ASSESSMENT OF BURROWING MAMMAL IMPACTS ON PAVED HIGHWAYS IN MONTANA

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Final Report

prepared for
THE STATE OF MONTANA
DEPARTMENT OF TRANSPORTATION

in cooperation with
THE U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

December 2010

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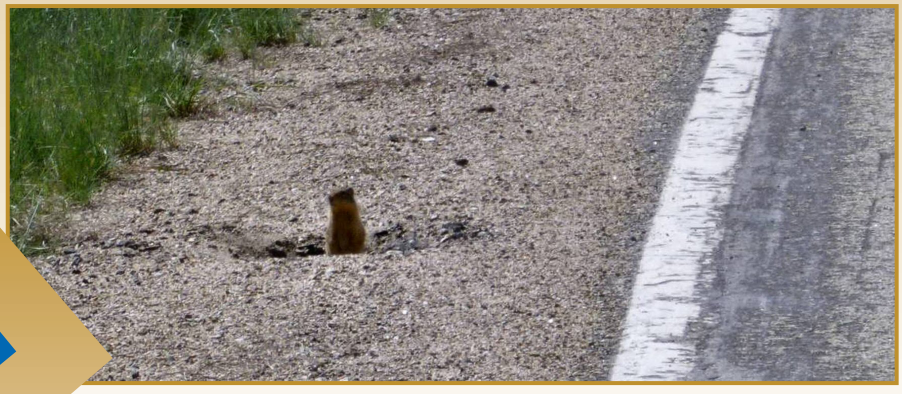

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Assessment of Burrowing Mammal Impacts on Paved Highways in Montana

Final project report

by

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16. Abstract The burrowing behavior of some rodents, insectivores, and mustelids has the potential to cause damage to paved roads or exacerbate existing deterioration. The main objective of this project was to characterize the nature and extent of burrowing mammal damage to paved roadways across Montana through 1) a targeted survey of MDT personnel, 2) follow-up interviews with a subset of survey respondents, and 3) site visits to several locations in Montana to document burrowing mammal damage to roadways. In general, the findings indicate that burrowing mammal activity does not inherently constitute a widespread maintenance problem for paved roads in Montana. However, there are localized cases where burrowing mammal activities do appear to contribute to pavement deterioration. It is recommended that MDT consider employing techniques to mitigate areas where chronic burrowing mammal activities are coincident with distresses in the pavement surface and support.			
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EXECUTIVE SUMMARY

The Montana Department of Transportation initiated an effort to assess the nature and extent of damage to paved roadways from burrowing mammals through: 1) a targeted survey of city, county, state and tribal personnel whose work is related to maintenance, inspection, management and design of paved roads in the state; 2) follow-up interviews with a subset of survey respondents who offered to be contacted for more information; and 3) site visits to 18 separate locations in Montana that are within the jurisdiction of MDT.

One hundred and forty-one of 353 survey recipients completed the survey for a response rate of 40 percent. Fifty-seven percent of all respondents indicated having observed paved roadway damage caused by burrowing mammal activity in their jurisdictions. Damage was typically limited to burrows or holes in the right-of-way or to shoulder erosion. Damage related to the paved road surface or road support was less common. Usually, such activity was noted along two-lane roads in rural grassland or ranchland settings. The species most commonly observed or suspected were ground squirrels and badgers. The predominant action taken by MDT personnel in response to such damage was to spot repair as needed, which was effective about half of the time. Most respondents disagreed with the statement that addressing burrowing-mammal-caused damage takes too much of their work time. Most respondents were neutral with regard to the issue demanding attention in the form of guidelines or funding.

Most of those interviewed indicated that they were certain they observed damage caused by burrowing mammals. Ground squirrels were the most commonly named culprit, and holes in the shoulder or right-of-way constituted the most common damage observed.

The majority of the sites visited in eastern Montana exhibited holes in the shoulder or right-of-way but actual damage to paved roads in these areas was nonexistent or minimal. Damage to the pavement substructure and road surfaces was more common in the western than in the eastern part of the state, but was still limited to relatively isolated areas. This damage was mainly from ground squirrels and badgers and was, at times, coincident with other common pavement distresses such as pavement cracking, potholes, or raveling of the pavement edges.

Burrowing mammal activity is most common along two-lane roads in rural grassland or ranchland settings but the extent of damage in these areas is primarily limited to burrows in the right-of-way. For the most part, burrowing mammal activities do not appear to have detrimental effects on the pavement surface or subsurface. The majority of the survey responses and site visits indicated that damage was limited to the presence of holes or burrows in the vegetated right-of-way with no imminent danger of severe deterioration of the pavement surface or pavement support structure.

Nevertheless, several sites in western Montana revealed how the effects of burrowing mammal activity may eventually result in damage of the pavement structure or worsen existing deterioration; however, these challenges were not widespread. In general, the findings indicated that burrowing mammal activity does not inherently constitute a widespread maintenance problem for paved roads in Montana, but spot locations that are experiencing burrowing mammal

damage are in need of solutions. It is recommended that MDT consider employing techniques to mitigate areas where chronic burrowing mammal activities are coincident with distresses in the pavement surface and support. Suggested techniques may include shoulder redesign, barriers to digging, and possibly vegetation management.

TABLE OF CONTENTS

Introduction....1
Survey and Interviews....3
Personal Experience of the Survey Respondents.... 3
Question 1—Job Responsibilities 4
Question 2—Agency and District/Jurisdiction 4
Question 3—Observation of Burrowing Mammal Damage 5
Question 4—Road Setting.... 6
Question 5—Types of Burrowing Mammal Damage 6
Question 6—Types of Roads Experiencing Burrowing Mammal Damage.... 7
Question 7—Habitat Type 8
Question 8—Soil Type.... 9
Question 9—Species Involved.... 10
Question 10—Visual Detection 10
Question 11—Period of Activity.... 11
Question 12—Respondent Action.... 11
Question 13—Repair Methods.... 13
Question 14—Mitigation Methods.... 13
Question 15— Direct Control Methods 14
Question 16—Effectiveness of Repair, Mitigation and Direct Control Methods.... 14
Question 17—Level of Burrowing Mammal Damage in Their Jurisdiction 14
Question 18—Guidance and Actions.... 14
Question 19—Other Experience with Burrowing Mammal Road Damage.... 15
Question 20—Location of Possible Sites with Burrowing Mammal Damage.... 15
Question 21—Contact Information.... 15
Telephone Interviews.... 16
Interview Question 1 16
Interview Question 2 16
Interview Question 3 16
Interview Question 4 16
Interview Question 5 17
Interview Question 6 17
Interview Question 7 17
Interview Question 8 17
Site Visits....18
Site No. 1—Interstate 90 near Greycliff 19

Site No. 2—Montana Highway 3 near Billings 20
Site No. 3—Interstate 90 Frontage Road near Hardin 21
Site No. 4—Interstate 90 near Hardin 22
Site No. 5—Secondary Highway 253 near Terry 23
Site No. 6—Montana Highway 59 South of Jordan 24
Site No. 7—Montana Highway 200 East of Grass Range 25
Site No. 8—US Highway 191 near Roy 26
Site No. 9—Interstate 90 near Cardwell 27
Site No. 10—Montana Highway 55 South of Whitehall 28
Site No. 11—Montana Highway 84 near Norris 29
Site No. 12—Interstate 15 Frontage Road near Dillon 30
Site No. 13—Montana Highway 43 near Wisdom 31
Site No. 14—Montana Highway 43 near Wisdom 32
Site No. 15—Secondary Highway 278 near Wisdom 33
Site No. 16—Montana Highway 1 near Anaconda 34
Site No. 17—Secondary Highway 348 near Philipsburg 35
Site No. 18—Secondary Highway 348 near Philipsburg 36
Summary and Conclusions 39
Summary of Survey 39
Summary of Interviews 39
Summary of Site Visits 39
Conclusions 40
References 42
Appendix A – Survey 43
Appendix B – Question 19 Open-Ended Comments 53
Appendix C – Interviewer Language 56
Appendix D – Interviewee Closing Remarks 58
Appendix E – Site Visit Checklist 61

LIST OF TABLES

Table 1. Distribution of Survey Invitees 3
Table 2. Affiliations of Survey Respondents 5
Table 3. Summary of Responses to Statements in Question 18. 15
Table 4. Summary of Damage Conditions Associated with Various Species of Burrowing Mammals 17
Table 5. Summary of Site Visits in Eastern Montana 37
Table 6. Summary of Site Visits in Western Montana 38

LIST OF FIGURES

Figure 1. Respondent work responsibilities with regard to paved roads. 4
Figure 2. Observation of burrowing-mammal-caused roadway damage. 5
Figure 3. Types of roads on which respondents typically work. 6
Figure 4. Types of burrowing mammal damage observed. 7
Figure 5. Type of roads with damage from burrowing mammal activity. 8
Figure 6. Habitat type associated with burrowing mammal activity. 9
Figure 7. Soil type associated with burrowing mammal activity 9
Figure 8. Species suspected to be involved with observed roadway damage. 10
Figure 9. Time of year respondents observed active burrowing mammal damage. 11
Figure 10. Typical action taken by respondents when they witness burrowing mammal damage. 12
Figure 11. Survey logic for questions 12 through 21 12
Figure 12. Typical methods of repairing burrowing mammal damage. 13
Figure 13. Map of Montana showing location of site visits. 18
Figure 14. Photos of Site 1: a) burrows near shoulder, b) burrows in right-of-way, c) burrow at base of shoulder, and d) burrow near sign post. 19
Figure 15. Photos of Site 2: a) abandoned burrow in shoulder, b) abandoned burrow covered with vegetation near shoulder, c) general layout and condition of roadway, and d) adjacent landscape. 20
Figure 16. Photos of Site 3: a) adjacent prairie dog town, b) abandoned burrow in right-of-way, c) reestablishment of vegetation near abandoned burrow, and d) exposed earth in right-of-way from burrowing activity. 21
Figure 17. Photos of Site 4: a) prairie dog mound, b) longitudinal view of roadway, c) reestablishment of vegetation near abandoned burrow showing outline of new growth area, and d) mottled landscape from burrowing mammal activity. 22
Figure 18. Photos of Site 5: a) low area in pavement, b) pocket gopher activity near shoulder, c) pocket gopher activity in right-of-way, and d) longitudinal view of roadway. 23

Figure 19. Photos of Site 6: a) longitudinal view of roadway, b) pocket gopher activity near road edge, c) pocket gopher activity near shoulder, and d) pavement distresses on shoulder. 24
Figure 20. Photos of Site 7: a) beaver dam below bridge, b) longitudinal view of roadway with beaver dam, c) view of beaver dam above bridge, and d) closer view of beaver dam above bridge. 25
Figure 21. Photos of Site 8: a) beaver dam above large culvert, b) beaver dam below culvert, c) culvert blocked from beaver activity, and d) longitudinal view of roadway near active beaver areas..... 26
Figure 22. Photos of Site 9: a) badger mound on embankment, b) badger mound on embankment, c) reestablishment of vegetation near badger hole, and d) longitudinal view of roadway..... 27
Figure 23. Photos of Site 10: a) ground squirrel mounds in right-of-way, b) longitudinal view of roadway, and c) longitudinal view of right-of-way. 28
Figure 24. Photos of Site 11: a) stream migration toward roadway, b) close-up of embankment erosion, c) longitudinal view of right-of-way adjacent to stream, and d) channel migration. 29
Figure 25. Photos of Site 12: a) pavement damage adjacent to ground squirrel activity, b) mounds in right-of-way, c) deterioration of pavement edge, d) mounds on shoulder, e) badger mound, and f) longitudinal view of roadway. 30
Figure 26. Photos of Site 13: a) transverse cracking in pavement coincident with ground squirrel activity, b) burrow in right-of-way, c) burrow under pavement, d) depth of burrow under pavement, e) ground squirrel near road edge, and f) longitudinal view of roadway..... 31
Figure 27. Photos of Site 14: a) transverse cracking in pavement coincident with ground squirrel activity, b) subsidence of paved shoulder near old burrow, c) badger burrow in right-of-way, and d) longitudinal view of roadway. 32
Figure 28. Photos of Site 15: a) burrow activity in right-of-way, b) ground squirrel burrow near shoulder, c) badger burrow near edge of road, and d) burrows near road sign. 33
Figure 29. Photos of Site 16: a) longitudinal view of embankment and roadway, b) small burrows on embankment, c) burrow near guardrail, and d) erosion of embankment from runoff water..... 34
Figure 30. Photos of Site 17: a) active ground squirrel burrow near roadway, b) burrow in right-of-way, c) badger burrow in right-of-way, and d) ground squirrel burrow under roadway. 35
Figure 31. Photos of Site 18: a) longitudinal view of roadway showing new pavement, and b) erosion of right-of-way from creek overflow. 36

INTRODUCTION

The burrowing activity of mammals within the highway right-of-way may result in infrastructure damage, which consequently may lead to increased maintenance costs, decreased level of service, and unsafe driving conditions. Potential types of damage may range from merely aesthetic to shoulder erosion and the undermining of structural fill, which could make the pavement subsurface vulnerable to water infiltration and premature failure. In 2004, the Federal Highway Administration (FHWA) and Texas Department of Transportation (TXDOT) sponsored a study of best management practices of pavement edge maintenance. The report listed rodents as one of the many factors that cause pavement edge drop-offs. Lawson and Hossain (2004) quoted an adage by Tracy Cumby of TXDOT, which they refer to as Tracy's law—"If you lose the edge, you lose the road"—to highlight the significance of road-edge maintenance.

The Montana Department of Transportation (MDT) conducted a burrowing mammal impact survey of departments of transportation (DOTs) in the United States and Canada in 2008. Approximately half of the 19 survey respondents experienced burrowing mammal damage problems. Internally, the MDT received enough feedback from its maintenance personnel about suspected burrowing mammal damage to pavement and shoulders in Montana to launch a statewide assessment of this maintenance issue.

The burrowing behavior of some rodents (e.g., ground squirrels and voles), insectivores (e.g., moles), and mustelids (e.g., badgers) has the potential to cause damage to roads or to exacerbate deterioration already taking place. In Montana, there are several burrowing mammal species that may be involved in roadbed damage under relatively dry conditions, including the Idaho pocket gopher (*Thomomys idahoensis*), northern pocket gopher (*Thomomys talpoides*), several vole species (*Microtus*, *Clethrionomys* and *Lemmiscus* spp.), Uinta ground squirrel (*Spermophilus armatus*), Columbian ground squirrel (*Spermophilus columbianus*), Wyoming ground squirrel (*Spermophilus elegans*), Richardson's ground squirrel (*Spermophilus richardsonii*), thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*), black-tailed prairie dog (*Cynomys ludoviscianus*), yellow-bellied marmot (*Marmota flaviventris*), and badger (*Taxidea taxus*). While moles are often named as culprits, the Family *Talpidae* has never been documented in the state of Montana (Foresman 2001; DuBois, 2010). Although not typically considered burrowing mammals, the habits of wetland-adapted species such as beaver (*Castor Canadensis*) and muskrat (*Ondatra zibethicus*) can also pose problems with roadbeds located near water features.

The first step to address burrowing mammal impacts to Montana's paved roads was to gather more information about the species involved, the road types and conditions that may lead to habitation and burrowing activity, and the types of damage present. As such, the main objective of this project was to characterize the nature and extent of burrowing mammal damage to paved roadways across Montana.

This objective was realized by:

- creating and distributing a survey to MDT Maintenance Section Supervisors and other transportation, municipal and natural resource agencies regarding their

experience with burrowing mammal damage to paved roadways (i.e., nature of damage, species involved, approaches to mitigation);

- conducting telephone interviews with individuals identified through the survey who offered to share their experiences with burrowing mammal impacts to roadways; and
- performing site inspections at selected locations in Montana to better understand the relationship between burrowing mammal activity and paved road damage.

SURVEY AND INTERVIEWS

Survey language was developed with input from the project's technical panel. The survey (Appendix A) was made available via www.surveymonkey.com from March 16 to April 9, 2010. An email invitation was distributed to 353 transportation-related personnel at MDT, Montana State Parks, municipalities, counties and tribes, as outlined in Table 1. Originally, airport personnel were included in the target audience but they were not contacted per MDT's recommendation. The cooperation from MDT, Local Technical Assistance Program (LTAP), Tribal Technical Assistance Program (TTAP), Montana League of Cities and Towns, and Montana Fish, Wildlife and Parks was instrumental in this distribution effort. A reminder email was sent on/around March 25, 2010, in an attempt to increase the response rate. One hundred and forty-one people out of 353 completed the survey for a response rate of 40 percent. Respondents had the option of not responding to any question on the survey. Percentages are based on total responses obtained for each question, as opposed to the total number of survey respondents, thereby eliminating the need for an "unknown" or "no response" category for each question.

Table 1. Distribution of Survey Invitees

Target Audience Groups	Number of Contacts
MDT Section Supervisors	100
County Supervisors and Foremen	97
City and Town Managers	58
Public Works Personnel	79
Tribal Transportation Managers	7
Regional Park Managers or Maintenance Supervisors	12
Total	353

The survey queried participants about their roles and affiliations, the setting and type of any observed damage, species involved, actions taken to address burrowing-mammal-related damage, and opinions about the issue. Participation in the survey was voluntary and anonymous; however, respondents could choose to identify themselves for the purposes of sharing information. Supplementary phone interviews were conducted with those survey respondents who offered to be contacted for more information.

For the purposes of this study, the area of interest included the entire right-of-way, but predominantly focused on the paved roadways and shoulders up to and including the toe of the slope. The majority of burrowing-mammal-caused roadway damage described in this report was burrows, holes or mounds in the shoulders along paved roadways rather than damage to the paved surface itself.

Personal Experience of the Survey Respondents

The first 12 questions on the survey asked participants questions about their job responsibilities, types of roads they typically work with, and their experience with burrowing mammals near the

road. The following subsections summarize the responses to each of these questions using basic summary statistics.

Question 1—Job Responsibilities

The first question on the survey asked participants to select which responsibilities they have as part of their work. Respondents were able to select more than one response to the question. Percent response is calculated based on the total number of respondents "*n*" who answered the question (in this case *n*=155 as indicated in Figure 1). Most respondents indicated that they are responsible for maintaining/repairing, inspecting, and/or managing rather than designing paved roads in the course of their work (Figure 1).

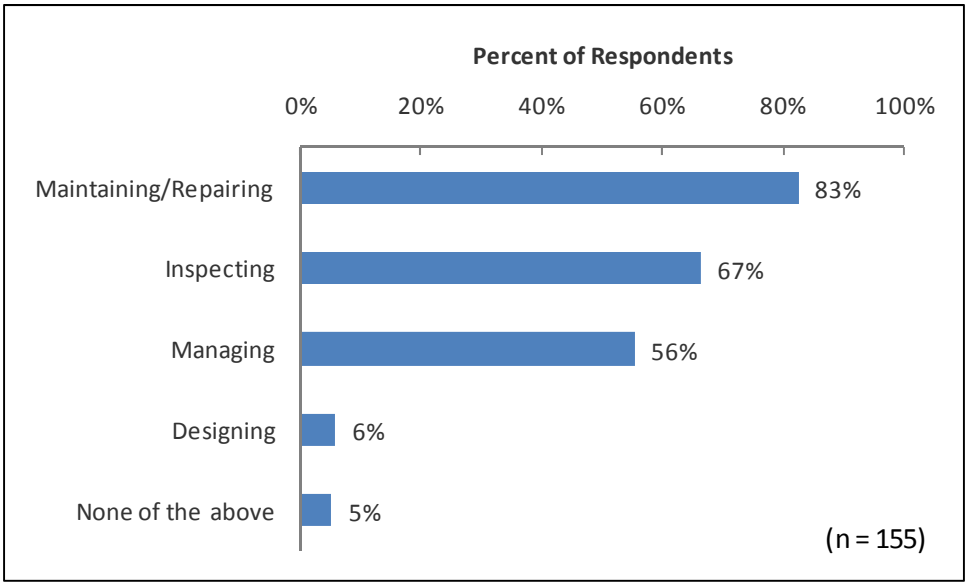


Figure 1. Respondent work responsibilities with regard to paved roads.

Question 2—Agency and District/Jurisdiction

The second question on the survey asked survey participants to provide their agency and/or district/jurisdiction. Since this question was open-ended, it was not possible to determine from the responses the exact affiliation of every respondent. A summary of the affiliations of the survey participants is provided in Table 2.

Table 2. Affiliations of Survey Respondents

Affiliation	Approx. Number of Respondents
Federal Highway Administration (Montana)	1
Montana Department of Transportation	78
State Park	7
County	7
City or Town	15
Unable to be determined	33
Total	141

Question 3—Observation of Burrowing Mammal Damage

When asked whether the survey participants have noticed burrowing-mammal-caused damage to paved roadways, including shoulders up to and including the toe of the slope, and other paved surfaces during the course of their work, more than half responded affirmatively (Figure 2—note: the total is more than 100 percent due to rounding).

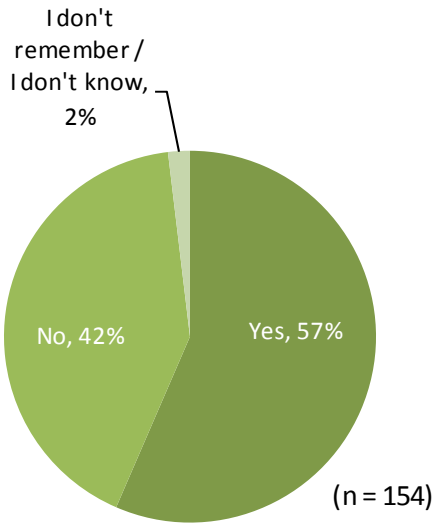


Figure 2. Observation of burrowing-mammal-caused roadway damage.

The survey was designed to skip questions 4 through 16 if the participant answered negatively to Question 3, i.e., not having noticed burrowing-mammal-caused pavement damage. Otherwise, participants would continue through the survey. Sixty-four respondents (42 percent of those who answered this question) indicated that they had not noticed burrowing-mammal-caused damage to roadways and were, therefore, directed to the opinion-based and follow-up questions near the end of the survey (questions 17 through 21).

Question 4—Road Setting

To further understand the setting of the roads on which survey respondents typically work, survey participants were given three choices from which to select: mostly rural, rural/urban interface, and mostly urban. More than half of the respondents indicated they typically work on rural roads (Figure 3).

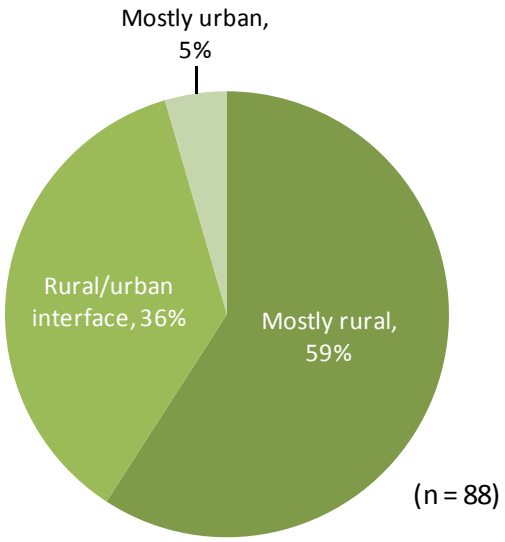


Figure 3. Types of roads on which respondents typically work.

Question 5—Types of Burrowing Mammal Damage

Survey participants were asked to select from a list of burrowing mammal damage types that they have observed on paved roads. The top three responses related to obvious burrowing mammal activity in the right-of-way, shoulder erosion, and obvious activity affecting the road surface or shoulder. To a lesser degree, respondents reported observing poor drainage, premature pavement failure, and paved road surface deterioration (Figure 4). Respondents were asked to select all that apply. Those who selected the "other" category for this question stated the following types of damage.

- Settlement of pavement due to burrowing away subgrade material under the asphalt
- Most of my problem is due to beavers blocking culverts

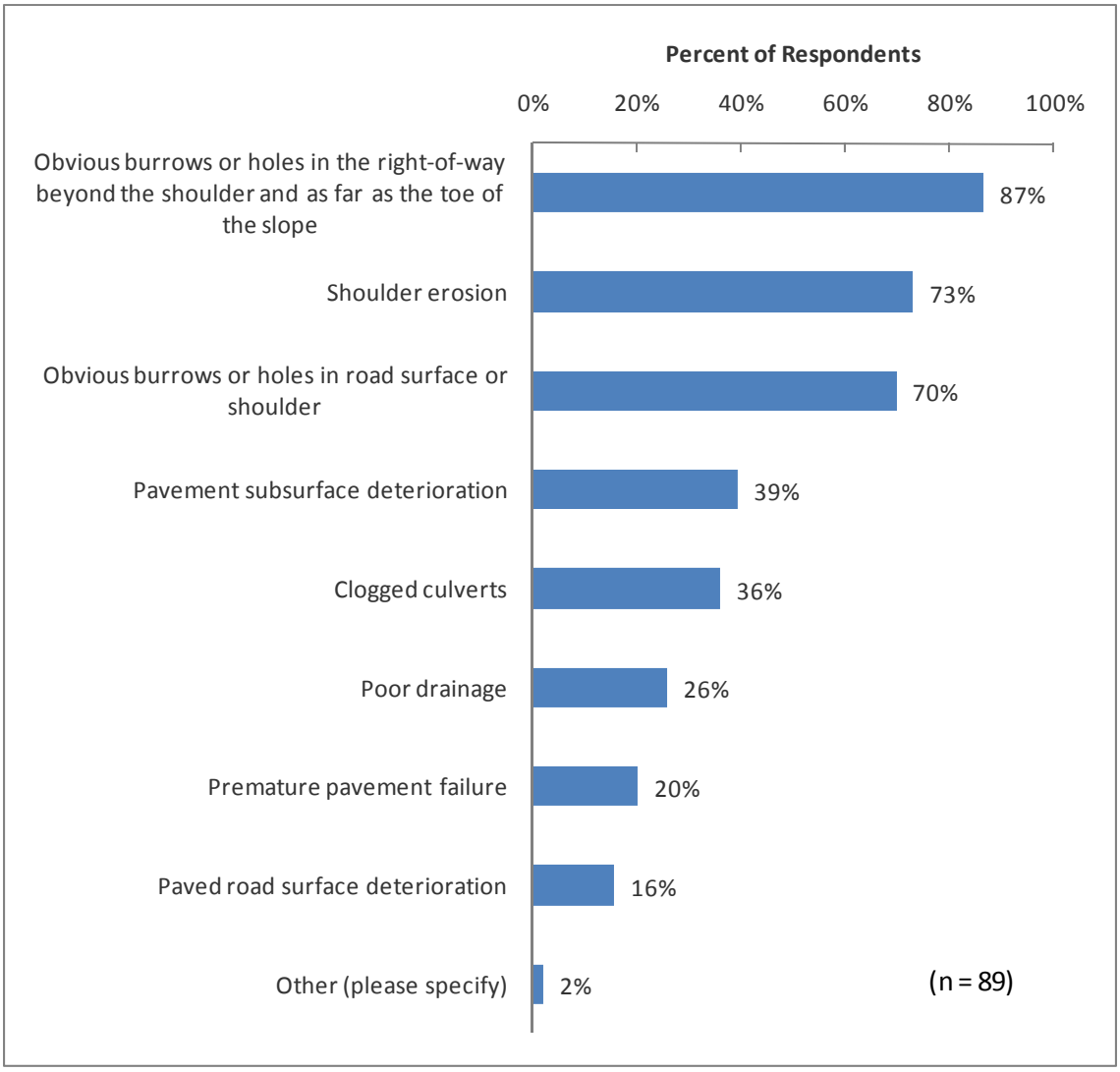


Figure 4. Types of burrowing mammal damage observed.

Question 6—Types of Roads Experiencing Burrowing Mammal Damage

Survey participants were given seven choices from which they could select one or more responses regarding the types of roads on which they have observed burrowing mammal damage. Respondents indicated that two-lane roads and interstate highways in rural areas are the road types most commonly affected by burrowing mammal activity (Figure 5). Those who selected the "other" category for this question added the following information related to the types of roads that experience burrowing mammal damage.

- Road is already in poor condition due to other non-burrowing animal reasons
- Paved walking trails

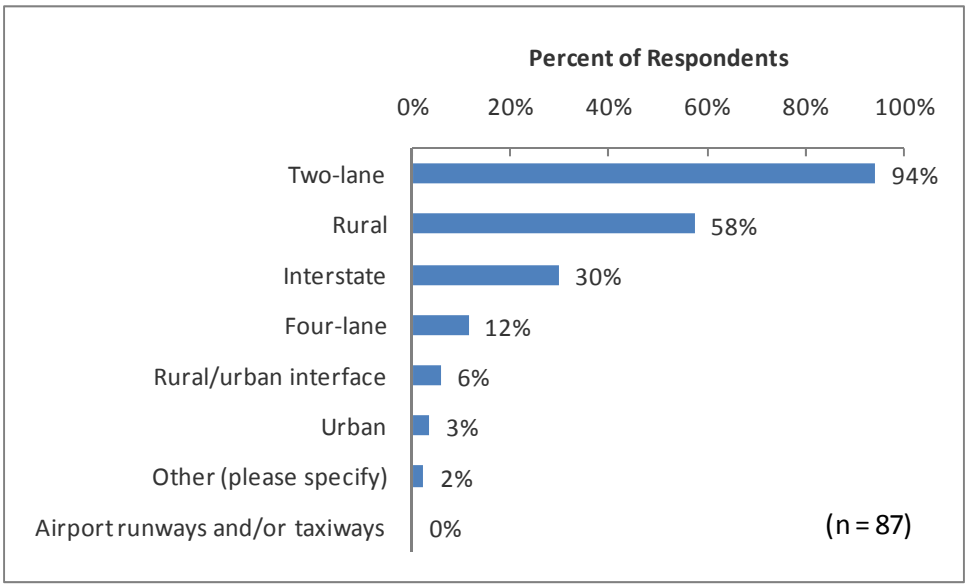


Figure 5. Type of roads with damage from burrowing mammal activity.

Question 7—Habitat Type

When asked in what type of habitat they have noticed burrowing mammal damage, respondents indicated that grasslands, ranchlands, and tilled farmland are the habitat/land use type most commonly affected by burrowing mammal activity (Figure 6). Respondents were asked to select all that apply. Those who selected the "other" category for this question (six respondents) stated that wetlands or water-related areas are additional types of habitat that experience burrowing mammal damage. Actual responses (unedited) are listed below.

- Riparian
- Water way
- Wetland areas immediately adjacent to right-of-way
- At the edge of the pavement and by culverts
- Wetland
- Where water is close to the road

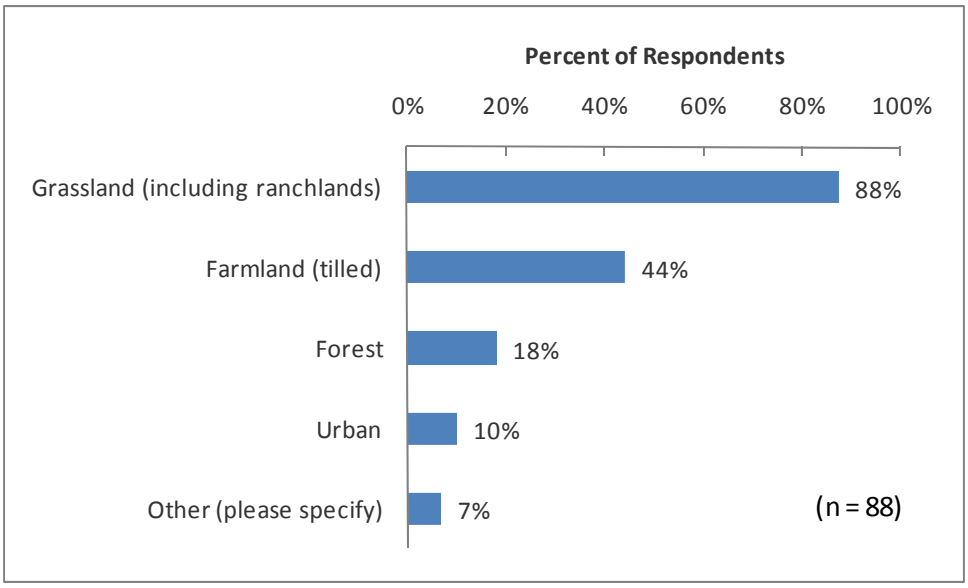


Figure 6. Habitat type associated with burrowing mammal activity.

Question 8—Soil Type

Survey participants were asked to select one or more of five soil types where they witnessed burrowing mammal damage. An additional category was offered to those participants who could not recall or did not know the type of soil associated with burrowing mammal damage. Overall, respondents indicated that sandy and clayey soil types are the most commonly affected by burrowing mammal activity; the soil types least affected were high lime silts and those with high iron content (Figure 7).

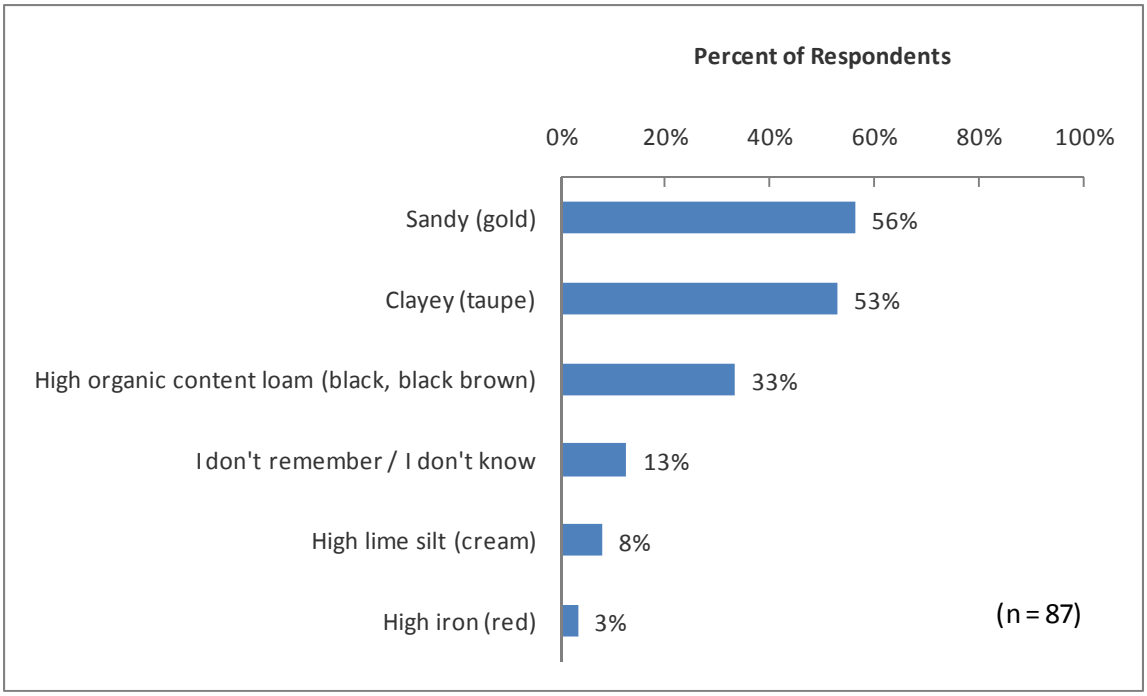


Figure 7. Soil type associated with burrowing mammal activity.

Question 9—Species Involved

Respondents were asked to select one or more of the six mammal species that are suspected to be involved with burrowing mammal damage to roadways. Survey participants most commonly suspected ground squirrels and badgers were involved with damage observed on or adjacent to paved roads (Figure 8). Voles and marmots were suspected the least. This question did not allow for "other" entries; however, responses to later questions and the follow-up interviews revealed that beaver and muskrat activity (although not typically considered burrowing mammals) were also thought to be involved with damage observed on paved roadways.

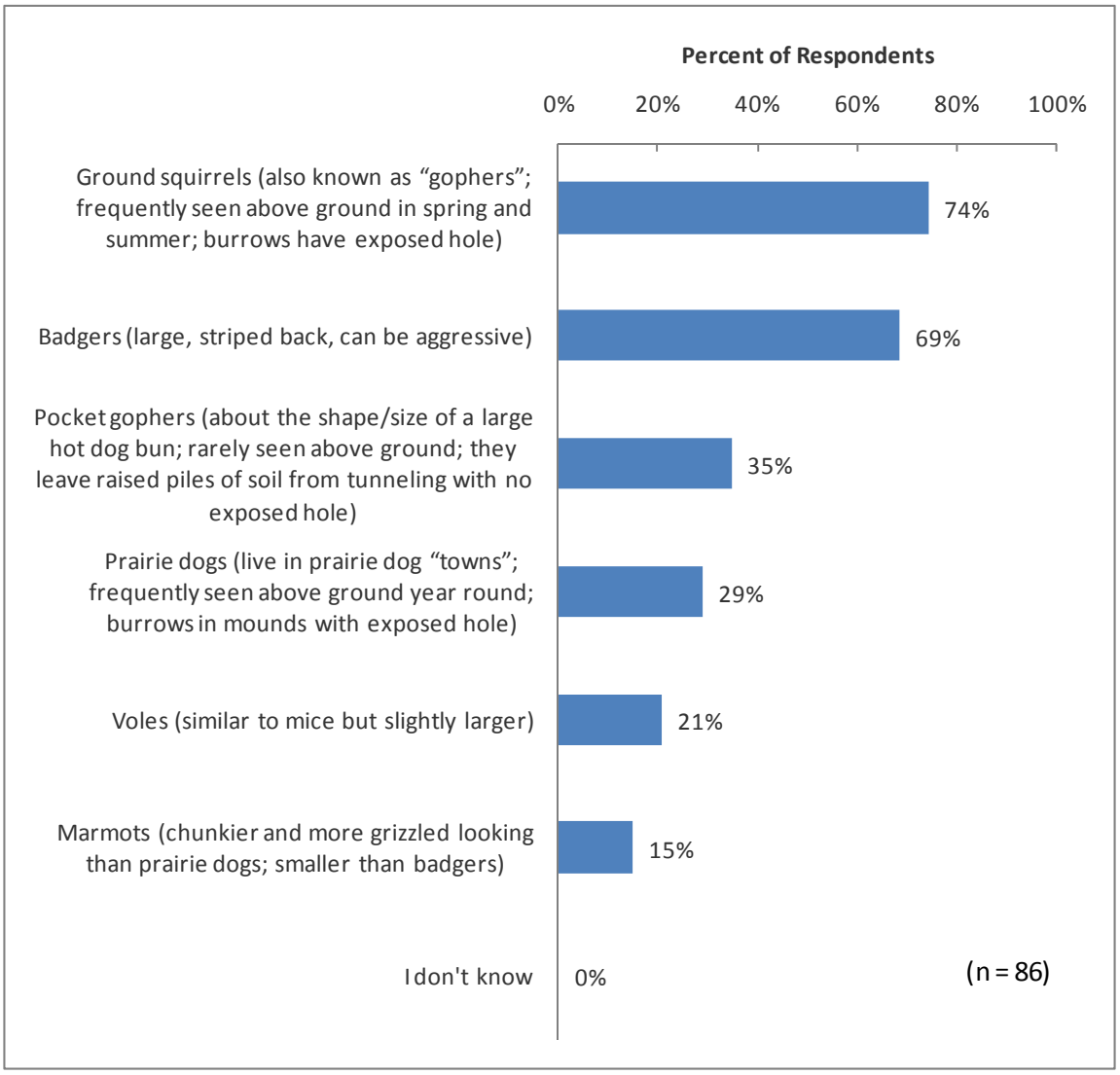


Figure 8. Species suspected to be involved with observed roadway damage.

Question 10—Visual Detection

Survey participants were asked whether they had actually seen the burrowing mammals suspected of having caused the damage to the roadway. Ninety two percent of the respondents (79 out of 86) responded affirmatively.

Question 11—Period of Activity

The most common time of year that survey respondents indicated they had observed active burrowing-mammal-caused damage to paved roadways was from February to August (Figure 9). This is consistent with the active period of species that hibernate during the remainder of the year (e.g., ground squirrels), but activity of some species can be observed all year long. Respondents were able to select one or more responses to this question.

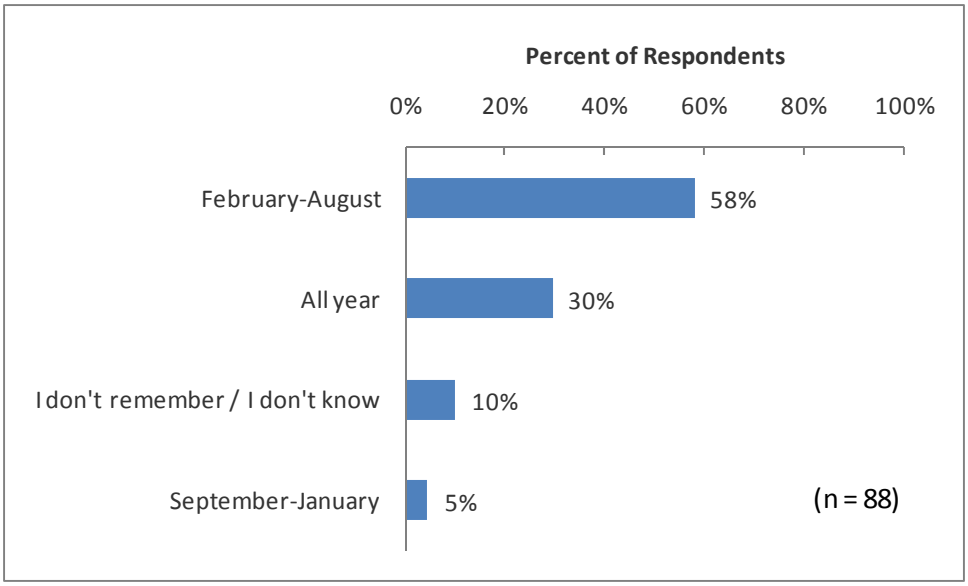


Figure 9. Time of year respondents observed active burrowing mammal damage.

Question 12—Respondent Action

Survey participants were asked to select which action best describes what they do when confronted with burrowing mammal damage. Of the nine options provided (Figure 10), most respondents (53 percent) indicated that they spot repair the affected areas. An additional 14 percent indicated that they employ some sort of mitigation technique to remedy the problem, and 21 percent indicated that they do nothing either because the problem is minimal, there is no guidance, or the problem is too widespread (n=88). Those who selected the "other" category for this question (five respondents) reported taking the following actions.

- I will clear culverts after informing environmental
- Informed supervisors of potential problems
- Usually shoulder damage—nothing needed for repair
- Notify game warden
- Nothing because the Landowner on the other side of the right-of-way fence does nothing.

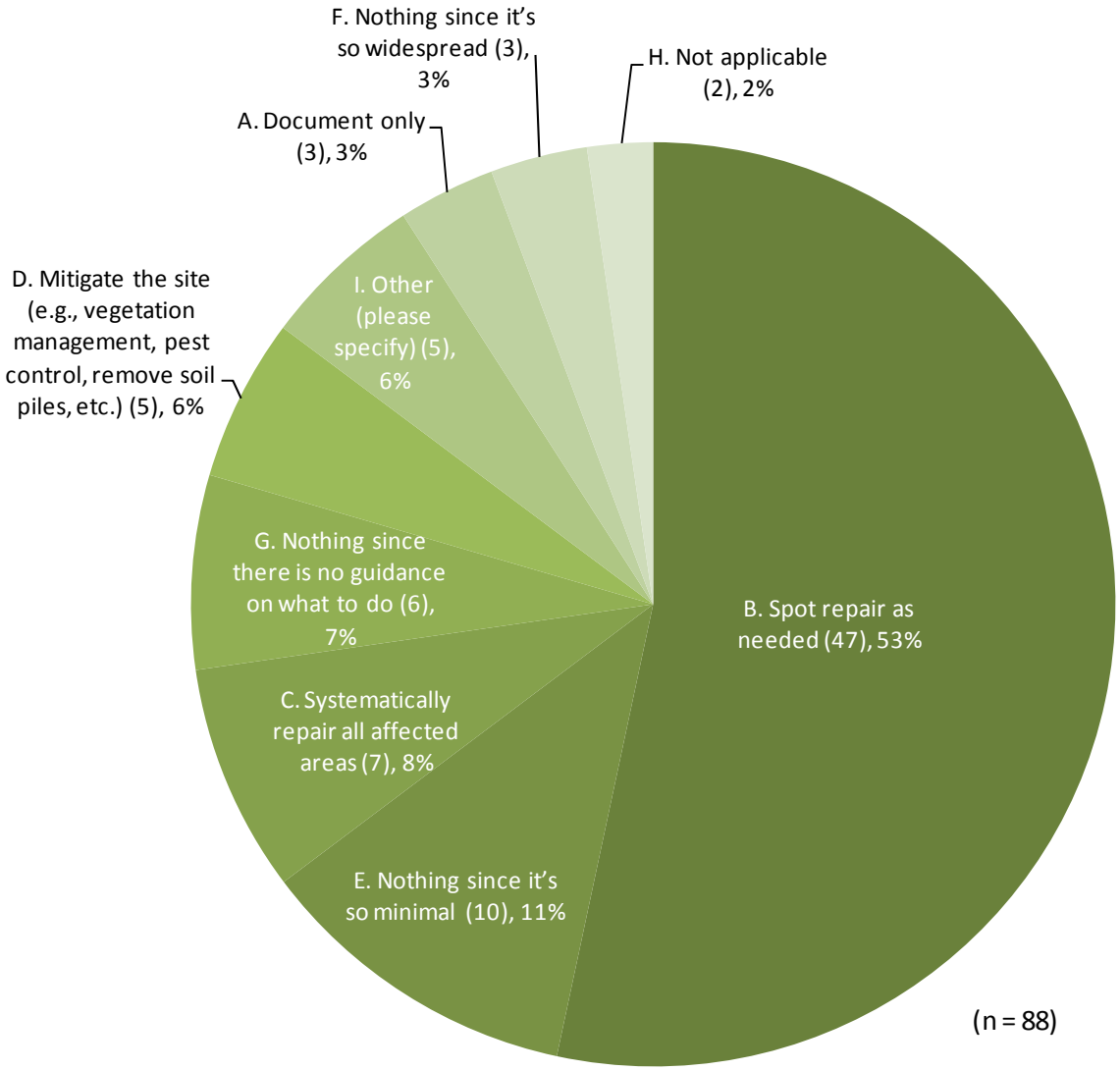


Figure 10. Typical action taken by respondents when they witness burrowing mammal damage.

Participation in specific questions during the remainder of the survey depended on participant responses beginning with Questions 12. The logic associated with Questions 12 through 21 is illustrated in Figure 11.

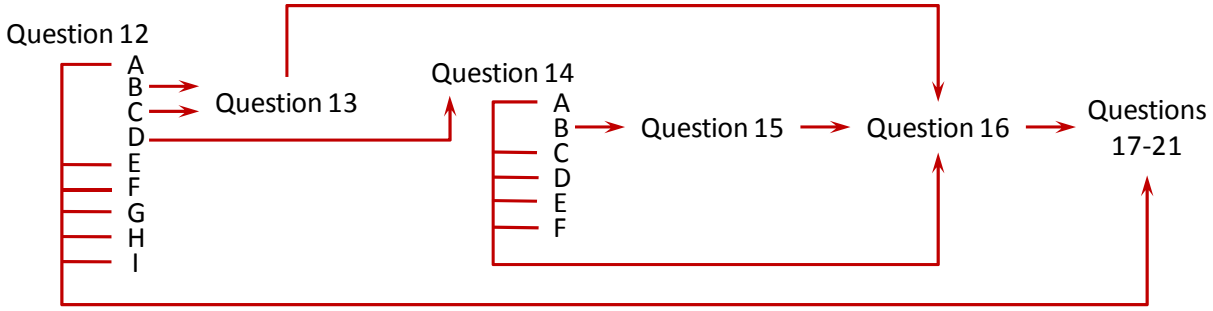


Figure 11. Survey logic for questions 12 through 21.

Question 13—Repair Methods

Fifty-three out of the 88 survey participants who answered question 12 indicated that they typically repair burrowing-mammal-caused damage when they see it, and were directed to Question 13, which asked about specific methods used to repair burrowing mammal damage. Survey respondents were able to select more than one response to this question. The most common methods of repair included stabilizing the pavement and/or shoulder and patching the pavement (Figure 12). Restoring the base or replacing the pavement was used to a lesser extent. Four respondents selected the "other" category for this question as listed below.

- Whatever is needed
- Fill holes in ditch, have not seen any damage to pavement as of yet
- Fill and compact hole
- We have tried to patch the holes in the shoulder with dirt, asphalt millings, and gravel chips

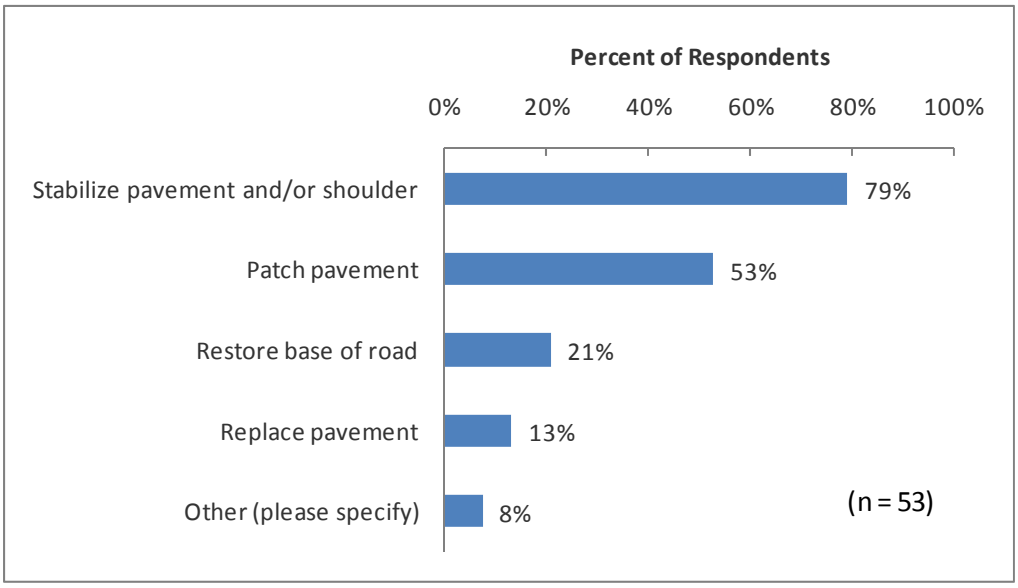


Figure 12. Typical methods of repairing burrowing mammal damage.

Question 14—Mitigation Methods

Five respondents indicated in Question 12 they typically mitigate the site in some way, although only four of those five completed Question 14. Survey participants were able to select more than one response to this question. Three of the four respondents indicated they manage vegetation to make it less attractive to the animals. Two respondents indicated they perform direct pest control, thereby leading them to Question 15. None of the respondents indicated they remove soil piles that may attract animals, install digging barriers on or beneath the shoulder material, or fill in tunnels, burrows, and/or animal holes. A single respondent indicated, using the "other" option, that they repair the road surface and subgrade.

Question 15— Direct Control Methods

Only one of the two respondents who indicated they perform direct pest control in Question 14, responded to Question 15. This respondent indicated he/she traps and shoots to directly control burrowing mammals but does not fumigate or apply poison baits.

Question 16—Effectiveness of Repair, Mitigation and Direct Control Methods

Questions 16, 17 and 18 utilized rated responses to assess respondents' opinions regarding a particular topic. The nature of ordinal scales allows conclusions to be drawn on a relative basis only. Differences between response values cannot be quantified because each respondent's assessment of the intervals between the response categories will vary. In general, results from these questions are qualitative and are intended to make general observations about the topics of interest. To analyze the ordinal (i.e., scaled) responses, numerical values were assigned to each of the five response categories.

Survey participants who answered Questions 13, 14, or 15 were directed to this question to determine their opinion about the effectiveness of repair, mitigation, and direct pest control methods, respectively, that they have employed. For purposes of analysis, the "completely ineffective" response was assigned a value of 1, the "mostly ineffective" response was assigned a value of 2, the "works half the time" response was assigned a value of 3, the "mostly effective" response was assigned a value of 4, and the "completely effective" response was assigned a value of 5. The "not applicable" responses were not assigned a numerical value. Respondents indicated that, on average, they believe repair works about half the time (mean = 3.14; n=56), mitigation works a little less than half time (mean = 2.73; n=26), and direct control works approximately half the time (mean = 3.18; n=22). There were nine "not applicable" responses for the repair category; nine "not applicable" responses for the mitigation category; and 14 "not applicable" responses for the direct control category. "Not applicable" responses were not included in *n* totals.

Question 17—Level of Burrowing Mammal Damage in Their Jurisdiction

Respondents were asked to rate suspected burrowing-mammal-caused damage in their work jurisdiction. Responses to this question were assigned numerical values to determine a single mean value. The "not a problem at all" response was assigned a value of 1, "very few localized problem areas" was assigned a value of 2, "occasional problem" was assigned a value of 3, "somewhat distributed throughout" was assigned a value of 4, and the "extremely widespread problem" response was assigned a value of 5. Generally, respondents indicated that they believed burrowing-mammal-caused damage was a negligible problem with extremely few localized problem areas (mean=1.48; n=143).

Question 18—Guidance and Actions

Respondents were asked several opinion statements to better understand the perceptions of maintenance staff related to burrowing mammals and their effect on Montana roadways. As before, numerical values were assigned to the various response categories to determine a single mean value for each question. In this case, the "strongly disagree" response was assigned a value

of 1, the "disagree" response a value of 2, "neutral" a value of 3, "agree" a value of 4, and the "strongly agree" response was assigned a value of 5. A summary of the means for each of the four statements provided in Question 18 is tabulated in Table 3. In general, respondents were relatively neutral regarding whether damage caused by burrowing mammals needed to be addressed in the form of guidelines or funding. In addition, respondents generally disagreed with the idea that too much effort was spent addressing such damage.

Table 3. Summary of Responses to Statements in Question 18.

Statement	Mean response	n
Burrowing mammals are a cause of damage to Montana's paved surfaces that needs to be addressed.	3.13	138
Guidelines area needed in order for personnel to adequately address pavement damage from burrowing mammals.	3.22	138
More funding is needed to address pavement damage from burrowing mammals.	2.80	137
Too much of my work time is spent addressing burrowing mammal-caused pavement damage.	2.02	136

Question 19—Other Experience with Burrowing Mammal Road Damage

All survey participants were provided an opportunity to share any other useful information related to burrowing mammal road damage. Forty-six survey participants provided a variety of information. Comments generally fell into five categories: no damage present (18 comments), possible problem (five comments), specific problems with roadways (eight comments), damage to other transportation facilities such as rest areas and gravel roads – not paved roads (six comments), and beaver-related information (eight comments). Actual responses are provided in Appendix B.

Question 20—Location of Possible Sites with Burrowing Mammal Damage

Survey participants were given the opportunity to provide specific location information for sites on paved roads in Montana that were likely to reveal burrowing mammal damage. Thirty-four survey participants provided some level of location information; eight indicated they knew of no current sites and two described the same location. This information was used to determine possible locations for site visits.

Question 21—Contact Information

Survey participants were asked to provide detailed contact information if they were willing to be contacted for further information. Thirty-five respondents provided this information. Twenty-six of the thirty-five were contacted via telephone to participate in a follow-up interview.

Telephone Interviews

Twenty-six individuals were contacted to participate in a telephone interview to gain more detailed information related to burrowing mammal damage to paved roadways in Montana. All interviewees were asked the same questions in a consistent and formal fashion to ensure uniformity of responses from the participants. The questionnaire used for this purpose is provided in Appendix C, which includes the introductory statement used to introduce the participants to the questionnaire and the interview process.

Interview Question 1

Yes or no: have you observed damage that you believe is caused by burrowing mammals? Twenty of the 26 people interviewed (77 percent) indicated that they believed they observed damage caused by burrowing mammals.

Interview Question 2

Those who answered affirmatively to question 1 were asked: *On a scale of 1 to 5 (1 being not certain at all and 5 being 100 percent certain), how certain are you that the damage you saw was caused by burrowing mammals*? Most interviewees who observed damage described in this study were certain it was caused by burrowing mammals (mean = 4.50).

Interview Question 3

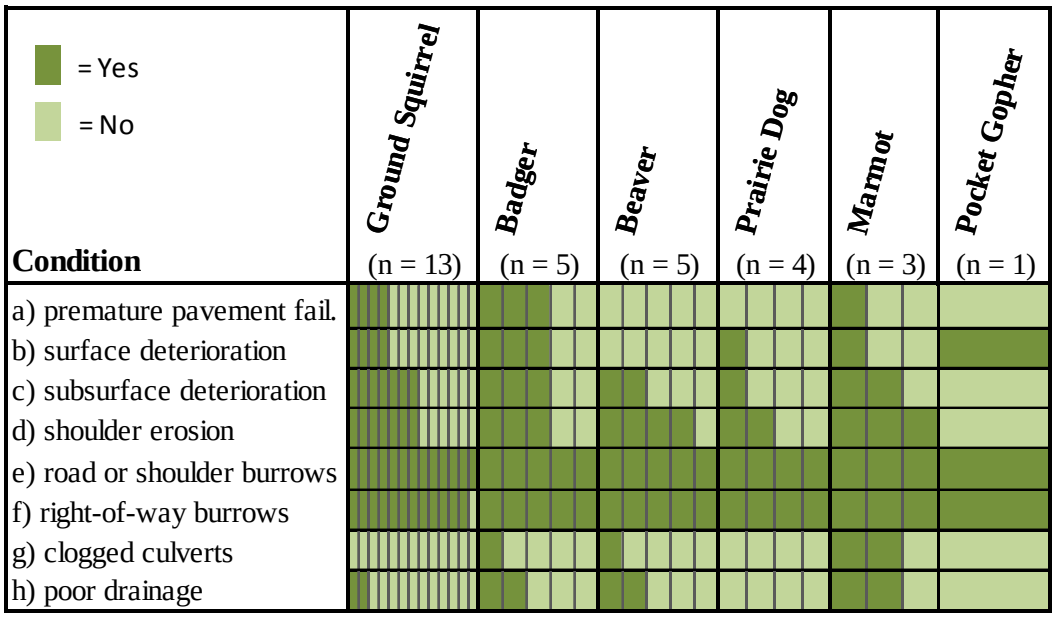
Another follow-up question was posed to those who had observed burrowing mammal damage by asking them: *What species do you think was/is involved?* Interviewees were able to provide more than one species, which some did. Six species were mentioned in conjunction with damage described in this study (numbers in parentheses indicate the number of instances that a species was mentioned): pocket gopher (1), ground squirrel (13), prairie dog (4), marmot (3), badger (5), beaver (5), and coyote (1).

Interview Question 4

Yes or no: have you observed the following conditions that you believe are associated with burrowing mammal activity? a) premature pavement failure, b) paved road surface deterioration, c) pavement subsurface deterioration, d) shoulder erosion, e) obvious burrows or holes in road surface or shoulder, f) obvious burrows or holes in the right of way beyond the shoulder and as far as the toe of the road, g) clogged culverts, h) poor drainage.

All five burrowing species mentioned were most often named in conjunction with burrows/holes in the road surface, shoulder, or right of way as far as the toe of the slope. In general, however, the sample sizes were small and provided limited insight (Table 4).

Table 4. Summary of Damage Conditions Associated with Various Species of Burrowing Mammals



Interview Question 5

How many different locations have you observed of damage associated with burrowing mammal activity? Interviewee responses generally ranged from 1 to 10 locations (mean = 3.32; n=19).

Interview Question 6

For the worst case you've seen, what is the length of roadway affected? Interviewee responses ranged from localized damage of 10 feet to sporadic damage across five miles. Most generally, however, the damage seemed to be less than a quarter of a mile.

Interview Question 7

Concerning the right of way beyond the shoulder to the toe of the slope, on a scale of 1 to 5 (1 being only the presence of burrows, 5 being dramatic pavement surface or subsurface deterioration that is obviously linked to burrows), how would you rate the typical damage you've seen? The majority of interview participants rated the damage they've seen as minor (mean =1.70; n=20), slightly more than mere presence of burrows.

Interview Question 8

The final question during the interviews provided an opportunity for interviewees to openly share their perspectives by being asked: *Would you like to share your perspective on the extent, issues, and/or causes related to this topic*? Responses to this open-ended question can be summarized as follows: did not wish to share perspectives (three comments), burrowing mammals are not a problem for paved roads (eleven comments), burrowing mammals can be a problem for paved roads (eight comments), wetland-related issue rather than a typical burrowing mammal issue (seven comments). Actual responses are provided in Appendix D.

SITE VISITS

Twenty-five sites emerged as candidates for further investigation, as suggested by survey respondents and interviewees. Criteria used to choose which sites to visit included:

- the presence of pavement-related damage from burrowing mammals in addition to evidence of animal activity;
- a sense of concern from the respondent that a problem exists;
- representation of a variety of species, damage types, and MDT Districts; and
- logistical considerations for travel planning.

Two general routes emerged as the most efficient means for Bozeman-based researchers to visit the greatest number and diversity of sites. One route went through eastern Montana (Sites 1 through 8) and the other went through western Montana (Sites 9 through 18). The general location of the site visits is shown in Figure 13.

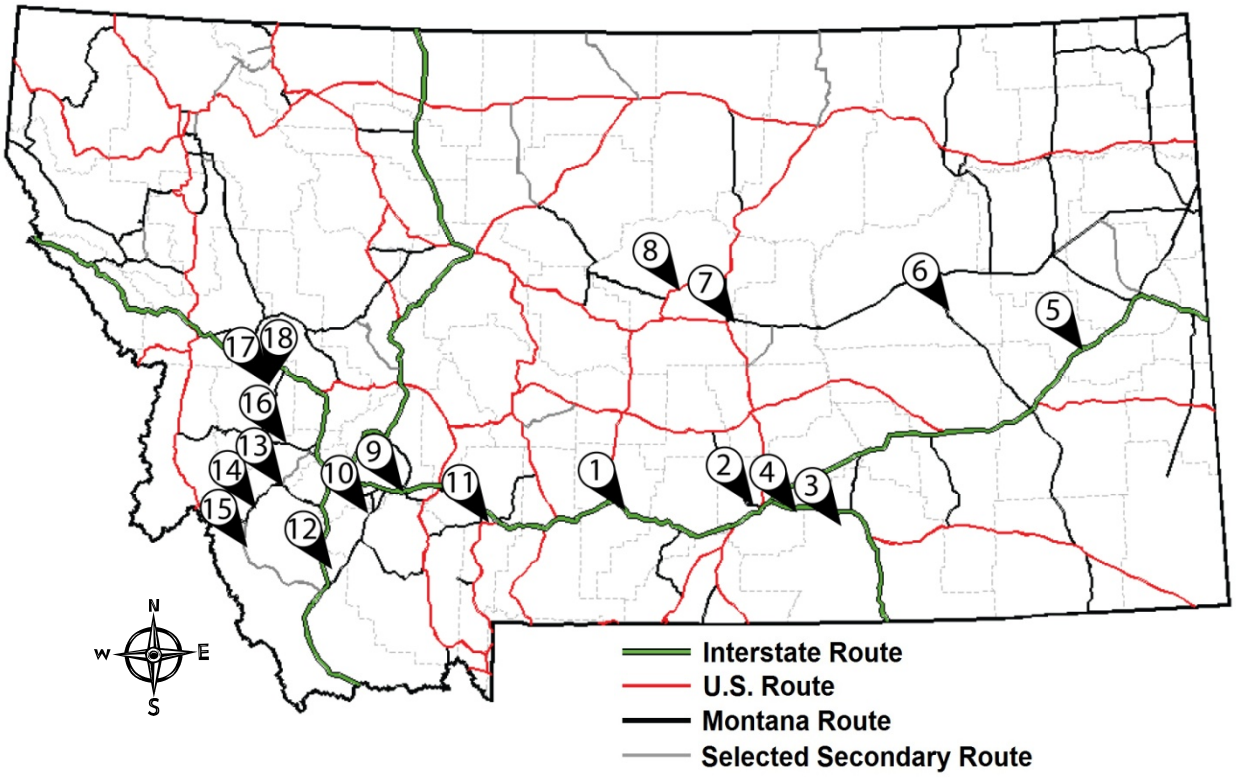


Figure 13. Map of Montana showing location of site visits.

A total of 18 individual sites in three MDT maintenance districts were visited over a one-week period in late June 2010. A site visit checklist (shown in Appendix E) was used to provide a consistent and systematic assessment of each site. Multiple photographs were taken at each site to document burrowing mammal activity, surrounding ecological conditions, and any pavement and roadside distresses. In most cases, MDT personnel were available to guide the research team

to the candidate locations and answer questions. Individual site descriptions and photos are provided in the following subsections.

Site No. 1—Interstate 90 near Greycliff

This site was on a four-lane divided interstate highway surrounded by grassland and ranchland with plentiful organic soils (Figure 14). Prairie dog holes were present in the right-of-way and unpaved shoulder along approximately a half mile of roadway, although holes near the road shoulder were shallow. No direct structural damage to the pavement surface or support structure was observed to be due to the activities of burrowing mammals. Many of the individual mounds were raised above the graded surface, which may cause a nuisance to mowers, although much of the vegetation in the area was short from feeding activities. Disturbed earthen mounds and feeding activities seem to have promoted weed growth in the area.

Figure 14. Photos of Site 1: a) burrows near shoulder, b) burrows in right-of-way, c) burrow at base of shoulder, and d) burrow near sign post.

Site No. 2—Montana Highway 3 near Billings

This site was located on a rural two-lane highway surrounded by grasslands and ranchland with sandy organic soils (Figure 15). Prairie dog holes were present in the right-of-way and the unpaved shoulder on both sides of the road. Activity within about 10 feet of the paved edge in the graveled shoulder was less developed and was likely the result of the dispersal of young. Most of these mounds were abandoned. MDT personnel indicated concern for water infiltration through burrows under the road, although no pavement or structural damage was apparent.

Figure 15. Photos of Site 2: a) abandoned burrow in shoulder, b) abandoned burrow covered with vegetation near shoulder, c) general layout and condition of roadway, and d) adjacent landscape.

Site No. 3—Interstate 90 Frontage Road near Hardin

This site was on a two-lane rural frontage road between active railroad tracks and an interstate highway and surrounded by grasslands and ranchlands having silty/clayey soil (Figure 16). Extensive prairie dog holes were present in the right-of-way and in adjacent lands, but no live animals were spotted during the site visit because of recent poisoning. MDT personnel expressed concern about the possibility of erosion on the cut slopes adjacent to the road due to burrowing activity and about vegetation loss from feeding animals. Vegetation around mounds and abandoned holes was reestablishing itself. Direct damage to the pavement structure and surface was not observed.

Figure 16. Photos of Site 3: a) adjacent prairie dog town, b) abandoned burrow in right-of-way, c) reestablishment of vegetation near abandoned burrow, and d) exposed earth in right-of-way from burrowing activity.

Site No. 4—Interstate 90 near Hardin

The fourth site visit was on a divided interstate highway surrounded by grasslands and ranchland with silty/clayey organic soils (Figure 17). Prior prairie dog activity was noted in the right of way, but there was no current activity at the site. Concerns over erosion due to mound activities were noted by MDT personnel. Vegetation near inactive mounds had become reestablished. Adjacent land showed signs of vegetation disturbance due to burrowing mammal activity. Mounds were of a significant distance from the paved road edge such that damage to the pavement surface or structural fill was not present or likely.

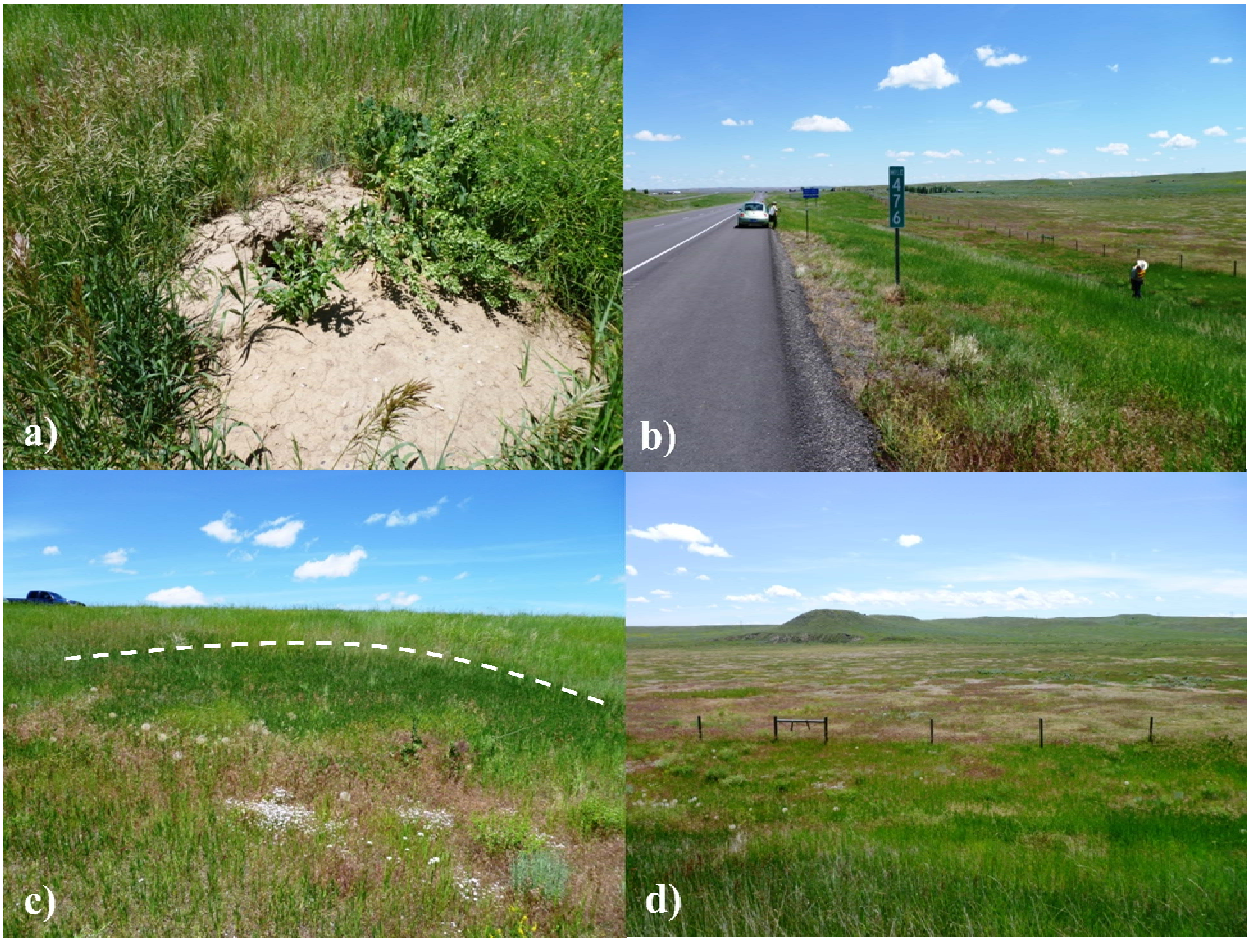


Figure 17. Photos of Site 4: a) prairie dog mound, b) longitudinal view of roadway, c) reestablishment of vegetation near abandoned burrow showing outline of new growth area, and d) mottled landscape from burrowing mammal activity.

Site No. 5—Secondary Highway 253 near Terry

This site was situated on a two-lane rural road surrounded by grassland/ranchland with plentiful organic soils (Figure 18). A few pocket gopher holes were present in the shoulder and right-of-way and mounds were present in areas with and without pavement damage. Ground squirrels and voles were also spotted in this region. Pavement damage was observed in a wet area that showed no sign of recent animal activity. MDT personnel voiced concerns over pavement damage as it relates to the burrowing mammal activity in the area, but also stated that increased truck traffic and wetter conditions likely play a significant role in pavement-related distresses. Nonetheless, burrowing mammal activity could increase the porosity of the soil, which could increase water-related distresses in the pavement structure. Further investigation is necessary to substantiate a direct link between burrowing mammal activity and pavement-related distresses at this site.

Figure 18. Photos of Site 5: a) low area in pavement, b) pocket gopher activity near shoulder, c) pocket gopher activity in right-of-way, and d) longitudinal view of roadway.

Site No. 6—Montana Highway 59 South of Jordan

This site was located on a two-lane rural road completely surrounded by grasslands and ranchland with plentiful organic and soft soils (Figure 19). Pocket gopher and badger activity was observed in the area; however, no animals were spotted during the site visit. Burrows were in the immediate vicinity of the pavement edge and extended into the right-of-way. Pavement distresses such as an occasional pothole and transverse cracking of the pavement were present on this stretch of roadway. MDT personnel voiced concerns about possible water infiltration into the pavement system due to burrowing mammal activity, which may lead to loss of structural integrity of the pavement. Tall grass and the lack of recent burrowing activity at the time of the visit made it difficult to determine whether visible pavement distresses were caused by burrowing mammals. This would need to be substantiated by further investigation, such as digging into and under the roadway with a backhoe.

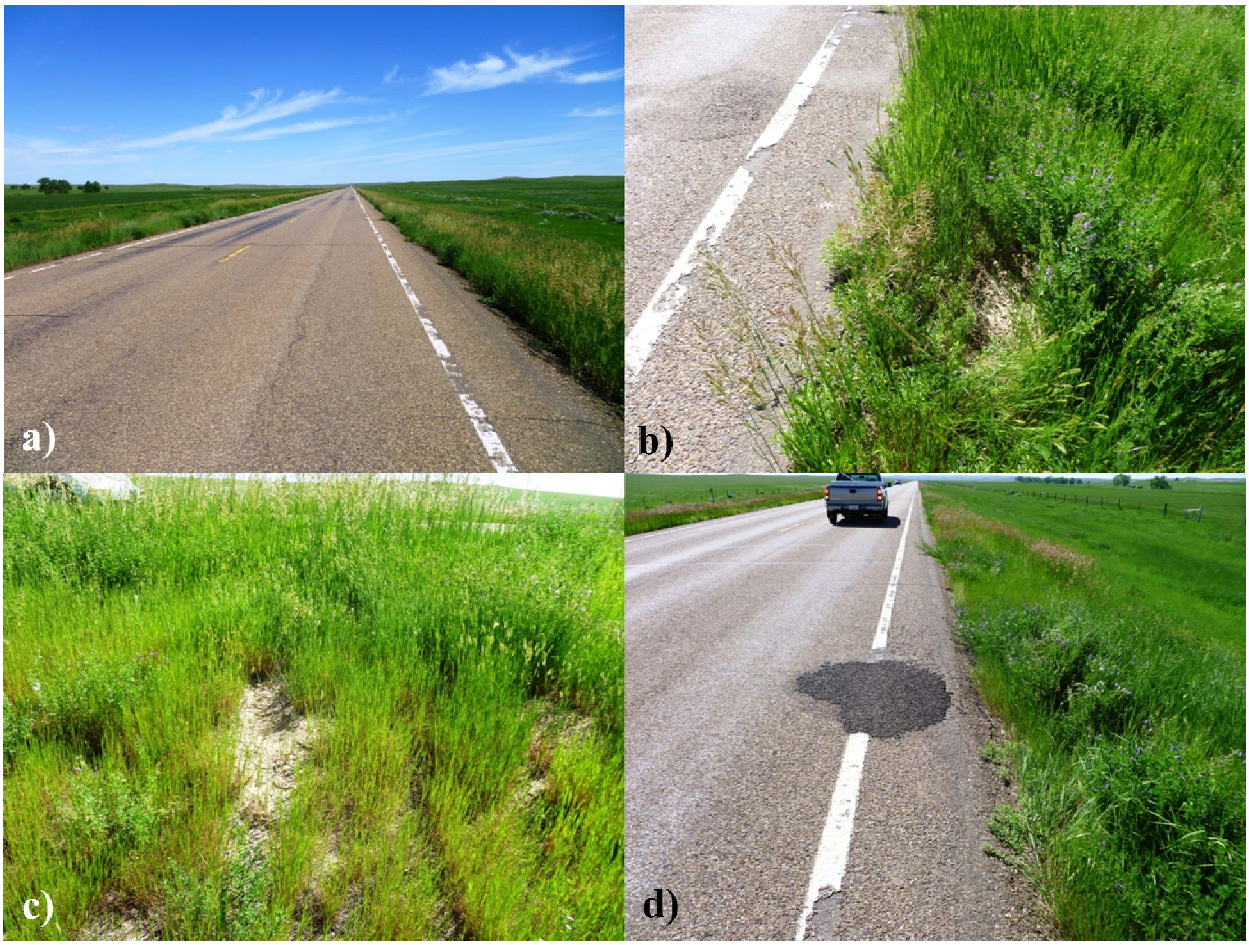


Figure 19. Photos of Site 6: a) longitudinal view of roadway, b) pocket gopher activity near road edge, c) pocket gopher activity near shoulder, and d) pavement distresses on shoulder.

Site No. 7—Montana Highway 200 East of Grass Range

This site centered on a rural two-lane bridge over an active creek surrounded by grasslands and ranchlands (Figure 20). Active beaver dams were observed upstream from the bridge, in riparian habitat. Creek flows were obviously affected from beaver activity, but were not posing any immediate stress or damage to the road or bridge structure. During higher flows, water, and/or debris may cause issues to the structure and/or roadway.

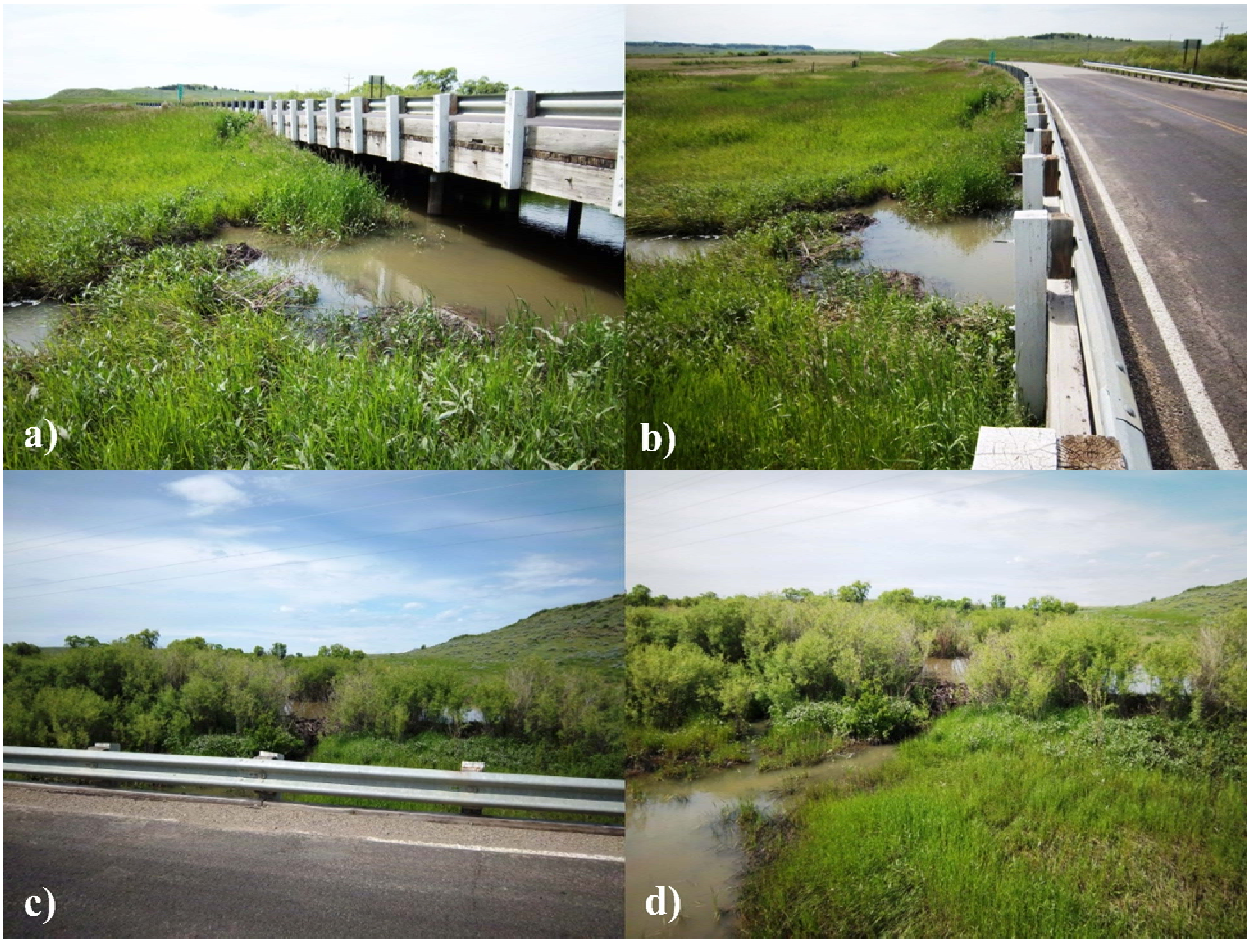


Figure 20. Photos of Site 7: a) beaver dam below bridge, b) longitudinal view of roadway with beaver dam, c) view of beaver dam above bridge, and d) closer view of beaver dam above bridge.

Site No. 8—US Highway 191 near Roy

This site was situated on a two-lane rural road surrounded by grassland and ranchland near an active riparian habitat (Figure 21). Issues in this area centered on beaver activity near several culverts, all of which contained active flows. Beaver activity has been documented in this area for 19 years. MDT personnel stated concerns of flooding because of frequently blocked culverts and the constant attention required by staff to clean out debris and prevent future damming. This has, at times, put maintenance crews at risk. Additionally, MDT personnel indicated that deposition of limbs and soil disturbance from beavers has affected mowing operations in the area. Large culverts in the vicinity have prevented the water from topping the road, so there was no apparent damage to the road substructure or pavement surface.

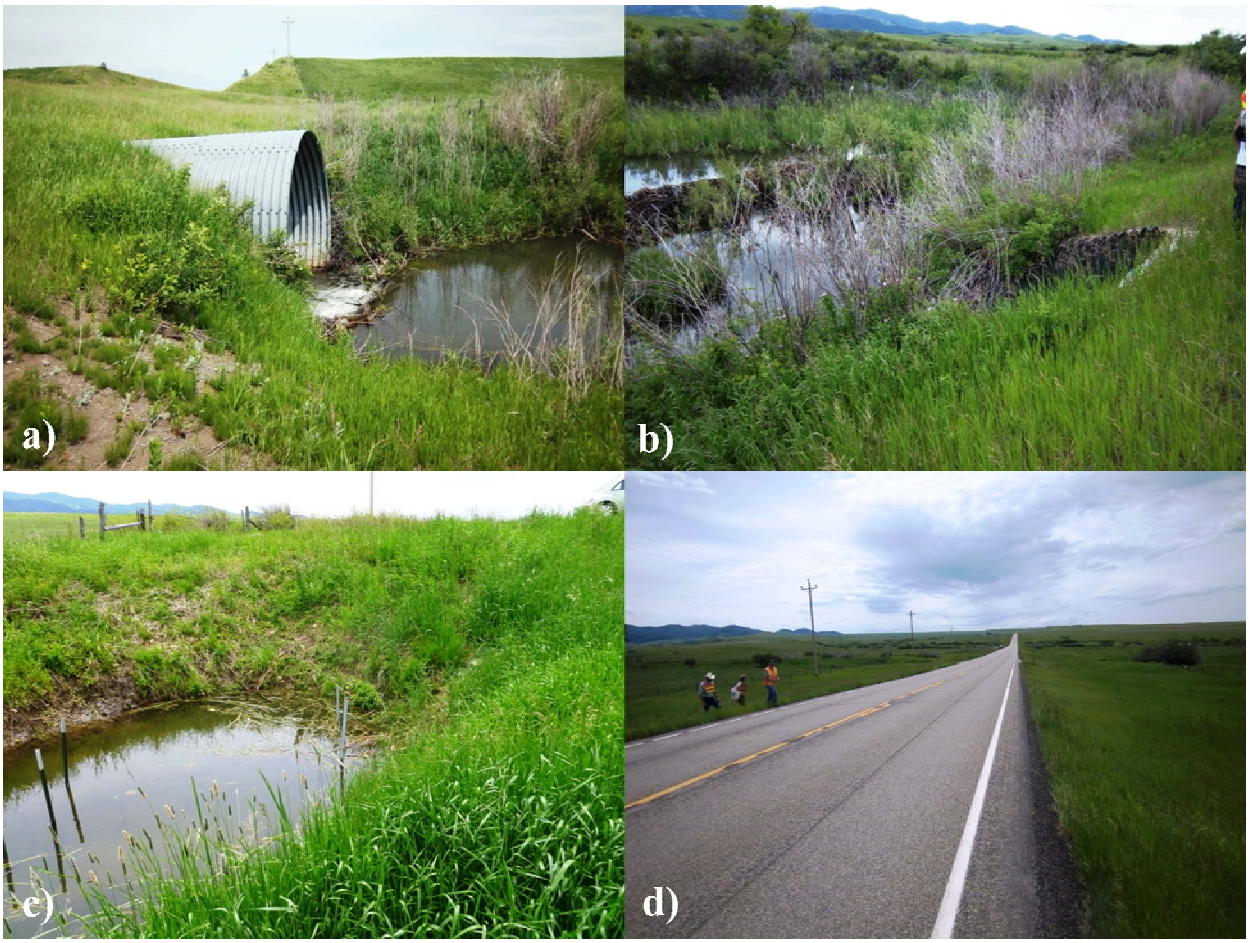


Figure 21. Photos of Site 8: a) beaver dam above large culvert, b) beaver dam below culvert, c) culvert blocked from beaver activity, and d) longitudinal view of roadway near active beaver areas.

Site No. 9—Interstate 90 near Cardwell

This site was located on a four-lane divided interstate highway surrounded by grassland and ranchlands spotted with small juniper bushes in silty soils (Figure 22). Several abandoned badger holes were located within the right-of-way along a quarter mile section of the highway. Badgers were not observed in the area and vegetation near the mounds was reestablishing. Mounds were prominent in an embankment adjacent to the drainage ditch on the north side of the westbound traffic lane. Burrowing activity may cause localized erosion issues but no indication of damage to the pavement or structural support was apparent or imminent.

Figure 22. Photos of Site 9: a) badger mound on embankment, b) badger mound on embankment, c) reestablishment of vegetation near badger hole, and d) longitudinal view of roadway.

Site No. 10—Montana Highway 55 South of Whitehall

This site was located on a two-lane rural highway near grass and ranchland with silty soils (Figure 23). Ground squirrels were observed in active burrows in the right-of-way beyond the toe of the shoulder. Disturbance to the landscape was minor and there was no indication of damage to the road and support structure.

Figure 23. Photos of Site 10: a) ground squirrel mounds in right-of-way, b) longitudinal view of roadway, and c) longitudinal view of right-of-way.

Site No. 11—Montana Highway 84 near Norris

This site was located on a two-lane rural road in a forested area near an active stream abundant with willows (Figure 24). The main issue in this area was beavers, but minimal pocket gopher presence was also noted. Past damming of the stream diverted the water from its natural channel, subsequently eroding the road embankment at the edge of the right-of-way. The structural integrity of the roadway and pavement surface showed no obvious signs of distress from this activity.

Figure 24. Photos of Site 11: a) stream migration toward roadway, b) close-up of embankment erosion, c) longitudinal view of right-of-way adjacent to stream, and d) channel migration.

Site No. 12—Interstate 15 Frontage Road near Dillon

This site was located on a rural two-lane road adjacent to irrigated and non-irrigated farm and ranchlands with silty organic soils (Figure 25). Extensive ground squirrel activity was observed along a three-mile stretch of the highway. Most activity in the right-of-way was near the irrigated farm ground even though overall ground squirrel density was greatest away from the right-of-way near the non-irrigated grassland areas. Burrowing activity from ground squirrels along the shoulder of the road apparently caused the pavement to collapse and/or deteriorate in several places. MDT staff had patched several of these areas to maintain roadway integrity. Several burrows close to the pavement edge appeared to extend under the pavement. Badger activity was also apparent in the right-of-way.

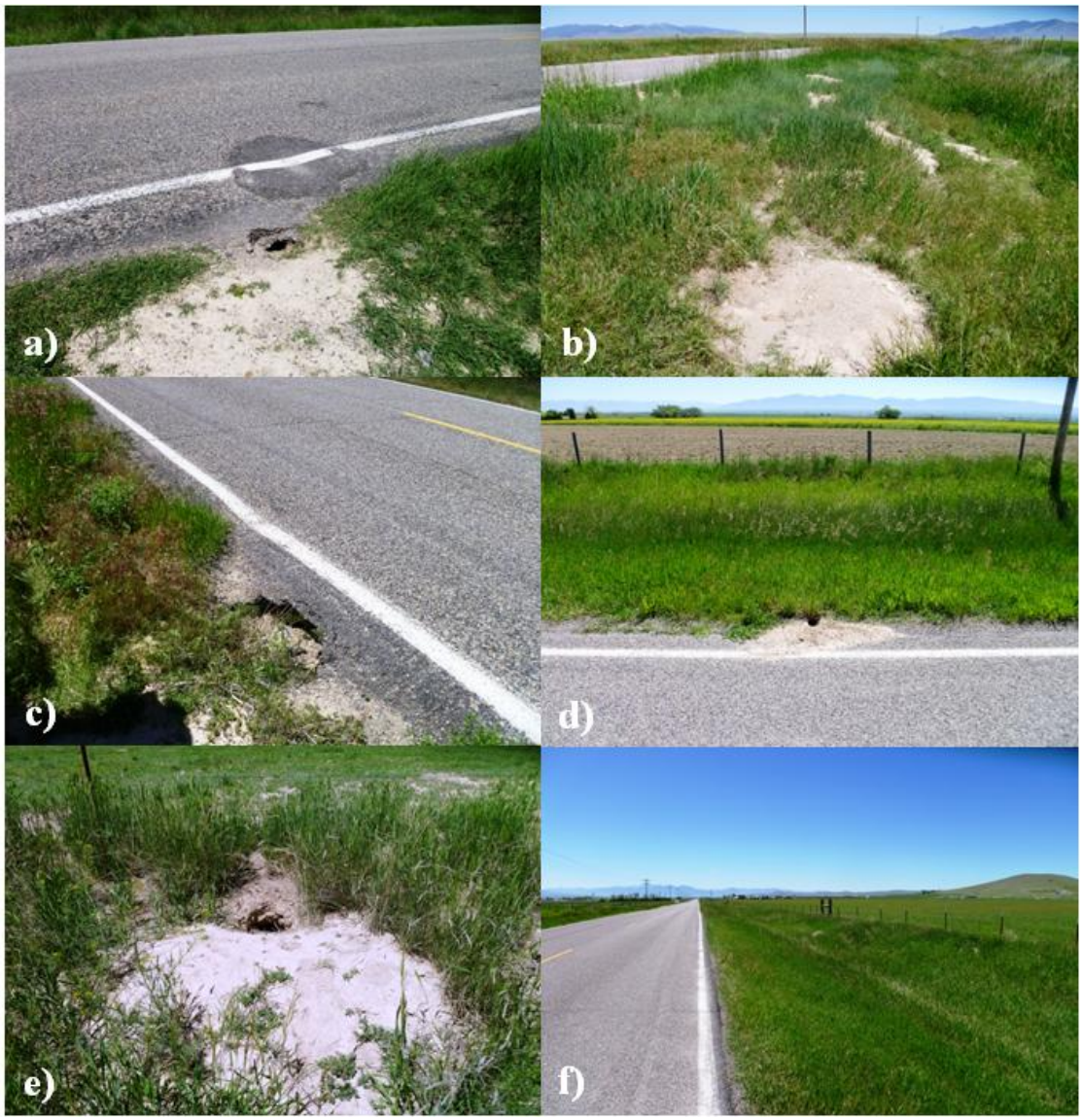


Figure 25. Photos of Site 12: a) pavement damage adjacent to ground squirrel activity, b) mounds in right-of-way, c) deterioration of pavement edge, d) mounds on shoulder, e) badger mound, and f) longitudinal view of roadway.

Site No. 13—Montana Highway 43 near Wisdom

This site was located on a rural two-lane highway near grass and ranchlands with sandy organic soils (Figure 26). Ground squirrel activity was observed in the right-of-way up to the pavement edge. In several cases, burrows extended under the roadway causing subsidence of the pavement and allowing infiltration of runoff water. One such burrow extended about three feet under the pavement. Subsided areas were also observed in conjunction with transverse cracking of the pavement but, in some cases, burrows may be accelerating the scour effect. MDT personnel noted that burrows under the road were found when sections of the road were excavated to conduct patching repair.

Figure 26. Photos of Site 13: a) transverse cracking in pavement coincident with ground squirrel activity, b) burrow in right-of-way, c) burrow under pavement, d) depth of burrow under pavement, e) ground squirrel near road edge, and f) longitudinal view of roadway.

Site No. 14—Montana Highway 43 near Wisdom

This site was approximately 10 miles from Site 13 on the same two-lane, rural highway (Figure 27). Ground squirrel and badger burrows were observed within the right-of-way up to the pavement edge for several miles. Similar to Site 13, some ground squirrel burrows extended under the pavement causing subsidence and further deterioration of existing cracks.

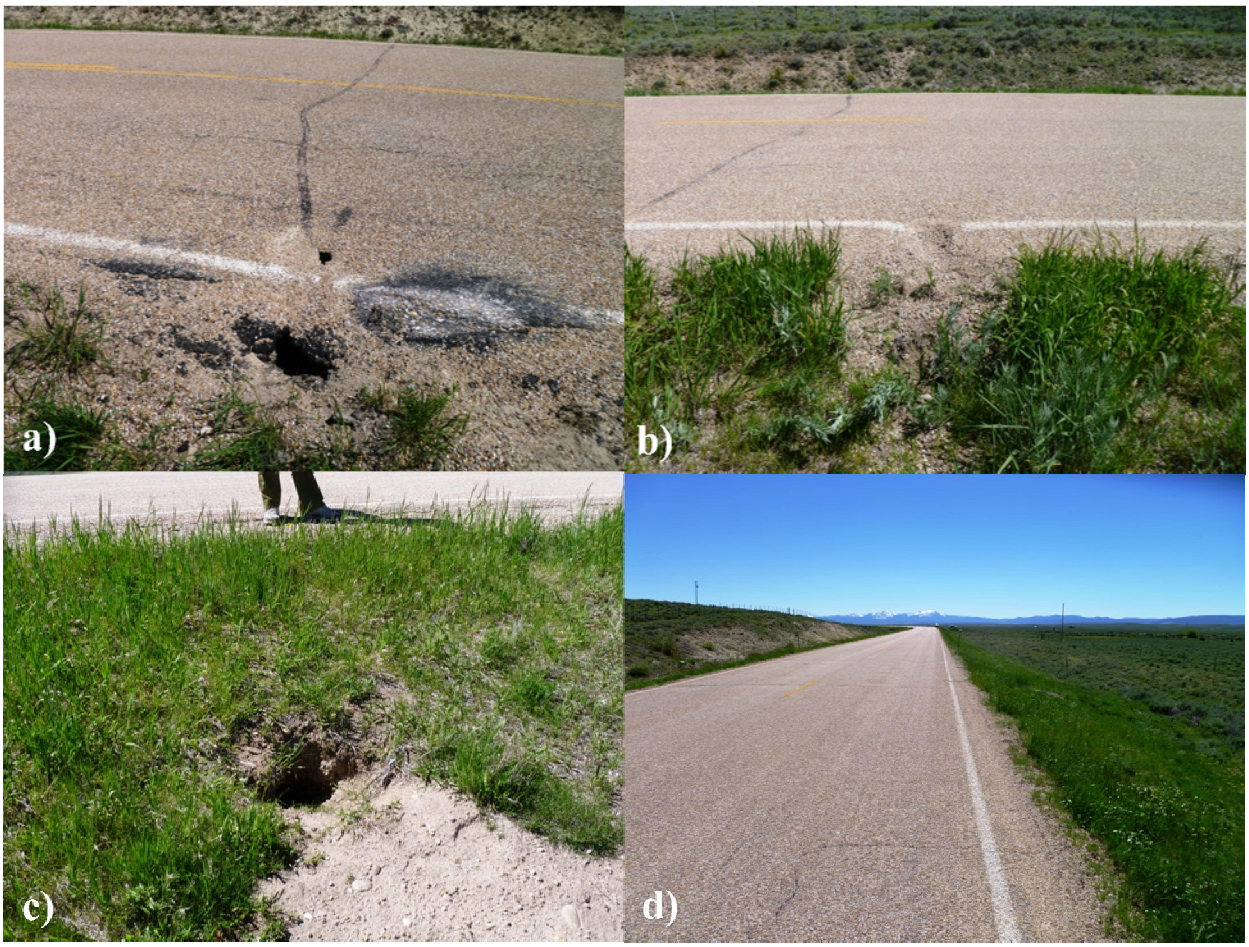


Figure 27. Photos of Site 14: a) transverse cracking in pavement coincident with ground squirrel activity, b) subsidence of paved shoulder near old burrow, c) badger burrow in right-of-way, and d) longitudinal view of roadway.

Site No. 15—Secondary Highway 278 near Wisdom

This site was on a rural two-lane highway adjacent to sub-irrigated grasslands and ranchlands (Figure 28). Sporadic ground squirrel and badger activity was observed over a one-mile stretch. Some of the burrows are at the edge of the paved surface and may be linked to nearby pavement distresses and/or subsidence. A recently applied chip seal obscured many areas where patches were used to repair areas associated with burrowing mammal activity.

Figure 28. Photos of Site 15: a) burrow activity in right-of-way, b) ground squirrel burrow near shoulder, c) badger burrow near edge of road, and d) burrows near road sign.

Site No. 16—Montana Highway 1 near Anaconda

This site was situated on a rural two-lane highway with a passing lane that traversed a large fill area in a high-elevation, forested region (Figure 29). Soils in the area were mostly sandy and/or granular with shallow organic materials. Drainage of water from the road during rain and snow events has eroded shoulder material adjacent to the paved surface and around the guardrail over a tenth of a mile section of road. MDT personnel indicated that burrows exacerbated erosion issues; however, substantial burrowing mammal activity was not observed during the site visit. Small burrows from mice or voles were found near the guardrail.

Figure 29. Photos of Site 16: a) longitudinal view of embankment and roadway, b) small burrows on embankment, c) burrow near guardrail, and d) erosion of embankment from runoff water.

Site No. 17—Secondary Highway 348 near Philipsburg

This site was situated on a rural two-lane road adjacent to sub-irrigated grass and ranchlands and partially forested areas with sandy, gravelly organic soils (Figure 30). Ground squirrel, pocket gopher, vole, and badger activity were observed. Pavement distresses on one section of road in the area were all repaired during a recent paving operation. Multiple transverse and longitudinal cracks were present in the pavement. The majority of the pavement distresses were due to the age of the pavement, poor base support, and significant log truck traffic. However, some ground squirrel burrows near the pavement edge extended under the road, which may initiate damage or exacerbate existing distresses. The shallow taper of the shoulder may also lend to further burrowing mammal activity.

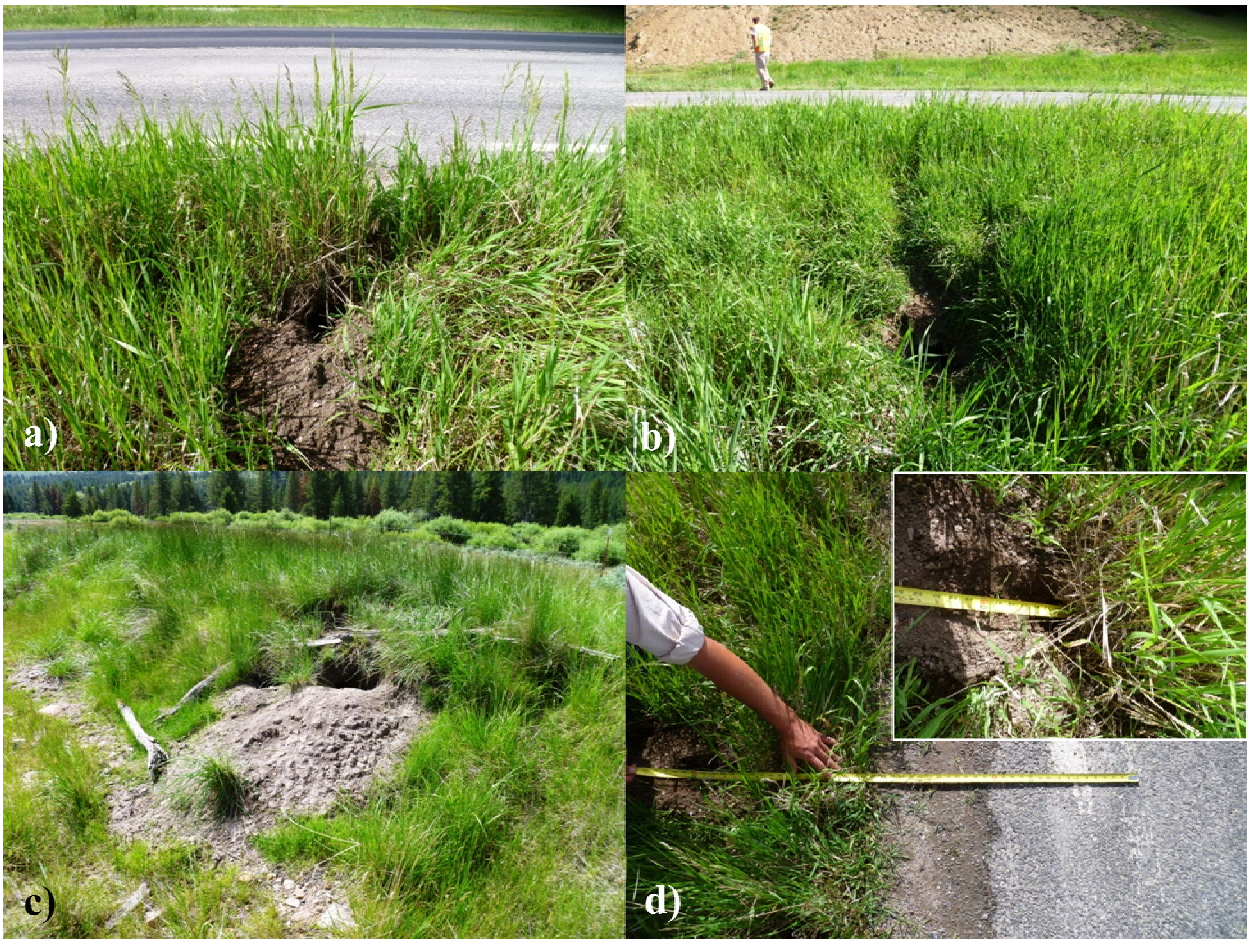


Figure 30. Photos of Site 17: a) active ground squirrel burrow near roadway, b) burrow in right-of-way, c) badger burrow in right-of-way, and d) ground squirrel burrow under roadway.

Site No. 18—Secondary Highway 348 near Philipsburg

This site was approximately one mile from Site 17 on the same two-lane road (Figure 31). Recent repairs were made to the road in this area due to damage from an adjacent creek when it overflowed due to beaver activity. MDT personnel indicated this area has recurrent beaver activity that affects the roadway and right-of-way.

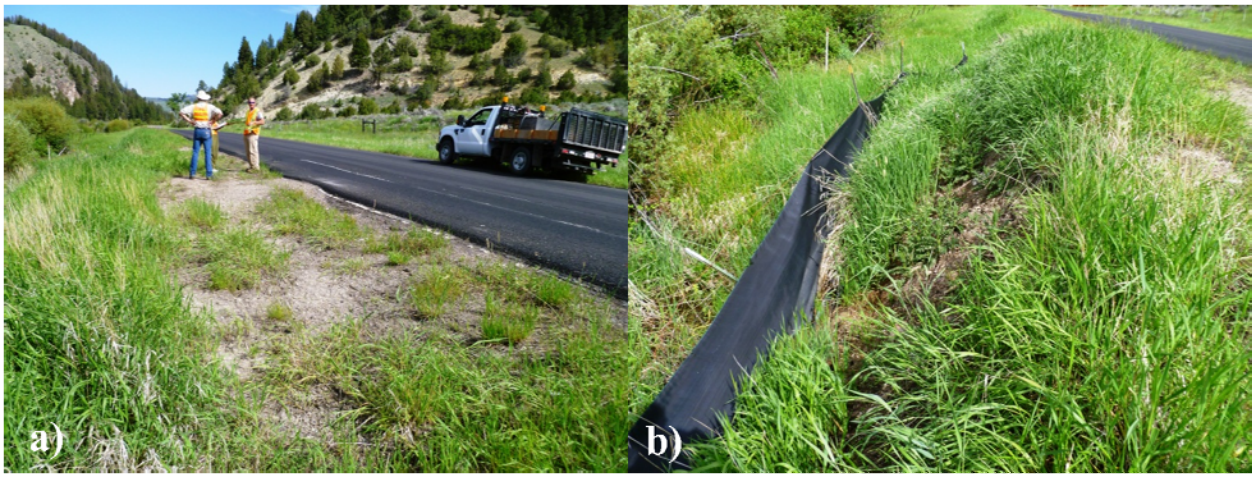


Figure 31. Photos of Site 18: a) longitudinal view of roadway showing new pavement, and b) erosion of right-of-way from creek overflow.

Table 5 summarizes the information collected from the eight site visits in eastern Montana (Sites 1 through 8). Table 6 summarizes the information collected from the ten site visits in western Montana (Sites 9 through 18). Qualitative assessments were made at each of the sites regarding the "density of burrows" and "intensity of damage." In terms of burrow density, a low rating was given for areas that had very few holes and large distances between neighboring holes. A moderate rating was given for areas where there were a greater number of holes but where neighboring holes were not at their maximum density, and a high density rating was given for areas where burrowing mammal activity in a certain area was nearing its peak capacity of activity. In terms of damage intensity, a low rating was given if the burrows had caused merely cosmetic damage to the landscape; a medium rating was given if the burrows had the ability to present further nuisance to maintenance personnel, such as increased difficulty in mowing or increased potential for water infiltration. A high rating was given in areas where burrowing mammal activity was coincident with pavement and/or substrate damage.

Table 5. Summary of Site Visits in Eastern Montana

Site #	Date visited	Road type	Habitat type	Species involved	Density of burrows	Intensity of damage	Length of roadway affected	Maintenance activities	Concerns
1	6/23/2010	rural four-lane; divided interstate	grass/ranchland	prairie dog	low	low	~1/2 mile	mowing	mowing nuisance[1], promotion of weed growth[1]
2	6/23/2010	two-lane; rural/urban interface	grass/ranchland	prairie dog	moderate	low	~1 mile	none	water infiltration into roadway[2]
3	6/23/2010	rural two-lane; rural	grass/ranchland	prairie dog	moderate/ high	moderate	~1/2 mile	poison	erosion of right-of-way[1], vegetation loss[1]
4	6/23/2010	rural four-lane; divided interstate	grass/ranchland	prairie dog	low	low	< 1/4 mile	none	erosion of right-of-way[1], vegetation loss[1]
5	6/24/2010	rural two-lane	grass/ranchland	ground squirrel; vole	low	low	< 1/4 mile	none	water infiltration into roadway[2]
6	6/24/2010	rural two-lane	grass/ranchland	pocket gopher	low	moderate	3-5 miles	small pavement patches near shoulder	loss of pavement structural integrity[1]
7	6/24/2010	rural two-lane	grass/ranchland; riparian	beaver	N/A	low	bridge	none	buildup of debris[2], blockage of flow[2]
8	6/24/2010	rural two-lane	grass/ranchland; riparian	beaver	N/A	moderate	several culverts	debris removal, filled holes in bank	buildup of debris[2]; blockage of flow[2]; bank, right-of-way erosion[1]; mowing challenges[1]

[1] concern stated by MDT and WTI personnel
[2] concern stated by MDT personnel

Table 6. Summary of Site Visits in Western Montana

Site #	Date visited	Road type	Habitat type	Species involved	Density of burrows	Intensity of damage	Length of roadway affected	Maintenance activities	Concerns
9	6/28/2010	rural four-lane; divided interstate	grass/ranchland, juniper shrubs	badger	low	moderate	~1/4 mile	none	erosion of embankment[1]
10	6/28/2010	rural two-lane	grass/ranchland	ground squirrel	low	low	~1/4 mile	none	none
11	6/28/2010	rural two-lane	forest, riparian	beaver, pocket gopher	low	moderate	~1/2 mile	cleaned culverts; embankment repair	clogged culverts[1]; diversion of stream into right-of-way causing erosion of embankment[2]
12	6/28/2010	rural four-lane; divided interstate	irrigated and non-irrigated farm and ranchlands	ground squirrel, badger	high	high	~3 miles	filled burrows near road edge; patched paved shoulder	deterioration and collapsing of paved shoulders[2]; water infiltration[2]
13	6/28/2010	rural two-lane	grass/ranchland	ground squirrel	moderate	high	3-5 miles	filled burrows near road edge; patched pavement and shoulder	deterioration and collapsing of paved shoulders[2]; water infiltration[2]
14	6/28/2010	rural two-lane	grass/ranchland	ground squirrel, badger	moderate	high	1-2 miles	filled burrows near road edge; patched pavement and shoulder	deterioration and collapsing of paved shoulders[2]; water infiltration[2]
15	6/28/2010	rural two-lane	sub-irrigated grass/ranchlands	ground squirrel, badger	low	moderate	1-1.5 miles	patched pavement and shoulder	deterioration and collapsing of paved shoulders[2]; water infiltration[2]
16	6/29/2010	rural two-lane + passing lane	forest	vole or mouse	low	low	~1/4 mile	none	erosion of embankment[2]
17	6/29/2010	rural two-lane	sub-irrigated grass/ranchlands	ground squirrel, pocket gopher, vole, badger	moderate	high	~2-4 miles	patched pavement and shoulder	deterioration and collapsing of pavement and paved shoulders[2]; water infiltration[2]
18	6/29/2010	rural two-lane	sub-irrigated grass/ranchlands	beaver	N/A	high	~150 feet	removed beaver dam; repaved highway; repaired right-of-way	erosion of embankment and undermining of pavement structure[1]

[1] concern stated by MDT and WTI personnel

[2] concern stated by MDT personnel

SUMMARY AND CONCLUSIONS

MDT personnel regularly notice burrowing mammals or their effects along Montana's paved road network. As such, MDT initiated this effort to assess the nature and extent of damage to paved roadways from burrowing mammals through: 1) a targeted survey of city, county, state and tribal personnel whose work is related to maintenance, inspection, management and design of paved roads in the state; 2) follow-up interviews with a subset of survey respondents who offered to be contacted for more information, most of whom were MDT personnel; and 3) site visits to 18 separate locations in Montana that are within the jurisdiction of MDT.

Summary of Survey

One hundred and forty-one of 353 invitees completed the survey for a response rate of 40 percent. MDT personnel were well represented in the survey respondent population. Fifty-seven percent of all respondents indicated having observed paved roadway damage due to burrowing mammal activity in their jurisdiction. Damage was typically limited to burrows or holes in the right of way or shoulder erosion; less damage was found related to the paved road surface or road support. Usually, such activity was noted along two-lane roads in rural grassland or ranchland settings. The species most commonly observed or suspected were ground squirrels and badgers. The predominant action taken by MDT personnel in response to such damage was to spot repair as needed, which was effective about half of the time. Most respondents disagreed with the statement that addressing burrowing-mammal-caused damage takes too much of their work time. Most respondents were neutral with regard to the issue demanding attention in the form of guidelines or funding.

Summary of Interviews

Seventy-seven percent of 26 interviewees indicated that they have observed burrowing-mammal-caused damage and the greater majority was certain that damage was indeed caused by the animals. Ground squirrels were the most commonly named culprit and holes in the shoulder or right of way constituted the most common damage observed.

Summary of Site Visits

The majority of the sites visited in eastern Montana were near grasslands or ranchlands that had clayey or organic soils. For the most part, prairie dogs were the source of burrowing activity within the right-of-way, although pocket gophers and badger activity was also observed. Two areas were in riparian locations with active beaver dams. Overall, damage to roads in these areas was minimal.

In western Montana, the majority of the roads with suspected burrowing mammal activity were also adjacent to grasslands and ranchlands, with some locations near forested or riparian areas. Ground squirrels and badger activity was the most prevalent; however, there was also some beaver activity. Other species observed in western Montana during this study include pocket gophers, voles, and possibly mice. Damage to the pavement substructure and road surfaces was more common among the western sites than at those in the eastern part of the state, but even in

the west this damage was still limited to relatively isolated areas. Burrowing mammal damage was mainly from ground squirrels and badgers and was typically concurrent with one or more other common pavement distresses (e.g., transverse or longitudinal cracking, sunken sections of pavement, or crumbling pavement edges).

Conclusions

Burrowing mammal activity is most common along two-lane roads in rural grassland or ranchland settings but the extent of damage in these areas is primarily limited to burrows in the right-of-way. Typically, burrowing mammal activities do not appear to have deleterious effects on the pavement surface or subsurface. The majority of the survey responses and site visits indicated that damage was limited to the presence of holes or burrows in the vegetated right-of-way with no sign of pavement distress or obvious cause for concern.

Site visits were conducted throughout the state of Montana and the sites were selected based on recommendations from MDT maintenance personnel and were used to assess the various levels of burrowing mammal damage to the pavement surface, underlying pavement structure, and adjacent right-of-way. These sites were assumed to be the worst areas in the state; however, the majority of the damage recorded during the site visits was related to holes or burrows in the right-of-way that had the potential for further pavement deterioration but that had not yet manifested themselves as such. Nevertheless, several sites in western Montana revealed how the effects of burrowing mammal activity may eventually result in damage to the pavement structure or worsening of existing deterioration; however, these challenges were not widespread. In general, the findings indicated that burrowing mammal activity does not inherently constitute a widespread maintenance problem for paved roads in Montana, but spot locations that are experiencing burrowing mammal damage are in need of solutions. Holes and mounds created by burrowing mammals can also affect roadside maintenance activities (e.g., mowing, controlling weeds, maintaining signs, etc.).

Solutions are needed for areas where burrows are clearly coincident with damage to the pavement surface and support; however, it is uncertain whether burrowing mammal activity was the primary cause of the pavement distresses or whether existing distresses or deterioration created an environment attractive to nearby burrowing mammals. Location, layout, pavement condition, vegetation, shallow shoulders, adjacent land use, traffic levels, etc. may play a role in providing an attractive habitat for burrowing mammals near some paved roads. Other factors such as proximity to water features may also contribute. Feedback from respondents indicated that beaver and/or muskrat activity has the potential to indirectly contribute to pavement damage (via blocked culverts, dams, and some burrowing); however, this is only for roads that coincide with water features.

It is recommended that MDT consider employing techniques to mitigate areas where chronic burrowing mammal activities are coincident with distresses in the pavement surface and support. Because MDT's jurisdiction is limited to the right-of-way, removal strategies will not be able to encompass adjacent farm and ranchlands that support the base populations of burrowing mammals. Therefore, performing any form of direct mammal removal, such as poisoning,

trapping, or shooting, will likely gain only short term relief from the problem. Furthermore, effective timing for direct removal methods is limited to certain times of the year, and constant removal of immigrating animals is generally difficult to manage. Suggested techniques may include shoulder redesign, barriers to digging, and possibly vegetation management.

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APPENDIX A – SURVEY

Burrowing Mammal Impacts on Paved Roads

1. Background

The Montana Department of Transportation is seeking information with regard to burrowing mammal-caused damage to paved roads and other paved surfaces.

The magnitude of this maintenance issue in Montana has not yet been fully determined, but where the problem does occur, it can pose complex maintenance, operational, and environmental challenges.

The purpose of this survey is to:
1. assess the variety and extent of burrowing mammal-caused damage to paved roads, and
2. identify locations with damage for possible on-site inspection.

Your participation in this survey is completely voluntary, you can withdraw at anytime without penalty and your identity will remain anonymous unless you choose to identify yourself for the purposes of sharing information.

The survey will take approximately 3-7 minutes to complete. We thank you for your participation.

2. Personal experience

1. In the course of your work, and with regard to paved roads, for which of the following are you responsible? (Please select all that apply.)

- ☐ Inspecting
- ☐ Maintaining/repairing
- ☐ Managing
- ☐ Designing
- ☐ None of the above

2. Please state your agency and district/jurisdiction.

3. In the course of your work, have you noticed burrowing mammal-caused damage to paved road beds, shoulders up to and including the toe of the slope, or other paved surfaces?

- ○ Yes
- ○ No
- ○ I don't remember / I don't know

3. Personal experience - continued

Page 1

Burrowing Mammal Impacts on Paved Roads

4. What types of roads do you typically work on? (Please choose best option.)

- ◯ Mostly rural
- ◯ Rural/urban interface
- ◯ Mostly urban

5. What type(s) of suspected burrowing mammal damage have you observed on paved roads? (Please select all that apply.)

- ☐ Premature pavement failure
- ☐ Paved road surface deterioration
- ☐ Pavement subsurface deterioration
- ☐ Shoulder erosion
- ☐ Obvious burrows or holes in road surface or shoulder
- ☐ Obvious burrows or holes in the right-of-way beyond the shoulder and as far as the toe of the slope
- ☐ Clogged culverts
- ☐ Poor drainage
- ☐ Other (please specify)

6. On what type(s) of paved roads have you noted such damage? (Please select all that apply.)

- ☐ Two-lane
- ☐ Four-lane
- ☐ Interstate
- ☐ Rural
- ☐ Urban
- ☐ Rural/urban interface
- ☐ Airport runways and/or taxiways
- ☐ Other (please specify)

Page 2

Burrowing Mammal Impacts on Paved Roads

7. In what habitat type have you noted such damage? (Please select all that apply.)

- [ ] Grassland (including ranchlands)
- [ ] Forest
- [ ] Farmland (tilled)
- [ ] Urban
- [ ] Other (please specify)

8. What type of soil is found in the area(s) where you noted such damage (what color is it)? (Please select all that apply.)

- [ ] High organic content loam (black, black brown)
- [ ] Sandy (gold)
- [ ] Clayey (taupe)
- [ ] High iron (red)
- [ ] High lime silt (cream)
- [ ] I don't remember / I don't know

9. What species do you suspect are involved in the area(s) where you noted such damage? Feel free to refer to the photos below. (Please select all that apply.)

- [ ] Voles (similar to mice but slightly larger)
- [ ] Pocket gophers (about the shape/size of a large hot dog bun; rarely seen above ground; they leave raised piles of soil from tunneling with no exposed hole)
- [ ] Ground squirrels (also known as "gophers"; frequently seen above ground in spring and summer; burrows have exposed hole)
- [ ] Prairie dogs (live in prairie dog "towns"; frequently seen above ground year round; burrows in mounds with exposed hole)
- [ ] Marmots (chunkier and more grizzled looking than prairie dogs; smaller than badgers)
- [ ] Badgers (large, striped back, can be aggressive)
- [ ] I don't know

Page 3

Burrowing Mammal Impacts on Paved Roads

Vole

(credit: fieldguide.mt.gov)

Pocket Gopher

(credit: National Park Service, http://www.nps.gov/romo/resources/plantsandanimals/names/checklists/mammals/pocket_gopher.html)

Burrowing Mammal Impacts on Paved Roads

Ground Squirrel
(credit: fieldguide.mt.gov)

Prairie Dog
(credit: fieldguide.mt.gov)

Page 5

Burrowing Mammal Impacts on Paved Roads

Marmot

(credit: fieldguide.mt.gov)

Badger

(credit: Oxbow Zollman Zoo in Olmstead County, Minnesota; Jonathunder; Wikimedia Commons)

Page 6

Burrowing Mammal Impacts on Paved Roads

10. In damaged areas, have you ever seen the animal(s) suspected to have caused the damage?

- ◯ Yes
- ◯ No

11. If you have seen active burrowing mammal-caused damage to paved roads, during what periods have you observed it? (Please select all that apply.)

- ☐ February-August
- ☐ September-January
- ☐ All year
- ☐ I don't remember / I don't know

12. What do you typically do when you see suspected burrowing mammal-caused damage?

***(Please choose the answer that best describes your situation.)**

- ◯ Document only
- ◯ Spot repair as needed
- ◯ Systematically repair all affected areas
- ◯ Mitigate the site (e.g., vegetation management, pest control, remove soil piles, etc.)
- ◯ Nothing since it's so minimal
- ◯ Nothing since it's so widespread
- ◯ Nothing since there is no guidance on what to do
- ◯ Not applicable
- ◯ Other (please specify)

4. Repair

Page 7

Burrowing Mammal Impacts on Paved Roads

13. What method(s) do you use when repairing burrowing mammal-caused damage? (Please select all that apply.)

- [ ] Patch pavement
- [ ] Replace pavement
- [ ] Stabilize pavement and/or shoulder
- [ ] Restore base of road
- [ ] Other (please specify)

5. Mitigate

14. What method(s) do you use to mitigate burrowing mammal-caused damage? (Please select all that apply.)

- [ ] Manage vegetation to make it less attractive to the animals
- [ ] Direct pest control
- [ ] Remove soil piles that may attract animals
- [ ] Install digging barrier on/beneath shoulder material
- [ ] Fill in tunnels, burrows, and/or animal holes
- [ ] Other (please specify)

6. Direct Pest Control

15. What method(s) do you use to directly control burrowing mammals? (Please select all that apply.)

- [ ] Fumigate
- [ ] Apply poison baits
- [ ] Trap
- [ ] Shoot
- [ ] Other (please specify)

7. Method Effectiveness

Page 8

Burrowing Mammal Impacts on Paved Roads

16. Please rate the effectiveness of the methods you use.

	Completely ineffective, the problem persists	Mostly ineffective, works some times in some places	Works half the time	Mostly effective, works most times in most places	Complete effective, problem no longer exists	Not applicable
Repair	○	○	○	○	○	○
Mitigation	○	○	○	○	○	○
Direct control	○	○	○	○	○	○

8. Personal opinion

17. Please rate suspected burrowing mammal-caused damage in your work jurisdiction.

- ○ Not a problem at all
- ○ Very few localized problem areas
- ○ Occasional problem
- ○ Somewhat distributed throughout
- ○ Extremely widespread problem

18. Please choose the option that best fits your opinion for each of the following:

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Burrowing mammals are a cause of damage to Montana's paved surfaces that needs to be addressed.	○	○	○	○	○
Guidelines are needed in order for personnel to adequately address pavement damage from burrowing mammals.	○	○	○	○	○
More funding is needed to address pavement damage from burrowing mammals.	○	○	○	○	○
Too much of my work time is spent addressing burrowing mammal-caused pavement damage.	○	○	○	○	○

Page 9

Burrowing Mammal Impacts on Paved Roads

19. Please share any other useful information to describe your experience with burrowing mammal-caused road damage.

20. If you know of any sites with probable burrowing mammal-caused damage, please provide road name, nearest town(s) and mile markers and/or GPS coordinates (if possible).

***If you choose, you may email specific location information to angela.kociolek@coe.montana.edu until April 15, 2010.**

21. If you are willing to be contacted, please provide your contact information (name, title, district/job location, email, phone).

9. Thank you

Please click "done" to complete the survey. Thank you!

Page 10

APPENDIX B – QUESTION 19 OPEN-ENDED COMMENTS

Open-ended responses to Question 19 were categorized into five major categories listed below. The responses are shown as they were written, with some minor editing to correct spelling only. Any information that may help identify the respondent was masked to protect anonymity.

No burrowing mammal damage (18 comments)

- None
- Na
- None
- None
- I am not familiar with any problems from burrowing mammals in our area.
- We don't have a problem
- No problems that I can ever recall requiring repair
- We have hardly any problems with animals
- Burrowing mammals are not a problem
- I have never seen a burrowing mammal dig a hole through a paved surface.
- Have employees in areas that deal with this more directly than me.
- We don't seem to have a problem
- It is not a big problem, or expense.
- Fill holes with nearby material, not a big problem here
- Not a problem, in the 18 yrs. I 've worked for MDT
- I have never had to repair a street damaged by a burrowing animal in my 10 years at the […] Division.
- I have not seen this evidence
- Burrowing damage is not the cause as much as it is the result of otherwise poor road condition, construction, and/or maintenance

No burrowing mammal damage, but problem may exist (5 comments)

- I can see where it may be a problem in some areas but not here at present
- I have not seen much, if any, actual damage to the paved surface although I would think that damage to the road bed is occurring.
- We need to have a way to deal with animals burrowing by roadways before they actually create a problem with the road surface.
- Occurrence is less than in past decades
- None so far but the potential is here. […]section, runs between several ponds that are inhabited by Muskrats and Beaver. There are always possible burrowing issues when they are present. The water level in the ponds along highway […] fluctuates a lot. This can cause an existing burrow to flood making it necessary to for them to burrow multiple times.

Burrowing mammal damage to roadways (8 comments)

- So far we do not have asphalt damage but we have extreme shoulder damage with holes and no vegetation.
- They burrow from the shoulder or slope under the pavement which causes a small sink hole in the pavement.
- it's pretty much spotty […]
- In most of our area it doesn't seem to be too big of a problem. We have gophers throughout. It makes the shoulders rough. We are in a drier area so that helps with erosion The badger holes seem to cause more of a problem with the pavement.
- Beavers burrowing under a paved road causing settlement, badgers digging hole in shoulder of road, gophers digging holes in shoulder of roads
- Badgers will burrow along shoulders only when there is a dead deer along the roadway if it it's [not] remove[d] asap
- Usually, when badgers or woodchucks dig holes in the road shoulder, we will fill the holes in and the animals will move on.
- Years ago I saw what happened to the pavement as a result of a Badger digging holes under a fill slope causing the road to collapse

Burrowing mammal damage in areas other than paved roads (6 comments)

- The most damage I have seen is at rest areas, to the lawn, and surrounding area.
- Spot Locations Like Rest Area Sites.
- Ground squirrel burrowing is a problem in my rest area lawns. I'm concerned that tourists might be bitten by possibly diseased animals, or injury might occur due to stumbling in holes/mounds. Trapping, poisoning not an option because ground squirrels are an attraction to travelers, and the pets they are traveling with.
- Most of our problem areas are in gravel roads, on our […] sewer lagoons.
- In my area the problem is more around the section shop.
- We have very few paved roads but do have problems with burrowing animals on our gravel roads. Unless this vermin is exterminated by the landowner they continue to do their damage.

Beaver damage to roadways (8 comments)

- I have not had any problems with burrowing animals. I have however had problem with Beavers blocking culvert and causing flooding over roadways
- Beavers are another problem
- Beaver & muskrats are a large cause for us in a lot of areas
- The most damaging events of this type we have experienced are from Beavers digging into the subgrade at or near the ditchline where a wetland with Beaver dams and Beaver activity is immediately adjacent to the road. Not too often, but a couple of times in the last 5 years or so. One incident was severe enough to cause settlement in the outside traffic rut of a roadway requiring moderate repairs. Other burrowing from smaller animals can leave humps of soil in the ditches or shoulder slopes outside the

pavement, and sometimes at the pavement edge. But if there is any damage it is minimal and seldom does it actually cause any pavement damage.

- Hasn't been a problem in the 10 years I have been here. Only animal related problem I have encountered are beavers whose dams create localized flooding on roads, but usually a stick of dynamite fixes that.
- Burrowing "bank beaver" is our problem where dams border the in slopes.
- Beavers should also have been addressed. They are the major ones for plugging culverts, digging holes in the shoulders, and causing water back up from plugged culverts. These animals cause most of our damage, and it takes an act of congress to get a permit to remove their dams across culverts, ditch lines, streams. They also kill the vegetation when water backs up behind their dams.
- Beaver dams[…] are raising water level along this road and causing problems with subgrade.

APPENDIX C – INTERVIEWER LANGUAGE

Introduction

"Thanks for being willing to talk to me. Just so you know, I'll be taking notes while we're talking. I expect this call to take no more than about 5-7 minutes of your time. I'd like to ask you a few specific questions that will help us identify and select sites to visit in order to better understand the nature and extent of pavement damage due to burrowing mammal activity. After I am done with my questions you'll have an opportunity to share potential additional information and your perspectives on this topic.

For the purposes of this project, "area of interest" is defined as the paved road surface, the pavement subsurface, shoulders, and the right of way beyond the shoulder as far as the toe of the slope, including culverts.

"Damage" refers to any of the following:

- Premature pavement failure;
- Paved road surface deterioration;
- Pavement subsurface deterioration;
- Shoulder erosion;
- Obvious burrows or holes in road surface or shoulder;
- Obvious burrows or holes in the ROW beyond the shoulder and as far as the toe of the slope;
- Clogged culverts; and
- Poor drainage.

Questions

1. (yes or no) Have you observed damage that you believe is caused by burrowing mammals?
2. (scale of 1-5; 1 being not certain at all and 5 being 100% certain) How certain are you that the damage you saw was *caused* by burrowing mammals?
3. What species do you think was/is involved?
4. (scale of 1-5; 1 not likely at all and 5 extremely likely) How likely is it that exposed soils or some other situation *attracted* the animals to the area where you saw damage associated with burrows?
5. (yes or no) Have you observed the following conditions that you believe are associated with burrowing mammal activity?
    - Premature pavement failure;
    - Paved road surface deterioration;
    - Pavement subsurface deterioration;
    - Shoulder erosion;
    - Obvious burrows or holes in road surface or shoulder;
    - Obvious burrows or holes in the ROW beyond the shoulder and as far as the toe of the slope;
    - Clogged culverts;
    - Poor drainage; and

- Other… explain.

6. (#) How many different locations have you observed of damage associated with burrowing mammal activity?
7. For the worst case you've seen, what is the length of roadway affected?
8. *Reminder that we are concerned with ROW beyond the shoulder to the toe of the slope*; scale of 1 to 5 (1 being *only* the presence of burrows, 5 being dramatic pavement surface or subsurface deterioration that is obviously linked to burrows) How would you rate the typical damage you've seen?
9. (yes or no) Would you be willing to guide us to the site(s)?
10. Would you like to share your perspective on the extent, issues, and/or causes related to this topic?"

APPENDIX D – INTERVIEWEE CLOSING REMARKS

At the conclusion of the interview, interviewees were given an opportunity to share their perspectives on the extent, issues, and/or causes related to this topic. The responses below are derived from notes taken by the interviewer during the phone interviews. Every attempt was made to obtain direct quotes in order to accurately reflect the intended meaning of the interviewee. The responses below have been transcribed from notes and, therefore, do include some interpretation by the interviewer/author. Some comments are listed under more than one category and are noted as such.

Did not wish to share perspective (3 comments)

Burrowing mammals are generally not a problem for paved roads (11 comments)

- In the urban setting where I work, it's never been issue. I killed 1,400 gophers last week for fun. I even see them in greenways near Wal-Mart but they are not causing a problem as far as I know.
- Probably not since I have not seen all that much. Maybe 10 years down the road.
- The wetland area is immediately adjacent. I have to guess at exactly what we saw. One guess is a beaver family in the wetland went working in standing water and dammed it up. Water flows into the bottom of the slope and they burrowed into the side of the road underneath or at water level. There was no direct damage to road surface. In the other case beaver burrowed straight in under the shoulder and several feet into and under the asphalt. A vehicle fell into the shoulder while mowing. We filled it in and the roadway sunk where they burrowed in. It's not exactly common, there may have been more. Other burrowing mammals don't seem to be much of a problem. Once in a while we see holes but usually not close to shoulder and they don't cause any problems. *(also listed in wetland-related comments below)*
- The only other thing is the rock chuck – marmot on Hwy 12. It's not a major problem. There is no extensive damage and nothing to roadway just the presence of them.
- I've shared as much as I can. I have nothing to add. It seems to be a situation going on but the road hasn't gotten any worse since we first saw it and patched it two years ago.
- For parking lots and rest areas, there are not a lot but some. Nope.
- Yes, I see it but not much and they've lived there forever.
- Okay. The only problem is at the lagoon but that's got nothing to do with pavement. We exterminate gophers only in that area. Don't kill them gophers! You probably don't like them.
- Yeah, I'm not saying they're not out there but I have not noticed problems.
- Beaver can cause problems but not at this time. Y'know, I'm probably not the best person because I don't have issues with this. It doesn't seem to be a problem in this district. *(also listed in wetland-related comments below)*

- No problems yet. Natural potholes in the land adjacent to the road fill with water so there are tons of muskrat and beavers. I will start inspections. It is a perfect set up because of the proximity of the road to water. So. It's not out of the realm of possibility that such damage could occur. *(also listed in wetland-related comments below)*

Burrowing mammals can be a problem for paved roads (8 comments)

- They make lots of holes! I see them stick their heads out of holes. Gophers attract badgers. If we got rid of them (badgers) we'd get rid of 90% of the problem. If we make feed less palatable they would move on. If it's environmentally friendly, I don't know, but pepper spray/mustard would be a good way to start. Now (April) is the time to see them.
- Nope. There is a ranch field on both sides. It has a sprinkler system and attracts badgers and other problems.
- Call any time. I will show you where it's at.
- Yeah. We have a hill on a primary road. The top of the hill is south facing so there is extensive burrowing. It's promoted by using sand in the area which is for easy digging. It's one of the first places that thaws out early in spring. It has inviting vegetation. The burrowing has created a channel for water. We had to patch twice in 6 years because the base under the pavement washed out. There is not great drainage because it's a flat area. It's a combination of events – there is ease of access of water down slope and it freezes up. MT Rt 1 west of Anaconda, the decomposed granite washes out easily. Using another soil type would not necessarily work because then vegetation would be a problem.
- I can show you a county road really affected by burrowing mammals. It's not hot asphalt but they mix water with gravel. I wonder if it's the traffic volume or maybe because it's not as hard or as thick but it's still three inches thick.
- It's warm and dry so they burrow under. Pocket gophers along I-15 only damage the ROW and makes it's rougher but MDT doesn't need to be concerned about that. It's such a simple fix just to poison why is there such a big deal about it? I solved the problem in 24 man hours for 1.5 miles. The worst area was already reconstructed for 12 miles. Still have burrowing mammals in the ROW but it's a non-problem. Just deal with it since there is no damage to the pavement.
- It's very minor in this District. Another division in Havre has a lot more problems. It's a sport to shoot gophers.
- Um, no, got it well covered. Greycliff, frontage and interstate.

Wetland-related issue rather than a typical burrowing mammal-related issue (7 comments)

- I specifically answered questions in terms of beavers. I would like to move road away from stream which should allow it to meander. More separation between roads and streams is needed, theoretically. Beavers play an important role but they also cause problems. We need to figure out a way to cohabitate. I appreciate that you want to know our opinion.

- Nope. But muskrats and occasionally beaver cause problems on the paved Headwaters walking trails near Three Forks Pond.
- The wetland area is immediately adjacent. I have to guess at exactly what we saw. One guess is a beaver family in the wetland went working in standing water and dammed it up. Water flows into the bottom of the slope and they burrowed into the side of the road underneath or at water level. There was no direct damage to road surface. In the other case beaver burrowed straight in under the shoulder and several feet into and under the asphalt. A vehicle fell into the shoulder while mowing. We filled it in and the roadway sunk where they burrowed in. It's not exactly common, there may have been more. Other burrowing mammals don't seem to be much of a problem. Once in a while we see holes but usually not close to shoulder and they don't cause any problems. (*also listed in "generally not a problem" comments above*)
- Keep in mind what I talked about was a rest area with parking lots and sidewalks. Columbian ground squirrels like Doritos! Some beaver on I-90 Henderson MM 22. The issue is because we must get permits to clear culverts so it becomes a hassle. But the traveling public likes to see beaver but landowners like to see them removed. We're between a rock and hard place. The stream is about 15-20 feet from the road or right on it. I have lots of concerns on the river and our impacts. If we take out the dams then there is more sediment. Beavers are a good thing and a bad thing at the same time.
- Beaver can cause problems but not at this time. Y'know, I'm probably not the best person because I don't have issues with this. It doesn't seem to be a problem in this district. *(also listed in "generally not a problem" comments above)*
- No problems yet. Natural potholes in the land adjacent to the road fill with water so there are tons of muskrat and beavers. I will start inspections. It is a perfect set up because of the proximity of the road to water. So. It's not out of the realm of possibility that such damage could occur. *(also listed in "generally not a problem" comments above)*
- I just think it's a good idea to understand the difficulty and see damage done. Beavers are far more destructive than anything else. They build dams in pipes, it backs up, kills vegetation, landowners get upset, rusts fence, water goes across the roadway. Beavers also dig out soil, the mower collapses in. We filled several holes. Stream water is right next to the ditch of road. Beaver will walk a ways from the stream. It's hard to get a permit to remove so it gives the beavers a chance to build and build. We can't remove the dams because of environmental and wetland regulations. They are more worried about beaver than the road or the traveling public.

APPENDIX E – SITE VISIT CHECKLIST

Burrowing Mammal Impacts on Paved Highways - Phase 1

Site Visit Checklist

Date _____

MDT District _____ Maintenance Area _____ Contact _____

Road Name _____ Specific Location _____

Road Type (circle) **two lane four lane interstate rural urban rural/urban interface other**_____

Habitat Type (circle) **grassland/ranchland forest tilled urban other**_____

Soil Type (circle) **clay sand high organic loam high iron high lime silt other** _____

Burrows or holes are present: (circle) **ROW as far as toe unpaved shoulder paved shoulder pavement subsurface pavement surface NA**

Any sign of pavement damage present: (circle) **YES [shoulder lanes | subsurface surface] NO**

Problems regarding drainage: (circle) **clogged culverts poor drainage flooding other** _____ **NA**

Damage rating*: (circle) **1 2 3 4 5**

* (1 = only the presence of burrows, 5 = dramatic pavement surface or subsurface deterioration that is obviously linked to burrows)

Length of roadway affected (in feet): _____ **NA**

Duration of time pavement has known to be damaged (in months/years): _____ **UNK NA**

Has site been repaired? **yes no unk** If so, how? _____

Species involved (or suspected*): **VOLE POGO RIGR COGR PRDO BADG MARM BEAV MUSK UNK NA other** _____

* indicate if only suspected: _____

Is there anything obvious that may have attracted animals like construction soil piles, etc.? **yes no**

Notes: _____

Documented with photos? (check) O

Species key: VOLE = any species of vole, POGO = Pocket gopher, RIGR = Richardson's Ground Squirrel, COGR = Columbian Ground Squirrel, PRDO = Black-tailed Prairie Dog, BADG = Badger, MARM = Yellow-bellied Marmot, BEAV = Beaver, MUSK = Muskrat.

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