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The Great Salt Lake's Two Deep Brine Layers

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Fig. 1. Bi-directional flow paths through the culverts and causeway fill that cause a deep brine layer in Gilb

Two major causeways that divide the Great Salt Lake have radically changed salt balances different sections of the lake, and have caused c brine layers to form. For you scrabble buffs limnologists call these layers €monimolimnions•. In 1959 the Southern Pacific Railway built a 13-mile rock-fill causeway across the main lake, dividing in half. This division causes the south arm (Gilbert Bay) to have a higher elevation and lower salinities than the north arm (Gunnison Bay). The high-density brine from Gunnison then flows back through the causeway fill material, through a breach, and until recently, through two culverts constructed to allow equilibration and salt transfer (Fig. 1)[1]. This brine settles into the deepest sections of Gilbert Bay, and because it is denser than the overlying layer, mixing between the two layers is limited. Approximately 45% of Gilbert Bay‚s bottom is covered by the deep brine layer (Fig. 2). A similar phenomenon occurs in Farmington Bay when Gilbert Bay water passes through the automobile causeway bridge and fill material and underflows the fresher waters in Farmington[2,3]. However, in this case, the overlying mixed layer is only about 5 feet thick, whereas in Gilbert, the mixed layer is about 20-24 feet thick.

Fig. 2. Extent of the deep brine layers i Gilbert and Farmington Bays. The deep brine layer in Gilbert is shown at a dep of 23, and at a lake level of 4200, base on the USGS map of R. Baskin. Th extent of the layer in Farmington Bay is shown at a depth of 3.5 and is only approximate because the bay‚s morphometry has not been careful mapped.

Algae and detritus produced in the upper mixed layer fall into the deep brine layer and decompose (Fig. 3). This decomposition strips oxygen from the water, releases nutrients, and promotes other microbial processes that produce high levels of hydrogen sulfide (Fig. 4). This ƒrotten-egg‚ gas is very toxic, and levels in the deep brine layers of both bays exceed EPA‚s chronic criteria for protecting invertebrates by more than 2000-fold[3,5]. Consequently, the lack of oxygen and toxicity of the deep brine layers result in dead zones where brine shrimp, brine fly larvae and other invertebrates can‚t survive.

Very high levels of mercury also accumulate in Gilbert Bay‚s deep brine layer[6,7], and much of it is in the highly toxic methyl-mercury form (Fig. 4). Concentrations of methyl mercury measured there are some of the highest ever reported in the United States. Some of this mercury may come from the sediments where heavy metals have accumulated due to smelting activities in the Salt Lake Valley. Levels may also be high because much of the sedimenting algae and detritus don‚t fall to the bottom because the high-density brines keep them in suspension, and they consequently release small amounts of mercury into the deep brine layer[7].

The high sulfide and mercury levels in the deep brine layers also affect the upper mixed layer because there is constant movement of the brine and contaminants upward. This occurs due to the continuous flow of heavy brines from the northern sources into Gilbert and Farmington Bays. Turbulence caused by winds "shaves" off the tops of the deep brine layers and mixes the salts, hydrogen sulfide, nutrients and mercury into the upper water column where they can then affect brine shrimp, brine flies and other organisms. One estimate indicates that 25% of Gilbert Bay's deep brine layer and mercury is mixed into the upper layer each year.[7] The amount of mixing in Farmington Bay is much greater, because the deep brine layer is only protected by a 3-foot thick overlying layer. When high winds mix, hydrogen sulfide from Farmington's deep brine layer reacts with oxygen in the upper layer, and the entire water column loses its oxygen.[3] This process occurs in California's Salton Sea, and kills all of the organisms in the sea. The release of hydrogen sulfide from Farmington Bay is also a major source of "lake stink".[3]

Fig. 3. Twenty liter Cubitainers of water collected Aug. 3, 2010 from the surface layer of Gilbert Bay (left and right), and from 23' in the darkly-stained deep brine layer (center).

Gilbert Bay's deep brine layer is in the spotlight now because the SP Railway recently closed the culverts that allowed much of the brine to move from Gunnison to Gilbert Bay. The loss of these brines will cause Gilbert to become fresher, potentially to the detriment of the brine shrimp and to the mineral extraction industries in the south. However, the decreased flow of brine should diminish the magnitude of the deep brine layer. A bridge is planned to replace the culverts and allow bi-directional flow of salts and water between the two bays. The size and configuration of this bridge will effect both the overall salinity of Gilbert Bay, and also the size of the detrimental deep brine layer. Consequently, managers and the railway are building salt and hydrological flow models that are helping them construct a bridge that will minimize the negative effects of the causeway on the lake's many uses.

Fig. 4. Salinity and toxic hydrogen sulfide and methyl mercury in the water column of Gilbert Bay. The gray area shows the deep brine layer starting at a depth of 21 feet (Aug. 3, 2010).[7]

References

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