8.2.4 whereby fixed location sampling and non-compulsory collection are discussed respectively.

Annual training expenses are estimated at $250,000 for development, provision, and participation in the training. This estimate is applicable for all options except for where all activities occur over one year where the costs associated with training are estimated to be twice as large; as a greater number of crews would be required to collect data over the shortened timeframe. The training cost associated with the collection activity described in 8.2.2 is approximately $500,000.

As part of an ongoing five-year condition evaluation cycle, the estimated annual cost will be approximately $2.1 to $2.25 million (in today's dollars) for continued training and data collection of culvert inventory and condition evaluation moving forward. This assumes 1/5 of all culverts are inspected each year as part of a five-year repeating cycle where every culvert is inspected once every five years. Therefore, the five-year costs associated with training and data collection for a culvert inventory and condition evaluation program are estimated at $10.5 to $11.25 million. These estimates do not include costs associated with development and implementation of asset management programs for culverts. There will be additional unknown expenses for training, equipment, and data handling.

8. CONCLUSIONS

This section provides key points from this study and provides a framework to assist the TAMC with the development and implementation of a strategy that can be used across the state to further streamline and standardize the collection of culvert data assets owned by local agencies throughout Michigan.

This pilot project revealed that the tools, business processes, and relationship building that the TAMC initiated for the collection of PASER road condition data has created a strong framework for the rapid collection of other asset data on the public road system. This is apparent from the significant capabilities that pilot participants demonstrated with their ability to collect a large volume of high quality asset inventory and condition data in a little over three months. This data was assembled and analyzed using existing business processes and resources. The majority of local agencies used their own forces for collection of data which indicates a domestic capacity to complete this type of activity.

- 49 participating local road agencies
- 13-week data collection window
- 49,644 culverts inventoried
- 90% of local agencies reported using Roadsoft

- 73% of local agency culverts are 24 inches in span or less, 90% are less than 48 inches in span
- 85% are buried 6 feet or less
- 67.2% of rated local agency culverts were 6 or higher out of 10
- Estimated local agency culverts in state – 196,000
- Estimated cost for initial data collection - $10 million

Pilot agencies successfully located nearly 50,000 culverts in the 13-week data collection window (April 30 – July 30). It is estimated that this number constitutes approximately 24% of the approximately 196,000 total local agency culverts in the state. While it is impressive that this level of effort can be mustered on short notice, the study also identified that a significant level of effort is required to inventory and rate local agency-owned culverts. It is estimated that it will take approximately $10 million and over 131,000 collection team hours to complete the initial data collection of local agency culverts.

Local agencies involved in the pilot collected data using a variety of tools. Over 90% of local agencies involved in the pilot used the Roadsoft LDC and Roadsoft to collect and store culvert asset data. The use of a unified tool such as Roadsoft provides data collection and storage consistency that eases downstream data processing and analysis due to data consistency. Local agencies illustrated that using other software systems such as ArcGIS can allow the fulfillment of local data needs while still allowing integration with statewide systems if data schemas are set up correctly.

Inventory data from culverts revealed that the majority (approximately 73%) of local agency owned culverts are small (24 inches in span or less), corrugated steel, circular culverts that are located less than 6 feet from the surface. Approximately 90% of culverts are 48 inches in span or less and over 85% of culverts have a depth of cover less than 6 feet. Larger and more deeply buried culverts are of specific interest because they present a larger consequence of failure in terms of risk to the public and expenditure of funds for repair.

Condition data indicates that local agency owned culverts are in serviceable shape with 27.0% of the rated culverts holding condition ratings of 8 or better, and 67.2% of the rated culverts holding conditions ratings of 6 or better. The mode (most frequent rating) for condition assessments was a 7.

Michigan has had a long history of applying asset management principals to roadway infrastructure. In 2018, the principles of asset management have grown to include a broader set of infrastructure assets. The Michigan legislature established the Michigan Infrastructure Council (MIC) through Public Act 323. The MIC shall develop a multiyear work plan, budget, and funding recommendation for asset management of infrastructure including but not limited to stormwater systems, drains, roads, and bridges. Public Act 324 amended PA 451 to form the Water Asset Management Council (WAMC) which in part will develop templates for the asset management of stormwater systems amongst other assets, including but not limited to culverts

and bridges. Lastly, Public Act 325 revises the enacting legislation for the TAMC by, in part, stating that the TAMC shall advise the MIC on infrastructure assets including culverts. Through these acts, the work of the TAMC, and the results of pilot projects like this, the future of asset management for Michigan infrastructure is looking bright.

Recommendations for Implementation

- Establish responsibility for division of infrastructure asset management between the TAMC and the WAMC
- The inventory fields established in the pilot should continue to be recommended by the TAMC as a minimum with local agencies expanding on those to meet their needs
- Provide a baseline data model and data standard for culvert data collection
- Training delivery and tool development for asset management should continue
- Continue maintenance of inventory and condition evaluation data
- Promote shared data use – many agencies are interested in some facet of culvert inventory data. Each agency may need to collect specific data but much of the inventory data could be shared between agencies to minimize repeated effort.
- Develop and support a state-wide culvert data collection program
- Future research
    - AASHTO is currently working on an updated condition assessment system which will need to be reviewed, modified if needed, and accepted for use in Michigan.
    - Establish globally unique identification (GUID) for culvert assets to assist in identifying and updating culvert data inventory
    - Create a cost model that relates physical features of culvert inventory to replacement and maintenance costs.

8.1. General Recommendations

8.1.1. *Overlap of Management Council Responsibility*

One of the first issues for the TAMC to address is the overlap in responsibility for managing statewide culvert assets that was recently created by Public Act 324 and 325 of 2018. Public Act 324 created the WAMC, which is charged with the management and oversight of drinking water, waste water, and storm water infrastructure. The act further defines storm water assets as including "*catch basins, curbs, gutters, ditches, … pipes, storm drains, …. culverts, bridges*".

Public Act 325 of 2018 is a revision of the enacting legislation for the TAMC. The Act states: *"The transportation asset management council shall advise the Michigan infrastructure council on a statewide transportation asset management strategy and the processes and tools needed to implement that strategy, beginning with the federal-aid eligible highway system and infrastructure assets that impact system performance, safety, or risk management, including signals and culverts.*"

The TAMC also clearly has a mandate to oversee bridge assets and has been doing so since its inception. This overlap in responsibility runs the risk of creating a procedural confusion which may slow forward progress on bridge and culvert assets until rectified.

Drinking water and waste water, and to an extent, storm water assets, all have an ongoing regulatory and compliance component associated with them. In that aspect there is a significant difference between the assets that WAMC is responsible for overseeing and the transportation assets that the TAMC is responsible for. This difference may provide a potential dividing line between the two council's responsibilities as it relates to culverts and bridges. For example, WAMC may provide guidance and support to asset owners for culvert and bridge assets as they relate to water quality issues. This could include items like aquatic organism passage, sediment load, or flooding and environmental issues related to a failure. This focus would allow the TAMC to continue to provide support and guidance relating to the overall functioning of culverts and bridges as they impact transportation.

8.1.2. *Tools and Training*

The pilot project developed a number of tools and training that are targeted at local road-owning agencies. These include condition rating guides, data handling processes, and data collection training using a standardized condition assessment. Roadsoft contains reporting tools which allow agencies to generate summary reports of their culverts by city/village/township and by culvert material type and allows agencies to create customized detailed reports showing information related to their continuing asset management needs. Many local agencies involved in the pilot said that they would continue to collect culvert data even after the culvert pilot data submittal deadline. This indicates that the tools and training not only made a coordinated pilot of this size possible, but it also spurred "spin off" activity that was of the local agency's own volition.

The training delivery and tool development for culvert asset management should continue regardless of the level of involvement and support the TAMC decides to provide for local agency culvert owners. Training and tools are the most basic level of support that allow local agencies to build a sustainable asset management process and culture. Providing recurring training will ensure that local agencies always have the technical knowledge to adopt asset management.

8.1.3. *Condition Assessment System and Inventory Fields*

Condition data for the modified FHWA culvert condition assessment system used in the pilot appears to have been relatively rapid to collect. Daily progress logs did not show a significant difference in the production rate for finding new culverts and finding and rating new culverts. The system provides an extensive list of distresses and includes a system to roll up distresses into a one number metric for aggregated reporting. Several local agencies commented that the

system should be simplified to a one number rating which would simplify collection and still provide specific condition data necessary for determining replacement.

The inventory fields collected during the pilot provide a high level of information that can be readily used to classify culverts and identify risk and cost factors associated with them. This level of data also provides a sound basis for local management of culvert assets. It is recommended that the TAMC continue to use the pilot inventory fields as a baseline minimum while allowing local agencies to collect more extensive data to meet local needs.

8.1.4. *Data Collection*

The free availability of Roadsoft and Roadsoft LDC, and the experience that Michigan local agencies have in collecting pavement data, are some of the reasons that the pilot was able to accomplish the large volume of data collection over a short timeframe. Approximately 90% of local agencies involved in the pilot used Roadsoft and Roadsoft LDC for the pilot data collection. Roadsoft is available for no cost to local transportation agencies in Michigan and has been widely adopted by Michigan's local transportation agencies prior to the start of the pilot. As such, many agencies already had the basic collection equipment and trained staff familiar with the software before the pilot started.

The predominate use of one asset management system provides opportunities for efficiency among local agencies, both in supporting the development and maintenance of the system, and also in the area of training and maintaining local agency staff. Commonly used systems allow local agencies to share staff resources and to act as peer mentors to one another.

Widely adopted single systems like Roadsoft also provide a consistent data format that speeds the roll up of data from a local level, to a regional and state level. The relationship between the CTT team that develops and supports Roadsoft and the State of Michigan ensures that the system will always provide the necessary functions for statewide collection.

While Roadsoft is used by the vast majority of Michigan local agencies, it is not the ideal tool for every local agency. Five local agencies involved in the pilot opted to collect data using other tools ranging from ArcGIS to a spreadsheet. The pilot illustrated that allowing a variety of tools for data collection can still allow a state-wide effort to be accomplished, and the data to be used at a state and local level, as long as basic data handling rules are followed.

At least two of the local agencies that opted to use ArcGIS developed their data model from the existing Roadsoft format. In a sense, the Roadsoft data model has become the de facto data format for the pilot. The TAMC should provide a baseline data model and data standard for culvert data collection. This unified data schema will allow the use of a variety of tools and the evolution of the data collection process. This ensures that local agency needs are met while still allowing easy compilation, sharing, and reuse of data.

The TAMC data standard should also include provisions for assignment, transfer, and update of a globally unique identification (GUID) for all culvert assets between local asset management systems and the TAMC state and regional databases. GUID's create a method for identifying assets that are already present to avoid duplication of asset registers or deletion of assets in close proximity which may be mistaken as duplicates.

Inventory data should be updated on a regular basis as culverts are replaced. Culvert conditions should be evaluated on a regular basis to ensure the data represents the current field condition of the culvert. Section 8.2 provides several options for process management of a culvert data collection.

8.1.5. *Shared Data Use*

There has historically been a significant interest in culvert data by fisheries, MDOT, Department of Environmental Quality (DEQ), DNR, and other natural resource agencies. Fisheries professionals are interested in many of the same inventory features that road owners are, but for different reasons. Fisheries professionals are primarily interested in the relative ease of aquatic organism passage (AOP) at culverts which are stream crossings. Figure 8-1 illustrates a culvert which is perched above the downstream flow line. This type of a culvert is a complete barrier to AOP leading to stream habitat fragmentation.

In many cases natural resource agencies have funded data collection of culvert data, and have frequently provided additional funding to road agencies to make culvert stream crossings more AOP friendly. In most cases this includes increasing the size of the culvert conduit and decreasing flow velocity through the culvert, both of which provide an increased flow capacity during rain events. This additional resiliency benefits both the natural resources and transportation agencies.

Figure 8-1: Perched culvert which presents a significant barrier to aquatic organism passage. Photo credit Bradley Link, Link Engineering Services, LLC.

The TAMC should provide access to culvert data for natural resources and fisheries agencies to promote the shared use of the culvert data. This data has the potential to provide the framework for joint funding of culvert reconstruction projects and shared data collection efforts between fisheries and transportation agencies.

The TAMC may need to consider adding data fields to the inventory collection standard to accomplish AOP analysis if there is significant cooperation between resource agencies and transportation agencies on culvert funding issues.

8.2. Process Management Recommendations

The TAMC has several options for developing and supporting a state-wide culvert data collection program, each with benefits and drawbacks. This section outlines the general concept behind each of the options but is not intended to be a fully developed program plan. This narrative may prove helpful as a starting point for discussions on next steps for the TAMC. Each of the options presented in this section were developed with the premise that a successful program must provide benefit for both the local asset owner and the state agency, which has always been a tenant of the TAMC's policies.

- Routine Coordinated Collection
    - A portion of asset network is collected each year with the entire network collected on a several-year cycle

- Infrequent Extensive Collection
    - Entire asset network collected at one time on a several-year cycle
- Fixed Location Sampling
    - A sample of the asset network is collected and results are extrapolated to the entire network
- Non-Compulsory Collection
    - No requirement to collect data on asset network but data would be accepted from volunteers.

8.2.1. *Option 1: Routine Coordinated Collection*

This method mandates an annual data collection cycle where a portion of the asset network is collected each year. A cycle of several years is required to collect data on the entire network. The TAMC's PASER pavement condition assessment collection is a good example of a routine coordinated data collection. PASER pavement condition data is collected on a two-year cycle, meaning that the entire network is updated every two years.

Culvert data would not require a short collection cycle like pavement data because culvert assets are designed to last for 50 to 100 years, while pavements are designed to last 15 to 25 years. Culvert data cycles could be as long as five to ten years, since this frequency would allow 10 to 20 data collection points over a culvert's design life and would only require a small portion (10 to 20 percent) of the road network to be collected each year.

Routine coordinated collection requires ongoing annual training and support to local agency infrastructure owners to maintain the consistency of data collection and maintain the process. This is not to say that every person involved in data collection would need to be trained every year, but rather that the training would need to be offered to allow people new to the process and people needing a refresher to have access to training.

A potential modification of this method would be to include a biased subset of culvert locations that are collected on more frequent data cycles. As an example, the TAMC could consider that any culvert rated 4 or lower needs to be inspected every year, or that culverts over a specific size or depth require more frequent inspections. These more frequent inspections provide increased data density on a population of interest. Inspecting poor quality culverts on an increased cycle ensures that local agencies are aware of risks are more likely to provide information to the TAMC on outcomes from culvert projects.

Benefits of Routine Coordinated Collection

Maintaining an ongoing, consistent collection activity provides a high likelihood that culvert asset management will develop as a business process and become part of the culture of the road owning agency. An annual effort allows local agencies to anticipate staffing needs and equipment resources. It also allows the formation of relationships between state, region, and

local agency employees. Ongoing processes typically become self-sustaining because the resources and knowledge to accomplish the process become routine.

Annual collection of culvert data on a portion of the road system increases the quality of the data at a state level by ensuring there are samples from each agency. This reduces sampling error and provides a consistent source of data that can be used as a proxy to monitor the overall condition of culvert assets both at a state and local level. This system also allows local agencies to maintain a full set of recent data on their entire network.

Drawbacks of Routine Coordinated Collection

Ongoing annual data collection becomes less efficient as the annual portion of the network that is required to be collected gets smaller. This is because all local agencies would need to train and maintain staff to collect a small portion of their network. At some point it becomes advantageous to sub-contract out these small local data collection efforts across jurisdictional boundaries to remain efficient; however, this negates some of the positive aspects of this method. Allowing local agencies to decide if they self-collect or join with others to group collect provides the largest flexibility to meet their local needs.

8.2.2. *Option 2: Infrequent Extensive Collection*

This method mandates periodic, system-wide, data collection efforts to create a snapshot of state wide conditions at specific periods in time. There is no ongoing, annual effort with this method, but rather one large event that targets a nearly complete collection every five to ten years. The United States Census is an example of this type of data collection mode.

Benefits of Infrequent Extensive Collection

Since collection only occurs once every several years, there is not an ongoing cost to maintaining human and equipment resources or costs associated with recurrent training. Training and staffing efforts would ramp up before a collection effort and spin down after the collection is complete. Data collected using this method can eliminate sampling error since the goal would be to collect all of the network in a single year. Data from a full collection would also be continuous in the sense that the state and local agencies would have a full, continuous sets of data on all culverts for each collection period. The level of effort necessary to complete this collection option would be similar to the level of effort necessary to compete a full data cycle of Option 1, with some potential savings in efficiency on training and travel.

Drawbacks of Infrequent Extensive Collection

This method has large labor and cost swings associated with it which may cause issues with local agency forces. Staffing up for a collection event may prove costly to individual agencies, and a spin down of staffing after a collection event means that the human resources to do asset management do not reside domestically in owner agencies. This ebb and flow of human capital

can result in significant barriers to adoption of asset management business processes and loss of institutional knowledge.

8.2.3. *Option 3: Fixed Location Sampling*

This method mandates periodic data collection on a fixed set of culvert locations throughout the state. The sampling locations would be pre-defined based on criteria that minimizes sampling error. The sampling size for this method would depend on the granularity of the analysis that the TAMC would like produce. For example, fewer samples are necessary to produce a state-wide estimate of overall culvert condition than would be necessary to differentiate condition based on geographic location, or other factors like material type. Sampling could be competed each year or on a longer cycle depending on the need the TAMC has to detect changes in condition. The quality control data collection that MDOT does for the TAMC is an example of this type of process.

Benefits of Fixed Location Sampling

This option provides one of the lowest-cost methods for obtaining data on a state level. The small size of the collection makes it possible to collect this data with shared resources such as regional contractors which further saves costs. This method would allow the TAMC to make general statements about culvert condition with a very low investment.

Drawbacks of Fixed Location Sampling

This method does not provide much if any benefit to individual local agencies because the small size of the sample needed to characterize state conditions provides almost no strategic or tactical information on the local level. Increasing the sample size to be able to provide benefit for local agencies negates the financial benefit of this option. This option is not likely to encourage the adoption of asset management as a business practice since there is negligible benefit at the local agency level. This option may in fact dissuade local agency implementation of culvert asset management because sampling will be seen as a low benefit activity.

8.2.4. *Option 4: Non-Compulsory Collection*

The first three options for data collection all assumed a required collection event. Required events provide the most control of the nature, extent, and frequency of data collection, but they also come with a downside in the form of cost. Non-compulsory collection would be the lowest cost option for the TAMC to collect some data from local agencies. This option would essentially relegate the TAMC to collecting any data local agencies wish to share on their culverts whenever they feel like sharing it.

Benefits of Non-Compulsory Collection

This method would be extremely low cost since the TAMC would only be maintaining an upload system and providing training guidance for data collection.

Drawbacks of Non-Compulsory Collection

This method would likely not produce a stable sample or census of data for analysis purposes. There is a high likelihood that data may be biased based on the agencies that participate each year. This method is not likely to create implementation of asset management.

8.3. Maintenance Data

Data on culvert maintenance and replacement is necessary in order for any of these methods to provide high quality data. Replacement and maintenance data provides the basis to determine needed budgets, replacement cycles and is necessary with any modeling effort. Regardless of the method for data collection that is chosen, submitting culvert maintenance and replacement projects annually to the state provides continuity and context to existing condition data.

8.4. Recommendations for Future Research

The pilot outlined a few areas that should be investigated when going to full scale production. The TAMC should investigate the following items:

8.4.1. *Condition Assessment Systems*

The rapid schedule for the pilot did not allow a full discussion on the integration of the culvert pilot rating system with the system MDOT uses, or discussion on the integration and migration of data to the new rating standard that is currently under development at the federal level. Generally speaking, these three systems have the same general function, assess similar defects, and have a similar scale direction. Options may exist to develop a migration function that will allow translation from one rating system to another.

AASHTO is currently in the final stage of publishing an updated culvert condition assessment system to replace the FHWA method. MDOT is also considering its system and how it will translate or integrate with the new AASHTO method. The TAMC will need to address the issue of either migrating to this new standard, remaining with the current standard, or creating a new, simplified rating system as some local agencies have suggested. Regardless of the system chosen, it will take time to develop the tools, training, and institutional knowledge to execute such a change.

8.4.2. *Globally Unique Identification (GUID) and Data Storage System*

GUID's allow the coordinated update and maintenance of assets across multiple databases. The TAMC needs to develop a standard system and business process for assigning and updating GUID's for culvert assets. This work will also be transferrable if the TAMC works with other non-road assets such as signals or signs.

The TAMC has clearly learned a significant amount about data storage and transfer while collecting PASER data over the last decade. A culvert data handling process needs to be developed after the TAMC decides on the data collection method. CSS will need to be closely consulted for this data handling process.

8.4.3. *Cost and Condition Model*

The TAMC will need to create a cost model that relates physical features of culvert inventory to replacement and maintenance costs. This model could be updated using bid costs or project reporting.

The TAMC should develop a simple network deterioration model which can be used to make projections on the condition of the state's culvert assets. More extensive deterioration models may also be considered for slab on abutment style culverts which are more similar to small bridges than pipe structures.

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