Contents

Contents ..... **iii**
1.0 Introduction **1-1**
1.1 Physical Setting 1-1
1.2 Resources Dependent on Great Salt Lake 1-5
1.3 Study Area 1-6
1.4 Lake Conditions during the Study Period 1-6
1.4.1 Lake Level 1-6
1.4.2 Surface Area and Volume 1-7
1.4.3 Salinity 1-7
1.4.4 Hydrology 1-8
1.5 Document Organization 1-9
2.0 Program Background **2-1**
2.1 Historical Perspective 2-1
2.2 Existing Regulatory Framework 2-1
2.3 Need for a Site-Specific Standard 2-3
2.4 Development of a Site-Specific Standard 2-3
3.0 Program Development **3-1**
3.1 Public Involvement, Consultation, and Coordination 3-1
3.1.1 Great Salt Lake Water Quality Steering Committee 3-1
3.1.2 Science Panel 3-5
3.1.3 Public Involvement Program 3-7
3.2 Program Development 3-8
3.2.1 Analytical Methodologies 3-8
3.2.2 Conceptual Model 3-11
3.2.3 Toxicity Threshold Values 3-15
3.2.4 Research Program 3-19
4.0 Program Objectives **4-1**
4.1 Program Objectives 4-1
4.1.1 Data Quality Objectives 4-1
4.1.2 Program Questions 4-1
4.2 Project Objectives 4-5
4.2.1 Project 1A, Concentration and Effects of Selenium in Shorebirds 4-7
4.2.2 Project 1B, Concentration and Effects of Selenium in Gulls, Grebes, and Ducks 4-9
4.2.3 Project 2A, Synoptic Survey of Selenium in Periphyton and Brine Fly Larvae from the Benthic Zone 4-11
4.2.4 Project 2B, Synoptic Survey of Selenium in Water, Seston, and Brine Shrimp 4-13
4.2.5 Project 3, Measurement of Selenium Loads to Great Salt Lake 4-15
4.2.6 Project 4, Measurement of Selenium Flux 4-17

4.2.7 Project 5, Predictions of Selenium Accumulation in *Artemia franciscana* under Conditions Realistic for the Populations Residing in the Great Salt Lake (Brine Shrimp Kinetics) 4-19
5.0 Program Results 5-1
5.1 Quality Assurance 5-1
5.2 Pending Results 5-1
5.2.1 Summary of Results 5-1
5.2.2 Project 1A, Concentration and Effects of Selenium in Shorebirds 5-2
5.2.3 Project 1B, Concentration and Effects of Selenium in Gulls, Grebes, and Ducks 5-8
5.2.4 Project 2A, Synoptic Survey of Selenium in Periphyton and Brine Fly Larvae from the Benthic Zone 5-19
5.2.5 Project 2B, Synoptic Survey of Selenium in Water, Seston, and Brine Shrimp 5-23
5.2.6 Project 3, Measurement of Selenium Loads to Great Salt Lake 5-27
5.2.7 Project 4, Measurement of Selenium Flux 5-31
5.2.8 Project 5, Brine Shrimp Kinetics Study 5-35
6.0 Quantitative Conceptual Model Development 6-1
6.1 Mass Balance Model 6-1
6.1.1 Water Mass Balance 6-1
6.1.2 Sediment 6-2
6.2 Bioaccumulation Model 6-3
6.2.1 Bird Dietary Item Tissue Concentrations 6-4
6.3 Birds 6-6
6.3.1 Statistics 6-7
6.3.2 Avian Model 6-8
6.3.3 Reproductive Effects 6-10
7.0 Quantitative Conceptual Model Results 7-1
7.1 Introduction 7-1
7.2 Mass Balance Model 7-1
7.3 Bioaccumulation Model 7-2
7.3.1 Water to Diet 7-3
7.3.2 Diet to Egg 7-3
7.3.3 Variability of Modeling Terms 7-7
7.3.4 Summary of Results 7-13
8.0 Implementation Issues 8-1
8.1 Considerations 8-1
8.2 Assessment and Management Framework 8-2
8.3 Long-term Verification 8-9
9.0 Key Observations and Conclusions 9-1
9.1 Key Observations 9-1
9.2 Conclusions 9-5
10.0 References 10-1

Tables

2-1 Beneficial Uses of Waters of Great Salt Lake
3-1 Great Salt Lake Water Quality Steering Committee Members, their Affiliations, and Alternates
3-2 Hatchability Reduction Estimate
5-1 Summary of Statistics for Selenium Analysis (µg/g dry weight) for Shorebirds
5-2 Summary Statistics for Selenium and Mercury Analyses (µg/g dry weight) for American Avocets (Shorebirds)
5-3 Summary Statistics for Selenium and Mercury Analyses (µg/g dry weight) for California Gulls
5-4 Summary Statistics for Selenium and Mercury Analyses (µg/g dry weight) for Eared Grebes
5-5 Summary Statistics for Selenium and Mercury Analyses (µg/g dry weight) for Common Goldeneyes
5-6 Summary Statistics for Body Mass, Liver Mass, and Fat Mass (grams wet weight) for Common Goldeneyes
5-7 Key Brine Fly Results from 2006–2007
5-8 Brine Shrimp Results from 2006–2007
5-9 Project 3 Data Summary
5-10 Project 4 Data Summary
6-1 Additional Data Used in Shorebird Regression Model
7-1 Measured versus Modeled Monthly Average Total Selenium Concentrations in Water (µg Se/L)
7-2 Variability of Monthly Geometric Means Used as Modeling Terms*
7-3 Diet and Egg Concentrations Calculated from Assumed Water Concentration
7-4 Water and Diet Concentration Calculated from Assumed Egg Concentration
7-5 Water and Diet Concentration Calculated from Assumed Egg Concentration
9-1 Egg Selenium Concentration vs. Best Estimate of Reduction in Mallard Egg Hatchability
9-2 Reduction in Mallard Egg Hatchability vs Best Estimate of Egg Selenium Concentration
9-3 Possible Outcomes for Shorebirds from the Bioaccumulation Model
9-4 Possible Outcomes for Gulls from the Bioaccumulation Model

Figures

1-1 Study Area
1-2 Lake Elevation and Inflow Volume throughout Study Period
1-3 Lake Elevation and Salinity
1-4 Lake Elevation and Inflow Volume 1993 to 2007
3-1 Organizational Structure
3-2 Process Chart for the Selenium Program
3-3 Simplified Conceptual Model for Selenium Cycling
3-4 Mallard Egg Hatchability versus Control as a Function of Selenium Concentration in Diet
3-5 Mallard Egg Hatchability versus Control as a Function of Selenium Concentration in Eggs
3-6 Delineation of Projects within the Conceptual Model
4-1 Program Questions Relative to Projects
4-2 Project 1A–Shorebirds
4-3 Project 1B–California Gulls, Eared Grebes, Common Goldeneye
4-4 Project 2A–Benthic Zone
4-5 Project 2B–Pelagic Zone
4-6 Project 3–Selenium Loads
4-7 Project 4–Selenium Flux
4-8 Project 5–Great Salt Lake
5-1 Project 1A – Shorebirds Sampling Locations
5-2 Project 1B – Gull, Eared Grebe, and Goldeneye Sampling Locations
5-3 Project 2A – Benthic Zone Sampling Locations
5-4 Project 2B – Pelagic Zone Sampling Locations
5-5 Project 3 – Selenium Load Sampling Locations
5-6 Project 4 – Selenium Flux Sampling Locations
6-1 Bioaccumulation Model Flow Chart
6-2 Measured vs. Modeled Brine Shrimp
6-3 Comparison of General Diet-to-Egg Selenium (Based on Mallard Studies) and Specific American Avocet and California Gull Models
6-4 Relationship between Shorebird Geometric Mean Diet and Egg Selenium (µg/g) at Various Locations
7-1 Bioaccumulation Model Flow Chart
7-2 Comparison of Three Brine Shrimp Models
7-3 Comparison of Three Shorebird Egg Models
7-4 Comparison of Three Gull Egg Models
8-1 Recommended Assessment and Management Framework for Selenium (Se) in Great Salt Lake
8-2 Major Variables Potentially Confounding the Relationship Between Waterborne and Egg Selenium
9-1 Tributary Selenium Loads

Appendices

A Conceptual Model for Selenium Cycling in the Great Salt Lake
B Threshold Values for Selenium in Great Salt Lake: Selections by the Science Panel
Threshold Values for Selenium in Great Salt Lake: Refined Selections by the Science Panel
Summary of Threshold Values for Selenium in the Great Salt Lake
C GSL Factsheet
Project 1A: Concentration and Effects of Selenium on Shorebirds at Great Salt Lake, Utah
Project 1A: Selenium and Mercury Concentrations in Breeding Female American Avocets at Ogden Bay, Great Salt Lake, Utah 2007
D Final Report: 2006 and 2007 Data Concentration and Effects of Selenium in California Gulls Breeding on the Great Salt Lake
Final Report: Concentrations of Selenium in Eared Grebes from the Great Salt Lake, Utah
Final Report: Concentrations of Selenium and Mercury in Common Goldeneyes from the Great Salt Lake, Utah
E Final Report Preliminary Analyses of Selenium Bioaccumulation in Benthic Food Webs of the Great Salt Lake, Utah
F Great Salt Lake Water Quality Studies Development of A Selenium Standard For The Open Waters of The Great Salt Lake Project 2B
Great Salt Lake Water Quality Studies Development of a Selenium Standard for the Open Waters of the Great Salt Lake Project 2B 2007 Update
G Estimation of Selenium Loads Entering the South Arm of Great Salt Lake, Utah
H Estimation of Selenium Removal Fluxes from the South Arm of the Great Salt Lake, Utah: Final Report 04-07-08
I Final Report for the "Brine Shrimp Kinetics Study, Project 5"
J Data Quality Assessment for the Great Salt Lake Water Quality Studies
K Avian Blood Sample Analysis Technical Memorandum
Selenium in Marine Birds Technical Memorandum
L Evaluation of Mercury Concentrations in Birds Collected from Great Salt Lake Technical Memorandum
M Science Panel White Papers

THIS PAGE INTENTIONALLY LEFT BLANK