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MEADE_IM 0901(195)32N_IM 0901(198)32N_I-90 Exit 32-40, WILDLIFE-VEHICLE COLLISION (WVC) ANALYSIS

I. INTRODUCTION

The purpose of this memo is to assess alternatives for reducing the frequency of wildlife-vehicle collisions (WVCs) along the I-90 from Exit 32 to Exit 40. WVCs are increasing on our nation's roadways and have negative impacts on drivers and wildlife populations[1]. In an average year in South Dakota (2004-2013), wildlife collisions resulted in 1.5 fatal crashes, 73.5 injury crashes and 4621 property-damage-only crashes at an estimated cost of $107.9 million[2]. Another $29.6 million could be added when considering the value of animals lost[3]. For the ten-year period between 2004 to 2013, the I-90 corridor had three of the twenty ranked WVC hotspots in the state with an average frequency between 10.81-25.22 WVC per mile. The WVC hotspot with the highest reported crash frequency in the state of South Dakota during that ten-year period was located along I-90 between MRM 9.9-10.2 near Spearfish. Our Existing Traffic Operations Technical Memorandum for the I-90 corridor between Exit 32 and Exit 40 outlines that WVCs account for 37% (2nd highest crash type) of total collisions between 2012 through 2016 with an overall crash frequency of 13.49 WVC per mile for the entire 10.9-mile corridor.

In 1999, the South Dakota Department of Transportation (SDDOT) worked with South Dakota Game, Fish and Parks (SD GFP) to provide wildlife fencing along the southwest side of I-90 near the Snyder Ranch (MRM 37.40 to MRM 40.00) in an attempt to mitigate WVCs. The fence was later extended a half mile in 2005. SD GFP has noted that the fence has worked in reducing animal crossings, but poor maintenance has led to disrepair and reduced effectiveness over time.

Correspondence with SD GFP and police reported crashes were used as the primary data sources for the analysis. Review of individual crash reports confirm that WVC collisions along the corridor mainly involve white-tailed deer and elk. SD GFP reported that populations of deer are present throughout the corridor and frequent residential areas such as the Blucksburg development between Exit 34 and Exit 37. Elk, however, tend to avoid developed areas[4]. SD GFP identified the Snyder Ranch area on the SW side of I-90 as an elk crossing location connecting two habitats on either side of the interstate[5]. There is also a population of elk near the Black Hills National Cemetery that has crossed I-90 due to a lack of habitat on the south side. The implementation of WVC mitigation measures in the corridor planning stage of the I-90 Corridor Study and Design Project will assist SDDOT in decision making for protecting motorists, decreasing WVC, and facilitating efficient movement of wildlife.

1 (Huijser, et al., 2008)

2 (Cramer, et al., 2016)

3 (Cramer, et al., 2016)

4 (Cook, 2018)

5 (Cook, 2018)

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II. IDENTIFICATION OF WILDLIFE-VEHICLE COLLISION HOTSPOTS

WVCs typically occur in dry weather and near mixed landscapes that provide animal cover[6]. They tend to spike during dimly lit hours of the day such as early mornings or late evenings, especially in the spring and fall months. The I-90 roadside landscape is ideal for WVCs due to the forested cover provided from the Black Hills National Forest and water sources on both sides of the highway. Along the study area, animal crashes remained consistent for the 5-year period between 2012 and 2016 with 92% of crashes over the period occurring in dry roadway conditions. Ninety-six percent (96%) of crashes involved property damage only, while 70% took place at unlighted locations. While only comprising of 9% of total WVCs, elk accounted for all incapacitating injuries, 33% non-incapacitating injuries, and 50% possible injuries. Trends are summarized in **Figure 2**.

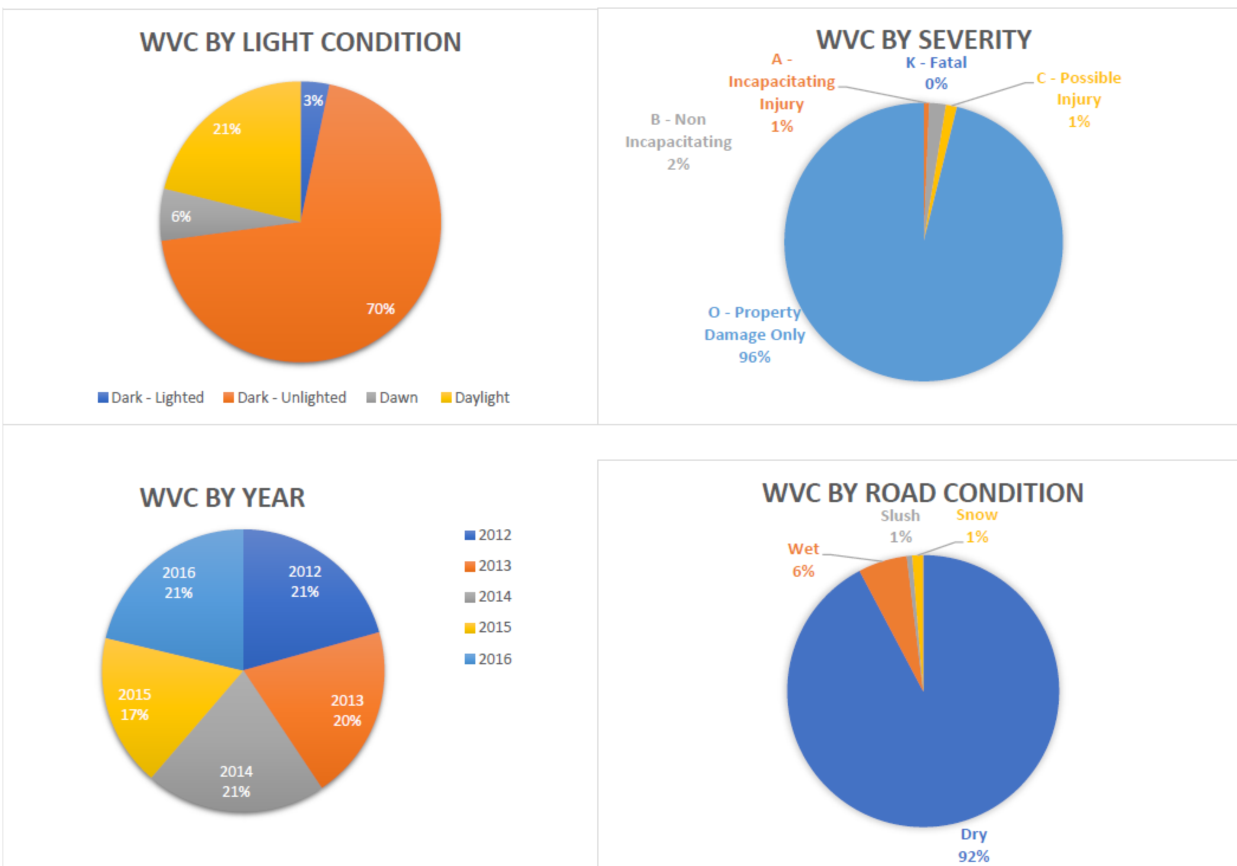

Figure 1. I-90 Crash Trends and Contributing Factors

Crash frequency, severity (EPDO Crash Frequency) and excess proportion of specific crash type were used to identify locations with a high incidence of WVCs. The I-90 focus area was

6 (Huijser, et al., 2008)

segmented based on exit locations. Overlapping 0.3-mile sub-segments[7] with 0.1-mile increment sliding windows were ranked by each performance measure to determine locations for further analysis as shown in **Table 1**. A table with the complete list of subsegments are shown in Appendix A – WVC Screening. Ten 0.3-mile hotspots were identified along the corridor using the performance measures outlined in **Table 1**. Hotspot locations along the study area are shown in **Figure 1.**

Table 1. Hotspot Rank by Performance Measure

Location	Subsegment	Begin MRM	End MRM*	Frequency	WVC Rate	Critical Rate Exceeded?	EPDO	Probability Exceeding Threshold*
Between Exit 32 and Exit 34	18	32.7	33.0	21	109	YES	31.5	0.17
	19	32.8	33.1	21	109	YES	31.5	0.17
	20	32.9	33.2	21	109	YES	31.5	0.17
	21	33.0	33.3	21	109	YES	31.5	0.17
	38	34.7	35.0	15	78	YES	15.0	0.16
	39	34.8	35.1	15	78	YES	15.0	0.13
	40	34.9	35.2	14	72	YES	14.0	0.13
Between Exit 34 and Exit 37	48	35.7	36.0	21	110	YES	21.0	0.083
	49	35.8	36.1	21	110	YES	21.0	0.083
	50	35.9	36.2	21	110	YES	21.0	0.083

**Probability that long term expected proportion of animal crashes at subsegment is greater than the long term expected proportion of segments along the entire study area*

<u>Subsegments 18-21 (MRM 32.7 to 33.3 - 0.6 miles)</u>

Four of ten hotspots were located just east of Exit 32 where the area-type changes in character from urban to rural. There was a total of 21 WVCs for the analysis period with a steady increase in crashes between 2012-2016. The average number of WVC/mile/year along these subsegments is 7.00 which is greater than comparable high crash segments along I-90 identified in the 2016 Report – Reducing WVC in South Dakota (Cramer, et al., 2016). Conditions suitable to animals crossing location include:

- Water sources located in the northeast and southwest sides of I-90
- Suitable terrain
- Tree cover in the southwest, median and northeast side of I-90
- Poorly maintained fence
- Due to steep side slopes and horizontal curvature it may be difficult for drivers to perceive animals approaching the roadway

Due to the outlined conditions, this hotspot is likely to benefit from improvements in WVC mitigation measures that target drivers versus those that target wildlife.

7 (Huijser, McGowen, Clevenger, & Ament, 2008)

<u>Subsegments 38-40 (MRM 34.3 to 35.2 – 0.9 miles)</u>
Three of ten hotspots were located just west of and within the functional area of the Exit 34 interchange. There was a total of 27 WVCs for the analysis period with a consistent frequency of crashes between 2012-2016. The average number of WVC/mile/year along these subsegments was 6.00 which is greater than comparable high crash segments along I-90 identified in the 2016 Cramer Report. Conditions suitable to animals crossing at this location include:

- A traversable stream with tree cover on both sides of I-90 near MRM 34.30
- Tree cover north of Exit 34 near MRM 34.32
- Poorly maintained fence within the interchange functional area
- No fence available combined with steep slopes along I-90 near MRM 35.0

<u>Subsegments 48-50 (MRM 35.7 to 36.2 – 0.5 miles)</u>
Three of ten hotspots were located between Exits 34 and 37. There was a total of 21 WVCs for the analysis period with a steady increase in crashes between 2012-2016. The average number of WVC/mile/year along these subsegments was 8.40 which is consistent with comparable high crash locations within the state identified in the 2016 Report – Reducing WVC in South Dakota (Cramer, et al., 2016). Conditions at this site do not fit the description of a typical crossing location as there is sparse residential development on the northeast side of I-90 and agricultural land uses on the southwest side. Conditions suitable to animals crossing at this location include:

- Tree cover on both sides of I-90 near MRM 36.5
- Water sources located on the east and west side of I-90

Due to the outlined conditions, this hotspot is likely to benefit from improvements in WVC mitigation measures that target drivers versus those that target wildlife.

<u>High Severity Subsegments 68-70 (MRM 37.7 to 38.2 – 0.5 miles)</u>
It is worth mentioning that WVCs with the highest severities were recorded between Exit 37 and the Tilford Point of Entry. EPDO crash frequency scores of 44.6 were recorded for each subsegment suggesting that there was at least 1 incapacitating injury recorded. There is cover and gentle grades on both sides of I-90 creating a suitable habitat for deer and elk. There may be opportunities to improve or repair fencing along this location.

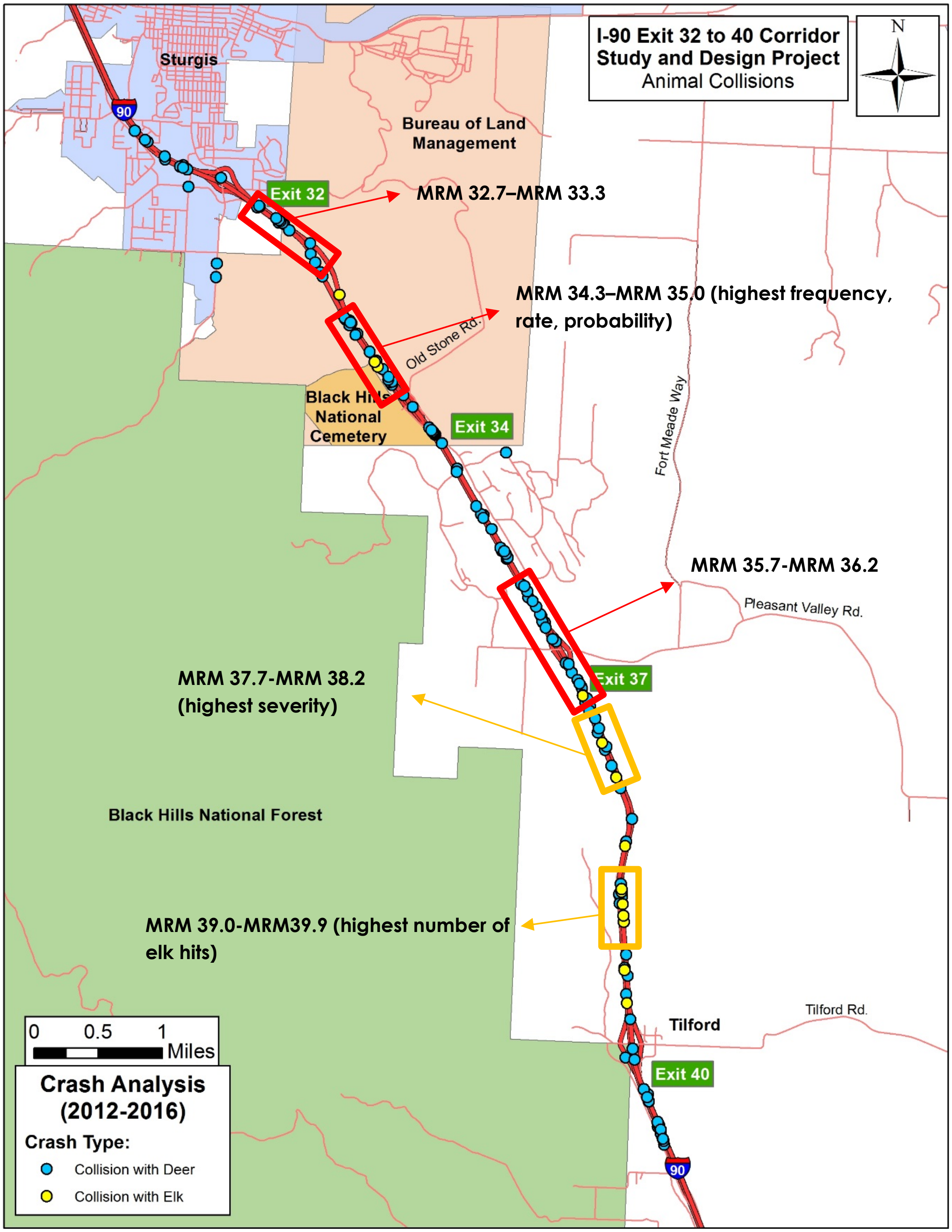

Figure 2. Animal Collision Hotspots (2012-2016)

III. WILDLIFE-VEHICLE COLLISION MITIGATION STRATEGIES

WVC mitigation measures are typically implemented to target wildlife or drivers along a facility. High cost mitigation measures for reducing WVCs through targeting wildlife include: wildlife fencing, crossing structures, and population reduction (hunting pressure). Whereas, high cost measures that target drivers include: Animal detection systems (ADS). Lower cost measures targeting drivers include static signs, use of in-place variable message boards, continuous lighting in high risk areas, and assessing existing infrastructure for retrofits (bridge/culvert passages for ungulates). The collision reduction application of the above-mentioned mitigation strategies as documented in research are shown in **Table 2** and discussed in the sections that follow.

Table 2. Mitigation Measures for WVC Reduction

Target	Mitigation Measure	Effectiveness	Cost
Animals	Fence	84%[1]	High
	Elevated Roadway/Crossing Structure	86%[2]	High
	Population Culling	50%[3]	Low
Drivers	ADS	87%[4]	High
	Fence, Gap, ADS	87%[5]	High
	Warning Signs (Static, seasonal, vms)	26%[6]	Low

1. *Clevenger et al. (2001): 80%; Dodd et al. (2007): 87%*
2. *Huisjer et al. 2007a*
3. *Huisjer et al. 2007a*
4. *Mosler-Berger and Romer (2003): 82%; Dodd and Gagnon (2008): 91%*
5. *Mosler-Berger and Romer (2003): 82%; Dodd and Gagnon (2008): 91%*
6. *Sullivan et al. (2004): 51%; Rogers (2004): 0%*

Target Species, Design, Best Practices

Fences

Useful for preventing large mammals such as deer and elk from entering the right-of-way. Fencing could be installed on both sides of the I-90 corridor. They could be metal wire, chain link, or electrified in nature. They should be at least 8' or higher (for mammals approaching from a sloped roadside) for larger mammals such as deer and elk. Posts should be 5" diameter and spaced in 14-18' intervals. Best practices suggest combining continuous fencing with gaps for crossing opportunities[8].

Crossing Structures

Used to provide connectivity for large mammals in combination with fencing or as a standalone measure. When used in combination with fencing it can be on average 86% effective in reducing WVCs. Structures can take the form of underpasses (culverts or open span bridges) or overpasses. Underpasses are usually installed in low-lying areas with road fill for cheaper construction. Overpasses are typically installed within cut areas in the roadway alignment.

8 (Huijser, McGowen, Clevenger, & Ament, 2008)

Crossing structures are costly and should only be installed where target species are likely to use them)[9]. Cost savings could be realized by retro-fitting large culverts to act as crossings.

Animal Detection Systems (ADS)

ADS use sensors to detect large animals such as deer and elk as they approach the road. When animals are detected, a sign is activated with the intention of making the driver alert or reducing speeds. ADS typically use infrared cameras or microwave radio signals. ADS should be placed at locations with a high number of WVCs with large animals as the cost of the system would be compensated by the savings from reduced collisions. ADS could be used as a standalone measure for segments up to 1.0-miles long or at gaps in fencing. Most ADS would require security and a 110V power source[10]. Costs typically range between $20,000 - $65,000 for installation with maintenance needed for technical issues.

Population Culling

Population culling (hunting pressure) is a relatively low-cost measure for reducing WVCs by eliminating many target species over a short period of time. This measure is typically applied to reduce white-tailed deer in suburban settings where other methods have failed. Effectiveness in reducing WVCs is 50% or less[11]. Cost range from $110-$373 per deer killed[12] and may need to be repeated periodically[13].

Proposed mitigation measures for each hotspot based on conditions highlighted in **Section II** and best practices mentioned above are summarized in **Table 3**.

Table 3. Hotspot Mitigation Measures

Location	Mitigation Measure	Reason
Subsegments 18-21 (MRM 32.7 to 33.3 - 0.6 miles)	Animal Detection System (ADS)	Existing fence ineffective, ADS targets drivers vs wildlife
Subsegments 38-40 (MRM 34.3 to 35.2 – 0.9 miles)	Fencing	Existing fencing does not cover entire interchange functional area
Subsegments 48-50 (MRM 35.7 to 36.2 – 0.5 miles)	Animal Detection System (ADS)	Existing fence ineffective, ADS targets drivers vs wildlife

9 (Huijser, McGowen, Clevenger, & Ament, 2008)
10 (Huijser, McGowen, Clevenger, & Ament, 2008)
11 (Huijser, McGowen, Clevenger, & Ament, 2008)
12 (Huijser, McGowen, Clevenger, & Ament, 2008)
13 (Huijser, McGowen, Clevenger, & Ament, 2008)

IV. COST BENEFIT ANALYSIS

A cost benefit analysis was performed for the installation of mitigation measures at hotspots that would likely benefit from a reduction in crashes. The cost benefit analysis was completed using the following steps from Reducing WVC in South Dakota (Cramer, et al., 2016):

1. Estimate costs of WVC from WVC crash data.
2. Estimate cost of WVC on wildlife populations.
3. Estimate percentage decrease in WVC crashes the mitigation is expected to provide.
4. Estimate lifespan of the mitigation including maintenance.
5. Determine benefit-cost ratio.
6. Determine how long it would take to pay for itself.

<u>Subsegments 18-21 (MRM 32.7 to 33.3 - 0.6 miles) – Installation of ADS System</u>

1. Determination of estimated Average Cost of WVC crashes

Crash Costs	Total WVC	WVC/yr.	Average Cost ($)[14]	Annual Cost ($)
Fatal - K	0	0	370,800	
Incapacitating Injury - A	0	0	370,800	
Non-Incapacitating Injury - B	1	.2	370,800	74,160
Possible Injury - C	0	0	370,800	
Property Damage Only - O	20	4	17,343	69,372
			Estimated Average cost of WVC	143,532

**Costs in 2007 dollars*

2. Cost of WVC to wildlife populations = 4.26 (crashes/year) * 5.26 (animals potentially killed and not reported) * 1000 (value per animal) = $22,092

3. Percentage decrease in WVC = 4.26 (crashes/year) * 0.87 (effectiveness of measure) = 3.65 (crashes prevented/year). Cost of animals saved = $19,220.04; Annual savings from prevented crashes = 3.65 (crashes/year) * $17,343 = $63,371.32

4. Lifespan of mitigation assumed = 50 years

5. Cost savings over life of mitigation due to crashes = 50 years * $63,371.32 = $3,168,566.10

   Cost savings over life of mitigation due to animals saved = 50 years * $19,220.04 = $961,002

6. Estimate of mitigation ADS system = $150,000 (conservative cost for design and installation of ADS system). Estimated cost of maintenance = $8,000 * 50 = $400,000. Total cost of installation and maintenance over 50 years = $550,000

[14] (Cramer, et al., 2016)

7. Benefit-Cost ratio = $\frac{3{,}168{,}566.10+961{,}002}{550{,}000}$ = 7.51

8. Payback period = $\frac{Total\ Cost\ over\ 50\ years}{Cost\ savings\ per\ year} = \frac{550{,}000}{63{,}371.32+19{,}220.04}$ = 7 years

NB. All costs in 2007 dollars.

<u>Subsegments 38-40 (MRM 34.3 to 35.2 – 0.9 miles) – Installation of Improved Fencing</u>

1. Determination of Estimated Average Cost of WVC crashes

Crash Costs	Total WVC	WVC/year	Average Cost ($)[15]	Annual Cost ($)
Fatal - K	0	0	370,800	
Incapacitating Injury - A	0	0	370,800	
Non-Incapacitating Injury - B	0	0	370,800	
Possible Injury - C	0	0	370,800	
Property Damage Only - PDO	27	5.4	17,343	93,652.20
			Estimated Average Cost of WVC	93,652.20

**Costs in 2007 dollars*

2. Cost of WVC to wildlife populations = 5.4 (crashes/year) * 5.26 (animals potentially killed and not reported) * 1000 (value per animal) = $28,404.00

3. Percentage decrease in WVC = 5.4 (crashes/year) * 0.84 (effectiveness of measure) = 4.54 (crashes prevented/year). Cost of animals saved = $23,859.36; Annual savings from prevented crashes = 4.54 (crashes/year) * $17,343 = 78,667.85.

4. Lifespan of mitigation assumed = 50 years

5. Cost savings over life of mitigation due to crashes = 50 years * $78,667.85 = $3,933,392.40

   Cost savings over life of mitigation due to animals saved = 50 years * $23,859.36 = $1,192,968

6. Estimate of fence = $39,600 ($15.00 per foot of fence for segment length). Estimated cost of maintenance = $2,000 * 50 = $100,000. Total cost of installation and maintenance over 50 years = $139,600

7. Benefit-Cost ratio = $\frac{3{,}933{,}392.40+1{,}192{,}968}{139{,}600}$ = 36.7

8. Payback period = $\frac{Total\ Cost\ over\ 50\ years}{Cost\ savings\ per\ year} = \frac{139{,}600}{78{,}667.85+23{,}859.36}$ = 1 year

NB. All costs in 2007 dollars.

[15] (Cramer, et al., 2016)

V. RECOMMENDATIONS

Based on the findings of the study we have determined it is economically and physically feasible for the SDDOT to install mitigation measures for reducing WVCs within the I-90 Corridor Study project limits. Opportunities for reducing crashes are available at the following hotspots:

- Subsegments 18-21 (MRM 32.7 to 33.3 - 0.6 miles)
- Subsegments 38-40 (MRM 34.3 to 35.0 – 0.5 miles)
- Subsegments 48-50 (MRM 35.7 to 36.2 – 0.5 miles)
- High Severity Subsegments 68-70 (MRM 37.7 to 38.2 – 0.5 miles)

Animal detection systems (ADS), retrofitting large culverts near hotspots to function as dedicated crossings and population culling should be further studied in places where fencing is ineffective. In addition, a policy for preventing WVCs should be implemented along the I-90 corridor.

VII. REFERENCES

Cook, A. (2018, 1 25). Stantec WO: PD-03-17, I-90 Exit 32-40 - SD Game, Fish, and Parks Meeting Minutes. Rapid City.

Cramer, P., Julia, K., Gunson, K., Shilling, F., Kenner, M., Chapman, C., & Berger, L. (2016). *Reducing WVC in South Dakota.* Pierre: SDDOT Department of Transportation, Office of Research.

Huijser, M., McGowen, P., Clevenger, A., & Ament, R. (2008). *Wildlife–vehicle Collision Reduction Study: Best Practices Manual.* Bozeman: Montana State University, Western Transportation Institute.

Huijser, M., McGowen, P., Fuller, J., Hardy, A., Kociolek, A., & Clevenger, A. (2008). *Wildlife-Vehicle Collision Reduction Study: Report to Congress.* Bozeman: Montana State University - Western Transportation Institute.

APPENDIX A – CRASH SCREENING

Segments	Sub-segment	Begin MRM	End MRM	I-90 Exit #	ADT	Total Crashes	Total WVC	WVC/year	WVC/mile/year	WVC/HMVMT (Rate)	Rc,I (Critical Rate)	probability	WVC by Year					Severity					Alt. EPDO
													2012	2013	2014	2015	2016	K	A	B	C	O	
	1	31.0	31.3		8200	0	0	0.00	0.00	0	50	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	2	31.1	31.4		8200	0	0	0.00	0.00	0	50	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	3	31.2	31.5		8200	4	3	0.60	2.00	20	50	0.000	0	1	2	0	0	0	0	0	0	3	3.0
	4	31.3	31.6		8200	4	3	0.60	2.00	20	50	0.000	0	1	2	0	0	0	0	0	0	3	3.0
	5	31.4	31.7		8200	4	3	0.60	2.00	20	50	0.000	0	1	2	0	0	0	0	0	0	3	3.0
	6	31.5	31.8		8200	4	3	0.60	2.00	20	50	0.000	0	1	2	0	0	0	0	0	0	3	3.0
	7	31.6	31.9		8200	0	0	0.00	0.00	0	50	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	8	31.7	32.0		8200	5	2	0.40	1.33	13	50	0.000	1	0	1	0	0	0	0	0	0	2	2.0
Before Exit 32	9	31.8	32.1		8200	18	6	1.20	4.00	40	50	0.000	2	0	2	0	2	0	0	0	0	6	6.0
	10	31.9	32.2		8200	18	6	1.20	4.00	40	50	0.000	2	0	2	0	2	0	0	0	0	6	6.0
	11	32.0	32.3	Exit 32	8200	22	6	1.20	4.00	40	50	0.000	2	0	2	0	2	0	0	0	0	6	6.0
	12	32.1	32.4	Exit 32	8200	4	0	0.00	0.00	0	50	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	13	32.2	32.5	Exit 32	8200	17	4	0.80	2.67	27	50	0.000	0	2	0	0	2	0	0	0	0	4	4.0
	14	32.3	32.6	Exit 32	8200	13	4	0.80	2.67	27	50	0.000	0	2	0	0	2	0	0	0	0	4	4.0
	15	32.4	32.7	Exit 32	8200	13	4	0.80	2.67	27	50	0.000	0	2	0	0	2	0	0	0	0	4	4.0
	16	32.5	32.8	Exit 32	8200	0	0	0.00	0.00	0	50	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	17	32.6	32.9	Exit 32	8200	0	0	0.00	0.00	0	50	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	18	32.7	33.0		10600	43	21	4.20	14.00	109	47	0.171	3	5	3	4	6	0	0	1	0	20	31.5
	19	32.8	33.1		10600	43	21	4.20	14.00	109	47	0.171	3	5	3	4	6	0	0	1	0	20	31.5
	20	32.9	33.2		10600	43	21	4.20	14.00	109	47	0.171	3	5	3	4	6	0	0	1	0	20	31.5
	21	33.0	33.3		10600	43	21	4.20	14.00	109	47	0.171	3	5	3	4	6	0	0	1	0	20	31.5
	22	33.1	33.4		10600	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	23	33.2	33.5		10600	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	24	33.3	33.6		10600	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	25	33.4	33.7		10600	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	26	33.5	33.8		10600	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	27	33.6	33.9		10600	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
Between Exit 32 and Exit 34	28	33.7	34.0		10600	17	8	1.60	5.33	41	47	0.000	2	1	2	1	2	0	0	0	0	8	8.0
	29	33.8	34.1		10600	17	8	1.60	5.33	41	47	0.000	2	1	2	1	2	0	0	0	0	8	8.0
	30	33.9	34.2		10600	17	8	1.60	5.33	41	47	0.000	2	1	2	1	2	0	0	0	0	8	8.0
	31	34.0	34.3		10600	17	8	1.60	5.33	41	47	0.000	2	1	2	1	2	0	0	0	0	8	8.0
	32	34.1	34.4		10600	18	12	2.40	8.00	62	47	0.060	2	3	2	4	1	0	0	0	0	12	12.0
	33	34.2	34.5		10600	18	12	2.40	8.00	62	47	0.060	2	3	2	4	1	0	0	0	0	12	12.0
	34	34.3	34.6		10600	18	12	2.40	8.00	62	47	0.060	2	3	2	4	1	0	0	0	0	12	12.0
	35	34.4	34.7		10600	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	36	34.5	34.8	Exit 34	10600	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	37	34.6	34.9	Exit 34	10600	1	1	0.20	0.67	5	47	0.000	0	0	1	0	0	0	0	0	0	1	1.0
	38	34.7	35.0	Exit 34	10600	30	15	3.00	10.00	78	47	0.162	4	5	4	2	0	0	0	0	0	15	15.0
	39	34.8	35.1	Exit 34	10600	30	15	3.00	10.00	78	47	0.162	4	5	4	2	0	0	0	0	0	15	15.0
	40	34.9	35.2	Exit 34	10600	29	14	2.80	9.33	72	47	0.176	4	5	3	2	0	0	0	0	0	14	14.0
	41	35.0	35.3		10500	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	42	35.1	35.4		10500	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	43	35.2	35.5		10500	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	44	35.3	35.6		10500	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	45	35.4	35.7		10500	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	46	35.5	35.8		10500	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	47	35.6	35.9		10500	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	48	35.7	36.0		10500	34	21	4.20	14.00	110	47	0.083	4	2	4	3	8	0	0	0	0	21	21.0
	49	35.8	36.1		10500	34	21	4.20	14.00	110	47	0.083	4	2	4	3	8	0	0	0	0	21	21.0
	50	35.9	36.2		10500	34	21	4.20	14.00	110	47	0.083	4	2	4	3	8	0	0	0	0	21	21.0
Between Exit 34 and Exit 37	51	36.0	36.3		10500	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	52	36.1	36.4		10500	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	53	36.2	36.5		10500	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	54	36.3	36.6		10500	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	55	36.4	36.7		10500	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	56	36.5	36.8		10500	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	57	36.6	36.9		10500	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	58	36.7	37.0	Exit 37	10500	5	1	0.20	0.67	5	47	0.000	0	1	0	0	0	0	0	0	0	1	1.0
	59	36.8	37.1	Exit 37	10500	20	7	1.40	4.67	37	47	0.000	1	1	2	1	2	0	0	0	0	7	7.0
	60	36.9	37.2	Exit 37	10500	20	7	1.40	4.67	37	47	0.000	1	1	2	1	2	0	0	0	0	7	7.0
	61	37.0	37.3	Exit 37	10500	15	6	1.20	4.00	31	47	0.000	1	0	2	1	2	0	0	0	0	6	6.0

yellow = high frequency

Segments	Sub-segment	Begin MRM	End MRM	I-90 Exit #	ADT	Total Crashes	Total WVC	WVC/year	WVC/mile/year	WVC/HMVMT (Rate)	Rc,I (Critical Rate)	probability	WVC by Year					Severity					Alt. EPDO
													2012	2013	2014	2015	2016	K	A	B	C	O	
Exit 37 to Tilford	62	37.1	37.4		10600	22	12	2.40	8.00	62	47	0.128	4	3	1	1	3	0	0	0	0	12	12.0
	63	37.2	37.5		10600	22	12	2.40	8.00	62	47	0.128	4	3	1	1	3	0	0	0	0	12	12.0
	64	37.3	37.6		10600	22	12	2.40	8.00	62	47	0.128	4	3	1	1	3	0	0	0	0	12	12.0
	65	37.4	37.7		10600	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	66	37.5	37.8		10600	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	67	37.6	37.9		10600	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	68	37.7	38.0		10600	24	4	0.80	2.67	21	47	0.000	2	1	1	0	0	0	1	0	0	3	44.6
	69	37.8	38.1		10600	24	4	0.80	2.67	21	47	0.000	2	1	1	0	0	0	1	0	0	3	44.6
	70	37.9	38.2		10600	24	4	0.80	2.67	21	47	0.000	2	1	1	0	0	0	1	0	0	3	44.6
	71	38.0	38.3		10600	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	72	38.1	38.4		10600	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	73	38.2	38.5		10600	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	74	38.3	38.6		10600	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	75	38.4	38.7		10600	10	2	0.40	1.33	10	47	0.000	0	1	0	0	1	0	0	0	0	2	2.0
	76	38.5	38.8		10600	10	2	0.40	1.33	10	47	0.000	0	1	0	0	1	0	0	0	0	2	2.0
	77	38.6	38.9		10600	10	2	0.40	1.33	10	47	0.000	0	1	0	0	1	0	0	0	0	2	2.0
	78	38.7	39.0	Tilford	10600	15	10	2.00	6.67	52	47	0.000	1	1	6	1	1	0	0	0	1	9	14.3
	79	38.8	39.1	Tilford	10600	15	10	2.00	6.67	52	47	0.000	1	1	6	1	1	0	0	0	1	9	14.3
	80	38.9	39.2	Tilford	10600	15	10	2.00	6.67	52	47	0.000	1	1	6	1	1	0	0	0	1	9	14.3
Tilford to Exit 40	81	39.0	39.3		10600	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	82	39.1	39.4		10600	3	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	83	39.2	39.5		10600	17	6	1.20	4.00	31	47	0.000	2	1	0	1	2	0	0	0	0	6	6.0
	84	39.3	39.6		10600	17	6	1.20	4.00	31	47	0.000	2	1	0	1	2	0	0	0	0	6	6.0
	85	39.4	39.7		10600	14	6	1.20	4.00	31	47	0.000	2	1	0	1	2	0	0	0	0	6	6.0
	86	39.5	39.8		10600	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	87	39.6	39.9		10600	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	88	39.7	40.0		10600	2	1	0.20	0.67	5	47	0.000	0	0	1	0	0	0	0	0	0	1	1.0
	89	39.8	40.1	Exit 40	10600	2	1	0.20	0.67	5	47	0.000	0	0	1	0	0	0	0	0	0	1	1.0
	90	39.9	40.2	Exit 40	10600	7	2	0.40	1.33	10	47	0.000	0	0	1	0	1	0	0	0	0	2	2.0
	91	40.0	40.3	Exit 40	10600	5	1	0.20	0.67	5	47	0.000	0	0	0	0	1	0	0	0	0	1	1.0
	92	40.1	40.4	Exit 40	10600	34	11	2.20	7.33	57	47	0.344	1	3	2	3	2	0	0	0	0	11	11.0
	93	40.2	40.5	Exit 40	10600	29	10	2.00	6.67	52	47	0.000	1	3	2	3	1	0	0	0	0	10	10.0
	94	40.3	40.6	Exit 40	10600	29	10	2.00	6.67	52	47	0.000	1	3	2	3	1	0	0	0	0	10	10.0
	95	40.4	40.7	Exit 40	10600	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	96	40.5	40.8	Exit 40	10600	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
Just After Exit 40	97	40.6	40.9		10400	0	0	0.00	0.00	0	47	0.000	0	0	0	0	0	0	0	0	0	0	0.0
	98	40.7	41.0		10400	7	4	0.80	2.67	21	47	0.000	2	1	0	1	0	0	0	0	1	3	8.3
	99	40.8	41.1		10400	7	4	0.80	2.67	21	47	0.000	2	1	0	1	0	0	0	0	1	3	8.3
	100	40.9	41.2		10400	7	4	0.80	2.67	21	47	0.000	2	1	0	1	0	0	0	0	1	3	8.3

yellow = high frequency
orange = high severity

	Frequency	Rate	Critical Rate	EPDO Frequency	Probability Exceeding Threshold
Subsegment	18	48	48	68	92
	19	49	49	69	40
	20	50	50	70	18
	21	18	18	18	19
	48	19	19	19	20
	49	20	20	20	21
	50	21	21	21	38
	38	38	38	48	39
	39	39	39	49	62
	40	40	40	50	63

Location	Subsegment	Frequency	Rate	Critical Rate	EPDO Frequency	Probability Exceeding Threshold	# Top 10s
Before Exit 32	1						0
	2						0
	3						0
	4						0
	5						0
	6						0
	7						0
	8						0
	9						0
	10						0
	11						0
	12						0
	13						0
	14						0
	15						0
Between Exit 32 and Exit 34	16						0
	17						0
	18	X	X	X	X	X	5
	19	X	X	X	X	X	5
	20	X	X	X	X	X	5
	21	X	X	X	X	X	5
	22						0
	23						0
	24						0
	25						0
	26						0
	27						0
	28						0
	29						0
	30						0
	31						0
	32						0
	33						0
	34						0
	35						0
	36						0
	37						0
	38	X	X	X		X	4
	39	X	X	X		X	4
	40	X	X	X		X	4

Rank	Number of Performance Measures Met	Subsegment
1	5	18
2	5	19
3	5	20
4	5	21
5	4	38
6	4	39
7	4	40
8	4	48
9	4	49
10	4	50

Location	Subsegment	Frequency	Rate	Critical Rate	EPDO Frequency	Probability Exceeding Threshold	# Top 10s
Between Exit 34 and Exit 37	41						0
	42						0
	43						0
	44						0
	45						0
	46						0
	47						0
	48	X	X	X	X		4
	49	X	X	X	X		4
	50	X	X	X	X		4
	51						0
	52						0
	53						0
	54						0
	55						0
	56						0
	57						0
	58						0
	59						0
	60						0
	61						0
Exit 37 to Tilford	62					X	1
	63					X	1
	64						0
	65						0
	66						0
	67						0
	68				X		1
	69				X		1
	70				X		1
	71						0
	72						0
	73						0
	74						0
	75						0
	76						0
	77						0
	78						0
	79						0
	80						0
Tilford to Exit 40	81						0
	82						0
	83						0
	84						0
	85						0
	86						0
	87						0
	88						0
	89						0
	90						0
	91						0
	92					X	1
	93						0
	94						0
	95						0
	96						0
Just After Exit 40	97						0
	98						0
	99						0
	100						0
	101						0

Rank	Number of Performance Measures Met	Subsegment

APPENDIX B – 2004-2013 WVC HOTPSOTS

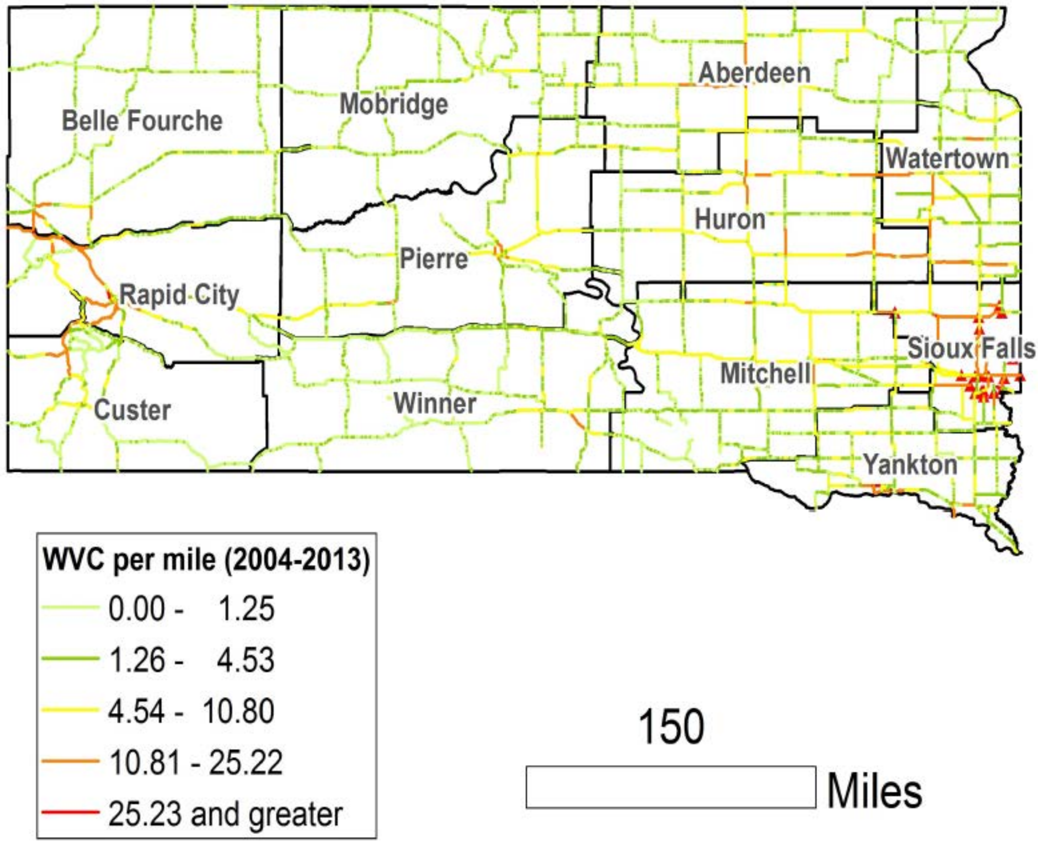

Figure 7. Reported WVC Crash Hotspots Rates per Mile per 10 Years on South Dakota Department of Transportation Administered Roads. Names Portray SDDOT Areas and Not Cities.

Table 6. Top 20 Hotspots for Reported WVC Crashes for South Dakota 2004-2013. Rates for Annual Basis.

Rank	Road	Description	Mile Post Segment	Length in Miles	WVC/ mile/yr.	SDDOT Region	Nearby City	County
1	I-90	END RAMP EAST & WEST EXIT 10	9.9 - 10.2 and 10.7 - 11.1	0.25 and 0.36	12.50	RAP	SPEARFISH	LAWRENCE
2	SD 50	BETWEEN SD 52 AND SD 153	374.8 – 375	0.20	5.27	MIT	YANKTON	YANKTON
3	44	EAST ST PATRICK ST RAPID	48.6	0.08	5.23	RAP	RAPID CITY	PENNINGTON
4	12 E	END EBL IN ABERSEN	288.3	0.04	4.95	ABR	ABERDEEN	BROWN
5	SD 45	SD 45 NORTH OF JCT W SD 26	129.6-129.7	0.11	4.40	ABR	POLLO	HAND
6	SD 50	BETWEEN SD 52 AND SD 153	MP 375 - 378	3.00	4.10	MIT	YANKTON	YANKTON
7	231 N	ELM ST BLACK HAWK	86.1 – 86.2	0.13	3.91	RAP	RAPID CITY	MEADE
8	SD 42	BEG AT SIX MILE RD SIOUX F	371.3 - 373.2	1.93	3.67	MIT	SIOUX FALLS	MINNEHAHA
9	016	END WBL NE OF HILL CITY	45.1	0.03	3.64	RAP	HILL CITY	PENNINGTON
10	29 N	END RAMP N2 EXIT 83	83.7 – 83.9	0.22	3.63	MIT	SIOUX FALLS	MINNEHAHA
11	85 S	BEGIN AT JCT US 85 S, JCT	10.2 – 45.1	34.9	3.54	RAP	SPEARFISH	LAWRENCE
12	I-90 E	Black Hawk	51	0.1	3.50	RAP	RAPID CITY	MEADE
13	231	#2 PINE HILLS ROAD - RAPID	82.3 – 85.3	2.9	3.10	RAP	RAPID CITY	PENNINGTON
14	SD 46	NEAR THE VERMILLION RIVER	356 - 357	0.6	3.06	MIT	CENTERVILLE	CLAY
15	314	S OF YANKTON, N OF JCT W US 81	382 – 382.1	0.1	3.06	MIT	YANKTON	YANKTON
16	SD 212	END DIVIDED SOUTH OF NEWE	36.3 – 36.4	0.1	3.05	RAP	NEWELL	BUTTE
17	83	JUNCTION OF SD 248	88.1 – 88.2	0.1	3.02	PIR	VIVIAN	LYMAN
18	34 W	JUNCTION SD 19	389.8 - 390	0.2	3.02	MIT	MADISON(?)	LAKE

Rank	Road	Description		Mile Post Segment	Length in Miles	WVC/ mile/yr.	SDDOT Region	Nearby City	County
19	I-90 E	END RAMP W2	EXIT 23	23.4 – 24.1	0.7	2.99	RAP	WHITEWOOD	LAWRENCE
20	79	JCT SD 79 MAVERICK JUNCTIN		26.5 – 26.7	0.2	2.92	RAP	HOT SPRINGS	FALL RIVER