URS

Stromeferry Options Appraisal

Geotechnical Desk Study Report

April 2013

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GLRP0001

Prepared for:
The Highland Council

UNITED KINGDOM & IRELAND

The Highland Council
Comhairle na Gàidhealtachd

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1. INTRODUCTION

1.1 Background

URS Infrastructure and Environment UK Ltd. (URS) was appointed by The Highland Council (THC) in October 2012 to undertake an options appraisal for the proposed Stromeferry Bypass. As part of the data acquisition for the appraisal a geotechnical desk study was commissioned to support the development of upgraded and/or new routes to replace the current A890 bypass of Stromeferry in the Scottish Highlands.

The existing route, the A890, serves as the main road link down the west coast of Scotland and is also a significant transit for east-west traffic travelling between the Isle of Skye and Inverness. The A890 is mainly single carriageway but frequently reduces to single track with passing places along the stretch between Attadale and Ardnarff. The road has been subjected to closures over the past three years due to failures in the adjacent rock slopes which has led to a need to either redevelop the existing route or provide a bypass of the existing road. Fifteen potential bypass/redevelopment options have been produced and these will be considered as part of this investigation.

The location of the site is depicted on URS Drawing No. 47065084/4001, included as Appendix A. Additionally a drawing, URS Drawing No. 47065084-609, showing the layout of the development options has been produced and has been included as Appendix B.

1.2 Objectives

The main objectives of the desk study were as follows:

- To assess the historical uses of the sites;
- To assess the general geology, hydrology and hydrogeology of the sites;
- To describe the existing sites surface conditions;
- Provide details of potential constraints for the development of the site;
- Provide a preliminary scope for Ground Investigation works.

1.3 Scope of Works

The following provides a summary of the assessment undertaken for the preparation of this report:

- Review of historical Ordnance Survey maps to determine the historical development of the site;
- Review of published geological and hydrogeological maps to understand the geological setting of the site;
- Review of available in-house records;
- Review of information provided by consultation;
- The identification and interpretation of geotechnical and environmental constraints and provision of recommendations for further exploratory works.

2. METHODOLOGY

2.1 Documentary Research

The history of the site and accounts of the environmental setting were compiled from an examination of available historical and current Ordnance Survey sheets, aerial photographs and published geological information.

2.2 Consultations

The following bodies were consulted during the course of the investigation:

- The British Geological Survey (BGS);
- The National Library of Scotland (NLS);
- The Coal Authority;
- Scottish Environment Protection Agency (SEPA);
- Scottish Natural Heritage (SNH);
- The Royal Commission of the Ancient and Historical Monuments of Scotland (RCAHMS);
- URS in-house information.

2.3 Previous Reports

Reports undertaken for the existing road alignment, historical ground investigation reports and option appraisal reports were made available to URS by THC, and URS also obtained additional reports from the BGS. The following reports were consulted during the course of this investigation:

- Whatlings (Foundations) Ltd, Report on Site Investigation for A890 South Strome to Auchtertyre Road Improvement, March 1974;
- Triax (Site Investigation) Ltd, Site Investigation at Loch Carron, July 1982;
- Holequest Ltd, Geological Survey and Borehole Logs, Loch a' Choire Leith Site Investigation Report, October 1986;
- James Williamson and Partners, Stromeferry Bypass A890, Slope Stability Appraisal (Cuddies Points to Ardnarff), January 1987;
- Mott MacDonald Scotland, A890 Stromeferry Bypass Alternative Routes: Inception Report, June 1991;
- Mott MacDonald Scotland, A890 Stromeferry Bypass New Route Studies: Tunnel Route Preliminary Assessment, August 1993;
- Highland Regional Council Regional Roads Unit, A890 Stromeferry Bypass Road Improvement, Feasibility of Widening the Existing Road Alignment, September 1993;
- Coffey Geotechnics Ltd, Annual Rock Slope Inspection, June 2009;
- Coffey Geotechnics Ltd, Annual Rock Slope Inspection, June 2010;
- URS, Stromeferry Bypass, A890 Slope Inspection Report, September 2012.

3. SITE DETAILS

3.1 Site Location

The site is comprised of fifteen route options, split into four corridors, for the bypass of a stretch of the A890 adjacent to Loch Carron, the Scottish Highlands.

The routes are centred on Loch Carron and generally connect the A890 at Achmore to the A890 at Strathcarron Junction. The approximate site centre is at national grid O.S. co-ordinates 190891, 838781.

3.2 Site Description

The site has been split into several corridor and route options and these may be summarised as follows:

Main Corridor	Route Name	Route Description
Outer North	Outer North 3 (ON3)	Follows the A890 from Achmore to Craeg Mhaol before crossing Loch Carron to Leaconasigh via a proposed bridge. The proposed route then runs north to meet with the A896, which it follows until reaching Strathcarron Junction to tie in with existing infrastructure.
North Shore	North Shore 2 (N2)	Follows the route of ON3 via either a proposed bridge or tunnel to Leaconasigh before following an existing road to Stromewood before trending north east to join with the A896.
	North Shore 6/7/8 (N6/7/8)	Follows the A890 from Achmore to Craeg Mhaol before crossing Loch Carron to Stromemore via a proposed bridge/tidal barrage, and then follows existing infrastructure east to reach the A896 at Kirkton.
Online	Online 1 (O1)	Follows the existing route along the A890 between Stromeferry and Strathcarron Junction with a proposed upgrade of the existing route, with either an extended avalanche shelter or remediated rock slope.
	Online 2 (O2)	Follows the existing route along the A890 from Stromeferry to Ardnarff before moving over to a proposed viaduct/embankment along Loch Carron to Cuddies Point where it re-joins the A890 to Strathcarron Junction.
	Online 3 (O3)	Follows the existing route along the A890 from Stromeferry to Choc Nam Mult before following a proposed tunnel to Cuddies Point where it re-joins the A890 to Strathcarron Junction.
	Online 4 (O4)	Follows the existing route along the A890 from Stromeferry to Strathcarron Junction. This represents a “do minimum” option.
	Online 5 (O5)	As O4, with a widening of the road by sharing with the railway between Ardnarff to Cuddies Point.
	Online 6 (O6)	As O4, but crosses the railway at Attadale to connect with the A896 at Kirkton via a new north trending road.

Main Corridor	Route Name	Route Description
	Online 7 (O7)	As O4, but with an extension of the existing avalanche shelter.
South	South 1 (S1)	Connects the A890 at Stromeferry to A890 at Attadale via an inland diversion through the River Attadale Valley.
	South 3 (S3)	Connects the A890 at Braeintra to A890 at Attadale via an inland diversion through the Glen Udalain, Glen Ling and River Attadale Valleys.
	South 4 (S4)	Connect the A890 south of Braeintra to the A890 at Attadale via an inland diversion through the Glen Udalain, Glen Ling and River Attadale Valleys.
	South 5b (S5b)	Connect the A890 at Braeintra to the A890 at Strathcarron via an inland diversion through the Glen Udalain, Glen Ling and River Attadale Valleys.

These routes are depicted on URS Drawing No. 47065084-609 included as Appendix B.

3.3 Site History

The following descriptions of the historical development of the site are based upon an examination of available current and historical Ordnance Survey (OS) maps obtained from the NLS along with information gleaned from historical reports. Copies of relevant historical maps are included in Appendix C.

Map/Date Reference	Identified Features
1875 – 1880	• Several settlements surrounding the site were identified as Stromeferry, Stromemore, Kirkton and Achintree along with associated dwellings, buildings and infrastructure; • An east-west trending unnamed road was noted in the far north of the site area, running from off site to the settlement of Lochcarron; • A northeast-southwest trending railway line denoted "Dingwall and Skye Line" was noted along the south bank of Loch Carron; • An unnamed road trending north-south was noted running offsite from Stromeferry; • An unnamed road was noted trending southwest to northeast along the north bank of Lochcarron to a junction just north of the loch.
1947 - 1957	• Attadale House and a pier were noted in the approximate centre of the south bank of Loch Carron; • The road identified at Stromeferry and on the north bank of Loch Carron was denoted as "A890"; • The road noted along the far north of the site was denoted the "B857".
1971	• The construction of the existing A890 bypass was completed. A major landslip was noted to have occurred during construction, resulting in the added construction of the avalanche shelter present along the route in the present day. At least three other smaller failures also occurred during construction[1].

Records of historical landslide/rockfall events along the existing rock slope were gleaned from the historical reports discussed in Section 5 and from information obtained from The Highland Council, and is summarised below:

Date	Details of Event
March 1990	200 tonnes failed blocking road and railway. Works were carried out on the slopes starting in September 1990, night working for 10 weeks by Albion Drilling. Traffic was in diversion for 8 weeks.
May 1998	May the 4th 1998, 8 tonnes of rock failed, not on road; May the 11th 1998, 1.5 tonnes of rock failed, not on road.

[1] See JWP Figure A3.1: Locations of documented old and recent landslides in study area included in their report and appended in this report as Appendix F.

Date	Details of Event
May 1999	40 tonnes of rock came down with one small block reaching the road.
October 2001	Emergency inspection, following landslide at 17:00, on Monday the 29th of October 2001. 500m^3 soils failed and resulting in a debris flow which blocked the road and railway. EDGE inspected the landslide between Wednesday the 31st Oct and Friday the 2nd of Nov.
October 2004	Two debris flows occurred. 4m^3 and 1m^3 minor and unlikely to have caused further destabilisation
January to February 2007	20m^3 failed but was contained by verge and ditch
May 2007	0.5m^3 to 1m^3 Rockfall from upper slopes of the A890 bypass, reaching the road and railway.
August 2008	Rockfall (two blocks) from upper slopes of the A890 bypass, reaching the road and cleared by THC.
June 2009	Block falling from the upper slopes of the A890 bypass, contained by rockfall netting.
September 2009	Rockfall from slope adjacent to the A890 bypass, reaching the road and railway boundary.
February 2010 – December 2011	Several small scale rockfalls along the A890 bypass were noted by THC during their monthly inspections. These were generally contained by rock netting and ditches, although some did reach the road.
December 2011	A major rockfall occurred leading to the closure of the A890 bypass until April 2012.
November 2012	A minor landslip occurred leading to disruption, but not closure, of the A890 bypass.
December 2012	The A890 bypass was closed for two days due to a major rockfall.

To summarise, the site has remained largely unchanged since records began in 1875, with the exception of the A890 bypass which was opened in 1971 following the excavation of a number of rock slopes for the road alignment.

There has been a history of rockfalls along the existing A890 Stromeferry Bypass from during construction to the present day. These included small events which were contained by remedial measures, to large scale events leading to closure of the road and/or major remediation.

4. ENVIRONMENTAL SETTING

4.1 Geology

Information regarding the geological conditions at the site was obtained from available published geological sheets[2] and is summarised below for each of the corridor options.

Route Name	Geology Description
ON3	Where mapped, the superficial deposits along the majority of ON3 are recorded to comprise moraine and undifferentiated drift, with the exception of the stretch of the route from Kirkton to Strathcarron Junction, which is recorded to be underlain by freshwater alluvia. No indication of the depth of the superficial deposits is given, however superficial deposits were not consistently mapped across the site indicating that they were thin or absent. The solid strata along route ON3 varies although generally belong to either the Moine Series or Lewisian Series. At Creag Mhaol, the solid strata are recorded to comprise epidiorite and hornblende schist affected by post-Cambrian (Caledonian) movement. Where the route crosses Loch Carron, the solid strata are recorded to comprise massive and foliated pyroxenic hornblendic and micaceous gneiss affected by post-Cambrian (Caledonian) movement, up to Loch Kishorn, where the strata are recorded to comprise the Daigbaig Formation and grey sandstone with shaly intercalations of the Torridonian Group up to where the route joins with the A896. The remainder of the route is recorded to be underlain by undifferentiated granulitic schists. The solid strata are generally recorded to dip towards Loch Carron at an unspecified angle.
N2, N6	Where mapped, the superficial deposits along the majority of N2, N4 and N6 are recorded to comprise moraine and undifferentiated drift, with the exception of the area between Kirkton and Strathcarron Junction, which is recorded to be underlain by freshwater alluvia. No indication of the depth of the superficial deposits is given, however superficial deposits were not consistently mapped across the site indicating that they were thin or absent. Around Stromeferry and Ardnarff the solid strata is changeable with massive and foliated pyroxenic hornblendic and micaceous gneiss affected by post-Cambrian movement; epidiorite and hornblende-schist affected by post-Cambrian movement; and flaggy quartz-feldspar granulite being recorded. Around Stromemore the routes were recorded to be underlain by massive and foliated pyroxenic hornblendic and micaceous gneiss affected by post-Cambrian movement and epidiorite and hornblende-schist affected by post-Cambrian movement. Beyond that myolonite was recorded up to, and around, Slumbay Island, with the remainder of the routes being underlain by undifferentiated granulitic schists of the Moine Series. The solid strata were generally recorded to dip towards Loch Carron at an unspecified angle.

[2] British Geological Survey, 1:50,000 Geological Sheets, 82: Lochcarron and 81E: Loch Torridon.

Route Name	Geology Description
O1, O2, O3, O4, O5, O6, O7	Where superficial deposits are mapped they are generally recorded to comprise moraine and undifferentiated drift of unspecified thickness. Where O6 crosses the head of Loch Carron, the superficial deposits are recorded to comprise marine alluvia. No indication of the depth of the superficial deposits is given, however superficial deposits were not consistently mapped across the site indicating that they were thin or absent. As with ON3, the solid strata vary across the route. Around Stromeferry and Ardnarff the strata is particularly changeable with massive and foliated pyroxenic hornblendic and micaceous gneiss affected by post-Cambrian movement; epidiorite and hornblende-schist affected by post-Cambrian movement; and flaggy quartz-feldspar granulite being noted. Along the remainder of the route, granulitic schists of the Moine series are noted to underlie the route. However, the strata immediately to the south of the routes along Loch Carron are recorded to comprise acid and hornblendic gneiss, amphibolite; and pelitic gneiss. The recorded dip varied from south east, to east, to north east.
S1, S3, S4, S5b	Where mapped, the superficial deposits along the routes were recorded to comprise morainic deposits with some undifferentiated drift and peat. No indication of the depth of the superficial deposits is given; however superficial deposits were not consistently mapped across the site indicating that they were thin or absent. The solid strata were recorded to comprise undifferentiated granulitic schists of the Moine Series, and were noted to dip to the south east.

4.2 Seismic Activity

The BGS recorded several historical earthquake events in the vicinity of the site, their locations and magnitudes are listed as follows:

Date	Location	Magnitude
03/12/1878	Kintail	3.3
06/08/1974	Kintail	4
10/08/1974	Kintail	4.4
27/11/1975	Kintail	4.1
12/02/1975	Loch an Lasaich	2.2
06/04/1978	Lochan Dubha	1.9
28/05/1978	Lochan Dubha	1.9
11/06/1978	Creag Mhor	2.3
11/08/1979	Carn Mor	1.5
30/08/1979	Loch Carron (near avalanche shelter)	2.3
07/02/1988	Criag Mhaol	2.4
08/02/1988	Criag Mhaol	1.9

4.3 Mining and Quarrying

Due to the nature of the underlying metamorphic bedrock, it is considered that the risk to the development with respect to mineral stability is very low.

In addition, no quarries were identified on or within 250m of the site boundary on the historical maps. However, an existing quarry was noted near Ardarroch on the approximate location of ON3 on aerial photography of the site available through Google maps.

4.4 Hydrology

Several watercourses were noted in vicinity of the routes. The main water bodies encountered are detailed in section 4.6.1.

4.5 Hydrogeology

The BGS aquifer maps[Ref. 3] and accompanying report[Ref. 4] indicated that:

- The alluvial and drift deposits recorded to underlie the majority of the site are regarded as a non-aquifer due to their low permeability.
- Groundwater flow within the bedrock recorded to underlie the site is classified as through fractures (bedding planes, joints and faults.) These rocks are classified as aquifers with a low to very low productivity.

Groundwater flow directions within aquifer units in the drift deposits will be influenced by the local topography and also by nearby surface waters. A hydraulic connection between groundwater below the site and surface water is unknown.

The Scotland and Northern Ireland Forum for Environmental Research (SNIFFER) groundwater vulnerability map[Ref. 5] and accompanying report[Ref. 6] have been consulted and the site has been given a vulnerability classification of 4, based on the assumption of there being approximately 1-3m of superficial deposits overlying bedrock. A vulnerability classification of 4 indicates that groundwater within bedrock beneath the site will be vulnerable to those pollutants not readily absorbed or transformed.

Where bedrock is exposed, or only a thin layer of topsoil is present, a vulnerability classification of 5 would be more appropriate. A vulnerability classification of 5 indicates that groundwater within the bedrock will be vulnerable to most water pollutants with rapid impact in many scenarios.

Groundwater bodies are classified by SEPA, from which the water quality ratings range from Good to Poor. A search of SEPA's River Management Basin Plan (RMBP) database was conducted regarding the groundwater quality beneath the site, and was found to be classified as "good".

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[3] BGS/SEPA, 2004. *Bedrock Aquifer Map and Superficial Aquifer Map*, Scale 1:100,000.

[4] BGS, 2004. *A GIS of aquifer productivity in Scotland: explanatory notes.* Commissioned Report CR/04/047N.

[5] Scotland and Northern Ireland Forum for Environmental Research (SNIFFER), 2004. *Vulnerability of Groundwater in the Uppermost Aquifer*, Scale 1:100,000.

[6] SNIFFER, 2004. *Development of a groundwater vulnerability screening methodology for the Water Framework Directive.*

4.6 Other Sources of Information

4.6.1 *Scottish Environment Protection Agency (SEPA)*

SEPA has implemented a new monitoring scheme and classification system to meet the requirements of the Water Framework Directive, whereby water bodies in Scotland are classed as High, Good, Moderate, Poor or Bad.

A search on SEPA's online database(Ref. 7) was conducted regarding water quality in the vicinity of the site. Of the watercourses identified on site, the following were assessed by SEPA:

Watercourse	Status
Abhainn Cumhang a Ghlinne	Good
River Carron	Good
River Attadale	High
Allt Cadh an Eas	Good
Allt Gleann Udalain	Good
Allt Loch Innis nan Seangan	Good
Loch Carron	Good

Groundwater beneath the site falls within the grouping 'Morar and Torridon', which was given a status of *Good* in 2008.

4.6.2 *Scottish National Heritage (SNH)*

A search on the online SNH database(Ref. 8), identified the following statutory designations on, or in the area surrounding, the routes:

Route Name(s)	Designation	Location and Orientation	Details
N6	Site of Special Scientific Interest (SSSI)		Site Name: Slumbay Island Site Code: 1445 Area: 7.52ha Feature Category: Structural and Metamorphic Geology Feature: Moine

[7] SEPA, 2009. *RBMP Interactive Map.* Available: http://213.120.228.231/rbmp. Last accessed 09 November 2011.

[8] SNH, 2012. *Sitelink.* Available: http://gateway.snh.gov.uk/sitelink/index.jsp

Route Name(s)	Designation	Location and Orientation	Details
ON3, N6	SSSI	Crosses ON3,	Site Name: Allt Nan Carnan Site Code: 47 Area: 16.77ha Feature Category: Broad-leaved, mixed and yew woodland Feature: Upland birch woodland
O1 – O7	SSSI	Immediately south of all O routes, except O3 with which it is directly North	Site Name: Attadale Site Code: 95 Area: 6.61ha Feature Category: Structural and Metamorphic Geology Feature: Moine

The entries are depicted on URS Drawing No. 47065084/4004, included in Appendix D.

4.6.3 *The Royal Commission on the Ancient and Historical Monuments of Scotland (RCAHMS)*

The Royal Commission on the Ancient and Historical Monuments of Scotland (RCAHMS) online database[Ref. 9] was consulted regarding the site's archaeological significance.

Numerous entries were recorded for the various routes. Full details of the entries recorded are included in Appendix D along with a location plan, URS Drawing Nos. 47065084/4002 and 47065084/4003.

[9] RCAHMS, 2009. *Pastmap*. Available: http://jura.rcahms.gov.uk/PASTMAP/start.jsp

5. SUMMARY OF PREVIOUS REPORTS

5.1 Whatlings (Foundations) Ltd, Report on Site Investigation for A890 South Strome to Auchtertyre Road Improvement, March 1974

Project Details	
Report Provided By:	BGS
Relevant Corridors/Routes:	Online and Southern Corridor (eastern extents)
Brief Description:	Site investigations report for the upgrade of the A890 between South Strome and Auchtertyre. Incudes borehole/trial pit records and test results as well as interpretive text.

5.1.1 *Introduction*

Whatlings (Foundations) Ltd (Whatlings) was tasked with investigating approximately 10km of the A890 between South Strome and Auchtertyre which was earmarked for upgrade from single carriageway to two lane single carriageway trunk road standard. A site investigation was undertaken at the request of the consulting engineers (Babtie, Shaw and Morton) to their requirements to provide information on the ground conditions prevailing along the route of the proposed road.

5.1.2 *Topography and Geology*

The topography and geology is discussed in some detail, however, much of the information provided was out with the study area of this report.

5.1.3 *Site Work*

The site works were undertaken between September and November 1973 with some further work undertaken in March 1974. The site works included boreholes (shell and auger and rotary), test pits, trial holes, dynamic penetration tests and the installation of standpipes within boreholes.

Whatlings provided the locations of the ground investigation positions on their drawings R2857/137 to R2857/142. These were provided as part of their report, included in Appendix F.

All logs were available to URS; however, many of the logs were illegible.

5.1.4 *Laboratory Work*

Testing was carried out in soils obtained as part of the investigation, however copies of the test results proved to be illegible.

5.1.5 *Ground Conditions*

Whatlings discussed the ground conditions in some detail; however much of the information was not relevant to the site considered by URS, as the information was out with the study area. However, a review of the legible logs relevant to the site has allowed URS to provide the summary of ground conditions as follows:

Strata	Depth to Base (mbgl)	Thickness (m)
Topsoil (occasionally peaty)	0.1 – 0.9	0.1 – 0.9
Peat	0.15 – 2	0.15 – 1.95
Dense Sand	0.7 – 3.3	0.5 – 2.4
Peat	0.15 – 1.8	0.15 – 1.95
Alluvium	0.4 – 2.2	0.23 – 2.1
Rockhead	Encountered from depth of between 1m and 2.7m	

Groundwater was encountered at between 0.3mbgl and 1.3mbgl.

5.1.6 *Comments on Ground Conditions in Relation to Foundation Design*

Whatlings provided a general site wide comment on foundation design. They stated that rockhead was at or near ground level across the majority of the site, and that much of the proposed road would require the removal of considerable quantities of rock. It was suggested that much of the spoil would be suitable for reuse, and also that measures for control of groundwater may have been necessary in areas where the natural drainage was poor and liable to impede upon the works.

5.1.7 *Structures*

Whatlings undertook an assessment of allowable bearing capacities of the soils at the site based on the analysis of dynamic penetration tests taken in the granular soils and on the assumption of an allowable settlement in the order of 25mm.

The assessment relevant to the current site is in relation to Ascaig Burn Culvert at Whatlings chainage 7550m.They state that the boreholes in this area showed over 5.7m of overburden which consisted of soft peat and sandy silt followed by dense sandy gravel below a depth of 1mbgl and 2mbgl. Rock was not encountered at the site of the proposed culvert. Whatlings suggest that the most suitable base for the culvert would be a strip or pad foundation placed at 2mbgl within the dense sandy gravel. Whatlings assessment of allowable bearing capacity in this layer were based on dynamic penetration test results in saturated soils and indicated values in the order of 150kN/m² to 200kN/m² at a depth of 2m.The concentrations of sulphate in samples were such that no special precautions were required, although the ground water in one borehole was slightly acidic.

5.1.8 *Earthworks and Rock Cuttings*

Whatlings provided general comment on the earthworks to be applied at the site, with information pertaining to a chainage of 6100m to 6350m pertaining to the current site. A large cut was proposed in this area and was expected to be in the order of 18m deep in ground which sloped to the north at gradients of approximately 1 in 2. The investigation revealed that less than 1m of superficial was present in this area, thus Whatlings assumed that there would be no issues with slope stability. Rockhead encountered in this area was found to be badly fractured and consisting of strongly foliated schist. This was consistent with shattering and subsequent weathering caused by the Moine Thrust which ran parallel to the proposed route in this area. The stability of any cutting in this area gave Whatlings cause for concern due to the nature of the rock and groundwater conditions.

5.2 Triax (Site Investigation) Ltd, Site Investigation at Loch Carron, July 1982

Project Details	
Report Provided By:	BGS
Relevant Corridors/Routes:	Outer and North (Immediately surrounding the settlement of Lochcarron)
Brief Description:	Factual report for a ground investigation. Borehole logs and test results provided.

The report received from Triax (Site Investigation) Ltd (Triax) contained neither text nor a legible site plan (four drawing were provided, but do not indicate exactly where the boreholes were). From the BGS website the general area of the investigation was centred on the settlement of Lochcarron and the logs suggest that the investigation comprised a total of eight boreholes and lab testing.

URS has summarised the ground conditions encountered as follows:

Strata	Depth to Base (mbgl)	Thickness (m)
Topsoil (occasionally peaty)	0.1 – 0.45	0.1 – 0.45
Soft Peaty Clay	1.0	0.9
Sand/Gravel	1.4 – 9.4	0.3 – 7.4
Clay	1.1 – 9.6	0.3 – 7.4
Rock	Encountered from depths of between 1.4mbgl and 9.6mbgl	

Groundwater was encountered in three boreholes at depths of between 0.5mbgl and 3.3mbgl.

Particle size distribution tests were undertaken on nine samples of soils obtained as part of the investigation, with the following range of results being obtained:

- Cobbles: 5 – 23%;
- Gravel: 40 – 80%;
- Sand: 7.5 – 60%;
- Clay and Silt: 55%.

One sample was also submitted for Atterberg limit testing. The sample achieved a liquid limit of 42% and a plastic limit of 16%, indicating a soil which was a silt of intermediate plasticity.

5.3 Holequest Ltd, Geological Survey and Borehole Logs, Loch a' Choire Leith Site Investigation Report, October 1986

Project Details	
Report Provided By:	BGS
Relevant Corridors/Routes:	Outer
Brief Description:	Site investigation report for works at Loch a' Choire Leith. Incudes borehole/trial pit records and test results as well as interpretive text.

5.3.1 *Introduction and Summary*

This report deals with geological factors affecting the proposed 2.7km raise in the level of Loch a' Choire Leith. The loch lies in a basin, the north of which contains two low points, or cols. The outlet of the Loch is the western col.

5.3.2 *Previous Investigations*

Earlier reports focused on the western col with only a preliminary inspection of the eastern col. These found that the western col appeared to be developed in uniform and sound bedrock and was not seen to pose any unusual geological problems. A preliminary survey of the eastern col was insufficient to reveal the likely nature of its core, and on this basis Holequest was commissioned to produce their report.

5.3.3 *Borehole Logs*

Holequest Ltd (Holequest) stated that all boreholes penetrated peaty soil 0.2m to 1.2m in thickness, underlain by brown sandy clay with increasing content of rock fragments with depth, ranging in thickness from 1m to 1.5m. Bedrock was found to consist of schists and gneisses which were slightly to moderately weathered. The borehole logs were available to URS to inspect, and are summarised as follows:

Strata	Depth to Base (mbgl)	Thickness (m)
Peaty topsoil/peat	0.3 – 1.2	0.3 – 1.2
Clay	1.0 – 1.5	0.1 – 1.0
Weathered Rock	1.0 – 2.3	0.2 – 1.1
Rock	Encountered from depths of between 1mbgl to 2.2mbgl.	

5.3.4 *Laboratory Testing*

Although not included in the body of the text by Holequest, laboratory testing results were appended to the report and available for URS to review. It was found that thirteen sample of rock were subjected to point load testing returning Is values of between 0.69MN/m² and 11.94MN/m² which indicated a weak to extremely strong rock, with an average value of 5.63MN/m² (very strong).

5.3.5 *Interpretation*

Holequest found that a blanket of superficial deposits of 1.5m thick comprising sandy clay with rock fragments with increasing density with depth covered the site. Bedrock consisted of interlayered gneisses and schists with angles of dip from 20° to 60° directed eastwards.

The whole area was also overlain by peaty soil ranging from 0.3m to 1.5m in thickness. In the westernmost two thirds of the profile rockhead rose northwards from the line of the boreholes to reach ground level.

5.4 James Williamson and Partners, Stromeferry Bypass A890, Slope Stability Appraisal (Cuddies Points to Ardnarff), January 1987

Project Details	
Report Provided By:	BGS
Relevant Corridors/Routes:	Online
Brief Description:	Slope stability appraisal for man-made slopes along the existing route. Also provides recommendation for remediation/bypass.

5.4.1 *Introduction*

James Williamson and Partners (JWP) was appointed by Highland Regional Council (HRC) to undertake a preliminary investigation into the instability of slope adjacent to the A890 Stromeferry Bypass, and to provide recommendations for remediation.

JWP report that the road bypassing the Strome Ferry crossing was completed in 1971 under the supervision of consulting engineers, Babtie, Shaw and Morton. During the construction of the road, a major landslip occurred and the existing avalanche shelter was constructed as a result. Major falls of rock were reported at one to two yearly intervals, often spilling onto the railway. British Rail (BR) claimed the cost of managing falls from HRC and also carried out daily inspections.

Numerous areas of fallen trees were noted by JWP on the hillside slopes above the rock faces. They report that tree planting was carried out in the early 1900s, but the trees were subsequently felled and removed in 1980 following some trees falling from the slope. Despite this, fallen trees were noted to be a regular problem, causing closures in the road and railway. Trees which had fallen but remained on the upper slopes were reported by JWP to be owned by HRC, although the legal liability for these trees was believed to lie with the landowner.

A number of boulders were also noted to rest on the upper slopes. These were reported to be affected by erosion, which eventually caused them to slide downwards. This surface erosion was combatted through a programme of planting birch, willow and rhododendron by HRC at the time of reporting.

At the time of JWP writing, HRC staff routinely inspected the route for rock falls, with small rock fall frequently being recorded and substantial failures occurring on an annual basis.

5.4.2 *Description of the Study Area*

The stretch of the A890 considered by JWP ran approximately 4km from Cuddies Point to Ardnarff, along the southern shore of Loch Carron. The road consisted of a single lane with passing places and was bound immediately to the north by the Kyle of Lochalsh railway line, and steep natural and blasted rock slopes to the south. A reinforced concrete avalanche shelter was noted approximately 0.7km from Cuddies Point. A local chainage system was established by HRC for the purpose of the study, with chainage zero being located near the car park at Cuddies Point and the end of the section under consideration at chainage 3850m near Ardnarff.

The road cut surface was recorded to lie between +5mOD and +10mOD, with the crest of the adjacent slopes at +30mOD. Above the crest the slopes continue to rise at angles of 40° to 45°, flattening to 20° to 30° at approximately +100mOD. Above the +300mOD contour, the hilltop level was noted some 900m from the road.

The near vertical slopes adjacent to the road were interpreted by JWP as being raised natural sea cliffs, and although the railway and road were thought by JWP likely to be constructed on fill materials, they were considered by JWP to be located on raised beach. Part of the material present at, or just above, sea level was thought to represent alluvial fan deposits from a number of streams whose courses ran directly northwest down the hillside slopes and into the rock, passing beneath the road and railway through culverts. The stream gullies were reported to be very pronounced features with steep sides.

The solid geology of the adjacent slope was identified by JWP to consist of complex Precambrian strata. Their review of geological maps indicated that all but the northernmost part of the study area was underlain by granulitic schists of the Moine series at road level, this being overlain by pelitic schist which in turn was overlain by ancient Lewisian gneisses. Lewisian strata occupy the route north of Cuddies Point. The solid strata were also recorded to dip to the southeast. The Moine thrust was considered by JWP to intersect the coast near Stromeferry and then run beneath Loch Carron, and did not enter the study area.

5.4.3 *Large Scale Areas of Differing Assessed Instability*

JWP divided the study area into four large scale zone areas based upon stability, as follows:

- Area 1: Chainage 0m – 324m;
- Area 2: Chainage 324m – 1522m;
- Area 3: Chainage 1522m – 3494m;
- Area 4: Chainage 3494m – 3850m.

The stability assessment of these individual areas was summarised in terms of four types of instability which were observed by JWP. These were:

- Type 1: Rockall from steep slope faces which lie immediately adjacent to the road;
- Type 2: Natural slopes which are steep, but are largely overgrown and the assessed hazard is less than type 1:
- Type 3: Landslips involving sliding and/or rotational failure of soil/rock from the hillside slopes above the crest of the rock slopes immediately adjacent to the road;
- Type 4: Fallen trees; soil and rock loosened by the uprooting of trees; and boulders and debris loosened by rain.

The stability assessment of each of the areas was summarised by JWP as follows.

<u>Area 1: Chainage 0m to 324m</u>

Relatively low slopes were present adjacent to the road, locally rising to approximately 6m high, and posing a limited type 1 hazard. Hillside slopes remote from the road were not considered to represent a hazard to the road user. Most failures to the slopes adjacent to the road were expected to be contained on the verge.

Area 2: Chainage 324m to 1522m

This area was noted by JWP to include the most pronounced stability problems, including Type 1, 3 and 4 hazards. Over the majority of the length there was considered to be a severe risk of debris striking and possibly blocking the existing road. Preventative measures were in place at the time of writing in the form of an avalanche shelter and slope meshing. Steel barriers were also erected to improve security at some points, and masonry clad concrete infill buttresses had been formed at the toe of the slope to support local overhangs. Monitoring tell-tales had been installed at some potentially unsafe blocks.

Area 3: Chainage 1522m to 3494m

Type 2 hazard slopes were identified by JWP at chainages 1522m to 2020m; 2365m to 2425m; 3005m to 3115m; and 3225m to 3305m. However, the slopes were not shown to be actively deteriorating and were partly overgrown. The slopes in general were considered by JWP to represent considerably less risk that the excavated slopes.

Area 4: Chainage 3494m to 3850m

Significant type 1 hazard slopes were present, often in the range of 10m to 15m in height merging with steep upper slopes. It was considered by JWP that there was a hazard from falling blocks striking the road at these locations. Meshing of the slopes in area 4 had previously been carried out.

5.4.4 *Summarised Detailed Appraisal*

The hazard rating used by JWP was as follows:

Hazard Rating	Consequences of Failure
Extreme Hazard	Large unstable masses where failure will block the carriageway.
Major Hazard	Likely failure will cause severe obstruction or blockage of the carriageway.
Moderate Hazard	Likely failure will not be contained by the verge and will affect part of the carriageway.
Minor Hazard	Likely failure is small scale or will be retained by the verge but may affect part of the carriageway.
Negligible Hazard	Likely failure is small scale and will have an insignificant effect, if any, on the carriageway.
No Hazard	No likely failure mechanisms, or, if present, they will not affect the carriageway.

The following summarises the hazard rating given to each area by JWP.

Area 1: Chainage 0m to 324m

JWP assessed that no extreme hazard were present, but major hazards occurred at chainages 109m to 120m and 130m to 157m. The overall hazard in area 1 was thus assessed as major.

Area 2: Chainage 324m to 1522m

Extreme and major hazards were identified in area 2 by JWP at the following chainages:

Chainage (m)	Hazard Rating	Chainage (m)	Hazard Rating
330 – 336	Major	596 – 600	Extreme
336 – 347	Extreme	683 – 692	Major
349 – 363	Major	706 – 717	Major
380 – 385	Extreme	790	Major
380 – 390	Major	833 – 956	Major
395	Extreme	993 – 1012	Extreme
400 – 420	Extreme	1110 – 1112	Major
432	Extreme	1160 – 1165	Extreme
433 – 436	Extreme	1174 – 1193	Major
346 – 454	Major	1258 – 1265	Major
454 – 500	Major	1271	Extreme
528 – 533	Extreme	1284 – 1293	Major
533 – 546	Extreme	1360 – 1370	Major
567	Major	1395 – 1430	Major
572 – 580	Extreme	1414	Major
590	Extreme	1434 – 1441	Major

The overall hazard was assessed as being major.

Area 3: Chainage 1522m to 3494m

The hazard rating at area 3 was mainly in the range of no hazard to minor hazard. Although large blocks were noted in some areas (chainage 3220m to 3300m, and 3455m to 3465m) these were not thought to be in an actively deteriorating condition.

Area 4: Chainage 3494m to 3850m

The slopes in area 4 were generally considered by JWP to represent a moderate hazard to the road user, whilst containing isolated features which would represent a major hazard to the road user. Small blocky features were retained within the verge by mesh on the slope face, however JWP identified a possible major hazard at chainage 3668m.

Hillside Slopes

Information available for the hillside slopes was insufficient to identify specific problems, however, general statements regarding the stability of the upper slopes were provided by JWP.

No hazards associated with the upper slopes were identified by JWP in Areas 1, 3 or 4. However, in area 2 an extreme hazard was identified by JWP in the form of felled trees located on the slopes. Numerous rock outcrops were also noted by JWP, presenting potential major hazards. The likelihood of a further large landslip failure had not been identified.

5.4.5 *Long Term Improvement Options*

JWP noted that major works would be necessary to provide a long term improvement in the hazard to road users. Three remediation options were provided to achieve this, as follows:

- Option 1: The road remains at/near its present alignment and width, with substantial slope works (reprofiling, anchoring, heavy meshing, etc.) or a road protection scheme put in place to reduce the hazard to road users, The types of protection works envisaged were structures such as avalanche shelters, avalanche barriers, or an elevated road.
- Option 2: the existing road is abandoned in favour of a new route.
- Option 3: the road remains at its approximate present route, but is widened to two lanes and separated from the slope by a rockfall zone. This option implies an increase in land space necessary to accommodate the road, railway line and the rockfall zone. This widening was to be achieved through excavating into the hillside slopes or by creating an embankment into the loch.

5.4.6 *Recommended Short Term Remedial Measure*

It was recommended that short term remedial measures be carried out to reduce the degree of hazard to the road users.

The hazard appraisal identified numerous extreme and major hazards within the slopes adjacent to the road, and JWP suggest that these should be subjected to some form of short term remediation. The following remedial measures were recommended by JWP.

Area 1: Chainage 0m to 324m

Minor to moderate hazards should be scaled, with heavy machine scaling possibly being applied at chainage 130m to 253m to cut back slopes and remove major hazard blocks. Otherwise JWP recommend local removal with the option to use displacement monitoring and anchoring.

Area 2: Chainage 324m to 1522m

In area 2 it was recommended that the rock faces be lightly scaled and the overhangs along the crest trimmed back. The mesh was also noted to require replacing, prior to which any fallen trees on the upper slope were recommended to be removed. The extreme hazards were generally dilated toppling or sliding “bluffs” or “noses” that were recommended to be removed with great care. It was also recommended that further inspection be carried out before detailed recommendations were given. It was also recommended that in the intervening time, these areas be monitored using tell-tales across the prominent joints. Rock bolting was tentatively recommended for some areas where potential sliding joints could fail.

Due to the narrow verge and nature of the rock, it was also recommended that this area be inspected regularly with clearance of the verge and ditch as necessary.

Area 4: Chainage 3494m to 3850m

The slopes of area 4 were noted to generally contain moderate hazards, however JWP identified a possible major hazard at chainage 3668m. JWP recommend that this potential sliding joint be monitored with tell-tales or secured with rock bolts, although consideration could also be given to the removal of the hazard by machine scaling.

In general, JWP noted that area 4 would benefit from light scaling, clearance of fallen debris resting on the face and removal of the young conifers growing on the face followed by re-meshing.

Hillside Slope

The fallen trees lying above the rock faces were recommended for removal. Additionally the head of stream channels and gullies were recommended to be cleared of accumulated debris.

5.4.7 *Recommendations for Future Work*

JWP recommend that further inspections should be undertaken prior to, and during, short term remedial works, particularly with the use of a light cradle to clarify the type of treatment, if any, that should be applied to major and extreme hazard rock masses. Before embarking on further field investigations related to the long term works, JWP also recommended that preliminary planning and feasibility studies should be carried out.

5.5 Mott MacDonald Scotland, A890 Stromeferry Bypass Alternative Routes: Inception Report, June 1991

Project Details	
Report Provided By:	THC
Relevant Corridors/Routes:	All
Brief Description:	Appraisal of alternative routes/remedial measures for the existing A890 Stromeferry Bypass.

5.5.1 *Introduction*

HRC commissioned Mott MacDonald Scotland (MM) to prepare a report on the feasibility of solutions the previously identified stability issues along the A890 Stromeferry Bypass, excluding options previously put forth by JWP.

MM's remit required the examination of alternatives which would permit the road route to be isolated from the slope stability problems. The options considered were:

- The construction of a bridge at Strome Narrows, with suitable approach roads;
- The construction of a tunnel at Strome Narrows, with suitable approach roads;
- The construction of a new road south of the existing alignment, bypassing the unstable slopes;
- Re-establishment of the vehicular ferry at Strome Narrows, including an upgrade of the approach roads;
- Construction of avalanche shelter type structures at required sections of the present road alignment to accommodate two carriageways;
- Realignment of the road onto the seaward side of the railway line;
- Construction of a tunnel to bypass the major remedial works suggested by JWP.

The study was also required to advise on the stability and stabilisation requirements of the rock slopes which were formed at the time of the road construction on the context of long term security of the railway, with the basis that an alternative road route was provided.

5.5.2 *Slope Instability on A890 Ardnarff to Cuddies Point*

MM summarised the stability issues identified along the route by JWP, which have been discussed by URS in section 5.4.

5.5.3 *Alternative Routes*

In considering possible means of avoiding the long term slope instability problems within the Ardnarff to Cuddies Point stretch of the A890, MM assessed the options for progress to preliminary report stage based upon their ability to provide a minimum 6m wide carriageway with 2m verges on either side, safety, and in cognisance of social, environmental and economic considerations.

The high level assessment by MM of each route option has been summarised in the following sections.

5.5.3.1 *Bridge Crossing*

5.5.3.1.1 *Introduction*

The location of a bridge at Strome Narrows would largely be determined by the need for the approach roads to traverse around the steep sided Creag Mhaol hill on the south shore. Two potential routes were selected, one spanning from Portchullin to Port à Mheirlich, and the other from South Strome to Strome Castle.

At each of the locations the average depth to sea bed level was estimated to be 10m to 15m and the underlying strata assessed to be metamorphic rocks. The waters to the east and west of the Narrows were noted to be considerably deeper, consistent with the rise in rockhead which occurs at the mouth of glacially formed fjords. It was therefore anticipated that superficial deposits would be relatively thin at the Narrows. It was stated that the conditions at the Narrows should provide foundations for a bridge at shallow depth and that the bridge may be an economic option.

The bridge alignment, width and minimum clearance had not been confirmed ta the time of writing, however both routes were considered to be flexible enough to meet a range of requirements.

The bridge crossings are depicted on MM's Figure 2, included in their report.

5.5.3.1.2 *Bridge Route 1 (Portchullin to Port à Mheirlich)*

The southern approach to this route traversed a raise beach which stood approximately 25m above shore level and was approximately 20m away from the high water mark. It was thought that this could provide a suitable platform to cross the existing railway and would also be useful in meeting the alignment of the bridge. It was envisaged that, should the deck level be low, the most economic crossing would be to extend the approach embankment a distance into the narrows. However, if the deck levels were 20m to 30m above sea level, the bridge spans would have to be extended to the shore line.

The alignment of the bridge could be skewed to meet a suitable landing point on the north shore. A steep rock face behind the shore line west of Port à Mheirlich was not considered to be a suitable landing point. At Port à Mheirlich itself, the shore line was said to remain reasonable level and could facilitate a link to the existing road. If this alignment was followed, the length of the bridge would be around 600m.

On the south shore a new length of road would be required to the link the bridge crossing with the A890 at Achmore, and at the north shore the existing single track would require to be upgraded to highway link standard between Port à Mheirlich and Lochcarron.

5.5.3.1.3 *Bridge Route 2 (South Strome to Strome Castle)*

South Strome is located on the east side of Creag Mhaol, and MM stated that should the approach road follow a route over South Strome it might be difficult to comply with Highway Link standard. This might mean that it would be necessary to move further east which would take the bridge out with the extent of the narrows.

The shortest distance from a point at or near South Strome across the loch was said to have the bridge spanning 550m onto the peninsula at Strome Castle at a point adjacent to an existing slipway.

The presence of rock outcrops at either bank indicated to MM that a suitable landing area would be found.

On the south shore the A890 was noted to run close to South Strome and thus only a short length of new road would be required. At the north shore, it was recommended that the existing single track road would require to be upgraded to Highway Link standard between Strome Castle and Loch Carron.

5.5.3.2 *Road Re-alignment*

5.5.3.2.1 *Introduction*

Several alternative road routes were considered, chosen and developed by MM from an examination of large scale Ordnance Survey maps and the use of stereoscopic viewing of aerial photographs. MM then undertook a site visit, walking the principal routes identified in more detail.

The road realignments are depicted on MM's Figure 3, included in their report.

5.5.3.2.2 *Road Alignment 1*

Road alignment 1 started 500m east of Stromeferry on the A890 and traversed uphill through Strome Forest to Loch an Arbair. The road then skirted the top of the hills adjacent to Loch Carron and descended to re-join the A890 at the Attadale bridge. The alignment was said to maintain the direct link between the communities of Stromeferry and Attadale. The alignment would however encounter problems in maintain gradient limits. MM's initial assessment also indicated that substantial rock cuts, embankments and bridge crossings would be required to facilitate the route.

5.5.3.2.3 *Road Alignment 2A*

Road alignment 2A left the A890 approximately 4km south of Stromeferry and followed an existing forestry track along Glen Udalain for 3km. The route then followed the River Udalain for 2.5km where it then bridged the river, then traversing through the forest plantation passing Loch nam Breac Mora and down through the forest at the head of the River Attadale floodplain. The area was densely forested in deep peaty soils which were drained by many small watercourses, thus the route would require clearing of large areas of forest with consequent compensation to the Forestry Commission.

MM stated that there should be few topographical problems with the route, and that the overall safety and comfort of the route would be a substantial improvement on the existing road.

5.5.3.2.4 *Road Alignment 2B*

The route 2B alignment followed route 2A until the latter crossed to the north bank of the River Udalain. Route 2b at this junction followed the line of a deer fence down the north bank of Allt Loch Innis nan Seangan before contouring round the hill south of Loch nam Breac Mora and crossing the pass west of Mam Attadale. Route 2B rejoined 2A 1km beyond Lochan Fuar.

Route 2B was the lowest of the three routes and geomorphology variable, predominantly peat measures with rocky outcrops.

5.5.3.2.5 *Consideration of other Routes*

A route following Achmore valley and passing north of Carn na Creige was examined by MM, but the adoption of Highway Link design was not found to be feasible due to the topography of the route.

A further route through Dornie and following the west side of Loch Long via Sallachy and Glen Ling to Attadale was considered, and while feasible would be detrimental to communities near Plockton and render the upgraded A890 between Auchtertyre and Stromeferry redundant but for minor local traffic.

5.5.3.3 *Ferry Crossing*

MM held initial discussions with interested parties regarding the reintroduction of a ferry crossing at Strome Narrows and found that the option was very unpopular, with it being viewed as a downgrade of the route. Aside from this, MM also found that there were several other problems with this option.

The existing slipway facilities were found to be inadequate for needs and would require complete replacement, additionally approaches to the ferry locations at both north and south Strome a difficult, if not impossible for heavy goods vehicles and buses, and have no facilities for queuing vehicles. Mooring facilities at both slipways would also require complete replacement.

5.5.3.4 *Causeway*

This option involved a two way link on the seaward side of the railway adjacent to the existing A890 Stromeferry Bypass by rock fill causeway or viaduct. The site reconnaissance, limited bathymetric survey information and its source information were examined by MM, who concluded that a causeway providing a 6m wide carriageway would be feasible over much of the Ardnarff to Cuddies Point shore. An 800m stretch immediately west of Cuddies Point was thought to present difficulties because of the depth of water. Two areas, comprising 150m of shoreline immediately west of the avalanche shelter and 200m of shoreline between the avalanche shelter and Cuddies Point, had depths close inshore of 13m and 22m respectively. The intervening depths of shoreline were found to have an average depth of 5m. For both deep water areas, MM state that a causeway option would not be possible without extensive filling or major piled or anchored cantilever structures.

The causeway/viaduct option is depicted on MM's Figure 5, included in their report.

5.5.3.5 *Avalanche Shelter*

MM gave consideration to extending avalanche protection using a structure either similar to that west of Cuddies Point or a simpler, cheaper solution using a corrugated steel sheet structure backfilled with crushed rock. They assumed that the shelter would also provide protection to the railway. If the shelter was not extended to the railway, a requirement for slope stability works would remain. Without site investigation to confirm the stability of embankment on the seaward side of the railway, it was not possible to assess whether ground conditions would allow such construction. A length of 1.2km had been identified as a SSSI, however MM's early discussions with the Nature Conservancy Council indicated that they would not lodge an objection if the safety of road users was threatened, although they preferred an option that would not obscure the protected rock feature.

The avalanche shelter option would require that the length of road would continue to be single track unless a rigid concrete construction was adopted, in which case traffic from one direction could travel on top of the shelter. Such an option would consist of a two storey reinforced concrete structure founded on rockhead. As a minimum of 3m from the nearside railway line was required by Network Rail, a lane width of 3.8m, assuming a 0.6m pier thickness, would be possible. A fill protection layer and a rock catch fence would be required to provide protection to the structure and nearby railway.

However, MM identified a disadvantage with this option, as the rock slopes were 30m high some 24m (for a single deck option) or 18m (for a two storey option) of slope would remain above the ceiling of the shelter. This would partly be taken up by soft covering over the top of the shelter; however some slope stability works would still have to be undertaken to prevent failed rock reaching the railway track. Additionally, they identified that the inherent problem with the shelter is the effect of breakdowns and accidents within the restricted carriageway width and the subsequent access difficulties for breakdown and emergency vehicles. The existing shelter would also require to be demolished and replaced.

The extended avalanche shelter is depicted on MM's Figure 5, included in their report.

5.5.3.6 *Tunnel Options*

5.5.3.6.1 *Introduction*

Two alternative road tunnel routes were considered by MM for incorporation in the preliminary report; Route 1, a potential crossing of the Strome Narrows, and Route 2, bypassing the 1.5km of rock slope which required remediation.

The tunnel options are depicted on MM's Figure 6, included in their report.

5.5.3.6.2 *Tunnel Route 1*

The approach road to this route followed a similar line to those in Bridge Route 1. Although the narrows were only recorded at 600m wide at that point, MM suggest that rock cover of at least twice the tunnel diameter below the deepest point of the crossing would dictate a total tunnel length of approximately 2300m, assuming maximum road gradients of 8%. As with Bridge Route 1 the south approach to the route traverses a raised beach at a height of 25m above shore level. Should site investigation indicate considerable depth to rockhead, the south portal would be located on the south face of Creag Mhaol. Construction of a link road from the A890 to the tunnel portal would be required. On the north shore, MM envisaged that the tunnel portal would be located north of Port à Mheirlich and require the upgrading of the existing single track road between North Strome and Lochcarron.

5.5.3.6.3 *Tunnel Route 2*

This route was to bypass the most critical unstable section of slope between chainages 0m and 1500m. The west portal would be located near the road crossing of the Allt an Fhraigaich stream, and the east portal approximately 400m east of chainage 0m, close to where the A890 crosses the Cuddies Point Burn. MM estimate that the total length of the tunnel would be approximately 1900m and would be sited some 200m back from the rocks slopes over the majority of its length.

5.5.3.7 *Tidal Power Generation*

A tidal power scheme across the entrance to Loch Carron has previously been investigated by the National Engineering Laboratory in 1978. Various locations for a barrage were examined, with the most favourable being across the Strome Narrows. However in 1978, the unit costs for North of Scotland Hydro-Electric Board (HSHB) electricity was only 1.15p/kWh, and it was therefore not economic to promote this scheme as it had a capital cost of approximately £10 million.

The primary purpose of the original scheme was to provide electricity, however a new road crossing of Loch Carron could make the scheme more economical. This would consist of a rockfall barrage constructed across the narrows with the road running along the crest, with bulb turbines being housed within the concrete caissons. Similar caissons would contain large sluices to allow water to enter Loch Carron on the flood tide and a shipping lock would also be required to allow access of vessels into the loch. A rough estimate was carried out based on the 1984 figures, which found that it would take 60 years to recover the additional costs associated with a tidal barrage scheme, unless a better electricity rate could be agreed.

The tidal barrage option is depicted on MM’s Figure 9, included in their report.

5.5.4 *Comparison of Options*

The route options discounted through the preliminary assessment where as follows:

- Road route from Dornie via Loch Long;
- Road route from Achmore valley passing north of Carn na Creige;
- Ferry crossing;
- Causeway.

The causeway option was not progressed as a detailed bathymetric survey would be required to progress the scheme which would have required a significant investment. It was not fully ruled out as an option, but was not further considered by MM as part of their report.

5.5.5 *Selection of Routes for Progress to Preliminary Report Stage*

5.5.5.1 *Bridge Options*

MM considered it worthwhile to progress both options. They recommended, if one route alone was to be pursued, it should be Route 1 from Portchullin to Port a Mheirlich.

5.5.5.2 *Road Options*

Route 2 was recommended for selection by MM if the selection for progress to preliminary report stage was to be restricted. Additionally, it was suggested by MM that HRC may consider it worthwhile to extend the original brief for the road alignment option to allow Route 2B to be extended, bypassing Attadale, and joining the original route near Strathcarron.

5.5.5.3 *Tunnel Options*

MM state that, of all the options considered, the most environmentally sympathetic are the two tunnel routes and that both should be taken forward to Preliminary Report Stage. However, they go on that it would be difficult to provide cost estimates for both tunnels with the same level of confidence as the other options without site investigations being undertaken.

5.5.5.4 *Avalanche Shelter*

In considering the avalanche shelter, MM stated that without preliminary site investigation it would not be possible to confirm the stability of the embankment on the seaward side of the railway and hence confirm the practicality of protection for both road and rail traffic. Consideration would also have to be given to the protection of the railway, should the shelter not encompass it and also to the SSSI. The visual intrusion was also thought to be a likely source of objection should this option reach planning stage.

5.5.6 *Recommendations*

During the preliminary report study MM recommended that the following options be designed and developed to a level of detail sufficient to allow cost/benefit comparisons to be made on a like for like basis:

Route	Details
Bridge Route 1	Bridge crossing from Portchullin to Port à Mheirlich including approach roads from Achmore to Portchullin and Highway Link upgrading from Lochcarron to Port à Mheirlich.
Bridge Route 2	Bridge crossing from North Strome to South Strom including approach roads from the A890 to South Strome and Highway Link upgrading from Lochcarron to North Strome.
Road Route 1	Road route following the line of existing A890 but at higher level. Junctions with the A890 would be at South Strome and Attadale.
Road Route 2A and 2B	Road route following Glen Udalain then either via Lochan Breac Mora or via Allt Loch Innis nan Seangan, reaching the existing A890 at Attadale. An extension to this route bypassing Am Maman may be worthy of consideration at this stage.
Tunnel Route 1	Tunnel crossing from Portchullin to Port à Mheirlich including approach roads from A890 to Portchullin and Highway Link upgrading from Lochcarron to Port à Mheirlich.
Tunnel Route 2	Tunnel bypassing area of major remedial works between Allt and Fhraigaich and Cuddies Point Burn.
Avalanche Shelter	Avalanche shelter between Allt an Fhraigaich and Cuddies Point offering direct rock fall protection to road traffic and indirect protection to rail traffic.
“Do Minimum” Option	Monitor existing slope but incorporating the maintenance and slope stabilisation works recommended by JWP.

It was anticipated that the economic evaluation of each of the schemes would include the following activities:

1. Preliminary design and development sufficient to confirm the practicality of each option and provide sufficient detail to allow costing;
2. Construction cost, dependent upon whether topographical or geotechnical studies are included within the scope of the preliminary report;
3. Potential disruption during construction should be assessed for road traffic;
4. Long term operation and maintenance costs;

5. Assessment of socio-economic aspects, with particular reference to improved local links and the growth of tourist economies through improved communications to large areas of the North West Highlands;

6. Environmental considerations including:

   – Ecology;

   – Visual impact;

   – Impact on settlements;

   – Mitigating measures.

MM also suggest that evaluation of the options should follow procedures set down in the Scottish Traffic and Environmental Appraisal Manual and should be presented in an appraisal framework as recommended within that manual.

5.6 Mott MacDonald Scotland, A890 Stromeferry Bypass New Route Studies: Tunnel Route Preliminary Assessment, August 1993

Project Details	
Report Provided By:	BGS
Relevant Corridors/Routes:	Online
Brief Description:	Appraisal of tunnel option put forth in the Alternative Routes Inception Report.

5.6.1 *Introduction*

MM had been involved with the studies along the A890 Stromeferry bypass since 1986, then under the guise of JWP. This report presented a preliminary feasibility study for a tunnel option which MM had given in a previous report[10]. MM carried out this work on behalf of HRC, with the objective being to progress feasibility activities which were originally outlined the inception report.

The tunnel proposed by MM would run from a portal near Cuddies Point Burn (at a level of 21mAOD) to a portal near the existing road at the valley of Allt an Fhaigaich (8.5mAOD) some 1.5km to the southwest. For the purposes of MM's study, chainage 0 was taken at Cuddies Point.

5.6.2 *Geology*

MM stated that the proposed tunnel route traverses Lewisian and Moinian metamorphic strata of Precambrian age. MM anticipated that eastward dipping thrusting structures would be present within the area of interest. They further go on, the overall strata and dip appeared to be 25° east, although with the possibility of discordant foliation between the Moinian and Lewisian rocks. Any superficial deposits present were thin and would not form part of the tunnel structure. Groundwater conditions were not known.

[10] Mott MacDonald Scotland, Alternative Routes Inception Report, June 1991 (summarised in Section 5.5)

5.6.3 *Anticipated Ground Conditions*

MM provided comments on the type of ground conditions likely to be encountered based upon limited site mapping and assumptions regarding significant matters e.g. water inflow. The purpose of this was to provide a basis for their assessment of scheme feasibility and costing.

A project specific ground classification was developed by MM as follows:

- Class 1: Substantially unweathered, tight rockmass of competent but foliated gneiss or psammitic schist. Likely to be well jointed, but with only very minor water inflows;
- Class 2: Substantially unweathered, but more fractured rockmass, possibly near faults. May be slightly to moderately weathered and with water inflows. Zones near portals are assumed to be in this class;
- Class 3: Fractured and sheared rockmass, possibly near faults. May be slightly to moderately weathered and with water inflows. Zones near portals are assumed to be in this class;
- Class 4: Severely faulted or fractured materials possibly with substantial water inflows, although any clayey infills may reduce or eliminate these.

To illustrate the disposition and range of ground conditions which may be expected, a correlation between the anticipated geology and rock classification was produced by MM, as follows:

Approximate Chainage	Geological Conditions	Assumed Length in Classes (m)			
		1	2	3	4
0 – 40	Portal zone in Lewisian Gneiss. May show openness and some weathering.			40	
40 – 420	Lewisian gneisses, generally competent.	280	40	10	
420 – 440	Gneiss affected by faulting.			20	
440 – 690	Lewisian gneisses, generally competent.	200	40	10	
690 – 710	Faulted ground: assumed to be severely fractured and sheared for illustrative purposes.				20
710 – 840	Lewisian gneiss, generally competent	100	20	10	
840 – 860	Fractured and sheared ground adjacent to fault zone.			20	
860 – 880	Faulted ground: assumed to be severely fractured and sheared for illustrative purposes.				20
880 – 900	Disturbed ground adjacent to fault zone.			20	
900 – 1110	Lewisian gneiss, generally competent	150	40	20	
1110 – 1210	Moinian politic schist.	20	70	10	
1210 – 1230	Faulted			20	
1230 – 1250	Moinian politic schist.	10	10		
1250 – 1360	Moinian siliceous schist.	30	70	10	
1360 – 1380	Faulted			20	
1380 – 1440	Moinian siliceous schist.	10	40	10	
1440 – 1460	Faulted			20	
1460 – 1490	Moinian siliceous schist.	10	20		
1490 – 1540	Portal Zone: assumed to be faulted and weathered for illustrative purposes.				50
Total		810	390	250	90

Standard empirical rock classification exercises based on correlations with precedent practice were carried out using assumed ground parameters to allow the development of anticipated excavation and support requirements. The findings of MM's study are detailed below:

Class	Length (m)	Excavation[11]	Support
1	810	Full face	Untensioned dowels on 1.5m to 2m grid with shotcrete, or rock bolts on 2.5m grid with localised mesh/shotcrete.
2	390	Top heading and bench may be necessary	Rock bolts on 1m to 2m grid with mesh/shotcrete in crown, shotcrete on sidewalls.
3	250	Top heading and bench	Rock bolts on 1m to 1.5m grid in crown and was with mesh/shotcrete. Possible use of light steel ribs.
4	90	Multiple drifts or other special techniques	Rock bolts on 1m to 1.5m grid with mesh/shotcrete. May require shotcrete arches with closed invert.

5.6.4 *Engineering Configuration*

MM developed a preliminary tunnel profile for feasibility and costing purposes, with the following assumptions being made:

- A kerb-to-kerb carriageway width of 6.5m was assumed;
- A vehicle headroom of 5.1m was assumed;
- A dynamic lateral clearance of 0.6m outside both kerb lines was assumed;
- A crossfall of approximately 3% was assumed to assist with drainage of surface water and provide adequate superelevation for the curves anticipated;
- A 2m path width was assumed, with security to be provided by a concrete or steel barrier;
- A double curvature wall/roof profile was selected;
- A cast in-situ concrete lining of 0.4m was assumed;
- An additional thickness of 0.1m outside the principle lining was assumed to allow for temporary sprayed concrete and a drainage membrane;
- The profile included adequate space for lighting and ventilation equipment.

[11] Assumed by MM to be drill and blast

A two lane configuration was used in line with the MM Inception report and as agreed in discussion was HRC. A single lane/traffic light controlled configuration would be compatible with the adjacent routes but would present road safety difficulties.

For simplicity, a continuous curved horizontal alignment was utilised by MM, however they suggested that design optimisation would address the possibility of incorporating straight sections within the tunnel.

5.6.5 *Principle Engineering Elements*

MM suggested that it is common practice to construct a concrete portal canopy structures over the road approaching the rock portals to provide security against any rockfall from the overlying portal face and natural slopes. For the tunnel route under consideration MM assumed that such structures may extend some 5m to 10m out from the natural ground at both portal structures.

A cast in-situ lining was adopted over the full length of the tunnel.

The need for ancillary structures along the tie-in section of the road between the existing A890 and the new tie-in was not addressed in any detail. However, MM state that a culvert may be required a Cuddies Point Burn and improvements be made to the existing bridge at Allt an Fhraigaich.

MM provisionally assumed that a wearing course of approximately 100mm would be appropriate, laid over a concrete regulating course of similar thickness over rockhead. Alternatives could include the use of compacted granular fill.

It was assumed that the tunnel would naturally drain towards the south-west portal. The preferred approach to handling groundwater inflows into the tunnel would entail inception by a geotextile drainage layer/impermeable membrane system. Flows would be channelled behind the lining to tunnel drainage pipes set in no fines concrete surrounds.

MM assumed that a mechanical ventilation system would be required, despite the low traffic figures, for smoke control in a fire emergency.

It was stated that minimum lighting must be provided in a tunnel, and at a higher level than normal if pedestrian access is permitted.

5.6.6 *Construction Aspects*

MM assumed that for the relatively short tunnel length involved and assuming drill and blast methods are used, excavation would be carried out from both ends, either simultaneously or sequentially. To shorten the overall time to completion, MM suggest that ancillary works could be carried out in advance of the tunnelling contract. If these were not undertaken, the tunnelling contractor would likely have to make temporary access arrangements, involving greater work and greater cost.

It was calculated that tunnelling would produce approximately 210,000m^3 of rock spoil allowing for a bulking factor of 1.4, equivalent to 390,000tonnes of broken rock. MM suggest that subject to suitability testing; a proportion of the Lewisian Gneiss could be used crushed as a construction aggregate for the tunnel construction, leaving a substantial quantity for disposal or use elsewhere.

5.6.7 *Programme and Cost Estimate*

The anticipated programme was not considered in detail; however, MM's discussions with a tunnelling contractor indicated that approximately 120 weeks would be required for tunnel excavation and lining/finishing works. MM state that this period could be shortened if the tunnel was driven concurrently from both portals. Taking account of portal construction, associated culverts and tie-in road works, MM anticipated an overall construction programme of 2½ years.

At the time of writing, MM provided an estimate of budget requirements for the scheme as set out below:

	£m
Tunnel and Lining	12
Contingency (25%)	3
M&E Installations	2
Other elements (culverts, etc.)	1.5
	18.5

It was noted that the commercial value of the excavated tunnel spoil to other projects may have enabled the figure to be reduced.

5.6.8 *Investigation and Design*

5.6.8.1 *Site Investigations*

Before project implementation, MM recommended that a number of site investigations would be required, with the following objectives:

- Clarify the disposition of the Lewisian and Moinian strata;
- Enhance understanding of the number, position, orientation and width of faulted zones;
- Determine the rock mass characterisation over the range of conditions expected;
- Determine groundwater conditions, particularly the permeability of faulted zones which could result in inflows into the tunnel;
- Materials testing should be undertaken to determine the acceptability for reuse.

On the basis of previous studies, MM considered that it would not be necessary to carry out specific investigations into topics such as mining activities or groundwater extraction. However, it was suggested that the investigation should extend to consideration of minerals which in dust form could present a health and safety hazard during tunnelling.

MM considered that there was a need for additional mapping-based investigation activities in advance of any major investigation such as borehole drilling.

It was anticipated that ground investigations would principally comprise rotary borehole drilling, with very little trial pitting being appropriate to locate rockhead in portal areas. For preliminary planning purposes, MM provided a possible ground investigation schedule:

- Cuddies Burn Portal: Downward inclined hole on tunnel axis. Two vertical holes on or near tunnel axis;

- Allt an Fhraigaich Portal. Sub-horizontal or gently downward inclined hole on tunnel axis. One vertical hole on tunnel axis. Possibly also on steeply inclined hole to investigate rock conditions below lineaments;

- Tunnel route. Three or four deep boreholes (of up to 200m) near the tunnel line. One or more of these holes could be inclined to investigate faulting. The upper parts of these holes need not be cored. However, the cored sections should extend both above and below tunnel level to assist in interpretive correlation between holes. Packer tests would be carried out to ascertain permeability. Piezometers would be installed to ascertain groundwater pressures, except in sections of boreholes located close to the tunnel, which should be grouted to prevent them feeding water to the tunnel itself.

Given the complex geological environment, MM stated that it was necessary to optimise the borehole information to assist with interpretation, boreholes should therefore be rigorously geologically logged in addition to normal engineering logging.

In addition to normal mechanical rock testing, MM suggested that consideration should be given to drillability testing relevant to evaluation of drill and blast excavation methods.

MM stated that the Contractor should produce a comprehensive factual report and that a separate interpretive document should also be prepared, discussing geological interpretation, selected design parameters and engineering implications.

MM estimated that the cost for such an investigation would be in the order of £150,000, including consultancy fees associated with the design procurement, site supervision and interpretation of the investigation.

5.6.9 *Environmental Aspects*

Detailed consideration of environmental matter was beyond the scope of the MM report, however they note three points:

- The tunnel would be regarded as having little environmental impact;

- Visual impact amelioration would need to be addressed at the portals. Techniques may include landscaping, stone cladding to concrete, etc;

- The tunnel would not impinge on the SSSI;

- An environmental study would be required to address the negative aspects of the construction stage.

5.6.10 *Conclusion*

MM summarised the principal conclusions as follows:

- A rock tunnel between Cuddies Point and Allt an Fhraigaich would be approximately 1.5km long and fall from a road level of approximately of approximately 21mAOD to 8.5mAOD;

- Rock bolts and sprayed concrete was anticipated to provide a temporary ground support for a drill-and-blast tunnel;

- A concrete lining was proposed for the whole length, together with comprehensive waterproofing and drainage measures;

- Reinforced concrete linings would be used at portal sections and possible within the tunnel at sections of poor ground. Geomorphological mapping suggested that faulting will affect the Allt an Fhraigaich portal area;

- A preliminary sizing exercise with reference to UK and European precedents indicates a need for a tunnel profile of approximately 100m². There may be scope to reduce the size and thus minimise cost;

- Construction may be expected to extend over 2 ½ years;

- The cost of estimate for the “basic” tunnel is £12million. However an overall budget requirement of £18.5million was suggested;

- It was suggested that it may be advantageous to encourage the participation of suitably experienced continental or Scandinavian contractors;

- It was also suggested that consideration should be given to alternative types of contract which would provide a suitable apportionment of risk, with reference to non-UK practice such as Norwegian systems which appear to assist in providing economical tunnel projects.

URS has provided further comment based upon the Mott MacDonald report, and these may be found in section 6 of this report.

5.7 Highland Regional Council Regional Roads Unit, A890 Stromeferry Bypass Road Improvement, Feasibility of Widening the Existing Road Alignment, September 1993

Project Details	
Report Provided By:	THC
Relevant Corridors/Routes:	Online
Brief Description:	Slope stability appraisal for man-made slopes along the existing route. Also provides recommendation for remediation/bypass.

5.7.1 *Introduction*

TRL Scotland (TRL) was commissioned by HRC Road Unit in September 1993 to evaluate the feasibility of widening the existing road (the A890 between Attadale and Ardnarff, locally known as the Stromeferry Bypass) by cutting into the hillside. Additionally, they were tasked with determining stable cutting slope geometrics and to advise on the appropriate excavation methods. This report relates directly to those routes in the ‘Online Corridor’.

The following forms a summary of the report written by TRL.

5.7.2 *Geology and Background*

TRL found that the Stromeferry Bypass was cut into the side of a steep glacial valley, with the strata belonging to the Lewisian and Moine groups of gneiss and schist. It was also noted that the road lay within the Caledonian thrust belt of North West Scotland, with the solid strata being subjected to thrusting as well as more recent shallow faulting. TRL stated that fragmentation blasting techniques were employed during the construction of the Stromeferry Bypass in 1967/1970, resulting in extensive and penetrative damage to the rock mass.

Furthermore that the combination of faulting and blasting has led to instability in the cutting since their construction.

5.7.3 *Field Work*

Discontinuity mapping was undertaken by TRL between 27 and 30 September 1993, with data being collected from the least stable 1.5km stretch of the route. Data from netted sections of the slope was obtained by visual means only as the netting was found to interfere with the compass used.

5.7.4 *Data Analysis*

The data collected was evaluated by TRL using two computer programmes (namely DIPS and ROCKS). They used a stereographic technique of analysis and allowed discontinuity data to be manipulated and evaluated. Stereo air photos and the geological maps of the site were also studied by TRL and used to establish regional structural trends and geomorphological features.

5.7.5 *Results and Rock Slope Design*

TRL found that the data collected from the site indicated that at least three structural domains were present. Domain 1 was located east of the avalanche shelter; Domain 2 the area of hillside above and immediately west of the avalanche shelter; and Domain 3 covered all of the rock slopes west of Domain 2 to the western limit of the study area.

TRL assessed each of these domains separately, as follows.

5.7.5.1 *Domain 1*

TRL found that the strata comprised Lewisian gneisses and showed segregation into light and dark coloured bands. The banding was parallel to the main rock fabric and showed little evidence of discordant veining or melt segregation. There appeared to be a thrust fault parallel to the main gneissosity, outcropping above road level near the western end of the netted area, rising slowly across the netted area where it appeared to "climb" or was faulted to a higher level.

TRL's analysis found three defined discontinuity sets, two bedding joint sets with the third being discontinuities parallel to foliation/gneissosity. TRL concluded that the most critical to the stability of the proposed cuttings were "set 1" joints; which were regular, planar, persistent, steeply dipping and closely parallel to the proposed road azimuth along much of domain 1.

TRL proposed that new rock cuttings be formed with a dip at 70° and be formed in two lifts with a 4m berm between the lifts. It was suggested that the berm location be dictated by available burden on the slope profile. TRL also recommended that where overburden exceeded 8m, the lower lift be extended to this point and presplit blasting be used and smooth blasting be used in excavating the top lift. It was noted that where the road azimuth swung from 315° to 325°, the final face may be left with a 'saw-tooth' appearance and that local treatment may be necessary to prevent toppling. TRL also recommended that a 4m wide by 1.5m deep rock trap be formed at the base of the main slope and a small catch fence/crash barrier be erected on the road verge.

TRL predicted that forming the cuts parallel to the dominant joint set would result in a face requiring no general remedial treatment and very little maintenance.

5.7.5.2 *Domain 2*

TRL recorded both gneiss and Moine schists in this domain, with the two rock types appearing to be juxtaposed by faulting. Numerous gullies observed were formed along the lines of these faults. Difficult terrain and time constraints prevented TRL from performing a full evaluation of Domain 2 and few discontinuity measurements were taken. However the data that was recovered indicated a pattern that appeared to be a hybrid of the other two domains complicated by joints parallel to numerous faults.

It was noted that the geotechnical properties of gully talus slopes, overburden and faulted rock mass indicated that any excavation in this domain would be likely to be met with considerable problems. TRL therefor recommended that the avalanche shelter be lift in place and, if the road were widened, another lane be added to it. It was also recommended that a very detailed study of both surface and subsurface rock structure and overburden/talus slopes be undertaken to inform the design of western approach excavations. TRL considered that some form of reinforced rock/soil or structural portals may be required.

The data collected for Domain 2 and field observations indicated to TRL that rock excavations were likely to be prone to large scale wedge failure. Additionally, they noted that the talus filling the gully immediately uphill of the avalanche shelter appeared to be the remnants of a slope failure that occurred during construction of the road.

Overall it was found that numerous faults and gullies in Domain 2 had rendered much of the rock mass unstable and susceptible to weathering and erosion. TRL considered it likely that large areas of protective treatment would be required if slopes were excavated.

5.7.5.3 *Domain 3*

The solid strata in this domain were generally formed by schists with local gneiss bands of the Moine series. The schistocity was noted to have been folded into the recumbent, tight, isoclinal folds, the axial plane of which was sub parallel to the regional trend of the Moine Thrust. Numerous faults, apparent as gullies in the rock slopes, were also noted by TRL.

Three principle discontinuity sets were determined by TRL for this domain, sets 1 and 2 were joints and set 3 parallel to the foliation. The joint sets were found to have broadly the same orientation as those in domain 1, but not as well defined. The scatter of set 1 was such that TRL split it into two subsets (namely 1a and 1b). The discontinuities parallel to the foliation showed considerable local variation in orientation, caused by the very tight, recumbent, isoclinal folding present in the Moine schist. Set 1 joints were noted by TRL to be the dominant discontinuities in domain 3 and where the road alignment varied from being sub parallel with set 1 joints, the dominant control became the intersection between set 1 and set 2 joints resulting in a potential for wedge failure. Additionally, there were minor discontinuity sets, 2a and 4, which did not appear to be present throughout the entire domain.

It was recommended by TRL that the rock cuttings be re-formed with a dip of 65° in two lifts with a 4m berm between lifts. As with Domain 1, the height of the berm was recommended to be dictated by the available burden on the proposed slope profile, TRL recommended that the top lift be excavated using smooth blasting and the bottom by presplit blasting techniques. Where very persistent joints were within 15° of the proposed presplit/smooth blast planes, TRL considered it was likely that the final face would partly follow the joints leading to an irregular face profile which may lead to localised stability problems. TRL further recommended that a rock trap, 4m wide by 1.5m deep, be formed at the toe of the slope and a small catch fence/crash barrier be erected on the road verge.

TRL expected a range of stability problems on the proposed cutting slopes due to the adopted slope angle of 65° and the wide range of discontinuity orientations within each set. To eliminate all failure potential, they note that a slope of around 50° would be necessary, but topographic constraints ruled this out and as a result provision for remedial work on the finished slope would be likely.

5.7.6 *Other Design Considerations*

5.7.6.1 *Construction Access Track/Top of Slope Berm*

TRL noted that to form the proposed rock cuttings, access to the steep hillside slopes would have to be provided for drilling plant. This would require an access track approximately 4m wide to be excavated into overburden and rock. However, TRL stress that if an unsupported, undesigned excavation was opened in the superficial deposits and/or surface of the rock, the risk of a large slip occurring would be high.

5.7.6.2 *Stability of the Existing Slopes and Hazard to the Rail Line*

TRL noted that all studies undertaken on the Stromeferry Bypass had one conclusion in common, that the existing slopes are unstable and represent a serious hazard to road users. If an inland bypass option were adopted, the unstable cliffs of the existing route would be avoided along with the difficulties of excavating further into the hillside. However, there would continue to be a hazard to the railway which runs parallel to the existing road. Thus TRL conclude, in the event of a completely new bypass being constructed it would still be necessary to carry out remedial works to protect the railway line.

5.7.6.3 *Construction Logistics*

Widening the Stromeferry Bypass by cutting in the hillside would, TRL state, involve large volumes of rock (estimated to be in excess of 250,000m^3) being excavated by blasting and TRL noted that it would be impractical for the road and railway to remain open during these works. TRL noted that the most likely scenario would be a complete closure of the railway for approximately 6 months, and the road for longer.

5.7.6.4 *Environmental Impact*

TRL stated that the works would have a significant environmental impact on the surrounding area, in particular the cuttings would be clearly visible from the village of Lochcarron on the other side of the loch. Although this impact could be reduced through positioning the berm to allow planting.

5.7.7 *Further Investigations*

TRL gave recommendations for further investigations, these are as follows:

- Field mapping and discontinuity surveys: more detailed and rigorous field mapping to define more accurately the limits of existing domains and identify any subdivisions and also to confirm slope design recommendations;
- Down hole CCTV surveys: inclined holes should be drilled above and on existing rock faces and then surveyed with down hole CCTV equipment. These holes should be located to fill any gaps in the surface discontinuity data, and careful consideration should be given to the orientation of the holes to maximise the data recovered;
- Trial pits/trenches: should be excavated on the upper slopes to establish the depth to and nature of rock head at as many locations as practical. These will also give an indication as to the quality of the overburden.

5.7.8 *Conclusions*

TRL concluded that the widening of the Stromeferry Bypass would be feasible, although not without considerable technical and contractual difficulties having to be addressed.

5.8 Coffey Geotechnics Ltd, Annual Rock Slope Inspection, June 2009

Project Details	
Report Provided By:	THC
Relevant Corridors/Routes:	Online
Brief Description:	Inspection report for existing man-made slopes along the existing bypass route. It should be noted that reference to slopes as "AA" is refereeing to Ardnarff to Attadale. Slope locations may be found in URS Drawing No. 46400079/SI/01, appended to the URS Slope Inspection Report discussed in section 5.11 (included in Appendix F)

5.8.1 *Introduction*

THC appointed Coffey Geotechnics Ltd (Coffey) as their consultants for advice on and inspection of the A890 Stromeferry Bypass rock slopes between Ardnarff and Attadale, following recommendation made by TRL (see section 5.7). The report included the following:

- Review of the monthly inspection reports;
- Ground level inspections of slopes AA1 to AA24;
- Inspection of landslide remedial works adjacent to AA20;
- Inspection of debris flow scar and remedial works between AA5 and AA6;
- Inspection of Frenchman's Burn;
- Inspection of crest above slopes AA5 to AA10 and AA11 to AA22b.

5.8.2 *Annual Rock Slope Inspection (April 2008 to June 2009)*

For the annual inspection, the periodic inspection reports undertaken by THC were reviewed to determine area which should be particularly investigated during the rock slope inspection. The following summary of these reports was provided by Coffey:

Slope	Chainage	THC Comment	Action/Comment
AA1	0023	Minor fall from weathered rock outcrop at slope 1 – could do with scaling – opposite "no parking sign". (8th July 2008).	From mass at crest of slope with tree above. Contained by ditch. Clear out ditch during annual maintenance.
		Additional stones in ditch by "no parking sign". (18th February 2009).	
AA4	0705	Couple of small stones in verge. (18th February 2009).	Block observed below recent deer track on slope above with two dead deer in ditch. Not a significant concern.
AA6	1390	Four stones in ditch from low level on face. (18th February 2009).	General ravelling contained by ditch. Clear out ditch during annual maintenance.

Slope	Chainage	THC Comment	Action/Comment
AA7	1720	Significant quantity of large cobble sized stones and some debris in lined cascade. (12th June 2008)	Left over from Phase IV contract in January 2008. Noticed previously by Coffey. Not a significant concern.
Frenchman's Burn	2200	Small amount of stones in each basin. (13th January 2009).	Clear out during annual maintenance.
AA13	2404	Small length of tree stump caught in bushes at top of slope at uplink end of slope – add to list of works for next contract. (13th January 2009).	Observed from ground level, due to level of vegetation on upper slopes could not be seen during annual inspection. Coffey to inspect when next passing and level of vegetation is reduced.
AA15	2592	Single stone in verge 5m before culvert. (12th June 2008).	Stone has not come from netted rock face.
AA16	2770	2nd tell-tale broken. (8th May 2008).	Replaced in June 2008.
AA17	2838	Chainage – 2883m large block feel onto road on Sunday afternoon (24/08/08) – moved by DLO to passing place at slope AA20. Block 450mm thick, 0.7m in height and split into two lengths 1.3m and 1m. Block fallen from slope above netted area though location not visible. (25th August 2008)	Potential source identified during Phase V works in October 2008 by Coffey.
AA18	2908	Shackle missing. (12th June 2008)	To be replaced when Coffey next in area.
AA19	2990	Chainage 3006m – 2 small stones and one cobble sized contained by mesh. (12th June 2008).	No significant concern.
		Additional Stones behind net at chainage 3012m (18th February 2009)	Minor ravelling to be expected, contained by netting.
AA22b	3386	Rock debris. (16th December 2009)	Appears to be from superficial reprofiling undertaken during Phase IV contract.
AA24	3627	Rock debris on corner 2m from end of net. From deterioration of rock nose with bolts. Rock around 2nd last rock bolt looks quite fractured. Easily contained by net. (16th December 2008).	Requires rope access inspection. 0.25m³ of debris at the toe of the slope. If the fractured material failed it should be contained by the netting.

5.8.3 *Findings of the 2008 – 2009 Annual Rock Slope Inspection*

Coffey initially undertook rock slope inspections from the bases of the slopes to highlight areas of concern. These areas were then inspected from the most appropriate locations.

Coffey summarised the principal recommendations from the annual inspection as follows:

Slope	Recommendations	Action	Timescale
AA1	Remove trees on edge of crest above the rock slope.	THC	**Outstanding** Next Phase (VI) of works.
	Clear out ditch.	THC	Annual Maintenance.
AA2	Clear out ditch.	THC	Annual Maintenance.
AA3	Abandon the tell-tale. The rock slope is performing satisfactorily, whilst the rock trap remains functioning.	None.	None.
AA4	#711 to 751 vegetation requires removal from slope.	THC	Next Phase (VI) of works.
	Clear out ditch.	THC	Annual maintenance.
AA7	Clear culverts.	THC	Annual maintenance.
AA9	#1906 heavy scaled area – keep under observation	THC & Coffey	All inspections
	Clear out ditch	THC	Annual maintenance
AA10	#2053 large partially undercut block on small ridge – keep under observation – annual inspections.	Coffey	Annual inspections
AA14 West	#2543 rock fall (<0.125m³) material lying on top of buttress. Keep under particular observation.	THC & Coffey	All inspections
AA17	#2860, column of fractured rock under existing netting by "Hugh MacKenzy" graffiti – keep under specific observation during periodic and annual inspections.	THC & Coffey	All inspections
AA18	Clear out ditch.	THC	Annual maintenance.
AA20	#3080 "I" beam post – the measurements do not enable monitoring of the whole wall. Hence additional tell tales should be installed.	THC & Coffey	All inspections
	The "I" beams require maintenance to treat existing corrosion and to protect steel work from further corrosion.	THC	**Outstanding** Next Phase (VI) of works.
	Clear culverts	THC	Annual maintenance.
AA22b	#3356, 3372 and 3382 – potential failures keep under particular observation during periodic and annual inspections.	THC & Coffey	All inspections.
AA24	#3672 rope access inspection of rock fall.	Coffey	Next Phase (VI) of works.
AA25, AA26N and AA26S	Slopes not considered a significant hazard. Hence, removed from slope inspection list. Recommend a visual inspection during the annual inspection, with reporting only if significant features observed.	Coffey	Annual inspections (ongoing)

5.8.4 *Additional Features Inspected*

5.8.4.1 *Debris Flow Scar and Remedial Works Between Rock Slopes AA5 and AA6*

Coffey stated that the slope drainage and erosion prevention works appeared to be functioning as designed. The erosion control matting was well vegetated. The top drainage catch pit/debris trap was full with sediment to the height of the pipe and would require clearing within 12months. The pipe extending from the drainage ditch had developed a leak in the uppermost joint in the pipe. The restraining collar below this joint was missing an attachment to the ground anchorage, and required repair. Coffey also recommended that the crest of the debris flow scar be planted with appropriate trees to help further stabilise the area.

5.8.4.2 *Frenchman's Gully*

Coffey found that the lower and upper stilling basins were clear of significant debris and that the Phase V remedial works were performing satisfactorily. They state that it is vital that the stilling basins are kept clear of debris accumulations. The southwest wall of the gully above the upper and lower stilling basin had been subject to erosion which was recommended to be kept under observation during all inspections.

5.8.4.3 *Gully Between Rock Slopes AA19 and AA20*

Coffey noted that the material at the toe of the gully had been replaced since the previous annual inspection, although the eastern face of the gully was subject to scour during periods of heavy rainfall. The hillside above the bank had previously undergone remedial works due to movement. No significant debris dams were observed in the gully.

5.8.4.4 *Landslide Remedial Works Adjacent to Rock Slope AA20*

Concrete beam, cables and temporary catch fence all appeared to Coffey to be functioning satisfactorily. Above erosion control matting a failure of superficial material in to the gully had been noted. It was recommended that the eroded face be kept under observation and monitored for any further signs of erosion.

5.8.4.5 *Natural Features*

Coffey found that the natural crags and trees above the manmade rock slopes AA11 to AA22 were representing a growing hazard to the road and railway, with recent examples noted as follows:

1. The rockfall from a natural crag above and between AA18 and AA19 which occurred on 4 May 2007. The material from which reached the road and railway;
2. On the afternoon of the 24 August 2008, two blocks were found on the road beneath slope AA17. Upon inspection of the upper slopes, the blocks were found to have come from a natural crag, travelled down the upper vegetated slope and over the crest of the netted slope. The initial cause of this rockfall was not identified, but may have been caused by the root action of the trees;
3. During the annual inspection, a block (0.5m x 0.5m x 0.3m) from the upper slopes was observed to have been retained by the netting at the crest of the slope AA18. The block appeared to have been funnelled into a small gulley feature, which the netting spanned across.

Above slopes AA11 to AA22 there were a large number of fallen trees lying across the slope that were starting to act as a slide system for any new fallen tree trunks, sending it down the slope towards the road. This was highlighted by the tree trunk leaning against the rock slope at AA14 east and the tree that landed on the road between slopes AA15 and AA16 during the

Phase V remedial works contract. The trees were therefore identified as presenting a significant hazard to the road and railway. In addition, the root balls of several upturned trees contained blocks of rock which had the potential to become dislodged and roll down the slopes and over the crests of AA11 to AA22.

5.9 Coffey Geotechnics Ltd, Annual Rock Slope Inspection, June 2010

Coffey produced a further rock slope inspection report in 2010, this was summarised by URS in their report titled "Stromeferry Bypass, A890 Slope Inspection Report" produced in September 2012. This summary is included in Section 5.10.4.1.

5.10 Major Failure at A890 Stromeferry Bypass, December 2011

A significant rockfall occurred at Section AA19 on the 22 December 2011. AA19 had been protected by drape mesh which split during a rockfall event, when approximately 100t of material failed. A second failure occurred on the morning of 31 December when approximately 100t of rock fell onto the road. The road was closed indefinitely until the area was stabilised. The stretch of rock cut was covered and anchored using TECCO mesh and the road was reopened to traffic in April 2012.

5.11 URS, Stromeferry Bypass, A890 Slope Inspection Report, September 2012

5.11.1 *Introduction*

URS was appointed by Highland Council in April 2012 to undertake a rope access inspection of the rock faces along the A890 between Attadale and Ardnarff locally known as the Stromeferry Bypass.

The work undertaken included a road level inspection of the site followed by a rope access inspection of specific areas of significance identified during the road level inspection.

The scope of works undertaken by URS was as follows:

- Review and summarise monthly inspection reports undertaken by the Highland Council in 2010 and 2011;
- Review inspection reports carried out by Coffey in 2009 and 2010;
- Undertake a road level inspection of the road cutting and drainage channels along the Stromeferry Bypass;
- Undertake a rope access inspection of features identified during the road level inspection considered to represent a risk to the road;
- Undertake an inspection of existing remedial works along the rock slopes;
- Identification of areas of potential risk and recommendation for remedial works.

5.11.2 *Site Description*

The site considered by URS comprised the slopes above the A890, orientated approximately southwest to northeast for a distance of 3.9km. The road generally varied in level between 5m above Ordnance Datum (AOD) and 12mAOD, but started to climb to 32mAOD in the north-eastern extent.

The majority of the site works undertaken by URS comprised inspection of the rock slopes immediately adjacent to the road; however the remit also included any rock face higher up the hill slope which may have presented a hazard to the road.

The majority of the rock slope was formed by side long cuttings with a single box cutting towards the north-eastern limit. The A890 forms the toe of the rock slope, with a railway line on the far side of the road. An avalanche shelter, which spans the road and railway, was noted to the north-east of the site.

The slopes inspected by URS were noted to comprise two landforms. The first consisting of steep near vertical rock slopes typically between 70° and 85°, which were excavated and reprofiled to allow construction of the road and railway. These were noted to range in height from less than 5m to over 40m in places. The majority of these slopes were poorly vegetated, although some slope did have to be devegetated for inspection purposes. In locations where the slope was offset from the road, vegetation talus slopes were observed at an angle of approximately 30° to 40°. The second landform identified by URS was situated above the rock slopes adjacent to the road and consisted of natural hillside which rose steeply towards the hills Cnoc nam Mult and Aonach Baile na Creige at angles of approximately 35° to 45° to a level approximately 350mAOD. Localised rock exposures were present on the upper slope between approximately 60mAOD and 80mAOD. A number of fallen trees were also noted.

Towards the northeast of the site was designated as a SSSI, designated Attadale and categorised as a feature of structural and metamorphic geology of the Moine, encompassing an area of 6.58ha.

For inspection and reporting purposes URS divided the site into slope sections matching those used by Coffey.

5.11.3 *Site Geology*

Information on the site geology was obtained by URS from the BGS Geoindex digital map database (1:50,000) and from observations on site.

Superficial deposits were found to be thin/non-existent along the majority of the rock slope. Alluvial deposits were recorded near Ardnarff and marine beach deposits, raised beach deposits and glacial till were recorded near Attadale. Localised peat deposits were noted on the hillside to the southeast of the rock slope.

The solid geology beneath the site was generally recorded by URS to comprise psammitic rock belonging to the Morar Group. Towards the north-eastern section of the rock slope, it crossed a relatively thin section of rock recorded as a gneissose pelite of the Basal Pelite Formation (also part of the Morar Group), before the rock type changed to orthogneiss of the Loch Duich Gneisses. Locally, orthoamphibolite was recorded within the Loch Duich Gneisses.

No major faults were recorded to cross the site, but some small normal faults were indicated in the area.

5.11.4 *Summary of Previous Inspection*

5.11.4.1 *Annual Rock Slope Inspection Report 2010, Coffey Geotechnics*

Annual rock slope inspections have been undertaken by Coffey Geotechnics. The table below summarises the principal recommendations made following the annual inspection undertaken in June 2010. Slopes where no issues were reported by URS have been omitted from the table.

Slope	Recommendations	Action	Timescale	Action completed at the time of July 2012 inspection	2012 URS Action
AA1	#0023 to #0178 Remove vegetation and light scale slope.	THC	Next Phase (VI) of works	Devegetation - Yes Scaling - No	Light scaling
	Remove trees on edge of crest above the rock slope.	THC	**Outstanding** Next Phase (VI) of works	Yes	No Action
	Clear out ditch	THC	Annual maintenance	Yes	No Action
AA2	Clear out ditch	THC	Annual maintenance	Yes	No Action
AA3	Abandon the tell-tale. The slope is performing satisfactorily, whilst the rock trap remains functioning.	None	None	No Action	No Action
AA4	#0705 to 0751 Remove vegetation and light scale slope.	THC	Next Phase (VI) of works	Devegetation - Yes Scaling - No	Light scaling
	#0712 Install dentition to base of undercut column.	THC	Next Phase (VI) of works	No	Dowelling of individual overhanging blocks
	Clear out ditch	THC	Annual maintenance	Yes	No Action

Slope	Recommendations	Action	Timescale	Action completed at the time of July 2012 inspection	2012 URS Action
AA6	#1420 Large fallen pine tree at crest of slope requires removal.	THC	Next Phase (VI) of works	URS unable to determine if this tree has been removed	No Action
AA7	Clear culverts	THC	Annual maintenance	Not inspected by URS	
AA9	#1906 Heavy scaled area – keep under observation.	THC & Coffey	All inspections	Area Inspected by URS	Keep under observation in future inspections
	Clear out ditch	THC	Annual maintenance	Yes	No Action
AA10	#2053 Large partially undercut block on small ridge – keep under observation – annual inspections.	Coffey	All inspections	Area Inspected by URS	Within extent of proposed catch fence
AA13	#2404 to 2491 Remove vegetation from rock slope at crest area.	THC	Next Phase (VI) of works	Yes	No Action
AA14 West	#2500 to 2539 Remove vegetation from upper slope.	THC	Next Phase (VI) of works	Yes	No Action
	#2543 Rock fall (<0.125m³) material lying on top of buttress. Keep under particular observation during periodic inspections.	THC & Coffey	All inspections	Area Inspected by URS	Clearance of failed material from behind netting
	Rope access inspection of area above buttress.	Coffey	Next Phase (VI) of works	Yes	No Action

Slope	Recommendations	Action	Timescale	Action completed at the time of July 2012 inspection	2012 URS Action
AA15	#2592 to 2760 Remove vegetation from rock slope and crest area.	THC	Next Phase (VI) of works	Yes	No Action
AA17	#2860 Column of fractured rock under existing netting by "Hughie MacKenzy" graffiti – keep under specific observation during periodic and annual inspections.	THC & Coffey	All inspections	Area Inspected by URS	Clearance of failed material from behind netting
AA18	Clear out ditch	THC	Annual maintenance	Yes	No Action
AA20	#3080 "I" beam post – the measurements do not enable monitoring of the whole wall. Hence, additional tell tales and inclinometer should be installed.	THC & Coffey	Next Phase (VI) of works	No	Removal of accumulated debris from behind rockfall barrier
	The "I" beams require maintenance to treat existing corrosion and to protect steel work from further corrosion.	THC	**Outstanding** Next Phase (VI) of works		
AA21	#3271 Removal block next to buttress	THC	Next Phase (VI) of works	No	Light scaling
AA22b	#3356, 3372 and 3382 Potential failures keep under particular observation during periodic inspections.	THC & Coffey	All inspections	Area Inspected by URS	Heavy scaling of nose, installation of additional reinforcing cables and repair to areas of damaged netting
	#3356, 3372 and 3382 Noses should be heavy scaled/removed under supervision of geotechnical engineer/engineering geologist.	THC & Coffey	Next Phase (VI) of works	No	
AA24	#3672 rope access inspection of area of rock fall.	Coffey	Next Phase (VI) of works	Area Inspected by URS	Repair vertical joins between netting panels where these were observed to have come apart during the inspection.

5.11.4.2 *Monthly Inspections*

A review of monthly inspections carried out by The Highland Council between 2nd February 2010 and 9th December 2011 was undertaken by URS.

The following table provides details of the inspections; however slopes where no issues were reported were omitted:

Slope	Chainage	Highland Council Observations
AA1	0023m	**16/03/2010:-** Small scale fall from 1m below crest into ditch. 3 loose rocks visible but will also likely be contained by ditch. Slight scaling required.
AA2	0176m	**24/02/2011:-** Both shackles missing on first net.
		15/03/2011:- Small rocks on existing pile near end of second net.
		09/12/2011:- Approximately 40T of superficial material was cleared from road. Culvert under road was blocked but cleared.
AA4	0705m	**02/02/2010:-** Small boulder in ditch from rock outcrop near toe of slope about midway along slope.
AA6	1390m	**15/04/2010:-** Very small fall – 3 stones into ditch from low level.
		10/12/10:- Small stones on road.
AA7	1720m	**10/12/10:-** Small stones on road.
		24/02/2011:- Possible loose block.
		09/12/11:- Culvert at end of pitched cascade (290199, 936993) blocked with gravel – water overflow and debris on road. Water diverted to adjacent culvert prior to reopening road.
AA8	1810m	**26/04/2010:-** Rock debris fall to west of gully at start of slope 8. Cleared by DLO. Needs to be investigated at annual inspection.
		10/12/10:- Small stones on road.
AA9	1873m	From 1906m, heavily scaled area – keep under observation (reported on all inspection sheets).
		09/12/2011:- Culvert at 290397, 937090 partially blocked with branches – water overflow and debris on road. Outlet clear but inlet to culvert under railway blocked. Branches removed prior to reopening road, location marked and Network Rail personnel on site advised of problem with culvert under railway.
French man's Burn (Allt na Fhrang	2200m	**02/02/2010 – 26/05/2010:-** Top basin approximately 1/3 full but lower basin still fairly clear.
		30/06/2010 – 10/12/2010:- Top basin fairly clear, lower basin clear.
		20/01/2011 – 20/05/2011:- Top basin nearly ½ full, lower basin less than 1/3 full.

Slope	Chainage	Highland Council Observations
aich)		**22/06/2011 – 02/12/2011:-** Top basin clear, lower basin clear.
		09/12/2011:- Burn had overflown on to road but rock traps effective. Burn under bridge clear. Top basin full, lower basin full.
AA11	2285m	**09/12/11:-** Some small stones on road but no sign of problem.
AA14	2500m	At 2543m material on top of buttress – keep under observation.
AA15	2592m	**26/05/2010:-** Approx. 0.6 x 0.4 x 0.1m thick block of material from uplink side of nose, 3m up, 5m from start of slope. More loose to follow but all has been and will be contained by netting.
AA16	2770m	**16/03/2010:-** Large block in rock trap.
		10/12/10:- Single slab (0.5 x 0.4 x 0.2m) contained by netting.
AA17	2838m	At 2860m column of fractured rock under netting by 'Hughie' graffiti – keep under observation.
AA18	2908m	**29/07/2010:-** Rock fall, contained by netting. Ch. 2292m (adjacent to culvert). 1 large triangular slab 0.2m thick by approx. 1m long and 4 smaller irregular blocks ranging from cobble to 0.3 x 0.3 x 0.3m boulder. Appears to have come from crest of slope.
		01/11/11:- Shackle at start of toe rope replaced.
Natural Crag above AA18 & AA19	Not given	**26/05/2010:-** New stones in pit at head of pipe. Mostly small but 3 are approx. 0.25 x 0.2 x 0.15m. Probably brought down gully by 2 dead tree branches. No sign of anything related to crag.
		10/12/10:- Large stone (0.6 x 0.4 x 0.3m) with other smaller stones on road cleared by DLO. Source unknown but appears to be from upper slopes.
		20/05/2011:- Small block (0.3 x 0.3 x 0.3m) from 4m up – contained by netting at Ch. 2880m. Further similar block above loose but will not lead to more extensive problem due to change in planes above.
AA19	2990m	**20/01/2011:-** Small pile of friable rock contained by netting at Ch. 3006m.

Slope	Chainage	Highland Council Observations
		02/12/2011:- 1m^3 of very friable rock at existing pile at Ch. 3010m.
Stream Gully between AA19 & AA20	3072m	**03/10/2011:-** One large block 0.3 x 0.4 x 0.6 & several small cobble sized stones fell from crest 7m high downlink of gully – falling into passing place.
		09/12/11:- Significant quantity of rock washed down gully. Overflowed with mud and gravel washed on to road but large blocks contained by rock trap. Rock fall from end of concrete beam. Has slipped under three restraint wires and exposed part and exposed part of rock bolt securing end of netting used to stabilise face. This needs further investigation.
AA20	3072m	Additional tell tales required to wall and monitor erosion of superficial materials within gully.
		02/02/2010:- Top tell-tale = -7.0, -2.0V. No change.
		16/03/2010 – 20/01/2011:- Top tell-tale = -8.0, -2.0V.
		24/02/2011 – 19/04/2011:- Top tell-tale = -9.0, -2.0V.
		20/05/2011:- Top tell-tale = -9.5, -3.0V. Continued movement.
		22/06/2011:- Top tell-tale = -10.0, -3.0V. Continued movement.
AA21	3188m	**16/03/2010:-** Cobbles contained by netting at Ch. 3227m and 3255m.
		26/08/2011:- Single block – 0.5 x 0.5 x 0.3m contained by netting. Source is from edge / underside of an overhang block which is bolted. Located to left of block restrained by rope. Ch. 3261m.
		02/12/2011:- Very large cobbles and one small plate shaped boulder at Ch. 3248m adjacent to previous.
		09/12/2011:- No new stones at location of recent minor falls. Small stones thrown directly on to road by force of water in stream which usually runs down rock face.
AA22B	3328m	3356m, 3372m & 3382m potential failures – keep under observation.
		02/02/2010:- Approximately 1m^3 rock fall contained within netting and barrier. Location is 6th post from west end of barrier.

Slope	Chainage	Highland Council Observations
		15/04/2010:- 3m^3 rock fall contained by netting and barrier adjacent to fall reported in February 2010. Fall centred 5m further along slope.
		10/12/10:- Active erosion of overburden from un-netted slopes between AA22 and AA23.
AA24	3627m	**02/02/2010:-** Accident damage to east end of netting. Netting pulled west along slope about 2m. Slight damage to netting. Main bottom restraint wire needs retightened. Original old wire broken and securing bolt pulled out.

URS found that the majority of the slope sections under inspection had indicated some form of instability, the majority of which were noted to be small scale. Additionally, at some points problems with the netting were identified.

5.11.5 *2012 Annual Inspection*

A road level inspection was carried out by URS between 13 and 18 May 2012 and involved a general site walkover and allowed the identification of potential failures and any other features of significance, e.g. possible pathways for falling material. A rope access inspection was carried out concurrently with the road level inspection between 14 and 18 May 2012, with an additional visit undertaken between 20 and 21 June to inspect the upper rock slopes.

Where existing rockfall netting had been installed, URS carried out inspections in order to obtain descriptions of its condition. This was carried out from both road and by rope access to obtain information on the condition of the top cable and top anchor points.

URS utilised Dips (Ref 12) a stereonet program for the analysis and presentation of structural data. Using the joint data recorded during the site inspections the potential for the presence of potential planar, wedge or toppling failures was assessed for each rock slope in turn.

The analysis was also used to identify plane failures similar to those associated with the large rock fall of December 2011.

5.11.6 *Risk Assessment*

A bespoke risk assessment was developed by URS for the rock slopes. The assessment considered the size of potential rockfall (hazard), the potential pathway for a fallen block to reach the carriageway, and the available sighting distance on the carriageway (the receptor). The ratings of hazard, pathway and receptor were multiplied to determine the level of risk for each of the rock faces.

URS found that nine slope were of a risk level of high and very high, namely, AA7, AA8, AA12, AA14West, AA15Upper, AA17 and AA22B.

5.11.7 *Recommendations*

Of the thirty-three slopes inspected, URS recommended that remedial works be undertaken on five of the rock slopes within a year, namely AA14West, AA15Upper, AA16-17Upper, AA19Upper and AA22B. These are detailed as follows:

Slope	Developing Hazards Observed	Recommended Remedial Works / Actions	Volume/area /length	Unit
AA14 West	Toppling Planar	Install new top anchors and top cable	20	No.
		Clear failed material from behind netting	25	m^3
AA15 Upper	Block fall Toppling	Controlled removal of block using pyrotechnic breaking capsules	4	m^3

[12] www.rocscience.com

Slope	Developing Hazards Observed	Recommended Remedial Works / Actions	Volume/area /length	Unit
AA16-17 Upper	Block fall Toppling Sliding	Controlled removal of blocks	10	m^3
AA19 Upper	Block fall Planar Ravelling Root jacking	Light scale face	3650	m^2
		Remove $2m^3$ tree stump currently retained by cable straps	2	m^3
		Remove fallen/ cut logs from ledge between AA19 and AA19 Upper	NA	Sum
AA22B	Toppling	Heavy scaling of nose at Ch. 3425	12	m^3
		Install additional cable reinforcement	2500	m^2
		Repair damaged netting	NA	Sum

These remedial works were scheduled to be included in the “Phase 7” remedial works due for implementation in May 2013. In addition to recommended remedial works, URS also provided recommendations for ongoing management actions by THC, as follows:

- Continued monthly inspections to identify the following:
  - Significant accumulations of failed debris within the netting;
  - Any damage to existing installations;
  - The size and location of any rockfalls.
- Ongoing annual inspections by a suitably qualified Engineering Geologist, with road level and targeted road access inspections;
- Five yearly detailed inspections by a suitable qualified Engineering Geologist using roped access to inspect all rock faces;
- The following other considerations were identified during the annual inspection:
  - Fallen trees on upper slopes;
  - Gully between AA5 & AA6;
  - Frenchman’s Burn;
  - Culverts.

Full copies of all the above reports are included in electronic format in Appendix F.

6. GEOTECHNICAL CONSIDERATIONS

6.1 Tunnelling

6.1.1 *Introduction*

This section outlines the main geotechnical considerations for selection and further development of the two route options comprising a tunnelling option. It forms an extract of information contained within a technical note, produced by URS' tunnelling section.

In compiling this information, consideration was given to the following codes and regulations:

- Design Manual for Roads and Bridges, BD78/99 – Design of Road Tunnels;
- Directive 2004/54/EC of the European Parliament and of the Council of 29 April 2004 on Minimum Safety Requirements in the Trans-European Road Network;
- Statutory Instruments, 2007 No 1520, Highways, Tunnels, the Road Tunnel Safety Regulations;
- The British Tunnelling Society, the Association of British Insurers, the Joint Code of Practice for Risk Management of Tunnel Works in the UK.

6.1.2 *Online Route 3*

6.1.2.1 *Alignment*

This option would require approximately 1.6km of tunnel between Cuddies Point and Ardnarff, and would run from the current alignment arching away from the shoreline to maintain rock cover to the tunnel. Cover to the tunnel will be in the order of 150m, with the road level varying from 8mAOD in the west to 24mAOD in the east.

6.1.2.2 *Geotechnical Conditions*

Based on the MM report discussed in Section 5.6, the ground conditions at the tunnel location are anticipated to primarily consist of gneiss and schist, and although the majority of the alignment is likely to be constructed in competent rock there will be areas of faulting and fractured rock mass.

6.1.2.3 *Design and Construction Considerations*

It is envisaged that the tunnel would be a "horseshoe" profile and that a structural invert would not be required unless the rock mass was heavily weathered and fragmented, in particular at the portals where it is likely that the rock mass quality would be lower.

Additional rock cuttings would be required at the tunnel portals to access sections of rock with sufficient cover of competent rock to allow tunnelling to commence. It is considered likely that excavation by drill and blast tunnelling methods will be the most economic. The use of a tunnel boring machine (TBM), though technically possible, would be unlikely to be economic given the short length of the tunnel and the high set up costs associated with TBM construction.

Based on a drill and blast methodology, rock support would be installed as required as the tunnel advances, including rock bolts, sprayed concrete and steel mesh or fibre reinforcement depending on rock mass quality. Installation of a permanent structural lining would follow, including the installation of a suitable drainage layer behind the permanent lining. Permanent lining could take the form of either in-situ cast or sprayed concrete.

It is envisaged that tunnelling would be carried out from both portals concurrently, without intermediate construction shafts given the high rock cover.

It is assumed that the tunnel will be designed as a drained tunnel, as is typical for such tunnels in rock. Given the gradient of the tunnel, it is likely that seepage water can be gravity fed to a suitable outlet at the lower portal.

6.1.2.4 *Ground Investigation*

Should this option be taken forward, a comprehensive ground investigation will be required. This should include a number of inclined cored rotary boreholes be undertaken to intercept the faults and attempt to establish fault widths and orientations. These boreholes could be drilled using a combination of rotary open-hole and rotary core to allow cores to be obtained from targeted areas, and thus reduce the cost. It is anticipated that the ground investigation could be undertaken from the existing road and from the rock face utilising rope access methods, dependent upon the confirmed tunnel alignments.

6.1.3 *North Shore Route 2b*

6.1.3.1 *Alignment*

Constraints imposed by the topography and approach roads lead to an indicative alignment with sharp bends in the tunnel and approaches, further development of the route may therefore consider a lengthening of the tunnel to provide a straighter passage beneath Strome Narrows.

6.1.3.2 *Geotechnical Conditions*

The route is likely to be underlain by solid strata comprising schist, gneiss and amphibolites underlying glacial deposits. At the time of writing it was not possible to differentiate the limits and lateral extent of these deposits, and further investigation will be required.

6.1.3.3 *Design and Construction Considerations*

Given that the tunnel is to be constructed beneath Loch Carron, there is potential for groundwater inflow although this may be stemmed by improved rock mass quality and the overlying impermeable glacial material. However, the potential for water inflow would still remain and infiltration water would be required to be pumped out of the tunnel at its lowest point, creating an ongoing operation cost. It is also likely that the tunnel would be constructed with a structural invert and undrained lining to prevent significant water inflow into the completed tunnel.

As with Online Route 3, it is considered that drill and blast tunnelling would offer the most efficient construction method in the anticipated ground conditions. Consideration to the groundwater flow would need to be given to prevent and delay in the construction process, and the site investigation would have to be designed to identify areas of faulted/fragmented rock that would make water inflow more likely. In this instance, mitigation measures such as grouting would be required. Additionally, probing will be necessary during construction to identify areas of high potential inflow ahead of the face to allow grouting to be carried out as the tunnel progresses.

6.1.3.4 *Ground Investigation*

Should this option be taken forward, a comprehensive ground investigation will be required. This should include inclined boreholes be undertaken at the crossing locations to confirm the loch bed geology, intercept the faults and attempt to establish fault widths and orientation. These boreholes could be drilled using a combination of rotary open hole and rotary core drilling to allow ‘spot coring’ at targeted areas to reduce drilling costs. Overwater drilling may also be appropriate dependent upon the prevailing weather conditions at the time of the investigation.

Shallow intrusive holes will also be required to establish the thickness and lateral extent of the glacial materials. It is anticipated that these holes would be undertaken using a combination of cable percussive, window sampling and machine excavated trial pits.

6.1.4 *Rock Cuts*

6.1.4.1 *On-line routes*

Regardless of the option chosen, some form of remediation will have to be undertaken on the rock slopes at the existing Stromeferry Bypass. It is likely that these works would comprise a reprofiling of the existing slopes, formed by taking cuts out of the original rock face, and/or upgrading existing protection measures (mesh, rock anchors).

TRL produced recommendations for reprofiling of the slopes in their report, discussed in Section 5.7, which are considered appropriate. TRL proposed that the majority of new rock cuttings be formed with a dip at 65° to 70° and be formed in two lifts with a 4m berm between the lifts. It was suggested that the berm location be dictated by available burden on the slope profile. Where very persistent joints were within 15° of the proposed presplit/smooth blast planes, TRL considered it was likely that the final face would partly follow the joints leading to an irregular face profile which may lead to localised stability problems. TRL also recommended that where overburden exceeded 8m, the lower lift be extended to this point and presplit blasting be used and smooth blasting be used in excavating the top lift. It was noted that where the road azimuth swung from 315° to 325°, the final face may be left with a ‘saw-tooth’ appearance and that local treatment may be necessary to prevent toppling. TRL also recommended that a 4m wide by 1.5m deep rock trap be formed at the base of the main slope and a small catch fence/crash barrier be erected on the road verge. TRL predicted that forming the cuts parallel to the dominant joint set would result in a face requiring no general remedial treatment and very little maintenance.

Within the area of the avalanche shelter, much of the rock mass was unstable and susceptible to weathering and erosion. TRL considered it likely that large areas of protective treatment would be required if slopes were excavated. These would likely comprise a combination of approaches such as meshing and anchoring.

Additionally, TRL noted that to form the proposed rock cuttings, access to the steep hillside slopes would have to be provided for drilling plant. This would require an access track approximately 4m wide to be excavated into overburden and rock.

6.1.4.2 *Off-line routes*

New route alignments should be designed to minimise the extent of new rock cuts where possible, however it is likely that new off-line routes will require new cut slopes to accommodate vertical and lateral alignments. Detailed assessment, similar to that previously adopted by TRL in during the assessment of widening the existing A890, will be required to permit appropriate design to utilise the existing discontinuities to the most stable orientation of cut face and minimise instability and the requirement for additional support measures and ongoing stability.

The opportunity to design visually sympathetic rock slopes, such as irregular berms and ledge planting should also be explored.

7. GEOTECHNICAL CONCLUSIONS AND RECOMMENDATIONS

7.1 Potential Constraints

7.1.1 *Outer North Corridor*

The outer north corridor consists of a single route option, namely ON3, which involves the upgrade of the A890 between Achmore and Craeg Mhaol; the construction of a bridge crossing at Strome Narrows; the construction of a new road from the proposed bridge to the A896; and the upgrade of the A896 to Strathcarron Junction. It is considered that the key geotechnical constraints to the construction of this route will be as follows:

- The topography of the area, particularly for the proposed new road and the approaches to the proposed bridge;
- Although only thin deposits have been noted, there may be peat in the area which will require to be identified and remediated as necessary;
- The thickness and permeability of the superficial deposits forming the bed of Loch Carron;
- As superficial deposits are likely to be thin across much of the route, the suitability of rock as a founding strata for both the proposed roads and bridge will have to be determined;
- As it is likely that some degree of earthworks would have to be undertaken as part of the construction for the route, the excavatability of the rock will have to be determined;
- The suitability of the rock for reuse as a construction material;
- The suitability of rock as a founding material for the proposed bridge;
- The condition of rock for water infiltration.

Additionally, some micrositing of the road alignment may be required in the vicinity of the existing quarry noted or/near the route.

7.1.2 *North Shore Corridor*

Five alternate route options have been proposed within the north shore corridor, namely N2, N6, N7 and N8. All of the routes involve the upgrade of an existing road along the north shore of Loch Carron and then the A896 to Strathcarron Junction. Where the routes differ is in their approach to Loch Carron, and the method of crossing the loch.

The geotechnical constraints to these routes will broadly agree with those discussed in the section 6.1.1. Where the routes cross Loch Carron out with the Strome Narrows (N6, N7 and N8) the depth to the bed of the loch may prove to be problematic, particularly in the amount of material which would be required to construct a tidal barrage, as proposed in option N8. Where a tunnel option is adopted, the nature and condition of the superficial deposits and bedrock would be key to the development.

7.1.3 *Online Corridor*

Several online options have been considered, including an upgrade of the route with an extended avalanche shelter or by securing the rock face; a diversion of the road onto a viaduct or embankment on Loch Carron; a tunnel bypassing the worst effected sections of slope; a "do minimum" option; and the widening of the road through a shared railway option.

Key to the majority of these options is the stability of the existing manmade and natural slopes adjacent to the route, which have demonstrably been shown to require remediation.

Investigations would be required to determine the most suitable method of remediation for the slope. Any remedial measure should also take cognisance of the SSSI located at the existing avalanche shelter.

Where a viaduct/embankment has been proposed, the key issue will be the depth to the loch bed, which, as previously discussed, may be a significant depth.

The tunnel option was discussed in some detail by MM in their report (see section 5.6) and by URS in Section 6.1. URS broadly agree with their conclusions in that the quality of the underlying solid strata will have to be determined along with the suitability of the rock for reuse.

7.1.4 *South Corridor*

Three bypass options are under consideration in the southern corridor, all of which connect the southern A890 to the northern A890, thus bypassing the manmade slopes entirely. Similar to route ON3, the geotechnical constraints for all of the options are likely to be the topography across the routes, the possibility of peat underlying the selected routes, the excavatability of the rock where “cut” will be required, and the suitability of the excavated material for reuse.

7.2 Recommended Ground Investigation Works

Regardless of the option chosen for development specific Phase 2 Ground Investigation works are considered necessary to obtain additional information to assess the potential constraints identified above. These investigations may consist of, but are not limited to, the following:

- Undertake services search;
- Limited machine excavated trial pits;
- Rotary cored boreholes;
- Standard sampling;
- Installation of groundwater monitoring wells and monitoring;
- Monitoring visits;
- Survey all exploratory positions;
- Geotechnical Laboratory Testing;
- Factual Report.

Due to the changeable nature of the solid strata in the area, it is recommended that a robust investigation be undertaken to, as accurately as possible; determine the nature of the rock.

Should a tunnelling option be adopted, it may also be prudent to include an allowance for a down hole geophysical investigation and for probing to accurately pin-point any areas of fracturing.

APPENDIX A SITE LOCATION PLAN, URS DRAWING NO. 47065084/4001

Plot Date : 25/04/2013 15:10:34
File Name : C:USERSHENRY MAINSDESKTOPSTROMEFERRY47065084 - 4001 REV 0 - SITE LOC PLAN

N

SITE LOCATION

Drawing Title	Scale @ A4 NTS		
THE HIGHLAND COUNCIL Stromeferry Options Appraisal Site Location Plan	Drawn HM	Checked AP	Approved PLM
	Date 25.04.13		Rev 0
	Drawing Number 47065084 - 4001		

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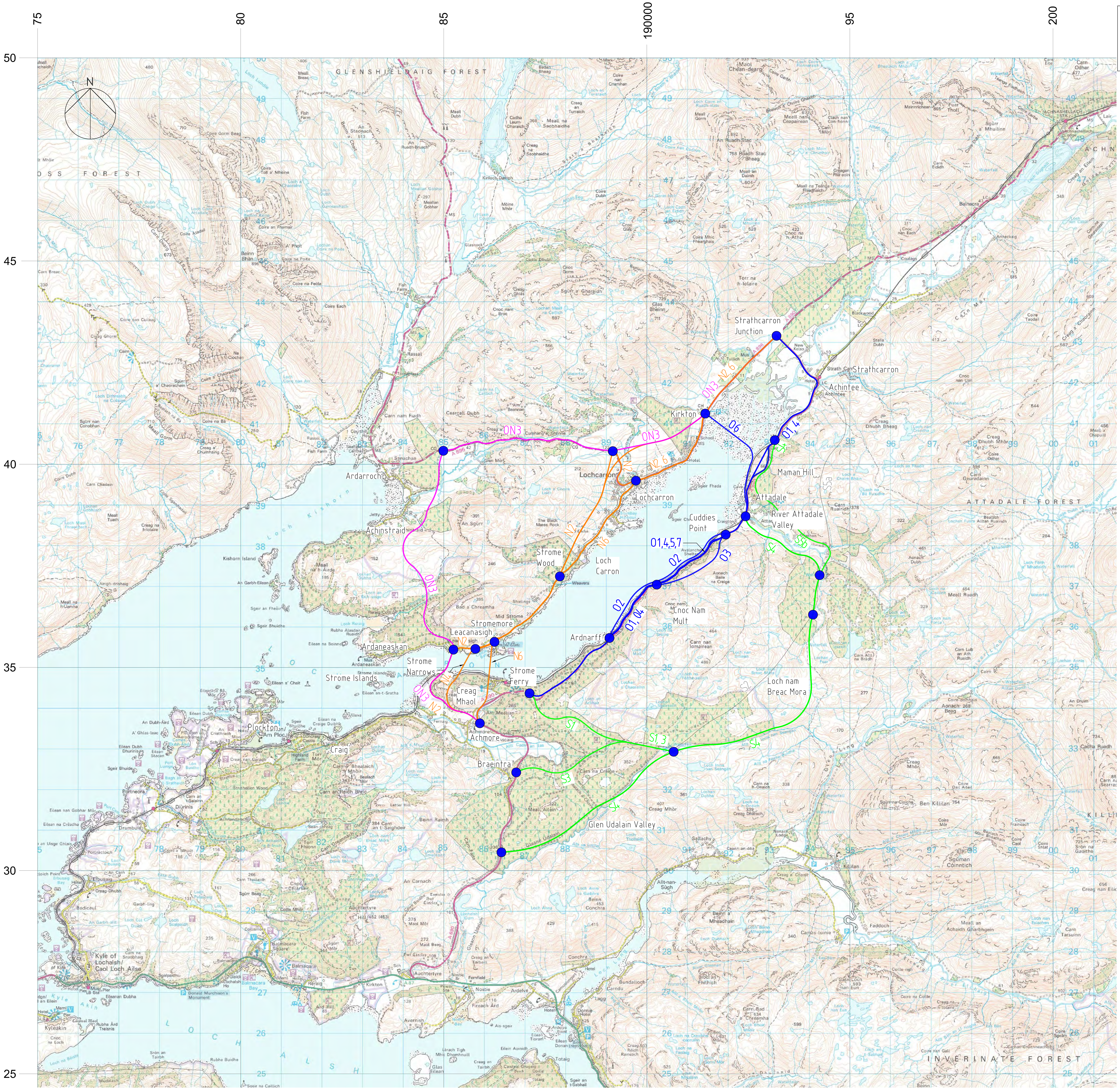
APPENDIX B PRELIMINARY ROUTE OPTIONS PLAN, URS DRAWING NO. 47065084-609



Strome Narrow Crossings	
Former	Report Reference
ON3 / N2	Western Crossing (Bridge & Tunnel)
N4	Central Crossing (Bridge)
N6	Eastern Crossing (High & Low Level Bridge & Barrage).

On-line Routes	
01	"Do minimum plus", On-line improvements to 7.3m carriageway.
02	2 to 4Km causeway / cantilever section to bypass worst affected rockfall area.
03	Approx 2Km tunnel sections to bypass worst affected rockfall area.
04	"Do minimum" existing route maintained as is (Baseline case).
05	Joint road / rail solution on shared track; 2Km section to bypass worst affected rockfall area.
06	Alternative link route Attadale to Kirkton including upper Loch crossing.
07	Approx 2Km section of extended avalanche shelter in worst affected area.

CONSTRUCTION RISKS	MAINTENANCE / CLEANING RISK	DEMOLITION RISKS

In addition to the hazard/risks normally associated with the types of work detailed on this drawing take note of above.
It is assumed that all works on this drawing will be carried out by a competent contractor working, where appropriate, to an appropriate method statement.

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION BOX

Key:

- Outer North Corridor Route Option Prefix ON
- North Shore Corridor Route Option Prefix N
- Online Corridor Route Option Prefix 0
- Southern Corridor Route Option Prefix S
- Discounted Routes
- Route Junction Points

Notes:
Preliminary Route Options following STAG Pre-Appraisal sifting.
Refer to Route Option Summary.
Retains original Route Option numbering convention adopted on drawing 47065084-602a

This drawing is for preliminary purposes only and is subject to amendment during design development. UNDER NO CIRCUMSTANCES MUST THIS DRAWING BE USED FOR CONSTRUCTION PURPOSES

Revision Details	By / Check	Date	Suffix
Updated route following team meeting 25/2/13 and 2nd SIFT	JH / ACM	26.2.13	A

Purpose of issue
DRAFT

Client
The Highland Council
Comhairle na Gàidhealtachd

Project Title
Stromeferry Options Appraisal

Drawing Title
Stage 1 Assessment
Route Options Plan
Sifted Route Options

Drawn	Checked	Approved	Date
DH	JI		JAN 2013

URS Internal Project No.	Suitability
47065084	-
Scale @ A1	**Zone / Mileage**
1:5000	-

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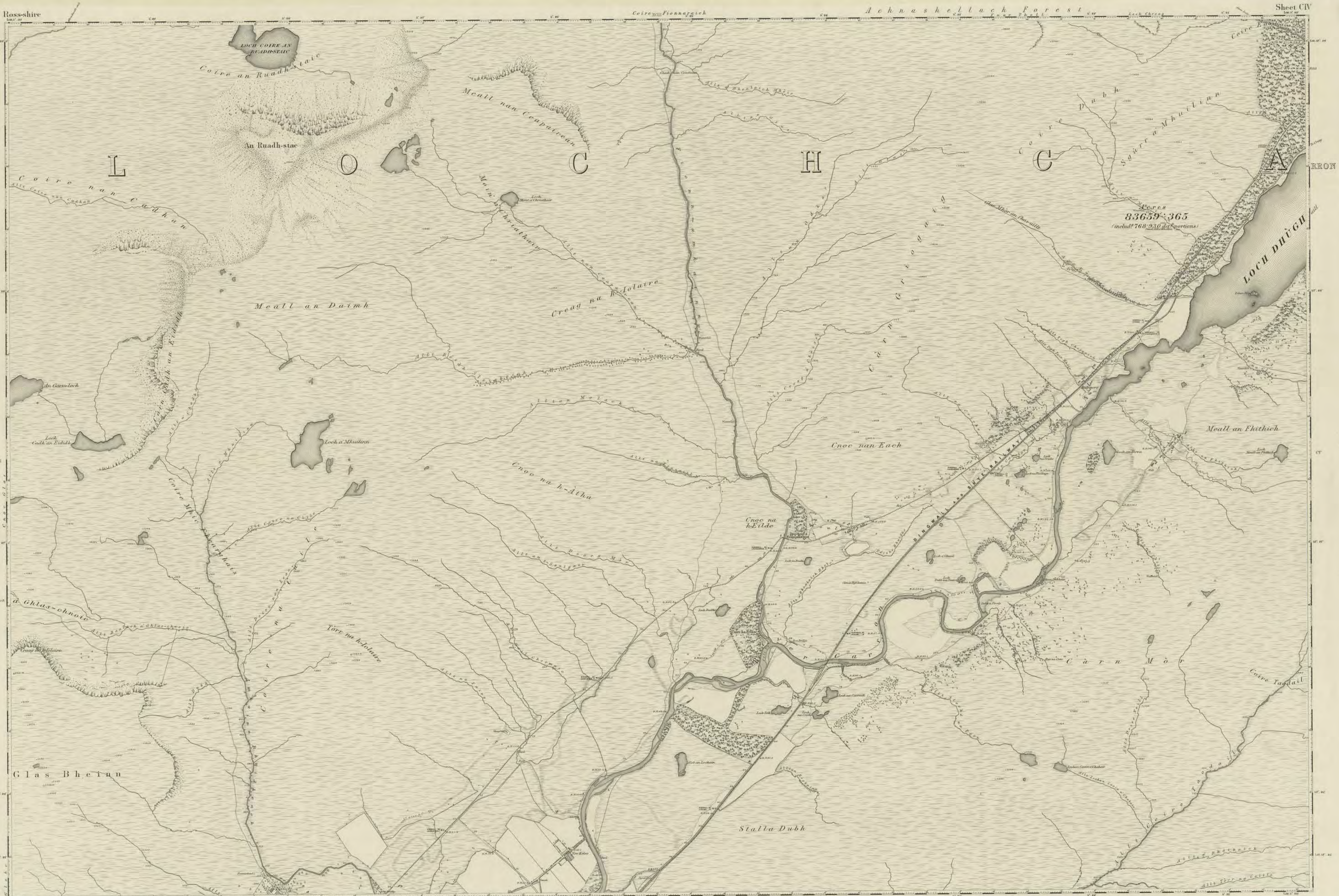
6 Ardross Street
Inverness
IV3 5NN
0141 354 6050
www.urscorp.eu

Drawing Number: 47065084 - 609
Rev: A

APPENDIX C HISTORICAL MAPS



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Ross-shire
Sheet CX
Applecross Forest
Beinn Bhàn
Wester Ross
CIII
CIX
CXI
CXVII
LOCHCARRON
89·030 Acres
N. Lochcarron Parish (detd. No. 3) 46·310 Acres
LOCHCARRON
(Detached No. 4)
Acres
491·960
Càrn nam Fiadh
Cnoc Dubh
Am Beannan
Sìthean Uaine
An Sgòrr
Blàr nan Clachan Mòra
Meall na h-Airde
Bad a' Chreamha
Lochan Dubha
Loch an Eich-uisge
Cnoc Mòr
Loch a' Choire Lèith
Loch nan Cailleach
Kishorn Island
Ard-darroch
Achintraid
Camus Dubh
Camusterrach
SLUMBAY
Cuag a' Ghlinne
LOCH KISHORN
LOCH CARRON
Carron
Loch Carron
Amach Pàirc Dhùghaill
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Ross-shire

Sheet CXI

CXVIII

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Ross-shire

Sheet CXVII

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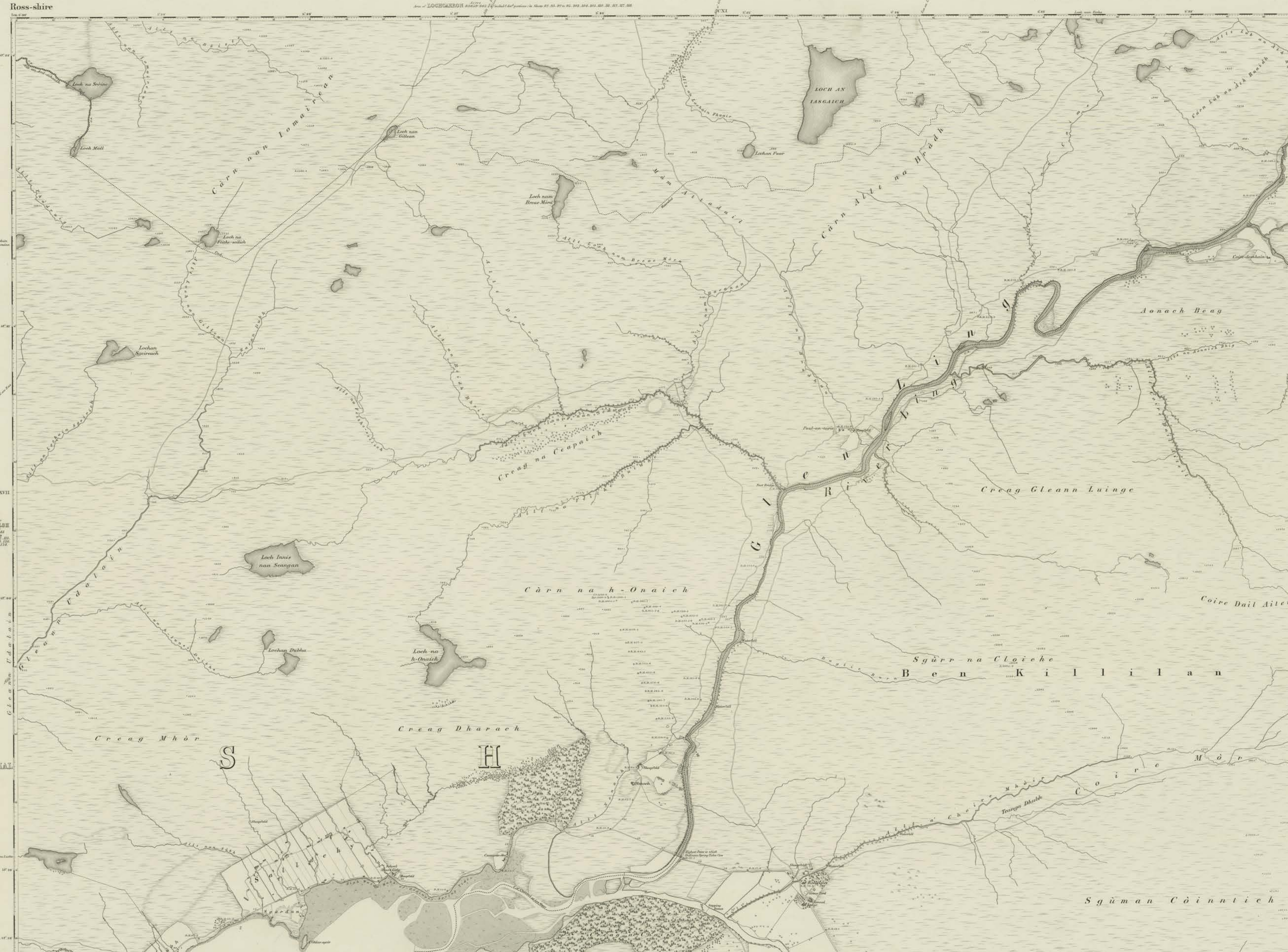
Scale: Six Inches to One Statute Mile or 880 Feet to One Inch.



Ross-shire
Sheet CXVIII
CXI
Loch na Sròine
Loch Moil
Loch nan Gillean
LOCH AN IASGAICH
Lochan Fuar
Loch nam Breac Mòra
Càrn nan Iomairean
Càrn Allt na Bradh
Creag a'
Lochan Sgeireach
Loch na Fiacha-aolaich
Aonach Beag
Glen Ling
River Ling
Creag na Ceapaich
Creag Gleann Luinge
CXVII
CXIX
Loch Innis nan Seangan
Càrn na h-Onaich
Coire Dail Aiteil
Lochan Dubha
Loch na h-Onaich
Sgùrr na Cloiche
Ben Killilan
Creag Mhòr
Creag Dharach
S
H
LOCHAL
Bealach Mhòr Bhenthain
Coire Mòr
Sgùman Còinntich
Killilan
Loch Long
CXXIV
Glen Elchaig
Price, Two Shillings and Sixpence.
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CXXVII

Price... Two Shillings and Sixpence.

Area of GLENSHIEL Acres 53521·055 in Sheets 123, 127 to 130, 131, 132, 133, 134, 135.

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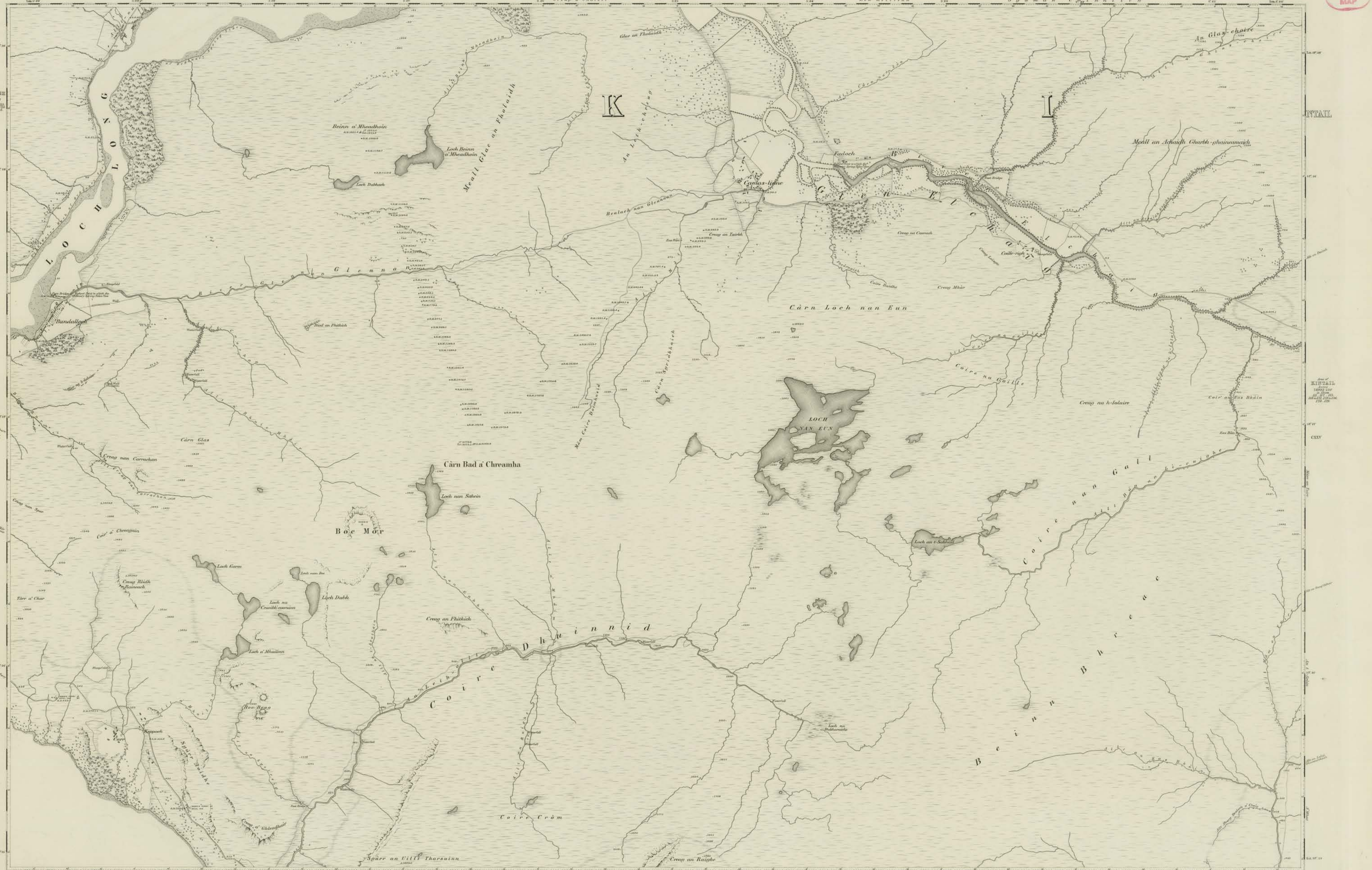
Outline engraved by E. Cottingham, the Writing by P.M. Andrew, the Ornament by S. Bell.



Scale : Six Inches to One Statute Mile or 880 Feet to One Inch – 1/10560

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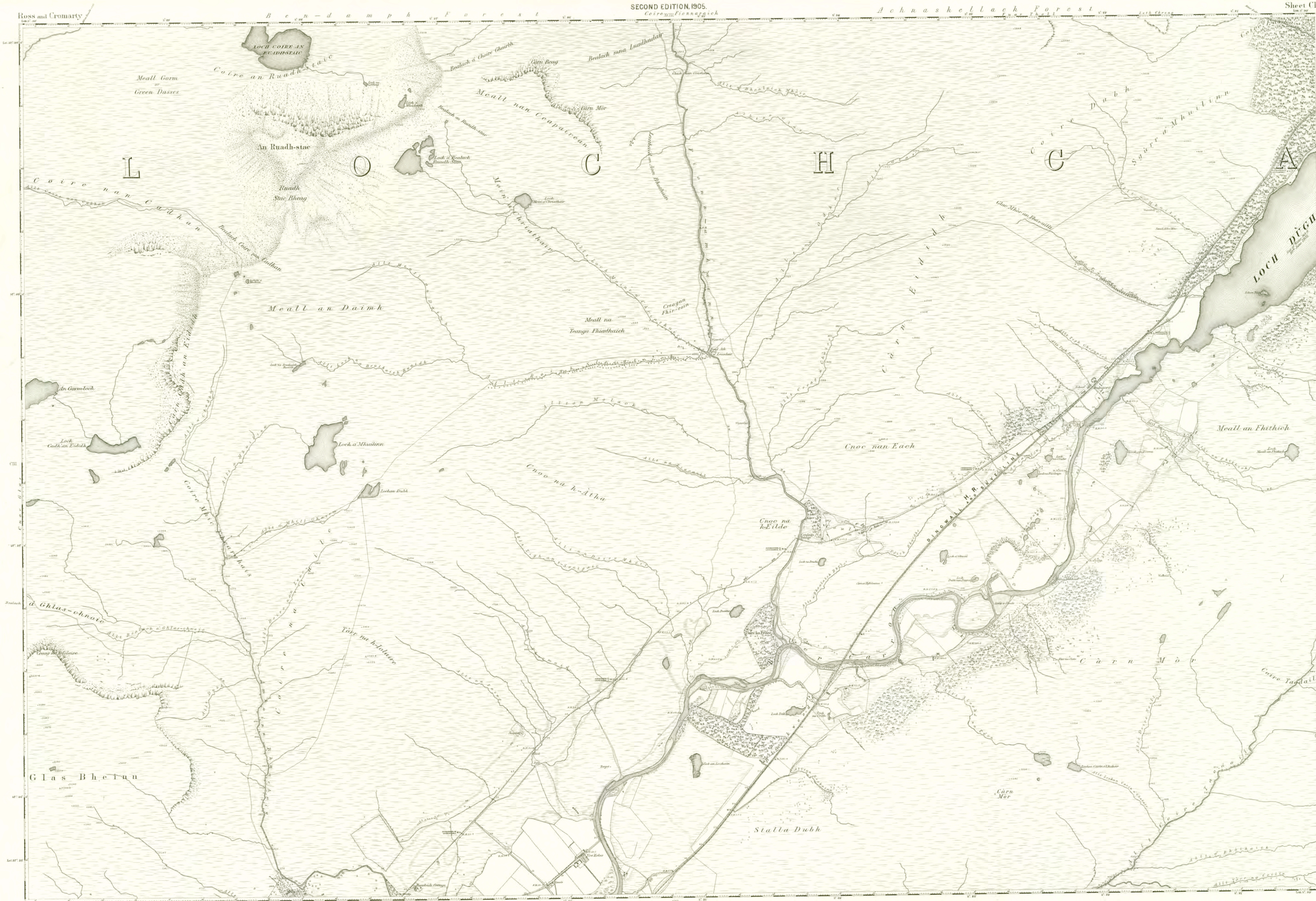
Scale . Six Inches to One Statute Mile or 880 Feet to One Inch – 1/10560



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The Altitudes are given in Feet above the Approximate Mean Water at Liverpool, and those indicated thus (B.M. 54·7) refer to Marks made on Buildings, Walls, &c.
Revised in 1902 Revision Published in 1905.


LOCHCARRON
CX
LOCH CARRON
LOCH REIRAIG
Aonach Pàirc Dhùghaill
Reraig
Meall an t-Sròm
Ardaneaskan
Plockton
Stromeferry
Am Meallan
Creag Mhaol
Craig an Duilisg
Torr Mor
Creagdarroch Wood
Strathellen Wood
LOCH LUNDIE
LOCH ACHAIDH NA H-INICH
Auchmadaroch
LOCH NA LEITIRE
Loch nam Gillean
Càrn a' Bhealaich Mhòir
Càrn an Beidh-bhric
Letter Hill
Beinn Raimh
Càrn Fada
Meall Ailein
Càrn na Creige
Bealach a' Chàise
Bealach Coir Aitean
Gleann Udalain
Loch na Smeòraich
Lochan Dubha
Loch an Arbhair
Càrn a' Chaoruinn
Ardnarff
Fernaig
Achmore
L O C H A L S H
CXVI
CXVIII
CXXIII
Beinn Conchra


Attadale Forest
Loch an Iasaich
Loch nan Gilean
Loch na Brae Móire
Càrn nan Iomairean
Càrn Allt na Bradh
Creag a'
Aonach Beag
Loch Innis nan Seangan
Càrn na h-Onaich
Lochan Dubha
Loch na h-Onaich
Creag Mhòr
Creag Dharach
Creag Mhòr
Coire Dail Aiteil
Sgùrr na Cloiche
Ben Killilan
Coire Mòr
Bealach Mhòr Bheathain
Sgùman Còinntich
Loch Thollaidh
Killilan
Loch Long
Glen Elchaig
Glen Ling
River Ling
Creag Capach
Lochan Sgeireach
Loch Mall
Loch na Sròine
S
H
CXVII
CXIX
CXXIV
KINTAIL
LOCHALSH
LOCHCARRON


Beinn Conchra
Loch Anna
Sgùrr Beag
Auchtertyre Hill
Maol Mòr
Kirkton Hill
Sgùrr Mòr
Maol Beag
BALMACARA BAY
Kirkton
Auchtertyre
Ard Hill
Avernish
Avernish Wood
Fireach Ard
Nostie
Nostie Bay
Ardelve
Eilean Tioram
Glas Eilean
LOCH ALSH
Coille na Tòtaig
Ardintoul Point
ARDINTOUL BAY
Ardintoul
Rudha na Caillich
Kyle Rhea
Loch Long
Loch Duich
Dornie
KINTAIL
GLENSHIEL
LOCHALSH


LOCHALSH
CXVIII
Creag a' Chaisil
Killilan Forest
Sgùman Coinntich
Ault-nan-sugh
LOCH LONG
Beinn a' Mheadhoin
Loch Beinn a' Mheadhoin
Loch Dubhach
Meall Glac a' Tolliadh
K
I
An Glas-choire
Meall an Araidh Gharbhgein
KINTAIL
Camus-luinie
Faddoch
Glen Elchaig
Creag na Cuineach
Càrn Loch nan Eun
Bealach a' Ghleannain
Gleann a Bhuinn Ghrannaig
Bundalloch
Bad an Fhithich
Càrn Glas
Creag nan Carrachan
Càrn Bad a' Chreamha
Loch Bhuic Mhòir
Bac Mòr
LOCH NAN EUN
Coire na Cuille
Creag na h-Iolaire
Coire nan Gall
Loch na Craoibh-caorainn
Loch nan Faoileag
Loch Gorm Mòr
Loch na Cuiche
Creag Riabhach
Loch a' Mhuilinn
Creag an Fhithich
Coire Dhuinnid
Loch na t-Seilich
Beinn Bhreac
Bac Beag
Wester Keppoch
Easter Keppoch
Carr
Coire Cràm
Sgùrr an Uillt Tharsuinn
Creag an Ruighe
Loch Duich
CXXIII
CXXV
CXXVIII

ORDNANCE SURVEY OF SCOTLAND

RAASAY & APPLECROSS

POPULAR EDITION ONE-INCH MAP (WITH NATIONAL GRID)

SHEET 25

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Scale - One Inch to One Statute Mile - $\frac{1}{63360}$

Scale of Miles

Scale of Yards

Scale of Kilometres

The Altitudes and Contours are given in Feet above Ordnance Survey Datum (Mean Sea Level.)

Contours surveyed on the ground. 50, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1250, 1500, 1750, 2000, 2250, 2500, 2750.

Other Contours interpolated and only approximately correct.

The Submarine Contours are given in Fathoms, and are taken from the Soundings of Admiralty Surveys.

THE NATIONAL GRID

To refer to a particular point:- (1) Read for each half of the reference the double figures printed in large type in the margins, which denote tens of Kilometres and Kilometres (2) Then, to obtain reading to nearest 100 metres, estimate position of point in tenths from the grid lines, which are 1000 metres apart.

THUS TO GIVE A NORMAL NATIONAL GRID REFERENCE ON THIS SHEET

EXAMPLE		Salacher	
East Take west edge of square in which point lies and read the large figures printed opposite this line on north or south margins Estimate tenths Eastwords	68 7 687	North Take south edge of square in which point lies and read the large figures printed opposite this line on east or west margins Estimate tenths Northwards	51 0 510
Reference		687510	

Similar references occur at intervals of 100 Kilometres i.e.:- in each of the figured squares in the diagram. The figure indicating the square should be added where necessary: thus as the point is in square 18 it may be referred to as 18/687510

The figures in the squares form part of the grid reference and have no relation to the sheet number of this series.

Numbers of the adjoining Sheets and incidence of 100Km grid squares

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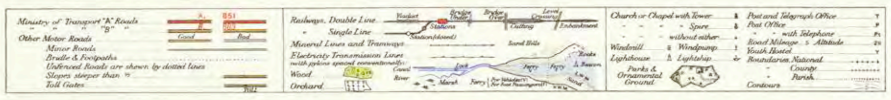
ORDNANCE SURVEY OF SCOTLAND

SOUND OF SLEAT

POPULAR EDITION ONE-INCH MAP (WITH NATIONAL GRID)

SHEET 35



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Scale of Miles

Scale of Yards

Scale of Kilometres

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Contours surveyed on the ground, 50,100,200,300,400,500,600,700,800,900,1000,1250,1500,1750,2000,2250,2500,2750,3000,3250.

Other Contours interpolated and only approximately correct.

The Submarine Contours are given in Fathoms, and are taken from the Soundings of Admiralty Surveys

The Loch Bed Contours are given in Feet and are taken from the Bathymetrical Survey of the Fresh Water Lochs of Scotland.

THE NATIONAL GRID

TO GIVE A GRID REFERENCE CORRECT TO 100 METRES

EXAMPLE *Armadale Castle*			
See diagram on right for Grid Letters. They are NG			
East: *Take west edge of kilometre square in which point lies and read the large figures printed opposite this line on north or south margins. Estimate tenths Eastwards*	64 / 0 / 640	North: *Take south edge of kilometre square in which point lies and read the large figures printed opposite this line on east or west margins. Estimate tenths Northwards*	04 / 6 / 046
Full 100 Metre Reference NG 640046			

The above Full Reference is unique. For many purposes the first grid letter can be omitted, giving a reference, G640046 which recurs at intervals of 500 Kilometres. If both grid letters are omitted, the resulting reference 640046 recurs at intervals of 100 Kilometres. When the area concerned is sufficiently restricted, as will usually be the case with maps on scales of one inch to the mile and larger, both the grid letters are normally omitted.

The incidence of grid letters and numbers on this sheet

NG (18)

NM (17)

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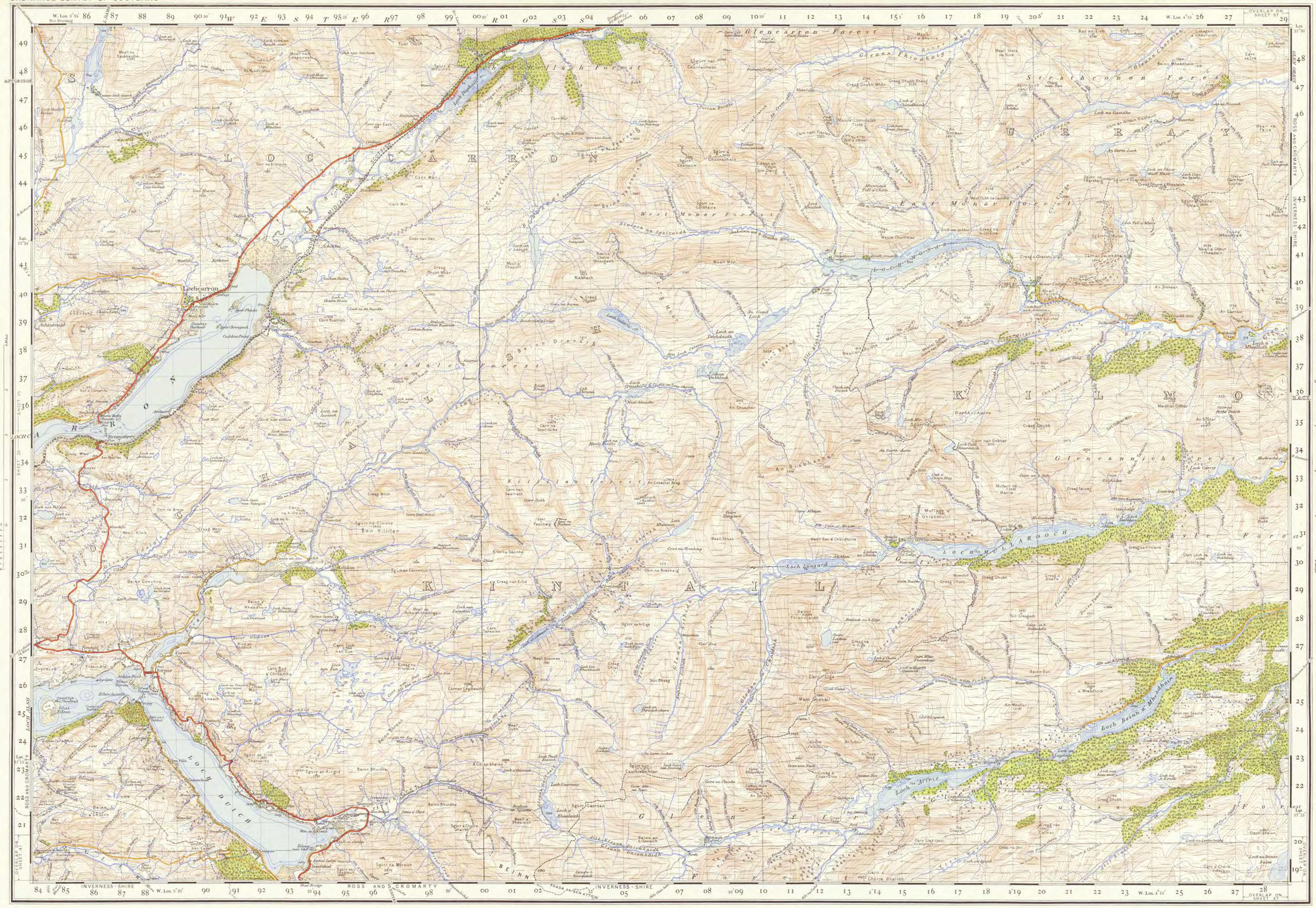
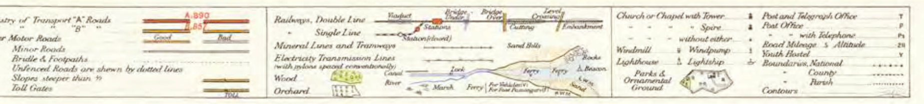
ORDNANCE SURVEY OF SCOTLAND

LOCHCARRON & DORNIE

POPULAR EDITION ONE-INCH MAP (WITH NATIONAL GRID)

SHEET 36





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Scale of Kilometres

The Altitudes and Contours are given in Feet above Ordnance Survey Datum (Mean Sea Level).

Contours surveyed on the ground 50, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1250, 1500, 1750, 2000, 2250, 2500, 2750, 3000, 3250, 3500, 3750

Other Contours interpolated and only approximately correct.

The Submarine Contours are given in Fathoms, and are taken from the Soundings of Admiralty Surveys.

The Loch Bed Contours are given in Feet, and are taken from the Bathymetrical Survey of the Fresh Water Lochs of Scotland.

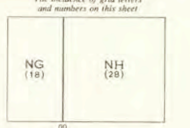
THE NATIONAL GRID

TO GIVE A GRID REFERENCE CORRECT TO 100 METRES

EXAMPLE	Stromeferry (RAILWAY STA.)		
See diagram on right for Grid Letters. They are NG			
East: Take west edge of kilometre square in which point lies and read the large figures printed opposite this line on north or south margins. Estimate tenths Eastwards	86 5 865	North: Take south edge of kilometre square in which point lies and read the large figures printed opposite this line on east or west margins. Estimate tenths Northwards	34 6 346
Full 100 Metre Reference NG 865346			

The above Full Reference is unique. For many purposes the first grid letter can be omitted, giving a reference, G 865346 which recurs at intervals of 500 Kilometres. If both grid letters are omitted, the resulting reference 865346 recurs at intervals of 100 Kilometres. When the area concerned is sufficiently restricted, as will usually be the case with maps on scales of one inch to the mile and larger, both the grid letters are normally omitted.

The incidence of grid letters and numbers on this sheet



Index to adjoining Sheets

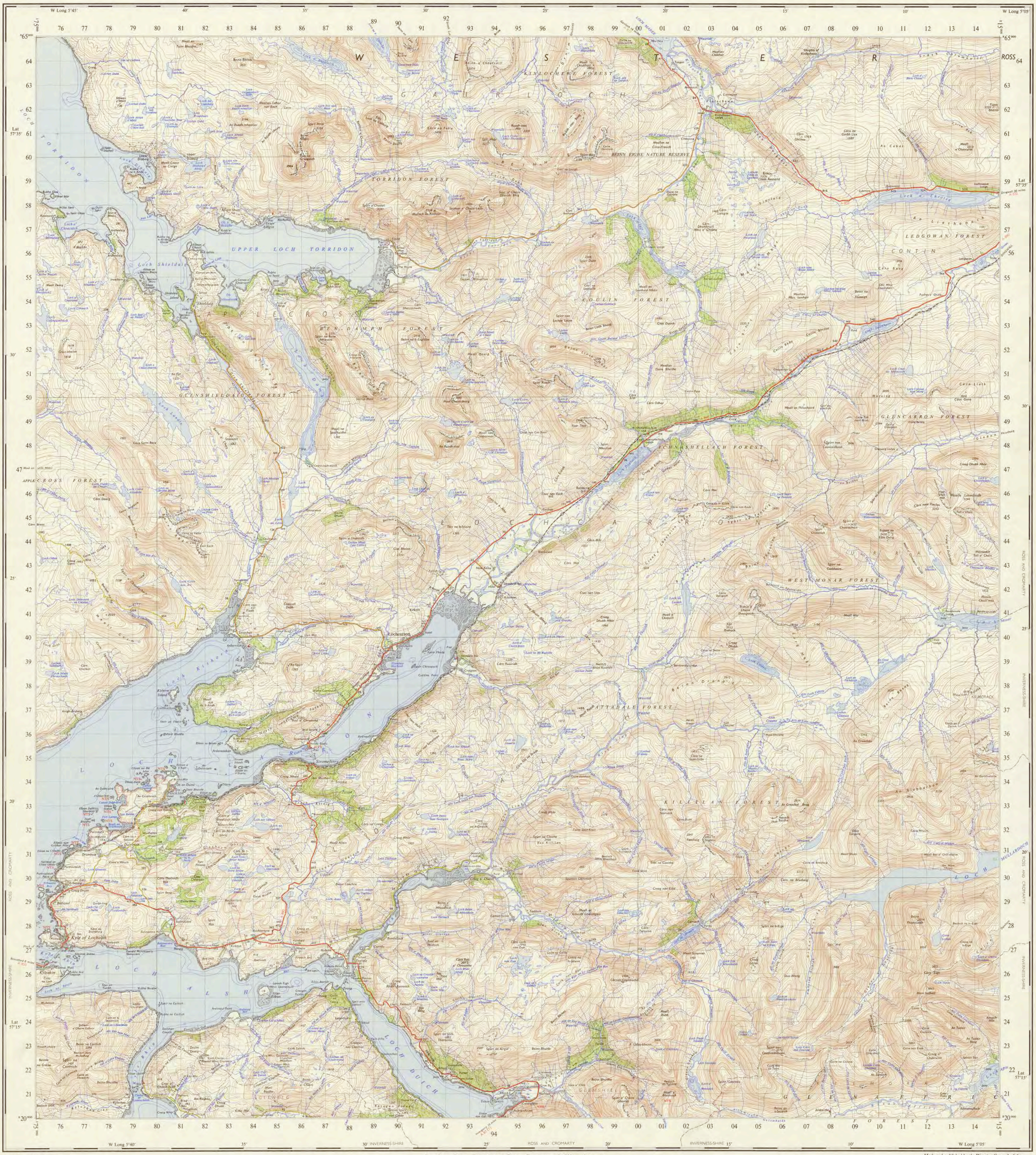
First published by the Director General at the ORDNANCE SURVEY OFFICE, CHESSINGTON, 1947. Revision Full 1927 with later Corrections.

PRICE :— Paper, flat 3/-, folded 4/-. Mounted & folded 6/6. Outline Edition (flat & unmounted) 3/-. All prices are net.

ORDNANCE SURVEY of GREAT BRITAIN
One Inch to One Mile Map (Seventh Series)

LOCHCARRON

SHEET 26



REVISION DIAGRAM

Fully Revised 1955

Index to adjoining Sheets. Hatching denotes overlaps

Difference from Grid North

(1) True North	
3° 11′ E	N W Corner
2° 37′ E	N E ,,
3° 08′ E	S W ,,
2° 35′ E	S E ,,

(2) Mag North about 9° W in 1961 decreasing by about ½° in four years

Magnetic North / Grid North / True North

Contours in Lochs are given in feet and are taken from the Bathymetrical Survey of Fresh Water Lochs of Scotland

The Submarine Contours are given in Fathoms and are taken from the Soundings of Admiralty Surveys

PRICE:- 3/6 net.

This map is also available in Folded or Mounted and Folded styles.

Scale: One Inch to One Statute Mile - 1/63360

TO GIVE A GRID REFERENCE CORRECT TO 100 METRES

Made and published by the Director General *of the*
ORDNANCE SURVEY, CHESSINGTON, SURREY, 1957
Reprinted with minor changes 1961
Printed by the Hydrographer of the Navy 1961

The representation on this Map of a Road, Track, or Footpath is no evidence of the existence of a right of way.

SHEET 26

SHEET 26

Superseded.

Lochcarron
Kirkton
Slumbay
Slumbay Harbour
Dalchuirn
Meall Mòr
Sgeir Fhada
Sgeir Chreagach
Cuddies Point
Attadale Ho.
Craigton
River Attadale
Strathan
Strathcarron
Achintee
New Kelso
Tullich
Glas Bheinn
Càrn Mòr
Blackwood
Cnoc nan Uan
Creag Dhubh Bheag
Creag Dhubh Mhòr
Loch nan Creadha
Lochan Dubha
Loch an Fhèoir
Loch a Chàirn Bhàin
Càrn Ruairidh
Lochan Fuara
Meall a' Chapuill
Loch an Laoigh
Creag a' Chaoruinn
Attadale
Forest
Loch an Iasaich
Loch nam Forca
Meall Ruadh
River Ling
Coire domhain
Allt Loch Innis nan Seangan
Loch Innis nan Seangan
Creag Mhòr
Sgùrr na Cloiche
Ben Killilan
Coire Dail Aiteil
Killilan
Sgùman Còinntich
Creag nan Eilid
Sròn na Gaoithe
Càrn na h-Onaich
Nonach Lodge
Ceann-an-oba
Camus-luinie
Faddoch
Carn Loch
Bundalloch
Beinn Conchra
Loch Anna
Conchra
Beinn a' Mheadhoin
Creag Mhòr
Meall Ailein
Gleann Udalain
Strath Ascaig
Braeintra
Am Meallan
Loch an Arbhair
Stromeferry
Strome Castle (Remains of)
Strome Carronach
Bad a' Chreamha
Mid Strome
Ardnarff
Loch Mall
Loch na Sròine
Càrn nan Iomairean
Lochan a' Chaoruinn
Achintraid
An Sgùrr
Northglen
Southglen
Coire Leith
Cearcall Dubh
Loch na Caillich
Sgùrr a' Gharaidh
Lochan Meall an t-Caillich
Torr na h-Iolaire
Auchtertyre
Loch nan Gillean
Loch na Leitire
Meall an Achaidh Charbhgein
Loch nan Ealachan
Càrn Tarsuinn
Reidh Breac
Càrn nan Searrach
Coire Dubh
LONDON MIDLAND
SHEET 25
SHEET 35

LEAT

POPULAR EDITION ONE-INCH MAP (WITH NATIONAL GRID)

SHEET 35

LOCH KISHORN
L O C H C A R R O N
Ardarroch
Achintraid
Courthill
Ardaneaskan
Kishorn Island
An Garbh-eilean
Sgeir an Fheòir
Sgeir Bhuidhe
Eilean na Bàne
Loch Reraig
Strome Islands
Eilean an t-Sratha
Eilean a' Chait
An Dubh-sgeir
Eilean na Bà Mòr
An Dubh-aird
Rudha Mòr
Ob an Duine
Sgeir Bhuidhe
Loch Coire nan Arr
Sgùrr a' Chaorachain
Meall Gorm
Allt a' Chumhaing
Russel Burn
Carn Breac
Meall Loch an Fheòir
Loch an Fheòir
Lochan Sgeirach
Loch Odhar
Loch a' Chaorainn
Loch a' Ghobhainn
Loch Dubh-riabhach
Loch Braigh an Achaidh
Càrn nan Uaighean
Lochan Goblach
Loch Meall Fhrasachaidh
Càrn Chailein
Lochan an t-Sagairt
Loch Airidh Alasdair
Loch Meall nam Fegdan
Lochan Dubha
Meall nan Àrde
Creag Shorm
Pier
Seafield
Sanachan
Northglen
Reraig
Uags
Ullava
Camas Deannal
Plockton
ROSS AND CROMARTY
Lat. 57° 25'
W. Lon. 5° 35'
OVERLAP ON SHEET 36.
OVERLAP ON SHEET 35
Mhaol
Strath Ascaig
L.M.&S.R.
A 896
B 857
45
44
43
41
40
39
38
37
36
35
34
72
73
74
75
76
77
78
79
80
81
82
83
85
45'
40'

LOCH CARRON
Lochcarron
Stromeferry
Loch Kishorn
Kishorn Island
Plockton
Duirinish
Kyle of Lochalsh
Balmacara
Dornie
Killilan
Attadale Forest
Strathcarron
New Kelso
Achintee
Attadale Ho
Craigton
Slumbay Harbour
Sgeir Chreagach
Cuddies Point
Ardaneaskan
Strome Castle
North Strome
South Strome
Strome Islands
Ardarroch
Achintraid
Tornapress
Kirkton
Ardnarff
Ben Killilan
Loch Long
Glas Bheinn
Cnoc nan Uan
Sallachy
Carnach
Auchtertyre
Nostie
Ardelve
Bundalloch
Ard Hill
Avernish
Creag Mhaol
Sgurr Mor
Beinn Conchra
Meall Ailein