# Final Report (SPR Project 90-00-RB10-012) on the Maintenance Asset Management Project Phase I

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# Final Report on the Maintenance Asset Management Project Phase I

## July 31, 2012

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**16 Abstract**

This project resulted in the development of a proof of concept for a features inventory process to be used by field staff. The resulting concept is adaptable for different asset classes (e.g. culverts, guardrail) and able to leverage existing DOT resources such as the videolog and LRS and our current technology platforms including Oracle and our GIS web infrastructure. The concept examined the feasibility of newly available technologies, such as mobile devices, while balancing ease of use in the field. Implementation and deployment costs were also important considerations in evaluating the success of the project. This project funds allowed the pilot to address the needs of two DOT districts. A report of findings was prepared, including recommendations for or against full deployment of the pilot solution.

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## Problem Identification

The Iowa DOT (IDOT) has a need to streamline field inventory/inspection of assets while maximizing the use of new technologies. Currently, field staff uses disparate methods for collecting and managing culvert inspection information. Often information is gathered using paper documents and redundant data entry. The districts lack consistent protocols for how location information is collected and stored, making it problematic to consistently map and analyze information using GIS or CAD software. In addition, it is difficult or impossible to use existing data in a spatially enabled enterprise data system to answer asset management questions.

## Project Scope

The goal of this research project was to standardize workflows, develop a potential enterprise database model, and identify technology that will make it easier and more streamlined to collect and maintain information about assets found in the field. It was our expectation that any system developed will be adaptable for multiple assets, easy to use for field staff, deployable across all districts, and readily tied into enterprise systems already in place. It was expected that this will be a small scale field trial with the possibility of future implementation based on recommendations that come out of the research project.

Through research funding allocated by FHWA and IDOT this project has worked to update the workflow for the IDOT culvert inspection process and evaluate several emerging mobile GPS-based technologies (GPS devices, tablet PCs, smart phones). The project also looked at collecting asset information throughout the life cycle of the asset (design through to maintenance) but was mostly focused on field data collection.

## Detailed Project Description

The project focused on several areas of interest. These include:

- A technology review of smart phones, handheld GPS units, laptop, and tablet hardware.
- A detailed review of tablet options
- A look at life-cycle process options
- And, tablet development of a prototype field data collection application.

The rest of this report will detail out our findings in these areas of interest as well as a recommendation for future research and potential enterprise-level deployment.

### Technology review – phone, GPS units, and laptop

At the start of the project, the project team had a list of criteria for our hardware evaluation. We expected to find that some hardware worked better, but all had to meet these minimum expectations to be considered for deployment. The evaluation criteria included, but are not limited to:

- Good screen visibility in outdoor situations,
- Hardware field durability (ok in rain, dirt, truck situations)
- Large screen size (5” or larger without being too large to carry easily in the field) yet reasonable size/weight
- Reasonably priced (with the idea that 200 or more of these will be deployed)
- Flexibility of the operating system (compatibly with major platforms such as Android, Apple, and Windows operating systems to follow any direction preferred by IT)
- Ability for Iowa DOT computer security measures to be implemented
- Ability to interact with accessories such as Bluetooth GPS devices
- Built in camera and microphone capabilities
- Touch screen rather than a stylus keypad to operate
- Long battery life (6 hours or longer was deemed acceptable)
- Option to use 3/4G cellular service
- Wi-Fi enabled.

***Smartphones***

The IDOT had already begun prototype development on a BlackBerry and Android phone, however, the person doing that development left the agency and testing was halted. The team also felt that, while the connectivity offered by a smart phone option is a plus, the cost of that connectively coupled with the small screen real-estate made the smart phone a less viable option when considering widespread deployment. Screen visibility with smartphones is difficult in a full daylight situation; however, due to the size, these are easier to handle in the field than a laptop.

***Handheld Rugged GPS Units***

Small scale field data collection was tested using a handheld Trimble GeoXT GPS unit. The research team was able to develop a geodatabase in the ArcMap software that allowed for a form with pull down options. It was difficult, without generating a large volume of ‘pages’ within the ArcPad GPS software window, to allow all pertinent information to be collected. The GeoXT unit we were using, being an older model, did not come equipped with a camera and required the use of a stylus to operate. We found visibility of the screen was not an issue and these are easy to use standing in a roadside ditch situation.

***Laptop***

We used a standard sized HP laptop with an external GPS puck to test a field data collection situation over several weeks. Again, we used a geodatabase in ArcMap to preformat database dropdowns and then collected data with the ArcPad software via the laptop rather than the GPS unit. This provided a bit more screen real estate, but was limited by the same issue as the handheld unit, which was the requirement for a separate process to push the data into an enterprise Oracle database. Screen visibility was difficult and we only tested this scenario from inside a vehicle from the side of the road. We found that a standard laptop would not be a good option in the field as the laptop is cumbersome, has poor field visibility, and is difficult to use in a standing position in a roadside ditch situation.

**Technology review – tablet options**

Due to the wide variety of tablets available on the market the research team felt it would be prudent to review the specifications for a number of tablet devices. This includes tablets that run with various operating systems including Google Android, Microsoft Windows, and Apple iOS.

For the most part the tablets we reviewed are all touch based, however, several used a stylus. We used the same criteria (page 7) for ranking each tablet and then applied a weighting system based on prioritization of these criteria. The two highest priority criteria are field screen visibility and field durability. The research team originally felt that price would be a big factor due to most of the consumer-grade tablets on the market being in the $400 - $600 range, however, the screen visibility on most of these inexpensive units, even with a screen protector, made them difficult to use outdoors. Other required features include Wi-Fi, a touch screen, and a built in rear camera.

Figure 1 shows a condensed version of our evaluation matrix and Figure 2 lists details of the evaluation criteria. The devices listed at the bottom of Figure 1 were deemed to be similar enough in features and scoring that they didn't require their own line. The two highest-rated tablets, based on our criteria and prioritization, were both ruggedized tablets. Ruggedized Android tablets are not yet common on the market and run about three times the initial cost of basic consumer-grade tablets, however they are still about half the cost of a heavy-duty ruggedized tablet PC (such as a ToughBook).

The research team met with the Iowa DOT Information Technology (IT) Division management team to talk through the future of tablets within the department and to establish whether there was any preference with respect to platform or operating system. During the discussions it became clear that the IT Division would support any of the operating systems under evaluation. The IT Division has a solution to manage the security of mobile devices, so that has become less of an issue than was originally anticipated. IT also indicated they would prefer a more ruggedized device be purchased under the assumption that these kinds of hardware can serve multiple functions and will have a longer lifespan than the consumer-grade devices.

| Tablet Brand | Unweighted Score | Weighted Score | Field Durability | Field Visibility | Screen Size | Cost | Operating System Flexibility | Security Capability | Peripheral Compatibility (Bluetooth/USB) | Built-In Camera and Microphone | Touch Screen | Battery Life | Cellular Option | Wi-Fi Enabled |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 4 | 5 | 2 | 3 | 2 | 2 | 2 | 3 | 3 | 2 | 1 | 3 |
| Apple IPAD 2 | 44 | 111 | 3 | 1 | 4 | 4 | 3 | 1 | 3 | 5 | 5 | 5 | 5 | 5 |
| Motorola XOOM | 47 | 118 | 3 | 1 | 4 | 5 | 5 | 1 | 3 | 5 | 5 | 5 | 5 | 5 |
| GD Itronix GD3080 Rugged Tablet PC | 44 | 128 | 5 | 5 | 3 | 1 | 3 | 3 | 5 | 5 | 5 | 3 | 1 | 5 |
| Panasonic Toughpad A1 | 56 | 149 | 5 | 5 | 4 | 2 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Trimble GeoXT Handheld GPS | 36 | 103 | 5 | 5 | 1 | 3 | 3 | 1 | 3 | 1 | 2 | 2 | 5 | 5 |
| Laptop ArcPad Based System | 41 | 97 | 2 | 1 | 5 | 2 | 3 | 5 | 5 | 5 | 1 | 2 | 5 | 5 |
| Blackberry Torch | 42 | 109 | 3 | 2 | 1 | 5 | 3 | 3 | 3 | 5 | 3 | 4 | 5 | 5 |
| Trimble Yuma | 51 | 138 | 5 | 5 | 3 | 1 | 3 | 5 | 5 | 5 | 5 | 4 | 5 | 5 |
| Juniper Systems Mesa | 43 | 118 | 5 | 5 | 2 | 1 | 3 | 1 | 5 | 3 | 3 | 5 | 5 | 5 |
| iX104C5 DMSR | 51 | 138 | 5 | 5 | 4 | 1 | 3 | 5 | 5 | 5 | 5 | 3 | 5 | 5 |
| **RTC-TF101 Rugged Android Tablet** | 56 | 149 | 5 | 5 | 4 | 2 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| **Totals** | **Acer Iconia Tab A500, Asus EeePad, Samsung Galaxy, Lenovo IdeaPad K1, Toshiba Thrive, Sony Tablet S, GD Intraonix GD3015 Semi Rugged Tablet PC** | | | | | | | | | | | | | |

**Figure 1 - Evaluation of the Tablets**

## Tablet Evaluation Criteria

| Scoring Categories | Max Score: | Score Criteria: |
|---|---|---|
| *Field Durability* | 5 | Tablet has good overall consumer reviews of being able to take a reasonable amount of abuse.<br>1 - Provides little or no reliability based on reviews; 3 - Provides some or good durability based on reviews; 5 - Specially designed to be ruggedized |
| *Field Visibility* | 5 | Tablet hasgood overall consumer reviews of visibility in the outdoors.<br>1 - Provides no or poor outdoor visibility based on reviews; 3 - Provides good outdoor visibility based on reviews; 5 - Specially designed to be highly visible outside |
| *Screen Size* | 5 | Diagonal Screen Size - Larger is better up to 15 inches<br>1 - 5.0 in or less; 2 - 5.1-7.0 in; 3 - 7.1-9.0 in; 4 - 9.1-11.0 in; 5 - 11.1 or more |
| *Cost* | 5 | Cost of each tablet without peripherals, unless peripheral is necessary to make it compatible with other standard configurations<br>1 - $1200 or more; 2 - $1000-$1199; 3 - $800-$999; 4 - $600-$799; 5 - Less than $600 |
| *Operating System Flexibility* | 5 | Operating System is compatible with more than one vendor tablet or application vendor<br>1 - Tablet specific OS/Limited Use; 3 - Vendor specific OS/Widely Used; 5 - Open OS/Widely Used |
| *Security Capability* | 5 | Ability to handle desired and needed security protocols (encryption)<br>1 - Minimal security capability; 3 - Most security needs addressed; 5 - All security needs addressed |
| *Peripheral Compatibility (Bluetooth/USB)* | 5 | Device has good capability with non-proprietary peripherals.<br>1 - No Bluetooth or USB; 3 - Good peripheral connectivity options, but limited peripherals ; 5 - Excellent peripheral connectivity and options |
| *Built-In Camera and Microphone* | 5 | Camera and Microphone are built into Tablet device.<br>1 - No camera or mic; 3 - One or the other is built in; 5 - Quality camera and mic built in |
| *Touch Screen* | 5 | Tablet has good overall consumer reviews of its touch screen.<br>1 - Provides little or unreliable touch screen function based on reviews; 3 - Provides good function based on reviews; 5 - Provides excellent function based on reviews |
| *Battery Life* | 5 | Good battery life when using necessary screen lighting and peripherals<br>1 - 2 hours or less of life; 3 - 4-6 hours of battery life; 5 - 10 or hours of battery life |
| *Wi-Fi Enabled* | 5 | Connectivity via Wi-Fi; and optionally Cellular<br>1 - no, 5 - yes |
| *Cellular* | 5 | Connectivity via Wi-Fi; and optionally Cellular<br>1 - no, 5 - yes |
| **Total Unweighted Points** | **60** | |

**Figure 2 - Tablet Evaluation Criteria**

**Review of life cycle data development – testing CAD import**

A part of this project was to look into areas of process improvement with the data development life-cycle. We believe we can improve the field data collection process to make it consistent and more fluid among the districts, however, much of the location and type information for given features originates in the design process. The research team feels that it is possible to use location and type information from design plans at the build stage which can then be verified in the inspection phase. The idea is that CAD-based features can then be pulled in to an enterprise geospatial system to help build the inventory of roadway features.

The research team met with several people from the design technology support group to talk through some of the issues related to this concept. It appears to be possible now to link to a Microsoft Access database that carries some information about the features. A test was conducted using Safe Software's FME translation software to extract culvert features from a CAD design file and push that information in to a GIS-based shapefile. The research team feels with a little more testing and some workflow changes this process could be adopted for the management of new feature location information.

**Asset Collection Tool and Tablet Testing**

A component of this research project was to work with a consultant having experience in field-based data collection for transportation agencies. Through the contract selection process, we ended up working with Transcend Spatial Solutions (Transcend) who has a project manager in Nevada, IA (near the DOT headquarters). Transcend has a tablet-based application under development with features similar to our requirements.

The original request from District 2 maintenance management was to look at the process for inventory and inspection of culverts. The districts are responsible for inspecting all culverts (over 36 inches) at least every two years. The issue is that most districts have their culvert information on small cards or in a binder with paper sheets for each culvert location. As a result, no good way exists to centrally manage or use the culvert inventory and inspection data.

We had several meetings with District 2 field staff responsible for collecting the culvert inventory and inspection information to understand their current process. We also looked at the District 1 process. Both D2 and D1 use a combination of paper forms and a district-specific MS Access database Using information from these meetings and from their existing databases, we were able to identify information that will be used to "seed" digital pick-lists (Figure 3) in the data collection application.

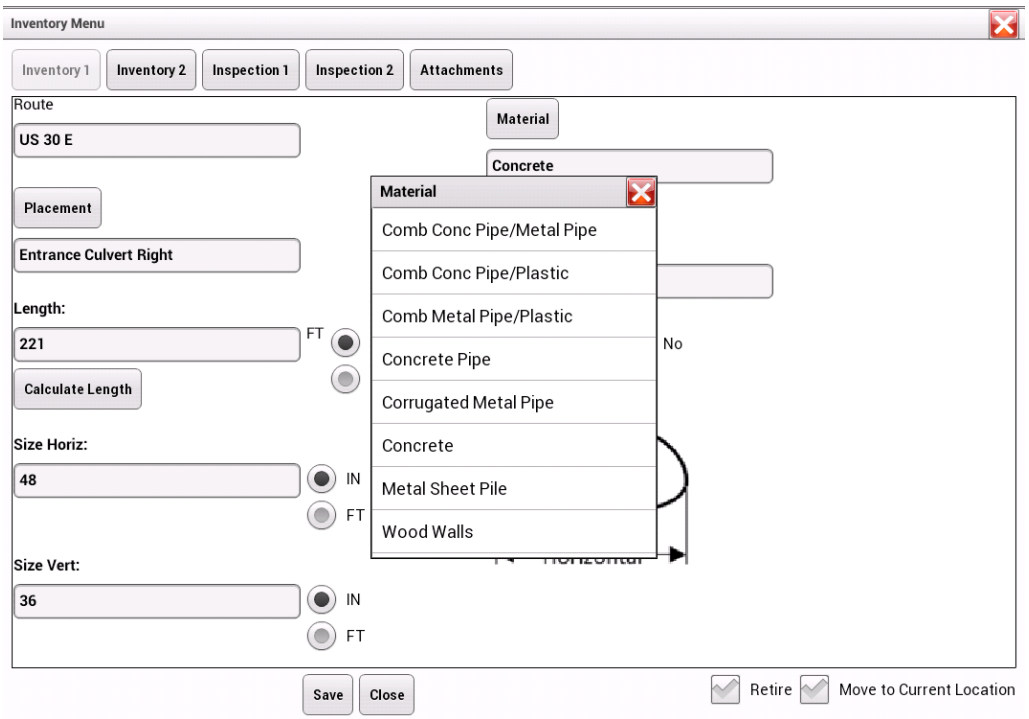


**Figure 3 - Pick-List Example**

Transcend was able to assemble several digital forms that allow for inventory as well as inspection of the features. For each feature (e.g. culvert) camera images, video, audio, and text notes can be captured and stored with the record (Figure 4).

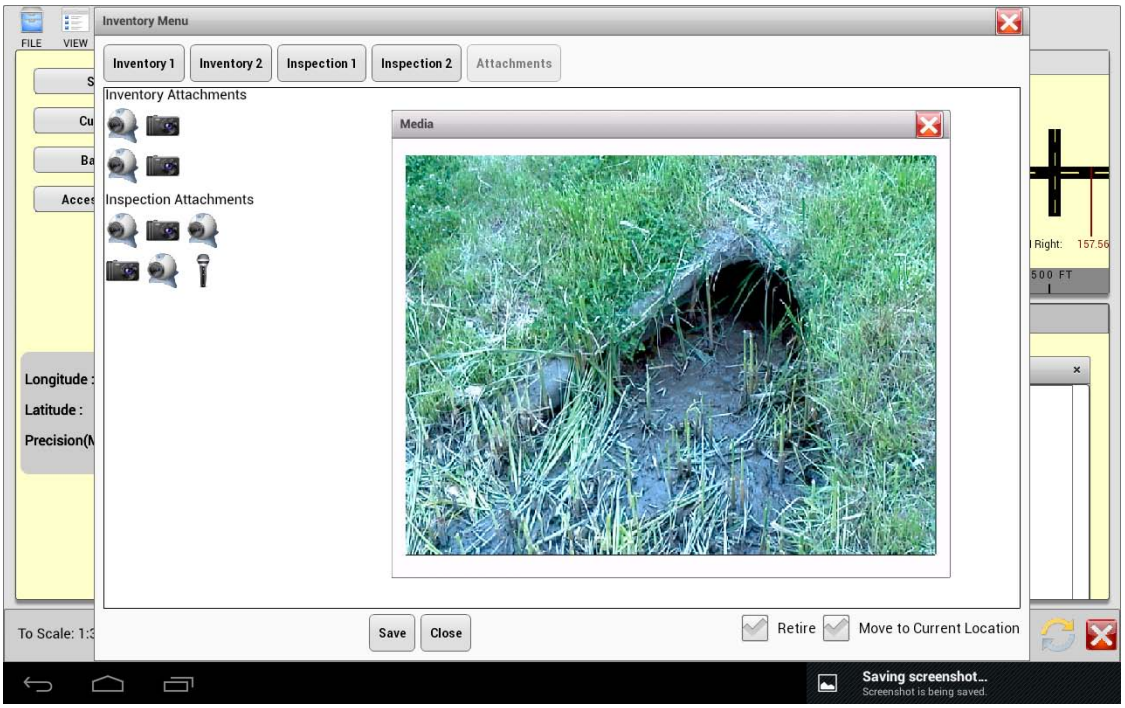


**Figure 4 - Picture of culvert collected in the field**

Figures 5 – 8 are the screens for the inventory and inspection data collection tool.

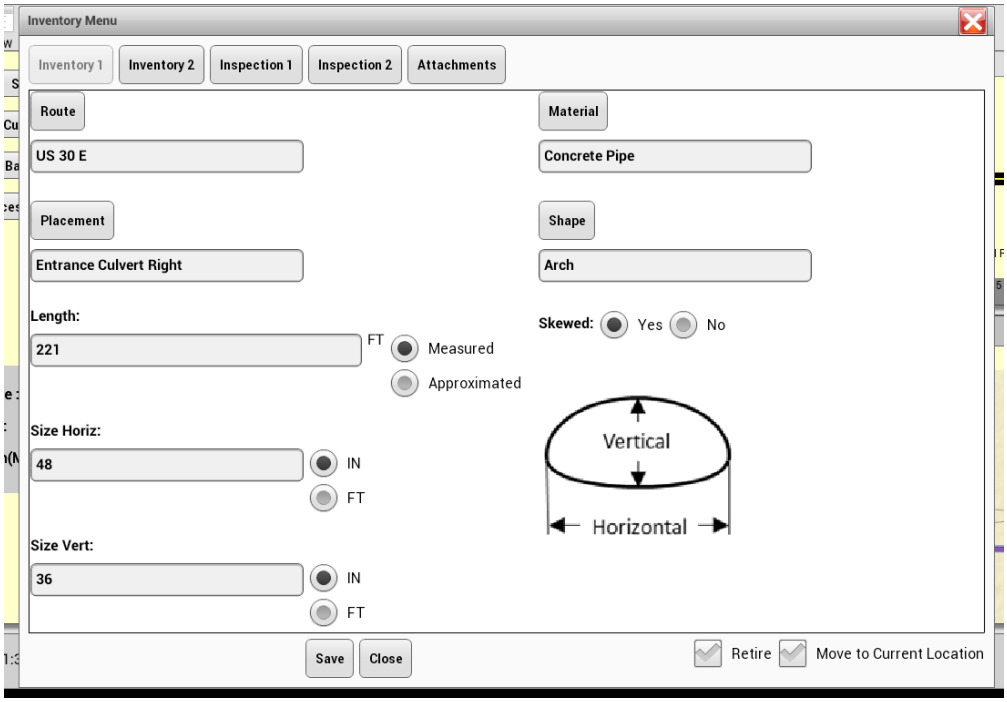


**Figure 5 – First Inventory Tab with Inventory Data**

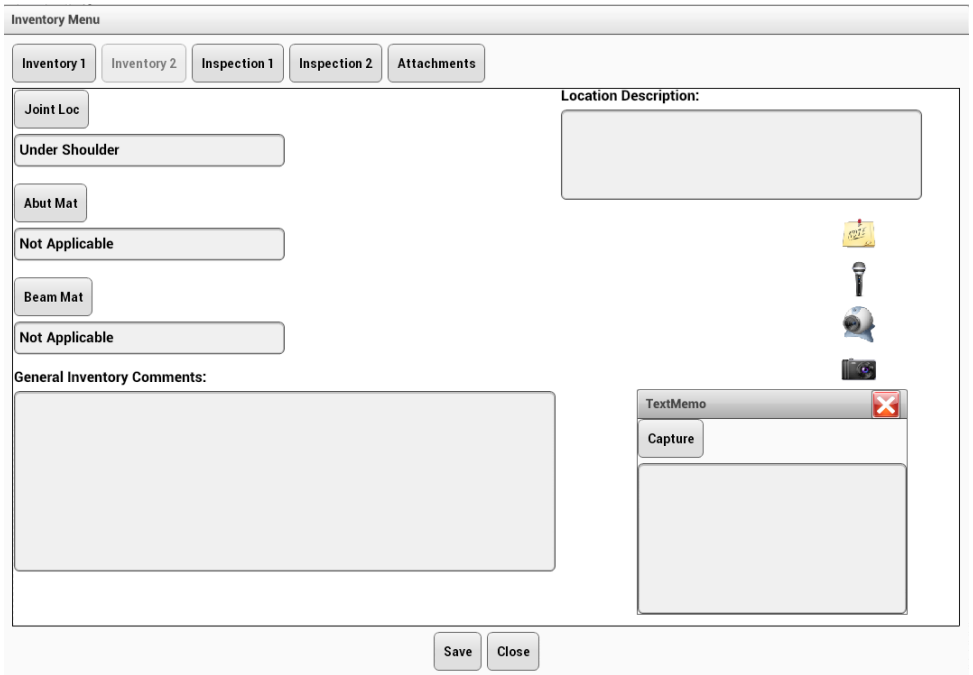


**Figure 6 – Second Inventory Tab with Inventory Information and Text Memo Active**


**Figure 7 – First Inspection Tab with Inspection Data**

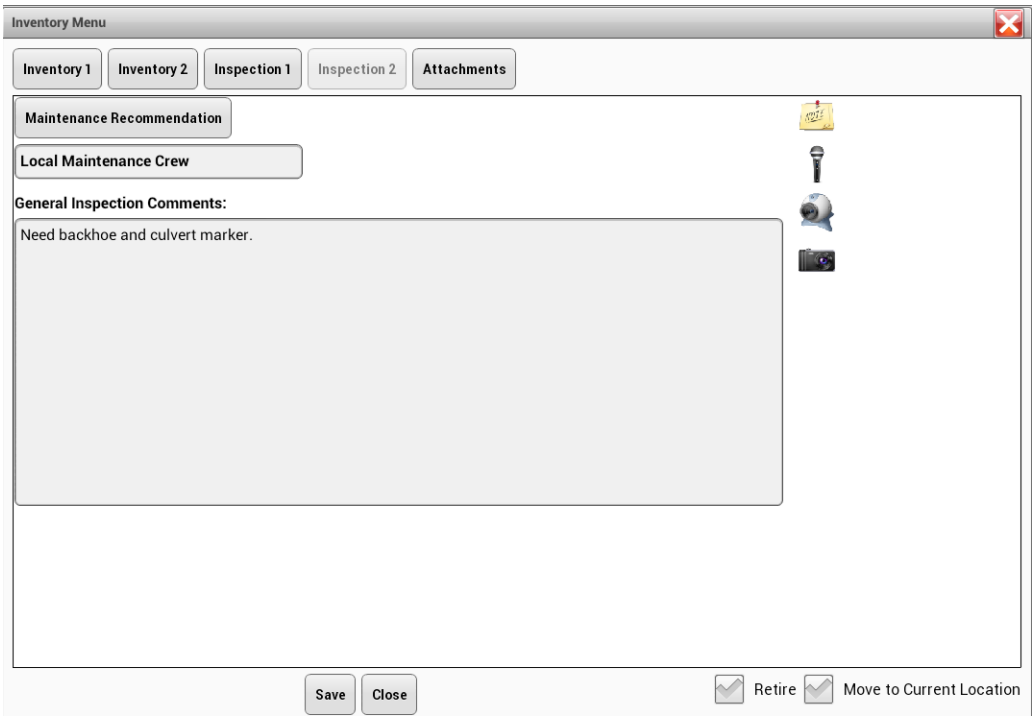


**Figure 8 – Second Inspection Tab with Inspection Data**

Other features of the application include a straight-line road diagram at the top of the interface. This shows the field personnel where they are on the road network. In the case of culverts, it also shows culverts already in the database; new culverts appear in the window as they are added to the inventory (Figure 9). Work will be done in a future prototype to indicate the shape and size of culverts in this window.

On the bottom of the prototype application main window several viewing options are available. The first one is a basemap (Figure 9). Currently the application pulls a generic map, but in future versions of the application the map will be the standard Iowa DOT basemap. It can be zoomed in and out on and shows the road and location where active data collection is happening for a person in the field.

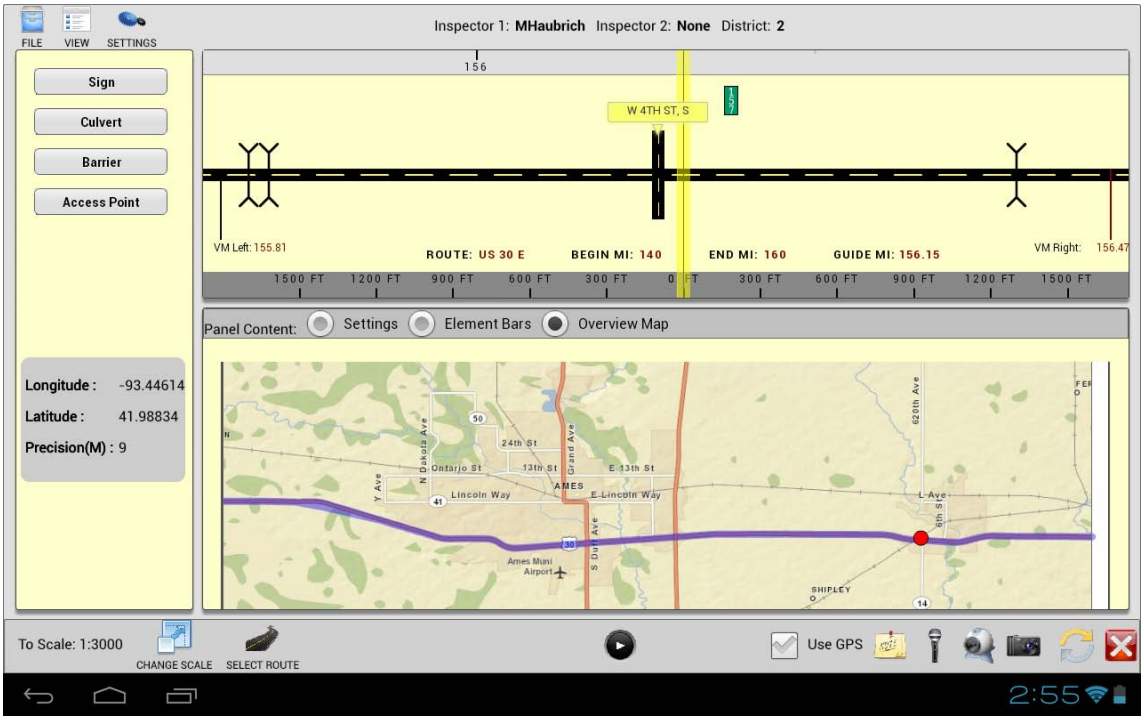


**Figure 9 – Straight-line diagram on top with culverts, cross roads and milepost signs with map window shown below. Buttons on the left give access to forms to collect new feature information**

The second display option for the bottom section of the user interface is “element” or “attribute” bars (Figure 10). These bars allow any data that can be associated with the road network to be displayed and labeled with respect to where the person is traveling or standing.

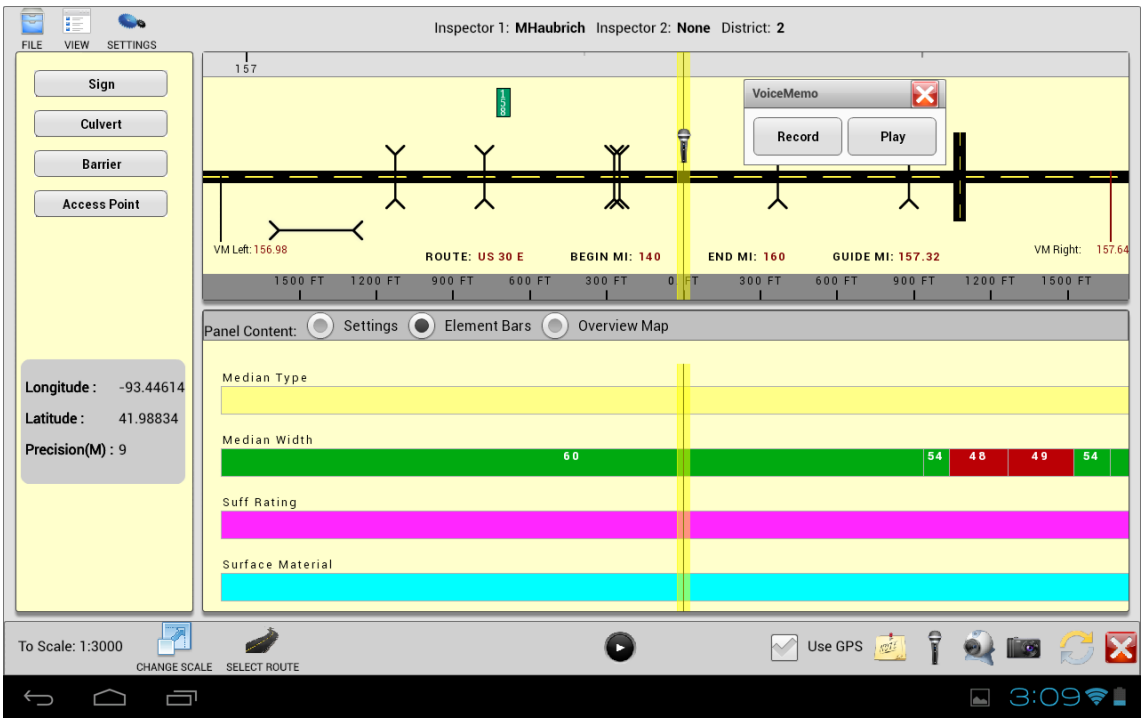


**Figure 10 – Element bars shown below the straight-line diagram. Point information can be collected outside of a specific feature for incidents along the roadway.**

The last significant feature in the existing application is the ability to collect incidents (Figure 11). In the case where something occurs along the roadway that is not part of the regular inventory or inspection application, field personnel can still capture relevant information such as deer kill sites, damaged Right-Of-Way fences, washouts, etc. The field personnel can collect images, video, audio, and text snipits that are stored with the incident record, along with a location (GPS latitude and longitude) that is correlated to the location on the roadway.

In future versions of the prototype a workflow process could be developed to notify the appropriate management entity and work towards mitigating or ameliorating these incidents.

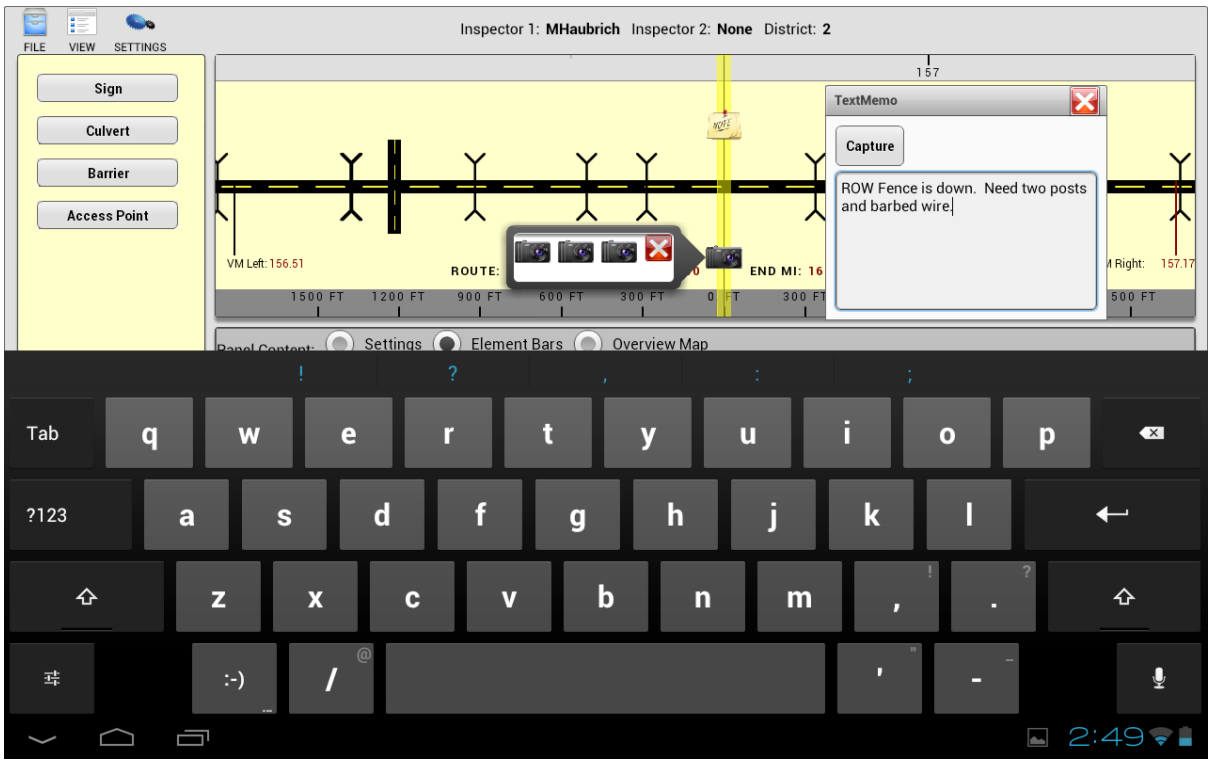


**Figure 11 – Keyboard data entry option for incident text boxes.**

Once the research team completed a solid prototype of the collection software, we spent a morning in the field with district maintenance and construction staff. Each staff member was encouraged to collect several culvert features and provide feedback on what they liked and did not like about the device and the interface.

Overall the field staff were very excited about what the provided functionality. They liked being able to capture pictures and having the preloaded pick lists available. They also liked the idea of being able to go back to the garage and sync up the data to the system, knowing it would be stored centrally and available by everyone needing access to it. The biggest obstacle we had during the field test was tablet screen visibility.

So far, the application has been running in a network-connected environment; meaning we had portable Wi-Fi hotspots during all field tests so we were able to pull data down live and push it back up while still in the field. The plan is to eliminate the need to be connected at all times. The future workflow will have a process to pre-load feature information onto the tablet each morning, collect data in a disconnected fashion, and then sync the data up with the central database at the end of the day. This pre-load and sync process will be based on the geographic area the device is expected to be used in during that working day. The geographic limit will allow for faster data transfer and more efficient use of device storage.

## Demos and Future Opportunities

Over the past month the research team has been meeting with various offices to demo the prototype application and talk about how something like this might also meet their needs. The team met with the Office of Traffic and Safety. They indicated in an interest in having billboard location inventory, access permit locations, roadway lighting locations, and potentially their sign inventory on a tablet application.

The team met with the DOT Operations Bureau staff, which led to meetings with staff in the Office of Materials. They are interested in having access to the milepost book which has pavement condition information shown in the element bars. They would also like to have this available to use with the geology staff to do field data collection.

The team also did demos for the Highway GIS Team, IT Management Team, the Highway Division Management Team, Office of Construction and several other one-on-one demos. The team has meetings scheduled with the Office of Local Systems, the Statewide Emergency Operations team, the District Maintenance Managers, and a scheduled demo for the Maintenance Supervisors Meeting in September.

Thus far, those who have seen the demo have been able to come up with a longer list of applications for it. Our intention is to purchase several more devices that meet our requirements in order to continue with field testing. We also plan to purchase and test a Windows-based unit and do some testing on a DOT-owned Apple iPad unit. The goal will be to identify the most promising hardware solutions that meet our needs and are cost-effective.

## Conclusions and Recommendations

Due to the apparent success of the prototype application, the research team put in a request for a second phase of the project. During Phase II the application will be adjusted to allow collection of multiple assets upon entry of the system. Currently, the system defaults to a culvert inspection splash screen (not shown). During Phase II, two to three additional assets will be integrated in the system with the first being the sign inventory. The element/attribute bars will have more pertinent pavement data loaded. The map will use the DOT basemap web service data.

The team plans to look into a workflow process for handling the incidents that are captured outside of the assets with preconfigured forms. We plan to spend some time rendering data as a web service and potentially developing some simple reports for management based on the asset condition data collected.

Based on our early feedback, it appears that both the field and central-office management are developing an expectation for an enterprise deployment of a system similar to our prototype. With that in mind, the team will be diligent in focusing on planning for deployment as we progress into Phase II of this research project.

## High Level Requirements for Phase II

While all of these requirements will be demonstrated in a pilot setting, they may not be fully developed into a full production and deployable version at the completion of the pilot project.

- Workflow recommendations for field staff need to be streamlined, efficient, deployable and repeatable for field staff across the state.
- Workflow recommendations should take into account of roadway assets throughout the life cycle of the asset (from design/ installation through decommission).
- Field data collection system needs to be simple to use in the field, preferably touch based and easy to see in full light situations.
- The system needs to be adaptable for collection of different kinds of field based assets (culverts, signs, etc), capture a spatial location, and as an option able to capture a photo of the asset.
- Assets already in the system need to be able to be checked in and out of the system for offline update in the field, and new features need to be able to be added with location (lat/long, route/mp, etc) and business data in the field.
- The system needs to be able to leverage the video log images, the Linear Referencing System (LRS), Oracle Spatial, and GIS Web Infrastructure (ArcGIS Server).
- It is preferred (but not a requirement) that the technology chosen **not** require a 3G/4G cellular data plan for data collection in the field.
- The system needs to be designed in such a way that it can integrate data into a larger asset management system or other existing systems.
- The system needs to meet IT encryption requirements.
- The system needs to be able to incorporate/consolidate data from multiple data sources.

The vendor (Transcend) will assist with the following during Phase II:

- Design an expandable features inventory/asset relational data model within an Oracle Spatial (or similar database) system, and work with IT staff to deploy a trial database system.
- Make recommendations on/provide a hardware solution that is low cost (prefer under $1,500), GPS enabled, light weight, and easy to use in the field.
- Make recommendations on/provide a web interface/dashboard for interacting with the data collected in the field.
- Assist in developing a desktop/web-based data validation (QA/QC) workflow.
- Assist with the development of final outcome paper, based on research findings evaluating the long-term deployment viability of in-house developed and semi-custom commercial of-the-shelf (COTS) systems.