WJE ENGINEERS ARCHITECTS MATERIALS SCIENTISTS

Wiss, Janney, Elstner Associates, Inc.
2751 Prosperity Avenue, Suite 450
Fairfax, Virginia 22031
703.641.4601 tel | 703.641.8822 fax
www.wje.com

WASHINGTON MONUMENT
POST-EARTHQUAKE SURVEY AND CONDITION ASSESSMENT

Summary Description of Seismic Event

On Tuesday, August 23, 2011 at approximately 1:51 PM EDT, a magnitude 5.8M_w earthquake was recorded by the U.S. Geological Survey (USGS) within the Central Virginia Seismic Zone, centered approximately 84 miles southwest of Washington, D.C. near Mineral, Virginia. The earthquake occurred at an approximate depth of 3.7 miles below the surface and was followed by several after-shocks with magnitudes that ranged between 2.0M_w and 4.5M_w. In contrast with *interplate* earthquakes that occur along relatively well-understood plate-boundaries in the earth's crust, this event was an *intraplate* earthquake, occurring at some distance away from a known plate-boundary. Due to the geology of the eastern seaboard of the Unites States (U.S.), even moderate earthquake events will usually be felt across a far wider region than an earthquake of equivalent magnitude in the west, shaking an inventory of buildings that tends to be significantly older than the building stock in seismic zones in the west and, therefore, generally designed to resist far smaller earthquake forces. The USGS is now reporting that this event was the most widely-felt earthquake in U.S. history.

There are a number of scales that are commonly used to describe the size, magnitude, and intensity of an earthquake. *Magnitude* is a measure of the energy release associated with an earthquake at its source, and can be measured in a variety of ways. The more commonly recognized *Richter* magnitude is measured using a logarithm of the amplitude of waves recorded by seismographs, while *Moment* magnitude is based on the area "slip" along a fault. The Modified Mercalli Intensity (MMI) scale is a measure of the effects of the earthquake in any given locale. While a given earthquake typically has only a single *magnitude* value associated with it, a Modified Mercalli Intensity level can be assigned to each and every location in a shaken region. The MMI scale narratively describes both the range of human perceptions associated with locally felt ground shaking, as well as the effects of the ground shaking on the built environment. For example, the recent earthquake that was recorded at 5.8M_w corresponded to a shaking intensity at the epicenter of "VII" on the MMI scale, which is described as *"Damage negligible in buildings of good design and construction; slight-to-moderate in well-built ordinary structures [and]; considerable damage in poorly built or badly designed structures, [with] some chimneys broken."*

In addition to the MMI scale, the intensity of locally felt ground shaking can also be measured by instruments which record the acceleration of the ground during an earthquake event, thus allowing the shaking intensity of a seismic event to be quantified by measurable data if a recording instrument exists in the locale of interest. While there is undoubtedly a relationship between the acceleration of the ground during an earthquake and the damage caused to buildings by ground shaking, the precise relationship cannot be well-defined because the effects of the earthquake in part depend on the type, configuration and quality of the buildings being shaken. The maximum acceleration of the ground, or "Peak Ground Acceleration" (PGA), is commonly used by engineers to characterize the local intensity of shaking during an earthquake, and can be loosely correlated to the MMI scale using the "Instrumental Intensity" (I_{mm}) map available from the USGS and referred to on their website as a "ShakeMap". As of this writing, we are unaware of any published recordings of ground acceleration measured in Washington DC during the August 23 earthquake. However, in the absence of that data, the ShakeMap provides some basis for estimating a range for the PGA in Washington DC during the recent seismic event. From the map, it can

be seen that the PGA estimated for Washington DC would correlate roughly to a "moderate" level of perceived shaking and a "very light" potential for damage. However, the aspect ratio and manner in which the Washington Monument was originally constructed have rendered it uniquely vulnerable to ground motion associated with an earthquake.

Initial Findings and Recommendations

Our initial survey of the Monument and review of documentation made available to date by the National Park Service (NPS) suggest that the structure itself remains fundamentally sound, with no visible evidence of distress observed to date that would indicate it has been structurally compromised in a way that would render it permanently unsuitable for its intended use and occupancy as a result of the earthquake. However, there are several conditions that exist both within and on the exterior of the Monument that will require further review and stabilization before the Monument can be safely reopened to the public. Those conditions include cracking and spalling of the exterior marble and underlying stone masonry elements, as well as loss of joint mortar and de-bonding of cementitious patching material used at various locations throughout the Monument. To further address these concerns, Wiss, Janney, Elstner Associates, Inc. (WJE) will work closely with NPS to complete the following:

- Close-range survey and documentation of the existing condition of the exterior surfaces of the Monument utilizing rope-access technology and individual members of the WJE Difficult Access Team (DAT) trained and certified by the Society of Professional Rope Access Technicians (SPRAT);
- Identification and removal by hand where feasible of loosened or partially de-bonded material observed during our DAT survey;
- Research, material selection, and implementation of a temporary stabilization and weatherization program to:
    - Mitigate the risk for rainwater penetration and moisture ingress into or through the joints, cracks, and exposed natural stone surfaces of the obelisk, and;
    - Minimize the potential for damage to or contamination of natural stone surfaces and substrates that could negatively affect the long-term repair and restoration of the Monument;
    - Stabilize or remove conditions determined through further review and analysis to be a potential fall-hazard or otherwise significant and, therefore, in the critical path toward the safe reopening of the Monument to the general public.

- Development and implementation of a technically sound, safe, and serviceable long-term stabilization, repair, and restoration program for the Monument to address conditions resulting from the earthquake.

The primary goal of this effort will continue to be to expedite re-opening of the Monument to the general public. However, safety remains the primary concern of the NPS and its engineering team. Weather permitting, we anticipate completion of our close-range survey and preliminary evaluation of our findings on or before October 14, 2001, after which we will be in a position to establish a timeline for re-opening of the Monument that is both responsive to the need for additional stabilization and mindful of its status as a national landmark and one of the most visited tourist attractions in the United States.