ESTABLISHING EQUILIBRIUM SKID RESISTANCE

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ABSTRACT
The skid resistance of a road is not constant and changes throughout the year, being at its highest in the late winter and at its lowest towards the end of the summer. Throughout the year the level will change depending on periods of rainfall and dry conditions. Highway Authorities must ensure that measurements of skid resistance are corrected to remove these seasonal effects so that maintenance treatments can be applied in priority regardless of when the survey work is undertaken. This paper describes the processes and procedure that Transit New Zealand, the operator of the strategic highway network in New Zealand, has introduced to minimise the seasonal effects, both within year and between years. The paper also identifies the improvements that have been introduced since regular surveys were introduced in 1998 and those that are being considered for the future

1.0 INTRODUCTION

Transit New Zealand has undertaken annual surveys of the skid resistance available on the New Zealand state highway network since 1996. The measurements are collected by SCRIM, Figure 1, and reported in their Road Asset Maintenance Management system, RAMM. Transit chose to standardise network skid resistance survey's with SCRIM because:

- It is robust equipment;
- The slip speed of the test wheel is close to the speed at which peak friction is generated;
- The lorry mounted design with large water tank make the survey capacity compatible with the length of the annual survey requirement;
- A good correlation has been found with data provided by skid cars.

The consultants in each Network Management Area (NMA, 24 in all across the network) are responsible for reviewing the measurements of skid resistance and, where appropriate undertaking remedial treatments to maintain an adequate level of skid resistance in the wet. Road Controlling Authorities in New Zealand are responsible for maintaining road surfacings to minimise the risk of a crash and it is in this context that the management of appropriate skid resistance is important.

The skid resistance of a road is not constant and changes throughout the year, being at its highest in the late winter and at its lowest towards the end of the summer. Throughout the year the level will change depending on periods of rainfall and dry conditions, traffic density and vehicle mix. Results from 10 years of data collection in England (1), show not only that there is within year variation but also that between year variation occurs depending on whether or not the summer is wetter or dryer than average; a wet summer leading to higher levels of skid resistance recorded on the network and vice versa. Such extensive long term frequent surveys have not been undertaken in New Zealand, but spot measurements over several years, confirm skid resistance varies in a comparable manner.

It takes about 3 months to survey the whole state highway network of 22,000 lane kilometres in New Zealand. In order to compare the measurement of skid resistance measured by SCRIM across the network over that period it is

Figure 1. SCRIM

necessary to be able to eliminate, or at least minimise the effects of seasonal variation. Transit have continuously reviewed and improved their procedure for applying seasonal corrections.

It is important to appreciate that this paper is concerned with the use of measurements of skid resistance as a long term priority indicator for the asset management of seal programmes, which uses skid resistance measured in the wheel paths. It is not appropriate for the direct use of skid measurements for crash investigation, which is concerned with the surface properties at the time and under the conditions occurring at the instant of an accident on the drive lines taken by the vehicles involved in the accident.

2.0 SEASONAL VARIATION

The suggested explanation of seasonal variation is that in the summer when the roads are dry most of the detritus is ground to fine flour that acts like a polishing agent for the road surfacing aggregate under the action of tyres. In addition, over long dry periods there will be a build-up of contamination, including oil, grease, tyre rubber, silt, clay and in rural area farm cattle effluent. In the winter when roads are wet for most of the time the fine detritus is leached away leaving the larger gritty material under the action of tyres this grit provides a medium that roughens the stone chips and increases the microtexture and consequently the skid resistance.

A number of options were considered to collect data to enable the most appropriate robust correction procedure. These included:

- 3 or 4 repeat surveys over the whole network each year – rejected on the grounds of expense even though it would provide the best estimate;
- Reduce the length of the network survey and repeat 3 or 4 times – rejected because although the results would accurately define changes in skid resistance at the network level it would not achieve the primary purpose of the surveys which is to identify the location of areas with low skid resistance. In New Zealand polishing is able to be managed reasonably consistently. But chipseals may exhibit a rapid reduction in skid resistance towards the end of their lives due to bitumen near the road surface.
- Survey sample lengths 3 times per summer, one at the same time as the main network survey - selected as the most cost effective solution.

To minimise seasonal effects, testing is limited to the summer months each year. The variation over the summer is estimated from measurements taken on a number of seasonal control sites; there have been 70 sites used until recently but this has now been increased to 109. The seasonal control sites have been set up across the network. The sites are located so seasonal changes in skid resistance across 9 areas that have been identified as representing reasonably consistent climate conditions within those areas can be estimated. Each of the 9 areas is considered to represent different climate conditions. The areas represented by letters from A to L are shown in Figure 2a and Figure 2b for the North Island and South Island respectively.

2.1 Within year Seasonal Correction Using MSSC

These seasonal control sites are tested three times each summer and the measurements used to give a Mean Summer SCRIM Coefficient (MSSC) for each site. The three seasonal control site measurements are spread across the summer season with one measurement at the start of the survey programme, one measurement when the adjacent highways are being surveyed and one measurement at the end of the survey programme. The procedure is shown diagrammatically in Figure 3.

Figure 2a.
North Island Seasonal Control Areas

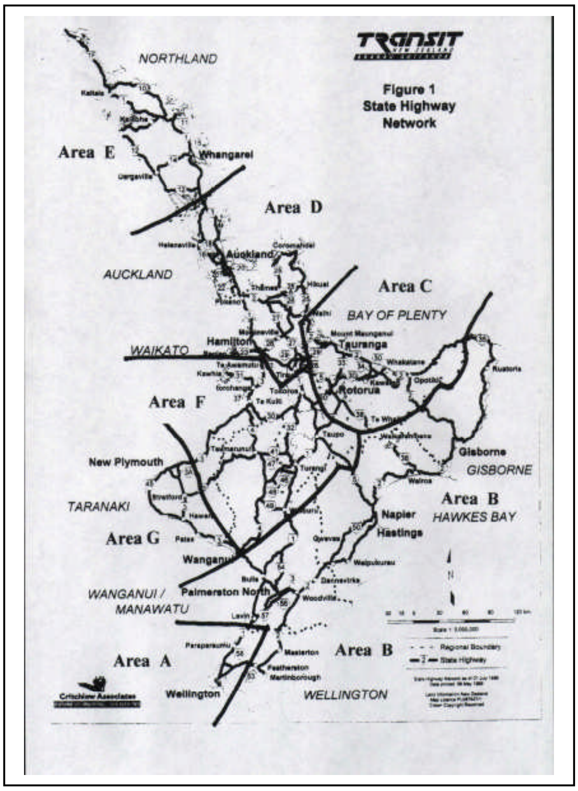


Figure 2b.
South Island Seasonal Control Areas

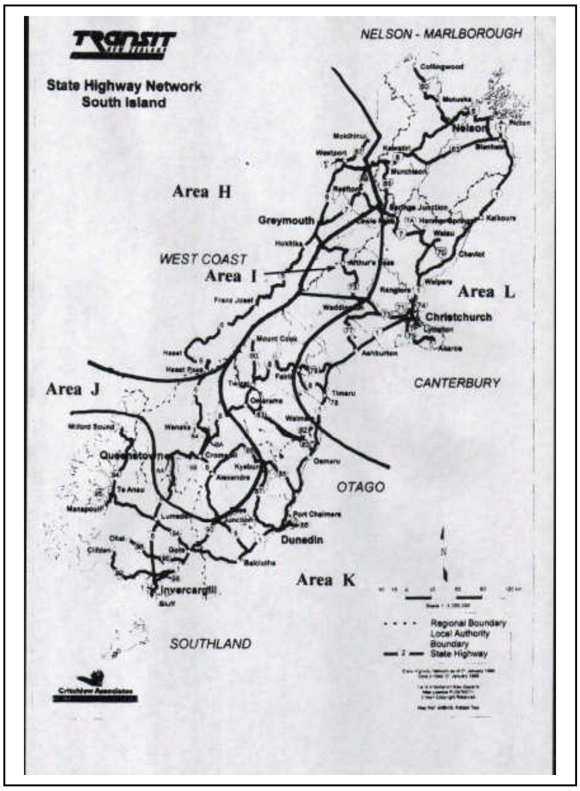
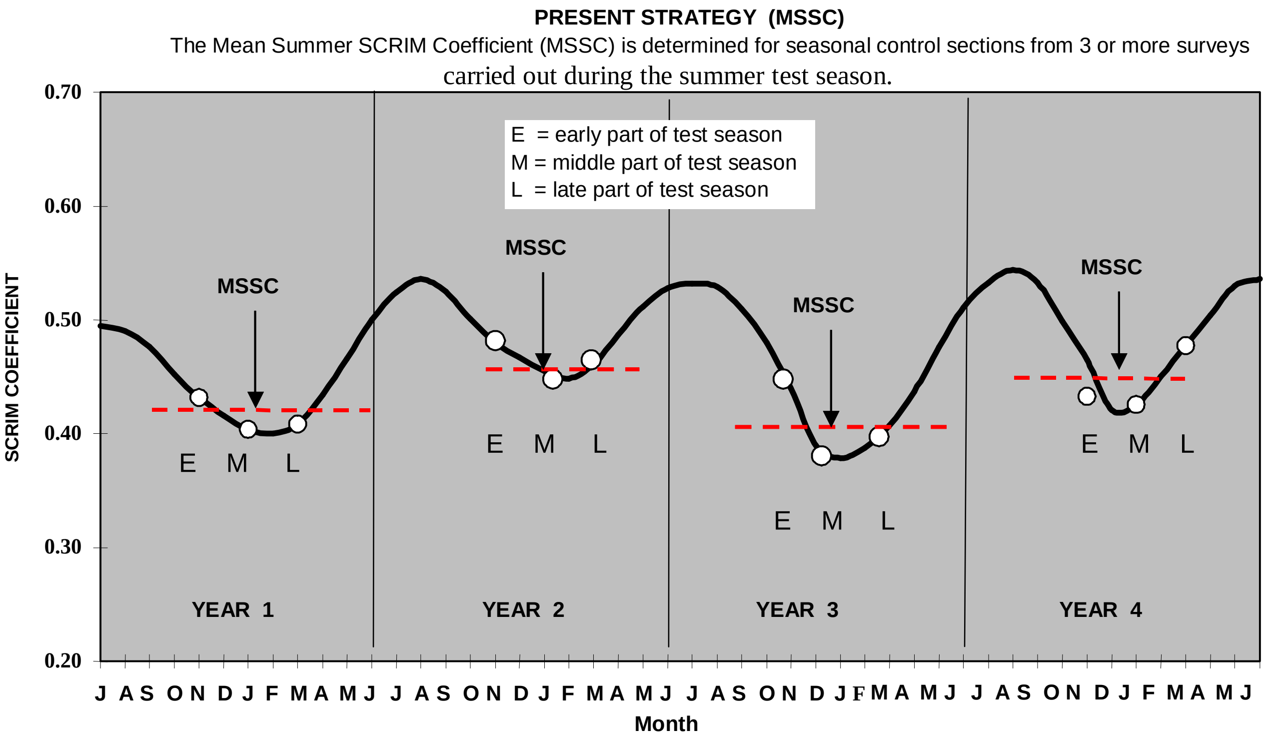


Figure 3. Procedure for Developing the MSSC at Each Control Site



The results from the seasonal sites allow network measurements to be corrected to a mean summer value, the Mean Summer SCRIM Coefficient, regardless of when the network was tested. This is done by calculating the correction factor necessary to convert the SC values recorded on the control site at the time the adjacent roads are tested to the control site's MSSC value. This correction factor is then applied to the network results within the climatologically similar area covered by each control site. An example of this is shown in Table1.

Table 1

Area Code	Site number	Run 1 Value 1st November	Run 2 Value 3rd January (main run)	Run 3 Value 20th February	MSSC	MSSC Correction Factor for Each Site	Mean area MSSC correction
H	45	0.539	0.581	0.564	0.561	0.965	
H	46	0.525	0.558	0.542	0.541	0.970	
H	65	0.554	0.592	0.541	0.562	0.949	
H	68	0.544	0.592	0.568	0.568	0.959	
H	69	0.568	0.631	0.634	0.611	0.968	0.962

The first column of Table 1 is the area code. Area H is a seasonal correction area for the South Island as seen in Figure 2b. The next column in the table gives the site number, which represents a 1 km length of road in area H. The next three columns show the SCRIM values obtained for the sites at different dates over the SCRIM season, in this case, November through to February. The MSSC column is the mean of the three readings for each site number. The MSSC correction factor is the MSSC divided by a particular run value that represents the date of the network survey for that area. In the example used in Table 1, it has been assumed the survey was performed in January therefore run 2 has been used to produce the correction factors. The final column is the mean of the 5 MSSC correction factors. To seasonally correct the SCRIM data collected in area H each of the 10 metre survey values is multiplied by the mean area MSSC correction factor.

Each of the seasonal control sites are 5 km long and the whole length is tested each year but currently only 1 km is used to calculate the MSSC. The remainder of the data is archived and can be accessed to provide continuity if the usual site has been altered in some way e.g. Resealed, water blasted. (

2.2 Between Year Seasonal Correction Using ESC

The MSSC provides a datum for controlling within year variations, however, New Zealand, in common with other countries, is experiencing year on year variations in weather patterns. This means that although the within year variation has been corrected the between year effects may be affecting the SCRIM results. This could have a significant role in selecting the correct allocation of funds in areas with lower wet road skid resistance if extreme weather conditions occur in any year. In a wet season, an unusually small number of sites would be below the investigatory level, while in a dry year, long lengths of normally acceptable skid resistance could be found to be deficient and require investigation. This could lead to situations where some sites will not be identified in wet years that in a normal year could fall below the investigatory levels established for use in New Zealand and visa versa for dry years. 2008 is an example of a dry summer in New Zealand and the correction for this years measurements could be of the order of 10% (NZ summer November 2007 – April 2008)

Transit has overcome this problem by using an Equilibrium SCRIM Coefficient (ESC). The principle used to produce the ESC factors is shown diagrammatically in Figure 4.

A four year rolling average is used for the ESC. The mean of the previous three and the current years annual MSSCs is calculated and this mean is used to produce an ESC factor for the forth year. The forth year area MSSCs are corrected for between year variations by applying the ESC factor. In the following year, the first year as shown in Figure 4 is removed from the calculation process and replaced by the latest year's MSSC.

Transit have decided to use four years and to use the current year but there are no hard and fast rules regarding the number of years to be used to produce the ESC. The number of years used is a balance between allowing for atypical years, not masking actual changes in the condition of the network and maintaining a reasonable pool of sites after losses through programmes of reseals. An example of the calculations used to produce the ESC is shown Table 2.

Figure 4. Procedure for Developing ESC for each area

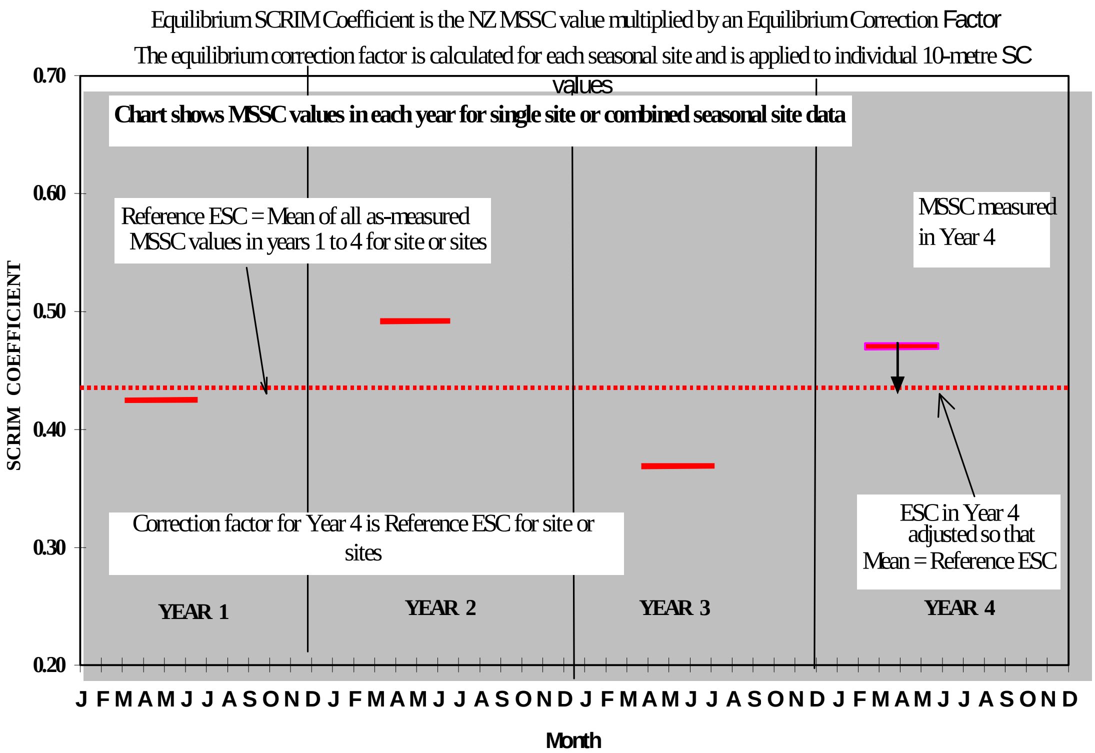


Table 2. Procedure use to calculate the ESC

Area Code	Site Code	Site MSSC 2004	Site MSSC 2005	Site MSSC 2006	Site MSSC 2007	Area MSSC 2004	Area MSSC 2005	Area MSSC 2006	Area MSSC 2007	ESC	ESC Correction Factor (2007)
H	45		0.619	0.587	0.501						
H	46	0.55	0.516	0.552	0.539						
H	65	0.562	0.582	0.551	0.565						
H	68	0.558	0.525	0.591	0.558						
H	69	0.612	0.522	0.63	0.588	0.571	0.553	0.582	0.520	0.556	1.070
J	72	0.579	0.545	0.605	0.576						
J	74	0.609	0.528	0.566	0.568	0.594	0.537	0.586	0.541	0.564	1.043
K	44	0.609	0.594	0.57	0.591						
K	49	0.47	0.432	0.463	0.455						
K	52	0.514	0.517	0.529	0.520						
K	70	0.606	0.562	0.548	0.572						
K	77	0.462	0.437	0.454	0.451	0.532	0.508	0.513	0.488	0.510	1.046
L	37	0.655	0.649	0.633	0.646						
L	38	0.567	0.531	0.538	0.545						
L	41	0.547	0.532	0.55	0.543						
L	66	0.535	0.49	0.507	0.511	0.576	0.551	0.557	0.509	0.548	1.077

In practice, because of maintenance work and other factors, four years of historical data is not always available. In those cases, it has been decided that three years of data will give a satisfactory result. However, in cases where there is less than three years data an ESC cannot be produced.

Column 1 of Table 2 shows the site codes for four climatologically similar areas. Column 2 shows the site number for the 1 km length of seasonal control site. The next four columns show the site MSSCs for each year. These are calculated by taking the mean of the three measurements over the summer season as shown in Table 1. Note that there is no data for Site 45 in the year 2004 but the three years of data can still be used. The area MSSCs are calculated by taking the mean of the site MSSCs for each areas H, J, K and L as shown in Table 1.

The area ESC is the mean of the area MSSCs. The 2007 ESC correction factor is calculated dividing the ESC by the area MSSC for 2007. In Table 2 the ESC correction factors are for 2007. Between year variations can vary typically from virtually zero for an 'average' summer, to ± 10% for exceptionally wet or dry years.
To seasonally correct for between year variations each of the 10 metre SCRIM coefficients that have been corrected for within year variation is adjusted by multiplying with the ESC factors for the particular area. In practice a total correction factor is provided for each area which is the product of the MSSC factor and the ESC factor.

3.0 PROCEDURE TO PRODUCE SEASONALLY CORRECTED DATA

The seasonal correction of SCRIM data is a critical activity because the factors can often change the measured values by ±5% and sometimes by ±10%; in the latter case this can represent 0.05 units of SCRIM Coefficient (SC).
The procedure used to produce seasonally corrected SCRIM data is shown on the Flow chart in Figures 5 and 6. The procedure uses comparative checks on data profiles each year as a first level check followed by viewing video images collected during the survey of the seasonal sites to confirm no changes have taken place. The process is also checked by an independent team before the corrections are applied and the results provided to area maintenance consultants to assist them to manage the network.

All data collected in the field from the seasonal correction sites is checked by the survey team by comparing the measurements and the calculated MSSC and correction factors with those used in previous years. Any anomalies are investigated by viewing the videos and interrogating the measurements in detail. If changes have occurred to the site then new 1km lengths are selected from the 5km seasonal corrections sites and the archived data recovered and inserted into the calculation spreadsheets. The survey team applies an internal audit on the results before data is supplied to an independent consultant for a second audit.

After audit the Combined Correction Factors are applied to the respective area. The seasonally corrected SC values are the values that are then compared with investigatory levels by the area maintenance consultants. (We need to use a consistent terminology)

4.0 FURTHER IMPROVEMENTS TO THE SEASONAL CORRECTION PROCESS

4.1 The number of sites

The seasonal correction process has generally worked well, although in some years a number of the areas had to be sub-divided because there was evidence that they were not exhibiting uniform behaviour across all the seasonal sites within the area. Where an area is split the number of sites in each sub-area is small; this left the process susceptible to loss of the ability to determine between year correction factors for those sub-areas if just one or two sites were removed, because of, for example, maintenance treatment. It was decided therefore to increase the number of sites to avoid this situation. This was done in 2007, increasing the number of sites from 70 to 109.

4.2 Method of calculating the correction factors

Occasionally, the correction process described produced anomalous results. When this occurred a detailed evaluation of the results was undertaken. It was observed from these detailed studies that rather than using the current procedure of applying a single correction factor based on the average level of skid resistance on the control site, it was more appropriate to produce a correction factor dependent on the level of skid resistance. This observation is entirely logical in that a small amount of polishing resulting from a dry period will result in a significant amount of polishing for an aggregate which has a harsh micro-texture but that the same amount of polishing will only produce a marginal increase in a similar piece of aggregate that is already smooth and polished.

A study is currently underway to assess the effect of introducing such a procedure at network level. The regression approach that is being investigated for correcting the main survey results for within and between year seasonal effects is identical to the single factor approach, except that the results are corrected using a linear regression equation generated from the MSSC and the main run survey over each of the control sites in an area.

The procedure is completed in two stages:-

- the MSSC linear correction equation is developed from the SC measurements combined for all sites in an area for each year by regressing the MSSC against the main run survey measurements;

- the ESC linear correction factor is developed from each years MSSC data combined for all sites in an area by regressing the average MSSC values (the ESC) against the current year MSSC values.

Conceptually the process is shown in Figure 7 for stage 1 of the process and stage 2 is identical changing only the axis titles to 'ESC' from 'MSSC' and 'current year MSSC' from 'main run'. The seasonal correction applied will vary according to the regression equation shown. Figure 8 shows the single factor process for comparison in the same format; a constant proportional change is made to all levels of skid resistance with this method.

When the regression approach was applied to the data it became evident that the method was much more sensitive to data quality, than had previously been appreciated. It is essential in the application of the regression approach that measurements from the seasonal sites truly represent exactly the same length of the network and that no effects due to non-seasonal effects are included in the data. The current process of determining the equilibrium correction factor is relatively insensitive to the influence of these errors in the data. When mean values are taken the cumulative affect of errors is small but when regression is applied the effects can significantly affect the slope and intercept of the regression line.

This methodology is still being explored, but the early results show promise.
A weakness of the regression approach can occur if the range of data from the 1 km long test section covers a small range of SC. The original reason for only taking a 1km length from the 5 km long seasonal control site was to ensure the SC values over the 4 year period were constant and to avoid a large amount of editing datasets. With the introduction of a regression approach, the benefits of using a wider range of SC (more likely to occur for a longer length of data) far outweigh the extra data handling that will be required.

Figure 5. Process diagram showing the production of MSSC and ESC and their respective correction factors for New Zealand, Part 1

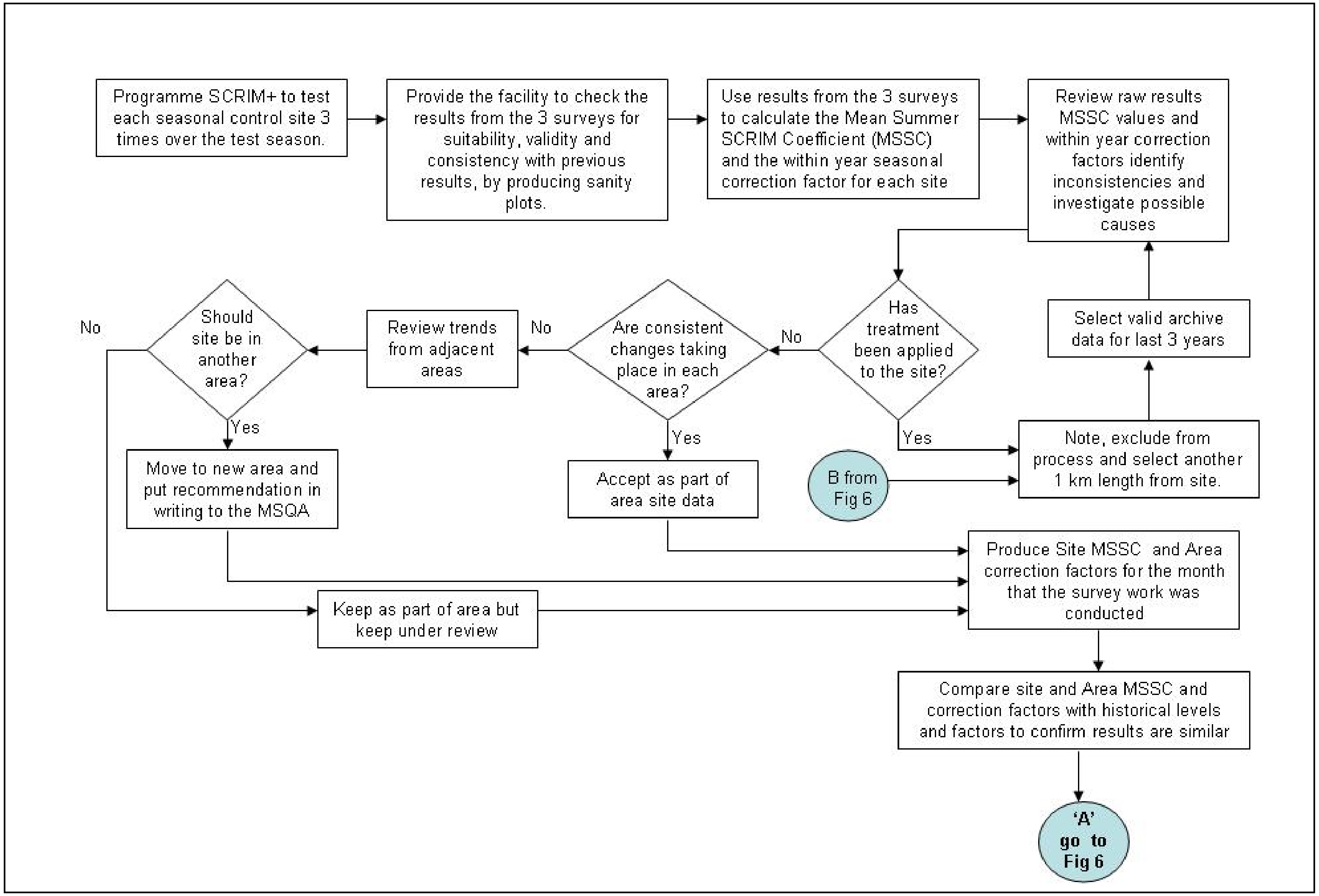


Figure 6. Process diagram showing the production of MSSC and ESC and their respective correction factors for New Zealand, Part 2

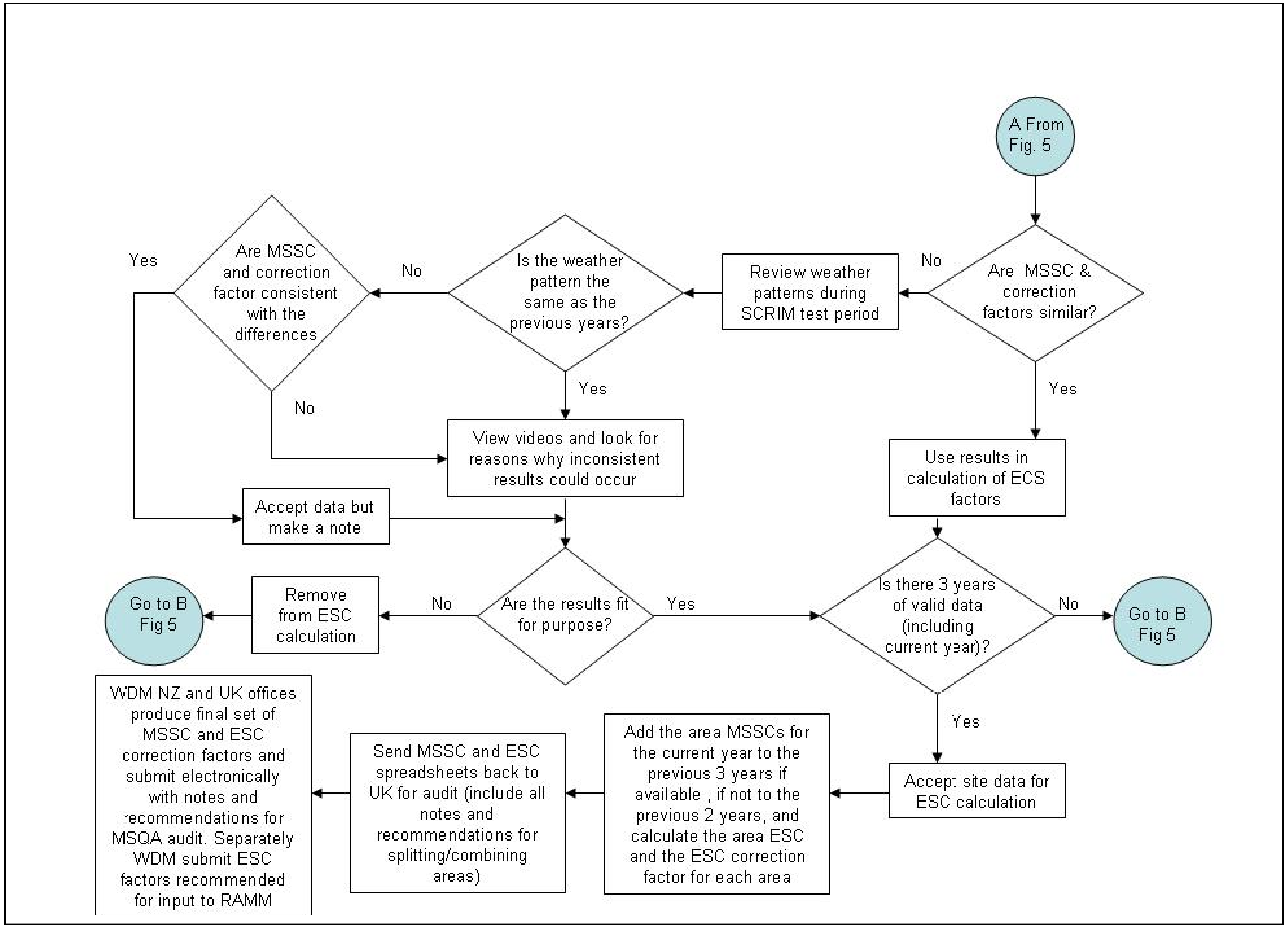


Figure 7. Main survey run regressed against MSSC for a control site.

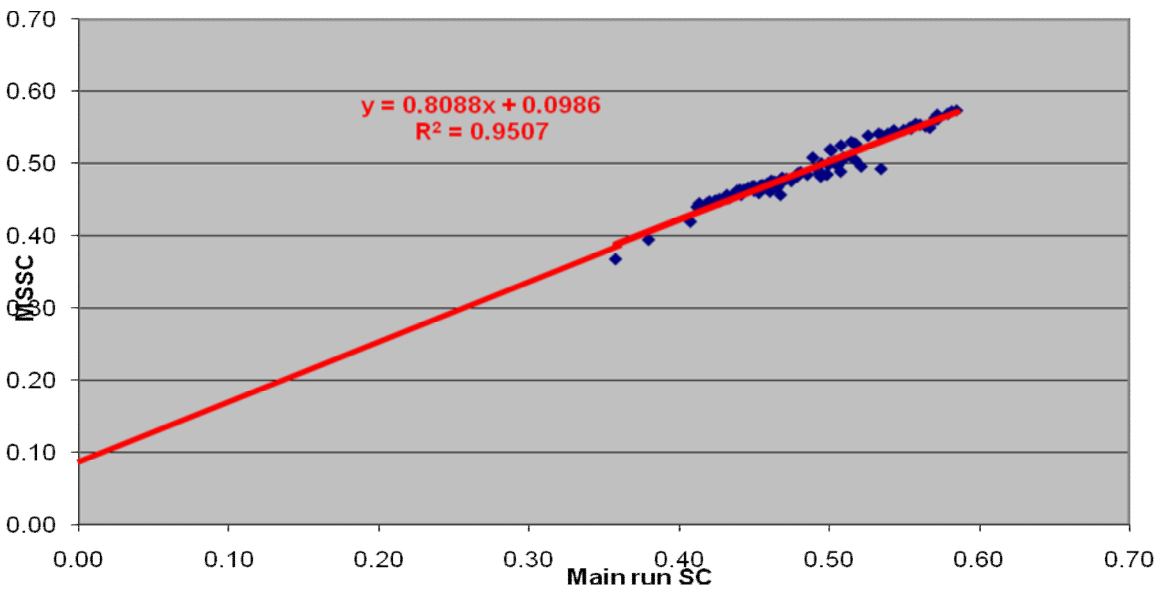
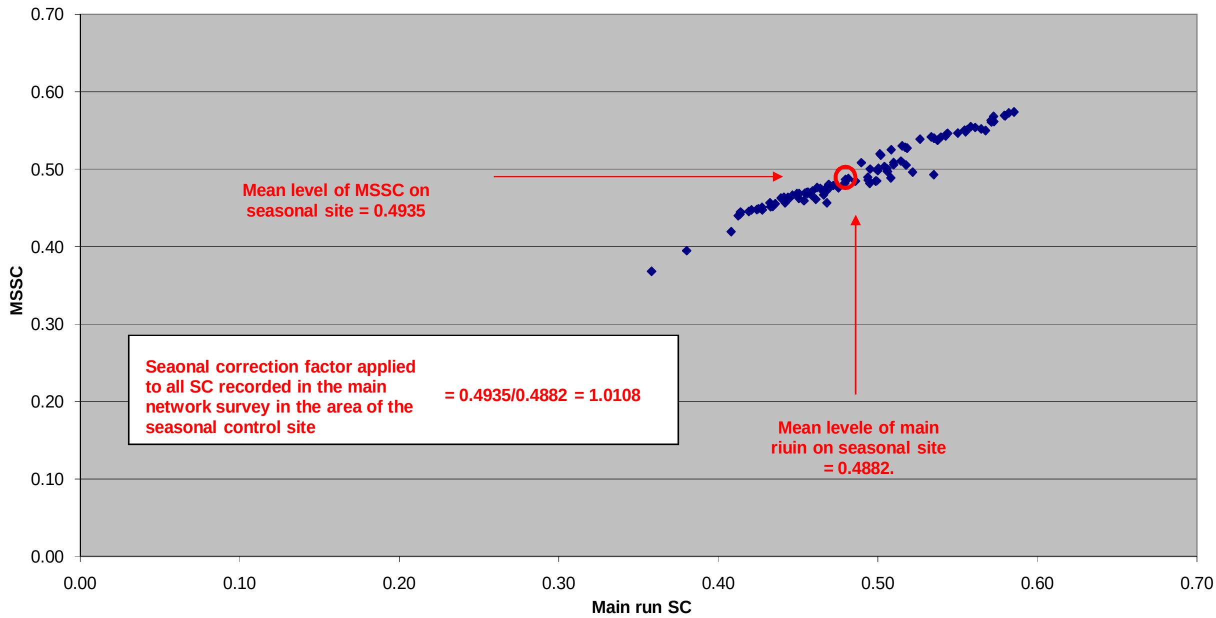


Figure 8 . Main survey run against MSSC for a control site with average correction factor determined.



4.3 Length of the seasonal control site data used in the analysis

From the work carried out on regression it has been decided that all valid data should be included in the calculation of seasonal correction factors. From 2008/09 all valid data will be used at every site; thus up to 5km will be used for calculating the MSSC and the ESC factors.

5.0 CONCLUSIONS

Seasonal correction is a very important part of the way Transit manages the skid resistance of its network. This paper has demonstrated the procedures used by Transit. The processes are detailed and carefully audited.

The general principles of the process have been applied over a number of years and it has shown to provide a reliable and robust method of correcting for seasonal effects.

The correction process has been updated periodically as knowledge has accumulated of the changes measured year on year. The most significant change has been the introduction of between year corrections, which were added to the within year correction process in 2004.

From 2007, 39 additional sites have been introduced to increase the number of sites and their spatial coverage in each of the 9 areas identified as having reasonably consistent weather conditions. From 2008, the full length of valid data from the full 5km length of the seasonal sites will be used in the analysis, rather than just 1 km as at present; this will increase the reliability with which the mean correction factors are determined.

Studies to assess the benefits of using a regression approach to create a range of correction factors related to the level of skid resistance are ongoing.

Reference

1. Hosking J,R. Woodford G,C. "Measurement of Skidding Resistance Part II. Factors Affecting the Slipperiness of a Road Surface" TRRL Laboratory Report 738, Transport and Road Research Laboratory, Crowthorne, Berkshire, 1976.