A Study of Candidate LPFM Transmitter Sites in Bellingham, WA

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Abstract

KVWV is a new, local, low-power FM radio station in Bellingham, WA which is in the early stages of station planning. Their studio location has been determined, however a suitable transmitter site has yet to be found. This report conducts a study of candidate transmitter locations while analyzing cost, signal propagation, signal reach of a target audience, adherence to FCC regulations, simplicity of installing a studio-transmitter link, and other factors. Although this document focuses on selection of a low power FM transmitter location in Bellingham, the document provides more general information that may be cited when constructing a low power FM station.

Acknowledgements

This project was advised in part by Dr. Andrew G. Klein through Western Washington University's independent study program. I would like to thank him for his assistance throughout the entire research project and leading me in the right direction when assistance was needed. His feedback on formulating this document and how to formally present the subject matter was key to success.

The radio station that added me onto their team, KVWV, was led by Matt Fulton. Matt has spent endless hours coordinating the startup for this radio station. He is always open for suggestions and truly wants this station to be "for Bellingham, by Bellingham". I would like to thank him for allowing me the opportunity to conduct this research.

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List of Abbreviations

DIY	Do It Yourself
ERP	Effective Radiated Power
FCC	Federal Communications Commission
FM	Frequency Modulation
IP	Internet Protocol
LPFM	Low Power Frequency Modulation
PC	Personal Computer
RF	Radio Frequency
SD Card	Standard Digital Card
STL	Studio-Transmitter Link
WA	Washington State

1 Introduction

A truly local radio station is important for the community because it provides a medium to inform, discuss, and analyze issues relevant to our everyday lives. With the constant growth of big networks, local issues can get drowned out by large broadcasting companies trying to feed the masses. It would be ideal for every town to have multiple local community radio stations to provide a wide variety of coverage but due to cost, interest, and limited band space this is not a reality. This can be solved by advocates taking initiative in building low power FM radio stations to create a more sustainable community.

An example of big networks overshadowing local networks lies in the midsized town of Bellingham, WA. Bellingham has always been supportive of local businesses and yet there are only a few local radio stations broadcasting within the city limits. There is a consensus amongst the community on the need for more local radio stations but many lack the funding needed to execute this goal.

Make.Shift Art Space, currently located in downtown Bellingham, WA, is a small DIY art and music venue dedicated to innovative, alternative art and music [1]. They are a nonprofit organization and have been recently granted a low power FM license by the FCC to begin broadcasting at 94.9 MHz on the FM dial under the call-sign KVWV. Some difficulties they will first need to overcome are estimating cost of equipment, making sure they adhere to FCC regulations, finding a viable studio to transmitter link, and locating a location for transmitting to ensure optimal coverage.

KVWV is looking for expertise on setting up their transmitter site. In this document, we will provide them with viable options to accomplish the tasks previously stated. In order to broadcast, KVWV first needs to set up their transmitter location. On top of this, there are different types of studio to transmitter links and antennas that need to be considered. Throughout this document I will provide key information on these, and many, other topics for KVWV to consider when building their station. At the end I will provide recommendations for KVWV that are informed by the research I have conducted.

2 Background

2.1 Low Power FM Radio Stations

A low power FM (LPFM) radio station is a non-commercial educational broadcasting service. The FCC established LPFM stations in January 2000 to offset the growing consolidation of station ownership in the wake of the Telecommunications Act of 1996. This act removed the increase of monopolies on radio ownership and halted the decline of locally produced radio programming [23]. There are two classifications in the United States for LPFMs. As defined by the FCC, Class L1 (LP100) has a maximum effective radiated power (ERP) of 100 watts whereas Class L2 (LP10) has a maximum ERP of 10 watts. Make.Shift was granted a Class L1 license. This power restriction limits stations to broadcasting in a local region.

2.2 FCC Guidelines

The FCC has very strict regulations for low power FM transmission. Failure to follow these codes can result in a hefty fine or even a loss of one's station. In this section, we describe some of the important transmission parameter requirements for LPFM.

2.2.1 Power (ERP)

The power output at the transmitter location is measured in effective radiated power (ERP). ERP is the standard for measuring radio frequency (RF) power with respect to transmitter power output, transmission line attenuation, RF connector insertion losses and antenna gain. Since Make.Shift has a Class L1 license, they are permitted to have an ERP of up to 100 watts at 30 meters height above average terrain (HAAT). HAAT will be explained in a further section. More than one watt ERP at 450 meters HAAT will not permitted to any association [14].

2.2.2 Height Above Average Terrain (HAAT)

The height above average terrain, or HAAT, is defined as the height of a geographical contour with respect to the height of the average terrain in the area. The FCC states an LPFM station with a HAAT that exceeds 30 meters will not be permitted to operate with an ERP greater than that which would result in a 60 dBu contour of 5.6

kilometers. The unit dBu measuring signal power and is measured with an unterminated load [26]. In simple terms, if one want their HAAT above 30 meters, one would have to decrease their output wattage [14]. One does not need to worry about field strength due to the ERP and height being directly related.

2.2.3 Antenna Polarization

The FCC permits non-directional antennas with horizontal only polarization, vertical only polarization, circular polarization or elliptical polarization. Directional antennas generally will not be authorized and may not be utilized in the LPFM service [14]. The types of antenna will be described in more detail below in section 2.3.

2.3 Antenna Types

Directional and non-directional refer to the horizontal angle(s) at which the antenna transmits. Directional antennas only transmit at one horizontal angle whereas non-directional antennas transmit at every horizontal angle. Non-directional antennas are ideal for FM radio transmission. Antenna polarization refers to the radio wave plane with respect to the Earth's surface. By changing the shape of the antenna, one can change the shape of the generated output radio waveform. Prior to WWII, horizontal antennas were seen as superior compared to their vertical counterparts at the time. This was due to the majority of the receivers being stationary. The reasoning being the majority of man-made radio noise is vertically polarized and using horizontally polarized antennas provides some favoritism against interference from noise [25]. However, when the "whip" antenna receiver was adopted for mobile antennas, vertical antenna transmitters were preferred [2]. From the "whip" increasing mobile antennas reception, vertical antennas became desired and horizontal antennas started to become obsolete despite their advantage for stationary receivers. The introduction of circular antennas made it possible to transmit radio waves both vertically and horizontally. This allowed for good reception on both stationary and mobile receivers.

2.3.1 Vertical Polarization

A vertical polarized antenna sends out information in the fashion of a linear waveform. This radio wave is perpendicular to the Earth's surface. A vertical polarized waveform is shown in figure 1.

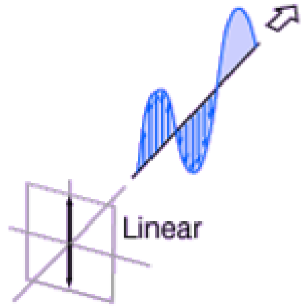

Figure 1: Vertical Polarization [3]

Vertical polarized antennas are best for mobile receivers as stated before. A popular example of this would be a car radio. This is due to the "whip" antenna (found on many cars) needing a vertical waveform to maximize reception.

2.3.2 Horizontal Polarization

Horizontal polarized antennas also transmit linear waves like vertical polarized antennas but as assumed, horizontally. This radio wave is parallel to the Earth's surface. This is shown in the diagram below.

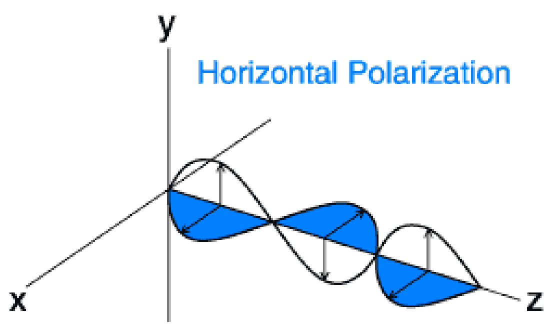

Figure 2: Horizontal polarization is shown by the blue wave form on the x-axis. This is apposed to vertal polarization which is on the y-axis. [24]

Horizontal polarized antennas are best for stationary receivers. An example for this would be a home stereo radio. These systems have trouble picking up vertically transmitted radio waves.

2.3.3 Circular Polarization

Circular polarized antennas are ideal for transmitting to all types of receivers. This is due to both vertical and horizontal receivers being able to pick up the transmitted data.

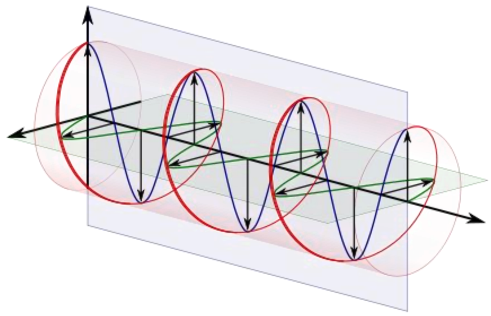

Figure 3: Circular Polariztion [4]

Circular polarized antennas are as common as vertical or horizontal polarized antennas, making them affordable due to availability.

2.4 Studio-Transmitter Link

2.4.1 Definition and Purpose of Studio-Transmitter Links

To send audio information from the studio to the transmitter site, a studio-transmitter link (STL) is used. It is not always ideal for the transmitter antenna to be physically located at the studio site (as explained below in section 2.4.2) so a link between the two locations must be made.

2.4.2 Types of Studio to Transmitter Links

There are many ways to send information to the transmitter location. However these different ways have advantages and disadvantages based on where ones studio is located, the location of the transmitter, what is between the two locations, how far apart the two locations are, and how much money one is willing to spend. Before packet networks were established, stations were restricted to transmitting information using a direct line of site link. If there are any structures in between the two sites the connection will be lost. On top of this these devices are very expensive costing thousands of dollars.

An alternative to this method would be streaming one's audio via the internet. The Barix Instreamer 100 and the Barix Exstreamer 120 is recommended. The reasoning for the Barix Boxes is expressed in selection 4.2.

Figure 4: Barix Exstreamer 120 [8]

Of course none of this can work if there is not an internet connection at the studio and the transmitter location. This is why it is very important to make sure there will be internet at the transmitter location. Using a line of sight method as an alternative is not worth the extra cost and energy to set-up.

2.5 Finding a Transmitter Location

There is a process when identifying an ideal location for one's transmitter. Ideally, one wants their location to be closest to their target audience as possible with the tower height well above any other structures or geographical terrain. The higher one's antenna, the larger their coverage.

The coverage is going to be an area with a radius around our transmitter location. Let us use Bellingham to find ideal locations. We first want to look at a population density map of the area to determine where the most listeners live. Below is a population density map of Bellingham generated by the Washington Department of Ecology, GIS Technical Services on using the 2000 Census Block Population data [10].

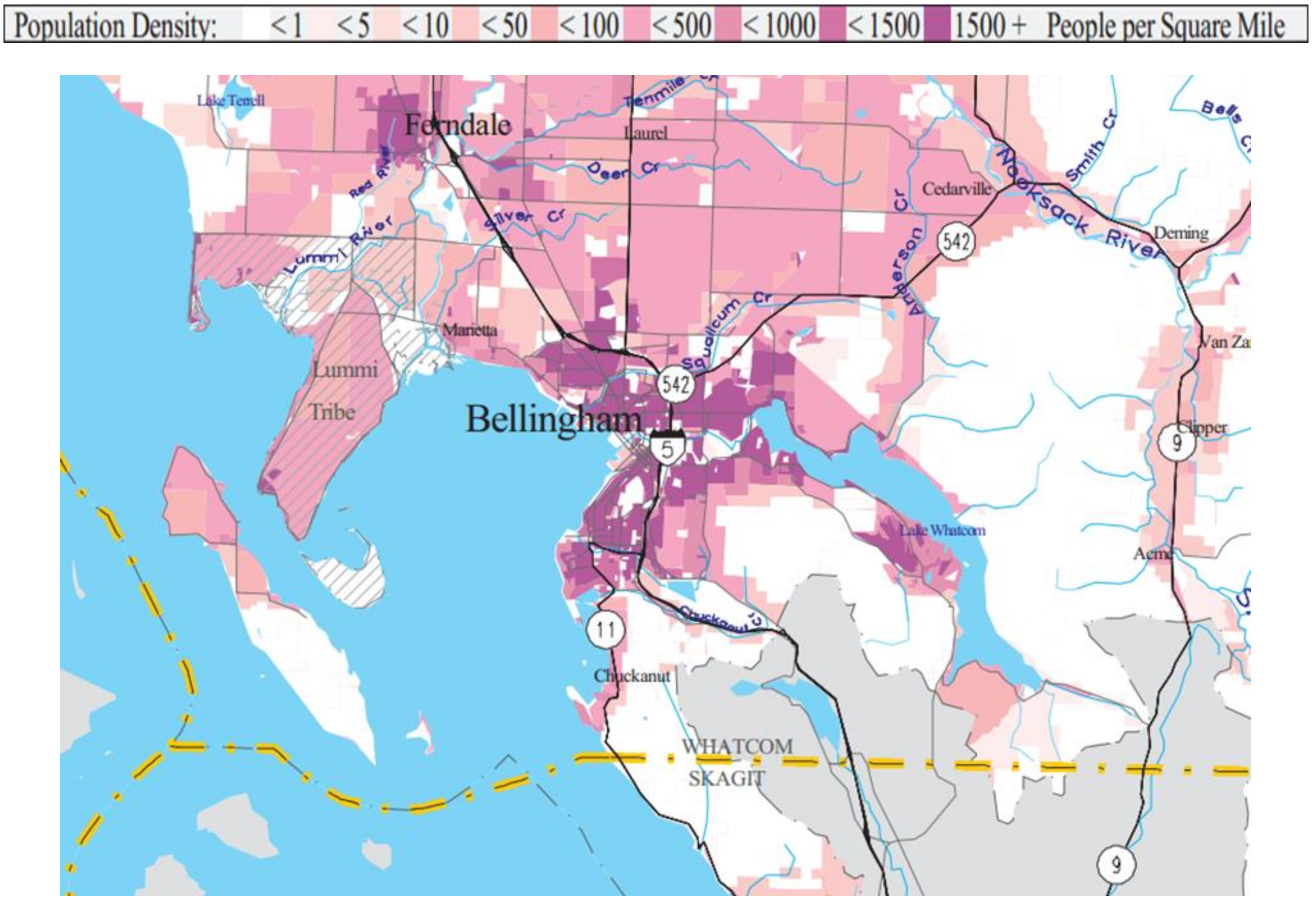

Figure 5: Population Density Map of Bellingham, WA [10]

As one can see, most of the population in Bellingham is centered near the downtown area with the majority of it being north of Sehome Hill (Sehome Hill being the large white spot in the middle of the densely populated area). We want out transmitter location to be in the center of this cluster. Now that we have an idea of where the majority of the population in the city is, let us cross reference this map with a neighborhood map to find target neighborhoods

Figure 6: Bellingham Neighborhood Coverage Map [11]

In figure 6, we can see that our target neighborhoods include the Lettered Streets, Sunnyland, York, Sehome, South Hill, Happy Valley, Samish, Roosevelt, and Puget. All these locations surround the downtown area where Make.Shift is located which is a plus. There is only one more map we need to cross reference to find our ideal locations, a topographical map of Bellingham. A topographical map will shows us the geographical terrain of the city using contour lines for elevation references.

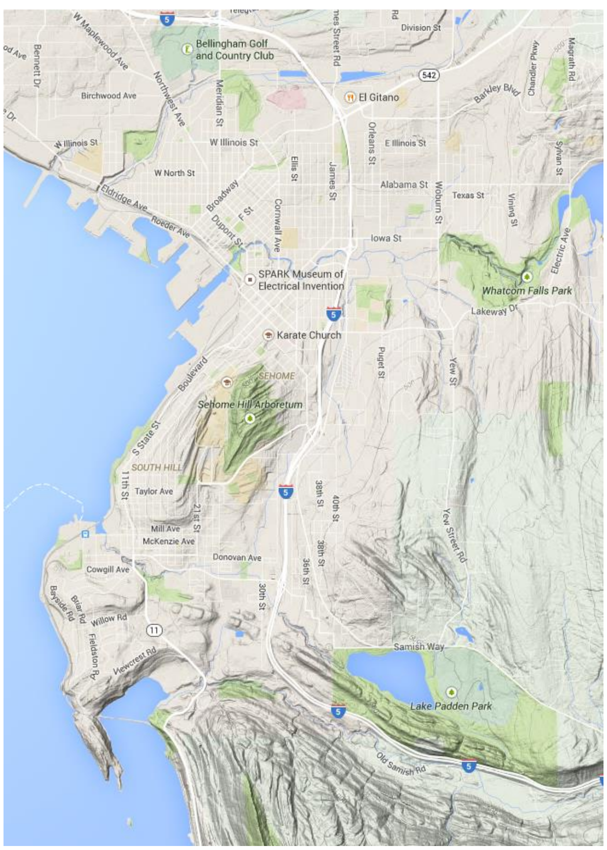

Figure 7: Bellingham Topographical Map [12]

As stated before we want to find an elevated location close to the center of the densest area. With this in mind, the obvious location would be Sehome Hill. It is higher than any other structures or geographical terrain, as shown in figure 7, making it an ideal candidate. Sehome Hill is also close to all the target neighborhoods we referenced earlier. Another good location would be the hill on Yew Street. Like the Sehome Hill it is high up and near our target neighborhoods. However, other constraints, as stated in section 2.2, can play a role in dismissing these locations.

3 Transmitter Locations

3.1 Ideal Locations

In the previous section we showed how some ideal locations for a transmitter site would be Sehome Hill and Yew Street. We can generate a coverage map to see what our coverage would be if these location was chosen. We will first observe the Sehome Hill location. This program, the Radio Coverage Prediction using Longley Rice, takes the geographical terrain in consideration using the Longley Rice model. Unfortunately it can only generate coverage maps using either vertical or horizontal polarized antennas, therefore a vertical polarization was used for the most accurate readings for car listeners (as stated in section 2.3.1). The other specifications are shown below.

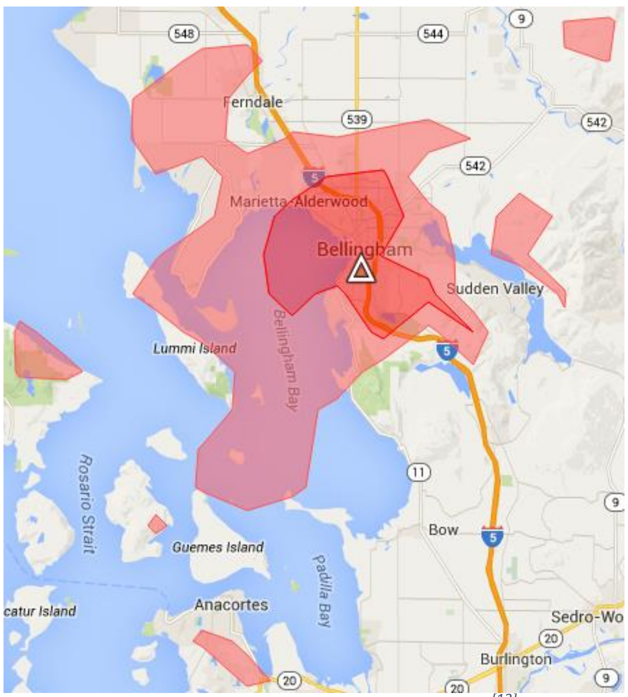

Figure 8: Sehome Hill Coverage Map [13]

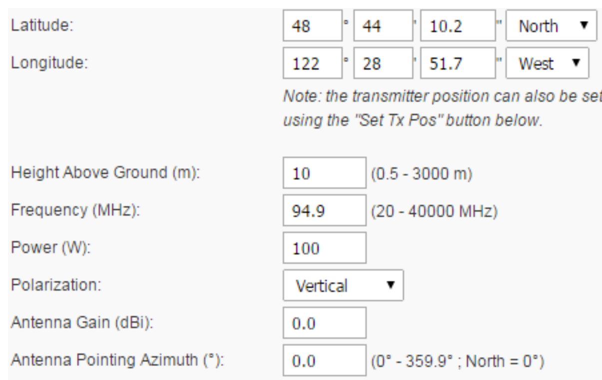

Figure 9: Sehome Hill Generate Coverage Data [13]

The light red color signifies a dBu value between 60 and 75. This is referred to the minimal usable field strength in an urban environment. Meaning anything outside of this area may not receive desirable reception. The dark red signifies a dBu value between 75 and 100, where coverage is strong [15].

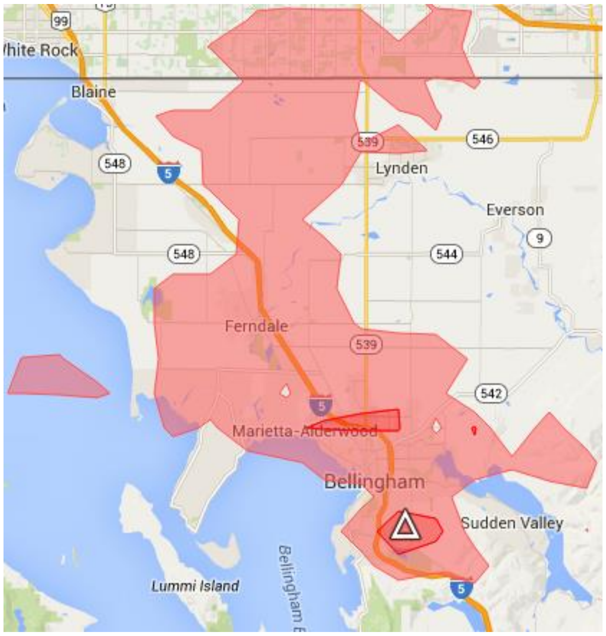

Figure 10: Yew Street Coverage Map [13]

Now we will observe the Yew Street

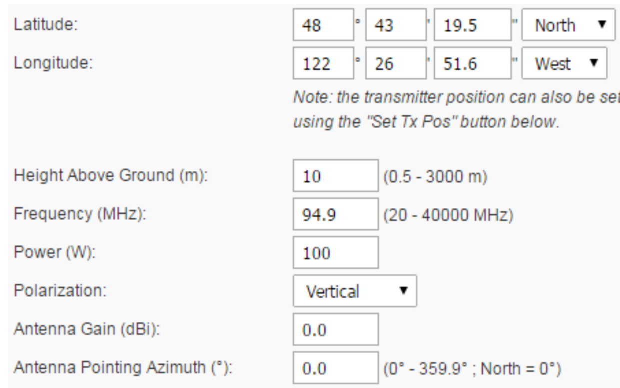

Figure 11: Yew Street Generated Coverage Data [13]

location. Notice how the increased height of the terrain dramatically enhanced the coverage. Although there is not as much of the "strong" coverage, our signal reaches as far as to Canada.

3.2 Location Constraints

Unfortunately for Make.Shift, KVWV will not be able to access Sehome Hill or Yew Street as an ideal location. This is due to the HAAT FCC regulation mentioned earlier in section 2.2.2. Both of these locations are well above the 30 meters HAAT limit. One may be thinking, why not just keep the locations and lower the ERP as stated earlier? Both location would require lowering the ERP below 20 watts. Below 20 watts is not desirable for transmitting an FM signal [5]. It is now clear from this information that the transmitter site will have to be close to the target audience and the HAAT of the transmitter as close to 30 meters as possible to maximize coverage.

3.3 Realistic Locations

Placing the transmitter on top of a tall building downtown can be a reasonable option. It will have the advantages of being close to our target neighborhoods and high above any obstructions. I have chosen five realistic locations for transmission. These locations include the Herald building, Bellingham Towers, the Leopold building, the Karate Church, and the

Faithlife Building. We will observe generated coverage maps for each of these locations in detail with proper building height estimates. These decisions were based on the criteria and idea brought up earlier in chapter 3.

The Herald building is an eight story building located at 1155 North State Street with plenty of roof space. I have already sent a proposal to Daylight Properties, the owners of the property, and they seem very interested. HAAT of -62 meters [17].

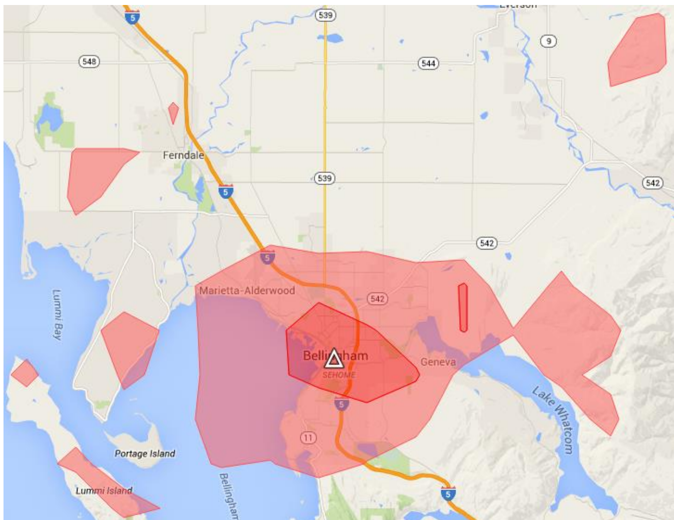

Figure 12: Herald Build Coverage Map [13]

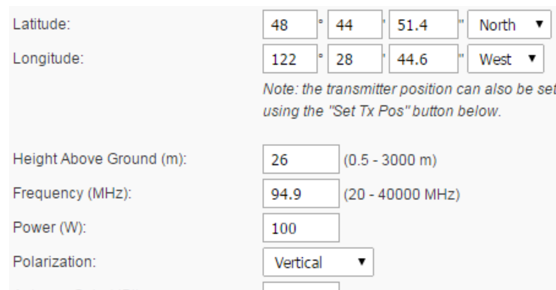
Latitude: 48 ° 44 ' 51.4 " North
Longitude: 122 ° 28 ' 44.6 " West
Note: the transmitter position can also be set using the "Set Tx Pos" button below.
Height Above Ground (m): 26 (0.5 - 3000 m)
Frequency (MHz): 94.9 (20 - 40000 MHz)
Power (W): 100
Polarization: Vertical

Figure 13: Herald Building Generated Coverage Data [13]

Bellingham Towers is a fifteen story building located at 119 North Commercial Street. This towering building is the tallest building in downtown Bellingham. HAAT of -44 meters [17].

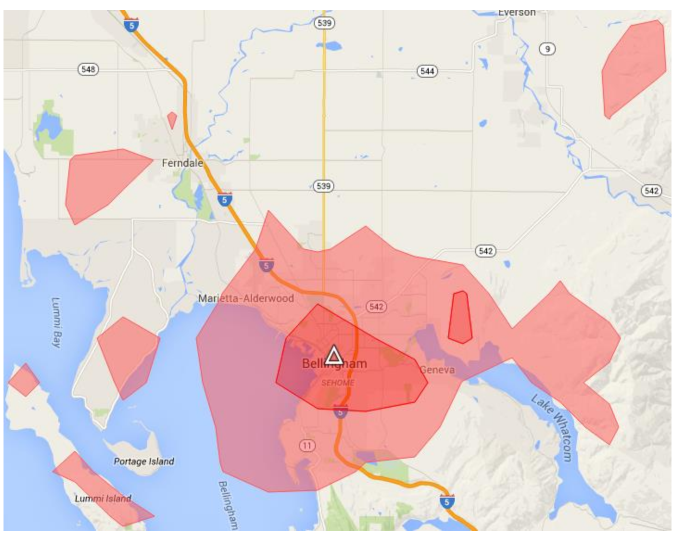

Figure 14: Bellingham Towers Build Coverage Map [13]

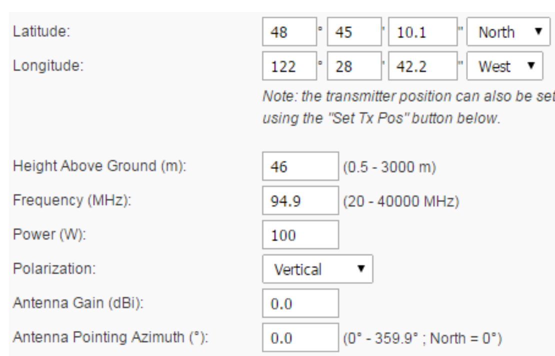
Latitude: 48 ° 45 ' 10.1 " North
Longitude: 122 ° 28 ' 42.2 " West
Note: the transmitter position can also be set using the "Set Tx Pos" button below.
Height Above Ground (m): 46 (0.5 - 3000 m)
Frequency (MHz): 94.9 (20 - 40000 MHz)
Power (W): 100
Polarization: Vertical
Antenna Gain (dBi): 0.0
Antenna Pointing Azimuth (°): 0.0 (0° - 359.9° ; North = 0°)

Figure 15: Bellingham Towers Building Generated Coverage Data [13]

The Leopold building is nine stories tall, located at 1224 Cornwall Avenue, and also not too far from Bellingham Towers. They have approved KVWV's request, if they choose, to start negotiating pricing. They said 14 square feet of roof space is definitely available. HAAT of -62 meters [17].

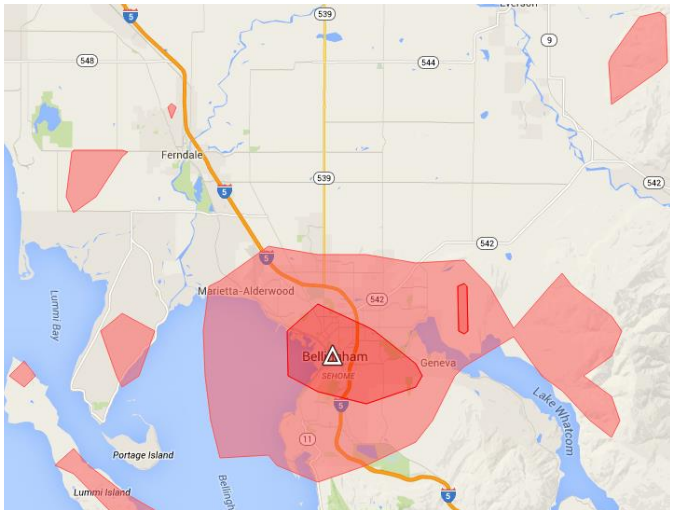

Figure 16: Leopold Build Coverage Map [13]

Latitude:	48 °	44 '	58.1 "	North
Longitude:	122 °	28 '	46.5 "	West
	Note: the transmitter position can also be set using the "Set Tx Pos" button below.			
Height Above Ground (m):	28	(0.5 - 3000 m)		
Frequency (MHz):	94.9	(20 - 40000 MHz)		
Power (W):	100			
Polarization:	Vertical			
Antenna Gain (dBi):	0.0			
Antenna Pointing Azimuth (°):	0.0	(0° - 359.9° ; North = 0°)		

Figure 17: Leopold Building Generated Coverage Data [13]

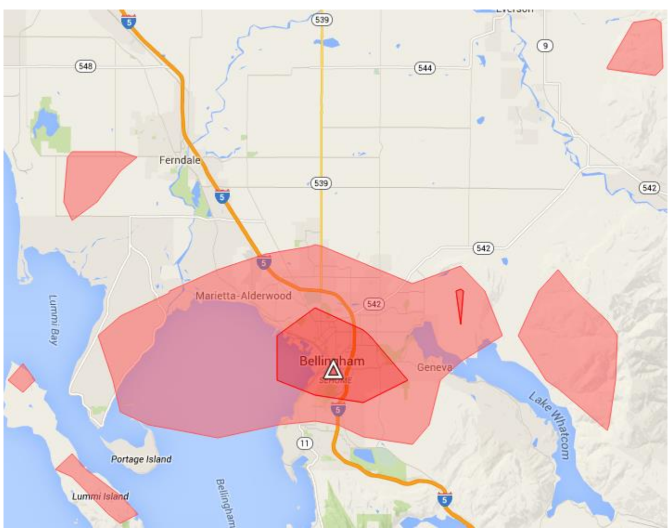

Figure 19: Karate Church Generated Coverage Data [13]

The Karate Church is now in the process of being reformed into a public library after being the Bellingham Academy of Self Defense for decades. After talking to the new owner, there is definitely interest. The antenna would be placed on the top of the bell tower to maximize height and coverage. HAAT of -49 meters [17].

Latitude:	48 °	44 '	41 "	North
Longitude:	122 °	28 '	37.3 "	West
	Note: the transmitter position can also be set using the "Set Tx Pos" button below.			
Height Above Ground (m):	12	(0.5 - 3000 m)		
Frequency (MHz):	94.9	(20 - 40000 MHz)		
Power (W):	100			
Polarization:	Vertical			
Antenna Gain (dBi):	0.0			
Antenna Pointing Azimuth (°):	0.0	(0° - 359.9° ; North = 0°)		

Figure 18: Karate Church Coverage Map [13]

The Faithlife building, located at 1313 Commercial St., is a six story structure and is currently the home of KMRE's LPFM ratio transmitter site. Communication with KMRE's head engineer, M. Gilbert, has already been established. KMRE is currently broadcasting at 102.3 MHz so there should be no issue with interference with KVWV broadcasting a t 94.9 MHz [16]. HAAT of -69 meters [17].

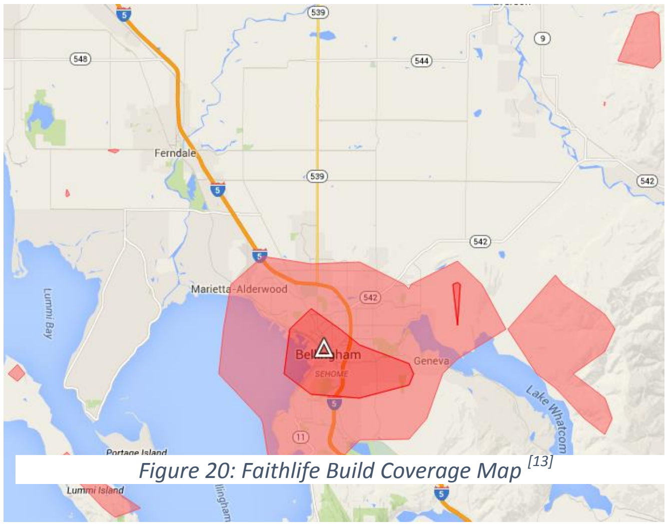

Figure 20: Faithlife Build Coverage Map [13]

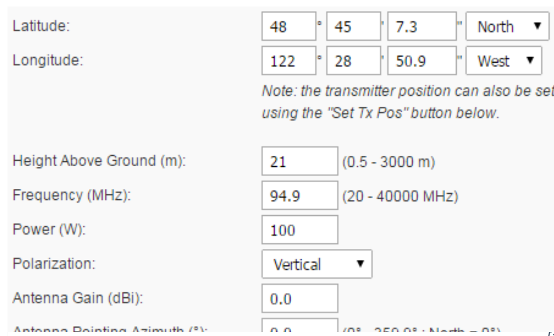

Figure 21: Faithlife Building Generated Coverage Data [13]

All these maps may look similar but they have important differences. The height differences are provided in table 1 below. Although the Karate Church map covers the most area, it is the only map not to clearly cover both Fairhaven and Happy Valley. The Karate Church map also covers low populated areas as observed back on the population density map. Bellingham Towers map is the only map to reach Bakerview Road. All of these things are good to keep in mind when basing a decision on signal coverage.

Location	Address	Estimated Roof Height (meters)	HAAT (meters)
Herald	1155 North State Street, Bellingham, WA 98225	26	-62
Bellingham Towers	119 North Commercial Street, Bellingham, WA 98225	46	-44
Leopold	1224 Cornwall Avenue, Bellingham, WA 98225	28	-62
Karate Church	519 E Maple Street, Bellingham, WA 98225	12	-49
Faithlife	1313 Commercial Street, Bellingham, WA 98225	21	-69

Table 1: Realistic Location Information

4 Cost Analysis

4.1 Antenna Cost

As stated in section 2.3.4, the ideal antenna used for FM transmission is a circular polarized antenna. Two models for this include the TFC1K and the TFC2K by Bext. T. Urick from Common Frequency recommended these two models of antennas by stating, “These are inexpensive broadcast-quality antennas”.

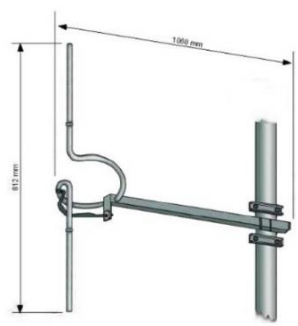

Figure 22: TFC1K [6]

Figure 23: TFC2K [7]

There is no large benefit of one antenna over the other. They both have the same power gain and are equally effective for transmission. These antennas are not large, being able to fit in a 1.1 by .9 meter box when expanded. Both antennas are lightning protected, making installation on a pole simple [6], [7]. One can increase the number of bays to increase their gain. This is as simple as adding another antenna on top of the first. One can purchase a single bay of the TFC1K for $570[19] or two bays of the TFC2K for $920 [20].

4.2 Studio to Transmitter Link Cost

From section 2.4.2, the Barix Instreamer 100 and the Barix Exstreamer 120 were recommended. The Barix Instreamer 100 is a live IP audio encoder. This is used at the studio location to stream one’s audio. The Barix Exstreamer 120 is used at the transmitter location to retrieve the audio from the sent IP address. The model number 120 is recommended because this model can automatically start playing files from a local Micro SD Flash Memory Card if the stream fails [8]. The Barix Instreamer 100[22] and Barix Exstreamer 120[21] can be purchased for the low cost of under $600.

4.3 Transmitter Location Prices

Many of the locations scouted out and mapped are currently under negotiation for rental fees. This will be resolved later after the logistics between the property managers have sorted out. The only known cost is for the Faithlife building. M. Gilbert appears willing to share the KMRE transmitter space for no additional fees. On top of this, he appears willing to let KVWV use his controller to communicate with the tower from the station. It is important to differentiate between reoccurring and onetime costs when comparing these different location's prices down the line; reoccurring, referring to monthly rental fees, and onetime costs, referring to an unprepared rooftop for transmission. These cost tradeoffs can overall dictate the transmitter location.

5 Conclusion

We have now gone over everything that needs to be considered for picking out and setting-up our transmitter location. FCC regulations on the power (ERP), height (HAAT), and polarization have been carefully reviewed. A circular polarized antenna was chosen to maximize reception for various receiver types. The Barix Instreamer 100 and the Barix Exstreamer 120 was suggested to stream audio from the studio to the transmitter location. Internet is needed for this sort of set-up. All the locations which were mapped out should not have an issue with obtaining internet on their roofs.

Out of the five locations which were scouted, I would recommend the Bellingham Towers or the Faithlife building. The Bellingham Towers building has the largest land coverage area as shown by the coverage map. This reaches all the way from Bakerview Street to Happy Valley. It is also right in the middle of KVWV's target audience. Bellingham Towers was no solely chosen for its close proximity to the Make.Shift studio but it does play a small factor in the decision of the transmitter location. Making visits to the building for technical repairs or paying rent would be as easy as a three minute walk from Make.Shift. From a coverage perspective, as stated before it would be difficult not to choose this location. However, we are currently unsure of rental costs due to being in the negotiation process with the property owner. If this does not work then I would advise using the Faithlife building. The Faithlife building's coverage is comparable to the other locations (shown in figures 12-21). M. Gilbert was very willing to get KVWV ready to broadcast. He could be a valuable asset to the team, as one of the most knowledgeable FM communications engineers in the Bellingham community. With free internet and power, this location would be the cheapest to maintain.

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