DRAINAGE FACILITY MANAGEMENT SYSTEM

Final Report

SPR 613

Oregon Department of Transportation

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by

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16. Abstract

This research project identified requirements for a drainage facility management system for the Oregon Department of Transportation. It also estimated the personnel resources needed to collect the inventory to populate such a system with data. A total of 213 data fields were identified and defined. A pilot data collection effort indicated that the time to gather and enter the information on one culvert was approximately 3 person-hours. Extrapolating the pilot project to the entire Oregon highway system indicates that there are between 23,000 and 25,000 culverts to be inventoried. Based in part on this research project, the drainage facility management system is under development and an inventory of all the culverts is underway.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
	NOTE: Volumes greater than 1000 L shall be shown in m^3.			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit	(F-32)/1.8	Celsius	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.196	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

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This project drew on the talents, knowledge, skills and goodwill of a very large number of people. First and foremost the authors wish to acknowledge the work of the temporary employees hired to collect culvert inventory data for the pilot project. They were (in alphabetical order) Mark Burens, Brent Cartwright, William Ferguson, Tawnia Forster, and Eric Zuern. As an indication of the quality and dedication of these individuals, four of the five have since been hired into other permanent positions at ODOT. Others working at, or for, ODOT also contributed to this project in a variety of ways. They include (in alphabetical order): John Brown, Joseph Dicicco, Milton Hill, Heather King, Michael Long, Susan Mead, Jeffrey Moore, Robin Ness, Robert Putman, David Ringeisen, Dennis Scofield, Kim Taylor, Douglas Tindall, Robert Trevis, Joseph Turner, and Wesley Taylor. The members of the Technical Advisory Committee for the project were: Gregory Apke, Timothy Banick, Shane Giffin, Scott King, Matthew Mabey, Bruce Novakovich, Lee Sparks, and John Woodroof. This project has far reaching implications for the entire agency and the participation of all these individuals contributed to the project's successful completion.

DISCLAIMER

DRAINAGE FACILITY MANAGEMENT SYSTEM

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1.0 INTRODUCTION

This report describes the process used to begin to develop an inventory and management system for the drainage facilities that are part of Oregon's highway system. The conclusions drawn from this process are also included. Field work, data management, and condition assessment all needed to be addressed as part of this process. Following completion of the research phase of the overall Drainage Field Management System (DFMS) project, work has continued on the development of the DFMS and the procedures used to collect the culvert data to populate the database. This report does not document this later work that is not yet finalized.

1.1 PROBLEM STATEMENT

The Drainage Facility Management System research project was begun to address the management of a growing and aging infrastructure for which no comprehensive, field verified inventory existed. While modern metal, plastic, and concrete materials can have projected service lives of 100 years, much of the Interstate system and other American highways were built in the 1950s and 1960s using culverts designed with 50 year service lives (*McGrath et al 2006*). This puts culverts in much the same age and service-life situation as Oregon's bridges were in before the third phase of the Oregon Transportation Investment Act (OTIA III).

This project was conducted in the context of larger asset management initiatives within both the Highway Division and the Transportation Development Division of the Oregon Department of Transportation. The requirements in General Accounting Standards Board Statement No. 34 (GASB 34), issued in 1999, contribute to this interest in expanding asset management in state DOTs (*PB Consult, Inc., 2004*).

An accurate inventory of assets is essential to the effective management of any system (*Wyant 2002*). No such inventory of drainage facilities existed for the Oregon highway system at the beginning of this project. The inventory that did exist in Oregon was spread between ODOT's Integrated Transportation Information System (ITIS) and Bridge Management System (BMS). These two databases are inadequate for culvert asset management because they do not contain the full breadth of information needed for proactive asset management. Additionally, ITIS had not been field checked and was of uncertain completeness. The culverts found in ITIS and the BMS have been incorporated into ODOT's TransGIS, this Geographic Information Systems (GIS) information is shown in Figure 1.1.

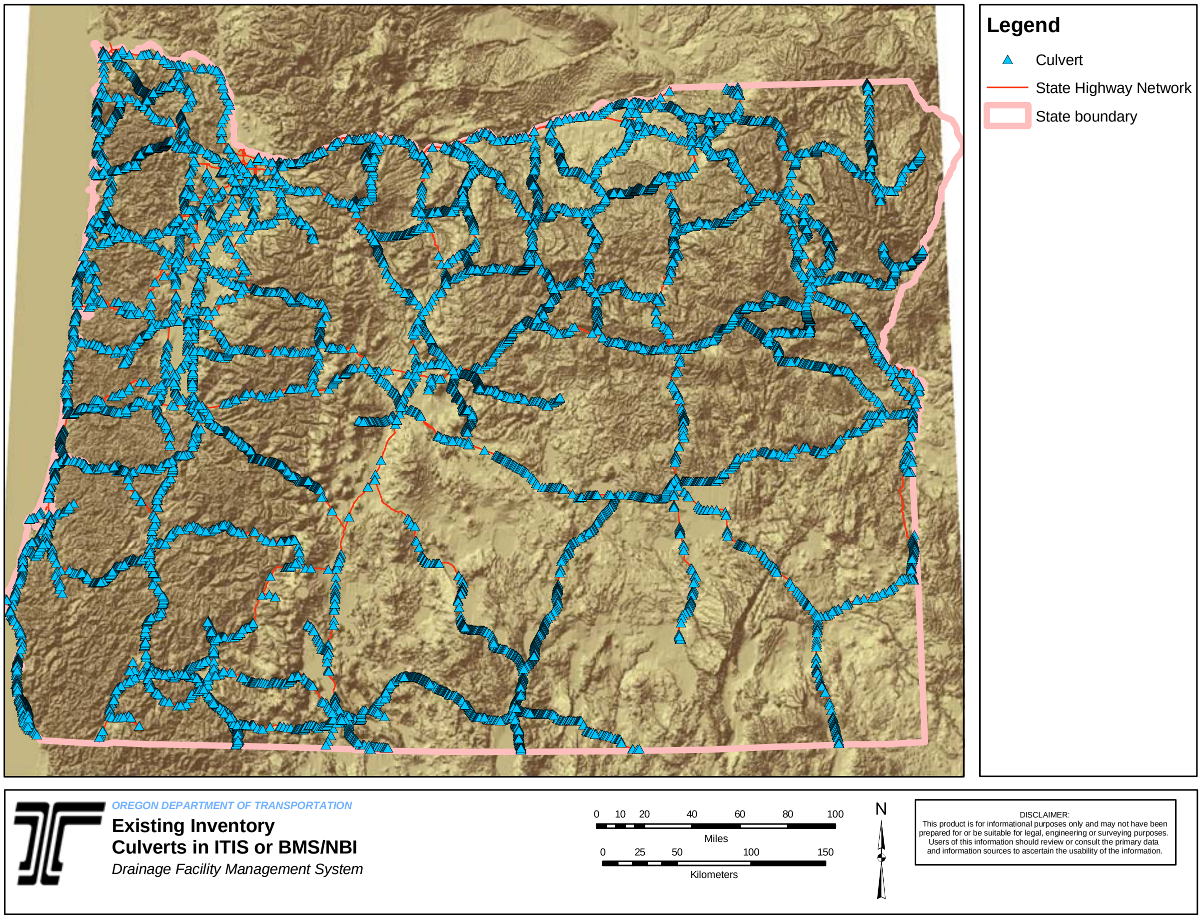

Figure 1.1: Map of culverts cataloged in either ITIS or BMS/NBI. The base map is a shaded relief map with the State highway system and Oregon border.

ODOT is not alone in this circumstance; in fact ODOT may be ahead of the norm. Perrin and Dwivedi (*2006*) surveyed the 50 state DOTs and received 28 responses. They concluded that many states were not yet even considering applying asset management to culverts and of those that were, often the triggering factor was a culvert failure(s). This contrasts with the now common practice of formally managing pavements and bridges. NCHRP issued Report Number 551 (*Cambridge Systematics 2006a and 2006b*), which deals with asset management, after work on this research project was essentially complete, but the contents of the report have likely indirectly influenced some of the content of this report.

Perrin and Dwivedi (*2006*) identified some of the benefits of culvert asset management as the following:

1) up-to-date inventory
2) reduced failures
3) reduced emergency repair costs and unplanned financial burdens
4) better budget planning
5) long term ability to identify actual life-cycle and performance of various materials

Implicit in this list is the view that an inventory is intrinsically valuable. While an incomplete inventory existed for ODOT's culverts, no centralized inventory exists for other types of drainage facilities. These other drainage facilities also represent a significant investment, require maintenance, and are necessary for the proper operation of the system and compliance with state and federal regulations. Consequently it is important that all drainage facilities be properly managed as assets.

1.2 RESEARCH OBJECTIVES

The Drainage Facility Management System research project was undertaken with two objectives stated in the Stage One Problem Statement: "1) Develop and implement an Oregon-specific system for inventorying and evaluating the condition of pipes, culverts, and storm water facilities based on the FHWA CMS. 2) Determine the time and effort required to collect, and input, data on all culverts, pipes, and storm water facilities within the entire ODOT system based on data collected during a small pilot project." The final work plan for the project was based on ODOT's Information Systems Branch developing the actual software with input from this research project. The development of processes and the pilot inventory were the focus of the work plan.

In retrospect the first objective was really a compound of three. This report is therefore organized around the following four objectives:

1. Methodology for Data Collection
2. Condition Assessment
3. Database Design
4. Cost and Resource Requirements Estimates

These objectives are consistent with the recent publications regarding asset management needs and objectives. For example, NCHRP Report 522 (*PB Consult, Inc., 2004*) identified the need for methods of condition assessment as one of five key unmet needs for implementing GASB 34. Wyant (*2002*) outlined the components of a full asset management system as following five items:

1) <u>Inventory</u>

2) <u>Assessment Methodology</u>

3) **<u>Initial</u>** and periodic **<u>assessments</u>**

4) Repair and Rehabilitation Options

5) <u>Linkage to larger management system</u>

Finally, Perrin and Dwivedi (*2006*) identified the essential elements of a comprehensive asset management system, specifically for culverts, as the following:

1) Goals

2) **<u>Inventory</u>**

3) Valuation

4) **<u>Condition</u>** and Performance Measures

5) Goal Achievement

6) Usage of the management system
7) **Performance Prediction**
8) **Integration of management systems**
9) **Consideration of the Qualitative**
10) Linked to Budget
11) **Engineering and Economic Analysis**
12) **Useful Output**
13) Feedback

This project addressed the underlined components to varying degrees. The remaining items will need to be put in place through policies and procedures that use the products derived from this project.

1.2.1 Methodology for Data Collection

There are dozens of ways that one could go about inventorying the drainage facilities in a highway system. Many of these were proposed and considered for this project. A couple of key data requirements quickly shortened the list of viable candidates. The data collection section of this report will outline the process by which an appropriate methodology was developed and the key elements of that preferred methodology.

1.2.2 Condition Assessment

The condition assessment task can be subdivided into four parts: 1) what data is needed for condition assessment, 2) what observations would provide that data, 3) how those observations should be stored in the database, and 4) how to translate the raw condition information into a simple, comparable assessment of the condition of the culvert. Section 2.2 of this report addresses each of these four points.

1.2.3 Database Design

The implementation and programming of the database was eventually turned over to ODOT's Information Systems Branch (ISB). However, this research project played a major roll in the specification of the required and desired data fields and some of the functionality needed for accessing and maintaining the data.

1.2.4 Cost and Resource Estimate

The final objective of this research project was to use the pilot data collection to estimate the scope of the task of inventorying all the drainage facilities and to develop estimates of the resources that would be needed to accomplish the task. The two key controls on this were the number of drainage facilities associated with Oregon's highway system and the process developed for inventorying them.

1.3 CULVERTS AND OTHER DRAINAGE FACILITIES

The problem statement clearly identifies the need to address all ODOT drainage facilities. The pilot project has focused nearly exclusively on a single class of drainage facility, namely culverts. Insights regarding the extrapolation of these results to other classes of drainage facilities are treated as postscripts in each major section of this report. These other drainage facilities include, for example, such things as dry wells and bio-swales.

There were several reasons for the decision to focus on culverts. The first is that culverts are one of the oldest and largest classes of drainage facilities. Therefore, the number of problematic members in the class is thought to be large and thus a priority. Because of physical and functional differences in the various classes of drainage facilities the development of data tables and supporting software must be done separately. Logistical and personnel resource constraints dictated that the different classes be handled in sequence rather than in parallel.

The resources available to this research project were also limited and it was concluded that it would be better to treat one class of drainage facility in detail rather than try to touch on all of them superficially. In this way it is hoped that future work will proceed forward with greater efficiency based on extrapolating the lessons learned from dealing with the culverts.

2.0 PROJECT RESULTS

2.1 METHODOLOGY FOR DATA COLLECTION

The envisioned use of the drainage facility inventory for asset management constrained the options for approaches to data collection. The first requirement was that some level of assessment or observation of the condition of the actual drainage facility was needed. Ideas such as windshield surveys, aerial photography, or using the digital video log of Oregon's highway system had no ability to address this need. Some drainage facilities are concealed in manholes as well. Another requirement was that details such as the actual geometry of the culverts were needed. Furthermore, direct observations of both the condition of culverts and the condition of associated embankments and water channels were deemed essential for performing a condition assessment for culverts. It was concluded that making direct, objective, facility by facility, measurements and observations was required. Appendix A is the procedure document that describes the final process that was developed. The remainder of this section of the report explores the issues and questions that arose in developing this procedure and describes the conclusions reached.

2.1.1 How much culvert information to collect

Even a simple, but complete, count of how many culverts there are under each highway segment could be considered a complete inventory. However, to be useful for asset management purposes, at least some additional information is needed. The most fundamental information that is needed is the size, material, and location of each culvert. Beyond this fundamental information there is a broad spectrum of data needed for asset management as it is envisioned at ODOT.

To manage an asset, such as culverts, the condition of the asset is needed in addition to the "what" and "where" of the asset. The overall condition and serviceability will be dependent not only on the state of the culvert structure itself, but also the conditions surrounding the culvert. Information about the soil, embankments, vegetation, stream, and channel associated with the culvert is also important information. Deterioration of a culvert isn't the only thing that could drive maintenance, repair, or replacement. Other factors such as fish passage, hydraulic adequacy, route importance, and other construction and maintenance activities planned for the highway should all influence the management of a culvert.

Discussions and deliberations regarding what data was needed led to the conclusion that the inventory needed to collect a broad and deep range of data to fully enable management of drainage facilities. The data was categorized into the following eight groups:

1. Location/Jurisdiction Data
2. Highway Data
3. Culvert Structure Data
4. Hydraulics Data

5. Geotechnical Data
6. Watershed Data
7. Maintenance/Inspection Data
8. Photographs

Appendix B contains a complete listing of the data fields identified by this research project.

Concluding that an extremely comprehensive suite of data was useful raised the question of the timing of collecting that large body of data. Much, but not all, of the data was always essential.

2.1.2 When to collect which culvert information

Regularly collecting a large amount of diverse data about culverts presents the dilemma of whether to collect all the data in one site visit or to somehow spread out the data collection. Three general scenarios emerged for dealing with this.

1. Collect all of the data in one comprehensive visit.
2. Collect the data in two or more phases.
3. Collect varying levels of detail based on need.

A great deal of the time and cost associated with collecting the data is taken up planning for and traveling to and from the culvert. The pilot data collection showed that even for an extensive suite of culvert observations and measurements, half for the time required for data collection was planning and travel. This indicates that the investment in visiting the culvert should be used to collect as much data as possible. It would be extremely inefficient to perform an enumeration of culverts separate from other observations and measurements. It was concluded that as much data as possible should be collected from the outset.

A graduated approach to the collection of culvert information is consistent with Beaver and McGrath's (*2005*) work in Utah where three levels of inspection were identified:

1) Qualitative visual inspection of the inlet and outlet
2) Qualitative inspection of culvert from end to end
3) Quantitative measurements and tests

Likewise, the subsequent frequency of inspection should be linked to need. Frequency of inspection has been suggested to be somewhere in the range of 2 to 5 years (*Perrin and Dwivedi 2006*), 3 years (*Ring 1984*) or 10 years under normal conditions and 3 years in aggressive environments (*NCHRP 1978*).

Utah proposed that selected "important" culverts be inspected every 2 to 5 years. They proposed that other culverts be inspected as part of roadwork operations (*Beaver and McGrath 2005*).

2.1.3 Who should collect which culvert information

The question of staffing for culvert data collection centered on the issue of how much technical knowledge and expertise was needed. The majority of the observations and measurements could be made by most individuals if they were trained for the process. It was carefully considered whether or not there were any observations or judgments that would routinely need to be made that would require special expertise or experience. It was concluded that such observations and judgments fell into two categories. First, many of the expert observations could be replaced with simpler ones that would provide the information needed for an expert evaluation or interpretation in the office. Some of the data fields were adjusted to accommodate this situation. Second, there were some expert observations and judgments that would only be called for after an assessment that the culvert was somehow inadequate. These much fewer cases could then be handled by an additional, expert site visit more efficiently than having someone with the necessary expertise inventorying all the culverts. This is especially true in these cases because such a follow-up visit would likely be made in any event. Training is needed for the data collection required for every culvert, but no specialized expertise or experience. Much more important is the training to the task and careful attention to making quality observations and measurements. The actual process is an acquired skill that argues for continuity of staff performing the work.

2.1.4 What instrumentation should be used for culvert measurements/observations

Instrumentation is needed for photographing, determining culvert location, and making quantitative measurements. A simple, consumer grade, digital camera performed very well for the purpose of photographing the culverts and their surroundings. There are combinations of hardware and software that would allow for the photos to automatically be tied to the other data collected. None of these systems was tried for the research project. The time stamp on digital photos provides a check against the time that GPS location and data collection takes place. In considering the process for dealing with the digital photos, no real need for a more automated system was perceived. Eventually the integration of GPS with digital cameras will likely be common enough that adopting it into the process will be a natural occurrence.

It was found that using both a GPS and a DMI (Distance Measuring Instrument, a high precision odometer) for establishing the culvert location was useful. This allowed for real world geographic coordinates to be directly established as well as a tie-in with ODOT's mile point reference system. ODOT's mile point reference system is commonly reported to a precision of one one-hundredth of a mile (~52 feet). Given this, even a consumer grade GPS would yield equivalent precision while the Selective Availability feature of the GPS system is turned off (*Snay 2008*). Looking to the future it is anticipated that ODOT will take advantage of the ease with which much higher precision, real world coordinates are possible. For this reason, differentially correctable resource grade GPS equipment was used. This equipment yields precisions better than one-thousandth of a mile in real world coordinates. Relative distances at a given culvert location are measured with a standard surveying tape.

Slopes of the embankment on inlet and outlet sides are both measured. The current procedure is to use a 24 inch electronic level such as is used in carpentry and landscaping. This provides a very quick, precise, digital measure of the slope on which it is placed. The limitation of this approach is that it is measuring a very small portion of the embankment. The embankments are often not simple, pure planar surfaces and so such a small sample doesn't always accurately reflect the overall embankment. The short length of the level also makes it susceptible to the effects of very small features such individual rocks or clumps of vegetation. As long as care and thought is taken in the placement of the level and the limitations of the measurement are recognized it should be adequate. If a similarly quick and easy process could be developed which yielded greater accuracy it would be a useful improvement.

The GPS records the elevation at the roadway surface and then a surveyor's rod and level are used to derive relative elevations of the features of the culvert and its surroundings. While the precision of resource grade GPS elevations is much less than the horizontal position, it is considered adequate for this purpose since the relative elevations of the different parts of the culvert installation are what is of primary concern.

Some consideration was given to using a laser range finder/inclinometer integrated with a GPS for locating and automatically recording the several features at a culvert. These devices are becoming more common with time. The difficulty directly targeting some of the features, such as the culvert invert, means that the range finder can not always be directly used for all the measurements.

2.1.5 How should culvert data be recorded in the field

Careful consideration was given to the way in which data was to be recorded in the field. The potential for using technology to record data was considered from the beginning. There was concern that the technological approach might be too fragile or cumbersome to be practical. Of the many possible solutions, three were given careful consideration. The traditional paper form was considered the standard to be improved upon when considering field data recording systems. A PDA (personal digital assistant, handheld computer) provides a way to portably record data electronically at minimal cost. Handheld GPS data-loggers combine the ability to record data electronically with precisely determined geographic position data.

The advantages of a pencil and paper form are that it can not break and almost everyone already knows how to operate it. The downside is that it introduces a transcription step which has the potential to introduce errors. It is also possible to fill out a form incorrectly or incompletely.

The advantage of a PDA is that the data is directly stored in an electronic form. The data will be stored and accessed electronically eventually in any event. While PDA's have become common, many people are not familiar with their operation and so an additional learning task may be added to the process. Most PDA's are not designed for a field environment and those that are carry a high price premium. There are some products available that are designed to protect a standard PDA in the field. Electronic data entry can be programmed to check that all the required data has been recorded and that the data entries are of a valid type or range.

Handheld GPS data loggers bring the advantage of GPS location data with them. Additionally they are almost universally ruggedly designed for the field environment. In the past they have been somewhat less user friendly than a PDA for data entry, but the latest generation are actually based on some of the same hardware and software as some PDA's. Consequently the GPS data logger shares the same programmability advantage as the PDA's.

Paper forms were initially preferred and tried. While the forms served their purpose as expected, the transcription of data from forms and the desire for a GPS location led to a GPS data logger being tried. The electronic data entry forms took some time to develop and refine but in the end the GPS data logger was judged to be at least equal to the paper forms in every respect and superior is some respects.

2.1.6 How should the location of culverts be determined and described

There continues to be discussion as to what is the best way to describe the location of culverts. Traditionally, what inventories there have been of the highway system have been based on mile point along a route. In the past this made sense since everything could be related to the highway by an easily measured distance. With the advent of GPS it is possible to obtain a three-dimensional location with greater ease and equal or greater accuracy. Features so located can then be directly related to the rest of the world. Features off the highway can be accurately located as well. Knowing where assets are merely with respect to distance along the centerline is no longer adequate since so much of what a state DOT does needs to be evaluated in the context of the surrounding environment. Linear referencing needs to be an extremely useful adjunct to the geographic location instead of vice versa. Modern GIS tools commonly include strong linear referencing functionality. Several DOTs have automated the process of moving between various positioning schemes including highway mile point.

2.1.7 Extrapolating to other drainage facilities

Issues such as location determination and field data recording are directly transferable to most or all other drainage facilities. The methods and instrumentation for making observations and measurements will likely be different for facilities other than culverts. Likewise it is possible that the skills needed for doing the inventory might be different. These details will need to be carefully considered for each class of drainage facility. Another aspect that can clearly be extrapolated is the role that planning and travel will play in the time required to conduct the inventory. Finally, the changes to the data requirements will be concentrated in a few of the eight data categories (as described in Section 2.1.1). The data fields for Location/Jurisdiction or Maintenance/Inspection may not need any changes, while an entire new category to replace culvert structure will be needed for each class of drainage facility and the needed photographs will also change.

2.2 CONDITION ASSESSMENT

Several types of information could contribute to a complete evaluation of the condition of a culvert. There are many, simple, objective observations that are indicative of condition. Examples of these are the presence or extent of corrosion, and damage to the roadway. An experienced inspector might also be able to make interpretive observations regarding condition. For example, instead of merely observing that there is corrosion on 100% of the invert, it could be interpreted that the corrosion was still superficial or, alternatively, that failure was imminent. There are observations that relate to condition that can be quantitatively measured. An example would be the length of the culvert that extends out from the existing embankment. There are also non-measurement observations that have discrete values such as a binary yes/no regarding the presence of a dip in a guardrail or selection from a short and simple list of options. All such observations could contribute to an assessment of condition. These different types of information need to be collected for a number of features at the site of a culvert.

For the purposes of the pilot project, ODOT chose to use a condition classification scheme with 4 qualitative categories, Good, Fair, Poor and Critical. Figure 2.1 shows the culverts inventoried as part of the pilot project, color coded for condition. By way of comparison, Utah used a 0-9 scoring system based on that of the FHWA (*Beaver and McGrath 2005*). Cahoon and Carson (*2002*) noted the challenges of evaluating culvert condition due to a lack of information about condition over time. They note that Missouri has one of the better data sets with observations dating back to the 1930s.

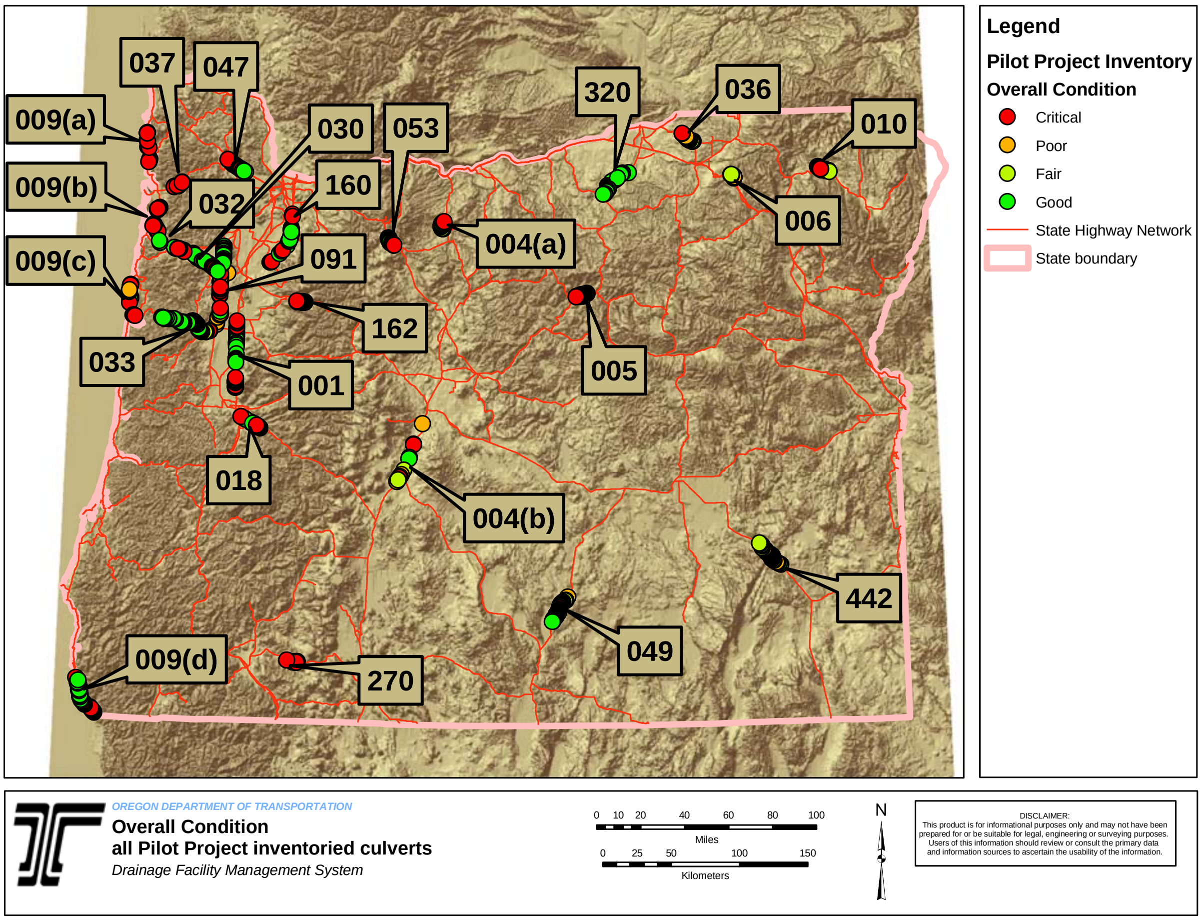

Figure 2.1: Map showing the location and condition of culverts inventoried as part of the research pilot project. The base map is a shaded relief map with the State highway system and Oregon border.

2.2.1 What information is needed to assess culvert condition

A complete assessment of culvert condition needs to include not only the culvert itself but also the embankment and the water channel. Numerous observations of each of these components can contribute to an assessment. Objective observations of what is present at the site are of primary importance for the inventory. Examples of this type of information are the material that the culvert is made of and the height of the embankment. Further observations that are direct indicators of deterioration of the culvert such as corrosion or sediment accumulation are also important. There are also observations that are indirect indications of problems with the culvert. Cracked pavement, sagging guardrails and seeps are examples of such indirect evidence of deterioration (refer to Appendix A for the complete list of the observations selected for culvert condition assessment).

Photographing the culvert, embankment, and channel allows for office based verification of the observations, expert consideration of the conditions, and analyses of changes over time. A standard set of pictures to be taken was developed with the option of taking additional photos as needed.

In addition to observations, the age of the culvert is an important attribute which will both give an indication of the expected condition of the culvert and the standards and practices that were used at the time of construction. In most cases this information is not available at the culvert site. Rather, the date of construction will need to be determined from examining construction records. None-the-less, it is an important part of an inventory for asset management purposes.

Finally, recording maintenance activities as part of the inventory will give an indication of existing or developing problems that would not otherwise be evident or might be masked by the maintenance. For example, a repaired guardrail would eliminate that piece of evidence of movement in an embankment.

Thirty three data fields or observations were recorded in a condition assessment study for Montana DOT. Of these, nine were found to be significant in predicting an expert opinion judgment of each culvert's overall condition. The implication would be that these nine properties are what the study's experts most depended on to arrive at their judgment or are strongly correlated to whatever observation is determining their evaluation.

The nine characteristics were *(Cahoon and Carson 2002)*:

1) Age
2) Scour at outlet
3) Evidence of major failure
4) Degree of corrosion
5) Invert of culvert worn away (this would appear to be a combination of the author's original "Coating of invert worn away" and "Holes in culvert invert" data fields)
6) Sedimentation of cross section
7) Physical blockage
8) Joint separation
9) Physical damage

2.2.2 How to use information to summarize culvert condition

One of the key objectives of the data to be collected as part of the inventory is to make an assessment of culvert condition. This could be done through a subjective, expert opinion process or through an automatic, computer-based process.

The pilot project used the subjective, expert opinion process. The data collected in the field was examined along with the photos and the condition was determined to be good, fair, poor, or critical. These four categories were intended to span a continuous spectrum ranging from good, meaning nothing needs attention, to critical, meaning that some aspect of the culvert installation needs immediate attention to protect life and property. Figure 2.2 shows the average condition of culverts by highway segment.

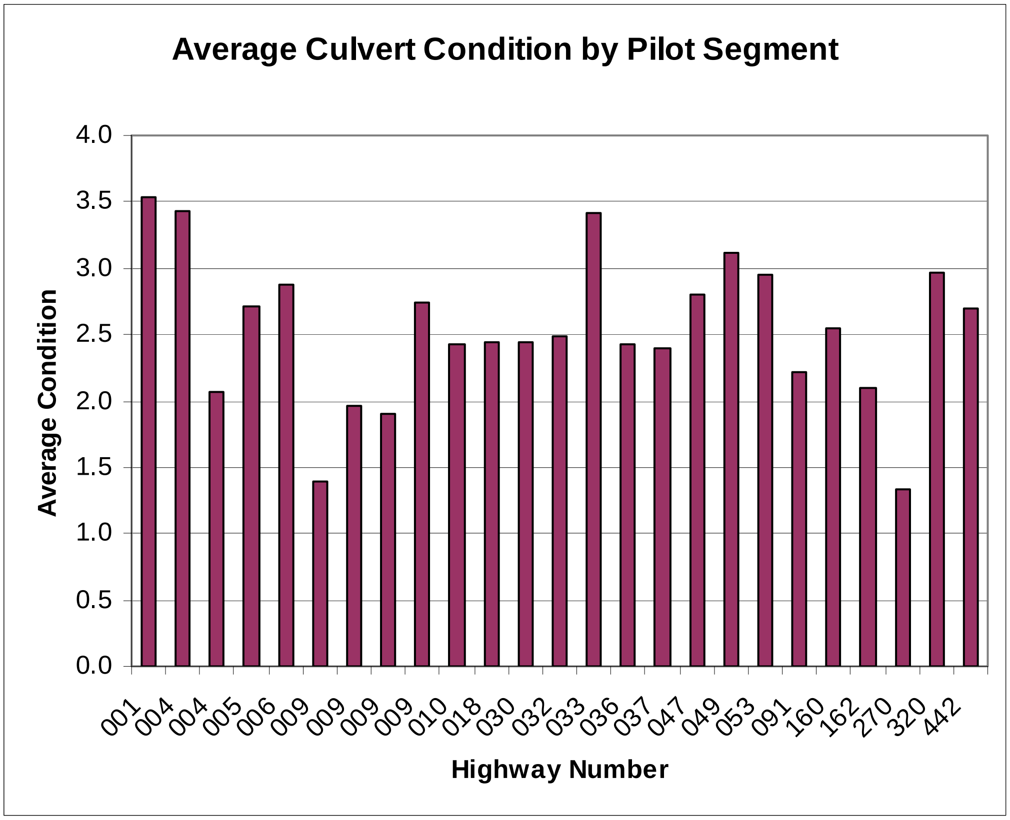

Figure 2.2: Graph showing the average culvert condition for each of the highway segments that was inventoried for the pilot project.

The pilot study indicates that the culverts in Oregon's state highway system have the following distribution of Overall Condition:

- Critical 32.7%
- Poor 11.4%
- Fair 14.4%
- Good 41.4%

This bimodal distribution, having mostly critical and good condition culverts with relatively few poor or fair condition culverts, could have arisen in a number of ways. It is possible that due to the highway system having been built over time, with periods of a great deal of construction and periods of relatively less construction, the age of culverts is unevenly distributed. Another interpretation would be that the deterioration of culverts tends to not be linear with respect to time and so culverts stay in good condition for a period of time and then rapidly deteriorate to critical condition where they remain until they are rehabilitated or replaced. Both of these interpretations would mean the distribution is an accurate representation of actual culvert conditions.

There are two other interpretations that are instead based on the distribution not being accurate. Rather they are an artifact of the data gathering or assessment processes. The first of these latter two interpretations is that the deterioration of fair and poor culverts is hidden or subtle enough that it is not observed or captured by the current inspection process. If this is the case, and four condition categories are really needed, then the inspection process would need improvement. The other interpretation is that, in general, the subjective approach being used clearly identifies good and bad culverts but is not taking correct notice of indications of degradation of the culverts in the good category that would put them in the fair or poor categories or that the implications of the observations are being interpreted as being too dire and are moving fair and poor culverts into a worse condition category. This situation would indicate a need for a change in the assessment process.

Given the subjective nature of the assessments used so far, it is difficult to distinguish if the condition assessments are accurate. An automated condition assessment based on the data in the inventory would be a useful check of the assessments. Automating the condition assessment would also be a time saver and assure consistency over time. Another important step to making the condition assessment less subjective is to continue to improve the procedure manual for the inventory process. That improvement process is underway, but not otherwise reported here.

Utah concluded that service life prediction was not possible due to a lack of prior inspection data/history and a paucity of construction date information (*Beaver and McGrath 2005*). Data collected in an asset management system will accumulate over time and should enable, or improve, service life prediction capabilities.

2.2.3 How to prioritize culverts for maintenance

Pipe condition is an obvious basis for culvert maintenance priority. In addition to the culvert condition there are several other factors that will be important to ODOT in prioritizing culvert maintenance and replacement.

The culvert itself might be fine, but if the embankment is failing around the culvert, then there is still a maintenance need and the culvert itself will eventually be impacted by the embankment failure. Another issue that needs to be considered in distinguishing between culvert priorities is fish passage. For example, it is possible that a poor culvert carrying a usually dry ditch might be a lower priority for replacement than a fair culvert that is blocking a large drainage of prime fish spawning habitat. The same might be true if instead a culvert has been found to be hydraulically inadequate for common flows.

More subtle is the influence of factors such as the average daily traffic (ADT) of the highway over the culvert, the detour length, alternate route traffic capacities, and other implications of culvert failure. These factors will also influence which culvert most needs to be replaced or rehabilitated.

Utah modified ratings based on importance and/or risk (highway type, culvert location, culvert size). Modification factors ranged from 0.75 to 1.33 (*Beaver and McGrath 2005*).

2.3 EXTRAPOLATING TO OTHER DRAINAGE FACILITIES

With the exception of ditches, most of the other types of drainage facilities have a much shorter history than culverts. To give an indication of the diversity of other drainage facilities, a partial listing is presented here:

- Ditches
- Dry wells
- Ponds (detention, evaporation, infiltration)
- Detention pipes
- Oil-water separators
- Filter packs
- Swales
- Check dams
- Outfall to stream/wetland
- Connection to storm sewer
- Connection to sanitary sewer
- Access manhole
- Storm drain pipe
- Catch basin
- Flow control manhole

Each of these has potential data fields in common (i.e. location, age, material). They also have differences. For example, the location of some facilities the is best described as a point, while for others it is a line or an area. To avoid confusion and errors during the inventory process, the data fields associated with any given facility will need to be determined by the type of facility being the first item specified. Pipe like facilities will have several condition indicators in common with culverts. Facilities such as ponds and catch basins will have fewer indicators in common but some, such as sedimentation, will be the same. Facilities like oil-water separators and filter packs will likely need a number of observations that are completely distinct from any made for culverts.

2.4 COST AND RESOURCE ESTIMATE

Given the absence of any inventory that purports to be exhaustive, the scope of the task of collecting an inventory of culverts or other drainage facility is problematic. The existence of two incomplete inventories of culverts across the entire state does provide a reference frame to be used to extrapolate estimates for culverts to the entire state. The key approach taken for culverts was to conduct a pilot inventory of every culvert on a sampling of small highway segments and compare those results with the existing, incomplete inventories. The complete absence of inventory information regarding other drainage facilities imposes greater uncertainty on any estimates to be made for those facilities.

2.4.1 How many culverts does ODOT own

Many of the culverts inventoried in the pilot data collection effort were unique, meaning they weren't recorded in ITIS or BMS. The range of the percentage of these unique or new culverts on the various pilot segments was 5.9% to 78.9%. Weighting these values for either the number of culverts or the number of miles in each segment indicates that new culvert entries will constitute between 32% to 37% of the complete inventory of culverts in Oregon's state highway system. This estimate is dependent on the pilot inventory being representative of the entire system. Extrapolating this estimate means that the total number of culverts to be inventoried and assessed is likely in the range of 23,000 to 25,000 culverts. It should be noted that if the pilot's average culverts per mile value is multiplied by the miles in the highway system a slightly larger number of ~28,000 results. This is very likely due the fact that there are some stretches of highway that are completely free of culverts in the ITIS database. Since none of these stretches was in the pilot study, the average number per mile in the entire system is likely lower. The probability that the total number of culverts in the system is significantly higher than ~25,000 is considered to be low. The total number of culverts to be inventoried directly affects the cost and effort required to complete the inventory.

This project inventoried 963 (or ~4%) of the culverts from across the state distributed across different highways and terrain. By comparison a Utah study inspected 272 culverts with the finding that the culverts were aging, but generally not in need of maintenance (*Beaver and McGrath 2005*) and a study for culvert condition assessment in Montana inspected a sample of 460 culverts from across the state (*Cahoon and Carson 2002*).

2.4.2 How complete is the existing culvert inventory

Based on the segments of highway inventoried in the pilot project, the existing inventory is 63% to 68% complete. The two values were derived by weighting the sample segments based on mileage or the number of culverts respectively. This means that there are likely 7300 to 9400 culverts that are not in ITIS or the BMS at all. This number is important for assessing the importance of conducting an inventory of all culverts versus simple inspecting and collecting data on the culverts already in the inventory.

2.4.3 How complete can is the new culvert inventory expected to be

There is much greater uncertainty regarding how complete a comprehensive inventory can be expected to actually be. This is because counting that which one doesn't observe is impossible.

Estimates based on the pilot study are also problematic because pilot study crews were told to ignore culverts over 6 feet for much of the time. The data that we do have indicates that we should expect between 1 and 3 percent of the existing culverts to be missed by the methodology that has been developed. This estimate is based on how many additional, or missed, culverts were found on follow up visits by the author to some of the pilot segments. The population of missed culverts will likely be dominated by smaller culverts serving intermittent to extremely intermittent drainages.

2.4.4 What staffing is needed to collect culvert data

The types of personnel that could be used include regular ODOT staff, temporary ODOT employees, a consulting firm, or a contract with a university. The customary treatment of travel status for both regular and temporary ODOT employees introduces considerable travel time overhead if the employees work all of the state based out of Salem. Having the field crews based out of cities within the region in which they will be working could provide a considerable savings.

The number of personnel will control the rate at which the inventory can be completed. Each two person field crew can be expected to inventory between 100 to 125 culverts in a 320 hour month (excluding vacation and sick leave). The number of field teams will determine how quickly the inventory is completed. One field team would take about 19 years to complete the inventory. Conversely 19 teams could complete it in one year. Training 19 teams all at once will introduce some inefficiencies because it means 19 learning months. Likewise it is unlikely that one crew could be kept staffed with the same personnel for 19 years.

2.4.5 How many person hours are needed per culvert

The staff time required for inventorying and assessing the culverts can be estimated by analyzing the rate and dates of culvert data collection and the pay roll hours. This time includes both time in the field as well as the time required in the office. Figure 2.3 shows that as more hours are worked in a month, more culverts are inventoried. Figure 2.3 also shows that the productivity of the pilot inventory crew seemed to improve over time. This is due to both the experience of the crew and the refinement of the inventory process used both in the field and in the office. Activities both in the field and in the office are important to the success and productivity of inventory efforts.

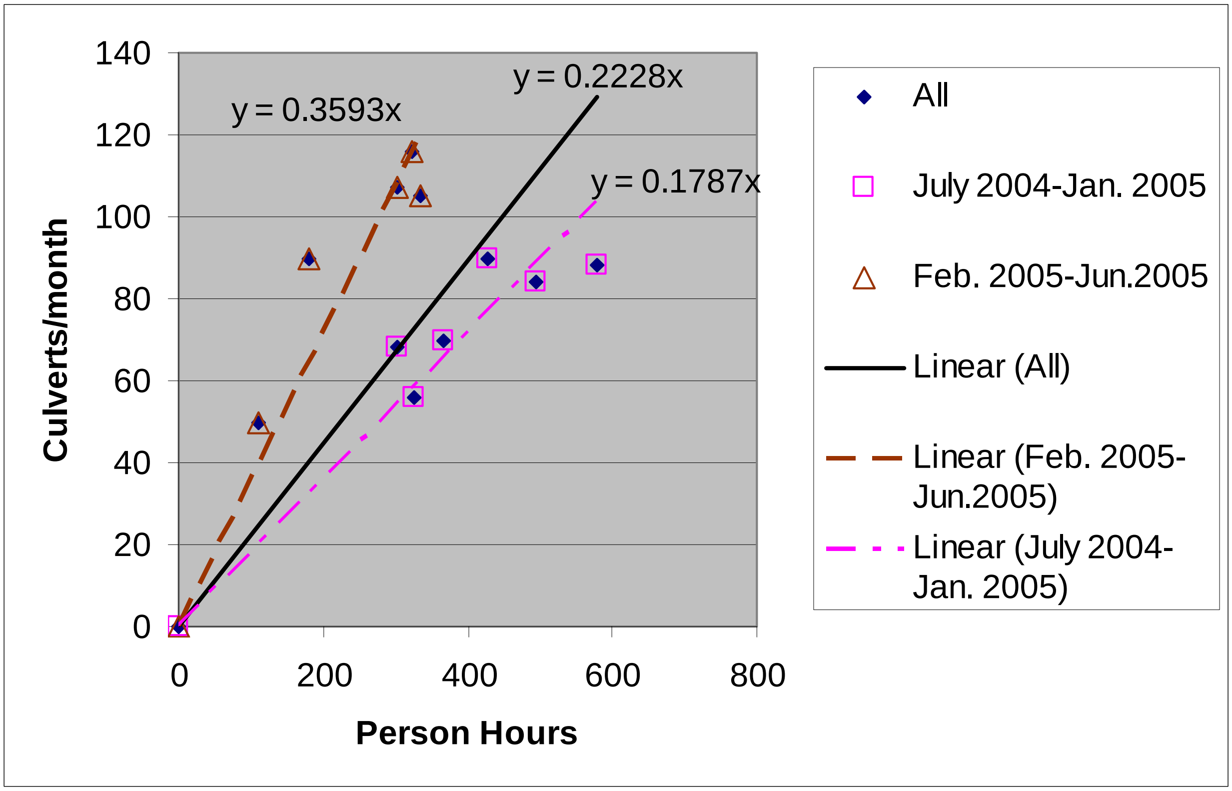

Figure 2.3: Graph of culverts inventoried per month versus person hours worked in that same month. Linear fits to the data with a zero y-intercept were used on the premise that zero hours should equal zero culverts.

2.4.5.1 Field time

The field time required for data collection can be broken down into the time required at a culvert site making observations and the time required traveling to the culvert sites. Figure 2.3 shows a plot of culverts inventoried per day over time. The graph shows a clear upward trend that accelerated as weather improved going into the summer of 2005.

2.4.5.1.1 Observation Time

Using the final methodology, 10 culverts per day is a reasonable target. This means that the observation time per culvert is in the range of 30 minutes to an hour, or 1 to 2 person hours per culvert. This is influenced primarily by the vegetation and terrain around the outlets and inlets of the culvert, the size of the culvert, the width of the road and shoulders, and the traffic volume. A key role that the vegetation and terrain play is in influencing how difficult it is to actually find the culverts. Under conditions of dense vegetation and/or rugged terrain simple finding the culvert can be very time consuming.

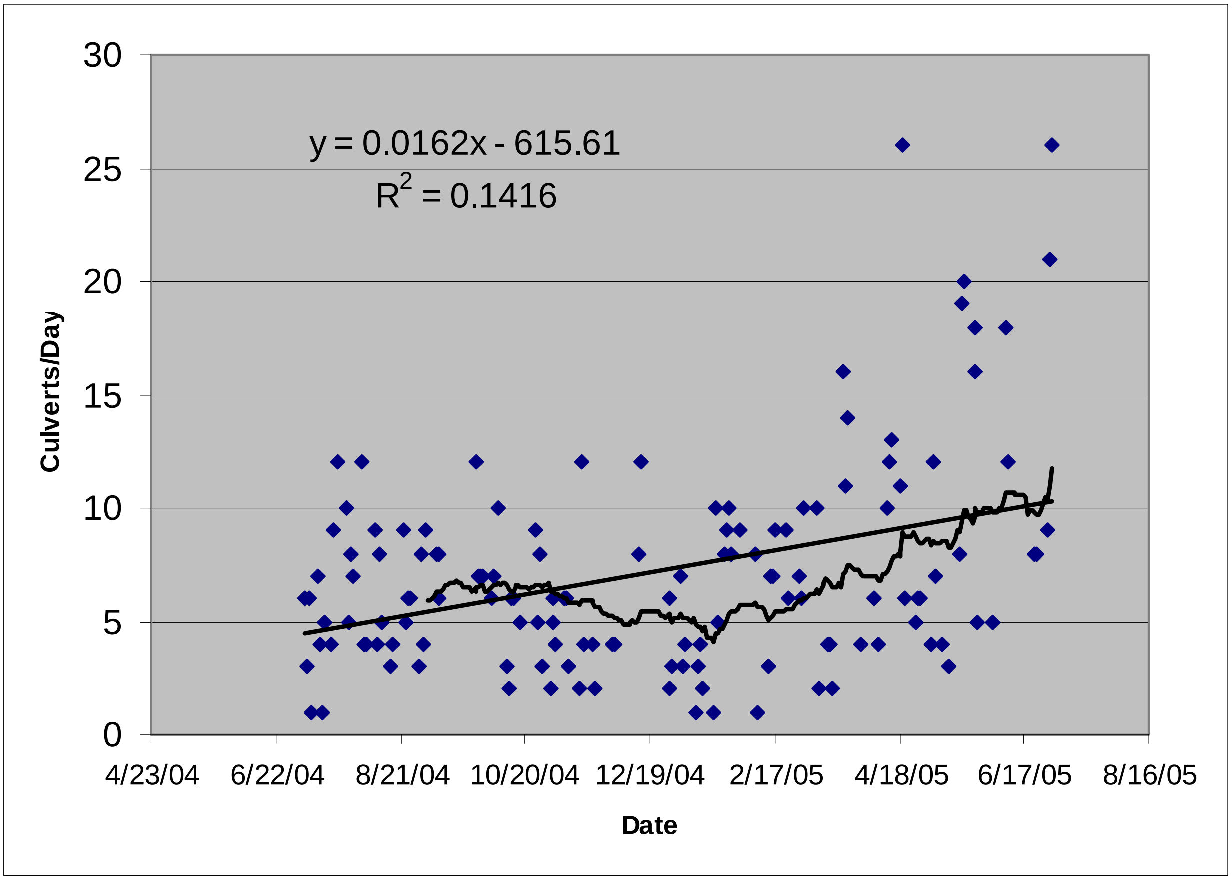

Figure 2.4: Graph of culverts inventoried per day over the course of the pilot project. No point is plotted for days when no field work was done.

2.4.5.1.2 Travel time

For Salem based crews the travel time is considerable. Most of the state is at a great enough distance to require overnight travel. When overnight travel is required the data collection work week is effectively reduced to 3 days. Travel time will likely average ½ to 1 person hour per culvert. Commuting to the field from a Salem base presented a problem for separating office time from commute time. The experience of the pilot project would seem to indicate that if the culverts are more than an hour away from Salem then it is probably worthwhile to use overnight travel. This conclusion would probably be even truer if contract labor made staying out over weekends more feasible than was the case during the pilot project.

2.4.5.2 Office time

The pilot study indicated an average of 4.5 total person hours per culvert. This number dropped to 2.8 hours per culvert for the last three months. Some of this drop is due to the field operation becoming more efficient. Some is also due to much of the planning and preparation work being completed in previous months. It is estimated that once stable staffing and methodology is in place that the average person hours per culvert will be 3 hours. Of this, something in the neighborhood of one-half-of-one person-hour will be office time.

2.4.5.2.1 Planning and preparation

A great deal of the planning and preparation time in the pilot project was related to the fact that it was a pilot and was started from scratch. Starting a production project based on what has been learned in the pilot will be less labor intensive. Nonetheless there will always be some planning and preparation required. If 3 hours per week is allotted (for planning and preparation) and 30 culverts are done per week then the planning and preparation load, per culvert, works out to 6 minutes per culvert. Five minutes per culvert is probably not an unreasonable number to use for projections of worker time.

2.4.5.2.2 Data transfer/input

The initial approach was to record data onto a paper form and then to transcribe the data into a database. Typing the data and error checking it is a time consuming task. Using the GeoExplorer GeoXT data logger should reduce the data transfer to less than 5 minutes per culvert and likely the value will be more on the order of 1 to 2 minutes. The input of condition assessment is more problematic. A subjective assessment could be formed in as little as 5 to 10 minutes, but it is also true that one could carefully analyze all the data for as much as an hour to arrive at a final assessment. For planning purposes an estimate of 10 to 15 minutes for data transfer and input is considered appropriate.

2.4.5.2.3 QA/QC

The pilot project did not explore issues of quality assurance or quality control to a significant degree. Follow up field checks of culverts dealt only with size and location. No errors in size were identified and only a small number of missed culverts (other than those over 6 feet) were identified. For a production inventory process an unobtrusive but effective QA/QC process needs to be developed to minimize random errors. Likewise a random audit process will need to be used to guard against systematic errors.

2.4.6 Is there a difference due to highway classification or geography

The number of culverts per mile and the condition of culverts in the Oregon state highway system were both parameters that the project sought to estimate, based on a sample, as accurately as possible. Since both these numbers likely vary in response to environmental and highway conditions, it was hoped that by using parameters that addressed these conditions the accuracy of the estimates could be improved. The number of culverts per mile, the rate of data collection, and average culvert condition at each of the pilot locations was compared to elevation, terrain roughness, eco-region, GIS mapped stream crossings, and 2nd Field hydrologic unit. No relationships were found to have predictive value. The variance in the number of culverts per mile, culverts per day, or culvert condition can not be reliably predicted using region scale assessments of the environmental conditions. This is like due to complex interactions between the various environmental parameters combined with the drainage design process accommodating greater precipitation through larger culverts rather than more culverts. In Utah it was also found that geographic location and elevation did not correlate with condition (*Beaver and McGrath 2005*).

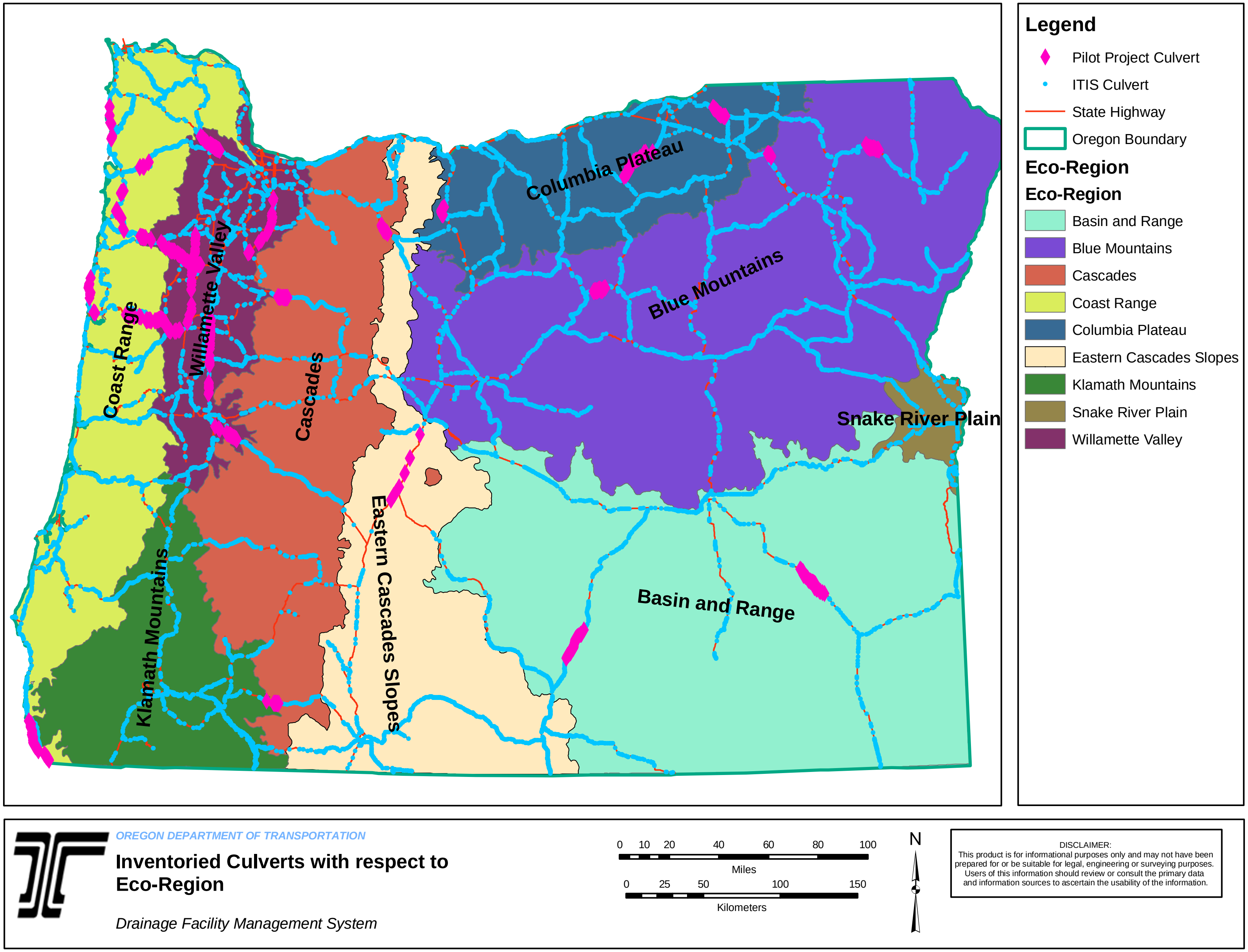

Figure 2.5: Inventoried culverts with respect to eco-region

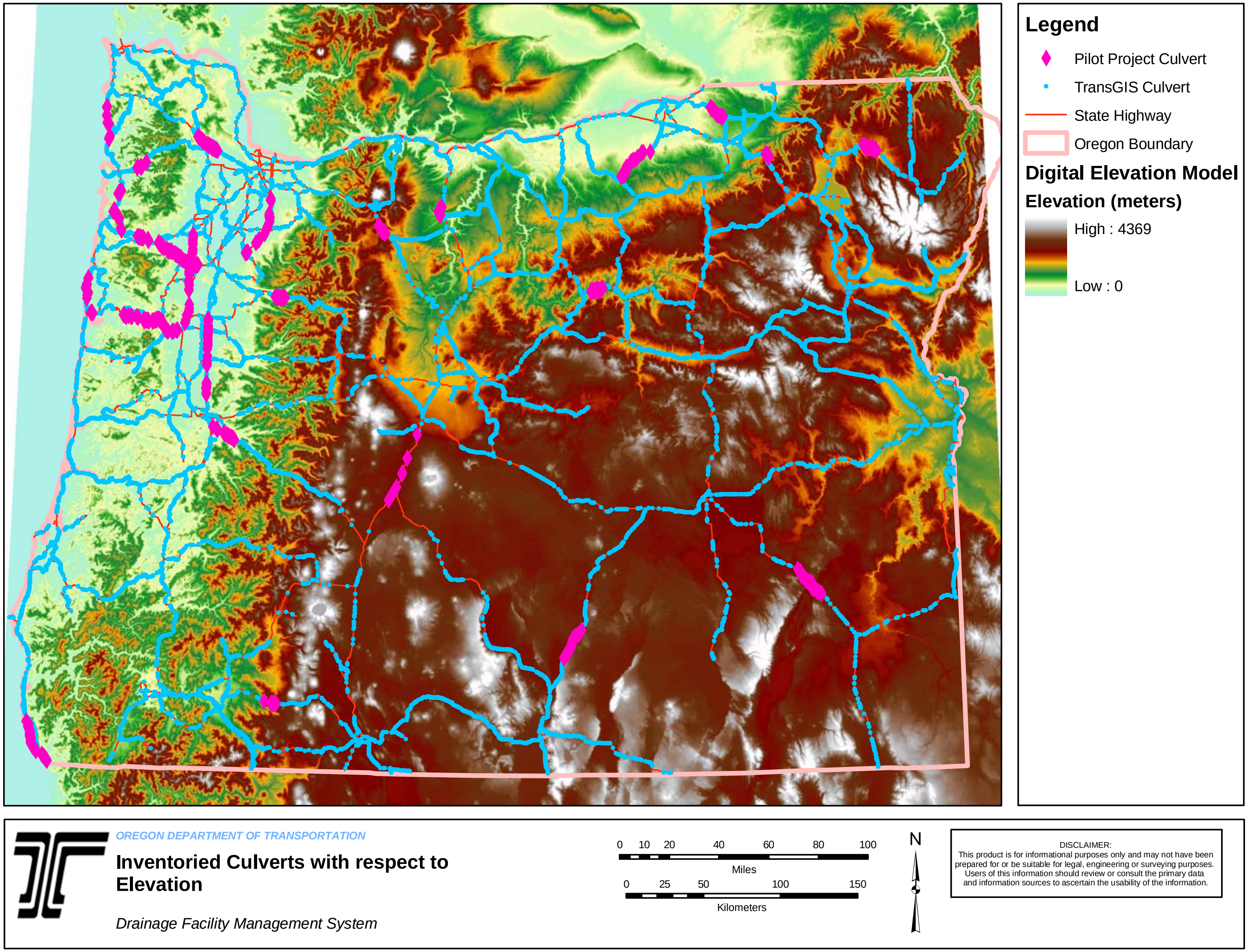

Figure 2.6: Inventoried culverts with respect to elevation

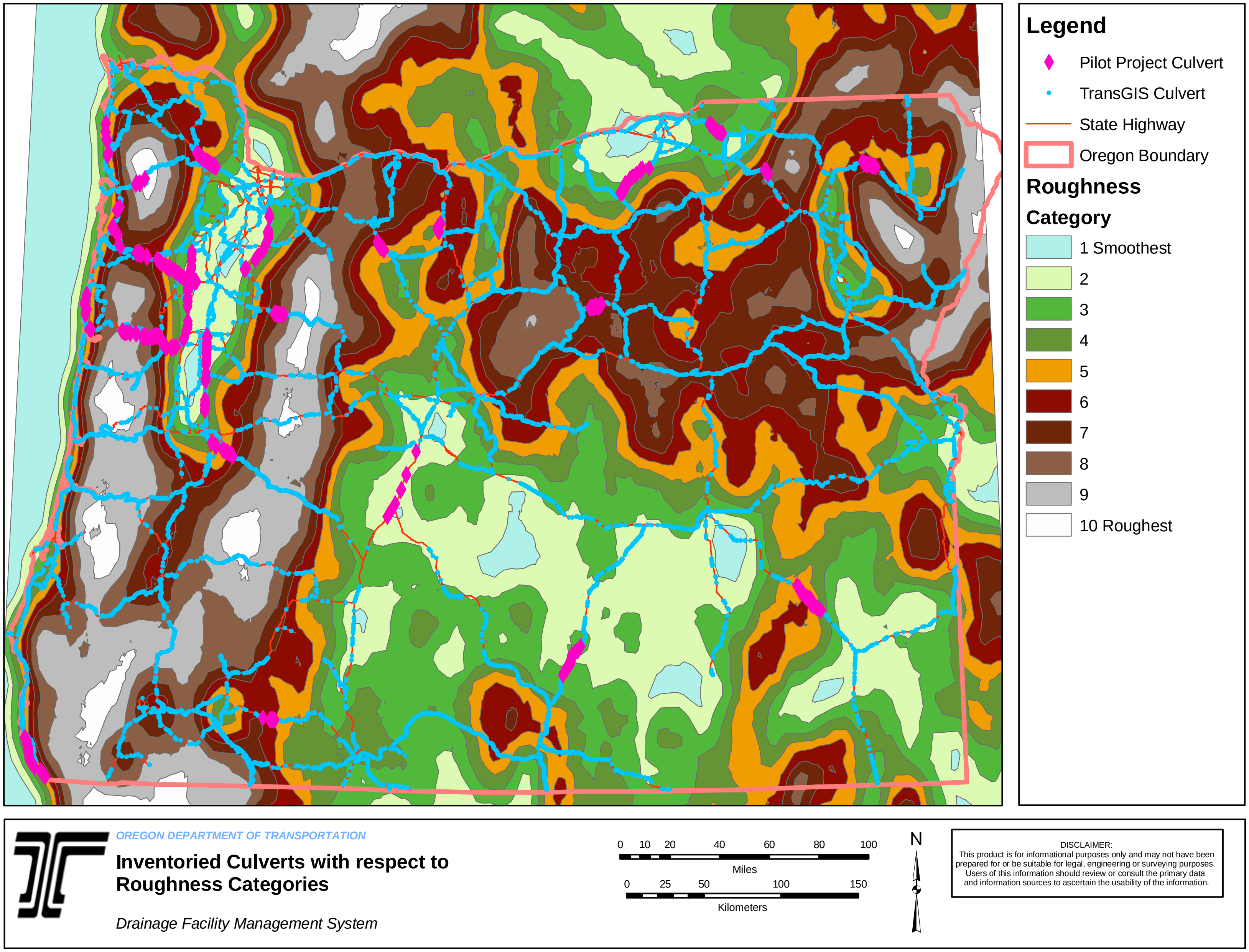

Figure 2.7: Inventoried culverts with respect to roughness categories

2.4.7 Matching existing culvert data with new culvert data

The new, detailed, GPS supported inventory consists primarily of culverts already in the existing inventories. Three methods were tried to match up culverts collected for the new field inventory with the culverts in the existing ITIS and BMS data sets. The first approach was to create tables from each data source of culverts with their mile points or geographic coordinates. The entries in these tables were then matched up by human inspection. The next approach was to look at a map display of the culvert locations from both data sets and to spatially match up culverts by human inspection. The final approach was to try and use GIS to automatically match up culverts from the two datasets with a nearest neighbor approach mitigated with other attributes such as culvert size and material.

Each of these approaches was labor intensive to explore, but the GIS approach held the promise of being able to be automated to be much less labor intensive. The results of these trials indicate that the pairing must be done by human inspection/comparison, record by record, in a table format. Using the spatial representation in a map view made it too tedious to look up the other attributes. The proper match is too often not the closest culvert for the GIS approach to be effective. Given that the ITIS and BMS geographic coordinates are backed out of a non-geographic linear referencing system, the geographic coordinates don't match up as well as using mile points for the new data set which were referenced to, nearby mile points of other features in the ITIS dataset.

2.4.8 Extrapolating to all drainage facilities

As was previously mentioned, a good portion of the time involved in conducting the inventory is related to traveling to the locations. This will also be true for other drainage facilities. It is possible that this may be true to a lesser extent if water treatment type facilities are more concentrated in urban areas or if there are more of these other facilities in the wetter, western portion of Oregon. How much time each facility takes will be most dependent on how many observations need to be made and recorded. Conceptually, it seems likely that some types of facilities will need much less time than a culvert and that few, if any, will need more time. The number of these various facilities is a complete unknown.

2.5 DATABASE DESIGN

The original problem statement referred to the FHWA's Culvert Management System (CMS). While this software was one starting point for designing ODOT's Drainage Facility Management System, it was clear from the beginning that ODOT needed additional features and data beyond what was in CMS. Once the decision was made that significant modification of CMS would be required to meet ODOT's objectives, a number of decisions about the database and software presented themselves. The following sections deal with issues of maintenance, platform, data fields, features, and integration dealt with by the research project. Finally, an attempt is made to extrapolate what was learned dealing with culvert to all drainage facilities.

2.5.1 Maintenance and ownership

The most fundamental, and therefore first, issue to be addressed in developing the database to hold the DFMS was what organizational unit was going to have ownership of the database and maintenance responsibility. Based on staffing, skills, and job descriptions it was clear that housing and maintaining the database in the Geo-environmental Section or the Research Section was not a sustainable long term solution. The preferred solution was to have Information Systems Branch (ISB) develop and house the database. Many other options, such as contracting with OSU, were also explored but in the end the way was opened for the preferred solution.

2.5.2 Platform

The platform on which to develop and operate the DFMS was largely dictated by the maintenance and ownership decision.

The number of records and number of users is such that a Microsoft Access® based database, running on Microsoft Windows XP®, would have been adequate for a statewide database. For example, Oregon DOT's Salmon Resource and Sensitive Area Mapping (SR-SAM) project geodatabase has several tables with as many records as Oregon likely has culverts. The size of the SR-SAM geodatabase is 500+Mbytes.

In 2002, Wyant indicated that no state DOT was using CMS, which is based completely on Access. Utah used an Access database with stand alone Visual Basic programs to handle inventory and inspection data input and reporting tasks (*Beaver and McGrath 2005*). Before ISB agreed to take on the DFMS project, the ODOT Research Section had ported ~90% of the code and functionality of CMS to a Visual Basic application.

ISB's preference is for SQL databases on server farms or mainframes. While development might be more difficult at an enterprise level, maintenance and reliability are like easier. It also appears that the system will eventually be more feature rich. One key benefit of this approach is the ability to store images within the SQL database as opposed to storing links to files in an Access database running on Windows XP.

2.5.3 Data fields

The beginning point for identifying data fields for the DFMS was to carefully look at the data fields in a variety of other culvert databases. The databases used for this were the following:

- ITIS (ODOT's Intelligent Transportation Inventory System)
- BMS (ODOT's portion of the National Bridge Inventory)
- A variety of Maintenance District spreadsheets
- The ODFW fish passage culvert inventory
- CMS (FHWA's Culvert Management System)

Another source of candidate information fields was the already existing Hydraulics Inspection Form. The data items for all these sources were laid out in adjacent spreadsheet columns to identify a complete set of unique data fields. As part of this process data categories were developed (See Appendix B for list of data fields and categories). Many fields were common to two or more of the sources. These duplicates were eliminated to arrive at a list of candidate fields. Some of the fields were judged to be superfluous and others were judged to provide information covered by other fields. This refined list was then augmented with additional fields that were deemed important to the planned functions of the database. Many of the fields in this final category were related to environmental issues. The inclusion of digital photos was another data item that none of the preexisting culvert databases had.

After a final list of data fields was completed the fields were further categorize as essential, optional, and derived. Essential fields were those that will be required to be filled in to create a record in the database. Optional fields consist of information useful for managing the culvert assets but which will not necessarily be collected for each culvert as it is inventoried. The derived fields are data that is either taken from other databases or is the result of a calculation based on other data.

At the end of the pilot project ODOT had identified 213 data fields for inclusion. By comparison the study for Utah DOT identified 31 inventory data fields and 77 inspection data fields (*Beaver and McGrath 2005*) and another for Montana DOT used 33 data fields (*Cahoon and Carson 2002*)

2.5.4 Features

The process of identifying the data fields needed in the DFMS also indicated some features that the database should have. This section is not a feature set or requirements document. Some general features are obvious, such as Utah concluded that there was a need for reports on inspections and inventory *(Beaver and McGrath 2005*). Rather, it relates some of the features that were identified as being desirable in the course of the research project.

The first feature that was clearly identified was the ability to include digital photo documentation of the culvert and its surroundings as part of the database. This conclusion was also reached by Utah DOT (*Beaver and McGrath 2005*). It was further concluded that the DFMS needed the ability to store both a standard set of views for each culvert as well as the ability to store additional photos of unique conditions. Thirteen standard photos were specified.

Another feature that was identified as important was the ability to keep a history of observations from each inspection over time (*Wyatt 2002*). The purpose of this is to capture the rate and nature of changes occurring at each culvert to aid in both the condition assessment and the prioritization. This history can also serve as a check on how one generation of observations compares to another. For example if most of the culverts improve in a generation of inspections, it is likely that the inspection process was some how different and perhaps in need of adjustment. It was decided that it was also important to extend this history to the photos as well.

Another feature that was identified as important was the ability to present a different user interface based on the needs of the user. For example, a district maintenance worker entering data about a maintenance operation that was performed on a culvert needs to be presented a very different set of menu choices and forms than a biologist working on fish passage issue. This is thought to be especially important to encourage the regular updating of information in the database.

2.5.5 Integration with existing and future enterprise systems

ODOT has a number of existing, legacy systems that relate to drainage facilities as well as a vision of asset management in the future. Both of these circumstances needed to be considered in the development of the Drainage Facility Management System.

The two key legacy systems that have connections to the DFMS are the Integrated Transportation Information System (ITIS) and the Bridge Management System (BMS). ITIS includes some basic information for most culverts in the 36 to 72 inch size range and even includes some culverts smaller than 36 inches. ITIS catalogues a wide range of features along the state highways. These are organized as records with fixed-length, character-code based fields. The primary fields that all records have in common are highway number and mile point. Due to the wide array of other features in ITIS, the DFMS will need to interoperate with ITIS, to some degree, for an indefinite period.

The BMS is a database modeled after, or based on, PONTIS, the FHWA/AASHTO bridge management software.

ODOT envisions, and is working towards, a highly integrated suite of management systems. The DFMS has been guided by this goal and is designed to avoid duplication of other system's data and instead draw data from those other systems that are the primary repository of the data.

2.5.6 Extrapolating to all Drainage Facilities

Each type of drainage facility will have its own set of data fields. Given the inherent flexibility of modern relational databases, it will be a straight forward task to develop and add additional tables for each facility type. The degree and nature of software coding to support and use those tables will likely be quite variable, but the work required for culverts is probably at the high end of that spectrum. Many of the other types of drainage facilities will have fewer data fields, fewer input and query forms, and fewer reports when compared what is needed for culverts.

3.0 CONCLUSION

Once the Information Systems Branch assumed responsibility for developing the software for the Drainage Facility Management System, the objective of the research project was to identify what data fields were needed in the system and the effort that would be required to complete an inventory to provide the data for the system.

The results of the pilot inventory effort indicated that ODOT has a total of approximately 23,000 to 25,000 culverts that are part of the state highway system. Of this total number it is estimated that approximately 7300 to 9400 are not recorded in ITIS or BMS, which are the two existing agency repositories of data about culverts.

The pilot inventory also indicated that approximately 3 person-hours of work are required per culvert to collect the basic level of information about each culvert. It appears that a two person field crew, after one month's training and practice, should be able to inventory 100 to 125 culverts per month.

Variations in culverts per mile and culverts inventoried per day cannot be predicted based on regional parameters such as terrain, elevation, eco-region, or highway classification. The variance within a highway segment is as big, or bigger, than the variance between segments.

Using the methodology developed in this project, ODOT will likely still be missing 1 to 3% of the culverts that are actually part of the highway system. Achieving >99% would likely double the cost of the inventory.

Use of a handheld GPS data logger clearly increased productivity of field data collection. It is also considered likely that its use improved accuracy in a number of ways.

The pilot inventory yielded a culvert condition distribution of:

- Critical 32.7%
- Poor 11.4%
- Fair 14.4%
- Good 41.4%

This distribution, with nearly 3/4th of the culverts in one of the two extreme categories, raises questions about the adequacy of the current subjective overall condition assessment. It is possible that this is the true distribution, but additional analysis of the assessment methodology is probably appropriate.

The purpose of this research project was to inform and facilitate the development of a Drainage Facility Management System for the Oregon Department of Transportation along with procedures for collecting the data to populate the system. This report summarizes what was done and learned through this research project. The DMFS has continued to be developed since this research was completed. Likewise the data collection procedures have continued to be refined.

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APPENDIX A:
CULVERT INSPECTOR SURVEY GUIDELINES
AS USED IN THE PILOT PROJECT

PURPOSE: The purpose of this guideline is to provide procedures for gathering existing culvert condition and geometric information for the culvert inventory program.

Locating culverts:

1. Office research: The Digital Video Log and Highway Reports should be researched to locate known culverts before going to the field. Print the Highway Inventory Summary for the section of highway to be surveyed today/this week.

Other possible sources: Bridge maintenance records (12" in diameter or larger), Bridge Log, discussion of local culverts with the highway maintenance supervisor responsible for the area.

2. Depending on terrain and shoulder width, drive or walk on shoulder to locate culvert. Mark pavement edge with paint at each culvert.

3. Starting at one end of highway section, set DMI and drive on shoulder, slowing down at each paint mark to record the mile point. Be as accurate as possible. You can also fill out most of the Location section of the Culvert Inspection Form at this time.

3a. *Getting accurate mile points:* To set the DMI, find a feature on the Highway Reports that is identifiable and nearby, i.e. an intersecting road or a culvert. A bridge is not necessarily a good starting point. Line up the truck with the chosen feature, start the DMI, drive to the marked culvert, and record the milepoint. The main thing here is to be consistent! If you start with the front wheel of the truck lined up with the starting feature, then record the milepoint when the front wheel of the truck is lined up with the culvert.

4. Again starting at one end of highway section, stop at each culvert to perform the inspection.

Culvert Inspection: Filling out the form

Open the Culvert Inventory Database, and start on the **Site Data** tab.
**Note: All measurements are in decimal feet, unless otherwise noted.

Before you get out of the vehicle:

Location:
1. At the very top of the form is the *Listed in ITIS* checkbox. If this culvert is listed on the ITIS Highway Reports, check this box.
2. The *Region*, *District*, and *County* fields are actually there for your benefit. It is not absolutely necessary to fill these out.
3. Fill out *Hwy ID*, *Milepoint*, *Roadway ID*, *Mileage Type*, and *Overlap Mileage Code* immediately with the help of the Highway Reports. You can also fill these out while you're locating the culverts.
4. If you have a GPS PDA that you can enter a culvert identifier and download the coordinates from, you can do this after you get back in the office. Make sure that the coordinates are matched to the correct culvert. If not, copy your GPS reading onto the form. You can use either *Northing*/*Easting* or *Latitude*/*Longitude*. The computer can calculate the other pair.

Mobility: These fields can be researched and entered when you get back to the office.

Inspection:
Fill out *Inspector ID* and *Inspection Date* fields. Never forget these!
The other fields can be entered when you get back to the office if necessary.

When you get out of the vehicle, take a look around:

Look for defects in the roadway and embankment in the vicinity of the culvert.

Culvert Details:
Note: You may not be able to see all of these features from the road. If so, you will need to wait until you go down the embankment to fill these fields out.

Structure Width is the width of the entire culvert structure. In some cases, this is simply the width of a barrel, or it could span multiple barrels and the wingwalls. You can measure this now, or when you are measuring the *Barrel Span* and *Barrel Rise.*
# of Barrels is self-explanatory.
Facility Usage is the type of passage, i.e. what passes through this culvert?
Inlet/Outlet Bank Materials is the type of material for protection against scour, directly surrounding the culvert.
The rest of these fields can be researched and entered when you get back to the office.

Culvert Features:
Note: You may not be able to see all of these features from the road. If so, you will need to wait until you go down the embankment to fill these fields out.

Inlet Side is the side of the road the inlet is on, when facing the direction of increasing mileage.
Orientation is the location of the culvert with respect to the roadway; i.e. crossing, approach right, approach left.
Skew (degrees) is the angle between a line perpendicular to the roadway and the centerline of the culvert.
Confined Space indicates whether the culvert is a confined space by OSHA definitions.
Tidal Influence indicates whether the culvert is within reach of ocean tides.
Inlet End Treatment lists the end treatment on the inlet side of the culvert.
Outlet End Treatment lists the end treatment on the outlet side of the culvert.

Roadway Ratings:
Take a look at the roadway, and enter ratings for *Guardrail Dip, Pvmt Cracks/Patches,* and *Roadway Sag.* For a description of each of these fields, see the Ratings Criteria below.
Enter a yes or no for *Right Curb* and *Left Curb* when you are facing the direction of increasing mileage.

Going down the embankments:

Look for defects in the roadway and embankment in the vicinity of the culvert.

Embankment Ratings:
Take a look down the embankments, and enter ratings for *Emb Pop Outs, Emb Seeps, Emb Erosion, Emb Vegetation* and *Deformed Trees.* For a description of each of these fields, see the Ratings Criteria below.

Hydraulic Ratings:
Go down to the culvert, and enter ratings for *Bank Protection, Channel Scour, Head/Wingwall Damage, Misaligned with Channel,* and *High Water Mark.* For a description of each of these fields, see the Ratings Criteria below.

Stream Data:
Stream Name is the name of the stream passing through the culvert, if applicable. This may be filled out in the office if necessary.
Beaver Activity indicates whether there are signs of beaver activity near the culvert.
Pollution Tie-In Risk rates the potential risk of a pollution spill entering the waterway near the culvert.

Fish Passage:
Enter the type of features installed to facilitate fish passage. These may be located inside the culvert or in the streambed near the culvert. There may be multiple features in the streambed; there are two fields to accommodate them.

Looking into the culvert:

After filling out the **Site Data** tab, switch to the **Barrel Info** tab and fill out the following data:

Information:
Most culverts will only have one barrel, in which case the *Barrel ID* will be "A." When a culvert has multiple barrels, assign the *Barrel ID* alphabetically in direction of increasing mileage. In other words, when walking in the direction of increasing mileage, the first barrel you come to is "A," the second is "B," the third is "C," and so on.
Barrel Span is the horizontal diameter of the interior of the barrel, in inches.
Barrel Rise is the vertical diameter of the interior of the barrel, in inches.
Barrel Length is the full length of the barrel, and is usually calculated from the Profile Measurements.
Barrel Slope is the slope of the barrel, and is usually calculated from the Profile Measurements.
Barrel Shape is self-explanatory; choose an option from the drop-down list.
Barrel Material is self-explanatory; choose an option from the drop-down list.
Type of Rehab is the type of the most recent rehabilitation of this culvert, if applicable.
Date of Rehab is the date of the most recent rehabilitation of this culvert, if applicable.
Coating is the factory coating applied to the barrel at the time of manufacturing, if applicable.
Lining 1 is the original lining applied to the barrel, if applicable.
Lining 2 is the secondary lining applied to the barrel, if applicable.

Ratings:
Look inside each barrel, and enter ratings for *Abrasion, General Barrel Damage, Blockage, Cracking, Invert Damage, Open Joints, Out of Round, Settlement, Piping Damage, Drift,* and *Vegetation Obstruction.* For a description of each of these fields, see the Ratings Criteria below.
Measure the *Sediment Depth* within the barrel inlet and outlet, in inches.
Maintenance Cost Est is the estimated cost of routine maintenance on this barrel.
Maintenance Comments is self-explanatory.

Measuring the cross-section:

After filling out the **Barrel Info** tab, switch to the **Profile Measurements** tab and fill out the following data:

Outlet: These are measured on the outlet side of the road.
Emb Top Elevation is the elevation of the edge of roadway. This may be an arbitrary datum.
Emb Height is the vertical height measured from the edge of roadway to the top of the barrel.
Emb Horiz Length is the horizontal distance measured from the edge of roadway to the top of the barrel where it exits the embankment.
Emb Slope Length is the length along the embankment slope measured from the edge of roadway to the top of the barrel where it exits the embankment.
Emb Slope Angle is the angle measured between horizontal and slope of embankment, in degrees.
Culvert Extension is the length of barrel extending out of the embankment.
Road to Toe Height is the vertical height measured from the edge of roadway to toe of slope.
Total Emb Height is the vertical height measured from the edge of roadway to the point where the slope ends.

Inlet: These are measured on the inlet side of the road. (Except for *Emb Top Width*)
Emb Top Elevation is the elevation of the edge of roadway. This may be an arbitrary datum.
Emb Height is the vertical height measured from the edge of roadway to the top of the barrel.
Emb Horiz Length is the horizontal distance measured from the edge of roadway to the top of the barrel where it exits the embankment.
Emb Slope Length is the length along the embankment slope measured from the edge of roadway to the top of the barrel where it exits the embankment.
Emb Slope Angle is the angle measured between horizontal and slope of embankment, in degrees.
Culvert Extension is the length of barrel extending out of the embankment.
Emb Top Width is the total width of the top of the embankment measured along the culvert centerline from the edge of roadway on the outlet side to the edge of roadway on the inlet side.

**Note: Regarding the fields *Emb Height*, *Emb Horiz Length*, *Emb Slope Length*, and *Emb Slope Angle,* it is only necessary to measure two of these on each side of the roadway. With any two of these measurements, you can calculate the other two.

Taking photos of the culvert site:

Take the following pictures with a digital camera. Make sure you keep track of the order of the photos, so that you can name them properly after they're downloaded from the camera. When you rename the photos, follow the naming convention HwyXXmpYY.YYA with "A" denoting photo identity. "XX" is the ODOT Hwy Number, and "YY.YY" is the milepoint. We found it was easiest to take the pictures in the following order:

MP Picture of whiteboard w/hwy & mp on it
A Roadway, looking toward increasing mp
B Roadway, looking toward decreasing mp
E Inlet end

F Inlet, from side
J Inlet, up embankment
M Inlet, upstream
H Inlet, down embankment
C Outlet end
D Outlet, from side
I Outlet, up embankment
L Outlet, downstream
G Outlet, down embankment
K (Optional) Embankment problems

A full description of each photo is in the table at the bottom of this document.

Ratings Criteria:

4=GOOD 3=FAIR 2=POOR 1=CRITICAL

OUTSIDE THE BARREL:

<u>GUARDRAIL DIPS</u>

4 = MINOR MISALIGNMENT OF POSTS.

3 = SIGNIFICANT MISALIGNMENT OF POSTS.

2 = MAJOR MISALIGNMENT OF SEVERAL POSTS IN A ROW.

1 = SEVERE MISALIGNMENT OF MANY POSTS.

<u>PAVEMENT CRACKS/PATCHES</u>

4 = HAIRLINE CRACKS

3 = MINOR CRACKING

2 = LARGE CRACKS, BROKEN PAVEMENT WITH SETTLEMENT. SMALL POTHOLES FORMED.

1 = SIGNIFICANT PAVEMENT SETTLEMENT/CRACKING. LARGE POTHOLES HAVE FORMED.

<u>ROADWAY SAG</u>

4 = MINOR LOCALIZED SETTLEMENT.

3 = SIGNIFICANT LOCALIZED SETTLEMENT.

2 = MAJOR SETTLEMENT ACROSS THE ROADWAY.

1 = SEVERE SETTLEMENT ACROSS THE ROADWAY.

<u>EMBANKMENT POP OUTS</u>

4 = ROADWAY EMBANKMENT HAS NO DEPRESSIONS.

3 = ROADWAY EMBANKMENT HAS ONLY SMALL DEPRESSIONS FORMED.

2 = ROADWAY EMBANKMENT HAS SOME EVIDENCE OF DEPRESSIONS AND/OR SLUMPS BEING FORMED.

1 = ROADWAY EMBANKMENT HAS LARGE DEPRESSIONS AND/OR SLUMPS FORMED.

EMBANKMENT SEEPS

4 = ROADWAY EMBANKMENT HAS NO VISIBLE MOIST AREAS ON THE SURFACE.

3 = ROADWAY EMBANKMENT HAS MOIST AREAS ON THE SURFACE.

2 = ROADWAY EMBANKMENT HAS VISIBLE WATER FLOWING OUT OF THE FILL ONTO THE SURFACE.

1 = ROADWAY EMBANKMENT HAS VISIBLE WATER FLOWING OUT OF THE FILL ONTO THE SURFACE ASSOCIATED WITH LARGE DEPRESSIONS.

EMBANKMENT EROSION

4 = NO EROSION IS EVIDENT ON EMBANKMENT. EMBANKMENT HAS HEALTHY VEGETATION ON IT.

3 = SOIL WASH IS EVIDENT ON EMBANKMENT. SOIL WASH IS WHEN THE SOIL ON UN-VEGETATED AREAS OF THE EMBANKMENT IS RELATIVELY SMOOTH AND HAS FORMED A HARD CRUST.

2 = RILLS HAVE FORMED ON EMBANKMENT. RILLS ARE SMALL, WELL-DEFINED CHANNELS A FEW INCHES DEEP.

1 = GULLIES HAVE FORMED ON EMBANKMENT. GULLIES ARE BASICALLY LARGE TO VERY LARGE RILLS.

EMBANKMENT VEGETATION

4 = EMBANKMENT SLOPES ARE WELL VEGETATED WITH MINOR STEEPENING AT TOE.

3 = EMBANKMENT SLOPES ARE SPARSELY VEGETATED WITH SOME STEEPENING AT TOE.

2 = EMBANKMENT SLOPES ARE VERY SPARSELY VEGETATED WITH MAJOR STEEPENING AT TOE.

1 = EMBANKMENT SLOPES ARE NOT VEGETATED WITH SLOPES NEAR VERTICAL AT TOE.

DEFORMED TREES ON SLOPES

4 = A FEW TREES BENT WITH AN ANGLE BETWEEN VERTICAL AND THE TRUNK CLOSEST TO THE GROUND 15 DEGREES OR LESS.

3 = A FEW TREES BENT WITH AN ANGLE BETWEEN VERTICAL AND THE TRUNK CLOSEST TO THE GROUND BETWEEN 15-30 DEGREES.

2 = SEVERAL TREES BENT WITH AN ANGLE BETWEEN VERTICAL AND THE TRUCK CLOSEST TO THE GROUND BETWEEN 30-45 DEGREES.

1 = SEVERAL TREES BENT WITH AN ANGLE BETWEEN VERTICAL AND THE TRUNK CLOSEST TO THE GROUND 45 DEGREES OR MORE.

BANK EROSION - INLET/OUTLET

4 = EMBANKMENT DIRECTLY SURROUNDING THE CULVERT SHOWS NO SIGN OF EROSION.

3 = EMBANKMENT DIRECTLY SURROUNDING THE CULVERT HAS MINOR EROSION.

2 = EMBANKMENT DIRECTLY SURROUNDING THE CULVERT HAS SIGNIFICANT EROSION PROBLEMS.

1 = EMBANKMENT DIRECTLY SURROUNDING THE CULVERT HAS LARGE AREAS OF SEVERE EROSION.

CHANNEL SCOUR - INLET/OUTLET

4 = RATIO OF CULVERT DIAMETER TO MAXIMUM SCOUR HOLE DEPTH IS GREATER THAN 10.

3 = RATIO OF CULVERT DIAMETER TO MAXIMUM SCOUR HOLE DEPTH IS 5 TO10.

2 = RATIO OF CULVERT DIAMETER TO MAXIMUM SCOUR HOLE DEPTH IS 2 TO 5.

1 = RATIO OF CULVERT DIAMETER TO MAXIMUM SCOUR HOLE DEPTH IS LESS THAN 2.

HEADWALL/WINGWALL DAMAGE

4 = MINOR CRACKING, MINOR SPALLING, NO OFFSETS, NO CHANGES IN VERTICAL OR HORIZONTAL ALIGNMENT.

3 = MINOR SETTLEMENT, SMALL OFFSETS, SMALL CHANGES IN VERTICAL OR HORIZONTAL ALIGNMENT.

2 = LARGE CRACKS, SIGNIFICANT SETTLEMENT, LARGE OFFSETS, OBVIOUS CHANGES IN VERTICAL OR HORIZONTAL ALIGNMENT.

1 = MAJOR CRACKING, OPEN JOINTS, SECTIONS MISSING, MAJOR CHANGES IN VERTICAL OR HORIZONTAL ALIGNMENT.

MISALIGNED WITH CHANNEL

4 = ANGLE MEASURED FROM UPSTREAM CHANNEL TO CENTERLINE OF CULVERT BARREL IS FROM 0 TO 15 DEGREES.

3 = ANGLE MEASURED FROM UPSTREAM CHANNEL TO CENTERLINE OF CULVERT BARREL IS FROM 15 TO 45 DEGREES.

2 = ANGLE MEASURED FROM UPSTREAM CHANNEL TO CENTERLINE OF CULVERT BARREL IS FROM 45 TO 90 DEGREES.

1 = ANGLE MEASURED FROM UPSTREAM CHANNEL TO CENTERLINE OF CULVERT BARREL IS LARGER THAN 90 DEGREES.

HIGH WATER MARK

4 = WATER MARKS NOT FOUND OR FOUND MORE THAN 5’ BELOW ROADWAY

3 = WATER MARKS WITHIN 5’ OF ROADWAY.

2 = WATER MARKS WITHIN 2’ OF ROADWAY.

1 = WATER MARKS SHOW ROADWAY OVERTOPPED.

INSIDE THE BARREL:

ABRASION: DON’T WORRY ABOUT THIS ONE.

GENERAL BARREL DAMAGE

4 = ONLY MINOR RUSTING OR SCALING IN BARREL.

3 = SIGNIFICANT RUSTING, NO HOLES OR DISTORTION.

2 = MAJOR DETERIORATION WITH LOSS OF SECTION AND HOLES DEVELOPING, GENERAL MAJOR SETTLEMENT OR DISTORTION.

1 = LOSS OF BARREL MATERIAL, LARGE HOLES DEVELOPED, SECTIONS MAY BE MISSING, SEVERE DISTORTION OR SETTLEMENT.

BLOCKAGE

4 = CULVERT BARREL IS BLOCKED FROM 0% TO 25% OF THE CROSS-SECTIONAL AREA AT THE WORST SECTION.

3 = CULVERT BARREL IS BLOCKED FROM 25% TO 50% OF THE CROSS-SECTIONAL AREA AT THE WORST SECTION.

2 = CULVERT BARREL IS BLOCKED FROM 50% TO 75% OF THE CROSS-SECTIONAL AREA AT THE WORST SECTION.

1 = CULVERT BARREL IS BLOCKED MORE THAN 75% OF THE CROSS-SECTIONAL AREA AT THE WORST SECTION.

CRACKING

4 = MINOR CRACKING, SPALLING, OR PITTING IS PRESENT.

3 = SIGNIFICANT LOCALIZED CRACKING, SPALLING, OR PITTING.

2 = MAJOR CRACKING THROUGHOUT BARREL, SPALLING, AND PITTING.

1 = SEVERE CRACKING, OFFSETS, LARGE HOLES IN BARREL, BARREL SECTIONS MISSING.

INVERT DAMAGE

4 = ONLY MINOR RUSTING OR SCALING.

3 = SIGNIFICANT RUSTING, NO HOLES OR DISTORTION.

2 = MAJOR DETERIORATION WITH LOSS OF SECTION AND HOLES DEVELOPING

1 = LOSS OF INVERT MATERIAL, HOLES DEVELOPED, BUCKLING OF CULVERT MATERIAL IN INVERT, PIPING OF EMBANKMENT MATERIAL OUT OF CULVERT.

OPEN JOINTS

4 = JOINTS AND SEAMS ARE TIGHT WITH NO OPENINGS

3 = MINOR OPENINGS - NO SIGNS OF INFILTRATION

2 = LARGER OPENINGS WITH SIGNS OF INFILTRATION

1 = LARGE OPENINGS, OFFSETS, VOIDS FORMING IN EMBANKMENT OUTSIDE OF CULVERT BARREL.

OUT OF ROUND

STEEL

4 = UP TO 5% CHANGE IN SPECIFIED DIMENSIONS

3 = FROM 5% TO 10% CHANGE IN SPECIFIED DIMENSIONS

2 = FROM 10% TO 20% CHANGE IN SPECIFIED DIMENSIONS

1 = MORE THAN 20% CHANGE IN SPECIFIED DIMENSIONS

CONCRETE

4 = UP TO 1% CHANGE IN SPECIFIED DIMENSIONS

3 = FROM 1% TO 5% CHANGE IN SPECIFIED DIMENSIONS

2 = FROM 5% TO 10% CHANGE IN SPECIFIED DIMENSIONS

1 = MORE THAN 10% CHANGE IN SPECIFIED DIMENSIONS

SETTLEMENT

4 = ALIGNMENT OF THE BARREL IS UNIFORM THROUGHOUT THE BARREL.

3 = ALIGNMENT HAS ONLY MINOR LOCALIZED DEFLECTIONS IN THE BARREL.

2 = ALIGNMENT HAS SIGNIFICANT DEFLECTIONS THROUGHOUT THE BARREL

1 = ALIGNMENT HAS SEVERE DEFLECTIONS THROUGHOUT THE BARREL

PIPING DAMAGE

4 = NO SIGNS OF FLOW THROUGH EMBANKMENT ON OUTSIDE OF BARREL

3 = EMBANKMENT MOIST ONLY IN AREAS SURROUNDING BARREL. NO EVIDENCE OF FLOW OR SEDIMENT TRANSPORT OBSERVED.

2 = SEEPAGE THOUGH EMBANKMENT, MOIST SOILS OBSERVED OUTSIDE OF BARREL, SEDIMENT TRANSPORT NOT OBSERVED.

1 = EVIDENCE OF FLOW THOUGH EMBANKMENT ALONG OUTSIDE OF BARREL. EVIDENCE OF SEDIMENT TRANSPORT OBSERVED.

DRIFT

4 = DRIFT FILLS CULVERT BARREL FROM 0% TO 25% OF THE CROSS-SECTIONAL AREA AT THE WORST SECTION.

3 = DRIFT FILLS CULVERT BARREL FROM 25% TO 50% OF THE CROSS-SECTIONAL AREA AT THE WORST SECTION.

2 = DRIFT FILLS CULVERT BARREL FROM 50% TO 75% OF THE CROSS-SECTIONAL AREA AT THE WORST SECTION.

1 = DRIFT FILLS CULVERT BARREL MORE THAN 75% OF THE CROSS-SECTIONAL AREA AT THE WORST SECTION.

VEGETATION OBSTRUCTION

4 = CULVERT FLOW IS RESTRICTED BY VEGETATION 0% TO 25% OF THE CROSS-SECTIONAL AREA AT THE WORST SECTION.

3 = CULVERT FLOW IS RESTRICTED BY VEGETATION 25% TO 50% OF THE CROSS-SECTIONAL AREA AT THE WORST SECTION.

2 = CULVERT FLOW IS RESTRICTED BY VEGETATION 50% TO 75% OF THE CROSS-SECTIONAL AREA AT THE WORST SECTION.

1 = CULVERT FLOW IS RESTRICTED BY VEGETATION MORE THAN 75% OF THE CROSS-SECTIONAL AREA AT THE WORST SECTION.

Photo Description Table

MP	Picture of whiteboard w/hwy & mp on it	Write the highway number and milepoint of the culvert on a small whiteboard, and take a picture of it. Used only for organizing and processing field photos.
A	Roadway, looking toward increasing mp	On the inlet side of the road, walk 50-100 feet from the culvert in the direction of decreasing mile-points, turn around, stand on fog line/shoulder, facing the direction of increasing mile-points. Take a picture of the roadway.
B	Roadway, looking toward decreasing mp	On the inlet side of the road, walk 50-100 feet from the culvert in the direction of increasing mile-points, turn around, and stand on fog line / shoulder, facing the direction of decreasing mile-points. Take a picture of the roadway.
C	Outlet end	Stand downstream of the outlet on the culvert centerline and face the outlet. Take a picture of the outlet opening
D	Outlet, from the side	Stand to the side of the outlet and face the outlet. Take a picture of the outlet opening.
E	Inlet end	Stand upstream of the inlet on the culvert centerline and face the inlet. Take a picture of the inlet opening.
F	Inlet, from side	Stand to the side of the inlet and face the inlet. Take a picture of the inlet opening.
G	Outlet, down embankment	Stand at the edge of the roadway above the outlet, and face the outlet. Take a picture of the embankment between the roadway and the outlet.
H	Inlet, down embankment	Stand at the edge of the roadway above the inlet, and face the inlet. Take a picture of the embankment between the roadway and the inlet.
I	Outlet, up embankment	Stand downstream of the outlet on the culvert centerline and face the outlet. Take a picture of the embankment between the outlet and the roadway.
J	Inlet, up embankment	Stand upstream of the inlet on the culvert centerline and face the inlet. Take a picture of the embankment between the inlet and the roadway.
L	Outlet, downstream	Stand near the outlet and face the stream channel that exists the culvert. Take a picture of the downstream area.
M	Inlet, upstream	Stand near the inlet and face the stream channel that enters the culvert. Take a picture of the upstream area.
K	(Optional) Major Problems	(Optional) Take a picture of any major roadway, embankment or culvert problems.

CULVERT INSPECTION FORM

Hwy No.	Route No.	M.P.	Latitude	Longitude	County	District	Region

Culvert No.	Position (Lt, Rt, Cross)	Skew (Degrees)	Span (in)	Rise (in)	Length (ft)	Slope (%)

Shape (Select one)	Material (Select one)	Lining (Select one)	End Type (each end)
Circular ☐	Concrete ☐	None ☐	Projecting ☐ I=inlet
Box ☐	Steel ☐	CMP ☐	Groove Projecting ☐ O=outlet
Arch ☐	Plastic ☐	Invert Paving ☐	Mitered to Slope ☐
Elliptical ☐	Aluminum ☐	Plastic ☐	Headwall ☐
	Timber ☐	CIPP ☐	Safety Grate ☐
	Masonry ☐	Tunnel liner ☐	Trash Rack ☐
	Ductile Iron ☐	Concrete ☐	
		Asphalt ☐	
Other:	Other:	Other:	Other:

(4 = Good for many years, 1 = Needs immediate attention)

Roadway over pipe	**Field Name**	**Rating**	**Remarks**
Pavement cracks or patches	PvmtCksPch		
Drainage curb present? (yes or no)	DrainCbLt DrainCbRt		
Guardrail dips	GuardRlDip		
Sags in roadway	RoadwaySag		
Recent signs of high water	RecentHgWt		
Erosion of side slopes and/or toe of slope	SSlopeEros		
Seeps or popouts	Seep_PopOt		
Deformed trees on slope?	TreeSlope		

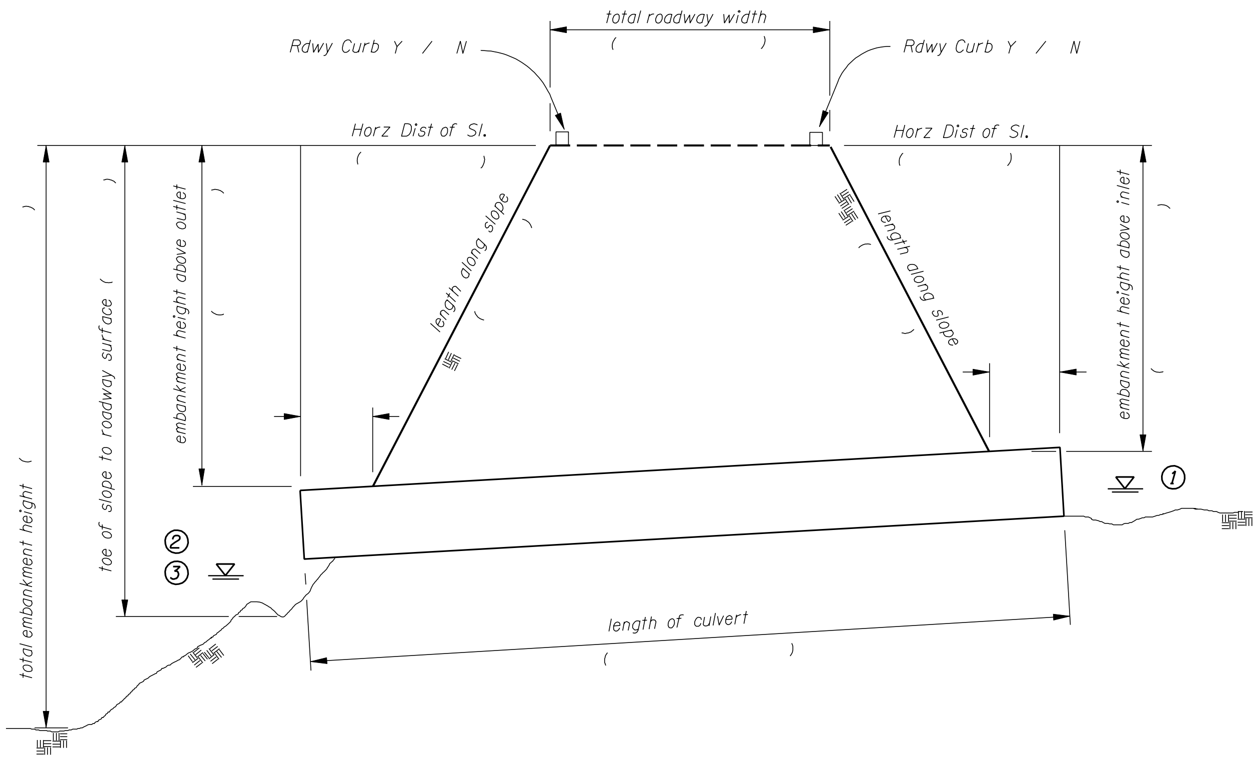
Channel and Channel Protection	**Field Name**	**Rating**	**Remarks**
Channel scour at inlet and/or outlet	ScourIn_Ot		
Bank protection at inlet Bank protection at outlet	InBankProt OtBankProt		
Channel embankment erosion	EmbankEros		
Recent high water above crown	HgWtrAbCr n		
Misalignment with channel	ChMisalign		
Drift	Drift		
Vegetation	Vegetation		

Culvert Barrel	**Field Name**	**Rating**	**Remarks**
General barrel damaged	BarrelDamg		
Invert damaged	InvertDmg		
Open joints	OpenJoints		
Piping occurring – damage found	Piping		
Out-of-round	OutOfRound		
Headwall &/or Wingwall damage	WallDamage		
Settlement	Settlement		
Blockage	Blockage		
Cracking	Cracking		
Silt (record depth of material found in barrel)	Silt		SiltDepth =
OVERALL CONDITION of culvert	OverallCon		

Measurements	Field Name	Rating	Remarks
Total roadway width (ft)	RdWidth		
Embankment height above inlet (ft)	EmbakHgtIn		
Horizontal distance edge roadway to toe of slope at inlet (ft)	HorzDistIn		
Distance culvert extends beyond inlet slope (ft)	HzCulExtIn		
Distance along embankment slope from roadway to toe at inlet (ft)	EmbSlLgIn		
Measured angle from horizontal to inlet embankment slope	EmbSlAngIn		
Embankment height above outlet (ft)	EmbakHgtOt		
Horizontal distance edge roadway to toe of slope at outlet (ft)	HorzDistOt		
Distance culvert extends beyond outlet slope (ft)	HzCulExtOt		
Distance along embankment slope from roadway to toe at outlet (ft)	EmbSlLgOt		
Measured angle from horizontal to outlet embankment slope (ft)	EmbSlAngOt		
Toe of slope to roadway surface at outlet (ft)	RdToToeOt		
Total height of embankment at outlet	TlEmbHgtOt		
Were fish observed? (yes or no){Adult/Juvenile}	FishObserv		
Depth of water at barrel inlet (in)	WaterDptIn		
Depth of water at barrel outlet (in)	WaterDptOt		
Distance outlet invert to water surface (in)	DptToPlOt		

Inspected by: _____________________________________ Date: ___________ Telephone number: __________________

Additional comments or recommendations:



① Depth Of Water At Barrel Inlet (in)

② Depth Of Water At Barrel Outlet (in)

③ Dist. From Outlet Invert To Extg W.S. (in)

Please take pictures in this order. Thx.

MP	Picture of whiteboard w/hwy & mp on it
A	Roadway, looking toward increasing mp
B	Roadway, looking toward decreasing mp
C	Inlet end
D	Inlet, from side
E	Inlet, up embankment
F	Inlet, upstream
G	Inlet, down embankment
H	Outlet end
I	Outlet, from side
J	Outlet, up embankment
K	Outlet, downstream
L	Outlet, down embankment
M	(Optional) Embankment problems

CULVERT INSPECTION FORM

WITH FISH PASSAGE INSPECTION

Hwy No.	Route No.	M.P.	Latitude	Longitude	County	District	Region

Culvert No.	Position (Lt, Rt, Cross)	Skew (Degrees)	Span (in)	Rise (in)	Length (ft)	Slope (%)

HUC#	Stream Name	Sub-Basin	Basin	River Mile

Culvert Shape (Shape)	Culvert Material (Material)	Culvert Lining (Lining)	Culvert End Type (InEndType/OtEndType) I=inlet O=outlet
Arch ☐	Aluminum ☐	Asphalt ☐	Projecting ☐
Box ☐	Concrete ☐	Invert paving ☐	Mitered to slope ☐
Circular ☐	Plastic ☐	Concrete ☐	Headwall ☐
Elliptical ☐	Steel ☐	Plastic ☐	Trash rack ☐
	Timber ☐	CIPP ☐	Square/ hdwall ☐
		Tunnel liner ☐	Groove /hdwall ☐
		CMP ☐	Groove projecting ☐
			Safety grate ☐
Other:	Other:	Other:	Other:

Streambed Material (StrbdMatIn/StrbdMatOt) I=inlet O=outlet	Fish Passage Features (FPassFeat)	Stream Unit Type (StrUnitTyp)	Land Formation (LandForm)
Silt ☐	Baffles ☐	Meadow Trench ☐	Hill Slope ☐
Sand ☐	Fish Rocks ☐	Braided ☐	High Terrace ☐
Gravel ☐	Roughened Chute ☐	Pool Riffle ☐	Low Terrace ☐
Cobbles ☐	Weirs ☐	Pool Step ☐	Alluvial Fan ☐
Boulders ☐	Spillway ☐	Cascade ☐	Flood Plain ☐
	Fish Ladder ☐	Colluvial Debris ☐	Road Fill (rip ☐
		Bedrock ☐	Wetlands- ☐
			Bedrock ☐
Other:	Other:	Other:	Other:

Rating: 4 = Good for many years, 1 = Needs immediate attention

Roadway over pipe	**Field Name**	**Rating**	**Remarks**
Pavement cracks or patches	PvmtCksPch		
Drainage curb present? Yes/No	DrainCurb		{If yes: Left/Right/Both}
Guardrail dips	GuardRlDip		
Sags in roadway	RoadwaySag		
Recent signs of high water	RecentHgWt		
Erosion of side slopes and/or toe of slope	SSlopeEros		
Seeps or popouts	Seep_PopOt		
Deformed trees on slope	TreeSlope		

Watershed Data	**Field Name**	**Remarks**
Habitat Miles Upstream	HabMiUpstr	
Canopy Cover (%)	CanopyCovr	
Wetland Vegetation Present? Yes/No	WetlandVeg	
Beaver Activity Observed? Yes/No	BvrActObs	
Fish Observed? Yes/No	FishObserv	{If yes: Adult/Juvenile}
Large Woody Debris near inlet/outlet? Yes/No	LgWoodDebr	{If yes: Inlet/Outlet/Both}
Tributary Junction near inlet/outlet? Yes/No	TribJunct	{If yes: Inlet/Outlet/Both}

Channel & Channel Protection	Field Name	Rating	Remarks
Channel scour at inlet and/or outlet	ScourIn_Ot		
Bank protection at inlet	InBankProt		
Bank protection at outlet	OtBankProt		
Embankment erosion	EmbankEros		
Recent high water above crown	HgWtrAbCrn		
Misalignment with channel	ChMisalign		
Drift	Drift		
Vegetation	Vegetation		

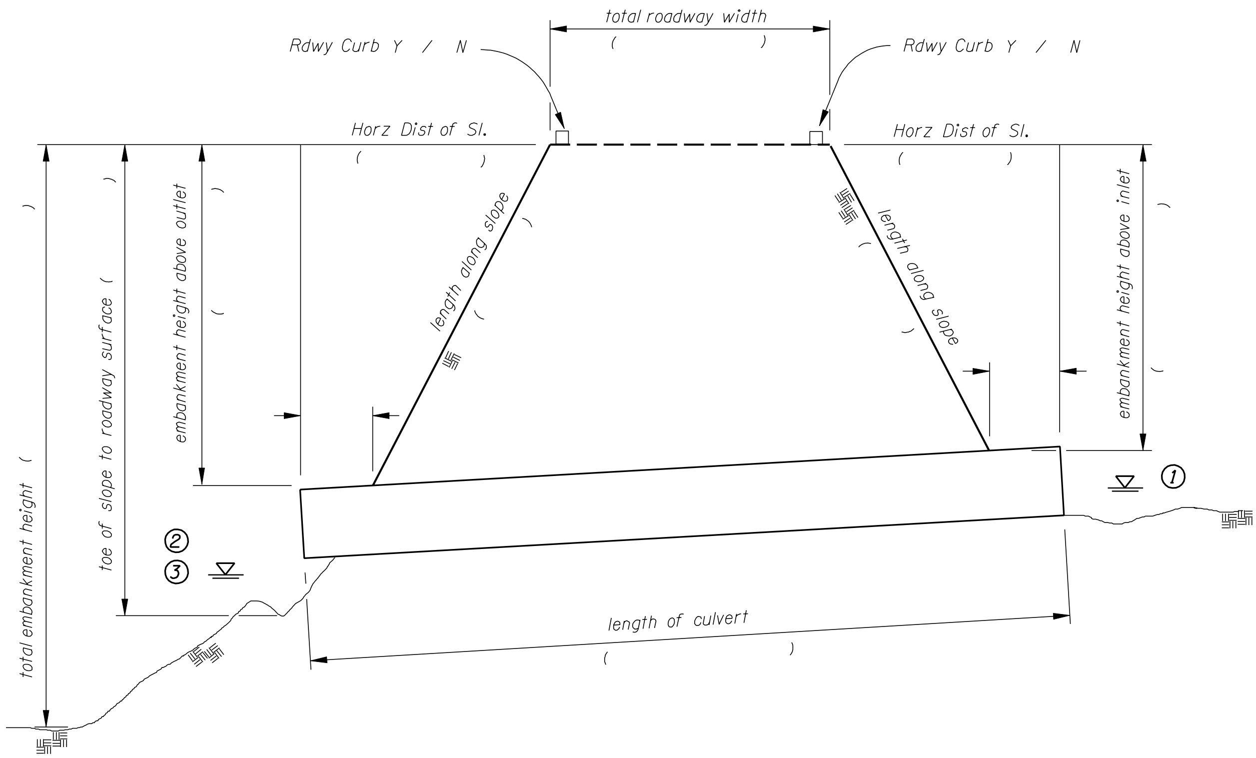
Culvert Barrel Conditions	Field Name	Rating	Remarks
General barrel damaged	BarrelDamg		
Invert damaged	InvertDmg		
Open joints	OpenJoints		
Piping occurring – damage found	Piping		
Out-of-round	OutOfRound		
Headwall &/or Wingwall damage	WallDamage		
Settlement	Settlement		
Blockage	Blockage		
Cracking	Cracking		
Silt (record depth of material found in barrel) (in)	Silt		
OVERALL CONDITION of culvert structure	OvCondCulv		

Flow Conditions & Water Quality	Field Name	Rating	Remarks
Influenced by Tides? Yes/No	TidalInf		
Influenced by River Backwater? Yes/No	BkwaterInf		
Avg Ordinary high water Width of stream (ft)	AvOrdHWWid		
Depth of water at barrel inlet (in)	WaterDptIn		
Average maximum depth of Inlet pool (in)	AvMaxDptIn		
Depth of water at barrel outlet (in)	WaterDptOt		
Average maximum depth of Outlet pool (in)	AvMaxDptOt		
Distance outlet invert to water surface (in)	DptToPlOt		
Flow Velocity at outlet (ft/s) 0-4 = Low 4-8 = Medium 8+ = High	FlowVeloOt		
Water pH	WaterpH		
Water Temperature (°C)	WaterTemp		
Water Conductivity (S/cm)	WaterCond		
OVERALL CONDITION of fish passage	OvCondFish		

Profile Measurements	Field Name	Rating	Remarks
Total roadway width (ft)	RdWidth		
Embankment height above inlet (ft)	EmbakHgtIn		
Horizontal distance edge roadway to toe of slope at inlet (ft)	HorzDistIn		
Distance culvert extends beyond inlet slope (ft)	HzCulExtIn		
Distance along embankment slope from roadway to toe at inlet (ft)	EmbSlLgIn		
Measured angle from horizontal to inlet embankment slope	EmbSlAngIn		
Embankment height above outlet (ft)	EmbakHgtOt		
Horizontal distance edge roadway to toe of slope at outlet (ft)	HorzDistOt		
Distance culvert extends beyond outlet slope (ft)	HzCulExtOt		
Distance along embankment slope from roadway to toe at outlet (ft)	EmbSlLgOt		
Measured angle from horizontal to outlet embankment slope (ft)	EmbSlAngOt		
Toe of slope to roadway surface at outlet (ft)	RdToToeOt		
Total height of embankment at outlet	TlEmbHgtOt		

Inspected by: ____ Date: ____________ Telephone number: ___________________

Additional comments or recommendations:



1 Depth Of Water At Barrel Inlet (in)

2 Depth Of Water At Barrel Outlet (in)

3 Dist. From Outlet Invert To Extg W.S. (in)

Please take pictures in this order. Thx.

MP	Picture of whiteboard w/hwy & mp on it
A	Roadway, looking toward increasing mp
B	Roadway, looking toward decreasing mp
C	Inlet end
D	Inlet, from side
E	Inlet, up embankment
F	Inlet, upstream
G	Inlet, down embankment
H	Outlet end
I	Outlet, from side
J	Outlet, up embankment
K	Outlet, downstream
L	Outlet, down embankment
M	(Optional) Embankment problems

APPENDIX B:
DATA FIELDS IDENTIFIED AS NEEDED BY DRAINAGE FACILITY MANAGEMENT SYSTEM RESEARCH PROJECT

Category	Data Field	Definition
Culvert Structure Data	Abrasion Rating	Based on the opportunity for wearing or grinding of the barrel material due to sediment or debris being dragged against the barrel (based on velocity, slope, and bedload)
Culvert Structure Data	Cracking Rating	Based on the size and extend of cracking in concrete
Culvert Structure Data	General Barrel Damage Rating	Based on condition criteria that are in turn dependent on the culvert material
Culvert Structure Data	Headwall &/or Wiingwall Damage	Was there any damage to the headwalls or wing walls
Culvert Structure Data	Invert Damage	Is the invert damaged in any way
Culvert Structure Data	Open Joints	Are there any open joints
Culvert Structure Data	Out-of-Round	Has the structure been deformed from its original or intended geometry
Culvert Structure Data	Pipe Condition Comments	Verbose comments about the condition of the pipe(s)
Culvert Structure Data	Pipe Condition Score	Computed condition rating based on the observations and ratings
Culvert Structure Data	Vegetation	Is the vegetation obstructing the inlet or outlet
Culvert Structure Data	Inlet Side Indicator	To which side is the culvert inlet as one faces the direction of increasing milepoint
Culvert Structure Data	Inlet Horizontal Culvert Extension Measured	What is the distance, measured at the culvert crown, from the embankment to the end of the culvert inlet.
Culvert Structure Data	Outlet Horizontal Culvert Extension Measured	What is the distance, measured at the culvert crown, from the embankment to the end of the culvert outlet.
Culvert Structure Data	Invert Elevation-Inlet	The elevation of the invert (bottom of the structure over which water passes) at the inlet (feet)
Culvert Structure Data	Invert Elevation-Outlet	The elevation of the invert (bottom of the structure over which water passes) at the outlet (feet)
Culvert Structure Data	Barrel ID	Some culverts are comprised of multiple barrels at the same location. This assigns an ID (i.e. "A." "B," etc.) to each barrel so that information specific to individual barrels can be stored
Culvert Structure Data	Coating	What, if any, coating or lining has been applied to the inside of the culvert (i.e. asphalt, plastic)
Culvert Structure Data	Confined Space	Does the structure include a confined space (Is there an OSHA definition of confined space?)
Culvert Structure Data	Culvert End Structure-Begin	Type of structure used on the beginning of the culvert
Culvert Structure Data	Culvert End Structure-End	Type of structure used on the end of the culvert
Culvert Structure Data	Historical	Is the structure historical. (unknown, no, yes but not of significance, yes and significant)
Culvert Structure Data	Culvert ID Number	Identifier of culvert
Culvert Structure Data	In ITIS	Is the structure an item in ITIS (if yes, then some data pulled from ITIS)
Culvert Structure Data	In BMS/NBI	Is the structure an item in the BMS/NBI (if yes then some data pulled from BMS/NBI)
Culvert Structure Data	Invert Surface	What does the invert surface consist of (i.e. is the bottom of the culvert a simulated stream bed, smooth concrete, wiered concrete etc.)
Culvert Structure Data	Material	What is the primary material the structure is built of
Culvert Structure Data	Misalignment with channel	Does the water have to significantly change direction to pass from the upstream channel into the structure or from the structure into the down stream channel
Culvert Structure Data	Number of Barrels/Spans	The number of openings in the structure which pass water.
Culvert Structure Data	Orientation / Position	Orientation of the culvert to the roadway (left side, crossing, etc)
Culvert Structure Data	Owner	Title holder or entity that owns the structure.
Culvert Structure Data	Rise	The vertical height dimension of a box, pipe arch, and arch structure. (inches)
Culvert Structure Data	Shape	What is the transverse cross sectional shape of the structure

Category	Data Field	Definition
Culvert Structure Data	Skew	The measure of the angle (degrees) of intersection between a line normal to the roadway centerline and the direction of the flow in a channel at flood stage in the lineal direction of the main channel. Negative if skewed to the left, Positive if skewed to the right.
Culvert Structure Data	Slope	the angle of the invert surface with respect to horizontal (rise/run%)
Culvert Structure Data	Span	the horizontal width dimension of such things as a box, pipe arch, or arch structure. May also be the horizontal distance between bridge piers or abutments. (inches)
Culvert Structure Data	Width	Width of the total culvert (sum of the barrel spans plus the space between them) (inches)
Culvert Structure Data	Length	Distance from inlet to outlet (feet)
Culvert Structure Data	Year Built	the year the drainage facility was finished or completed.
Culvert Structure Data	Previous V-Number(s)	Number(s) assigned for storage of construction documents that cover the location of this culvert
Culvert Structure Data	Most Recent V-Number	V-number of the most recent construction plans that cover the location of this culvert
Culvert Structure Data	Culvert Structure Comments	Verbose comments about any special issues regarding the structure
Culvert Structure Data	DoNotExportGIS	Do not export the data to GIS
Geotechnical Data	Deformed Tree Rating	Rating based on the degree and prevalence of deformation of trees growing on the embankment
Geotechnical Data	Embankment Vegetation	Description of vegetation, if any, growing on the embankment
Geotechnical Data	Embankment Pop-outs	Are there noticeable outward/downward displacements of parts of the embankment or topographic feature
Geotechnical Data	Embankment Seeps	Are there any seeps in the embankment or topographic feature
Geotechnical Data	Guardrail Dips	Was deformation of the guard rails observed
Geotechnical Data	Pavement Cracks or Patches	Were cracks or patches observed in the pavement
Geotechnical Data	Piping Damage	Has moving water removed any material from the embankment
Geotechnical Data	Sags in roadway	Had the roadway deviated from its original grade
Geotechnical Data	Settlement	Has the embankment settled
Geotechnical Data	Erosion of Side Slopes	Was there evidence of erosion of the side slopes of the roadway
Geotechnical Data	Embankment height above inlet	What is the elevation difference between the culvert crown at the inlet and the top of the embankment (feet)
Geotechnical Data	Embankment height above outlet	What is the elevation difference between the culvert crown at the outlet and the top of the embankment (feet)
Geotechnical Data	Slope angle--Inlet Embankment	What is the gross slope of the embankment or topographic feature around the inlet (rise/run%)
Geotechnical Data	Slope Angle--Outlet Embankment	What is the gross slope of the embankment or topographic feature around the outlet (rise/run%)
Geotechnical Data	Slope Length--Inlet Embankment	What is the length of the slope of the embankment or topographic feature. Minimum distance measured top to bottom along ground surface near the inlet (feet)
Geotechnical Data	Slope Length--Outlet Embankment	What is the length of the slope of the embankment or topographic feature. Minimum distance measured top to bottom along ground surface near the outlet (feet)
Geotechnical Data	Inlet Horizontal Distance Top to Crown Measured	The horizontal distance from the top of the embankment to the point where the embankment intersects the crown of the culvert inlet
Geotechnical Data	Outlet Horizontal Distance Top to Crown Measured	The horizontal distance from the top of the embankment to the point where the embankment intersects the crown of the culvert outlet
Geotechnical Data	Outlet Road to Toe Height Measured	The vertical distance from the edge of the road to the toe of the embankment on the outlet side.
Geotechnical Data	Total Embankment Height	Total distance from the bottom of the embankment to the crown of the road (feet)
Geotechnical Data	Soil pH	What is the pH of the soil which the structure is imbedded
Geotechnical Data	Soil Resistivity	What is the electrical resistivity of the soil in which the structure is imbedded

Category	Data Field	Definition
Geotechnical Data	Total Top Width of Embankment	What is the width of the embankment or topographic feature penetrated by the structure. Convex inflection point to convex inflection point (feet)
Geotechnical Data	Inlet Embankment Top Elevation Measured	The elevation of the top of the embankment on the inlet side
Geotechnical Data	Outlet Embankment Top Elevation Measured	The elevation of the top of the embankment on the outlet side
Geotechnical Data	Geotechnical comments	Verbose comments about the geotechnical conditions
Geotechnical Data	Geotechnical slope stability score	The computed rating of the geotechnical stability of the material surrounding the structure(System Calculated).
Hydraulics Data	Embankment Protection-Inlet	What, if any, bank protection is in place at the inlet to the structure
Hydraulics Data	Embankment Protection-Outlet	What, if any, bank protection is in place at the outlet from the structure
Hydraulics Data	Blockage Rating	Rating based on the degree to which the culvert was blocked by material inside the culvert
Hydraulics Data	Inlet Channel Scour Rating	Rating based on the degree to which the channel upstream of the inlet has been scoured down due to flow changes induced by the culvert
Hydraulics Data	Outlet Channel Scour Rating	Rating based on the degree to which the channel downstream of the outlet has been scoured down due to flow changes induced by the culvert
Hydraulics Data	Inlet Barrel Sediment Depth Measured	Depth of sediment deposited on the invert of the culvert barrel just inside the inlet
Hydraulics Data	Outlet Barrel Sediment Depth Measured	Depth of sediment deposited on the invert of the culvert barrel just inside the outlet
Hydraulics Data	Drift	How much debris is present within the barrel
Hydraulics Data	Recent high water above crown	Were there signs of water crossing the roadway
Hydraulics Data	Recent signs of high water	Were there signs of water recently having been high
Hydraulics Data	Stream Bank Erosion Rating	Based on the stream banks 100 feet upstream and downstream of the culvert
Hydraulics Data	Backwatered	Does the water level from the down stream water body extending back into the outlet
Hydraulics Data	Depth of Inlet Pool	Depth of water in the inlet pool (water outside the inlet of the structure, inches)
Hydraulics Data	Depth of Outlet Pool	Depth of water in the outlet pool (water outside the outlet of the structure, inches)
Hydraulics Data	Distance outlet invert to water surface	Distance from the bottom, interior surface of the structure (the invert) to the water surface immediately below the outlet (inches)
Hydraulics Data	Flow Depth at Barrel Inlet - Measured	The depth of water measured at the inlet to the structure (inches)
Hydraulics Data	Flow Depth at Barrel Outlet - Measured	The depth of water measured at the outlet of the structure (inches)
Hydraulics Data	Flow depth of water in inlet Channel thalweg	Depth of the water observed in the main flow part of the channel immediately upstream of the inlet to the structure (inches)
Hydraulics Data	Flow depth of water in outlet Channel thalweg	Depth of the water observed in the main flow part of the channel immediately upstream of the outlet to the structure (inches)
Hydraulics Data	Flow Velocity at Barrel Inlet - Measured	The velocity of the water measured at the inlet to the structure (feet/sec)
Hydraulics Data	Flow Velocity at Barrel Outlet - Measured	The velocity of the water measured at the outlet of the structure (feet/sec)
Hydraulics Data	Flow Velocity in Channel Thalweg - Measured Downstream	The velocity of water measured in the main part of the water body channel (below outlet, feet/second)
Hydraulics Data	Flow Velocity in Channel Thalweg - Measured Upstream	The velocity of water measured in the main part of the water body channel (above inlet, feet/second)

Category	Data Field	Definition
Hydraulics Data	High Flow 1 Discharge	The Q (discharge, cubic-feet/second) that the structure will be handling under "high flow 1" conditions (from the ODOT Hydraulics Manual)
Hydraulics Data	High flow 1 Depth - Computed	The depth of water computed for the structure when the handling the "high flow 1" discharge (from the ODOT Hydraulics Manual, inches)
Hydraulics Data	High Flow 1 Design Storm	Based on the ODOT Hydraulics Manual, nominally a 25 year recurrence event
Hydraulics Data	High flow 1 Velocity - Computed	The velocity of water computer for the structure when handling the "high flow 1" discharge (from the ODOT Hydraulics Manual, feet/second)
Hydraulics Data	High Flow 2 Discharge	The Q (discharge or volume of water per unit time) that the structure will be handling under "high flow 2" conditions (from the ODOT Hydraulics Manual)
Hydraulics Data	High flow 2 Depth - Computed	The depth of water computed for the structure when the handling the "high flow 2" discharge (from the ODOT Hydraulics Manual, inches)
Hydraulics Data	High Flow 2 Design Storm	Based on the ODOT Hydraulics Manual, nominally a 50 year recurrence event
Hydraulics Data	High flow 2 Velocity - Computed	The velocity of water computed for the structure when handling the "high flow 2" discharge (from the ODOT Hydraulics Manual, feet/second)
Hydraulics Data	High Water Mark	The elevation of the highest point in or around the structure with evidence of having been covered by standing water
Hydraulics Data	Hydraulic adequacy	Is the hydraulic capacity of the structure (its ability to pass water through it) adequate for high flow conditions expected to be handled?
Hydraulics Data	Low Flow Discharge	The Q (discharge, cubic-feet/second) that the structure will be handling under "low flow" conditions
Hydraulics Data	Low flow Depth - Computed	The depth of water computed for the structure when the handling the "low flow" discharge (inches)
Hydraulics Data	Low Flow Design Storm	The Recurrence interval (years)
Hydraulics Data	Low flow Velocity - Computed	The velocity of water computer for the structure when handling the "low flow" discharge (feet/second)
Hydraulics Data	Ordinary High flow Depth	The depth of water computed for the structure when the handling Ordinary High Water as defined by the ODOT Hydraulics Manual (inches)
Hydraulics Data	Ordinary High flow Velocity - Computed	The velocity of water computer for the structure when handling Ordinary High Water as defined by the ODOT Hydraulics Manual (feet/second)
Hydraulics Data	Ordinary High Water Flow	The Q (discharge, cubic-feet/second) that the structure will be handling during Ordinary High Water as defined by the ODOT Hydraulics Manual
Hydraulics Data	Ordinary High Water Width	Width of the stream channel during Ordinary High Water as defined by the ODOT Hydraulics Manual
Hydraulics Data	Tidal	Is the water level below (and possibly through) the structure affected by tides
Hydraulics Data	Hydraulics Comments	Space for verbose comments related to the hydraulics of the culvert
Location/Jurisdiction Data	Overall Condition	Summary rating of the overall condition of the culvert
Location/Jurisdiction Data	County	County of structure location
Location/Jurisdiction Data	District	ODOT Maintenance district were the structure is located
Location/Jurisdiction Data	Easting	Derived from the Longitude-Latitude of the drainage facility. The east-west coordinate under the State Plane Coordinate System
Location/Jurisdiction Data	Latitude	The Latitude of the drainage facility (decimal degrees)
Location/Jurisdiction Data	Latitude-Longitude Quality	Quality of the latitude/longitude data
Location/Jurisdiction Data	Longitude	The Longitude of the drainage facility (decimal degrees)

Category	Data Field	Definition
Location/Jurisdiction Data	Mileage Type	A prefix used to make milepoints unique in areas where there are multiple occurrences of a milepoint on a single highway. Y= Spur mileage. Z= Overlapping mileage. When a road is lengthened in the middle due to realignment, Z-mileage is created. T= Temporary mileage (i.e. detour or construction).
	Overlapping mileage code	Milepoint overlapping code is used only in conjunction with mileage type of 'Z'. It indicates a unique series of overlapping 'Z' mileages. The first chronological occurrence of 'Z' mileage will have a ovlap_mlge_cd of 1, the second chronological occurrence will have a ovlap_mlge_cd of 2, etc.
Location/Jurisdiction Data	Milepoint	The linear positioning reference along the center line of all state highways
Location/Jurisdiction Data	Northing	Derived from the Longitude-Latitude of the drainage facility. The north-south coordinate under the State Plane Coordinate System
Location/Jurisdiction Data	Quadrangle	Topographic mapsheet name on which the structure is located
Location/Jurisdiction Data	Region	ODOT region
Location/Jurisdiction Data	State	State of structure location
Location/Jurisdiction Data	Location Comments	Verbose comments regarding the location of the culvert
Maintenance/Inspection Data	Inspection Responsibility	Entity responsible for inspecting structure
Maintenance/Inspection Data	Date of Inspection	What was the date of the last inspection
Maintenance/Inspection Data	Inspector Name	What was the name of the inspector
Maintenance/Inspection Data	Inspector Class	What type of inspector is this person (i.e. Maintenance Worker, Biologist, Geotechnical Engineer, Hydraulics Engineer, Contractor, Intern)
Maintenance/Inspection Data	Telephone Number	Telephone Number for contacting the lead person (on-site) conducting the inspection/inventory
Maintenance/Inspection Data	Oregon Emp ID	ORID Number
Maintenance/Inspection Data	Inspection Comments	Verbose Comments regarding the inspection
Maintenance/Inspection Data	Inspection Interval	what is the inspection interval (years)
Maintenance/Inspection Data	Date of next inspection	What is the scheduled date for the next inspection
Maintenance/Inspection Data	Inspection History	
Maintenance/Inspection Data	Environmental inspection interval	Interval between scheduled environmental inspections (years)
Maintenance/Inspection Data	Date of next environmental inspection	Date when the next environmental inspection should take place
Maintenance/Inspection Data	Monitoring period for environmental	Time(s) of the year when environmental inspection should take place. (i.e. range(s) of months, September through October)
Maintenance/Inspection Data	Maintenance Responsibility	Entity responsible for maintaining structure (i.e. ODOT District 9, Marion County, John Q. Public)
Maintenance/Inspection Data	Maintenance Crew Number	ODOT maintenance crew number
Maintenance/Inspection Data	Date of maintenance work	Date of the last maintenance work
Maintenance/Inspection Data	Type of maintenance work completed	Type of maintenance work completed
Maintenance/Inspection Data	Maintenance Comments	Verbose Comments about the maintenance/repair
Maintenance/Inspection Data	Maintenance Frequency	What is the frequency of maintenance visits to the structure (years)
Maintenance/Inspection Data	Date of Replacement/Rehabilitation	what was the date of the last replacement/rehabilitation work
Maintenance/Inspection Data	Type of Replacement/Rehabilitation	Type of replacement/rehabilitation was completed
Maintenance/Inspection Data	Replacement/Rehabilitation Comments	Verbose Comments about the replacement/rehabilitation
Maintenance/Inspection Data	Recommended Maintenance	Type of maintenance work recommended
Maintenance/Inspection Data	Maintenance Cost Estimate	What is the estimated cost of planned maintenance (dollars)

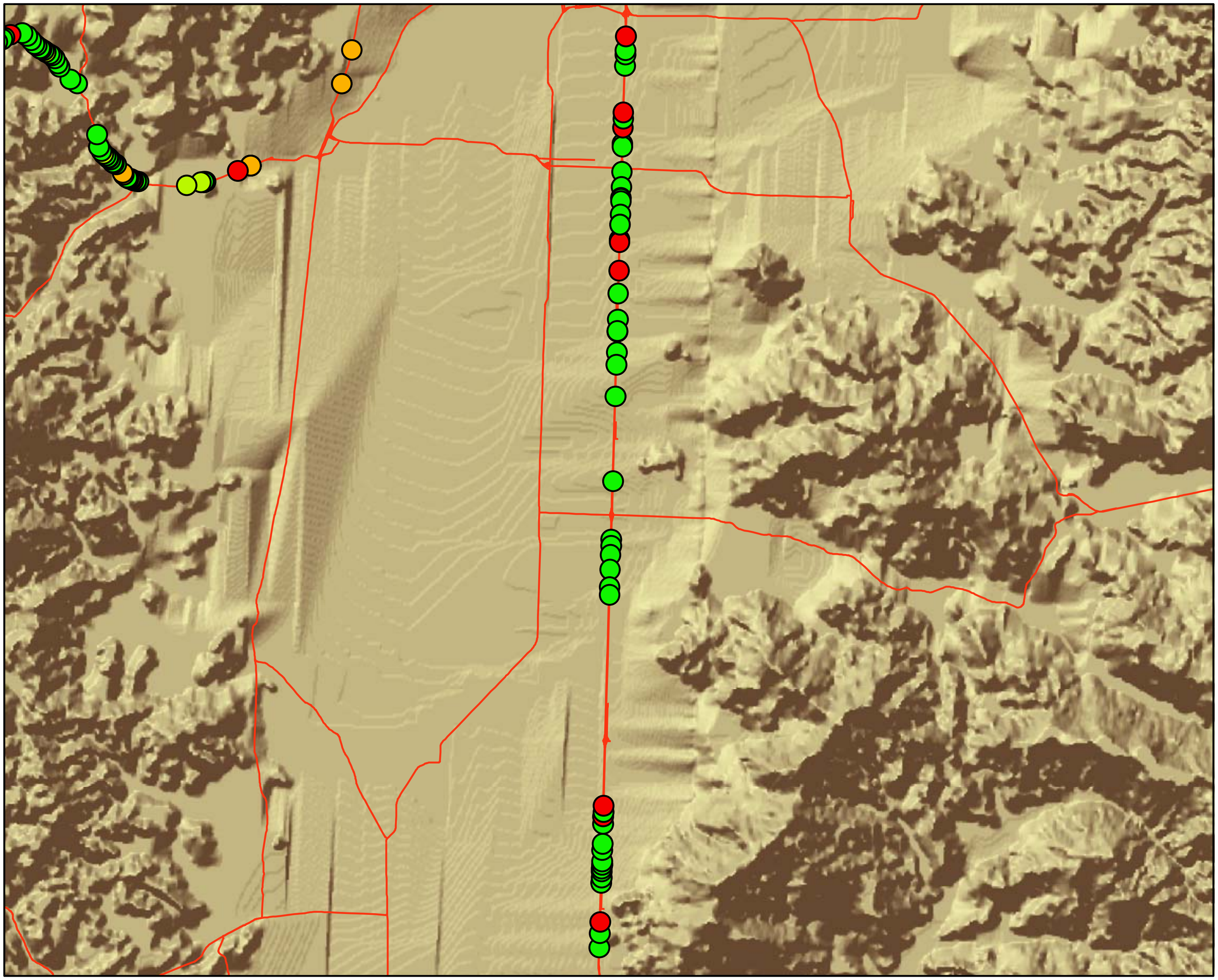
Category	Data Field	Definition
Maintenance/Inspection Data	Recommended Replacement/Rehabilitation	Type of replacement/rehabilitation action recommended
Maintenance/Inspection Data	ReplacementRehabilitation cost estimate	Estimated cost of replacement/rehabilitation of the structure (dollars)
Maintenance/Inspection Data	Recommended Action	Replace/rehabilitate, Maintain/Repair, or Do Nothing
Maintenance/Inspection Data	Traffic Disruption Frequency	how often is traffic disrupted by problems with the structure (years)
Maintenance/Inspection Data	Maintenance Priority	What is the priority rating of planned maintenance/repair
Maintenance/Inspection Data	Pollution Tie-In Risk	
Photographs	Photo 1	Picture of whiteboard w/hwy & mp on it
Photographs	Photo A	Photograph of the roadway looking toward the culvert crossing in the direction of increasing MP
Photographs	Photo B	Photograph of the roadway looking toward the culvert crossing in the direction of decreasing MP
Photographs	Photo C	Photo of inlet end from upstream
Photographs	Photo D	Photo of inlet from side
Photographs	Photo E	Photo from inlet looking up embankment
Photographs	Photo F	Photo from inlet looking upstream
Photographs	Photo G	Photo from edge or roadway looking down at inlet
Photographs	Photo H	Photo of outlet end from downstream
Photographs	Photo I	Photo of outlet from side
Photographs	Photo J	Photo from outlet looking up embankment
Photographs	Photo K	Photo from outlet looking downstream
Photographs	Photo L	Photo from edge or roadway looking down at outlet
Photographs	Photo M	Photos of embankment problems (also Photos N, O, P, etc as needed for problems)
Photographs	Photographs Comments	Verbose comments regarding the photographs (i.e. what problems are being shown in M-Q)
Roadway Data	Elevation of Roadway	The elevation of the centerline of the roadway where it crosses over the structure.
Roadway Data	Route Number	Provides easy identification for those not steeped in the ODOT highway numbers (i.e. OR217, US20, I5)
Roadway Data	AADT	Annual Average Daily Traffic.
Roadway Data	AADT Year	The year for which the AADT is recorded
Roadway Data	Average Truck Percent	What percentage of the AADT consists of trucks. Definition of truck to be based on a broad, inclusive definition such as >20,000 GVWR
Roadway Data	Detour Length	If failure or construction blocks traffic, what is the length of the detour imposed by the closure. Presumably in miles.
Roadway Data	Functional Class	The functional classification of the roadway passing over the structure.
Roadway Data	Highway Number	The official ODOT highway number
Roadway Data	Drainage Curb Left	Is there a curb on the left side of the roadway (facing increasing milepoint)
Roadway Data	Drainage Curb Right	Is there a curb on the right side of the roadway (facing increasing milepoint)
Roadway Data	Roadway Width	What is the width of the paved roadway where it crosses the culvert
Roadway Data	Roadway Comments	Verbose comments regarding the roadway at the culvert
Watershed Data	Adult Fish Observed	were adult fish observed at the last inspection
Watershed Data	Canopy Cover	What percentage of the stream near the culvert is shaded by vegetation canopy
Watershed Data	Fish Passable Structure	Is the structure fish passable

Category	Data Field	Definition
Watershed Data	Watershed Comments	Verbose comments about the environmental conditions
Watershed Data	Fish Passage Features	What features does the structure include to facilitate the passage of fish
Watershed Data	Fish Passage Requirements	What types of fish need to pass through the structure (i.e. upstream adult only, up and down stream adults and juveniles)
Watershed Data	Habitat Miles Upstream	how many miles of accessible/usable habitat exist upstream (miles)
Watershed Data	Habitat Quality	What is the quality designation of the habitat in the stream up stream of the structure. (ODFW uses Good, Fair, Poor, and Unknown. Another scheme is No Impairment, Moderate Impairment, Severe Impairment)
Watershed Data	Juvenile Fish Observed	were juvenile fish observed at the last inspection
Watershed Data	Large Woody Debris	Is there large woody debris present (near the inlet, outlet, both, or neither)
Watershed Data	Wetland Vegetation Present	Is the vegetation characteristic of a wetland present in the vicinity of the culvert (yes or no)
Watershed Data	Land Formation	What type of terrain surrounds the site of the structure (i.e. hill slope, flood plain)
Watershed Data	Overall Condition Fish	What is the overall condition for fish passage, based upon the other observations
Watershed Data	Water Condition	What is the overall water quality at the culvert
Watershed Data	Basin	What is the name of the drainage basin (from list of names associated with the second HUC field) the structure is located in.
Watershed Data	Basin Area	What is the area of the upstream drainage basin (acres)
Watershed Data	HUC	Hydrologic Unit Code (USGS coding convention for hydrologic units of all sizes)
Watershed Data	River Mile	At what river mile does the structure occur at on the water body (these are analogous to highway milepost, miles).
Watershed Data	Stream Unit Type	a description of the stream environment (i.e. backwater pool, small cobble riffile, off-channel area)
Watershed Data	Streambed Material-Inlet	What does the stream bed at the inlet consist of
Watershed Data	Streambed Material-Outlet	What does the stream bed at the outlet consist of
Watershed Data	Sub Basin	What is the name of the subbasin (from list of names associated with the third HUC field) the structure is located in.
Watershed Data	Tributary Junction	Is the culvert near a junction between water bodies (inlet, outlet, both, or neither)
Watershed Data	Water Body receiving	What is the destination of the water carried by this structure. (i.e. ODOT ditch, tributary of Rock Creek, Nehalem River)
Watershed Data	Water Body Source	What is the source of the water carried by this structure. (i.e. Parking Lot, tributary of Salmon Creek, Yamhill River)
Watershed Data	Water pH	The pH of the water flowing through the structure
Watershed Data	Water Conductivity	The electrical resistivity of the water flowing through the structure (microS/cm)
Watershed Data	Water Temperature	The temperature of the water exiting the culvert barrel
Hydraulics Data	Beaver Activity Inspection Condition	Is there evidence of Beaver activity in, or near, the culvert

Data on the Standard Culvert Inspection Form is shaded gray

Additional data on the Culvert Inspection Form with Fish Passage Inspection is shaded blue

APPENDIX C:
MAPS OF CULVERTS INVENTORIED BY PILOT PROJECT CLASSIFIED BY CONDITION



Legend

Pilot Project Inventory

Overall Condition

- Critical
- Poor
- Fair
- Good
- Highway Network

OREGON DEPARTMENT OF TRANSPORTATION

Overall Condition

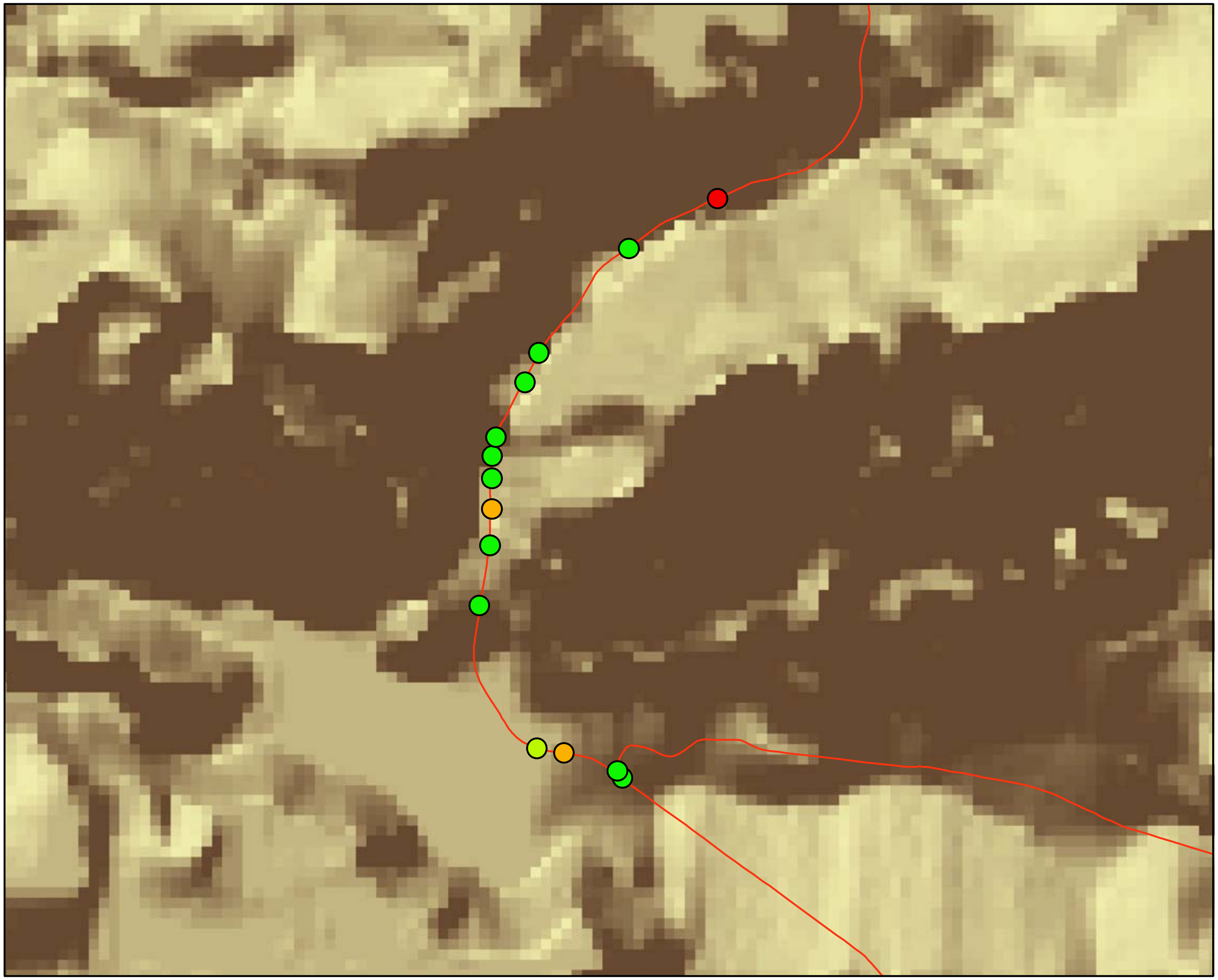
Highway 001 Pilot Project inventoried culverts

Drainage Facility Management System

0 1 2 4 6 8 10
Miles

0 2.5 5 10 15
Kilometers

N



Legend

Pilot Project Inventory

Overall Condition

- Critical
- Poor
- Fair
- Good
- Highway Network

OREGON DEPARTMENT OF TRANSPORTATION

Overall Condition

Highway 004 (a) Pilot Project inventoried culverts

Drainage Facility Management System

0 0.15 0.3 0.6 0.9 1.2 1.5
Miles

0 0.25 0.5 1 1.5
Kilometers

N

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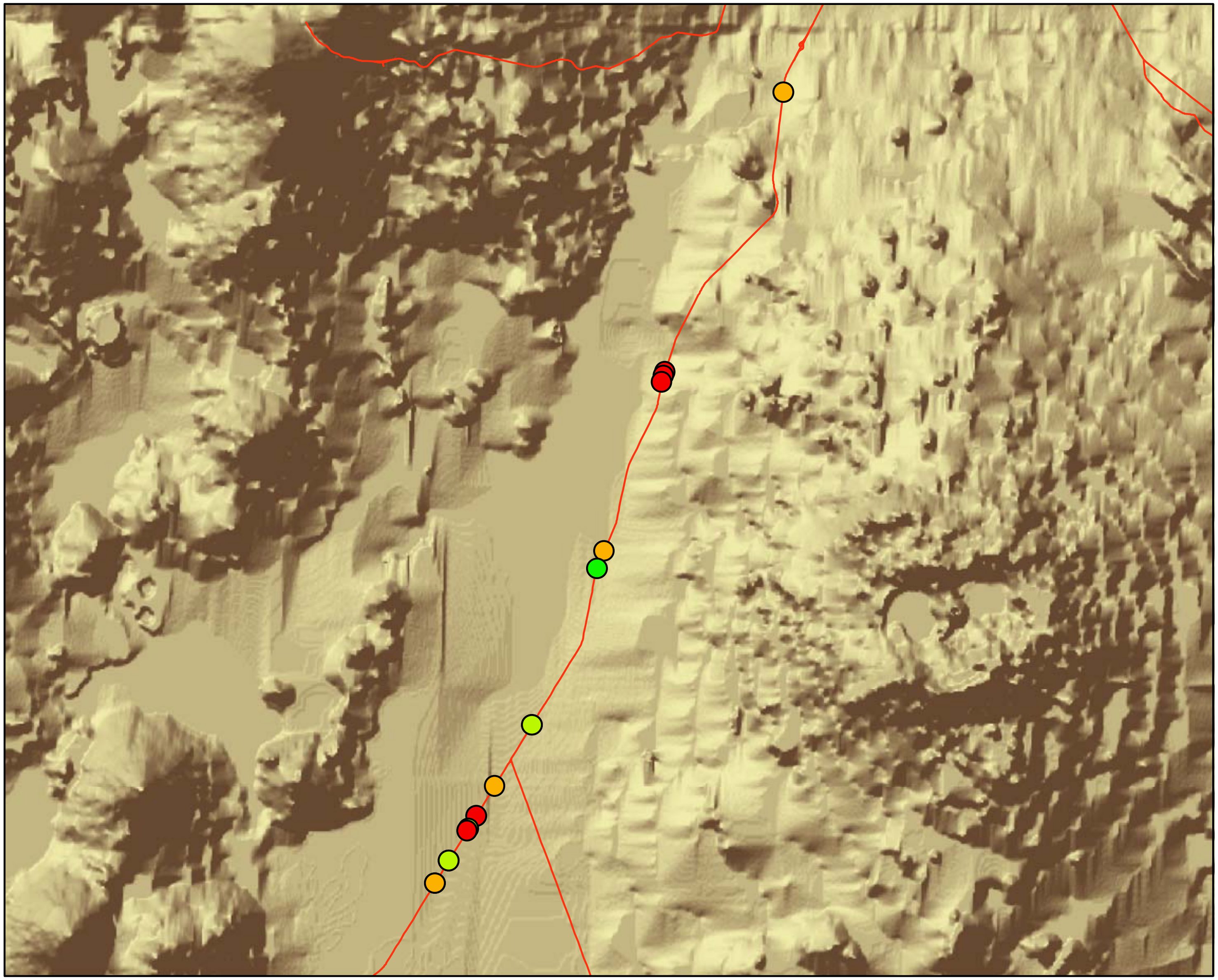

Legend

Pilot Project Inventory

Overall Condition

- Critical
- Poor
- Fair
- Good
- Highway Network

OREGON DEPARTMENT OF TRANSPORTATION

Overall Condition

Highway 004 (b) Pilot Project inventoried culverts

Drainage Facility Management System

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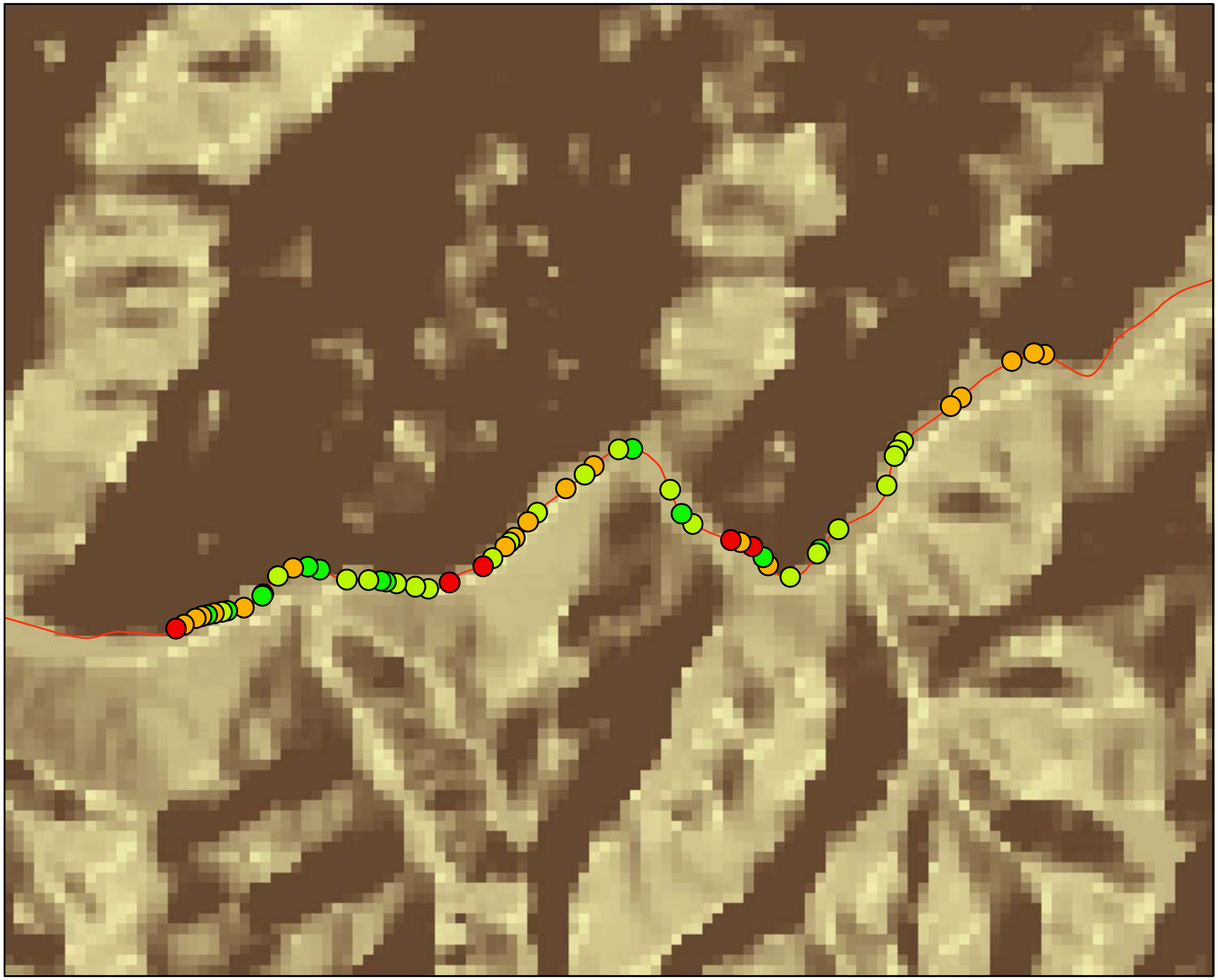


Legend

Pilot Project Inventory

Overall Condition

- Critical
- Poor
- Fair
- Good
- Highway Network

OREGON DEPARTMENT OF TRANSPORTATION

Overall Condition
Highway 005 Pilot Project inventoried culverts

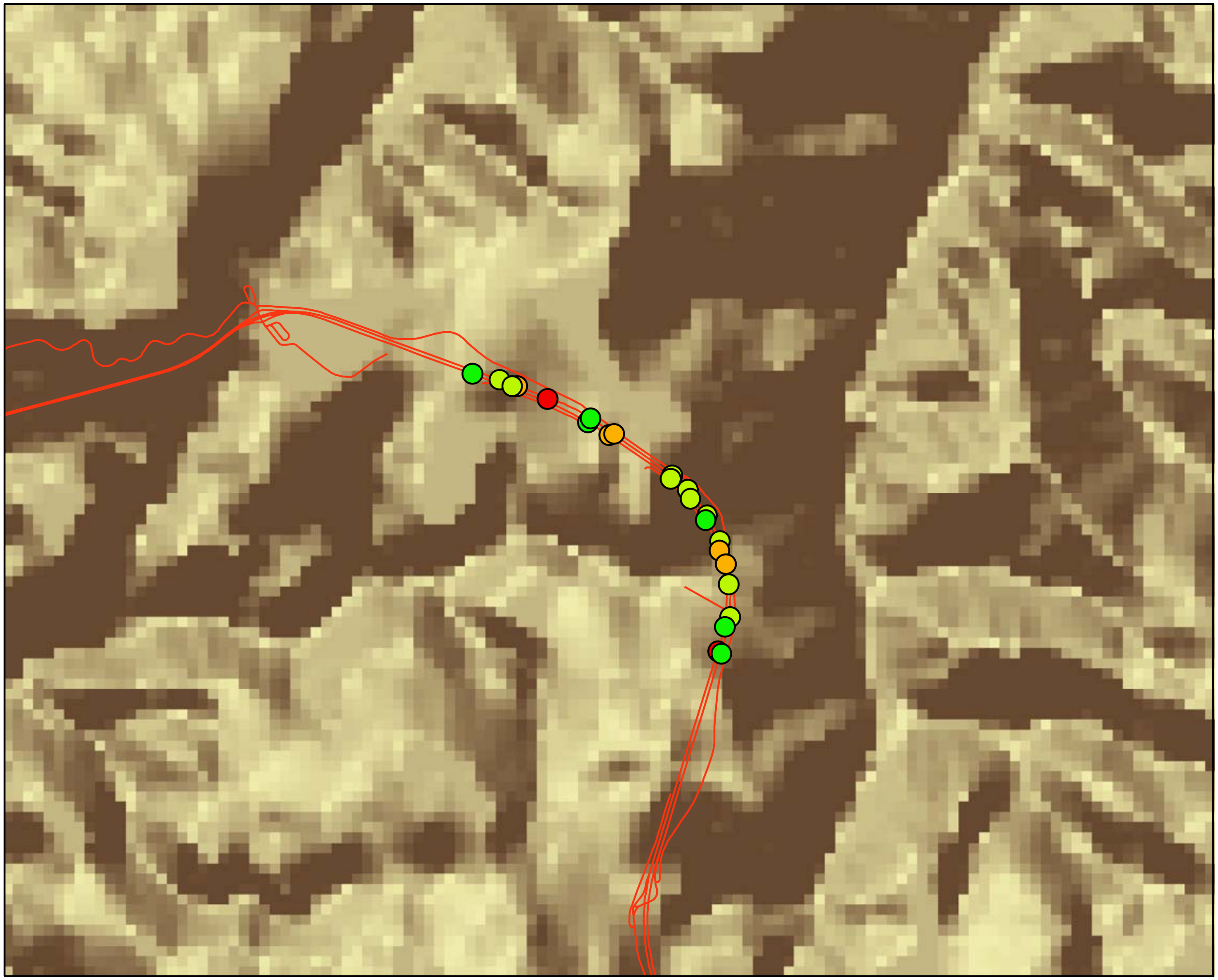
Drainage Facility Management System

0 0.125 0.25 0.5 0.75 1 1.25
Miles

0 0.35 0.7 1.4 2.1
Kilometers

N

C-5



Legend

Pilot Project Inventory

Overall Condition

- Critical
- Poor
- Fair
- Good
- Highway Network

OREGON DEPARTMENT OF TRANSPORTATION

Overall Condition

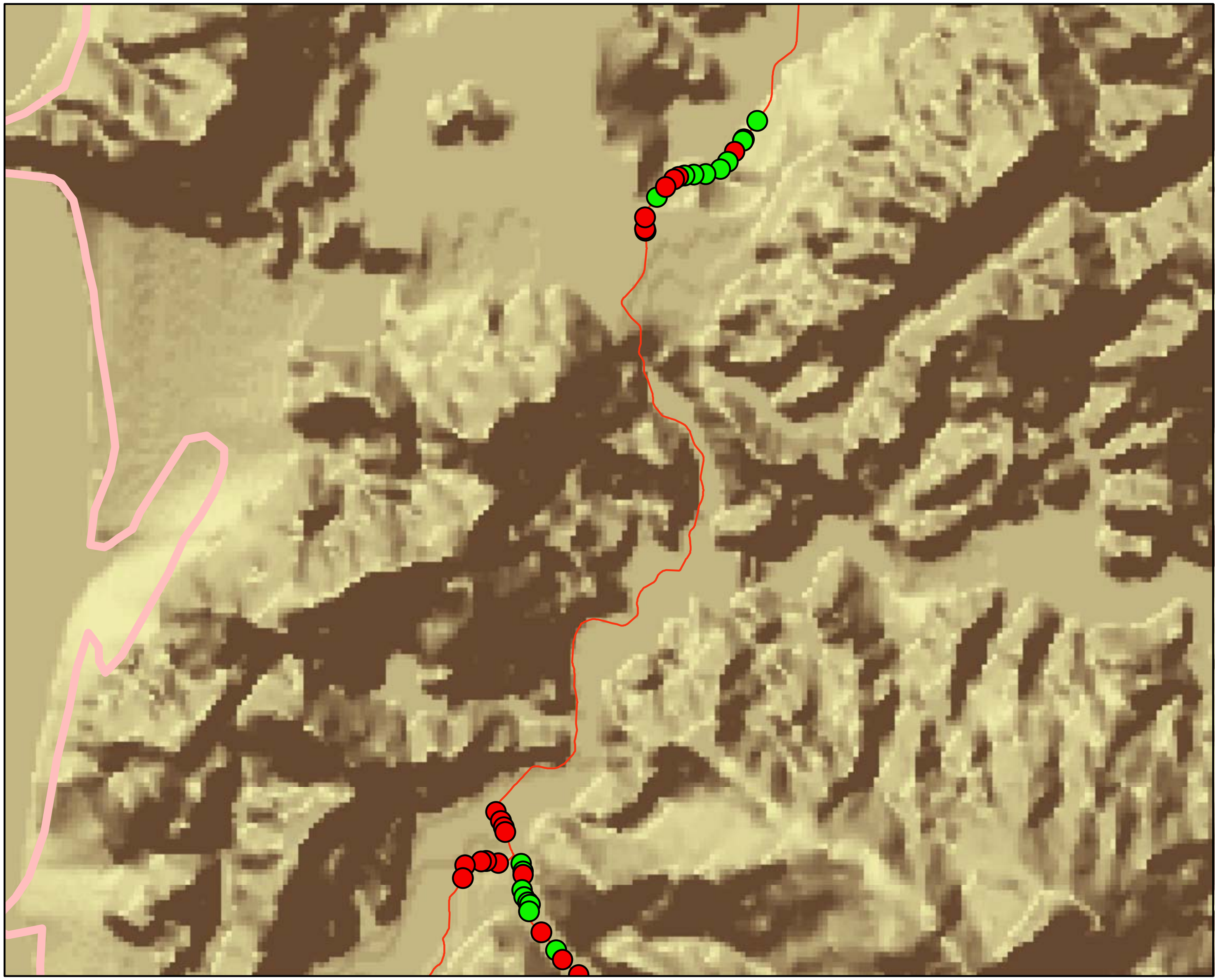
Highway 006 Pilot Project inventoried culverts

Drainage Facility Management System

0 0.125 0.25 0.5 0.75 1 1.25
Miles

0 0.2 0.4 0.8 1.2
Kilometers

N



Legend

Pilot Project Inventory

Overall Condition

- Critical
- Poor
- Fair
- Good
- Highway Network

OREGON DEPARTMENT OF TRANSPORTATION

Overall Condition

Highway 009 (b) Pilot Project inventoried culverts

Drainage Facility Management System

0 0.35 0.7 1.4 2.1 2.8 3.5

Miles

0 0.5 1 2 3

Kilometers

N

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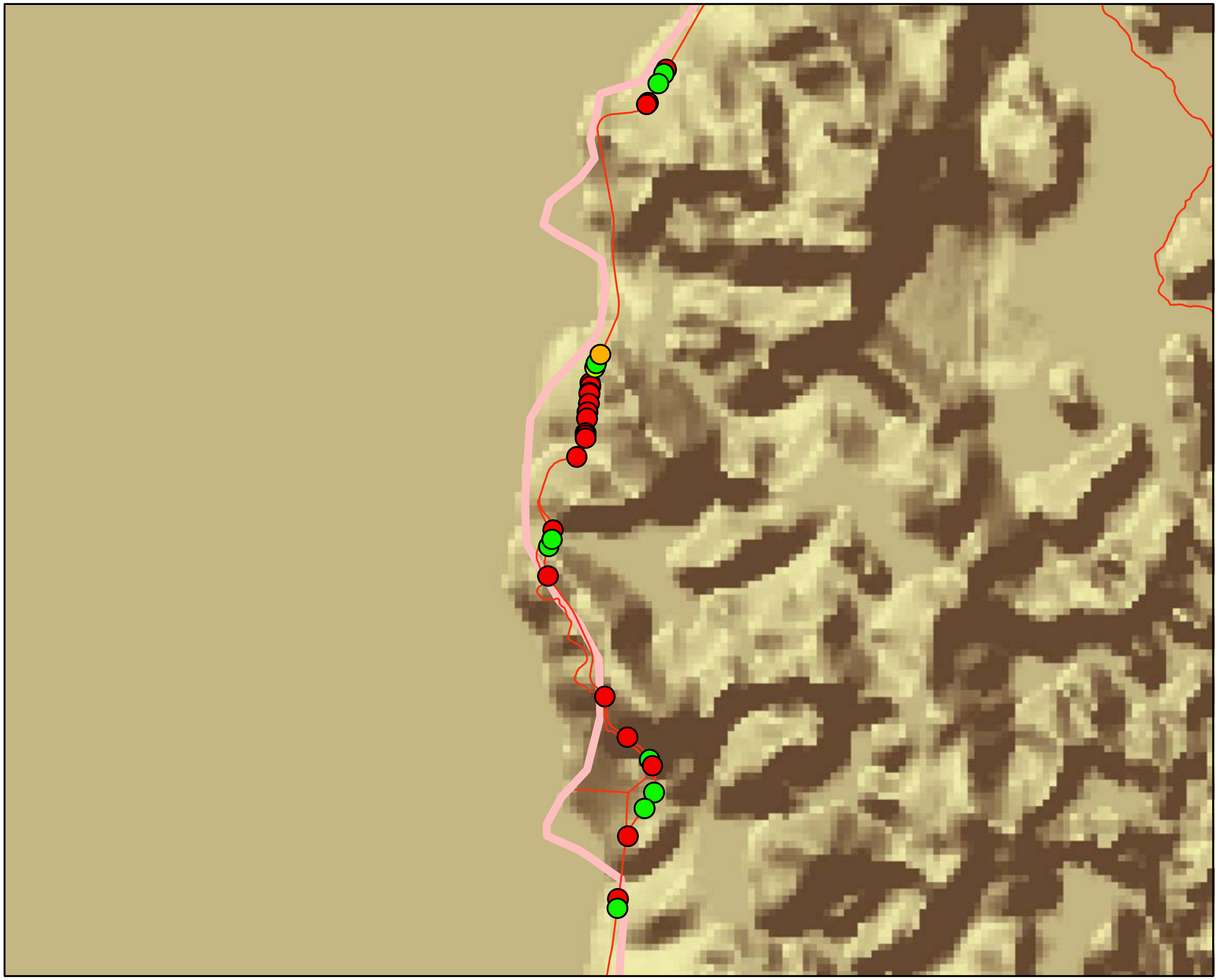

Legend

Pilot Project Inventory

Overall Condition

- Critical
- Poor
- Fair
- Good
- Highway Network

OREGON DEPARTMENT OF TRANSPORTATION

Overall Condition

Highway 009 (c) Pilot Project inventoried culverts

Drainage Facility Management System

0 0.25 0.5 1 1.5 2 2.5
Miles

0 0.375 0.75 1.5 2.25
Kilometers

N

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Legend

Pilot Project Inventory

Overall Condition

- Critical
- Poor
- Fair
- Good
- Highway Network

OREGON DEPARTMENT OF TRANSPORTATION

Overall Condition

Highway 009 (d) Pilot Project inventoried culverts

Drainage Facility Management System

0 0.5 1 2 3 4 5

Miles

0 1.25 2.5 5 7.5

Kilometers

N

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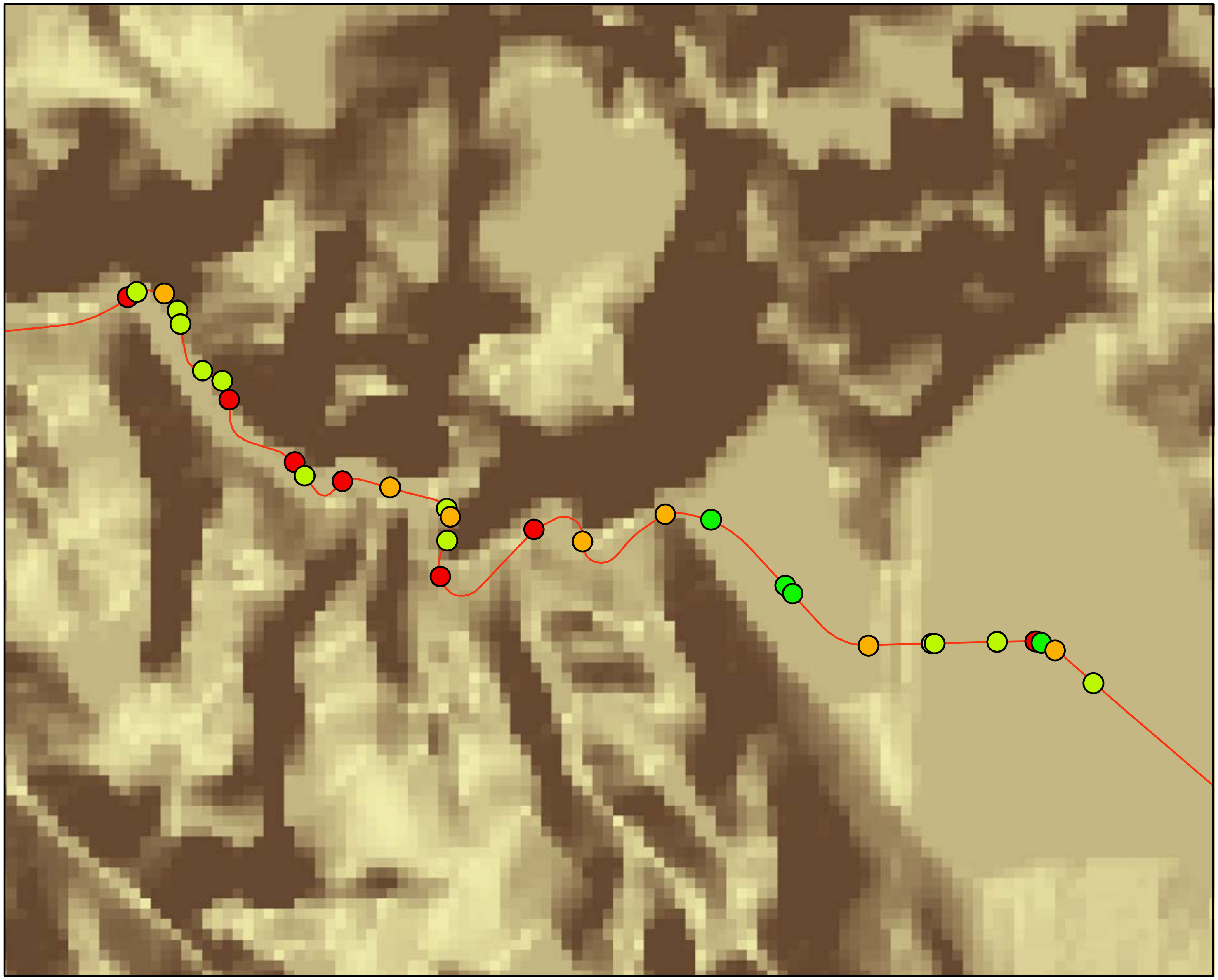

Legend

Pilot Project Inventory

Overall Condition

- Critical
- Poor
- Fair
- Good
- Highway Network

OREGON DEPARTMENT OF TRANSPORTATION

Overall Condition

Highway 010 Pilot Project inventoried culverts

Drainage Facility Management System

0 0.125 0.25 0.5 0.75 1 1.25
Miles

0 0.2 0.4 0.8 1.2
Kilometers

N

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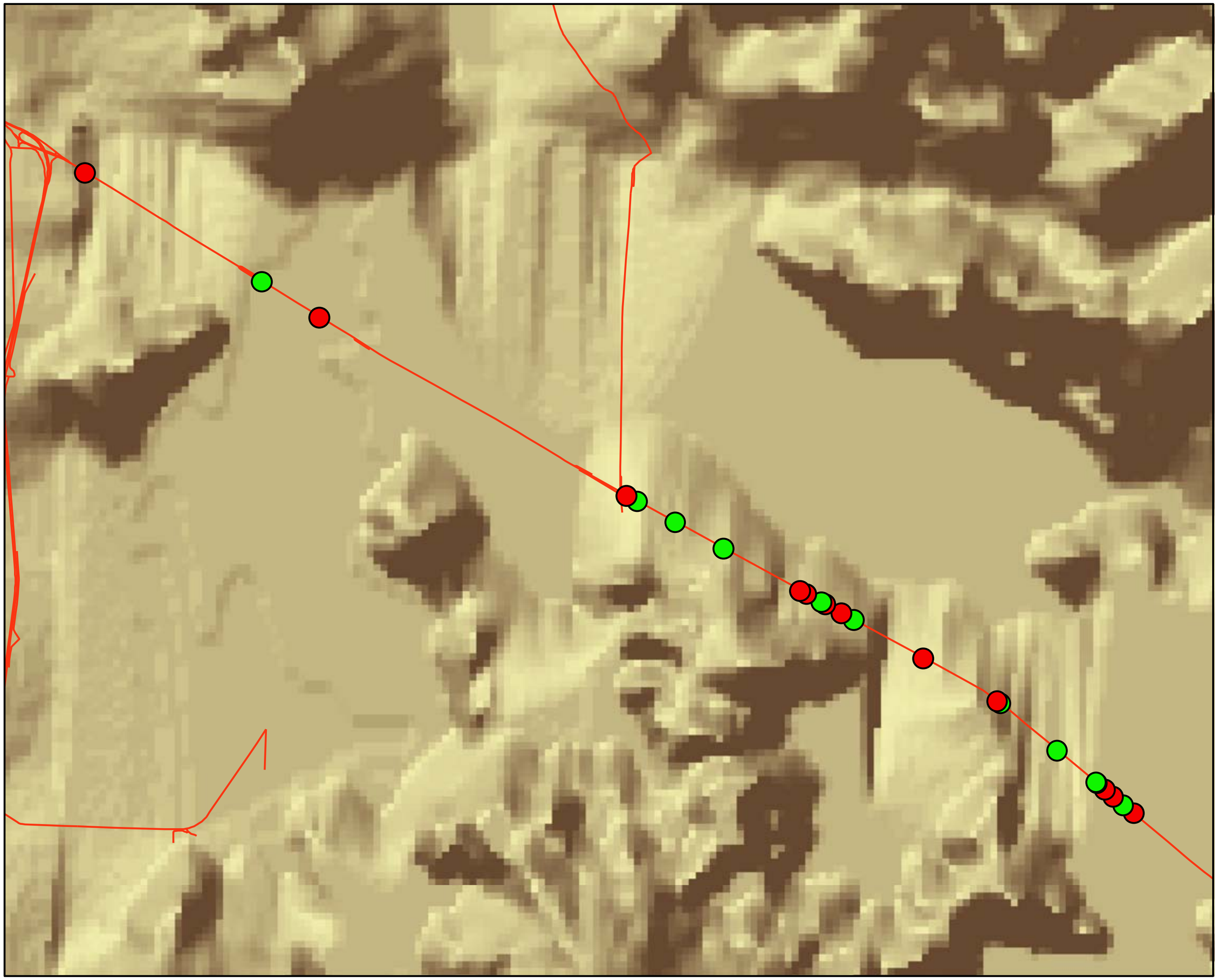

Legend

Pilot Project Inventory

Overall Condition

- Critical
- Poor
- Fair
- Good
- Highway Network

OREGON DEPARTMENT OF TRANSPORTATION

Overall Condition

Highway 018 Pilot Project inventoried culverts

Drainage Facility Management System

0 0.2 0.4 0.8 1.2 1.6 2

Miles

0 0.5 1 2 3

Kilometers

N

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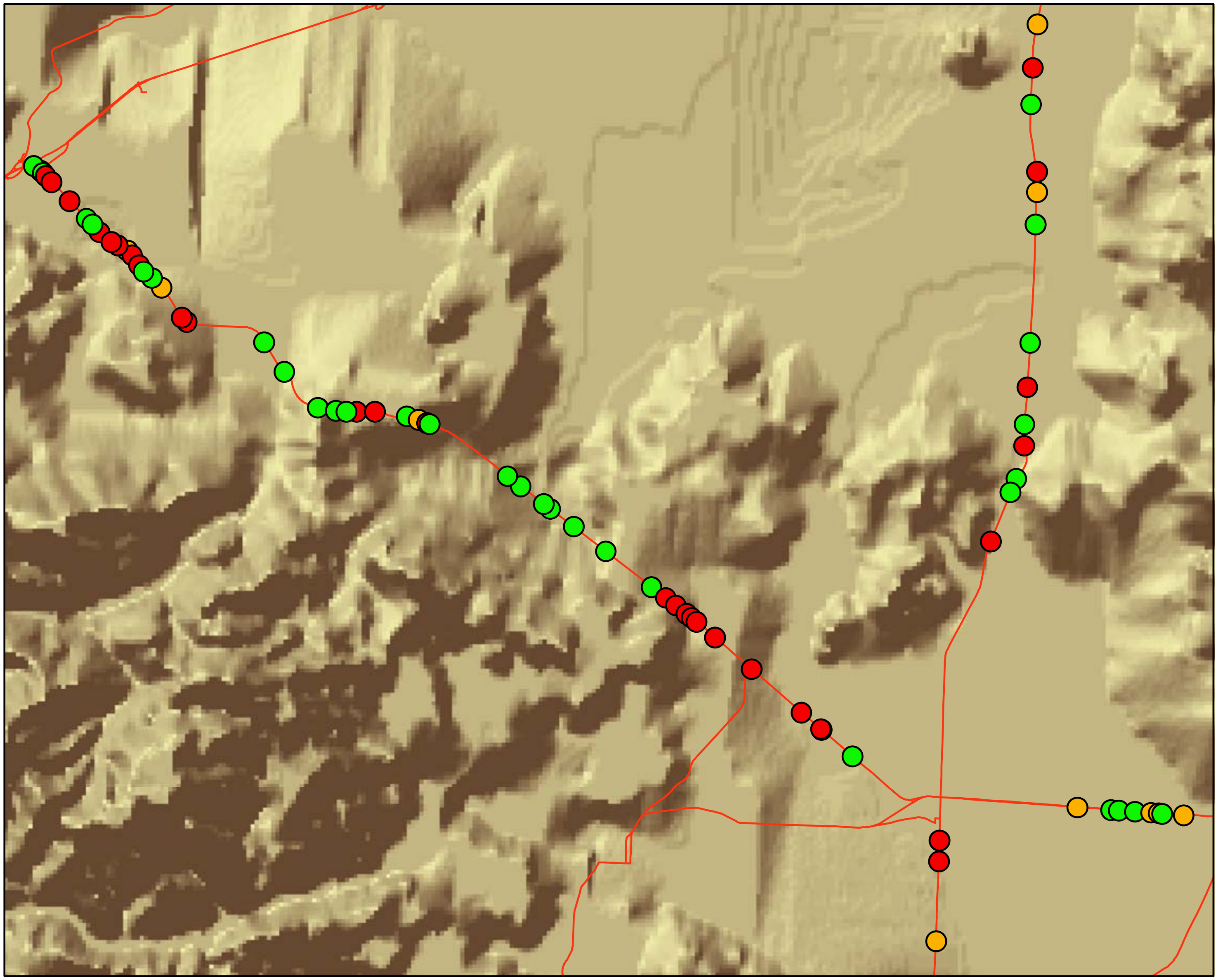

Legend

Pilot Project Inventory

Overall Condition

- Critical
- Poor
- Fair
- Good
- Highway Network

OREGON DEPARTMENT OF TRANSPORTATION

Overall Condition

Highway 030 Pilot Project inventoried culverts

Drainage Facility Management System

0 0.375 0.75 1.5 2.25 3 3.75

Miles

0 0.5 1 2 3

Kilometers

N

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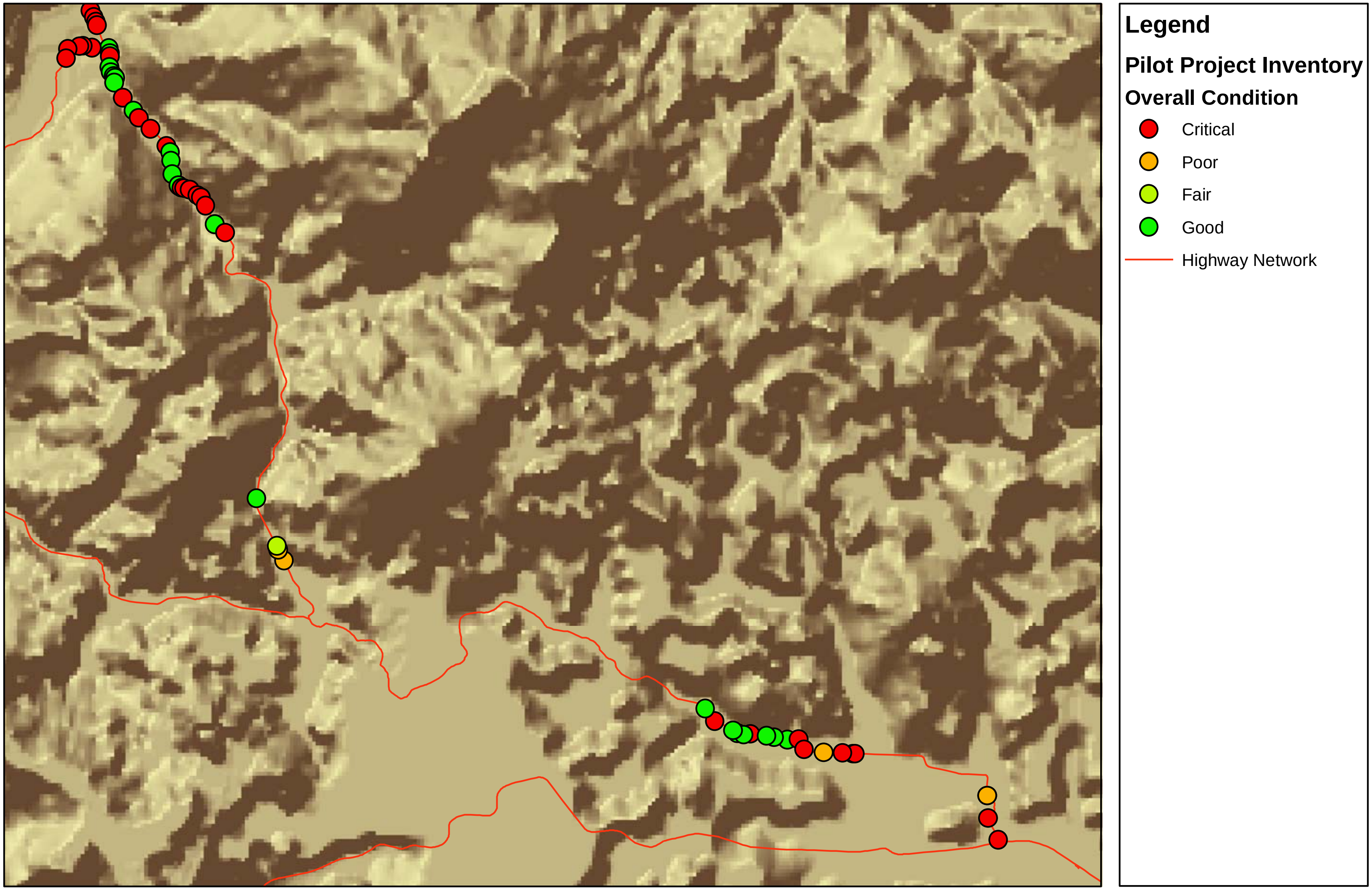


OREGON DEPARTMENT OF TRANSPORTATION

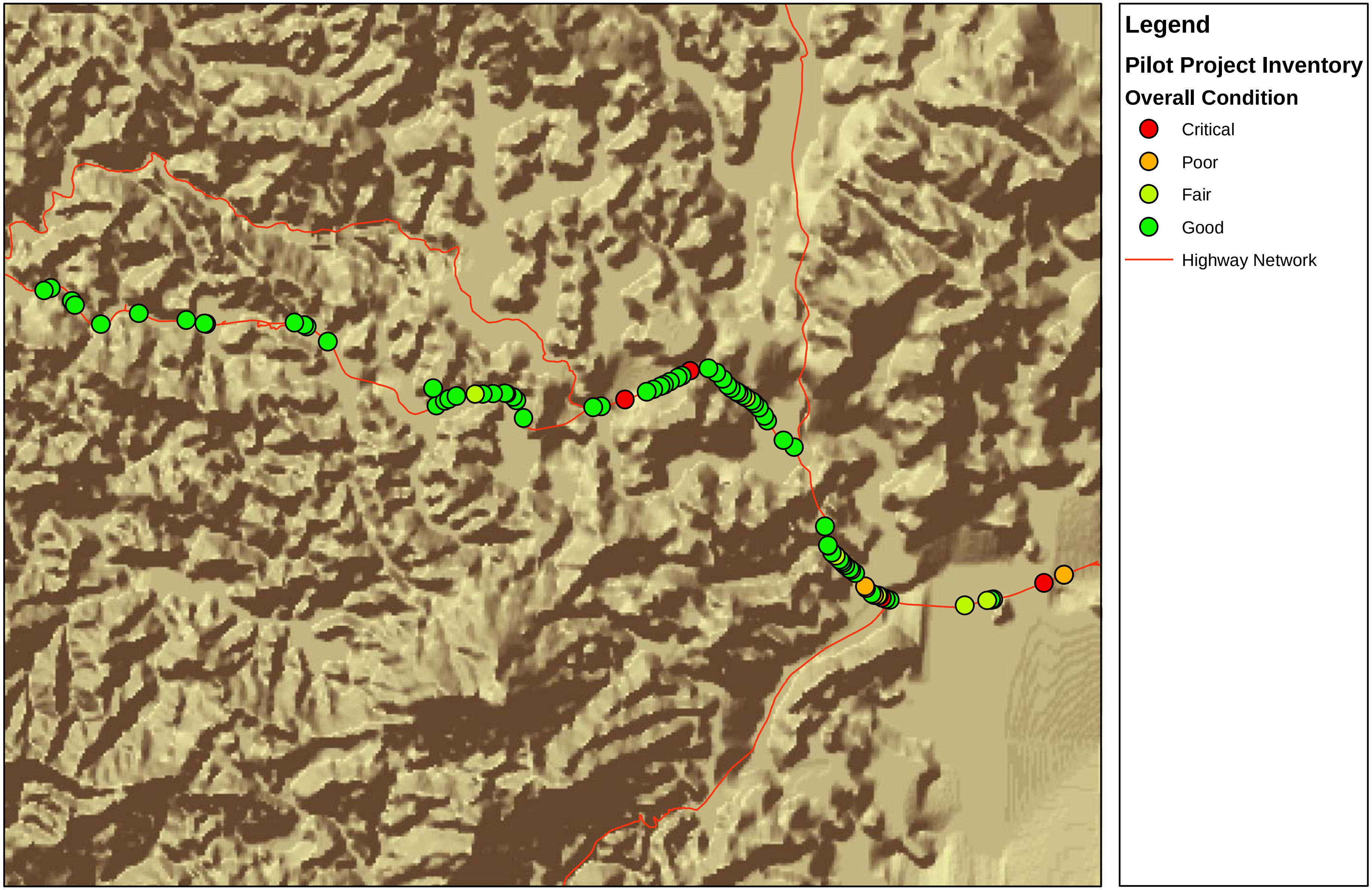
Overall Condition

Highway 032 Pilot Project inventoried culverts

Drainage Facility Management System

0 0.375 0.75 1.5 2.25 3 3.75
Miles
0 0.5 1 2 3
Kilometers

N



OREGON DEPARTMENT OF TRANSPORTATION

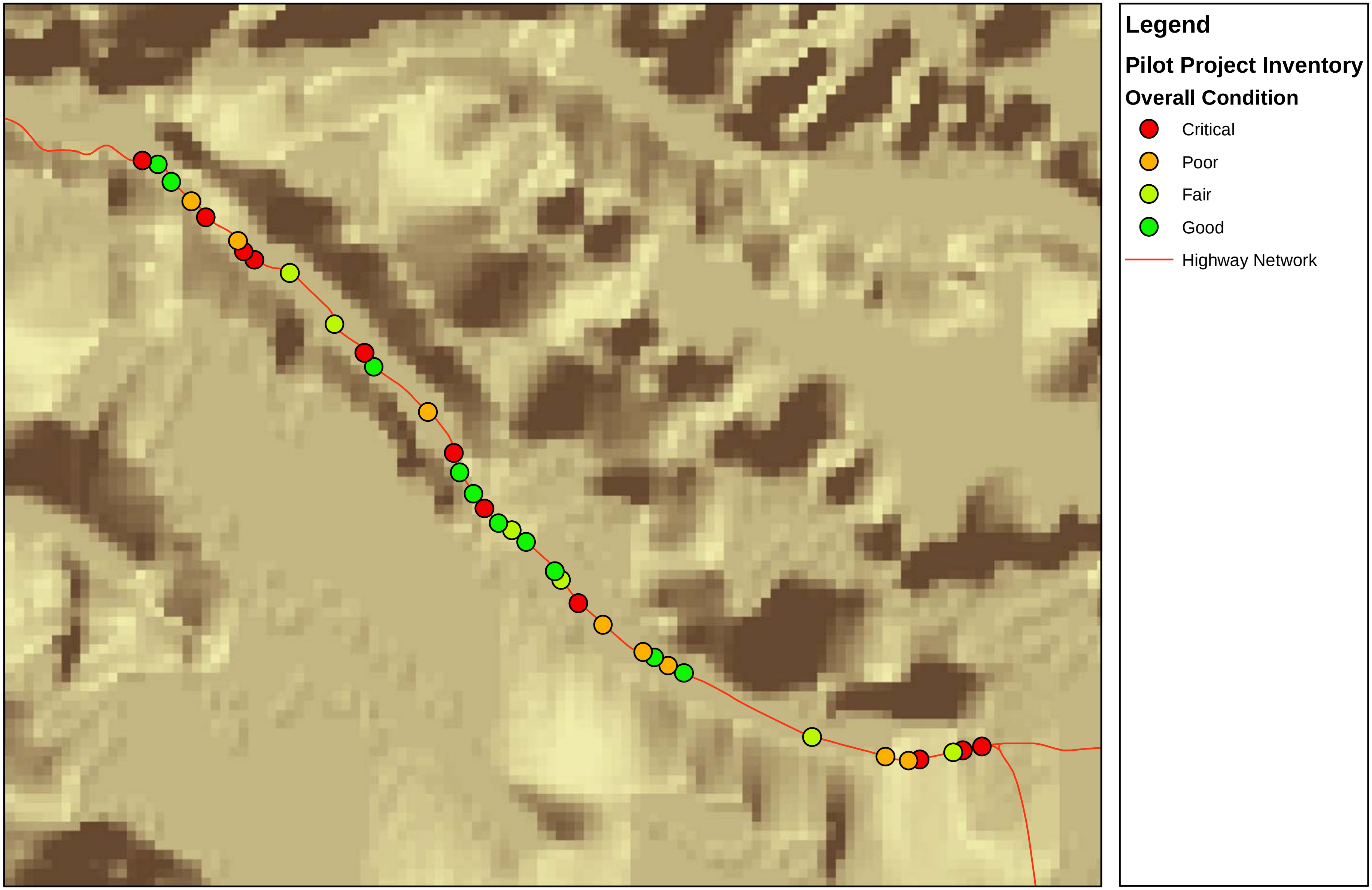
Overall Condition

Highway 033 Pilot Project inventoried culverts

Drainage Facility Management System

0 0.5 1 2 3 4 5
Miles
0 1.5 3 6 9
Kilometers

N



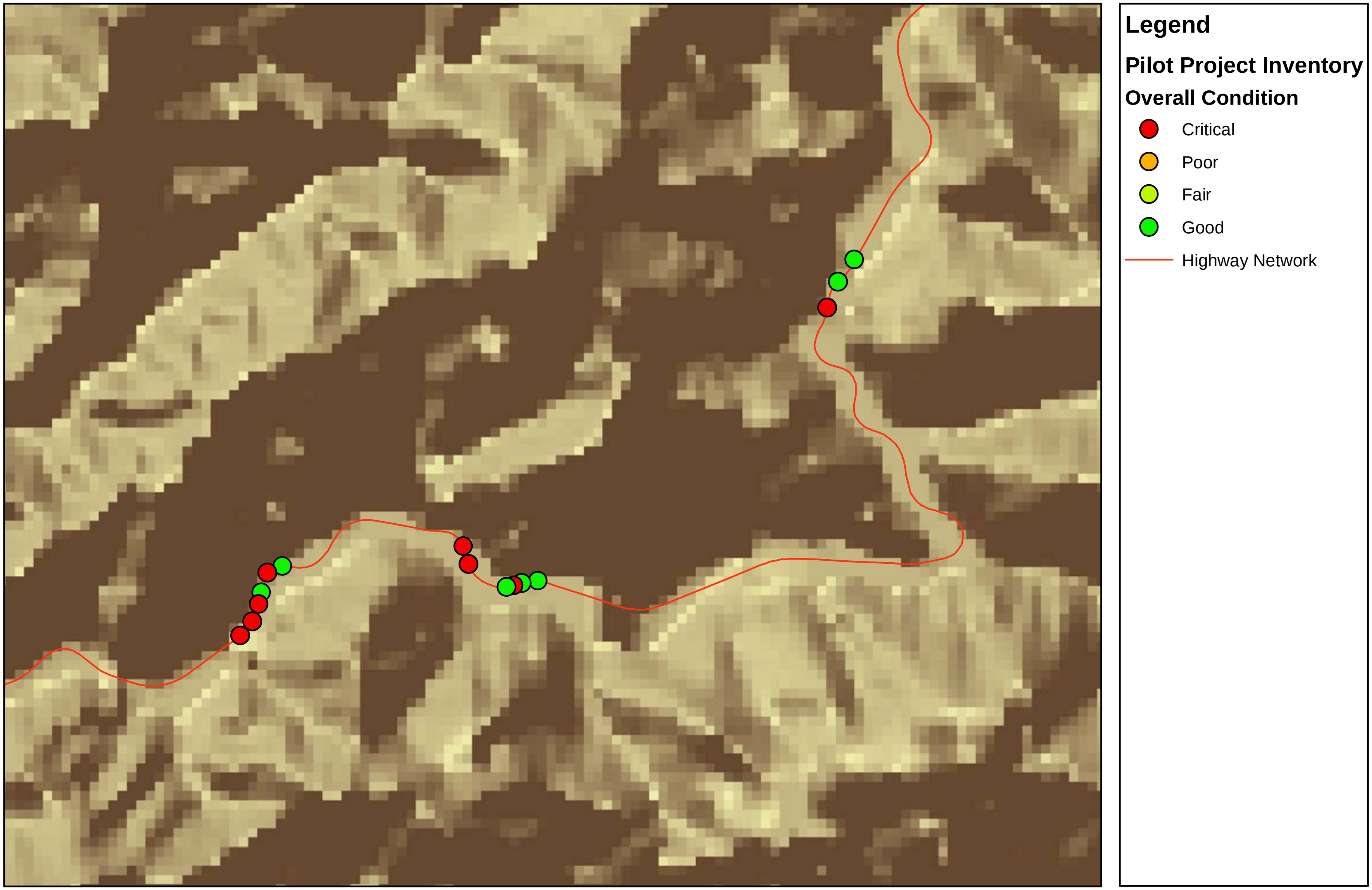
C-14

OREGON DEPARTMENT OF TRANSPORTATION

Overall Condition

Highway 036 Pilot Project inventoried culverts

Drainage Facility Management System



OREGON DEPARTMENT OF TRANSPORTATION

Overall Condition

Highway 037 Pilot Project inventoried culverts

Drainage Facility Management System

0 0.15 0.3 0.6 0.9 1.2 1.5
Miles
0 0.25 0.5 1 1.5
Kilometers

N

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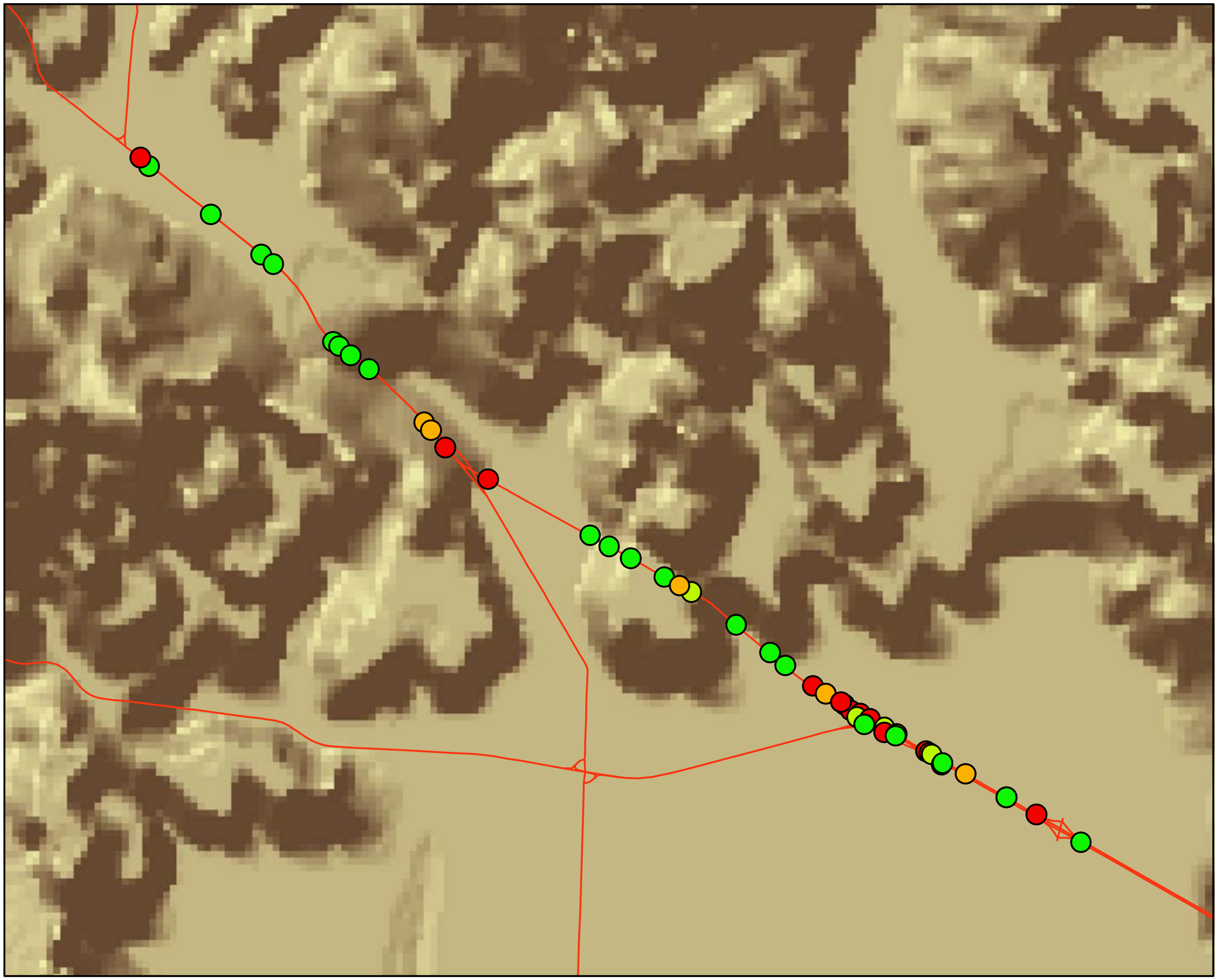

Legend

Pilot Project Inventory

Overall Condition

- Critical
- Poor
- Fair
- Good
- Highway Network

OREGON DEPARTMENT OF TRANSPORTATION

Overall Condition

Highway 047 Pilot Project inventoried culverts

Drainage Facility Management System

0 0.25 0.5 1 1.5 2 2.5
Miles

0 0.3750.75 1.5 2.25
Kilometers

N

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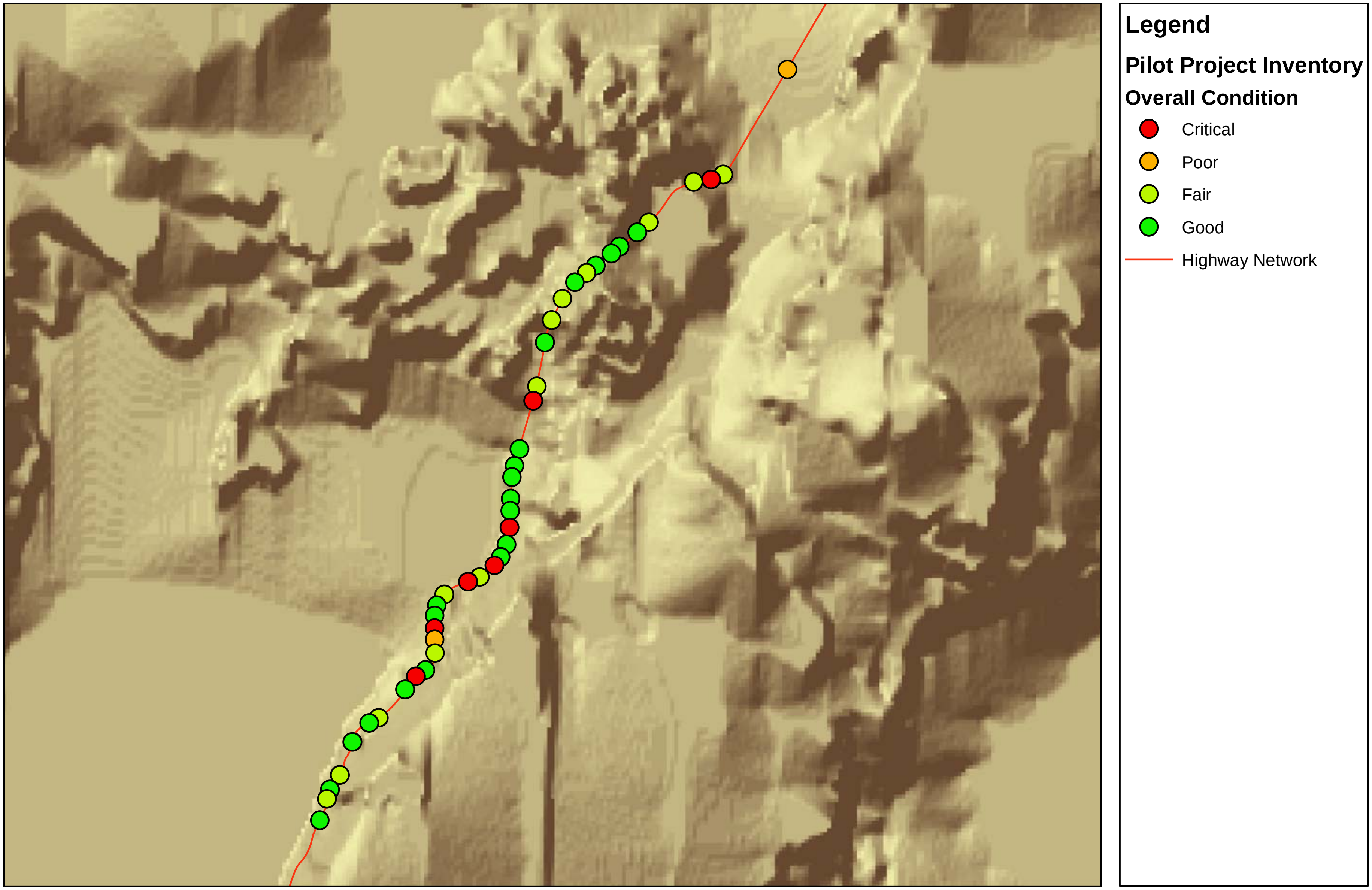
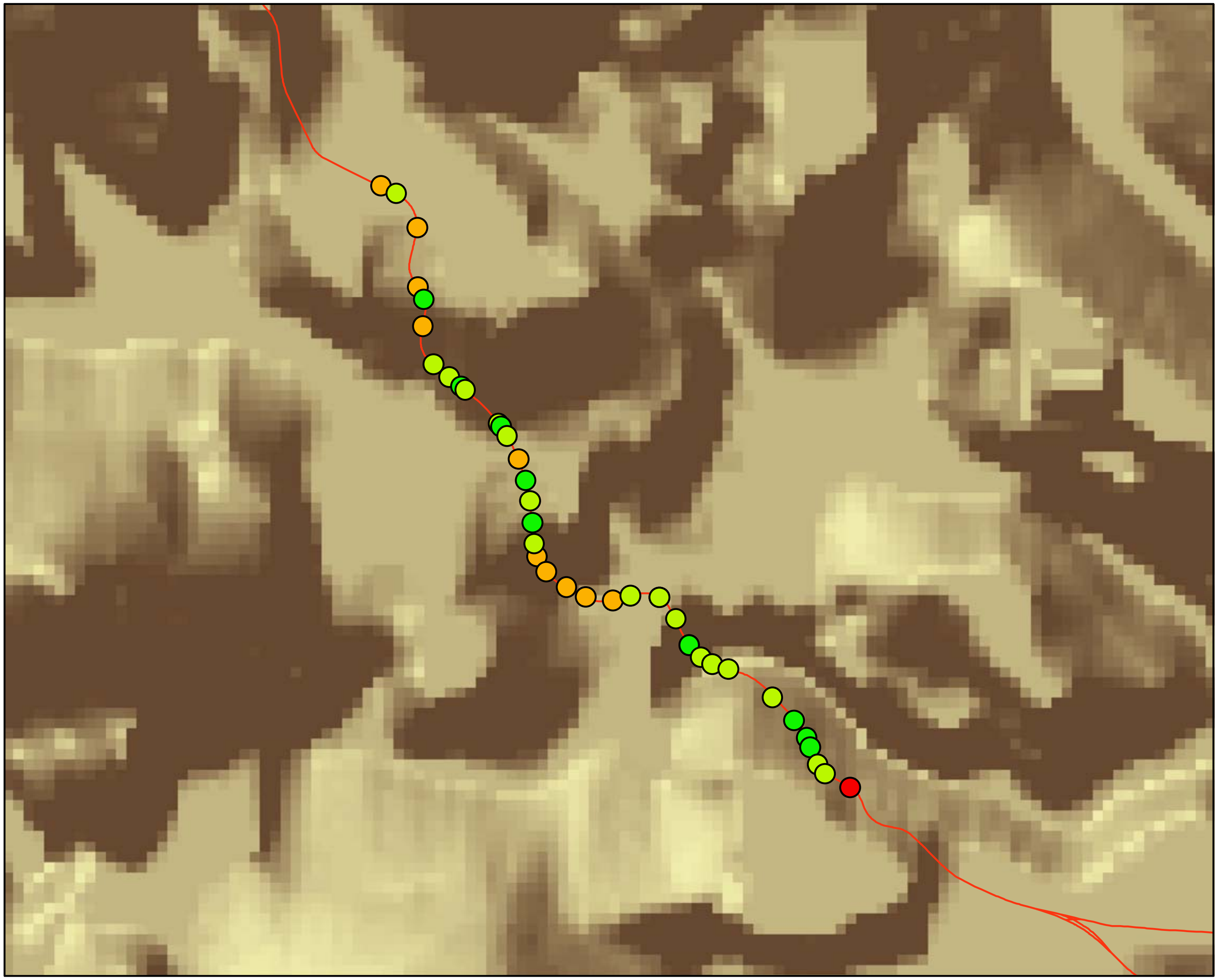


OREGON DEPARTMENT OF TRANSPORTATION

Overall Condition

Highway 049 Pilot Project inventoried culverts

Drainage Facility Management System



Legend

Pilot Project Inventory

Overall Condition

- Critical
- Poor
- Fair
- Good
- Highway Network

OREGON DEPARTMENT OF TRANSPORTATION

Overall Condition

Highway 053 Pilot Project inventoried culverts

Drainage Facility Management System

0 0.125 0.25 0.5 0.75 1 1.25
Miles

0 0.35 0.7 1.4 2.1
Kilometers

N

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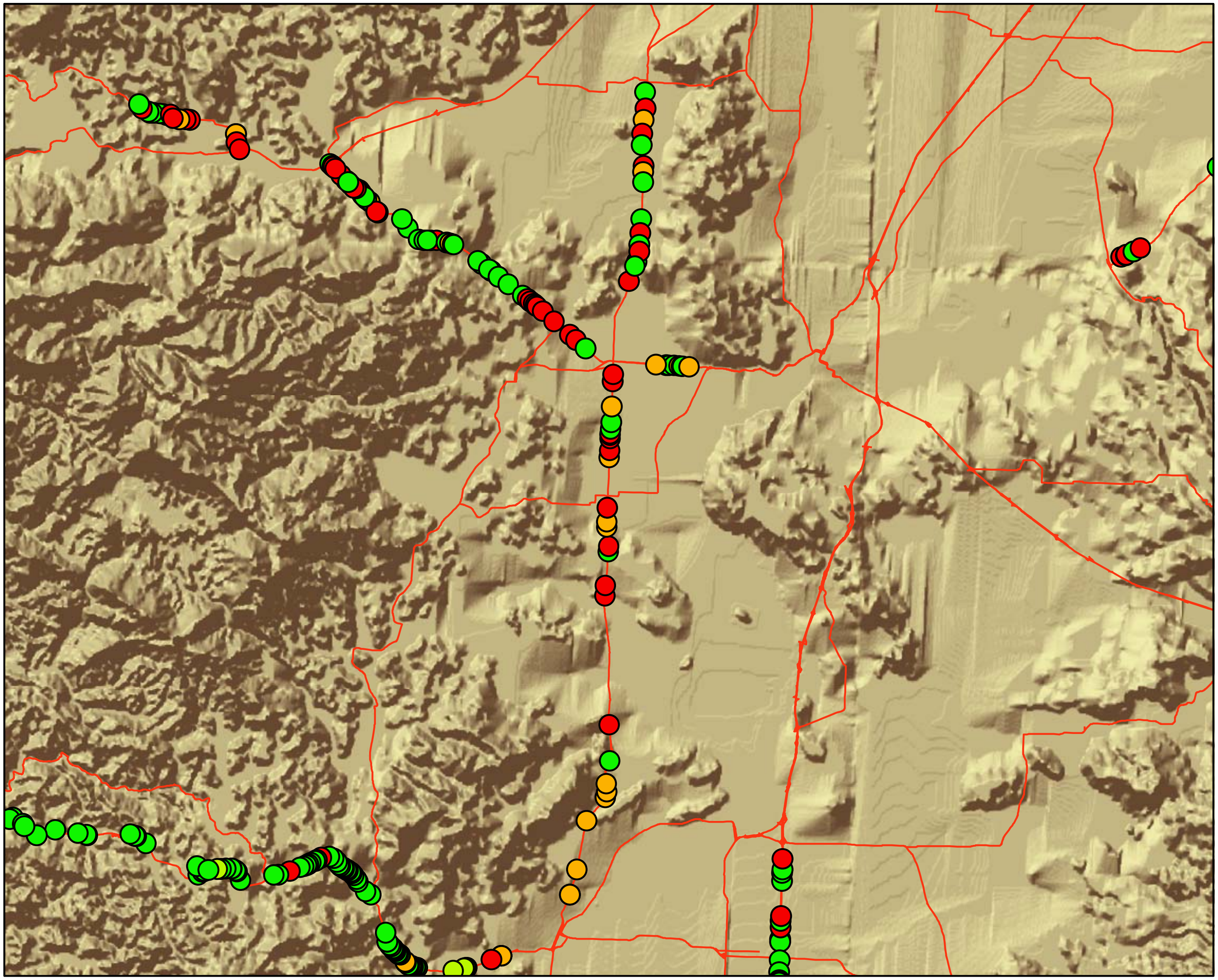

Legend

Pilot Project Inventory

Overall Condition

- Critical
- Poor
- Fair
- Good
- Highway Network

OREGON DEPARTMENT OF TRANSPORTATION

Overall Condition

Highway 091 Pilot Project inventoried culverts

Drainage Facility Management System

0 1.25 2.5 5 7.5 10 12.5

Miles

0 1.5 3 6 9

Kilometers

N

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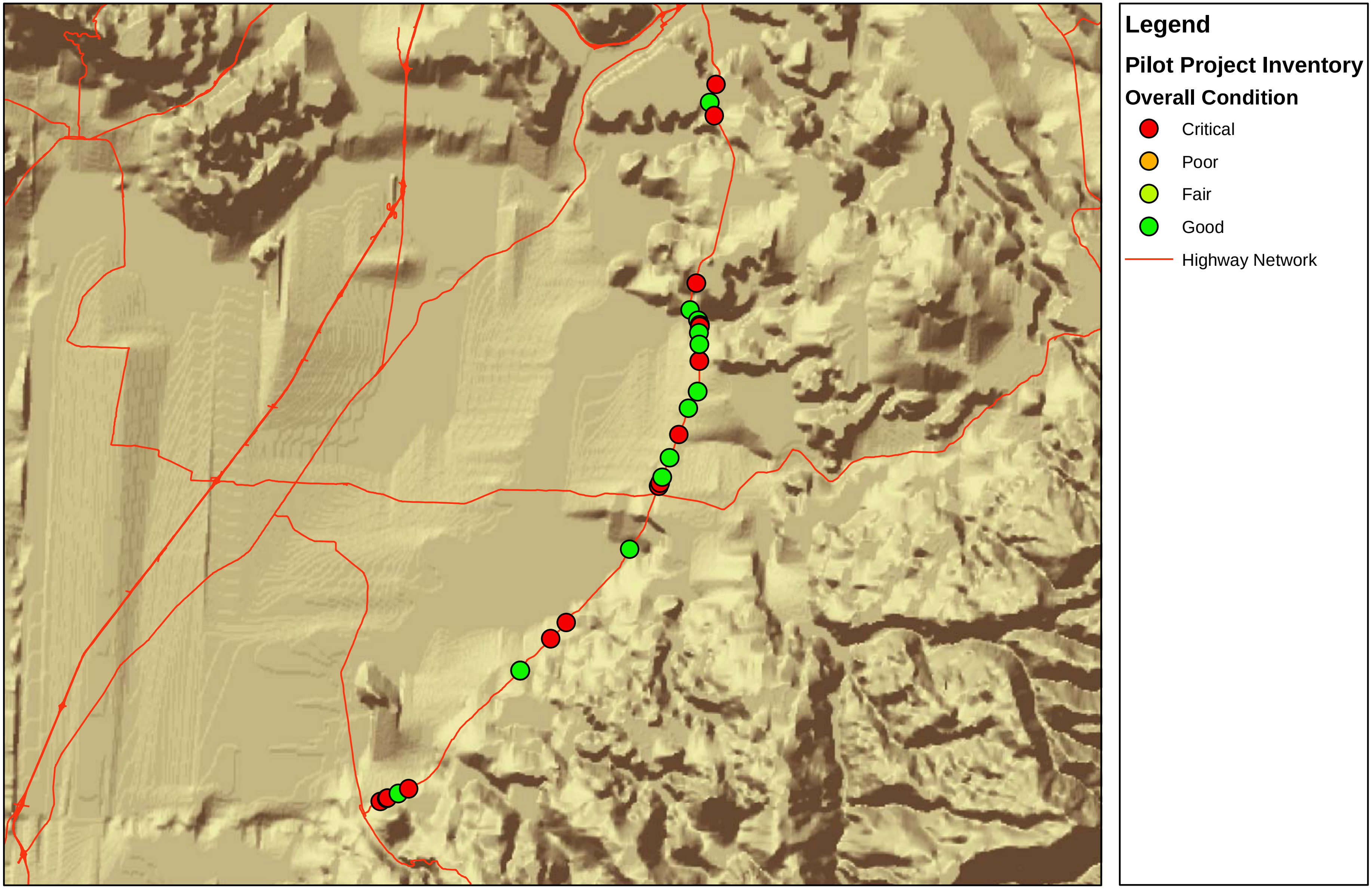

OREGON DEPARTMENT OF TRANSPORTATION

Overall Condition

Highway 160 Pilot Project inventoried culverts

Drainage Facility Management System

0 0.5 1 2 3 4 5
Miles
0 1 2 4 6
Kilometers

N

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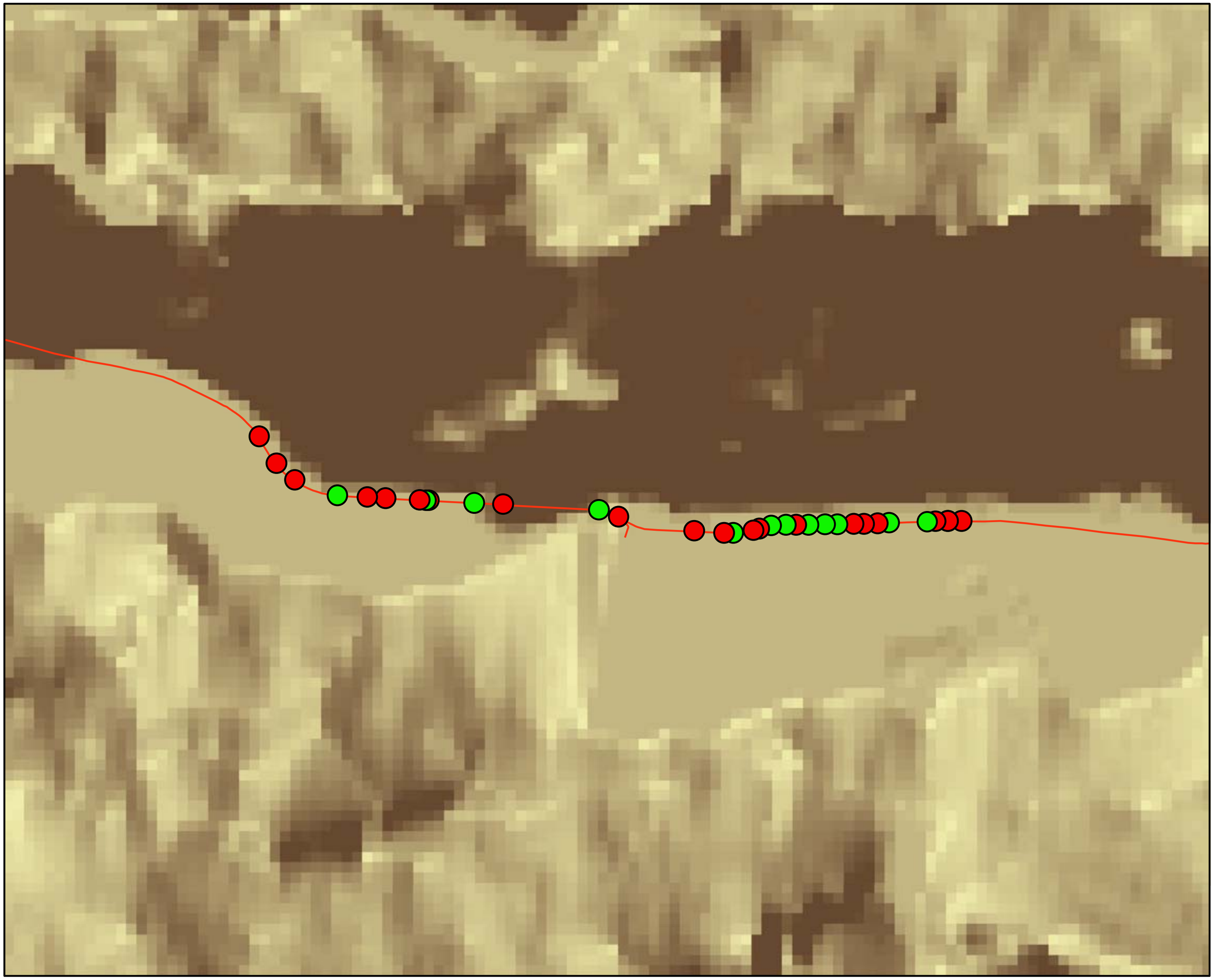


Legend

Pilot Project Inventory

Overall Condition

- Critical
- Poor
- Fair
- Good
- Highway Network

OREGON DEPARTMENT OF TRANSPORTATION

Overall Condition

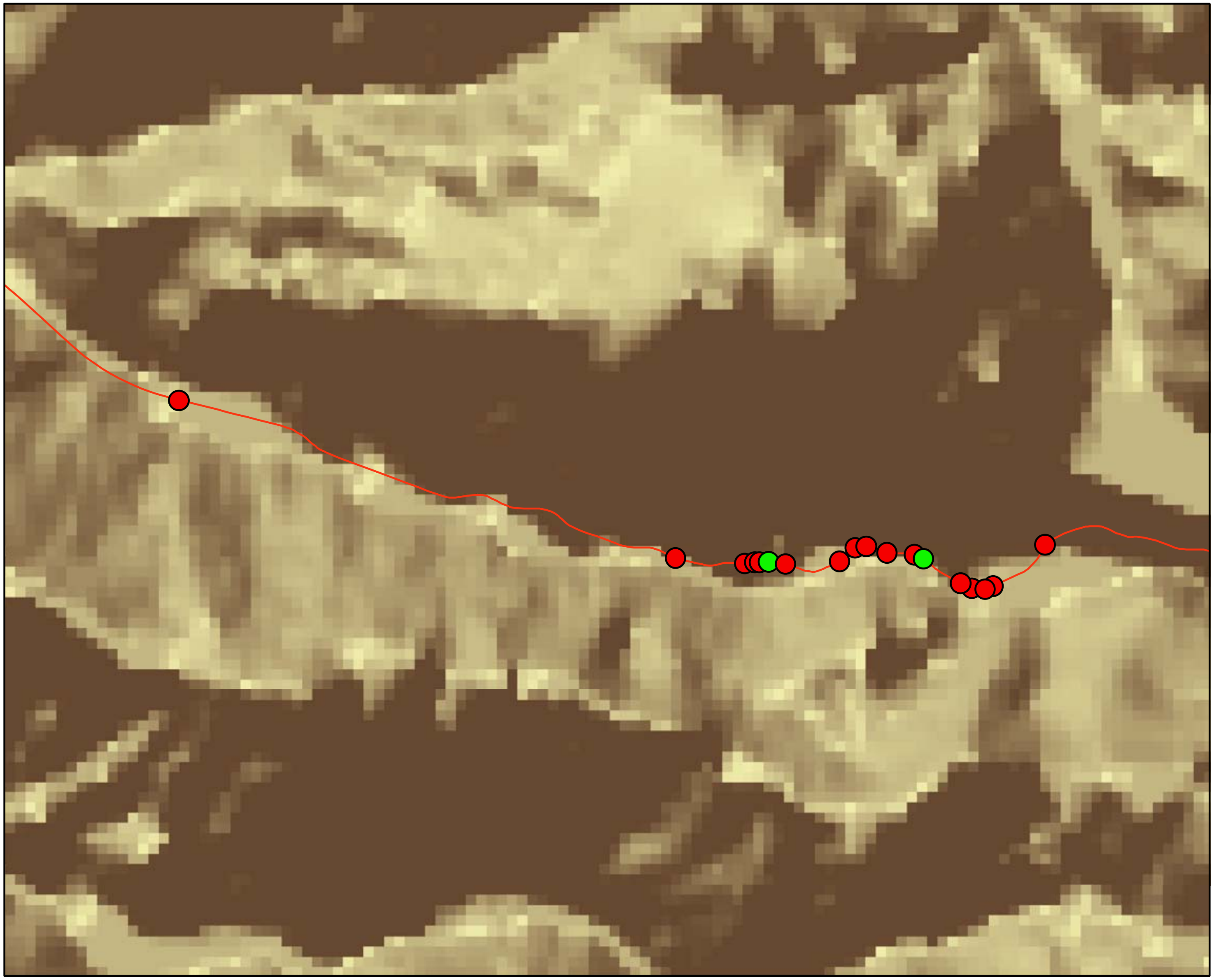
Highway 162 Pilot Project inventoried culverts

Drainage Facility Management System

0 0.15 0.3 0.6 0.9 1.2 1.5
Miles

0 0.4 0.8 1.6 2.4
Kilometers

N



Legend

Pilot Project Inventory

Overall Condition

- Critical
- Poor
- Fair
- Good
- Highway Network

OREGON DEPARTMENT OF TRANSPORTATION

Overall Condition

Highway 270 Pilot Project inventoried culverts

Drainage Facility Management System

0 0.125 0.25 0.5 0.75 1 1.25
Miles

0 0.35 0.7 1.4 2.1
Kilometers

N

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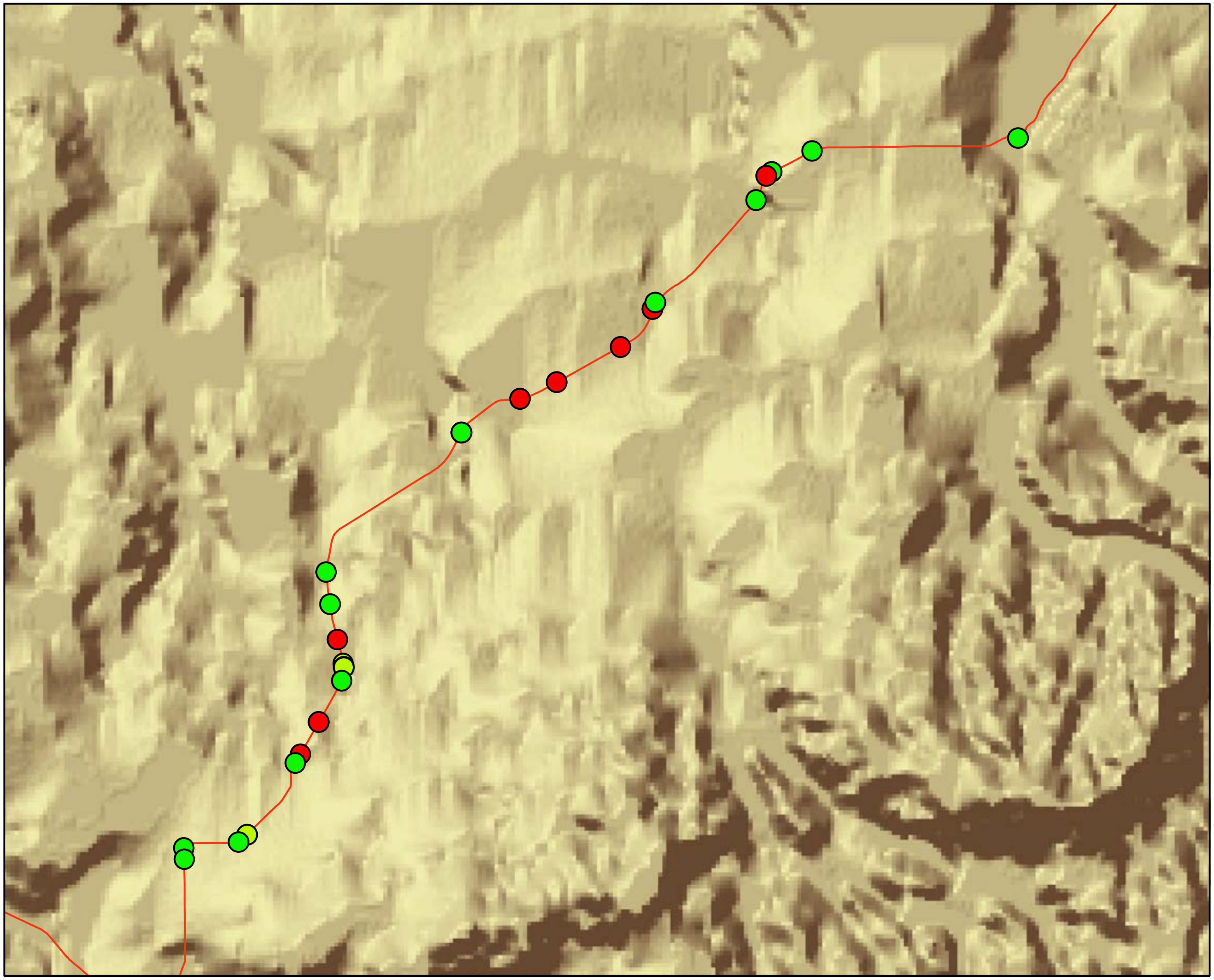

Legend

Pilot Project Inventory

Overall Condition

- Critical
- Poor
- Fair
- Good
- Highway Network

OREGON DEPARTMENT OF TRANSPORTATION

Overall Condition

Highway 320 Pilot Project inventoried culverts

Drainage Facility Management System

0 0.3 0.6 1.2 1.8 2.4 3

Miles

0 0.5 1 2 3

Kilometers

N

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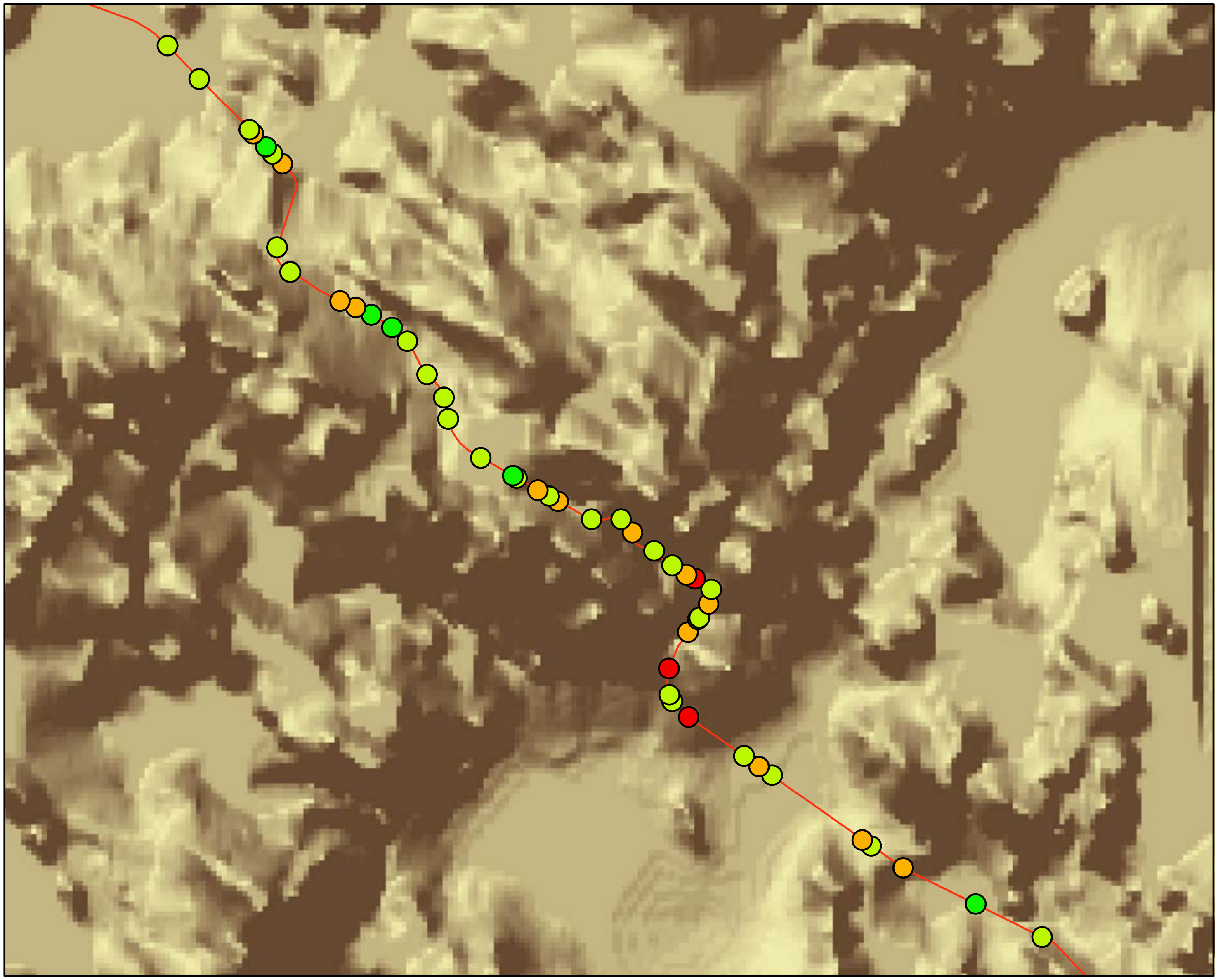

Legend

Pilot Project Inventory

Overall Condition

- Critical
- Poor
- Fair
- Good
- Highway Network

OREGON DEPARTMENT OF TRANSPORTATION

Overall Condition

Highway 442 Pilot Project inventoried culverts

Drainage Facility Management System

0 0.25 0.5 1 1.5 2 2.5
Miles

0 0.4 0.8 1.6 2.4
Kilometers

N

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