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SUMMARY OF DRAINAGE ANALYSIS IN THE SCOTTISH HIGHLANDS

Demonstration Project Report

ABSTRACT

A well performing drainage system is one the most important factors in sustainable road management. Almost all road structures work well and last longer when they are kept dry, and numerous research studies have shown that that poor drainage is often the main cause of road damages. This knowledge is however often ignored in everyday roads maintenance practices and previous ROADEX projects have reported that poor drainage is the one of the biggest factors affecting Northern European rural roads, and many parts of the main road network too.

The “Drainage analysis” methodology was developed in the ROADEX project to locate those critical road sections, needing improvement and regular maintenance. In this data is first collected visually, and by video, from a moving vehicle and later supplemented with inputs from other historic road, such as roughness and rutting information.

This report “*A Summary of Drainage Analysis in the Scottish Highlands*” describes the results of a series of drainage analysis surveys in the Lochalsh and Wester Ross area of Scotland. The total length of the roads analysed was approximately 127km. Typical drainage problems in the test area included high grass verges and road sections constructed on side sloping ground. Well performing sections were noted on sections where the drainage had been improved and the road condition was flawless.

The draiange analyses carried out show that defective sections of road drainage can be fairly easily located with the drainage analysis method and that improvement plans can be made for the affected sections based on the results. The reports finds that improving drainage, and removing high roadside verges, is likely to produce major savings in the annual paving costs for Highland roads. In addition traffic safety will be improved thanks to reduced shoulder deformation.

KEYWORDS

Drainage, analysis, verge, pavement, life time, rutting, IRI

PREFACE

This task “*Summary of drainage analysis results in the Scottish Highlands*” was carried out under ROADEX IV work package 3, “Local demonstrations”.

The field measurements were performed by Seppo Tuisku with the help of The Highland Council. Sandy MacVarish from The Highland Council TEC Services participated in the field surveys. The processing and analysis of measured data was done by Seppo Tuisku. The report was written jointly by Seppo Tuisku and Annele Matintupa. Timo Saarenpää and Pekka Maijala from Roadscanners Oy helped with the handling of the rutting data supplied by the clients (roughness data was not available in Highland Council area). Timo Saarenketo steered the demonstrations as lead manager of the ROADEX D1 “Drainage Maintenance Guidelines” group. Ron Munro helped with the demonstration arrangements and also checked the language. Mika Pyhähuhta from Laboratorio Uleåborg designed the report layout.

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1. INTRODUCTION

1.1 THE ROADEX PROJECT

The ROADEX Project is a technical co-operation between road organisations across northern Europe that aims to share road related information and research between the partners. The project was started in 1998 as a 3 year pilot co-operation between the districts of Finland Lapland, Troms County of Norway, the Northern Region of Sweden and The Highland Council of Scotland and was subsequently followed and extended with a second project, ROADEX II, from 2002 to 2005, a third, ROADEX III from 2006 to 2007 and a fourth, ROADEX IV from 2009 to 2013.



Figure 1: The Northern Periphery Area and ROADEX IV partners.

The Partners in ROADEX IV “Implementing Accessibility” comprised public road administrations and forestry organisations from across the European Northern Periphery. These were The Highland Council, Forestry Commission Scotland and Comhairle Nan Eilean Siar from Scotland, The Northern Region of The Norwegian Public Roads Administration, The Northern Region of The Swedish Transport Administration and the Swedish Forest Agency, The Centre of Economic Development, Transport and the Environment of Finland, The Government of Greenland, The Icelandic Road Administration, and The National Roads Authority and The Department of Transport of Ireland.

The aim of the Project was to implement the road technologies developed by ROADEX on to the Partner road networks to improve operational efficiency and save money. The lead partner for the project was The Swedish Transport Administration and the main project consultant was Roadscanners Oy of Finland.

A main part of the Project was a programme of 23 demonstration projects showcasing the ROADEX methods in the Local Partner areas supported by a new pan-regional “ROADEX Consultancy Service” and “Knowledge Centre”. Three research tasks were pursued as part of the project: “Climate change and its consequences on the maintenance of low volume roads”, “Road Widening” and “Vibration in vehicles and humans due to road condition”.

All ROADEX reports are available on the ROADEX website at www.ROADEX.org.

1.2 THE DEMONSTRATION PROJECTS

Twenty three demonstration projects were planned within the ROADEX IV project. Their goal was to take selected technologies developed by ROADEX out on to the local road networks to have them physically used in practice to show what they could achieve. The projects were funded locally by the local Partners, designed and supervised by local staff, and supported by experts from the ROADEX consultancy.

The demonstrations were managed in 6 groups by a nominated lead manager from ROADEX:

- D1 - "Drainage Maintenance Guidelines"
- D2 - "Road friendly vehicles and Tyre Pressure Control"
- D3 - "Forest Road policies"
- D4 - "Rutting, from theory to practice"
- D5 - "Roads on Peat"
- D6 - "Health and Vibration"

This report deals with the demonstrations project in the D1 "Drainage Maintenance Guidelines" group carried out in Highland area in Scotland.

2. ROADS SURVEYED

This drainage analysis surveys of this report were carried out on several roads in the Lochalsh and Western Ross areas of the Scottish Highlands. These road sections were chosen by The Highland Council and are shown in Figure 2.

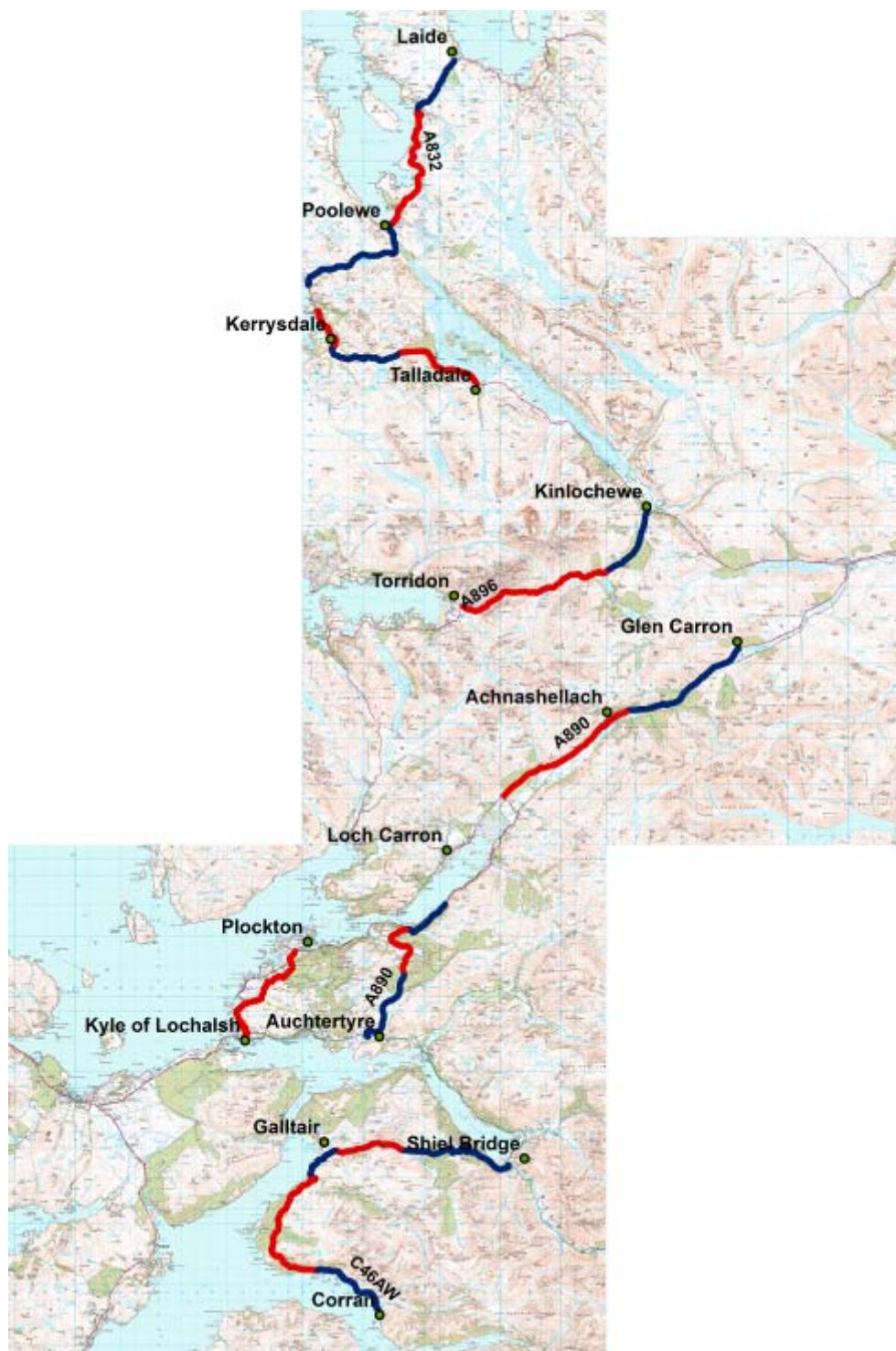


Figure 2: Surveyed roads in Highland

The A832 road was surveyed from Laide to Talladale excluding a short section in Gairloch. The A896 road was surveyed from its junction with the A832 road in Kinlochewe westwards to Torridon.

The A890 road survey started from its junction with the A87 road in Auchtertyre and carried on to Ardnarff grid from where a short section was excluded and then the survey continued from the junction with the A896 to Glen Carron. The C46AW road was surveyed from Shiel Bridge to Corran. The local road from Kyle of Lochalsh to Plockton was also included in this project (table 1).

The landscape and terrain along the roads surveyed was very variable. Part of the roads were coastal and many sections were located on loch shores where the landscape was side sloping. Subgrade soil types varied from glacial moraines to bedrock and there were also some sections where roads were built on peat soils.

Table 1. The surveyed road sections and their lengths.

Road	Start point	End point	Length
A832	Loch Maree Hotel	Slattadale cattle grid	5912
A832	Slattadale	Kerry Glen	5730
A832	Kerry Glen	Gairloch Pier	2731
A832	Gairloch	Poolewe	8643
A832	Poolewe	Drumchork	10106
A832	Drumchork	Laide	4162
A890	Glen Carron	Achnashellach Rail Bridge	8934
A890	Achnashellach Rail Bridge	Strathcarron junction	10301
A890	Strome Ferry	Ardnaff cattle grid	3465
A890	Braeintrà	Strome Ferry	4671
A890	Auchtertyre (A87)	Braeintrà	5593
A896	Diabaig Junction	Cowlin Estate junction	10947
A896	Cowlin Estate junction	A832 Junction	4875
C46AW	Shiel Bridge	Moyle junction	9388
C46AW	Moyle junction	Ferry junction	4637
C46AW	Ferry Junction	Eilanreach	2929
C46AW	Eilanreach	4th Grid	9840
C46AW	4th Grid	Corran	5581
	Kyle of Lochalsh	Plockton	8535

3. DATA COLLECTION, FIELD SURVEYS

3.1. GENERAL

Data collection for the Highland drainage demonstration projects was carried out in March 2010. The weather was fine at the beginning of the surveys but later deteriorated to rain which caused difficulties on the road.

The survey started from on the A890 road and continued to the C46AW road and then later to the A832 and A896 roads. The local road from Kyle of Lochlash to Plockton was also surveyed.

Prior to the commencement of the surveys roads were divided into sub-sections. These varied between 5-10 kilometres, with a couple of sections less than 5 km. Junctions, bridges and cattle grids were used as section break points as they were easy to locate during the surveys.

3.2. VIDEO AND GPS

Drainage analysis in the field was carried out on one road section at a time and both sides of the road were analyzed separately. The Highland Council provided the van for the survey. A CamLink video-logging system by Roadscanners Oy was installed to the van roof (Figure 3). The driving speed during the data collection was about 30 km/h and the vehicle was driven close to the road shoulder so that the video cameras had the best possible view of the ditch and road side. An APD Communications INCA 2 GPS device was used for GPS positioning. All the data was linked to GPS coordinates using Road Doctor CamLink software.



Figure 3: The Highland Council provided the survey van that was used in the project. Video cameras were placed in the orange CamLink box for shelter from the rain and dust.

Two video cameras, located in the CamLink box, were used in the survey. One camera was used to record the road view, and the second camera to record the ditch view.

A Panasonic Toughbook laptop with Road Doctor™ CamLink software was used to record the video data from the cameras and drainage classification of data. Preliminary classifications were recorded in the vehicle using the laptop keyboard (Figure 4). Audio comments were also recorded to help data interpretation in the office. These audio comments were mainly about soil type, presence of ditches and their condition, and to correct any mistakes with classification made with keyboard. The preliminary analysis was adjusted later in the office. This was made with the help data from the road camera, supplemented by data from the ditch camera view which was very useful in having a closer record of the ditches.



Figure 4: The laptop was used for data collection on the road.

4. DRAINAGE ANALYSIS

4.1. GENERAL

Road drainage arrangements in Scotland differ fairly significantly from Nordic countries where the ROADDEX drainage survey method was originally developed. Main difference is that verges are quite common on older road sections.

It was noted that French drains or even storm water sewer systems were used as part of the drainage system in the most demanding sections. These arrangements were still working well in general, but in some cases they were blocked or just inadequate. The drainage in the newly upgraded sections of road seemed to be working well. Usually these had open ditches.

4.2. TYPICAL DRAINAGE DEFICIENCIES IN THE SURVEYED SECTIONS

4.2.1. ROAD A832

Six sections were surveyed on the A832 road; Loch Maree Hotel-Slattadale, Slattadale-Kerry Glen, Kerry Glen-Gairloch Pier, Gairloch-Poolewe, Poolewe-Drumchork and Drumchork-Laide (Figure 5).



Figure 5: Surveyed sections on the A832 road

4.2.1.1. A832 LOCH MAREE HOTEL - SLATTADALE CATTLE GRID

This section started at the Loch Maree Hotel and ended in Slattadale at a cattle grid. The length of the section was 5912m. The beginning of the section had high verges which blocked surface water flowing from the road. The left ditch was poor and full of bushes. In the upgraded section, starting from 1400m, the drainage was in good shape



Figures 6: Left: High verge and bushes, Right: Good drainage in upgraded section

4.2.1.2. A832 SLATTADALE – KERRY GLEN

The section from Slattadale cattle grid started as a 2-lane road but after 550m it changed to single track. The single track part had several severe drainage deficiencies especially at the end of section. The length of the surveyed section was 5730m and ended at the junction with the B8056 road.



Figures 7: Severe drainage problems towards the end of the section

4.2.1.3. A832 KERRY GLEN – GAIRLOCH PIER

The A832 road changed back to a two-lane road in Kerry Glen. Verges were present along nearly all the section length. These clearly blocked any surface water flowing away from the road surface. At 1300m there was a narrow road cut which did not have a drainage system. Another longer road cut started at 1600m which did have open ditches. These ditches were narrow and shallow. At the end of the section there was a French drain in a road cut that seemed to be working well. The length of the surveyed section was 2731m and ended at Gairloch Pier.



Figures 8: Left: Problematic verges, Right: Narrow road cut without ditches

4.2.1.4. A832 GAIRLOCH – POOLEWE

The section started from the junction with the B8021 road in Gairloch. The length of the surveyed section was 8643m and ended at the junction with the B8057 road in Poolewe. The road profile was mostly side sloping ground (76%) and the drainage deficiencies found were typical for this road profile. Verges were seen to cause drainage problems in this section. This was also the case on the length of new pavement from 7600m to 8400m where the presence of verges is expected to cause drainage difficulties into the future..



Figures 9: Drainage deficiencies on the upper side of the side sloping profile



Figures 10: High verge in section where the paving is new

4.2.1.5. A832 POOLEWE – DRUMCHORK

This section commenced at the junction with the B8057 road in Poolewe. The length of the section was 10106m and ended at the junction with the road to Drumchork village. The first part of the section lay in the village area of Poolewe where water outlets take care of the drainage.

The pavement was in fairly good condition between Poolewe and Drumchork. There were a couple of short lengths with old and weak pavement. The road was generally located in side sloping ground (73%) with many drainage deficiencies in the upper side of the slope.



Figures 11: Drainage deficiencies in side sloping ground in section Poolewe – Drumchork

4.2.1.6. A832 DRUMCHORK – LAIDE

The final section surveyed on the A832 was from the junction to the village of Drumchork and ended at the junction to Laide. The length of the section was 4162m. The pavement was quite new in this section and was in relatively good shape. The road profile was mainly side sloping (78%). The drainage deficiencies noted were typical for the kind of road profile but they did not appear to have affected the pavement condition as much as in other sections. The reason for this could be that the paving was quite new and the effect of any drainage shortcomings had not yet become visible. Recent drainage maintenance work had taken place from 450m to 1050m where the ditch on the left side had been cleaned out but the verge had also been rebuilt.



Figures 12: Rebuilt verge, Right: Good offlets on rebuilt verge

4.2.2. ROAD A890

Five sections were surveyed on the A890 road; Auchtertyre (A87) to Braeintru, Braeintru to Strome Ferry, Strome Ferry to Ardnaft cattle grid, Achnashellach Rail Bridge to Strathcarron junction and Achnashellach Rail Bridge to Glen Carron (Figure 13).

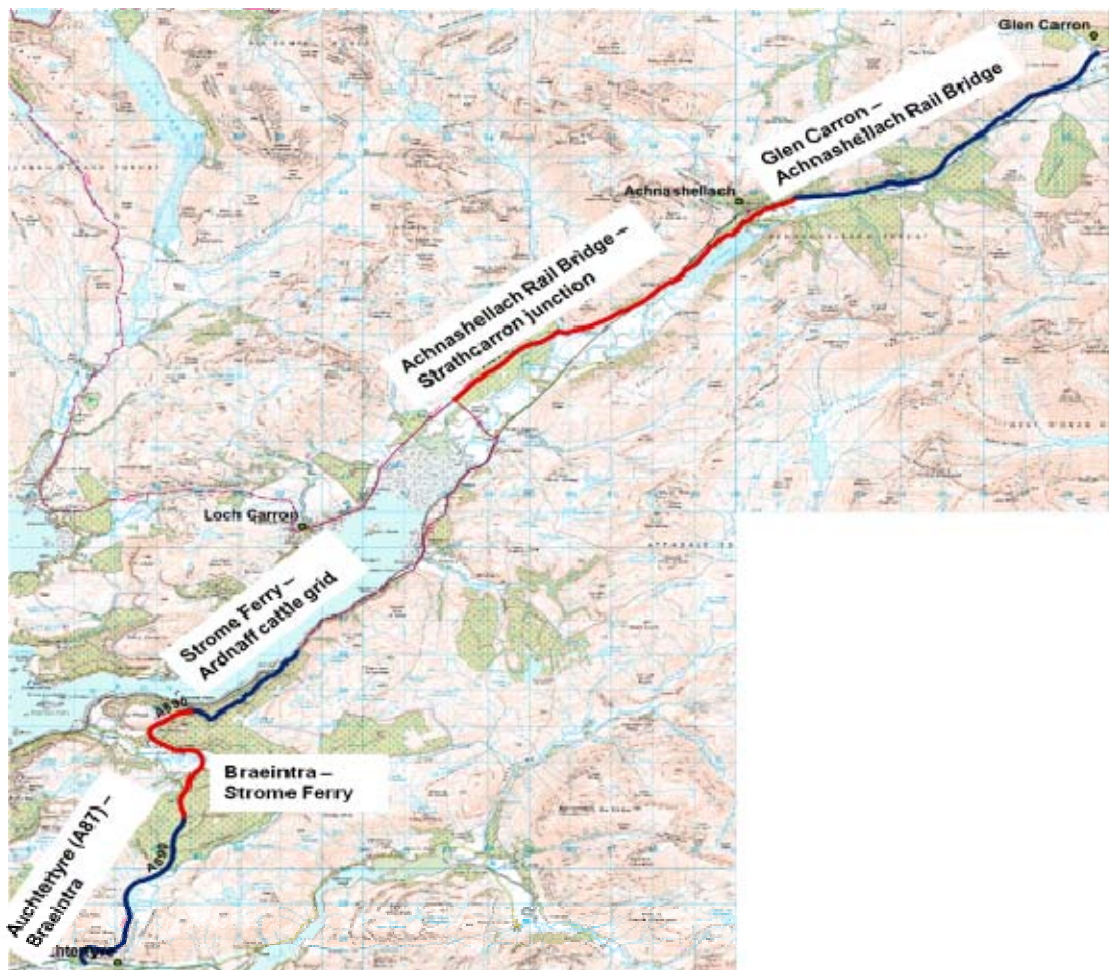


Figure 13: Surveyed sections from the road A890

4.2.2.1. GLEN CARRON - ACHNASHELLACH RAIL BRIDGE

The surveyed section started at the bridge at Glen Carron and had length of 8934m. From the beginning to 1350m the road had been upgraded and the drainage was in good condition. The verges had been removed. The road mainly followed a valley for the full section and the road profile steeply slopes from right to left. The drainage deficiencies identified were typical for this kind of road profile. The presence of verges caused drainage problems at times.



Figures 14: Left: Upgraded section where the verges have been removed, Right: Older structure with high verges



Figures 15: Inadequate drainage in steep side sloping road profile

4.2.2.2. ACHNASHELLACH RAIL BRIDGE - STRATHCARRON JUNCTION

This section started at the railroad bridge and ended at the junction of the A896 road to Strathcarron. The surveyed length was 10300m. Nearly all of the section was narrow single track road with passing places. In many cases the ditches around passing places were inadequate or totally absent. This section was mostly in side sloping road profile and nearly all the drainage deficiencies were in the upper side of the road profile (in this case in the right side). Towards the end of the section there was a part where the ditch on the upper side had been cleaned, but water still remained in the cleaned ditch at times.



Figures 16: Poor drainage and also the trees grow dangerously close to the road



Figures 17: Drainage problems with the passing places

4.2.2.3. STROME FERRY - ARDNAFF CATTLE GRID

This short section of road (3465m) was located on the mountain side for its full length and the road profile was naturally side sloping. The road had a steep gradient (downhill for the survey) that dropped approximately 150m in elevation over the length. There was an upgraded portion within the section from 1220m to 2920m which included most of the steep gradient. This upgraded part was in very good condition and the drainage was working well. Some sections inside the upgraded part had high verges that might need additional offlets to ensure that surface water is taken away quickly from the road surface. At 2250m there was a road cut on the right (upper side) which had an inadequate ditch. The older parts of the section had several severe drainage shortcomings.



Figures 18: Left: High verges in the upgraded section might need some offlets added at times, Right: Shallow ditch at 2250m on the right side of the road (upper side of the side slope)



Figures 19: Inefficient ditches and high verges in the old structure

4.2.2.4. BRAEINTRA - STROME FERRY

This section started from the junction to the village of Braeintrá. Length of the section was 4671m and ended at the viewpoint at Strome Ferry. At the start of the section the drainage had been improved recently. The ditch had been cleaned and the wide offlets were working. Towards the end of the section there were some parts where the verges needed some attention.



Figures 20: Left: Wide offlets which are cleaned, Right: High verge, not enough offlets

4.2.2.5. AUCHTERTYRE (A87) – BRAEINTRA

The section started at the junction with the A87 road in Auchtertyre. The length of the section surveyed was 5593m and ended at the junction to Braeintrá village. The road rises nearly 200 metres in this section and has a variable road profile. There were many drainage issues with verges. Some offlets were blocked and in some cases additional offlets should be provided.



Figures 20: Problems with the verge

4.2.3. Road A896

Two sections were surveyed on the A896 road; Diabag Junction to Cowlin Estate junction and Cowlin Estate junction to the A832 Junction (Figure 21).

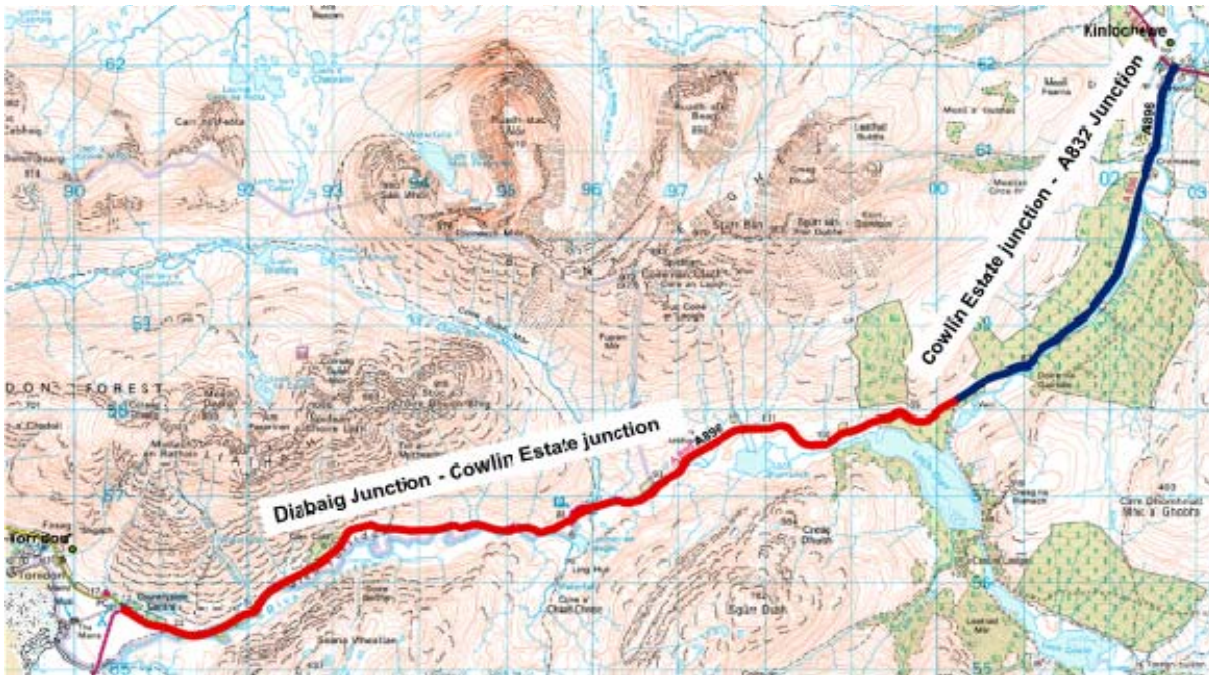


Figure 21: Surveyed sections from the road A896

4.2.3.1. DIABAIG JUNCTION - COWLIN ESTATE JUNCTION

This section started at the junction to Torridon village and ended at the junction to the Cowlin Estate. The length of the section was 10947m. The road was mainly single track road but there were a few short two-lane sections to help overtaking. The condition and the age of the pavement varied widely. The drainage problems found were typical for the circumstances. Verges were common and there were several side sloping sections with drainage problems in the upper side of the slope.



Figures 22: Inadequate drainage in the upper side of the slope



Figures 23: Left: Recently built verge which should be removed or have more offlets at 8400m, Right: Problematic verge on passing place

4.2.3.2. COWLIN ESTATE JUNCTION - A832 JUNCTION

The second section surveyed on the road was from Cowlin Estate junction to the A832, a length of 4875m. The road was single track and had a side sloping road profile for the first 3 kilometres which is in. There were several sections in the upper side of the side slope (this case left side) with typical drainage problems for this kind of profile.



Figure 24: Poor ditch and verge blocking the water

4.2.4. Road C46AW

Five sections were surveyed on the C46AW road; Shield Bridge to Moyle junction, Moyle junction to Ferry junction, Ferry junction to Eilanreach, Eilanreach to the 4th cattle grid and the 4th grid to Corran (Figure 25).



Figure 25: Surveyed sections road C46AW

4.2.4.1. SHIEL BRIDGE – MOYLE JUNCTION

The Shiel Bridge (A87) to Moyle junction was single track road with a two lane section in the middle from 5750m to 6500m. The section length was 9388m. The road lay on a hillside and nearly all of the section had a steep side sloping road profile. The road rose by nearly 350m in elevation over the first part of the section and returned down again in the second part. At the start of the section there was a combination of stone walls and verges close to the road which left no room for open ditches. Verge problems were also common later inside the section.



Figure 26: Stone walls and verges block the water



Figures 27: Drainage problems in side sloping road profile

4.2.4.2. MOYLE JUNCTION – FERRY JUNCTION

The side sloping road profile continued in this single track section from Moyle junction to Ferry junction. The length of the section was 4637m and there were many drainage problems in the right (upper) side of the road.

4.2.4.3. FERRY JUNCTION – EILANREACH

The first 1900m of this section was in the village of Glenelg and there were water outlets available to take care of surface water. The final part of the section was mostly in side sloping road profile and in the upper side had several drainage deficiencies which were typical for this kind of road profile.



Figures 28: Left: French drain in the upper side of the side sloping ground, Right: Poor drainage

4.2.4.4. EILANREACH – 4TH GRID

This section of road was from Eilanreach to the “4th cattle grid”. The length of the section was 9840m. The road profile in this single track section was mainly side sloping but there were many short lengths of road cuts which had inadequate drainage systems.



Figures 29: High verges and shallow ditches in a road cut

4.2.4.5. 4TH GRID – CORRAN

This section continued from the 4th cattle grid to the village of Corran which was also the end of the public road. The length of the section was 5581m. From the beginning to the village the road was mostly in steep sloping profile and there were several drainage shortcomings typical for this kinds of circumstances. The drainage was in good condition in the village area from 3800m to the end of the road.



Figures 30: Left: Improved section, good ditch and no verge: Right: Problems on the upper side

4.2.5. Kyle of Lochalsh – Plockton

This section starts in Kyle of Lochalsh at the junction of Main Street and Plock Road. The length of the section was 8535m and ended at the railroad bridge in Plockton. For the first two kilometres of the section the road was in good condition and drainage generally worked well. The road then became partly single track and the condition of the pavement varied. There were several problematic sections where the drainage was not working efficiently enough. Most of these problems were in side sloping ground.



Figures 31: Left: Problematic verge, Right: No ditches in road cut



Figures 32: Problematic section in steep side sloping road profile near Kyle of Lochalsh

4.3. DRAINAGE CLASSIFICATION

The drainage classification of the surveyed roads was carried out using the principles that will be presented in this chapter. A complete description of the ROADDEX drainage analysis classification is given in the ROADDEX report “*Drainage Survey Method Description*”.

4.3.1. Class 1; Drainage in Good Condition

Drainage Class 1 means that the drainage condition is faultless. The cross-section of the road has preserved its form well and water flows unrestricted from the pavement to the ditch. Water has also a clear passage in the ditches. Where a verge is present it has enough offlets to let the water flow to the ditch.



Figures 33: Examples of road sections with drainage Class 1 in Highland

4.3.2. Drainage Class 2; Drainage in Adequate Condition

In drainage Class 2 there can be some visible changes to the road cross-section. The road shoulder has narrow verges or vegetation growth that is preventing the free flow of surface water from the road surface into the ditch. There is some vegetation in the ditch that restricts water flow and creates damages. Some soil is sliding from the road side slope into the ditches and raising the bottom of the ditch. This hinders water flow and raises the ground water level.



Figures 34: Examples of road sections with drainage Class 2 in Highland

4.3.3. Drainage Class 3; Drainage in Poor Condition

Drainage Class 3 covers those road sections with severe drainage problems. The road shoulder has a high verge and/or dense vegetation that are causing ponding on the traffic lane or on the shoulder. Vegetation is growing in the ditches and restraining the flow of water creating dams in the ditches. Unstable soil is flowing from ditch slopes into the bottoms of ditches and blocking the flow of water. Clogged culverts or outlet ditches is preventing the flow of water in the ditch. All of these situations lead to the development of deformation and damage in the road cross-section.



Figure 35: Examples of road sections with drainage Class 3 in Highland

4.4. VERGE CLASSIFICATION

The ROADDEX drainage demonstration project in Scotland Highland was the first project where drainage analysis was tested in environment where verges were common. In this first project the verges were classified into two classes. Later in the projects in Ireland and the Western Isles drainage the classification was developed to three classes.

4.4.1. Verge Class 1; No verges

Class 1 verges cover those road sections where there is no verge and water can flow freely from road surface. Figure 33 presents two examples of verge Class 1 road sections.



Figure 36: Two examples of verge Class 1, i.e. road sections without verges.

4.4.2. Verge Class 2; Verges exist

Class 2 verges cover all road sections with verges. The height of verges can vary from low verges, which only have a minor effect, to high ones which clearly prevent surface water flowing away from road surface. The spacing and type of offlets vary. In some sections the offlets can be totally blocked which then leave the water running in the edge of the pavement. In sections where drainage maintenance has been carried out the offlets are usually well open and water can flow freely from the road surface.



Figure 37: Examples of verge Class 2, roads with a verge. The effect of verges on the workings of the road drainage system varies a lot in different circumstances.

5. DRAINAGE ANALYSIS RESULT

5.1. STATISTICAL RESULTS OF THE SURVEY

5.1.1. Summary of the Roads

Most of the road sections surveyed were located on a side sloping road profile. Many of the sections were in the coastal area and some were located on hillsides. This resulted in the percentage of the side sloping road profile to be as high as 75% (Figure 37). What was also remarkable was that the percentage of embankment profile was very low, only about 3% of the surveyed roads. This was significantly less than in other drainage projects, e.g. in Ireland and the Western Isles where the percentage of embankment was 10-13%.

Average drainage class was the best in road sections classified as embankment (Figure 38) and the weakest average drainage was found in side sloping road profile. The differences between road profiles were quite small, excluding embankments which in average have better drainage condition.

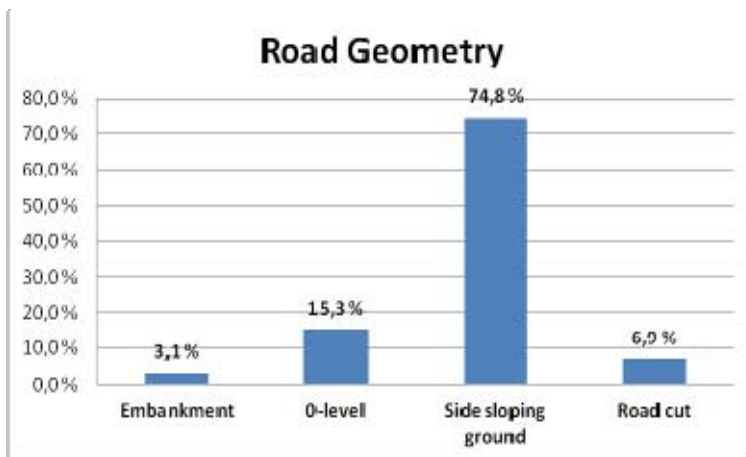


Figure 38: Distribution of the road profile

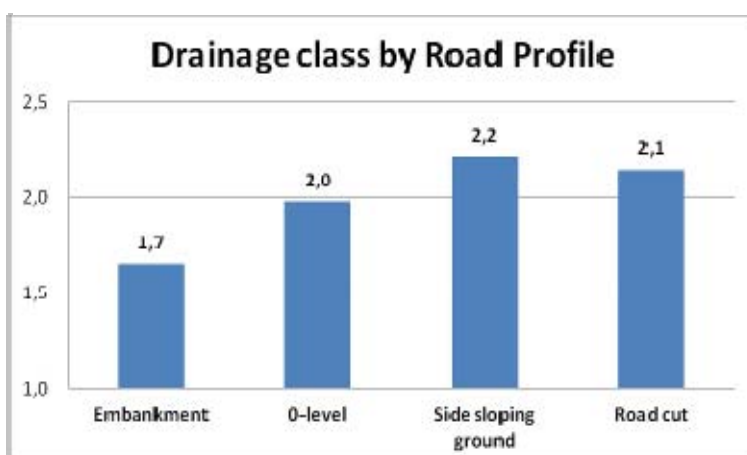


Figure 39: The average drainage class in different road profiles

5.1.2. Summary of Drainage and Verge Classes

The drainage condition on the surveyed roads was divided into three different classes: Class 1 (Good condition), Class 2 (Adequate condition) and Class 3 (Poor condition). In the Highland drainage project the verges were classified into two classes: Class 1 (No verges), Class 2 (Verges exist). The distribution of the drainage classes and verge classes are shown in Figures 39 and 40. Most of the surveyed sections were classified as drainage Class 2 (49.4%). Verges were not present in only 15.5% of the surveyed sections. These statistics clearly indicate that the average drainage in the Highland roads surveyed is in poor condition.

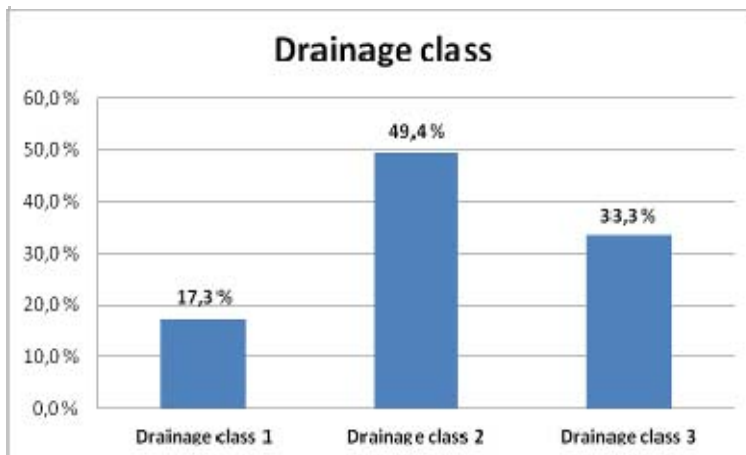


Figure 40: Distribution of drainage classes

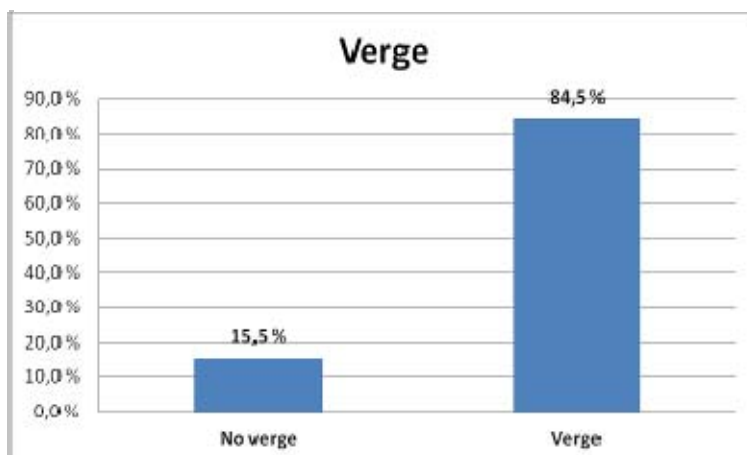


Figure 41: Distribution of verge classes.

5.1.3. Drainage Condition in Average

The drainage and verge classes of each section were examined statistically. The distribution of average drainage classes in each surveyed section is presented in Figures 41 and 42. The best sections for drainage class from a statistical point of view are the A832 section from Loch Maree Hotel to Slattadale grid and the A890 section from Braeintra to Strome Ferry. The worst sections for drainage deficiencies statistically were the A832 Slattadale – Kerry Glen section and the A890 section from Achnashellach Bridge to Strathcarron junction.

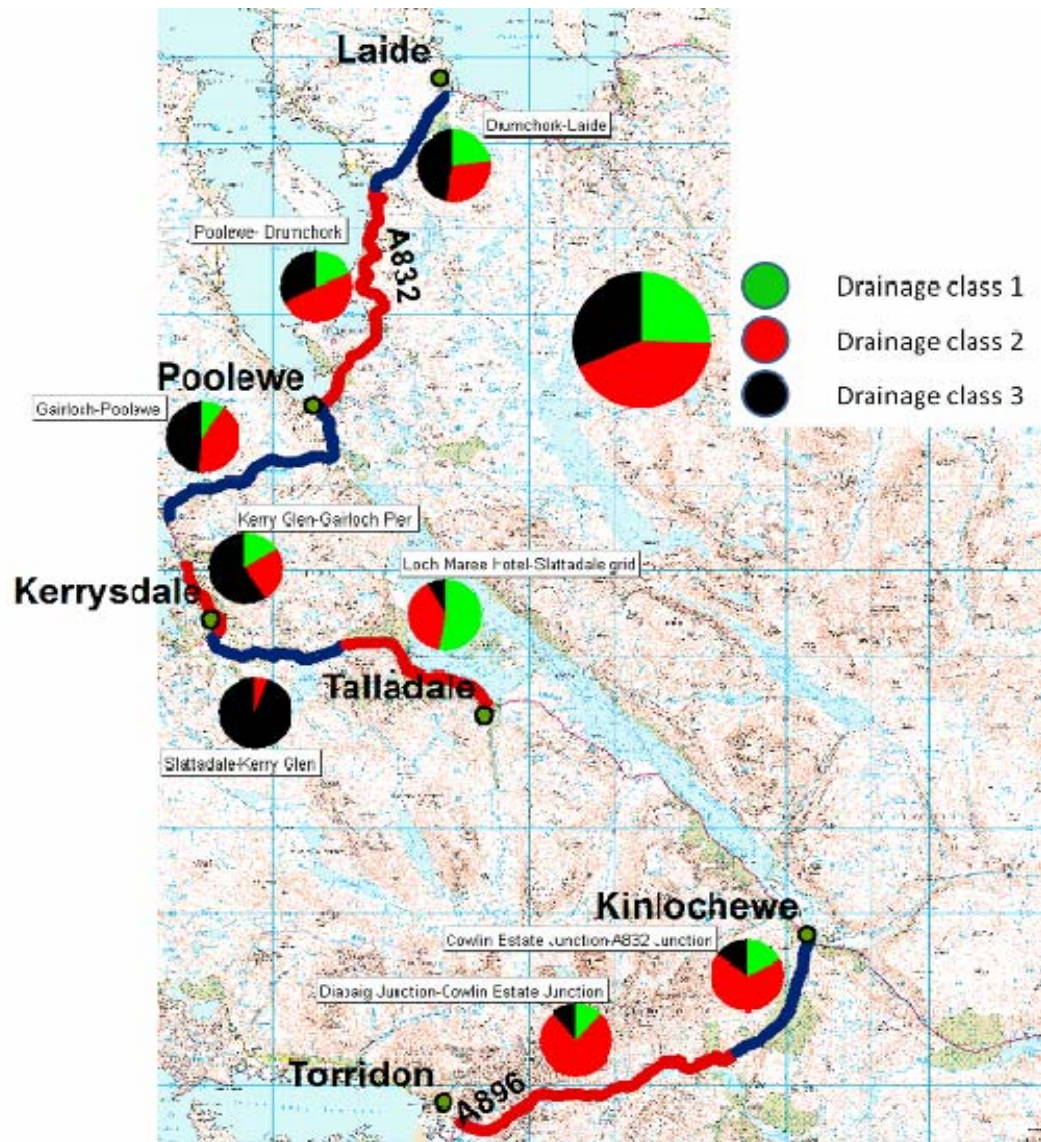


Figure 42: Distribution of average drainage classes in roads A832 and A896

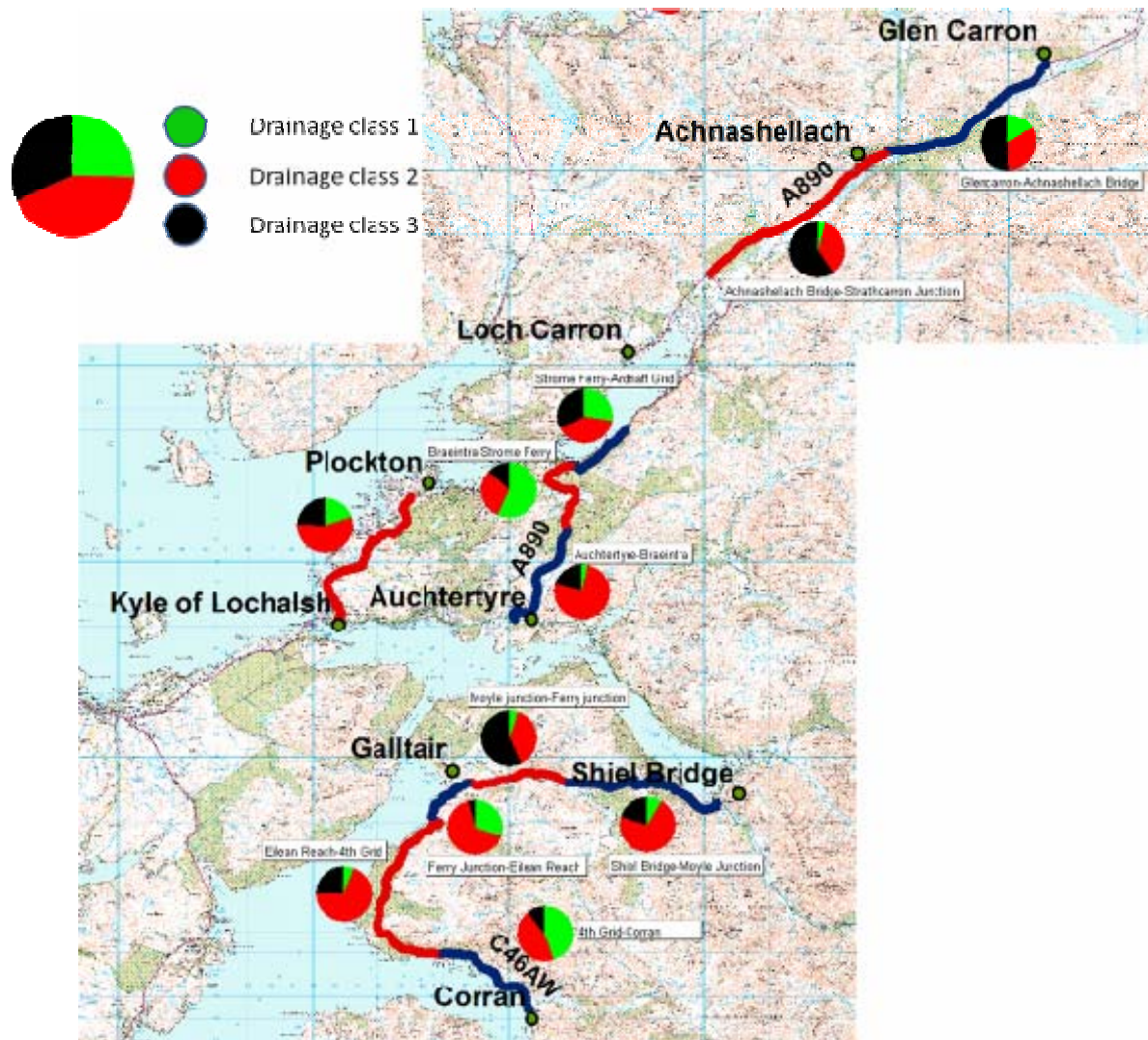


Figure 43: Distribution of average drainage classes in roads A890 and C46AW

As previously mentioned verges were classified into two basic classes, verges exist or verges absent. In nearly all of the surveyed sections the “verges exist” percentage was as high as 75 - 100%. There were couple of exceptions to this general rule where the “verges exist” percentage was low. In the C46AW road there were three sections where the percentage was between 25% and 55% and in the A832 there was one section with 33% of verges.

More detailed statistical maps of each surveyed road section are presented in the Appendix. These maps are printed from Road Doctor project trees to show the drainage deficiencies in a more detailed way.

In addition to the drainage analysis carried out for the Highland demonstration project suggestions were also made for some poorly performing sections. These sections were identified for “special maintenance measures” and this information has been sent separately to the respective road maintenance managers. A “special maintenance section” means that measures are needed for both ditches and verges. If the design only mentions the verge, it means that only the verge needs some operations (e.g. removal of verges or making more offlets).

5.2. DRAINAGE AND ROAD PERFORMANCE

5.2.1. Effect of Drainage on Rutting

The historic data supplied by The Highland Council TEC Services did not include roughness data (IRI) which meant that it was not possible to carry out an IRI correlation analysis. However, in similar drainage projects the IRI has usually correlated well with the drainage deficiencies.

The correlation between drainage and rutting on the road sections surveyed was clear but low. The mean rutting values were 2-7% higher for road sections with drainage Classes 2 and 3. One reason for this rather low factor could be that many of the surveyed roads surfaces were old and the condition of the pavement was quite poor throughout regardless of the drainage condition.

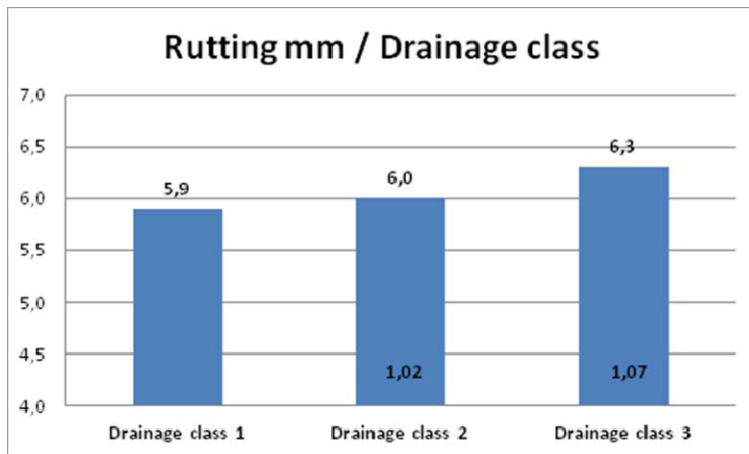


Figure 49: The average rut depth value for each drainage class. The value on the top of the column shows the average rut depth value on each drainage class. The factor inside the column shows how many times bigger the value is compared to the value for Class 1.

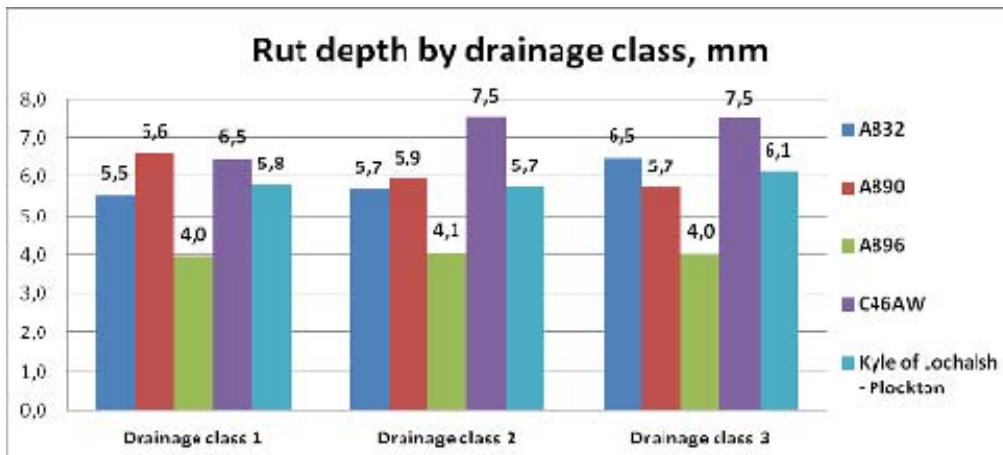


Figure 50: The mean rut depth values classified by drainage classes in surveyed roads.

5.2.2. Effect of Verges on Rutting

Verges also have an effect on roughness and rutting. As already mentioned the verges in the Highland projects were classified into two classes. The correlation between rutting and the presence of verges was clear: the rutting value in sections without verges was 5.6mm on average, and in sections with verges the value was 6.1mm. It was not possible to examine the effect of verges on roughness as roughness data was not available. Overall for the circumstances of the

Highland area, it appears that the presence of verges has a slightly greater effect on rutting values than drainage problems, although the distribution of road sections without verges is relatively small (15.5%).

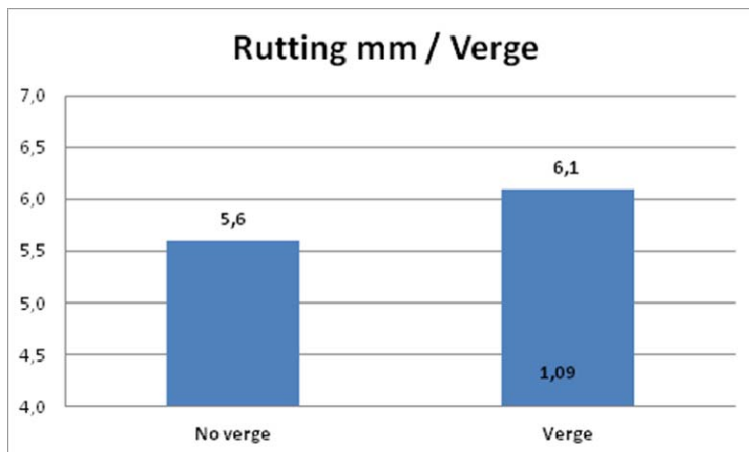


Figure 51: The average rutting value compared to verge classes. The value on the top of the column shows the average rutting value in each drainage class. The factor inside the column shows how many times bigger the value is compared to the value for Class 1.

5.2.3. Damage Inventory on Roads A832 and C46W

A basic damage inventory was carried out on the A832 and C46W road sections in order to compare the visual road damages to the adjacent drainage classification. This was done as there had been a difficulty in obtaining road profilometer data for all road sections at the beginning of the project. Later this difficulty was resolved and the visual damage inventory was no longer necessary. The results of the work already done on the A832 and C46W are shown here for completeness.

The road surface condition was classified in four basic classes:

- Class 0 = No visual damages
- Class 1 = Minor damages
- Class 2 = Moderate damages
- Class 3 = Severe damages

Examples of the damage inventory classification from road A832 are shown in Figures 52 and 53.



Figures 52: Left: Class 0= No visual damages, Right: Class 1= Minor damages



Figures 53: Left: Class 2= Moderate damages, Right: Class 3= Severe damages

The results from the analysis of the A832 and C46W roads show a much better correlation between visual pavement distress classification and drainage class (Figures 54 and 55). For instance, the average pavement distress class was two times higher in drainage Class 3 (poor) sections compared to drainage Class 1 (well working) sections.

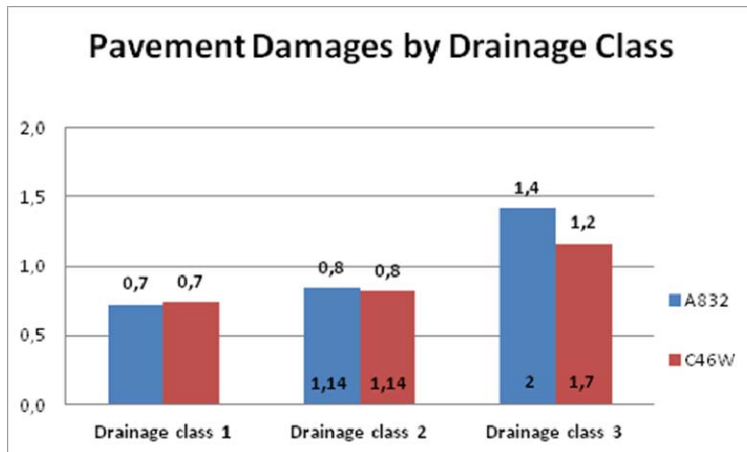


Figure 54: Pavement damages by drainage class on the roads A832 and C46W

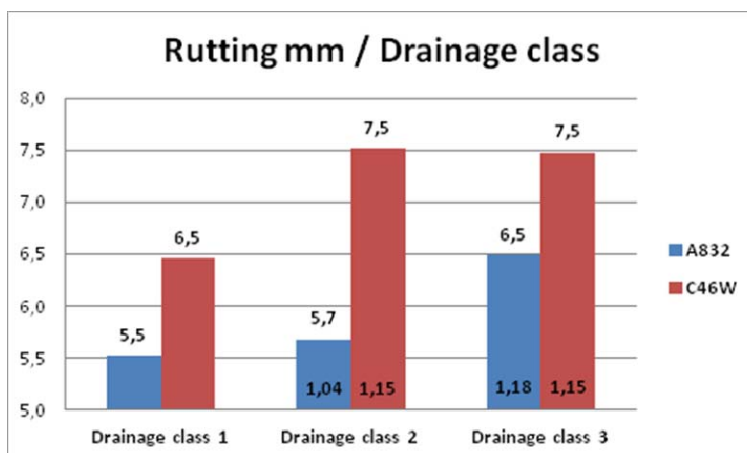


Figure 55: Rutting mm by drainage class on the roads A832 and C46W

6. DRAINAGE AND PAVEMENT LIFE TIME

The lifetime of a road section is determined by its worst 10 % sub sections. The results of the drainage analyses in the Highland area confirm the findings from other ROADEX partner countries that improving the drainage condition in critical sections, and maintaining it in good condition, will increase the pavement lifetime by 1.5 - 2.0 times. The conclusion is that if rehabilitation and drainage maintenance can be carried out together in an economic fashion they can lead to major savings in the annual paved road network costs.

Figures 56 and 57 show that the pavement lifetime factor (the ratio of the worst 10% rutting class) on the road sections surveyed was very variable. Each of the surveyed roads had sections where the factor was low (<1.05). Only the A896 road fails to have any sections with high (>1.3) factors. Sections with the highest factors (>1.5) can be seen on the A832 road (two sections), and A890 road (one section). road drainage improvements would be very economical in these sections .

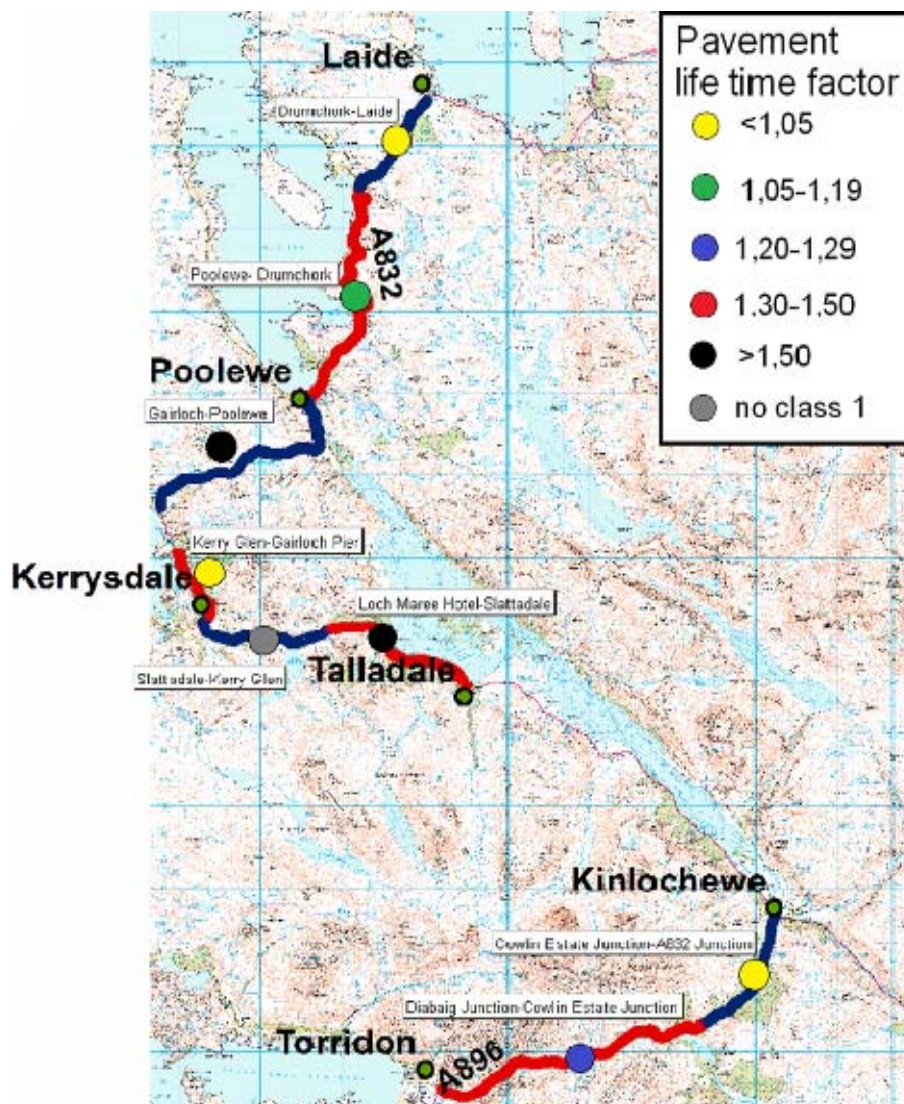


Figure 56: Pavement lifetime factor in road sections surveyed on roads A832 and A896

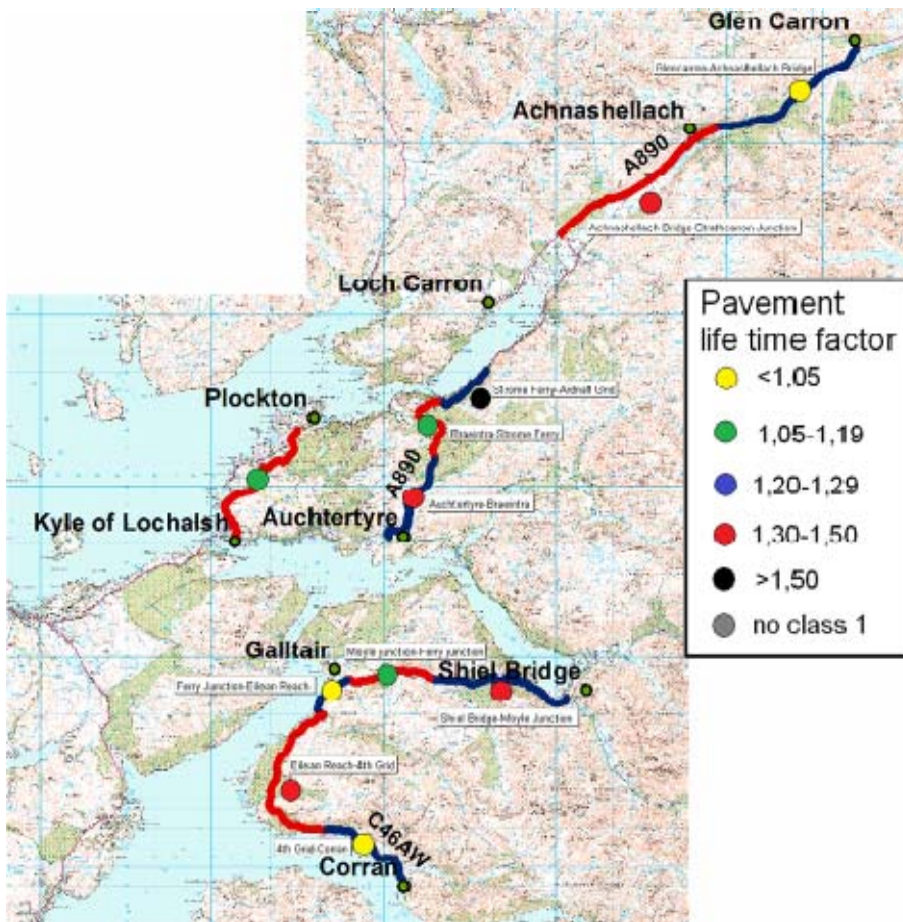


Figure 57: Pavement lifetime factor in road sections surveyed on roads A890 and C46W

7. DRAINAGE IMPROVEMENT DESIGN

In many ROADEX countries drainage, and drainage improvement, has a low priority despite research proving that it is important that road drainage should be kept in a good condition. At present a number of issues have to be addressed when planning drainage work. What is the best way to organise it? Should the work be the responsibility of the maintenance or pavement contractor? Etc.

It is not just enough that problematic sites are improved, it is vital that the improved sections are also kept in a good condition. Constant monitoring and maintenance of the improved drainage is vital to ensure that good drainage work remains effective.

When a drainage improvement is carried out the work should be done carefully. It is more important to pay attention to the longitudinal gradient of the ditch and the removal of obstacles blocking the water flow (big stones, flowing soil, etc.), than to dig the ditch deeper. Ditches that are dug too deep increase the risk of side slope erosion. It is recommended that the bottom of the ditch should be 20-30cm deeper than the bottom of the road structure and that the longitudinal gradient of the side ditch should be at least 4 ‰ (4 mm/m).

If the ditch has steep side slopes, it is better to carry out the improvement works in the early summer so that the local vegetation has enough time to grow back before winter to reduce the risk of erosion.

The most noteworthy feature of the surveyed sections in the Highland area is the high incidence of verges in the sections that have not been upgraded yet. New verges are also being built on roads. Removing these verges will be challenging as in many cases there will be cables inside them. The solution for road sections where verges are producing problems is to remove the verge or make more offlets.

8. CONCLUSIONS

This demonstration project was conducted on nine test roads in the Highland area of Scotland. The lengths of roads varied between 2.7km to 10.9km. The surveys were carried out in March 2010.

In general the drainage was assessed to be in adequate condition: 49.4% of the surveyed roads were classified as drainage Class 2 but in only 17.3 % of the road length was the drainage good. The reason for this is mainly the presence of roadside verges. These were common in the Highland area and were present on 84.5% of the surveyed roads. Typically the problematic sections were located on side sloping ground. Some roads were narrow with pavement damages and drainage problems.

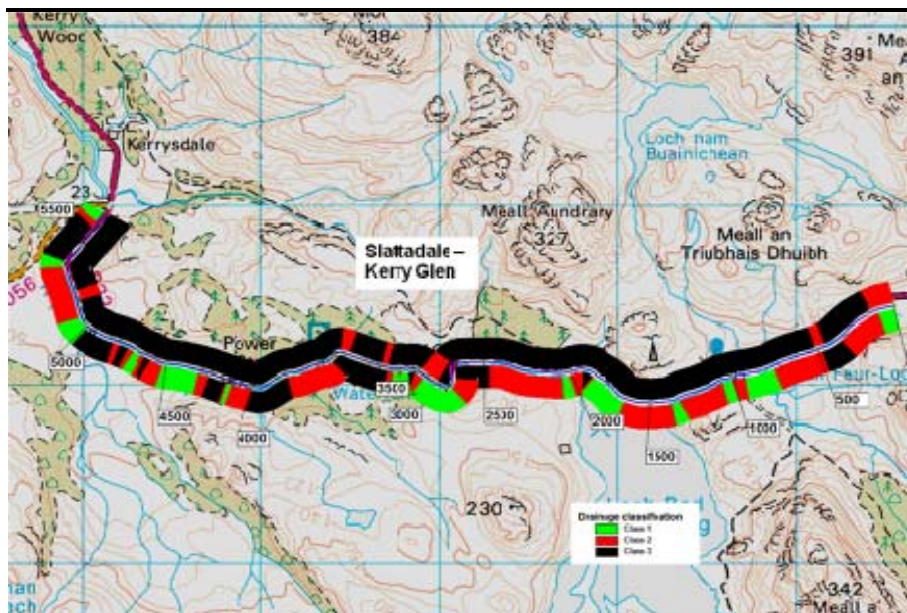
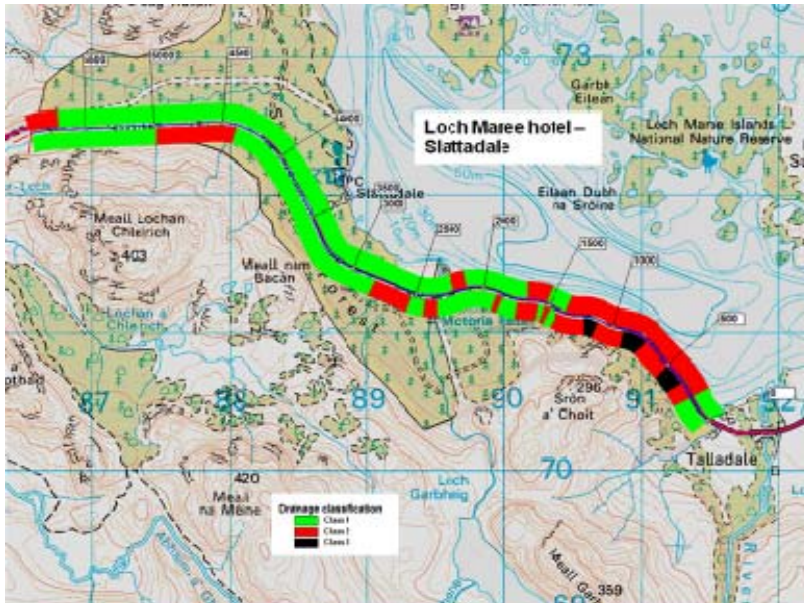
Overall the drainage classes and verge classes correlated quite well with the available rut depth values. On average the rut depth value in drainage Class 3 was about 7% higher more than in drainage Class 1. Correlation between the presence of verges and the rutting value was stronger. The average rut depth value was approximately 9% higher in sections with verges present. The average pavement distress index was roughly two times higher in drainage Class 3 compared to drainage Class 1.

This demonstration project has confirmed that poor drainage has a major effect on pavement condition and pavement lifetime. If the existing drainage on the poorest road sections can be improved, the potential savings in annual paving costs can be up to 30 %. Verges were seen to be causing major problems on the road network and it is recommended that a new policy should be developed on what should be done about verges. Possible options could be removing them completely, or building more offlets and accepting the increased maintenance costs for them.

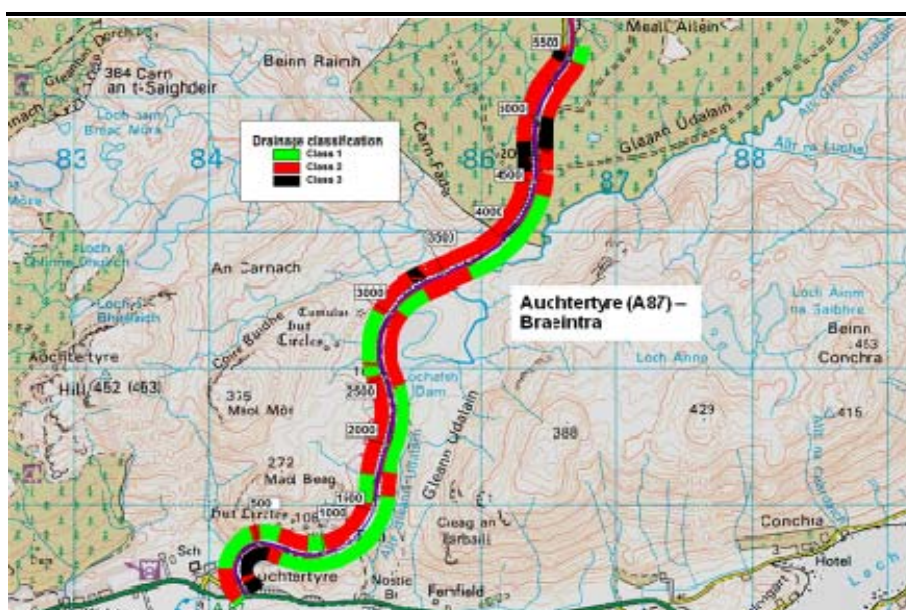
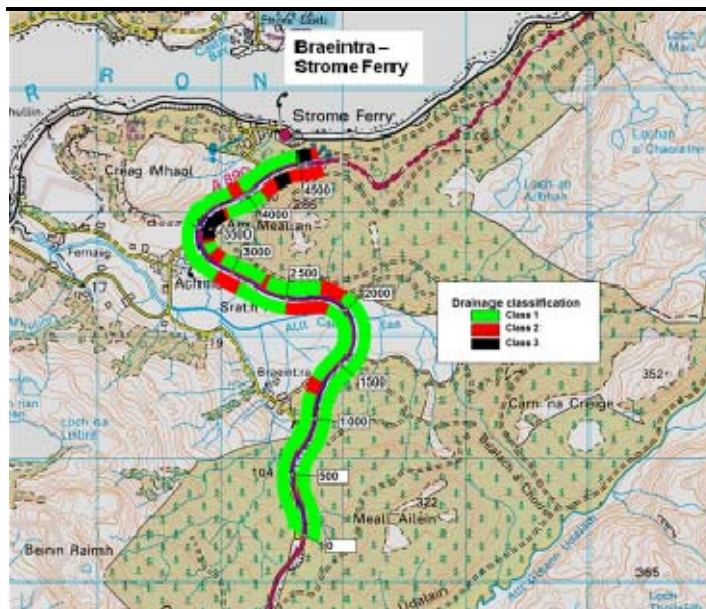
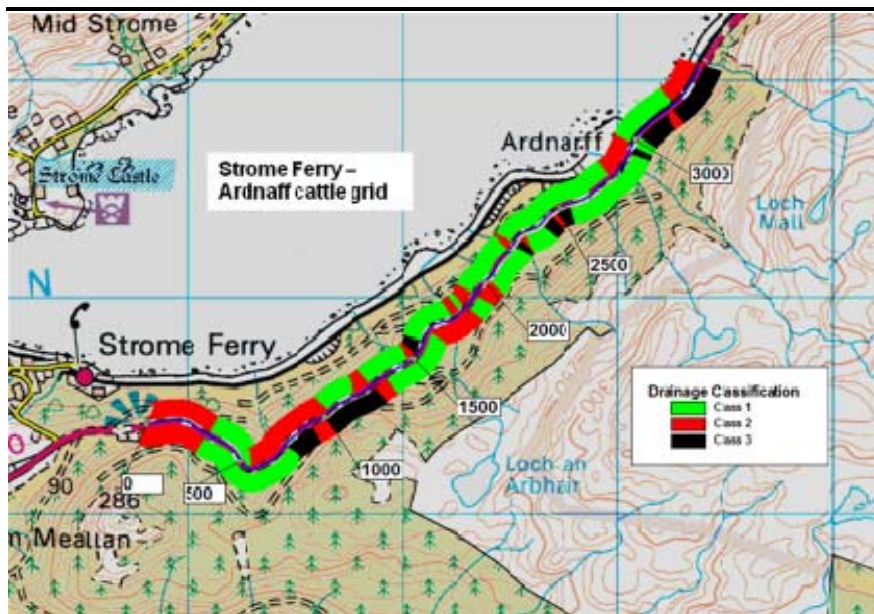
In summary, the ROADDEX drainage analysis guidelines have been proven to be suitable for use on Highland roads. It is however important that verges should be analysed also in areas where they are typical as they will have a major impact on the efficient working of the road drainage system.

9. APPENDIX

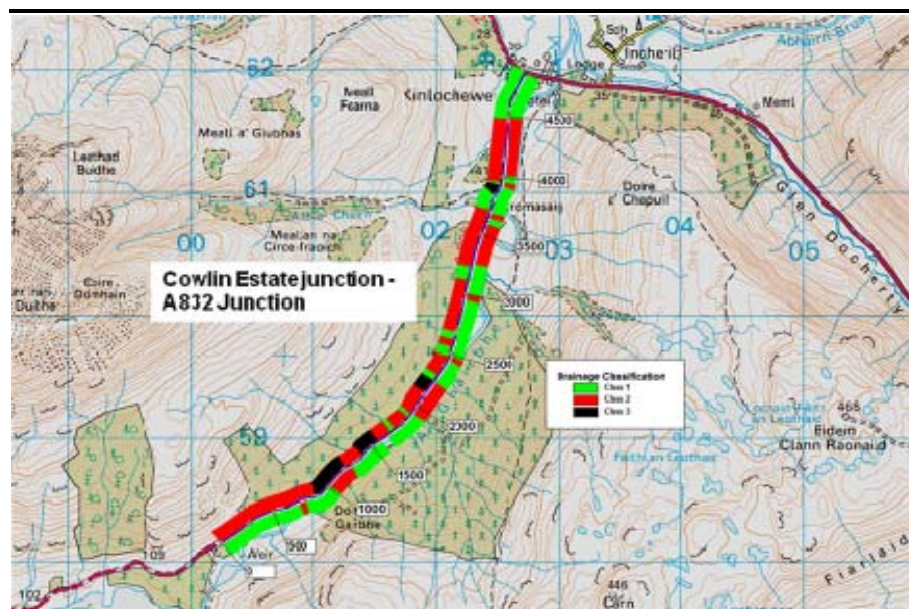
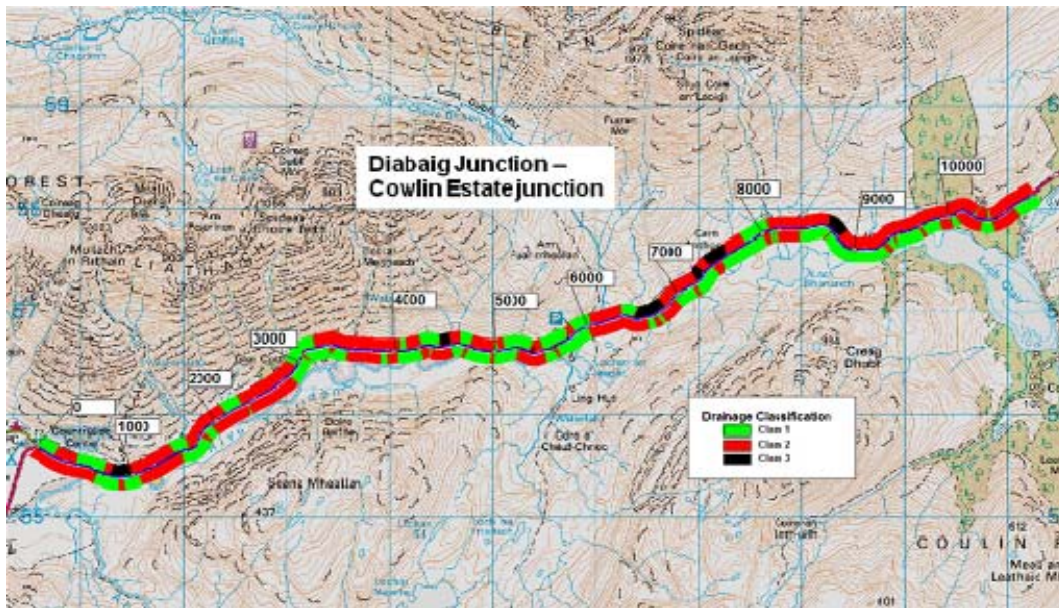
ROAD A832; DRAINAGE CLASSIFICATION



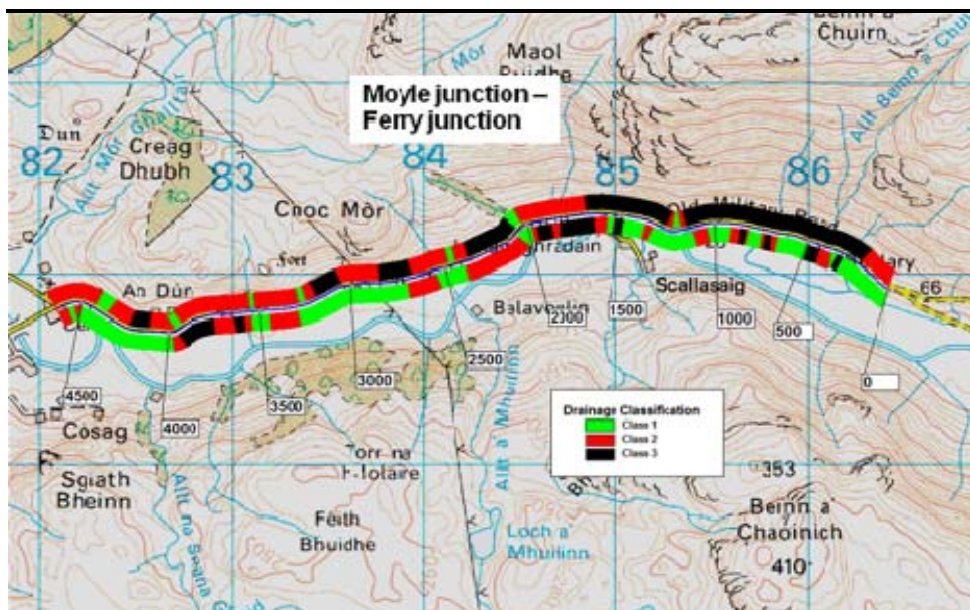
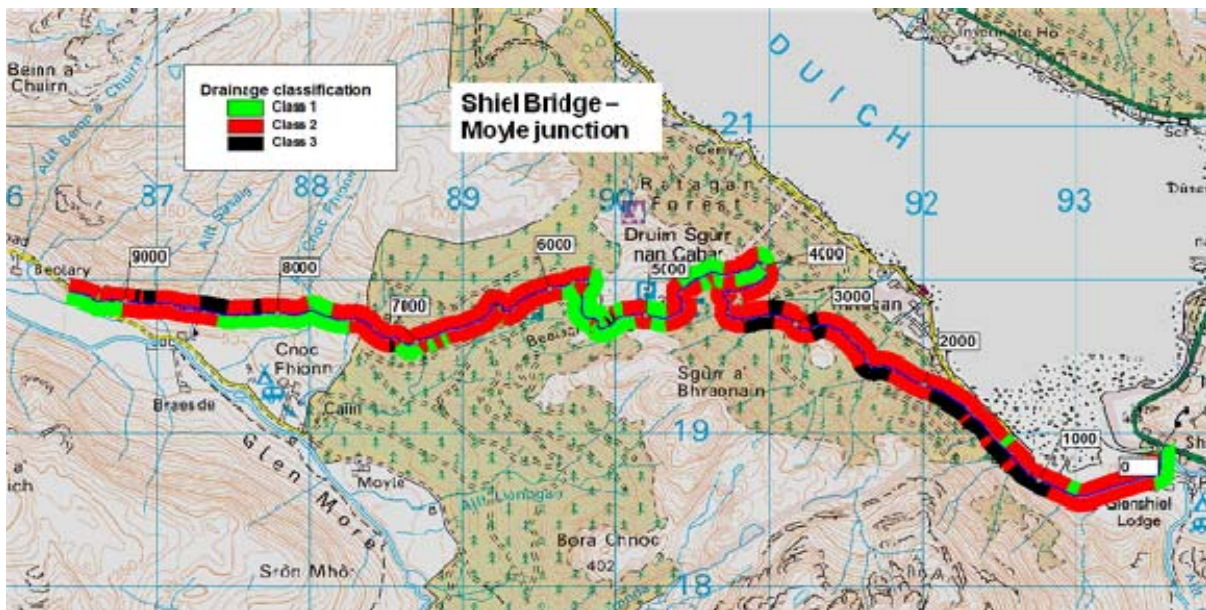
ROAD A890; DRAINAGE CLASSIFICATION

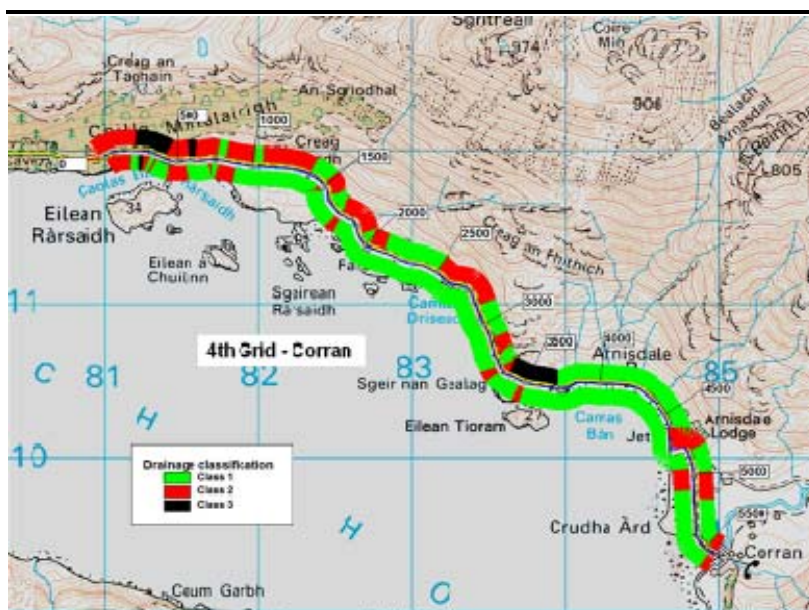
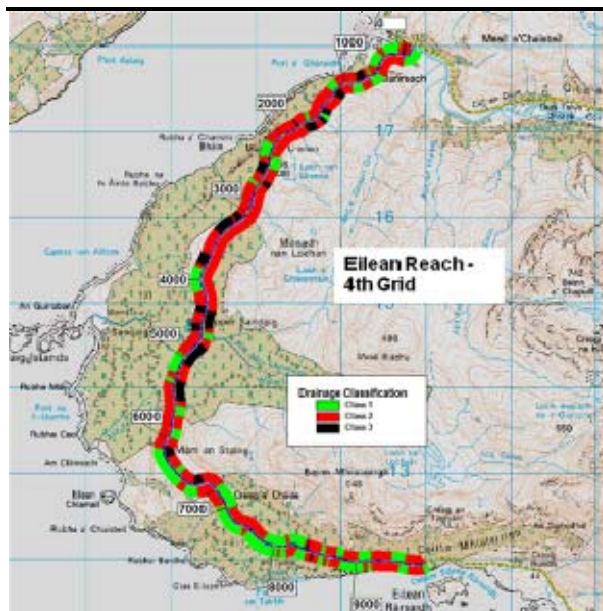


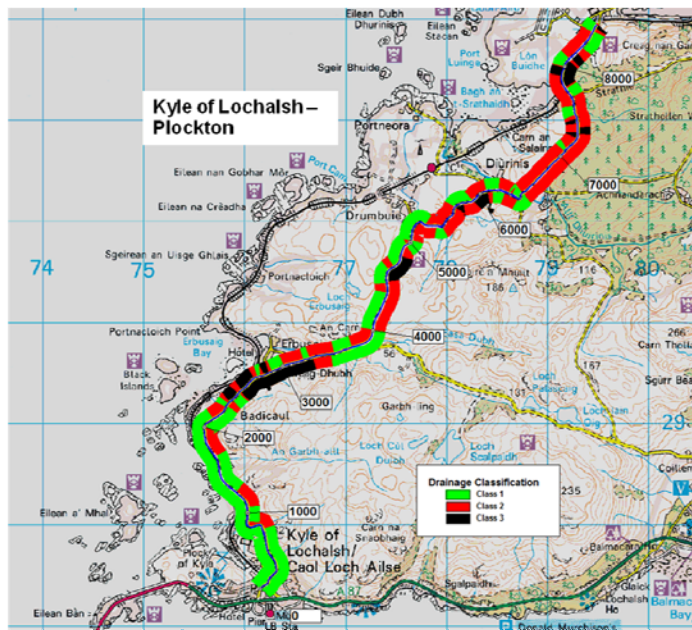
ROAD A896; DRAINAGE CLASSIFICATION



ROAD C46W; DRAINAGE CLASSIFICATION









ROADEX PROJECT REPORTS (1998–2012)

This report is one of a suite of reports and case studies on the management of low volume roads produced by the ROADEX project over the period 1998-2012. These reports cover a wide range of topics as below.

- Climate change adaptation
- Cost savings and benefits accruing to ROADEX technologies
- Dealing with bearing capacity problems on low volume roads constructed on peat
- Design and repair of roads suffering from spring thaw weakening
- Drainage guidelines
- Environmental guidelines & checklist
- Forest road policies
- Generation of 'snow smoke' behind heavy vehicles
- Health issues raised by poorly maintained road networks
- Managing drainage on low volume roads
- Managing peat related problems on low volume roads
- Managing permanent deformation in low volume roads
- Managing spring thaw weakening on low volume roads
- Monitoring low volume roads
- New survey techniques in drainage evaluation
- Permanent deformation, from theory to practice
- Risk analyses on low volume roads
- Road condition management of low volume roads
- Road friendly vehicles & tyre pressure control
- Road widening guidelines
- Socio-economic impacts of road conditions on low volume roads
- Structural innovations for low volume roads
- Treatment of moisture susceptible materials
- Tyre pressure control on timber haulage vehicles
- Understanding low volume pavement response to heavy traffic loading
- User perspectives on the road service level in ROADEX areas
- Vehicle and human vibration due to road condition
- Winter maintenance practice in the Northern Periphery

All of these reports, and others, are available for download free of charge from the ROADEX website at www.ROADEX.org.

