**TRANSPORTATION POOLED FUND PROGRAM**

**QUARTERLY PROGRESS REPORT**

**Lead Agency: Utah Department of Transportation**

**INSTRUCTIONS:**

*Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.*

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| **Transportation Pooled Fund Program Project #**  **TPF-5(296)** | | **Transportation Pooled Fund Program - Report Period:**  \_ Quarter 1 (January 1 – March 31, 2014)  \_ Quarter 2 (April 1 – June 30, 2014)  \_ Quarter 3 (July 1 – September 30, 2014)  **x Quarter 4 (October 1 – December 31, 2014)** | |
| **Project Title:**  Simplified SPT Performance-Based Assessment of Liquefaction and Effects | | | |
| **Name of Project Manager(s):**  David Stevens | **Phone Number:**  801-589-8340 | | **E-Mail**  [davidstevens@utah.gov](mailto:davidstevens@utah.gov) |
| **Lead Agency Project ID:**  FINET 42065, ePM PIN 12436  UDOT PIC No. UT13.407 | **Other Project ID (i.e., contract #):**  UDOT Contract No. 148753 | | **Project Start Date:**  March 6, 2014 |
| **Original Project End Date:**  November 30, 2016 | **Current Project End Date:**  November 30, 2016 | | **Number of Extensions:** |

Project schedule status:

**X** On schedule \_ On revised schedule \_ Ahead of schedule \_ Behind schedule

Overall Project Statistics:

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| **Total Project Budget** | **Total Cost to Date for Project** | **Percentage of Work**  **Completed to Date** |
| $88,000.00 (current contract)  $148,000.00 (total committed) | $48,000 | 35% |

***Quarterly*** Project Statistics:

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| **Total Project Expenses**  **and Percentage This Quarter** | **Total Amount of Funds**  **Expended This Quarter** | **Total Percentage of**  **Time Used to Date** |
| 0% | $0 | 30% |

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| **Project Description**:  Liquefaction of loose saturated sands results in significant damage to buildings, transportation systems and lifelines in most large earthquake events. Liquefaction and the resulting loss of shear strength can lead to lateral spreading and seismic slope displacements, which often impact bridge abutments and wharfs, damaging these critical transportation links at a time when they are most needed for rescue efforts and post-earthquake recovery.  While most updated seismic provisions now adopt a risk-targeted approach to design ground motions for superstructures, other critical aspects of geotechnical engineering, such as liquefaction and ground deformation evaluation, are still based on the older concept of deterministic hazard evaluation. Recent advances in performance-based earthquake engineering (PBEE) in geotechnical engineering (e.g., Kramer and Mayfield 2007; Rathje and Saygili 2008; Bradley et al. 2011; Franke and Kramer 2013) have introduced probabilistic uniform hazard-based procedures for evaluating seismic ground deformations within a performance-based framework from which the likelihood of exceeding various magnitudes of deformation within a given time frame can be computed. However, the ability to apply these performance-based procedures on everyday projects is generally beyond the capabilities of most practicing engineers.  This study proposes to create and evaluate *simplified* performance-based design procedures for the *a priori* prediction of liquefaction triggering, lateral spread displacement, seismic slope displacement, and post-liquefaction free-field settlement using the standard penetration test (SPT).  Objectives for this study include:  1. Derive new simplified performance-based procedure for liquefaction triggering, lateral spread displacement, free-field post-liquefaction settlements, and Newmark seismic slope displacements.  2. Develop liquefaction parameter maps in GIS format associated with each of the hazards included in objective 1 at return periods of 475 years, 1033 years, and 2475 years for each of the states participating in the study.  3. Evaluate the new simplified performance-based liquefaction procedures against conventional (i.e., AASHTO) liquefaction analysis procedures.  4. Develop a simplified design procedure that will allow the designer to envelope the performance-based and conventional results to select which result will govern the design.  Tasks for this study include, regarding the participating states:  1. Derivation and validation of a new simplified liquefaction triggering model (Year 1).  2. Derivation and validation of simplified lateral spread displacement models (Year 1).  3. Derivation and validation of simplified post-liquefaction settlement models (Year 2). (Not funded in original contract.)  4. Derivation and validation of simplified Newmark seismic slope displacement models (Year 2). (Not funded in original contract.)  5. Assessment of grid spacing considerations in various seismic environments for map development (Years 1 & 2). (Partially funded in original contract.)  6. Development of liquefaction parameter maps at targeted return periods in GIS file format (Years 1 & 2). (Partially funded in original contract.)  7. Comparison of simplified, conventional, and deterministic analysis approaches (Years 1 & 2). (Partially funded in original contract.)  8. Development of a simplified design procedure and an analysis spreadsheet that incorporates both performance-based and conventional methods (Years 1 & 2). (Partially funded in original contract.)  9. Preparation of the annual and final reports (Years 1 & 2).  10. Dissemination of results in appropriate engineering journals and conferences (Years 1 & 2).  11. Technical Advisory Committee meetings (Years 1 & 2), including a final workshop to train partner states on the new performance-based liquefaction hazard methods.  Dr. Kevin Franke of BYU is the Principal Investigator for this research project. The technical advisory committee (TAC) for the study includes representatives from UT, AK, CT, ID, MT, and SC state DOTs. |

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| **Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):**  Task 1 – 100% complete.  Task 2 – 100% complete. It was determined that the addendum to the TAC quarterly update report for Tasks 1 and 2 was no longer needed since the original content is correct.  Task 3 – Not funded currently.  Task 4 – Not funded currently.  Task 5 – 50% complete.  Task 6 – 50% complete. The TAC quarterly update report and maps for initial portions of Tasks 5 and 6 were updated based on TAC review comments, and then shared with the TAC. Issues with the MSF equation were discussed with the TAC, and were resolved by the research team.  Task 7 – 40% complete. BYU continued work on this task.  Task 8 – 40% complete. BYU continued work on this task. The TAC agreed to extend the completion date for initial portions of Tasks 7 and 8 to February.  Task 9 – No work yet.  Task 10 – 50% complete. Two journal manuscripts were prepared for submission to the ASCE Journal of Geotechnical and Geoenvironmental Engineering and reviewed by the TAC.  Task 11 – 30% complete. An October TAC web-conference was held to review progress.  Contract – No changes were made. |
| **Anticipated work next quarter**:  Task 1 – Completed.  Task 2 – Completed.  Task 3 – None.  Task 4 – None.  Task 5 – None.  Task 6 – Liquefaction triggering maps will be re-developed and corrected based on selection of a different MSF relationship.  Task 7 – BYU will complete this task for Year 1.  Task 8 – BYU will continue work on this task and will seek feedback/recommendations from the TAC. The TAC quarterly update report for initial portions of Tasks 7 and 8 will be prepared and shared with the TAC, along with the draft analysis spreadsheet.  Task 9 – BYU will prepare the annual report.  Task 10 – None.  Task 11 – A web-conference will be held in March with the TAC to review progress on Tasks 7 and 8, the draft analysis spreadsheet, and the annual report.  Contract – FFY 2015 funding from the study partners will be added to the research contract to fully fund the planned scope of work. The contract amendment may also include a revised task schedule. |

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| **Significant Results:**  Research activities this quarter consisted of a comparison between performance-based, deterministic, and pseudo-probabilistic (i.e., AASHTO conventional) approaches for a hypothetical soil profile in an area of high seismicity (San Francisco), an area of moderate seismicity (Salt Lake City), and an area of low seismicity (Butte). We are still evaluating these results to better understand them and to make proper recommendations to the TAC. However, it appears that regional seismicity and return period has a significant effect on which approach tends to govern. Preliminary results suggest that the AASHTO conventional approach is inconsistent between regions of different seismicity (Franke et al. 2014). Deterministic and performance-based approaches appear much more consistent. At lower return periods (e.g., 475 years, or 10% probability of exceedance in 50 years), the performance-based approach appears to govern design irrespective of regional seismicity. At higher return periods (e.g., 2475 years, or 3% probability of exceedance in 75 years), the deterministic approach seems to govern in areas of high seismicity, the performance-based approach seems to govern in areas of low seismicity, and the governing approach could vary in areas of moderate seismicity. Our findings regarding this topic will be clearly presented in the next report.  Liquefaction loading/parameter maps were re-developed using the Idriss and Boulanger (2008) recommended relationships for the MSF (please refer to “Circumstances affecting project or budget”). These updated maps are approximately 90% complete, and will be completed by the extended February 2015 deadline.  Two journal manuscripts were prepared and were reviewed by the TAC. These manuscripts (listed below) were subsequently submitted for review to the ASCE *Journal of Geotechnical and Geoenvironmental Engineering*.   1. Ekstrom, L.T. and Franke, K.W**.** (under review). A Simplified Procedure for the Performance-Based Prediction of Lateral Spread Displacements 2. Ulmer, K.J. and Franke, K.W. (under review). Simplified Performance-Based Assessment of Liquefaction Triggering using Liquefaction Loading Maps   A simple calculation spreadsheet for use by DOTs and their respective consultants began development this quarter. Currently, the spreadsheet consists of a “shell” and some basic input functionality. Development of calculation and output functionality will continue into next quarter. |
| **Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that**  **might affect the completion of the project within the time, scope and fiscal constraints set forth in the**  **agreement, along with recommended solutions to those problems).**  A numerical error was identified in the development of the first set of liquefaction loading maps. Additionally, it was observed that approximately 5% of the simplified performance-based liquefaction triggering results that incorporated the Boulanger and Idriss (2014) MSF introduced significant bias into the computed liquefaction triggering hazard. The TAC discussed these issues and decided that the 2008 MSF should be used for this study. As a result, all liquefaction loading maps were re-developed a second time after correcting the numerical error and incorporating the 2008 Boulanger and Idriss MSF. These challenges required an extension of the deadline for Tasks 7 and 8 to February 2015, but no additional budget was required for these activities. |

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| **Potential Implementation:**  With the developed grid-spacing recommendations, engineers could potentially use performance-based liquefaction tools such as PBLiquefY or EZ-FRISK to develop their own liquefaction loading and/or lateral spread displacement reference maps for geographic areas of interest in the U.S. Once the calculations spreadsheet is completed and validated, engineers will be able to use it with the liquefaction loading and lateral spread displacement reference maps that were developed as part of this study to calculate site-specific, probabilistic estimates of liquefaction triggering and lateral spread displacement hazard at return periods of 475, 1033, and 2475 years. |