that will contain the new 6.7 km-long approach channel between the new Pacific Lock and Gatún Lake. Our studies of the fault involved over 70 geologically logged trenches, including three locations where we excavated the fault in 3D to determine earthquake recurrence, displacement magnitudes and fault slip kinematics. We were able to determine that it has had three surface-rupturing earthquakes in the last 1.500 years, with the last event almost certainly occurring on May 2, 1621 AD. These three events all had 2–3 m of right-slip displacement, with a minimum of 8.1 m cumulative. Detailed 3D trenching of a deformed alluvial channel within the dam's footprint resolved 3.0±0.2 m right-lateral slip in the 1621 event. The fault is complex as it exploits weak, low-angle, west-dipping bedding planes of the La Boca Formation to rupture through to the surface as a series of north-stepping, en-echelon, west-dipping fault petals that roll over near the surface to almost horizontal.

The AD 1621 Panama Viejo Earthquake, the Camino de Cruces, and the Pedro Miguel Fault: an Archeoseismology Success Story

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Based on other trenching studies, the Pedro Miguel fault was determined to have experienced 3 surface rupturing events in the last 1600 years. Using the ca 1520 Spanish Road "Camino de Cruces" (CdC) as a piercing line across the Pedro Miguel fault (PMF), we undertook a detailed study to determine if rupture of the PMF generated the AD 1621 "Panama Viejo" earthquake. The CdC was constructed using rounded basaltic cobblestones that are not native to the local area. Using tectonic geomorphic mapping, stream bank exposures, and hand-excavated trenches, we exposed the PMF through the area where it crosses the CdC. Fault exposures demonstrate that the youngest alluvial deposits are offset, and the fault projects into the surface topsoil. The CdC is sharply deformed where it crosses the fault, trail cobbles are incorporated into, and overthrust, by the most recent fault scarp, and the CdC shows evidence for having been rebuilt across the fault. Combining the small geomorphic offsets and the trail offset makes a pre- and post-event reconstruction of 2.8 m of fault slip highly accurate. We conclude that the PMF last ruptured on May 2, 1621 and caused the earthquake that destroyed Panamá Viejo. As such, the PMF becomes the controlling structure for the seismic hazard to the Panama Canal.

Geologic Analysis During Construction of a Secant Pile Wall at Wolf Creek Dam, Jamestown, Kentucky

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Seepage problems associated with a karst foundation at Wolf Creek dam are currently being remediated by the construction of a 2-ft wide by 275-ft-deep and 3,800-ft-long concrete wall. This Secant Pile wall is constructed by drilling 50-in diameter piles on 31.5 and 35 in centers. Prior to Secant Pile construction, a 1,400+-hole grouting and exploration program was completed by several contractors to form grout curtains upstream and downstream of the Secant Pile wall. All of the grout borings was logged by drillers and geologists. This resulted in an extensive database of subsurface data with more data near the more critical areas. Geologic predictions of subsurface conditions are made on a weekly basis before each element of the Secant pile Wall is advanced. The original concerns were largely dam safety related so that the contractor and Corps of Engineers would be aware of upcoming cavities or other unusual subsurface conditions. Over time the "Geologic Look Ahead" proved a great resource for the production crews and quality control staff. Weekly meetings are held with the construction staff to address anticipated subsurface conditions. A geologic report of every hole is provided to the drillers before advancement. Because of the large amount of data and the highly variable karst geology, a careful understanding of what data to use and what data to ignore, is imperative. Where the karst features are most pervasive a 3D model was created.

Application of Block Theory to Rock Scour Assessment

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Scour of rock is a complex process and can be very problematic for dams or bridges when excessive scour threatens stability. Removal of individual rock blocks is one of the principle mechanisms by which scour can occur, particularly in unlined spillways, on dam abutments, and at bridge piers. To alleviate some of the complexity, commonly used methods for scour prediction tend to simplify the rock mass using rectangular block geometries (e.g., Bollaert 2002) or incorporate empirical relationships for the rock mass and do not actually model the physical scour process (e.g., Annandale 1995, 2006). More recent attempts have been made by Wibowo and Lin (2009), Li and Liu (2010) and Bollaert (2010) to include varying discontinuity orientations, but have been limited to two dimensions. Such 2D simplifications may be adequate in scenarios where blocks are rectangular in nature (such as flat lying sedimentary rocks). For other rock types, however, these assumptions can be very problematic, particularly for block analysis where the 3D orientation of discontinuities within the rock mass largely influence block removability. Accordingly, these simplifications take away from the site-specific nature of the analysis and any subsequent predictions may be unrealistic. To better represent the 3D structure of the rock mass, block theory (Goodman & Shi 1985) has been applied to evaluate stability of removable rock blocks subject to hydraulic forces. Block theory provides a rigorous methodology to identify removable blocks, determine potential failure modes, and assess stability. A case study is presented for an actively eroding unlined rock spillway channel at a dam site in Northern California. This work has been performed as part of an on-going research project to evaluate the erodibility of rock blocks.

An Assessment of 6th -12th Grade Climate and Energy Standards in the Southeast United States

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Climate and energy education is often overlooked in state science standards. However, given the environmental, human, and economic impacts that are associated with these issues, which will only become more critical in the future, they should be an integrated focus in educational standards refinement and revision. Climate and energy concepts should be, at minimum, introduced in the 6th grade and have a strong presence by the 12th grade. Students leaving high school, after having exposure to a robust climate and energy science curriculum, will be well prepared to tackle the issue of climate and energy that the country faces. Eleven states in the Southeastern U.S. (Texas, Louisiana, Mississippi, Arkansas, Tennessee, Kentucky, Alabama, Georgia, Florida, South Carolina, and North Carolina) were reviewed. Standards from earth and space science and environmental curriculums were inventoried and examined for the presence and depth of climate and energy concepts. The individual states were compared to the climate and energy principals and each state was compared against the other southeastern U.S. states. Recommendations for improvement of each of the eleven state science standards are discussed.

Water-Rocks Interaction and Arsenic Pollution in Chelpu-Region Water Resources (North Eastern Iran)

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This presentation documents hydrogeochemistry and arsenic concentration in 23 groundwater samples from Chelpu area in north of Kashmar (NE Iran), one of volcano-hosted hydrothermal systems from the Eocene volcanic activities, in an attempt to identify the environmental conditions and mineral-solution reactions governing arsenic aqueous cycling. An intense zone of hydrothermal alteration is present in the Paleogene sedimentary rocks. Argillic type of alteration along with jarosite, alunite, montmorillonite and kaolinite has developed as products of this intense alteration process. Associated minerals are stibnite, realgar, orpiment, pyrite and quartz. Water quality index (WQI) for studied samples indicate low quality of the waters for drinking. According to Piper diagram studied samples generally include Na–HCO_3, Na–SO_4, Na–Cl–HCO_3 and Na–SO_4–HCO_3–Cl bearing waters. Ternary diagram of Cl-HCO_3-SO_4 indicates the occurrence of mixing processes in the area, which are likely to be due to hydrothermal system in the studied area. Amongst the trace elements, the highest dissolved concentrations were those of As, Hg, Li, Ni, Ba, Mn, Zn and B. Arsenic (As) concentrations range from 0.022 to 65.43 μg/l. They increase with increasing SO_{42}-, Li+, K+ and Sb_3+. According to Gibbs diagram the water composition of studied samples are highly affected by water-rocks interactions. Correlation coefficient of As-Li, As-Sb, As-K and As-SO_4-2 are 0.9, 0.64, 0.88 and 0.89 respectively. Markedly positive dependencies of As with those elements and sulfate anion may indicate in oxidation of realgar (As_4S_4) and orpiment (A_s2S_3) as result of prolonged water-rock interaction in argillic alteration, where reducing groundwater environments, extensive leaching and advanced argillic alteration of host rocks takes place, releasing arsenic to solutions. Together with such factors, strong fracture systems may have collectively affected the properties of studied natural spring waters.

Landslide Inventory Mapping on the Wasatch Plateau, Manti-LaSal National Forest, Utah

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The Wasatch Plateau in central Utah is an area of extensive landsliding that has historically impacted Manti-LaSal National Forest lands. Landslides have damaged roads, trails, campgrounds, and water quality. We use ArcGIS to map and store landslide information for land-management analysis and evaluation. We map and inventory prehistorical and historical landslides at 1:24,000-scale using stereo aerial photographs and orthophoto imagery. We utilize several sets of aerial photos to characterize historical landslide activity for a 71-year period from 1940 through 2011. The characteristics of each landslide are attributed and stored in a geodatabase for analysis. The landslide inventory area consists of 512 mi^2, and mapping has been completed for 178 mi^2. The landslides range from small rock falls and debris flows to large earth flows up to 2.5-mi long. The Wasatch Plateau is underlain by the landslide-prone Tertiary-Cretaceous North Horn Formation, which is dominantly shale and contains the majority of mapped landslides. Landslides are also present in the Tertiary Flagstaff and Cretaceous Price River, Castlegate, and Black Hawk Formations. The inventory shows the location of landslides, and since future landsliding is generally based on past landslides, the inventory is useful for predicting future problems. ArcGIS is useful for understanding the relationship between landslides and streams, roads, bridges, campgrounds, trails, and timber sales. Understanding the extent and relative activity of landslides and their potential impacts allows for informed land-management decisions and improves anticipating problems from future landslide movement.

Factors Affecting Landslide Susceptibility of the Colluvium Derived from the Kope Formation, Cincinnati, Ohio

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Cincinnati, OH, is one of the most landslide susceptible areas in the United States. Government and private entities spend several million dollars annually to repair landslide damage. Landslides within the Cincinnati area generally occur in colluvium, classified as low plasticity clay, derived from the Kope Formation. The Kope Formation is comprised of approximately 80% shale, inter-bedded with 20% limestone. Two main types of slope failures occur in the Cincinnati area: rotational and translational. We created an inventory map using LiDAR data of the landslides that occurred in the colluvium. From the landslide inventory map, ten landslides were chosen for detailed study. Undisturbed samples were collected from each site. Of the ten landslides, seven were rotational and three were translational. One sample, representative of the slide material, was collected from each rotational landslide. Two samples were collected from each translational landslide, one from the overlying colluvial soil and one from underlying bedrock. We conducted laboratory tests to determine natural water content, Atterberg limits, shear strength parameters, dry density, grain size distribution, and slake durability. For the translational landslides, we determined shear strength parameters by shearing the sample along the contact between the bedrock and the overlying colluvium. Preliminary results show that low strength parameters, steep slopes, undercutting of slope toes by streams, and human activities are responsible for the landslide susceptibility of the colluvium derived from the Kope Formation.

Saving Time and Money with Direct Sensing Technologies: A Case Study

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Rapid Site Characterization (RSC) was conducted to evaluate the nature and extent of a fuel oil plume and differentiate it from other contaminant plumes at the site. The site is a former petroleum storage and distribution facility located in eastern New Jersey that was initially used as a portion of a larger manufactured gas plant site from approximately 1900 to 1918. Various weights of fuel oil were stored in an on-site 1.5 million-gallon above-ground storage tank (AST) and smaller above- and below-ground storage units from the mid-1930s until the mid-1980s. An unknown quantity of fuel oil leaked from the onsite ASTs and the associated piping into shallow soil and groundwater. Site characterization activities conducted at the site included Cone Penetration Testing (CPT), Laser Induced Fluorescence (LIF), confirmatory direct push soil sampling and Hydropunch® groundwater sampling. The CPT, LIF, direct push soil, and Hydropunch® results were used to create a 3D conceptual site model to identify data gaps, direct field operations real-time, estimate the extent of the fuel oil plume, and differentiate it from compounds not related to the operations conducted by the client. Results of the confirmation soil and groundwater sampling indicate that the real-time measurement technologies were effective at achieving the project objectives, reducing the overall project costs, and increasing the efficiency of the investigation.

Holtwood Hydroelectric Expansion Project: Extensive Rock Reinforcement Program Adjacent to Existing Power Station

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PPL Holtwood's Hydroelectric Expansion Project is located on the lower Susquehanna River in Lancaster County, Pennsylvania, next to its existing 107 MW powerhouse facility with a 2,400-ft-long, 55-ft-high dam, which has been in operation since 1910. Hydraulically undersized for the available river flow, PPL Holtwood is in the process of constructing a 125 MW expansion, which includes the addition of a two-turbine hydroelectric powerhouse (approximately 170-ft wide by 225-ft long) located adjacent to the existing 10 unit hydroelectric plant. The project requires a series of excavations up to 120 ft. deep, removing 350,000 yd^3 of bedrock to facilitate the construction of the new powerhouse, and an additional 943,000 yd^3 of bedrock for the expansion of the existing intake and tailrace channels. The majority of the excavation work has been done in-the-dry using upstream and downstream cofferdams. The project has been challenging because excavations were required immediately adjacent to and below the existing 100-year-old power station structure, which must remain in operation throughout the construction period. Haley & Aldrich was responsible for developing the geotechnical site characterization for the project, developing recommendations for soil and rock excavation and excavation support strategies to minimize risk to existing structures, as well as providing design services during construction, including owner support for contractor submittal reviews and field engineering support for blasting, rock reinforcement, curtain grouting and slope drains. This presentation provides an overview of the intricate and extensive rock reinforcement program for the main intake,