6%	Brine shrimp density	Sulfides	3/1	3	review literature for possible thresholds
Bear River Bay	Aquatic Life	>6%	Brine shrimp density	pH	3/1	3	review literature for possible thresholds
Bear River Bay	Aquatic Life	>6%	Brine shrimp density	Salinity	3/1	3	existing literature values (Wurtsbaugh,

5C Bear River Bay Open Water							
GSL Assessment Unit	**Designated Use**	**Salinity (correlates approximately to water level of 4198 ft)**	**Direct Indicators**	**Indirect Indicator**	**Utility or applicability of the Indicator (1-3 with 3 as highest)**	**Confidence in the Indicator (1-3 with 3 as highest)**	**Threshold Value Available (Y/N) + Value**
							Belovsky)
Bear River Bay	Waterfowl	>6%	Population Counts of indicator bird species		3	3	Based upon long term (multi-year) trends in population counts
Bear River Bay	Waterfowl	>6%	Hg Tissue Conc. in Birds (see Hg assessment framework)		3		

Table TL-4. Farmington Bay Draft Assessment Framework

5D Farmington Bay Open Water							
GSL Assessment Unit	**Designated Use**	**Salinity (correlates approximately to water level of 4198 ft)**	**Direct Indicators**	**Indirect Indicator**	**Utility or applicability of the Indicator (1-3 with 3 as highest)**	**Confidence in the Indicator (1-3 with 3 as highest)**	**Threshold Value Available (Y/N) + Value**
Farmington Bay Open Water	Secondary Contact Recreation		Health Advisories; Reports of Rashes or Illness		3	1	threshold and the utility is currently under evaluation: anedoctal information indicates human health impacts
Farmington Bay Open Water	Secondary Contact Recreation	<6%		Cyanotoxins			order of magnitude above the WHO Human Health criteria (20 ug/l); 3 x times in a growing season (frequency) and duration should be considered; geometric mean of several samples
Farmington Bay Open Water	Secondary Contact Recreation	<6%	Cyanotoxins	Large surface mats of algae; aerial observation of color, density, etc.	3/1	3	significant increase in the # of blooms or in the frequency, extent,and duration of bloom;requires adequate historic aerial imagery or development of a baseline from 2007
Farmington Bay Open Water	Secondary Contact Recreation	<6%		Enterococci			mean Enterococci density (single sample max value) of: 501 col/100 mL. Need to evaluate if Enterococci fate and survival align with pathogen fate in higher salinity

5D Farmington Bay Open Water							
GSL Assessment Unit	**Designated Use**	**Salinity (correlates approximately to water level of 4198 ft)**	**Direct Indicators**	**Indirect Indicator**	**Utility or applicability of the Indicator (1-3 with 3 as highest)**	**Confidence in the Indicator (1-3 with 3 as highest)**	**Threshold Value Available (Y/N) + Value**
							environments.
Farmington Bay Open Water	Aquatic Life	<6%	Algae composition	Chlorophyll a	3/3 direct/indirect	3	Chl a literature thresholds: >60 ug/l (NEEA) for 3x in the growing season; TSI thresholds links to DO depletion
Farmington Bay Open Water	Aquatic Life	<6%	Algae composition	TSI Values	2/3		increasing trend in TSI chl a values over time tending towards hypereutrophy
Farmington Bay Open Water	Aquatic Life	<6%	Algae composition	TSI Values	3		significant increase in TSI values between listing cycles
Farmington Bay Open Water	Aquatic Life	<6%	Algae composition	% Blue-Green Dominance	2		blue-green algae as dominant taxa for 3x in the growing season - current UDWQ lakes approach
Farmington Bay Open Water	Aquatic Life	<6%	Algae composition	Paleolimnology	2/2		Comparison of historic diatom composition to present day
Farmington Bay Open Water	Aquatic Life	<6%	Algae composition	Cyanotoxins	3/1	1	need to review existing literature to evaluate possible link to aquatic life; future studies may be needed
Farmington Bay Open Water	Aquatic Life	<6%	Algae composition	Large surface mats of algae; aerial observation of color, density, etc.	3/1	1	Measure the # of blooms per year; significant increase in the # of blooms, extent, or the duration of bloom; requires adequate historic aerial imagery or development of a baseline from 2007; need more information
Farmington Bay Open Water	Aquatic Life	<6%	Algae composition	Excess nutrients (N&P)	3/2	3	Nutrient concentrations shows increasing trend over time or a significant increase between reporting cycles; future research needed to develop site-specific numbers
Farmington Bay Open Water	Aquatic Life	<6%	Algae composition	Redfield Ratio			Increasing trend in deviation from the expected Redfield ratio
Farmington Bay Open Water	Aquatic Life	<6%	Macroinvertebrate composition and abundance		2	1	No current thresholds - may not be worth exploring as a threshold - may relate to Phase II studies with

5D Farmington Bay Open Water							
GSL Assessment Unit	**Designated Use**	**Salinity (correlates approximately to water level of 4198 ft)**	**Direct Indicators**	**Indirect Indicator**	**Utility or applicability of the Indicator (1-3 with 3 as highest)**	**Confidence in the Indicator (1-3 with 3 as highest)**	**Threshold Value Available (Y/N) + Value**
							links to brine flies/shrimp populations
Farmington Bay Open Water	Aquatic Life	<6%	Zooplankton composition and abundance		2	3	no current thresholds; review marine literature for possible thresholds; future research needed to develop thresholds
Farmington Bay Open Water	Aquatic Life	<6%	Zooplankton composition and abundance	DO	2/2		DO concentrations < DO tolerances of zooplankton for a specified duration (24 hr average) or frequency (3x/ growing season)
Farmington Bay Open Water	Aquatic Life	<6%	Zooplankton composition and abundance	pH	2/2		no current thresholds; review marine literature for possible thresholds
Farmington Bay Open Water	Aquatic Life	<6%	Zooplankton composition and abundance	Sulfides			review literature for possible thresholds
Farmington Bay Open Water	Aquatic Life	<6%	Zooplankton composition and abundance	Ammonia Concentrations			EPA WQ criteria
Farmington Bay Open Water	Aquatic Life	>6%	Brine shrimp density		3	3	evaluate use of DWR's brine shrimp data and relate to FB populations
Farmington Bay Open Water	Aquatic Life	>6%	Brine shrimp density	DO	3/1	2	DO concentrations < 2mg/l for (24 hr average) or frequency (3x/ growing season) a specified duration or frequency days
Farmington Bay Open Water	Aquatic Life	>6%	Brine shrimp density	Sulfides	3/1	3	review literature for possible thresholds
Farmington Bay Open Water	Aquatic Life	>6%	Brine shrimp density	pH	3/1	3	review literature for possible thresholds
Farmington Bay Open Water	Aquatic Life	>6%	Brine shrimp density	Salinity	3/1	3	existing literature values (Wurtsbaugh, Belovsky)
Farmington Bay Open Water	Waterfowl	>6%	Population Counts of indicator bird species		3	3	Based upon long term (multi-year) trends in population counts
Farmington	Waterfowl	>6%	Hg Tissue Conc. in Birds (see Hg		3		

5D Farmington Bay Open Water							
GSL Assessment Unit	**Designated Use**	**Salinity (correlates approximately to water level of 4198 ft)**	**Direct Indicators**	**Indirect Indicator**	**Utility or applicability of the Indicator (1-3 with 3 as highest)**	**Confidence in the Indicator (1-3 with 3 as highest)**	**Threshold Value Available (Y/N) + Value**
Bay Open Water			assessment framework)				

Table TL-5. GSL Transitional Wetlands Draft Assessment Framework

5E GSL Transitional Wetlands									
GSL Area	**Designated Use**	**Hydrology**	**Salinity (correlates approximately to water level of 4202 ft)**	**Direct Indicators**	**Indirect Indicator**	**Utility or applicability of the Indicator (1-3 with 3 as highest)**	**Comments**	**Confidence in the Indicator (1-3 with 3 as highest)**	**Threshold Value Available (Y/N) + Value**
Transitional Wetlands	Secondary Recreation				Health Advisories; Reports of Rashes or Illness	3		1	thresholds are associated with human health
Transitional Wetlands	Secondary Contact Recreation		<6%		Cyanotoxins			order of magnitude above the WHO Human Health criteria (20 ug/l); 3 x times in a growing season (frequency) and duration should be considered; geometric mean of several samples	
Transitional Wetlands	Secondary Contact Recreation		<6%	Cyanotoxins	Large surface mats of algae; aerial observation of color, density, etc.	3/1	3	significant increase in the # of blooms or in the frequency, extent,and duration of bloom;requires adequate historic aerial imagery or development of a baseline from 2007	
Transitional Wetlands	Secondary Contact Recreation		<6%		Enterococci			mean Enterococci density (single sample max value) of: 501 col/100 mL. Need to evaluate if Enterococci fate and survival align with pathogen fate in higher salinity environments.	
Transitional Wetlands	Aquatic Life		<6%	Algae composition; Nodularia	Chlorophyll a	3/3 direct/indirect	Thresholds yet to be developed	3	no current threshold; needs to be developed
Transitional Wetlands	Aquatic Life		<6%	Algae composition; Nodularia	Cyanotoxins	3/3	Thresholds yet to be developed	1	thresholds are associated with human health
Transitional Wetlands	Aquatic Life			Algae composition; Nodularia	Large surface mats of algae; aerial observation of color, density, etc.	3/1		I1	review available data from other terminal lakes; develop threshold by evaluating blooms over time using aerial observations

5E GSL Transitional Wetlands

GSL Area	Designated Use	Hydrology	Salinity (correlates approximately to water level of 4202 ft)	Direct Indicators	Indirect Indicator	Utility or applicability of the Indicator (1-3 with 3 as highest)	Comments	Confidence in the Indicator (1-3 with 3 as highest)	Threshold Value Available (Y/N) + Value
Transitional Wetlands	Aquatic Life			Algae composition; Nodularia	Excess nutrients (N&P)	3/2	Thresholds yet to be developed	3	Redfield ratio literature and other marine literature
Transitional Wetlands	Aquatic Life			Macroinvertebrate composition and abundance		2	Thresholds yet to be developed	1	No current thresholds - may not be worth exploring
Transitional Wetlands	Aquatic Life			Zooplankton composition and abundance		2		3	no current thresholds; may review marine literature for possible thresholds
Transitional Wetlands	Aquatic Life			Zooplankton composition and abundance	DO, pH	2/2	Thresholds yet to be developed		
Transitional Wetlands	Waterfowl			Population Counts of indicator bird species		3	Eared grebes? Pelicans?	3	Based upon long term (multi-year) trends in population counts
Transitional Wetlands	Waterfowl			Macroinvertebrate composition and abundance		2	To determine available food resources	3	Literature data and Cavitt's study
Transitional Wetlands	Waterfowl			Hg Tissue Conc. in Birds (see Hg assessment framework)		3	Thresholds yet to be developed		