Evaluation of Box Culvert Maintenance Methods

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for the

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16. Abstract		
Traditional methods, such as using a vactor truck, for clearing culverts greater than 48 inches of debris and accumulated sediment may be inefficient and costly. A survey of states outside of Ohio has shown several regularly use remote controlled equipment for cleaning large culverts. A MicroTraxx MT 3234 was purchased from Rohmac, Inc. and evaluated on culverts in Ohio over the months of July and August of 2014. Performance statistics show that the MicroTraxx unit cleared culverts as fast as traditional methods using half as many man-hours. An analysis of the Ohio culvert database shows that close to 8,600 culverts across the state can be accessed by the MicroTraxx MT 3234 unit and could provide ODOT cost savings in the future if the MicroTraxx were deployed for this purpose.		
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EVALUATION OF BOX CULVERT MAINTENANCE METHODS

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Prepared in cooperation with the Ohio Department of Transportation

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The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view of policies of the Ohio Department of Transportation (ODOT) or the Federal Highway Administration (FHWA). This report does not constitute a standard, specification or regulation.

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Customary Unit	SI Unit	Factor	SI Unit	Customary Unit	Factor
Length			Length		
inches	millimeters	25.4	millimeters	inches	0.039
inches	centimeters	2.54	centimeters	inches	0.394
feet	meters	0.305	meters	feet	3.281
yards	meters	0.914	meters	yards	1.094
miles	kilometers	1.61	kilometers	miles	0.621
Area			Area		
square inches	square millimeters	645.1	square millimeters	square inches	0.00155
square feet	square meters	0.093	square meters	square feet	10.764
square yards	square meters	0.836	square meters	square yards	1.196
acres	hectares	0.405	hectares	acres	2.471
square miles	square kilometers	2.59	square kilometers	square miles	0.386
Volume			Volume		
gallons	liters	3.785	liters	gallons	0.264
cubic feet	cubic meters	0.028	cubic meters	cubic feet	35.314
cubic yards	cubic meters	0.765	cubic meters	cubic yards	1.308
Mass			Mass		
ounces	grams	28.35	grams	ounces	0.035
pounds	kilograms	0.454	kilograms	pounds	2.205
short tons	megagrams	0.907	megagrams	short tons	1.102

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

AADT—Average Annual Daily Traffic

CMM—Culvert Management Manual

DEC—District Environmental Coordinator

DOT—Department of Transportation

EUAC—Equivalent Uniform Annual Cost

FHWA—Federal Highway Administration

NCHRP—National Cooperative Highway Research Program

OAC—Ohio Administrative Code

ODOT—Ohio Department of Transportation

RFP—Request for proposal

SHA—State Highway Administration

TIMS— Transportation Information Mapping System

USACE—United States Army Corps of Engineers

EXECUTIVE SUMMARY

Each year, Ohio Department of Transportation (ODOT) maintenance personnel clear drainage pipes and culverts of debris and sediment. In most cases, the method of cleaning is with vactor truck crews using hand-guided, highly pressurized hoses. These methods often require a significant amount of man-hours to perform. This type of work is also a risk to worker safety due to confined space concerns. Culverts with large fills or significant lengths provide more challenges to maintenance crews because of poor accessibility to the culvert inlet and outlet. In the past ten years in Ohio, increased attention has been paid to culvert inspection which has resulted in a more proactive stance in cleaning partially blocked culverts.

This research assesses the cleaning practices for large (>34" for box and 48" for circular) culverts across the state of Ohio, investigates large culvert cleaning alternatives in other states through surveys and interviews, reviews the published and unpublished literature on culvert blockage and cleaning, and evaluated field use of remote controlled culvert cleaning equipment. Literature review findings conclude that preventative maintenance can extend the life of a culvert and minimize the risk of culvert failure. In Ohio, surveys show that the cleaning of the large culverts is problematic with work frequently being limited to just the length immediately accessible to the inlet and outlet. Four of the responding transportation officials from other states mentioned that their highway department have used a remote controlled culvert cleaning machine and found them to be cost effective. Three of these four used one brand: MicroTraxx Tunnel Mucker. One of these states, California, performed a detailed assessment of the equipment throughout the state from 2008 to 2012 and preliminary results show significant cost savings versus traditional culvert cleanout methods.

Culvert cleaning equipment manufacturers were investigated and quotes were collected. After a period of due diligence, the MicroTraxx MT 3234 machine was purchased. This machine was then used throughout the summer of 2014 on seven culverts in and around Columbiana County. Four of these culverts were cleaned entirely in one working day with the MicroTraxx. An average removal rate of 12.0 cubic yards of material removed per engine-hour was calculated across all culverts. Crews required for the work ranged from five to seven depending on accessibility and whether a flag crew was needed to close one lane of traffic. Across all culverts, an average of 0.9 man-hours were needed to remove 1 cubic yard of material. Quantitative data on traditional cleaning methods of large culverts in Ohio is lacking. However, anecdotal information about cleaning of culvert 1 using a vactor truck suggests the use of a MicroTraxx unit is many times faster with respect to onsite equipment time while using half as many man-hours as the traditional vactor truck method. Similar results were found in the Caltrans study.

There are 82,634 culverts inventoried in Ohio as of September, 2014. Based on criteria development from this research, 8,694 possess the physical characteristics that make them eligible for cleaning with MicroTraxx equipment. These candidate culverts are not evenly displaced throughout the state with Districts 9 and 10 having over 1,000 each. In terms of the overall amount of blocked culverts, Districts 3, 5, 10, and 11 show the greatest need for culvert cleaning equipment. These four districts all rank in the top third of districts for candidate culverts with at least 30% of the opening blocked at the time of inspection with respect to the total number of culverts and cumulative length of these blocked culverts. Districts 3, 5, and 8 have the greatest amount of daily traffic over culverts with at least 30% of the opening blocked

at the time of inspection. Given the large number of candidate culverts, remote controlled equipment could be useful for future ODOT culvert maintenance.

CHAPTER I: INTRODUCTION

1.1 Background

As described in the Request for Proposal (RFP) for this project, the "Ohio Department of Transportation (ODOT) maintenance crews perform culvert clean out on a yearly basis for culverts greater than 34" box and 48" circular. Sediment and debris build up are typically removed by hand methods. These methods create safety concerns for the employees including confined space and increased risk for worker injury along with low efficiency due to the time consuming nature of the work. There are situation where maintenance (as determined by bridge inspection) is not performed at all due to the complex terrain and the difficulty in using heavy equipment due to limitations on accessing the site. The lack of sediment and debris removal then creates drainage issues which in turn affect ODOT roadway and eventually, the safety of the traveling public. ODOT forces also may use a vactor jet machine to blow out the sediment which is also an extremely time consuming method."

ODOT is currently in the process of inventorying and inspecting culverts across the state. Culvert inspection procedures are well documented in the Culvert Management Manual (updated January 2014). Culvert inspection focuses on identifying potential features that may lead to culvert failure so that these issues can be identified and culverts repaired before failure occurs. While the risk of culvert failure increases with age, routine maintenance, including sediment removal, can extend the expected service life of a given culvert as well as mitigate risks to traffic during extreme flood events. However, in many cases, traditional culvert cleaning methods are inadequate due to site specific conditions and may require significant labor and equipment allocations. A cost effective strategy for culvert maintenance, including an evaluation of potential new technologies, is needed.

1.2 Objectives and Goals

The overall goal of this project is to evaluate methods of culvert cleanout and provide a best practices recommendation for cleaning box culverts greater than 34 inches in height and circular culverts greater than 48 inches in diameter. The project was conducted in two phases, with Phase I focused on establishing the current state of the practice for culvert cleaning and preliminary evaluation of remote control equipment use and Phase II focused on field assessment of a remote controlled culvert cleaning machine and a discussion of cost/benefit analysis compared to traditional practices. Phase 1 was completed in time for inclusion in the Interim Report and is included as Chapters 2 and Chapters 3 of this final report. The objectives of Phase I were as follows:

- Determine the state of current procedures and practices by Ohio DOT and other state DOTs for culvert cleanout with a focus on maintenance costs, schedules, and best management practices.
- Identify manufacturers of existing remote control culvert cleanout equipment, survey equipment users to assess experiences and concerns, and recommend an appropriate unit for use in Ohio based on cost, environmental impact, labor hours needed, reliability, safety, and performance.

To achieve these objectives, three tasks were completed as shown in

Figure 1-1:

- Task One: Evaluate Available Data and Reports on Culvert Clean Out Procedures and Practices of Other State DOTs
- Task Two: Evaluate Available Data and Reports on Culvert Clean Out Procedures and Practices in Ohio
- Task Three: Conduct Preliminary Evaluation of Commercially Available Remote Control Culvert Cleanout Units

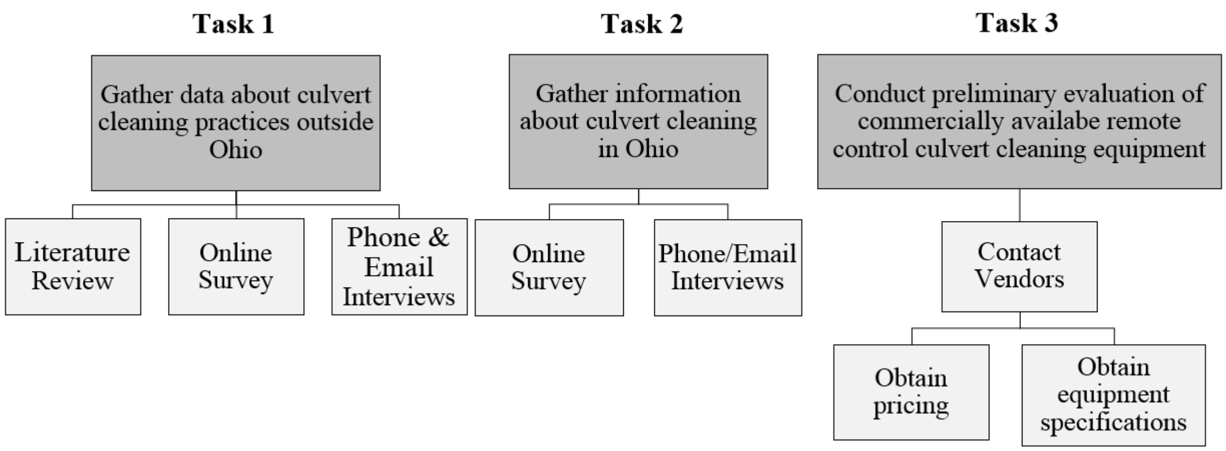

Figure 1-1: Summary of task emphasis and subtasks completed during Phase I.

Phase 2 was carried out in the spring and summer of 2014 after the decision was made to acquire a remote controlled culvert cleaning machine. The objectives of Phase II were as follows:

- Determine the advantages and disadvantages of the remote controlled culvert cleaning machine as applied to culverts in the field by ODOT personnel.
- Compare performance and debris removal efficiencies of the remote control equipment to trials performed in other states.
- Compare performance and debris removal efficiencies of the remote control equipment to traditional methods: vactor truck and by hand.
- Identify culvert characteristics that indicate whether it is a candidate for cleaning with remote control equipment and assess deployment strategies.

To achieve these objectives, four tasks were completed as shown in

Figure 1-2:

- Task Four: Prepare Interim Report and Purchase Equipment
- Task Five: Field Evaluation of Culvert Cleanout Methods
- Task Six: Conduct Cost/Benefit Analysis

- Task Eight: Culvert Clean-out Decision Support System Development

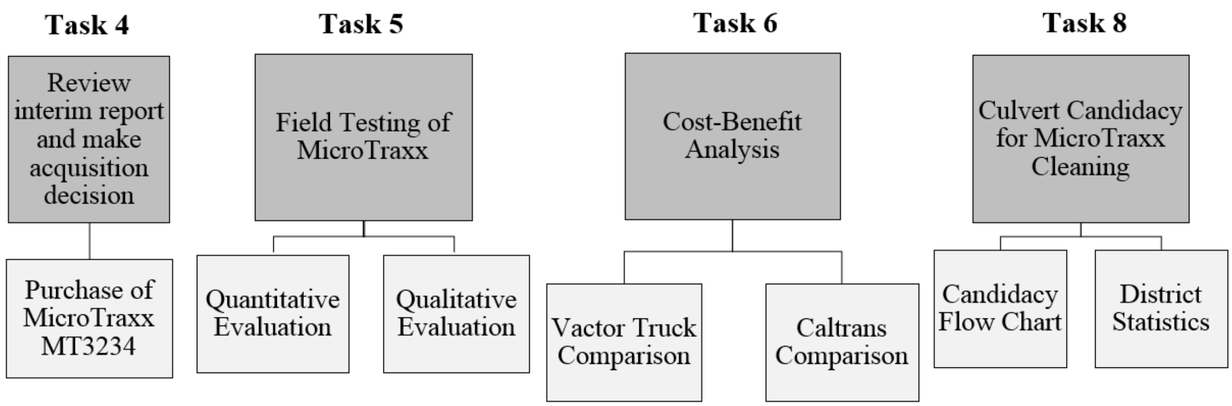

Figure 1-2: Summary of task emphasis and subtasks completed during Phase II.

1.3 Report Organization

This report is organized into six chapters. Chapter 1 describes the goals and objectives of this research project, Chapter 2 focuses on the results of the literature review, Chapter 3 provides the results of the assessment of the current state of the practice for culvert maintenance inside and outside of Ohio, Chapter 4 discusses the acquisition and performance of the remote controlled culvert cleaning equipment, Chapter 5 discusses statewide application of the remote controlled culvert cleaning device and which districts where the equipment might have the greatest need, and Chapter 6 provides conclusions and implementation recommendations.

CHAPTER II: LITERATURE REVIEW

2.1 Introduction

The literature review, which included both published and unpublished reports, focused on current research in the areas of culvert maintenance and inspection and the use of remote control culvert cleaning equipment. The results are summarized in three distinct areas: culvert failure, culvert maintenance and inspection, and the use of remote control culvert cleaning equipment. Relevant reports were identified through online searches, personal communication with state DOT personnel, and journal publication databases.

2.2 Culvert Failure

Culverts are engineered structures designed to convey water while also supporting an overlying earthen load and/or traffic. The Ohio DOT defines culverts as structures that span a distance of less than ten feet (or have a diameter less than ten feet) as measured along the centerline of the road; bridges are defined as structures spanning more than ten feet (Ohio DOT Manual of Bridge Inspection, 2010). Because culverts convey water under roadways, culvert failure can be catastrophic, resulting in sinkholes, flooding, damage to the roadway, and delays to the traveling public (Perrin and Jhaveri, 2003). Culvert repair can be costly for state agencies because the emergency nature of culvert repair can lead to higher material and labor costs when compared with scheduled culvert repair or replacement. Indirect costs, including travel delay, are also high when a culvert unexpectedly fails (Perrin and Jhaveri, 2003). In 2001, a corrugated metal pipe culvert near Maple Heights, Ohio, failed (Figure 2-1), damaging one lane of the roadway and requiring repairs that cost $384,000 (Perrin and Jhaveri, 2003).

Figure 2-1: Failure of a corrugated metal culvert along Interstate-480 in Cuyahoga County, Ohio. Photograph taken from Broviak, 2005.

As culverts near their expected service life, the likelihood of culvert failure increases. In their “Engineering and Design Conduits, Culverts, and Pipes Manual” (revised 1998), the US Army Corps of Engineers recommends that a project service life of 100 years be used when designing new culverts (US Army Corps of Engineers, 1998), but the effective service life of a culvert is impacted by a number of factors, including the culvert material, properties of the water moving through the culvert, soil properties, and culvert placement (NCHRP, 2007). Culverts can be made of flexible or rigid materials (Perrin and Jhaveri, 2003), including plastic, corrugated steel, aluminum (Figure 2-2), concrete (Figure 2-3), wood, or stone (Keller and Sherar, 2003, Perrin and Jhaveri, 2003). Each material has a different set of guidelines for installation, maintenance, inspection, and durability (Noll and Frascella, 2010). The choice of material is generally based on cost at design time, but higher costs may be incurred over the life of the culvert due to a selection of less durable materials (Keller and Sherar, 2003, Perrin and Jhaveri, 2003, NCHRP, 2007), and it is often recommended that a life cycle cost analysis (LCCA) be conducted when choosing the culvert material.

Figure 2-2: Example of flexible corrugated metal culvert. Photograph taken from Keller and Sherar, 2003.

Figure 2-3: Example of concrete circular culvert with wing walls. Photograph taken from Keller and Sherar, 2003.

2.3 Culvert Inspection and Maintenance Procedures

A number of researchers have investigated alternative strategies for culvert inspection, maintenance, and repair (Mitchell, et. al., 2005; Meegoda, et. al., 2005; Najafi, et. al., 2008; Hunt, et. al., 2010; Najafi and Bhattachar, 2011), which can minimize unexpected culvert failure (Tenbusch, 2010) and extend service life (Najafi, et. al., 2008). A number of factors, including corrosion, abrasion, physical damage, ground stability, erosion, increased peak flows due to upstream development, environmental changes, and sedimentation can lead to failure as culverts age (Tenbusch et al., 2009, NCHRP, 2007). These factors can be identified and a decision for rehabilitation or repair made during routine culvert inspection.

While culvert inspection provides one means of identifying culverts that require maintenance, routine culvert cleaning and maintenance (i.e. maintenance activities conducted on a predetermined schedule) can be a relatively low cost approach to extending the life of a culvert (Najifi, et. al., 2008; Tenbusch et al., 2009). Debris build up can be especially problematic during storm events, when a blocked culvert can reduce the ability of water to flow through it, causing flooding (Najifi, et. al., 2008). However, according to a survey of state DOT conducted by the National Cooperative Highway Research Program (NCHRP), only 20% of state agencies reported having a preventive maintenance program for culverts. The majority of respondents indicated that their approach to culvert maintenance is reactive rather than proactive (NCHRP, 2007).

In 2003, ODOT initiated a District-based Culvert Inventory and Inspection Program, which was field tested and deemed sound (Mitchell et. al., 2005). In 2011, this program moved from a District-based program into a statewide program. In the current program, culverts are inventoried and inspected by qualified personnel, and inspection results are uploaded to a centralized database system. During culvert inspections, information about the current condition of each culvert is collected by a qualified individual (ODOT Culvert Management Training). Figure 2-4 shows part of the ODOT culvert inspection form CR-86 (Ohio DOT Culvert Management Manual Appendix B, 2013).

STATE OF OHIO DEPARTMENT OF TRANSPORTATION

CULVERT INSPECTION REPORT

CR-86 07-13

CULVERT FILE NUMBER   CULVERT NUMBER ______ (CO) ______ (ROUTE) ______ (ID) - ______ (SLM)   DISTRICT ______

SPAN ______ SHAPE ______ MATERIAL ______ LENGTH ______

ROADWAY ID ______ ENTRY CLASS ______ NUMBER OF CELLS ______.

LATITUDE ______ LONGITUDE ______

FEATURE INTERSECTION:

CULVERT			
1. General		2. Culvert Alignment	
3. Shape		4. Seams or Joints	
5. Slab		6. Abutments	
7. Headwalls*		8. End Structure	
CHANNEL			
9. Channel Alignment		10. Protection	
11. Culvert Waterway Blockage		12. Scour*	
APPROACHES			
13. Pavement		14. Guardrail	
15. Embankment			
16. Level of Inspection		GENERAL APPRAISAL & OPERATIONAL STATUS	

*Only a bold box for structures that are Headwall or Scour critical. These items should not govern the GA if they are not determined to be critical upon the judgment of the inspector.

Figure 2-4: Partial culvert inspection ODOT form CR-86.

While bridges are required to be inspected annually, the frequency of culvert inspection is left to the individual districts (Syar, 2012, ODOT Manual of Bridge Inspection, 2010). From the Culvert Management Manual (2013), the recommended culvert inspection frequency is as follows:

- "Inspect all culverts with a span of 12 inches up to 48 inches prior to routine roadway maintenance activities (i.e.: resurfacing) or every 10 years, whichever is less.
- Inspect all culverts with a span greater than 48 inches but less than 120 inches every 5 years.
- Inspect all culverts that have a General Appraisal of 4 or less annually." A general appraisal of less than 4 indicates that the culvert is in generally poor condition.

In addition to the culvert maintenance and repair required as a result of inspection, the ODOT Online Bridge Maintenance Manual Preventative Maintenance/Repair Guidelines for Bridges and Culverts (Ohio DOT) also recommends the following preventative maintenance measures be conducted:

- For corrugated metal culverts, pour concrete in the base once corrosion has begun
- Clean interior
- Remove vegetation from inlet
- Remove trees growing above culvert
- Place riprap along exposed footers

Traditional ODOT Methods for cleaning culverts include manual cleaning, which can be labor intensive, or the use of Vactor® trucks for material collection, which can result in the generation of a waste water stream that must then be managed. For culverts that are designated as confined spaces, manual cleaning requires that personnel be trained for confined space entry, which can also add to the cost of culvert maintenance. ODOT's statewide inventory includes a confined space designation for each culvert, as appropriate. This existing data can be used to aide in the selection of an appropriate, cost effective method for cleaning each culvert.

2.4 Use of Remote Control Culvert Cleaning Equipment

To reduce the risks and training costs associated with confined space entry, and to reduce the generation of waste water associated with the use of an eductor truck for culvert clean out, a third option is the use of remote controlled equipment that can enter the culvert, collect the material, and bring it outside the culvert for disposal. As shown in Figure 2-5, other state DOT have already begun using this technology. The Oregon DOT was able to use a remote controlled Ditch Witch Model SK-500 to remove debris from a culvert after a landslide. Clean up time was reduced from two weeks to three days using this technology (http://www.youtube.com/watch?v=3N56zw5edJk).

Also shown in Figure 2-5 is the MicroTraxx tunnel mucker, manufactured by Rohmac, Inc. Numerous state DOT and municipalities have purchased or used this equipment, which is specifically designed for culvert cleanout (personal communication, Rohmac, Inc.). The use of this unit is currently being evaluated by Caltrans, where they are rotating the unit among Districts. The unit is equipped with GPS tracking, and spends approximately four weeks per year in each District. Initial testing of the unit has shown that it can remove material from a culvert at a rate of ten cubic yards per hour, and that material removal with the tunnel mucker is approximately four times faster than with a traditional eductor truck method (Caltrans Division of Research, 2013). Based on evaluation over a four year period and nearly 1,000 hours of engine run time, researchers concluded that the use of this machine reduces costs, increases operational speed, and reduces worksite injuries (Velinsky, et al., 2012).

Figure 2-5: Remote controlled culvert cleanout equipment.

CHAPTER III: CURRENT PRACTICES FOR CULVERT MAINTENANCE AND INSPECTION

3.1 Introduction

To establish the current state of the practice for culvert maintenance and inspection, a combination of an online survey and telephone interviews were utilized. These surveys and interviews focused on maintenance schedules, strategies for culvert cleaning, and experience with remote control culvert cleaning equipment.

To assess the current state of the practice for culvert maintenance in other states, an online survey was developed using Survey Monkey (www.surveymonkey.com). The survey was divided into three subsections: inspection, maintenance, and remote control equipment (Appendix A) and distributed by email to personnel involved in asset management from all 50 states on November 18, 2013. Contact information was obtained from the U.S. Department of Transportation Federal Highway Administration (FHWA) website (http://www.fhwa.dot.gov/infrastructure/asstmgmt/amcontacts.cfm). The survey requested contact information be provided for follow-up purposes.

Because the main focus of this research is establishing best management practices for use in Ohio, an additional online survey was developed using Survey Monkey (www.surveymonkey.com) and distributed to the Highway Management Administrator (HMA) in each of the twelve ODOT districts on November 15, 2013 (Appendix B). The survey focused on current practices for culvert maintenance. The main goal of this survey was to identify best management practices in Ohio and learn from their successes and failures, as well as to gain an understanding of the labor issues associated with current cleanout methods and the impact of not properly maintaining these structures.

3.2 Culvert Maintenance outside Ohio

A total of 23 personnel responded to the request for participation in the culvert maintenance survey. Detailed summaries of responses to questions six through twenty-five are provided below. The first five survey questions were used to identify the individual completing the survey and request contact information for follow up, and those data are not provided here.

3.2.1 Survey Results

Question 6: Does your state DOT maintain an inventory of culverts?

A total of 20 responses were received for this question. As shown in Figure 3-1, 65% of respondents indicated that their state does maintain an inventory of culverts, and 35% indicated that their state does not maintain a culvert inventory. Online one state responded that they are making their culvert inventory available online.

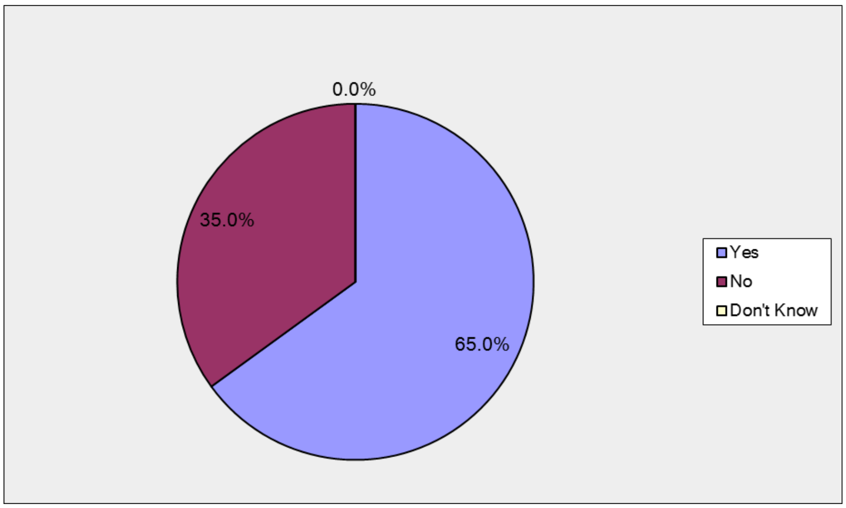

Figure 3-1: Results of survey question 6.

Question 7: Does your state have a standard operating procedure for culvert inspection?

Of the twenty responses received for this question, 50% indicated that their state does not have a standard operating procedure for culvert inspection, while 45% indicated that their state does have a standard operating procedure for culvert inspection (Figure 3-2). Two respondents indicated that this information is publicly available.

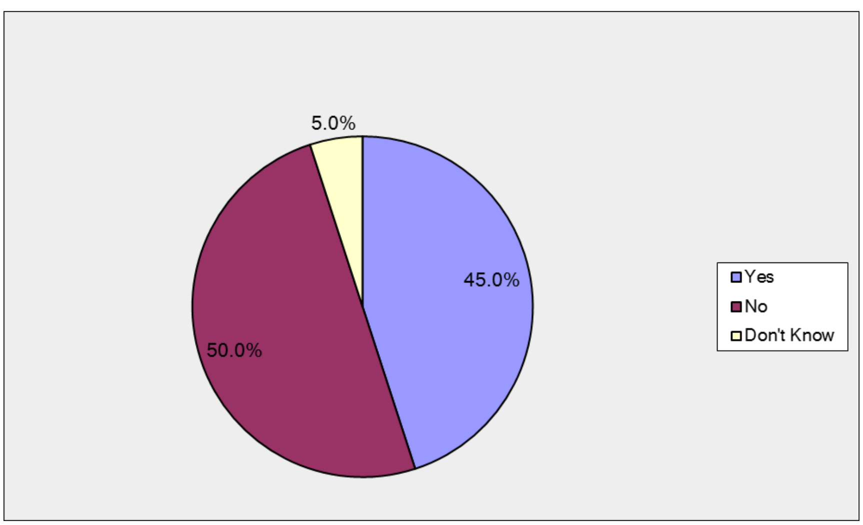

Figure 3-2: Results of survey question 7.

Question 8: How frequently are culverts inspected?

10.5% of respondents indicated that culverts are inspected every other year, while 89.5% indicated an alternative inspection frequency (Figure 3-3). Two respondents indicated that an inspection frequency will be established when their culvert inventory is complete, four respondents indicated that inspections are done on an 'as-needed' basis or when a problem is identified, one respondent indicated that culverts are inspected at 1, 2, 4, or 6 year intervals, depending on condition ratings, another respondent indicated a 3-year inspection frequency, while yet another indicated that culverts are inspected twice per year.

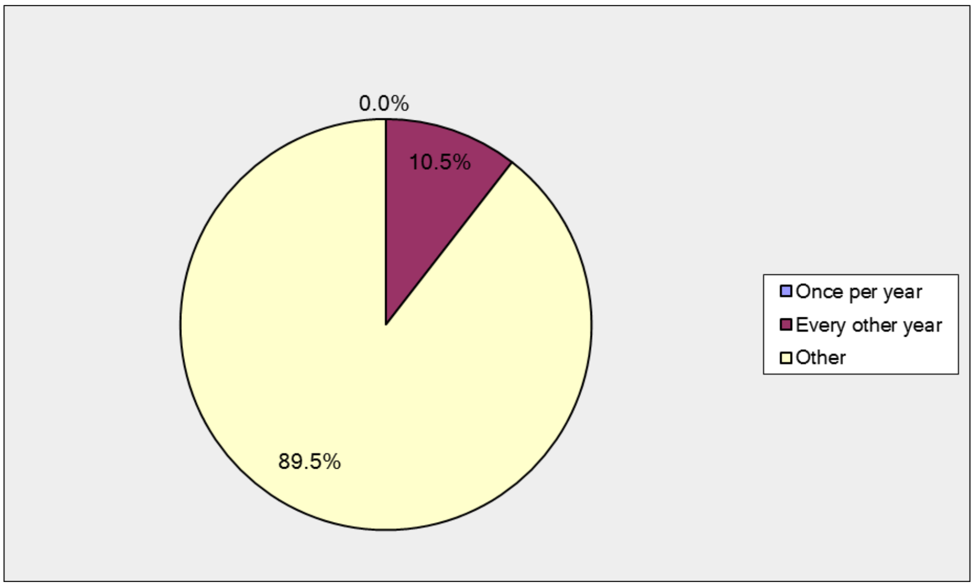

Figure 3-3: Results of survey question 8.

Question 9: Are culvert inspection used to generate work orders for repair and/or maintenance of culverts?

Of the twenty respondents to this question, 65% indicated that culvert inspections are used to generate work orders, while 35% indicated that they are not (Figure 3-4).

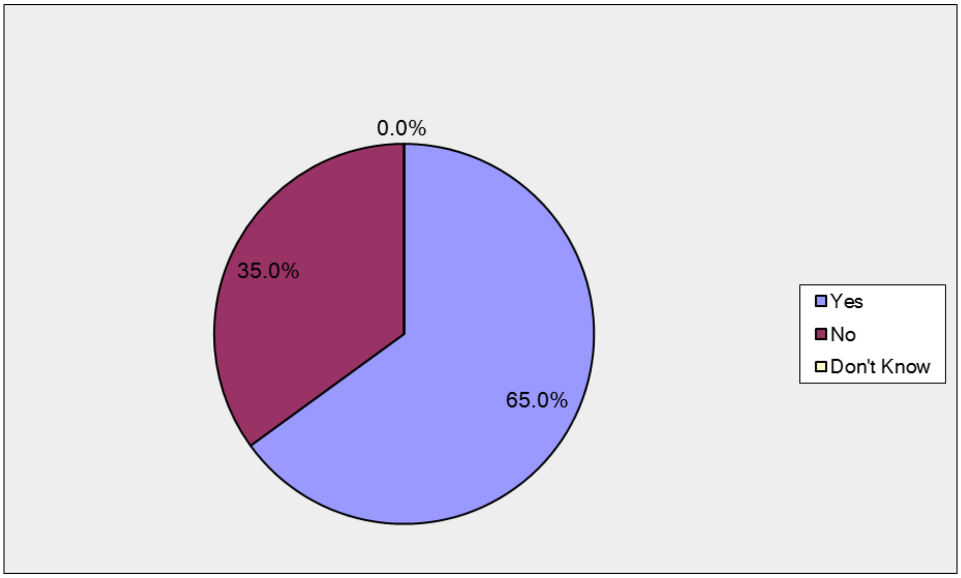

Figure 3-4: Results of survey question 9.

Question 10: Are culverts cleaned on a routine schedule?

As shown in Figure 3-5, 95% of respondents indicated that a routine schedule for cleaning culverts has not been established.

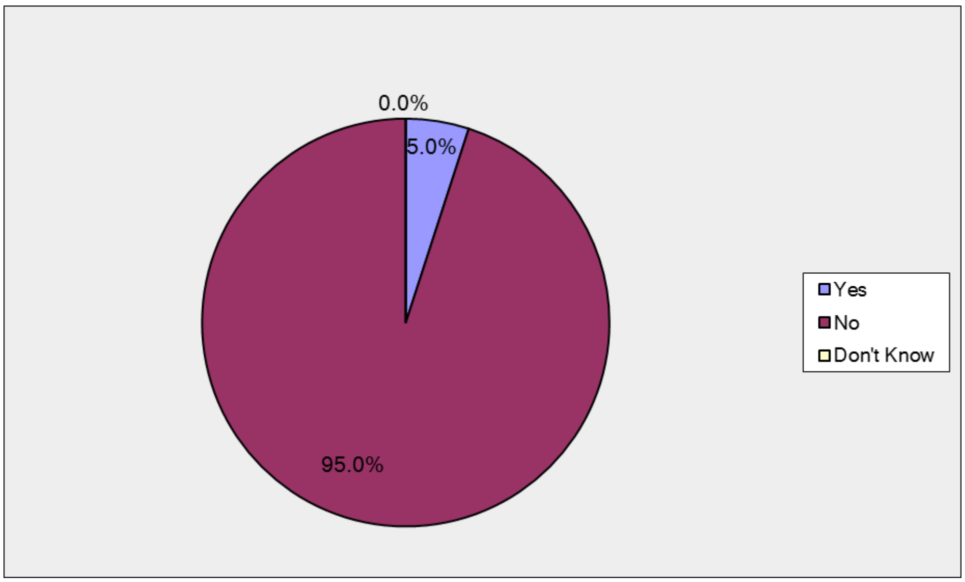

Figure 3-5: Results of survey question 10.

Question 11: How frequently are culverts cleaned?

85% of respondents to this question indicated that culverts are cleaned on an 'as-needed' basis (Figure 3-6). Of the respondents indicating another frequency, one respondent indicated that culvert cleaning schedules vary by region, another that cleaning is scheduled based on reported problems, and another that they are trying to establish a cleaning schedule.

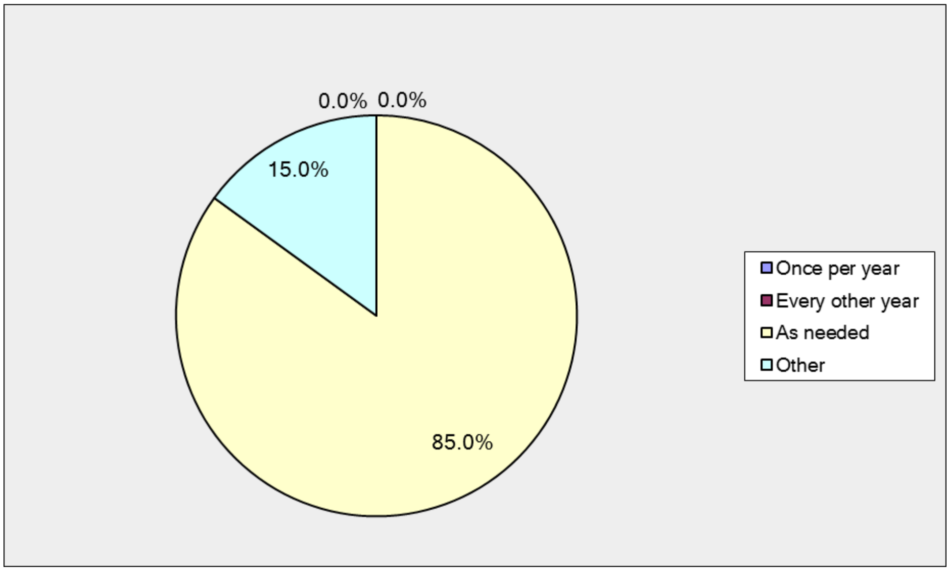

Figure 3-6: Results of survey question 11.

Question 12: How is culvert cleaning scheduled?

35% of respondents to this question indicated that culvert cleaning schedules are based on the results of culvert inspection, while 65% of respondents indicated another method for scheduling culvert cleaning (Figure 3-7). Two respondents indicated that cleaning is scheduled depending on geography or known areas with drainage problems, two indicated that cleaning schedules are dictated by budget, while six respondents indicated that cleaning is scheduled when a problem is identified.

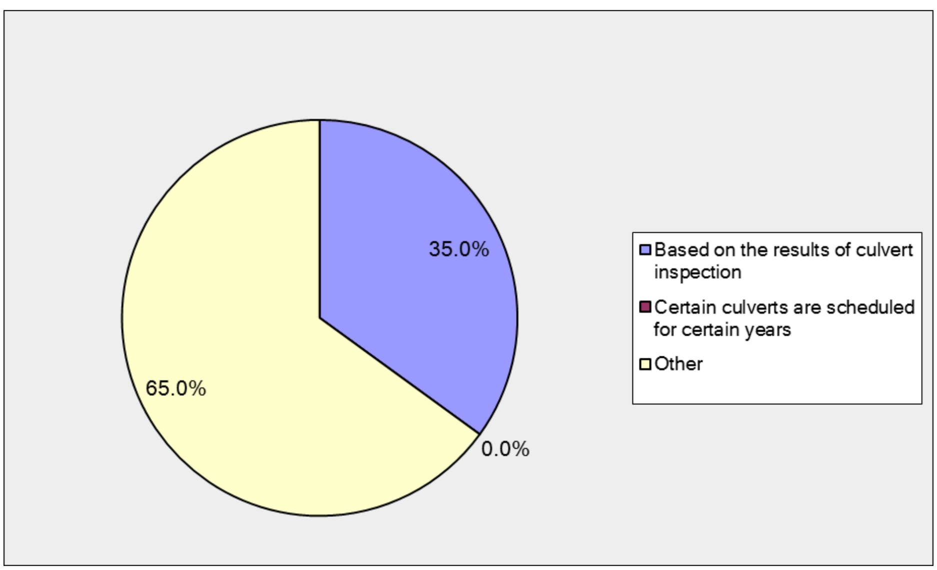

Figure 3-7: Results of survey question 12.

Question 13: How are culverts greater than 36 inches in diameter cleaned?

Of the 20 respondents to this question, 65% reported that large diameter culverts are manually cleaned, 70% reported that a vactor truck is used for sediment removal, 10% indicated that remote control culvert cleaning equipment has been used, and 30% indicated another method for cleaning large culverts (Figure 3-8). Because respondents were allowed to select multiple answers to this question, the numbers do not sum to 100%. Three of the respondents indicated that small track mounted equipment (skid steer, Bobcat, loader) is used when it will fit into the culvert opening.

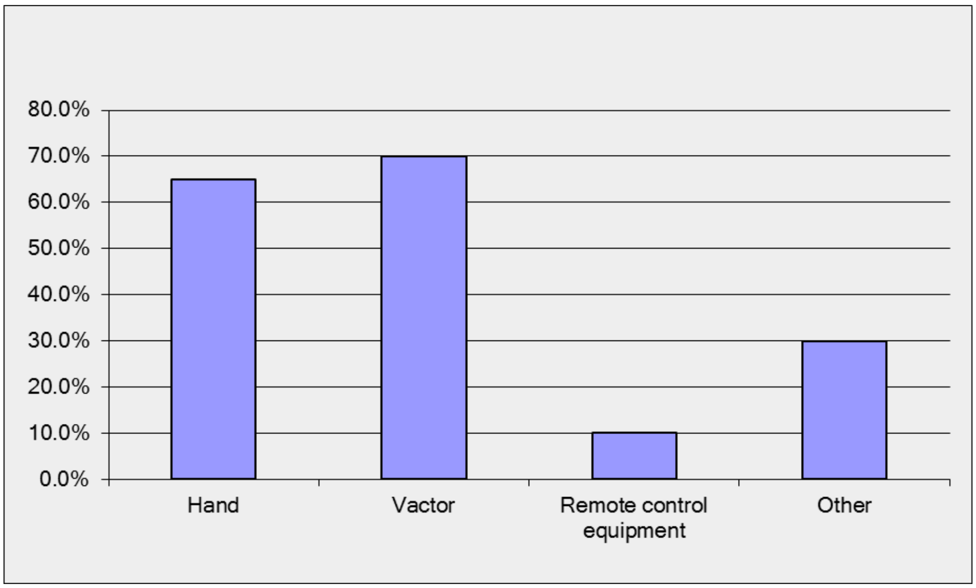

Figure 3-8: Results of survey question 13 (note: because respondents were allowed to select multiple responses, totals exceed 100%).

Question 14: Have you encountered specific environmental issues with large culvert cleanout activities (e.g. permitting issues, etc.)?

55% of respondents to this question indicated that they have not had environmental issues with large culvert cleanout activities, while 30% indicated that they have, and 15% indicated that they were unsure (Figure 3-9). One respondent indicated that permitting requirements depend on the proximity to outfall locations, another indicated that special permits are required for culverts that have been identified as fish passage culverts, while another indicated that there are state and federal permitting requirements for protected streams.

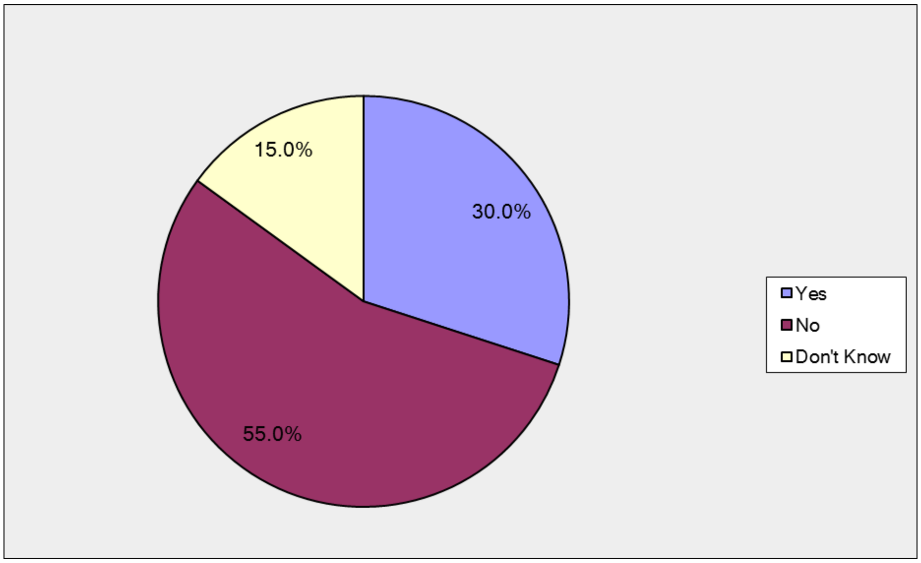

Figure 3-9: Results of survey question 14.

Question 15: Does your organization have any issues with culvert material collection and disposal (e.g. additional handling or disposal requirements)?

As shown in Figure 3-10, 50% of respondents indicated that they do not have issues with culvert material collection and disposal, while 30% indicated that they do, and 20% indicated that they were unsure (Figure 3-10). One respondent indicated that invasive weeds and any contaminated materials must be hauled directly to a landfill for disposal; while another respondent indicated that sometimes material can be left on the edges of the stream bank (not a permitted practice in Ohio), and other times it must be hauled off-site for disposal.

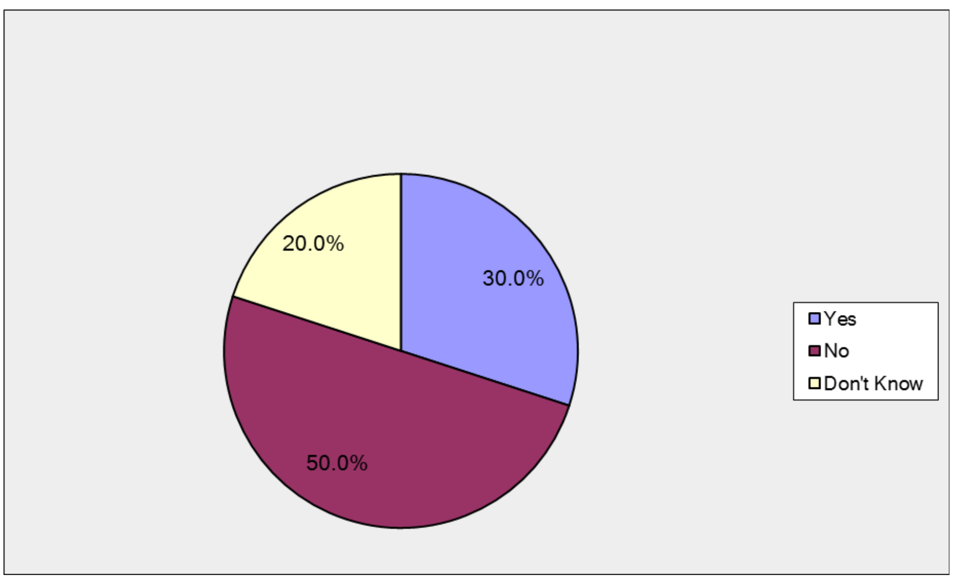

Figure 3-10: Results of survey question 15.

Question 16: Has your state used remote control culvert cleaning equipment?

75% of respondents to this question indicated that their agency has not used remote control culvert cleaning equipment, while 15% have, and 10% were unsure (Figure 3-11).

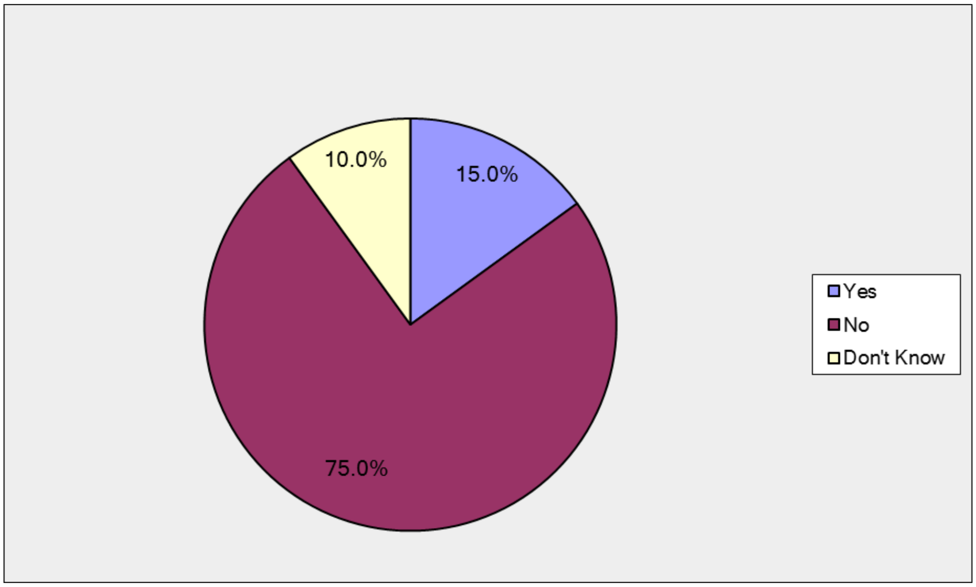

Figure 3-11: Results of survey question 16.

The remaining survey questions addressed experience with remote control culvert cleaning equipment, so only those respondents who indicated that they have used this equipment in question 16 were asked to complete this part of the survey. The following section summarizes the experience of four states in using this equipment.

Question 17: Does your organization own or rent the equipment?

One respondent indicated that their organization owns the equipment, one indicated that they rent it, and two were unsure (Figure 3-12).

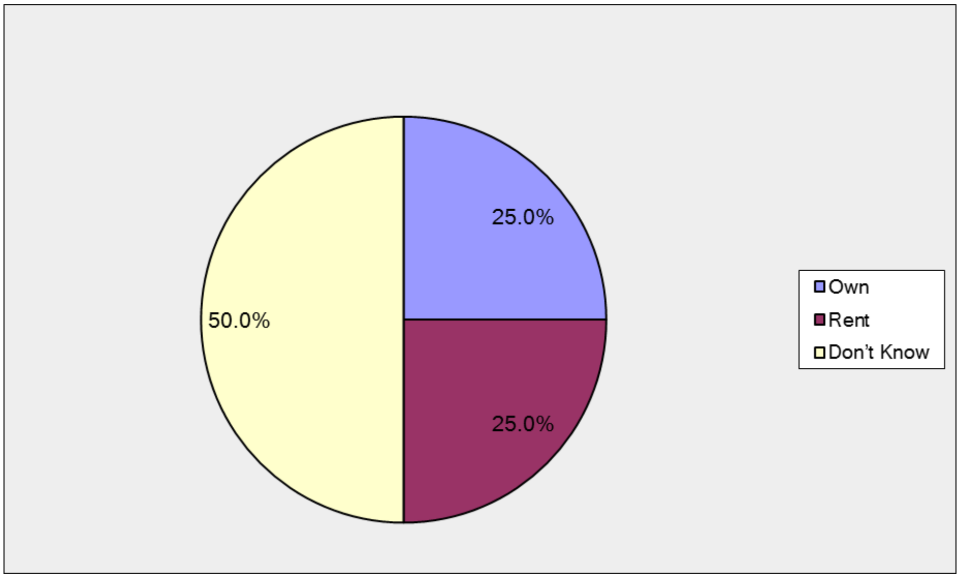

Figure 3-12: Results of survey question 17.

Question 18: How long have you been using this equipment?

As a follow up, the respondents were asked about the length of time they have been using the equipment. One respondent indicated that the equipment is new within the last five years, another within the last eight months.

Question 19: What type of equipment did you use?

Two respondents indicated that they use the MicroTraxx Tunnel Mucker, one using model SL436, and another using MT 3234. Other equipment manufacturers were not reported.

Question 20: Is this equipment used routinely by your organization? (i.e. it is the first choice for large culvert cleanout)

Only one respondent reported that this equipment is used routinely (Figure 3-13).

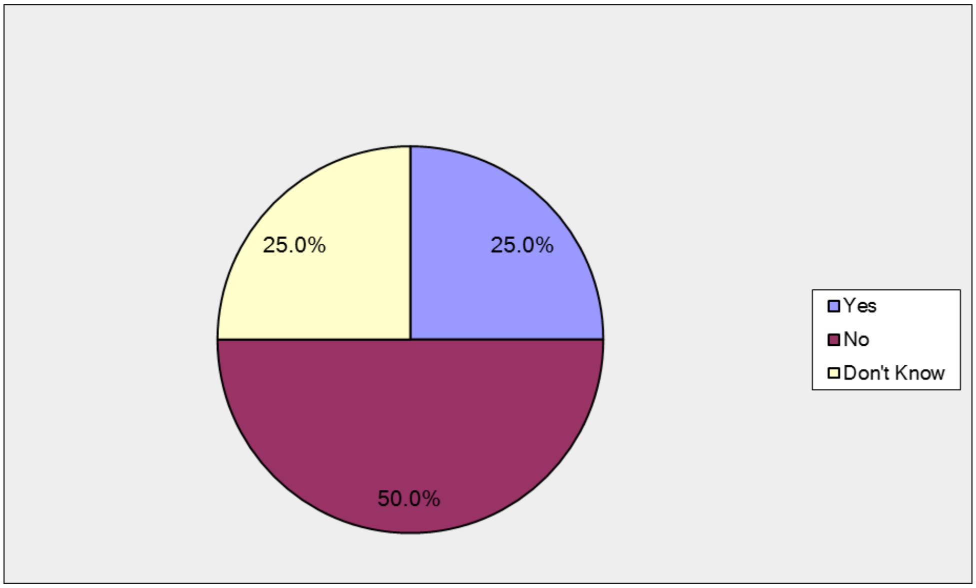

Figure 3-13: Results of survey question 20.

Question 21: Have you developed a method for deploying the remote control cleanout equipment?

Two respondents indicated that they have developed a method for the deployment of remote control equipment, while two indicated that their organization has not (Figure 3-14).

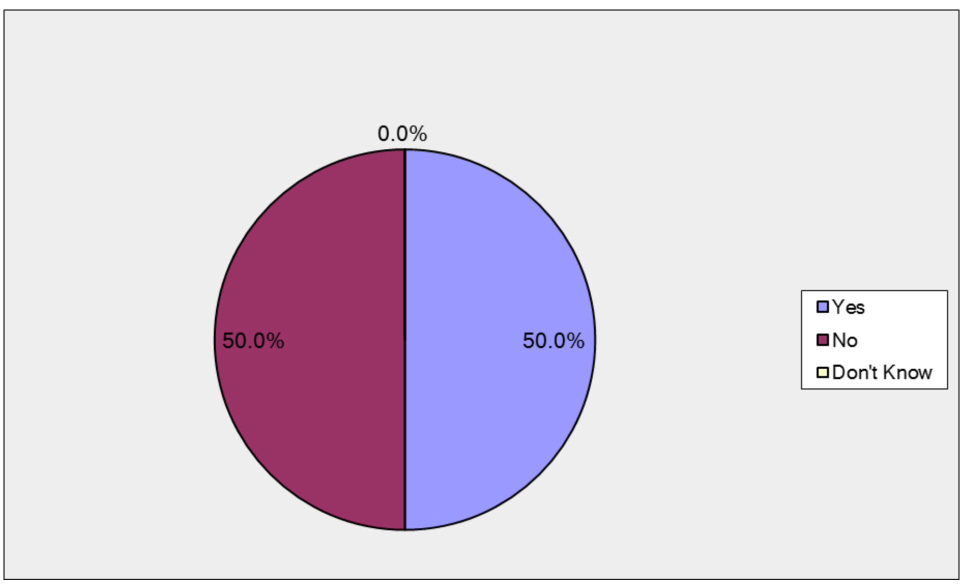

Figure 3-14: Results of survey question 21.

Question 22: Was extensive training required to enable personnel to effectively use the equipment?

Two respondents indicated that equipment training was extensive, while one indicated that it was not and one indicated that they were unsure (Figure 3-15).

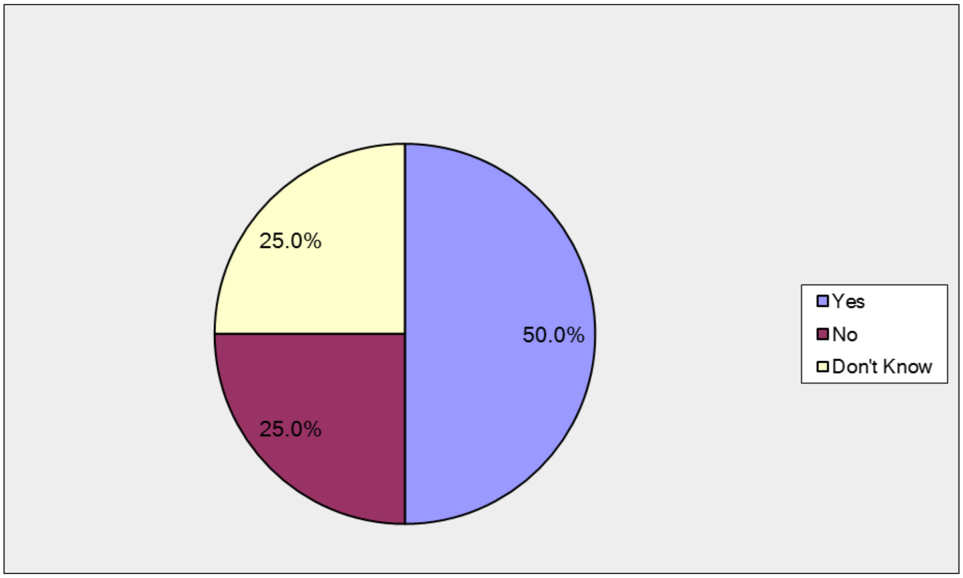

Figure 3-15: Results of survey question 22.

Question 23: Are special permits required to use the equipment?

Two respondents indicated that special permits are required to use remote control culvert cleaning equipment, while one indicated that they are not, and one was unsure (Figure 3-16).

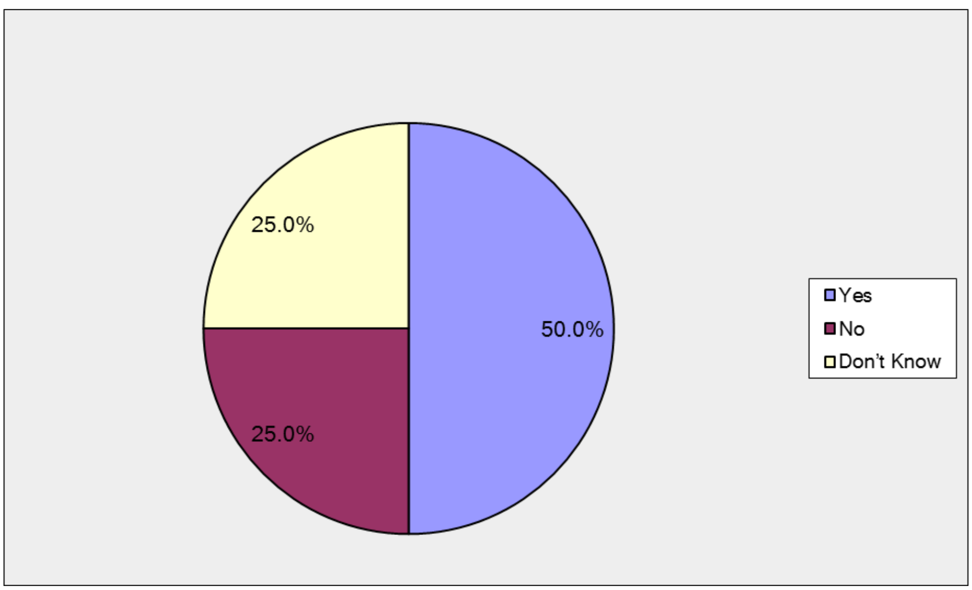

Figure 3-16: Results of survey question 23.

Question 24: Have you encountered any environmental issues while using this equipment?

Three out of four respondents indicated that they have encountered environmental issues while using remote control culvert cleaning equipment (Figure 3-17). One respondent indicated that sometimes, stream alteration permits are required, but not always. The respondent also indicated that there are air quality issues for the equipment operators. Regarding issues with the equipment, one respondent indicated that at a distance of 140 feet into a 60-inch diameter pipe, the device lost its connection with the remote. The equipment also had issues in getting enough air for operation.

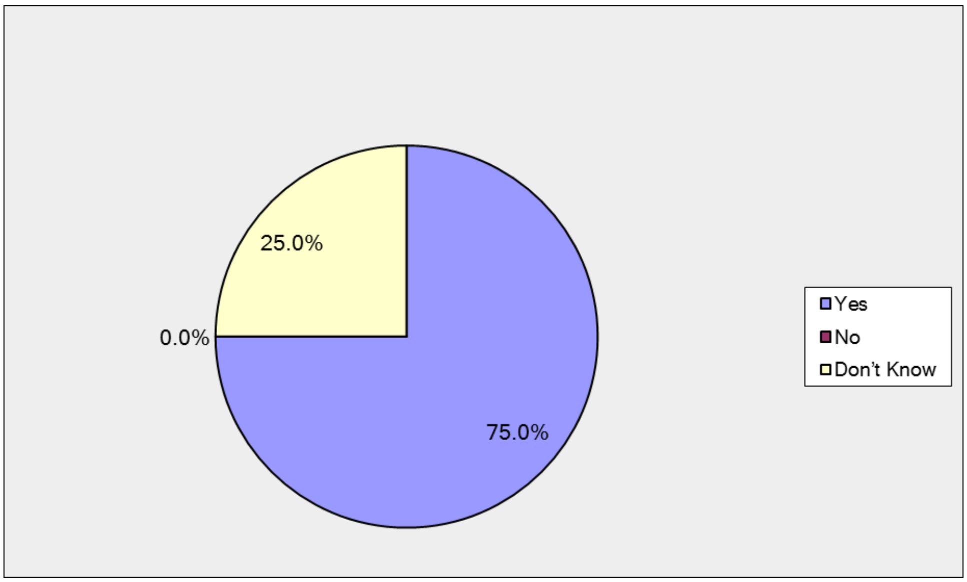

Figure 3-17: Results of survey question 24.

Question 25: Was the use of this equipment considered a success?

Three out of four respondents indicated that they considered their experience with remote control culvert cleaning equipment a success (Figure 3-18).

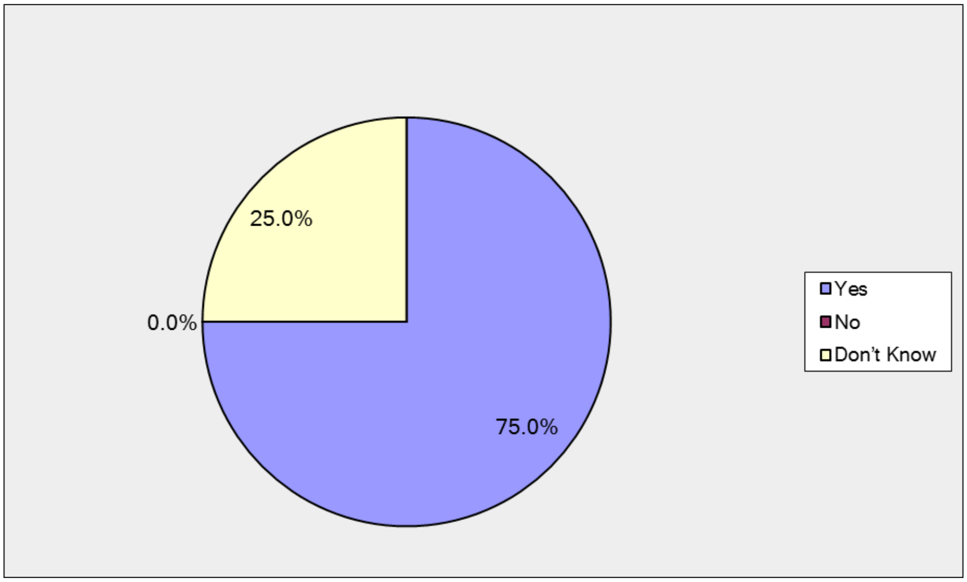

Figure 3-18: Results of survey question 25.

3.2.2 Summary

The following conclusions can be made based on the results of survey of current culvert maintenance and inspection practices in other states:

- Most states that participated in the survey do not routinely inspect or remove sediment from large culverts.
- Most states that participated in the survey reported that culvert cleaning and maintenance is reactive (i.e. when a failure or overflow occurs), rather than proactive. This may be in part due to budgetary constraints.
- The majority of respondents indicated that debris is removed from large culverts using traditional vactor or hand methods.
- Four respondents indicated that they have had positive experiences using remote control equipment for culvert cleaning, with two of those states indicating that they have used the MicroTraxx Tunnel Mucker by Rohmac, Inc.

3.3 Culvert Maintenance in Ohio

A total of 37 responses (with multiple responses from county garage managers) to the survey of culvert maintenance and inspection practices in Ohio were received, with 11 of the 12 ODOT Districts participating. Detailed survey responses to questions six through twelve are provided below.

3.3.1 Survey Results

Question 6: Does your county have a completed culvert inventory?

As shown in Figure 3-19, 88.6% of respondents indicated that their county has a completed culvert inventory. However, it should be noted that multiple responses were received from some Districts, so multiple responses may have been received from an individual county.

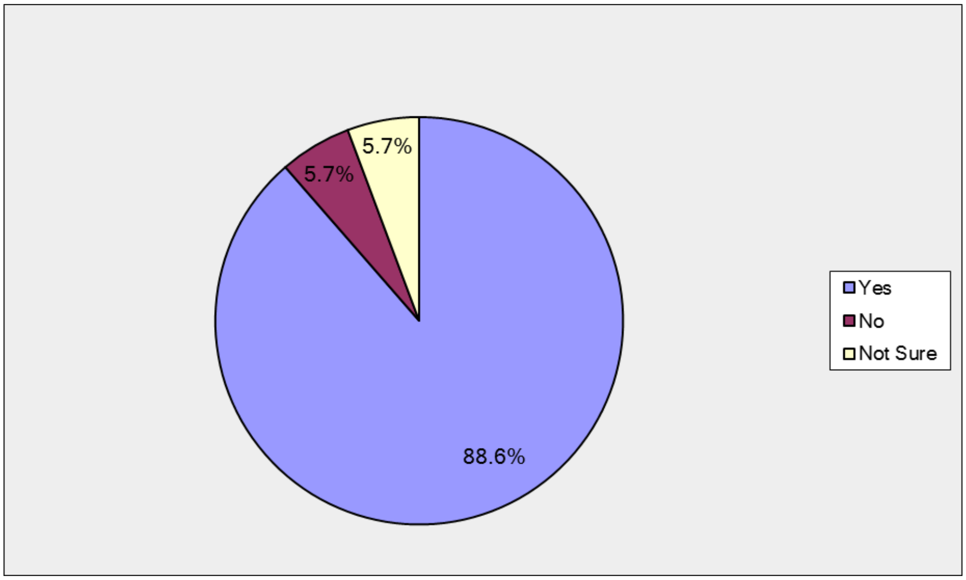

Figure 3-19: Results of ODOT Survey question 6.

Question 7: Are large culverts routinely inspected by DOT personnel in your county?

As shown in Figure 3-20, 80% of respondents indicated that culverts are routinely inspected in their county, while 20%, or seven respondents, indicated that culverts are not routinely inspected.

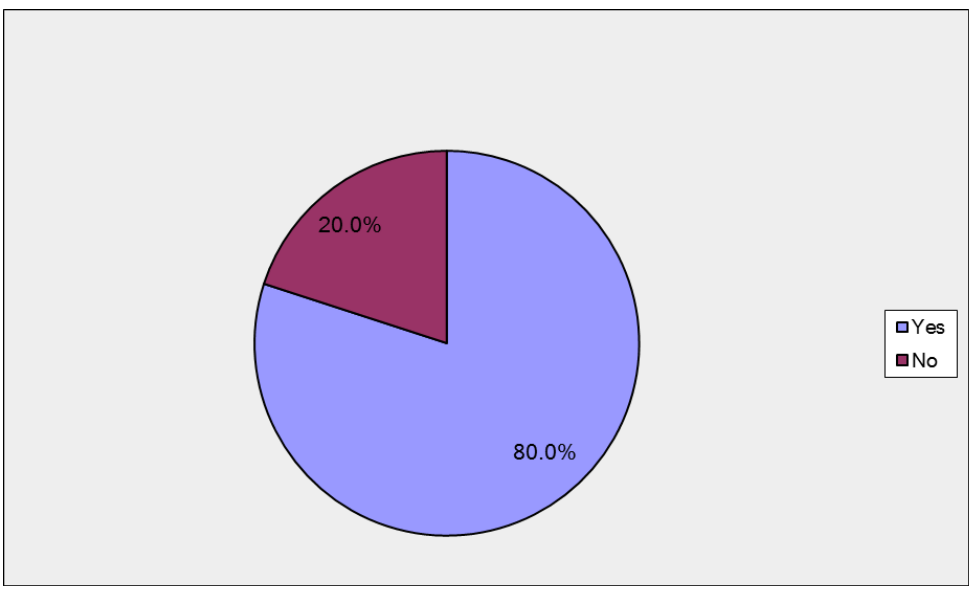

Figure 3-20: Results of ODOT Survey question 7.

Question 8: Is culvert maintenance scheduled in advance?

80% of respondents indicated that culvert maintenance is scheduled in advance. The majority of respondents indicated that maintenance is scheduled based on the results of routine culvert inspection or culvert inspections that are conducted in anticipation of roadway projects. Culvert maintenance is also conducted after storm events.

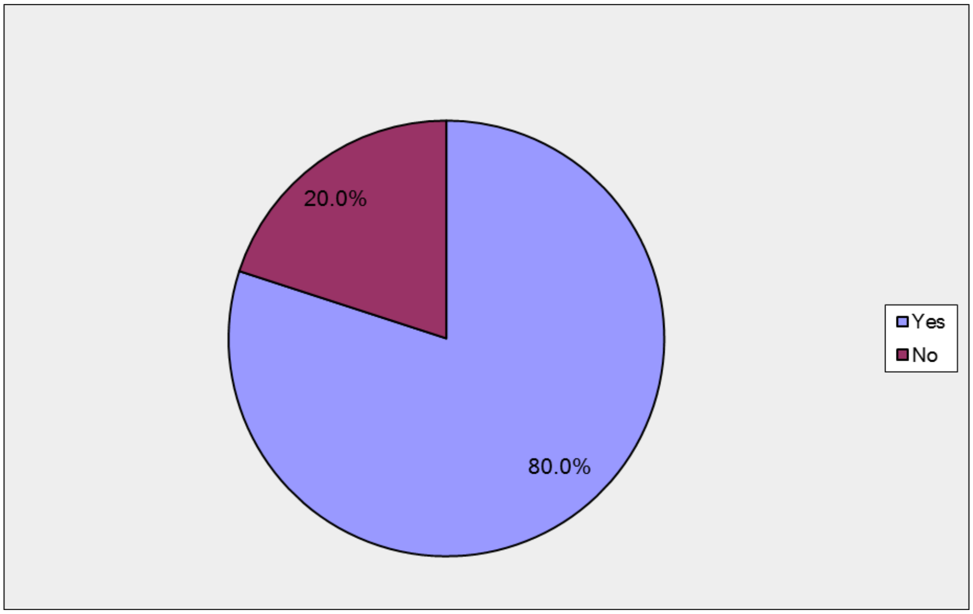

Figure 3-21: Results of ODOT Survey question 8.

Question 9: How are culvert cleaning activities initiated?

As shown in Figure 3-22, more than 90% of respondents indicated that culvert maintenance is initiated based on culvert inspection, while 73% indicated that the physical characteristics of the culvert are also considered when scheduling maintenance activities. Other reported causes of culvert maintenance included complaints, experience, and observations of field personnel. Because users were allowed to select more than one answer to this question, the percentages do not total to 100%.

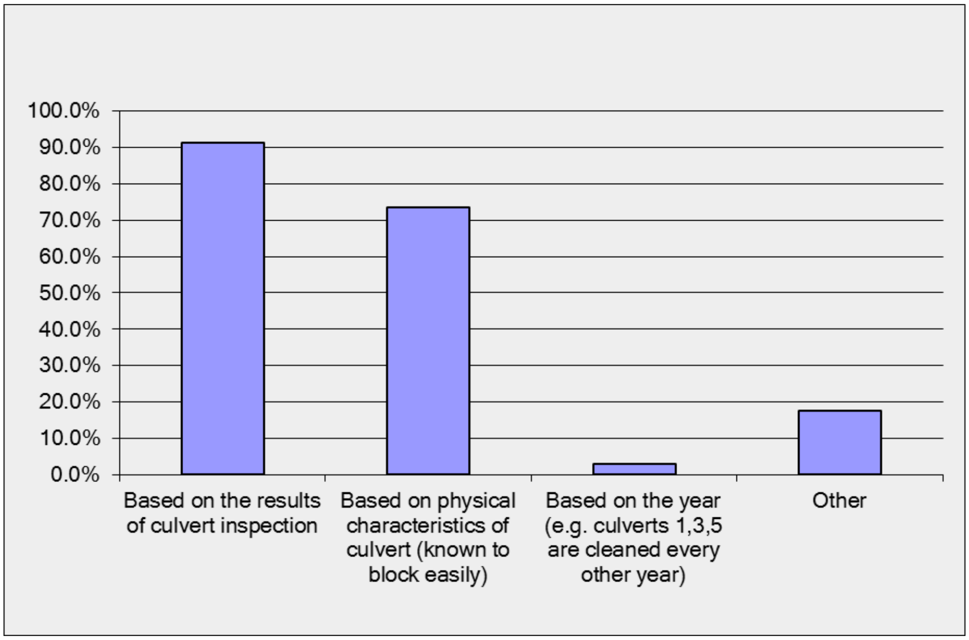

Figure 3-22: Results of ODOT Survey question 9 (note: because respondents were allowed to select multiple answers, totals exceed 100%).

Question 10: How are culverts greater than 36” currently cleaned?

As shown in Figure 3-23, 61% of respondents indicated that large culverts are cleaned by hand, while 51% indicated that Vactor equipment is used, and 45% indicated another means of culvert cleaning. Again, because users were allowed to select more than one answer, percentages do not total to 100%. Several respondents indicated that culverts larger than 36” are not cleaned, or that the ends are cleaned using heavy equipment (i.e. backhoe), allowing the water to remove the remaining debris. In some cases, contractors are used to clean the culverts.

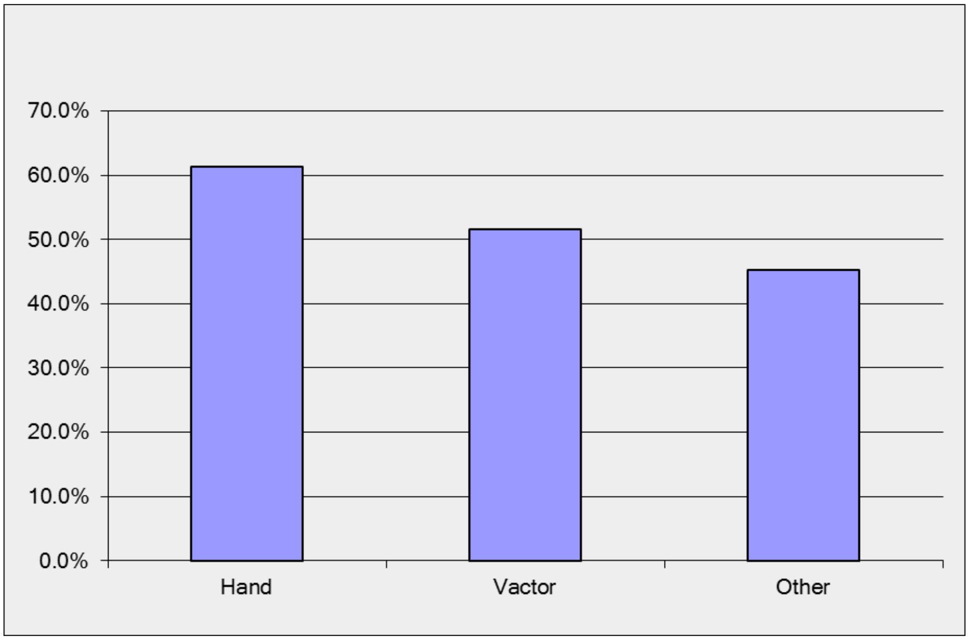

Figure 3-23: Results of ODOT Survey question 10 ((note: because respondents were allowed to select multiple answers, totals exceed 100%).

Question 11: Have you encountered specific environmental issues with large culvert cleanout activities (e.g. permitting issues, etc.)?

As shown in Figure 3-24, 63% of respondents indicated that they have not encountered environmental issues with large culvert cleanout, while 37% of respondents indicated that they have. Some of the issues reported include:

- Internal Environmental Assessment forms are required prior to excavating material
- Culverts larger than 24" require permits for work to be conducted
- Wetland issues
- Occasional issues with debris disposal

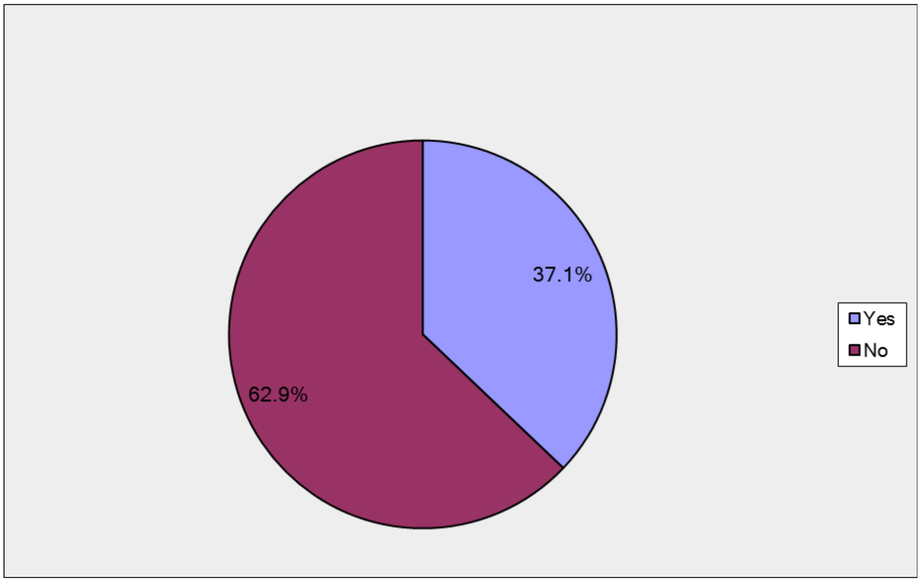

Figure 3-24: Results of ODOT Survey question 11.

Question 12: Does your county have any issues with culvert material collection and disposal (e.g. additional handling or disposal requirements)?

As shown in Figure 3-25, 77% of respondents indicated that they have not encountered issues with material collection and disposal, while 23% indicated that they have. Several respondents reported that they are required to find approved areas for the materials. While some of the counties have designated approved disposal areas, others reported difficulty in finding locations to dispose of vactor debris.

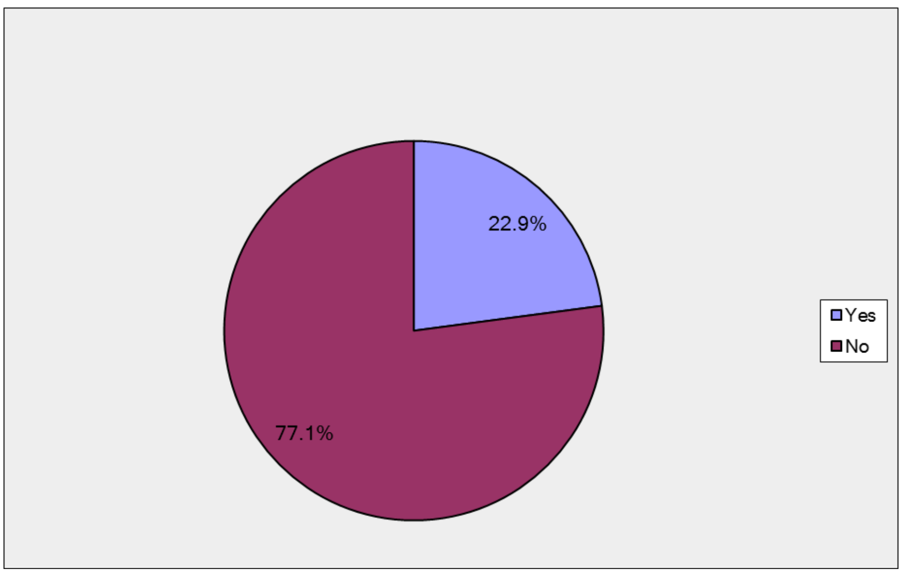

Figure 3-25: Results of ODOT Survey question 12.

3.3.2 Summary

The results of the survey of Ohio DOT personnel indicated that the majority of Districts responding have a completed culvert inventory, that culverts are routinely inspected, and that the results of these inspections are used to schedule maintenance activities. Details on scheduling were not provided. While large culverts are commonly cleaned by hand or vactor truck, other strategies, including the removal of debris from the inlet/outlet using heavy equipment, and the use of contractors who specialize in this activity, were also reported.

CHAPTER IV: REMOTE CONTROL EQUIPMENT ACQUISITION AND FIELD EVALUATION

4.1 Introduction

The focus of this chapter is the acquisition and use of remote controlled equipment for cleaning large culverts. Task 3, a preliminary evaluation of commercially available remote control culvert cleaning equipment, was detailed in the Interim Report and is also summarized in this chapter. The evaluation was based on the results of the literature review, feedback from other state DOT personnel (Task 1), feedback from ODOT personnel (Task 2), cost, and necessary training. Shortly after the Interim Report was issued, the decision was made to purchase a MicroTraxx Tunnel Mucker 3234 from Rohmac, Inc. The field evaluation of the equipment performance was included in Task 5, which the bulk of this chapter discusses. The end of this chapter discusses the cost-benefit analysis of the MicroTraxx during 2014 (Task 6).

4.2 Preliminary Evaluation

4.2.1 Vendor Information

Five vendors were contacted to obtain information on remote control culvert cleaning equipment: Rohmac, Inc., KT Grant, Inc., Bobcat of Akron, Ditch Witch of Akron, and Ditch Witch Corporate Headquarters. Of the five vendors contacted, Rohmac, Inc., and KT Grant, Inc. would be able to provide equipment meeting the specifications of this project. Bobcat does not manufacture remote controlled equipment that meets the size requirements for cleaning culverts (personal communication, Bobcat). Ditch Witch does not sell remote controlled equipment through local distributors (personal communication, Ditch Witch). On further communication with personnel from Ditch Witch Research and Development (R&D), it was determined that Ditch Witch does not have any remote control units in their product line, and that the Ditch Witch model that had been configured to meet the needs of the Oregon DOT (described in Section 2.4 above) was retired as it did not meet product specifications (Ditch Witch, personal communication). Although Ditch Witch indicated they would be willing to work with ODOT to create a remote control product, if desired, it was unlikely they would have been able to accommodate the acquisition schedule, which includes field testing within a few months (Ditch Witch, personal communication). Table 4-1 summarizes the list of companies contacted and their ability to supply equipment that would be suitable for cleaning large culverts.

Table 4-1: Vendors contacted for inquiry regarding remote control culvert cleaning equipment

Vendor Contacted	Equipment Available?
Rohmac, Inc.	Yes
Bobcat (Akron, Cleveland)	No
Ditch Witch (Akron)	No
Ditch Witch (corporate)	Not off the shelf
KT Grant, Inc.	Yes

Based on Table 4-1, only Rohmac, Inc. and KT Grant, Inc. were able to provide equipment that would meet the specifications of this project in time for field testing in summer 2014; however, at the time a decision needed to be made regarding equipment acquisition, KT Grant, Inc. was not able to provide pricing information.

Rohmac, Inc. manufactures two MicroTraxx models that are designed for culvert cleaning. According to Rohmac, Inc. personnel, this equipment has been purchased or used by 16 state DOTs, along with several state and county governments for cleaning culverts. Table 4-2 summarizes the list of entities using MicroTraxx, while Table 4-3 summarizes the two MicroTraxx Equipment Models meeting ODOT specifications. In the survey of other state DOT, the only model of remote control culvert equipment reported was MicroTraxx (Section 3.2.1). In addition, MicroTraxx was the equipment of choice for the Caltrans evaluation of remote control culvert cleaning equipment (Section 2.4).

Table 4-2: Entities that have purchased or used the MicroTraxx Tunnel Mucker for cleaning culverts (provided by Rohmac, Inc.).

Purchased	Used
PennDOT	NJ DOT
Caltrans	NY DOT
INDOT	KYTC
TNDOT	NE DOT
MoDOT	SD DOT
VDOT	TX DOT
NY Thruway	WV DOT
ALDOT	Michigan County Gov’ts
UDOT	
Phoenix, AZ	
Scottsdale, AZ	
Newport News, VA	

Table 4-3: Comparison of MicroTraxx equipment models and preliminary cost estimates (provided by Rohmac, Inc.).

Model	SL 436	MT 3234
Dimensions		
Height	42”	32”
Width	42”	34”
Length	120”	134”
Fits Culvert Size		
Box	48”	34”
Circular	60”	48”
Weight	5,600 pounds	4,500 pounds
Bucket Capacity	$^{1}/_{3}$ cubic yard	$^{1}/_{4}$ cubic yard
Base Cost	$100,000	$95,000
Training Cost	$1,900/day	$1,900/day

4.2.2 Summary

Based on the availability of remote control culvert cleaning equipment (i.e. only one manufacturer was identified that was able to meet the specifications of this project), as well as feedback from other state DOT, and the information provided by Caltrans regarding the cost effectiveness of the MicroTraxx Tunnel Mucker, it was determined that is was likely that the MicroTraxx Tunnel Mucker would meet the requirements of this project. Two models were available: the SL 436 and the MT 3234. The MT 3234 is the smaller product, and would meet the project specifications for culvert size (box culverts 34” and circular culverts 48”). A detailed product brochure is provided in Appendix E.

4.3 Equipment Acquisition and Training

4.3.1 Acquisition Decision

After reviewing the Interim Report, project stakeholders elected to move forward with the purchase of the Rohmac, Inc. MicroTraxx MT 3234. The primary reason for the selection of the MT 3234 unit was the machine’s ability to enter box culverts greater than 34 inches in height as defined in the project objectives; the SL 436 had an equipment height of 42 inches that precluded the use in culverts less than 4 feet in diameter or height. The MT 3234 unit possessed a height of 32 inches which allowed it to enter box culverts with a height greater than or equal to 34 inches and circular culverts possessing diameters of 48 inches or larger. The MT 3234 model was also slightly cheaper.

4.3.2 Delivery and Training

On the morning of May 29, 2014, the MicroTraxx MT 3234 machine was delivered to Columbiana County Garage in Lisbon, Ohio by an employee of Rohmac, Inc. Table 4-4 details the items purchased and delivered by Rohmac, Inc. Multiple copies of the Operation, Maintenance, and Parts Manual accompanied the equipment. This manual, except for the Parts section, can be found in Appendix F.

Table 4-4: Delivered items by Rohmac, Inc. to ODOT at Columbiana County Garage on May 29, 2014.

Name	Item Number	Quantity
Model MT 3234 MicroTraxx Loader	000-0113073	1
Manual Emergency Pendant Control Box	002-0013602	1
MG 32 Grapple Attachment	002-1407200	1
48” Dozer Blade Attachment	002-1406600	1
Bit with Mounting Block and Bolts	039-2021001	5

The standard machine comes with a ¼ cubic yard bucket attachment which can be removed and replaced with two alternative attachments which were purchased as well. A grapple attachment, pictured in Figure 4-1**Error! Reference source not found.**, was purchased for the clearing of tree trunks, branches, and other large debris that may block a drainage pipe and is unreachable by larger, more traditional equipment. The second attachment is a 48 inch wide blade (Figure 4-2) to be used at the end of the box culvert cleaning process because it can more efficiently clear the residual sediment at the culvert bottom than the bucket attachment, which was designed for scooping and hauling.

Figure 4-1: MicroTraxx 3234 unit with grapple attachment at Columbiana County Garage training session held on May 29, 2014.

Included with the loader was the wireless remote control (see Appendix F). The remote has a tilt switch which will automatically shut off the machine if it senses the operator has a fallen or if the controller is tipped too severely. The electrical components sourced for the wireless remote have a reported range of 300 feet. However, using a maximum range of 200 feet is advised by Rohmac, Inc. representatives based on experience with the controller (personal correspondence with Rohmac representative). Should contact be lost with the machine or some other issue, the MicroTraxx can be controlled with the Emergency Pendant Control Box which must be attached to the back of the unit via its 20 foot long cord.

Figure 4-2: Four foot wide blade attachment delivered to Columbiana County Garage on May 29, 2014.

After a walkthrough of the machine components and the pre-operation checklist (Figure 4-3), the Rohmac, Inc. representative started the MT 3234 and demonstrated the controls. After a short time, Columbiana County workers took turns operating the machine and practiced the bucket controls on stockpiles that were present in the construction yard (see Figure 4-4 and Figure 4-5). Each new operator seemed to comfortably learn the controls in less than ten minutes of operation.

Figure 4-3: The engine training presentation of the MicroTraxx MT 3234 unit performed by a Rohmac, Inc. representative at Columbiana County Garage on May 29, 2014.

Figure 4-4: A practice run of the MicroTraxx MT 3234 unit operated by an ODOT maintenance worker under the supervision of a Rohmac, Inc. representative at Columbiana County Garage on May 29, 2014.

Figure 4-5: Another photograph of the MicroTraxx MT 3234 training session held at Columbiana County Garage on May 29, 2014.

4.4 Field Evaluation

4.4.1 Site Selection

Utilization of the MicroTraxx MT 3234 to clean culverts was begun on July 1, 2014 after taking a few weeks to acquire a properly sized trailer, scheduling support equipment, and waiting for acceptable weather conditions. In July and August of 2014, the MT 3234 was deployed to seven culverts in and around Columbiana County. Six culverts are inside the county while one is located in Mahoning County about 1.5 miles east of the city limit of Salem. The seven culvert sites are shown in Figure 4-6. The sites were selected by Columbiana County Garage staff based on historical knowledge of blockage issues. Culvert 1 bridge database structure number 5001277, was the most problematic structure known to local ODOT staff with a full cleaning having been required no more than five years ago. Before deployment, each site was also checked using the online environmental webmap.

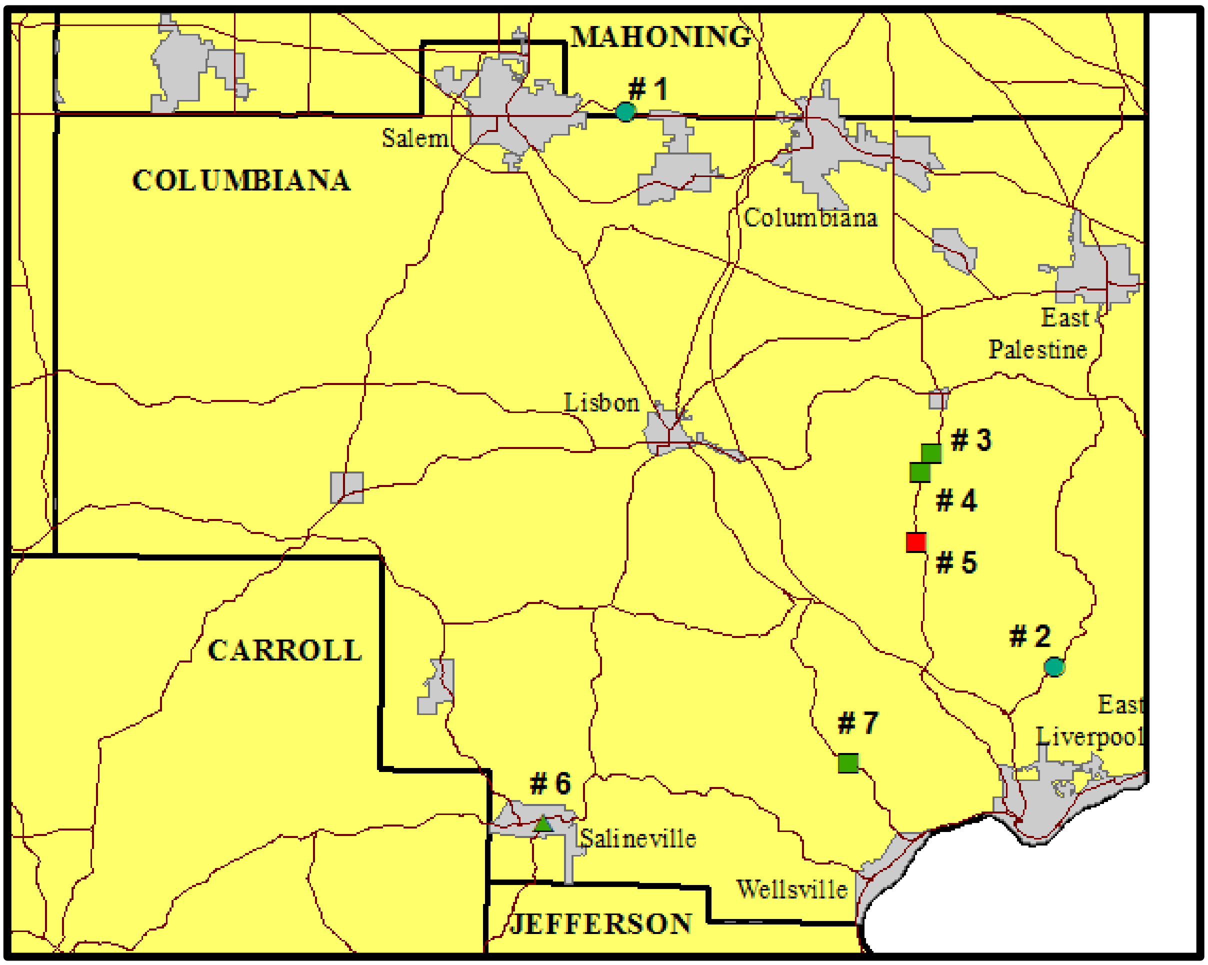

Figure 4-6: A map of all culverts that the MicroTraxx MT 3234 unit was deployed to for the months of July and August of 2014. Square symbols represent culverts that are found in the culvert database. Circle symbols represent culverts that are found in the bridge database. A triangle indicates that the culvert was not currently within any database.

Of these seven culverts, two were classified as bridges due to their spans being greater than 10 feet. Detailed characteristics of all seven culverts can be found in Table 4-5. These details were measured in the field. In some cases, there was a discrepancy between the dimensions of the culvert and what was listed in TIMS. For instance, culvert 4 had a listed height of 1.5 feet in the TIMS database but it was measured to be 4 feet on site at the time of cleaning. Using TIMS to determine culverts for cleaning with the MicroTraxx would have resulted in this culvert being overlooked. Also, culvert 5 was listed as an arch culvert in TIMS, but its shape is actually a horizontal ellipse. This type of discrepancy may not be critical to decision making but is indicative of the need to collect and maintain accurate data within the TIMS database.

In general, setting schedules for culvert cleanouts was problematic because of the uncertainty with weather. The MicroTraxx unit was not deployed on days where a possibility of rain was in the forecast to minimize the risk of having to abandon a cleaning operation midway and duplicate mobilization and setup costs. This uncertainty had a slight ripple effect on worker and equipment scheduling.

Table 4-5: Characteristics of culverts cleaned by the MicroTraxx.

	ID	Route	Date	Shape	Material	Height (ft.)	Width (ft.)	Length (ft.)	TIMS Blockage Rating[1]	TIMS Fill (ft.)
1	5001277	14	7/1-7/2	Box	Concrete	4	13	50	3[2]	2
2	1504363	170	7/8-7/9	Box	Concrete	4	15	97	2[2]	4.5
3	150071812	7	7/23	Box	Concrete	5.5	5	43	-	-
4	150071749	7	7/24	Box	Concrete	4	4	47	-	-
5	150071555	7	7/25	H. Ellip.	CM, SP	3	5.5	117	6	3
6	No ID in TIMS	164	8/19	Arch	CM	4	8	145	-	-
7	150450304	45	8/21	Box	Concrete	3	4	37	5	4

[1]The waterway blockage rating for culverts is on a scale from 0 to 9 where a lower rating indicates more blockage. (CMM)
[2]Culverts 1 and 2 are classified as bridges. The blockage rating is different for bridges where the scale is from 1 to 4 with a lower rating indicating less blockage. (Bridge Inventory Coding Guide)

4.4.2 Cleaning Operations

During the summer study period, the MicroTraxx MT 3234 unit was deployed to the seven culverts for approximately nine days in the field. The work was tracked using the Culvert Cleanout Tracking Form (see Appendix G). The form logged dimensions of the culvert measured by maintenance workers to verify those dimensions with the TIMS database. Specifics about the debris in the culvert such as depth and type were also recorded. Information regarding the operational characteristics such as engine run time, the number of ODOT personnel on site and their general responsibilities, and the general work plan of the MicroTraxx and all support equipment were documented. A synopsis of the important data from cleaning operations is displayed in Table 4-6 while a comprehensive recap taken directly from the completed tracking forms can be found in Appendix G.

Figure 4-7: Cleaning operations at the outlet end of culvert 1 on July 1, 2014. The excavator and dump truck are located out of the ROW and separated from traffic by a guardrail. As a result, no traffic control was necessary.

Figure 4-8: Typical support equipment stationed in the southbound lane of Route 7 above the downstream end of the culvert 3 where material removed by the MicroTraxx is being deposited. Traffic is limited to one lane during entire operation. Photo taken on July 23, 2014.

Upon reaching a site, maintenance crews locate a staging and parking area somewhere near the culvert. Support equipment, usually an excavator and a dump truck, are then driven into position. For some operations like culvert 1 and 5, for instance, there are flat landing areas outside of the right-of-way and clear zones sufficient for both the dump truck and excavator to be positioned (see Figure 4-7). In such cases, the average crew required for the site is reduced from 7 to 5 workers. However, in most cases, a landing area outside of the clear zone is not available and the best location for the support equipment is in the road lane or shoulder on the side of the culvert the operator of the MicroTraxx is positioned. This requires that one lane of traffic must be blocked for most, if not all, of the time work is performed on the culvert (see Figure 4-8).

Locating the support equipment within a lane of traffic is only viable if the excavator can reach the bottom of the culvert and streambed while keeping close to its full range of motion. The excavator must shape the channel bottom at a culvert end to provide enough room from the MicroTraxx equipment to rotate to unload its bucket away from the entrance so its movement is not impeded by the deposited material. Culverts with high fills and no existing access points to culvert ends will be a challenge for the excavator to remove deposited loads from the MicroTraxx as well as to shape the channel bed. The excavator at culvert 4 had limited access to the channel from the roadway and had to be driven onto the road embankment, as shown in Figure 4-9, to better shape the channel for MicroTraxx maneuverability. But, the positioning on the slope proved to be unstable so the excavator had to revert back to the original positioning on the roadway (Figure 4-10).

Figure 4-9: Excavator positioning on roadway fill at culvert 4 to gain access to the channel so that shaping for the MicroTraxx can be better performed.

Figure 4-10: Preparatory channel shaping at the outlet of culvert 4 for MicroTraxx cleaning from roadway.

Figure 4-11: The lowering of a metal plate into position just downstream of the outlet end of culvert 4 to help with traction issues experienced by the MicroTraxx unit.

With the reduced access to the culvert outlet, the channel could not be finely graded and that, combined with poor soil and water conditions, resulted in slowed MicroTraxx operation. The unit had trouble entering and exiting the culvert. Columbiana County staff came up with a solution to the problem where a large metal plate was placed just downstream of the outlet to provide better traction (Figure 4-11). This proved to be successful as cleaning efficiency was noticeably improved but performance was still poor relative to the other six culverts of the study period; the resulting labor and MicroTraxx removal efficiencies (see Table 4-6) were one of the lowest of all seven culverts. Access to channel bottom by the excavator is significant to removal efficiency. Culverts with small fill depths can typically be accessed easily by the excavator from the roadway or shoulder.

After culvert 4 was successfully cleaned, the MicroTraxx was deployed to culvert 5, an elliptical culvert with a rise of 36”. Though the height of the MicroTraxx is 32”, the manufacturer stipulates that the unit should only enter circular culverts with diameters of 48” or greater and box culverts with heights of 36” or greater. The culvert had over 1ft of debris and the decision was made to test whether the equipment could be effective inside the culvert. With careful steering, the machine was able to enter the culvert without significant problems as long as the machine was in near perfect alignment with the culvert (Figure 4-13).

Figure 4-12: The 32” high MicroTraxx MT 3234 unit entering culvert 5, a 36” corrugated metal elliptical culvert at the beginning of cleaning operations.

Once the unit cleaned out the first 5-10 feet, removal efficiency plummeted for several reasons. First and foremost, the lack of vertical space, though manageable at the entrance, became a significant issue when the bucket was operated. Scooping the bucket into sediment and debris provided resistance and tended to push the MicroTraxx into misalignment with the culvert. This became problematic when the machine was put in reverse.

Just as significantly as the lack of vertical space, reduced unit efficiency could be attributable to the MicroTraxx taking up a significant portion of the culvert opening and limiting the vision of the operator (Figure 4-12). In many cases, even with the culvert a few feet inside the culvert, the operator would back out the machine thinking the bucket needed to be unloaded and it would be empty. This reduction in efficiency due to lack of vision would likely apply to culverts of larger rises if the lengths were significant enough. Though the temptation might be present for structures larger than culvert 5, an operator should not follow the unit into the culvert to provide greater vision because of safety concerns. ODOT's confined space policy requires that a worker wear an air quality monitor with audible and visual alarms when any culvert is accessed, even in absence of the machine. Inside a culvert with a remote controlled cleaner, a worker is at risk of exhaust inhalation and limited ability to avoid the machine in the event of a malfunction or operator error.

Figure 4-13: Cleaning progress in culvert 5, a 36" tall corrugated metal elliptical culvert at the time of abandonment.

In addition to the previously stated reasons, the manufacturer's recommended culvert dimensions should be adhered to because the vertical clearance inside the culvert might be smaller than at the outlets. Reasons for this may be due to joints or seams, settlement, or other deformations. In culvert 5, the MicroTraxx became temporarily stuck on what is suspected to be a joint in the corrugated metal sections of the structure. In Figure 4-13, a flange or seam is visible. Due to the risk of damage to the unit caused by the culvert, work was abandoned.

During the study, an onsite characteristic that had to be managed carefully was the water depth. The MicroTraxx unit could not be placed in water deep enough to disrupt engine activities.

Rohmac, Inc. materials do not specify a maximum water depth but operators are usually close enough to monitor the depth carefully. The water depth inside a culvert was typically never an issue, but the depths at both ends were sometimes problematic. The excavator taking deposited material dumped by the MicroTraxx unit at the entrances to the culvert would create uneven areas which would cause the MicroTraxx to dip the rear end of the unit in the water occasionally. To counteract this tendency, the operators would elevate the engine housing unit, a function of the MicroTraxx MT 3234, after exiting the culvert and lower it when entering it, if necessary. This process contributed to minor time delays each time the machine entered the culvert which added up over the course of cleaning operations. But this delay was only necessary when the height of the culvert was near the minimum allowable for entry; for culverts with a rise at least 6 inches larger than the manufacturer's recommendations allowed, the housing unit at the rear of the MicroTraxx could be elevated during the entire operation.

Figure 4-14: MicroTraxx unit in the middle of cleaning operations on culvert 1 with rear unit raised to prevent water interference. Some water is escaping through vents at the bottom of the housing unit indicating the end was dunked temporarily as it entered the culvert.

4.4.3 Remote Controlled Cleaning Equipment Performance Summary

Table 4-6: Performance statistics for MicroTraxx MT 3234 deployed to seven culverts in and adjacent to Columbiana County in July and August of 2014.

	Average Debris Depth (ft)	Length Cleaned (ft)	Est. Material Removed (cy)	Est. Man-hours	Labor Removal Efficiency (cy/man-hr)	Engine Time (hr)	MicroTraxx Removal Efficiency (cy/hr)
1	3.17	50	76.2	27.4	2.8	8.2	9.3
2	2.32	97	125.2	98.0	1.3	8.8	14.2
3	1.75	43	13.9	15.0	0.9	2.1	6.6
4	0.83	47	5.8	17.2	0.3	2.5	2.3
5	1.75	15	4.4	16.2	0.3	1.0	4.4
6	2.25	145	91.3	57.0	1.6	4.0	22.8
7	0.50	36	2.7	50.0	0.1	NR	NR
Summary Values			319.5	280.8	1.1	26.6[1]	12.0[1]

[1]Summary MicroTraxx values do not consider culvert 7 for which an engine time was not recorded.

The performance of the MicroTraxx MT 3234 unit on seven culverts in and around Columbiana County during July and August met, and exceeded in some cases, expectations of the Columbiana County work crew. The overall average removal efficiency for the MicroTraxx unit for these culverts is 12 cubic yard of material per one hour of engine time. The high removal efficiencies of the significantly blocked large box culverts, classified as bridges in TIMS, brought the overall average up. Removal efficiencies waned, to as low as 2.3 and 4.4 cubic yards per hour, as culvert openings became smaller, which can partially be attributed to a reduction in visibility. Higher fill depths over the culvert or other accessibility issues for support equipment also detrimentally impacted removal efficiencies because the channel at the culvert outlet could not be properly shaped for maximum equipment maneuverability.

The overall removal rate for labor came to be 1.1 cubic yard of material for every on-site man-hour. These rates were more variable dependent on site conditions which were hard to quantify or record. For instance, the amount of work performed on channels above and below culverts not in direct support of culvert cleaning operations were included in on-site time and varied depending on the culvert. However, the issues about culvert entrance accessibility that effected unit removal efficiencies also have an impact on labor rate efficiencies, most notably in the need for flaggers when support equipment must be located within a clear zone.

4.4.4 Miscellaneous Notes about Remote Controlled Equipment Use

Outside of the July and August study period, deployment of the MicroTraxx unit was continued. One notable instance was the cleaning of a 4 foot tall, 14 foot wide box culvert in Holmes County that was nearly completely blocked with sediment. This culvert was cleaned in about seven hours of on-site time. Please refer to Figure 4-15 and Figure 4-16 for before and after photos of the culvert.

Figure 4-15: Before photograph of Holmes County box culvert cleaned in December of 2014.

Figure 4-16: After photograph of Holmes County box culvert cleaned in December of 2014.

A second use of the MicroTraxx after the summer study period worth noting is the cleaning out of debris and installation of embankment stone underneath a low clearance bridge in Medina County (Figure 4-17). Over a three day period, the unit cleared sedimentation from under the bridge and installed 140 tons of dump rock.

Figure 4-17: MicroTraxx clearing debris from low clearance bridge on State Route 606 in Medina County in preparation for installation of 140 tons of dump rock.

The use by Medina County personnel in installing of rock in an area inaccessible to traditional equipment is an example of alternative uses of the machine not explored in this study. The machine is a capable tool for many work tasks where traditional equipment is ill-suited or worker deployment is too dangerous. One possible new utilization of the MicroTraxx is within trenches not meeting the proper standards for manned entry.

Lastly, during the study period, research staff noticed that for some culverts blockage issues may occur more frequently than others due to site characteristics and potential design errors. For instance, in looking at the alignment of the stream on both sides of culvert 1, it seems the installation of culvert 1 increased the total flow path of the waterbody considerably. The original alignment of the road likely was not perpendicular to the stream and if the culvert were installed in the original streambed, the required culvert length, keeping the road alignment in place, would have been twice the size, and twice the cost, of the culvert length installed. This lengthening of flow path reduces the velocity of the water for this section of the stream which likely resulted in increased sedimentation rates. The cleaning of this culvert, culvert 1, will likely be a regular maintenance item for ODOT. Depending on the frequency of cleaning in the years to follow, the installation of measures within the stream that reduce sedimentation in the culvert by inducing sedimentation upstream or complete culvert replacement may be a more cost effective alternative. A history of cleanout activities on this culvert and other known problematic structures from this point forward should be maintained so that an informed decision can be made in the future.

4.5 Cost/Benefit Comparison to Traditional Methods

4.5.1 Comparison to Vactor Truck Method in Ohio

The data necessary to perform detailed cost/benefit calculations which compare remote control culvert efficiencies to traditional methods is lacking. One reason for the absence of usable data is that the tracking system currently used by ODOT does not differentiate between the cleaning of culverts and the cleaning of pipe and drop inlet networks along more urban freeways. More significantly, the tracking system also does not record an estimate of the quantity of material removed for each structure. The lack of data associated with the vactor truck cleaning method does not allow for an apples-to-apples comparison to the more detailed data collected for the remote controlled equipment in this study. Furthermore, the second cleaning alternative mentioned in the RFP, cleaning by hand, does not seemed to be used frequently for large culvert cleaning and shares the same problems with the vactor cleaning method regarding a lack of data availability.

Figure 4-18: Photograph of outlet end of culvert 1 before MicroTraxx application. Photo taken July 1, 2014.

However, while observing the cleaning of culvert 1 in Mahoning County, it was conveyed to the research group that this culvert had been cleaned out recently with a vactor truck. This work was said to have been performed over two weeks. To go beyond the basic comparison that the MicroTraxx cleaned culvert 1 in two days while the vactor truck took two weeks, we can make rough approximations about the vactor truck cleaning to compute removal rates for comparison to the MicroTraxx. Principal among these assumptions is that the amount of material within the culvert was equivalent to what was removed by the MicroTraxx this summer. Please refer to Figure 4-18 and Figure 4-19 for before and after photographs of culvert 1 cleaned by the MicroTraxx MT 3224. Assuming the culvert was 75% clogged results in an estimation that 76.2 cubic yards of debris was removed using both methods. Additional assumptions for the vactor method are 60 hours of onsite time with a crew of 2 men. These assumptions result in an equipment removal efficiency of 1.3 cubic yards of material removed per 1 hour of vactor truck on site time; the MicroTraxx unit operated at a 9.3 cubic yards per hour efficiency for this culvert. The labor removal efficiency for the vactor truck is calculated to be 0.6 cubic yards of debris removed per 1 man-hour; the MicroTraxx unit had a labor removal efficiency of 2.8 cubic yards removed per man-hour for this culvert, though the average efficiency of the study period is 1.1.

Figure 4-19: Photograph of culvert 1 after cleaning by the MicroTraxx machine taken on the second day of work. Approximately 76 cubic yards of material were removed in 8.2 hours of machine time. Photo taken July 2, 2014.

Using this one culvert, we note significant improvements in removal efficiencies for both labor and equipment when using the MicroTraxx unit compared to the vactor truck method. Though, this is only one data point and different conditions may lead to different conclusions. It should also be noted that the need to deploy support equipment (a dump truck and excavator) with MicroTraxx usage should also be considered when assessing total efficiency.

So, while the confidence in quantitative comparisons between the methods may be weak, qualitative considerations regarding the nature of the work suggest the use of a remote controlled culvert cleaner is the superior method. The vactor method often requires personnel to enter the culvert, triggering confined space regulations, and slowly dislodge debris with the high pressure hose. This type of work is considerably more strenuous and hazardous than work performed with the MicroTraxx unit, where nearly all work is performed by machines. The MicroTraxx MT 3234 seems to be overwhelmingly preferred method of the maintenance crews.

Not enough data on the MicroTraxx unit has been collected to justify detailed cost computations for this study. Though as more culverts are cleaned and records kept, the confidence in any cost computations will become stronger.

4.5.2 Caltrans Study

As mentioned previously in this report, Caltrans performed a lengthier study of a remote controlled culvert cleaner, also a MicroTraxx unit but the SL 436 model, over a four year span. The data collected by Caltrans was more comprehensive with work from over 400 hours of engine time logged (unpublished data provided to researchers). They found the average removal efficiency for the machine to be close to 5 cubic yards per engine hour but noted efficiencies greater than 10 for culverts on two lane roads with shorter lengths (Velinsky and White 2012). Velinsky and White (2012) also stated that the remote controlled culvert cleaner was 4 times as fast as cleaning with a vactor truck.

The removal rates found in the Caltrans study match those found in our seven culvert study, where the average removal rate was 12 cubic yards per engine-hour. It should be noted that the higher overall efficiency evident in our study can be attributed to the fact that all ODOT sampled culverts were on two-lane roadways and had an average length of 70 feet (culvert 5 excluded), which was about half the average length of the cleaned culverts in the Caltrans study (unpublished data provided to researchers). In general, it is expected that removal efficiencies decrease as culverts lengths increase due to the increase in average drive time and reduced visibility.

CHAPTER V: STATEWIDE CULVERT ASSESSMENT FOR REMOTE CONTROLLED CLEANING EQUIPMENT

5.1 Introduction

The success of the MicroTraxx unit compared to traditional methods currently practiced by ODOT and the positive reviews from operators demonstrate that remote control culvert cleaning equipment is a worthy technological asset. As discussed in Chapter 4, a wide range of removal efficiencies were the result of varying site conditions and culvert characteristics. At the beginning of this project, the intention of the research team was to come up with a method of determining what method of cleaning (remote controlled equipment, vactor truck, or by hand) would be the most effective based on site conditions and culvert characteristics (Task 8: Culvert Clean-out Decision Support System Development). However, because of the lack of data with the performance of the traditional methods, the remainder of this project will focus on identification of site conditions and culvert characteristics that effect candidacy for cleanout using the MicroTraxx MT 3234 unit and those conditions effecting the equipment's performance efficiency.

This study will help ODOT in prioritizing deployment. Over the two month study period, the MicroTraxx unit was deployed to seven culverts over nine days. When compared to the relatively short engine times recorded for each culvert, one might expect that greater deployment frequencies can be realized as familiarity with machine improves. However, when considering the efforts needed to schedule supporting equipment, coordinate manpower, wait for good weather, and obtain approval from underground utility agencies, a rate of about four culverts cleaned per month is reasonable. This is a comparable rate to what the Caltrans study experienced over the four year period where their unit was deployed an average of 59 days every year (personal communication). So, the proper identification of candidate culverts and cleaning demand across the 12 ODOT districts becomes critical for making deployment decisions.

5.2 MicroTraxx Culvert Candidacy List

5.2.1 Factors Influencing Candidate Selection

When considering culvert candidacy, there are three groups or classes of factors that are considered. The first class are those that determine whether the machine can even possibly enter the culvert. The second class includes all of the environmental evaluations that must be made. The last class are those characteristics of the culvert site that will factor into how efficient the cleaning with the remote controlled equipment will be.

Class 1: Feasibility Attributes Determining Normal Candidacy

The first group of characteristics are those that assess the feasibility of the MicroTraxx unit entering a culvert. Most of these factors are strictly defined, unambiguous, and can be found in the top half of Figure 5-1. Included in this group are the characteristics of the culvert itself like the rise, the culvert material, and what kind of structure, if any, are located at each end of the pipe. All of these Class 1 characteristics can be queried using the TIMS database.

Culvert Rise: The MicroTraxx MT 3234 unit has a height of 32" and a width of 34". The instructions provided by Rohmac, Inc. make it clear that the machine will fit in a box culvert with a 36" rise and a circular culvert with a 48" diameter. Field evaluation confirms these are the minimum requirements.

Material: At over two tons and exerting a 5.5 psi ground pressure, it is reasonable to restrict the machine from entering culverts that are made up of materials that are not as durable as CMP or concrete. The Culvert Management Manual lists twenty different materials. Of these, excluding pipes made of vitrified clay, brick, field tile, corrugated plastic, and timber is prudent.

Inlet and Outlet Structures: The Culvert Management Manual identifies 10 different types of structures that are at the inlet and outlet end of the pipe. Three of these structures—catch basin, inlet, and manhole—would prevent access to the pipe from the MicroTraxx. If both ends of the pipe contained one of these three structure types, the culvert could not be entered by the MicroTraxx.

Class 2: Environmental Characteristics of the Culvert Site and Waterway

Environmental Regulations of Culvert Maintenance: Because of the size of the culverts being considered in this study, work in or around a water body will be required for nearly 100% of all sites. Excavation from and/or fill in and around a water body is highly regulated through a myriad of laws from different authorities and each regulation must be assessed before cleaning operations can be initiated. Accessory activities such as staging, vegetation clearing, and vehicle and equipment storage can also invoke a variety of environmental regulations. Not only are a significant amount of regulations potentially applicable, but most regulations are nuanced and contain exemptions and conditions that can be difficult to interpret accurately. The penalty for violating many of these regulations can be severe, often requiring stoppage of work, coordination with resource agencies, fines, restoration and mitigation costs, bad public relations for the agency, and possibly fines and jail time for those responsible. To point out a few, the following regulations could possibly impact the work plan for a culvert cleaning operation within and around a waterbody:

- State and National Scenic River laws
- Endangered Species Act and Ohio endangered species laws (bat, plants, mussels, etc.)
- Clean Water Act
- Rivers and Harbors Act Sections 9 and 10
- National, State, and Local floodplain regulations
- Migratory Bird Treaty Act
- Bald and Golden Eagle Protection Act
- National Historic Preservation Act
- Various regulations regarding the management of wastes and materials

Fortunately, there is an existing procedure already in place at ODOT for verifying compliance with the wide ranging environmental regulations. This procedure is the Highway Operations Environmental Checklist and it should be followed for each candidate culvert site. While some of the possible regulations can be checked online through the webmap, a site visit and rough work plan is required to properly consider all environmental regulations. After the work plan is created and staff have visited the site to assess issues not identifiable through the webmap, operators should contact the District Environmental Coordinator (DEC). The DEC is responsible for fully understanding these regulations and should be utilized to minimize the risk of environmental damage and violation of applicable laws.

Class 3: Attributes Influencing Ideal Candidacy

The last group of factors are not as stringent as the first two, meaning that they are not automatic disqualifiers for remote control cleaning candidacy. However, they will indicate how difficult the cleaning operation may be and are, therefore, important to document. These factors were identified in the field evaluation of the MicroTraxx to impact removal efficiency and are found below and at the bottom half of Figure 5-1.

Fill Depth/Access: As documented in section 4.4.2, access to the culvert end by the supporting excavator is important to MicroTraxx performance. In most cases observed in this study (all two lane roads), the excavator was positioned above the culvert in the roadway at least part of the time. A fill depth that restricted the range of motion of the excavator could be problematic. A fill height of 10 feet was just used as an example in Figure 5-1; the determination for what the actual fill depth should be is dependent on the excavator type and size available to the particular ODOT garage performing the work. Vehicular access to a culvert end would alleviate this concern.

Culvert Length: The Rohmac, Inc. representative has said that the maximum range of the remote control is listed at 300 feet, but some users have reported smaller maximum ranges of close to 200 feet. Culverts longer than 400 feet, or 200 feet if access is only available at one end, should be considered as non-ideal for MicroTraxx utilization.

Water Depth: Rohmac, Inc. materials and representatives do not provide a strict maximum depth of water the MicroTraxx unit can operate in. When the rear of the MicroTraxx unit is raised, a function of the MT 3234, it is at least 12 inches off the ground. In the operating area within the channel, at a minimum 10 feet from the culvert opening, a smooth landing area cannot be guaranteed. As a result, during its normal operation, the MicroTraxx dipping its back end into the water cannot be avoided. An 8 inch maximum water depth is reasonable based on limited observations of the unit this summer and may need to be adjusted after additional trials.

Except for water depth, the Class 3 characteristics can be queried in the TIMS database but should be verified in the field. Not meeting one of these characteristics would not disqualify a culvert for MicroTraxx cleaning but would likely require additional attention from ODOT personnel during cleaning operations. For instance, a culvert with high fill and no vehicular access to an opening might require a day's worth of earthwork to grade a path to an opening on the road fill. Or, if water depths are too high, the stream may need to be pumped around the culvert in order for it to be accessed by the remote controlled unit. Culverts that are favorable to all of these secondary factors would be considered ideal candidate culverts for remote control machine cleaning.

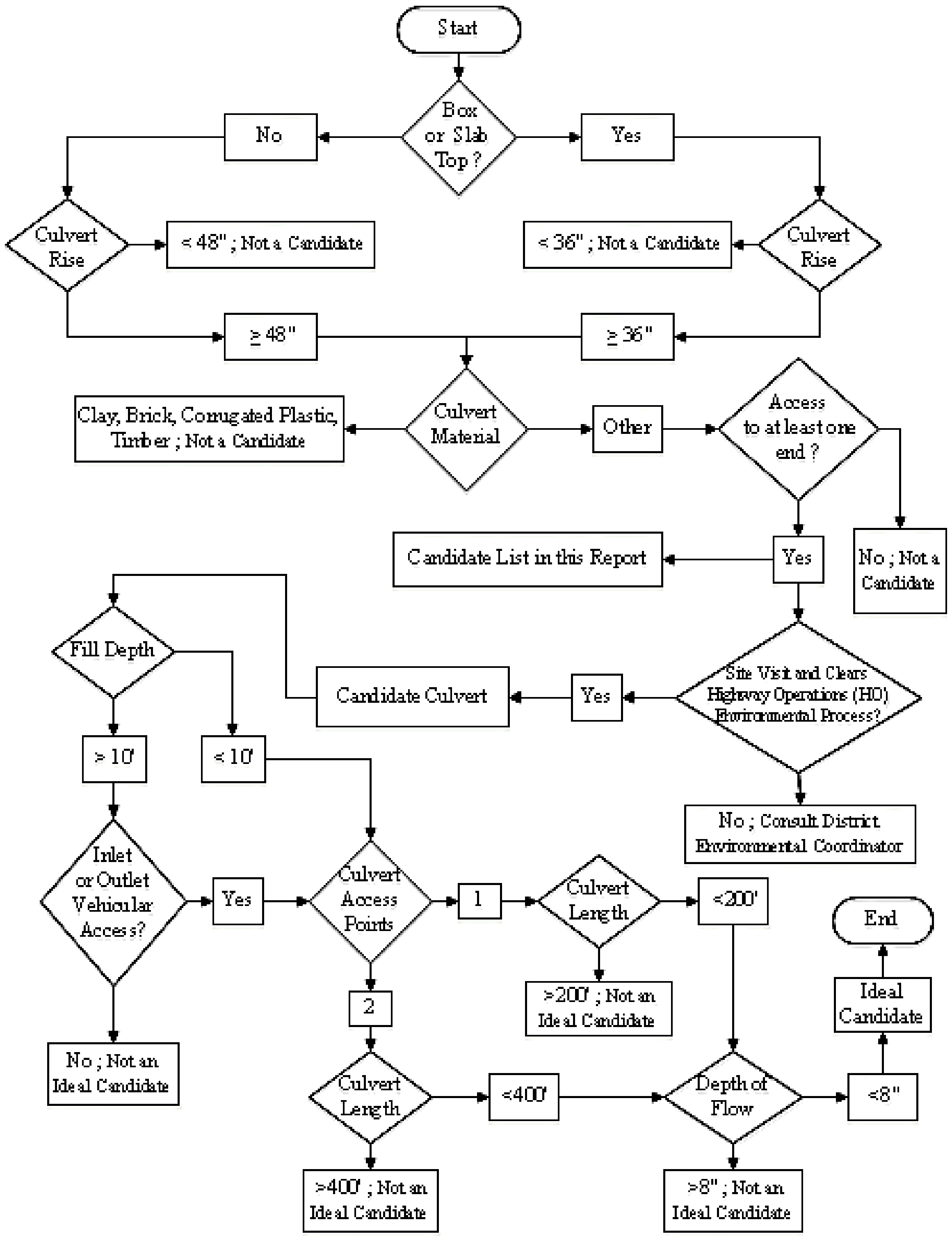

Figure 5-1: Flow chart used to determine whether a culvert is a candidate for MicroTraxx MT 3234 cleaning (top half) and whether a culvert is an ideal candidate (bottom half). The logic in this chart (top half) was used to generate the candidate list of culverts discussed in this chapter. The environmental process should be followed to determine true candidacy.

5.2.2 Candidate List Generation

The Class 1 candidate characteristics were considered to the culvert database in an effort to quantify the amount of culverts in Ohio that could be cleaned by a MicroTraxx MT 3234. The same logical steps could be followed for other machines with different dimensions and cleaning characteristics. Environmental questions were not considered due to in incredible complexity of all the environmental issues. The environmental webmap associated with Highway Operations Environmental Checklist could address some of the questions, but making any decisions regarding candidacy would result in an incomplete picture of true total candidacy figures. ODOT personnel must consider all environmental regulations for each candidate culvert.

Class 3 factors (fill height, culvert length, and water depth) are not included in the analysis because these are only indicators of how difficult cleaning of the MicroTraxx will be and require site investigation for confirmation. Also, it is impractical to estimate the water depth, especially without reliable watershed data (drainage area values are missing on at least 75% of all culverts in the TIMS database).

When the culvert database was accessed from the Ohio TIMS website on September 4, 2014, there were 82,634 culverts inventoried and recorded. The first factor we looked at was culvert rise since it was previously studied in the Interim Report. The height restriction rules were applied to the database with the intent to eliminate culverts that were too short. However, a problem we encountered, which would come up frequently in future steps, was that the database was missing many values for culvert rise. Of the 82,634 culvert, 23,093 (27.9%) of them contained missing values for the rise attribute. Of the 59,541 culverts with a culvert rise value recorded, only 7,574 (12.7% of recorded rise entries) showed heights sufficient for entry by the MicroTraxx. Culvert span was considered only to confirm the culverts were at least wide enough for the machine (36 inches) and to include circular culverts that were at least 48 inches in diameter where a rise value was omitted. At the end of this step, 8,911 culverts remained. This value is likely an underestimation because it assumes that no culvert in the 20,000 culverts for which a rise was not recorded could be a candidate.

The next two steps were eliminating the culverts that were made of unsuitable material (vitrified clay, brick, field tile, corrugated plastic, and timber) and where two drop inlet structures (inlet, manhole, or catch basin) prohibit access. In both cases, missing values for these TIMS attributes were dealt with in the opposite way as the rise attribute because the majority of culverts which had values entered were favorable to culvert candidacy. For the rise attribute, most culverts were too small for MicroTraxx candidacy. For instance, when looking at culvert material, of the 8,911 culverts, only 80 had a missing value and 107 had an item not listed in the CMM. Of the culverts with a material recorded, over 99% of these were made of acceptable culvert materials. Using similar logic, blank entries for inlet and outlet structures were assumed to be positive for candidacy.

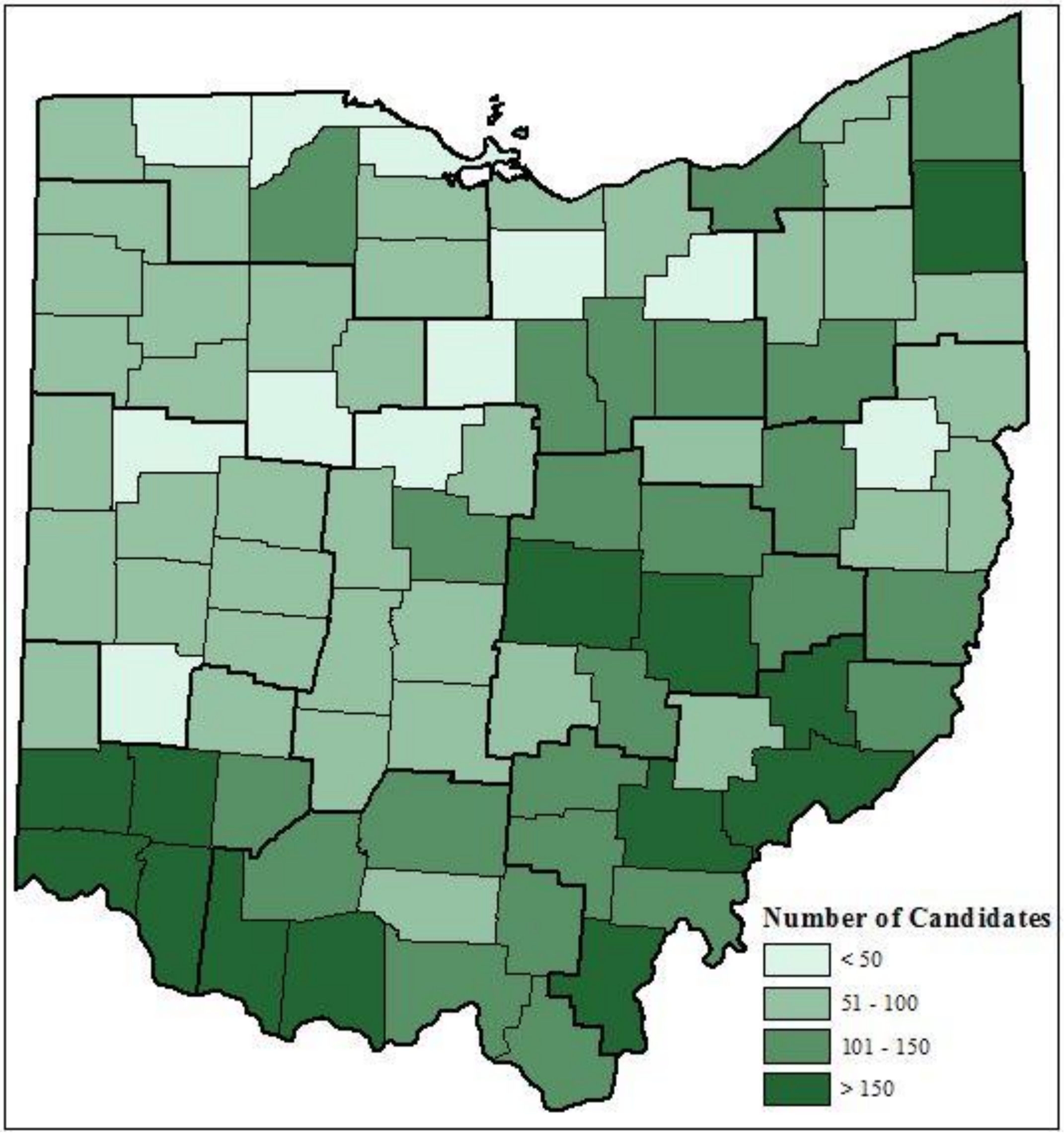

Figure 5-2: Statewide distribution of candidate culverts. Counties with darker shades of green have a greater number of candidate culverts.

At the end of these steps, a list of 8,594 MicroTraxx candidate culverts was generated. A colorimetric statewide map is exhibited in Figure 5-2 with twelve district specific maps found in Figure 5-3 thru Figure 5-14. A table that shows the number of candidate culverts in each county is provided in Appendix H. Further analysis of this list is provided in Table 5-2 where the culvert waterway blockage rating (page 57 of the CMM) for the candidate list is provided. The blockage rating is a scale from 0 to 9 where a value of 0 is a completely clogged culvert and a 9 is a completely unobstructed culvert. Culverts are required to be cleared if they are found to have a blockage of at least 30%, a rating of 4 or lower. Culverts with less than 5% opening blocked with debris have a rating of 7 or greater. Culverts with a rating of 5 or 6, with between 5% and 30% of the culvert obstructed, do not require immediate cleanout but should be monitored.

Table 5-1: TIMS blockage rating statistics for candidate culvert list by district.

District	All Culverts in TIMS Database	MicroTraxx Candidate Culverts	0-4 Blockage Rating		5-6 Blockage Rating		7-9 Blockage Rating		No Blockage Rating
			No.	% of ratings[1]	No.	% of ratings[1]	No.	% of ratings[1]	
1	7786	591	4	9.1%	10	22.7%	30	68.2%	547
2	5423	557	0	0.0%	21	3.9%	513	96.1%	23
3	6126	591	49	11.1%	114	25.9%	278	63.0%	150
4	6697	693	24	3.7%	123	19.1%	497	77.2%	49
5	9543	913	16	9.9%	40	24.8%	105	65.2%	752
6	4683	552	6	1.1%	52	9.6%	484	89.3%	10
7	7419	530	1	1.5%	9	13.8%	55	84.6%	465
8	7226	993	8	2.8%	76	26.3%	205	70.9%	704
9	9982	1117	17	1.6%	123	11.3%	944	87.1%	33
10	14356	1253	44	6.0%	149	20.2%	545	73.8%	515
11	1428	579	74	15.1%	140	28.5%	277	56.4%	88
12	1965	225	6	3.4%	52	29.1%	121	67.6%	46
State-wide	82634	8594	249	4.8%	909	17.4%	4054	77.8%	3382

[1]The percentage listed in each blockage category is computed by dividing the number of culverts with that blockage rating divided by all culverts where a rating was provided for that district.

249 of the 8,594 MicroTraxx candidate culverts have a blockage rating that required cleanout at the time of inspection, greater than 30% blockage. 909 of the candidate culverts have a blockage rating that shows notable blockage but do not require immediate attention. 3,382 culverts had no blockage rating recorded. The next section of this report looks at the best way to handle the culverts without a blockage rating and how the districts compare with respect to blockage rating among the candidate culverts.

5.3 District-wide Analysis of Deployment Need

Evaluating the number of candidate culverts in a district is not the only measure of demand for the equipment. Just as important is looking at the counts of blocked culverts (ratings of 0 thru 4). However, some districts are primarily composed of candidate culverts where the blockage rating is not entered. So, looking for just the absolute counts of blocked culverts (ratings of 0 thru 4) may be misleading. Table 5-2 accounts for culverts with missing ratings by projecting the statewide rates for blocked, marginal (rating of 5 or 6), and good (rating of 7, 8, and 9) culverts onto the number of culverts with missing blockage ratings. This provides a more realistic estimate accounting for all 8,594 candidate culverts. For instance, in the culvert database, District 1 only has four culverts recorded with a rating for 4 or less; but, over 90% of the candidate culverts having missing blockage ratings. Across the state, 4.8% of culverts possess a blockage rating of 4 or lower. This 4.8% was then applied to the missing values in District 1 (called “projected” blocked culverts) and added to the recorded count to get an estimate for the total blocked culverts in District 1 of 30.

Table 5-2: Computations using the statewide average percentages for 0-4, 5-6, and 7-9 blockage categories in the last row of Table 5-1 to account for culverts with missing database blockage ratings by district.

District	No Blockage Rating	Projected, based on state averages			Factored Total (Projected + Actual)		
		0-4	5-6	7-9	0-4	5-6	7-9
1	547	26	95	426	30	105	456
2	23	1	4	18	1	25	531
3	150	7	26	117	56	140	395
4	49	2	9	38	26	132	535
5	752	36	131	585	52	171	690
6	10	0	2	8	6	54	492
7	465	22	81	362	23	90	417
8	704	34	123	547	42	199	752
9	33	2	6	25	19	129	969
10	515	25	90	400	69	239	945
11	88	4	15	69	78	155	346
12	46	2	8	36	8	60	157
Statewide	3382	161	590	2631	410	1499	6685

In addition to comparing the total amount of factored candidate culverts with greater than 30% obstruction (rating of 4 or lower) within a district, two other inquiries were performed. The first inquiry was used to examine the estimated length of blocked culverts in a district. For this analysis, the average lengths of candidate culverts in the district was used for a culvert if it had a missing length or if it was projected using the statewide blockage rate. The second inquiry looked at the risk of the district by adding all estimating the daily traffic travelling over a blocked culvert. Similar to the previous evaluation, projected culverts were assumed to be the district average AADT for candidate culverts (there were no missing AADT values). The results are provided in Table 5-3 and discussed in greater detail in the subsections to follow.

Table 5-3: District ranking table for MicroTraxx culvert candidacy based on different factors where rank 1 indicates the largest value and 12 the smallest.

District	MicroTraxx Candidate Culverts		Factored Blocked Candidate Culverts[1]		Length of Blocked Culverts (Factored)[2]		Summed AADT of Blocked Candidate Culverts (Factored)[3]	
	No.	Rank	No.	Rank	Feet	Rank	No.	Rank
1	591	7	30	6	3,246	7	159,349	9
2	557	9	1	12	95	12	6,410	12
3	591	6	56	3	6,591	4	707,642	1
4	693	5	26	7	4,964	6	477,260	5
5	913	4	52	4	7,224	2	539,199	3
6	552	10	6	11	350	11	20,144	11
7	530	11	23	8	2,566	8	193,249	8
8	993	3	42	5	5,532	5	680,231	2
9	1,117	2	19	9	2,406	9	110,714	10
10	1,253	1	69	2	6,604	3	225,238	7
11	579	8	78	1	9,764	1	479,488	4
12	225	12	8	10	2,006	10	363,537	6

[1]Factored Blocked Candidate Culverts are actual culverts with a waterway blockage rating of less than 4 plus 4.8%, the statewide blockage rate, of all culverts with an empty blockage rating in that district.
[2]Accumulated length of all blocked candidate culverts in a district. For culverts with both a length and rating in the database, the actual length was used. All others used the district average.
[3]Accumulated AADT of all blocked candidate culverts in a district. For culverts, with a missing blockage rating, the average AADT for all candidate culverts was used.

5.3.1 MicroTraxx Candidate Culverts in District 1

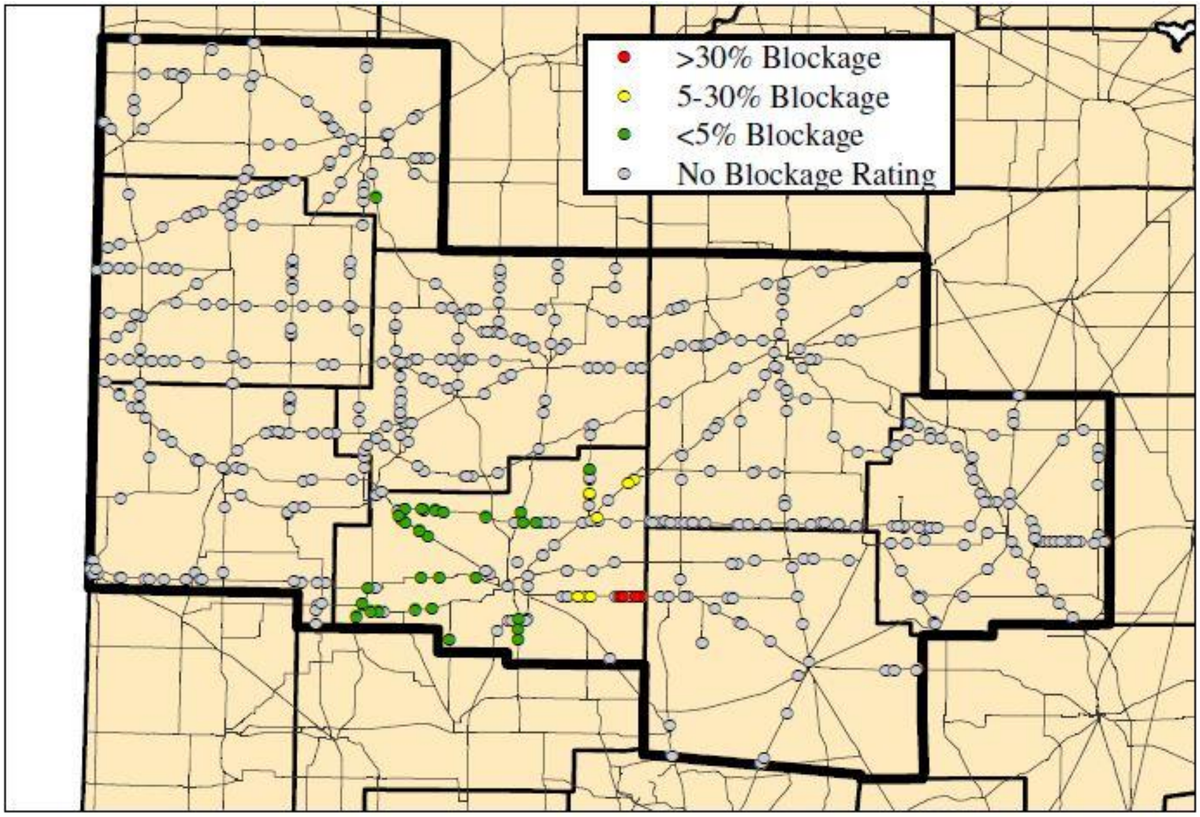

Figure 5-3: MicroTraxx MT 3234 candidate culvert map for District 1 using TIMS data downloaded on September 4th 2014.

District 1 has the fourth-most culverts of any size in the culvert database but only the seventh-most MicroTraxx candidate culverts. From Figure 5-3, it's clear the issue for this district is that waterway blockage rating is not recorded for all but 1 culvert outside of Allen County. In Allen County, only four candidate culverts had the hydraulic opening blocked by at least 30% obstruction. Because of the significant number of culverts with missing blockage ratings, there is a greater degree of uncertainly that the projection of blocked culverts within District 1 is 30 when considering the statewide blockage rate computed in Table 5-1. The other characteristics evaluated in Table 5-3 are more reflective of the average AADT and average lengths for the candidate culverts in District 1. Greater efforts in culvert inventory and inspection would help with the assessment of the MicroTraxx deployment need in District 1.

5.3.2 MicroTraxx Candidate Culverts in District 2

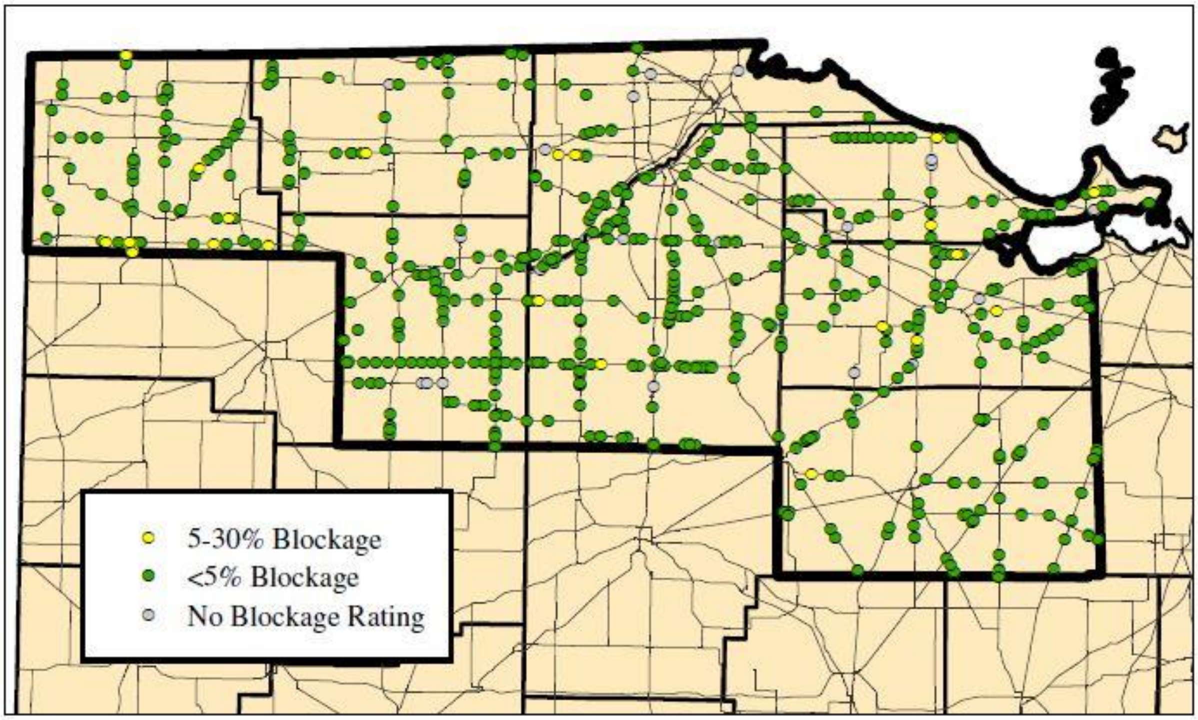

Figure 5-4: MicroTraxx MT 3234 candidate culvert map for District 2 using TIMS data downloaded on September 4th 2014.

District 2 has the ninth-most culverts within the culvert database as well as the ninth-most MicroTraxx candidate culverts. However, from the blockage rating information in the culvert database, an immediate need does not seem to be present. District 2 ranks the lowest for all factors other than the total amount of candidate culverts because there was no culvert with a blockage rating less than 5 and there were so few inventoried culverts with a missing rating that only one culvert was projected to be at least 30% blocked when the statewide rates (Table 5-2) were applied.

These numbers, indicating that there is the least need for MicroTraxx cleaning in District 2, should be considered with the efforts devoted to culvert cleaning in the district currently. District 2 is very active and effective at both maintaining culvert inventory records and maintenance of culverts that are blocked.

5.3.3 MicroTraxx Candidate Culverts in District 3

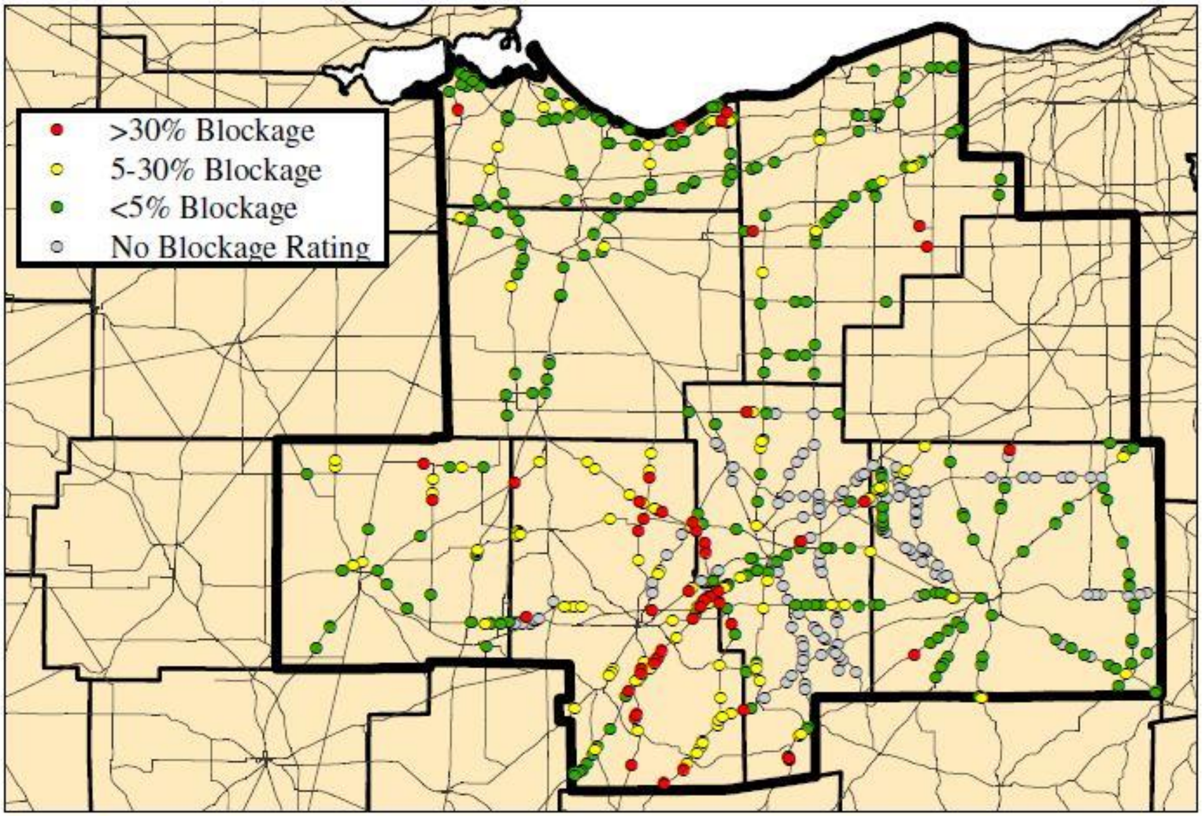

Figure 5-5: MicroTraxx MT 3234 candidate culvert map for District 3 using TIMS data downloaded on September 4th 2014.

District 3 has the eighth-most culverts of any size in the culvert database and the sixth-most MicroTraxx candidate culverts. This district has the third greatest amount of blocked culverts with 56 estimated. Of these, 49 were true entries in the database with most being located around Ashland and Mansfield with many of these located on Interstate 71. This has the effect of District 3 being the district with the most daily vehicle trips over a culvert with a blockage rating of 4 or less at the time of inspection with just over 700,000 vehicles a day. Additionally, the case is most likely severely understated because District 3 seems to have two big gaps in the culvert inventory with much of Huron County and all of Medina County without a candidate culvert mapped, which indicates a need to inventory these counties.

5.3.4 MicroTraxx Candidate Culverts in District 4

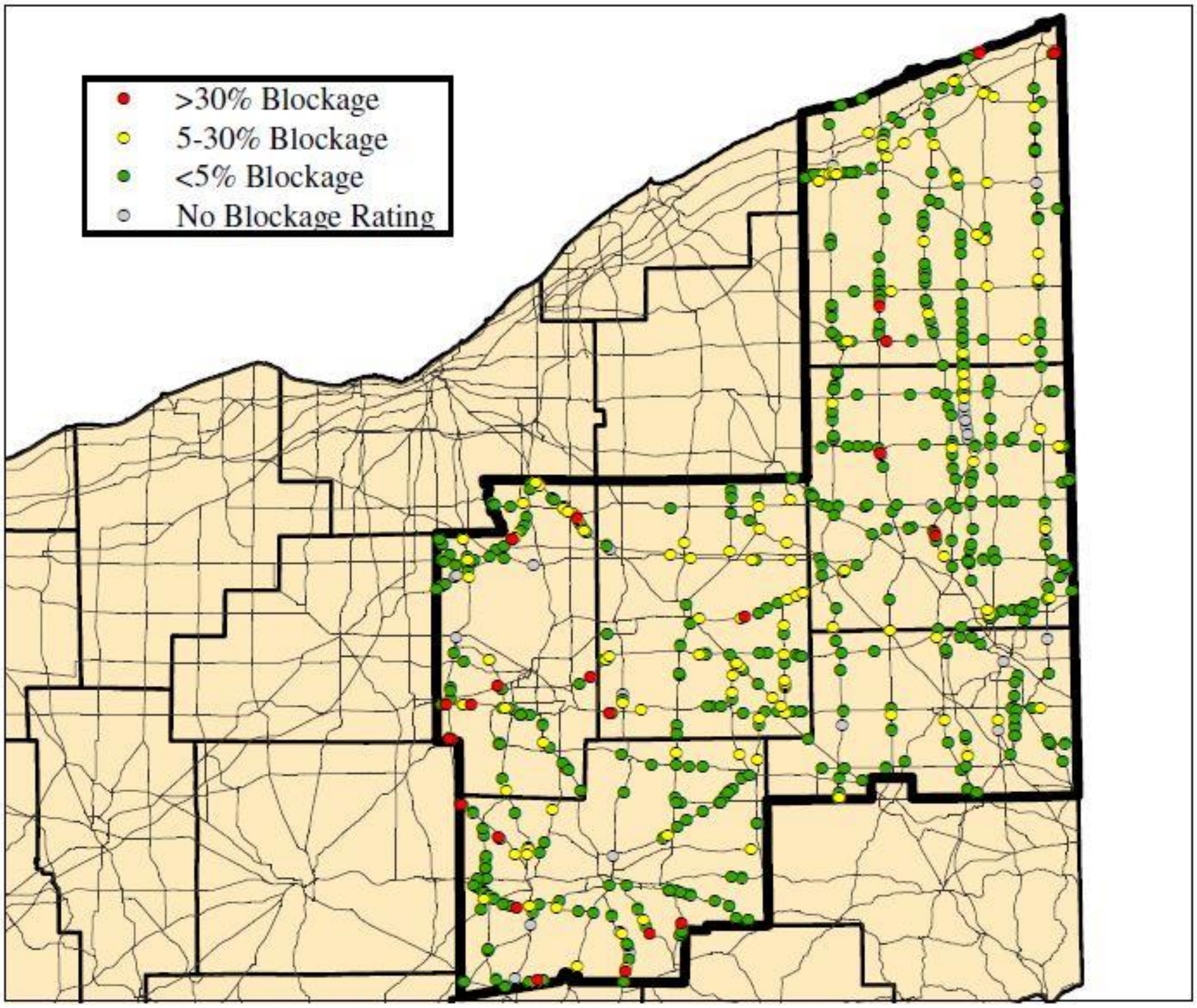

Figure 5-6: MicroTraxx MT 3234 candidate culvert map for District 4 using TIMS data downloaded on September 4th 2014.

District 4 has the seventh-most culverts of any size in the culvert database and the fifth-most MicroTraxx candidate culverts. District 4 is also average in terms of ranking of AADT over blocked culverts and length of blocked culverts within the district. With most of the inventoried culverts having a waterway rating, the confidence that can be placed in these results is one of the highest of all districts.

5.3.5 MicroTraxx Candidate Culverts in District 5

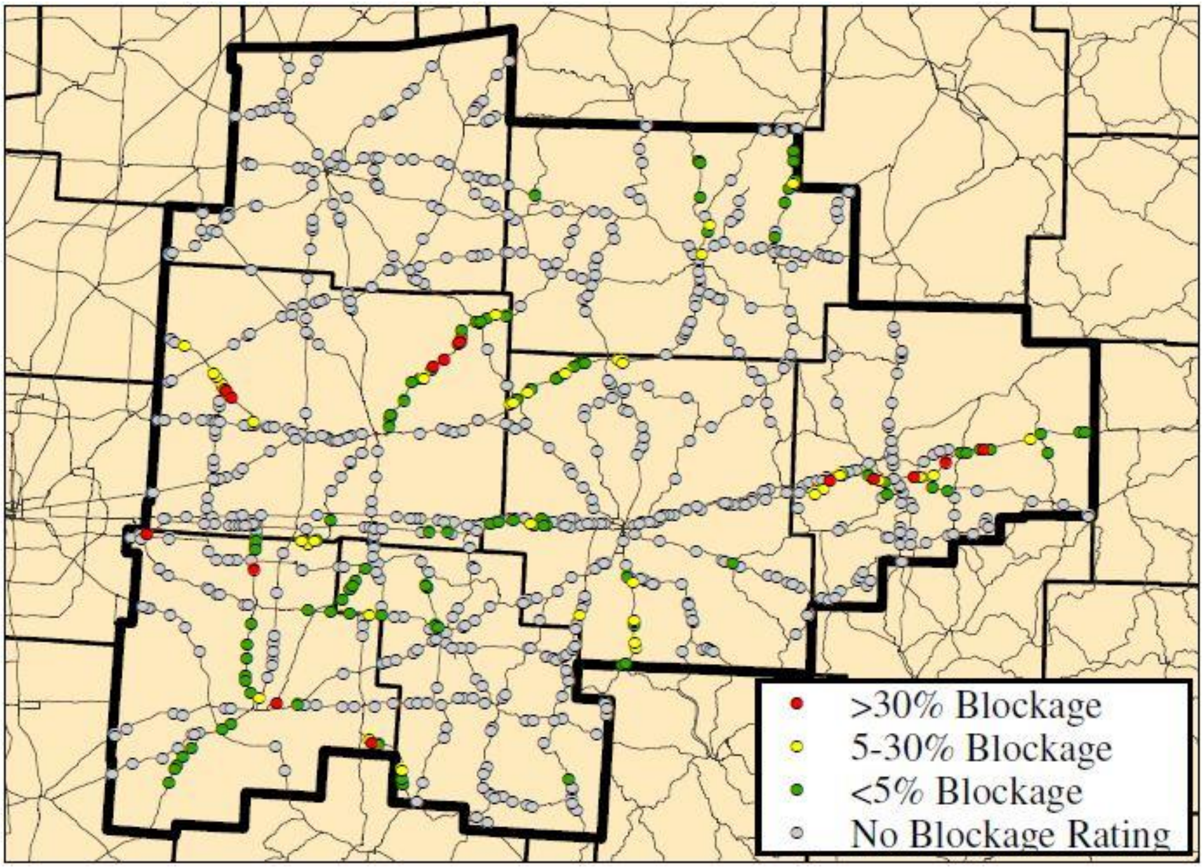

Figure 5-7: MicroTraxx MT 3234 candidate culvert map for District 5 using TIMS data downloaded on September 4th 2014.

District 5 has the third-most culverts of any size in the culvert database and the fourth-most MicroTraxx candidate culverts with 913. The district also ranks fourth in the state with respect to the total estimated number of blocked candidate culverts with 52. However, as can be seen in Figure 5-7, most of these blocked candidate culverts are projections based on the statewide blockage rate since 752 have missing waterway blockage ratings. District 5 has the second largest length of blocked culverts and the third-most amount of vehicles traveling over blocked culverts in the state, but these values are more reflective of the average values of all candidate culverts in this district. Greater efforts in culvert inventory and inspection would help with the assessment of the MicroTraxx deployment need in District 5.

5.3.6 MicroTraxx Candidate Culverts in District 6

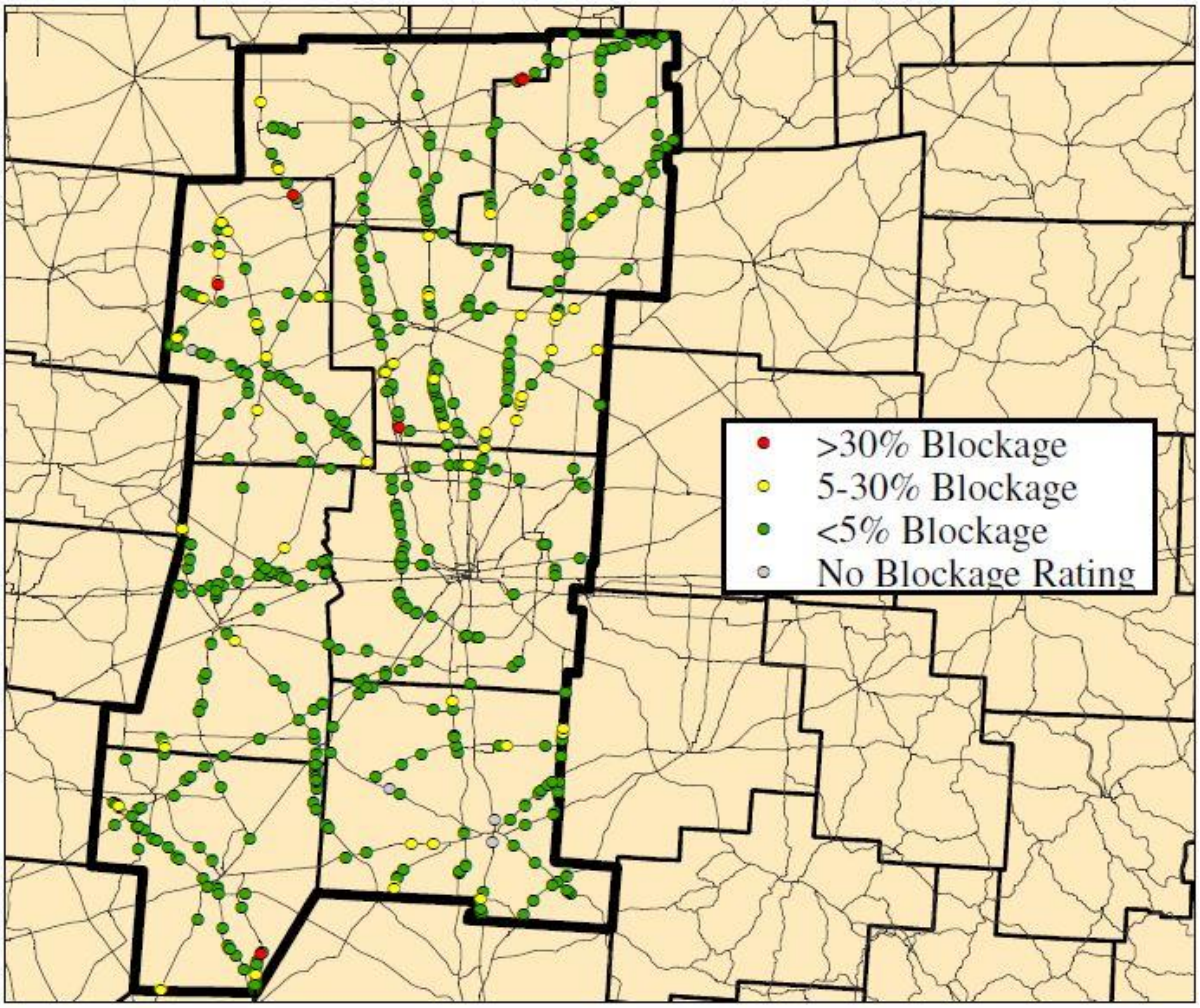

Figure 5-8: MicroTraxx MT 3234 candidate culvert map for District 6 using TIMS data downloaded on September 4th 2014.

District 6 has the tenth-most culverts of any size in the culvert database as well as the tenth-most MicroTraxx candidate culverts with 552. With respect to the blockage factors (total, AADT, and accumulated length), District 6 is ranked eleventh in all categories. At the time of inspection, there were only an estimated 6 culverts with a blockage rating of 4 or less in the district with a total length of 350 feet. A little over 20,000 vehicles a day is estimated to travel over these six culverts.

5.3.7 MicroTraxx Candidate Culverts in District 7

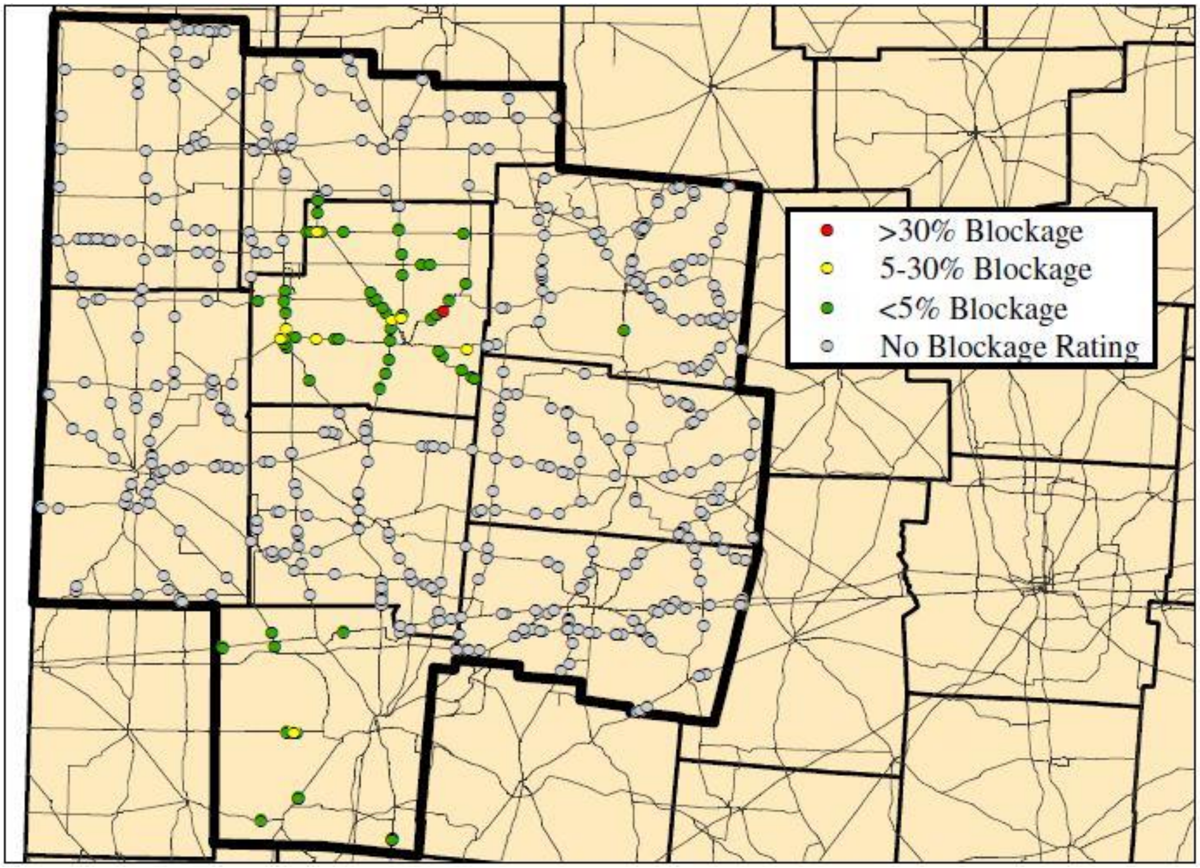

Figure 5-9: MicroTraxx MT 3234 candidate culvert map for District 7 using TIMS data downloaded on September 4th 2014.

District 7 has the fifth-most culverts of any size in the culvert database but only the second-fewest MicroTraxx candidate culverts with 530. District 7 ranks eighth in all blockage rankings (total number, AADT, and accumulated length). However, this is mostly due to projection of the statewide blockage rate on the candidate culverts with the missing waterway rating (all counties except for Shelby and Montgomery). 22 of the 23 projected blocked culverts are attributed to the application of the statewide blockage rate to the missing values. Additionally, Montgomery County does seem to have a full inventory. Greater efforts in culvert inventory and inspection would help with the assessment of the MicroTraxx deployment need in District 7.

5.3.8 MicroTraxx Candidate Culverts in District 8

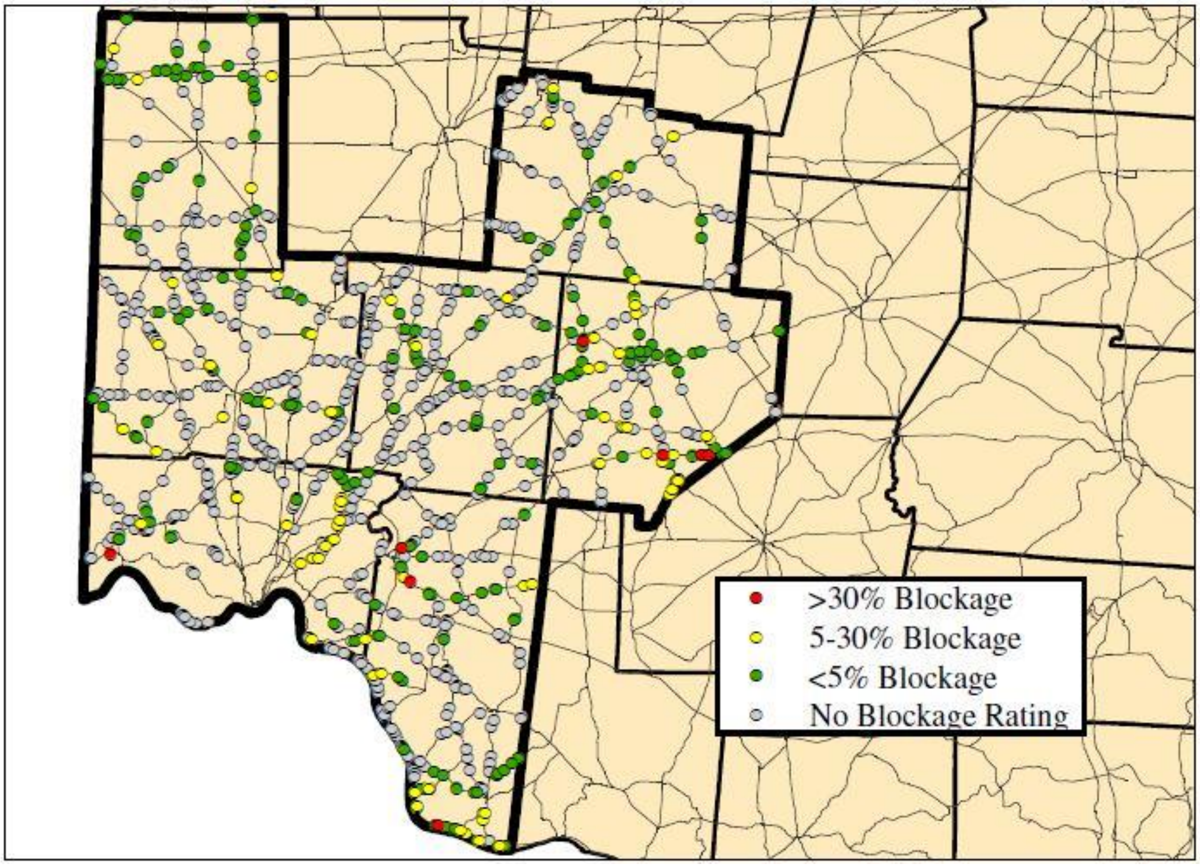

Figure 5-10: MicroTraxx MT 3234 candidate culvert map for District 8 using TIMS data downloaded on September 4th 2014.

District 8 has the sixth-most culverts of any size in the culvert database but the third-most MicroTraxx candidate culverts with 993. 70% of these candidate culverts have missing waterway blockage ratings for which the statewide blockage rate is applied to. The result is an estimate of 42 total blocked culverts in the district which is fifth-most in the state as well as the fifth-most accumulated length of blocked culverts. Because of the high volume roads around Cincinnati, this district ranks second in the state for accumulated daily traffic over blocked culverts with over 680,000 trips per day. Greater efforts in culvert inventory and inspection would help with the assessment of the MicroTraxx deployment need in District 8.

5.3.9 MicroTraxx Candidate Culverts in District 9

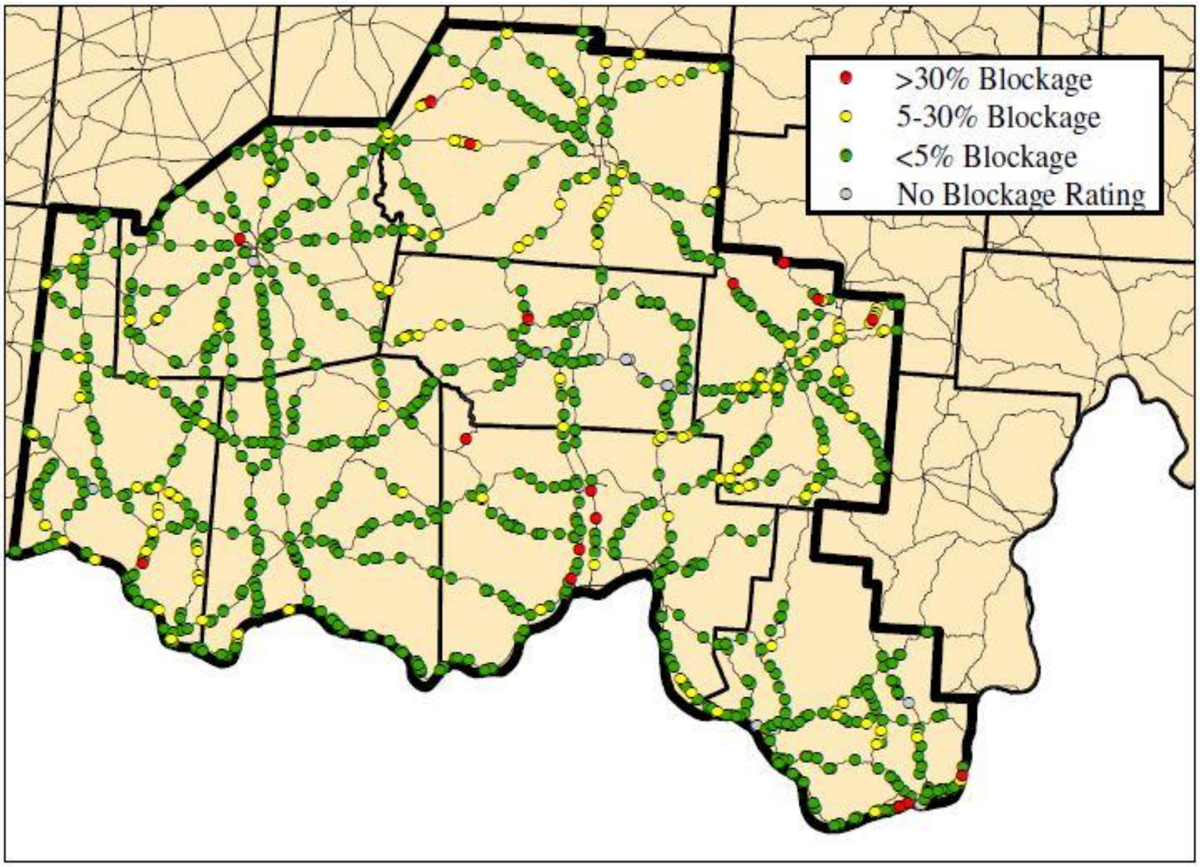

Figure 5-11: MicroTraxx MT 3234 candidate culvert map for District 9 using TIMS data downloaded on September 4th 2014.

District 9 has the second-most culverts of any size in the culvert database as well as the second-most MicroTraxx candidate culverts with 1,117. However, candidate culvert blockage statistics show the District 5 is one of the better districts with only about 19 culverts with greater than 30% of the opening obstructed at the time of inspection. This is ninth greatest number in the state and results in the ninth-most accumulated length of blocked candidate culverts in the state as well. The rural nature of the district gives a slightly lesser importance to this district with just over 100,000 vehicles traveling over these 19 blocked candidate culverts per day, the tenth most of any district in the state.

5.3.10 MicroTraxx Candidate Culverts in District 10

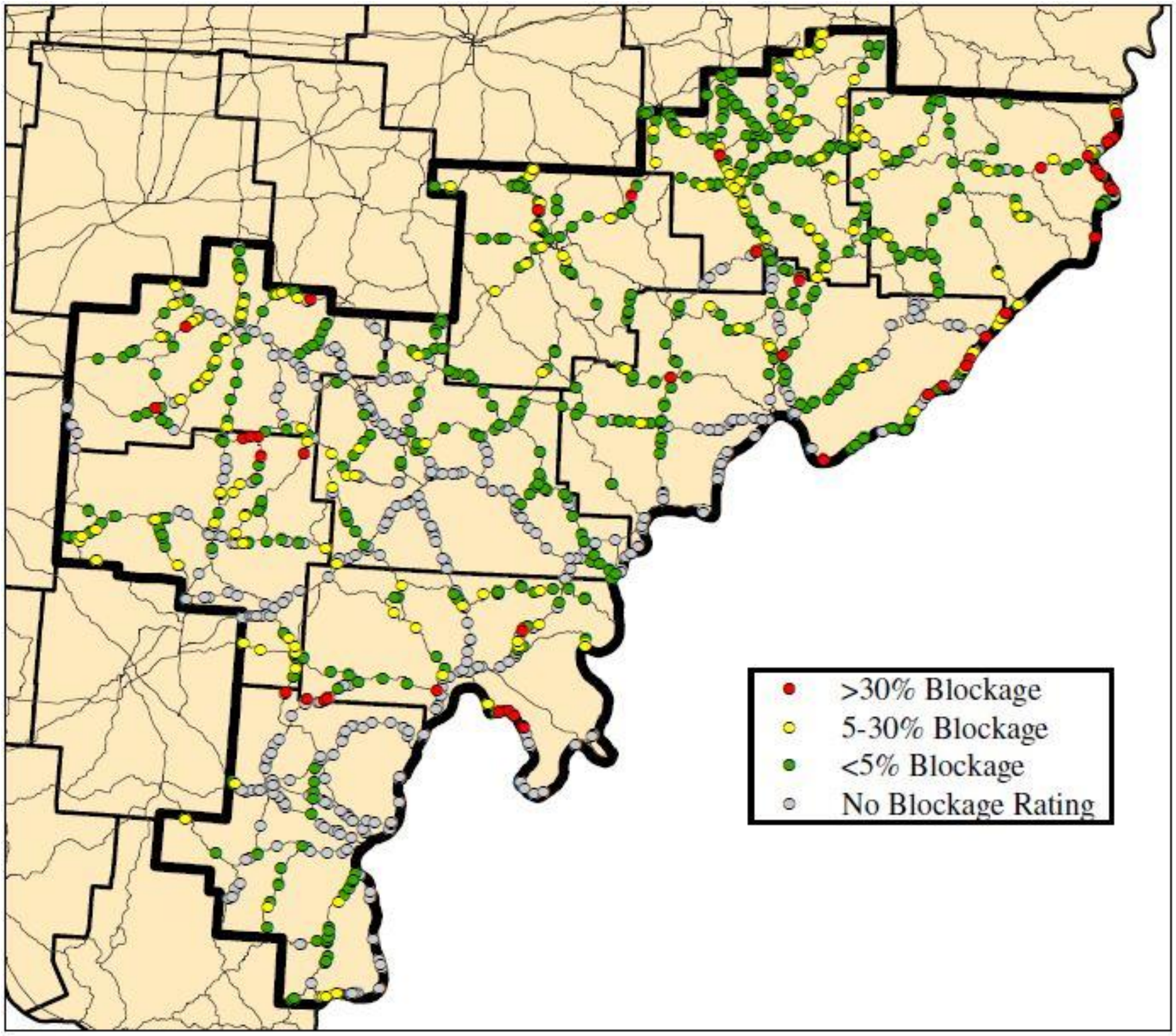

Figure 5-12: MicroTraxx MT 3234 candidate culvert map for District 10 using TIMS data downloaded on September 4th 2014.

District 10 has both the most culverts of any size in the culvert database and the most MicroTraxx candidate culverts than any other district in the state. There are 1,253 candidate culvert located in District 10 with an estimated 69 candidate culverts with a blockage rating of 4 or less, the second-most in the state. These 69 culverts have a length of approximately 6,600 feet, the third highest length for any district in the state. The rural nature of the district brings down the priority with respect to accumulated daily traffic over the blocked culverts being the seven-worst number for any district in the state at just over 225,000 vehicles per day.

5.3.11 MicroTraxx Candidate Culverts in District 11

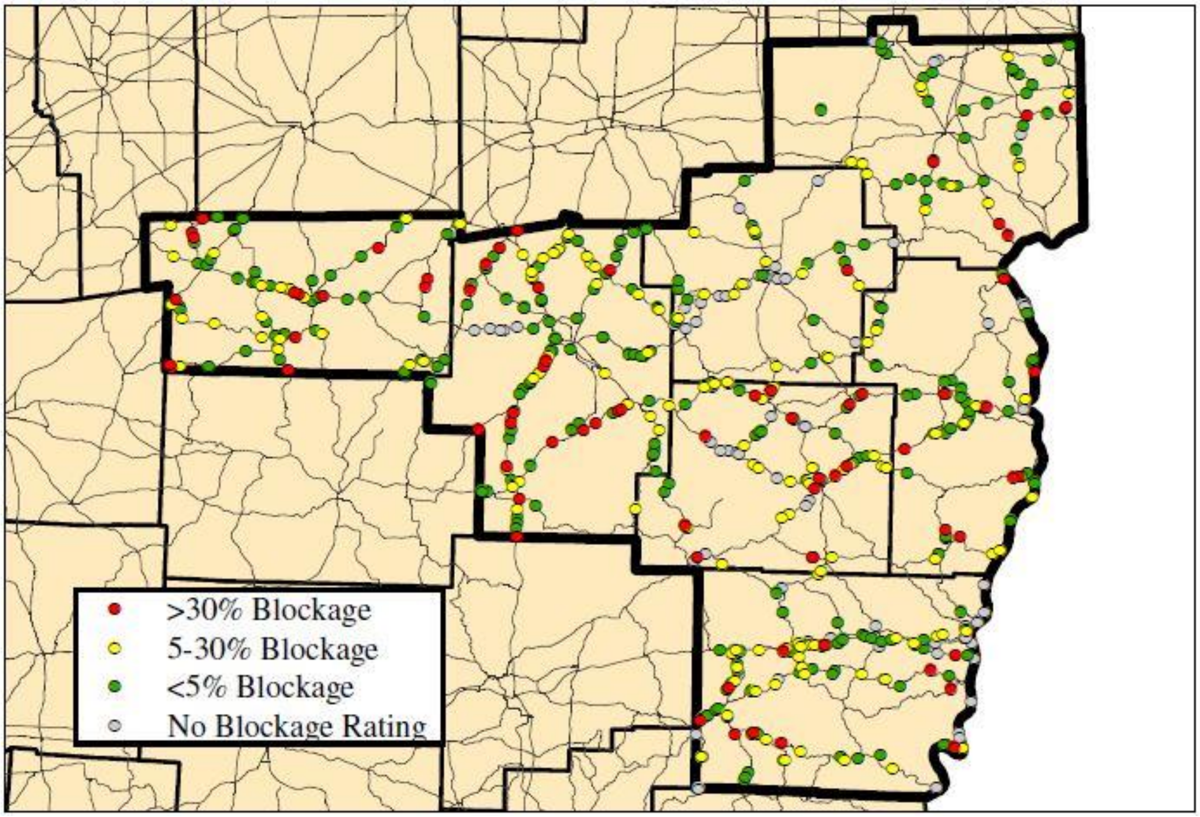

Figure 5-13: MicroTraxx MT 3234 candidate culvert map for District 11 using TIMS data downloaded on September 4th 2014.

District 11 has the least amount of culverts of any size in the culvert database but the eighth-most MicroTraxx candidate culverts with 579. District 11 has more candidate culverts with a blockage rating of 4 or less at the time of inspection than any other district in the state with a projected total of 78. This district also has a low amount of missing entries for waterway blockage so most of these 78 culverts are from actual inspections (74). District 11 ranks first in the accumulated length of blocked culverts with 9,764 feet, over 2,500 feet greater than the district with the second greatest accumulated length. About 480,000 vehicles per day travel over these 78 culverts, the fourth highest AADT in the state. These numbers are most likely an underestimate of the demand in this district because it appears many roads still need to be inventoried; one of the seven culverts the MicroTraxx was applied to in this study was not in the culvert database.

5.3.12 MicroTraxx Candidate Culverts in District 12

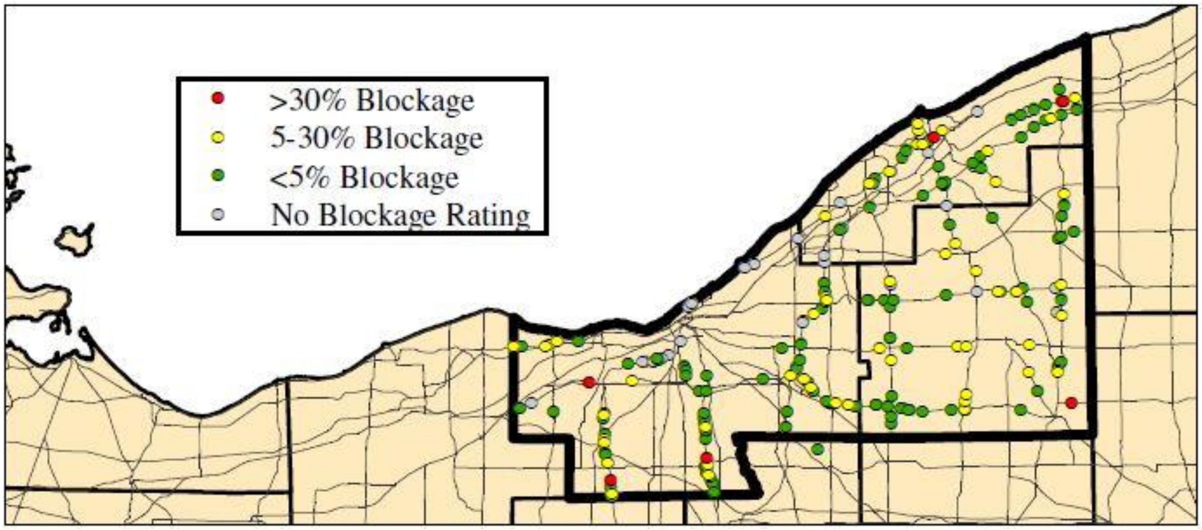

Figure 5-14: MicroTraxx MT 3234 candidate culvert map for District 12 using TIMS data downloaded on September 4th 2014.

District 12 has the second fewest culverts of any size in the culvert database and the fewest MicroTraxx candidate culverts with a mere 225. The estimated candidate culvert count with a blockage rating of 4 or less is 8, the third fewest of any district in the state. District 12 also has the tenth-most accumulated length of blocked culverts at just over 2000 feet. The high traffic for this district increases the accumulated traffic rank to the district with the sixth most vehicles per day (360,000) traveling over a culvert blocked by at least 30% at the time of inspection.

5.4 Culvert Candidacy Summary

To determine whether a culvert is a candidate for cleaning with a MicroTraxx MT 3234 unit, the rise, material, and structures at ends must be known. In most cases, these three attributes can be queried in the culvert database to avoid an unnecessary field investigation for a non-candidate culvert. An evaluation of the culvert database that was available on the TIMS website on September 4, 2014 found that there are 8,594 culverts across the state that are candidates to be cleaned by the MicroTraxx MT 3234. A candidate list of culverts for other remote controlled machines with different dimensions and performance characteristics can be made using the same steps.

Of the 8,594 MicroTraxx candidate culverts, 249 of them were at least 30% blocked at the time of inspection. Assuming that culverts with missing waterway blockage ratings are found at the same rate, the total estimated amount of culverts across the state that were at least 30% blocked is adjusted to 410. It is unknown, due to the lack of records kept on culvert cleaning, how many culverts would become at least 30% blocked during the time it takes to clean these 410 culverts. Keeping greater records on culvert cleaning statewide would allow for a better understanding of the accumulation rate of debris in culverts and greater confidence in deployment strategies for existing assets.

Some districts are in greater need of increased attention to the clearing of culverts than others. Considering total number of candidates, projected blocked candidates, total length of blocked culverts, and accumulated traffic across blocked culverts, Districts 3, 5, 10, and 11 are in the greatest need of more attention paid to culvert cleaning activities; Districts 2, 6, and 7 show the least need.

5.5 Bridge Application

Considering that two out the seven culverts evaluated during the study period were classified as bridge structures due to large spans and the post-study application on Median and Holmes County bridge structures, it is relevant to mention that the remote control unit is also useful for structures other than those classified as culverts. After reviewing the bridge structure database of nearly 45,000 structures, there are approximately 13,000 structures that are either a frame or box culvert that convey a waterway. Most of these structures would be a candidate for culvert cleaning. In some cases, however, water depth may be an issue. For actual bridge structures where low clearances prohibit the use of traditional excavation equipment, the MicroTraxx can be a useful tool for many maintenance tasks.

CHAPTER VI: CONCLUSIONS AND IMPLEMENTATION

6.1 Conclusions

The conclusions for each task completed in this project are detailed below.

Task 1: Evaluate Available Data and Reports on Culvert Clean Out Procedures and Practices of Other State DOTs

- Based on the results of the literature review, it is clear that preventative maintenance can be a cost effective strategy for extending the service life of a culvert and minimizing culvert failure.
- Four state DOT who have used remote control culvert cleaning equipment were identified through the online survey. Three of these respondents used the MicroTraxx Tunnel Mucker, and reported it successful.
- Caltrans is in the midst of a research project designed to assess the cost effectiveness of using remote control culvert cleaning equipment. The MicroTraxx Tunnel Mucker is currently being successfully rotated through multiple Caltrans Districts. Research results indicated that the use of remote control equipment would yield significant cost savings versus traditional culvert cleanout methods.

Task 2: Evaluate Available Data and Reports on Culvert Clean Out Procedures and Practices in Ohio

- Surveys were sent to all 12 ODOT Districts; personnel from 11 of 12 Districts responded.
- Survey results indicated that ODOT does not currently use remote control equipment for cleaning culverts; culverts are typically cleaned by hand or vactor methods.
- Culvert cleaning activities are generally performed as the result of culvert inspections.
- Culvert cleaning also occurs in response to complaints.
- Cleaning the interior of large culverts can be problematic. This can result in debris being removed from only the inlet/outlet, or hiring a contractor to complete the work.

Task 3: Conduct Preliminary Evaluation of Commercially Available Remote Control Culvert Cleanout Units

- Five distributors of remote control culvert cleaning equipment were contacted.
- Two distributors would be able to provide remote control equipment that would meet the requirements of this project.
- Only one of these distributors was able to provide pricing information (Rohmac, Inc. maker of MicroTraxx).
- MicroTraxx has been used or purchased by 16 state DOT, along with several state and county governments for cleaning culverts.
- Rohmac, Inc. manufactures two tunnel mucker models: the SL 436 and the MT 3234. The MT 3234 is the smaller product, and would meet the project specifications for culvert size (box culverts 34” and circular culverts 48”).

Task 5: Field Evaluation of Culvert Cleanout Methods

- MicroTraxx MT 3234 was deployed to seven culverts in and around Columbiana County in the summer of 2014.
- The machine removed an average 12 cubic yards of material per hour it operated.
- 1.1 cubic yards of material were removed for every one man-hour on site.
- Performance efficiencies dropped when the excavator supporting the MicroTraxx unit had limited access to culvert openings such as large culvert fill depths.
- Performance efficiencies dropped in situations where water depths at culvert openings required the operator to raise and lower engine housing unit
- Removal efficiency results were comparable to the findings of the Caltrans study.
- Cleaning of culverts using remote controlled cleaner is the preferred by operators over traditional methods
- MicroTraxx unit is a useful tool for tasks other than culvert cleaning where low clearance prohibits use of large equipment and where risk to worker injury is high.

Task 6: Cost/Benefit Analysis

- Available data on vactor truck costs was lacking.
- Statements by ODOT representatives that culvert 1 was cleaned by a vactor truck in two weeks was used to calculate approximate removal rates for the vactor method. The MicroTraxx culvert cleaned culvert over a period of two days and was only in operation for 8 hours.
- Results are similar to those of the Caltrans study which found the remote control culvert cleaner to be 4 times as fast as using a vactor truck.

Task 8: Clean Out Decision Support System Development

- Of the 82,634 culverts in the TIMS database, 8,594 of them were candidates just based on opening size, culvert material, and entry point requirements.
- 28% of all culverts in the database are missing the value for culvert rise which indicates this candidate list could expand as TIMS database is updated.
- The candidate list did not consider whether the culvert was located in an environmentally sensitive area which would result in the list narrowing.
- Factors that should be considered for deployment by ODOT personnel that would reduce removal efficiency include fill depth or availability of alternative access to culvert inlet, culvert length, and depth of water.
- Candidate list does not include culverts of greater than 10 foot span, which are classified as bridges. The bridge database contains over 13,000 box culverts and frames that convey a waterway statewide that could be easily cleaned by remote controlled equipment. Though, some of these may possess water flow too deep.
- Districts 8, 9, and 10 have the greatest amount of candidate culverts.
- Districts 3, 10, and 11 have the greatest amount of estimated candidate culverts with at least 30% of the opening blocked.
- Districts 5, 10, and 11 have the longest accumulated length of candidate culverts with at least 30% of the opening blocked.

- Districts 3, 5, and 8 have the most traffic traveling over a candidate culvert with at least 30% of the opening blocked.

6.2 Implementation

In implementing these findings, ODOT should consider the following recommendations for the immediate, short term, and long term time periods to maximize the value of this project.

Immediate

- **Continue taking qualitative and quantitative performance data for existing equipment and compare to imminent Caltrans Report.**
  The performance standards of the equipment in this report are based on the utilization of the machine on only seven culverts over less than 50 hours. Continued focus on logging data will generate greater confidence in future decisions.

- **Purchase SL 436 unit for Rohmac, Inc. and compare operational statistics to MT 3234.**
  The increased maneuverability of the SL 436 unit, due to a shorter length, taller engine components, and the ability to rotate independent of the treads, may outweigh the reduction in culverts that the taller unit can be applied to. Considering structures in the culvert database and long span culverts classified as bridges, there are about 22,000 conduits for the MT 3234 unit. The SL 436 is 10 inches taller and has a candidate list of close to 18,000 total structures.

- **Deploy new equipment and consider redeployment of existing equipment to districts of greatest need (3, 5, 8, and 10).**

- **Explore the feasibility of incorporating a live feed video display in the cleaning of lengthy culverts or those with poor visibility.**
  A reliable video feed from the front of the MicroTraxx unit will reduce the risk to the work crew that comes with confined space entry. A video feed would also likely increase removal efficiency due to better perception of bucket fullness.

Short-Term (< 1 year)

- **Determine optimal equipment sharing regime so resources can be spread throughout the state.**
  Maximizing the number of utilization days for the equipment via sharing will minimize costs. The optimal sharing regime will be strongly influenced by organizational configurations within ODOT.

- **Create a standard operational procedure for the site selection process for culverts to be cleaned by remote-controlled equipment that involves a review by the DEC at the appropriate time for each potential site.**
  Frequent interaction with the DEC will greatly reduce the risk of fines levied against ODOT. However, disorderly contact with the DEC may greatly increase workload and

decrease effectiveness. The exact system and timing for contact with DEC will be dictated by the resource sharing regime.

Long-Term (> 1 year)

- **Encourage all districts to keep TIMS database up to data by completing inventory and maintaining required inspection frequency.**
  Greater reliability of information within the TIMS database will help future acquisition and allocation decisions be more successful. Incomplete or outdated records could lead to missing culverts with dangerous blockage conditions and increased risk to the public.

- **Develop a means to record all culvert cleanout occurrences and maintenance details (e.g. labor, material cleaned etc.).**
  Historical data will assist in projecting future culvert cleanout demand and assist in determining the equipment rotation within a district. A better understanding of the frequency that problematic culverts require cleaning maintenance may lead to a statistically significant identification of environmental factors that influence higher debris accumulation. A better tracking system will also allow for a reasonable estimate of lifetime costs for an existing culvert to be made that would allow for the consideration of alternatives that may be more cost effective over time. Such alternatives include complete structure replacement and alterations to the stream that reduces the accumulation of sediment within the culvert.

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APPENDIX A: RESULTS OF OTHER STATE DOT CULVERT SURVEY

Agency	Job Title	Does your state DOT maintain an inventory of culverts?	If yes, is it available online?	Does your state have a standard operating procedure for culvert inspection?	If yes, is it available online?
Iowa DOT	State Maintenance Engineer	No		Yes	SOP for larger culverts
Wyoming Department of Transportation	State Maintenance Engineer	No		No	Our maintenance manual suggests inspections in spring and fall and after a heavy precipitation event if practical.
Michigan DOT	Region Support Engineer	No		No	
ODOT	Roadway Services Manager	Yes	In-house	No	We have a manual - in house.
Delaware DOT	maintenance engineer	Yes		No	
MnDOT	HydInfra Coordinator	Yes	no	Don't Know	yes http://www.dot.state.mn.us/bridge/pdf/hydraulics/HYDINFRA_Culvert_and_Storm_Drainage_System_Inspection_Manual.pdf
CA Dept. of Transportation	Senior Transportation Engineer	Yes		Yes	
North Carolina Dept. Transportation	State Management Systems Engineer	Yes	Not available online	Yes	No, for the NBIS culverts only
DelDOT	Central District Engineer				
Idaho Transportation Department	Maintenance Services Manager	No		No	
ODOT District 10	Highway Management Administrator	Yes	YES - For internal use only. It is not available to the public.	Yes	YES, definately for internal use. Not sure if available for public view.
Kansas Department of Transportation	Bureau Chief of Maintenance	No		No	
Delaware DOT	Assitant Director, Bridge				
New York State Dept of Transportation	Drainage Program Manager	Yes	No	Yes	No
State of Alaska, DOT Maintenance and Operations	Maintenance and Operations Specialist	Yes	No	Yes	No
NDDOT	State Maintenance Engineer	Yes	No	No	
Arizona Department of Transportation	Assistant State Maintennace Engineer	Yes	We have a feature inventory system that is being currently populated with geo-referencing	Yes	We evaluate pecentage blocked of opennings, rusting and erosion at the inlet and outlet.
CT DOT	Drainage Engineer	No		No	
Nevada Department Of Transportation	Maintenance Managment Corrdinator II	No		No	
Utah Department of Transportation	Deputy Maintenance Engineer	Yes	Yes, but with some issues at the moment. We are using ESRI ArcGIS to display online, but the source data resides in a business system (oracle based), and data is transferred monthly. As of now, the data is there, but images of the culverts are being linked a different way.	Yes	It is not, but it is based on the old FHWA inspection guide. This guide is currently being revised by an NCHRP study (NCHRP 14-26 Culvert and Storm Drain System Inspection). It should be completed within the next year.
SCDOT	Director of Maintenance	Yes	We are in the process of inventorying all crossline culverts 36" and greater	Yes	No
SDDOT	Asset Management Engineer	Yes	Not currently available	No	
ODOT Distric 2/Roadway Services	Roadway Services Manager				

Agency	How frequently are culverts inspected?	Other (please specify)	Are culvert inspections used to generate work orders for repair and/or maintenance of culverts?	Are culverts cleaned on a routine schedule?	How frequently are culverts cleaned?	Other (please specify)
Iowa DOT	Every other year		Yes	No	As needed	
Wyoming Department of Transportation	Other	twice per year is recommended.	Yes	No	As needed	
Michigan DOT	Other		No	No	As needed	
ODOT	Other	We inspect all the culverts on a road that is going to be resurfaced in advance so any needed work can be completed before resurfacing. Others are inspected at frequencies determined by there rating.	Yes	No	As needed	
Delaware DOT	Other	inspected based on size. 48" greater are inspected	Yes	No	As needed	
MnDOT	Other	1, 2,4 or 6 years depending on condition rating	Yes	No	Other	a culvert may be cleaned if someone reports a problem
CA Dept of Transportation	Other	As needed	Yes	Yes	As needed	
North Carolina Dept. Transportation	Every other year		Yes	No	As needed	
DelDOT						
Idaho Transportation Department	Other	Without a developed program, we usually inspect culverts randomly or when a problem is identified.	No	No	Other	As needed.
ODOT District 10	Other	Depends on numerous factors such as diameter and previous inspection condition.	Yes	No	As needed	
Kansas Department of Transportation	Other	When there is a drainage issue, or settlement in the road above, MQA inspections.	No	No	As needed	
Delaware DOT						
New York State Dept of Transportation	Other	Varies by region.	Yes	No	As needed	Varies by region.
State of Alaska, DOT Maintenance and Operations	Other	We have just started this process	No	No	As needed	This is how it has been in the past, I am trying to get a schedule together for this.
NDDOT		District Discression	No	No	As needed	
Arizona Department of Transportation	Other	We are currently inspecting all the culverts. This fucntion is done at the district level and there is no specifc time frame attached to it.	No	No	As needed	
CT DOT	Other	When necessary, or when we do a repavement project	Yes	No	As needed	
Nevada Department Of Transportation	Other	As needed basis	Yes	No	As needed	
Utah Department of Transportation	Other	We recently completed a complete inventory with pictures, which took 4 years to complete using college interns during the summer break. Otherwise, they are to be inspected by local maintenance personnel every other year.	Yes	No	Other	As needed, but we are running behind. Our MMQA measure for "failed" is a culvert that is more than 25% filled. These are often common due to the high sediment loads in many of our sandy areas.
SCDOT	Other	We are in the inventory phase and will establish an inspection frequency after this is complete	Yes	No	As needed	
SDDOT	Other	Every 3 years	No	No	As needed	
ODOT Distric 2/Roadway Services						

Agency	Response	Other (please specify)	Hand	Vactor	Remote control equipment	Other	Other (please specify)
Iowa DOT	Based on the results of culvert inspection		Hand				
Wyoming Department of Transportation	Based on the results of culvert inspection		Hand	Vactor			
Michigan DOT	Other	as needed	Hand	Vactor			
ODOT	Other	Both as a result of formal inspections and if noticed by road crews performing other work.		Vactor			
Delaware DOT	Based on the results of culvert inspection		Hand				
MnDOT	Other	there are no culvert cleaning scheduling guidelines statewide, but 8 individual Districts might set their own rules.	Hand	Vactor		Other	Jet-rod, skidsteer has been mentioned as cleanout equipment for large culverts, cleanout by contract has used other methods
CA Dept of Transportation	Other	There are several factors, but basically they are schedualed on an as needed baisis.		Vactor	Remote control equipment		
North Carolina Dept. Transportation	Other	as needed	Hand			Other	by hand or equipment if possible
DelDOT							
Idaho Transportation Department	Other		Hand	Vactor			
ODOT District 10	Other	Based upon inspection results and known areas with drainage problems. Only clean the ones that need cleaned.	Hand	Vactor		Other	Kubota tractor w/ loader when will fit. Skid Steer.
Kansas Department of Transportation	Other	As needed	Hand			Other	small track loader.
Delaware DOT							
New York State Dept of Transportation	Other	Some are cleaned based on inspection, some are cleaned by contract availability, some are cleaned in the course of .routine maintenance.	Hand	Vactor	Remote control equipment	Other	Skid Steer (Bobcat), excavator
State of Alaska, DOT Maintenance and Operations	Other	I would like have a two year cleaning schedule, unless it is an active area.		Vactor			
NDDOT	Other	District geography varies. Districts take this into account when scheduling	Hand				ends cleaned with equipment
Arizona Department of Transportation	Based on the results of culvert inspection		Hand	Vactor			We are currently in the procurement phase of a Vactor 2100 and we will have a dedicated team to run this opeartion.
CT DOT	Based on the results of culvert inspection			Vactor			
Nevada Department Of Transportation	Based on the results of culvert inspection			Vactor			
Utah Department of Transportation	Other	As budget and culvert condition will allow.				Other	Hand and Vactor
SCDOT	Other	At this time they are cleaned as the need is discovered. We are in a reactive mode and are not proactive at this time.	Hand	Vactor			
SDDOT	Based on the results of culvert inspection			Vactor			
ODOT Distric 2/Roadway Services							

Agency	Have you encountered specific environmental issues with large culvert cleanout activities (e.g. permitting issues, etc.)	If yes, please specify	Does your organization have any issues with culvert material collection and disposal (e.g. additional handling or disposal requirements)?	If yes, please specify
Iowa DOT	No		Yes	It is not always possible to place spoil material in the area of removal due to regulations or due to good judgement.
Wyoming Department of Transportation	No		No	
Michigan DOT	Don't Know		Don't Know	
ODOT	No		No	
Delaware DOT	No		No	
MnDOT	Yes	culverts in public waters (streams, lakes, wetlands) require permit to clean, and careful methods	Yes	collection of dredge material and proper disposal is generally required but no special disposal is needed (it is not considered hazardous material)
CA Dept of Transportation	Yes		Don't Know	
North Carolina Dept. Transportation	Yes		Yes	Environmental requirements for disposal
DelDOT				
Idaho Transportation Department	Don't Know		No	
ODOT District 10	No	We work with our Environmental Specilist prior to each project. We are always provided the opportunity to maintain our highway system.	No	
Kansas Department of Transportation	No		No	
Delaware DOT				
New York State Dept of Transportation	Yes	We must satisfy certain state and federal permitting requirements for protected streams.	Yes	Invasives and contaminated materials must be trucked to proper disposal site.
State of Alaska, DOT Maintenance and Operations	Yes	Culverts that are cataloged as a fish culvert need to have special permits.	No	
NDDOT	No		No	
Arizona Department of Transportation	Yes	Depending on how close we are to outfalls.	Yes	Sometimes we are allowed to leave the material on the bank edges. In other cases we have to dispose the material. Once we have the Vactor 2100, our process might change.
CT DOT	No		No	
Nevada Department Of Transportation	No		Yes	
Utah Department of Transportation	No		Don't Know	
SCDOT	No		No	
SDDOT	Don't Know		Don't Know	
ODOT Distric 2/Roadway Services				

Agency	Has your state used remote control culvert cleaning equipment?	Does your organization own or rent the equipment?			How long have you been using this equipment?	What type of equipment did you use?		Is this equipment used routinely by your organization? (i.e. it is the first choice for large culvert cleanout)	Have you developed a method for deploying the remote control cleanout equipment?	Was extensive training required to enable personnel to effectively use the equipment?	Are special permits required to use the equipment?	Have you encountered any environmental issues while using this equipment?	If yes, please specify	Was the use of this equipment considered a success?	If no, why not?
		Own	Rent	Don't Know		Manufacturer	Size								
Iowa DOT	No														
Wyoming Department of Transportation	No														
Michigan DOT	No														
ODOT	No														
Delaware DOT	No														
MnDOT	No														
CA Dept of Transportation	Yes			Don't Know	Don't know	Don't know	Don't know	No	Yes	Yes	Yes	Yes		Yes	
North Carolina Dept. Transportation	No														
DelDOT															
Idaho Transportation Department	No														
ODOT District 10	Don't Know														
Kansas Department of Transportation	No														
Delaware DOT															
New York State Dept of Transportation	Yes		Rent		within last five years	microtraxx SL 436		No	No	No	No	Yes	Same as above	Yes	
State of Alaska, DOT Maintenance and Operations	No														
NDDOT	No														
Arizona Department of Transportation	No														
CT DOT	No														
Nevada Department Of Transportation	No														
Utah Department of Transportation	Yes	Own			8 months	Micro Traxx	MT 3234	Yes	Yes	Yes	Yes	Yes	Stream Alteration Permits may be required, but sometimes not. Additionally, there are air quality issues for the operators. It was observed that when cleaning a 60 inch pipe, that about 140 feet in, the device lost connection with the remote. The device also is not getting enough air for operation. The culverts present a confined space issue.	Yes	
SCDOT	No														
SDDOT	Don't Know			Don't Know				Don't Know	No	Don't Know	Don't Know	Don't Know		Don't Know	
ODOT Distric 2/Roadway Services															

APPENDIX B: RESULTS OF ODOT CULVERT SURVEY

In what District are you located?	What county are you responding for?	What is your title?	Does your county have a completed culvert inventory?	Are large culverts routinely inspected by DOT personnel in your county?	Is culvert maintenance scheduled in advance?	
Open-Ended Response	Open-Ended Response	Open-Ended Response	Response	Response	Response	If yes, please specify
11	columbiana	Transportation	Yes	Yes	No	
6	all	Highway Management	Yes	Yes	Yes	
9	Lawrence	Transportation Manager	Yes	No	Yes	With the exception of a
District 12	Lake & Geauga	Transportation	Yes	No	Yes	The culverts are
9	lawrence	Transportation Manager	Yes	Yes	Yes	Our culverts are
Dist 9	Scioto	TM1	Yes	Yes	Yes	After culverts are
District 9	Jackson	Transportation Manager 2	Yes	Yes	Yes	Based on our inspection
9	adams	tm 1	Yes	Yes	Yes	
3	Ashland / Wayne	Transportation	Yes	Yes	Yes	maintenance activities are
3	District employee	Maintenance Engineer				
District 9	Ross County	County Manager	Yes	Yes	Yes	During inspection process
1	District Office	HMA	Yes	Yes	No	Inspections drive future
9	Adams	TM1	Yes	Yes	No	
District 11	Carroll	Transportation	Yes	Yes	Yes	
district 11	jefferson	county manager	Yes	Yes	No	We check our culverts
9	Pike	Transportation	Yes	Yes	Yes	We clean culverts at least
District 11	Harrison	County Manager	Yes	Yes	Yes	Inpect and replace when
11	Tuscarawas	County Manager	Yes	No	Yes	In preparation for paving
11	Holmes	County Manager	Yes	Yes	Yes	We inspect culverts 1-3
7	Nine counties in west-	Highway Management	Not Sure	Yes	No	
11	District 11	HMA	No	Yes	Yes	Generally planned in
9	Scioto	Transportation	Yes	Yes	Yes	We do a yearly inspection
9	Highland	Transportation	Not Sure	Yes	Yes	We inspect culverts pryor
District 9	Adams	Transportation Admin.	Yes	Yes	Yes	Replacements done year
District 9	Lawrence	Lawrence County	Yes	Yes	Yes	We check culverts to see
Dist 08	Clermont Co.	Transportation Manager	Yes	No	Yes	By inspection, we decide
2	Williams, Fulton, Henry,	HMA	Yes	Yes	Yes	Whenever possible and
9	Brown	Transportation	Yes	Yes	Yes	
9	District office	Highway Management	Yes	Yes	Yes	On eyear in advance of
8	Greene	Transportation	Yes	Yes	No	
District 8	I work with all Counties in	District Bridge Engineer	Yes	Yes	No	No systematic process is
8	Hamilton	Transportation	Yes	No	Yes	Try to have a compiled list
8	Warren	Transportation	Yes	Yes	Yes	
Dist. 8	Clinton	County Manager	Yes	No	Yes	
8	District 8	Roadway Services				
ODOT District Four	ATB, MAH, POR, STA,	Roadway Services	No	Yes	Yes	Based on culvert
10	Athens, Gallia, Hocking,	Roadway Services	Yes	No	Yes	Equipment is shared

In what District are you located?	How are culvert cleaning activities initiated?					How are culverts greater than 36" currently cleaned?
Open-Ended Response	Based on the results of culvert inspection	Based on physical characteristics of culvert (known to block easily)	Based on the year (e.g. culverts 1,3,5 are cleaned every other year)	Other	Other (please specify)	Hand
11	Based on the results of					Hand
6	Based on the results of	Based on physical	Based on the year (e.g.			Hand
9	Based on the results of	Based on physical		Other	All culvertas are	
District 12	Based on the results of				or as a need or problem	
9	Based on the results of	Based on physical				Hand
Dist 9	Based on the results of	Based on physical		Other	Based on complaints.	Hand
District 9	Based on the results of	Based on physical				Hand
9	Based on the results of	Based on physical				Hand
3	Based on the results of					
3						
District 9	Based on the results of			Other	Complaints	Hand
1	Based on the results of	Based on physical				
9		Based on physical				
District 11	Based on the results of	Based on physical				
district 11		Based on physical				
9	Based on the results of	Based on physical				Hand
District 11	Based on the results of					Hand
11		Based on physical				
11	Based on the results of	Based on physical				
7	Based on the results of	Based on physical				Hand
11	Based on the results of	Based on physical				
9	Based on the results of	Based on physical				
9	Based on the results of			Other	Cleaned if plugged by	Hand
District 9	Based on the results of	Based on physical				Hand
District 9	Based on the results of	Based on physical				Hand
Dist 08	Based on the results of	Based on physical				Hand
2	Based on the results of	Based on physical				Hand
9	Based on the results of				Also by seeing a problem	
9	Based on the results of			Other	Complaints, road	Hand
8	Based on the results of	Based on physical				
District 8	Based on the results of	Based on physical				Hand
8					Combination of the first	
8	Based on the results of					
Dist. 8	Based on the results of	Based on physical				Hand
8						
ODOT District Four	Based on the results of	Based on physical		Other	Experience, observations,	
10	Based on the results of	Based on physical				Hand

In what District are you located?				Have you encountered specific environmental issues with large culvert cleanout activities (e.g. permitting issues, etc.)		Does your county have any issues with culvert material collection and disposal (e.g. additional handling or disposal requirements)?
Open-Ended Response	Vactor	Other	Other (please specify)	Response	If yes, please specify	Response
11		Other	not at all			Yes
6		Other	Equipment when practical	Yes	Stream alinement permits	No
9		Other	The ends of the culverts	Yes	Yes, all culverts larger	Yes
District 12		Other	If a culvert >36" is	No		No
9	Vactor	Other		No		No
Dist 9	Vactor	Other	Ditch out ends and let the	No		No
District 9				No		No
9				Yes		No
3		Other	they are not typically	Yes	we always seek a permit	No
3				Yes	Prior to any excavating or	Yes
District 9	Vactor			No		No
1	Vactor			No	Have issues with debris	Yes
9			depends on what you	Yes	tree blocking getting to	No
District 11		Other	Excavator	Yes	Wetlands	Yes
district 11			all thev above! the inlet	No		Yes
9		Other	at times we excavate	No		No
District 11		Other	Contract if needed	No		No
11	Vactor			No		No
11	Vactor		We currently have no	No	Any work performed is ran	No
7	Vactor			No		No
11	Vactor			Yes	Securing enviromental	Yes
9				No		No
9	Vactor			No		No
District 9				No		No
District 9	Vactor			No		No
Dist 08	Vactor			Yes	We ask for permission to	No
2	Vactor			No		No
9		Other	Typically in our county we	No	We submit all pipes that	No
9		Other	culverts greater than 36"	Yes	stream entry issues.	No
8			It depends on what the	No		No
District 8	Vactor		Typically by Vactor, but	Yes	One occasion that I was	
8	Vactor			No		No
8	Vactor			Yes	Anything over 26" has to	No
Dist. 8				No		No
8						
ODOT District Four		Other	Dig sump at head and	No		No
10	Vactor	Other	small tractor with front	Yes	Permit regulations limit	Yes

In what District are you located?		
Open-Ended Response		If yes, please specify
	11	
	6	
	9	Yes, the material needs to
District 12		However, all storm sewer
	9	
Dist 9		
District 9		
	9	
	3	
	3	Fill may not be placed
District 9		
	1	Not every county has a
	9	
District 11		EPA aprroved dumpsites
district 11		We have approved dump
	9	
District 11		
	11	
	11	We have approved waste
	7	
	11	Must be an approved
	9	
	9	
District 9		
District 9		
Dist 08		
	2	
	9	
	9	
	8	
District 8		I am unaware with what
	8	
	8	
Dist. 8		
	8	
ODOT District Four		
	10	It is costly to haul material

APPENDIX C: EQUIPMENT COSTS

Office (304) 259-2201 • Fax (304) 259-2217
ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

26 November 2013

Quotation Number: 131126JCR01
Ohio DOT
c/o University of Akron
Attn: Ms. Marla Kennedy

ROHMAC INC is pleased to quote the following:

One- **MicroTraxx SwingLoader, Model SL 436**
Radio Remote Controlled, Diesel Powered Track Loader
As per Specification Sheet: 130417 MICROTRAXX SL 436

Including:
Parts Manual on CD (2 copies), Parts and Operations Manuals (3 hard copies)
Six (6) Month Equipment Warranty, see attachment

Selling Price.. $ 99,550.00

One- **MicroTraxx Loader, Model MT 3234**
Radio Remote Controlled, Diesel Powered Track Loader
As per Specification Sheet: 130423 MICROTRAXX MT 3234

Including:
- Parts Manual on CD (2 copies), Parts and Operations Manuals (3 hard copies)
- Six (6) Month Equipment Warranty, see attachment

Selling Price.. $ 91,650.00

<u>Options:</u>

One- **Manual Emergency Control Box**
Part Number: 0020013602

Selling Price... $ 913.00

One- **Power Take Off (PTO) for Attachments**
Connection point located on lifting arms
7gpm@2500psi

Selling Price... $ 878.00

Office (304) 259-2201 • Fax (304) 259-2217
ROHMAC, INC.
P. O. Box 335 • Mt. Storm, West Virginia 26739

Quotation Number: 131126JCR01 Con't
Ohio DOT, U of Akron, Marla Kennedy
Page 2

One- **Extended Machine Warranty (Additional Six (6) Months)**

Selling Price...$ 5,000.00

One- **Bucket Tooth**
Bolt on Design, Mounting Hardware Included
Part Number: 0392021001

Selling Price.. $ 71.00

One- **SL 436 Backhoe/Excavator Attachment w/ 12" Bucket**
QDS Mount, PTO Option Required
Part Number: 0020013201

Selling Price...$ 4,897.00

One- **Dozer Blade, 66"**
QDS Mount, Manual Angle Adjustment
Part Number: 0020014601

Selling Price.. $ 2,994.00

One- **Grapple Attachment, Model MG 32**
Requires PTO option.

Selling Price...$ 3,818.00

Quotation Valid:	60 Days
Terms:	Net 30 Days
Delivery:	12 to 14 Weeks ARO, Typical
Freight:	FOB Mt. Storm, WV 26739 (Origin)

Thank you for considering our products!

Quoted by: Jeremy Rohrbaugh ROHMAC INC 26 Nov 2013 Date

APPENDIX D: BID SPECIFICATIONS

MICROTRAXX™ Model SL 436 Bid Specifications

1. Unit shall be ***MICROTRAXX***™ Model SL 436 Radio Remote Controlled Loader with Bucket Attachment
2. Unit shall be capable of cleaning 48” box culverts, 60” round culverts, or bridges
3. Unit shall be 42” height
4. Unit shall be 42” width
5. Unit shall be 120” in length
6. Basic unit weight shall be 5600 lb
7. Unit lift capacity of 1550 lb
8. Bucket Capacity 1/3 cu yd
9. Controls shall be a minimum 7 function radio remote control with Joystick and Paddle operators
10. Unit shall have a swing capacity of 360 degrees when loaded
11. Unit shall be equipped with a quick disconnect system for attachments
12. Unit shall be steel track driven
13. Drive system will be 2 hydraulic motors with planetary gearbox, with spring applied hydraulic release brakes
14. Unit will have 2 travel speeds 80/160 fpm
15. Unit shall have 4700 lb drawbar pull
16. Ground Pressure shall be 7.5 psi loaded
17. Engine shall be diesel 4 cylinder 35.1 hp Kubota or equivalent
18. Fuel capacity shall be minimum 11 gallons
19. Hydraulic Fluid Capacity shall be 31 gallons
20. Hydraulic Fluid shall be biodegradable
21. 6 month standard warranty
22. Operation, Parts, and Maintenance manuals (3) paper copies and electronic copy on cd

OPTIONAL

- Backup Cable Remote Control to move machine if radio disabled
- Attachments
  - Blade
  - Bolt on Bucket Teeth – 5 required
  - Grapple (requires PTO)
  - Backhoe
  - PTO for attachments
- Additional 6 month warranty

23. Unit shall be ***MICROTRAXX***™ Model MT 3234 Radio Remote Controlled Loader with Bucket Attachment
24. Unit shall be capable of cleaning 36” box culverts, 48” round culverts, or bridges
25. Unit shall be 32” height
26. Unit shall be 34” width
27. Unit shall be 140” in length
28. Basic unit weight shall be minimum 4500 lb
29. Unit lift capacity minimum of 1400 lb
30. Bucket Capacity 1/4 cu yd
31. Controls shall be a minimum 7 function radio remote control with Joystick and Paddle operators
32. Unit shall be equipped with a quick disconnect system for attachments
33. Unit shall be steel track driven
34. Drive system will be 2 hydraulic motors with planetary gearbox, with spring applied hydraulic release brakes
35. Unit will have 2 travel speeds minimum of 55/110 fpm
36. Unit shall have minimum 3500 lb drawbar pull
37. Ground Pressure shall be 5.5 psi loaded
38. Engine shall be turbo diesel 3 cylinder 30 hp Kubota or equivalent
39. Fuel capacity shall be minimum 10 gallons
40. Hydraulic Fluid Capacity shall be minimum 20 gallons
41. Hydraulic Fluid shall be biodegradable
42. 6 month standard warranty
43. Operation, Parts, and Maintenance manuals (3) paper copies and electronic copy on cd

OPTIONAL

- Backup Cable Remote Control to move machine if radio disabled
- Attachments
    - Blade
    - Bolt on Bucket Teeth – 4 required
    - Grapple (requires PTO)
    - PTO for attachments
    - Duck Bill
- Additional 6 month warranty

APPENDIX E: PRODUCT BROCHURE OFFERED DURING BIDDING PROCESS

Model SL 436

Specifications

DIMENSIONS:		
Overall Width:		**42" /1067mm**
Overall Height:		**42" /1067mm**
Overall Length:		**120" / 3048mm**
LIFT CAPACITY:		**1550 lb / 703 kg**
BUCKET CAPACITY:		**1/3 yd³ / 0.255 m³**
WEIGHT:		**5600 lb / 2540 kg**
GROUND PRESSURE LOADED:		**7.5 psi / 51.7 kPa**
DRAWBAR PULL:		**4700 lbf / 20.9 kN**
DIESEL ENGINE:		**35.1 HP / 26.2 kW**
SWING ROTATION:		**360°**
TRAM SPEED	**LOW**	**80 FPM / 24.4 MPM**
	HIGH	**160 FPM / 48.8 MPM**
BIODEGRADABLE HYDRAULIC OIL		
RADIO REMOTE CONTROL		
QDS SYSTEM FOR ATTACHMENTS		
FITS 48" / 1200 mm BOX OR 60" / 1500 mm ROUND CULVERTS		

MICROTRAXX Remote Control Equipment

is manufactured and sold by:

www.rohmacinc.com

ROHMAC INC

P.O.Box 335
792 Old Laurel Run Rd
Mt Storm WV 26739

304 259-2201
304 259-2217 (fax)
info@rohmacinc.com

MICROTRAXX

Radio Remote Controlled Equipment

SL 436

CULVERT CLEANING

Power for Confined Spaces

Center of Gravity Lift Point

Hazardous Location Work Ability

All Terrain Steel Track Drive

Radio Remote Controlled

Eliminate Confined Space Issues

Other attachments available

Eliminate Confined Space Issues

Specifications

DIMENSIONS:		
Overall Height:		**32" / 813 mm**
Overall Width:		**34" / 864 mm**
Overall Length:		**134" / 3404 mm**
LIFT CAPACITY:		**1500 lb / 680 kg**
BUCKET CAPACITY:		**¼ yd³ / 0.2 m³**
WEIGHT:		**4600 lb / 2130 kg**
GROUND PRESSURE		
LOADED:		**5.5 psi / 37.9 kPa**
DRAWBAR PULL:		**3700 lbf / 16.46 kN**
DIESEL ENGINE:		**26.1 HP / 19.5 kW**
TRAM SPEED:	**LOW**	**55 FPM / 16.8 MPM**
	HIGH	**110 FPM / 33.5 MPM**
BIODEGRADABLE HYDRAULIC OIL		
RADIO REMOTE CONTROL		
FITS 36" / 900 mm BOX OR 48" / 1200 mm		
ROUND CULVERTS		

MICROTRAXX Remote Control Equipment is manufactured and sold by:

www.rohmacinc.com

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P.O.Box 335
792 Old Laurel Run Rd
Mt Storm WV 26739

304 259-2201
304 259-2217 (fax)
info@rohmacinc.com

MICROTRAXX

Radio Remote Controlled Equipment

MT 3234

CULVERT CLEANING

Power for Confined Spaces


Radio Remote Controlled
MICROTRAXX
MT 3234

APPENDIX F: MICROTRAXX MT 3224 OPERATION AND MAINTENANCE MANUAL

MICROTRAXX

Customer	University of Akron
Model Number	MT3234
Serial Number	0000113073

Operation, Maintenance, and Parts Manual

Manufactured By:

ROHMAC, INC.

PO Box 335
Mount Storm WV 26739
PHONE 304 259-2201
FAX 304 259-2217
info@rohmacinc.com

MACHINE SPECIFICATIONS

DIMENSIONS:	
Overall Height:	**32”**
Overall Width:	**34”**
Overall Length:	**140”**
WEIGHT:	**4850 LB.**
GROUND PRESSURE:	**5.5 PSI LOADED**
LIFT CAPACITY:	**1500 LB.**
ENGINE HORSEPOWER:	**32.8 HP @ 3000RPM**
TRAM SPEED:	**55 FT / MIN LOW TRAM** **110 FT / MIN HIGH TRAM**
DRAWBAR PULL:	**3700 LB.**
BUCKET CAPACITY:	**1/4 CU YD.**

MACHINE WILL FIT IN A 36” BOX OR 48” ROUND CULVERT.

BIODEGRADABLE HYDRAULIC OIL

RADIO REMOTE CONTROL

CABLE REMOTE CONTROL

QDS SYSTEM FOR ATTACHMENTS

ROHMAC INC.

ADDRESS:	P.O. Box 335 Mount Storm, WV 26739
PHONE:	304-259-2201
FAX:	304-259-2217
MODEL:	***MICROTRAXX***
MODEL NUMBER:	MT3234
MACHINE POWER:	Turbo Charged 3 Cylinder Diesel
SERIAL NUMBER:	0000113073
MANUFACTURED FOR:	University of Akron

New Equipment Warranty

ROHMAC, INC. warrants the equipment sold hereunder to be free from defects in material and workmanship, under normal use and service for a period of six (6) months from the date of delivery to the original purchaser.

Should any such defects develop within the six (6) months after delivery, upon prompt notice thereof from the buyer, and return of defective material to **ROHMAC, INC.**'s plant, transportation charges prepaid, **ROHMAC, INC.** will repair or replace such material without charge.

ROHMAC, INC.'s liability is limited exclusively to repair or replacement of defective material.

This warranty does not apply to any products, articles, or parts purchased or obtained from other manufacturers or suppliers except to the extent that the original manufacturer or supplier expressly warrants such items.

This warranty does not apply to any goods, which may have been subjected to misuse or abuse, or failure to operate or maintain in accordance with instructions.

The foregoing is exclusive and is in lieu of all other warranties expressed, implied or statutory, including the warranty or merchantability or suitability for any use.

In no event will **ROHMAC, INC.** be liable for any incidental or consequential damages or loss of profits

CONTENTS

CONTENTS

Section I

Operation and Safety Information

CONTROL PANEL LAYOUT:

ILLUSTRATION #	FUNCTION
1	Master Switch
2	Ignition Switch
3	Throttle
4	Tachometer / Hour Meter
5	Glow Plug Indicator
6	Tattle Tale
7	Engine Oil Pressure Gauge
8	Engine Coolant Temperature Gauge
9	Volt Meter
10	Light Switch
11	Hydraulic Oil Temperature Indicator (Optional)
12	Fault Lamp (Optional)
13	Remote Circuit Breaker
14	Lights / Fuel Shutoff Circuit Breaker
15	Audible Fault Alarm (Optional)
16	Back-up Alarm (Optional)

REMOTE CONTROL LAYOUT:

ILLUSTRATION #	FUNCTION
1	Aux 1 (Spare)
2	Aux 2 (Spare)
3	High Tram On / Off
4	Stop / Engine Off
5	Engine Start
6	Hydraulic Enable On / Off
7	Engine Up
8	Engine Down
9	Blade Left / GrappleClose
10	Blade Right / Grapple Open
11	Left Tram Reverse
12	Left Tram Forward
13	Right Tram Reverse
14	Right Tram Forward
15	Bucket Tilt Up
16	Bucket Tilt Down
17	Boom Up
18	Boom Down

CABLE REMOTE CONTROL LAYOUT:

ILLUSTRATION #	FUNCTION
1	Emergency Stop Button
2	Left Tram
3	Right Tram
4	PTO Open / Close (Spare)
5	Boom Up / Down
6	Engine Up / Down
7	Tilt Up / Down
8	Hydraulic Enable

WARNING!

- **ONLY** trained and qualified persons should operate this machine
- **NEVER** attempt to operate this machine in an unsafe manner
- **NEVER** stand or allow bystanders inside the swing arc of the machine
- **NEVER** approach a running machine, always deactivate by pressing stop button on remote control first
- **NEVER** leave the machine running unattended
- **NEVER** leave radio transmitter activated and unattended
- **ALWAYS** check that area around machine is clear before operating
- **ALWAYS** Stand clear of the machine while it is in operation
- **ALWAYS** operate the machine in properly ventilated areas.
- **NEVER** refuel the machine while the engine is running.
- **ALWAYS** Test all radio and machine shutdowns for proper function prior to operation
- **SHUTDOWN** the machine immediately in the event of malfunction or emergency by pressing the red stop button on the remote control

Fig 10-A

PRE-OPERATIONAL CHECKS

- Confirm all controls and safety devices are in proper working condition.
- Refer to Maintenance section and perform all necessary maintenance.
- Check the fuel level. **(Fig 10-A)**
- Check the hydraulic oil level. **(Fig 10-B)**
- Check the engine oil level using the dipstick located beside the throttle lever. **(Fig 10-C)**


Fig 10-B

Fig 10-C

PRE-OPERATIONAL CHECKS CONTINUED:

Fig 11-A

- Check the engine coolant level by removing the radiator cap. **(Fig 11-A)**

CAUTION: DO NOT open the radiator cap while the engine is hot.

STARTING PROCEDURES:

Turn the Master Disconnect Switch to the "**ON**" position.

To energize the machine the Radio or the Manual Remote Control System must be connected.

Radio Remote Control Operations
To start the radio remote follow the procedures below:

Illustration #	Functions
1	Remote Key
2	Start Button

1. Place a charged battery into the transmitter
2. Turn the Remote Key 1, clockwise, located on the right side of the remote.
3. Push and pull the red stop switch located on the face of the remote.
4. Push the start button 2, for five "5" seconds, this is also located on the right side of the remote.

NOTE: All Radio function switches must be in the off or neutral position

5. Turn the Ignition switch to the "On" Position, if necessary turn the key to preheat for a few seconds to preheat the engine.
6. To start the engine manually, turn the key to the "START" position and hold until the engine starts.
7. To start the machine by remote control, lift and toggle the engine start switch.

NOTE: When attempting to start engine, do not allow the starter motor to crank for more than 20 seconds at a time. After starter motor has cranked for 20 seconds, allow 2 minutes in between each starting interval for the starter motor to cool.

8. Once engine starts, use the throttle lever to set desired engine operating speed.

STARTING PROCEDURES CONTINUED:

9. Move clear of the machine. Lift and toggle the hydraulic enable switch to power the machine hydraulic movement functions. **CAUTION**: The machine will now move when the remote operators are moved. Refer to the remote control layout for function operators.

NOTE: The radio remote control has a tilt switch feature that will stop function output if the transmitter is tilted too far. When the transmitter is tilted beyond the limit, a tone will sound and the indicator LED will flash. To restore function level the transmitter. The radio remote control has a timeout feature that will shut down the machine if no function output command is detected for 5 minutes. The indicator LED will turn from green to amber to red when the battery needs recharged. As the battery discharges, the radio range will also decrease. See radio remote control manual for more information.

SHUTDOWN PROCEDURES:

- Move machine into area to be parked
- Retract all hydraulic parts, set attachment on ground
- Return engine to idle speed
- Press the **STOP** button on the transmitter to turn off the machine.
- Turn off ignition key switch
- Turn off master disconnect switch

NOTE: The engine control must be reset to restart the engine. To reset, press the red stop switch and restart the remote control or turn the ignition key off and back on.

CABLE REMOTE CONTROL:

In the event that the radio remote control ceases to function properly, the cable remote control can be used to move the machine to a safe location and troubleshoot the system. To use the cable remote control, shutdown the machine, disconnect the 19 pin connector from the radio receiver and connect the cable control to the wiring harness. Use the cable box controls to start and move the machine to the desired location. **STAND CLEAR** of the machine while using the cable remote control.

BASIC OPERATION:

To tram the machine forward push both tram levers away from you, to tram in reverse pull both levers towards you. Turn the machine by using one of the tram levers, or by moving each of the tram levers in opposite directions simultaneously.

BASIC OPERATION CONTINUED:

To engage high tram use the High Tram enable switch to allow the machine to travel faster. Digging with high tram enabled is not recommended as available torque is reduced.

Using the right most joystick on the remote will operate the boom, moving the joystick away from you will lower the boom, moving it toward you will raise the boom. Moving the joystick left tilts the bucket up, while moving the joystick right tilts the bucket down. The left most joystick controls the Engine Raise and the optional PTO functions. Moving the joystick away from you will raise the engine, moving it toward you will lower the engine. Moving the joystick left or right will activate the optional PTO function. Moving a joystick between the two functions will cause two functions to happen simultaneously. For example, moving the joystick away from you and to the right will cause the boom to lower while the bucket tilts down.

CHANGING ATTACHMENTS

- Lower boom attachment to safe position on floor or secure cribbing
- Shutdown machine
- Remove Keeper Pins and hydraulic hoses (if equipped) from attachment
- Perform machine startup procedure
- Using bucket tilt separate boom and attachment, and connect to new attachment, set in safe position on floor or secure cribbing
- Shutdown engine
- Install keeper pins and hydraulic hoses
- Perform machine startup procedure and operate normally

NOTES:

Section III

Maintenance Information

SERVICING THE MACHINE:

CAUTION!

Before performing any service or maintenance to this machine, ensure that it has been properly de-energized by shutting down the engine and flipping the Master Disconnect Switch to the "OFF" position, secure the machine from movement, and insure hydraulic pressure is relieved.

KUBOTA ENGINE SERVICE SCHEDULE:

CAUTION: Always perform maintenance on a cold engine to reduce risk of scalding and other serious burns.

DAILY "SHIFT" MAINTENANCE:

- Serpentine belt, tension if needed
- Drain fuel water separator
- Check engine oil, add if necessary
- Crankcase breather tube
- Check radiator is free of debris, clean if necessary.
- Air Filter Restriction
- Engine Coolant Level & Radiator Cap
- Hydraulic return filter restriction gauge

FIRST 50 HOUR MAINTENANCE:

- Replace lubrication oil and filters.

250 HOUR MAINTENANCE:

- Change lubricating oil and filters
- Check the overhead settings

500 HOUR MAINTENANCE:

- Fuel pre-cleaner screen.
- Replace Fuel Filter
- Battery and cable connections

1000 HOUR MAINTENANCE:

- Change fuel pump / strainer if necessary
- Flexible fuel leakage lines
- Adjust Valve clearance
- Check Engine Mounts
- Replace Engine Coolant

3000 HOUR MAINTENANCE:

- Check Injection Valve
- Check Crankcase Pressure Vent
- Replace Timing Belt

DISCONNECT the radio receiver prior to welding on machine.

ALWAYS place ground clamp as close to weld as possible.

2 YEAR MAINTENANCE:

- Replace serpentine belt
- Check Engine Monitoring System, Replace if necessary

OVERALL MACHINE SERVICE SCHEDULE:

While preforming maintenance on the engine it is important to review the other systems of the **MT3234** to maintain top performance.

OIL COOLER:

The oil cooler keeps hydraulic oil at a better operating temperature, especially when ambient temperatures are high. It is important to keep the oil cooler clean and free of debris, it is recommended that the cooler be cleaned especially after working in deep mud or very dusty conditions.

NOTE: sluggish hydraulic performance may be a result of above normal hydraulic oil temperature; caused by a dirty oil cooler!

HYDRAULIC OIL AND FILTER:

Check the Hydraulic oil level before each use, proper fill level is midway in sight gauge.

The filter should be checked every 250 hours when engine oil is changed, or when indicator shows need for replacement.

250 HOUR MAINTENANCE CHECK:

Every 250 hours check that all hoses are in place and not leaking; check that all electrical connections are secure and not corroded. If a frayed hose or wire is detected; replace. Remember to always test machine functions are operating correctly before proceeding with any work activity.

TRACK DRIVE MOTOR LUBRICATION:

The track drive motor gear oil should be changed at the following intervals:

First:	250 hours or 2 months
Second and after:	1000 hours or 1 year

Use only **SAE -30-CD** gear oil.

The proper oil fill level is midline (half way up) on the planetary housing.

NOTE: Refer to the track drive motor Instruction Manual for more detailed instructions

NOTE: When the **MT3234** is operated in water that submerges the track drive motors, check the gearbox oil, if any water is present in the case, drain the oil and replace immediately

SERVICING THE MACHINE:

NOTES:

- **Perform maintenance such as oil changes and coolant system flushes on level ground to ensure proper drainage of old fluids.**
- **To reduce the risk of accidental fire be sure to properly clean up all fluids that may have spilled when performing maintenance, ex. diesel fuel, hydraulic oil, motor oil, etc.**
- **When running the *MICROTRAXX* MT3234 in a muddy environment be sure to keep radiator clean and free of mud to ensure efficient cooling and reduce risk for overheating.**
- **It is recommended that whenever the hydraulic oil is drained that the suction strainer be examined and cleaned, replace if necessary.**

ENGINE INFORMATION

Make: **KUBOTA**

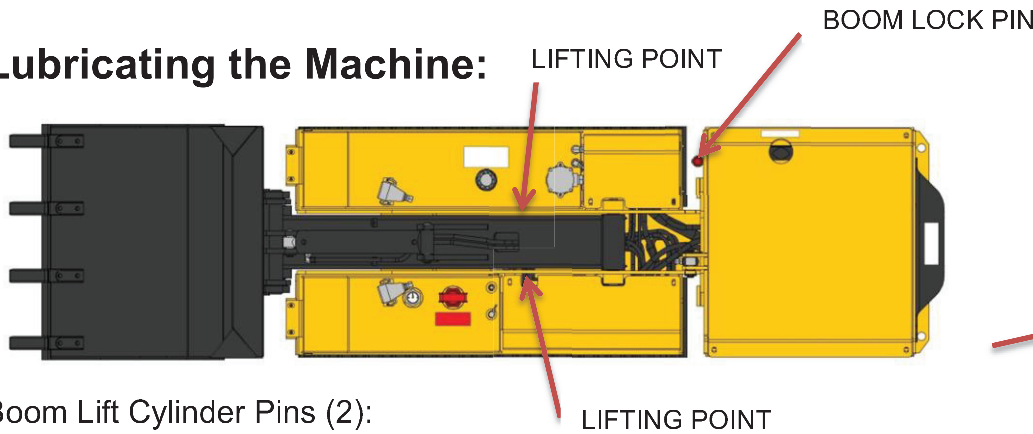
Model Number: **D1105TE-1-3**

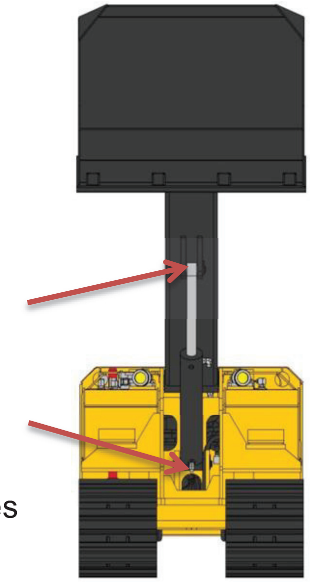
Serial Number: **1DN8765**

FLUID SPECIFICATIONS

Fuel: Capacity:	Ultra Low Sulfur Diesel Fuel **ONLY!** 13 Gallons
Hydraulic Oil: Capacity:	Biodegradable Hydraulic Oil P/N 0403023001 21.5 gallons **Warning: Do not substitute!**
Engine Oil: Capacity:	15W40 Motor Oil SPEC. MIL-L-2104C 1.35 gallons
Coolant: Capacity:	Biodegradable Antifreeze P/N 0405010027 Fill until tubes are covered by 5mm layer of coolant: 50/50 water antifreeze mix. Approx. 1 gallon **Warning: Do not substitute!**
Gear Oil:	SAE-30-CD or equivalent
Grease:	Mobil EAL 102 Biodegradable Grease P/N 0403001006

Lubricating the Machine:





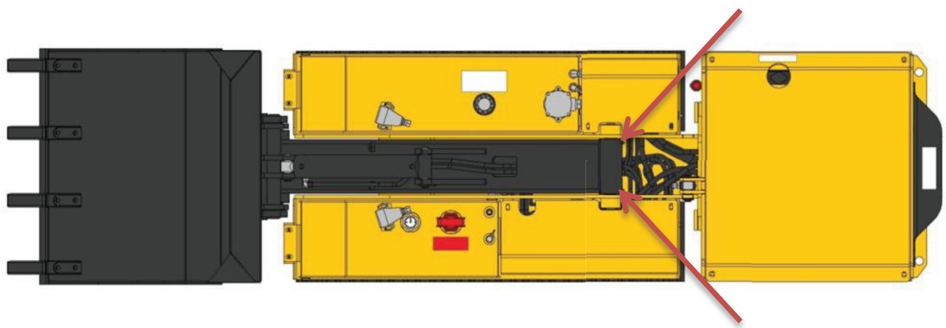
Boom Lift Cylinder Pins (2):

2-3 pumps of grease on a weekly basis.

ALWAYS lock out boom by sliding Boom Lock Pin through lifting holes in chassis.

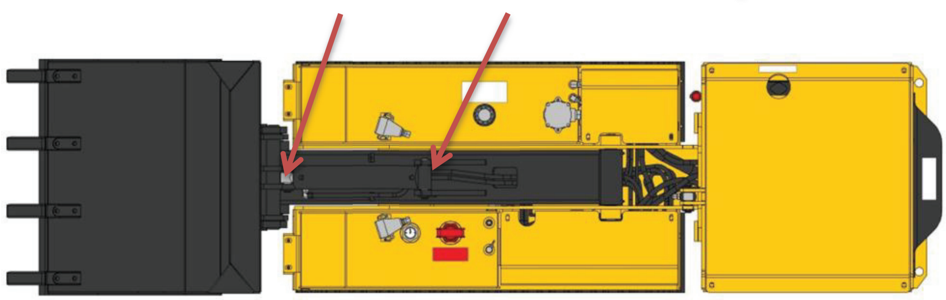
Boom Pivot Pin (2):

2-3 pumps of grease on a daily basis.



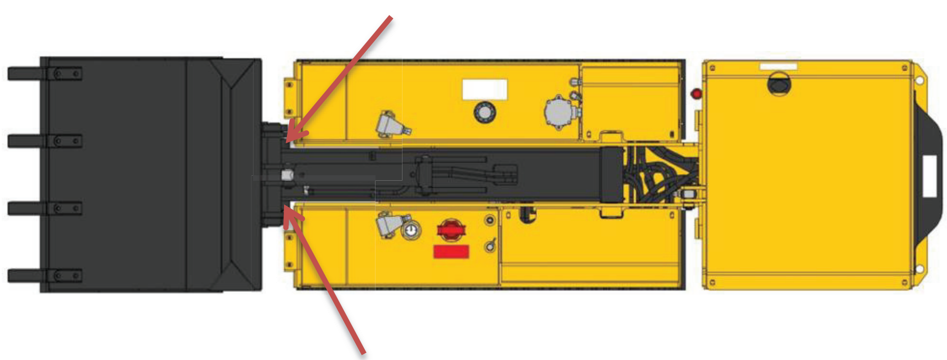
Tilt Cylinder Pins (2):

2-3 pumps of grease on a weekly basis.



Bucket / Tool Pivot Pin (2):

2-3 pumps of grease on a daily basis.

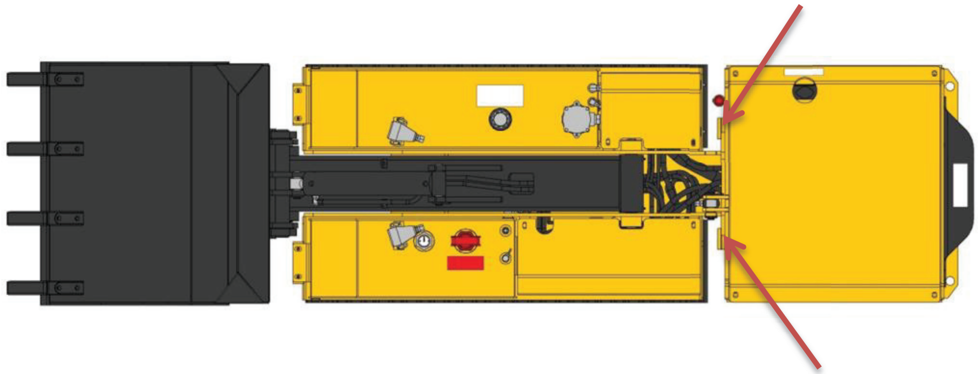


Lubricating the Machine:

Engine Slide (2)

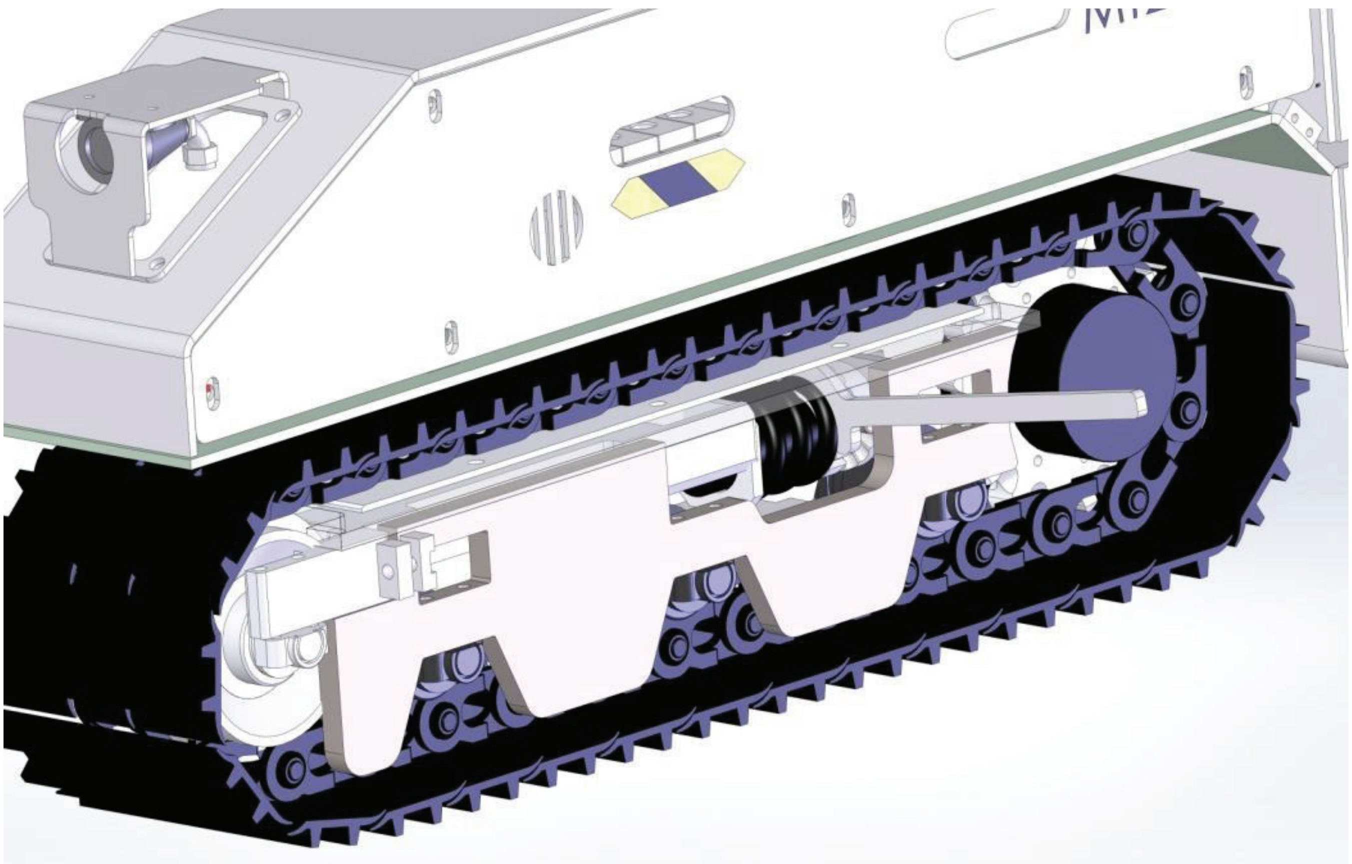
Raise engine compartment fully and wipe grease on slides.

Do this on a weekly basis.



Track Take-up Adjustment:

Track tension is adjusted using the provided spanner wrenches to turn the track tension cam. Turning the tension cam one click will move the idler yoke out ¼”. Only tighten until excess slack is removed from chain. Over tightening the chain will increase wear on all track components leading to a shortened service life.



APPENDIX G: CULVERT CLEANOUT TRACKING FORM AND SUMMARY TABLES

CULVERT CLEANOUT TRACKING FORM

CULVERT FILE NUMBER

DISTRICT ________ COUNTY ________________________________ ROUTE ________________

SLM ____________ MAINTENANCE RESPONSIBILITY ________________________________

MATERIAL ____ SHAPE ________________

LENGTH ____________________ HEIGHT/DIAMETER ______________ WIDTH ____________

WATER? PONDED / FLOWING / NO NUMBER OF BARRELS ______________________

DEBRIS DEPTH AT INLET __________ AT OUTLET __________ AVERAGE ____________

OPERATOR NAME ____ DATE ________________

NUMBER OF MEN ON CREW AND RESPONSIBILITIES ________________________________

CREW START TIME ______ AM/PM CREW END TIME ______ AM/PM TOTAL HR ______

BREAK START ______ AM/PM BREAK FINISH ______ AM/PM TOTAL HR ______

ENGINE START HOUR __________ ENGINE END HOUR __________ TOTAL HR ______

PIPE LENGTH CLEANED TODAY ________ TYPE OF DEBRIS ________________________

PLEASE DESCRIBE THE PROCESS TAKEN IN CLEANING OUT THE CULVERT.
INCLUDE IDENTIFICATION OF ALL EQUIPMENT ON SITE, WHICH END MOST OF THE WORK WAS DONE AT, ACCESSIBILITY, AND ANY PROBLEMS ENCOUNTERED.

NUMBER TRUCKLOADS OF SOIL/DEBRIS TAKEN FROM WORK AREA:

Culvert Number	Location	Dates	Type	Material	Height (ft)	Width (ft)	Length (ft)	# of Barrels	Length Cleaned (ft)	Average Debris Depth (ft)	Men on Crew	On-site (hours)	Man-hours	Engine Hours	Material Removed from Culvert (yd^3)	Removal Rate (yd^3/engine-hour)	Removal Rate (yd^3/man-hours)	Equipment Notes
MAH14 0974	Route 14, 0.2miles west of County Route 99	7/1/14	Box	Concrete	4	13	50	1	~40	3.17	5	4.57	22.85		76.2			Microtraxx, Gradall XL3100, dump truck
Identified as bridge on TIMS		7/2/14							~10		6	0.75	4.50					
		2							50				27.35	8.2	76.2	9.3	2.8	
SFN=1504363 Bridge	Route 170, 2.09 Mile Marker	7/8/14	Box	Concrete	4	15	54	1	54	2.38	7	7.00	49.00	??	71.4	??	1.5	Microtraxx, Gradall (on rubber), dump truck
		7/9/14							43	2.25	7	7.00	49.00	??	53.8	??	1.1	Microtraxx, Gradall (on rubber), dump truck
		2							97				98.0	8.8	125.2	14.2	1.3	
150071812-TIMS	Route 7, 18.25 Mile Marker (Old Bowers Farmers Market)	7/23/14	Box	Concrete	5.5	5	43	1	43	1.75	6	2.50	15.00	2.1	13.9	6.6	0.9	Microtraxx, dump truck, CAT 314E LCR Excavator
150071787-TIMS	Route 7, 18.07 Mile Marker (Gas Valve Station)	7/23/14	Box	Concrete	2.5	3	34	1	0	1.50								Microtraxx, dump truck, CAT 314E LCR Excavator
150071749-TIMS	Route 7, 17.656 Mile Marker (Elk Run Landfill)	7/24/14	Box	Concrete	4	4	47	1	47	0.83	7	1.75	17.25	2.5	5.8	2.3	0.5	Microtraxx, dump truck, CAT 314E LCR Excavator
150071555-TIMS	Route 7, ~15.86 Mile Marker (slightly south of Middle Beaver Auto Wrecking)	7/25/14	Arch	CMP	3	5.5	117	1	15	1.75	5	3.25	16.25	1.0	4.4	4.4	0.3	Microtraxx, dump truck, CAT 314E LCR Excavator

Culvert Number	Location	Dates	Type	Material	Height (ft)	Width (ft)	Length (ft)	# of Barrels	Length Cleaned (ft)	Average Debris Depth (ft)	Men on Crew	On-site (hours)	Man-hours	Engine Hours	Material Removed from Culvert (yd^3)	Removal Rate (yd^3/engine-hour)	Removal Rate (yd^3/man-hours)	Equipment Notes
Not in TIMS	Route 164, 2000ft south of Route 39 in Salineville, OH	8/19/14	Arch	CMP	4	8	145	1	145	2.25	6	9.50	57.00	4.0	91.3	22.8	1.6	Two dump trucks, Trackhoe, Microtraxx
150450 304-TIMS	Route 45 @ Buzzard Road (4 miles north of Wellsville Ohio)	8/21/14	Box	Concrete	3	4	36	1	36	0.50	5	10.00	50.00	-	2.7	-	0.1	1 dump truck, Microtraxx, 1 trackhoe
Work not performed during study period and not included in average removal rate values																		
-	Route 520 in Holmes County	12/9/14	Box	-	4	14	-	1	-	3.5	2	7.00	14.00	-	-	-	-	MicroTraxx, 1 excavator, and multiple dump trucks

Culvert Number	Process Notes
MAH140974	mucked inlet and outlet ends to bottom of culvert depths with Gradall, used microtraxx bucket attachment to dig out culvert from outlet end. Spoil was dumped into a pile in streambed where the Gradall from the streambank loaded it into a nearby dump truck bed. On second day, due to area along stream bank, the eastbound lane of traffic was blocked off as work focused on the upstream end. The microtraxx was then to push debris from inlet to outlet end rather than scooping.
SFN=1504363 Bridge	* work on the 8th and 9th used 8.8 engine hours* Remove debris from culvert with microtraxx, load material out with Gradall. 7 crew members (including flaggers) *work on the 8th and 9th used 8.8 engine hours* Remove debris from culvert with microtraxx and loaded out with gradall. 7 crew members required: 2 flaggers, 1 truck driver, 3 operators, and one foreman
150071812-TIMS	Southbound lane closed off with excavator and dump trucked parked above outlet (western) culvert end. Streambed 20ft from the culvert outlet excavated and placed in dump truck. MT placed at outlet end and backs into the culvert upstream to push/lift material out of the culvert at the outlet end. After lunch, the MT was spun 180 degrees to push/lift material to the outlet end to finish the cleanout. Upstream of the culvert inlet the excavator built an earthen dam that slowed the water slightly from the work area and seemed to help with cleanout. Two dump truck loads of material was cleaned from culvert and upstream and downstream ends.
150071787-TIMS	Excavator cleaned out the ditch at the outlet end of the culvert but the culvert was too small for the MT to fit
150071749-TIMS	MT unit was originally brought to site on July 23rd and lowered in to stream downstream of culvert but due to traction issues, the effort was abandoned. On the 24th a steel plate was lowered into the outlet to give more traction and stability. The outlet was too deep for unit to operate in. Significant preparation of the stream channel was performed by the excavator to widen the stream bed to place the steel plate appropriately. The inlet end of the culvert was a drop inlet structure with several pipes entering it. The excavator was in the southbound lane with two flaggers controlling traffic. Steam was further widened so the unit could turn around within the stream bed, With MT unit driving on the plate, it would still slip. requiring the excavator to correct it frequently. Outside of the pipe, the stream possessed a water depth of 6-8 inches, but inside of the culvert the depth of water was 12-16 inches with a lot of it ponded. Due to the shape of the outlet channel, there were difficulties exiting and entering the culvert as bucket loads of sediment were removed from the culvert. After cleaning, landfill was asked to draw down retention basin on the uphill side to clear culvert. Removing the steel plate from the stream proved to be difficult because the MT unit had driven it into the soil.
150071555-TIMS	Excavator cleaned out streambed 40ft downstream of culvert outlet (west side). Enough room existed on west side of the road that the excavator could be moved around freely and traffic did not need to be blocked. The dump truck parked next to the fence on the asphalt pad on the side of the south side of the road. Microtraxx was lowered into the outlet end of the culvert. MT was directed upstream to scoop material and when full backed up to dump at the culvert outlet for the excavator to pickup. Because of the tight space limiting the manuverability of the MT, the excavator had to clear the waterway nearly every MT trip. Though the MT could enter the culvert with some difficultly, the 36" culvert height proved to be too small. On one trip about 15ft into the culvert, the MT became stuck and after some stuggling, ripped off the protective cover of the engine. The cleanout of this culvert was abandoned after the mechanic fixed the shape of the protective cover and provided 4 new bolts that were sheared off. Two dump truck loads of material was taken, mostly from the streambed downstream of the culvert outlet.

Culvert Number	Process Notes
Not in TIMS	Work was performed in the dry. A work zone was set up and two flaggers were used. Two trucks were used and one broke down. The material in the culvert was shale. The trackhoe was used to cleanout culvert ends and to clear material removed from culvert by Microtraxx. Two flaggers, two drivers, one trackhoe operator, one MT operator; 8 truckloads were removed
150450304-TIMS	Nearly all work was done at the outlet end of the box. 2 Flaggers were on site, one truck driver, and two operators; 3 truckloads were removed (most of the cleaning must have been at the inlet and outlet ends within the stream
Work not performed during study period and not included in average removal rate values	
-	Cleaned debris from inlet with excavator. Proceeded to clean the debris from the inlet side. Excavator loaded debris material into dump trucks to haul away. Approximately 15 ft from the outlet, we pushed the remaining material out the outlet and loaded it out with excavator. Cleaned the outlet to the bottom of the culvert.

APPENDIX H: CANDIDATE CULVERT LIST FOR MICROTRAXX MT 3234 BY COUNTY

Adams	158	Hamilton	151	Muskingum	184
Allen	97	Hancock	81	Noble	178
Ashland	144	Hardin	32	Ottawa	49
Ashtabula	150	Harrison	72	Paulding	79
Athens	191	Henry	92	Perry	114
Auglaize	50	Highland	141	Pickaway	69
Belmont	130	Hocking	139	Pike	100
Brown	157	Holmes	79	Portage	89
Butler	203	Huron	27	Preble	87
Carroll	48	Jackson	143	Putnam	93
Champaign	59	Jefferson	71	Richland	111
Clark	79	Knox	103	Ross	139
Clermont	174	Lake	54	Sandusky	67
Clinton	115	Lawrence	150	Scioto	129
Columbiana	51	Licking	200	Seneca	67
Coshocton	114	Logan	86	Shelby	52
Crawford	37	Lorain	61	Stark	119
Cuyahoga	106	Lucas	43	Summit	98
Darke	64	Madison	60	Trumbull	177
Defiance	53	Mahoning	60	Tuscarawas	128
Delaware	107	Marion	34	Union	68
Erie	77	Medina	0	Van Wert	72
Fairfield	89	Meigs	107	Vinton	112
Fayette	65	Mercer	53	Warren	172
Franklin	81	Miami	74	Washington	198
Fulton	40	Monroe	104	Wayne	134
Gallia	153	Montgomery	13	Williams	64
Geauga	65	Morgan	71	Wood	135
Greene	91	Morrow	68	Wyandot	84
Guernsey	109			**Total**	**8594**