Utility Location Technologies R01B Lesson Learned

The goal of *SHRP2 Utility Location Technologies* (R01B) is to utilize advanced geophysical imaging technologies to supplement standard Subsurface Utility Engineering (SUE) methods using two technologies identified from the original research, Multi-Channel Ground Penetrating Radar (MCGPR) and Time-Domain Electromagnetic Induction (TDEMI). From early 2017 to May 2019, six state DOTs participated in the R01B project: Virginia, Ohio, Arkansas, Montana, Oregon and California (Table 1). This list of lessons learned has been synthesized based on interviews with the state participants, the collective peer exchange conversations that took place quarterly during this SHRP2 program, and observations from the Subject Matter Expert (SME) who provided technical and logistical support to each state. The list starts with a general set of lessons learned for the implementation process. Then, it is structured chronologically according to the project work flow and how the R01B product was implemented at the DOT level. This format is intended to aid future users of these Utility Location Technologies to provide insights for smooth application on future transportation projects.

Table 1. Agencies that Received Funds to Implement the R01A, R01B, and R15B Products

Round 3	Round 5	Round 6	Round 7
R15B: • Iowa • Kentucky • Michigan • New Hampshire • Oklahoma • South Dakota • Texas	**R01A:** • California • DC • Kentucky • Texas • Utah	**R01B:** • Arkansas • California • Ohio • Oregon **R15B:** • California • Delaware • Indiana • Maryland • Oregon • Utah	**R01A:** • Indiana • Michigan • Montana • Oregon • Pennsylvania • Washington **R01B:** • California • Indiana • Montana **R15B:** • Montana • Pennsylvania • South Carolina • Utah • Vermont • Washington

Implementation – Lessons Learned

- Coordination is the key. A project utilizing the Utility Location Technologies requires investment and participation from a variety of departments within the state as well as service providers, and the public. It is imperative to contract with qualified service providers willing and able to integrate standard SUE information.

- During the implementation process, states wanted to invite individuals covering operations, safety, right-of-way, surveying, design, and other departments to participate in the technical training and Peer Exchange calls with other states (i.e., their respective departments).
- One state worked on the regional level inviting the utility coordinators, design staff, project managers, and as other stakeholders to understand the process; this was very effective.
- Participating states need routine communication with their FHWA divisions to ensure a clear understanding of how the SHRP2 funding process works and to see a systematic use of allocated monies be spent, at a minimum, during each funding quarter of a multi-year project. During the course of the project there were times when states struggled to spend and maintain allocation of the SHRP2 federal funds for their use. For example, the Federal authorization ran out due to the project being listed in-active and then the state was required to reapply. The only way to keep a long-term project off inactive status is to charge labor hours to it, but several states were utilizing their own project-work hours because it was apparent that the majority of time and funding dollars would being spent by the subcontracted service provider.
- The Peer Exchange format of information sharing between the participating states permitted everyone to gain from experiences, challenges and questions encountered at each step of the process; it proved very helpful to further the process, create consistency, and efficiency.
- A unique challenge is to identify an upcoming state project at the right stage of development and scale to use the R01B product. For example, Montana was fortunate to find an urban project with enough survey information already acquired, and the design team far enough along to allow this Utility Location Technologies project to get involved and started in a timely manner.
- The total process shows as much what not to do, as what to do when using Utility Location Technologies implementing advanced geophysical methods.

Training – Lessons Learned

- Training is valuable with about the right mix of classroom versus equipment demonstrations.
- The classroom training developed focuses on the physics and technical aspects of both technologies, but more time might be spent on practical & recent examples of utility locating projects with these technologies.
- Benefits and limitations of each geophysical method are explained in detail.
- The demonstrations in the parking areas, or hands-on part of the training will be more effective when locating known utilities at the respective DOT facility. That is, if both methods detect / image at least one known utility (based on plans), an easy correlation will demonstrate the methods and their value more effectively.
- The training explains the difference between standard SUE practices and Utility Location Technologies application for R01B as well as the need to correlate both sets of data for final interpretation.
- The training explains the use of hand-held (smaller) MCGPR and TDEMI systems for ROW usage versus covering the lanes with a towed-array.
- States with in-house existing / working knowledge of GPR appreciated watching more systems perform in action during the demonstration.
- Multiple states had heard of TDEMI before but didn’t understand how much there is to learn about electromagnetics as is shown when the systems perform during the demonstration.

- States will benefit from discussion regarding contractor costs for Utility Location Technologies services and/or an overview of costs for services required during their procurement process. As the trainers were the SME contractors they did not discuss this.

Contracting – Lessons Learned

- Determining whether a DOT has a state-wide on-call contract in-place can dramatically affect the time it takes to award a contract. Multiple states are now looking to get an on-call provider in geophysics to shorten the timeline for procurement.
- Sending the solicitation to qualified vendors, as provided to the states, is helpful to down-select in the procurement process.
- One contractor may not be skilled in both MCGPR and TDEMI so multiple awards or sub-agreements work well.
- Define requirements of multi-coil TDEMI, as well as the number of channels for MCGPR ("multi" is not two) in the solicitation.
- An on-call contractor can use a subcontract agreement with specialty subcontractors relatively easy.
- Procuring a qualified Utility Location Technologies vendor may include significant hurdles. Solicitation and procurement nuisances add delays, because they are competitive bids. Examples of procurement issues include:
    - Potential contractors attempting to qualify using an air-launch and single antenna GPR system;
    - Assistance from the SME helps states learn how to solicit qualified contractors and avoid the marketing hype;
    - The qualified-contractor procurement process may take much longer than anticipated (1.5-yr process for one state);
    - Prospective vendors need to provide daily- or hourly-rate pricing (i.e., how typical standard SUE providers are contracted);
    - Cost to contract Utility Location Technologies services may surprise states and be more expensive than they anticipate, and states should narrow their project down to the right size site(s) to fit the funding;
    - New Federal acquisition regulations, based on the contract value alone, can cause delays and special attention is necessary;
    - The unique Utility Location Technologies skills are not yet found in most existing (DOT) service menu options, thus they must be created to become "in a box" options (e.g., surveying);
    - If a state does not have an established SUE program or on-call contract, it influences how the procurement for a Utility Location Technologies solicitation is designed and processed; and
    - Support from state-to-state for R01B contract terminology and verbiage created a "procurement/ solicitation document" which is very helpful to expedite the process.
- It is important to verify the contract document includes all aspects of the project including:
    - Coordination (site logistics & traffic)
    - Data acquisition
    - Analysis and interpretation
    - Report with digital deliverables

- Once contracted and working with their DOT project lead, the service providers may be very receptive to providing geophysical insights and assistance regarding the nuance of either technology.

Data Collection & Analysis – Lessons Learned

- It is critical to understand the time required for field data acquisition (for either or both technologies) based on site-specific conditions. For example, along unobstructed roadways both of the towed-array MCGPR and TDEMI systems can efficiently acquire data at about 5 miles an hour.
- Using roughly 3 to 4 passes on a 2-lane road it is straightforward to estimate field time and traffic controls.
- When the hand-portable systems are deployed for off road areas (i.e., sidewalks and ROW) acquisition takes longer and is more difficult to predict the field time and/or the impact on traffic.
- Typically, two crews can work simultaneously (the MCGPR and TDEMI systems) to cut down the impact to traffic and the public.
- Both TDEMI and MCGPR systems must be tied to centimeter-level accuracy using RTK GPS to provide spatial confidence (comfort) with the results.
- Using the towed-arrays, approximately 8 hours on-site can produce about 80,000-line feet (~15 miles) of either TDEMI or MCGPR. This is an enormous amount of data acquired in a single shift.
- Using TDEMI data collection, one night-shift of data collection yields over a week's worth of data analysis and interpretation.
- Using towed MCGPR systems, a 4-to-8-hour shift of data collection takes weeks of intensive processing time before the interpreted results can be delivered.
- MCGPR and TDEMI data, when acquired utilizing high-accuracy GPS, can be correlated with existing site SUE information allowing results to be combined with other SHRP2 Utility Bundle products; that is, the 3D Utility Location Data Repository (R01A) and Identifying and Managing Utility Conflicts (R15B).
- Requests for data versus results do not mean the same thing. Data are what the vendors are looking at in the field and assessing in the office (with specialized software), whereas results are the plan maps of what utilities were successfully imaged below the site. Raw/field data are useful and an important part of quality control while in the field.
- Quality assurance occurs during the data analysis to create the map compilation of imaged utilities, and correlate with all the previously acquired SUE information.

Traffic Controls – Lessons Learned

- Traffic control plans are critical. They must be communicated early in the planning, and followed through in the field by the contractors, state staff, and all on-site support crew.
- Lane closures are more effective for the towed array systems, and signage for sidewalk/ROW areas (e.g., "Shoulder Work Ahead," "Survey Crew Ahead," etc.).
- To acquire quality TDEMI data, the most practical and efficient time to work is at night, particularly for the lane-width, towed-array, multi-coil TDEMI systems. This is because parked or moving vehicles in adjacent lanes cause significant interference with the system, rendering the data useless.
- Night work can also be much more efficient due to less traffic, and since day light isn't necessary to collect data with either towed-array.
- The hand-held single-coil TEDMI data acquisition along on sidewalks and ROW areas works well during the day light hours.

- Public notification campaigns work well for lane closures, several block roadway closure(s) and associated detours.
- A trailing "arrow truck" behind the MCGPR vehicle/trailer is all that's required, because MCGPR data are not impacted by adjacent vehicles.
- Although MCGPR data quality is not compromised while in traffic (like TDEMI), it is still slow moving (about 5 mph), and thus less safe in heavy traffic, intersections, and other congested traffic areas.

Technical – Lesson Learned

In the Field:

- Understand your project site conditions as much as possible; including considering ground verification with hand-held systems prior to initiating a large-scale MCGPR and TDEMI Utility Location Technologies program.
- The significant technical lessons from R01B project sites include:
  - TDEMI images metallic utilities, it cannot image PVC, HDPE and Fiber utilities;
  - TDEMI does not provide depth to a utility;
  - Towed-array TDEMI results show value for spatial positioning;
  - TDEMI results outside the roadway (i.e., ROW areas) show the ability to map utility line trends;
  - MCGPR works well through asphalt, concrete, and course-grained subgrade soils, but it cannot image utilities in clay-rich soils;
  - MCGPR is able to image utilities at greater depths than hand-held (single-channel) GPR instruments;
  - MCGPR produces such high-resolution results that defining the size and geometry of utility vaults and ducts is possible;
  - GPR data quality is impacted by (recent) salt on a roadway;
  - GPR does not work well on icy roadway or standing-water conditions;
  - Neither the MCGPR nor TDEMI can image below a pavement overlay on top of concrete with significant rebar present; and,
  - Having an open area at the job site for system build-up, equipment calibration, and crew deployment is necessary, particularly if night work is necessary.

- R01B required the Utility Location Technologies to deploy towed-array MCGPR and TDEMI for lane-width imaging below-the-roadway; however, below sidewalks and ROW areas the hand-held instruments work quite effectively.
- With good quality MCGPR data and result correlation with preexisting SUE information the Utility Location Technologies has the promise to cut down positive-location holes; however, these advanced geophysical UTL methods also detect more "anomalies" than SUE methods, which mean the perception that less test-holes may be required may be misguided. It is anticipated that both experience and time will determine if this is true.
- Because no depth information comes from TDEMI results, they add little- to no- value for 3D solutions.
- To gain the most from these Utility Location Technologies, an experienced geophysicist and (state) utility engineer should work together to understand how utilities were emplaced/constructed.

- Caltrans invested in both hardware and software for Utility Location Technologies as it has committed funding to develop both in-house capabilities and on-all contract services due to proven usefulness of SUE.
- Procurement of MCGPR hardware and software for Caltrans indicates the value and usefulness of the Utility Location Technologies to benefit construction projects; as it gets institutionalized at the state level, many more will see the benefit of this technology. Other IAP states have shown interest in obtaining in-house capabilities.
- Training for in-house processing of Utility Location Technologies data can be procured from experienced service providers or equipment manufacturers.

Reporting & Deliverables:

- States want to receive the digital field data to possibly process in-house, so they learn how to apply quality assurance and quality controls.
- Data analysis and the time to deliver results varied, primarily because of the amount of data acquired, but also experience of the contractor.
- The time from data acquisition to delivery of results decreased as the R01B state projects progressed, and as contractors also learned lessons to speed up delivery. Much of this can be attributed to new non-standard hardware and software for MCGPR and TDEMI Utility Location Technologies systems.
- States need to coordinate communication between the Utility Location Technologies contractor and their on-call provider to confirm the level of- and the use of- existing SUE information, because not using previous SUE results at a site makes interpreting the advanced geophysical results difficult if not well understood beforehand. Without coordination and sharing of information delivery time is delayed.
- State staff learned MCGPR data can be much more complicated and complex than they had previously thought.
- TDEMI data analysis does not yield depth to utilities, only plan mapping.
- Manage and set final delivery expectations for results at the contract award meeting, not during the project. They should include:
  - Get one report if multiple Utility Location Technologies contractors are involved;
  - Define the contractor’s role to present the results to state staff during and after data processing;
  - Have the contractor agree upon a schedule for result delivery after understanding the amount of data to be acquired, processed, analyzed and interpreted, then put into required file format;
  - In the contract, be sure to include delivery of digital: 1) field data; 2) processed data; 3) final results in agreed upon formats (e.g., Acad and e-Design); and, (if appropriate); 4) 3D video files for visualization of results (in compatible file format to state needs); and,
  - After delivery of the interpreted results, plan for multiple meetings with your contractor and the state department staff (involved in the project planning), to understand what- and learn how- the interpreted results will be used; as well as qualify any limitations to them regarding reliability.
- The TDEMI data seems to have limited usefulness on multiple projects. Since it does not provide any estimate of depth, it is more akin to the standard SUE information, just better positioning and georeferencing because of the GPS integration with the system(s).

- States often ended up with a large amount of data, of which some is useful, and some isn't. There was very little guidance given on how the data were to be processed, calibrated and presented to the state. State time required to parse through the final results and reformat them for internal use became a challenge; working closely with the service provider is key to reducing the impact to the project and unpredicted state staff time.
- A method matrix is under development for these R01B Utility Location Technologies comparing field, office, and reporting time from project to project. These metrics will allow states who want to use these technologies on future projects to better understand the timeline to go from award to results. Additionally, it will help states understanding the contract pricing structure for Utility Location Technologies field, processing, and reporting efforts.

Costs – Lessons Learned

- Due to timing for this R01B implementation, nothing can be stated regarding a cost-savings associated with the use of Utility Location Technologies, as no state project has gone to construction.
- Contractor cost to perform the required MCGPR and TDEMI surveys for their projects may be higher than states anticipate.
- There are only two or three qualified MCGPR and/or TDEMI contractors, and their capital investment in the instrument and software makes the services for utility mapping expensive.
- MCGPR systems are commercially available from multiple manufacturers. These instruments range from hand-held to towed-array systems,
- MCGPR processing software is generally proprietary to the manufacturers, but some commercially available software can handle multi-channel data sets.
- TDEMI data for all R01B state projects were acquired with the Geonics EM61-MK2; a unique instrument that is commercially available; it can operate in single-coil mode, or multi-coil/"ganged" arrays (i.e., used for the R01B towed-array surveys).
- Software to process multi-coil TDEMI data is commercially available but expensive, and not necessary for single-coil TDEMI.
- Utility Location Technologies appear to be cost prohibitive for small-scale projects, but useful to image utilities at large, vulnerable, suspect, and/or complex sites.
- States would have liked to have funds to perform intrusive testing to confirm the interpreted result and verify the success of each method.