Circulation Story

A. General Notes about the Sea.
   1. Lake is polymictic, or stratified according to meteorological conditions.
   2. Lake is thermohaline, stratified into layers with differing temperatures and salinity, both of which affect the density of the water.
   3. We need a layman's definition of lake stratification.
   4. There is also evidence of long period internal gravity waves within the lake.
   5. Inflow is 1,410,000,000 cubic meters per year, lake volume is 9,870,000,000 cubic meters, and one-seventh of the total volume is replaced each year by inflow.
   6. Water Quality (Salton Sea Restoration Draft EIS/EIR, 2000): fresh water is less dense than salt water, and in estuarine environments, fresh water tends to float over saltier water in a "salt wedge", extending from the mouth of the river. In the Salton Sea, however, the freshwater inflows mix rapidly with ambient salt water, forming a relatively abrupt transition from freshwater to salt water.

B. During the Spring of 1997, the following conditions were encountered:
   1. <u>Northern Basin</u>
      a. Stronger vertical stratification that remained in place except for approximately two weeks in April.
      b. Greatest degree of stratification occurs in May when hypolimnion (deep water) temperatures remain constant and epilimnion (surface water) temperatures rose dramatically.
   2. <u>Southern Basin</u>
      a. Weaker vertical stratification except during approximately two weeks in May.
      b. Hypolimnion temperatures plunge periodically, indicating an exchange of hypolimnion water from the northern basin.
   3. Check temperature and precipitation data from climate section – this may support the water conditions listed above.

C. <u>Water Circulation versus Transportation</u> of sediments, nutrients, or contaminants.
   1. Circulation is normally driven by momentum from tributary inflows (New, Alamo and Whitewater Rivers), pressure forces associated with waves and tides, Coriolis forces, and wind stress or shear.
   2. Due to the Sea's large size, shallow depth, small hydrologic influx, and prolonged exposure to prevailing winds, the hydrodynamics of the Sea are driven by wind and Coriolis forces. Thus, wind stress is the primary force driving the circulation within the Sea. Actual prevailing wind direction graphics are present in the models to follow the text.

D. <u>Wind Conditions</u> (Salton Sea Restoration Draft EIS/EIR, 2000).
   1. The predominant wind direction is from the northwest to the southeast, with a more pronounced eastward component being expressed in the south end of the Sea.

2. Figure 10 shows rose diagrams which illustrate the frequency in which the wind was blowing for the CIMIS stations 127 (Salton City), and 154 (State Recreation Area). These diagrams are better at displaying wind directions than the vector diagrams and even the AM and PM maps I included in this analysis.
3. During the testing period, wind speed averaged 3.4 miles per hour at the north end of the Sea and 7.8 miles per hour at the south end of the Sea. Water speed was approximately one-tenth of the wind speed.

E. Lake Circulation Modeling.

1. Using the RMA-10 three-dimensional model, lake bottom and shoreline friction, Coriolis effect, and wind stress effects are all represented. This model can also be used to model vertical stratification, but current studies are baseline in nature and assume the water column is vertically homogeneous.
2. Results of the model are as follows: flow at the surface is to the southeast until contact with the shoreline is made, and then the water "piles up" due to hydrostatic pressure, producing a slightly higher water level at that end of the Sea, which in turn causes a downward flow, called downwelling, pushing water to the bottom of the lake for a return to the northwest.
3. The mid-depth and bottom current vectors, which are approximately equal, are slower than the surface velocity, and direction is opposite to the prevailing wind direction (to the northwest), with upwelling at the northwest boundary of the Sea.
4. This return is presumably at the base of the epilimnion layer (the upper layer of the lake) with little penetration of the hypolimnion waters (the lower layer in the lake), except during turnover events in which the lake loses its stratification.
5. The gyre is strongest in the southwest part of the Sea, with flow circulating horizontally and vertically around the center of the gyre.
6. This model does not account for varying meteorological conditions, water quality variations by source (including gradients of temperature and salinity) or turbulence.
7. The 2D model is useable when there is no vertical stratification within the Sea, but since the stratification is present throughout the majority of the year, the 10D model provides the best representation of circulation within the Sea.

F. Graphic Components of the Circulation Story:

1. A graph showing the variation in water velocity in a wind-driven circulation system. The top part of the graph shows the rapid movement of water to the southeast due to wind shear, and the lower part of the graph shows the return of water to the northwest, but with a drag effect from bottom friction. Please refer to Figure 1.
2. If we have a map of the CIMIS station locations elsewhere in the Atlas, we should show a link to said map as a way to stage the meteorological component of these circulation studies; if not, some representation of the weather stations is needed.

3. Plan views of the Sea with morning and afternoon wind data modeled into consistent speed and direction vectors. This is more complicated than our usual prevailing wind material, but is a more accurate representation. This display, shown in Figures 5 & 6, will also show how different morning and afternoon wind is (they are virtually in opposite directions).
4. Plan view of the Sea with the wind speed and direction averaged from several meteorological stations. This graphic is important in that there is a direct correlation to surface circulation that is visually apparent. This correlation is striking enough that the AM and PM comparison may be discarded. In addition, the diurnal variation in wind intensity and speed may be more appropriate to the climate section of the Atlas.
5. What we will not be doing:
    a. We could also include graphs to show changes in temperature, solar radiation and relative humidity, which are as expected at the Sea. This is important in characterizing the environmental conditions, which should also be presented in the climate section, although that section may be more regional in scope.
    b. Water quality conditions affect the density of lake water, which affects lake circulation: temperature, salinity and suspended matter load (sediments). For initial modeling, the water column was considered to be virtually homogeneous, so the impact of these parameters on circulation was not analyzed.
    c. Obviously, sediment distribution will be analyzed independently from circulation.
    d. Water circulation modeling normally involves calibrating the models for bottom roughness, horizontal and vertical turbulence, and wind stress, but none of that information is available in the references in hand.
6. A longitudinal cross-section of the Sea that emphasizes the presence of the north and south sub-basins, possibly with arrows to indicate the direction of flow within the gyre.
    a. This is obviously limited by stratification within the water column of the Sea, which is the normal condition. Some sort of shading could also be included to illustrate the stratification within the water column.
    b. The visual impact of the graphics will be drastically improved if the relative depths are done in color, as was done in the original.
    c. However, we should use our own self-generated bathymetry since it has undergone a certain degree of peer review through conference presentations and meetings with BOR staff. Of course, we should use our own shading routines.
    d. Please refer to Figure 2 on the following page to view the graphics.
7. Plan views of the Sea displaying velocity and direction vectors of lake circulation so that epilimnion currents can be compared to the mid-level and bottom circulation gyres.

   a. Dominant wind direction and speed are also indicated in the graphic.
   b. Relative water velocity is indicated, but the rates are comparable to one another. More meaning would be communicated if these rates were compared to other hydrographic systems.
   c. Graphic content could be made more compelling with color, and data might appear more meaningful combined with sediment grain sizes or other data. Please refer to Figures 3 & 4.
8. Much of the circulation story is the alteration to existing circulation patterns that would occur if and when engineering alternatives are implemented. Restricted circulation in many of the alternatives will cause stagnation in some parts of the Sea. We may, however, wish to avoid this issue due to the politics involved.
9. Lastly, we can show the final, modeled surface and bottom velocity maps, in which a strong counterclockwise gyre is visible in the south basin and a lesser clockwise gyre is present in the north basin. The expressions of these gyres are visible in both the surface and bottom currents, but the velocity is considerably slower at the bottom, as would be expected. This could be an excellent transition to the sediment presentation.