During the week of December 6-10, 2010, science staff from the New Mexico Bureau of Geology and Mineral Resources (NMBGMR) and National Cave and Karst Research Institute (NCKRI) conducted electrical resistivity (ER) surveys at White Sands National Monument. The purpose of these surveys was to characterize the local and sub-regional hydrology of the dune fields and adjacent areas within the Monument, and their relationship to regional hydrologic conditions in the Tularosa Basin. This report provides a brief description of the results of this work.

Methods
The basic operating principal for electrical resistivity surveys involves generating a direct current between two metal electrodes implanted in the ground, while the ground voltage is measured between two additional implanted electrodes. Given the current flow and measured voltage drop between two electrodes, the subsurface resistivity between the electrodes can be determined and mapped. Results of ER surveys are based on a computer-generated inverse model of measurements made in the field, and are referred to as the apparent resistivity.

Resistivity profiles detect vertical and lateral variations in resistivity in the subsurface. The presence of water or water-saturated soil or bedrock will strongly affect the results of a resistivity survey. Saltwater and brine have very low resistivity, ranging from <1 to a few tens of ohm-meters. Fresh water will show a much higher apparent resistivity, up to several thousand ohm-meters depending on dissolved solids content. Brackish water will display a spectrum of apparent resistivity values ranging from brine to pure water. Air-filled pore space in sediment above the water table will also have very high resistivity. In a relatively homogeneous system such as dune sand, the total dissolved solids (TDS) content of the groundwater in an area will be the principal factor controlling apparent resistivity.

Dune sands are considered to be an exceptionally challenging environment for conducting electrical resistivity surveys, in part because of the very high contact resistance usually encountered between the electrodes and the sand. A secondary objective of this study was to determine the effectiveness of ER methods in the dune field environment at White Sands National Monument.

Results

Bruce Allen piezometer area
On Monday, 12/6, we conducted a 28 electrode ER survey at 3 meter electrode spacing (Figure 1). The terrain-corrected resistivity profile shows a maximum depth of investigation of ~18 m (59 ft). A shallow zone of very low apparent resistivity on the southeast end of the profile probably results from a thin perched aquifer containing brackish water. A deeper zone of somewhat fresher water is suggested by higher resistivity values below 1204 m elevation, separated by a thin aquitard. Another pocket of fresher water is indicated by higher resistivity values in the dune area at the northwest end of the line. This high resistivity area appears to be connected with higher resistivity values further to the east, and suggests that the dunes may serve as a recharge area for the local hydrologic system southeast of the dune field.
On Tuesday, 12/7, we revisited the site near Dr. Allen’s piezometers and conducted another 28 electrode survey using a supplemental infinity electrode, providing greater depth of investigation of ~31 m (101 ft) (Figure 2). The same hydrologic features were observed, overlying a broader area of low resistivity below ~1190 m elevation, suggesting the presence of an extensive brine aquifer at greater depth beneath the perched systems.

**Film area**

On Wednesday, 12/8, we conducted a 42 electrode rollalong ER survey across the large dune in the film area (Figure 3), where NMBGMR personnel have a tensiometer, rain gauge and other hydrologic equipment deployed. The rollalong method incorporates a 50% overlap and allows for longer resistivity survey lines. Using a 6 meter electrode spacing, we achieved a depth of investigation of ~32 m (105 ft). The most distinctive features of this survey are the extensive zones of low apparent resistivity beginning ~5 meters below ground level, an indication that the dunes are probably saturated with very brackish water. Small areas of very high resistivity, indicated by bright orange and red colors, are probably artifacts of the inversion process, and an indication of the high noise level of this data set.
Lost River area

On Thursday, 12/9, we transported the ER equipment to the northeast corner of the Monument, near the area where Lost River disappears beneath the dunes. We attempted to conduct a long survey of 672 meters over the projected path of Lost River. Although some of the data collected was compromised by logistical problems, we were able to recover 168 meters of the survey data (Figure 4). Using a 6 meter electrode spacing, we achieved a depth of investigation of ~36 m (118 ft). Two broad zones of very low resistivity below ~1190 m elevation probably represent brine-filled sand. A smaller zone of relatively high resistivity below the 125 m position on the profile, ~20 m below ground level, suggests the presence of a lens of porous sand containing fresher water.

Monitoring well 3 area

On Friday, 12/10, we conducted a 28 electrode ER survey with 6 m electrode spacing near MW3 (Figure 5), extending across the access road into the monument and into the edge of the dune field. The shallow area of very high resistivity at the center of the profile is caused by highly compacted sediment and asphalt where the survey line crossed the road bed. A zone of relatively low resistivity ~5 m below ground level, shown in green and extending across most of the profile, probably represents a perched aquifer containing slightly brackish water. Underlying the perched aquifer is an extensive zone of very low resistivity ~15 m below ground level, suggesting the presence of an extensive brine aquifer at greater depth below the perched system.

Bruce Allen piezometer area, revisited

After completion of the MW-3 survey, equipment was relocated to Dr. Allen’s piezometer area and a 42 electrode rollalong survey was conducted at 6 m electrode spacing, allowing us to continue the surveys conducted on Monday and Tuesday farther

Figure 4: 28 electrode ER survey over projected westward extension of Lost River. 6 meter electrode spacing.

Figure 5: 28 electrode ER survey, 6 m electrode spacing, near MW3.
into the dunes. Maximum depth of investigation was ~40 m (131 ft). Higher resistivity zones in the dune field near the northwest end of the survey line strongly suggest that the dunes there are locally saturated with relatively fresh water ~3 meters below ground level. We identified the shallow perched aquifer containing brackish water again, although at lower resolution due to the broader electrode spacing. The most distinctive feature of this survey line is a zone of very low resistivity 15-18 m below ground level, suggesting the presence of an extensive brine-filled aquifer at greater depth (a recurring feature in most of the ER surveys conducted at White Sands).

Figure 6: 42 electrode ER survey near Dr. Allen’s piezometers, 6 m electrode spacing.

**Conclusions**

Preliminary results of electrical resistivity surveys at White Sands National Monument clearly indicate that resistivity methods can be conducted in aeolian dune sand, in spite of very high contact resistance. Total dissolved solids content of groundwater contained within the dunes and adjacent areas appears to be the principal factor controlling apparent resistivity distribution. In most areas surveyed, shallow perched aquifers containing water of variable TDS overlie an extensive brine-filled aquifer system at greater depths (usually 15-20 m below ground level).