



Geochemical Modeling of Controls on Dissolved As, Mn, and Fe in the Dexter Pit Lake, Tuscarora, Elko County, Nevada



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Abstract:

The Dexter Pit Lake located outside of Tuscarora, Nevada is a mature mine pit lake which began filling in 1990. Lake water is near neutral (pH 7-9) and has low total dissolved solids, however, several elements periodically attain concentrations near or above EPA primary and secondary drinking water standards. Elements of interest include As (primary drinking water standard), Fe and Mn (secondary drinking water standards). The lake is in an open pit resulting from mining of a 40 Ma epithermal gold deposit characterized by a primary mineralogy of quartz and alkali feldspar with accessory sulfide minerals such as galena and chalcocite. The pit lake has been the focus of previous hydrologic studies which have investigated and modeled the local hydrodynamics. These studies indicate that the pit lake is a flow-through system, meaning that pit lake water may interact significantly with surrounding ground and surface waters.

Current research is using geochemical data combined with hydrodynamics to model the controls on dissolved As, Mn, and Fe. Preliminary data analysis suggests that the dissolved concentrations of these elements are controlled predominantly by reductive dissolution, oxidative precipitation, and surface adsorption. Seasonal stratification develops during spring and summer and results in the formation of an oxidized epilimnion and a reduced hypolimnion. Annual overturn of lake water in early winter most likely results in the oxidative precipitation of dissolved Mn and Fe from the hypolimnion, which in turn removes As from solution through adsorption. Following this trend of decreasing dissolved concentrations, thermal and chemical stratification is again induced, causing subsequent increases in dissolved concentrations of As, Mn and Fe (increasing from 6 to 17, 150 to 350, and 150 to 300 µg/L respectively) in the hypolimnion. This cycle occurred in both 1999 and 2000. Numerical modeling of the Dexter Pit Lake system will focus on quantifying the controls of adsorption and mineral precipitation reactions on the concentration of dissolved species. Modeling will use the program EQ3/6 to link chemical and hydrologic processes and produce predictions of pit lake chemistry. Statistical analyses such as principal component analysis will also be applied to test for subtle trends in the data.

Study Location:

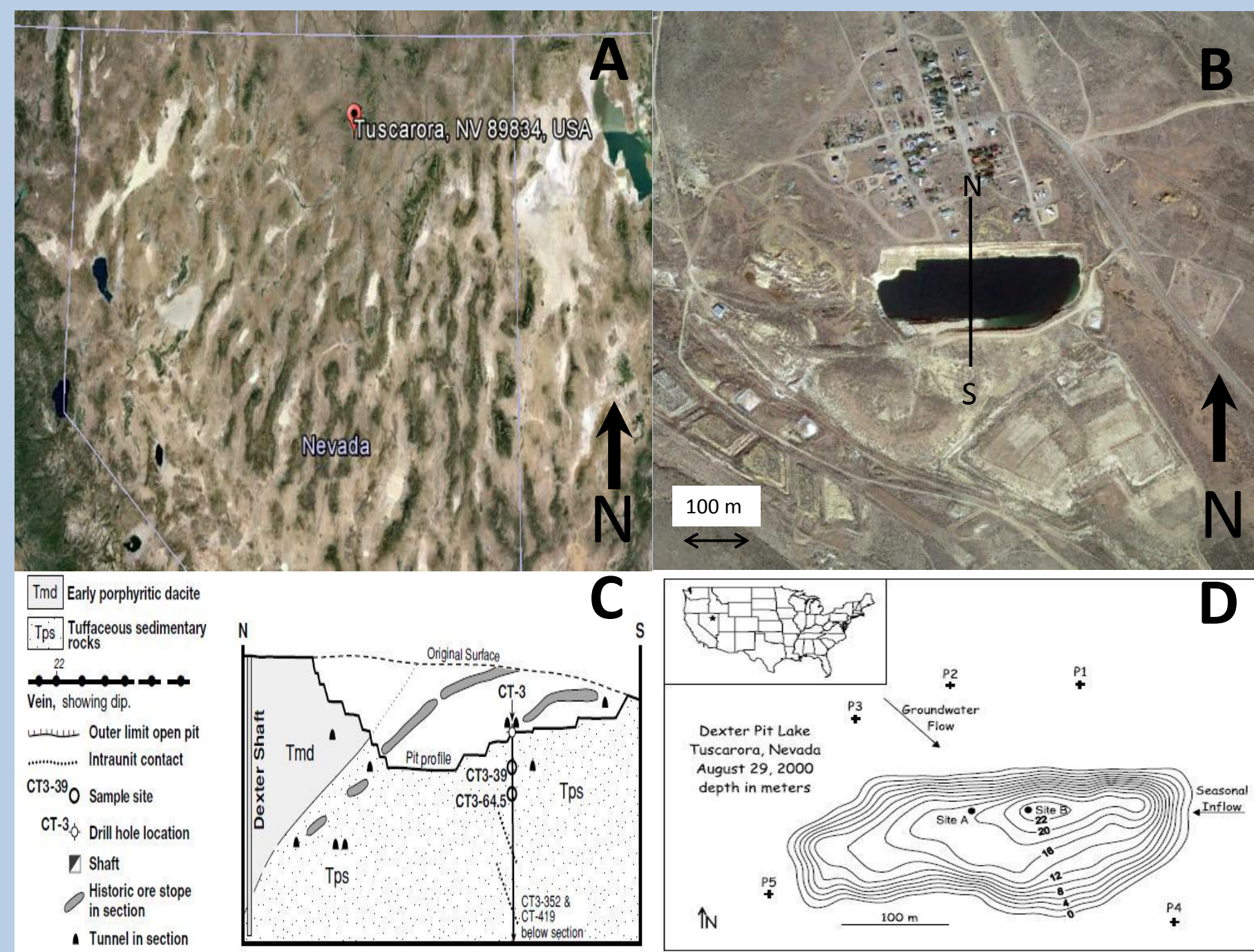


Figure 1: A) Regional map of northern Nevada showing location of the town of Tuscarora. B) Google Earth image of the Dexter Pit Lake to the south of the town of Tuscarora, with line of cross section seen in (C). C) N-S cross section through Dexter Pit showing lithologic units. From Castor et al. (2003). D) Bathymetric map of Dexter Pit Lake showing geochemical sampling locations A and B. From Balistrieri et al. (2006).

Methods:

Samples for this project were collected on an approximately monthly basis from January 1999 through November 2000. Concentrations of major cations (Ca, Mg, Na, and K) and B were determined by inductively-coupled plasma – atomic emission spectroscopy (ICP-AES). Minor ion concentrations were measured by inductively-coupled plasma – mass spectrometry (Briggs, 1996; Balistrieri et al., 2006). Geochemical reaction path modeling is being conducted using the program, EQ3/6 (Wolery and Jarek, 2003). This model will simulate mineral precipitation and dissolution, evaporation, mixing, and redox reactions.

Data:

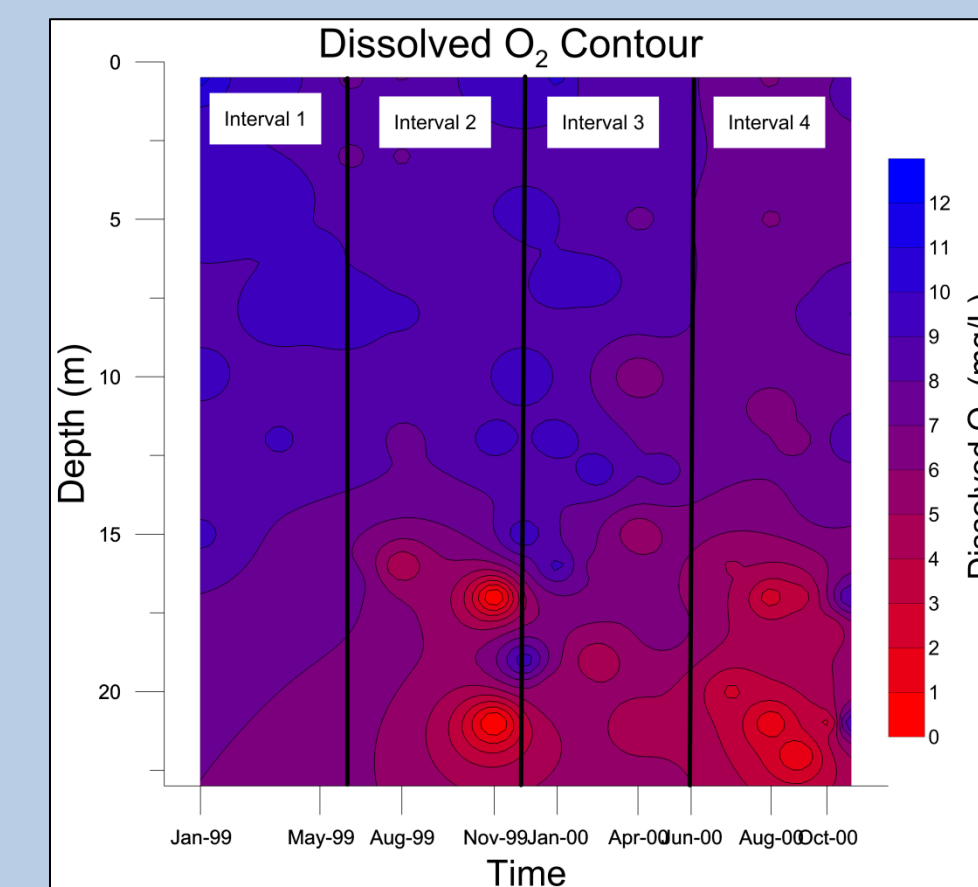


Figure 2: Contour plot showing the concentration of dissolved O₂ as a function of time and depth. Intervals correspond with those seen in Figure 9.

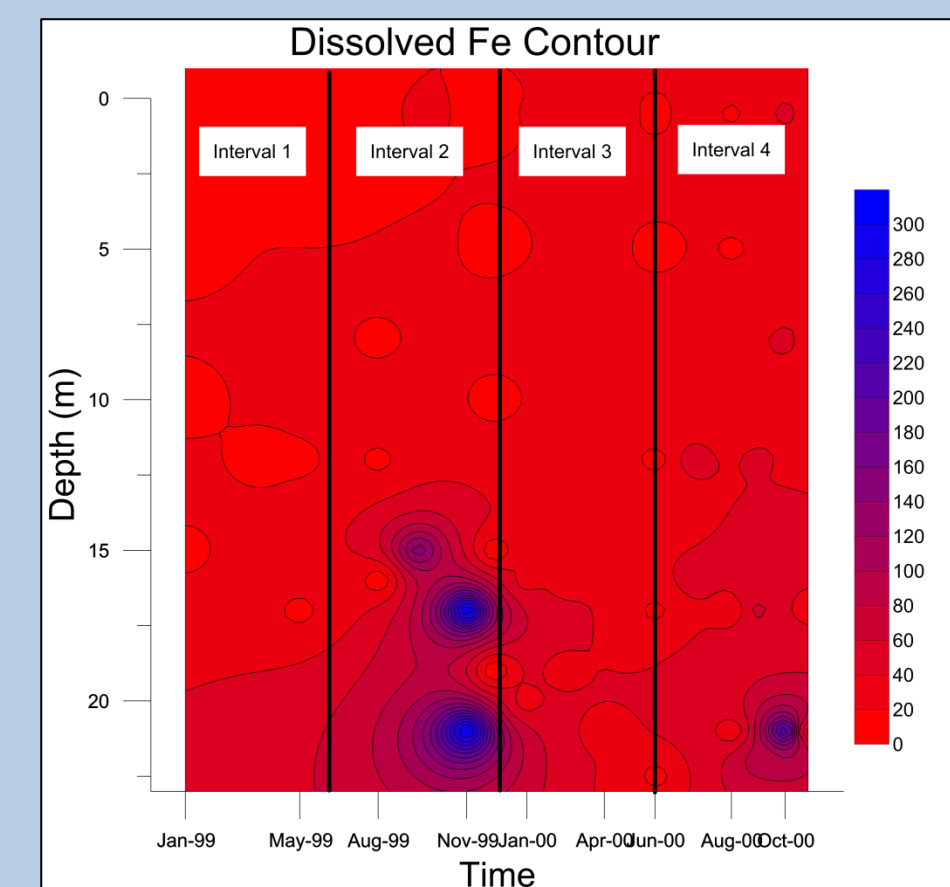


Figure 3: Contour plot showing the concentration of dissolved Fe as a function of time and depth. Intervals correspond with those seen in Figure 9.

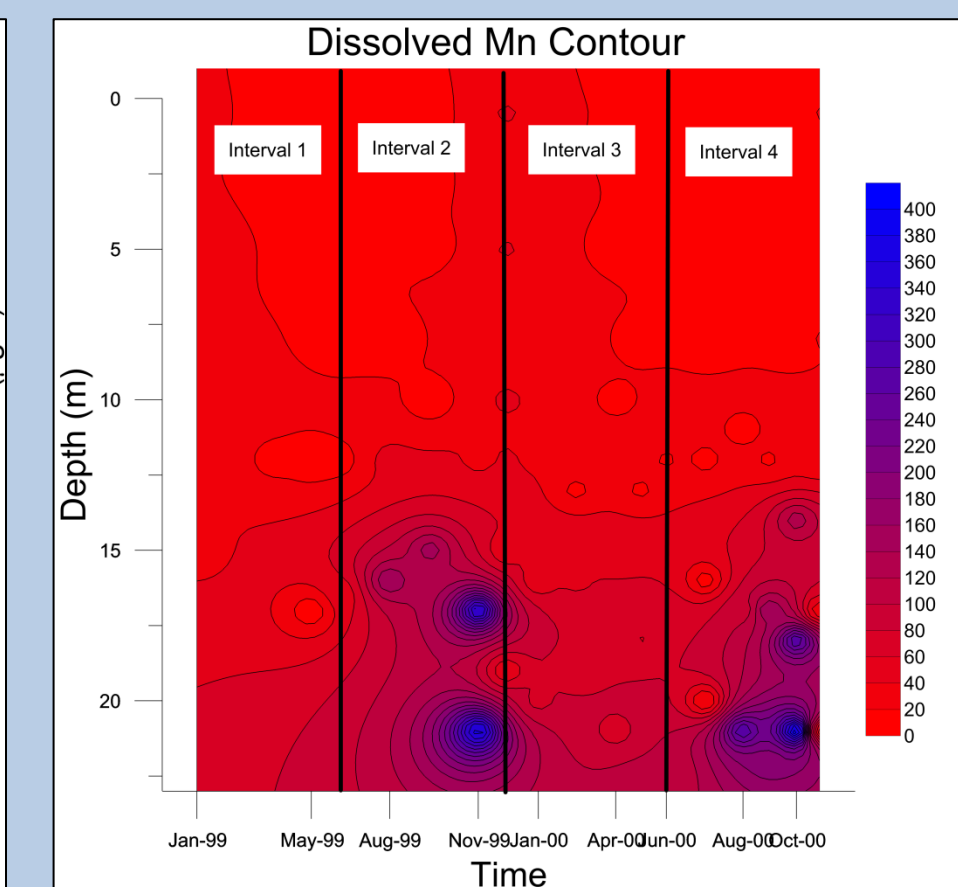


Figure 4: Contour plot showing the concentration of dissolved Mn as a function of time and depth. Intervals correspond with those seen in Figure 9.

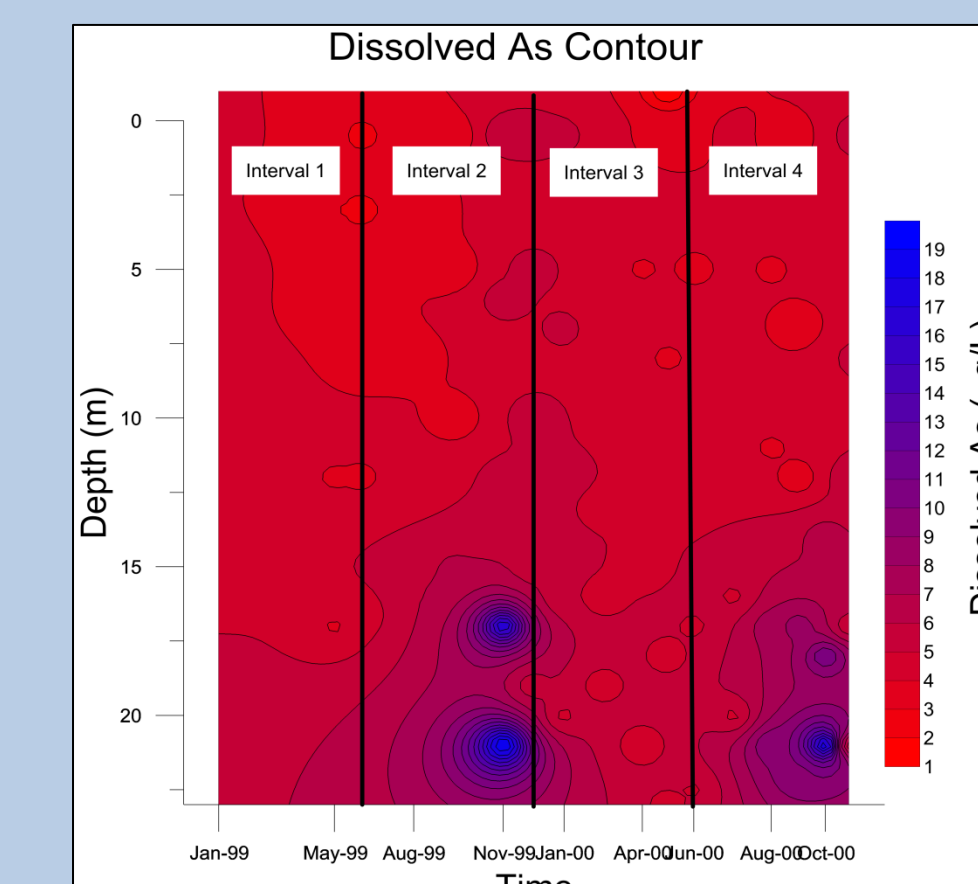


Figure 5: Contour plot showing the concentration of dissolved As as a function of time and depth. Intervals correspond with those seen in Figure 9.

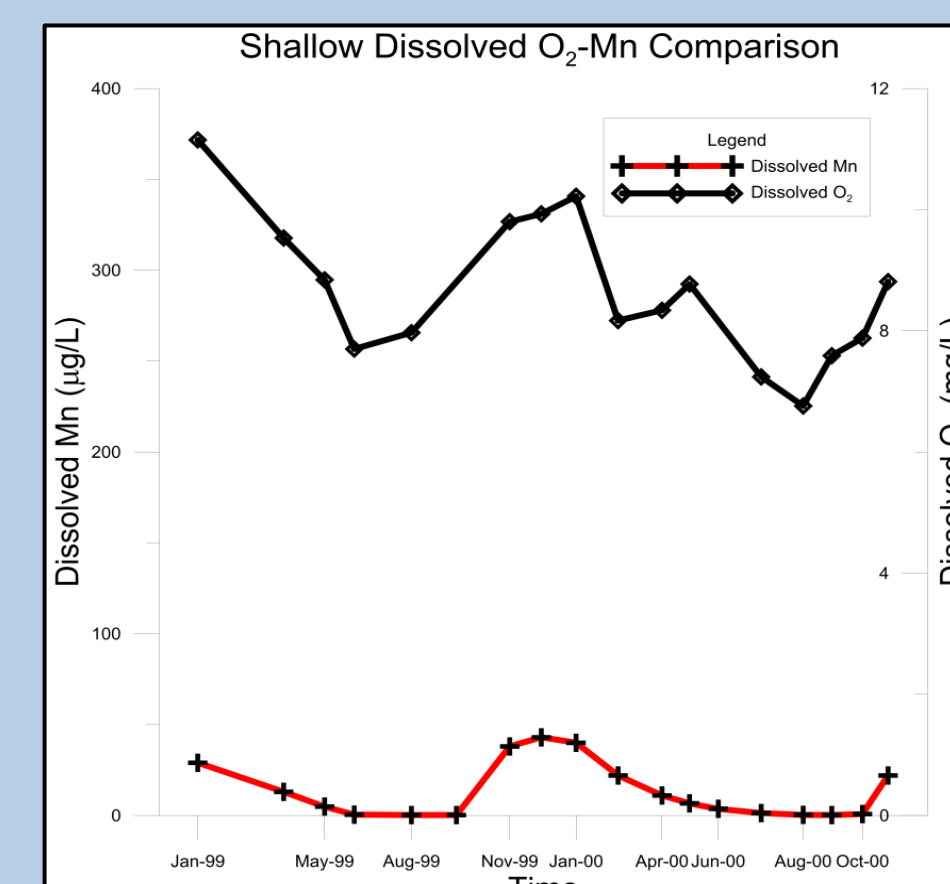


Figure 6: Comparison of dissolved O₂ to dissolved Mn through time in the depth interval 0-0.5 m. Trends indicate that Mn never reaches appreciable concentrations in surface waters. Increases in dissolved O₂ may be due to temperature dependent solubility in winter months.

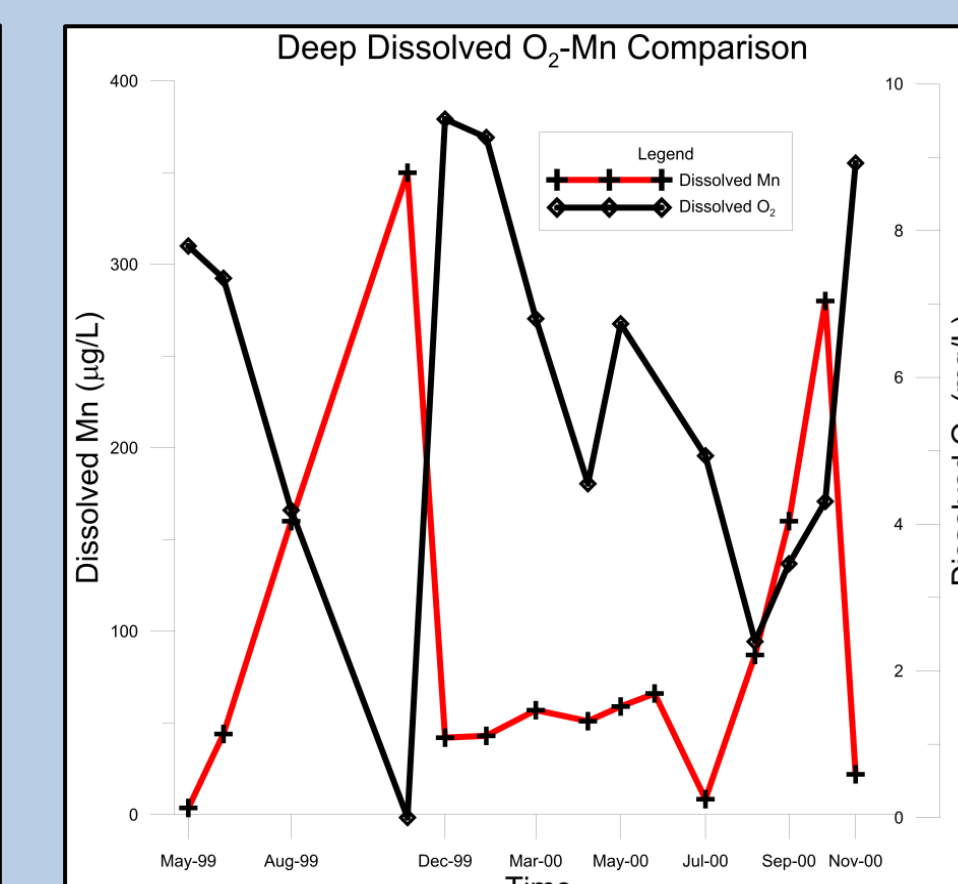


Figure 7: Comparison of dissolved O₂ to dissolved Mn through time in the depth interval 15-19 m. The general inverse correlation between the two constituents indicates that the presence or lack of dissolved O₂ may exert a control on dissolved Mn values.

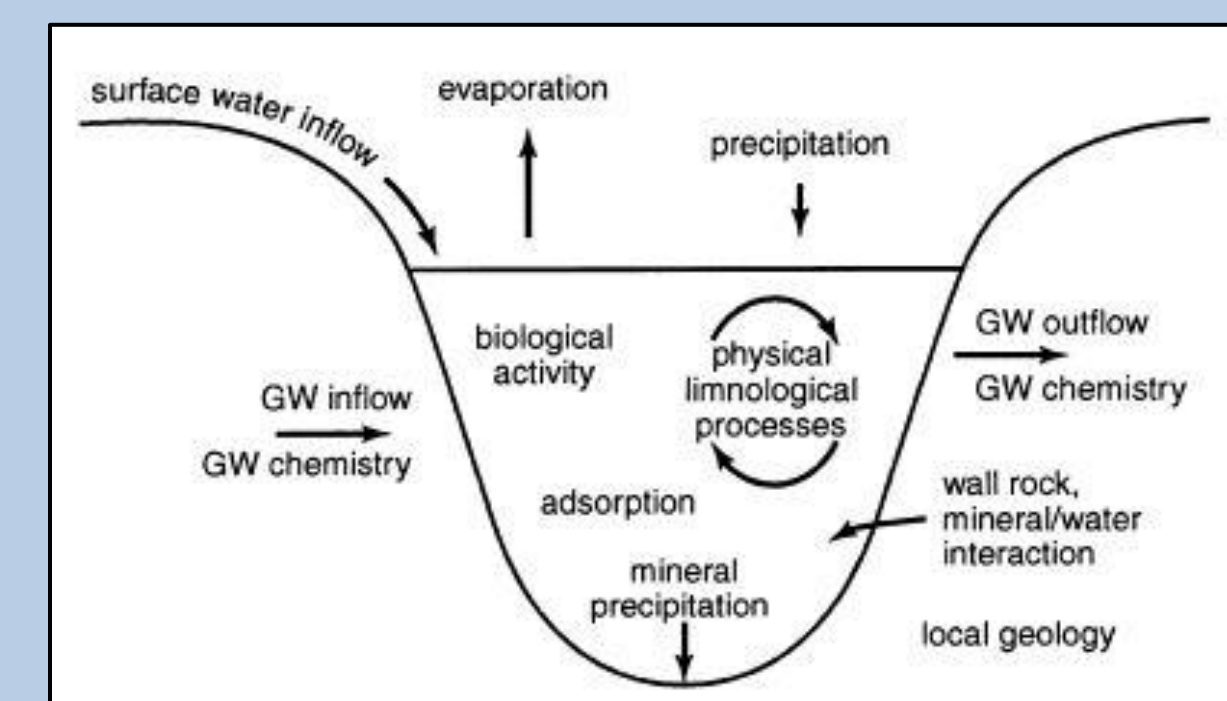


Figure 8: Generalized conceptual model of a mine pit lake and geochemical and hydrological processes taking place within the system. From Tempel et al. (2000).

Conceptual Model:

Prior to the use of numerical modeling it is necessary to create a conceptual model which incorporates both chemical and hydrologic processes. This conceptual model will draw from processes illustrated on Figure 8. Based on graphical analysis it is likely that reducing conditions in the hypolimnion are caused by a stratification induced low in O₂, seen in Figure 2, interval 2 (Balistrieri et al., 2006). These reducing conditions likely subsequently cause the dissolution of Mn and Fe (hydr)oxides, which in turn release adsorbed As (Pedersen et al., 2006). Following overturn and oxidation of the water column, seen in interval 3, Mn and Fe (hydr)oxides are likely re-precipitated, causing uptake of As through adsorption. The steps involved in these cycles have been chronologically ordered in the conceptual model below (Figure 9).

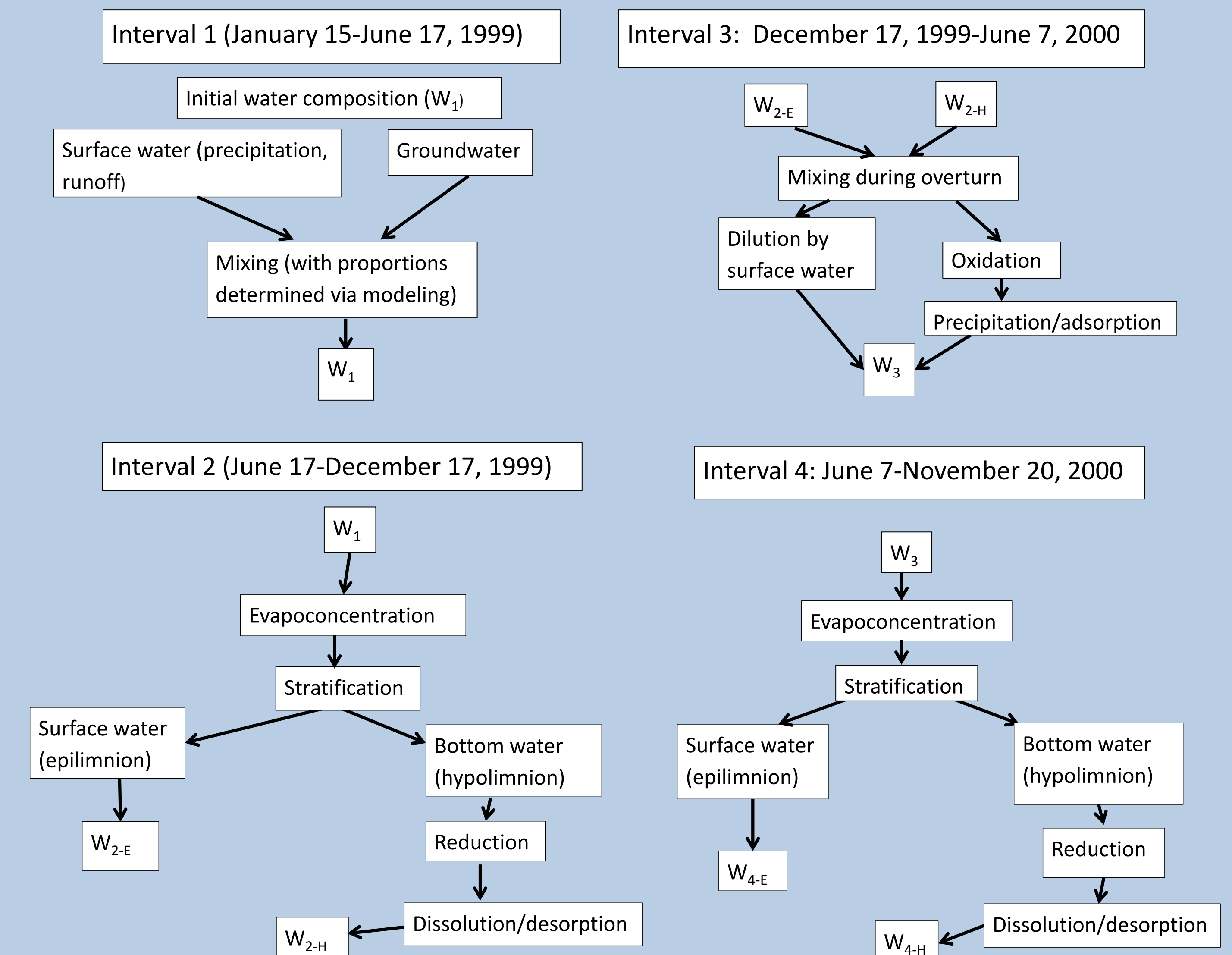


Figure 9: Chronological order of steps involved in conceptual model. The chemical structure of the lake during each interval may be seen in Figures 2-5. Water composition created during each interval seen above (W₁, W_{2-E}, W_{2-H}, etc.) will be used in the subsequent step of reaction path modeling.

References:

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