

APPENDIX H

Noise and Vibration Impact Assessment

PART 1 OF 2

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Acronyms and Abbreviations

ANR	average noise reduction
Board	Surface Transportation Board
C.F.R.	Code of Federal Regulations
dB	decibel
dBA	A-weighted decibel
EIS	environmental impact statement
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
Hz	Hertz
L _{eq}	level equivalent
MDT	Montana Department of Transportation
OEA	Office of Environmental Assessment
PPV	peak particle velocity
RMS	root-mean-square
SSM	supplementary safety measure
VdB	root-mean-square vibration velocity

Appendix H

Noise and Vibration Impact Assessment

H.1 Introduction

This appendix describes the methods that the Surface Transportation Board's (Board) Office of Environmental Analysis (OEA) used to estimate and analyze the potential effects of noise and vibration from construction and operation of the proposed rail line.¹

As described in Section H.6, *Mitigation Feasibility Analysis*, OEA analyzed the feasibility of noise mitigation for receptors that would be adversely affected by noise. OEA used this analysis to develop the recommended noise mitigation described in Chapter 19, *Mitigation*. Because the degree of noise mitigation would depend on future rail traffic, exact mitigation details are not specified here. However, the mitigation analysis does evaluate possible combinations of quiet zones and building sound insulation that could be employed for the low, medium, and high coal production scenarios.

Section H.8, *Glossary*, provides definitions of technical terms. Figures H-1 through H-79, which show the noise contours and receptors for each of the build alternatives, are compiled at the end of this appendix.

H.2 Wayside Noise Model

Wayside noise refers to all noise generated by rail cars and locomotives (but not including horn noise). OEA used noise measurements from past noise studies (Surface Transportation Board 1998a, 1998b) as the basis for the wayside noise level projections for the proposed rail line.

The basic equation used for the wayside noise model is as follows.

$$SEL_{cars} = L_{eqref} + 10\log(T_{passby}) + 30\log(S/S_{ref})$$

For locomotives, the corresponding equation is as follows.

$$SEL_{locos} = SEL_{ref} + 10\log(N_{locos}) - 10\log(S/S_{ref})$$

The total train sound exposure level is computed by logarithmically adding SEL_{locos} and SEL_{cars} .

¹ This appendix provides supporting information for Chapter 7, *Noise and Vibration*, of this *Draft Environmental Impact Statement for the Tongue River Railroad*. This information should not be interpreted as stand-alone information and must be read in combination with the associated chapter.

$$DNL_{100'} = SEL + 10\log(N_d + 10*N_n) - 49.4$$

$$DNL = DNL_{100'} + 15\log(100/D)$$

The $10\log(x)$ term in the previous equations can be used to determine the increase (or decrease) in train noise level associated with changes in traffic volumes assuming that the other factors affecting noise (speed, train consist and length, time of day, and number of locomotives) are equivalent. The change in noise level associated with two different traffic volumes would be as follows.

$$\Delta \text{ (dB)} = 10\log(N_2/N_1) \quad \text{where } N_1 \text{ and } N_2 \text{ are two different traffic volumes (trains/day)}$$

For example, if rail traffic doubled, the increase in noise level would be $10\log(2) = 3 \text{ dB}$.

The following parameters apply to the equations above.

SEL_{cars} = Sound exposure level of railcars (A-weighted decibels [dBA])

L_{eqref} = Level equivalent of railcar

T_{passby} = Train passby time, in seconds

S = Train speed, in miles per hour

S_{ref} = Reference train speed

SEL_{locos} = Sound exposure level of locomotive

SEL_{ref} = Reference sound exposure level of locomotive

DNL = Day-night average noise level

N_{locos} = Number of locomotives

N_d = Number of trains during daytime

N_n = Number of trains during nighttime

D = Distance from tracks, in feet

Table H-1 shows the reference wayside noise levels used in this study and Exhibit H-1 shows the wayside noise frequency spectrum used in the calculations.

Table H-1. Reference Wayside Noise Levels

Description	Average Level (dBA)
Locomotive SEL (40 miles per hour at 100 feet)	95
Railcar L_{eq}	82
Notes:	
Source: Surface Transportation Board 1998a, 1998b	
dBA = A-weighted decibels; SEL = sound exposure level; L_{eq} = level equivalent	

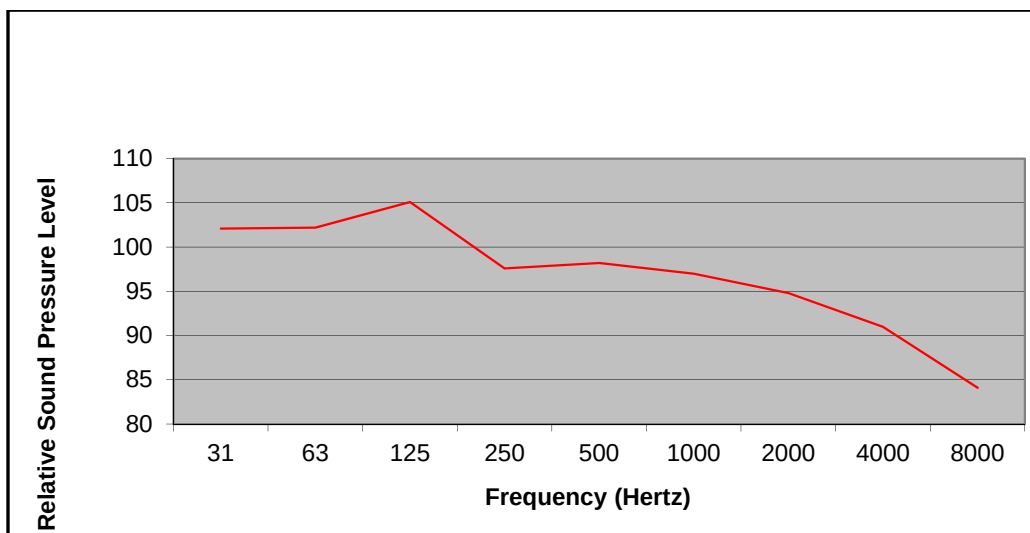


Exhibit H-1. Wayside Noise Spectrum (Surface Transportation Board 2002)

H.3 Horn Noise Model

Freight train horn noise levels can vary for a variety of reasons, including the manner in which an engineer sounds the horn. Consequently, it is important to determine horn noise reference levels based on a large sample size. A substantial amount of horn noise data are available from the *Draft Environmental Impact Statement, Proposed Rule for the Use of Locomotive Horns at Highway-Rail Grade Crossings* (Federal Railroad Administration 1999), hereafter referred to as the 1999 Federal Railroad Administration (FRA) Draft Environmental Impact Statement (EIS).

The FRA data indicate that horn noise levels increase from the point at which the horn is sounded at 0.25 mile from the grade crossing to when it stops sounding at the grade crossing. In the first 0.125-mile segment, the energy average sound exposure level measured at a distance of 100 feet from the tracks was found to be 107 dBA, and in the second 0.125-mile segment, found to be 110 dBA. The 1999 FRA Draft EIS simplified the horn noise contour shape as a 5-sided polygon, when it is actually a teardrop shape. The *Final Environmental Impact Statement, Construction and Operation of a Rail Line from the Bayport Loop in Harris County, Texas* (Surface Transportation Board 2003) discusses this subject in detail. OEA used the more accurate teardrop contour shape for this analysis. The attenuation or drop-off rate of horn noise is assumed to be 4.5 dBA per doubling of distance away from the tracks (Federal Railroad Administration 1999).

Table H-2 lists the reference horn noise levels used in this study, and Exhibit H-2 shows the horn noise spectrum used in the calculations.

Table H-2. Reference Horn Noise Levels

Description	Average Level (dBA)
Horn SEL 1st 0.25 mile	110
Horn SEL 2nd 0.25 mile	107

Notes:
Source: Federal Railroad Administration 1999
dBA = A-weighted decibels; SEL = sound exposure level

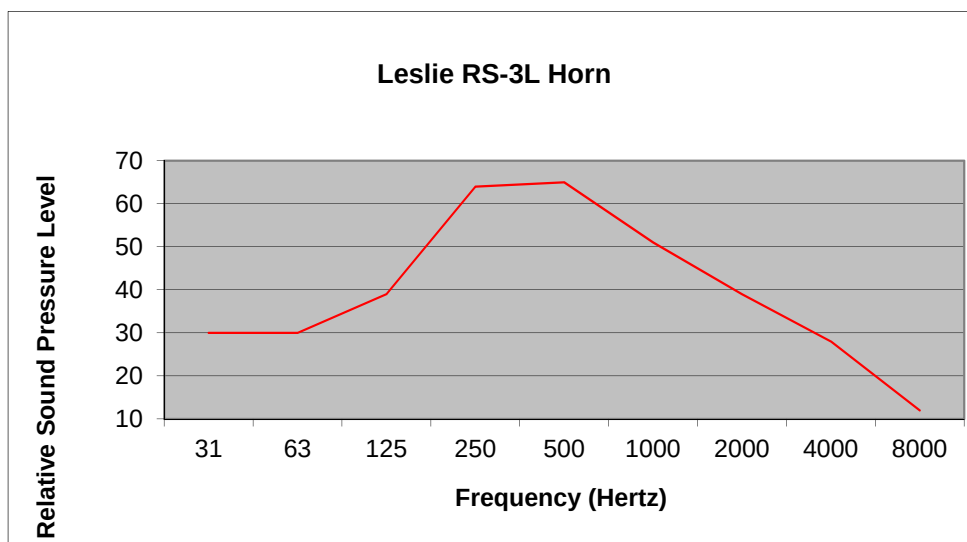


Exhibit H-2. Horn Noise Spectrum (Surface Transportation Board 2002)

H.4 Rail Line Operation Vibration Analysis Methods

OEA based the vibration assessment methods on Federal Transit Administration (FTA) methods (2006). Vibration level due to train passbys is approximately proportional to:

$$V = 20 \times \log (\text{speed}/\text{speed}_{\text{ref}})$$

Where:

V = ground-borne vibration velocity

Speed = train speed

$\text{speed}_{\text{ref}}$ = reference speed of the train relative to its corresponding vibration level

Published (FTA) ground-borne vibration levels are adjusted for train speed by this equation and distance from the rail line to estimate vibration levels at receptor locations.

There are two ground-vibration impacts of general concern: annoyance to humans and damage to buildings. In special cases, activities that are highly sensitive to vibration, such as microelectronics fabrication facilities, are evaluated separately. Two measurements

correspond to human annoyance and building damage for evaluating ground vibration: peak particle velocity (PPV) and root-mean square (RMS) velocity. PPV is the maximum instantaneous positive or negative peak of the vibration signal, measured as a distance per time (such as millimeters or inches per second). This measurement has been used historically to evaluate shock-wave type vibrations from actions like blasting, pile driving, and mining activities, and their relationship to building damage. RMS velocity is an average, or smoothed, vibration amplitude, commonly measured over 1-second intervals. It is expressed on a log scale in decibels (VdB) referenced to 0.000001×10^{-6} inch per second and is not to be confused with noise decibels. It is more suitable for addressing human annoyance and characterizing background vibration conditions because it better represents the response time of humans to ground vibration signals.

Peak particle velocity (PPV) is an instantaneous positive or negative peak of a vibration signal, measured as a distance per time.

Root-mean-square (RMS) velocity (VdB) is a measure of ground vibration in decibels used to compare vibration from various sources.

H.5 Construction Noise and Vibration Analysis Methods

OEA based the construction noise impact assessment on FTA methods (2006), known as the General Assessment construction noise guidelines, shown in Table H-3.

Table H-3. Federal Transit Administration General Assessment Construction Noise Guidelines

Land Use	1-hour L_{eq} (dBA) ^a	
	Day	Night
Residential	90	80
Commercial	100	100
Industrial	100	100

^a L_{eq} = level equivalent; dBA = A-weighted decibels

The FTA General Assessment for construction noise is used when details of the construction schedule are not known, as is the case here. The method calls for estimating combined noise levels from the two noisiest pieces of construction equipment and determining locations at which their operation would exceed the noise guidelines in Table H-3.

Construction vibration levels are estimated according to the following equation.

$$PPV_{\text{equipment}} = PPV_{\text{ref}} \times (25/D)^{1.5}$$

Where:

$PPV_{\text{equipment}}$ = The peak particle velocity in inches per second of the equipment adjusted for distance

PPV_{ref} = The reference vibration level in inches per second at 25 feet

D=The distance from the equipment to the receptor

Estimated construction vibration levels are then compared with the building damage criterion.

H.6 Mitigation Feasibility Analysis

OEA analyzed the feasibility of noise mitigation for receptors that would be adversely affected by noise. OEA used this analysis to develop the recommended noise mitigation described in Chapter 19, *Mitigation*. Because the degree of noise mitigation would depend on rail traffic, exact mitigation details are not specified here. However, this mitigation analysis considers possible combinations of quiet zones and building sound insulation that could be employed for the low, medium, and high coal production scenarios.

Table H-4 shows the receptors in the study area that would be adversely affected by locomotive horn noise at grade crossings or by wayside noise. This distinction is important because there are different noise reduction strategies for horn noise and wayside noise. The number of affected receptors is shown for the low, medium, and high coal production scenarios.² The data in Table H-4 show that the majority of affected receptors would be along the existing Colstrip Subdivision.

For the purpose of developing potential mitigation measures, the sections that follow Table H-4 discuss various types of noise mitigation techniques that could be applied to the receptors listed in Table H-4.

² The coal production scenarios (low, medium, high) reflect different levels of rail traffic, depending on which build alternative is licensed, which mines are induced or developed, and the production capacities of those mines. The coal traffic scenarios are described in Appendix C, *Coal Production and Markets*. The related rail traffic is summarized in Chapter 2, Section 2.3.3, *Rail Traffic*.

Table H-4. Receptors at 65 DNL or More with a 3 dBA or Greater Increase

Build Alternative	Low Production Scenario			Medium Production Scenario			High Production Scenario		
	Horn	Wayside	Total	Horn	Wayside	Total	Horn	Wayside	Total
Tongue River	0	1	1	0	1	1	2	3	5
Tongue River East	0	0	0	0	0	0	1	0	1
Colstrip (Existing Subdivision)	0 (12)	1 (22)	1 (34)	1 (28)	1 (37)	1 (65)	2 (35)	3 (54)	5 (89)
Colstrip East (Existing Subdivision)	0 (12)	0 (22)	0 (34)	0 (27)	0 (36)	0 (63)	0 (33)	0 (51)	0 (84)
Tongue River Road	0	1	1	0	2	2	1	4	5
Tongue River Road East	0	0	0	0	1	1	0	1	1
Moon Creek	0	1	1	0	1	1	2	3	5
Moon Creek East	0	0	0	0	0	0	1	0	1
Decker	0	0	0	0	0	0	0	1	1
Decker East	0	0	0	0	0	0	0	0	0

H.6.1 Building Sound Insulation

Building sound insulation refers to improving the noise reduction characteristics of a building envelope in order to reduce the intrusion of outdoor noise into the building. Sound insulation treatments usually involve improving the sound insulation characteristics of windows and doors, which is where noise usually enters a building.

To provide building sound insulation, windows and doors can be replaced with special acoustical windows and doors. Split-system or central air conditioning may need to be installed so that windows do not need to be opened. Additional insulation can be provided by sealing or relocating vents and in some cases acoustically reinforcing walls and ceilings. Sound insulation of a building typically reduces the noise level inside by about 10 decibels. Noise levels outside the structure are not affected.

Both wayside and horn noise can be mitigated by building sound insulation.

Building sound insulation costs vary depending on a number of factors such as the overall size of the building and the number of windows and doors. A recent survey of international airport sound insulation programs shows an average cost of \$40,000 per house (Payne pers. comm.). Aircraft sound insulation strategies can differ from those implemented for rail projects. Rail building sound insulation projects often have lower per house costs because

they require less extensive treatment requirements (for example, fewer building facades are exposed to noise).

H.6.2 Locomotive Warning Horn Mitigation

Because locomotive warning horns are intentionally loud to warn motorists of oncoming trains as required by FRA regulations, reduction of the noise level of warning horns is not an option. Noise barriers at grade crossings are generally not feasible because large openings are necessitated by cross streets. In addition, noise barriers create safety concerns because they can interfere with adequate sight lines between trains and motorists. Furthermore, locomotive horns are located high up on the locomotive; thus requiring very tall noise barriers to achieve noise level reductions at receptor locations. As stated previously, building sound insulation can be employed to reduce horn noise inside of a building.

While some success in reducing noise has been found by replacing locomotive horn sounding with stationary warning horns at grade crossings (which generally have a smaller noise footprint than a locomotive horn), many communities have successfully reduced horn noise by implementing the FRA quiet zone program. FRA's final Train Horn Rule (9 Code of Federal Regulations [C.F.R.] Part 222, 2005) presents the requirements of a quiet zone and supplementary safety measures to mitigate the risks of not sounding train horns (Section H.6.5, *Quiet Zone Analysis*).

H.6.3 Noise Barriers

Wayside noise mitigation options include noise barriers. Noise barriers can be effective when the barrier substantially blocks the line-of-sight between a receptor and train noise sources (wheel/rail interface, locomotive engine, and exhaust opening). Since train noise can pass over the top and around the ends of the barrier, both noise barrier height and length are factors in determining potential noise barrier performance.

In addition to its physical dimensions, the extent to which a noise barrier protects a certain number of residences is also important. For example, if a noise barrier's cost was substantially greater than the value of the protected residence(s), the barrier may not be cost efficient. Montana Department of Transportation (MDT) evaluates the cost effectiveness of noise barriers based on the cost-effectiveness index (Montana Department of Transportation 2011).

$$\text{Cost Effectiveness Index} = \frac{\text{Total Barrier Cost}}{\text{ANR} \times \text{BR}}$$

Where ANR = average noise reduction of benefitted receptors (dBA)

BR = Number of benefitted receptors (≥ 5 dBA improvement)

MDT uses \$35 per square foot to plan the costs of noise barriers. The cutoff for determining barrier feasibility is a cost effectiveness index of \$4,900.00 or less.

H.6.4 Noise Barrier Analysis

The only receptors in Table H-4 that would be affected by wayside noise of sufficient quantity that are also close enough to each other to warrant consideration of a noise barrier analysis are those in the City of Colstrip (Chapter 7, *Noise and Vibration*). All other receptors that would be affected by project-related wayside noise are solitary and would not meet the cost effectiveness criteria as defined by MDT.

OEA analyzed a noise barrier 1,190 feet long and 20 feet tall using the noise assessment software Computer Aided Noise Assessment, or CadnaA, for the low production scenario, which would protect 15 receptors with an average noise reduction of 7.4 dBA. For this example, the calculated cost-effectiveness index is \$7,483, which is not considered feasible by MDT criteria. For the medium and high production scenarios, the number of receptors that would be adversely affected and subsequently protected by a noise barrier increases with the cost-effectiveness index, at \$6,772 for the medium production scenario and \$5,188 for the high production scenario. The noise barrier is not considered feasible for any production scenario by MDT's cost-effectiveness index criterion of \$4,900.

H.6.5 Quiet Zone Analysis

FRA's final Train Horn Rule at 49 C.F.R. Part 222 provides a safe and effective way to reduce locomotive horn noise. Quiet zones are areas in which horns do not have to be sounded as long as certain FRA safety requirements are met. In some cases, completely sealing off the rail corridor via four quadrant gates is needed to comply with the rule.

FRA's quiet zone calculator calculates a quiet zone risk index factor for highway/rail at-grade crossing. Input to the calculation includes cross-street traffic volume, train speed, and number of trains per day. FRA considers it safe not to sound the horn at a particular grade crossing if the quiet zone risk index is below the nationwide significant risk threshold of 14,347.

The railroad is not required to pay for the installation or maintenance of grade-crossing protection measures needed to establish quiet zones. Quiet zones have been established by railroads and communities working together. Establishment of a quiet zone requires coordination with FRA to identify appropriate supplementary safety measures or alternative safety measures, identify potential funding sources, prepare funding applications and grant requests, and coordinate with representatives of potential funding organizations.

Quiet zone analyses (using FRA's quiet zone calculator) were performed for grade crossings in the study area where receptors would be adversely affected by horn noise. Table H-5 shows the results of this analysis for the three new grade crossings associated with new track.

Table H-5. Summary of Proposed New Public, At-Grade Rail/Highway Crossings^a

Crossings	Street Name	AADT	Number of Daily Trains	Train Speed (mph)	Number of Receptors	Coal Production Scenario	Build Alternatives	Protection ^b	Risk Index with Horns	Quiet Zone Risk Index Factor ^c	Estimated Cost ^d
East Tongue River Road	East Tongue River Road	50	7.4	40	1	Low, Medium, High	Colstrip, Tongue River, Tongue River Road, Moon Creek	Gates	2245.25	3745.08	\$150,000
Tongue River Road – S-447	Tongue River Road	50	11.9	40	1	Low, Medium	Colstrip, Colstrip East, Tongue River, Tongue River East, Tongue River Road, Tongue River Road East	Gates	2993.18	4992.62	\$150,000
Moon Creek Road	Moon Creek Road	120	18.6	40	1	High	Tongue River	Gates	5483.46	9146.41	\$150,000

Notes:

^a Assumes new 24-hour quiet zones.

^b All crossings proposed for a Quiet Zone require gates.

^c Risk index factors as compared to the nationwide significant risk threshold of 14,347.00. Quiet zone risk index factors below this threshold may be designated as quiet zones.

^d These estimated costs are to upgrade the crossing from current passive protection (signage) to active protection (gates and flashing lights) to meet the minimum requirements of a quiet zone (Federal Highway Administration 2015).

TRRC plans for passive protection (e.g., signage) with horn sounding at these three grade crossings. With this protection, FRA's calculator indicates that the risk index would be well below the nationwide significant risk threshold of 14,347. If conventional gates were installed at these grade crossings to comply with quiet zone requirements, the cost would be \$150,000 per crossing. The resulting cost per protected dwelling would be more than three times the cost of building sound insulation. Quiet zones do not appear to be a reasonable approach for horn noise reduction at these locations.

H.6.5.1 Existing Colstrip Subdivision

Table H-6 shows the results of quiet zone analyses for the existing Colstrip Subdivision. For three of the grade crossings (Old Highway 10, W Fork Armells Creek Road, and Wimer Road) on the existing Colstrip Subdivision. Quiet zone requirements would require the installation of gates at an estimated cost of \$150,000 per crossing. This cost for one protected dwelling unit would be more than three times the cost of building sound insulation. Quiet zones do not appear to be a reasonable approach for horn noise reduction for these three particular grade crossings on the existing Colstrip Subdivision.

Table H-6. Summary of Existing Public, At-Grade Rail/Highway Crossings along the Colstrip Subdivision^a

Crossings	Street Name	AADT	Number of Daily Trains	Train Speed (mph)	Protection ^b	Risk Index with Horns	Quiet Zone Risk Index Factor ^c	Estimated Cost ^d
Low Coal Production Scenario								
060499U	Old Highway 10	498	10	40	Gates	6,976.77	11,637.26	\$150,000
060514U	W Fork Armells Creek Rd	32	10	40	Gates	1,486.68	2,646.59	\$150,000
060524A	Wimer Road	16	10	25	Gates	941.76	1,570.86	\$150,000
086276D	Pine Butte Dr	949	10	40	Gates (existing)	9,828.94	12,545.11	N/A
099063F	Willow St	1,177	10	40	Gates (existing)	11,962.64	16,903.82	N/A
Medium Coal Production Scenario								
060499U	Old Highway 10	498	15	40	Gates	6,976.77	14,454.75	\$150,000
060514U	W Fork Armells Creek Rd	32	15	40	Gates	1,486.68	2,646.59	\$150,000
060524A	Wimer Road	16	15	25	Gates	941.76	2,048.20	\$150,000
086276D	Pine Butte Dr	949	15	40	Gates (existing)	9,828.94	15,405.84	N/A
099063F	Willow St	1,177	15	40	Gates (existing)	11,962.64	19,953.68	N/A
High Coal Production Scenario								
060499U	Old Highway 10	498	22	40	Gates	6,976.77	17,748.02	\$150,000
099063F	Willow St	1177	22	40	Gates (existing)	10,134.18	27,326.94	N/A

Notes:

^a Assumes new 24-hour quiet zones.

^b All crossings proposed for a quiet zone require gates; crossings that already meet this requirement are noted.

^c Risk Index factors as compared to the nationwide significant risk threshold of 14,347.00. Quiet zone risk index factors below this threshold may be designated as quiet zones. Quiet zone risk index factors above the nationwide significant risk threshold are highlighted.

^d These estimated costs are to upgrade the crossing from current passive protection (signage) to active protection (gates and flashing lights) to meet the minimum requirements of a quiet zone (Federal Highway Administration 2015)

Table H-7 shows the Colstrip Subdivision grade crossings with existing gates that would need supplementary safety measures to qualify for quiet zone designation.

Table H-7. Summary of Existing Public, At-Grade Rail/Highway Crossings along the Colstrip Subdivision with SSMs^a

Crossings	Street Name	Protection ^b	Quiet Zone Risk Index Factor ^c	Estimated Cost without SSMs ^d	SSM (New Four Quad Gates) ^{e, f}	Quiet Zone Risk Index Factor	Estimated Cost with SSM	SSM (Least Expensive Option)	Quiet Zone Risk Index Factor	Estimated Cost with SSM 12
Low Coal Production Scenario										
099063F	Willow St	Gates (existing)	16903.82	N/A	8	3780.57	\$280,000	12	5250.79	\$13,000
Medium Coal Production Scenario										
060499U	Old Highway 10	Gates	14454.75	\$150,000	8	2601.86	\$280,000	12	3613.69	\$13,000
086276D	Pine Butte Dr	Gates (existing)	16394.68	N/A	8	2951.04	\$280,000	12	4098.67	\$13,000
099063F	Willow St	Gates (existing)	19953.68	N/A	8	4469.88	\$280,000	12	6208.17	\$13,000
High Coal Production Scenario										
060499U	Old Highway 10	Gates	17748.02	\$150,000	8	3194.64	\$280,000	12	4437.01	\$13,000
099063F	Willow St	Gates (existing)	27326.94	N/A	8	5215.47	\$280,000	12	7243.71	\$13,000

Notes:

^a Assumes new 24-hour quiet zones.

^b All crossings proposed for a quiet zone require gates, crossings that already meet this requirement are noted.

^c Risk Index factors as compared to the Nationwide Significant Risk Threshold of 14,347.00. Quiet zone risk index factors below this threshold may be designated as quiet zones. Quiet zone risk index factors above the nationwide significant risk threshold are highlighted.

^d These estimated costs are to upgrade the crossing from current passive protection (signage) to active protection (gates and flashing lights) to meet the minimum requirements of a quiet zone (Federal Highway Administration 2015)

^e SSMs can be used to reduce the quiet zone risk index factor to below the threshold and then can be designated a quiet zone.

^f SSM Code 8 = Four quadrant gates new installation, no vehicle presence detection. Least expensive option out of all four quadrant gate upgrades.

^g SSM Code 12 = Mountable medians with reflective traffic channelization devices

ssm = supplementary safety measures

Based on the results from the quiet zone calculator, the Willow Street grade crossing in the Colstrip Subdivision could be designated as a quiet zone if upgraded with a median barrier because it already has gates. Under the high production scenario, this would benefit 31 receptors. The estimated cost for a median barrier would be \$13,000, or \$420 per protected receptor. Using the \$40,000 per house figure for sound insulation, sound insulating the 31 receptors would cost \$1.2 million. Consequently, it appears that a quiet zone would be a much more cost-effective approach than sound insulation at this location.

Because the Pine Butte Drive grade crossing has existing gates, it could be upgraded to a quiet zone with the installation of a median barrier. This would result in a rating below the Nationwide Risk Index Threshold. Because the estimated cost of a median barrier is

\$13,000, a quiet zone at this location appears to be more cost effective than sound-insulating one receptor at \$40,000.

Table H-8 shows the estimated costs of a hypothetical noise mitigation strategy for the entire project area for each build alternative (including proposed new track and the existing Colstrip Subdivision). The table assumes that the Willow Street and Pine Butte Drive grade crossings would be upgraded to a quiet zone, but all other adversely impacted receptors would be mitigated with building sound insulation treatments (at \$40,000 per receptor).

Table H-8. Example Mitigation Costs for Study Area

Build Alternative	Low Production Scenario			Medium Production Scenario			High Production Scenario		
	Horn	Wayside	Total	Horn	Wayside	Total	Horn	Wayside	Total
Tongue River		\$40,000	\$40,000		\$40,000	\$40,000	\$80,000	\$120,000	\$200,000
Tongue River East		\$0	\$0		\$0	\$0	\$40,000	\$0	\$40,000
Colstrip	\$13,000	\$920,000	\$933,000	\$106,000	\$1,480,000	\$1,586,000	\$146,000	\$2,160,000	\$2,306,000
Colstrip East	\$13,000	\$880,000	\$893,000	\$106,000	\$1,440,000	\$1,546,000	\$146,000	\$2,040,000	\$2,186,000
Tongue River Road	\$0	\$40,000	\$40,000		\$80,000	\$80,000	\$40,000	\$160,000	\$200,000
Tongue River Road East	\$0	\$0	\$0		\$40,000	\$40,000	\$0	\$40,000	\$40,000
Moon Creek	\$0	\$40,000	\$40,000		\$40,000	\$40,000	\$80,000	\$120,000	\$200,000
Moon Creek East	\$0	\$0	\$0		\$0	\$0	\$40,000	\$0	\$40,000
Decker	\$0	\$0	\$0		\$0	\$0	\$0	\$40,000	\$40,000
Decker East	\$0	\$0	\$0		\$0	\$0	\$0	\$0	\$0

H.7 References

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H.7.1 Personal Communications

Payne, M. August 13, 2014—Personal communication with David Coate.

H.8 Glossary

Ambient noise	The sum of all noise (from human and naturally occurring sources) at a specific location over a specific time is called ambient noise.
Day-night average sound level	The energy average of A-weighted decibel sound levels over 24 hours, which includes a 10-decibel adjustment factor for noise between 10 p.m. and 7 a.m. to account for the greater sensitivity of most people to noise during the night. The effect of nighttime adjustment is that 1 nighttime event, such as a train passing by between 10 p.m. and 7 a.m., is equivalent to 10 similar events during the daytime.
Decibel (dB)	A standard unit for measuring sound pressure levels based on a reference sound pressure of 0.0002 dyne per square centimeter. This is nominally the lowest sound pressure that people can hear.
Decibel, A-weighted (dBA)	A measure of noise level used to compare noise from various sources. A-weighting approximates the frequency response of the human ear.
Hertz (Hz)	A unit of frequency equal to one cycle per second.
Peak particle velocity (PPV)	The maximum instantaneous positive or negative peak of the vibration signal, measured as a distance per unit time (such as millimeters or inches per second). This measurement has been used historically to evaluate shock-wave type vibrations from actions like blasting, pile driving, and mining activities, and their relationship to building damage.
Root-mean-square vibration velocity (VdB)	An average or smoothed vibration amplitude, commonly measured over 1-second intervals. It is expressed on a log scale in decibels (VdB) referenced to 0.000001 inch per second and is not to be confused with noise decibels.

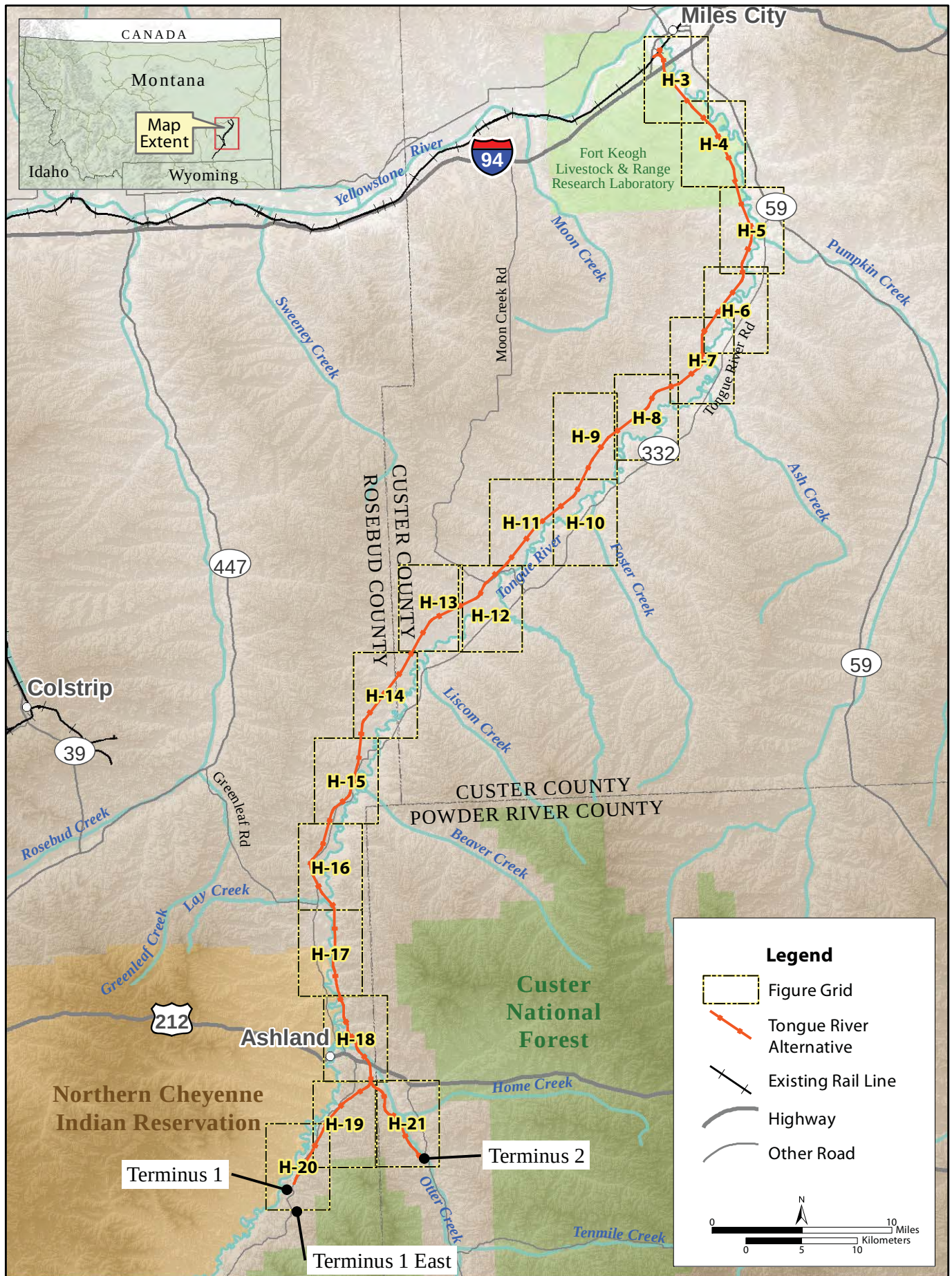


Figure H-1. Figure Grid for the Tongue River Alternative

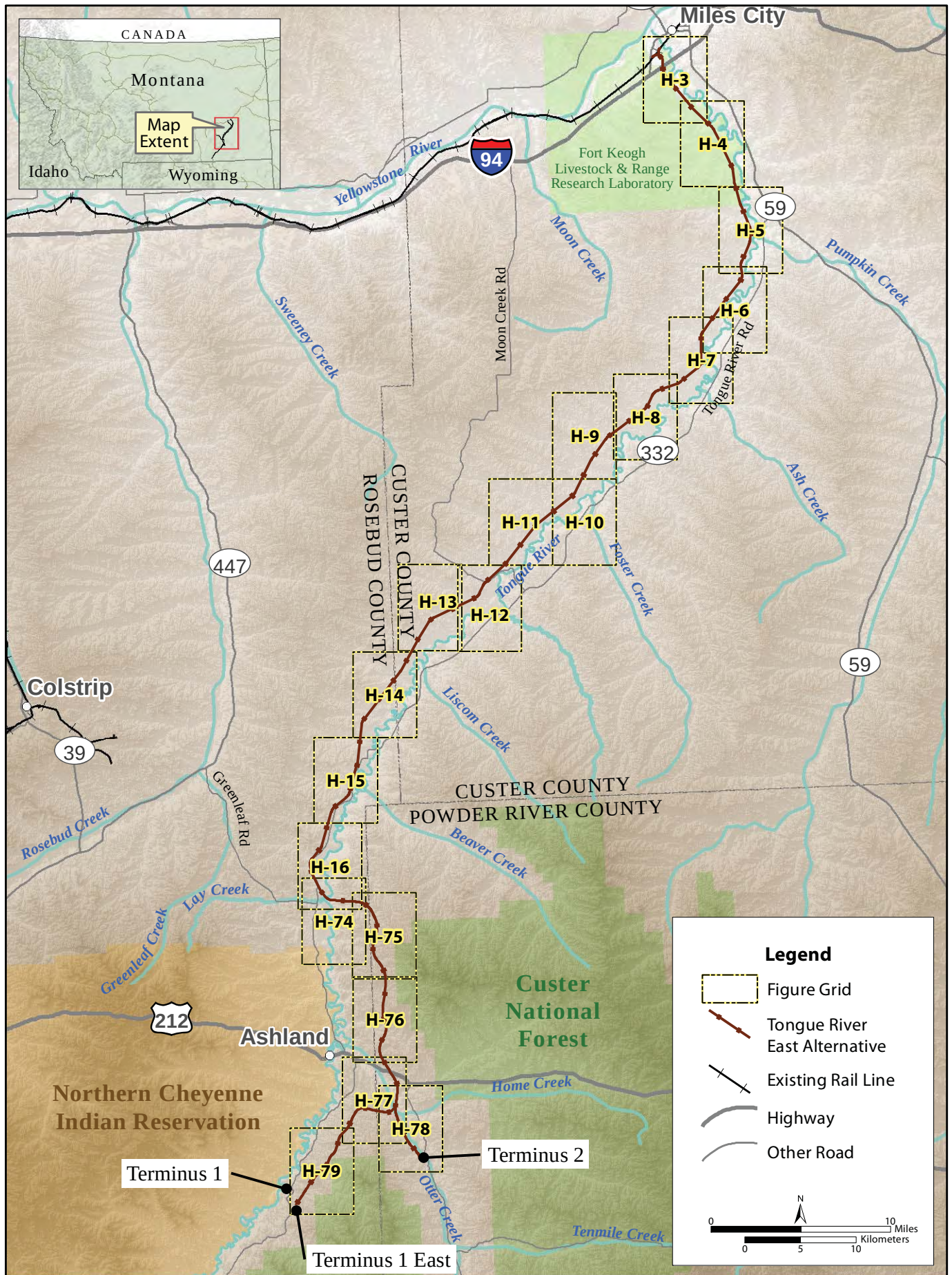


Figure H-2. Figure Grid for the Tongue River East Alternative

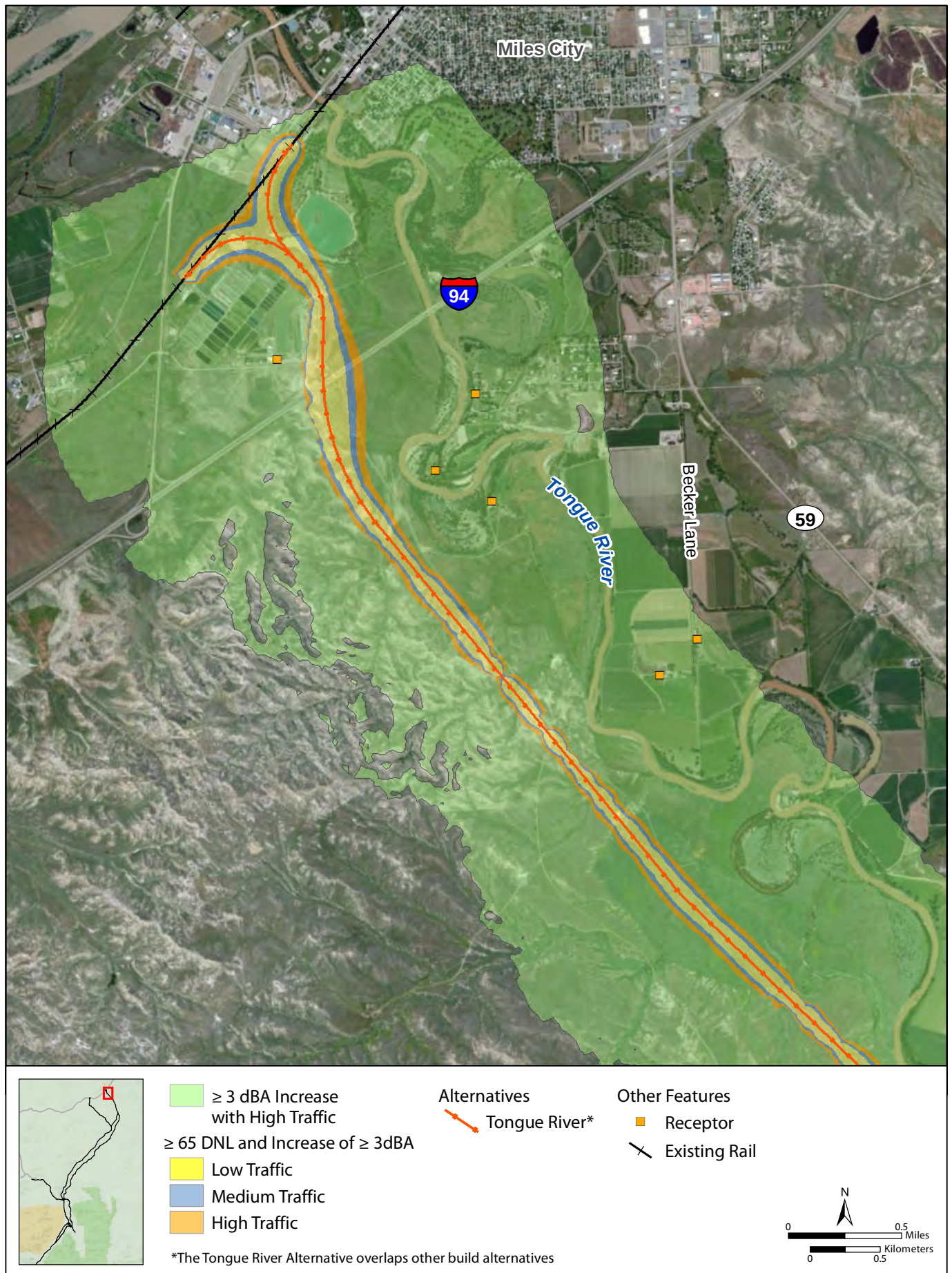


Figure H-3. Noise Contours and Receptors for the Tongue River Alternative*



Figure H-4. Noise Contours and Receptors for the Tongue River Alternative*

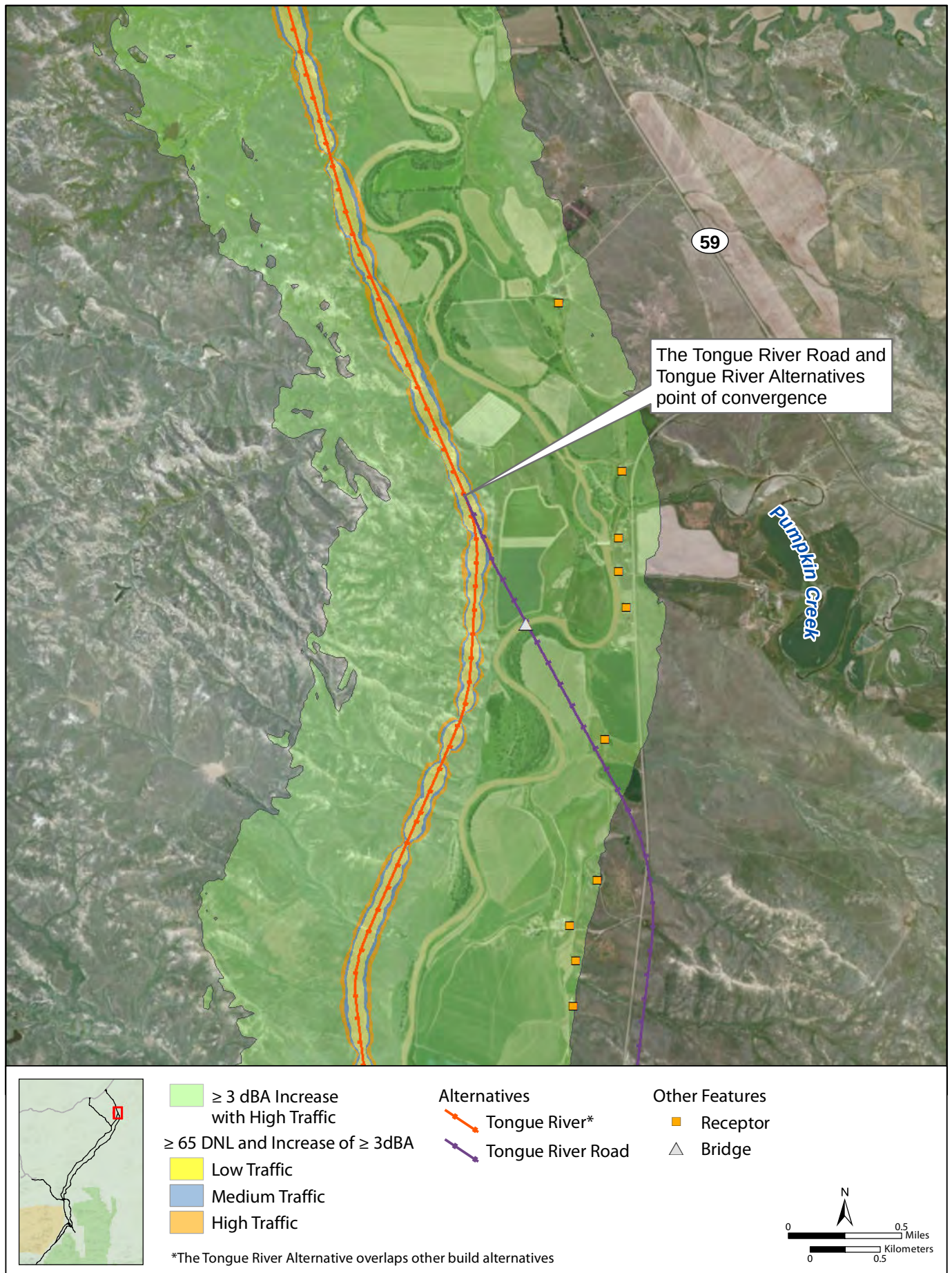


Figure H-5. Noise Contours and Receptors for the Tongue River Alternative*

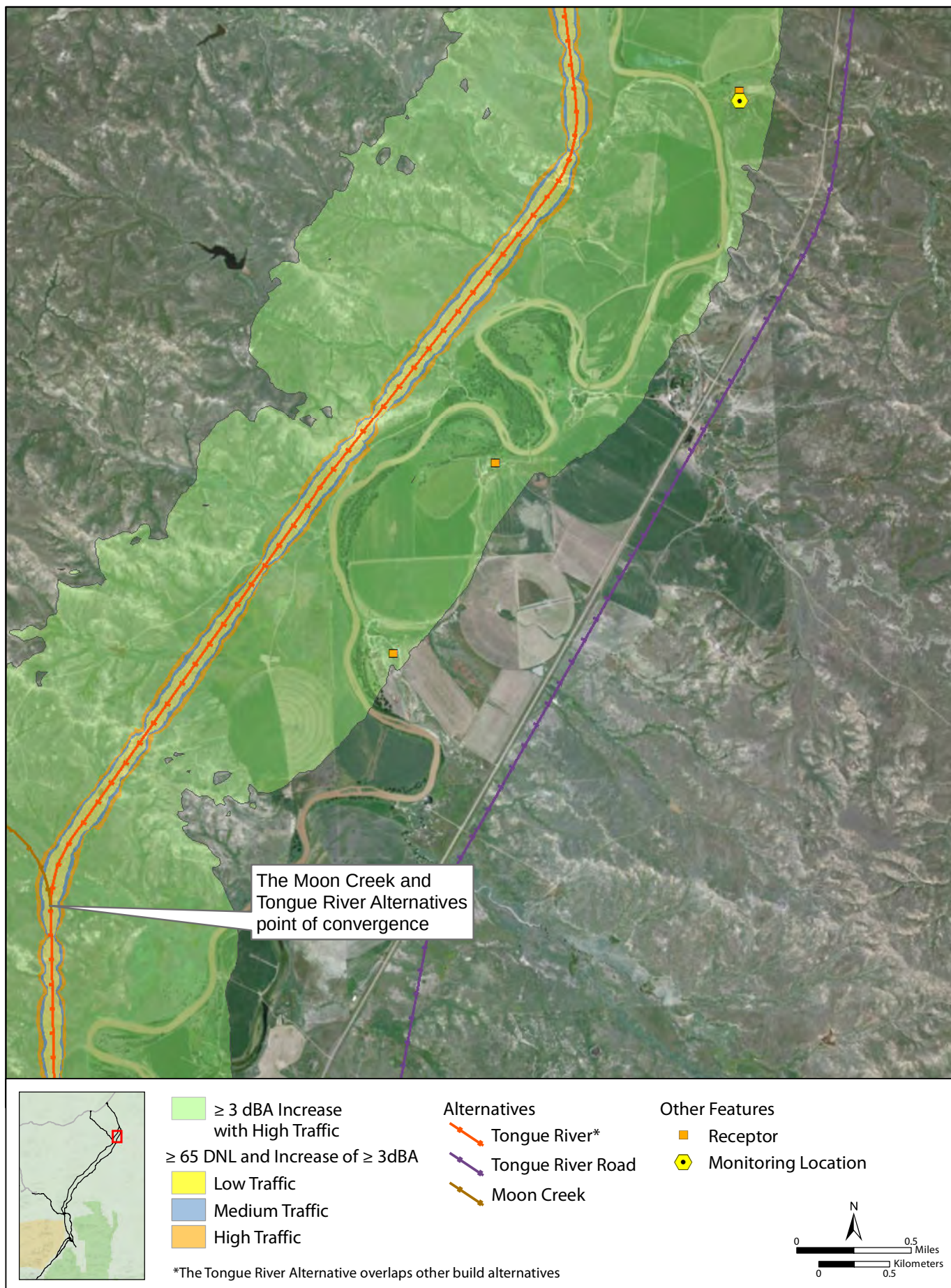


Figure H-6. Noise Contours and Receptors for the Tongue River Alternative*

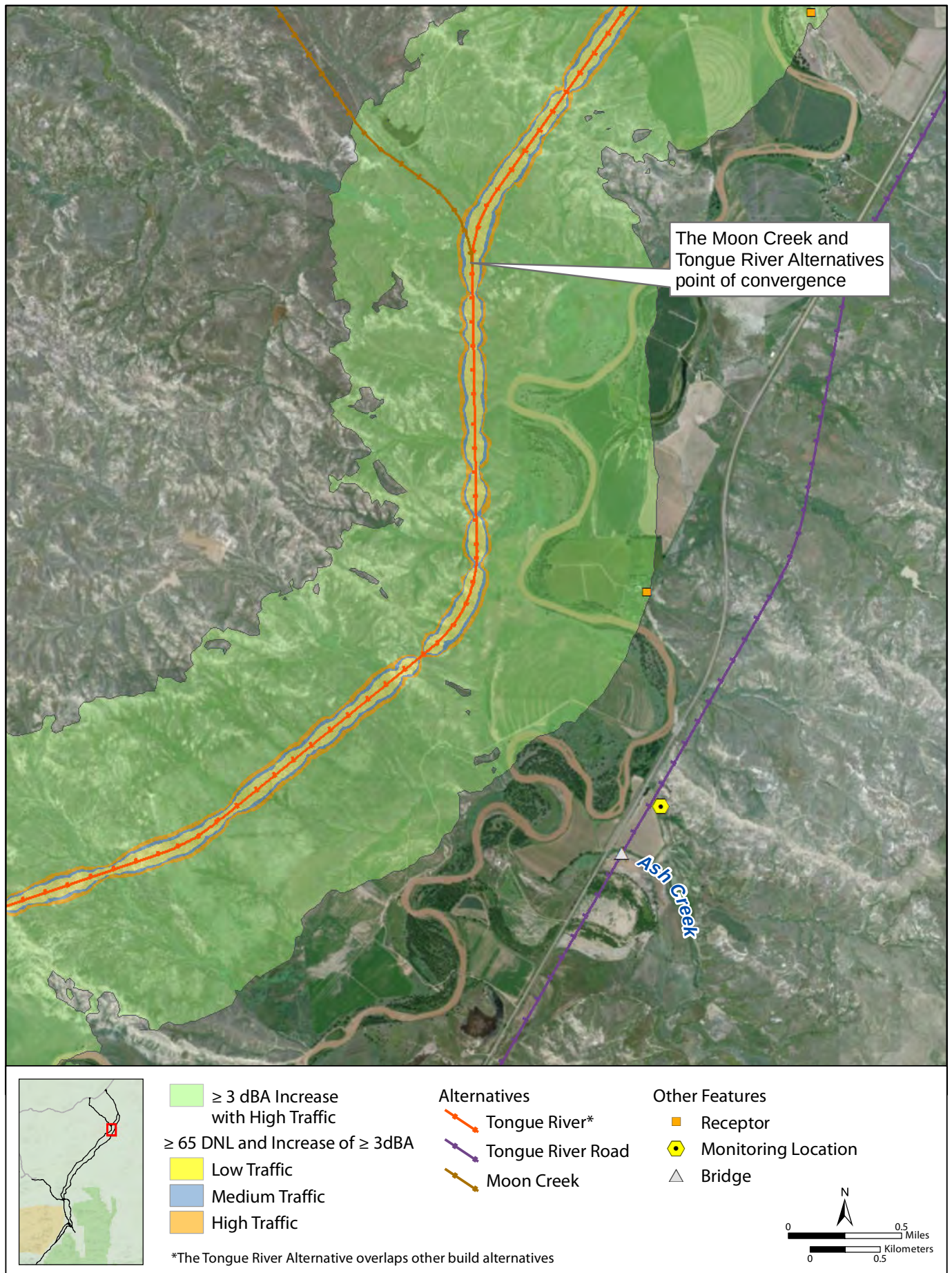


Figure H-7. Noise Contours and Receptors for the Tongue River Alternative*

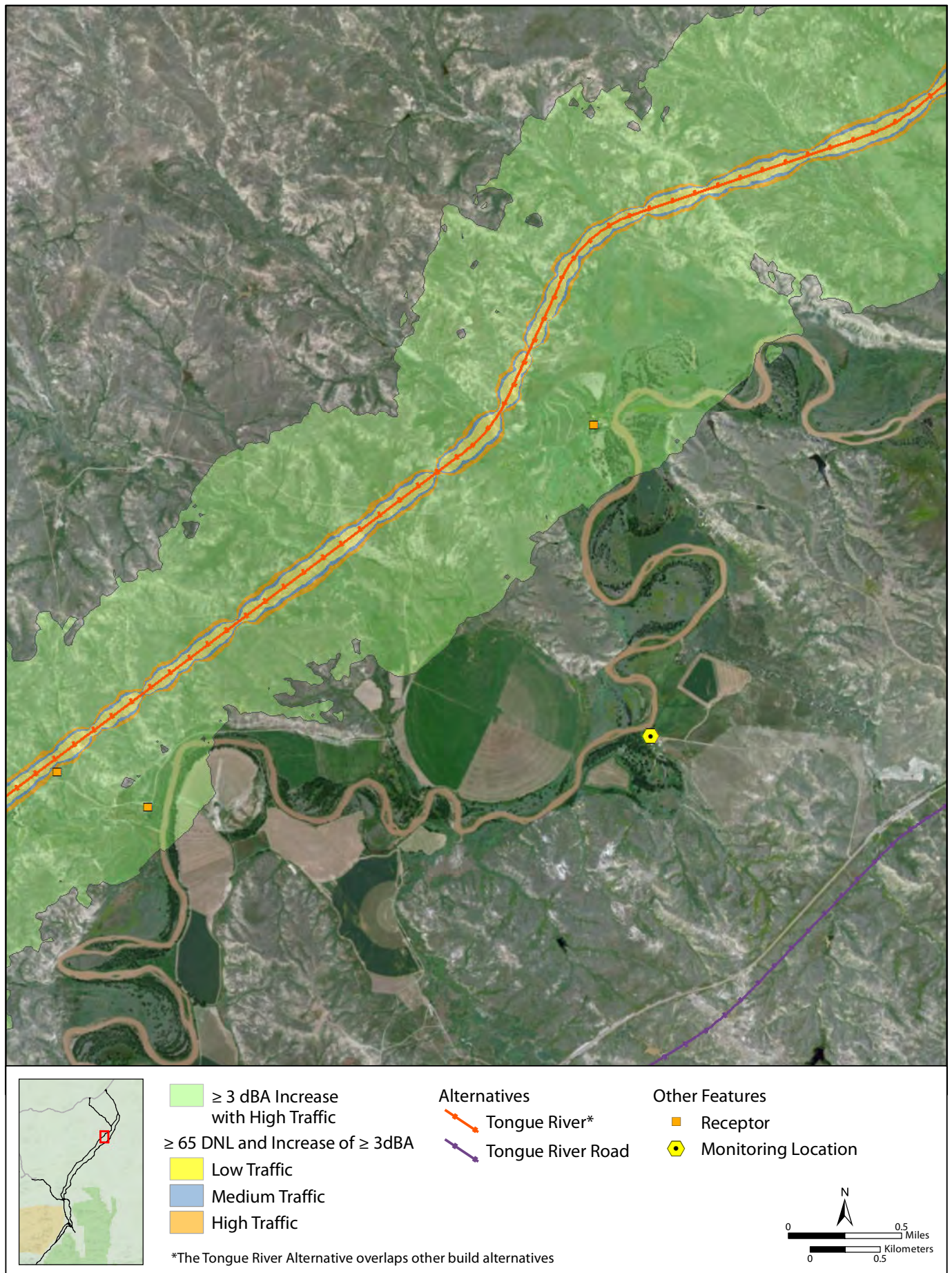


Figure H-8. Noise Contours and Receptors for the Tongue River Alternative*

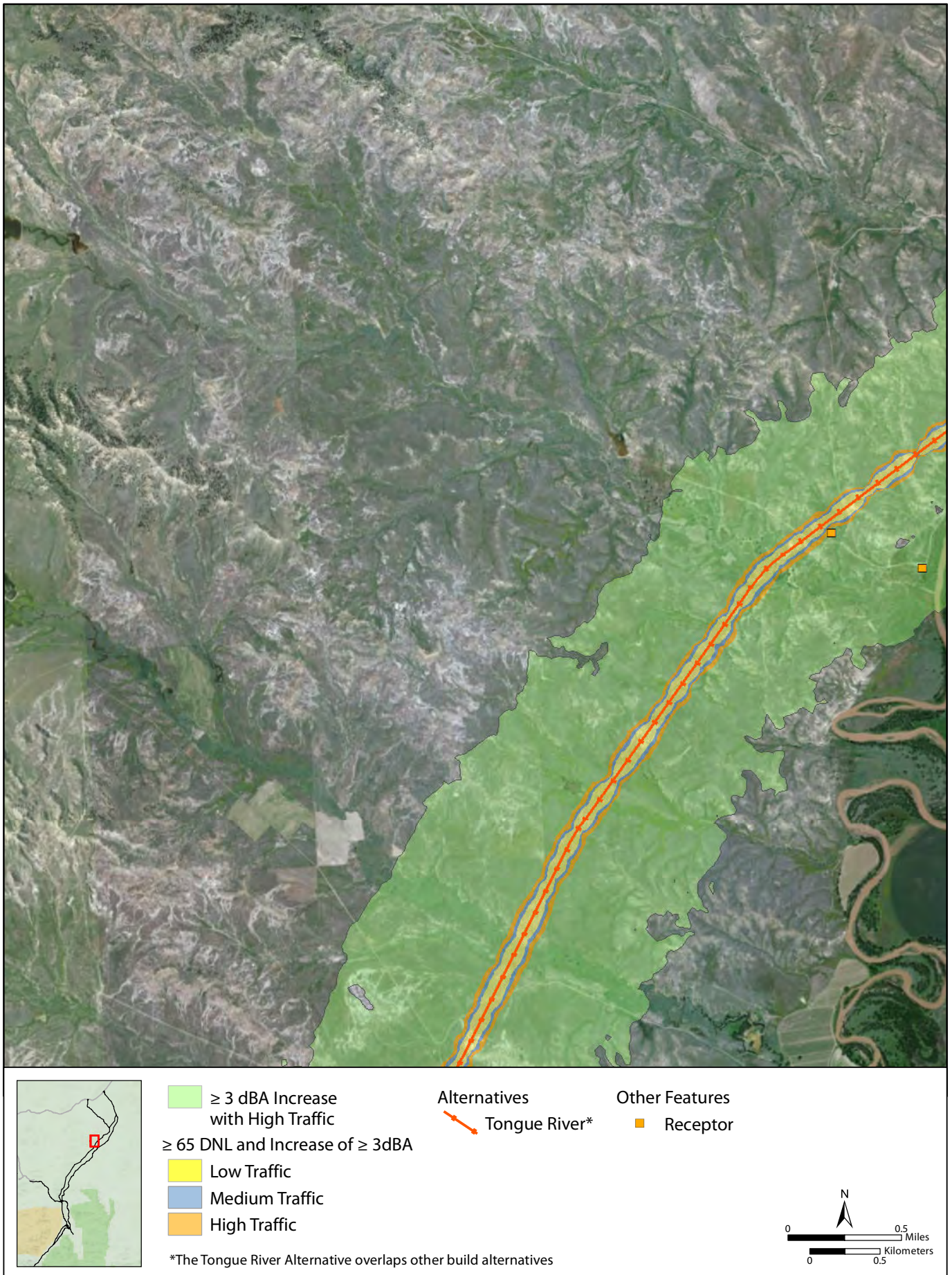


Figure H-9. Noise Contours and Receptors for the Tongue River Alternative*

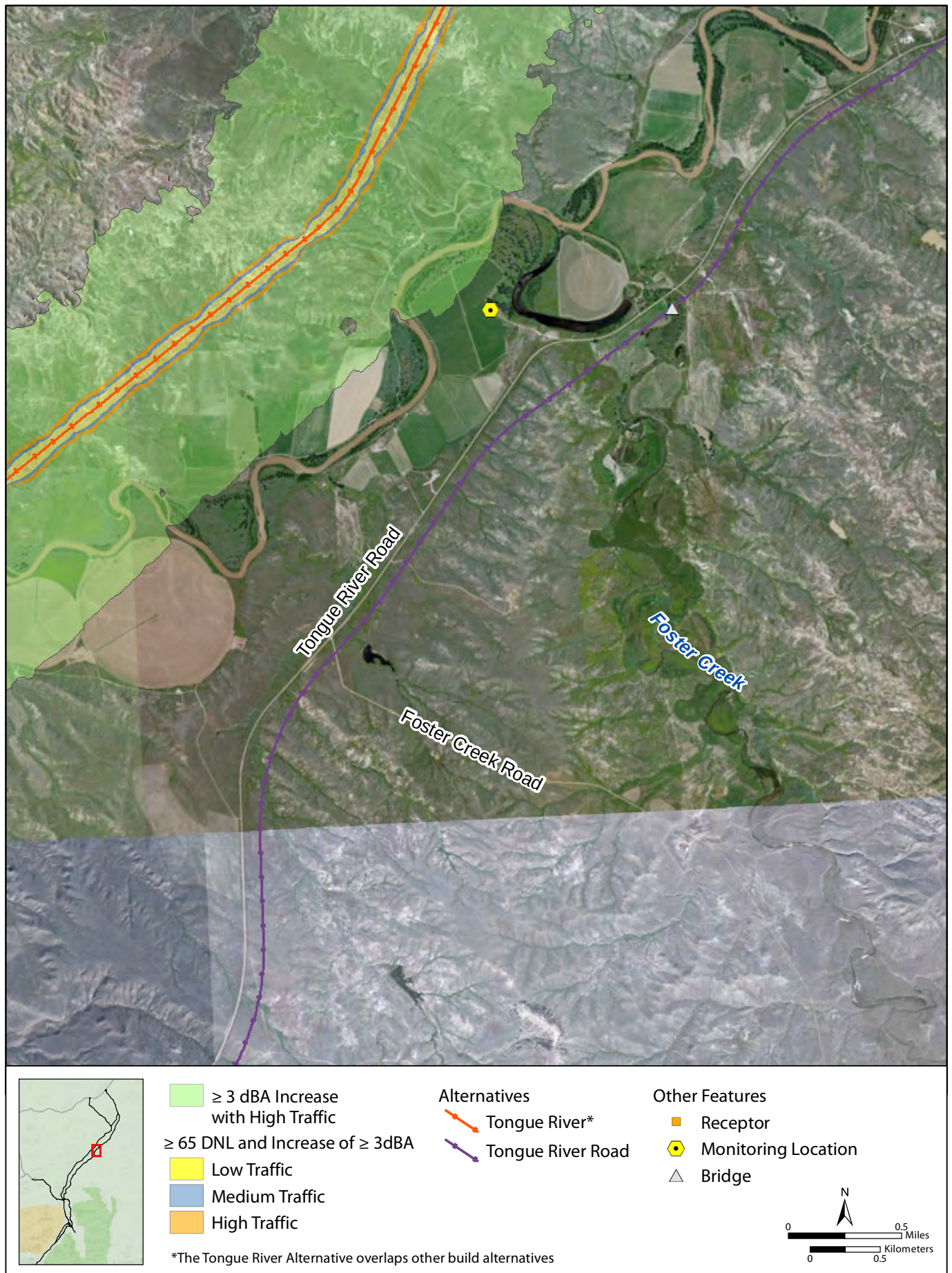


Figure H-10. Noise Contours and Receptors for the Tongue River Alternative*



Figure H-11. Noise Contours and Receptors for the Tongue River Alternative*

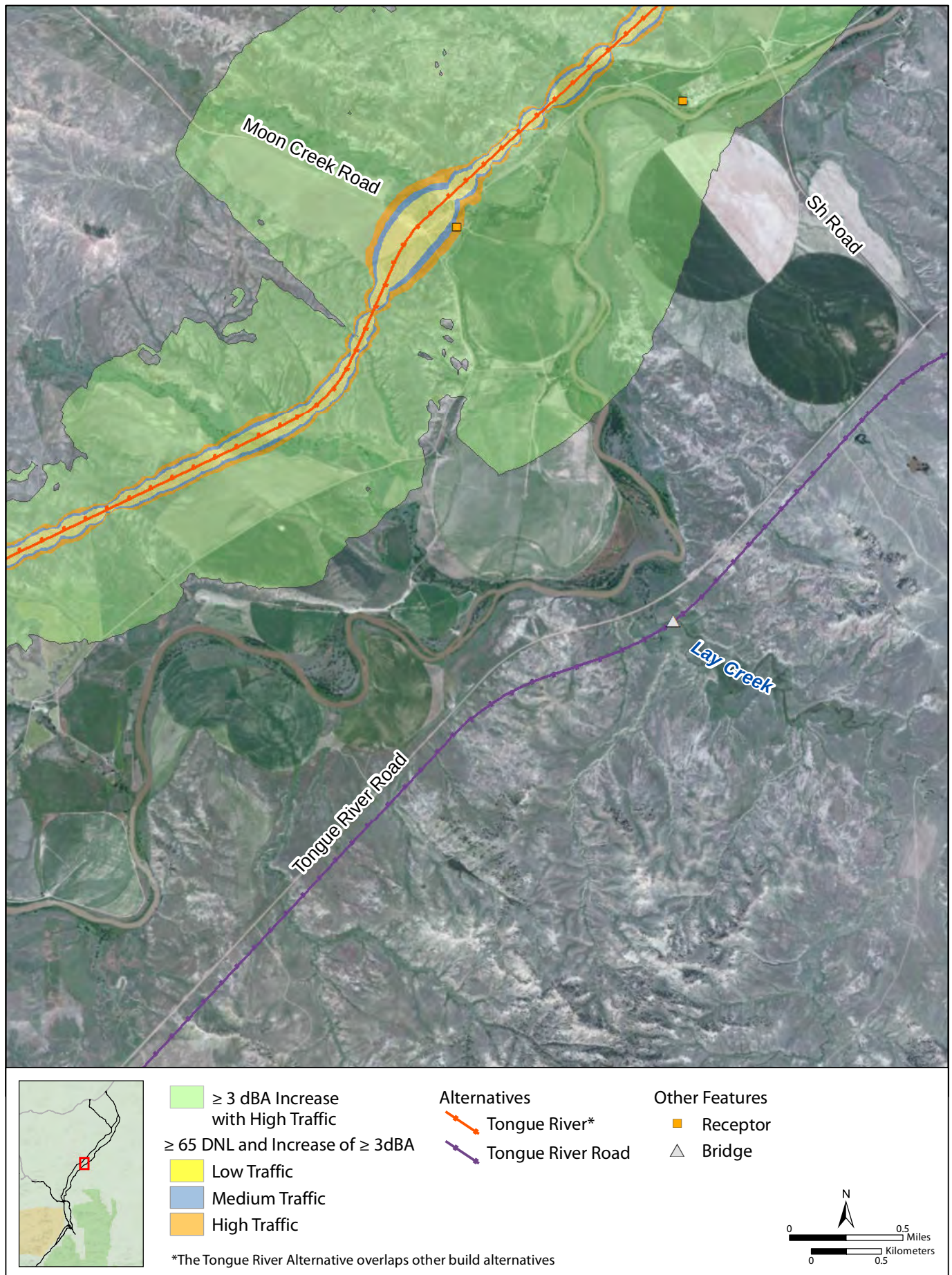


Figure H-12. Noise Contours and Receptors for the Tongue River Alternative*

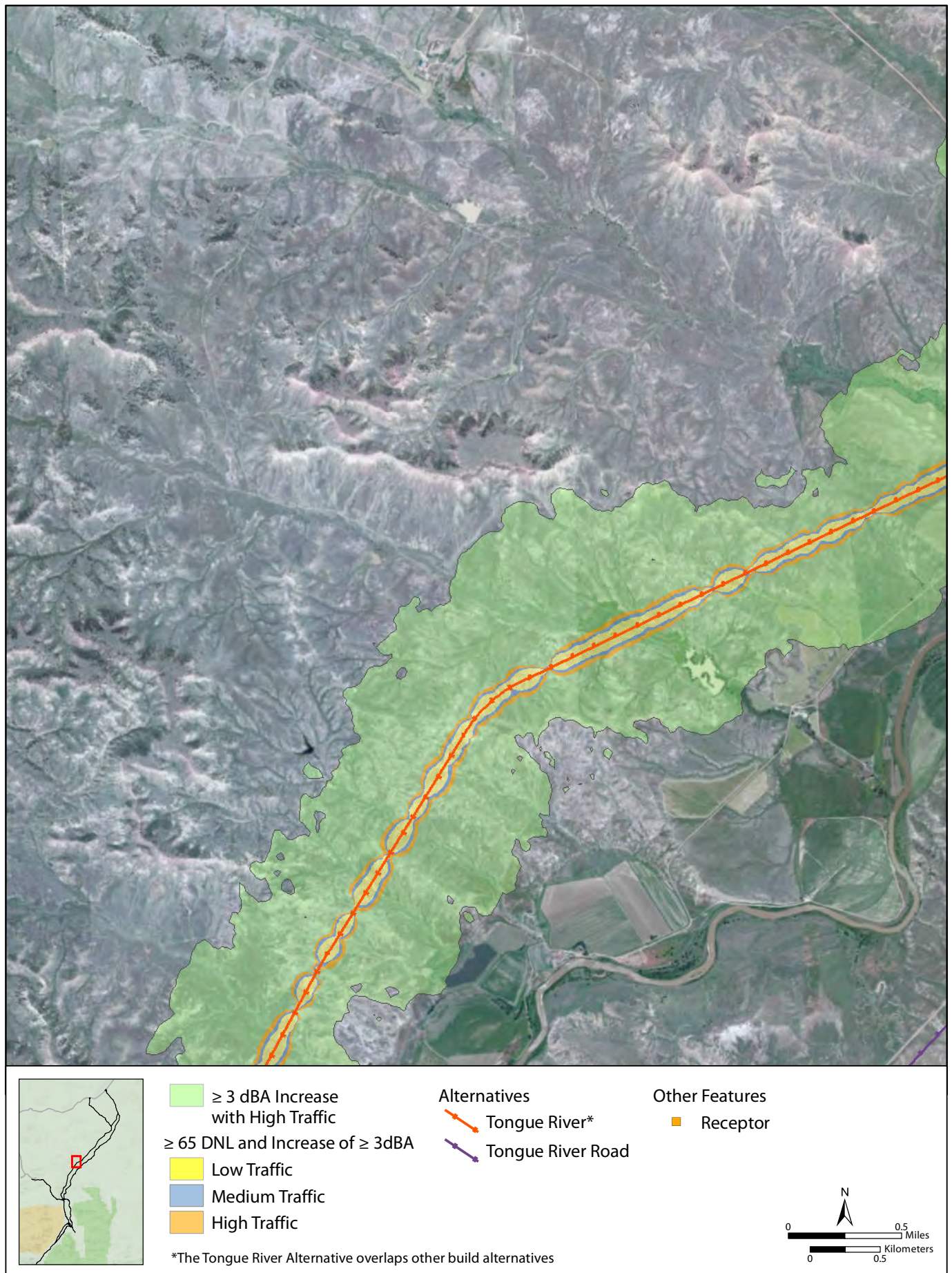


Figure H-13. Noise Contours and Receptors for the Tongue River Alternative*

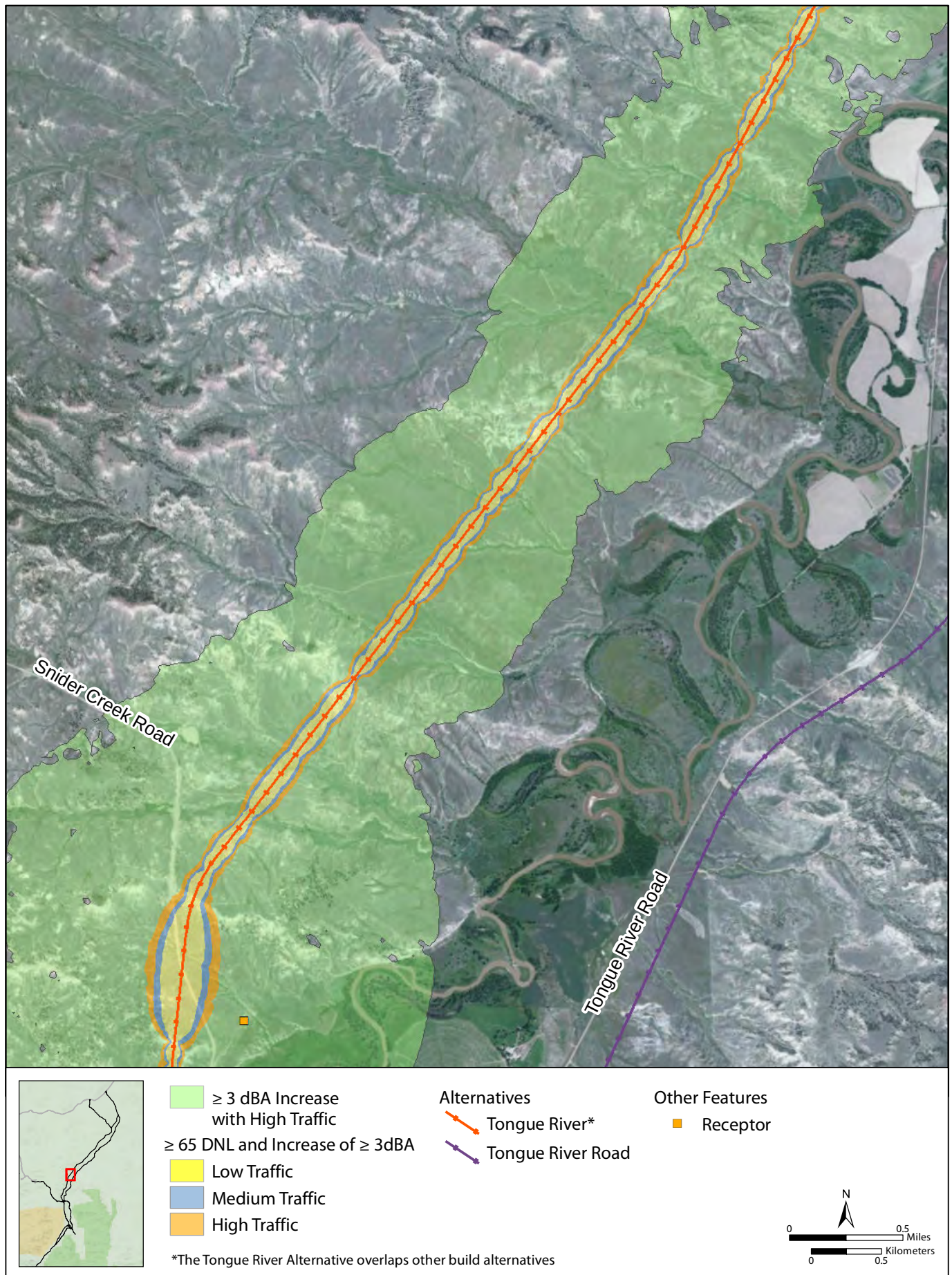


Figure H-14. Noise Contours and Receptors for the Tongue River Alternative*

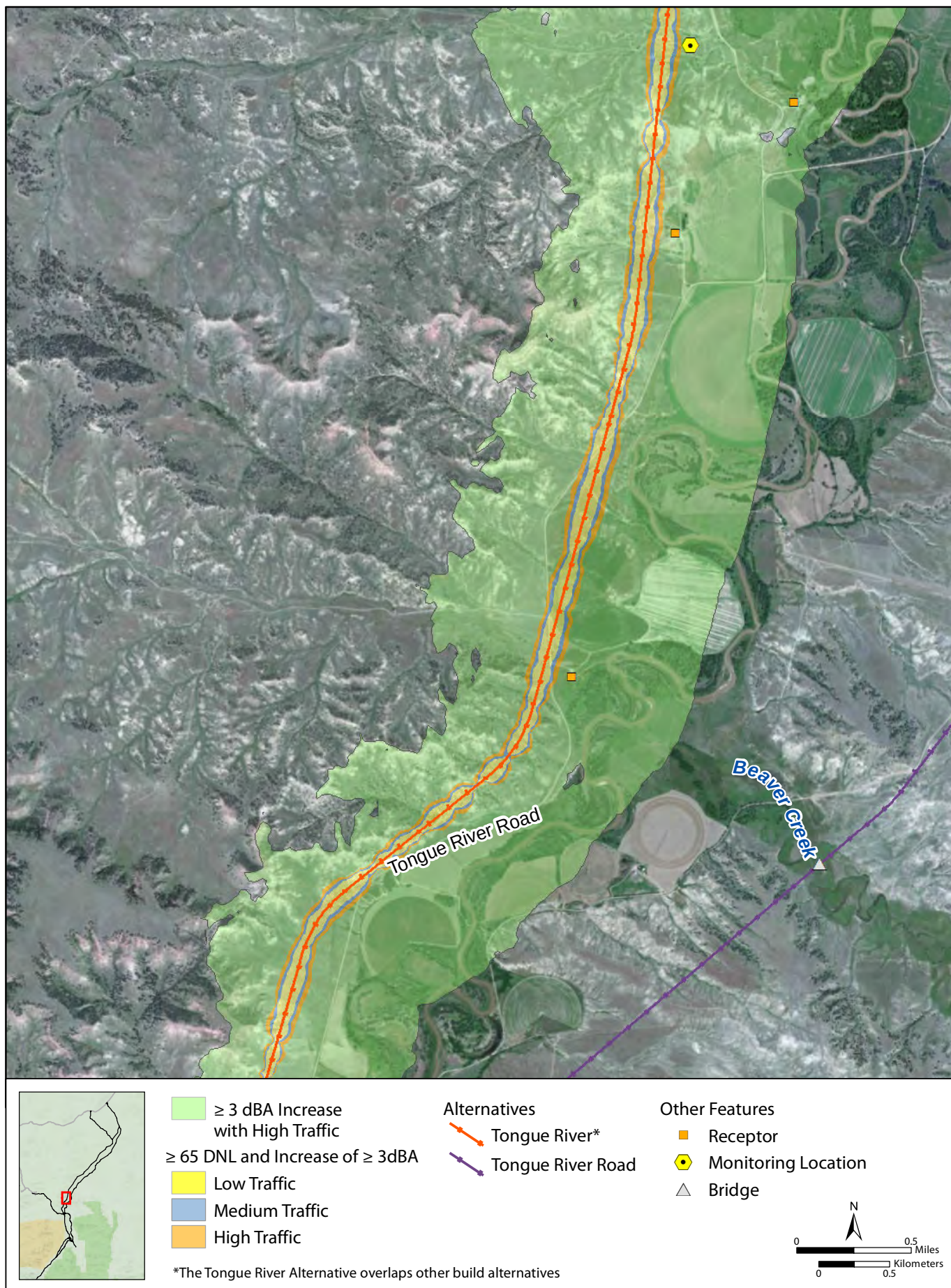


Figure H-15. Noise Contours and Receptors for the Tongue River Alternative*

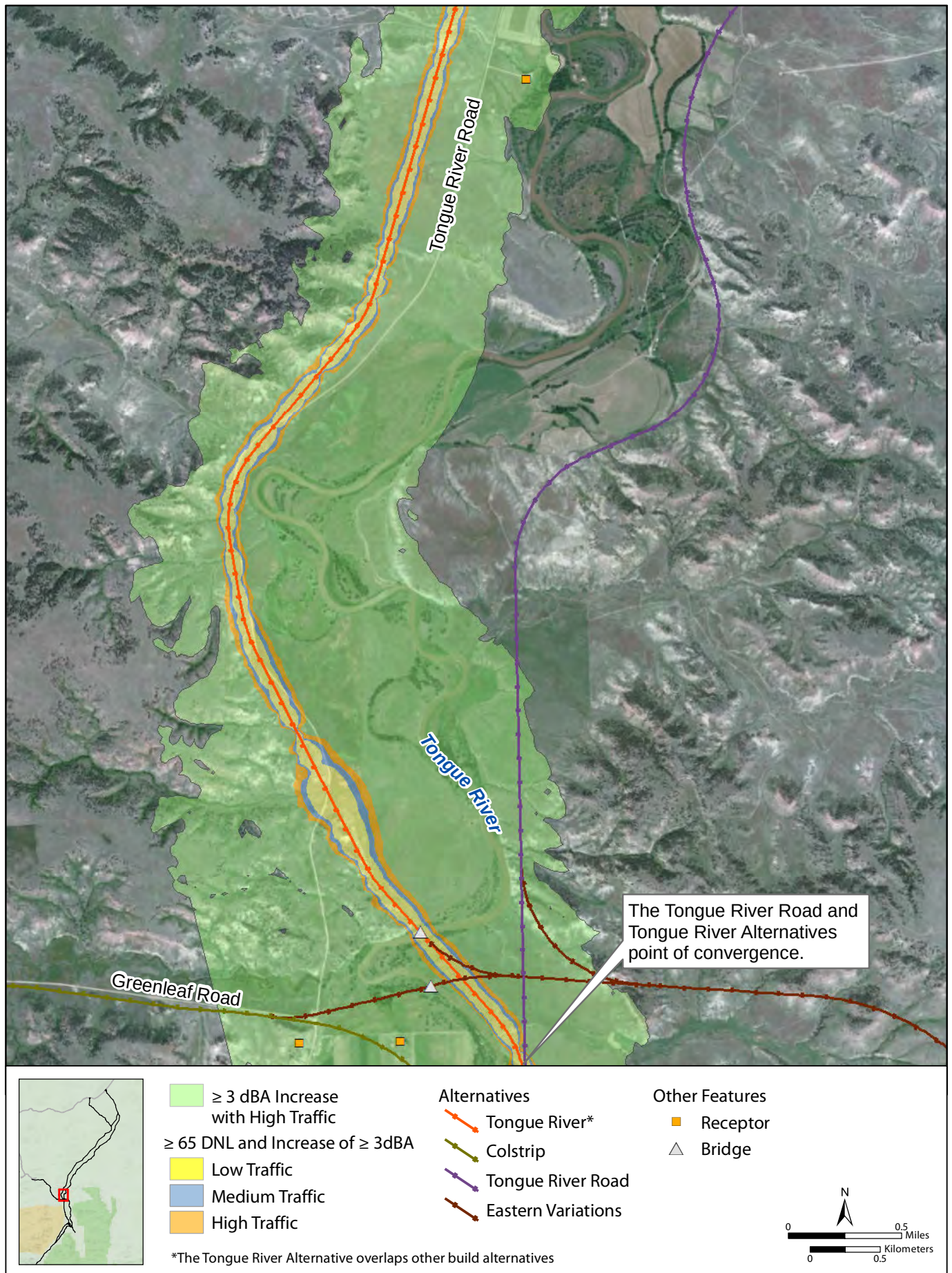


Figure H-16. Noise Contours and Receptors for the Tongue River Alternative*

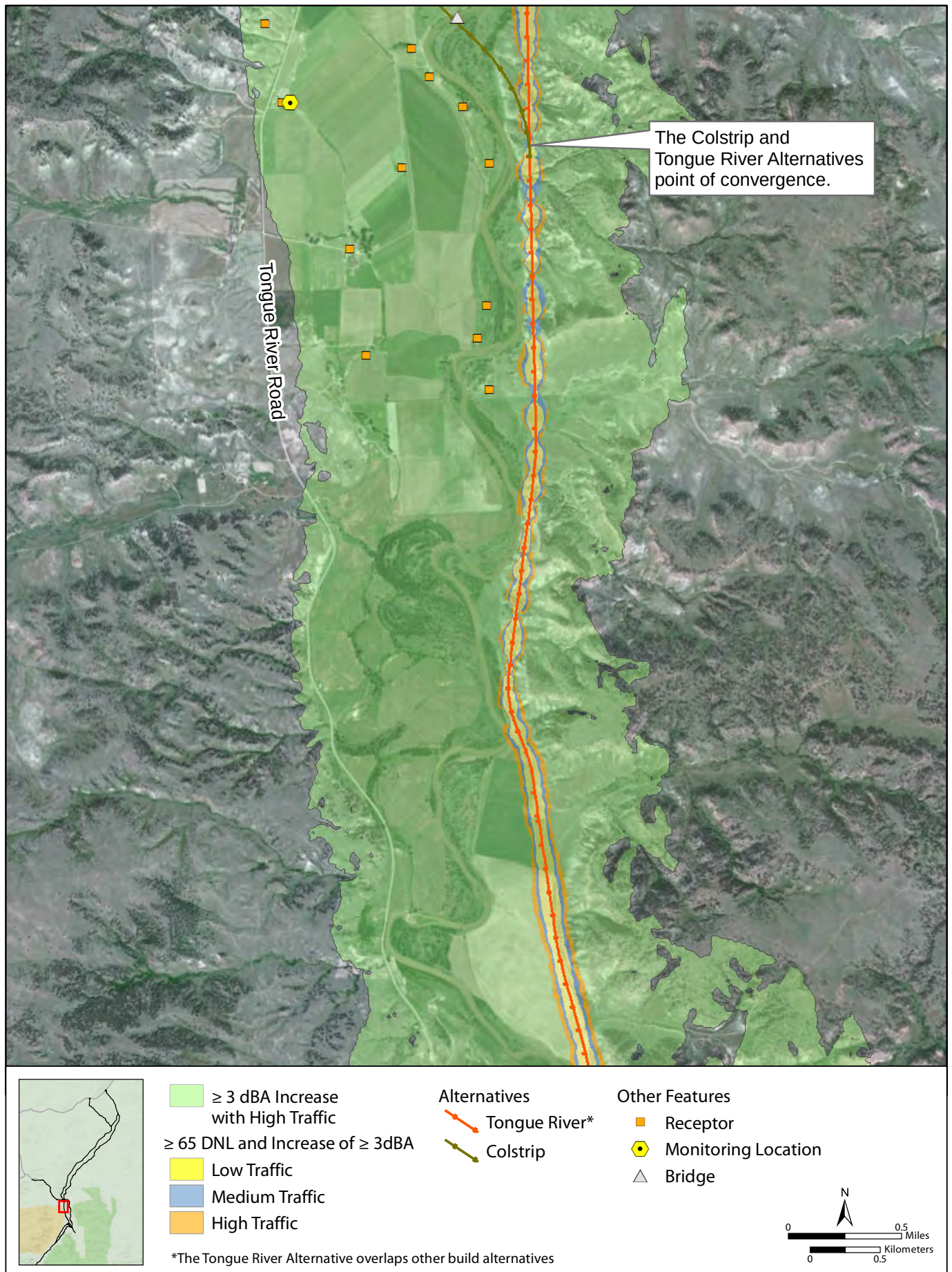


Figure H-17. Noise Contours and Receptors for the Tongue River Alternative*

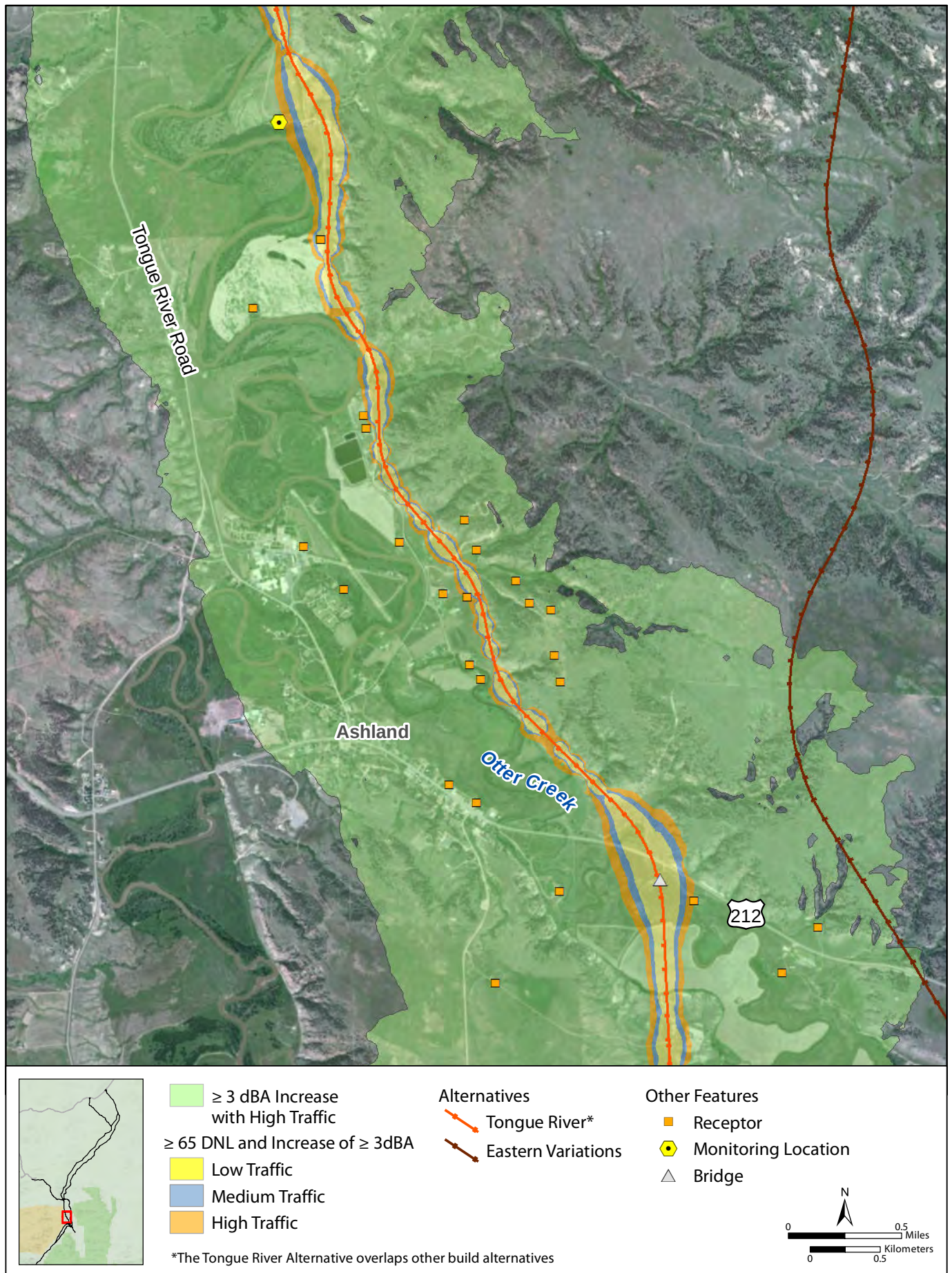


Figure H-18. Noise Contours and Receptors for the Tongue River Alternative*

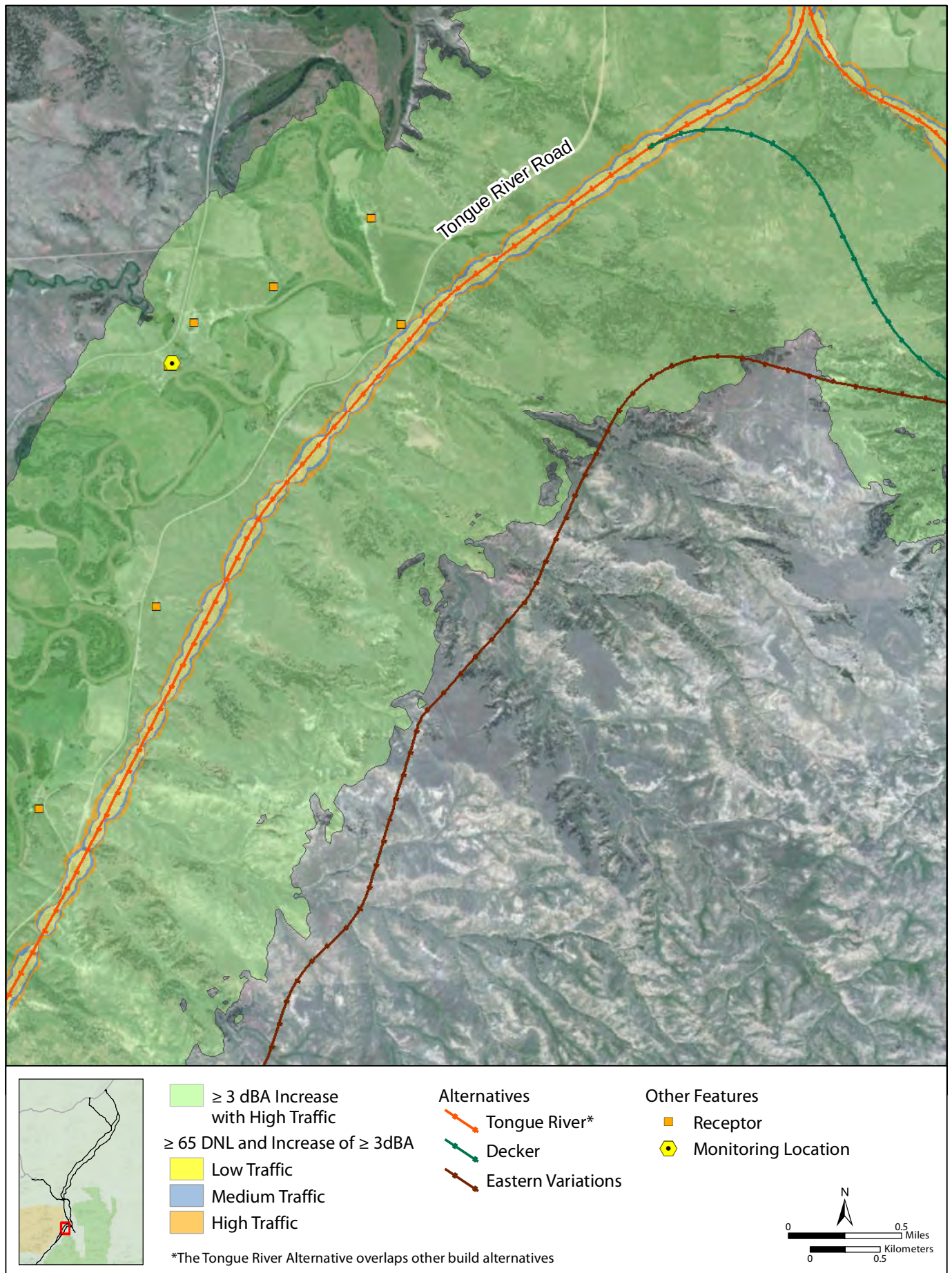


Figure H-19. Noise Contours and Receptors for the Tongue River Alternative*

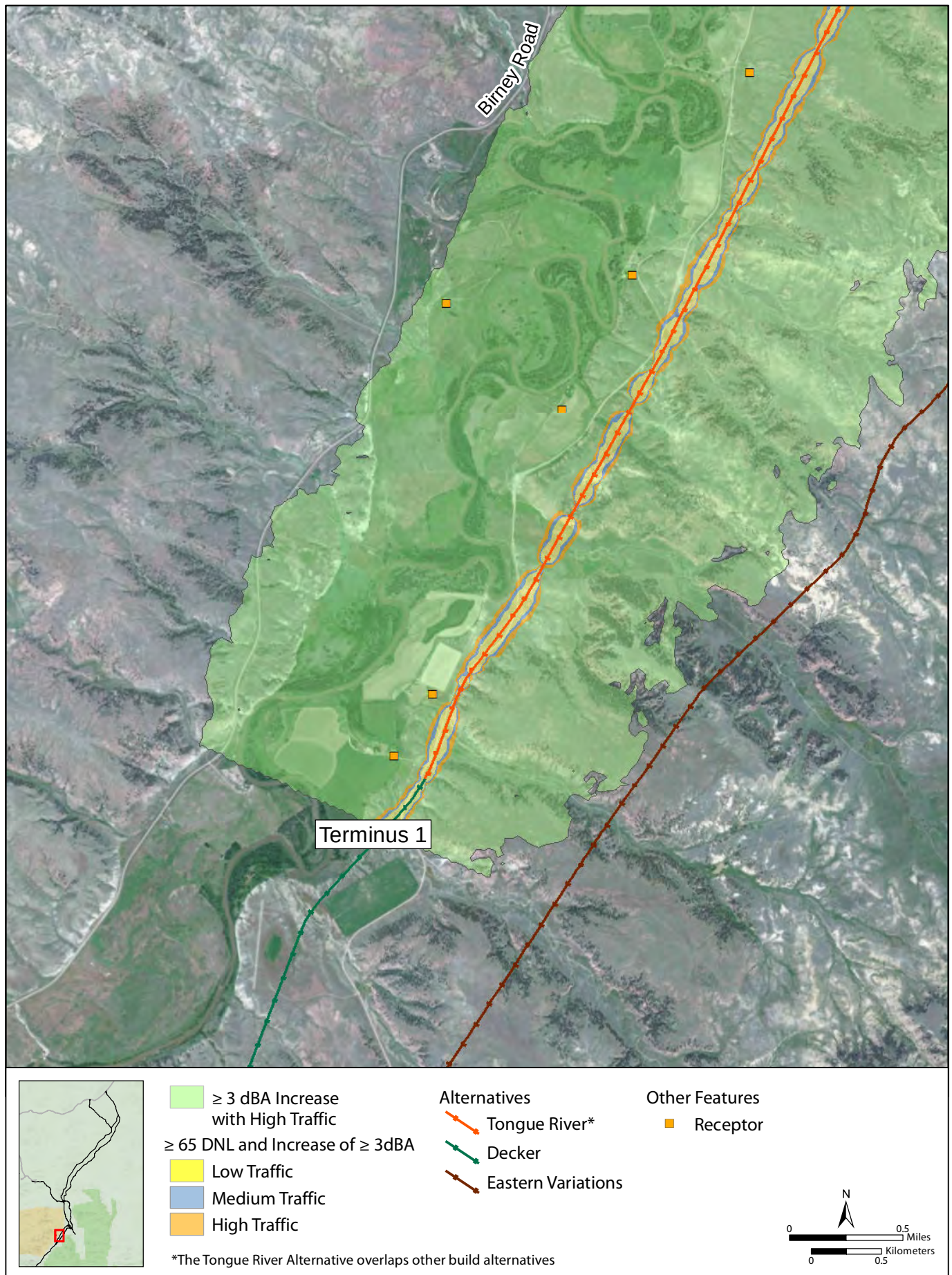


Figure H-20. Noise Contours and Receptors for the Tongue River Alternative*

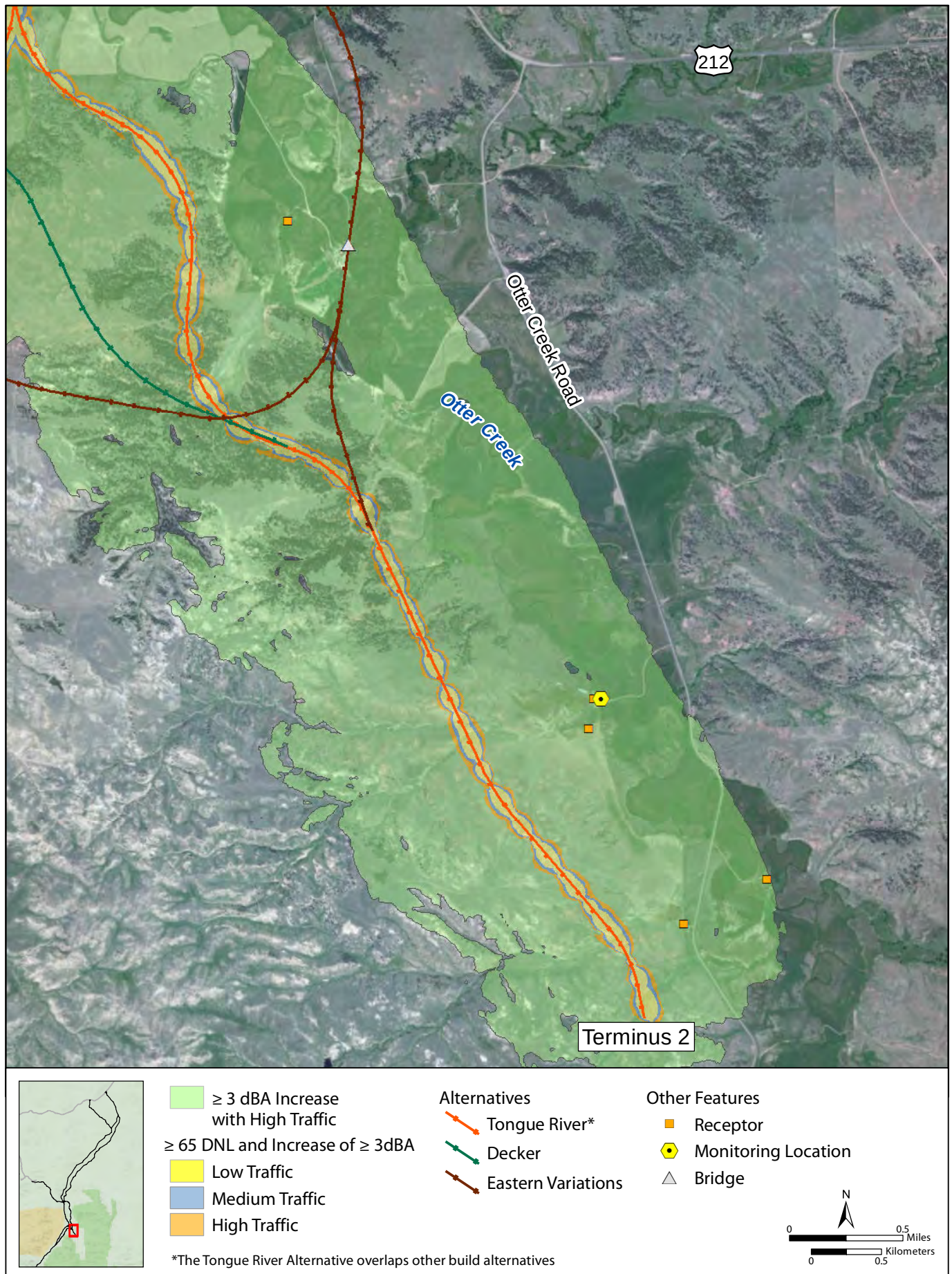


Figure H-21. Noise Contours and Receptors for the Tongue River Alternative*

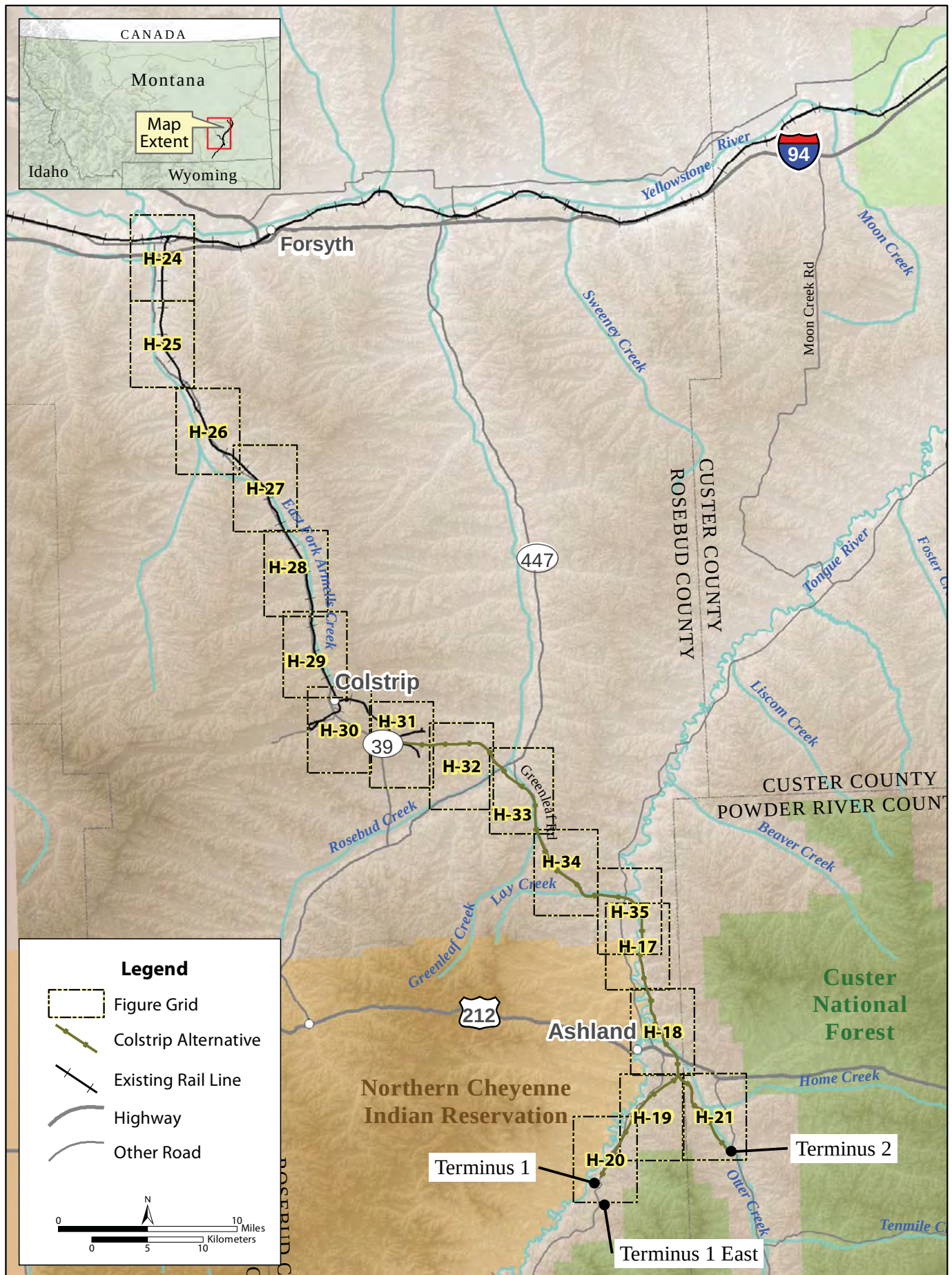


Figure H-22. Figure Grid for the Existing Colstrip Subdivision and the Colstrip Alternative

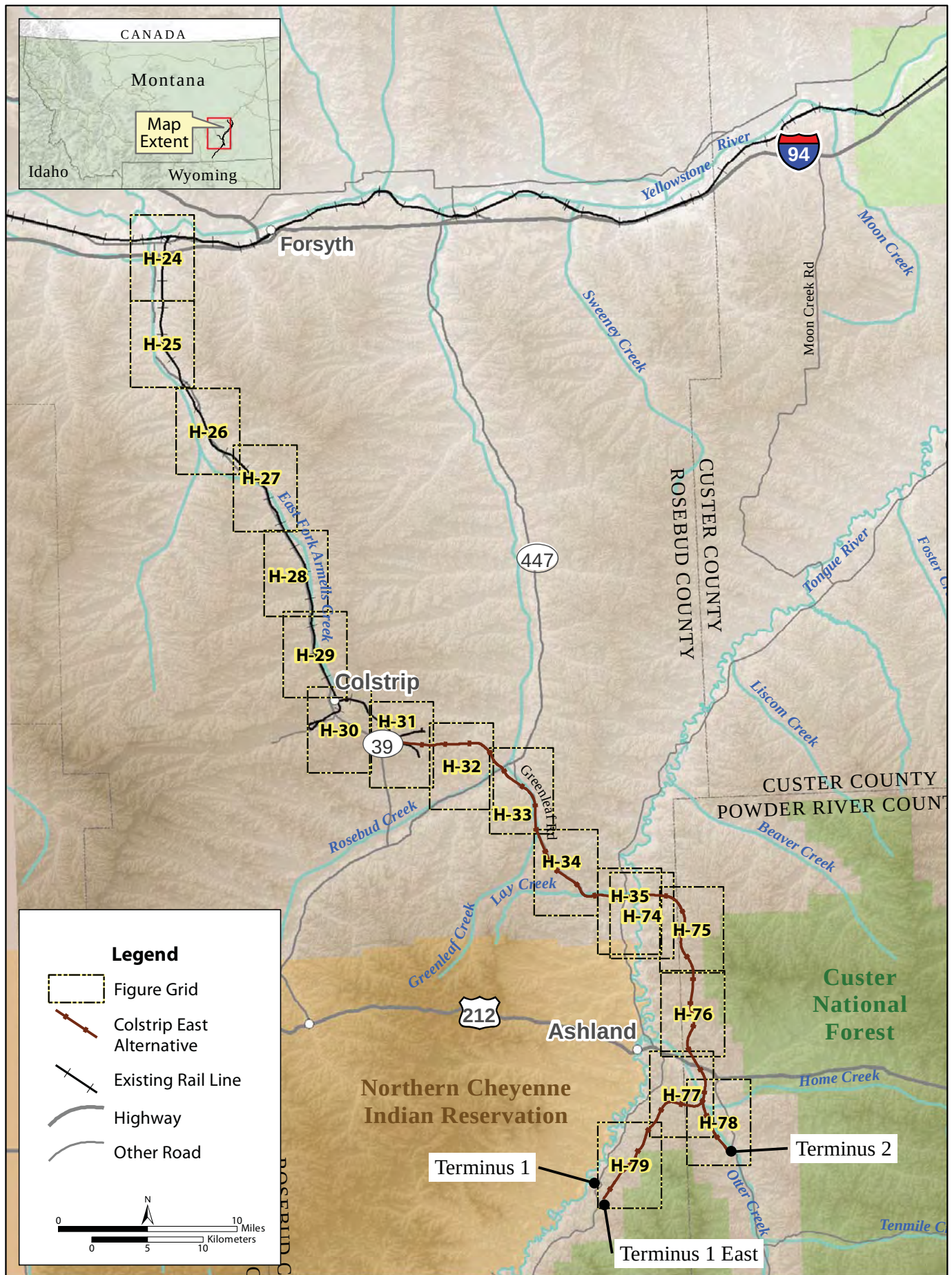


Figure H-23. Figure Grid for the Existing Colstrip Subdivision and the Colstrip East Alternative

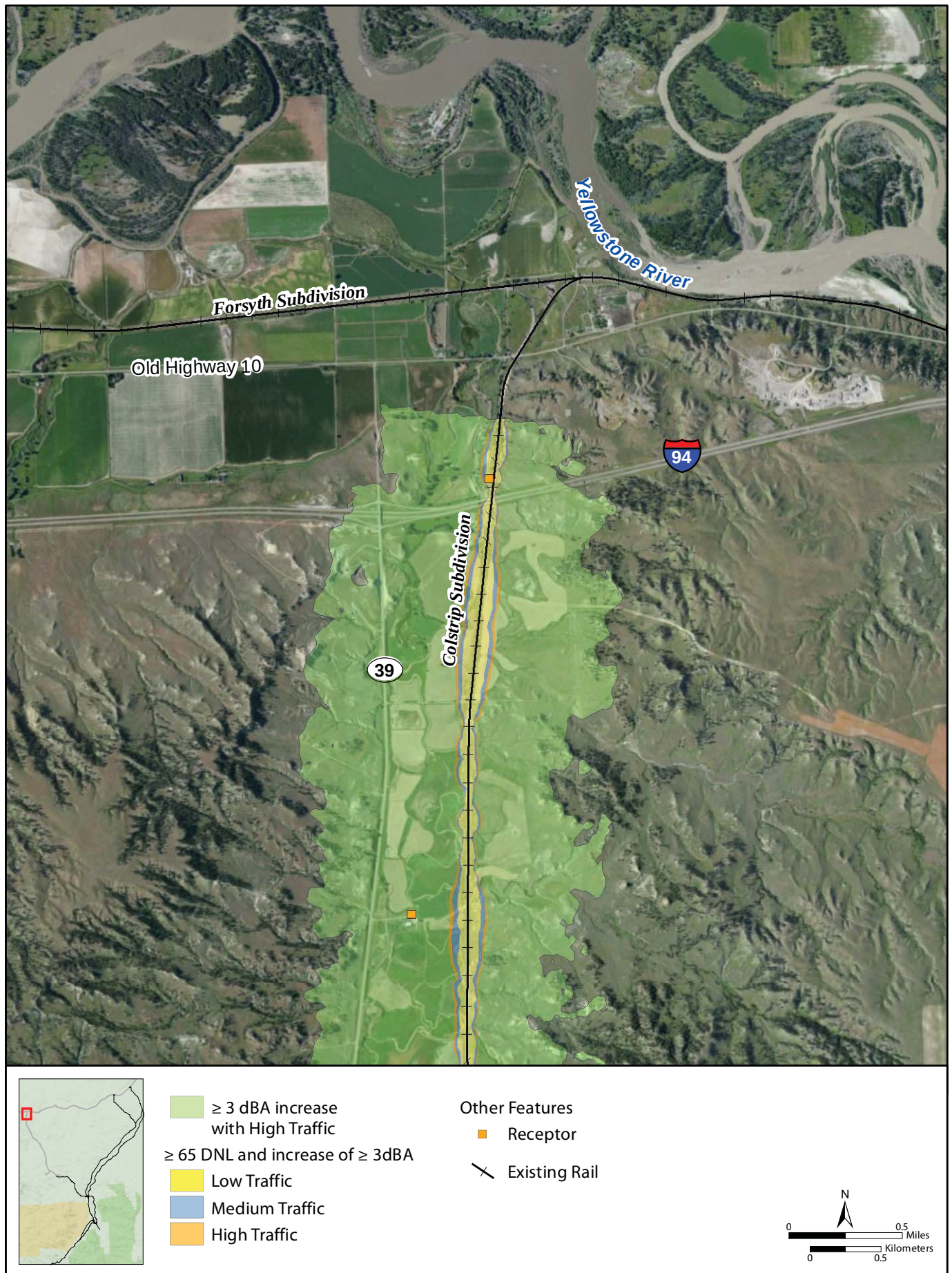


Figure H-24. Noise Contours and Receptors for the Existing Colstrip Subdivision and the Colstrip Alternative

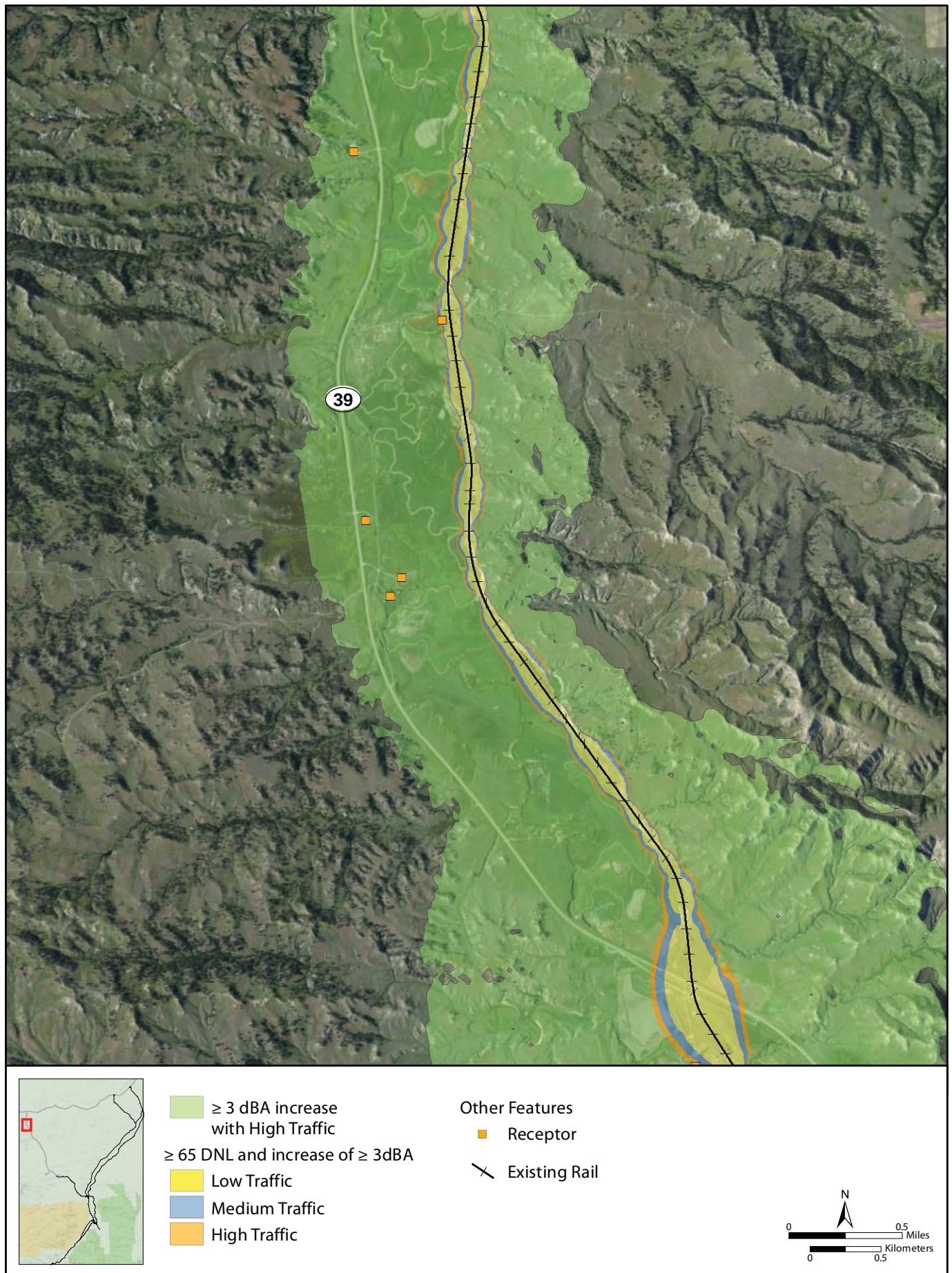


Figure H-25. Noise Contours and Receptors for the Existing Colstrip Subdivision and the Colstrip Alternative



Figure H-26. Noise Contours and Receptors for the Existing Colstrip Subdivision and the Colstrip Alternative



Figure H-27. Noise Contours and Receptors for the Existing Colstrip Subdivision and the Colstrip Alternative

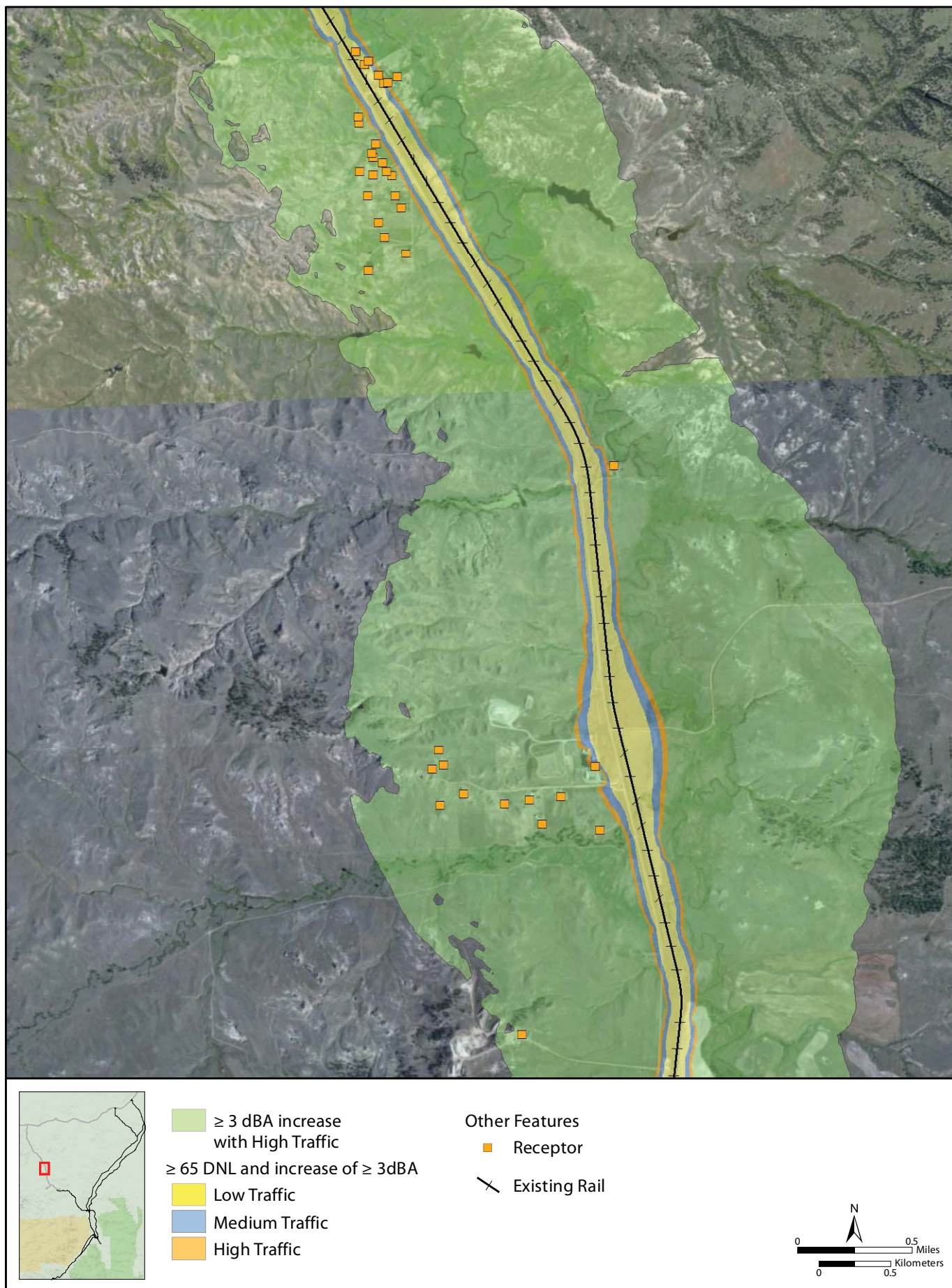


Figure H-28. Noise Contours and Receptors for the Existing Colstrip Subdivision and the Colstrip Alternative

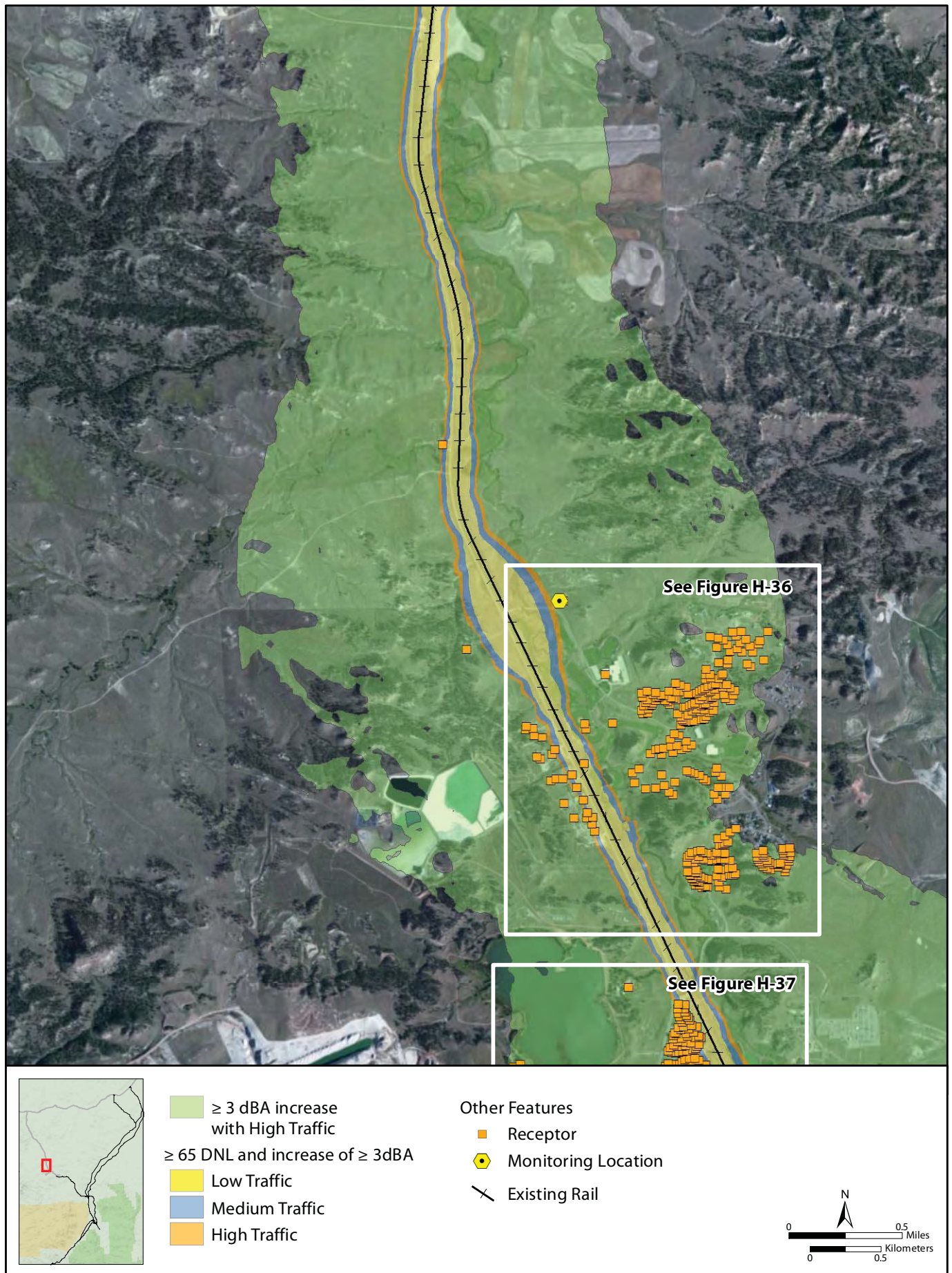


Figure H-29. Noise Contours and Receptors for the Existing Colstrip Subdivision and the Colstrip Alternative

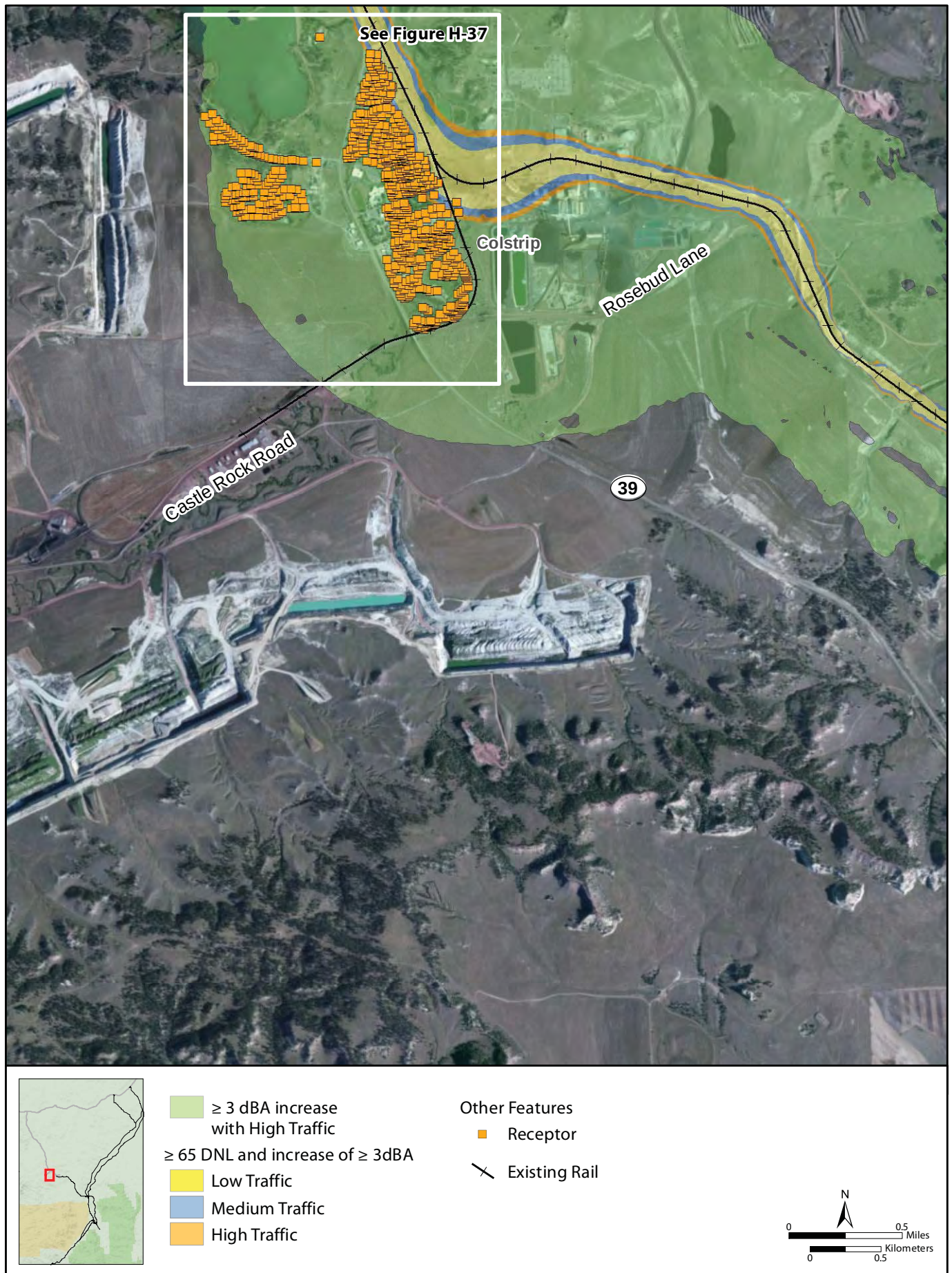


Figure H-30. Noise Contours and Receptors for the Existing Colstrip Subdivision and the Colstrip Alternative