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VTRC 07-CR15

DEVELOPMENT OF THE INTERCONNECTIVITY AND ENHANCEMENT (ICE) MODULE IN THE VIRGINIA DEPARTMENT OF TRANSPORTATION'S GEOTECHNICAL DATABASE MANAGEMENT SYSTEM FRAMEWORK

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Abstract

An Internet-based, spatiotemporal Geotechnical Database Management System (GDBMS) Framework was implemented at the Virginia Department of Transportation (VDOT) in 2002 to manage geotechnical data using a distributed Geographical Information System (GIS) methodology. GDBMS Framework was initially envisioned as a tool for archiving and accessing geotechnical data over the Internet. The original design concept of a non-proprietary open system and open architecture resulted in a flexible and easily expandable application. With progressive enhancements, GDBMS Framework has evolved into a functional and user-friendly system, providing geotechnical data analysis and design capabilities. One of the most valuable features of this system is user-selectable dynamic generation of fence diagrams.

In this project the Interconnectivity and Enhancement (ICE) module was developed and implemented. Key components of the ICE module are interoperability and interconnectivity among existing applications, data sources and GDBMS modules. Also further refinements were made to the existing GDBMS Framework functionalities.

The study recommends that the enhanced database be used for all new VDOT geotechnical data postings. It is estimated that the system can save VDOT approximately $272,000 per year based on the projected workload of 136 bridges per year. Other types of transportation-related data (bridges, pavements, drainage structures, traffic control devices, safety hardware, and environmental site assessments) can also be easily included in this database structure.

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ABSTRACT

An Internet-based, spatiotemporal Geotechnical Database Management System (GDBMS) Framework was implemented at the Virginia Department of Transportation (VDOT) in 2002 to manage geotechnical data using a distributed Geographical Information System (GIS) methodology. The GDBMS Framework was initially envisioned as a tool for archiving and accessing geotechnical data over the Internet. The original design concept of a non-proprietary open system and open architecture resulted in a flexible and easily expandable application. With progressive enhancements, the GDBMS Framework has evolved into a functional and user-friendly system, providing geotechnical data analysis and design capabilities. One of the most valuable features of this system is user-selectable dynamic generation of fence diagrams.

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INTRODUCTION

In 2001, the Geotechnical Research Advisory Committee (GRAC) of the Virginia Transportation Research Council (VTRC) identified a need to implement an Internet-based, spatiotemporal Geotechnical Database Management System (GDBMS) Framework using a distributed Geographical Information System (GIS) methodology for data management, archival retrieval, and analysis. Subsequently, a feasibility study was conducted by Ishibashi and Yoon to identify a number of GDBMS implementation alternatives.[1] The GIS-based approach was recommended as the most viable implementation model in terms of ease of use, cost-effectiveness, flexibility, and future expandability.

After the initial feasibility study, a demonstration pilot of the GDBMS Framework implementation was carried out for the Third Hampton Roads Crossing Project (HR3X). The main goal of the HR3X pilot study was to design, develop, and implement a practical Internet-based GDBMS Framework for accessing and utilizing geotechnical data. In 2003, the GDBMS Framework was further developed and scaled up to facilitate a statewide model, and subsequently the Woodrow Wilson Bridge and Route 1 Interchange site was added as a second project module.[2] Implemented statewide, the Internet-accessible, GIS-based GDBMS Framework has been actively utilized and recognized by Virginia Department of Transportation (VDOT) engineers as an effective and efficient tool to manage geotechnical data. One of the most valuable features of this system is user-selectable dynamic generation of fence diagrams. It allows for rapid display of multiple cross-section views of subsurface data by geotechnical engineers.

The initial conceptualization of the GDBMS Framework was to facilitate geotechnical data archiving, access, and retrieval. As the rate of utilization of the GDBMS Framework grew, VDOT engineers recognized that additional analysis and design functionalities could be incorporated. In response, five geotechnical engineering software applications (DRIVEN, RSS, LPILE Plus, SHAFT, and GALENA) that are frequently used to calculate slope stability, drilled shaft, and pile capacity were identified. The Analysis and Design Module (ADM) functionality for these five applications was designed, developed, and implemented to the GDBMS Framework in 2004.[3] ADM was designed to automatically extract, filter, translate, and generate input data sets inside the GDBMS Framework when a borehole site is selected, allowing VDOT engineers to perform specific analysis and design calculations.

In addition to the development of the ADM module, a powerful data search algorithm, *GDBMS Borehole Search Rabbit*, was implemented. This new search algorithm provides both hierarchical and partial search capabilities based on the GDBMS site module, VDOT project number, source-level gINT project file, and borehole designation. Once a borehole data search is completed, VDOT engineers can directly access particular site data in various formats, such as the original legacy data format, translated standard data format, gINT and Excel files of translated standard data format, and borehole data log and laboratory results.

Additional automated file upload capability (Bilateral Data Transferability [BDT]) functionality was developed and implemented in 2005 to allow VDOT geologists to upload completed geotechnical gINT data files to the GDBMS server, with a pre-screening and QA/QC validity check prior to the final posting.[4] This BDT module was implemented based on the latest geotechnical gINT data template and library (vtrc6.glb) used by VDOT. In addition, a new functionality to export dynamically generated fence diagrams into MicroStation in a DXF format was developed and implemented.

PURPOSE AND SCOPE

The purpose of this project was to develop and implement an Interconnectivity and Enhancement (ICE) module in the existing GDBMS Framework to improve and enhance interoperability and interconnectivity among existing applications, data sources, and GDBMS modules. In addition, further refinements were implemented in the existing GDBMS Framework functionality, such as coordinate-based scale correction in dynamic fence diagram procedures. Additional tasks were performed to maintain, update, and enhance existing GDBMS Framework components such as the Third Crossing of Hampton Roads (HR3X) project module and development of translative data templates for the newly revised gINT data template and library (vtrc7.glb) files currently used by VDOT materials personnel and consultants.

The following tasks were performed in the existing GDBMS Framework:

(1) Development and implementation of nine district-level GDBMS Framework modules (Bristol, Culpeper, Fredericksburg, Hampton Roads, Lynchburg, Northern Virginia, Richmond, Salem, and Staunton), and population of 290 borehole data locations.

(2) Development and implementation of a prototype translative data template for the new vtrc7 data standard (further enhancement to the vtrc6 data standard used at VDOT)

(3) Development and implementation of Geodetic to the Virginia SPCS (State Plane Coordinate System) coordinate transformation routine for the dynamic fence diagram generation procedure to display proportional spacing of borehole locations.

(4) Addition of 299 new borehole data elements to the Third Crossing of Hampton Roads (HR3X) project module, translated to the VDOT standardized data format.

(5) Enhancement of BDT module functions and user interface.

(6) Modification and update of the SMTP I/O process control and automatic notification procedure for the BDT module.

(7) Enhancement to the "Administrative Procedures" corresponding to vtrc6- and vtrc7-specific module functions and required user interface changes.

(8) Installation of 1-m resolution rectified orthogonal aerial photograph layer from VGIN (Virginia Geographic Information Network) SDE (Spatial Database Engine) at the production server hosted by VDOT GIS Division (SDE Ortho layers are not mountable at the development server, Matrix2) hosted by the VDOT Central Office Materials Division.

METHODS

The VDOT GDBMS Framework program source codes were revised, expanded, and updated to add vtrc6-series district-level modules based on an adaptive translative engine for the VDOT gINT data template and library. After each module directory structure was replicated, district-specific codes were modified and updated correspondingly. BDT module functions and user interfaces were correspondingly updated and enhanced. The "Administrative Procedures" tool was also updated to reflect district-level expansion in the GDBMS Framework. The "Administrative Procedures" tool is an administrator level management tool used by VDOT maintainers. The schematic relationship and dependency among various GDBMS components are illustrated in Figure 1.

RESULTS

An Internet-based, spatiotemporal geotechnical database with Interconnectivity and Enhancement (ICE), Bilateral Transferability (BDT), and the Analysis and Design Module (ADM) can be accessed on the Internet at http://matrix2/website/index.html inside VDOT. The entire database is also mirrored for outside access by VDOT consultants at http://gis.virginiadot.org/ (GDBMS Framework hyperlink). For security reasons, BDT functionality is available only on the internal VDOT network.

The results of the ICE implementation in the GDBMS Framework environment are shown in Figures 2 through 7.

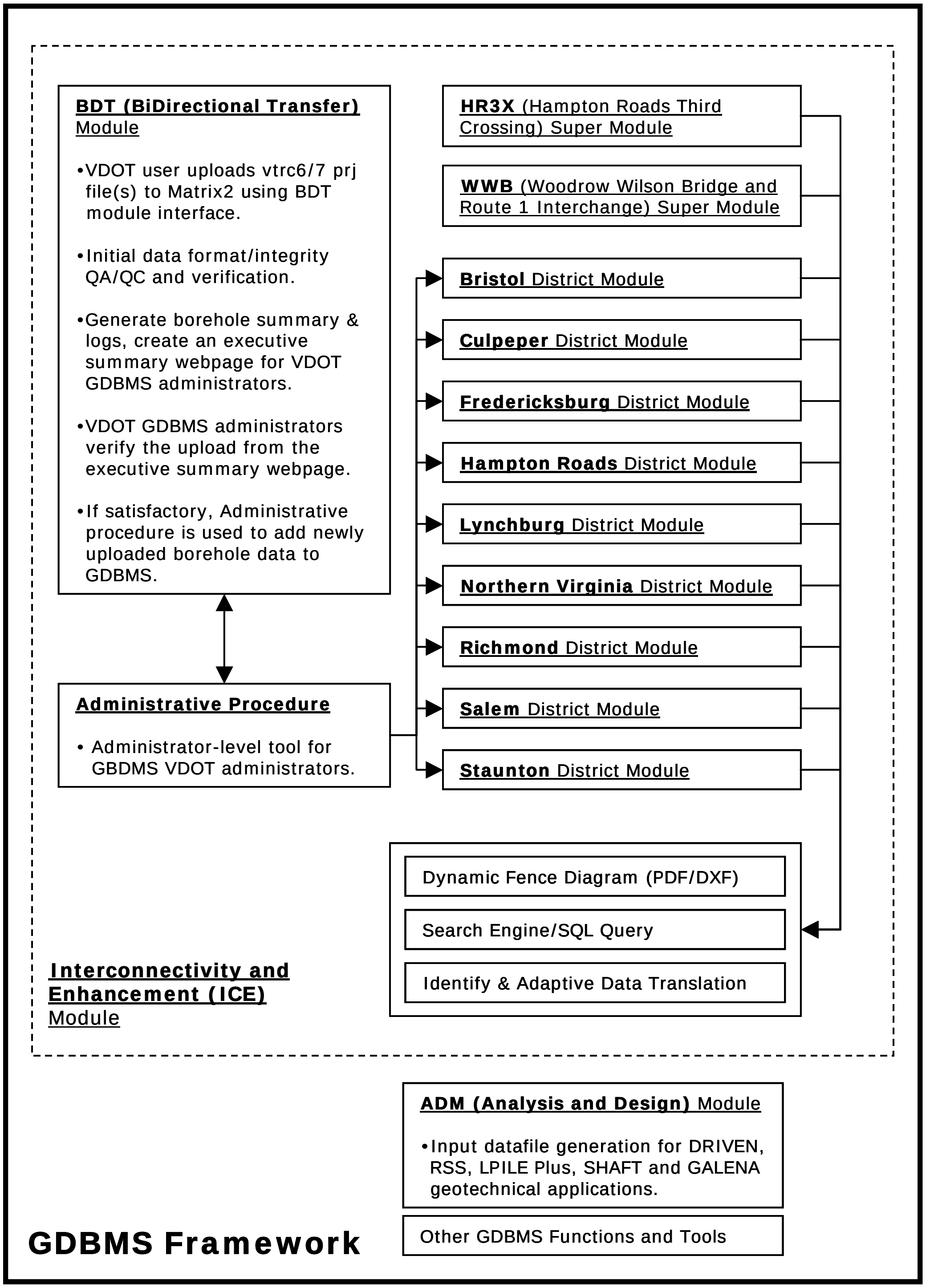

Figure 1. Schematic Relationship and Dependency Among Various GDBMS Framework Components

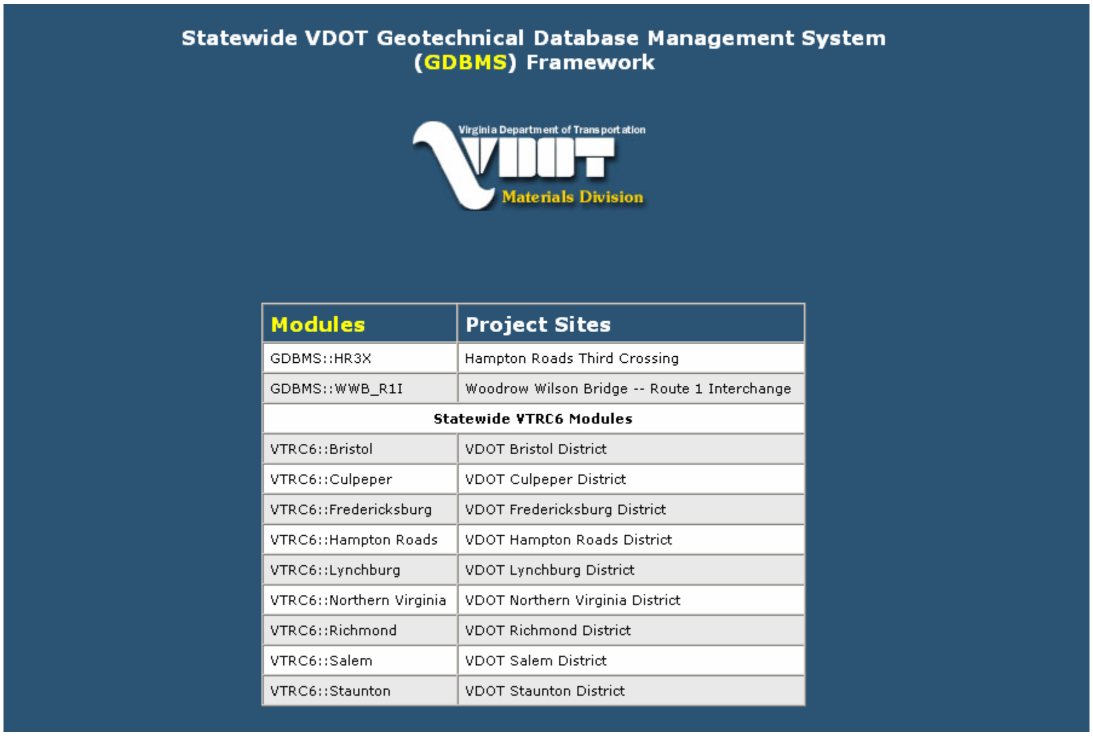

Figure 2. VTRC6 Data District-Level Modules Managed by ICE and BDT

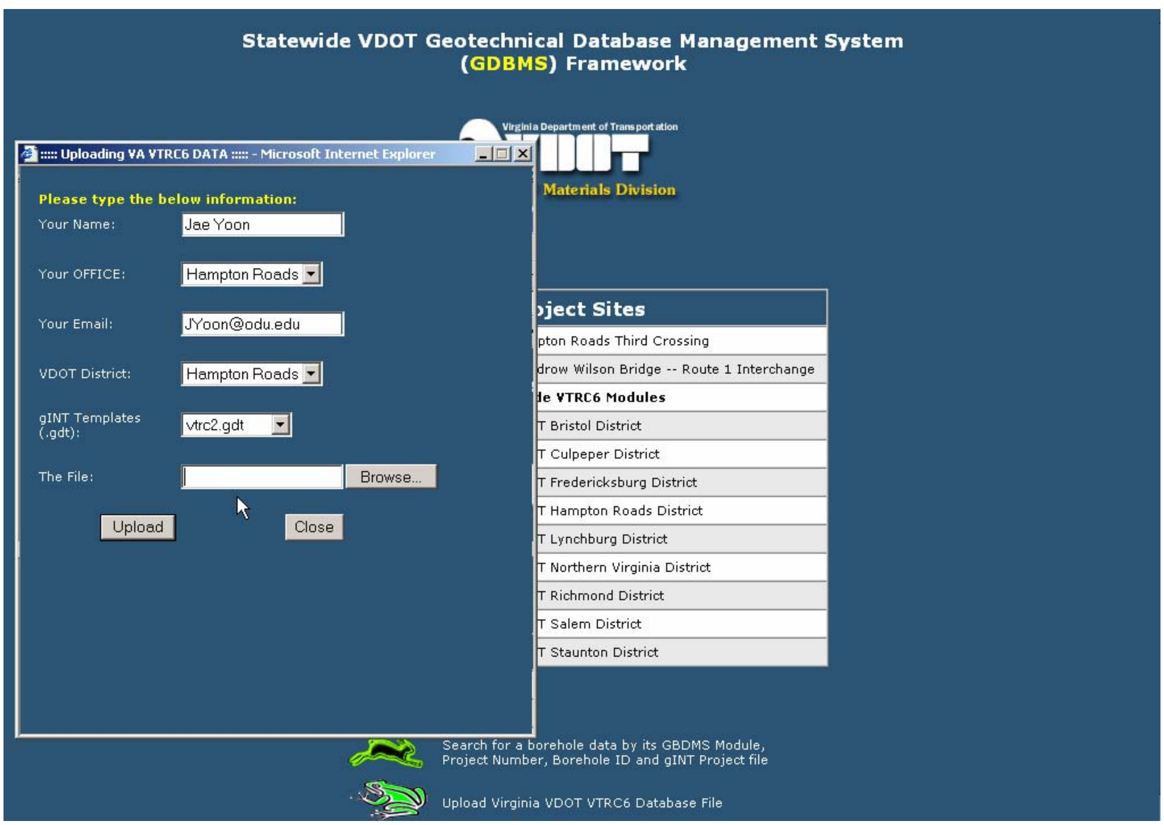

Figure 3. Example of ICE and BDT Module Data Upload to GDBMS Framework

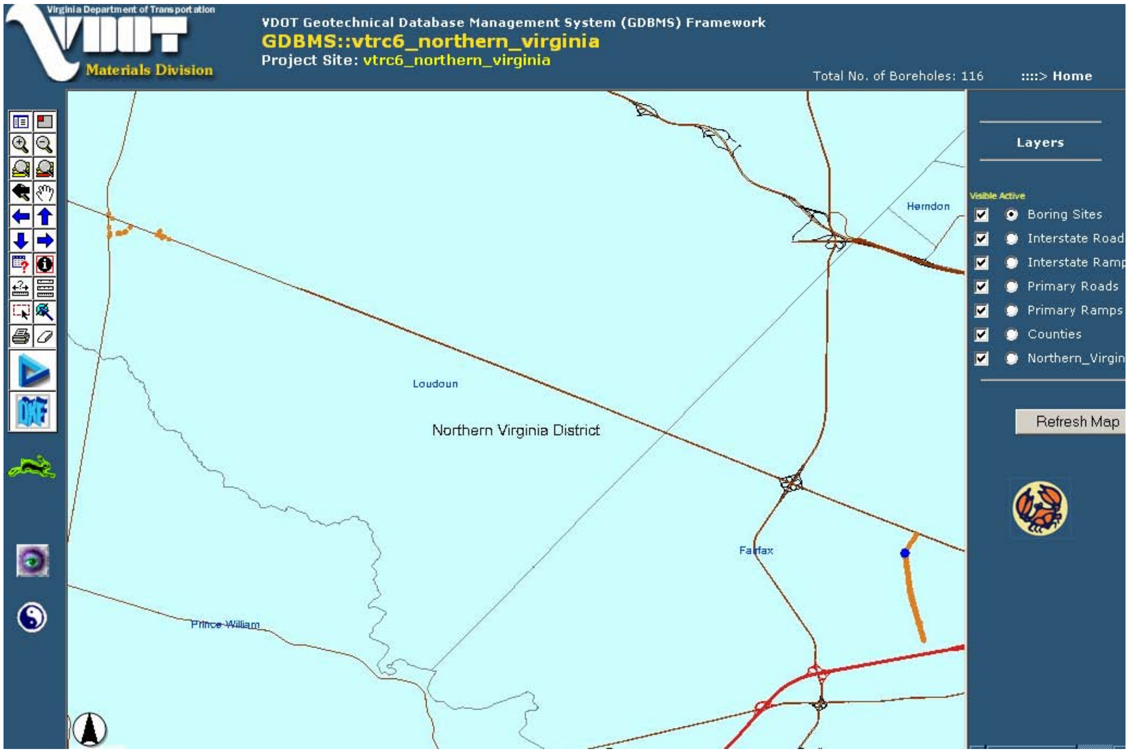

Figure 4. Example of Borehole Data in Northern Virginia District, Created with ICE and BDT

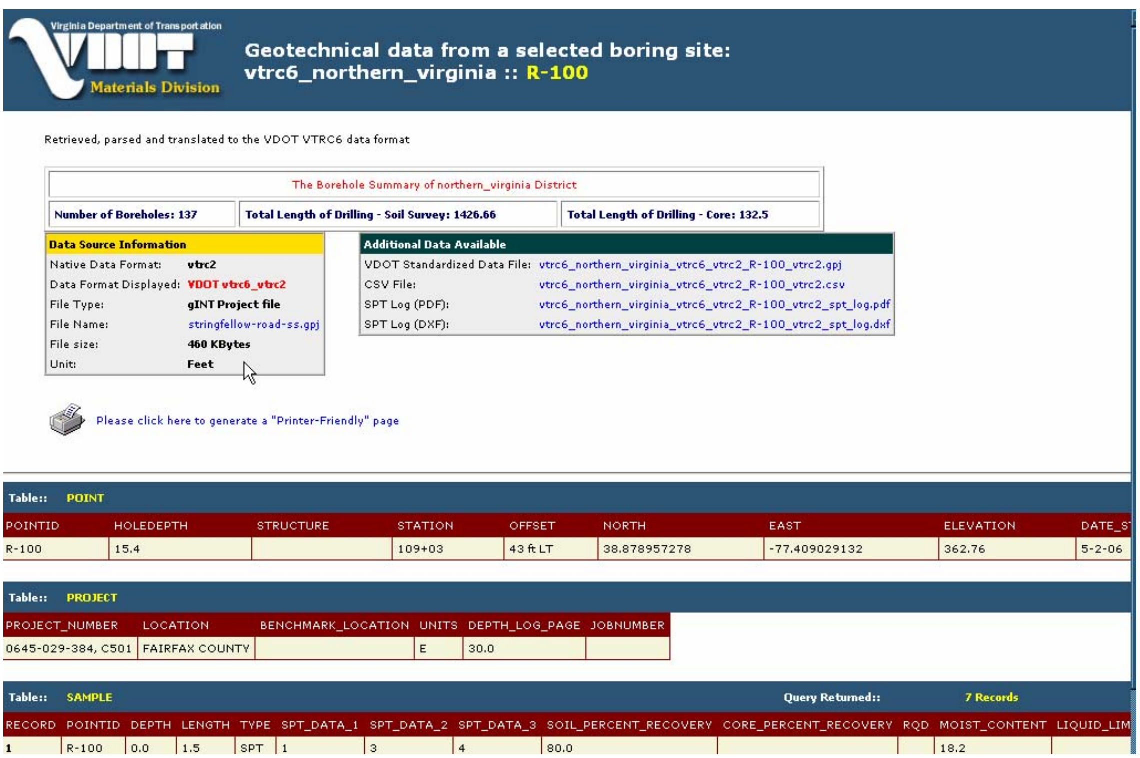

Figure 5. Example of Adaptive Translation of VTRC6-series Borehole Data

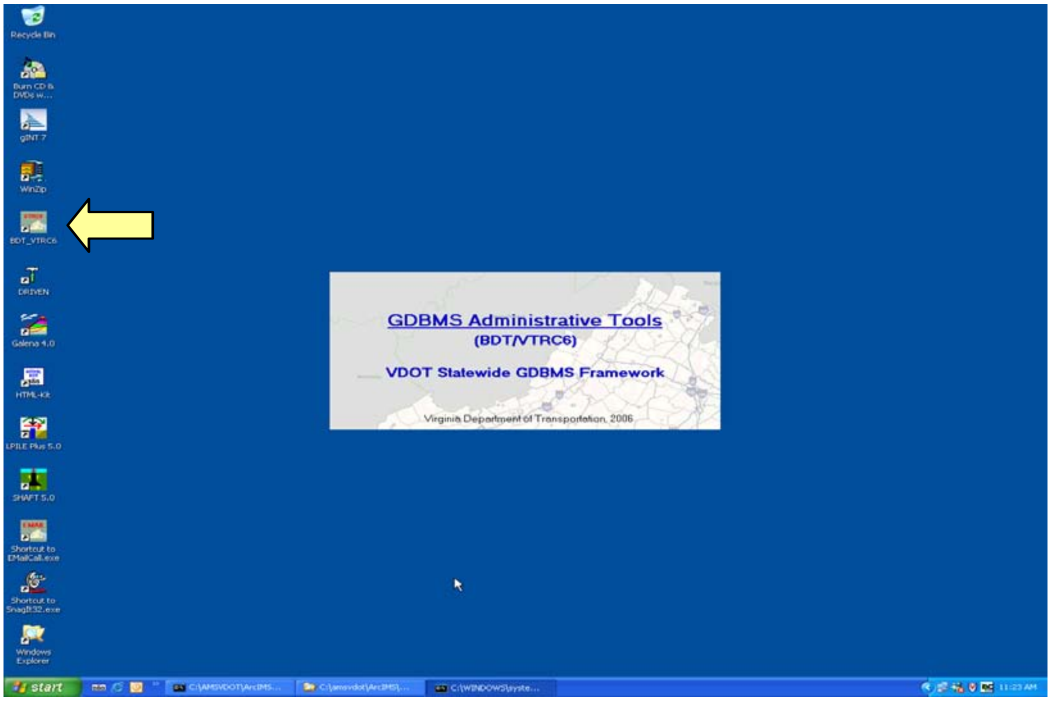

Figure 6. "Administrative Procedure" Tool Implemented in ICE and BDT Modules

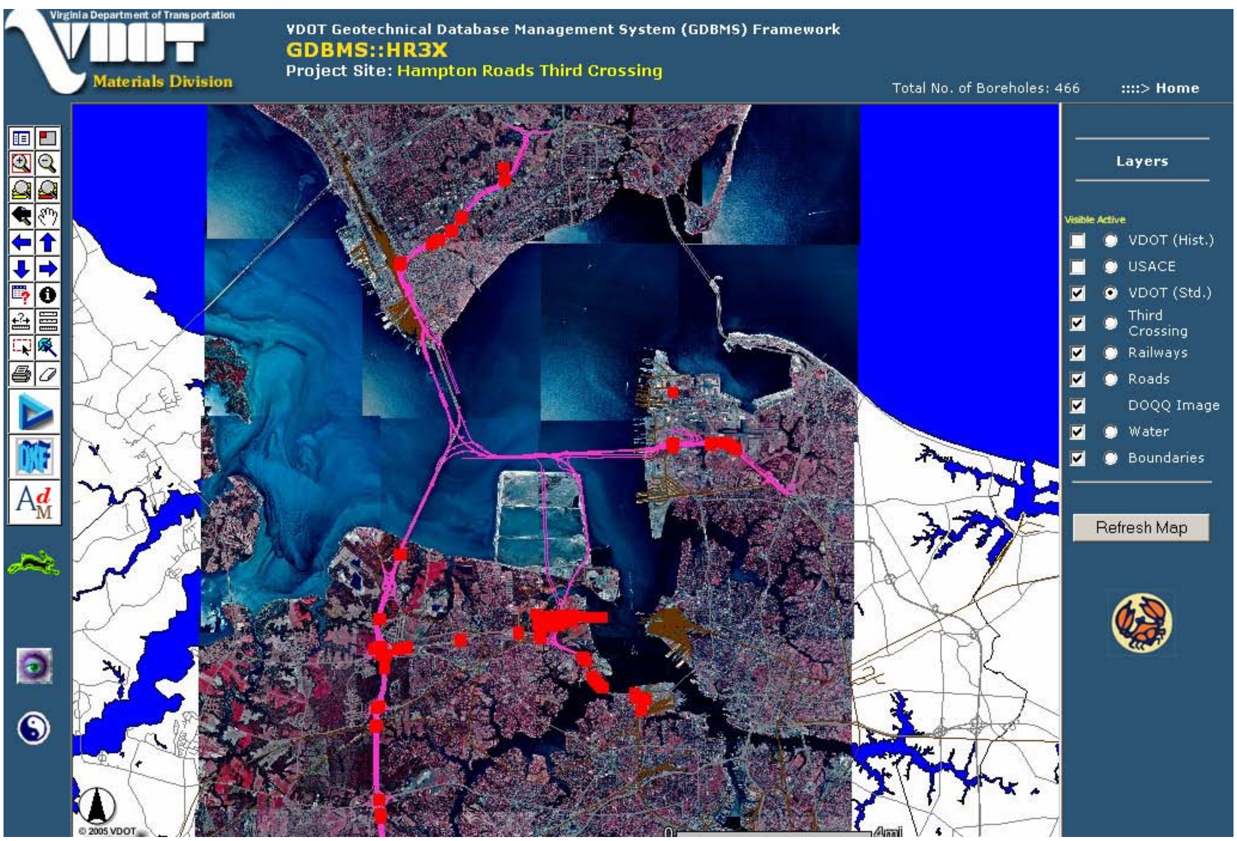

Figure 7. New Borehole Data (displayed in red) Added to Third Crossing of Hampton Roads (HR3X) Project Module Using ICE

CONCLUSION

- *GDBMS Framework modules were developed and implemented in the Internet-based VDOT Geotechnical Database. These modules were equipped with interactive data retrieval and automated file upload with QA/QC verification capabilities. Compared to a previously used procedure of manual data entry by IT personnel, the ICE and BDT module combination provided VDOT engineers with a quick and effective tool to manage geotechnical data.*

RECOMMENDATIONS

1. *VDOT's Materials Division should enter all new borehole data collected by VDOT into the enhanced GDBMS Framework.*

2. *VDOT's Materials Division should consider the feasibility of entering the legacy geotechnical data into the system.*

SUGGESTIONS FOR FURTHER RESEARCH

In addition to enlarging the current geotechnical data category, the GDBMS Framework could be further extended to include other types of transportation-related data, such as:

- Laboratory geotechnical data
- Pavement management information
- Bridge construction plans
- Bridge inspection reports
- Drainage structures
- Guardrails
- Overhead traffic signs
- Historic sites (bridges, landmarks)
- Sinkhole locations
- Environmental site assessments.

Each new data type could be incorporated as an additional layer in the existing system and a new design and analysis functionality could be programmed to improve efficiency while reducing operating costs.

COSTS AND BENEFITS ASSESSMENT

Cumulative ICE/BDT/ADM module implementation will result in more efficient and streamlined geotechnical data management at VDOT. Manual tasks, previously delegated to the

IT support personnel, have now been automated. It is estimated that 2 hours of labor will be saved per each new borehole data item that needs to be verified, added, and incorporated in the GDBMS Framework.

The following assumptions were used to estimate the monetary costs and benefits of implementing the ICE/BDT/ADM modules:

(1) Typical time saved by using ICE/BDT/ADM per boring: 2 hr.

(2) Typical bridge: three-span structure with four foundation units.

(3) Typical bridge construction project: 10 boreholes.

(4) Projected rate of construction: 820 bridges during 6 years.[3]

(5) Consultant billing rate: $120/hr.

(6) VDOT hourly rate: $80/hr.

Thus, since VDOT constructs an average of 136 bridges per year (820 bridges per 6 years), implementing the ICE/BDT/ADM modules would result in 2,720 hours of work saved annually (136 bridges × 20 hours/bridge). Assuming that 50 percent of the saved time is consultant time and 50 percent is VDOT time, the total annual savings for VDOT is estimated to be $272,000 ([1,360 hours × $120/hour] + [1,360 hours × $80/hour]).

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