

Interim Proposal to Raise Wind Limits on the M48 Bridge.

Introduction

The M4 Prince of Wales Bridge (POW) and M48 Severn Bridge, known collectively as the Severn River crossings are national assets held by the Secretary of State for Transport (SoS).

They are maintained and operated by National Highways on behalf of the SoS and the activities, functions and obligations are set out in the 2015 Highways England Framework document - Annex C Protocol agreements, which was transferred to the NH licence in 2021.

These Severn Crossing Protocols with DfT provide additional funds for Traffic Officers in the SW and specifically for Incident Management and the co-ordination of Road Closures in relation to both Bridges.

During adverse weather conditions the Severn Estuary can funnel weather systems along the estuary causing hazardous conditions on the crossings. The newer POW Bridge has barriers to deflect wind and thereby reduce the risk, but the older M48 Bridge does not. The M48 Bridge is a grade 1 listed structure and therefore it is not possible to modify the structure to accommodate wind deflectors.

Since September 2007 the SW Region have been implementing High Wind Traffic Management with measures such as the filtering of vulnerable traffic¹ on the M48 Bridge. Thereby keeping the bridge open longer for some customers, while maintaining customer safety.

Filtering was initially suspended during the COVID19 Pandemic. Following a safety study in 2021² filtering was permanently suspended due to the risk to Traffic Officers maintaining the filter and the increasing levels of frustration for customers of vulnerable vehicles. Technical solutions, which present less risk to Traffic Officers and provide full filtering are being investigated but it will take some time to conclude the investigations, agree funding and complete any subsequent scheme.

Aim

The aim of this paper is to raise the wind speed at which the M48 Bridge is closed, within the bounds of safety, while alternative technical solutions are investigated. This will in turn:

¹ Filtering of vulnerable traffic, or filtering, is a manual process by Traffic Officers with the aim of removing motorcycles and vehicles over 6'9" (2.1m) from crossing the M48 Bridge and divert them along a safer, longer route.

² High wind traffic management – M48 Severn Bridge

- Reduce the number of closures.
- Improve customer satisfaction.
- Reduce the emissions caused by using a diversion route.
- Support the economy in South Wales and the West of England.

Restrictions

Closures of the M48 Bridge have risen in recent years due to operating restrictions during the Covid-19 pandemic and subsequent identification of risk. This has had an adverse impact on customer satisfaction, vehicle emissions as well as a degree of negative socioeconomic impact. It is therefore important to understand how the restrictions have changed since they were first introduced.

A set of limitations was developed and implemented in 2007 which operated up to the start of the pandemic³. Those traffic limitations were:

30 Knots	=	34.6 MPH	SET 40 MPH
35 Knots	=	40.3 MPH	LEEWARD LANES CLOSURE
40 Knots	=	46.1 MPH	FILTERING (Closure 22:00-06:00)
60 Knots	=	69.1 MPH	CLOSURE

Table 1

Due to operational restrictions during the pandemic the option for filtering was removed. As traffic volumes were light and working from home became the norm. The traffic limitations from this point became:

30 Knots	=	34.6 MPH	SET 40 MPH
35 Knots	=	40.3 MPH	LEEWARD LANES CLOSURE
40 Knots	=	46.1 MPH	CLOSURE

Table 2.

The revised limitations adopted during the pandemic were retained following a safety review of the filtering process, however this caused an increase in customer complaints as traffic volumes increased post pandemic.

In addition, between June 2022 and March 2023, the restrictions on the M48 bridge were lowered further due to extensive cabling works and mirror lane 1 closures. Customer complaints rose as a result. The restrictions for this period were:

30 Knots	=	34.6 MPH	SET 40 MPH
35 Knots	=	40.3 MPH	CLOSURE

Table 3.

³ Source, Traffic Officer Manual, Regional Specifics, South West,
<https://highways.sharepoint.com/TrafficOfficers/Manual/SitePages/tom-wi-025.aspx>

Restrictions have recently returned to the previous state with a full closure at 46.1mph, however, customer complaints still remain relatively high. National Highways objective is to eventually return to filtering using a safer technical solution for filtering, whereby, raising the closure limit, within the bounds of safety, will reduce the number and duration of closures in the interim period.

Proposal

The proposal is to raise the closure speed to gusting 45 Knots wind speed, while keeping the speed restrictions and leeward lane restrictions unchanged, see below:

30 Knots	=	34.6 MPH	SET 40 MPH
35 Knots	=	40.3 MPH	LEEWARD LANES
45 Knots	=	51.8 MPH	CLOSURE

Table 4.

Benefits

The graph below, chart 1, shows the measured wind gusts at 3 locations on the M48 bridge for the period 06:32 on 1st October 2021 to 23:58 on 31st March 2022. This period was chosen due to:

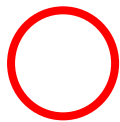
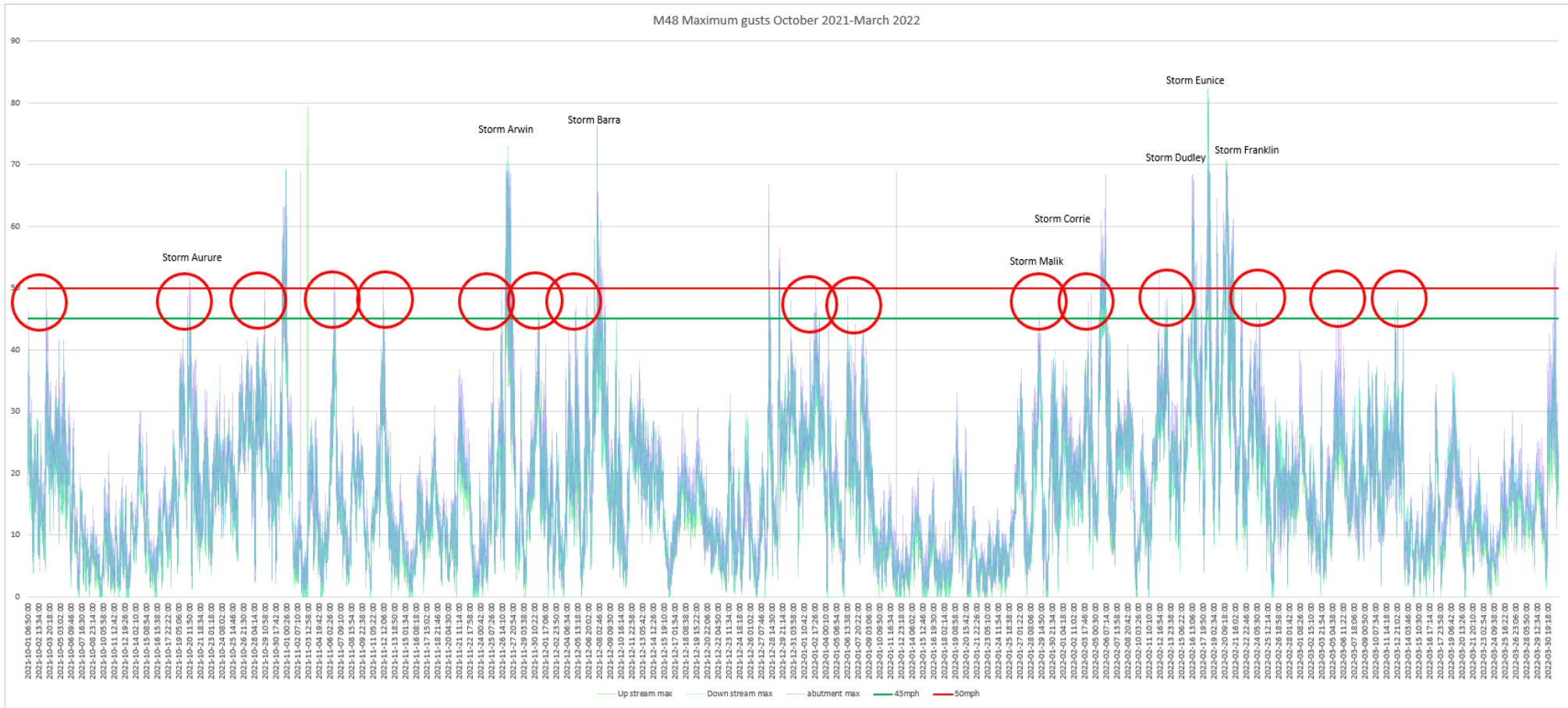
- An unusual period of storm activity with associated strong gusting winds.
- The data for this period was intact and of the best quality available.
- The anemometers on the M48 Bridge had been recently calibrated by Campbell Scientific, the manufacturers, immediately prior to this period.
- The period details some other wind phenomena, which is explored further under the heading of Risks.

The socioeconomic benefits from reducing the number of closures of the M48 Bridge are difficult to accurately measure due to the complexity of the primary, secondary and tertiary benefits. However, it is fair to state that any safe reduction in the number of closures will:

- Improve customer satisfaction.
- Reduce vehicle emissions caused by using a longer divert route.
- Support the economy in South Wales and the West of England.

The estimated improvement associated with an increase of 5 mph is approximately 70%.

Chart 1.



Areas circled in red under this proposal would not close the M48 Bridge to traffic and represent approximately 70% of closures in this period.

Risks

There are 2 main risks associated with increasing the closure speed on the M48 Bridge. They are:

1. Risk of overturning vehicles.
2. Risk of unforeseen gusts or short duration squalls.

Risk of overturning vehicles

In order to consider the risks to vehicles we must first categorise vehicles into a number of representative groups⁴. In this case we have considered the following categories:

- Vehicles under 2.1m in height.
- Small box lorry.
- Large box lorry.
- Articulated lorry
- Double-deck bus.

Under the original operating criteria, vehicles under 2.1m in height were able to continue over the M48 Bridge up to a wind speed of 60 knots, 69.1 mph. Therefore, as the proposal is well beneath this limit it can be assumed that this category will be safe and needs no further investigation.

There have been many academic studies and experiments carried out over a long period of time regarding the risk of overturning vehicles. We will be utilising a study carried out by Professor Chris J. Baker and Dr David Soper on behalf of The University of Birmingham and published by the Institute of Civil Engineers in 2018³. This study pulls together the findings of numerous previous studies giving a methodology which can be applied to the M48 Bridge.

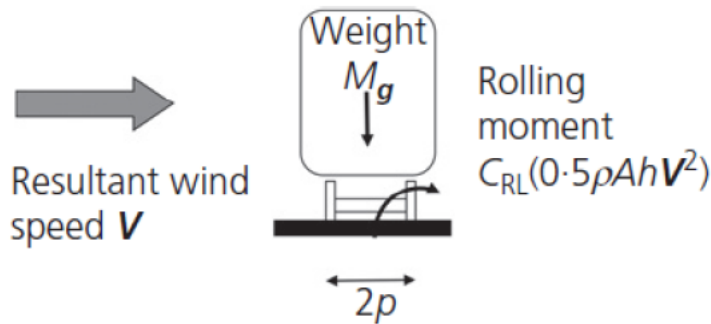
The M48 bridge is not a single structure, it is a series of structures which join to cross the River Severn and River Wye and from west to east consisting of:

1. **The Wye Bridge:** A cable-stayed bridge with two single-leg pylons supporting the bridge deck from the centre of the roadway. The deck is an orthotropic box girder design.
2. **The Beachley Viaduct:** Box girder construction supported on steel trestles.
3. **The Severn Bridge:** Conventional suspension bridge with 2 steel towers and an orthotropic steel box girder deck.
4. **The Aust Viaduct:** Twin box girder with a concrete deck.

Although the M48 Bridge has roadside barriers and parapets which will offer some wind protection, there is no formal wind protection through the length of the crossing.

⁴ Calculation of the overturning wind speed of large road vehicles at exposed sites. Professor Chris J Baker and Dr David Soper. <https://www.icevirtuallibrary.com/doi/10.1680/jtran.18.00102>

Therefore, if we theoretically consider the road surface to be suspended in mid-air with absolutely zero protection, any protection offered by the barriers and parapets will only increase the safety buffer on any theoretical wind limits.



M = Vehicle mass Kgs

g = gravity m/s^2

A = reference area gravity m/s^2

h = reference height m

ρ = density of air kg/m^3

p = wheelbase half width m

α = proportion of wheel unloading

Following the methodology developed by Professor Baker and Dr Soper⁵, it is possible to derive a wind velocity at which an overturning incident will occur; c . This is defined by the following expression:

$$c = \sqrt{\frac{\alpha M g p}{\rho C_{RL}(30) A h}}$$

This overturning wind velocity, c , can now be applied to the categories of vehicle which we believe to be at risk. This will give the limit of safety for each type of vehicle, when stationary, shown in both m/s and mph.

	Unladen Mass: kg	Laden Mass: kg	L: m	H: m	p: m	$C_{RL}(30)$	C: m/s		C: mph	
							Unladen	Laden	Unladen	Laden
Small box lorry	7000	16000	8.0	3.5	1.2	0.4	40.2	60.8	89.9	136
Large box lorry	9000	18000	12.0	3.5	1.2	0.4	37.2	52.7	83.2	117.8
Articulated lorry	16000	40000	15.0	4.0	1.2	0.5	34.3	54.2	76.7	121.2
Double-deck bus	10000	14000	12.0	4.4	1.2	0.4	29.7	35.2	66.4	78.7

Table 5.

Professor Baker and Dr Soper have shown in their report that the overturning wind velocity, c , also decreases as vehicle speed increases. Hence, the values of c in

⁵ Calculation of the overturning wind speed of large road vehicles at exposed sites. Professor Chris J Baker and Dr David Soper. <https://www.icevirtuallibrary.com/doi/10.1680/jtran.18.00102>

Table 5 can then be further modified to give a value when traveling at 40mph. As shown below in table 6:

	C.mph @40mph		Safety Margin mph	
	Unladen	Laden	Unladen	Laden
Small box lorry	81.5	>100	29.7	>50
Large box lorry	75.0	>100	23.2	>50
Articulated lorry	68.5	>100	16.7	>50
Double-deck bus	58.5	71	6.7	19.2

Table 6.

At this stage it is important to remember that the speeds quoted in Table 6 are the maximum gusting speeds acting on a totally unprotected vehicle and that the structure of the bridge, although not defined, will only add to the safety margin.

Risk of unforeseen gusts or short duration squalls

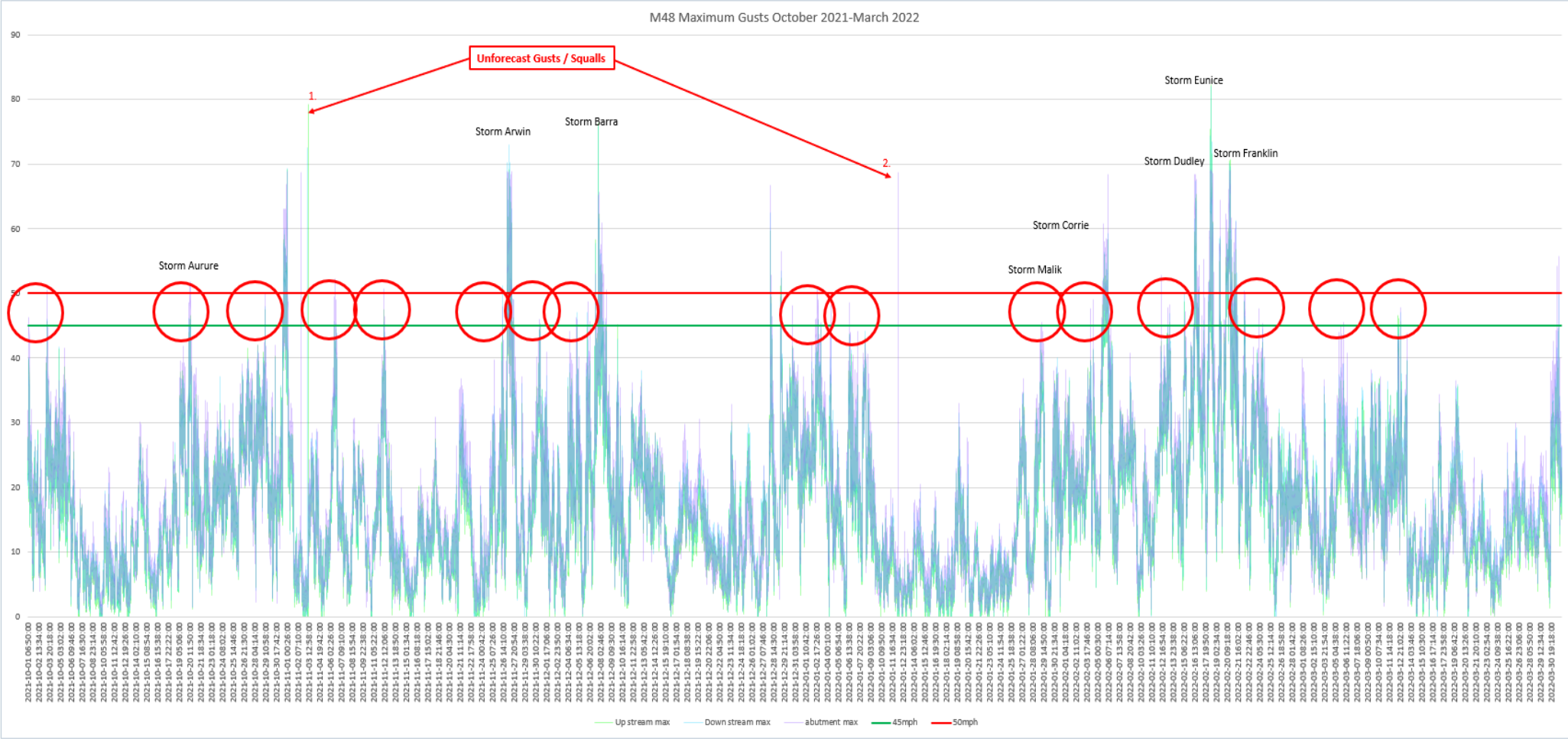
Wind is a function of heating, cooling, friction and the rotation of the earth causing movement within the layers of the atmosphere. Due to the complex nature of the movement of the atmosphere a small change many miles away may cause a sudden, unexpected gust or short-lived squall at ground level. These gusts can be very localised and are normally short lived.

Unfortunately, this type of gust cannot be accurately forecast and with no physical barriers on the crossing structure, there are few mitigating actions that can be taken to avoid incidents from such gusts which will therefore remain as a risk. It is understood that there have been instances of vehicles overturning due to such gusts.

It is proposed that the only mitigation for this form of risk available to National Highways is to ban the most vulnerable vehicles from using the M48 Bridge completely. This would only affect double-deck buses.

The selected data which has been laid out in graphical format, has 2 good examples of unforeseen gusts, see chart 2, 3 & 4, below.

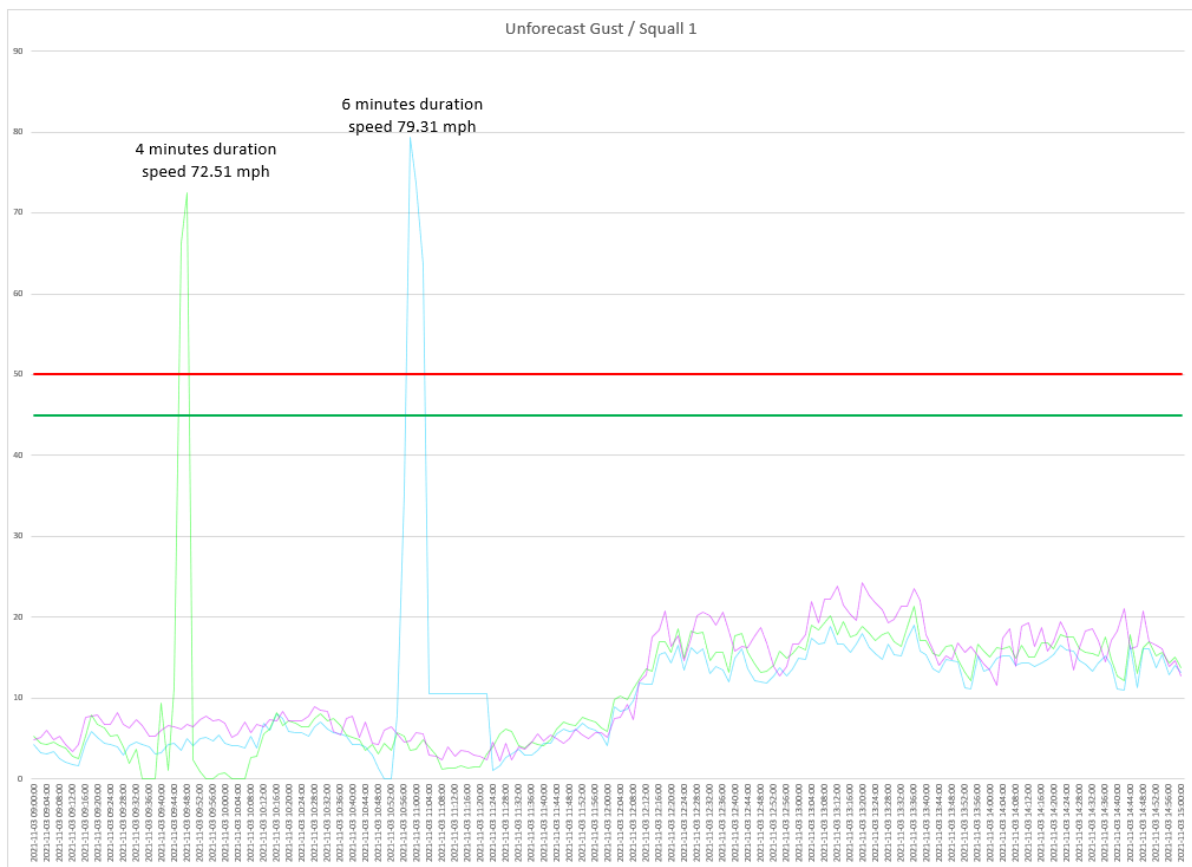
Chart 2.



Two unforeseen, very strong gusts.

Unforeseen gust 1

Chart 3.



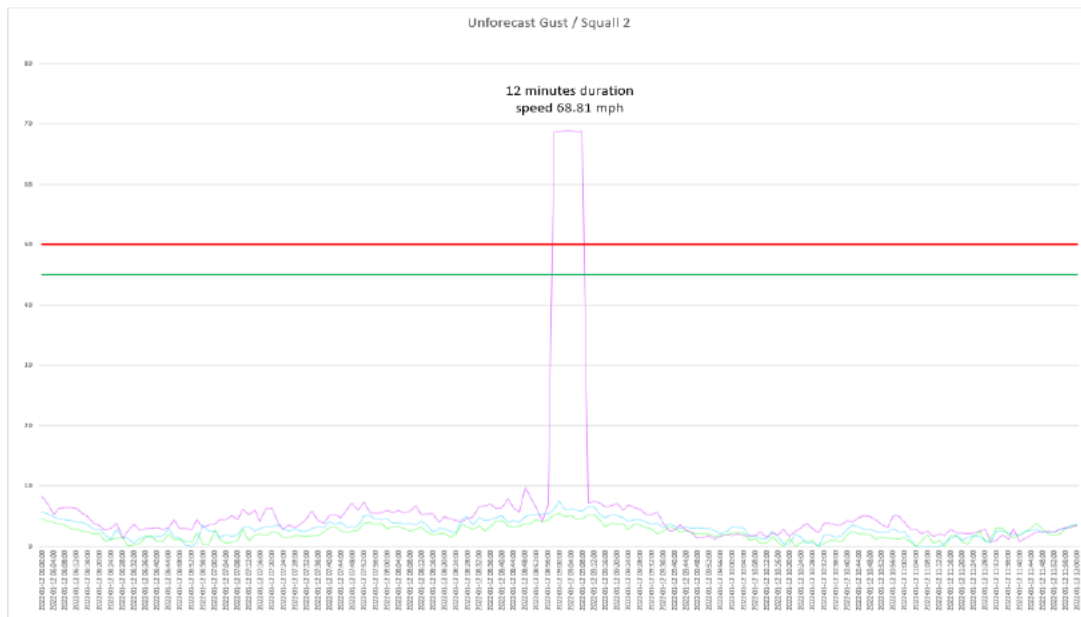
On 03/11/2021 during the morning period the ambient range of wind gusts was well below 10 mph. Two sudden spikes can be clearly seen within the wind trace. These spikes are well over 70 mph, almost 10 times the ambient conditions, for durations of 4 and 6 minutes.

Professor Baker and Dr Soper⁶ clearly state in their paper that a gust of 1 to 3 seconds is sufficient to cause a vehicle to overturn if the vehicle's value of c , as shown in the previous section, is below the gust speed. Therefore, these short periods of time are at a high risk of overturning of the most vulnerable vehicles on our network.

⁶ Calculation of the overturning wind speed of large road vehicles at exposed sites. Professor Chris J Baker and Dr David Soper. <https://www.icevirtuallibrary.com/doi/10.1680/jtran.18.00102>

Unforeseen gust 2.

Chart 4.



On 12/01/2022 during the morning period the ambient range of wind gusts was well below 10 mph, a sudden squall can be seen, 12 minutes in duration and peaking at 68.81 mph. Again, this period would be a high-risk period for any vehicles with a low value of c.

Conclusion & Recommendations

It is recommended that the proposed wind gust limits set out in table 4 are adopted as soon as possible, while a technical solution is sought to reintroduce full filtering on the M48 Bridge.

30 Knots	=	34.6 MPH	SET 40 MPH
35 Knots	=	40.3 MPH	LEEWARD LANES
45 Knots	=	51.8 MPH	CLOSURE

Table 4.

These limits give a reasonable safety margin, detailed in table 6 to continue safe operations on the M48 Bridge.

It is also recommended that to mitigate against sudden unforeseen gusts or squalls the most vulnerable vehicles, double deck buses, are banned from using the M48 Bridge and divert to the Prince of Wales bridge which offers a high degree of protection.



[Redacted], Southwest ROC Operations Manager