Strategic highway improvements to minimize environmental impacts within the Canadian Rocky Mountain National Parks

T.M. McGuire and J.F. Morrall

Abstract: This paper describes how strategic highway engineering improvements have been developed or adopted to mitigate the unique environmental impact highways and roads have within Canadian Rocky Mountain national parks, which are also World Heritage Sites. Three levels of strategic highway development are presented. The first is the re-capitalization of existing park roads. Examples are presented from several national parks where parkways and low-volume roads were reconstructed or repaired in ways to reduce terrain impacts. The second is the development of the passing lane system on the Trans-Canada Highway in the Rocky Mountain national parks to defer twinning. The third example is the twinning of 18.6 km of the Trans-Canada Highway. Twinning represents a logical next step following the passing lane phase. This paper describes how highway engineering improvements were developed to address and mitigate numerous potential twinning impacts identified during environmental assessment. Included within the environmental mitigation measures are fencing and animal crossing structures, addressing wildlife movement, biodiversity, and mortality as well as stream, terrain, and vegetation disturbance minimization techniques. Research has found that the mitigation measures have been effective in reducing wildlife and vehicle collisions by 97%.

Key words: highway, sustainable, national park, environment.

Résumé : Cet article décrit comment les améliorations stratégiques en génie routier ont été développées ou adoptées pour atténuer l'impact environnemental que les autoroutes et les routes ont dans les Parcs Nationaux des Montagnes Rocheuses, qui sont aussi des Sites d'Héritage Mondial. Trois niveaux de développements routiers stratégiques sont présentés. Le premier est la récapitalisation des routes de parcs existantes. Des exemples sont présentés de plusieurs Parcs Nationaux où des chemins et des routes à faible volume furent reconstruits ou réparés de façon pour réduire les impacts du terrain. Le second est le développement du système de la voie de passage sur l'autoroute transcanadienne dans les Parcs des Montagnes Rocheuses pour différer le jumelage. Le troisième exemple est le jumelage de 18,6 km de l'autoroute du transcanadienne. Le jumelage représente la prochaine étape logique qui suit la phase de la voie de passage. L'article décrit comment les améliorations en génie routier furent développées pour adresser et atténuer plusieurs impacts potentiels du jumelage identifiés durant l'évaluation environnementale. Ci-incluses dans les atténuations environnementales furent des séries de mesures, comme des systèmes de clôture et de passage d'animaux pour adresser les mouvements de la faune, la biodiversité et la mortalité, ainsi que les techniques de minimisation de dérangement de cours d'eau, de terrain, et de végétation. La recherche a trouvé que les mesures d'atténuations ont été efficaces dans la réduction des collisions faune/véhicule par 97 %.

Mots clés : autoroute, durable, parc national, environnement.

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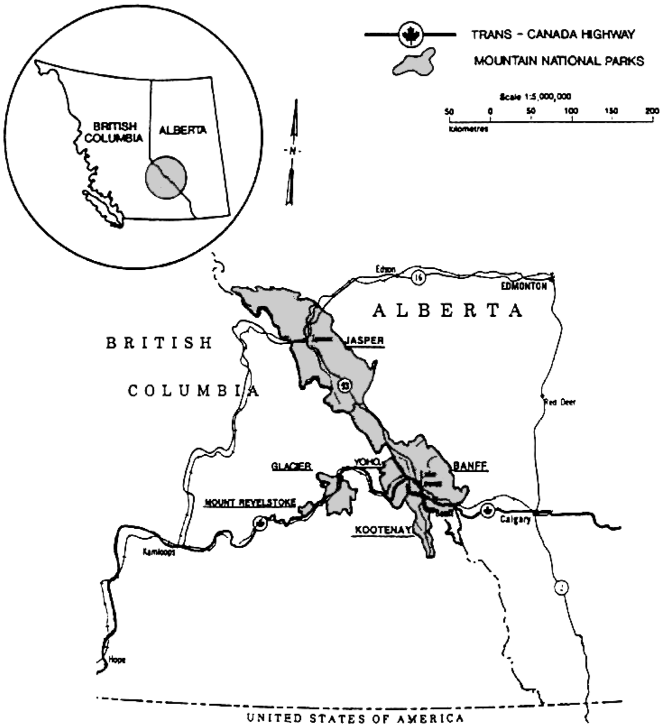
Introduction

Parks Canada is responsible for the maintenance and repair of approximately 1200 lane km of highways and roads within the Rocky Mountain national parks of Banff, Yoho, Kootenay, Jasper, Glacier, and Mount Revelstoke. Of this total, approximately 500 lane km are major through highways that are part of provincial highway systems, including the Trans-Canada Highway (TCH) as shown in Fig. 1.

The TCH and other major highways passing through national parks are part of a national transportation system that responds to transportation objectives and demands that are not always compatible with national park objectives. Major transportation corridors can have a number of damaging impacts on park environments. They act as barriers to natural animal movement and are a source of mortality. Exhaust

Fig. 1. Regional setting of the mountain national parks.



emissions contribute to declining air quality, particularly in valley bottoms. Routine winter maintenance requires gravel and salt. Extracting gravel from park land damages habitat and alters the natural landscape. Spills of hazardous materials can occur accidentally in transportation corridors. Previous road construction has resulted in changes to alluvial fans, natural water channels, and seasonal processes such as flooding. In turn, this affects aquatic habitat, nutrient and productivity levels, seasonal fish movement, erosion rates, and water quality.

Strategic development of the highway system

Any proposed development in the Canadian national parks, including highways, is subject to the most rigorous environmental assessment procedures in Canada as outlined within the 1992 Canadian Environmental Assessment Act (CEAA). This, along with the National Parks Act (NPA), 1930, 1988 amendments, and 1994 policy statement stressing the ecological role of national parks, provide the basic guidelines for highway improvements. The National Parks Act of 1930 states that “The Parks are dedicated to the people of Canada for their benefit, education, and enjoyment … such parks shall be maintained and made use of so as to leave them unimpaired for the enjoyment of future generations.”

Five strategic objectives have been established for highways and roads within national parks to comply with the NPA. In order of priority they are

(1) resolution of public safety concerns by applying current traffic engineering design standards
(2) protection of the infrastructure investment through reconditioning
(3) rehabilitation of environmental damage caused during original construction and ensuring all improvements respect environmental requirements
(4) improving the level of service through low-cost operational improvements so that present highway design life can be extended until capacity increases are necessary
(5) rationalization of visitor services into efficient nodes where visitor use can be both confined and enhanced

Rehabilitation of existing park roads

The TCH and other provincial-numbered highways passing through the Rocky Mountain national parks represent approximately 40% of the highways and roads that Parks Canada is responsible for. The remaining roads are low-volume and low-design speed parkways as well as roads servicing park facilities and offering scenic drives. Some of these roads were constructed as make-work projects during the Great Depression and involved minimal concern for desirable geometric design standards and construction methods. During the 1960s, some of these roads were improved primarily with asphalt overlays and minor alignment improvements. In the 1970s and 1980s, park visitation increased dramatically, leading to heavier usage of these roads and increased deterioration of pavements not designed for this level of loading. This deterioration far outstripped the available funding levels of Parks Canada to maintain and repair them.

Faced with major recapitalization costs to bring some of these roads up to current standards, the options of complete closure or “decapitalization” to a lower standard are now being considered. Decapitalization options being assessed include returning the road to a gravelled or chipsealed surface from the existing badly broken and potholed asphalt surface. This reduced standard may also in turn lead to reduced usage of the road and thus help alleviate over utilization and crowding of the park facilities to which these roads provide access. Other cost reduction options being considered include restricting access to transit buses to carry visitors to attractions on narrower roads with pavement alignment, strength, and surfaces reflective of these vehicles.

Lack of funding to rebuild roads in traditional fashion and the environmental impact of such construction methods have led Parks Canada to pursue more sustainable rehabilitation practices for its low-volume roads. One of the greatest impacts from normal reconstruction and paving projects in heavily treed, mountainous terrain is the creation of large cleared areas resulting from road widening, re-alignment, and development of borrow and aggregate pits.

Parks Canada, in redeveloping several of its parkways, such as the Bow Valley Parkway within Banff National Park, chose to minimize and mitigate impact on terrain and vegetation by following the existing alignment and splitting the two-way roadway in several areas to permit the road to circumvent sensitive natural environments and, thus, reduce impact on terrain by grade separating the lanes (Fig. 2). Geometric standards allowed for the introduction of curves that were at a lower design speed than the overall roadway

Fig. 2. Lane separation Bow Valley Parkway.

Fig. 3. Hot-in-place recycling on the Trans-Canada Highway and Icefields Parkway.

and pavement widths with minimal 1-m shoulders, but with 5:1 landscaped sideslopes. These parkways have lower overall design speeds of 90 km/h and posted speeds of 60 km/h to accommodate sight-seeing and pleasure driving. Traffic is restricted to passenger vehicles, recreational vehicles, and tour buses.

Borrow and aggregate sources within parks represent a large negative impact on the parks. Usually located within valley bottoms close to streams and rivers, not only do they negatively impact on terrain and vegetation but, while active, can create a barrier to wildlife movement. Rehabilitation of these pits is often a long and costly process and can add significantly to the overall cost of a project, as does the alternative of trucking in material from outside the parks. Therefore, Parks Canada in recent years on the Icefield Parkway and the Trans-Canada Highway has embarked on a program of hot-in-place recycling of asphalt pavements to improve pavement surface ride, eliminate rutting, improve friction, and reduce cracking. Utilizing the existing highway asphalt pavement, the material is heated with a series of heaters and scarified into a windrow where an asphalt rejuvenating agent is added; the material is re-laid by a conventional paving operation, as shown in Fig. 3. The process thus avoids the need to open or expand existing aggregate pits that represent a limited resource within national parks and reduces air pollution from asphalt plant production as well as associated excavation, crushing, and trucking of material.

The cost of hot-in-place recycling is approximately \$20 000 per lane per kilometre as compared with \$10 000 per lane per kilometre for chip seal and \$50 000 per lane per kilometre for 60-mm hot mix asphaltic concrete overlay. Chipsealing requires the extraction of aggregate and requires potholes and other minor pavement deformations to be corrected prior to chipsealing. Whereas hot-in-place recycling does not improve pavement strength or correct severe pavement deformation, minor deformation and cracking can be corrected at approximately 40% the cost of a traditional overlay. This method of rehabilitation has been used by Parks Canada since 1993 on both low- and high-volume – load highways to extend the life of pavements by at least 5 years or longer if followed by a chipseal and to defer the need for more costly overlays.

Passing lane system on the Trans-Canada Highway

The Trans-Canada Highway (TCH) is the major route that transverses the Canadian Rocky Mountain national parks of Banff, Yoho, Glacier, and Mount Revelstoke and provides access via the Icefields Parkway to Jasper National Park, the Yellowhead Highway, and to Kootenay National Park via Highway 93 South. The TCH was officially opened in 1962 and at 7900 km in length is the longest paved highway in the world stretching from Pacific to Atlantic oceans. The TCH through the Canadian Rocky Mountain national parks shown in Fig. 1 was constructed as a two-way, two-lane highway, with 3.65-m lanes and 3.0-m paved shoulders. The design speed is 113 $km \cdot h^{-1}$ and the nominal posted speed is 90 $km \cdot h^{-1}$, although posted speeds vary between 60 and 90 $km \cdot h^{-1}$. The highway passes through level, rolling, and mountainous terrain.

Traffic volumes on this section of the TCH vary from a high annual average daily traffic (AADT) of 14 870 in 1997 at the Banff National Park east gate to a low of 4 400 in Yoho National Park. Summer average daily traffic (SADT) in 1997 at both locations was 21 580 and 8 380 in Banff National Park and Yoho National Park, respectively. Historical traffic data indicate a long-term linear growth trend of 2–2.5% per annum (Parks Canada 1999).

Traffic composition varies widely depending on season and time of day. Recreational vehicles can account for up to 25% of the traffic stream during daylight hours in summer months. Heavy trucks (semi-tractor trailers and combination units such as B-trains) can account for up to 50% of the traffic stream at night during winter months on the TCH in Glacier National Park.

Passing–Climbing lane system

It is recognized that twinning of the TCH through the Rocky Mountain national parks may be inevitable in the very long term. The overall strategy adopted by Parks Canada is to extend the design life of the TCH as long as possible as a two-lane facility, subject to maintaining safety and an acceptable level of service. This has been accomplished

Table 1. Passing and climbing lane system on the Trans Canada Highway in the mountain national parks.

Mountain national park	Number of passing and climbing lanes	Length of system (km)	% of total highway length in park
Banff[a]			
Eastbound direction	1	2.24	10.2
Westbound direction	3	4.50	18.0
Yoho			
Eastbound direction	6	17.30	37.7
Westbound direction	5	9.01	19.6
Glacier			
Eastbound direction	7	13.83	31.4
Westbound direction	5	9.63	21.8
Mount Revelstoke			
Eastbound direction	1	1.97	15.4
Westbound direction	1	0.93	7.3
Total number	29		

[a]Phase IIIA TCH twinning has replaced two passing lanes in Banff reducing the passing lane system from six to four.

by constructing a passing–climbing lane system and intersection improvements. The passing lane program will be followed by sequential twinning and grade separation of critical intersections.

Parks Canada pioneered the concept of a system of passing–climbing lanes in the early 1980s (Morrall and Blight 1985). This was a departure from previous highway engineering practice, which considered only isolated climbing lanes on long steep upgrades. During the early days of the passing lane project, conventional highway engineering studies continually rejected passing lanes in favour of twinning. Analysis procedures of the day, such as the 1965 Highway Capacity Manual (HCM) (Highway Research Board 1965), had served for two decades as the primary guide for determining the level of service on two-lane highways. The level of service analysis procedures in the 1965 HCM manual (Highway Research Board 1965) did not account for the effect of passing lanes on level-of-service. Therefore, it is not surprising that previous studies of the TCH (Transport Canada 1985) rejected passing lanes in favour of twinning. Although the then just released 1985 Highway Capacity Manual (Transportation Research Board 1985) included a number of refinements, such as the introduction of percent time delayed, average speed instead of operating speed, and the effect of directional split, in determining the capacity and level of service on a two-lane highway, the procedures still did not account for the effect of passing lanes on level of service.

To determine the need for passing lanes, and their effect on the level of service, a traffic simulation model of the TCH was utilized (Morrall 1987). The simulation model used was the TRARR (Traffic on Rural Roads) model developed by the Australian Road Research Board (Hoban et al. 1985). The overall objective of the level of service analysis was to determine if the TCH, with low-cost operational improvements such as passing lanes and intersection improvements, could provide an acceptable level of service until the twinning was required (Morrall and Thompson 1990).

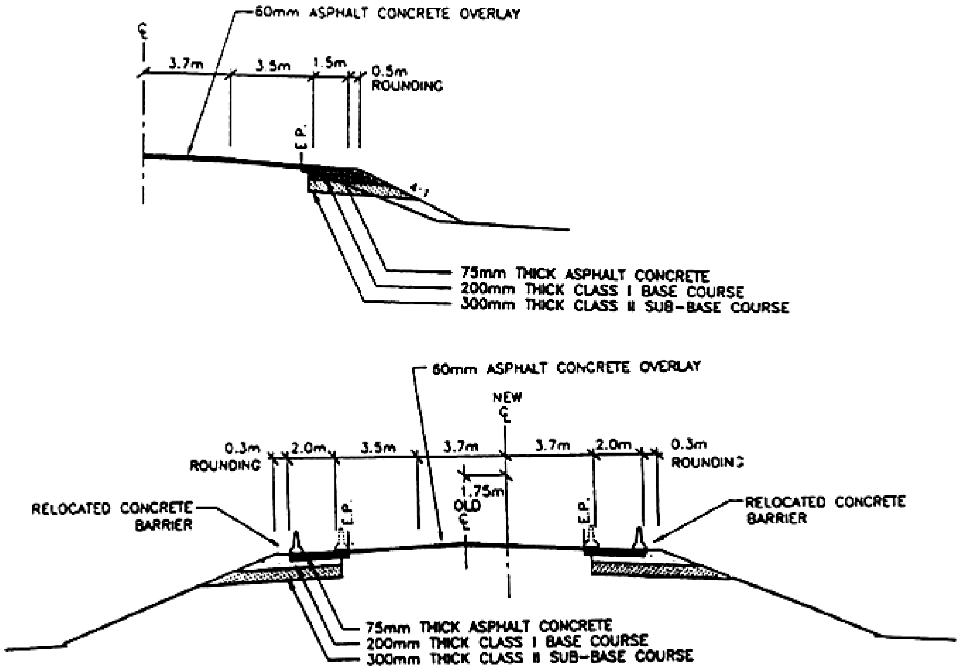
The need and location of passing lanes on the TCH was based on a criteria of 60% time spent following, which corresponds to level of service C in the 1985 Highway Capacity Manual (Transportation Research Board 1985). In Glacier National Park, identification of potential passing lane locations was also based on the need to increase traffic storage capacity to hold vehicles safely during avalanche stabilization as well as the aforementioned level of service criteria (Morrall 1991).

The passing–climbing lane system on the TCH in the four mountain parks consists of 29 auxiliary lanes, as summarized in Table 1, providing an average spacing of 8.3 km and 9.1 km between assured passing opportunities eastbound and westbound, respectively. While passing lanes and climbing lanes are classified as auxiliary lanes, they have two distinct functions. A climbing lane is an auxiliary lane provided for the diversion of slow vehicles from the through lane and, hence, the passing of slow vehicles on upgrades. A passing lane is an auxiliary lane to improve passing opportunities that are restricted because of roadway geometry, downhill grades, or lack of adequate gaps for passing in the oncoming traffic stream. A passing–climbing lane system consisting of 12 auxiliary lanes has been constructed on the Kootenay Parkway, and passing–climbing lane systems are under development for the Icefields Parkway and Yellowhead Highway in Jasper National Park.

The effect of the passing lane system has resulted in a 6–7% reduction in percent time spent following in the 500–700 vehicles per hour range, thereby keeping the overall percent time spent following to less than 60% and, hence, by definition, level of service C. A more important impact of the passing lane system is a 20–25% increase in the number of overtakings in the 500–700 vehicles per hour range (Morrall and Thompson 1990). An unique aspect of the passing lane system on the TCH are two downgrade passing lanes located on long downgrades in Glacier and Yoho national parks.

Construction of the passing lanes involved shifting the highway centerline by approximately 1.75 m and construct-

Fig. 4. Cross-section standards for passing lanes on the Trans-Canada Highway.



ing pavement widening on one or both sides depending on terrain, environmental constraints, and existing shoulder width. Shoulder widths were reduced to 1.2 m in the passing zone to minimize environmental impact and cost. Costs were approximately $90 000 per kilometre for widening on one side and about $125 000 per kilometre for widening on both sides, excluding final full-width overlay. Full-width overlay of the highway, once widened, added another $150 000 per kilometre. Depending upon the option selected, costs range between one tenth and one quarter the cost of twinning (excluding environmental mitigations). Figure 4 depicts typical cross sections of passing lanes.

Highway twinning

Project description

The need for twinning is based on maintaining an acceptable level of service and highway safety. The passing lane system on the TCH helped extend the design life of the highway as a two-lane facility by approximately 15 years. However, steadily increasing commercial, private, and tourist traffic has ultimately led to the need to commence twinning the TCH in Banff National Park in phases over the past decade (Parks Canada 1995). The latest 18.6-km stretch between Sunshine and Castle Mountain Interchanges, and known as Phase IIIA, was completed in 1998.

This section of the TCH prior to twinning comprised two lanes with passing lanes added in the early 1980s using existing shoulders to enhance the level of service as part of the strategy to extend the design life of the TCH. Accident rates were higher than the average Canadian two-lane highway and double that on the adjacent four-lane divided section. A level of service (LOS) analysis determined that for 2000 h of the year the highway was operating at LOS D and E which affected 1.6 million vehicles or 54% of the yearly volume of 3 million vehicles. Thus, this section of the TCH was operating well below the design LOS C. During summer months, daily volumes between 18 000 and 20 000 vehicles per day were recorded on a regular basis. In addition, this section had a high wildlife collision mortality, affecting the safety of the driving population as well as the animal population (Parks Canada 1995).

The phase IIIA twinning project involved the construction of 18.6 km of rural divided freeway with a design speed of 110 km (posted at 90 $km \cdot h^{-1}$). The cross section for each carriageway consists of two 3.7-m lanes, a 3-m outside shoulder, 2-m inside shoulder, and variable median widths averaging 14 m. Grades do not exceed 3% and the alignment was carefully fitted into the existing topography while making use of the existing two-lane highway. The east and west carriageways are separated by a grass median for a length of 14.1 km, by a treed median for a length of 3 km, and by a concrete barrier median for a length of 1.5 km. Constructed at a cost of $31 million, approximately 30%, or $9.2 million, was for environmental assessment and mitigation measures.

Environmental challenges and mitigation measures

The design and implementation of such a large-scale project in an environmentally sensitive and high profile setting as Banff National Park created a wide variety of challenges. The importance of addressing these challenges is reinforced by Parks Canada's legislated requirement to give the maintenance of ecological integrity and biological diversity the highest priority in management and administration of the parks. An extensive environmental assessment and public review process, lasting over 2 years, was undertaken prior to project approval. The main areas of environmental concern related to the project included potential effects on wildlife, vegetation, and aquatic systems. The success of any measures introduced to minimize effects of the project, as well as employing sustainable construction practices was reflective of a national park setting.

Fig. 5. Buried apron for wildlife exclusion fence.

Fig. 6. Animal overpass.

Wildlife

The highway follows along the bottom of the Bow River Valley, through a relatively rare montane ecosystem. The project area provides valuable habitat for a wide variety of wildlife species, including elk, deer, moose, wolf, black bear, grizzly bear, cougar, lynx, coyote, wolverine, as well as a number of small mammals, birds, reptiles, and amphibians. The primary concern resulting from the interaction between the highway and wildlife is the potential for vehicle–wildlife collisions, with resulting wildlife mortality, as well as human injury or fatality. Although ungulates represent the highest proportion of animals killed, population impacts are thought to be most severe for rare or uncommon species with low reproductive rates, such as wolf, bear, and cougar.

The problem of wildlife mortality resulting from vehicle collisions was addressed through the installation of 2.4-m-high wildlife exclusion fencing along the right-of-way. The fence height has proven adequate to prevent most species from jumping or climbing the fence. The fence is located as close to the highway as allowed by traffic safety clear-zone requirements and logistical constraints, except in a few areas with high aesthetic values. The fence fabric has a reduced mesh size varying from 150 × 150 mm to 50 × 150 mm at the bottom to reduce intrusion by smaller animals. A variety of wildlife species have been known to penetrate the exclusion fencing on previous projects by pulling up or digging beneath the fence. To reduce this potential problem, a 1.5-m chain link fencing apron was attached to the fence and buried at a 45° angle (shown in Fig. 5). Total cost of exclusion fencing was approximately $1.9 million with the buried apron representing 15% of this cost.

The use of fencing creates a barrier to movement for many species that require different, widely separated habitats during different seasons and phases of their life cycles. Due to concern over the effects of this habitat fragmentation on such rare or uncommon species, it was decided to try a particularly innovative approach to increasing the opportunities for wildlife to safely cross the Trans-Canada Highway. Two wildlife overpasses, 50 m in width and costing $1.75 million each, were constructed at locations determined by research and wildlife–vehicle accident data to be wildlife movement corridors (Fig. 6). A cross section of an animal overpass is shown in Fig. 7. The structures were built of precast concrete arches off site to allow rapid construction with minimal site and traffic disruption. The concrete head walls at the ends of the structures were cast-in-place using coloured concrete to match the large native boulders salvaged from the project site that were used to retain earth fill between, above, and on approaches to the arches. Fill salvaged from the project was used to create gentle approaches to the structures as well as 2-m-high berms along the outside of the structures to reduce traffic noise and visual disturbance. Approaches were shaped to retain maximum amounts of existing vegetation. Native trees and shrubs indigenous to Banff National Park were planted on and around the overpasses to provide wildlife cover and reduce the impact on aesthetics.

In addition to the two overpasses, 14 underpass structures of varying size provide additional crossing opportunities for a range of wildlife within this 18.6-km stretch of highway. These underpasses include two walkways in association with major creek crossing structures (Fig. 8), three 4 × 7 m elliptical steel culverts (Fig. 9), and four 3 × 2.4 m concrete boxes. Most underpass approaches have been designed and landscaped to provide maximum vegetative cover and have earth berms protecting the approaches from traffic noise and visual disturbance.

Vegetation and aquatic systems

The project had the potential to negatively impact both rare vegetation and aquatic resources through direct habitat loss and the introduction of potentially harmful surface runoff, including winter road maintenance salt, into sensitive vegetated wetland areas, streams, and the Bow River. The alienation of valuable existing montane that comprises 4% of Banff National Park's 6640 km^2 but where the majority of flora and fauna occur was also of prime concern.

Reduction in right-of-way width and avoidance of wetlands were achieved through careful alignment design, strict clearing limits, varying cut–fill slopes to lie between 2 to 1 and 3 to 1, and use of steep rock fills. These allowed the potential impact on vegetation and aquatic systems to be minimized. Colonies of rare plants were marked and brought to the attention of equipment operators to avoid disturbance.

Fig. 7. Cross sectional dimensions of animal overpass structure.

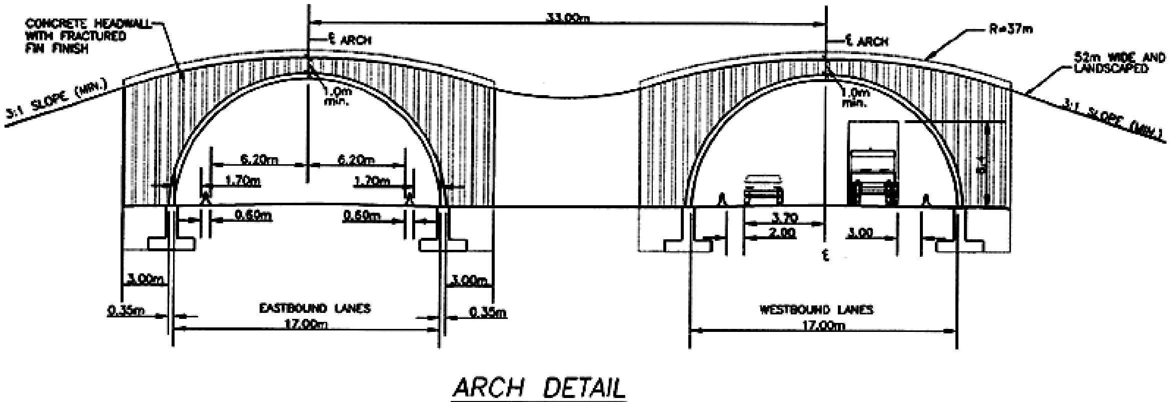


Fig. 8. Animal walkway at Redearth Creek.

Fig. 9. Wildlife underpass 4 × 7 m culvert.

The National Parks Act precludes the introduction of non-native species into park lands. Hence, seeds and cuttings were collected from native shrubs and trees along the road right of way and were used to start 49 000 seedlings within greenhouses that were subsequently planted to help rehabilitate disturbed slopes affected by construction. Disturbed areas were seeded with a native grass mixture specially formulated from commercially available species but which were reflective of the native grasses found in the project area.

Through much of the project area, the highway is in close proximity to the Bow River, as well as numerous sensitive wetlands. The Bow River system provides habitat for a variety of species, including endangered populations of native bull trout and west slope cutthroat trout. Associated wetlands provide habitat for waterfowl, semi-aquatic mammals, and amphibians.

The highway was designed to avoid encroachment on the Bow River and to minimize disturbance to streams and wetlands in areas adjacent to the project. This was primarily accomplished through the use of steep fills of coarse rock or pre-cast, coloured, and textured concrete reinforced earth retaining walls to match nearby rock. In the few cases where encroachment on wetlands could not be avoided, a no net loss objective was applied. A wetland habitat area, equivalent to wetland areas disturbed during construction, was built at a site near the new highway. It is expected to provide habitat for amphibians, waterfowl, and small mammals.

A variety of measures were undertaken to reduce potential negative effects during the installation of culverts and stream crossings by timing work to avoid critical fish life-phases and fully spanning the wetted perimeter of stream banks. To reduce both short- and long-term construction effects on water quality and aquatic resources, drainage was designed to flow into vegetated areas rather than into water bodies. Where this was not possible, settling basins or ditch blocks were built to allow settlement of suspended materials from road surface runoff and to contain hazardous material spilled during accidents. To reduce potential siltation caused by construction activities from entering streams and the rivers, settling ponds, ditch blocks, straw bales, and geotextiles were installed as required to slow and filter water through disturbed areas. Culverts carrying water year-round were installed at gradients compatible with fish passage, and culvert bottoms and outlets were lined with rock to reduce erosion and eliminate drops that could prevent fish passage.

Sustainable construction practices

The physical beauty of the project area and surrounding landscapes is a primary reason for the popularity and status of Banff National Park. Maintaining the aesthetic integrity of the project site and views were an important consideration during project design and construction, as was maintaining a minimum level of service C traffic flow through the construction area. The project traverses a variety of terrain types, including steep earth and rock slopes. Opportunities to avoid difficult terrain were limited by the proximity of the Bow River on one side of the highway, steep side slopes on the other, and a requirement to minimize the areal extent of disturbance and resultant habitat loss.

Tree clearing limits were designed to reduce disturbance while avoiding long straight edges, particularly in dense, uniform pine stands. Clearing edges were modulated to follow natural landforms. Tree limbs, stumps, and nonmerchantable debris were chipped and stockpiled for composting and use in future Parks Canada projects, thus avoiding traditional burning of grub and the resulting air pollution. Smaller diameter timber was bucked into firewood for use within park campgrounds or sold to contractors for use in furniture or log cabin rails. Merchantable timber was sold for lumber, posts, or rails with the proceeds applied against the cost of the project.

The new highway was designed to minimize its footprint by utilizing existing alignment and varying median width including centerline concrete jersey barrier sections to avoid wetlands and reduce the amount of terrain and habitat disturbance. Steep rock fills–cuts, downhill retaining walls, and the use of salvaged rock to improve stability of steep fill slopes helped achieve this goal. Cut slopes were shaped and modulated to avoid unnatural, uniform appearance. Natural gullies and ridges were continued from the undisturbed surrounding areas through the disturbed slopes wherever possible. Outcrops of rock were incorporated into slopes to create visible relief and contrast. To minimize off-site disturbance to landform, cuts and fills were balanced and most rock and aggregate materials were obtained from within the highway right-of-way.

Erosion potential was reduced through the creation of benches on larger cut slopes and rapid revegetation through hydro seeding and tree planting. In particularly steep areas, and areas adjacent to sensitive wetland habitats, a special tackifier and mulch was used. Siltation fences and other temporary measures were introduced to control erosion.

Maintaining traffic through the construction area was of paramount concern. Hourly traffic volumes were analyzed and blasting was scheduled to coincide with low-volume periods when the highway was shut down for no more than one half hour to allow blasting and clean up to occur. Blasts, therefore, had to be sized accordingly. A 1-800 number was advertised on radio and in newspapers for motorists to get daily information on blast-closure schedules. To reduce congestion through the construction zones, contractors were permitted to haul on the existing highway only at night. Animal overpass structures were designed with no false work, and detours were implemented only during daylight hours for the 7 days required to erect the precast arches for each overpass.

The major environment mitigation measures used during design and construction are summarized in Table 2.

Environmental monitoring

Environmental and design committees consisting of engineers, biologists, technicians, and administrators were established and met independently and jointly to review and solve environmental issues and concerns related to the project. A full-time environmental surveillance officer responsible for ensuring that the proper environmental protection measures were undertaken and that the committee's recommendations were implemented was hired. All workers on the project were given an environmental briefing outlining environmental rules, concerns, and expectations prior to the commencement of work. Regular meetings with contractors were held to assess performance related to environmental protection measures. Non-quantifiable items such as silt fencing and other erosion control measures were paid on a time and material basis to ensure prompt attention to these matters.

Physical construction of the subject section of highway is complete; however, the project will not officially be complete for several years. At the time of project approval, a commitment was made to carry out a detailed monitoring program to ascertain the effectiveness of mitigations. An intensive 4-year research program to determine the effectiveness of the TCH wildlife protection measures is underway. Ungulates, coyotes, cougars, and black bear have discovered and use all the crossing structures quite readily while wolves and grizzly bears seem to be needing a longer familiarization period. Table 3 provides a record of total through-passages by various species at the major animal overpasses and underpasses in the project area as of September 1999 (Clevenger 1999). Study results, while monitoring effectiveness of structures, also provides highway designers the opportunity to compare cost effectiveness of various structure types for future highway mitigation measures.

While the usage results are encouraging, the overpasses remain subject to high public and media attention. Most people are satisfied that $31 million was a reasonable expense for 18.6 km of highway to achieve the needed twinning and to protect Canada's flagship park, with 30% of that budget expended on environmental protection measures. Some specialized interest groups criticize that the highway continues to be a significant barrier to some species movement and further mitigations including elevating the roadway for significant distances need to be undertaken. Only time and the environment will ultimately judge the success of the mitigations and, hence, the project.

Summary

The corridor recapitalization plan for the Trans-Canada Highway through the mountain national parks of Banff, Yoho, Glacier, and Mount Revelstoke will extend the design life of the existing facility into the twenty-first century. Timely reconditioning and a system of passing lanes and climbing lanes will allow an acceptable level of service to be maintained for the design life. The passing and climbing lane system was constructed at a cost of approximately 10% the cost of twinning. However, as twinning is inevitable towards the end of the design life, all work proposed is compatible with that long-term objective.

The passing lane system in Banff National Park has extended the design life of the TCH between Sunshine and Castle Junction interchanges as a two-lane facility by approximately 15 years. Twinning represents a logical next step in a program of sequential twinning following the passing lane phase. The TCH twinning program, which began in

Table 2. Major environmental mitigation measures

Design
Highway footprint designed to minimize alienating land from park
Highway designed to minimize landform impacts and be aesthetically pleasing
Utilize steep rockfills to avoid wetlands and river
Minimize traffic disruptions
Construction
Chipping and (or) composting all grubbed and limbed material
All merchantable timber sold for lumber, post, and (or) rails (>125 mm diameter)
Smaller timber bucked up for park campground firewood
All old steel W-beam guiderail salvaged from highway recycled
All old creosoted posts recycled or disposed of in properly designated landfill
All surplus native topsoil stockpiled for future use
No falsework in streams. Work near streams restricted to late fall to early May
Cut–fill balanced to reduce off right of way impacts
Majority of granular material (260 500t) obtained, processed, and stockpiled on new right of way
All back slopes shaped and contoured to provide natural appearance
Angle of back slopes kept as steep as possible
Asphalt plant equipped with state of the art bag house to reduce emissions
All old asphalt pavement milled and re-used in road structure
Wetlands – fish habitat reconstructed to replace impacted areas (no net loss)
Existing culvert grades adjusted in potential fish spawning streams to permit fish passage again
Retention ponds – “Stormscepter” catch basins built to reduce siltation and (or) fuel spills into nearby watercourses
Temporary erosion control silt fences and straw ditch blocks installed to minimize siltation during construction
Total of 16 animal highway crossing opportunities built (approximately one per kilometre)of varying size including 2–50 m overpasses; 3 elliptical CSP underpasses (4 × 7 m), 4 concrete box culverts (2.4 × 3 m)
Special openings in concrete guiderail every 50 m to permit small mammals and waterfowl to cross
Entire length 18.5 km of highway fenced on both sides with 2.4 m high variable size mesh game fence c/w buried chain link apron
45 ha of road right of way and borrow areas mechanically seeded using special indigenous seed mix specially grown by or for Parks Canada
Old borrow pit used as storage and staging area partially rehabilitated for ungulate grazing
25 ha of special hydro seeding mix with tackifier plus special bonded fibre matrix to reduce erosion and encourage growth on steep slopes and near wetlands and watercourses.
39 000 lodge pole pine and white spruce seedlings grown from seeds collected within the park and planted
9700 native shrubs grown from seeds collected along right of way and planted
1500 plantation grown trees (1–3 m) and 2800 nursery grown indigenous shrubs planted
Full-time environmental surveillance officer on project keeping log
Full-time environmental mitigation evaluation team employed after construction
Environmental briefings conducted with all contractor staff at commencement of contract

Table 3. Wildlife passage frequency by crossing structure type Trans-Canada Highway twinning Sunshine to Castle Mountain interchanges Banff National Park.

	Number of crossings			
Structure type	Total	%	Average number of crossings per structure	Average construction cost of structure ($/m)
4, 2.4 × 3 m Concrete Box Culvert	416	18	104	2 800
3, 4 × 7 m elliptical CSP culverts	517	22	172	5 400
2, Creek pathways within open span CSP culverts	268	11	134	560
2, 52 m overpasses	1147	49	574	33 650

Note: Crossings between December 1997 and September 1999.

1979, now totals 47 km and is considered a leading Canadian example of a balance between highway development and environmental protection and mitigation. Figure 10 provides an overview of a twinned section of the TCH.

A wide range of environmental protection measures have been developed and advanced along this stretch of road, including extensive wire fencing in combination with animal crossing structures. Research has found that this mitigation

Fig. 10. Overview of a four-lane section of the Trans-Canada Highway in Banff National Park.

method has been effective in reducing wildlife–vehicle collisions by 97% for most species. Some species, such as ungulates, have adapted more quickly to using animal crossing structures than others such as wolves and grizzly bears. Monitoring of animal behaviour and usage continues to provide better understanding of how structural and landscape characteristics influence the effectiveness of animal overpasses and underpasses.

In summary, the highway investment strategy adapted by Parks Canada conforms to the environmental policy and code of ethics approved by the Transportation Association of Canada (1992). In particular, Parks Canada has been vigilant in the protection of surface and ground water, conservation of land resources, ensuring the protection and enhancement of natural habitats for the long-term survival of plants, animals, and aquatic life, as well as the preservation of historical and archaeological resources. Parks Canada has integrated environmental considerations into day-to-day activities and long-term decision making within the framework of an open communications policy with the general public and all stakeholders.

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