DIRECT TESTIMONY OF MICHAEL L. RUCKER

My name is Michael Rucker, and I am a Senior Associate Geotechnical Engineer for Wood Environment & Infrastructure Solutions, Inc. (Wood). Since 2018, I have served as Wood's lead investigator for the collapse potential of the Carlsbad brine well (Cavity). I am a registered professional engineer and hold B.S. and M.S. degrees in Civil Engineering from the Massachusetts Institute of Technology. My curriculum vitae is attached as Rucker Exhibit 1.

Although the Cavity is more stable than before, there are substantial uncertainties regarding stability in certain areas. The geological structures beneath and around the Cavity are complex and fractured, and are currently not known with sufficient certainty to characterize the risk of seismic activity to the Cavity (Rucker Exhibit 2). Additionally, the monitoring conducted so far was designed for the specific purposes of monitoring Cavity stability and providing essential measurements in support of Cavity remediation activities, not detecting and quantifying off-site seismic activity due to drilling and completing horizontal wells (Rucker Exhibit 3).

Until the remediation project is completed, seismic activity has a non-negligible but unquantifiable potential to further jeopardize the Cavity's stability. The goal of the remediation project is to reduce void space in the Cavity as much as feasible. By reducing available void space, on-going future raveling of the void roof (and bulking or swelling of the raveling roof materials) may fill the upper void that remains once remediation has ended, which may, in turn, reduce instability in the void, helping to reduce the likelihood that the void will migrate upward and extend into the overlying groundwater aquifer.

The Cavity is in a state of partial collapse. A portion of the Cavity roof previously collapsed into void space left from the dissolution of halite resulting from brine production (Rucker Exhibits 4 and 5). Although it is not known when partial collapse started, it appears to have occurred between 2000 and 2010. OCD records indicate that the Eugenie #2 well tubing (casing), which is located over the Cavity, still extended through the collapsed portion of the Cavity and into the underlying halite formation when the well was cemented and abandoned in 2000. Additionally, since OCD initiated pressure monitoring in July 2010, the Eugenie #1 well has not exhibited unexplained, very rapid (minutes or less) fluid pressure changes greater than a modest 0.5 psi; 0.5 psi fluid pressure drops happened on two occasions (October 25, 2014 and November 10, 2015). On the other hand, several Magnitude 4.0 to 4.1 seismic events occurred between 1999 and 2010 (Rucker Exhibit 6). Also, the Eugenie #1 pressure was bled off to zero psi at ground surface for a sonar survey in 2007. Any or all of these seismic and pressure change events could have been trigger event candidates for the initial and early-stage collapse of the cavity.

Seismic events have a non-negligible but unquantifiable potential to jeopardize the Cavity's stability. Failures in the void roof and walls may result from an accumulation of stresses and displacements in the rock mass, and likely correlations between seismic activity and Cavity degradation have been documented (Rucker Exhibit 5). For instance, the Magnitude 5.0 event on March 26, 2020 (Rucker Exhibit 7) appears to have triggered significant roof fall and rubble pile settlement (Rucker Exhibit 7). Sonar surveys bracketing the event were conducted in February and May 2020, and they show significant changes in the Cavity. (It is important to note that the sonar surveys may not have detected additional zones of rubble pile settlement that then were covered over by sand deployed into the void.) Additionally, borehole tiltmeters show the occurrence of very small but permanent ground displacements occurring during and after seismic events (Rucker Exhibits 8 and 9). These events are of particular concern because regional seismic activity is rapidly increasing due to induced seismicity resulting largely from waste fluid injection (Exhibit 10). Given the frequency of regional seismic activity, which ranges from about Magnitudes 3.0 to

5.0 at distances of about 70 to 80 km from the Cavity, seismic events pose a potential hazard to the Cavity.

Drilling and/or completing horizontal wells in the vicinity of the Cavity could establish or exacerbate conditions that, combined with subsequent seismic events, result in rock fall and rubble settlement. Recent technical literature indicates that fracking activity may cause induced seismic events up to approximately Magnitude 3.0. Seismic-caused ground motion, commonly measured and quantified as the parameter "Ground Motion Particle Velocity" (GMPV), is a function of the magnitude and distance of the seismic event. At a hypocenter distance of about 3.3 km from the Cavity (accounting for both surface distance and fracking depth), the estimated GMPV for a Magnitude 3.0 event might be equal to the estimated GMPV of a Magnitude 4.8 event at a distance of about 75 km (Rucker Exhibit 11). Thus, a Magnitude 3.0 fracking-induced event with a hypocenter located 3.3 km from the Cavity could have the potential to produce ground motions only somewhat smaller than the Magnitude 5.0 earthquake that occurred 75 km from the Cavity on March 26, 2020. Moreover, even smaller magnitude seismic events closer to the Cavity could result in GMPVs similar to larger magnitude events farther from the Cavity. Finally, changes in formation hydraulic pressures around the Cavity due to imposed drilling fluid pressures in the general vicinity might influence stresses at the Cavity. For instance, recent changes in the Eugenie #1 annulus pressure trends appear to correlate to nearby drilling activity in March and April of 2021 (Rucker Exhibit 9).

Another risk of seismic activity in the vicinity of the Cavity is the contamination of ground water. The Cavity is filled with pressurized brine. Between 2010 and 2018, the valves at the Eugenie #1 well connecting into the Cavity were never opened, and the brine pressure at the ground surface gradually increased from 14 psi to 65 psi. This stable and gradually increasing brine pressure indicates that the Cavity is sealed and, except for wells penetrating into the Cavity zone, there were no paths for brine to be released or to escape prior to the start of remediation in 2018.

The Cavity roof is currently at a depth of about 340 feet (Rucker Exhibit 5). As gradual and progressive failure of roof rock occurs, the top of the void likely continues to propagate upward. As upward propagation continues, the remaining void gradually becomes filled with roof rock rubble due to the collapsed roof rock collecting onto the rising rubble floor of the void; bulking of the roof rock rubble causes the void rubble floor to rise faster than the void roof. Remediation by filling void space with sand reduces the volume of roof rock rubble bulking needed to reduce the size of the void, and may eventually stop the void roof's upward migration and reduce instability in the void roof. The regional freshwater aquifer overlying the Cavity extends from a depth of about 40 feet below ground surface to at least 206 feet (deep monitor well bottom), and possibly as deep as the top of an about 10- to 15-foot thick clay/claystone breccia layer (hydrologic barrier) at a depth of about 260 feet. If seismic activity, including seismic activity induced by drilling and/or well completion, compromises the rock overlying the void before the void is sufficiently filled, roof failure or rock fracturing has the potential to provide a path for millions of gallons of pressurized brine to escape and contaminate the aquifer.

Until the Cavity is more stable, OCD cannot specify appropriate conditions that would allow SPC to drill and/or complete a horizontal well in a manner that does not increase the risk and likelihood of injury to neighboring properties, including the Cavity, public health, public infrastructure, and environment, including ground water. A complete understanding of the Cavity's structure and dynamics is not technologically possible and will remain uncertain. It is impossible to effectively map and inspect the rock mass around the Cavity and to determine the rock mass strengths and geometries controlling Cavity stability which ultimately confine the movement of the brine. Without such detailed knowledge of the Cavity's surrounding materials, its ultimate strength and stability will remain unknown.

It is useful to compare the situation at the Cavity with the more developed engineering involved in mining and construction blasting. Criteria have been developed for allowable vibrations imposed on (typically residential) structures to effectively prevent or limit cosmetic cracking in such structures due to mining and construction blasting. These criteria were developed through years of research and empirical verification by pre- and post-blasting inspections and vibration monitoring, and have been used for enforcement of blasting operations since 1987. The Cavity is not a residential structure, and a body of available technical literature and experience does not exist for this unique situation. As a result, we must rely on detailed monitoring to provide data concerning operational adequacy or inadequacy. As such, monitoring provides a current and backwards look into the Cavity system's behavior. It can warn of imminent Cavity failure, but cannot with certainty provide recognizable clues to predict Cavity failure.