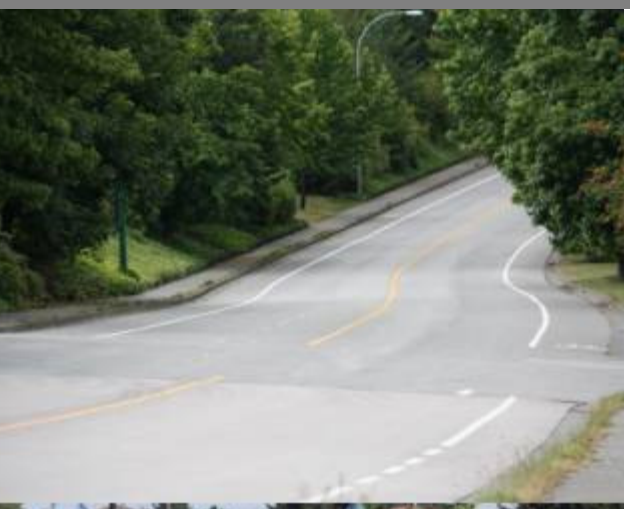
CANADIAN ROAD ASSESSMENT PROGRAM (CanRAP) FEASIBILITY STUDY



Option for Technical Elements of a CanRAP Methodology

TRANSPORT CANADA

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1. INTRODUCTION

Road Assessment Programs use a systematic analysis of road segments to address safety shortcomings, mitigate risks and inform drivers about the safety of the roads they travel. The objective of the Canadian Road Assessment Program (CanRAP) Feasibility Study, which emulates the International Road Assessment Program, was to test the feasibility of instituting a Canadian Road Assessment Program, using data from the three provinces (British Columbia, Alberta, and Saskatchewan).

Note that CanRAP is not an existing program, and the purpose of this study is to determine whether it is feasible. This report summarizes the results and findings of the following tasks:

- Define CanRAP Methodology and Technologies
- Identify RAP Methodology and Technologies from Other Countries for Revision to Fit into the Canadian Context
- Determine the Variety of Risk Maps Needed
- Pilot Testing
- Recommend CanRAP Methodologies and Technologies

Section 2 of the report summarizes the requirements on RISK Mapping. It defines the data requirement and methodology for CanRAP to "duplicate" what has been done in other RAPs. ***Section 2*** also provides a discussion on a number of issues relating to the CanRAP RISK Mapping methodology and opportunities to improve the existing methodology.

Section 3 of the report summarizes the requirements on STAR Rating. It defines potential data requirement and methodology for CanRAP to "duplicate" what has been done in other RAPs. ***Section 3*** also provides a discussion on a number of issues relating to the CanRAP STAR Rating methodology and opportunities to improve the existing methodology.

Section 4 of the report provides the results of a pilot testing exercise for a section of the Trans Canada Highway corridor located in British Columbia.

Section 5 of the report provides the study team's conclusion on the technical feasibility of the CanRAP Methodology.

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2. RISK MAPPING

This part of the report is divided into 3 sections. ***Section 2.1*** describes a recommended CanRAP methodology for RISK Mapping based on the existing methodologies used by EuroRAP, AusRAP and usRAP. ***Section 2.2*** provides a discussion on the potential issues associated with the existing RISK Mapping approach. ***Section 2.3*** describes potential improvements that could be considered for the CanRAP methodology, addressing some the issues discussed in ***Section 2.2***.

2.1 RISK MAPPING METHODOLOGY FOR CANRAP

2.1.1 COLLISION AND TRAFFIC VOLUME DATA REQUIREMENT

It is recommended that CanRAP assess roads according to *ALL* casualty collisions (i.e., fatal and injury collisions) using a five-year collision time period. The use of casualty collisions is consistent with some of the RAPs from other jurisdictions and it is believed that a higher level of data consistency will exist if casualty data is used rather than using total collisions, which would include property damage only (PDO) collisions. There appears to be considerable variability in the definition and reporting of PDO collision data between Canadian provinces, which creates potential difficulties associated with the access and reliability of the data. The differences in casualty data appear to be less than PDO data, although there are likely some differences.

Some RAPs use three years of collision data but it is proposed that five years of collision data be used for CanRAP. There are two reasons for this suggestion. Firstly and similar to Australia, much of Canada's rural highway system is characterized by long distances between known landmarks and relatively low traffic volumes on rural highways. As such, many of the CanRAP segments might have a very low collision frequency if three years of collision data were used. Five years of collision data should allow for a suitable collision frequency. Secondly, since it is proposed that only casualty collisions be used for CanRAP (rather than all collisions) a longer timeframe is required to ensure that the frequency of fatal and injury collisions is suitable for the Can RAP analysis.

The traffic volume data for CanRAP need to be supplied by the various road authorities. All road authorities have traffic volume data in some format, which can be used and converted into the annual average daily traffic (AADT) for the CanRAP analysis.

2.1.2 ROAD SEGMENTATION

The practice of splitting a stretch of highway into sections for the purpose of calculating collision measures and evaluating safety differs significantly among road jurisdictions and safety researchers. In some cases, a fixed segment length may be used, which is often arbitrarily selected (e.g., 5.0 kilometers). Others use segment lengths that vary between

a pre-specified minimum and maximum limits, while others might split a stretch of highway to ensure homogeneity in terms of the traffic and geometric characteristics.

The appropriate segmentation of highways is a critical component of CanRAP, which can have a significant impact on the results that are produced. There are two potential problems that should be considered in the segmentation process. Selecting highway sections that are too short and calculating safety measures such as the collision rate will produce biased results that can have considerable variability among successive sections. Alternatively, if very long sections are selected, the effect of higher risk sections that are located within the longer segment will be moderated because of the averaging over a long segment length. Furthermore, the identification of shorter, problematic sections that are located within a longer segment would not be possible.

It is felt that the most important criterion for highway segmentation is to ensure that the sections are homogeneous in terms of major traffic and geometric characteristics. In addition, since a target user of the output from CanRAP might be the road user, it is important that the start and end locations are easily identifiable. It is anticipated that the CanRAP RISK Maps could be provided to road-users to 1) aid them in selecting the 'safest' route and 2) to warn them of high-risk locations on the route selected.

The following process is recommended for the highway segmentation for CanRAP. It is noted that the highway segmentation process is currently limited to rural highways to be consistent with other RAPs. The segmentation of urban roadways and urban features (e.g., intersections) is possible but will require a different segmentation process and the development of different safety indicators for both the RISK Mapping and STAR Rating.

Step 1: Select highway segments that have a meaningful and identifiable start and end locations, in order that a typical motorist can understand the segment. For example, this might be the highway segment between two small, remote communities or the highway through a gated, national park. It is noted that segments that are meaningful to the provincial highway authority may or may not be suitable for this purpose. It is expected that this step will likely identify segments that could be quite long (e.g., 100 kilometers in length or more), which is acceptable for this first step.

Step 2: After the meaningful segments are identified (Step 1), the segment should be reviewed to ensure that it has broadly similar operational and geometric design characteristics, i.e. similar functional or design classification, number of lanes, cross section elements and design parameters. The provincial highway classification system may be used for this task to ensure that each segment is homogeneous. If the segment is not considered to be suitably homogeneous,

the segment should be split based on the different operational and/or geometric design characteristics.

Step 3: The segments must be checked to ensure that an adequate casualty collision frequency exists on the segment. It is proposed that each segment should have at least one casualty collision per kilometer per five years. This threshold is set at a reasonable level and is consistent with AusRAP. If this casualty collision frequency criterion is not satisfied, then adjacent segments should be combined until this condition is met, ensuring that the adjacent segments are similar in character and homogeneous. If the adjacent segments are not of similar character, then the segment can either be joined with a nearby segment or it can be allowed to have less than the minimum collision frequency threshold.

Step 4: For all segments, search for 'shorter segments less than 10 kilometers' that exhibit a higher level of safety risk (note that the different safety risk levels will be defined in a subsequent section of this chapter), such that the shorter segment can be distinguished from the longer segment. For example, if one segment is 100 kilometres long, there may be 'short' segments within the 100 kilometers that exhibit higher risk provided that a 'short segment' should have a minimum length of 10 kilometers because this is a length that could likely be recognizable to the road user. An attempt should be made to select recognizable start and end points for the short sections to aid motorists in the identification of the segment. The search can be a manual search or it can be done with a program.

Although the highway segmentation process attempts to be systematic, it is recognized that some engineering judgment will be required in order to define appropriate highway segments. It would be quite unusual to have adjacent sections of similar character have significantly different safety performance. Also, the segment lengths will likely be suitable long such that meeting the minimum collision frequency threshold should not be too difficult.

The segmentation methodology is an improvement over other RAP methodologies, as the CanRAP segmentation attempts to follow a more systematic procedure, whereas other RAP segmentation processes appear to be criteria based and are more subjective.

2.1.3 Safety Performance Measures

In order for CanRAP to replicate the existing RAP methodologies from AusRAP, EuroRAP and usRAP, the RISK Mapping would include 4 safety performance indicators, which are listed below and subsequently described.

1. Collision Density (CD);
2. Collision Rate (CR);
3. Collision Rate / Average Collision Rate (CR/ACR); and ,
4. Potential For Casualty Collision Reduction (PCCR).

1) Collision Density (CD):

Collision density (CD) is a very simple safety performance indicator that is based on the observed collision frequency, which shows the annual casualty collision frequency per kilometre of roadway. The intent of this safety measure is to identify locations where the highest and lowest numbers of collisions occur on the highway network, without any consideration given to the level of traffic volume that exists on the segment. The collision density (CD) is expressed in casualty collisions per year, per kilometre and is calculated as follows:

$$\text{Collision Density} = (\text{Coll}_{(F+I)} / N_y) / L$$

Where: $\text{Coll}_{(F+I)}$ = number of casualty collisions (fatal + injury);
N_y = number of years of collision data (use 5 years); and,
L = length of the segment (km).

2) Collision Rate (CR):

The collision rate (CR) is a safety measure that is used to show the likelihood of a road-user being involved in a collision. The difference between collision density and collision rate is that collision rate includes the consideration of exposure (traffic volume), thereby attempting to normalize the safety measure between roads with different traffic volumes levels. The collision rate is expressed as the annual casualty collisions per 100 million vehicles kilometres traveled and is calculated as follows:

$$\text{Collision Rate} = (\text{Coll}_{(F+I)} / N_y) / [(L * \text{AADT} * 365) / 100{,}000{,}000]$$

Where: $\text{Coll}_{(F+I)}$ = number of casualty collisions (fatal + injury);
N_y = number of years of collision data (use 5 years);
L = length of the segment (km); and,
AADT = AADT estimate for link (vehicles per day).

3) Collision Rate to Average Collision Rate Ratio (CR/ACR)

This safety performance indicator is simply the ratio of the casualty collision rate for a segment (i.e., safety measure 2) divided by the average casualty collision rate for a similar type of highway. To determine this safety measure, the average casualty collision rates by road type is required. From the provinces included in the feasibility study, each had collision data and traffic volume data that could be (or currently is being) used to

calculate collision rates and average collision rates. The types of highways would include the range of highways that exist, as defined by each province. A (CR/ACR) value that is greater than 1.0 indicates that the location is considered to be 'worse' than average, whereas a value that is less than 1.0 means the location is 'better' than average. This safety performance indicator is calculated as follows:

$$(CR / ACR) = \{(Coll_{(F+I)} / N_y) / [(L * AADT * 365) / 100{,}000{,}000]\} / ACR$$

Where:
- $Coll_{(F+I)}$ = number of casualty collisions;
- N_y = number of years of collision data;
- L = length of the segment (km);
- AADT = weighted AADT estimate for link; and,
- ACR = average collision rate (by highway type)

4) Potential for Casualty Collision Reduction (PCCR)

This safety measure provides information on the number of casualty collisions that might be reduced if the collision rate on a highway section, which has a risk level above the average collision rate, were reduced to an average collision rate. It is calculated by taking the difference between the collision rate (CR) and the average collision rate (ACR) and multiplying this difference by the exposure to obtain a collision frequency, expressed in casualty collisions saved per year on the segment.

$$PCCR = (CR – ACR) \times [(L * AADT * 365) / 100{,}000{,}000]$$

2.1.4 Mapping Safety RISK

In keeping with other RAPs, the RISK Map protocol for CanRAP could employ a colour coding system to show the relative levels of road safety risk. Most of the RAPs use five risk bands to show the various levels of risk, as presented in ***Table 1*** below.

Table 1. Proposed CanRAP RISK Categories

Dark Green	Low	Road links considered to have the lowest safety risk
Light Green	Low-Medium	
Yellow	Medium	Road links considered to have a moderate safety risk
Red	Medium High	
Black	High	Road links considered to have the highest safety risk

Some of the RAPs (AusRAP and EuroRAP) establish risk levels that are stratified into 20% (quintiles), each representing 20% of the reference group for comparison. In contrast, usRAP has varying proportions within each risk category, such that the lowest safety risk roads may represent 40% of the total road network, whereas the highest risk category on each map may include only 5% of the total roadway length. These actual portions will need to be established in a pilot project based on benchmarks or road safety targets in consultation with the road authorities.

For CanRAP, it is recommended that the relative risk categories be defined so that each category in increasing order of safety risk contains a progressively smaller portion of the roadway system (i.e. similar to the usRAP).

The actual values used to define the different risk levels cannot be determined at this feasibility stage. However, it is expected that there will be regional differences in the safety measure values between the Canadian provinces. Using similar risk categories and the colour coding system proposed will allow each province to have equal proportions of roadway within each category. There is also a need to create a national benchmark to allow for the comparison between provinces. This will require determining adjustment factors to account for the differences between jurisdictions (e.g., collision reporting practices, topography, roadway design characteristics, etc.). This concept is discussed further in ***Section 2.2.4***.

Once the initial set of actual safety measure values are established for each risk category and for each province or nationally, these values can be held constant over time to serve as the basis for performance tracking. For example, it is expected that with on-going improvements to the highway network, the proportion of 'BLACK' roads will reduce while the proportion of 'GREEN' roads will increase. This should aid road authorities in the understanding of the progress made to improve the level of safety on the rural highway network.

2.2 RISK MAPPING METHODOLOGY ISSUES

This section provides a discussion of several important issues in the development of RISK Maps. These issues include: 1) the use of property damage only (PDO) collisions for the CanRAP RISK Maps, 2) establishing the different risk levels for each safety measure, 3) issues associated with differences between Canadian provinces, and 4) using collision rate versus collision frequency as a safety measure.

2.2.1 USE OF PROPERTY DAMAGE COLLISIONS

Collision data is normally categorized into three groups, including fatal collisions, injury collisions and property damage only (PDO) collisions, although some jurisdictions will have specific categories for different levels of injury (e.g., severe injury, moderate injury

and minor injury). Typically, PDO collision data can represent over 50% of the total collision data and as such, this collision data can be very useful for engineering analysis such as the identification of collision prone locations, analyzing collision trends, patterns and causation. The use of total collision data (Fatal, Injury and PDO) is helpful in identifying collision prone locations and analyzing collision characteristics because collision data is often very limited when specific locations (i.e., short segments (1.0 – 3.0 kilometers) or rural intersections) are examined. However, for the purposes of CanRAP, the need for the use of all collision data is reduced because of the increased length of the segments that could be used.

Furthermore, there appears to be considerable variability in the definition and reporting of PDO collision data between Canadian provinces. This will create potential difficulties associated with the access and reliability of the PDO data for use in generating CanRAP RISK Maps. Using PDO data will also create more difficulties when trying to examine the safety performance between the Canadian provinces due to the difficulties in trying to normalize the differences in PDO data.

The use of PDO collision data for CanRAP RISK Maps is not recommended. However, if the PDO collision is available, it could be used in any subsequent engineering analysis that is conducted by the road authorities.

2.2.2 Establishing Risk Categories

In establishing the different levels of risk that will be used for the CanRAP RISK Maps, it is important to consider the benchmarks or reference group that will serve as the basis for the comparison and measurement of risk. The risk calculated for a segment can be compared against either the entire road network or it can be compared against similar types of roadways. The outcome and how the results are presented on a CanRAP RISK Map will be very different depending on the benchmarks / reference groups that are used. This concept is best explained by way of an example, as provided below.

Consider two highway segments located in a specific jurisdiction. The first segment is a low-volume, rural 2-lane highway and the second segment is a high-volume urban, multi-lane freeway. The data associated with these 2 segments and the collision rate measure is shown in ***Table 2*** below. Also included in the table is the average collision rate (ACR) by road type and for all highways.

Table 2. Illustrative Example of RISK Categorization

Segment Information	Rural, 2-Lane Highway	Urban, Multi-Lane Freeway
Traffic Volume (vpd)	2,500	50,000
Segment length (km)	25	10
Casualty Collisions / 5 years	30	120
Collision Rate (CR) (Coll./100MVKm)	26.3	13.2
Average Collision Rate (ACR) (Coll./100MVK)	29.1	11.6
Average Collision Rate (ACR) (Coll./100MVK) for ALL Highways	19.1	

If the basis for comparison is a reference group consisting of all highways, then a RISK Map of collision rate (CR) would show that the high-volume, multi-lane freeway is 'safer' than the low-volume two-lane highway (i.e., 13.2 is less than 19.1 and 26.3 is greater than 19.1). In contrast, if the basis for comparison is a reference group that consists of similar types of roadways, then a RISK Map of the collision rate (CR) measure would show that the low-volume two lane highway is 'safer' than the high-volume, multi-lane freeway (i.e., 26.3 is less than 29.1, whereas 13.2 is greater than 11.6).

For the CanRAP RISK Mapping, it is recommended that the collision density (CD) and the collision rate (CR) measures use all highways as reference group for the basis for comparison. The CR/ACR and the PCCR measures must use a reference group consisting of similar types of roads as the basis for comparison.

Using all highways as the basis for comparison is useful for a road-user by producing a **ROUTE Selection RISK Map**, which is based on the relative risk of different types of roadways. In other words, if a road user has two route options, each with the same length, then the road user can use the ROUTE Selection RISK Map to select the 'safer' route, which would typically be associated with the higher road classification.

The other two safety measures (CR/ACR) and PCCR both make use of average collision rate (ACR) values from a reference group consisting of similar roadways rather than using a reference group that includes all highways for the basis for comparison. This approach will allow road-users to identify which sections are the most hazardous once their selected route has been determined. The (CR/ACR) measure could be used to produce a **RISK-LEVEL Location Map** that could be made available for the public and the road authorities.

It is recommended that for 'public distribution', the collision rate (CR) measure be used to produce a ROUTE Selection Map and the (CR/ACR) measure be used to produce a HIGH-RISK Location Map. All other maps should be for internal use only.

2.2.3 Potential for Conflicting Information

There is a potential that the RISK Maps, as used in by other RAPs, could have conflicting results that might be confusing. Again, this concept is described by way of an example.

Consider the same 2 highway segments as the previous example. The first segment is a low-volume, rural 2-lane highway and the second segment is a high-volume urban, multi-lane freeway. The information associated with these segments and the collision density and collision rate measures are shown in ***Table 3*** below.

Table 3. Illustrative Example of potential for Conflicting Information

Segment Information	Rural, 2-Lane Highway	Urban, Multi-Lane Freeway
Traffic Volume (vpd)	2,500	50,000
Segment length (km)	25	10
Casualty Collisions / 5 years	30	120
Collision Density (CD) (Coll./km/yr)	0.24	2.40
Collision Rate (CR) (Coll./100MVKm)	26.3	13.2

Since the collision density (CD) measure does NOT consider traffic volume levels, the RISK Map produced from the collision density (CD) will tend to show that the high-volume, multi-lane freeways are 'worse' than low-volume two-lane highways (i.e., 2.40 versus 0.24 in ***Table 3***). In contrast, since the collision rate (CR) measure DOES consider traffic volume levels, the RISK Map produced from the collision rate (CR) will tend to show that the low-volume two lane highways are 'worse' than high-volume, multi-lane freeways (i.e., 26.3 versus 13.2 in ***Table 3***). This example shows that the RISK Maps for collision density (CD) and collision rate (CR) could likely produce contradictory results, which ultimately could cause significant confusion if both of these maps were provided to the road-user.

The other RAPs have proposed the use of the collision density (CD) map, which is a very simple map that can easily be reproduced for a CanRAP initiative. However, the overall value of the collision density as a meaningful safety performance indicator is questioned. The output produced from a collision density map will likely distinguish highways by traffic volume levels (as the collision frequency is positively correlated with the traffic volume), which is likely linked to the road classification scheme (i.e., high classification facilities will have higher traffic volume and as such, will have a higher collision density (CD)). The value of this map is likely very limited for road authorities. In addition and as described above, the results from the collision density (CD) measure could conflict with the results from the collision rate (CR) measure and the other safety performance indicators, which could cause confusion, especially if both maps were made available to

the public. As such, it is recommended that consideration be given to abandoning the collision density (CD) measure for CanRAP.

2.2.4 PROVINCIAL / NATIONAL BENCHMARKS?

The intent of CanRAP is to produce regional and national maps that show the relative levels of safety risk. Although each province will likely have the necessary inputs to create the CanRAP RISK Maps, the inputs from each province will be somewhat unique. For example, the threshold for reportable collision data can vary between provinces which could cause regional differences in average collision rates, differences in topography and weather conditions could also cause variations in safety performance, and even driver behaviour can vary among jurisdictions.

Due to the potential variability between provinces, it may be more prudent to evaluate each province against the benchmarks established for that province (e.g., BC segments would be compared against the average collision rates in BC and Alberta segments would be compared against Alberta average values). For smaller jurisdictions where there is less variability in driving environments and police reporting practices, a national safety benchmark may be used (if available). For other jurisdictions, where there are significant differences, local safety performance benchmarks could be used (if available). It is possible to do both, assuming national benchmarks could be established. Furthermore, the mapping of safety risk into 20% (quintiles) or other level of safety risk could be done within each province such that an equal quantity of 'higher risk' and 'lower risk' roads is shown within each province. However, the shortfall with this approach is that regional differences will not be clearly understood and there is a potential that a 'higher risk' condition in one province may be classified as a 'lower risk' condition in another province.

Alternatively, if national safety performance benchmarks can be established and used to compare provincial roadways, the regional differences may be determined. This information could be valuable for road users by allowing them the opportunity to gain the knowledge that road risk might be different between various Canadian jurisdictions. This information may also be useful for the Federal Government to aid in determining national road safety priorities. The potential concern with this approach is that the provincial highway authorities may have some concerns in this national comparison, due to the inherent differences that exist between jurisdictions.

This issue may need to be explored further beyond this feasibility study, if and/or when, CanRAP expands to include all provinces. Apart from the provincial and territorial buy-in for a national benchmarking approach, the technical feasibility will be based on whether or not equitable national safety performance benchmarks can be formulated that considers the differences (e.g. standards, topography) between provincial roadways.

2.2.5 Should Collision Rates Be Used To Develop Risk Maps?

For many years, the prevailing measure of safety was the collision rate. Two reasons were most likely behind this practice. First, the collision rate reflects exposure, which is believed to be the major road-related factor affecting collision occurrence. Second, collision frequency is not a stand-alone measure of safety. The random nature of collisions alerted safety researchers that a location's observed collision rate does not reflect its true safety level. As a result, they fitted probability distributions to collision rates observed on similar locations and took the means of these distributions as estimates of the locations' true collision rates. Later, they used Bayesian techniques to further refine these estimates. But still, there was a need for quantitative relationships that enable the prediction of the safety of road entities based on their various characteristics. Consequently, safety researchers resorted to statistical modeling in order to capture systematic relationships between collisions, traffic volumes, and road geometry. Initially, they employed ordinary or normal linear regression for this purpose. However, they gradually realized that normal linear regression is inappropriate for collision modeling. Several researchers demonstrated that traffic collision data does not meet the standard conditions that make this type of regression an appropriate modeling technique.

It has become recognized that the technique of generalized linear regression modeling (GLM) offers the most appropriate approach for developing collision prediction models. Recently, GLM has been used almost exclusively for this purpose. A great number of models developed by this technique reveal that the relationship between collision frequency and exposure is frequently nonlinear, which means that the collision rate is not an appropriate representative of safety. This finding has led a growing number of safety researchers to abandon the use of collision rate as a measure of road safety.

There is currently a wide recognition by researchers that collision prediction models are a more robust measure for estimating road safety as they overcome the shortcomings associated with collision rates. These models predict the collision frequency of a road location as a function of the location geometric and traffic characteristics. The upcoming Highway Safety Manual in the United States is an attempt to introduce the use of models, amongst other safety evaluation techniques, by transportation engineers and planners. Some Canadian provincial agencies have developed their own models, e.g. British Columbia and Ontario. Whether this tool will become widely implemented remains unknown at this time. **Therefore, for CanRAP it is recommended that some risk maps could be developed using collision prediction models if and when they become available.**

2.2.6 Renewal of the Maps

Similar to other RAPs, it is recommended that the CanRAP maps be updated on an annual basis for monitoring and evaluation purposes.

2.3 OPPORTUNITIES FOR IMPROVEMENT

This chapter presents some new ideas that might offer some additional value in the generation of the CanRAP RISK Maps.

2.3.1 THE USE OF COLLISION PREDICTION MODELS (CPMS)

For the RISK Maps based on collision rate ratio (CR/ACR) and the potential for casualty collision reduction (PCCR), it is recommended that collision prediction models (CPMs) be used instead of collision rates. Since CPMs predict collision frequency and not collision rates, the collision rate ratio (CR/ACR) measure would be re-named the collision frequency ratio (CFR). The following example is a demonstration of the concept:

Assume that a rural arterial un-divided two-lane highway section in British Columbia has a length (*L*) of kilometers and average annual daily traffic (AADT) of 9,000 vehicles per day. The observed injury and fatal collision frequency over the last five years is recorded as 60 collisions. To estimate the collision frequency ratio (CFR) and the potential for casualty collision reduction (PCCR), the following CPM, which has been developed for arterial undivided two-lane highways in British Columbia, should be used:

Injury + Fatal Collisions/5 years = $0.00542 \times (AADT)^{0.7279} \times (L)^{0.9403}$ (Dispersion Parameter $\kappa = 5.02$)

To calculate the CFR and PCCR, the following process is proposed:

Step 1:
The predicted fatal + injury collision frequency over a 5-year timeframe (F+I Coll. / 5 yrs) can be estimated as follows:

(F+I Coll. / 5 yrs) $= 0.00542 \times (9000)^{0.7279} \times (10)^{0.9403}$
$= 34.52$ F+I Collisions/5 yrs

Step 2:
The Empirical Bayes (EB) approach is used to refine the estimate of the expected number of collisions for the highway section by combining the observed number of collisions on the highway section with the predicted number of collisions, which is obtained from CPMs in order to yield a more accurate, location-specific safety estimate. The EB estimate of the expected number of collisions at any location can be calculated by using the following equation:

$EB_{\text{safety estimate}} = \alpha \times \text{prediction} + (1-\alpha) \times \text{observed}$

Where:

α	$= \kappa / (\kappa + \text{prediction})$
observed	= Observed number of collisions/5yrs
prediction	= Predicted collisions estimated from the CPM (collisions/5yrs)
κ	= Model dispersion parameter as given with each CPM

$\alpha = 5.02 / (5.02+34.52) = 0.13$

Therefore:

$EB_{\text{safety estimate}}$ = 0.13 (34.52) + (1-0.13)(60)
= 56.68 F+I Collisions / 5 yrs

Step 3:
Using the equations from ***Section 2.1.3***, the collision frequency ratio (CFR) measure and the potential for casualty collision reduction (PCCR) measure can be calculated as:

CFR = 56.68 / 34.52
= 1.64

PCCR = (56.68 – 34.52)
= 22.16 F+I collisions / 5 years

For agencies that do not have CPMs, they can still use other safety measures such as collision rates for the interim.

2.3.2 Producing Collision Cost Maps

For the potential for casualty collision reduction (PCCR) RISK Map, a useful addition for the road authority might be to convert the number of fatal and injury collisions that can be reduced (i.e., the difference between the calculated value and the average value) into a dollar value (collision cost value). It is noted that this map will only show locations that are 'worse' than the benchmark or average value so a great deal of the network will not be included.

Most road authorities assign monetary values to the different collision severity types. This information is used to evaluate the safety benefits from improvements to the highway sections. Although this is not part of the objectives of CanRAP and may not be valuable information for the road user, it may offer some value to the road authorities to identify segments where the potential safety benefits are significant and could be realized with road infrastructure investment. Furthermore, this RISK Map may be helpful in setting road safety priorities for each province.

The range of collision cost values used by the different agencies across Canada is expected to be considerable, however, it may be useful to explore this concept and use national values (or provincial values) for collisions costs, and use these in generating a RISK Map for collision costs. These maps could potentially favor segments with fatal collisions, but in context with other types of RISK Maps, collision cost-based maps could highlight certain aspects of the safety performance of roadways.

3. STAR RATING

This part of the report is divided into three sections. ***Section 3.1*** describes a recommended CanRAP methodology for STAR Rating based on the usRAP methodology. The usRAP methodology was used because the usRAP had the benefit to "learn" from AusRAP and EuroRAP and enhance the methodology. As well, road design practices are more similar between the US and Canada. ***Section 3.2*** provides a discussion on the potential issues on the development of STAR Rating. ***Section 3.3*** describes potential improvements to the CanRAP methodology to address some of the issues discussed in ***Section 3.2***.

3.1 STAR RATING METHODOLOGY FOR CANRAP

The STAR Rating methodology is adapted from the usRAP with some modifications due to data availability. The changes are documented in ***APPENDIX A***. Similar to other RAPS, this methodology is recommended for rural (inter-urban) high-speed roads.

Relative Road Protection Scores (RPS) are determined for three types of collisions on rural highways:

- Head-on collisions
- Run-off-road collisions
- Intersection collisions

The scoring for each of the collision types and a procedure for determining RPS scoring and STAR Ratings for CanRAP is described in the following sections. Note that it would be preferable to use the same road segment defined in the RISK Mapping for use in the STAR Rating. This is consistent with all RAPs.

3.1.1 RPS FOR HEAD-ON COLLISIONS

The relative road protection scores are shown in ***Table 4*** and the STAR Rating criteria are shown in ***Table 5***.

Table 4. RPS for Head-on Collisions

Median Treatment	85th Percentile or Posted Speed (km/h)					
	≥110	100	90	80	70	≤60
	Relative Road Protection Score					
Median width 21.3m or more	0.6	0.6	0.6	0.6	0.6	0.6
Median width 15.2 to 21.2m	0.8	0.8	0.8	0.8	0.8	0.8
Median Barrier	0.8	0.8	0.8	0.8	0.8	0.8
Median width 9.1m to 15.1m	1	1	1	1	1	1
Median width 3.7m to 9.0m	4	4	3	2	1	1
Median width 0.9m to 3.7m	16	11	7	4	2	1
Undivided with centreline rumble strips	27	17	8	5	2	1
Undivided with marked centreline only	38	24	12	7	2	1

Table 5. Star Rating Criteria for Head-on Collisions

Number of STARS	Head-on RPS
4	0-2
3	2.01-5
2	5.01-10
1	Over10

The STAR Rating Criteria needs to be revised in future phases, and expanded to a 5-star rating to be consistent with Risk Mapping and future developments of the STAR Rating methodology.

3.1.2 RPS FOR RUN-OFF-ROAD COLLISIONS

The usRAP uses design parameters including clear zone width, side slope, presence of barrier, and speed to determine the RPS for Run-off-road collisions. "Adjustment" factors (which are essentially collision modification factors, or CMFs) for lane and shoulder width are included in usRAP to better account for the probability of run-off-road collisions. usRAP had raised concerns as to the accuracy of the side slope measurements and clear zone distance from photo-logs. The three Canadian provinces currently do not have accurate clear zone or side slope data. We propose that the roadside be measured as "Standard", "Barrier Present", "Below Average" for the interim until such time that the critical roadside measurements can be obtained accurately in a cost-efficient manner. These three measures for the roadside may be deduced from the data, photo-logs, or from a drive through assessment. The relative road protection scores for fill slopes and cut slopes are shown in ***Table 6***.

Table 6. RPS for Run-off-road Collisions

Clear Zone & Sideslope condition	85th Percentile or Posted Speed (km/h)					
	≥110	100	90	80	70	≤60
	Relative Road Protection Score					
Standard - Fill Slope	8	7	7	6	5	3
Standard – Cut Slope	3	2	4	3	2	2
Roadside Barrier Present	14	11	8	6	5	3
Below Average – Fill Slope	21	17	15	12	10	6
Below Average – Cut Slope	11	9	7	6	5	2

The RPS needs to be adjusted with lane width and shoulder width adjustment factors. These factors are essentially collision modification factors (CMFs) and are shown in ***Tables 7*** and ***8,*** and the STAR Rating criteria are shown in ***Table 9***.

Table 7. Lane Width Adjustment Factors

Lane Width	Adjustment Factor
3.65m or more	1.00
3.35m	1.15
3.05m	1.30
2.75m or less	1.50

Table 8. Shoulder Width Adjustment Factors

Shoulder Width	Adjustment Factor for Shoulder Types			
	Paved	Gravel	Composite	Turf
2.44m or more	0.58	0.59	0.61	0.64
1.83m	0.67	0.68	0.69	0.72
1.22m	0.77	0.77	0.79	0.81
0.61m	0.87	0.88	0.88	0.89
No shoulder	1.00	1.00	1.00	1.00

Table 9. Star Rating Criteria for Run-off-road Collisions

Number of STARS	Run-off-road RPS
4	0-5
3	5.01-10
2	10.01-15
1	Over15

3.1.3 RPS FOR INTERSECTION COLLISIONS

The relative road protection scores for intersection collisions are shown in ***Table 10***, and the STAR Rating criteria are shown in ***Table 11***.

Minor driveways are driveways that provide access to single-family or double-family residences, or entrances to un-inhabited fields / farm land. Major driveways are all other types of driveways, including multi-family residences, and commercial, industrial, and institutional sites. Signalized driveways are treated as signalized intersections.

The RPS for intersections with turn lanes should be applied to any intersection with either left-turn or right-turn lanes on the road being evaluated.

A long acceleration lane is defined as having a length of 244 meters or more, and short acceleration is defined as having a length of less than 244 meters. For deceleration lanes, 'long' is defined as having a length of 275 meter or more, while 'short' is defined as having less than 275 meters of length.

Table 10. RPS for Intersection Collisions

Junction Type	85th Percentile or Posted Speed (km/h)					
	≥110	100	90	80	70	≤60
	Relative Road Protection Score					
Minor driveway (unsignalized)	0.50	0.25	0.25	0.25	0.25	0.25
Major driveway (unsignalized)	2.00	1.63	1.25	1.00	0.75	0.50
Merging manoeuvre only; long accel. lane	0.50	0.50	0.50	0.50	0.50	0.50
Merging manoeuvre only; short accel. lane	1.25	1.25	1.00	0.75	0.50	0.50
Diverging manoeuvre only, long decel. lane	1.08	1.08	1.08	1.08	1.08	1.08
Diverging manoeuvre only, short decel. lane	2.69	2.69	2.69	2.69	2.69	2.69
Roundabout	1.25	1.25	1.00	0.75	0.50	0.50
3-leg unsignalized int. w/ turn lanes	2.00	1.63	1.25	1.00	0.75	0.38
3-leg unsignalized w/o turn lanes	4.25	3.38	2.50	2.00	1.50	0.88
3-leg signalized int. w/ turn lanes	8.25	6.00	4.00	3.00	2.25	1.50
3-leg signalized w/o turn lanes	10.75	7.75	5.00	3.75	2.75	2.00
4-leg unsignalized int. w/ turn lanes	6.75	4.63	3.25	2.00	1.50	1.13
4-leg unsignalized w/o turn lanes	10.25	7.00	5.00	3.25	2.50	1.75
4-leg signalized int. w/ turn lanes	17.75	12.88	8.25	6.25	4.50	3.13
4-leg signalized w/o turn lanes	21.50	15.50	10.00	7.50	5.50	3.75

The RPS is calculated by summing the scores for all driveways, merging and diverging lanes, roundabouts, and intersections within a roadway section and then dividing this value by the length of the section length in kilometres.

Table 11. Star Rating Criteria for Intersection Collisions

Number of STARS	Intersection RPS
4	0-8.1
3	8.2-16.1
2	16.2-24.1
1	Over 24.1

3.1.4 Procedure for Determining STAR Ratings

Head-on Collisions

1. Determine the median treatment and speed for a roadway segment according to ***Table 4***.

2. Determine the RPS for the segment using ***Table 5***. Use a weighted average RPS if the median treatment or speed varies among sub-segments.

3. Using the weighted RPS for the whole segment, determine the STAR Rating for Head-on collisions.

Run-off-road Collisions

4. Determine the roadside condition and speed for a roadway segment according to ***TABLE 6***.

5. Determine the RPS for the segment using ***Table 6***. Use a weighted average RPS if the roadside condition or speed varies among sub-segments.

6. Apply lane and shoulder width adjustment factors (***Tables 7 and 8***) to the RPS.

7. Using the adjusted RPS for the whole segment, determine the STAR Rating for Run-off-road collisions from ***Table 9***.

Intersection Collisions

8. Determine the Junction Type and speed for a roadway segment according to ***Table 10***.

9. Determine the RPS for each junction using ***Table 10***.

10. Sum the RPS for all junctions and divide by the segment length in kilometres.

11. Using the weighted RPS (per kilometre), determine the STAR Rating for Intersection collisions from ***Table 11***.

Overall STAR Rating

12. Determine the overall STAR Rating as a weighted average of the Star Ratings for Head-on, Run-off-road and Intersection Collisions using the weights as shown below.

RPS Category	Weight (Percent)
Head-on Collisions	XX%
Run-off-road Collisions	YY%
Intersection Collisions	ZZ%

The values for the weighting will need to be defined. They can come from national data for consistent national comparison; or the weight could be the provincial / territorial average as is done for the usRAP pilot projects.

13. The overall STAR Rating is determined by rounding the weighted average STAR Rating to the nearest integer.

Similar to other RAPs, the STAR Rating maps could be updated on an annual basis for monitoring and evaluation purposes.

3.2 STAR RATING METHODOLOGY ISSUES

This section provides a discussion of several important issues in the development of STAR Rating. These issues are discussed below and include:

- Data
- Correlation with RISK Mapping
- Subjectivity of the RPS
- Canadian Road Conditions

3.2.1 DATA ISSUES

The STAR Rating system used by the various RAPs makes use of a drive-through assessment of the network in combination with photo-log systems. With the advent of data collection efforts in highway asset management, many of the data elements collected by the RAPs are available through the asset management databases of the pilot provinces (e.g. British Columbia and Alberta). This can translate into significant

savings in terms of reducing the STAR Rating work, and the results are likely to be more accurate than using a somewhat "subjective" rating via a drive through.

For jurisdictions that do not have the necessary data elements or a photo-log system, the data collection for STAR Rating would be more challenging. This data can still be collected through various means. Taking Saskatchewan for example, the majority of the data exists to conduct a STAR Rating system. However, it would require the extraction of relevant data from as-built drawings that reside in various regional offices. This could be labour intensive, but the data can nevertheless be assembled. It is expected that various provinces and territories will have varying degrees of data available to develop a STAR Rating system. The "gap analysis" survey will provide some preliminary indication as to the level of effort required for assembling the data.

Another potential issue with the data is the accuracy and availability of roadside data, (i.e. side slopes and the width of the clear zone). These two elements are important in determining the consequence of a run-off-road collision, as is evident in the AASHTO Roadside Design Guide (1996). However, due to the presence of vegetation along the side slope, it remains a challenge to accurately determine the side slope and the width of the clear zone. Until this challenge is resolved, the study team proposes the following alternatives for CanRAP for the assessment of the roadside:

Preferred Method (as documented in Section 3.1):

The roadside condition is divided into three categories:

1. Meets Standard
2. Barrier Present
3. Sub-standard

The British Columbia Ministry of Transportation appears to have the roadside data categorized in this manner for some corridors. An example is the strip map data used in the pilot testing in ***Section 4***. However, the roadside data, e.g. clear zone width, side slopes and protection, for most of the western provinces would likely require an assessment using photo-logs or a drive-through. This method is the preferred method because it recognizes the limitations of an assessment based on observations, and represents a practical and reasonable way to assess roadside conditions. Rather than dividing the roadside into many categories with subtle differences, which would be challenging for even trained observers to assess, the stratification of this method would be relatively simpler for deployment.

Alternative Methods (to use in conjunction with Photo-Log or Drive Through Assessment)

If a photo-log or drive through assessment is to be conducted, the roadside conditions can be assessed using a procedure developed by Zegeer et al[1], which is used in the Interactive Highway Safety Design Model (IHSDM) to predict safety performance on 2-lane, rural highways. This alternative method of assessment is described below:

Roadside hazard is ranked on a seven-point categorical scale from 1 (best) to 7 (worst). The seven categories of roadside hazard rating are defined in ***Table 12*** as follows:

Table 12. Alternative Method for Assessing the Roadside

Hazard Rating	Comments	Illustration
1	• Wide clear zones greater than or equal to 9 m from the pavement edge line. • Side slope flatter than 1:4. • Recoverable.	
2	• Clear zone between 6 and 7.5 m from pavement edge line. • Side slope about 1:4. • Recoverable.	
3	• Clear zone about 3 m from pavement edge line. • Side slope about 1:3 or 1:4. • Rough roadside surface. • Marginally recoverable.	
4	• Clear zone between 1.5 and 3 m from pavement edge line. • Side slope about 1:3 or 1:4. • May have guardrail (1.5 to 2 m from pavement edge line). • May have exposed trees, poles, or other objects (about 3 m from pavement edge line).	

[1] Zegeer, C. V., D. W. Reinfurt, J. Hummer, L. Herf, and W. Hunter, "Safety Effects of Cross-Section Design for Two-Lane Roads," *Transportation Research Record 1195*, Transportation Research Board, 1988.

5	• Clear zone between 1.5 and 3 m from pavement edge line. • Side slope about 1:3. • May have guardrail (0 to 1.5 m from pavement edge line). • May have rigid obstacles or embankment within 2 to 3 m of pavement edge line.	
6	• Clear zone less than or equal to 1.5 m. • Side slope about 1:2. • No guardrail. • Exposed rigid obstacles within 0 to 2 m of the pavement edge line. • Non-recoverable.	
7	• Clear zone less than or equal to 1.5 m. • Side slope 1:2 or steeper. • Cliff or vertical rock cut. • No guardrail. • Non-recoverable with high likelihood of severe injuries from roadside collision.	

Source: Harwood, D.W. et al, "Prediction of the Expected Safety Performance of Rural Two-Lane Highways", FHWA-RD-99-207, December 2000.

Similar to the IHSDM roadside hazard rating, a more refined and efficient methodology adapted from the IHSDM was used in a major corridor project in B.C. This methodology, as shown in ***Figure 1*** below, provides a roadside hazard score using a matrix of side slope and width of clear zone. This can also be used as an alternative method.

Note that trained observers will still be required to estimate the width of the clear zone and the steepness of the side slopes for both alternative methods. For this alternative method, the RHR scores would need to be translated into equivalent RPS scores.

Figure 1. Roadside Hazard Rating used in B.C.

RHR SCORES WITHOUT THE USE OF ROADSIDE BARRIER							
	Clear Zone (meters)						
Side-Slope	> 12.0	12.0 - 10.0	10.0 - 8.0	8.0 - 6.0	6.0 - 4.0	4.0 - 2.0	<2.0
>4.0:1	1	1	2	3	4	5	6
4.0:1	1	1	2	3	4	5	6
3.5:1	2	2	2	3	4	5	6
3.0:1	3	3	3	4	5	6	7
2.5:1	4	4	4	5	6	7	7
2.0:1	5	5	5	6	7	7	7
<2.0:1	6	6	6	7	7	7	7

RHR SCORES WITH THE USE OF ROADSIDE BARRIER (Where applicable (Note)1 and placed at least 1.5 m from lane edge)							
	Clear Zone (meters)						
Side-Slope	> 12.0	12.0 - 10.0	10.0 - 8.0	8.0 - 6.0	6.0 - 4.0	4.0 - 2.0	<2.0
>4.0:1	1	1	2	3	4	4	4
4.0:1	1	1	2	3	4	4	4
3.5:1	2	2	2	3	4	4	4
3.0:1	3	3	3	4	4	4	4
2.5:1	4	4	4	4	4	4	4
2.0:1	4	4	4	4	4	4	4
<2.0:1	4	4	4	4	4	4	4

Note 1: Roadside Barrier not normally placed under conditions where the RHR Score is less than 4, however, if roadside barrier is placed under the clear zone and side-slope conditions, then a RHR Score of 4 must be used.

3.2.2 Correlation with RISK Mapping

One shortcoming of the STAR rating system used by the various RAPs is that it mainly concerns itself with mostly one aspects of risk, namely, the consequence of a collision. As discussed in the Canadian Road Safety Audit Guide[2], risk is a function of exposure, probability and consequence. What are currently missing from the STAR Rating system are the exposure and probability components of road safety risk. As a result, the causation effect of collisions (i.e. probability and exposure) in the STAR Rating system has been largely ignored. There are indications that the various RAPs are trying to improve the correlation between the RISK Mapping and the STAR Rating by incorporating causation elements in the future development of the STAR Rating protocol. It is however unclear at this time whether the two measures need to be correlated. Some experts argue that the two can be made to correlate rather well using different measures other than collision rate, and there are experts that believe that the two need not be correlated.

Nonetheless, another reason for the lack of correlation between the STAR Rating and the RISK Mapping is that the STAR Rating only covers three crash types: namely head-on, run-off-road, and intersection collisions, where as the RISK Mapping accounts for all collision

[2] de Leur, P., Ho, G., and Zein, S., *Canadian Road Safety Audit Guide*, Transportation Association of Canada, 2001.

types. Firstly, if a jurisdiction has a larger proportion of collisions other than the three types included in STAR Rating, one would expect the correlation to be extremely weak.

One could argue that the causation and nature of head-on and run-off-road collisions are somewhat similar and only the consequences differ. In both cases, it starts with a single errant vehicle losing control. If the errant vehicle goes to the left, it could side swipe a vehicle traveling on the adjacent lane if it is a multi-lane highway (i.e. more than two lanes); it could also end up in the median depending largely on the speed of the vehicle and the median width; it could cross the median and end up in the roadside of the opposing travel direction if it does not collide with a vehicle traveling in the opposite direction; and it could cross the median and collide with an on-coming vehicle. Only the last instance will be documented by the police as a head-on collision. If the errant vehicle goes to the right and end up on the roadside, it would be coded as a run-off-road collision. However, for both cases, if the errant vehicle collides with a roadside hazard, it could be coded as a fixed object collision. As this discussion has illustrated, an errant vehicle losing control could be coded as a head-on, run-off-road, sideswipe or fixed object collision depending on what it collides with. However, the important element of what caused the vehicle to go errant in the first place is somewhat missing from the design elements. For example, the roadway alignment (horizontal and vertical), and design consistency are factors that can lead to a vehicle becoming errant and leaving the roadway. Perhaps the correlation could be improved by producing a RISK Map for run-off road, head-on, fixed object, and sideswipes (not at intersections) and compare with a STAR Rating for only the head-on and run-off-road protocols. Alternatively, other factors could be included into the STAR Rating approach.

Another major type of collision in the STAR Rating is intersection collision. It is well documented in the literature that traffic volume (or exposure) is the main influence on the safety performance / collision occurrence at intersections (and on road segments). The design elements would certainly influence the safety performance, but to a much lesser degree than exposure.

In the STAR Rating methodology, it was attempted to use mainly design elements to try to correlate to historical safety performance. This may further explain the lack of correlation between the two RAP protocols. The current STAR Rating procedure also incorporates intersection STAR Ratings as part of the segment's STAR Rating by taking an average over the length of the segment. This process has the potential effect of lowering the effect of an intersection with poor safety performance depending on the length of the segment and the proportion of the various collision types used in the weighting. It would be more reasonable to compare the RISK Mapping of intersection crashes only with the STAR Rating for intersections.

The STAR Rating procedure is feasible in Canada, however, it remains a "work in progress" until more robust and sophisticated methods and procedures are developed. As a result, not all road authorities who participate in RAP put heavy emphasis on the STAR Rating, but in fact, their focus and emphasis are on the RISK Maps.

RISK Mapping provides a measure of the historical safety performance of a roadway segment based on collision data. Once the higher risk segments are identified, then treatment can be implemented to improve the safety performance of the segments. This represents a reactive component of a comprehensive road safety management system. The STAR Rating was likely conceived as a proactive component of road safety management system by attempting to measure the level of protection provided to errant vehicles that may result in head-on, and run-off-road collisions. The proactive component is obviously an important element of a road safety management system, and the STAR Rating methodology will likely evolve over time.

If CanRAP wants to proceed with the STAR Rating Protocol, it is recommended that more research and development be conducted to finalize the methodology. An interim methodology is provided in the later section for completeness, and the interim methodology should be assessed in a pilot project before any conclusions could be drawn.

3.2.3 Subjectivity of the Road Protection Score (RPS)

The RPS is developed by the various RAPs, and the value of the score is provided in a relative scale, but how it was derived was not documented in any of the RAP documents. It was reported that the RPS drew extensively on the research conducted for the development of Road Safety Risk Manager, a commercial software developed to compare the collision risk at a site before and after the implementation of a treatment. It is unclear whether the research used in the development of RPS was based on Australian data, or whether it captures the relative risk from a worldwide basis, i.e. is the relative risk applicable to places outside of Australia. Although the numbers assigned to the various design elements appears to be reasonable, the final RPS value only represents a relative risk score. The definitions of these values (in ranges) are provided by the number of stars. The assignment of the number of stars (in both RISK Mapping and STAR Rating) appears to be different amongst the various RAPs.

The usRAP introduced the use of collision modification factors (CMFs) in its STAR Rating methodology to improve the collision causation elements. In the usRAP, the CMFs used were called "adjustment factors". However, CMFs are more than adjustment factors. In road safety engineering analysis, the safety effect of a particular treatment is often determined using collision modification factors. Highway agencies typically developed their own CMF values for different safety countermeasures on a system-wide basis, based on past and current evaluation research and safety projects. These values are commonly expressed as a percentage reduction in the total number of collisions, or in some cases, CMFs are available for different collision types and collision severities. The TAC Geometric Design Guide has already documented a number of CMFs for basic design elements.

It is worthwhile for CanRAP to consider using CMFs to determine the STAR Rating of a road segment or an intersection. The use of CMFs is demonstrated in the Pilot, as presented in ***Section 4***. Furthermore, CMFs are generally well understood by road safety engineers, and reliable CMFs are based on robust before-and-after evaluation. Lastly, the CMFs are available directly from the literature without any modification or manipulation and can be updated rather easily.

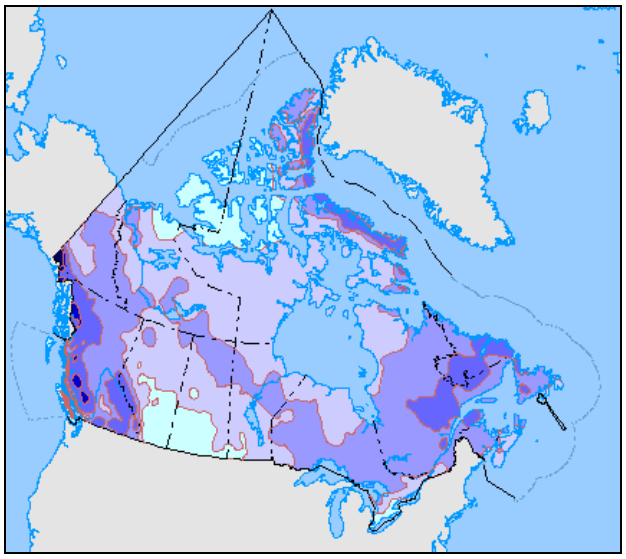
3.2.4 Canadian Road Conditions

The three Western Provinces identified weather and wildlife collisions as unique to Canadian conditions[3].

Weather

Due to the wide ranging weather conditions in Canada, including seasonal changes, it may not be very useful to provide the drivers with a STAR Rating map that is based entirely on summer conditions when the road surface and the roadside are significantly different than winter conditions. The various RAPs have not identified this as an issue, perhaps due to the more mild weather conditions in those countries. However, for a driver to be presented with a STAR Rating map in the winter time that is based on summer road conditions may be misleading. It is recommended that this issue be addressed in the future phases of CanRAP. One possible solution to address this condition is to include a weather "adjustment" factor to the STAR Rating calculations. This adjustment factor could be derived from snow fall accumulation maps as shown in ***Figure 2*** below.

Figure 2. Average Maximum Snow Depth Map



Less than 30 cm 30 to 49 cm 50 to 99 cm 100 to 199 cm
200 to 299 cm 300 cm and greater

Source: Natural Resources Canada website

Another possible suggestion is to review the summer and winter performance compared to the average, and /or produce summer or winter maps.

[3] Note that lighting conditions (i.e. light versus dark) were not identified in the discussions, nor do other RAPs consider such conditions.

WildLife

Another issue that is of concern to rural road authorities in Canada are wildlife collisions. This is a significant problem in rural communities in Canada, and due to the size of some of the types of animals involved in high speed crashes, the consequences can be very serious. Other RAPs did not identify this as an issue, but the three western provinces interviewed all agreed that wildlife collisions are an important issue in their jurisdiction.

Similar to the weather related risk assessment, the risk involving wildlife collisions could be included in future development of the CanRAP STAR Rating protocol. For example, the BC Ministry of Transportation has data to rank the highway network according to the exposure to wildlife. However, this data may or may not be available in each province or territory.

3.3 OPPORTUNITIES FOR IMPROVEMENT

As discussed in ***Section 3.2.3***, collision modification factors can be used to identify and rank specific locations that offer the greatest potential for improvement to safety. This would allow road authorities to focus on higher risk segments that are currently experiencing safety problems and thus, help to develop mitigation plans to improve safety performance.

Two methods can be used for the identification and the ranking of locations that have the highest potential for improvement (PFI) using Collision Modification Factors. The PFI is measured in terms of a potential for improvement in the safety level of a location compared to a "nominal" value, e.g. a CMF of 1.0.

Both methods are discussed below. The first method is directed at specific highway sections. In contrast, the second method calculates an overall safety performance measure for a longer segment consisting of several sections. The segment is likely to be defined for an entire highway or a highway section linking two major destinations. This PFI is an average potential for improvement of all sections on a given highway. The measure used to represent the potential for improvement is the overall collision modification factor, which combines the safety effect of the various cross-sectional and longitudinal design elements.

3.3.1 IDENTIFY AND RANK SPECIFIC SECTIONS WITH HIGH PFI

For any highway sections, an overall collision modification factor is calculated as shown in the following equation:

$$C_{Overall} = \left(CMF_1 \times CMF_2 \times CMF_3 \ldots CMF_X\right)$$

Then individual sections can be assigned to five categories and displayed on maps using a color-coding system for the five categories. One approach would be to define the relative PFI categories so that each category, in increasing order of risk, contains a progressively smaller portion of the roadway system (similar to the usRAP). Thus, roads estimated to have the lowest PFI may represent 40% of the total road network whereas the highest PFI category may include only 5% of the total roadway network.

3.3.2 IDENTIFY AND RANK LONGER HIGHWAY SEGMENTS WITH HIGH PFI

The second approach to identify and rank longer highway segments (e.g. a corridor) that have a high potential for improvement is based on the equation shown below. The equation includes the collision modification factor and the section length in determining the overall PFI rank.

$$PFI_{Overall} = \frac{\sum_{i=1}^{n} L_i \, CMF_i}{\sum_{i=1}^{n} L_i}$$

where: L_i = The length of section i, and

CMF_i = The overall CMF associated with section i.

4. CANRAP METHODOLOGY: PILOT TESTING

4.1 OVERVIEW AND INPUTS FOR THE CANRAP METHODOLOGY PILOT TESTING

In order to examine the various safety performance measures and methodologies that are associated with both the RISK Mapping and the STAR Rating for CanRAP, a pilot test has been formulated and is presented in this chapter.

The pilot test involved obtaining actual data that would allow for the calculation of the CanRAP safety indicators. The pilot test is based on a section of Highway 1, the Trans Canada Highway (TCH), located in eastern British Columbia between the east boundary of Revelstoke National Park and the west boundary of Yoho National Park. In total, data was obtained for approximately 144 kilometers of highway, which was extracted from a set of strip maps produced for a BC MOT Planning Project[4]. The strip maps allowed for the extraction of all data at 100-meter intervals, which is consistent with the accuracy of the collision location coding in BC.

Data was not available from the TCH corridor for a segment that covers Glacier National Park. However, data for this section of the corridor was 'manufactured' for the pilot in order to aid in the illustration of the proposed process and safety indicators. An example of the strip map is provided in Appendix B.

4.1.1 SEGMENTATION

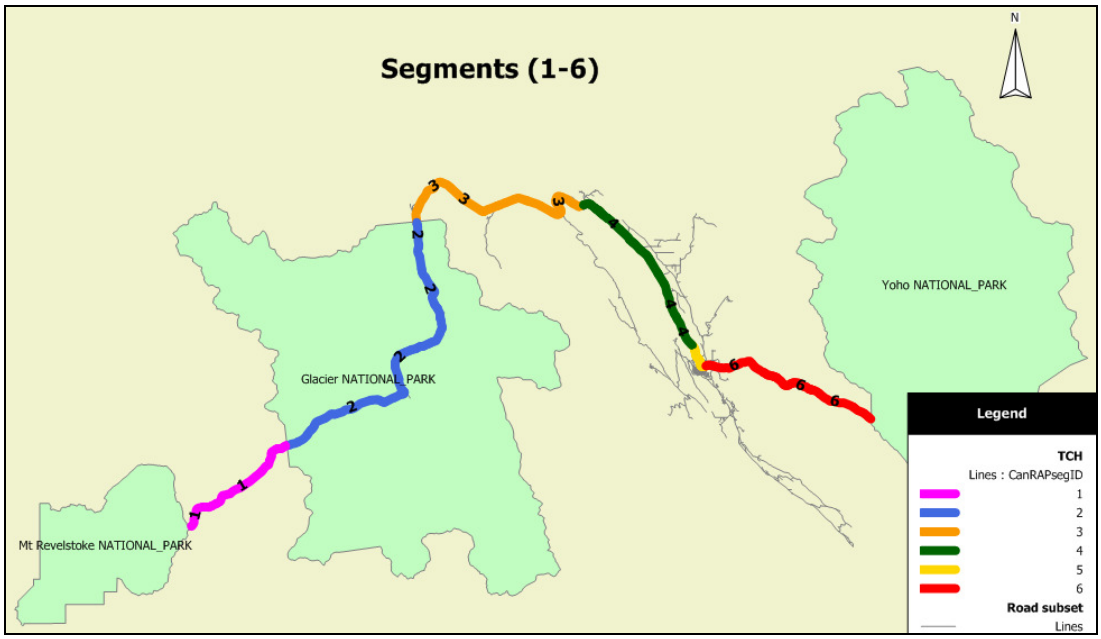
The segmentation process that was described in Section 2.1.2 was completed for the 144 kilometer corridor. The segmentation was based on meaningful and identifiable start and end points, which would be easily understood by the road users. Once these segments were established, the other criteria were checked to ensure that each segment was appropriate. For example, the minimum casualty collision frequency threshold value was checked and it was determined that this criteria was satisfied for all segments. In total, six segments were identified, with the longest segment being 43.8 kilometers in length and the shortest being 4.6 kilometers in length. The segments used are listed in ***Table 13*** and shown in ***Figure 3*** below.

Table 13. Summary of Segments used for Pilot Testing

Segment	Start of Segment Identifier	End of Segment Identifier
1	East Boundary Mt. Revelstoke National Park	West Boundary Glacier National Park
2	West Boundary Glacier National Park	East Boundary Glacier National Park
3	East Boundary Glacier National Park	West Approach: Community of Donald
4	West Approach: Community of Donald	West Approach: Community of Golden
5	West Approach: Community of Golden	East Approach: Community of Golden
6	East Approach: Community of Golden	Yoho National Park (Kicking Horse Canyon)

[4] Trans Canada Highway: Cache Creek to the Rockies – Existing Conditions Report.

Figure 3. Segments used for Pilot Testing



4.1.2 Input Data to Determine CanRAP Safety measure

The data for the RISK Mapping was easily obtained, as it included only the collision frequency (by collision severity level) and the average annual daily traffic (AADT) volume on each of the segments. Also obtained, was the road classification for each segment. To calculate some of the safety measures (e.g., CR/ACR and PCCR) the average collision rate by road classification was also obtained, as well as the provincial average collision rate for all highways. The data for the RISK Mapping (by segment) is provided in ***Table 14*** below.

Table 14. Summary of Data for RISK Mapping

	Collisions				Road Data	
Segment	Fatal (per/yr)	Injury (per/yr)	(F + I) (per/yr)	Road Class	Length (km)	Volume (ADT)
1	1.0	10.8	11.8	RAU2	18.4	4551
2	1.8	20.8	22.6	RFD4	43.8	4599
3	0.8	13.0	13.8	RAU2	30.0	4648
4	0.4	9.4	9.8	RAU2	23.6	6065
5	0.0	3.6	3.6	UAU2	4.6	5015
6	1.4	18.8	20.2	RAU2	23.5	4430

The road character data, which used to support the STAR Rating system, was obtained from the strip maps. This data was extracted at 100-meter intervals along the entire length of the 144 kilometer corridor. This data included the following:

- Road classification (also used for the RISK Maps),
- Intersection/access or ramp type (signalized, stop-controlled, acceleration, etc.)
- Number of movements allowed at intersection/access or ramp,
- Cross-sectional data, including:
  - Cut or fill section,
  - Clear-zone (substandard, achieved or CRB),
  - Shoulder width (metres), and,
  - Lane width (metres).
- Number of lanes,
- Median width (metres) or presence of median barrier,
- Horizontal curve (either tangent or curve (curve given in radius of curve)),
- Grade (%),
- Posted speed (km/hr), and,
- Wildlife (high, moderate, low or fence).

The process to extract the data for the STAR Rating was somewhat involved and did take considerable time because it was extracted manually (i.e., from hard copies). However, the quality of the data is considered beneficial in support of a robust STAR Rating system. It is estimated that approximately 100 kilometres of data could be extracted per day (manually), which could be improved with automated processes.

4.2 Testing CanRAP Methodology / Safety Measure

4.2.1 CanRAP RISK Maps

The safety measure used in the existing RAPs that could be replicated in CanRAP is provided in ***Table 15*** below. The results for the four maps are shown, including those based on collision density (CD), collision rate (CR), collision rate ratio (CR/ACR) and the potential for casualty collision reduction (PCCR). These values are simply calculated from the collision and traffic volume data (as shown in ***Table 14***). In developing RISK Map 4, the negative values would not likely be shown as these are locations that perform better than average and thus, no casualty collision reductions are expected.

Table 15. Existing RISK Map Safety Measures

Segment	RISK Map 1 CD ((F+I)/km/yr	RISK Map 2 CR ((F+I)/MVKm	ACR ((F+I)/MVKm	RISK Map 3 CR/ACR Ratio	RISK Map 4 PCCR (F+I Coll/yr)
1	0.64	0.39	0.34	1.14	1.41
2	0.52	0.31	0.23	1.34	5.69
3	0.46	0.27	0.34	0.80	-3.50
4	0.42	0.19	0.34	0.55	-7.96
5	0.78	0.43	0.52	0.82	-0.78
6	0.86	0.53	0.34	1.56	7.28

Table 16 below presents the other calculation of the safety measures that were proposed as potential enhancements for the existing RAPs. The opportunities for Improved RISK Maps included the use of CPMs to calculate 1) the ratio of the observed to predicted with an empirical Bayes refinement (referred to as the CFR in ***Table 16***). The same approach was also used for the PCCR, which shows the number of casualty collision that could be prevented on each segment. Finally, a 'potential for improvement' safety measure is presented, which is based on the average collision costs in British Columbia. A road-class specific average collision cost value was used in the analysis, but this could easily be adjusted to an overall average cost (severe collision).

Table 16. Opportunities for RISK Map Enhancements

	New Safety Measures / Opportunities for Improved RAP Risk Maps					
Segment	**Predicted (F+I)/yr**	**CPM K Value**	**EB Estimate (F+I) Coll/yr**	**CFR (EB/Pred)**	**PCCR (EB-Pred)**	**PFI Collision Cost**
1	9.6	3.43	11.2	1.16	1.59	$248,600
2	10.2	3.97	19.1	1.87	8.92	$1,078,900
3	14.6	3.43	13.9	0.96	-0.63	($99,000)
4	15.2	3.43	10.8	0.71	-4.43	($694,000)
5	3.2	1.15	3.5	1.10	0.32	$29,000
6	11.5	3.43	18.2	1.59	6.72	$1,051,600

4.2.2 CanRAP STAR Rating

The STAR Rating used in the existing RAPs that could be replicated in CanRAP is provided in ***Table 17*** below. These values are simply calculated from the procedure described in ***Section 3.1***. A 'potential for improvement' (PFI) safety measure using CMFs that was proposed as potential enhancements for the existing STAR Rating is also presented in ***Table 17***. The STAR Rating was calculated using the proportion of head-on, run-off-road, and intersections collisions on provincial highways. The proportions used were 7 percent, 42 percent and 51 percent, respectively.

Table 17. Existing STAR Rating and Proposed Enhancement Using CMFs

Segment	STAR Rating	PFI Value (CMF-1)
1	**3**	**-0.12**
2	**4**	**-0.58**
3	**3**	**0.02**
4	**3**	**0.25**
5	**4**	**0.31**
6	**3**	**0.12**

Note: a negative value indicates no potential for improvements

When comparing the results from this very limited sample, it is interesting to note that segment 2 achieved a very good STAR Rating and a very low CMF value (indicating relatively better performance than "nominal" value). However, for segment 5 which has the same STAR Rating, the CMF values indicated a segment with good potential for improvements.

When compared with the results from the RISK Mapping, there are conflicting information that relates back to the issue of correlation between Risk Maps and Star Rating. For example, segment 2 which exhibited a high PCCR, the STAR Rating indicated that it is a relatively low risk road.

This further demonstrates that the STAR Rating methodology will need further research and development before it can be used effectively as a reliable tool to assess road safety performance.

4.3 PILOT TESTING CANRAP METHODOLOGY: RISK AND STAR MAPS

This section discusses a methodology used to develop example Risk and Star Maps using data from a section of the Trans-Canada Highway (TCH) between Mt. Revelstoke and Yoho National Parks in B.C. This methodology is a demonstration of the feasibility and issues in creating such maps, and not necessarily the recommended method.

4.3.1 BASE DATA

Spatial data was needed to accurately represent the network topology of the road network, which in this case is the TCH. The spatial data set used to represent the roads by the Province of B.C. is the Road Atlas of BC (know as the "digital road atlas" or DRA) maintained and provided by GIS Innovations Ltd.

4.3.2 SOFTWARE

The primary GIS software used in this demonstration is the Manifold GIS System (developed by CDA International Ltd.). Manifold is a full-fledged GIS package that can handle various data formats and provides a number of advanced analytics to allow for the manipulation of various datasets and mixed projections.

4.3.3 METHODOLOGY

The development of RISK and STAR maps within a GIS environment would require knowledge of basic GIS skills. Without going into such details, the general steps in creating these maps for this demonstration were as follows:

1. Load the base road network
2. Setup projection (UTM Zone 11) and datum (NAD83)
3. Query and extract relevant road links (study area TCH)
4. Create fields to hold the following values:
    - SegmentID
    - Map 1 values
    - Map 2 values
    - Map 3 values, Etc.
5. Select links and associate to segment by assigning the corresponding SegmentID (refer to Table 13 and Figure 3)

6. For each link, assign RISK Map and STAR Rating values as per Tables 15-17 to the corresponding database field
7. Create thematic maps by specifying the values categories and colour schemes (as per Table 1)

Step 7 is critical in that the parameters specified for the thematic mapping colour schemes can influence the resulting look of the map. These parameters can vary with different GIS packages and so the translation of these categories and colour schemes into the GIS environment should be done with caution to ensure consistency. As discussed in Chapter 2, this would be an issue with any maps produces using computed values such as PCCR or PFI. However, it would not be such an issue for STAR maps as they use a standard normalized values system with ranges from 1-4/5.

Thematic Mapping by Relative Segment Width

In addition to using standard colour coding schemes in these maps, this pilot testing demonstrates thematic mapping of the road segments with varying segment width corresponding to their values (safety indicator). This provides an additional visual dimension in which the information is portrayed by size as well as colour. And as the widths are relative in size to the values, they can provide better relative comparisons of the risk values associated with the segments and not confined to specific categories.

Thematic Mapping in 3D

For more aesthetically-pleasing renderings, Google Earth Plus was utilized to display the resulting GIS data files from Manifold (via. KML export). This provided the ability to view the resulting RISK and STAR maps adjacent to actual surroundings by incorporating the orthophotos naturally provided in Google Earth Plus. This also provides the ability to view in 3-dimensions for additional contour rendering (digital elevation modeling) features and a unique way of viewing the actual relative differences of RISK and STAR map values (rather than aggregated/reduced into colour categories) by incorporating the z-axis.

There has been some concerns with "over estimation" when maps are presented in 3D when taken out of context. The reason for the possible "over estimation" is that these maps actually represent the data more precisely than colour-coded categories. They provide linear values in actual relative proportion with each other. In fact, these are better in the validation of the data and show the problems associated with the current methodology much more clearly (mainly the segmentation issues and the associated "aggregation errors" attributed to categorizing within a limited number of categories). Also note that it is advised these maps are only for demonstration purposes and should not be distributed to the public, but only to safety professionals who will understand the context of road safety and value/limitations of any graphical mapping methodology of road risk.

4.3.4 RESULTING RISK AND STAR MAPS

For purposes of demonstration as to the types of RISK and STAR maps that could be produced, as well as the various ways in which these maps could be rendered, the following pages provide graphic representations of the results of the pilot testing of the 144 km section of TCH from the east boundary of Revelstoke National Park and the west boundary of Yoho National Park. Note that the colour coding used in these maps does not correspond to any risk categories, and the categories will need to be defined in the future as discussed in Section 2.

The maps are displayed in the following pages, and include renderings by 1) segment colour coding (2D), 2) segment colour and relative values portrayed in the z-axis (3D).

Figure 4. RISK Map 1 – Collision Density [(F+I)/km/yr] by Colour Coding

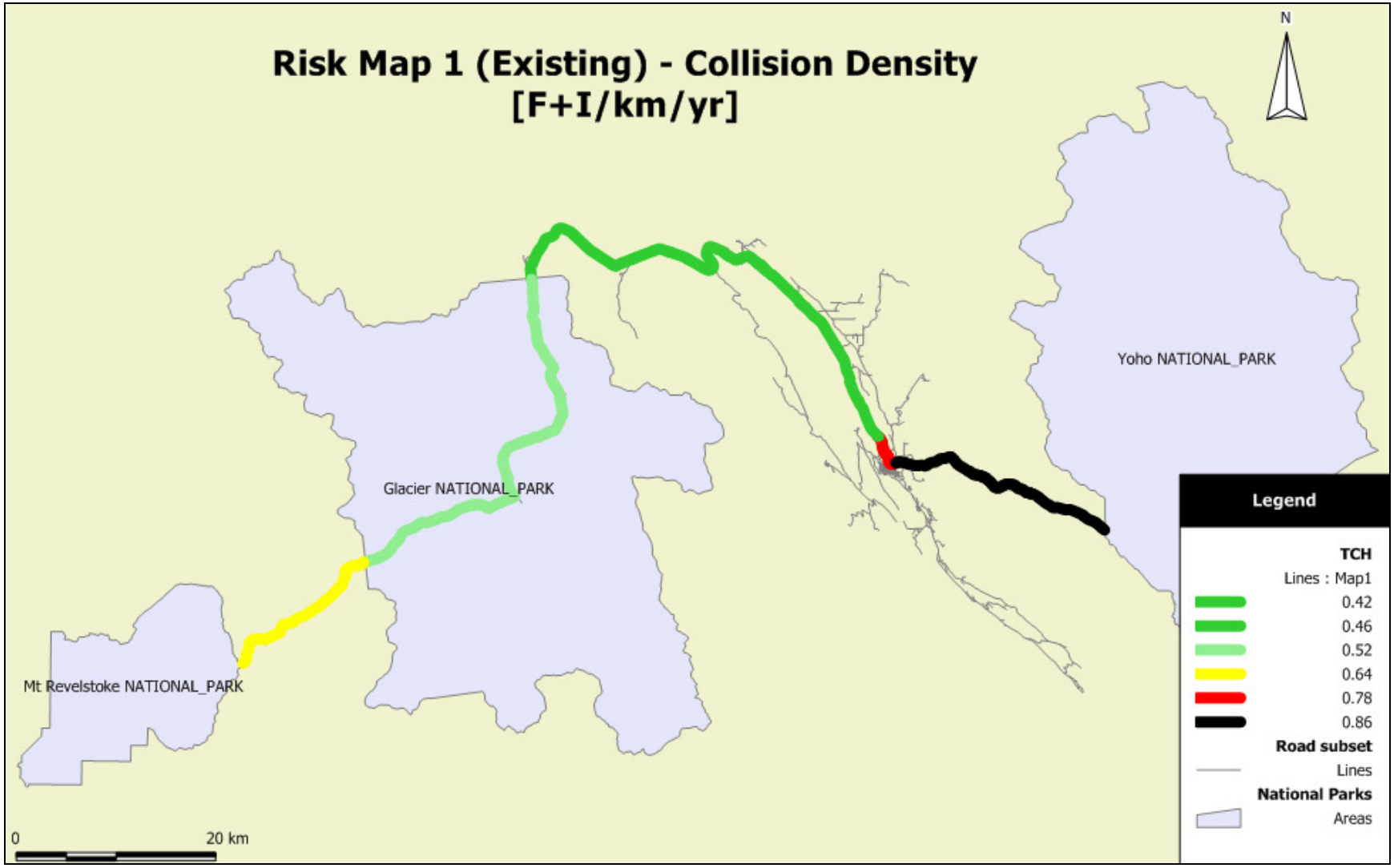


Figure 5. RISK Map 1 – Collision Density [(F+I)/km/yr] by Colour and Relative Width Coding

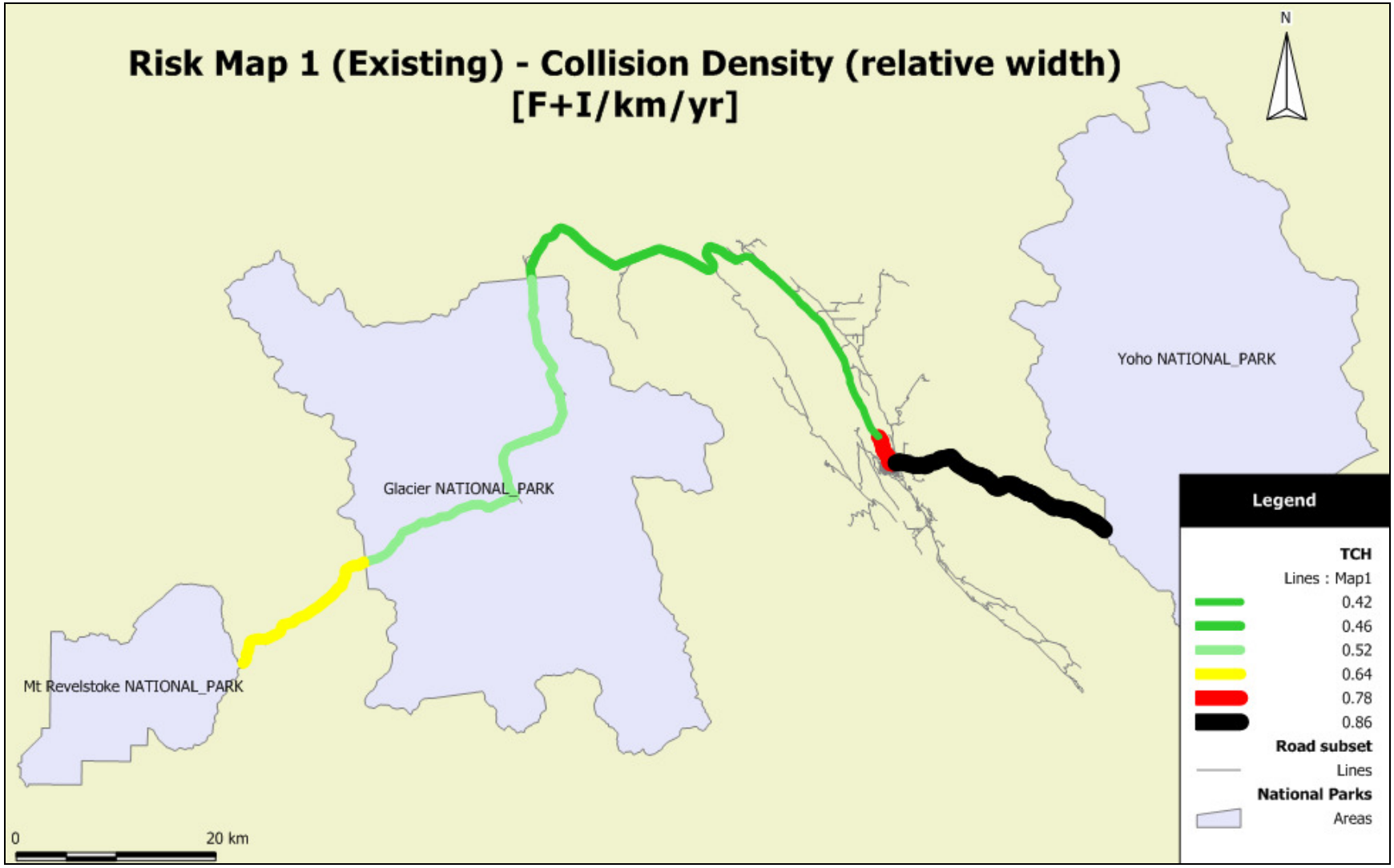


Figure 6. RISK Map 1 – Collision Density [(F+I)/km/yr] by Colour and Relative Height Coding

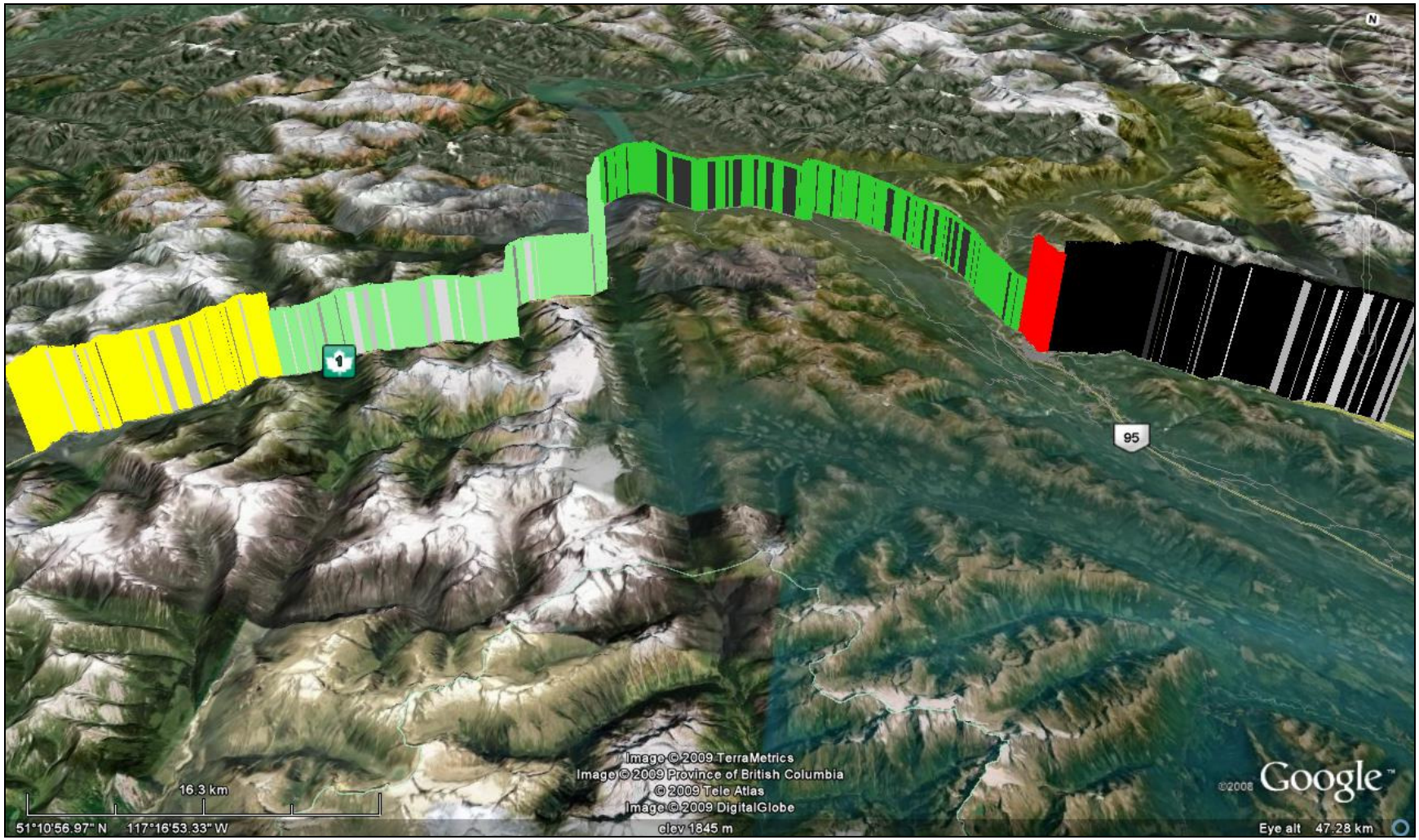


Figure 7. RISK Map 2 – Collision Rate [(F+I)/MVKm] by Colour Coding

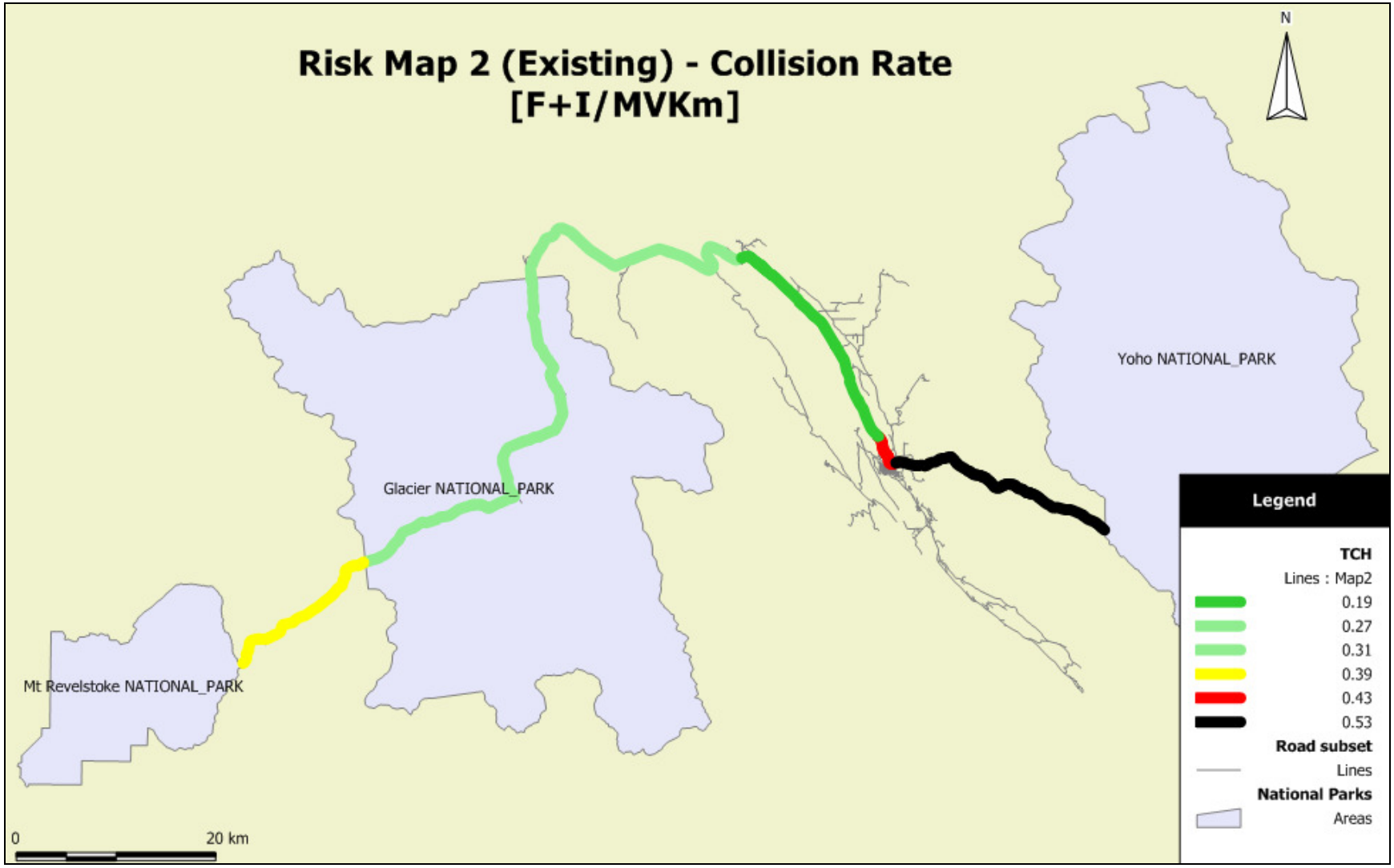


Figure 8. RISK Map 2 – Collision Rate [(F+I)/ MVKm] by Colour and Relative Height Coding

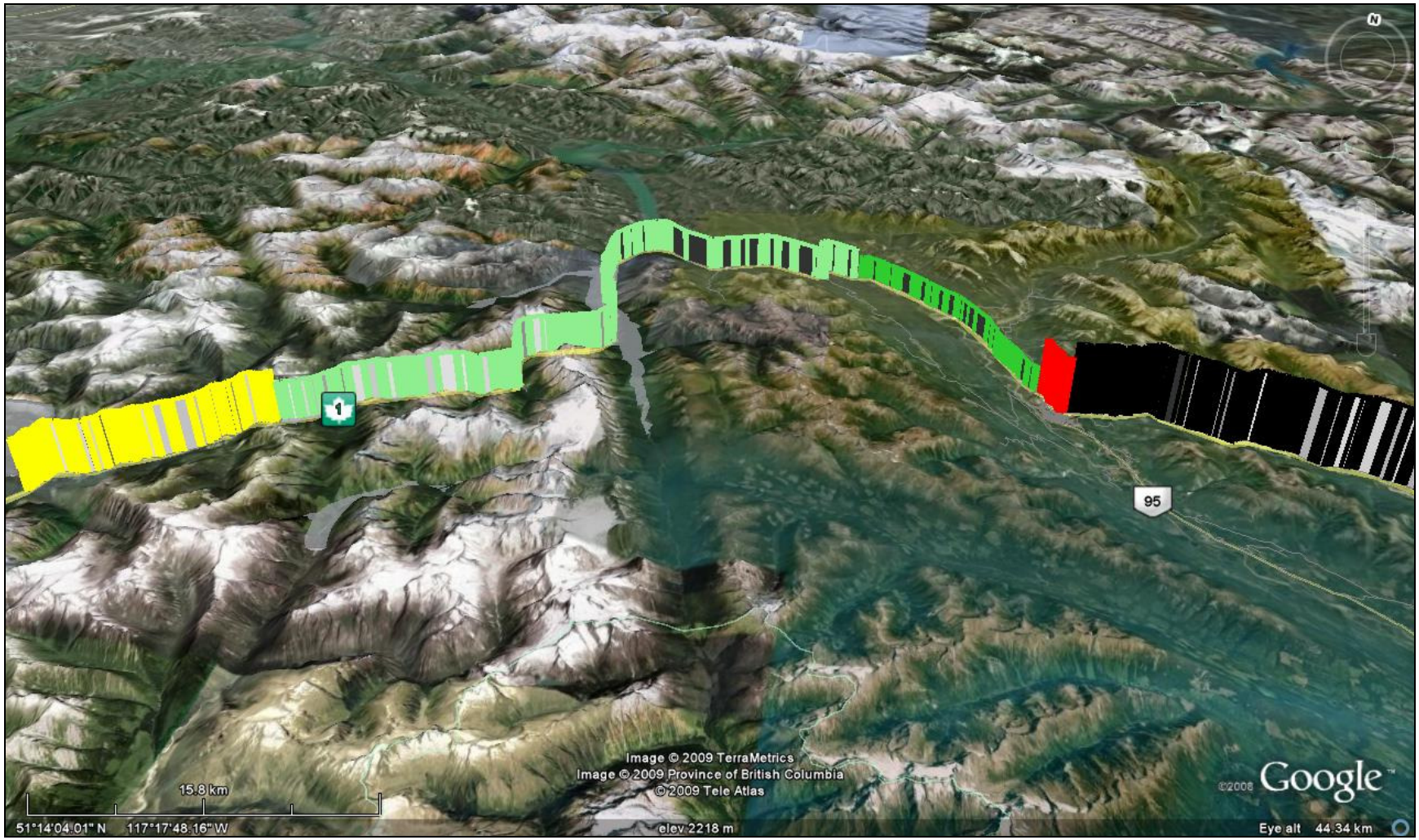


Figure 9. RISK Map 3 – Collision Rate Ratio [CR/ACR] by Colour Coding

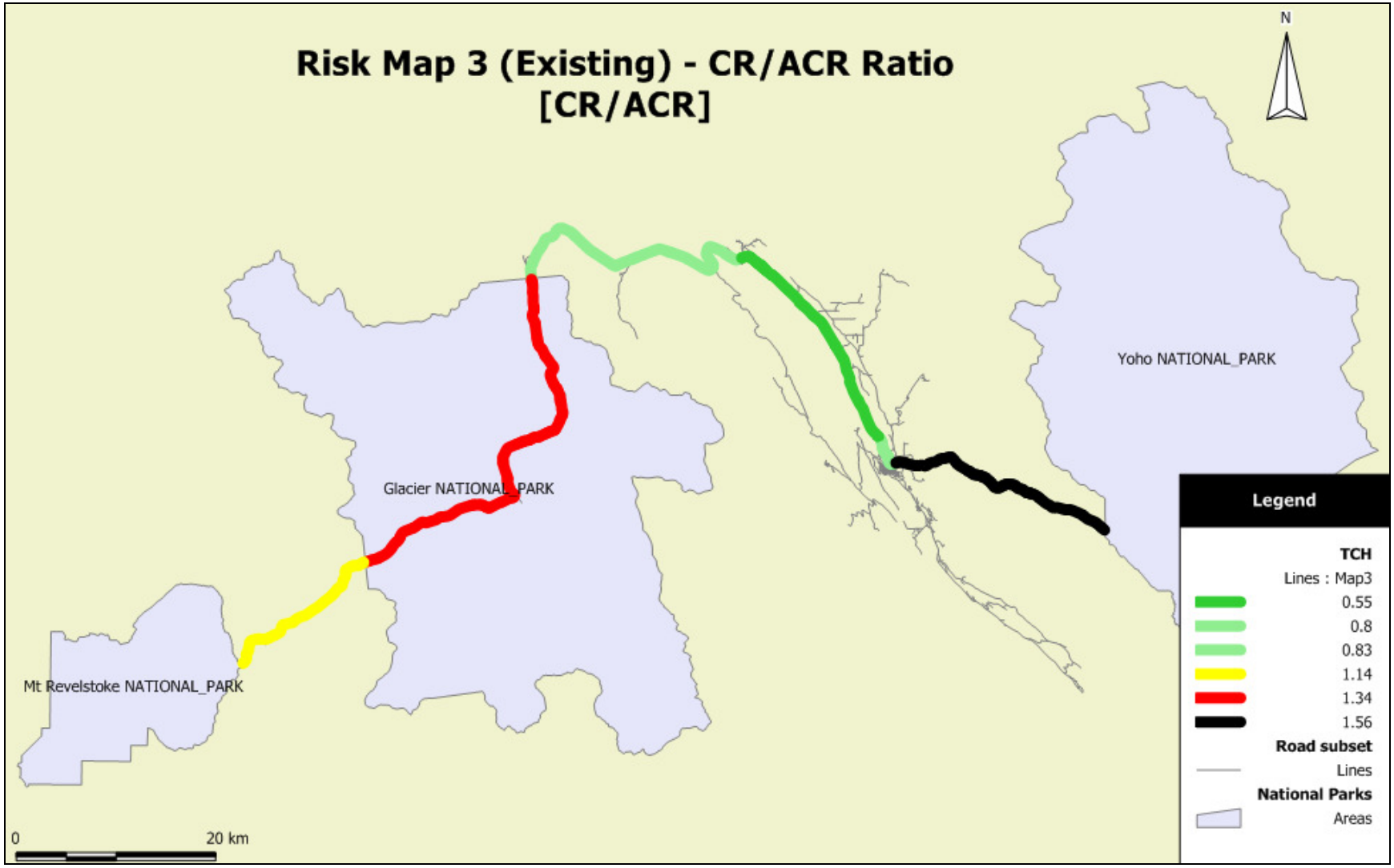


Figure 10. RISK Map 3 – Collision Rate Ratio [CR/ACR] by Colour and Relative Height Coding

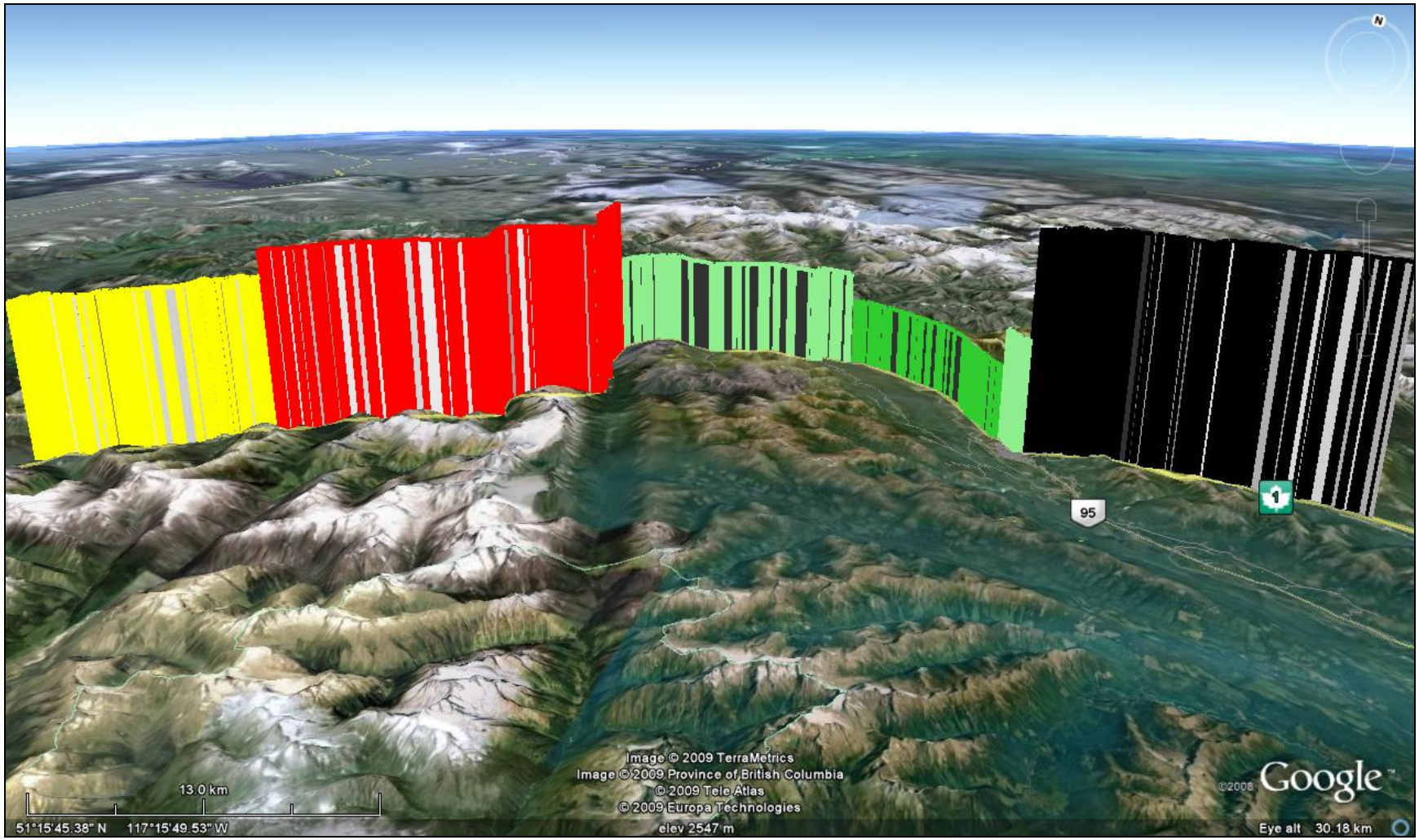


Figure 11. RISK Map 4 – Potential for Casualty Collision Reduction [F+I Coll/yr] by Colour Coding

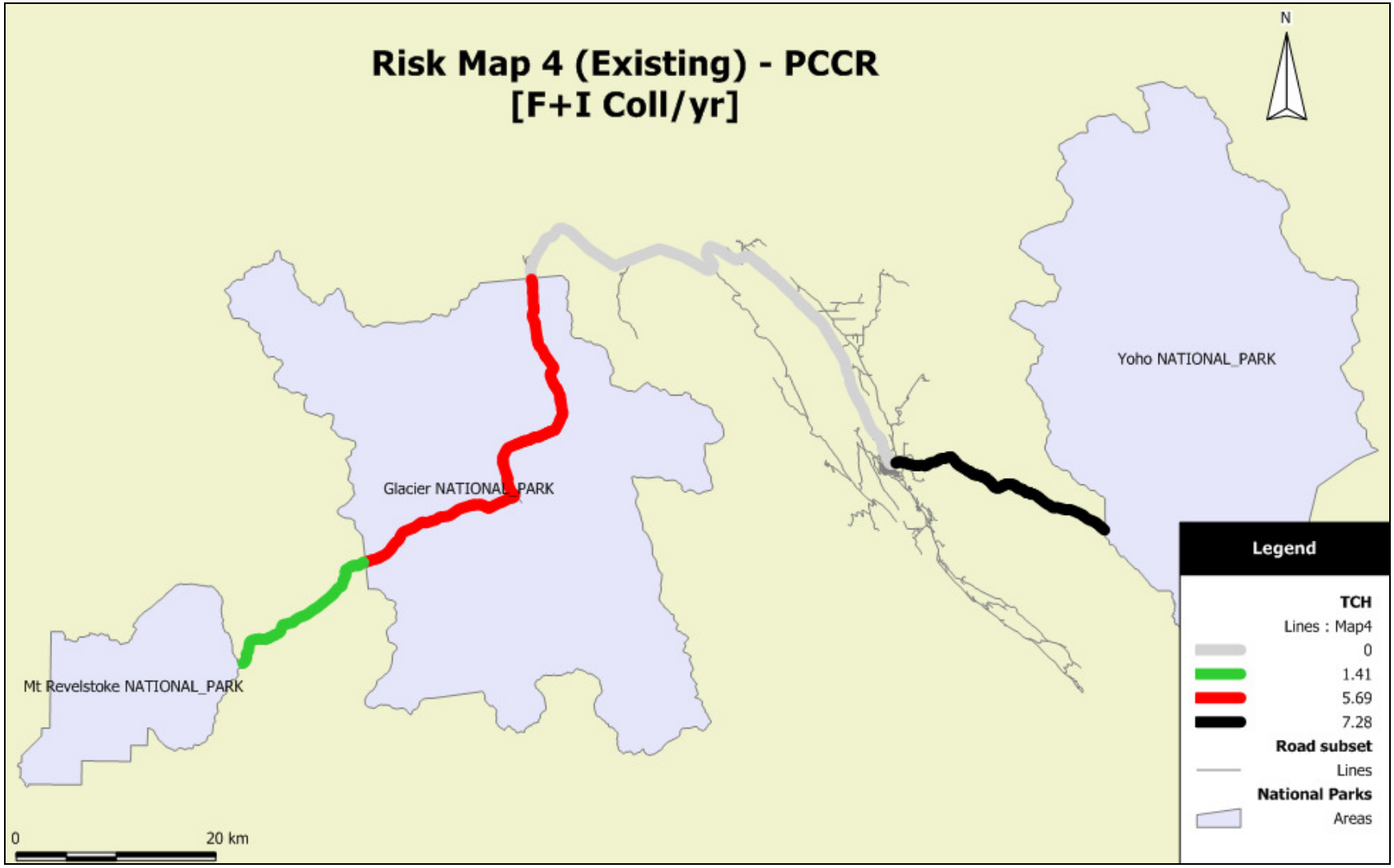


Figure 12. RISK Map 4 – Potential for Casualty Collision Reduction [F+I Coll/yr] by Colour and Relative Height Coding

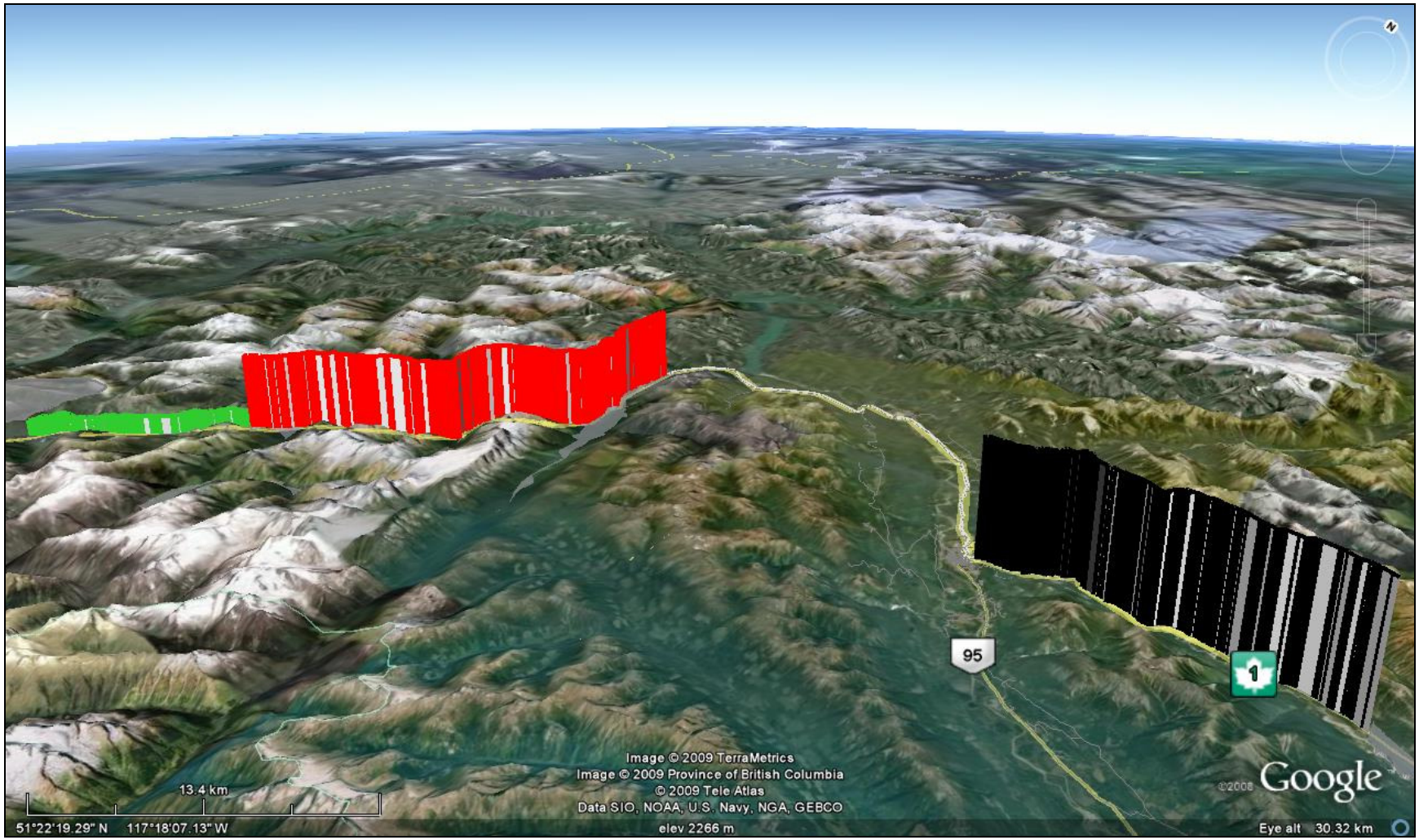


Figure 13. RISK Map 5 – Collision Frequency Ratio [EB/Pred] by Colour Coding

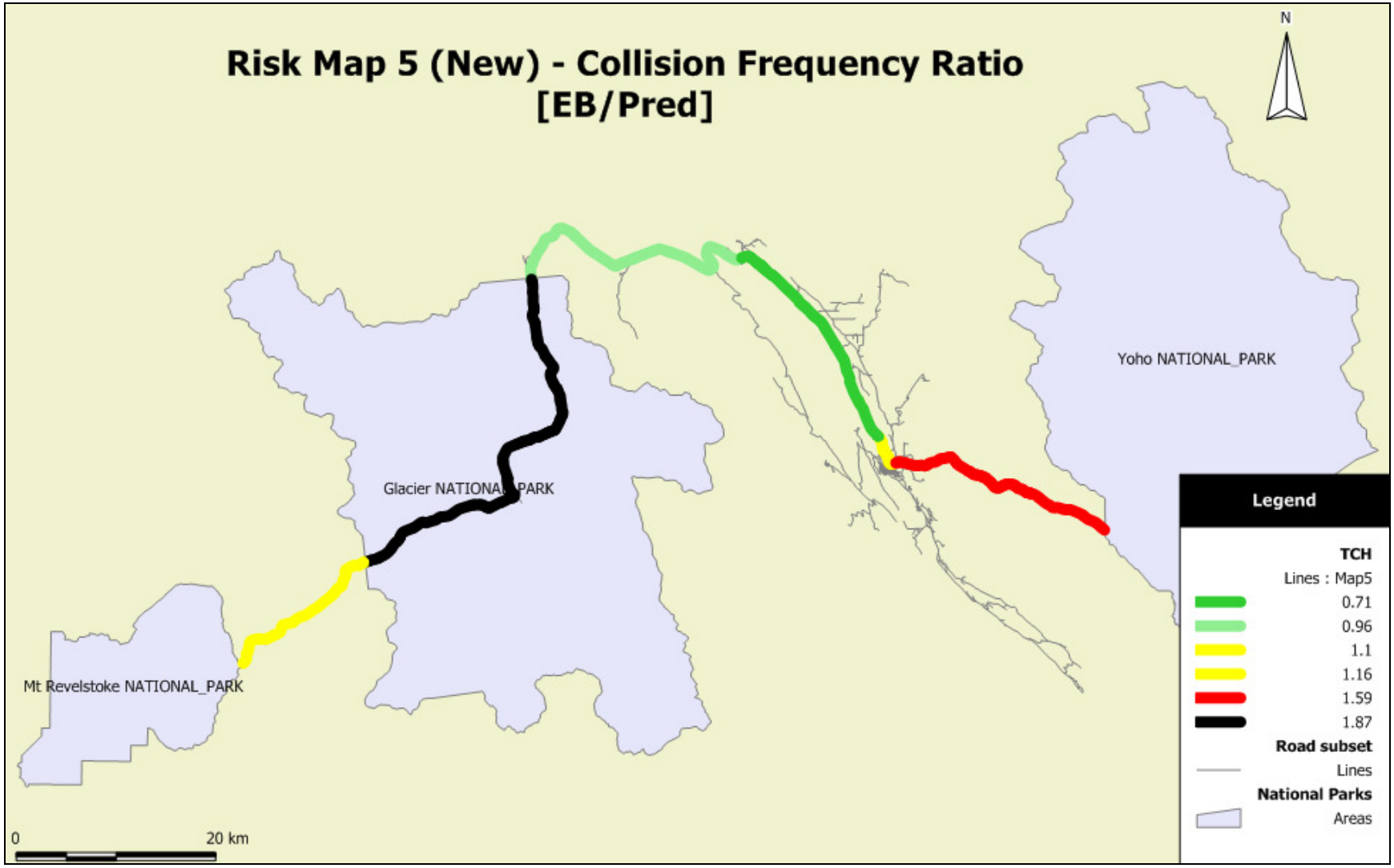


Figure 14. RISK Map 5 – Collision Frequency Ratio [EB/Pred] by Colour and Relative Height Coding

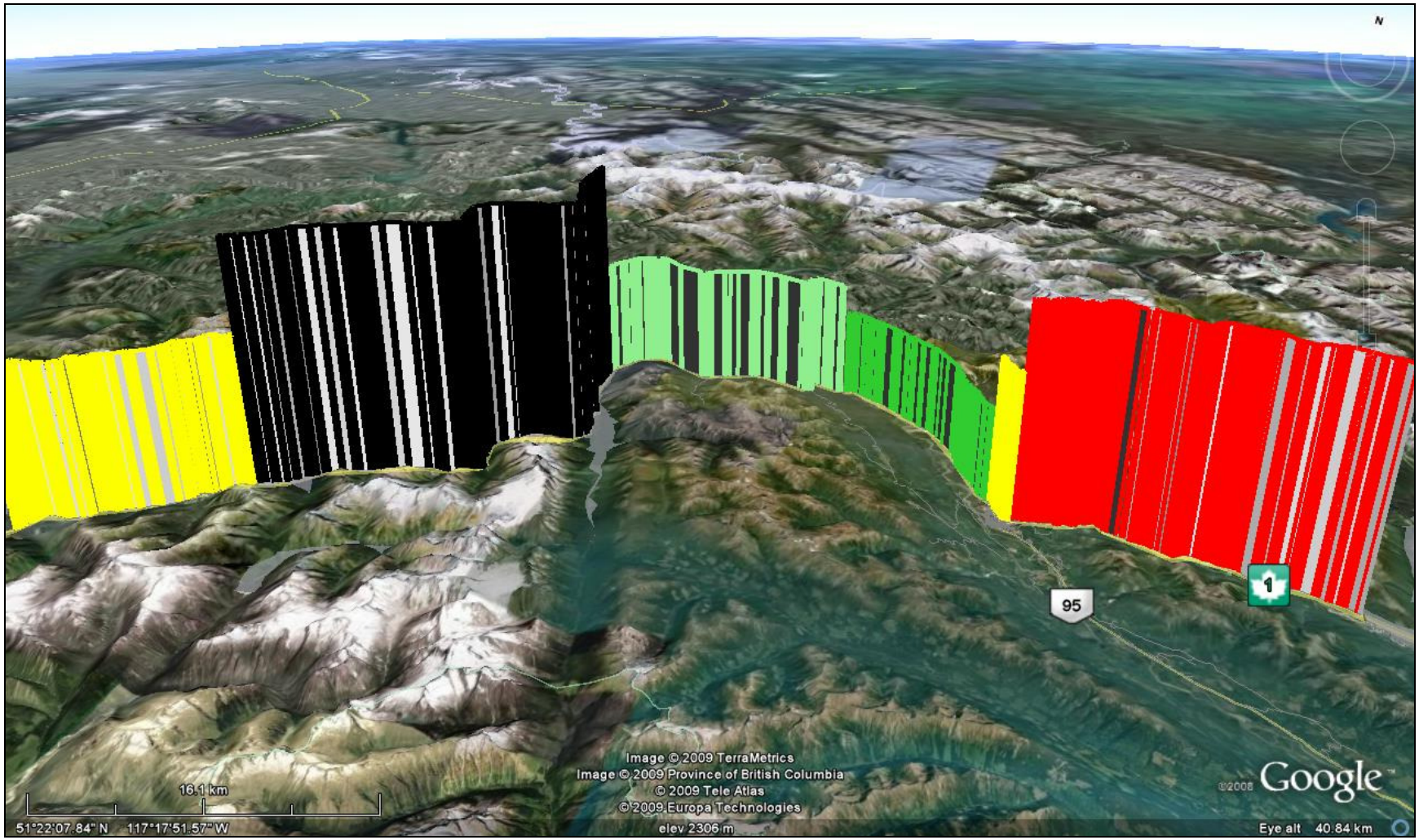


Figure 15. RISK Map 6 – Potential for Casualty Collision Reduction [EB-Pred] by Colour Coding

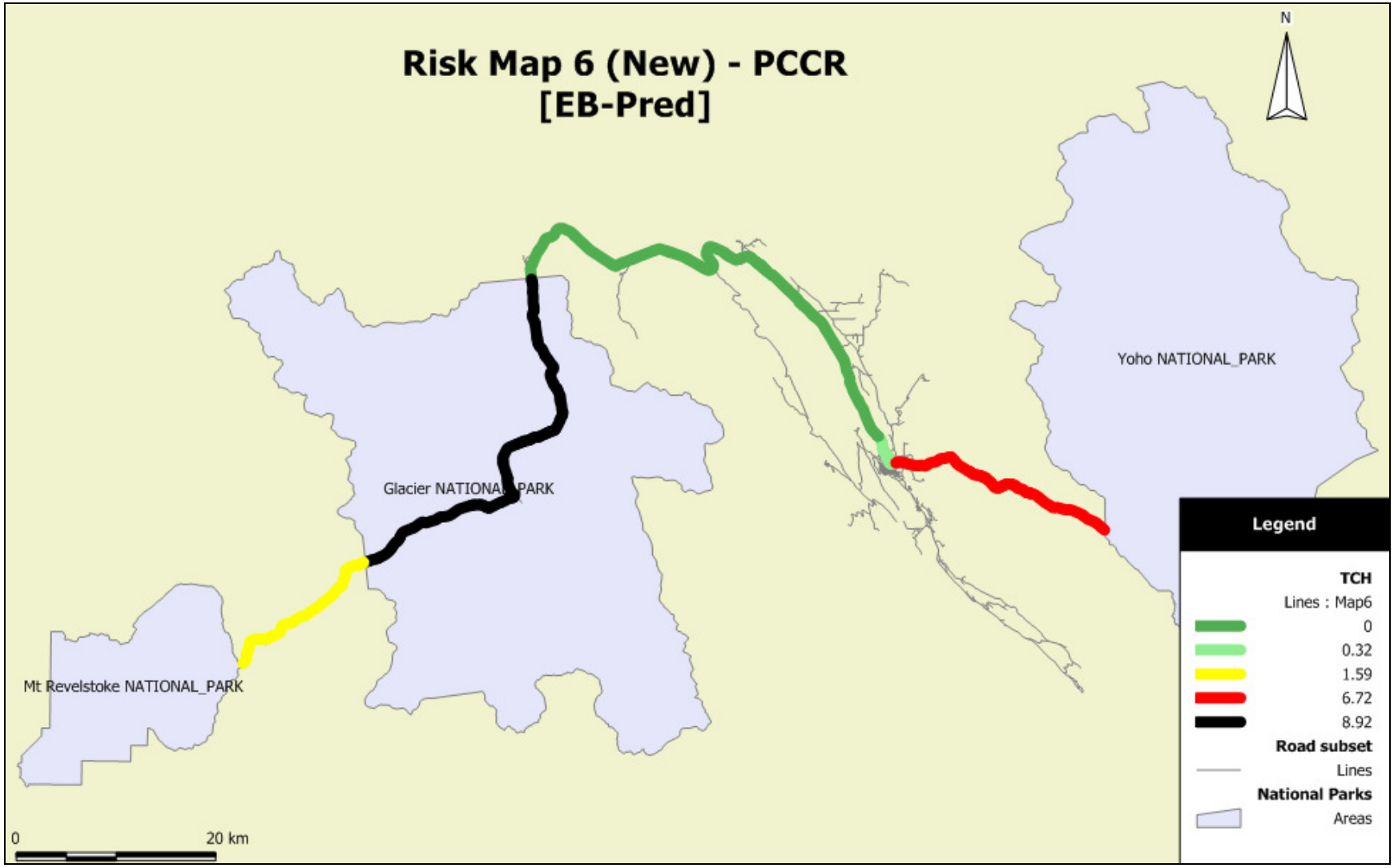


Figure 16. RISK Map 6 – Potential for Casualty Collision Reduction [EB-Pred] by Colour and Relative Height Coding

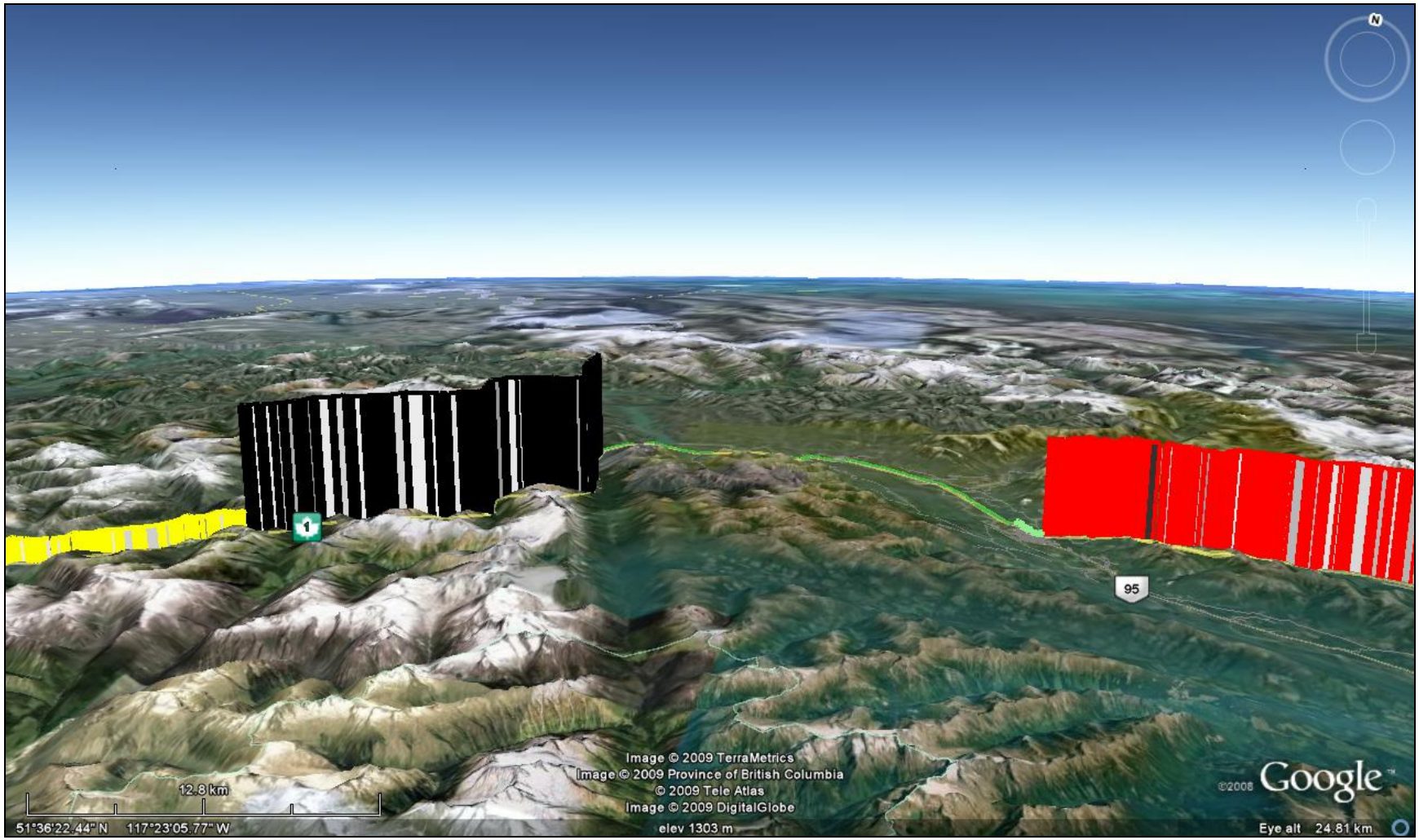


Figure 17. RISK Map 7 – Potential for Improvement Collision Cost by Colour Coding

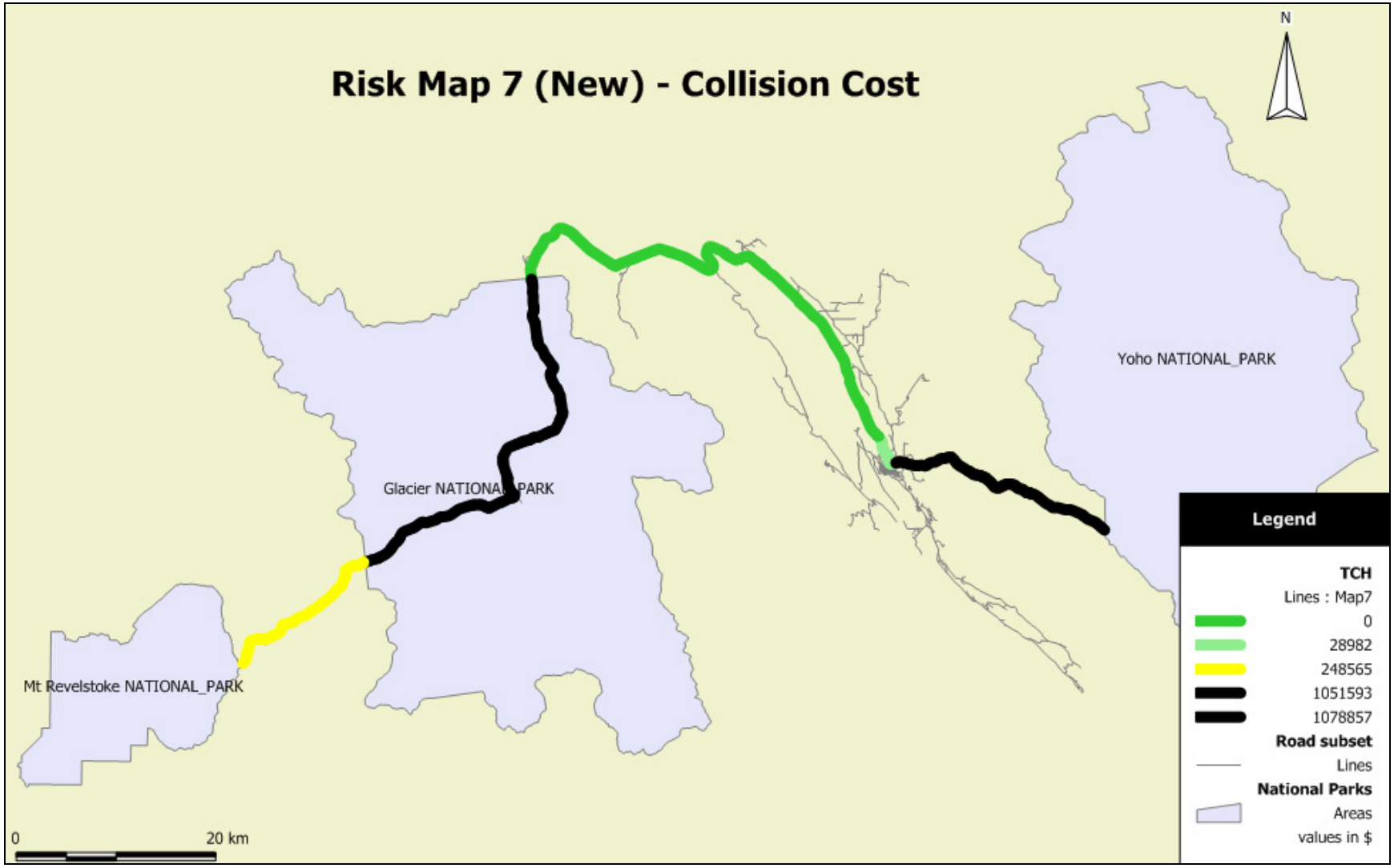


Figure 18. RISK Map 7 – Potential for Improvement Collision Cost by Colour and Relative Height Coding

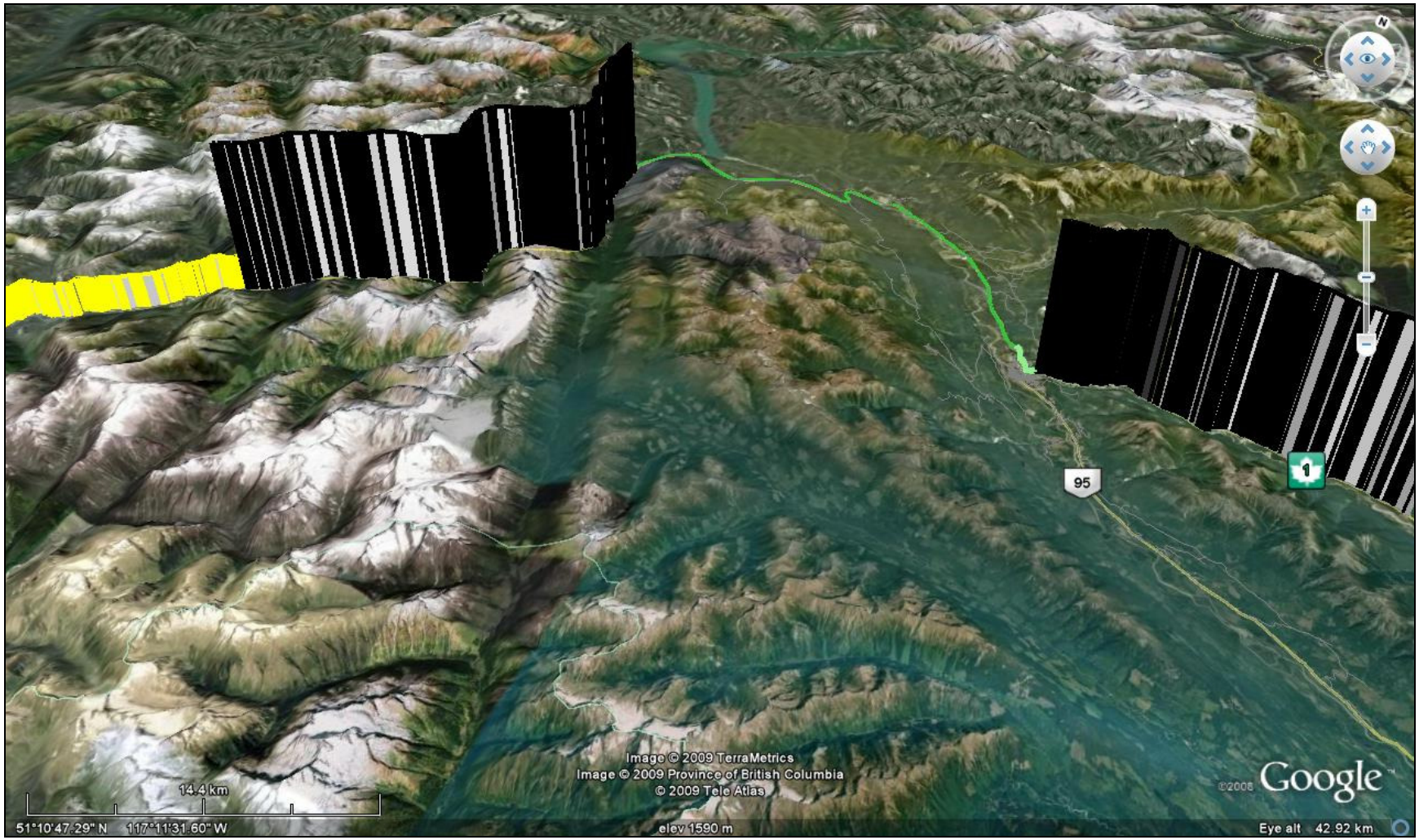


Figure 19. RISK Map 8 – STAR Rating by Colour Coding

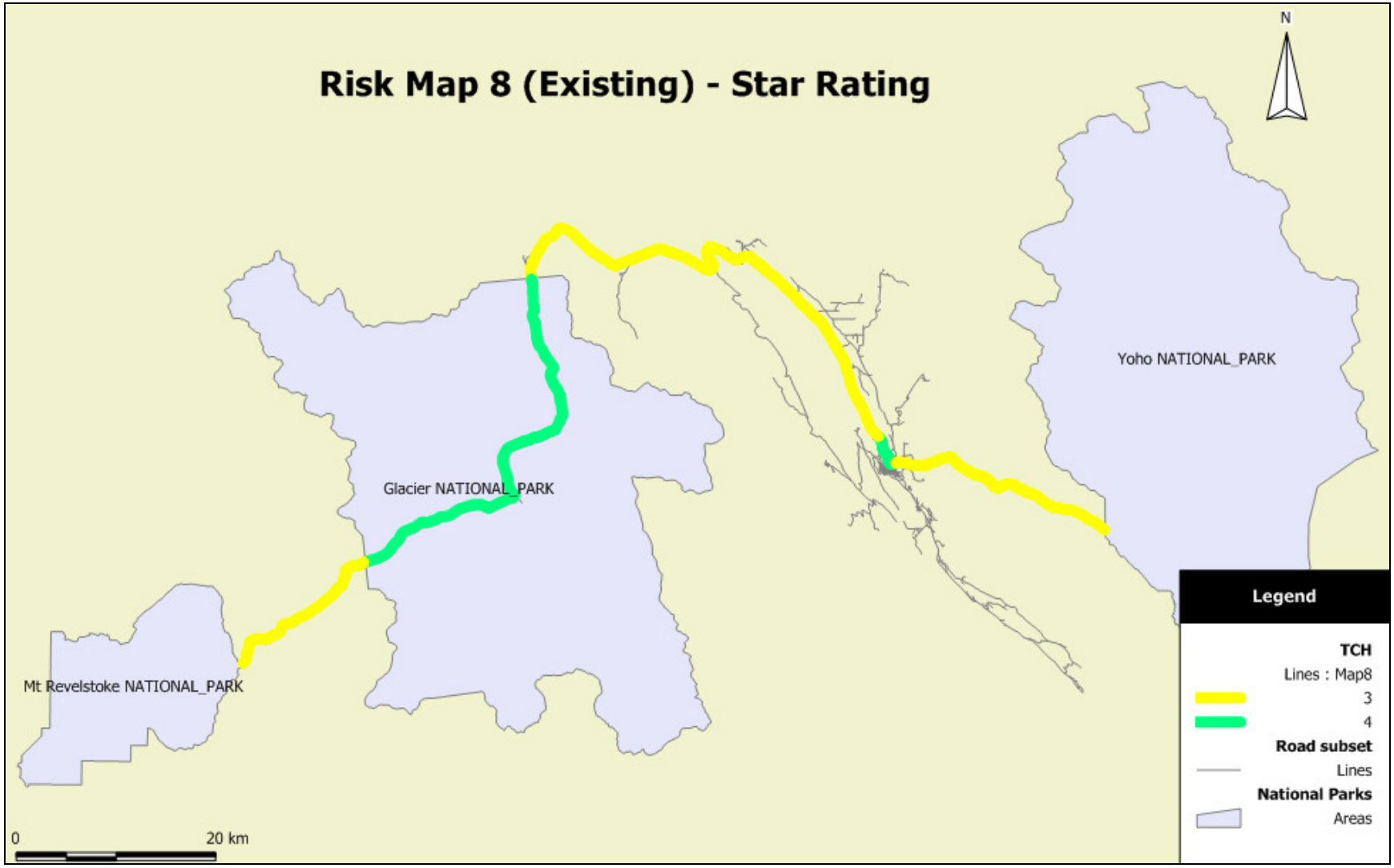


Figure 20. RISK Map 8 – STAR Rating by Colour and Relative Height Coding

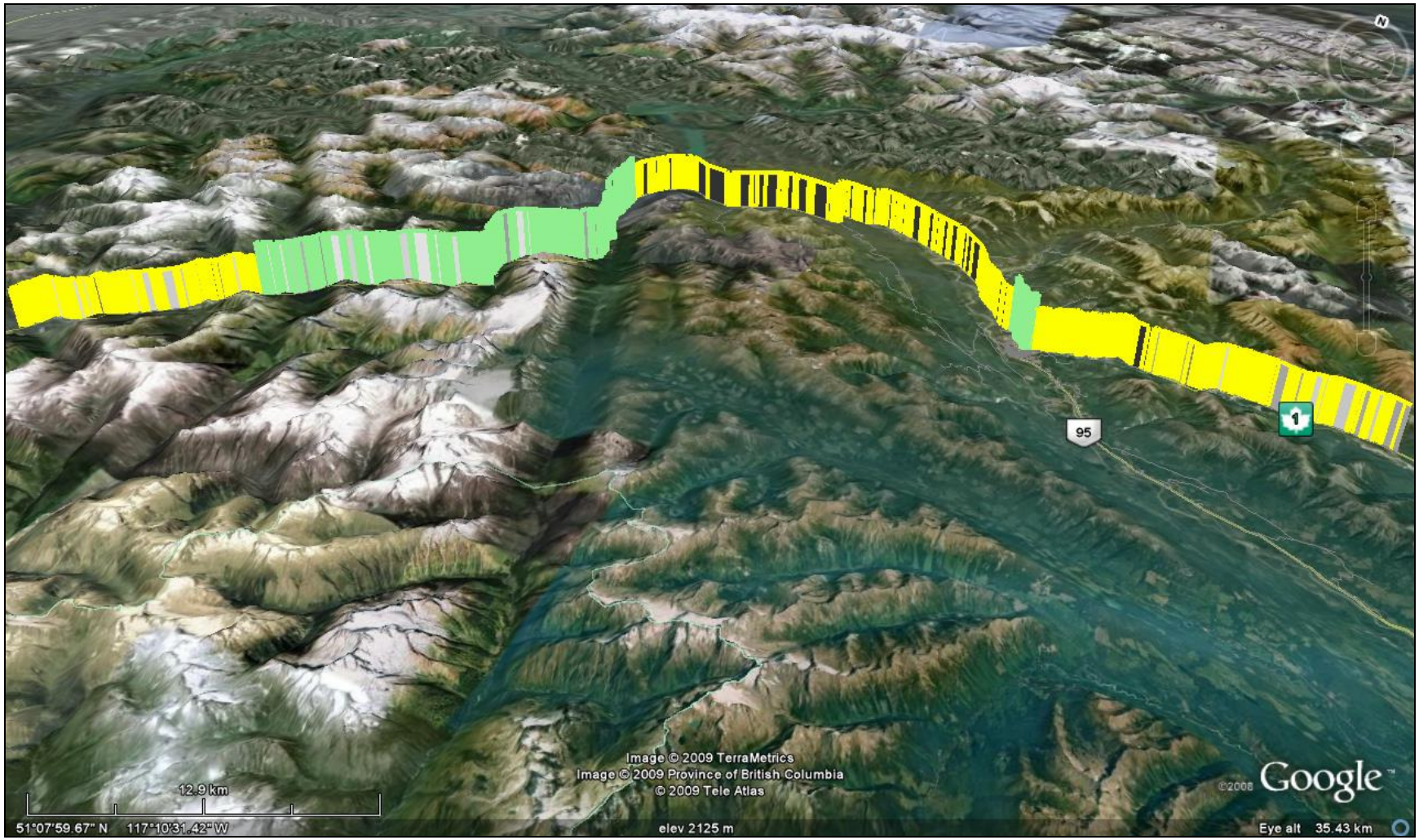


Figure 21. RISK Map 9 – STAR Rating PFI Value [CMF-1] by Colour Coding

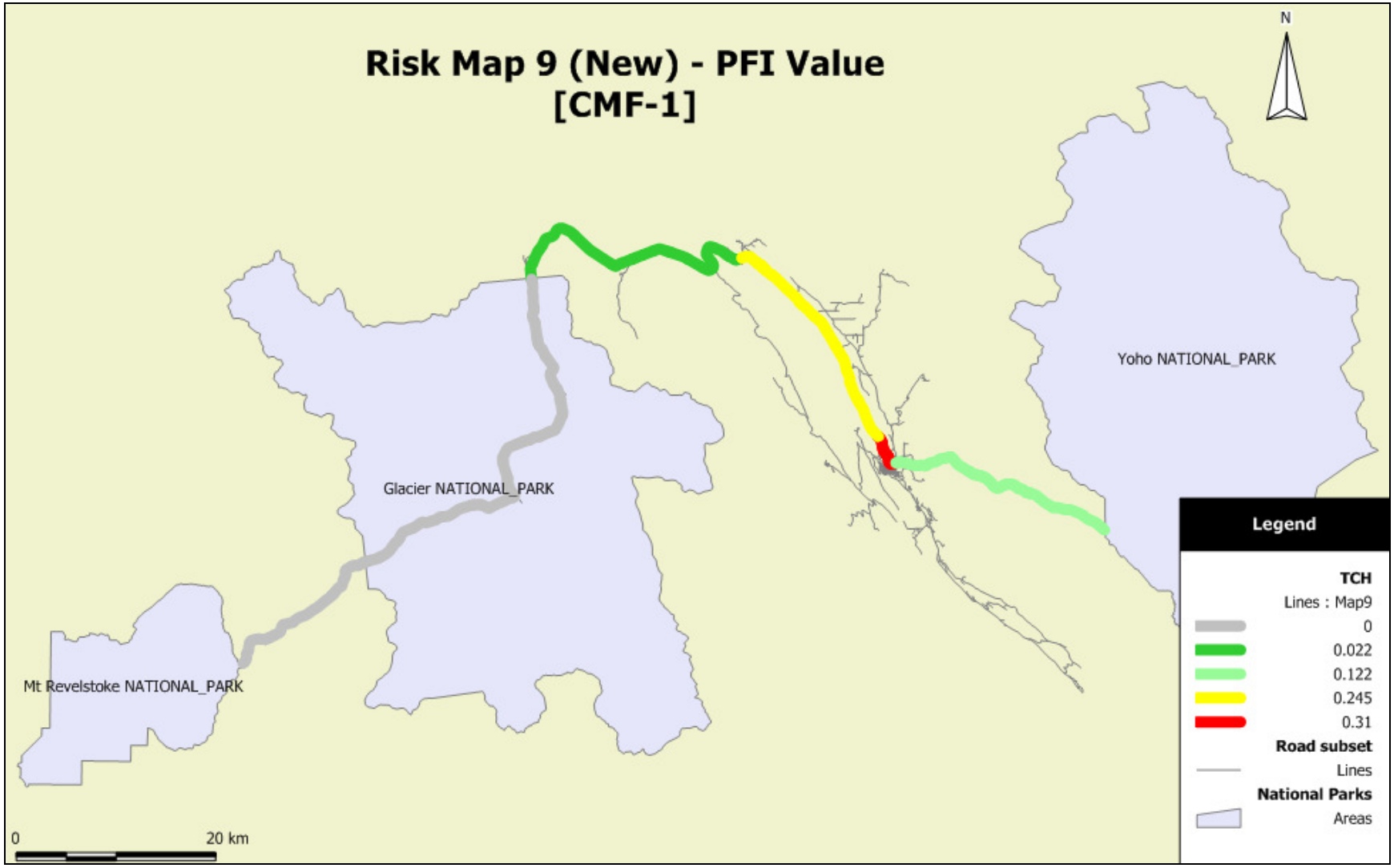
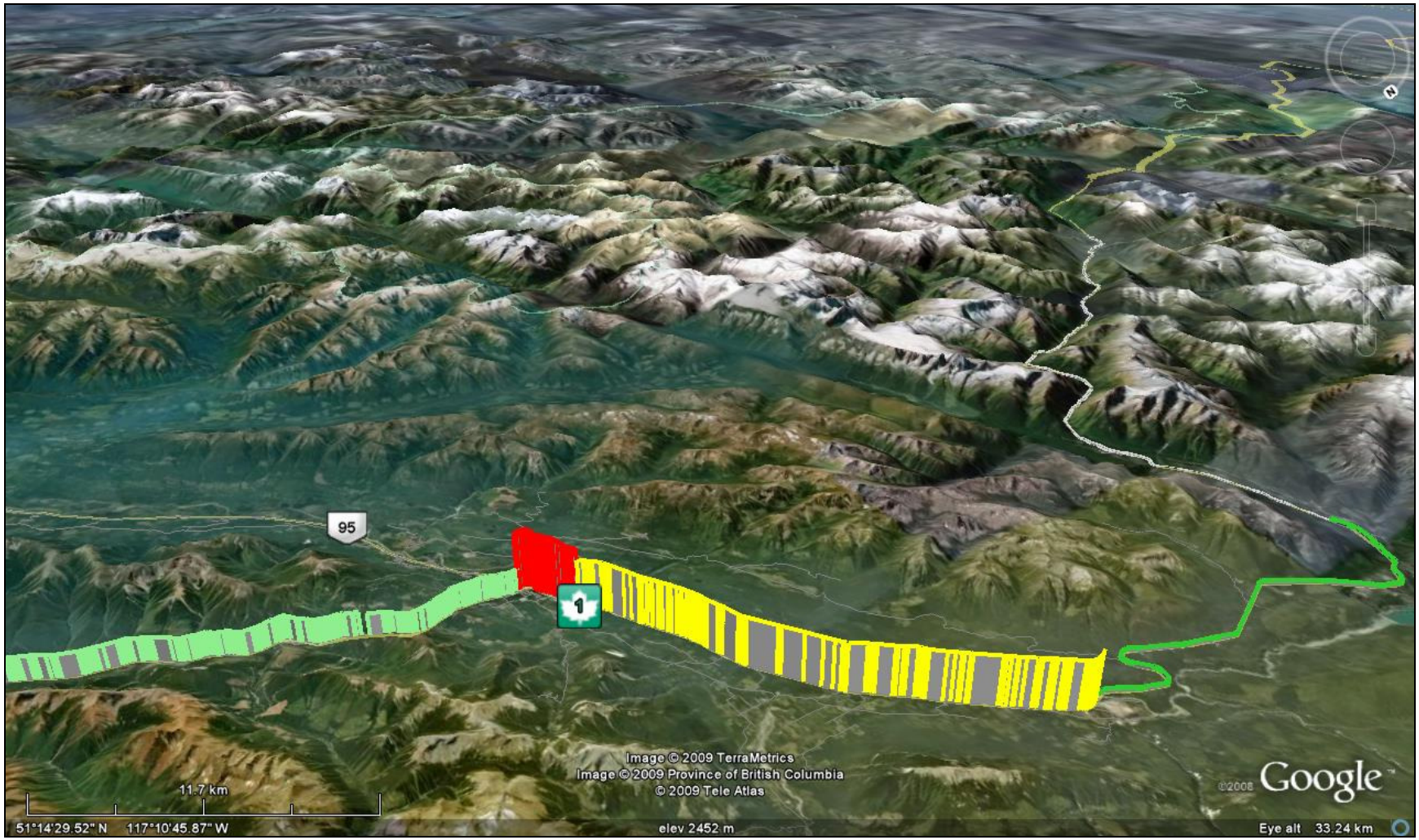


Figure 22. RISK Map 9 – STAR Rating PFI Value [CMF-1] by Colour and Relative Height Coding



4.3.5 DISCUSSION

The graphical visualization of the CanRAP RISK and STAR Ratings presented in this *demonstration* show a number of possibilities as to how such maps can be produced and visualized. The standard colour coded segment maps are effective in communicating the relative safety levels of a road network. Furthermore, utilizing varying segment widths to portray the relative degree of safety can also provide additional information beyond the limitations of the colour categories. However, the only drawback in using a limited range of colour categorization is in the step-wise classification of segments. An example of this limitation is when two similarly valued segments are different enough to be classified in two separate colour categories, while being grouped with other segments that are much more different but within the range of the colour classification. The use of a larger number of colour categories would address this problem, however would also complicate the interpretation and summary of the thematic maps.

The use of the z-axis to portray the degree of safety within a 3-dimentional environment allows for the production of maps that provide a more true and comparable visualization of relative differences in values (rather than the "truncated" categorization of values into colour ranges). This method of visualization would address the issue of using a limited number of colour categories, while portraying segment values correctly for more accurate relative comparisons. Also, these visualizations allow for more effective validation of segment data, provide a richer environment for interactive analysis and the communication of information[5], as well as presenting the information in an attention grabbing medium that can showcase road safety.

4.3.6 ISSUES

Compatibility between Safety Analysis Segmentation and GIS Road Network Segments

Segmentation lengths of GIS road networks are typically varied for a number of reasons (access point, geometry, features, etc.). GIS road segment however are, on average, much shorter relative to segmentation requirements for the identified CanRAP safety analyses. In most cases, the segments for analysis (for Risk and Star ratings analysis) would be an aggregate of GIS road segments. However, the exact end/start points of GIS segments may not coincide exactly with the analysis segments and require the use of GIS techniques such as splitting and merging of links.

[5] One caution is the potential misuse of such visualizations to use the 3D perspectives to "distort" the safety information by making some parts of the map look larger than others.

Thematic Mapping

The thematic mapping process (Step 7 of the methodology in Section 4.3.3) is critical in that the parameters specified for the thematic mapping colour schemes can influence the resulting look of the map. These parameters can vary with different GIS packages and so the translation of these categories and colour schemes into the GIS environment should be done with caution to ensure consistency. As discussed in Chapter 2, this would be an issue with any maps produces using computed values such as PCCR or PFI. However, it would not be such an issue for STAR maps as they use a standard normalized values system with ranges from 1 to 4 or 5.

5. CONCLUSIONS

The RAP Protocols of RISK Mapping and STAR Rating to assess the road safety performance of high speed rural highways can be replicated in the three Western Provinces. The methodologies were relatively straight forward, and were largely adopted from the various RAPs. Some provinces which lack roadway inventory data will require more effort in developing a STAR Rating for their roads. This report has documented potential methodologies for conducting a Canadian Road Assessment Program that will largely duplicate other RAPs.

However, the study also identified a number of issues related to existing RAP Protocols. A number of enhancements to the RAP methodologies were recommended to address these issues using state-of-the-art knowledge in road safety engineering for consideration if a Road Assessment Program is to be carried out in Canada.

Conducting road safety assessment on the road network is a valuable component of any good road safety management program. It is beneficial for any road authorities to have good information on how their road network is performing, and how they perform against each other in order to make decisions on the courses of action to take. The results of a road assessment can also be used to set road safety targets.
Another benefit of RAP is to help raise the public awareness of road safety, and the key role that the road infrastructure plays in improving road safety.

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APPENDIX A

Changes to usRAP STAR Rating Methodology

A1. RPS FOR HEAD-ON COLLISIONS

The scoring for head-on collisions have been adopted from usRAP, with the units changed from imperial to metric units. Note that some rounding was applied to the speed conversion, and the RPS was prorated for the 100 km/h and 60 km/h categories, and the range was expanded to cover speeds of more than 110 km/h and less than 60 km/h.

A2. RPS FOR RUN-OFF-ROAD COLLISIONS

The scoring for run-off-road collisions have been adopted from usRAP, with the units changed from imperial to metric units. Note that some rounding was applied to the speed conversion, and the RPS was prorated for the 100 km/h and 60 km/h categories, and the range was expanded to cover speeds of more than 110 km/h and less than 60 km/h. The usRAP RPS scores were adjusted to reflect the three categories proposed for CanRAP by taking the average RPS for Standard, Barrier Present, and Sub-standard for each speed category, and using the range of values from the TAC Geometric Design Guide for Canadian Roads, Table 3.1.3.1. The RPS was rounded to the nearest integer. A side slope of 4:1 or more is defined to be meeting standards, and likewise a side slope of less than 4:1 is defined as Sub-standard for all speeds.

The lane width adjustment factors in ***Table 7*** were taken from the TAC Geometric Design Guide for Canadian Roads (Figure 2.2.2.1). Note that the factor for 3.35m wide lane is slightly different than the one used in usRAP (11 feet wide lane – 1.05), and the rest of the factors are the same. Note that factors shown are valid for AADT of 2,000 vph or more.

The adjustment factors in ***Table 8*** were adopted directly from the usRAP.

A3. RPS FOR INTERSECTION COLLISIONS

The scoring for intersection collisions have been adopted from usRAP, with the units changed from imperial to metric units. Note that some rounding was applied to the speed conversion, and the RPS was prorated for the 100 km/h and 60 km/h categories, and the range was expanded to cover speeds of more than 110 km/h and less than 60 km/h.

For roundabouts, the usRAP provided scoring up to 110 km/h for "low speed roundabout" which does not make sense, and similarly scoring is also provided for "high speed roundabout" for speeds of 70 km/h or lower. For CanRAP, the usRAP roundabout RPS has been combined, using values up to 70 km/h for "low speed roundabout" and above 70km/h for "high speed roundabout".

No description was given in the usRAP for what "Merging Manoeuvre" is, and it appears to account for the scoring for interchanges. In addition, no definitions were given for "long" or "short". Furthermore, no RPS is available for diverging movements. This is critical for evaluating rural interchanges as the diverging movements typically exhibit a higher collision risk than the merging movement as shown in ***Table A1*** below. The RPS for diverging movements were derived from the values in ***Table 10*** by multiplying the values for merging manoeuvre by a factor of 2.15 which is the ratio of accident rates at exit ramp to entrance ramp on rural interchanges. For the purpose of CanRAP, long acceleration lane is defined as 244m or more, and short acceleration is defined as less than 244m long. For deceleration lanes, long is defined as 275m or longer, while short is less than 275m. These values were obtained from NCHRP Synthesis 299, Page 109 on interchange collisions.

Table A1 Collision Rate by Interchange Unit

ACCIDENT RATE BY INTERCHANGE UNIT AND AREA TYPE (*261*)

Interchange Unit	Rural		
	Vehicle-Miles (100 million)	No.of Accidents	Accident Rate[a]
Deceleration Lane	2.51	348	137
Exit Ramp	0.57	199	346
Area Between Speed Change Lanes	6.52	554	85
Entrance Ramp	0.59	95	161
Acceleration Lane	3.68	280	76
Acceleration–Deceleration Lane	0.49	87	116
Total	14.36	1,563	109[b]

Notes: 1 mi = 1.61 km.
[a]Accidents per 100 million vehicle-miles.
[b]Average accident rate.

Source: NCHRP Synthesis 299, Table 70

The STAR Rating values in ***Table 11*** are converted to RPS per kilometre from RPS per mile.

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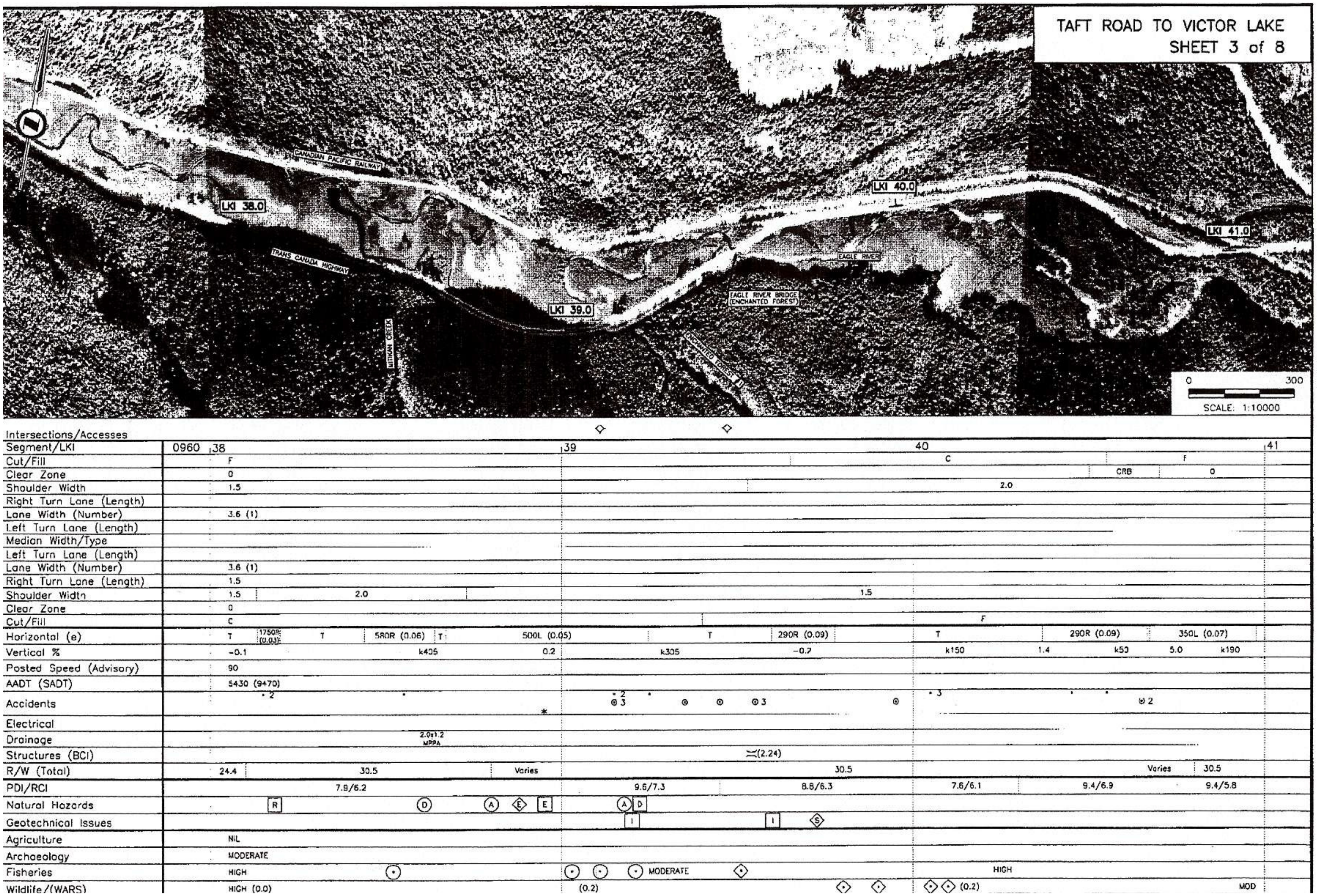
APPENDIX B

Example of Strip Maps used for Pilot Test


TAFT ROAD TO VICTOR LAKE
SHEET 3 of 8
CANADIAN PACIFIC RAILWAY
LKI 38.0
TRANS CANADA HIGHWAY
LKI 39.0
LKI 40.0
LKI 41.0
EAGLE RIVER
EAGLE RIVER BRIDGE (ENCHANTED FOREST)
MITHAN CREEK
0 300
SCALE: 1:10000
Intersections/Accesses
Segment/LKI 0960 38 39 40 41
Cut/Fill F C F
Clear Zone 0 CRB 0
Shoulder Width 1.5 2.0
Right Turn Lane (Length)
Lane Width (Number) 3.6 (1)
Left Turn Lane (Length)
Median Width/Type
Left Turn Lane (Length)
Lane Width (Number) 3.6 (1)
Right Turn Lane (Length) 1.5
Shoulder Width 1.5 2.0 1.5
Clear Zone 0
Cut/Fill C F
Horizontal (e) T 1750R (0.03) T 580R (0.06) T 500L (0.05) T 290R (0.09) T 290R (0.09) 350L (0.07)
Vertical % -0.1 k405 0.2 k305 -0.7 k150 1.4 k53 5.0 k190
Posted Speed (Advisory) 90
AADT (SADT) 5430 (9470)
Accidents 2 2 3 3 3 2
Electrical
Drainage 2.0x1.2 MPPA
Structures (BCI) (2.24)
R/W (Total) 24.4 30.5 Varies 30.5 Varies 30.5
PDI/RCI 7.9/6.2 9.6/7.3 8.8/6.3 7.6/6.1 9.4/6.9 9.4/5.8
Natural Hazards R D A E E A D
Geotechnical Issues I I S
Agriculture NIL
Archaeology MODERATE
Fisheries HIGH MODERATE HIGH
Wildlife/(WARS) HIGH (0.0) (0.2) (0.2) MOD