Louisiana Transportation Research Center

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Geotechnical Information Database, Phase III - pLog Enterprise - Enterprise GIS-Based Geotechnical Data Management System Enhancements - Final Report

by

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13. Abstract
The Louisiana Department of Transportation (DOTD) has been collecting geotechnical data in the District labs for many years in a variety of different formats, and in many cases, District personnel are inputting the same data repeatedly in different systems. Accessing this data and combining it with new data for the purpose of design, analysis, visualization, and reporting is difficult because the data has been generated by disparate systems and stored in various digital and non-digital formats. Essentially, there is no single system or repository nor an integrated, systematic approach for collecting, managing, reporting, archiving, and retrieving the vast amount of geotechnical data that is collected or generated by District labs each year.

With advances in computing capabilities, software tools are available that streamline the entire data management process from data collection through reporting, archiving, and map-based retrieval/reporting. Dataforensics configured an off-the-shelf Geotechnical Data Management System

to fulfill the needs of the DOTD District labs. It enables the District labs to store their geotechnical data in a consistent database format while improving the reliability and making it more accessible to key stakeholders by integrating with SiteManager and dTIMS (CoreLog).

Additionally, Dataforensics has incorporated the DOTD Pile Load Test Data into this Enterprise database for Headquarters, which replaces an in-house built system and provides a basis for future expansion to incorporate all the data from the 10-2GT project into this new enterprise system.

Project Review Committee

Each research project will have an advisory committee appointed by the LTRC Director. The Project Review Committee is responsible for assisting the LTRC Administrator or Manager in the development of acceptable research problem statements, requests for proposals, review of research proposals, oversight of approved research projects, and implementation of findings.

LTRC appreciates the dedication of the following Project Review Committee Members in guiding this research study to fruition.

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Abstract

The Louisiana Department of Transportation (DOTD) has been collecting geotechnical data in its District laboratories for many years in a variety of different formats. In many cases, District personnel are inputting the same data repeatedly in different systems because there are various different users of geotechnical data (construction, design, and pavement management) that need this data in different software. Accessing this data and combining it with new data for the purpose of design, analysis, visualization, and reporting is difficult because the data has been generated by disparate systems and stored in various digital and non-digital formats. Essentially, there is no single system or repository nor an integrated, systematic approach for collecting, managing, reporting, archiving, and retrieving the vast amount of geotechnical data that is collected or generated by District labs each year.

With advances in computing capabilities, software tools are available that streamline the entire data management process from data collection through reporting, archiving, and map-based retrieval/reporting. Dataforensics configured an off-the-shelf Geotechnical Data Management System to fulfill the needs of the DOTD District labs. It enables the District labs to store their geotechnical data in a consistent database format while improving the reliability and making it more accessible to key stakeholders by integrating directly with SiteManager (construction) and dTIMS (CoreLog for pavement management) eliminating the need to re-input the same data repeatedly in different systems.

Additionally, Dataforensics has incorporated the DOTD Pile Load Test Data into this enterprise geotechnical data management system for the Geotechnical Design Section. This involved significant data cleaning and conversion from its native format Access database into the database structure configured for DOTD as part of this project. This database replaces an in-house built system and one configured as part of the 14-1GT project while providing nearly identical functionality in an enterprise environment, making it more accessible and providing a basis for a potential future research project where all the Site Investigation and Laboratory Testing data from the 10-2GT project can be managed within this environment. This will then provide a comprehensive Geotechnical Data Management System with all borehole data (shallow and deep), in-situ tests, laboratory tests for shallow and deep boreholes, and pile load test spatially referenced with a built-in GIS environment.

The data management system configured as part of this project, will have significant implications on the DOTD. First, it will allow DOTD to re-use existing subgrade soil survey (shallow borehole) data, which potentially allows districts to reduce the exposure

of District personnel to the hazards of drilling boreholes through pavement. This is particularly important on busy roadways that have resulted in DOTD personnel being struck by cars.

Additionally, by having all shallow borehole data in an environment that facilitates their complete workflow, it prevents the repetitive data entry that is happening today which is a potential source of errors due to human error transcribing the same data from one system to another.

Furthermore, being able to eventually incorporate all the deep borehole data will enable DOTD to have a better picture of all subsurface conditions that they may encounter on future projects or where projects are expanding the capabilities of existing infrastructure.

Lastly, it will enhance DOTD's ability to respond to what might be termed "extreme events." This refers to the engineering consequences of natural events (such as hurricanes) and man-induced events (such as bridge and other waterfront structure impacts by ships or barges). In many cases, organizations such as DOTD are required to be able to return the impacted structure to some level of functionality in a very short period or else demolish and rebuild a replacement structure in a "fast-track" mode. Having this GIS-based geotechnical data management system improves their ability to find, utilize, and share the appropriate geotechnical data to meet these challenging project demands.

Acknowledgments

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Implementation Statement

The comprehensive Enterprise Geotechnical Data Management system configured in this project will allow DOTD to collect, manage, and report their geotechnical data associated with Shallow Boreholes/Subgrade Soil Survey significantly more efficiently and in a more consistent manner. Today each District is managing their subsurface data slightly differently as well as reporting their data differently. In many cases, these differences are quite minor, but the lack of standardization has implications on their processes and what data is actually usable and reusable over the long term. The data management system configured for this project incorporates borehole data, lab testing data, and pile load test data using the HoleBASE SI and KeyLAB software as its core components.

This data management system helps meet the needs of the District labs by allowing them to automate various reports they manually compile today in differing formats and using varying software. It also makes the data collected by the District labs readily accessible by design personnel in DOTD Headquarters, providing additional benefits. Furthermore, it eliminates the redundant data entry in at least three different software packages in addition to the existing Excel spreadsheets that are used for calculating many of the lab test results today.

This project builds on the work completed in projects 03-1GT, 10-2GT, and 14-1GT [1, 2, 3] to further DOTD's ability to find, use, and re-use subsurface data. It potentially helps reduce the amount of drilling in busy roadways that District lab personnel must perform by providing a mechanism for finding and reusing existing historical data, thus reducing the change of being struck by oncoming traffic. Including the Pile Load Test data in the system potentially helps DOTD improve their understanding of pile behavior by providing the basis for combining this valuable data with existing site investigation data.

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Introduction

District Lab

There are two processes that District labs perform related to managing subsurface investigation and lab testing data that are affected by this research project: subgrade soil surveys and borrow pits. The data for the subgrade soil survey in particular is a valuable asset for DOTD. It can be utilized on current projects for which the data is being gathered and be re-used on future projects. This has the capability of reducing the need for DOTD employees to go into the dangerous roadway environment where they are exposed to vehicular traffic, and potentially collect the same data they may already have. This data is also useful within the pavement management group as well as for users in design sections from headquarters (pavement, bridge, and geotechnical sections) as well as design personnel in each District. Accordingly, a consistent process for collecting, managing, reporting, storing, sharing, and retrieving this data has been implemented as part of this research project.

Subgrade Soil Survey

A subgrade soil survey consists of three general types of data:

- Shallow borehole related field data
- Laboratory testing data
- Dynamic Cone Penetrometer (DCP) data

At a high level, shallow borehole field data consists of soil layer depth intervals and descriptions as well as sample details. The lab testing data consists of test results associated with the samples obtained in the field such as American Association of State Highway Transportation Officials (AASHTO) Classification, ASTM Classification, pH, and Resistivity. DCP data includes depth, blows, and penetration of the DCP obtained in the field.

The District lab personnel performs these subgrade soil surveys and the associated lab testing. District lab personnel also perform lab testing for construction-related projects. For these projects, laboratory personnel must perform many of the same laboratory tests used in the subgrade soil survey, but the processing/reporting of the test results are potentially different depending on the department requesting the testing.

For example, data is input in SiteManager instead of generating a subgrade soil survey report if it is a construction-related project. This highlights that the same test is being performed using multiple systems, thus creating an unnecessarily complex workflow for the lab personnel, especially because the laboratory tests being performed are identical. Furthermore, this data is also input into CoreLog (dTIMS) for pavement management purposes.

District personnel write the data on paper, type the data into Excel to calculate the results, and then type the data into SiteManager, type the data into CoreLog, and then type the Subgrade Soil Survey reports in Word. In some cases, districts are using CoreLog to generate the Subgrade Soil Survey report.

As Dataforensics interviewed personnel in each District variations to this process were also noted. In some cases District personnel input data into multiple systems such as SiteManager even when the project is not construction-related because they don't have a process of their own and they believe having the data in a SiteManager is valuable even though finding the data in SiteManager after the fact requires having the SiteManager ID (which essentially means it isn't retrievable).

Accordingly, having a single system/process that can be used consistently by the District lab personnel yet can provide data to their clients in a format they need is ultimately what the District labs need. Moreover, this data management system should ensure the data is available from a long-term perspective and is readily accessible and re-usable.

Borrow Pit

A borrow pit investigation is essentially the same process from a data perspective as District lab personnel perform for the subgrade soil survey, other than that DCP testing is not performed and the boreholes (or excavation) are performed to a deeper depth (15-50 ft.). Accordingly, the same system described herein can be used to facilitate both processes.

This data is potentially of less importance from a long-term perspective because the material will be excavated assuming it meets the specification and thus will no longer be present once it has been excavated. In the short term, it is useful until the borrow pit is exhausted such that District personnel can retrieve results of past borrow pit investigations at the same site, which they are unable to easily do today. It is also useful to have this data from a long-term perspective for scenarios the material has not met the required specifications to be utilized by DOTD, so DOTD knows not to bother testing the same material again. Accordingly, it is important to categorize this data as a borrow pit because at some point it will no longer be relevant or useful for scenarios where it does not meet DOTD's requirements.

Headquarters

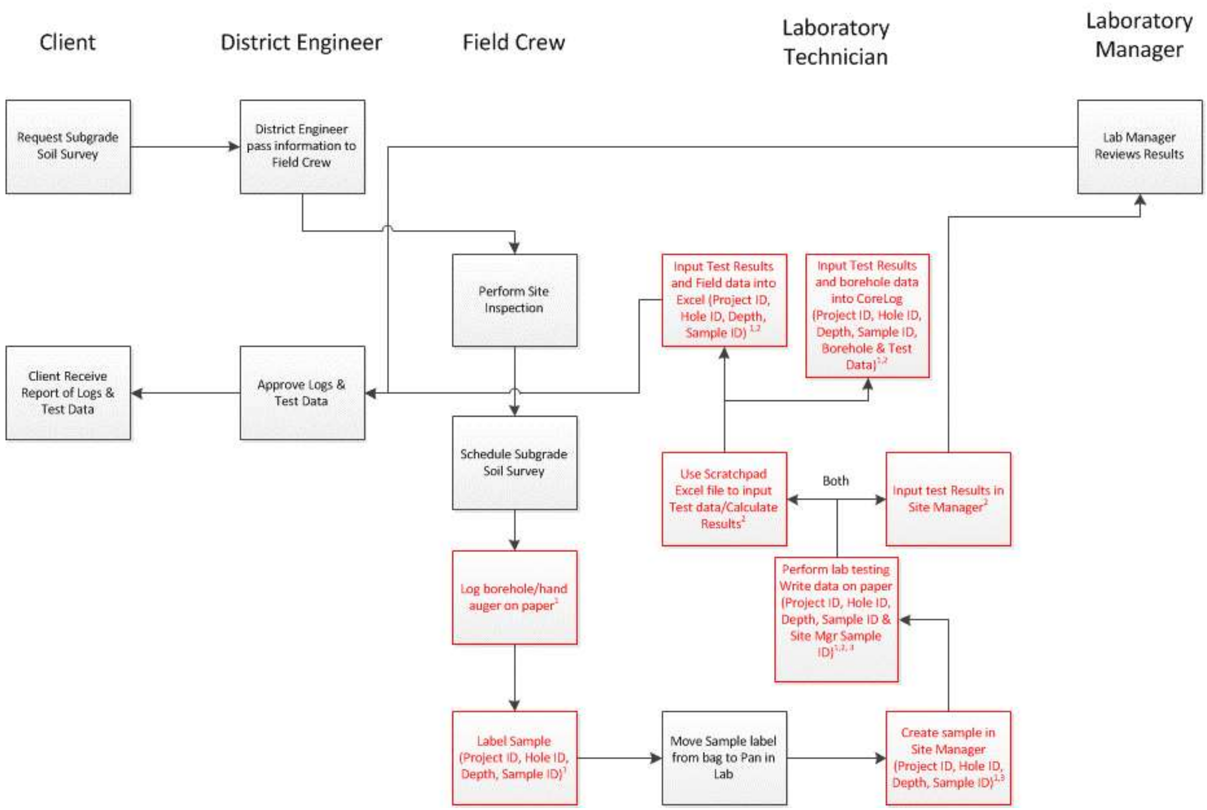
The Pile Load Test data incorporated as part of this project is related to the data management process for the Geotechnical Design Section at Headquarters. It builds upon the work from the 14-1GT project performed by Geostellar Engineers.

Process for Managing Subsurface Investigation Data in the District Labs

The traditional process for managing geotechnical data associated with Subgrade Soil Survey and Shallow Boreholes used by DOTD currently is similar to the approach utilized throughout a large portion of the geotechnical industry. An example of the inefficient, disconnected, and discontinuous nature of this traditional process is shown in Figure 1, where, in each task for the project, a subset of the data already input elsewhere in the process is repeatedly input in separate and disconnected systems, which is highlighted by the red boxes. In order to ensure adequate data quality, QA/QC should be performed for each of the data entry processes; otherwise, errors associated with repeated transcription, as well as typographical, spelling, or even calculation errors may be introduced in the process.

As Figure 1 shows, position titles are capitalized in the figure and in the following text. The Client requests the subgrade soil survey which is transmitted to the District Engineer. This is then passed to the Field Crew who performs the site inspection, schedules the subgrade soil survey, then logs the boreholes on paper, and handwrites the sample labels. The Laboratory Technician receives the samples and moves the label from the bag to the pan, creates a sample in the SiteManager software, performs lab testing where the data is written on paper, types the data into Scratchpad to calculate the results, inputs the results calculated in Scratchpad into SiteManager, inputs the test results again in Excel and inputs the test results again into CoreLog. The Lab Manager then reviews the results and sends it to the District Engineer for approval. Once approved, the results are sent to the Client.

Figure 1. Swim lane diagram for District 02 lab



Similarly, a flow chart illustrating the District lab workflow process is shown in Figure 2. Once again, it is noted that each type of data is input three or four times: field data on paper, field data in CoreLog, field data in Excel and then lab data on paper, lab data in Scratchpad, lab data in Excel, and lab data in CoreLog. In some cases, lab data is also input into SiteManager. This very inefficient process is potentially prone to errors associated with transcription and typographical mistakes. It also means that, in many cases, District personnel are not inputting data into CoreLog because it is an extra step and therefore DOTD is losing data for pavement management. Lastly, DOTD is unable to retrieve this data other than manually finding it in cardboard boxes or disparate files located on servers.

The primary focus of this project is streamlining and integrating the tasks in the red boxes in Figure 1 where redundant data entry is happening today in the laboratory.

Figure 2. Current District lab data management process

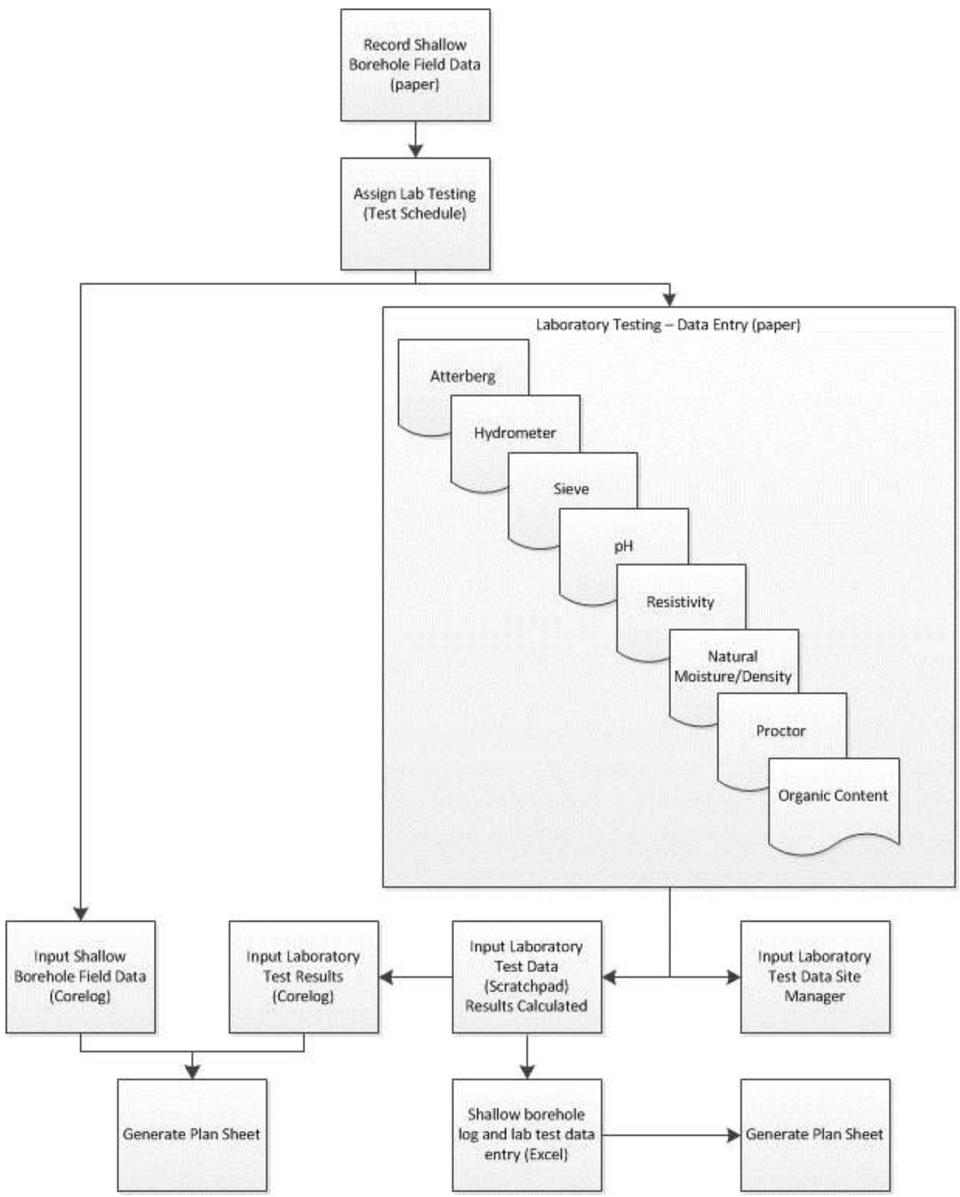
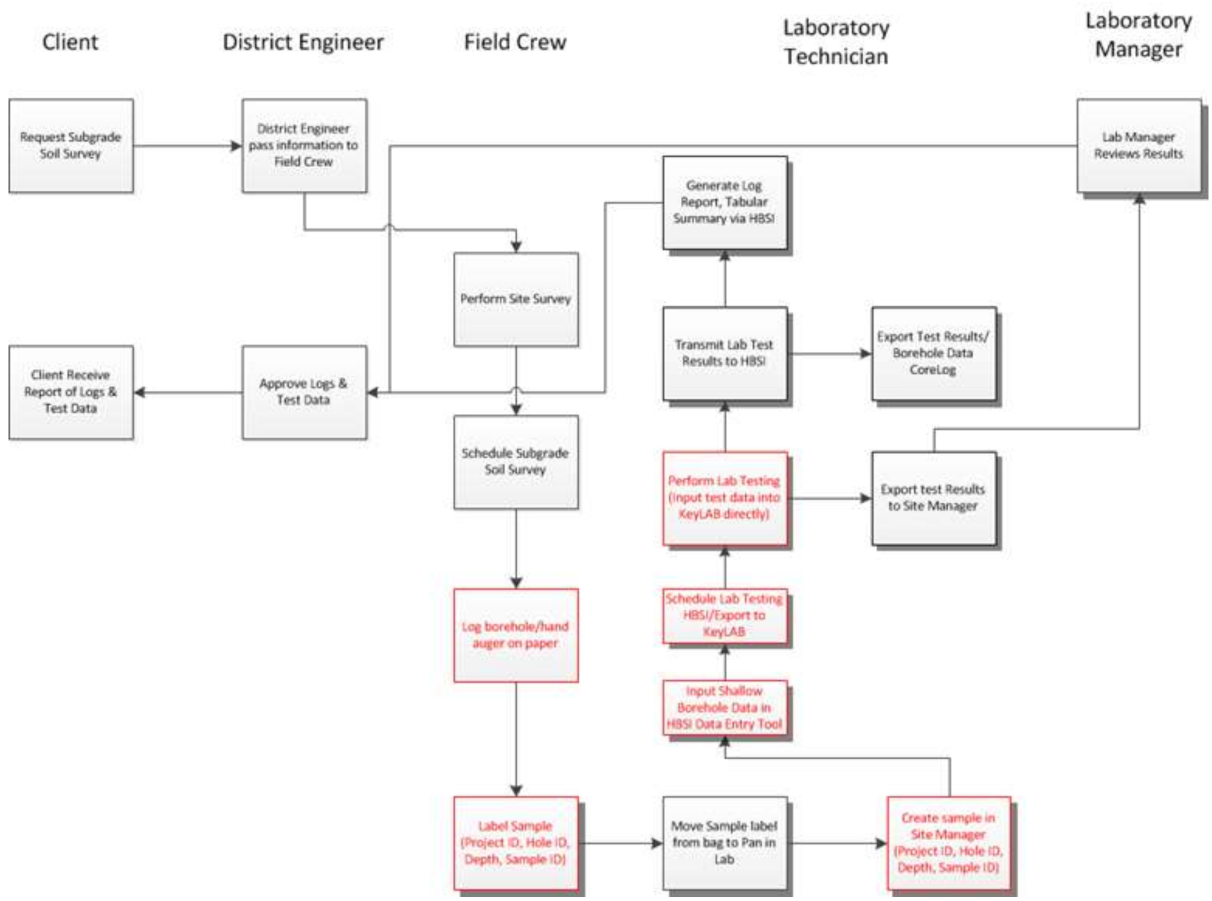


Figure 3 depicts the streamlined data management process configured as part of this project. Note the PRC and District labs did not want to streamline the field processes; accordingly, only the process after creating the Sample in SiteManager has been optimized.

Figure 3. Proposed data management process



Specifically, Figure 3 shows how the same process in Figure 1 can be simplified by transmitting data digitally and eliminating the redundancy in data entry. The process is fundamentally the same. Position titles are capitalized in the figure and in the following text. The Client requests the subgrade soil survey, which is transmitted to the District Engineer. This is then passed to the Field Crew who performs the site inspection, schedules the subgrade soil survey, and then logs the boreholes on paper, and handwrites the sample labels. The Laboratory Technician receives the samples and moves the label from the bag to the pan, creates a sample in the SiteManager software, inputs data into the HoleBASE data entry tool, schedules the lab testing, and sends that to KeyLAB for testing. They perform lab testing and can either input the raw data directly into KeyLAB or write it on paper and then type the data into KeyLAB. Test results are exported to SiteManager, CoreLog, and HoleBASE for use by the relevant users in different sections. The Lab Manager then reviews the results and sends it to the District Engineer for approval. Once approved, the results are sent to the Client.

Literature Review

Dataforensics compiled questionnaire results regarding the current processes and systems used for managing subgrade soil survey and shallow borehole related data across each District lab. Dataforensics also performed in-person interviews and held many web meetings with District lab personnel to identify similarities and differences between the District labs. Members of each District lab shared examples of the types of reports used in their existing data management processes.

The results of these interviews, questionnaires, and web meetings are described and depicted in the Figure 1 and 2, which highlight the redundant data entry. Dataforensics identified there was no standardized method across Districts for managing shallow borehole and subgrade soil survey data nor was there any standardized method for managing the laboratory testing data associated with these investigations. Accordingly, the work performed in this project accounts for differences across each District assembled into a standardized methodology for managing this data.

Lastly, Dataforensics reviewed the work performed in previous related projects from 03-1GT, 10-2GT, and 14-1GT. Ultimately, the recommendation to move to the Keynetix software (HoleBASE and KeyLAB) was recommended to provide future growth opportunities and continued enhancements to the data management process for both shallow borehole, deep borehole, in-situ testing, and pile load test related data.

Objective

With advances in computing capabilities, software tools are available that streamline the entire data management process from data collection through usage, reporting, archiving and map-based retrieval/reporting. Dataforensics established a plan to ensure that DOTD continues to advance their geotechnical data management capabilities which will keep them as a leader among all DOTs with respect to their data management processes. In order to realize this goal, Dataforensics has identified a scope of work that incorporates tasks and strategies that require expertise in geotechnical engineering, database systems, GIS technologies, and process flow, as well as software development and integration. This scope considers DOTD's current data and reporting needs as well as future re-use of data, reporting, data mining. It also integrates the geotechnical data management system with other systems such as dTIMS (CoreLog) for pavement management and SiteManager for construction to allow other consumers of geotechnical data to take advantage of the large quantities of geotechnical data being collected by the Districts.

Based on feedback from DOTD personnel regarding limitations of the gINT-based system configured in the 10-1GT project, Bentley/gINT's lack of support for geotechnical data interchange (DIGGS), and the lack of innovation and new capabilities in the gINT product line over the last decade, a minor but significant change in the project objective was discussed with the PRC. Several alternative solutions were provided along with pros and cons of each approach, risks of each approach, and costs associated with each approach. The PRC determined which alternative they wanted Dataforensics to implement as part of this research. The end result is a comprehensive geotechnical data management system for DOTD that includes all data for shallow boring, DCP, borrow pit, and pile load test data. It does not include deep borehole data because that would have to be configured as part of a follow on project since it was not part of the initial scope. Having the data (instead of having copies of the scanned reports) provides DOTD with the ability to generate reports, find and reuse the shallow borehole data, and a potential future project could migrate the capabilities configured in the 10-1GT project into this new platform based on the Keynetix products.

This decision was prophetic from the standpoint that Bentley acquired the Keynetix products in May 2019 and that the future of geotechnical data management revolves around the Keynetix Cloud. However, they have indicated that development of both gINT and Keynetix desktop-based products will continue at the same pace. Accordingly, getting HoleBASE and KeyLAB configured for the Keynetix product line is the first step for DOTD to potentially move to the cloud-based solution as part of a follow-on project.

Scope

The scope of the project focused on the creation of comprehensive database structure and reports that facilitate the data management process for geotechnical data associated with subgrade soil survey data, shallow borehole data, DCP data, and the laboratory testing associated with these processes.

The type of data included in this database structure is limited to:

- Shallow borehole data collected in the field (samples, soil descriptions, DCP, etc.) and laboratory data that is often generated as a result of the samples obtained from the borehole.

- Pile Load Test Data compiled by DOTD personnel and in the 14-1GT project by Geostellar Engineers.

Specific lab testing capabilities configured for this project include test sheets setup to mimic the existing Scratchpad Excel format provided by DOTD. These tests include natural moisture content, Atterberg Limits, sieve, hydrometer, organic content, shrinkage limit, specific gravity, Proctor (various T418 methods and ASTM methods), pH, and Resistivity tests. They provide the capability where DOTD could record all data digitally directly in the KeyLAB software instead of having to write it on paper and then transcribe it into the KeyLAB software (single source data entry) should DOTD want to do that at some point.

Additionally, data cleansing and data migration tools were developed that facilitated loading the data from the Pile Load Test database into HoleBASE. The scope was limited to data compiled in the 14-1GT project in the Access database provided by Geostellar Engineers.

Methodology

The methodology utilized for this project can be divided into four main tasks with a deliverable associated with each task:

- Shallow borehole database design and report configuration
- Laboratory test sheet configuration
- Pile load test database configuration and data migration
- Pile load test report configuration

Shallow Borehole Database Design and Report Configuration

The initial task of the project involved researching the current data management processes and software utilized for processing and storing subgrade soil survey, shallow borehole data, and laboratory testing data within each DOTD District. The investigation included interviewing DOTD District personnel using questionnaires and teleconferences as well as in person meetings with many of the districts. Additionally, meetings with the PRC committee members and DOTD's Headquarters Geotechnical Design Group and Information Technology were performed. During this process, the types of data to be stored within the system as well as representative examples of the various reporting formats were obtained.

Streamlining the geotechnical data management process was the primary focus of this study, so the next task focused on adding the necessary fields into the comprehensive database structure in HoleBASE where eventually all borehole, in-situ testing, laboratory testing data, and pile load testing data can be stored. The data structure that Dataforensics configured within HoleBASE for the North American market contained nearly all of the necessary fields for storing the geotechnical data already. Accordingly, only fields specific to DOTD's process that are principally associated with DOTD specific location related data such as Visidata Direction, Milemarker, Control Section, etc. or metadata (data describing the data) that is DOTD centric such as the District responsible for the data.

Once data could readily be input in HoleBASE, reports were configured based on the requirements determined in the initial task to mimic existing processes related to the subgrade soil survey (shallow borehole log) and DCP data analysis and reporting. For the subgrade soil survey reports, two different report styles were configured: a graphical boring log and a tabular subgrade soil survey report. The graphical log is similar to one of the reports used by one of the Districts. The tabular report is slightly different than what each District is generating today, but it incorporates aspects from each District into a standard report. These reports were presented to the District labs in various District lab engineer (DLE) meetings for feedback and then refined to a finalized state.

HoleBASE is natively an enterprise system that contains permissions, so as District and Design personnel are trained on the system, users will be created in HoleBASE with the required permissions for them to complete their aspect of the workflow.

Laboratory Test Sheet Configuration

Results of the initial task of the project provide details on most of the requirements for the laboratory test sheet configuration. To completely define the laboratory requirements, examples of the test sheets that were to be configured in the KeyLAB software were provided along with explanation of any requirements for each test sheet. This document was provided to the PRC and District lab personnel for review and feedback. This was compiled into a final version of the requirements, which were then used for the test sheet configuration.

Once each test sheet was configured in KeyLAB, example data from test sheets provided by DOTD was used to verify the test results calculated using the sheets in KeyLAB provided the test results calculated by DOTD. The draft sheets were demonstrated to the District labs that would use the sheets for feedback and the refined to a finalized form.

Once the sheets were finalized, the AGS data interchange standard export from KeyLAB to HoleBASE was tested to ensure the finalized data was now available for designers to use along with the field data, DCP data, pile load test data, and any other data ultimately stored in HoleBASE.

Pile Load Test Database Configuration and Data Migration

When the requirements were identified in the initial task of researching DOTD’s needs, the researchers attempted to configure the database structure within HoleBASE. During this process, Dataforensics identified that HoleBASE was unable to accommodate all of the Pile Load Test Data. Accordingly, a specification was developed in combination with the developer of the HoleBASE software (Keynetix) to add the required capabilities into HoleBASE. Unfortunately, getting these capabilities implemented required a significant amount of effort on their part and a couple of different iterations/attempts to get the functionality working properly. As such, incorporating these capabilities into HoleBASE has been a major source of delay on the project. However, those capabilities have been finalized and tested by Dataforensics.

Following the testing of the new capabilities, Dataforensics configured the database structure for all the Pile Load Test data tables and imported data from the Access database provided in the 14-1GT project by Geostellar Engineers. Importing the data required writing a custom data migration utility to export the data from the single access database into an access database for each project (note that HoleBASE imports data from gINT access databases that are only single project databases). Once that had been accomplished, data cleanup was necessary for a significant amount of the data in these files. Typically, the cleanup was a result of mistakes in compiling the historical data, which is to be expected. A full description of the changes to the data are documented in Appendix A.

- Duplicate Records for Test Pile Events – This scenario is where there were two records that have the identical the date/time for two different tests (e.g., CAPWAP and static performed at exactly the same time). As this is not possible to do, the date/time and elapsed time were modified slightly for these records to make them unique. This type of duplication is simply a result of compiling historical data.

- Duplicate Test Piles – This scenario is where there are two test piles that have the same Test Pile ID within the same project. As this doesn’t comply with proper data management practice and DOTD would not name the test piles the same on a project DOTD personnel were consulted for these scenarios. Ultimately, they were deleted from the database because they were a result of historical data migration where proper database normalization concepts were not implemented in the database schema in the 14-1GT project.

- Static Data Duplicate Data – There were many records in the static load test data that had duplicate elapsed time values with different deflections for the same test pile event. This would violate the laws of physics as an object at a certain time cannot be in two different places (e.g. have two different deflection values).

Accordingly, the record that had a larger deflection was changed to a slightly larger elapsed time (336 hours vs. 337 hours).

Pile Load Test Report Configuration

Jesse Rauser, from DOTD, had developed an Excel spreadsheet that retrieved data from the Pile Load Test Access database and facilitated analyzing and visualizing pile load test results. Accordingly, this spreadsheet was modified to retrieve data from HoleBASE while maintaining its calculation functionality and visualization capabilities. The spreadsheet used Excel macros for retrieving data from the database. All of these data access capabilities were able to be removed because of the native integration between HoleBASE and Excel. Accordingly, only the calculation-related macros are still being used. Once this configuration was completed, the results were compared against the results determined using DOTD's database to verify all functionality was working properly. Throughout this process, web meetings with DOTD were held to verify functionality was working correctly.

Discussion of Results

Three alternative software solutions were provided to the PRC in the interim report as potential solutions for the data management challenges facing the District labs. HoleBASE and KeyLAB were determined to be the most reliable platform to build upon at this time. These software packages are part of a modern enterprise software platform that continues to evolve and enhance how users are managing their geotechnical data versus the previous platform (gINT), which has not been improved over the last 10 years, noting that the gINT platform was the basis of the work performed in the 10-2GT project by Dataforensics.

This HoleBASE and KeyLAB system allows better workflow-related capabilities between field, laboratory, and consumers of geotechnical data in the various design section (Bridge, Geotechnical, Pavement, and Pavement Management). Additionally, the software supports all the data types used by the Geotechnical Design Section for deep boreholes and provides future expansion capabilities for the DOTD such that a comprehensive system that includes all subsurface geotechnical data is available. It includes built-in mapping capabilities (Geographic Information System (GIS)) such that DOTD personnel can use the mapping capabilities while the project is on-going as well as for finding historical data. It also includes the capabilities to manage all of the scanned document data developed in the 03-1GT project. So, ultimately, via a follow-on project, it can consolidate/replace the capabilities the 03-1GT project and 10-2GT projects making these systems up to date with current technology.

Lastly, because it is a native enterprise environment, it does not require DOTD personnel to perform an additional step at the end of each project to get the data into the Enterprise GIS environment, which eliminates the potential for data loss, which is one of the challenges and lessons learned based on the 10-2GT project.

Since Dataforensics proposed this option for DOTD, HoleBASE is now available natively in a cloud environment. This is an example of how the platform is continuing to evolve to better support the needs of users and facilitate data management and data interchange between data produces (District labs/consultants) and data consumers (design personnel/consultants).

The Keynetix Cloud environment provides for future expansion of DOTD's data management capabilities that would be a comprehensive inclusion of the work performed in 10-2GT, 15-1GT, and 03-1GT projects. For example, all documents included in 03-1GT associated with DOTs on the map could be loaded into the HoleBASE environment and made available via a web portal. Furthermore, this solution architecture enables DOTD to provide a web portal native to HoleBASE and available to internal DOTD personnel and/or external consultants and consumers of geotechnical data (contractors, other government agencies, etc.). The cloud-based environment includes a web mapping service that can be accessed in DOTD GIS environments and native mapping environment within the Cloud Portal. Accordingly, much of the same functionality available within the pLog Enterprise application developed in the 10-2GT project is available out of the box in Keynetix Cloud; however, Keynetix Cloud does not have the limitations associated with attempting to run gINT in a web-based environment because it is built upon modern .NET/enterprise web-based technology.

Training

Dataforensics conducted training sessions at each District Laboratory on the HBSI software and the customized DOTD templates. Training videos, other reference documents, and contact information are available to DOTD staff via the links provided in Appendix B. The HoleBASE and KeyLAB software links provide initial and reference information to both new and experienced laboratory staff. Contact information is also included on the intranet webpage. Additionally, the training information will help Section 67 as this software is incorporated into their deep boring processes.

Conclusions

This project developed a consistent approach for the District labs to manage their geotechnical data for shallow boreholes, DCP, and the associated laboratory testing. This project will allow DOTD to streamline their data management process for borehole lab testing, while providing long-term availability of the data in a modern enterprise geotechnical data management system. By standardizing the database structure, standardizing the workflow process, and configuring custom reports, DOTD personnel in various districts can more easily access and report their geotechnical data while simultaneously improving the quality and reliability of the data.

Providing a single system for managing all active site investigation-related data for the Districts while enabling it to easily be retrieved in the HoleBASE data management system, allows District users and Design Section users to access and utilize the data. With the HoleBASE built-in GIS interface (map), the Design Section can access boring logs, and other geotechnical data via the system. The GIS interface can access many different sources and types of data within and outside the Department. The quick and easy access to valuable data, including the mapping applications in the GIS will streamline and facilitate finding and analyzing the data.

This project builds upon the work completed in the 03-1GT and 10-2GT projects that created a reference resource, which will continue to grow over time and will aid in the evaluation of specific geotechnical site data. Ultimately, this will allow for more accurate and cost-effective design decisions. Additionally, this project migrated data compiled in the 14-1GT project into the system in order to provide a more reliable and accessible data store for the pile load test data. Ultimately, combining the pile load test data with deep borehole data will provide tremendous data mining opportunities where performance of specific pile foundations can be assessed and compared to expected performance based on actual soil properties in the database.

Since project kickoff and throughout the development, various meetings, demonstrations, and training sessions have occurred with various members of the PRC as well as the District lab users. The technology utilized in the system described herein uses off-the-shelf software products HoleBASE and KeyLAB with no custom development required.

Recommendations

Website and Server Maintenance

Maintenance and periodic updates should be applied to the software in order to ensure it continues to function properly and its performance is optimal. This will require combined efforts and ongoing support of both the IT team at DOTD and Dataforensics. The subscription for the first year for Keynetix Software (HoleBASE and KeyLAB) were included with research, meaning DOTD can use the software until August 2020. DOTD will be contacted by Dataforensics within a couple of months of support expiration in order to renew the subscription for an additional one-year period.

Personnel and Access

It is recommended that at least one Geotechnical Design section employee and one IT employee be trained on setting up users and managing the users within HoleBASE and KeyLAB environment. HoleBASE does support Active Directory Integration, so over the long-term, managing users in HoleBASE with this technology may be easier for DOTD as the number of users grows over time. More information can be found on this technology at the following URL:

http://assist.keynetix.com/Content/HoleBASESI/UserGuides/Windows%20Authentication.htm

Migration to Keynetix Cloud

As part of a future project, Dataforensics recommends migrating the capabilities of the existing project into Keynetix Cloud. Keynetix Cloud provides the same functionality available in HoleBASE Desktop based products but in a cloud environment. It also enables many additional integration capabilities.

For example, a more automated integration with KeyLAB was scheduled to be released by the end of 2019 where lab schedules can be sent from HoleBASE to KeyLAB and results can be sent from KeyLAB to HoleBASE without having to create AGS files. Additionally, it has an application programming interface (API) that enables integration with other systems. So, if DOTD wants to include all borehole locations on a custom DOTD website map interface or generate borehole logs from the map, the API can be used to facilitate this process with minimal development required. Lastly, various third parties are developing integrations for Keynetix Cloud to facilitate other aspects of the project workflow whether it is 3-D visualization using augmented reality technology (HoloLens) or modeling using the Leapfrog software.

Finally, Keynetix Cloud will enable DOTD to receive data from consultants directly (e.g., consultants can upload project data into a queue that once approved by DOTD personnel loads the data into Keynetix Cloud) as well as provide access to any geotechnical data in Keynetix Cloud to their consultants. Any concerns related to DOTD intranet/internet access are alleviated with this technology as well because the system is running in the Cloud outside of the DOTD network, which means no VPN access for external users will be required.

Future Modules

Dataforensics recommends a future project that will combine the work from 03-1GT, 10-2GT, and 15-1GT leveraging the capabilities of Keynetix Cloud. At a high level, this will allow:

1. A single system for deep borehole, shallow boreholes, CPT data, and pile load test data.
2. The relevant capabilities (log reports, section reports, and other reports) configured in the 10-2GT project in gINT would need to be configured in Keynetix Cloud.
3. The configuration created in the 15-1GT project would be loaded directly into Keynetix Cloud allowing all capabilities from the 15-1GT project to be cloud accessible.
4. Archiving of documents from the 03-1GT project such that they are available on the web-based and internal map in HoleBASE and the PDF documents can be accessed within the system.

Additionally, once the shallow boreholes and pile load test data are combined with the deep boreholes and their associated lab test data, and the CPT data in Keynetix Cloud, DOTD may consider adding spatial and non-spatial data mining algorithms into the system to automatically search for and identify trends in the data that are not obvious until they are specifically examined. Data mining allows users to gain a better understanding of their data by discovering new patterns in their large datasets. Keynetix Cloud provides the technology to facilitate this type of advancement via its modern representational state transfer (REST) based API.

Acronyms, Abbreviations, and Symbols

Term	**Description**
AASHTO	American Association of State Highway and Transportation Officials
	application programming interface (API)
ASTM	American Society of Testing Materials
CPT	Cone Penetration Test
DCP	Dynamic Cone Penetrometer
DIGGS	Data Interchange for Geotechnical and Geoenvironmental Specialists
DLE	District Lab Engineer
DOTD	Louisiana Department of Transportation and Development
ft.	Foot, Feet
gINT	Bentley Geotechnical Software
GIS	Geographic Information System
LRFD	Load Resistance Factored Design
LTRC	Louisiana Transportation Research Center
PRC	Project Review Committee
QA/QC	Quality Assurance/Quality Control
REST	representational state transfer
SiteManager	Site Manager Software

References

[1] Gautreau, G.P., Bhandari, P. "Development of a Geotechnical Information Database." 03-1GT Final Report, LTRC, Baton Rouge, LA., Nov 2008.

[2] Deaton, S.L. "Geotechnical Information Database – Phase II" 10-2GT Final Report, LTRC, Baton Rouge, LA., May 2013

[3] Tavera, E.A., Burnworth, G.H., Rix, G.J., and Jung, J, "Calibration of Region-Specific Gates Pile Driving Formula for LRFD," 14-1GT Final Report #561, LTRC, Baton Rouge, LA, May 2016

Appendix A

Changes to Pile Load Test Data to Support Data Migration

The changes listed herein are changing date/times, elapsed times, removing duplicate data for the purposes of cleaning it up, and providing proper referential integrity in the data.

Changes in H.000000 - 68

1. Elapsed time [hours] (req) was changed from 336 to 337 FOR ID 831.
2. Changed DateTimeTested 1/26/2014 12:01:00 AM in Test Pile Events

Changes in H.000000 - 291

Problem: Test Events has duplicate data e.g. ID 1036 & ID 1039 have the same Date Tested and Elapsed time.

1. For ID 1039 ELAPSED TIME CHANGED FROM 360-361
2. Date tested for ID 1038 changed from 12/4/1996 4:00:00 PM to 5:00:00 pm

Changes in H.000000 – 304

1. Time changed for ID 1140 from 4:00:36 to 4:00:38 to eliminate duplicate data
2. Time changed for ID 1143 from 4:00:36 to 4:00:38 to eliminate duplicate data

Changes in H.000995

1. Two test pile 3's are present in this project. Test Pile 3 with an ID of 496 was deleted as it was duplicate data from Test Pile 3 ID 498.

H.001569

1. Bent 4 (ID 1222) elapsed time changed from 0.01 to 0.02 to eliminate duplicate data
2. The time was changed after load applied to 0.1 hr.
3. Deleted all data after 1218 for ID 7885 (time after 300.1) as it was erroneous data

H008008

1. Time added 10 min. after ID 2198

H008273

1. Deleted a duplicated record TP-11 8/2/2011 TIME 163.9

H000000 -49

1. TP1 (ID 2981) Time changed from 0.01 to 0.2 to eliminate duplicate data.

H.000000 – 69

Various items with duplicate data – changed values to provide uniqueness

1. TP3 ID 861 and tp4 ID 890 elapsed time changed from 336 to 337
2. Static data ID 4311- 0.01 to 0.2
3. Static data ID 4312 - 0.02 to 0.4
4. Static data ID 4313 - 4332 add 0.1 to all
5. Static data ID 5080 – changed 0.01 to 0.1
6. Static data ID 5081 – changed 0.02 to 0.2
7. Static data ID 5083 to 5108 - added 0.1
8. Static data ID 5108 - 1
9. Static data ID 5109 - 2

h.000000 - 114

1. TestEvent ID 934 elapsed time changed from 336 to 337
2. Static data ID 6094 time changed from 5 to 4

h.000000 -167

1. TestEvent ID 805 elapsed time changed from 336-337
2. Static data ID 2481 changed from 120 - 121

h.000000 190

1. TestEvent ID 849 and 854 elapsed time changed from 336-337
2. Static data ID 4088 time changed from 0.01 to 0.1, ID 4089 time changed from 5.01 to 5.1, ID 4093 time changed from 975 to 975.1, ID 4178 time changed from 0.01 to 0.1

h.000000 - 204

1. Static data ID 5712 elapsed time changed from 0.01 to 0.1
2. TestEvent TP2 ID 916 elapsed time changed from 336 to 337

h.000000 - 231

1. Static data ID 5177 to 5203 all added 0.1 to time
2. TestEvent ID 893 elapsed time changed from 336 to 337

h000000 300

1. TestEvent ID 1128 DateTimeTested changed from 4:00:36 to 4:00:37

h000000 305

1. TestEvent ID 1146 DateTimeTested changed from 4:00:36 to 4:00:37

h000268

1. TestEvent ID 1253 DateTimeTested changed from 2/21/2005 12:00:36 AM to 2/21/2005 12:00:37 AM

h000830

1. TestEvent ID 1198 DateTimeTested changed from 1/29/2010 to 1/29/2010 12:00:01 AM

h002410

1. StaticData ID 48 Time changed from 115.0 to 115.1.

h.002215

1. TestEvent ID 1181 DateTimeTested changed from 10/2/2014 12:00:36 AM to 10/2/2014 12:00:37 AM

h003090

1. TestEvent ID 1274 & 1277 DateTimeTested changed from 8/21/2006 12:00:36 AM to 8/21/2006 12:00:37 AM and 8/21/2006 12:00:38 AM
2. TestEvent ID 1268 & 1278 DateTimeTested changed from 10/2/2006 12:00:36 AM to 10/2/2006 12:00:37 AM and 10/2/2006 12:00:38 AM
3. TestEvent ID 1263 & 1264 DateTimeTested changed from 9/29/2006 12:00:36 AM to 9/29/2006 12:00:37 AM and 9/29/2006 12:00:38 AM
4. StaticData ID 8125, 8127, 8129, and 8131 Time all added 0.1 min from the original time to avoid duplicate data

h005683

1. StaticData ID 2159 Time changed from 120.1 to 120.2

h.006138

1. TestEvent ID 1182 Time changed from 11/7/2014 12:00:36 AM to 11/7/2014 12:00:37 AM

h.006205

1. Testevents ID 1207 changed from 8/27/2007 12:00:36 AM to 8/27/2007 12:00:37 AM

h.008142

1. StaticData ID 890 Time changed from 52.6 to 52.7

h.009309

1. All Time in Staticdata was changed from 11/5/2014 to 11/5/2014 12:00:36 AM

h.009933

1. TestEvents ID 1176 Elapsed time changed from 0.01 to 0.02
2. TestEvents ID 1184 Elapsed time changed from 0.01 to 0.02
3. TestEvents ID 1185 Elapsed time changed from 0.01 to 0.03

Appendix B

Tutorials and Training Documents

A training video that walks through the workflow process has also been created and can be accessed from the following link at https://youtu.be/WXk4FAmQa7w

The following DOTD Intranet link contains training documents used to train the District labs: http://apps2/engineering/geotech/

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