Scottish Trunk Road
Network Management Contract

South East Unit

Queensferry Crossing
Automated Barrier Deployment Procedure
Procedure: 209SE

November 2024

TRANSPORT SCOTLAND
CÒMHDHAIL ALBA

BEAR Scotland Limited
South East Unit Central Office, Forth Road Bridge, South Queensferry, EH30 9SF

Registered Office: BEAR House, Inveralmond Road, Perth, PH13TW
Registered in Scotland No.206139

experience that delivers

Document Control

Issue and Revision Record					
No.	**Date**	**Originator**	**Checker**	**Approver**	**Description**
1	26/01/2024	11(2)	11(2)	11(2)	For Issue
2	04/06/2024	11(2)	11(2)	11(2)	Update to Procedure
3	13/11/2024	11(2)			Update to Procedure

Distribution List

Copy Number	Name Organisation Position	E-mail	Electronic (E) Paper (P) Both (E&P)
1	11(2) Transport Scotland Network Manager	11(2)	E
2	11(2) Transport Scotland National Operations Manager - Resilience	11(2)	E
3	To be confirmed Transport Scotland Head of Transport Resilience - Roads	To be confirmed	E
4	11(2) Transport Scotland Network Resilience Manager	11(2)	E
5	11(2) Transport Scotland Network Resilience Manager	11(2)	E
6	11(2) Transport Scotland Network Resilience Manager	11(2)	E
7	11(2) Transport Scotland Chief Bridge Engineer	11(2)	E
8	To be confirmed Transport Scotland Head of Major Bridges and Bridges Asset Management	To be confirmed	E
9	11(2) Transport Scotland Bridges	11(2)	E
10	11(2) Transport Scotland Forth Bridges Unit Manager	11(2)	E
11	11(2) Performance Audit Group Technical & Systems Manager	11(2)	E
12	11(2) Performance Audit Group Structures Advisor	11(2)	E
13	11(2) BEAR Scotland	11(2)	E

	Network Manager		
14	Central Office Network Hub BEAR Scotland Incident Liaison Officer	11(2)	E* & P
15	11(2) BEAR Scotland Unit Bridges Manager	11(2)	E
16	11(2) BEAR Scotland Queensferry Crossing Manager	11(2)	E
17	11(2) BEAR Scotland Forth Road Bridge Manager	11(2)	E
18	11(2) Operations Manager Traffic Scotland	11(2)	E
19	11(2) Business Management and Systems Manager	11(2)	E

*The most up-to-date version of this Automated Barrier Procedure is available electronically to appropriate staff on the BEAR Scotland intranet system.

Contents

1. Introduction

1.1 Automated Barrier Deployment Procedure and Plan Owner

1.1.1 This is the Automated Barrier Deployment Procedure for the M90 Queensferry Crossing (SE-QCABD-Procedure) provided under the Scottish Trunk Road Network Management Contract for the South East Unit, which will operate from 16 August 2020 for the initial Contract Term until to 15 August 2028.

1.1.2 Within this SE-QCABD-Procedure, the term "NMC" is a reference to the above contract.

1.1.3 The person within BEAR Scotland responsible for this plan is:

11(2)
Queensferry Crossing Manager
Mobile: 11(2)

1.1.4 This SE-QCABD-Procedure has been developed to detail how BEAR Scotland will deal with the high-level planning and management arrangements for emergency closures that affect the Queensferry Crossing.

1.2 Scope – Geographical Extent

1.2.1 This SE-QCABD-Procedure covers the following sections of the M90/A90/A9000 Scotstoun to North Queensferry:

- M90 Admiralty Junction to Queensferry Junction
- A90 Queensferry Junction to A90/M90 Interchange at Scotstoun Trunk Road to A90 Barnton local road
- A9000 Echline Junction to Ferrytoll and Admiralty Junctions Trunk Road.
- B800 Scotstoun to A904 Newbridge and to M9 Trunk Road.

1.3 Purpose of Plan

1.3.1 The purpose of this SE-QCABD-Procedure is to set out how BEAR Scotland will implement incident response operations and mitigation activities for an emergency event that occurs on the Queensferry Crossing.

1.4 Updating the SE-QCABD-Procedure

1.4.1 This SE-QCABD-Procedure is a controlled document within BEAR Scotland's Quality Management System.

1.4.2 The SE-QCABD-Procedure will be kept under continuous review and will, at intervals not exceeding twelve months, either updated and reissued, or be the subject of an issued statement declaring that the plan has been reviewed and that no update is required.

1.5 Distribution of the SE-QCABD-Procedure

1.5.1 This SE-QCABD-Procedure will be distributed on first issue and on each re-issue as detailed on Page 3.

2. Weather Forecasting

2.1 Refer to Queensferry Crossing Ice Accretion Procedure: 168SE for determining weather forecasting and potential ice accretion events.

3. CCTV

3.1 CCTV is available to monitor traffic conditions on the M90 Queensferry Crossing.

4. Media and Communications

4.1 The Engagement Manager (EM) shall represent BEAR Scotland in all dealings with the media including television companies, radio stations and the local, regional and national press relating to operations in the event of any restrictions on the Queensferry Crossing.

4.2 The EM shall initiate communications which present the Operating Company and Transport Scotland in a positive manner to the media, customers and stakeholders.

4.3 The EM shall prepare and issue factual media releases for public information, notifying the local, regional and national media as appropriate of any restrictions on the Queensferry Crossing.

4.4 The overhead gantry VMSs shall provide information regarding potential upcoming use of FRB due to an emergency event.

5. Automated Barrier Deployment Phasing

The following deployment and removal phases detail the requirements from each stakeholder as to their operations for each phase of the automated barrier deployment at which agreed warning messages notifying the public about the forthcoming traffic management diversion will be implemented.

As operation of the automated barrier is under an emergency event, and dependent on the resources available to facilitate the operation of the automated barriers, traffic management operations is not specific to one defined operator and as such is defined in the procedure as "*TM Operations"*.

5.1 Ice Accretion Forecasting

5.1.1 Weather forecasting service (Mercury) shall be referred to in determining the severity of the weather front approaching the Forth Bridges. Notification of a SEVERE weather forecast requires stakeholders to prepare for potential diversion over FRB.

5.1.2 Liaise with relevant stakeholders about potential for QC closure and using FRB.

5.1.3 BEAR Scotland operations to pre-set traffic management signage and equipment that displays use of FRB.

5.1.4 For management of ice accretion on Queensferry Crossing see Procedure 168SE.

5.2 Pre-Deployment Phase

5.2.1 Following the decision to close the Queensferry Crossing, the automated barrier procedure shall be implemented, diverting traffic over FRB.

5.2.2 TM Operations, that are onsite on standby, shall deploy 1no. IPV and 1no. van to the hard shoulder below Gantry 90820 and 90070 and wait for traffic to stopped and the red 'X'.

5.2.3 BEAR Scotland Control Room shall advise Traffic Scotland National Control Centre and activate *QFC Barrier Closure – Stage 2* plan to display agreed signage for all approach routes to QC. Police Scotland to advise if police resource is available.

5.2.4 Gantry 90820 (southbound) and 90070 (northbound) to display red "X" over all lanes forcing traffic to stop and these gantries on all approaches. Police Scotland in attendance to ensure vehicles come to a stop. TRISS units (if available) to open board and display message "QC CLOSED WAIT HERE" and block carriageway if police presence is not available.

5.2.5 Gantries approaching 90820 and 90060 to display count down in speed from 70 to 50, 30 and 20 until Gantries 90820 and 90060 are reached.

5.2.6 Following traffic stopped at the gantry, the IPV shall deploy across the carriageway, blocking any traffic from driving towards the automated barriers. The operatives in the IPV shall speak with the public and explain why the traffic is stopped.

5.2.7 Once traffic is stopped below the gantries and Queensferry Junction is closed, TM Operations van located below the gantries to drive the length of the closed road following last vehicle in both directions, ensuring no vehicles remain on the bridge and confirming QC is clear.

5.2.8 TM Operations to close M90/A9000 Ferrytoll on slip southbound, diverting all traffic back towards M90 Admiralty Junction (1C) preventing vehicles waiting too long. Non motorway traffic shall be held within the A9000 slip road as these vehicles are unable to travel on the motorway.

5.2.9 Cones to be place along A9000 NB (PTL) towards Ferrytoll Junction, closing lane 2. Signage to be setup to state "NON-MOTORWAY TRAFFIC ONLY" to allow vehicles not permitted on the motorway to use the PTL including public transport. Motorway traffic attempting to reach Ferrytoll Junction to be diverted to Admiralty Junction then join M90 SB to come off at Ferrytoll off slip SB with the exception of public transport.

5.2.10 Pedestrian crossing located on the north approach to FRB to be switched off and closed to the public. Pedestrians to be diverted to the underpass.

5.2.11 TM Operations to close Queensferry Junction on slips in both directions, diverting traffic along A904 (Builyeon Rd) to Echline Junction and down the Echiline NB on-slip where will be traffic held at the traffic signals until automated barriers are deployed. An operative will be required to manually operate the lights during the pre-deployment phase. Cones to be placed across the bus lane and abnormal load holding area.

5.2.12 South side southbound PTL towards Edinburgh to be segregated from A9000 using cones to prevent vehicles entering the PTL from the A9000. Traffic looking to travel southbound can merge using the on-slip SB from Echiline Junction but will be required to travel the A90 towards Edinburgh.

5.2.13 Existing Lane 2 closure on south side, southbound link road below Echline Junction to be removed prior to the release of traffic.

5.2.14 Lane 1 (auxiliary lane from Edinburgh to Queensferry Junction) northbound to be closed with the taper starting between Gantry 90070 and B800 overbridge.

5.2.15 BEAR Engagement Team and Traffic Scotland National Control Room to provide updates through social media and Forth Bridges website about pending closures and diversions.

5.3 Deployment Phase

5.3.1 TM Operatives and Traffic Scotland Control Room to confirm last vehicle has passed through on both carriageways with TM Operations van following last vehicle, confirming all clear prior to the automated barrier opening and IPV moving from the hard shoulder to block traffic.

5.3.2 Generators are required to power the system during its operation until permanent power supply is installed. These will be located next to the distribution boards that are connected to the control cabinets.

5.3.3 2no. BEAR Operatives are required to deploy the automated barrier system from the VEVA control cabinets at each location. One operative to monitor operation of the system and the other to observe movement and to check for any obstacles and moving vehicles until the automated barriers are in their deployed position, lowered and locked in place for the duration (refer to Operation Manual for operation of automated barrier system) of the diversion. If required, an emergency stop button on top of the automated barrier can be pressed should the system needed to be stopped.

5.3.4 The intelligent road studs (IRS) are located in 3no. areas:

- North of QC where the north link road connects with M90 mainline.
- North of FRB where the north link road connects with the A9000.
- South of QC where the south link road connects with the M90/A90 mainline.

5.3.5 The IRS are required to be switch on following deployment of the automated barriers. The control cabinets for the IRS are located next to the automated barrier control cabinets.

5.3.6 Street lighting located on the link roads to be switched on.

5.3.7 Following deployment of the automated barriers, TM Operations shall drive the diverted route over FRB to ensure the diversion is fit for purpose and not cones/equipment/rubbish is on the road prior to releasing the traffic.

5.4 Release Phase

5.4.1 Following deployment of the barriers, traffic to be released and allowed to drive through the automated barriers. Gantries 90820 (southbound) and 90070 (northbound) to change from red "X" to "30" over the carriageways following the implementation of *QFC Open via FRB – Stage 3* plan.

5.4.2 TM Operations IPV blocking the road will now move allowing traffic to flow. The IPV shall run the route, guiding the traffic through the diversion route. Police vehicles to follow if present.

5.4.3 Traffic held at the traffic signals on the Echline NB on-slip to be released using the manual controls on site.

5.4.4 Gantries on approaches to the barrier (not listed in Section 5.4.1) to show count down on speed to 30mph.

5.4.5 If available, TRISS units to change their message boards to read "FRB OPEN FOLLOW ME" and TRISS vehicles to drive through diversion to lead traffic the travel route.

5.4.6 VMS signage to display message "FRB OPEN TO TRAFFIC".

5.4.7 BEAR Scotland Control Room and Traffic Scotland National Control Centre to monitor traffic travelling through diversion.

5.4.8 BEAR Scotland Operations TRISS units (if available) to remain onsite to monitor diversion and provide assistance should an issue arise with the traffic management.

5.4.9 TM Operatives to monitor traffic joining Echline Junction and undertake checks at Queensferry Junction ensuring no vehicles enter the closed section of the M90.

5.4.10 TM Operations to undertake hourly checks of the TM through the barriers to ensure no issues with the traffic flows.

5.4.11 All gantries on M90 not used (including those on the QC) to show red "X" across all lanes.

5.5 Removal Phase

5.5.1 BEAR Scotland Control Room shall advise Traffic Scotland National Control Centre and activate *QFC Barrier Closure – Stage 2* plan to display agreed signage for all approach routes to QC. Police Scotland to advise if police resource is available.

5.5.2 VMS on gantries 90820 and 90070 to display message "FRB CLOSED WAIT HERE"

5.5.3 Police Scotland (if available) to sit in hard shoulder next to gantries 90820 and 90070 and gantries to change “30” to red “X” across all lanes to stop traffic. BEAR Scotland TRISS (if available) units to display message “FRB CLOSED WAIT HERE.”

5.5.4 TM Operations, that are onsite on standby, shall deploy 1no. IPV and 1no. van to the hard shoulder below Gantries 90820 and 90070 and wait for traffic to stop using the red ‘X’.

5.5.5 Following traffic stopped at the gantry, the IPV shall deploy across the carriageway, blocking any traffic from driving towards the automated barriers. The operatives in the vehicles shall speak with the public and explain why the traffic is stopped when safe to do so.

5.5.6 TM Operations to change the traffic signals to red on the Echline junction NB on-slip preventing further traffic traveling the A9000. Echline on slip SB/Public Transport Link to remain open.

5.5.6 TM Operations van, located in the hard shoulders, to drive the length of the diversion route behind the last vehicle to confirm no more traffic on FRB.

5.5.7 BEAR Scotland Operations and Traffic Scotland Control Centre to confirm last vehicle has passed through the diversion. Confirmation with Control Room to be completed prior to removal of traffic management.

5.5.8 Once completed, barriers to be removed from the deployed position and IRS to be switched off.

5.5.9 Gantries showing red “X” to show end of restrictions and traffic released. VMS message board to state “QC OPEN” and Police units to leave area. IPVs to drive on to QC showing motorists QC has been reopened.

5.5.10 A9000 NB towards Ferrytoll Junction to return to normal operating conditions, removing the cones and signage for non-motorway traffic and blocking the north link road by reinstating the cones.

5.5.11 TM Operations to change the traffic signals to green on the Echline junction NB on-slip, releasing remaining held traffic on to the A9000.

5.5.12 South side PTL SB towards Edinburgh to have cones removed and return to normal operating conditions.

5.5.13 Lane 2 on south side link road, southbound carriageway to have cones reinstated for normal operating conditions.

5.5.14 Queensferry Junction on-slips to be re-opened for use. TRISS units to display message “QC OPEN TO TRAFFIC” and moves out the way.

5.5.15 M90/A9000 SB/PTL on-slips SB to be opened to traffic.

5.5.16 Approach gantries to show end of restrictions sign and message to state “QC OPEN.”

5.5.17 BEAR Scotland Unit Bridge Manager to ensure a post incident inspection is carried out following removal of the diversion.

6. Operational Plans

6.1 Ice Accretion Event Forecast

Process	Organisation	Action
Risk Identification and State of Alert	Mercury	Highlight potential Issue severe weather warning
	BEAR Scotland	Initiate pre-event preparations: o Liaison with relevant Stakeholders as required. o Pre-set diversion signing for implementation of diversion route o Arrange operational standby if required o Arrange MART standby if required
	Traffic Scotland National Control Centre	Use variable message signs to advise travelling public of severe weather potential
	Transport Scotland	Initiate MART if necessary

6.2 Implementation of Deployment Phases

6.2.1 Pre-Deployment Phase

Process	Organisation	Action
Pre-deployment of automated barrier	BEAR Scotland Control Room	Advise Traffic Scotland National Control Centre by phone. Update the Forth Bridges website. Advise Police Scotland a closure is required Traffic signals top of Ferrytoll onslip SB to be switched to red and traffic held until barriers are deployed
	BEAR Scotland Operations	Pedestrian crossing north of FRB to be switched of and pedestrians diverted to underpass Operatives to advise when last vehicle has passed through the closed section Operatives access control cabinets for automated barrier and intelligent road studs (Possibility of TRIS units to be utilised if Police Scotland are unable to attend. Sign boards on TRIS units to display QC CLOSED WAIT HERE Until FRB is open (Option))
	TM Operations	Setup traffic management to stop vehicles entering M90/A9000 SB slip road diverting up to Admiralty Junction. Queensferry Junction on slips to be closed with diversion signs set towards Echline Junction. Traffic to drive down to the traffic signals and wait until automated barriers are deployed. Public transport link on south side towards Edinburgh to have cones segregating the link from the A9000 running lane.
	BEAR Scotland Engagement Team	Update sent out providing information on QC closure and FRB open
	Traffic Scotland National Control Centre	Populates Traffic Scotland website and advises media. Activates QC Barrier Closure – Stage 2 Plan. Sets strategic variable messages signs as agreed to detail warning of QC closure. Approach gantries to show count down of speed from '70' to '50' to '30' to '20' Gantries located next to automated barriers to show red 'X' across all lanes Monitors traffic flows on approach routes
	Police Scotland	Provide units if attendance is possible Police units to sit in hard should next to gantries displaying red 'X' unit automated barrier deployed

6.2.2 Deployment Phase

Process	Organisation	Action
Deployment of automated barrier	BEAR Scotland Control Room	Advise Traffic Scotland National Control Centre by phone. Update the Forth Bridges website.
	BEAR Scotland Operations	Confirm final vehicles are clear of bridge and junctions before deployment. Operatives activate automated barriers and deploy across road after confirmation final vehicle has cleared bridge. Ensure sequential lights are activated on automated barriers and reflective chevrons are visible. Intelligent road studs to be switched on. (Possibility of TRIS units to be utilised if Police Scotland are unable to attend. Sign boards on TRIS units to display: QC CLOSED WAIT HERE Until FRB is open (Option))
	TM Operations	Vehicles heading SB will be diverted to Admiralty Junction and held until barriers are deployed. North side A9000 NB to be closed to traffic except from non-motorway traffic with signage to be setup to reflect this. Traffic to drive down Echline junction on-slip NB to the traffic signals and wait until automated barriers are deployed. Public transport link on south side towards Edinburgh to have cones segregating the link from the A9000 running lane. IPV to move from hard shoulder and block all lanes during deployment of automated barrier. TM Operations van to follow last vehicle and confirm QC is clear.
	BEAR Scotland Engagement Team	Update sent out providing information on QC closure and FRB open
	Traffic Scotland National Control Centre	Populates Traffic Scotland website and advises media. Sets strategic variable messages signs as agreed to detail warning of QC closure Gantries located next to automated barriers to show red ‘X’ across all lanes
	Police Scotland	Police units to sit in hard should next to gantries displaying red ‘X’ unit automated barrier deployed

6.2.3 Release Phase

Process	Organisation	Action
Release of traffic	BEAR Scotland Control Room	Advise Traffic Scotland National Control Centre by phone. Update the Forth Bridges website.
	BEAR Scotland Operations	Operatives' lower barrier system and lock in place. Controls to be switched off and cabinets locked Pedestrian crossing north of FRB to be switched off and pedestrians diverted to underpass (If TRISS units utilised, sign boards to display FRB OPEN FOLLOW ME TRISS units to drive through closure
	TM Operations	A9000 SB PTL to remain closed to traffic. Traffic held at Echline Junction on-slip traffic signals to be released and allowed to join mainline traffic. IPVs on both sides to drive through the closures, guiding traffic through the closure
	BEAR Scotland Engagement Team	Update sent out providing information on QC closure and FRB open
	Traffic Scotland National Control Centre	Populates Traffic Scotland website and advises media. Activate QC Open via FRB – Stage 3 Plan. Sets strategic variable messages signs as agreed to detail warning of QC closure and FRB open to traffic. Gantries located next to automated barriers to show '30' across all lanes. Monitors traffic flows on the approach routes to the bridge
	Police Scotland	Police units to allow traffic to travel through the diversion

6.2.4 Removal Phase

Process	Organisation	Action
Removal of automated barriers and re-opening of QC	BEAR Scotland Control Room	Advise Traffic Scotland National Control Centre by phone. Update the Forth Bridges website. Advise Police Scotland event has subsided, and closure of automated barriers is required
	BEAR Scotland Operations	Operatives access control cabinets for automated barrier Operatives to advise when last vehicle has passed through the closed section Pedestrian crossing north of FRB to be switched on and pedestrians resume use. (Possibility of TRISS units to be utilised if Police Scotland are unable to attend. Sign boards on TRISS units to display FRB CLOSED WAIT HERE Until QC is open (Option)) Operative to remove the automated barrier once traffic management is removed.
	TM Operations	Remove traffic management from M90/A9000 Ferrytoll on-slip SB Queensferry Junction on slips to be opened to traffic Cones segregating south side, SB PTL to be removed
	BEAR Scotland Engagement Team	Update sent out providing information on re-opening of QC
	Traffic Scotland National Control Centre	Populates Traffic Scotland website and advises media. Sets strategic variable messages signs as agreed to detail warning of FRB closure and removal of diversion Gantries located next to automated barriers to show red 'X' across all lanes until gates are closed
	Police Scotland	Provide units if attendance is possible Police units to sit in hard should next to gantries displaying red 'X' unit automated barrier deployed Police release traffic following removal of red 'X' over the lanes

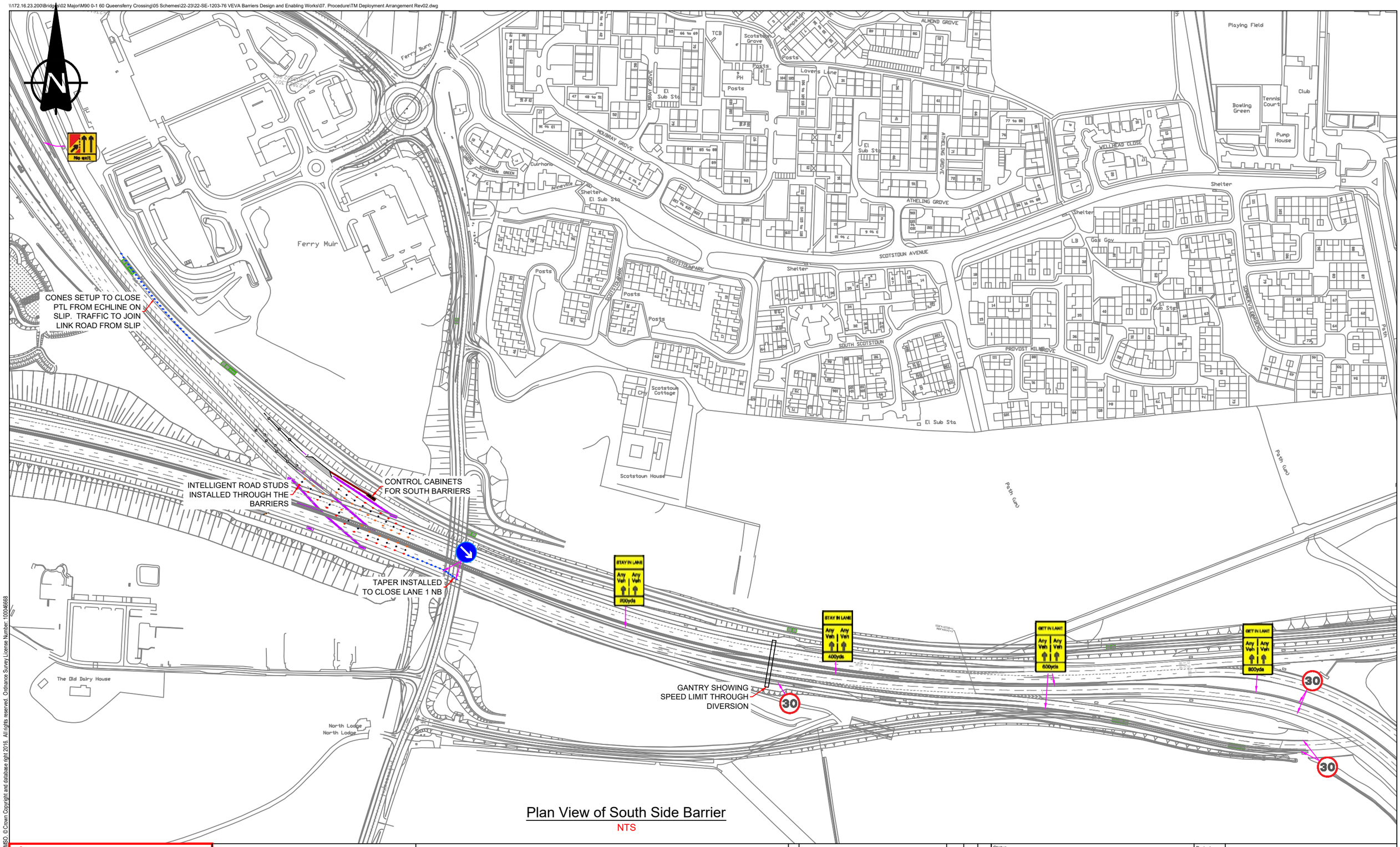
6.3 Post Incident Inspection

6.3.1 Following removal of the diversion off FRB, a post incident inspection shall be undertaken on FRB ensuring no deterioration has occurred during it operation as the primary Firth of Forth crossing.

7. Alternative Routes for Traffic, Pedestrians and Cyclists

7.1 All vehicles permitted to use a motorway will be diverted via Queensferry Crossing.

7.2 In the event that both Queensferry Crossing and Forth Road Bridge are not usable, then all traffic will be diverted to Kincardine Bridge in the event of high winds during the emergency event.



Plan View of South Side Barrier

NTS

RESIDUAL DESIGN HAZARDS

(The following information has been collected from Pre-construction Information and the Bear Scotland CDM Hazard Management Process.)

1.

NOTES

1. Do not scale this drawing, only use figures dimensions. The Contractor is to bring to the attention of the Project Engineer any discrepancies contained in this drawing prior to work commencing. Where required this drawing is to be read in conjunction with scheme design drawings and scheme specifications.

Rev	Description	Date	Drawn	Chkd
A	Inclusion of intelligent road studs	18/04/24	11(2)	
0	Original	31/01/24	11(2)	

Status: INFORMATION

Client: TRANSPORT SCOTLAND / CEISTEAN ALBA

South East NMC

BEAR SCOTLAND

www.bearscot.com

Project	M90 0-1 60 Queensferry Crossing Automated Barrier Installation
Title	Automated Barrier Deployment Traffic Management Layout South Side
Drawing No.	22-SE-1203-76-TM-002
Rev	A
Scale:	NTS
Size	A1
Date	18/04/2024
Designed:	Eng
Drawn:	Tech
Checked:	Eng
Approved:	Eng

\\172.16.23.200\Bridges\02 Major\M90 0-1 60 Queensferry Crossing\05 Schemes\22-23\22-SE-1203-76 VEVA Barriers Design and Enabling Works\07. Procedure\TM Deployment Arrangement Rev02.dwg

GET IN LANE
Any Veh | Any Veh
600yds

30

GET IN LANE
Any Veh | Any Veh
800yds

M90 FERRYTOLL/A9000
SB ONSLIP TO BE
CLOSED DURING THE
DIVERSION

ROAD CLOSED

30

STAY IN LANE
Any Veh | Any Veh
400yds

30

STAY IN LANE
Any Veh | Any Veh
200yds

INTELLIGENT ROAD
STUDS TO BE SWITCHED
ON FOR THE DIVERSION

COUPLE OF CONES TO BE
PLACED AT THE END OF THE
OPEN BARRIER TO DELINEATE
TRAFFIC FROM END

30

NEW CENTRAL
RESERVE BARRIER
ON NORTH LINK ROAD

30

INTELLIGENT ROAD
STUDS TO GUIDE
TRAFFIC THROUGH
THE CROSSOVER

Non Motorway Traffic

TAPER TO BE SETUP
FOR SIGNAGE STATING
"NON-MOTORWAY
TRAFFIC ONLY"

30

30

M90
Non Motorway Traffic

Shipbreaking Yard
Warehouse
Sharrock Terrace
RC Chapel
The Bungalow
Pond
Jamestown
Rock Cottage
Cruicks Quarry
Gallow Bank
Ferrytoll Quarry
St Margarets Marsh
Mud and Boulders
Ferry Hills
Ferry Loch
Air Shaft
Tunnel
Playground
Path
Community Centre
North Queensferry

Plan View of North Side Barrier

NTS

NOTES

1. Do not scale this drawing, only use figures dimensions. The Contractor is to bring to the attention of the Project Engineer any discrepancies contained in this drawing prior to work commencing. Where required this drawing is to be read in conjunction with scheme design drawings and scheme specifications.

Rev	Description	Drawn	Chkd
B	Altering of traffic management	11(2)	
A	Inclusion of intelligent road studs	11(2)	
O	Original	11(2)	

Status: INFORMATION

Client: TRANSPORT SCOTLAND

South East NMC

BEAR SCOTLAND

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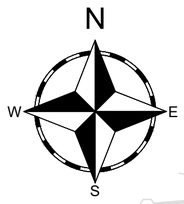
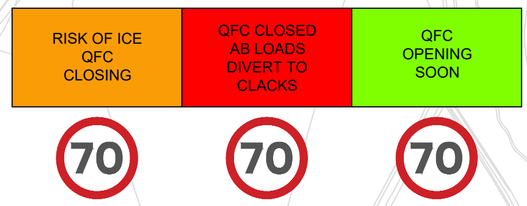
Project: M90 0-1 60 Queensferry Crossing
Automated Barrier Installation

Title: Automated Barrier Deployment
Traffic Management Layout
North Side

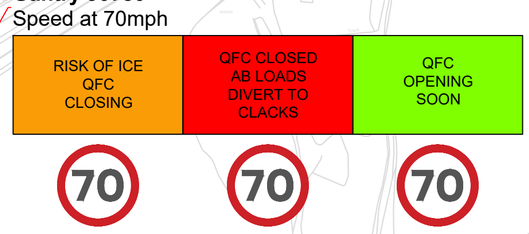
Drawing No.	22-SE-1203-76-TM-001	Rev	B
Scale:	NTS	Size	A1
Designed:	11(2)	Drawn:	11(2)
Checked:	11(2)	Approved:	11(2)
Date	06/11/2024		



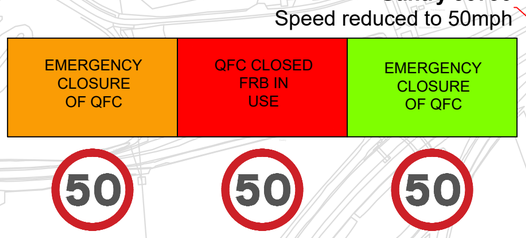
Gantry 90770
Speed at 70mph



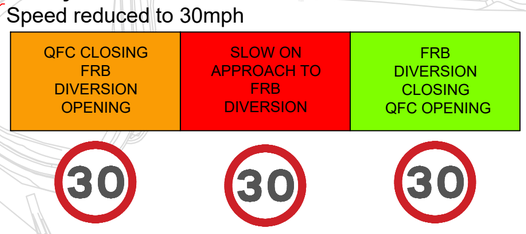
Gantry 90780
Speed at 70mph



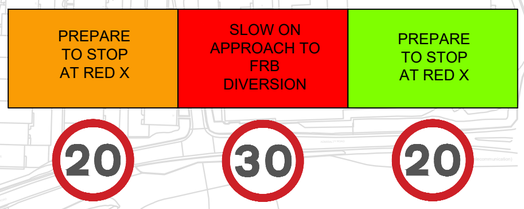
Gantry 90790
Speed reduced to 50mph



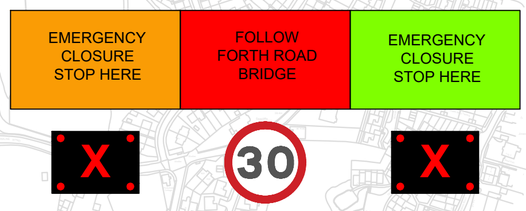
Gantry 90800
Speed reduced to 30mph



Gantry 90810
Speed reduced to 20mph



Gantry 90820
Gantry where traffic is held
when automated barriers open



Queensferry Crossing Closing Message

Queensferry Crossing Closed Message

Queensferry Crossing Opening Message

Do not scale this drawing

Rev	Date		Checked
A	29/10/24	INFORMATION - Changes to VMS text	11(2)
0	28/08/24	INFORMATION	11(2)

Rev.

A

Status

INFORMATION

Client

TRANSPORT SCOTLAND
CÒMHDHAIL ALBA

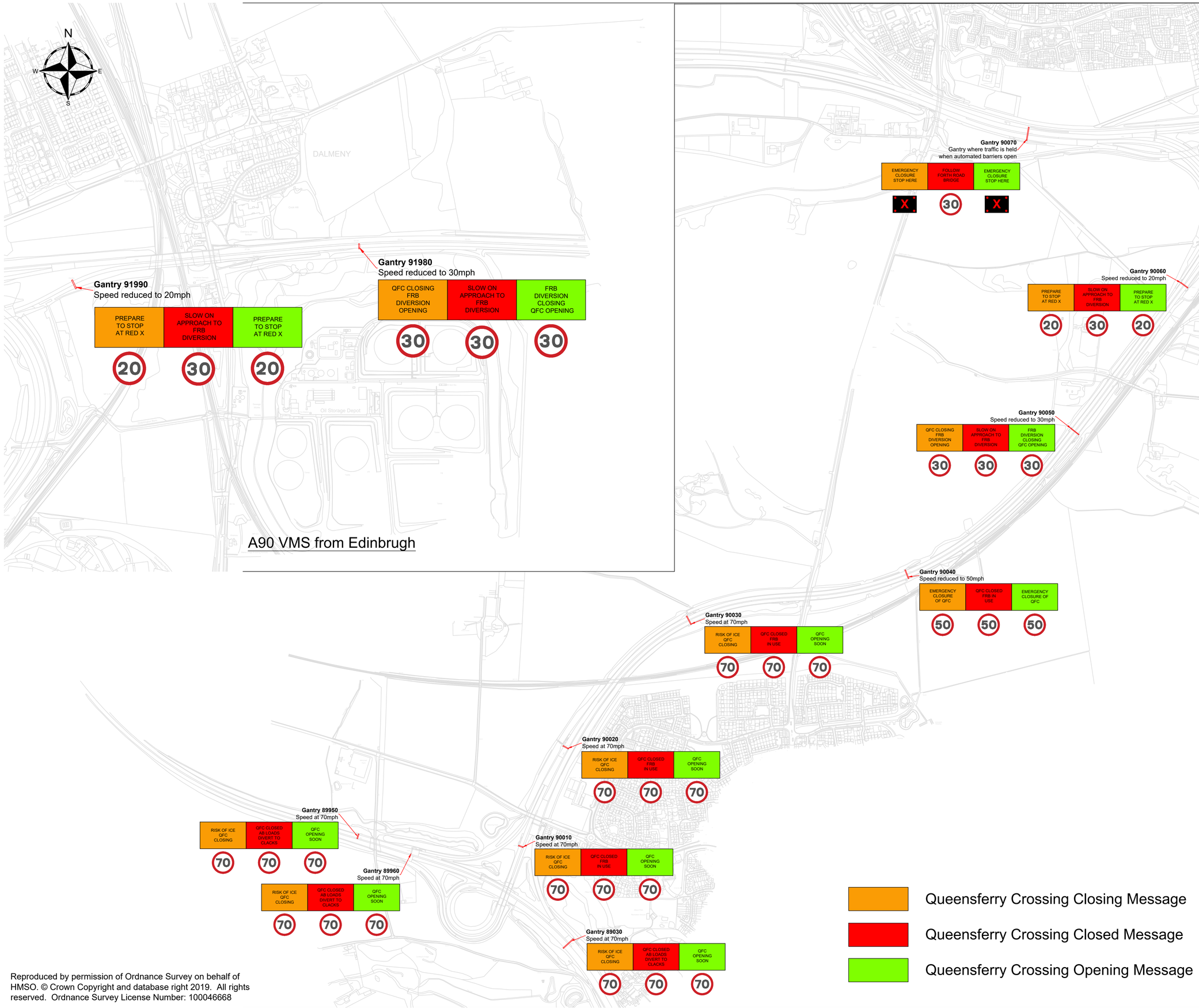
Project

M90 Queensferry Crossing
Automated Barriers

Title

Automated Barrier Deployment
North Approach
Gantry Layout
VMS Messaging

Drawing No.	22–SE–1203–76–200	0 A	
Scale	Scaled @ A1	Date	29/10/2024
Designed 11(2)	Drawn 11(2)	Checked Chkd	Approved Appr



Drawing Number

22-SE-1203-76-201

Do not scale this drawing

Rev	Date		Checked
A	29/10/2024	INFORMATION - Changes to VMS text	LLD
0	28/08/2024	INFORMATION	LLD

Status

INFORMATION

Rev.

A

Client

TRANSPORT SCOTLAND
CONNECTING ALBA

BEAR SCOTLAND

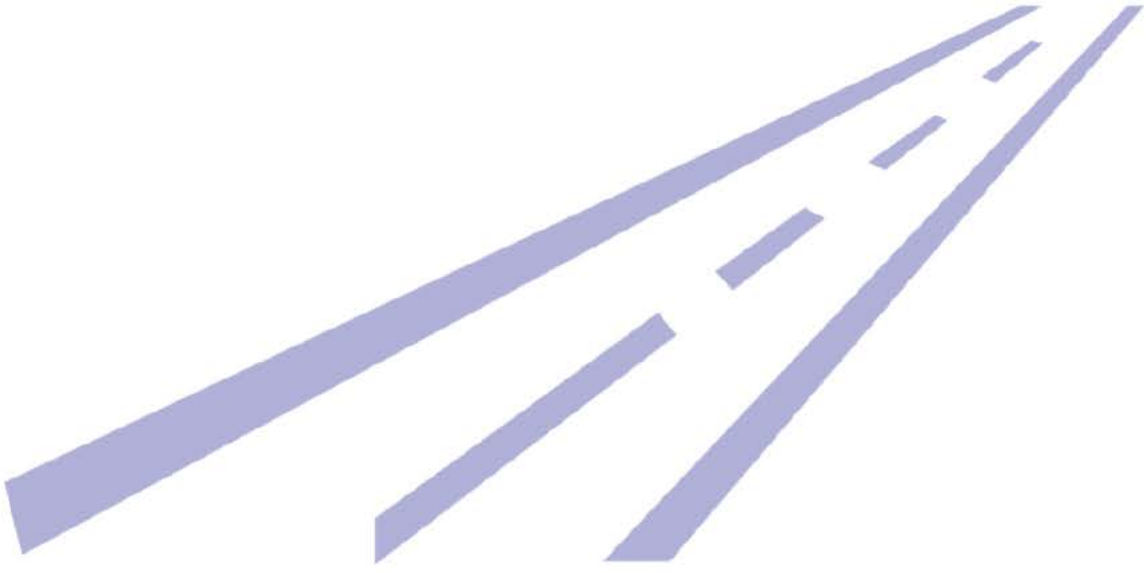
Project	M90 Queensferry Crossing Automated Barriers
Title	Automated Barrier Deployment South Approach Gantry Layout VMS Messaging
Drawing No.	22-SE-1203-76-201 | 0 | A
Scale	Scaled @ A1
Date	29/10/2024
Designed LLD	Drawn LLD | Checked Chkd | Approved Appr

Scottish Trunk Road Network Management Contract

South East Unit

Queensferry Crossing Ice Accretion Procedure: 168SE

TRANSPORT SCOTLAND
CÒMHDHAIL ALBA



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Document Control

Issue and Revision Record					
No.	**Date**	**Originator**	**Checker**	**Approver**	**Comments**
1	23/11/20	11(2)	11(2)	11(2)	
2	22/11/21	11(2)	11(2)	11(2)	Updates on procedure
3	18/10/23	11(2)	11(2)	11(2)	Updated to include automated barrier protocol for closure of QC
4	16/09/24	11(2)	11(2)	11(2)	Updated to include KVT forecasting and automated barrier protocol

Weather Forecast

Online weather forecasting tool **KVT** has advised high risk of ice accretion.
Or **Mercury IMP** has advised Severe risk of ice accretion.

Yes → Traffic Management and Automated Barrier Teams Mobilised at South Queensferry Depot → Notify Severe Weather Manager to carry out additional snow clearing and gritting in location of potentially stationary diversion traffic.

No

Weather Forecast

Online weather forecasting tool **Mercury IMP** has advised high risk of ice accretion.
KVT has shown no risk of Ice Accretion

Patrols Mobilised → Notify Abnormal Load Duty Manager of potential Ab Load Restrictions

Is the high risk out with normal working hours

Yes → (Patrols Mobilised)

No → No patrols required. To be monitored by ICE Accretion Duty

Is ice / snow accreting to the stays or tower at height?

No → Monitor until patrols are no longer required.

Yes → Traffic Management and Automated Barrier Teams deployed to site in anticipation for diversion.

Traffic Management and Automated Barrier Teams deployed to site in anticipation for diversion. → Notify Bridge/Ice Accretion Duty Manager → Notify Abnormal Load Duty Manager restrictions required → Notify Severe Weather Manager to carry out additional snow clearing and gritting in location of stationary diversion traffic.

Data Collection

Mercury IMP – Capture record
KVT – Capture record
Stay temperature sensor - Record 9 sensors
Stay cameras – Store videos
Estimate horizontal visibility

Control Room

Reduce speed to 30mph
Record date and time.
Notify Traffic Scotland and Police Scotland of potential diversion.

Is ice visibly falling off the

No → Continuously monitor ice falling for following 24hrs – Standby monitor
Continue patrols until forecasted

Yes

Have any vehicles reported immediate damage?

Yes → (Ice ACCRETION DAMAGE RISK MATRIX)

No

Is it hitting the bridge deck?

No → Continue to monitor closely

Yes

How big are the impact

ICE ACCRETION DAMAGE RISK MATRIX
Approximate Average Impact Areas

Ice Form	Haptic Description	<50mm²	50 - 100mm²	100 - 250mm²	250 - 500mm²	>500mm²
Dry / Light	Soft snowball - Lands	LOW	LOW	LOW	LOW	LOW
Frozen / Light	Crunchy dry snow - Lands	LOW	LOW	MEDIUM	MEDIUM	MEDIUM
Wet / Dense	Slushy Ice Ball - Splatter	LOW	MEDIUM	MEDIUM	HIGH	HIGH
Frozen / Dense	Frozen Water - Shatter	LOW	HIGH	HIGH	HIGH	HIGH

Low Risk		Maintain 30mph and Monitor
Medium Risk		Maintain 30mph and prepare for closure.
High Risk		Prepare to Close and Divert

Low/Medium risk → Is the ice still falling?

Yes → (How big are the impact)

No → Is the weather forecast improving?

No → Monitor

Yes → Remove any restrictions in conjunction with Automated Barrier Procedure: 209SE

High Risk Identified → Is the forecast wind speed greater than >50mph?

Yes → **IMPLEMENT PROCEDURE FOR DIVERSION ONTO KINCARDINE BRIDGE**

Refer to BEAR SE Standard Incident Diversion Route for the deployment of traffic management to divert to Kincardine bridge.

No → **IMPLEMENT AUTOMATED BARRIER PROCEDURE FOR DIVERSION ONTO FORTH ROAD BRIDGE**

Refer to BEAR Queensferry Crossing Automated Barrier Deployment Procedure: 209SE for the deployment of the dedicated automated barriers and diversion of traffic from M90 Queensferry Crossing on to A9000 Forth Road Bridge. Automated barrier procedure to be followed until weather event has subsided and strategic re-opening of the Queensferry Crossing to traffic has been decided.

PROCESS FLOWCHART

1. Scope

1.1 The purpose of this document is to detail the procedures by which potential ice formation on the Queensferry Crossing is forecast, monitored and managed in accordance with Schedule 2 Section 6, Clause 6.1.10 (m) of the Network Management Contract.

1.2 The Queensferry Crossing was not designed to mitigate ice accretion, therefore as data and experience is developed this procedure shall be updated as required. The Forth Road Bridge does not experience the same issues with ice accretion.

2. Definitions

2.1 Ice Patrol Team means a 2-person team, based within a works vehicle, dedicated to monitoring the bridge for potential ice formation to exposed areas of the structure (cable stays, towers, overhead gantries). This team will use visual inspection and image stabilising binoculars as required.

2.2 Works Vehicle means a conspicuous 4WD vehicle with appropriate livery, strengthened windscreen glass and flashing amber beacons, operating within the hard shoulder of a motorway.

2.3 The Ice Accretion Duty Manager means the on-call manager who accesses and monitors live conditions within the online Mercury Platform.

2.4 Mercury IMP means the online platform that holds the specialist Icing Risk Forecast to be used for determining Queensferry Crossing Ice Accretion status. KVT is an additional, independent online platform that holds specialist icing Risk Forecast that has been refined to more accurately forecast the most severe events. It is expected that Mercury IMP will provide a more conservative estimation of icing risk. It is expected that KVT will provide a more accurate estimation of the most severe ice accretion risks to enable an enhanced response.

2.5 WSDO means the on-duty Winter Service Duty Officer, based in the Control Room.

2.6 Vaisala Weather Station Platform means an online portal, provided by Vaisala, where live weather data from weather stations mounted on, and in proximity to Queensferry Crossing can be accessed.

2.7 MetDesk means the Expert Weather forecaster contracted by BEAR Scotland. MetDesk can be contacted 24hrs a day on 01296 628373 or via the Control Room.

2.8 Control Room means the BEAR Control Room located within South East Unit Central Office at South Queensferry.

2.9 Maintenance Team or Automated Barrier deployment teams means the team based at South Queensferry Depot comprising specialist trades staff.

2.10 Operations Team means the teams based at South Queensferry, Rosyth, Burghmuir or Bonnyrigg comprising skilled highway operational staff.

2.11 Traffic Management resources means those operational resources trained in NHSS 12 and experienced in installing Chapter 8 compliant traffic management on the network.

2.12 6 Point Plan means the actions agreed with Transport Scotland to be taken during weather conditions potentially conducive to ice formation on the structure (excluding the road surface).

3. Responsibilities

3.1 The Unit Bridges Manager is responsible for:

- overseeing the implementation and operation of this process
- identifying staff and resources necessary to fulfil the role of Ice Patrol Teams
- identify Traffic Management Resources that may be necessary to support any required bridge closure / associated diversion route requirements
- informing the BEAR Management Team

3.2 The Ice Accretion Duty Manager, reporting to the Unit Bridges Manager is responsible for:

- ice accretion decision making in accordance with this procedure
- liaising directly with the Maintenance Duty Supervisor on Ice Patrol requirements
- deploying Traffic Management resources
- deploying staff to carry out automated barrier diversion.
- liaising with the Network Manager, Severe Weather Manager, Control Room, Maintenance and Operations teams and the other Ice Accretion Managers.

3.3 The Maintenance Duty Supervisor is responsible for:

- resourcing and supplying the staff to form the Ice Patrol Teams
- resourcing and deploying the Ice Patrol Teams.
- resourcing and supplying the staff to form the staff to carry out automated barrier diversion.

3.4 The Network Manager is responsible for:

- management of the control room function
- liaison with WSDO, Severe Weather Manager, Bridges Manager and Communications Manager as required
- liaison with Transport Scotland, Traffic Scotland and Police Scotland.

3.5 The Forth and Queensferry Bridges Managers are responsible for:

- the safety of the bridges and their users
- checking authorisation of operators on the bridges
- mobilisation and deployment of Roped Access Specialists
- overall control on the management of the care and safe use of the access systems on the Queensferry Crossing / Forth Road Bridge.

3.6 The Engagement Manager is responsible for:

- managing the Communications Team
- liaison with the WSDO, Severe Weather Manager and Network Manager.
- overseeing updates to the Forth Bridges website and social media channels.

4. 6 Point Plan

4.1 The 6 Point Plan incorporates the following actions:

- Heightened focus on monitoring of prevailing weather conditions (24/7 during weather conditions potentially conducive to ice formation)
- Enhanced Patrols, carried out on a 24/7 basis during weather conditions 'potentially conducive to ice formation'
- Increased Data & Intelligence gathering from Site observations
- Pre-mobilisation / pre-laying of Traffic Management
- Deployment of traffic diversion utilising the automated barriers to divert traffic over the Forth Road Bridge during Ice Accretion events to reduce delays to traffic.
- Enhanced Stakeholder communications

4.2 The method of carrying out the works has been developed to align with the 6 Point Plan introduced following the emergency closure of Queensferry Crossing in February 2020.

5. Assessing the risk of Ice Formation

5.1. To provide software and IT resilience there are two ice accretion risk forecasting software platforms as follows:

a. Mercury IMP platform:
The Ice Risk forecast on the Mercury IMP, is developed from an algorithm utilising the criteria in Appendix A. The criteria to determine the level of risk is inherently conservative to ensure patrols are provided in all instances where weather conditions are potentially conductive to ice formation. Found at the following website (all users require individual user ID):
https://ui.ts.implatforms.co.uk/

b. KVT Platform:
The NCEP Global Forecast System (GFS) is a global forecast model, run by the US National Centre for Environmental Prediction. It includes an ensemble of 31 models, each with slightly different physics models and/or perturbed starting conditions.
Icing predictions for the models are now piped into the Arup Bridge Monitoring Service database and made available for displace in a web based dashboard. The dashboard has been modified to allow toggling between individual or averaged model outputs. Details are provided in Appendix B. Found at the following website:

https://monitoring.bridges.arup.com/d/1EEIbqN4k/queensferry-crossing-ice-accretion-dev?orgId=1

5.2. The Ice Accretion Duty Manager will monitor the Icing Risk forecast within the Mercury platform and the MetDesk forecast (36-hour, and 2-5 day) to ascertain whether weather conditions that may be conducive to ice formation are forecast. This is shown as red-high and/or black-severe on the Mercury IMP graph.

5.3. The inclusion of text such as “sleet / snow / hail / freezing rain / wintry showers” or similar within the MetDesk forecast reports (36-hour, and 5-day) are considered conditions that may be conducive to ice formation.

5.4. If conditions that may be conducive to ice formation are described within the 36-hour forecast then a heightened focus on prevailing weather conditions will be implemented.

5.5. Observations made to date indicate that the climatic / meteorological criteria set out in Appendix A, existing concurrently, may likely be associated with ice formations.

5.6. KVT Risk forecasting tool derives the mass of ice accumulating on a hypothetical horizontal cylinder. Work carried out during the model calibration/validation study has established an empirical basis for the levels of icing which are associated with known icing events. An icing mass of 0.5kg per linear meter collector is used to predict icing risk, details can be found in Appendix B. Throughout the winter this icing mass threshold shall be monitored to ensure the number of mobilisations are commensurate with the level of risk.

6.0 When 'conditions that may be conducive to ice formation' are forecast on Queensferry Crossing

6.1 At least 36 hours in advance of mercury IMP or KVT indicating conditions that may be conducive to ice formation:

- The Maintenance Duty Supervisor will identify staff and resources necessary to fulfil the role of Ice Patrol Teams.
- All members of the Ice Patrol Teams will be briefed and inducted into the safe operation of undertaking patrols
- The Ice Accretion Manager will identify Traffic Management Resources that may be necessary to support any required bridge closure / associated diversion route requirements
- The Control Room shall advise Transport Scotland / Traffic Scotland / Police Scotland that Ice Monitoring Teams and associated resources are expected to be in operation. This shall be confirmed once Patrols commence.
- The Ice Accretion Manager shall advise the Communications Manager to pre-prepare website and social media feeds.

6.2 24-12 hours in advance of mercury IMP or KVT indicating conditions that may be conducive to ice formation:

- The Ice Accretion Duty Manager will continue to monitor forecasted conditions within Mercury for changing parameters identified
- Consultation with Met Desk shall be maintained as necessary to obtain up to date expert forecaster opinion.
- Regular updates shall be provided to Transport Scotland / Traffic Scotland / Police Scotland as required by the Control Room.

6.3 2-hours in advance of mercury IMP or KVT indicating conditions that may be conducive to ice formation until passing of the period forecast:

- The Ice Accretion Manager will inform the Communications Manager that conditions that may be conducive to ice formation are expected in the next 2 hours.
- Consultation with MetDesk shall be maintained throughout to obtain up to date expert forecaster opinion.
- Regular updates shall be provided to Transport Scotland / Traffic Scotland / Police Scotland as required by the Control Room in the form of Sit Reps.
- Sit Reps will be sent at regular intervals until the passing of the period forecast.

7.0 Ice Monitoring Teams

7.1 The Maintenance Duty Supervisor will mobilise and have patrolling from the hard shoulder of the Queensferry Crossing, a 2-person Ice Patrol Team located within the confines of a Works Vehicle from one hour before the conditions that may be conducive to ice formation.

7.2 Ice Patrol Team will continue to patrol and inspect exposed areas of the Queensferry Crossing (cable stays, towers, overhead gantries) for potential ice formation to exposed areas of the structure. This team will use visual inspection and image stabilising binoculars as required. Special attention is drawn to the stay cables.

7.3 Where appropriate a thermal imaging camera may be used to gather technical data. (this previously indicated surface temperatures of -4.5C to -1.0C during ice formation observations).

7.4 Each tower and cable section are to be visually inspected and the outcome of the inspections recorded on Form 585SE – QC Ice Monitoring Survey. A referencing diagram is also included on the form.

7.5 Regular communication between the Ice Patrol Teams and the Control Room and the Ice Accretion Duty Manager shall be maintained via radio / mobile phone as appropriate and safe to do so.

7.6 Ice Patrol Teams will continue to visually monitor the situation until one hour after the conditions that may be conducive to ice formation forecast time has passed.

7.8 If ice/snow formations are observed on the exposed areas of the bridge or if witnessed falling to the carriageway then the Control Room and Ice Accretion Duty Manager shall be immediately notified. This information will be disseminated to the Severe Weather Manager and Network Manager via the Control Room, see Section 9.0.

7.9 On completion of Ice Patrols, the completed QC Ice Monitoring Surveys (Form 585SE) shall be returned to the Control Room and retained electronically in BEARnet.

8.0 Traffic Management Resource

8.1 Throughout the winter, traffic management resources will be on standby 24 hours a day, 7 days a week and can be mobilised when required. If Mercury IMP has forecast a severe risk or if KVT has forecast a high risk, traffic management resources will be pre-mobilised and available within the South Queensferry Depot comprising skilled highway operational staff.

8.2 Pre-positioning of traffic management, where appropriate, shall be carried out during off-peak times and will be mobilised in advance by the Ice Accretion Duty Manager.

8.3 The decision to close QC due to shedding ice will be made in line with the decision making flowchart attached to this procedure.

8.4 Upon instruction from the Ice Accretion Duty Manager, the Traffic Management Resource shall mobilise, with the support of Police Scotland where feasible, to implement a closure of the QC, see section below.

9.0 Ice formations observed on any exposed area of the cables or the towers of Queensferry Crossing or Forth Road Bridge.

9.1 If the Ice Patrol Teams identify the formation of ice then the location, extent, and as much detail as possible is to be conveyed to the Ice Accretion Duty Manager and the Control Room. A mandatory 30mph speed limit should be imposed as soon as ice begins to accumulate to the cables, believed could be accumulating to the cables. Ice Patrol Teams are advise to err on the side of caution and advise the Ice Accretion Duty Manager as soon as possible to enable early speed reductions and pre-mobilisation of traffic management resources and automated barrier teams. It is expected that false alarms, with additional pre-mobilisation of teams that are ultimately not required.

9.2 The Ice Accretion Duty Manager shall undertake a risk assessment using an agreed form. It should be recognised that although falling ice is a hazard to road users, stopping traffic, diverting traffic and extending road users travel duration in inclement weather is also a hazard. This is exacerbated by drivers' behaviour in using mobile phones whilst driving to determine alternative routes. The risk of stopping and diverting traffic is considered medium and therefore traffic should only be diverted if falling ice presents a higher risk.

9.3 The Ice Accretion Duty Manager will instruct the Control Room to begin implementation of a closure of the Queensferry Crossing, on the grounds of safety in accordance with Procedure 209SE.

9.4 Procedure 209SE will be implemented to deploy the Automated Vehicle Restraint Barriers to divert vehicles from M90 Queensferry Crossing on to A9000 Forth Road Bridge.

9.4 The Ice Accretion Duty Manager will inform the Unit Bridges Manager, Severe Weather Manager, Network Manager and Engagement Manager of the requirement to close the bridge.

9.6 The Control Room will request Police Scotland assistance to support any closure. Police presence is not required to deploy the diversion on to Forth Road Bridge using the automated barrier system, however, if Police presence is possible then this should be sought as it significantly reduces the time required to implement a closure.

9.7 The Control Room shall notify Traffic Scotland of the closure, and request that procedure 209SE is implemented. Overhead Gantry signage will be implemented as per agreed procedure.

9.8 The WSDO shall send a group email to all concerned stakeholders informing them that the bridge is closed and a diversion is being implemented. The WSDO shall send a group email when the diversion has been successfully implemented. The group email will be the same as that used for high wind closures and include TS emergency email address.

9.9 The Unit Bridges Manager will notify the BEAR Management Team of the closure and diversion to the Forth Road Bridge.

9.10 The closure of the Queensferry Crossing to all traffic shall be undertaken in line with procedure 209SE utilising the automated vehicle restraint barrier system.

9.11 The Forth Bridges Website and social media channels will be updated as necessary by the Communications Team.

10.0 Dealing with ice that has formed

10.1 Ice Patrol Teams will remain on the bridge throughout the closure period. They will continue to monitor and observe for ice formation / ice falling and report this to the Ice Accretion Duty Manager and Control Room.

10.2 The Ice Accretion Duty Manager will continue to compare Forecast weather data with site data to correlate trends.

10.3 Control Room will remotely request that Traffic Scotland direct available CCTV cameras to monitor and record the areas of concern.

10.4 If conditions are unsafe for the Operating Company personnel, then conditions will continue to be monitored remotely.

10.5 It should be noted that in most instances, the safest method of removal is to allow the ice accretions to melt or fall off naturally.

11.0 Reopening

11.1 Once the forecast indicates an improvement in conditions, and Ice Monitoring Teams confirm no remaining areas of ice formations exist, the Ice Accretion Duty Manager will instruct the removal phase of procedure 209SE to be instigated. To cause minimal delays to traffic the re-opening shall be carried out at night between 10pm and 5am.

11.2 The WSDO will inform the Severe Weather Manager and Network Manager. The Ice Accretion Duty Manager will advise the Unit Bridges Manager and Engagement Manager of the same.

11.3 Close liaison with Police Scotland and Traffic Scotland will be maintained throughout by the Control Room.

11.4 The Forth Bridges Website and social media channels will be updated as necessary, via the Communications Team.

11.5 If required, the Control Room will request Police Scotland support to assist the Traffic Management Resource in re-opening the bridge.

11.6 The WSDO shall send a group email to all concerned stakeholders informing them that the bridge has reopened to all vehicles. The group email will be the same as that used for high wind closures and include TS emergency email address.

11.7 The 30mph speed restriction on the approaches and across the crossing will be maintained until all Traffic Management Resources are clear of the network in the vicinity of the bridge and its approaches.

11.8 The Unit Bridges Manager will notify the BEAR Management Team that the bridge has reopened.

12.0. Associated documents

- Network Management Contract – Schedule 2, Section 6.
- South East Unit – Winter Service Plan & Appendix WSP 11.
- Queensferry Crossing – Wind Management Plan.
- Forth Road Bridge - Wind Management Plan.
- Form 585SE – QC Ice Monitoring Survey.
- Procedure 209SE – Queensferry Crossing Automated Barrier Deployment Procedure

Appendix A – Mercury IMP – Risk Forecasting

Observations made to date indicate that the following climatic / meteorological criteria, existing concurrently, may likely be associated with ice formations.

RELATIVE HUMIDITY (RH) – This is a measure of moisture content of the air, and influenced by dew point and air temp – accessed via the Vaisala live output:

- RH% above 90% = 'be aware'
- RH above 95% = 'be very aware'
- RH >97% = 'expect issues'
- **Squalls were observed as influencing RH by 5% within minutes of blowing through. Therefore, any RH within 85% should be monitored.**

DEW POINT (DP) – This is the temp at which moisture comes out of the air but does not fall as rain – accessed via the Vaisala live output

- Dew Point = below +2^{0}C, trending towards 0^{0}C
- **Squalls were observed as influencing Dew Point by 3^{0}C within minutes of blowing through.**

AIR TEMP

- Air temp below +1.0^{0}C and above 0^{0}C – produces 'wet snow'
- **Squalls were observed as reducing air temperature by 3.5^{0}C within minutes of blowing through. Therefore, any air temperatures below +4.5^{0}C should be monitored**

WIND

- Wind speed and direction = to be determined, but to date winds >20mph observed on 10/02/20

OTHER

- When the air temperature and dew point converge between 0^{0}C and +1^{0}C = Be Very Aware
- Squalls can very quickly (minutes) influence all variables negatively

Appendix B – KVT – Risk Forecasting

4.1 Design concept

The pilot study phase was intended to allow operationalisation of the improved forecast model developed by KVT and evaluation of how the model performs compared to the existing Mercury forecasts. A proof-of-concept version of the system was developed in advance of the onset of the initial study period to provide the core features necessary to demonstrate the effectiveness of the system.

Figure 16. Logical diagram of Phase 1 Pilot system

Figure 16 shows a simple logical diagram of the proof of concept system. It consists of the following core components:

- **NCEP Global Forecast System (GFS)**: This is the main global forecast model run by the US National Centre for Environmental Prediction. Model outputs are refreshed on a 6 hour cycle and can be accessed free of charge via a public API. GFS is one of a number of global forecast models, others include the ECMWF Integrated Forecast System (used as a basis for the current forecasts shown in Mercury), the German ICON model and the UKMO Unified Model.
- **KVT Forecast Model**: Each time an updated GFS forecast is completed, the KVT forecast system automatically downloads the data and uses it to drive a high resolution, regional forecast model centred over the bridge. This model is based on the open source Weather Research and Forecasting simulation code and is unchanged from the model developed during Phase 1 – model validation.

  The forecast model is scheduled to run on a High-Performance Compute (HPC) cluster on a 6-hour cycle, after which it will post process a subset of the model data to produce probabilistic ice accretion forecasts.
- **KVT Forecast API**: Once the forecast weather simulation and post processing is complete, data are made available via an API. This secure API is designed based on industry standard principles (REST) and enables remote access to the forecast data based on a set of well-defined queries. This component marks the boundary of the "KVT system".
- **Arup Job Poller**: This component sits on the boundary of the "Arup system" and provides functionality that could ultimately be replicated by Mercury. It comprises a script that runs on a regular schedule to check for updates and extract data from the KVT Forecast API when available.

- **Arup Bridge Monitoring Service**: This component is based on a standardized digital solution that Arup have developed specifically for bridge monitoring. It includes a database that is optimized for time-series data, enabling rapid queries across various periods of time.
- **Arup Web Dashboard**: For simplicity, and to ensure compartmentalisation of the pilot system and current system in Mercury, a standalone web based dashboard was created for viewing the forecast data.

Future development phases may require direct integration of the KVT system with Mercury and flexibility has been retained such that this can be straightforwardly achieved.

4.2 Forecast model and API

The KVT model has been constructed using the open source WRF simulation code. The model outer extent encompasses the whole of the UK and parts of northern Europe at a 20km horizontal resolution. An inner domain, centred over the bridge, is nested within the outer domain and encompasses most the Scotland and parts of Northern England as well as the coastline of Antrim and North Down (see Figure 17 left image).

Wind speeds, air temperatures and precipitation presented in the dashboard are taken from grid point nearest the bridge (node *a1* - see Figure 17 right image). To improve the robustness of the forecasts, ice accretions predictions are made for adjacent grid points (nodes *a2 – a9*) as well as node *a1*. This results in an ensemble of time series for accreted ice mass, which reduces potential for instances where the model predicts high risk conditions near to the bridge but this is not reflected in the forecast.

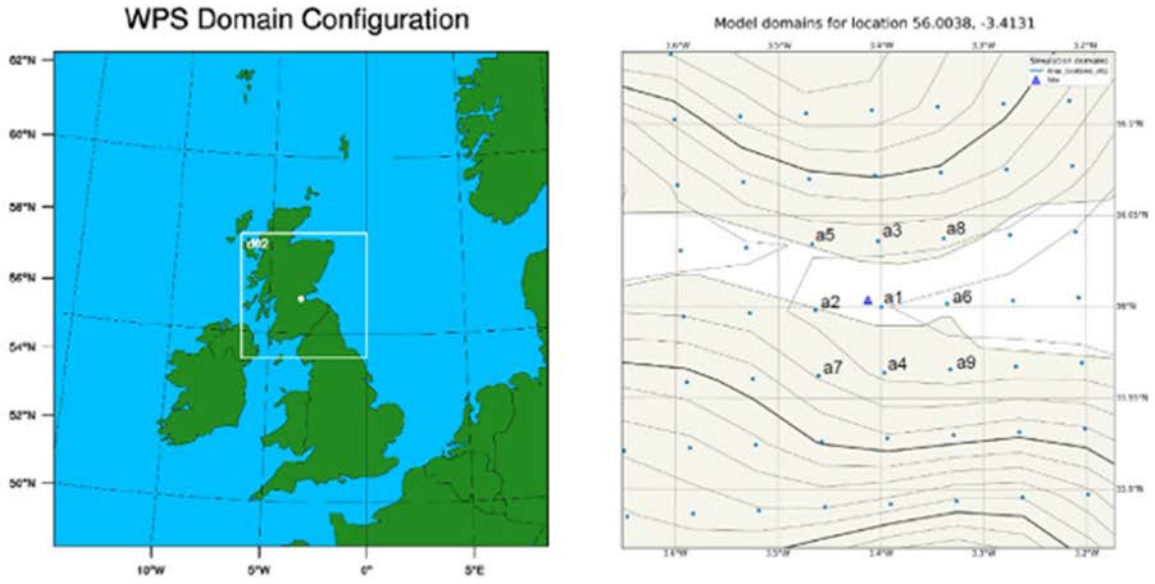

Figure 17: Left image: extent of KVT high resolution forecast model, the inner white square shows the boundary of an inner, nested zone with a horizontal resolution of 4km x 4km. Right image: zoomed in view of model grid, showing the nodes used to produce the processed forecasts, node a1 is used for wind, temperature and precipitation as shown in the dashboard, nodes a1 – a9 are all used in the ice accretion predictions to produce a range of estimates.

An example ensemble of ice accretion predictions is shown in Figure 18 for the significant icing event during Feb 2020. These outputs offer a range of options for formulation of risk levels shown in the dashboard and provide some indication of uncertainty in the model predictions (i.e. if all nodes predict the same thing then it can be seen as a more robust prediction).

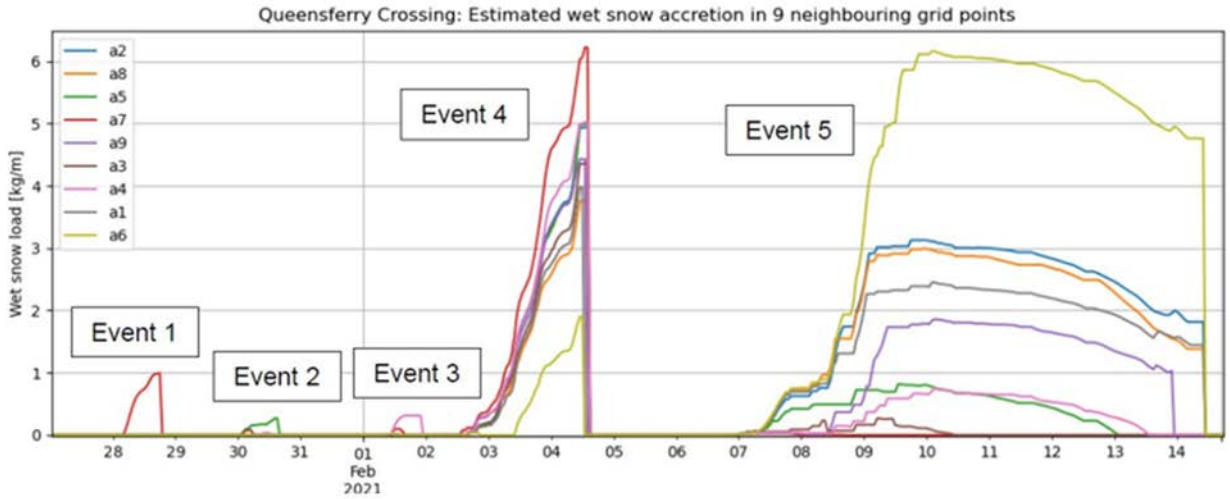

Figure 18: Calculated wet snow quantities accreted on a nominal collector (a cylinder with 1m diameter) for grid points a1 – a9 during the February 2020 icing event.

4.3 Dashboard

A standalone dashboard has been developed to provide live access to the pilot system forecasts. The dashboard has been developed using Grafana, an open source data analytics and visualisation Web app. A sample output is shown in Figure 19.

While the main intention behind its use has been to efficiently facilitate the pilot study while avoiding interference with normal operation of the Mercury system, this platform also provides a means for ongoing development and experimentation with potential new features, such as integrated display and logging of messages from patrol staff and documentation of the decision process during risk periods.

Figure 19: Sample dashboard display.