CAMBRIDGE CITY COUNCIL

# Air Quality Monitoring Mill Road, Cambridge

## AQ Mesh Assessment

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# Executive Summary

## Introduction

As part of the Air Quality Grant Fund for 2018/19, Cambridge City Council was awarded funding from Defra to undertake air quality monitoring for a traffic intervention using a "low cost" sensor.  This work goes towards testing the viability of these "low cost" sensors which are appearing on the market and to assess the effect of the traffic intervention on air quality.

The traffic intervention involved the temporary closure of one of the main routes from the east into Cambridge (Mill Road) whilst work was undertaken to a railway bridge which this road passes over.  The bridge works were to increase the capacity on the railway line and join up two ends of the Chisholm Trail (a walking and cycling route across Cambridge). There was a lot of interest from councillors, Cambridgeshire County Council, Greater Cambridge Partnership (City Deal funded body), members of the public and businesses on Mill Road as to the impact of the closure on air quality. Therefore these works presented the opportunity to trial low cost sensors in a real setting to both evaluate the effectiveness of the sensors and the impact to air quality of the bridge closure.

The aims of the project were:

1) Assess the potential changes in air quality as a result of a road closure
2) Assess the potential changes in traffic volumes and modes as a result of a road closure
3) Assess whether there are any link between potential traffic changes and air quality as a result of a road closure
4) Assess the performance of Low-cost monitors in a real life scenario

## Methodology

The AQ Mesh monitors (low cost sensor), $NO_2$ diffusion tubes and traffic monitors were placed on Mill Road and other roads which were part of the diversion route for the bridge closure.  Additional air quality monitoring was provided by Cambridge City Council's continuous monitors, which were also used to calibrate the AQ Mesh Monitors.

The data from the monitoring for the closure period and for a number of months following the closure period are presented in this report.

## Conclusions

The report has assessed the data against the aims and has the following conclusions:

All of the air quality monitoring showed that pollutant concentrations followed expected seasonal trends with no discernable significant changes in pollutant concentrations during the road closure.

Traffic volumes altered significantly on some of the roads which were closed and which formed part of the diversion route. However there was no discernable change in vehicle mode as a result of the road closure.

Despite the significant changes in traffic volumes on some of the roads in the study area, there was no discernable corresponding change in air pollutant concentrations. Changes in air pollutant concentrations appeared to be affected by seasonal variation rather than changes in traffic volumes.

Nitrogen dioxide ($NO_2$) concentrations followed the same diurnal pattern as the traffic volumes on the majority of the roads in the study area. No diurnal pattern was seen in the particulate concentrations on any of the roads in the study area which matched the diurnal profile for the traffic data.

The AQ Mesh monitors were easy to install and provide a good indication of pollutant trends. However, monitored concentrations of $NO_2$ by the AQ Mesh appear to be affected by high temperatures and therefore are less reliable method for monitoring absolute concentrations when compared to the continuous monitors (approved method). The raw data from the AQ Mesh monitors requires subsequent QA/QC checks and calibration. This could affect the resources required for projects using these monitors as this work would need to be undertaken prior to analysis of the data.

# Contents

# 1. Introduction

As part of the Air Quality Grant Fund for 2018/19, Cambridge City Council was awarded funding from Defra to undertake air quality monitoring for a traffic intervention using a “low cost” sensor. This is part of the work towards testing the viability of these “low cost” sensors which are appearing on the market and to assess the effect of the traffic intervention on air quality.

The traffic intervention involved the temporary closure of one of the main routes from the east into Cambridge (Mill Road) whilst work was undertaken to a railway bridge which this road passes over. The bridge works were to increase the capacity on the railway line and join up two ends of the Chisholm Trail (a walking and cycling route across Cambridge). There was a lot of interest from councillors, Cambridgeshire County Council, Greater Cambridge Partnership (City Deal funded body), members of the public and businesses on Mill Road as to the impact of the closure on air quality. Therefore these works presented the opportunity to trial low cost sensors in a real setting to both evaluate the effectiveness of the sensors and the impact to air quality of the bridge closure.

## 1.1. Project Aims

The project aims which we therefore assessed were:

1) Assess the potential changes in air quality as a result of a road closure
2) Assess the potential changes in traffic volumes and modes as a result of a road closure
3) Assess whether there are any link between potential traffic changes and air quality as a result of a road closure
4) Assess the performance of Low-cost monitors in a real life scenario

The project partnered with Cambridge County Council who installed the traffic monitoring in the area to allow us to assess the effect of the closure on traffic volumes and mode of transport.

Cambridge University were also involved in the project looking at the impacts on health of the closure, public behaviour and public perceptions.

Cambridge County Council and Cambridge University have produced separate reports in relation to their specific study areas.

# 2. Methodology

Cambridge City Council was informed that Network Rail was undertaking major works to the railway bridge on Mill Road. The work would require the bridge to be closed to traffic during the duration of the works. The works were to open up one of the railways arches to allow for additional track capacity for the line and also to allow the Chisholm Trail (a new walking and cycling trail across Cambridge) to be linked via a tunnel, rather than creating a diversion over the bridge, which would have involved some form of pedestrian crossing.

The bridge was due to be closed to all traffic from 1st July 2019 until 27th August 2019, a total of 7 weeks. This was subsequently revised with the bridge being closed to all motorised traffic for the closure period but mainly open for cyclists and pedestrians. There were a number of dates during the working period where the bridge was also closed to pedestrians and cyclists to ensure that particular works could take place without endangering the public.

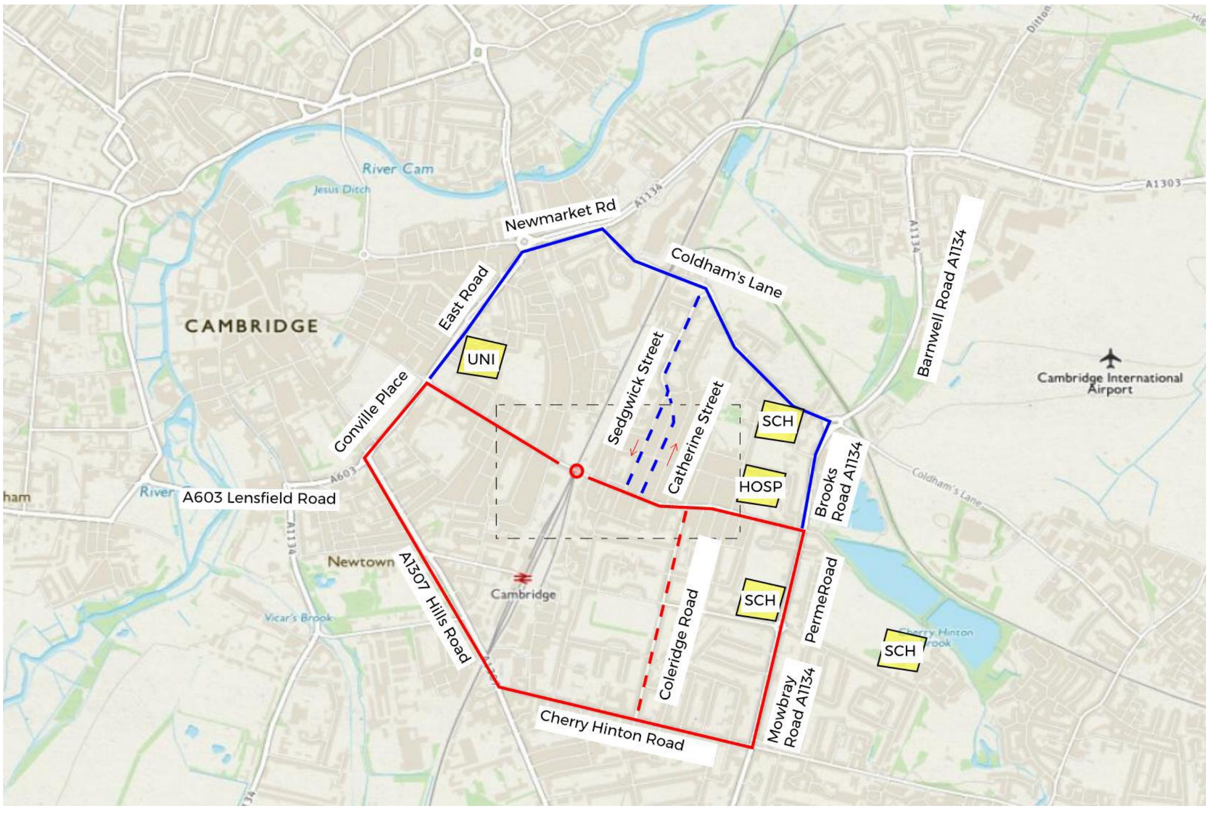
Diversion routes were put in place to allow traffic to be re-routed. Access was maintained for residents and businesses. A bus route which usually passes the length of Mill Road was also re-routed. Air quality and traffic monitoring was put in place on both the diversion routes as well as Mill Road.

The study was based on just the bridge being closed and no other factors. However, the first week of the bridge closure major gas works began on Mill Road which closed one side of the road eith side of the bridge resulting in the need for temporary traffic lights to control traffic movements. In addition a fire on Mill Road close to its junction with Devonshire Road, closed this section of Mill Road for at least a week. These additional factors are discussed as part of the review of results in section 3.

## 2.1. Area of Study

Mill Road is a major route from the east into the city of Cambridge. It connects two major roads, East Road and the inner ring road. One of Cambridge's multi-storey car parks is at the junction of Mill Road and East Road. The road is home to a number of independent small shops and businesses, as well as being a residential area and is heavily used by cars, vans and bikes. It also provides a route to Cambridge Station avoiding other major roads in the area and is therefore heavily frequented by taxis. Mill Road Bridge which was subject to the closure is located in the central section of the road. The closure only closed the bridge but this prevented through traffic from either end. It did however allow the normal route to Cambridge Station used by the taxis to remain open. The closure allowed access to those roads on either side of the bridge for residents and businesses. The eastern and western end of the road was therefore open. The area surrounding Mill Road is mainly residential with narrow terraced streets and narrow pavements.
Diversion routes were put in place for vehicles which used Mill Road as a through road to be re-routed on major roads in the area.
The location of Mill Road in Cambridge and the diversion routes are shown in Figure 2.1.

## Figure 2.1 Mill Road and Diversion Routes




**Diversion Route North Diversion**
Mill Road, Cambridge - Usrn: 5401489
Brooks Road, Cambridge - Usrn: 5400520
*> Sedgwick Street, Cambridge - Usrn: 5400500*
*> Catharine Street, Cambridge - Usrn: 5400473*
Cromwell Road, Cambridge - Usrn: 5400523
Coldhams Lane (C298), Cambridge - Usrn: 5401480
Newmarket Road, Cambridge - Usrn: 5401491
East Road, Cambridge - Usrn: 5401344

**South Diversion**
Mill Road, Cambridge - Usrn: 5401489
*> Coleridge Road, Cambridge - Usrn: 5401481*
Perne Road (A1134), Cambridge - Usrn: 5401492
Cherry Hinton Road (C235), Cambridge - Usrn: 5400564
Hills Road, Cambridge - Usrn: 5401485
Gonville Place, Cambridge - Usrn: 5400426

## 2.2. Monitoring

### 2.2.1. Low costs monitors (AQ Mesh)

Using the 2018/2019 air quality grant funding from Defra, eight AQ Mesh monitors were purchased. The AQ Mesh monitor was chosen in this instance as Cambridge City Council had previously worked with Cambridge University in developing the monitors and therefore were familiar with the technology. In addition the monitors could be used with solar panels which are advantageous when installing a large number of monitors over a wide area where power sources may be limited. Cambridge City Council was keen to see how the monitors performed using this form of power.

One of the AQ Mesh monitors was placed with a continuous monitor at Gonville Place. The other AQ Mesh monitors were placed at either end of Mill Road and on the diversion routes around Mill Road. Where possible the low cost monitors were situated in close proximity with the traffic monitors, which were installed by Cambridgeshire County Council (2.2.4).

A picture of each AQ Mesh monitor and its location can be found in Appendix A.
The AQ Mesh monitors use a electrochemical method to monitor gaseous pollutants such as $NO_2$ and an optical particle counter to monitor particles. The measurement of particulates by the AQ Mesh is undertaken by using a pump to draw air into the instrument for sampling. As the pump requires more power than the internal battery supplied with the AQ Mesh an additional source of power is required. The power source can either come from street furniture such as a lighting column or from a large solar panel which can be fixed alongside the monitor. We were able to install solar panels for each of the monitors, which meant we did not need to connect to an external power source such as a lamp columns, although lamp columns were used to attach the monitor to as they are convenient street furniture.
All of the AQ Mesh monitors measured nitrogen dioxide ($NO_2$), particulates (both $PM_{10}$ and $PM_{2.5}$), carbon dioxide and temperature.
All of the AQ Mesh monitors were installed in 1st week of July and left in situ until January 2020. We had originally hoped to install the AQ Mesh monitors in May/June but there were delays with procurement.
At the end of the monitoring period in January, all of the AQ Mesh monitors were moved to the continuous monitor at Gonville Place and run for a period of 3 weeks. This was to allow the monitors to be compared against each other to see how much they had drifted from the original settings as well as seeing how closely all of the AQ Mesh monitors matched the continuous monitor. This process assisted us in calibrating the AQ Mesh monitors.

Appendix B details the calibration methodology used for the AQ Mesh monitors.

### 2.2.2 Diffusion Tubes

Cambridge City Council has a comprehensive network of around 80 $NO_2$ diffusion tubes spread over the City. There were 2 diffusion tubes located on Mill Road prior to the project being undertaken. However it was thought that a further 14 diffusion tubes would assist with the project and fill gaps in the network. To ensure consistency with the other tubes in Cambridge City's network the same supplier and preparation method was used for the additional Mill Road tubes. Details of the tube preparation methodology and supplier can be found in Appendix C.

The additional 14 tubes were installed in February 2019 to ensure there was monitoring in place before the bridge closure took place. The additional tubes remained in place for 12 months until January 2020. The tubes were placed where possible close to the AQ Mesh monitors. We were keen to see whether the AQ Mesh monitors and the diffusion tubes showed similar trends in concentrations.

Those tubes which were already in situ were in place for 3 years prior to the project. This allows comparisons between years to be drawn to see whether changes in trends in the tubes were the results of the road closure or related to seasonal variations.

### 2.2.3 Continuous Monitors

Cambridge City Council operates 5 continuous monitors in its area. The one within the study area was Gonville Place. Gonville Place measures $NO_2$, $PM_{10}$ and $PM_{2.5}$. This monitor has been in situ for a number of years and therefore provides a good reference point for data. It also allows us to see whether there are any differences in air quality as a result of the bridge closure or whether these differences are related to seasonal variations.

The monitor samples every 15 minutes with the data being presented as hourly averages on Cambridge City Council's website, which allows members of the public and other interested parties to view and download the data.

The monitor is maintained according to the requirements of Local Air Quality Management Technical Guidance 2016. Further details of the quality assurance, servicing and calibration procedures can be found in Appendix D.

### 2.2.4 Traffic

Cambridge County Council, via their Smart Cambridge Programme, installed 15 Vivacity traffic sensors at various locations around Mill Road. These sensors used cameras to record numbers of cyclists, pedestrians, cars and other vehicles (LGV, OGV1 and OGV2) before, during and after the bridge closure to assess the effect on traffic and also the effect on the mode of traffic used in the area.

The cameras record the types of travel mode used and then log this on their internal data loggers. The original camera feed is then deleted to ensure data is anonamised.

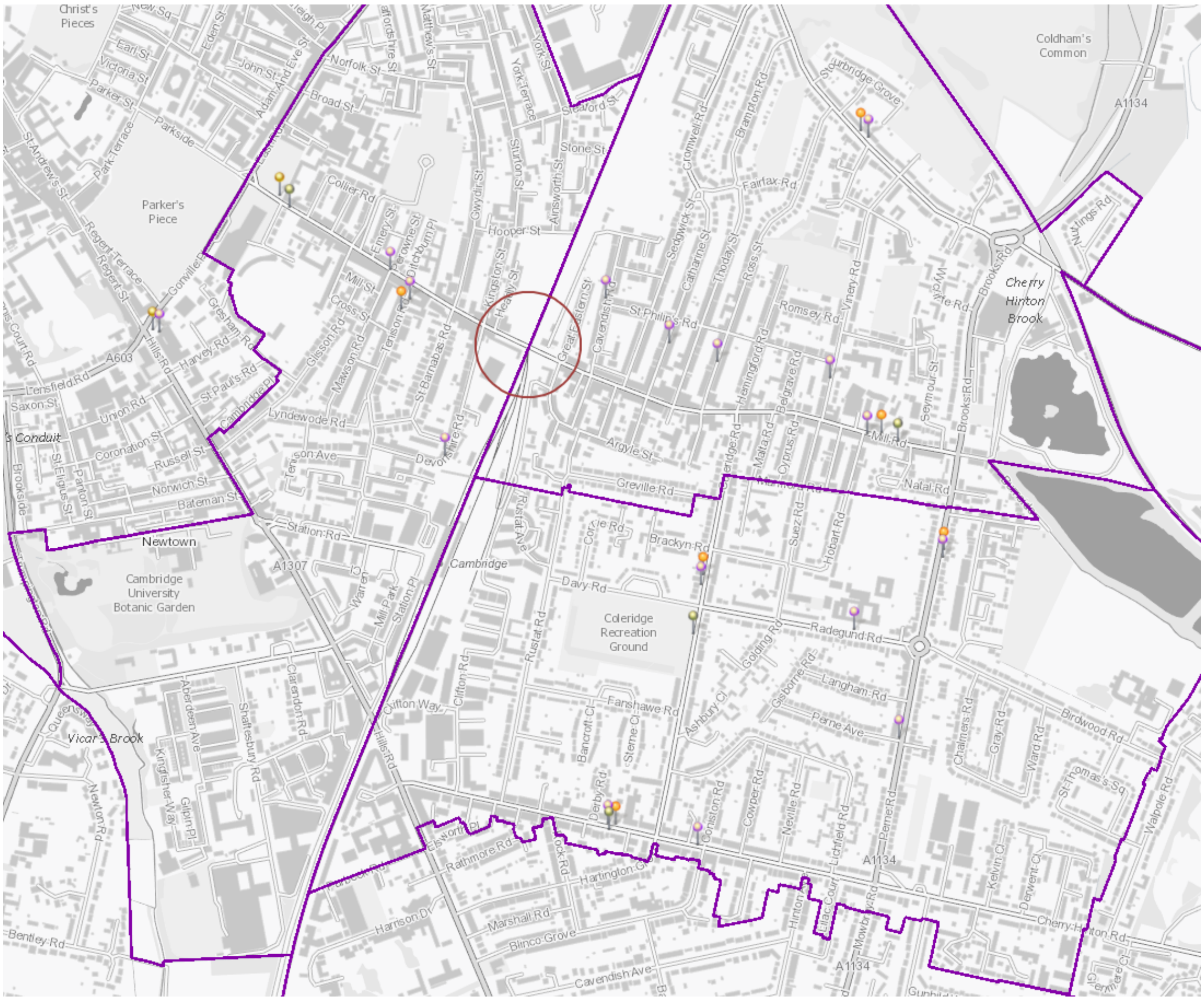
To ensure the sensors were recording data accurately manual counts of travel mode were undertaken at a number of sensor locations during the baseline phase. These showed that the data from the sensors accurately recorded the traffic data.

Data was provided as hourly average readings.

### 2.2.5 Location of Monitors

The location of the monitoring used on Mill Road is shown in Figure 2.2.

**Figure 2.2 Location of Monitoring**




Key: Ward Boundaries    AQ Mesh Monitor    Traffic Monitor

Area of closure    Diffusion Tube

### 2.2.5 Data Presentation:

The diffusion tube data, raw hourly AQ Mesh data and the traffic data was presented on the Cambridgeshire Insight website. This is a platform provided by Cambridgeshire County Council which allows data gathered on public projects to be made accessible to the general public in an open data format.

The traffic data was downloaded from this website for use in this project as hourly counts of vehicle type.

The data from the continuous monitors is made available to the pubic via the Cambridge City Council's website.

# 3. Results

The results are presented for each monitoring type on their own and then as cumulative results to see if individual trends are refelected across all monitoring types for air quality and if there is any connection between air quality and traffic data.

## 3.1 Continuous Monitors

There are five continuous monitors in Cambridge, one is located in the vicinity of Mill Road, at Gonville Place. Data from all of the monitors has been looked at for the project. The monitor at Gonville Place has also been used to assist with the calibration of the AQ Mesh moniotrs (Section 2.2.1) and is the location for the triplicate set of tubes for Cambridge City Council's diffusion tube survey.

The results for the continuous monitors for $NO_2$, $PM_{10}$ and $PM_{2.5}$ for 2019 are shown in Appendix E.

### 3.1.1 $NO_2$

All of the five continuous monitors in Cambridge measure $NO_2$. The trend for all of the monitors show higher $NO_2$ concentrations in the winter months with lower concentrations in the summer months. This is the normal seasonal variation in $NO_2$ concentrations across the UK. This is shown in Figure 3.1.

The monitor at Parker Street appears to show higher $NO_2$ concentration during the bridge closure, than would be expected at this time of year. This monitor is located in a street canyon and as the highest peaks in $NO_2$ concentrations were at times of high temperatures in Cambridge, the meteorology at this location could contribute to higher $NO_2$ concentrations.

The monitor at Gonville Place does not show a peak in $NO_2$ concentrations during the third week of the road closure as shown by the other continuous monitors. This is due to a loss of data at this monitor as there was an issue with the air conditioning unit at this site. The air conditioning unit failed due to a period of extremely warm weather when Cambridge recorded the highest temperature in the UK. This is explored in more detail in Appendix B.

Reviewing the data at Gonville Place for the past 4 years shows that during the road closure in comparison to previous years, $NO_2$ concentrations were lower in 2019, so although there appears to be slightly higher concentrations during the bridge closure these concentrations are not higher than concentrations at this time in previous years. This is shown in Figure 3.2.

In conclusion, the bridge closure does not appear to have affected $NO_2$ concentrations as recorded by the continuous monitor at Gonville Place.

**Figure 3.1 Weekly average $NO_2$ Gonville Place, Montague Road, Parker Street, Newmarket Road and Regent Street 2019**

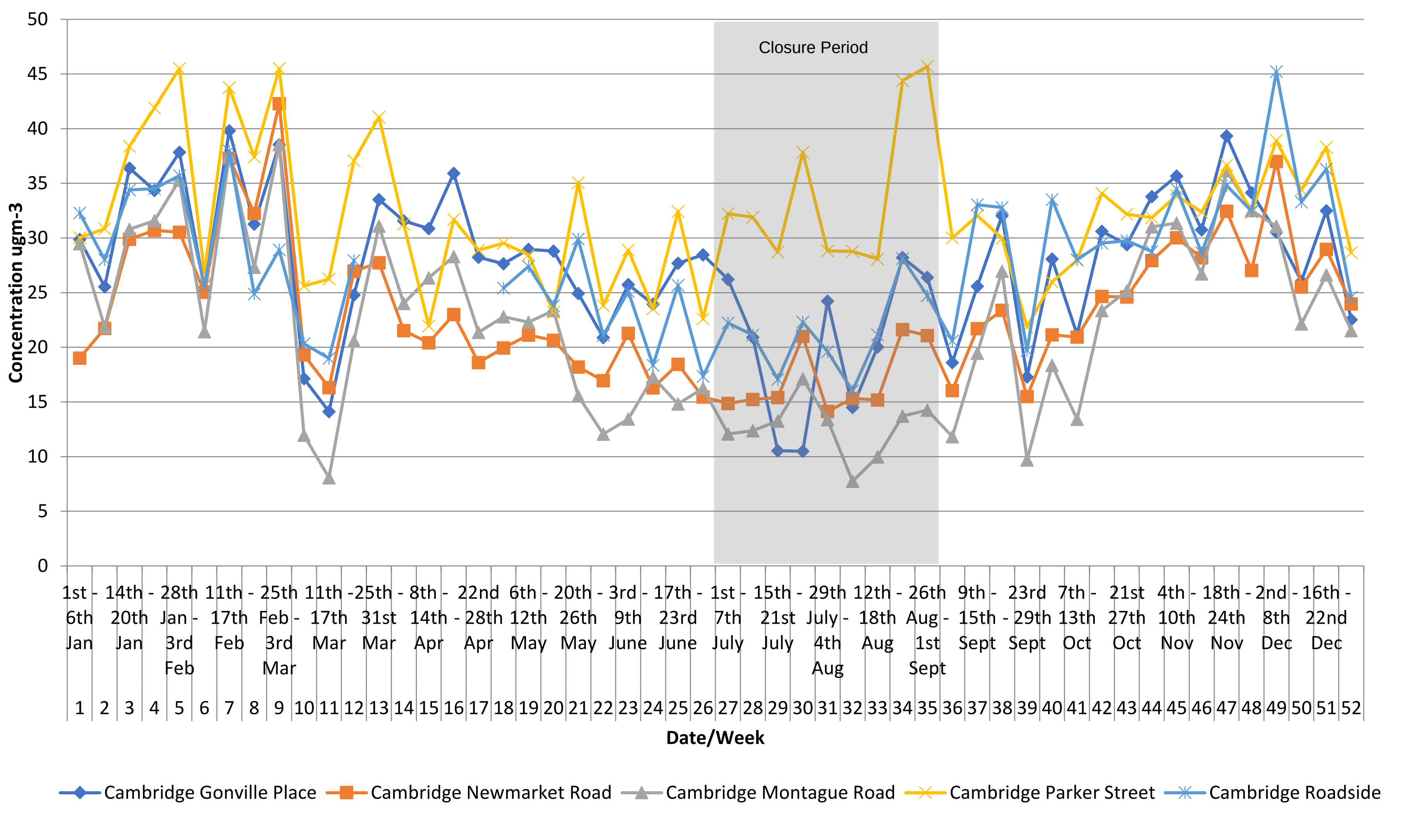
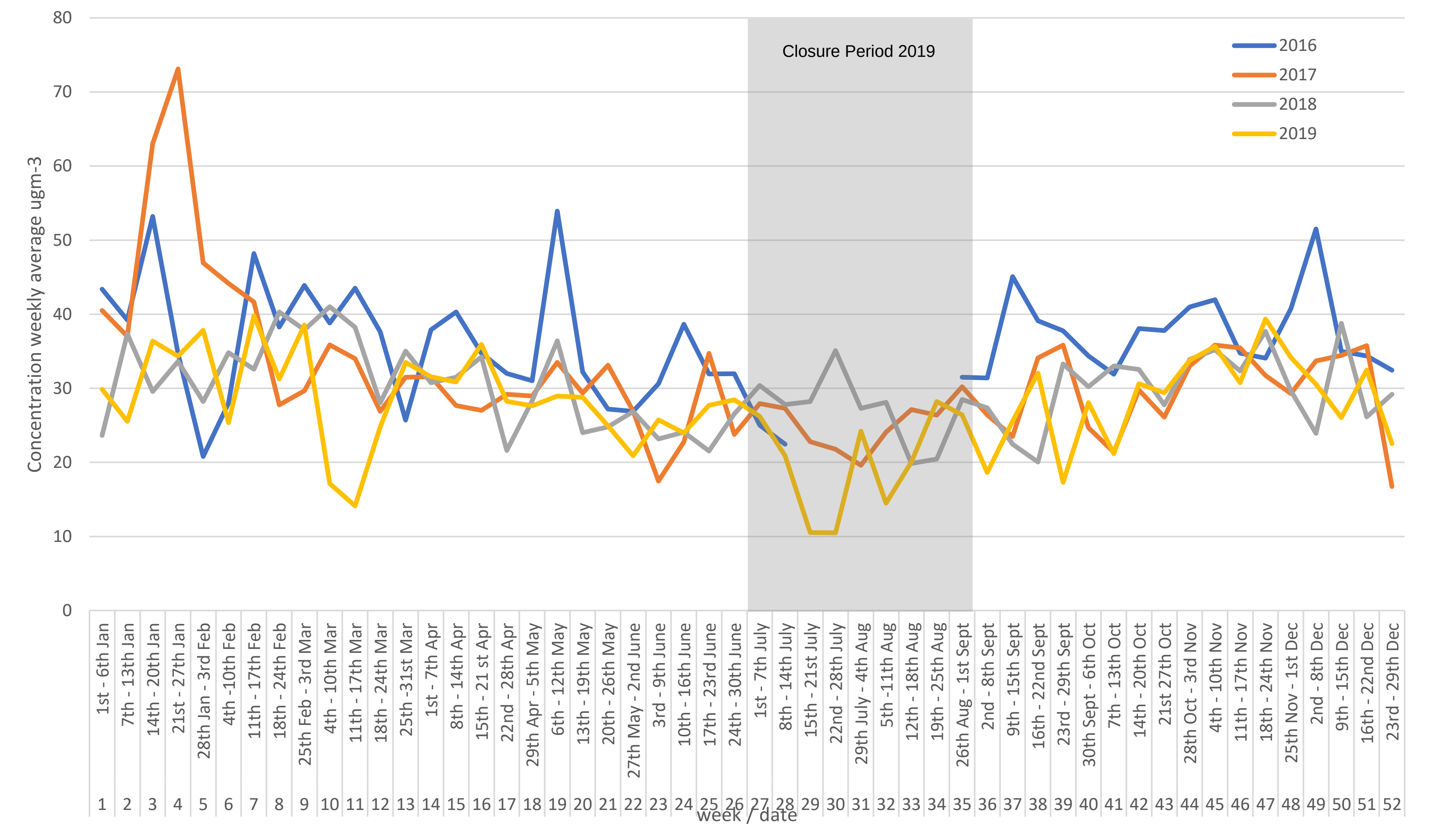


**Figure 3.2 Weekly average $NO_2$ Gonville Place 2016 -2019**



### 3.1.2 $PM_{10}$

Three of the continuous monitors in Cambridge measure $PM_{10}$. These are located at Montague Road, Gonville Place and Parker Street.

$PM_{10}$ concentrations across the city are subject to seasonal variation, with typically higher concentrations in the winter months in comparison to the summer months. In addition wind directions and speeds can also have a significant impact on $PM_{10}$ concentrations as the UK. In southern England in particular, is subject to "pollution episodes" where particulates are transported over large distances from mainland Europe and Africa. There were no pollution episodes in July or August 2019 for $PM_{10}$.

During the closure period in 2019 the general wind direction was from the south-west, south and south-east. Wind speeds were generally low. These wind directions and speeds are consistent with the good weather experienced over this period.

In general the monitoring for $PM_{10}$ at the continuous monitors show a similar trend with higher concentrations in the first part of 2019 with lower concentrations during the rest of the year. The monitor at Gonville Place recorded, in general, lower concentrations than the other monitors during 2019 as shown in Figure 3.3, with the exception of the the road closure period where the monitor at Gonville Place recorded slightly higher concentrations than the other monitors in the City.

Looking through the data for Gonville Place for the past 4 years, shown in Figure 3.4, there does not appear to be a significant difference in the data recorded at Gonville Place for 2019 in comparison to the other years.

In conclusion, the bridge closure did not result in an increase in $PM_{10}$ concentrations as recorded by the continuous monitor at Gonville Place.

**Figure 3.3 Weekly average $PM_{10}$ Gonville Place, Montague Road, Parker Street 2019**

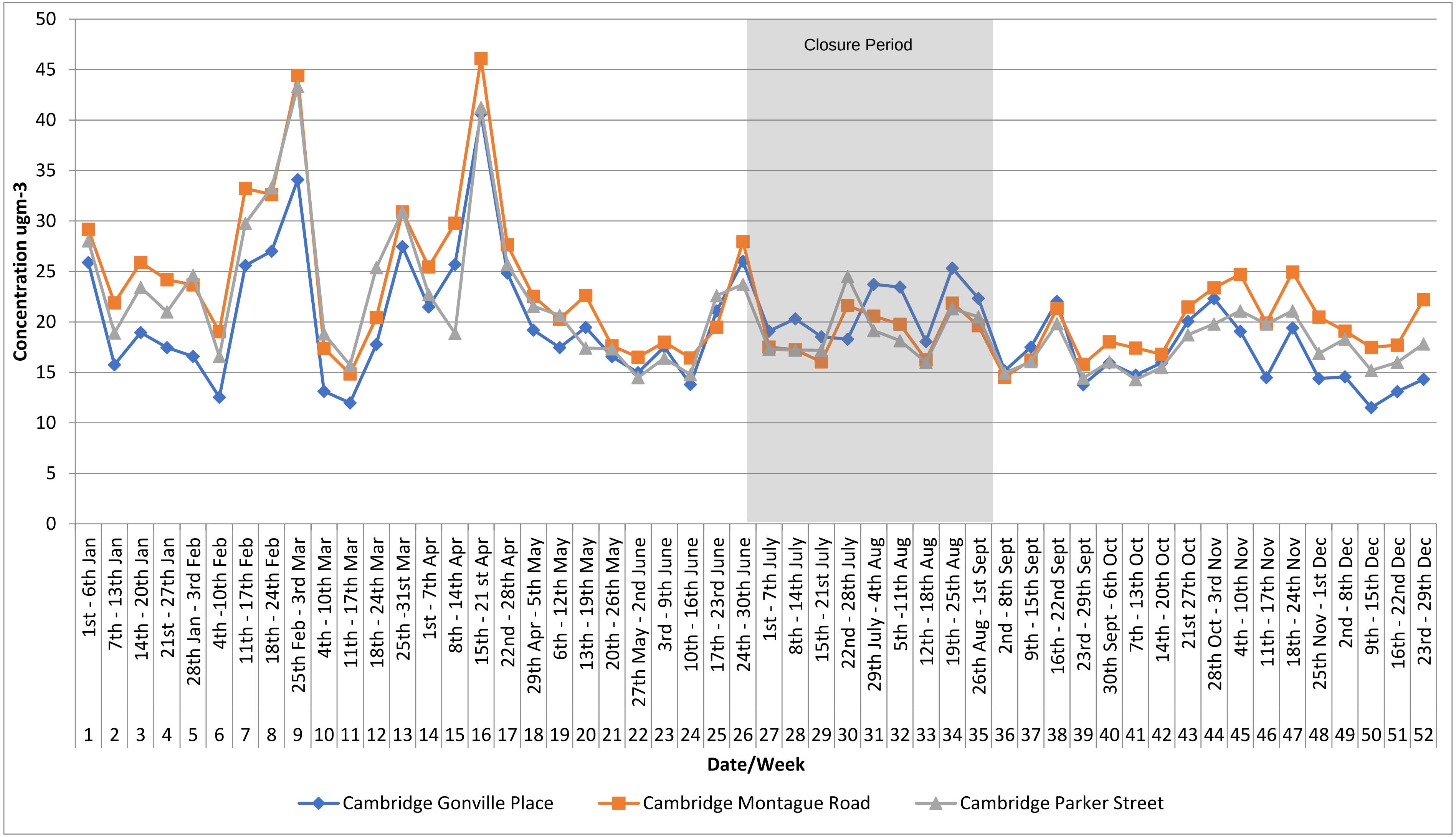
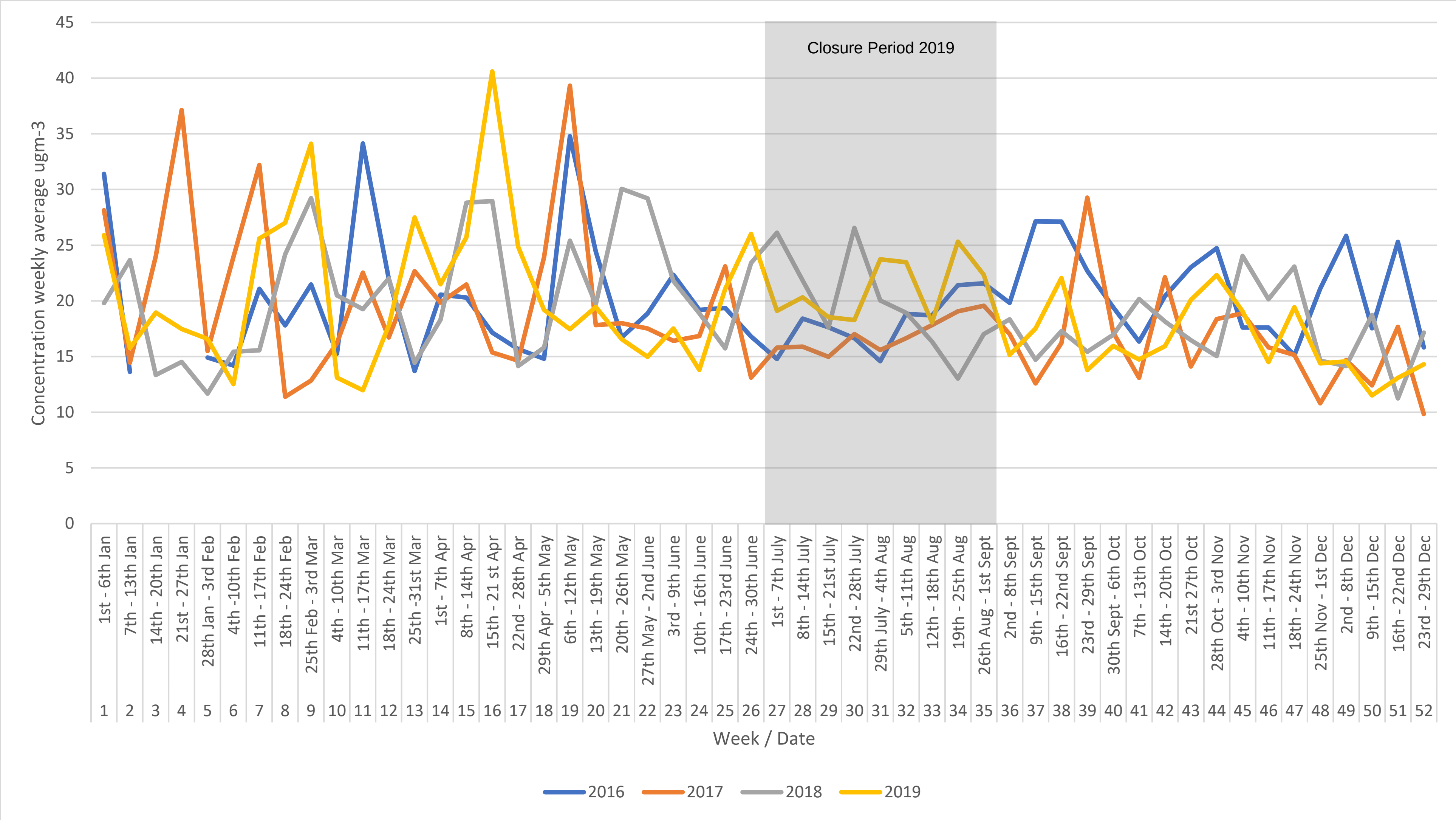


**Figure 3.4 Weekly average $PM_{10}$ Gonville Place 2016 -2019**



### 3.1.3 $PM_{2.5}$

Only two of the continuous monitors in Cambridge measure $PM_{2.5}$, these are Gonville Place and Newmarket Road.

As with $PM_{10}$, $PM_{2.5}$ concentrations across the city are subject to seasonal variation, usually higher concentrations in the winter months in comparison to the summer months. In addition wind directions and speeds can also have a significant impact on $PM_{2.5}$ concentrations as the UK. In southern England in particular, is subject to "pollution episodes" where particulates are transported over large distances from mainland Europe and Africa. There were no pollution episodes in July or August 2019 for $PM_{2.5}$.

For most of 2019 the two monitors recorded similar concentrations of $PM_{2.5}$, with the monitor at Newmarket Road consistently recording concentrations that were lower than at Gonville Place, which is usual for these two sites. This is shown in Figure 3.5.

The period of the road closure saw both monitors record some of the lowest concentrations of $PM_{2.5}$ for the whole year, although this is consistent with the expectation for seasonal variation.

Comparing previous years $PM_{2.5}$ concentrations at Gonville Place shows that concentrations recorded in 2019 were in general lower during the road closure than for the same time period in previous years. This is shown in Figure 3.6.

In conclusion there appears to be no change in $PM_{2.5}$ concentrations as recorded by the continuous monitor at Gonville Place as a result of the road closure.

**Figure 3.5 Weekly average $PM_{2.5}$ Gonville Place and Newmarket Road 2019**

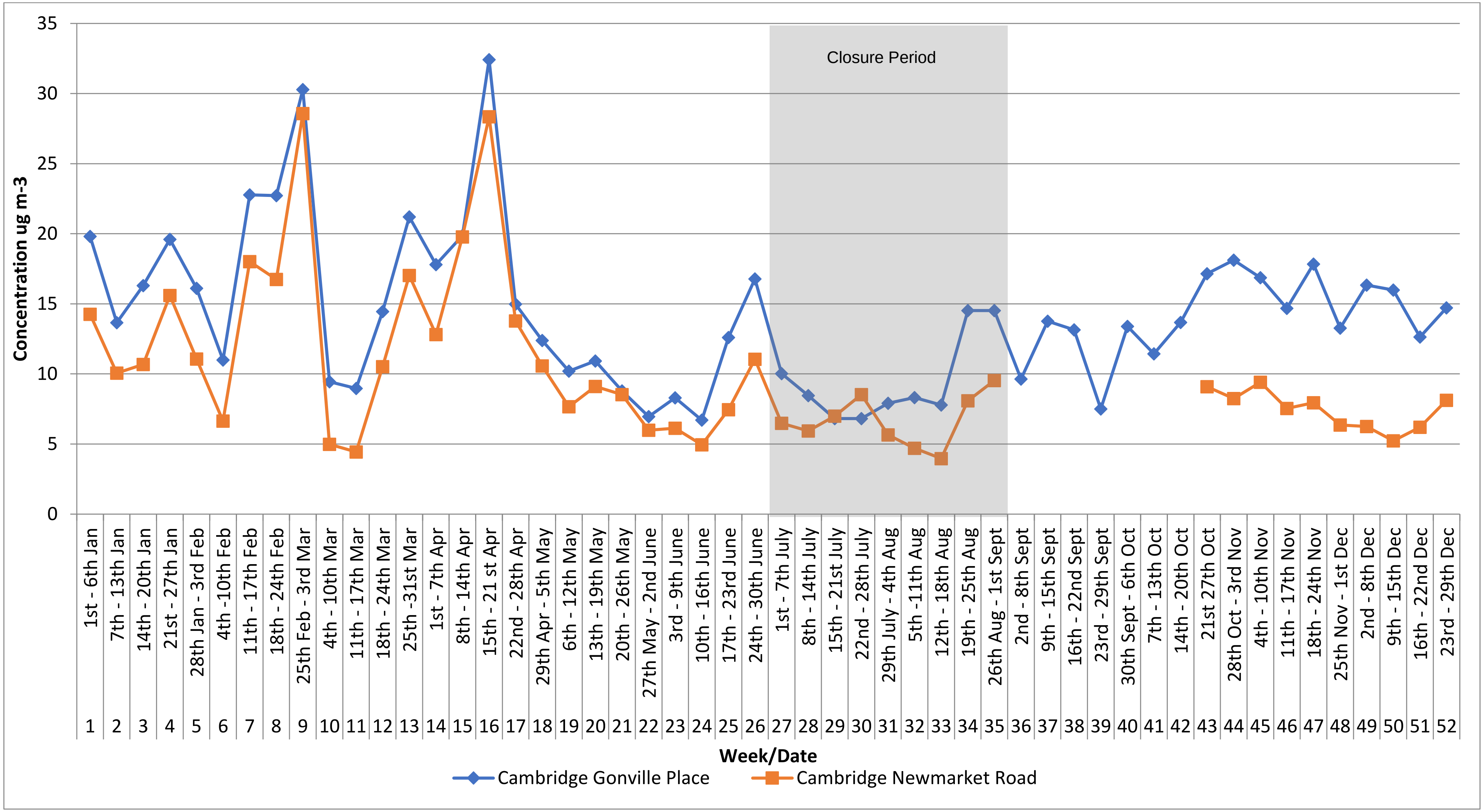
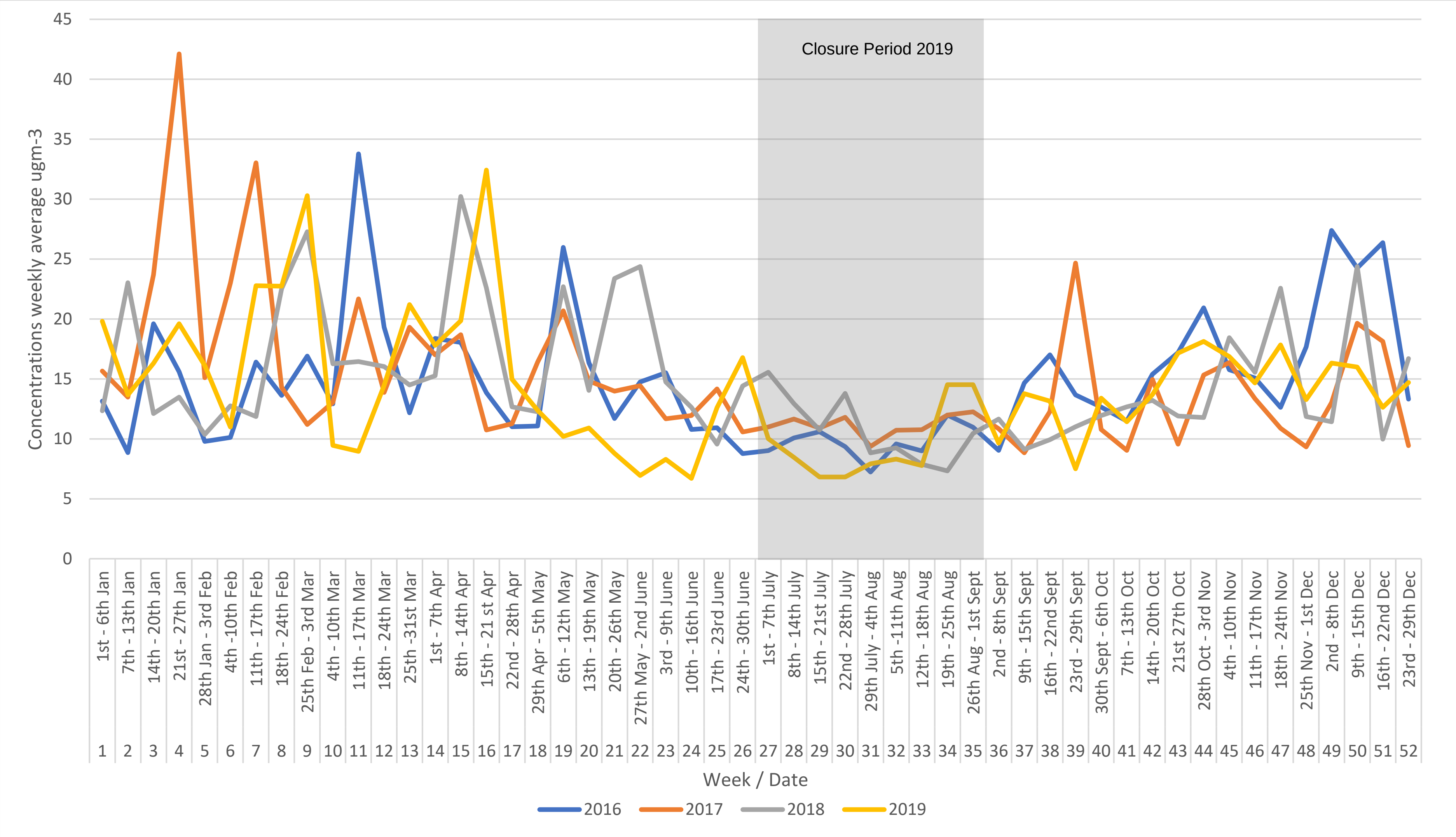


Figure 3.6 Weekly average $PM_{2.5}$ Gonville Place 2016 -2019



## 3.2 AQ Mesh

The AQ Mesh monitors were placed at locations as shown in Figure 2.2. The following sections detail results from the monitors individually and then as a comparison over the period of monitoring. The results are shown for $NO_2$, $PM_{10}$ and $PM_{2.5}$. All results shown are calibrated results as per the calibration method outlined in Appendix B. The monitoring period was from 8th July until the end of 2019. The closure of Mill Road was from 1st July to 27th August 2019. The closure period includes weeks 1-7 as shown on the charts.

Data capture for monitors 189 (Mill Road West) and 292 (Coldhams Lane) was affected durting August which makes comparison with the closure period and the re-opening of the bridge difficult at these two locations.

The results for the AQ Mesh monitors for $NO_2$, $PM_{10}$ and $PM_{2.5}$ for 2019 are shown in Appendix F.

### 3.2.1 $NO_2$ Results Summary

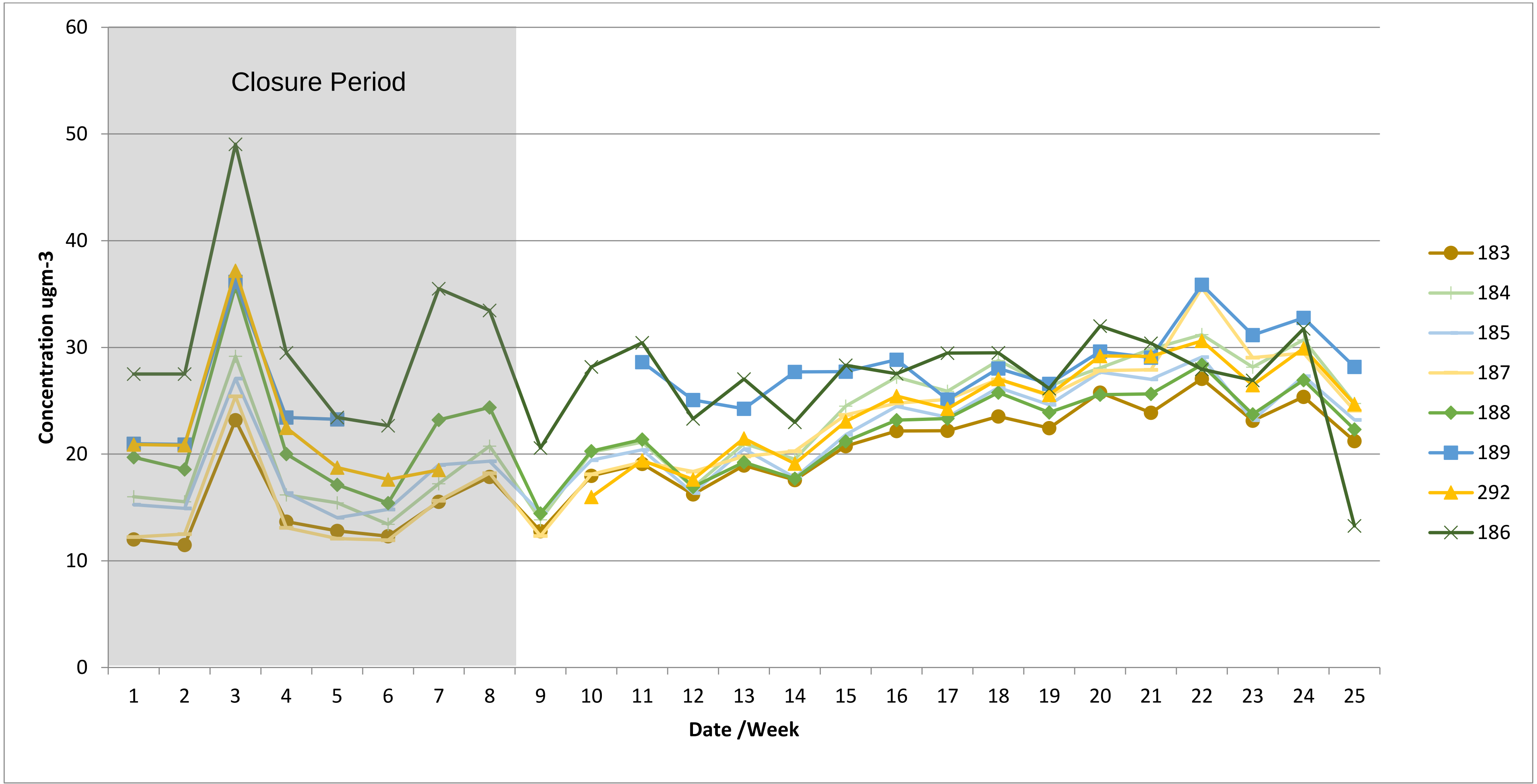
The results from all the AQ Mesh Monitors are summarised in Figure 3.7 for $NO_2$, as weekly average concentrations. All of the AQ Mesh monitors show a peak in concentrations around 3rd week of the closure, with a slightly smaller peak at the end of August. These peaks in concentrations coincide with days of very high ambient temperatures, suggesting that temperature can affect the results.

Figure 3.7 shows much greater variability in $NO_2$ concentrations during the bridge closure period with much less variability in concentrations from the beginning of October and for the rest of the monitoring period. Monitors 184 (Tenison Road) and 187 (Coleridge Road) appear to show lower concentrations during the bridge closure than the other monitors but by October are showing higher concentrations than the other monitors. It is unclear whether this change is a result of the road closure or seasonal variation.

In general the monitoring locations showed seasonal trends in $NO_2$ concentrations, with lower concentrations over the summer months and increases in $NO_2$ concentrations through October and November. With the exception of the spike in concentrations in week 3 and 7. Monitor 186 (Gonville Place) appears to show less of this seasonal profile with less variability in concentrations as time passes from Summer into Autumn, as concentrations increased during October rather than when the bridge reopened at the end of August.

Diurnal profiles were also created for each site. These showed that concentrations of $NO_2$ showed the typical pattern of a peak in the morning around 8am and a peak in the evening around 5pm. By comparing the diurnal profile of the bridge closure period with the total monitoring period showed some differences at the monitoring locations. These graphs showed that during the bridge closure the majority of monitoring locations showed lower $NO_2$ concentrations during the morning and evening peak than for the total period. In general $NO_2$ concentrations in the evenings for both the bridge closure period and the total period were similar. Monitor 186 (Gonville Place) did not follow this trend with the diurnal profile being of similar concentrations for both the total period and the period of the bridge closure.

**Figure 3.7 Comparison of $NO_2$ weekly averages AQ Mesh**




Notes: 183-Mill Road East, 184-Tenison Road, 185-Cherry Hinton Road, 186-Gonville Place, 187-Coleridge Road, 188-Perne Road, 189 Mill Road West, 292-Coldhams Lane.

### 3.2.2 $PM_{10}$ Results Summary

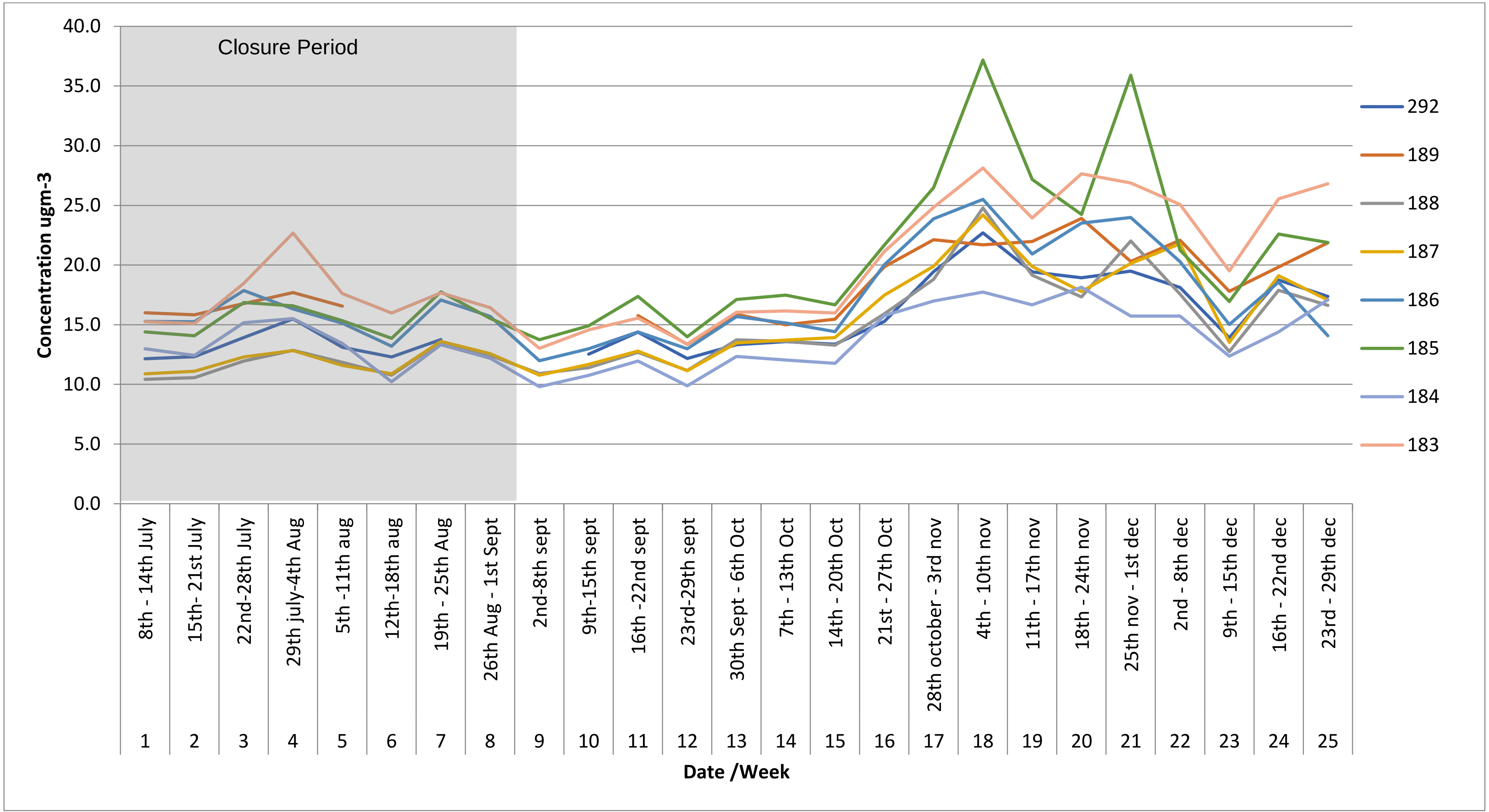
The results from all the AQ Mesh Monitors are summarised in Figure 3.8 for $PM_{10}$, as weekly average concentrations.

Figure 3.8 shows a clear trend of lower $PM_{10}$ concentrations at all locations prior to October when concentrations rise rapidly and remain at a higher concentrations level through November and January. Some locations do appear to show high concentrations of $PM_{10}$ during November particularly locations 185 (Cherry Hinton Road) and 183 (Mill Road East). Both locations have shown higher concentrations than the other locations throughout the monitoring period. However there is not a clear change in concentrations between the closure period and the re-opening of the bridge suggesting that the road closure has had no effect on $PM_{10}$ concentrations and the change in concentrations is actually seasonal variation.

All of the monitoring locations showed a spike in concentrations of varying concentrations on 3rd August between 4am and 7am. This spike in concentrations was not shown in $PM_{2.5}$ concentrations and suggests a localised source of $PM_{10}$. The wind direction at this time was from east. Unfortunately we haven't been able to identify this source.

The diurnal profile for $PM_{10}$ for the monitors shows very little variation during the day. The majority of sites show similar concentrations throughout the day for both the total monitoring period and for the closure period.

**Figure 3.8 Comparison of $PM_{10}$ weekly averages AQ Mesh**




Notes: 183-Mill Road East, 184-Tenison Road, 185-Cherry Hinton Road, 186-Gonville Place, 187-Coleridge Road, 188-Perne Road, 189 Mill Road West, 292-Coldhams Lane.

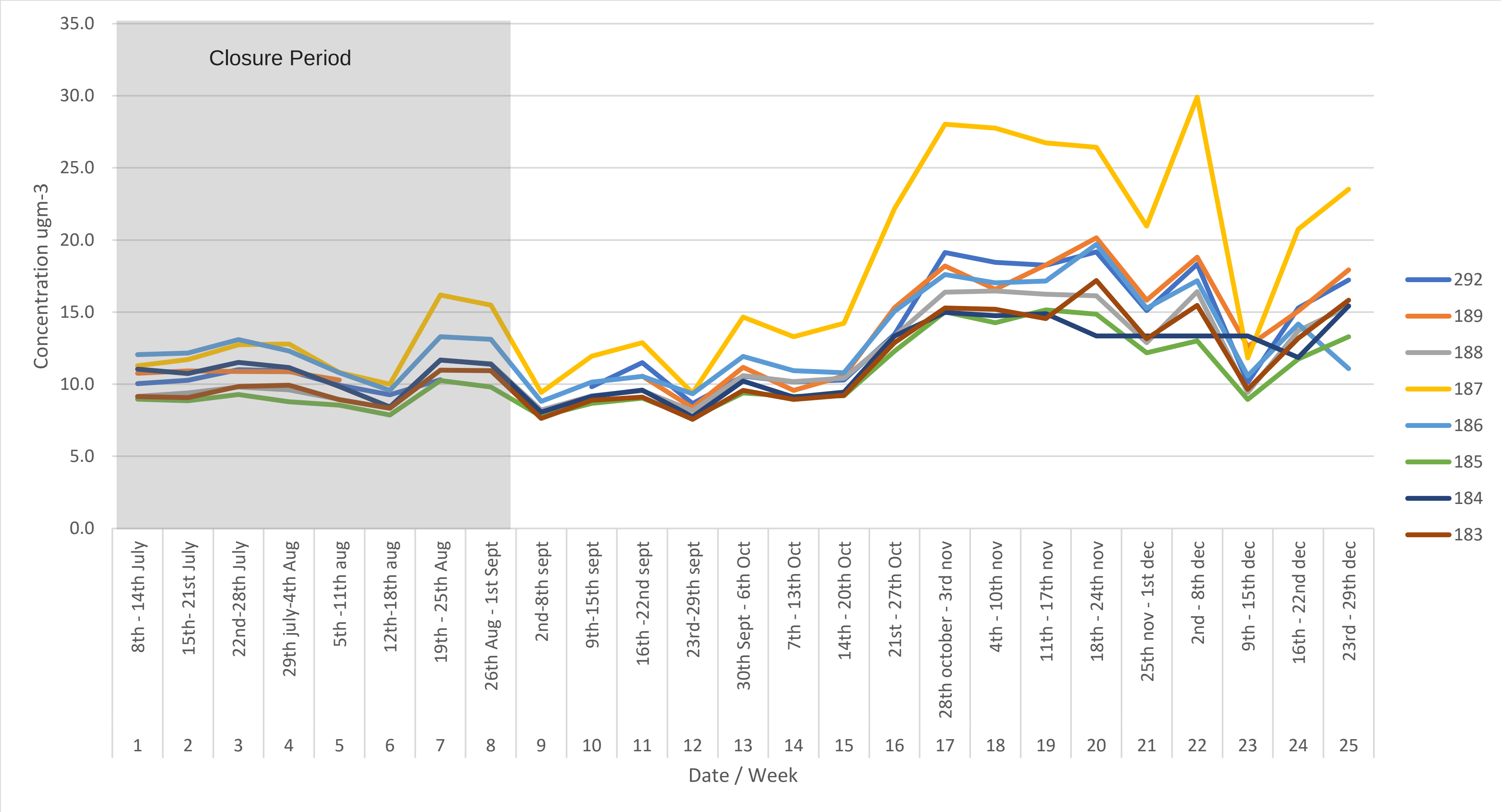
### 3.2.3 $PM_{2.5}$ Results Summary

The results from all the AQ Mesh Monitors are summarised in Figure 3.9 for $PM_{2.5}$, as weekly average concentrations.

Figure 3.9 shows a clear trend of lower $PM_{2.5}$ concentrations at all locations prior to October when concentrations rise rapidly and remain at a higher concentrations level through November and January. Some locations do appear to show high concentrations of $PM_{2.5}$ during November particularly location 187 (Coleridge Road). This location showed higher concentrations than the other locations throughout the monitoring period.

There is not a clear change in concentrations between the closure period and the re-opening of the bridge suggesting that the road closure has had no effect on $PM_{2.5}$ concentrations and the change in concentrations is actually seasonal variation.

**Figure 3.8 Comparison of $PM_{2.5}$ weekly averages AQ Mesh**




Notes: 183-Mill Road East, 184-Tenison Road, 185-Cherry Hinton Road, 186-Gonville Place, 187-Coleridge Road, 188-Perne Road, 189 Mill Road West, 292-Coldhams Lane.

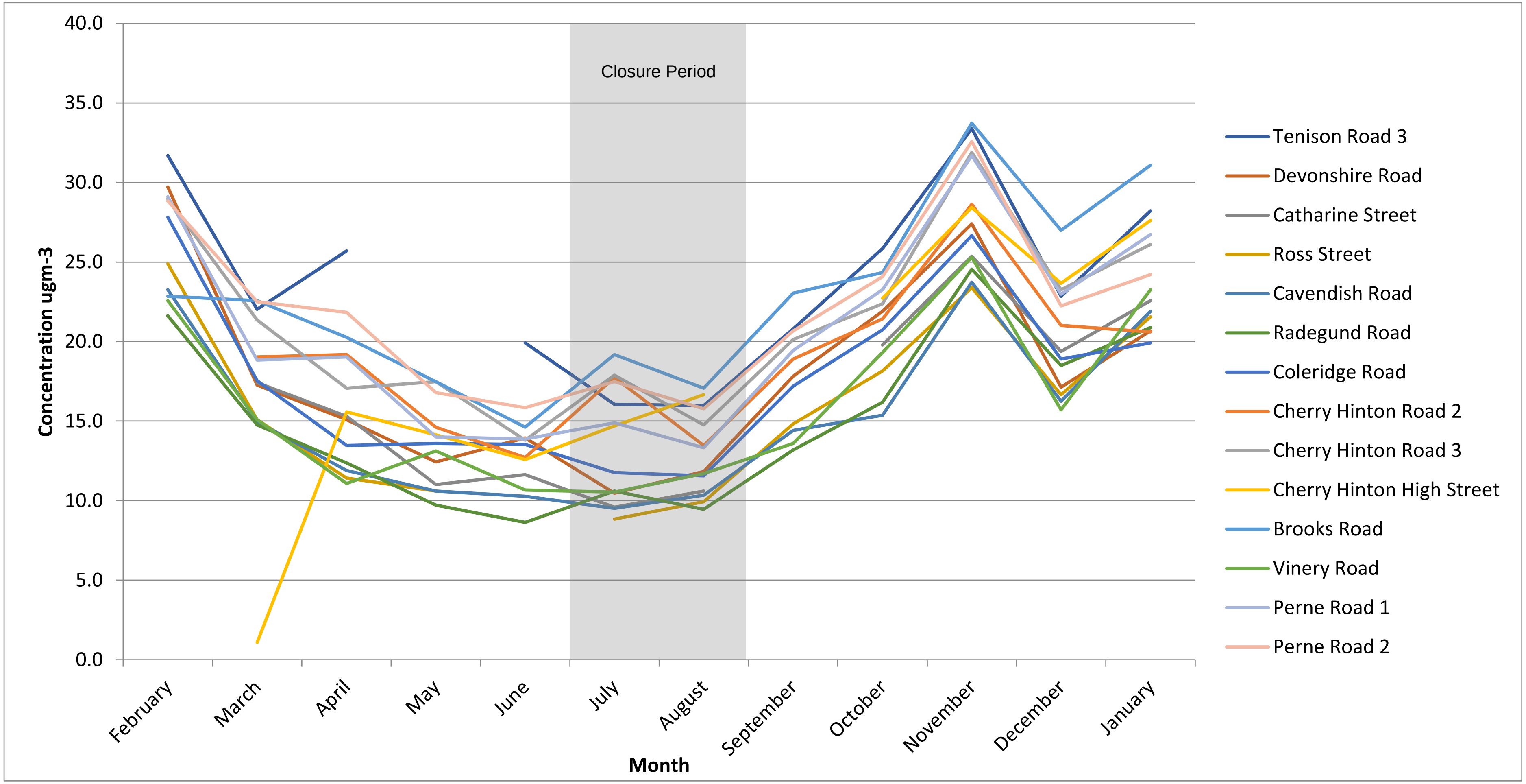
## 3.3 $NO_2$ Diffusion Tubes

There is already a comprehensive network of diffusion tubes around Cambridge measuring trends in nitrogen dioxide concentrations. For the study we added an additional 14 diffusion tubes to ensure that we did not have any gaps in the data.

### 3.3.1 Additional Mill Road $NO_2$ diffusion tubes

The following graph (Figure 3.10) shows the results from the 14 diffusion tubes for the monitoring period to highlight any trends. The diffusion tubes were in place from February 2019 until January 2020. They have been bias corrected using the factor used for the other Cambridge City tubes. Further details of the bias correction, laboratory QA/QC procedures and the raw results for the diffusion tubes can be found in Appendix C.

**Figure 3.10 – Mill Road $NO_2$ diffusion tubes monthly trend**



The graph shows that the monthly concentrations follow the usual pattern seen in diffusion tubes over an annual period, with higher concentrations in the winter months and lower concentrations during the summer months. As shown by the AQ Mesh and the continuous monitors in Cambridge, there are higher concentrations in November overall.

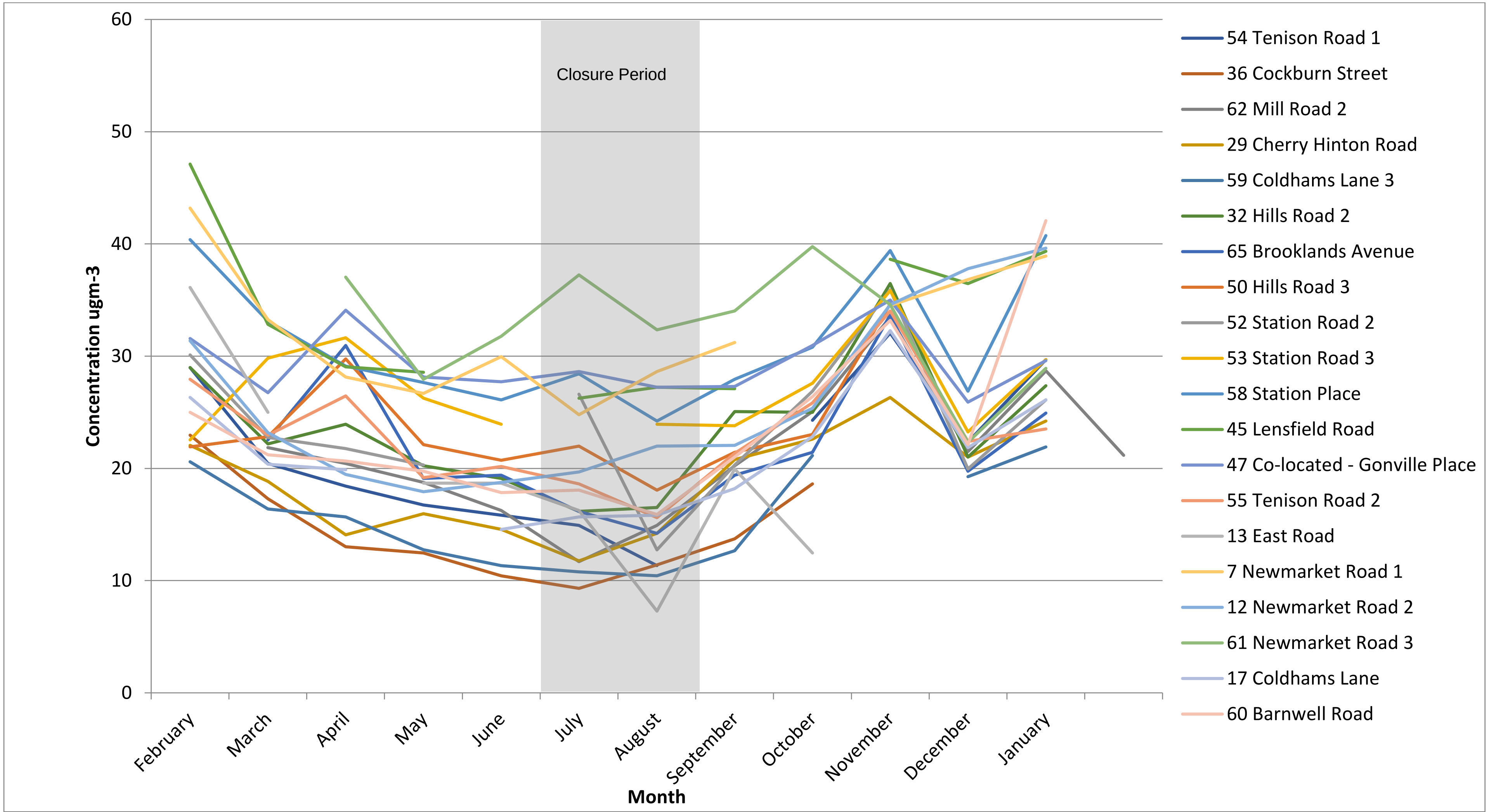
The graph appears to show a peak in concentrations in July at the following locations: Brookes Road, Perne Road 2, and Cherry Hinton Road 2 and 3. These are the roads which are on the signposted diversion route for the Mill Road closure. This suggests the $NO_2$ concentrations may have been affected by the road closure. However this observation is based on only 1 monthly value and could be related to meteorological factors, such as higher temperature in July.

### 3.3.2 Existing Cambridge $NO_2$ Diffusion Tubes

A number of the existing tubes for Cambridge City Council are located on the routes which could have been affected by the road closure.

This section analyses the results for the monitoring period from those $NO_2$ diffusion tubes.

**Figure 3.11 Existing $NO_2$ diffusion tubes.**



In general the existing $NO_2$ diffusion tubes in the area of Mill Road, as shown by Figure 3.11, show the same annual trend as the other tubes with higher values in the winter and lower values in the summer. However the results across the City are very variable and its difficult to observe a clear trend.

Some of the tube locations appear to not follow the expected trend in the summer months with peaks in July when you would expect lower values. These are: 61 Newmarket Road, 50 Hills Road, 47 Gonville Place and 58 Station Place.

The disadvantage of diffusion tubes is that a missing tube can mean a loss of 1 months data. For this project several of the tube locations had missing tubes in the summer months which may affect how the results are viewed and so no clear conclusions as to the impact of the road closure can be drawn.

## 3.4 Traffic Data

Vivacity Traffic sensors were used in the study to record the amount of traffic along the roads in the study area. The sensors were in place from the beginning of June. The following graphs show the traffic data collected by transport mode from June until December 2019.

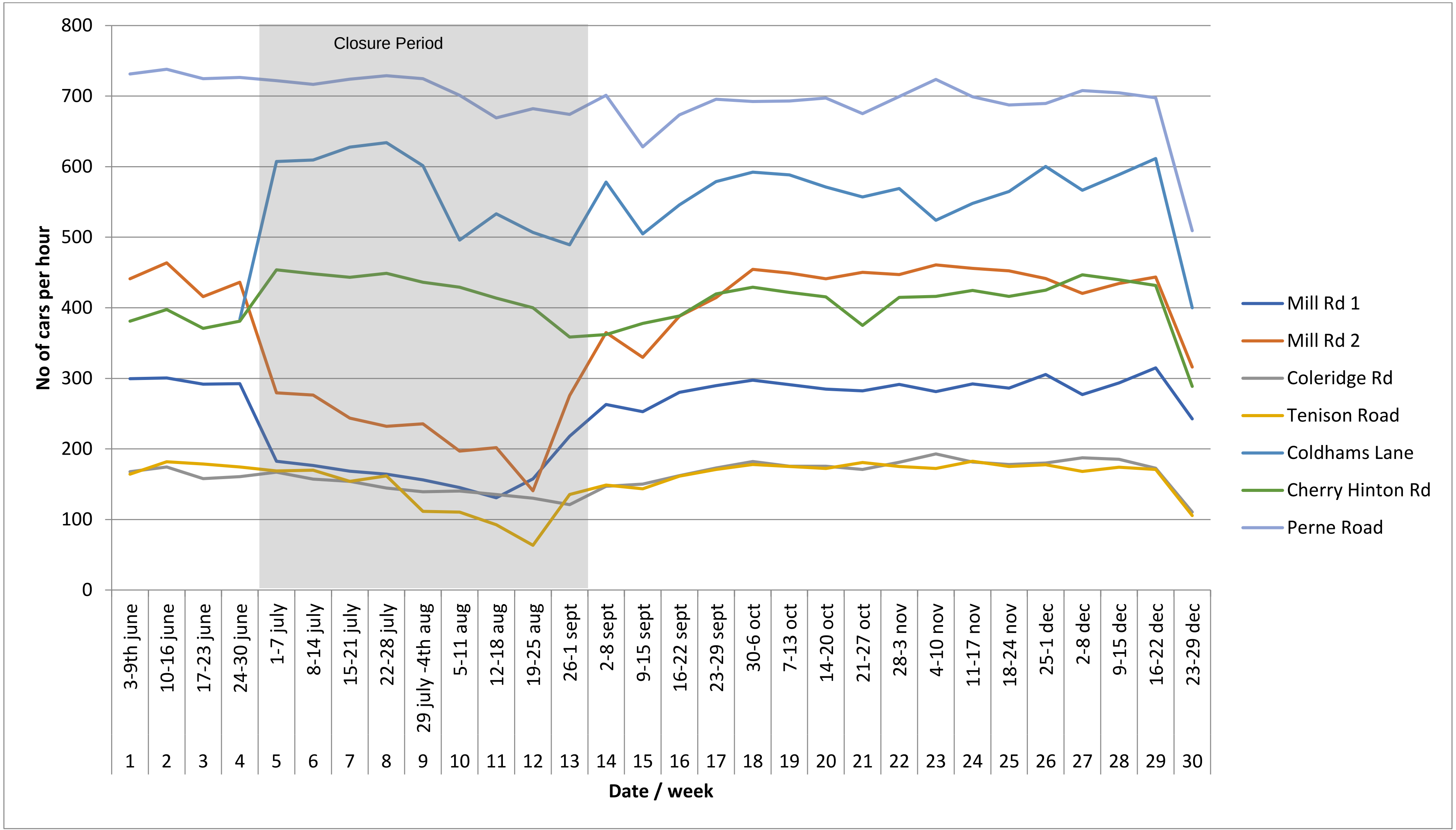
The results for the individual traffic sensors are shown in Appendix H.

### 3.4.1 Comparison of Traffic Data

**Cars**

Figure 3.12 shows the traffic data over the monitoring period as an hourly average for the weeks of the monitoring period for cars.

**Figure 3.12 Comparison of weekly averages cars**



The graph shows that there is a variation in how the amount of cars on the roads in the study area changes over the monitoring period.

The graph shows that Perne Road and Coldhams Lane had the largest volumes of traffic during the whole monitoring period.  Coleridge Road and Tenison Road experienced the lowest traffic volumes during the monitoring period.

The graph appears to show an initial increase in traffic volumes with the closure of the bridge on Coldhams Lane and Cherry Hinton Road, although traffic levels appear to return to their pre-bridge closure levels during August.

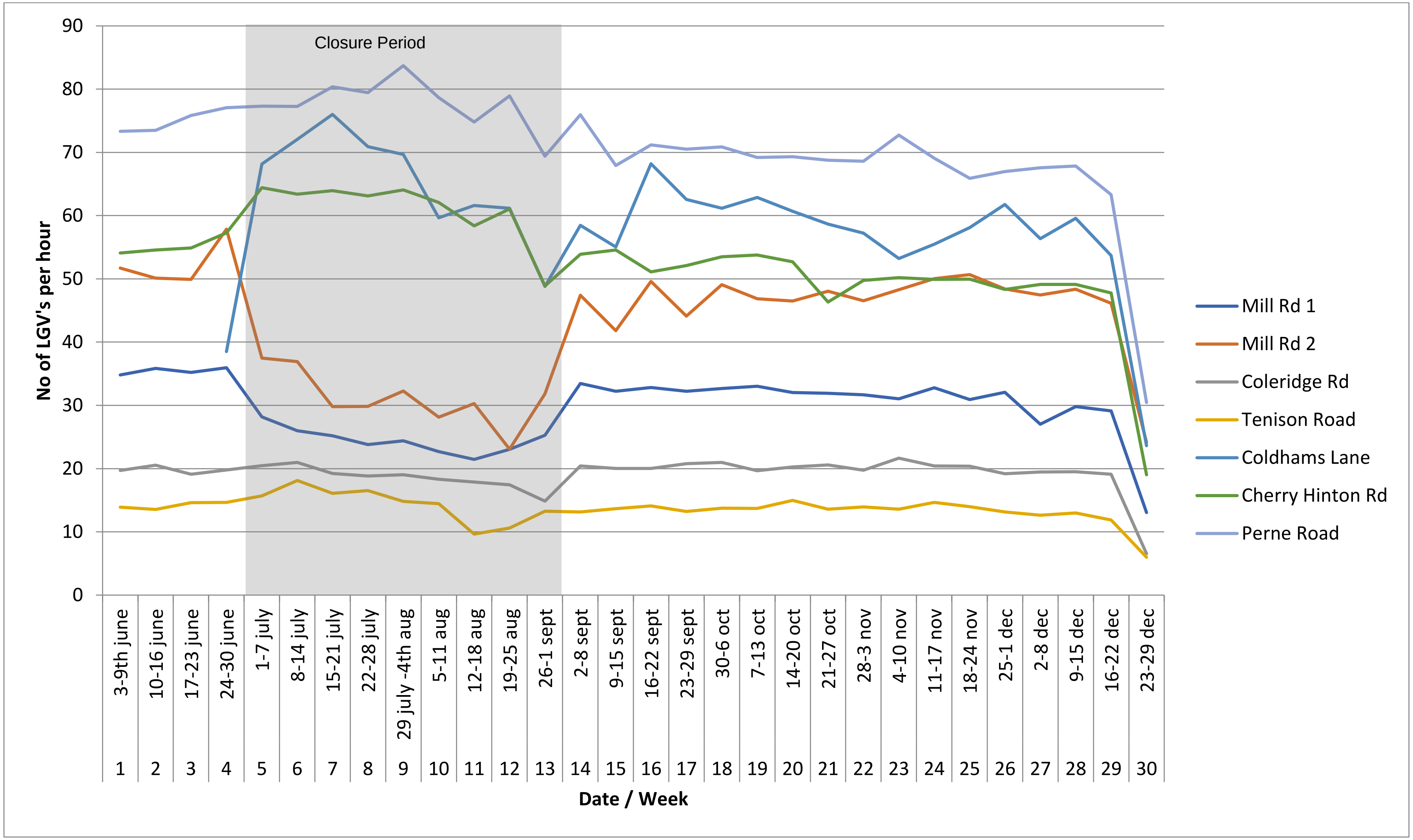
The graph shows a reduction in traffic volumes with the bridge closure at both of the Mill Road sensors, with a rapid return to pre-bridge closure volumes once the bridge re-opens.  Coleridge Road and Tenison Road show a smaller decline in traffic volumes with the bridge closure.  Tenison Road shows a steeper drop in traffic volumes during August.  This could be related to the gas main works which restricted access to this street during August.

The graph suggests that the closure has had an impact on the number of cars using the roads in the study area.

**LGVs**

Figure 3.13 shows the traffic data over the monitoring period as an hourly average for the weeks of the monitoring period for LGVs.

## Figure 3.13 Comparison of weekly averages LGVs



The graph shows that the largest volumes of LGVs were on Perne Road and Coldhams Lane.  The lowest volumes of LGVs were on Coleridge Road and Tenison Road.

The graph shows that during the bridge closure there was a significant decrease in LGVs on Mill Road.  A slightly smaller decrease on Tenison Road and Coleridge Road. The graph appears to show an increase in LGVs on Cherry Hinton Road, Perne Road and Coldhams Lane during the bridge closure.  By September LGV volumes appear to have returned to the pre-bridge closure levels on all of the roads in the study.

The graph suggests that the closure has had an impact on the number of vans using the roads in the study area.

**Changes in Modal split**

The tables in Appendix H summarises the modal split for each of the roads in the study and the change in hourly average traffic volumes for the weeks before, during and after the closure.

The roads which showed the biggest change in car and LGV volumes with the re-opening of the bridge were the two parts of Mill Road (Increase in cars of 75% and 83% and increase in LGV's of 24% and 46%).  Those roads which saw the least change in cars and LGV's were Coldhams Lane and Perne Road.  The road which saw the largest increase in cars and LGVs's during the road closure was Cherry Hinton Road (13% cars and 13% LGV's increase).  The number of cars and LGV's decreased on Cherry Hinton Road once the road re-opened (7% cars and 22% LGV's decrease).

On Tenison Road the monitor recorded a decrease of 26% in the volume of cars during the road closure, however saw a 2% increase in the number of LGV's and an increase in the number of OGV's and buses on this road at the same time.  Following the re-opening of the bridge cars increased by 27% but LGV's reduced by 10%.  This could be related to the numbers of LGV's associated with the gas works using this road to access the site during the closure which were not there once the bridge re-opened. Perne Road also saw a 5% increase in LGV's during the bridge closure.

**Diurnal Flows**

Diurnal plots were created for the traffic data.  These show that for all of the roads the pattern of diurnal flows throughout the day altered slightly during the closure period. All the roads experienced a morning peak but this was much earlier and then finished earlier during the closure period than during the total monitoring period.  During the closure period the increase in traffic volumes during the day began around 4am and started to decrease around 4pm.  For the total monitoring period the increase in traffic volums began around 7/8 am and finished around 6/7pm.

For LGV's the peak in vehicle numbers during the closure also showed a different pattern in the closure period, with the number of vehicles increasing around 3/4am and decreasing around 12/1 pm. Unlike the total monitoring period where vehicle numbers increased around 7am and decreased around 3pm.

Unlike with the air quality $NO_2$ diurnal flows there was not a pronounced morning and evening peak in traffic volumes.

## 3.5 Comparison between different methods

### 3.5.1 Continuous Monitors and AQ Mesh

The comparison of the AQ Mesh sensors and the continuous monitors is shown in Appendix B as this is part of the calibration of the AQ Mesh Monitors.

The AQ Mesh sensor which was co-located with the continuous monitor at Gonville Place shows good correlation with $NO_2$ concentrations throughout the monitoring period. For $PM_{10}$ and $PM_{2.5}$ the trend in the data is the same however there is an offset for both, with the AQ Mesh recording consistently lower concentrations than the continuous monitor.

The AQ Mesh monitors appear to be more affected by high temperatures than the continuous monitor, however the continuous monitors do have air conditioning units as part of their operating mechanism. The continuous monitor at Gonville was not working for a short period during the closure of the bridge when temperatures in Cambridge were very high. The average weekly values were therefore much lower at the continuous monitor at Gonville for this period. The continuous monitor at Parker Street is the other closest contuous monitor. Reviewing the weekly average $NO_2$ concentrations at the Parker Street monitor during the bridge closure period shows the same trend in pollutant concentrations as for the AQ Mesh monitors, although not as high concentrations. The data from both types of monitor suggests that at significantly higher ambient temperatures, such as those experienced at the end of July in 2019, the $NO_2$ concentrations are higher.

At the end of the monitoring project all of the AQ Mesh monitors were placed with the Gonville Place monitor for a 3 week period. During this time all of the AQ Mesh monitors recorded the same trend in $NO_2$, $PM_{10}$ and $PM_{2.5}$ concentrations as the continuous monitor. In addition all of the AQ Mesh monitoring results were very similar suggesting that the monitors themselves are consistent in their measurements. As with the AQ Mesh monitor which was placed with the continuous monitor throughout the monitoring period there was a offset observed for the particulate concentrations.

### 3.5.2 Diffusion Tube and AQ Mesh

Several of the diffusion tubes are co-located or close to some of the AQ Mesh locations. Diffusion tubes are often used to analyse trends in $NO_2$ concentrations in an area and the co-location of the diffusion tubes with the AQ Mesh allows us to see what the differences in concentrations are and whether the two methods show the same trend in concentrations.

As the diffusion tubes are monthly averages we have compared them against the monthly averages for the AQ Mesh. The monthly period chosen was that used for the collection dates for the $NO_2$ diffusion tubes as supplied by Defra. (Ref https://laqm.defra.gov.uk/assets/dttimetable2019v1.pdf)

The comparison of the diffusion tubes with the AQ Mesh monitors showed that the diffusion tubes and AQ Mesh followed the same trend across the monitoring period. For locations on Coleridge Road, Cherry Hinton Road and Tenison Road $NO_2$ concentrations were very close with differences between 1-2 ugm$^{-3}$. For locations on Coldhams Lane and Mill Road East concentrations were further apart with around 10 ugm$^{-3}$ difference in $NO_2$ concentrations over the monitoring period as a whole.

The AQ Mesh monitor and the diffusion tube at Mill Road East were located on opposite sides of the road as the diffusion tube was part of the Cambridge City network prior to the project and could not be moved. The AQ Mesh could not be put with it as the diffusion tube was placed on a sign post and the AQ Mesh would have obscured the sign.

The AQ Mesh Monitor and the diffusion tube at Coldhams Lane were however placed on the same lamp column although about a metre apart in height. Meteorological conditions may have played a part in the differences in concentrations recorded.

### 3.5.3 Traffic Data Vs Continuous Monitors

None of the traffic sensors were placed close to the continuous monitors. No comparisons can therefore be undertaken between the continuous monitors data and the traffic monitoring data.

### 3.5.4 Traffic Data Vs AQ Mesh

Several of the AQ Mesh monitors were co-located with the Vivacity Traffic sensors. The following section analyses whether the changes in traffic data discussed in the previous section have affected the air quality trends observed.

Although there were significant changes in traffic data across the monitoring period at certain locations, these do not appear to have had a significant effect on concentrations of $NO_2$ and $PM_{10}$ across the monitoring period. It could be that a more significant change in traffic is required to produce a noticeable change in concentrations of $NO_2$ and $PM_{10}$.

Mill Road 1 (Eastern end of Mill Road) saw a reduction of 45% in traffic over the bridge closure. For the same time period the AQ Mesh at this location showed a reduction in $NO_2$ of around 5 $ugm^{-3}$ with no discernable change in $PM_{10}$ concentrations. However it is unclear whether the drop in $NO_2$ concentrations is the result of the traffic levels falling or whether this is due to seasonal variation as we would expect $NO_2$ concentrations to fall during July and August as shown by the annual trends in the continuous monitors for the past 4 years.

### 3.5.5 Summary

The data suggests that all of the air quality monitoring methods recorded similar trends in $NO_2$, $PM_{10}$ and $PM_{2.5}$ concentrations.

However it appears that the AQ Mesh pods record data at lower levels for $PM_{10}$ and $PM_{2.5}$ when compared to the continuous monitors. This can be corrected via calibration.

For the diffusion tubes the trends are the same for $NO_2$ and values at some locations are very similar.

The traffic monitors recorded some significant falls in traffic volumes as a result of the road closure, however no significant falls in $NO_2$, $PM_{10}$ or $PM_{2.5}$ concentrations were recorded by any of the air quality monitoring equipment. Slight changes in $NO_2$ concentrations have been recorded at some locations but it is unclear whether this is the normal seasonal variation or the effect of the road closure.

## 3.6 Issues

When planning the project, the only expected road closure in the area was going to be the bridge on Mill Road. However during the 1st week of the bridge closure major gas main works were undertaken on Mill Road on both sides of the bridge and in some of the residential streets leading off Mill Road. The gas works closed one lane of Mill Road with temporary traffic lights put in place. These works may have affected the number of vehicles which were using Mill Road in addition to the bridge closure.

During the third week of the bridge closure there was a fire in one of the buildings on Mill Road. This building was located between the bridge and Tenison Road on the western side of the bridge. Due to concerns regarding the structure of the building, Mill Road was then closed from this point and one of the diversion routes (Devonshire Road) was therefore unavailable for a period during the closure.

The study was not set up to look at the effects of these additional factors and it is unclear what effects these will have had on the results.

# 4 AQ Mesh Performance

## 4.1 Installation

In Cambridge the lamp collumns are maintained by Cambridgeshire County Council. In order to install the AQ Mesh sensors on lamp coulmns in the area we were required to apply for a licence from Cambridgeshire County Council. The application process can take up to 6 weeks. As we were working in partnership with Cambridgeshire County Council they were able to inform us of the requirements so this process took place quickly and smoothly.

The AQ Mesh when used for undertaking gaseous sampling is able to run on its own internal battery for several months. However when undertaking monitoring for particulates as well a pump is needed to draw through a set amount of air to sample. The addition of the pump requires additional power. Traditionally this power has been provided by an external source such as a lamp column.

The AQ Mesh Sensors could be fitted with a solar panel, so no connection with a lamp column was required and other street furniture could also be used.

By utilising the solar panels we could install all of the panels within a day with the aid of a cherry picker and one operative. When we took them down at the end of the study we were able to do this with a ladder and 2 operatives. As we did not need to utlise the power from the lamp column the cost to the council was only for the assitance with installation and decommissioning. No costs were incurred for the cost of powering the AQ Mesh monitors from the lamp column.

## 4.2 Maintenance

The solar panels worked really well in most locations and provided the appropriate amount of power needed to run the AQ Mesh successfully.

The monitor at Mill Road West (189) where there were a large number of mature trees, covered the solar panel in sap and we think inhibited the ability of the solar panel to actually provide enough charge to the monitor. This meant we had a few instances where we lost power to the monitor. This monitor had to be returned to the manufacturer whilst the study was ongoing to be repaired.

The maintenance contract which was in place meant we didn't have to access the monitors and try to work any technical problems which also proved to be useful.

However the maintenance contract did not include the contractor checking that the monitors were working correctly and sending data. This meant we had to check on a regular basis that the data was being sent to the website for viewing. The website did allow alerts to be set up if certain thresholds were met but didn't allow thresholds to be set if no data was being received.

## 4.3 Data Handling

The data from the monitors was the raw data without further calibration. The data was uploaded to the Cambridgeshire County Council Cambridgeshire Insight website to allow members of the public to see with the caveat that it was subject to change following calibration.

We received a large number of requests from other organisations and the public for the API to download the data directly from the AQ Mesh platform where the data was held. However the website restricted us to a certain number of API's which we could share without incurring additional cost. We were also concerned that people would use the data without being aware that it was subject to QA/QC checks and the need for subsequent calibration. There was an expectation from members of the public and other parties that the monitors would just produce exact results without any consideration of margins of error inherent in all monitoring methodologies.

## 4.4 Summary

The AQ Mesh monitors were easy and quick to install in all of the locations which we required using existing street furniture.

Working with our Cambridgeshire County Council colleagues enabled us to use their knowledge of the systems in place to utilse the lamp columns which also made installation easier. We are now in a better position to utilise these processes and contacts we have made on future projects.

We were able to learn the optimum locations for installation as a result of this project, especially when utilising the solar panels.

As this was a research project we spent a large proportion of time once the monitoring had been completed undertaking the QA/QC checks and working out the calibration methodology. In future we would hope that this process would be quicker when using the AQ Mesh and undertaken during the monitoring period so we could provide QA/QC checked and calibrated data for the public and partners earlier.

# 5 Conclusions

The report conclusions are summarised below.  These relate back to the aims of the study.

## 5.1 Acheivement of Aims

1. **Assess the potential changes in air quality as a result of a road closure**

   The monitoring in place proved successful at collecting pollutant concentration data.  However there were no discernable significant changes in pollutant concentrations at any of the monitoring locations.  Slight changes in pollutant concentrations were observed at a few of the monitoring locations but these changes could not be separated from expected seasonal variations in pollutant conentrations.

2. **Assess the potential changes in traffic volumes and modes as a result of a road closure**

   The traffic data appear to show changes in traffic volumes with the bridge closure at certain monitoring locations.  This appears to be a temporary situation with traffic volumes quickly returning to their previous levels once the bridge re-opens.  There does not appear to be any change in mode as a result of the bridge closure with drivers seeking alternative routes rather than changing mode.

3. **Assess whether there are any link between potential traffic changes and air quality as a result of a road closure**

   The changes in traffic volumes do not appear to have had a significant effect on air quality.  There is no significant change in pollutant concentrations as a result of the bridge closure and the slight changes observed at some locations coincide with expected seasonal variation and therefore cannot be necessarily attributed to changes in traffic volumes.  There also appears to be only slight changes in $NO_2$ diurnal flows when comparing the closure period with the total monitoring period.  There were no discernable changes in particulate concentrations as a result of the road closure in any of the data sets.

4. **Assess the performance of AQ Mesh (Low-cost monitors) in a real life scenario**

   The results from the AQ Mesh monitor at Gonville Place showed a very similar trend in concentrations to the continuous monitors, as well as similar values for $NO_2$ concentrations.

   The values for particulates ($PM_{10}$, $PM_{2.5}$) required an upwards adjustment when compared to the continuous monitor concentrations, as this was deemed the more accurate measurement. The same trend in concentrations was apparent at both the AQ Mesh monitor and the continuous monitor.

The AQ Mesh monitors also reported similar values to the $NO_2$ diffusion tubes and followed the same trends where these were collocated.

From the analysis of the AQ Mesh data at Gonville Place, it appears that the AQ Mesh monitors are more sensitive to higher temperatures than the continuous monitors. This is likely to be because there is no inbuilt air conditioning system. This should be remembered during periods of very high temperatures when using this monitoring as $NO_2$ concentrations appear higher than normal but this may not actually be the case.

When all placed together at Gonville Place following the end of the monitoring period, the AQ Mesh monitors recorded very similar values to each other suggesting that the monitors measure consistently.

The AQ Mesh data can be directed downloaded via an API link. However QA/QC checks and subsequent calibration of the results is then required. Depending on resources available this can take a significant amount of time which can delay the presentation of results.

## 5.2 Main conclusions

The main conclusions from the study are as follows:

1) The AQ Mesh monitors are a useful method for monitoring trends in pollutant concentrations and can show spikes in concentrations.
2) The AQ Mesh monitors are easy to use in terms of installation.
3) When interpreting the results an understanding of what QA/QC and calibration procedures have been undertaken is required to ensure the results from the AQ Mesh monitors are interpreted correctly.
4) Due to the sensitivity to temperature for $NO_2$ concentrations and the uplift to particulate results required in calibration, we would be hesitant to use the data as an absolute measure of pollutant concentrations but rather an indicator method to discern trends and differences in concentrations across a wide area.
5) The data from the study shows significant changes in traffic volumes did occur, but there was no discerable significant change in pollutant concentrations. The study also shows that although $NO_2$ concentrations do appear to be linked to traffic volumes, as shown by the diurnal profiles; particulate concentrations are not noticeably influenced by traffic volumes.

## 5.3 Future Use

The study found that the AQ Mesh is capable of measuring trends in pollutant concentrations and can pick up spikes in data, as well as measuring consistently.

We intend to use the AQ Mesh monitors on a project to look at the trends in particulate concentrations around the City. We are particularly interested to see whether there are differences in trends in particulates at different locations across the City away from roads.

We will also be making this report and data available to the public and other organisations for use in future projects. This will assist with planning changes to infrastructure in the City when considering trying to initiate modal shift in types of transport used as well as having a better understanding of the impact traffic can have on air quality in the City.

# Appendix A – AQ Mesh Monitor Locations

**Figure A1 Monitor 183 Mill Road East**

**Figure A2 Monitor 184 Tenison Road**

**Figure A3 Monitor 185 Cherry Hinton Road**


Figure A4 Monitor 186 Gonville Place

**Figure A5 Monitor 187 Coleridge Road**

**Figure A6 Monitor 188 Perne Road**

**Figure A7 Monitor 189 Mill Road West**

**Figure A8 Monitor 292 Coldhams Lane**

# Appendix B – Calibration Methodology and Discussion AQ Mesh

## Introduction

The AQ Mesh monitor uses a chemical signature of the gases measured in order to measure the amount of those gases.  The calibration process seeks to align the monitor with localised conditions.

## Calibration Methodology

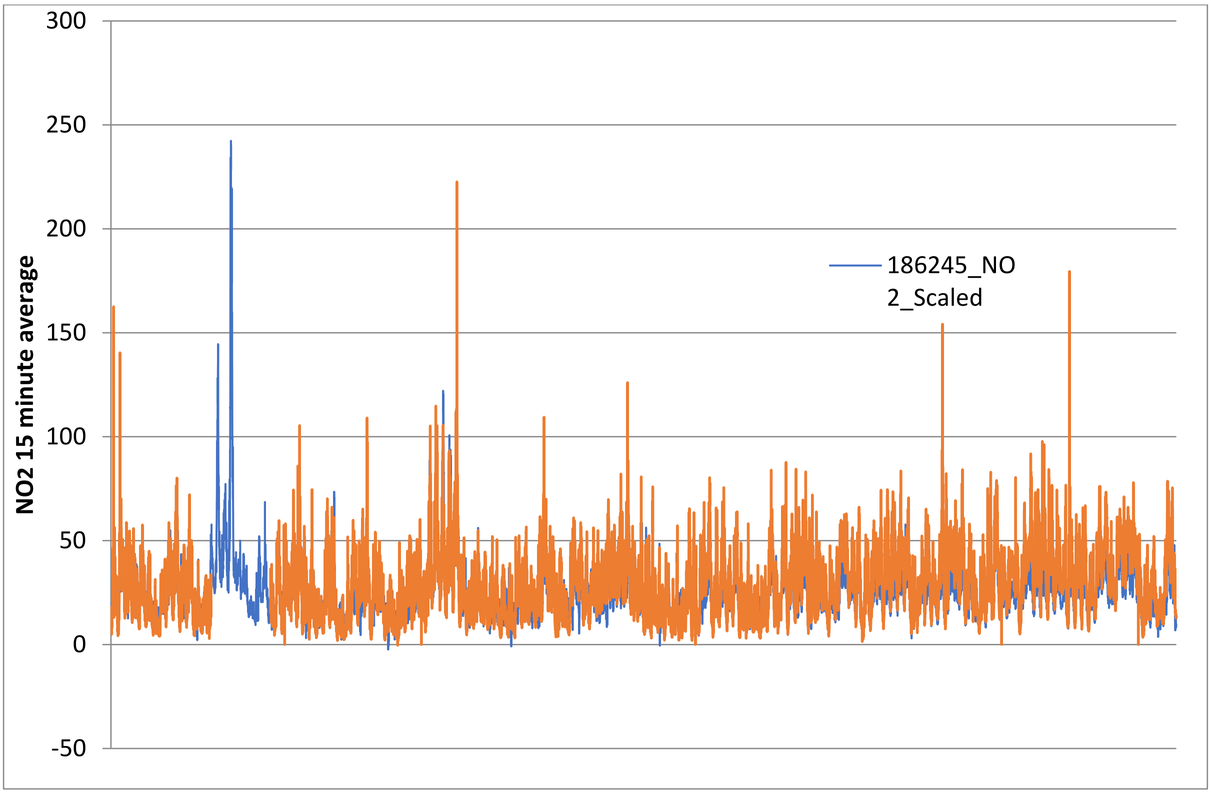
Eight AQ Mesh monitors were purchased for the project.  One of these monitors was placed with one of our continuous monitors.  This would allow us to calibrate the monitors against it.

The following graphs show the comparison of the monitoring results for the continuous monitor and the AQ Mesh which were collocated together for the whole of the monitoring period, from July to December 2019.

The figures show nitrogen dioxide ($NO_2$), Particulate matter less than 10 microns in size ($PM_{10}$), and Particulate matter less than 5 microns in size ($PM_{2.5}$).

### Nitrogen Dioxide ($NO_2$)

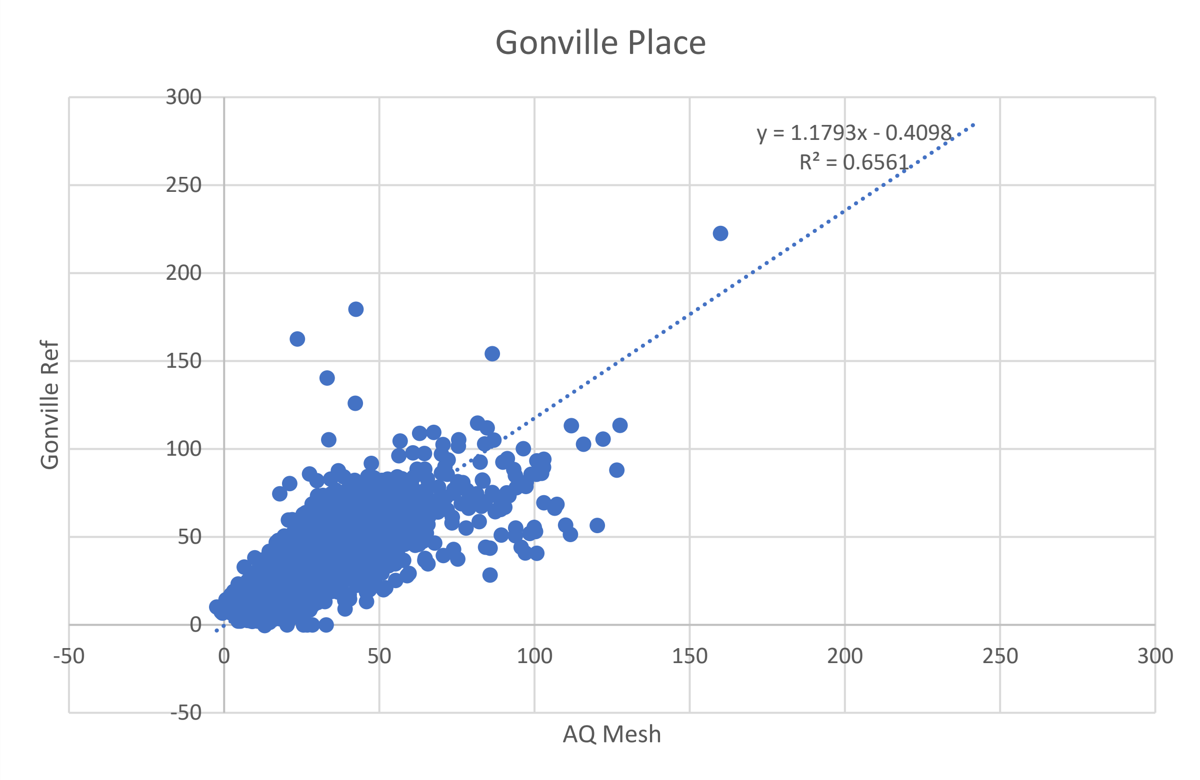
**Figure B1 $NO_2$ comparison**




As shown by the graph the comparison between the AQ Mesh and Continuous monitor readings throughout the monitoring period is good.

To further understand the relationship the following comparison was undertaken as shown in Figure B2.

**Figure B2 Relationship between Continuous monitor and AQ Mesh**

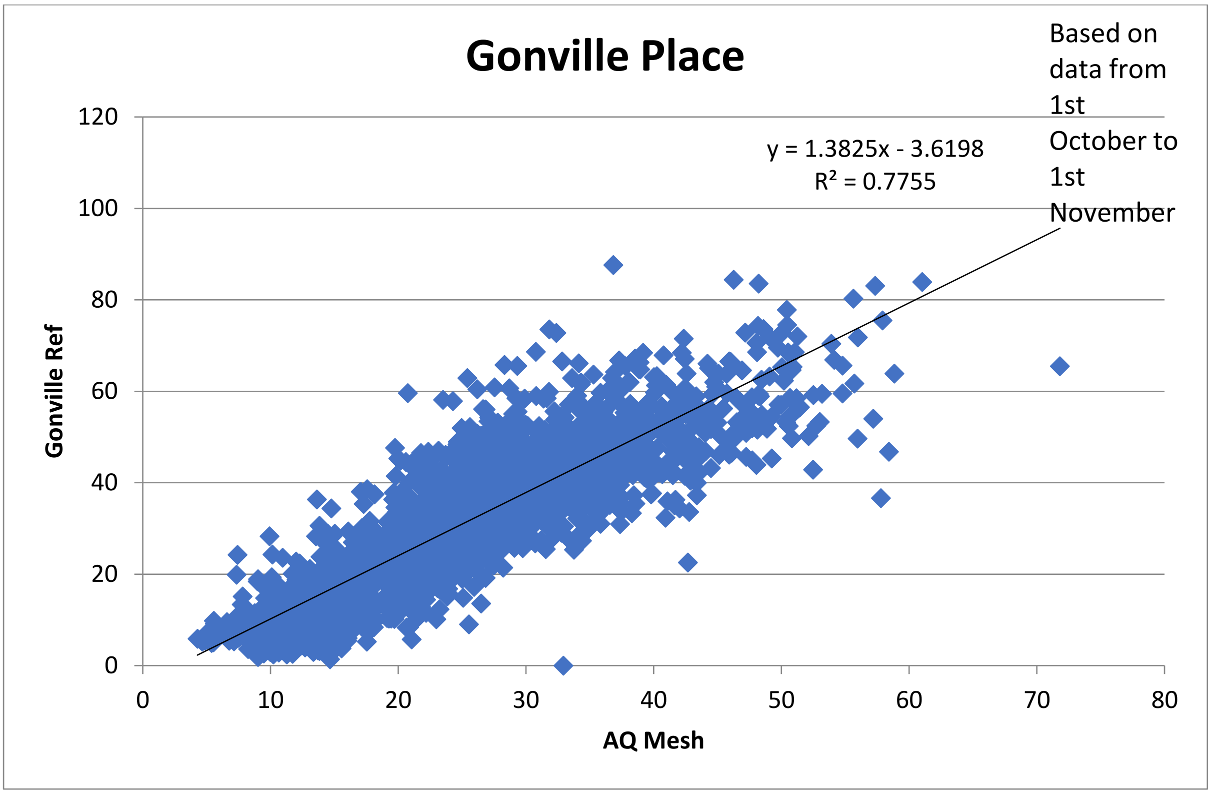



The scatter plot shows a good relationship between the two monitors.

Discussion with the University of Cambridge who have been using the AQ Mesh monitors on the Breathe London Project suggested that instead of using the whole period of monitoring a period where there is little variation in peaks and troughs in the data should be chosen for calibration purposes. This also removes the period in July when the continuous monitor was not operational due to the replacement of the air conditioning unit.

Using the period 1st October to 1st November produces the following relationship graph.

**Figure B3 Relationship between Continuous Monitor and AQ Mesh (University Method)**

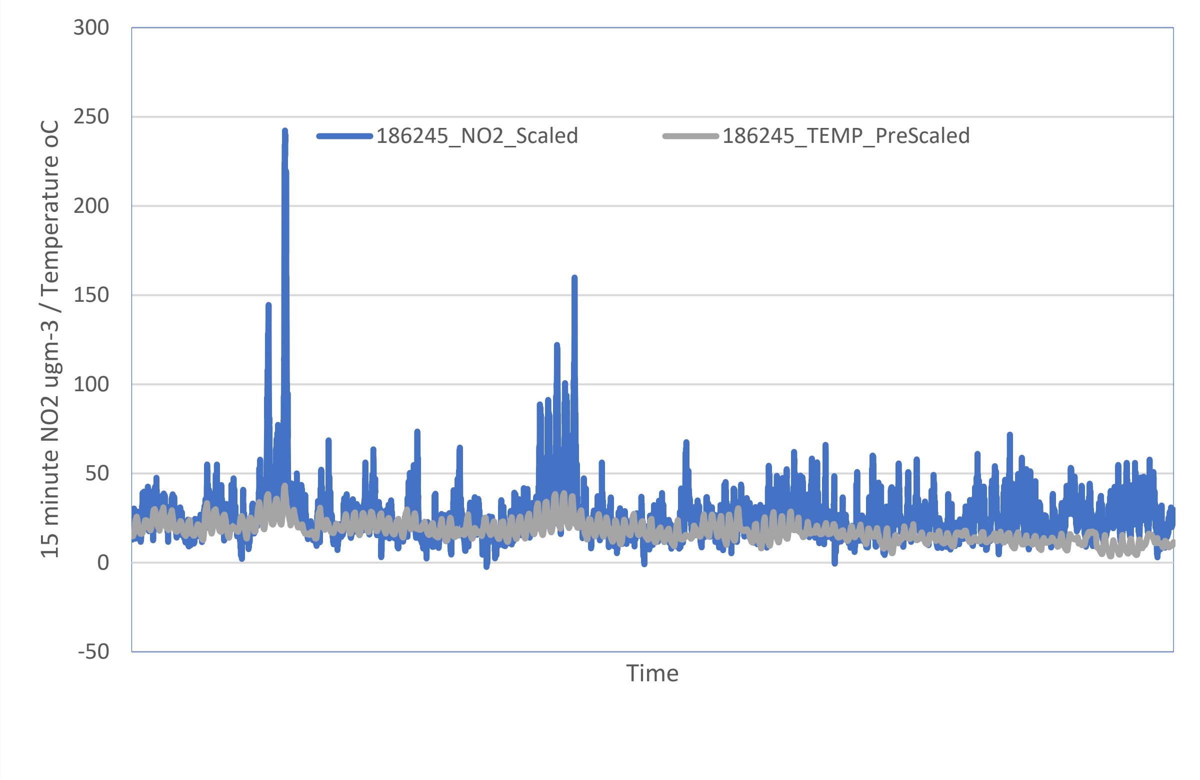



Using this method produces a much more linear relationship between the two monitors with less outliers. However, there is more of a pronounced offset suggesting that the AQ Mesh monitor produces higher concentrations than the continuous monitor.

The offset shown by these graphs could be related to temperature.

The following figure shows the relationship between temperature and the AQ Mesh monitor at Gonville Place for the monitoring period.

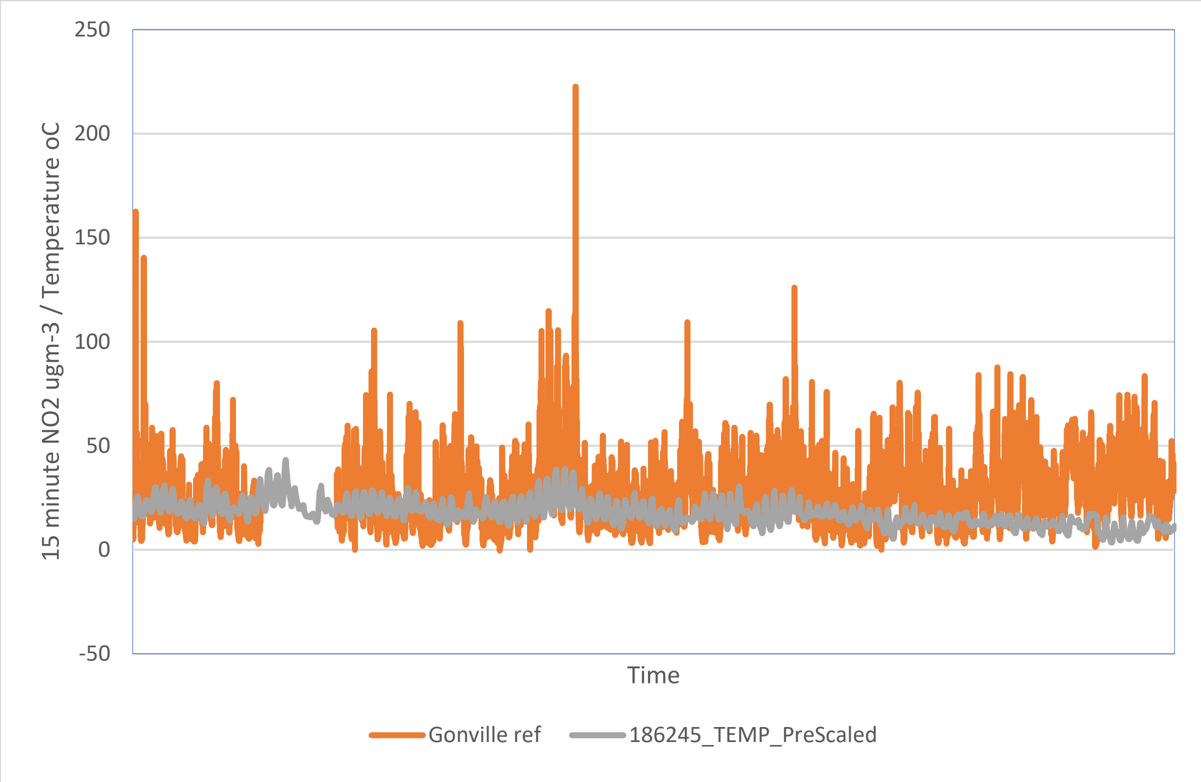
**Figure B4 AQ Mesh Gonville compared to Temperature**




The graph shows that there appears to be a relationship between periods of high temperature and higher $NO_2$ concentrations shown by the AQ Mesh. However it is difficult to see whether the same relationship is shown for lower temperatures which do not appear to affect the AQ Mesh monitor readings to the same degree.

Comparing the temperature with the readings from the continuous monitor at Gonville Place produces the following graph.

**Figure B5 Gonville Place Continuous monitor Vs Temperature**

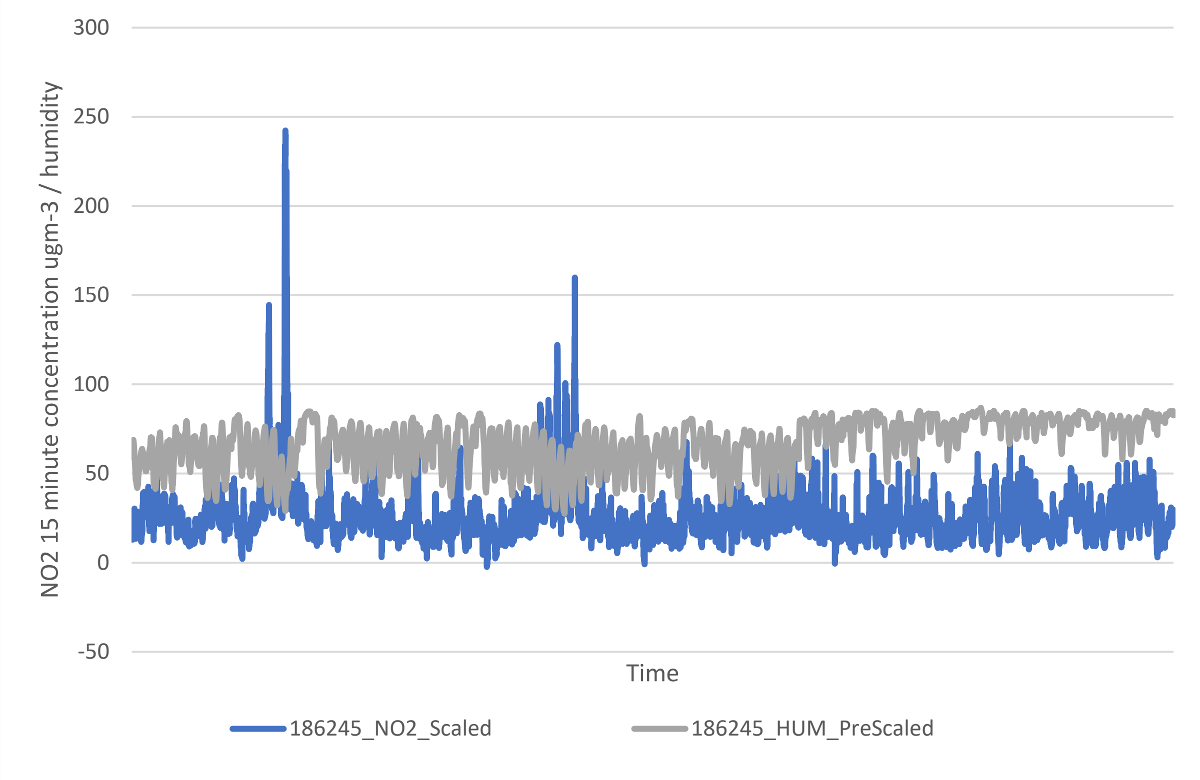



Unlike the AQ Mesh monitor the continuous monitor appears to be less affected by changes in temperature than the AQ Mesh monitor. This is to be expected as the continuous monitor is fitted with an air conditioning unit which should maintain the instrument at the same temperature.

As the AQ Mesh unit does not contain an air conditioning unit it could also be affected by the ambient humidity.

The following graph shows the comparison between humidity and the readings from the AQ Mesh over the whole period.

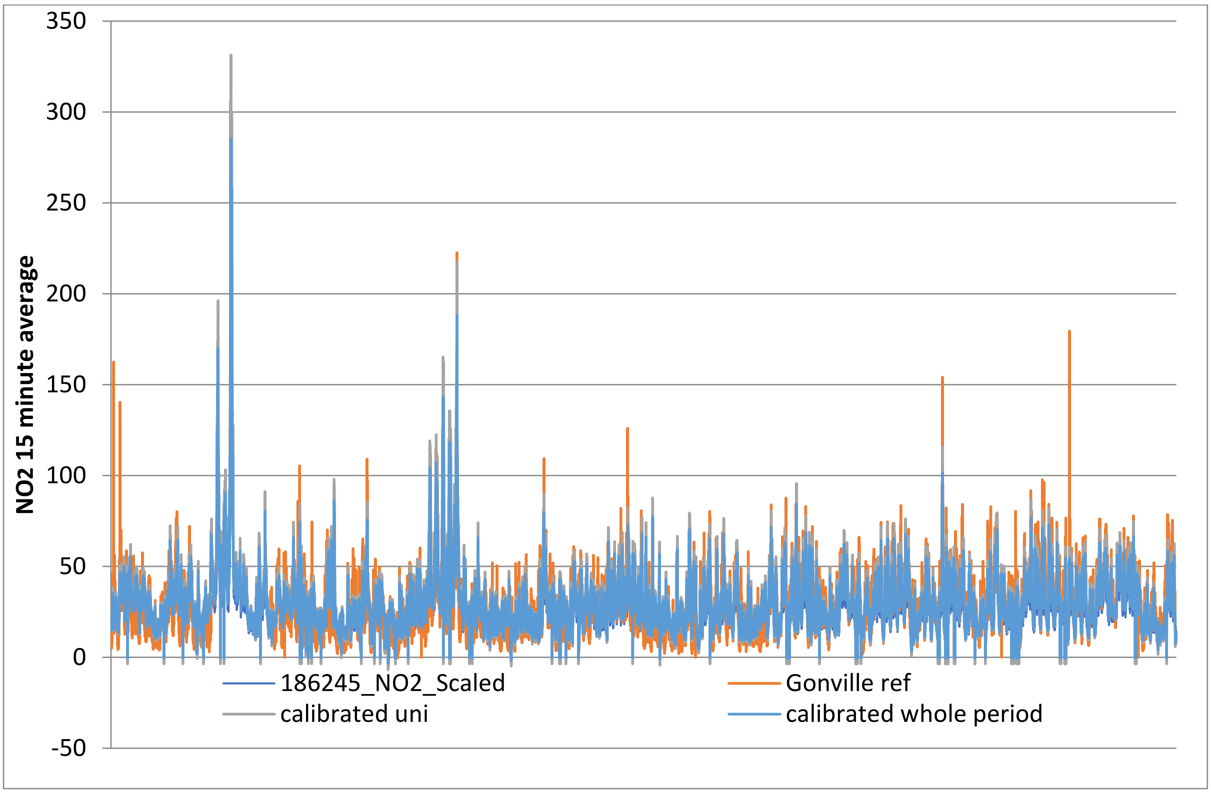
**Figure B6 AQ Mesh Gonville Place Vs Humidity**




Humidity appears to rise slightly during the autumn and remains relatively higher than compared to the summer months. However, this does not appear to have made a significant difference to the values recorded by the AQ Mesh monitor.

Given the above data and discussion there were two values which we could use to calibrate the monitor using the ‘classic method’ - where we compare the data with the continuous monitor for the whole period. The following figure shows the values obtained from using the whole data set and the short period as recommended by the University.

**Figure B7 NO$_2$ calibration methods**

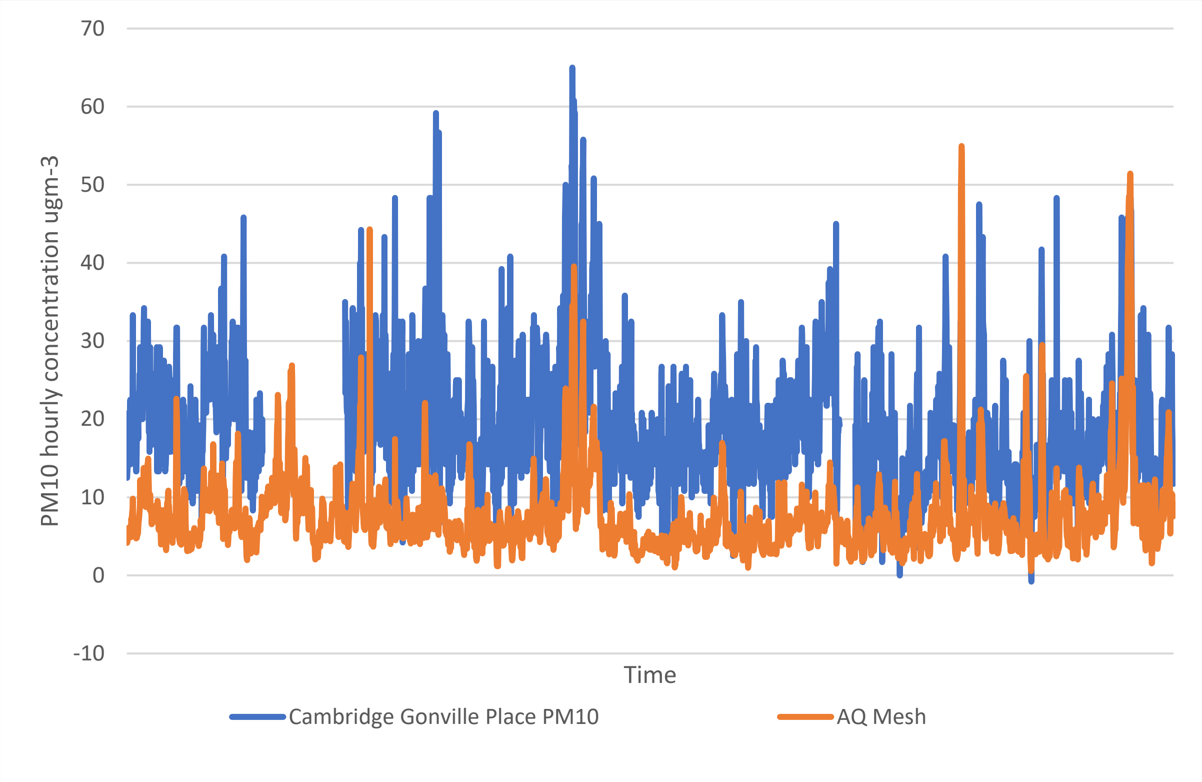



The graph shows that the calibration methods both improve the results given by the AQ Mesh. There is more variability within the Gonville reference monitor results than the AQ Mesh and the calibration does take out some of the variability in the AQ Mesh results.

Based on the above we decided to use the whole period results to calibrate the monitor for NO$_2$.

## Particulate Matter – $PM_{10}$

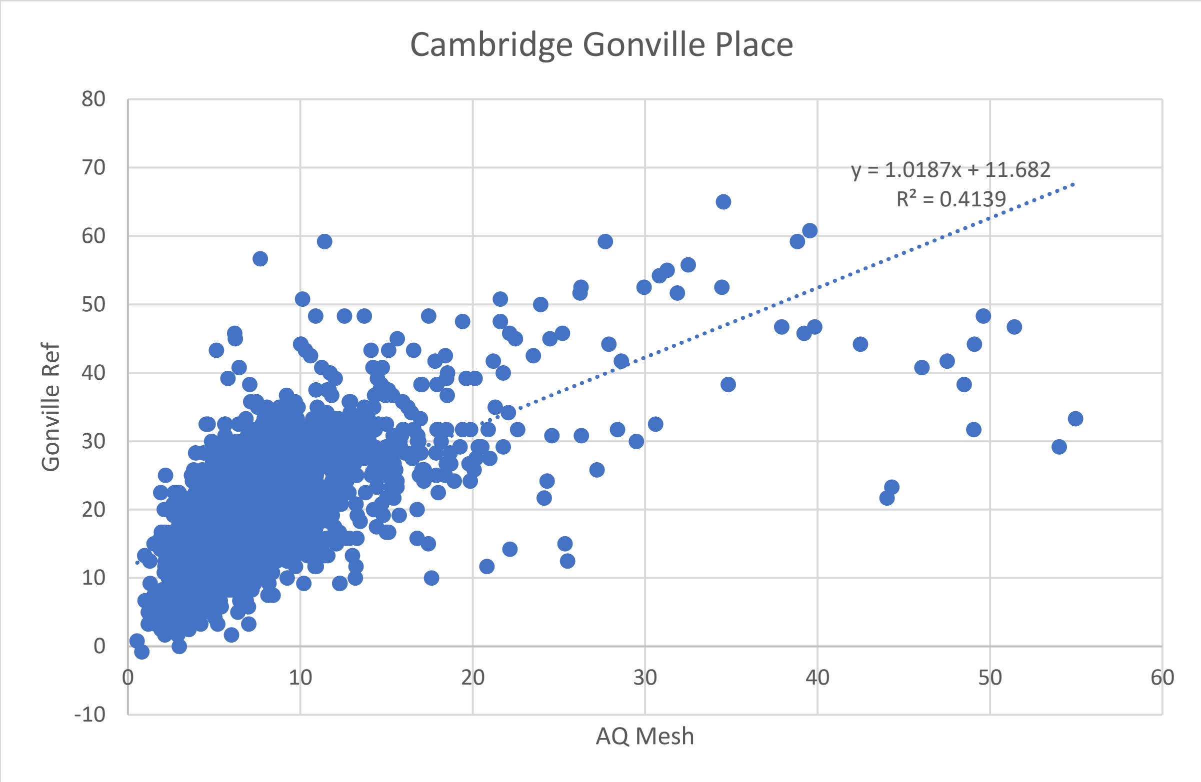
**Figure B8 $PM_{10}$ comparison**




The graph shows the hourly concentrations for $PM_{10}$ for both the AQ Mesh and the continuous monitor at Gonville Place. The graph shows that the trend in data is very similar, although there is a large offset in values and peaks in the data are not always reflected by both types of monitor.

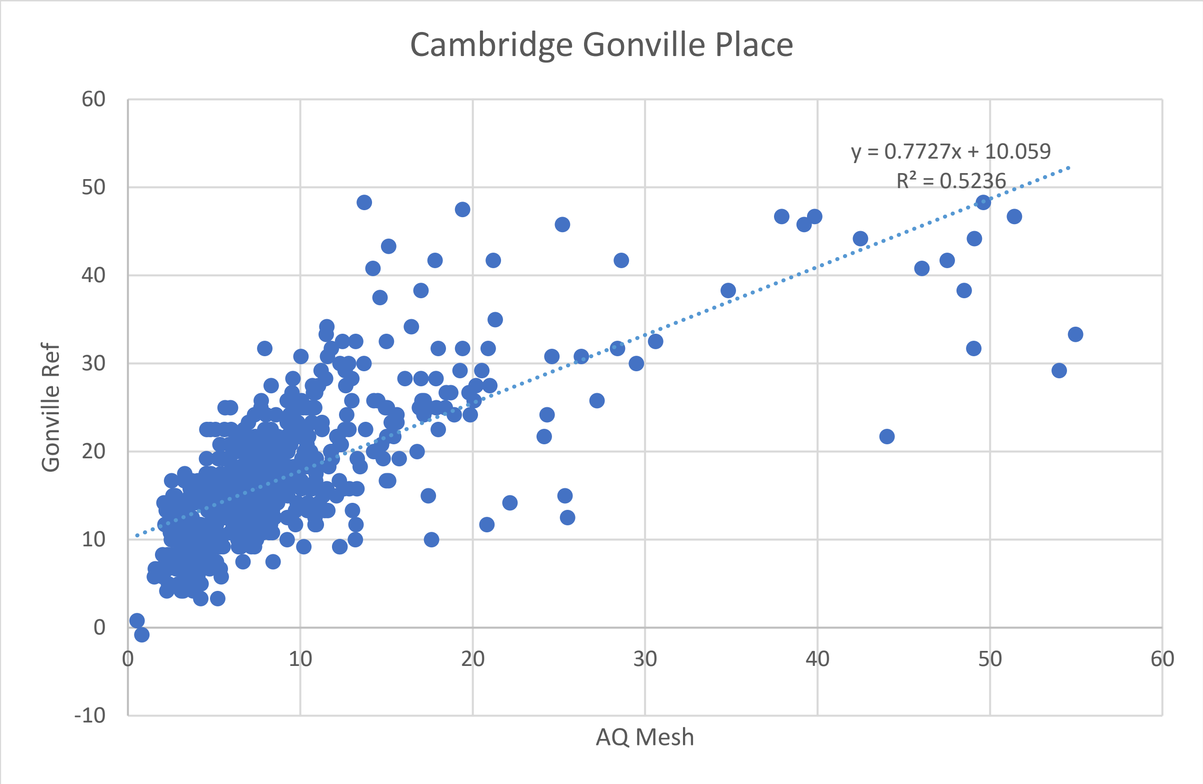
This offset is shown in more detail with the following graph.

**Figure B9 Gonville Place Vs AQ Mesh $PM_{10}$**




As shown by the graph the offset between the two types of monitor is around 10 ug $m^{-3}$. In addition, the graph shows that at higher values the difference between the two types of monitor appear to be more pronounced.

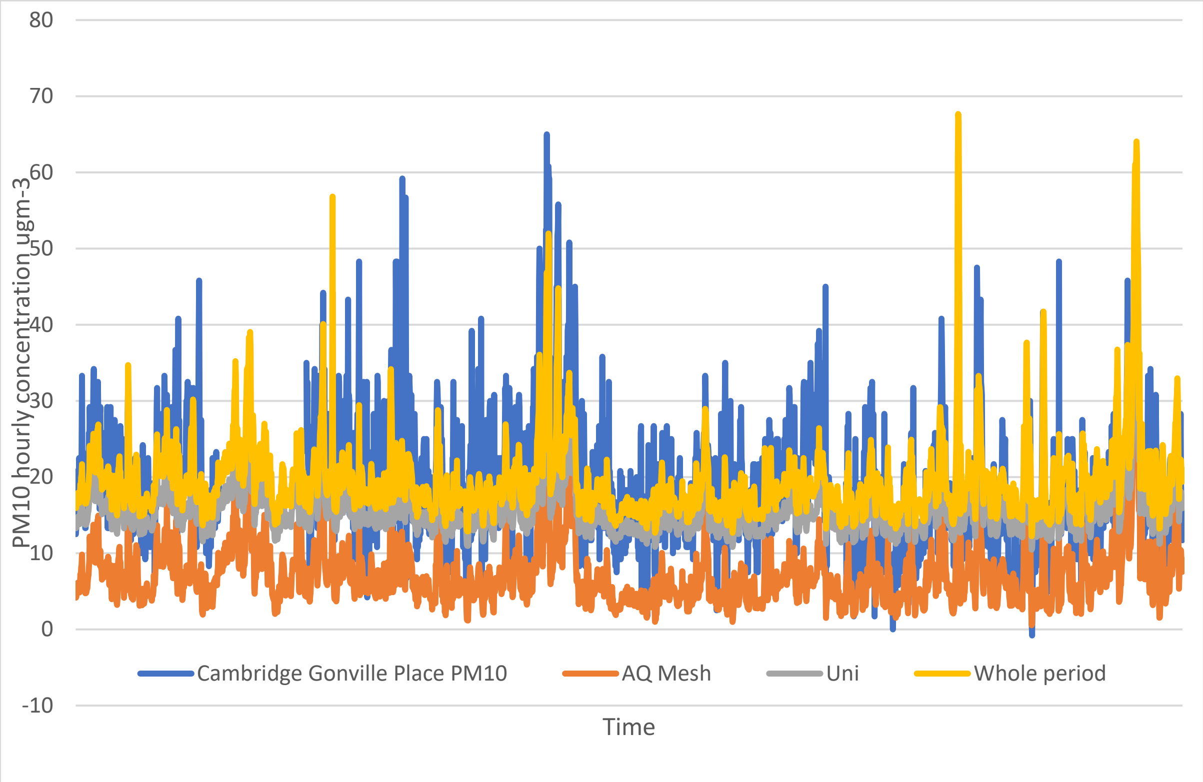
**Figure B10 Ref Vs AQ Mesh 1st Oct – 1st Nov 2019**




This graph just looks at the stable period for October to see if this method of undertaking the calibration produces a better calibration than using the whole period.

The following figure shows the data from the AQ Mesh calibrated using the two methods proposed.

**Figure B11 Calibrated AQ Mesh data comparison $PM_{10}$**

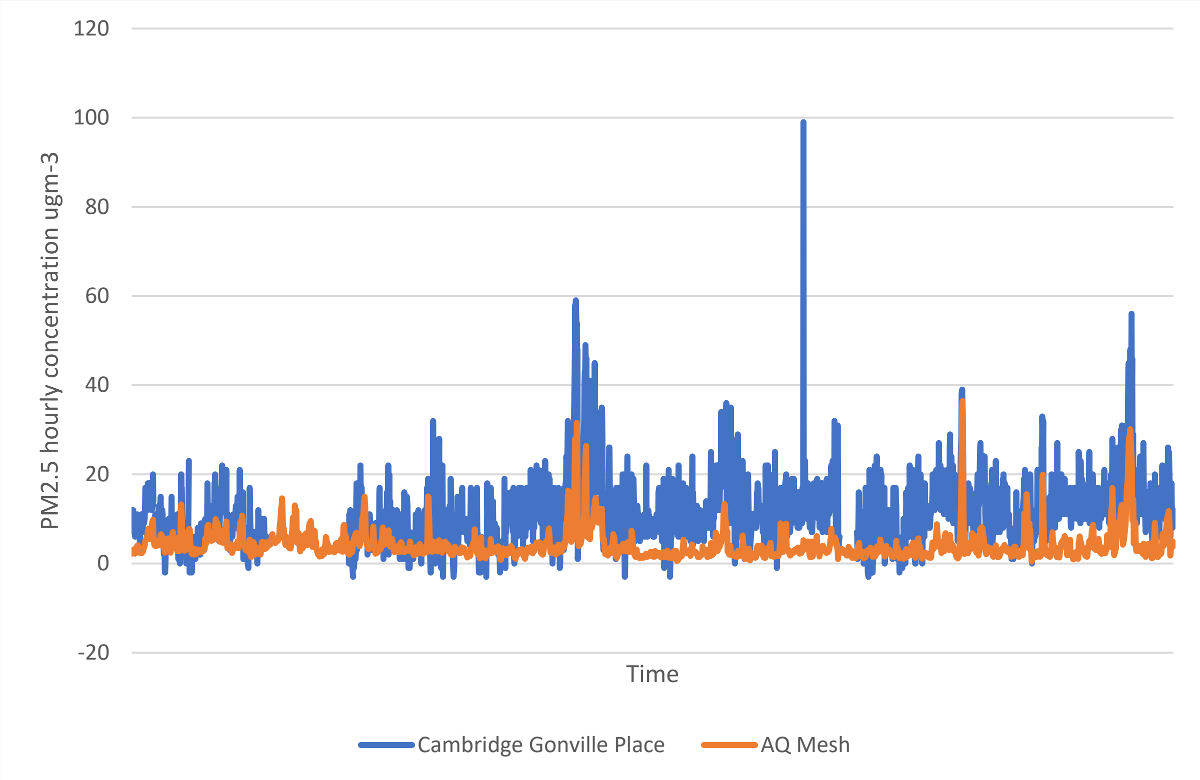



The graph shows that the calibration methods reduce the offset observed between the AQ Mesh and the continuous monitor but do not improve the variability in measurements for the AQ Mesh. The use of the university method in some cases increase the values recorded to be considerably higher than the continuous monitor.

Based on the graph above we decided to use the whole period method.

## Particulate Matter ($PM_{2.5}$)

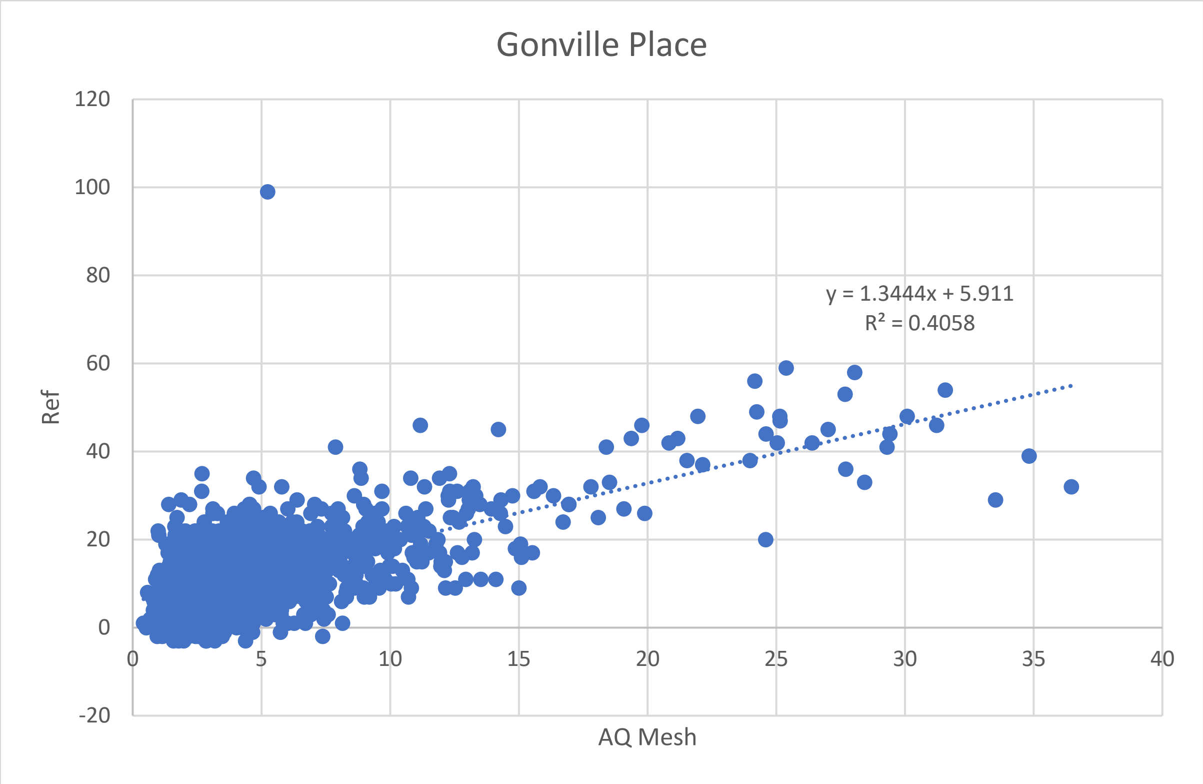
**Figure B12 $PM_{2.5}$ Gonville Place**




The graph shows that the trend in $PM_{2.5}$ concentrations from both the AQ Mesh and continuous monitor is broadly the same. However the AQ Mesh measures consistently lower than the continuous monitor and appears to have less variability in its measurements.

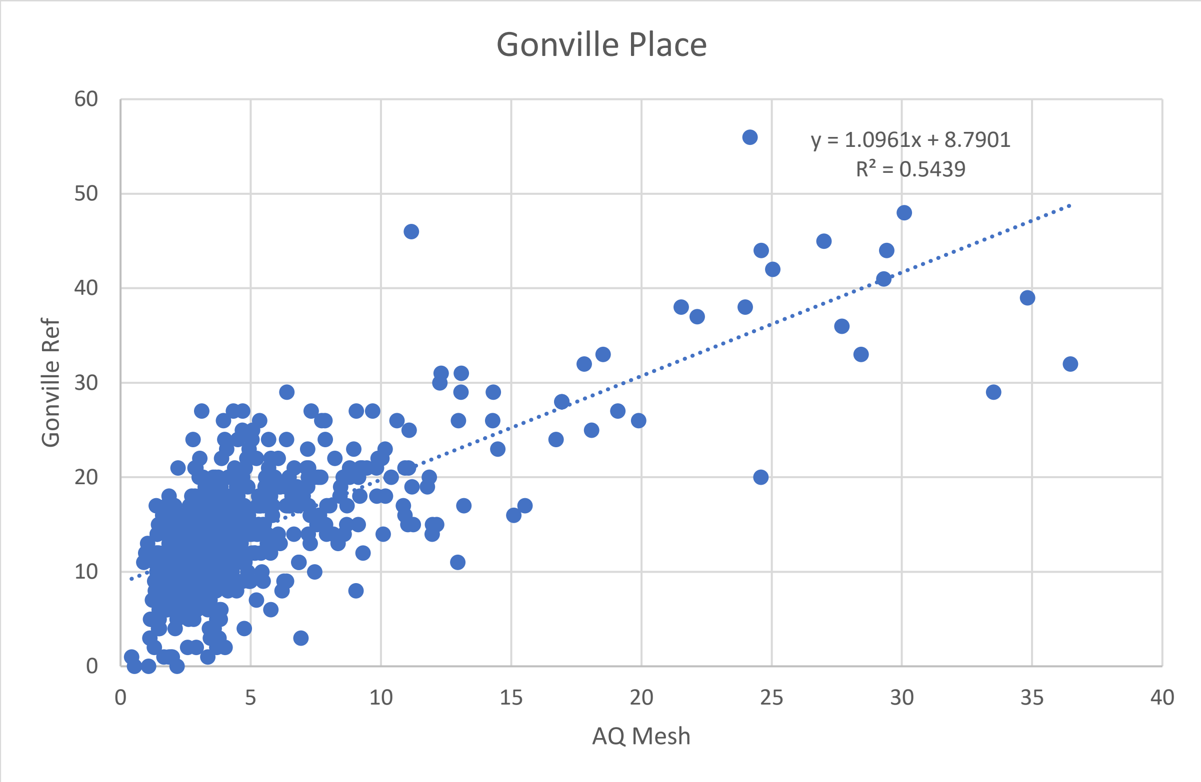
The following figure shows the comparison between the two monitors.

**Figure B13 Continuous Vs AQ Mesh $PM_{2.5}$**



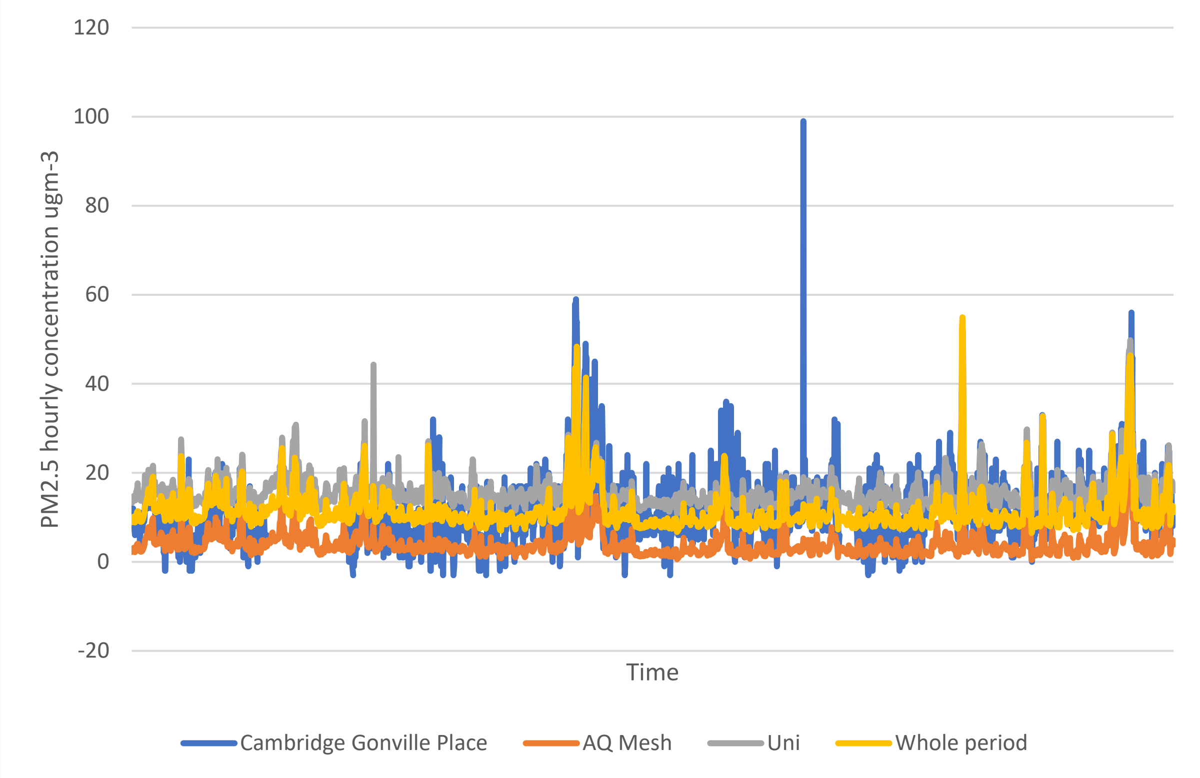

The graph shows that there is a clear offset between the AQ Mesh and the continuous monitor in terms of values. As with the $PM_{10}$ there is less correlation between the methods at higher concentrations for the $PM_{2.5}$ measurements.

**Figure B14 University comparison October 2019**




The graph shows the comparison between the AQ Mesh measurements and the Gonville Continuous monitor for October only as this was considered to be a relatively stable period with less outliers. The graph does show fewer outliers; the measurements broadly follow the same trend. The offset is greater than that using the whole data set.

**Figure B15 Calibrated $PM_{2.5}$ concentrations**




Both calibration methods as shown by the graph improve the offset for the $PM_{2.5}$ measurements. As there is more variability in the Reference data it is difficult to see which calibration method works best as the Uni method offset is greater by the whole period method appears to show more variability.

To be consistent with $NO_2$ and $PM_{10}$ we decided to use the whole period method for calibration.

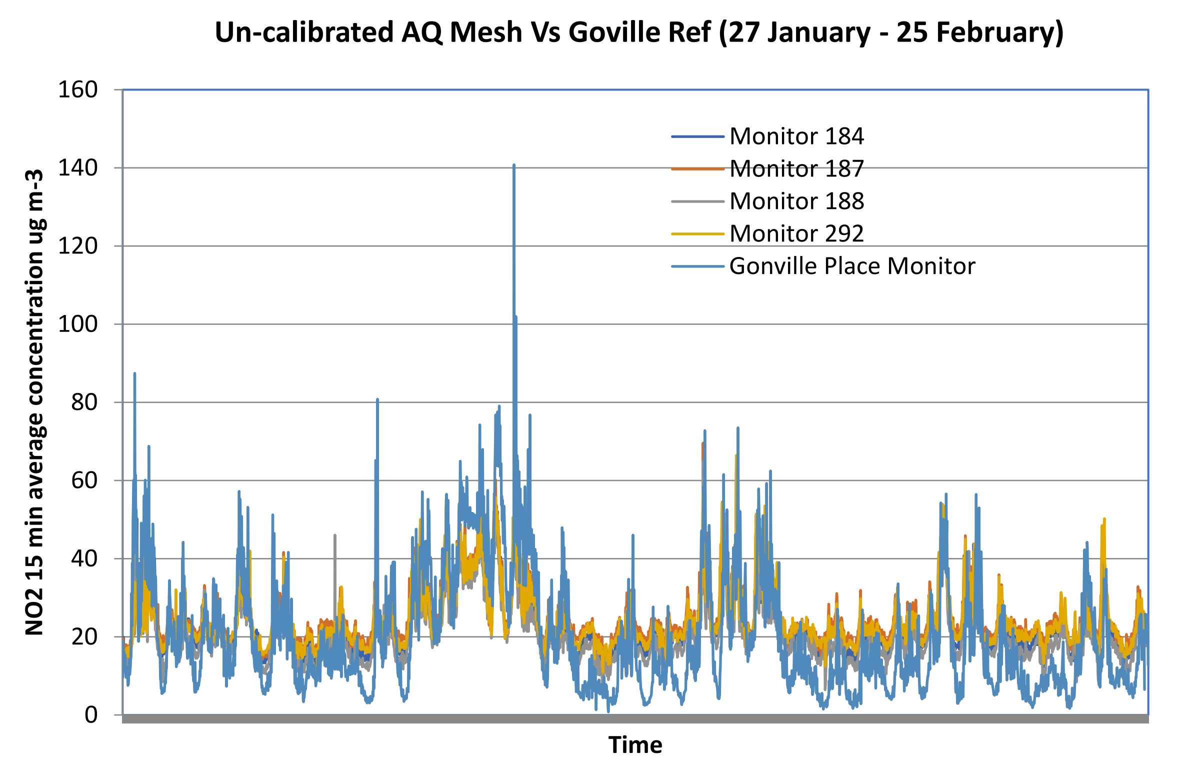
## Other sites calibration method

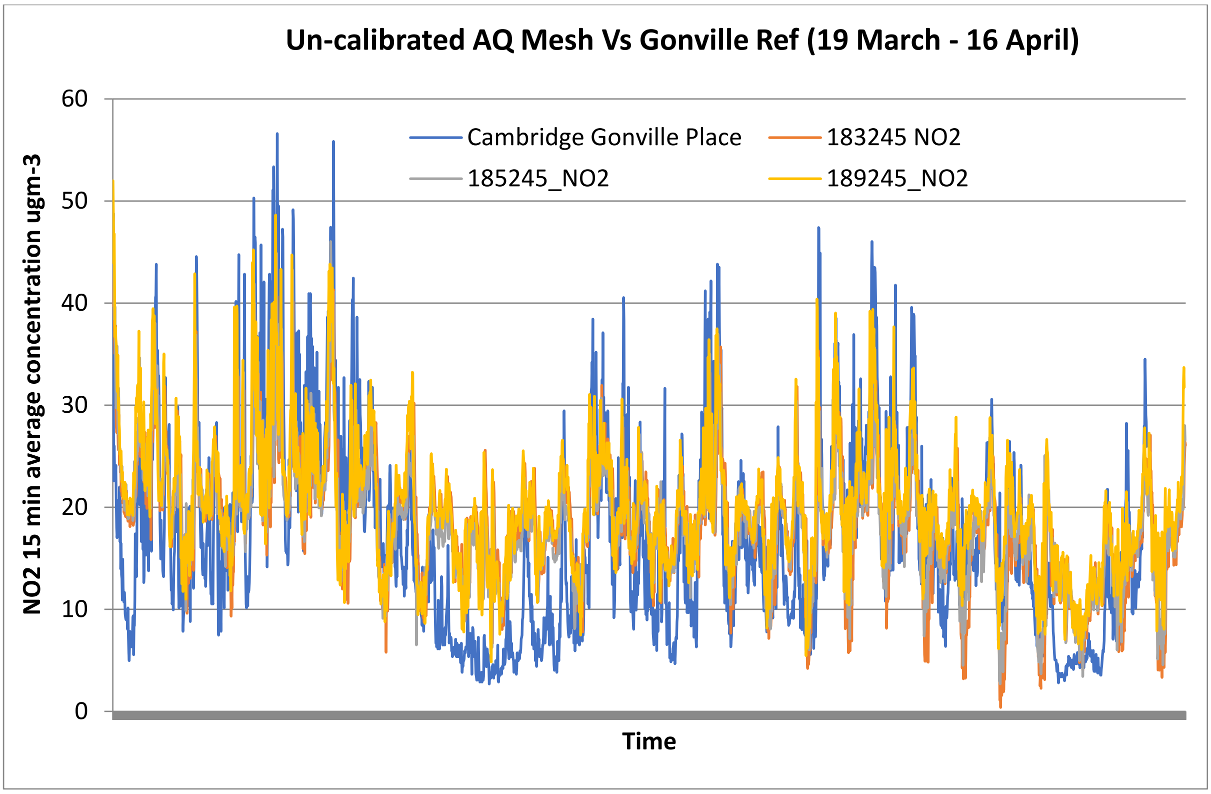
The University of Cambridge has developed a method for calibration for other monitors within the area. This involves having one AQ Mesh situated with the continuous monitor and using the readings from this to adjust the other AQ Mesh monitors in the area. This is similar to the method used for diffusion tubes to gain a "local" calibration factor. For the purposes of this project we have decided to use the same "local" factor for all the monitors. This factor is based on the whole period of monitoring rather than the short period as it gives the most data to cover all localised conditions. All the sites are considered to be roadside and in a similar location to the Gonville Place monitor and are therefore considered to be suitable for the use of a localised factor.

At the end of the monitoring period we were able to locate the other AQ Mesh monitors with the Gonville Place reference monitor. However, we were only able to do this for short periods and not at the same time.  This exercise however allowed us to see how each of the individual monitors performed against each other.

The results of this exercise are shown in the following figures.

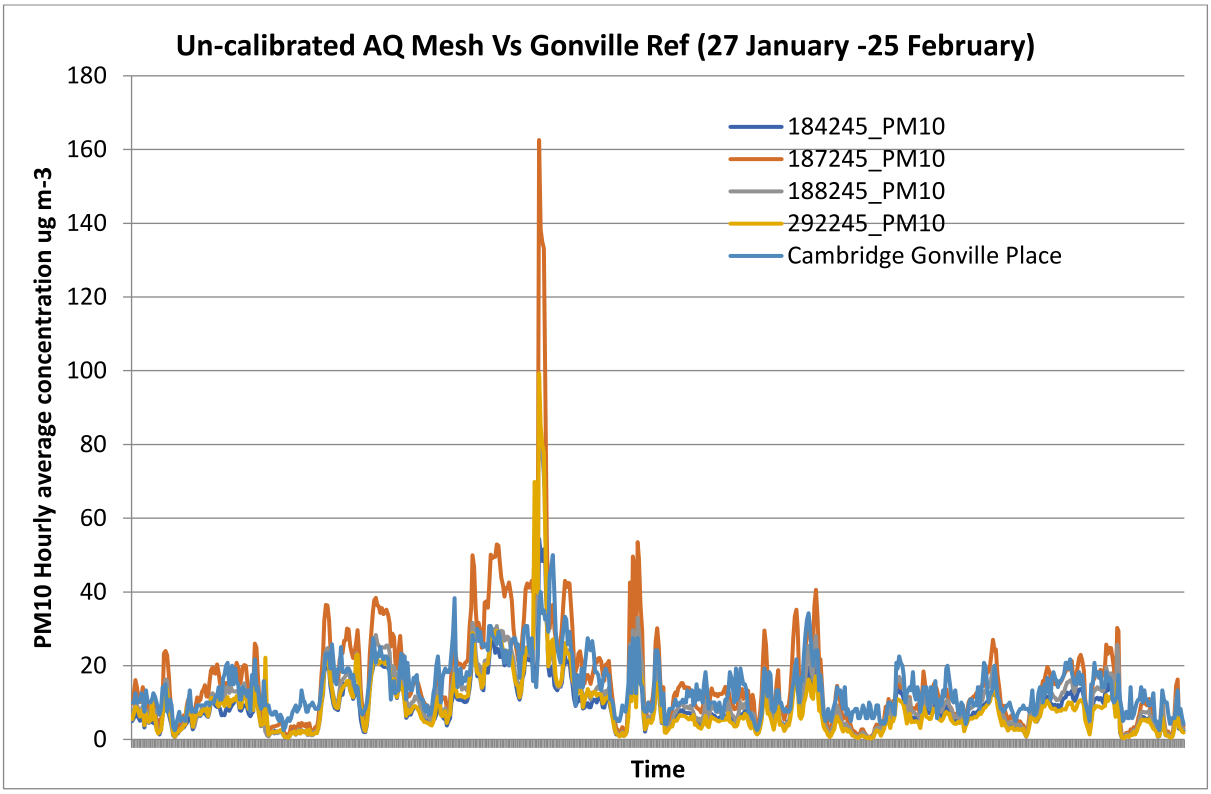
**Figure B16   Comparison of all monitors at Gonville Place ($NO_2$)**

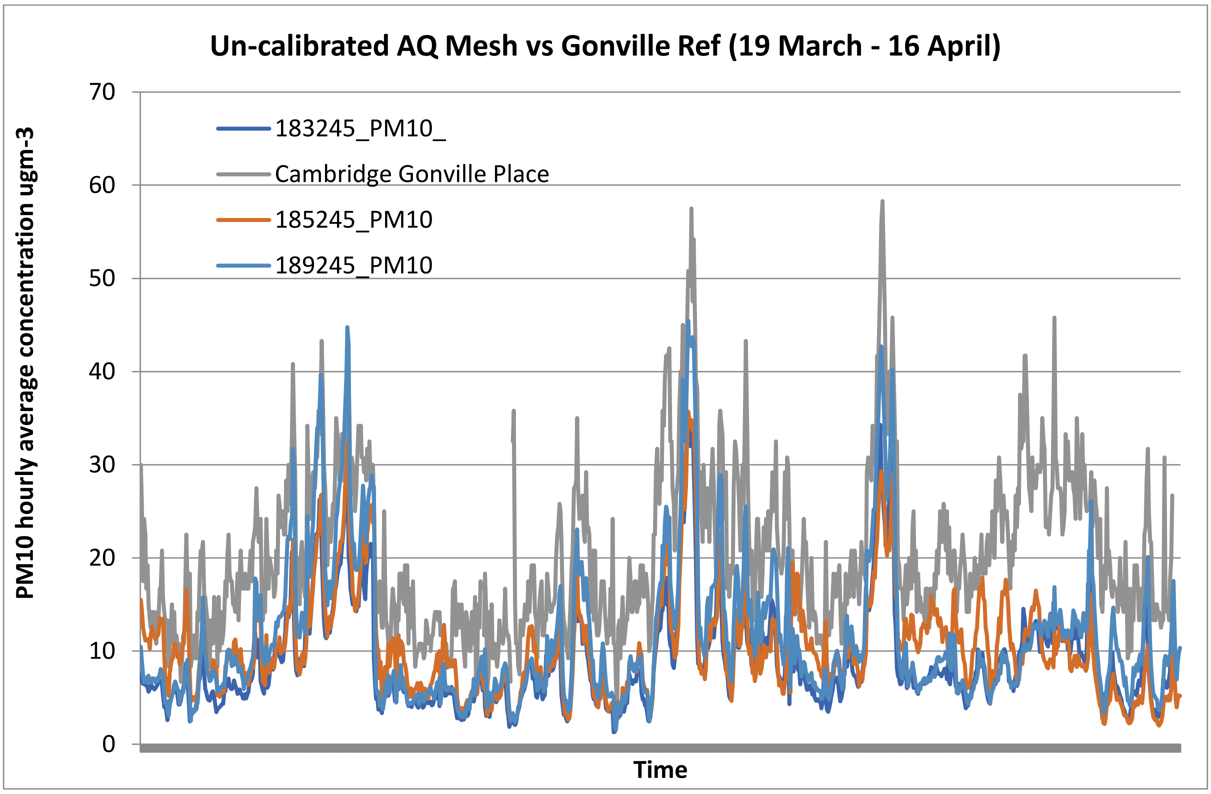





The graphs above show the un-calibrated measurements from the AQ Mesh instruments at Gonville Place. Both graphs show that the monitors follow broadly the same trend as the Gonville Place monitor. There is variability between each of the AQ Mesh monitors, but this is of a much smaller degree suggesting that the monitors are consistent with each other. Looking at both graphs and the previous graphs it appears that the AQ Mesh monitors are not as good at measuring lower levels of $NO_2$ than the continuous reference monitor.

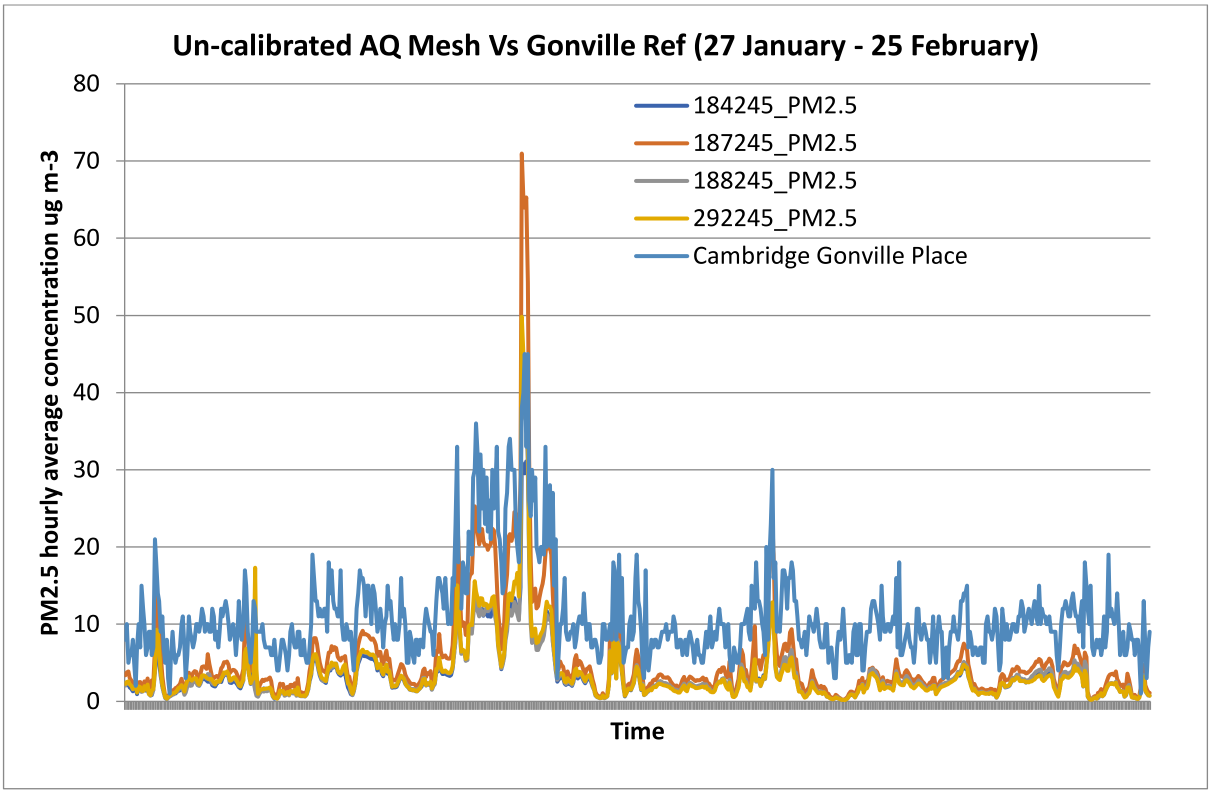
**Figure B17 Comparison of all monitors at Gonville Place ($PM_{10}$)**

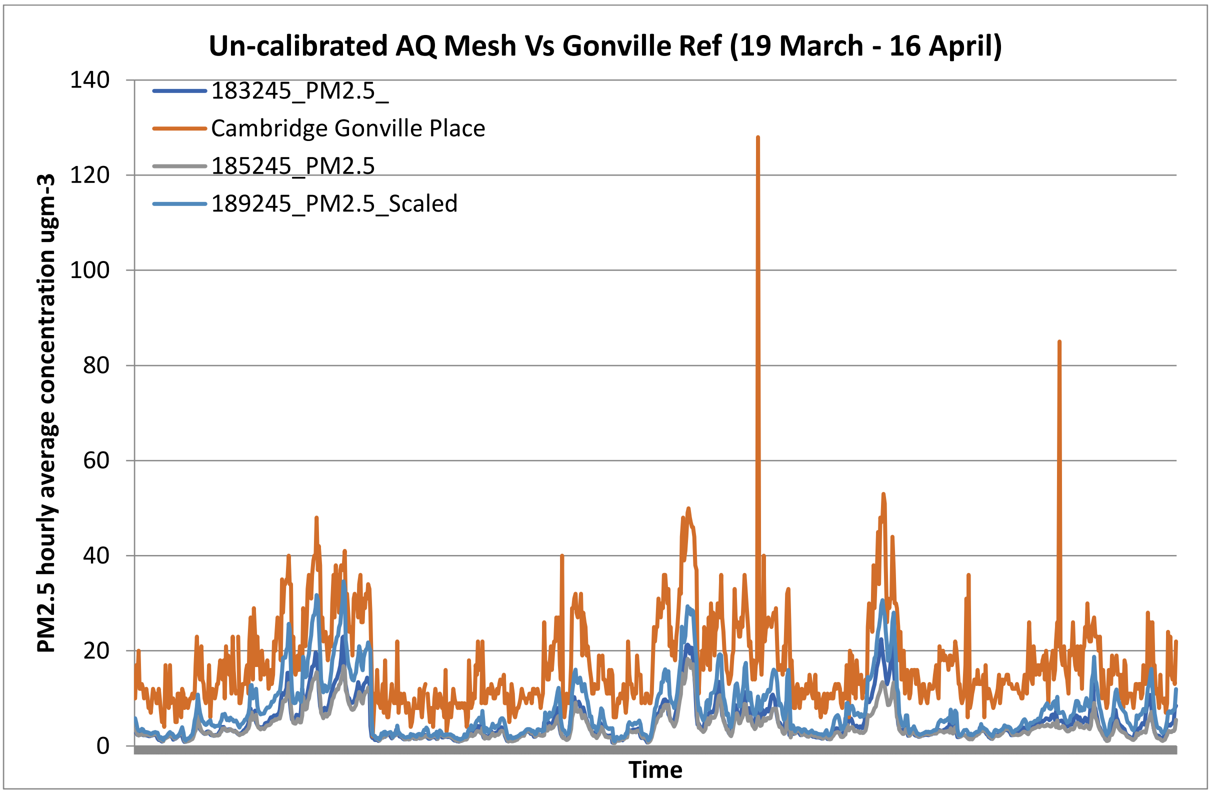



The graph shows for $PM_{10}$ that the AQ Mesh is broadly following the same trend as the Gonville Reference monitor. In general the AQ Mesh monitors are reading similar values.

**Figure B18 Comparison of all monitors at Gonville Place ($PM_{2.5}$)**




The graphs for $PM_{2.5}$ show clearly that the trend in measurements taken by both types of monitor is broadly the same. In addition the graphs also show that for $PM_{2.5}$

the AQ Mesh show consistently similar values with an offset from the Gonville Place reference monitor of similar magnitude.

# Appendix C – Diffusion Tube technical details

## QA/QC

Socotec UK Ltd (formerly ESG) supply and analyse the nitrogen dioxide ($NO_2$) tubes for Cambridge City Council. The tubes are prepared by spiking acetone: triethanolamine (50:50) onto the grids prior to being assembled. The tubes are desorbed with distilled water and the extract is analysed using a segmented flow autoanalyser with ultraviolet detection. Socotec UK Ltd, Didcot is one of the laboratories that follows the AIR PT intercomparison scheme for comparing spiked Nitrogen Dioxide diffusion tubes; SOCOTEC currently holds the highest rank of a **Satisfactory** laboratory.

Exposure periods for the diffusion tubes are those of the UK Nitrogen Dioxide Diffusion Tube Network run by National Physical Laboratory, with the tubes being changed every four or five weeks.

QA/QC procedures are as detailed in the UK $NO_2$ Diffusion Tube Network Instruction Manual. Some diffusion tube data were rejected from the dataset in line with guidance. Low concentrations are rare at urban background or roadside sites and are likely to result from an analytical problem or a faulty tube and therefore are rejected, particularly if they are an isolated occurrence. High concentrations are included unless there is a reason to reject them.

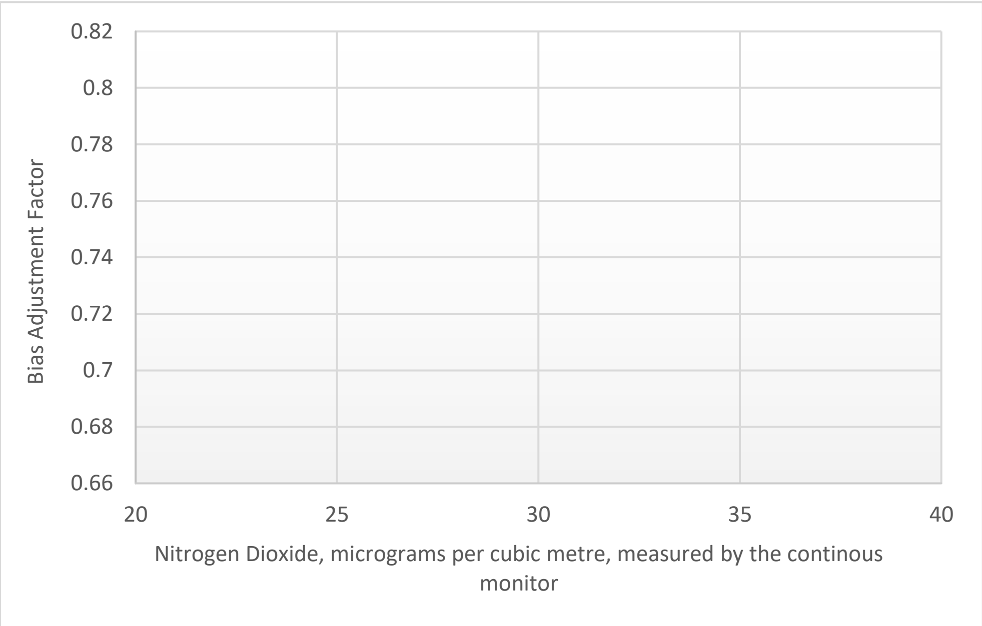
### Bias Adjustment

The results are bias-adjusted using a locally derived co-location factor. For 2019 this is 0.68 compared with a nationally derived factor of 0.75 for the ESG Didcot 50%TEA in acetone method. This locally derived factor compares the results from the continuous monitor with the average from the triplicate tubes all located at Gonville Place, Cambridge. The locally derived factor is used as it is more representative of the local situation compared with the national factor, as well as for consistency.

The bias-adjustment factor has been falling gradually as levels of nitrogen dioxide have fallen at the triplicate site Gonville Place, as shown in the graph below. We have discussed this with various air quality professionals in recent years; our understanding is that the relationship between the diffusion tube measurements and the continuous monitor measurements drifts at lower levels of nitrogen dioxide (as measured by the continuous monitor).

For this study the local bias adjustment factor has been used in the study.  This is so that those tubes which are part of Cambridge City's existing diffusion tube network in the area of the study can be compared against the new tubes installed for the study.

**Figure C1 Calculation of Bias adjustment factor**



| | NO2 | BA |
|---|---|---|
| **2015** | 35 | 0.8 |
| **2016** | 36 | 0.77 |
| **2017** | 31 | 0.7 |
| **2018** | 30 | 0.71 |
| **2019** | 28 | 0.68 |
| | **RSQ 0.87** | |

**Adjustment of DUPLICATE or TRIPLICATE Tubes**

AEA Energy & Environment
From the AEA group

| Diffusion Tubes Measurements | | | | | | | | | | Data Quality Check |
|---|---|---|---|---|---|---|---|---|---|---|
| Period | Start Date dd/mm/yyyy | End Date dd/mm/yyyy | Tube 1 µgm⁻³ | Tube 2 µgm⁻³ | Tube 3 µgm⁻³ | Triplicate Average | Standard Deviation | CV | 95% CI of mean | Diffusion Tubes Precision |
| 1 | 03/01/2019 | 07/02/2019 | 44.8 | 45.7 | 46.2 | 45.6 | 0.71 | 1.56 | 1.76 | Good |
| 2 | 07/02/2019 | 07/03/2019 | 45.1 | 41.7 | 44.8 | 43.9 | 1.88 | 4.29 | 4.68 | Good |
| 3 | 07/03/2019 | 05/04/2019 | 38.2 | 38.0 | 36.6 | 37.6 | 0.87 | 2.32 | 2.17 | Good |
| 4 | 05/04/2019 | 30/04/2019 | 48.7 | 41.8 | 44.3 | 44.9 | 3.49 | 7.77 | 8.68 | Good |
| 5 | 30/04/2019 | 29/05/2019 | 40.2 | 39.5 | 36.1 | 38.6 | 2.19 | 5.68 | 5.45 | Good |
| 6 | 29/05/2019 | 03/07/2019 | 39.6 | 40.6 | 40.0 | 40.1 | 0.50 | 1.26 | 1.25 | Good |
| 7 | 03/07/2019 | 02/08/2019 | 40.9 | 40.1 | 38.0 | 39.7 | 1.50 | 3.78 | 3.72 | Good |
| 8 | 02/08/2019 | 02/09/2019 | 38.9 | 36.7 | 38.5 | 38.0 | 1.17 | 3.08 | 2.91 | Good |
| 9 | 02/09/2019 | 01/10/2019 | 39.0 | 38.8 | 38.9 | 38.9 | 0.10 | 0.26 | 0.25 | Good |
| 10 | 01/10/2019 | 08/11/2019 | 44.2 | 44.6 | 40.4 | 43.1 | 2.32 | 5.38 | 5.76 | Good |
| 11 | 08/11/2019 | 05/12/2019 | 50.0 | 47.5 | 50.9 | 49.5 | 1.76 | 3.56 | 4.38 | Good |
| 12 | 05/12/2019 | 07/01/2020 | 37.0 | 36.8 | 40.6 | 38.1 | 2.14 | 5.61 | 5.31 | Good |
| 13 | 07/01/2020 | | | | | | | | | |

It is necessary to have results for at least two tubes in order to calculate the precision of the measurements

Jaume Targa, for AEA

Version 04 - February 2011

**Site Name/ ID:** Gonville Place

**Adjusted measurement (95% confidence level)**
**Without periods with CV larger than 20%**
Bias calculated using 11 periods of data
Tube Precision: 4 Automatic DC: 100%
Bias factor A: 0.68 (0.65 - 0.72)
Bias B: 47% (40% - 54%)
*Information about tubes to be adjusted*
Diffusion Tube average: 41 $\mu gm^{-3}$
Average Precision (CV): 4
Adjusted Tube average: 28 +/- 1 $\mu gm^{-3}$

**Adjusted measurement (95% confidence level)**
**with all data**
Bias calculated using 11 periods of data
Tube Precision: 4 Automatic DC: 100%
Bias factor A: 0.68 (0.65 - 0.72)
Bias B: 47% (40% - 54%)
*Information about tubes to be adjusted*
Diffusion Tube average: 41 $\mu gm^{-3}$
Average Precision (CV): 4
Adjusted Tube average: 28 +/- 1 $\mu gm^{-3}$

## Annualisation

Where sites record data capture for the 12 month monitoring period below 75% an annualisation calculation is required as set out in LAQM TG16.

None of the additional tubes for the study had a data capture less than 75% and therefore annualisation calculations were not required for those tubes.

One of the existing tubes which was used in the study had a data capture lower than 75%. The annualisation calculations for this site during 2019 are presented below. All automatic monitors achieved over 75% data capture.

Annualisation was based on the average of three AURN background sites within 50 miles radius of Cambridge.

**Figure C2 Calculation of Annualisation for DT13 East Road – 66% data capture**

| | Borehamwood Meadow Park | East Road | Borehamwood Meadow Park |
|---|---|---|---|
| January | 30.3 | 36.6 | 30.3 |
| February | 32.5 | **51.6** | 32.5 |
| March | 19.0 | 35.7 | 19.0 |
| April | 20.1 | | |
| May | 14.9 | 26.7 | 14.9 |
| June | 13.0 | 26.7 | 13.0 |
| July | 14.5 | 23.2 | 14.5 |
| August | 17.8 | | 17.8 |
| September | 17.4 | 28.5 | 17.4 |
| October | 21.6 | 17.8 | 21.6 |

| | | | |
|---|---|---|---|
| November | 30.5 | | |
| December | 23.9 | | |
| Average | 21.3 | 30.9 | 20.1 |
| Am/Pm | 1.1 | | |
| | | | |
| Estimated Annual Mean | 32.7 | | |
| Bias-adjusted | 22.2 | | |

| | Wicken Fen | East Road | Wicken Fen |
|---|---|---|---|
| January | 14.4 | 36.6 | 14.4 |
| February | 14.3 | **51.6** | 14.3 |
| March | 7.9 | 35.7 | 7.9 |
| April | 7.9 | | |
| May | 6.2 | 26.7 | 6.2 |
| June | 4.5 | 26.7 | 4.5 |
| July | 5.3 | 23.2 | 5.3 |
| August | 5.6 | | |
| September | 5.3 | 28.5 | 5.3 |
| October | 8.0 | 17.8 | 8.0 |
| November | 13.6 | | |

| | | | |
|---|---|---|---|
| December | 9.8 | | |
| Average | 8.6 | 30.9 | 8.2 |
| | | | |
| Am/Pm | 1.0 | | |
| | | | |
| Estimated Annual Mean | 32.1 | | |
| Bias-adjusted | 21.8 | | |

**Average 22.0**

# Appendix D – Continuous Monitors Technical Details

Cambridge City Council has five continuous monitors; all are at roadside sites. The monitoring station at Regent Street is situated at the offices of Cambridge City Council in Mandela House. It is part of the National Automatic Urban Network (AURN) on behalf of DEFRA and has been in place since 1993. Monitors for Gonville Place and Parker Street were commissioned in 1998. The monitor at Newmarket Road was commissioned in 2001 in response to perceived data shortfalls for urban feeder roads following the first round of R&A. The monitoring station at Montague Road was commissioned in April 2007, using the monitors formerly located in Silver Street.

Each of the sites is calibrated and maintained every 2-3 weeks by the Local Site Operator (LSO), Cambridge City Council. The sites are serviced every six months. Equipment Support Unit (ESU) services are provided by Matts Monitors. The sites are audited by Ricardo Energy & Environment either as part of the AURN or through the 'Calibration Club'. All data is collated and ratified externally by Ricardo Energy & Environment. The results are ratified and returned as hourly sequential data.

### $PM_{10}$ and $PM_{2.5}$ Monitoring Adjustment

The $PM_{10}$ monitors have had the BAM Gravimetric Equivalent correction factor applied by the QA/QC contractor.

The $PM_{2.5}$ monitor at Gonville Place does not require correction as it has a heated inlet.

The $PM_{2.5}$ monitor at Newmarket Road has had the conventional TEOM Gravimetric Equivalent correction factor applied by the QA/QC contractor.

### Automatic Monitoring Annualisation

All automatic monitoring locations within Cambridge City Council recorded data capture of greater than 75% therefore it was not required to annualise any monitoring data. In addition, any sites with a data capture below 33% do not require annualisation.

# Appendix E  Continuous Monitors Results

## Nitrogen Dioxide

The following graph shows the average hourly $NO_2$ concentrations at the continuous monitors across the city in 2019.

Figure E1 shows a similar trend across the sites in 2019.
Weekly average concentrations have also been plotted which produce Figure E2.

Figures E1 and E2 show that the highest concentrations are recorded at Parker Street monitor in 2019. Figures E1 and E2 also show that concentrations in general are higher in winter than in the summer except for Parker Street where concentrations in July and August are comparable to concentrations recorded in the winter months.

Gonville Place would have been an alternative route for people accessing Cambridge and potentially could have seen an increase in traffic volumes. It difficult to see if there is an increase in concentrations at Gonville Place during the closure as we know the monitor was not working for a few days which could have meant lower concentrations were recorded during weeks 30 and 31. All of the monitors appear to show a peak in concentrations during July and August which coincide with periods of very high ambient temperatures. This is not shown by Gonville Place in July due to loss of data. Parker Street shows the highest concentrations during the bridge closure. This monitor is located in a street canyon close to the bus station in Cambridge and the concentrations recorded at this location could be related to the localised conditions.

**Figure E1 Hourly average $NO_2$ concentrations (ugm[-3]) at continuous monitors in Cambridge in 2019.**

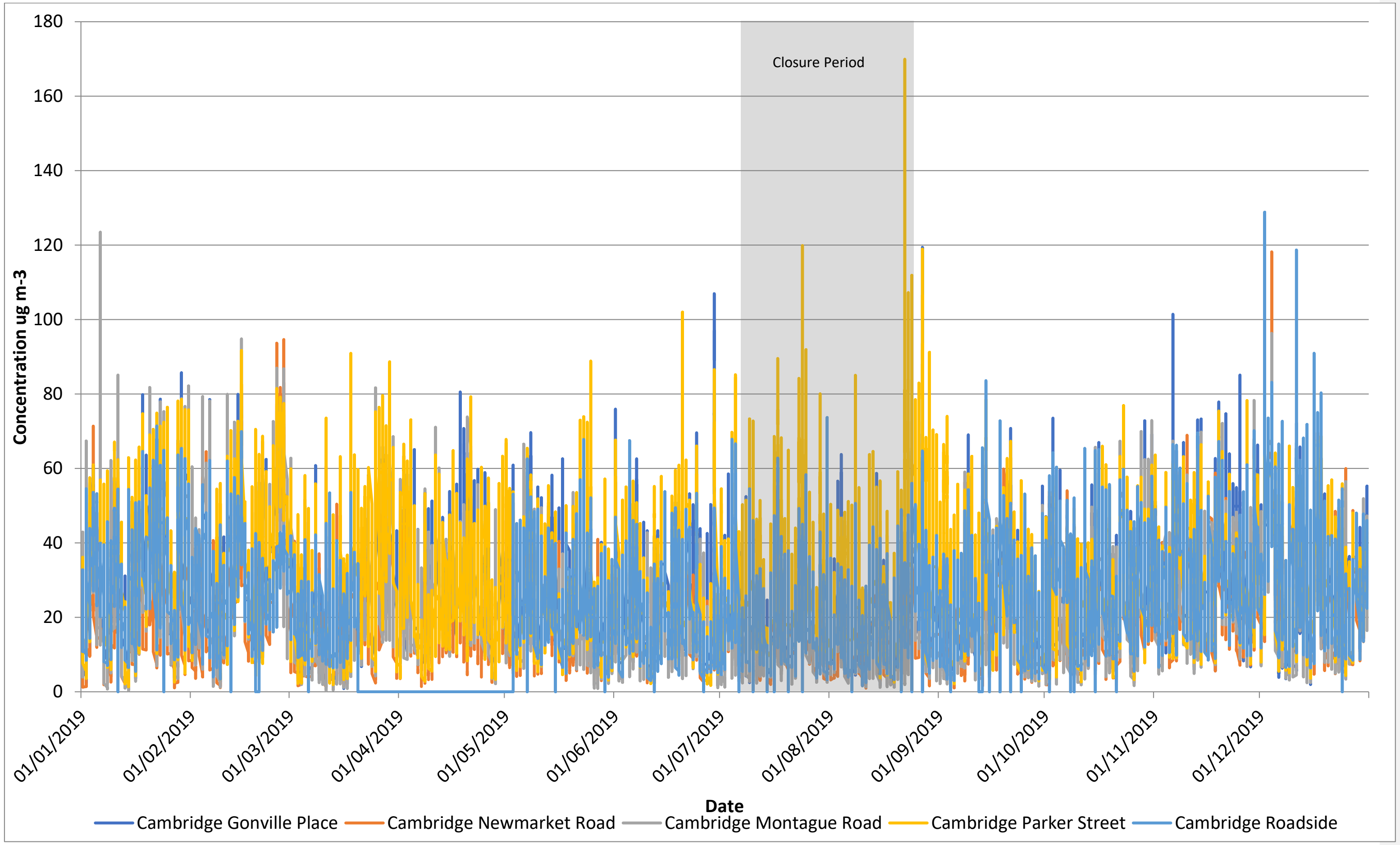
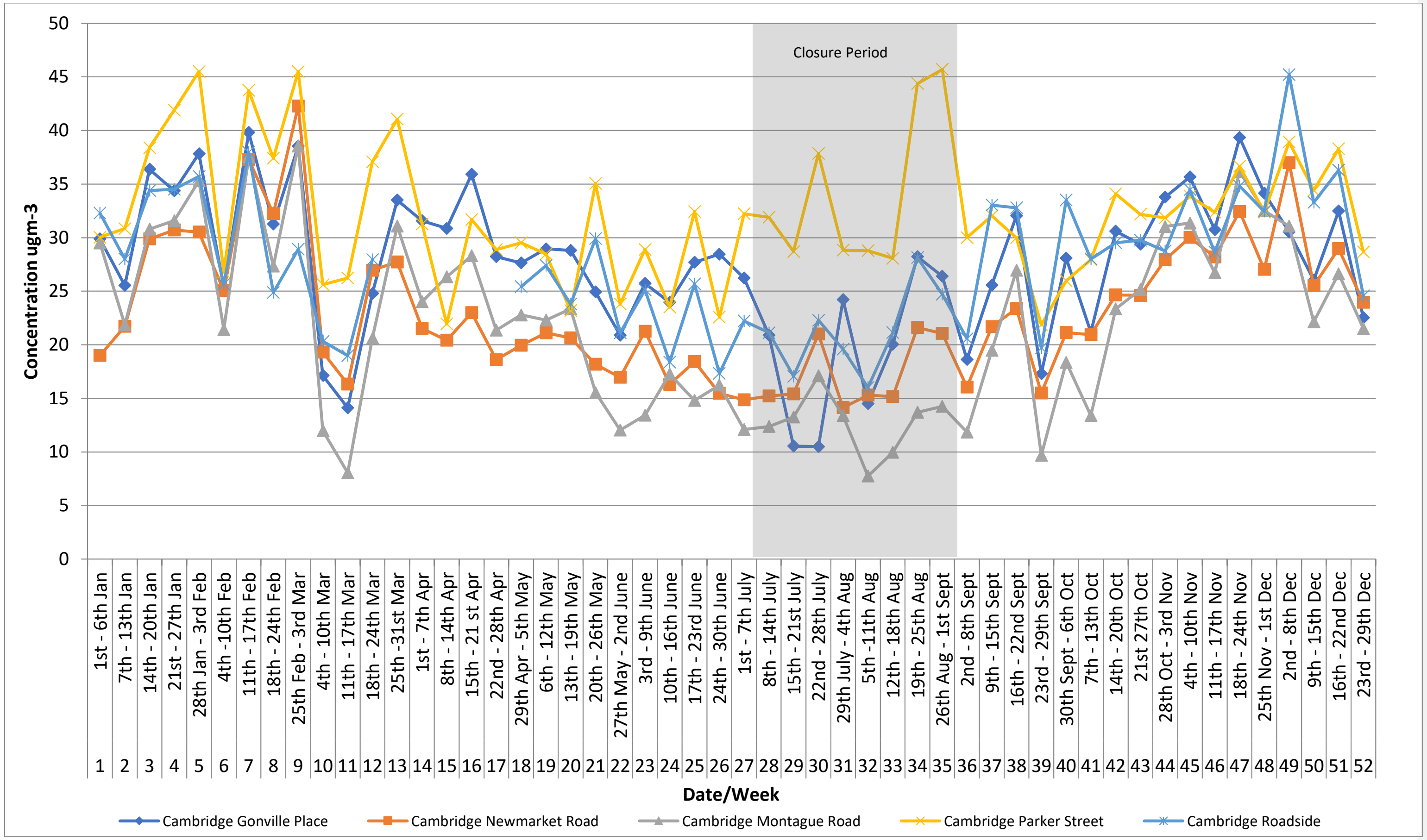


**Figure E2 Weekly average $NO_2$ concentrations ($ugm^{-3}$) at continuous monitors in Cambridge in 2019.**



## Particulate Matter ($PM_{10}$)

Figure E3 shows the average hourly $PM_{10}$ concentrations at the continuous monitors across the city in 2019. $PM_{10}$ is measured at three locations within the City, Gonville Place, Montague Road and Parker Street.

Figure E3 shows a general trend of similar concentrations across the year with higher concentrations in the first quarter of the year. Figure E3 also shows that concentrations appear to be more stable in the latter part of the year as compared to the beginning of the year when there is a lot of variation in concentrations. Peaks in concentrations at Parker Street and Gonville Place are likely to be linked to a nearby event.

Weekly average concentrations have also been plotted which produce Figure E4.

Figure E4 shows that the weekly averages were significantly higher during the first part of 2019 than during the latter part of 2019, with much more variation in concentrations. The pattern shown by the continuous monitors is in general the same suggesting an underlying dominant background source. The monitors at Montague Road and Parker Street show similar concentrations throughout the year. The monitor at Gonville appears to show lower concentrations than the other monitors except for a short period in the Summer during the road closure. It is unclear whether the results for the weeks included are an accurate reflection for Gonville Place during the road closure as there was a fault with the monitor in weeks 30 and 31. The concentrations during these weeks could be higher or lower than shown. For the last part of the year, as with the first part of the year the three monitors show greater variation in their recorded concentrations with Gonville Place recording lower concentrations that the other monitors, although all three monitors follow the same trend.

**Figure E3 Hourly average $PM_{10}$ concentrations ($ugm^{-3}$) at continuous monitors in Cambridge in 2019.**

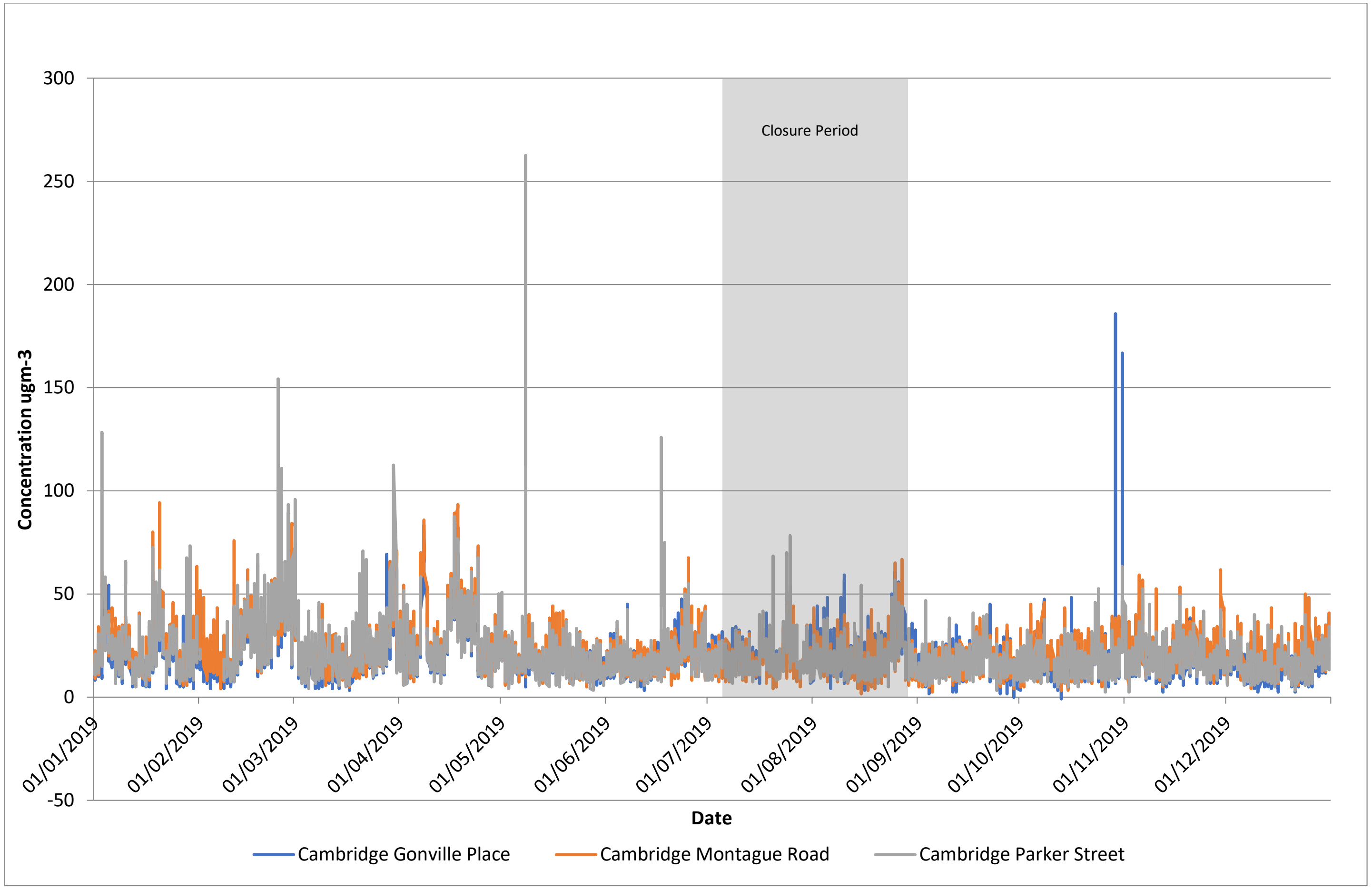
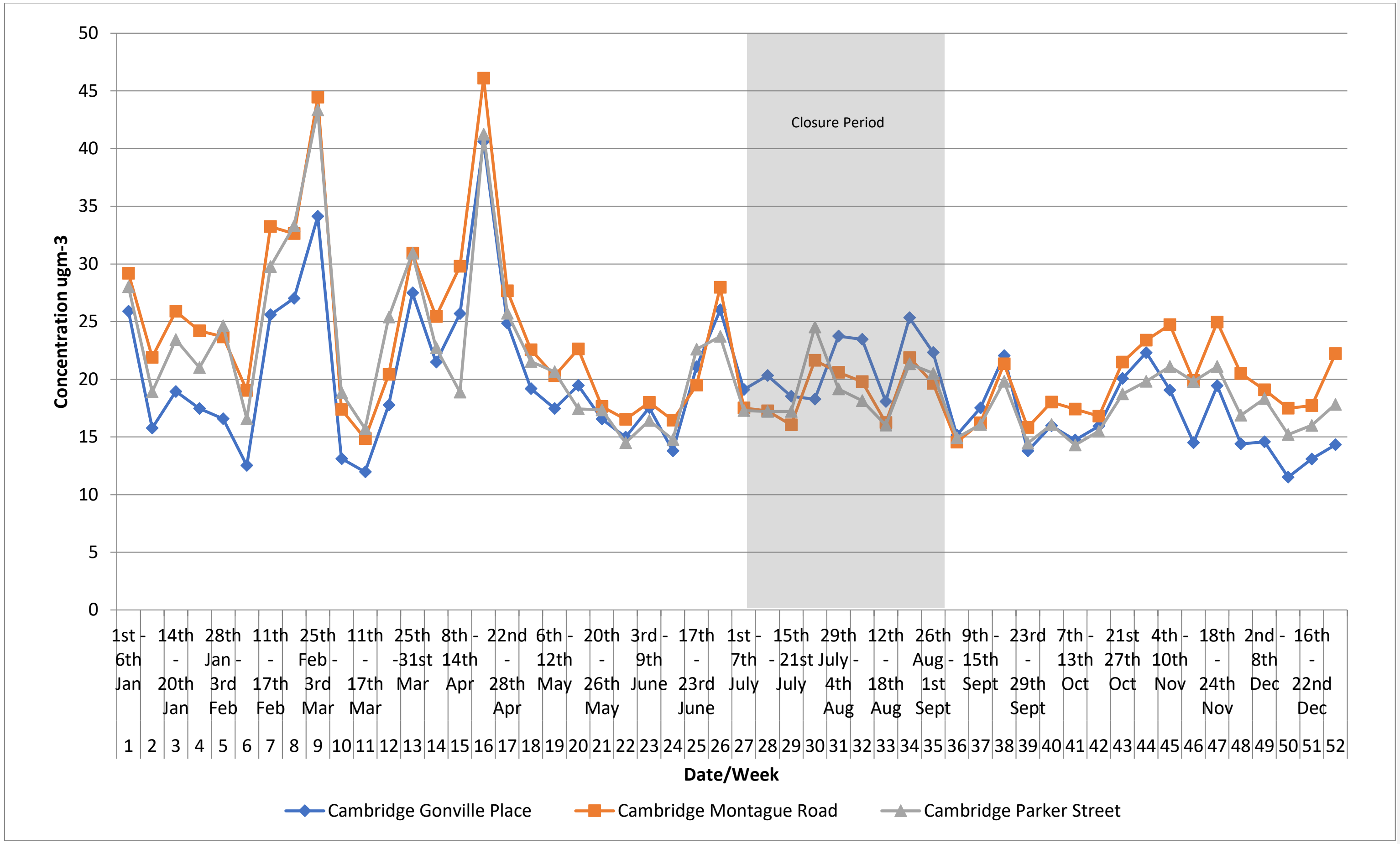


**Figure E4 Weekly average $PM_{10}$ concentrations (ugm$^{-3}$) at continuous monitors in Cambridge in 2019.**



## Particulate Matter ($PM_{2.5}$)

Figure E5 shows the average hourly $PM_{2.5}$ concentrations at the continuous monitors across the city in 2019. $PM_{2.5}$ is measured at two locations within the City, Gonville Place and Newmarket Road.

Figure E5 shows that in general both sites record similar trends across the year. The Gonville Place monitor appears to record concentrations which are more varied in range than the Newmarket Road monitor and generally higher over the course of the year. The $PM_{2.5}$ concentrations for both monitors appear to be higher at the beginning of 2019 than at the end.

Figure E6 also appears to show that concentrations were higher in the beginning part of 2019 for both sites. As with Figure E5, concentrations at Gonville Place are higher than those at Newmarket Road. During the end of July the monitor at Gonville Place was not working so weeks 30 and 31 may show lower concentrations due to this event. Figure E6 also shows that for the first half of the year concentrations at Gonville Place and Newmarket Road are similar and follow the same trend. From the end of June concentrations start to have a greater degree of separation. From the end of October the concentrations at Newmarket Road follow a different trend and are much lower. During September there was a fault with the monitor at Newmarket Road and it was replaced. This could explain the change in trend. For the weeks when the bridge was closed (27 - 35) some of the lowest concentrations of $PM_{2.5}$ were recorded at both monitors. This includes weeks 30 and 31 when the Gonville Place monitor was not working. During these weeks there was a higher value recorded at Newmarket Road which then saw a rapid decline. Concentrations of $PM_{2.5}$ at Gonville Place increased during the latter half of August and then again in October where they remained stable till the end of the year. It is unclear whether the road closure had an effect on $PM_{2.5}$ concentrations.

**Figure E5 Hourly average $PM_{2.5}$ concentrations ($ugm^{-3}$) at continuous monitors in Cambridge in 2019.**

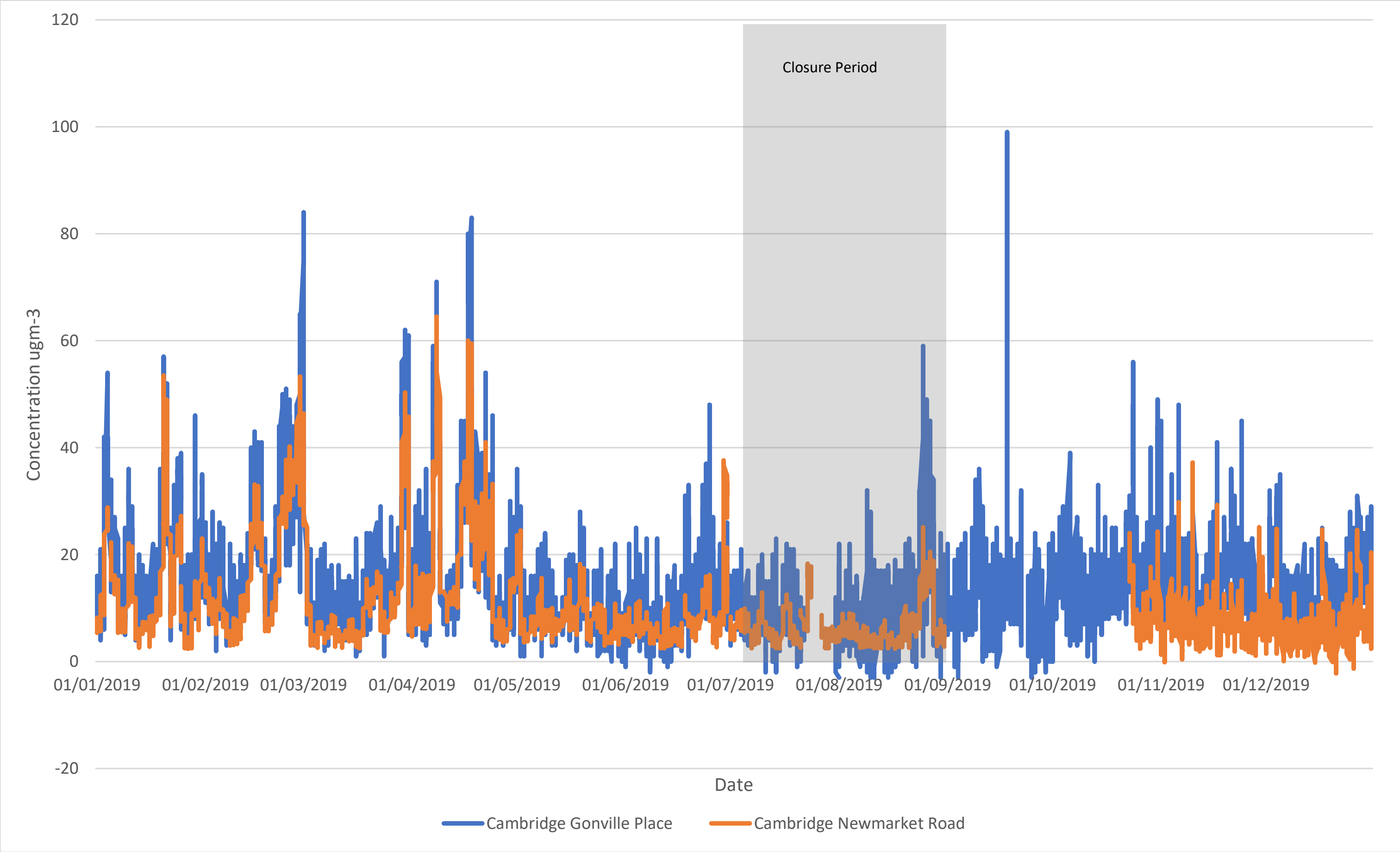
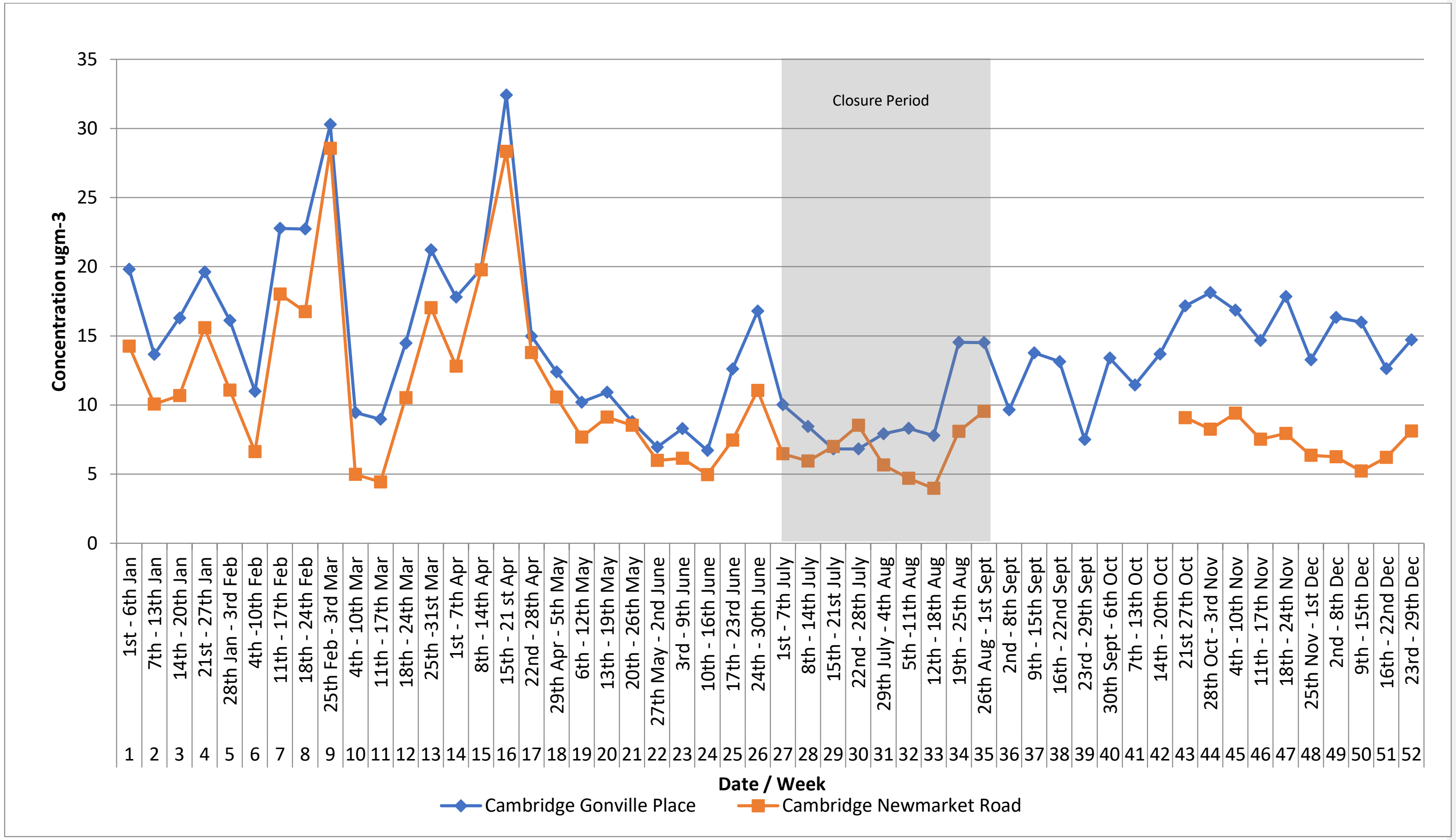


**Figure E6 Weekly average $PM_{2.5}$ concentrations ($ugm^{-3}$) at continuous monitors in Cambridge in 2019.**



## Yearly Comparison – Gonville Place

At Gonville Place we have data going back to 2016 for each pollutant. We can therefore assess whether there have been any changes in data in 2019 as compared to other years during the monitoring period and after the monitoring period.

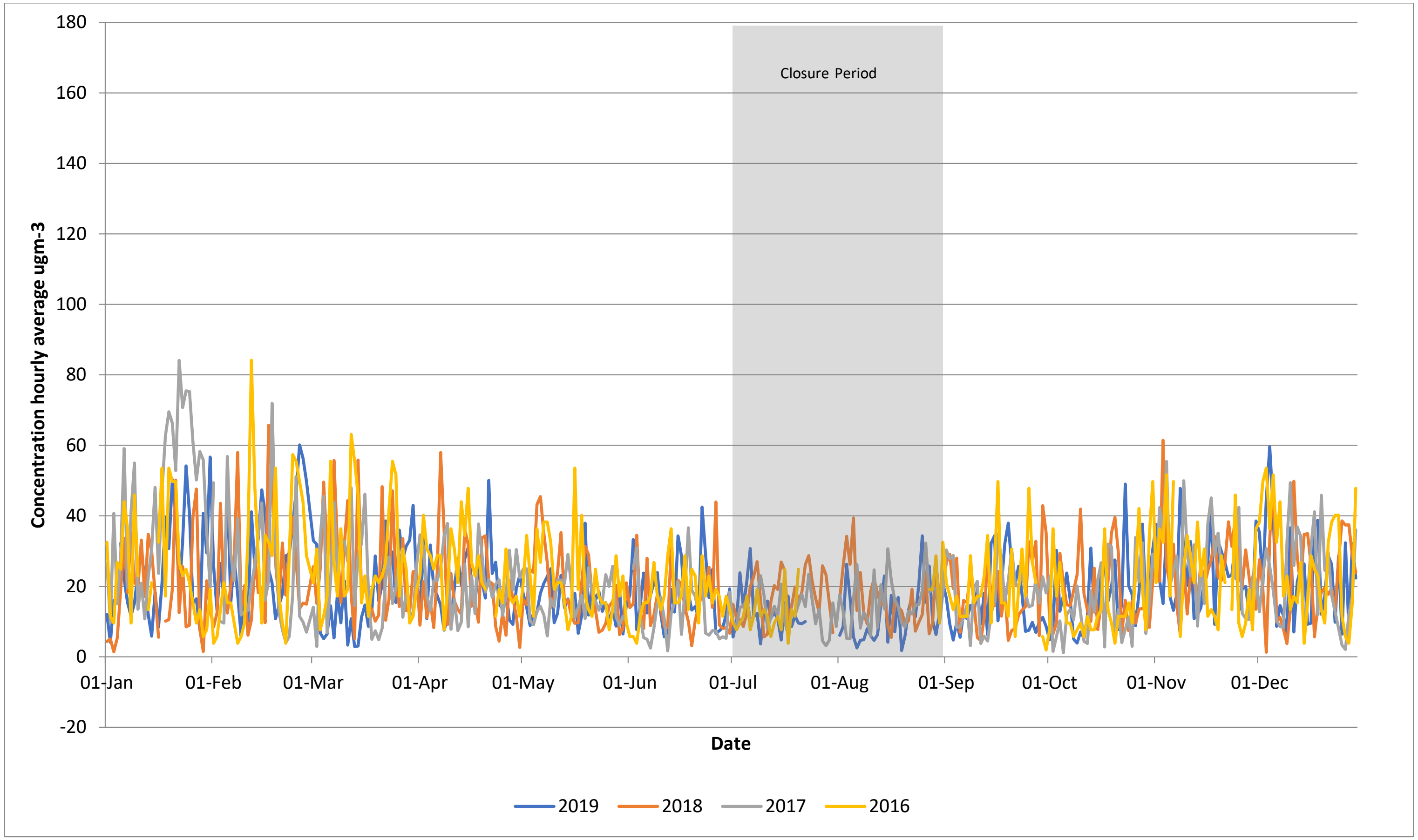
Figure E7 for $NO_2$ shows a similar trend across the years with concentrations lower in the summer and higher in the winter. Missing data for 2019 and 2016 over the summer period makes it difficult to see if there was a significant difference between the years. The lower recordings for 2019 could be the result of a fault with the monitor and no data being recorded.

Figure E8 for $PM_{10}$ over the past 4 years at Gonville Place shows a similar trend across the years. There does not appear to be much variation between the summer and winter months. It is difficult to interpret whether $PM_{10}$ concentrations are higher during the closure period for 2019 than for the other years. It appears higher for the closure period than 2016 and 2017 but 2018 also shows higher results for this period.

Figure E9 for $PM_{2.5}$ for the past 4 years at Gonville Place show a trend of higher concentrations in the winter months and lower concentrations in the summer months. There does appear to be a slight trend of slightly higher concentrations during the winter months as opposed to the summer months.

For 2019 during the closure period $PM_{2.5}$ concentrations appear to be lower than in previous years whereas for the rest of the year they are similar values and are neither higher or lower.

**Figure E7 – Graph of $NO_2$ 2019 compared to other years Gonville Place.**




**Commented [AL1]:** Different colours for the same year is a bit confusing. Also if you could mark up the closure period it would be helpful.

**Commented [AMH2R1]:** Sorted

**Figure E8 Graph of $PM_{10}$ 2019 compared to other years Gonville Place.**

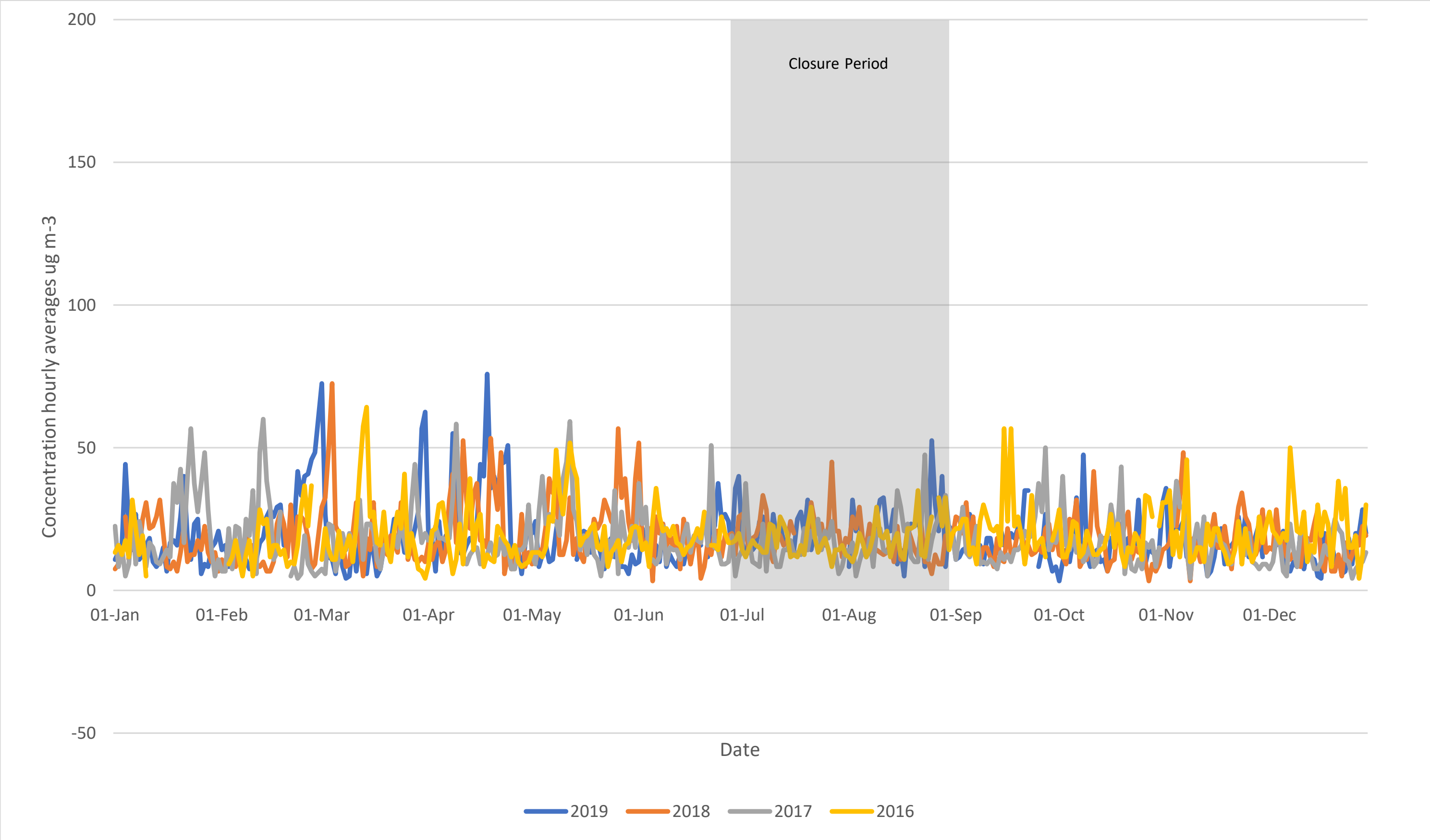
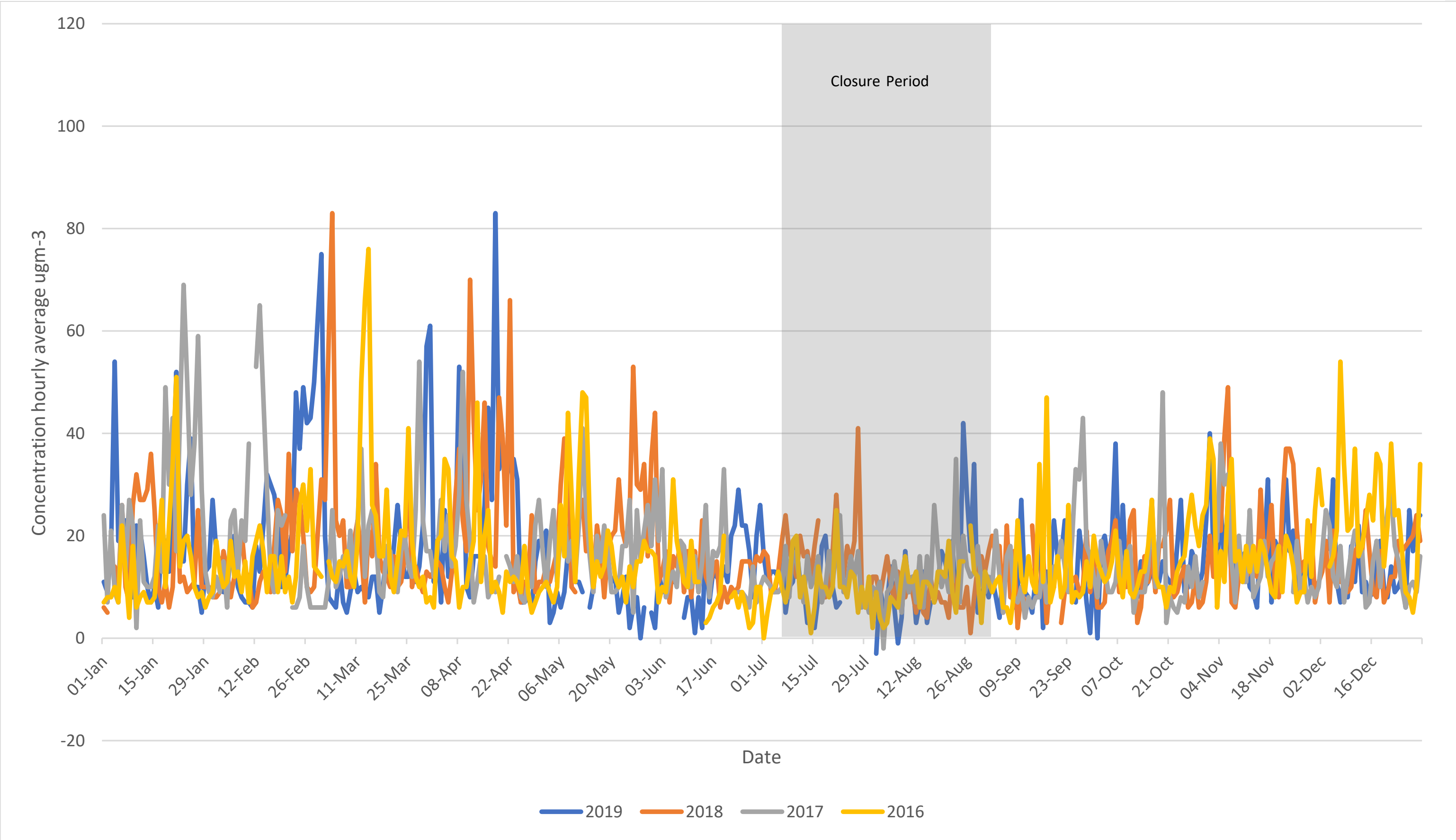


**Figure E9 Graph of $PM_{2.5}$ 2019 compared to other years Gonville Place.**



# Appendix F – AQ Mesh Monitoring Results

These are the monitoring results from the AQ Mesh pods for the monitoring period 8th July to 29th December. The full details of the calibration methodology for the AQ Mesh is outlined in Appendix B.

A map showing the location of the AQ Mesh pods is shown in the main report in Figure X.

## Pod 292 Coldhams Lane

Figures F1 to F6 show the15 minute data collected for 292 Coldhams Lane for $NO_2$, $PM_{10}$ and $PM_{2.5}$ for the monitoring period as 15 minute averages, weekly averages and as a diurnal profile. This monitor is located on Coldhams Lane, between Vinery Road and Ross Street. It has been colocated with an existing diffusion tube (17). A vivacity Traffic monitor is also placed close by on the same side of the road.

**Figure F1 15 minute average $NO_2$ ($ugm^{-3}$) July to December 2019 Pod 292 (Coldhams Lane)**

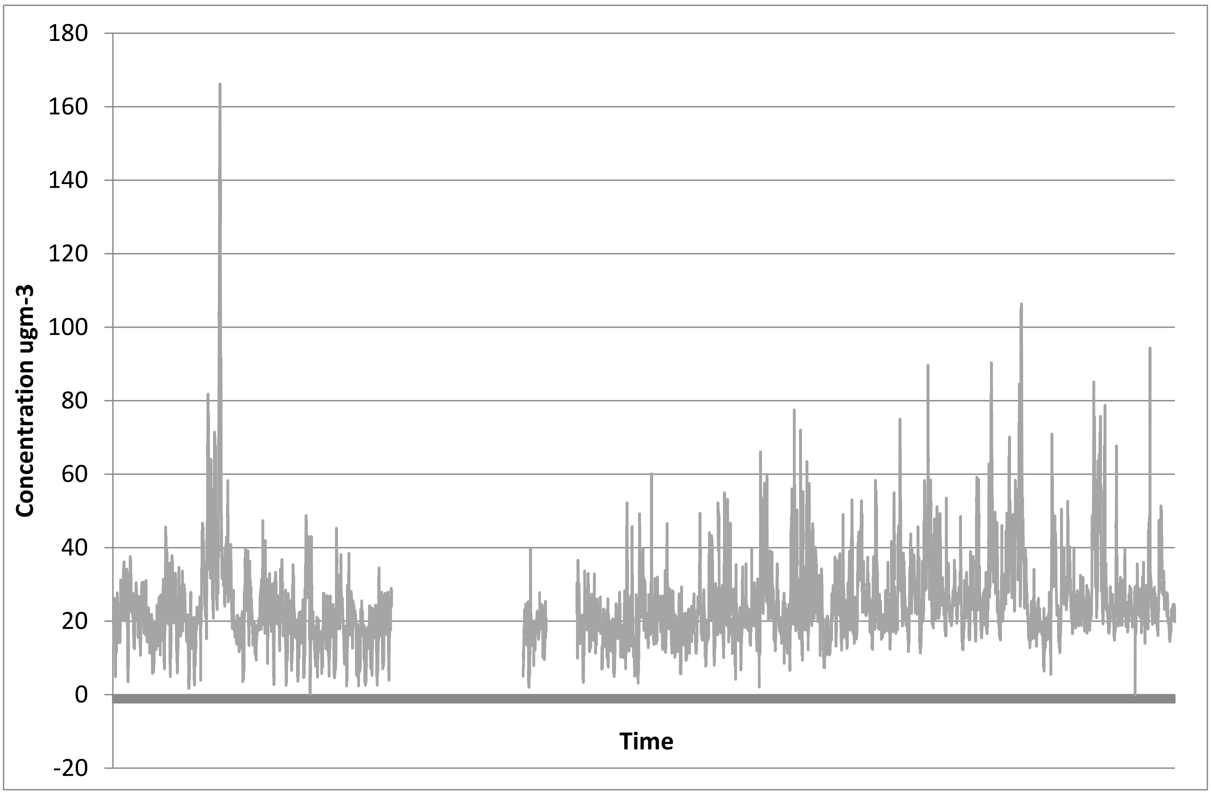


**Figure F2 Weekly Averages $NO_2$ ($ugm^{-3}$) Pod 292 Coldhams Lane**

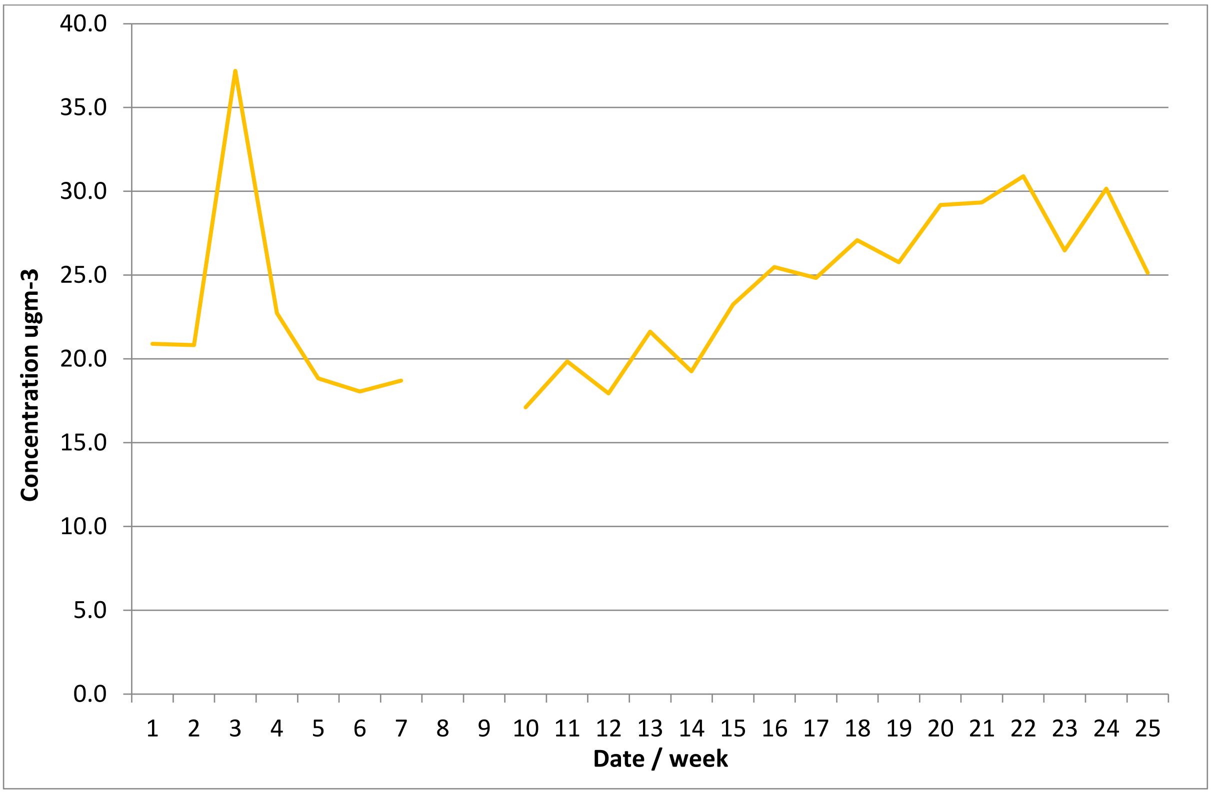
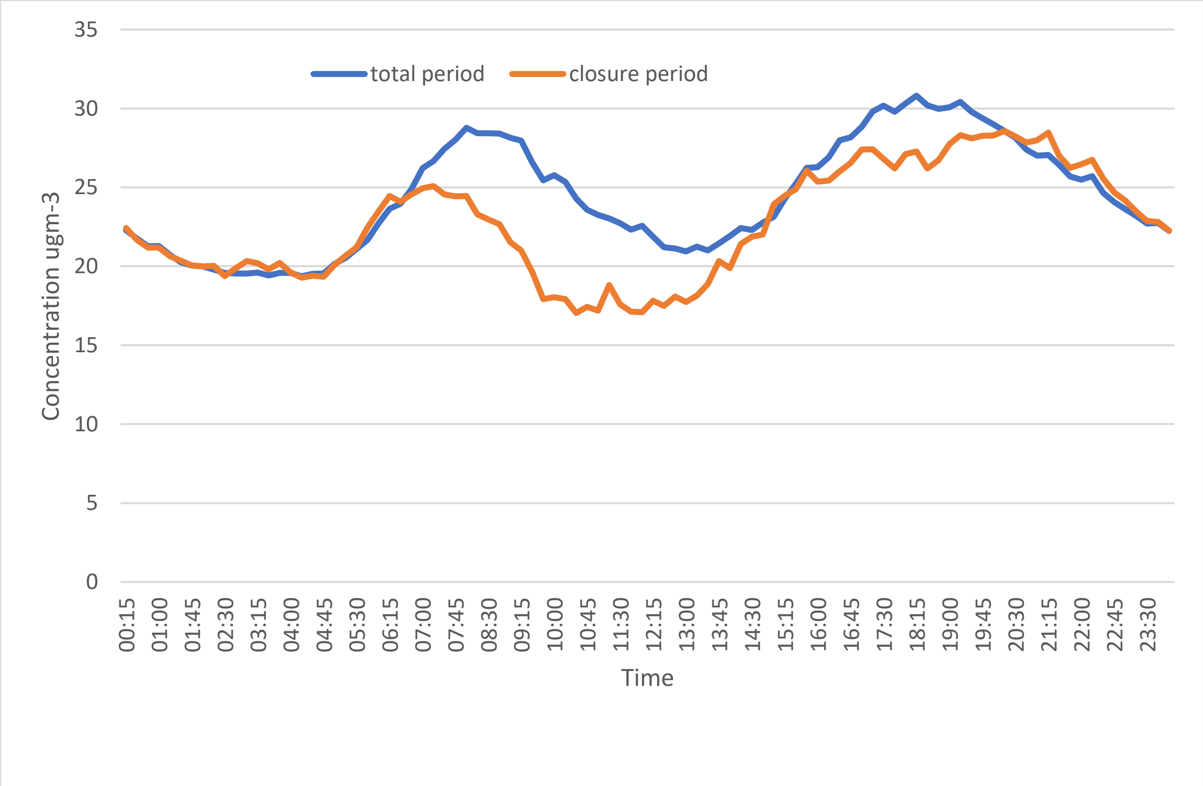



**Figure F3 Diurnal Profile during closure and for total period $NO_2$ (15 minute averages $ugm^{-3}$) Pod 292**



The figures show a spike in $NO_2$ concentrations in the third week of the monitoring period, whilst the bridge is closed. The spike appears to be related to the high readings recorded between 23rd July and 27th July with the highest reading recorded on 25th July at 16:00. This period coincided with the highest temperature recorded in England during 2019. Missing data due to a technical fault with the monitor is experienced between 25th and 8th September. Without the peak in concentrations in week 3 it appears that concentrations were lower during the road closure. Following the reopening of the road the concentrations appear to have increased towards November and December. The general trend is as would be expected for $NO_2$ during summer, autumn and winter in the UK.
The diurnal profile is for Monday to Sunday and shows that peaks are experienced during the rush hour periods in the morning and afternoon. The closure period appears to show a lower peak in the mornings and evenings before showing a similar concentration for the total period overnight.

**Figure F4 15 minute average $PM_{10}$ and PM2.5 ($ugm^{-3}$) July to December 2019 Pod 292 Coldhams Lane**

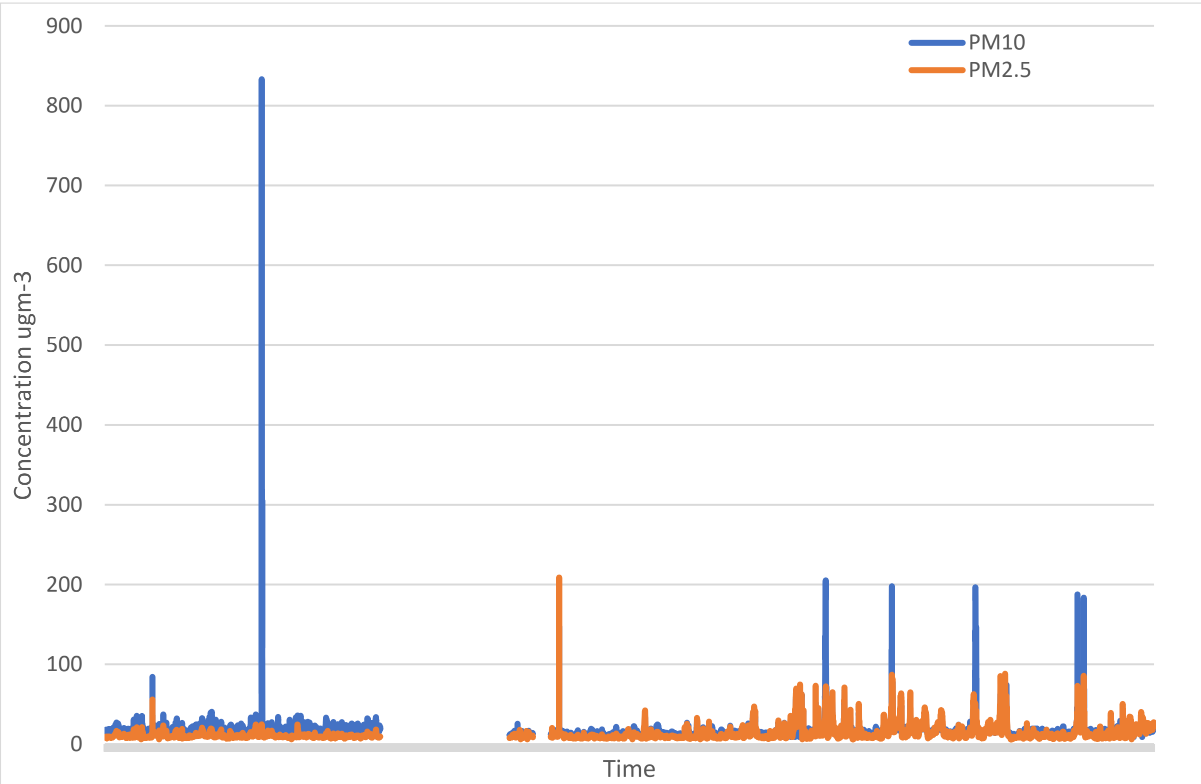


**Figure F5 Weekly Averages $PM_{10}$ & $PM_{2.5}$ (ugm$^{-3}$) Pod 292 Coldhams Lane**

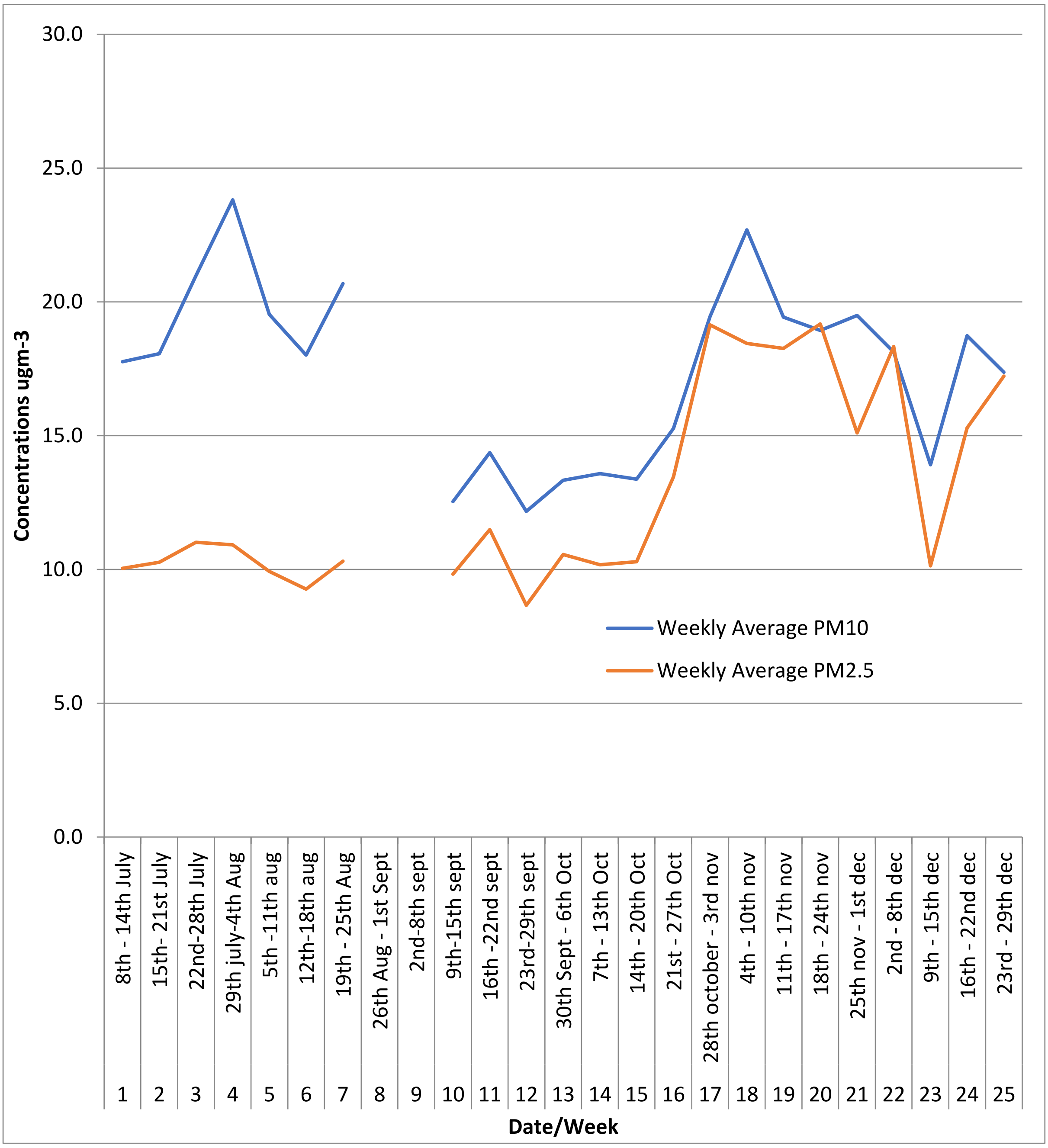
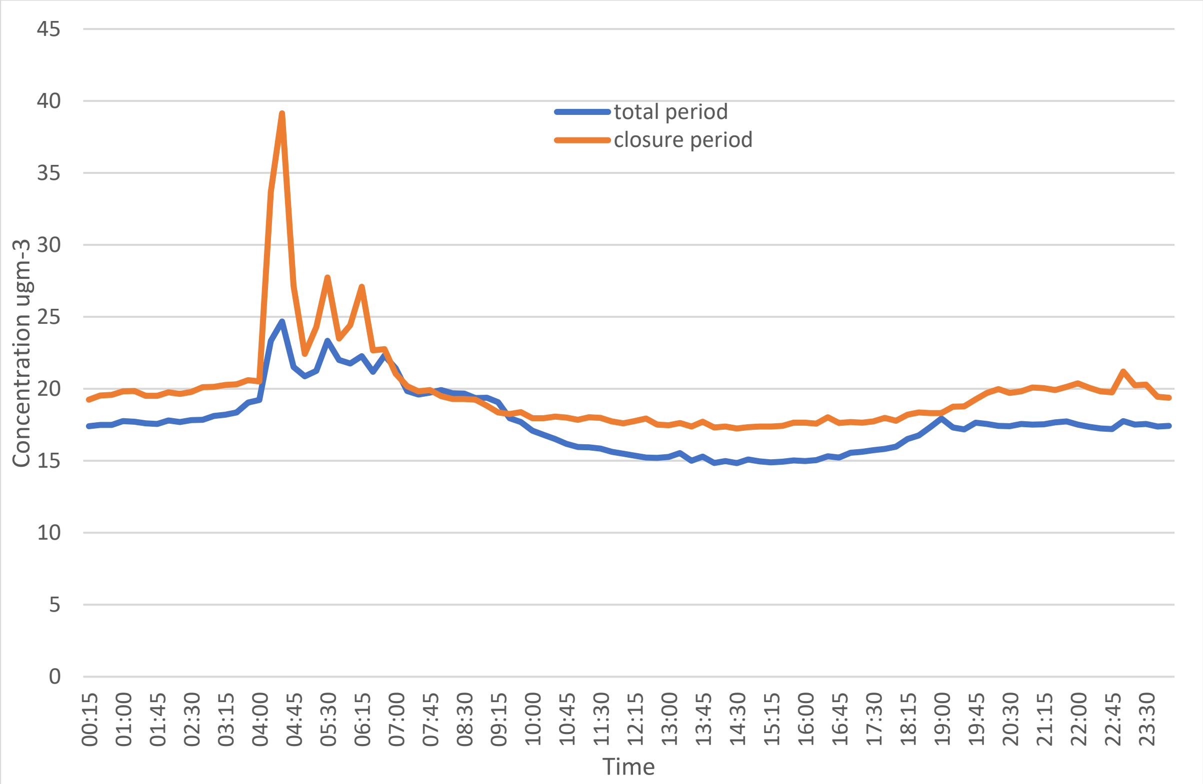


**Figure F6 Diurnal Profile during closure and for total period $PM_{10}$ (15 minute averages $ugm^{-3}$) Pod 292**




The figures show a spike in $PM_{10}$ concentrations during week 4. This is related to elevated concentrations on 3rd August between 4am and 6.30 am, although this is not shown for $PM_{2.5}$. This suggests that the spike in $PM_{10}$ is related to a specific source. Missing data for weeks 8 and 9 makes it difficult to see if there was a change in $PM_{10}$ and $PM_{2.5}$ concentrations following the re-opening of the bridge. The diurnal profile for $PM_{10}$ is slightly higher during the closure period. The spike in concentrations on 3rd August could have affected the peak shown around 4am - 6.30am in the diurnal graph.

## Pod 189 Mill Road West

Figures F7 to F12 show the15 minute data collected for 189 Mill Road West for $NO_2$, $PM_{10}$ and $PM_{2.5}$ for the monitoring period as 15 minute averages, weekly averages and as a diurnal profile. This monitor is located alongside Petersfield Gardens at the western end of Mill Road. A traffic monitor has been placed on the opposite side of the street.

**Figure F7 15 minute average $NO_2$ ($ugm^{-3}$) July to December 2019 Pod 189 (Mill Road West)**

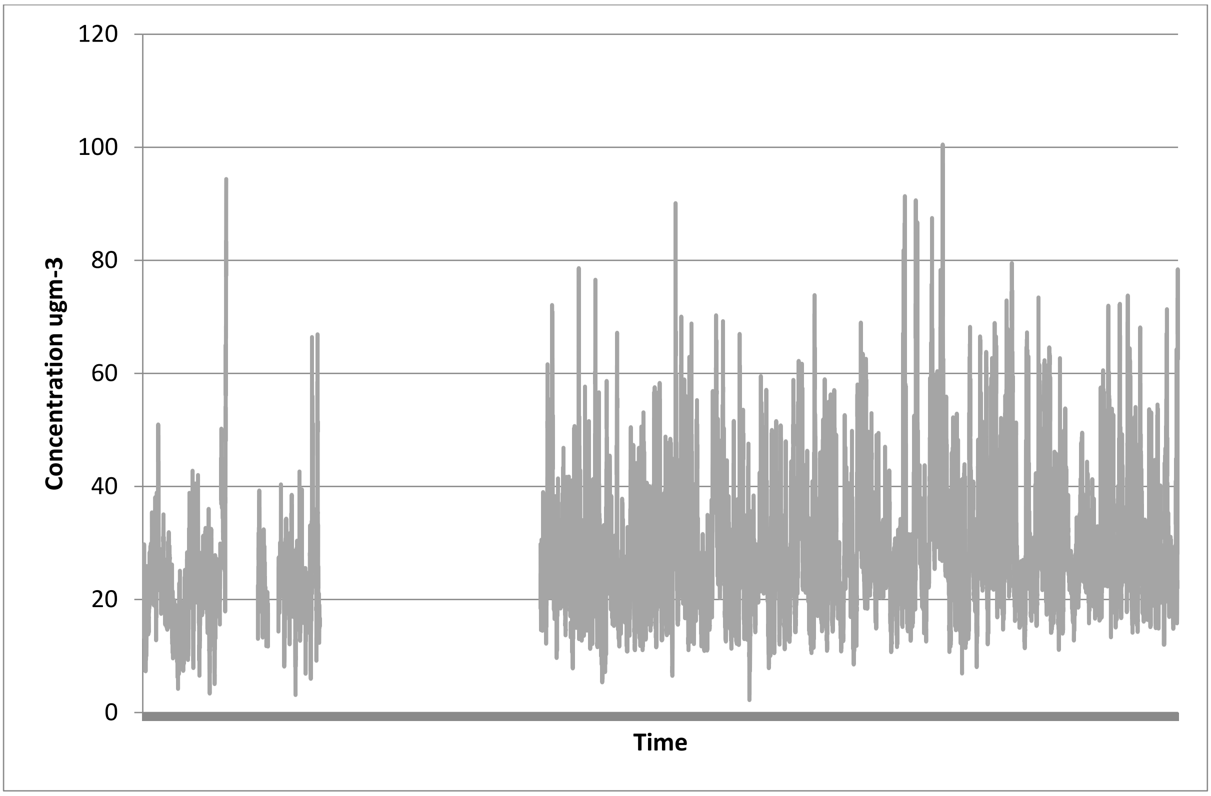



**Figure F8 Weekly Averages $NO_2$ Pod 189 Mill Road West**

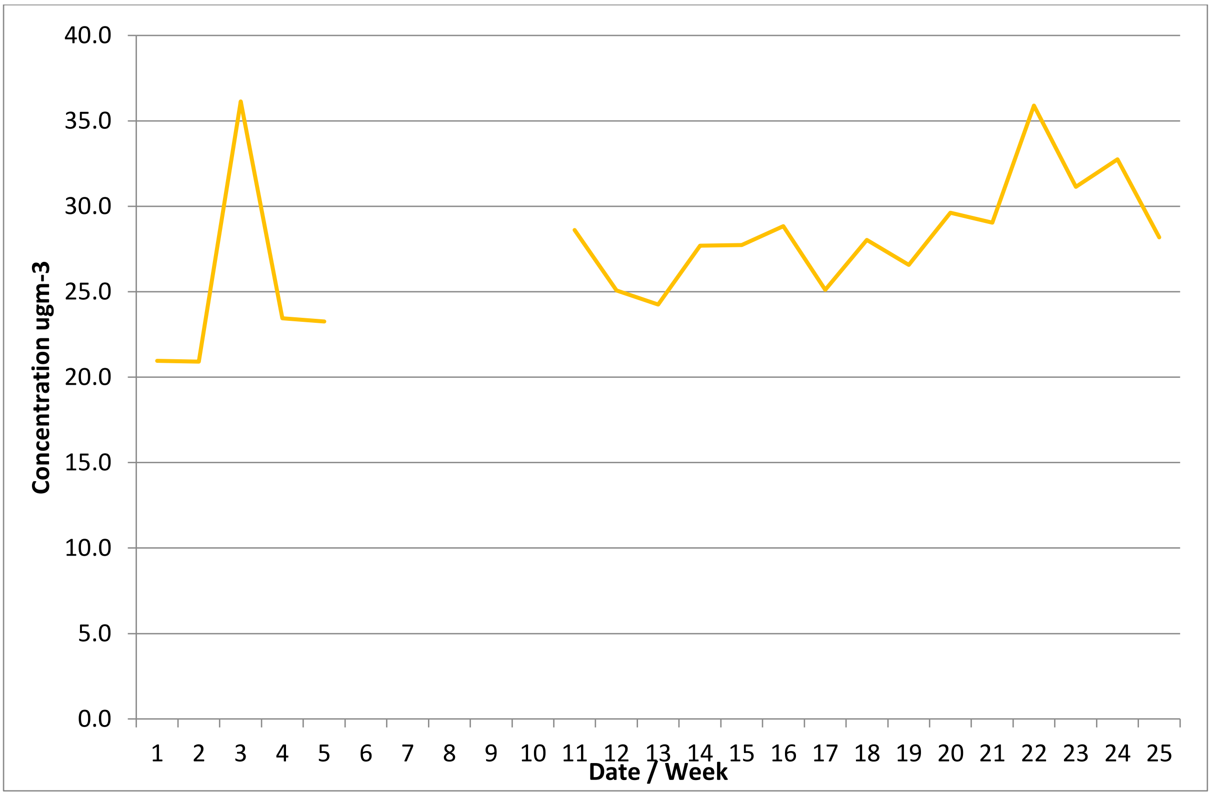
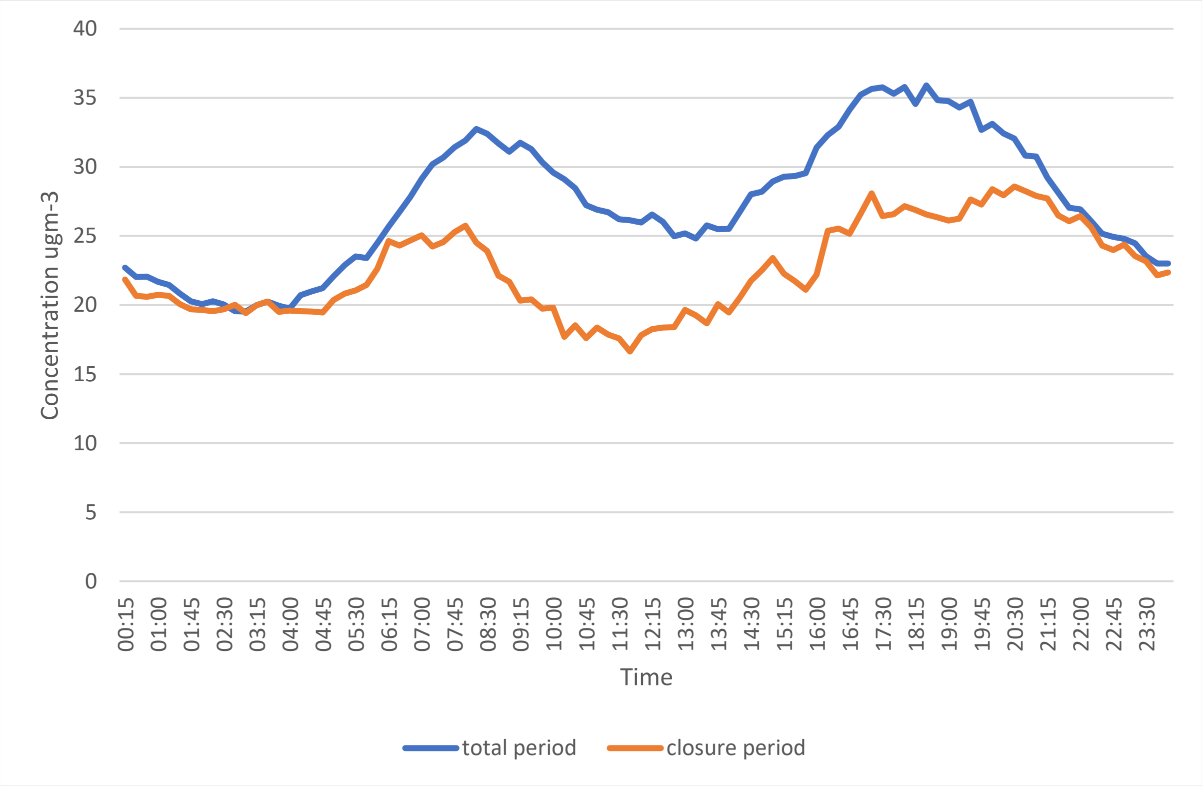


**Figure F9 Diurnal Profile during closure and for total period $NO_2$ (15 minute averages ugm$^{-3}$) Pod 189**




The graphs show a spike in the weekly average $NO_2$ concentrations in the third week of the monitoring period, whilst the bridge is closed. The spike appears to be related to the high readings recorded between 23rd July and 27th July with the highest reading recorded on 25th July at 16:00. This period coincided with the highest temperature recorded in England during 2019. Missing data due to a technical fault with the monitor is experienced between 11th August and 15th September. Without the peak in concentrations in week 3 it appears that concentrations were lower during the road closure. Following the reopening of the road the concentrations appear to have increased but not to a large degree. The general trend is as would be expected for $NO_2$ dueing summer, autumn and winter in the UK.

Due to the missing data it is difficult to see if there was any effect of road closure on the data.

The diurnal profile shows that at peak times he closure period experienced lower $NO_2$ concentrations, although concentrations were around the same during the nightime.

**Figure F10  15 minute average $PM_{10}$ and $PM_{2.5}$ ($ugm^{-3}$) July to December 2019 Pod 189 Mill Road West**

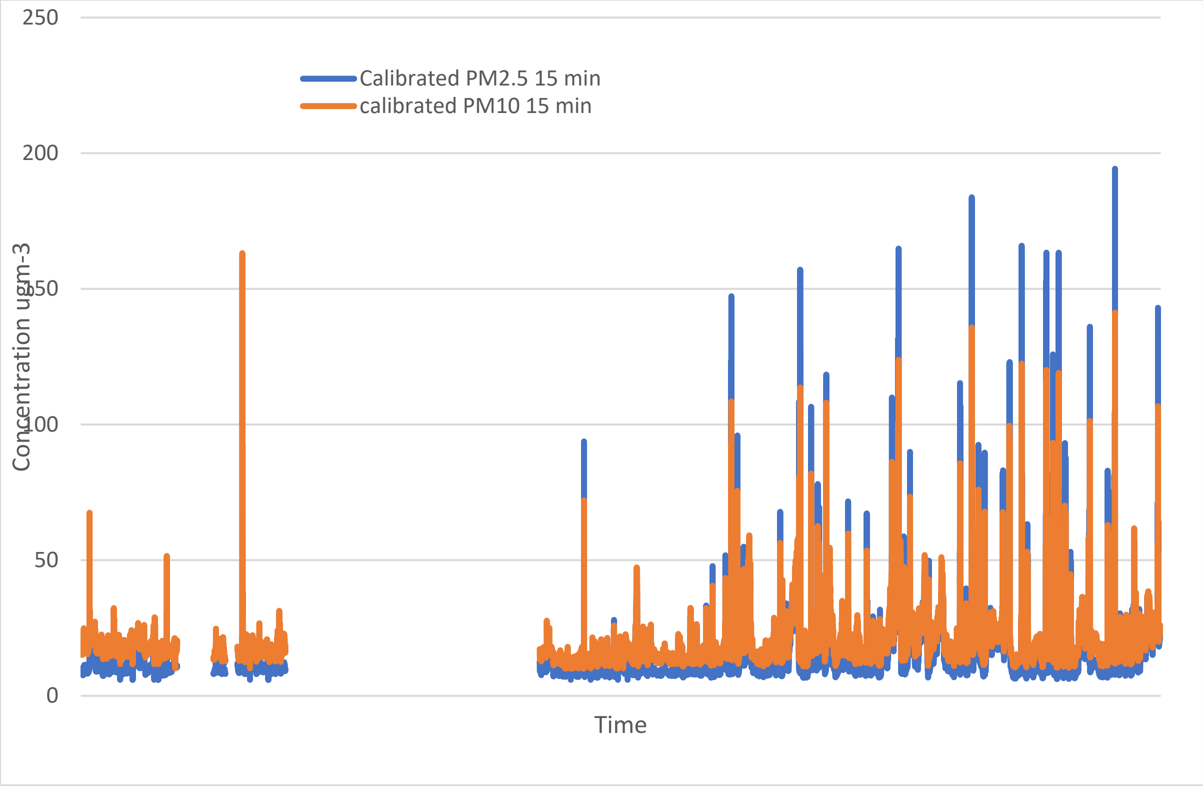


**Figure F11 Weekly Averages $PM_{10}$ & $PM_{2.5}$ Pod 189 Mill Road West**

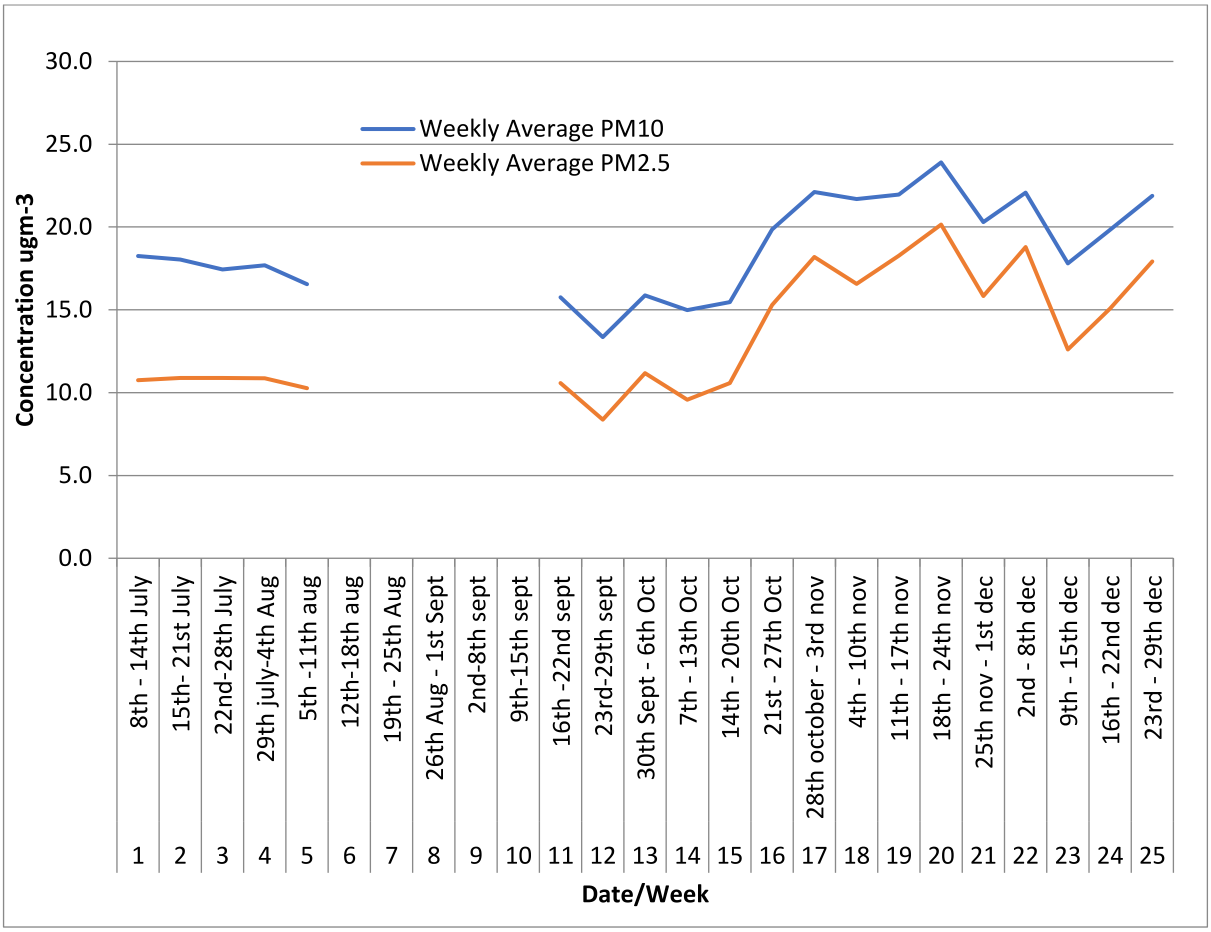
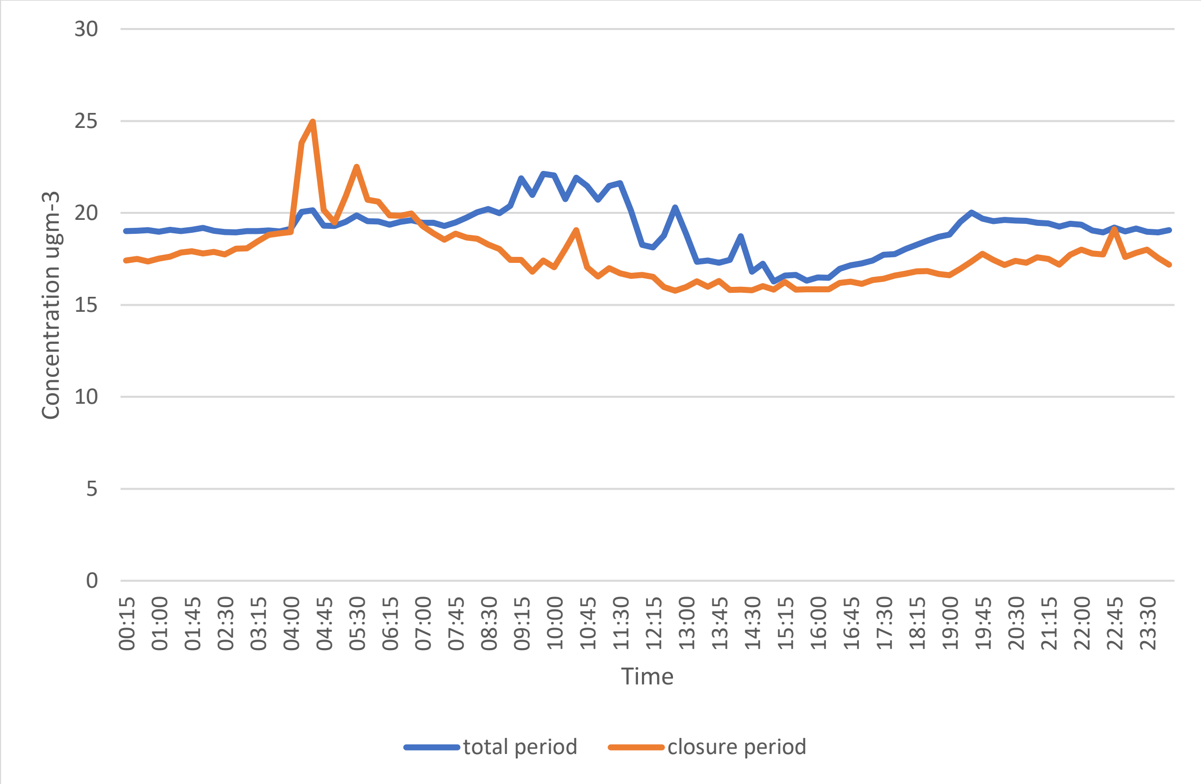


**Figure F12 Diurnal Profile during closure and for total period $PM_{10}$ (15 minute averages $ugm^{-3}$) Pod 189**




The 15 minute concentration graph shows a spike in $PM_{10}$ concentrations on 3rd August between 4am and 6 am. This is not reflected in the $PM_{2.5}$ concentrations suggesting that the source was just $PM_{10}$ sized particles. Missing data for weeks 6 - 10 makes it difficult to see if there was a change in concentrations following the re-opening of the bridge. Concentrations appear to have remained stable through July, August and September, with an increase in concentrations in weeks 16 and 17 during October with these higher concentrations maintained through to November and December.

The dirnal graph is broadly similar throughout both the total monitoring period and the closure period. The closure period is slightly lower concentrations and the peak around 4am could be the result of the spike on 3rd August.

## Pod 188 Perne Road

Figures F12 to F17 show the15 minute data collected for 188 Perne Road for $NO_2$, $PM_{10}$ and $PM_{2.5}$ for the monitoring period as 15 minute averages, weekly averages and as a diurnal profile. This monitor is located on Perne road between its junctions with Mill Road and Radegund Road.

**Figure F12 15 minute average $NO_2$ (ugm$^{-3}$) July to December 2019 Pod 188 (Perne Road)**

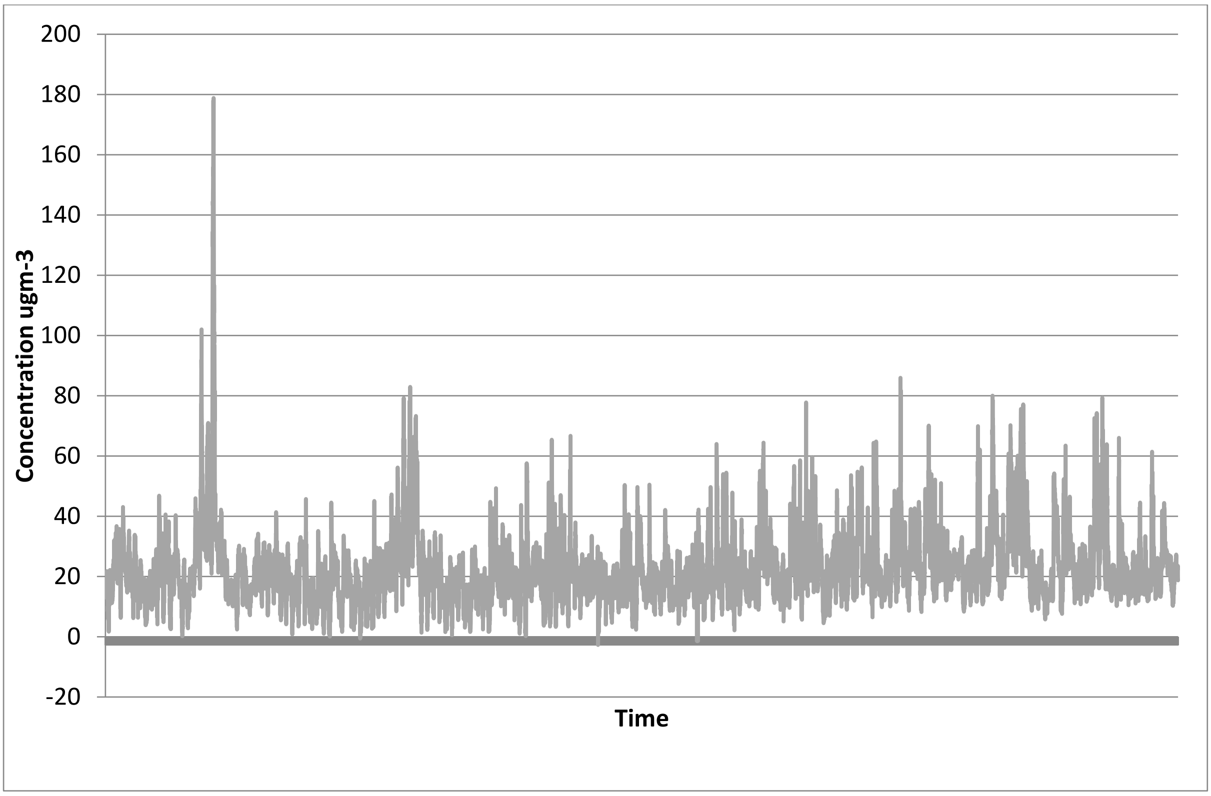



**Figure F13 Weekly Averages $NO_2$ Pod 188 Perne Road**

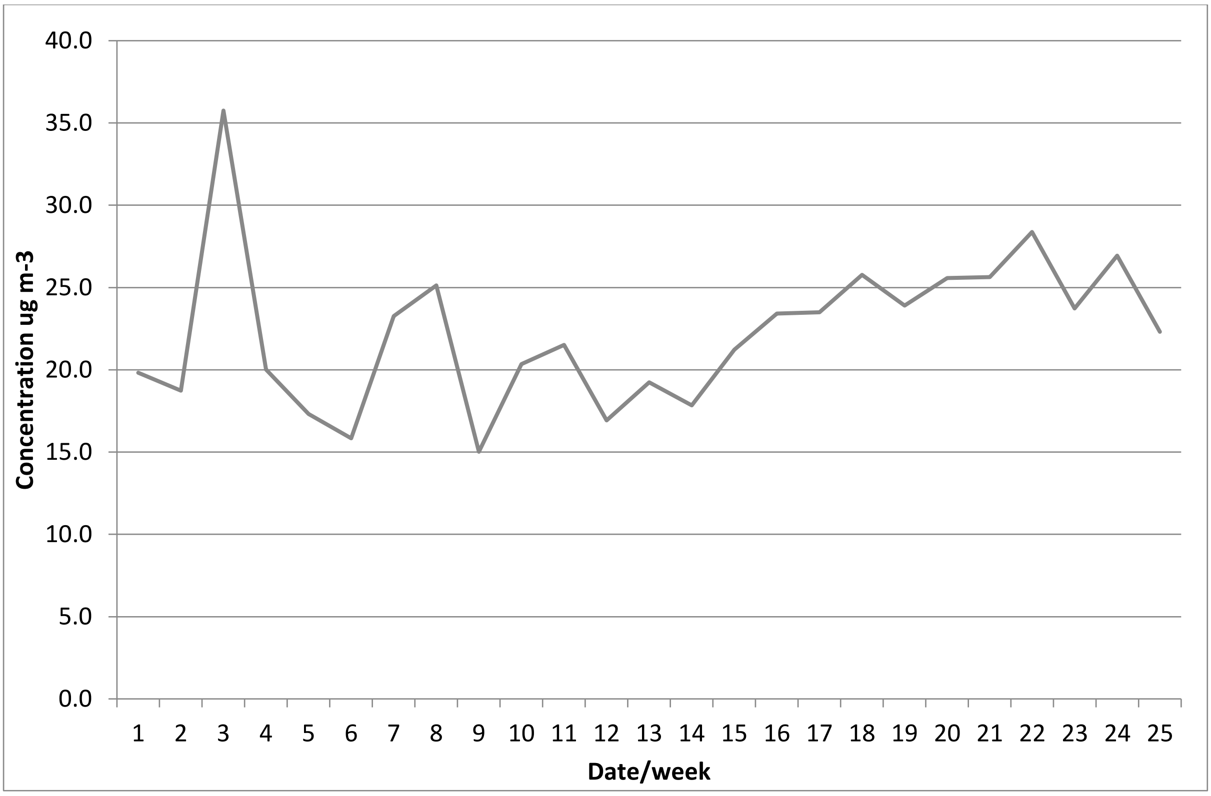
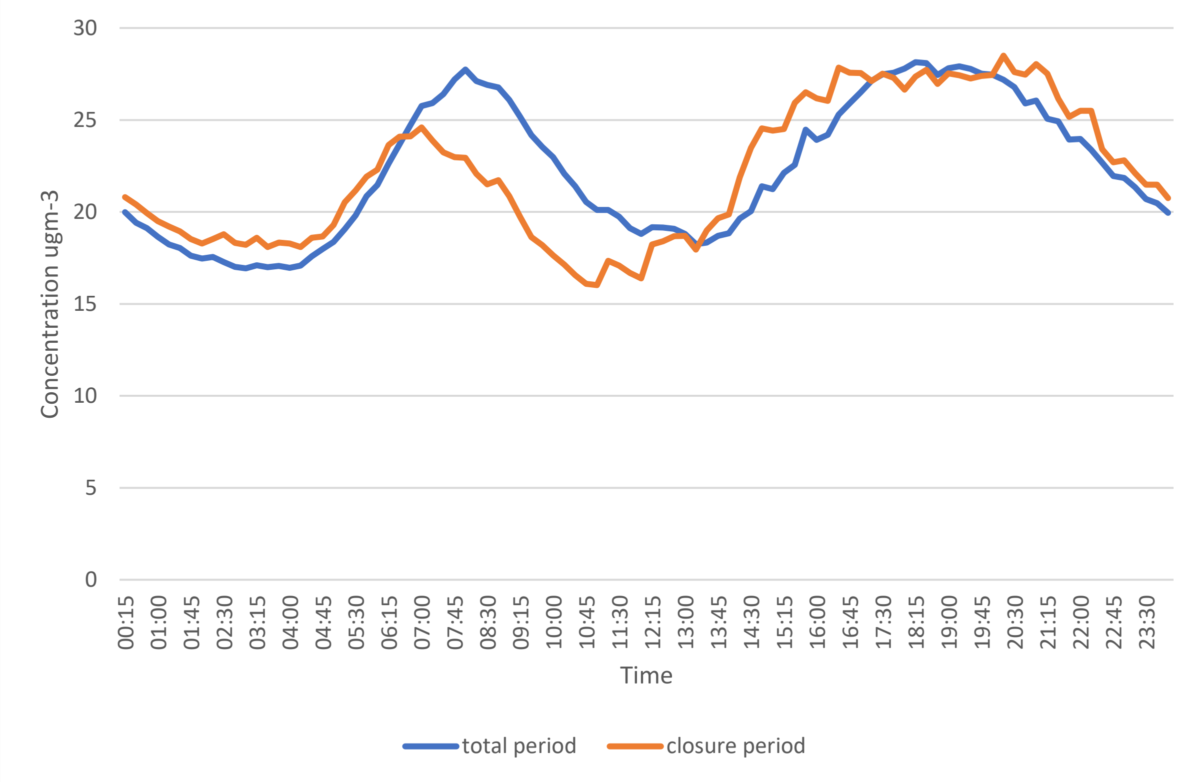


**Figure F14 Diurnal Profile during closure and for total period $NO_2$ (15 minute averages ugm$^{-3}$) Pod 188**




The graphs shows a spike in $NO_2$ concentrations in week 3. This is as a result of a peak in concentrations on 25th July around 15:00 with a return to similar averages by 27th July. This coincides with the hottest day of the year in 2019. Concentrations appear to be similar across the whole monitoring period with a slight increase from week 14 (October) which suggests the increase is unrelated to the road closure. The diurnal profile shows that the morning peak is lower during the closure period but very similar during the evening peak.

**Figure F15 15 minute average $PM_{10}$ & $PM_{2.5}$ ($ugm^{-3}$) July to December 2019 Pod 188 (Perne Road)**

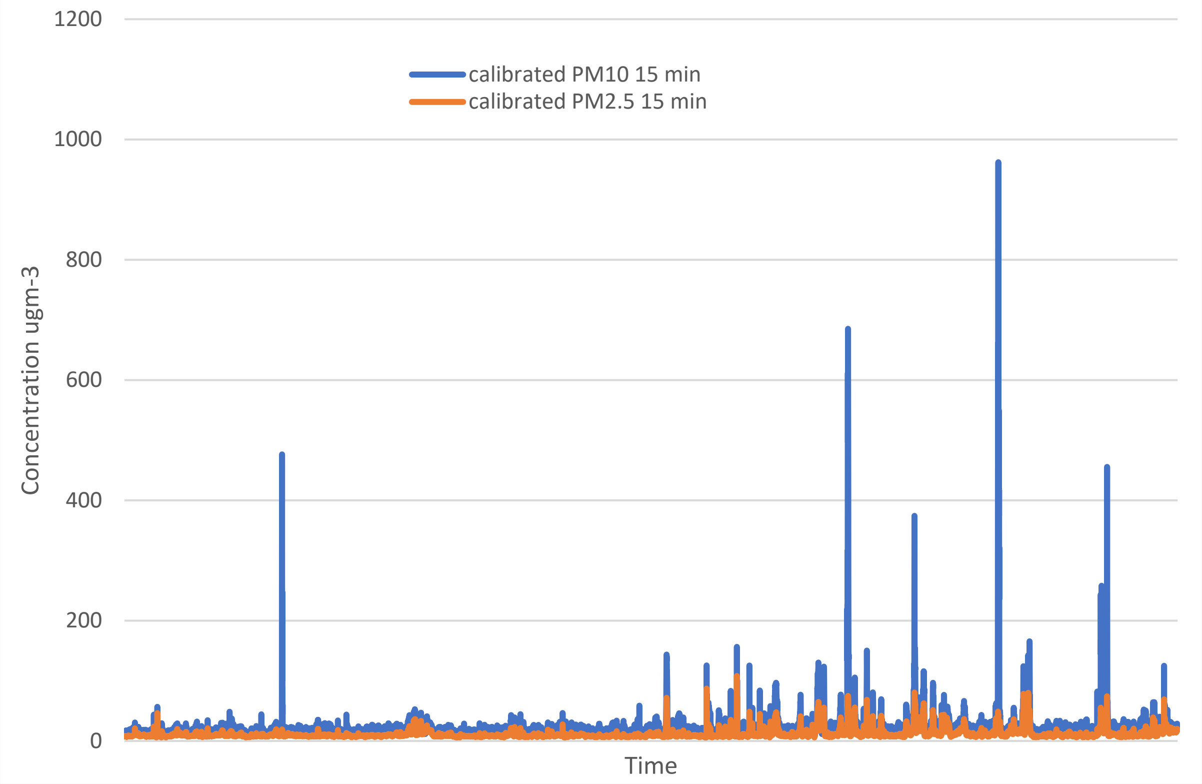


**Figure F16 Weekly Averages $PM_{10}$ & $PM_{2.5}$ Pod 188 Perne Road**

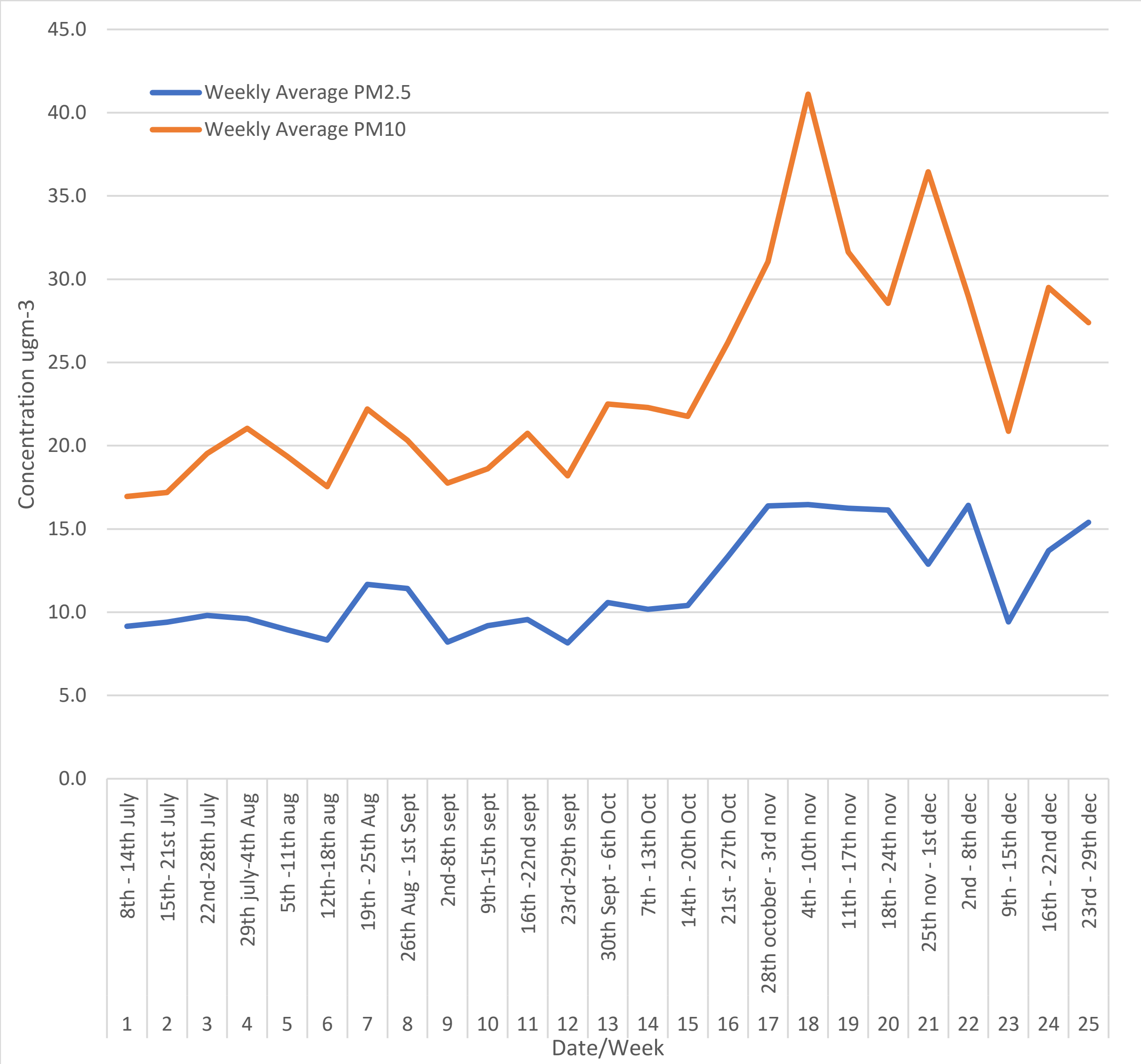
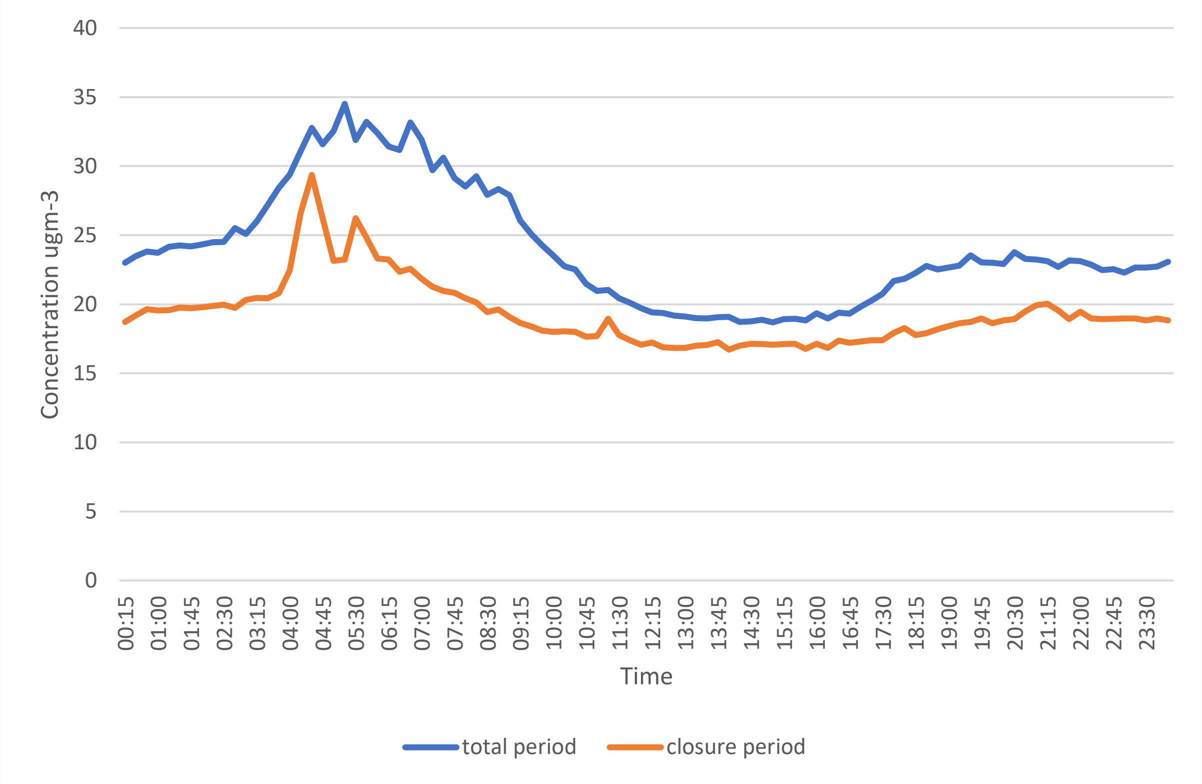


**Figure F17 Diurnal Profile during closure and for total period $PM_{10}$ (15 minute averages $ugm^{-3}$) Pod 188**




The 15 minute concentration graph shows that there is a spike in $PM_{10}$ concentrations on 3rd August between 4am and 6.45am. This only affects $PM_{10}$ concentrations, which suggests the source was of $PM_{10}$ particulates.
The graph shows that the concentrations remain relatively stable until week 16/17. It is unclear whether the road closure has an effect on $PM_{10}$ concentrations at this location.
The diurnal profile shows a peak in concentrations around 4am to 6am which suggests it is influenced by the spike in concentrations on 3rd August. In general the closure peiod shows lower concentrations throughout the day than the total period.

## Pod 187 Coleridge Road

Figures F18 to F23 show the15 minute data collected for 187 Coleridge Road for $NO_2$, $PM_{10}$ and $PM_{2.5}$ for the monitoring period as 15 minute averages, weekly averages and as a diurnal profile. This monitor is located on Coleridge Road between its junctions with Mill Road and Radegund Road. A traffic monitor has been placed further down the street just after the juction with Radegund Road alongside Coleridge Recreation Ground.

**Figure F18 15 minute average $NO_2$ (ugm$^{-3}$) July to December 2019 Pod 187 (Coleridge Road)**

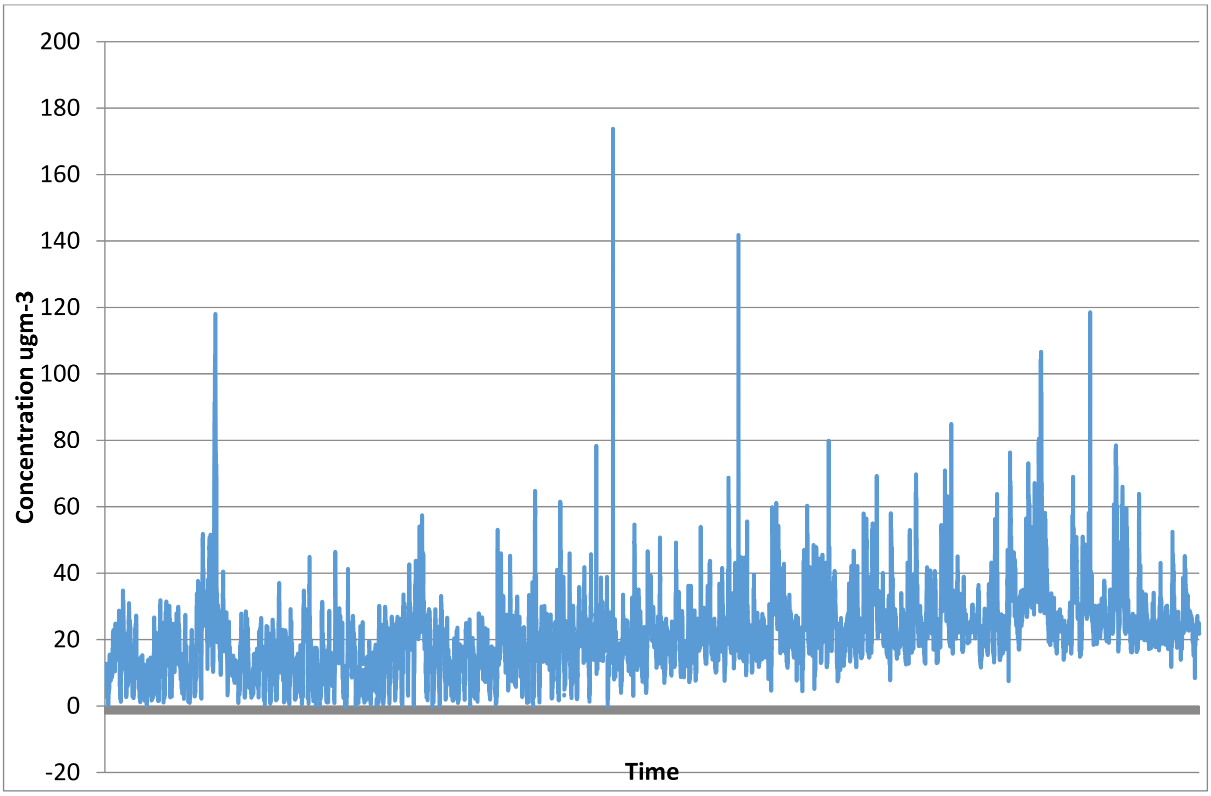



**Figure F19 Weekly Averages $NO_2$ Pod 187 Coleridge Road**

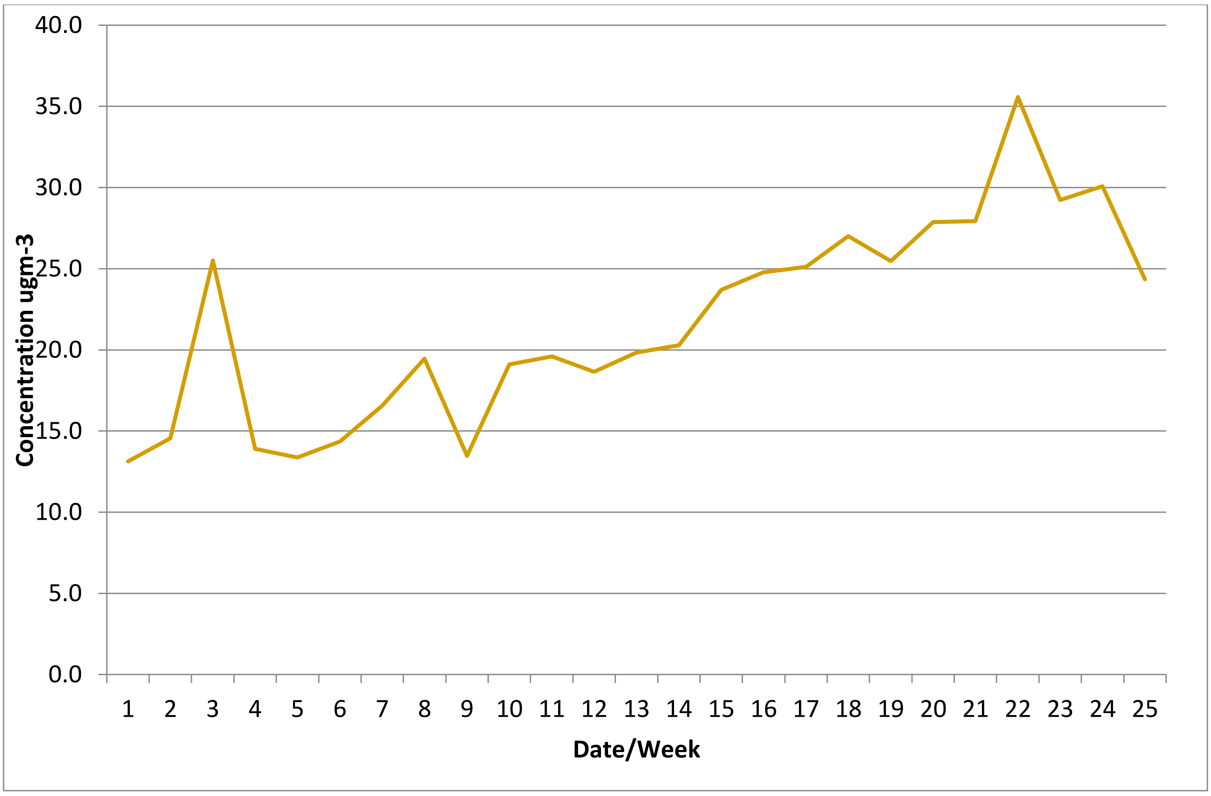
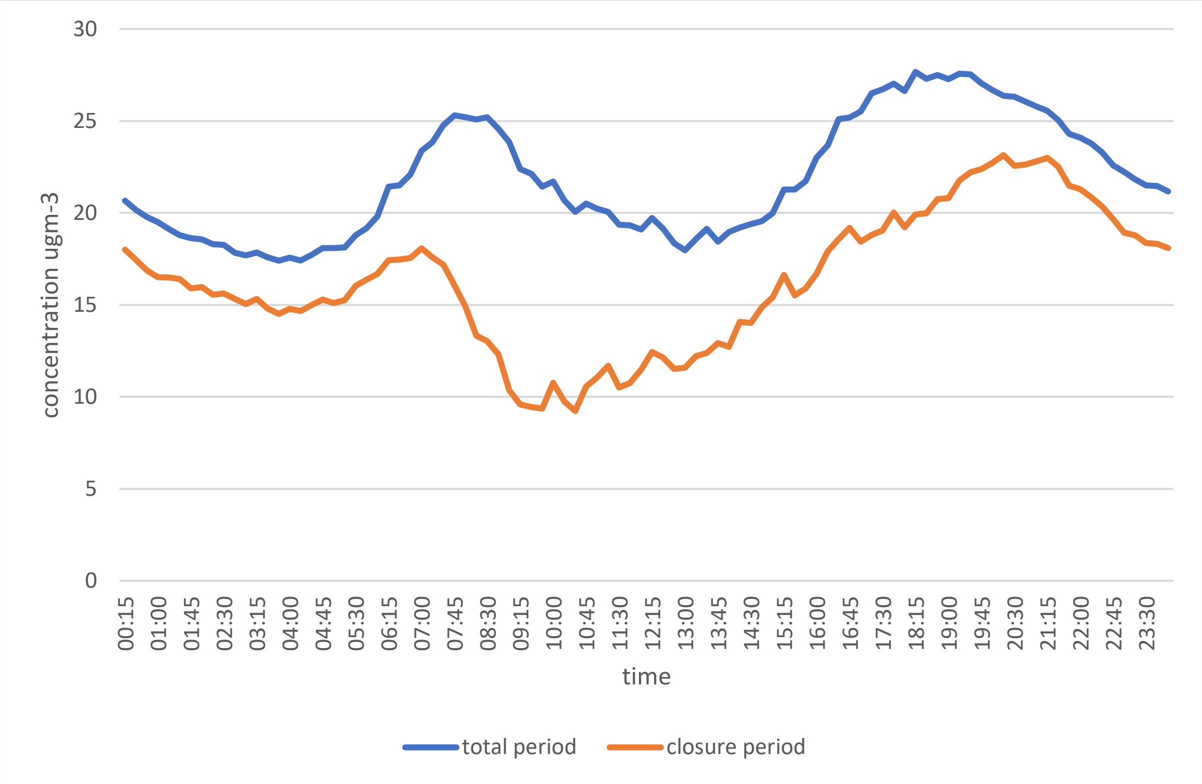


**Figure F20 Diurnal Profile during closure and for total period $NO_2$ (15 minute averages ugm$^{-3}$) Pod 187**




The graphs show a peak in concentrations around the third week of the monitoring period. This coincides with the hottest day of the year in 2019 on 25th July. The graph also shows that concentrations at this location are very low during the closure period with an increase in concentrations as the bridge reopens in week 8. There is then a gradual increase in concentrations through to the end of the year.

The diurnal plot shows a difference in concentrations between the total period and the period for when the bridge was closed with a much lower and shorter peaks and overall concentrations throughout the day.

**Figure F21 15 minute average $PM_{10}$ & $PM_{2.5}$ ($ugm^{-3}$) July to December 2019 Pod 187 (Coleridge Road)**

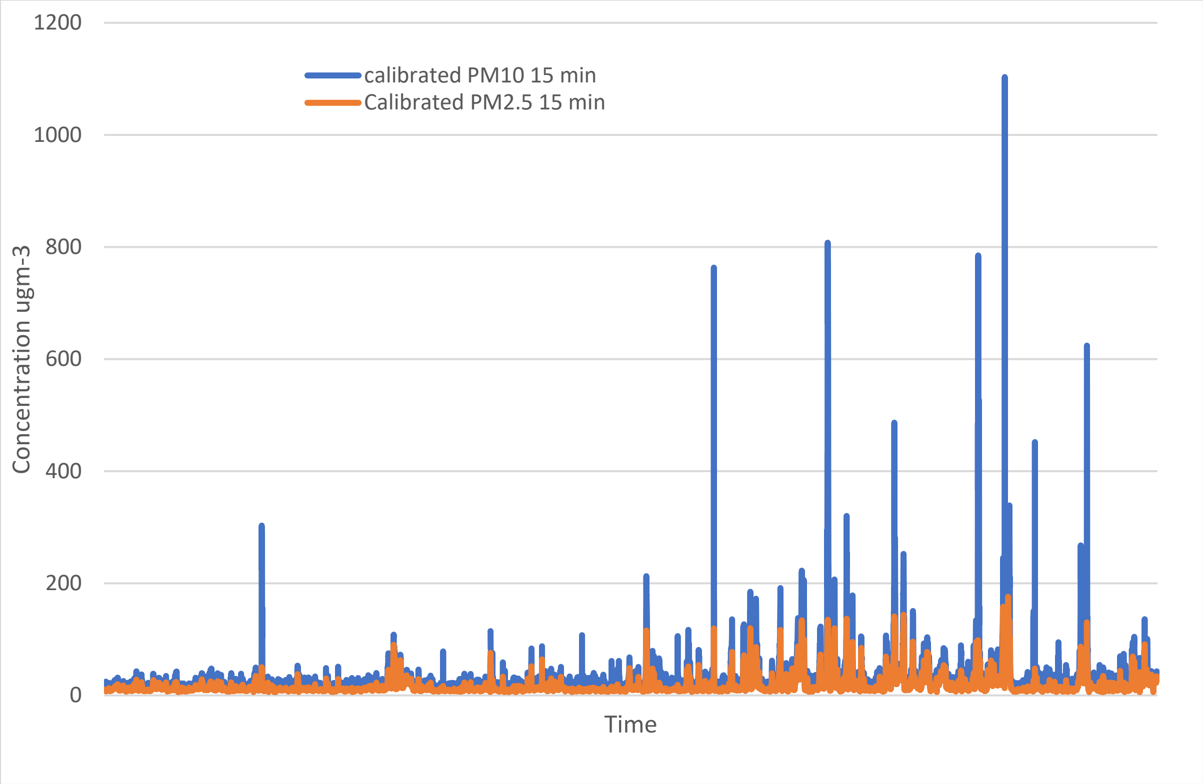


Figure F22 Weekly Averages $PM_{10}$ & $PM_{2.5}$ Pod 187 Coleridge Road

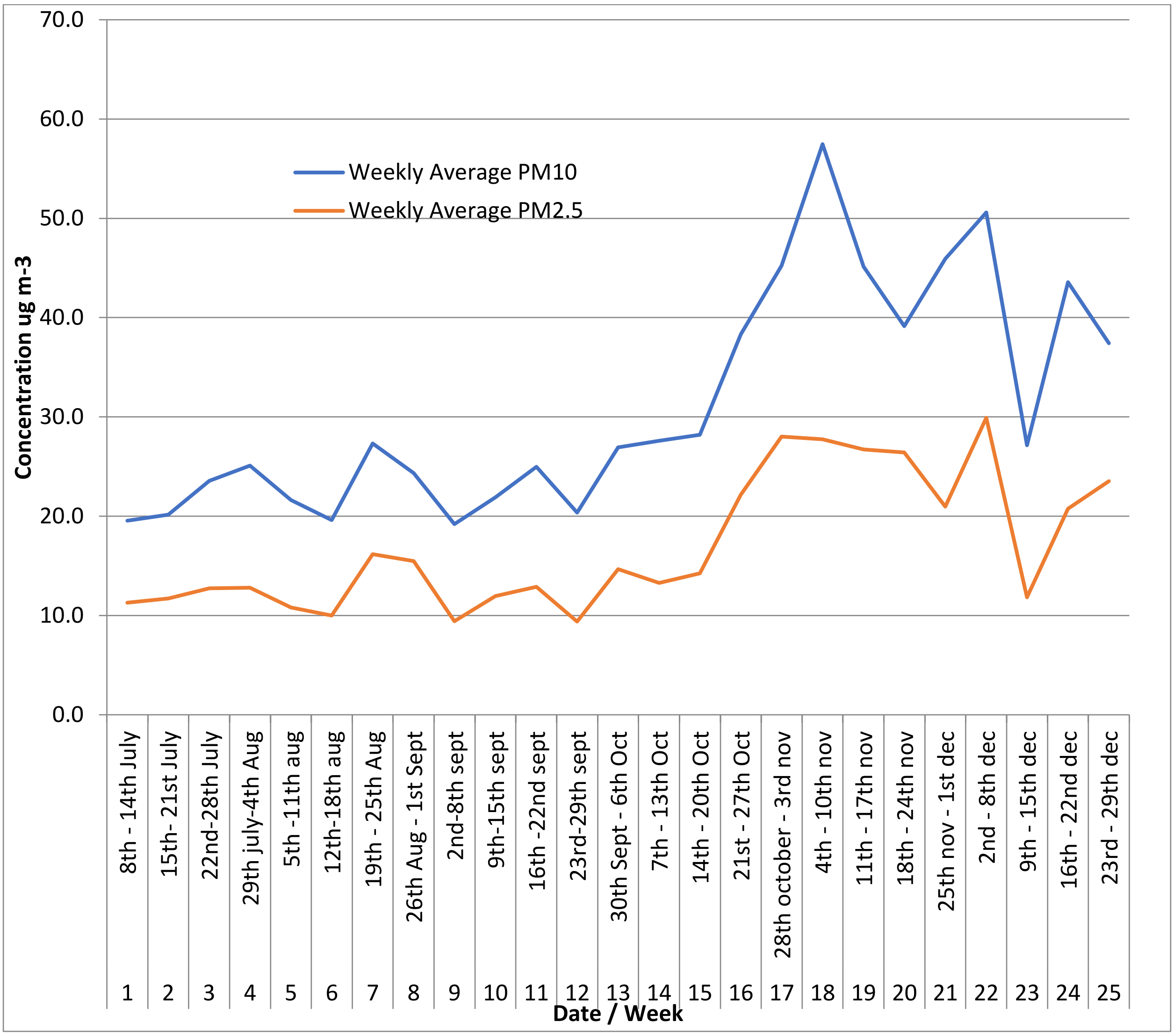
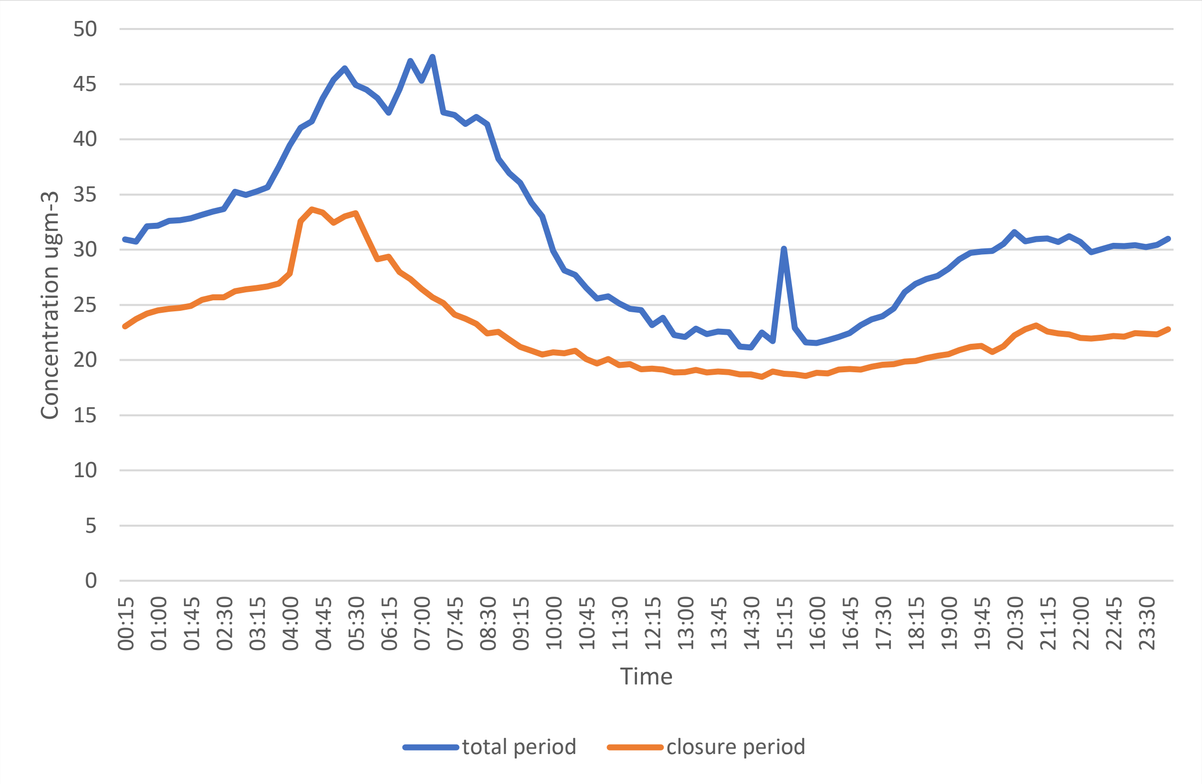


**Figure F23 Diurnal Profile during closure and for total period $PM_{10}$ (15 minute averages $ugm^{-3}$) Pod 187**




The graphs show that $PM_{10}$ and $PM_{2.5}$ concentrations are generally stable between July and October when there is an increase over the last few months of the year. This is shown by an increase in the number of spikes in $PM_{10}$ and $PM_{2.5}$ concentrations when compared to the earlier part of the year. There does not appear to be a change in $PM_{10}$ and $PM_{2.5}$ concentrations as a result of the road closure.

The diurnal profile shows a clear difference between the closure period and the total monitorng period. There appears to be a peak in concentrations in the morning and a slight peak trowards the end of the day. Its is unclear why the data shows the diurnal profile.

## Pod 186 Gonville Place

Figures F24 to F29 show the15 minute data collected for 186 Gonville Place for $NO_2$, $PM_{10}$ and $PM_{2.5}$ for the monitoring period as 15 minute averages, weekly averages and as a diurnal profile. This monitor is located at Gonville Place. This monitor has been colocated with the continuous monitor at Gonville Place and is also the location for the triplicate diffusion tubes for Cambridge City Council. The monitor is at the junction of Gonville Place and Hills Road.

**Figure F24 15 minute average $NO_2$ ($ugm^{-3}$) July to December 2019 Pod 186 (Gonville Place)**

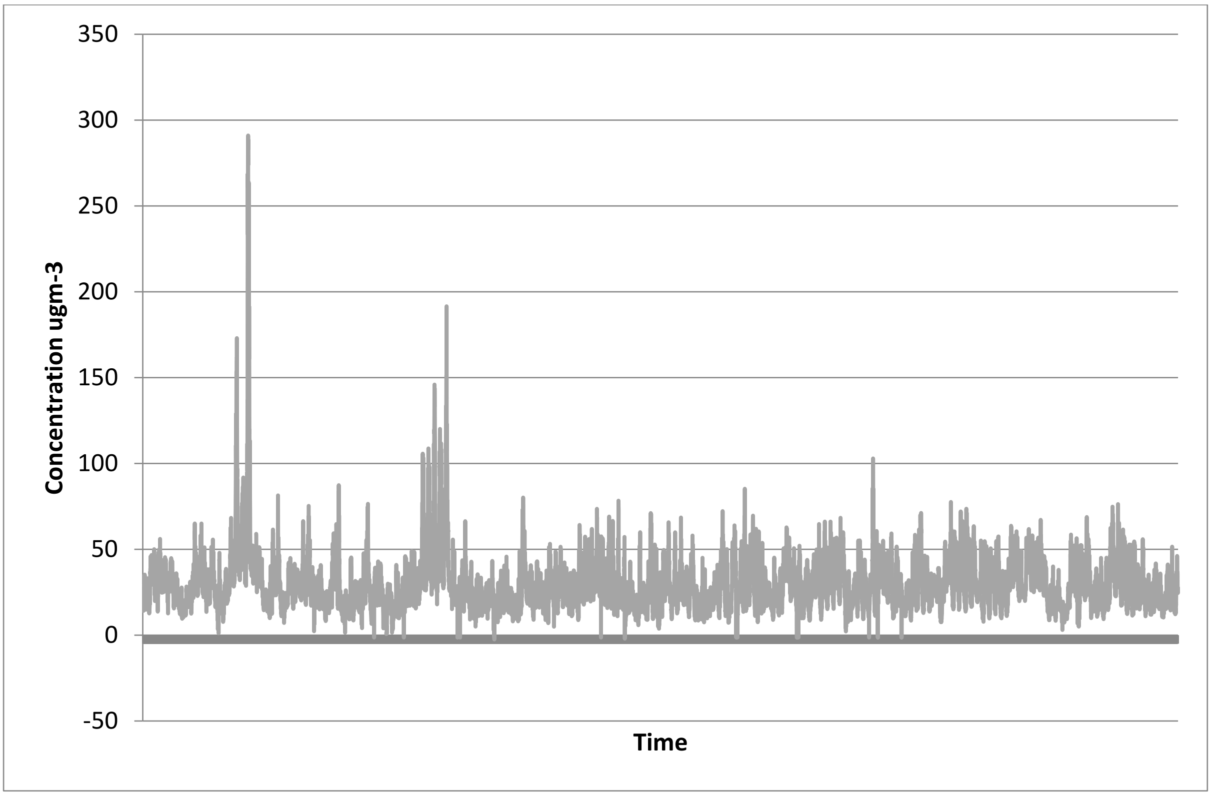



**Figure F25 Weekly Averages $NO_2$ Pod 186 Gonville Place**

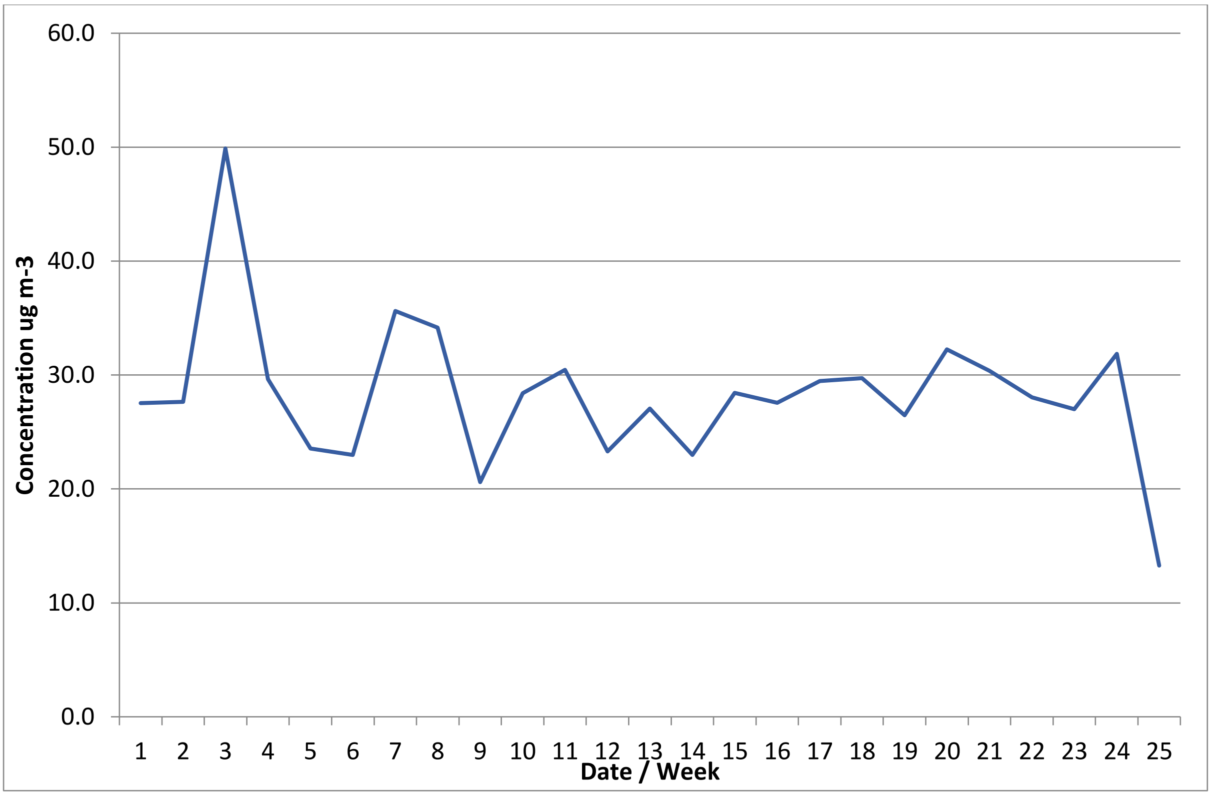
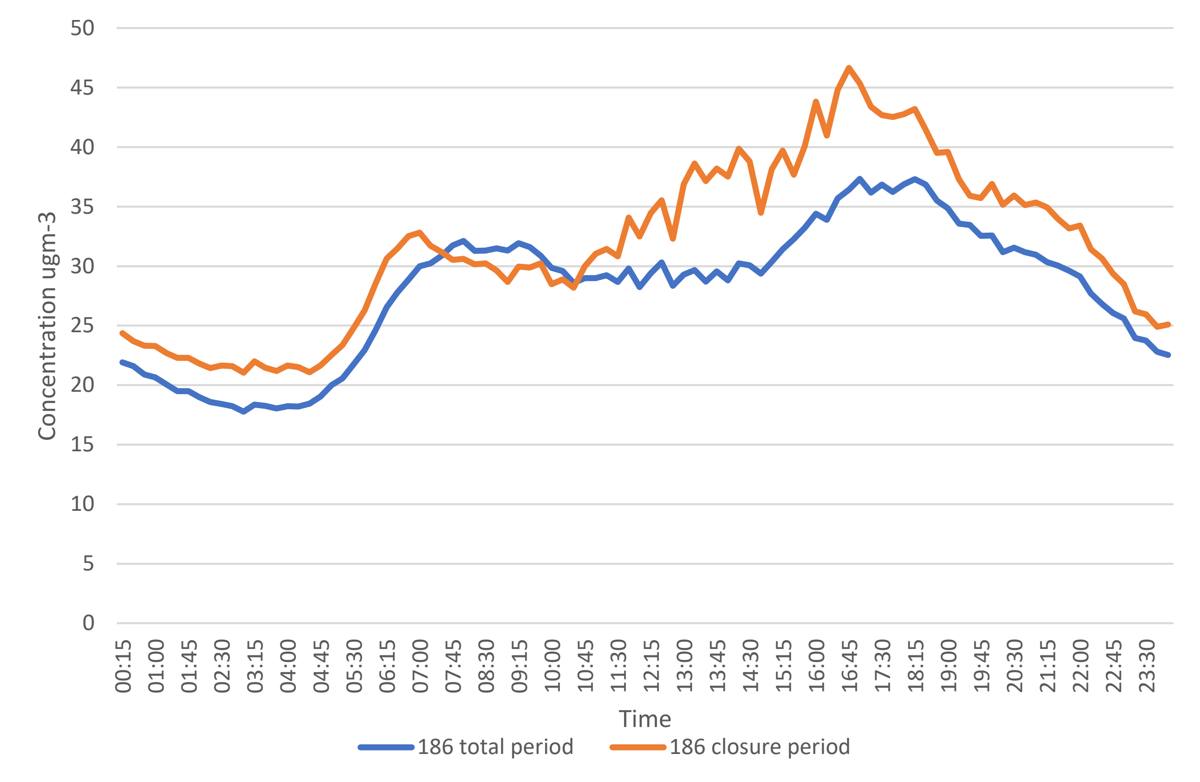


**Figure F26 Diurnal Profile during closure and for total period $NO_2$ (15 minute averages $ugm^{-3}$) Pod 186**




The graphs show a spike in concentrations during the third week of the monitoring period, this coincided with high concentrations on 25th July, which was the hottest day in 2019 and a further peak during the latter part of August which coincides with hotter temperatures and the August bank holiday. For the remainder of the monitoring period there seems to be a fairly consistent concentrations shown by the monitor. From the graph it is unclear whether the road closure had an impact on $NO_2$ concentrations at this location.

The diurnal profile shows peaks during the morning and then rising towards the afternoon peak. The closure period and the total period show similar concentrations across the day except for the evening peak where the closure period concentrations are higher.

**Figure F27 15 minute average $PM_{10}$ & $PM_{2.5}$ ($ugm^{-3}$) July to December 2019 Pod 186 (Gonville Place)**

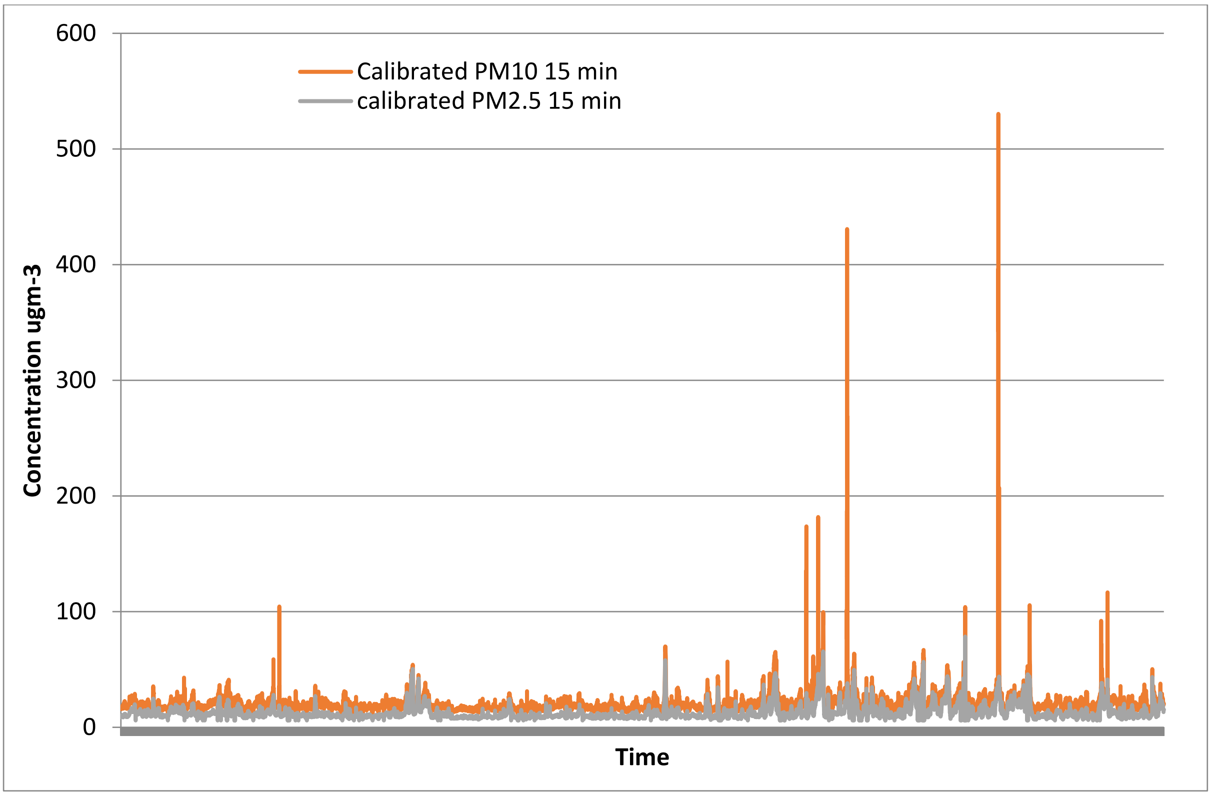


**Figure F28 Weekly Averages $PM_{10}$ & $PM_{2.5}$ Pod 186 Gonville Place**

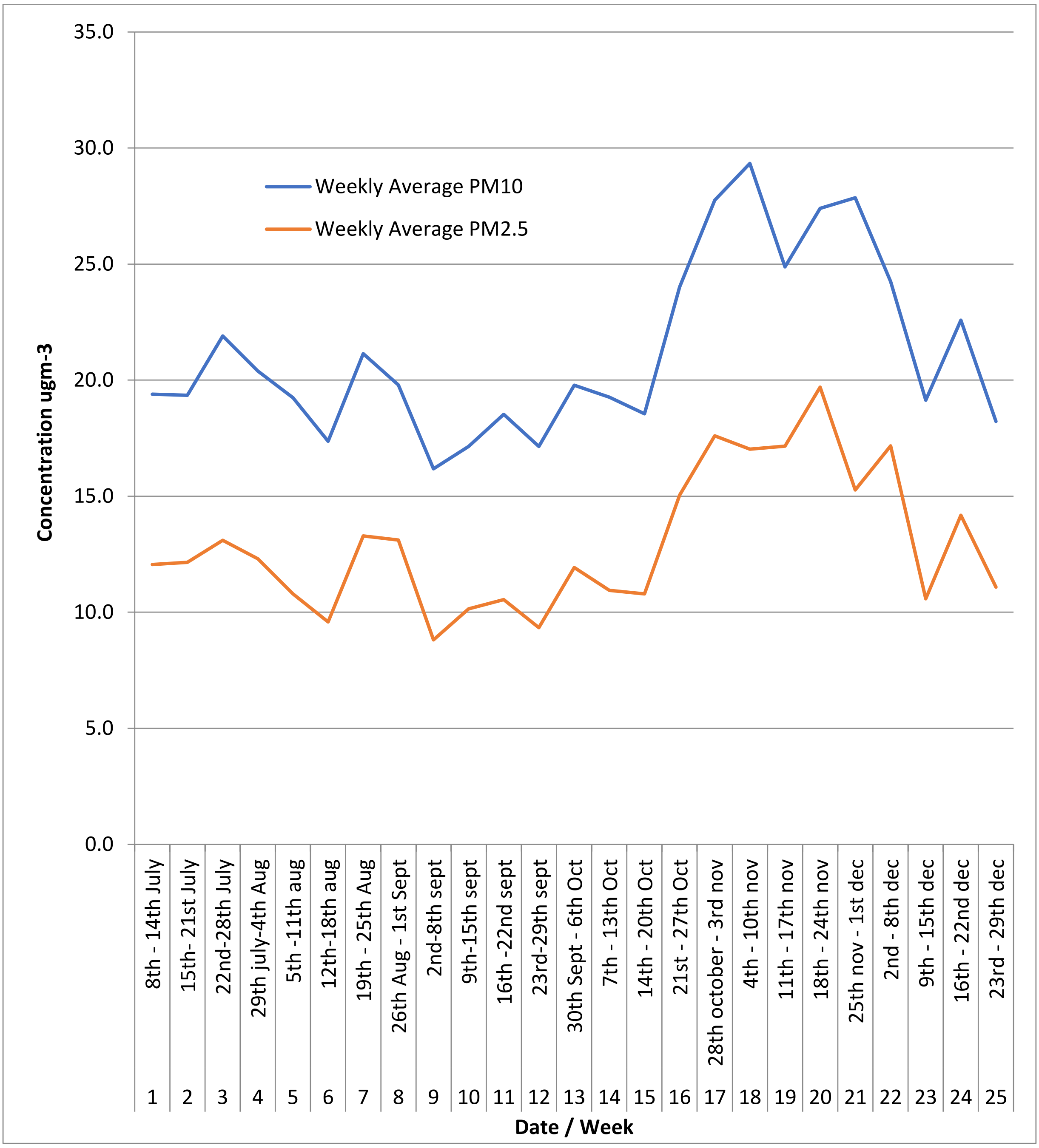
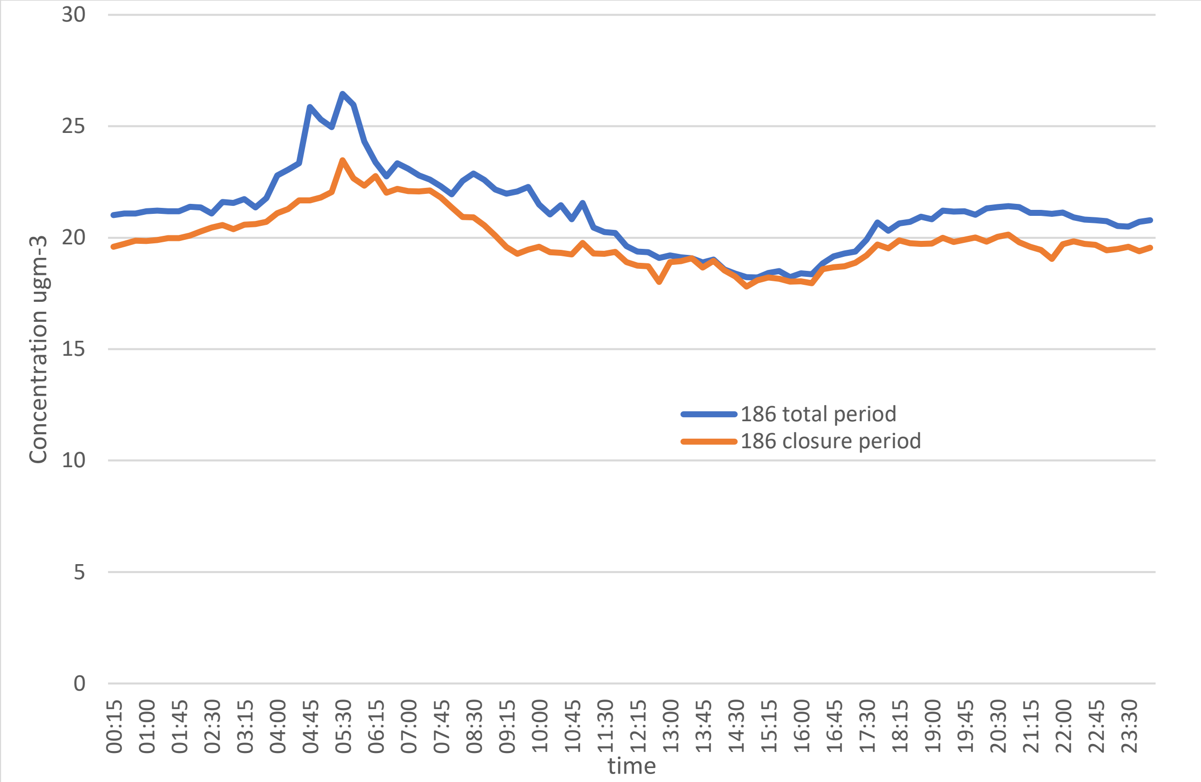


**Figure F29 Diurnal Profile during closure and for total period $PM_{10}$ (15 minute averages $ugm^{-3}$) Pod 186**




The graphs show that $PM_{10}$ and $PM_{2.5}$ concentrations between July and October were stable. Concentrations appear to increase in November and decrease again in December, with some high spikes in $PM_{10}$ concentrations in November. The graph appears to show a slight increase in concentrations when the bridge reopened when compared to previous weeks but reduces again in September.

The diurnal profile shows similar concentrations between the closure period and the total period with a slight elongated peak in concentrations during the morning.

## Pod 185 Cherry Hinton Road

Figures F30 to F35 show the15 minute data collected for 185 Cherry Hinton Road for $NO_2$, $PM_{10}$ and $PM_{2.5}$ for the monitoring period as 15 minute averages, weekly averages and as a diurnal profile. This monitor is located on Cherry Hinton Road opposite Fairways Guest House and was co-located with a diffusion tube. A traffic monitor has been placed on the opposite side of the road to the AQ Mesh monitor.

**Figure F30 15 minute average $NO_2$ ($ugm^{-3}$) July to December 2019 Pod 185 (Gonville Place)**

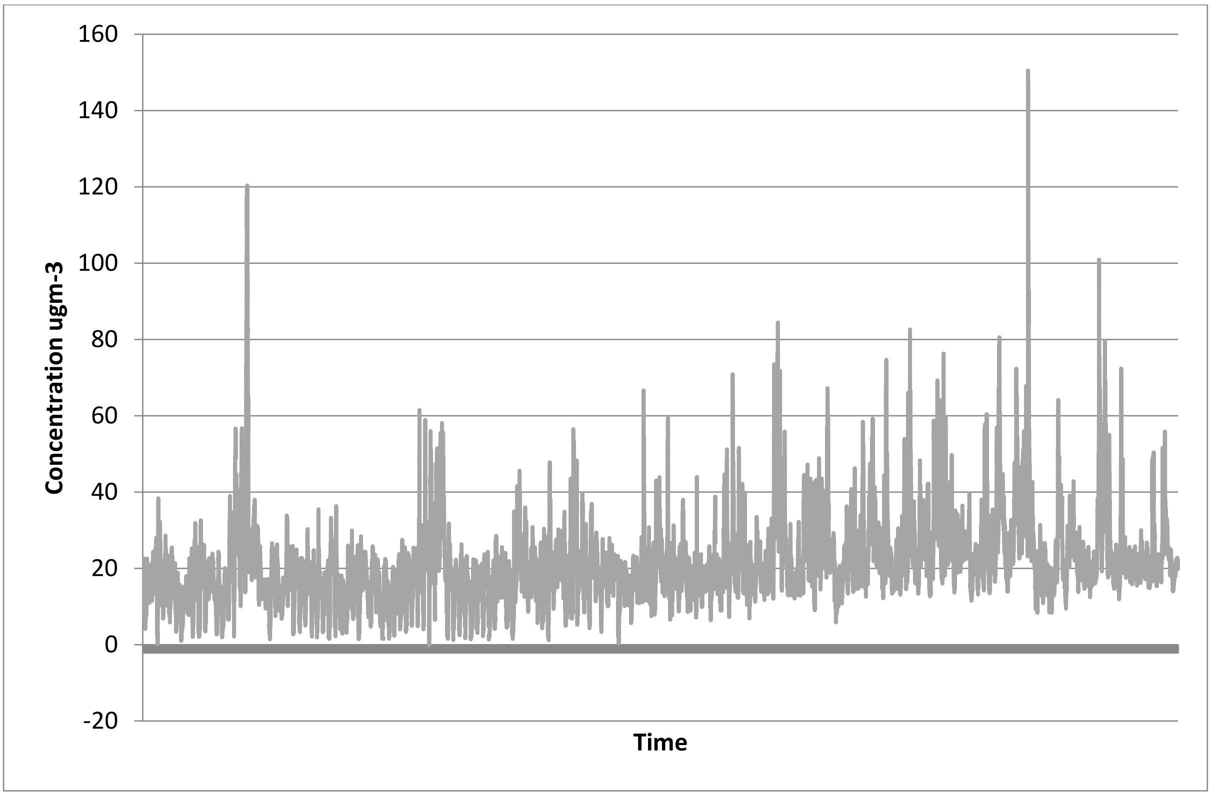


**Figure F31 Weekly Averages $NO_2$ Pod 185 Cherry Hinton Road**

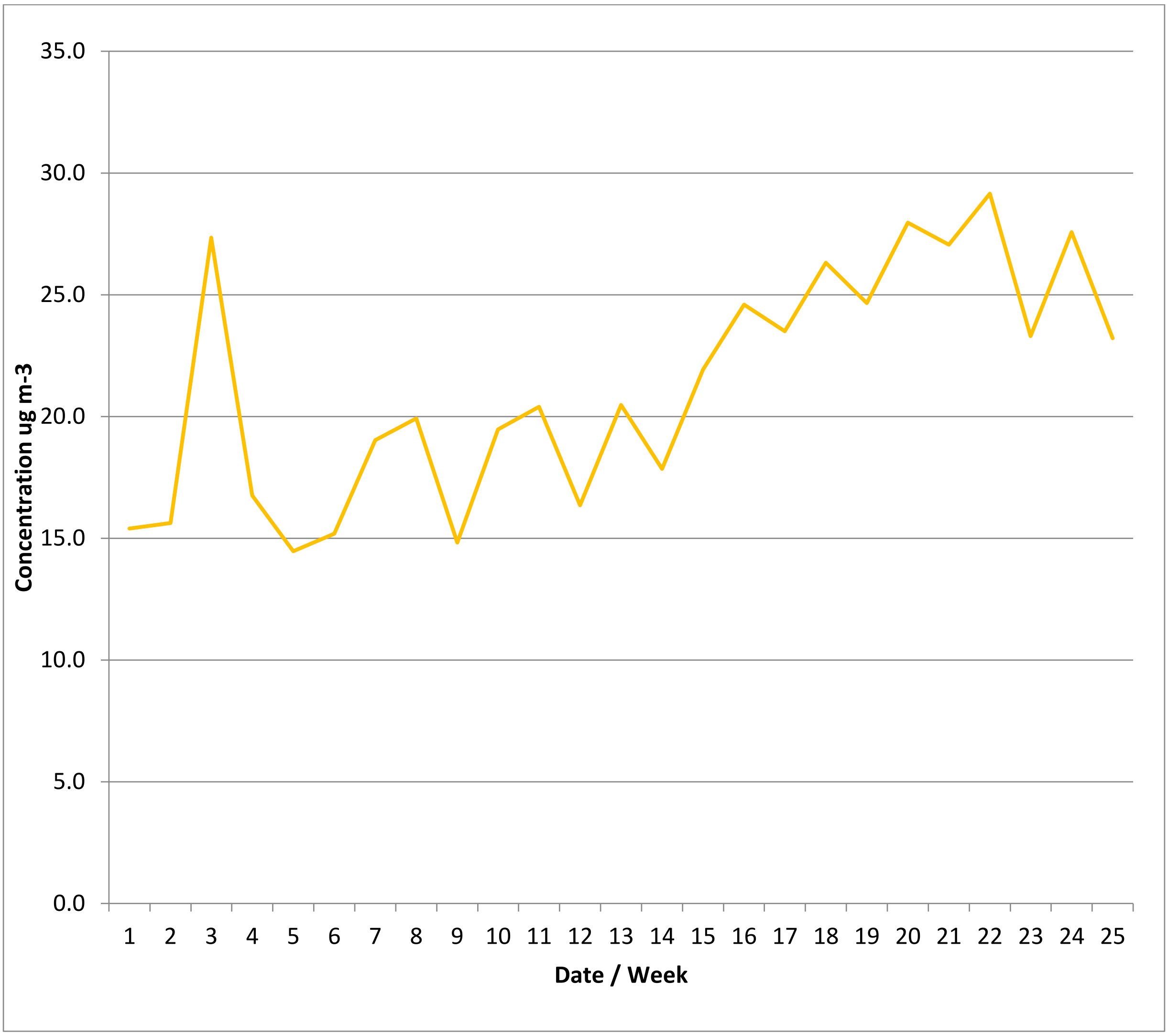
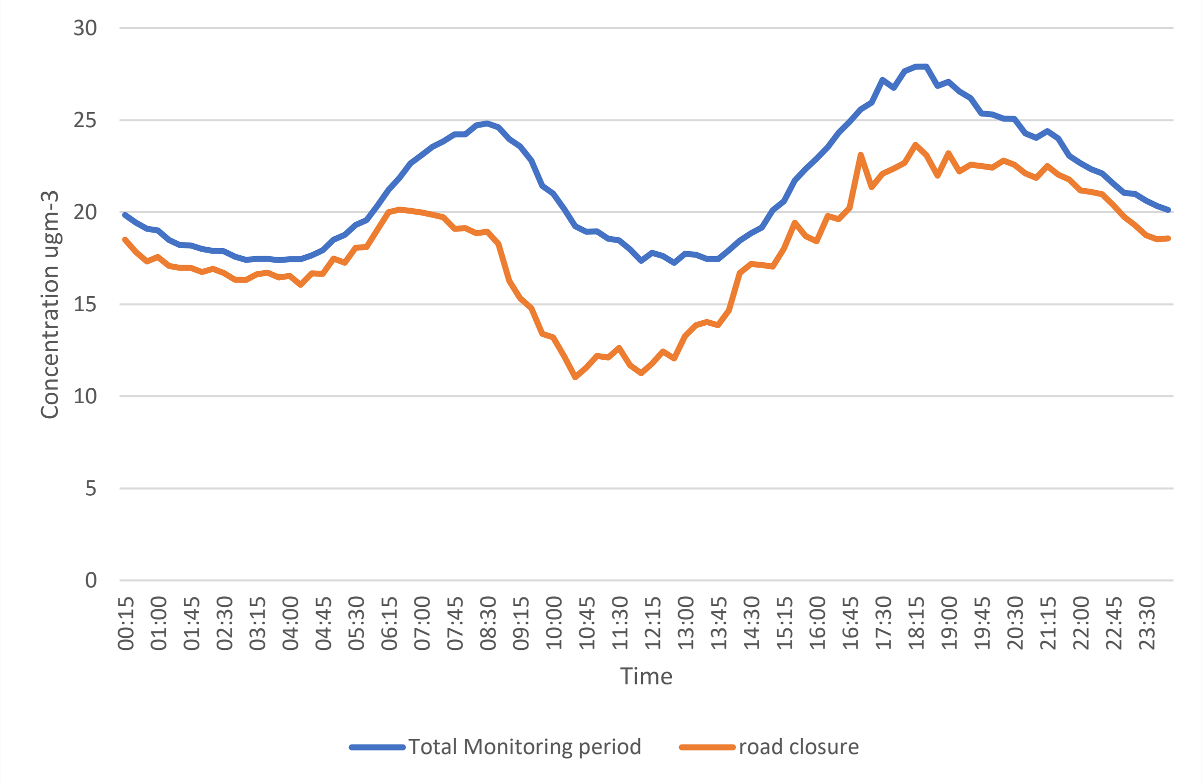


**Figure F32  Diurnal Profile during closure and for total period $NO_2$ (15 minute averages $ugm^{-3}$) Pod 185**




The graphs show a spike in concentrations in week 3. This occurred due to high concentrations between 23rd and 27th July. It coincides with the hottest day in England on 25th July.

It is unclear whether the concentrations during the bridge closure were lower than during the rest of the monitoring period but there does appear to be an upward trend in concentrations from the end of August. This could be normal seasonal variation in $NO_2$ concentrations.

The diurnal profile shows a difference between the total monitoring period and the road closure period especially in the morning peak. Concentrations are more similar during night time.

**Figure F33 15 minute average $PM_{10}$ & $PM_{2.5}$ ($ugm^{-3}$) July to December 2019 Pod 185 (Gonville Place)**

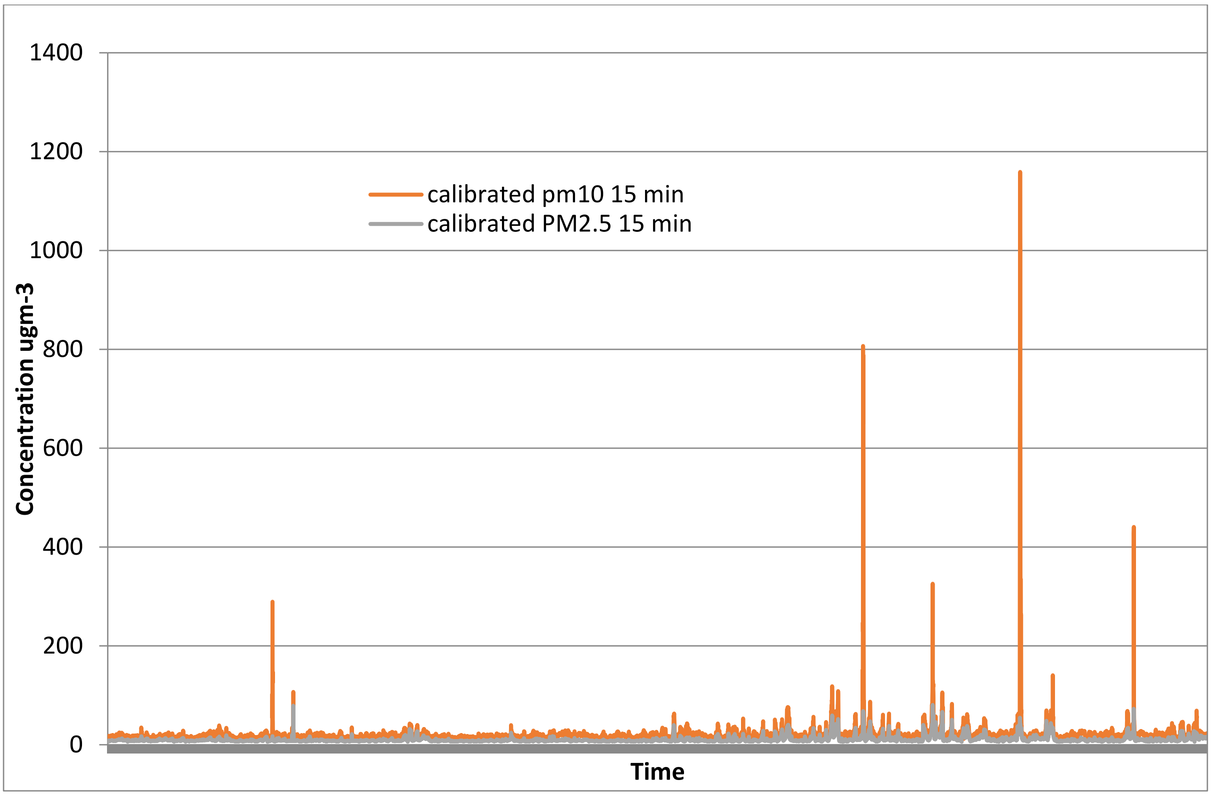


**Figure F34 Weekly Averages $PM_{10}$ & $PM_{2.5}$ Pod 185 Cherry Hinton Road**

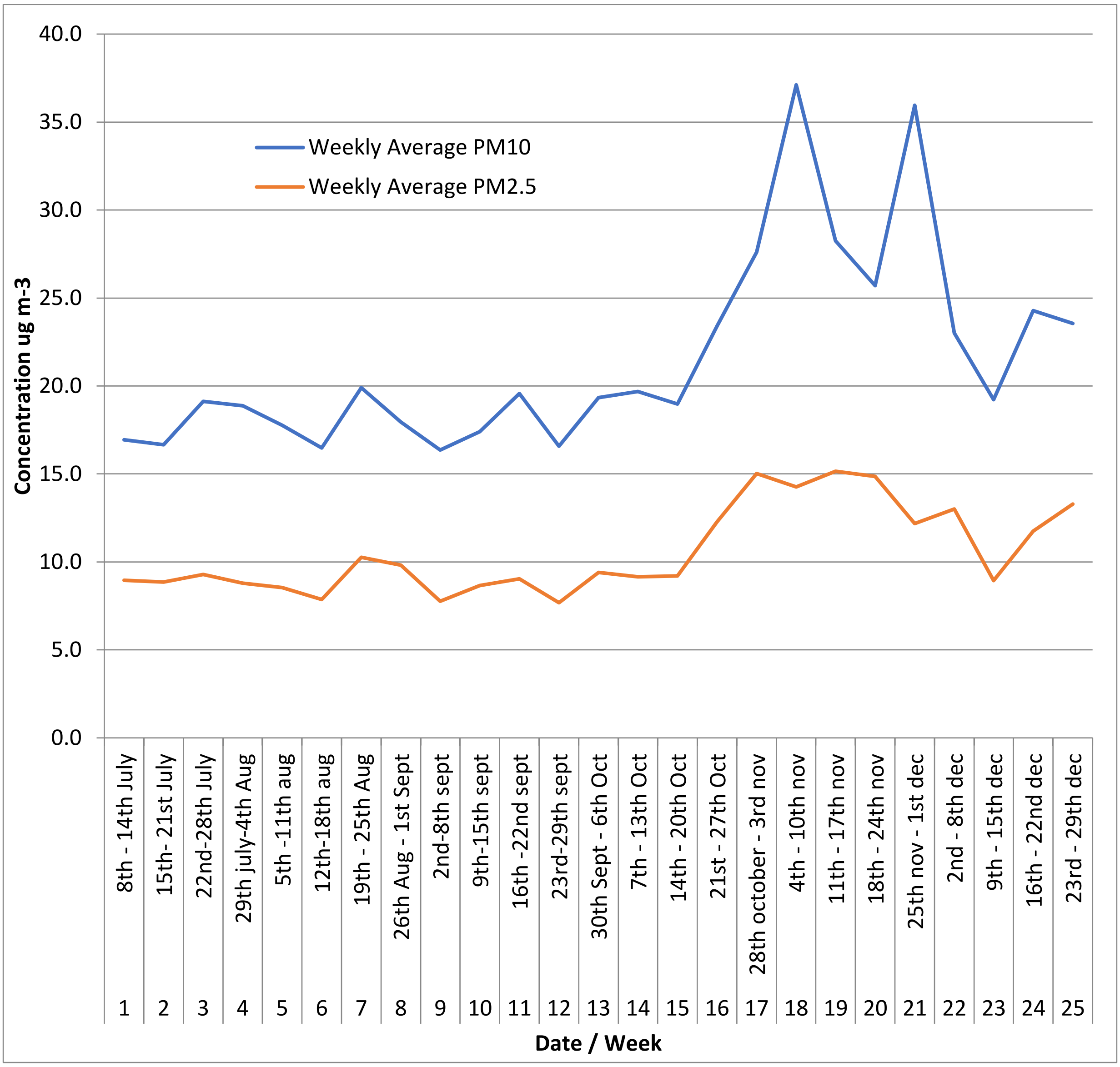
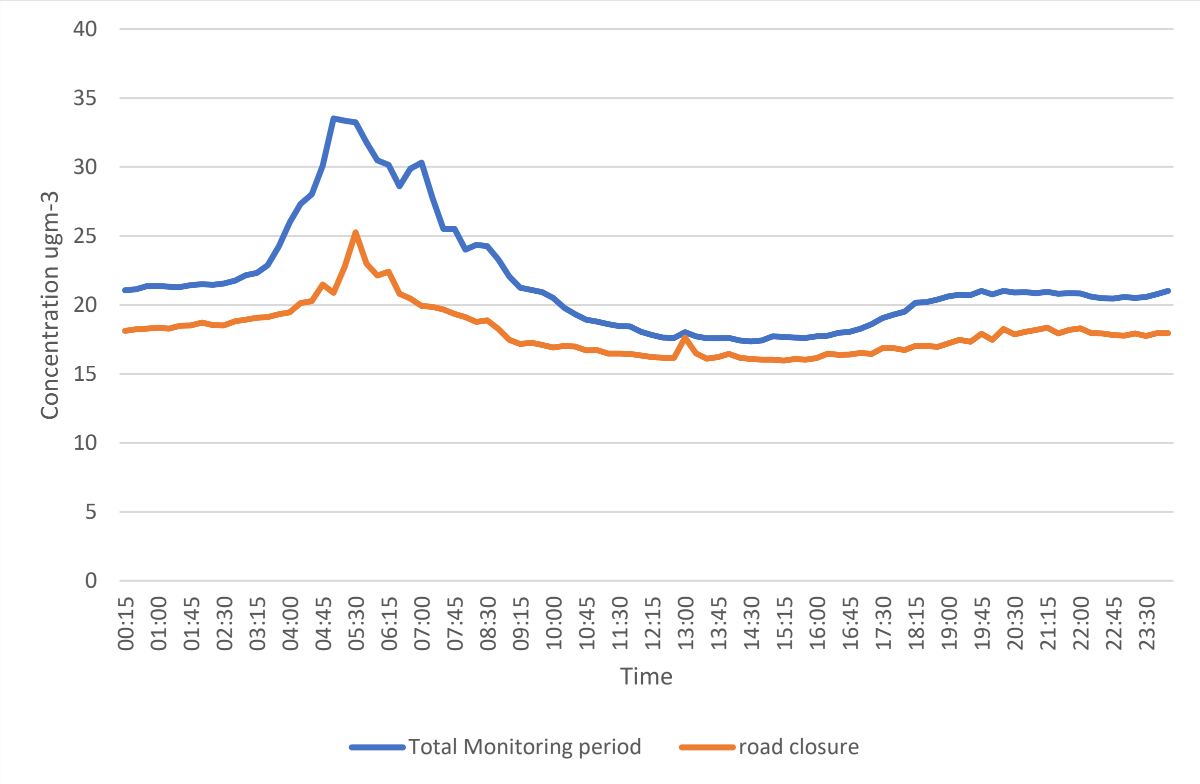


**Figure F35 Diurnal Profile during closure and for total period $PM_{10}$ (15 minute averages $ugm^{-3}$) Pod 185**




The graphs show that $PM_{10}$ and $PM_{2.5}$ concentrations were very similar between July and October with little variation. In addition there does not appear to be any effect of the road closure and re-opening on concentrations. However, concentrations increased during October and November, this could be due to seasonal variations. The diurnal profile shows a peak in concentrations in the morning for both the total monitoring period and the road closure period. The concentrations between the road closure period and the total monitoring period are broadly similar throughout the day.

## Pod 184 Tenison Road

Figures F36 to F41 show the15 minute data collected for 184 Tenison Road for $NO_2$, $PM_{10}$ and $PM_{2.5}$ for the monitoring period as 15 minute averages, weekly averages and as a diurnal profile. This monitor is located on Tenison Road close to its junction with Mill Road, a diffusion tube was located nearby.

**Figure F36 15 minute average $NO_2$ (ugm$^{-3}$) July to December 2019 Pod 184 (Tenison Road)**

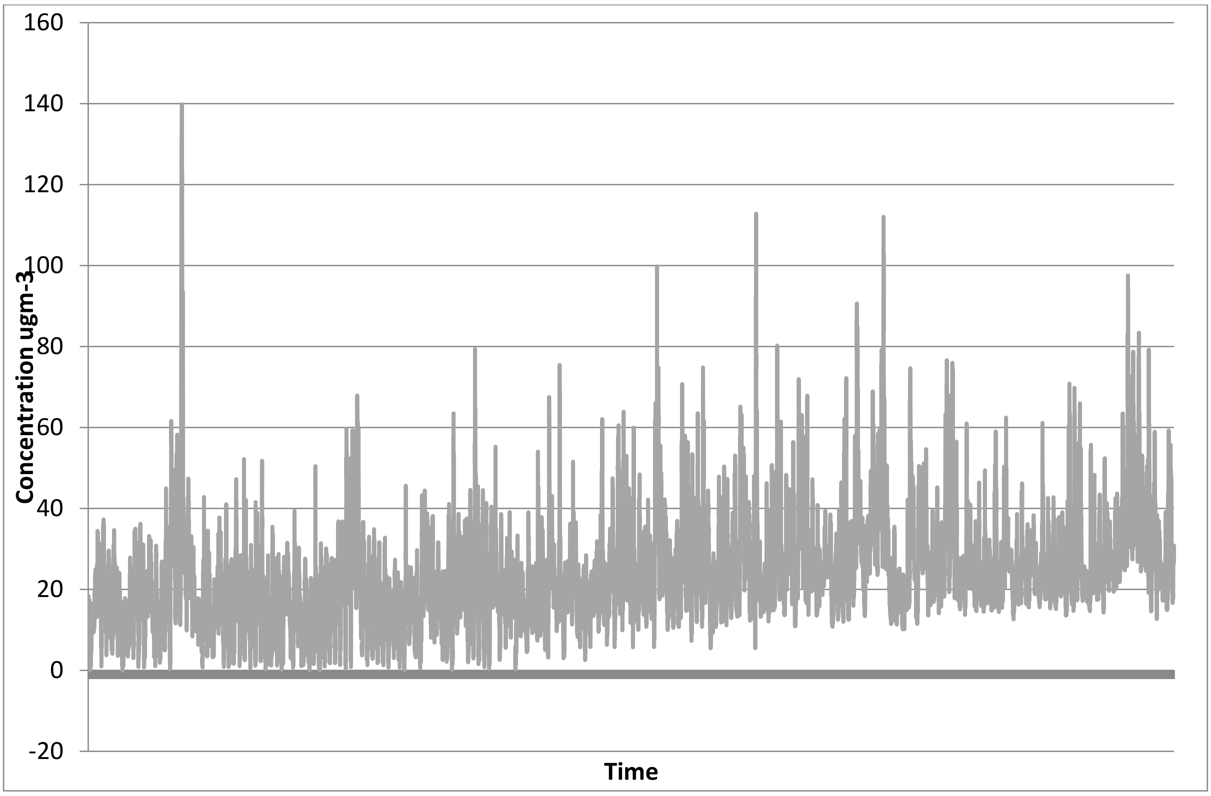



**Figure F37 Weekly Averages $NO_2$ Pod 184 Tenison Road**

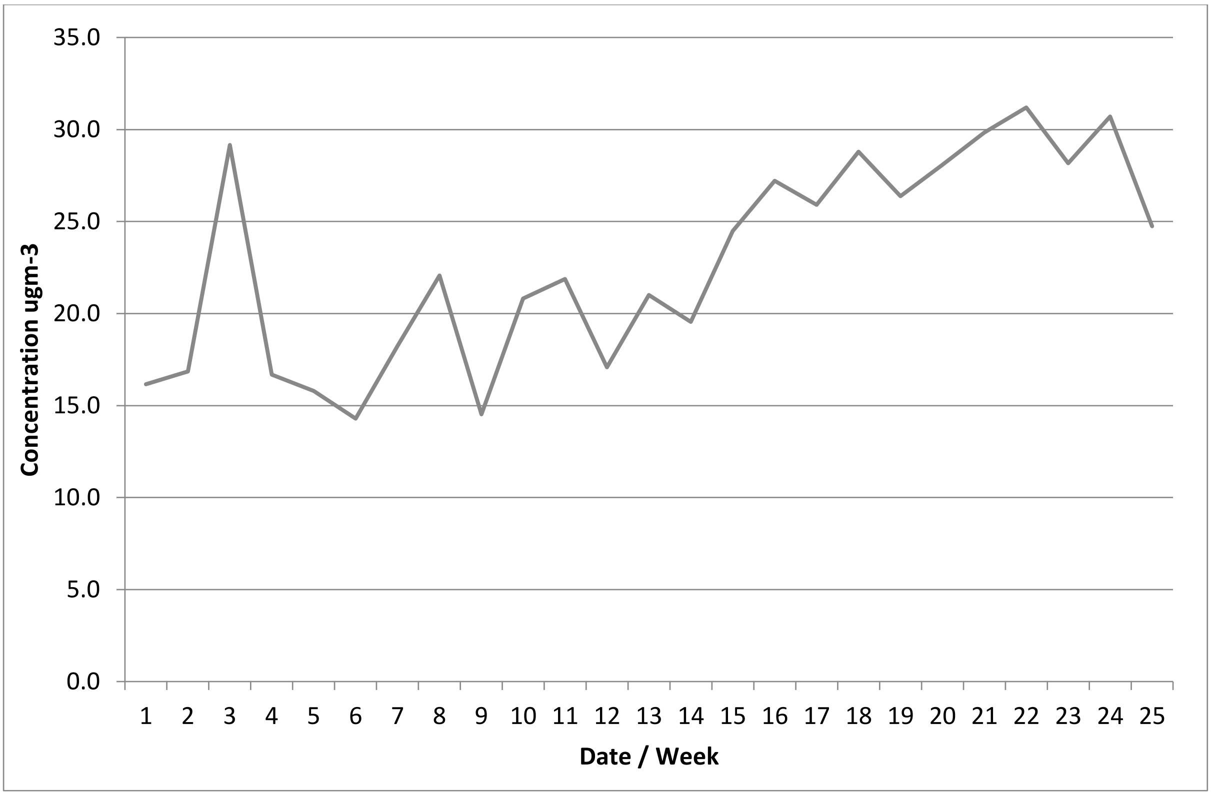
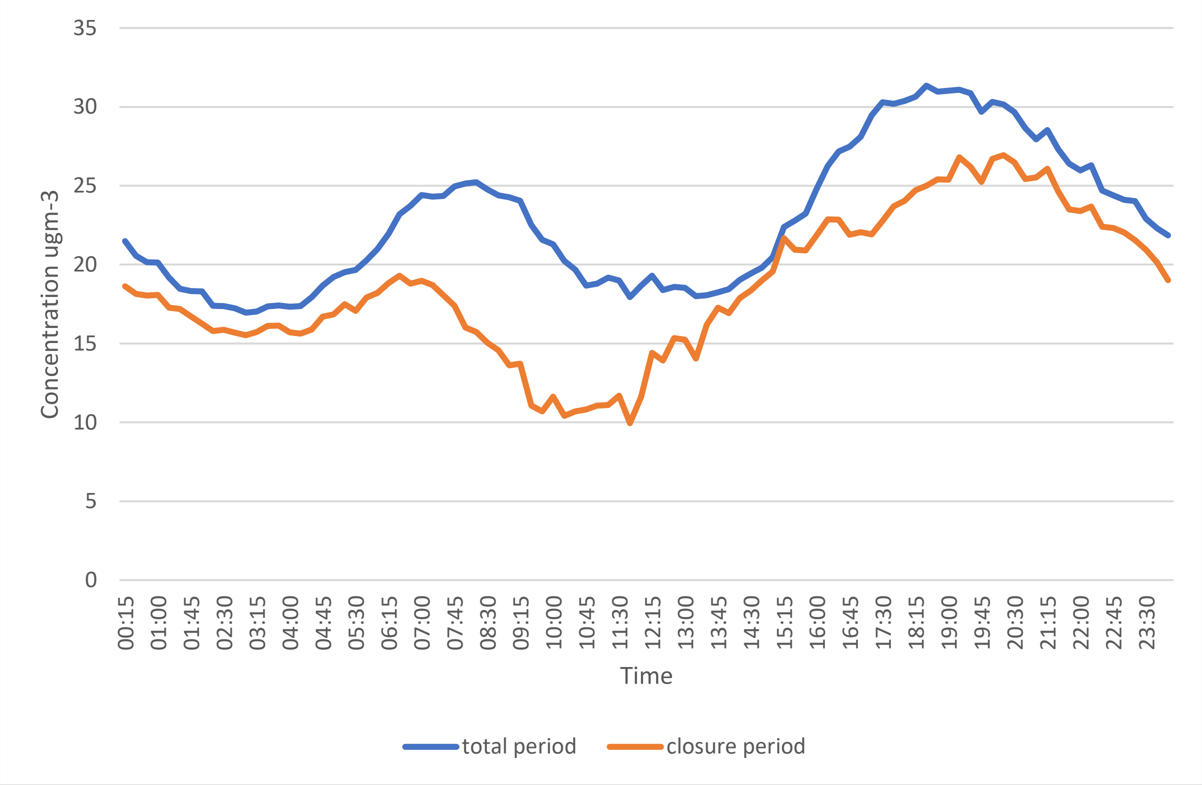


**Figure F38 Diurnal Profile during closure and for total period $NO_2$ (15 minute averages $ugm^{-3}$) Pod 184**




The graphs show a spike in week 3 consistent with higher concentrations between 23rd and 27th July. This coincided with the hottest day in England in 2019. Concentrations drop again however during the remainder of the bridge closure. Concentrations appear to increase once the bridge is open steadily rising during October and November.

The diurnal profile shows two distinct peaks in the morning and evening, although the closure period has lower concentrations in the morning peak and evening peak with similar concentrations throughout the rest of the day.

**Figure F39 15 minute average $PM_{10}$ & $PM_{2.5}$ ($ugm^{-3}$) July to December 2019 Pod 184 (Tenison Road)**

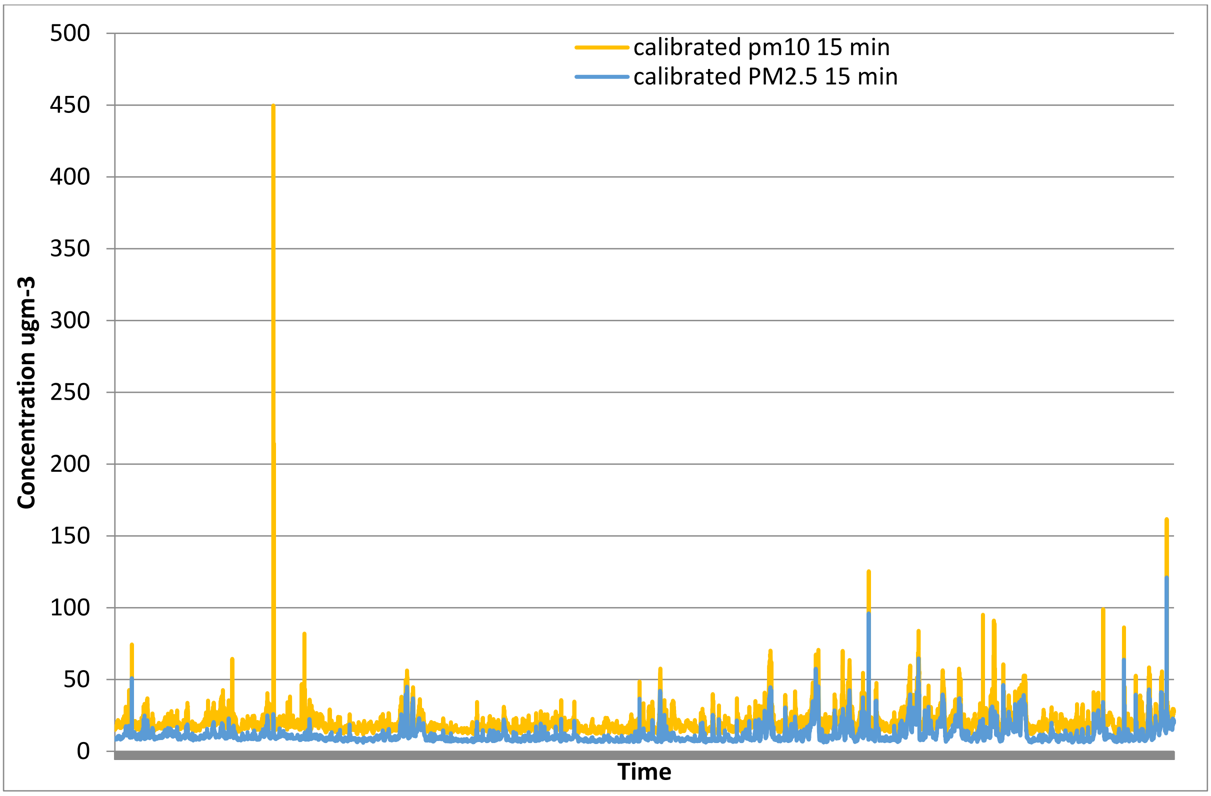


**Figure F40 Weekly Averages $PM_{10}$ & $PM_{2.5}$ Pod 184 Tenison Road**

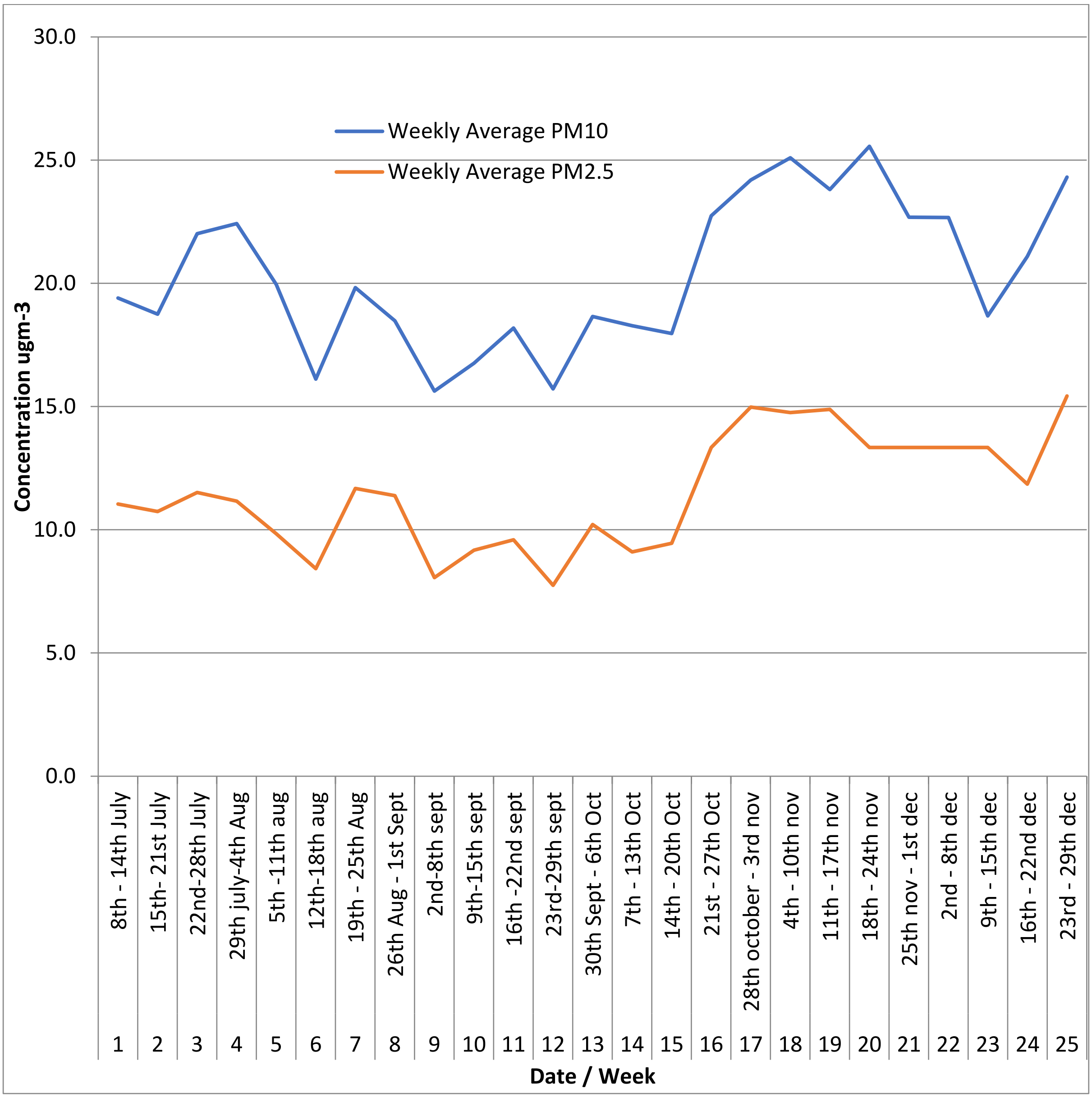
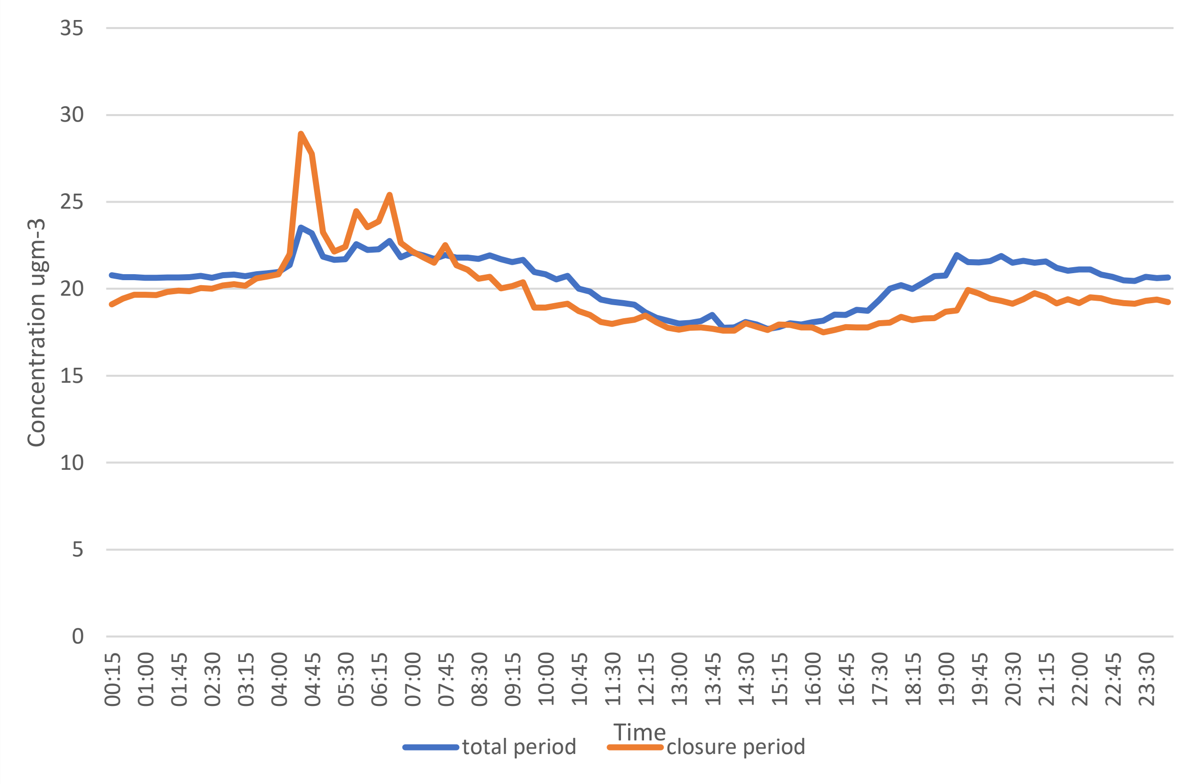


**Figure F41 Diurnal Profile during closure and for total period $PM_{10}$ (15 minute averages $ugm^{-3}$) Pod 184**




The graphs show a slightly higher concentration of $PM_{10}$ and $PM_{2.5}$ during the bridge closure. This may be related to the construction work being undertaken at the bridge and also the gas works and fire which took place on Mill Road during the bridge closure which could have affected concentrations. Concentrations were lower once the bridge re-opened and then rose again during October and November.
The diurnal profile shows that concentrations during the bridge closure peaked slightly in the mornings but were lower during the evening. The remainder of the day the concentrations were similar during the closure period and the total period.

## Pod 183 Mill Road East

Figures F42 to F47 show the15 minute data collected for 183 Mill Road East for $NO_2$, $PM_{10}$ and $PM_{2.5}$ for the monitoring period as 15 minute averages, weekly averages and as a diurnal profile. This monitor is located on the eastern end of Mill Road adjacent to the entrance for the Cambridge Mosque, a diffusion tube was located nearby at the junction of Mill Road and Hobart Road. A traffic monitor has been placed opposite the AQ Mesh monitor.

**Figure F42 15 minute average $NO_2$ ($ugm^{-3}$) July to December 2019 Pod 183 (Mill Road East)**

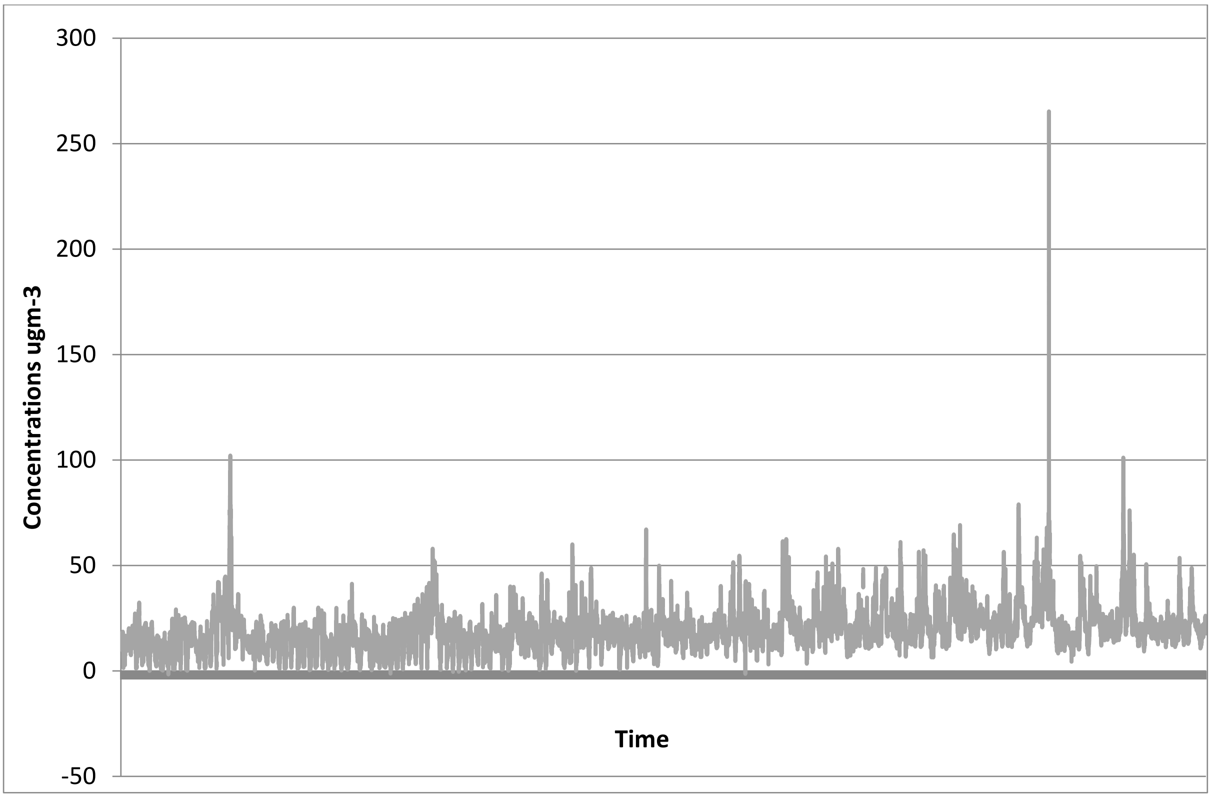



**Figure F43 Weekly Averages $NO_2$ Pod 183 Mill Road East**

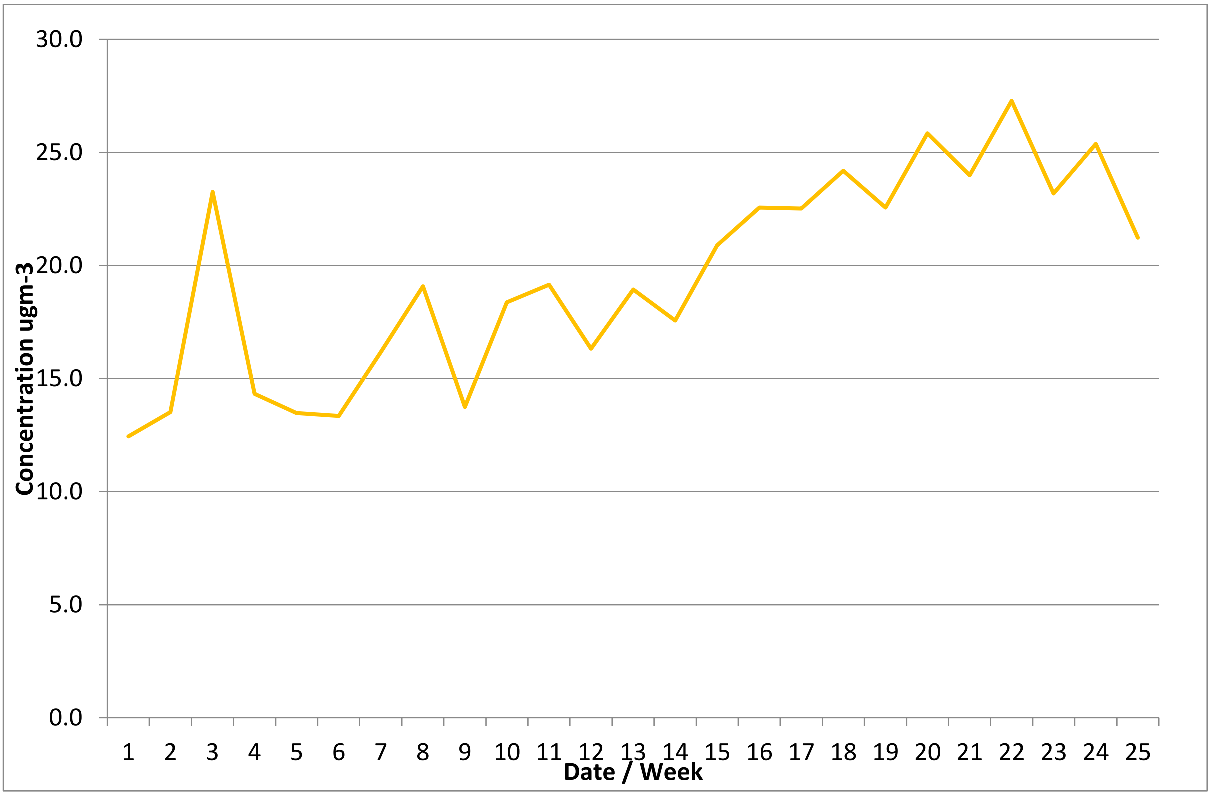
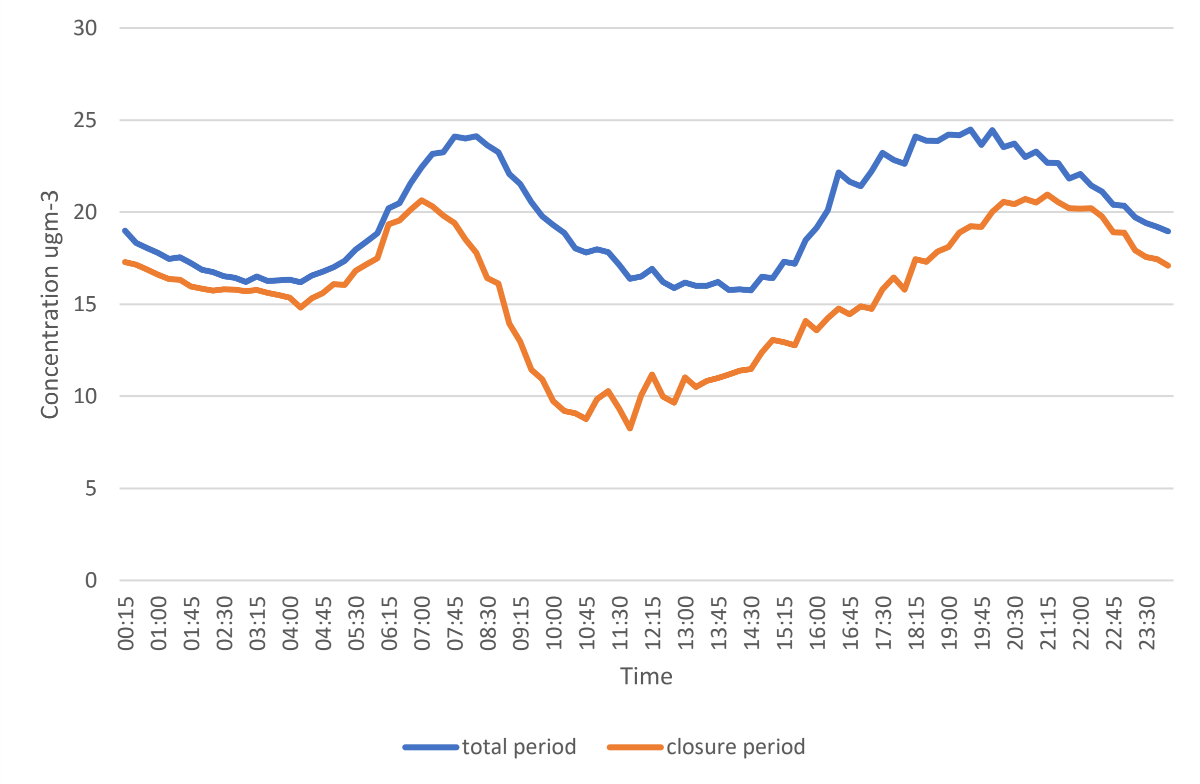


**Figure F44 Diurnal Profile during closure and for total period $NO_2$ (15 minute averages ugm$^{-3}$) Pod 183**




The graphs show a spike in concentrations during week 3 as a result of high concentrations between 23rd and 27th July. This coincided with the hottest day of 2019. The graphs appear to show an increase in concentrations following the re-opening of the bridge. Concentrations then appear to steadily increase until the end of November, where they appear to level out.

The diurnal profile shows that concentrations were lower in the morning and evening peak and lower also during the day during the closure period. However, concentrations were similar during the night time for the closure period and the total period.

**Figure F45 15 minute average $PM_{10}$ & $PM_{2.5}$ ($ugm^{-3}$) July to December 2019 Pod 183 (Mill Road East)**

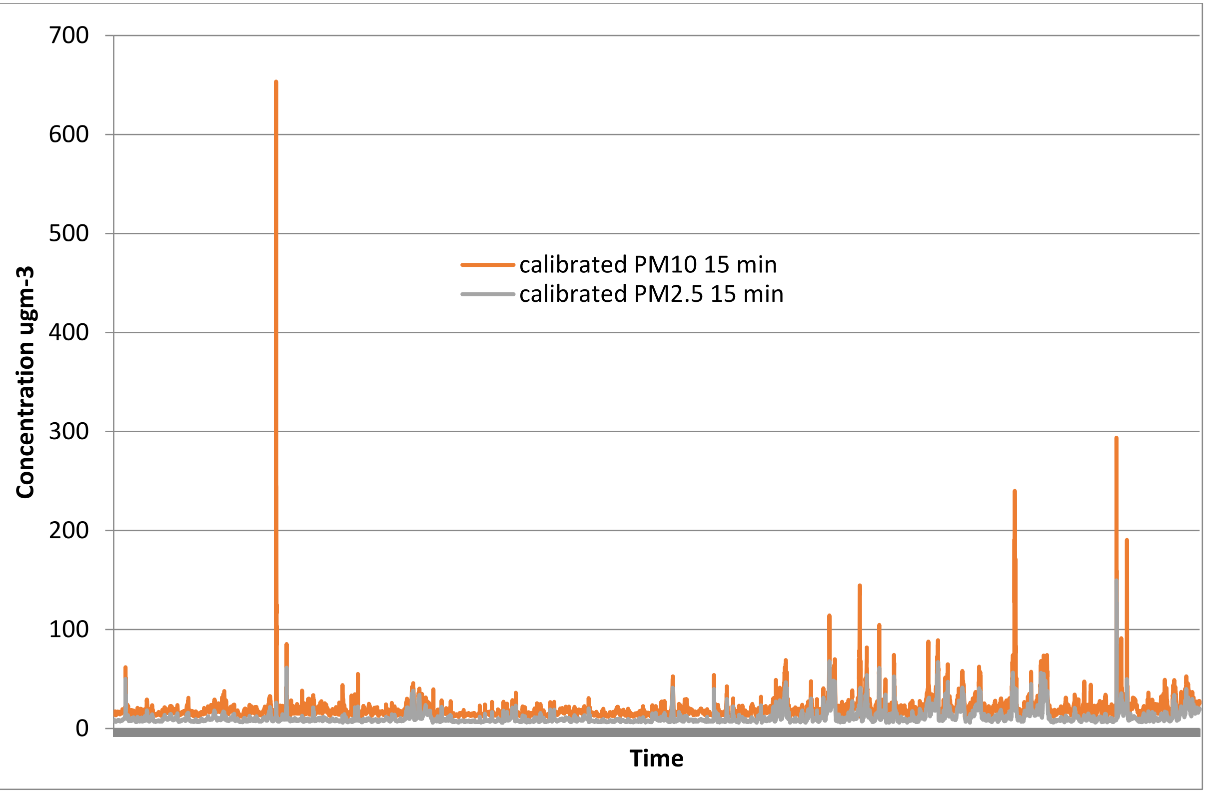


**Figure F46 Weekly Averages $PM_{10}$ & $PM_{2.5}$ Pod 183 Mill Road East**

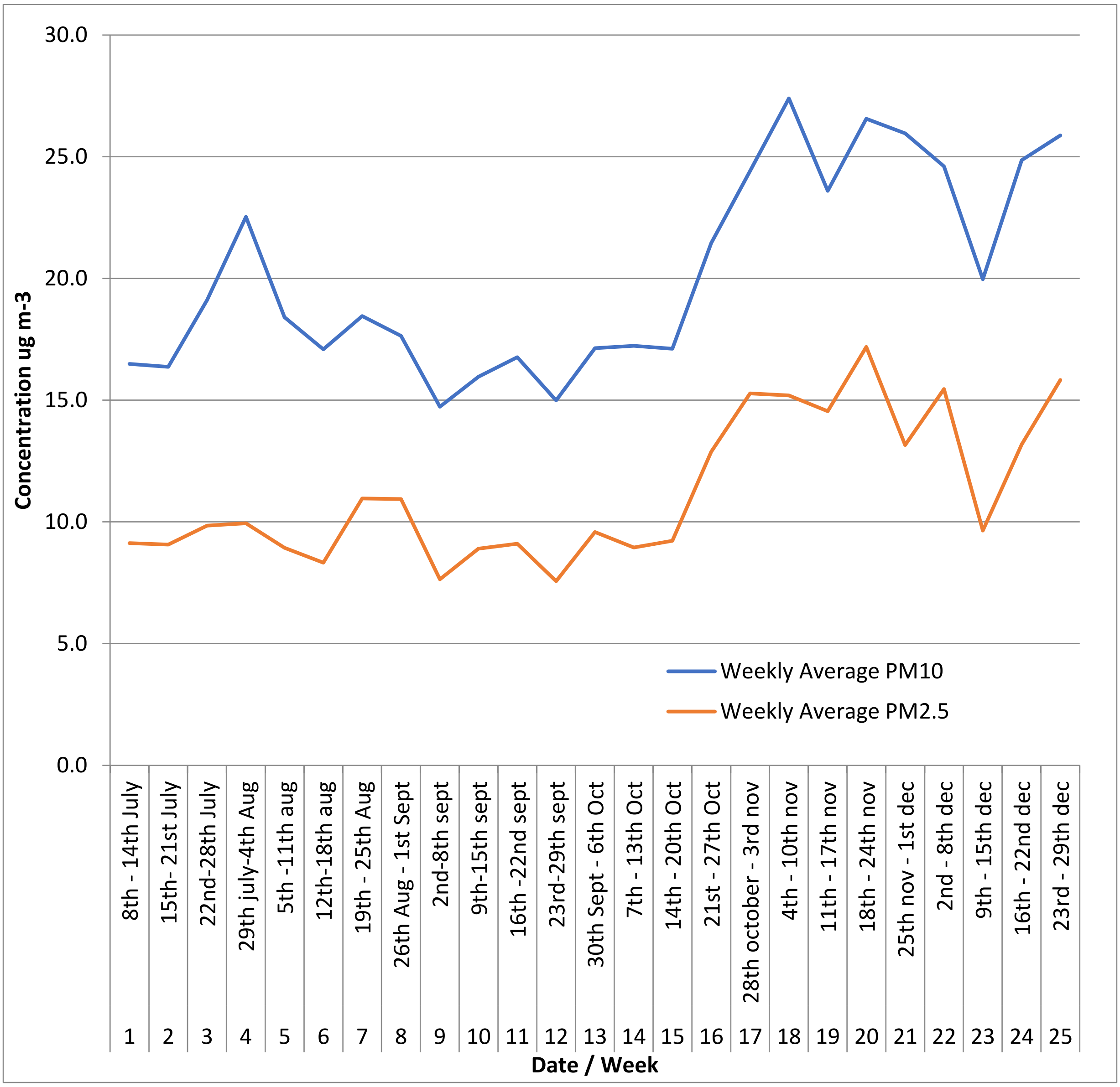
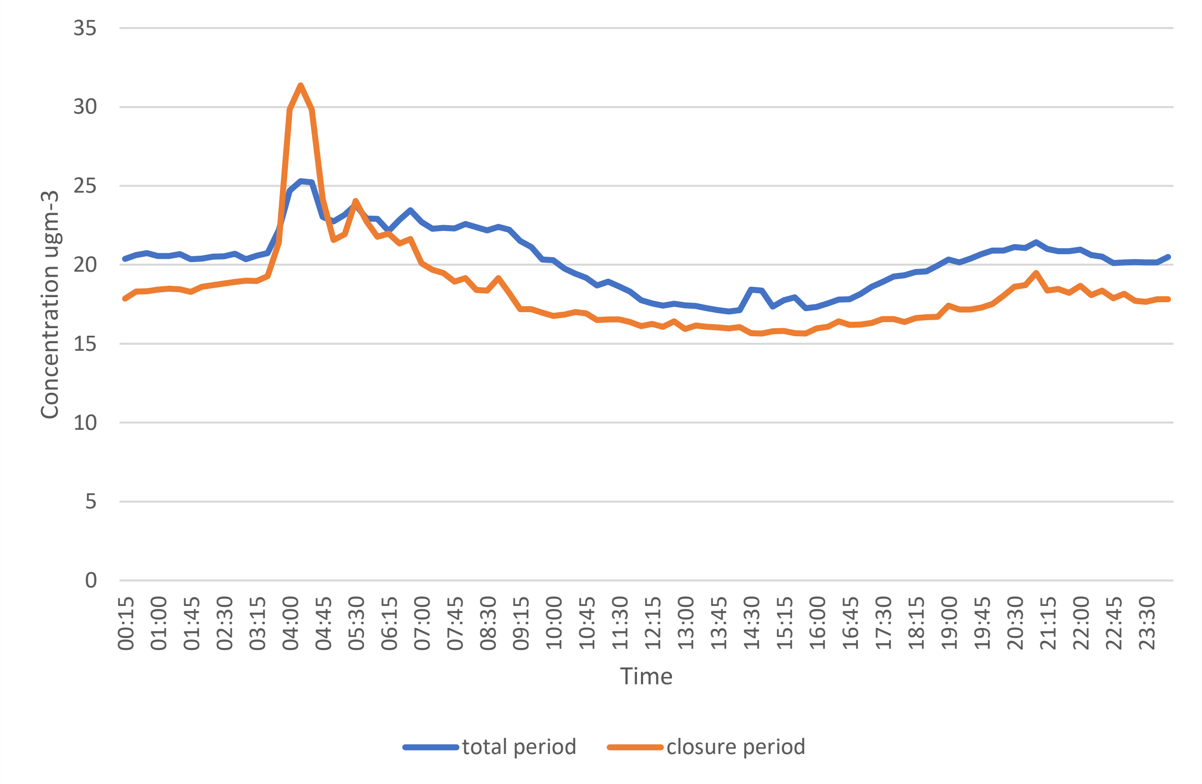


**Figure F47 Diurnal Profile during closure and for total period $PM_{10}$ & $PM_{2.5}$ (15 minute averages $ugm^{-3}$) Pod 183**




The graphs show that there was a spike in $PM_{10}$ concentrations during week 4 of the monitoring period. In general, without this spike the trend in $PM_{10}$ concentrations appears to be fairly stable during the closure period. This spike is not shown by $PM_{2.5}$ concentrations suggesting the source was mainly $PM_{10}$ particles. $PM_{2.5}$ concentrations remained stable throughout the closure period. $PM_{10}$ and $PM_{2.5}$ concentrations begin to increase during October and November. The graphs do not seem to show any difference in $PM_{10}$ and $PM_{2.5}$ concentrations with and without the bridge closure.

The diurnal profile shows a peak in the morning, especially for the closure period. This could be linked to the spike in $PM_{10}$ concentrations during this time. In general, the total period shows slightly higher concentrations than the closure period.

# Appendix G – Diffusion Tube Results

## Table G1 Diffusion tube results $NO_2$ ugm$^{-3}$ as monthly average

| | | NA1S | NA2S | NA3S | NA4S | NA5S | NA6S | NA7S | NA8S | NA9S | NA10S | NA11S | NA12S | Average for year | Average for year bias corrected | Data capture per tube for 12 months |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | February | March | April | May | June | July | August | September | October | November | December | January | | *0.68 | |
| **1** | **Tenison Road 3** | 46.6 | 32.4 | 37.8 | m | 29.3 | 23.6 | 23.5 | 30.6 | 38 | 49.1 | 33.6 | 41.5 | 35.1 | 25 | 92% |
| **2** | **Devonshire Road** | 43.7 | 25.4 | 22.2 | 18.3 | 20.5 | 15.4 | 17.4 | 26.2 | 32.2 | 40.3 | 25.2 | 30.4 | 26.4 | 19 | 100% |
| **3** | **Catharine Street** | m | 25.6 | 22.5 | 16.2 | 17.1 | 14.1 | 15.6 | m | 29.1 | 37.3 | 28.5 | 33.2 | 23.9 | 17 | 83% |
| **4** | **Ross Street** | 36.6 | 22.2 | 16.8 | 15.6 | m | 13 | 14.6 | 21.8 | 26.7 | 34.4 | 24.5 | 31.7 | 23.4 | 16 | 92% |
| **5** | **Cavendish Road** | 34.2 | 22 | 17.5 | 15.6 | 15.1 | 14 | 15.2 | 21.2 | 22.6 | 34.9 | 23.9 | 32.2 | 22.4 | 16 | 100% |
| **6** | **Radegund Road** | 31.8 | 21.7 | 18.2 | 14.3 | 12.7 | 15.6 | 13.9 | 19.4 | 23.8 | 36.1 | 27.2 | 30.7 | 22.1 | 15 | 100% |
| **7** | **Coleridge Road** | 40.9 | 25.8 | 19.8 | 20 | 19.9 | 17.3 | 17 | 25.3 | 30.5 | 39.2 | 27.8 | 29.3 | 26.1 | 18 | 100% |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **8** | **Cherry Hinton Road 2** | m | 28 | 28.2 | 21.5 | 18.7 | 26.1 | 19.8 | 27.8 | 31.5 | 42.1 | 30.9 | 30.3 | 27.7 | 19 | 92% |
| **9** | **Cherry Hinton Road 3** | 42.6 | 31.4 | 25.1 | 25.7 | 20.3 | 26.3 | 21.7 | 29.6 | 32.9 | 46.9 | 34.2 | 38.4 | 31.3 | 22 | 100% |
| **10** | **Cherry Hinton High Street** | m | 1.6 | 22.9 | 20.8 | 18.5 | 21.6 | 24.5 | m | 33.4 | 41.8 | 34.8 | 40.6 | 26.1 | 18 | 83% |
| **11** | **Brooks Road** | 33.6 | 33.2 | 29.8 | 25.7 | 21.5 | 28.2 | 25.1 | 33.9 | 35.8 | 49.6 | 39.7 | 45.7 | 33.5 | 23 | 100% |
| **12** | **Vinery Road** | 33.2 | 22.2 | 16.3 | 19.3 | 15.7 | 15.5 | 17.2 | 20 | 28.4 | 37.2 | 23.1 | 34.2 | 23.5 | 16 | 100% |
| **13** | **Perne Road 1** | 42.8 | 27.7 | 28 | 20.6 | 20.4 | 21.9 | 19.6 | 28.6 | 34.2 | 46.6 | 33.8 | 39.3 | 30.3 | 21 | 100% |
| 14 | Perne Road 2 | 42.4 | 33.1 | 32.1 | 24.7 | 23.3 | 25.7 | 23.2 | 30.4 | 35.4 | 47.9 | 32.7 | 35.6 | 32.2 | 23 | 100% |
| Monthly data capture | | | 79% | 100% | 100% | 93% | 93% | 100% | 100% | 86% | 100% | 100% | 100% | 100% | 95% | |

*Notes:*

*Monitoring starting February 2019.*

*Bridge works start 1st July*

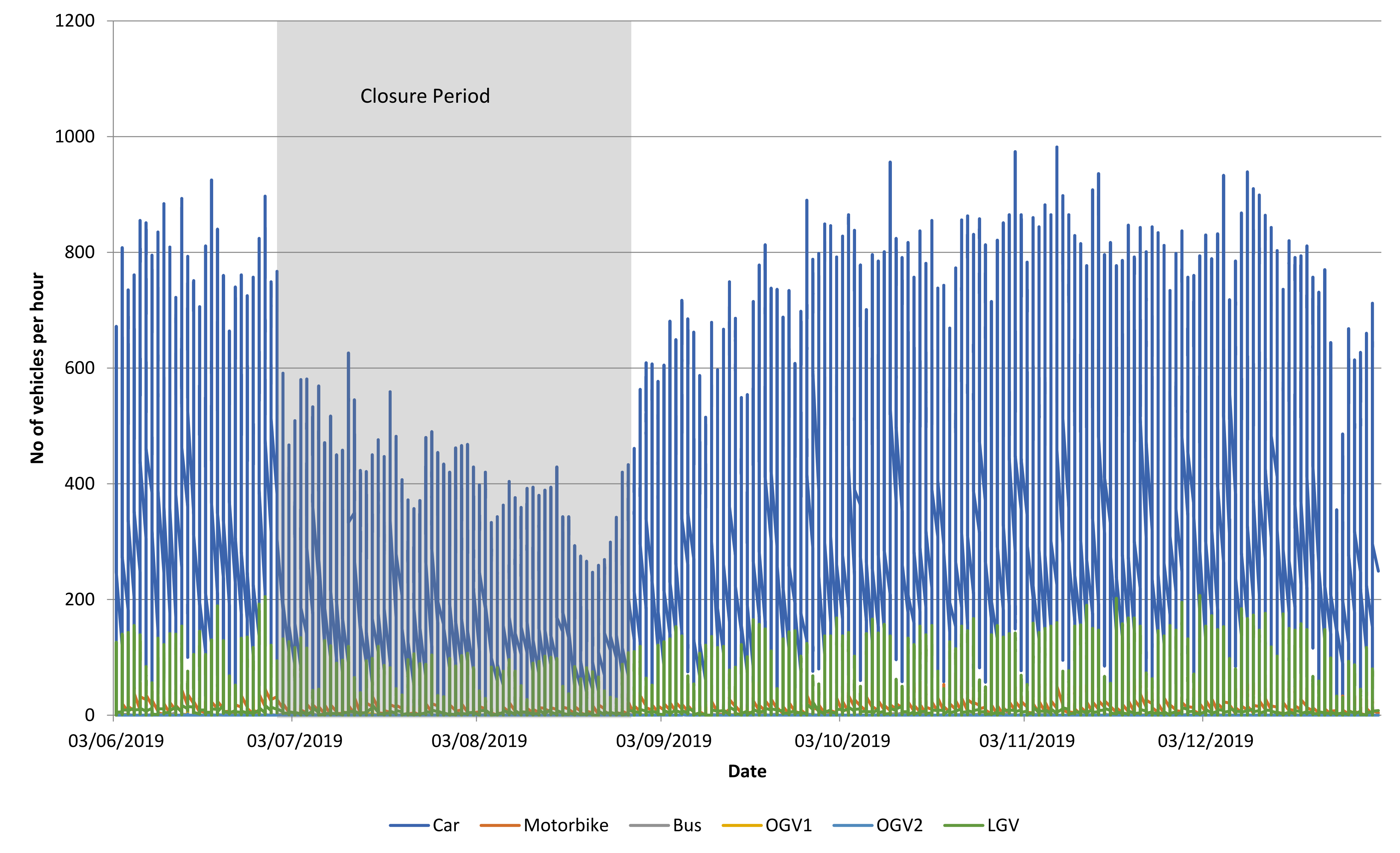
# Appendix H – Traffic Monitoring Results

## Mill Road 1

This sensor was located on Mill Road at the eastern end close to the Mosque.

Figure H1 shows that the vehicles which were using Mill Road were mainly cars and LGV’s (Light goods vehicles). The graph shows that there was a drop in the number of cars following the bridge closure. Numbers of LGV’s also appeared to drop during the bridge closure as well. Vehicle numbers appear to return to pre-bridge closure levels over a period of a few weeks after the bridge re-opened.

**Figure H1 Mill Road 1 traffic data**

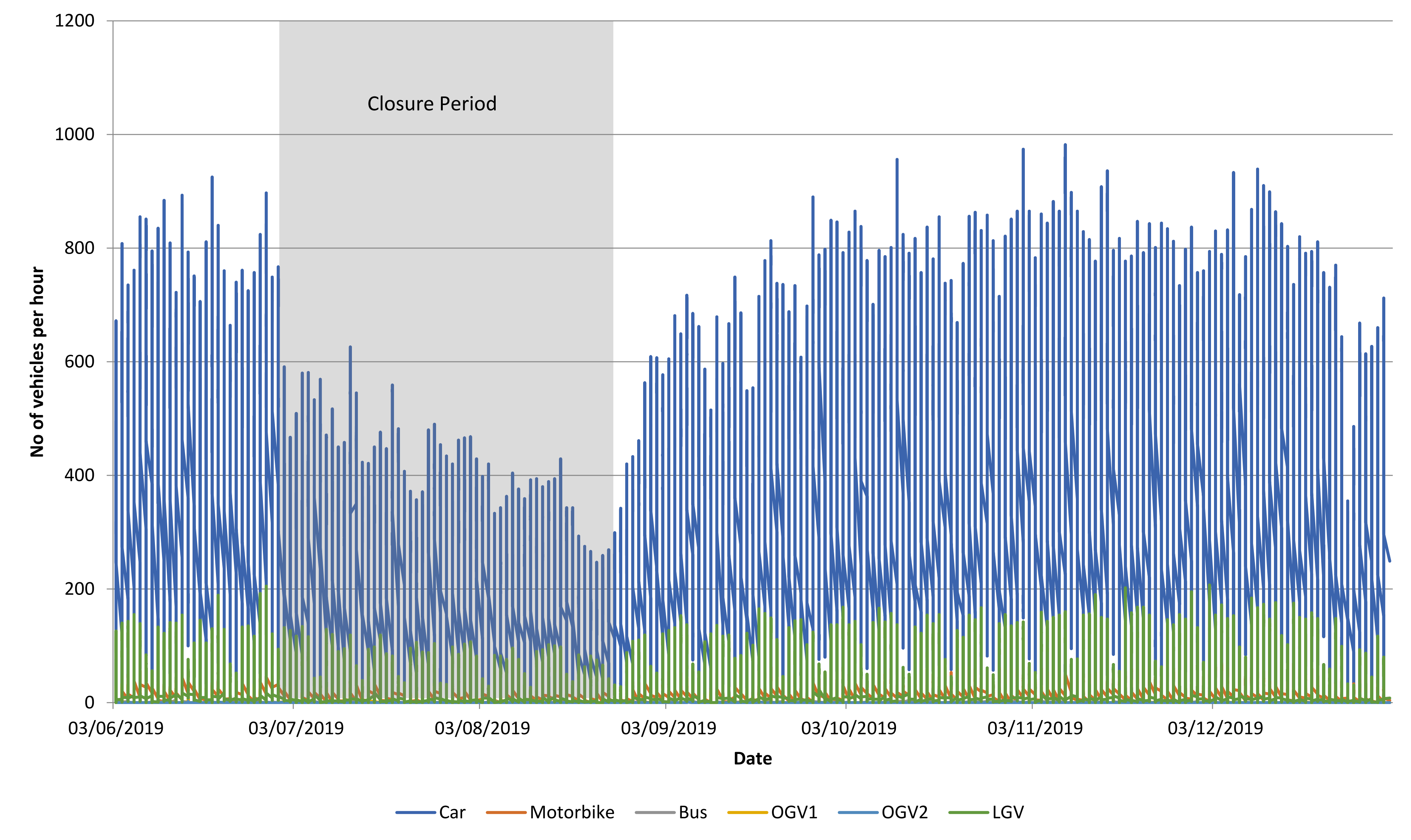


## Mill Road 2

This sensor was located on Mill Road at the western end close to the junction with Mortimer Road.

Figure H2 shows that the main vehicle types using this section of Mill Road were cars and LGV’s.  The bridge closure appears to have resulted in a steady decline in the number of cars using this section of Mill Road over the closure period.  There is less of a pronounced decline in the number of LGV’s.  This may be due to the Travis Perkins (Hardware Store) located on Devonshire Road which is accessed via Mill Road.  Following the bridge re-opening the vehicles numbers appear to sharply increase and then have a slower rate of increase back to pre-closure levels.

**Figure H2 Mill Road 2 traffic data**

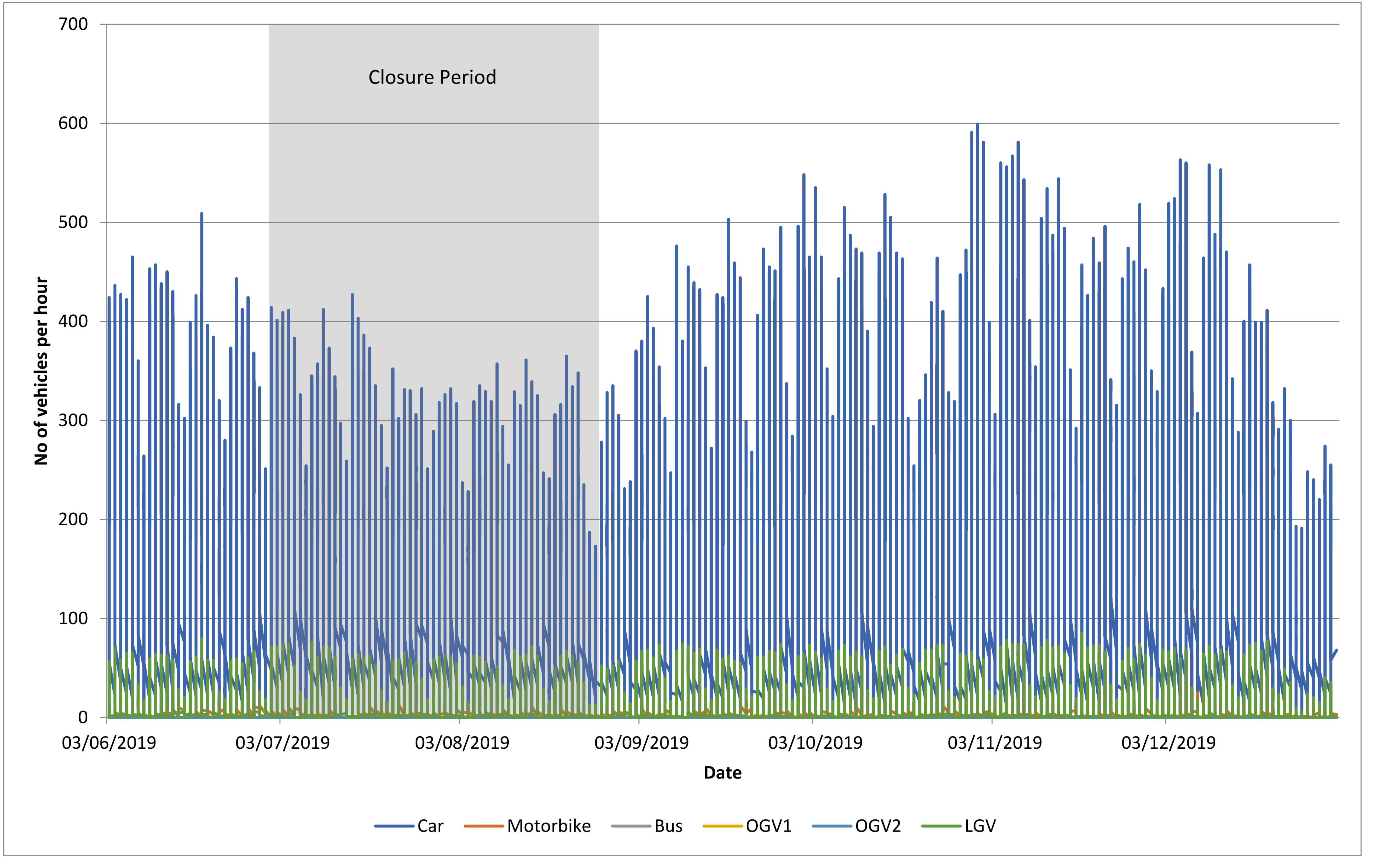


## S3 Coleridge Road

This sensor was located on Coleridge Road outside Coleridge Recreation Ground.

Figure H4 shows that the dominant type of vehicle on this road is cars. There appears to be a slight decrease in cars during the bridge closure period, although there appears to be a greater variability in traffic levels across the monitoring period both before and after the closure. The closure does not appear to have affected the number of LGV’s using this road.

**Figure H4 Coleridge Road traffic data**

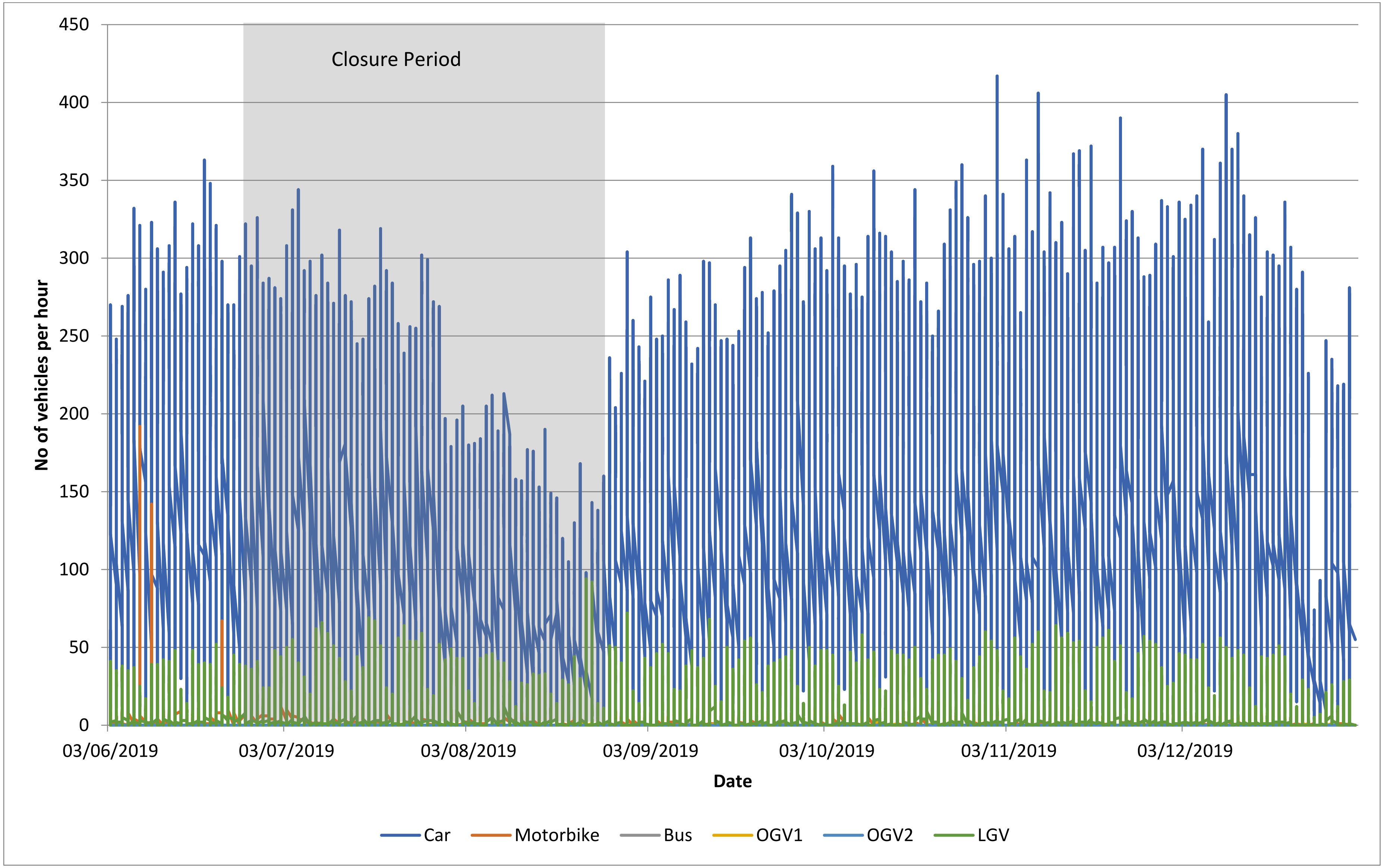


## S5 Tenison Road

This traffic sensor was located on Tenison Road, close to the air quality monitor.

The majority of traffic on Tenison Road appears to be cars and LGVs.  There are a few days at the beginning of the monitoring period when many motorcycles appear to be using this road.  Figure H5 shows that there is a drop in traffic data during the bridge closure, although for the last few days of the closure there appears to be a significant increase in the number of LGV’s.  The number of LGV’s during the monitoring period fluctuates and it is difficult to see if their numbers also decrease during the bridge closure.

**Figure H5 Tenison Road Traffic Data**



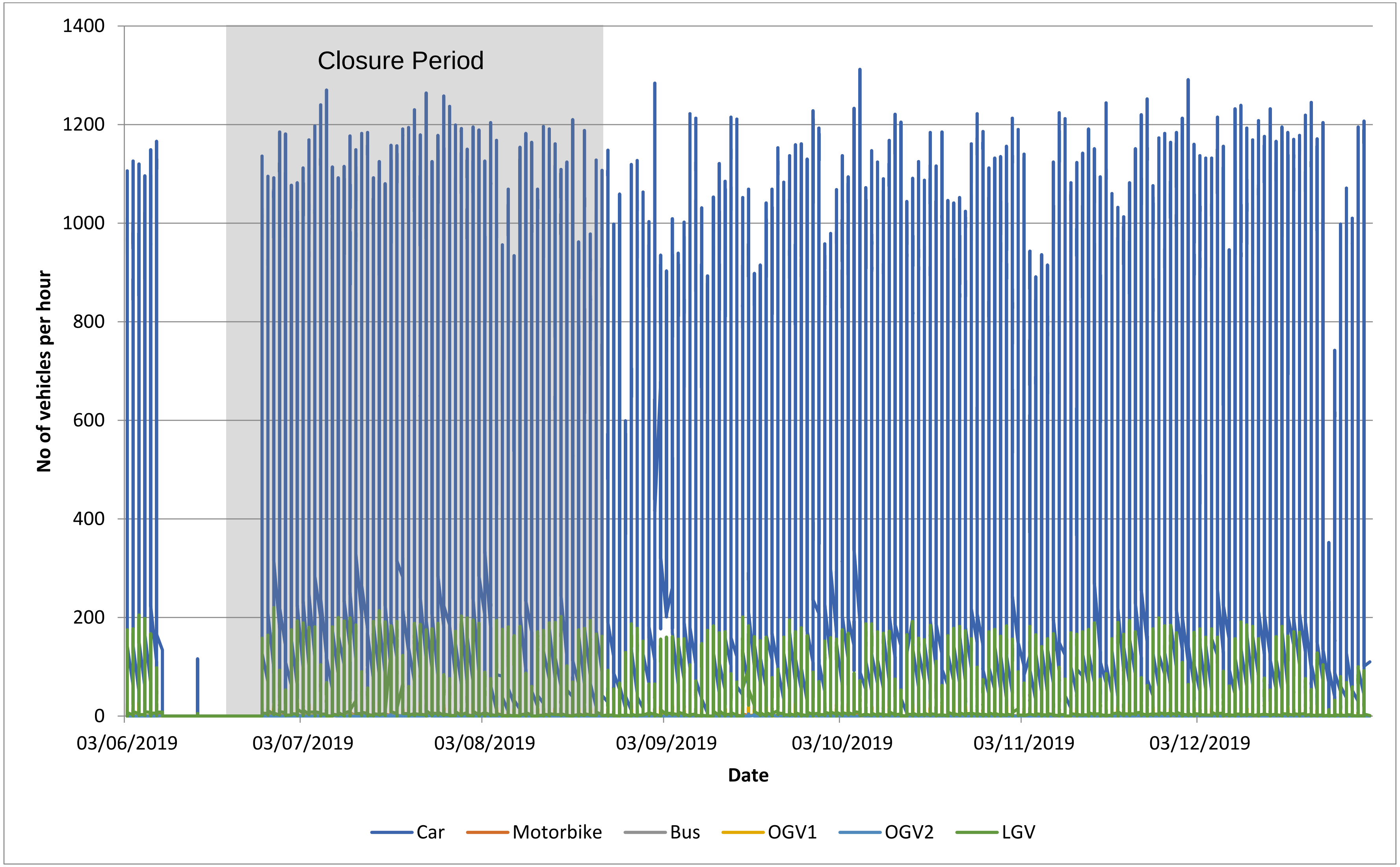
## S7 Coldhams Lane

This monitor was located between Vinery Road and Ross Street towards the junction with Barnwell Road.  There is a pedestrian crossing nearby which could result in some stop/start traffic being recorded at this location.  During the summer there were roadworks along this road which restricted traffic to single file.

Figure H6 shows that car and LGVs are the dominant vehicle type on Coldhams Lane.  The graph also shows that there was no traffic during most of June due to a fault with the monitor.

It does not appear there were any significant changes to traffic on Coldhams Lane during or after the bridge closure.

**Figure H6 Coldhams Lane Traffic Data**



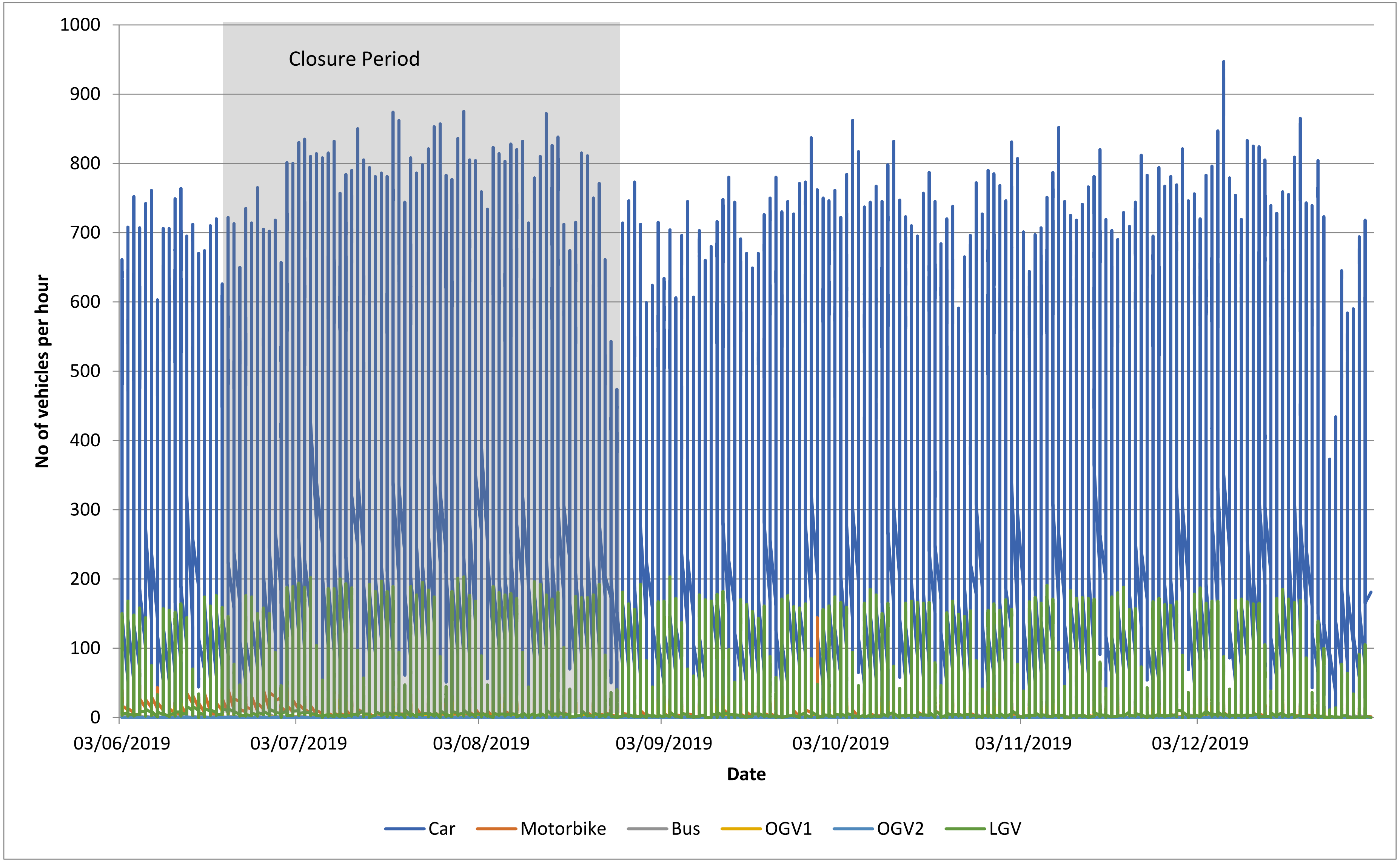
## S8 Cherry Hinton Road

This monitor is located between Coleridge Road and Rock Road.

Figure H7 shows that the dominant vehicle type is cars with the second dominant vehicle type being LGV's. There is also a brief spike in motorbike numbers during September.

Traffic levels appear to be slightly higher during July and August, but it is not clear whether this is a significant increase. Levels of LGV's appear to increase during July and August but then remain at these levels for the rest of 2019. This could be LGV's finding an alternative route and then deciding to remain on the alternative route following the bridge closure.

**Figure H7 Cherry Hinton Road Traffic Data**



## Perne Road

This monitor is located on Perne Road between Mill Road and Radegund Road.

Figure H8 shows that the dominant vehicle type is cars with LGV’s being the second dominant vehicle type.

The graph appears to show no change in the number of vehicles during the monitoring period.

**Figure H8 Perne Road Traffic Data**