New Twist for Stabilized Roads

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Abstract

Surface grading, aggregate loss, and dust palliatives required to safely maintain heavily used gravel roads can approach $20,000 per km per year.

An example of this is the Tahsis Road on the West Coast of Vancouver Island. The road is multi-purpose, and serves as the only public access to a community, a main log haul route for Western Forest Products and numerous recreational users in the summer months. Complicating maintenance, the road has grades of up to 18 % and is used by industry's 150 tonne logging trucks.

In response, British Columbia Ministry of Transportation District Staff in consultation with others, commenced small scale field trials in 2000 for a **"New Twist" for a Stabilized Hard Surface Road.**

Three steps have evolved to the new relatively simple twist and are covered in this paper. Aggressive Base Stabilization is undertaken with high application rates of MgCl. After stabilization the surface is sealed, further strengthen and bonding surface created with a favourably charged cationic prime. Graded Aggregate Seal is then applied in a double lift to create the final wearing surface.

The end product when correctly applied results in a sealed hard surfaced road that will carry heavy loads. Ongoing surface maintenance costs such as grading and re-graveling have been eliminated. Ministry experience therefore suggests that the stabilization/sealing investment is a practical and economical process that even with a periodic re-application of a new wearing surface provides economic returns.

Acknowledgements

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1.0 Introduction

Public expectations are high and industry need for a smooth all season gravel road is a challenge.

It is widely recognized that grading and gravel resurfacing costs are in direct proportion to traffic volumes, weather and road alignment. Maintenance costs can approach $20,000 per year on busier resource roads.

An example of this is the road to the community of Tahsis on Vancouver Island. The road is the only land link to the outside world for residents and it is shared with the logging industry. The route is entirely gravel and terrain is mountainous.

In 2000 the Courtenay Office of the Vancouver Island District, in response to public pressure, undertook a review of existing stabilization techniques. Feric (Forest Engineering Research Institute of Canada), US Forest Service, Industry and MoT (BC Ministry of Transportation) experts were consulted for ideas and costs.

As a result of this review, a project team was formed to undertake a review and field test several more affordable options. Initial product was applied in 2000 followed by further testing and refinements in 2003 and 2005.

2.0 Background

2.1 The History

The Head Bay Forest Road (Tahsis Road) is a 62 km, mostly gravel, route that serves as the only road link for the residents of Tahsis to the outside world. Originally constructed by the forest company to access timber, there was little attention to grades or alignment. As a result grades of up to19 % exist in areas where the road traverses two different mountain passes.

The route continues to serve and is economically essential to logging operations. As a consequence, heavy industrial traffic (100 to 150 tonne) are permitted to use this route for hauling logs and heavy equipment to different dryland sorts.

In 1991 the MoT agreed to undertake maintenance responsibilities for this route due to the high percentage of public use. Unfortunately, MoT inherited the perennial washboard, pothole and dust complaints from the local road users and tourists.

Road improvements have been made (striving for a 9 metre width), however, the major funding required to reduce road grades to more acceptable levels has not and will not be found. The significant traffic which can approach 500 vehicles a day during the dry summer months, quickly pulls the road apart (especially on hills) resulting in significant and excessive washboard. Grading a particular section would occur two and three times a week during the busiest periods. Dust palliatives and base stabilization helped but when used at the recommended application rates became ineffective by late July due to lack of moisture.

Aggregate retention was also a big problem. Traffic, dust, heavy rain (annual precipitation of 3 metres or 120 inches), grading and snowplowing all contribute to surface aggregate loss. Others, FERIC [2,3] and Innovative [4] acknowledge and report on aggregate loss. For MoT, especially on hills, a re-gravel program every three years seemed to be required for maintaining a gradable surface at an approximate annual cost of $10,000 per km.

2.2 The 2000 Challenge

Tourism (west coast fishing is the big attraction), aquaculture, local residential use and industry all drive the need for enhanced road conditions.

Cost effective maintenance, especially on hills, is the challenge. FERIC [2] confirm that the cost of maintenance is a function of slope and traffic volume. As percentage slope doubles, grading costs almost double if a standard roughness factor is to be maintained.

In response to this challenge, the District Highways Manager had a project team formed and funding allocated. This team in 2000 reviewed existing documentation, life experiences, as well as the harsh weather and elected to try three affordable solutions for a more permanent stabilization method. Three initial hills were treated with aggressive techniques:

Gold River Hill - grades 11 to 14 % were stabilized with a magnesium chloride solution (MgCl) at an application rate of 3.4 litres per square metre and protected with a double lift of graded aggregate seal.

Conuma Hill – grades 15 to 17 % were stabilized with a magnesium chloride solution (MgCl) at an application rate of 4.0 litres per square metre without a graded aggregate seal.

JackPine Hill – grades 15 to 19 % were stabilized with B.C. Stabilizer at an application rate of 5.6 litres per square metre and protected with a graded aggregate seal.

On all three sites the depth of stabilization ranged from 75 to 100 mm.

Follow-up observations were made.

All three sites in the short term resulted in a hard, almost concrete like road base. However, on Conuma Hill the heat and dry summer weather in August resulted in the treated surface unraveling and the washboard returned.

The best performing and the most economical site seemed to be Gold River Hill. However, construction in this application was complicated by being unable to achieve a bond between the MgCl and the emulsion layers. Basically the High Float Emulsion used for Graded Aggregate Seal broke on contact with the MgCl used for stabilization. This premature break resulted in a lack of absorption or coating of the road surface aggregate which subsequently caused the High Float Emulsion to lift from the surface when the seal aggregate spreading process began. Bare patches resulted. Correction required re-applying emulsion and aggregate by hand sprayer and shovels prior to undertaking a second lift of Graded Aggregate Seal.

2.3 The 2000 Conclusions

BC Stabilizer required extensive mixing pre application (1 part water, 1 part lignosulfate and 1 part SS 1) plus significant more grader time to blend and work the product into the surfacing aggregate. MgCl was consequently significantly cheaper, quicker and easier to apply, however, possible leaching of MgCl and the reaction or pre-mature break of the emulsified HF 150 when it came into contact with MgCl was a concern.

The emulsion supplier was consulted and the situation explained. Catatonic/Anionic reactions were generally felt to be responsible for the lifting and premature "breaking" of the asphalt emulsion. Ludvik Mazuch presented a theory and explanation for this reaction in his Head Bay 2003 project report [1].

3.0 Developing the "New 2003 Twist"

3.1 Development

From a local MoT perspective it was recognized that if the 2000 project was going to continue, affordability and ease of construction needed to be the primary factors warranting consideration.

Time is money.

The aggressive application of MgCl, when covered with Graded Aggregate Seal, seemed to be performing well. However, in recognition of the earlier problems associated with lifting (lack of bond) and concerns of others relating to leaching led MoT to consider options that would improve durability and workability of the process.

Graded Aggregate Seal, especially when enhanced with a polymer modified high float emulsion (HF 150 P) is a flexible pavement. Notwithstanding, maintaining and enhancing road base strength is known to be critical for the long term life of any pavement.

3.2 Seeking Solutions

In British Columbia, MoT will apply an emulsion prime to prepared aggregate surfaces in advance of conventional paving. Knowing this, advice was sought from Industry, Ministry expert, (Ludvik Mazuch) and others from the local Mot office.

The Emulsion Supplier of the HF 150 P suggested a Cationic Primer (CSS 1). Consultation occurred with our Ministry expert and it was agreed that in theory this product could be a good fit. It was hoped that the Cationic MgCl stabilized gravels would be friendlier and less reactive to the like charged asphalt primer.

Closing a Provincial road for more than thirty minutes is not generally an option. Testing and product performance had to be workable for the public and MoT's contract crews. Consequently, testing was done of the CSS 1 in comparisons to SS 1 on numerous 1 (one) square metre gravel test sections to evaluate product performance. Curing time, bond to MgCl, penetration and overall stickiness to vehicle tires were considered. Furthermore, to enhance and evaluate prime penetration into MgCl stabilized gravels, water dilution of the cationic emulsion in differing ratios was undertaken and evaluated.

CSS 1 diluted (0.6 litres water to 0.4 litres CSS 1 water, at an application rate of 1.5 litres mixed product per square metre) was the maximum product quantity and dilution factors that could be applied to satisfied the above mentioned criteria. Asphalt penetration in all cases was limited to about 4 mm.

With the CSS 1 at the above mention ratio the road aggregate had a good coating of emulsion and a curing time of twenty minutes. The SS 1 in comparison did not have a good coating of aggregate and cured in ten minutes.

4.0 The 2003 Construction Process

Should a comparison wish to be made, the Tahsis road base is constructed with shot rock or native pit run gravel at varied thicknesses. Depth of these materials generally depends on whether it is a swamp, cut and fill or over native bedrock. Up-grading the road generally requires reshaping with pit run and recapping with a 100 mm lift of 19 mm modified High Fines Surfacing Aggregate. Steel drum rollers and rubber tired compaction equipment is used in this process.

4.1 Tahsis Road Aggregate

Naturally occurring gravels adjacent to the Tahsis Road all tend to be gap graded. When crushed, sufficient finer sand sizes are generally not available for easily fitting the product into the middle of traditional uniform gradation limits. Coarse aggregate is however available to obtain high fracture counts that can help carrying the heavy loads using this route. Leagh Pit, for example, will produce aggregate having an average 70 % fracture on a single face. Other pits, containing finer materials, typically produce fracture counts in the 55 % range.

Heavy rainfall and the need for an all season road, combined with other factors have led the Ministry to target fines content for High Fines Surfacing Aggregate into the 4.5 to 7 % range.

It may be of interest, that MoT used as a cost saving measure, surfacing aggregate from Leagh Pit as a MoT type A Graded Aggregate Seal Chip. For MoT purposes this saved considerable trucking or crusher mobilization cost.

4.2 Magnesium Chloride(MgCl)

This product is readily available on the West Coast of British Columbia and seems to be the preferred product by MoT contractors for dust control and stabilization of gravel roads.

Others have theoretically argued the benefits of MgCl over CaCl and Lignosulfates. Officially MoT takes no position. Should the reader wish more information the author has recently learned that the U.S. Army Engineers, Boeing and the Transportation Association of Canada have undertaken extensive testing of these products.

In British Columbia, this product is typically sprayed as a 30 % brine solution. Standard application rates for stabilization have been established at 2.0 litres per square metre for stabilization.

The **recommended aggressive treatment at 4 litres** per square metre is double the current MoT Standard for Stabilization. A very tight, hard, macadam-like pavement is the result of the application while optimum moisture conditions exist.

The aggressive application rate seems substantially higher than industry or suppliers typically have recommended to the author of this report. 4 Litres per square metre of MgCl will not be absorbed all at once in a 30 to 40 mm surface layer. Consequently, three methods for applying the product were used and evaluated:

> **Method 1:** grade and windrow 40 to 50 mm thickness of surfacing aggregate onto road shoulders. Apply 2 litres MgCl to the newly exposed surface. Allow it to absorb and possibly rework with grader. Retrieve the outside windrow, laying the gravel over the previously treated surface. Apply 2 additional litres over this new surface. Then work, shape and compact surface gravels to industry standards.

Method 2: grade and leave small shoulder windrows to catch surplus materials. Apply two litres MgCl. Apply 40 to 50 mm thick fresh surfacing aggregate followed by an additional 2 litre treatment of MgCl. Grade and re-compact.

Method 3: grade and apply 2 litres MgCl in year 1 to gravel surface. This allows the MgCl to penetrate the surfacing aggregate. The following year, grade and apply 2.0 litres, hopefully for the desired effect.

All three methods have been tried on the Tahsis Road. **Method 1** offers the greatest assurance of obtaining the desired amount of product to the right area. With **Method 3** the bulk of MgCl applied during year 1 seems to survive in the road base until year 2 however dilution and possible leaching is a risk and a concern.

MoT experience confirms that aggregate gradation is a factor that will influence MgCl absorption. Gold River Hill as an example continues to carry very heavy loads but the maximum MgCl absorption was 3.4 litres per square metre during the application process.

4.3 The Cationic CSS 1 Prime

Shades Tanker Service was the successful contractor for the application of CSS 1 and Graded Aggregate Seal. One distributor truck was to be used for both prime and seal application.

In preparation for applying the Cationic CSS 1, the glazed finish of the MgCl surface required scraping with a grader. Small windrows of gravel were left on the road shoulder to catch and prevent any surplus run-off from entering ditches. The CSS 1 and water were mixed in the distributor truck for twenty minutes. A single lane of traffic was closed and the mixed product was then applied to one lane of the prepared surface and allowed to cure for approx 25 minutes. Mot staff had already opted to modestly reduce product application rates from earlier test results to ensure over application of product was not achieved. Mix ratios applied to the road therefore leaned towards a little richer mix of 0.7 water to 0.5 litres CSS 1 which when combined, were applied at a rates of 1.3 to 1.4 litres per square metre.

Mix ratios were approximate from measurements taken at the back of tanker trucks and were therefore somewhat crude. In addition, MoT agreed the area to be sprayed had to be matched against the size of the available distributor truck.

Blinding Sand was applied using a conventional winter sanding unit. Pick-up of the prime by public vehicles was not a problem provided we were patient enough to wait for a cured road surface. In some cases, longer curing times were required prior to adding Blinding Sand. This was at least partially a function of ambient air temperature, moisture in the road and the amount of shading from overhanging trees.

The cured sanded primer was then opened to traffic and the same process was followed on the opposite side of the road. When the second lane was complete, the road surface was considered ready for Graded Aggregate Seal.

4.4 Application of Graded Aggregate Seal

Based on MoT experience, the emulsion selected in the graded seal mix design was a HF 150 P. The rubberized polymer enhances stickiness and gives the end product flexibility.

Basically, a double lift of Graded Aggregate Seal was applied over the CSS 1 prepared sections. Bottom lift aggregate for the 2003 trials was a Type A, 19 mm crush gravel from Leach Pit. The top lift in two instances was a Class D and on a third section, Stolz Creek, a Class A aggregate was used.

This work generally went well except for some equipment problems precipitated by the steepness of the terrain.

It is worth noting that the contractor's crew commented positively on the difference the pre-seal made to the overall smoothness and apparent hardness of the road.

4.5 Field Construction

In 2003, three sections were treated utilizing the above mentioned process:

- Conuma Hill: grades 17 to 19 %; MgCl applied per Method 2, length 1000 metres to a width of 7 metres

- Leagh Creek: flat area; MgCl applied per Method 3, length 1000 metres to a width of 8 metres

- Stolz Creek: grades 12 to 14 %; MgCl per Method 3, length 650 metres to a width of 6.5 metres

In 2005, two sections were treated utilizing only part of the above mentioned process:

- The top of Jackpine and the Tlupana Flats; however, these two areas did not get the full application of MgCl for reasons not covered in this paper.
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- Failures in the Graded Aggregate Seal have subsequently occurred.

4.6 Construction Costs

Unit costs are somewhat proportional to the amount of work being undertaken. Larger projects see economy of scale. On the Tahsis Road, MoT undertook small scale work on generally short 1 km or less segments. In addition, on Vancouver Island all materials come in via ferry and are trucked to the point of need. This adds significant expense.

Notwithstanding, and based on 2003 costs plus inflation it is estimated that current costs for this process on the Tahsis Road are estimated to be:

- MgCl applied - 29 cents per square metre x 4 litre per metre equates to $1.16 per sq metre.
- CSS 1 applied – 0.55 litres per square metre equates to 60 cents per square metre.
- Graded Aggregate Seal - two lifts per square metre generally equates to a cost of $4.10 per square metre.

Today's total cost for this small scale treated section is therefore estimated at $5.86 per square metre or $43,950 per km (at a 7.5 metre width). Larger scale projects, where material transportation costs could be reduced, would see savings.

4.7 Comments

1) Observations made during and immediately after the process confirms that the process is quite workable with limited non-specialized equipment.

2) CSS 1 absorbs most into little depressions or more open porous aggregate areas. After sanding, vehicle traffic further works the sand into these possibly weaker areas resulting in a noticeably harder, more uniform surface.

3) Application of HF 150P over the CSS 1 sealed and sanded surface seemed to improve workability for the subsequent application of aggregate. Perhaps this was a result of no HF 150 P loss into the road base.

4) After the fact, on a few occasions, tracked excavators and log loading equipment have sneaked onto or across the treated surface. Provided the operator does not try to aggressively turn his rig on the road surface no obvious damage is done.

5) MoT believes good quality **angular aggregate** combined with **positive drainage** is key and **essential** to developing road base road base strength. Where these conditions do not exist this "New Twist for Stabilized Roads" will most probably not succeed.

5.0 Conclusions

In 2007 the Gold River Hill, Jackpine, Conuma, Leigh Creek and Stolz Creek test sections all remain intact. Heavy traffic (150 tonnes) loads have been carried. Maintenance costs have been reduced by eliminating grading, gravel surfacing, and dust control costs. In addition, ditch cleaning and culvert clearing frequencies are reduced.

The public response is positive. From their perspective, it feels and looks like they are driving on pavement.

Environmentally, there is almost no airborne dust and water quality is improved by reduced road silt in ditches and creeks.

Earlier expressed concerns relating to leaching, winter chains damaging graded aggregate seal or vehicles excessively sliding off the road in the winter months has not materialized.

As an added bonus, the MgCl treated sections do not seem to freeze during the winter months which reduce frost damage.

- MoT Field results support and confirm that MgCl when aggressively used in high application rates to treated depths of 75 to 100 mms has significant load carrying capability. Lesser quantities or no quantities of MgCl have led to early surface failures.

- The Cationic Emulsion, CSS 1 sealer creates a most serviceable bonding surface for future application of Graded Aggregate Seal. Furthermore, the sealer tightens and absorbs most into the weaker more porous treated granular areas. Water proofing the surface is also believed to be enhanced.

- HF 150 P and CSS 1 when used as a sealer are compatible emulsion products. Early indications are that workability and effectiveness of the HF 150 P Graded Aggregate Seal is enhanced by the pre-seal operation.

- Graded Aggregate Seal is a wearing surface. Re-application of this surface will periodically be required in a single lift. Frequency for re-application is a function of traffic volume, road grade and surface aggregate type. On the Tahsis Road it is believed that this frequency for re-application is every 3 to 7 years.

- Provided that there is positive drainage from the road surface and that the wearing surface is maintained, MoT believes there is evidence to suggest at least a ten year life to this enhanced stabilization technique.

6.0 Recommendations

For extended load carrying capacity MgCl needs to be distributed through the 75 to 100 mm of surfacing aggregate. Saturation amounts will most probably vary with aggregate gradation. Gold River Hill stabilized in 2000 is a prime example of extra grading effort that continues to reward MoT with 7 plus years of useful life.

If a year is to elapse between applications of MgCl, such as Method 3, a heavier application of product in the second year should be considered and evaluated.

Cationic Prime emulsions cannot be sprayed or mixed with Annionic Emulsions unless thorough cleaning is done of distributor units. Two different distributor trucks, one for each product would be a desirable option.

Water used for diluting the Cationic CSS 1 is recommended to be at air temperature or a little warmer.

Larger sized, Graded Aggregate Chips holds winter sand better on the road. Ride ability for public vehicles in the summer months is not significantly affected.

7.0 References

1. Mazuch L. "Head Bay Graded Aggregate Seal Project", in house report, Geotechnical and Materials Engineering, British Columbia Ministry of Transportation (Summer 2003)

2. Provencher, Y. "Controlling the State of the Road Surface through Gradin Management, Feric (1994)

3. Bennet, D. "Performance Evaluation of a Tall Oil Pitch Emulsion for Stabilizing Unpaved Forest Road Surfaces" Feric (November 1994)

4. Innovative - Road Saver Brochure. Referenced in their materials are "US Army Corps of Engineers" (1986) Technical Report GL-86-20 and Colorado State University Study on the "Relative Effectiveness of Road Dust Suppressants".

Smooth Surface – Original Cross-section has been maintained

Stolz Creek-March 2007

Leagh Creek-March 2007

Gold River-Hill-March 2007

<u>a better view of "the End Product"</u>

Conuma Hill - March 2007: 17 to 19 % grade - Heavy winter sand on surface keeps the folks on the road in the winter months.

Evaluating The Cationic CSS 1

- Measuring

- Applying

- A few Test Sections

- Stickiness

Typical section of the Tahsis Road – Dust, potholes, washboard and loose gravel

A section of the Tahsis Road treated with MgCl - One of Western's logging trucks headed for a load

Grading in the MgCl - Freight truck, gravel truck and loaded logging truck on return trip

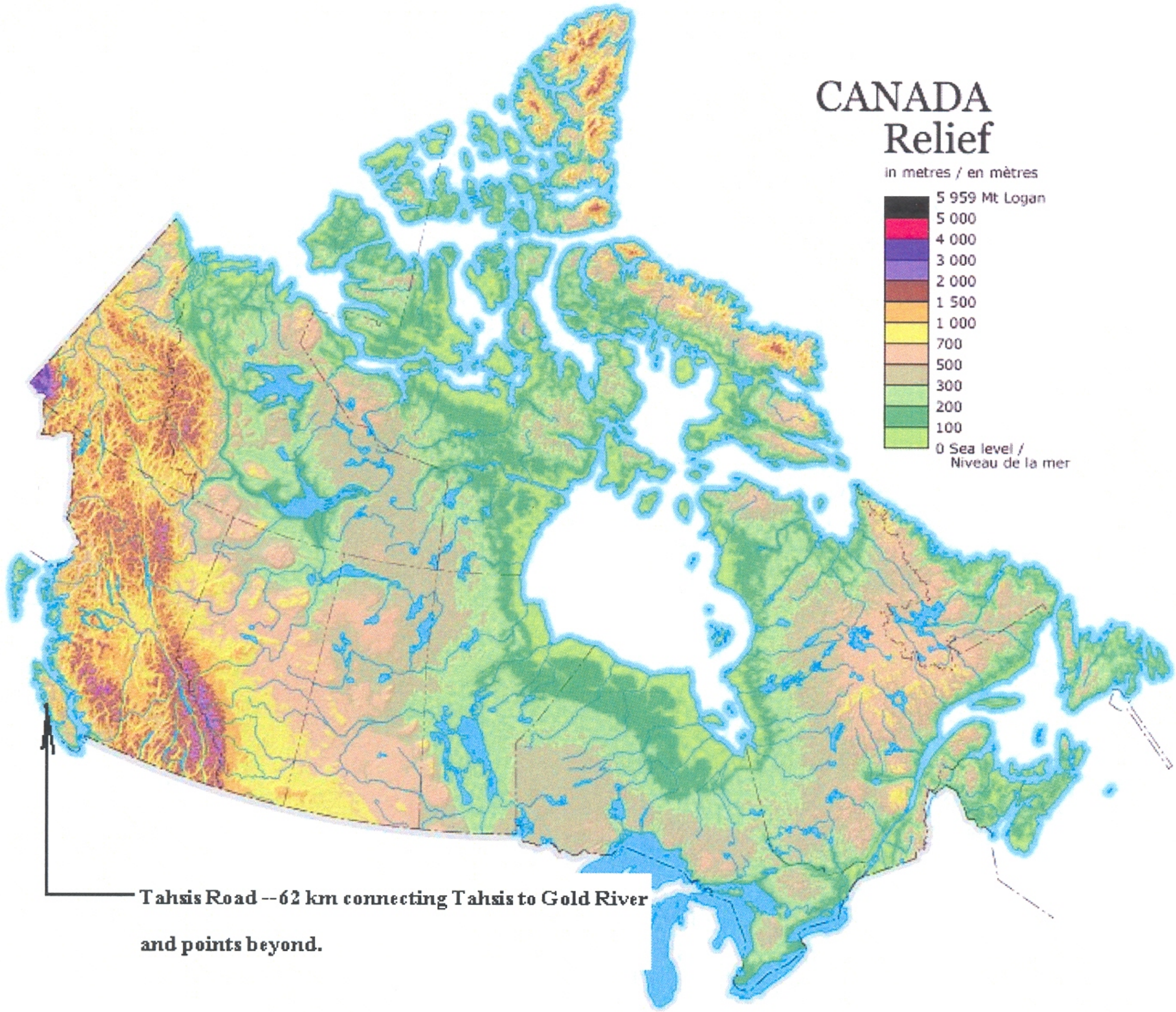
Spraying the Cationic Prime

CSS1 (on the left) applied over MgCl stabilization. Application was a mixture of 0.5 litres CSS1 and 0.6 litres water per square metre.

On the right a sand cover applied over the CSS1 that permits single lane traffic to be maintained. On the left, Shades Tanker Services applies bottom lift Class A Graded Aggregate Seal.

The dreaded early morning shaded section. After 20 minutes the product is still liquid and not cured.

Rolling the first lift of Graded Aggregate Seal. On the left, the sand over the CSS 1 sealed section is quiet dry and being rolled smooth by the traveling public.


CANADA
Relief
in metres / en mètres
5 959 Mt Logan
5 000
4 000
3 000
2 000
1 500
1 000
700
500
300
200
100
0 Sea level /
Niveau de la mer
Tahsis Road --62 km connecting Tahsis to Gold River
and points beyond.

The Weather is an added Challenge

Snow Banks
Late March 2007

Tahsis Road blocked by flood debris
November 2006

Heavy Rain destroys bridge approach
November 2006