# APPENDIX 7.I

## Water Quality Modelling Methods

# Table of Contents

**7.I.1 INTRODUCTION ..... 1**

**7.I.2 MODEL DEVELOPMENT ..... 1**

7.I.2.1 Mass Balance Equations ..... 1

7.I.2.2 Surface Water Partition Coefficients ..... 3

7.I.2.3 Baseline Case Flow and Concentration Inputs ..... 3

7.I.2.4 Application Case Flow and Concentration Inputs ..... 4

**7.I.3 DERIVATION OF NATURAL SURFACE WATER QUALITY INPUTS ..... 7**

7.I.3.1 Step 1 – Data Preparation and Examination ..... 7

7.I.3.2 Step 2 – Outlier Detection ..... 8

7.I.3.3 Step 3 – Distribution Fitting ..... 9

7.I.3.4 Step 4 – Test Goodness of Fit ..... 9

7.I.3.5 Step 5 – Bounding the Selected Distribution ..... 10

**7.I.4 BASELINE MODEL CALIBRATION APPROACH ..... 11**

**7.I.5 REFERENCES ..... 14**

**TABLES**

Table 7.I.2-1: Summary of Projected Effluent Quality for Effluent Treatment Facility Option 3 (Ion Exchange) ..... 6

Table 7.I.3-1: General Procedure for Assigning a Maximum Bound to a Distribution with an Unreasonable Extreme Value ..... 11

Table 7.I.3-2: Summary of Calibration Factors Applied to the Baseline Case Model ..... 12

**FIGURES**

Figure 7.I.2-1: Baseline Flow Schematic for Water Quality Model in GoldSim™ ..... 2

**APPENDICES**

**Attachment 7.I.I**
Derived Distribution Statistics for Seasonal Background Surface Water Quality and $Kd_{sw}$ Inputs

**Attachment 7.I.II**
Calibration of Baseline Predictions to Observed Baseline Data

## 7.I.1 INTRODUCTION

This appendix presents a detailed description of the surface water quality model developed in the GoldSim™ modelling environment to predict water quality concentrations in surface waters potentially affected by the NICO cobalt, gold, bismuth, and copper Project (NICO Project) proposed by Fortune Minerals Ltd. (Fortune). The purpose of this document is to detail model inputs, approaches, assumptions, and other supporting information that were not fully presented in Section 7.6 of the Developer's Assessment Report (DAR).

## 7.I.2 MODEL DEVELOPMENT

The NICO Project Water Quality Model (WQM) was developed using GoldSim™, which is a modelling platform for developing dynamic, probabilistic simulations of complex systems (GoldSim Technology Group 2010). The Contaminant Transport (CT) module in GoldSim™ is an extension of the modelling system that specifically supports simulation of the release, transport, and fate of mass (i.e., chemical constituents) within engineered and/or natural environmental systems. The CT module includes model elements used to represent environmental volumes and pathways, and the solid and/or fluid media present within them.

The WQM was constructed as a network of waterbodies, each with a defined surface area and average volume as determined by baseline bathymetric surveys (Annex C, Section 2.2), that ultimately flow into the Marian River. A constant volume assumption (i.e., outflows = sum of inflows) was used for the waterbodies in the model.

A schematic of the WQM for the NICO Project is provided in Figure 7.I.2-1. The figure illustrates the nodes included in the model, the inflows and outflows for each node and linkages between the nodes.

### 7.I.2.1 Mass Balance Equations

The following mass balance equation was used in GoldSim™ CT Cell elements to calculate constituent concentrations in modelled waterbody nodes:

$$C = \frac{\sum_{i=1}^{n} I_i + m - I_o}{V} \qquad \text{(equation 1)}$$

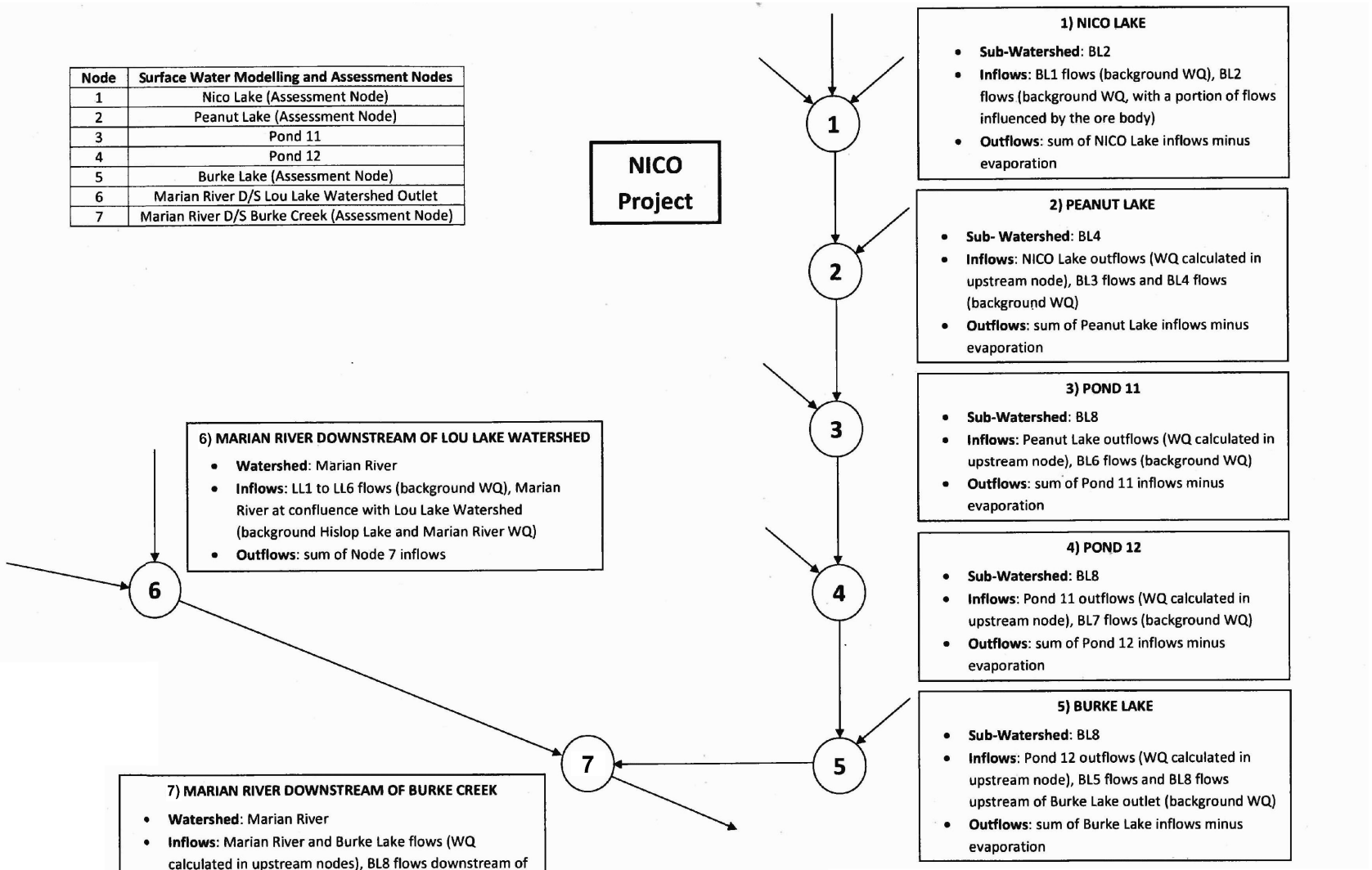
where:

| | | |
|---|---|---|
| $C$ | = | predicted concentration in the waterbody (milligrams per litre [mg/L]); |
| $I_i$ | = | mass in inflow 'i' discharging into the waterbody (mg); |
| $m$ | = | mass in the waterbody (mg); |
| $I_o$ | = | mass in outflow from the waterbody (mg); |
| V | = | volume of the waterbody (L); and |
| $n$ | = | number of inflows. |

Mass loading for each inflow was calculated based on the concentration and flow rate for each source or a direct mass input in the case of dust deposition. Mass loading for the outflow was calculated based on the average concentration in the waterbody and the sum of inflows, as the waters were assumed to be completely mixed during each time step. The WQM ran on a daily timestep.

| Node | Surface Water Modelling and Assessment Nodes |
|---|---|
| 1 | Nico Lake (Assessment Node) |
| 2 | Peanut Lake (Assessment Node) |
| 3 | Pond 11 |
| 4 | Pond 12 |
| 5 | Burke Lake (Assessment Node) |
| 6 | Marian River D/S Lou Lake Watershed Outlet |
| 7 | Marian River D/S Burke Creek (Assessment Node) |

**NICO Project**




**1) NICO LAKE**
- **Sub-Watershed**: BL2
- **Inflows**: BL1 flows (background WQ), BL2 flows (background WQ, with a portion of flows influenced by the ore body)
- **Outflows**: sum of NICO Lake inflows minus evaporation

**2) PEANUT LAKE**
- **Sub- Watershed**: BL4
- **Inflows**: NICO Lake outflows (WQ calculated in upstream node), BL3 flows and BL4 flows (background WQ)
- **Outflows**: sum of Peanut Lake inflows minus evaporation

**3) POND 11**
- **Sub-Watershed**: BL8
- **Inflows**: Peanut Lake outflows (WQ calculated in upstream node), BL6 flows (background WQ)
- **Outflows**: sum of Pond 11 inflows minus evaporation

**4) POND 12**
- **Sub-Watershed**: BL8
- **Inflows**: Pond 11 outflows (WQ calculated in upstream node), BL7 flows (background WQ)
- **Outflows**: sum of Pond 12 inflows minus evaporation

**5) BURKE LAKE**
- **Sub-Watershed**: BL8
- **Inflows**: Pond 12 outflows (WQ calculated in upstream node), BL5 flows and BL8 flows upstream of Burke Lake outlet (background WQ)
- **Outflows**: sum of Burke Lake inflows minus evaporation

**6) MARIAN RIVER DOWNSTREAM OF LOU LAKE WATERSHED**
- **Watershed**: Marian River
- **Inflows**: LL1 to LL6 flows (background WQ), Marian River at confluence with Lou Lake Watershed (background Hislop Lake and Marian River WQ)
- **Outflows**: sum of Node 7 inflows

**7) MARIAN RIVER DOWNSTREAM OF BURKE CREEK**
- **Watershed**: Marian River
- **Inflows**: Marian River and Burke Lake flows (WQ calculated in upstream nodes), BL8 flows downstream of Burke Lake outlet (background WQ), flows from local Marian River watershed area (background WQ)

LEGEND

(1) MODELLING NODE

→ FLOW PATH

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

# BASELINE FLOW SCHEMATIC FOR WATER QUALITY MODEL IN GOLDSIM

Golder Associates
Edmonton, Alberta

| | | | | |
|---|---|---|---|---|
| PROJECT 09.1373.1004.9000 | | | FILE No. E-WQ-006-CAD | |
| DESIGN | JP | 29/06/10 | SCALE AS SHOWN | REV. 0 |
| CADD | GMF | 17/05/11 | FIGURE: 7.I.2-1 | |
| CHECK | JV | 17/05/11 | | |
| REVIEW | JV | 17/05/11 | | |

The following mass balance equation was used to predict concentrations at the Marian River downstream of the outlet creek from Burke Lake:

$$C = \frac{\sum_{i=1}^{n} c_i q_i}{\sum_{i=1}^{n} q_i} \qquad \text{(equation 2)}$$

where:

$C$ = predicted concentration in the river (mg/L);

$c_i$ = concentration in inflow 'i' contributing to the total flow in the river (mg/L); and

$q_i$ = flow rate of inflow 'i' ($m^3/s$).

## 7.I.2.2 Surface Water Partition Coefficients

Constituent mass partitioning between media is a built-in functionality of the GoldSim™ CT module. In the WQM, this functionality was used to partition constituent mass between suspended solids and water, supporting predictions of total and dissolved metals concentrations. The dissolved phase water concentration was calculated from the predicted total water column concentration ($C_{wctot}$), suspended solid-water partition coefficient ($Kd_{sw}$) and TSS concentration (Equation 3).

$$C_{dw} = \frac{C_{wctot}}{1 + Kd_{sw} * TSS * \frac{1\ kg}{1000000\ mg}} \qquad \text{(equation 3)}$$

Although literature values are available for partition coefficients of most metals, partition coefficients were selected as calibration parameters due to the variability associated with their numerical values. Partition coefficient values observed in different environmental systems and reported by various agencies may vary by several orders of magnitude. Therefore, observed baseline water sample concentrations were used to derive partition coefficients for use in the WQM.

The suspended solid-water partition coefficient ($Kd_{sw}$) was calculated from the total water column concentration ($C_{wctot}$), dissolved phase water concentration ($C_{dw}$) and total suspended solids concentration (TSS). The calculation was derived by rearranging Equation 3 to arrive at Equation 4.

$$Kd_{sw} = \frac{C_{wctot} - C_{dw}}{C_{dw} * TSS * \frac{1\ kg}{1000000\ mg}} \qquad \text{(equation 4)}$$

## 7.I.2.3 Baseline Case Flow and Concentration Inputs

For the Baseline Case model, all inflows were from natural sources. Natural surface flows were included in the WQM as daily background surface water flow time series, derived for each sub-watershed in the Lou Lake and Burke Lake watersheds, and for the Marian River immediately upstream of the confluence with the outlet of Burke Lake. The flow series were derived from concurrent hydrometric monitoring records over a period of 26 years, from 2 Water Survey of Canada stations with similar latitudes and watershed areas that are similar to the Burke Lake and Marian River watershed areas. These background flow time series were calibrated to flows

observed during baseline monitoring programs. Details on the derivation of the background flow time series are provided in Annex G, Sections 5.6 and 5.7.

The water quality of 3 natural water sources were derived from baseline monitoring data and used as inputs to the WQM, including:

- local waters not influenced by the NICO Project ore body (e.g., Nico Lake inflows, Reference Lake watershed, Lou Lake, and Lion Lake);
- local waters directly influenced by the NICO Project ore body (e.g., Grid Pond, Little Grid Pond); and
- the Marian River watershed (e.g., Hislop Lake and the Marian River upstream of Burke Creek).

Methods used to derive the water quality of these natural waters and to calibrate the Baseline Case model are described in Sections 7.I.3 and 7.I.4.

### 7.I.2.4 Application Case Flow and Concentration Inputs

The Application Case model was built upon the calibrated Baseline Case model, incorporating alterations that reflect changes in surface water quantity and quality inputs as a result of NICO Project activities. The Application Case model accounts for the following NICO Project-related changes:

- Reductions in background flows associated with:
  - changes in watershed areas due to mine footprint development and reclamation;
  - predicted reductions in base flow recharge; and
  - water withdrawals from Lou Lake;
- Discharges from the Effluent Treatment Facility (ETF) to Peanut Lake;
- Seepages to Nico Lake during operations from the Surge Pond, Plant Site Sump, and Seepage Collection Ponds;
- Flows from treatment wetlands to Nico Lake beginning at closure, which were assumed to intercept seepage flows from the Surge Pond and Seepage Collection Ponds; and
- Deposition of suspended particulates and associated metals during the construction and operations phases, using assumptions consistent with those described in Section 7.6.2 of the DAR that were modified for application on a daily versus annual basis:
  - particulates deposited throughout the Burke Lake watershed area are not retained on the landscape and report to surface waters;
  - the particulate mass fraction (and associated metals) less than or equal to 10 µm (i.e., $PM_{10}$ fraction) remains in suspension indefinitely;
  - the particulate mass fraction (and associated metals) greater than 10 µm (i.e., larger than $PM_{10}$ fraction) is assumed to settle to lake sediments instantaneously;
  - metals concentrations were assumed to be uniformly distributed among all particulate mass fractions;

- annual maximum rates of particulate deposition report to surface waters during the open-water season (i.e., May through October); and
- particulate deposition accumulates during winter and the accumulated mass reports to surface waters at a constant rate during May and June.

Discharge from the Sewage Treatment Plant (STP) to Peanut Lake was not included in the model, as the rate of release is small, relative to discharges from the ETF and receiving environment flows, and ammonia concentrations in the STP effluent are expected to be below the site-specific water quality objectives value.

Detailed information on predicted changes to base flow recharge is provided in Appendix 11.I. Information on withdrawal rates from Lou Lake is provided in Section 3.9 of the DAR, and in Appendix 11.II. Detailed information on the NICO Project water balance and associated receiving water inputs and site water chemistry predictions is provided in Appendix 7.II, and additional detail regarding application of the site flows and chemistry predictions in the WQM is provided below.

Site water chemistry predictions were prepared on a monthly basis for early operations, late operations (worst case), and closure using the corresponding water balance predictions. The maximum monthly concentrations were carried forward to a water treatment options analysis, which included predictions of ETF discharge quality during operations. Projected ETF discharge quality is presented in Table 7.I.2-1 for the treatment option selected for the DAR, and was included in the WQM. Maximum site water quality predictions were also used directly in the WQM for seepages to Nico Lake during operations. A linear interpolation was applied annually between the 2 sets of operations flows and chemistry predictions (i.e., early operations and late operations/worst case) for each source reporting to Nico and Peanut lakes (i.e., seepage and ETF discharges).

Monthly concentration predictions for waters influent to the treatment wetlands (Wetland Treatment Systems No. 1, 2, and 3; Appendix 7.II) were applied to flows to Nico Lake during closure. These influent concentrations were adjusted to cap predicted exceedances of site-specific water quality objectives concentrations at the respective objective concentrations. No further adjustments were applied due to uncertainty regarding the constituent-specific effectiveness of the planned passive treatment system.

**Table 7.I.2-1: Summary of Projected Effluent Quality for Effluent Treatment Facility Option 3 (Ion Exchange)**

| Constituent | Units | Early Operations | Worst Case |
|---|---|---|---|
| **Major Ions** | | | |
| Calcium | mg/L | 1.7 | 3.6 |
| Chloride | mg/L | 2.9 | 5.4 |
| Magnesium | mg/L | 0.64 | 1.24 |
| Potassium | mg/L | 26.5 | 52.7 |
| Sodium | mg/L | 3.5 | 12.0 |
| Sulphate | mg/L | 7.8 | 21.1 |
| **Nutrients** | | | |
| Ammonia | mg-N/L | 1.54 | 1.54 |
| Nitrate | mg-N/L | 1.55 | 1.55 |
| Phosphorus | mg/L | 0.014 | 0.026 |
| **Total Metals** | | | |
| Aluminum | mg/L | 0.024 | 0.058 |
| Antimony | mg/L | 0.00028 | 0.00051 |
| Arsenic | mg/L | 0.0041 | 0.0072 |
| Barium | mg/L | 0.008 | 0.011 |
| Beryllium | mg/L | 0.000066 | 0.00015 |
| Boron | mg/L | 0.022 | 0.059 |
| Cadmium | mg/L | 0.000037 | 0.000037 |
| Chromium | mg/L | 0.00033 | 0.00033 |
| Cobalt | mg/L | 0.0045 | 0.0047 |
| Copper | mg/L | 0.0014 | 0.0016 |
| Iron | mg/L | 0.375 | 0.465 |
| Lead | mg/L | 0.00007 | 0.00015 |
| Manganese | mg/L | 0.0026 | 0.0028 |
| Mercury | mg/L | 0.0000012 | 0.0000016 |
| Molybdenum | mg/L | 0.0028 | 0.0055 |
| Nickel | mg/L | 0.0010 | 0.0017 |
| Selenium | mg/L | 0.0025 | 0.0063 |
| Silver | mg/L | 0.00026 | 0.00026 |
| Thallium | mg/L | 0.00026 | 0.00026 |
| Uranium | mg/L | 0.0035 | 0.0061 |
| Vanadium | mg/L | 0.00018 | 0.00024 |
| Zinc | mg/L | 0.0050 | 0.0058 |

mg/L = milligrams per litre

## 7.I.3 DERIVATION OF NATURAL SURFACE WATER QUALITY INPUTS

For each natural surface water type noted in Section 7.I.2, unique probability distributions were derived and assigned to each of the water quality constituents used to describe the quality of that water. Available surface water quality data were compiled and used to develop the distributions following a standardized screening process. The process included the following steps:

- Step 1 - determine if there are sufficient data to support the development of a probability distribution;
- Step 2 - identify and remove outliers from the measured data;
- Step 3 - fit 3 possible probability distributions to the remaining data;
- Step 4 - assess the goodness of fit for all applicable distributions to determine the most appropriate distribution type; and
- Step 5 - determine the minimum and maximum bounds to define a reasonable range for the chosen distribution.

A detailed description of each of the steps is presented below.

### 7.I.3.1 Step 1 – Data Preparation and Examination

The standardized screening process consisted of first replacing any values that were below the method detection limit (MDL) with a value equivalent to half the MDL. For some constituents, the dataset contained results that were of little value, because they were analyzed with high analytical detection limits. Such high results were eliminated from the dataset, because they can bias the selected distribution. This step mainly applied to data that were collected in the baseline programs prior to 2008.

Once the non-detectable results were addressed, the dataset was examined for 3 special cases that may occur during the distribution fitting process. These included: 1) datasets with less than 10 observations; 2) datasets with numerous observations at a single value; and 3) datasets with all observations less than the MDL.

A lognormal or delta-lognormal distribution was imposed when there were less than ten observations in the dataset. In this situation, a lognormal distribution was selected when more than 50% of the observations were reported as above the method detection limit. Conversely, a delta-lognormal distribution was selected when 50% or more of the observations were reported as less than the method detection limit and there were less than ten observations in the dataset. Both distributions were characterized using a coefficient of variation equal to 0.6, consistent with U.S. EPA recommendations (U.S. EPA 1991).

If the dataset consists of numerous observations at a single value, professional judgment was used to assign a distribution. In some cases, a distribution was assigned based on a surrogate water type. In other cases, the chosen distribution was a constant value (i.e., a Dirac function).

If all data were reported as less than the MDL, a distribution was assigned based on a surrogate water type or a zero value was assumed.

### 7.I.3.2 Step 2 – Outlier Detection

"Outlier" is a collective term that refers to either a contaminant or a discordant observation (Beckman and Cook 1983). A contaminant observation is a value that may induce bias to the fitted distribution, and the reason for its characteristics can be explained. A discordant observation is a value that appears surprising or discrepant to the investigator, but the origin of the result is unknown.

If a measurement was identified as an outlier, the origin of the result was investigated to validate the results of the outlier detection tests. Outliers of explainable origins (i.e., there was a reason for the anomalous result) were considered contaminants and removed from the dataset without further consideration. Outliers of unknown origin were considered discordant observations and retained in the dataset for further investigation. Three statistical tests were used to identify outliers. These included the 3σ rule, the Hampel identifier and the combined Rosner - Dixon test, descriptions of which are presented below. An observation was considered an outlier only if all 3 tests identified it as one. By using multiple tests, the possibility of misdiagnosis was reduced (Jain 1981; Beckman and Cook 1983; WMO 1985; Pearson 2001; Kottegoda 1984). Misdiagnosis is often referred to as: 1) *swamping* or Type I error, when a normal datum is falsely identified as an outlier, or 2) *masking* or Type II error, when an outlier is falsely identified as a normal datum (Jain 1981; Beckman and Cook 1983).

The 3 statistical tests commonly identify an observation "x" as an outlier if "x" meets the following criterion:

$$x > L + kS \qquad \text{(equation 5)}$$

where L is a location parameter (i.e., a reference in the sample domain), S is a scale or dispersion parameter, and k is a parameter that indicates a tolerance level to dispersion. The 3 outlier tests differ in their definition of L, S, and k as described below. Ideally, the observations would be independent of one another, and follow a normal distribution. Lognormal data must be log transformed prior to the application of the detection tests.

The 3σ rule is the most common of the outlier tests, because it is simple to implement and uses well known statistical properties. That is, the mean and the standard deviation define L and S (Pearson 2001). The 3σ rule test is a single-outlier detection test, so consecutive testing for many-outlier detection is required (Beckman and Cook 1983). The mean and standard deviation are calculated for the dataset being analysed. If the maximum value is identified as an outlier (i.e., it is greater than the sum of the mean and 3 standard deviations), it is removed from the dataset. A new mean and standard deviation are then calculated for the remaining data, and the maximum observed value is again tested. This iterative process continues until no outlier is detected. Although simple to implement, this test has been known to perform Type II errors (Pearson 2001). Consecutive testing may attenuate this problem in the best case, or possibly generate Type I errors in the worst case.

The Hampel identifier was developed to address some of the masking issues that can affect the 3σ rule (Pearson 2001). Hampel (1985) first proposed this test, and it was evaluated further by Davies and Gather (1993) and Pearson (2001). Although this test has not yet been used systematically on water quality data, its resemblance with the 3σ rule makes it suitable for that purpose. The Hampel identifier can be considered as a many-outlier detection test, so an iterative process is not needed. This test may result in either Type I or II errors, depending on the nature of the data.

The Rosner test was specifically designed to reduce the masking effect encountered in other outlier detection tests. The Rosner test is considered a suitable test for outliers in water quality data (Gilbert 1987; Jain 1981), but is only applicable when the sample size is greater or equal to 25. The first version of the test was presented in

Rosner (1975; 1983), and an evaluation performed by Jain (1981) validated the efficiency of the test. However, Jain (1981) noted the importance of carefully selecting the number of outliers expected in the dataset, since the test will only analyze as many outliers as specified by the user. The number of outliers is set at 30% of the sample size for this analysis, since it was unlikely that more than 30% of the dataset were outlier values. This test is suspected to perform Type I errors (Beckman and Cook 1983).

When the sample size was less than 25, the Dixon test was used in place of the Rosner test (Dixon 1950, 1951, 1953; Sokal and Rohlf 1981; Gilbert 1987). Because it is a single-outlier detection test, it is recommended that consecutive testing be performed to account for the possible presence of multiple outliers, similar to the 3σ rule. This test may perform Type II errors, although consecutive testing may attenuate this problem in the best case, and possibly generate Type I errors in the worst case.

As mentioned previously, the 3σ rule, Hampel identifier and the combined Rosner - Dixon tests were used in combination to avoid Type I and II errors. An observation was considered an outlier only if all 3 tests identified it as one, and even then, the outliers were examined subsequently to check the validity of the procedure. Outliers were only eliminated when calculating the mean and standard deviation of the selected distribution. The upper bound of the distribution was determined using the entire dataset, including outliers, because an outlier may represent a reasonable, worst-case concentration.

### 7.I.3.3 Step 3 – Distribution Fitting

The general formats of the fitted distributions were normal, lognormal or delta-lognormal. These 3 types of distributions can generally be used to characterize water quality information in any receiving waterbody (U.S. EPA 1991). A delta-lognormal distribution describes a dataset that contains a combination of measurements that follow a lognormal distribution and non-detectable results that occur with a certain probability (U.S. EPA 1993). In practice, the delta-lognormal distribution was applied by combining a lognormal and uniform distribution. The average of the MDLs formed the upper bound of the uniform distribution and the lower bound of the lognormal distribution. The percentage of time that each distribution was sampled was proportional to the percentage that exists in the observed dataset. For example, if the dataset was found to follow a delta-lognormal distribution, and 80% of the measurements were below the MDL, the uniform distribution was sampled 80% of the time, whereas the lognormal distribution was sampled the remaining 20% of the time.

To identify which distribution best described the parameter in question, all 3 distributions were initially fitted to the available measured data. Statistical goodness-of-fit tests, such as the Chi-square test, the Kolmogorov-Smirnov test and the squared correlation coefficient (Sokal and Rohlf 1981), were used to determine which distribution type was most appropriate (see Step 4).

### 7.I.3.4 Step 4 – Test Goodness of Fit

The Chi-square test is a common non-parametric procedure used to evaluate the goodness of fit of probability distributions. It is a standard test for frequency analysis, and its description, limitations and usage can be found in Ang and Tang (1975), Conover (1980), Sokal and Rohlf (1981), and Walpole and Myers (1978). The Chi-square test examines the uniformity of the probability of non-occurrence of the values of the dataset. It was assumed that the probability distribution chosen for a dataset was adequate if this condition of uniformity was met. Uniformity was determined by counting how many values fall within given ranges of quantiles. The numerical result of this test was assumed to follow a Chi-square distribution. If the numerical result was below that from the Chi-square distribution for a given quantile (usually 0.95) and for a given degree of freedom, then

the distribution was assumed to be suitable. The Chi-square test can be difficult to apply to water quality data, since datasets may often be too small, or contain too many replicates for the test to provide useful results. Therefore, the test was employed only to provide support in the decision process, not as a decision criterion.

Like the Chi-square test, the Kolmogorov-Smirnov test is a non-parametric procedure used to evaluate the goodness of fit of probability distributions (Ang and Tang 1975; Conover 1980; Gilbert 1987; Sokal and Rohlf 1981). This test compares the differences between the observed (i.e., the Weibull distribution) and predicted cumulative frequency distributions (i.e., the normal, lognormal and delta-lognormal distributions) and determines whether the maximum difference is significant. The maximum difference was assumed to follow the Kolmogorov-Smirnov distribution (French et al. 1992). The distribution was rejected if the maximum difference was greater than that from the Kolmogorov Smirnov distribution at the 0.95 quantile. This test was used as a decision criterion. It was required that the probability distribution pass this test for it to be selected as the best distribution for the dataset under investigation. However, if none of the available distributions passed this test, then the final criterion for selecting the most appropriate distribution was the squared correlation coefficient.

A visual inspection was often performed to aid in selecting the most appropriate distribution. The squared correlation coefficient can replace a visual inspection, and can offer a better opportunity for the automation of the goodness of fit process (Stedinger et al. 1993). The squared correlation coefficient is a standard statistical measure, and one of the main advantages of this test is that it allows the available probability distributions to be ranked in terms of fit (Stedinger et al. 1993). In general, the probability distribution with the highest squared correlation coefficient was considered the most appropriate for the dataset. The significance of the squared correlation test was be evaluated to ensure that the relationship is not obtained by chance or random fluctuations (Walpole and Myers 1978).

### 7.I.3.5 Step 5 – Bounding the Selected Distribution

If left unbounded, distributions can produce exceptionally high concentrations that are not realistic to the aquatic system. Therefore, each distribution was assigned a minimum and maximum value. The minimum value of the distribution was set to zero for the normal and delta-lognormal distributions, or a value very close to zero (e.g., 0.00000001) for the lognormal distribution. By default, the maximum bound was set to either the sum of the mean and 3 times the standard deviation, or the maximum value observed, whichever was the largest. In some cases, the sum of the mean and 3 times the standard deviation may have resulted in a value that was much higher than the maximum observed value and too high to be physically reasonable. In these situations, the extreme value produced by the distribution may be replaced with the lower, maximum observed value multiplied by a weighting factor that varies between 1 and 3. The smaller the size of the data sequence, and/or the larger the standard deviation, the larger the weighting factor applied. In general, if the extreme value seemed unreasonable, the maximum limit was adjusted using the approach presented in Table 7.I.3-1.

**Table 7.I.3-1: General Procedure for Assigning a Maximum Bound to a Distribution with an Unreasonable Extreme Value**

| Number of Samples in Dataset | Adjustment for Assigning Maximum Bound |
|---|---|
| <10 | no adjustment |
| between 10 and 30 | an upper limit of 2 or 3 times the maximum observed value was imposed, depending on the variability of the data |
| between 30 and 80 | an upper limit of 2 times the maximum observed value was imposed |
| >80 | an upper limit equivalent to the maximum observed value was imposed |

A similar process was used to derive distributions for calculated surface water-suspended sediment partition coefficients, with the exception that the lower and upper bounds were limited to the maximum and minimum calculated $Kd_{sw}$ values. Tables summarizing the derived distribution statistics for seasonal background surface water quality and $Kd_{sw}$ inputs are provided in Attachment 7.I.I.

## 7.I.4 BASELINE MODEL CALIBRATION APPROACH

Calibration of the baseline WQM was completed by comparing available water quality monitoring data with simulated background concentrations in Nico, Peanut, and Burke lakes. Background conditions in these lakes are equivalent to those developed under the Baseline Case. Background concentrations are the product of natural surface runoff water quality. The general calibration approach consisted of the following steps:

- Step 1 – Derive seasonal background probability distributions (i.e., for open water and under-ice seasons) for local waters not influenced by the NICO Project ore body (non-ore-influenced waters) and local waters directly influenced by the NICO Project ore body (ore-influenced waters).
- Step 2 – Run the water quality model and compare the cumulative frequency distribution curves developed for both the “modelled background” and the observed data. If curves are visually divergent for a particular constituent, proceed to Step 3.
- Step 3 – For each constituent, examine the background probability distributions assigned to ore-influenced and non-ore-influenced surface waters and modify as appropriate using a calibration factor. Repeat Step 2 and proceed to Step 4 if the cumulative frequency curves are still divergent.
- Step 4 – Use a trial and error approach to adjust the calibration factor (i.e., repeat Steps 2 and 3) until the comparison is acceptable.

Since calibrations applied to upstream nodes influence modelling results in downstream nodes, adjustments and checks made under any particular calibration step were applied sequentially, upstream to downstream, prior to moving to the next calibration step. Table 7.I.3-2 summarizes the adjustments required to obtain an acceptable background calibration. Figures summarizing the calibration of baseline predictions to observed baseline data are provided in Attachment 7.I.II.

**Table 7.I.3-2: Summary of Calibration Factors Applied to the Baseline Case Model**

| Waterbody | Nico Lake | | | | Peanut Lake | | Burke Lake | |
|---|---|---|---|---|---|---|---|---|
| Background Inflow | Ore-Influenced | | Non-Ore-Influenced | | Non-Ore-Influenced | | Non-Ore-Influenced | |
| Season | Open Water | Under-Ice | Open Water | Under-Ice | Open Water | Under-Ice | Open Water | Under-Ice |
| **Major Ions and TDS** | | | | | | | | |
| Calcium | 0.75 | 0.75 | 0.5 | 1 | 0.75 | 1 | 0.75 | 2 |
| Chloride | 0.5 | 2 | 0.25 | 1.75 | 0.5 | 1 | 0.75 | 2 |
| Magnesium | 0.75 | 1 | 0.75 | 1.5 | 0.75 | 1.5 | 0.75 | 2 |
| Potassium | 0.75 | 1.5 | 0.75 | 1.5 | 1 | 1.5 | 1.5 | 1.5 |
| Sodium | 0.75 | 1.5 | 0.75 | 1.5 | 1 | 1.5 | 1 | 2 |
| Sulphate | 0.25 | 0.5 | 0.5 | 0.75 | 0.25 | 0.75 | 0.75 | 2 |
| Total dissolved solids | 0.5 | 1 | 0.5 | 2 | 0.5 | 1.5 | 0.5 | 2 |
| **Nutrients** | | | | | | | | |
| Nitrogen - ammonia | 0.25 | 0.5 | 0.25 | 0.5 | 0.25 | 0.75 | 0.25 | 1 |
| Nitrogen - nitrate | 0.25 | 2 | 0.25 | 2 | 0.25 | 2 | 0.25 | 2 |
| Nitrogen - total Kjeldahl | 0.75 | 1.5 | 0.75 | 1.5 | 0.6 | 1.25 | 0.75 | 1.25 |
| Phosphorus - total | 0.75 | 0.1 | 1 | 0.25 | 1 | 0.25 | 1 | 0.25 |
| **Total Metals** | | | | | | | | |
| Aluminum | 0.75 | 0.25 | 0.6 | 0.1 | 1.1 | 0.25 | 0.75 | 0.1 |
| Antimony | 0.6 | 0.1 | 1.25 | 0.1 | 1 | 0.25 | 1 | 0.25 |
| Arsenic | 0.35 | 0.02 | 1 | 1 | 1.5 | 0.5 | 1.5 | 0.5 |
| Barium | 0.75 | 1 | 0.6 | 1.5 | 1 | 1 | 0.75 | 1.5 |
| Beryllium | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Boron | 0.5 | 1 | 0.25 | 1 | 0.5 | 0.5 | 0.25 | 0.5 |
| Cadmium | 0.5 | 1 | 0.5 | 1 | 0.5 | 1 | 0.5 | 1 |
| Chromium | 0.75 | 0.25 | 0.75 | 0.25 | 1 | 0.25 | 1 | 0.25 |
| Cobalt | 0.1 | 0.25 | 0.5 | 0.75 | 0.5 | 1 | 0.5 | 1 |
| Copper | 0.4 | 0.1 | 1 | 0.25 | 0.75 | 0.25 | 1 | 0.25 |
| Iron | 1 | 0.05 | 2 | 0.1 | 1.5 | 0.25 | 1.5 | 0.25 |

**Table 7.I.3-2: Summary of Calibration Factors Applied to the Baseline Case Model (continued)**

| Waterbody | Nico Lake | | | | Peanut Lake | | Burke Lake | |
|---|---|---|---|---|---|---|---|---|
| Background Inflow | Ore-Influenced | | Non-Ore-Influenced | | Non-Ore-Influenced | | Non-Ore-Influenced | |
| Season | Open Water | Under-Ice | Open Water | Under-Ice | Open Water | Under-Ice | Open Water | Under-Ice |
| Lead | 0.5 | 1 | 0.5 | 1 | 0.5 | 1.5 | 0.75 | 1.5 |
| Manganese | 1 | 1 | 0.25 | 1.5 | 0.25 | 1.5 | 0.25 | 2 |
| Mercury | 0.75 | 1 | 0.2 | 0.4 | 0.2 | 0.4 | 0.2 | 0.4 |
| Molybdenum | 0.5 | 0.75 | 0.5 | 1 | 0.5 | 1 | 0.75 | 1 |
| Nickel | 0.25 | 1 | 0.25 | 1.5 | 0.75 | 1.5 | 0.5 | 1.5 |
| Selenium | 0.5 | 1.5 | 0.5 | 1.5 | 0.5 | 1.5 | 0.5 | 1.5 |
| Silver | 0.5 | 0.25 | 0.5 | 0.25 | 0.5 | 0.25 | 0.5 | 0.25 |
| Thallium | 0.5 | 1 | 1 | 2 | 1 | 2 | 1 | 2 |
| Uranium | 0.25 | 0.25 | 0.5 | 0.5 | 0.5 | 0.75 | 0.75 | 1.5 |
| Vanadium | 0.5 | 1 | 0.25 | 1 | 0.25 | 1 | 0.5 | 1.25 |
| Zinc | 1 | 0.1 | 1.5 | 0.25 | 1.5 | 0.25 | 1.5 | 0.25 |

## 7.I.5 REFERENCES

Ang. A.H.S., and W.H. Tang. 1975. Probability concepts in engineering planning and design, Volume 1 - Basic Principals. John Wiley & Sons, New York.

Beckman, R.J., and R.D. Cook. 1983. Outliers. Technometrics, 25: 119-149.

Conover, W.J. 1980. Practical nonparametric statistics, 2nd Edition. John Wiley & Sons, New York.

Davies, L., and U. Gather. 1993. The identification of multiple outliers. Journal of the American Statistical Association, 88: 782-801.

Dixon, W.J. 1950. Analysis of extreme values. Annals of Mathematical Statistics, 22: 488-506.

Dixon, W.J. 1951. Ratios involving extreme values. Annals of Mathematical Statistics, 22: 68-78.

Dixon, W.J. 1953. Processing Data for Outliers. Biometrics, 9: 74-89.

French, W.H., S.A. Teukolsky, W.T. Vetterling, and B.P. Flannery. 1992. Numerical recipes in fortran – the art of scientific computing, 2nd Edition. Cambridge University Press, New York.

Gilbert, R.O. 1987. Statistical methods for environmental pollution monitoring. John Wiley & Sons, New York.

GoldSim Technology Group. 2010. GoldSim Probabilistic Simulation Environment. User's Guide Version 10.1.

Hampel, F.R. 1985. The breakdown points of the mean combined with some rejection rules. Technometrics, 27: 95-107.

Jain, R.B. 1981. Percentage points of many-outlier detection procedures. Technometrics, 23: 71-75.

Kottegoda, N.T. 1984. Investigation of outliers in annual maximum flow series. Journal of Hydrology, 72: 105-137.

Pearson, R.K. 2001. Exploring Process Data. Journal of Process Control, 11: 179-194.

Rosner, B. 1975. On the detection of many outliers. Technometrics, 17: 221-227.

Rosner, B. 1983. Percentage points for a generalized ESD many-outlier procedure. Technometrics, 25: 165-172.

Sokal, R.R., and F.J. Rohlf. 1981. Biometry – the principles and practice of statistics in biological research, 2nd Edition. W.H. Freeman and Company, New York, 859 pages plus statistical tables.

Stedinger, J.R., R.M. Vogel and E. Foufoula-Georgiou. 1993. Frequency Analysis of Extreme Events. In: Maidment, D.R. (ed), Handbook of Hydrology, McGraw-Hill, New York, Chapter 18.

U.S. EPA. (United States Environmental Protection Agency) 1991. Technical Support Document for Water Quality-Based Toxics Control. Office of Water Enforcement and Permits, Office of Water Regulations and Standards, US Environmental Protection Agency, Washington, DC, Appendix E.

U.S. EPA. 1993. Statistical Support Document for Proposed Effluent Limitations Guidelines and Standards for the Pulp, Paper and Paperboard Point Source Category. EPA 821-R-93-023.

Walpole, R.E., and R.H. Myers. 1978. Probability and Statistics for Engineers and Scientist, 2nd Edition. Macmillan Publishing, New York.

WMO (World Meteorological Organization). 1985. Guidelines for Computerized Data Processing in Operational Hydrology and Land and Water Management. Joint FAO/WMO Publication, WMO Report No. 634, Geneva, Switzerland, Part 2.

# ATTACHMENT 7.I.I

## Derived Distribution Statistics for Seasonal Background Surface Water Quality and $Kd_{sw}$ Inputs

**Table 7.I.I-1 Background Quality of Local Non-Ore-Influenced Waters (Open Water Season)**

| Parameter | Units | Selected Distribution | Average[a] | Standard Deviation[a] | 95th Percentile[a] | Delta[b] | D[c] | Sample Size | Number of Outliers |
|---|---|---|---|---|---|---|---|---|---|
| **Conventional Parameters** | | | | | | | | | |
| Total dissolved solids | mg/L | lognormal | 50 | 1.7 | 120 | - | - | 84 | 0 |
| Total suspended solids | mg/L | lognormal | 2.7 | 2.0 | 8.1 | - | - | 46 | 0 |
| **Major Ions** | | | | | | | | | |
| Calcium | mg/L | lognormal | 8.1 | 1.6 | 17 | - | - | 92 | 0 |
| Chloride | mg/L | normal | 1.6 | 0.70 | 2.7 | - | - | 85 | 2 |
| Magnesium | mg/L | normal | 3.3 | 0.97 | 4.9 | - | - | 92 | 0 |
| Potassium | mg/L | normal | 0.94 | 0.29 | 1.4 | - | - | 92 | 0 |
| Sodium | mg/L | normal | 2.3 | 0.74 | 3.5 | - | - | 92 | 0 |
| Sulphate | mg/L | normal | 2.3 | 1.37 | 4.6 | - | - | 72 | 0 |
| **Nutrients** | | | | | | | | | |
| Nitrogen - ammonia | mg-N/L | lognormal | 0.014 | 3.3 | 0.10 | - | - | 92 | 0 |
| Nitrogen - nitrate | mg-N/L | lognormal | 0.026 | 4.0 | 0.25 | - | - | 92 | 0 |
| Nitrogen - total Kjeldahl | mg/L | delta-lognormal | 0.59 | 1.4 | 1.03 | 0.011 | 0.025 | 92 | 2 |
| Phosphorus - total | mg/L | lognormal | 0.014 | 1.6 | 0.031 | - | - | 89 | 4 |
| **Total Metals** | | | | | | | | | |
| Aluminum | mg/L | lognormal | 0.061 | 3.3 | 0.42 | - | - | 92 | 0 |
| Antimony | mg/L | lognormal | 0.00015 | 3.0 | 0.00095 | - | - | 92 | 0 |
| Arsenic | mg/L | lognormal | 0.00079 | 1.5 | 0.0016 | - | - | 92 | 1 |
| Barium | mg/L | lognormal | 0.0086 | 1.4 | 0.015 | - | - | 92 | 1 |
| Beryllium | mg/L | delta-lognormal | 0.000016 | 1.7 | 0.000032 | 0.50 | 0.000005 | 14 | 0 |
| Boron | mg/L | lognormal | 0.011 | 1.9 | 0.032 | - | - | 28 | 0 |
| Cadmium | mg/L | lognormal | 0.000006 | 2.2 | 0.000022 | - | - | 56 | 0 |
| Chromium | mg/L | lognormal | 0.00041 | 2.8 | 0.0023 | - | - | 43 | 0 |
| Cobalt | mg/L | lognormal | 0.00010 | 2.3 | 0.00039 | - | - | 42 | 0 |
| Copper | mg/L | lognormal | 0.0012 | 1.8 | 0.0033 | - | - | 92 | 0 |
| Iron | mg/L | lognormal | 0.21 | 2.3 | 0.80 | - | - | 92 | 3 |
| Lead | mg/L | lognormal | 0.00007 | 2.0 | 0.00022 | - | - | 70 | 0 |
| Manganese | mg/L | lognormal | 0.019 | 4.2 | 0.20 | - | - | 92 | 0 |
| Mercury | mg/L | delta-lognormal | 0.00023 | 1.7 | 0.00027 | 0.88 | 0.0000081 | 56 | 0 |
| Molybdenum | mg/L | lognormal | 0.00018 | 2.0 | 0.00058 | - | - | 42 | 0 |
| Nickel | mg/L | lognormal | 0.00078 | 1.7 | 0.0019 | - | - | 92 | 0 |
| Selenium | mg/L | normal | 0.00019 | 0.000085 | 0.00033 | - | - | 92 | 4 |
| Silver | mg/L | delta-lognormal | 0.000024 | 1.7 | 0.000039 | 0.74 | 0.0000036 | 27 | 0 |
| Thallium | mg/L | lognormal | 0.0000012 | 1.5 | 0.0000023 | - | - | 14 | 0 |
| Uranium | mg/L | delta-lognormal | 0.00024 | 1.5 | 0.00047 | 0.015 | 0.00005 | 70 | 5 |
| Vanadium | mg/L | lognormal | 0.00044 | 2.4 | 0.0018 | - | - | 92 | 1 |
| Zinc | mg/L | lognormal | 0.0025 | 2.36 | 0.010 | - | - | 92 | 0 |

[a] Represents the geometric standard deviation for lognormal and delta lognormal distributions; averages and 95th percentiles calculated

[b] Proportion of data that were reported as less than the method detection limit (MDL).

[c] Average of all non-detectable values; reported as half the corresponding MDL.

**Table 7.I.I-2 Background Quality of Local Non-Ore-Influenced Waters (Under-Ice Season)**

| Parameter | Units | Selected Distribution | Average[a] | Standard Deviation[a] | 95th Percentile[a] | Delta[b] | D[c] | Sample Size | Number of Outliers |
|---|---|---|---|---|---|---|---|---|---|
| **Conventional Parameters** | | | | | | | | | |
| Total dissolved solids | mg/L | normal | 52 | 18.1 | 82 | - | - | 22 | 0 |
| Total suspended solids | mg/L | lognormal | 2 | 2.4 | 10 | - | - | 24 | 0 |
| **Major Ions** | | | | | | | | | |
| Calcium | mg/L | normal | 12 | 5.4 | 21 | - | - | 22 | 0 |
| Chloride | mg/L | normal | 1.5 | 0.61 | 2.5 | - | - | 22 | 0 |
| Magnesium | mg/L | normal | 4.4 | 1.1 | 6.1 | - | - | 22 | 0 |
| Potassium | mg/L | lognormal | 1.3 | 1.2 | 1.7 | - | - | 22 | 0 |
| Sodium | mg/L | lognormal | 2.8 | 1.3 | 4.3 | - | - | 22 | 0 |
| Sulphate | mg/L | lognormal | 2.3 | 1.7 | 5.7 | - | - | 22 | 0 |
| **Nutrients** | | | | | | | | | |
| Nitrogen - ammonia | mg-N/L | delta-lognormal | 0.045 | 4.5 | 0.38 | 0.35 | 0.0038 | 17 | 0 |
| Nitrogen - nitrate | mg-N/L | lognormal | 0.087 | 1.8 | 0.22 | - | - | 22 | 0 |
| Nitrogen - total Kjeldahl | mg/L | lognormal | 1.0 | 1.5 | 1.9 | - | - | 22 | 0 |
| Phosphorus - total | mg/L | lognormal | 0.016 | 1.5 | 0.033 | - | - | 22 | 1 |
| **Total Metals** | | | | | | | | | |
| Aluminum | mg/L | lognormal | 0.050 | 4.0 | 0.49 | - | - | 22 | 0 |
| Antimony | mg/L | delta-lognormal | 0.00066 | 1.7 | 0.0012 | 0.68 | 0.00019 | 22 | 0 |
| Arsenic | mg/L | normal | 0.00058 | 0.00010 | 0.00075 | - | - | 22 | 3 |
| Barium | mg/L | normal | 0.011 | 0.0057 | 0.021 | - | - | 22 | 0 |
| Beryllium[d] | mg/L | delta-lognormal | 0.000016 | 1.7 | 0.000032 | 0.5 | 0.000005 | 14 | 0 |
| Boron | mg/L | normal | 0.019 | 0.012 | 0.039 | - | - | 14 | 0 |
| Cadmium | mg/L | delta-lognormal | 0.00006 | 1.7 | 0.00012 | 0.55 | 0.0000086 | 20 | 0 |
| Chromium | mg/L | lognormal | 0.00052 | 1.3 | 0.00084 | - | - | 24 | 0 |
| Cobalt | mg/L | delta-lognormal | 0.00094 | 1.7 | 0.0017 | 0.67 | 0.00013 | 15 | 0 |
| Copper | mg/L | lognormal | 0.0013 | 1.6 | 0.0027 | - | - | 22 | 0 |
| Iron | mg/L | lognormal | 0.19 | 4.2 | 2.0 | - | - | 22 | 0 |
| Lead | mg/L | lognormal | 0.000097 | 2.2 | 0.00036 | - | - | 25 | 0 |
| Manganese | mg/L | lognormal | 0.018 | 4.4 | 0.2 | - | - | 22 | 0 |
| Mercury[d] | mg/L | delta-lognormal | 0.00023 | 1.7 | 0.00027 | 0.88 | 0.0000081 | 56 | 0 |
| Molybdenum | mg/L | normal | 0.00024 | 0.00012 | 0.00042 | - | - | 14 | 0 |
| Nickel | mg/L | lognormal | 0.0010 | 1.5 | 0.0019 | - | - | 22 | 0 |
| Selenium | mg/L | lognormal | 0.00017 | 1.7 | 0.00042 | - | - | 15 | 0 |
| Silver | mg/L | lognormal | 0.000055 | 1.4 | 0.000097 | - | - | 20 | 0 |
| Thallium[d] | mg/L | lognormal | 0.0000012 | 1.5 | 0.0000023 | - | - | 14 | 0 |
| Uranium | mg/L | lognormal | 0.00034 | 1.8 | 0.00089 | - | - | 22 | 0 |
| Vanadium | mg/L | delta-lognormal | 0.0019 | 1.3 | 0.0026 | 0.5 | 0.00035 | 22 | 0 |
| Zinc | mg/L | delta-lognormal | 0.0051 | 1.7 | 0.0085 | 0.73 | 0.0019 | 22 | 0 |

[a] Represents the geometric standard deviation for lognormal and delta lognormal distributions; averages and 95th percentiles calculatec

[b] Proportion of data that were reported as less than the method detection limit (MDL).

[c] Average of all non-detectable values; reported as half the corresponding MDL.

[d] Limited information available; using statistics derived for the open water season

**Table 7.I.I-3 Background Quality of Local Ore-Influenced Waters (Open Water Season)**

| Parameter | Units | Selected Distribution | Average[a] | Standard Deviation[a] | 95th Percentile[a] | Delta[b] | D[c] | Sample Size | Number of Outliers |
|---|---|---|---|---|---|---|---|---|---|
| **Conventional Parameters** | | | | | | | | | |
| Total dissolved solids | mg/L | normal | 104 | 26 | 147 | - | - | 22 | 0 |
| Total suspended solids | mg/L | normal | 2.4 | 0.98 | 4.1 | - | - | 17 | 1 |
| **Major Ions** | | | | | | | | | |
| Calcium | mg/L | normal | 21 | 3.8 | 28 | - | - | 24 | 0 |
| Chloride | mg/L | lognormal | 0.56 | 2.7 | 2.9 | - | - | 23 | 0 |
| Magnesium | mg/L | normal | 7.3 | 1.3 | 9.5 | - | - | 24 | 0 |
| Potassium | mg/L | normal | 1.6 | 0.27 | 2.0 | - | - | 24 | 0 |
| Sodium | mg/L | normal | 3.7 | 0.65 | 4.7 | - | - | 24 | 0 |
| Sulphate | mg/L | normal | 29 | 6.8 | 40 | - | - | 19 | 0 |
| **Nutrients** | | | | | | | | | |
| Nitrogen - ammonia | mg-N/L | lognormal | 0.028 | 2.5 | 0.12 | - | - | 24 | 0 |
| Nitrogen - nitrate | mg-N/L | lognormal | 0.025 | 4.6 | 0.32 | - | - | 24 | 0 |
| Nitrogen - total Kjeldahl | mg/L | lognormal | 0.52 | 1.3 | 0.82 | - | - | 24 | 0 |
| Phosphorus - total | mg/L | normal | 0.063 | 0.026 | 0.11 | - | - | 22 | 0 |
| **Total Metals** | | | | | | | | | |
| Aluminum | mg/L | lognormal | 0.061 | 1.6 | 0.13 | - | - | 26 | 0 |
| Antimony | mg/L | normal | 0.00090 | 0.00029 | 0.0014 | - | - | 26 | 2 |
| Arsenic | mg/L | normal | 0.19 | 0.032 | 0.25 | - | - | 26 | 0 |
| Barium | mg/L | normal | 0.0077 | 0.0016 | 0.010 | - | - | 26 | 1 |
| Beryllium | mg/L | delta-lognormal | 0.00003 | 1.7 | 0.0000 | 0.75 | 0.000025 | 8 | 0 |
| Boron | mg/L | lognormal | 0.013 | 1.3 | 0.019 | - | - | 14 | 0 |
| Cadmium | mg/L | lognormal | 0.000013 | 2.0 | 0.000040 | - | - | 16 | 0 |
| Chromium | mg/L | lognormal | 0.00036 | 2.7 | 0.0019 | - | - | 16 | 0 |
| Cobalt | mg/L | lognormal | 0.0051 | 1.3 | 0.0075 | - | - | 26 | 0 |
| Copper | mg/L | lognormal | 0.0094 | 1.5 | 0.018 | - | - | 26 | 0 |
| Iron | mg/L | normal | 0.075 | 0.026 | 0.12 | - | - | 26 | 3 |
| Lead | mg/L | lognormal | 0.000064 | 2.7 | 0.00032 | - | - | 22 | 0 |
| Manganese | mg/L | lognormal | 0.0041 | 1.8 | 0.011 | - | - | 26 | 0 |
| Mercury | mg/L | lognormal | 0.0000077 | 1.5 | 0.000016 | - | - | 16 | 0 |
| Molybdenum | mg/L | normal | 0.0027 | 0.00075 | 0.0040 | - | - | 16 | 0 |
| Nickel | mg/L | lognormal | 0.00055 | 2.7 | 0.0028 | - | - | 26 | 0 |
| Selenium | mg/L | normal | 0.00020 | 0.000056 | 0.00029 | - | - | 26 | 1 |
| Silver[d] | mg/L | delta-lognormal | 0.000024 | 1.7 | 0.000039 | 0.74 | 0.0000036 | 27 | 0 |
| Thallium | mg/L | lognormal | 0.0000034 | 1.7 | 0.0000085 | - | - | 2 | 0 |
| Uranium | mg/L | lognormal | 0.0024 | 1.4 | 0.0044 | - | - | 22 | 0 |
| Vanadium | mg/L | lognormal | 0.00037 | 2.2 | 0.0013 | - | - | 25 | 0 |
| Zinc | mg/L | lognormal | 0.0045 | 1.9 | 0.014 | - | - | 26 | 0 |

[a] Represents the geometric standard deviation for lognormal and delta lognormal distributions; averages and 95th percentiles calculatec

[b] Proportion of data that were reported as less than the method detection limit (MDL).

[c] Average of all non-detectable values; reported as half the corresponding MDL.

[d] Limited information available; using statistics derived for non-ore-influenced waters (open water season)

**Table 7.I.I-4 Background Quality of Local Ore-Influenced Waters (Under-Ice Season)**

| Parameter | Units | Selected Distribution | Average[a] | Standard Deviation[a] | 95th Percentile[a] | Delta[b] | D[c] | Sample Size | Number of Outliers |
|---|---|---|---|---|---|---|---|---|---|
| **Conventional Parameters** | | | | | | | | | |
| Total dissolved solids | mg/L | lognormal | 187 | 1.7 | 464 | - | - | 6 | 0 |
| Total suspended solids | mg/L | lognormal | 3.2 | 1.7 | 8.0 | - | - | 6 | 0 |
| **Major Ions** | | | | | | | | | |
| Calcium | mg/L | lognormal | 40 | 1.7 | 100 | - | - | 6 | 0 |
| Chloride | mg/L | delta-lognormal | 1.1 | 1.7 | 2.2 | 0.5 | 0.416666667 | 6 | 0 |
| Magnesium | mg/L | lognormal | 13 | 1.7 | 32 | - | - | 6 | 0 |
| Potassium | mg/L | lognormal | 2.4 | 1.7 | 6.1 | - | - | 6 | 0 |
| Sodium | mg/L | lognormal | 5.8 | 1.7 | 14 | - | - | 6 | 0 |
| Sulphate | mg/L | lognormal | 56 | 1.7 | 139 | - | - | 6 | 0 |
| **Nutrients** | | | | | | | | | |
| Nitrogen - ammonia | mg-N/L | lognormal | 0.48 | 1.7 | 1.2 | - | - | 6 | 0 |
| Nitrogen - nitrate | mg-N/L | delta-lognormal | 0.45 | 1.7 | 0.93 | 0.5 | 0.062 | 6 | 0 |
| Nitrogen - total Kjeldahl | mg/L | lognormal | 1.4 | 1.7 | 3.4 | - | - | 6 | 0 |
| Phosphorus - total | mg/L | lognormal | 0.031 | 1.7 | 0.077 | - | - | 6 | 0 |
| **Total Metals** | | | | | | | | | |
| Aluminum | mg/L | lognormal | 0.028 | 1.7 | 0.069 | - | - | 6 | 0 |
| Antimony | mg/L | lognormal | 0.00067 | 1.7 | 0.0017 | - | - | 6 | 0 |
| Arsenic | mg/L | lognormal | 0.16 | 1.7 | 0.41 | - | - | 6 | 0 |
| Barium | mg/L | lognormal | 0.015 | 1.7 | 0.036 | - | - | 6 | 0 |
| Beryllium[d] | mg/L | delta-lognormal | 0.000026 | 1.7 | 0.000041 | 0.75 | 0.000025 | 8 | 0 |
| Boron[d] | mg/L | lognormal | 0.013 | 1.3 | 0.019 | - | - | 14 | 0 |
| Cadmium | mg/L | lognormal | 0.000039 | 1.7 | 0.000096 | - | - | 4 | 0 |
| Chromium[d] | mg/L | lognormal | 0.00036 | 2.7 | 0.0019 | - | - | 16 | 0 |
| Cobalt | mg/L | lognormal | 0.012 | 1.7 | 0.029 | - | - | 6 | 0 |
| Copper | mg/L | lognormal | 0.0064 | 1.7 | 0.016 | - | - | 6 | 0 |
| Iron | mg/L | lognormal | 0.84 | 1.7 | 2.1 | - | - | 6 | 0 |
| Lead | mg/L | lognormal | 0.00022 | 1.7 | 0.00056 | - | - | 6 | 0 |
| Manganese | mg/L | lognormal | 0.055 | 1.7 | 0.14 | - | - | 6 | 0 |
| Mercury[d] | mg/L | lognormal | 0.0000077 | 1.5 | 0.000016 | - | - | 16 | 0 |
| Molybdenum | mg/L | lognormal | 0.0030 | 1.7 | 0.0074 | - | - | 6 | 0 |
| Nickel | mg/L | lognormal | 0.0016 | 1.7 | 0.0040 | - | - | 6 | 0 |
| Selenium | mg/L | delta-lognormal | 0.00043 | 1.7 | 0.00068 | 0.75 | 0.0002 | 4 | 0 |
| Silver[e] | mg/L | lognormal | 0.000055 | 1.4 | 0.000097 | - | - | 20 | 0 |
| Thallium[d] | mg/L | lognormal | 0.0000034 | 1.7 | 0.0000085 | - | - | 2 | 0 |
| Uranium | mg/L | lognormal | 0.0066 | 1.7 | 0.017 | - | - | 6 | 0 |
| Vanadium | mg/L | delta-lognormal | 0.00086 | 1.7 | 0.0015 | 0.67 | 0.0003 | 6 | 0 |
| Zinc | mg/L | lognormal | 0.0081 | 1.7 | 0.020 | - | - | 6 | 0 |

[a] Represents the geometric standard deviation for lognormal and delta lognormal distributions; averages and 95th percentiles calculated

[b] Proportion of data that were reported as less than the method detection limit (MDL).

[c] Average of all non-detectable values; reported as half the corresponding MDL.

[d] Limited information available; using statistics derived for the open water season

[e] Limited information available; using statistics derived for non-ore-influenced waters (under-ice season)

**Table 7.I.I-5 Background Water Quality in the Marian River (Open Water Season)**

| Parameter | Units | Selected Distribution | Average[a] | Standard Deviation[a] | 95th Percentile[a] | Delta[b] | D[c] | Sample Size | Number of Outliers |
|---|---|---|---|---|---|---|---|---|---|
| **Conventional Parameters** | | | | | | | | | |
| Total dissolved solids | mg/L | lognormal | 89 | 1.3 | 130 | - | - | 13 | 0 |
| Total suspended solids | mg/L | lognormal | 3 | 1.7 | 7 | - | - | 5 | 0 |
| **Major Ions** | | | | | | | | | |
| Calcium | mg/L | normal | 17 | 2.5 | 21 | - | - | 13 | 0 |
| Chloride | mg/L | lognormal | 2.0 | 1.4 | 3.3 | - | - | 13 | 0 |
| Magnesium | mg/L | normal | 7.4 | 1.4 | 10 | - | - | 13 | 0 |
| Potassium | mg/L | normal | 1.3 | 0.17 | 1.6 | - | - | 13 | 0 |
| Sodium | mg/L | normal | 2.5 | 0.49 | 3.3 | - | - | 13 | 0 |
| Sulphate | mg/L | normal | 13 | 4.1 | 20 | - | - | 12 | 0 |
| **Nutrients** | | | | | | | | | |
| Nitrogen - ammonia | mg-N/L | lognormal | 0.0095 | 3.7 | 0.082 | - | - | 10 | 0 |
| Nitrogen - nitrate | mg-N/L | lognormal | 0.032 | 2.4 | 0.13 | - | - | 13 | 0 |
| Nitrogen - total Kjeldahl | mg/L | lognormal | 0.57 | 1.3 | 0.88 | - | - | 13 | 0 |
| Phosphorus - total | mg/L | lognormal | 0.012 | 1.3 | 0.019 | - | - | 13 | 0 |
| **Total Metals** | | | | | | | | | |
| Aluminum | mg/L | lognormal | 0.070 | 1.7 | 0.17 | - | - | 13 | 0 |
| Antimony | mg/L | lognormal | 0.000017 | 1.7 | 0.000043 | - | - | 1 | 0 |
| Arsenic | mg/L | normal | 0.00042 | 0.00020 | 0.00074 | - | - | 13 | 0 |
| Barium | mg/L | normal | 0.012 | 0.0024 | 0.016 | - | - | 13 | 0 |
| Beryllium[d] | mg/L | delta-lognormal | 0.000016 | 1.7 | 0.000032 | 0.5 | 0.000005 | 14 | 0 |
| Boron | mg/L | delta-lognormal | 0.026 | 1.7 | 0.025 | 0.92 | 0.025 | 13 | 0 |
| Cadmium | mg/L | lognormal | 0.000019 | 1.7 | 0.000048 | - | - | 9 | 0 |
| Chromium | mg/L | delta-lognormal | 0.00026 | 1.7 | 0.00052 | 0.5 | 0.0004 | 2 | 0 |
| Cobalt | mg/L | delta-lognormal | 0.000073 | 1.7 | 0.00015 | 0.5 | 0.0001 | 2 | 0 |
| Copper | mg/L | lognormal | 0.00071 | 1.7 | 0.0017 | - | - | 13 | 0 |
| Iron | mg/L | lognormal | 0.11 | 1.7 | 0.26 | - | - | 13 | 0 |
| Lead | mg/L | delta-lognormal | 0.00021 | 1.7 | 0.00030 | 0.8 | 0.00005 | 10 | 0 |
| Manganese | mg/L | lognormal | 0.015 | 1.3 | 0.025 | - | - | 13 | 0 |
| Mercury[d] | mg/L | delta-lognormal | 0.0002327 | 1.7 | 0.00027 | 0.88 | 0.0000081 | 56 | 0 |
| Molybdenum | mg/L | lognormal | 0.00015 | 1.7 | 0.00038 | - | - | 2 | 0 |
| Nickel | mg/L | delta-lognormal | 0.00031 | 1.7 | 0.00063 | 0.5 | 0.0001 | 2 | 0 |
| Selenium | mg/L | delta-lognormal | 0.00056 | 1.7 | 0.00072 | 0.85 | 0.00020 | 13 | 0 |
| Silver[d] | mg/L | delta-lognormal | 0.000024 | 1.7 | 0.000039 | 0.74 | 0.0000036 | 27 | 0 |
| Thallium[d] | mg/L | lognormal | 0.0000012 | 1.5 | 0.0000023 | - | - | 14 | 0 |
| Uranium | mg/L | lognormal | 0.00055 | 1.3 | 0.00087 | - | - | 10 | 0 |
| Vanadium | mg/L | lognormal | 0.00056 | 1.4 | 0.00092 | - | - | 13 | 0 |
| Zinc | mg/L | lognormal | 0.0040 | 3.0 | 0.025 | - | - | 13 | 0 |

[a] Represents the geometric standard deviation for lognormal and delta lognormal distributions; averages and 95th percentiles calculatec

[b] Proportion of data that were reported as less than the method detection limit (MDL).

[c] Average of all non-detectable values; reported as half the corresponding MDL.

[d] Limited information available; using statistics derived for non-ore-influenced waters (open water season)

**Table 7.I.I-6 Background Water Quality in the Marian River (Under-Ice Season)**

| Parameter | Units | Selected Distribution | Average[a] | Standard Deviation[a] | 95th Percentile[a] | Delta[b] | D[c] | Sample Size | Number of Outliers |
|---|---|---|---|---|---|---|---|---|---|
| **Conventional Parameters** | | | | | | | | | |
| Total dissolved solids | mg/L | lognormal | 111 | 1.7 | 277 | - | - | 8 | 0 |
| Total suspended solids | mg/L | delta-lognormal | 3.1 | 1.7 | 5.8 | 0.63 | 1.3 | 8 | 0 |
| **Major Ions** | | | | | | | | | |
| Calcium | mg/L | lognormal | 24 | 1.7 | 59 | - | - | 8 | 0 |
| Chloride | mg/L | lognormal | 2.5 | 1.7 | 6.2 | - | - | 8 | 0 |
| Magnesium | mg/L | lognormal | 10 | 1.7 | 26 | - | - | 8 | 0 |
| Potassium | mg/L | lognormal | 1.8 | 1.7 | 4.5 | - | - | 8 | 0 |
| Sodium | mg/L | lognormal | 3.5 | 1.7 | 8.7 | - | - | 8 | 0 |
| Sulphate | mg/L | lognormal | 20 | 1.7 | 49 | - | - | 8 | 0 |
| **Nutrients** | | | | | | | | | |
| Nitrogen - ammonia | mg-N/L | lognormal | 0.026 | 1.7 | 0.064 | - | - | 8 | 0 |
| Nitrogen - nitrate | mg-N/L | delta-lognormal | 0.079 | 1.7 | 0.16 | 0.5 | 0.045 | 6 | 0 |
| Nitrogen - total Kjeldahl | mg/L | lognormal | 0.70 | 1.7 | 1.7 | - | - | 8 | 0 |
| Phosphorus - total | mg/L | lognormal | 0.007 | 1.7 | 0.018 | - | - | 5 | 0 |
| **Total Metals** | | | | | | | | | |
| Aluminum | mg/L | lognormal | 0.025 | 1.7 | 0.062 | - | - | 8 | 0 |
| Antimony[d] | mg/L | lognormal | 0.000017 | 1.7 | 0.000043 | - | - | 1 | 0 |
| Arsenic | mg/L | delta-lognormal | 0.00069 | 1.7 | 0.0011 | 0.75 | 0.0003 | 8 | 0 |
| Barium | mg/L | lognormal | 0.014 | 1.7 | 0.035 | - | - | 8 | 0 |
| Beryllium[e] | mg/L | delta-lognormal | 0.000016 | 1.7 | 0.000032 | 0.5 | 0.000005 | 14 | 0 |
| Boron | mg/L | lognormal | 0.015 | 1.7 | 0.038 | - | - | 5 | 0 |
| Cadmium | mg/L | delta-lognormal | 0.000030 | 1.7 | 0.000057 | 0.6 | 0.000005 | 5 | 0 |
| Chromium[d] | mg/L | delta-lognormal | 0.00026 | 1.7 | 0.00052 | 0.5 | 0.0004 | 2 | 0 |
| Cobalt[d] | mg/L | delta-lognormal | 0.000073 | 1.7 | 0.00015 | 0.5 | 0.0001 | 2 | 0 |
| Copper | mg/L | delta-lognormal | 0.00086 | 1.7 | 0.0016 | 0.63 | 0.0005 | 8 | 0 |
| Iron | mg/L | lognormal | 0.12 | 1.7 | 0.29 | - | - | 8 | 0 |
| Lead[d] | mg/L | delta-lognormal | 0.00021 | 1.7 | 0.00030 | 0.8 | 0.00005 | 10 | 0 |
| Manganese | mg/L | lognormal | 0.029 | 1.7 | 0.072 | - | - | 8 | 0 |
| Mercury[e] | mg/L | delta-lognormal | 0.00023 | 1.7 | 0.00027 | 0.88 | 0.0000081 | 56 | 0 |
| Molybdenum | mg/L | lognormal | 0.00019 | 1.7 | 0.00047 | - | - | 5 | 0 |
| Nickel | mg/L | lognormal | 0.00092 | 1.7 | 0.0023 | - | - | 8 | 0 |
| Selenium[d] | mg/L | delta-lognormal | 0.00056 | 1.7 | 0.00072 | 0.85 | 0.00020 | 13 | 0 |
| Silver[e] | mg/L | delta-lognormal | 0.000024 | 1.7 | 0.000039 | 0.74 | 0.0000036 | 27 | 0 |
| Thallium[e] | mg/L | lognormal | 0.0000012 | 1.5 | 0.0000023 | - | - | 14 | 0 |
| Uranium | mg/L | lognormal | 0.00081 | 1.7 | 0.0020 | - | - | 8 | 0 |
| Vanadium | mg/L | delta-lognormal | 0.00086 | 1.7 | 0.0014 | 0.75 | 0.0003 | 8 | 0 |
| Zinc[d] | mg/L | lognormal | 0.0040 | 3.0 | 0.025 | - | - | 13 | 0 |

[a] Represents the geometric standard deviation for lognormal and delta lognormal distributions; averages and 95th percentiles calculated

[b] Proportion of data that were reported as less than the method detection limit (MDL).

[c] Average of all non-detectable values; reported as half the corresponding MDL.

[d] Limited information available; using statistics derived for the open water season

**Table 7.I.I-7 Suspended Solid-Water Partition Coefficient Distributions**

| Parameter | Units | Selected Distribution | Average[a] | Standard Deviation[a] | Distribution Bounds | | Sample Size[c] | Number of Outliers |
|---|---|---|---|---|---|---|---|---|
| | | | | | Minimum[b] | Maximum[b] | | |
| **Total Metals** | | | | | | | | |
| Aluminum | L/kg | lognormal | 389508 | 3.5 | 22670 | 9750000 | 100 | 0 |
| Antimony | L/kg | lognormal | 90710 | 3.2 | 16667 | 1285714 | 22 | 0 |
| Arsenic | L/kg | lognormal | 40629 | 3.8 | 325 | 600000 | 53 | 0 |
| Barium | L/kg | lognormal | 27950 | 4.2 | 681 | 1000000 | 67 | 0 |
| Beryllium | L/kg | lognormal | 114843 | 1.7 | 125000 | 428571 | 2 | 0 |
| Boron | L/kg | lognormal | 50777 | 2.7 | 5865 | 750000 | 13 | 0 |
| Cadmium | L/kg | normal | 476506 | 459556 | 2105 | 1855173 | 17 | 0 |
| Chromium | L/kg | lognormal | 273837 | 3.3 | 35714 | 9000000 | 12 | 0 |
| Cobalt | L/kg | lognormal | 120862 | 3.9 | 1250 | 2545454 | 46 | 0 |
| Copper | L/kg | lognormal | 97702 | 2.8 | 11066 | 2259457 | 46 | 0 |
| Iron | L/kg | lognormal | 221925 | 3.2 | 10855 | 7592319 | 111 | 1 |
| Lead | L/kg | lognormal | 177619 | 3.8 | 6454 | 8823528 | 29 | 0 |
| Manganese | L/kg | lognormal | 171837 | 7.4 | 2076 | 12735294 | 85 | 0 |
| Mercury | L/kg | lognormal | 1175922 | 1.7 | 300000 | 6206467 | 7 | 0 |
| Molybdenum | L/kg | lognormal | 42850 | 2.7 | 5348 | 666666 | 41 | 0 |
| Nickel | L/kg | lognormal | 67654 | 3.9 | 372 | 1259260 | 39 | 0 |
| Selenium | L/kg | constant | 50000 | - | - | - | 1 | 0 |
| Silver[d] | L/kg | none | - | - | - | - | 0 | 0 |
| Thallium[d] | L/kg | none | - | - | - | - | 0 | 0 |
| Uranium | L/kg | lognormal | 34845 | 4.2 | 291 | 1000000 | 53 | 0 |
| Vanadium | L/kg | lognormal | 261297 | 3.1 | 15625 | 3000000 | 33 | 0 |
| Zinc | L/kg | lognormal | 200611 | 3.8 | 9524 | 7600000 | 39 | 0 |

[a] Represents the geometric standard deviation for lognormal distributions; averages calculated prior to truncation

[b] Distributions for calculated coefficients bounded at the lowest and highest calculated values

[c] Number of calculated partition coefficient values

[d] Insufficient data available to calculate partition coefficients

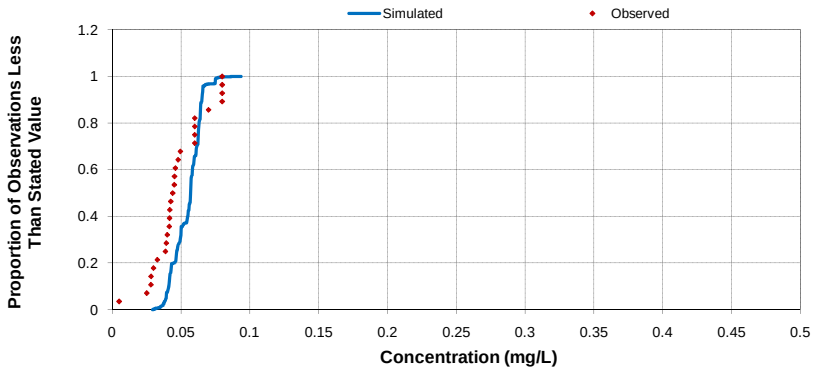
# ATTACHMENT 7.I.II

## Calibration of Baseline Predictions to Observed Baseline Data

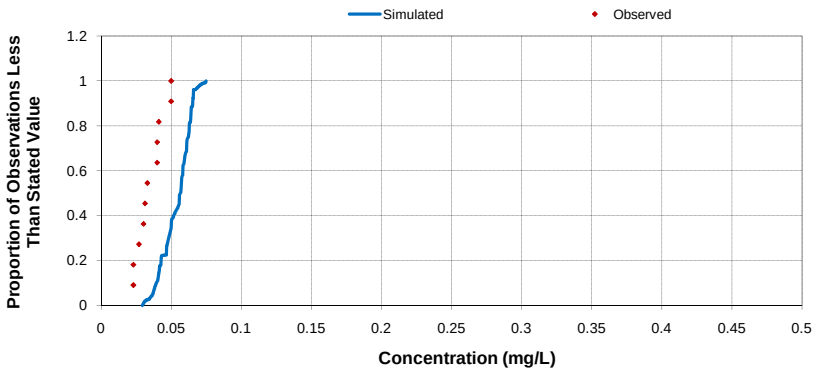
**Figure 7.I.II-1: Comparison of Observed and Predicted Baseline Concentrations of Aluminum in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

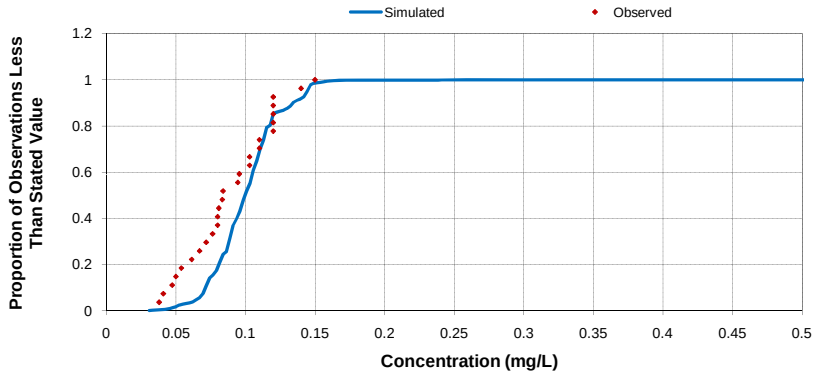



Under-Ice

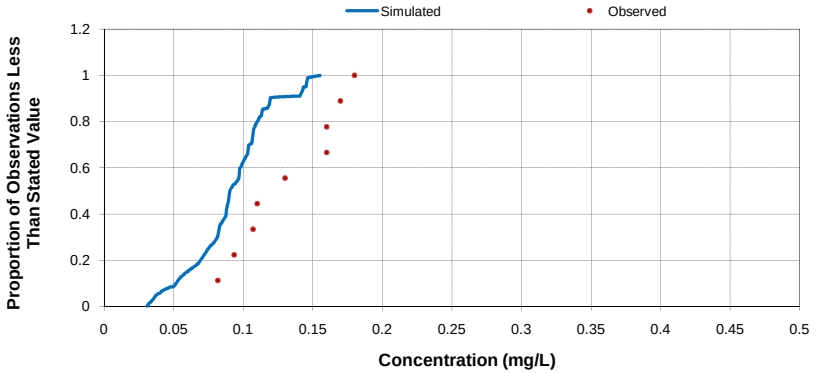



**Peanut Lake**

Open Water

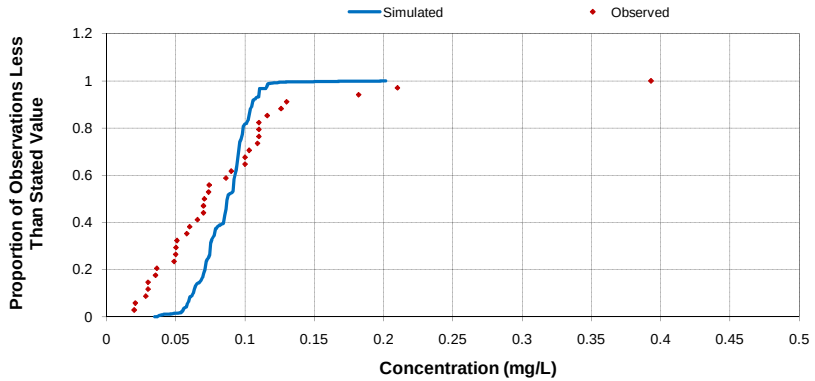



Under-Ice




**Burke Lake**

Open Water




Under-Ice

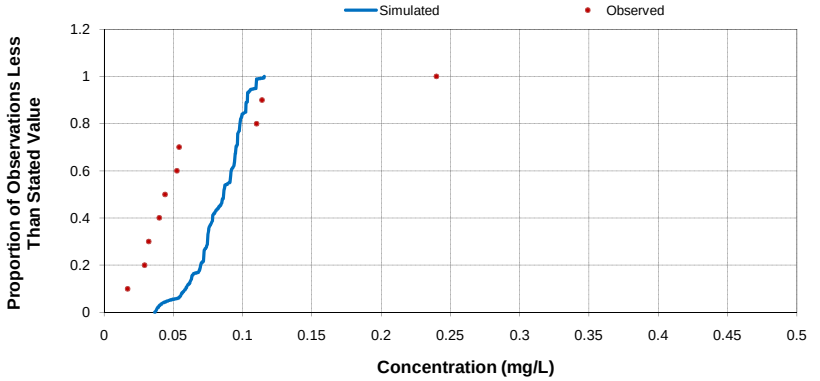
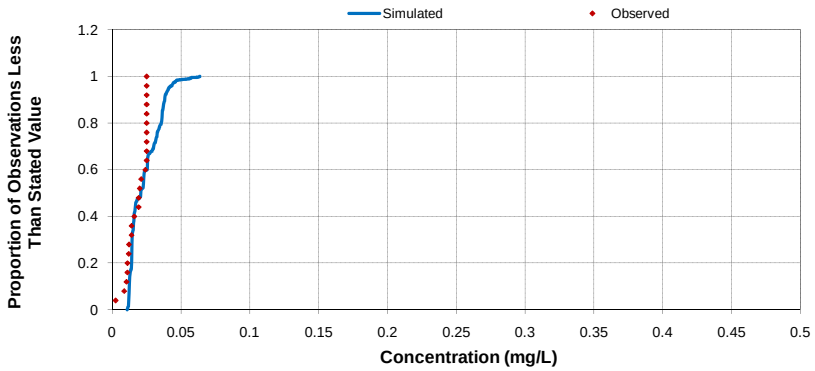


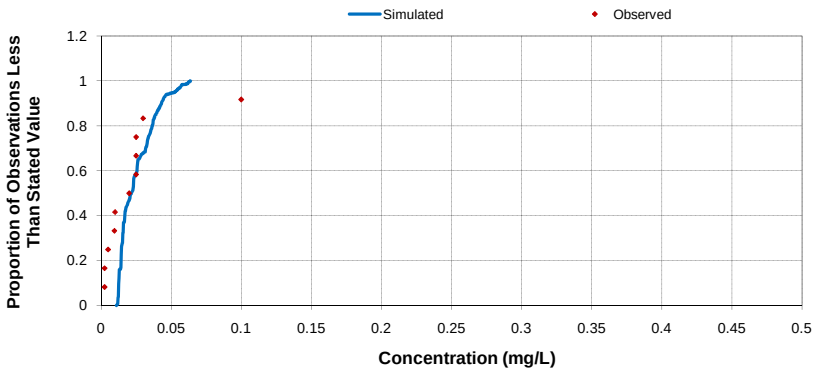
**Figure 7.I.II-2: Comparison of Observed and Predicted Baseline Concentrations of Ammonia in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

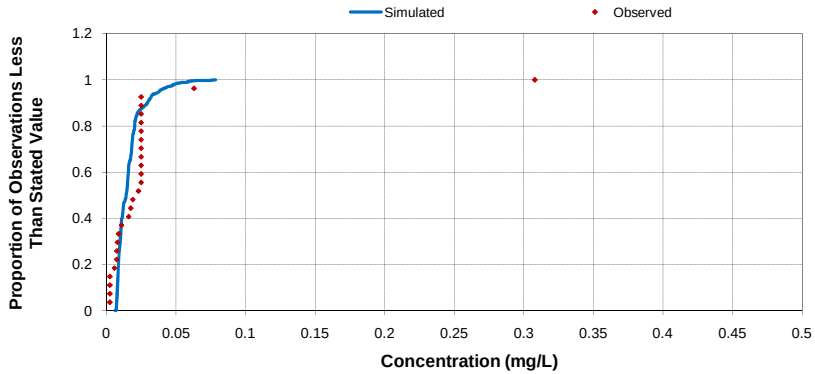



Under-Ice

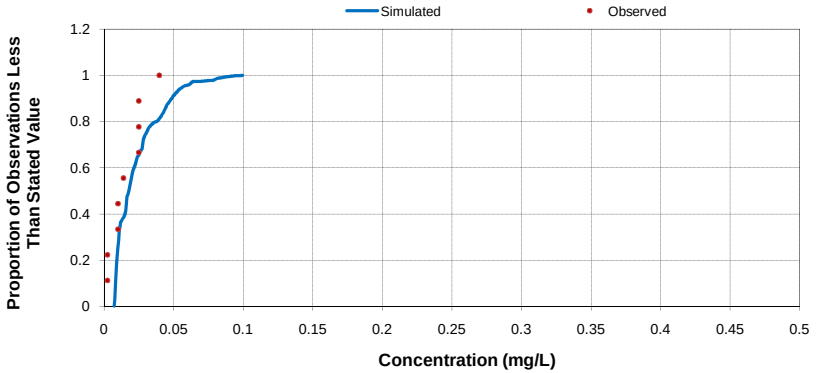



**Peanut Lake**

Open Water

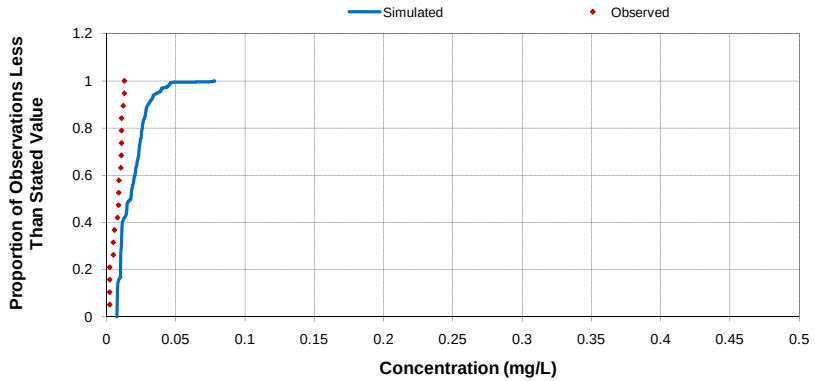



Under-Ice




**Burke Lake**

Open Water




Under-Ice

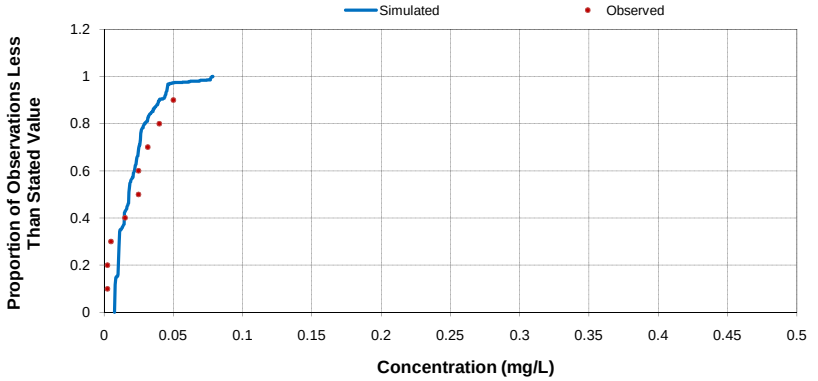
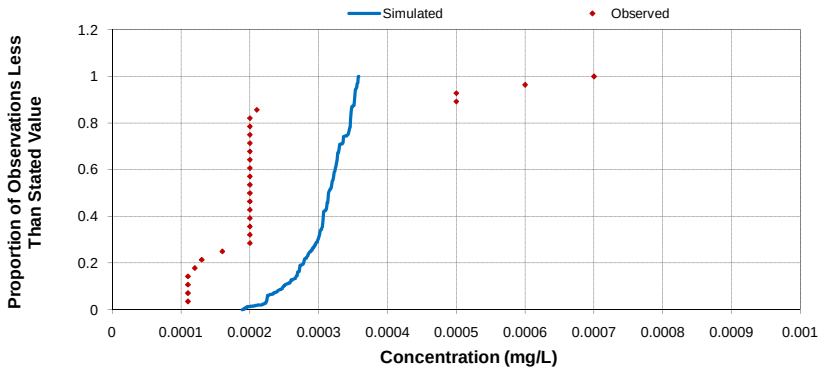


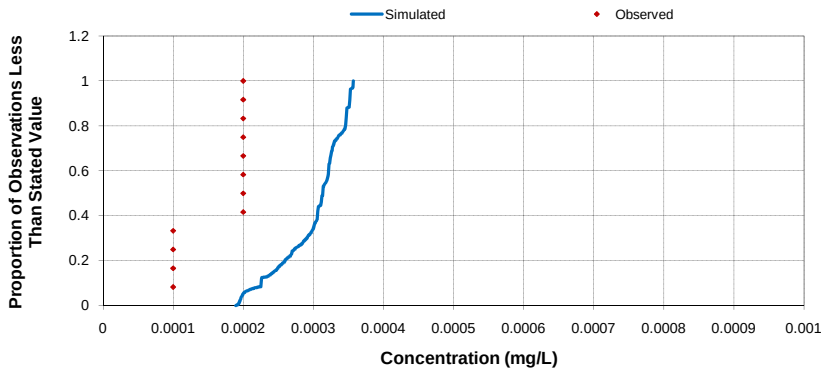
**Figure 7.I.II-3: Comparison of Observed and Predicted Baseline Concentrations of Antimony in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

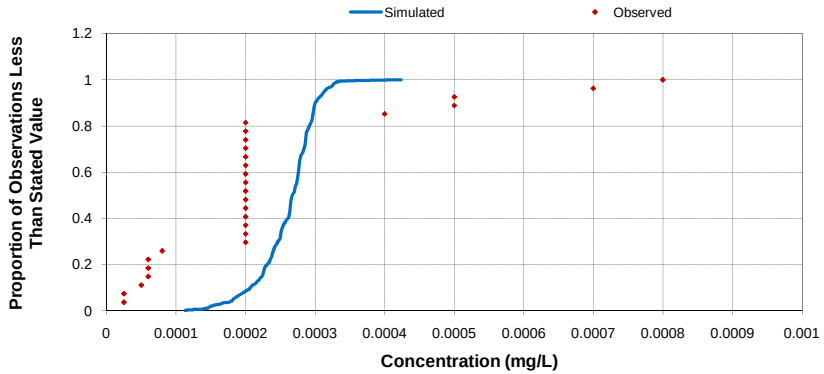



Under-Ice

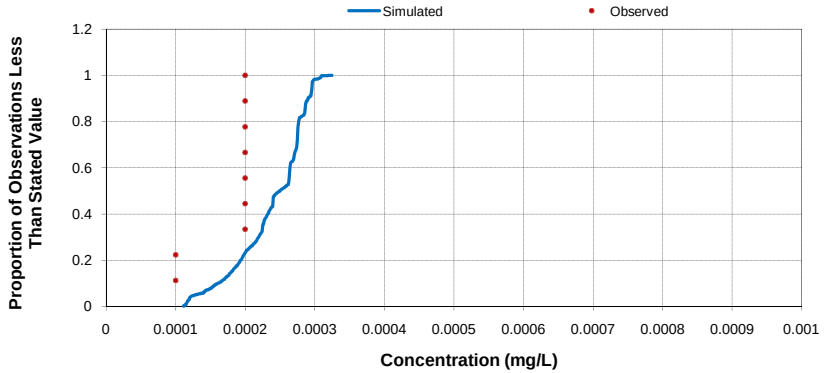



**Peanut Lake**

Open Water

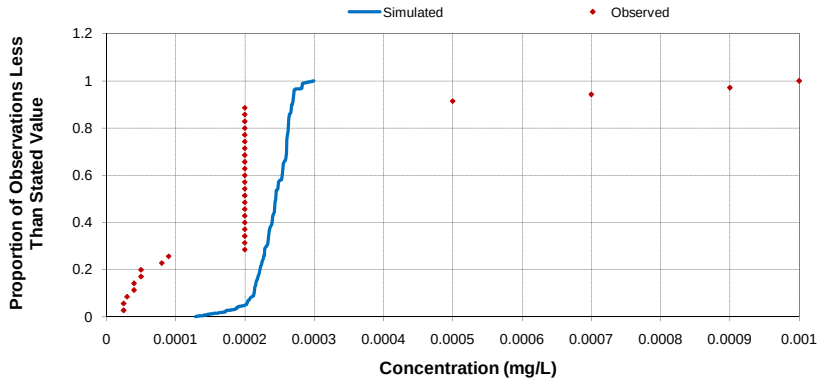



Under-Ice




**Burke Lake**

Open Water




Under-Ice

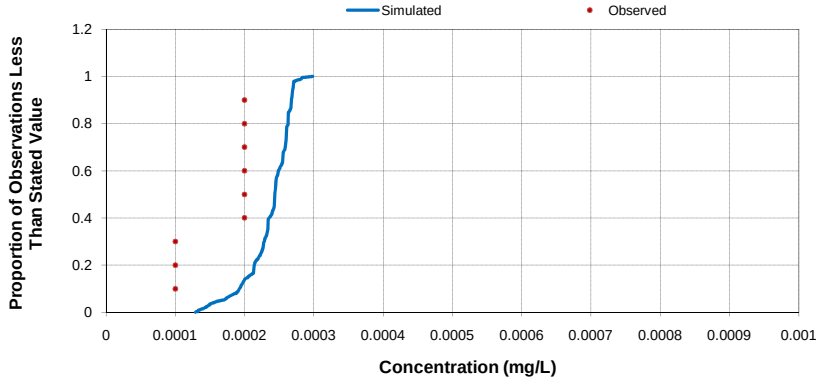
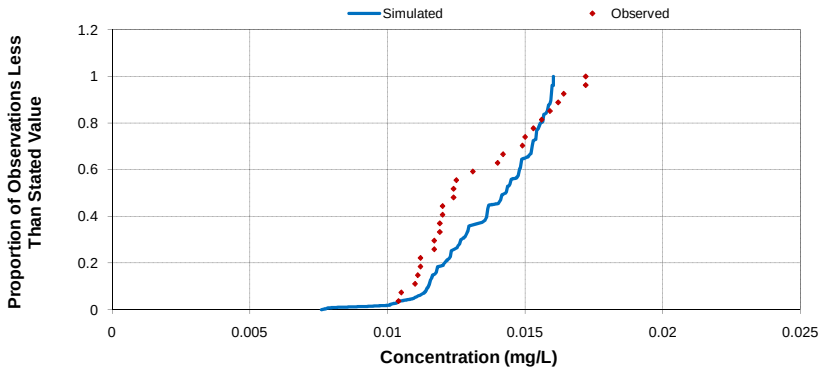


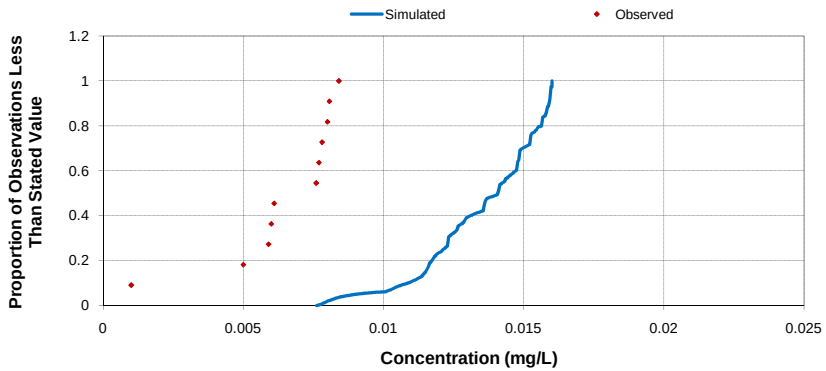
**Figure 7.I.II-4: Comparison of Observed and Predicted Baseline Concentrations of Arsenic in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

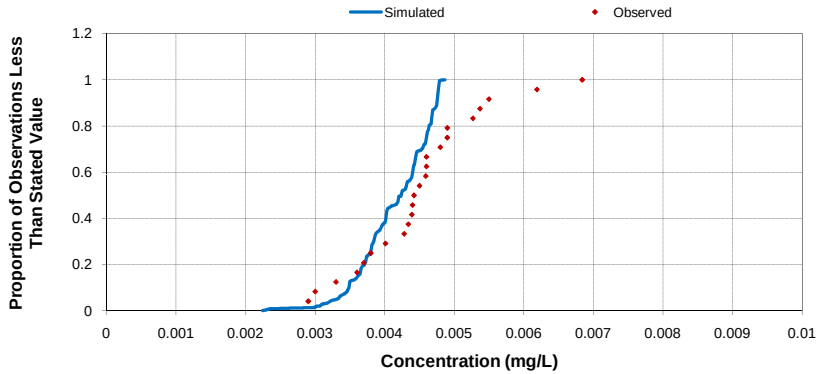



Under-Ice

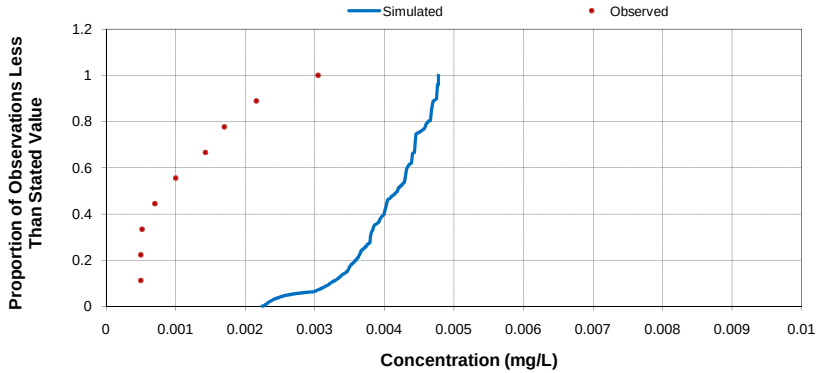



**Peanut Lake**

Open Water

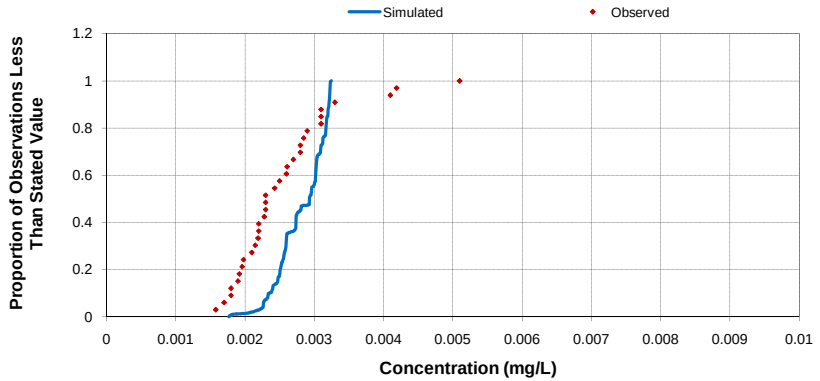



Under-Ice




**Burke Lake**

Open Water




Under-Ice

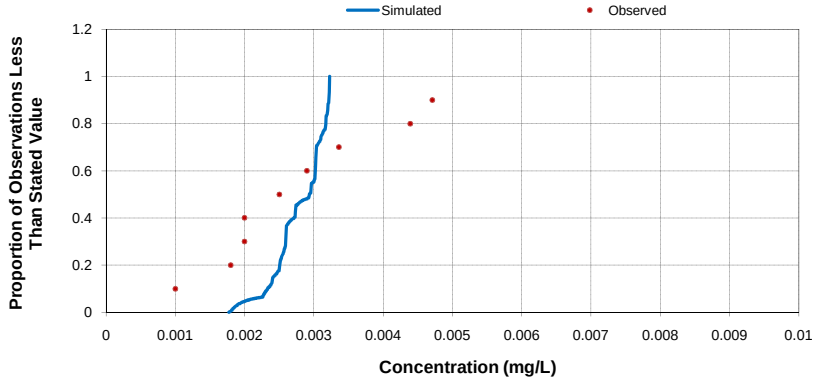
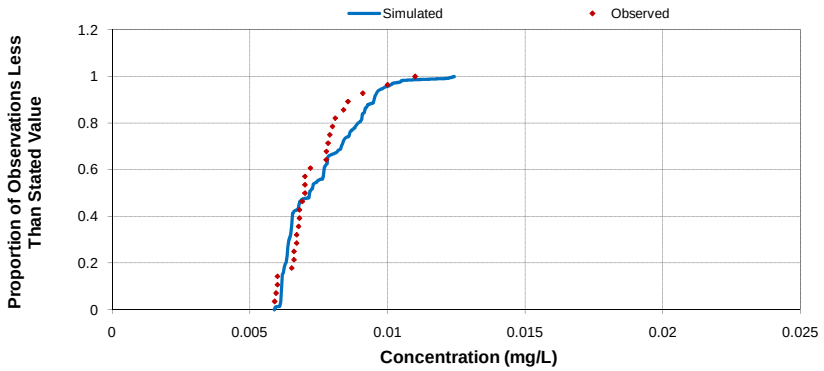


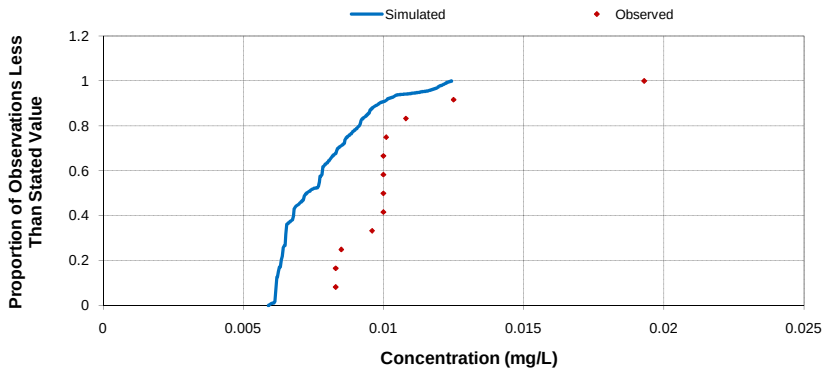
**Figure 7.I.II-5: Comparison of Observed and Predicted Baseline Concentrations of Barium in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

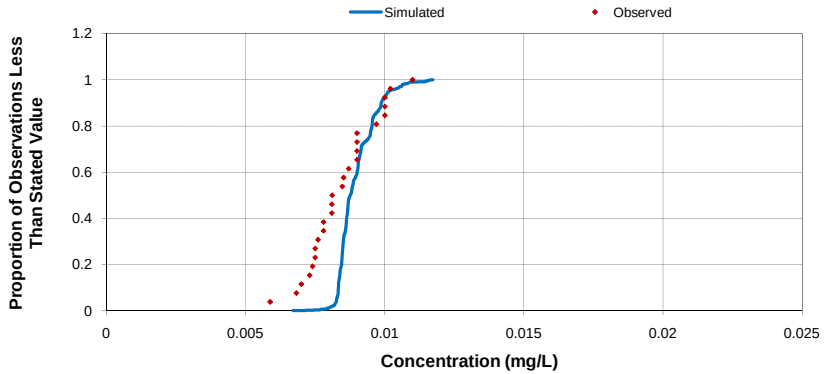



Under-Ice

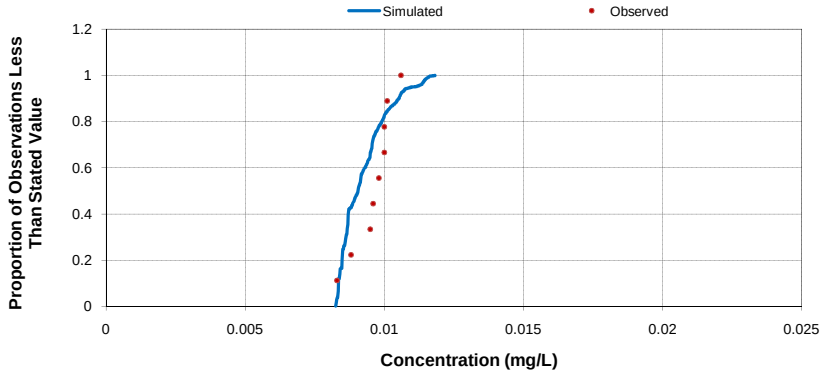



**Peanut Lake**

Open Water

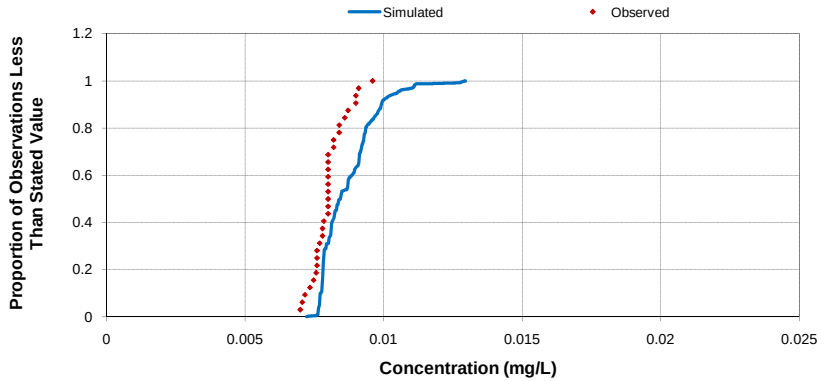



Under-Ice




**Burke Lake**

Open Water




Under-Ice

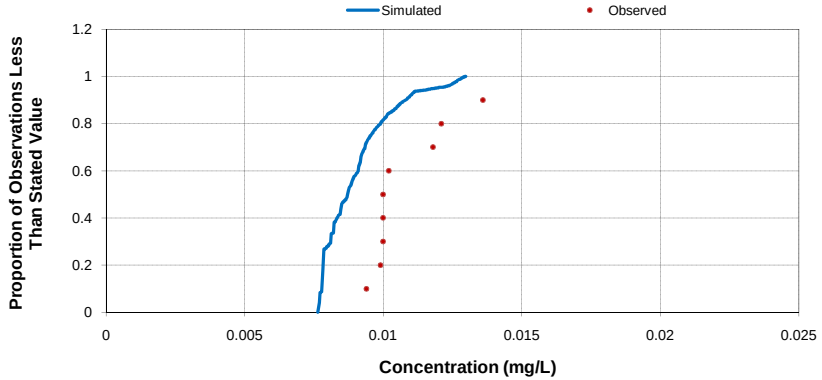
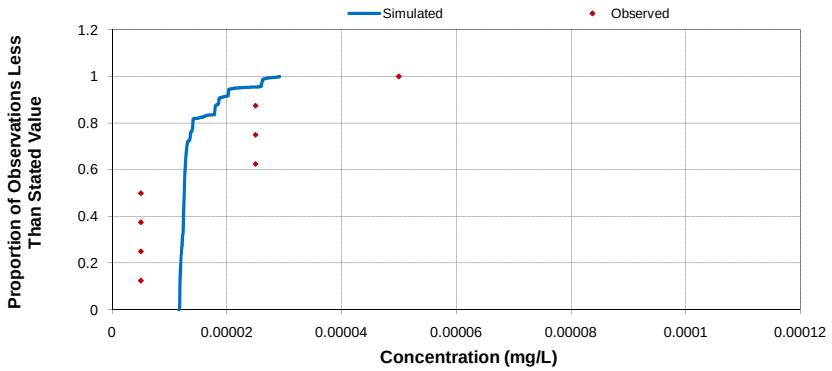


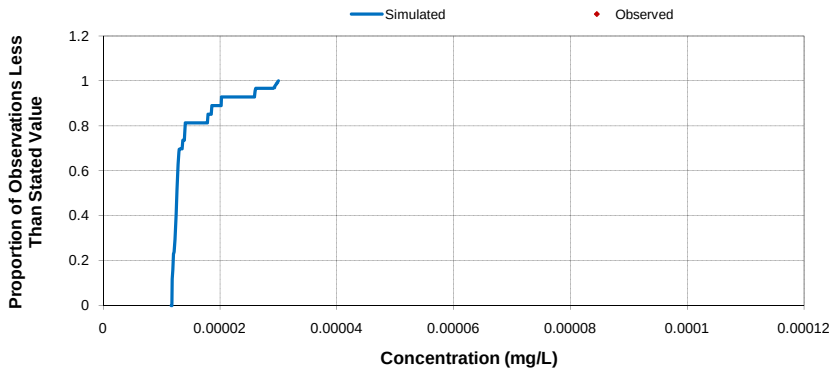
**Figure 7.I.II-6: Comparison of Observed and Predicted Baseline Concentrations of Beryllium in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

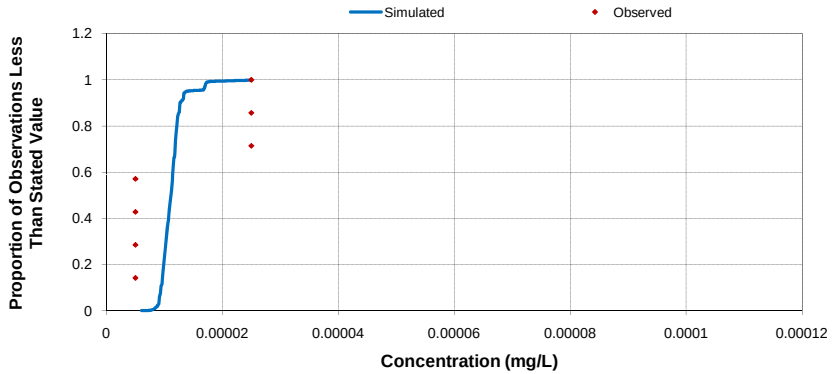



Under-Ice

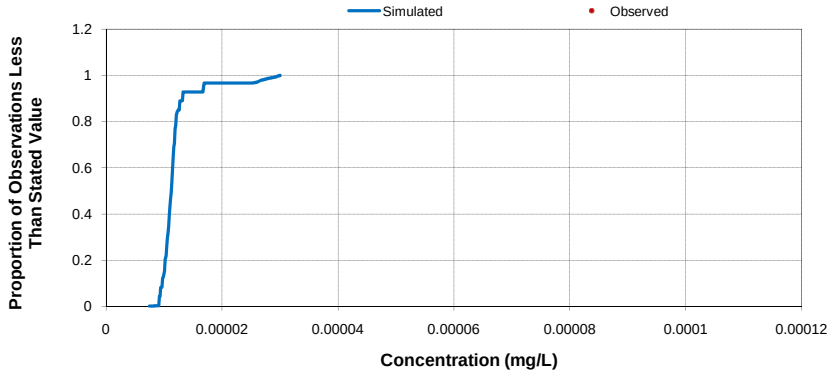



**Peanut Lake**

Open Water

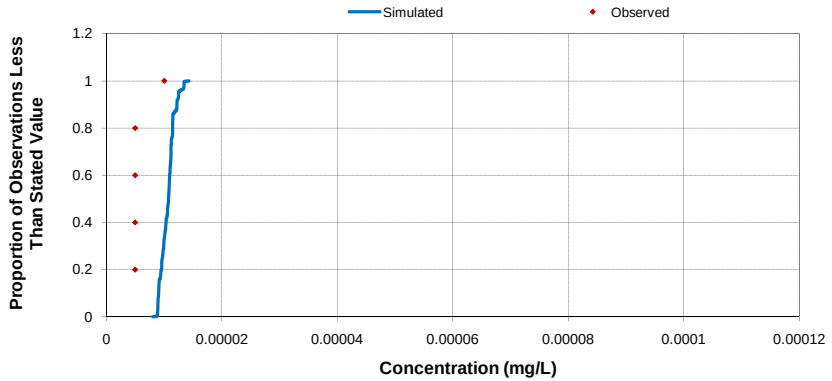



Under-Ice




**Burke Lake**

Open Water




Under-Ice

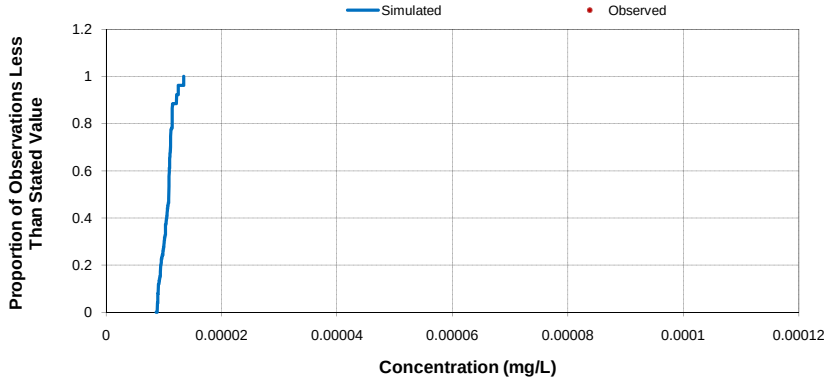
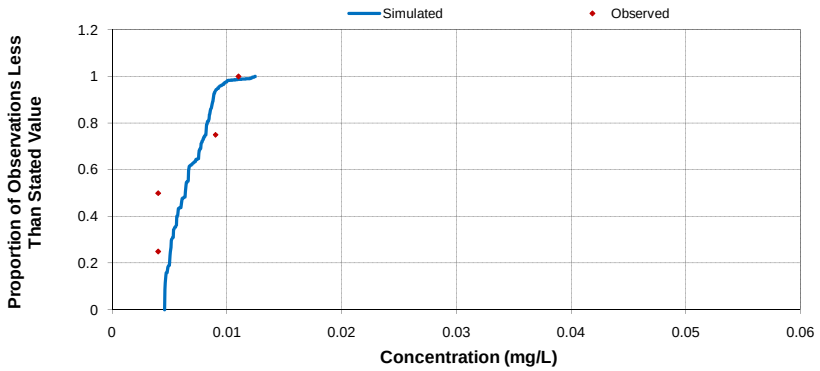


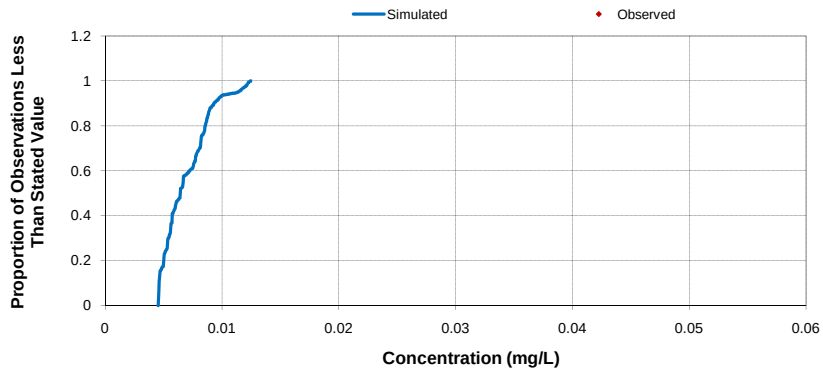
**Figure 7.I.II-7: Comparison of Observed and Predicted Baseline Concentrations of Boron in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

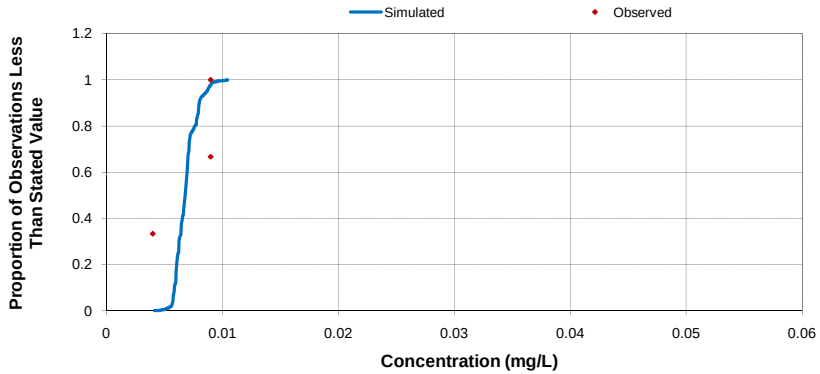



Under-Ice

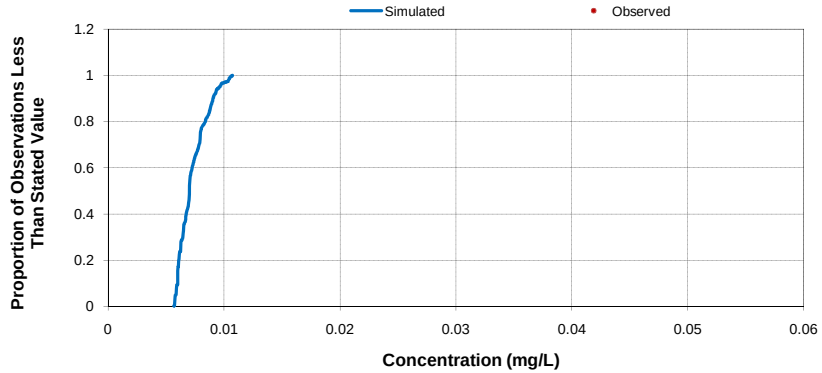



**Peanut Lake**

Open Water

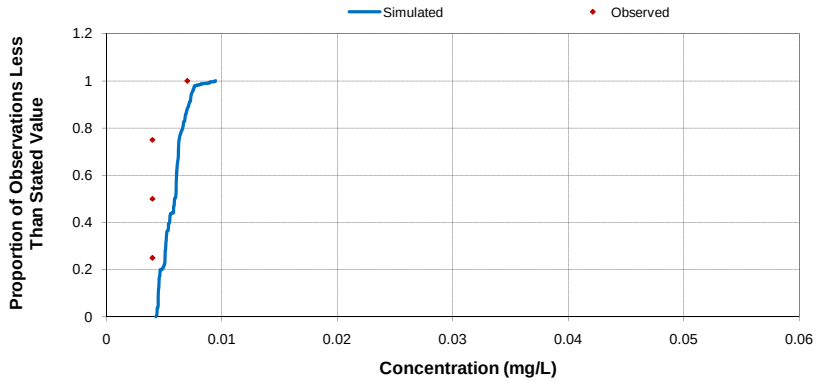



Under-Ice




**Burke Lake**

Open Water




Under-Ice

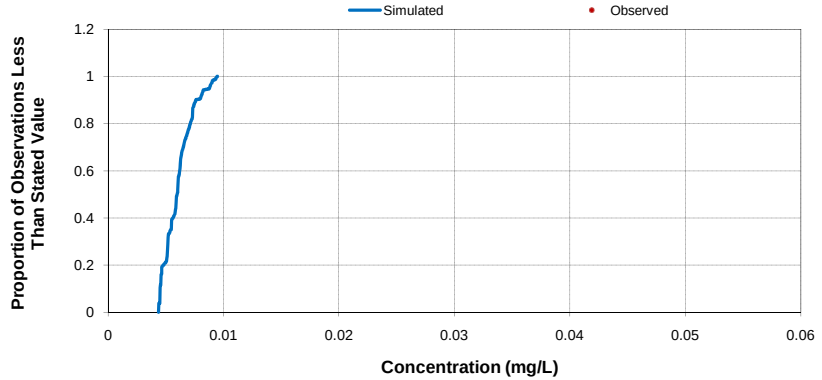
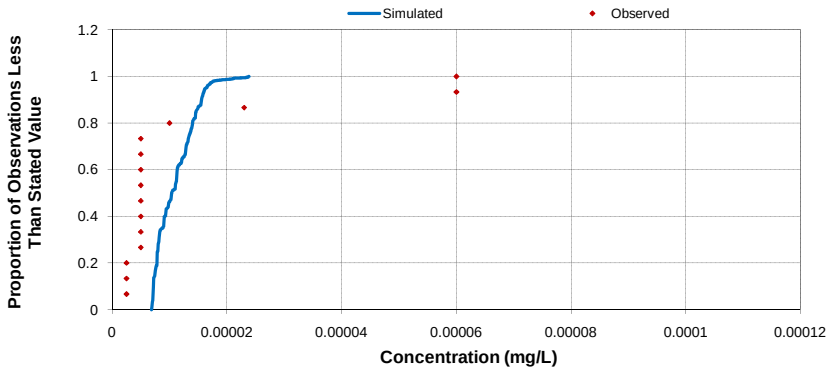


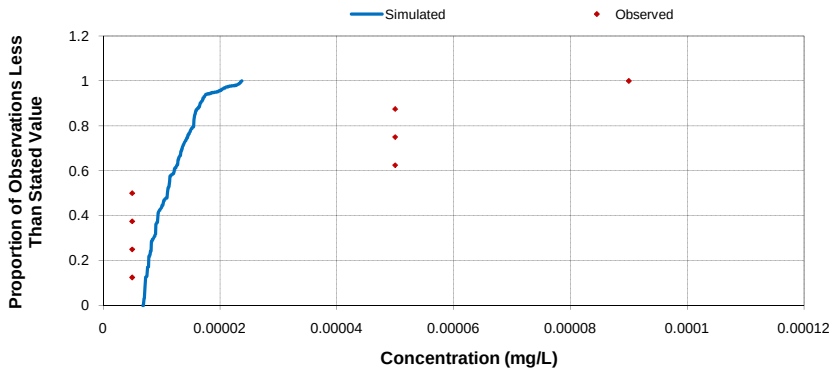
**Figure 7.I.II-8: Comparison of Observed and Predicted Baseline Concentrations of Cadmium in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

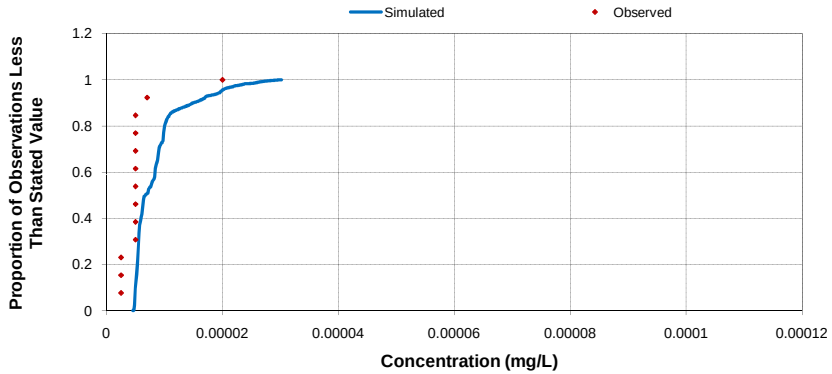



Under-Ice

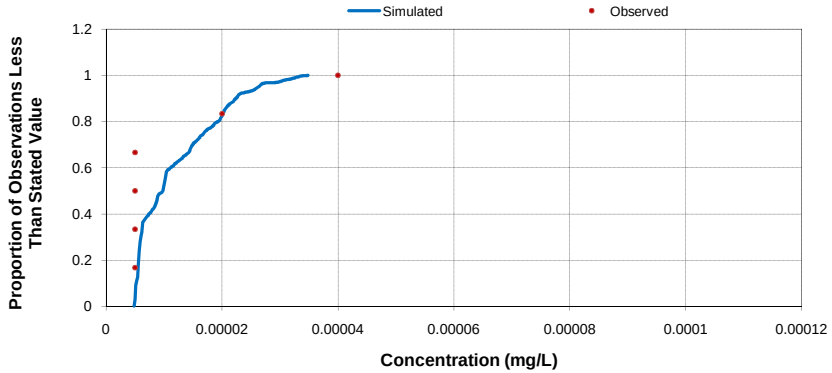



**Peanut Lake**

Open Water

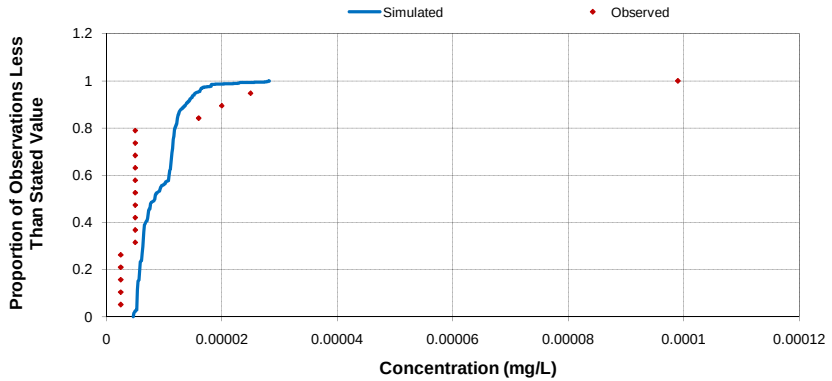



Under-Ice




**Burke Lake**

Open Water




Under-Ice

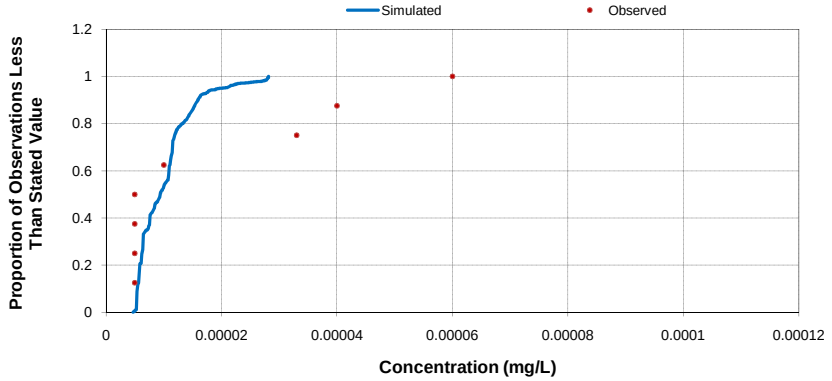
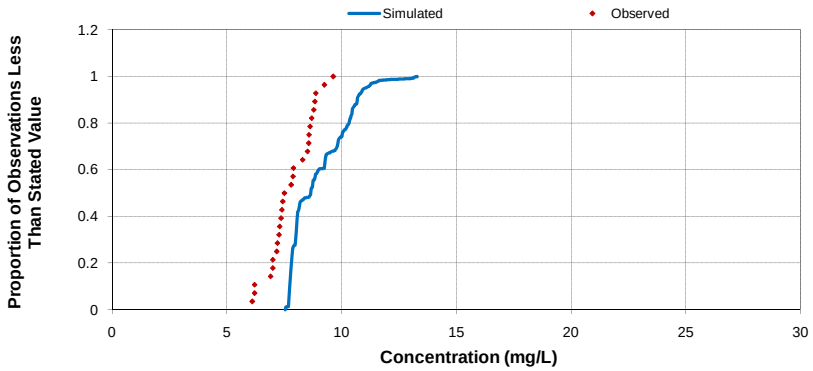


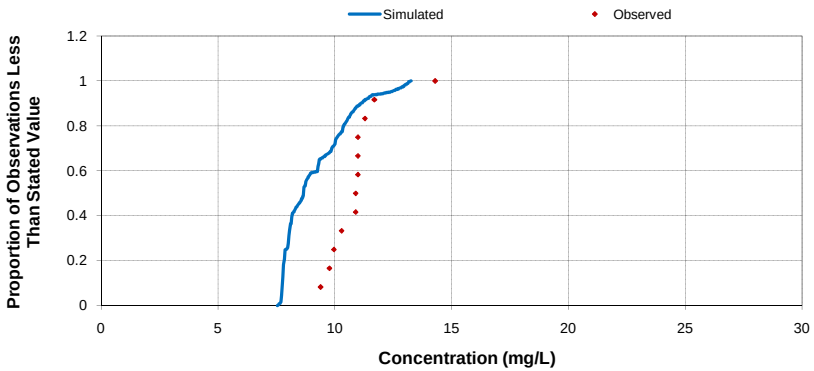
**Figure 7.I.II-9: Comparison of Observed and Predicted Baseline Concentrations of Calcium in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

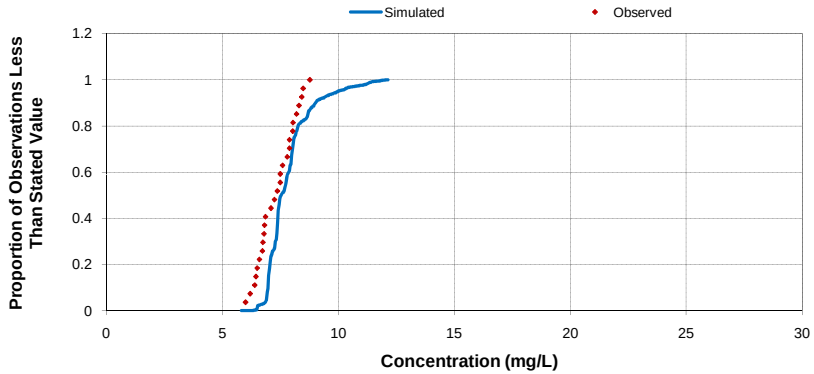



Under-Ice

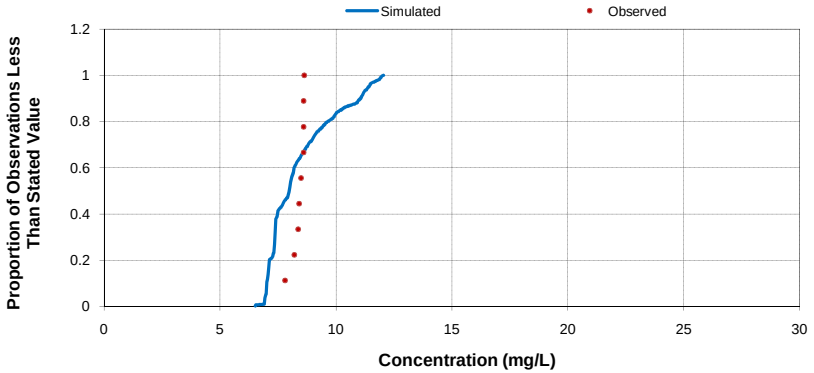



**Peanut Lake**

Open Water

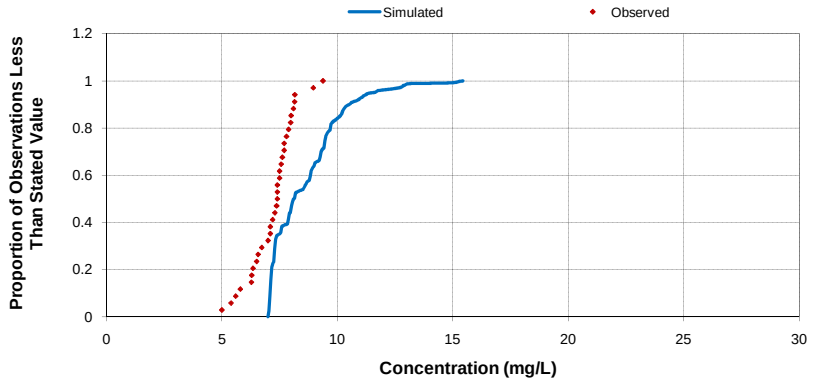



Under-Ice




**Burke Lake**

Open Water




Under-Ice

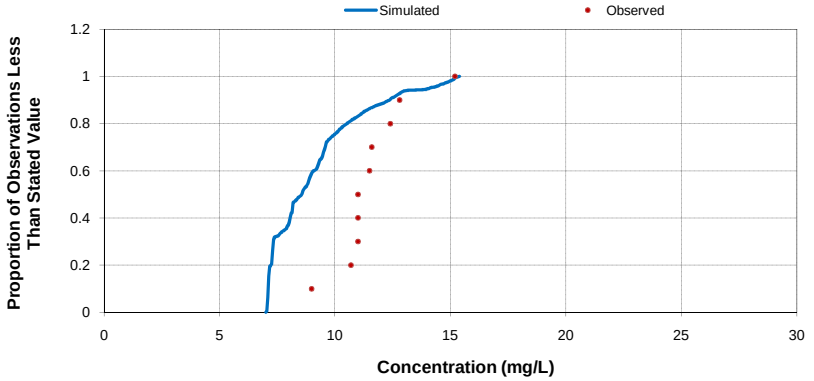
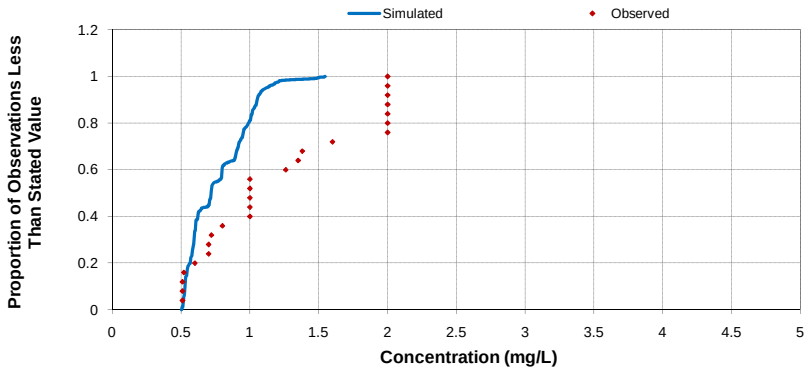


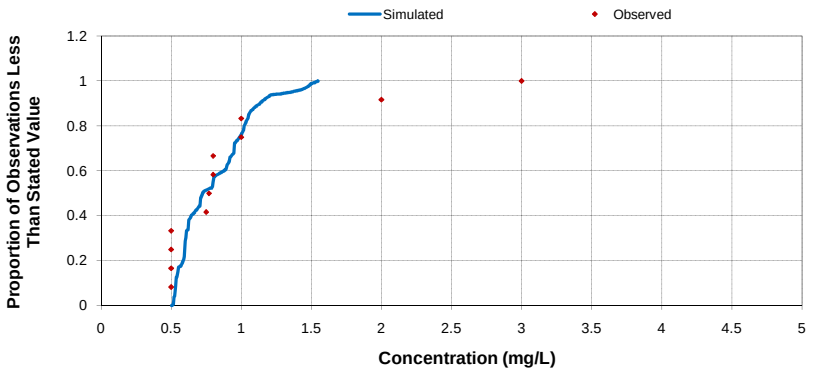
**Figure 7.I.II-10: Comparison of Observed and Predicted Baseline Concentrations of Chloride in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

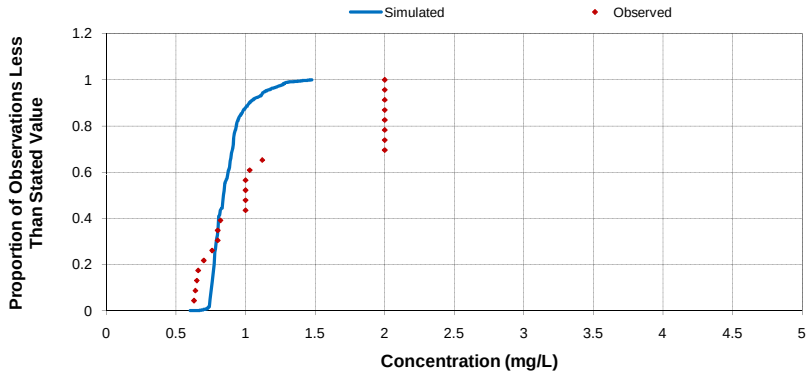



Under-Ice

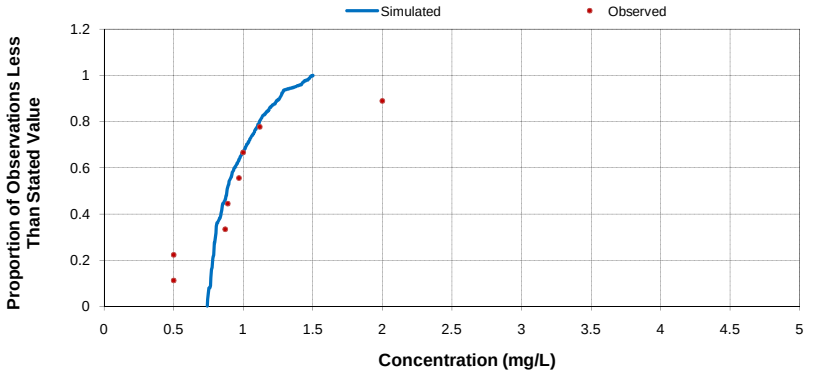



**Peanut Lake**

Open Water

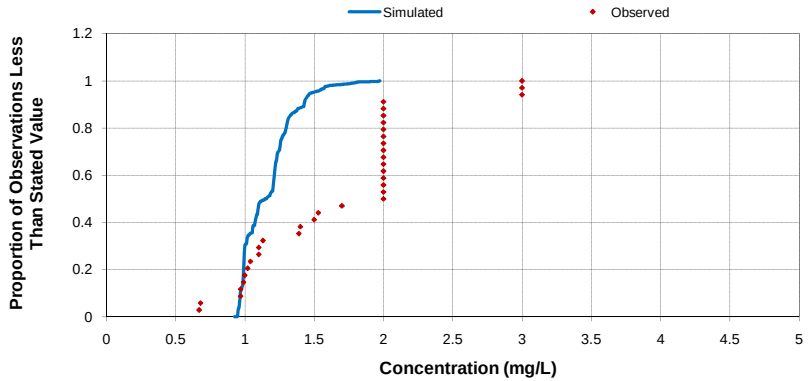



Under-Ice




**Burke Lake**

Open Water




Under-Ice

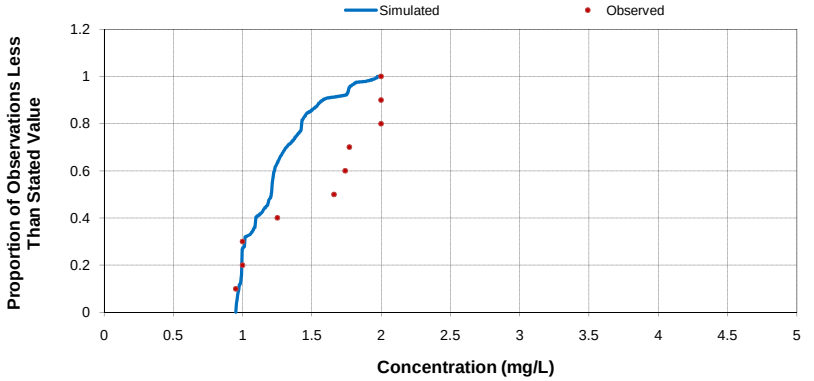
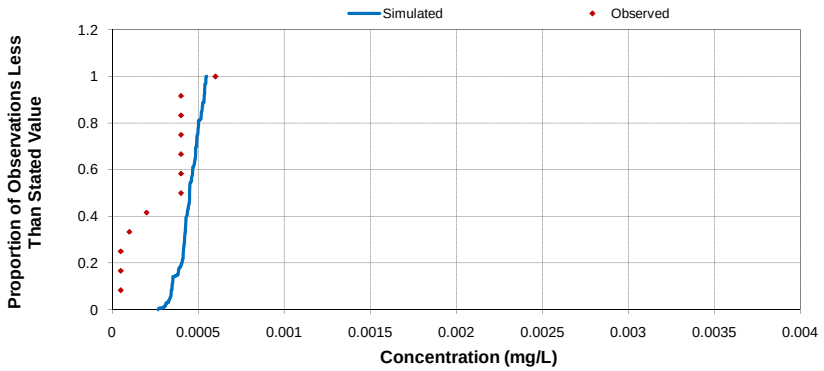


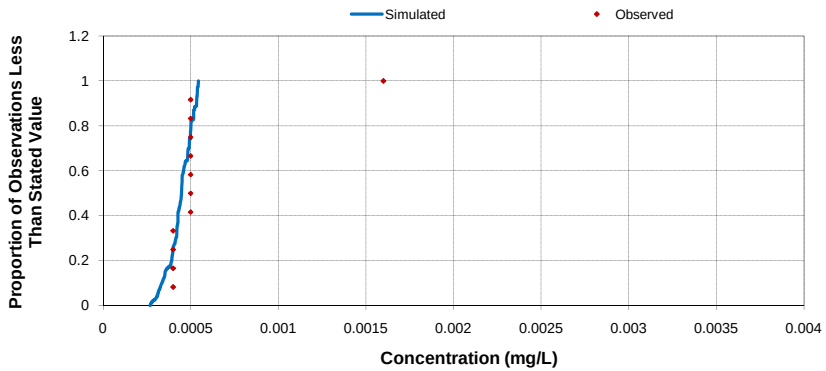
**Figure 7.I.II-11: Comparison of Observed and Predicted Baseline Concentrations of Chromium in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

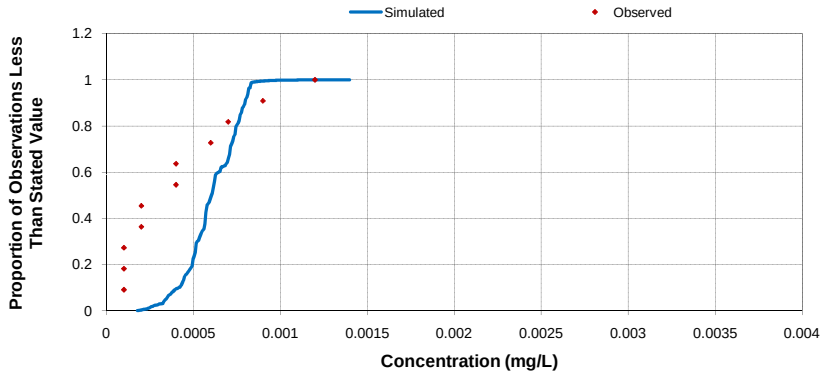



Under-Ice

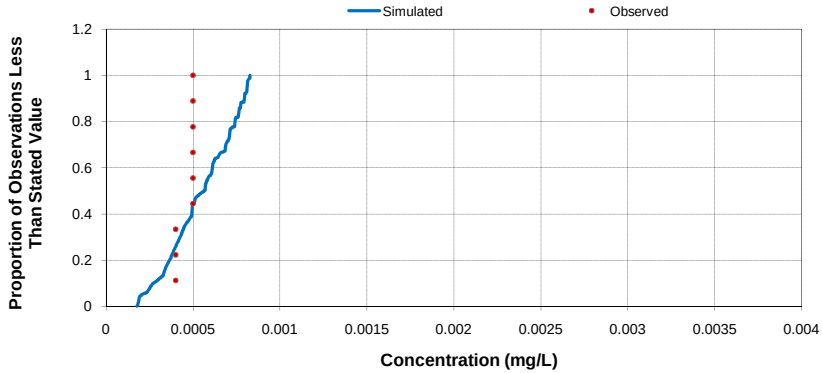



**Peanut Lake**

Open Water

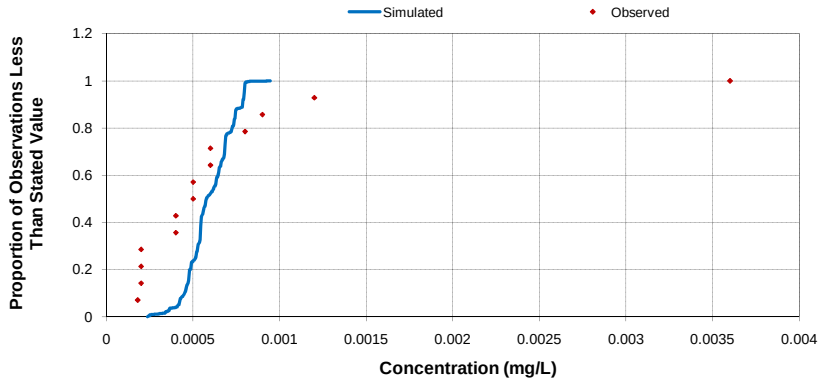



Under-Ice




**Burke Lake**

Open Water




Under-Ice

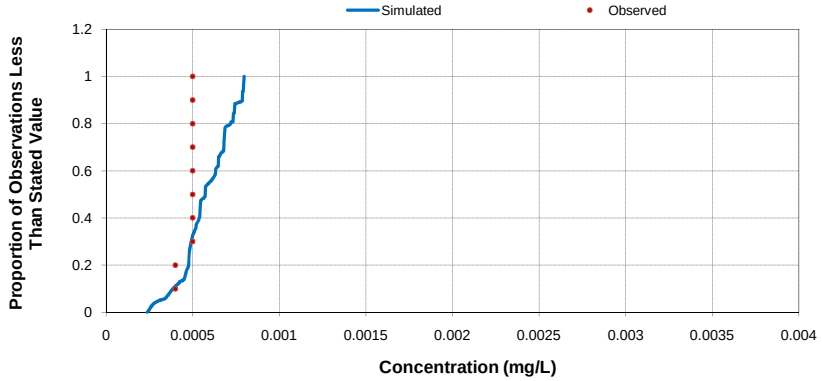
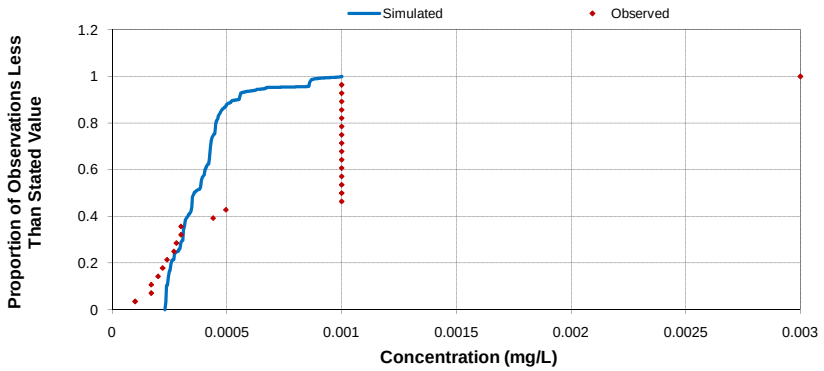


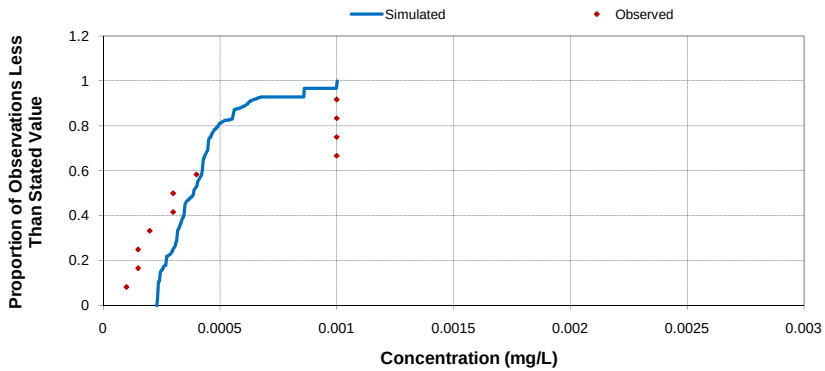
**Figure 7.I.II-12: Comparison of Observed and Predicted Baseline Concentrations of Cobalt in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

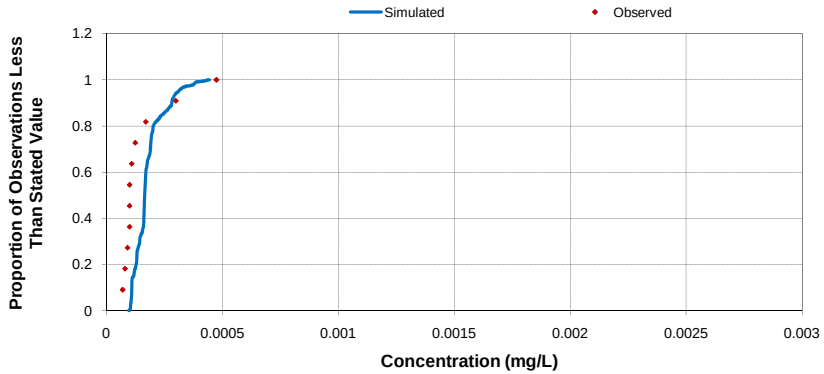



Under-Ice

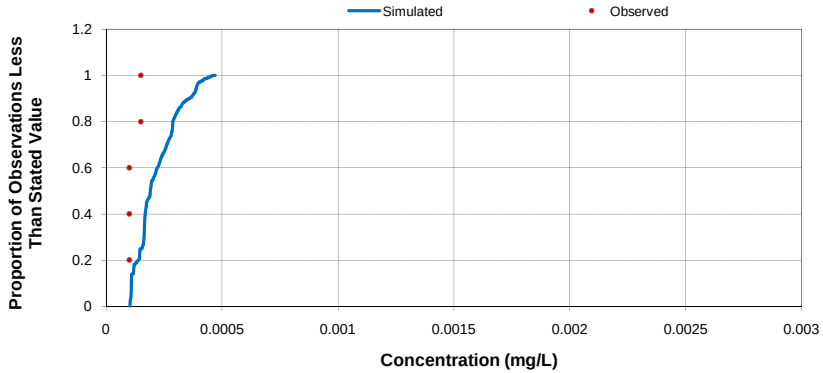



**Peanut Lake**

Open Water

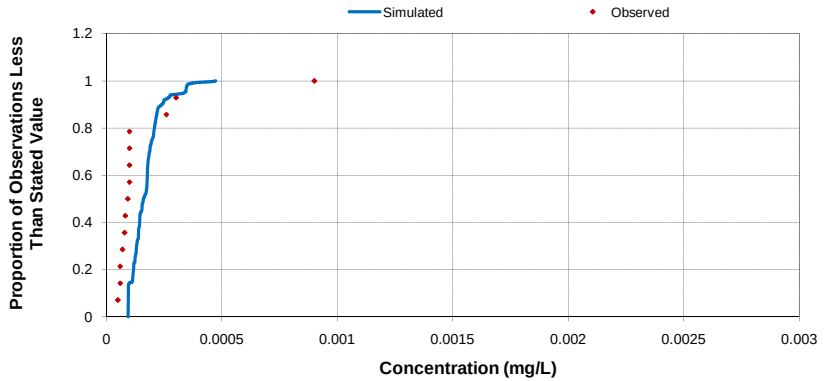



Under-Ice




**Burke Lake**

Open Water




Under-Ice

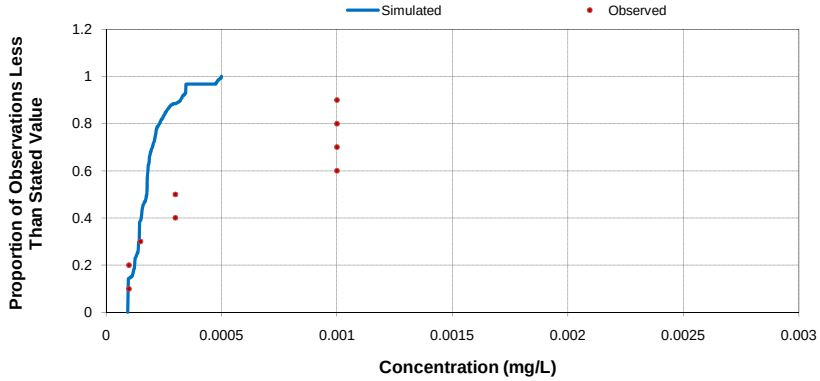
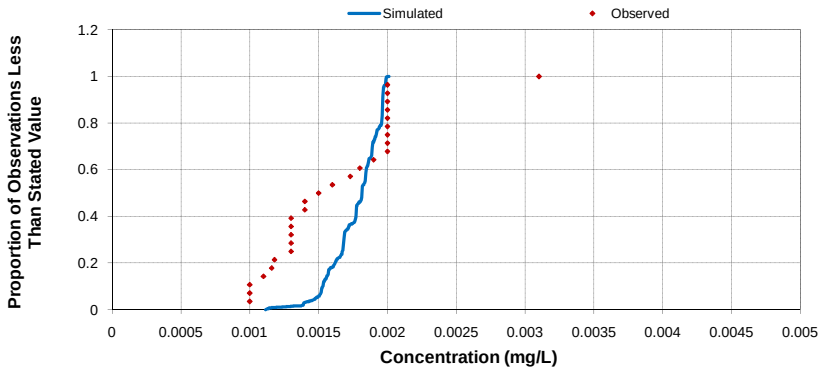


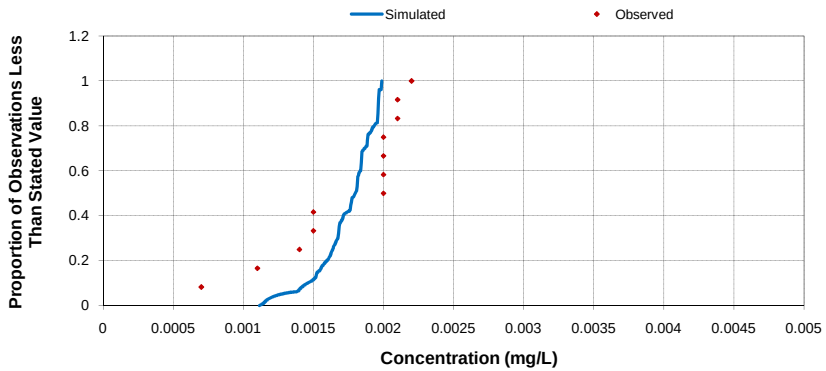
**Figure 7.I.II-13: Comparison of Observed and Predicted Baseline Concentrations of Copper in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

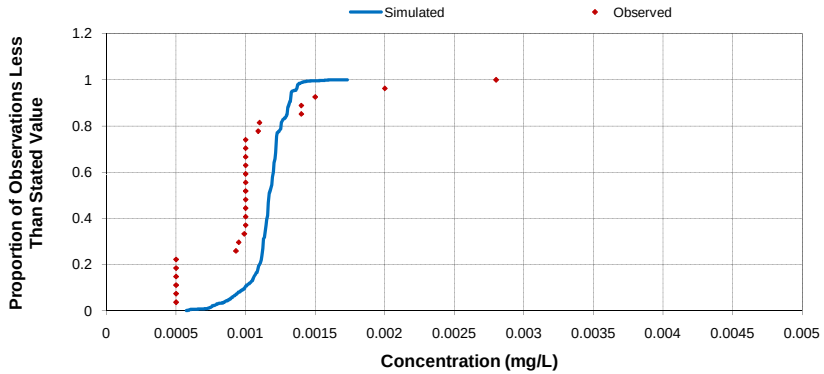



Under-Ice

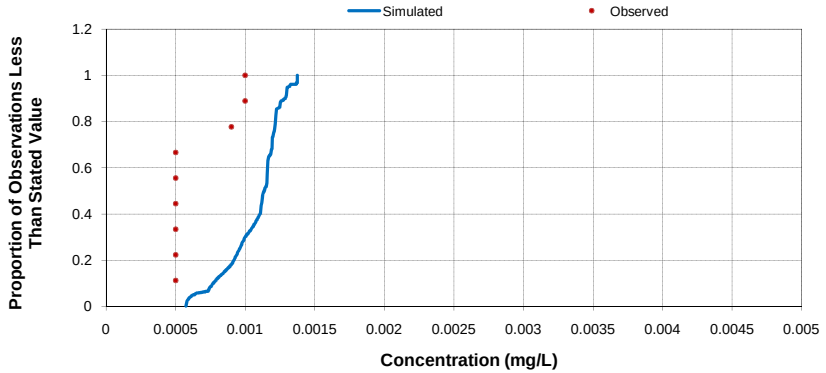



**Peanut Lake**

Open Water

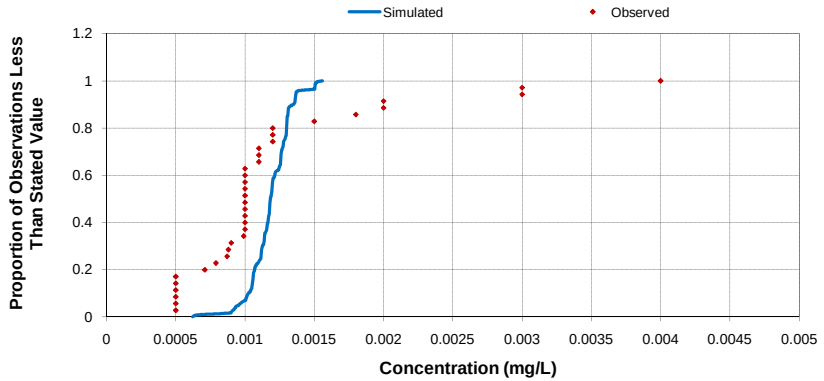



Under-Ice




**Burke Lake**

Open Water




Under-Ice

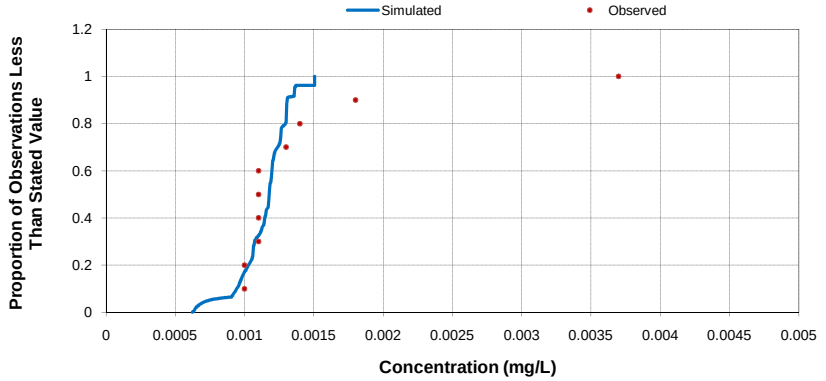
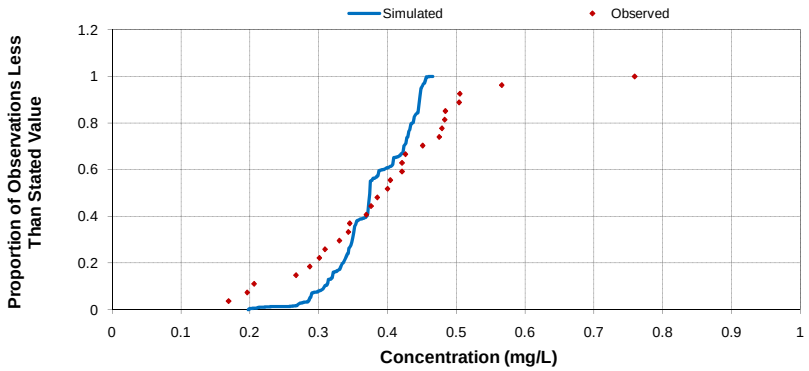


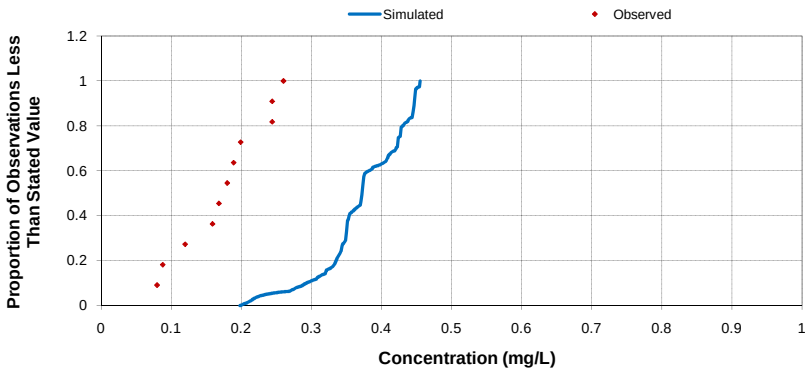
**Figure 7.I.II-14: Comparison of Observed and Predicted Baseline Concentrations of Iron in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

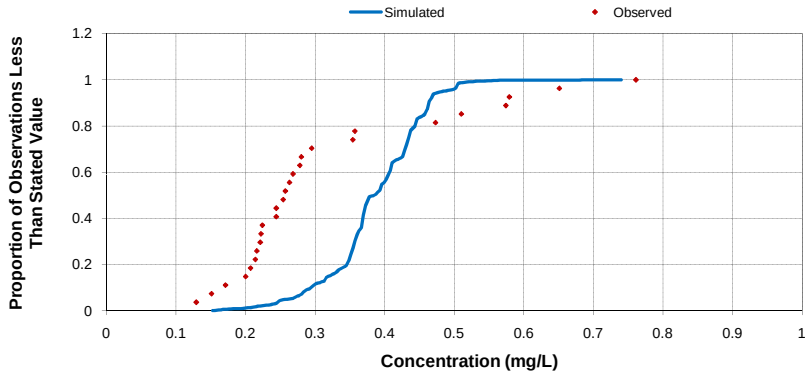



Under-Ice

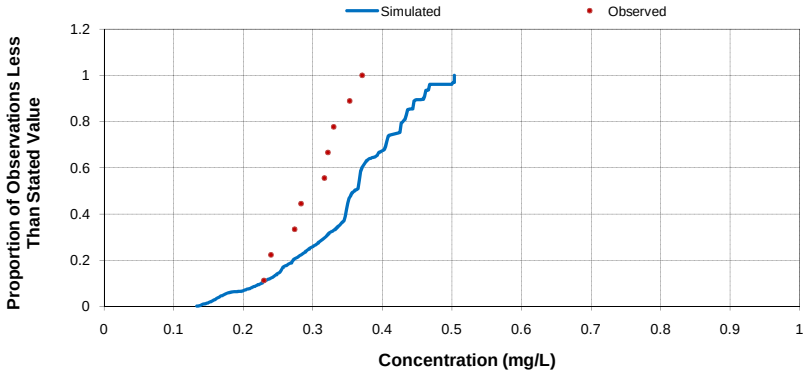



**Peanut Lake**

Open Water

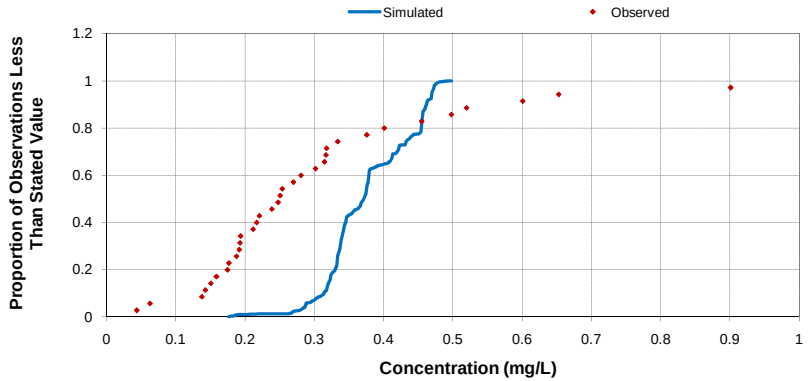



Under-Ice




**Burke Lake**

Open Water




Under-Ice

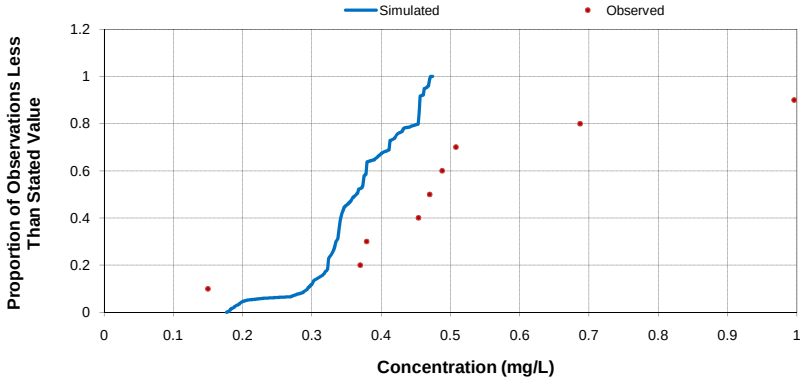
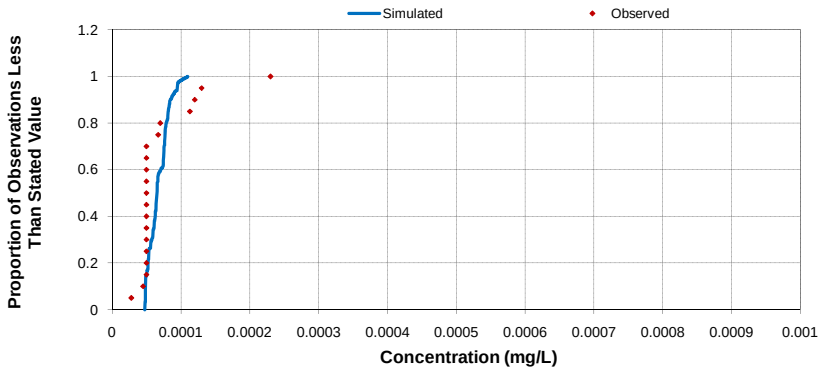


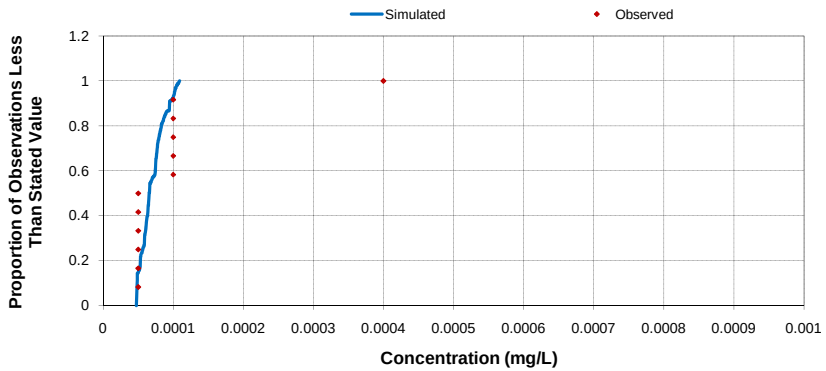
**Figure 7.I.II-15: Comparison of Observed and Predicted Baseline Concentrations of Lead in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

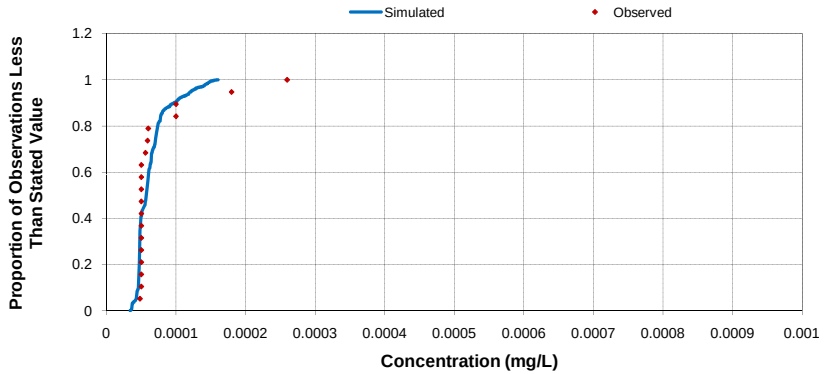



Under-Ice

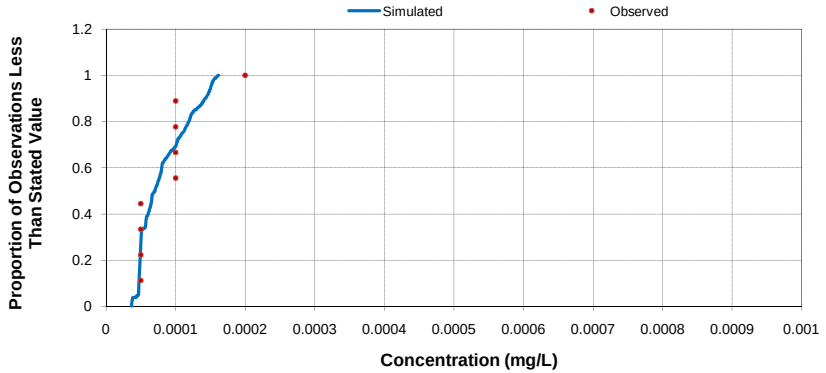



**Peanut Lake**

Open Water

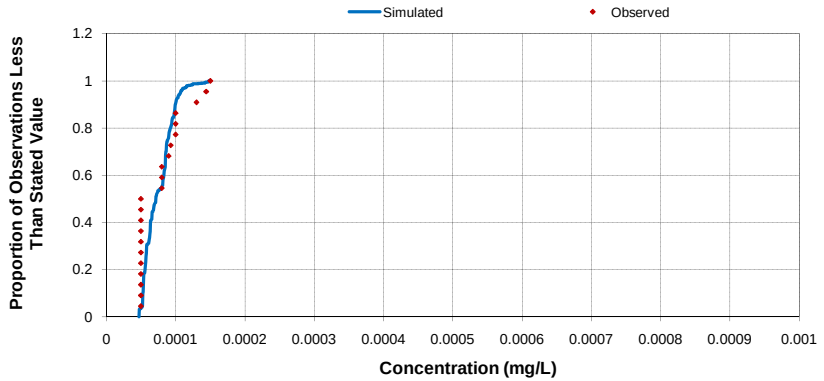



Under-Ice




**Burke Lake**

Open Water




Under-Ice

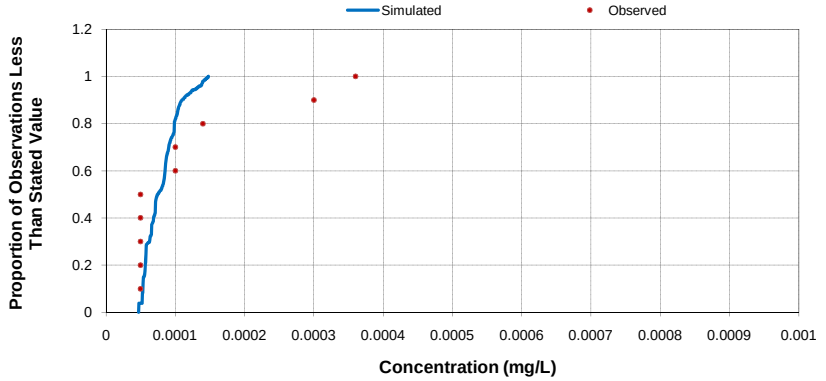
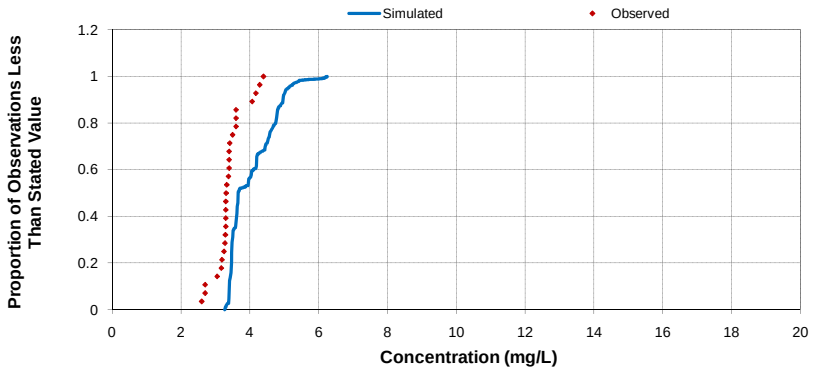


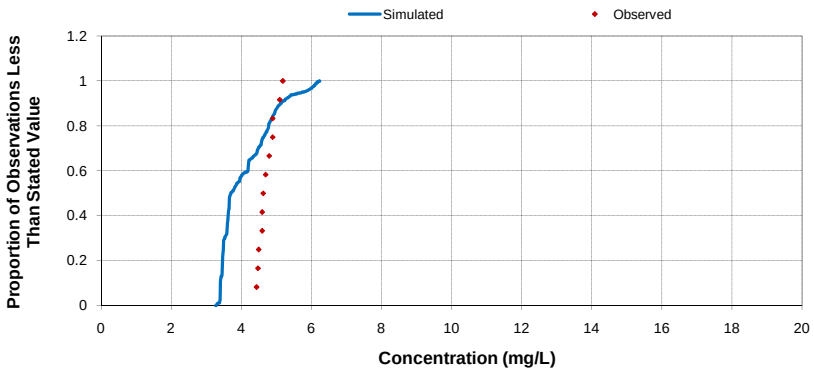
**Figure 7.I.II-16: Comparison of Observed and Predicted Baseline Concentrations of Magnesium in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

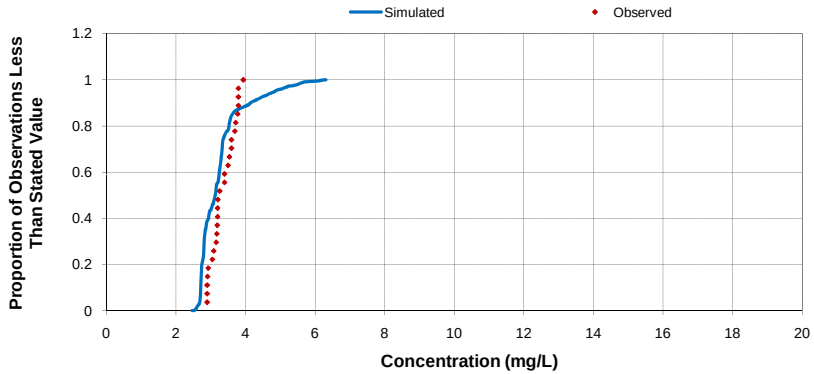



Under-Ice

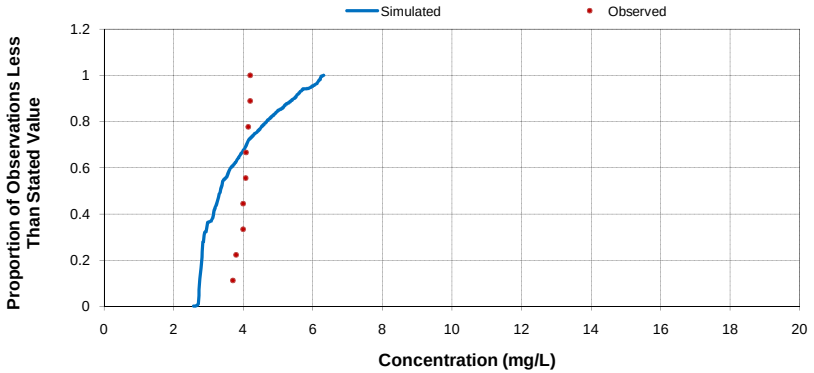



**Peanut Lake**

Open Water

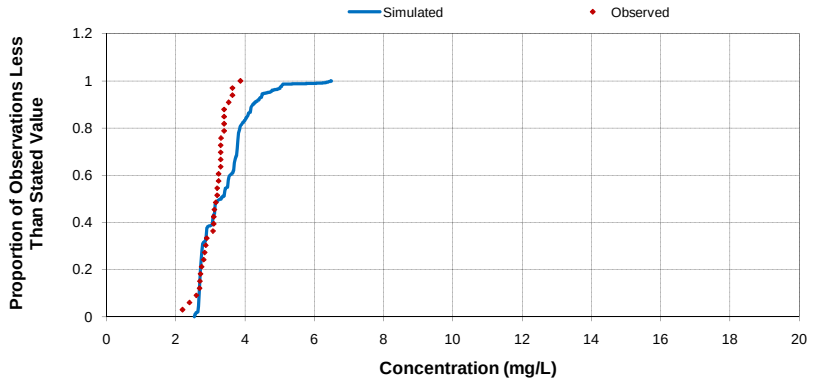



Under-Ice




**Burke Lake**

Open Water




Under-Ice

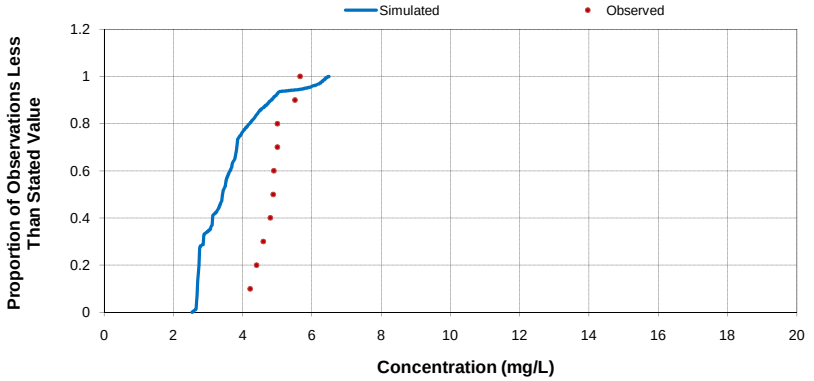
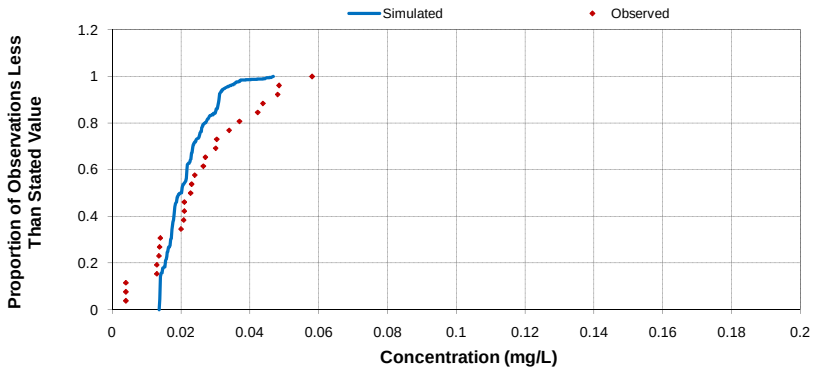


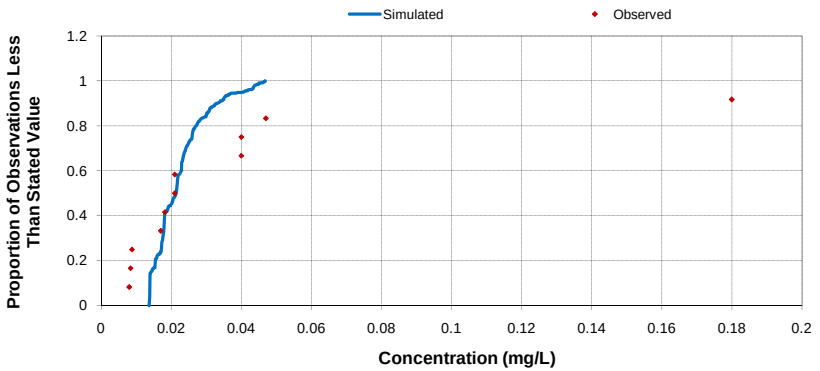
**Figure 7.I.II-17: Comparison of Observed and Predicted Baseline Concentrations of Manganese in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

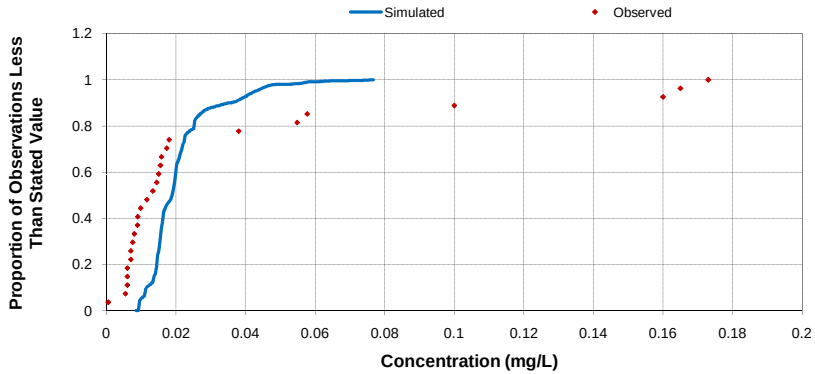



Under-Ice

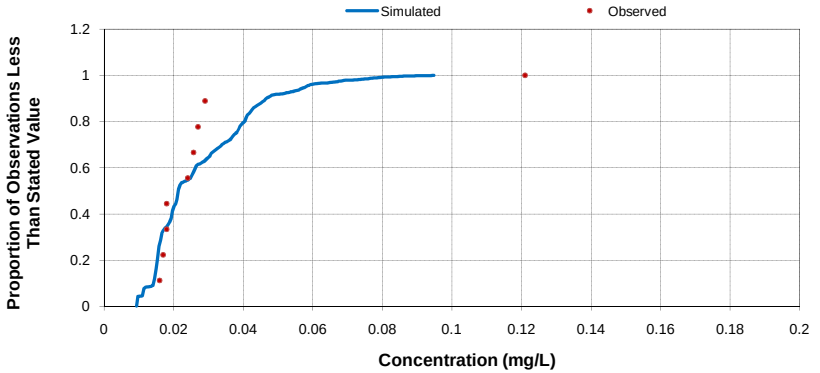



**Peanut Lake**

Open Water

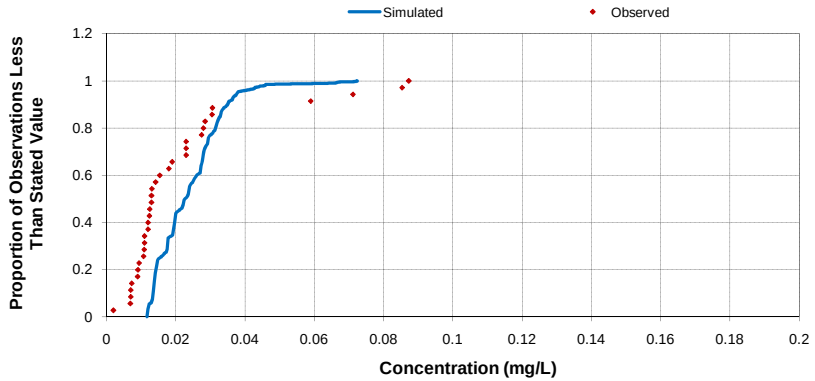



Under-Ice




**Burke Lake**

Open Water




Under-Ice

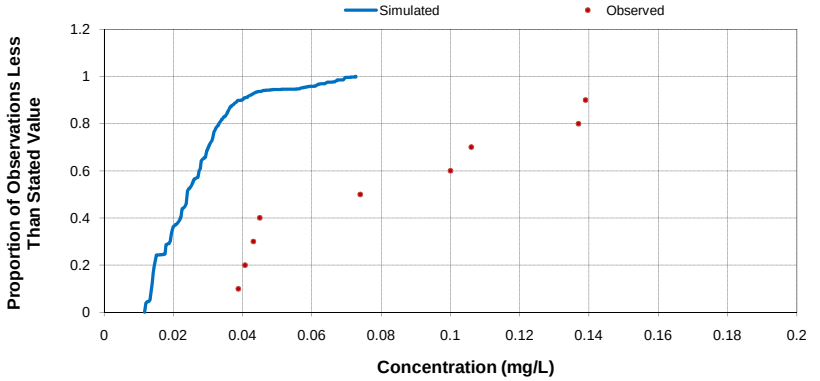
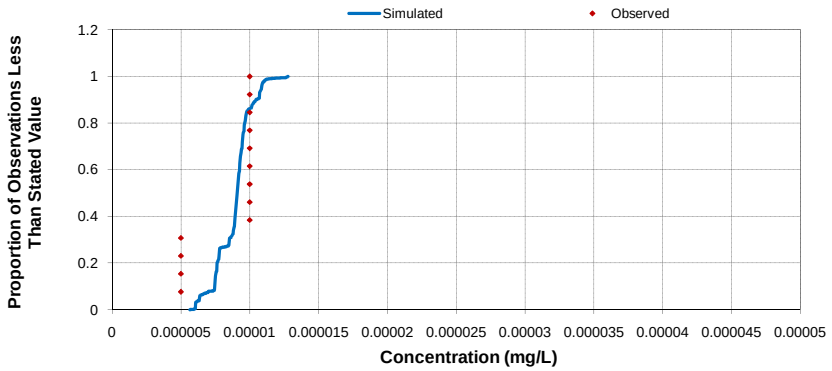


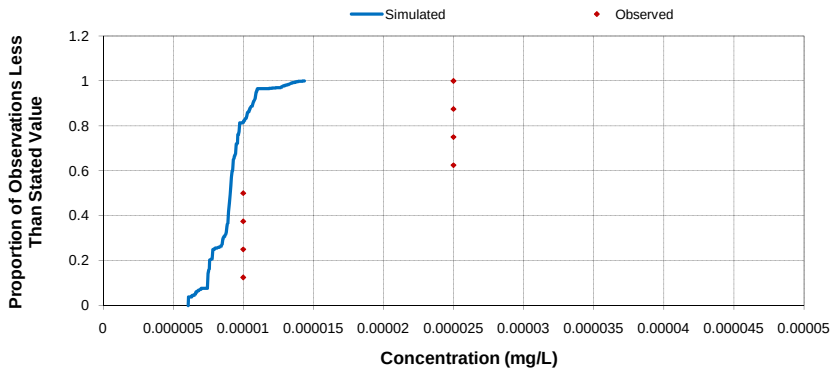
**Figure 7.I.II-18: Comparison of Observed and Predicted Baseline Concentrations of Mercury in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

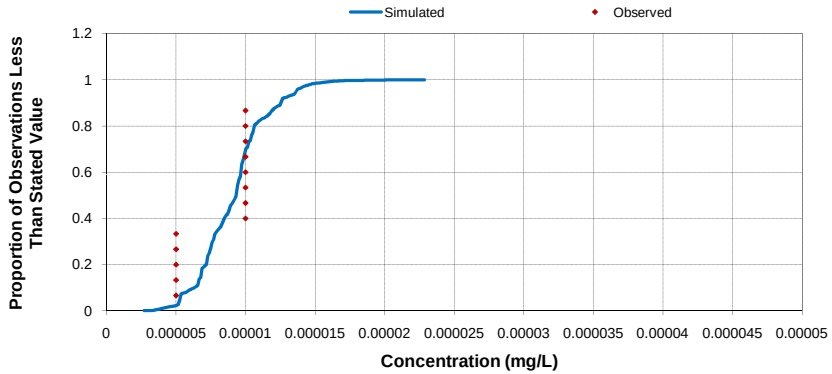



Under-Ice

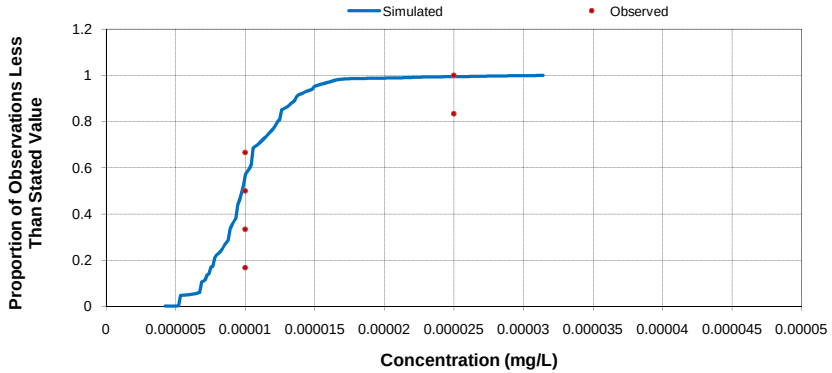



**Peanut Lake**

Open Water

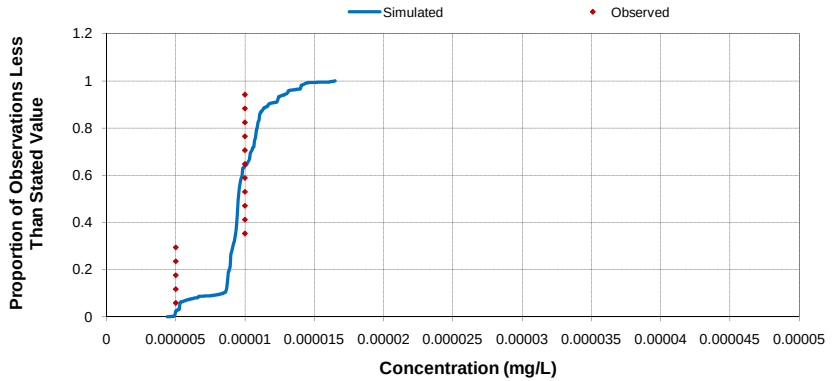



Under-Ice




**Burke Lake**

Open Water




Under-Ice

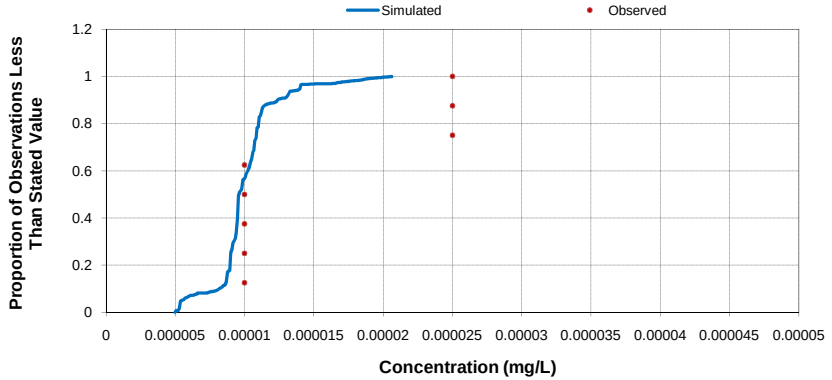
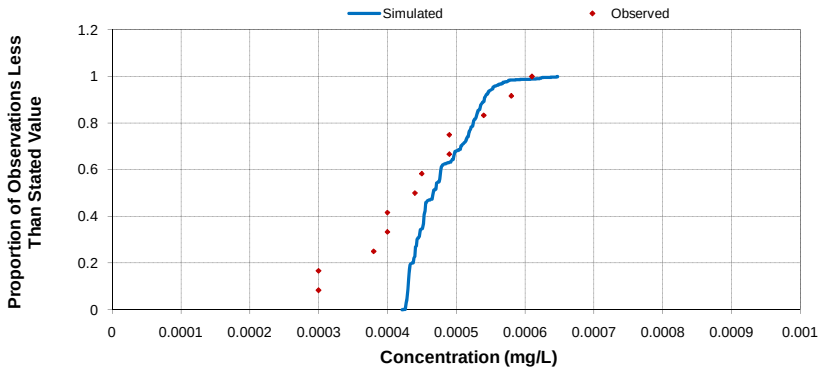


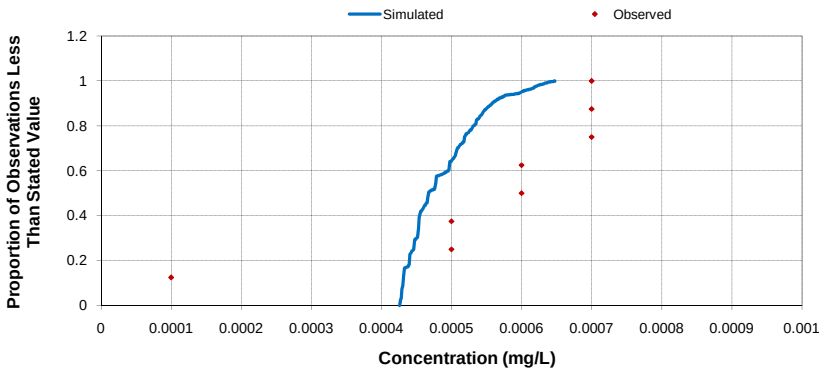
**Figure 7.I.II-19: Comparison of Observed and Predicted Baseline Concentrations of Molybdenum in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

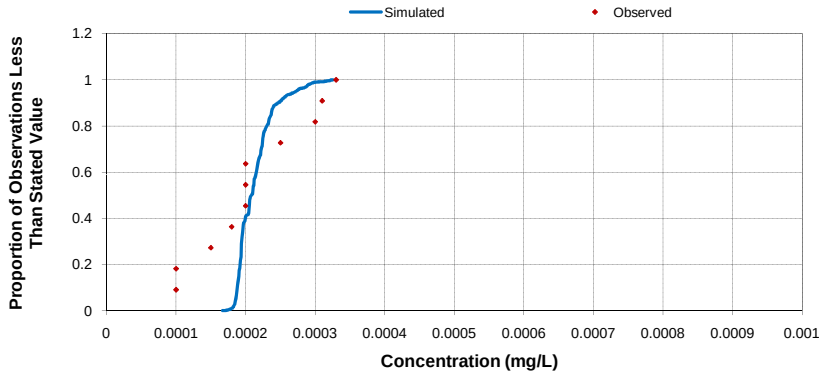



Under-Ice

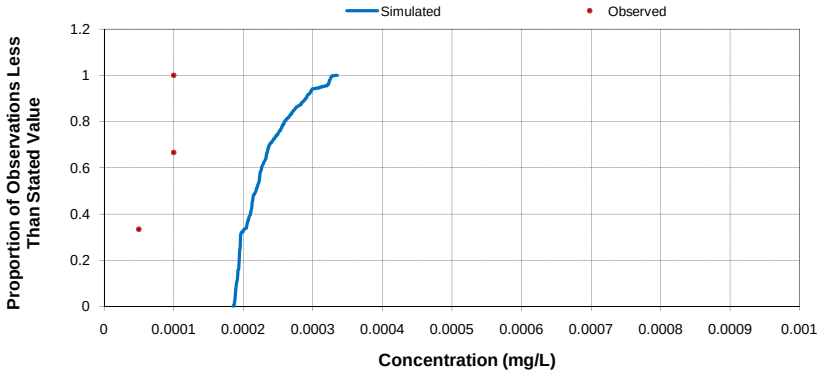



**Peanut Lake**

Open Water

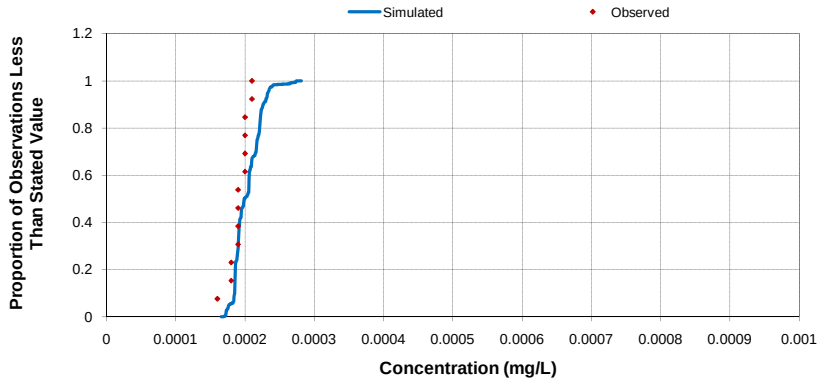



Under-Ice




**Burke Lake**

Open Water




Under-Ice

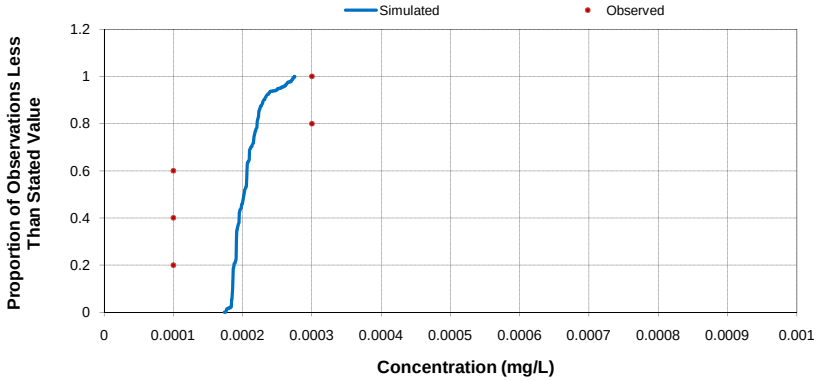
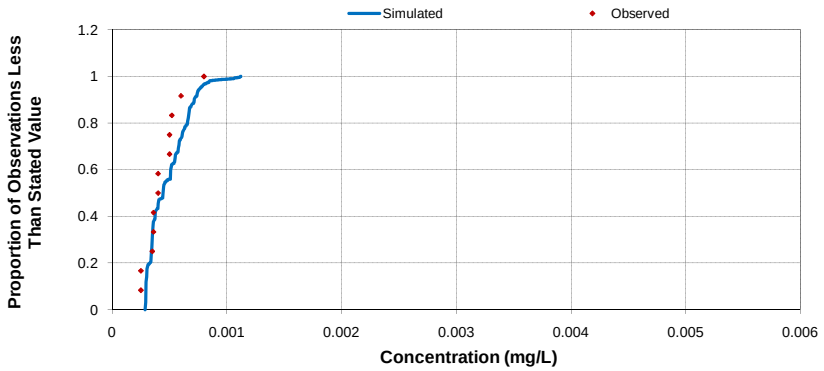


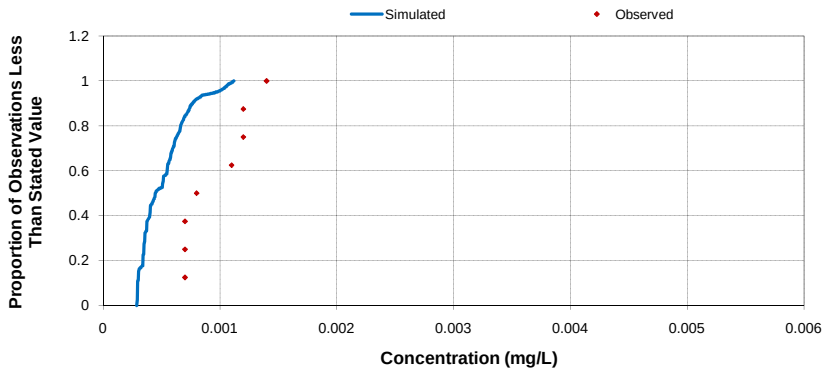
**Figure 7.I.II-20: Comparison of Observed and Predicted Baseline Concentrations of Nickel in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

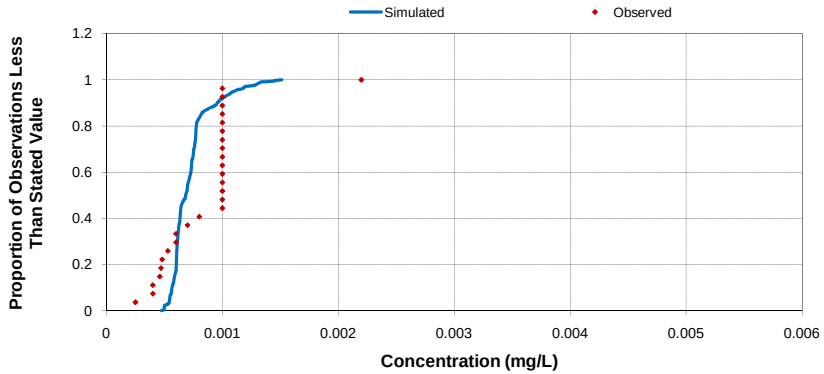



Under-Ice

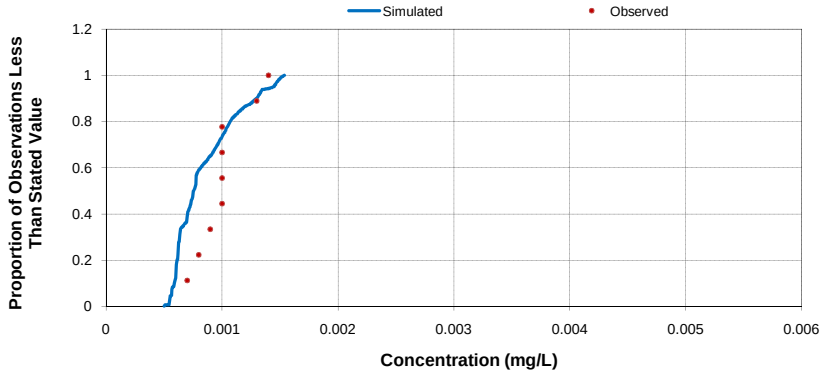



**Peanut Lake**

Open Water

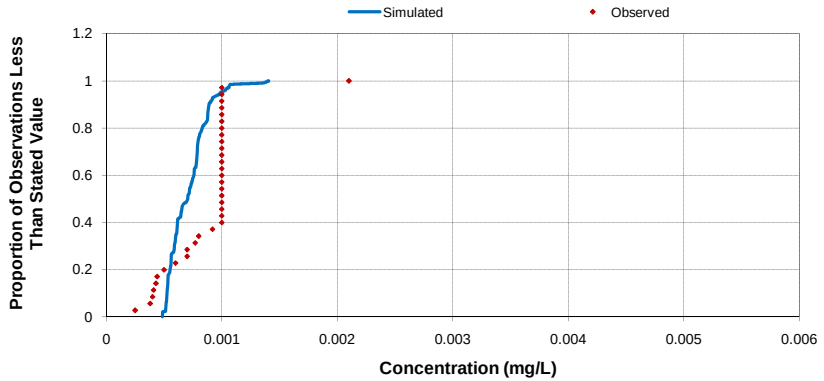



Under-Ice




**Burke Lake**

Open Water




Under-Ice

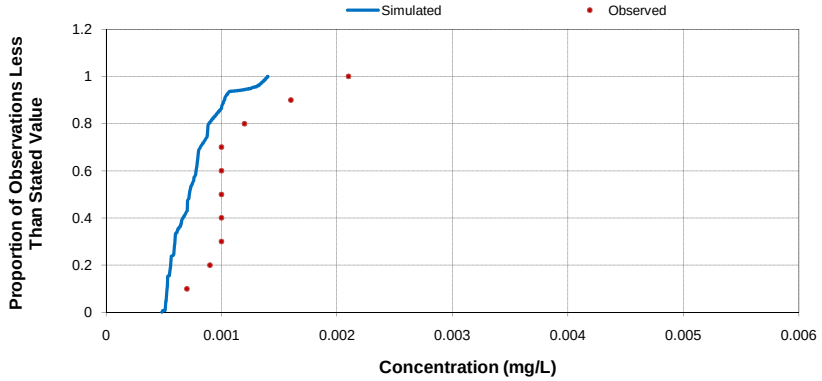
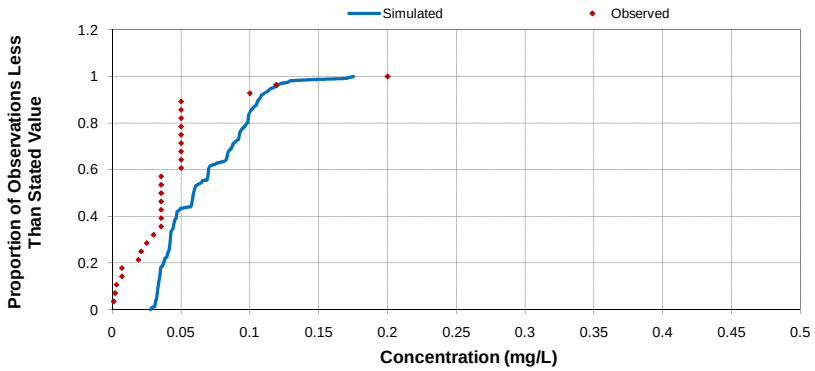


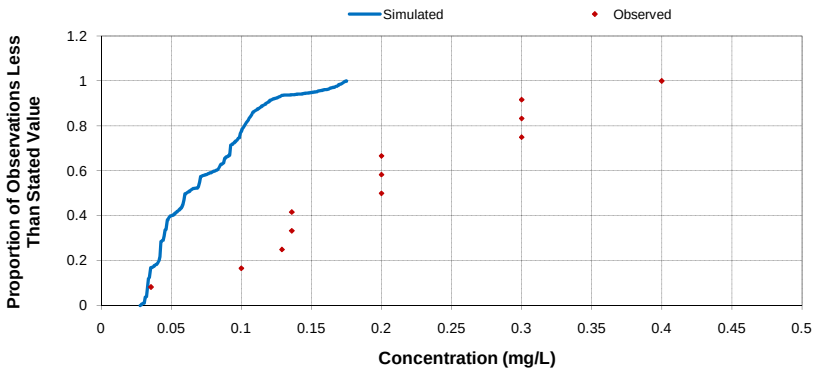
**Figure 7.I.II-21: Comparison of Observed and Predicted Baseline Concentrations of Nitrate in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

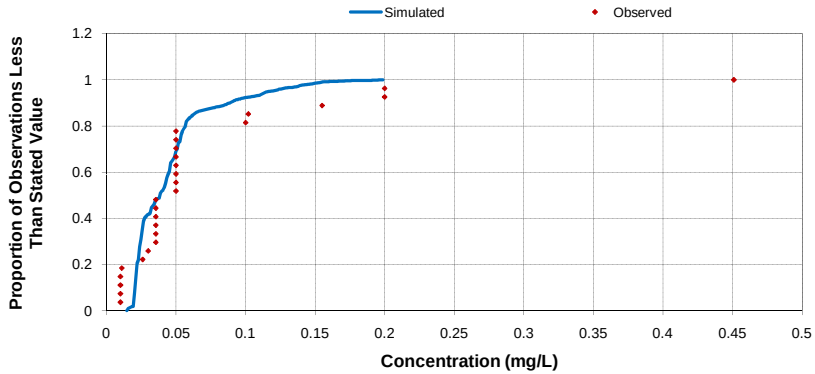



Under-Ice

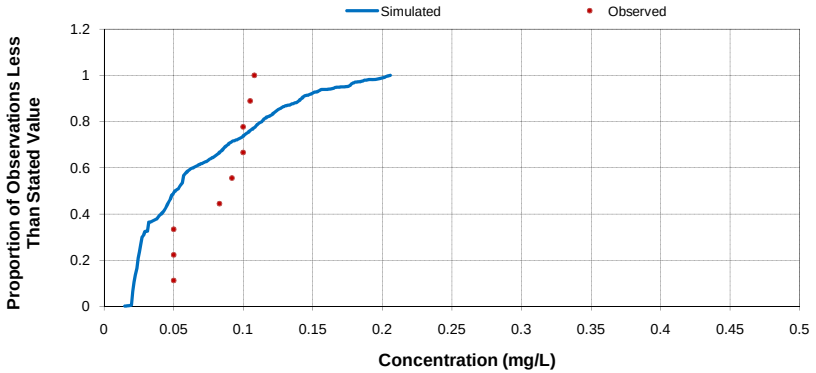



**Peanut Lake**

Open Water

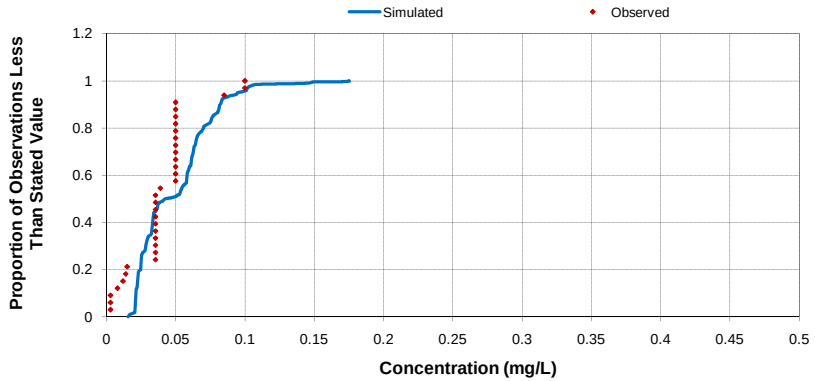



Under-Ice




**Burke Lake**

Open Water




Under-Ice

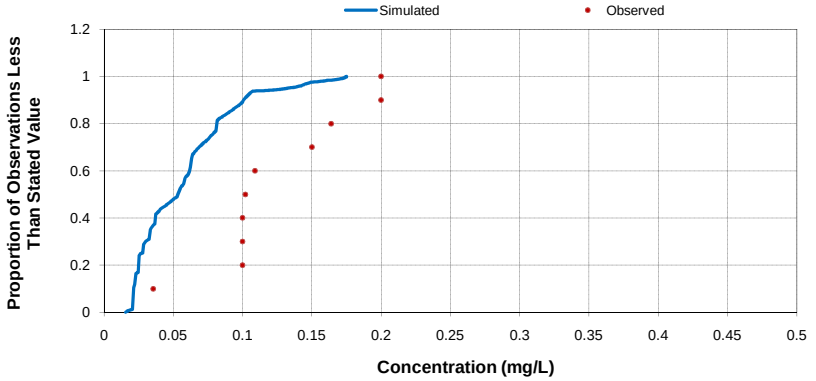
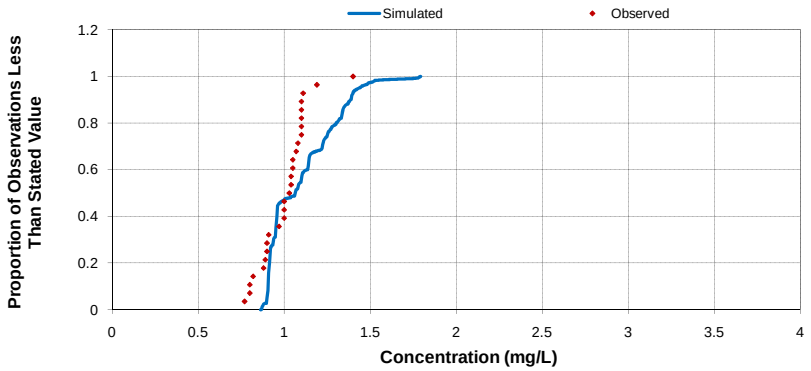


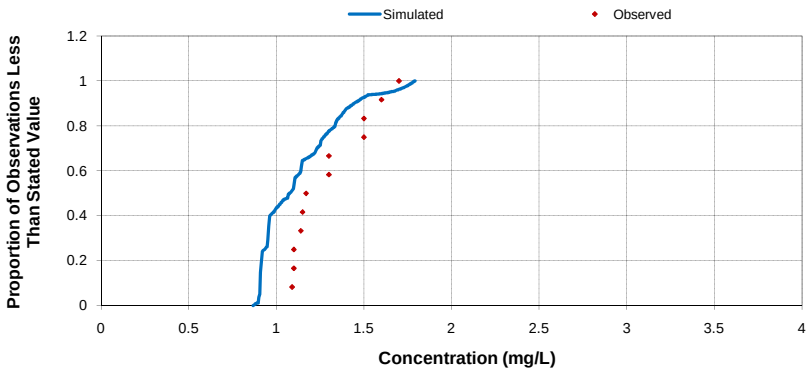
**Figure 7.I.II-22: Comparison of Observed and Predicted Baseline Concentrations of Potassium in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

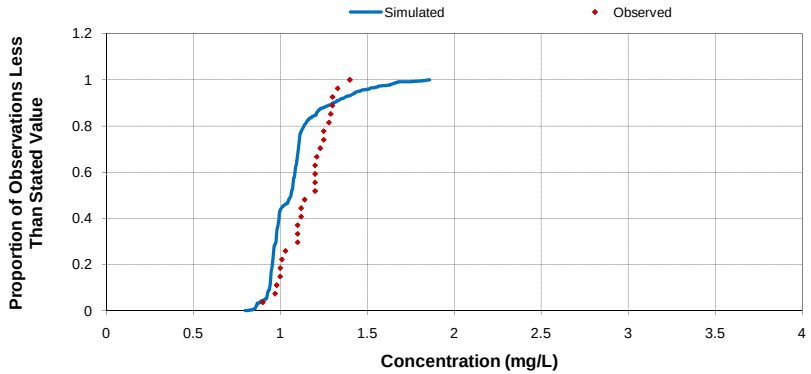



Under-Ice

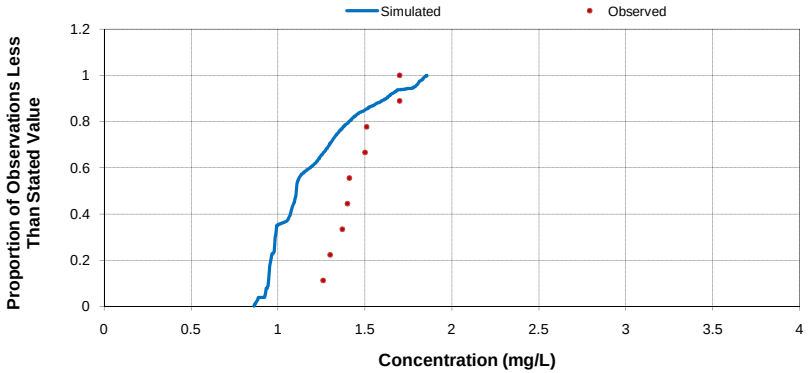



**Peanut Lake**

Open Water

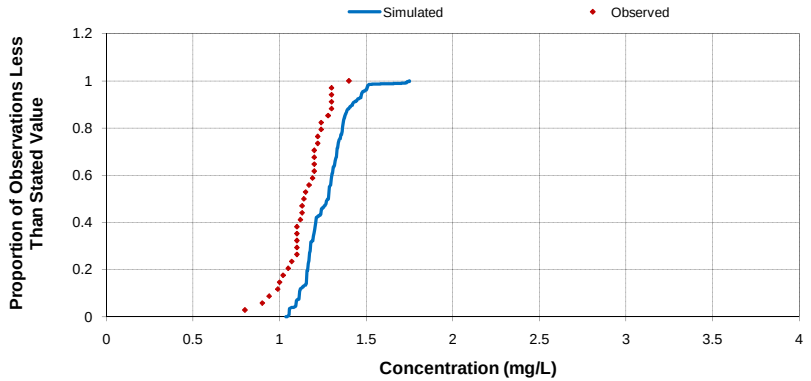



Under-Ice




**Burke Lake**

Open Water




Under-Ice

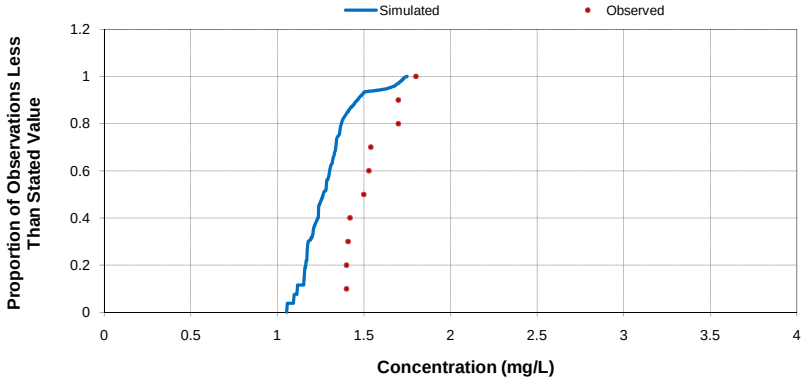
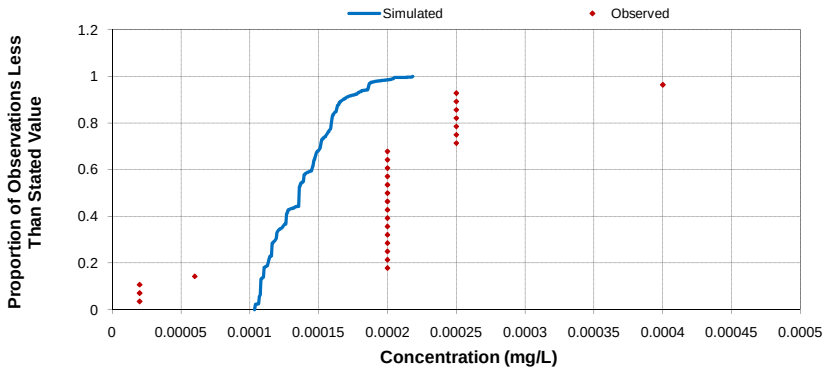


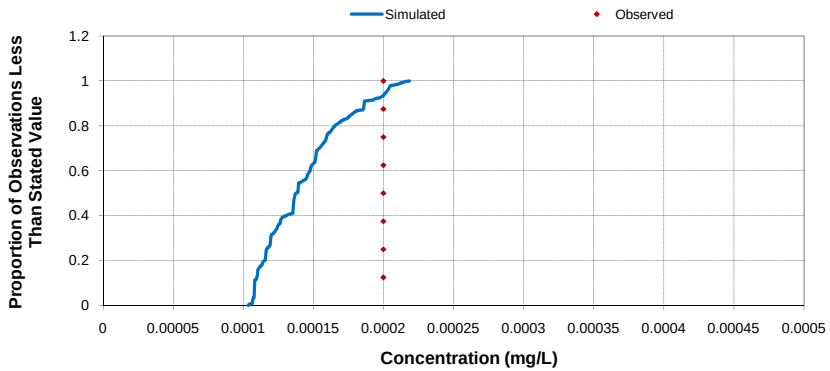
**Figure 7.I.II-23: Comparison of Observed and Predicted Baseline Concentrations of Selenium in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

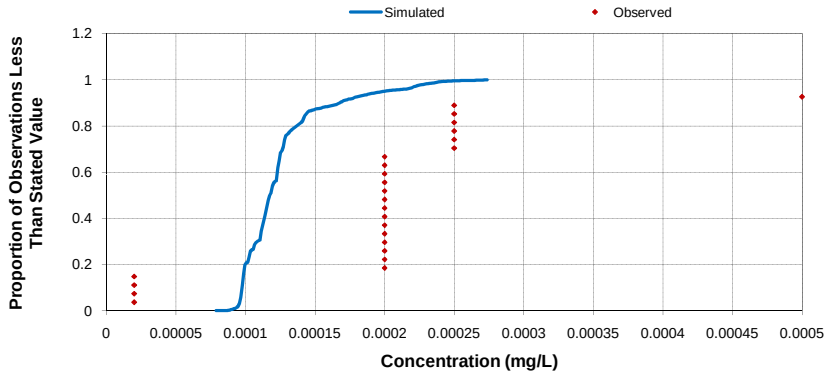



Under-Ice

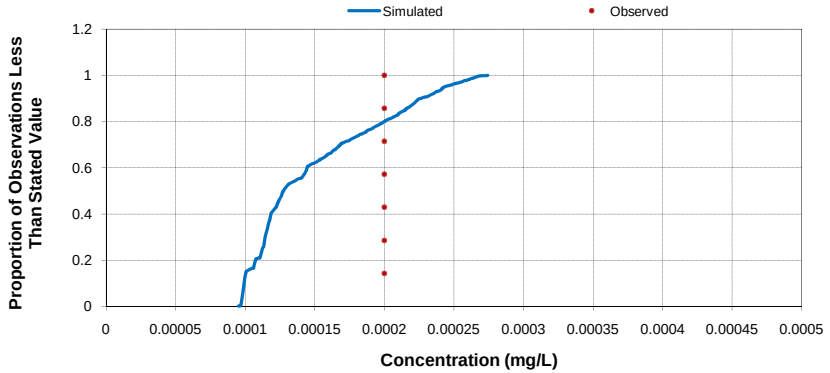



**Peanut Lake**

Open Water

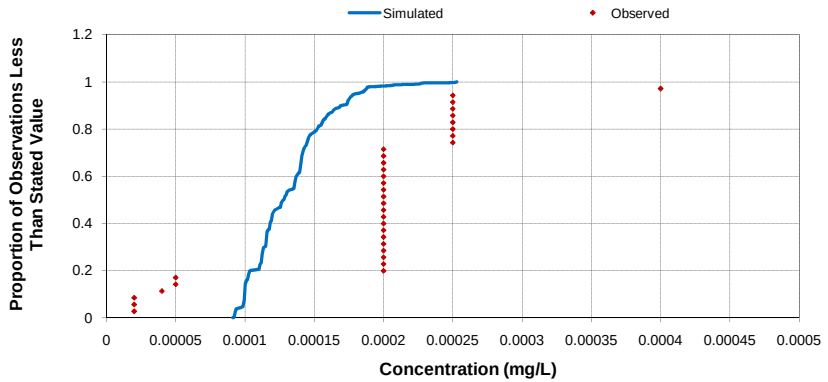



Under-Ice




**Burke Lake**

Open Water




Under-Ice

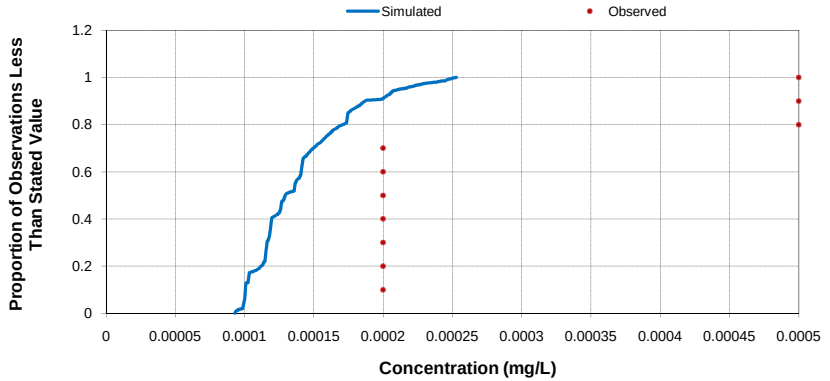
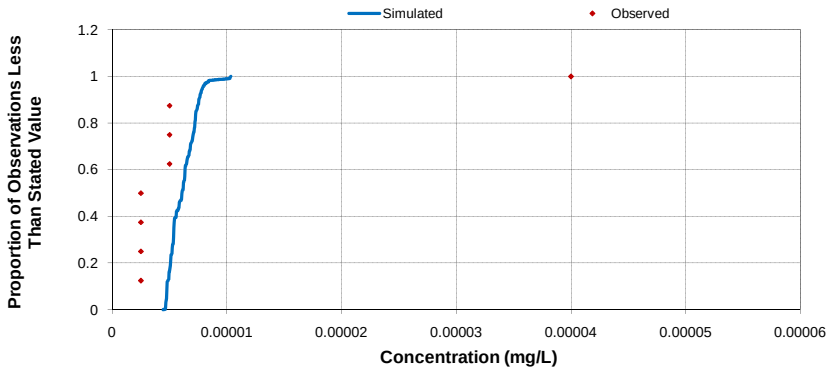


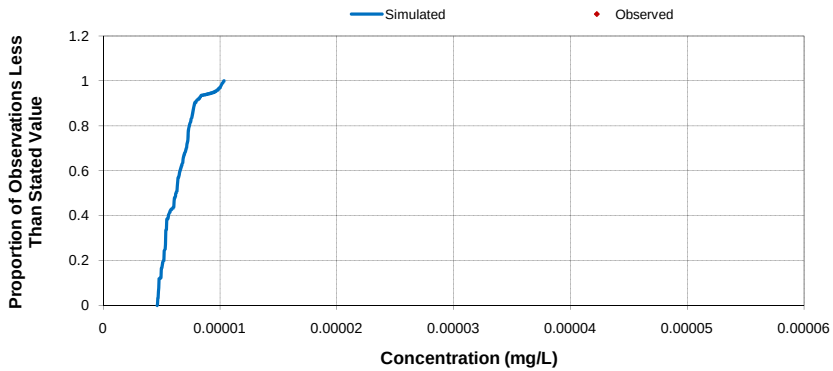
**Figure 7.I.II-24: Comparison of Observed and Predicted Baseline Concentrations of Silver in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

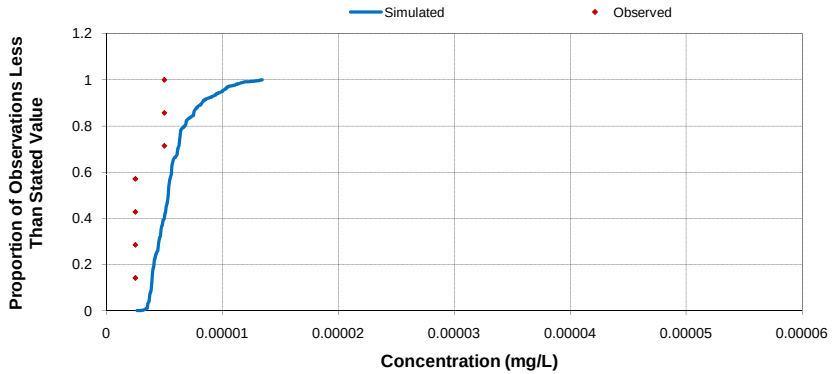



Under-Ice

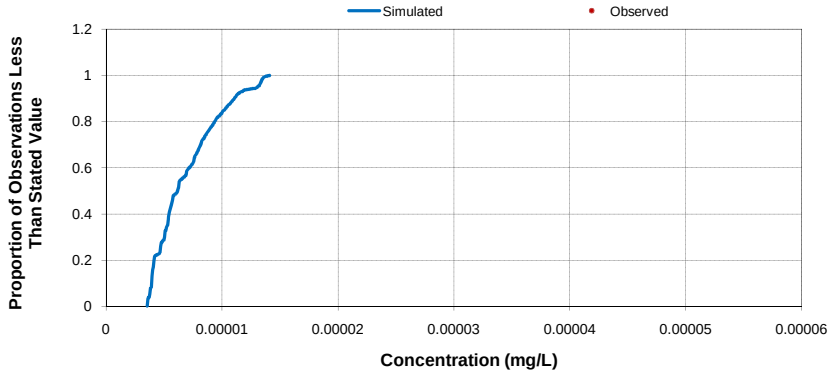



**Peanut Lake**

Open Water

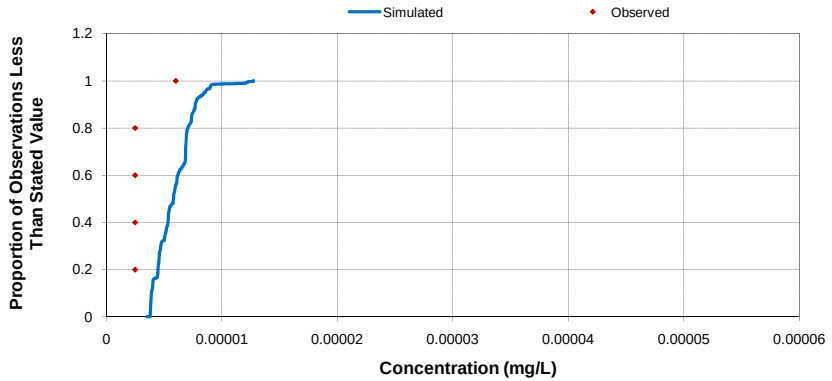



Under-Ice




**Burke Lake**

Open Water




Under-Ice

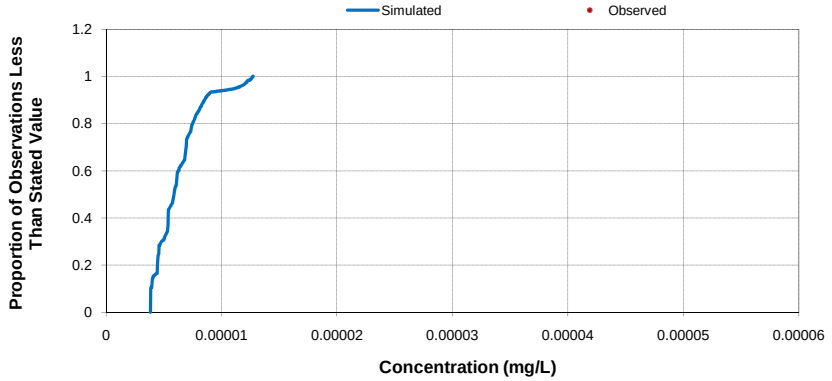
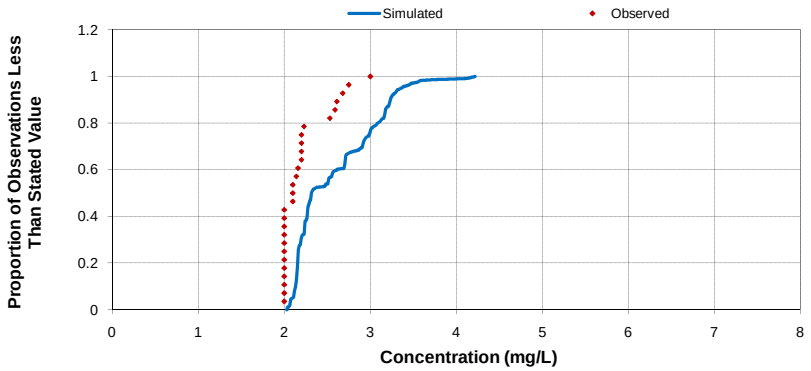


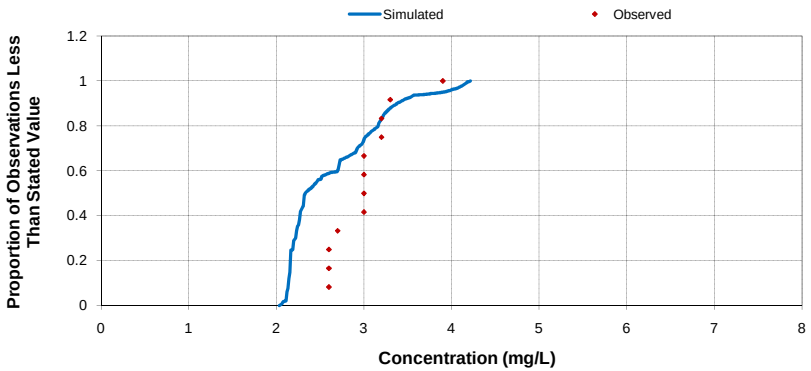
**Figure 7.I.II-25: Comparison of Observed and Predicted Baseline Concentrations of Sodium in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

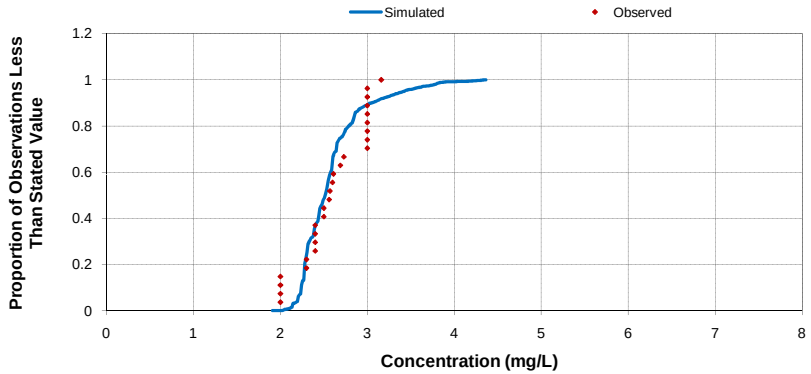



Under-Ice

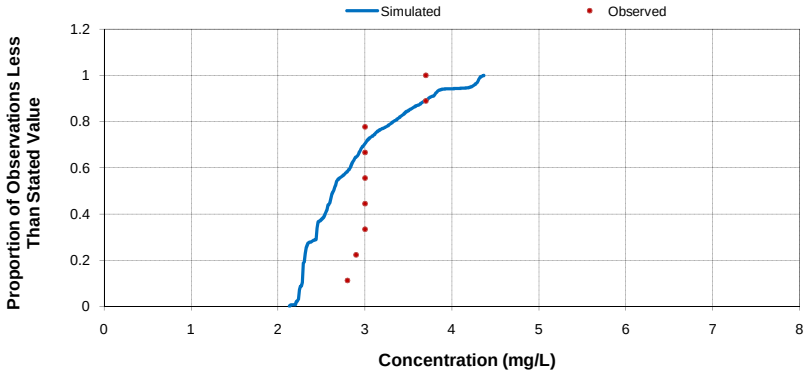



**Peanut Lake**

Open Water

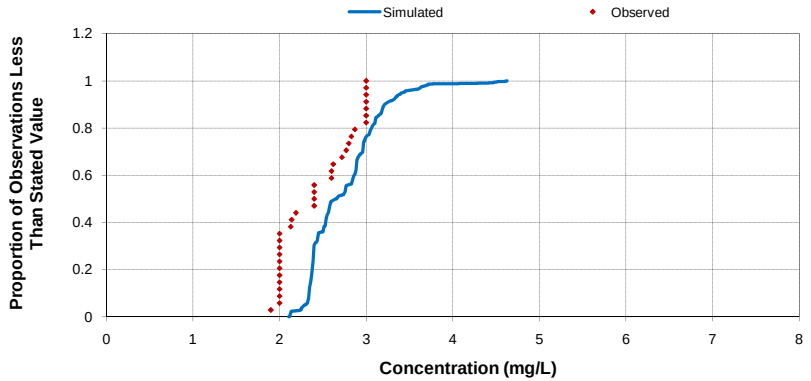



Under-Ice




**Burke Lake**

Open Water




Under-Ice

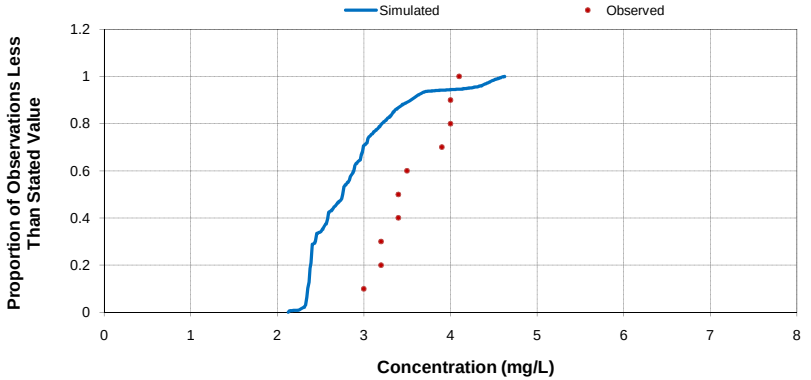
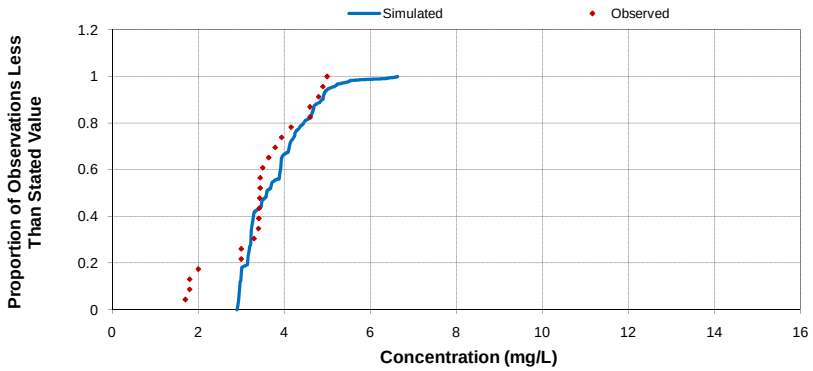


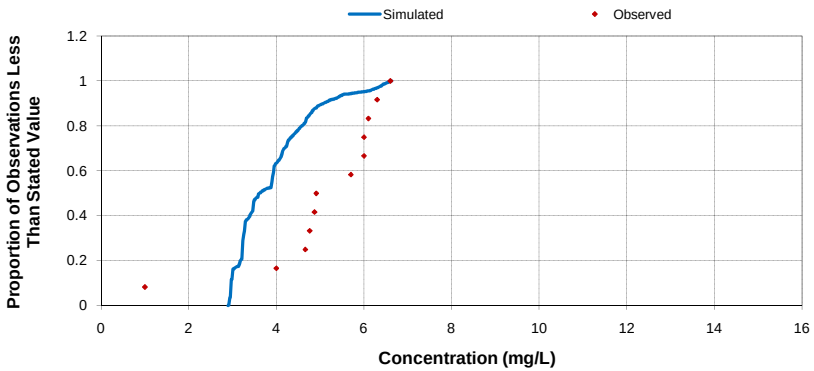
**Figure 7.I.II-26: Comparison of Observed and Predicted Baseline Concentrations of Sulphate in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

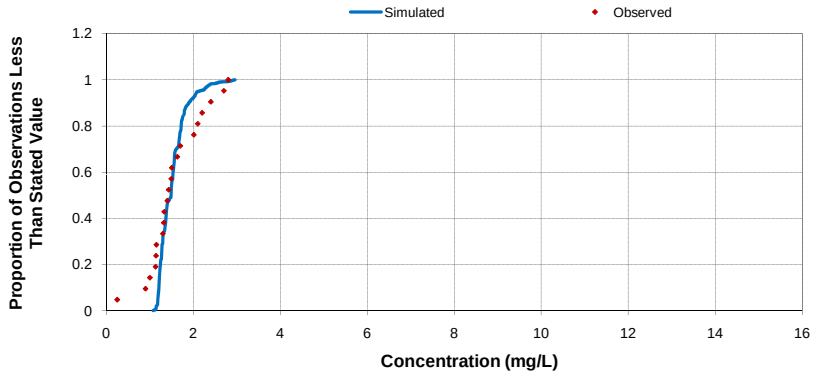



Under-Ice

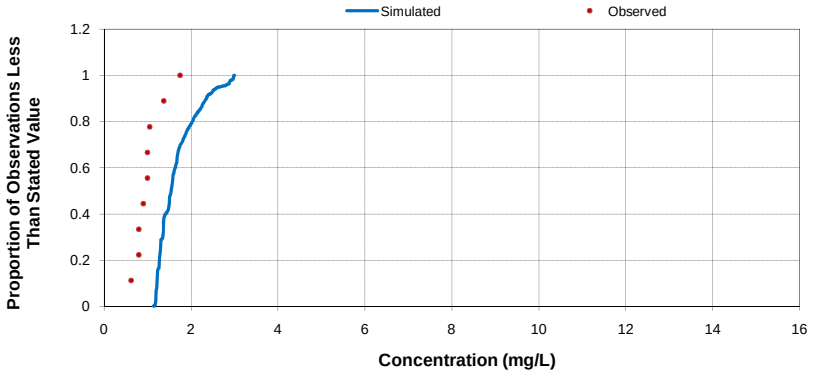



**Peanut Lake**

Open Water

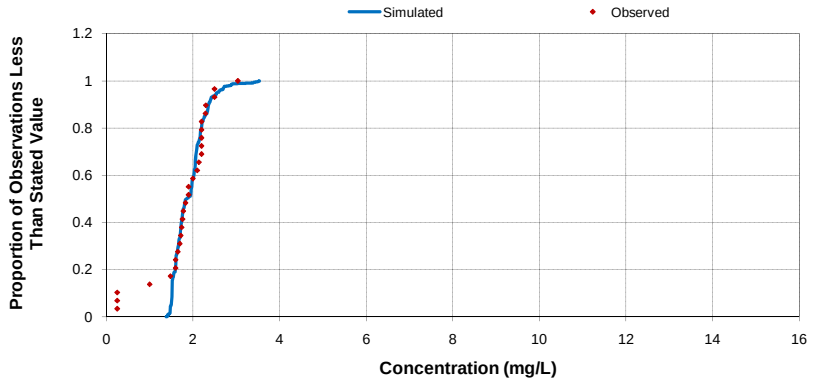



Under-Ice




**Burke Lake**

Open Water




Under-Ice

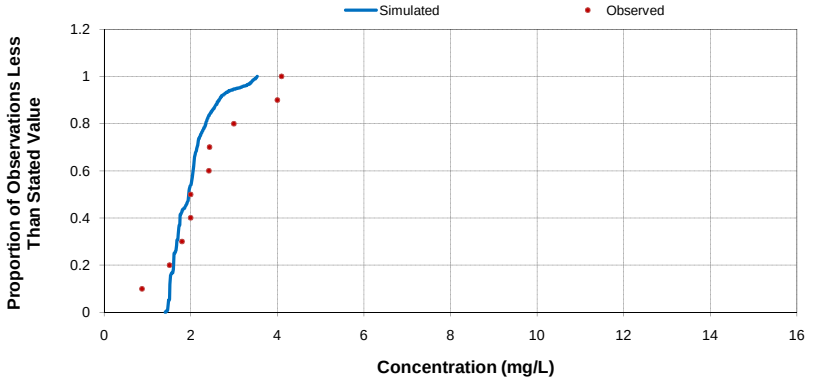
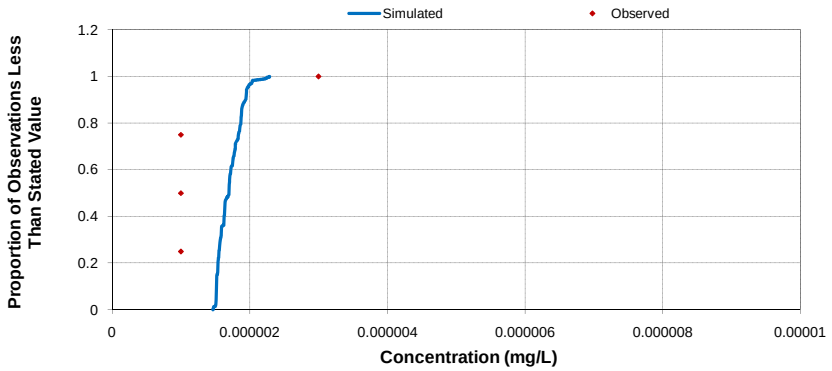


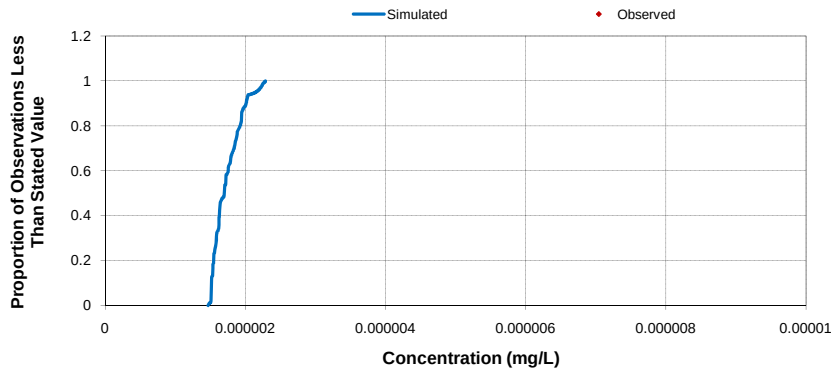
**Figure 7.I.II-27: Comparison of Observed and Predicted Baseline Concentrations of Thallium in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

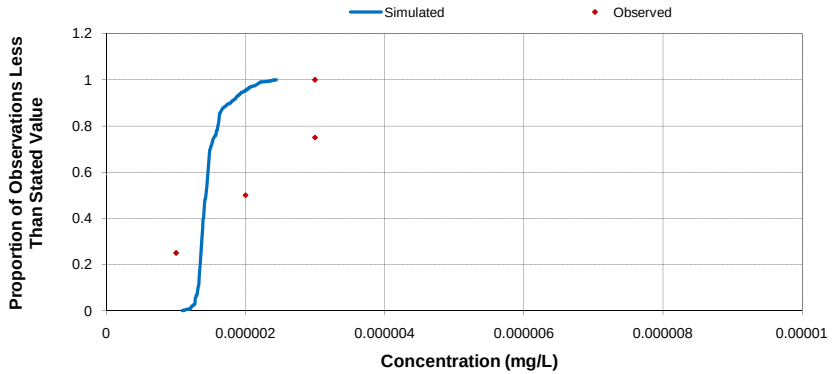



Under-Ice

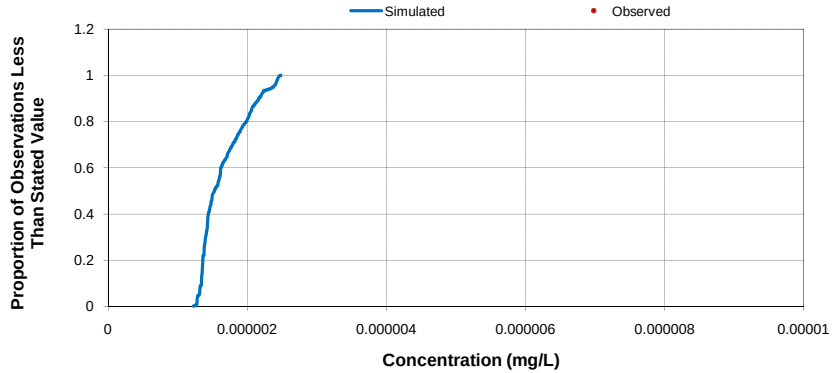



**Peanut Lake**

Open Water

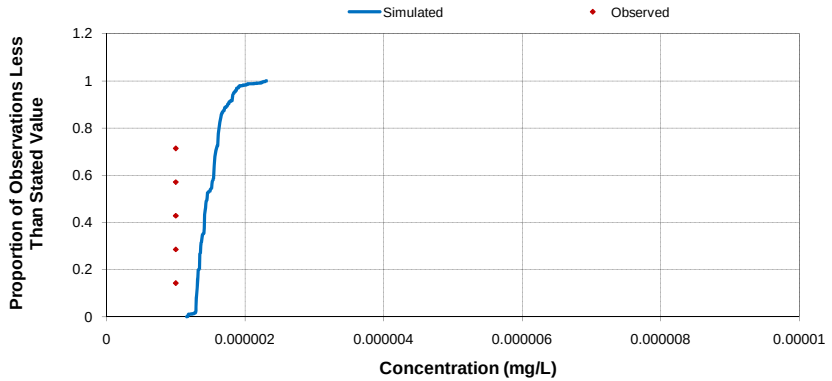



Under-Ice




**Burke Lake**

Open Water




Under-Ice

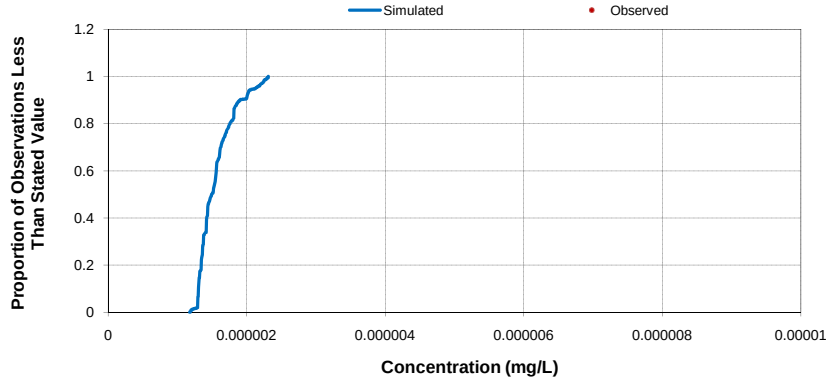
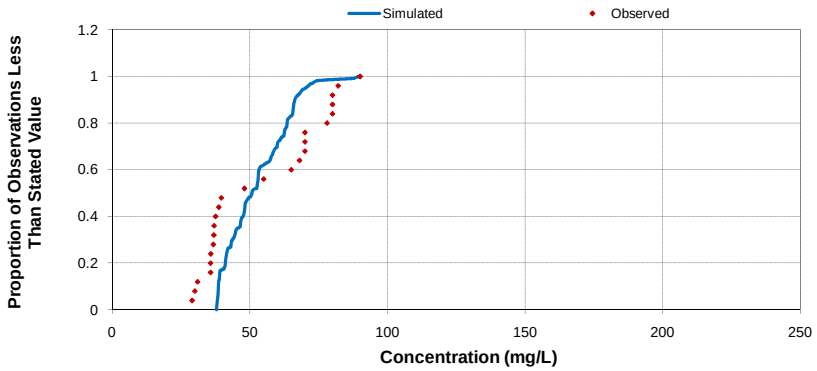


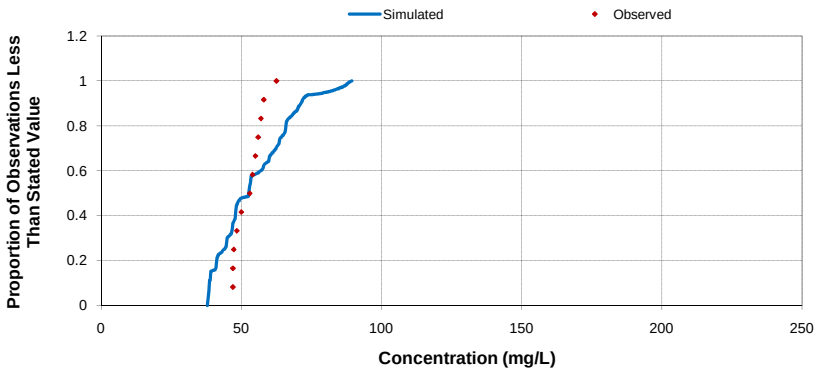
**Figure 7.I.II-28: Comparison of Observed and Predicted Baseline Concentrations of Total Dissolved Solids in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

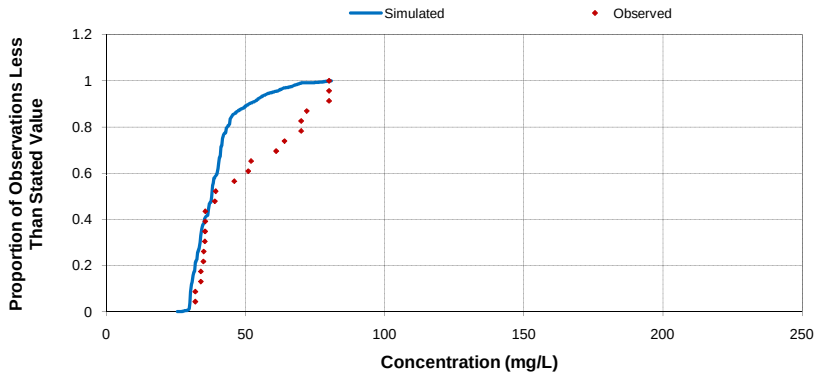



Under-Ice

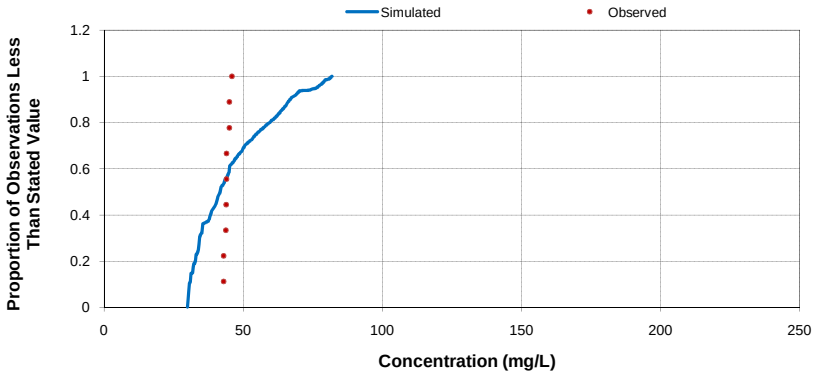



**Peanut Lake**

Open Water

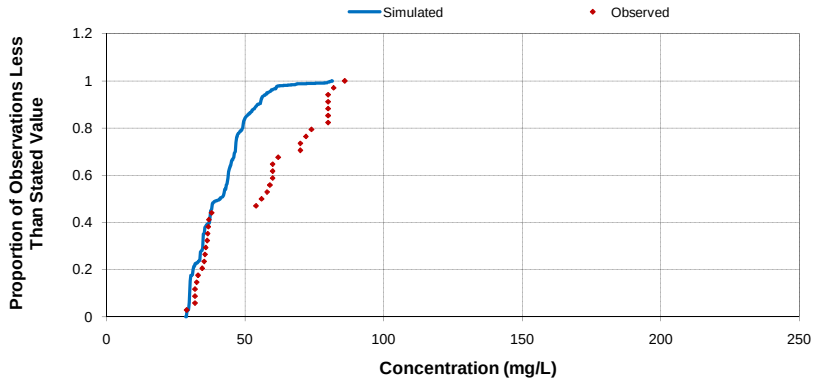



Under-Ice




**Burke Lake**

Open Water




Under-Ice

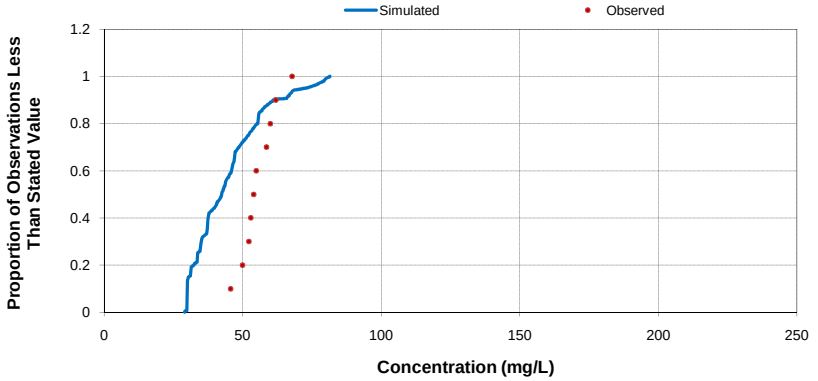
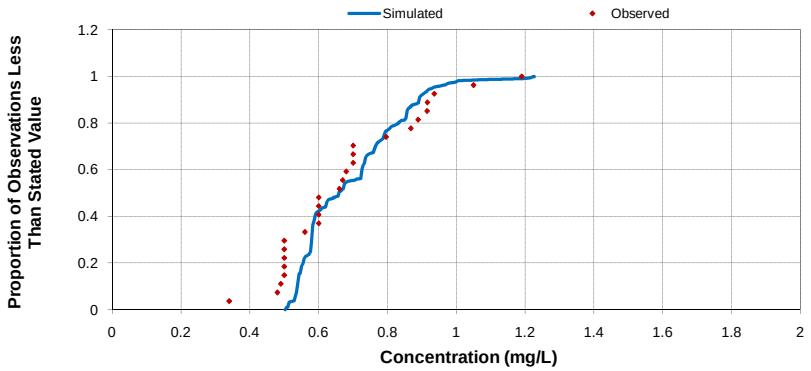


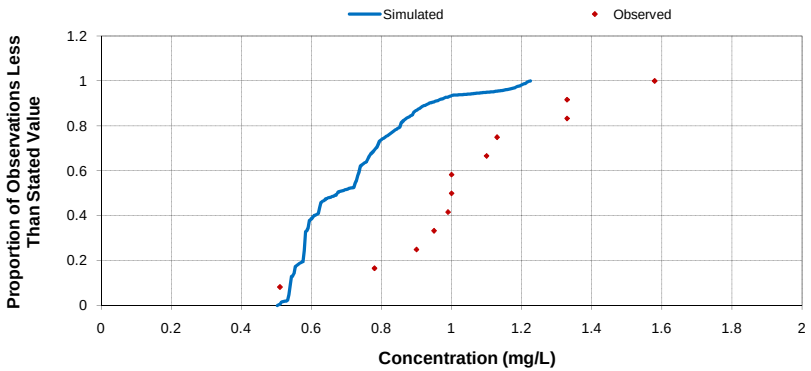
**Figure 7.I.II-29: Comparison of Observed and Predicted Baseline Concentrations of Total Kjeldahl Nitrogen in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

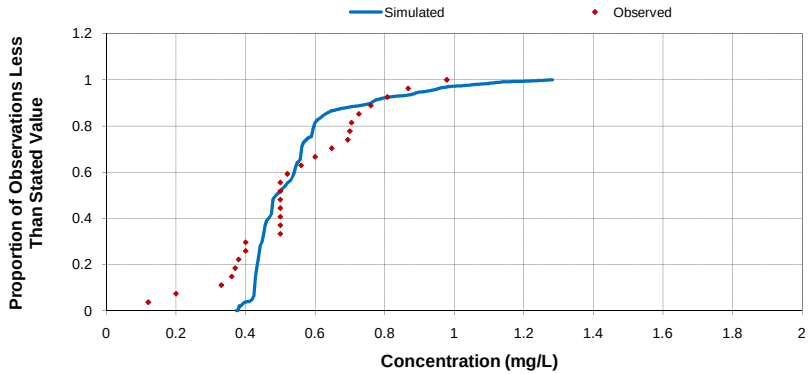



Under-Ice

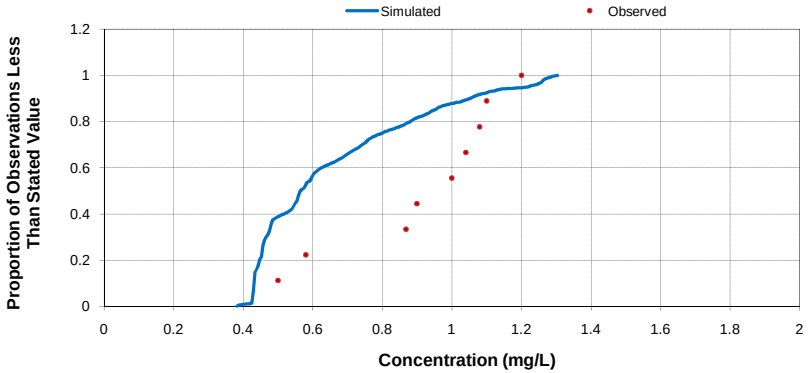



**Peanut Lake**

Open Water

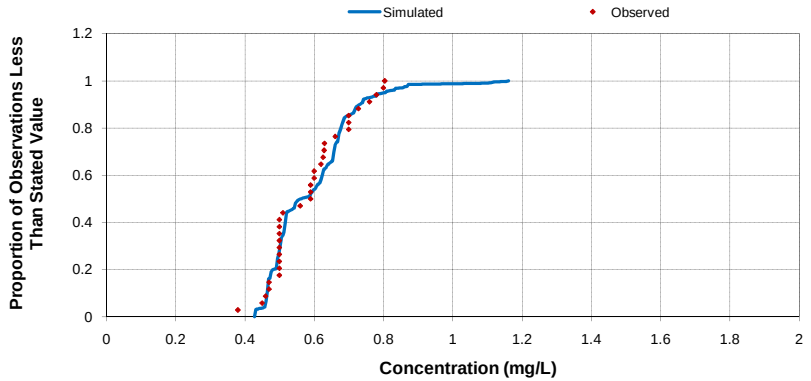



Under-Ice




**Burke Lake**

Open Water




Under-Ice

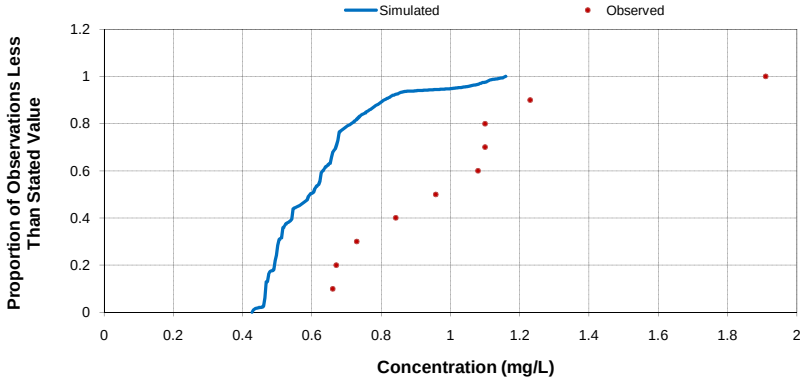
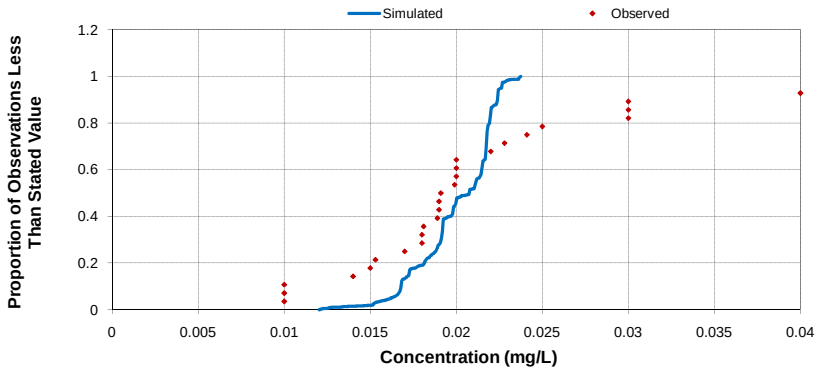


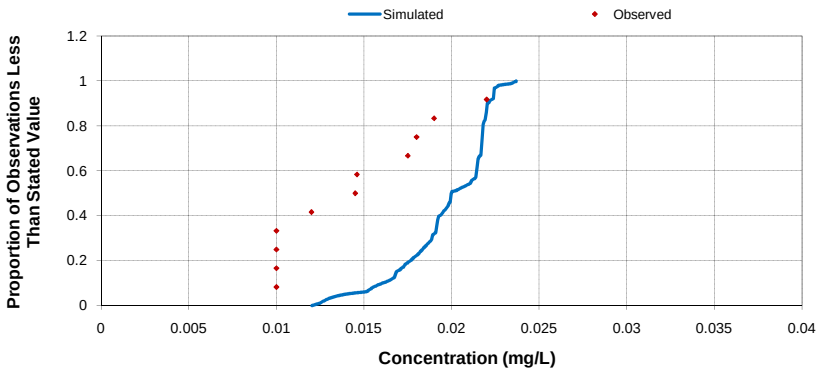
**Figure 7.I.II-30: Comparison of Observed and Predicted Baseline Concentrations of Total Phosphorus in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

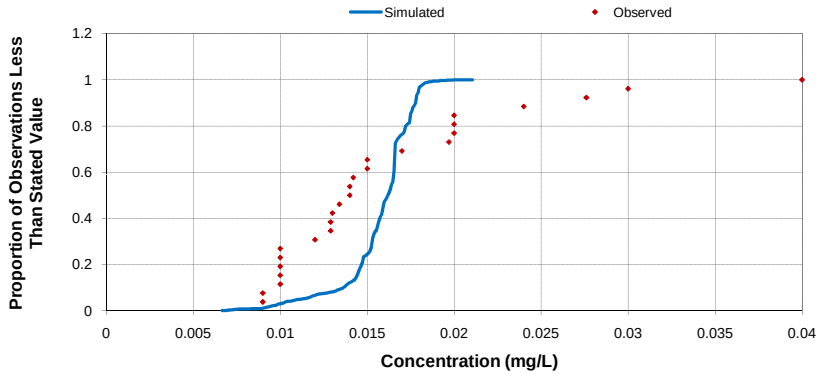



Under-Ice

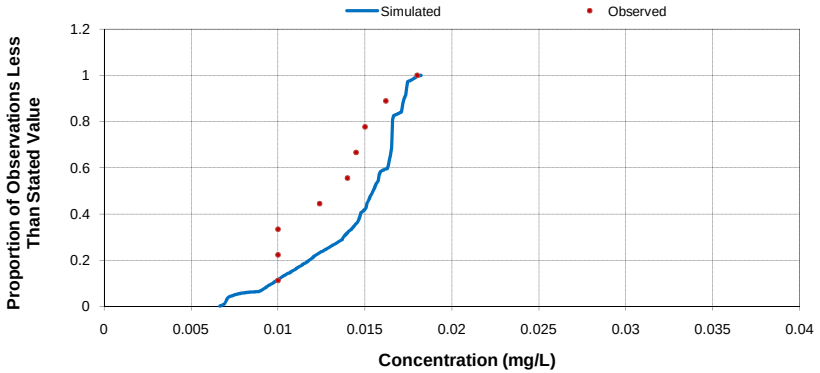



**Peanut Lake**

Open Water

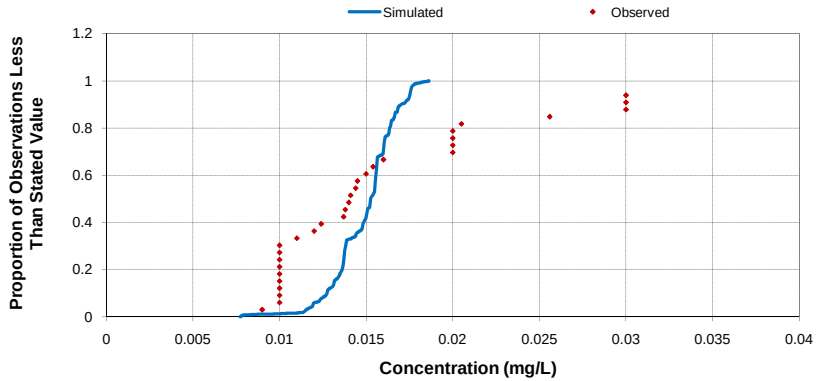



Under-Ice




**Burke Lake**

Open Water




Under-Ice

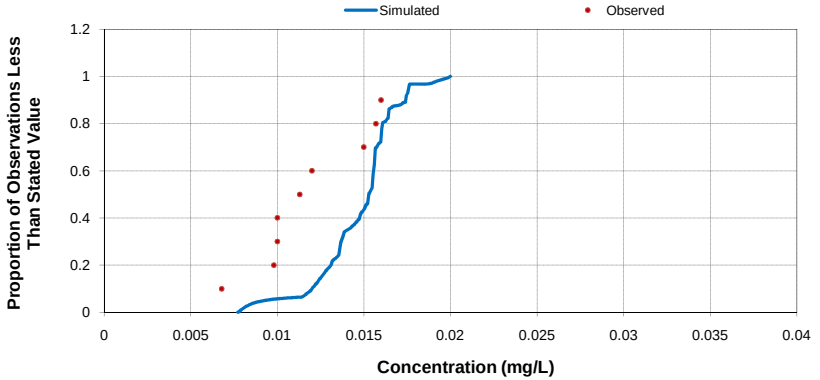
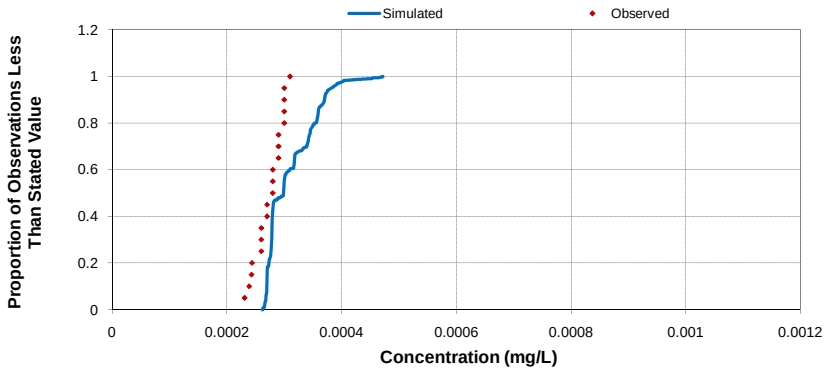


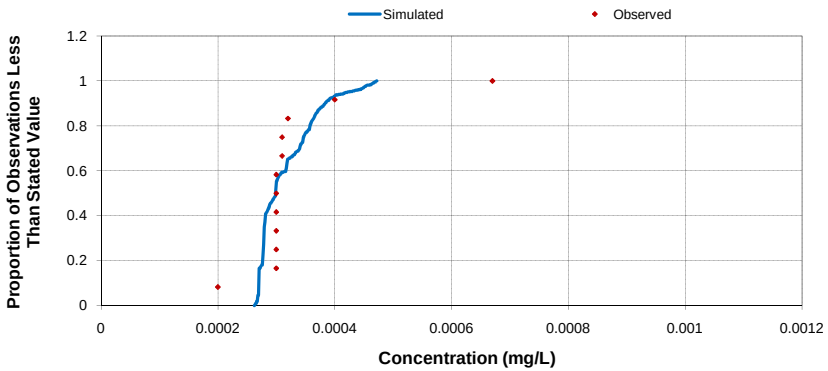
**Figure 7.I.II-31: Comparison of Observed and Predicted Baseline Concentrations of Uranium in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

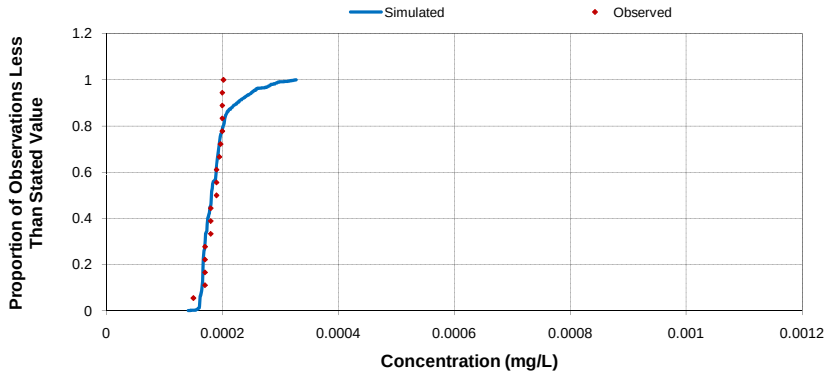



Under-Ice

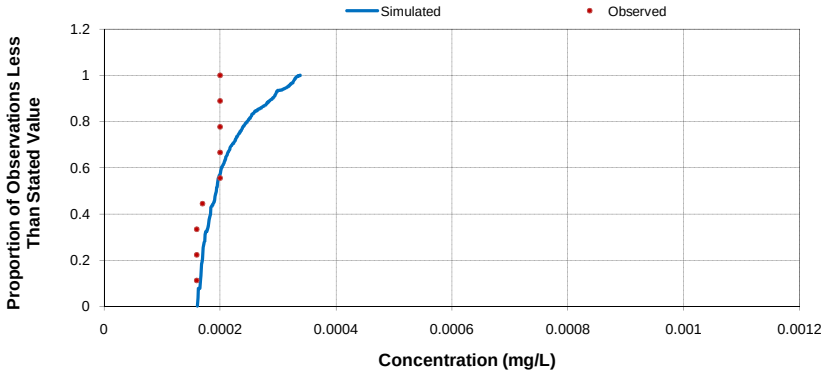



**Peanut Lake**

Open Water

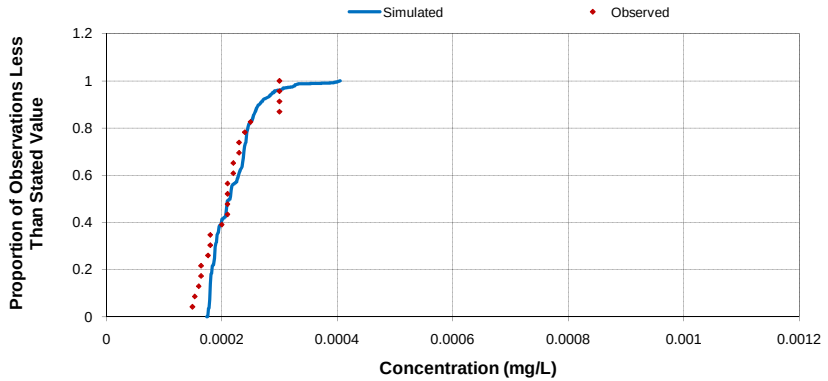



Under-Ice




**Burke Lake**

Open Water




Under-Ice

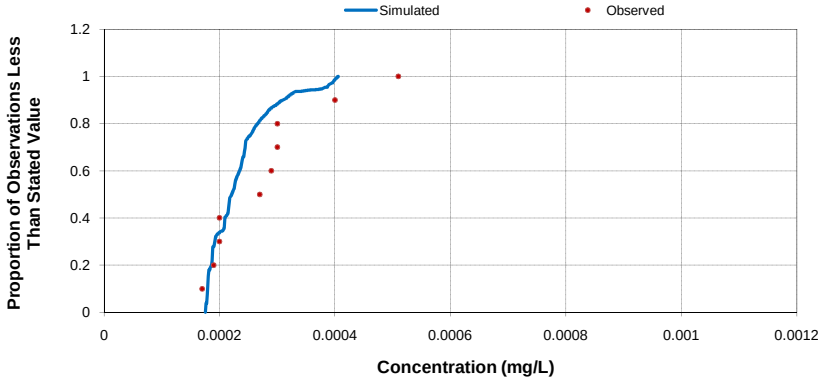
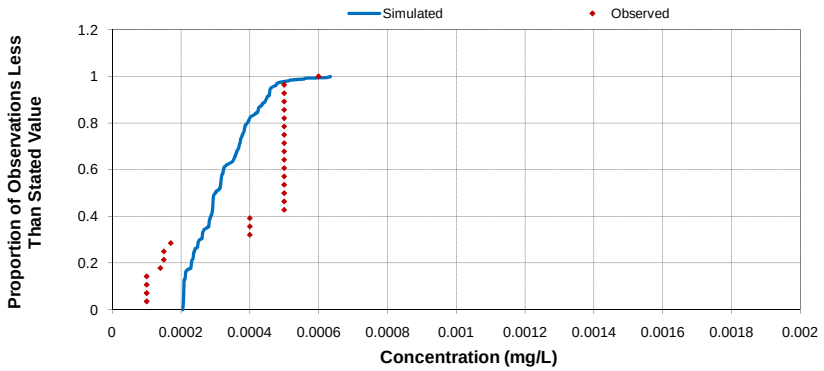


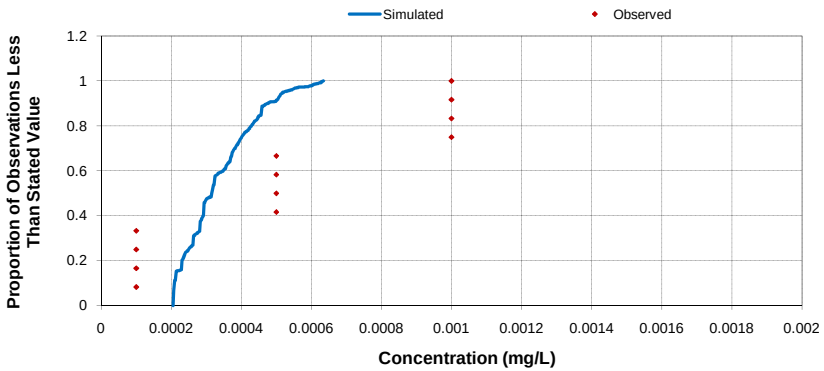
**Figure 7.I.II-32: Comparison of Observed and Predicted Baseline Concentrations of Vanadium in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

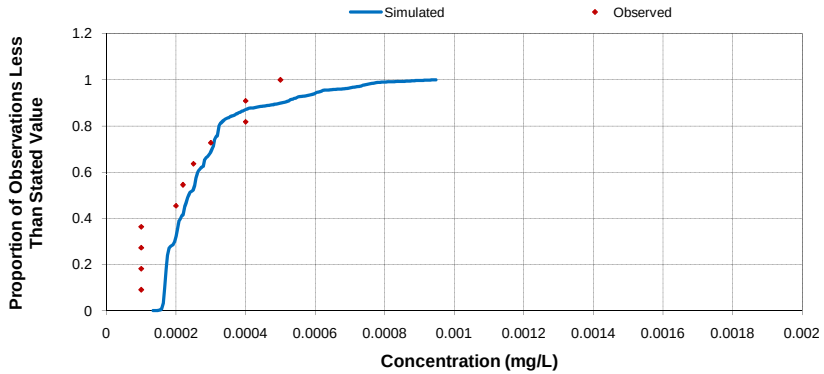



Under-Ice

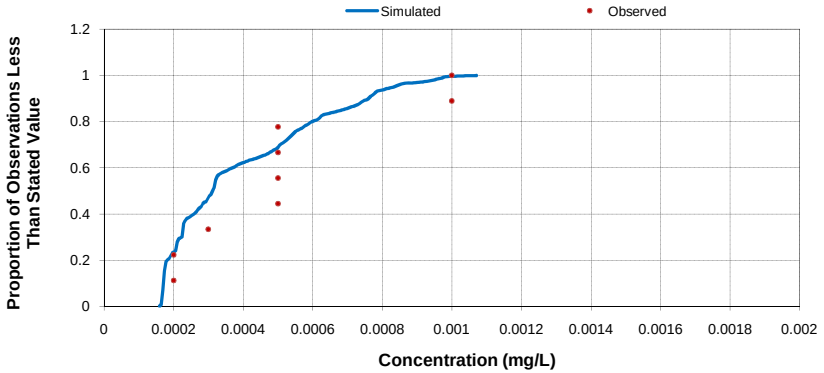



**Peanut Lake**

Open Water

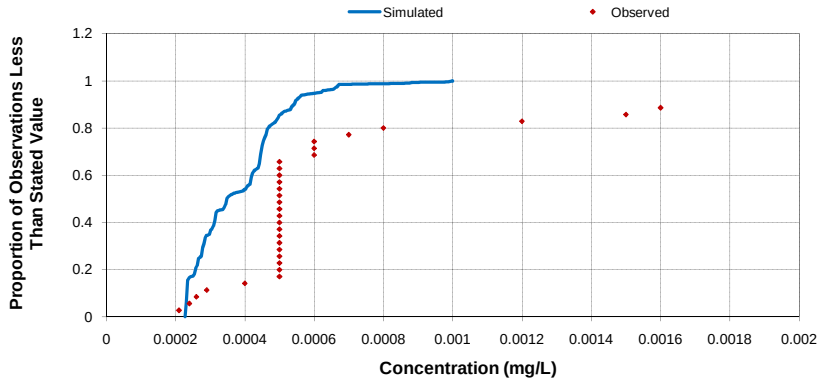



Under-Ice




**Burke Lake**

Open Water




Under-Ice

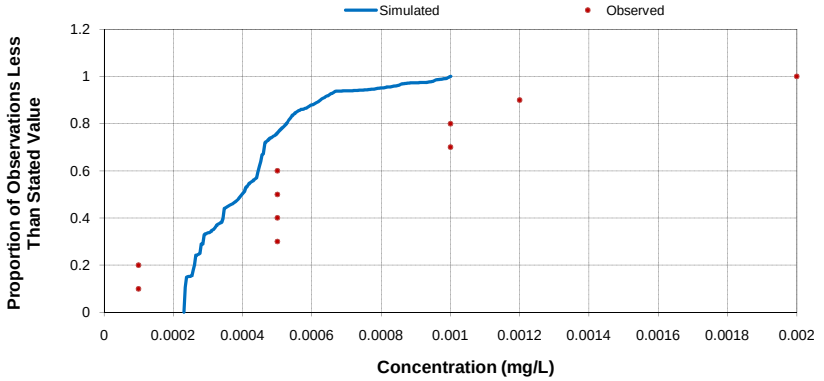
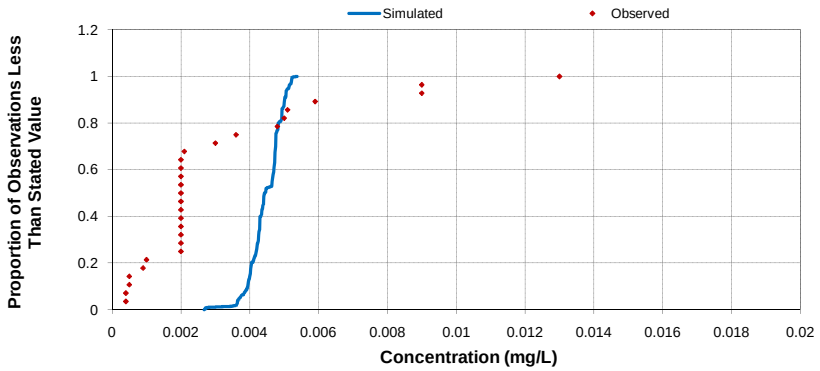


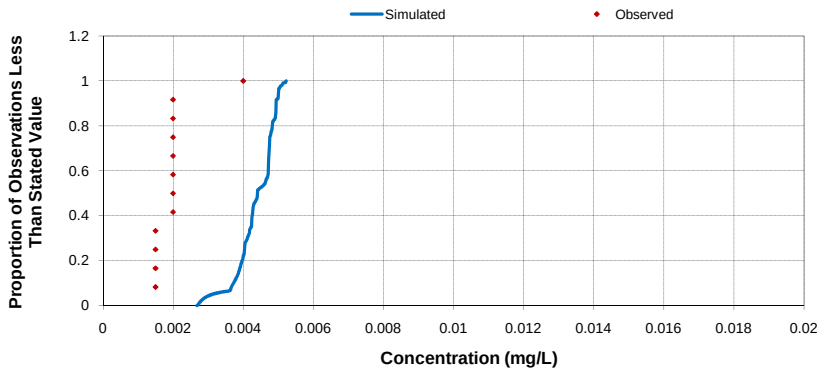
**Figure 7.I.II-33: Comparison of Observed and Predicted Baseline Concentrations of Zinc in Nico Lake, Peanut Lake, and Burke Lake**

**Nico Lake**

Open Water

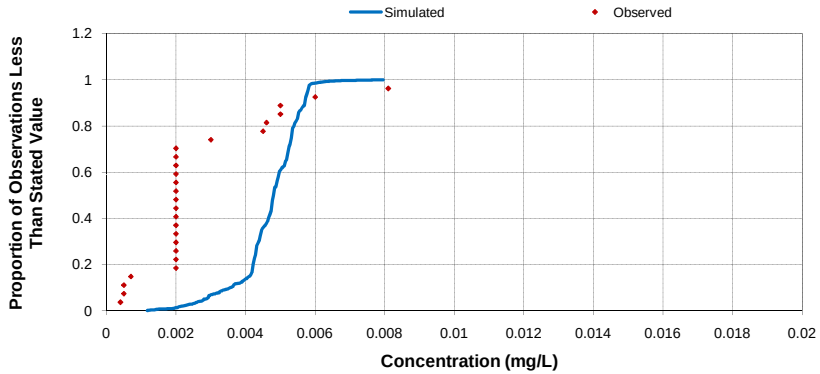



Under-Ice

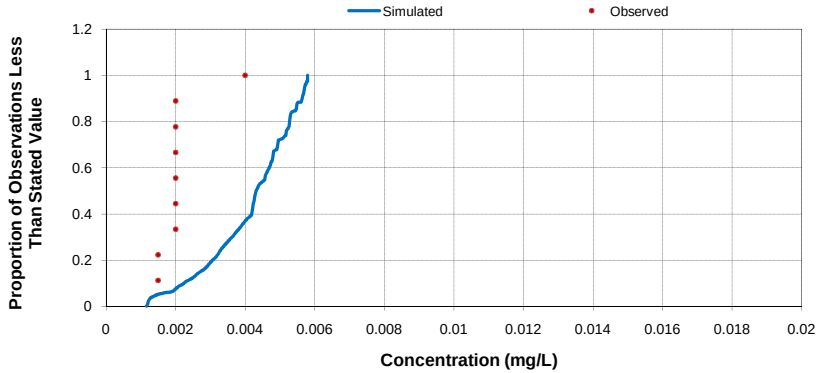



**Peanut Lake**

Open Water

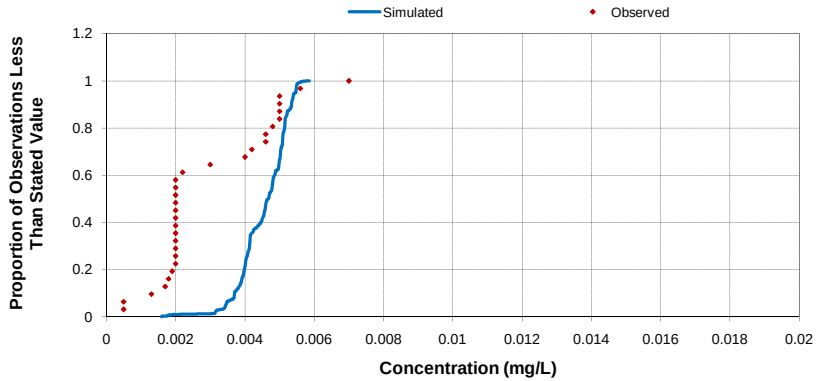



Under-Ice




**Burke Lake**

Open Water




Under-Ice