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Culvert Asset Management System: Best Practices/Pilot Project

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16. Abstract

This study identifies best practices for culvert asset management systems in state departments of transportation (DOTs). Researchers conducted an extensive literature review and surveyed state DOTs, with 47 states responding. In the survey, 33 states reported that they inspect small culverts. Nineteen states reported that they had culvert inspection manuals. The survey also found that culvert inspections are carried out by DOT maintenance staff, student or summer interns/workers, bridge inspectors, or central staff. Twenty-one state DOTs reported that they provided culvert inspection training, either developed in-house (15 states) or based on bridge inspection (6 states). Researchers also identified the most common data fields collected in culvert inspection and inventory databases, as well as the most common technologies (e.g., Trimble, iPad, paper, or a combination) used for field collection of data. Photos are incorporated into the inventory data system in 21 states. Inventory software included state-developed systems, Agile Assets, and AASHTOWare.

The study offers recommendations for best practices as well as national needs:

- Due to the large number of small culverts and constrained state DOT resources, the best practice appears to be establishing a tiered or risk-based process for determining the frequency of culvert inspections. Inspections would be more frequent for culverts in poor condition or with other risk factors such as traffic, age, size, material type, and weather/environmental conditions.
- A national culvert inspection manual is under development and may be available as soon as 2017. This will update the 1986 Federal Highway Administration *Culvert Inspection Manual*.

If a state wants to proceed with a culvert inspection program prior to that document release, several other state DOTs have developed in-state manuals that can be used for reference.

- Staffing a culvert inspection program can be managed through district maintenance or bridge employees, central office staff, or through employment of seasonal or student intern personnel.
- It would be beneficial to have a national entity develop a culvert inspection training program that focuses on unique aspects of small culverts as well as inspection technologies.

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CULVERT ASSET MANAGEMENT SYSTEM: BEST PRACTICES/PILOT PROJECT

Final Report

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PREFACE

The research reported herein reviewed literature on the topic of culvert asset management, identified best practices by contacting other state departments of transportation via a survey instrument, and developed summaries and findings based on this work.

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This report presents the results of research conducted by the author(s) and does not necessarily reflect the views of the New Mexico Department of Transportation. This report does not constitute a standard or specification.

ABSTRACT

This study identifies best practices for culvert asset management systems in state departments of transportation (DOTs). Researchers conducted an extensive literature review and surveyed state DOTs, with 47 states responding. In the survey, 33 states reported that they inspect small culverts. Nineteen states reported that they had culvert inspection manuals. The survey also found that culvert inspections are carried out by DOT maintenance staff, student or summer interns/workers, bridge inspectors, or central staff. Twenty-one state DOTs reported that they provided culvert inspection training, either developed in-house (15 states) or based on bridge inspection (6 states). Researchers also identified the most common data fields collected in culvert inspection and inventory databases, as well as the most common technologies (e.g., Trimble, iPad, paper, or a combination) used for field collection of data. Photos are incorporated into the inventory data system in 21 states. Inventory software included state-developed systems, Agile Assets, and AASHTOWare.

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- A national culvert inspection manual is under development and may be available as soon as 2017. This will update the 1986 Federal Highway Administration *Culvert Inspection Manual*. If a state wants to proceed with a culvert inspection program prior to that document release, several other state DOTs have developed in-state manuals that can be used for reference.
- Staffing a culvert inspection program can be managed through district maintenance or bridge employees, central office staff, or through employment of seasonal or student intern personnel.
- It would be beneficial to have a national entity develop a culvert inspection training program that focuses on unique aspects of small culverts as well as inspection technologies.

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GLOSSARY OF ABBREVIATIONS

The following are abbreviations used within the paper, listed in alphabetical order:

AASHTO – American Association of State Highway and Transportation Officials

CFR – Code of Federal Regulations

CIMS – Culvert Information Management System

CMS – Culvert Management System

CSCP – Corrugated Steel Culvert Pipes

CSV – Comma Separated Value

DOT – Department of Transportation

FHWA – Federal Highway Administration

GASB – Government Accounting Standards Board

GIS – Graphic Information System

MS4 – Municipal Separate Storm Sewer System

NBIS – National Bridge Inspection Standards

NCHRP – National Cooperative Highway Research Program

NHI – National Highway Institute

NMDOT – New Mexico Department of Transportation

NPDES – National Pollutant Discharge Elimination System

SI&A – Structure Inventory & Appraisal

TAM – Transportation Asset Management

TAMP – Transportation Asset Management Program

1 INTRODUCTION

Culverts are important infrastructure assets, but they are frequently overlooked by agencies because they are often inconspicuous. Despite the fact that culverts are not as visible as lane miles of pavement, each state is responsible for thousands, and in many cases, hundreds of thousands of culvert pipes. Unfortunately, often agencies do not consider how to manage their culverts until after a catastrophic failure of a culvert occurs. While conducting an inventory of a state's culverts can be a daunting task, in the long run, it can prevent or mitigate culvert pipe collapse (FIGURE 1).

FIGURE 1 Grants, NM Culvert Collapse (Courtesy New Mexico Department of Transportation)

Managing culvert assets can bring state departments of transportation (DOT) several benefits including (1):

- An up-to-date inventory,
- Reduced failures through regular inspection,
- Reduced emergency repair costs and unplanned financial burden,
- Better budget planning for repair and replacement, and
- Long term ability to identify actual life cycle and performance of various pipe materials.

The main purpose of this study is to:

1) Identify culvert asset management systems and best practices in other states
    a. Review literature on the topic of state of the practice of culvert inspection and inventory
    b. Conduct a survey of state departments of transportation
    c. Synthesize the findings of (a) and (b)
2) Identify key data fields and data formats for consideration by the New Mexico Department of Transportation (NMDOT) for an inventory as well as key data fields that will facilitate long-term integration of the inventory into the state's Agile Assets transportation asset database.

The Code of Federal Regulations (CFR) 650.305 differentiates between a bridge and culvert, as shown in FIGURE 2.

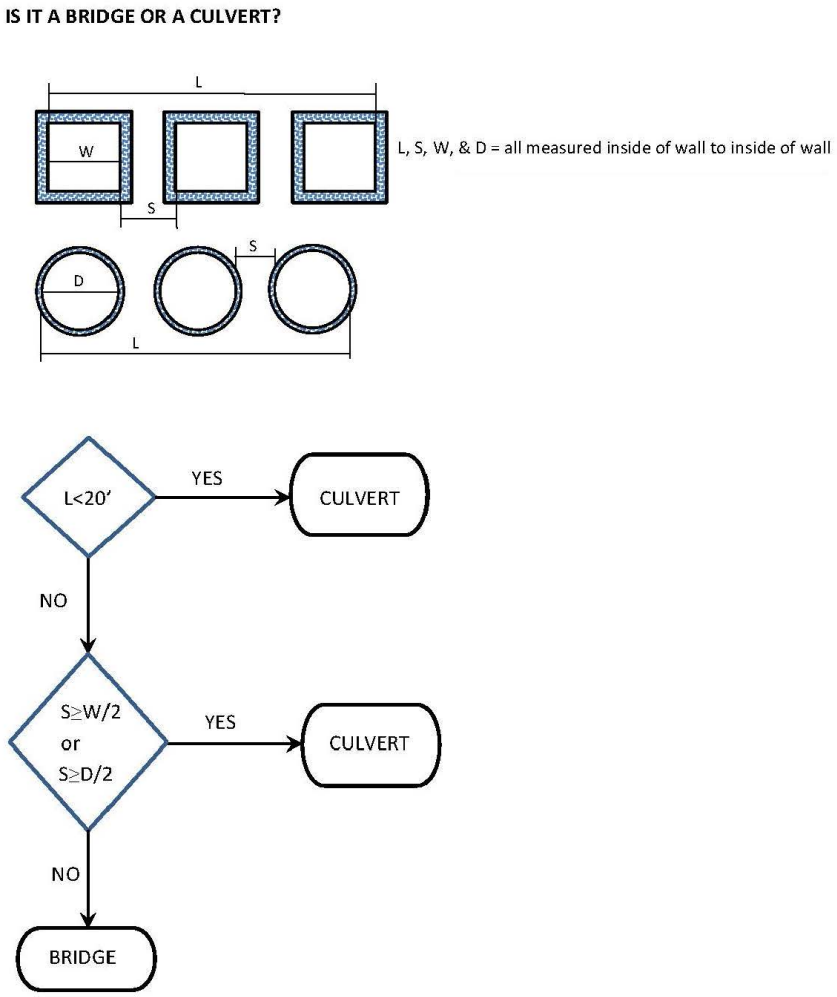

FIGURE 2 Bridge or Culvert? (Courtesy NMDOT)

Descriptively, a bridge is defined as (2):

> *A structure including supports erected over a depression or an obstruction, such as water, highway or railway, and having a track or passageway for carrying traffic or other moving loads, and having an opening measured along the center of the roadway of more than 20 feet between undercopings of abutments or spring lines of arches or extreme ends of openings for multiple boxes; it may also include multiple pipes, where the clear distance between openings is less than half of the smaller contiguous opening.*

Bridges have a set, mandatory inspection frequency. In contrast, openings where L is less than 20 feet (e.g. a culvert) currently have no federal inspection and inventory requirements. The focus of this research project was culverts, or those that do not qualify as bridges, which were defined as "small culverts." This is an important point, as during the literature review and

subsequent state DOT surveying effort, it was found that many state DOTs were already collecting information on culverts that extended beyond the 20 foot cut-off.

The next section presents the literature review, first discussing national studies on culvert inspection and inventory, followed by a discussion of other literature found on inspection and then inventory, typically by state. The survey section presents the state DOT survey methodology, instrument, results and conclusions. Subsequently, there is a section on findings regarding key data fields. The last section of this report is the summary.

2 LITERATURE REVIEW

The literature review is divided into five sections: 1) national documents on culvert inspection and inventory; 2) culvert inspection; 3) culvert inventory; and 4) bridge vs. culvert designation, and 5) summary.

The first section features publications by the Federal Highway Administration (FHWA) and through the National Cooperative Highway Research Program (NCHRP). Documents include the *Culvert and Storm Drain System Inspection Manual* (3); the appendix for this manual is anticipated for release sometime in 2017.

Seven sub-sections can be found within the culvert inspection section: a) staff/contractor who inspects culverts, b) frequency of culvert inspections, c) culvert inspection manuals, d) rating systems, e) tools, f) data, and g) cost. The sub-sections within inspection focus on the who, how often, tools, and how much it costs agencies to perform culvert inspections.

Five sub-sections can be found within the culvert inventory section: a) states that have inventories, b) software, c) common data fields, d) integration with asset management systems, and e) culvert location determination. The sub-sections within inventory attempt to identify the leading states in culvert asset management, and identify the evolving tools that they use to manage culverts, such as software.

The bridge vs. culvert designation section identifies states that were already inspecting culverts beyond the requirements of existing federal statutes, as identified in the literature.

2.1 NATIONAL DOCUMENTS ON CULVERT INSPECTION & INVENTORY

In 1986, the FHWA published its *Culvert Inspection Manual* (4). Even then, FHWA noted:

> *While the importance of the NBIS [National Bridge Inspection Standards] inspection program cannot be overemphasized, the SI&A [Structure Inventory & Appraisal] data sheets are oriented toward bridges rather than culverts; thus, they do not allow an inspector to collect either detailed condition data or maintenance data. Additionally, the NBIS program does not specifically address structures where the total opening length is less than 20 feet. However, some type of formal inventory and inspection is needed for culverts that are not bridge length. In many cases, the failure of a culvert or other structure with openings under 20 feet long can present a life-threatening hazard… Ideally, all culverts should be inventoried and periodically inspected.*

The 1986 manual also specifies that a good reporting system should include inventory data, a structure file for each structure to be inspected, a procedure for planning and scheduling inspections, a system for recording inspection results, and a system for updating structure files.

In 2002, the NCHRP published *Assessment and Rehabilitation of Existing Culverts* (5). This NCHRP Synthesis reiterated the importance of culvert inventory and inspection systems:

> *Guidelines need to be developed and implemented to systematically track and assess the condition of pipes over time. The data collected during these assessments should be kept in a pipe management system for better management of all pipes, scheduling of maintenance activities, justification of funding needs, prioritization of pipe work, and any other analysis that may arise.*

Several national standards have been implemented that require a set schedule of inspections, but these typically apply to structures greater than twenty feet. Government Accounting Standards Board 34 (GASB-34) requires that infrastructure assets have a condition assessment completed every 3 years (6). Similarly, the American Association of State Highway and Transportation Officials (AASHTO) *Volume XIV: Highway Drainage Guidelines for Culvert Inspection and Rehabilitation* (7), called for regular inspection of culverts. The 2007 AASHTO *Highway Drainage Guidelines, Fourth Edition* updated the recommended process and requirements for culvert inspection, noting:

> *Many thousands of kilometers [miles] of roadways were constructed during the building boom of the 1950s and 1960s as part of the development of our system of interstate highways. To protect the vast investment in this system and the network of other State and local roads, pavement management systems and bridge management systems have been developed and adopted… Perhaps because culverts are less visible than bridges and pavement, they have been given far less attention. However, the aging of the interstate system and other routes, combined with the lack of drainage system inspection and maintenance, has resulted in hundreds of thousands of culverts that are nearing the end of their useful service life…A key element of a successful culvert maintenance program is periodic inspection.*

While the current federal initiative on transportation asset management (TAM) has primarily focused on roadways and bridges to date, it is possible that culverts will ultimately be added to the assets that should be inventoried and monitored for condition as the TAM program evolves. For example, the FHWA TAM website recommends (8):

> *Implementing an asset management program starts with establishing your organization's strategic objectives for managing and improving its assets and identifying the specific measurable performance and service levels needed to meet those objectives. An asset management plan can then be developed that covers all transportation-related assets, identifying what is working well, where improvements are needed, and the necessary data that should be collected. It is important to know what assets are in place and their condition and expected performance.*

NCHRP 14-26 (3) recently published an overview of the First Edition of the *Culvert and Storm Drain System Inspection Manual*, which is an update to the 1986 FHWA *Culvert Inspection Manual* (4). The appendix to this overview is anticipated to be available in 2017. This new manual recommends component-level evaluation, as compared with looking at the overall culvert condition. The authors identified that the failure of culverts not only impacts safety, but also the economy, as re-routing traffic may reduce traffic to businesses. They highlighted the magnitude of the challenge associated with managing culverts because there are more than ten times the number of culverts in the field as compared to bridges. The authors conclude that preservation is more cost-efficient than replacement, hence, agencies can make better use of their limited financial resources by creating a culvert asset management system. For culverts, the report recommends four *types* of inspections common to bridges:

1) initial inspection,
2) routine inspection,
3) special inspection, and
4) damage inspection.

An initial inspection occurs after the structure is commissioned, typically at the conclusion of a project. Routine inspections are conducted according to a defined frequency. They include both visual and nondestructive assessments. Special inspections, which occur in addition to routine inspections, are performed to monitor a specific distress condition. Damage inspections are typically event-driven and they are unscheduled.

The fifth inspection used for bridges which was not recommended by Beaver and Richie (3) for culverts was "In-Depth Inspection." Instead, they recommend that the "schedule for inspection frequency should carefully consider…consequence of failure" and recommend that culvert inspection schedules consider factors such as culvert size, condition, age, average daily traffic, environmental conditions and special function. They also recommended the "development of software for inventory and inspection tracking." In particular, the inspection must be able to incorporate maintenance data.

The FHWA created case studies in 2007 and 2014 on select agencies on the topic of culvert maintenance ((9), (10)). Culvert inspection and inventories that were reviewed include: Alabama, Maryland, Minnesota, Oregon, Ohio, Vermont, Los Angeles County (CA), and Shelby County (AL). In the subsequent sections and sub-sections of this report, information taken from these case studies will be discussed.

2.2 INSPECTION

This section discusses several topics related to culvert inspection, including staffing, frequency, inspection manuals, rating systems, tools, data and cost.

2.2.1 Staff/Contractor Who Inspect Culverts

Previous research has identified four staffing strategies for culvert inspection: use of maintenance personnel who also perform other maintenance duties, use of student interns/workers, use of bridge inspectors, and dedicated culvert inspection personnel. However,

it should be noted that not all of the recommendations made by researchers have been implemented (e.g. dedicated culvert inspection personnel).

Three studies indicated that maintenance personnel were responsible for culvert inspections ((9), (11), (12)). However, several authors note the need to provide them with the right equipment to do their job and the knowledge to understand conditions of concern (11). For example, the Ohio DOT's central office initiated training of personnel from all districts to introduce new policy and inspection rating procedures (12).

Two studies discussed the use of student workers or interns (13; 14). Gharaibeh et al. (13) discussed a graphic information system (GIS) that was developed and tested in El Paso, TX with the aid of undergraduate and graduate students from Texas A&M. The students were tasked with reviewing drawings for data that were then entered into the inventory database. In addition, the researchers for this project know of a similar exercise done by Montana State University and the City of Bozeman that used undergraduate students to collect data on irrigation ditches.

Only NBIS certified instructors are allowed to inspect Minnesota's culvert pipes spanning more than 10 feet (9). Maryland DOT reported that its 18 full-time, in-house bridge inspectors within their Bridge Inspection and Remedial Engineering Division inspect culverts and small structures down to a 5 foot span in addition to performing bridge inspections (9). Culverts from 3 to 5 feet in span are inspected and inventoried by another division within the Maryland DOT, the Highway Hydraulics Division. Staff performing the inventories within this division do not receive NBIS training; rather, they receive an in-house training.

Bowers et al. (14) recommended "dedicated and trained staff" for performing culvert inspections. However, they also indicated that if summer interns were hired for small culvert inspection, that over a 10 week internship, at 40 hours each week, a total of 2,000 inspections could be completed.

2.2.2 Frequency of Culvert Inspections

Three approaches to culvert inspection were found in the literature and have been defined by the researchers as 1) reactive, 2) a set schedule, and 3) a tiered approach.

2.2.2.1 Reactive

In the 2007 FHWA case study, Alabama was identified as inspecting culverts in a reactive nature, as the agency does not have a set inspection schedule (9).

2.2.2.2 Set Schedule

Several federal mandates require a set-schedule of inspections, but these typically apply to structures greater than 20 feet. GASB-34 requires that infrastructure assets have a condition assessment completed every 3 years (6). Similarly, AASHTO's *Volume XIV: Highway Drainage*

Guidelines for Culvert Inspection and Rehabilitation (15), mandates regular inspection of culverts.

Minnesota's culverts under the Bridge Inspection Unit (those spanning more than 10 feet) are inspected every 12 to 24 months (9). Minnesota DOT's estimated 67,000 small culverts (spans less than 10 feet) whose maintenance falls within the Hydraulics Unit, do not have a set inventory frequency (9). However, the 20 percent of culverts that have an outfall in a Municipal Separate Storm Sewer System (MS4) are required to be inspected annually.

Indiana inspects 20 to 25% of its small culverts (those spanning less than 48 inches) annually; therefore each of their approximately 90,000 culverts are inspected every 4 to 5 years (14). Maryland DOT's Highway Hydraulics Division inspects its estimated 287,500 small culvert pipes, those spanning from 3 to 5 feet, on a three year cycle to match up with the National Pollutant Discharge Elimination System (NPDES) cycle (9).

In 2005, Mitchell et al. (16), performed a study for the Ohio DOT entitled, "*Risk Assessment and Update of Inspection Procedures for Culverts*." Part of the study involved surveying state DOTs on highway culvert management policies and inspection/rating procedures. Forty responses were received, including one each from British Columbia, Washington D.C., and Puerto Rico. The researchers of the study found that survey respondents were typically inspecting culverts spanning 10 to 20 feet every 1 to 2 years. In contrast, Mitchell et al. (16) found that the smaller culverts (those whose span is less than 10 feet) were inspected every 4 to 5 years.

Studies have also identified local governments with set inspection schedules. Shelby County (AL) inspects its 88 culverts and small bridges every 4 years or when storm events occur (9). Los Angeles County (CA) inspects its 5,000 culverts annually (10).

The federal mandates typically apply to a smaller number of culverts. Sometimes state DOTs may have developed cut-offs, such as inspecting culverts down to a 10 foot span, to find a balance between the amount of staff able to perform inspections and the number of culverts. Therefore, while the federal mandate typically drives more frequent inspections (every 3 years or less), when talking about smaller culverts which are more numerous, they are inspected less frequently, about every 4 to 5 years. However, for agencies like Los Angeles County, which has only 5,000 small culverts to inspect, the cycle is more frequent.

2.2.2.3 Tiered Approach

Several sources have recommended a tiered approach to culvert inspection. If the conditions do not cause concern, the culverts can be inspected less frequently, and if the culvert condition is concerning, they can be inspected more frequently. The tiers may be based simply on culvert condition or may be more elaborate to include other factors such as sediment, pH, average daily traffic, material type, size, and pipe age.

Meegoda et al. (6) recommended a framework in which if a culvert has a "good" rating, a future inspection may be delayed by the duration of a typical cycle, which in turn is a more effective use of agency resources.

Beaver and McGrath (11) recommend using the culvert asset management tool and an importance modifier (based on roadway class function, culvert drain type, and culvert span) to establish a list of important culverts that require routine inspections. These recommendations state that inspections for important culverts should be at intervals of no more than 5 years, with a reduction to 2 years if the rating is low.

Ohio DOT indicated a preference to inspect small culverts every 5 years (12). This may include the Level 1 inspection, which is visual observation of the culvert ends, with no person or device entry to evaluate the majority of the 100,000 culverts in the state. The more detailed Level 2 inspections will be conducted on selected culverts identified in the Level 1 inspections.

The Maryland DOT reported inspecting culverts on a 4-year cycle unless the condition warrants, which reduced the inspection cycle to every 2 years (9).

New York State DOT (17) also takes a tiered approach, which recommends: an annual inspection for culverts rated a 1 or 2 (generally poor), biannual inspection for culverts rated 3 or 4, or a quadrennial inspection for culverts rated a 5, 6, or 7 (generally good).

An inspection frequency for the New Jersey DOT was proposed based on: sediment, pH, location, and age (18). TABLE 1 describes the proposed inspection periods based on these criteria.

TABLE 1 Frequency of Inspections Linked to Criteria, New Jersey

Rating Level	I	II	III
Inspection Frequency	10 Years	3 Years	1 Year
Basis for Time Interval	Self-cleaning design (10-year flood) for small diameter culverts	FHWA (1995) guidelines	Reported problems
Basis for Level	Free of corrosion and debris	Evidence of corrosion and/or debris	Reported clogging or collapse
Sediment	Low abrasion-minor bedloads of sand and gravel V<1.5 m/s	Moderate abrasion-bedloads of sand and gravel 1.5m/s<V<5m/s	Severe abrasion-heavy bedloads of gravel and rock V>5m/s
pH	5.8<pH<8.0	5.0<pH<5.8	pH<5.0
Location: (Corrosion/Erosion-Conductivity Maps & Historical Data)	Low or none	Medium	High
Pipe Age as % of Design Life	30%	50%	100%

The examples above show that when agencies are concerned with the condition of a culvert, they may inspect it as frequently as annually when using a tiered approach. However, when the

inspection of a culvert has not shown it to exhibit conditions of concerns, the frequency of inspection of that culvert appears to be approximately every 4 or 5 years.

The reactive approach to inspecting culverts seems to be the most ambiguous. The two other approaches, set schedule and tiered, both have frequencies of 4 or 5 years; however, the tiered approach does not require this of all culverts, rather only the ones with conditions of concern. Using a tiered approach for culvert inspection appears to be a best practice approach to ensuring that culverts are inspected while not overloading staff as a result of the significant magnitude of small culverts.

2.2.3 Culvert Inspection Manuals

The FHWA developed the first *Culvert Inspection Manual* in 1986, which was previously discussed in the section on National Documents on Culvert Inspection & Inventory.

The Ohio DOT published its first culvert inspection manual in 1990 (16). Therefore, it appears as if it was the first state agency to create such a manual. During this phase of the project, an exhaustive search for culvert inspection manuals was not performed. Rather, those identified while reviewing the literature were reviewed. The subsequent task, surveying state DOTs, was used to request that state DOTs direct the researchers to a state's culvert inspection manual if available. However, in addition to the Ohio DOT culvert inspection manual, culvert inspection manuals were also identified in the literature or found for: Arizona, California, Connecticut, Indiana, Kansas, New York, and Oregon ((16), (17), (19), (20)).

In the FHWA case study report (9), Maryland DOT was identified as having a bridge inventory manual, but not a bridge or culvert *inspection* manual.

While the Ohio DOT first published a manual in 1990, the agency has since published updates. The 1990 culvert inspection manual was updated because of the following problems identified with the manual 1) no rating system for headwalls/wingwalls, roadway surfaces and embankment slopes was included, 2) the 1-4 scale could not detect gradual deterioration of culverts, 3) the visual rating system was not detailed enough, and 4) the manual did not include culverts with protective coatings or thermoplastics (16). Interestingly, a lot of the issues identified for updating the 1990 culvert inspection manual were also discussed as reasons behind the update of the 1986 FHWA *Culvert Inspection Manual*. However, only three of the four recommendations by (16) will be found in the new *Culvert and Storm Drain System Inspection Manual* (3): a visual rating system, condition assessment for plastic pipes, and roadside compatibility. In contrast to moving away from the 1-4 scale (e.g. to a ten point scale) as recommended by (16), the *Culvert and Storm Drain System Inspection Manual* recommends a five point scale.

The New York State DOT culvert inspection manual, *Culvert Inventory and Inspection Manual* (17), indicated that the New York Office of Operations Management is responsible for the organization and maintenance of culvert inspection and inventory programs, including the database. New York State DOT defines a "large culvert" as a culvert with an opening (measured perpendicular to the centerline of the culvert), as being greater than or equal to 5 feet. The manual indicated that New York State DOT is using a nine point rating system, where 1 is totally

deteriorated or in failed condition and 7 is a new condition without deterioration. An eight indicates "not applicable." A nine indicates that the condition is unknown. Based on a 1 through 7 rating, ratings of 1 and 2 require annual inspection, 3 and 4 biannual inspection, and 5 through 7 quadrennial inspection. The manual recommends bringing photos of a prior inspection for comparison purposes. Photo examples of conditions are provided in a companion guide to the manual, the New York State DOT *Culvert Inspection Field Guide* (21).

2.2.4 Rating Systems

There were several rating scales identified in the literature. The most common scale in the literature is the five point scale. Additionally, Ohio DOT used a ten point rating scale. The following sub-sections present the five point, the ten point, and other rating scales found in the literature. It should be noted that these are scales that were found within a report; it does not necessarily mean that DOTs are not using other types of scales or that maybe the ten point scale is more common than what was found. It may mean that such rating systems were not readily documented, highlighting the need for more research on the topic of small culverts.

2.2.4.1 Five Point Rating Scale

Literature identified the Montana, Ohio and New Jersey DOTs as having used a five point rating scale at some point in time. Montana DOT was reported to have given an overall culvert rating, ranging from 1 (worst) to 5 (best) (22). Nasir et al. (13) developed a rating scale from 1 (poor) to 5 (best) based on a "thorough review of the literature," including Ohio DOT's "well-developed and well-documented *Culvert Inspection Manual*" (current version is titled, *Culvert Management Manual* (19)).

Meegoda et al. (18) proposed five condition ratings for the New Jersey DOT, as follows:

1. Condition State 1 (Excellent): no evidence of corrosion, no visible deterioration, no action recommended
2. Condition State 2 (Good): minimal likelihood of collapse in short term, possibility for further deterioration
3. Condition State 3 (Fair): failure unlikely in the near future, deterioration likely
4. Condition State 4 (Poor): advanced corrosion, failure likely in near future
5. Condition State 5 (Very Poor): culvert failed, pipe needs to be repaired or rehabilitated

2.2.4.2 Ten Point Rating Scales

Historically, Ohio DOT inspected culvert structures sporadically, often at times of road repair by Ohio DOT personnel, using a low resolution scale from 1 to 4 with a visual inspection method (12). This was done for the over 100,000 culverts in the state. However, it appears that Mitchell et al. (16) recommended changing Ohio DOT's 1 to 4 rating scale to a 0 to 9 rating scale. They also recommended more frequent inspections for culverts 1) with low cover and 2) that are

deteriorating. Therefore, it appears that the Ohio DOT took the recommendations from Mitchell et al. (16) to move from a five point rating scale to a ten point rating scale when inspecting the following items:

- General condition
- Alignment
- Shape
- Seams and Joints
- Concrete slab
- Abutment
- Headwalls
- End Structure
- Channel Alignment
- Channel Protection
- Waterway Blockages
- Scouring
- Culvert Approach
- Overall Culvert Condition
- Operational Status of Culvert

The report provides a series of tables for each of the items to be inspected that describe what could qualify as a 9, 8, 7, and so forth. It is a written description, not a visual depiction.

This conclusion that Ohio DOT moved from a 1 to 4 to a ten point scale is further validated by the report by Masada et al. (12) who indicated that the Ohio DOT uses a 0 to 9 culvert condition rating scale, as shown in TABLE 2.

TABLE 2 Ohio DOT culvert condition rating system (12)

Code	Category	Description
9	Excellent	New condition; galvanizing intact; no corrosion
8	Very Good	Discoloration of surface; galvanizing partially gone along invert but no layer of rust
7	Good	Discoloration of surface; galvanizing gone along invert but no layers of rust; minor pinholes (with an area less than 3 in^2/ft^2) in pipe material located at ends of pipe (length not to exceed 4 ft and not located beneath roadway)
6	Satisfactory	Galvanizing gone along invert with layers of rust; sporadic pitting of invert; minor pinholes (with an area less than 6 in^2/ft^2, 4% in pipe material located at end of pipe (length not to exceed 4 ft and no located beneath roadway)
5	Fair	Heavy rust and scale; pinholes (with an area less than 15 in^2/ft^2, 10%) throughout pipe material; section loss and perforations at ends; holes in metal at end in invert and not located under roadway

4	Poor	Extensive heavy rust; thick and scaling rust throughout pipe; deep pitting; perforation throughout invert with an area less than $30in^2/ft^2$, 20% overall thin metal; which allows for an easy puncture with chipping hammer
3	Serious	Extensive heavy rust; thick and scaling rust throughout pipe; deep pitting; perforations throughout invert with an area less than 36 in^2/ft^2, 25%; overall thin metal, which allows for an easy puncture with chipping hammer; end section corroded away
2	Critical	Performance throughout invert with an area greater than 36 in^2/ft^2, 25%
1	Imminent	Pipe partially collapsed
0	Failed	Total failure of pipe

Therefore, it appears that in contrast with the upcoming recommendations for a five point scale (3), Ohio DOT had moved towards a ten point scale. However, there is some ambiguity between what was recommended during research projects as compared with what was actually implemented by Ohio DOT. This will be revealed from the findings of the survey work for this project.

2.2.4.3 Other Rating Scales

Meegoda et al. (6) developed a framework for the inspection, maintenance, and replacement of corrugated steel culvert pipes (CSCP). They developed a framework that utilizes four condition states to define the state of deterioration of the culvert. The condition states are defined as:

- "Condition State 1: A CSCP in this state has no visible deterioration or evidence of active corrosion.
- Condition State 2: When forming of surface or freckled rust is observable, the pipe is considered to have moved to this state. A pipe in this state may exhibit flaking and minor section loss of less than 10% of its thickness.
- Condition State 3: Flaking and swelling with surface pitting that is considered equivalent to a 10% to 30% loss of thickness.
- Condition State 4: The functionality of a pipe in this state is compromised due to extensive deterioration, perforations leading to soil loss, pipe distortion, and caving."

The New York State DOT (17) used a nine point culvert inspection scale, as shown in TABLE 3.

TABLE 3 New York State DOT Culvert Inspection Scale

Rating	Description
9	Condition and/or existence unknown
8	Not applicable
7	New condition, no deterioration
6	Used to shade between ratings 5 and 7
5	Minor deterioration but functioning as originally designed
4	Used to shade between ratings 3 and 5, functioning as originally designed
3	Serious deterioration or not functioning as originally designed
2	Used to shade between ratings of 1 and 3
1	Totally deteriorated or in failed condition, potentially hazardous

If a rating of 9 is used, then the reasoning must be explained in the rating comments section. Therefore, this scale is very similar to the ten point scale but without the 0.

Like New York State DOT, the Indiana DOT uses a nine point scale. However, for Indiana DOT a 1 is defined as the worst state and 9 the best. The scale is applied to 1) embankments, 2) end sections, 3) flow lines, 4) culverts and 5) general conditions (14). An analysis performed by Purdue University, found that there was bias for items to be rated a 9 ("uniformly positive"). The researchers proposed a scale that uses a 1, 3, 5, 7, and 9. They recommended the use of photos to better depict the condition of the culvert. They also recommended removing the "general condition" rating. All three of these recommendations, essentially moving away from the nine point scale, using photos to depict the condition of a culvert, and removing the overall or general condition rating are in line with the most recent recommendations (3). Finally, Bowers et al. (14) recommended adding an "incomplete" field if at the time of inspection the culvert was submerged in water.

2.2.5 Tools for Inspection

Discussions of two inspection tools were found in the literature. However, it is known that other tools, like an inspection robot or car with camera, are being used by agencies to assist with inspections. In the absence of available information about these tools, this section discusses that which was found.

In a review of the Indiana DOT's small culvert asset management program, Bowers et al. (14) recommended that the DOT investigate the "numerous database tablet applications." However, by using such a tool, they recommended that static data (e.g., size, type and length of the culvert) be retained so that it would not have to be re-entered.

Researchers developing the case study for FHWA indicated that Los Angeles County was working on videotaping all of their culverts (10). However, it was unclear if they have since completed their effort, as they had 5,000 culverts to videotape.

2.2.6 Inspection Data to Collect

TABLE 4 compiles the types of data that state DOTs collect or recommend collecting during culvert inspection, based on the available literature. Some states collect the same types of data for both inspection and inventory, so there is some duplication between this table and the corresponding TABLE 5 in the subsequent inventory section.

TABLE 4 Data To Collect Literature Review Summary

Field	Number of Times Found in Literature Review References	Associated References
Inspection Date	6	(6), (13), (14), (16), (21), (22),
Inspector Name	6	(6), (13), (14), (16), (21), (22)
Culvert Shape	6	(9), (13), (14), (16), (22), (23)
Current Overall Condition Rating	6	(6), (9), (14), (16), (21), (23)
Asset Identification	6	(9), (13), (14), (16), (21), (23)
Comments	5	(6), (13), (14), (16), (21),
Culvert Length	5	(6), (14), (16), (22), (23)
Culvert Material	5	(6), (13), (16), (22), (23)
Mile Marker	4	(6), (13), (21), (22)
County Code	4	(13), (16), (21), (23)
Embankment Condition Rating	4	(13), (16), (21), (23)
Roadway Surface Condition Rating	4	(13), (21), (16), (23)
General Structure Rating	3	(9), (13), (21)
Channel Alignment Rating	3	(9), (16), (21)
Entry Class	3	(9), (16), (21)
Road Name	3	(13), (16), (21)
Construction Date	3	(16), (22), (23)
Culvert Span	3	(13), (16), (23)
Road ID	2	(6), (22)
Headwall Rating	2	(9), (21)
Wingwall Rating	2	(13), (21)
Average Daily Traffic of Roadway Above Culvert	2	(16), (22)
Culvert Latitude	2	(13), (16)
Culvert Longitude	2	(13), (16)
Depth of Cover	2	(16), (22)
Abutment Rating	2	(9), (16)

Field	Number of Times Found in Literature Review References	Associated References
Channel Protection Rating	2	(9), (16)
Culvert Height	2	(13), (16)
Culvert Width	2	(13), (16)
Inlet Condition Rating	2	(6), (16)
Outlet Condition Rating	2	(6), (16)
Longitudinal Slope of Culvert	2	(6), (16)
Protective Coating	2	(13), (16)
Seams and Joints Rating	2	(9), (16)
Slab Rating	2	(9), (16)
Wall Thickness	2	(6), (16)
Channel Scour Rating	2	(16), (21)
Guide Railing Rating	2	(16), (21)
Settlement Rating	2	(16), (21)
End Protection Condition Rating	2	(13), (23)
Culvert Rise	2	(16), (23)
Number of Cells	2	(16), (23)
Footing Condition Rating	2	(16), (23)
Invert Condition Rating	2	(16), (23)
Culvert Diameter	2	(6), (23)

2.2.7 Cost

Very little information was found in the literature regarding the cost of inspection. However, three sources provided very different types of information along this thread. The first and second sources of information provided an estimate of the amount of money needed to maintain culverts. The third presented an example of how a tool could be used to assist with determining whether or not a culvert needed to be replaced or inspected.

The Montana DOT has more than 35,000 road-crossing culverts and 18,000 side culverts (53,000 total) and spends an estimated $500,000 per year on culvert maintenance (22). Los Angeles County performs culvert and storm drain maintenance with an annual budget of $5 million; they have 5,000 culverts in their inventory (10).

New Jersey DOT's Culvert Information Management System (CIMS) attempts to enhance the previous system used by New Jersey DOT by adding in financial information (18). In order to determine costs for rehabilitation/replacement the following financial information was collected:

- Number of culverts in network

- Age or date of installation with years inspected and cleaned
- Year to be considered
- Condition state based on prior inspection
- Expected life and variance for each culvert
- Cost of installation for each culvert
- Current value of the culvert after do nothing/rehabilitation/replacement
- Cost of circuitry (circuitry delay and circuitry vehicle operating costs or the detour length and operating cost of vehicle)
- Cost of inspection for each culvert
- Cost of rehabilitation for each culvert
- User cost of failure for each culvert (includes only if roadway collapses and ensuing traffic delays)
- User cost for each culvert

The CIMS allows the user to input financial information, information about the culvert and its current condition, and any other relevant information. If the pipe treatments are easily determined based on this information, the user may receive messages like "Replacement" or "Inspection". If the current condition and age of the culvert are known, the recommended treatment form will retrieve information on recommended techniques which are pulled from a treatment policy table.

As shown in the above sub-section, it is notable that when managing 5,000 culverts, Los Angeles County is using $5 million to maintain them. In contrast, for Montana DOT's 53,000 culverts, only $500,000 is being spent. Clearly, Montana DOT is spending significantly less than Los Angeles County on culvert maintenance. However, what is interesting is not who is spending more or less, but rather that it provides a reader with an idea of the amount of fiscal investment that is minimally needed to maintain the infrastructure.

2.3 INVENTORY

Inspecting culverts does not necessarily lead to the inventorying of culverts or vice versa. However, inventorying culverts can assist a DOT with understanding the magnitude of the challenge that culverts, small culverts in particular, present from an asset management perspective. This section is sub-divided by first identifying states in the literature that were found to have inventories, the software these states are using (if information is provided), common data fields in the inventory which were found to typically match the data collected during inspection, whether or not a culvert inventory was integrated with the larger asset management of the state, and how the location of a culvert was determined.

2.3.1 States that have inventories

Evidence was found in the literature that Alabama, Minnesota, Missouri, Ohio, Utah and Vermont have culvert inventories.

Alabama inventories culvert pipes from 20 feet down to 15 inches. The state has inventoried approximately 184,775 drainage structures (9).

Minnesota uses two inventory systems: Pontis and HYDINFRA (9). The former is for culverts greater than 10 feet; the latter is for those less than 10 feet.

In 2000, a report on the status of Missouri DOT's experience with culvert inspection indicated that they had 5,000 culverts inventoried in a database (24).

Ohio DOT created a culvert management system for those less than 10 feet in diameter as a result of a culvert that failed under a major interstate (16). Ohio has 79,000 culverts that fall into this category.

As of 2005, Utah DOT initiated a program to track the culvert inventory, evaluate in situ culvert performance, and establish a program to manage the culvert inventory and procurement policies (11). This started with creating a database to record culvert size, material, other characteristics, inspection information; and was followed-up by a second project which created a culvert management system, established a general condition of the inventory through field inspections, and recommended changes to monitoring culvert condition over time.

The Vermont DOT has asset management and performance measures written into statute (10). The agency has been working on inventorying culverts that range in size from 6 to 20 feet in span for more than two decades.

2.3.2 Software

Pontis has historically been used as the software for inventorying bridges. Minnesota DOT uses Pontis software for larger culvert pipes (16). A survey of state DOTs by Najafi et al. in 2008 (23) found that the Virginia DOT, Idaho DOT, and Delaware DOT used Pontis to inventory their culverts; however, it is unclear if this extends beyond culverts not classified as bridges.

California was identified as using MS ACCESS to inventory their culverts in a 2008 study by Najafi et al. (23). Vermont DOT also indicated that it uses a Microsoft Access database (16). Michigan DOT also uses a database (16).

Several states have developed their own state-specific software. HYDINFRA, developed specifically for Minnesota DOT, is used by the agency for culvert pipes less than 10 feet (16). Similarly, the Utah DOT uses its own Utah DOT Culvert Database to manage its culvert pipes (11). The New York State DOT uses its own Culvert Inventory and Inspection Systems database system to maintain culvert data (17). The Oregon DOT's Drainage Facility Management System is "an Oracle-based database with a Cold Fusion user interface" (10). Alaska, Indiana, and Ohio were all identified as having their own in-house developed software (23); however, again these sources did not specify the size of the culverts that they were inventorying.

In a 2005 study by Mitchell et al. (16), Washington State DOT indicated that it had started to make use of GPS to track culvert locations. In 2009, Gharaibeh et al. (13) proposed an idea to use GIS tools for stormwater drainage asset management. The *inventory module* contains

databases for each component of the drainage system (culverts, channels, etc.) and attributes of each component including length, material, cross section, and construction date.

2.3.3 Common Data Fields

TABLE 5 identifies data fields that were found in two or more sources during the literature review.

TABLE 5 Inventory Fields

Field	Number of Times Found in Literature Review References	Associated References
Culvert Shape	4	(13), (21), (25), (23)
Culvert Material	4	(13), (21), (25), (23)
Culvert Length	3	(13), (25), (23)
Comments	3	(13), (21), (25)
Asset Identification	3	(13), (21), (23)
Depth of Cover	3	(13), (21), (23)
Construction Date	3	(13), (21), (23)
Current Overall Condition Rating	2	(13), (25)
County Code	2	(21), (23)
Mile Marker	2	(21), (23)
Culvert Latitude	2	(23), (25)
Culvert Longitude	2	(23), (25)
Average Daily Traffic of Roadway Above Culvert	2	(13), (23)
Maintenance Responsibility	2	(21), (23)
Municipality	2	(23), (25)
End Treatment - Type/Material/Thickness	2	(21), (23)
Culvert Opening Height	2	(13), (25)
Culvert Opening Width	2	(13), (25)
Bank Protection	2	(21), (23)
Stream Bed Material	2	(21), (23)

2.3.4 Integration with Asset Management Systems

The Utah Culvert Database culvert database asset management program, with the culvert rating system with importance multipliers allows for the priority ranking of culverts for inspection, maintenance, and replacement (11).

The Oregon DOT's Drainage Facility Management System is integrated with the agency-wide asset management system, TransInfo (10). Oregon DOT has been using TransInfo for about ten years.

2.3.5 Culvert Location Determination

In the Utah Culvert Database system utilized by Utah DOT, all culverts are identified in inspection and inventory records by a culvert identifier composed of the state route number and the accumulated mileage (11).

2.4 CULVERT VS BRIDGE

The federal definition for a bridge was discussed in the introduction, as it played a major part in the focus of this research. However, the literature search revealed that states were inspecting and in many cases inventorying structures that extended beyond this definition. Maryland, Minnesota, Ohio, and New York are four such states. Maryland, like New York, inspects culverts with spans as small as 5 feet (9). Minnesota DOT extend the federal definition to inspect culverts down to 10 feet (9). Finally, the Oregon and Ohio DOTs inspect culverts down to 1 foot (10).

3 SURVEY

This section summarizes the findings from a survey sent to all 50 state departments of transportation asking whether or not they currently inventory and inspect "small culverts," and if so, how. First, a basic overview of the survey is presented, followed by a discussion of the survey results.

3.1 SURVEY METHODOLOGY

The survey was made available to personnel at all fifty state DOTs from Wednesday, May 11, 2016 through Wednesday, July 6, 2016. Potential survey respondents were identified by 1) a list provided by NMDOT and 2) a search of state DOT staff directories for individuals listed as bridge engineers, hydrologic engineers, or asset management engineers. Often times, the initial respondent re-directed the researchers to another individual after reviewing the survey instrument. The initial contact was made via email identifying the purpose of the project and providing the survey respondent with the opportunity to respond to the survey either via a SurveyMonkey link or by telephone. A follow-up phone call was made to survey respondents if they had not responded to the survey within a week of the email invitation. All of the survey respondents used the web link to access the survey.

3.2 SURVEY INSTRUMENT

The research team developed a survey instrument containing thirty-one questions for this effort. It can be found in Appendix A: Survey Instrument.

3.3 SURVEY RESULTS

Forty-seven of the fifty states who were sent the survey provided input. In comparison, in 2009, an effort by Perrin and Dwivedi (1) attempted to survey all fifty states on the status of culvert asset management and received only twenty-eight responses. This section presents the results for each survey question. Using the results, the research team also prepared a classification of states based on the current status of their small culvert inspection and inventory program.

Question 1 – State Department of Transportation

Question 1 asked, "Which state department of transportation do you represent?" All but three states (Hawaii, Louisiana, and Texas) responded to the survey. Both Hawaii and Texas entered the survey, provided their state name, but did not provide any further information. Delaware, Georgia and Kentucky only answered the first few questions. Louisiana is the only state that did not appear to have attempted to complete the survey.

Question 2 & Question 3 – Culvert Inspection Manual

Question 2 asked, "Does your state have a culvert inspection manual?" If the survey respondents answered affirmatively, they were sent to Question 3, which asked, "Would you be willing to provide a link to the culvert inspection manual or provide us with a copy upon request?"

FIGURE 3 shows the status of each state DOT regarding whether or not it has a culvert inspection manual.

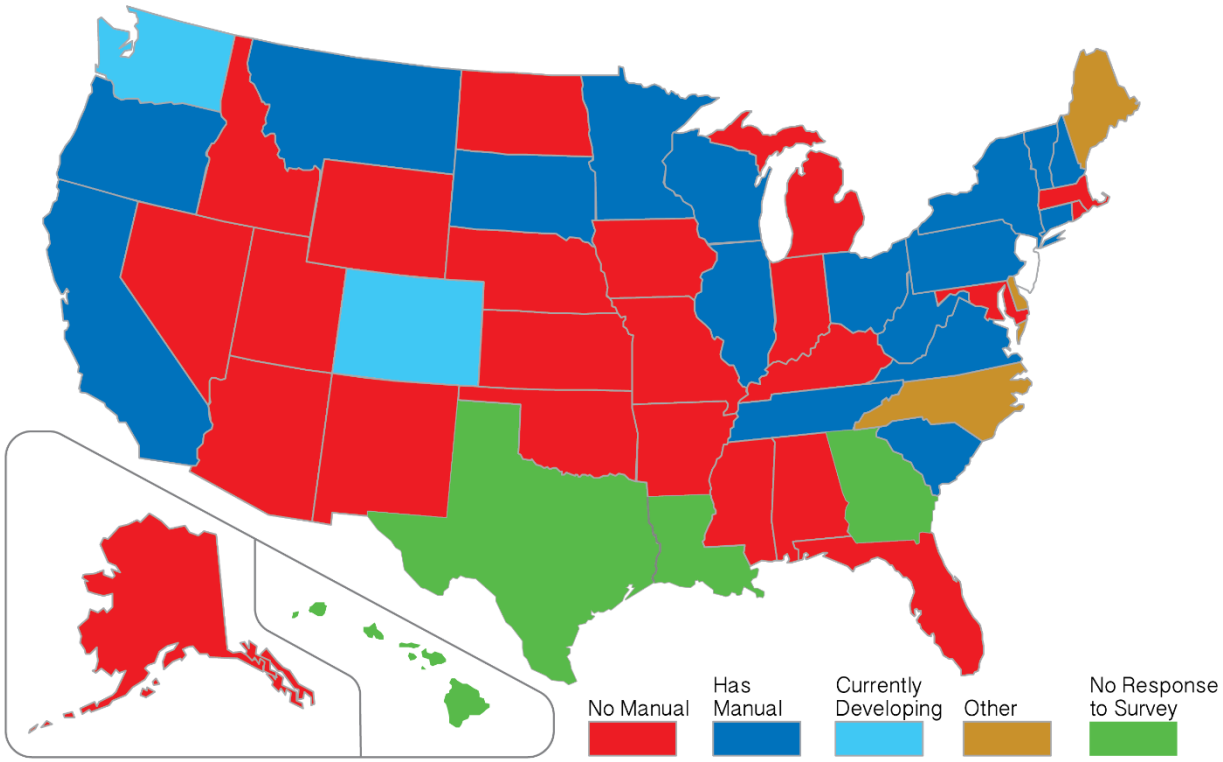

FIGURE 3 State DOTs & Culvert Inspection Manuals

FIGURE 3 shows that the vast majority of respondent states, twenty-two states in total (AL, AK, AZ, FL, ID, IN, IA, KS, KY, MA, MD*, MI, MO, MS, NE, ND, NM, NV, OK, RI, UT, & WY), do *not* have a culvert inspection manual. (Note: *Two responses were received from Maryland with one indicating that the state does have one and another indicating that it does not have one. However, the one that came from a complete set of responses was taken as the final answer.) This result contradicts the findings of (16), who found that Arizona, Indiana and Kansas had developed their own inspection manual.

Nineteen states (CA, CT, GA**, IL, MN, MT, NH, NJ, NY, OH, OR, PA, SC, SD, TN, VA, VT, WI, & WV) indicated that they do have a culvert inspection manual. (Note: **Of the three partial responses from Georgia, two indicated that they have one, one indicated that the state does not have one.)

Two states, Washington and Colorado, indicated that they are in the process of writing one.

Three states, Maine, North Carolina, and Delaware, provided an "Other" answer. Maine indicated that it has adopted Federal Lands Highway's *Culvert Assessment and Decision-Making Procedures Manual* (26). North Carolina indicated that the use of a culvert inspection manual is optional, as there was no official policy. Delaware indicated that it has an inspection policy related to a NPDES permit.

Links to inspection manuals that were provided by survey respondents can be found in Appendix B: Survey Question Details and open-ended responses; not all survey respondents provided links to their manuals.

Question 4 – FHWA CMS

Question 4 asked, "Did your state use/ever use the Federal Highway Administration's Culvert Management System (CMS)?"

Of the states that responded to the survey, California was the only state that responded yes. Vermont indicated that it had "Evaluated [the] system." Several survey respondents indicated that they were unsure.

Question 5 & Question 6 – Definition of a Culvert vs. Bridge

Question 5 presented FIGURE 2 to survey respondents and asked, "Thinking about how your state inventories bridges, does your definition for what is inventoried extend beyond the definition shown above?" The following two responses were provided:

- Yes (e.g., L < 15 is the cut-off for what our state inventories)
- No, we only inventory that which is defined as a bridge as shown above.

If survey respondents indicated that, yes, their definition differed somehow, they were asked, "How is your state's inventory for bridges different than the CFR definition?"

This question was asked because by a federal mandate, each state is required to inspect and have an inventory for its bridges. However, the literature showed that several states inspected bridges more extensively than federally required.

Twenty-four states (AL, AK, AZ, AR, CA, CO, FL, ID, IA, MI, MO, MS, NC, NE, NM, NY, OK, SC, SD, TN, UT, WA*, WV & WY), representing a majority of the states that responded to the survey, only inventory that which is defined as a bridge by CFR 23 650.305. (Note: Washington had two entries, which contradicted one another. However, the entry that had all of the fields complete was used as the final entry.) Nineteen states (CT, IL, IN, KY, MA, MD, ME, MN, MT, ND, NH, NJ, NV, OH, OR, PA, RI, VT, & WI) indicated that they included structures in their bridge inventory that extended beyond the CFR 23 650.305 definition (FIGURE 4). The Virginia DOT did not provide a response.

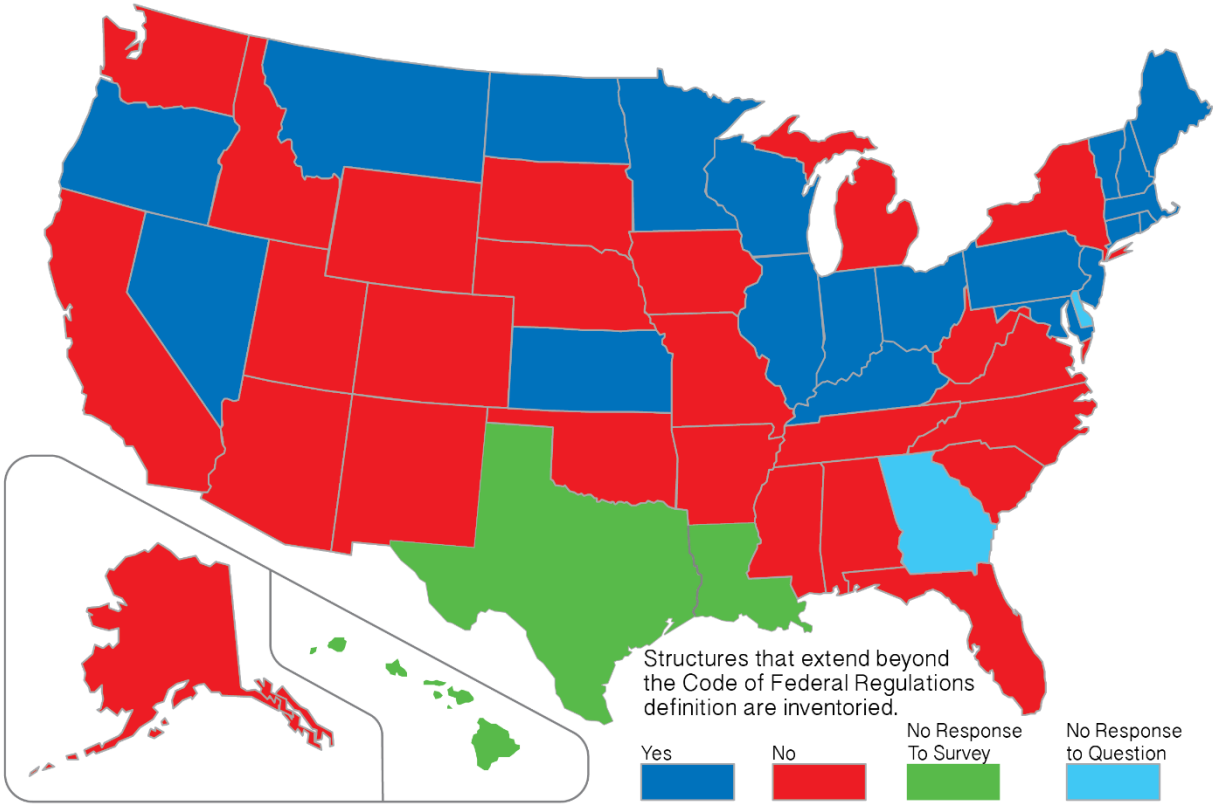

FIGURE 4 Inventories Beyond CFR

Twelve states extend their length (L) beyond 20' (RI, NJ, CT, IL, NH, ME, MA, MN, OH, MT, ND, and PA), with thresholds of 5', 6', 8', or 10'. The majority of the states that extended beyond the threshold (MA, ME, MN, NH, OH) did so down to 10', with several indicating that this was in part driven by some law within the state. Indiana and Vermont both followed CFR 23 650.305, but they indicated that they also had a two tiered inventory for structures less than 20'. Maryland and Oklahoma indicated that they followed CFR 23 650.305, but that they treated "batteries" of culvert pipes differently. Kansas indicated that it essentially treated all the culverts in their inventory the same, with the clarification that the 20' was measured along the "centerline of the roadway." Finally, Nevada indicated that it is inventorying all of its culverts in response to the NPDES MS4 permit.

Question 7 – Small Culvert Pipes, Inspection

After presenting survey respondents with the CRF figure in the previous set of questions, survey respondents were then asked, "Does your state inspect small culverts?" Three potential responses were presented to the survey respondent:

- Yes
- No
- Other (please specify).

If survey respondents indicated "No," they were then directed to Question 26. Otherwise, they were asked a set of questions related to "small culvert pipes." FIGURE 5 shows that the majority of states responded with the affirmative, that they inspect small culverts.

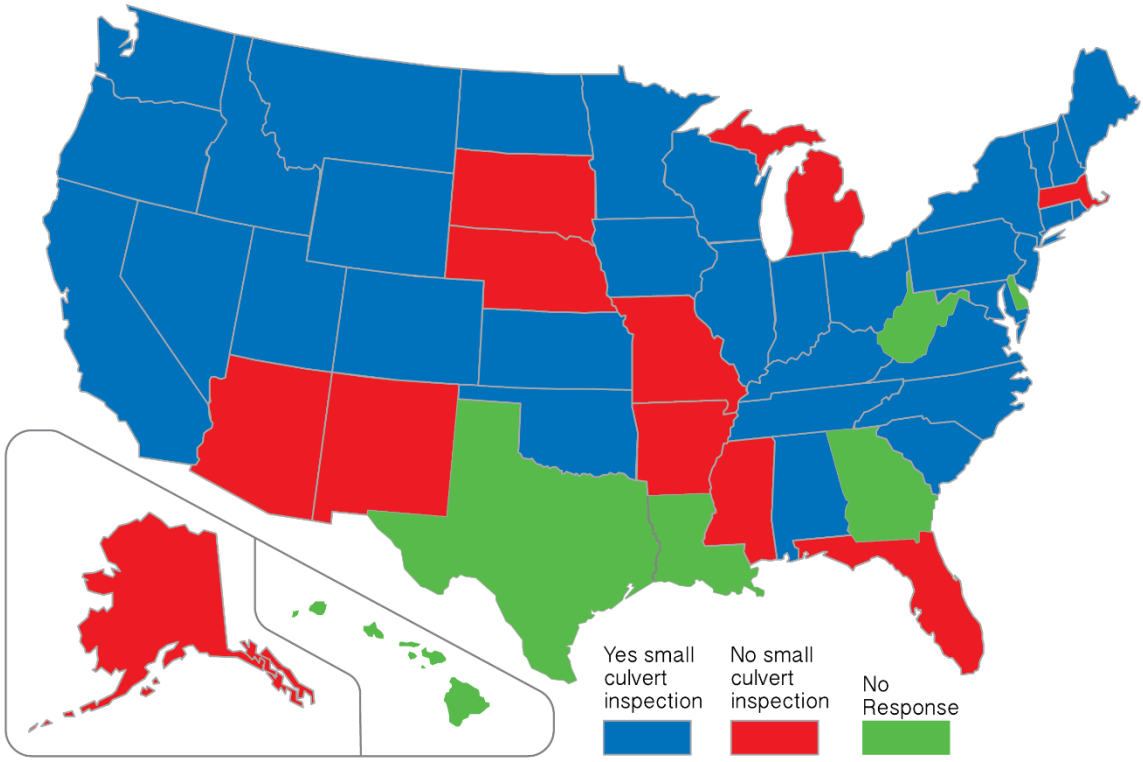

FIGURE 5 Inspect Small Culverts

Thirty-three states (AL, CA, CO, CT, ID, IL, IN, IA, KS, MD, ME, MN, MT, NC, ND, NH, NJ, NV, NY, OH, OK, OR, PA, RI, SC, TN, UT, VA, VT, WA, WV, WI, & WY) indicated that they inspect small culvert pipes. Eleven states (AK, AZ, AS, FL, MA, MI, MO, MS, NE, NM, & SD) indicated that they did not inspect small culvert pipes. However, the extent of a small culvert inspection appears to vary, as some states indicated that they only did so if the culvert needed to be "replaced or extended" or for "sediment and debris blockage."

Question 8 – Definition of a Small Culvert

If state survey respondents indicated that their state inspected small culvert pipes, they were then asked, "What is your state's definition of a small culvert."

Some survey respondents took issue with the terminology "small culvert pipes." However, as was shown previously, state DOTs have different thresholds for inventorying bridges. Many states simply indicated that "small culvert pipes" were those which were the opposite of the CFR 23 650.305 bridge definition (AL, AZ, CA, MO, MT, NM, & OK). Other states provided low and high threshold diameters (e.g. 4' to 20') of small culverts that they inspect (CA, CO, IL,

MD, MN, OH, OR, TN, VT, & WY). Some states provided a maximum value (ID, KS, NV, NH, NY, NC, ND, PA, UT, VA, & WV) and others a minimum value (CT, IA, RI, & SC). Indiana and Maine had multiple categories for inspection, in which one category lined up with CFR, another was an intermediate category, and the final one grouped together the smallest culvert pipes. Finally, Washington indicated that it had no definition, and Wisconsin's definition was a bit unclear.

Question 9 – Number of Small Culverts

To obtain an estimate of the number of small culverts that state DOTs are maintaining across the U.S., state survey respondents were asked, "How many small culverts does your state have? Is this figure approximate or exact?"

If a state answered "No" to Question 7, it was not presented with Question 9. States that fall into this category include: AK, AS, FL, MA, MI, MS, NE, & SD. Only Alabama, which indicated that it does inspect small culverts, did not provide an answer regarding an estimated number of small culvert pipes in the state. States that provided some type of information on the number of small culverts in the state, whether an estimate or just indicating that the number is unknown, are as follows: AZ, CA, CO, CT, ID, IL, IN, KS, MD, ME, MN, MO, MT, NC, ND, NH, NM, NV, NY, OH, OK, OR, PA, SD, TN, UT, VA, VT, WA, WI, WV, & WY. (Note: There are a few states in this list that originally indicated that they do not inspect small culverts, but also provided information regarding the number of small culverts in their state.) It should be noted, it appears that many states, while they inspect small culverts, do not have an inventory, thereby limiting their ability to report how many small culverts their state owns. The estimated numbers, by state, can be found in FIGURE 6.

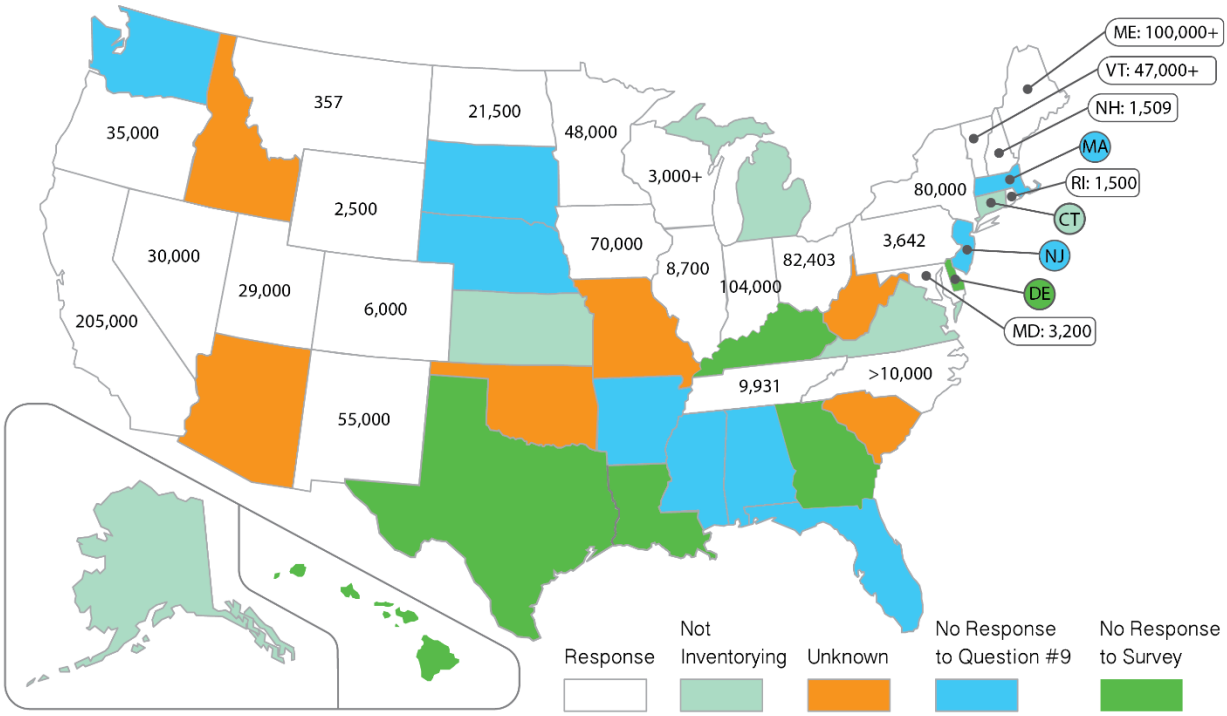

FIGURE 6 Number of Small Culverts by State

FIGURE 7 identifies the number of small culverts as compared with the area of the state in square miles (27).

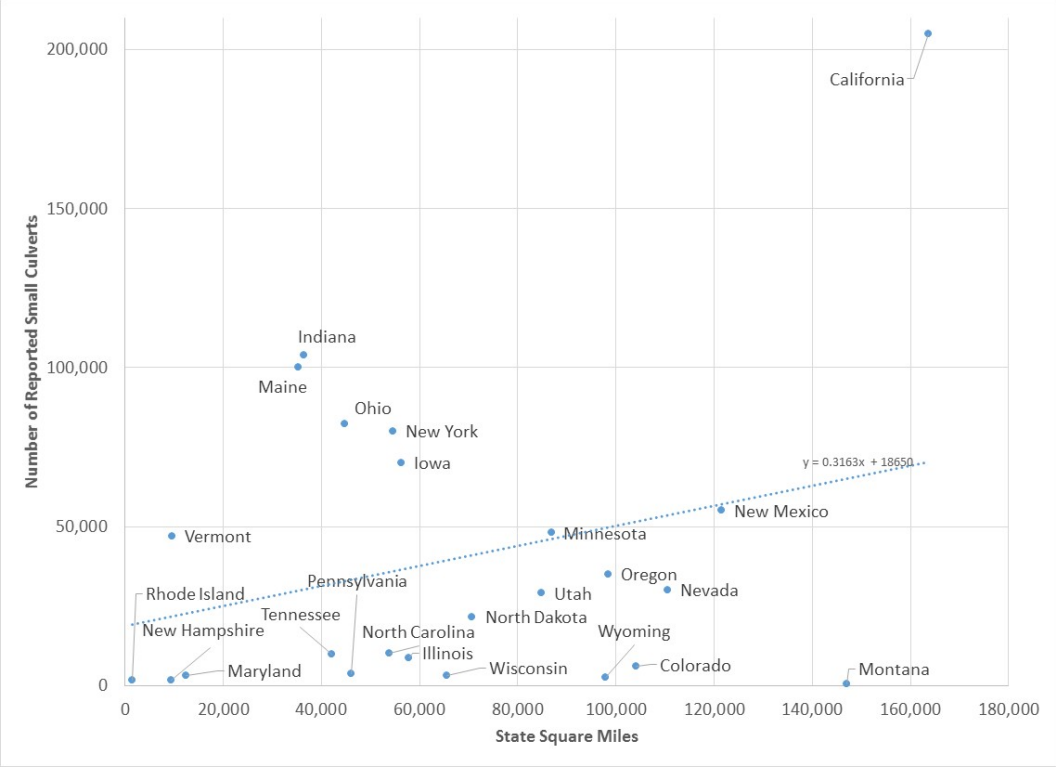

FIGURE 7 Number of Small Culverts by Square Mile of State

Question 10 – Small Culvert Pipe Material

Question 10 asked, "What types of materials are your culvert pipes made of, and what percentage of the number of small culvert pipes statewide do they represent?" Survey respondents were presented with five material types (steel, aluminum, reinforced concrete, plastic, and timber) that were found during the literature review, with boxes in which they could enter the percentage of the state count. They were also allowed to enter another material type in an "Other" box.

Ten states (AL, IN, KS, ME, NJ, OR, WA, WV, WI & VA) did not provide information on materials even though they had indicated that they inspect small culvert pipes. Of the states that provided a response, none of the states identified an additional material type in the "Other" box. However, when searching for culvert inspection manuals, researchers found that, for example, New Hampshire DOT has a manual for inspections of historic stone culverts: *Historic Stone Highway Culverts in New Hampshire Asset Manual* (28). Therefore, TABLE 6 should be treated as the available information for the five types of culvert materials listed in the survey. In addition, several states indicated that the provided percentages were only estimates. In fact, some of the numbers provided by states were found to add up beyond 100%.

TABLE 6: Percentage of Culvert Material Types Used in States

STATE	Steel	Aluminum	Reinforced Concrete	Plastic	Timber
Arizona	90		10		
California	50		45		
Connecticut	30	5	60	5	
Idaho	60	5	20	15	
Illinois	5		95		
Iowa	25		70	5	
Maryland	30		70		
Minnesota	20		75	5	
Montana	90		10		
Nevada	60		35	5	
New Hampshire	35	5	40	20	
New Mexico	70		30		
New York	25		65	5	
North Carolina	30	10	55	5	
North Dakota	5		95		
Ohio	25		55	20	
Oklahoma	15	10	75		
Pennsylvania	5		90		
Rhode Island	40	15	40		5
South Carolina	10	10	75	5	
Tennessee	15		85		
Utah*	85	5	10	5	15
Vermont	55	5	30	10	
Wisconsin	40		60		

*Note: The total exceeds 100; however, these are the numbers provided.

As expected, all of the states that provided a response indicated that some proportion of their culvert pipes were made with steel and reinforced concrete materials. Arizona and Montana primarily use steel culverts. Illinois, North Dakota, Pennsylvania, and Tennessee primarily use reinforced concrete. Connecticut, Idaho, New Hampshire, North Carolina, Ohio, Oklahoma, Rhode Island, South Carolina, Utah, and Vermont use a mix of the culvert materials presented.

FIGURE 8 suggests that for western state survey respondents, steel is more prominently used (highlighted in blue), whereas survey respondents in eastern states tended to indicate larger usage of concrete (highlighted in grey), with the heaviest representation in the Midwest (i.e. Illinois, Minnesota, Wisconsin).

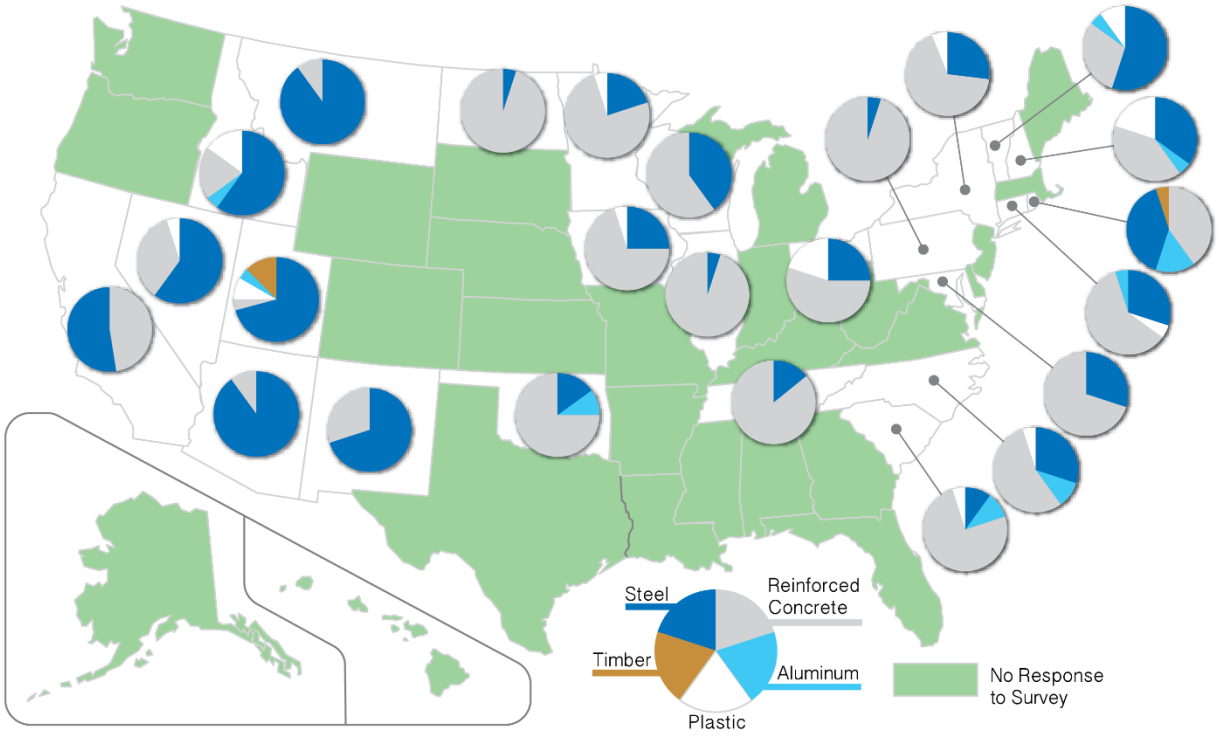

FIGURE 8 Material Type of Small Culvert Pipes

Question 11 – Frequency of Small Culvert Inspection

Question 11 asked, "How frequently does your state inspect small culverts?" Eight response options were provided as follows:

- Annually
- Every 2 years
- Every 3 years
- Every 4 years
- Every 5 years
- Every 6 years or more
- After storm events
- Other (please specify)

FIGURE 9 provides an overview of the inspection frequency by state DOTs. Note, "Not Applicable," are states that conduct inspections but may not do them via a formalized manner or schedule.

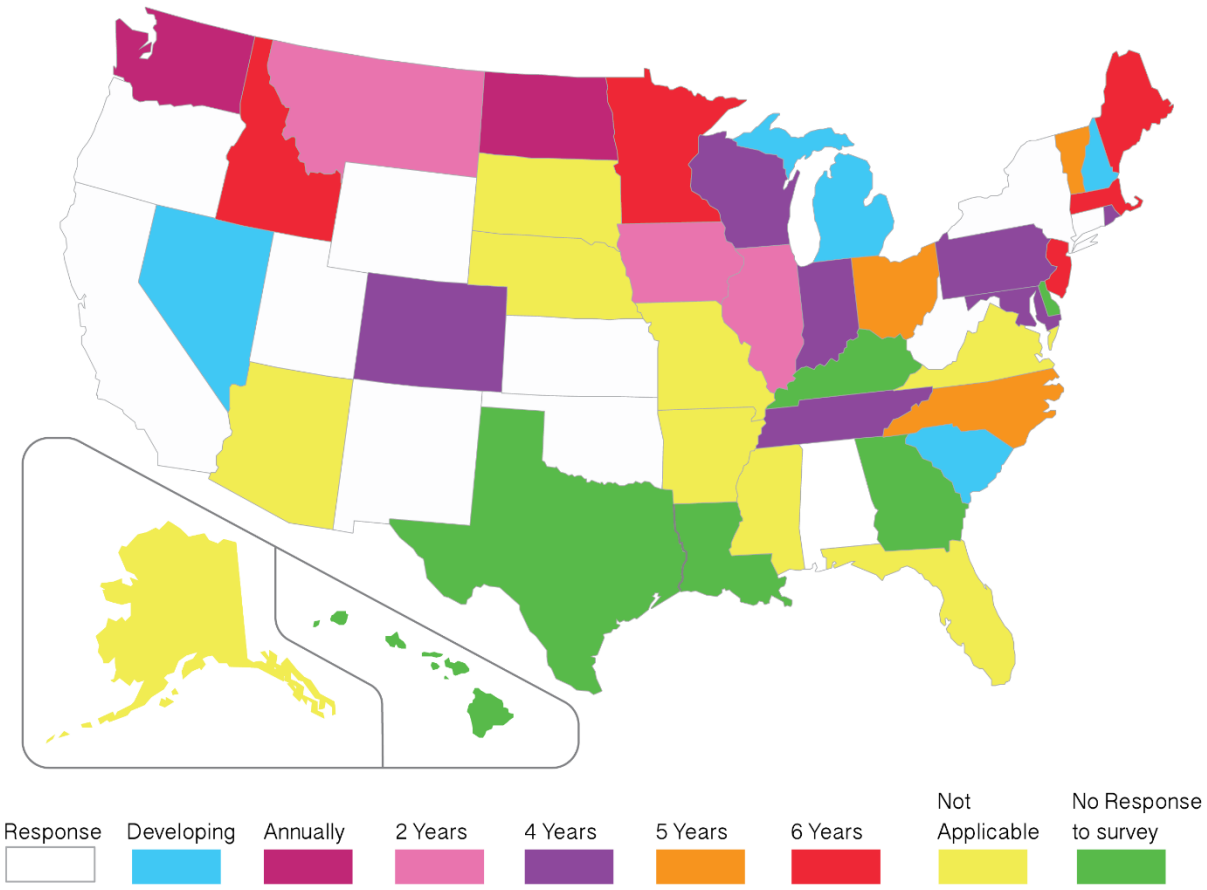

FIGURE 9 Frequency of Small Culvert Pipe Inspection by State

There are a few important points that come through based on the responses. First, as shown in the map, three states (MI, SC & NV) indicated that they are in the development phase of a small culvert pipe inspection and inventory program. In addition, some states provided an inspection frequency, but also added additional qualifiers, such as inspecting more frequently if the condition of culvert warranted concern. Other states indicated that they did not have a frequency with which they inspected culverts, but they did so on a project-by-project basis or in response to flood events. This additional information is captured in FIGURE 10.

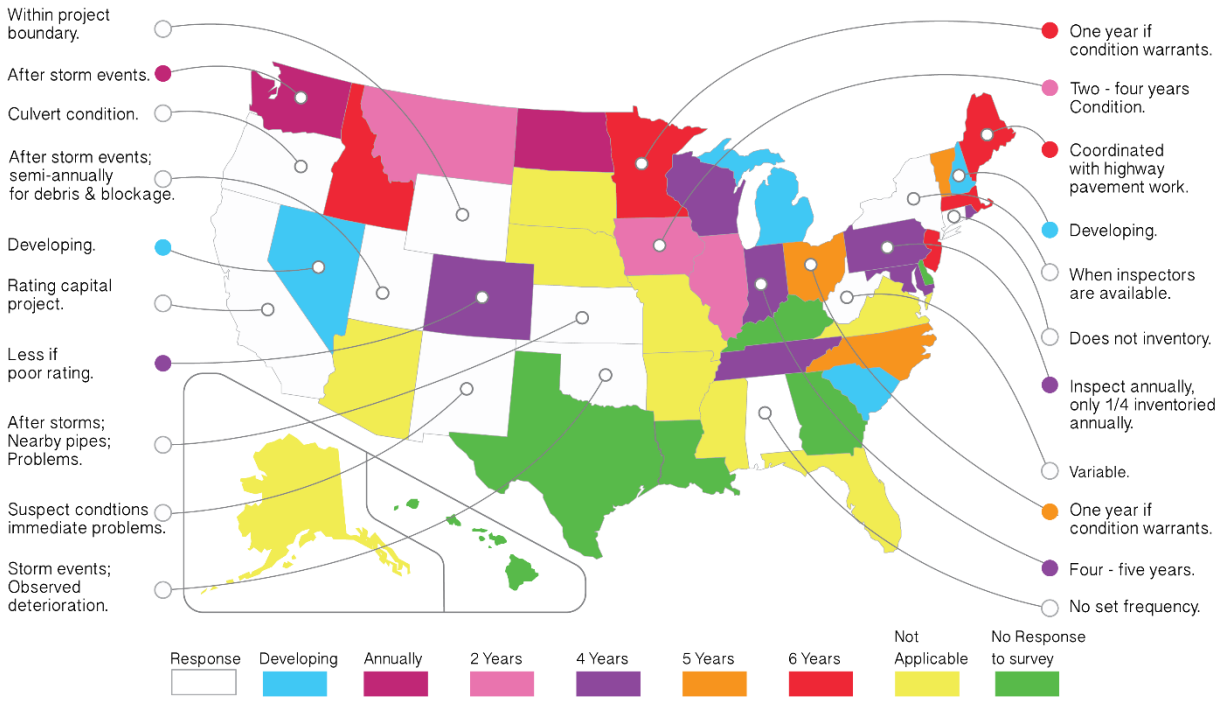

FIGURE 10 Inspection Frequencies with Added Information

Considering the inspection frequencies and the number of small culvert pipes (Question 9) that a state has, the magnitude of small culverts that exist in many states makes frequent inspections fiscally challenging, if not impossible. This observation alone highlights the importance of thorough inspections when inspections can be performed, as it is very likely that they will not be done again in the near future. Two states, Minnesota and Ohio, seem to have found a good balance between maintaining an inspection frequency that will not overwhelm staff, while addressing the need to monitor small culvert pipes whose conditions present concern. It is no surprise that these two states have been leaders in small culvert inspection and inventory programs. Therefore, it seems that the inspection frequency should be a reflection of available in-house staff or funding for a contractor. For those culverts that are in poor condition, they would be inspected more frequently until it is possible to replace them.

Question 12 – Staff for Small Culvert Management

Question 12 asked, "How many people are needed within your state to perform the inspections of small culvert pipes? Are they permanent employees, interns, or contractors?"

Question 9, which asked states to identify the number of small culverts they had, showed the sheer magnitude of the challenge of inspecting and inventorying small culvert pipes. States are estimating that they have thousands of small culvert pipes, noting that their inventories are often not complete. The response from one DOT to this question about number of people needed summed it up best, "More than we have." Yet, some states are finding ways to grapple with this volume, while getting the information that they need. For example, five states (MN, NH, PA, WA and WI) indicated that they are making use of student workers, college interns, or summer workers. The researchers followed-up with each of these states to obtain further information on

their use of student interns, which will be discussed in 3.4.1. However, Ohio, a state that has one of the most robust small culvert programs, indicated specifically that it does NOT make use of student interns for its small culvert asset management program. Five states (ID, ND, OK, SC & UT) indicated that the inspection of small culverts falls to maintenance. Two states (MT & TN) indicated that they make use of bridge inspectors; however, it appears that both of these states have limited the scope of their small culvert programs. One state (IN) indicated that both bridge and maintenance crews are tasked with the inspection and inventory of small culverts.

Question 13 – Small Culvert Pipe Inspection Training

Question 13 asked, "What kind of training do you provide to inspectors of small culvert pipes?"

Many states indicated that they do not offer any sort of training for small culvert inspection (AL, AZ, ID, ME, NM, OK, & VA). Six state survey respondents (CO, IL, MD, NY, RI, & TN) indicated that those inspecting small culverts receive the same inspection training as those that inspect bridges. The fifteen states that indicated that they provide some type of in-house developed training include: CA, IN, IA, KS, MN, NH, NC, ND, OH, OR, PA, SC, UT, WV, and WI. However, there is much variability in the descriptions of the thoroughness related to this training. Caltrans, for example, indicated that its training consisted of "confined space, general safety and culvert inspection, and robotic equipment operation." Others indicated that they offered on the job training, or just simply that the training was "informal." Some states indicated that the amount of training provided to inspectors was up to the discretion of each district.

There currently is no National Highway Institute (NHI) training for small culvert inspection available. After contacting NHI about currently available trainings, the NHI representative directed the inquirer to two courses presently offered by NHI: FHWA-NHI-134108H (Plan Reading: Culvert Plans – WEB-BASED) and FHWA-NHI-135056 (Culvert Design). One of the most significant recommendations that will be made as a result of this research is that NHI or some similar entity develop a training for small culvert inspection. To convey the severity and need for such a training, the following is an excerpt provided by one of the survey respondents regarding a culvert that had failed on a state roadway:

> *"…it was inspected by [the state]…They [the inspectors] inspected the small culvert [at an earlier date]. During this inspection, they found that scour had undermined the culvert outlet. This culvert had been widened with a metal pipe. The scour caused the failure of this widened section with the result that the outlet was partly blocked. Our inspectors should have recognized this as a serious problem and downgraded the culvert to CRITICAL condition. They should have prepared a detailed inspection report and submitted it immediately so that remedial action could have been rapidly taken. Sadly, they did not recognize the seriousness of the problem. They continued to say the culvert was in FAIR condition…Unfortunately, we did not have much time for a response (and what time we did have was wasted because the depth of the problem remained unrecognized until failure occurred) since this culvert was hit by a heavy flood event just…days later… This flood completed the destruction of the culvert and resulted in a fatality…The failure of our inspectors to recognize the seriousness of the problem was unfortunate and seems to indicate[d] that additional training in small culvert inspection*

is needed. Unfortunately, [there is] little training readily available on this topic from the normal sources such as the National Highway Institute."

Question 14 – Small Culvert Inspection Scale

Question 14 asked, "What type of inspection scale does your state use for small culverts?" Four responses were provided:

- 1-4
- 0-9
- A qualitative scale
- Other (please specify)

FIGURE 11 shows the states that responded using the three defined categories by the question response (recall that Delaware, Georgia, Hawaii, Kentucky, Louisiana, and Texas either provided little information or did not respond to the survey, see Question 1). For those listed as "No Response," this includes both those that indicated that they had a small culvert inspection program and those that do not. The majority of the states indicated that they used a qualitative scale. Note that Maine had indicated that it used "Good, Fair, Poor and Critical;" however, this is a qualitative scale, and from the survey effort, the researchers identified that the small culvert asset management program was developed in collaboration with the three states of this region (Maine, New Hampshire, and Vermont). Therefore, considering that two of the three indicated that they use the "Good, Fair, Poor and Critical" scale whereas New Hampshire indicated that it used a qualitative scale, they all were grouped into this category. Several of the states (ID, NC, ND, WI) that indicated that they used another scale, which were grouped into the "Other" category, indicated that it was based on condition or the deficiencies. South Carolina used a scale similar to those that used a 1-4, except that they had a fifth category (e.g., 1-5). New York indicated that it was moving from the 0-9 scale to the 1-4 scale. It seems that New York State DOT concurred with the NCHRP 14-26 finding that "there was not enough distinction between ratings to justify the ten-point scale" (3). Nevada DOT indicated that it was currently developing the rating system for its small culvert asset management program.

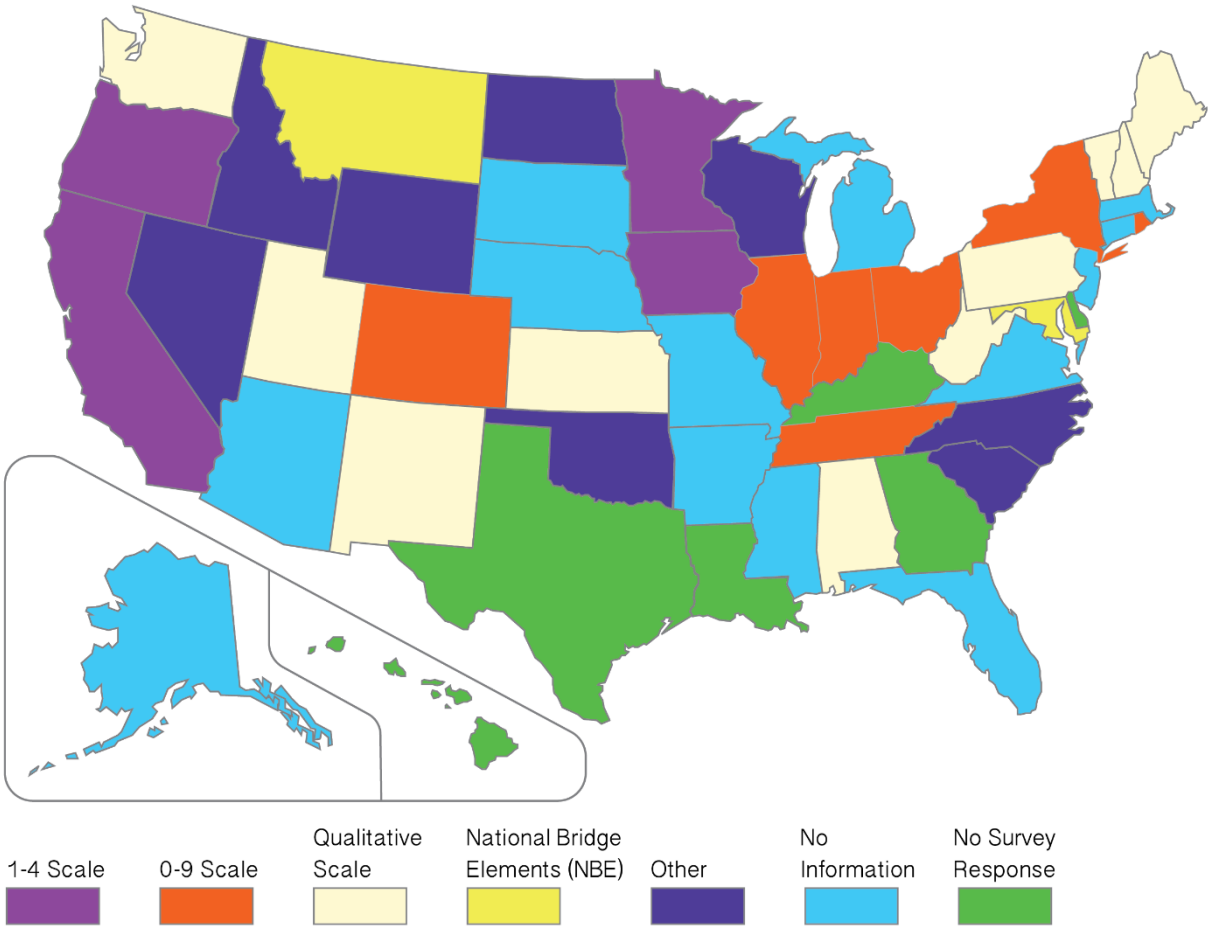

FIGURE 11 Inspection Scale for Small Culverts

Question 15 – New Installation Inspection

Question 15 asked, "Is it standard practice for your state to inspect a NEW small culvert immediately after it is installed?" Three responses were provided:

- Yes
- No
- Other (please specify)

FIGURE 12 shows which states inspect the small culvert immediately after installation, which ones do not, which states provided a different method, which states did not provide a response (typically because they indicated that they do not inspect small culverts), and the three states that did not provide a survey response.

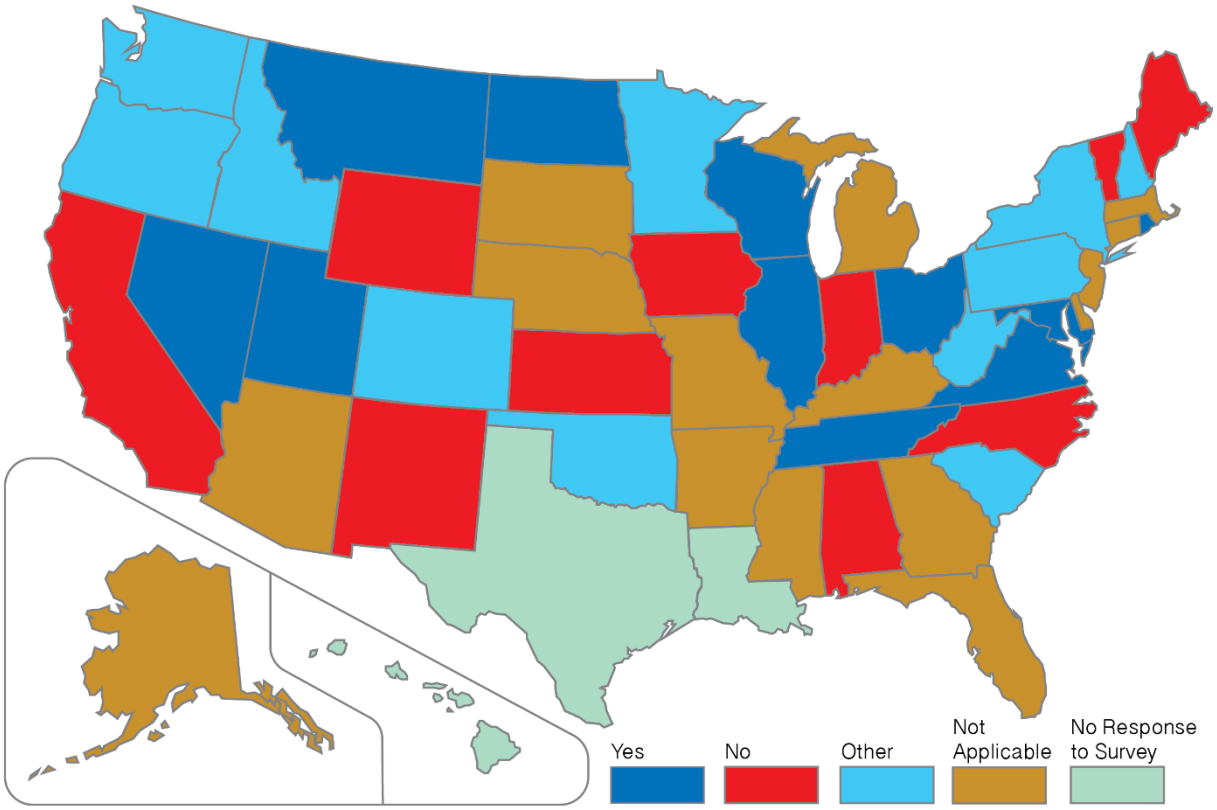

FIGURE 12 Small Culvert Inspection Practices After New Installation

Eleven states (IL, MD, MT, NV, ND, OH, RI, TN, UT, VA, & WI) indicated that they do inspect small culverts immediately after they are installed. Ten states (AL, CA, IN, IA, KS, ME, NM, NC, VT, & WY) indicated that they did not. (Note: There were two survey responses for CA that contradicted one another. However, considering that full information was provided for the respondent who indicated "No," this was taken as the final answer.) For the eleven states that chose "Other," the majority indicated that some or all of the small culverts are inspected during the construction phase as a part of that contract. States also indicated that at some later period of time the newly installed culverts are inspected for the purposes of small culvert asset management, typically in line with the on-going inspection program.

Question 16 – Small Culvert Data Collection Tools

Question 16 asked, "What type of device does your state use to collect data (e.g., an iPad, Trimble) for small culvert pipes? Would you recommend it to other states?"

FIGURE 13 shows the types of data collection tools used by the various DOTs.

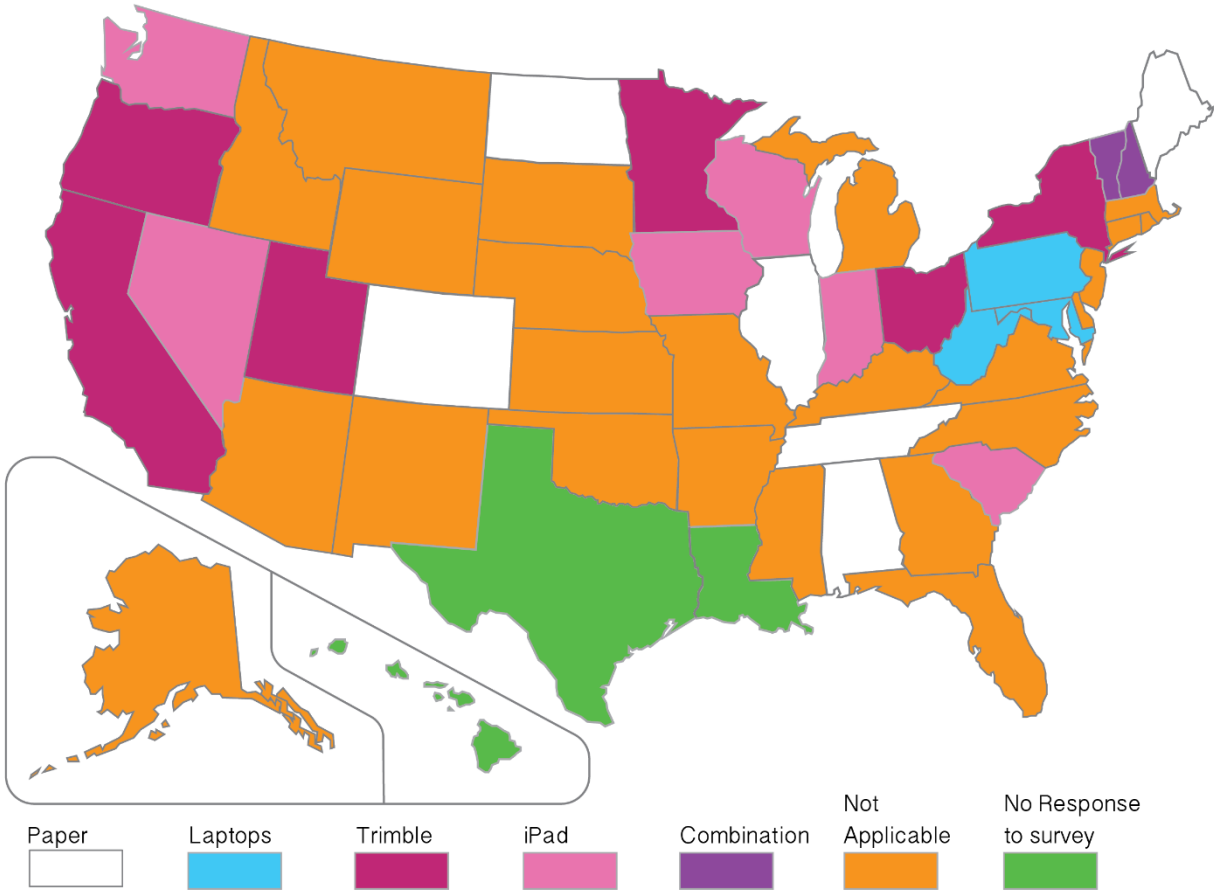

FIGURE 13 Small Culvert Data Collection Tools

Six states (AL, CO, IL, ME, ND, & TN) reported using paper records. Three states (MD, PA & WV) indicated that they made use of laptops, with some type of software or application to enable them to collect data. Six states (CA, MN, NY, OH, OR, & UT) reported using some type of Trimble unit. Six states (IA, IN, NV, SC, WA & WI) reported using an iPad in some capacity. Two states (NH & VT) indicated that they are using a combination of Trimble and iPad. Vermont DOT elaborated with, "Trimble mapping grade units for initial collection and inventory. iPads and other mobile devices for re-inspection and updates. Have to have a mix of accuracy and tools." The Ohio DOT indicated that while it currently uses Trimble to collect the data, it is planning on moving towards utilizing an iPad application. Therefore, based on the present technology, which is rapidly evolving, it appears that the majority of the states are moving toward the use of iPads. However, some of the respondents commented on the level of accuracy that iPads can enable and the need for cellular connection as potential problems with using iPads or the like.

Question 17 – Small Culvert Pipes Inventory Software

Question 17 asked, "What software does your agency use to inventory small culvert pipes? Three responses were provided:

- AASHTOWare Bridge Management (formerly Pontis)
- Agile Assets

- Other (please specify)

Three of the states (CO, RI, & WY) indicated that they are using AASHTOWare. However, it is interesting to note that in Question 9, these three states indicated that they had relatively few small culverts when compared with states like Ohio and Minnesota that have well documented small culvert management programs. Indiana and Utah currently use Agile Assets and two other states (MN & NY) indicated that they are planning on using Agile Assets in the near future. The Ohio DOT, on the other hand, indicated (in a follow-up interview) that the agency had considered Agile Assets, but then chose to go in a different direction. There were several states (IL, MN, ND, OH, PA & WI) that indicated that they were using a state-specific inventory program for their small culvert pipes.

Question 18 – Small Culvert Inventory Data

Question 18 asked, "Please list any data that you record in your inventory on the status of a culvert, or send an inventory sheet."

The following states provided inventory information: CO, IA, ME, MD, MT, MN, NC, ND, NH, OH, OR, PA, RI, SC, UT, WA, WI, WV, & WY. Illinois indicated that it treats its small culverts from 6 to 20 feet the same as bridges; however, the respondent did not provide information about the inventory attributes. Nevada indicated that it would send the list via email, but it has not been received. The PennDOT respondent directed the researchers to a website, but it was unclear which reference he was referring to. Maine, Maryland, Minnesota, North Dakota, Pennsylvania, West Virginia, and Wyoming provided a short synopsis of their information or directed the researchers to other sources. The remaining states provided inventory sheets, which in some cases were simple one pages sheets and in others long list of attributes. When reviewing the data inventoried across the states that provided this information, the following TABLE 7 lists inventory data that were found six or more times in the information provided by state survey respondents.

TABLE 7: Frequently Found Inventory Data

Inventory Data	Frequency	Within State
Culvert Shape	11	IA, IN, OH, OR, PA, SC, TN, UT, VT, Waukesha County, WI
Culvert Length	10	IA, IN, OH, OR, PA, SC, TN, UT, Waukesha County, WI
Culvert Material	10	IA, OH, OR, PA, SC, TN, UT, VT, Waukesha County, WI
Comments	8	IA, IN, OH, OR, TN, UT, VT, Waukesha County
County Code	7	IN, OH, PA, SC, TN, UT, WI
Road Name	7	IA, IN, OH, PA, TN, UT, VT
Culvert Width	6	IA, PA, UT, VT, Waukesha County, WI
Number of Barrels	6	IA, OR, SC, TN, UT, Waukesha County
Culvert Latitude	6	IN, OH, SC, TN, UT, WI
Culvert Longitude	6	IN, OH, SC, TN, UT, WI
Mile Marker	6	IA, OR, SC, TN, UT, VT

Additional attributes, found in less than six of the sources, can be found in the Appendix B: Survey Question Details and open-ended responses.

Question 19 – Eliminated Small Culvert Inventory Data

Question 19 asked, "Have you stopped collecting any types of data, or are you planning to, in your small culvert inventory? If so, why?"

The interpretations of this question by survey respondent seem to vary. However, a response by the New Hampshire Department of Environmental Services, New Hampshire Geological Survey touched on the reasoning behind the question, "The primary reason is that the volume of culverts that NH has assessed as part of its initiative has exceeded the existing staff capacity…" Maine DOT expressed a similar sentiment indicating that it is "evaluating how to more reasonably deal with inspection cycles and condition ratings." Ten states (IA, IN, MT, ND, OH, PA, RI, SC, TN & WY) simply indicated 'no,' they were not planning on removing any of the data fields currently corrected. The number of small culverts in these states varies from those with a lot (OH) to those with few (MT); therefore, the magnitude of the data collection does not seem to have a clear influence. One interesting contradiction is that while Colorado DOT was considering including culvert slope, Oregon DOT was planning on removing this, finding that it, "could not get need[ed] accuracy with equipment plus this information is not used for culvert design as a more accurate survey grade would be used for slope and channel profile." The New Hampshire DOT indicated that it was considering including "wildlife crossing designations" in its small culvert data inventory.

Question 20 – Integrating Photos in Small Culvert Inventory

Question 20 asked, "Does your small culvert inventory allow you to incorporate photos into it? If so, how?'

FIGURE 14 shows which states currently incorporate photos.

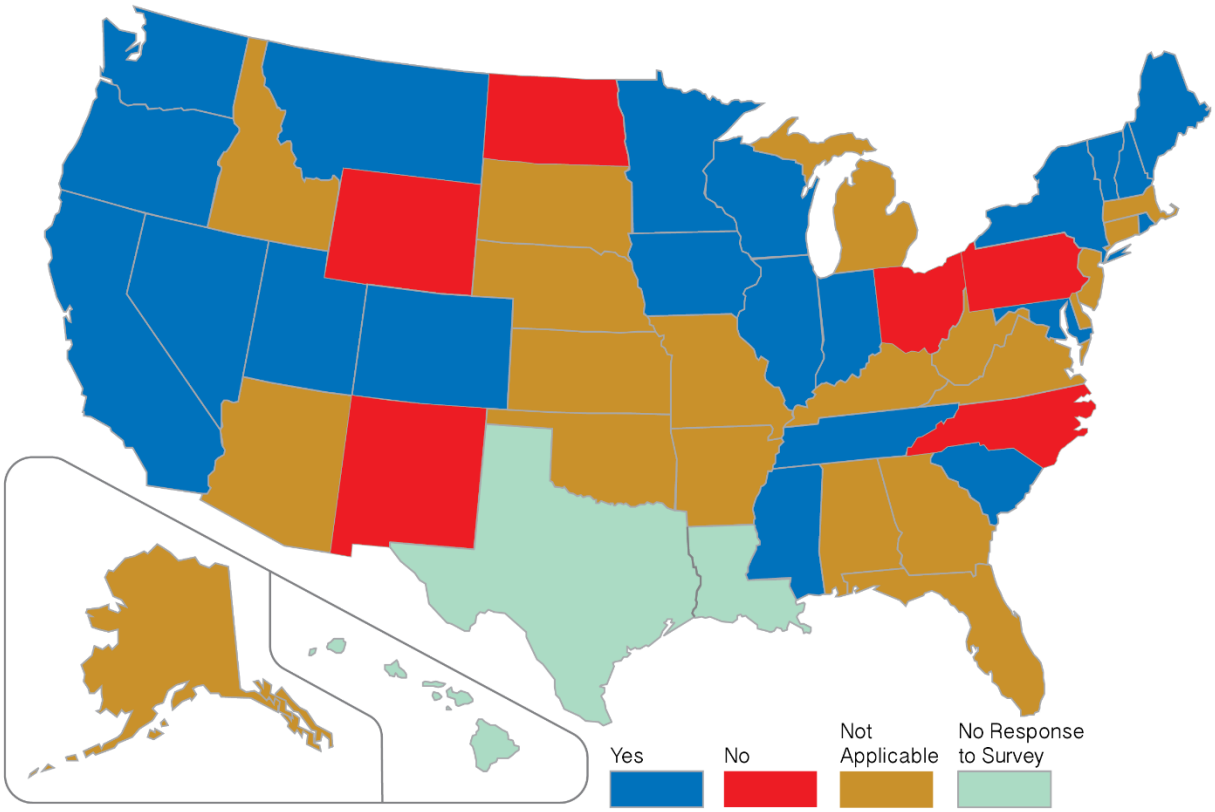

FIGURE 14 Ability to Incorporate Photos into Small Culvert Inventory

Twenty-one of the state respondents (AL, CA, CO, IL, IN, IA, ME, MD, MN, MT, NV, NH, NY, OR, RI, SC, TN, UT, VT, WA, & WI) indicated yes, and provided some additional details. Clearly, there is value in having a photo of the condition state of small culverts. In fact, making use of photos for condition ratings is the recommendation of NCHRP 14-26 (3). A few states (NC, ND, NM, OH, PA, & WY) indicated that they cannot incorporate photos. (Note: Ohio indicated that it took photos and stored them elsewhere.) While it is a bit unclear based on the answers provided, the responses indicate that for the most part, photos are taken and made available via a folder on the statewide network. Many survey respondents indicated that they took photos with the iPads, which were uploaded later. Therefore, there appears to be a preference for iPads or the like because of their capability to take photos, likely with relative ease. In addition, a case study of the Washington State DOT mobile device application can be found below.

Question 21 – Inventory Implications of Small Culvert Replacements

Question 21 asked, "What happens to a small culvert record in your inventory when the culvert is replaced?"

The majority of the respondents seemed to indicate that the record is retained in some capacity, whether or not it is stored as "inactive" or the like depends upon the inventory system used. In addition, the Wisconsin DOT indicated that within the last 10 years, the agency started retaining

a record in its software. Interestingly, the Utah DOT, which indicated in an earlier question that it uses Agile Assets explained, "We currently do not have an efficient way of doing this. Culvert record should be manually updated in the OMS database when the culvert is modified. However, there is no check for whether or not this actually gets done." The Ohio DOT expressed a similar sentiment when explaining why it chose not to use Agile Assets. It appears, therefore, that there may be some challenges with automatic updates when using Agile Assets, although since the questions asked were not specific to this tool, this cannot be definitively concluded.

Question 22 – Cost of Small Culvert Inventory Platform

Question 22 asked, "Approximately how much did it cost to create/purchase the platform that your state uses to inventory small culvert pipes?"

Only six state survey respondents (IA, ME, MN, NH, SC & VT) provided specific dollar amounts regarding the cost to create or purchase a platform for inventorying small culvert pipes. Therefore, their responses are included below.

"$100,000"

"The whole system cost about $3 million over the past 20 years…but culverts are only a piece of a system"

"Best guess is about $200,000 every 4 years for updates to in-house software plus roughly $150,000 annual IT maintenance."

"Less than 100k for small culvert platform."

"The platform we use is the iPad, the app cost $120,000 to have developed"

"Roughly 300K for hardware/software for collection"

However, it appears that, while system dependent, the cost can range anywhere from $50,000 to $300,000 for the actual system. Maintenance costs of the system extend beyond this estimate and are addressed in Question 23. However, these costs are estimates, as there was limited information provided by the state survey respondents. For many of the survey respondents that did not provide costs, they indicated that it was part of a larger system, or developed in-house (AL, IL, MD, MT, NV, ND, PA, TN, & WI).

Question 23 – Cost of Maintaining Small Culvert Inventory Platform

Question 23 asked, "What are the approximate costs of software/hardware to maintain the inventory system for small culvert pipes?"

Limited information regarding the cost of the software for maintaining the inventory system was provided. However, of those state survey respondents who provided cost information, several indicated that the costs were "minimal." Several states indicated that they used in-house staff to

maintain their systems, so actual costs were unavailable. The two states that provided actual dollar amounts indicated that the cost for maintenance of the software for inventorying small culvert pipes was either $40 or $20,000, annually. Therefore, there was a wide range provided.

Question 24 – Cost of Small Culvert Personnel

Question 24 asked, "What are the approximate personnel costs to maintain the inventory system for small culvert pipes?"

Similar to the last question about cost, there were a limited number of responses, and of those provided, many survey respondents did not provide a monetary value. Of those who did, there seemed to be a mix in the dollar amount provided. Some respondents seem to provide the price for just the software system whereas others appeared to provide the cost to obtain the data for the inventory. For example, Maine DOT indicated that it was from $50,000 to $100,000 for the "system" which can be interpreted as the software system. In contrast, Caltrans indicated that the cost was $2.5 million. Of the responses provided, it appears that the maintenance of the software is about $100,000 and roughly one full-time employee for maintaining the inventorying system, whereas for the cost of personnel to provide the data for the inventory system, is roughly $1 million to $2 million annually. Again, these are very general estimates based on limited information and as such, these estimates should only be taken as "ball park" figures.

Question 25 – Prioritizing Small Culvert Replacement

Question 25 asked, "How does your agency prioritize replacing small culverts?' Four potential responses were provided:

- As-needed
- Age of culvert
- Remaining life span
- Other (please specify)

FIGURE 15 provides an indication of the approach that state DOTs use to replace small culverts.

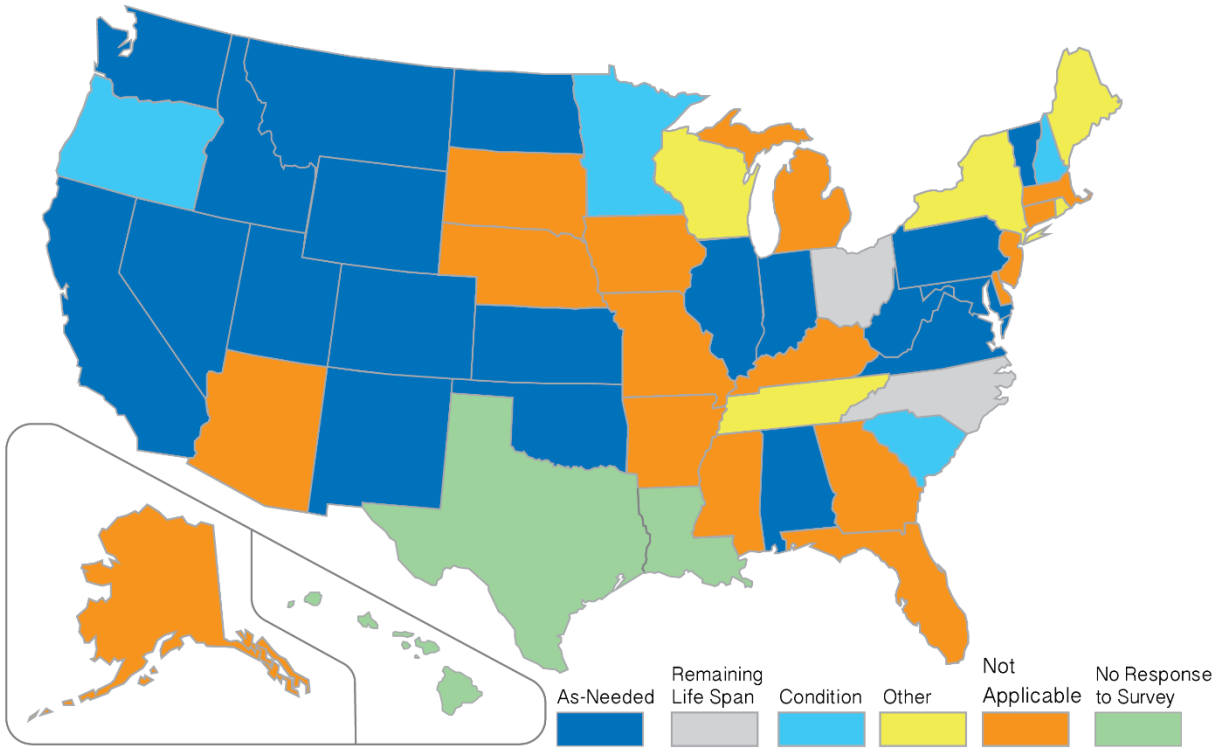

FIGURE 15 Prioritizing Small Culvert Replacement

Of the thirty-two states (AL, CA, CO, ID, IL, IN, IA, KS, MD, MT, NV, NM, ND, OK, PA, UT, VT, VA, WA, WV, & WY) that provided a response to this question, twenty-one of them indicated that they replace small culverts on an "as-needed" basis. A few of the "other" responses indicated some permutation of "as-needed," such as, "As needed or when highway is upgraded or widened" (TennDOT). Only two states, North Carolina and Ohio, indicated that they currently replace small culverts based on remaining life span. Wisconsin indicated, however, that it will be utilizing deterioration modeling in the future. Oregon and South Carolina indicated that the type of route had an influence on small culvert replacement. New Hampshire was the only state that indicated that the environmental perspective had an influence on small culvert replacement. Finally, a few states indicated that the condition had an effect on their replacement of small culverts (MN, NH, OR, & SC).

Question 26 – Inspection of Locally Owned Small Culverts

Question 26 asked, "Does your state inspect locally owned culverts?" Four potential responses were provided:

- Yes
- No
- Unsure
- Other (please specify).

Survey respondents who indicated that they did not inspect small culvert pipes skipped Question 8 through Question 25, continuing the survey at this question.

FIGURE 16 summarizes which states inspect locally owned small culvert pipes; it shows that the majority of states indicated that they do not.

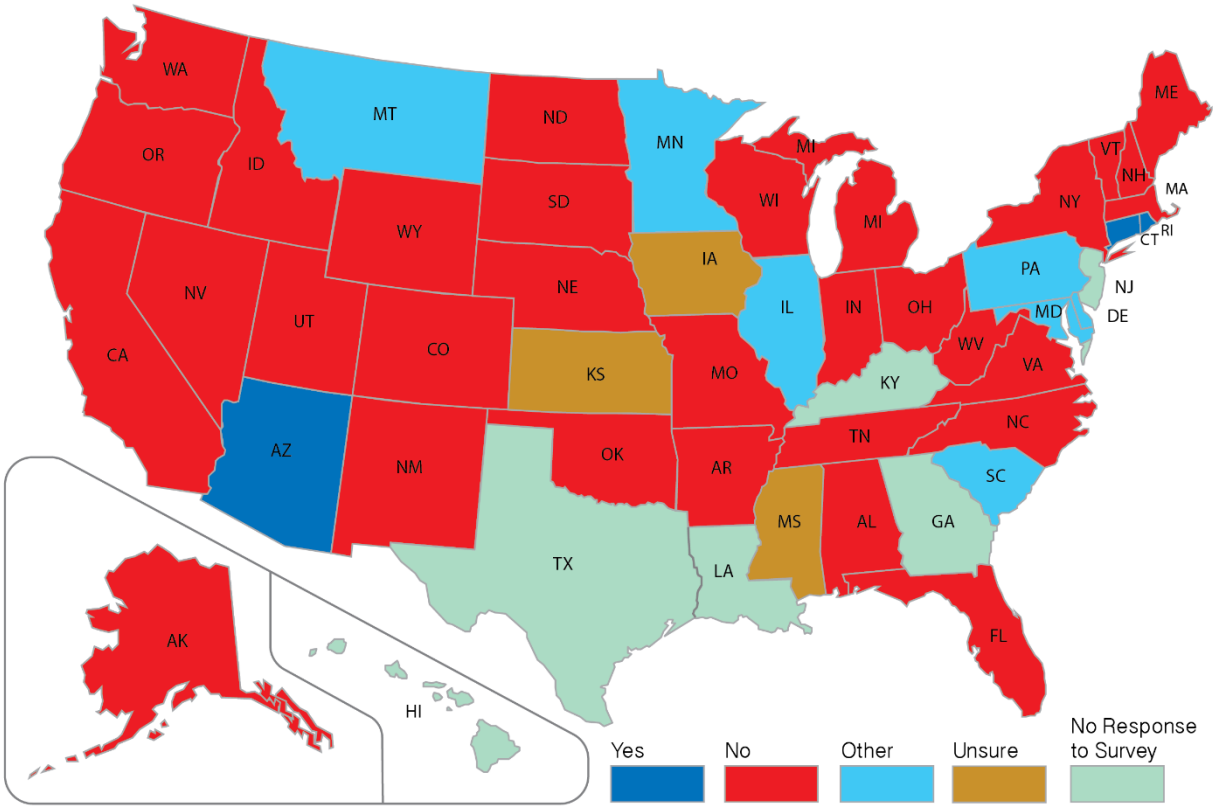

FIGURE 16 Inspection of Locally Owned Culverts by State

Thirty-one states (AL, AK, AS, CA*, CO, FL, ID, IN, ME, MA, MI, MO, NE, NV, NH**, NM, NY, NC, ND, OH, OK, OR, RI, SD, TN, UT, VT, VA, WA, WV, WI & WY) or sixty-two percent of all states in the United States (seventy percent when considering only states that provided survey responses) affirmed that they do not inspect local culverts. (Note: * There were multiple respondents from this state; one indicated no, another survey respondent was unsure. **The New Hampshire DOT indicated that the state does not inspect, whereas the New Hampshire Department of Environmental Service, New Hampshire Geological Survey indicated that the state does.) Therefore, the majority of state DOTs do not take on the responsibilities of inspecting local culvert pipes. However, one survey respondent indicated that several separate culvert pipe failures under a locality's jurisdiction have resulted in fatalities, thereby making this an area of concern.

Three states indicated that they were unsure as to whether or not their state inspected local culverts (IA, KS & MS), and six provided additional information regarding their practices for inspection of small culverts under local jurisdiction:

"It is recommended but not required for local agencies to have a small structure inventory."
"Local jurisdictions generally inspect per own criteria"
"If they are within the highway right of way they might be inspected."
"If W or D > 8 ft and on (TE route)"
"In general, we don't inspect small locally owned culverts unless they are under a state road."
"Only bridge length culverts"

Generally, the responses suggest that due to the sheer magnitude of small culverts under the roadway, states have to identify some limit to ensure that the workload is manageable.

In an email response, the Connecticut DOT survey respondent indicated that Town-owned structures greater than 20 feet in length are inspected. In addition, the respondent indicated that about once every 20 years, staff members are inspecting Town owned structures greater than 6 feet and less than 20 feet.

Question 27 – Localities Inspecting Small Culverts

Question 27 asked, "Do you know of any localities within your state that are inspecting their culverts?"

Six states (IL, MD, NV, NH, OR, & SD) indicated that they knew of localities within their state that were inspecting small culverts, but they did not provide more specific information. They were not requested to do so.

Three states (CO, ND, & OH) indicated that they knew of local entities that were inspecting their culverts, and they provided additional information regarding the status, such as making the statewide culvert database accessible to a locality (OH). Three also indicated that they did not believe a locality was inspecting their culverts, but they could not be sure (OK, PA, & TN).

There was one exemplary state that engages localities in the need to inspect and inventory small culverts: Vermont. The state has a website (https://www.vtculverts.org/) entitled, "VTCULVERTS" (FIGURE 17).

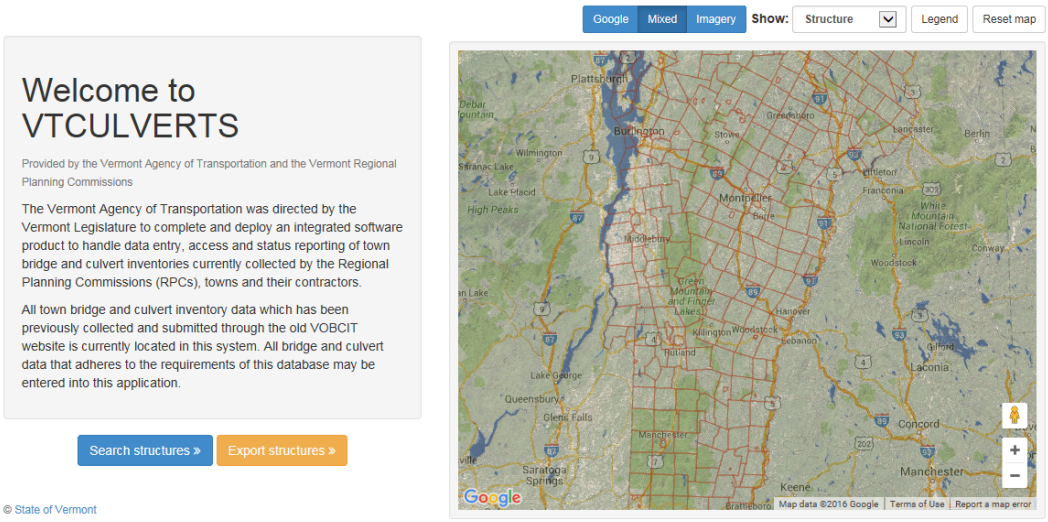

FIGURE 17 VTCULVERTS (Courtesy Vermont DOT; Vermont Association of Planning & Development Agencies; Resource Systems Group)

It provides the following information regarding a culvert structure:

- Type (Bridge or Culvert)
- Municipality
- Road
- Inventory Date
- Culvert Type (Other, Arch, Mixed, Round, etc.)
- Culvert Material (Other, Concrete, Aluminum, etc.)
- Height
- Width
- Length
- Overall Condition (Unknown, Closed, Urgent, Critical, Poor, Fair, etc.)

Within the map containing the culverts, one can search based on importance or condition of the culvert. In addition to allowing the user to view the culverts using a Google Map, the user can export the data in a shapefile or comma separated value (CSV) format. Clicking on a specific culvert allows the user to view the information about the culvert and photos for the culvert if they are available.

Five counties and two cities were specifically identified by respondents as inspecting small culverts:

- Shelby County (AL)
- Maricopa County (AZ)
- Pima County (AZ)
- Ada County Highway District (ID)
- Rock County (WI)
- Colorado Springs (CO)
- Phoenix (AZ)

In addition, the researchers know that Waukesha County, Wisconsin, both inspects and inventories culverts within its jurisdiction.

Question 28 – Drop Inlets

Question 28 asked, "Does your state inspect drop inlets?" Four response options were provided:

- Yes
- No
- Unsure
- Other (please specify).

The following table separates the responses into those that answered yes, no, unsure, and other.

TABLE 8: Drop Inlet Inspection

Yes	No	Unsure	Other
Alabama	Alaska	Massachusetts	Arizona
California	Arkansas	Mississippi	Colorado
Indiana	Connecticut	Wisconsin	Illinois
Maine	Florida		Iowa
Nevada	Maryland		Kansas
New Hampshire	Missouri		Michigan
Ohio	Montana		Minnesota
Pennsylvania	Nebraska		New Mexico
Rhode Island	New York		Oklahoma
South Dakota	North Carolina		Oregon
Vermont	North Dakota		South Carolina
Washington	Tennessee		Utah
	West Virginia		
	Wyoming		

Of the states that chose "other," in general, drop inlets were inspected as needed. For example, if the state had concerns or if it was convenient to inspect them during the inspection of a neighboring feature, they were inspected.

Question 29 – Culvert Failure

Question 29 asked, "To the best of your knowledge, has a culvert(s) ever failed within your state?" Three potential responses were provided:

- Yes
- No
- Other (please specify).

FIGURE 18 shows that the majority of the states in the United States have had at least one small culvert failure.

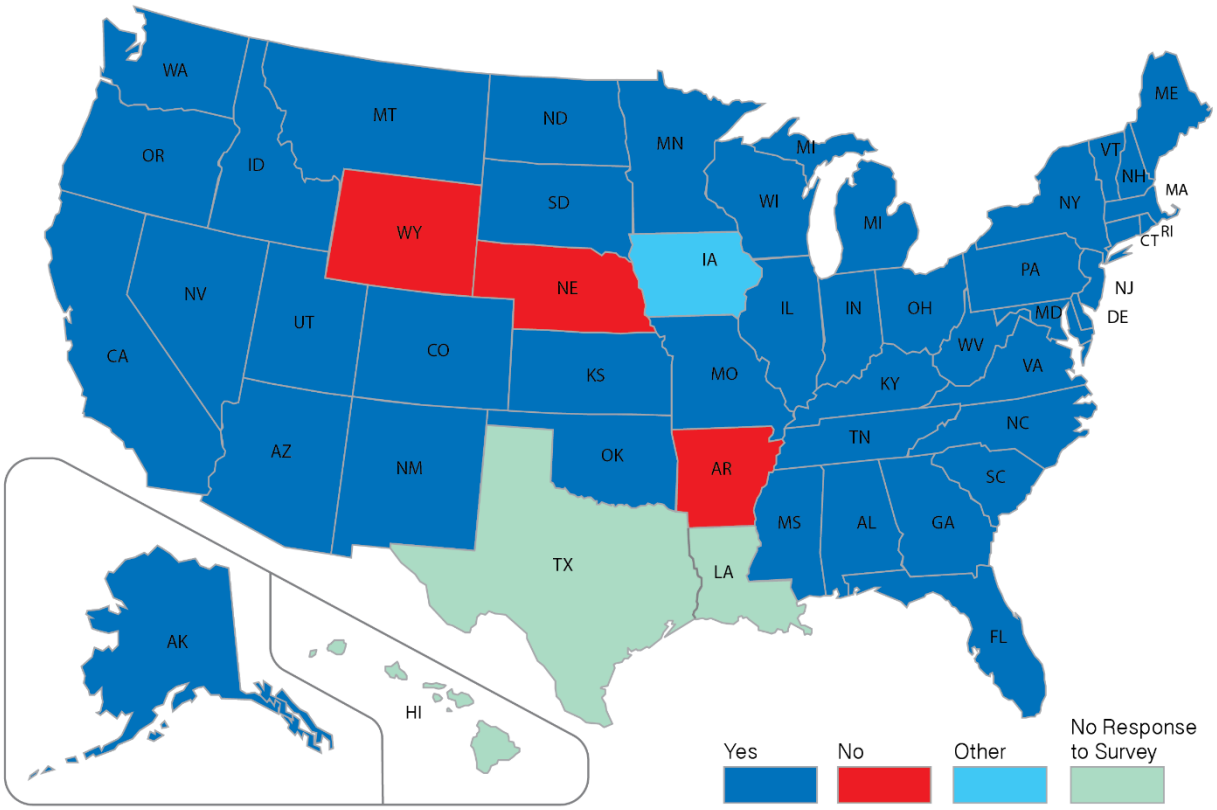

FIGURE 18 Culvert Failures

Only four of the states (AR, MS, NE, WY) that provided a complete survey response indicated that their state has not experienced a culvert failure. (Note: While Oklahoma had indicated that it did not experience any culvert failures, in Question 29, it identified culvert failures and as such, is included in the list of states that have experienced culvert failures.) It is interesting to note that these states also have some of the least developed small culvert inventory systems (TABLE 9). Only one state, Iowa, chose "Other." The Iowa respondent indicated that, "*Depends on the definition of failed. None have collapsed and caused injury to my knowledge*." The question was purposefully left vague to allow states to provide additional information if they choose. Thirty-six states, seventy-percent, indicated that they have experienced culvert failures: AL, AK, AZ, CA, CO, CT, FL, ID, IL, IN, KS, ME, MD, MA, MI, MN, MO, MT, NV, NH, NM, NY, NC, ND, OH, OK, OR, PA, RI, SC, SD, TN, UT, VT, WA, and WV.

Question 30 – Culvert Failure Details

Question 30 asked, "Please tell us about culvert pipe(s) that failed." Seven pieces of information were asked about culvert pipe failures:

A. What was (were) the size(s)?
B. What was (were) it (they) made of?
C. How old was (were) the pipe(s)?
D. What were the repair costs?
E. Were there any road closures as a result of the failure?

F. Did your state change any policies or procedures (e.g., inspection frequency, created an inventory) as a result of the failure?
G. Is there an understanding of what may have caused the failure (e.g., corrosion collapse, soil loss, sink hole)?

Overall, the magnitude of the problem is apparent when states report:

"We experience relatively frequent culvert "failures.""

"various sizes"

"Small culverts fail fairly often…"

Some survey respondents indicated that failures resulted in the loss of lives.

Question 31 – Research Comments/Questions

Question 31 asked, "Please provide any other comments or questions regarding this research."

Only fourteen survey respondents provided comments. Many survey respondents used this space to identify the individual who provided the information for the survey from the state. Therefore, for future surveys, it is recommended that a question ask for name and contact information of the final survey respondent in case there is a need to follow-up. However, this must be balanced with the need to provide survey respondents with anonymity, if that is desired. Other survey respondents expressed interest in the outcome of the research. One respondent summed it up well with:

"It would be interesting to know how other States approach the significant problem of aging structure that are under 20 feet in length."

Some survey respondents very shortly summed up the status of their small culvert inspection and inventory program with comments such as:

"We are in the process of setting up culvert collection."

"Field offices do not keep consistent inspection records for small culverts."

"Our system isn't perfect, but it's continuously improving."

"Michigan is in the process of developing a Transportation Asset Management System. One of the first assets to be tracked will be culverts with diameters 1' to 10'."

"The information provided in this survey was based on small culverts that were less than CFR required bridge length but greater or equal to 8 ft and on interstate or TE routes. There are thousands (no idea of how many) of small culverts outside of this range and route designations that are inspected and maintained by State maintenance force."

"NCDOT does not at this time have established policies and guidance for small culvert inspection and inventory. Much of this responsibility is primarily handled at the Division level, and each of our 14 Divisions may function somewhat differently and independently as to their specific practices as deemed relevant to meet the local needs. Our role in the central Raleigh NCDOT business units is to serve to support the Division Offices in this regard."

"We do not have a set method for inventorying our culverts. We have data from a one-time statewide inventory collected by engineering interns. That data is not managed or updated."

Categorizing State Small Culvert Inspection & Inventory Programs

The following table provides a categorization of all states based on the information provided in the survey responses. Five categories were created: 1) No Small Culvert Inspection/Inventory Program, 2) Partial or In-Progress Small Culvert Inspection/Inventory Program, 3) Intermediate Small Culvert Inspection/Inventory Program, 4) Advanced Small Culvert Inspection/Inventory Program, and 5) No Response.

TABLE 9: Small Culvert Inspection & Inventory Programs by State

	No Small Culvert Inspection and/or Inventory Program	Partial or In-Progress Small Culvert Inspection and/or Inventory Program	Intermediate Small Culvert Inspection and/or Inventory Program	Advanced Small Culvert Inspection and/or Inventory Program	No Response
1	Alaska	Alabama	Colorado	California	Delaware
2	Arizona	Idaho	Iowa	Illinois	Georgia
3	Arkansas	Kansas	Maryland	Indiana	Hawaii
4	Connecticut	Nevada	Montana	Maine	Kentucky
5	Florida	New Jersey	New York	Minnesota	Louisiana
6	Massachusetts	New Mexico	North Dakota	New Hampshire	Texas
7	Michigan	North Carolina	Pennsylvania	Ohio	
8	Mississippi	Oklahoma	Rhode Island	Oregon	
9	Missouri	South Carolina	Tennessee	Vermont	
10	Nebraska	Virginia	Utah	Wisconsin	
11	South Dakota	Washington			
12		West Virginia			
13		Wyoming			

3.4 POST-SURVEY FOLLOW-UP

3.4.1 Student Workers/Interns

A primary topic of interest that NMDOT wanted to learn more about was the use of interns to assist with a small culvert inspection and inventory program. Therefore, the following five questions were asked as a follow-up to state DOTs that indicated that they made use of interns:

- What do you feel are the advantages of using student workers?
- What are the disadvantages?
- From your state's experience with small culvert asset management, what are some of the tasks that your state has found to be a good fit for student workers?
- What kind of oversight did you provide to student workers?
- Where did you recruit student workers from (only local universities or elsewhere)?

Minnesota and Wisconsin provided direct responses to the questions. In summary, the two respondents seemed to agree that student workers can bring the latest in technology to the DOT. One interesting point made by the Wisconsin DOT respondent is that student workers help improve inspections by the questions that they ask. However, the respondents also agreed that the short-term nature of student employment is a drawback. The Minnesota DOT seemed to rely more heavily on student workers for GIS assistance. Both respondents, however, indicated that student workers assist with inspection along with a qualified employee. Both respondents emphasized that a student essentially serves as an assistant to a permanent employee. Finally, both respondents indicated that local universities were their primary sources of student workers.

3.4.2 Washington State DOT's Mobile Device

In 2008, Washington State DOT developed a mobile application using a Windows platform. By 2013, maintenance employees were frustrated with the cumbersome nature of the mobile application. As a result, the Washington State DOT began an effort to build a new application in a more user-friendly environment. Previously there were only a few hundred tablets for 1500 maintenance employees. With the new mobile application, the agency provided approximately 1100 iPads to the maintenance employees. The mobile application is called the Highway Activity Tracking System (HATS). Culvert inspection is only a small part of this mobile application. The entire application is centered on a GIS map. FIGURE 19 shows an example of the interface of the mobile device.

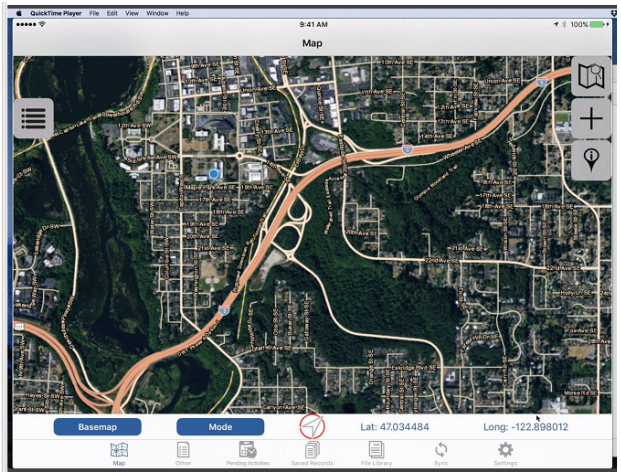

FIGURE 19 GIS Map for Washington State DOT Mobile Application

Every device is designed to work offline, since an internet connection is not always available. In the past, the mobile application required a user to load the device prior to heading out to the site, as the map was not live. Now, the user is able to work anywhere on the map. The underlying database for the application is Sequel. In addition, while the developers put some controls regarding who can or cannot add a feature, they tried to limit these restrictions. They have a "hide" feature that retains features that no longer exist, which can help if someone makes a mistake by accidently deleting a feature. To date, they have had no "big data" issues; however, the system has only been deployed since July of 2015. They do not currently limit the number of photos that a technician can add, and within the year, staff members have already added 50,000 photos. However, note that they are currently in the phase of inventorying existing culverts. There is the potential that this number will change significantly next year, as many photos might be part of establishing a baseline. While the mobile application currently does not include a guide for culverts, it does include guidance documents for other assets, like guardrails.

The development of the tool required six months of "straight" programming time, divided between two in-house programmers. They worked with a committee, made up of maintenance employees, typically those reportedly more open to technology, to provide input on the tool's development. Washington State DOT believes that the participation of these employees was instrumental in the development of the mobile application. It cost an estimated $1 million to get the project "out-the-door," with a large portion of the budget allocated to the cost of the iPads themselves. While the agency has not completed a formal evaluation to date, thus far, agency representatives believe the systems will prove themselves cost-effective over time, especially for documenting evidence for lawsuits. While there was some initial resistance in using the systems from the workforce (which has an average age of 50), users are now asking for more advanced systems. One significant advantage with their resulting product, is that unlike other asset management systems, the Washington State DOT device is slimmed down, which makes it more user-friendly. Washington State DOT also believes that tools like this can be used to attract a younger workforce, a significant concern considering that in the next five to eight years, eighty percent of its current workforce is expected to retire.

3.5 SURVEY CONCLUSIONS

Almost all fifty states provided a response to the survey for this research. Therefore, the researchers feel confident in the fact that the conclusions drawn present a thorough representation of the current state of the practice of small culvert inventory and inspection.

States are devoting greater effort to development of culvert inventory and culvert inspection systems, which aligns to national trends, as seen in publications from FHWA, GASB, and the forthcoming NCHRP report. Today, 33 states reported that they inspect culverts. Nineteen states reported that they had culvert inspection manuals; two states were in the process of developing a culvert inspection manual.

Defining frequency of inspections in each state was difficult because answers about frequency were often clarified with text indicating that inspections were triggered as much by culvert condition and external events as by routine inspection. The more valuable insight from this portion of the project is that it is critical that state DOTs balance available resources against culvert inspection needs. The most effective approach toward this was the tiered or risk-based inspection approach, whereby culverts with deteriorated condition or higher risk concerns (traffic, environmental, etc.) are inspected more frequently. The tiered approach allows each state to direct inspection teams to the locations with the greatest risk of failure or potential need for corrective maintenance, while continuing routine, but less frequent, inspection of other culverts.

There appears to be a need for a national culvert inspection training program. 21 states provided training targeted to culvert inspection, either developed in-house (15 states) or based on bridge inspection (6 states). An inquiry to the National Highway Institute (NHI) found that there is current no such course.

Mitigating the failure of small culverts supports Towards Zero Deaths and helps hold down overall state DOT costs, as a single culvert failure can cost millions to repair and cause avoidable crashes, unnecessary detours and traffic congestion. A rigorous culvert inspection program can cost less annually than the cost to replace a single failed culvert.

4 CULVERT ASSET MANAGEMENT SYSTEMS: OPTIONS FOR NEW MEXICO DEPARTMENT OF TRANSPORTATION

This project called upon the researchers to provide at least three options to NMDOT for implementing a culvert management system. The following text discusses the most common practices with regard to elements of these systems. These options serve as a menu for New Mexico (or any other state DOT considering this topic) to consider.

Which culverts to inspect?
The survey found two approaches to determining which culverts to inspect: Expanding the definition of bridges in the bridge inspection process and/or creating a separate database and inspection process for smaller culverts. Twelve states include culverts below twenty feet with thresholds of 5', 6', 8', or 10'.

Alternatively, many states conducted separate inspection programs for smaller culverts, often operating a separate database, and sometimes a culvert inspection training program and culvert inspection manual.

What inspection rating scale should be used?
Seven states indicated they use a 0-9 scale. Four states used a 1-4 scale. Ten states indicated they use a qualitative culvert rating scale. The preliminary NCHRP (3) recommendation is for a five-point scale, with a rating of 1 (Good) indicating a like-new component, with little or no deterioration that is structurally sound and functionally adequate and a rating of 5 indicating the component is failing.

How frequently should culverts be inspected?
As a general best practice, a state DOT should balance considerations of culvert condition and other risk factors against available resources in determining how often to inspect culverts. The NCHRP report (3) tentatively labels this a tiered inspection system, whereby agencies inspect culverts in a regular cycle that is accelerated for culverts in particularly poor condition or that exhibit other risk factors. For example, Ohio DOT conducts both routine inspections and interim inspections, with the latter "used for monitoring a particular known or suspected deficiency" (19). New York State DOT determines the recommended culvert inspection frequency based on the condition of the culvert (17).

One alternative to the tiered approach is routine inspection, whereby a state DOT inspects each culvert in a regular cycle. Seven survey respondents indicated that culverts are inspected every four years in their states. Five states inspected culverts every six years. Three states each reported inspection cycles of two years and five years.

A third approach toward timing of inspections is to target culvert inspections to locations where there are specific concerns about culvert condition – what the NCHRP report has tentatively labeled a special inspection. At least two states in the survey did not indicate routine frequency of inspections but indicated that inspections were tied to culvert conditions.

Fourth, inspection frequency may be determined in reaction to weather/climatic events to determine the extent of damage and need for maintenance. Four states highlighted this catalyst to culvert inspections.

NMDOT should also consider conducting an *initial* (3) or *inventory* (19) inspection when a culvert is first constructed to set out baseline conditions in the culvert.

Should NMDOT develop its own inspection manual?
As NMDOT considers whether and how to develop a culvert inspection process, one of the first steps in the process would be development of its own inspection manual. Two options stand out for consideration. First, it may be advisable to wait until 2017 when the new NCHRP report is finalized and released. In part, the report is recommending that inspections rely significantly on comparing conditions of the culvert under review to photos available in the report. It is anticipated that this will be an authoritative document that will provide guidance on all aspects of culvert inspection. NMDOT may want to monitor comments and development of this document over the next year or so.

Alternatively, if NMDOT wants to initiate an inspection program more quickly, it may want to review existing inspection manuals that have been developed by some of the more advanced states in this area. Existing state manuals that might be referenced include Ohio DOT, Minnesota DOT, Caltrans, NYDOT, Pennsylvania DOT and Vermont DOT.

Who will conduct inspections?
The survey identified four different approaches to staffing culvert inspections. Five states make use of student interns/workers and summer workers. Five states used maintenance staff. Two states used bridge inspectors. At least one state used central office staff.

Minnesota and Wisconsin shared several insights about use of students, observing that the students are beneficial because they understand the latest technology and may ask useful questions, but there was also a belief that students should serve as assistants to permanent employees.

How should culvert inspectors be trained?
The two most common approaches to training inspectors were use of an in-house training program (15 states) and use of bridge inspection training (six states). If NMDOT plans to initiate a culvert inspection program, the state may want to contact one or more states with an in-house training program to see what can be adapted to New Mexico's needs.

What equipment should be used to gather culvert inspection data?
The survey identified four common approaches to collection of culvert data: Trimble (six states), iPad (six states), paper (six states), and laptops (three states).

What software should be used to collect and store inventory and inspection data?
The survey found that six states used in-house software; four states use or are moving toward using Agile Assets software, and three states use AASHTOWare software. At present, New Mexico has an in-house inventory of 55,590 culverts.

What data fields should be collected in a culvert inventory? Inspection database?
The most common data fields are presented in detail elsewhere in this document. NMDOT should review these fields to determine which would be most meaningful, how to integrate them with the existing database, as well as how to define each field in a data dictionary.

5 KEY DATA FIELDS

Task two of the research project for NMDOT requested that researchers identify key data fields and data formats that can be used for all NMDOT inventories to facilitate integrating all fixed asset data into a single Transportation Asset Management Program (TAMP) database in the future. Early in the study, the researchers were presented with an existing NMDOT culvert inventory database that contained data on latitude, longitude, highway number, mile marker, material and other information for 55,590 culverts. However, many of the fields found in the inventory were blank. Staff from the Asset Management and Planning Division within NMDOT reviewed the existing database and indicated that the WGS 84 coordinates could be used to align the inventory to the state's linear referencing system and/or could the coordinates could be used to integrate the culvert database into NMDOT's maintenance management system/Agile Assets TAMP database in the future if/when a decision is made to proceed.

The existing culvert database is only an inventory database. Unfortunately, it was created more than 10 years ago and lacks a data dictionary to define individual data fields. If NMDOT wishes to use the culvert database for inspection purposes, additional data fields must be added and a detailed data dictionary should be developed. NMDOT Drainage Bureau staff identified the following fields as required if NMDOT were to move forward with a culvert inspection database: latitude, longitude, county, route, mile post, DOT district, patrol yard, date of inspection, ID number, shape, material type, diameter (in feet), width (in feet), height (in feet), number of pipes/barrels, overall rating of structure, and list of conditions or problems associated with the structure. Additionally, the following fields would be beneficial: city, water feature name, year of construction, as-built plans, comment field, length (in feet), elevation invert of structure invert, elevation invert of structure outlet, skew, inlet end treatment, outlet end treatment, part of storm sewer system, ownership, photographs, channel type (Rosgen classification or NHI), channel condition upstream, channel condition downstream, flowing water (yes/no), sediment amount, and other comments.

Considering TABLE 5 and TABLE 7 in the Literature Review along with the findings from the state surveying effort, the researchers identified the key data fields for inclusion in a culvert inventory and/or inspection documents. These data fields show up at least five times in the literature or state review.

TABLE 10: Key Data Fields

Field	Frequency in Literature	Frequency in State Review	Total
Culvert Shape	8	11	19
Culvert Material	8	10	18
Culvert Length	7	10	17
Comments	6	8	14
Current Overall Condition Rating	8	5	13
Inspection Date	7	5	12
Asset Identification	6	5	11
County Code	4	7	11

Mile Marker	5	6	11
Inspector Name	6	5	11
Culvert Latitude	4	6	10
Culvert Longitude	4	6	10
Road Name	3	7	10
Depth of Cover	5	4	9
Construction Date	5	3	8
Culvert Width	2	6	8
Culvert Span	3	4	7
Culvert Height	2	5	7
Number of Barrels	1	6	7
Road ID	2	5	7
Average Daily Traffic of Roadway Above Culvert	4	1	5
Culvert Diameter	2	3	5
Maintenance Responsibility	2	3	5
Municipality	2	3	5
Inlet Condition Rating	2	3	5
Outlet Condition Rating	2	3	5
Inventory Date	1	4	5
Roadway Surface Condition Rating	4	1	5

The asset identification number will allow an agency to identify a specific culvert in its database. Typical location information that is collected includes: County, Municipality, Road Name, Road ID, Mile Marker, Latitude, and Longitude. This information will help an inspector determine where the culvert is located. Furthermore the maintenance responsibility information will let the inspector know who to contact if culvert rehabilitation needs to take place.

Adding information on the average daily traffic of the roadway above the culvert could allow for priority maintenance or increased inspection frequency under roads that would cause a greater impact if the culvert were to fail.

Many of the resources keep track of the construction date, which would allow for the determination of culvert service life.

Basic culvert information was collected by most of the references including: shape, material, length, width, span, height, and number of barrels. These are basic measurements that can be taken when the culvert is inventoried.

Keeping track of inspections is important. Adding information on the inspector and inspection date will allow for a historical record of all culvert inspections. This information would also allow for the responsible party to be available for questions should they come up during future inspections. During the culvert inspection, many of the references determine a condition rating of

the culvert, the inlet, and the roadway. Keeping track of the overall condition of the culvert over time will allow for the determination of condition over lifespan. This condition rating will also let the DOT know if culvert rehabilitation or replacement needs to take place. The condition of the inlet and outlet allows for a more in-depth view of the culvert. These ratings will require that an inspector check the inlet and outlet for any damage or physical blockages that may be affecting the hydraulic capacity of the culvert. The roadway rating will require the inspector to look for conditions like pavement cracking, sagging, and shoulder erosion. These signs can be easily viewed by the inspector and can be indicators that something is wrong with the underlying culvert. Depth of cover is an important measurement that can be taken during a culvert inspection to determine if there is a suitable amount of cover above the culvert and to check that the earth around the culvert has not eroded.

A comments field will allow inspectors to add any additional information that they believe is important but doesn't necessarily fit into any of the other data fields.

6 SUMMARY

The number of surveys received, only a few short of all fifty states, provides the researchers with confidence in the conclusions that are drawn as a result of the data. In fact, compared to other research efforts, where responses were obtained from only about half of the states, the information obtained provided a broad understanding of the current state of small culvert asset management across the United States. The only potential limitation of the data received is that there is always inherent bias dependent upon the survey recipient who provided the responses. However, the researchers relied most often on states to pass on the survey invitation to the individual within the agency who could best answer the survey by not restricting the number of times an agency could access the survey. In many cases, the final respondents followed-up with the researchers identifying themselves as having responded to the survey.

Culvert inspection manuals do exist, with approximately half of the states currently having or in the process of developing a culvert inspection manual. Interestingly enough, it appears that the majority of the states that have or are developing a manual are states that lie along or near the east and west coasts of the United States, lie along the great lakes, or are in the north of the United States. With the exception of Colorado, the interior states including most of the desert states and the more central Midwestern states like Kansas, Nebraska and Oklahoma, do not have culvert inspection manuals. It appears that the states that could be impacted by rising waters seem to be leading the charge with developing culvert inspection manuals. National geography aside, it seems that there is a general move towards developing culvert inspection manuals, whether they are a stand-alone state document, or an adoption of a national level document, like Federal Lands Highway's *Culvert Assessment and Decision Procedures Manual*. As such, it is anticipated that the states that indicated that they affirmatively do not have a culvert inspection manual at present will likely adopt the outcome of the NCHRP 14-26 effort.

Twenty feet is the current threshold for differentiating between a bridge and a culvert. However, it appears that states are already inspecting down to ten feet. In some states, this was driven by a state law or the National Pollutant Discharge Elimination System permit. So, it seems like there are existing incentives to extend inspections beyond 20 feet. However, performing the inspections does not necessarily correlate with having an inventory. Therefore, while it seems like benefits can be achieved through extending the sizes of culvert included in inspections, it also seems that providing incentives to states to inventory these culverts is needed.

In addition, while some states took issue with defining culverts that extended beyond the 20 foot definition as small culverts, often preferring their own definition, the majority of states indicated that they do some type of small culvert inspection. A state's definition of a small culvert, however, varied. As such, while one can compare the definition with the number of culverts that a state was inspecting, to get a general idea of why there were differences in the number of small culverts, there is still a lot of variability. For the most part, it appears that in most states that have a more encompassing definition, the numbers of culverts range from about twenty or thirty thousand upwards to two hundred thousand or more. The main point is that there are a lot of small culverts in every state. Therefore, there is a need to prioritize both inspection and replacement. Many states address the need to inspect a large number of small culverts by

implementing a tiered system: culverts in relatively good condition were inspected less frequently, while culverts exhibiting conditions of concern were inspected more frequently until the funds could be identified to replace them.

While some states seem to embrace more options for culvert materials, the majority of states still use some type of steel and concrete. Steel seemed to be more prominently used in the west and concrete in the east, particularly around the great lakes. Little to no information was provided regarding the types of materials used in the central and southeastern parts of the United States.

Again, in response to the expansive numbers of culverts, states indicated that they struggle to inspect and inventory the small culverts, with these duties often falling on the shoulders of maintenance staff. In many cases, there were concerns that these staff were not provided with the instruction needed, and as a result, there is a call for the development of a course that focuses on small culvert inspection. When considering the need for staff to support these inspections and to some degree the need for support with inventorying, some states are finding value in engaging student interns. However, a primary sentiment is that a state interested in this direction should make sure to invest in training and working with the students, rather than expecting them to work as independent additions to the staff.

Regarding inspection scales, the trend appears to be a five point inspection scale, as recommended in the upcoming NCHRP 14-26 document. In addition, inspectors should be provided with photos of defects to aid them with their inspections.

Several states are developing their own in-house software to support inspections and the inventories of culverts. By developing it in-house, they are able to make modifications over time, as reported by Washington State DOT regarding its mobile inspection tool.

The culvert inspection shape is the most prominently occurring inventory data piece, found in both the survey and literature. Culvert length and material were found to be the two most frequently included data pieces in the inventory as a result of the survey findings. In general, it appears that many fields are needed, and DOTs should determine what those are as a reflection of the objectives they are trying to achieve as a result of their inventory. Few states were found to have added or removed inventory data. Incorporating photos into the inventory still seems to be cumbersome, primarily as a result of the storage space required.

A limited amount of cost information for inventory systems was provided, but of that available, DOTs and localities alike indicated that the value of them far exceeded the expense, as they often assisted with prioritizing their needs.

While DOTs realize the need for inspecting locally owned culverts, many seem to be overwhelmed at the magnitude of dealing with the problems within state right-of-way. However, Vermont has a good example of a tool to facilitate management of locally-owned culverts, which the state can share with state DOTs that are interested.

Drop inlets seem to be unanimously off-of-the-radar at present. It seems that once states get a handle on both asset management tools, and tools to manage small culverts, then tools for managing drop inlets could be the next need.

Most often, states seem to have initiated a program to inventory small culverts as a result of multiple small culvert failures within their state. Realizing that others are addressing these challenging issues, it seems many states, like New Mexico, are moving in the direction of becoming more proactive in addressing this need.

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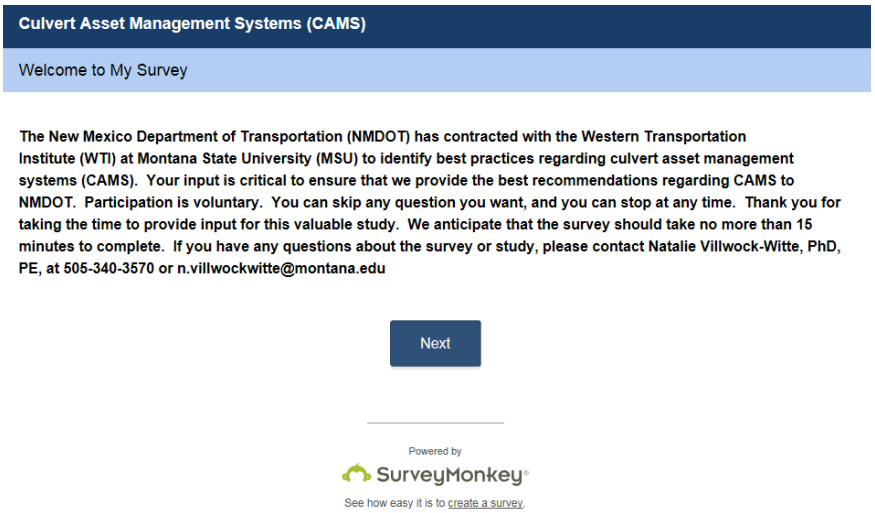
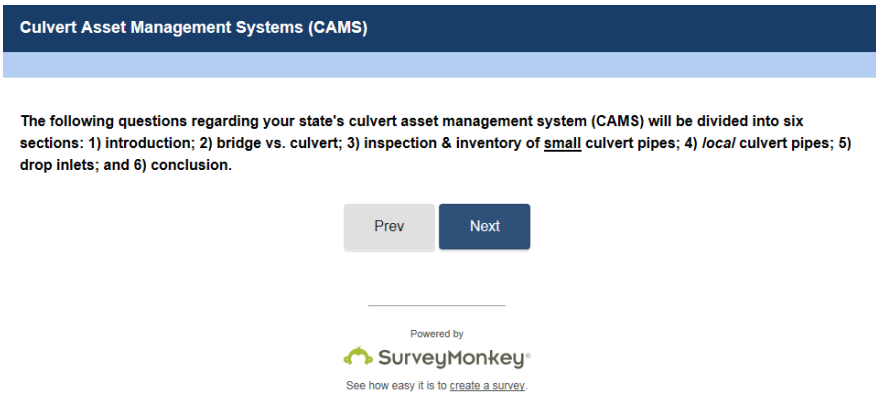
8 APPENDIX A: SURVEY INSTRUMENT

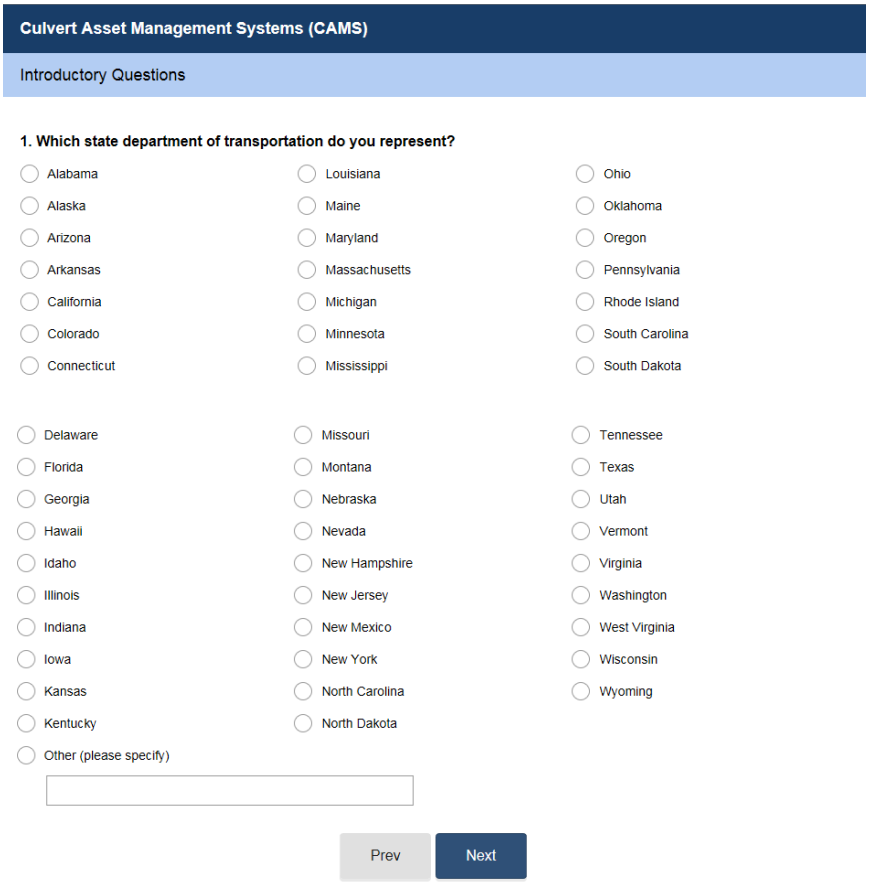
Introduction



Introduction, continued



Question 1



Culvert Asset Management Systems (CAMS)

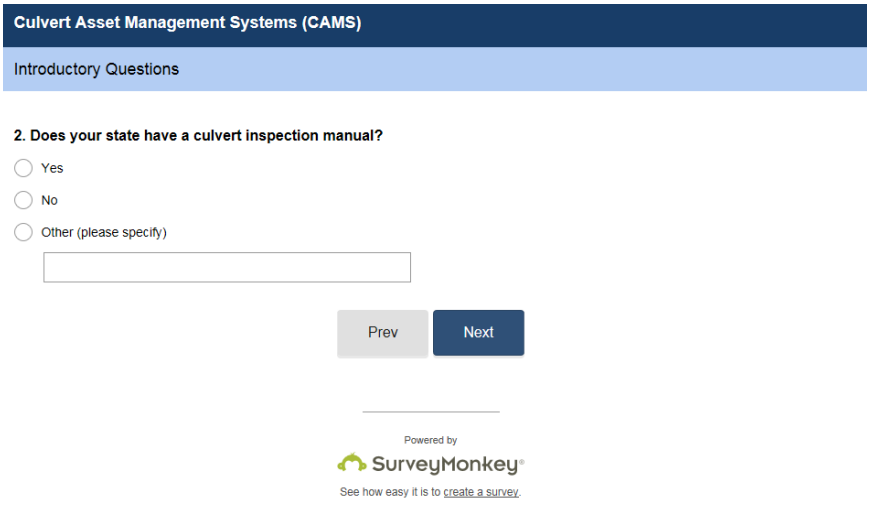
Introductory Questions

1. Which state department of transportation do you represent?

- Alabama
- Alaska
- Arizona
- Arkansas
- California
- Colorado
- Connecticut
- Delaware
- Florida
- Georgia
- Hawaii
- Idaho
- Illinois
- Indiana
- Iowa
- Kansas
- Kentucky
- Louisiana
- Maine
- Maryland
- Massachusetts
- Michigan
- Minnesota
- Mississippi
- Missouri
- Montana
- Nebraska
- Nevada
- New Hampshire
- New Jersey
- New Mexico
- New York
- North Carolina
- North Dakota
- Ohio
- Oklahoma
- Oregon
- Pennsylvania
- Rhode Island
- South Carolina
- South Dakota
- Tennessee
- Texas
- Utah
- Vermont
- Virginia
- Washington
- West Virginia
- Wisconsin
- Wyoming
- Other (please specify)

Prev Next

Question 2



Culvert Asset Management Systems (CAMS)

Introductory Questions

2. Does your state have a culvert inspection manual?

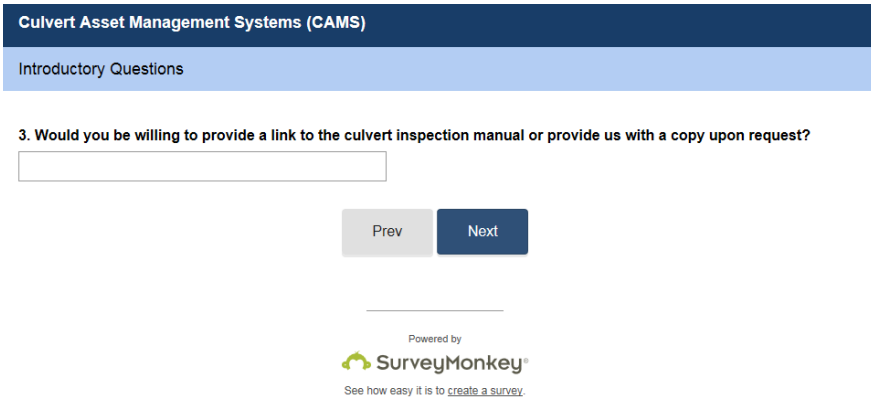
- Yes
- No
- Other (please specify)

Prev Next

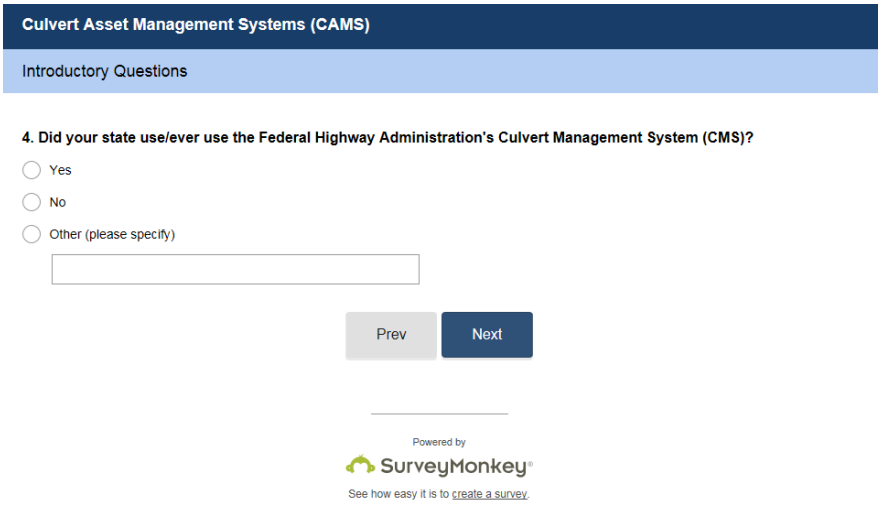
Powered by SurveyMonkey

See how easy it is to create a survey.

Question 3 (Note, skipped if Question 2 response is "No.")



Question 4



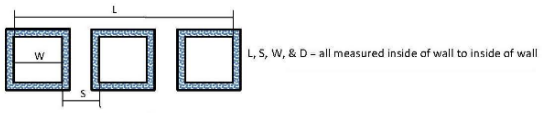
Question 5

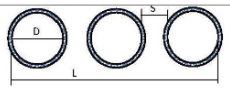
Culvert Asset Management Systems (CAMS)

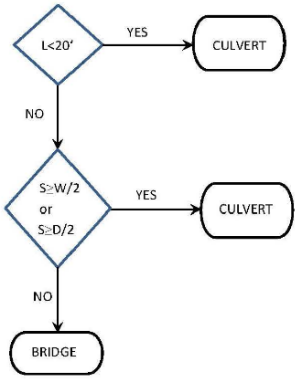
Bridge vs. Culvert

According to the Code of Federal Regulations (CFR), 23 650.305, a bridge and culvert are defined as shown by the graphic below.

IS IT A BRIDGE OR A CULVERT?





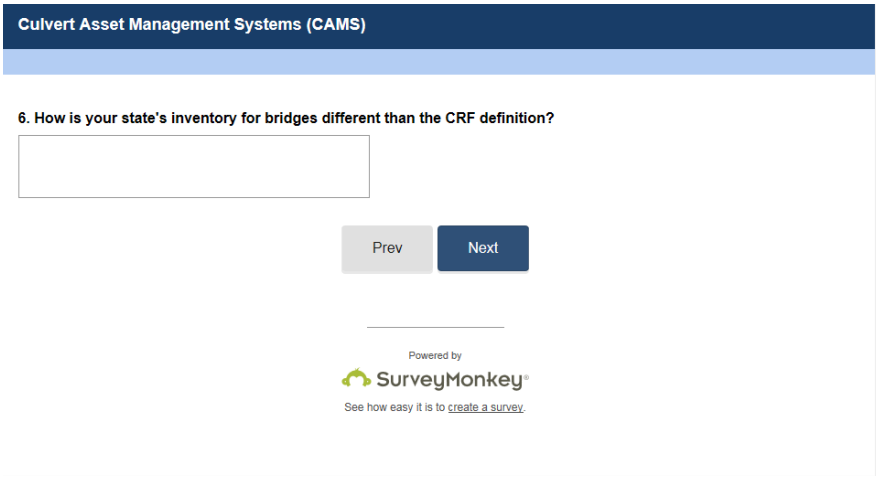


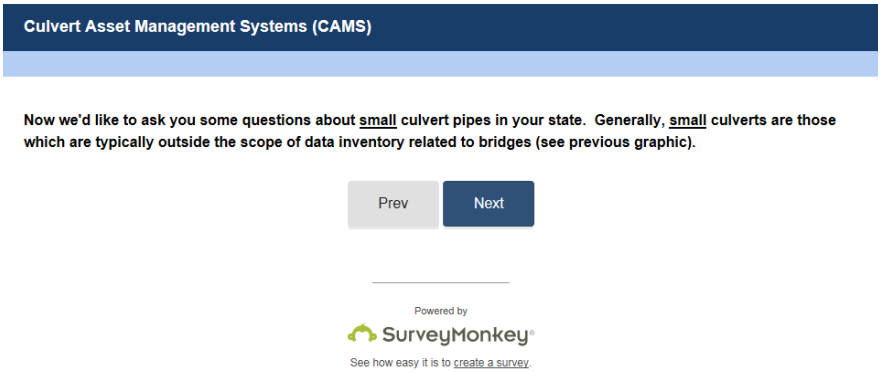
5. Thinking about how your state inventories bridges, does your definition for what is inventoried extend beyond the definition shown above?

- ◯ Yes (e.g. L < 15 is the cut-off for what our state inventories)
- ◯ No, we only inventory that which is defined as a bridge as shown above.

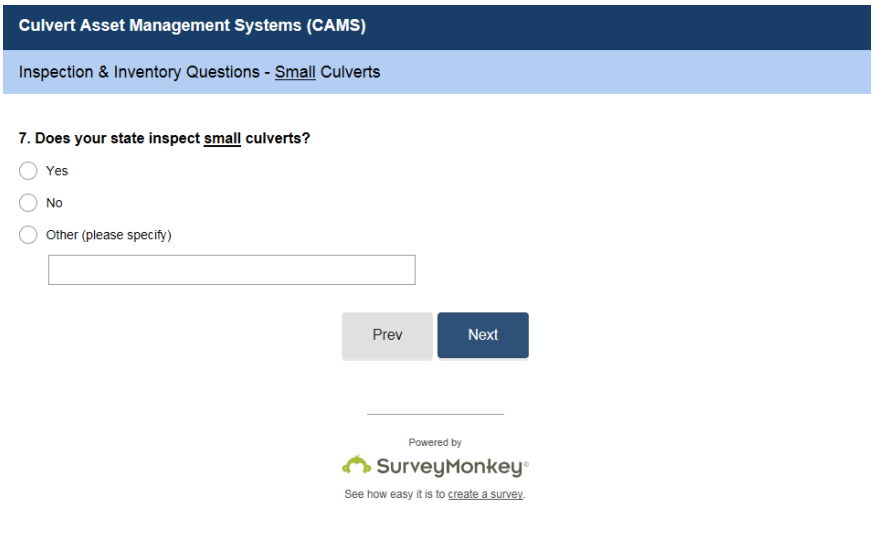
Prev Next

Question 6

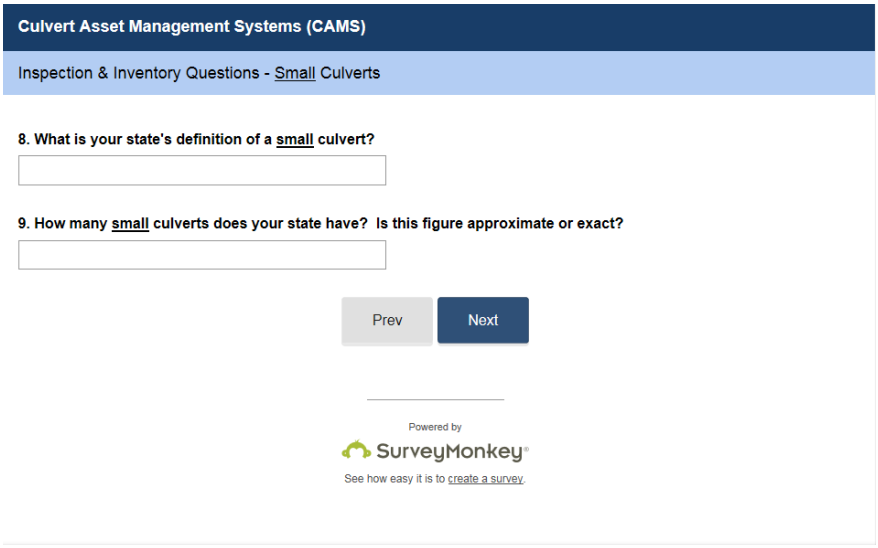




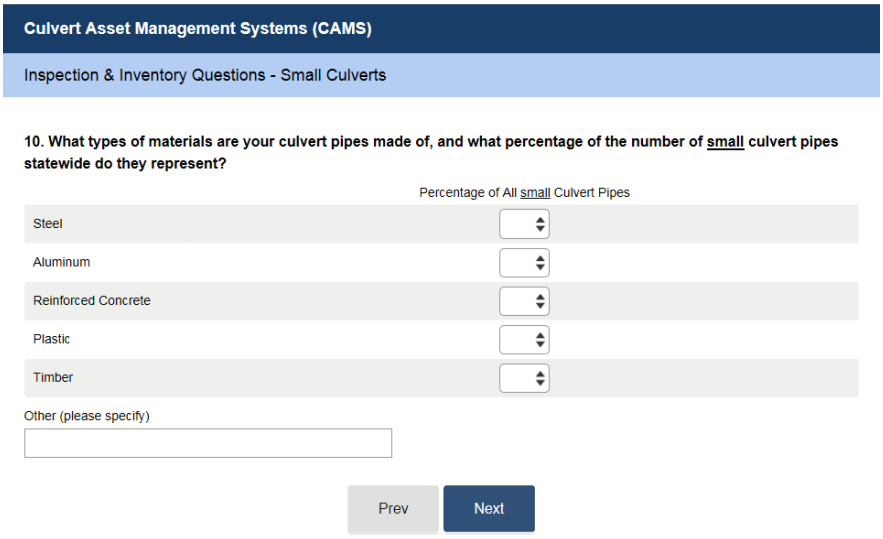
Question 7



Question 8 & Question 9



Question 10



Question 11

Culvert Asset Management Systems (CAMS)

Inspection & Inventory Questions - Small Culverts

11. How frequently does your state inspect small culverts?

- [ ] Annually
- [ ] Every 2 years
- [ ] Every 3 years
- [ ] Every 4 years
- [ ] Every 5 years
- [ ] Every 6 years or more
- [ ] After storm events
- [ ] Other (please specify)

Question 12 & Question 13

12. How many people are needed within your state to perform the inspections of small culvert pipes? Are they permanent employees, interns, or contractors?

13. What kind of training do you provide to inspectors of small culvert pipes?

Prev Next

Question 14 & Question 15

Culvert Asset Management Systems (CAMS)

Inspection & Inventory Questions - Small Culverts

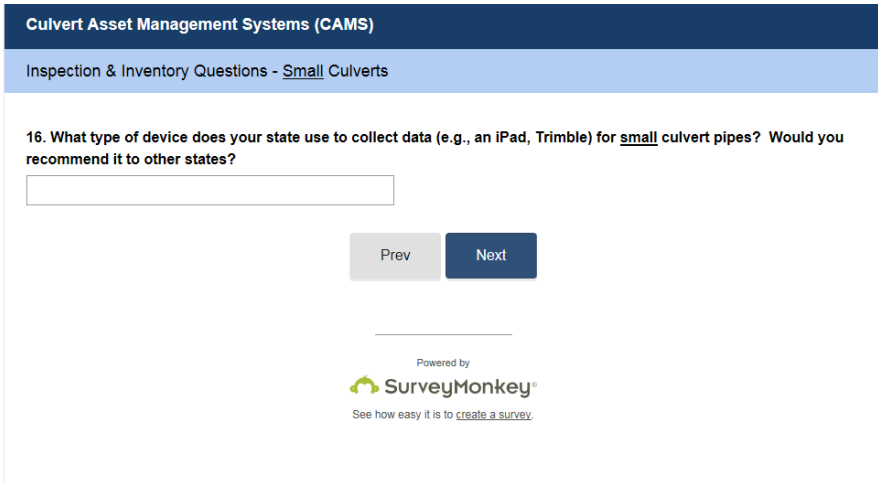
14. What type of inspection scale does your state use for small culverts?

- ( ) 1-4
- ( ) 0-9
- ( ) A qualitative scale
- ( ) Other (please specify)

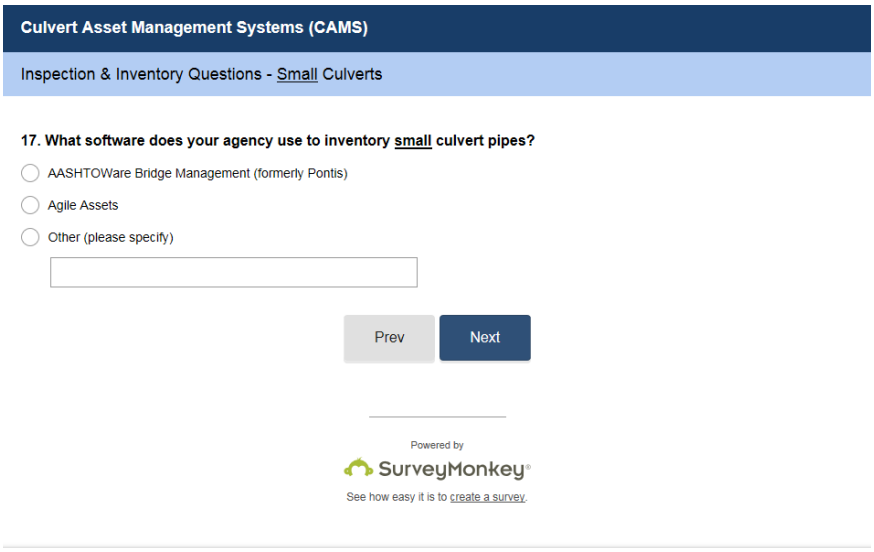
15. Is it standard practice for your state to inspect a NEW small culvert immediately after it is installed?

- ( ) Yes
- ( ) No
- ( ) Other (please specify)

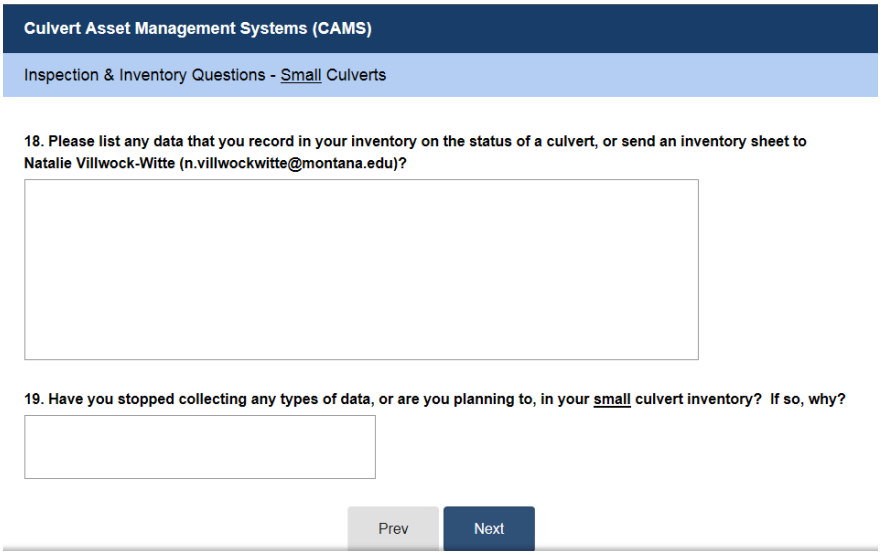
Question 16



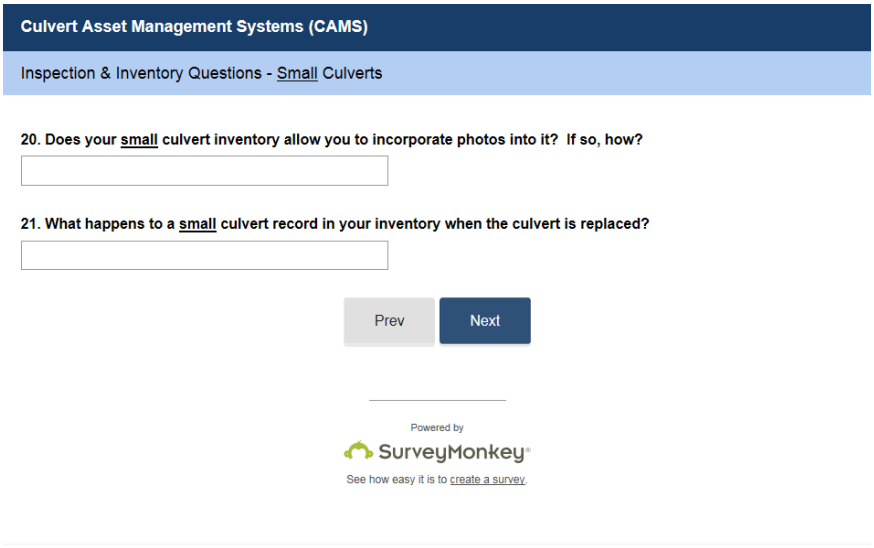
Question 17



Question 18 & Question 19



Question 20 & Question 21



Question 22, Question 23, & Question 24

Culvert Asset Management Systems (CAMS)

Inspection & Inventory Questions - Small Culverts

22. Approximately how much did it cost to create/purchase the platform that your state uses to inventory small culvert pipes?

23. What are the approximate costs of software/hardware to maintain the inventory system for small culvert pipes?

24. What are the approximate personnel costs to maintain the inventory system for small culvert pipes?

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Question 25

Culvert Asset Management Systems (CAMS)

Inspection & Inventory Questions - Small Culverts

25. How does your agency prioritize replacing small culverts?

- As-needed
- Age of culvert
- Remaining life span
- Other (please specify)

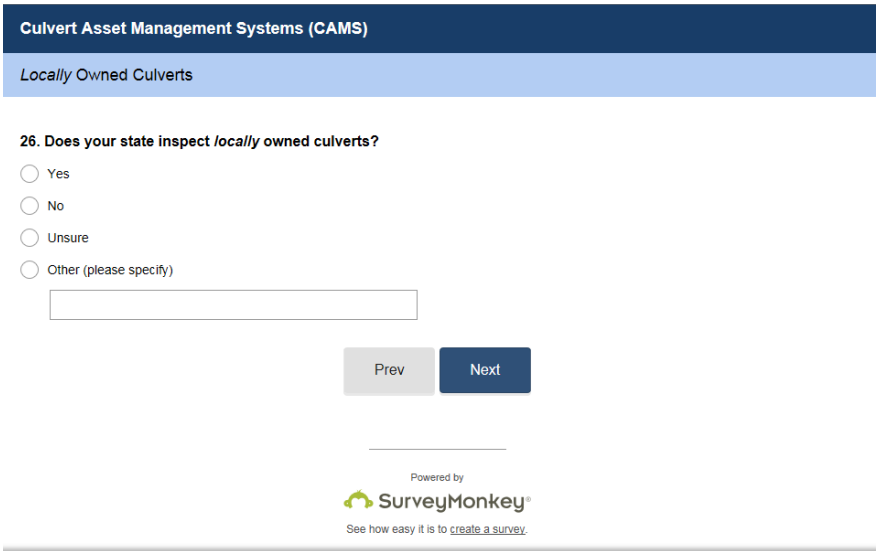
Prev Next

Culvert Asset Management Systems (CAMS)

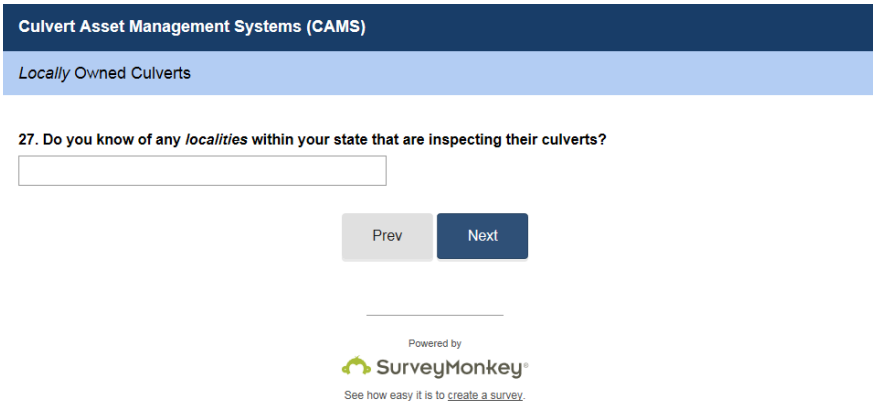
Now we'd like to ask you some questions about culvert pipes owned by *localities* (e.g. city, county, private, other) in your state.

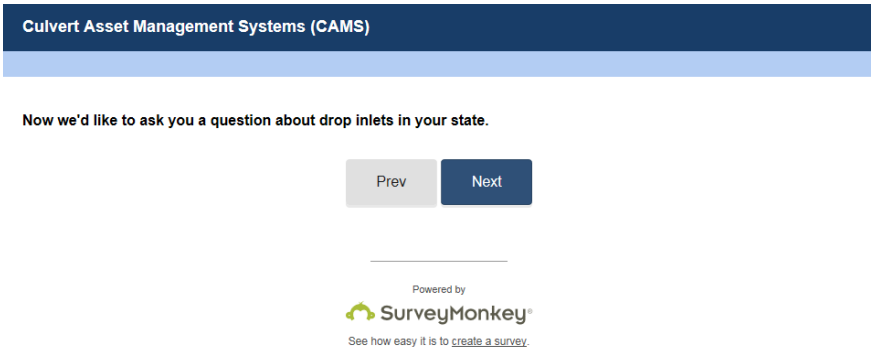
Prev Next

Question 26

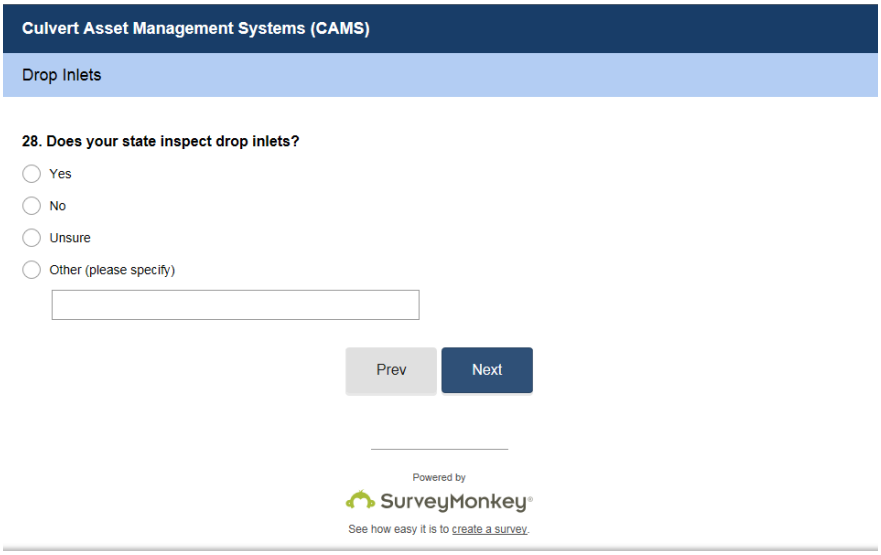


Question 27

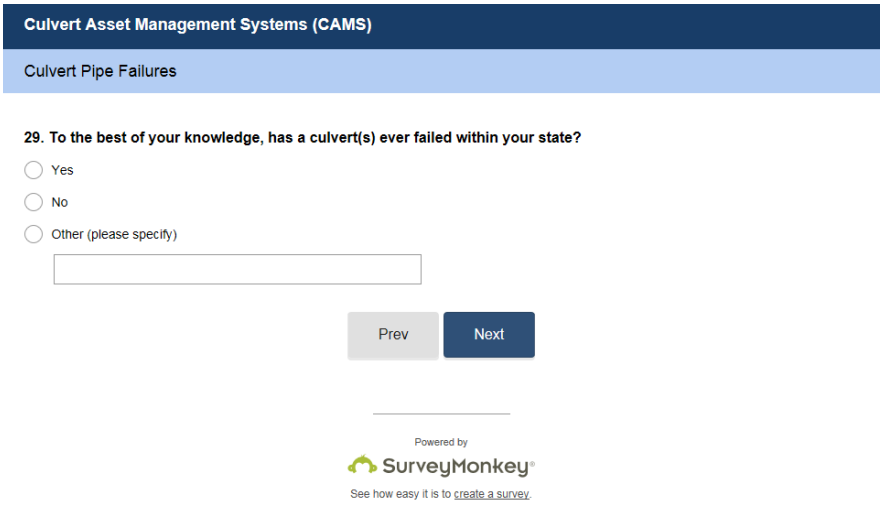




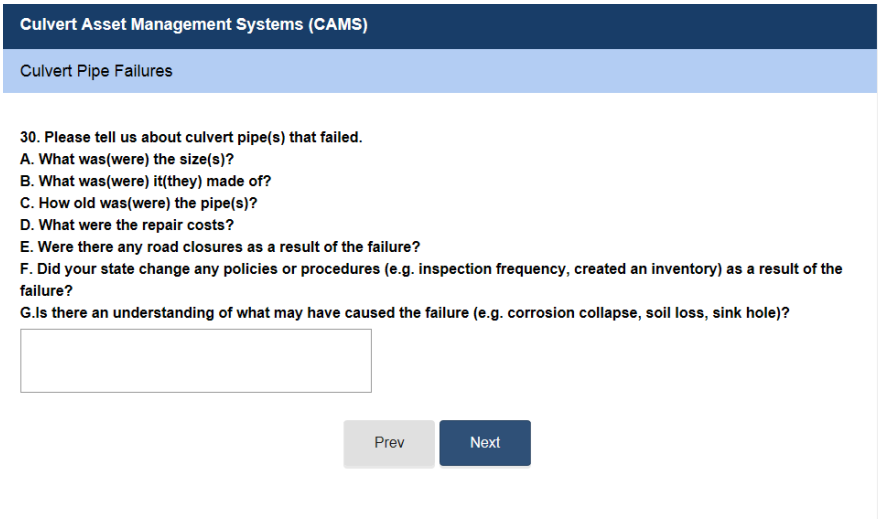
Question 28



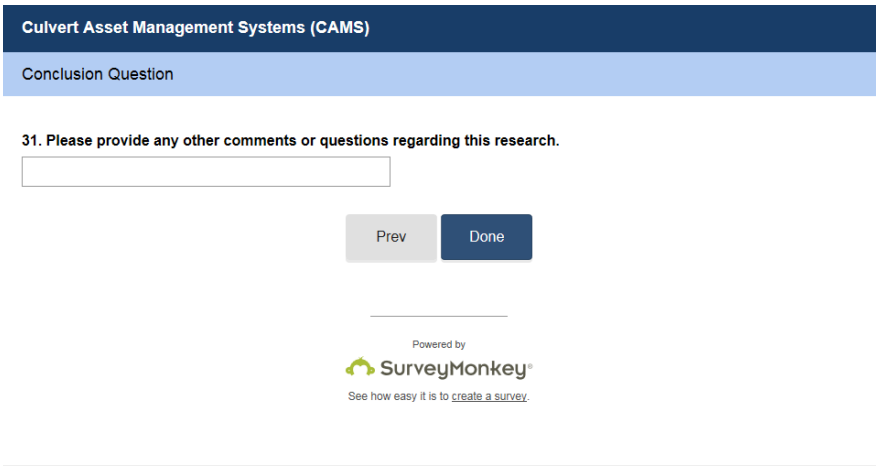
Question 29



Question 30



Question 31



9 APPENDIX B: SURVEY QUESTION DETAILS AND OPEN-ENDED RESPONSES

Question 3 – Links to Provided Inspection Manuals

TABLE 11 provides links to culvert inspection manuals that were provided.

TABLE 11: Culvert Inspection Manual Links

State	Link Provided
California	http://www.dot.ca.gov/hq/oppd/dib/dib83-04.pdf
Colorado	https://www.codot.gov/library/bridge/inspection-code-guide
Connecticut	http://www.ct.gov/dot/lib/dot/documents/dpublications/inspection_manual_061905.pdf
Illinois	http://www.idot.illinois.gov/Assets/uploads/files/Doing-Business/Manuals-Guides-&-Handbooks/Highways/Bridges/Inspection/Structural%20Services%20Manual%202015.pdf (See Section 3 of the Structural Services Manual 2015 Edition)
Minnesota	http://www.dot.state.mn.us/bridge/pdf/hydraulics/hydinfra-culvert-and-storm-drainage-system-inspection-manual.pdf
Montana	http://www.mdt.mt.gov/other/webdata/external/bridge/Bridge-inspection-manual.pdf
New Hampshire	*A follow-up to the survey respondent for the link resulted in identifying that the survey respondent had retired.
New Hampshire	Historic Stone Culverts: http://www.nh.gov/dot/org/projectdevelopment/environment/documents/CulvertManagementManual.pdf
New Jersey	http://www.state.nj.us/transportation/eng/structeval/downloads.shtm
New York	https://www.dot.ny.gov/divisions/operating/oom/transportation-maintenance/repository/CulvertInventoryInspectionManual.pdf
Ohio	https://www.dot.state.oh.us/Divisions/Engineering/Hydraulics/Culvert%20Management/Culvert%20Management%20Manual/CMM%20-%20July%202015.pdf
Oregon	ftp://ftp.odot.state.or.us/techserv/geo-environmental/Hydraulics/Culvert/Table_Contents_Culvert_Manual_D-04.pdf
Pennsylvania	Link requested
South Carolina	http://www.scdot.org/doing/technicalpdfs/suptechspecs/permanent_pipe_culverts.pdf
South Dakota	Manual not received from SDDOT
Tennessee	Hard copy provided to NMDOT
Vermont	Hard copy provided to NMDOT
Virginia	http://www.virginiadot.org/business/resources/const/inspection_manual.pdf
West Virginia	Manual not received from WVDOT
Wisconsin	Hard copy provided to NMDOT

TABLE 12: Inventory Fields Identified by States Less Than 5 Times

Field	Frequency	Within State
Asset Identification	5	OR, TN, UT, VT, WI
Culvert Height	5	IA, PA, VT, Waukesha County, WI
Current Overall Condition Rating	5	IA, PA, SC, TN, UT
Inspection Date	5	IN, OR, SC, UT, Waukesha County
Inspector Name	5	IN, OH, SC, VT, Waukesha County
Road ID	5	OH, OR, PA, SC, WI
Culvert Span	4	OH, OR, TN, WI
Depth of Cover	4	IN, OH, SC, VT
Status	4	IA, IN, OH, UT
Inlet End Treatment	4	OH, SC, UT, VT
Inventory Date	4	IA, OH, PA, TN
Construction Date	3	OH, UT, WI
Culvert Diameter	3	IN, UT, VT
Skew Angle	3	OH, OR, Waukesha County
Inlet Condition Rating	3	IA, SC, VT
Outlet Condition Rating	3	IA, SC, VT
Outlet End Treatment	3	SC, UT, VT
District	3	IN, OH, SC
Municipality	3	UT, VT, WI
Maintenance Responsibility	3	OH, UT, WI
Road Direction (N, S, W, E)	3	IN, PA, WI
Culvert Rise	2	OH, OR
Marker Post (is there a culvert marker present)	2	VT, Waukesha County
Skewed (yes/no)	2	IA, Waukesha County
Inlet Type	2	OR, PA
Outlet Type	2	OR, PA
Barrel Condition Rating	2	SC, Waukesha County
Erosion	2	VT, Waukesha County
Scour	2	Waukesha County, WI
Scour Rating (Inlet and Outlet)	2	SC, TN
Inspection Type	2	IN, OH
DOT Region	2	UT, WI
Ownership	2	UT, WI
Side of the Road (right, left, median, highway)	2	IA, IN
Maintenance Recommended	2	IA, Waukesha County
Road Width	2	TN, WI
Design Discharge 'Q'	2	OH, WI
Drainage Area	2	OH, WI
Flowing or Standing Water	2	UT, Waukesha County