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State Project No. 30000960 / LTRC Project No. 13-8GT

Bayou Corne Sinkhole: Control Measurements of State Highway 70 in Assumption Parish, Louisiana

INTRODUCTION

The sinkhole located in Assumption Parish, Louisiana, threatens the stability of Highway 70, a state maintained route. In order to mitigate the potential damaging effects of the sinkhole on this infrastructure, the Louisiana Department of Transportation and Development (DOTD) has requested accurate and precise measurements of control points along the affected portion of the highway. The Center for GeoInformatics (C4G) at Louisiana State University (LSU) was contracted to measure and collect horizontal and vertical positions at various locations along the highway using Global Positioning Systems (GPS) enhanced by a real-time network (RTN) of continuously operating reference stations (CORS) maintained by C4G.

OBJECTIVE

The fundamental objective for this project was to measure and assess the surface stability of the portion of Highway 70 that is potentially vulnerable to the sinkhole. Using GPS enhanced by RTN maintained by C4G, both horizontal and vertical positions were measured and collected at 20 point locations along the north shoulder of the highway and 8 locations on the bridges over Bayou Corne (west of the sinkhole) and Grand Bayou (east of the sinkhole).

SCOPE

Initially, the project identified 21 road surface control points for GPS measurements along Highway 70. All GPS measurements included the horizontal and vertical positions of the control points along the highway corridor bounded by Bayou Corne in the west and Bayou Choupique in the east. The field observations initially included two separate control measurements per session. This workflow produced two unique GPS datasets that were combined to provide a single weighted solution for each control point.

Following a request by DOTD to modify the data collection tasks, acquisition of weighted positions were abandoned in November 2012 in order to support an additional day of measurements at eight control point locations on the bridges over Bayou Corne and Grand Bayou. Furthermore, a control point was dropped from the workflow due to poor positional accuracy resulting from nearby tree canopy.

METHODOLOGY

The methods employed for this study were organized into three complementary tasks: field measurements, data processing, and data distribution. These tasks, including data backup strategies, are described in the following text.

Field Measurements

Field measurement tasks were organized into three distinct observation periods. The methods employed for measuring data points are discussed in the final report.

Observation Periods

During the 10-month period between September 2012 and June 2013, the highway control points were observed a total of 23 times. Thirteen bridge control point observations were collected between November 2012 and June 2013.

Measurement Techniques

In order to avoid measurements potentially influenced by the sinkhole, all field observations were collected using GPS equipment (e.g., data collectors, antennas, and cellular modems) maintained by C4G and augmented by the C4Gnet RTN. Measurements at

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PRINCIPAL INVESTIGATOR:
Joshua Kent

LTRC CONTACT:
Mark Morvant
225-767-9124

FUNDING:
SPR: TT-Fed/TT-Reg

Louisiana Transportation Research Center

4101 Gourrier Ave
Baton Rouge, LA 70808-4443

www.ltrc.lsu.edu

each control point were comprised of occupations lasting 300 one-second epochs (i.e., 5 minutes).

As per best practice techniques for minimizing the effects of atmospheric instability and mitigating unfavorable satellite geometries, measurements were initially collected at separate times during each day in the field (i.e., session). Positional solutions were computed using a weighted average technique that emphasized accuracy by minimizing positional dilution of precision (PDOP) and root-mean square error (RMSE) values quantified by the equipment. This technique produced a single weighted solution for each position.

In November 2012, weighted positional measurements were abandoned in order to support a request by DOTD to add the measurements at control points on the Bayou Corne and Grand Bayou bridges. Accordingly, 28 points were regularly measured: 20 locations along Hwy 70, 4 positions on the Bayou Corne bridge, and 4 positions on the Grand Bayou bridge.

CONCLUSIONS

No discernible movement of Highway 70 or the bridges over Bayou Corne, Grand Bayou, and Bayou Choupique have been detected relative to the sinkhole during the report's measurement period. Sporadic measurements collected in the field demonstrate random and systematic errors that confound detailed analysis for determining significant trends. A more effective strategy would employ long-term occupations that can better account for both random and systematic errors.

Despite the biases, the average range of horizontal error observed for the highway control points was 0.19 ft. (5.8 cm), which included a minimum error of 0.007 ft. (0.21 cm) and a maximum of 0.48 ft. (14.6 cm). The average range of vertical error observed along the highway was 0.3 ft. (9.14 cm), with a minimum value of 0.001 ft. (0.3 cm) and a maximum of 0.45 ft. (13.7 cm). For the bridge control point observations, the average range of horizontal error was 0.098 ft. (3 cm), with a minimum of 0.005 ft. (0.15 cm) and a maximum of 0.18 ft. (5.5 cm). The average range of vertical error observed for the bridges was 0.16 ft. (4.9 cm), with a minimum of 0.0 ft. (0 cm) and a maximum of 0.14 ft. (4.3 cm).

Sporadic vs. Long Term Occupation

As depicted in the results, static, ad hoc occupations of control points are susceptible to random and systematic errors. Random errors refer to measurement variability caused by unknown and unpredictable changes in environmental conditions that can vary in magnitude and direction (Grewal, Weill, & Andrews, 2007). Examples include, but are not limited to: erroneous orbital information of GPS satellites (e.g., relativistic effects of gravity), atmospheric instability in the lower (e.g., troposphere) and upper (e.g., ionosphere) atmosphere, and signal interference due to multi-path reflections. Systematic errors are typically caused by predictable changes in the environmental conditions and/or processes. Examples include, but are not limited to: user and instrument error (e.g., clock synchronization, software malfunctions); unfavorable satellite geometry; signal interference due to tree canopy cover; and finally the hydrographic heave and shrink on the local soils (related to the swamp and near-by bayous).

Long-term occupations are less susceptible to both random and systematic error by reducing their influence on the measurement solutions. For instance, random error can be reduced by occupying a location for a long period of time. Doing so provides a more reliable measurement of surface conditions by averaging, or smoothing, outlier values over time. The predictable, systematic errors can be constrained by following best practices when performing static occupations and using models to remove the unwanted sources of interference. For instance, known sources of multipath interference can be excluded (e.g., masked) from the positional solutions, user error can be mitigated, and EMI can be isolated. Errors expected for a fixed CORS station can be reduced to estimated precisions between 0.8 in. – 1.18 in. (2-3 cm) horizontal and 1.96 in. – 2.75 in. (5-7 cm) vertical (orthometric) (Armstrong, 2013).

It is important to note that systematic error that cannot be constrained may be indicative of movement associated with regional subsidence, or even the sinkhole itself.

RECOMMENDATIONS

C4G recommends deploying continuously operating GPS reference stations (CORS) as a cost effective monitoring strategy for improving the accuracy, precision, and consistency of the surface stability. The variability associated with short-term, static GPS observations makes identifying specific trends difficult due to the myriad of random and systematic error associated with the techniques. While these biases can be reduced, they cannot be eliminated. Utilization of a network of CORS will permit second-by-second monitoring of the surface that, when correlated with the C4Gnet RTN, can minimize biases that plague the sporadic occupations of the current project. Additionally, utilization of a CORS will better detect trends and movement of the road surface, which decision makers and emergency managers require for establishing situational awareness and ensuring public safety. Therefore, nominal observation precision can be constrained to within 1.18 in. (3 cm) horizontal and 3.1 in. (8 cm) vertical under ideal conditions.

Improve Monitoring of Highway Stability Using CORS Technology

Installing multiple CORS along the highway will provide consistent, accurate, and reliable telemetry of surface conditions. Additionally, the CORS network can be correlated with the C4Gnet RTN, a network of 70 CORS sites distributed across the State. In doing so, positional accuracy and precision will be improved by mitigating various sources of random error (e.g., atmospheric and satellite geometry). This logic is planned as part of LTRC research project 13-9GT.