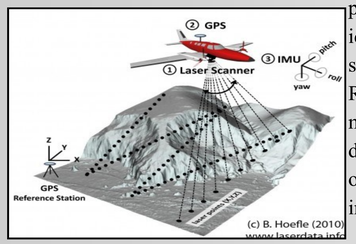
Detecting Potential Sinkholes Near Vehicular Roadways Using Remote Sensing

Regene Tell, Department of Civil, Constructions, and Environmental Engineering
Robert W. Peters, PhD., P.E., Department of Civil, Construction, and Environmental Engineering

Abstract

Sinkhole occurrence is caused by the hydrology of groundwater entrance into the carbonic bedrock, where it becomes acidic, and slowly dissolves soluble rock; ultimately forming a void suitable for a concave bowl-shaped depression. The purpose of this investigation is to identify methods capable of identifying sinkholes near vehicular roadways. Research shows that the airborne laser mechanism is the most capable at detecting a potential sinkhole, because of the ability to compute a displacement in angle of the laser during flight.



Sinkhole Discussion

Sinkholes originate in the lithosphere and asthenosphere due to the hydrology of groundwater causing erosion/dissolution to the cover layer of limestone, or carbonic bedrock. The groundwater becomes slightly acidic, and then becomes karst terrain of dissolved sediments, developing a void that will reach a maximum support capacity on the earth's crust, and form a concave cavity.

There are three significant types of sinkholes:

- Solution Sinkholes

  Occur when thin layers of soil and sand cover carbonic bedrock creating a permeable layer for groundwater to divert through

- Cover-Collapse Sinkholes

  Occur when the void in the limestone possesses a larger void are than the subsurface area

- Cover-Subsidence Sinkholes

  Occur when the cover layer (crust) is composed of heterogeneous sediments that allow sand particles though to fill the void in the limestone bedrock

Geosynthetic-Reinforced soils develop tensile forces to inhibit the movement of loose soils. Compaction grout is composed of Portland cement, water and sand. Grout pipes are penetrated to the cover layer of limestone bedrock. The chemical grouting process involves the polymeric substance, polyurethane. Polyurethane liquid foam is injected at low atmospheric pressures through $^{5}/_{8}$–inch tube, the polymer then expands slowly, realigning loose sediments, and forming and impenetrable surface. Attaching brackets to concrete slab foundations, or underpinning, using steel pipes hydraulically driven to the cover layer of limestone bedrock.

Mechanisms To Detect Sinkhole Formation

Listed below are some of the most efficient technological devices that can be used to detect potential sinkholes and their capability characteristics:

- Infrared Thermography

  Characterizes material properties through heat imaging

  Water contains a high heat emissivity content that ranges from 0.98-0.995

  - this aids in the search in terrain that contain high water content in soil

  Limitations include distinguishing reflected, or incident radiation cast on the surface of an object and the actual temperature of the object formulates a discrepancy. This means that all of the incident radiation on the surface of the object is absorbed, and results in an increase in temperature of the object (Lai, 2005)

  Passive Thermography

  - collects the temperature of the object without the need of an external heat source
  - any changes in temperature can result in either coring or ultrasonic frequency

  Active Thermography

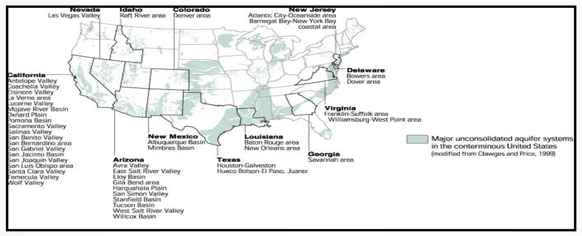
  - heat is applied to the surface of an object to reveal defects in size or depth in soil variations

- Airborne Laser Technology

  Laser propulsions are fed through a fuselage, located at the inferior region of an airplane. Once the laser is over the designated area, computer programming is given to emit roughly 33,000 laser pulses per second to the ground in a saw-toothed pattern (Lai, 2005). The airplane then collects satellite GPS coordinates to assess orthogonal angle are maintained throughout flight. However, satellite GPS does not provide accurate coordinates due to the planes constant orthogonal rotation. Inertial measurement units calculate angular displacement as a percent error, and uses the percent error for correct trajectory laser points. The trajectory points are entered into the Digital Elevation Model (DEM) where low-lying circular depressions are inspected as potential sinkholes.

- Uninhibited Aerial Vehicle Synthetic Aperture Radar (UAVSAR)

  Polarized waves are transmitted by the radar pod, located attached to the inferior region of the Gulfstream III, sending and receiving radio waves. The Gulfstream, in this instance, was flown for several trials over a particular area multiple times with the Precision Autopilot software controlling the airplane. The UAVSAR has the capability of measuring soil moisture, detecting heat activity underneath snow with depths between three to four feet, performong analysis of levees for flood control, identifying subsidence due to oil pumping, and ground movement functioning after earthquakes.



Conclusions

Based upon the features and characteristics of these mechanisms, the airborne laser technique provides the most accurate data for locating potential sinkholes. The mechanisms ability to use inertial measurement unit as a rationale for the variations in angular dislodgment provides coverage for the differentiation in GPS coordinates provided by both airplane and satellite.

References

1. Christy, A. A., (1993). "Effect of Particle Size on Diffuse Reflectance Infrared Spectra of Polystyrene Spheres". Vibrational Spectroscopy, 5(2): 233-244. Retrieved from http://www.sciencedirect.com/science/article/pii/0924203193870733
2. Dunn, M. G., (1993). "Bedrock", in J. Evers (Ed.), Exploring Your World: The Adventure of Geography.National Geographic Society. Retrieved from http://education.nationalgeographic.com/education/encyclopedia/bedrock/?ar_a=1
3. Mattson, B., (2013, March). "Electromagnetic Spectrum". Retrieved from http://imagine.gsfc.nasa.gov/docs/science/know_l1/emspectrum.html
4. Robertson, J.. (2013, March 11). "The Science of Sinkholes". Retrieved from http://www.usgs.gov/blogs/features/usgs_top_story/the-science-of-sinkholes/?from=textlink
5. Bloomquist, D., Shrestha, R., and Slatton, C., (2005). "Early Sinkhole Detection and Verification Using Airborne Laser and Infrared Technologies", in P. Lai, (Ed.), Gainsville: University of Florida. Retrieved from http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_GT/FDOT_BC354_54_rpt.pdf

Acknowledgements

I would like to give my greatest gratitude to my mentor Dr. Robert W. Peters, NCTSPM, and The Department of Civil, Environmental, and Construction Engineering at the University of Alabama at Birmingham.