DEPARTMENT OF ELECTRONIC & ELECTRICAL ENGINEERING

University of Strathclyde Engineering

Feasibility Study:

Using TV White Space for Internet Connectivity in the Loch Lomond & Trossachs National Park

Centre for White Space Communications

Version 0.01

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Executive Summary

This report describes the results of an initial investigation in to the feasibility of using TVWS to provide connectivity to the newly outlined management zones within Loch Lomond National Park, facilitating a more convenient method of connectivity for park rangers.

The investigation was carried out by the University of Strathclyde's Centre for White Space Communication [CWSC], which has been actively contributing to the development of white space technology for over five years. The Centre has been involved in several successful collaborative projects across a range of areas, including rural broadband deployment, and is currently concluding a TVWS pilot project in Orkney.

The results in this report will, it is hoped, provide the Loch Lomond and Trossachs National Park Authority with a technical insight in to the various options available to them in addressing their current connectivity problems.

The terrain within the National Park creates a number of issues for telecommunications, in both wired and wireless systems. Due to the rural locations involved, connection to a telephone exchange via underground cabling will involve significant civil engineering works. In addition, a mountainous environment with a high density of foliage can cause issues with some forms of wireless communication, because of the reduced line-of-sight capabilities between transmitter and receiver. TV White Space technology has certain characteristics that make it considerably more suitable than other candidate wireless technologies that operate at higher frequencies.

Due to the size of the total area to be covered it is recommended that fourteen groups, or clusters, of priority coverage locations are formed. Of these, seven were identified as outside mobile broadband services and determined to be a higher priority. For each of these clusters, a basestation unit would be established in a position that provided coverage to all of the key locations within.

Each basestation would require access to internet connectivity backhaul and power supply. A number of ranger vehicles would then be fitted with client radio units, which would connect to these established basestations over TV White Space and allow for internet access. Wi-Fi access points would then allow for staff and park visitors to use their internet-enabled devices for permit requisition and other servies.

The CWSC recommend that a phased approach is adopted, starting with one cluster which may be connected with relative ease in comparison with the more difficult ones. A suitable candidate might be one of the clusters identified around the Loch Earn, Loch Long, or Balquhidder areas. However, this will be dependent on negotiation with land owners.

By tackling one cluster in the first instance, a great deal with be learned about the detailed installation difficulties, which will feed directly into planning activities and decision-making for subsequent clusters. This phased approach also provides for a decision-gate process to be employed, thereby reducing overall risk while at the same time maximizing the overall chances of success.

It is hoped that this feasibility study will be useful in guiding the LLTNP Authority's plans, and we would welcome the opportunity to engage further on more detailed planning for connecting an initial cluster.

Contents

1 INTRODUCTION

In March 2017, new seasonal by-laws were introduced, creating multiple camping management zones across the 460,900-acre Loch Lomond and Trossachs National Park (LLTNP) in an attempt to reduce anti-social behaviour in the area. Under this new legislation, anyone staying overnight in a campsite or one of the outlined management zones requires a permit. Permits are obtained online through the National Park's website.

It is important that staff and the public are able to access the internet, or phone signal, to enable booking of permits and campsite pitches when out in the field. The NPA staff also need to be able to connect regularly to staff for safety and general information.

Unfortunately, due to the extremely rural location of the campsites within the Park, connectivity is not readily available. A recent coverage summary showed that a large portion of the outlined management zones have poor, or even non-existent, mobile broadband coverage. This problem, coupled with the large distances involved in travelling to the limited number of fixed locations where with internet connectivity does exist, means that issuing permits to campers is not a trivial task, and it also severely limits the ability for park ranges to request help in case of emergencies.

Recently introduced regulations in the UK have allowed for licence-exempt use of certain channels in the TV band. This so-called TV White Space (TVWS) communication technology has significant potential to provide this connectivity, despite the large distances and difficult terrain involved. This report describes the results of an initial investigation in to the feasibility of using TVWS to provide connectivity to the newly outlined management zones, facilitating a more convenient method of connectivity for park rangers.

The investigation was carried out by the University of Strathclyde's Centre for White Space Communication (CWSC), which has been actively contributing to the development of White Space technology and regulation for more than five years. The Centre has been involved in several successful collaborative projects across a range of areas, including rural broadband deployment, and is currently concluding a TVWS pilot network project in Orkney.

The results presented in this report will, it is hoped, provide the Loch Lomond and Trossachs National Park Authority with an insight in to the various options available to them in addressing their current connectivity problems.

2 THE CONNECTIVITY CHALLENGE

Broadband deployment is an ongoing challenge faced by many rural communities across the UK. In many remote areas, this is due to the lack of modern infrastructure with many homes and businesses reliant on existing copper-cable asynchronous digital subscriber (ADSL) technology. Often this leads to high latency, low data rate connectivity caused by the long distance between the telephone exchange and end user premises. Emerging superfast broadband alternatives, such as fibre-optic cabling and 4th Generation (4G) mobile technologies, require substantial capital investment and often require major subsidy in operating costs in hard-to-reach, sparsely populated rural areas.

Following the introduction of the new by-laws, rangers in LLTNP will require the ability to query and issue permits for any campers within the new designated management zones. It would be extremely beneficial to be able to perform this task in the field, without the need to travel back to a fixed premise with an existing internet connection. In addition to this, enforcement of this new legislation introduces an additional potential risk to the employees' safety, which could be significantly reduced through connectivity to a local Park office.

Within each management zone, several key permit areas and campsite locations have been identified by the Loch Lomond and Trossachs National Park Authority[1]. Connectivity should be available for park rangers at each of these locations. Following a survey of phone coverage completed in 2015[2], it is obvious that several of these key locations fall in areas with limited, or non-existent, mobile connectivity. This means that we need to explore an alternative method of providing connectivity to these areas.

The proposed system uses emerging TVWS technologies to provide connectivity to these remote locations. Due to the properties of signals within the TV Band, TVWS signals do not require direct line-of-sight (LOS) for connectivity, and are better at penetrating obstacles such as foliage than higher-frequency technologies such as conventional Wi-Fi[3]. Like most electronic technology evolution, TVWS equipment costs are falling while data rates and technical performance are improving.

Conceptually, to provide connectivity, several TVWS 'basestation' radios would be established throughout the National Park. Each basestation unit would be connected to a 'Point of Presence' (PoP), essentially an internet source, either directly or through a backhaul link. This backhaul could be a dedicated microwave link, or even another TVWS link; the choice is generally dependent on what options are available and feasible to implement.

A number of ranger vehicles would then be fitted with a TVWS 'client' radio, also known as a 'CPE' radio. These CPEs would then connect wirelessly to each basestation as the vehicles move through the park, providing internet access to an on-board Wi-Fi access point via the TVWS link.

The above description of the basic concept is simplistic in that it conveniently ignores a number of challenges that need to be addressed. These include:

- TVWS coverage: The TVWS basestations need to be located in positions which allow good connectivity to the key locations. While TVWS has certain favourable propagation characteristics, it is not limitless, and basestation sites need to be chosen such that there exists an adequate amount of signal coverage.

[1] A map showing the boundary locations of the Management Zones, potential campsites and potential permit areas is included in Appendix A.

[2] A map showing the location of phone coverage quality and measurement locations within the National Park is included in Appendix B.

[3] See Appendix C for an overview of White Space communication.

- TVWS spectrum availability: The TVWS spectrum is managed in 8 MHz channels, and channel availability is dependent on the location of the TVWS radios. It is essential that at least one channel is available for the basestation and client to make use of.
- Backhaul connectivity: The basestations need to be able to communicate with the vehicle-based CPEs and then relay this data to/from the Internet. This means that they need 'backhaul' connectivity, in one form or another, to a PoP. In some instances, it may be possible to use satellite connectivity as backhaul.
- Basestation power: Each basestation unit requires an electrical source via a 'power over ethernet' (POE) adaptor. This can be from either a conventional mains supply or a custom-designed renewable energy-powered mast.
- Site permissions and access: The choice of basestation position is determined not only by technical requirements but also by other factors such as site permissions, planning permission for masts, ease of access, terms and conditions of access being granted, etc. This typically requires negotiation with landowners or property managers.

Fourteen groups, or clusters, of key locations and permit areas were created based on the projected coverage capabilities of TVWS basestations in the National Park. Of these fourteen clusters, seven were identified as being outside the coverage of mobile broadband services and as such were classified as higher priority.

In the following sections, more detailed analysis is presented for each of the high priority clusters, encompassing the above challenges and highlighting others where appropriate. In addition, the challenges relating to the installation of the unique client units will be outlined, including some potential solutions.

3 USING TVWS TO PROVIDE CONNECTIVITY IN KEY LOCATIONS

In this section, the above challenges outlined in Section 2 are considered in more detail for each of the high priority clusters, where mobile coverage is at its worst. Information on the remaining seven clusters of campsites is included in Appendix D

3.1 Loch Long Area

Figure 3-1 shows the generated boundary for the Loch Long area, along with various notable points of interest. Some of these points have the potential to be basestation locations, subject to access restrictions, or simply a possible source of power or backhaul.

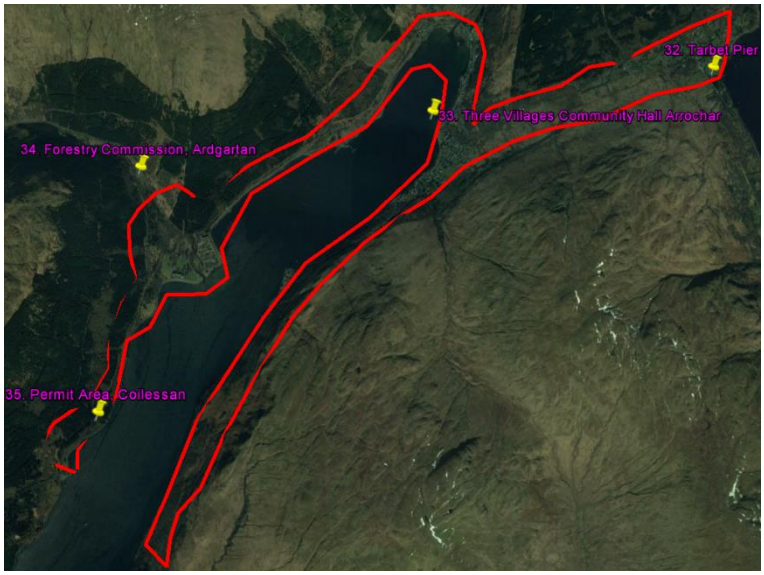

Figure 3-1: The Loch Long cluster showing contained points of interest.

Figure 3-2 shows the permit and campsite locations that would be served by the installed basestation. While some of the locations exist outside the generated boundary, the connectivity supplied would still alleviate concerns regarding staff safety and reduce the total travel distance required for park staff to issue permits.

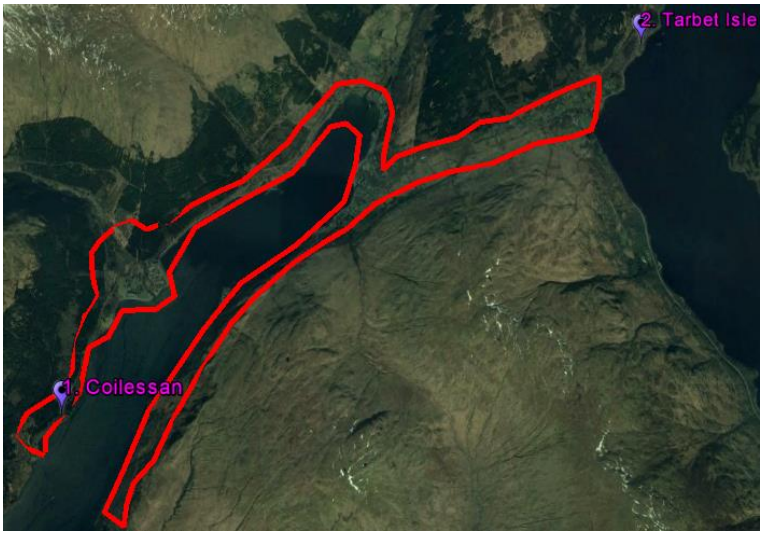

Figure 3-2: The Loch Long cluster showing contained permit locations and campsites.

Figure 3-3 shows the 'best' basestation locations for the Loch Long cluster as far as TVWS coverage is concerned. Green-coloured areas represent 'good' locations, while yellow-coloured areas represented 'reasonable' locations, and blue-coloured areas represent 'poor' locations. The map assumes a single installed basestation, with the intention of providing maximum coverage for the outlined cluster boundary.

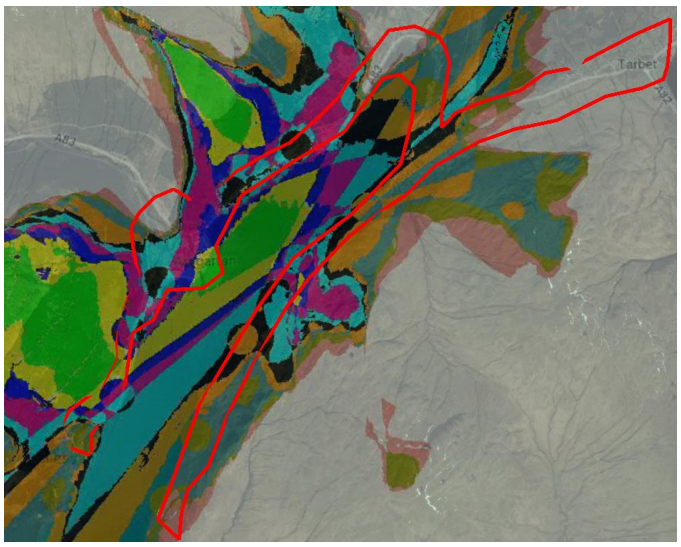

Figure 3-3: 'Optimal' basestation locations to provide coverage for the entire Loch Long cluster. (Green is best; blue is worst.)

While this may be an optimal implementation as far as TVWS coverage is concerned, the above simulations do not account for site access, power provision or backhaul connectivity. Rather, the aim is to narrow down the options of potential basestation locations to obtain one that is spectrally suitable while also meeting the outlined logistical criteria.

It was advised that the Arrochar Hotel may, potentially, be a suitable location for a basestation with regards to power supply, internet backhaul access, and site access, and it is also located in a reasonable location to supply coverage for the area. Installation of a basestation at this point would be subject to negotiation with the land or property owner.

Figure 3-4 shows the simulated coverage profile, assuming a basestation antenna height of 12m Above Ground Level (AGL). Areas highlighted in green are expected to have a received signal strength of at least 25 dB above the noise sensitivity threshold of the TVWS radio. This value is referred to as the 'Signal to Noise Ratio' (SNR). In these areas, we would expect a received signal strength of at least -76dBm, which may be expected to support a data rate of around 20 Mbit/s from a single 8 MHz TVWS channel. Similarly, areas highlighted in yellow are expected to have an SNR value of 10-25 dB. Areas highlighted in red would be expected to have very little or no connectivity.

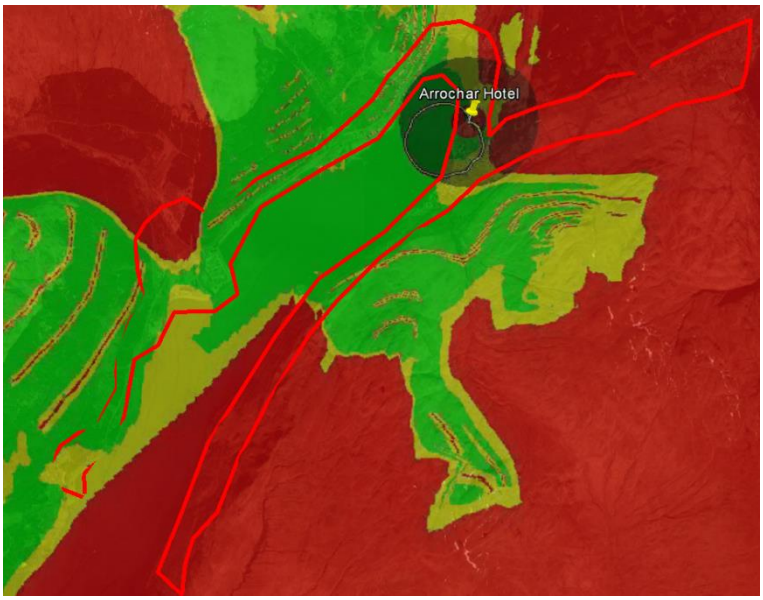

Figure 3-4: Coverage profile assuming a 12m antenna height at the Arrochar Hotel location within the Loch Long cluster. (Green indicates a strong signal reception; Red indicates poor/no reception.)

TVWS spectrum availability depends on several factors related to the radios and their surrounding locations. Access to the available TVWS spectrum is controlled using a regulator-approved geo-location database. Queries to an Ofcom-approved database suggest that there are multiple channels available for use in the Loch Long. Figure 3-5 and Figure 3-6 show a representation of channel availability for basestations located in two different locations within the Loch Long area.

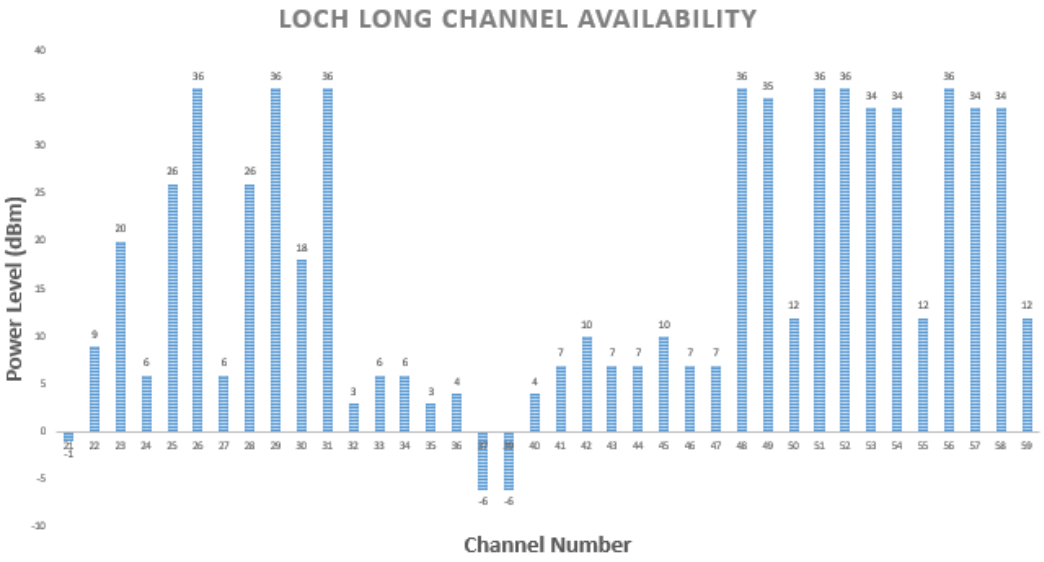

Figure 3-5: A spectrum availability profile from within the Loch Long cluster.

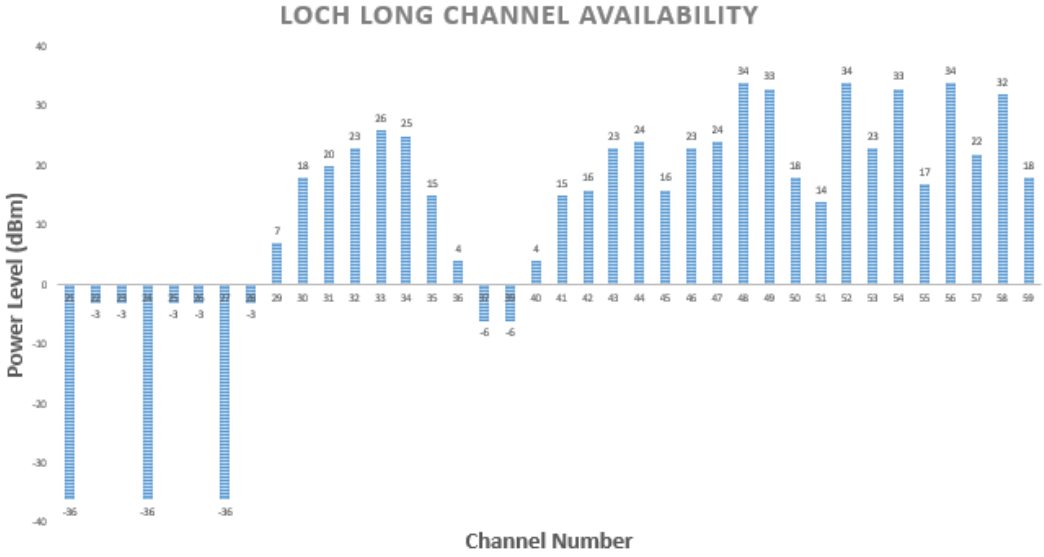

Figure 3-6: A spectrum availability profile from within the Loch Long cluster.

Looking at these profiles, high quality channels are available at multiple points within the boundary area. For this application, any channel that allows transmission at 30 dBm or greater, with a maximum value of 36 dBm, is considered. A summary of available channels in the area and associated transmit powers is shown below in Table 3-1.

Loch Long Channel Selection	
Channel	**Power Level (dBm)**
48	34
52	34
54	31
56	34

Table 3-1: Commonly available channels within the Loch Long area.

3.2 Balquhidder

Figure 3-7 and Figure 3-8 show the generated boundary surrounding the Balquhidder permit area, in addition to the Inverlochlarig Visitors shelter. This site is not a viable source of power or backhaul and has been disregarded as a potential basestation site.

Figure 3-7: The Balquhidder cluster showing contained points of interest.

Figure 3-8: The Balquhidder cluster showing contained permit locations and campsites.

Figure 3-9 shows the 'optimum' basestation locations for the area. Again, this only considers total achievable coverage for a single installed basestation and does not account for factors such as available backhaul, site access or power. Green-coloured areas represent good locations, while yellow-coloured. areas represented 'reasonable' locations, and blue-coloured areas represent poor locations.

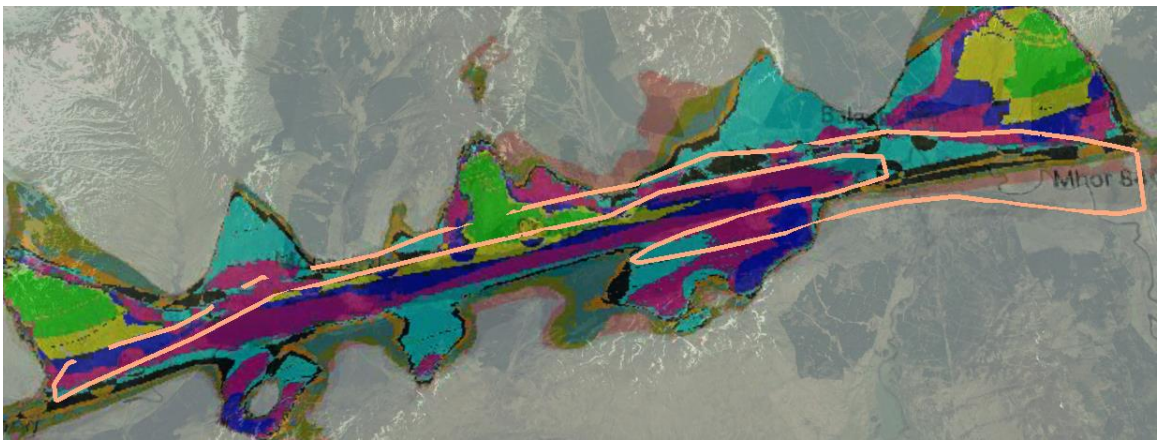

Figure 3-9: 'Optimal' basestation locations to provide coverage for the entire Balquhidder cluster. (Green is best; blue is worst.)

It was advised that the Monachyle Mor Hotel could possibly be considered for basestation deployment with access to power supply and internet backhaul. Unfortunately, the site is not in the best location to provide full coverage for the area. Figure 3-10 shows the achievable area coverage if a basestation was installed at this location. As before, the green-highlighted areas indicate a strong signal reception, while in red-highlighted areas we would expect little to no connectivity.

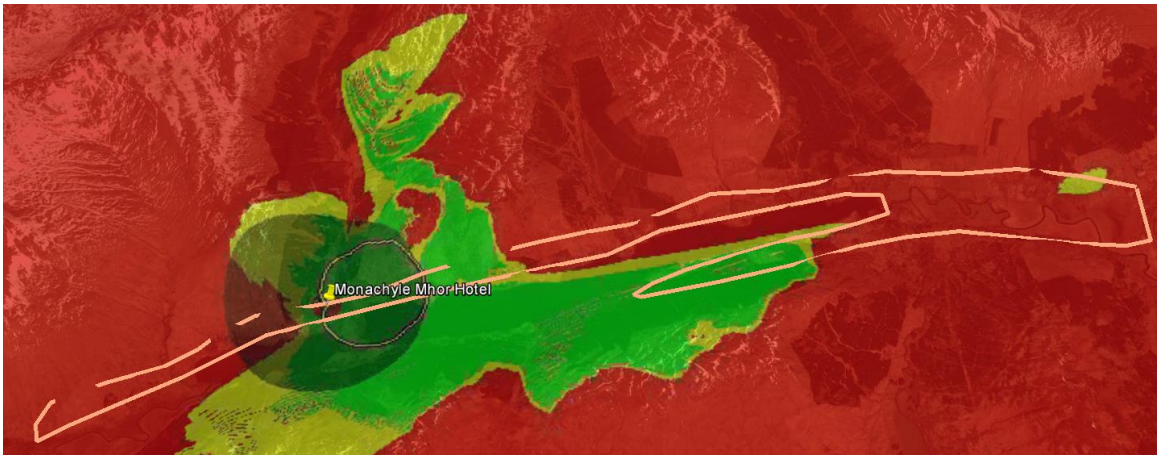

Figure 3-10: Coverage profile assuming a 12m antenna height at the Monachyle Mor Hotel location within the Balquhidder cluster. (Green indicates a strong signal reception; Red indicates poor/no reception.)

A spectral profile for the Balquhidder area was created using an Ofcom-approved database. As there are a reduced number of permit areas within the cluster, only a single location query was used, with the results shown in Figure 3-11.

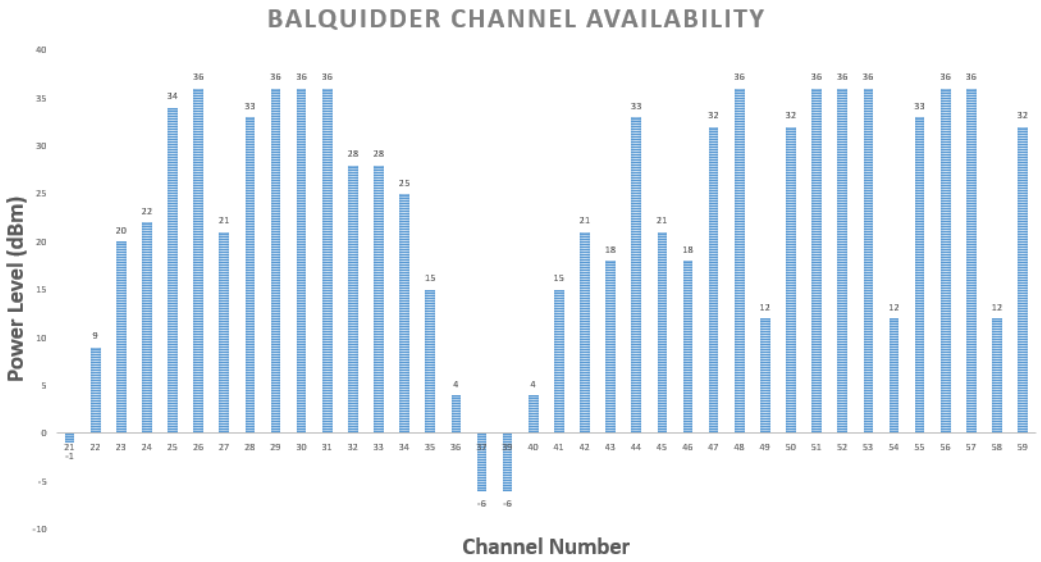

Figure 3-11: A spectrum availability profile from within the Balquhidder cluster.

From the above availability profile, it is clear there are several suitable channels in the cluster area, with a transmit power of greater than 30 dBm, which could be used for connectivity.

3.3 Frenich Farm

Due to the size of the Frenich Farm area, it was not possible to find a location where a single TVWS could provide coverage. Therefore, it was decided that two separate clusters would be created.

3.3.1 Southern Frenich Farm Cluster

The first of these, in the south of the Frenich Farm area, includes the Loch Chon campsite among the permit areas and is shown in Figure 3-12 and Figure 3-13. This was a location that was identified as having suitable power and site access properties, but would be not have the required backhaul capabilities. If this were selected as the site of the implemented basestation, a 'chain' of TVWS links would be required to provide backhaul to the site. This would involve installation of additional basestations to create the connection, most probably pointing towards the northern cluster in the area. It is unlikely that microwave technology would be feasible for the backhaul, due to the terrain involved. Further investigation of backhaul options would be required.

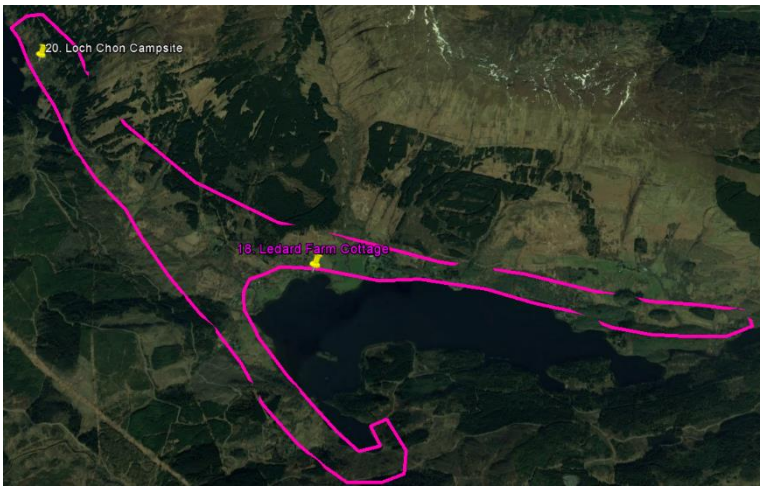

Figure 3-12: The Southern Frenich Farm cluster showing contained points of interest.

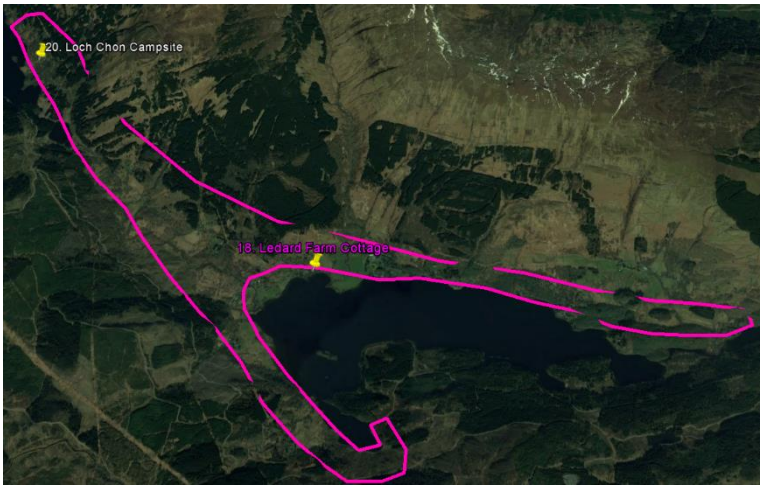

Figure 3-13: The Southern Frenich Farm cluster showing contained permit locations and campsites.

Figure 3-14 shows the simulation results to find the 'optimum' basestation locations for the area. As can be seen, the Loch Chon campsite permit area is extremely close to one of the green-coloured areas, representing a good installation location.

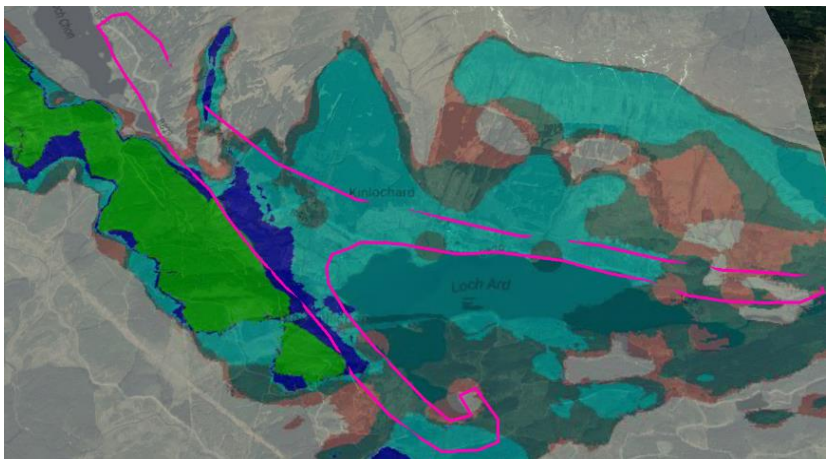

Figure 3-14: 'Optimal' basestation locations to provide coverage for Southern Frenich Farm cluster. (Green is best; blue is worst.)

The Macdonald Forest Hills Hotel and Spa was identified as a possible basestation deployment location with access to power supply and internet backhaul. Figure 3-15 shows the achievable area coverage if a basestation was installed at this location. Again, the green-highlighted areas indicate a strong signal reception, while in red-highlighted areas we would expect little to no connectivity. While much of the southern cluster would be served by this installation, the Loch Chon campsite appears to be outside the achievable coverage area. However, TVWS installation in this area would reduce the amount of travelling required by park rangers to issue permits and alleviate some of the safety concerns due to lack of connectivity.

Figure 3-15: Coverage profile assuming a 12m antenna height at the Forest Hills Hotel location within the Southern Frenich Farm cluster. (Green indicates a strong signal reception; Red indicates poor/no reception.)

As before, an Ofcom-approved database was consulted to determine the frequency availability within the area, with the results shown in Figure 3-16 and Figure 3-17. In this case, there does not appear to be an abundance of channels available. Across the two measurement points, only Channel 56 is commonly available at a suitable transmission power. This is an unusual phenomenon in such a rural location, and it is suspected that there is potentially an error within the database in

these locations. However, this is an issue that will require investigation and discussion with Ofcom, which is beyond the scope of this report.

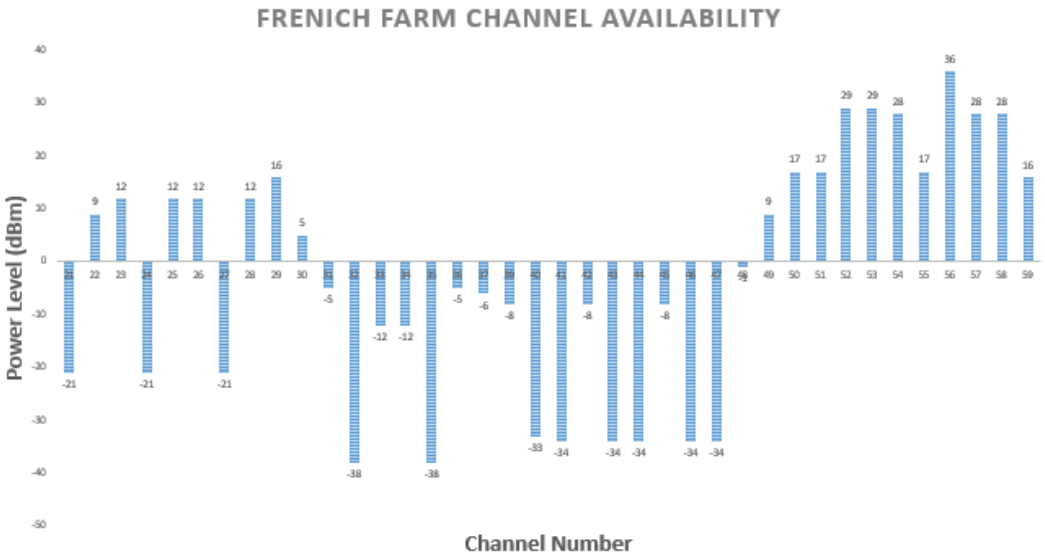

Figure 3-16: A spectrum availability profile from within the Southern Frenich Farm cluster.

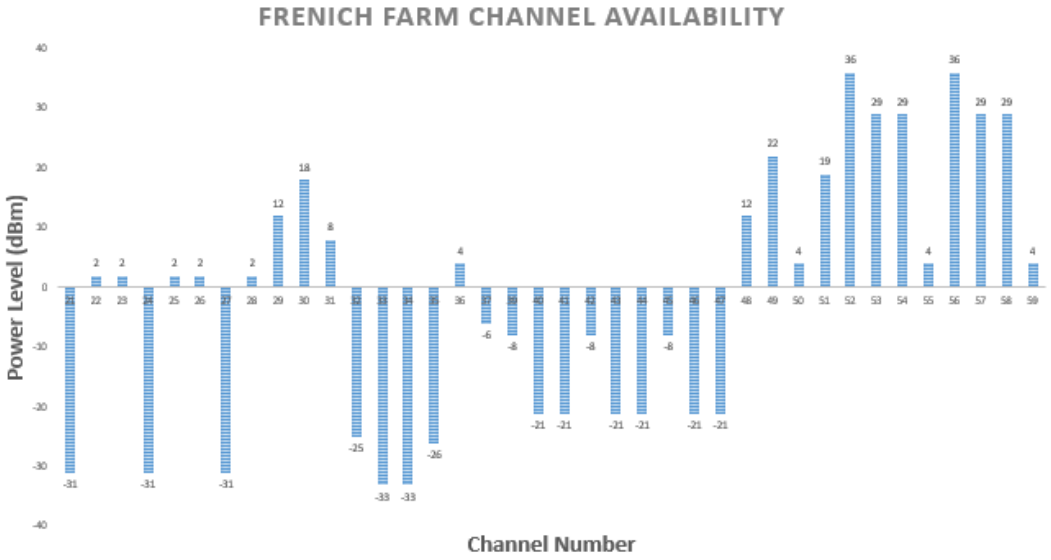

Figure 3-17: A spectrum availability profile from within the Southern Frenich Farm cluster.

3.3.2 Northern Frenich Farm Cluster

The second cluster within the Frenich Farm area is shown below in Figure 3-18 and Figure 3-19. This is an area that does not contain any key permit locations, but is often travelled by park staff and is outside the available mobile coverage areas. Basestations may also be required in this cluster if additional TVWS installations are required to provide backhaul link connectivity to the Southern cluster.

Figure 3-18: The Northern Frenich Farm cluster showing contained points of interest.

Figure 3-19: The Northern Frenich Farm cluster showing contained permit locations and campsites.

Figure 3-20 shows the results of the simulations used to find the 'best' basestation locations for the area. As can be seen, a great deal of the area is highlighted blue, indicating a weak area for an installation, before any consideration is given to power or backhaul.

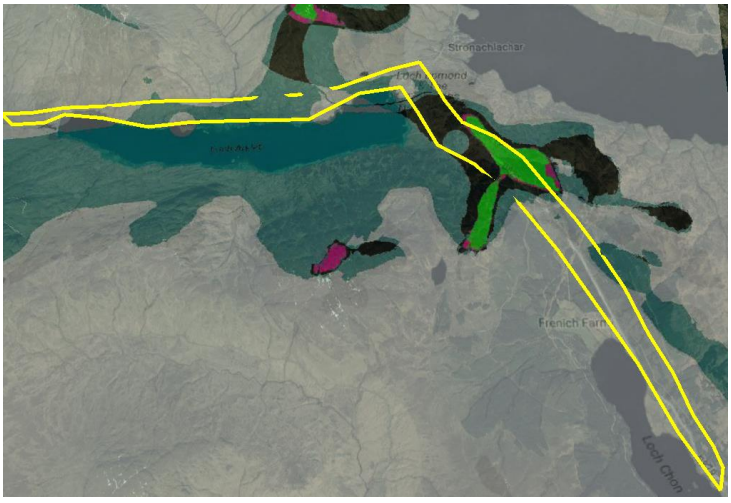

Figure 3-20: 'Optimal' basestation locations to provide coverage for Northern Frenich Farm cluster. (Green is best; blue is worst.)

A BT Substation was suggested as a potentially accessible location with power and backhaul capabilities. Looking at the optimal locations suggested by simulation, it would seem unlikely that a

basestation at this site could provide coverage to the area. This is confirmed by the completed coverage analysis shown in Figure 3-21.

If it was necessary to create a 'chain' of TVWS links to provide backhaul to the Southern Frenich Farm area, at least two basestations would be required in the Northern region to connect to an installation at the Loch Chon site. In addition, one of these installations would likely need to be a lightweight renewable-energy basestation, due to the lack of alternative sites in the cluster, powered by solar and wind energy. CWSC has experience in developing this kind of technology for radio masts. Further analysis of this option would be required before concrete recommendations would be possible.

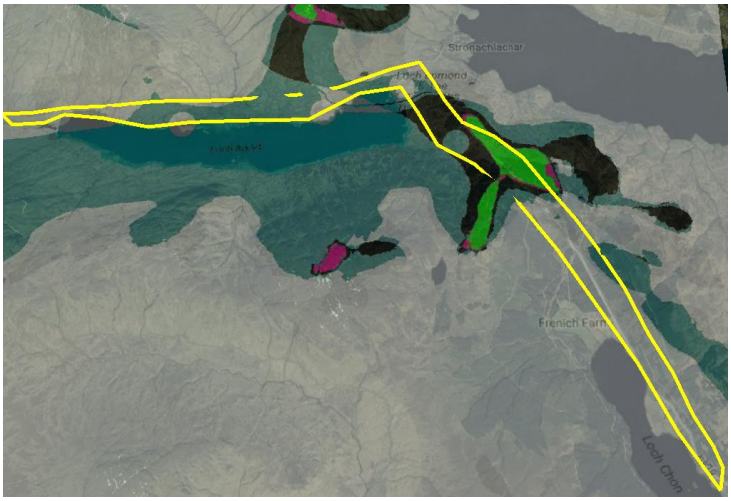

Figure 3-21: Coverage profile assuming a 12m antenna height at BT Substation within the Northern Frenich Farm cluster. (Green indicates a strong signal reception; Red indicates poor/no reception.)

The spectrum availability profile was created to assess the channel availability in this Northern cluster. Figure 3-22 and Figure 3-23 show the results. Unlike the Southern cluster, there appear to be several channels available with sufficient transmit powers. A summary of this spectral analysis is included in Table 3-2.

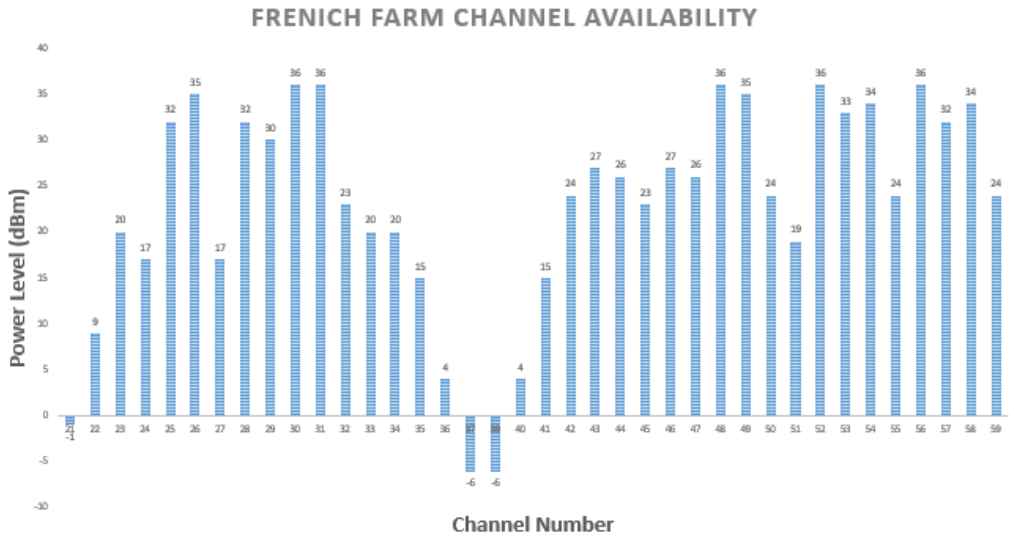

Figure 3-22: A spectrum availability profile for the North Frenich Farm cluster.

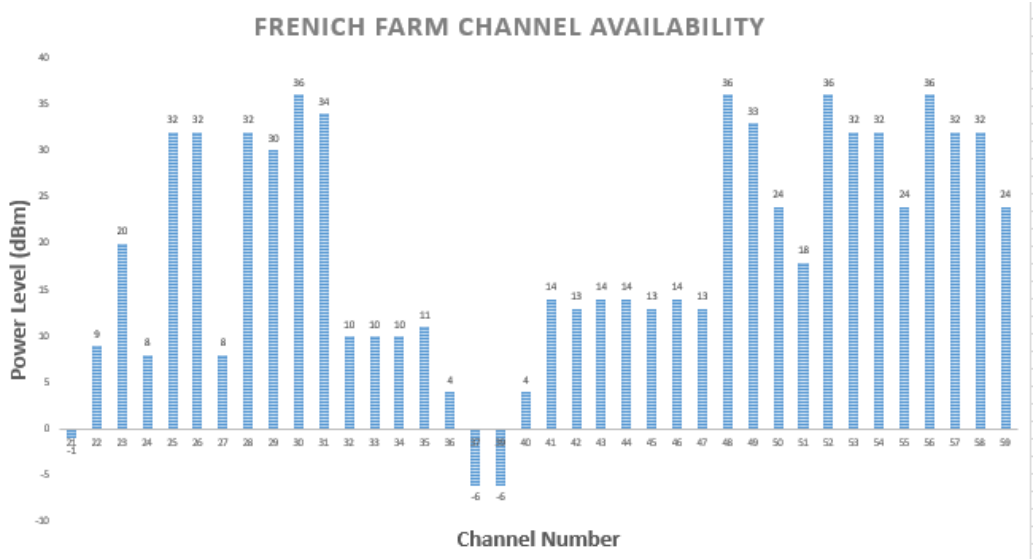

Figure 3-23: A spectrum availability profile for the North Frenich Farm cluster.

Frenich Farm Channel Selection	
Channel	**Power Level (dBm)**
25	32
26	32
28	32
29	30
30	36
31	34
48	36
49	33
52	36
53	32
54	32
56	36
57	32

58	32

Table 3-2: Commonly available channels within the Northern Frenich Farm cluster.

3.4 Loch Achray

Figure 3-24 and Figure 3-25 show the generated boundary for the Loch Achray area with contained points of interest and several key permit locations and campsites.

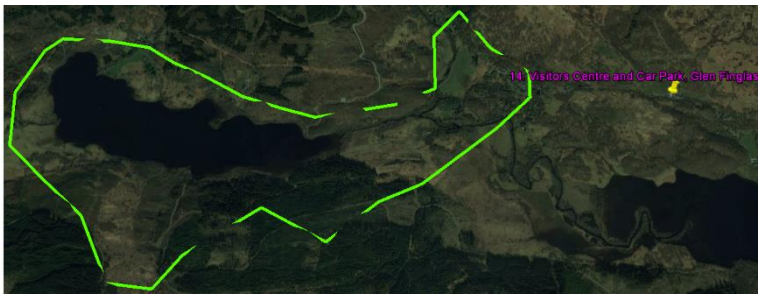

Figure 3-24: The Loch Achray cluster showing contained points of interest.

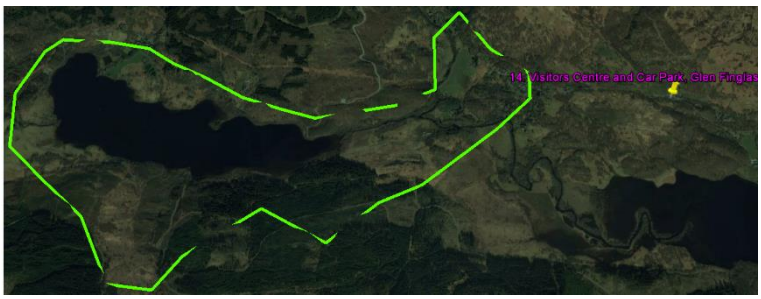

Figure 3-25: The Loch Achray cluster showing contained permit locations and campsites.

The 'optimal' basestation locations for the area are shown below in Figure 3-26. Green-coloured areas represent good locations, while blue-coloured areas represent poor locations.

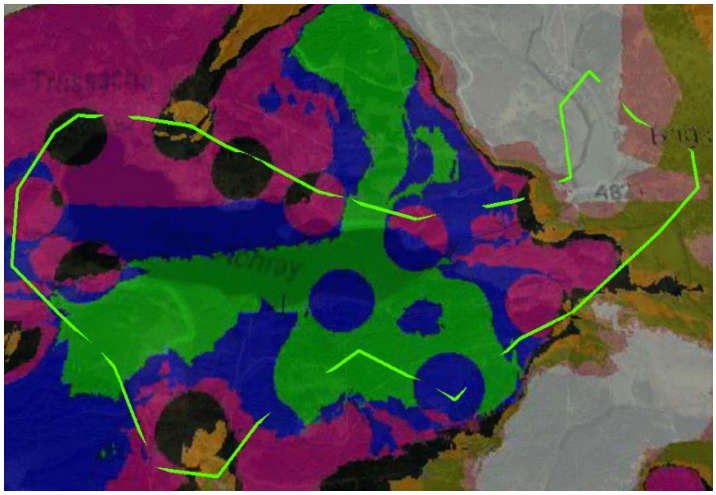

Figure 3-26: 'Optimal' basestation locations to provide coverage for Loch Achray cluster. (Green is best; grey is worst)

The Loch & Glens Hotel was suggested for a possible basestation installation, with reasonable site access, power supply and internet backhaul. As can be seen from Figure 3-26, it is also located in an area expected to provide good coverage, which is confirmed by the simulations shown in Figure 3-27.

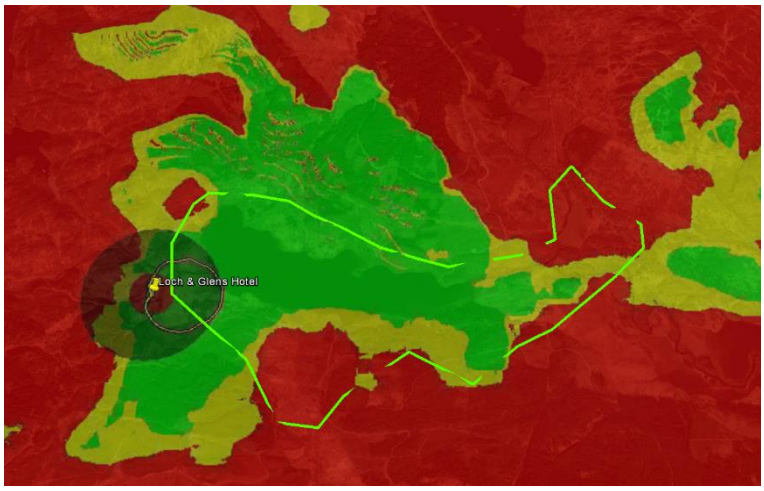

Figure 3-27: Coverage profile assuming a 12m antenna height at Loch & Glens Hotel within the Loch Achray cluster. (Green indicates a strong signal reception; Red indicates poor/no reception.)

A spectral profile for the Loch Achray cluster was completed using an Ofcom-approved database. As there are several permit areas in the vicinity, a single location query for an approximately central point was used, with the results shown in Figure 3-28. Clearly, there are a number of suitable channels within the cluster than can be used at the maximum transmit power of 36 dBm.

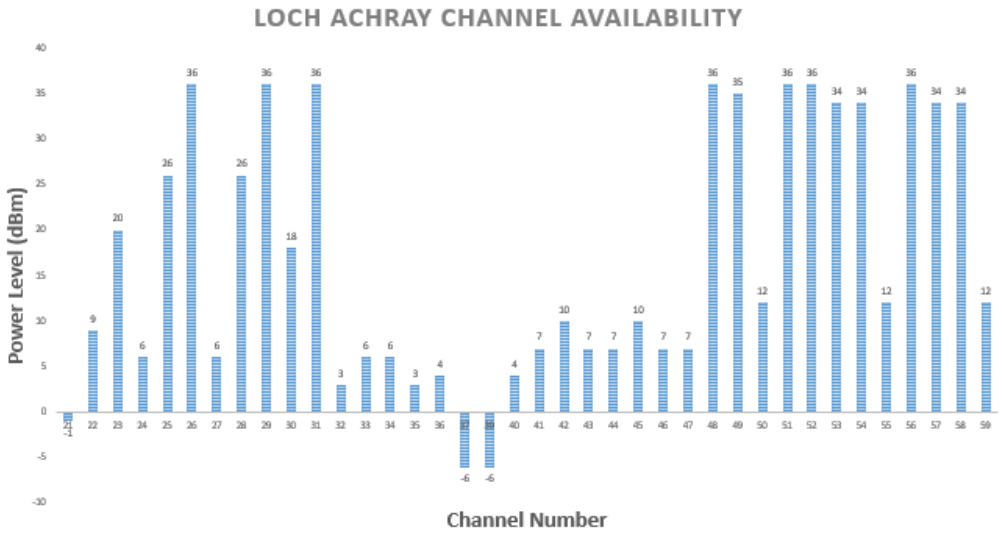

Figure 3-28: A spectrum availability profile for the Loch Achray cluster.

3.5 Loch Drunkie

Figure 3-29 and Figure 3-30 show the generated boundary surrounding the Loch Drunkie permit area, in addition to the Forrest Drive road entrance and the Glen Finglas Visitors Centre. Neither of these sites were identified as a viable source of power or backhaul and were initially been disregarded as potential basestation sites.

Figure 3-29: The Loch Drunkie cluster showing contained points of interest.

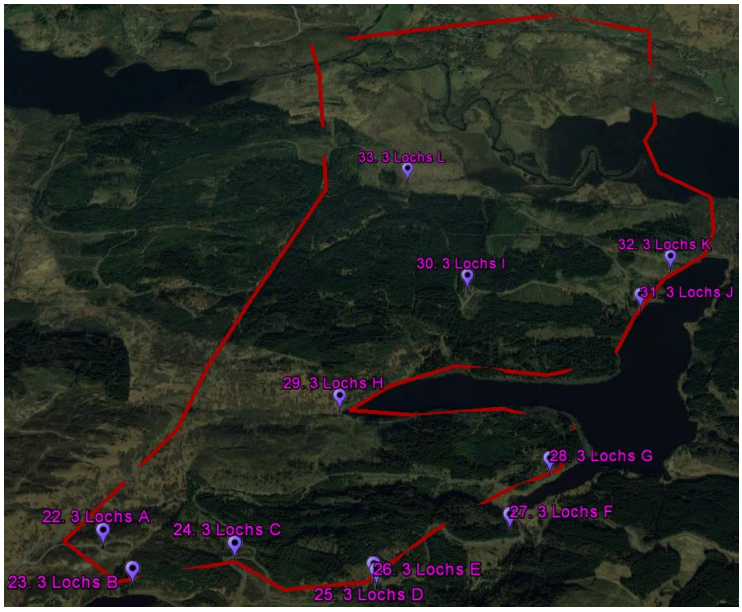

Figure 3-30: The Loch Drunkie cluster showing contained permit locations and campsites.

The simulation output to calculate the 'best' basestation location is shown below in Figure 3-31. As can be seen, a large amount of the area is considered unsuitable, with the preferred green-coloured areas falling some distance away from practical site locations with power and backhaul

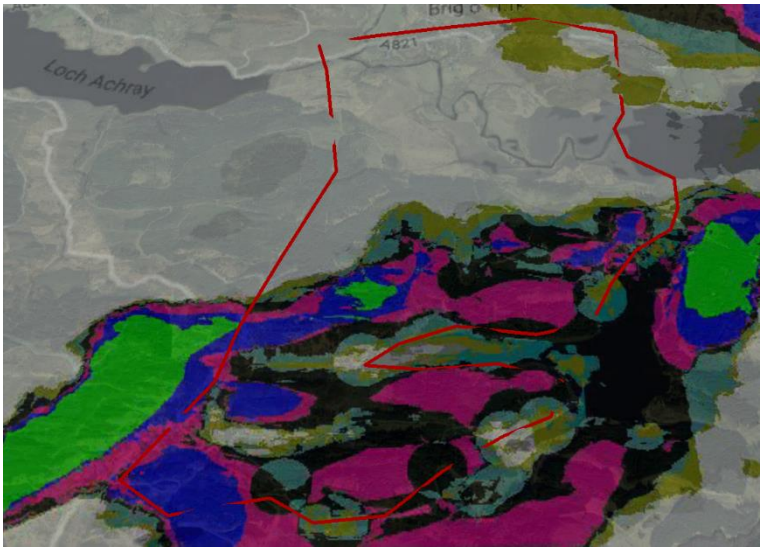

Figure 3-31: 'Optimal' basestation locations to provide coverage for Loch Drunkie cluster. (Green is best; grey is worst.)

It was suggested that the Lodge Forest Visitor Centre could be used to provide backhaul connectivity to the area, with a basestation installed at the Three Lochs Forrest Drive site. A Wi-Fi access point could then be fitted at this basestation, allowing park visitors the opportunity to purchase permits before entering a long stretch of one-way road.

To assess the viability of this proposal, the connectivity between the Lodge Forest Visitor Centre and Three Lochs Forrest Drive was assessed; the results are shown in Figure 3-32.

Figure 3-32: Assessing the LOS connectivity between The Lodge Forest Visitor Centre and the potential basestation location at Three Lochs Forrest Drive.

While the distance between the two points is only slightly more than two kilometres, the terrain elevation is around 180m. This causes a significant amount of signal attenuation, with the expected receiver SNR to be around 1 dB. This would suggest that, in this current form, the link is unusable for backhaul connectivity. It may be possible to provide this with the installation of an additional basestation, most likely a lightweight renewable mast at the elevation peak.

Unfortunately, there were no other PoP locations identified within the cluster. If the Lodge Forest Visitor Centre cannot be used to provide backhaul it may be necessary to create a backhaul link to the nearby Loch Achray cluster. Further analysis would be required to fully assess the requirements of this proposal, which is outside the scope of this report.

As before, an Ofcom-approved database was consulted to determine the frequency availability within the area, with the results shown in Figure 3-33 and Figure 3-34. A summary of these representations is included in Table 3-3, where multiple suitable transmission channels are identified.

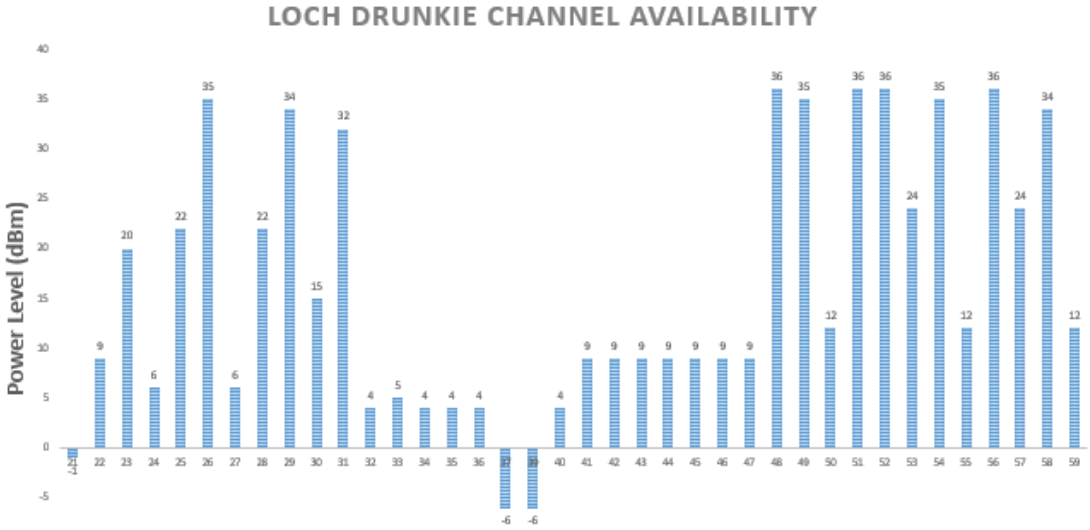

Figure 3-33: A spectrum availability profile for the Loch Drunkie cluster.

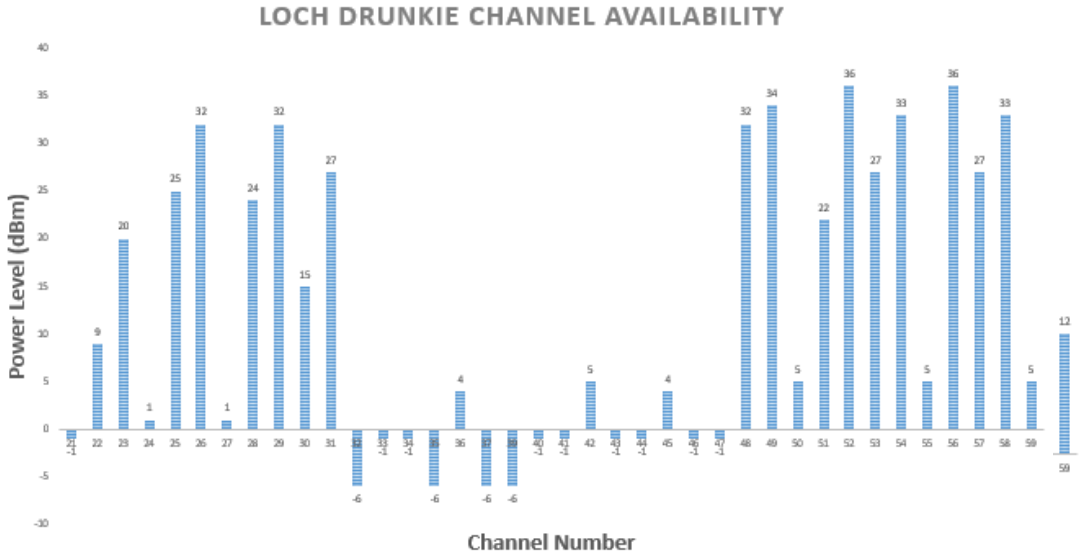

Figure 3-34: A spectrum availability profile for the Loch Drunkie cluster.

Loch Drunkie Channel Selection	
Channel	**Power Level (dBm)**
26	32
29	32
48	32
49	34
52	36
54	33
56	36
58	33

Table 3-3: Commonly available channels within the Loch Drunkie cluster.

3.6 Loch Earn

Figure 3-35 and Figure 3-36 show the generated boundary surrounding the Loch Earn permit area, in addition to the National Park Office at Lochearnhead. While this originally was considered as a potential site for basestation installation, concerns were raised regarding site access and land negotiation, so an alternative location would be required.

Figure 3-35: The Loch Earn cluster showing contained points of interest.

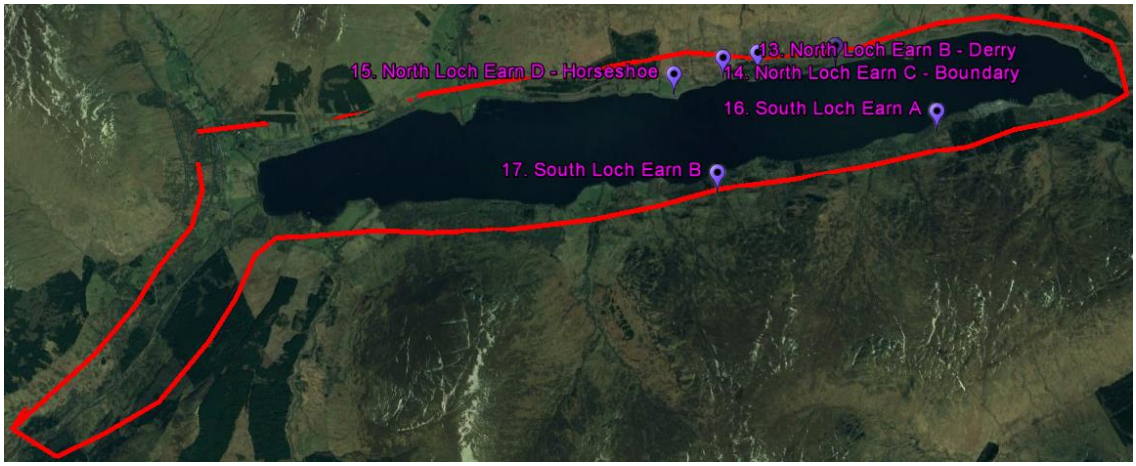

Figure 3-36: The Loch Earn cluster showing contained permit locations and campsites.

The simulation output to calculate the 'best' basestation location is shown in Figure 3-37. As can be seen, the preferred green-coloured areas are around the Duncraggan area.

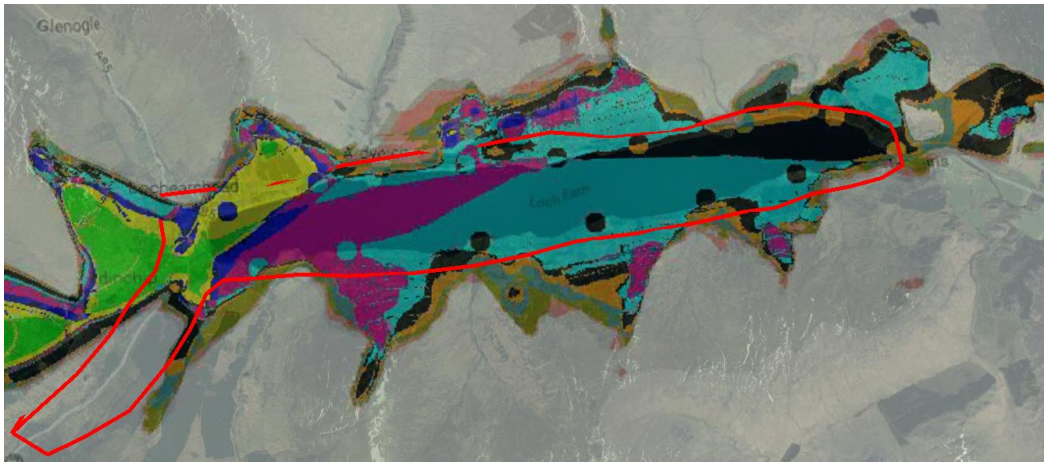

Figure 3-37: Optimal' basestation locations to provide coverage for Loch Earn cluster. (Green is best; grey is worst.)

A local police station within the Duncraggan area was identified for a potential basestation installation, which would probably have power and backhaul capabilities with a reasonable level of site access subject to negotiation with Police Scotland. The coverage profile for this potential installation is included in Figure 3-38.

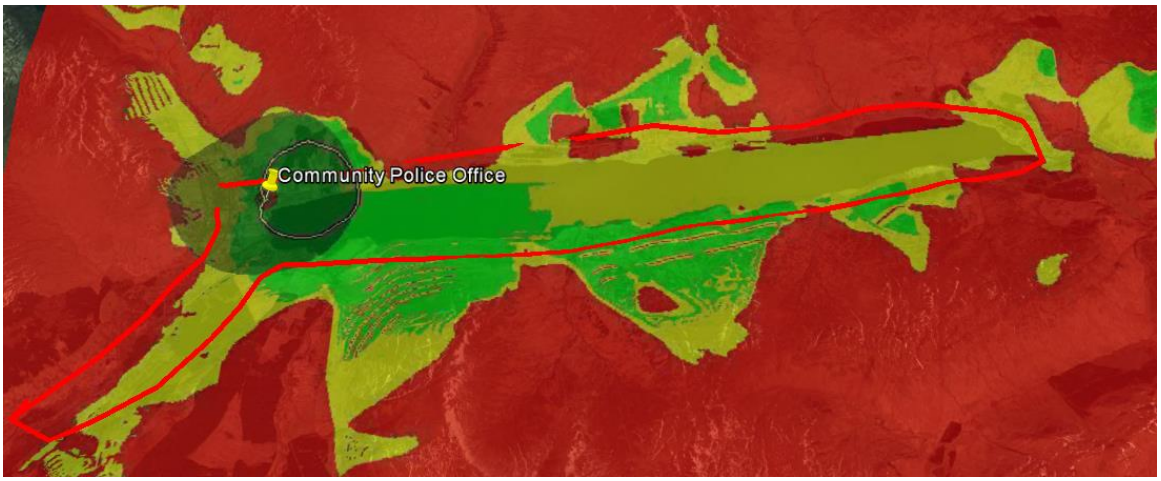

Figure 3-38: Coverage profile assuming a 12m antenna height at Loch & Glens Hotel within the Loch Achray cluster. (Green indicates a strong signal reception; Red indicates poor/no reception.)

Queries to an Ofcom-approved database suggest that there are multiple channels available for use in the Loch Earn area. Figure 3-39 and Figure 3-40 show a representation of channel availability for basestations located in the cluster. A summary of available channels and the associated transmit powers is included in Table 3-3, where multiple maximum power transmission channels can be identified.

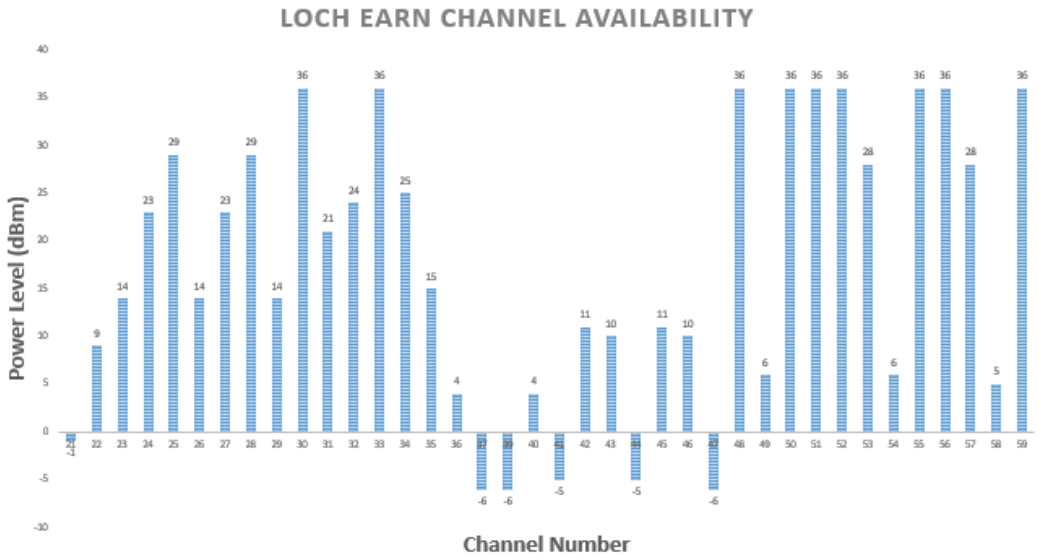

Figure 3-39: A spectrum availability profile for the Loch Earn cluster.

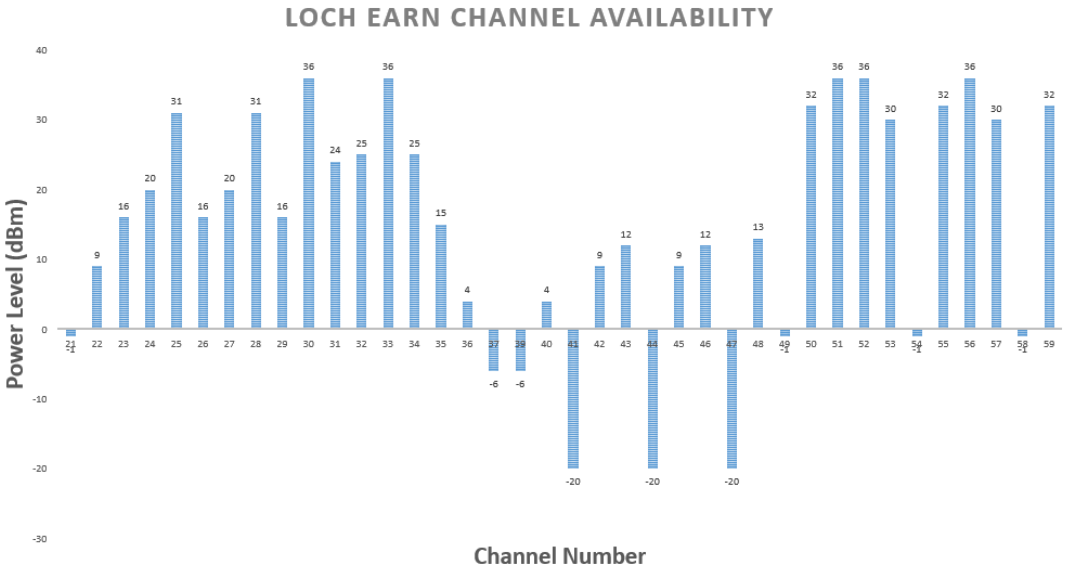

Figure 3-40: A spectrum availability profile for the Loch Earn cluster.

Loch Drunkie Channel Selection	
Channel	**Power Level (dBm)**
30	36
33	36
50	32
51	36
52	36
55	32
56	36
59	32

Table 3-4: Commonly available channels within the Loch Earn cluster.

4 EQUIPMENT REQUIRED

The equipment required for deploying TVWS connectivity falls essentially into two categories: 1) equipment required at basestation sites; 2) equipment required on vehicles.

4.1 Equipment at basestation sites

Each basestation site consists of at least one TVWS radio and a TVWS antenna, plus a means for providing backhaul connectivity.

Figure 4-1 shows an example of a TVWS basestation site in Orkney. The TVWS antenna (turquoise-coloured) is at a height of approximately 12 metres above ground level (AGL), and the TVWS radio is housed in the cabinet at the base of the tower. Backhaul connectivity is provided by a dedicated point-to-point microwave link. (The dish antenna for this is just visible, about 1m below the TVWS antenna.)

Figure 4-1: Example TVWS basestation site in Orkney.

Note that a supply of electricity must be available at each basestation site for the purpose of powering the various pieces of equipment. In cases where electricity is not already available and where it would be too costly to install, renewable-energy basestations (powered by solar and wind energy) may be an option. CWSC has experience in developing this kind of technology for radio masts, as illustrated in Figure 4-2.

Figure 4-2: Self-powered 'Wind-Fi' masts developed by CWSC.

In essence, therefore, the equipment required at each basestation site is:

- TVWS radio(s). These may be mounted on the mast or in a cabinet on the ground.
- TVWS antenna.
- Microwave dish radio for backhaul (unless backhaul access is available and accessible at the site).
- Accessories, i.e. RF cable, CAT5e cable, mounting brackets, etc.

4.2 Equipment on Vehicles

To connect to an installed basestation unit, each vehicle that is to be used as a Wi-Fi access point must also be fitted with a TVWS client radio and an antenna. A standard TVWS client radio is powered via Power-over-Ethernet (POE), so an additional adapter would be required in order to operate it from a car battery.

Alternatively, one of CWSC's existing suppliers/partners has designed a TVWS client device specifically for use in vehicles (see Figure 4-3), and this currently the leading candidate for recommendation.

Figure 4-3: TVWS radio designed for in-vehicle installation.

5 ESTIMATING THE COSTS

Because the characteristics of the clusters vary widely, each cluster becomes essentially a mini-project in its own right. For the most part, the clusters are separate and independent of one another, the notable exception being the Northern and Southern Frenich Farm clusters, where it is very likely that one will need to provide backhaul connectivity for the other.

In this section, some indicative cost estimates are provided for illustrative purposes, subject to the caveat that a full and proper costing exercise would be required for each cluster before definitive cost estimates would be possible.

Costs are segmented into:

- Capital costs, i.e. the cost of equipment and materials required to build the network.
- Operating costs, i.e. the costs associated with ongoing operation and maintenance of the network post-installation.
- Design and install costs, i.e. the cost of designing and installing the equipment.

5.1 Capital Cost Estimates

The capital costs will comprise the TVWS equipment and backhaul equipment plus masts and construction materials.

5.1.1 Capital costs per basestation site

The capital costs for a basestation site depend on the approach taken for realizing the site. In the simplest case, a lightweight pole may be bolted to the outside wall of a building in which electrical power and Internet access is available. In more difficult cases, a free-standing mast may be required, and in the extreme case, this may need to be self-powered and may also require separate backhaul radio links to be included.

Rough cost estimates are shown in Table 5-1 for a site that requires a free-standing mast with access to electrical power but no Internet access. A site that requires a simpler wall-mounted pole may typically be expected to cost about half of the amount shown in Table 5-1, while a mast that needs to be self-powered may cost more than double the amount shown in Table 5-1.

Equipment	**Cost**
1x mast	£2,000
1x outdoor cabinet	£500
1x TVWS radio (BS)	£5,000
1x TVWS antenna	£500
1x microwave radios and antennas (for backhaul link)	£2,500
Accessories (RF cable, Cat5e cable, poles, mounting kits, etc.)	£750
Total per basestation site	**£11,250**

Table 5-1: Estimated capital costs for a basestation site which requires a free-standing mast and has on-site access to electrical power but no Internet backhaul.

5.1.2 Capital costs per vehicle

The capital cost estimates for each vehicle are shown in Table 5-2, in which it is assumed that each vehicle will require a TVWS CPE radio and a Wi-Fi access poimt.

Equipment	**Cost**
1 x TVWS radio (CPE)	£2,500
1 x TVWS antenna (omni)	£1,000
1 x in-vehicle Wi-Fi access point	£500
Accessories (RF cable, Cat5e cable, poles, mounting kits, etc.)	£750
Total per ferry	**£4,750**

Table 5-2: Estimated capital costs per vehicle.

5.2 Operating Cost Estimates

Once the TVWS equipment has been installed, the operating costs will be governed mainly by annual backhaul fees and any site rental fees that may have been necessary to agree to. There may also be some costs associated with managing the radio network.

Maintenance costs will be fairly minimal, and are likely to comprise just maintenance/replacement of equipment when necessary. LLTNP may, of course, elect to purchase a maintenance contract with a suitable company who will charge an annual maintenance fee that would need to be negotiated and agreed.

5.3 Design and Install Cost

The costs of designing and installing the network will be subject to negotiation with a number of suppliers. Such costs would include:

- Network design and planning – Costs will depend on the approach taken for each cluster, and would require further investigation and discussion regarding site selection and development as well as backhaul and power access. This cost is mainly time-based (i.e. number of Man-Hours x Rate).
- Civil works required for site preparation for free-standing masts in remote locations. This cost will depend on various factors, in particular the accessibility of the site location. It is difficult, therefore, to give a reliable estimate, and quotes would be required from potential suppliers, but it could potentially be in the region of £20,000 or more per site.
- Installation of masts – Again, this depends on quotes from potential suppliers, but may be around £5,000 - £10,000 per mast, depending on the remoteness of the site.

Other costs will also exist, but the above costs are, we believe, likely to be the main ones.

6 CONCLUSIONS & NEXT STEPS

The Loch Lomond and Trossachs National Park is very challenging terrain for telecommunications, whether wired or wireless, and providing coverage, even in just a few high priority clusters, is difficult. TV White Space technology has certain characteristics that make it considerably more suitable than other wireless technologies that operate at higher frequencies, but certain clusters (notably the Southern and Northern Frenich Farm clusters) will remain very challenging.

Due to the size of the total area to be covered, it is recommended that a phased approach is adopted, starting with one cluster which may be connected with relative ease in comparison with the more difficult ones. (A suitable candidate might be one of the Loch Earn, Loch Long, or Balquhidder clusters.) By tackling this one cluster in the first instance, a great deal with be learned about the detailed difficulties and this will feed directly into planning activities and decision-making for subsequent clusters. This phased approach also provides for a decision-gate process to be employed, thereby reducing overall risk while at the same time maximizing the overall chances of success.

It is hoped that this feasibility study will be useful in guiding the LLTNP Authority's plans, and we would welcome the opportunity to engage further on more detailed planning for connecting an initial cluster.

Appendices

A BOUNDARY LOCATIONS

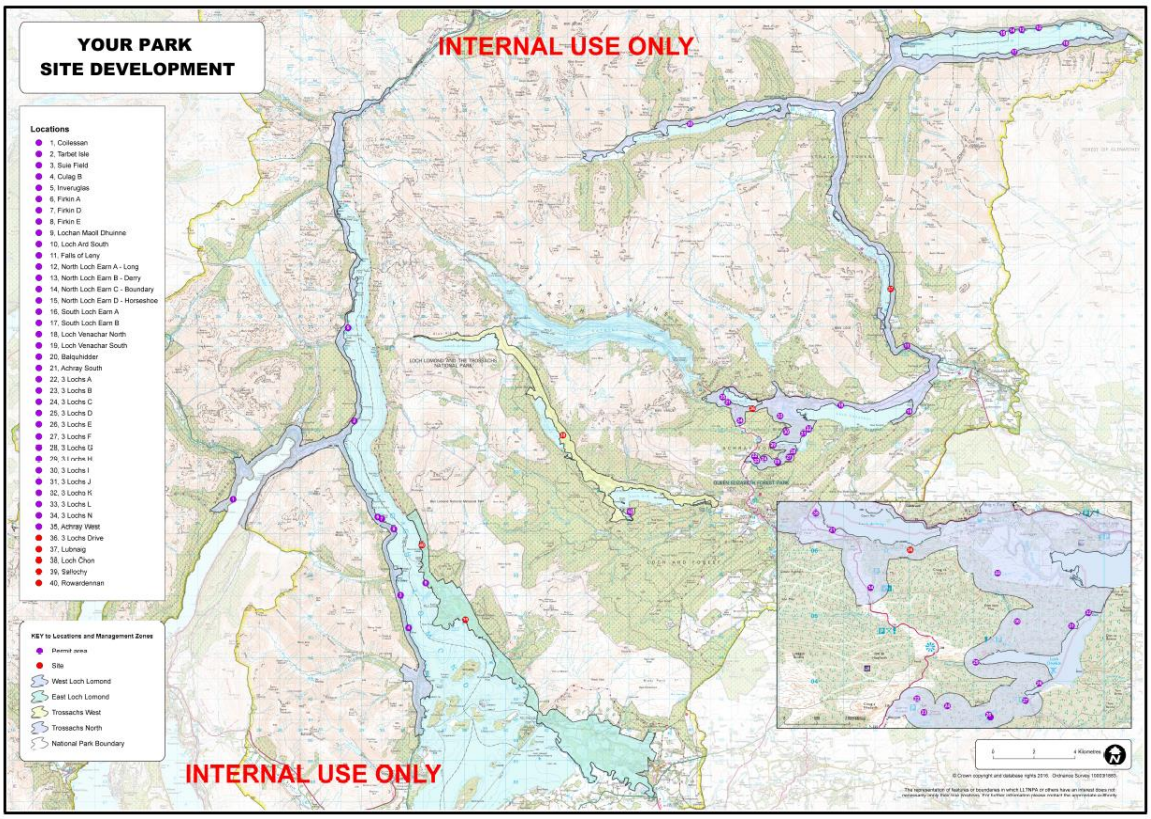

Figure A-1: Boundary locations.

B MOBILE PHONE COVERAGE

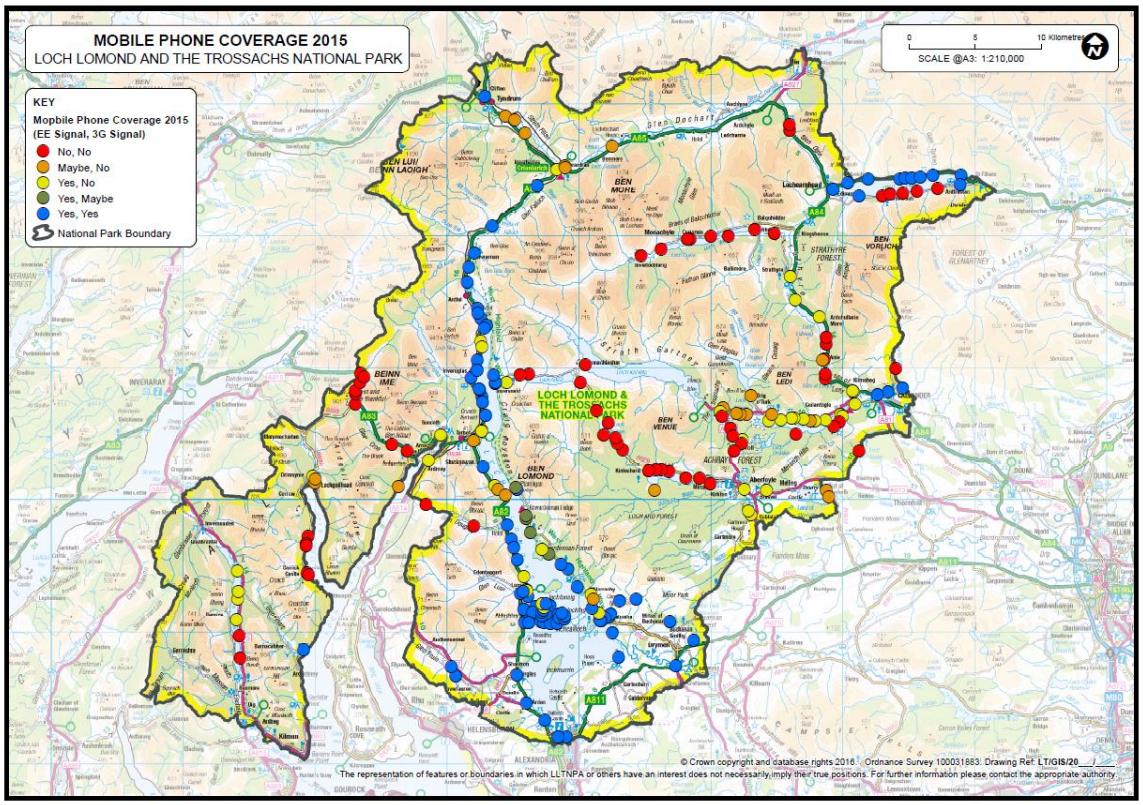

Figure B-1: Mobile phone coverage in the Loch Lomond area.

C WHITE SPACE – AN INTRODUCTORY OVERVIEW

'White Spaces' are portions of radio spectrum which are not used by existing licensees at all times or in all locations. Figure C-1 illustrates the concept, showing unused 'white spaces' between licensed transmissions. With demand for wireless connectivity increasing, the exploitation of white space is an attractive way of making more efficient use of radio spectrum.

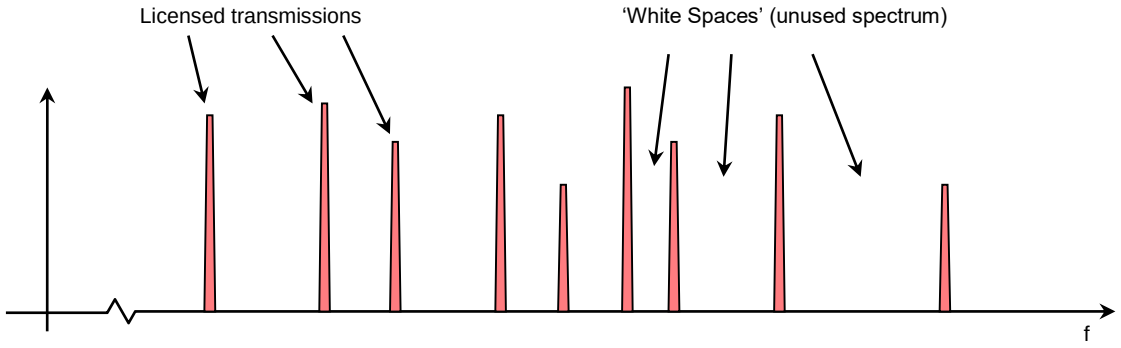

Figure C-1: Graphic illustration of licensed transmissions at certain frequencies, with 'white spaces' between them.

In many countries, analogue television broadcasts are being switched off and replaced by more spectrally efficient digital television transmissions, and the white spaces that exist in the UHF TV band (470 MHz - 790 MHz in ITU Region 1, which includes Europe) have good propagation and penetration characteristics.[1] This potentially makes them suitable for use in rural broadband applications, where transmission links may be several kilometres in length and may involve challenging terrain such as hills, foliage, and water.

The US regulator (FCC) and the UK regulator (Ofcom) have made certain parts of the TV band available for use on a licence-exempt basis. This represents an interesting and novel development in the management of spectrum, as it involves unlicensed transmissions being interleaved with those of licensed users such as TV broadcasters and 'Programme Making and Special Events' (PMSE) users. Several other regulators around the world are actively considering similar approaches. Figure C-2 shows an illustration of white space transmissions existing alongside licensed transmissions.

[1] Radio signals at 470-790 MHz are better able to diffract over hills and penetrate objects such as foliage than signals at higher frequencies such as 2.4 GHz or 5.8 GHz.

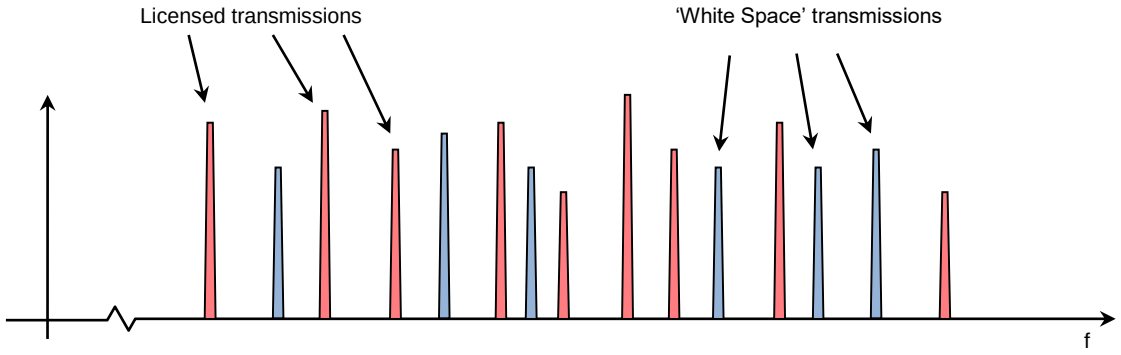

Figure C-2: Some of the 'white space' spectrum may be utilized by licence-exempt devices interleaving their transmissions with those of licensed users.

Allowing licence-exempt devices to interleave their transmissions with those of licensed users does, however, present challenges in ensuring that such unlicensed transmissions will not adversely interfere with the licensed transmissions. The approaches adopted by the FCC and Ofcom differ slightly, but both involve the use of a regulator-approved database which White Space Devices (WSDs) will need to consult before being allowed to access the spectrum.

D LOWER PRIORITY CLUSTERS

Figures D-1 to D-12 show the lower priority clusters which have not been specifically analysed as part of this study, but which may form part of future activities should this be required.

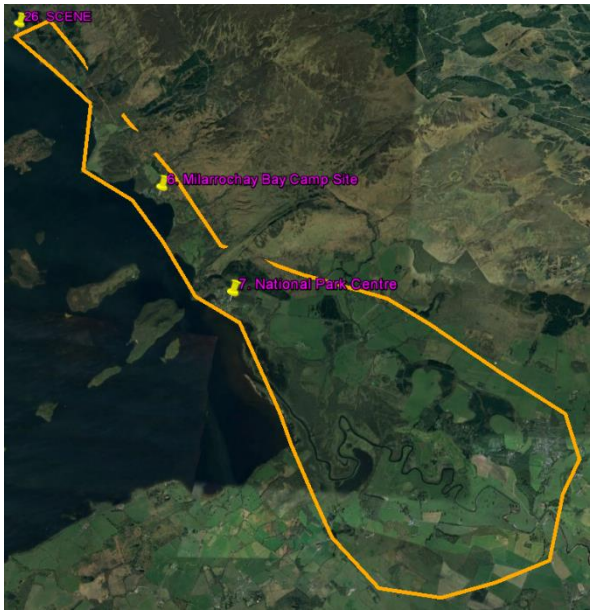

Figure D-1: Loch Lomond (1).

Figure D-2: Loch Lomond (2).

Figure D-3: Loch Lomond (3).

Figure D-4: Loch Lomond (4).

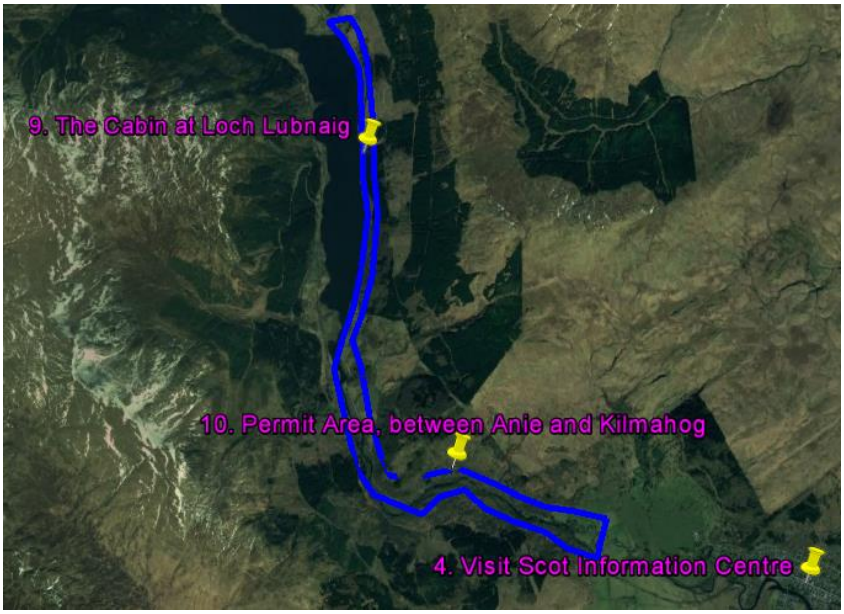

Figure D-5: South Loch Lubnaig.

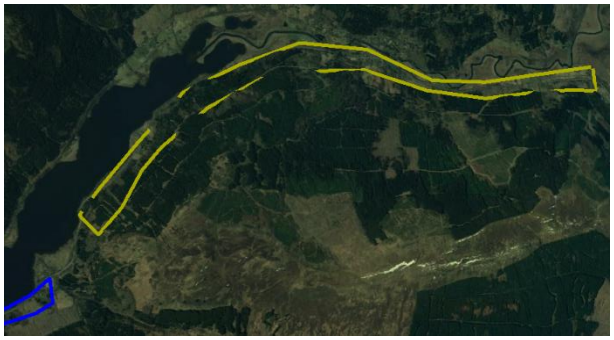

Figure D-6: North Loch Nunabig.

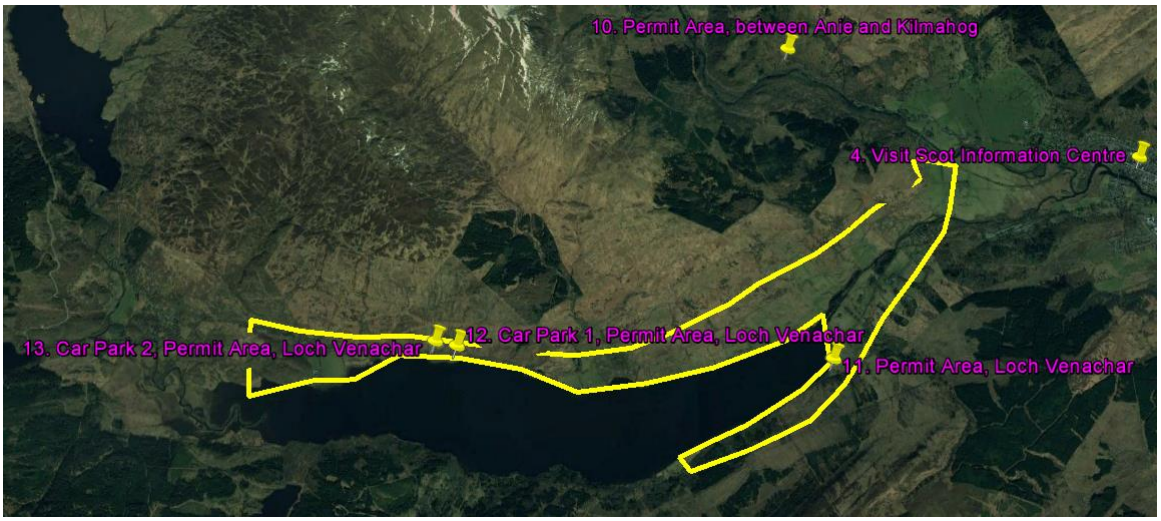

Figure D-7: Loch Venachar.