OISTINS NOISE CHARACTERIZATION STUDY

PROJECT REPORT

Environmental Protection Department

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Christ Church Post Office

Pentecostal Assemblies of the West Indies

Inter-American Development Bank

The Royal Barbados Police Force /Oistins Police Station

Ministry of Transport and Works

Barbados Meteorological Department

Grantley Adams International Airport

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Glossary

- Decibel (dB): a unit of sound level
- IDB: Acronym for Inter-American Development Bank. This was a monitoring site.
- L10: The sound level that was exceeded during 10% of the measuring time in dB(A).
- L90: The sound level that was exceeded during 90% of the measuring time in dB(A).
- Leq: The continuous equivalent sound level which is the single sound pressure level (SPL) that, if constant over the stated measurement period, would contain the same sound energy as the actual monitored fluctuating sound level over the measurement period.
- Lmax: The maximum sound pressure level (SPL) value measured during the duration of monitoring.
- Lmin: The minimum sound pressure level (SPL) value measured during the duration of monitoring.
- PAWI: Acronym for Pentecostal Assemblies of the West Indies. This was a monitoring site.
- Pink noise- a reference signal whereby all acoustic energy is distributed uniformly by octave throughout the audio spectrum; making the total sound power in each octave equal.
- Sound pressure level (SPL): A logarithmic measure of the effective sound pressure of a sound relative to a reference value. It is measured in decibels (dB) above a standard reference level.
- WHO: Acronym for World Health Organization.

1.0 Executive Summary

Oistins, one of Barbados' four major towns, had typical commercial activity as well as offshore landing for ships delivering fossils fuels to the island, a fish landing and fish market site, in the flight path for all planes arriving at Barbados' sole airport (Grantley Adams International Airport) and was home to Oistins Bay Gardens, an open air entertainment venue. Oistins Bay Gardens had an active night life especially on Fridays as there was a fish fry and lime with amplified music. On Saturdays and some other week nights there was also entertainment but typically with lower sound levels. The fish fry had become a major component of Barbados' tourism product, the main foreign exchange earner which accounts for approximately 12% of GDP (Barbados Tourism Investment Inc., 2017).

The World Health Organization (WHO) sets the noise limits for commercial areas such as Oistins at L_{Aeq}70dBA over 24hrs and L_{Amax} 110dBA. For residential areas, WHO sets limits at L_{Aeq} 55dBA during the day (16hrs) and L_{Aeq} 45dBA during the night (8hrs) (World Health Organization:, 1999). Barbados' Cabinet adopted the WHO Guidelines for Community Noise as policy in 2007.

The Environmental Protection Department (EPD) designed and implemented this Oistins Noise Characterization Study in order to gather baseline data and characterize the sound levels which persons were exposed to while in/near Oistins. This project focused on Oistins' central core as this area would have the highest people counts and activity levels and should provide the highest ambient sound levels for Oistins as well as the highest number of persons that should be affected. Additionally since the EPD has a role to play in permitting developments as well as investigating complaints within the context of continually reducing buffer/separation distances from sensitive receptors, it was deemed useful to explore predictive modelling as a decision making tool for open air entertainment venues like Oistins Bay Gardens, which are quite popular in Barbados. Currently there is limited noise data on Barbados with most of the focus being complaints and not the general noise climate.

In summary the project involved daily monitoring over a week at each of three sites (North, East and West of the Oistins mixed corridor) in Oistins as well as short term monitoring at two sites within the mixed corridor. The monitoring locations used were Christ Church Post Office (east of central core), Pentecostal Assemblies of the West Indies (north of central core), Inter-American Development Bank (west of central core), Oistins Bay Gardens (the entertainment area), and near Welches (close to a residential area within the central core). No site was chosen to the south of the central core as this was the seaside. In addition to sound level data, meteorological data, traffic counts and activity surveillance data were collected. Analyses were carried out on the data including comparing the measured data with predicted measurements. The prediction models used were the inverse square law and an attenuation model based on ISO 9613. The noise descriptors collected were on the A-scale, fast response: L_{A10}, L_{A90}, L_{Aeq}, L_{Amax}, and octave band analysis.

Some of the important findings and conclusions of the study were:

- In general the noise levels persons were exposed to at the sites monitored in Oistins were within WHO guidelines for community noise for industrial, commercial shopping and traffic areas. However the values <u>exceeded the guideline values for residential areas</u>. The sound levels over a week, with and without entertainment, varied from $L_{Aeq,15min}$ 57 to 75dBA, $L_{Amax, 15min}$ 71to 103dBA and $L_{Amin, 15min}$ 48 to 65dBA.
- The eastern side of the central core (Christ Church Post Office Site) was noisiest and the northern end (IDB) was the quietest. The sound levels at Christ Church Post Office and IDB generally were constant between 6:30am and 6:00pm after which the levels dipped. For the three sites (Christ Church Post Office, Pentecostal Assemblies of the West Indies, Inter-American Development Bank) the $L_{eq,24hr}$ ranged from 57 to 69dBA, the $L_{Amax, 24hr}$ from 85 to 103dBA, the $L_{A10,24hr}$ from 59 to 74dBA and the $L_{A90,24hr}$ ranged from 49 to 60dBA.
- The $L_{Aeq, 15min}$ at 10m in front of the stage at the Bay Garden site (83-94BA) as well as the 63Hz, 125Hz and 31.5Hz being the dominant octaves were consistent with entertainment sound level values reported in literature. During Friday night entertainment the sound levels at Oistins Bay Gardens were $L_{Aeq, 15min}$ 83 to 94dBA, $L_{Amax,}$

$_{15min}$ 93 to 103dBA, $L_{Amin, 15min}$ 57 to 88dBA at 10m in front of the stage with the dominant octaves being 63Hz, 125Hz and 31.5Hz. At Christ Church Post Office and PAWI when entertainment music was played at Bay Gardens the 63Hz and 125Hz octaves generally increased significantly (compared to the other octaves). There was also a notable increase in 31.5Hz octave at PAWI.

- Strong positive correlations were found between traffic and noise levels (i.e. an increase of traffic volume was associated with an increase in noise levels) at two sites- IDB and PAWI. However at Christ Church Post Office the relationship varied, with weekend days showing low to moderate correlations between traffic and noise levels. Therefore another source, besides traffic, was influencing the noise levels at the Post Office site. It is suggested that entertainment noise was the likely source.
- With respect to the prediction models, the inverse square law model and the excess attenuation model (based on ISO 9613) predicted the L_{Aeq} within +/-3 dBA. The ISO-9613 based model predicted slightly better values than the inverse square law but took significantly longer to calculate and required more data input (e.g. height of receptor, height of source, separation distance, humidity, temperature, barrier dimensions, directionality etc.).
- Low frequency analysis as well as the overall A-weighted noise descriptors are important when assessing entertainment noise.

The following recommendations were made:

- In order to maintain the sound levels in Oistins at acceptable levels, future projects or programmes planned for Oistins should take sound levels into consideration. Suggested ways of reducing/managing the sound levels in Oistins are:
    - *Monitoring, educating the public and setting reduction targets:* Suggestions include the installation of a permanent monitoring station(s), setting a reduction target (e.g. decrease by 5dBA in 10 years) and creating a public awareness of the effects of noise.

- *Reducing traffic noise*: Possible options are paving roads with noise dampening asphalt, maintaining the road surface, encouraging the use of quieter vehicles (e.g. with tax deductions, reduce importation taxes), discouraging the unnecessary use of vehicle horns, using electric powered buses.
- *Reducing the impact of noise at the receptor*: This could be done by setting a minimum sound transmission class of building materials in the area and restricting the number of dwellings and density in some areas. Installing noise barriers/buildings or setting buffer areas may also be investigated but will most likely be impractical due to space limitations.
- *Minimizing the impact of the entertainment noise*: Some measures that could be implemented in Oistins are an enforced cut-off time, the use of a sound level limiter, instructing sound engineers/ disk jockeys to reduce the bass component, orient the speakers as much as possible away from the direction of sensitive receptors (e.g. South East/ in the direction of the stalls which could act as barriers), use multiple, small, low power speakers compared to fewer but more powerful speakers and reduced sound limits as the night progresses.

- Determining a suitable assessment criteria for entertainment noise was outside the scope of this study but it is suggested that the decibel increase in the overall A-weighted sound level as well as the increase in the 63 and 125Hz octaves at the receptor location be assessed. Alternatively limits could be set on each 1/1 octave or 1/3 octave of interest. More details are provided in Section 7.0 of this report.
- A workplace noise evaluation was outside the scope of this project but given the high sound levels ($L_{Aeq,\ 15min}$ at 10m in front the stage ranged from 83-94dBA), and that the entertainment continues around these levels for at least 6hrs it should be investigated as workers and patrons were often closer than 10m to the stage. (In Barbados the lower workplace noise limit is 80dBA (L_{Aeq8hr}) and the upper limit is 85dBA ($L_{Aeq\ 8hr}$).
- Similar baseline data should be collected for other areas in Barbados.
- Further training and resources should be obtained for capacity building of the

Environmental Protection Department and by extension Barbados.

2.0 Introduction

Oistins originated as a small fishing village on the south coast of Barbados and was one of Barbados' four major towns. According to the National Physical Development Plan (Amended 2003) *"Oistins incorporates the downtown core and surrounding residential neighbourhoods, enveloping Welches on the west, Pegwell on the east and Durants to the north. The central area of Oistins consists of a retail oriented high street bordered by Oistins beach, fish processing and market complex (Berinda Cox Fish Market) and beach parks."* (Government of Barbados, 2003).

Oistins is approximately 1.5km^2 with a central core of about 0.13km^2 [1].In addition to the commercial activity Oistins provided offshore landing for ships delivering fossils fuels to the island and was in the flight path for all planes arriving at Barbados' sole airport, Grantley Adams International Airport. Approximately 35 flights passed daily during the monitoring period (including commercial and cargo planes) generally between 5:00am and 10:00pm (Grantley Adams International Airport, 2017). Traffic counts indicated that 5,381 to 18,583 vehicles passed through Oistins central core daily. The housing stock in and around Oistins ranged from chattel houses to multi storey concrete houses. Outside of the central core but within wider Oistins area were residences, churches and schools.

The town had an active night life, especially on Fridays as it hosted a fish fry and lime with amplified music at an open air venue called Oistins Bay Gardens. According to Oistins Bay Gardens' management there were fifty-six (56) vendors/stalls that operated from stalls at Oistins Bay Gardens, many of these persons being self-employed. Thirty-one (31) were primarily involved in the fish fry, twenty-three (23) were craft vendors and two (2) were shops that existed before Oistins Bay Gardens was developed. The fish fry and lime, which usually started around 6pm generally continued until 1-2am, was well patronized by locals and visitors to the island. On some nights there were sponsored events or promotions e.g. Banks (beer) calendar girls but usually there was just a DJ who played amplified music with some persons performing (e.g. gymnastics) for tips/money. In addition to the fish fry activities there were vendors selling local craft, shoes and jewelry and persons playing dominoes. The fish fry had become a major component of Barbados' tourism product, the main foreign exchange earner which accounts for

[1]Estimated using the National Physical Development Plan (Amended 2003) and Google Earth Pro

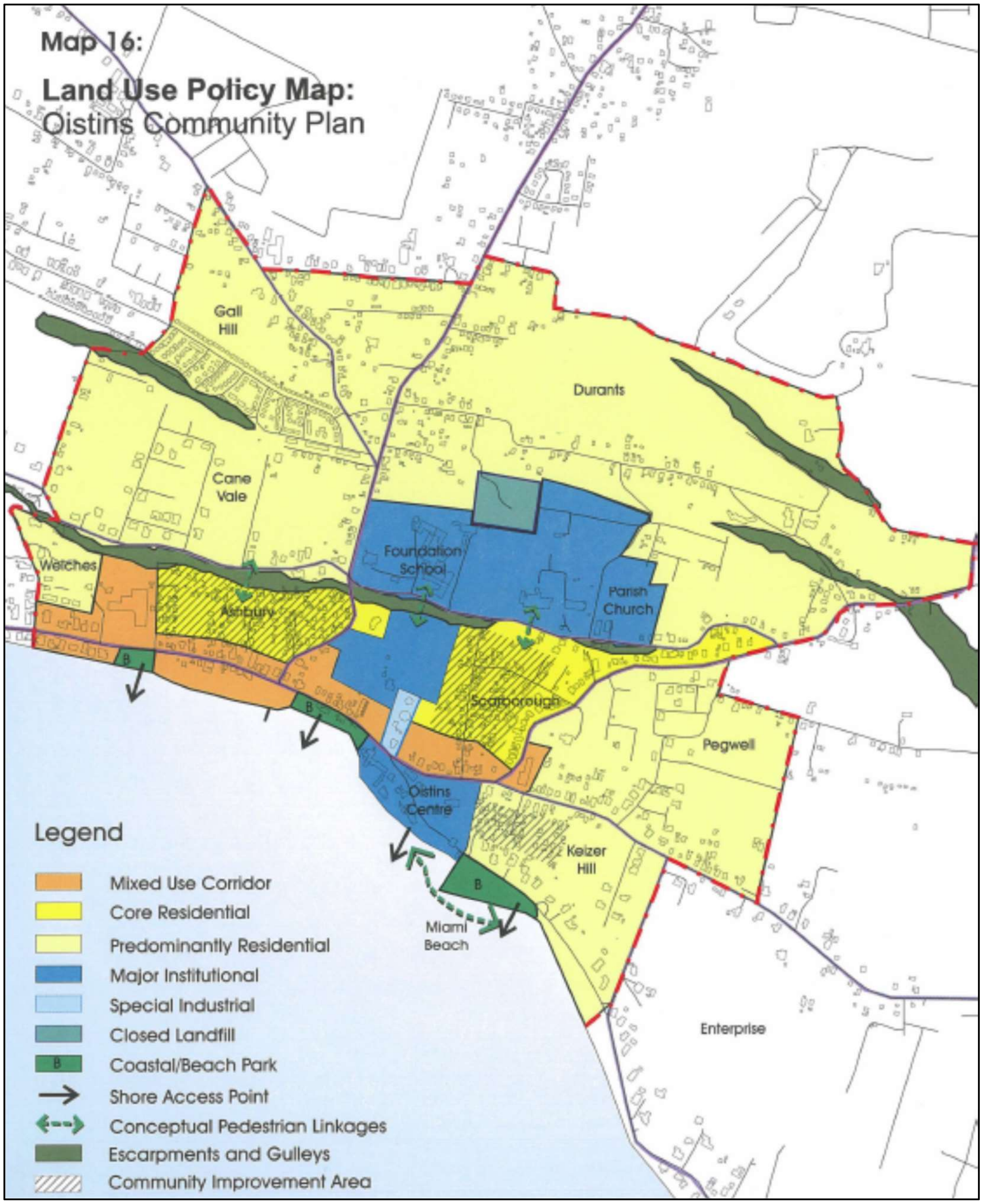
approximately 12% of GDP (Barbados Tourism Investment Inc., 2017).

The Environmental Protection Department (EPD) designed and implemented this Oistins Noise Characterization Study in order to gather baseline data and characterize the sound levels which persons were exposed to while in/near Oistins. The open air entertainment venue within Oistins, that is an integral part of its culture, was also specially assessed. The data that could be gathered from the entertainment noise was viewed as informative, given that outdoor entertainment is a part of Barbadian culture with the potential to negatively impact on nearby sensitive receptors. Currently there is limited noise data on Barbados with most of the focus being on noise levels due to complaints and not the general noise climate.

It is true that noise is subjective and often defined as “unwanted sound” (Cowan, 1994) resulting in it being difficult to set noise limits. According to the World Health Organization (WHO) Guidelines for Community Noise, exposure to high noise levels can lead to various health effects including temporary or permanent hearing loss, interference with speech communication, sleep disturbance as well as annoyance. WHO sets the noise limits for commercial areas at L_{Aeq}70dBA over 24hrs and L_{Amax} 110dBA. For residential areas WHO sets limits at L_{Aeq} 55dBA during the day (16hrs) and L_{Aeq} 45dBA during the night (8hrs). Further WHO advised that in order to avoid hearing impairment, noise exposures should never exceed 140dB for adults and 120dB for children (World Health Organization:, 1999). Barbados’ Cabinet adopted the WHO Guidelines for Community Noise as policy in 2007. Additionally as EPD has a role to play in permitting developments as well as investigating complaints within the context of continually reducing buffer/separation distances from sensitive receptors, it was deemed useful to explore predictive modelling as a tool in the decision making for open air entertainment venues, which are quite popular in Barbados.

This project focused on Oistins’ central core as shown by the orange/peach areas in Figure 1 below, since this area would have the highest people counts and activity levels and should provide the highest ambient sound levels for Oistins as well as the highest number of persons that should be affected. The central core encompassed the commercial entities. There were clusters of residences within Oistins core, identified as “Core residential” in the Physical Development Plan, which would present a challenge in terms of setting noise limits as it suggests incompatible activity especially during loud entertainment events or intense commercial activity. Though the setting of noise limits is outside the scope of this project, a suggested process is outlined in Section 7.0. The Wider Oistins area encompassed all the coloured areas on the map.

Figure 1: Map of Oistins



The monitoring locations used were Christ Church Post Office (east of central core), Pentecostal Assemblies of the West Indies (north of central core), Inter-American Development Bank (West of central core), Oistins Bay Gardens (the entertainment area), and Near Welches (close to a residential area within the central core). No site was chosen to the south of the central core as this was the seaside/ bay area. The project involved surveillance of the activities carried out in the area, monitoring of sound levels, traffic counts and weather conditions; analysis of the data, writing of a final report and close out of project. This document is the final report for the project.

Goal and Objectives

The goal of this project was to characterize the sound environment of Oistins' central core.

This goal was broken down into the following research questions:

1. What were the noise descriptors at the monitoring sites during 24hr monitoring? ($L_{Aeq,15min}$, $L_{A10,15min}$, $L_{A90, 15min}$, $L_{Amax, 15min}$)
2. What were the major sources of noise identified?
3. What were the noise levels that persons in Oistins were exposed to during Friday night outdoor entertainment? ($L_{Aeq,15min}$, $L_{A10,15min}$, $L_{A90, 15min}$, $L_{Amax, 15min}$, $_{15min}$, octave band data)
4. How did predictive modelling using the inverse square law compare with measured values?
5. How did predictive modelling using the excess attenuation model (based on ISO 9613) compare with measured values?
6. How did the noise levels recorded compare with WHO guidelines?
7. Were the twenty-four (24hr) sound levels on Sundays statistically different to those recorded on other days of the week?
8. Was there a correlation between the traffic counts and the noise levels recorded?

Scope

The assessment focused on:

- Recording, analysing and reporting the sound levels (A-scale: L_{10}, L_{90}, L_{eq}, L_{max}, and octave band analysis) at the three specified sites within Oistins during the period 21st May 2017 to 19th July 2017.

The assessment did **not** focus on:

- Other sections of Oistins that were outside of the core
- Other possible noise descriptors
- Other time periods
- Workplace noise, as it was not under the purview of the Environmental Protection Department
- Indoor noise e.g. inside the receptors house/building

Limitations, Assumptions and Risks

The following limitations, assumptions and risks were inherent to the project:

Assumptions

- The period of monitoring produced data that was representative of typical sound levels in Oistins.

Limitations

- Some activities were dependent on the timeliness of the response from stakeholders. Frequent contact with stakeholders was done to identify problems as early as possible.
- The staff assigned to conduct the project had other substantive tasks and this led to time constraints due to increased workload in those areas.
- Any unusual, noisy events or activities occurring near the monitoring site would skew the results. Random visits during the monitoring period to each site were conducted in an effort to identify any such occurrences and make any necessary changes to the

monitoring (e.g. monitor on another day).

- Noise readings should not be taken during heavy rain or high winds above 5m/s. Extra contingency days were added to the schedule as rain can prevent monitoring. Wind speeds were noted.
- The availability of suitable, secure locations with flat roofs was a challenge as typical Barbadian residential homes and most buildings were not built with flat roofs. As a result, 24hr monitoring within a residential area was not conducted as suitable locations were not identified. Shorter term, attended monitoring (four hours) was conducted near to the nearest residential area (near Welches).
- Due to technical difficulties or other issues there may not be any loud music on a proposed monitoring Friday night. Extra contingency days were added to the schedule.
- Attended measurements within the Oistins Bay Gardens may change the manner in which the DJ and sound engineers operated.

Risks

- Insufficient resources to conduct all the activities of the project. If this occurred the scope would be adjusted appropriately.
- Damage to equipment e.g. lightning or rain or malfunction. The equipment was insured and the Royal Barbados Police Force was notified of the project. If damage occurred the scope of the project would be adjusted and/or the option of sourcing alternative equipment considered. Additionally alternative sources of the data may be possible e.g. Barbados Meteorological Department.
- Persons at the entertainment site may offer resistance or destructive interference. The Director of the National Conservation Commission (agency responsible for Oistins Bay Gardens) as well as the Royal Barbados Police Force were informed of the project and their permission/assistance was requested.

3.0 Literature Review

Towns are often crowded and a hive of activity which results in noise being produced. Some of the noisiest towns around the world were; Burdwan, West Bengal with levels of 64-85 dB (U.S. National Library of Medicine , 2006) and Delhi, India with an average noise level of 80dB (Datta, Sadhu, Gupta, & al, 2006). Other noisy towns in the world include Cairo, Egypt and Tokyo, Japan. The major sources of noise in these cities were often associated with transportation (and honking of horns), construction and entertainment (Citiquiet, 2014). In Barbados an assessment of the noise levels in Bridgetown, the capital, was done from 1st June 2012 to 3rd February 2013 and the 24hr noise levels in general ranged from L_{Aeq} -60 to 65dBA with one site near a bus terminal reaching L_{Aeq} 70dBA. The WHO set a limit of $L_{Aeq,24hr}$ 70dBA and L_{Amax} 110dBA for industrial/commercial areas, which has been acceded to by the Government of Barbados in 2007.

Managing noise in cities required a multipronged approach. Some initiatives used by various jurisdictions included measuring noise levels and creating an awareness of them, setting noise limits for different areas/times of day, reducing speed limits in the city, creating quiet areas, installing noise barriers, paving roads with noise dampening asphalt, using quieter tyres, setting a minimum sound transmission class of building materials, establishing buffer zones between receptors and commercial premises, restricting the number of dwellings and density in some areas and managing flight movements. Some of these initiatives had other environmental benefits such as reduced air pollution (SoundEar, 2016), (The RMA Quality Planning Resource, n.d.). Buffer distances were often not considered practical in inner-city areas as differing land uses tend to be located in close proximity. In such circumstances, measures such as the use of noise barriers or insulation may present a more realistic management method (The RMA Quality Planning Resource, n.d.). A key element in managing noise in towns involved knowing the noise levels in the town. This would involve monitoring at selected sites and/or using prediction models.

One study carried out for the Brisbane City Council indicated that measuring the noise levels was the better approach compared to modelling when assessing an entertainment district (Borgeaud, 2005). The reasoning was that established models dealt with well-defined sources (e.g. road, rail or industrial noise) and generally models required significant amounts of digital terrain data, to allow useful data to be predicted. However where the noise sources were variable (e.g. people noise, entertainment noise and air conditioning plant) noise modelling became less suitable and noise monitoring of actual levels was more appropriate (Borgeaud, 2005). In summary, two sets of data were collected - short two (2) minute measurements taken at a grid of points based on the road network (with more sites in areas with more noise sources) and daily measurements taken over a week at selected locations using 15 minute intervals. Measurements were typically taken on the footpath at 5 - 7m from the nearest through traffic, and at 1.5m above street level. The study acknowledged that fifteen (15) minute samples were often used for assessment of environmental noise but in order to enable the large number of locations to be covered in the allocated time frame, levels were measured for 2 minutes at each location. Infrequent and extraneous noise sources were excluded from the 2 minute samples. The parameters collected were L_{max}, L_{10}, L_{eq}, L_{90}, L_{min} and 1/1 Octave (16Hz – 8 kHz).

Another study used eleven (11) measurement locations to assess the levels of entertainment noise that should propagate towards residential dwellings in the vicinity of a proposed entertainment venue, the proposed Black Horse Music Festival site in Sedlescombe, England (Sound Solutions Consultants, 2010). All noise measurements were taken at a height of 1.2-1.5m from the ground in an open area under favourable weather conditions. A simulation of expected, representative levels of entertainment noise from the proposed entertainment site was done and a $L_{Aeq,1min}$ of 95dB was measured at the mix position. A pink noise signal (20Hz – 20kHz) was subsequently generated through the main stage public address (PA) system at 95dB(A) and monitoring conducted at each of the measurement locations. The $L_{Aeq,1min}$ in the presence of pink noise was recorded. All noise measurements were corrected for equivalent $L_{A90,\ 1min}$ background noise levels taken without the noise source in operation. Pink noise was used for the propagation tests given the even distribution of energy across the entire audible range (Sound Solutions Consultants, 2010).

While the methodology used for measuring entertainment noise in different studies may vary depending on resources available many of the studies reviewed such as Marston's Inn and Taverns: Bannerbrook, Coventry, UK (Enzygo Environmental Consultants, 2012) used variations of the methods described in the two preceding studies. In general the protocols set out in ISO 1996-2:2007 were used in many instances (e.g. microphone height or preferable weather conditions).

With respect to selecting monitoring sites there were various strategies including the accepted international grid method (International Standard Organization, 2007), systematic random sampling using a grid, stratified sampling based on land use, stratified sampling based on the road type, and the categorization method based on road function (Gozalo, 2016). The grid method was widely used in many scientific fields because its use guaranteed the statistical principle of equal probability and, moreover, a uniform coverage of the area under study. However, the grid method had drawbacks such as the existence of a high sound level variability in cases of proximity to the noise sources or the existence of large physical obstacles. Land use or activities conducted in the urban area that would impact the sound levels can also be used to determine sampling points. Stratified sampling based on road type or the categorization method based on road function utilized the generally accepted assumption that road traffic was the most important source of noise in cities, and for most streets it was considered the main cause of the spatial and temporal variability of that noise. The difference in the two sampling methods being that road type uses the categories identified by the government agency responsible for transport/roads while the categorization involved looking at the functionality of the road and may take into account variables such as the flow of vehicles, the type of traffic, the average speed, and urban variables which may have a clear relationship with functionality. Consequently, the categorization method was found to be more accurate than the road type method to assess the impact of noise pollution on the population and the grid method was found to have significant variation in noise levels between grids.

To assist with designing the Oistins Noise Monitoring project a presurvey of the Oistins area was conducted by the Environmental Protection Department in 2013-2014 during which 5-

15 minute sound levels were monitored at various sites throughout Oistins to gauge the noise levels of the area and guide this project. The sampling method proposed by the presurvey took into account the grid method, land use as well as the simple road structure. Based on the data obtained from the presurvey, the shape of the central core (a strip), its small size (0.13km^2) and the general homogeneous nature of the activities (besides the fish fry which occurs on specific nights) the presurvey recommended that one monitoring site should be located to the North, East and West of the central corridor and one within the central core. As Oistins Bay Gardens was a popular nighttime outdoor entertainment venue, a monitoring site within the venue was also added. It was also noted that in a previous presurvey for the characterization study carried out on Bridgetown, the Capital of Barbados, the strict grid approach was used and it was found that areas with similar activity types had similar sound levels e.g. sites near bus terminals had similar levels, residential areas had certain levels and highly trafficked areas had similar levels.

While some studies, as above, measured noise levels in entertainment areas there are some studies which modelled/ predicted the noise levels. The inverse square law, Equation 1, is an idealized prediction model which assumed equal sound propagation in all directions. It does not take into account reflective surfaces which could increase sound levels or barriers which could decrease them. Nevertheless, the inverse square law is the logical first estimate of the sound you would get at a distant point in a reasonably open area (Hyperphysics, n.d.).

Equation 1: $$L_{p2} = L_{p1} - 20log(\frac{R_1}{R_2})$$

In addition to the inverse square law there are other types of models including:

- The practical engineering methods (ISO 9613 falls into this category) which involved the calculation of noise levels by adding each separate sound attenuation factor. The method predicts the equivalent continuous A-weighted sound pressure under favourable meteorological conditions. The method used sound power levels and directivity of the source, as well as various attenuation factors in the environment (e.g. air absorption, ground attenuation, barriers, vegetation and reflection from nearby surfaces, etc.) to estimate the sound pressure level at the downwind receiver location.

- The approximate semi-analytical methods which were similar in structure to the engineering methods but were based on simplified analytical solutions of the acoustic wave equation. Simple ray tracing models are the most popular in this category.
- The hybrid models which involved solving the wave equation or Helmholtz equation to deduce the sound field. The procedure for solving the wave equation is generally difficult to implement due to the complexity of the atmospheric-acoustic environment. (Hoare Lea Acoustics)

In ISO 9613 the overall equation or concept is given by Equation 2 (International Standards Organization, 1996)

Equation 2: $L_{ft}\,(DW) = L_w + D - A$ *Where*

L_W -is the sound power level in each octave, in dB, produced by the point source relative to the reference sound power of 1picowatt (1pW)

D-is the directivity correction

A-is the octave band attenuation, in dB, that occurs between the source and the receiver

The attenuation term accounts for changes in the sound level due to the separation distance, atmosphere, ground, barriers and other factors such as vegetation. With respect to barriers when the line of sight between a source and receiver was obstructed by a rigid, non-porous wall or building, appreciable noise reductions can occur. For single screens, ISO 9613-2 suggests a maximum attenuation of 20dB while for multiple screens it suggests 25dB. The equation ISO 9613 used for barriers were:

Equation 3: $A_{bar} = D_z - A_{gr} > 0$, *for diffraction around the top edge*

Equation 4: $Abar = D_z > 0$, *for diffraction around a vertical edge*

Equation 5: $D_z = 10 \log10 (3 + (C2 / \lambda)\, C3\, z\, Kmet)$ *, in dB*

Where

A_{bar} - attenuation due to screening/barrier

Dz - is the barrier attenuation for each octave band

A_{gr}- ground attenuation

z- path difference

λ -wavelength of the octave band center frequency

C2 = 20 for cases where ground plane reflections are included or C2 = 40 in special cases when ground is modeled with image sources

C3 = $(1 + (5\lambda/e)^2) / (1/3 + (5\lambda/e)^2)$ for multiple or finite thickness screens or C3 = 1 for single screens

e -distance between the screens (or thickness of the barrier) in the direction of the source and receiver

K_{met} is the correction factor for meteorological influences, and defined as

K_{met} = exp (-(1/2000) ((dss·dsr·d) / 2z) 1/2)) for z > 0 (5) or Kmet = 1 for other values of z or lateral diffraction

A simplification of the Maekawa barrier equation also commonly used when estimating barrier attenuation for spherical fields was:

A_{bar}=10 log (3+20N) with N=2∂/λ>0, ∂- path difference and λ-wavelength

There have been other barrier equations developed. For example the Kurze-Anderson formula is also commonly used and Yamamoto and Takagi also developed or proposed formulas (Attenborough, Ming Li, & Horoshenkov, 2007).

The assessment of noise pollution sourced from entertainment places in Antalya, Turkey was based on ISO 9613-2 as used in the SoundPLAN software (SARI D., 2014). Another study used the inverse square law to assess the noise levels resulting from a development, Terra-Topgolf project in San Jose California, due to entertainment noise (Bollard Acoustical Consultants Inc., 2016).

The concept of near field and far field influenced the distance from the source/stage that measurements would be taken. Acoustic science has found that sound waves behave differently in the near field compared to the far field. Close to the source, in the near field of the source, the sound waves originating from all points on the source can combine to produce complicated patterns of sound. At a sufficient distance from the source, in the far field, the sound field tends to settle down into a succession of smooth wave fronts and the intensity falls off in accordance with the inverse square law (i.e. 6dB per doubling of distance). Therefore simple prediction methods based on the inverse square law may be extended to real sources, but only for far field positions and only sound pressure levels measured in the far field may be used to predict levels at other far field distances. In general, the extent of the near field, or the start of the far field cannot be defined precisely. Ideally, to be in the far field, the distance from the source should be several wavelengths of the lowest frequency sound considered and also several times the dimension of the source. In a few instances one or two wavelengths (at the lowest frequency) and one or two source dimensions away may be sufficient (Institute of Acoustics, 2016). Also it was necessary to take into account the directivity of the sound source.

According to the Manchester City Council's Planning and Noise Technical Guidance around 95dB L_{Aeq} can be emitted from a lively bar, with nightclubs sometimes reaching 105dB L_{Aeq}. The Technical Guidance noted that the 63Hz and 125Hz octave bands should also be considered as they can be up to 115dB L_{Aeq} and 110dB L_{Aeq} respectively but were not well represented by the A-weighting and are often responsible for the "bass" noise complaints. Existing noise standards/criteria are usually based on A-weighted sound level (dBA) which effectively filters out low frequency and hence are not appropriate for evaluating sound in these low frequencies. The guidance document also noted that limits could also be placed on levels in these octave bands or even on the 1/3 octave bands. However the 1/3 octave bands was not widely used due to the difficulty in obtaining 1/3 octave band sound insulation performance data for various construction materials (Manchester City Council, 2015).

Another study entitled A Practical Evaluation of Objective Noise Criteria used for the Assessment of Disturbance due to Entertainment Music found that a 1/3 octave bandwidth analysis is an essential part of any new assessment criterion and that the German criterion DIN 45680 should be considered in further research toward the development of such a criterion. This study also noted the shortcomings of using A-weighted criteria in the assessment of disturbance due to music from entertainment premises as it involved a large negative correction at the lower end of the frequency spectrum. Further, the study points out that WHO guidelines advised that A-weighted measures are inappropriate when prominent low-frequency components are present. The problem is exacerbated by the fact that low frequency energy in the music is more transmissible over distance and through building structures; low frequency noise tended not to be present in the background noise environment and the introduction of a low frequency bass beat will be more noticeable to nearby residents, particularly late at night. The document also indicated that the Institute of Acoustics – Good Practice Guide on the control of noise from Pubs and Clubs – Draft Annex 2 had suggested criteria for use with entertainment noise which had been withdrawn. Instead, the concept of inaudibility within habitable rooms was used. (McCullough & Hetherington, 2005).

In an effort to look at entertainment noise from a balanced perspective, the enjoyment of patrons should be considered as the activity can be revenue generating and contribute to the jurisdiction's economy. In the study The Sound Exposure of the Audience at Music Festivals, it was noted that when the average sound exposure from the concerts was 95.1dBA, 70% of the volunteers considered the sound volume was good while 25% thought it too loud. However when the average sound level during a concert reached 100dBA, the proportion of volunteers who considered the sound level too loud rose to 40% while 55% judged the level as just right. Only 5% thought it too low. Thirty-six percent of the 601 people questioned in the survey indicated that they had experienced post exposure tinnitus (PET). For 86% of them, the tinnitus disappeared after 24 hours although in two cases the tinnitus had become permanent (Mercier & Hohmann).

A balance was therefore needed between the noise levels preferred by the entertainers/patrons and those preferred by nearby residents. Some of the measures that have been used to strike this balance included a cut-off time, specified noise limits at the nearest residential boundary, development of a noise management plan (e.g. siting the stage(s) and noisy equipment as far away from residents as possible), using the topography of the site or an existing structure as barriers where possible, instructing sound engineers for each stage to keep the bass noise down, keeping the local community informed about the music festival operating times and providing them with a contact number for the event manager. Also some jurisdictions have a preference for multiple, small, low power speakers compared to fewer but more powerful speakers, mounting speakers at a downward 45 degree angle and as far down the pole as possible if applicable, the use of a sound level limiter and reactive management in real time in case noise levels exceed the limits set and post assessment of performance with respect to noise. Carrying out noise measurements the day before an event and during sound checks could also assist in checking the effectiveness of the measures employed (Noise Guide for Local Government Part 3 Noise management principles).

Typically, unless the venue is very remote, it is not possible to establish noise limits that prevent annoyance at every residence. However, noise limits can prevent the noise levels from being any higher than necessary. Noise limits are set for each concert/venue based on factors such as the separation distance from the nearest residence, the length of the event, the commencement and finishing times and the number of similar events held per year. The impact on residents needs to be weighed against the cultural, social and economic needs/expectations of the broader community to determine if the venue is suitable and if the event should proceed (Noise Guide for Local Government Part 3 Noise management principles). The World Health Organization (WHO) also gives recommendations regarding the sound-level exposure at ceremonies, festivals, and entertainment events. The WHO sets the limit at 100 dBA $L_{Aeq,4hr}$ less than five times per year with $L_{A,Fmax}$ of 110 dBA (Mercier & Hohmann). Though an assessment of workplace noise is not a part of this study, in Barbados the Workplace (Noise) Regulations 2007 proposed a lower workplace noise limit of 80dBA (L_{eq8hr}) and an upper limits of 85dBA ($L_{eq\ 8hr}$) with an L_{Cpeak} of 140dBC (Government of Barbados, 2007).

<u>Summary of Main Points Learned</u>

The review of literature revealed different measurement and prediction methods used in assessing noise in towns as well as from entertainment areas. As most measurement procedures were based on ISO 1996-2, this method formed the basis of the methodology employed. Though ISO 1996-2 was the basis, research showed that enhanced selection of sampling sites beyond the grid method identified by ISO 1996-2, to include categorization based on land use was prudent. As a result, land use in addition to the grid method was utilized during site selection. The enhanced site selection method also allowed for better use of resources within the time constraints. The sample time of fifteen (15) minutes was used as this was found to be the preferred sample time in most of the studies reviewed. As studies and articles identified low frequency noise as problematic during entertainment events but underrepresented in A-weighted sound levels, 1/1 octave band data was collected. Some emphasis was placed on the sound in the 63Hz and 125Hz bands as these bands were identified as problematic, with some jurisdictions suggesting special limits be set on these octaves.

With respect to prediction of noise it was clear that there were no predictive models specifically for entertainment noise. The inverse square law was commonly used to estimate the entertainment noise that reached receptors with ISO 9613 used in some instances. In terms of the equations used to determine barrier attenuation in ISO 9613, several alternatives were found in literature, some of which were easier to implement without sophisticated software (e.g. Maekawa, Kurze-Anderson and Yamamoto and Takagi formulas). The Maekawa barrier equation, one of the simpler barrier equations commonly referenced in literature, was substituted for the ISO 9613's barrier equation in this study given the lack of suitable sophisticated software and 3D maps/digital terrain maps of the area. Research also identified an important limitation of predictive modelling, which was that only levels in the far field can be predicted. This was used in determining the location of the microphone, i.e. distance from the stage when measuring the noise at the entertainment venue. Additionally as previous studies have found that bass noise is typically present but underrepresented in typical A-weighted noise descriptors, octave band analysis was carried out.

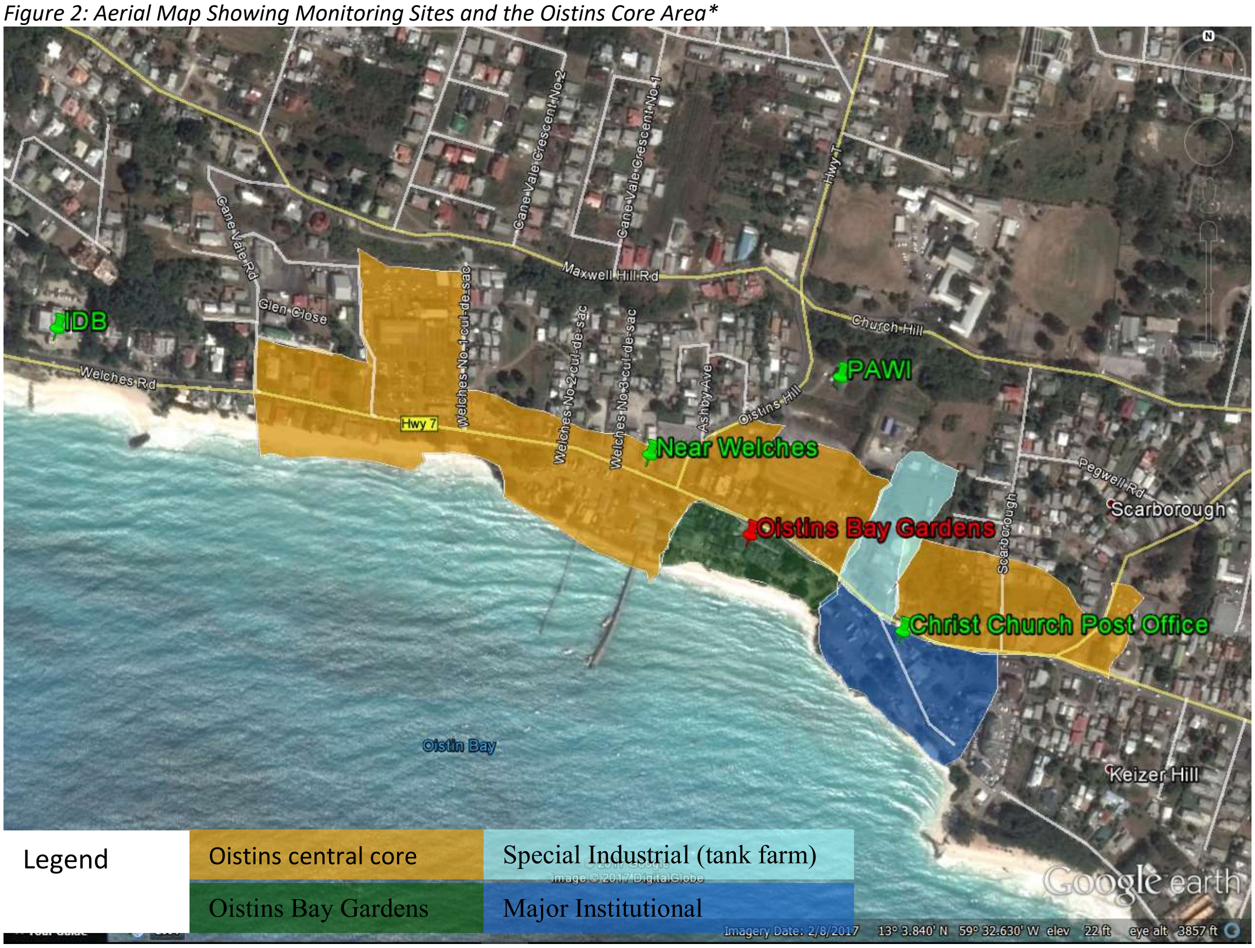
As transportation was identified as a main source of noise in studies across the world as well as in the study of Bridgetown (the capital of Barbados), a correlation between noise and traffic counts was investigated.

4.0 Study Area

The three monitoring locations selected for twenty-four hour (24hr) monitoring were Pentecostal Assemblies of the West Indies (PAWI), Christ Church Post Office and Inter-American Development Bank which were to the North, East and West respectively of the mixed corridor/

central Oistins. The list of the contact persons and contact information for the sites was in Appendix F. In addition to the twenty-four hour monitoring, the sound levels in Oistins Bay Gardens (main entertainment venue) and at a site near Welches (a residential area within the central Oistins) were monitored for a shorter period of time (approximately 4hrs). The description and pictures of the monitoring locations are provided below.

*Figure 2: Aerial Map Showing Monitoring Sites and the Oistins Core Area**



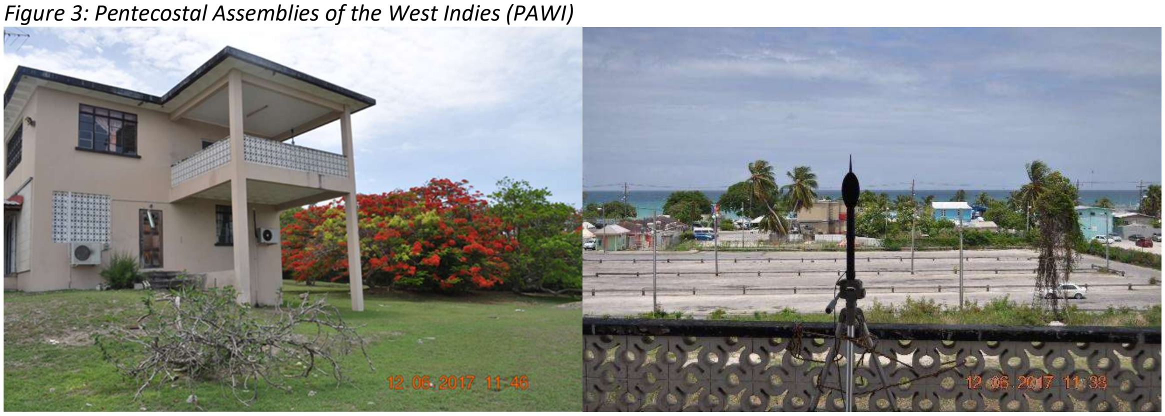
*sketch of Oistins Core Area as delineated in Barbados' Physical Development Plan

Pentecostal Assemblies of the West Indies (PAWI)

The Pentecostal Assemblies of the West Indies (PAWI) was a guest house and office used by the Pentecostal Church. It was located in a "transition area" between central Oistins/ mixed corridor and residences to the North of the central corridor. The GPS coordinates were N13 03.890 W59 32.500. Formally the Physical Development Plan of Barbados (2003) zoned the area as major institutional and it was adjacent to both the residential and central core. It was located approximately 30 metres from Oistins Hill, an inclined road where moderate traffic volumes passed and part of some bus/mass transit routes. It was also approximately 200 metres from the main stage in Oistins Bay Gardens and approximately sixty metres (60m) away from a car park used by patrons of Oistins Bay Gardens. Also near to PAWI were several houses, Christ Church Foundation (a secondary school) and Christ Church Parish Church (an Anglican Church). This location was monitored from 13th - 19th June 2017.

The PAWI had a large upper patio which was 20ft (6m) above ground level and accessible by interior stairs. The dimensions of the patio were 13.5ft (4.1m) long by 15.5ft (4.7m) wide (from wall of building to the front of the patio) and the ceiling was 9ft 3 inches (2.8m) above the floor. The microphone was placed 13ft 4inches (4.05m) from the wall of the building, 7.5ft (2.28m) from each side of the patio and 4ft 5” (1.34m) from the ceiling. Pictures of the building as well as the monitoring equipment on the patio of the building are shown in (Figure 3).

Figure 3: Pentecostal Assemblies of the West Indies (PAWI)



<u>Christ Church Post Office</u>

The Christ Church Post Office was located along Oistins Main Road, the main street in Oistins and was near the Eastern outskirts of the mixed corridor. It was a branch post office where mail was processed and other postal related activities occurred. Surrounding the Christ Church Post Office were the Oistins Police Station, Randall Philips Polyclinic, Oistins Bus terminal, the sea (including a fuel oil jetty), a tank farm (for fuel) and some residences. It was approximately 196m from the stage in Oistins Bay Gardens. The GPS coordinates were N 13 3.746 W 59 32.468. Formally the Physical Development Plan of Barbados (2003) zoned the area as major institutional. It was noted that it was also adjacent to the central core.

The building had a flat roof which was 24.6ft (7.5m) above the ground and accessible via an internal staircase. The microphone was placed at a corner of the roof with the nearest reflecting surface being 14ft 2inches (4.3m) away. This site was monitored from 21st -27th May 2017. Pictures of the building as well as the monitoring equipment on the roof of the building are shown in Figure 4.

Figure 4: Christ Church Post Office

Inter-American Development Bank (IDB)

The Inter-American Development Bank (IDB) building was located along Welches Road, a main road artery into Oistins. IDB is an international funding agency and as a result mainly administrative activities occurred at the building. IDB is located to the west of the Oistins mixed corridor (approximately 200m from the western edge of the mixed corridor and 770m from Oistins Bay Gardens). Nearby were hotels/guest houses, residences and the sea. The GPS coordinates were N13 3.923, W5932.973. Formally the Physical Development Plan of Barbados (2003) zoned the area as residential. The site was approximately 225m from the western edge of the central core and 770m from Oistins Bay Gardens. Monitoring occurred at this site from 12th to 18th July, 2017.

The microphone was placed in the corner of a large, uncovered, upper level deck to the front of the property. The deck was 18.8ft (5.7m) above ground level and the microphone was 4.8ft (1.5m) above the floor and accessible by interior stairs. The nearest reflecting surface (wall of the building) was 30.8ft (9.4m) away from the microphone. Pictures of the building as well as the monitoring equipment on the deck of the building were shown in Figure 5.

Figure 5: Inter-American Development Bank (IDB)

<u>Near Welches</u>

The Inter-American Development Bank (IDB) building was the closest, most suitable building for twenty-four hour (24hr) monitoring that was located to the west of the Oistins central core. However it was a considerable distance (approximately 770m) from Oistins Bay Garden. An interim location within the central core was identified near the Welches area and was used for the predictive modelling. The building was unoccupied during monitoring.

The site was located along Oistins Main Road, the main street in Oistins, and was within the mixed corridor. This site was located to the west of the Oistins mixed corridor (approximately 130m from Oistins Bay Gardens). It was near to the Berinda Cox Fish Market (fish processing facility), restaurants, a gas station and several shops/vendors. The GPS coordinates were N13 3.848 W59 32.618. Formally the Physical Development Plan of Barbados (2003) zoned the area Oistins mixed corridor/central core. Monitoring occurred at the site on 23rd June 2017 between 4:30pm and 9:00pm. The sound level meter/ microphone was placed

5ft (1.5m) above the ground at the front of the building and 13.3ft (4m) from the building's wall. Pictures of the building as well as the monitoring equipment are shown in Figure 6.

Figure 6: Near Welches

<u>Oistins Bay Gardens</u>

Oistins Bay Gardens was an outdoor fish fry and entertainment area located within the Oistins mixed corridor. It was a popular entertainment spot for locals as well as tourists where fish was grilled on the spot and amplified music played primarily from the main stage. The food vendors were located in stall/huts around the main stage and a few also played amplified music. The Oistins Bay Gardens was managed by the Government of Barbados and was a significant aspect of Barbados' tourism product. Tourism is Barbados' main foreign exchange earner. Near Oistins Bay Gardens were several restaurants, shops, the sea, the busy Oistins Main Road, gas stations and the Berinda Cox Fish Market. The GPS co-ordinates were N13 03.801 W59 32.554. Formally the Physical Development Plan of Barbados (2003) zoned the area as Oistins central core. The microphone was set up 10m away from the main stage /speakers and 4ft 11inches (1.5m) above the ground. The speakers were directed/pointed to the North East direction. The measurements at this location were used to represent the sound pressure level close to the speaker but within the far field. Management of Oistins Bay Gardens indicated that the open air entertainment is held on Fridays (the loudest and most patronized day) as well as Saturdays. At random, other stalls or businesses may play music on any day of the week. This location was monitored between 4pm and 9pm on the 26th May, 16th June and 23rd June, 2017. Pictures of the building as well as the monitoring equipment near the stage are shown in Figure 7.

Figure 7: Oistins Bay Gardens

<u>Summary of monitoring sites</u>

Table 1 below summarizes the characteristics of the monitoring sites used in this study.

Table 1: Summarized characteristics of the monitoring sites

Monitoring site	**Brief description**	**Distance & direction from Oistins Bay Gardens (stage)**	**Monitoring period**	**Physical Development Plan of Barbados (2003) Zone**
Pentecostal Assemblies of the West Indies (PAWI) GPS coordinates: N13 03.890 W59 32.500	Guest house with a large balcony 20ft above ground level. It was located in a “transition area” between central Oistins/ mixed corridor and	Approximately 200m, north of the main stage in Oistins Bay Gardens. There was no direct line of sight	13th - 19th June 2017	Major institutional

Monitoring site	Brief description	Distance & direction from Oistins Bay Gardens (stage)	Monitoring period	Physical Development Plan of Barbados (2003) Zone
	residences to the North of the central corridor.	to the stage.		
Christ Church Post Office GPS coordinates: N13 3.746 W 59 32.468	Post office (branch) with a flat roof 24.6ft above ground level. It was located near commercial activity, a bus terminal, the sea, as well as the Oistins Main Road within Oistins.	Approximately 196m, east of the main stage in Oistins Bay Gardens. There was no direct line of sight to the stage.	21st -27th May 2017	Major institutional and was adjacent to the central core
Inter-American Development Bank (IDB) GPS coordinates: N13 3.923 W59 32.973	International funding agency/ office with a large deck 18.8ft above ground level. It was located along Welches Road, a main road artery into Oistins as well as residences/ hotels.	Approximately 770m, west of the main stage in Oistins Bay Gardens There was no direct line of sight to the stage.	12th to 18th July, 2017	Residential
Near Welches GPS coordinates: N13 3.848 W59 32.618	Unoccupied building along the main street in Oistins. The microphone and tripod were placed on the ground level, 1.5m above the ground. The building was surrounded by commercial activity.	Approximately 130m, west of the main stage in Oistins Bay Gardens There was no direct line of sight to the stage.	23rd June 2017 from 4:30-9pm	Mixed corridor/ central core
Oistins Bay Gardens GPS co-ordinates: N13 03.801 W59 32.554	Outdoor fish fry and entertainment area on the ground level. During monitoring the microphone and tripod were placed on the ground level, 1.5m above the ground and 10m from the stage. The area was surrounded by commercial activity	Not applicable	This location was monitored from 4:00pm – 9:00pm on the 26th May, 16th June and 23rd June, 2017.	Mixed corridor/ central core

Monitoring site	Brief description	Distance & direction from Oistins Bay Gardens (stage)	Monitoring period	Physical Development Plan of Barbados (2003) Zone
	and the sea. The speakers sat on the stage and were directed/pointed to the North East direction.			

5.0 Methodology

Summary

Monitoring of the general noise climate of Oistins involved unattended monitoring over a week at three receptor sites –Pentecostal Assemblies of the West Indies (North), Christ Church Post Office (East) and Inter-American Development Bank (West). As the western end of the corridor was a significant distance from the main commercial activity, short term attended monitoring was also conducted at an interim site to the west (near Welches) of the entertainment venue.

Monitoring the entertainment noise involved short term attended monitoring conducted simultaneously in Oistins Bay Gardens (entertainment venue) on the Friday nights when another sound level meter was at one of the receptor sites mentioned in the preceding paragraph. For example on Friday 26th May, 2017, short term monitoring was conducted between 4:00pm and 9:00pm in Oistins Bay Gardens, which was during the time that another sound level meter had been stationed at the Christ Church Post Office from 21st -29th May, 2017.

In addition to sound level data, meteorological data, traffic counts and activity surveillance data were collected. Bruel & Kjaer 2270 sound level meters (Type 1) were used during monitoring. Further details on the equipment used are in Appendix H. Analyses were carried out on the data including comparing the measured data with predicted measurements.

Further details

Project planning had included identification of potential locations, preliminary talks with prospective owners and final selection of locations, preparation of lists (checklists, contact lists, schedules), preparation for monitoring, meeting with team members for night monitoring, equipment test runs and engaging other stakeholders (e.g. Ministry of Transport and Work, Royal Barbados Police Force, Barbados Meteorological Services, Grantley Adams International Airport).

The measurement methodology was based primarily on ISO 1996-2: 2007 Acoustics – Description and measurement of environmental noise. Based on the information from the pre-survey conducted for the area, three sites (Christ Church Post Office, PAWI and IDB (See Figure 2) were selected for unattended, 24hr monitoring using the following criteria:

- The activity within the mixed corridor was generally homogenous except when outdoor entertainment was hosted within Oistins Bay Gardens.
- The mixed corridor was small (approx. $0.13km^2$) with one main street.
- The identification of potential suitable monitoring locations taking into account factors such as security, accessibility, roof type and roof height.
- The expected change in activity during the night. For example the Post Office was the nearest building to the entertainment activity which occurred on certain nights.

As no suitable secure site was identified within the Oistins central core, short term monitoring was conducted within the open air entertainment venue, Oistins Bay Gardens, and at a downwind site near the Welches residential area. At each of the receptor sites the sound level meter was set up on a roof/balcony for a week (24hr monitoring sites) or on ground level (short term 4hr monitoring sites). The sound levels were recorded using fifteen (15) minute logging intervals. Additionally a logarithmic daily average of the fifteen (15) minute data was calculated and logged by the sound level meter.

The monitoring techniques employed during 24hr and short-term monitoring were as follows:

- For the 24hr monitoring the microphone was positioned 3m-11m above the ground, 1.2m-1.5m above the floor level and at least 3.5m away from any reflecting structure other than the ground. For short term monitoring sites the microphone was positioned

1.2m-1.5m above the ground level, at least 3.5m away from any reflecting structure other than the ground and for the Oistins Bay Garden site -10m in front of the stage.

- A windscreen was used during monitoring.
- The fast weighting was used when taking the measurements.
- It was preferred that the wind speed was between 1 and 5m/s, measured at a height of 3m to 11m above the ground and when there was no heavy precipitation.
- In-field calibration was done twice weekly for the 24 hour monitoring sites, while for short term monitoring, calibration was done before and after each session.

The noise descriptors collected were on the A-scale, fast response: L_{A10}, L_{A90}, L_{Aeq}, L_{Amax}, and octave band analysis. Logarithmic averaging was used in determining daily values. An external power supply (12V) was used as the primary power supply with the sound level meter's internal batteries as backup. The portable noise monitoring option –Type 3571 outdoor monitoring kit was used as this was an enclosure designed to facilitate outdoor monitoring over long periods.

Surveillance of the activities occurring at each site was done from April to December 2014 and June to July 2017 in order to identify the potential sources of noise. Each day of the week was assessed during the day and at night at least in triplicate for each site.

The meteorological data was obtained from Barbados Meteorological Services (original plans of using a localized weather meter were abandoned because it was damaged). The meteorological data collected were temperature, wind direction, wind speed, relative humidity, barometric pressure and cloud cover. Other data collected during the project included the type of instrumentation used, start and stop times, GPS location, description of any source(s) of noise and the type of area or zone. The survey form used to record the data is shown in Appendix G. At EPD's request, the Ministry of Public Works and Transport placed traffic counters on the roads near to the monitoring sites. The schedule outlining when the traffic counters were deployed at the various locations is shown in Appendix H. The Royal Barbados Police Force (RBPF) was informed of the project, monitoring locations and their assistance in surveillance was requested.

The collected data was analyzed and a predictive modelling based on two models (inverse square law and ISO 9613) was done. The software packages used for analysis were SPSS Statistics and Microsoft Excel. The aerial maps were produced using Google Earth.

6.0 Results

What were the weather conditions during monitoring?

"The data collected from the Barbados Meteorological Services indicated that in general the winds blew from the East, the wind speeds varied from 6.7 to 10.8 m/s, the temperature ranged from 25.2 to 28.3^{o}C, relative humidity from 69% to 90%, atmospheric pressure 1005.2 to 1008.3 mbar, cloud cover varied from 3/8 to 7/8, and the rainfall generally ranged from 0- 2mm of rainfall but it was noted that there were days where the rainfall varied from 4- 45mm of rainfall during monitoring "

Meteorological data was obtained from the Barbados Meteorological Services' nearest weather station which was located at the Grantley Adams International Airport (GAIA), approximately 5km away from Oistins (See Appendix A). Wind speed, temperature, relative humidity and atmospheric pressure were obtained. The wind vane and anemometer were located at a height of 30ft (9.1m) while the precision aneroid barometer was at a height of 49ft (15m) above ground level. The temperatures were measured at 4.3ft (1.3m) above the ground.

In the original project design localized meteorological data was to be collected using a Kestrel weather monitor placed next to the sound level meter. Some data was collected at the Christ Church Post Office using the Kestrel for the period 19th- 26th May 2017 (See Appendix A). However due to damage to the Kestrel weather monitor, the contingency plan of obtaining data from a nearby weather station was implemented. It was noted that the localized weather data suggested calmer wind speeds at the monitoring site than the data collected at the Airport. This could be due to the built up nature of the town compared to the open field where the weather equipment is located at the Airport coupled with the difference in the heights of the anemometers (the anemometer at GAIA was 30ft above the ground while the Post Office was 24.6ft above ground). Additionally the GAIA was at a higher altitude than Oistins.

What were the noise descriptors for the monitoring sites during 24hr monitoring?

"For the three sites the L_{eq} ranged from 57 to 69 dBA, the L_{Amax} from 85 to 103dBA, the L_{10} from 59 to 74dBA and, the L_{90} ranged from 49 to 60dBA."

The daily noise descriptors for the three sites used (Christ Church Post Office, PAWI and IDB) for twenty-four hour (24hr) monitoring are summarized graphically (Figure 8 to Figure 12) and in tabular form below (Table 2). Calibration of the sound level meter was done twice per week resulting in the data set for those days being split into two parts, as a result the L_{Aeq}, L_{A10} and L_{A90} were reported as a range on those days. Graphs of the raw fifteen (15) minute data are in Appendix B.

For the three sites the L_{Aeq} ranged from 57 to 69 dBA, the L_{Amax} from 85 to 103dBA, the L_{A10} from 59 to 74dBA and the L_{A90} ranged from 49 to 60dBA. It was noted that the sound levels were generally higher at the Christ Church Post Office than the IDB which in turn was generally higher than those recorded at PAWI.

Figure 8: Daily L_{Aeq} values at each site

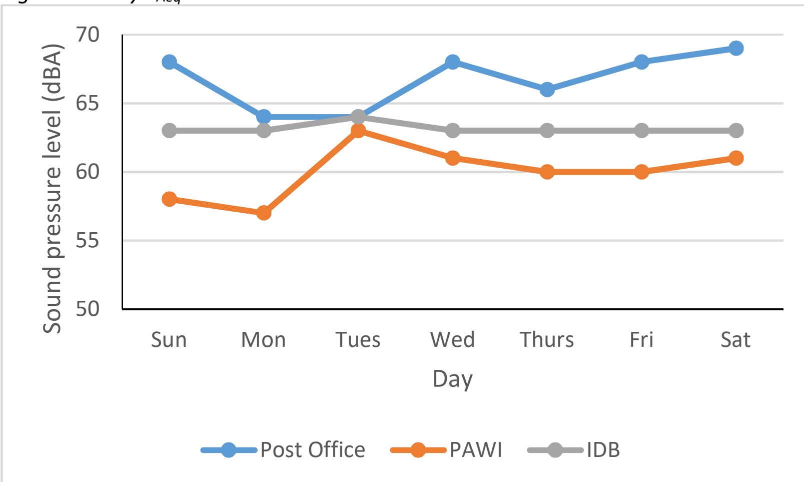


Figure 9: Daily L_{A10} values at each site

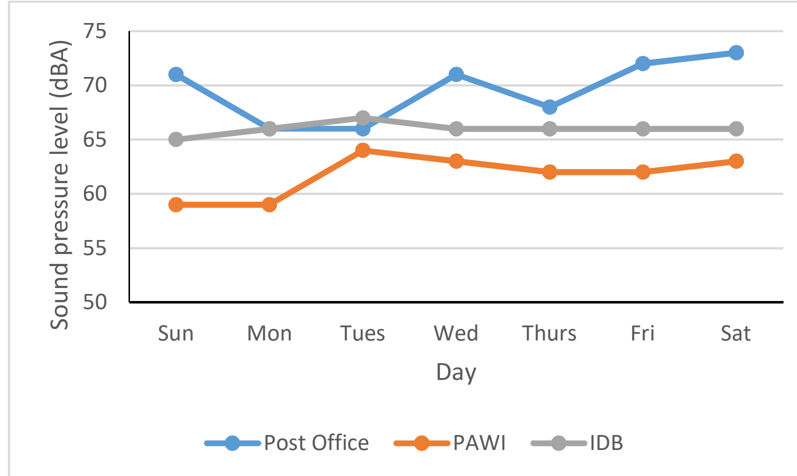


Figure 10: Daily L_{A90} values at each site

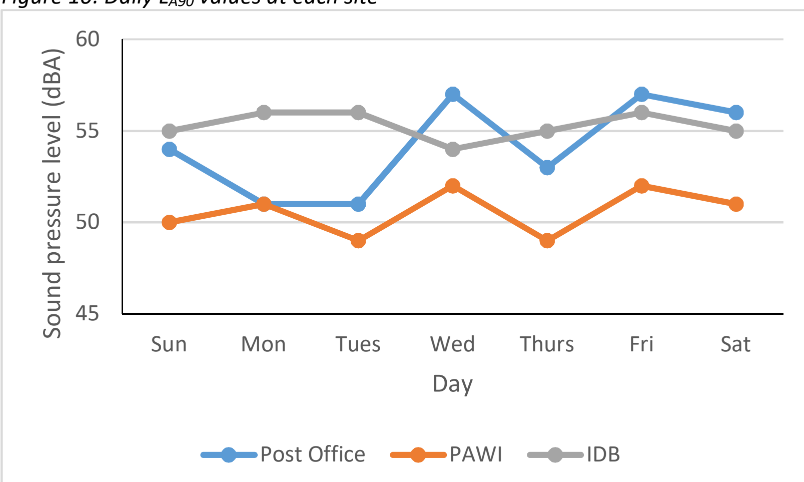


Figure 11: Daily L_{Amin} values at each site

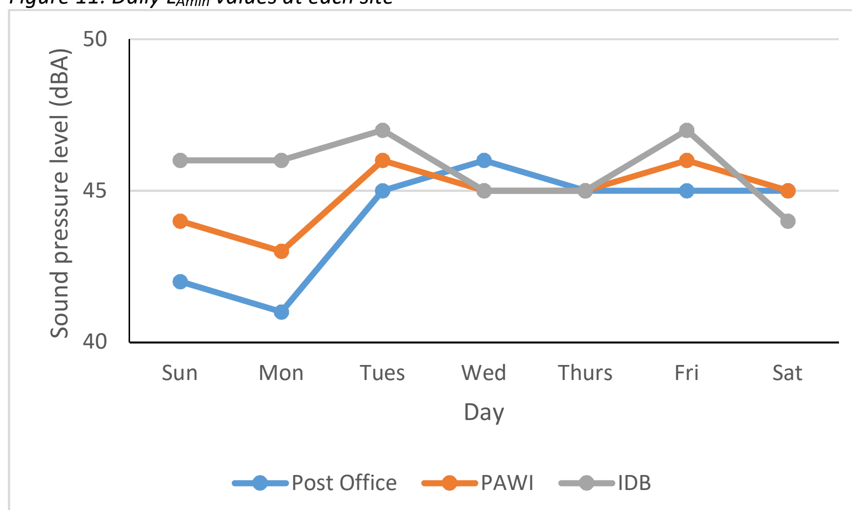


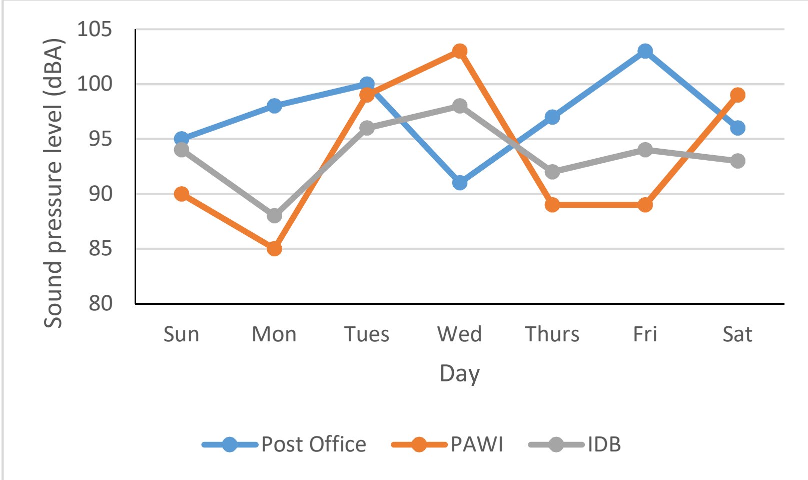
Figure 12: Daily L_{Amax} values at each site	
	

Table 2: Noise descriptor results

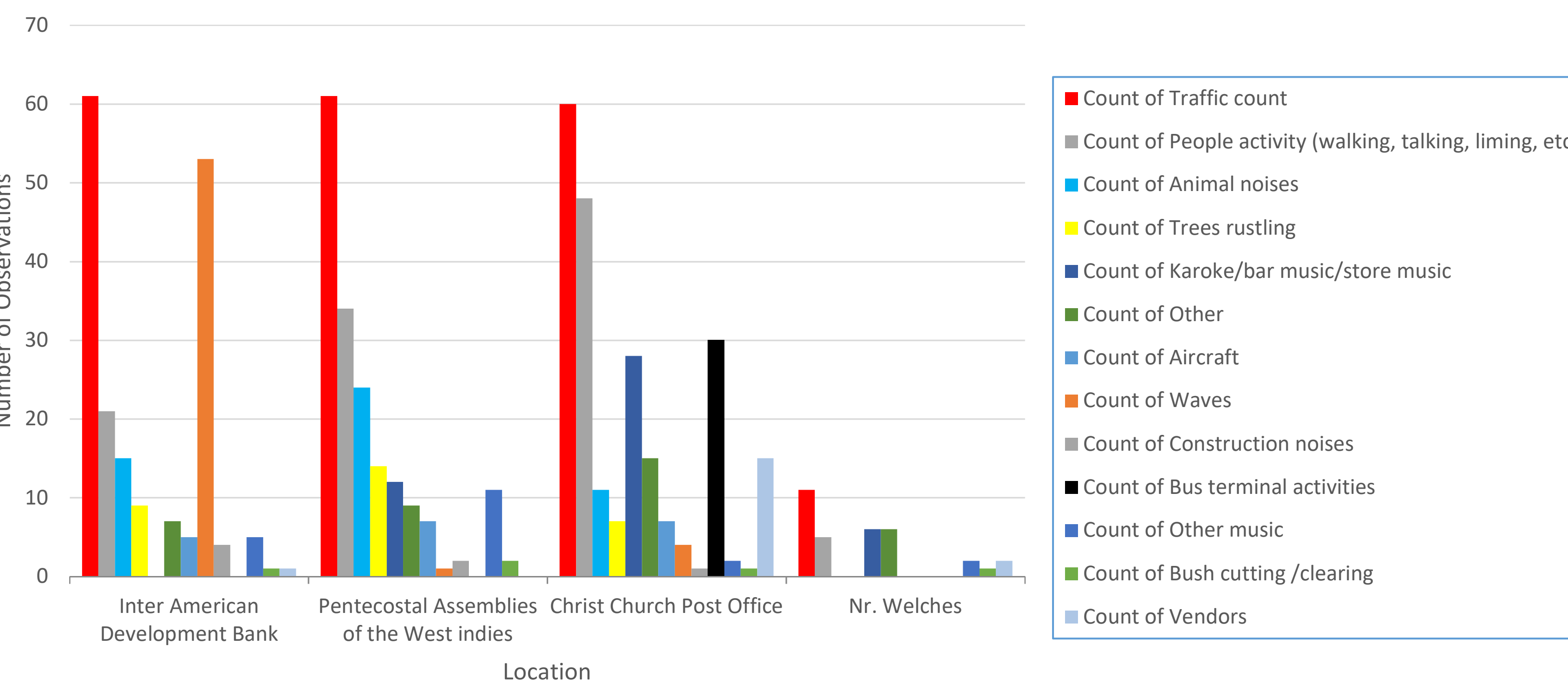
	Christ Church Post Office (21st – 28th May, 2017)	PAWI (13th- 19th June, 2017	IDB (12th- 18th July 2017)
Sunday	L_{Aeq}: 68 L_{A10}: 71 L_{A90}: 54 L_{Amin}: 42 L_{Amax}: 95	L_{Aeq}: 58 L_{A10}: 59 L_{A90}: 50 L_{Amin}: 44 L_{Amax}: 90	L_{Aeq}: 63 L_{A10}: 65 L_{A90}: 55 L_{Amin}: 46 L_{Amax}: 94
Monday	L_{Aeq}: 64 L_{A10}: 66 L_{A90}: 51 L_{Amin}: 41 L_{Amax}: 98	L_{Aeq}: 57 L_{A10}: 59 L_{A90}: 51 L_{Amin}: 43 L_{Amax}: 85	L_{Aeq}: 62- 63 L_{A10}: 66 L_{A90}: 54- 57 L_{Amin}: 46 L_{Amax}: 88
Tuesday	L_{Aeq}: 64 L_{A10}: 66 L_{A90}: 51 L_{Amin}: 45 L_{Amax}: 100	L_{Aeq}: 63 L_{A10}: 64 L_{A90}: 49 L_{Amin}: 46 L_{Amax}: 99	L_{Aeq}: 64 L_{A10}: 67 L_{A90}: 56 L_{Amin}: 47 L_{Amax}: 96
Wednesday	L_{Aeq}: 63- 70 L_{A10}: 66-73 L_{A90}: 49-60 L_{Amin}: 46 L_{Amax}: 91	L_{Aeq}: 59-63 L_{A10}: 61-65 L_{A90}:49-54 L_{Amin}: 45 L_{Amax}: 103	L_{Aeq}: 63 L_{A10}: 66 L_{A90}: 54 L_{Amin}: 45 L_{Amax}: 98
Thursday	L_{Aeq}: 66 L_{A10}: 68 L_{A90}: 53 L_{Amin}: 45 L_{Amax}: 97	L_{Aeq}: 60 L_{A10}: 62 L_{A90}: 49 L_{Amin}: 45 L_{Amax}: 89	L_{Aeq}: 63 L_{A10}:: 66 L_{A90}: 55 L_{Amin}: 45 L_{Amax}: 92
Friday	L_{Aeq}: 63- 70 L_{A10}: 66- 74 L_{A90}: 50- 60 L_{Amin}: 45 L_{Amax}: 103	L_{Aeq}: 58-61 L_{A10}: 60-63 L_{A90}: 51-53 L_{Amin}: 46 L_{Amax}: 89	L_{Aeq}: 62- 64 L_{A10}: 66- 66 L_{A90}: 55-57 L_{Amin}: 47 L_{Amax}: 94
Saturday	L_{Aeq}: 69 L_{A10}: 73 L_{A90}: 56 L_{Amin}: 45 L_{Amax}: 96	L_{Aeq}: 61 L_{A10}: 63 L_{A90}: 51 L_{Amin}: 45 L_{Amax}: 99	L_{Aeq}: 63 L_{A10}: 66 L_{A90}: 55 L_{Amin}: 44 L_{Amax}: 93

What were the major sources of noise identified?

"Traffic was the most frequent source of noise identified followed by people (e.g. talking, liming) and animals (e.g. birds)"

The activities observed during surveillance conducted April to December 2014 and June to July 2017 at the monitoring sites were shown in Figure 13 below. The types of activities observed as well as the frequency with which they were observed are shown. The sources of noise observed included traffic, aircraft, sea waves, people related activities such as talking or playing, animal noises, construction, music and bus terminal activities. As expected, the most frequent sources of noise observed were traffic and people related noises. Sources that were observed infrequently or at relatively few sites were placed in the "Other" category for example sirens.

re 13: Activities observed at each location



	Traffic	People activity	Animal noises	Trees rustling	Karaoke/ bar / store music	Other	Aircraft	Waves	Construction noises	Bus terminal activities	Other music	Bush cutting /clearing	Vendor
	61	21	15	9		7	5	53	4		5	1	1
VI	61	34	24	14	12	9	7	1	2		11	2	
ce	60	48	11	7	28	15	7	4	1	30	2	1	15
r ches	11	5			6	6					2	1	2

What are the noise levels that persons in Oistins were exposed to during Friday night outdoor entertainment? ($L_{Aeq,\ 15min}$, $L_{A10,\ 15min}$, $L_{A90,\ 15min}$, $L_{Amax,\ 15minr}$, octave band data)

> *"During Friday night entertainment the sound levels 10 m from the stage at Oistins Bay Gardens were $L_{Aeq,\ 15min}$ 83- 94dBA,$L_{Amax,\ 15min}$ 93 to 103dBA, $L_{Amin,\ 15min}$ 57-88dBA. At the monitoring sites the sound levels varied from $L_{Aeq,\ 15min}$ 57 to 75,$L_{Amax,\ 15min}$ 71- 103dBA, $L_{Amin,\ 15min}$ 48 to 65dBA."*

Within Oistins Bay Gardens

The monitoring data collected on 26th May 2017 and 23rd June 2017 between 4:30pm and 9:00pm at 10m from the stage was summarized in Table 3 below. Monitoring was also conducted on 16th May, 2017 but there was no amplified music played between the 4:00-9:00pm monitoring period due to a human resource issue with the DJ. Oistins Bay Garden management indicated that the music started later that night when the issue was rectified. Graphs with the raw data are in Appendix B. It was noted that patrons as well as workers were often closer than 10m to the stage. The wide variation in values was expected given that changes occurred in the volume and type of music, that there were sometimes short breaks for announcements and sound checks at the beginning were sometimes very loud.

Table 3: Noise levels 10m in front of the stage in Oistins Bay Gardens

Descriptor	Value	Date and time recorded
$L_{Aeq,\ 15min}$	83 to 94dBA	26th May 2017 and 23rd June 2017 between 4:30pm and 9:00pm
$L_{Amax,\ 15min}$	93 to 103dBA	
$L_{Amin,\ 15min}$	57 to 88dBA	

Octave band data was also collected in Oistins Bay Gardens as well as at the 24hr monitoring sites (See Appendix C). This was primarily for use in the modelling or prediction using ISO 9613. It was noted that when the music started the 63Hz octave was dominant and had the greatest increase in sound pressure level. The 125Hz and 250Hz octaves had similar increases in sound pressure levels with the 125Hz generally being the second loudest followed by the 250Hz.

At 24hr receptor, monitoring sites

According to Oistins Bay Management, Friday nights from 6pm to midnight/1am the following morning were typically the loudest nights and had the most patrons. The sound levels recorded at each site on Friday from 6pm to midnight were tabulated below:

Table 4: Noise levels at monitoring sites during Friday night entertainment

Descriptor	Christ Church Post Office 26th May 2017	PAWI 16th June 2017	Near Welches 23rd June 2017	IDB 14th July 2017
$L_{Aeq, 15min}$	64- 75dBA	57-66 dBA	68-73dBA	61-64 dBA
$L_{Amax, 15min}$	79- 103dBA	71- 87 dBA	85-99dBA	73-86 dBA
$L_{Amin, 15min}$	55-65dBA	48- 58 dBA	58-63dBA	48-53dBA

At the Christ Church Post Office (196m to the East of the stage), when the music started the 63Hz octave dominated with notable increases in the 31.5Hz, 125Hz and 250Hz. At PAWI (approximately 200m north of the stage), during the Friday night entertainment, the 63Hz dominated with notable increases in the 31.5Hz and 125Hz. At IDB (770m west of the stage), there was no notable change in the octaves on any day. The notable increase of low frequencies at the monitoring sites was expected given the character of the source (music with bass) as well as that low frequency noise travels further.

How does predictive modelling using the inverse square law compare with measured values?

"In general the inverse square law predicted the L_{Aeq} within-2.4 to +3.0dBA at the Post Office and within -0.8 to +2.8dBA at the monitoring site near Welches."

In general the inverse square law predicted the L_{Aeq} within -2.4 to +3 dBA at the Post Office, the exceptions being at 19:00 -19:15pm (4.0dBA difference), 19:45-20:00 pm (4.6dBA difference) and 20:00-20:15pm (3.8dBA difference). It had rained lightly during that period. With respect to the site near Welches the inverse square law predicted the L_{Aeq} within -1 to +3dBA, with one exception being the 19:30-19:45pm reading which showed a difference of 4.6dBA. There was no clear possible explanation for this variation.

The following concept was used to predict the sound levels at the receptor:

Total Sound = Background sound level + Entertainment sound level

where

Entertainment sound level= $L_{p,known\ distance}$- Distance Attenuation

The inverse square law (Equation 1) was used to estimate the distance attenuation due to the entertainment noise (L_{Aeq}) at two locations (Christ Church Post Office and a location near Welches area). Average background sound levels were calculated using the data collected at least an hour (in 15 minute readings) prior to the entertainment. The total sound was then predicted by logarithmic summing of the entertainment sound and the background sound. A summary of the results is provided in Table 5 and Table 6 followed by detailed sample calculations. Summary calculations were provided in Appendix D.

Table 5: Summary of results obtained for Christ Church Post Office using inverse square law

R_1=10m	R_2=196m		Inverse square law				
			Entertainment	Background	Total Sound	Actual	Difference (Predicted-Actual)
Project Name	Start Time	Elapsed Time	LAeq	LAeq	LAeq	LAeq	LAeq
	6/23/1718:15	00:15:00	64.97	70.04	71.22	70.08	1.13
	6/23/17 18:30	00:15:00	66.56	70.04	71.65	72.49	-0.84
	6/23/17 18:45	00:15:00	65.22	70.04	71.28	69.12	2.16
	6/23/17 19:00	00:15:00	67.73	70.04	72.05	69.28	2.77
	6/23/17 19:15	00:15:00	68.28	70.04	72.26	70.01	2.25
	6/23/17 19:30	00:15:00	69.58	70.04	72.83	68.22	4.61
	6/23/17 19:45	00:15:00	69.58	70.04	72.83	71.09	1.74
	6/23/17 20:00	00:15:00	71.31	70.04	73.73	72.48	1.25
	6/23/17 20:15	00:15:00	70.10	70.04	73.08	71.08	2.01
	6/23/17 20:30	00:15:00	71.19	70.04	73.66	73.11	0.55
	6/23/17 20:45	00:05:27	70.06	70.04	73.06	73.57	-0.52

Table 6: Summary of results obtained for the Near Welches site using inverse square law

R_1=10m	R_2=130m		Inverse square law				
			Entertainment	Background	Total Sound	Actual Total Sound	Difference (Predicted- Actual)
Project Name	Start Time	Elapsed Time	LAeq	LAeq	LAeq	LAeq	LAeq
	6/23/17 18:15	00:15:00	64.97	70.04	71.22	70.08	1.13
	6/23/17 18:30	00:15:00	66.56	70.04	71.65	72.49	-0.84
	6/23/17 18:45	00:15:00	65.22	70.04	71.28	69.12	2.16
	6/23/17 19:00	00:15:00	67.73	70.04	72.05	69.28	2.77
	6/23/17 19:15	00:15:00	68.28	70.04	72.26	70.01	2.25
	6/23/17 19:30	00:15:00	69.58	70.04	72.83	68.22	4.61
	6/23/17 19:45	00:15:00	69.58	70.04	72.83	71.09	1.74
	6/23/17 20:00	00:15:00	71.31	70.04	73.73	72.48	1.25
	6/23/17 20:15	00:15:00	70.11	70.04	73.08	71.08	2.01

	6/23/17 20:30	00:15:00	71.19	70.04	73.66	73.11	0.55
	6/23/17 20:45	00:05:27	70.06	70.04	73.06	73.57	-0.52

Sample calculations using Christ Church Post Office data

Entertainment Sound level

Distance attenuation calculation: Using 10m for the source microphone (R_1), 196m for the receiver microphone at the Post Office (R_2)

$$L_{p1} - L_{p2} = 20 \log (R_2 / R_1) = 20 \log (196/10) = 25.9dB$$

A-weighting: The applicable weighting is applied based on IEC 61672:2, See Table 7 below.

Table 7: A-weightings

Frequency (Hz)	63	125	250	500	1kHz	2kHz	4kHz	8kHz
A-weighting	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1

Distance attenuation and A-weighting applied to the octave band data: Using the 26th May, 2017, 17:30pm 63Hz data of 109.5dB

Estimated A-weighted sound pressure level at Post Office in 63Hz octave band

= 109.5-25.9 -26.2 = 57.4 dBA

15min L_{Aeq} of Entertainment sound (decibel addition of octave data): Using 26th May, 2017, 17:30pm 63Hz -8kHz data, all of which had been adjusted for distance attenuation and A-weighting as above

L_{Aeq}, 15min= $10 \log (10^{L1/10} + 10^{L2/10} + 10^{L3/10} + ...10^{Ln/10})$=
$10\log(10^{5.75}+10^{5.7}+10^{5.67}+10^{5.68}+10^{5.63}+10^{5..67}+10^{4.71}+10^{3.87})$= 64.7dBA

Background level: Using the values averaged over the hour preceding the start of the entertainment noise (i.e. 16:30- 17:30 pm on 26th May 2017)

A-weighting: As above the applicable A-weighting is applied based on IEC 61672:2.

15 min L_{Aeq} (decibel addition of octave data): Using 26th May, 2017, 16:30pm 63Hz -8kHz data, all of which had been adjusted for A-weighting

L_{Aeq}, 15min= $10 \log (10^{L1/10} + 10^{L2/10} + 10^{L3/10} + ...10^{Ln/10})$=
$10\log(10^{4.82}+10^{4.98}+10^{5.56}+10^{6.05}+10^{6.13}+10^{5.86}+10^{5.21}+10^{4.22})$= 65.9dBA

Average background L_{Aeq} (logarithmic average of the four 15 minute data sets):
L_{Aeq}= $10 \log ((10^{L1/10} + 10^{L2/10} + 10^{L3/10} + 10^{L4/10})/4)$= $10\log((10^{6.59}+10^{6.85}+10^{6.59}+10^{6.39})/4)$=
66.3dBA

Total sound level (decibel addition, estimated) = Background sound level (at receptor, actual average) + Entertainment Sound level (at receptor, estimated)

Total sound level (estimated) = 10log ($10^{6.63}$+ $10^{6.47}$) =68.6dBA (for the period 17:30-17:45pm)

Comparison with measured L_{Aeq} (17:30-17:45pm)

The measured level was 65.6dBA, indicating a difference of 3dBA.

How does predictive modelling using the excess attenuation model (based on ISO 9613) compare with measured values?

"In general the excess attenuation model (based on ISO 9613) predicted the L_{Aeq} within +/-3 dBA at the Post Office and within -2 to +1.5dBA at the monitoring site near Welches."

In general the inverse square law predicted the L_{Aeq} within +/-3 dBA at the Post Office, the exceptions being at 19:00 -19:15 pm (+3.5 difference) and 19:45-20:00 pm (+4 dB difference). It had rained lightly during that period. With respect to the site near Welches the inverse square law predicted the L_{Aeq} within -2 to +1.5dBA, with one exception being the 19:30 pm reading which showed a difference of 3dBA. There was no clear possible explanation for this variation.

The following concept based on ISO 9613 was used to predict the sound levels at the receptor:

Total Sound = Background sound level+ Entertainment sound level

where

Entertainment sound level= $L_{p,\text{known distance}}$+Directivity Index- Distance Attenuation-Atmospheric Attenuation-Ground Attenuation-Barrier Attenuation

The above concept based on ISO 9613 was used to estimate or predict the sound level due to the entertainment noise and total sound (L_{Aeq}) at two locations (Christ Church Post Office and a location near Welches area). Average background sound levels were calculated using the data collected a least an hour (in 15 minute readings) prior to the entertainment. The total sound was then predicted by summing the entertainment sound and the background sound. The results were tabulated below in Table 8 and Table 9. A sample detailed calculation was also provided below and summary calculations in the Appendix E. Other attenuation factors such as reflection and vegetation were not considered as the meter was placed at least 3.5m from any reflective surface other than the ground and there was sparse vegetation.

Table 8: Summary of results obtained for Christ Church Post Office using excess attenuation model

R_1=10m	R_2=196m		Entertainment	Background	Total Sound	Actual	Difference (predicted-actual)

R₁=10m	R₂=196m		Entertainment	Background	Total Sound	Actual	Difference (predicted-actual)
Project Name	Start Time	Elapsed Time	LAeq	LAeq	LAeq	LAeq	LAeq
	5/26/17 17:30	00:15:00	63.63	66.34	68.20	65.64	2.57
	5/26/17 17:45	00:15:00	55.88	66.34	66.72	65.16	1.55
	5/26/17 18:00	00:15:00	55.22	66.34	66.67	64.21	2.46
	5/26/17 18:15	00:15:00	55.28	66.34	66.67	64.23	2.44
	5/26/17 18:30	00:15:00	56.73	66.34	66.79	64.48	2.31
	5/26/17 18:45	00:15:00	58.94	66.34	67.07	65.64	1.43
	5/26/17 19:00	00:15:00	60.12	66.34	67.27	63.73	3.54
	5/26/17 19:15	00:15:00	61.80	66.34	67.65	66.28	1.37
	5/26/17 19:30	00:15:00	62.68	66.34	67.90	65.65	2.25
	5/26/17 19:45	00:15:00	64.68	66.34	68.60	64.60	4.00
	5/26/17 20:00	00:15:00	66.97	66.34	69.68	66.67	3.01
	5/26/17 20:15	00:15:00	66.50	66.34	69.43	72.70	-3.27

Table 9: Summary of results obtained for Near Welches using excess attenuation model

R_1=10m	R_2=130m		ISO 9613 based model				Difference
			Entertainment	Background	Total Sound	Actual	(predicted-actual)
Project Name	Start Time	Elapsed Time	LAeq	LAeq	LAeq (ISO 9613)	LAeq	LAeq
	6/23/17 18:15	00:15:00	61.50	70.04	70.61	70.08	0.53
	6/23/17 18:30	00:15:00	61.87	70.04	70.66	72.49	-1.84
	6/23/17 18:45	00:15:00	61.02	70.04	70.55	69.12	1.43
	6/23/17 19:00	00:15:00	62.48	70.04	70.74	69.28	1.46
	6/23/17 19:15	00:15:00	63.20	70.04	70.86	70.01	0.84
	6/23/17 19:30	00:15:00	64.80	70.04	71.18	68.22	2.96
	6/23/17 19:45	00:15:00	64.64	70.04	71.14	71.09	0.05
	6/23/17 20:00	00:15:00	66.66	70.04	71.68	72.48	-0.80
	6/23/17 20:15	00:15:00	66.49	70.04	71.63	71.08	0.55
	6/23/17 20:30	00:15:00	67.34	70.04	71.91	73.11	-1.21

Sample calculations using Christ Church Post Office data

Entertainment Sound level

$L_{p,known\ distance}$= 109.5dB (10m from the stage)

Directivity Index= 3dB as the speakers were located on the floor of the stage i.e. they were treated as a hemispherical source

Distance attenuation calculation: Using 10m for the source microphone (R1), 196m for the receiver microphone at the Post Office (R2)

L_{p1} -L_{p2} = 20 log (R2 / R1) = 20 log (196/10)= 25.9dB

Atmospheric Attenuation

The atmospheric attenuation coefficients (dB/km) quoted in ISO 9613 for 30^{o}C, 70% relative humidity were used given the meteorological data (Appendix A) for the area. The coefficients used in each octave were stated below:

Temperature (^{o}C)	Relative humidity (%)	63 Hz	125 Hz	250Hz	500Hz	1kHz	2kHz	4kHz	8kHz
30	70	0.1	0.3	1.0	3.1	7.4	12.7	23.1	59.3

Atmospheric Attenuation = 0.1 x 196/1000 = 0.0196dB in 63Hz octave band, at Christ Church Post Office which was 196m from the source.

Ground Attenuation= -3dB as the ground was hard

Barrier Attenuation using Maekawa formula= 10 log (3+20N), where N=2 x path difference/wavelength. Table 10 provided the barrier specifications.

Table 10: Barrier specifications

Description	A stall with a single hip roof
Barrier height	5.5m
Source height	2.5m
Receiver height	9m
Barrier to source distance (measured using Google Earth Pro)	45m
Barrier to receiver distance (measured using Google Earth Pro)	151m

Path difference =$\sqrt{45^2+3^2}+\sqrt{151^2+3.5^2}-\sqrt{196^3+6.5^2}$ =0.0327m

N_{63Hz}= 2x 0.0327x63/340= 0.01211

Barrier Attenuation = 10log(3+(20x0.01211))=5.109dB in 63Hz octave band.

The barrier attenuation in the other octaves were calculated similarly.

Total attenuation

Total attenuation in each octave =Distance Attenuation + Atmospheric Attenuation + Ground Attenuation + Barrier Attenuation

In 63Hz Total attenuation = 25.845+0.0196-3+5.1085=27.973dB

A-weighting: The applicable weighting is applied based on IEC 61672:2, See Table 7 above.

Total attenuation and A-weighting applied to the octave band data: Using the 26th May, 2017, 17:30pm 63Hz data of 109.51dB

Estimated A-weighted sound pressure level at Post Office in 63Hz octave band= 109.51+3 -27.973-26.2= 58.337dBA

15min LAeq of Entertainment sound (decibel addition of octave data): Using 26th May, 2017, 17:30pm 63Hz -8kHz data, all of which had been adjusted for total attenuation and A-weighting as above

LAeq, 15min= 10 log ($10^{L1/10}$ + $10^{L2/10}$ +$10^{L3/10}$ +......$10^{Ln/10}$)=
10log($10^{5.83}$+$10^{5.75}$+$10^{5.65}$+$10^{5.53}$+$10^{5.25}$+10^{5}+$10^{3.59}$+$10^{1.78}$)= 63.6dBA

Background level: Using the values averaged over the hour preceding the start of the entertainment noise (i.e. 16:30- 17:30 pm on 26th May 2017)

A-weighting: As above the applicable A weighting is applied based on IEC 61672:2.

15 min LAeq (decibel addition of octave data): Using 26th May, 2017, 16:30pm 63Hz - 8kHz data, all of which had been adjusted for A-weighting

$L_{Aeq, 15min}$= 10 log ($10^{L1/10}$ + $10^{L2/10}$ +$10^{L3/10}$ +...$10^{Ln/10}$)=
10log($10^{4.82}$+$10^{4.98}$+$10^{5.56}$+$10^{6.05}$+$10^{6.13}$+$10^{5.86}$+$10^{5.21}$ +$10^{4.22}$)= 65.9dBA

Average background LAeq (logarithmic average of the four 15 minute data sets):
LAeq= 10 log (($10^{L1/10}$ + $10^{L2/10}$ +$10^{L3/10}$ +$10^{L4/10}$)/4)= 10log(($10^{6.59}$+$10^{6.85}$+$10^{6.59}$+$10^{6.39}$)/4)= 66.3dBA

Total sound level (decibel addition, estimated) = Background sound level (at receptor, actual average) + Entertainment Sound level (at receptor, estimated)

Total sound level (estimated)= $10\log(10^{6.63}+10^{6.36})$=68.2dBA (for the period 17:30-17:45pm)

Comparison with measured L_{Aeq} (17:30-17:45pm)

Measured level was 65.6dBA. Therefore a difference of 2.6dBA.

In general the ISO 1996 model provided marginally better results than the simpler inverse square law. A comparison of the main differences between using the ISO 1996 model and the inverse square law model is provided in the discussion section of this report.

How did the noise levels recorded compare with WHO guidelines?

"The sound levels at all the sites monitored were within the WHO guidelines for commercial areas however it exceeded the guideline values for residential areas."

The World Health Organization's guideline for industrial, commercial shopping and traffic areas; indoors and outdoors, is an L_{eq} of 70dB with a L_{max} of 110dB over a 24hr period. The $L_{Aeq,24hr}$ varied from 57 to 69dBA and the L_{Amax} varied from 85 to 103dBA. Therefore all the areas monitored were within the WHO guidelines for industrial, commercial shopping and traffic areas. (See Table 2). As Oistins was largely a commercial area the noise limits used were for commercial areas but it was noted that there are residences within the town.

The diverse land use within Oistins could present a problem when comparing it to many international standards including the World Health Organization's Community Guidelines as they often do not account for mixed use areas but provide noise limits for individual zones/areas e.g. residential, industrial or commercial. The World Health Organization's guideline for residential areas is an L_{Aeq} of 55dBA during the day (16hrs) and at night (8hrs) an L_{Aeq} of 45dBA with a L_{max} of 60dBA. Fifteen (15) minute samples were taken continuously each day at each site. At the Christ Church Post Office the $L_{Aeq,\ 7:00\text{-}23:00}$ varied from 61-76dBA and the $L_{Aeq,\ 23:00\text{-}7:00}$ varied from 52-76dBA while at PAWI the $L_{Aeq,\ 7:00\text{-}23:00}$ varied from 54-71dBA and the

$L_{Aeq,\ 23:00\text{-}7:00}$ varied from 48-67dBA. At IDB the $L_{Aeq,\ 7:00\text{-}23:00}$ varied from 61-73dBA and the $L_{Aeq,23:00\text{-}7:00}$ varied from 56-65dBA (See Table 11). Therefore all of the sites monitored were above the WHO guidelines for residential areas. This is especially instructive as PAWI and IDB were near residential areas.

Table 11: Range of L_{Aeq} values at the monitoring sites

Time	Post Office	PAWI	IDB
7:00-23:00	61 -76 dBA	54-71 dBA	61-73 dBA
23:00-7:00	52 -76 dBA	48-67 dBA	56-65 dBA

Were the 24hr sound levels (*L_{Aeq}*) on Sundays statistically different to those recorded on other days of the week?

"The L_{Aeq} values recorded on Sundays were similar or quieter than any other day of the week at PAWI and IDB. However at Christ Church Post Office Sundays were similar or louder than any other day of the week."

For the analysis the 24hr Sunday data for each site was compared to each weekday's data for that particular site. The data was first tested for normality using histograms, the Kolmogorov–Smirnov (KS) statistic and probability plots. Based on the tests conducted, in general the data was not found to be normally distributed and the non-parametric Wilcoxon Signed Rank Test was used for the comparison analysis. It was noted that there were some data sets (e.g. at the PAWI location) that approached normality however to allow for all the data sets to be analysed similarly a non-parametric test was used. Culturally or historically Sundays were quiet days in Barbados. In Oistins, however Sundays were not always statistically different to other days of the week.

The Wilcoxon Signed Rank Test showed that at the Post Office, Sundays were not statistically different to Wednesday, Thursday, Saturday or even Friday (See Table 12). A graph showing the LAeq over the week was also provided in

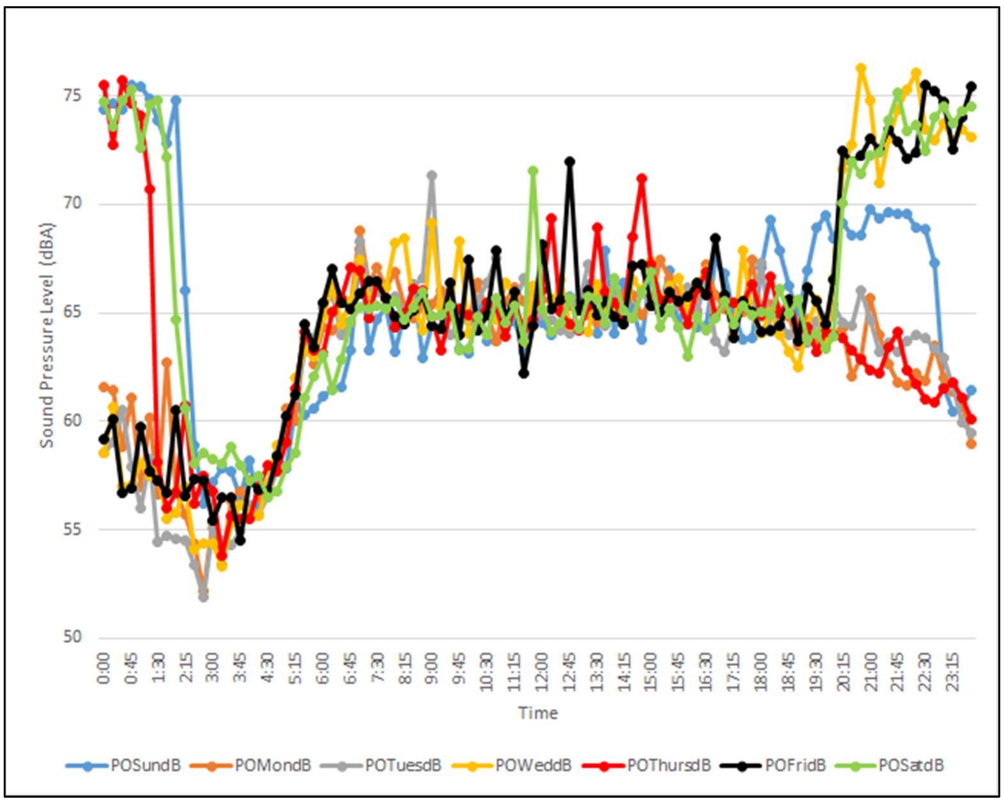
Figure 14. This was expected as this site was relatively near to Oistins Bay Gardens and in the general direction in which the speakers pointed. This was a difference/shift to the norm in other parts of the island. Sundays were similar to Wednesday, Thursday, Saturday and Friday but statistically different to Monday and Tuesday with these days being quieter than Sunday. This was not a norm as Sunday was typically the quietest day of the week.

Table 12: Results of Wilcoxon Signed Rank Test for Christ Church Post Office comparing Sunday's Leq values with other weekday Leq values

Null Hypothesis	Sig.	Decision
The median of differences between POMondB and POSundB equals 0*	0.005	Reject the null hypothesis
The median of differences between POTuesdB and POSundB equals 0*	0.003	Reject the null hypothesis
The median of differences between POWeddB and POSundB equals 0*	0.475	Retain the null hypothesis
The median of differences between POThursdB and POSundB equals 0*	0.057	Retain the null hypothesis
The median of differences between POFridB and POSundB equals 0*	0.239	Retain the null hypothesis
The median of differences between POSatdB and POSundB equals 0*	0.129	Retain the null hypothesis

*PO- Christ Church Post Office, dB- decibels. Asymptotic significances are displayed. The significance level is 0.05,

Figure 14: Variation of L_{Aeq} values over the week at Christ Church Post Office



The Wilcoxon Signed Rank Test showed that at PAWI, Sundays were statistically different to every day of the week except Monday. Sunday and Monday were quieter than the other days (See Table 13). This result is similar to the cultural norm. A graph showing the L_{Aeq} over the week was also provided in Figure 15.

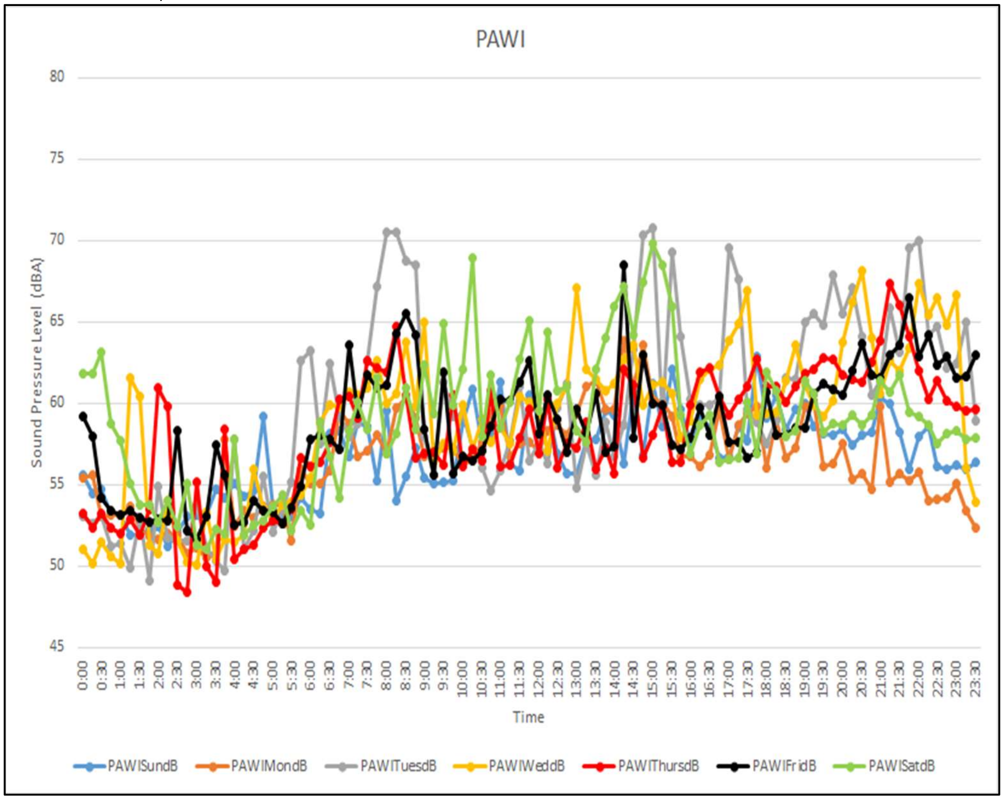
Table 13: Results of Wilcoxon Signed Rank Test for PAWI comparing Sunday's Leq values with other weekday Leq values

Null Hypothesis	Sig.	Decision

The median of differences between PAWIMondB and PAWISundB equals 0	0.054	Retain the null hypothesis
The median of differences between PAWITues and PAWISundB equals 0	0.000	Reject the null hypothesis
The median of differences between PAWIWeddB and PAWISundB equals 0	0.000	Reject the null hypothesis
The median of differences between PAWIThursdB and PAWISundB equals 0	0.001	Reject the null hypothesis
The median of differences between PAWIFridB and PAWISundB equals 0	0.000	Reject the null hypothesis
The median of differences between PAWISatdB and PAWISundB equals 0	0.000	Reject the null hypothesis

*PO- Christ Church Post Office, Asymptotic significances are displayed. The significance level is 0.05

Figure 15: Variation of L_{Aeq} values over the week at PAWI comparing Sunday's Leq values with other weekday Leq values



The Wilcoxon Signed Rank Test showed that at the IDB, Sundays were statistically different to Monday, Tuesday, Friday and Saturday but were not statistically different to Wednesday and Thursday (See Table 14). Sunday was similar to Wednesday and Thursday but quieter than Monday, Tuesday, Friday and Saturday. This trend is also close to the cultural norm as basically Sunday was either the same or quieter than the other days of the week. A graph showing the LAeq over the week was also provided in

Figure 16.

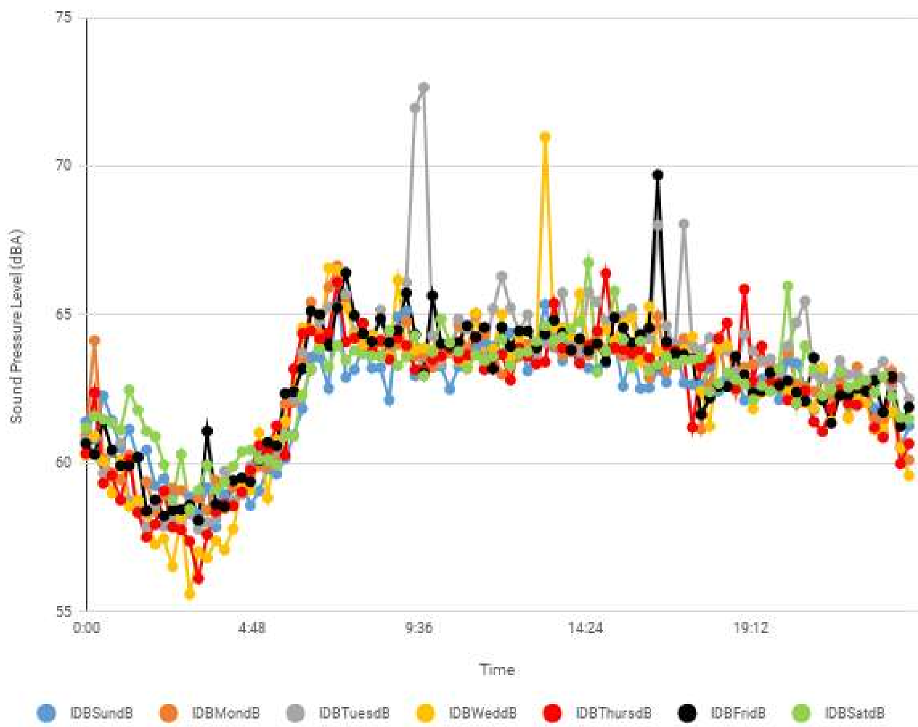
Table 14: Results of Wilcoxon Signed Rank Test for IDB comparing Sunday's Leq values with other weekday Leq values

Null Hypothesis	Sig.	Decision
The median of differences between IDBMondB and IDBSundB equals 0	0.018	Reject the null hypothesis
The median of differences between IDBTuesdB and IDBSundB equals 0	0.000	Reject the null hypothesis

The median of differences between IDBWeddB and IDBSundB equals 0	0.430	Retain the null hypothesis
The median of differences between IDBThursdB and IDBSundB equals 0	0.759	Retain the null hypothesis
The median of differences between IDBFridB and IDBSundB equals 0	0.000	Reject the null hypothesis
The median of differences between IDBSatdB and IDBSundB equals 0	0.000	Reject the null hypothesis

*PO- Christ Church Post Office, Asymptotic significances are displayed. The significance level is 0.05

Figure 16: Variation of L_{Aeq} values over the week at IDB



Was there a correlation between the traffic counts and the noise levels recorded?

"The relationship between LAeq and traffic counts was investigated using Spearman's rank order correlation. At Christ Church Post Office there was varying correlation between the two variables with weak, moderate and strong, positive correlations being found. At PAWI there was generally strong,

positive correlation between the two variables. At IDB there was strong, positive correlation between the two variables."

The correlation between traffic counts and noise levels was investigated using the Spearman's rank order correlation for each site. Spearman's rank order correlation was used to determine the strength and direction of the relationship between the two variables. The sign (positive or negative) indicated the direction of the relationship. A positive correlation coefficient would indicate that as traffic increased the noise levels increased while a negative correlation coefficient would indicate that as traffic decreased the noise levels increased. The value of the coefficient indicated the strength of the relationship. The ranges provided in Table 15 were used to describe the strength of the relationship (Cohen, 1988). The traffic count data is provided in Appendix J.

Table 15: Ranges used in description of the strength of the relationship

Range of r values	Interpretation
r=.10 to .29 or r=-.10 to -.29	Small
r=.30 to .49 or r=-.30 to -.49	Medium
r=.50 to 1.0 or r=-.50 to -.1.0	Large

At the Christ Church Post Office there was a strong, positive correlation between the hourly L_{eqs} and the hourly traffic counts on Monday, Tuesday and Thursday. There was a medium, positive correlation on Wednesday and Friday and low, positive correlation on Saturday and Sunday. These mixed results suggest that traffic was not the only significant contributor to noise at this location. As the days which exhibited low to moderate correlation between sound levels and traffic counts were all the weekend days (which were popular entertainment nights at Bay Gardens it is likely that entertainment noise was also a significant contributor to the noise climate. As management of Oistins Bay Gardens indicated that at random a stall may play music during the week, this could account for the medium correlation on Wednesday also. Additionally the survey of noise sources at each site revealed that traffic, people and entertainment noise were the three most observed activities at the Christ Church Post Office. The results of the statistical analysis are below:

Table 16: Correlation analysis of hourly L_{eqs} with hourly traffic counts at Christ Church Post Office

Day	Spearman Rank Order	Correlation Description

	Correlation Coefficient**	
Sunday	0.222	Weak positive correlation
Monday	0.775	Strong positive correlation
Tuesday	0.727	Strong positive correlation
Wednesday	0.341	Medium positive correlation
Thursday	0.552	Strong positive correlation
Friday	0.397	Medium positive correlation
Saturday	0.142	Weak positive correlation

** Correlation is significant at the .01 level (2-tailed).

At the PAWI site there was a strong, positive correlation between the hourly L_{eqs} and the hourly traffic counts on all days except Tuesday when there was a moderate correlation. Therefore as traffic counts increased so did the L_{eqs}. While these values indicated a strong positive correlation it was noted that these values were on the lower end of the "strong correlation" range indicated in Table 15. The results of the analysis are below:

Table 17:: Correlation analysis of hourly L_{eqs} with hourly traffic counts at PAWI

Day	Spearman Rank Order Correlation Coefficient**	Correlation Description
Sunday	0.566	Strong positive correlation
Monday	0.579	Strong positive correlation
Tuesday	0.490	Moderate positive correlation
Wednesday	0.595	Strong positive correlation
Thursday	0.621	Strong positive correlation
Friday	0.649	Strong positive correlation
Saturday	0.563	Strong positive correlation

** Correlation is significant at the .01 level (2-tailed).

At the IDB site there was a very strong, positive correlation between the hourly L_{eqs} and the hourly traffic counts. Therefore as traffic counts increased so did the L_{eqs}. The results of the analysis are below:

Table 18:: Correlation analysis of hourly L_{eqs} with hourly traffic counts at IDB

Day	Spearman Rank Order Correlation Coefficient**	Correlation Description
Sunday	0.725	Strong positive correlation
Monday	0.767	Strong positive correlation
Tuesday	0.839	Strong positive correlation
Wednesday	0.800	Strong positive correlation
Thursday	0.762	Strong positive correlation
Friday	0.834	Strong positive correlation

Saturday	0.785	Strong positive correlation

** Correlation is significant at the .01 level (2-tailed).

It should be noted that the above results only indicated if high traffic counts and high sound levels (or vice versa) tend to occur together. Whether this link was a direct link or indirect link was not investigated. For example, increased traffic counts could mean an increase in other sources of noise e.g., person related sounds and general business activity which could instead be the direct factor(s) for increased sound levels.

In summary, the study found that an increase of traffic volume was associated with an increase in noise levels at two sites (IDB and PAWI) while at Christ Church Post Office the relationship varied, with weekend days showing low to moderate correlation between traffic and noise levels.

7.0 Discussion

The sound levels in all the areas monitored met the WHO guidelines for industrial, commercial shopping and traffic areas (i.e. L_{Aeq} of 70dB and a L_{Amax} of 110dB over a 24hr period) as the (L_{Aeq}) for the three sites ranged from 57 to 69dBA and the L_{Amax} from 85 to 103dBA. However the sound levels exceeded the WHO guidelines for residential areas (i.e. L_{Aeq} of 55dBA during the day (16hrs, 7:00-23:00) and at night (8hrs, 23:00-7:00) an L_{Aeq} of 45dBA). At the Christ Church Post Office the $L_{Aeq,\ 7:00-23:00}$ varied from 61-76dBA and the $L_{Aeq,\ 23:00-7:00}$ varied from 52-76dBA. At PAWI the $L_{Aeq,\ 7:00-23:00}$ varied from 54-71dBA and the $L_{Aeq,\ 23:00-7:00}$ varied from 48-67dBA. And at IDB the $L_{Aeq,\ 7:00-23:00}$ varied from 61-73dBA and the $L_{Aeq,\ 23:00-7:00}$ varied from 56-65dBA. Therefore all the sites monitored exceeded the WHO guidelines for residential areas while being acceptable for a commercial/industrial area. This was especially instructive as PAWI and IDB were near residential areas. The diverse land use within Oistins could present a problem when comparing it to many international standards including the World Health Organization's Community Guidelines as they often do not account for mixed use areas but provide noise limits for individual zones/areas e.g. strictly residential or strictly commercial. Currently in Barbados the WHO guideline levels are used as absolute limits. In some jurisdictions however the increase above the background is used (e.g. a BS4142 assessment).

Both assessment criteria have their pros and cons. Suggested assessment criteria for the entertainment noise are provided at the end of this section.

The most observed sources of noise was traffic followed by people (e.g. talking or soliciting of customers), animals (e.g. birds) and entertainment noise. As would be typical in towns, the areas were mainly used for commercial activities with some having added types of activities e.g. entertainment and mass transportation activities. The intent of the study was to monitor within at least one of the residential areas but no suitable location with a flat, secure space could be identified.

The results indicated that the eastern side of the central core (Christ Church Post Office Site) was noisiest and the northern end was the quietest. PAWI had the lowest L_{Aeq} for any 24hr period, with Christ Church Post Office being the highest (marginally above IDB on most days). The same trend was observed with the L_{A10}. With the L_{A90} PAWI again was the lowest but IDB generally had the highest value. This was expected at the eastern end is surrounded by the greatest activity such as a bus terminal, traffic congestion, commercial shops and vendors. On the other hand the northern site (PAWI) is surrounded by a moderately used roads (and no congestion usually) and residential areas. IDB's most significant sources of activity were high traffic volumes and the sea wave action (during quiet periods) and hence expected to fall between the two other sites.

Visual inspection of the graphs in Appendix B revealed that the sound levels at Christ Church Post Office and IDB generally were constant between 6:30am and 6:00pm after which the levels dipped. The exception being at Christ Church Post Office where the sound levels would rise when there was entertainment music being played in the central core area. At PAWI there was no clear trend in the noise levels over the course of the day. It was possible, though not verified, that the activities at PAWI may have influenced the readings or the inclined road coupled with the widely varying traffic volumes resulted in significant variation in the sound levels during the day.

In Barbados Sundays were typically quiet and while this trend was noted during monitoring at the IDB and PAWI locations it was not evident at the Christ Church Post Office location.

Statistical tests as well as visual inspection of the L_{Aeq} data indicated that the noise levels on Sunday at the post office was similar to some of the regular weekdays. Additionally there was mixed correlation coefficient results at the Post Office site, indicating that traffic was not the only major contributor to the noise climate at that location. Based on the surveillance of activities at the site, entertainment noise was most likely a significant contributor also. At the other locations there was a strong, positive correlation with traffic indicating that as traffic increased at those locations so did the sound levels.

Suggested ways of reducing/managing the sound levels in Oistins are:

- *Monitoring, educating the public and setting reduction targets:* Suggestions include the installation of a permanent monitoring station(s), setting a reduction target (e.g. decrease by 5dBA in 10 years), creating a public awareness of the effects of noise.
- *Reducing traffic noise*: Possible options are paving roads with noise dampening asphalt, maintaining the road surface, encouraging the use of quieter vehicles (e.g. with tax deductions, reduce importation taxes), discouraging the unnecessary use of vehicle horns, use of electric powered buses.
- *Reducing the impact of noise at the receptor*: This could be done by setting a minimum sound transmission class of building materials in the area and restricting the number of dwellings and density in some areas. Installing noise barriers/buildings or setting buffer areas may also be investigated but will most likely be impractical due to space limitations.
- *Minimizing the impact of the entertainment noise*: Some measures that could be implemented in Oistins are an enforced cut-off time, the use of a sound level limiter, instructing sound engineers/ disk jockeys to reduce the bass component, orient the speakers as much as possible away from the direction of sensitive receptors (e.g. South East/ in the direction of the stalls which could act as barriers), multiple, small, low power speakers compared to fewer but more powerful speakers and reduced sound limits as the night progresses.

The wind speed recorded at the Grantley Adams International Airport (GAIA) was above the preferred 1-5m/s and there was rainfall on some days during monitoring. A windscreen was used to reduce the effect of the wind and it was noted that GAIA's station was located in an open field while within Oistins there were buildings which could shield/reduce the wind speed. Nonetheless, it was therefore possible that the sound levels recorded during monitoring were higher than those which would be recorded under preferable weather conditions.

During entertainment, the $L_{Aeq,\ 15min}$ at 10m in front the stage was 83-94dBA, which was consistent with values reported in literature. Workplace noise evaluation was outside the scope of this project but given the high values of the L_{Aeq} and that the entertainment continues at around these levels for at least 6hrs it should be investigated as workers as well as patrons are often closer than 10m to the stage. In Barbados the draft Workplace (Noise) Regulations 2007 proposed a lower workplace noise limit of 80dBA (L_{eq8hr}) and an upper limit of 85dBA ($L_{eq\ 8hr}$) (Government of Barbados, 2007).

The 31.5Hz, 63Hz and 125Hz were the dominant octaves during entertainment. At Christ Church Post Office and PAWI when entertainment music was played the 63Hz and 125Hz octaves generally increased significantly (compared to the other octaves). For example at Christ Church Post Office on 26th May 2017 it was noted that the spectrum of the sound level changed when the entertainment began. During the day generally the 16Hz octave had the most sound energy followed by the 31.5Hz, 63Hz, 125Hz, 250Hz, 500Hz, 1000Hz, 2000Hz, 4000Hz and lastly 16000Hz. However when the music began the 63Hz and 125Hz dominated the spectrum at the Post Office. A similar trend was noted on some other days which suggest that music was played (See Appendix C) as there was a significant increase in the energy content in the 63Hz and 125Hz. It was also noted by Oistins Bay Management that music was sometimes played on other days but at a lower level. There was also a notable increase in 31.5Hz octave at PAWI (See Appendix C). On Sunday and Thursday there were comparatively lower increases in the 63Hz and 125Hz bands suggesting low music levels. At PAWI on 16th June 2017 it was noted that the spectrum of the sound level during the entertainment period realized a notable increase in the 31.5 Hz, 63Hz and 125Hz. However unlike Christ Church Post Office the spectrum at PAWI during the day was not usually uniform but contained erratic bursts of energy in the middle to upper frequencies e.g. 2kHz to 4kHz resulting in these octave having very similar sound levels to the lower frequencies such as 125Hz and 250Hz and 1kHz. As stated earlier the reason for the erratic spectrum is unclear. At IDB the frequency spectrum exhibited similar trends on all days monitored with no significant change in the character of the noise during entertainment periods. This is in keeping with the fact that noise from Oistins Bay Gardens is not usually audible at this end of the mixed corridor. It was also noted that the 63Hz is often dominant at this location during the quieter periods of the day at this location due to a decrease in the sound energy at the 16Hz and 31.5Hz. In Oistins Bay Gardens during entertainment the lower frequencies contained the most sound energy and the higher frequencies the least. The only anomalies were the 16Hz and 31.5Hz. A possible reason for these two anomalies was that at 10m from the stage (source) the sound level meter/microphone was within the near field for these frequencies hence the erratic behavior (See Appendix C).

Given the low frequency content of the music, the acoustic principle that low frequencies travel long distances, that low frequencies are under-represented in A-weighted descriptors and that sounds in these frequencies are typically associated with complaints, it would be best when assessing entertainment noise to assess the low frequencies as well as the overall A-weighted noise descriptors. Determining a suitable assessment criteria/procedure was outside the scope of this study but a possible one is outlined at the end of this section.

The Environmental Protection Department approved developments across the island and as a result have to assess the potential impact on nearby receptors. Additionally open air entertainment was part of Barbadian culture and supports the economy but the noise can also be a nuisance to nearby receptors. The study looked at two prediction noise models- inverse square law and an ISO 9613 based model- and compared the results to the measured noise levels. In general both models predicted the downwind location's value (the site near Welches) better than the upwind location (Christ Church Post Office). The ISO-9613 based model predicted slightly better values than the inverse square law but took significantly longer to calculate and required more data input (e.g. height of receptor, height of source, separation distance, humidity, temperature, barrier dimensions, directionality etc.). For regulatory purposes, especially given the lack of sophisticated software, the inverse square law is suggested as a suitable model/ estimate when predicting outdoor noise. With both methods the assumption used was that background levels remained constant (or close to) during entertainment. As was noted earlier the sound levels typically dropped around 6pm, which is the same time that the music started. This may explain why in many cases both models overestimated the levels i.e. the residual level (pre entertainment) was not what the residual levels were during entertainment.

Suggested evaluation criteria for entertainment noise

As the Oistins mixed corridor is used for both commercial and residential purposes, this could present challenges with using absolute values as limits. The below criteria are suggested criteria for assessing entertainment noise.

- At the nearest existing/potential residence (1m from the façade), to the North, East, South and West of the venue, the L_{AF90} without the entertainment noise should not increase by more than 3dB when the entertainment noise occurs between 9:00 and 23:00hrs (or to be determined on a case by case basis).
- At the nearest existing/potential residence (1m from the façade) to the North, East, South and West of the venue the L_{AFeq} without the entertainment noise should not increase by more than 3dB when the entertainment noise occurs between 9:00 and 23:00hrs (or to be determined on a case by case basis).
- At the nearest existing/potential residence (1m from the façade) to the North, East, South and West of the venue the L_{eq} of the 63Hz and the L_{eq} of the 125Hz (1/1 octave band) without the entertainment noise should not increase by more than 3dB when the entertainment noise occurs between 9:00 and 23:00hrs (or to be determined on a case by case basis).
- Noise outside of these hours 23:00pm -9:00 am (or to be determined on a case by case basis) should cause no increase in the L_{AF90}, L_{AFeq}, L_{eq} of the 63Hz or the L_{eq} of the 125Hz.
- In general for proposed loud entertainment venues, especially those to be used regularly, it would be prudent that an estimate of the sound levels to be expected at the

nearest existing/potential residence should be done. This could be done via measurement or calculation or a combination. Similarly, if a housing development is to be constructed close to an approved entertainment venue (e.g. within 500m) the housing developer and prospective owners should be made aware that persons in this environment may experience above average sound levels.

- Factors to be considered include the building materials used by the surrounding houses, the contribution to the national economy, the frequency of the activity, the temporal/permanent nature of the activity, any barriers, possible changes to the environment (e.g. increase or decrease in the number of buildings), noise control measures the entertainment venue has/will have in place (e.g. noise limiters, policies, orientation of speakers, height of speakers, enclosures, outdoor versus indoor entertainment, barriers, location of venue buildings)

The rationale for allowing a three decibel (3dB) increase is that this increase represents a doubling of acoustic energy and is barely perceptible by most persons (Bolt Baranek and Neuman, 1973). It should be noted that five decibel (5dB) change is readily noticeable. As indicated earlier A–weighted noise descriptors under represent the lower octaves and the 63Hz and 125Hz were identified as being prominent lower octaves in entertainment music. Hence these octaves were identified for specific analysis. The above suggested procedure is not expected to be static but rather dynamic and allowed to evolve with increased knowledge and discussion.

8.0 Conclusions, Recommendations and Critical Assessment

The following conclusions were made:

- In general the noise levels persons were exposed to while in Oistins, at the sites monitored, were within W.H.O. guidelines for community noise for industrial, commercial shopping and traffic areas. However the values exceeded the guideline values for residential areas. The sound levels over a week, with and without entertainment, varied from $L_{Aeq,15min}$ 57 to 75, $L_{Amax,\ 15min}$ 71- 103dBA, $L_{Amin,\ 15min}$ 48 to

65dBA.

- Traffic noise was the main observed activity near the monitoring sites followed by people (talking, liming) and animals (e.g. birds).
- The relationship between L_{Aeq} and traffic counts was investigated using Spearman's rank order correlation. At Christ Church Post Office there was varying correlation between the two variables with weak, moderate and strong, positive correlations being found. At PAWI there was generally strong, positive correlation between the two variables. At IDB there was strong, positive correlation between the two variables. The study found that an increase of traffic volume was associated with an increase in noise levels at two sites (IDB and PAWI) while at Christ Church Post Office the relationship varied, with weekend days showing low to moderate correlation between traffic and noise levels. The low to moderate correlation on weekend days at the Christ Church Post office suggests another source, most likely entertainment noise, was influencing the noise climate at that site during the weekends.
- The results indicated that the eastern side of the central core (Christ Church Post Office Site) was noisiest and the northern end was the quietest. The sound levels at Christ Church Post Office and IDB generally were constant between 6:30am and 6:00pm after which the levels dropped. The $L_{eq,24hr}$ ranged from 57 to 69dBA, the $L_{Amax, 24hr}$ from 85 to 103dBA, the $L_{A10,24hr}$ from 59 to 74dBA and the $L_{A90,24hr}$ ranged from 49 to 60dBA at the monitoring sites.
- During entertainment, the $L_{Aeq, 15min}$ at 10m in front the stage was 83-94BA and the 63Hz, 125Hz and 31.5Hz were the dominant octaves which was consistent with values reported in literature. At the receptor monitoring sites the sound levels varied from $L_{Aeq, 15min}$ 57 to 75dBA,$L_{Amax, 15min}$ from 71 to 103dBA and $L_{Amin, 15min}$ from 48 to 65dBA. During Friday night entertainment the sound levels at Oistins Bay Gardens were $L_{Aeq, 15min}$ 83- 94dBA, $L_{Amax, 15min}$ 93 to 103dBA, and $L_{Amin, 15min}$ 57 to 88 dBA at 10m in front of the stage. The dominant octaves during entertainment were the 31.5Hz, 63Hz and 125Hz. At Christ Church Post Office and PAWI when entertainment music was played

the 63Hz and 125Hz octaves generally increased significantly (compared to the other octaves). There was also a notable increase in 31.5Hz octave at PAWI.

- In general the inverse square law predicted the $L_{Aeq,24hr}$ within-2.44 to +3.0 dBA at the Post Office and within -0.8 to +2.8dBA at the monitoring site near Welches. In general the excess attenuation model (based on ISO 9613) predicted the L_{Aeq} within +/-3 dBA at the Post Office and within -2 to +1.5dBA at the monitoring site near Welches. The ISO-9613 based model predicted slightly better values than the inverse square law but took significantly longer to calculate and required more data input (e.g. height of receptor, height of source, separation distance, humidity, temperature, barrier dimensions, directionality etc.). With both methods the assumption used was that background levels remained constant (or close to) during entertainment. As was noted earlier the sound levels typically dropped around 6pm, which is the same time that the music started. This may explain why in many cases both models overestimated the levels i.e. the residual levels (pre entertainment) was not what the residual levels were during entertainment.
- The L_{Aeq} values recorded on Sundays were similar to or quieter than any other day of the week at PAWI and IDB. However at Christ Church Post Office Sundays were similar to or louder than any other day of the week. This observation at Christ Church Post Office is atypical of Sundays in Barbados but was expected as entertainment music is played (though quieter) on Sundays.
- It is suggested that low frequencies (63Hz and 125Hz) as well as the overall A-weighted noise descriptors be investigated when assessing entertainment noise. Determining a suitable assessment criteria was outside the scope of this study but it is suggested that the increase in these octaves at the receptor location could be a possible assessment method in addition to the A-weighted noise descriptors. Alternatively limits could be set on each octave or 1/3 octave of interest. A possible assessment process and criteria are outlined in Section 7.0.

The following recommendations and critical assessment are made:

- In order to maintain the sound levels in Oistins at acceptable levels, future projects or programmes planned for Oistins should take sound levels into consideration.
- Suggested ways of reducing/managing the sound levels in Oistins are:
    - *Monitoring, educating the public and setting reduction targets:* Suggestions include the installation of a permanent monitoring station(s), setting a reduction target (e.g. decrease by 5dBA in 10 years), creating a public awareness of the effects of noise.
    - *Reducing traffic noise*: Possible options are paving roads with noise dampening asphalt, maintaining the road surface, encouraging the use of quieter vehicles (e.g. with tax deductions, reduce importation taxes), discouraging the unnecessary use of vehicle horns, using of electric powered buses.
    - *Reducing the impact of noise at the receptor*: This could be done by setting a minimum sound transmission class of building materials in the area and restricting the number of dwellings and density in some areas. Installing noise barriers/buildings or setting buffer areas may also be investigated but will most likely be impractical due to space limitations.
    - *Minimizing the impact of the entertainment noise*: Some measures that could be implemented in Oistins are an enforced cut-off time, the use of a sound level limiter, instructing sound engineers/ disk jockeys to reduce the bass component, orient the speakers as much as possible away from the direction of sensitive receptors (e.g. South East/ in the direction of the stalls which could act as barriers), multiple, small, low power speakers compared to fewer but more powerful speakers and reduced sound limits as the night progresses.
    - *Mandatory compensation for affected properties:* The compensation could be in the form of retrofitting the property to improve sound insulation.
- As the Oistins mixed corridor is used for both commercial and residential purposes, this could present challenges with using absolute values as limits. The criteria identified in

Section 7.0 are suggested criteria for assessing entertainment noise/ mixed used areas.

- Similar baseline data should be collected for other areas in Barbados.
- Depending on the purpose of the study/investigation, only areas where short-term sampling during the busiest/noisiest periods exceeds desired limits may require further long-term monitoring. This could be part of the criteria for site selection, as it would increase the efficiency with which resources are used.
- Further training and resources should be obtained for capacity building of the Environmental Protection Department and by extension Barbados.
- A workplace noise evaluation was outside the scope of this project but given the high sound levels ($L_{Aeq,\ 15min}$ at 10m in front the stage ranged from 83-94dBA), and the fact that the entertainment continues at around these levels for at least 6hrs it should be investigated as workers and patrons were often closer than 10m to the stage. (In Barbados the lower workplace noise limit is 80dBA (L_{eq8hr}) and the upper limit is 85dBA ($L_{Aeq\ 8hr}$).
- The selection of the values to be used as the residual noise levels would have affected the accuracy of the predictive models. Based on the assumption that the residual level remained constant, pre-entertainment values (4:30pm -6:00pm) were used as the residual levels during entertainment. However an assessment of the trend in sound levels in Oistins showed that the sound levels dropped after 6pm. Therefore too high a background or residual for the entertainment period may have been assumed leading to overestimates of the predicted values.
- Due to lack of sophisticated software a simplified approach, one of Maekawa's formulas, was used to calculate the barrier attenuation and only the highest barrier was considered opposed to the method outlined in ISO 9613. This may be responsible for some of the variation between the ISO based predicted levels and the measured levels.
- The receptor points in this study were chosen based on the boundaries outlined for Oistins central core in Barbados' Physical Development Plan and the available resources.

With respect to comparing the measured level with the predicted levels, these sites gave a preliminary idea as to the suitability of the models. However based on the outcome a more rigorous study e.g. using more receptor sites at regular intervals e.g. at 20m, 40m, 60m etc. would allow for more comprehensive data to be acquired and firmer conclusions. At the sites used for this study (130m and 196m from the source) the residual noise was a significant contributor.

- In planning a measurement survey, defining the entertainment area is crucial as well as identifying all the major sources. It was noted that while there was one main stage, some businesses also played amplified, entertainment music.
- 1/3 octave analysis would have allowed for a better assessment of the entertainment noise as there would be enhanced sensitivity of the data allowing for tones and trends to be clearer.

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Appendix A: Meteorological Data

Appendix A 1: Meteorological data during monitoring at Christ Church Post Office (21st - 28th May 2017)

DAY	CLOUDS (/8)	WIND DIRECTION (Degree direction)	WIND SPEED (knots)	DRY BULB (°C)	RH (%)	StN PRESSURE (mbar)	MSL (mbar)	24 HR Rainfall (mm)
21	4	90	18	28.2	75	1005.8	1013.5	0.0
22	6	80	17	28.2	74	1006.7	1014.4	0.0
23	7	85	19	28.1	75	1007.5	1015.2	0.0
24	6	90	18	28.1	71	1008.2	1015.9	0.0
25	3	85	16	28.0	71	1008.3	1016.0	0.0
26	3	90	16	27.9	69	1007.6	1015.3	14.9
27	5	100	15	27.0	80	1007.3	1015.0	2.0
28	6	105	16	27.8	81	1007.3	1015.0	0.1

Appendix A 2: Meteorological data during monitoring at PAWI (13th - 19th June 2017)

DAY	CLOUDS (/8)	WIND DIRECTION (Degree direction)	WIND SPEED (knots)	DRY BULB (°C)	RH (%)	StN PRESSURE (mbar)	MSL (mbar)	24 HR Rainfall (mm)
13	7	85	16	27.5	79	1006.2	1013.9	18
14	7	55	13	25.2	90	1007.4	1015.1	45
15	5	90	16	27.3	79	1007.5	1015.2	0
16	4	80	16	27.8	73	1007.3	1015.0	0
17	4	75	17	27.5	74	1006.4	1014.1	2.2
18	6	100	17	27.2	84	1005.3	1013.0	8.4
19	7	90	21	27.1	79	1006.3	1014.0	20.1

Appendix A 3 Meteorological data during monitoring near Welches/Digicel (23rd June 2017)

DAY	CLOUDS (/8)	WIND DIRECTION (Degree direction)	WIND SPEED (knots)	DRY BULB (°C)	RH (%)	StN PRESSURE (mbar)	MSL (mbar)	24 HR Rainfall (mm)
23	4	100	13	27.6	75	1005.2	1012.9	0

Appendix A 4: Meteorological data during monitoring at IDB (12th - 18th July 2017)

DAY	CLOUDS	WIND DIRECTION (Degree direction)	WIND SPEED	DRY BULB	RH	StN PRESSURE	MSL	24 HR Rainfall (mm)
12	5	100	13	28.0	78	1007.3	1015.0	0
13	6	75	16	28.3	78	1007.6	1015.3	0.2
14	6	100	17	27.8	83	1007.0	1014.7	5.8
15	5	80	15	27.6	80	1006.9	1014.6	1.5
16	3	85	15	28.1	74	1006.4	1014.1	0.0
17	5	90	17	28.1	76	1006.9	1014.7	4.0
18	6	105	19	27.5	82	1007.0	1014.7	1.0

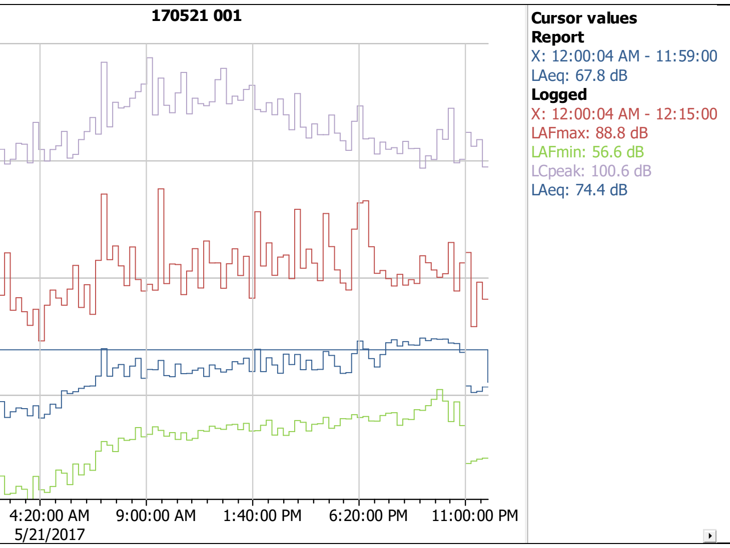
Appendix A 5: Localized Meteorological data during monitoring at Christ Church Post Office (19th - 26th May 2017)

	Date span: 19TH- 24th	Date span: 24th -26th
Wind speed(m/s)	Max: Avg: Min: (not recorded inadvertently)	Max:9.1 Avg: 1.9
Relative humidity (%)	Max:100 Avg: 68.6 Min: 60.1	Max: 76.5 Avg: 69.5 Min:61.4
Temperature: (^{o}C)	Max:33.4 Avg: 29.2 Min:25.9	Max:33.8 Avg: 29.1 Min: 26.4
Atmospheric Pressure (mbar)	Max:881.9 Avg: 864.2 Min: 838.7	Max:874.7 Avg: 859.7 Min: 833.7

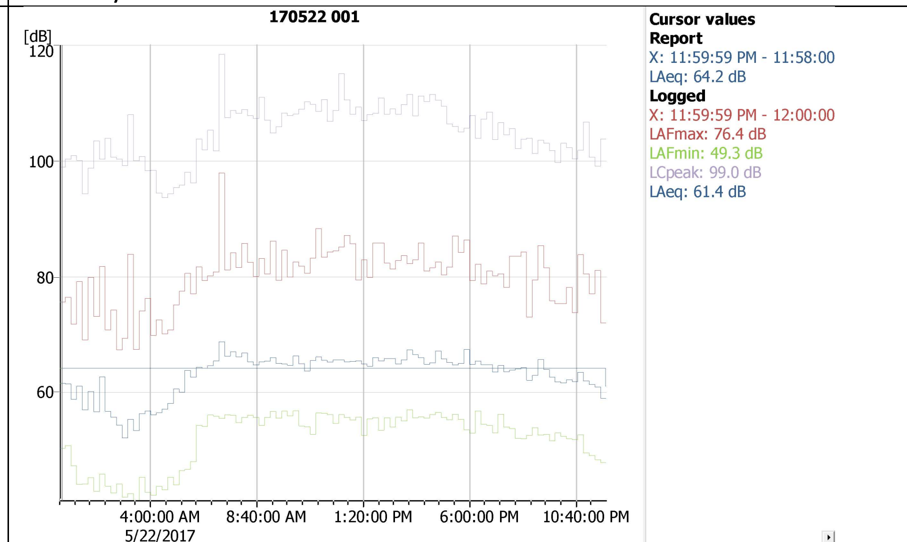
endix B: Graphs of raw noise data

endix B 1: Christ Church Post Office

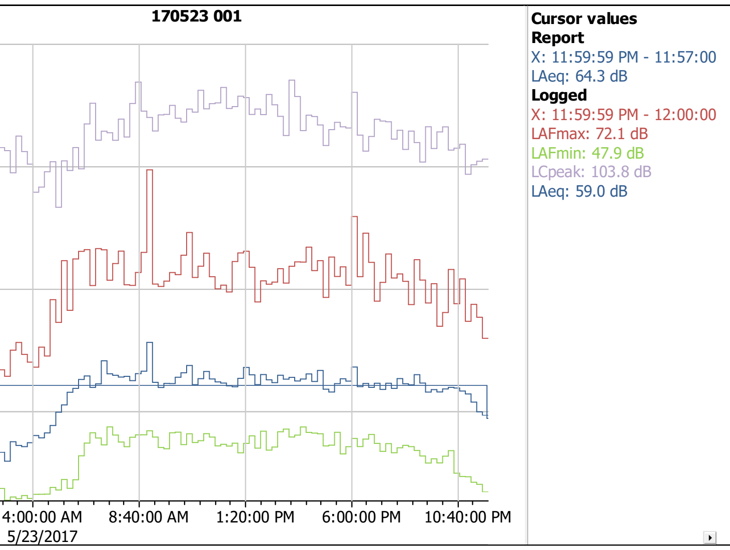
y 2017



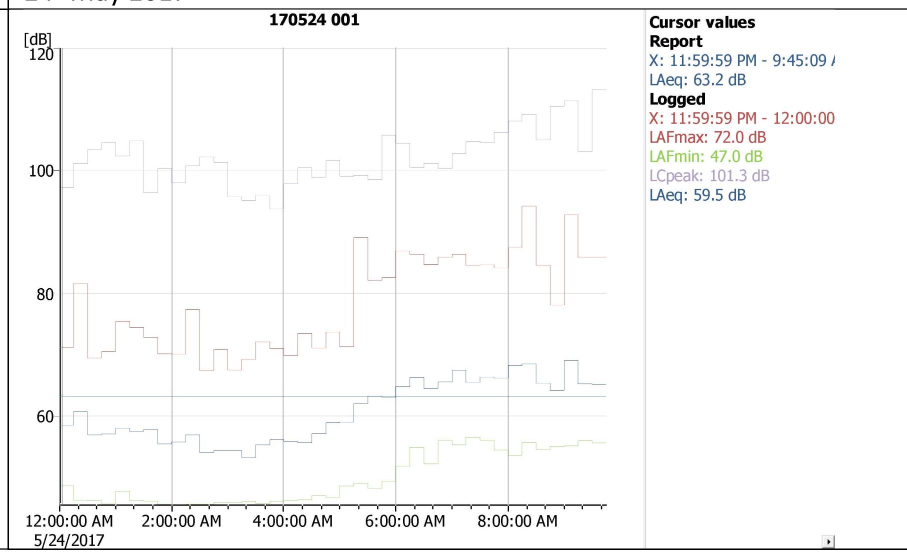
22nd May 2017



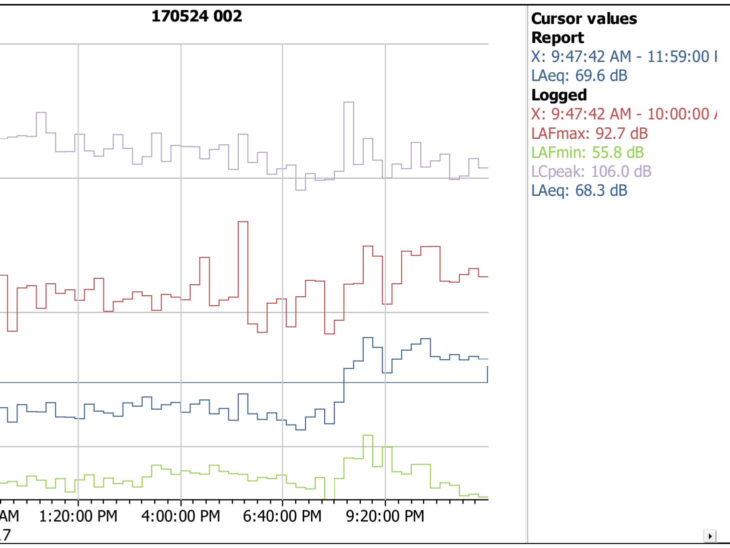
y 2017



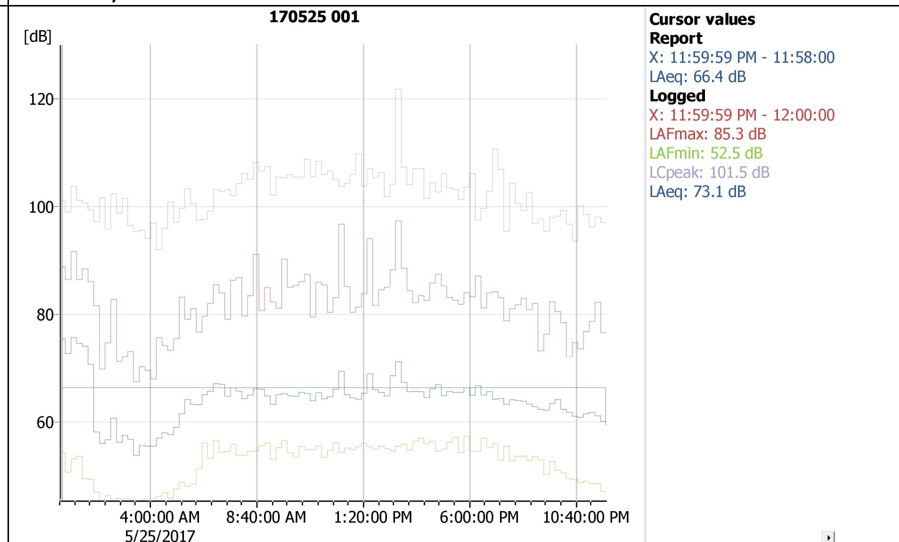
24th May 2017



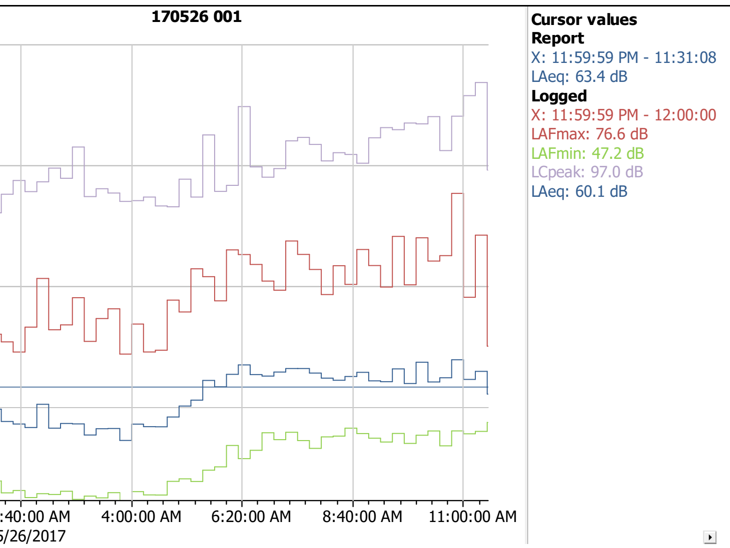
y 2017



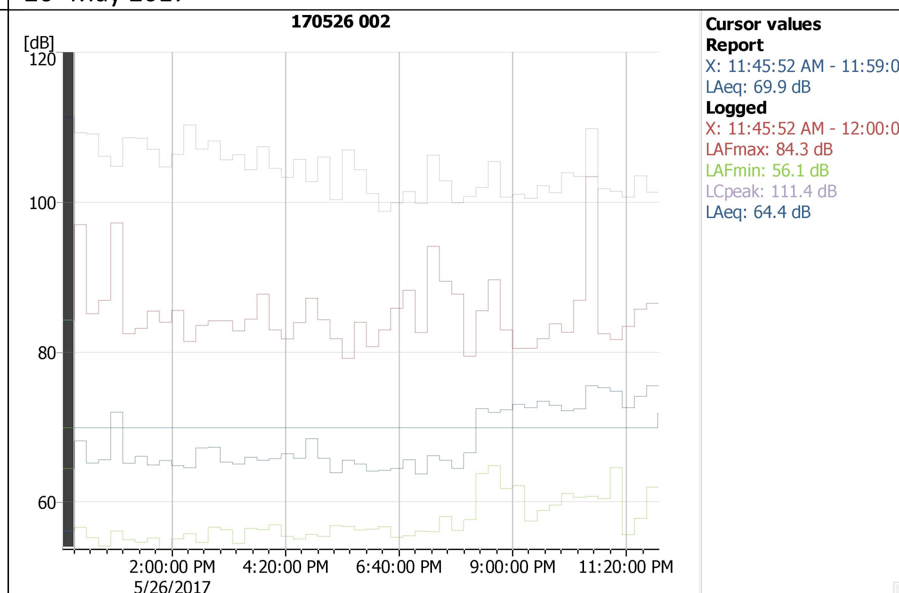
25th May 2017



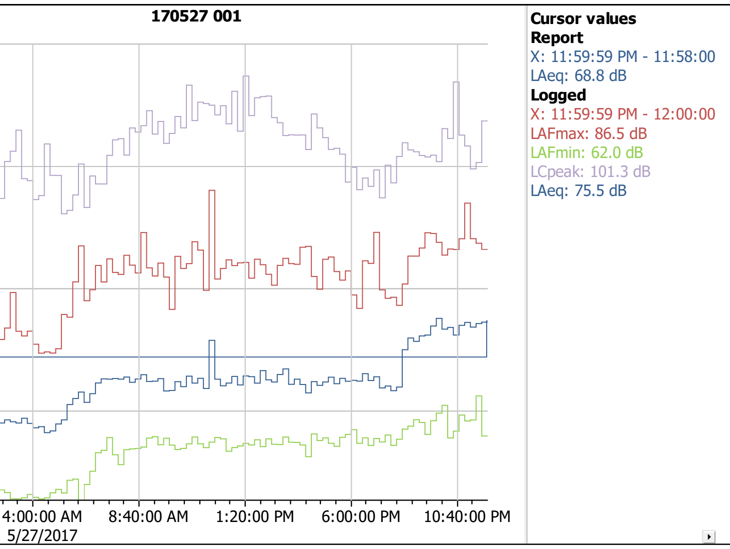
y 2017



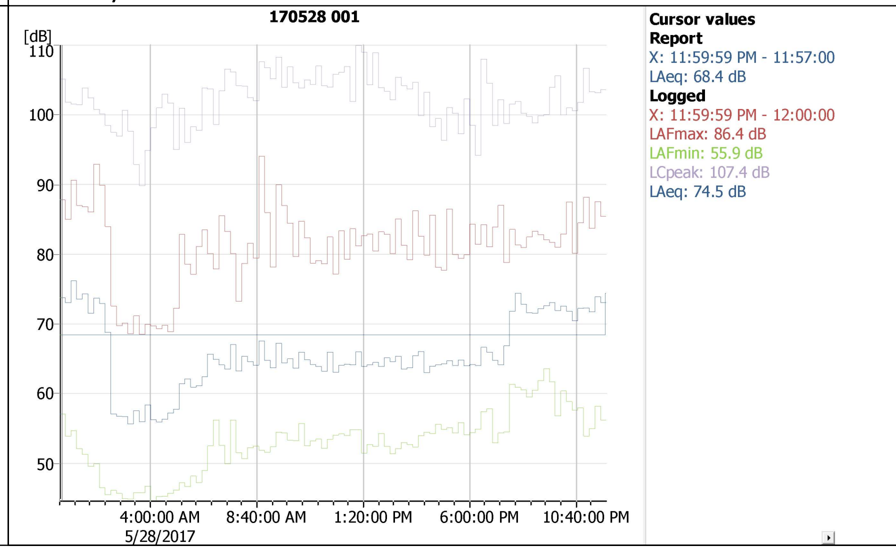
26th May 2017



y 2017

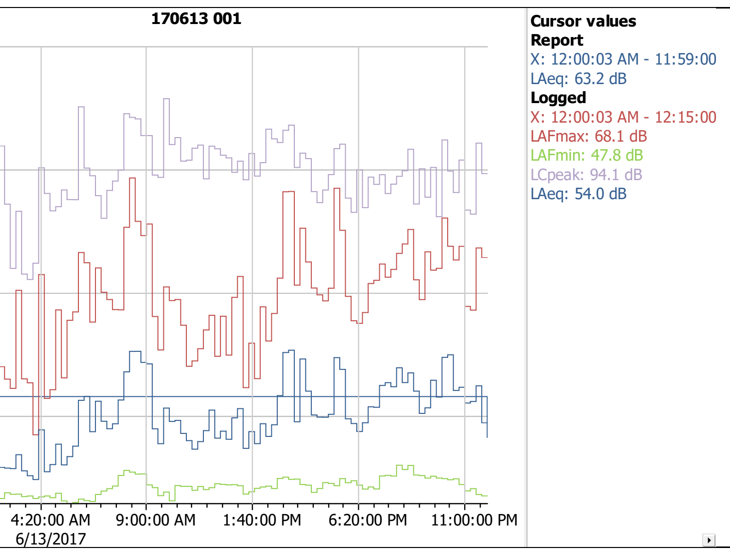


28th May 2017

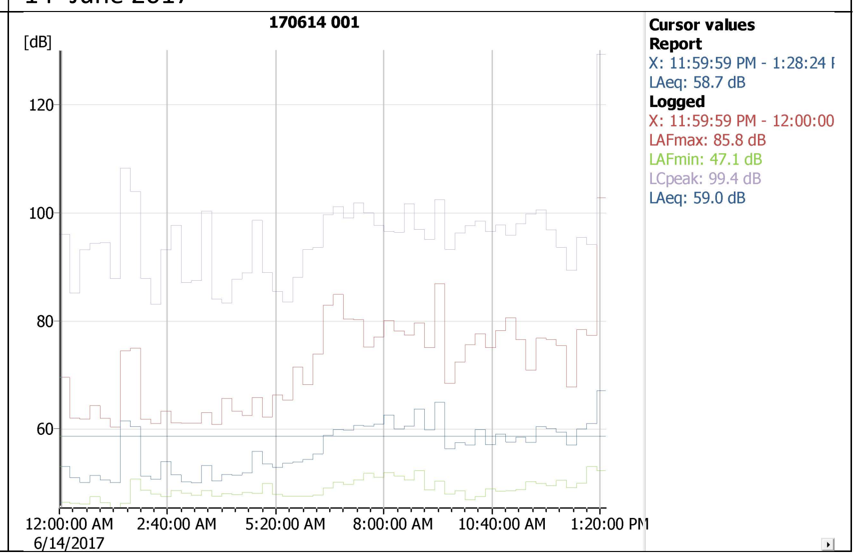


endix B 2: Pentecostal Assemblies of the West Indies

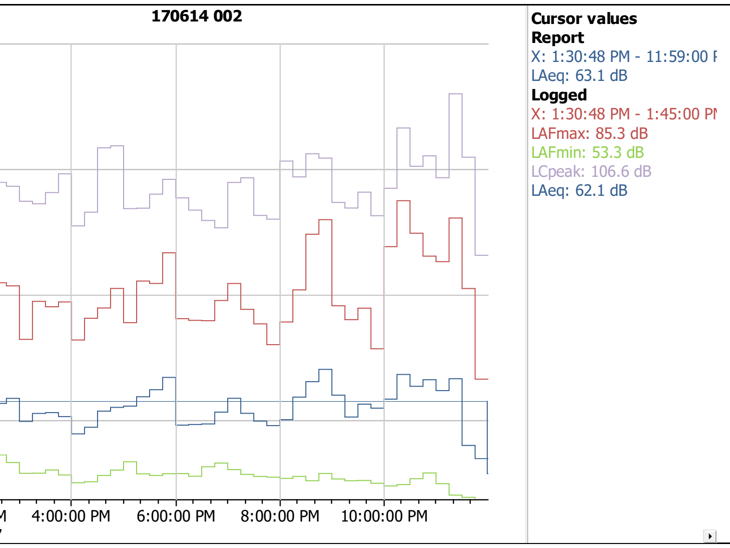
e 2017



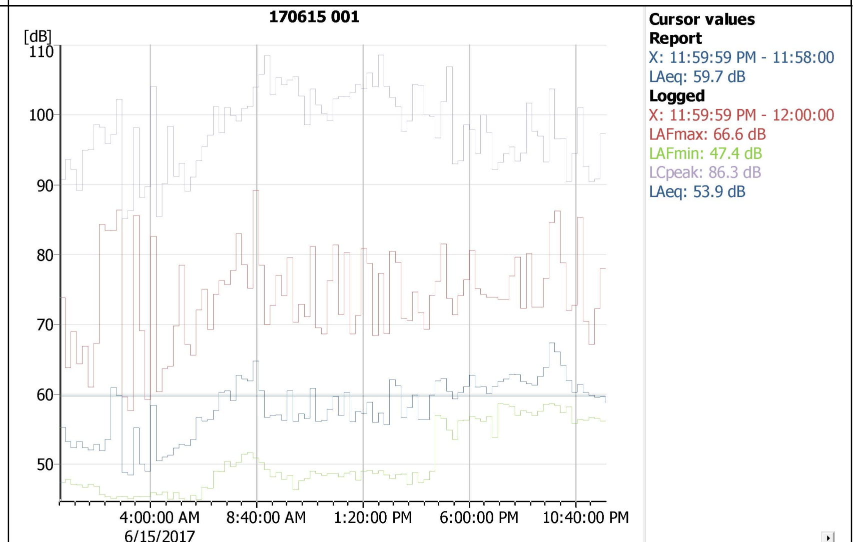
14th June 2017



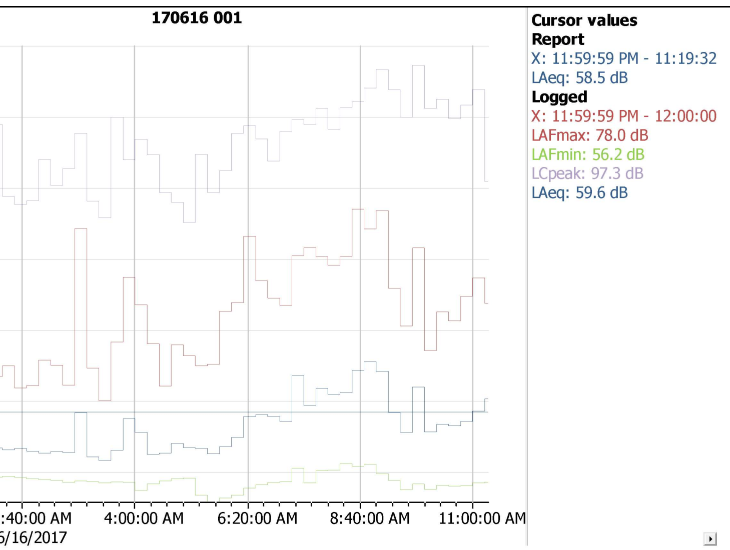
e 2017



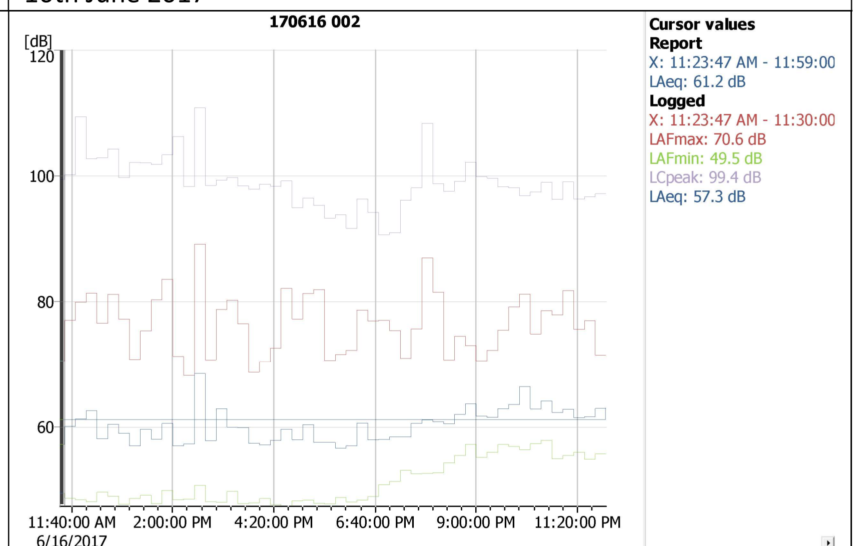
15th June 2017



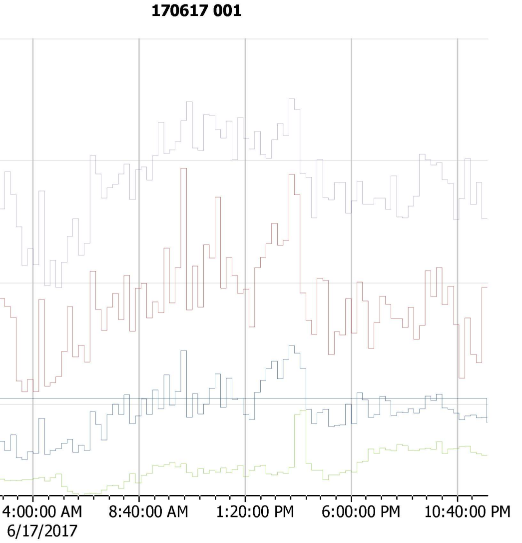
ne 2017



16th June 2017

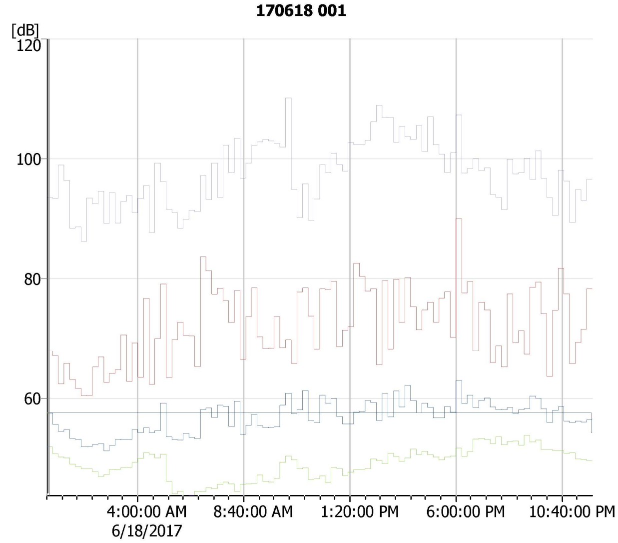


e 2017



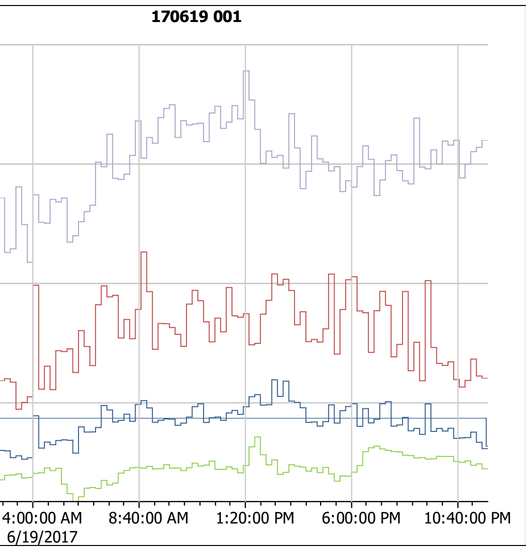
Cursor values
Report
X: 11:59:59 PM - 11:58:00
LAeq: 61.1 dB
Logged
X: 11:59:59 PM - 12:00:00
LAFmax: 71.5 dB
LAFmin: 55.8 dB
LCpeak: 97.2 dB
LAeq: 63.0 dB

18th June 2017



Cursor values
Report
X: 11:59:59 PM - 11:57:00
LAeq: 57.6 dB
Logged
X: 11:59:59 PM - 12:00:00
LAFmax: 79.3 dB
LAFmin: 51.7 dB
LCpeak: 90.6 dB
LAeq: 57.9 dB

e 2017



Cursor values
Report
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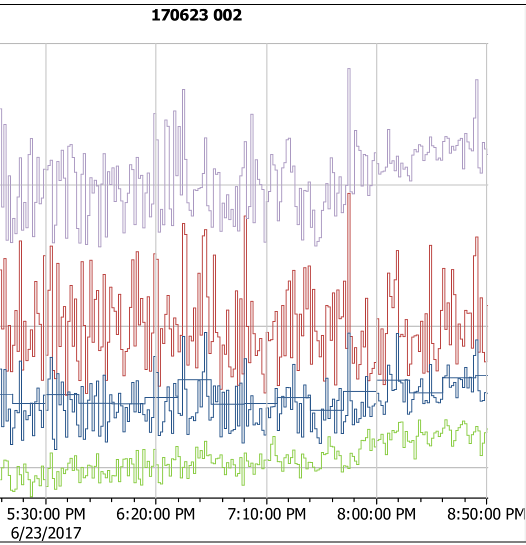
LAeq: 57.5 dB
Logged
X: 11:59:59 PM - 12:00:00
LAFmax: 78.3 dB
LAFmin: 49.6 dB
LCpeak: 96.6 dB
LAeq: 56.4 dB

endix B 3: Welches

e 2017



Cursor values
Report
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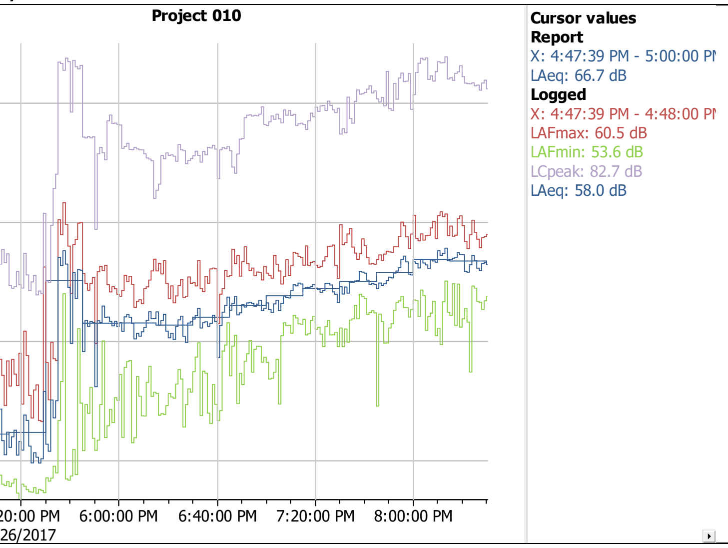
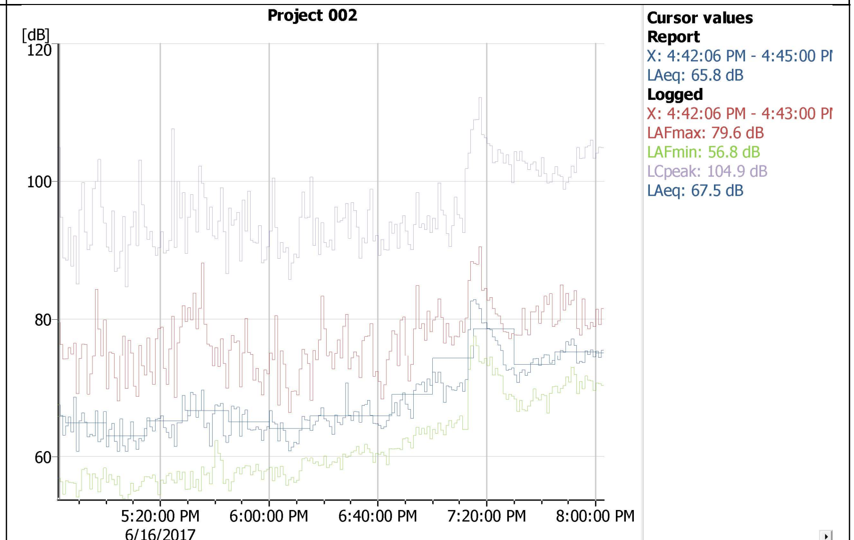
LAeq: 70.3 dB
Logged
X: 4:42:58 PM - 4:43:00 PI
LAFmax: 70.7 dB
LAFmin: 62.0 dB
LCpeak: 90.7 dB
LAeq: 63.4 dB

endix B 4: Oistins Bay Gardens

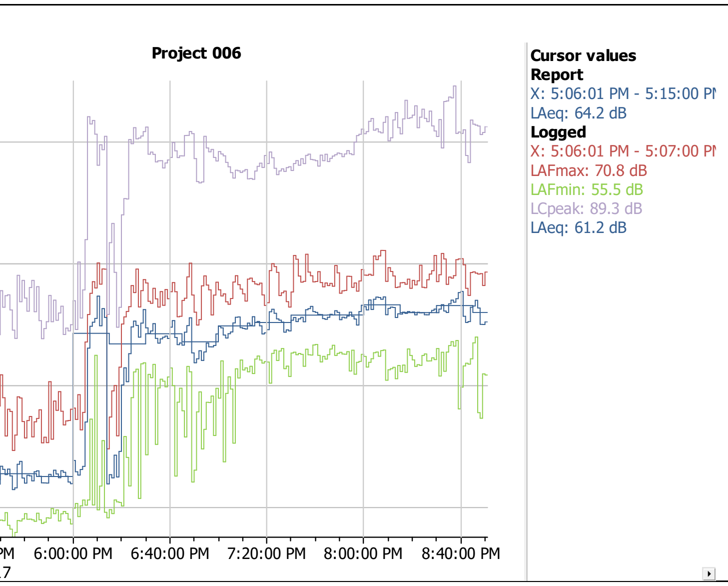
ay 2017



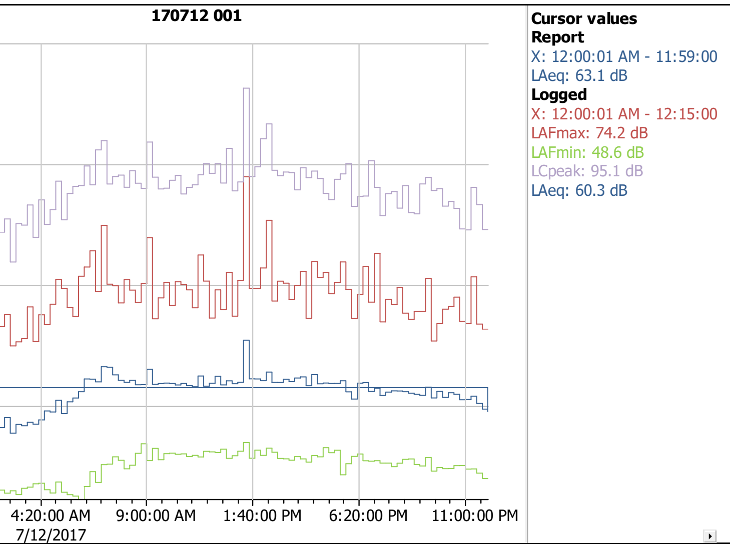
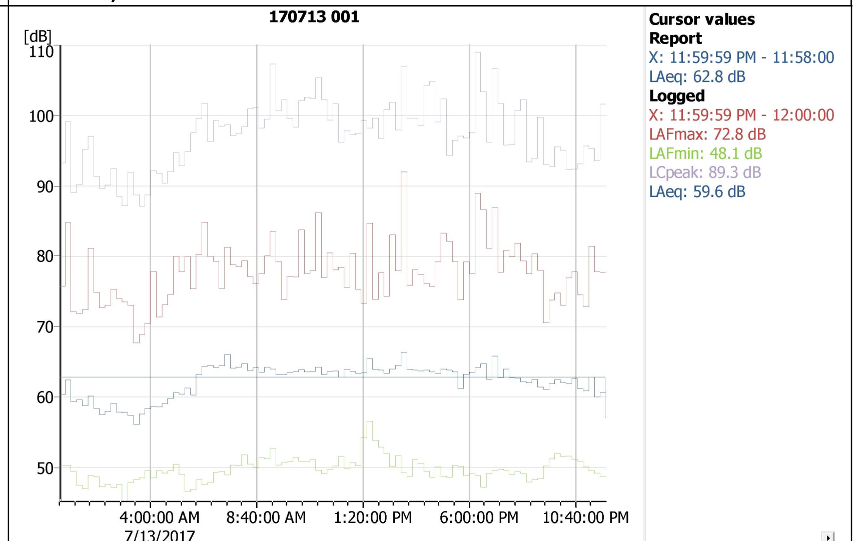
16th June 2017

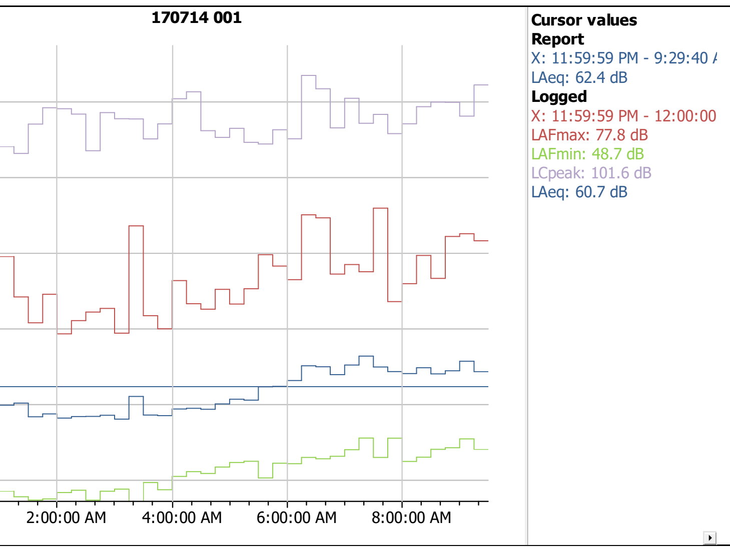
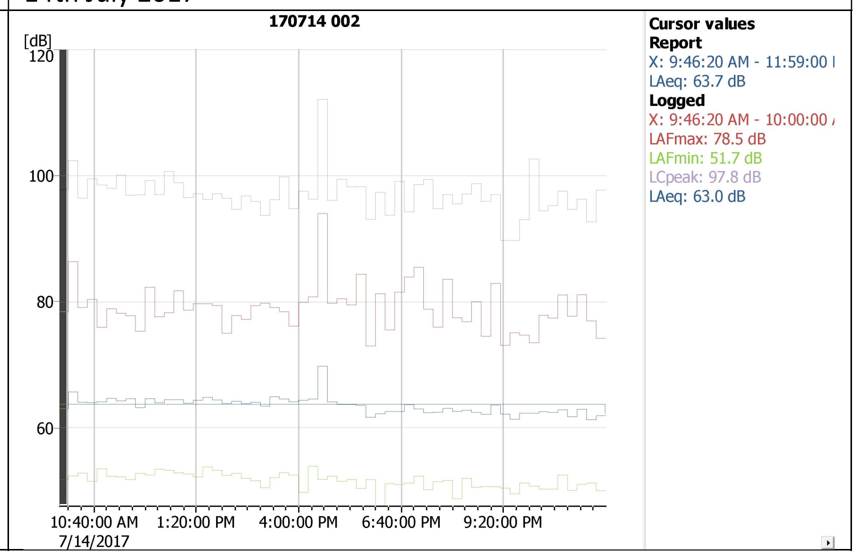


e 2017

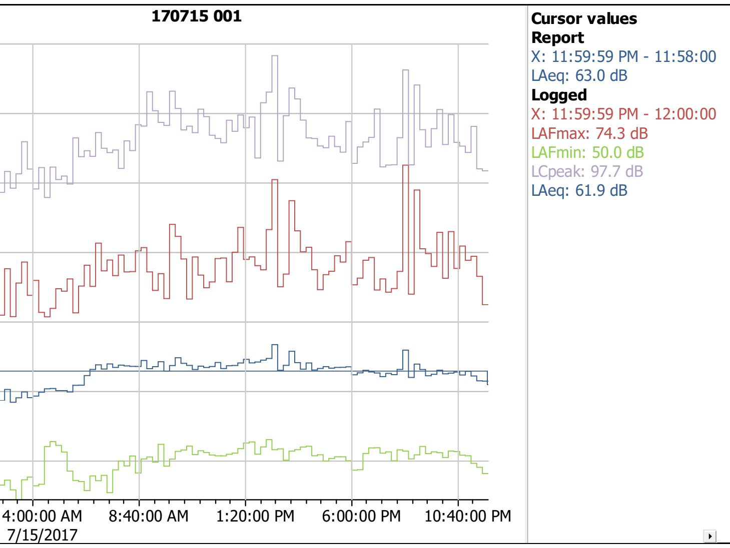


endix B 5: Inter-American Development Bank

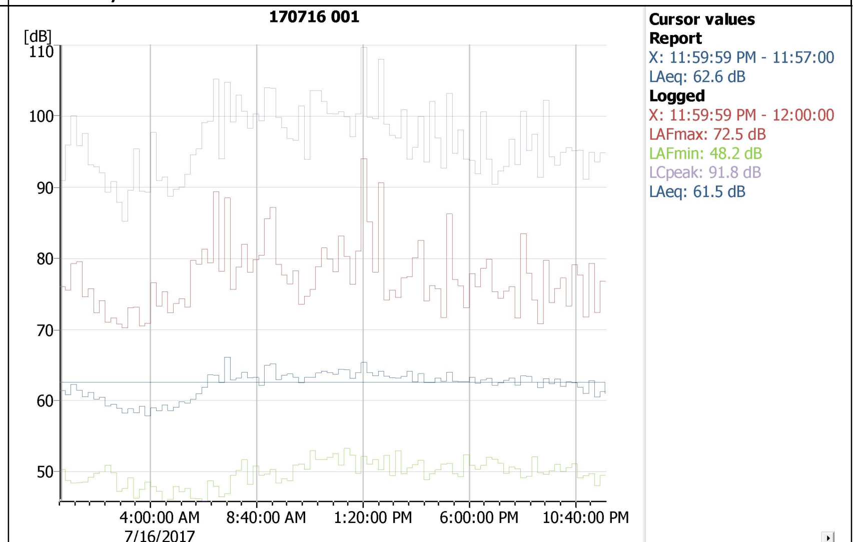
y 2017	13th July 2017
	

y 2017	14th July 2017
	

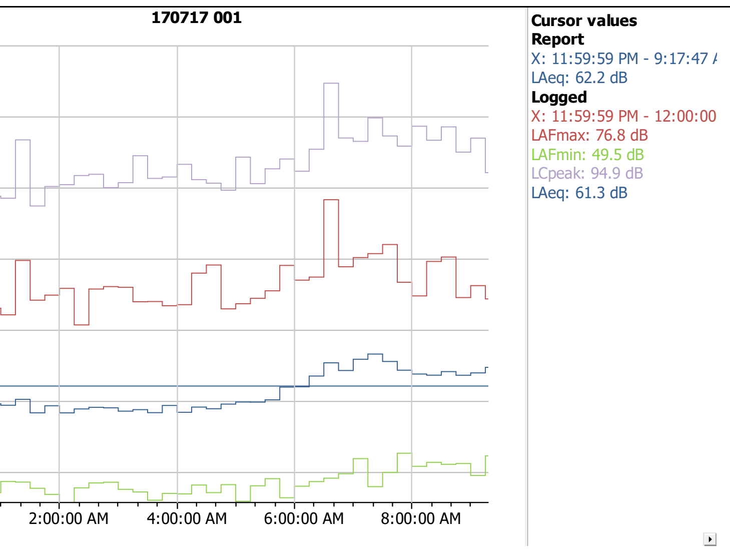
y 2017



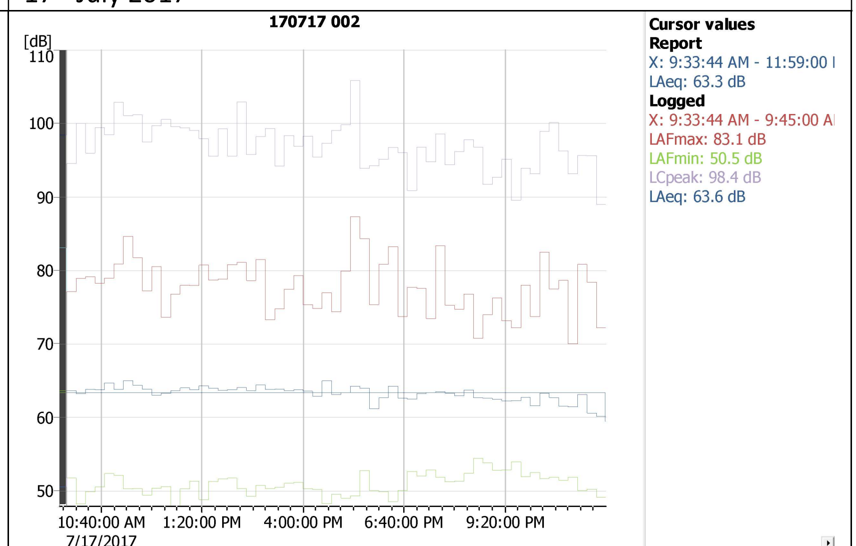
16th July 2017



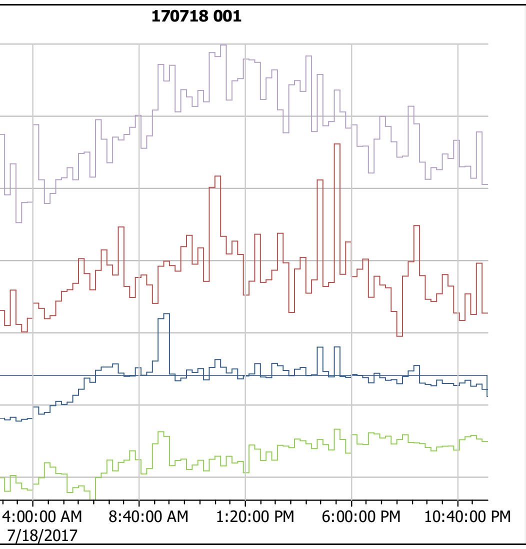
y 2017



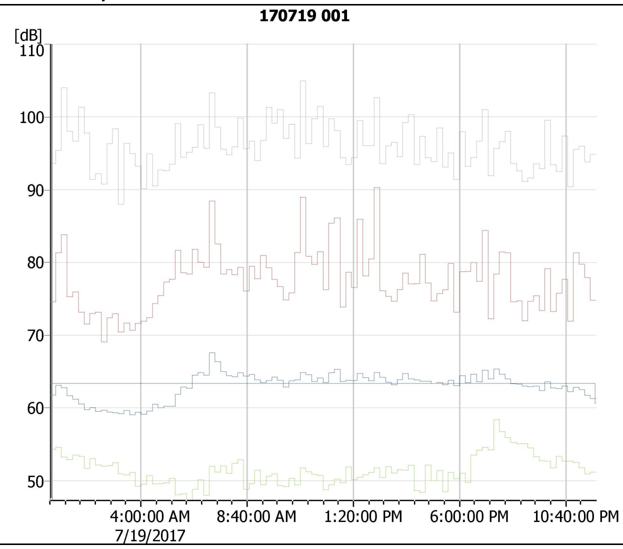
17th July 2017



y 2017	19th July 2017



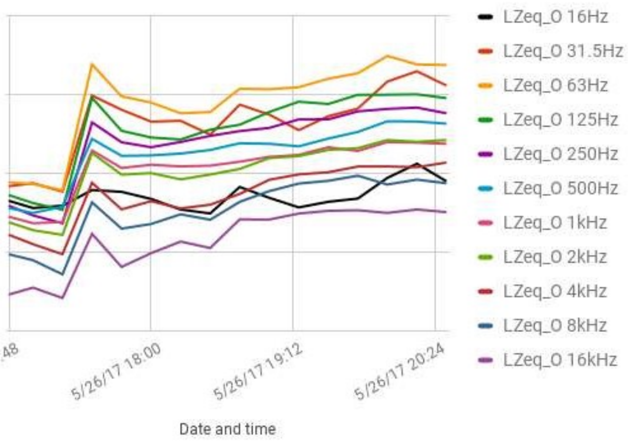
Cursor values
Report
X: 11:59:59 PM - 11:58:00
LAeq: 64.1 dB
Logged
X: 11:59:59 PM - 12:00:00
LAFmax: 72.2 dB
LAFmin: 49.1 dB
LCpeak: 89.0 dB
LAeq: 60.1 dB

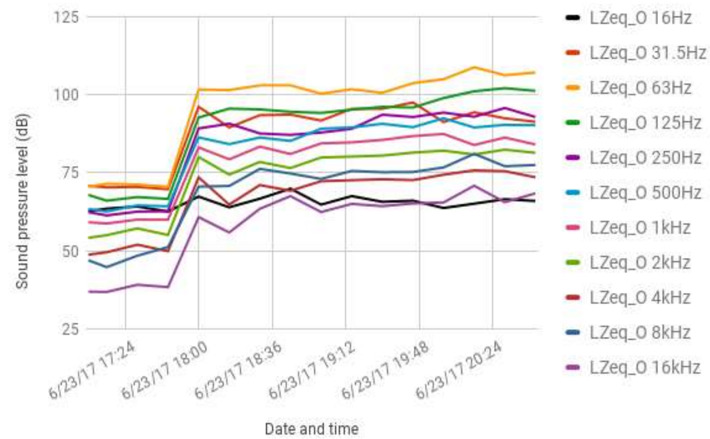


Cursor values
Report
X: 11:59:59 PM - 11:57:00
LAeq: 63.3 dB
Logged
X: 11:59:59 PM - 12:00:00
LAFmax: 74.7 dB
LAFmin: 55.0 dB
LCpeak: 90.6 dB
LAeq: 62.2 dB

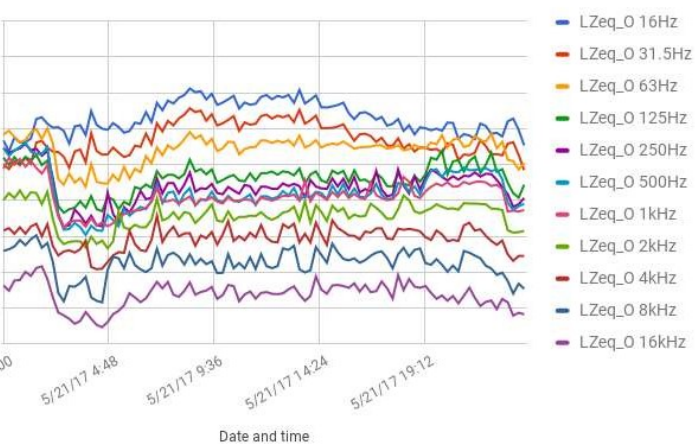
ndix C: Frequency Analysis Data

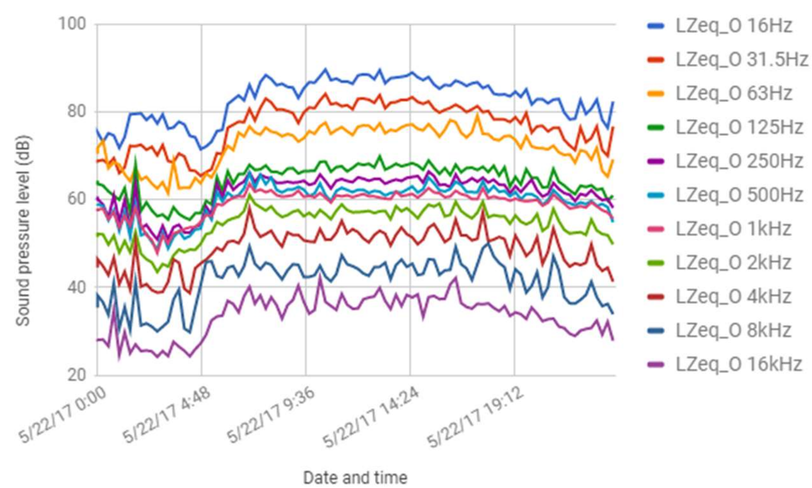
C 1: Frequency analysis of entertainment sound at 10m from the stage on 2017	*Appendix C 2: Frequency analysis of entertainment sound at 10m from the stage on 23rd June 2017*



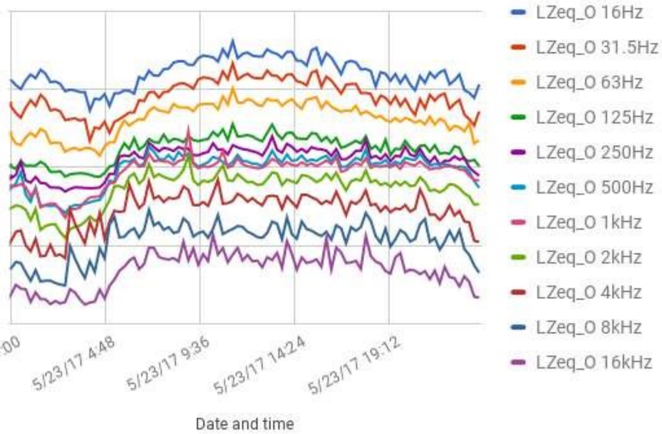


C 3: Frequency analysis of sound levels at Christ Church Post Office on 21st 7	*Appendix C 4: Frequency analysis of sound levels at Christ Church Post Office on 22ndt May, 2017*

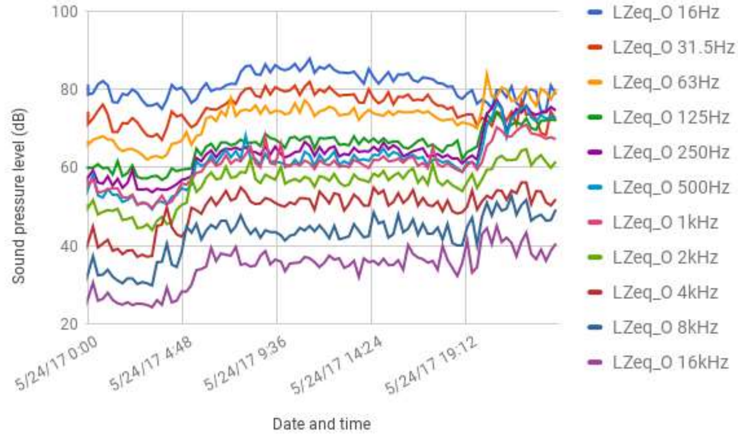




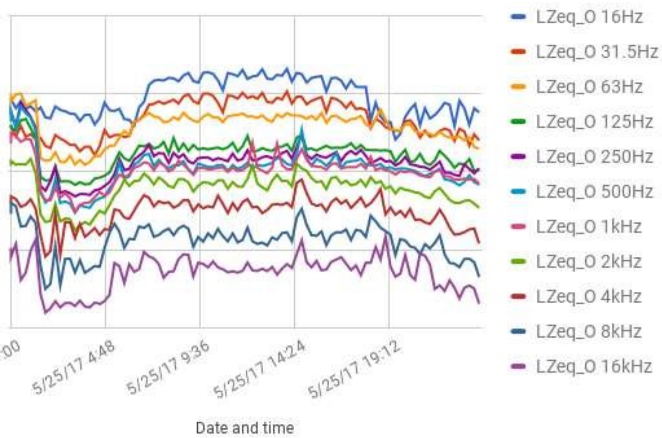
C 5: Frequency analysis of sound levels at Christ Church Post Office on 23rd
7



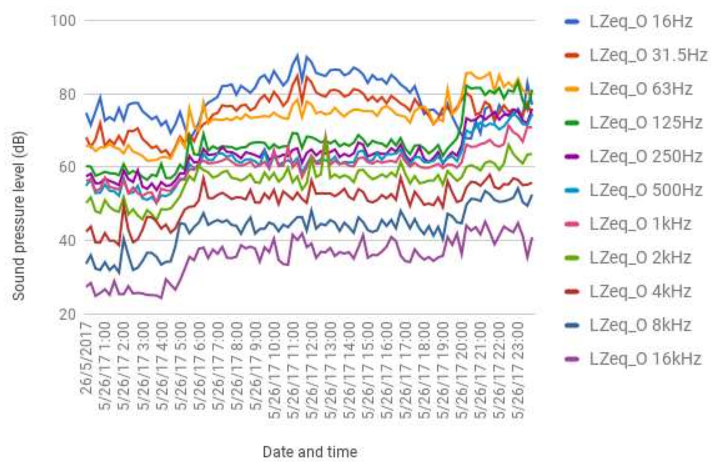
Appendix C 6: Frequency analysis of sound levels at Christ Church Post Office on 24th May, 2017



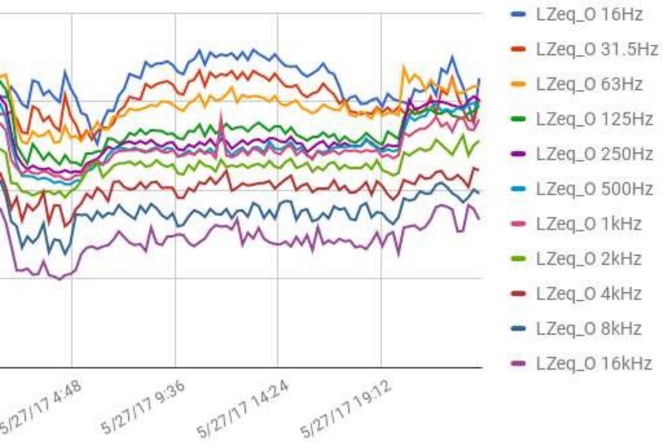
C 7: Frequency analysis of sound levels at Christ Church Post Office on 25th
7



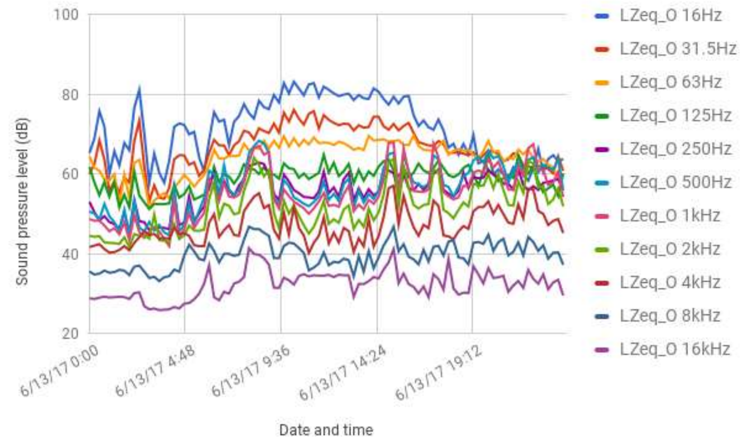
Appendix C 8: Frequency analysis of sound levels at Christ Church Post Office on 26th May 2017



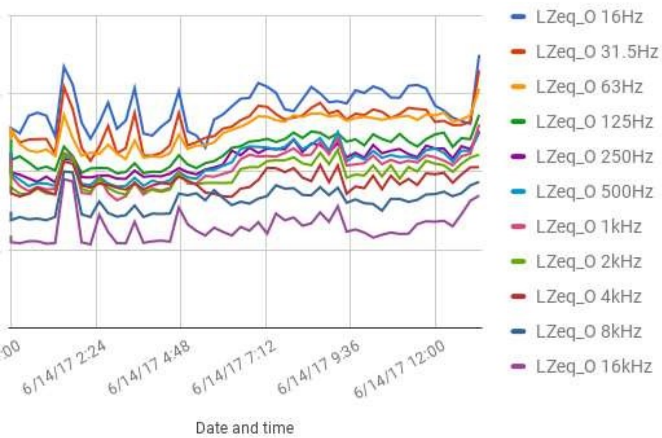
C 9: Frequency analysis of sound levels at Christ Church Post Office on 27th
7



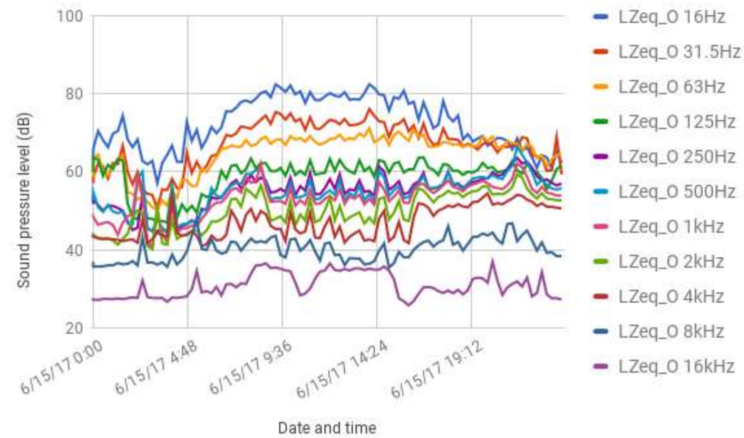
Appendix C 10: Frequency analysis of sound levels at PAWI on 13th June, 2017



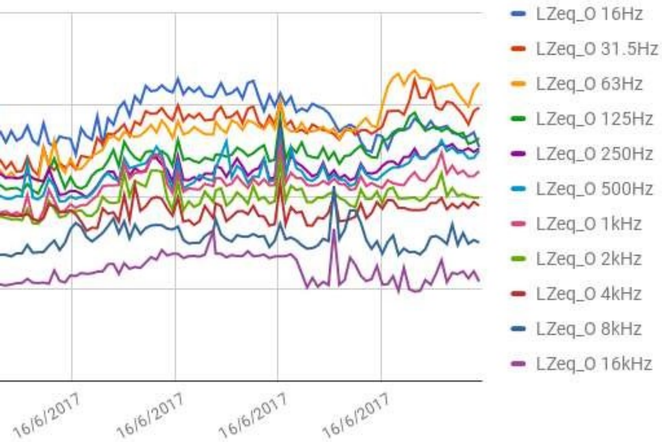
C 11: Frequency analysis of sound levels at PAWI on 14th June, 2017



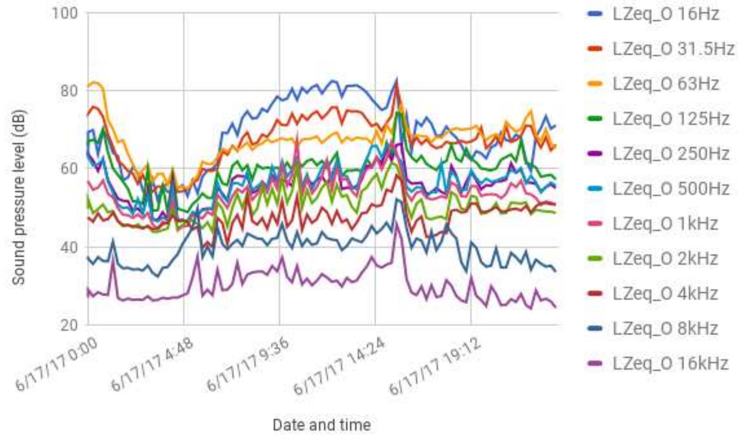
Appendix C 12: Frequency analysis of sound levels at PAWI on 15th June, 2017



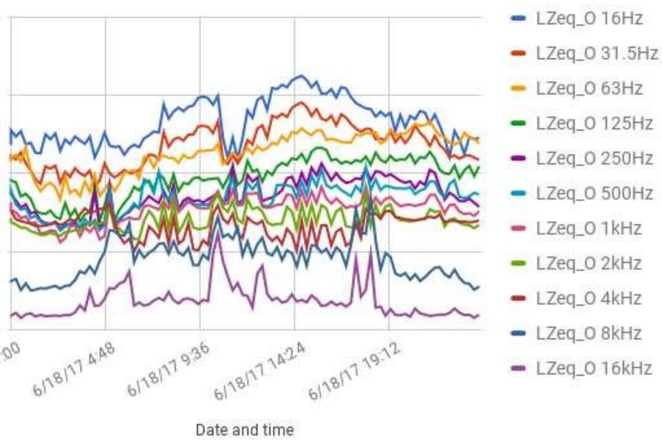
C 13: Frequency analysis of sound levels at PAWI on 16th June, 2017



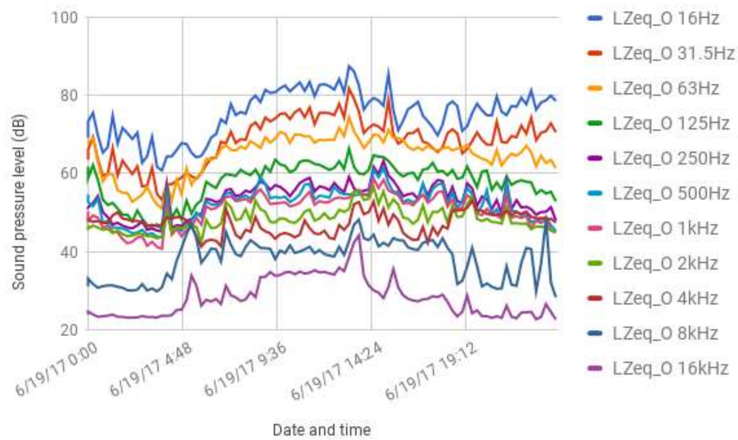
Appendix C 14: Frequency analysis of sound levels at PAWI on 17th June, 2017



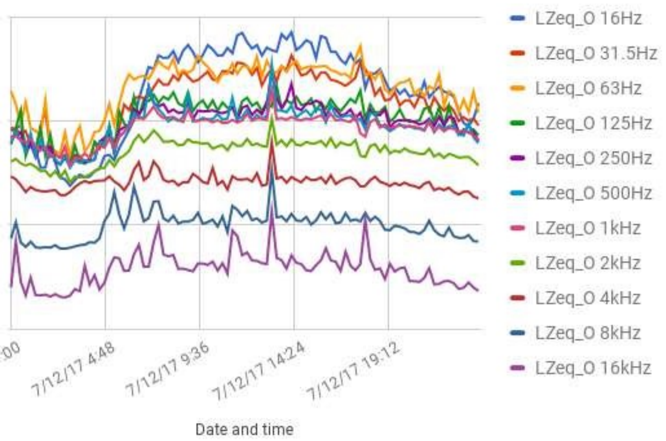
C 15: Frequency analysis of sound levels at PAWI on 18th June, 2017



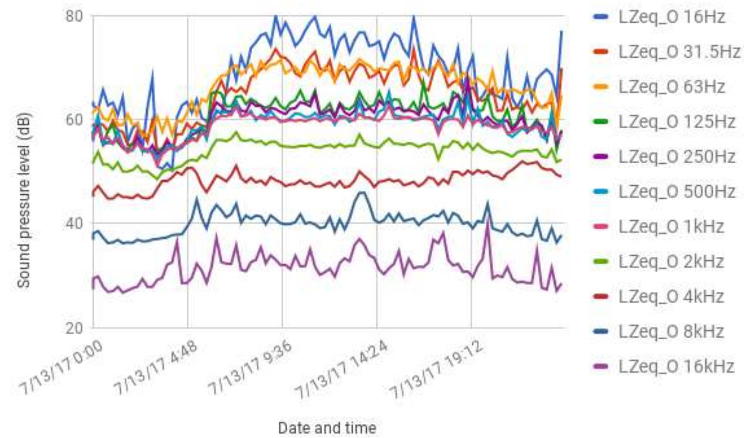
Appendix C 16: Frequency analysis of sound levels at PAWI on 19th June, 2017



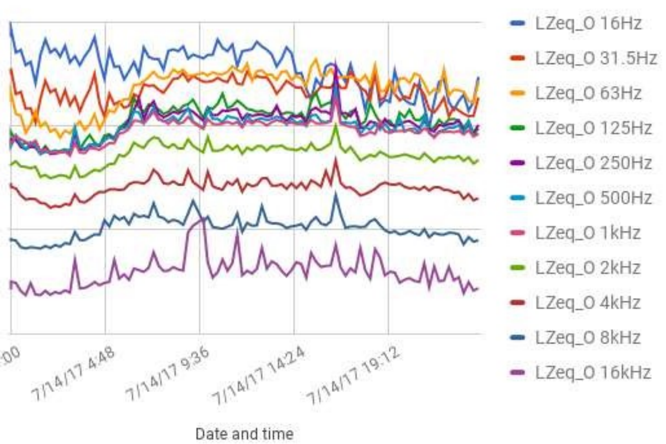
C 17: Frequency analysis of sound levels at IDB on 12th July, 2017



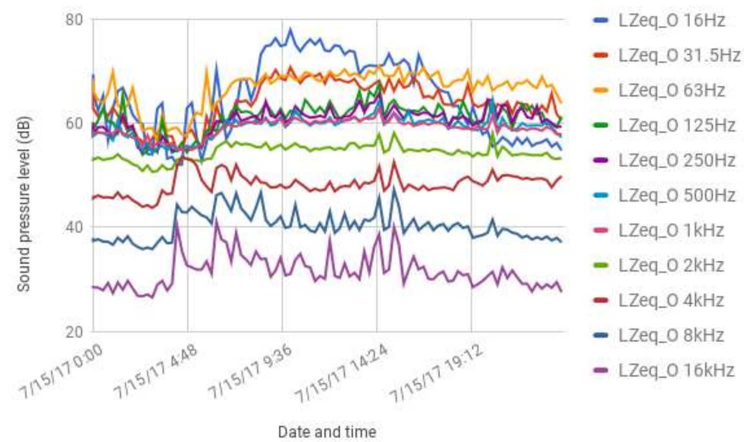
Appendix C 18: Frequency analysis of sound levels at IDB on 13th July, 2017



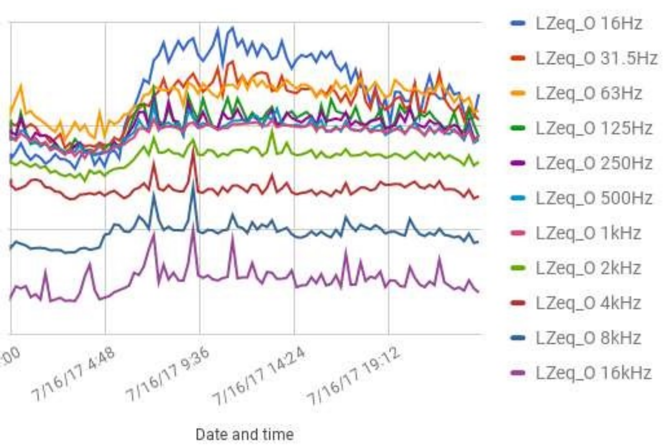
C 19: Frequency analysis of sound levels at IDB on 14th July, 2017



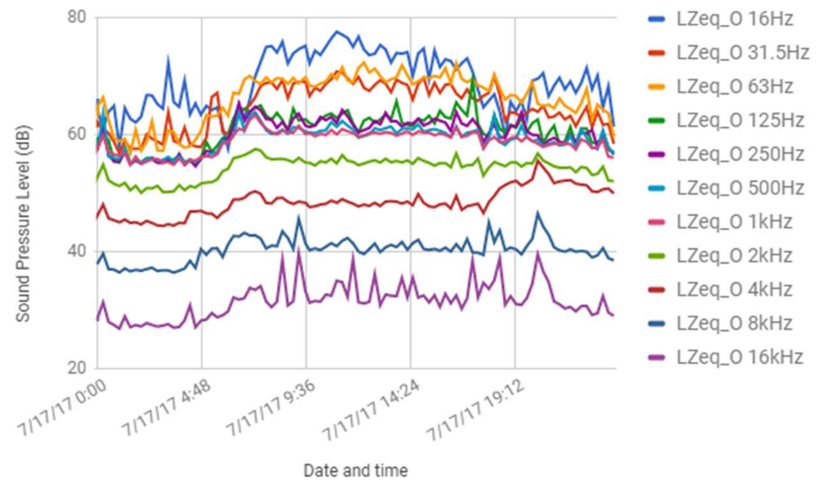
Appendix C 20: Frequency analysis of sound levels at IDB on 15th July, 2017



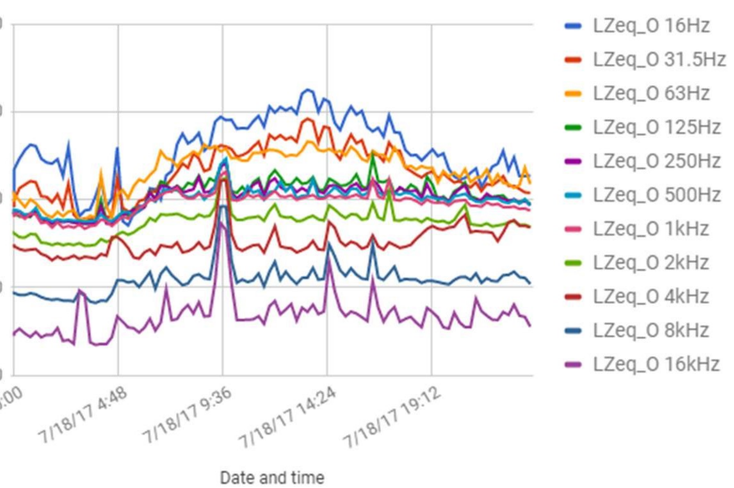
C 21: Frequency analysis of sound levels at IDB on 16th July, 2017



Appendix C 22: Frequency analysis of sound levels at IDB on 17th July, 2017



C 23:: Frequency analysis of sound levels at IDB on 18th July, 2017



nmary of Calculations for Christ Church Post Office

data from Sound Level Meter (during entertainment, 10m from source)

ect e	Start Time	Elapsed Time	LZeq_O 63Hz	LZeq_O 125Hz	LZeq_O 250Hz	LZeq_O 500Hz	LZeq_O 1kHz	LZeq_O 2kHz	LZeq_O 4kHz	LZeq_O 8kHz
ect 010	5/26/17 17:30	00:15:00	109.51	98.9	91.1	85.85	82.19	81.38	71.93	65.69
ect 010	5/26/17 17:45	00:15:00	99.35	88.42	84.78	80.47	76.6	74.5	63.46	57.35
ect 010	5/26/17 18:00	00:15:00	97.39	86.3	83.21	80.61	77.65	75	66.07	58.83
ect 010	5/26/17 18:15	00:15:00	93.98	85.66	84.87	81.19	77.11	72.99	63.76	61.9
ect 010	5/26/17 18:30	00:15:00	94.39	88.77	86.81	82.33	77.36	74.53	64.95	60.18
ect 010	5/26/17 18:45	00:15:00	101.76	90.35	88.32	84.46	78.61	76.31	68.37	65.86
ect 010	5/26/17 19:00	00:15:00	101.62	94.4	89.34	84.3	80.16	79.76	72.86	69.27
ect 010	5/26/17 19:15	00:15:00	102.26	97.66	92.04	83.49	80.76	80.38	74.57	71.67
ect 010	5/26/17 19:30	00:15:00	104.96	96.94	92.07	85.96	83.19	82.34	75.26	72.54
ect 010	5/26/17 19:45	00:15:00	106.71	99.85	94.59	88.07	82.02	82.91	77.08	74.16
ect 010	5/26/17 20:00	00:15:00	112.2	99.88	95.38	91.44	84.85	85.49	77.09	71.36
ect 010	5/26/17 20:15	00:15:00	109.5	100.01	95.79	91.37	84.67	84.93	76.88	72.92
ance Attenuation (dB)			25.84	25.84	25.84	25.84	25.84	25.84	25.84	25.84
eighting			-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1

mated Entertainment Sound Level (Inverse square law applied /distance attenuation
A-weighted, at receptor)

ect e	Start Time	Elapsed Time	LZeq_O 63Hz	LZeq_O 125Hz	LZeq_O 250Hz	LZeq_O 500Hz	LZeq_O 1kHz	LZeq_O 2kHz	LZeq_O 4kHz	LZeq_O 8kHz	LAeq
ect 010	5/26/17 17:30	00:15:00	57.46	56.95	56.65	56.80	56.34	56.73	47.08	38.74	64.
ect 010	5/26/17 17:45	00:15:00	47.30	46.47	50.33	51.42	50.75	49.85	38.61	30.40	57.
ect 010	5/26/17 18:00	00:15:00	45.34	44.35	48.76	51.56	51.80	50.35	41.22	31.88	57.
ect 010	5/26/17 18:15	00:15:00	41.93	43.71	50.42	52.14	51.26	48.34	38.91	34.95	57.

ect 010	5/26/17 18:30	00:15:00	42.34	46.82	52.36	53.28	51.51	49.88	40.10	33.23	58.4
ect 010	5/26/17 18:45	00:15:00	49.71	48.40	53.87	55.41	52.76	51.66	43.52	38.91	60.4
ect 010	5/26/17 19:00	00:15:00	49.57	52.45	54.89	55.25	54.31	55.11	48.01	42.32	62.0
ect 010	5/26/17 19:15	00:15:00	50.21	55.71	57.59	54.44	54.91	55.73	49.72	44.72	63.3
ect 010	5/26/17 19:30	00:15:00	52.91	54.99	57.62	56.91	57.34	57.69	50.41	45.59	64.5
ect 010	5/26/17 19:45	00:15:00	54.66	57.90	60.14	59.02	56.17	58.26	52.23	47.21	66.0
ect 010	5/26/17 20:00	00:15:00	60.15	57.93	60.93	62.39	59.00	60.84	52.24	44.41	68.3
ect 010	5/26/17 20:15	00:15:00	57.45	58.065	61.34	62.32	58.82	60.28	52.03	45.97	67.9

gground Sound Pressure level (A-weighting applied, at receptor)

ect ne	Start Time	Elapsed Time	LZeq_O 63Hz	LZeq_O 125Hz	LZeq_O 250Hz	LZeq_O 500Hz	LZeq_O 1kHz	LZeq_O 2kHz	LZeq_O 4kHz	LZeq_O 8kHz	LAeq
526 002	5/26/17 16:30	00:15:00	48.24	49.78	55.59	60.47	61.3	58.64	52.05	42.18	65.9
526 002	5/26/17 16:45	00:15:00	47.79	51.78	57.53	61.61	63.55	62.65	58.12	46.91	68.4
526 002	5/26/17 17:00	00:15:00	47.51	48.94	54.68	59.29	61.55	59.34	54.1	44.6	65.8
526 002	5/26/17 17:15	00:15:00	45.91	47.43	53.06	57.39	60.06	56.73	50.44	42.17	63.9
									Average Background LAeq (dBA)		66.3

l Sound (measured/actual, A-weighted, at receptor)

ect ne	Start Time	Elapsed Time	LZeq_O 63Hz	LZeq_O 125Hz	LZeq_O 250Hz	LZeq_O 500Hz	LZeq_O 1kHz	LZeq_O 2kHz	LZeq_O 4kHz	LZeq_O 8kHz	LAeq
	5/26/17 17:30	00:15:00	49.12	49.74	54.37	59.43	61.13	58.72	54.25	44.66	65.0
	5/26/17 17:45	00:15:00	49.93	49.86	56.84	59.52	60.14	56.8	52.58	42.14	65.1
	5/26/17 18:00	00:15:00	50.3	49	53.64	58.08	59.76	57	50.7	40.58	64.2
	5/26/17 18:15	00:15:00	48.82	47.59	52.72	58.23	59.79	57.52	51.02	42.75	64.2
	5/26/17 18:30	00:15:00	45.62	48.57	53.85	58.41	60.32	57.49	50.57	40.18	64.4
	5/26/17 18:45	00:15:00	46.82	49.88	55.49	59.7	60.88	59.04	52.67	42.57	65.0
	5/26/17 19:00	00:15:00	46.32	46.98	52.27	57.96	59.69	56.36	50.04	39.26	63.7
	5/26/17 19:15	00:15:00	54.98	48.94	54.16	59.25	60.66	60.12	57.1	46.16	66.2

	5/26/17 19:30	00:15:00	48.25	50.32	55.46	59.79	60.62	58.75	54.03	45.44	65.
	5/26/17 19:45	00:15:00	49.56	51.72	54.47	58.38	59.84	57.41	51.43	43.82	64.
	5/26/17 20:00	00:15:00	53.14	55.76	57.34	61.15	61.3	58.37	51.93	43.55	66.
	5/26/17 20:15	00:15:00	59.44	66.16	64.69	66.83	66.14	61.19	55.38	48.57	72.

			Inverse Square Law			Actual	Difference (Predicted-Actual)
			Entertainment	Background	Total Sound	Total Sound	
ect ne	Start Time	Elapsed Time	LAeq	LAeq	LAeq	LAeq	LAeq
	5/26/17 17:30	00:15:00	64.71	66.34	68.61	65.64	2.97
	5/26/17 17:45	00:15:00	57.55	66.34	66.88	65.16	1.72
	5/26/17 18:00	00:15:00	57.44	66.34	66.87	64.21	2.66
	5/26/17 18:15	00:15:00	57.21	66.34	66.84	64.23	2.61
	5/26/17 18:30	00:15:00	58.46	66.34	67.00	64.48	2.52
	5/26/17 18:45	00:15:00	60.50	66.34	67.35	65.64	1.71
	5/26/17 19:00	00:15:00	62.00	66.34	67.70	63.73	3.98
	5/26/17 19:15	00:15:00	63.30	66.34	68.09	66.28	1.82
	5/26/17 19:30	00:15:00	64.56	66.34	68.55	65.65	2.91
	5/26/17 19:45	00:15:00	66.07	66.34	69.22	64.60	4.62
	5/26/17 20:00	00:15:00	68.35	66.34	70.47	66.67	3.80
	5/26/17 20:15	00:15:00	67.99	66.34	70.26	72.70	-2.44

mary of calculations for the site near Welches

data from Sound Level Meter (during entertainment, 10m from source)

ect e	Start Time	Elapsed Time	LZeq_O 63Hz	LZeq_O 125Hz	LZeq_O 250Hz	LZeq_O 500Hz	LZeq_O 1kHz	LZeq_O 2kHz	LZeq_O 4kHz	LZeq_O 8kHz
ect 006	6/23/17 18:15	00:15:00	101.4	95.48	90.65	84.12	79.25	74.38	64.77	70.74
ect 006	6/23/17 18:30	00:15:00	102.91	95.22	87.53	86.23	83.32	78.42	71.03	76.21
ect 006	6/23/17 18:45	00:15:00	102.92	94.46	87.08	85.15	80.97	76.46	69.21	74.72
ect 006	6/23/17 19:00	00:15:00	100.24	94.11	87.82	89.05	84.36	79.84	72.26	72.99
ect 006	6/23/17 19:15	00:15:00	101.68	95.14	89.04	89.46	84.68	80.14	72.58	75.54
ect 006	6/23/17 19:30	00:15:00	100.53	96.04	93.53	90.62	85.47	80.45	72.88	75.14
ect 006	6/23/17 19:45	00:15:00	103.62	95.82	92.8	89.54	86.69	81.4	72.61	75.21
ect 006	6/23/17 20:00	00:15:00	104.87	98.85	94.2	92.38	87.38	82.03	74.34	76.66
ect 006	6/23/17 20:15	00:15:00	108.71	101.02	92.89	89.45	83.83	80.8	75.74	81.02
ect 006	6/23/17 20:30	00:15:00	106.14	102.01	95.67	90.29	86.22	82.35	75.46	77.05
ect 006	6/23/17 20:45	00:06:01	107.06	101.15	92.8	90.17	84.01	81.35	73.52	77.45
ance nuation			22.28	22.28	22.28	22.28	22.28	22.28	22.28	22.28
eighting			-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1

nated Entertainment Sound Level (Inverse square law applied /distance attenuation
A-weighted, at receptor ,130m from source)

ect e	Start Time	Elapsed Time	LZeq_O 63Hz	LZeq_O 125Hz	LZeq_O 250Hz	LZeq_O 500Hz	LZeq_O 1kHz	LZeq_O 2kHz	LZeq_O 4kHz	LZeq_O 8kHz	LAeq
ect 006	6/23/17 18:15	00:15:00	53.12	57.20	59.37	58.84	56.97	53.10	43.49	47.46	64.9
ect 006	6/23/17 18:30	00:15:00	54.63	56.94	56.25	60.95	61.04	57.14	49.75	52.93	66.5
ect 006	6/23/17 18:45	00:15:00	54.64	56.18	55.80	59.87	58.69	55.18	47.93	51.44	65.2
ect 006	6/23/17 19:00	00:15:00	51.96	55.83	56.54	63.77	62.08	58.56	50.98	49.71	67.7

ect 006	6/23/17 19:15	00:15:00	53.40	56.86	57.76	64.18	62.40	58.86	51.30	52.26	68.28
ect 006	6/23/17 19:30	00:15:00	52.25	57.76	62.25	65.34	63.19	59.17	51.60	51.86	69.58
ect 006	6/23/17 19:45	00:15:00	55.34	57.54	61.52	64.26	64.41	60.12	51.33	51.93	69.58
ect 006	6/23/17 20:00	00:15:00	56.59	60.57	62.92	67.10	65.10	60.75	53.06	53.38	71.31
ect 006	6/23/17 20:15	00:15:00	60.43	62.74	61.61	64.17	61.55	59.52	54.46	57.74	70.11
ect 006	6/23/17 20:30	00:15:00	57.86	63.73	64.39	65.01	63.94	61.07	54.18	53.77	71.19
ect 006	6/23/17 20:45	00:06:01	58.78	62.87	61.52	64.89	61.73	60.07	52.24	54.17	70.00

kground Sound Pressure level (Before entertainment, A-weighting applied, at
ptor, 130 from source)

ect ne	Start Time	Elapsed Time	LZeq_O 63Hz	LZeq_O 125Hz	LZeq_O 250Hz	LZeq_O 500Hz	LZeq_O 1kHz	LZeq_O 2kHz	LZeq_O 4kHz	LZeq_O 8kHz	LAeq
523 002	6/23/17 16:45	00:15:00	51.12	55.7	60.34	64.64	65.8	64.49	58.03	49.9	70.73
523 002	6/23/17 17:00	00:15:00	52.82	59.83	61.97	64.55	64.97	62.56	56.47	48.88	70.43
523 002	6/23/17 17:15	00:15:00	52.86	55.14	58.26	63.2	64.26	62.11	56.92	49.66	69.11
523 002	6/23/17 17:30	00:15:00	56.02	59.78	61.06	63.26	64.68	62.89	60.86	53.34	70.44
523 002	6/23/17 17:45	00:15:00	51	56.97	60.13	63.73	63.7	61.7	56.71	47.62	69.22

Average Background LAeq (dBA): 70.04

l Sound (measured/actual, A-weighted, at receptor, 130m from receptor)

ect ne	Start Time	Elapsed Time	LZeq_O 63Hz	LZeq_O 125Hz	LZeq_O 250Hz	LZeq_O 500Hz	LZeq_O 1kHz	LZeq_O 2kHz	LZeq_O 4kHz	LZeq_O 8kHz	LAeq
523 002	6/23/17 18:15	00:15:00	56.64	60.48	63.11	64.7	63.37	60.14	55.56	47.33	70.08
523 002	6/23/17 18:30	00:15:00	57.04	59.21	63.32	65.65	66.81	66.16	61.88	51.09	72.49
523 002	6/23/17 18:45	00:15:00	53.7	56.45	60.81	63.32	62.98	61.53	57.89	50.62	69.12
523 002	6/23/17 19:00	00:15:00	54.86	60.7	60.42	60.96	64.81	60.82	55.57	46.63	69.28
523 002	6/23/17 19:15	00:15:00	54.16	59.3	61.56	63.67	64.08	62.45	58.69	50.11	70.01
523 002	6/23/17 19:30	00:15:00	53.08	55.7	59.33	61.95	62.35	61.08	57.34	49.83	68.22
523 002	6/23/17 19:45	00:15:00	61.22	60.39	64.88	64.05	64.13	62.39	56.25	48.89	71.09
523 002	6/23/17 20:00	00:15:00	60.95	62.93	64.58	64.66	66.78	64.73	59.1	52.05	72.48
523 002	6/23/17 20:15	00:15:00	64.63	63.31	62.36	61.7	63.28	62.83	56.68	46.99	71.08
523 002	6/23/17 20:30	00:15:00	64.48	66.27	65.52	65.17	65.33	63.84	58.25	48.85	73.11
523 002	6/23/17 20:45	00:05:27	64.07	67.19	67.85	64.51	65.09	63.24	57.37	52.54	73.57

			Inverse square law			Actual Total Sound	Difference (Predicted-Actual)
			Entertainment	Background	Total Sound		
ect ne	Start Time	Elapsed Time	LAeq	LAeq	LAeq	LAeq	LAeq
	6/23/17 18:15	00:15:00	64.97	70.04	71.22	70.08	1.13
	6/23/17 18:30	00:15:00	66.56	70.04	71.65	72.49	-0.84
	6/23/17 18:45	00:15:00	65.22	70.04	71.28	69.12	2.16
	6/23/17 19:00	00:15:00	67.73	70.04	72.05	69.28	2.77
	6/23/17 19:15	00:15:00	68.28	70.04	72.26	70.01	2.25
	6/23/17 19:30	00:15:00	69.58	70.04	72.83	68.22	4.61
	6/23/17 19:45	00:15:00	69.58	70.04	72.83	71.09	1.74
	6/23/17 20:00	00:15:00	71.31	70.04	73.73	72.48	1.25
	6/23/17 20:15	00:15:00	70.11	70.04	73.08	71.08	2.01
	6/23/17 20:30	00:15:00	71.19	70.04	73.66	73.11	0.55
	6/23/17 20:45	00:05:27	70.06	70.04	73.06	73.57	-0.52

endix E: Predictions using a concept similar to ISO9613

mary of Calculations for Christ Church Post Office

data from Sound Level Meter (during entertainment, 10m from source)

ect e	Start Time	Elapsed Time	LZeq_O 63Hz	LZeq_O 125Hz	LZeq_O 250Hz	LZeq_O 500Hz	LZeq_O 1kHz	LZeq_O 2kHz	LZeq_O 4kHz	LZeq_O 8kHz
ect 010	5/26/17 17:30	00:15:00	109.51	98.9	91.1	85.85	82.19	81.38	71.93	65.69
ect 010	5/26/17 17:45	00:15:00	99.35	88.42	84.78	80.47	76.6	74.5	63.46	57.35
ect 010	5/26/17 18:00	00:15:00	97.39	86.3	83.21	80.61	77.65	75	66.07	58.83
ect 010	5/26/17 18:15	00:15:00	93.98	85.66	84.87	81.19	77.11	72.99	63.76	61.9
ect 010	5/26/17 18:30	00:15:00	94.39	88.77	86.81	82.33	77.36	74.53	64.95	60.18
ect 010	5/26/17 18:45	00:15:00	101.76	90.35	88.32	84.46	78.61	76.31	68.37	65.86
ect 010	5/26/17 19:00	00:15:00	101.62	94.4	89.34	84.3	80.16	79.76	72.86	69.27
ect 010	5/26/17 19:15	00:15:00	102.26	97.66	92.04	83.49	80.76	80.38	74.57	71.67
ect 010	5/26/17 19:30	00:15:00	104.96	96.94	92.07	85.96	83.19	82.34	75.26	72.54
ect 010	5/26/17 19:45	00:15:00	106.71	99.85	94.59	88.07	82.02	82.91	77.08	74.16
ect 010	5/26/17 20:00	00:15:00	112.2	99.88	95.38	91.44	84.85	85.49	77.09	71.36
ect 010	5/26/17 20:15	00:15:00	109.5	100.01	95.79	91.37	84.67	84.93	76.88	72.92
ance nuation			25.84	25.84	25.84	25.84	25.84	25.84	25.84	25.84
ctivity x			3	3	3	3	3	3	3	3
. orption			0.0196	0.0588	0.196	0.6076	1.4504	2.4892	4.5276	11.6228
und cts			-3	-3	-3	-3	-3	-3	-3	-3
iers			5.11	5.42	5.98	6.92	8.35	10.29	12.64	15.29
l nuation			27.97	28.32	29.02	30.38	32.65	35.63	40.02	49.75
eighting			-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1

nated Entertainment Sound Level (Total attenuation and A-weighted, at receptor)

ect ne	Start Time	Elapsed Time	LZeq_O 63Hz	LZeq_O 125Hz	LZeq_O 250Hz	LZeq_O 500Hz	LZeq_O 1kHz	LZeq_O 2kHz	LZeq_O 4kHz	LZeq_O 8kHz	LAeq
	5/26/17 17:30	00:15:00	58.34	57.48	56.48	55.27	52.54	49.95	35.91	17.84	63.63
	5/26/17 17:45	00:15:00	48.18	47.00	50.16	49.89	46.95	43.07	27.44	9.50	55.88
	5/26/17 18:00	00:15:00	46.22	44.88	48.59	50.03	48.00	43.57	30.05	10.98	55.22
	5/26/17 18:15	00:15:00	42.81	44.24	50.25	50.61	47.46	41.56	27.74	14.05	55.28
	5/26/17 18:30	00:15:00	43.22	47.35	52.19	51.75	47.71	43.10	28.93	12.33	56.73
	5/26/17 18:45	00:15:00	50.59	48.93	53.70	53.88	48.96	44.88	32.35	18.01	58.94
	5/26/17 19:00	00:15:00	50.45	52.98	54.72	53.72	50.51	48.33	36.84	21.42	60.12
	5/26/17 19:15	00:15:00	51.09	56.24	57.42	52.91	51.11	48.95	38.55	23.82	61.80
	5/26/17 19:30	00:15:00	53.79	55.52	57.45	55.38	53.54	50.91	39.24	24.69	62.68
	5/26/17 19:45	00:15:00	55.54	58.43	59.97	57.49	52.37	51.48	41.06	26.31	64.68
	5/26/17 20:00	00:15:00	61.03	58.46	60.76	60.86	55.20	54.06	41.07	23.51	66.97
	5/26/17 20:15	00:15:00	58.33	58.59	61.17	60.79	55.02	53.50	40.86	25.07	66.50

kground Sound Pressure level (A-weighting applied, at receptor)

ect ne	Start Time	Elapsed Time	LZeq_O 63Hz	LZeq_O 125Hz	LZeq_O 250Hz	LZeq_O 500Hz	LZeq_O 1kHz	LZeq_O 2kHz	LZeq_O 4kHz	LZeq_O 8kHz	LAeq
	5/26/17 16:30	00:15:00	48.24	49.78	55.59	60.47	61.3	58.64	52.05	42.18	65.91
	5/26/17 16:45	00:15:00	47.79	51.78	57.53	61.61	63.55	62.65	58.12	46.91	68.47
	5/26/17 17:00	00:15:00	47.51	48.94	54.68	59.29	61.55	59.34	54.1	44.6	65.86
	5/26/17 17:15	00:15:00	45.91	47.43	53.06	57.39	60.06	56.73	50.44	42.17	63.90
									Average Background LAeq (dBA)		66.34

l Sound (measured/actual, A-weighted, at receptor)

ect e	Start Time	Elapsed Time	LZeq_O 63Hz	LZeq_O 125Hz	LZeq_O 250Hz	LZeq_O 500Hz	LZeq_O 1kHz	LZeq_O 2kHz	LZeq_O 4kHz	LZeq_O 8kHz	LAeq
	5/26/17 17:30	00:15:00	49.12	49.74	54.37	59.43	61.13	58.72	54.25	44.66	65.639
	5/26/17 17:45	00:15:00	49.93	49.86	56.84	59.52	60.14	56.8	52.58	42.14	65.162
	5/26/17 18:00	00:15:00	50.3	49	53.64	58.08	59.76	57	50.7	40.58	64.211
	5/26/17 18:15	00:15:00	48.82	47.59	52.72	58.23	59.79	57.52	51.02	42.75	64.231
	5/26/17 18:30	00:15:00	45.62	48.57	53.85	58.41	60.32	57.49	50.57	40.18	64.482
	5/26/17 18:45	00:15:00	46.82	49.88	55.49	59.7	60.88	59.04	52.67	42.57	65.637
	5/26/17 19:00	00:15:00	46.32	46.98	52.27	57.96	59.69	56.36	50.04	39.26	63.728
	5/26/17 19:15	00:15:00	54.98	48.94	54.16	59.25	60.66	60.12	57.1	46.16	66.275
	5/26/17 19:30	00:15:00	48.25	50.32	55.46	59.79	60.62	58.75	54.03	45.44	65.647
	5/26/17 19:45	00:15:00	49.56	51.72	54.47	58.38	59.84	57.41	51.43	43.82	64.602
	5/26/17 20:00	00:15:00	53.14	55.76	57.34	61.15	61.3	58.37	51.93	43.55	66.668
	5/26/17 20:15	00:15:00	59.44	66.16	64.69	66.83	66.14	61.19	55.38	48.57	72.699

			Entertainment	Background	Total Sound	Actual	Difference (predicted-actual)
ect e	Start Time	Elapsed Time	LAeq	LAeq	LAeq	LAeq	LAeq
	5/26/17 17:30	00:15:00	63.63	66.34	68.20	65.64	2.57
	5/26/17 17:45	00:15:00	55.88	66.34	66.72	65.16	1.55
	5/26/17 18:00	00:15:00	55.22	66.34	66.67	64.21	2.46
	5/26/17 18:15	00:15:00	55.28	66.34	66.67	64.23	2.44
	5/26/17 18:30	00:15:00	56.73	66.34	66.79	64.48	2.31
	5/26/17 18:45	00:15:00	58.94	66.34	67.07	65.64	1.43
	5/26/17 19:00	00:15:00	60.12	66.34	67.27	63.73	3.54
	5/26/17 19:15	00:15:00	61.80	66.34	67.65	66.28	1.37
	5/26/17 19:30	00:15:00	62.68	66.34	67.90	65.65	2.25
	5/26/17 19:45	00:15:00	64.68	66.34	68.60	64.60	4.00
	5/26/17 20:00	00:15:00	66.97	66.34	69.68	66.67	3.01
	5/26/17 20:15	00:15:00	66.50	66.34	69.43	72.70	-3.27

mary of calculations for the site near Welches

data from Sound Level Meter (during entertainment, 10m from source)

ect e	Start Time	Elapsed Time	LZeq_O 63Hz	LZeq_O 125Hz	LZeq_O 250Hz	LZeq_O 500Hz	LZeq_O 1kHz	LZeq_O 2kHz	LZeq_O 4kHz	LZeq_O 8kHz
ect 006	6/23/17 18:15	00:15:00	101.4	95.48	90.65	84.12	79.25	74.38	64.77	70.74
ect 006	6/23/17 18:30	00:15:00	102.91	95.22	87.53	86.23	83.32	78.42	71.03	76.21
ect 006	6/23/17 18:45	00:15:00	102.92	94.46	87.08	85.15	80.97	76.46	69.21	74.72
ect 006	6/23/17 19:00	00:15:00	100.24	94.11	87.82	89.05	84.36	79.84	72.26	72.99
ect 006	6/23/17 19:15	00:15:00	101.68	95.14	89.04	89.46	84.68	80.14	72.58	75.54
ect 006	6/23/17 19:30	00:15:00	100.53	96.04	93.53	90.62	85.47	80.45	72.88	75.14
ect 006	6/23/17 19:45	00:15:00	103.62	95.82	92.8	89.54	86.69	81.4	72.61	75.21
ect 006	6/23/17 20:00	00:15:00	104.87	98.85	94.2	92.38	87.38	82.03	74.34	76.66
ect 006	6/23/17 20:15	00:15:00	108.71	101.02	92.89	89.45	83.83	80.8	75.74	81.02
ect 006	6/23/17 20:30	00:15:00	106.14	102.01	95.67	90.29	86.22	82.35	75.46	77.05
ance			22.28	22.28	22.28	22.28	22.28	22.28	22.28	22.28
ctivity			3	3	3	3	3	3	3	3
. orption			0.013	0.039	0.13	0.403	0.962	1.651	3.003	7.709
und cts			-3	-3	-3	-3	-3	-3	-3	-3
iers			6.08	7.07	8.57	10.57	12.96	15.63	18.46	21.37
l			25.37	26.39	27.98	30.25	33.20	36.56	40.74	48.36
eighting			-26	-16	-9	-3	0	1	1	-1

mated Entertainment Sound Level (Total attenuation and A-weighted, at receptor)

ect ne	Start Time	Elapsed Time	LZeq_O 63Hz	LZeq_O 125Hz	LZeq_O 250Hz	LZeq_O 500Hz	LZeq_O 1kHz	LZeq_O 2kHz	LZeq_O 4kHz	LZeq_O 8kHz	LAeq
ect 006	6/23/17 18:15	00:15:00	53.03	56.09	56.67	53.87	49.05	41.82	28.03	24.38	61.5
ect 006	6/23/17 18:30	00:15:00	54.54	55.83	53.55	55.98	53.12	45.86	34.29	29.85	61.8
ect 006	6/23/17 18:45	00:15:00	54.55	55.07	53.10	54.90	50.77	43.90	32.47	28.36	61.0
ect 006	6/23/17 19:00	00:15:00	51.87	54.72	53.84	58.80	54.16	47.28	35.52	26.63	62.4
ect 006	6/23/17 19:15	00:15:00	53.31	55.75	55.06	59.21	54.48	47.58	35.84	29.18	63.2
ect 006	6/23/17 19:30	00:15:00	52.16	56.65	59.55	60.37	55.27	47.89	36.14	28.78	64.8
ect 006	6/23/17 19:45	00:15:00	55.25	56.43	58.82	59.29	56.49	48.84	35.87	28.85	64.0
ect 006	6/23/17 20:00	00:15:00	56.50	59.46	60.22	62.13	57.18	49.47	37.60	30.30	66.0
ect 006	6/23/17 20:15	00:15:00	60.34	61.63	58.91	59.20	53.63	48.24	39.00	34.66	66.4
ect 006	6/23/17 20:30	00:15:00	57.77	62.62	61.69	60.04	56.02	49.79	38.72	30.69	67.3

kground Sound Pressure level (A-weighting applied, at receptor)

ect ne	Start Time	Elapsed Time	LZeq_O 63Hz	LZeq_O 125Hz	LZeq_O 250Hz	LZeq_O 500Hz	LZeq_O 1kHz	LZeq_O 2kHz	LZeq_O 4kHz	LZeq_O 8kHz	LAeq
kground ual), A ghted	42909.69792	00:15:00	51.12	55.7	60.34	64.64	65.8	64.49	58.03	49.9	70.7
523 002	42909.70833	00:15:00	52.82	59.83	61.97	64.55	64.97	62.56	56.47	48.88	70.4
523 002	42909.71875	00:15:00	52.86	55.14	58.26	63.2	64.26	62.11	56.92	49.66	69.1
523 002	42909.72917	00:15:00	56.02	59.78	61.06	63.26	64.68	62.89	60.86	53.34	70.4
523 002	42909.73958	00:15:00	51	56.97	60.13	63.73	63.7	61.7	56.71	47.62	69.2

Average Background LAeq (dBA) 70.0

l Sound (measured/actual, A-weighted, at receptor)

ect ne	Start Time	Elapsed Time	LZeq_O 63Hz	LZeq_O 125Hz	LZeq_O 250Hz	LZeq_O 500Hz	LZeq_O 1kHz	LZeq_O 2kHz	LZeq_O 4kHz	LZeq_O 8kHz	LAeq
523 002	6/23/17 18:15	00:15:00	56.64	60.48	63.11	64.7	63.37	60.14	55.56	47.33	70
523 002	6/23/17 18:30	00:15:00	57.04	59.21	63.32	65.65	66.81	66.16	61.88	51.09	72
523 002	6/23/17 18:45	00:15:00	53.7	56.45	60.81	63.32	62.98	61.53	57.89	50.62	69
523 002	6/23/17 19:00	00:15:00	54.86	60.7	60.42	60.96	64.81	60.82	55.57	46.63	69
523 002	6/23/17 19:15	00:15:00	54.16	59.3	61.56	63.67	64.08	62.45	58.69	50.11	70
523 002	6/23/17 19:30	00:15:00	53.08	55.7	59.33	61.95	62.35	61.08	57.34	49.83	68
523 002	6/23/17 19:45	00:15:00	61.22	60.39	64.88	64.05	64.13	62.39	56.25	48.89	71
523 002	6/23/17 20:00	00:15:00	60.95	62.93	64.58	64.66	66.78	64.73	59.1	52.05	72
523 002	6/23/17 20:15	00:15:00	64.63	63.31	62.36	61.7	63.28	62.83	56.68	46.99	71
523 002	6/23/17 20:30	00:15:00	64.48	66.27	65.52	65.17	65.33	63.84	58.25	48.85	73

			ISO 9613 based model				Difference (predicted-actual)
			Entertainment	Background	Total Sound	Actual	
ect ne	Start Time	Elapsed Time	LAeq	LAeq	LAeq (ISO 9613)	LAeq	LAeq
	6/23/17 18:15	00:15:00	61.50	70.04	70.61	70.08	0.53
	6/23/17 18:30	00:15:00	61.87	70.04	70.66	72.49	-1.84
	6/23/17 18:45	00:15:00	61.02	70.04	70.55	69.12	1.43
	6/23/17 19:00	00:15:00	62.48	70.04	70.74	69.28	1.46
	6/23/17 19:15	00:15:00	63.20	70.04	70.86	70.01	0.84
	6/23/17 19:30	00:15:00	64.80	70.04	71.18	68.22	2.96
	6/23/17 19:45	00:15:00	64.64	70.04	71.14	71.09	0.05
	6/23/17 20:00	00:15:00	66.66	70.04	71.68	72.48	-0.80
	6/23/17 20:15	00:15:00	66.49	70.04	71.63	71.08	0.55
	6/23/17 20:30	00:15:00	67.34	70.04	71.91	73.11	-1.21

Appendix F: Stakeholder Contact List

Name	Title/Position	Address	Contact numbers
Mrs. Margaret Ashby, Postmaster General Ms. Best, Deputy Postmaster General Ms. Woneta Higgins, Post Mistress (Oistins) - 535-3407	Postmaster General	Barbados Postal Service Cheapside Bridgetown Christ Church Post Office	436-4800 Ms. Higgins (535-3407)
Gloria Benn Official contact: Bishop Gerald Feale	PAWI	Bishop Gerald Feale Pentecostal Assemblies of the West Indies PO Box 8002 Oistins Christ Church	420-7721
Richard Holder, Supervisor Mr. Thompson, Deputy General Manager	Oistins Management	General Manager National Conservation Commission Codrington St. Michael	253-5406 (Holder)
Mr. Juan Carlos De La HozVinas Representative	IADB	Mr. Juan Carlos De La HozVinas Representative Inter-American Development Bank "Hythe" Welches, Maxwell Main Rd, Maxwell, Ch. Ch. BB17068	627-8500, 627-8525 (Ms. Beverly Worrell, secretary)
Station Sergeant Craigg Oistins Police Station	Police		418-2612
Jason Hurley	Traffic Section MTW		467-7469/7468

OISTINS NOISE CHARACTERIZATION STUDY 2017
NOISE MEASUREMENT FORM

Location Name:___________________ **GPS Coordinates**: N 13 ________ W 59 °

Address/ Location:

Contact person & number:

Site Description: Description of location (Type of area/zone, activities conducted, topography, nature of ground):

Land Use Designation:……………………………………………………………..

Activities: ……..

……….

Topography: ……..

Nature of ground: …………………………………………………………………………………………………

Sound Environment Description: Description and location of (major) sources of ambient noise: (cars, amplified music, steady tone, impulsive, etc.):

Sources: ……..

<u>Sketch of Site (showing sampling location)</u>

Instruments& Accessories used:

☐ Brüel&Kjær 2270 SLM S/N: ....

☐ Brüel&Kjær 4952 microphone S/N: ....

☐ Brüel&Kjær 4231 calibrator S/N:

☐ Battery supply: S/N: internal battery-............

☐ Windscreen

☐ Kestrel Weather monitor

☐ Outdoor noise monitoring kit

☐ Other(s): ....

General Weather Description:

	Date span:	Date span:	Date span:	Date span:
Wind speed	Max: Avg: Min:	Max: Avg: Min:	Max: Avg: Min:	Max: Avg: Min:
Relative humidity (%)	Max: Avg: Min:	Max: Avg: Min:	Max: Avg: Min:	Max: Avg: Min:
Temperature: ^{o}C	Max: Avg: Min:	Max: Avg: Min:	Max: Avg: Min:	Max: Avg: Min:
Atmospheric Pressure mbar	Max: Avg: Min:	Max: Avg: Min:	Max: Avg: Min:	Max: Avg: Min:

	Date:	Date:	Date:	Date:
Precipitation (Y/N)				
Wind Direction				
Cloud Cover				

asurement of Noise Levels

ht above ground level:					Distance from nearest reflective surface (not the ground)					Operators:
ord # in er	Start Date& Time	End Date & Time	Leq (dBA)	L10 (dBA)	L90 (dBA)	Lmin (dBA)	Lmax (dBA)		Comments (sounds observed, any extraneous, etc.	

ipment Calibration

ipment	Calibration Date & Time	Current Sensitivity	Comments

MEMBER TO:

- Install the SLMs internal battery
- Switch external battery
- Take pictures
- Calibrate SLM
- Re-start meter

mments

DATE &TIME	COMMENTS

Appendix H: Instrumentation specifications

Equipment (brand and model)	**IEC compliance**	**Date of last factory calibration**
Bruel & Kjaer 2270 SLM* S/N: 3009267	IEC 61672-1:2002 Class 1 IEC 612:1995 w. Am. 1, 1/1 and 1/3 Oct Band Class 0 IEC 60804:200 Type 1 IEC 60651:1979 w. Am.1&2 Type 1	2016-04-12
Bruel & Kjaer 2270 SLM* S/N: 3009263	IEC 61672-1:2002 Class 1 IEC 612:1995 w. Am. 1, 1/1 and 1/3 Oct Band Class 0 IEC 60804:200 Type 1 IEC 60651:1979 w. Am.1&2 Type 1	2016-04-12
Bruel & Kjaer 4952 microphone S/N: 3052521	IEC 61672 Class 1 ANSI S 1.40 -1984	2016-04-06
Bruel & Kjaer 4952 microphone S/N: 3080409	IEC 61672 Class 1 ANSI S 1.40 -1984	2016-10-25
Bruel & Kjaer 4231 calibrator S/N: 2085222	IEC 942 ,1988 Class 1 ANSI S 1.40 -1984	2015-10-08

*SLM- sound level meter,

Appendix I: Dates traffic counters were deployed

Christ Church Post Office	9th – 15th July 2017
Pentecostal Assemblies of the West Indies	5th -11th August 2017
Inter-American Development Bank	12th -18th July 2017

Appendix J: Traffic Counts

	Post Office							PAWI							IDB						
Time	Sun	Mon	Tues	Wed	Thurs	Fri	Sat	Sun	Mon	Tues	Wed	Thurs	Fri	Sat	Sun	Mon	Tues	Wed	Thurs	Fri	Sat
0:00	126	76	57	69	49	54	138	54	45	36	30	32	30	129	95	73	38	58	43	47	134
0:15	141	77	54	62	50	71	100	46	35	24	25	26	24	83	83	65	29	49	39	63	104
0:30	120	89	46	52	39	67	92	34	53	30	25	26	24	93	114	59	24	44	34	53	92
0:45	94	43	36	31	61	56	93	40	32	23	15	25	28	91	88	36	36	29	43	47	101
1:00	88	42	21	37	32	45	103	25	22	18	17	14	22	98	55	37	25	30	32	42	113
1:15	90	35	26	31	42	51	97	22	30	15	20	12	13	54	68	36	9	27	32	36	97
1:30	59	39	22	29	29	38	82	34	31	11	19	6	13	50	61	26	15	23	18	27	81
1:45	51	32	25	25	21	34	67	22	28	12	12	8	16	39	44	26	14	26	14	17	60
2:00	52	19	9	23	13	27	49	29	27	8	11	16	8	37	35	20	11	17	13	25	57
2:15	46	26	11	15	31	22	63	26	37	9	5	12	5	27	42	27	12	18	29	19	48
2:30	24	21	7	17	19	22	50	19	35	5	7	4	8	32	33	23	8	17	17	22	34
2:45	30	27	9	18	17	20	41	25	35	7	8	12	8	21	23	25	14	21	10	22	36
3:00	22	18	18	17	18	21	42	19	21	7	6	4	14	23	28	8	10	10	13	9	31
3:15	32	20	14	21	9	15	46	16	20	9	10	7	16	16	24	21	7	16	7	15	31
3:30	23	9	12	20	18	14	44	15	23	7	9	3	8	25	27	12	13	14	11	14	35
3:45	27	12	13	22	16	25	49	13	13	5	11	4	14	15	17	18	7	18	16	16	33
4:00	23	19	19	13	21	17	51	10	13	8	13	8	16	24	29	17	17	16	17	18	40
4:15	23	22	31	35	30	22	45	16	10	13	6	11	14	12	28	25	24	23	29	22	36
4:30	19	32	29	34	19	28	38	12	21	8	7	6	11	17	23	31	17	25	28	19	35
4:45	27	37	36	45	43	34	37	11	8	11	21	9	17	15	28	28	32	32	28	28	30

5:00	33	42	40	47	49	44	42	11	14	16	14	13	11	20	25	41	35	36	39	37	38
5:15	48	52	61	57	52	59	46	13	15	18	17	21	26	24	38	31	38	41	38	41	33
5:30	53	69	65	83	63	72	62	23	21	27	29	25	23	26	42	48	40	39	47	61	37
5:45	64	97	93	98	62	84	69	43	33	33	39	43	25	49	41	73	64	76	56	68	69
6:00	89	105	118	138	141	129	71	39	41	23	44	37	50	41	52	79	99	107	104	103	69
6:15	120	174	166	172	161	165	91	51	52	48	50	39	62	35	57	121	111	138	116	113	58
6:30	130	217	188	187	166	192	118	38	42	75	58	56	58	59	97	145	127	142	148	161	84
6:45	155	229	198	224	209	209	152	59	52	73	76	67	80	80	104	168	178	183	177	156	105
7:00	165	225	237	216	222	205	123	48	55	76	84	74	74	88	104	186	190	183	173	190	121
7:15	152	225	245	265	237	233	163	56	68	91	92	97	88	79	111	198	205	215	199	192	127
7:30	153	263	253	264	263	276	202	52	59	105	112	114	61	99	117	203	181	211	200	204	139
7:45	195	277	247	266	267	281	197	69	77	127	122	76	95	128	145	223	225	226	221	227	176
8:00	210	230	282	274	278	265	192	79	77	108	95	84	82	112	147	205	211	228	222	215	153
8:15	218	277	280	274	280	297	222	96	73	112	95	88	65	93	156	194	201	218	236	229	161
8:30	214	277	265	275	291	263	222	117	78	125	115	106	80	126	139	228	220	218	223	194	163
8:45	207	248	285	276	260	265	251	96	75	98	116	112	68	118	158	193	243	253	168	214	183
9:00	223	251	268	264	253	280	244	92	65	111	103	109	87	95	143	229	227	209	206	213	170
9:15	226	282	254	249	251	255	249	127	80	128	77	107	63	148	169	224	206	192	201	211	197
9:30	225	256	268	247	243	271	254	119	85	112	82	92	69	126	156	212	229	223	208	211	191
9:45	255	240	258	261	238	259	268	99	70	91	85	91	54	130	187	231	194	211	194	182	176
10:00	239	270	268	253	241	250	287	89	74	116	69	57	83	123	181	191	189	223	208	224	220
10:15	264	261	244	242	253	270	270	80	88	96	77	51	51	113	174	206	210	200	197	214	225

10:30	243	261	249	260	249	253	266	59	85	126	93	73	25	129	152	195	186	203	195	210	205
10:45	256	253	238	241	253	290	279	81	71	108	56	75	57	128	171	222	197	197	200	229	230
11:00	264	270	279	267	249	279	291	109	95	100	71	71	66	133	155	201	217	200	223	219	229
11:15	241	279	269	257	264	266	282	118	74	104	76	76	78	132	185	187	197	196	194	233	242
11:30	255	271	251	266	235	252	296	88	89	124	71	81	41	151	193	194	214	197	215	205	236
11:45	240	251	268	241	292	256	289	106	71	115	108	92	30	118	236	211	211	232	224	213	247
12:00	256	286	263	275	271	277	309	116	84	110	74	67	34	131	233	225	242	244	215	230	251
12:15	257	279	281	280	261	262	312	140	69	126	93	80	54	143	176	222	201	248	210	235	233
12:30	270	273	269	260	261	255	278	117	88	128	79	59	46	166	217	233	206	209	243	240	228
12:45	244	265	264	272	279	264	253	101	73	101	90	52	49	143	223	229	225	204	230	224	244
13:00	252	254	267	258	276	265	277	124	82	110	84	98	52	127	204	203	217	246	220	214	236
13:15	256	276	245	264	263	269	297	120	75	115	84	82	21	134	164	207	198	217	242	224	249
13:30	247	287	264	250	265	247	290	114	86	87	100	77	64	148	174	215	214	218	226	217	251
13:45	218	262	258	267	256	268	293	109	72	87	66	38	40	129	172	218	209	202	217	241	254
14:00	224	249	252	268	266	271	300	108	71	86	95	26	28	144	178	219	204	231	214	215	259
14:15	208	260	273	271	255	266	295	92	76	86	57	50	18	139	211	219	208	226	202	236	241
14:30	219	264	251	251	250	267	292	102	66	112	88	59	24	131	185	209	229	248	201	226	248
14:45	207	237	231	240	235	261	287	96	82	81	37	79	36	120	181	196	195	211	230	216	222
15:00	229	256	262	244	272	276	276	102	78	84	90	56	30	146	180	249	187	195	239	233	216
15:15	197	241	249	248	257	299	268	81	72	92	109	67	71	120	181	221	210	201	188	219	240
15:30	216	223	221	247	251	282	251	106	85	92	139	88	19	122	154	209	206	196	205	242	212
15:45	232	240	256	253	256	273	210	102	75	87	135	49	22	132	152	188	201	199	194	224	188

xl

16:00	235	275	256	252	287	268	260	85	77	104	131	43	25	129	156	210	167	225	224	247	213
16:15	221	312	278	212	275	295	271	80	76	93	142	105	52	153	164	197	189	209	214	227	219
16:30	227	285	282	291	303	272	280	100	71	104	148	77	75	129	205	269	246	219	229	234	215
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18:00	220	279	260	280	283	249	246	124	124	114	141	23	35	157	204	212	188	252	216	183	196
18:15	266	291	254	301	254	229	260	102	146	109	97	37	23	151	178	206	185	195	194	178	221
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19:00	290	273	268	254	261	202	247	103	155	122	142	93	122	139	172	167	165	173	183	180	206
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20:45	217	210	188	177	153	145	202	96	152	95	103	108	106	136	172	133	113	130	118	148	160
21:00	214	174	187	201	193	176	238	101	153	95	100	95	118	130	138	113	87	138	139	161	198
21:15	182	162	160	181	180	152	199	93	138	80	105	91	149	129	176	108	92	118	135	167	165

21:30	174	172	177	166	172	119	179	85	133	66	96	70	124	118	145	113	93	123	135	147	171
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22:00	145	127	136	136	128	110	203	76	85	76	98	73	110	92	154	76	97	113	120	159	167
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