

Drivers' understanding of temporary and permanent slippery road signage January 2017

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Abbreviations and acronyms

ANOVA	analysis of variance
AWVMS	advanced warning variable message sign
ISO	International Organization for Standardization
LED	light emitting diode
MoTSaM	<i>Manual of traffic signs and markings</i>
MTA	Motor Trade Association
MUTCD	<i>Manual of uniform traffic control devices</i>
Transport Agency:	New Zealand Transport Agency
SCRIM	sideway-force coefficient routine investigation machine
SRS	slippery road surface
UK	United Kingdom
US	United States
USA	United States of America
VMS	variable message sign

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Executive summary

Research has suggested the signs currently used in New Zealand to warn drivers of lower than desired road surface friction are not well understood. With changes to the NZTA T10 specification in 2010, increasing the range of curves and raising the minimum standards for sideways-force coefficient routine investigation machine (SCRIM) investigatory levels for high-risk curves, the number of areas identified as having lower than desired skid resistance has increased. The NZ Transport Agency therefore identified the need to develop a consistent, understandable and cost-effective way of warning drivers of the potential for lower skid resistance in these and other areas renowned for periodic slippery conditions. In order to develop such an intervention, the NZ Transport Agency required the investigation of drivers' detection, comprehension and behavioural responses to slippery road surface (SRS) signs, which are intended to communicate to drivers that a road does not have the desired surface friction and/or may be slippery under certain conditions.

Literature review and public focus groups

During the research project, alternative sign designs were developed based on the ergonomic principles identified in the literature review (familiarity of sign, compatibility and standardisation). These were put forward for consideration by a representative group of the public alongside the current WR3 and TR2 signs in an interactive workshop. Participants in the workshop were asked to identify any issues associated with the current New Zealand SRS signs (WR3, TR2) and the alternatives, as well as provide quantifiable preference information on the current and alternative signs on each of the cognitive features. Participants were asked to indicate which signage option they thought would be best understood by drivers, and importantly why they thought this would be the case. Participants were also asked to indicate their preferences for the accompanying message on the supplementary plates. Participants were asked to identify ways in which they believed their understanding and anticipated response to the signs and text (both current and alternatives) could be improved further. Participants worked with the facilitators to produce a preferred design and shortlist their top three preferences.

Following the interactive workshop with the public, an interactive session, guided by the same principles, was held to elicit expert opinion on the current and alternative signage. The preferences of the Steering Group for the different signage options were established before the results of the public interactive session were revealed. The group then discussed and integrated these preferences in order to shortlist signage options for on-road testing.

After considering the findings of the public focus group and the discussions held by the Steering Group, the following three signage options were selected for on-road trial:

- 1 Main plate only (currently in use)
- 2 Main plate + new supplementary plate: SLOW WHEN WET
- 3 Main plate + new supplementary plate: SLIPPERY WHEN WET

All signs were tested using the temporary signage colour and dimensions.

On-road trials

The on-road trials of the selected signage options were conducted in three locations, representing three different curve radii: 250–350m; 150–250m; and less than 150m. The locations were identified through liaison with the NZ Transport Agency, and were coordinated in conjunction with Capital Journeys (the network outcome contract holder for the Greater Wellington region). All three locations were on SH58.

Driver behaviour was observed naturalistically, using speed as the key performance measure. Driver speed was obtained at each location using metrocount tube counters. In each location, metrocounters were placed following the signage, immediately prior to the start of the curve, to capture drivers' entry speeds. Changes in speed measured before the addition of any signs (baseline) and after the addition of each sign were used to demonstrate which of the signage options was most effective in producing the desired behaviour changes. Signs were in position for five weeks with data from the final two weeks analysed at each site to ensure any variation in speed caused by congestion, crashes and road works on a particular day could be controlled for along with any initial novelty effects.

Signs were erected from 16 November 2015 to 28 March 2016. There was a total of three rotations within this period, ensuring each signage option was tested at all three different curve radii. For each rotation, the signs were in position for a minimum of two weeks prior to the metrocounters being placed on the road. This aimed to reduce any novelty effect of the signs.

In dry conditions the signs made no practical difference to vehicle speed; however, in wet conditions the presence of a sign resulted in both a significant reduction in free vehicle speed in all three curves. Planned comparisons revealed that at each curve a different signage option led to the greatest speed reduction: 'Slippery when wet' at site 1; 'Slow when wet' at site 2; and no supplementary plate at site 3. 'Slow when wet' led to the greatest reduction in free vehicle speed in the wet from the baseline (no sign), across the curves, resulting in a 7km/h reduction at site 2. The average speed for each sign type by site can be seen in table ES1.

Table ES1 Vehicle speeds in wet weather by sign type at site 1

Sign type	km/h		
	Site 1	Site 2	Site 3
No sign	79.9 (10.3)	87.3 (8.9)	57.6 (5.3)
No supplementary plate	78.5 (10.1)	83 (7.4)	52.8 (5)
Slippery when wet	74.6 (8.4)	80.7 (6.8)	54.2 (5.8)
Slow when wet	75.6 (8.6)	80.1 (8.3)	54.1 (4.7)

Based on this iterative design and testing process the following recommendations were made to the NZ Transport Agency:

- 1 The literature suggests, and our focus groups support, the idea of maintaining the current signage 'syntax' or 'grammar' (ie shape, colour, placement) used in this country. For this reason, we recommend that SRS signs maintain the diamond shape with black on yellow (permanent) or orange (temporary).
- 2 A major point of discussion was the crossed tracks in the main plate icon. The focus groups revealed that while crossed tracks reduced the semantic closeness and concreteness of the icon in the SRS sign, they increase its meaningfulness to them by conveying a sense of potential danger and need for

caution. This was deemed likely to induce actual behaviour change in the form of reducing speed. It is therefore recommended that crossed tracks be maintained in any future icon development.

- 3 The on-road study found the presence of any SRS signage (the main plate only, main plate + 'Slippery when wet' supplementary plate, and main plate + 'Slow when wet' supplementary plate) significantly reduced driver speed in both wet and dry conditions (although reductions in the dry were not of practical significance). It is therefore recommended the NZ Transport Agency continue to signpost all areas where reduced surface friction is likely to impact on driver safety.
- 4 In two of the three curves tested in the on-road study, the addition of a supplementary plate resulted in a significantly greater speed reduction than the main plate alone. It is therefore recommended one of the supplementary plates tested in this study be added to the main plate in order to signpost temporary areas of reduced surface friction.
- 5 The supplementary plate 'Slow when wet' was associated with the greatest level of speed reduction at all three sites compared with no sign at all: vehicle speeds were approximately 7km/h slower when the 'Slow when wet' sign was in place than when no sign was in place. Given these results, it is recommended the SRS main plate be accompanied with the 'Slow when wet' supplementary plate in both temporary and permanent situations.
- 6 SRS signage is also used to signpost situations where surface friction may be reduced by factors other than wet, such as frost, gravel, concrete roads, and ice and grit. Supplementary signage currently exists for each of these conditions. We recommend the same message format shown to be effective in this study be adopted for these conditions too. For example, 'Slow when frosty' or 'Slow: ice/grit'.
- 7 The finding that the main plate alone is effective at producing a speed reduction means a full-scale replacement of all permanent supplementary plates and the addition of the supplementary plate to all temporary signage is not required immediately if this proves financially or logistically problematic. Instead, it is recommended these changes be carried out in conjunction with scheduled maintenance and when new signs are erected, potentially targeting higher risk locations earlier.
- 8 Although they were not the focus of this study, based on the findings in the literature review it is recommended the variable message warning sign, including the text 'Slow down', continue to be used at particularly high-risk sites, and its effectiveness examined in future research projects.
- 9 In terms of future proofing, the message, syntax and icon could be made available for inclusion in specific software updates for any in-vehicle message systems that include weather detection.

Abstract

This project aimed to assist the development of understandable, cost-effective static signage to warn drivers of the potential for lower skid resistance in areas renowned for periodic slippery conditions. The research began with a literature review in which the features influencing road signage effectiveness, in terms of both conspicuity and comprehension, were identified. Based on these findings, alternative signage designs were developed and investigated in relation to the current SRS signage through a public focus group followed by an expert focus group. The outcomes of this process led to the selection of two alternative supplementary plates to be used with the main plate. These signs were constructed to the temporary signage design specifications and compared to the current temporary SRS signage (which consists of a main plate only) in an on-road trial. Metrocounters measured the free vehicle speed associated with each of the signs at three different curves in both wet and dry conditions. In dry conditions the signs made no practical difference to vehicle speed; however, in wet conditions the presence of a sign resulted in both a significant and practical reduction in free vehicle speed in all three curves. Planned comparisons revealed the sign that led to the greatest reduction in free vehicle speed in the wet differed at each of the curves.

1 Introduction

Skid resistance, or road slipperiness, can affect the grip between vehicle tyres and the road and consequently the ability of drivers to maintain control of their vehicles. Skid resistance varies depending on road conditions and is most often an issue when roads are wet. Currently in New Zealand, locations where skid resistance is lower than desired are signposted by either an orange sign for temporary situations, such as roadwork activities, where skid resistance is reduced, or a yellow sign for situations where non-temporary conditions, such as climatic conditions (wet, ice, shading etc), can reduce surface friction.

Research (eg Charlton 2006) has suggested the signs currently used in New Zealand to warn drivers of lower than desired road surface friction are not well understood. With changes to the NZTA T10 specification in 2010, increasing the range of curves and raising the minimum standards for sideway-force coefficient routine investigation machine (SCRIM) investigatory levels for high-risk curves, the number of areas identified as having lower than desired skid resistance has increased. The NZ Transport Agency ('the Transport Agency') therefore identified the need to develop a consistent, understandable and cost-effective way of warning drivers of the potential for lower skid resistance in both these areas and other areas that are renowned for periodic slippery conditions.

To develop such an intervention, the Transport Agency required the investigation of drivers' detection, comprehension and behavioural responses to traffic control devices intended to communicate to drivers that a road does not have the desired road surface friction and/or may be slippery under certain conditions. This would allow the development of recommendations as to how best warn drivers of these potentially hazardous conditions and encourage condition-appropriate driving behaviour in both short-term (temporary) and ongoing (more permanent) slippery road situations.

1.1 Goal and objectives of the research project

The goal of this research project was to investigate drivers' detection, understanding and behavioural responses to traffic control devices intended to communicate deficiencies in road surface friction to drivers, and to develop a consistent and understandable way of warning drivers of the road surface friction deficiencies in adverse conditions. To achieve this goal, the researchers had the following objectives:

- Review the existing international and New Zealand literature and assess current best practice examples of signage used to indicate lower than desired road surface friction.
- Investigate issues of detection and comprehension with existing signage as well as suggested alternatives.
- Investigate driver behaviour in response to selected signage designed to communicate lower than desired road surface friction.
- Collate, integrate and workshop quantitative and qualitative findings in order to deliver recommendations on how best to warn drivers that the road surface friction is below the New Zealand investigatory level and encourage appropriate driving behaviour.

1.2 Key project stages

The research work consisted of four main stages, aimed at addressing the objectives identified in section 1.1:

- **Stage 1: A detailed and critical literature review of relevant literature and best practice.** This involved identifying how road surfaces below the investigatory level are currently signposted in international jurisdictions using both static and dynamic signage and the level of comprehension and detection associated with these signs; identifying the human factors principles found to influence road sign comprehension and detection; reviewing measures used to empirically investigate the impact of different road surface signage; and examining the impacts of signage on driver behaviour.
- **Stage 2: Interactive workshops.** This involved conducting two workshops. The first served to elicit qualitative data from the public on issues of detection and comprehension with existing signage, as well as the suggested alternatives (developed from the literature review), and to investigate the potential impact of each sign type on anticipated driver behaviour. The second involved an interactive session with the Steering Group to elicit expert opinion on the current and alternative signage and to contrast this with the public's opinions and preferences in order to shortlist signage designs for on-road testing.
- **Stage 3: On- road trials of shortlisted signage options.** This involved on-road testing to objectively measure the impact of the selected signage options on real-world driving behaviour, including driver speed, and workshopping a set of draft recommendations with the Steering Group to ensure recommended signage options are appropriate, practical and implementable.
- **Stage 4: Final reporting.** This involved incorporating findings from the qualitative and quantitative studies and final workshop, with an emphasis on providing recommendations to the Transport Agency for the consistent use of signage indicating road surfaces that are below the investigatory level for surface friction.

1.3 Report structure

Chapter 1 of this report introduces the project and the research objectives.

Chapter 2 describes the literature review findings.

Chapter 3 describes the interactive workshop methods and results

Chapter 4 describes the on-road trials methods and results

Chapter 5 integrates the findings from chapters 3 and 4 and sets out a series of recommendations for the consistent use of signage indicating road surfaces that are below the investigatory level for surface friction.

The appendices give further details of tools used and statistical analyses conducted.

2 Literature review

2.1 Introduction

The conditions that can result in lower than desired road surface friction are often non-permanent and unpredictable in their exact location, duration and the nature of the hazard they represent to drivers. This makes slippery conditions, including lower than is desired road surface friction, difficult to sign post (Carson and Mannering 2001). In New Zealand, road surface friction for the state highway network and a number of roads administered by road controlling authorities, is measured using the SCRIM methodology with reference to investigatory and threshold levels of skid resistance, see specification NZTA T10 2013 (NZ Transport Agency 2013). Locations where the SCRIM coefficient falls below the investigatory level for macrotexture and microtexture are prioritised for investigation and potential treatment.

This report discusses the signage currently used to depict lower than desired road surface friction, both in New Zealand and internationally and discusses how these signs are understood by drivers. It then reviews general ergonomic principles relating to signage comprehension and how these can apply to potential slippery road surface (SRS) signs. Following this, the report describes the impact of SRS signage on driver behaviour, before finally setting out recommendations for the alternative signage that was investigated in the subsequent phases of the research.

Figure 2.1 New Zealand permanent (code WR3) and temporary (code TR2) slippery road surface signs



2.2 New Zealand and international signage

2.2.1 New Zealand signage







The sign for both permanent and temporary deployment consists of an icon of a skidding car on a diamond plate (figure 2.1).

The permanent sign (WR3; NZ Transport Agency 2016) consists of a black symbol and border on a reflectorised yellow background. It is never erected alone and is combined with an approved supplementary plate informing the driver of the conditions contributing to the hazard. Approved supplementary plates are outlined in table 2.1, and also consist of black text and borders on reflectorised yellow backgrounds.

The temporary sign (TR2; NZ Transport Agency 2016) consists of a black symbol and border on a reflectorised fluorescent orange background, and can also be erected with a supplementary plate

according to the conditions. These supplementary plates also have black text and borders on reflectorised fluorescent orange backgrounds and can be mounted in either a standard form or with a backing board. These variations are also outlined in table 2.1.

Table 2.1 New Zealand slippery road surface traffic control devices

Traffic control device code and description	Supplementary plates for slippery road surface signs	Condition
WR31 Background: reflectorised yellow		Ice situations
WR32 Background: reflectorised yellow		Wet situations
WR33 Background: reflectorised yellow		End of seal situations
WG4 Background: reflectorised yellow		Used when hazard extends over long distances of multiple road hazard sections occurring in close proximity. May be augmented 100mm below WR31, WR32 or WR33.
Background: reflectorised fluorescent orange		For use with backing board
TR21 Background: reflectorised fluorescent orange		Ice and gravel situations

The signs are erected ahead of short hazardous road sections. Where multiple road sections occur close together, an additional supplementary plate is used to communicate the total distance for which the hazard warning applies. The minimum distance of how far ahead the sign is erected before reaching the hazardous road section is determined by the operating speed of the road. Examples of these distances are given in table 2.2.

Table 2.2 Signage distances by road operating speed

Operating road speed (k/h)	Distance (m)
50	65
70	100
90	140
100	160

The size and shape of the components of each sign, including the radius, side length, height, width, yellow/orange border width and black border width are specified for different sign sizes in the NZ Transport Agency (2008) *Traffic control devices manual* (see for example the slippery surface sign specifications on www.nzta.govt.nz/resources/traffic-control-devices-manual/sign-specifications/view/118).

Variable message signs (VMS) are also used in New Zealand to warn drivers of road surfaces below the investigatory level for surface friction. Figure 2.2 depicts the New Zealand VMS for a SRS. The Transport Agency's specifications for this sign, which is actuated by the speeds of vehicles, stipulate that above an adjustable lower limit between 10 and 20km/h below the speed limit the graphic be displayed and above a nominated upper limit the text also be displayed, with the sign remaining black at other times (NZ Transport Agency 2011b, p14)

Figure 2.2 New Zealand slippery road surface warning sign (NZ Transport Agency 2011b, p14)



2.2.2 International sign options

Symbols used internationally to depict lower than desired SRS or a road surface friction have similar features to the New Zealand signage. These are typically an image of an off-balance vehicle followed by tyre tracks. The main differences in the signs are:

- shape (mostly diamond as in New Zealand, Australia, USA, or triangular as in the UK and Europe)

- colour (mostly yellow/black, yellow/red, or red/white combinations for permanent signage)
- whether the vehicle tracks in the symbol cross or not.



The differences in the sign depend on whether it is cautionary, warning, permanent or temporary, though this is mostly communicated through colour.






Table 2.3 provides a summary of the different kinds of images used in static signage to communicate SRS to drivers. The model of the vehicle in the images differs by country as does the presence of a driver in the depicted vehicle and whether the driver is shown wearing a safety belt.

The symbols used are only capable of communicating a greater than normal skidding risk, but not how much greater the risk may be. This is because the level of risk is reliant on both the environment and car/driver specific factors. Examples of such include, but are not limited to, the road condition, speed and skid resistance.

The 1968 Vienna Convention on Road Signs and Signals and the 1971 European Agreement supplementing the 1968 Convention on Road Signs and Signals set out a system of shapes, colours and preferred symbols for road signage in order to enhance understandability of signs across international jurisdictions. Sixty-nine nations are signatories to the convention, although New Zealand is not one of them. For danger warning signs, such as for SRS, the Convention prescribes the use of either an equilateral triangle shape with a white or yellow background and red border or diamond shape with a yellow background and black border. These conventions are reflected in all the signs included in table 2.3 despite not all countries being signatories. Other signage types, such as prohibitory and mandatory signs, have their own specifications in the Convention. The symbol component specified for SRS signs in the Convention is shown at the bottom of table 2.3 and includes crossed vehicle tracks.

Table 2.3 Internationally used slippery road surface signage

Sign type	Examples of countries using similar variations of signs	Common features of signs	References
	New Zealand, Australia, Japan	Diamond shaped sign Either yellow or orange for use as caution, warning, permanent or temporary sign Symbol has crossing skid tracks	New Zealand 2012: www.nzta.govt.nz/resources/traffic-control-devices-manual/sign-specifications/?category=&term=slippery Australia: Safe Drive Directory Japan: National Police Agency of Japan 2011
	US, Canada, Brazil, Columbia	Diamond shaped sign Either yellow (permanent) or orange (temporary) Vehicle tracks are not crossing	US: US Department of Transportation 2009 Canada: Council of Uniform Traffic Control Devices for Canada 1991 Brazil, Columbia: Comparison of MUTCD-influenced traffic signs accessed 18 August 2014

Sign type	Examples of countries using similar variations of signs	Common features of signs	References
	Greece	Triangle shaped sign Red border Yellow background Vehicle tracks are crossing	All: Comparison of European road signs accessed 18 August 2014
	Sweden, Poland, South Korea, Finland	Triangle shaped sign Red border Yellow background Vehicle tracks are not crossing	All: Comparison of European road signs accessed 18 August 2014
	Britain, South Africa, Austria, Germany, Israel, Mauritius, Nepal, The Netherlands, Singapore, Switzerland	Triangle shaped sign Red border White background Vehicle tracks are crossing	UK: Department of Transport 2013 All: Comparison of European road signs accessed 18 August 2014
	Czech Republic, Italy, Norway, Ukraine	Triangle shaped sign Red border White background Vehicle tracks are not crossing	All: Comparison of European road signs accessed 18 August 2014
			Image A,9, Part 1: Convention on Road Signs and Signals – Annex 3. United Nations 1968

2.3 Comprehension of slippery road surface signage

Road signage comprehension has received a significant amount of attention in the research literature over several decades (eg Johansson and Bucklund 1970; Green and Pew 1978); however, only a small proportion of this literature has looked specifically at the comprehension of SRS signs. The studies that have included SRS signs and the specific findings in relation to these signs (where possible to determine from the literature) are summarised in table 2.4.

Of most relevance to the current research is the comprehensive study conducted by Charlton and Baas (2006) for the Transport Agency (also published in Charlton 2006). In this study, Charlton (2006) examined both static and dynamic comprehension as part of a suite of measures designed to assess the effectiveness of hazard warning signs used on New Zealand roads. Static comprehension involved the

presentation of a still image of a sign and participants verbally stating its meaning. Dynamic comprehension was measured by participants in a driving simulator, steering a yellow circle in the image to keep it approximately 15m ahead on the road. When participants encountered a warning sign they were required to press on the brake pedal and name the sign aloud. For SRS signs (both permanent and temporary), Charlton (2006) found comprehension accuracy ranged from 50–70% for dynamic comprehension and 84–94% for static comprehension. For both measures these were the lowest percentages of the 16 hazard warning signs assessed. When these results were combined with other measures, including attentional and search conspicuity and implicit and explicit recognition, and ranked, the two SRS signs performed worst compared with the other hazard warning signs tested. As a measure of comprehension Charlton and Baas concluded that dynamic comprehension had greater external validity but the static comprehension results showed greater concordance with other measures and other research. In either case, the SRS signs performed poorly.

Charlton's (2006) findings reflect similar results found by Dewar et al (1997) in a study examining comprehension of the signage set out in the *Manual on uniform traffic control devices* (MUTCD) (Department of Transportation 2009). The SRS sign was found to be one of the 12 most poorly comprehended signs out of the 86 MUTCD signs tested, with only 44.6% of people correctly identifying its meaning. This compares with warning signs indicating pedestrian crossings and playgrounds which were identified correctly by 91.9% and 96.6% of participants respectively.

In contrast, Shinar et al (2003) found, of the 31 signs tested in a cross-cultural study including populations from five different countries, the SRS sign was one of 10 signs correctly identified by over 90% of participants. In a follow-up study Ben-Bassat and Shinar (2006) found the SRS sign was one of nine signs correctly identified by over 90% of participants. Bazire and Tijus (2009) found 97% of their participants were able to correctly identify the SRS sign.

Table 2.4 Studies comprehension of slippery road surface signage

Study	Signage	Method	Slippery road surface sign findings
Charlton (2006); Charlton and Baas (2006)	New Zealand signage	Static and dynamic comprehension using driving simulator	SRS signs performed worst across suite of measures
Dewar et al (1997)	US signage	Static comprehension of projected images	Correctly identified by 44.6% (bottom 12 of 86)
Shinar et al (2003)	Signage common to Israel, Finland, Poland, Canada, Australia (plus some specific to each)	Static comprehension using image cards	Correctly identified by more than 90% of participants
Ben-Bassat and Shinar (2006)	Signage common to Israel, Finland, Poland, Canada, Australia (plus some specific to each)	Static comprehension using computer	Correctly identified by more than 90% of participants
Bazire and Tijus (2009)	French signage	Identify the sign as real or pseudo	Correctly identified by 97% of participants

Dewar et al (1997) reported a number of participants interpreted the SRS sign as meaning a winding or rough road and Charlton (2006) also found the permanent SRS sign (PW41) was identified by some participants as a winding road warning, while the temporary SRS sign (TW4) was identified as a road works warning. In the dynamic comprehension task some participants simply identified these signs as 'some

warning sign'. Although these findings represent only two studies, they point to the potential for an alternative design of the SRS sign to enhance comprehension. The following sections set out the design principles developed from more general studies of comprehension of road and other hazard warning signage that have implications for the design of alternative SRS signs.

2.4 Ergonomics principles guiding signage comprehension

Redesigning road signs in accordance with ergonomic principles has been shown to enhance signage comprehension (Dewar et al 1997). Three ergonomic principles have been identified as significantly correlated with the probability of drivers correctly comprehending traffic warning signs (Ben-Bassat and Shinar 2006):

- familiarity
- compatibility
- standardisation.

Familiarity relates to the frequency with which drivers experience a sign; compatibility relates to the degree of correspondence between the symbols and text making up a sign and the message it is attempting to convey; and standardisation relates to the consistency with which the colour, shape, symbols and other features of the sign are used to represent that particular message. While it is not possible in the design process to influence drivers' familiarity with a specific sign, it is possible to include sign features that are familiar to drivers from their use in other forms of signage. If these familiar components are used in a manner consistent with other signs it is possible to achieve a high degree of standardisation leading to higher levels of comprehension. The specific design features reflected in these ergonomic principles relate to either visual features (eg size, shape, and colour) or cognitive features (Ng and Chan 2009).

2.4.1 Visual features

Visual features are governed to some extent by the ISO (2011) Standard 3864-1 for graphical symbols – safety colours and safety signs. Part one of this standard specifies the shape and colour of signs and the relationship between sign dimensions and sight distance; part three specifies size of borders, exclusion zones, and the shape and size of human forms used; and part four gives the chromaticity coordinates and luminance factor for object colours of ordinary materials, phosphorescent materials and unpowered internally illuminated safety signs under external illumination. The ANSI Z535.6 American National Standard for Product Safety Information in Product Manuals, Instructions, and Other Collateral Materials (from the American National Standards Institute) also governs colours, symbols and text used to provide warnings and information. The ANSI standards are not entirely reconciled with the ISO standards, but a degree of harmonisation has been attempted (Hall et al 2006).

Specifications for the size and shape of the New Zealand SRS signs are given in the *Traffic control devices manual* (www.nzta.govt.nz/resources/traffic-control-devices-manual/sign-specifications/?category=&term=slippery). Research suggests drivers are influenced by the particular 'grammar' used in the signage they are exposed to (Bazire and Tijus 2009), for example, diamond shaped signs represent a particular type of information/warning, while round shaped signs represent another.

Disrupting this grammar can have a negative effect on comprehension, therefore it is not advised that the shape or size of the SRS be altered outside the current specifications. Despite the influence of grammar, Bazire and Tijus (2009) demonstrated the drivers' main focus when interpreting road signs was on the icon or symbol component of the signs. Hence, the remaining chapters of this report focus on the colour and symbolic features of the signage.

The use of red in warning signs has been shown to denote the highest level of warning, and is associated most strongly with hazards across cultures (Ng and Chan 2009). The use of red is consistent with drivers' expectations that red requires attention and potentially indicates warning or negation. In New Zealand red is associated with stop signs, lane closures on motorway VMS signs, wrong way signs and road closure signs. The use of red on SRS signs may, however, denote too high a level of warning, given that the conditions that may result in reduced road surface friction (eg when wet, when there is gravel on the road) will not be present at all times. A red diamond shaped sign may also appear too similar to stop signs (red being strongly associated with stop/go indication), potentially leading drivers to suddenly slow when it is not necessary or when it may be dangerous to do so (eg in heavy traffic), causing rear-end collisions. Maintaining a yellow background for permanent signs and an orange background for temporary signs would be consistent with the New Zealand signage syntax; however, minor adjustments to colour could be of some benefit. For example, the use of fluorescent versions of yellow/orange could be investigated. In part 1 of the *Traffic control devices manual* (NZ Transport Agency 2010, chapter 8) fluorescent orange and yellow-green are already approved for use on some signs in New Zealand because these colours have been shown to enhance detection, conspicuity and recall of signage without causing distraction. The manual recommends fluorescent materials be used in situations where visibility is poor, high levels of conspicuity is required, or where a high percentage of drivers are older drivers. Fluorescent orange is required for temporary traffic control and fluorescent yellow-green is approved for permanent warning signs for vulnerable road users such as pedestrians and cyclists."

2.4.1.1 Visual conspicuity

Although the primary focus of this research was on the comprehension of SRS signage, a brief discussion of visual conspicuity is necessary when discussing the visual features of signage. This is particularly the case given that the weather conditions most likely to result in reduced road surface friction, and where it is most important that signage options are effective in leading to desired behaviour changes, are also likely to reduce sign conspicuity (ie adverse weather conditions). Conspicuity refers to the extent to which a sign can attract drivers' attention. Two sorts of conspicuity have been examined in the literature: *attention conspicuity*, which refers to an object's capacity to attract attention, or to be noticed when the observer has not been directed to specifically look for its occurrence. The other is *search conspicuity*, which refers to the capacity of an object to be located rapidly and reliably in a search (Cole and Hughes 1984). Measures to increase conspicuity of road signage include changing the size, colour and reflectivity of the signage; however, there are relatively few studies that have investigated the impact of these changes. Summala and Hietamaki (1984) found that adding flashing lights increased attentional conspicuity (also see section 2.6 for discussion of the impact of flashing lights on driver behaviour). In the New Zealand context, Charlton (2006) examined the attentional and search conspicuity of 16 hazard signs. The temporary and permanent SRS signs were the worst performing of the tested signs for attentional conspicuity (both having less than a 20% detection rate) and the permanent (yellow) SRS sign also poor performing in search conspicuity (less than 30% detection rate), while the 'red' temporary sign had a detection rate of over 65% in the search conspicuity task. Interestingly Charlton (2006) had included new colour combinations (yellow-green) and larger format versions of two of the hazard warning signs, but contrary to the pattern of results for other signs, these were found to *decrease* in the search conspicuity task. Charlton (2006) suggests this may be the result of participants having noticed these

signs, but not felt they constituted a hazard or hazard warning. This contrasted with the flashing VMS format that was much more likely to be identified by the participants when scanning for hazard warnings. These results indicate while visual conspicuity is important, comprehension of the sign as indicative of a hazard is highly important.

2.4.2 Cognitive features

McDougall et al (1999) describe five cognitive features that are important to consider when designing comprehensible symbols or icons. These are:

- familiarity: frequency of encounters
- concreteness: depicting objects in the real world, opposite to abstract
- complexity: amount of detail
- meaningfulness: relevance/instructiveness
- semantic distance: relatedness or closeness of symbol to what it represents.

Ng and Chan (2007) tested the importance of these factors in the 'guessability' of traffic signs and found that signage guessability was best predicted by semantic distance (referred to as semantic closeness in this work), ie the closer the icon to what it was intended to represent, the easier it was to guess its meaning. The remaining factors were also all significantly positively correlated with signage guessability. Higher levels of familiarity were the second-best predictor of high guessability, followed by higher levels of meaningfulness, concreteness and then simplicity (the inverse of complexity).

Ou and Liu (2012) also found all five design features were significantly related to comprehension, with semantic distance relating most strongly; however, in this research this was followed by meaningfulness, concreteness, familiarity and simplicity.

Other research has found only one of these design features to be significantly related to comprehension. McDougall et al (2001) found the correlation between semantic distance and comprehension was the most significant, while in a later study to the one described above, Ng and Chan (2008) found only familiarity was significantly related to comprehension. Going beyond road signs, Wang and Chi (2003) found meaningfulness was correlated with comprehension of hazard warning icons. Many of these studies examining the factors related to symbol comprehension and effectiveness are summarised in Zhang and Chan (2013) and Ng and Chang (2009).

These cognitive design features are highly interrelated (McDougall et al 1999; Ng and Chan 2008) and also map back to the higher level ergonomic principles described by Ben-Bassat and Shinar (2006). The familiarity of a symbol or icon is obviously related to the overall familiarity of a sign, while the concreteness of a symbol may contribute in part to the level of *spatial compatibility* – defined by Ben-Bassat and Shinar (2006, p83) as the 'physical arrangement in space, relative to the position of information and directions' – with which a sign is associated. Likewise, the level of meaningfulness of a symbol is likely to relate to the *conceptual compatibility* – defined as the 'extent to which symbols and codes conform to people's associations' – associated with a sign. There are notable similarities too, between *physical representation* – defined as the 'similarity between the content of the sign and the reality it represents' and the design feature semantic distance. Spatial compatibility, physical compatibility and physical representation are all sub-components of Ben-Bassat and Shinar's (2006) compatibility principle. This demonstrates the linkage between symbol design and overall comprehension of signage.

Interestingly, although it would be in line with the concept of semantic closeness and physical representation, none of the SRS signs identified internationally depict water on the road surface or rainy conditions. This is despite these conditions being relevant to the warning provided by the sign. This maybe the result of adhering to other design features, particularly simplicity; however, a search for images of pedestrian 'slippery when wet' signs revealed that symbols of water in the form of a puddle on the ground have been included in some of these signs (see figure 2.3). This was, therefore, considered a possible adaptation for the on-road SRS signs to be examined in the next phase of the project.

Figure 2.3 Pedestrian slippery when wet signs depicting water



(Sources: www.safetysign.com/products/p1846/caution-slippery-when-wet-sign,
www.safetysign.com/products/p21341/caution-slippery-when-wet-sign,
www.pbp1.com/Property/Product/Parking/Lot-Supplies/A-Frame-Signs/SFS104)

2.4.3 Text component

As well as the symbolic components of signage, it is important to consider the accompanying text components. In New Zealand the permanent SRS sign is always presented in conjunction with a supplementary plate (as shown in table 2.1). However, the temporary W3-2 SRS sign does not have a supplementary plate unless it is associated with ice/grit (W3-2.1). Including a text element alongside the pictorial element of the directional information or map-type sign is important for enhancing comprehension. Early studies into the recognition of symbolic road signs (eg Ells and Dewar 1979) suggested symbolic representations were better comprehended by drivers, particularly in reduced conditions. More recent studies, however, indicate traffic signs that include a combination of text and symbols are more likely to be correctly comprehended and are also comprehended faster than symbols alone (Shinar and Vogelzang 2013). The addition of symbols to signs was only found to enhance comprehension over text signs when the symbols were familiar to drivers (Shinar and Vogelzang 2013).

Currently in New Zealand, for situations where the road surface friction is below the investigatory level as a result of adverse conditions, the supplementary plate WR32 is used (see table 2.1). The text on this sign is 'When wet', making the interpretation of the warning as a whole dependent on the interpretation of the SRS sign, as this alone provides drivers with the information about *what* is to be expected when the conditions are adverse. In other jurisdictions, permanent SRS signage is not accompanied with a warning in text form; for example, in the UK the *Traffic signs manual* (Department for Transport 2013) specifies only that the permanent and temporary SRS signs can be accompanied by a distance sign and does not specify any other supplementary plates. Likewise, in the US, the MUTCD (Department of Transportation 2003) does not specify supplementary plates for permanent SRS signs. However, there are also examples where supplementary plates describing the risk of SRSs more fully are used, for example, in Canada with the text 'slippery when wet' (Council of Uniform Traffic Control Devices 2014). This same text is also used

on supplementary plates in the US in conjunction with bicycle SRS signs (Department of Transportation 2003). In the UK, where the road surface is slippery due to loose gravel a supplementary plate with the text 'Skid risk' is used; however, the loose gravel sign is different from the SRS sign and it is specified that the 'Skid risk' sign can only be used with the loose gravel sign (Department for Transport 2013).

Both 'Slippery when wet' and 'Skid risk' are advantageous because they explain the risk in full without relying on comprehension of the symbolic component of the SRS sign. What these text messages do not contain, however, are action words that indicate the desired behavioural response they are aimed at inducing in the drivers. Including a direct reference to an action or behavioural response in the message text may increase drivers' ability to respond appropriately. In this context such text could include 'Slow down when wet', 'Caution when wet', or 'Reduce speed when wet'. The text 'Slow down' is currently used on VMS SRS signs in New Zealand (see figure 2.2).

2.5 Other factors influencing driver comprehension

The focus of this project was to examine drivers' understanding of, and response to, SRS signage with the purpose of improving how SRS situations are signposted to *all* drivers. The focus of this research was, therefore, on factors specific to the signs that influence comprehension; however, a number of driver-related factors were identified as influencing signage comprehension (although, not specifically SRS signage). As it was beyond the scope of the research to develop signs specifically targeted at different groups, only a small space is given in this report to the discussion of these factors.

Zhang and Chan (2013) have summarised the driver factors investigated in relation to driver comprehension. They include:

- Age: Generally, no effect has been found, and where effects have been found there is no consensus on effect direction.
- Experience: This appears to be confounded with age, with some studies finding no influence when age is controlled for. Ng and Chan (2008) found a negative relationship to year licensed. Borowsky et al (2005) found experienced better than inexperienced at usual positions but worse in unusual positions.
- Gender: Males appear better but gender is potentially confounded with education level.
- Education: Tertiary or higher levels of education appear better than lower levels of education (Al-Madani and Al Janahi 2002)
- Cultural background: Drivers comprehend local signs better than foreign ones, but there is also a main effect for country. The effects of training are shown to enhance performance of different cultures to similar levels.

Overall, drivers with higher education are better able to comprehend signage, but there is no consensus on the impact of age, gender, or culture (Zhang and Chan 2013).

2.6 Effect of signage on driver behaviour

While a large proportion of research into the effectiveness of different signage options has focused on drivers' comprehension of the 'meaning' of the signs, Fisher (1992) suggested rather than meaning and recall, what is fundamentally important for a sign to be effective is that it induces the desired behaviour

change in drivers. Fisher also suggested the effect of traffic signs might be implicit or unconscious, based on findings from an observational study in which it was shown a significant proportion of drivers who reduced their speeds as they passed a warning sign did not recall seeing the sign. This is supported by Charlton and Baas (2006) finding that, while SRS signs were the worst performers in the suite of measures including comprehension and conspicuity, in observations they were associated with one of the largest reductions in speed. This being the case, while it is important to investigate drivers' comprehension of signage options, and to identify any barriers to detection and understanding and ways in which these could be enhanced, it is also necessary to examine whether signage options do, in fact, promote the desired behavioural response in drivers.

There is evidence that static state SRS signs do not have the desired impact on driver behaviour or crash rates. Carson and Mannering (2001) analysed the impact of static ice-warning signs (a SRS sign) on ice-crash rates using sophisticated statistical modelling techniques and found the presence of static ice-warning signs did not significantly affect ice crash frequency. Rämä and Kulmala (2000) did, however, find that VMS indicating SRS due to ice resulted in an average decrease in mean speed of 1.2km/h of cars travelling in free-flow traffic at two out of three test sites.

Rämä and Kulmala (2000) also found the reductions in mean speed were even greater when the VMS sign was flashing rather than steady, with mean speeds reduced by 2.1km/h. Evidence suggests the addition of a flashing warning to signage or the use of flashing VMS signage can potentially enhance the driver's response rate to the signs (Summala and Hietamäki 1984; Charlton 2006). Charlton (2006) concluded flashing signage increases both attentional conspicuity and the probability of a sign being interpreted as indicative of a hazard, but the type of signage most effective is dependent on the hazard.

Charlton (2006) did not include VMS versions of the slippery road signage in his analysis (flashing VMS were tested for road works and school signs, but VMS and dynamic signs are used to indicate lower than desired road surface friction in both New Zealand and internationally. Elsewhere VMS are also triggered by weather or road conditions that result in reduced surface friction, such as rain, ice or snow. For example, the signs tested by Rämä and Kulmala (2000) were triggered by a combination of local automatic weather monitoring stations, road weather closed circuit television and field personnel.

VMS triggered by weather or road condition sensors have the advantage of being able to provide drivers with an indication of an escalation in conditions. The signs can be displayed only when reduced friction conditions apply, decreasing the likelihood of drivers becoming habituated to their message. A disadvantage of such signs is the potential to mislead drivers with false positives or negatives if sensors or vehicle detectors are not working properly. Another disadvantage of VMS signage is it can be relatively expensive compared with static signage options. A solution to this prohibitive cost is the inclusion of dynamic, sensory triggered elements on static warning signs. International examples of such signs include the Icy Road BlinkerSign Solar Powered Sign designed by Wisconsin company, TAPCO, shown in figure 2.4. Such signs have the potential to provide the advantages of enhanced attentional conspicuity, hazard indication and decreased habituations provided by flashing VMS signs in a cost-effective manner. A number of issues are, however, associated with powering these kinds of signs, including the short lives associated with deep cycle batteries, the size of the solar arrays required to power these and the fact that sunlight is least reliable during winter when the signs are most needed. New technologies, such as the solar-powered ice-sensing pavement markers recently trialled in Otago and currently being considered for inclusion in Land Transport Rule (Traffic Control Devices, 2004) may address some of these issues. They allow up to 300 hours of continuous lighting and could be adapted for use on static signage. It is acknowledged that the addition of flashing lights to SRS signage would not be a realistic option for the

large number of these signs located across the country; however, they may offer a potential solution for particularly high-risk sites.

Figure 2.4 Static icy road signs with dynamic elements incorporated



Source: www.tapconet.com/solar-led-division/icy-road-solar-powered-sign

2.7 Literature review summary

Comprehension of SRS signs has been investigated in only a few studies, and evidence from these studies suggests these signs are not always well understood by drivers. In New Zealand, they have been found to be one of the least well understood road signs. VMS versions of these signs have been shown to have some impact on driver behaviour such as speed and headway, but only one study has examined the impact of static SRS signs and this concluded the signs were not having the desired effect of reducing crash frequency. This research project addressed this gap by examining static signage options qualitatively in order to identify issues of comprehension and detection, and then testing whether these signs were comprehended in operational terms by testing the impact of the static signs on real-world driving behaviour.

The ergonomic principles described above give some guidance to the type of sign design that would be most comprehensible to New Zealand drivers. A comprehensible sign must be familiar, compatible and standardised. The symbolic component must, most importantly, be semantically close to what it is intended to represent, while being meaningful, concrete and simple. For a new sign design, it is not possible to influence its familiarity because drivers will not have had exposure to the signage previously. It is, however, possible to ensure the components of the sign are kept familiar where possible. It is also possible to design in keeping with the other ergonomic principles. Based on the findings from this literature review, the following recommendations guided the design of SRS signage for trial with focus groups in the next phase of the research.

2.7.1 Recommendations for further testing

- 1 In line with the principles of familiarity, compatibility and standardisation, it was recommended the same signage 'grammar' as is currently used for hazard warning signs in New Zealand be maintained. This meant maintaining the diamond shape.

- 2 In line with the principles of familiarity and standardisation, it was recommended a similar colour scheme as is currently used be maintained, (ie yellow for permanent, orange for temporary), but that new variations of the colours be trialled including the fluorescent yellow-green currently approved for use on other roadside warning signs (NZ Transport Agency 2010a).
- 3 Also in line with the principles of familiarity and standardisation, it was recommended the symbolic component of any new signs do not differ too greatly from the designs currently used internationally. This will assist comprehension for people moving or travelling to New Zealand and the transition of New Zealanders to other countries.
- 4 It was recommended the symbolic component of the sign be as semantically close as possible to a slippery surface and a sliding car. The current image depicts two tyre tracks twisting behind a car. To better represent the movement of a car's wheels slipping, a number of potential new signage options adopted the use of uncrossed tracks, similar to the tracks shown in the signs currently used in Scandinavia, Italy, and Poland for example (see figure 2.5 left and centre).
- 5 The USA also uses uncrossed tracks in their signage (figure 2.5 right); however, to make the signage more meaningful to drivers (by demonstrating potential danger) as well as maintaining semantic closeness, it was recommended that in a number of the potential new signage options the car be depicted on two wheels as shown in figure 2.5 left and centre, preferably with a larger gap between the end of the track and the wheel on the raised side of the vehicle as in figure 2.5 left and centre. This provided the perspective that the vehicle is rolling off a surface.
- 6 In relation to both semantic closeness and meaningfulness, it was recommended the individual vehicle tracks be depicted wider near the bottom of the sign, narrowing as they get closer to the vehicle symbol. This provided the perspective of the vehicle travelling across a surface and getting further away. This perspective was used for signs in the countries indicated in point 4 above (see figure 2.5 left and centre).
- 7 To maintain simplicity, it was recommended the symbol include a car only without a driver or safety belt (as are included in the signage in the USA; figure 2.5 right).
- 8 Research suggests the tracks in the SRS sign are sometimes identified as meaning curvy or winding road. To prevent this misinterpretation and to enhance the concreteness of the sign, it was recommended the image of a road (either with a centre line or without) be included along with the car and track symbols. It was acknowledged that while this might increase concreteness it would reduce simplicity and so would require further consideration. Nonetheless, it was recommended this design go forward to the interactive phase.
- 9 The inclusion of a symbolic depiction of the conditions in which it is relevant (ie in adverse conditions) could enhance semantic closeness and meaningfulness, and therefore potentially enhance comprehension. It was acknowledged that the addition of a water component to the signage would reduce simplicity and so would require further consideration. Nonetheless, it was recommended a design including a depiction of surface water adapted from pedestrian 'Slippery when wet' signage go forward to the interactive phase.
- 10 Research suggests SRS signage with flashing light components leads to desired driver behaviour change. Although interactive signs were not the primary focus of this study due to the prohibitive cost and habituation factors associated with installing these on all SRS signage across the country, cost-effective flashing components could still be used on a selection of high-risk sites. It was recommended

a low cost, light emitting diode (LED)-based flashing component be added to the signage options and considered in the interactive phase. Given red is the colour most highly associated with hazards, it was recommended red LEDs be used.











- 11 It was also recommended fluorescent versions of both the permanent and temporary sign colours be put forward for consideration, as these colours have been shown to enhance detection, conspicuity and recall of signs, and New Zealand drivers are already familiar with the use of these colours for situations where it is particularly important to draw attention to the signage.
- 12 Research has also shown comprehension is improved with a combination of symbols and text, so it was recommended the supplementary plates continue to be used in conjunction with the symbolic signage. It was recommended a number of text variations be put forward for consideration alongside the current 'When wet' text, including 'Slippery when wet', 'slippery surface', and text including action words, such as 'slow down when wet' and 'caution when wet'.







Based on the recommendations above, the signage options shown in figure 2.5 were included in the public and steering group interactive workshops.

Figure 2.5 Left: tracks uncrossed, vehicle on two wheels; centre: tracks uncrossed, vehicle on two wheels; right: tracks uncrossed, vehicle on four wheels



Table 2.5 Signage options for public and steering group interactive workshops

Option	Description	Permanent signage options*	Temporary signage options**
1	Current sign		
2	Tracks uncrossed, vehicle on two wheels, perspective applied to tracks		
3	As above plus road edge		
4	As above plus road edge and centre line		
5	As above plus red LED component (note, LEDs could be tested with all the above signage)		

Option	Description	Permanent signage options*	Temporary signage options**
6	As above plus fluorescent yellow-green for permanent and fluorescent orange for temporary (note, these colours could be tested with all the above signage)		
7a	As above with a water symbol (note, water symbols could be tested with all the above signage as shown in the two examples below)		
7b			
7c			

*All permanent signs = reflectorised yellow

**All temporary signs = reflectorised fluorescent orange

3 Interactive workshops

3.1 Methodology

3.1.1 Procedure

The alternative sign designs developed from the literature review were put forward for consideration by a representative group of the public alongside the current WR3 and TR2 signs (table 2.5) in an interactive workshop. Discussions were guided by the three ergonomic principles shown to be significantly correlated with signage comprehension (Ben-Bassat and Shinar 2006):

- familiarity of sign
- compatibility
- standardisation.

As part of the exploration of these principles, attention was given to the five cognitive features shown to be important when designing comprehensible symbols (McDougall et al 1999):

- familiarity of symbols: frequency of encounters
- concreteness: depicting objects in the real world, opposite to abstract
- complexity: amount of detail
- meaningfulness: relevance/instructiveness
- semantic distance: relatedness or closeness of symbol to what it represents.

Discussions on behavioural change were also be guided by five usability criteria (Neilson 1993):

- 1 Learnability (understanding, comprehension on first encounter)
- 2 Efficiency (effectiveness, desired behavioural response)
- 3 Memorability (understanding, comprehension on subsequent encounters)
- 4 Errors (rate of miscomprehension)
- 5 Satisfaction (preferences, positive/negative aspects of signs).

These usability criteria have previously been used successfully to guide the design of surveys to elicit useful design information on a number of visual products, including in-vehicle information systems and motorway signage options (Trotter et al 2011). The discussion guide for the interactive workshop is set out in table 3.1.

Participants in the workshop were asked to identify any issues associated with the current New Zealand SRS signs (WR3 and TR2) and the alternatives listed in chapter 2, table 2.5, as well as provide quantifiable preference information on the current and alternative signs on each of the cognitive features. Participants were asked to indicate which signage option they thought would be best understood by drivers, and

importantly why they thought this would be the case. Participants were also asked to indicate their preferences for the message on the accompanying supplementary plates. Participants were asked to identify ways in which they believed their understanding and anticipated response to the signs and message (both current and alternatives) could be improved further. Participants worked with the facilitators to produce a preferred design and shortlist their top three preferences.

Table 3.1 Interactive discussion guide

Discussion topics	Questions/activities (<i>facilitator activities in italics</i>)
Current signage	<p><i>Facilitator shows current signage (temporary and permanent) and describes meaning</i></p> <ul style="list-style-type: none"> • What do you think these signs mean? • Have you seen signs like this before? • In what kind of situation would you see these signs? • What is the difference between these two signs (temporary and permanent)? • Under what conditions do you think these signs would be relevant to drivers? • How would you respond if you saw these signs? In dry conditions? In adverse conditions? • For how long would you expect a temporary sign to be in place?
Alternative signage rankings	<p><i>Facilitator gives brief explanations of the five cognitive features correlated with comprehensible symbols, including examples</i></p> <ul style="list-style-type: none"> • Participants complete a one-page form indicating their top three signs on each of the five components: semantic closeness, familiarity, meaningfulness, concreteness and simplicity, as well as overall preference
Top 3 discussion	<i>Facilitator sums overall scores and presents top three for discussion</i>
1 Strengths and weaknesses	<ul style="list-style-type: none"> • How easy is it to understand the warning message conveyed by these signs? • How easy do you think other drivers would find it to understand the warning message conveyed by these signs? • What aspects of these signs are particularly effective? • What do you particularly like about these signs? • What aspects of these signs could be misunderstood? • What do you particularly dislike about these signs?
2 Behavioural questions	<ul style="list-style-type: none"> • Do you feel these signs would encourage you to reduce your speed in adverse conditions? • Do you feel these signs would encourage other drivers to reduce their speed in adverse conditions? • Do you feel these signs would encourage you to leave more room if you were following a car into a curve? • Do you feel these signs would encourage other drivers to leave more room if they were following a car into a curve?
3 Combination design	<ul style="list-style-type: none"> • Can we create an improved design that would be easy to understand and further encourage drivers to reduce their speed and headway? <p><i>Facilitator combines suggested signage elements on whiteboard to develop a preferred signage option</i></p>

Discussion topics	Questions/activities (<i>facilitator activities in italics</i>)
Text	<ul style="list-style-type: none"> • Facilitator presents alternative wordings alongside current 'When wet' wording. • Which message do you think most effectively warns drivers of the risk posed by adverse conditions? • Which message would be most likely to encourage drivers to reduce their speed and headway? • Can we create an improved message that will further encourage drivers to reduce their speed and headway?
Confirmation of preferences	<i>Facilitator confirms final design and text combination, and 2nd and 3rd preferences</i>

3.1.2 Participants

3.1.2.1 User interactive workshop

There is evidence in the literature that a number of driver-specific factors influence signage comprehension. Although there is not always consensus on the size and direction of these effects (Zhang and Chan 2013), in order to account for any of these driver influences potential participants in the public interactive workshop were pre-screened to include a range of:

- ages
- driving experience
- gender
- education levels
- motorcyclists, heavy vehicle drivers, as well as car drivers

Ten participants were recruited through Opus' extensive national networks. A \$50 MTA or supermarket voucher incentive (depending on participant's preference) was offered to participants to encourage participation in the interactive workshop and to show appreciation for their time in participating. The workshop ran for two hours.

3.1.2.2 Expert interactive workshop

Following the interactive workshop with the public, an interactive session, guided by the same principles, was held during the first Steering Group meeting to elicit expert opinion on the current and alternative signage. The preferences of the Steering Group for the different signage options were established before they knew the results of the public interactive workshop. The group then discussed and integrated these preferences in order to shortlist signage options for on-road testing.

This iterative approach allowed issues of signage acceptability and implementation to be identified early in the investigation and ensured the signage options that went forward for testing in the on-road trials had real potential, not only to result in desired driving behaviour change, but also to enhance the cost-effectiveness and the likely suitability of the resulting signage options for real-world implementation.

3.1.3 Data analysis

Findings from the public interactive workshop were analysed using qualitative analysis techniques including analysis of themes. Where possible participants' preferences for different signage options were quantified and responses analysed using chi-square testing and percentage comparisons.

3.2 Results

A number of themes emerged throughout the interactive workshops held with the public and the Steering Group. The main themes and discussion points are summarised in the following sections. These findings are representative of the opinions gained from a small sample and together with the literature review were used to advise the next stage of work, the on-road trials.

3.2.1 Public interactive workshop

A public interactive workshop was held in Wellington city to examine how drivers comprehend and understand the current SRS signage and to gauge reaction to potential alternative signage developed from the literature review findings. Recruitment involved the distribution of advertisements through existing Opus networks, as well as through a list of participants who had previously indicated they would like to be contacted for Opus Research studies. Advertisements were also shared over the social media site, Facebook, and posted in local cafes and nearby businesses. The advertisements promoted a 'snowball' recruitment technique, encouraging those who took note of the advertisements to share information about the study with others to raise the opportunity for a larger participant base. Those interested in participating were asked to contact the researchers for further information.

Screening questions were sent to those who indicated an interest in participating in the study. These were used to achieve a diverse sample, and to ensure a range of opinions was represented. Participants were selected and invited to attend the study based on their answers to the screening questions. A summary of the sample is outlined in table 3.2.

Table 3.2 Summary of sample collected for the interactive workshop

Measures	Sample
Age range	24–64 years (mean = 33.1 years, SD = 12.7 years)
Gender	4 female 6 male
Education level	1 no formal education 2 high school 1 certificate 1 diploma 3 undergraduate 1 graduate 1 missing
Occupation type	6 full time 1 part time 2 student 1 other (maternity, retired, etc)
Licence type	10 vehicle (private) 1 motorbike

Measures	Sample
	2 heavy truck 1 forklift
Licence class	9 full 1 restricted

The focus group was held after work hours in the evening and was approximately two hours long. To encourage open discussion, the focus group size was limited to 10 participants. This was considered the maximum number of participants to allow successful facilitation of the group, and ensure every participant had the opportunity to voice their opinion effectively.

The discussion programme was provided to the participants, outlining potential questions to be discussed during the course of the interactive workshop. The questions were broad and designed to promote further conversation between participants and encourage open discussion. Participants were advised the focus group facilitators were interested in their opinions and their understanding and perceptions of the signage. They were advised topics might arise organically through the discussion that were not outlined on the programme. Participants were encouraged to express their opinions freely and made aware there were no right answers to the questions posed in the interactive workshop.

A short survey was given to participants prior to the beginning of discussions to assess their knowledge of the current permanent and temporary SRS signage. The survey was conducted first to ensure participants' perspectives were captured prior to them being influenced by others in the group. Following this, the researchers provided a short introduction to the SRS signs and described, with examples, the five cognitive design principles that have been found to influence signage comprehension (see section 2.4.2). Participants were then presented with nine signage options (figure 3.1), eight of which were alternatives to the current SRS sign and asked to rank their top three options in order of preference on each of the design principles, as well as their overall most preferred. The signs were presented as they would appear in both permanent and temporary signage (eg reflectorised yellow for permanent signs and reflectorised fluorescent orange for temporary) and included a short description of the sign options that highlighted changes made to a specific feature, eg crossed tracks, fluorescent colour and so on. Participants were asked to rank their top three preferences by allocating the lowest number (one) to their third favourite sign and the highest number (three) to their most preferred design for each category. All focus group materials, including the ranking of potential signage designs can be viewed in appendices A to D.

The top three signs were identified by summing together scores in the overall most preferred column for each sign. The highest overall ranking indicated the most preferred sign design. A summary of the results is presented in table 3.3. Following this ranking exercise, discussion around the strengths and weakness of current signage was opened with participants.

Figure 3.1 Permanent sign options presented to focus group participants to rank

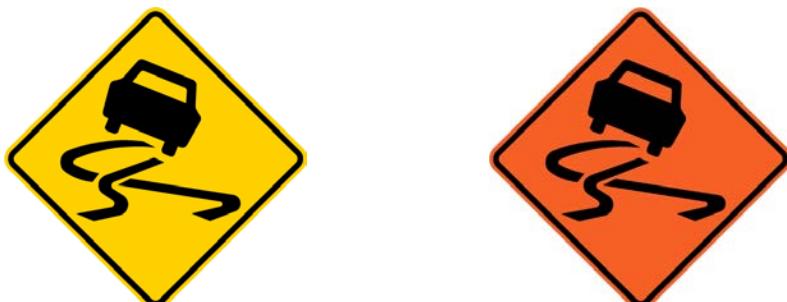


Table 3.3 Most highly ranked signs, showing rankings by category (letters correspond to sign numbers in figure 3.1).

Sign option	Familiarity	Simplicity	Concreteness	Meaningfulness	Semantic closeness	Overall most preferred
Most preferred	A	B	D	D	D	B
2nd most preferred	B	A	B	C	B	F
3rd most preferred	D,E,F	F	A	A	A,C	A

3.2.1.1 Understanding of current signage

Figure 3.2 Current permanent (left) and temporary (right) signs presented to focus group participants to discuss



Assessing New Zealand drivers' understanding of the current SRS signage (figure 3.2) is important in order to ensure any misunderstandings are adequately addressed by alternative signage options. To gauge focus group participants' experience with SRS signage, participants were asked in the survey conducted prior to the commencement of the focus group, to indicate their exposure to SRS signage. Responses show participants frequently observed the current SRS signage (table 3.4).

Table 3.4 Reported sign exposure (survey responses)

	Frequency	Percentage
Often	9	90%
Once or twice	1	10%
Never	0	0%
I don't know	0	0%

Participants in the focus group were relatively experienced drivers, with 90% of them holding a New Zealand full driver licence. Thus, there is potential that the perceptions of naïve drivers of this signage may be under represented. However, it is fair to assume themes raised by experienced drivers may apply to drivers less familiar with driving on New Zealand roads.

The survey results indicated participants felt SRS signage was used primarily for conditions where ice, snow or wet weather had reduced the road surface friction. When asked where they felt it was relevant to use such signs, participants indicated that in addition to the situations where signage is currently used, road works and winding roads were also relevant (table 3.5).

Table 3.5 Conditions under which signage is used and where would it be relevant (survey responses)

	Situations		Relevant	
	Frequency	Percentage	Frequency	Percentage
Wet	4	40%	6	60%
Ice	4	40%	4	40%
Snow	1	10%	1	10%
Road-works	0	0%	1	10%
Winding road	6	6%	1	10%
Gravel	2	2%	0	0%
Other situations	6	6%	5	5%

Discussion in the focus group revealed a common misunderstanding that SRS signage only applied to adverse weather conditions. Participants indicated their decision to lower their travelling speed depended on their interpretation of the severity of the weather.

I know where (a slippery road sign is) ...I know that when it's wet or icy (that) that's when I bother to slow down.

Survey responses indicated participants were aware of the need to alter their driving in adverse conditions when encountering a SRS sign. However, 50% indicated that in fine weather conditions they would not alter their driving behaviour (table 3.6). This supports the idea drivers may be unaware roads can have an inadequate road surface friction in dry conditions, which presents a hazard to drivers navigating them, especially when extraneous variables such as the tread on a tyre and travelling speed are taken into account.

Table 3.6 Reported driver behaviour and dry and adverse conditions

	Dry conditions		Adverse conditions	
	Frequency	Percentage	Frequency	Percentage
No change	5	50%	0	0
Slow down	2	20%	10	100%
Increase awareness	3	30%	0	0

The inconsistency between the concept of permanent signage and the impermanence of the conditions that exacerbate a SRS was proposed as a reason for driver non-compliance with both temporary and permanent SRS signage. Specifically, it was raised in the focus group that permanent SRS signage can be erected for communicating hazards that exist only under certain conditions (eg temporary situations), as conveyed in the quotes below.

...You're putting up a permanent sign for a temporary issue...If it says slippery when frosty and it's a beautiful sunny day and 2 in the afternoon chances are it's not slippery

There are so many roads in New Zealand that don't have those signs that should. And I find myself questioning them

Numerous strengths and weaknesses of the current signage options were raised during discussion. The cognitive principles were rarely explicitly discussed; however, implicit references were often made, for example, participants who raised issues regarding the tracks crossing on the sign suggested such a scenario was 'physically impossible', implying the real-world representation (eg semantic closeness) of the sign was lacking.

3.2.1.2 Strengths of current signage

The current pictogram of a skidding vehicle was thought to avoid confusion with a winding road, due to the crossed tyre tracks following the tipping vehicle, as illustrated in the quotes from two participants:

They...decided to cross the lines to avoid confusion with a winding road.

If you're crossing the (tracks) it clarifies that there might be a crash...

Participants in the focus group acknowledged the sign looked distressing enough to raise driver awareness of the potential road hazards ahead, some suggesting the sign could achieve this regardless of sign exposure.

If you knew nothing at all about the language of the country and you saw that sign it does indicate that something is about to go wrong with your car and maybe you should pay attention.

In some ways the sign gets your attention because you look at it and go 'What?'

The current symbol was described as being attention grabbing and effective at suggesting to drivers that the area through which they were about to drive warranted greater caution.

...It looks like it could be (really) bad if you do slip, because it could go crazy

Thus, participants concluded the current symbol sufficiently conveyed the need for motorists to exercise safer driving practices, eg reducing speed.

3.2.1.3 Weaknesses of current signage

Participants expressed some concern with the concreteness of the current signage option, particularly with regard to the vehicle tracks trailing the vehicle.

The thing that annoyed me [about the current sign] was that those marks are physically impossible..."¹

While participants felt the current sign might raise awareness to drivers of the potential of a hazard, they also felt it was unclear in conveying what specific hazard the driver was potentially being exposed to. It was suggested this contributed to the confusing nature of the sign, as exemplified in these comments by two participants:

I think [the current sign] suggests wheels may disconnect at random

I think it is a confusing sign. You look at it and go 'what does that mean?'

Conversation around alternative options suggested the current signage lacks instructiveness. Participants advocated for various methods that could be used to indicate when the reduced road surface friction posed a real danger to drivers. Such methods included increased sign frequency for particularly dangerous roads or alternative colour options to indicate degrees of severity for reduced surface friction.

Maybe you could use a colour code for severity of slipperiness. Pink for really slippery, yellow for not so slippery, orange for sometimes slippery

...if certain areas are really bad, would you double the signs?

...sometimes you go past the sign a few times and go... 'Okay, maybe I'll slow down'...

Participants did, however, acknowledge that introducing multiple, alternative colours to black and yellow might be too confusing due to a lack of familiarity with alternative colour options.

Participants indicated that drivers only felt it necessary to abide by the signs under certain conditions (eg rain, snow). It was further raised amongst the focus group that the sign did not command compliance.

¹ The notion that the crossed skid marks depicted in WR3 and TR2 are impossible reflects the perceptions of the focus group participants, not that of the authors or the research owner. Expert advice from a Senior Engineer at the Transport Agency indicates that such tracks could indeed be produced by an out-of-control vehicle (Richard Bean, pers comm, 26 August 2016).

Specifically, the colour of the permanent signage meant it could be incorrectly interpreted as an advisory sign, as opposed to a warning sign. Some participants also felt signage could be interpreted as applicable to large vehicles and not to smaller vehicles.

I always think of yellow as optional – if you have a speed sign you go ‘Well that’s optional’

Further issues relating to the understanding of the current SRS signage are described later in this report, as part of the discussions around alternative signage design.

3.2.1.4 Preferred signage options

Based on the summation of participant’s rankings of the alternative signage options, three signs were identified as most preferred overall (figure 3.3), one of which is the current signage option, which placed third. The options placed first and second, ahead of the current signage used, had the same pictogram for both alternative options (uncrossed tracks), the difference being the background colour used (standard yellow or fluorescent yellow-green). Participants were able to discuss the understanding of their preferred alternative signage options in comparison to signage currently used.

Figure 3.3 Top three most preferred slippery road surface signs, in order of preference



3.2.1.5 Strengths of alternative signage

The focus group supported the use of the fluorescent colour background, and felt altering the colour so the sign stood out from surrounding road signage would encourage better driving behaviour.

Changing the colour...So that it stands out from everything else on the road...may make a difference to what people think.

Participants felt using a brighter colour for the background could better aid vulnerable road users, as observed in the discussion below.

Participant 1: *The sign definitely needs to be brighter*

Participant 2: *...mostly for vulnerable road user*

Participants also indicated they preferred the perspective of the tyre treads. When asked whether it affected the icon size, participants suggested the perspective still improved their interpretation of the signage, the understanding potentially being that the hazard lay ahead of them.

You’ve added perspective to your [signs] and I think it looks better

Even if the icon is a tiny bit smaller...it would still make a difference

Participants discussed the ease with which the signage options could be understood by visitors driving on New Zealand roads. It was thought to be reliant on the consistency with international signage used to communicate the same warning. It was also felt the sign effectively communicated the potential for hazard to all drivers regardless of their familiarity with New Zealand roads and driving practices.

...It depends on what they've come from, so...what is consistent internationally.

I think for a driver paying attention anywhere... (If) they saw a sign like that, they would know something (is) up.

3.2.1.6 Weaknesses of alternative signage

Participants felt the signs with uncrossed tyre treading trailing the vehicle (eg the first and second most preferred signage) better reflected a vehicle skidding, that is to say, the symbol is more concrete. However, participants suggested it was far easier to misinterpret these signs. Specifically, they were concerned these signs could be incorrectly interpreted to mean the road was winding. This was the primary concern of focus group participants with regard to alternative signage.

Because (sign 1) and (sign 2) do just look like it could be mistaken for a windy road.

3.2.1.7 Other possible improvements

Participants suggested one way to improve driver understanding of the SRS sign was to add tread marks to the tracks trailing the vehicle in the icon currently used. While this may increase the complexity of the design, it was thought this would better communicate the tracks were left by the car.

Participant: I think I have seen (signs) with the tracks having tyre patterns. That might solve the problem of the sign being confused for a winding road

It was also suggested that altering the current icon to depict a vehicle skidding rather than tipping could better communicate the skidding risk associated with travelling on a road where a reduced road surface friction hazard is in place.

If there was something to change, it could be the car as opposed to the marks...it's looking like it is about to roll over instead of sideways. So the angle of the car should be changed...to indicate the car is travelling sideways not tipping

Despite the discussion of both the above points, when later asked to design the ideal sign, participants decided against implementing either of these suggestion. This is discussed further in section 4.3.

Participants also suggested the combination of static and dynamic signage could better provoke the desired behaviour in drivers. Participants felt that adding emphasis on static signs with either flash lights or flashing messages would result in drivers instinctively adopting more cautious driving practices.

I think regardless of what the picture ... if you had lights to show 'be cautious' it'd probably make people slow down even if they didn't understand that it was (going to) be slippery

Participants did caution such signage should be reserved for particularly hazardous sections of roads to avoid over exposure, and consequently drivers becoming inattentive to their risk of skidding.

3.2.1.8 Temporary signage

In the survey, prior to the commencement of the focus group discussions, participants were presented with images of the permanent and temporary signs and were asked what the two different signs represented.

The majority of the participants correctly indicated the difference to be whether the signs were temporary or permanent, 20% of participants suggested the colour of temporary signage indicated an increased level of danger (table 3.7).

Table 3.7 Understanding of temporary sign colour

	Frequency	Percentage
Permanent versus temporary	6	60%
Increased level of danger	2	20%
No comment	2	20%

Much of the participants' experience of temporary SRS signage had been with its use in road works; in fact, the responses of participants indicated a number of them were unaware the temporary SRS signage could be erected in situations other than road works. These participants reported seeing the signs in areas where road works were not apparent, which, they felt caused them to pay less attention to the signs.

...one minute you go through road works you see those signs, you go '[Yes], there [are] road works' and slow down. The next three or four lots of signs, there's no road works. So the next time you see those signs you think sweet there's no road works and the next minute there's a crazy man throwing a spade at your car because you've just gone through road works

The facilitator informed the focus group of situations other than road works where temporary signage could be erected, and participants discussed the duration they felt temporary signage should be erected before it was removed or replaced with permanent signage. Participants felt having temporary signs in place too long would contribute to driver non-compliance.

I think the temporary sign post time should be shorter and a permanent sign put up instead

I think people who drive the road regularly will stop paying attention to the temporary sign

Sometimes, if you're going over to Whitby from over Haywood's they have temporary signs there and they've been there for months so I'm like, 'Nah, I'll just go normal speed'

In the initial survey, 20% of participants indicated the duration of the temporary signage should be restricted to one month and (40%) answered the temporary signage should be remain in place until the hazard was removed (table 3.8). This was discussed in the focus group and participants reiterated they favoured a maximum period of a month, suggesting the hazards should be addressed within this month period.

Probably more a month. I think of a temporary one as being used for road works and it may be there today or tomorrow. I always think the reason why a temporary sign is put up is because there is work being done or the road will be fixed soon.

Table 3.8 Expected temporary signage periods (survey responses)

	Frequency	Percentage
A week	2	20%
A month	2	20%
Till hazard is reduced	2	20%
Till hazard is removed	4	40%

3.2.1.9 Supplementary plates

The discussion around supplementary plates focused on two main themes:

- plate instructiveness
- plate clarity.

Supplementary plates were regarded as an effective means of enhancing driver understanding and compliance.

Participants suggested recommending an appropriate travel speed on the supplementary plates would encourage appropriate driving behaviours from road users (including naïve drivers and visitors travelling on New Zealand roads) who were unsure of what warning message was being conveyed by the signage.

It reckon it would be a good idea to have the speed because you don't know what speed to travel through the area.

They might not understand the actual sign but they can always understand the speed.

Participants felt such an intervention would be effective where the hazard was continuously in place, but noted it would be ineffective where road surface friction was only reduced in certain conditions. To communicate an appropriate speed would require identifying the speed best suited to the worst condition on that road section. Such a speed recommendation would be too conservative in situations where a permanent sign was erected, but the warning was only in effect during certain road conditions (eg wet, ice).

If it's a permanent problem then you can suggest a speed I suppose but if it's not permanent then it's harder. You have to decide on a speed and whether the conditions warranted.

Would you rather have a suggest speed limit or the distance? It's hard to put the speed limit because you're putting up a permanent sign for a temporary issue. But if it's when wet then that's not a permanent problem.

Participants considered a possible misinterpretation of a recommended speed on the supplementary plates could be reading it as the speed limit, as illustrated in the quote below:

People might think that it is the actual speed limit they need to be doing and slow right down

Participants felt if the supplementary plates were to include a recommended speed, the signage would need to communicate to drivers how long the recommended speed was in place for, and under what conditions it was applicable. This was felt to be particularly true for instances where the warning would need to be in effect for long distances.

The thing with that is, how long is (the reduced speed) in place?

...it would depend on the distance it would be in place for...5kms (is) actually a long time.

The addition of why the road is slippery – there’s a sign with a car that looks out of control they need that accompanied with why their car may be out of control. Additional information – you need to know why.

Encouraging any behaviour other than reducing speed, ie encouraging greater headway in adverse road conditions was thought to require signage other than the SRS signage.

I don’t know how you would get a sign to encourage people to leave a gap...

I’ve seen signs reminders that say “watch your following distance”, which is probably all you could do...

Focusing specifically on the wording of the supplementary plates, participants identified phrases containing a command or instruction as more likely to elicit greater behaviour change, while avoiding the misinterpretation that could result from the inclusion of a recommended speed. Suggested phrases that fell into this category of command included ‘reduce speed (now)’ and ‘slow down’, with participants showing a preference for the latter.

Participants also indicated the supplementary text should include reference to the conditions under which the warning would be relevant, such as wet, frost, or gravel conditions, with the caveat that drivers who were unpractised in English would potentially still have trouble correctly identifying the warning message conveyed by the sign.

That’s the problem with words, if you can’t read them, if you’re eye sight isn’t very clear or you don’t know the language it means nothing

3.2.1.10 New design

Following the discussions of the alternative signage options, participants were asked to design their ideal SRS sign (figure 3.4), the features of which are discussed below.

Figure 3.4 Focus group developed alternative slippery road sign design



Car angle

In the absence of dynamic sign features, participants agreed to keep the vehicle in the icon angled. It was felt to be the most effective way of communicating the potential severity of a crash occurring on a stretch of road where the warning was in effect. It was thought for the purpose of communicating the severity of a crash and drawing attention to the sign, the angle at which the vehicle was presented in the sign need not be representative of real world conditions.

I like the car on an angle. It makes me worry. It makes me worry [because] I know my car should [not] look like that. You may slide side-ways but that [angled car] looks wrong...

I don't know if it has to be representative of what [is] about to happen...it grabs your attention.

Tracks

With the addition of other features, participants favoured the crossing of tracks trailing the vehicle. This was preferred over incorporating tread marks in the tracks which could over complicate the image. Crossing the tracks also aided in communicating a risk of crashing.

If you are crossing the lines it clarifies that there might be a crash rather than (there being) two wheels.

I don't think crossing the tracks is a bad thing because it shows chaos

Background colour

Participants suggested the use of fluorescent yellow-green for the background colour.

Additional features

Introducing road edges was agreed to effectively avoid confusion with a winding road, instead being taken to mean a vehicle skidding out of control on a straight road.

I like the lines that showed the road because it showed it more out of control. This would let you get past the confusion of the windy road because the road is straight and the car was going out of control.

Participants did not like the inclusion of road marking which indicated the centre of the road as this was felt to be too complex and potentially confusing. The use of splashes and other water images best indicated the road was slippery when wet, but participants felt these over complicated the signage. It was thought drivers would not have enough time to observe all the sign features and interpret the warning.

The one with the median line was confusing

I think the ones that depicted water would be good, if that is why you slip. Like slippery when wet (or) when there is a change of aqua planning.

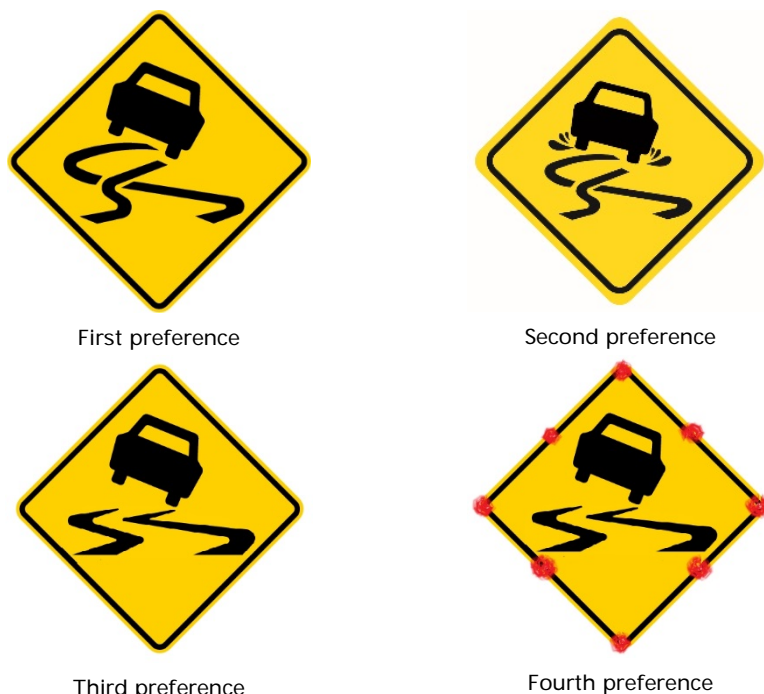
When you (are) driving along and you see a splash of water you are like 'Oh, what else was on there' (as you drive past).'

3.2.2 Steering Group interactive workshop

The project Steering Group, consisting of technical experts from the Transport Agency, New Zealand Automobile Association, New Zealand Roadmarkers Federation and the Road Safety Manufacturers Association, as well as representatives from two local government areas, were consulted in order to supplement findings gained through the public interactive workshop and to decide on the final versions of the signage to go forward to the on-road trials. The group was asked to complete the same sign ranking exercise as was used in the public focus group, indicating their overall three most preferred signage options. The group was reminded of the cognitive design principles identified in the literature review (familiarity, simplicity, concreteness, meaningfulness, semantic closeness), but unlike the public interactive workshop, the Steering Group was not required to rank the signage presented on the each of the principles separately.

From the summation of rankings allocated to the suggested signage options, the following four signs were identified as being the most preferable.

Figure 3.5 Preferred sign options as selected by the Steering Group (all in the current permanent background colour of reflectorised yellow)



3.2.2.1 Preferred signage options

The Steering Group considered the current reduced road surface friction sign was not necessarily the most effective symbol by which to communicate this road hazard to drivers, nor did it effectively convey the desired behavioural response from drivers, in terms of the actions necessary to mitigate hazards.

You can understand why the sign may easily be misunderstood. There is quite a complex level of cognition required to do the right thing anyway. First you have to understand what the sign means. Then you have to decide does it apply today, ask if the sign applies to that and the supplementary [plate] is supposed to give you some guide to that. Then you have to decide, how much do I have to slow down, what do I have to do, so there is a whole lot of stuff

going on and very few signs have that degree of interpretation, decision making and getting it right.

3.2.2.2 The current sign

Despite this, the Steering Group's first preference was for the current sign:

The fundamental design and familiarity and everything else of the sign and the semantic (disposition) of it (the sign), the symbol is doing everything it reasonably can in simple terms and it is used internationally with slight variations and I think the one we've got is as good as any and probably better than some.

While the members acknowledged the current SRS signage is one of the most poorly understood road warning signs, and agreed more could be done to improve the understanding of the current sign, they also felt it could still be effective at eliciting the desired behavioural response (eg reduced speed, increase headway) from drivers.

What I found interesting was that regardless of that, people still slowed down for it. At the end of the day whether they understand it or not, if we can get the desired reaction from people then we're winning.

3.2.2.3 Alternative signage options

The Steering Group discussed the viability of electronic signage, static signage with electronic components such as flashing lights, and alternative coloured static signage. It was agreed that, while features of electronic signage could be effective in encouraging the appropriate behavioural response from drivers, there were intricacies around the implementation of technological innovations for particular road safety protocols that meant they were not considered a viable solution by the group, as illustrated in the statement below. The group did agree electronic signage options should be reserved for high-risk driving conditions.

... the red flashing lights have a regulatory meaning which is never [going to] go with a warning sign.

In relation to signs with fluorescent backgrounds, particularly fluorescent yellow-green selected by the focus group, the Steering Group discussed the fact that this colour had been reserved to represent vulnerable road users (eg cyclists, pedestrians, children and elderly). They felt it should remain specific to these road users.

I've always thought the options of the yellow-green fluorescent background or the flashing red legs are nice ideas but never starters.... The (fluorescent) yellow-green has been reserved for vulnerable road users and I would be reluctant to go against that principle. To start using it for something else because it is slightly more visible or highlights it a bit more then why not [use it on] some other warning sign that is the next on the list then you end up with the situation with all our permanent currently yellow warnings signs are [fluorescent] yellow-green and you've lost that advantage for the vulnerable road users.

When every corner has a curve warning sign on it, you start off with a warning sign and a great addition to the safety of the roads, but people get used to what's going on. Once we have [a technical innovation] and it's been shown to work then the application broadens. Without further innovation then we're back to where we're started with a sign for every hazard.

The Steering Group suggested the second most preferred sign (figure 3.5) was effective for indicating conditions where road surface friction was reduced as a result of wet conditions; however, it was thought to be insufficient for communicating risk of slippery conditions other than those related to the wet.

We use this basic sign when it is wet, icy, gravel, any slippery condition. It is not necessarily for when wet.

Despite these potential difficulties with comprehension, the Steering Group queried how much improvement to the symbol itself was necessary if, as existing evidence suggested, the majority of drivers executed the appropriate behavioural response in reaction to the sign, even if they did not fully understand it.

...But as I've said the research indicates that people still do what we want them to do, so are we really concerned if they don't understand why they're doing it.

3.2.2.4 Supplementary plates

The Steering Group also considered the text of the supplementary plates used with the SRS sign:

Another interesting thing I found in the summary paper you gave us was that these signs or any range of signs basically seem to have better comprehension when there was a supplementary text message.

Members of the Steering Group at first found this to be counter intuitive, and expressed the belief that an appropriate symbol should be sufficient for adequate sign comprehension:

... I've always worked on the principle that if you have an appropriate symbol you don't need the text. It's universal, everyone understands it, but it seems its only traffic engineers that really understand it. I was surprised that adding a text message helped when the fundamental principle was getting people confused. That seems to point us to where we should be going

However, following discussion of supplementary plates, the Steering Group was in support of testing an alternative supplementary plate as a means of improving the comprehension of the SRS signage.

The Steering Group deliberated about what improvements to the supplementary plate would result in the greatest improvement in comprehension. The signage was seen as lacking information on the behavioural response expected from drivers. The addition of a supplementary plate communicating the appropriate action (eg elicit a slower driving speed) was thought to be valuable to supplement the primary signage.

The public focus group participants had selected the phrase 'Slow down when wet'. The Steering Group suggested the word 'down' in this phrase was superfluous and suggested 'Slow when wet' would convey the same message. The Steering Group also suggested the addition of the word 'slippery' could enhance driver comprehension:

...I would've thought that a simple improvement would be to add the word 'slippery' at the moment the current supplementary plate only says 'when wet' and that's assuming that people understand what the symbol is telling them in the first place.

If the addition of text improves the cognition of the sign itself so much then adding the word slippery would presumably increase peoples understanding of the sign a whole lot in that first instance, but that still doesn't tell them what they are supposed to do.

As was the case in the public focus group, the Steering Group discussed whether a recommended or advisory speed could be included on the supplementary plate in order to encourage drivers to reduce their speed. Members of the Steering Group suggested an advisory speed would elicit the desired driving behaviour whether or not the warning was correctly understood by the driver.

... an advisory speed with the appropriate supplementary, when wet or something like that, which might elicit another degree of understanding that one here is a warning sign so I have to do, what am I supposed to do and the idea is a number to give you some guidance.

The Steering Group discussed potential advisory speeds, and raised the issue that the appropriate speed at each site would vary based on the severity of the conditions, (ie the driver must travel considerably slower in heavy rain compared with fine rain or mist).

It's hard to recommend a speed around a slippery corner in the wet because it's going to vary.

In the wet if you have a lowered skid resistance it isn't going to vary that much. It's still going to be very much lower than you negotiated in the dry conditions.

The capability of modern vehicles to negotiate the curve at quite a bit faster than that speed, that speed being a comfortable speed and is supposed safe speed in conditions other than ice. So you should be able to get around the corner even when it's wet, but not necessarily with the lowered skid resistance. So I think you could still have an advisory speed.

The Steering Group was reluctant to overuse text in the supplementary plate. Specifically, concern was raised about whether excessive use of text in the plates could result in drivers failing to consider the signage. For example, having two supplementary plates (one communicating the hazard, the other indicating the appropriate action to take) was considered too much text.

I'm not excited about two (supplementary) plates. I'm not in favour of it either because it goes against the whole principle about the amount of information you're feeding people but it seems if people cannot understand the entire message from just the symbol, and it seems as though they can't.

The more information you throw at them the more likely they are to ignore the whole thing because there is too much. Put up a whole page of text and they'll just go I can't read that. If you have a supplementary for more than two kilometres people forget.

3.2.2.5 On- road trial options

Following the discussion of the preferred signage options, alternative signs and supplementary plates, the Steering Group decided the various selected signage options did not differ significantly enough from the current signage to warrant testing alternative designs. Instead, the Steering Group decided to focus on alternative supplementary plate options.

I think from the discussion today most people seem satisfied that that is reasonable. The other thing from the research is that adding a supplementary plate with a text message to help expand on the meaning, the desired instruction and all those sorts of things is the way to make the sign work better. I think that what we've chosen there as supplementary plates will give us a reasonable indication if that is going to add something or not.

The group identified two alternative supplementary plate options for testing in the on-road trial component of work. These were to be tested, along with the current supplementary plate, with the current SRS sign.

Do we know to any extent the behavioural response to the existing sign? So I suppose the question is should we use up one of the three options for the existing sign and see what kind of speed change we get with the existing sign

There are two supplementary plates that need testing, it's the alternative supplementary plate which is slow down

The third option is slow (when wet). We don't need the word down just slow when wet

3.2.2.6 Summary

After considering the findings of the public focus group and the discussions held by the Steering Group, the three signage options were selected for on-road trial:

- 1 Main plate only (currently in use)
- 2 Main plate + new supplementary plate: 'SLOW WHEN WET'
- 3 Main plate + new supplementary plate: 'SLIPPERY WHEN WET'

All signs were tested using the temporary signage colour (reflectorised fluorescent orange) and dimensions. Signs as they appeared in position on-road can be seen in figures 3.6, 3.7 and 3.8.

Figure 3.6 Temporary sign with no supplementary plate (reflectorised fluorescent orange)



Figure 3.7 Temporary sign with 'Slow when wet' supplementary plate (reflectorised fluorescent orange)



Figure 3.8 Temporary sign with 'Slippery when wet' supplementary plate (reflectorised fluorescent orange)



4 On- road trial

4.1 Methodology

4.1.1 Procedure

The purpose of this phase was to objectively measure driving behaviour in response to the three signage options identified in the previous workshop phase in a real-world setting.

4.1.1.1 Signage performance

Driver behaviour was observed naturalistically, using speed as the key performance measure. Change in speed measured before the addition of any signs (baseline) and after the addition of each sign was used to demonstrate which of the signage options was most effective in producing the desired behaviour changes. Data was collected for five weeks for each signage option (the two chosen and the current signage) at each site to ensure any variation in speed, including changes caused by congestion, crashes and road works on a particular day could be controlled for. Speed data from the final two of the five-week rotations was analysed to ensure any novelty effects that might result from introduction of a new sign at each location had dissipated over the prior three weeks.

Driver performance measures were obtained at each location using metrocount tube counter/classifiers provided by HTS Group Limited. In each location metrocounters were placed following the signage, immediately prior to the start of the curve, in order to capture drivers' entry speeds.

All road signs tested were constructed following the design specifications set out in the NZ Transport Agency's (2008a) *Traffic control devices (TCD) manual*, including specifications for sign dimensions, font size and type, materials and luminance. All sign designs, including alternative and location signage, were reviewed by the Transport Agency's Traffic Control Device Committee and given permission for on-road use for the trial period. A Gazette notice authorising the trial, which set out the specification for the supplementary plates used, was published following the committee's meeting as NZ Gazette 9 July 2015, no.74, au3962. (<https://gazette.govt.nz/assets/pdf-cache/2015/2015-au3962.pdf?2015-07-09%2010:01:07>).

4.1.1.2 Experimental validity

The naturalistic method allowed measurement of realistic driver responses, reducing the potential for participant bias or self-selection bias that can occur with recruited participants. It also allowed a larger, more representative sample of drivers already using the road class or road geometry to be examined. Each signage option was trialled separately in the test locations. This is important to ensure experimental control over extraneous environmental factors so any changes observed in key measures could be considered evidence of the intervention.

4.1.1.3 Treatment locations

The on-road trials of the selected signage options were conducted in three locations, representing three different curve radii: 250–350m; 150–250m; and less than 150m. The locations were identified through liaison with the Transport Agency, and were coordinated in conjunction with the network outcome contract holder in the Greater Wellington region. All three locations were on State Highway 58.

All potential locations on this route were visited and checked in order to ensure:

- flat grade
- minimised proximity to intersections or heavily used driveways
- maximised preview distance
- sufficient space for signage.

Details of the selected locations were as follows:

Site 1: Radius 270m; curve length 160m; left-hand curve; speed limit on approach 100km/h (figure 4.1).

Figure 4.1 Approach to curve (left: red line = position of metrocounter) and map of location for site 1 (right)



Site 2: Radius 184m; curve length 300m; right-hand curve, speed limit on approach 100km/h (figure 4.2).

Figure 4.2 Approach to curve (left: red line = position of metrocounter) and map of location for site 2 (right)



Site 3: Radius 88m; curve length 90m; left-hand curve; speed limit on approach 80km/h (figure 4.3).

Figure 4.3 Approach to curve (left: red line = position of metrocounter) and map of location for site 3 (right)



These locations were not sign-posted with SRS signs prior to the trial. Using locations that did not require SRS signage reduced the risk experienced by drivers travelling through areas with unfamiliar signage, but did not reduce the validity of the trials as reduced surface friction is not generally easily visible to drivers, meaning drivers were unaware that the addition of signage in area was not due to the surface friction at the sites having fallen below a desired level. Opus liaised with the network outcome contract holder to arrange consent for the erection of the signage and necessary traffic controls. Each signage option was tested at each of the selected sites.

4.1.1.4 Treatment conditions (dry and adverse)

The key performance measures for each signage option (speed) were measured during dry conditions as well as adverse weather conditions. A key premise behind the method was dry conditions offered road surface conditions that are essentially 'ideal', while adverse weather is a common cause of reduced road surface friction. Conditions where road surface friction is lower than desired will produce different patterns of driver behaviour including lower speeds, therefore baseline (no sign) measures were taken in both adverse and dry conditions so the impact of the conditions on key performance measures could be established and then any additional impact of the signage options calculated. It was important in examining the impact on driver behaviour of signage options under adverse conditions to take into account the weather conditions that were most likely to result in reduced road surface friction, and where it was most important that signage options were effective in leading to desired behaviour changes.

4.1.2 Data analysis

Metrocount data was extracted from the raw data files to a Microsoft Excel format and was analysed using the SPSS 19.0 (Statistics Package for the Social Sciences version 19.0) analysis package which allowed for easy manipulation and recoding of the data, as well as detailed data checking and quality assurance processes. This software also allowed advanced statistical analysis and graphing capability for ease of presentation. Analysis of variance (ANOVA) was used to examine differences between signage options and treatment conditions (ie adverse and dry).

Rainfall data was obtained from the MetService website from the weather gauge located at Pinehaven Stream at Pinehaven Reserve, which was the closest gauge to the curve locations.

4.1.3 Draft recommendations workshop

The results from phases 3 and 4 were compiled and compared with international data on the detection, understanding and behavioural impact of SRS signage (reviewed in phase 1) and a series of recommendations developed as to how best to warn drivers about less than optimal surface friction. A summary of the findings and recommendations were drafted and presented in a workshop to the Steering Group. Participants in the workshop commented on the findings and recommendations from the perspective of practical implementation and their input was incorporated into the development of recommendations for the use of SRS signs given in chapter 5.

4.2 Results

Baseline (no sign) speed measurements of all three sites were taken using metrocounters from 23 September 2015 to 2 October 2015. During this period rainfall ranged from 0.2mm an hour to 1.4mm in an hour.

Once these baseline (no sign) measurements had been collected the signs were erected from 16 November 2015 to 28 March 2016. There was a total of three rotations within this period, with each rotation having a sign at one of the three different sites, a summary of these can be seen in table 4.1. The rotation ensured that each signage options was tested at all three different curve radii.

Table 4.1 Sign rotations during study period

Site	Rotation one	Rotation two	Rotation three
	16/11/15 to 25/01/16	25/01/16 to 29/02/16	29/02/16 to 28/03/16
One Radius 270m	No supplementary plate	Slippery when wet	Slow when wet
Two Radius 184m	Slippery when wet	Slow when wet	No supplementary plate
Three Radius 88m	Slow when wet	No supplementary plate	Slippery when wet

For each rotation, the signs were in position for a minimum of three weeks prior to the metrocounters being placed on the road. This three-week period aimed to reduce any novelty effect of the signs (ie motorists slowing simply because they have encountered something new on the road, rather than as a result of the signs themselves). Following this period of time, the metrocounters were placed at each site for two weeks to record vehicle speed around each curve. The position of the metrocounter at each site can be seen in figures 4.1, 4.2 and 4.3. During the period the metrocounters were in place there were eight days of rain (two in rotation 1; three in rotation 2; three in rotation 3). Rainfall ranged from 0.1mm an hour to 13.6mm an hour (during periods when it did rain).

On the completion of the third rotation, the metrocount data from the baseline (no sign) period and all three rotations were combined and analysed in the following manner:

- Only free following vehicle speeds were analysed, eg vehicles with at least four seconds of headway

- All speeds more than two standard deviations below the mean were removed from the analysis to control for those slowing for other reasons than rain, eg pulling over to the side of the road
- When comparing wet weather vehicle speeds, only vehicles travelling in rainfall between 1.4mm and 2.9mm an hour were analysed to control for any effect caused by large variations in rainfall (this was to ensure comparable rain levels when looking at the analyses).

Once the data had been prepared a one-way ANOVA was conducted by site with planned comparisons for all four conditions (no sign, sign with no supplementary plate, sign with 'slippery when wet' and sign with 'slow when wet' supplementary plates).

For site 1, the results revealed there was a significant effect of signage on free vehicle speeds compared to baseline (no sign), $F(3, 823) = 9.14, p < 0.01, r = 0.18$. Planned contrasts revealed that the presence of any sign significantly reduced vehicle speed compared to no sign at all, $t(823) = -3.30, p < 0.01$ (one tailed), $r = 0.11$. Furthermore, the sign correlated with the greatest level of speed reduction compared to no sign at all was the sign with the supplementary plate that said 'Slippery when wet', which contributed to a 5.3km/h speed reduction from 79.9km/h to 74.6km/h, $t(823) = 4.554, p < 0.01$ (one tailed), $r = 0.15$.

Similarly, for site 2 there was also a significant effect of signage on free vehicle speeds compared to baseline (no sign), $F(3, 256.38) = 17.75, p < 0.01, r = 0.24$. Site 2 planned contrasts revealed that, as with site 1, any sign significantly reduced vehicle speed compared with no sign at all, $t(69.57) = -5.348, p < 0.01$ (one tailed), $r = 0.54$. Unlike site 1, the sign correlated with the greatest level of speed reduction compared with no sign at all had the supplementary plate 'Slow when wet', which contributed to a 7.2km/h speed reduction from 87.3km/h to 80.1km/h, $t(94.38) = 5.89, p < 0.01$ (one tailed), $r = 0.52$.

Finally at site 3 there was again a significant effect of signage on free vehicle speeds compared with baseline (no sign), $F(3, 1140) = 20.24, p < 0.01, r = 0.23$. As with sites 1 and 2, the planned contrasts revealed that any sign significantly reduced vehicle speed compared with no sign at all, $t(1137) = -7.017, p < 0.01$ (one tailed), $r = 0.20$. Different again to site 1 or 2 the sign that correlated with the greatest reduction in vehicle speed compared with no sign at all was the sign with no supplementary plate affixed, which contributed to a 4.8km/h speed reduction from 57.6km/h to 52.8km/h, $t(1137) = 7.781, p < 0.01$ (one tailed), $r = 0.23$.

The average speed for each sign type by site can be seen in table 4.2.

Table 4.2 Mean free vehicle speeds and 85th percentile speeds in wet weather by sign type at sites 1, 2 and 3

Sign type	km/h (standard deviation)								
	Site 1			Site 2			Site 3		
	n	Mean	85th percentile	n	Mean	85th percentile	n	Mean	85th percentile
No sign	72	79.9 (10.3)	91.2 (10.3)	64	87.3 (8.9)	98.5 (8.9)	92	57.6 (5.3)	65.9 (5.3)
No supplementary plate	68	78.5 (10.1)	88.9 (10.1)	331	83 (7.4)	90.3 (7.4)	269	52.8 (5.0)	57.6 (5.0)
Slippery when wet	278	74.6 (8.4)	82.9 (8.4)	404	80.7 (6.8)	87.4 (6.8)	322	54.2 (5.8)	59.0 (5.8)
Slow when wet	409	75.6 (8.6)	84.8 (8.6)	239	80.1 (8.3)	88.1 (8.3)	458	54.1 (4.7)	58.7 (4.7)

Note: The lowest mean/85th percentile speed at each site is indicated in bold font.

A preliminary analysis was also conducted in dry weather conditions and while the results indicated there were significant differences between the four conditions this was an artefact of the large sample size and amounted to actual speed changes of approximately 1km/h. So, while this is a statistically significant finding, it has no practical significance compared with the 7km/h speed change seen in wet conditions as exhibited at site 2.

The 85th percentile speeds followed a similar pattern to the mean speeds. The only difference being at site 1 where the sign alone did not correlate with a significantly lower speed than in the baseline (no sign) condition; and at sites 2 and 3 where the signs with the supplementary plates did correlate with a significantly lower speed compared with the baseline (no sign), but did not differ significantly from each other.

4.2.1 Recommendations workshop

4.2.1.1 Key decisions and discussion points

A workshop with the Steering Group was conducted on 7 July 2016. Members were presented with a review of the project, the on-road study results and the overall recommendations from the project.

Key discussion points focused around:

- the applicability of the findings to permanent SRS signage
- the recommendation of 'Slippery...' versus 'Slow...' supplementary plate text
- the extrapolation of findings to other SRS supplementary plate text.

The Steering Group discussed the usage of both permanent and temporary signage, and public understanding of the differences between each. This is covered to an extent in the focus group results, but could be followed up in future on-road studies. The current on-road study tested temporary signage, but the results could also be applied to permanent signage. The permanent signage already in use on the network in New Zealand is always erected with a supplementary plate ('When wet', 'When frosty', 'Gravel road'), unlike the temporary signage, which is erected alone or with 'Ice/grit'. The permanent signage, therefore, already makes use of the added benefit, in terms of driver speed reduction, provided by a supplementary plate. The literature review and focus group results indicate that upgrading the supplementary plate on the permanent signs to either 'Slippery when wet' or 'Slow when wet' could increase the beneficial effect of the supplementary signage. This would also provide consistency between the temporary and permanent signage but it is not a priority, given the results here demonstrate the effectiveness of a supplementary plate, which in the case of the permanent signs, is already in place.

The Steering Group was keen to discuss further which of the two supplementary signs would be recommended. The mean speed results showed that at each curve a different sign led to significantly slower mean speeds compared with the baseline (no sign), and the 'Slow when wet' sign had the greatest effect (a 7km/h reduction in mean speed). The 85th percentile data was very similar, with 'Slow when wet' and 'Slippery when wet' being equally effective at reducing driver speed at two of the three sites. Given the on-road study results point to the effectiveness of a supplementary plate but do not distinguish strongly between the two, the steering group endorsed drawing on the focus group results and literature to recommend one over the other. The public focus group participants' final recommendation for their preferred supplementary text was 'Slow down when wet'. This aligns with literature that suggests the inclusion of action words indicating the desired behavioural response from drivers increases the drivers'

ability to respond appropriately. From this discussion it was decided that of the supplementary signs tested, 'Slow when wet' would be recommended.

Finally, the Steering Group was interested in the potential for extrapolating the form of the message to other supplementary signs used in conjunction with the SRS main signs: 'When wet', 'When frosty', 'Gravel road', 'Ice/grit'. The research on which the current 'Slow when wet' message was developed (ie the focus group findings and behaviour response literature) is fundamental rather than specific to wet conditions only. It is therefore appropriate to generalise these findings to other SRS conditions; for example: 'Slow when frosty' and 'Slow: Gravel road' supplementary plates could be applied to both permanent and temporary SRS signs.

5 Discussion and recommendations

5.1 Discussion

This project aimed to assist in the development of understandable static signage to warn drivers of the potential for lower skid resistance in areas renowned for periodic slippery conditions. To do so the research team conducted an iterative design process, beginning with a literature review in which the features influencing road signage effectiveness, in terms of both conspicuity and comprehension, were identified. Based on these findings, alternative signage designs were developed and investigated in relation to the current SRS signage through a public focus group followed by an expert focus group. One of the key discussion points during these groups was the use of crossed versus uncrossed vehicle tracks in the icon on the main plate. This is one of the key ways in which these signs differ internationally. While the focus group participants felt crossed tracks were less realistic in terms of how a car would really move in slippery conditions (reduced semantic closeness and concreteness), they also considered this 'unreality' conveyed a greater sense of danger and need for caution. The participants decided this increased sense of danger outweighed the reduced realism as it was more likely to encourage drivers to reduce speed, so despite extensive discussion, the use of crossed tracks was maintained. Ultimately it was decided instead of changing the main plate or icon, changes to the supplementary signage text would be tested.

The outcomes of this process led to the Steering Group selecting two alternative supplementary plates to be used with the main plate already in use. These signs were constructed to the temporary signage design specifications (set out in NZ Gazette 9 July 2015, no.74, au3962. <https://gazette.govt.nz/assets/pdf-cache/2015/2015-au3962.pdf?2015-07-09%2010:01:07>) and compared with the current temporary SRS signage (which consists of a main plate only) in an on-road trial (see figures 3.6, 3.7 and 3.8).

Metrocounters were used to measure the free vehicle speed associated with each of the signs at three different curves in both wet and dry conditions. Field trials of three SRS signage conditions were compared with the baseline (no sign) to test their effectiveness in reducing free vehicle speed in wet conditions.

In dry conditions the signs made no practical difference to vehicle speed; however, in wet conditions the presence of a sign resulted in both a significant and practical reduction in free vehicle speed on all three curves. This indicates drivers were correctly responding to the signage in wet conditions, showing an observable indicator of comprehension and a positive behavioural response. Planned comparison statistical tests revealed the sign that led to the greatest reduction in free vehicle speed in the wet differed at each of the curves.

One explanation for the effect of the signage could be that the novelty of a sign appearing in a previously unsignposted area could induce drivers to slow down regardless of the message presented in the sign. However, having the road signs in each position for a minimum of two weeks prior to testing, as was done in this study, should have reduced any potential novelty effects. There is also evidence from the literature indicating that comprehension of SRS signage, and signage in general, may not be necessary to induce the desired behavioural responses (eg Charlton and Baas 2006), and may not even take place at a conscious level (Fisher 1992). In contrast, findings from this study do indicate a level of conscious processing as the signs induced a much greater speed reduction in wet conditions than in dry. Given these are the conditions the signs specifically warn about in the supplementary plates, drivers must be comprehending and processing this information and adjusting their behaviour according to the relevance of the message to the conditions in which they are driving.

The sign with no supplementary plate describing the conditions had an impact on vehicle speed compared with no sign, and was the most effective sign on the tightest curve, indicating, that even as they currently appear on-road SRS signage does promote the desired behavioural response in drivers. This supports the findings of Rämä and Kulmala (2000) that VMS SRS signs resulted in an average decrease in mean speed of 1.2km/h of cars travelling in free flow traffic at two out of three test sites in ice-prone areas. The fact that a more substantial speed reduction was found in this study (1.4km/h site 1; 4.3km/h site 2; 4.8km/h at site 3) using the static signage currently on the road, indicates the importance of continuing to signpost at risk areas and suggests that even greater speed reductions could be possible through the use of VMS (see Rämä and Kulmala 2000; Carson and Mannering 2001; Charlton and Baas 2006) on the areas deemed of greatest risk.

While such VMS would need to be reserved for particular high-risk areas owing to the expense of such signs and the desire not to minimise their effectiveness through overuse and overexposure, this study also demonstrates the potential benefits of reasonably minor changes to the supplementary plates accompanying the main plate currently in use. On two of the three curves a sign with a new supplementary plate led to the greatest reduction in driving speeds. The 'Slippery when wet' sign led to mean speed reductions ranging from 3.4km/h at site 3 to 6.6km/h at site 2, and 85th percentile speed reductions ranging from 3.9km/h at site 3 to 11.1km/h at site 2; and the 'Slow when wet' sign led to mean speed reductions ranging from 3.5km/h at site 3 to 7.2km/h at site 2 and 85th percentile speed reductions ranging from 5.3km/h at site 3 to 10.4km/h at site 2. These reductions were significantly greater than the reductions attributable to the main plate alone. This fits with research indicating the combination of text and symbols is more effective than symbols alone (Shinar and Vogelzang 2013). Currently, the temporary TW-4 SRS sign does not have a supplementary plate unless it is associated with ice/grit (TW4.1). This indicates the addition of a supplementary plate, such as the one tested here to TW-4, could have a significant influence on driver speed in wet conditions. Also, the signs resulted in speed reductions across different curve radii (or tightness of the curve), with curves tested between 88m and 270m, indicating they would have a positive effect across similar curves on the network.

The permanent SRS sign was presented in conjunction with a supplementary plate, the text being 'When wet'. The interpretation of the warning was thus dependent on the interpretation of the main plate as this alone provides drivers with the information about *what* is to be expected when the conditions are adverse. The addition of either 'Slippery' or 'Slow' to the 'When wet' supplementary plate on the permanent SRS sign could be beneficial because these words explain the risk in full independently of comprehension of the symbolic component of the sign. The 'Slow when wet' message is particularly advantageous as it includes direct reference to the desired behavioural response and ties in with the text currently used on VMS SRS signs in New Zealand ('Slow down'; see figure 2.2). The 'Slow when wet' supplementary plate resulted in the greatest mean speed reduction obtained in this study – a 7km/h speed reduction on curve 2 (184m radius) and a reduction in the 85th percentile speed of over 10km/h on the same curve.

The inclusion of an additional word in the standard permanent supplementary plates (ie adding 'Slow' to 'When wet', 'When frosty' and 'Gravel road') would involve minimal additional cost, particularly as the minor change in wording, and the finding here that even the main plate alone is effective at producing a speed reduction, means any change could be carried out when signs require replacement and new signs are erected, rather than necessitating the full-scale replacement of all permanent supplementary plates. The addition of the supplementary plate to all temporary signage could also be carried out in conjunction with scheduled maintenance and as new signs are erected. The only consideration to account for here is consistency of signage during the transition period.

5.2 Conclusion

This research has demonstrated that static signage can be effective in inducing the desired behavioural response (speed reduction) in situations where reduced road surface friction has the potential to affect driver safety. The particular message on the signage appears to be less important than its presence, as each sign tested was the most effective sign at one of the sites in wet conditions, and all were significantly more effective than the baseline (no sign) condition. However, the 'Slow when wet' supplementary plate signage led to the greatest overall speed reduction in wet conditions when compared with the baseline. Drivers appear to be able to distinguish when the message on the sign is most relevant as the difference at each site is of practical significance in wet conditions but not in dry conditions. Based on these findings, the following recommendations are made for future SRS signage design.

5.3 Recommendations:

- 1 The literature suggests, and our focus groups support, the idea of maintaining the current signage 'syntax' or 'grammar' (ie shape, colour, placement) used for signage in this country. For this reason, we recommend SRS signs maintain the diamond shape with black on yellow (permanent) or orange (temporary).
- 2 A major point of discussion was the crossed tracks in the main plate icon. The focus groups revealed that while crossed tracks reduced the semantic closeness and concreteness of the icon in the SRS sign, they increase its meaningfulness to them by conveying a sense of potential danger and need for caution. This was deemed as likely to induce actual behaviour change in the form of reducing speed. It is therefore recommended that crossed tracks be maintained in any future icon development.
- 3 The on-road study found the presence of any SRS signage (the main plate only, main plate + 'Slippery when wet' supplementary plate and main plate + 'Slow when wet' supplementary plate) significantly reduced driver speed in both wet and dry conditions (although reductions in the dry were not of practical significance). It is therefore recommended all areas are signposted where reduced surface friction is likely to impact on driver safety.
- 4 In two of the three curves tested in the on-road study, the addition of a supplementary plate resulted in a significantly greater speed reduction than the main plate alone. It is therefore recommended one of the supplementary plates tested in this study be added to the main plate in order to signpost temporary areas of reduced surface friction.
- 5 The supplementary plate 'Slow when wet' was associated with the greatest level of speed reduction at any of the three sites compared with no sign at all: vehicle speeds were approximately 7km/h slower when the 'Slow when wet' sign was in place than when no sign was in place. Given these results, it is recommended that the SRS main plate be accompanied with the 'Slow when wet' supplementary plate in both temporary and permanent situations.
- 6 SRS signage is also used to signpost situations where surface friction may be reduced by factors other than wet, such as frost, gravel, concrete roads, and ice and grit. Supplementary signage currently exists for each of these conditions. We recommend the same message format shown to be effective in this study be adopted for these conditions too. For example, 'Slow when frosty' or 'Slow: ice/grit'.

- 7 The finding that even the main plate alone is effective at producing a speed reduction means a full scale replacement of all permanent supplementary plates and the addition of the supplementary plate to all temporary signage is not required immediately if this proves financially or logistically problematic. Instead, it is recommended these changes be carried out in conjunction with scheduled maintenance and as new signs are erected, potentially targeting higher-risk locations earlier.
- 8 Although they were not the focus of this study, based on the findings in the literature review it is recommended the VMS warning sign including the text 'Slow down' continue to be used at particularly high-risk sites, and its effectiveness be examined in future research projects.
- 9 In terms of future proofing, the message, syntax and icon could be included in specific software updates for any in-vehicle message systems that include weather detection.

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Appendix A: Public interactive workshop survey

Part 1: Current signage questionnaire



Sign A



Sign B

Please look at Sign A and Sign B above and answer the following questions:

1. What do you think these signs mean?

- Sign A

- Sign B

2. Have you seen signs like this before?

- Often
- Once or twice
- Never
- I don't know

3. In what kind of situation would you see these signs? (E.g. On what kinds of roads? In what kinds of circumstances?)

4. What is the difference between these two signs?

5. Under what conditions do you think these signs would be relevant to drivers?

6. How would you respond if you saw these signs:













7. In dry conditions?





a) In adverse conditions?

8. For how long would you expect a temporary (orange) sign to be in place?

Appendix B: Alternative sign options for public interactive workshop

Table B.1 Rankings of potential designs

Option	Description	Permanent signage options	Temporary signage options	Familiarity	Simplicity	Concrete-ness	Meaningful-ness	Semantic distance
1	Current sign							
2	Tracks uncrossed, vehicle on two wheels, perspective applied to tracks							
3	As above plus road edge							
4	As above plus road edge and centre line							
5	As above plus red LED component (Note, LEDs could be tested with all the above signage)							
6	As above plus fluorescent yellow-green for permanent and fluorescent orange for temporary (note: these colours could be tested with all the above signage)							

Option	Description	Permanent signage options	Temporary signage options	Familiarity	Simplicity	Concreteness	Meaningfulness	Semantic distance
7a	As above with a water symbol (note: water symbols could be tested with all the above signage as shown in the two examples below)							
7b								
7c								

Appendix C: Public workshop ranking results













Scores for alternative signs under each of the cognitive features presented to participants.




Table C.1 Summary of sign ranking results for overall preference and five cognitive features

Sign option	Familiarity	Simplicity	Concreteness	Meaningfulness	Semantic closeness	Overall ranking
1	20 (1st)	11 (2nd)	7 (3rd)	11 (3rd)	10	9 (3rd)
2	11 (2nd)	16 (1st)	12 (2nd)	8	11 (2nd)	15 (1st)
3	5	6	9	12 (2nd)	10	8
4	6	5	15 (1st)	16 (1st)	14 (1st)	8
5	6	2	4	3	3	7
6	6	9 (3rd)	4	4	3	10 (2nd)
7a	0	0	0	0	0	0
7b	0	0	3	0	3	3
7c	0	0	0	0	0	0

Appendix D: Alternative sign options for Steering Group workshop

Table D.1 Rankings of potential designs

Option	Description	Permanent signage options	Temporary signage options	Overall
1	Current sign			
2	Tracks uncrossed, vehicle on two wheels, perspective applied to tracks			
3	As above plus road edge			
4	As above plus road edge and centre line			
5	As above plus red LED component (note: LEDs could be tested with all the above signage)			
6	As above plus fluorescent yellow-green for permanent and fluorescent orange for temporary (note: these colours could be tested with all the above signage)			

Option	Description	Permanent signage options	Temporary signage options	Overall
7a	As above with a water symbol (note: water symbols could be tested with all the above signage as shown in the two examples below)			
7b				
7c		