Bonneville Power Administration Microwave Radio Stations Historic Resources Technical Report

Washington, Oregon, Idaho, and Montana

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Cover Photo: North Bend Microwave Radio Station, 1957 (NARA:NorthBendMWNARAbox18of52-008).

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Acronyms

AC	alternating current
AIEE	American Institute of Electrical Engineers
BPA	Bonneville Power Administration
DC	direct current
ECC	Eastern Control Center
FTL	Federal Telecommunication Laboratories
kV	kilovolt
MF	medium frequency
MPDM	Multiple Property Documentation Form
mph	miles per hour
NHPA	National Historic Preservation Act of 1966
NRHP	National Register of Historic Places
SCADA	supervisory control and data acquisition system
SHPO	State Historic Preservation Officer
UHF	ultra-high frequency
USACE	United States Army Corps of Engineers
VHF	very high frequency
WWII	World War II

1. Introduction

The Bonneville Power Administration (BPA) is a federal agency under the U.S. Department of Energy, which owns and operates more than 15,000 miles of high-voltage transmission lines, supported by substations, communications, and maintenance facilities. These transmission lines carry most of the Pacific Northwest's high-voltage power from generation facilities to users throughout the region. Beginning in the 1950s, BPA established a microwave radio network that operated in parallel to the transmission grid, enabling system communication and remote operational control (Kramer 2012:F-67).

The current study focuses on BPA's microwave communication sites built prior to 1975. The study evaluates the eligibility of approximately 50 microwave radio station sites for inclusion on the National Register of Historic Places (NRHP), applies the NRHP Criteria for Evaluation to determine their historical significance, and assesses whether the facilities retain sufficient historical integrity of location, setting, design, materials, workmanship, feeling, and association.

BPA has retained AECOM to evaluate BPA's historic microwave radio station sites, the results of that evaluation are provided in this historic resources technical report.

1.1 Components of BPA's Microwave Radio Stations

Each microwave radio station functions as a "repeater," which is a combined receiver/transmitter facility enabling two-way microwave signals to cover longer distances thus enhancing system operability. Microwaves are a specific type of radio wave that are short, travel in a straight line at the speed of light, and do not follow the curvature of the earth. For these reasons, BPA's radio stations are generally located on high ground, thereby creating microwave links between end locations and with mobile field crews that are beyond "line of sight" propagation range.

BPA's primary microwave radio station components are the antenna tower and station building that houses microwave equipment and an emergency backup power generator (radio stations may have separate generator housing). The tower supports microwave/ultra-high frequency (UHF) antennas for direct communications between end locations, and whip antennas for very-high frequency (VHF) mobile communication (Strong et al. 1957:659). The parabolic microwave antenna was a distinctive piece of equipment that visually differentiated microwave radio installations from earlier radio installations.

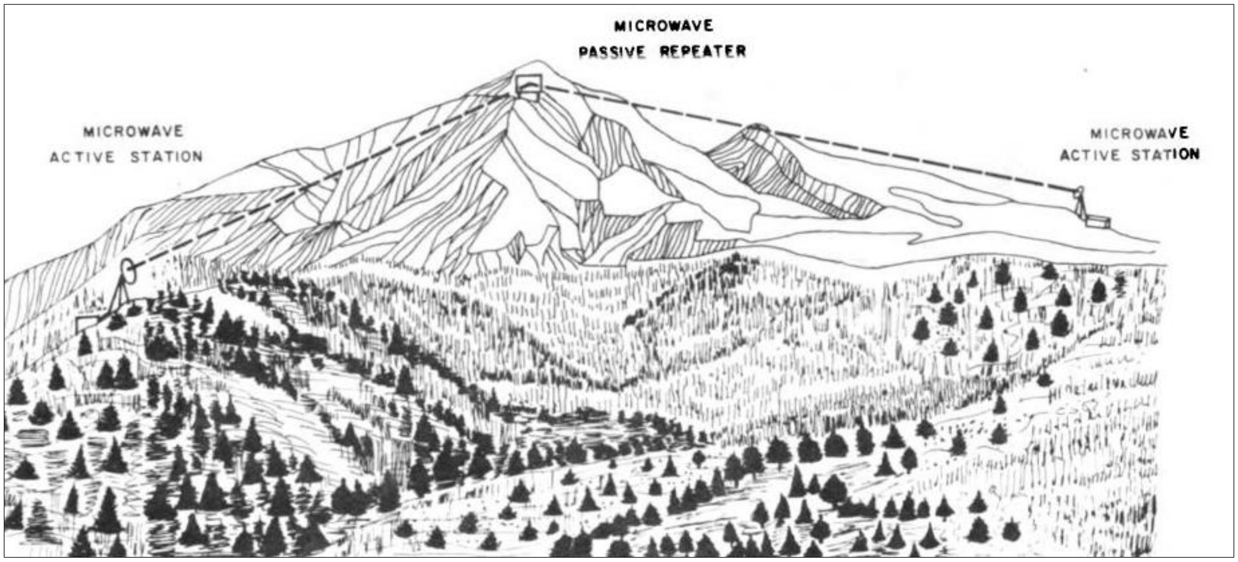


Figure 1. This drawing illustrates principles of microwave technology related to line of sight, repeaters, and passive repeaters. Here, the "microwave passive repeater" overcomes the line of sight obstacle, an intervening mountain, to reflect transmissions between adjacent radio stations (BPA 1977:V-27).

BPA's communication system also incorporated a type of microwave transmission equipment known as a "passive repeater." BPA's passive repeaters consist of aluminum panel reflectors mounted on steel or wood frames. Passive repeaters reflect transmissions from radio stations, thereby helping overcome line of sight obstacles such as topography (Figure 2). A passive repeater requires neither an on-site power source, such as a transmission line or generator, nor an independent microwave transmission source. Passive repeater sites therefore require no station building to house equipment. Few passive repeaters remain in the BPA system.

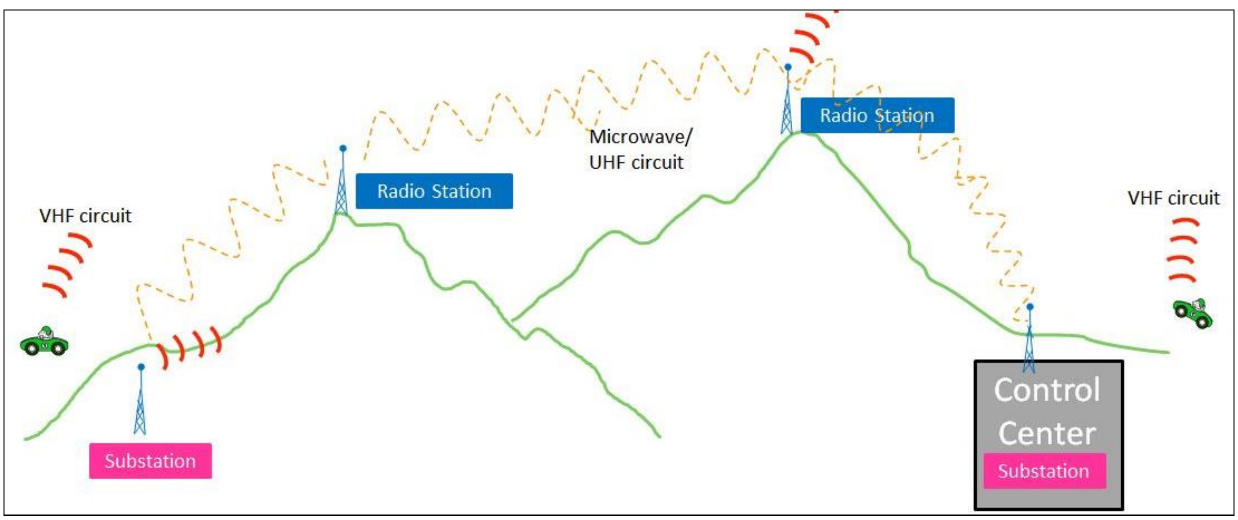


Figure 2. Illustration of communication via microwave/UHF circuits and VHF circuits, showing transmission between two end locations. The sites use "line of sight propagation between antennas mounted to towers to receive and transmit those communications. The system also enables communication between a mobile unit and an end location and between two mobile units using mobile equipment and VHP whip antennas mounted on radio station antenna towers (BPA 1977:V-27).

BPA dedicated its new microwave communication system in late 1949 and by the mid-1950s, grid operations had noticeably improved. BPA's communication system continued to evolve in efficiency and capacity over the following decades. Upgrades included new antenna, transmission, and power-generating equipment. During a major upgrade in the 1980s, BPA added new parabolic microwave antennas throughout the system. Although BPA's communication system still uses microwave technology, BPA has been incorporating fiber-optic communications technology since 1994. For the last decade, BPA has been converting its communication system from analog to digital (BPA 2012:86-88). All of BPA's existing radio stations remain in operation.

1.2 Regulatory Framework

As a federal agency, BPA must comply with the requirements of the National Historic Preservation Act of 1966 (NHPA) (54 United States Code (U.S.C.) § 300101 et seq.) and its implementing regulations (36 Code of Federal Regulations Part 800). This study meets BPA's obligations under Section 110(a) of the NHPA (54 U.S.C. § 306102), and provides NRHP evaluations to support future work under Section 106 of the NHPA (54 U.S.C. § 306108).

BPA's existing and planned projects that involve historic microwave radio stations include the demolition and removal of station buildings and antenna towers, installation of new replacement buildings, and improvements to access roads. BPA will follow Section 106 procedures for these projects. BPA's planned undertakings currently undergoing Section 106 review include demolition of buildings at the Applegate, Buck Butte, Grizzly Mountain, Indian Mountain Pine Mountain, Shaniko, and Swan Lake microwave radio station sites.

Figure 3. Biddle Butte Microwave Substation, 1951, workers forming building foundation (NARA:BiddleBNARAbox10-023)

2. Methods

The microwave radio station sites included in this study are in remote locations in Washington, Oregon, Idaho, and Montana. The sites are situated to permit line of sight transmission with each other, and with other BPA communication facilities. These facilities generally consist of a station building and an antenna tower, and may include additional features such as an engine generator building, oil tank, or outhouse. The simple and uniform layouts at these remote sites enabled AECOM to conduct an analysis using recent BPA site photographs, aerial images, historic photographs, and available historical data to complete the NRHP evaluations.

BPA's historic microwave communication system was established between 1950 and 1974 to serve its entire transmission grid. Although the system's development occurred on a regional rather than statewide level, Section 6 provides tables that show the findings for Washington, Oregon, Idaho, and Montana to facilitate future coordination and consultation efforts. Appendix A provides NRHP eligibility maps for BPA's overall transmission region and for each state. Appendix B provides site forms for each radio station site that meets the requirements of the respective State Historic Preservation Officers (SHPOs).

2.1 NRHP Evaluation Process

The evaluations use the criteria for evaluation provided in the BPA Pacific Northwest Transmission System Multiple Property Documentation Form (MPDF) (Kramer 2012). AECOM prepared a historic context related specifically to BPA's radio and microwave communication development to identify significant trends in system development, technology, and building types.

2.1.1 Minimum Eligibility Requirements

The MPDF states that for a Microwave Radio Station to be eligible, it must, at minimum, meet all of the following standards:

- Designed by or purchased at the direction of the Bonneville Power Administration;
- Owned and operated all or in part by the Bonneville Power Administration during some portion of the period of significance; and
- Construction initiated prior to 1975.

The resources in this study are evaluated as individual sites that contain, at a minimum, an antenna tower and station building—essential features that characterize the site. The "site" NRHP resource type was selected as the preferred way of evaluating these resources due to the importance of individual locations selected for the stations. Within the NRHP, a "site" is defined as "the location of a significant event, a prehistoric or historic occupation or activity, or a building or structure, whether standing, ruined, or vanished, where the location itself possesses historic, cultural, or archeological value regardless of the value of the any existing structure" (NPS 1997:15). Consistent with this approach a NRHP-eligible BPA microwave communication station site must retain both the original station building and tower, ***as well original line of sight*** to other associated microwave communication sites (emphasis added).

2.1.2 Range/Variation

Microwave radio stations exist throughout the BPA system, and include a range of built resource types.

Station buildings include metal, manufactured, volumes, site-built concrete block, precast panel and other "vault" structures with a variety of roof and finish types. Most station buildings are small, utilitarian volumes, with little exterior detail. Stations located in severe, mountain top locations are specifically designed for those severe conditions, with varied materials and forms, including "snow roofs" and similar designs to withstand extreme climates.

Antenna towers range from steel lattice-work structures visually similar to "derricks" in form (i.e., tapering upward from a wide base to a narrow top), as well as monopole towers. Stations also have outdoor electrical and switching equipment, creating a complex, multi-component character.

BPA uses passive repeaters to help close microwave links where obstacles in the signal path block direct line-of-sight transmission. Passive repeaters are reflective aluminum panels mounted on steel or wood structures, and do not require independent power sources. Due to their limited features, passive repeaters are not considered historic resources, and are not evaluated as part of this study.

2.1.3 Integrity Considerations

Integrity was assessed using the guidelines provided in the MDPF, as well as additional integrity conditions, as outlined below.

Location/Setting

Microwave transmission requires a clear line of sight; therefore, the location is the most critical aspect of the each facility. Setting is conveyed through the original line of sight to other microwave facilities, as well as the general surroundings. The settings are generally characterized as remote areas at high elevations, situated atop mountains and buttes in forested areas, sagebrush steppe, and above tree line elevations.

It is suitable for original buildings and towers to be moved within the site boundary without diminishing integrity of location as long as all other aspects of integrity remain.

The sites are often near other communication towers and buildings associated with local, state, and federal agencies that optimize the same elevations and viewpoints for microwave and very high frequency (VHF) radio communication. The presence of other facilities near BPA's sites does not diminish the integrity of setting.

Design/Materials/Workmanship

Microwave radio stations may contain multiple resources, with both indoor and outdoor structures and buildings. Integrity in design, materials, and workmanship is retained through continued function and overall original character. The retention of historic buildings and antenna towers conveys the construction methods and workmanship of the site's historic period.

Modifications, especially upgrades to internal operational equipment for improved efficiency or function, do not affect integrity. Modifications that result in exterior modification for improved function, such as the installation of exterior equipment or changes to door configurations, do not generally impact integrity. Some of BPA's earliest microwave radio station sites contained windows, but all have since been infilled. This system-wide change does not impact integrity but may be significant unto themselves as they reveal the agency's shift towards increased security at their microwave radio stations.

Additions to microwave radio stations do not affect integrity, provided they are designed using compatible methods and materials that meet the *Secretary of the Interior's Standards for Rehabilitation* (36 CFR Part 67). Changes to scale and building form, or the use of new exterior cladding materials that change the appearance of the station building diminish integrity of design, materials, and workmanship.

The removal and/or replacement of a tower or station building impacts integrity due to the loss of the site's key features. The removal of secondary features, such as an oil tank, outhouse, or engine generator building is less likely to diminish integrity.

Sites potentially eligible under Criterion C must display a high level of integrity to relate to a particularly significant technology or key design in the development of the microwave/radio network. Changes are considered minimal if they do not alter the historically significant aspects of the technology, and the site retains a majority of visual and technical components of the original design (Kramer 2012:F-68).

Feeling and Association

Microwave radio stations demonstrate integrity of feeling when they effectively convey their original construction and their role in the development of the BPA Transmission System. The retention of original buildings and structures convey the feeling of the site's historic period.

Microwave radio stations reflect the development of an interconnected, centrally controlled transmission network, and therefore are associated with the development of the BPA transmission system, and have strong association with its significance.

Sites potentially eligible under Criterion C are exemplary of a particularly significant technology or key design in the development of the microwave radio network.

Microwave radio station sites retain integrity of association through the continued function of its historic features. Sites that contain a new station building, even if the original station building remains, have lost integrity of association and feeling with their historic period development. The construction of a new station building replaces the function of the original building, regardless of whether it remains onsite. In these situations, BPA will eventually demolish the obsolete building.

Figure 4. Hungry Horse Dam Microwave Radio Station with line of sight to Teakettle Mountain Passive Repeater.

3. Historic Context

3.1 Bonneville Power Administration in the Pacific Northwest

The BPA, part of the U.S. Department of Energy, is a nonprofit federal power administration that markets wholesale hydroelectric energy throughout the Pacific Northwest. BPA's transmission system, which provides nearly one-third of the region's electric power, operates primarily in Idaho, Oregon, Western Montana, and Washington, as well as sections of California, Nevada, Utah and Wyoming, and interconnects with systems in British Columbia, Canada (BPA.gov 2017). An integral component of BPA's power transmission network is its communication system, which facilitates critical data transmission throughout the grid. A more detailed discussion of BPA's history is available in Curran (1998), Kramer (2010), and Kramer (2012).

Congress created BPA in 1937 as part of President Franklin Roosevelt's "New Deal" to market power from Bonneville Dam, the Columbia River's first federal dam. In 1938, BPA's first administrator, James Delmage Ross (1872-1939), proposed a "Master Grid" transmission network to connect Bonneville Dam and the newer Grand Coulee Dam with the Portland, Oregon and Puget Sound, Washington areas. The Master Grid plan tied Pasco, Yakima, Spokane, and Ellensburg in Washington via a 230-kilovolt (kV) circuit loop. The network also linked to Washington and Oregon coastal areas and extended south through Oregon's Willamette Valley to the California border through radiating 115-kV lines designed to deliver smaller loads (Curran 1998:1; Kramer 2012:2). In May 1938, Congress's first appropriation of $3.5 million enabled BPA to begin Master Grid network construction. Between 1938 and 1945, BPA built 3,000 circuit miles of transmission lines, and interconnected with existing public, private, and municipal distribution systems. The system supplied inexpensive Columbia River power to rural communities and attracted major industries to the region (Curran 1998:2, 58).

The Master Grid (1938-1945) functioned through a network of high-voltage lines, as well as numerous substations and related facilities (Kramer 2012:2). During World War II (WWII), the Master Grid network advanced the region's significant wartime industries by supplying power to support shipyard production, and to aluminum manufacturing sites for aircraft construction. BPA also powered the Hanford site, where the U.S. produced plutonium used in the atomic bombs dropped on Japan in 1945 (Kramer 2010:5). After the war and the defense industry's decline, BPA power facilitated development of regional agriculture and industry, including timber (Kramer 2010:5). BPA's Master Grid communication system consisted primarily of carrier equipment operating at radio frequencies, which was the era's industry standard for utilities.

During the System Expansion Period (1946-1974), a time of rapid power system development, BPA connected new power generation facilities on the Columbia River and its tributaries to help accommodate the region's post-war growth. The Columbia River Treaty (1964) between the U.S. and Canada, and establishment of the Pacific Northwest-Southwest Intertie enabled BPA to further expand its network and begin marketing surplus power to other power grids (Kramer 2010:5; Kramer 2012:3). In 1950, during the System Expansion Period's early phase, BPA introduced the Pacific Northwest's first large-scale microwave radio communication system, substantially enhancing the power grid's efficiency and reliability, and greatly reducing operating costs. This microwave-based system ultimately replaced BPA's outdated radio frequency communication system. The new system consisted of "radio stations" built at high-ground sites, such as ridges and mountain peaks; and associated equipment installed at end locations, such as control centers and power substations, as well as being carried in mobile field units.

The radio stations provided instantaneous communication between end locations and with field crews involved in construction or maintenance activities. The newly activated microwave circuits enhanced data transmission functions for power line fault location, supervisory (remote) control of substations, telemetering, and others. The system also integrated communication and controls between BPA and other members of the Northwest Power Pool, an organization of the region's major electrical utilities that formed on August 1, 1942 (BPA 1943:14). The power pool originally included BPA, Montana Power (NorthWestern Energy), Idaho Power, British Columbia Electric, Tacoma City Light, Utah Power and Light (Rocky Mountain Power), Pacific Power and Light, Seattle City Light, Washington Water Power, Puget Sound Power and Light (Puget Sound Energy), and Portland General Electric (BPA 1951:28; Kershner 2016). The Northwest Power Pool now has 32 members. BPA's new communication system was crucial to dependable power pool operations throughout the region.

As BPA expanded the radio station network during the 1950s and 1960s, it implemented technological innovations to increase capacity and reliability. Completion of the William A. Dittmer Control Center in 1974 marked the end of BPA's System Expansion Period, as well as the end of BPA's manual control systems. Dittmer housed new computer-based management systems that relied on microwave communication facilities to gather and transmit the massive amounts of data (BPA 1972:24). The implementation of Public Law 93-454, which transformed BPA's funding and operations, also helped mark the end of the System Expansion Period (Kramer 2012:3).

Since its inception, BPA has continually adapted to evolving regional and national priorities by incorporating new electric distribution, management, and communication technologies through system upgrades and expansion (Kramer 2012:ii). BPA's innovations in the field of microwave-based communications exemplify its ability to incorporate technological advances for improved operations.

3.2 Radio Stations

3.2.1 BPA's Early Communication Technology

Beginning in the 1940s, BPA's innovations in microwave-based communication technology and its application to the BPA power transmission system substantially enhanced the grid's efficiency and reliability, and greatly reduced operating costs. By 1946, BPA recognized that rapid power system expansion required enhanced communications facilities. Microwave-based communications, in conjunction with control facilities, became a crucial component in BPA's system by enabling constant and instantaneous monitoring and regulation of power transmission (BPA 1977:V-26-V-28). Microwave facilities remained the "backbone" of BPA's communication system through the 1980s (BPA 2012:85).

Communications has been a critical aspect of grid operation since BPA's first transmission lines were completed. In 1939, BPA completed a comprehensive analysis of communication requirements for current and future operations, which examined power line carrier, radio equipment, and landline telephone facilities (BPA 1939:57). Power line carrier equipment operates at radio frequencies, which are much slower than microwave frequencies, to transmit communications and information over power transmission lines (OSHA 2019). During the 1940s, most utilities used a power line carrier as the standard mode of long-distance communication for system operations. This included BPA and the other Northwest Power Pool members (Stevens and Stringfield 1950:3). As the power pool's rapidly increasing use began to overload the available carrier spectrum, major interference and communication disruptions occurred (Stevens 1950:83). The system suffered from other serious inadequacies, such as inability to prevent discretely located faults from prompting large-scale system failures. Consequently, when a lightning strike deactivated a section of high-voltage transmission line between two major BPA substations, intervening service areas would also lose power. In addition, transmission line failures disrupted electricity-dependent radio communications, forcing dispatchers to use a long-distance telephone system (Baker 1953).

For point-to-point communications, such as between two substations, BPA used carrier equipment, which operated like an ordinary telephone. As described in BPA's 1939 annual report, "Calls placed by means of a rotary dial on the base of the instrument will ring only the called station, and the ring will be received in the same manner as a standard telephone" (BPA 1939:57). Carrier equipment was in a separate room at each substation control house and used an automated emergency generator in case of power supply interruption. For mobile communication between field crews and substations, and for emergency backup, BPA used a mobile radio system at strategically located substations. Radio transmitting-receiving equipment was installed about 0.5 mile from the substation control house, and the substation operator remotely controlled the radio equipment from a unit on his desk. To communicate with the substation operator, field crews used battery-operated mobile radio units mounted on their vehicles, as well as a microphone, loudspeaker, and control panel inside the vehicle (BPA 1939:57).

The radio station built in June 1941 at the Eugene substation was a typical BPA communications installation, and its facilities closely resembled those of the later microwave-based radio stations. Both types of radio stations employed antenna towers and small station buildings. The 1941 Eugene radio station, built near the substation, had a 98-foot steel antenna tower and a small station building that housed transmitter/receiver equipment. The substation controlled radio station operations by means of an underground cable. Field crews using mobile radio units could communicate with the Eugene radio station and with the control center at North Vancouver substation, which was later renamed to honor BPA's first administrator, James Delmage (J.D.) Ross (*Eugene Register-Guard* 1941). The radio transmitter also allowed emergency communication between the Eugene and North Vancouver/Ross substation.

In addition to the radio-based system, BPA also used Pacific Telephone & Telegraph landlines supported by transmission line structures. By the late 1940s, BPA was in the process of installing radio equipment at six substations and preparing to activate 15 mobile radio sets. At that time, the North Vancouver/Ross – Raymond and North Vancouver/Ross – Bonneville Dam carrier communication circuits had already been placed in operation (BPA 1940:141). A laboratory was built at the North Vancouver/Ross substation for use in designing and maintaining communication system equipment (BPA 1940:142). The following year, BPA lauded "Major developments in the operation of the physical transmission system during the fiscal year [which] included the establishment of mobile line patrols equipped with short-wave radio, the design and installation of carrier telephone service over major lines of the system, and the development of procedures for emergency break-down relief on all parts of the transmission network" (BPA 1941:72).

Bonneville dispatcher at communications turret controls operation of 61 substations on the grid system.

Figure 5. BPA dispatcher using "communications turret" to control substation operations in mid-1940s, before implementation of a microwave-based communication system (BPA 1946:29).

BPA's program to incorporate microwave technology into its communication system necessitated new facilities and equipment. The microwave communication system was built primarily as a network of "radio stations" enabling communication between end locations, such as control centers and power substations, and with mobile field crews (BPA 1950a:5).

3.2.2 BPA's Original Microwave-Based Communication System and Its Functions

Scientists first began experimenting with microwave-based communication technologies during the early 1930s (Cantelon 1995:563). As WWII approached, intensive efforts in radar development led to a surge in new microwave-related uses and heightened awareness of microwave properties (NASEM 1994). After the war, companies that had manufactured radar devices for the military used their knowledge and experience to advance commercial microwave-based networks for telephone, television, and utilities (Cantelon 1995:564). Meanwhile, BPA was working to apply the new technology to modernize the Pacific Northwest power grid's capabilities. BPA enjoyed flexibility in communication system planning; because unlike many older utilities, BPA did not already have in place an "extensive system of open wire phone lines" (Stevens 1949:39). BPA was, therefore, free to use microwave channels where most effective, as well as other channels. For instance, microwave worked best for "backbone routes" where numerous channels were required, while power line carrier suited situations where few channels were required and communication occurred over long distances (Stevens 1949:40).

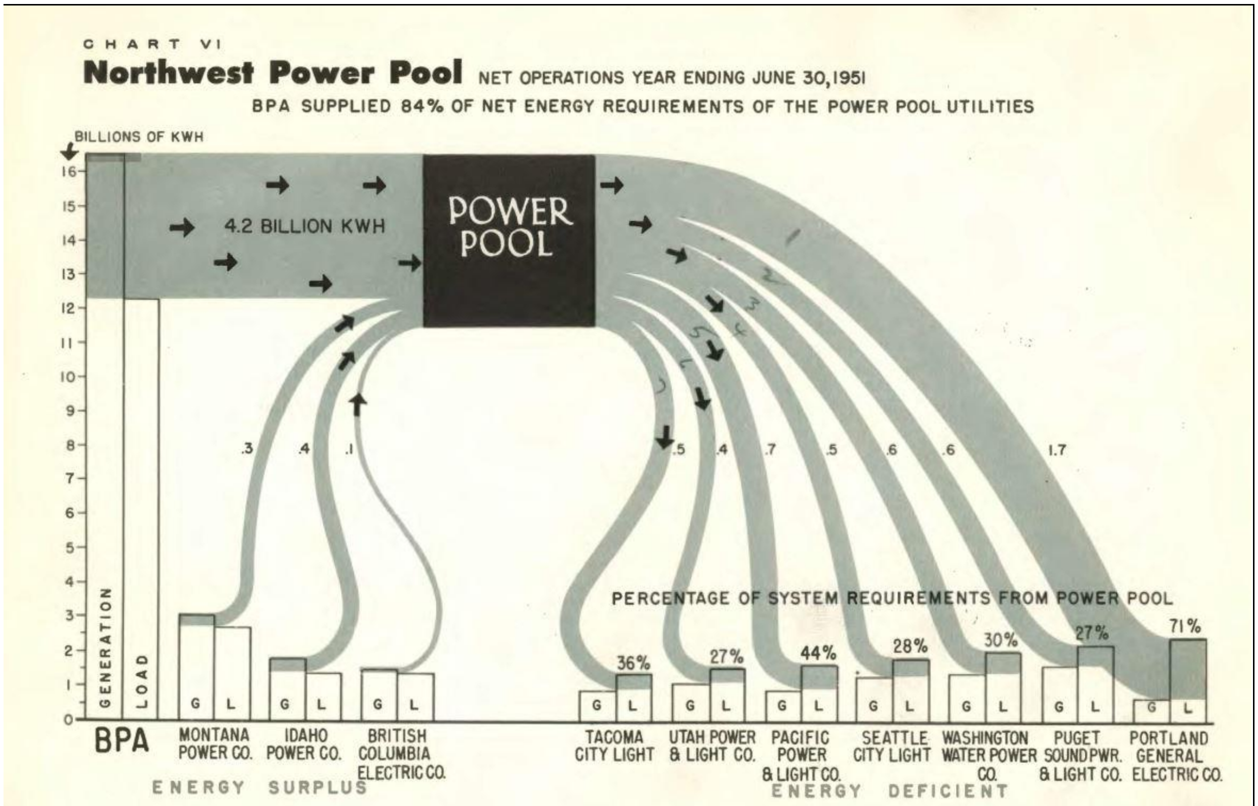


Figure 6. Northwest Power Pool net operations for Fiscal Year 1950, illustrating the interconnected nature of operations between BPA and other power pool members (BPA 1951:28).

First placed into operation in 1950, BPA's new microwave-based system provided more efficient communication links; reduced the need for new transmission lines; and shortened outages (Baker 1953). BPA engineers Richard F. Stevens and Theodore W. Stringfield identified the key advantages of microwave over common carrier, including channel reliability, lack of interference, easy maintenance, and "superior performance" (Stevens and Stringfield 1950:3). Unlike earlier radio stations, microwave radio stations did not depend on transmission circuits, and therefore were not inactivated by transmission line failures.

In addition to improving conventional voice communication, BPA's new system provided enhanced capabilities in supervisory (remote) control, transmission line fault location and isolation, telemetering, and facsimile.

Supervisory (Remote) Control

BPA engineers found conditions on the grid "particularly favorable to the use of supervisory control" (Stevens and Stringfield 1950:6). Stevens and Stringfield noted that BPA's status as a wholesale power distributor meant that personnel were not required to maintain a power distribution system. Therefore, many of BPA's substations, which were widely dispersed through the Northwest, had only one operator, and were frequently unmanned. Nevertheless, prompt switching could be necessary to restore service. In these cases, supervisory (remote) substation control was an inexpensive way to improve service reliability. Before implementation of microwave-based communications increased availability of effective channels, only three substations had supervisory controls. Microwave system expansion plans included installation of supervisory controls at 18 additional substations in Fiscal Years 1950 – 1952 (Stevens and Stringfield 1950:6).

Enhanced supervisory control capacity, in conjunction with transportation improvements, directly impacted the distribution of substations and the design of new substation control houses. Increased supervisory control meant less need for staffed control houses, resulting in smaller control house buildings. Meanwhile, better roads and vehicles enabled BPA to more widely distribute "support nodes," and use centrally located support facilities over larger service areas. These factors led BPA to select small, simple utilitarian buildings for many 1950s substations, forgoing the Streamline Moderne designs of the Master Grid period (Kramer 2012:E-32).

As BPA added more supervisory control installations, it upgraded system functions. In 1958, BPA installed a microwave supervisory control system at Keeler substation near Hillsboro; the first of its type in the Northwest. The $35,000 installation supplied "pushbutton control" for more than a third of Portland's power supply. It also supported electronic operations of the Oregon City substation, one of West Portland's principal switching and transforming centers. The new system ensured "maximum reliability of service" by instantaneously reporting at Keeler any lightning strikes, voltage drops, fire, illegal entry, or other emergency conditions at Oregon City substation (*Oregonian* 1958a).

Transmission Line Fault Location and Isolation

Applications to fault location was one of microwave's most novel uses in the BPA system, providing "a means of instantly measuring, and recording on a chart, the distance to transmission line faults" (Stevens 1950:83). The earlier method of locating and isolating transmission line faults was slow and imprecise, and often required field patrol of long line sections using "cumbersome photographic" documentation methods (Stevens 1950:83; BPA 1950b). The new system was proposed by BPA engineers Richard F. Stevens and Theodore W. Stringfield, and developed by the Federal Telecommunication Laboratories (FTL) (*Science News Letter* 1950:92).

The new fault location process was initiated with BPA's first microwave link between the J.D. Ross Control Center and the Snohomish Substation in Washington. The BPA *Currents* employee newsletter reprinted a related *Newsweek* article dated February 13, 1950:

> Engineers of the Bonneville Power Administration are convinced that they will soon be able to locate all kinds of breaks within 1,000 feet, the distance between towers along the great Northwestern public power lines . . . The system now being installed between substations at Snohomish and J.D. Ross, Washington, depends on having a high-frequency radio line connecting stations along the line. (BPA already uses radio for inter-station communication.) When a break in the power line occurs, electric waves rise at the faulty point and zip toward both stations at the speed of light. The wave reaching one of the stations is automatically sent through the radio system to the other station. Thus at the second station the two waves arrive a few thousandths of a second apart. An electronic brain measures this infinitesimal time lag, figures out where the break occurred, and types out an SOS. Repair crews can immediately be dispatched to the point of trouble (BPA 1950b).

FTL's equipment recorded how long it took (in microseconds) for surges generated by the fault to arrive at a certain point on the transmission line. The time lapse data were converted into distance (miles) and printed onto a paper chart (Stevens 1950:83). As reported by Eugene's *Register-Guard*, a "special video channel will use a fault location technique perfected by Bonneville engineers whereby the exact location of an outage or fault on a transmission line can be automatically located through measuring the surge from the fault" (Currey 1951). In February 1950, the *Science News Letter* also published a short article describing the first system link between Ross and Snohomish as an "automatic radio sleuth [which] tracks down trouble on high voltage power lines in seconds" (*Science News Letter* 1950:92). Specifically, the link employed “pulse time modulation radio relays and prints at a terminal station, the time, and location within 600 feet [as opposed to 1,000 ft., as reported by *Newsweek*], of high voltage faults that occur anywhere on the line” (*Science News Letter* 1950:92).

Telemetering

Telemetering, another function of the new system, automatically communicates data about current generation at each dam, power loads on interconnected lines, reactive power on the system, and other vital operations information. Telemetering prevents loss of system energy by allowing informed dispatchers to “keep all machines working at maximum capacity” (BPA 1948:2). Telemetering channels also support the fault location function by recording the effect of a line fault on other parts of the system. This permitted dispatchers to immediately advise substation operators and generating stations of power surges from the fault, and provide instructions to balance power flow and stabilize voltage conditions (Currey 1951).

Before the new microwave system was activated, BPA was the only Northwest Power Pool member without telemetering facilities. BPA dispatchers often worked without the latest generating information, which was obtained inefficiently through telephone calls. Furthermore, BPA’s use of telephone calls to obtain generating information further clogged the already overloaded voice channels (BPA 1948:2-3). In spring 1950, BPA ordered equipment to provide for telemetering interchange with most of the other Northwest Power Pool members (Stevens and Stringfield 1950:4-5). Power pool members also integrated their own telemetering equipment with BPA. For instance, the Eugene Water & Electric Board, a municipal utility, used telemetering to measure the precise amount of power purchased from BPA, as well as the amount of power the utility contributed to the power pool during periods of high generation (Jaques 1954).

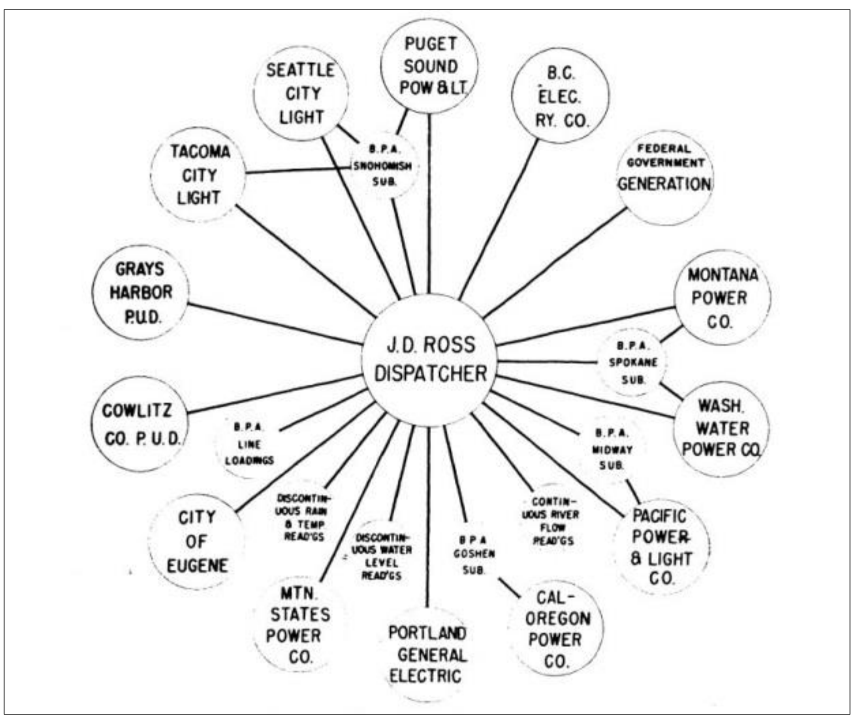


Figure 7. BPA’s telemetering program schematic, centered at the J.D. Ross Complex, showing interconnections with BPA power substations and Northwest Power Pool members (Stevens and Stringfield 1951:32).

Facsimile

A facsimile channel was also used to relay imagery, such as maps, data tables, and sketches between BPA sites, as well as for voice communications. BPA had previously purchased facsimile transmitter-receivers in 1946 for experimental use over carrier channels; however, the frequency response of the carrier channels was inadequate compared to microwave channels (Stevens and Stringfield 1950:6).

3.2.3 Initial Operations in the 1950s

BPA's First Microwave Links

BPA began upgrading its communication system with microwave technology during a period when the federal government was investing hundreds of millions in regional power development and reclamation. These investments underscored the Northwest's substantial population growth and industrial expansion, which resulted in increasing demands for inexpensive power (*Oregonian* 1951). In its 1949 annual report, BPA noted that during the previous decade, power consumption in the Northwest had more than tripled, the region's population had increased by nearly 45 percent (compared to about 15 percent nationwide), and industries were experiencing steady expansion (BPA 1949:41).

The preliminary phases of BPA's new microwave communication system corresponded with the opening of the new J.D. Ross control center in Vancouver, Washington, on December 17, 1949. Ross embodied BPA's technological advances in centralized system operations. The new facility was designed to control "the rapidly expanding NW power system and new microwave installations scheduled for 1950" (*Mail Tribune* 1949). The *Oregonian* proclaimed Ross's new control center as "[O]ne of the most modern power dispatching centers on the coast" (*Oregonian* 1949a). The newspaper described the interior control facilities as using a "three-position power dispatcher's turret [that] provides the central control for dispatching operations with power line carrier, telephone, special leased wire and microwave radio communication facilities" (*Oregonian* 1949a). With integration of the new microwave communication system, Ross would have the capabilities to adequately serve the entire Northwest Power Pool, and to coordinate combined transmission facilities representing the grid's approximately 14,000 miles of lines and 400 substations (*Oregonian* 1949a).

Figure 8. Philco advertisement from the May/June 1953 issue of Signal magazine (AFCA 1953:71). Note the reference in the right column to Bonneville Power Administration as a "famous" commercial user of Philco microwave equipment.

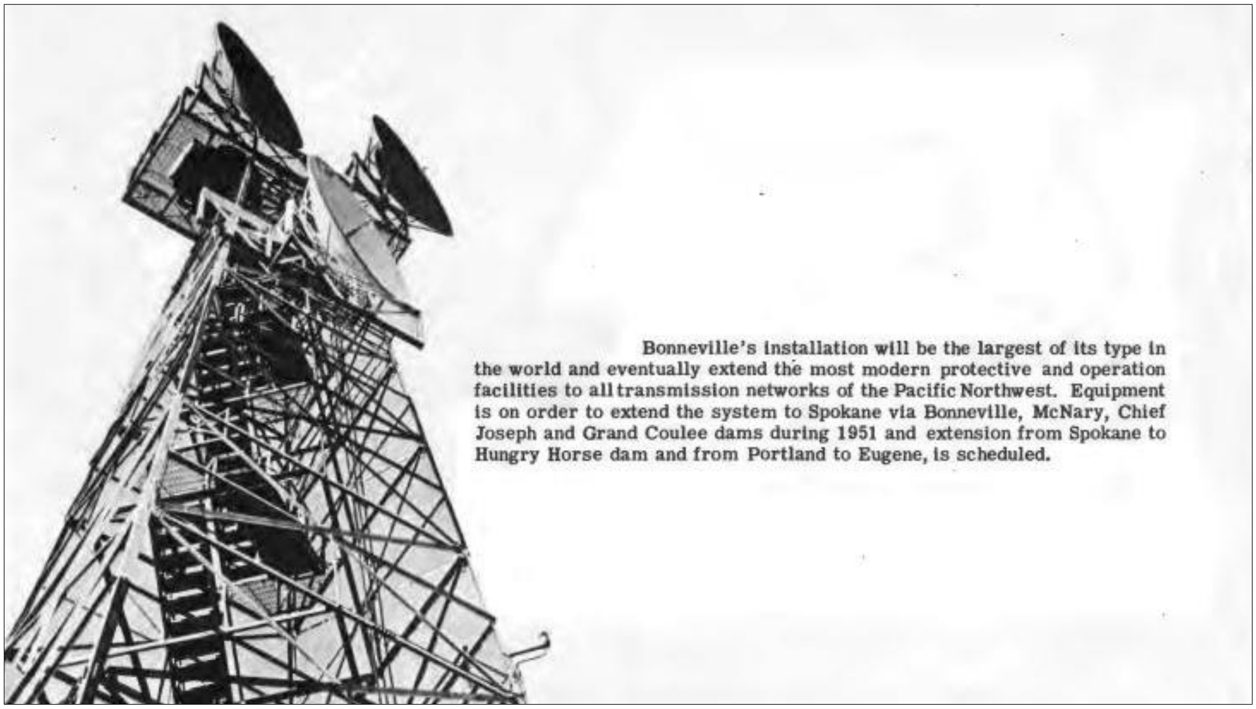


Figure 9. BPA's 1950 Annual Report stated that the new microwave communication system "will be the largest of its type in the world and eventually extend the most modern protective and operation facilities to all transmission networks of the Pacific Northwest" (BPA 1950:44).

In February 1950, BPA contracted for $633,492 with Philco Corporation of Philadelphia, Pennsylvania, to complete the new microwave communication system. Philco had produced hundreds of microwave radar units during WWII, and was a leading supplier of modern microwave equipment. Near the end of the war, in April 1945, Philco had demonstrated the world's first television broadcast using microwave radio relay rather than wires or cables. The telecast extended 152 miles between Washington D.C. and Philco's WPTZ radio station in Philadelphia (Cantelon 1995:562). BPA's new microwave system was to be one of the nation's largest, supplying "modern protective and operating devices for network transmission facilities valued at over $100,000,000" (BPA 1950a:5). The contract provided that Philco would complete the system within 360 calendar days by constructing microwave stations along the BPA power transmission system (Oregonian 1950a). Preliminary activation of the microwave channels on September 5, 1950 was followed by a special equipment demonstration for regional American Institute of Electrical Engineers (AIEE) members. Another system preview occurred later that month, on September 21, for the Institute of Radio Engineers (BPA 1950c:3).

On October 5, 1950, BPA's first system link between Ross, in Vancouver, and Snohomish was officially dedicated. The Ross – Snohomish link, extending approximately 200 miles between the terminal stations, connected the Ross control center with BPA substations and Northwest Power Pool dispatchers in the Puget Sound area, and with the BPA Seattle District office (Stevens 1950:82). BPA engineer and Design Section chief Richard F. Stevens described the 200-mile section as "the first installation of its size and scope by a power utility"; while the *Oregonian* hailed it as the "largest microwave radio communication system in the world" (Stevens 1949:39; *Oregonian* 1950b). Washington State representative Henry M. Jackson used the new system to deliver a congratulatory message from Snohomish substation to BPA administrator Paul J. Raver and chief engineer Sol E. Schultz at the Ross control center (BPA 1950c:3).

The initial installations, which cost over $900,000, consisted of co-located microwave equipment at substations near Snohomish, Covington, Seattle, Olympia, and Vancouver (Stevens 1950:82). The earth's curvature and line-of-sight requirements necessitated independently located radio stations at Squak Mountain (1950), Chehalis (1950), and Rainier (1950), with antenna tower heights ranging from 50 to 150 feet. The 50-foot tower near Squak Mountain's 2,000-foot peak provided sufficient height for the link's longest microwave transmission "hop" – 54.7 miles from Snohomish to Olympia.

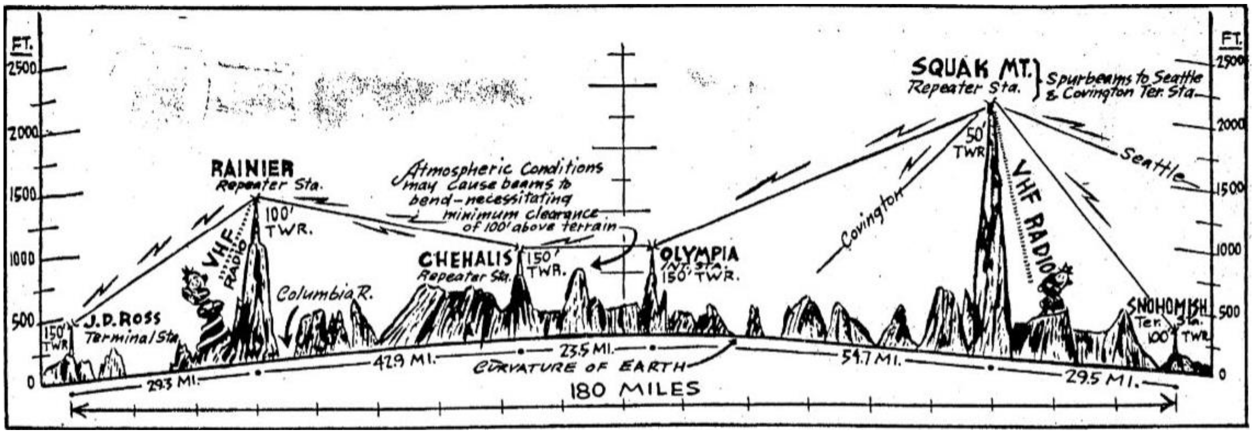


Figure 10. This drawing, which appeared in local newspapers, illustrates the Ross – Snohomish microwave link, including intermediate substations and radio stations. The drawing also notes VHF circuits used by mobile units (Oregonian 1950b).

The FTL, headquartered in Nutley, New Jersey, fabricated certain system equipment for Philco, and FTL engineers supervised those final equipment tests. With the anticipated addition of multiplexing units, allowing multiple signals to travel simultaneously over the same circuit, BPA's new system had a 23-channel capacity, not subject to interruptions from power failures (Stevens 1950:82).

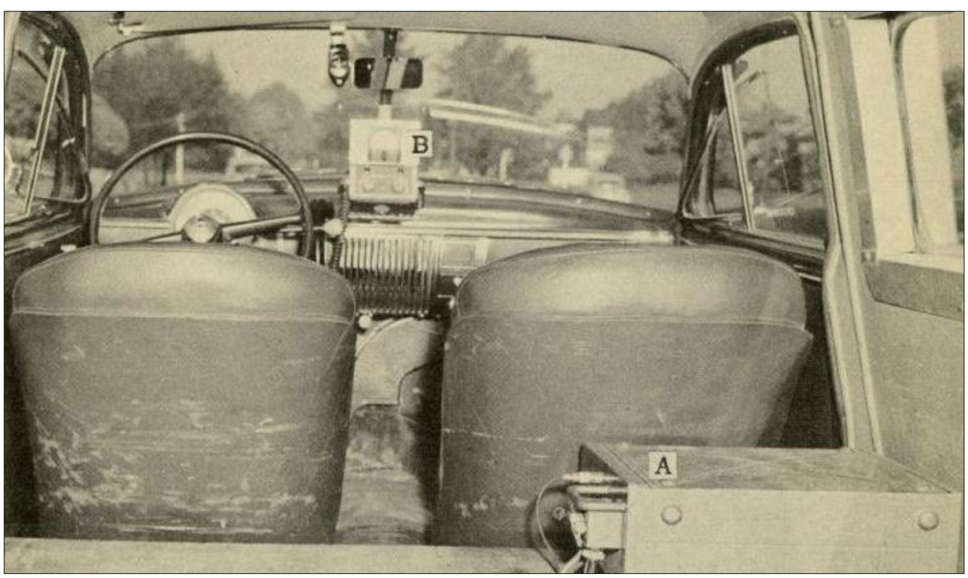


Figure 11. Survey car installation of VHF radio equipment for mobile field units, 1951 . A is the radio transmitter/receiver unit; B is the control head and field strength meter, with attached handset (BPA ECDU 1951).

With the world on the cusp of the space age, the newly installed microwave equipment captured the imagination. The parabolic antennas, mounted to steel towers, measured up to 10 feet in diameter, and inspired humorous newspaper comments about “flying saucer attachments” mounted on “giant antenna towers” (Currey 1951). Herbert C. Baker, staff writer for the Eugene *Register-Guard*, mused that the new system would “do everything in the power line except turn your home appliances on and off. And it may have a lot to do even with that” (Baker 1953). Referencing the fictional space hero featured in a 1950-1951 television series, Baker joked that BPA’s new microwave system was evidence that “[T]here’s some truth to that Buck Rogers stuff” (Baker 1953).

Figure 12. Squak Mountain radio station, August 10, 1950 (NARA:Squak1NARAbox27of52-021). Squak Mountain was built as one of three radio “repeater” stations within BPA’s Ross – Snohomish microwave link. New steel towers with parabolic microwave antennas, such as those found at Squak Mountain, inspired references to “flying saucer attachments” mounted on “giant antenna towers” (Currey 1951).

The Ross – Snohomish link began operations with a seven-channel capability: two for voice communication, one for service to monitor local equipment between repeater stations, one telemetering voice channel, two for relaying, and one for video fault location (BPA 1950c:3). At the outset, the system provided voice communication between dispatching centers, substation operators, and the Portland-Vancouver BPA offices. The telemetering, relaying, and fault location operations were activated afterwards (BPA 1950d:25).

BPA’s second link connected Ross with Spokane, Washington, by way of the Columbia River power plants at Bonneville, McNary, Chief Joseph, and Grand Coulee, and other intermediate substations (Figure 13) (BPA. 1950c:3). The third link connected the northern end of the Ross – Snohomish link with an intermediate point on the Ross – Spokane link. This link provided direct routing for protective relay channels associated with transmission lines crossing the northern Cascade mountain range. This link also completed a loop, which allowed alternate routing of traffic to a large number of radio stations in the event of equipment failure at any point on the loop (Stevens and Stringfield 1950:12).

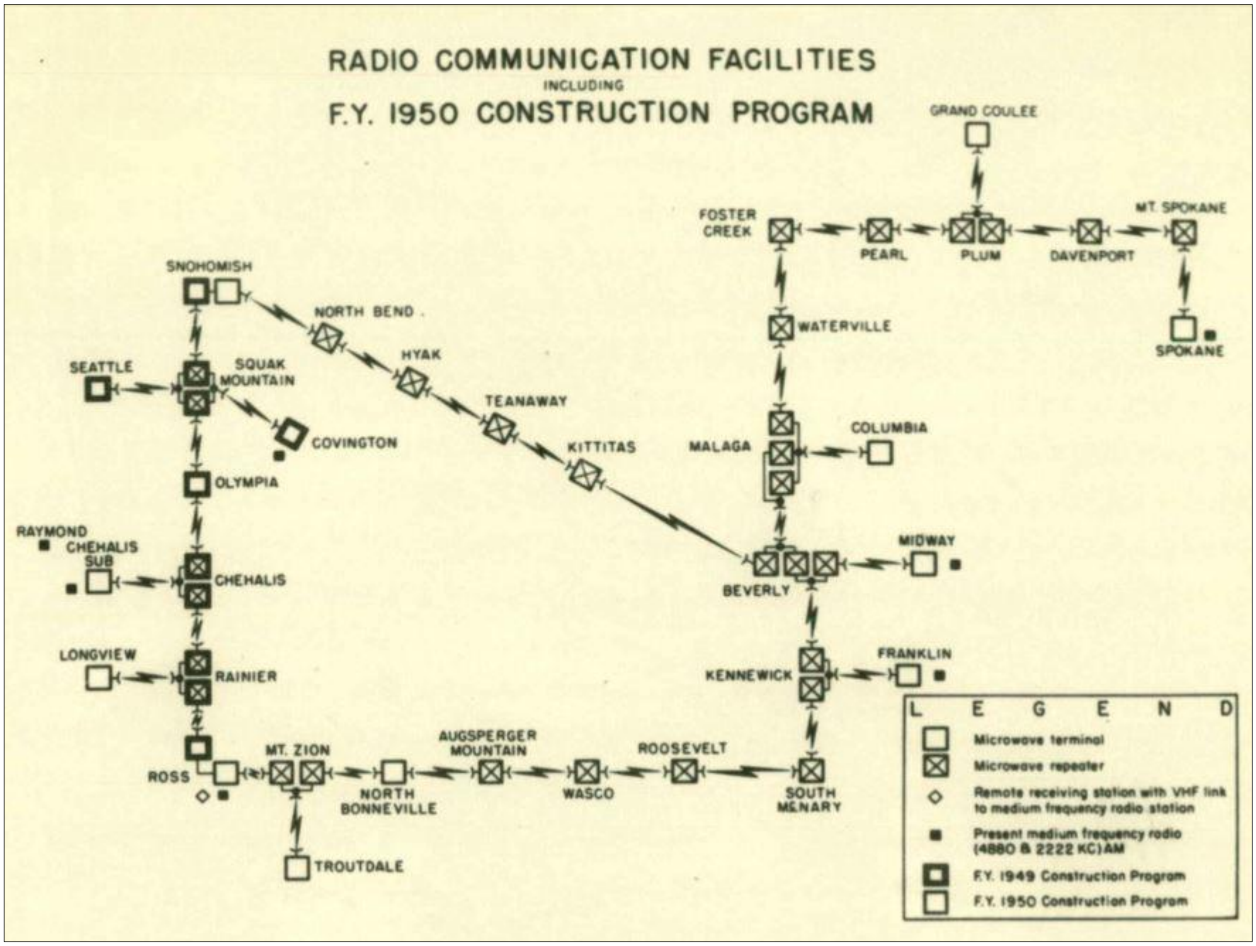


Figure 13. This drawing depicts the Ross – Snohomish system link, completed in FY 1949. It also shows upcoming construction projects for FY 1950 (Stevens and Stringfield 1950:17).

Building Construction

BPA's early radio station sites had one- or two-story buildings with at least 200 to 300 square feet of floor space (BPA 1977). BPA initially used prefabricated buildings with aluminum panel construction for smaller station buildings, and concrete-block or poured-concrete construction for larger buildings (Stevens and Stringfield 1950:12). None of the original prefabricated aluminum panel buildings remain in the BPA radio station system. The first radio stations had auxiliary gasoline-driven motor generator sets that automatically activated during extended power outages. Sufficient propane fuel was stored in tanks at each station to provide continuous operation for at least 2 weeks. Electronic equipment at each station operated directly from a direct current (DC) power supply consisting of battery and dual charger (Stevens 1950:82).

Adaptations for Mountainous Regions

The harsh conditions at remote radio station sites, particularly in mountainous areas, required BPA engineers to adapt radio station sites, buildings, and equipment to withstand the elements. Radio stations at high elevations are particularly susceptible to heavy ice and snow. Deep snow accumulation blocks entrances to station buildings; while snow, ice, freezing fog, and intense winds test the structural integrity of antenna towers. These elements also damage antennas and interfere with microwave transmissions. Figure 14 illustrates the extreme weather challenges associated with high-ground radio stations.

Figure 14. Augspurger Mountain Radio Station, February 5, 1954, showing BPA personnel removing ice from the tower ladder (NARA:AugspurgerMW2NARAbox7-008).

To address the challenges posed by extreme winter weather, BPA customized buildings, towers, and other equipment for certain high-ground stations, and integrated passive repeaters into the communication system.

Two-Story Station Buildings

Although most BPA radio stations have one-story buildings, extreme winter conditions in mountainous regions required building design adaptions. In the Columbia River Gorge and Snoqualmie Pass, snow depths, sometimes exceeding 20 feet, blocked ground-floor building entrances. To permit interior building access at these sites during deep snow periods, BPA constructed two-story concrete buildings with both first- and second-story entrances (Figure 13).

The two-story building has an exterior ladder leading from the ground to a platform abutting the second-story entrance. The platform also functions as a canopy to shelter the first-story entrance. The first-floor interior contains the main power panels and emergency equipment, including the generator. The second floor contains the microwave and VHF mobile radio equipment. The building's inlet and outlet ports and exhaust vents are installed close to the roofline, another adaptation to prevent obstruction from deep snow (Strong et al. 1957:659).

Figure 15. Rockdale Radio Station, in Snoqualmie Pass, on May 27, 1954, showing ladder leading to second-story entrance (NARA:Rockdale2NARAbox21of52-008).

Figure 16. Rockdale Radio Station on February 9, 1954. Even the platform in front of the second-story entrance has an accumulation of snow. The exhaust vents are located near the roofline to prevent obstruction by snow (NARA:Rockdale2NARAbox21of52-013).

Antenna Towers

BPA's standard radio station antenna towers were designed to withstand 100-mile-per-hour (mph) winds and 0.5 inch of ice (Strong et al. 1957:661). BPA also designed a tower adapted to mountainous station locations, where snow and ice tend to warp horizontal tower components. Based on a site's anticipated snow depth and icing conditions, BPA proportionally increased design loading per lineal foot. For instance, a "design loading of 2,500 pounds per lineal foot of horizontal member is used where snow depths up to 15 feet are encountered, and 3,000 pounds for above 15 feet" (Strong et al. 1957:661). Figure 17shows heavy ice accumulation on horizontal tower members at Augspurger Mountain.

Antenna Equipment

Severe weather adaptations for radio stations included special protective equipment. In areas with adjacent power transmission towers, cyclone wire fencing secured to a steel frame protected microwave antennas from sleet and ice chunks falling off the nearby conductors. In locations where frost accumulation on parabolic antennas interfered with microwave transmissions, BPA developed a "thermo-microdome." Fabricated with 3-ply fiberglass fabric and laminated with polyester resinate, this specially designed, conical-shaped cap protected the antenna's entire front surface (Figure 17). A heating element was imbedded into the material to further deter ice accumulation (Strong et al. 1957:658-659).

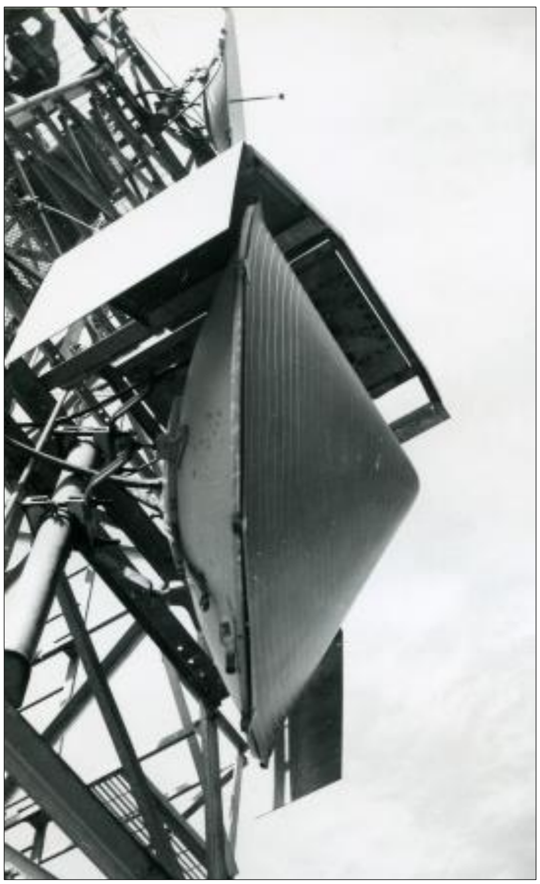


Figure 17. BPA's thermo-microdome antenna cover (detail left) provided antenna protection in icy conditions at Augspurger microwave/radio station (right) (NARA:AugspurgerMW1NARAbox7-025, -035).

Passive Repeaters

BPA's incorporation of passive repeaters—reflective aluminum panels mounted to steel or wood structures—helped adapt the system to extreme winter conditions and saved money on construction costs. By using passive repeaters, BPA could locate associated radio stations at more accessible sites. At Rockdale, for instance, topography interfered with line-of-sight propagation between the Rockdale radio station (1955) in Snoqualmie Pass and adjacent radio stations at North Bend (18.8 miles away) and Easton (12.2 miles away) (Figure 16). As illustrated in Figure 19, BPA built the Rockdale radio station at an accessible site near the newly constructed U.S. Highway 10. BPA then installed passive repeaters (Rockdale north reflector and Rockdale south reflector) on two nearby peaks to deflect the Rockdale radio station's microwave beam over the pass. With the Rockdale north reflector (Elevation 4,300 feet) on a peak over 2,000 feet above the Rockdale radio station (Elevation 2,230 feet), the station and its microwave equipment avoided the more severe weather at the higher elevation. In addition, by building the Rockdale station near the highway, BPA avoided the expense of access road construction

Figure 18. Rockdale North Reflector/passive repeater, February 9, 1954 (NARA:Rockdale2NARAbox21of52-016).

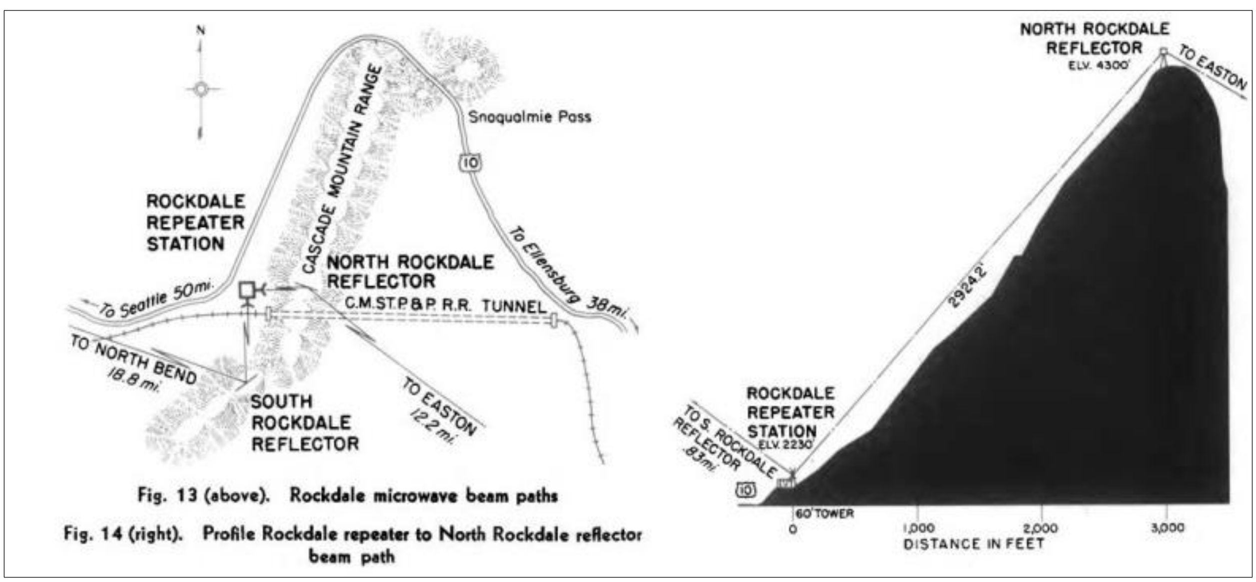


Figure 19. Rockdale Radio Station repeater scheme (Strong et al. 1957:659). The Rockdale radio station's transmissions are reflected by the North Rockdale reflector to Easton and by the South Rockdale repeater to North Bend.

3.2.4 1950s System Expansion

During the 1950s, BPA's new microwave communication system continued expanding to support the growing power grid. Microwave equipment was installed in power substations at Vancouver (Ross), North Bonneville, Trinidad (Columbia), Snohomish, Coulee City (Grand Coulee), Spokane, and Vernita (Midway) in Washington; and at Troutdale and Umatilla in Oregon. Independently located microwave radio stations were planned for Washington in Cape Horn (likely sold or demolished), Wasco (1953), Cook (likely sold or demolished), Kennewick (1955), Beverly (1953), Malaga (1955), Waterville (1953), Bridgeport (likely sold or demolished), Pearl (renamed Del Rio), Plum (1953), Davenport (1955), Spokane (1953), North Bend (1954), Hyak (not constructed), Teanaway (1954), and Kittitas (abandoned); and in Roosevelt for Oregon (1953) (BPA 1950a:5). Extension from Spokane to Hungry Horse Dam in Western Montana and from Portland to Eugene was scheduled for late 1952 (BPA 1950c:3). The Hyak site, located within today's Snoqualmie ski resort area, was never developed, and the nearby Rockdale microwave radio station was built instead (Westby 2019).

BPA's Willamette Valley system link encompassed the Oregon City, Salem, and Alvey (Goshen) substations, where microwave equipment was installed. Associated radio stations were built on Prospect Hill (1953) near Salem; in West Portland (1954); and near Coburg (1954). Another unidentified station was also constructed near Salem. In February 1951, Eugene's *Register-Guard* reported on BPA's proposed construction of microwave facilities at the nearby J.P. Alvey substation in Goshen, making the substation "the southern terminal of the world's largest utility microwave system" (Currey 1951; BPA 1954:37).

On January 22, 1955, BPA transferred power dispatching operations from the Ross control center in Vancouver to the BPA headquarters in Portland (BPA 1955:39). Microwave facilities at the Portland headquarters enabled dispatchers to communicate with 90 local mobile maintenance and operating vehicles (*Oregonian* 1955).

Figure 20. BPA's second Portland headquarters shortly after construction, including new microwave communication equipment mounted on the roof (Photograph provided by BPA c. 1955).

By 1955, microwave facilities between Portland and Spokane were placed in operation for voice communication, while BPA continued to work on activating these facilities for other types of communication capabilities (BPA 1955:39). The expansion of the communications system in north-central and eastern Washington included newly built radio stations at Wenas (likely sold or demolished), Sunnyside (1956), and Stampede Pass (likely sold or demolished). In combination with other area stations scheduled for completion in fall 1956, these new stations would complete a "land mobile radio system covering over 90 percent of transmission and substation facilities in the State of Washington" to instantly dispatch operation and maintenance crews to handle emergencies and equipment failures (*Observer* 1955; *Oregonian* 1954; BPA 1954:37).

Table I. Microwave Radio Communication System Data, May 28, 1957

System	No. of Stations	Total Length, Miles	No. of Channels	Equipment Manufacturer	RF Frequency Band, Mc
North	9	245	23	FTR*	1,700–1,850
	4	12	5	Motorola	7,125–7,425
South	10	170	23	FTR*	1,700–1,850
	6	130	1	Philco	7,125–7,425
East	30	728	24	Philco	7,125–7,425
J. D. Ross	2	9	23	FTR*	1,700–1,850

* FTR—Federal Telephone and Radio Corporation.

Figure 21. This table indicates that by May 28, 1957, BPA had 61 microwave radio facilities (Strong et al. 1957:656).

3.2.5 Oregon's South Coast

During the 1940s and 1950s, BPA served the South Coast area with a 115-kV transmission line; the area's only large-scale power source. Before BPA installed its coastal microwave link in 1954, intense coastal storms and flooding could leave the isolated area between Coos Bay and Gold Beach without power for extended periods. BPA's transmission line maintenance crews, using medium-frequency (MF) radio sets in the field, were capable of only intermittent contact with each other and with Alvey substation near Eugene. The communication system was clearly inadequate to address local line failures. In fall 1950, BPA began investigating how to replace MF channels with VHF channels and repeater stations to facilitate reliable communication between coastal BPA substations and field maintenance crews (Marihart and Wylie 1956:531-532). By 1955, the system was operational more than 97 percent of the time, a substantial improvement from the earlier MF system (Marihart and Wylie 1956:538).

BPA's five south coast radio stations were specifically designed to withstand the most severe local weather and maintain system reliability. The station sites included Goodwin Peak (1953), Leneve (1953), Noti (1954), Winchester Bay (likely sold or demolished), and Cape Blanco (likely sold or demolished). Each station's modular aluminum building was prefabricated at BPA's central workshop, transported to the station site, and mounted on a concrete slab. The buildings measured 10.5 feet wide, and between 14 and 20 feet long. The design called for separate radio equipment and emergency power equipment rooms with their own exterior entrances. Thermostatic space heaters maintained climate controls in the radio room. The emergency power room contained an automatic fire extinguishing system and propane-driven engine generators with 200-gallon tanks, providing sufficient reserves for a 10-day operation. At station locations subject to high winds, the building was secured to the ground with guy cables (Figure 22) (Marihart and Wylie 1956:534-535).

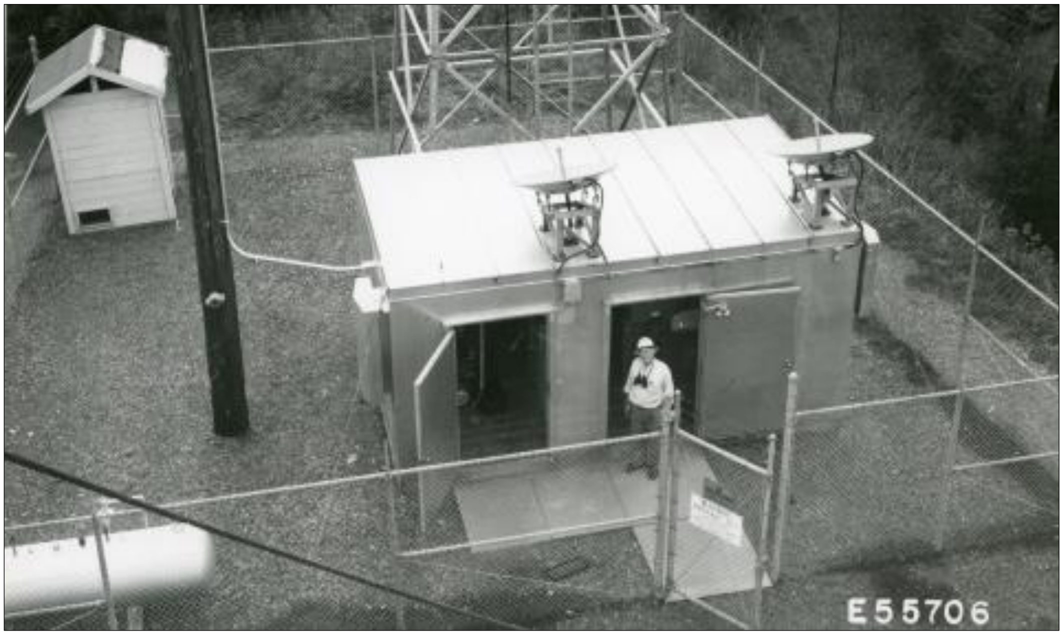
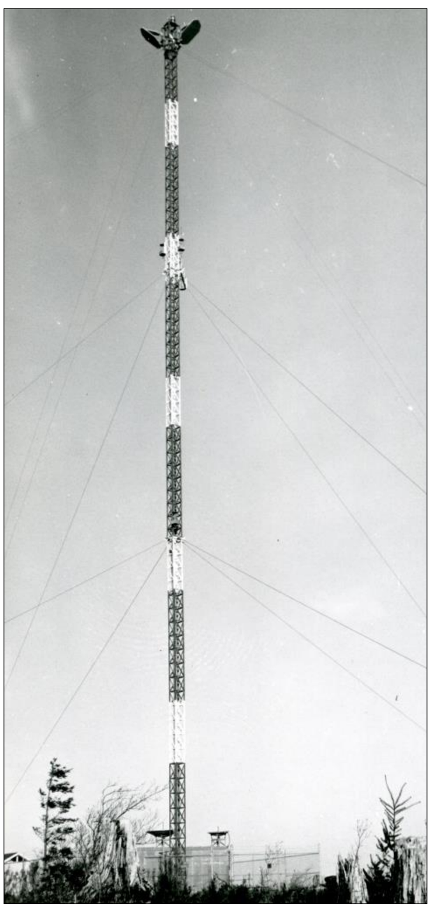


Figure 22. Goodwin Peak Radio Station, April 28, 1961 (NARA:GoodwinPeakNARAbox31-03). The radio station building is secured to the ground with guy cables. The radio and emergency power equipment rooms have separate exterior entrances.

BPA used one of three tower types at the five coastal radio stations, depending on station location and function:



1. The 50-foot self-supported lightweight steel transmission tower with top-mounted platform was installed at Noti and Goodwin Peak radio stations. This type of tower supported the two reflector antenna combinations used at these stations (Marihart and Wylie 1956:534).
2. The 50-foot guyed wooden H-frame structure was installed at Cape Blanco, a station site located on "a rocky promontory." BPA anticipated that this tower type would withstand the location's severe weather conditions, including wind gusts of 120 mph (Marihart and Wylie 1956:534-535).
3. The guyed steel lattice pole tower with 2-foot cross section varied in height depending on the radio station site. This tower type was adapted from the standard dead-end tower generally used at power substations. BPA installed the tower at the Winchester Bay and Leneve radio stations, which made it possible to "span a close intercept between the two stations" (
4. Figure 23) (Marihart and Wylie 1956:534-535).

Figure 23. Leneve Microwave Radio Station with guyed lattice pole (antenna tower) (NARA:LeneveNARAbox15of52-013).

3.2.6 Lenkurt System Upgrades in the 1960s

After the microwave communication system had been in operation for about 13 years, BPA initiated a substantial system upgrade. In June 1963, BPA awarded Lenkurt Electric Co., Inc. of San Carlos, California, a $1.7 million contract to design, develop, and install a 26-station microwave radio system to begin operations in September 1964 (*Eugene Register-Guard* 1963; Charitz 1963:38A). For three decades after WWII, Lenkurt Electric Co. specialized in the design and manufacture of advanced communications equipment. Founded in 1944 by Lennart Erickson and Kurt Appert and based in San Carlos, California, the company employed 3,000 workers at its peak. Lenkurt merged with General Telephone and Electronics Company in 1959, operating as a wholly owned subsidiary (Horgan 2010). Lenkurt's planned system for BPA extended over 660 miles between the terminal stations at BPA's Portland headquarters and Spokane. The 600-channel capacity "backbone" microwave system initially offered 72 channels, and replaced the existing 24-channel system (Charitz 1963:38A).

Figure 24. 1954 advertisement for Lenkurt Electric Co., touting the company's new multiplexing microwave equipment that used "frequency division techniques" and encouraged "full utilization of microwave communications" (Radiocom, Inc. 1954:7).

The September 1963 issue of the *Electrical Engineering* journal described BPA's new system specifications:

"Operating in the 7,125- to 8,400-mc government band, the system for the Bonneville project will include Lenkurt's transistorized 76C microwave system, transistorized 46A multiplex, 34A multiplex, 53B order wire, 936C alarm and control, 23B telegraph multiplex, and 9401A base-band regulator . . . Lenkurt also will furnish and install a fixed uhf [ultra high frequency] base radio facility, which will be integrated with the administration's present VHF mobile equipment. The VHF facilities will make possible rapid communications between all dispatchers in the power network and mobile fleet, thereby assuring maintenance when required at any point in the system" (Charitz 1963:38A)."

The new system incorporated existing or stock equipment and pre-existing microwave paths, with some modifications. Only four new paths were required for the following links: Biddle Butte – Augspurger Mountain, Roosevelt – Kennewick, Kennewick – Pomeroy substation, and Kennewick – Ice Harbor substation. After field visits by BPA and Lenkurt engineers during summer 1963, BPA installed dual polarized antennas at several sites to allow operation of new and existing microwave equipment on the same antenna (Shank and Lawrence 1965:44).

The new system fulfilled similar functions as the original. It also addressed the system requirements to reliably operate a network of expanding line and generation facilities owned by both BPA and the United States Army Corps of Engineers (USACE). By the time the upgraded system had been placed into operation, it linked 21 dams, 9,000 miles of high-voltage transmission lines, and nearly 250 substations; with the promise of dependable relay, line, and generation control for all current and future BPA and USACE facilities. New channels controlled generation at existing federal dams and the John Day powerhouse facilities, under construction on the Columbia River. Channels were also established for control of the USACE's four Snake River hydroelectric projects: Ice Harbor, Lower Monumental, Little Goose, and Lower Granite (at that time, the last three projects were under construction). Finally, the system was "an integral part of the dispatching system tying BPA's Portland headquarters and computer facilities with members of the Northwest Power Pool" (Shank and Lawrence 1965:43-44).

SP	Spare	CB	Common battery extension
TF	Tone frequency	DE	Dial extension
FA	Fault alarm	SV	Service
MO	Monitor	OW	Order wire
DL	Dial line	TP	Trigger pulse
DT	Dial trunk	MR	Mobile radio
RT	Ringdown trunk	TT	Relaying

Figure 25. Types of service channels on BPA's 600-channel "backbone" microwave communication system, installed in 1965 (Shank and Lawrence 1965:43).

BPA continued to upgrade and expand the new Lenkurt system. In December 1965, BPA awarded a 6-month, $420,000 contract to Collins Radio Co. of Richardson, Texas, for a "five-hop" microwave system to encompass a portion of the Bellingham, Washington area. The *Bellingham Herald* reported that, "Equipment will be integrated with present Bonneville control and communication system and be utilized for line-protective relaying, line-fault location, supervisory and 'load' frequency control, telemetering, VHF base station control, power dispatching, maintenance and communication" (*Bellingham Herald* 1965a). The system made an 83-mile hop from Snohomish to Squak Mountain (southeast of Seattle), then north to Lookout Mountain (south of Bellingham). It then branched north in three directions to Bellingham, Custer, and Intalco Aluminum Corporation (*Bellingham Herald* 1965b).

By 1966, BPA was operating 15 of its 273 substations by remote control from central locations, using control channels to operate circuit breakers, manage voltages, and meter power flow (BPA 1966:27). The *Seattle Times* noted that, "[B]esides its achievements in extra-high voltage transmission, Bonneville has scored numerous other technological 'firsts' [including] use of microwave communications to control and operate high voltage equipment" (Coffman 1967).

Armadillo Manufacturing Co.

As the radio station network was upgraded and expanded, BPA continued incorporating advanced building technology. During the late 1960s, BPA contracted with the Colorado-based Armadillo Manufacturing Co. for prefabricated portable fiberglass buildings to use at its radio stations. Armadillo's patented building design was "characterized by its structural stability, unitary construction and weather resistance" (Walz et al.1968). The prefabricated "Armadillo" buildings were pre-stressed to counteract external and internal loads, accommodated vents and doors, and could be installed atop concrete piers or footings (Walz et al. 1968).

The Armadillo buildings were well-suited to environmental conditions at BPA's remote radio stations. According to the patent documentation, the building type was "best exemplified by … its use in housing packaged electronic systems, such as for microwave communication stations.

Customarily, these stations are situated in isolated locations and necessitate an enclosure which has good insulating and weather resistance" (Walz et al. 1968). The weather-resistant building was "capable of withstanding heavy loading, both externally and internally, such as, may be attributable to wind, snow, or equipment and personnel housed within the building" (Walz et al. 1968). A 1966 Armadillo advertisement, found in *Signals*, published by the Armed Forces Communications and Electronics Association, emphasized the versatility of its buildings, which were "designed to meet individual requirements; manufactured of rugged, airtight, waterproof, fiberglass and honeycomb; completely equipped and tested; and then installed by Armadillo on that mountain top or swamp bottom site – ready to move in and use. No worries concerning weather or climate either" (AFCA 1966:60).

3.2.7 Pacific Northwest – Southwest Intertie

BPA's microwave communication system upgrade was critical to enabling construction of the Pacific Northwest – Southwest Intertie ("Intertie"), a monumental engineering achievement that connected the West Coast's main power grids. The largest transmission project in the nation's history, the Intertie was built to "balance power needs in the West" and permit the Northwest and Southwest to share surplus electrical power (BPA.gov 2018).

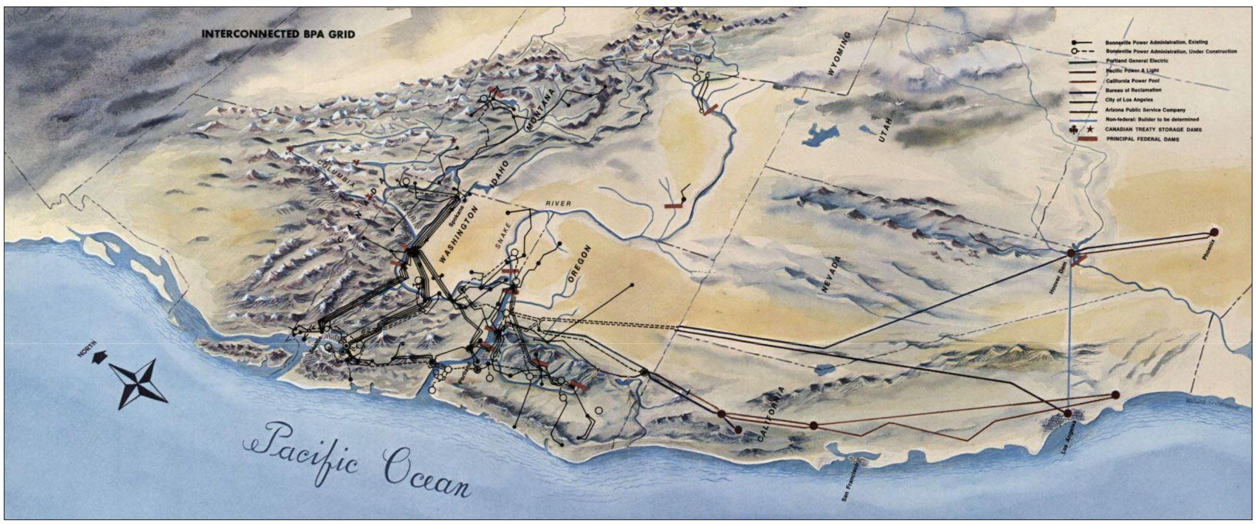


Figure 26. Illustration of the BPA Grid, including the Intertie extending into California and Nevada (BPA 1966). The Intertie connected various types of transmission facilities with the Columbia River's federal dams, including power, compensation, and converter stations. System functioning required a reliable communication system.

Intertie construction lasted from 1965 to 1970; and on completion, two 500-kV/AC transmission lines (1967 and 1968) extended approximately 940 miles from the John Day Dam on the Columbia River southward through the Central Valley of California, terminating at the Lugo substation near Los Angeles. The third transmission line, an 800-kV/DC (1970), extended from the Celilo Converter Station, near the Dalles Dam on the Columbia River, extending southward through Central Oregon and Nevada before terminating at the Sylmar Converter Station near Los Angeles (BPA 2018). At the time of completion, it was United States' first and the world's largest DC transmission power line (Coffman 1967; BPA 1966:29). A third 500-kV/alternating current (AC) line came online in 1992, extending from the Alvey Substation near Eugene, Oregon, south to the Tesla Substation near San Francisco. Today, the intertie links electrical systems from utilities in eleven states plus British Columbia, including "the largest hydrosystem (BPA), the largest municipal system (Los Angeles), and the largest privately-operated system (Pacific Gas and Electric) in the United States" (BPA 2018).

Intertie operations required an advanced, centralized communications system. In Fiscal Year 1966, BPA contracted with Collins Radio Co. for nearly $2 million in microwave communication facilities for the Intertie, which was expected to increase BPA's control system capacity by one-third (BPA 1966:26-27). The facilities formed a dispatch system link from BPA's Portland headquarters to the Intertie area's power system (*Bellingham Herald* 1965a).

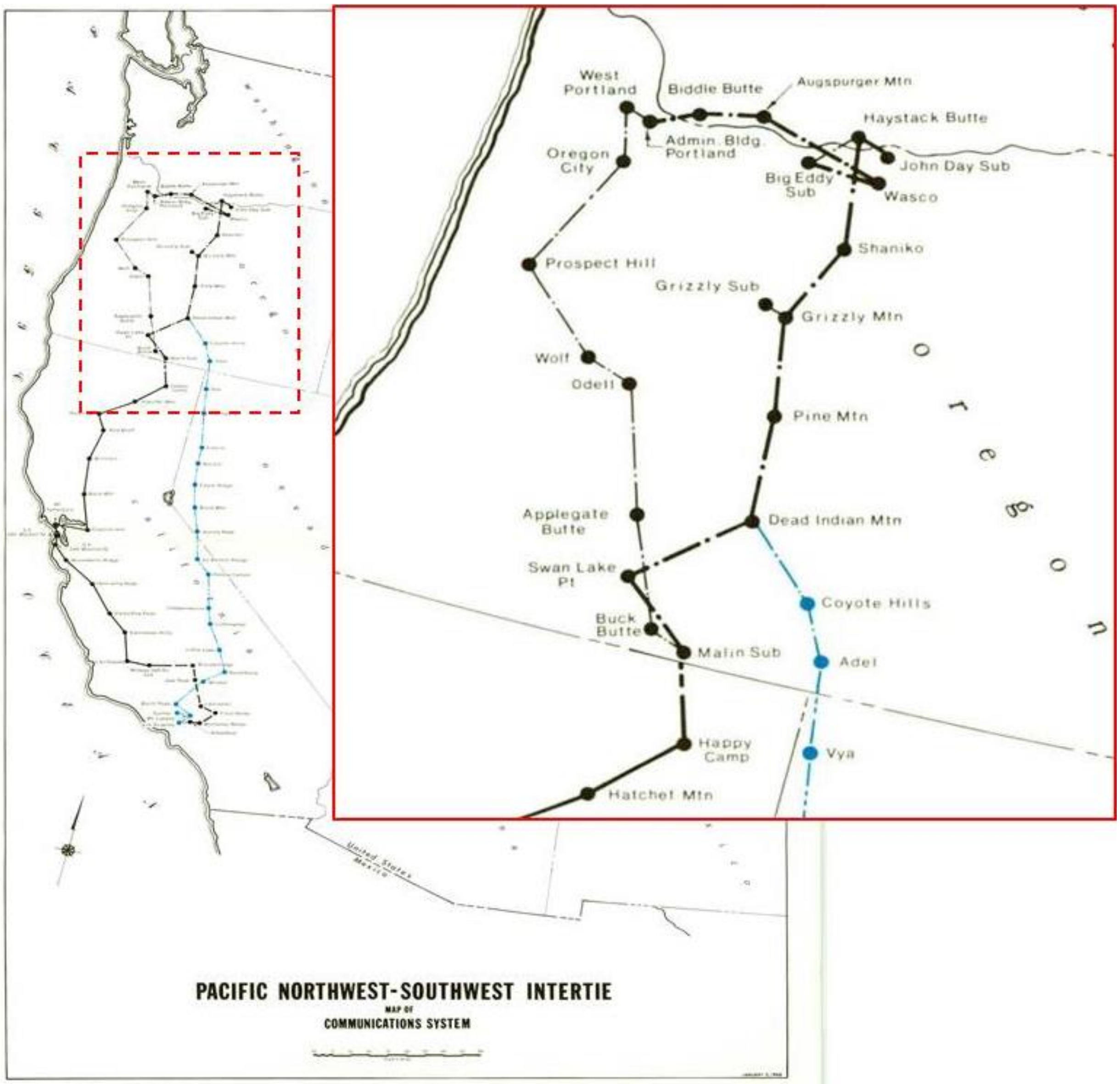


Figure 27. Intertie map with associated radio stations. The following radio stations were built in anticipation of the Intertie: Applegate Butte, Buck Butte, Grizzly Mountain, Haystack Butte, Indian Mountain, Pine Mountain, Shaniko, and Swan Lake, all built in 1968, except for Swan Lake, built in 1969 (Intertie 1968).

In its 1966 annual report, BPA reaffirmed the role of its newly upgraded microwave communication system:

> The control system for a large network of power lines must work without a second's interruption or the supply of electric energy to vast areas can suddenly be cut off. BPA's power operations are controlled with a system of extremely reliable communications channels supported by two small custom computers. The system is more than a communications system. It senses the changing conditions on the power network and gives the dispatchers the long arm they need to reach out across the network and respond. It also permits dispatchers to balance generation with loads in ways that make the most efficient use of the dams and the water flowing from one dam to another and on to the sea (BPA 1966:26-27).

Figure 28. Unidentified personnel testing BPA's microwave equipment (BPA 1966:26).

Before completion of the Intertie, BPA operated 56 radio stations linked to over "65,000 circuit miles of audio channels, some of which can carry up to 600 messages at once" (BPA 1966:27). In anticipation of the Intertie's completion, BPA planned an additional 22 new radio stations "equipped for 38,600 circuit miles of control channels" (BPA 1966:27).

3.2.8 Radio Stations and Beautility Principles

By the early 1970s, the BPA microwave communication system consisted of 190,000 circuit miles that paralleled the power grid (Marihart 1972:1). The increasing number of new radio stations prompted BPA to examine "beautility" concepts to reduce visual impacts on the landscape. BPA's beautility program began in 1965 to update design and aesthetic concepts for BPA properties. The concepts recommended by Stanton, Boles, MaGuire and Church Architects followed modern architectural trends for commercial and industrial buildings (Kramer 2012:33). Although Stanton, Boles focused primarily on appearance planning for substations, the firm also noted issues related to transmission towers and microwave antenna towers. Although not generally visible or accessible to the public, radio station sites still visually impacted the landscape: they were built on high ground, contained tall antenna and transmission towers, and required up to three cleared acres (Stanton, Boles 1966:15).

BPA's Fiscal Year 1972 environmental statement reflects efforts to incorporate the applicable beautility principles from BPA's "Appearance Program Practices" guidelines, including 1) site selection to satisfy both engineering and aesthetic considerations; 2) transitions zones to "blend the station into the landscape" and 3) streamlined yard structures with lower profiles (BPA 1966).

Strategies to incorporate these guidelines involved site development, towers, buildings, construction materials, and equipment. BPA limited clearing of trees and vegetation to minimum required to clear and grade the site, build access roads, and erect antenna and transmission towers. Taller towers were placed in heavily timbered areas to reduce the need for clearing (BPA 1970b:44-47). BPA found that siting towers on hill slopes could provide the necessary microwave beam path for line-of-sight propagation, while minimizing visual impact to the setting (BPA 1970b:42-43). BPA also limited the maximum height and profiles of antenna towers and associated equipment.

3.2.9 Dittmer Control Center: BPA Moves Centralized Control Back to Vancouver

In 1966, BPA announced its plan to remove its central controls from the Portland, Oregon, headquarters building and return it to the Ross Substation site in Vancouver, Washington, 10 miles to the north (BPA 1966:27). Named for William A. Dittmer, BPA's power manager from 1940 to 1953, the new control center at Ross was designed to incorporate power dispatching and centralized computer systems, and supervisory (remote) control for Portland area substations. Dittmer also contained space for substation operator training, visitor viewing, and offices (*Oregonian* 1969; BPA 1967:9).

Figure 29. Drawing for proposed William A. Dittmer Control Center at Ross Substation in Vancouver, Washington (BPA 1969:28).

BPA collaborated with North American Rockwell Corporation, prime contractor for the Apollo space program, to develop computerized systems for automatic grid control at Dittmer. The new computer system would replace the existing manual control program based at the Portland headquarters. BPA described the system as processing "vast amounts of power measurements from substations and powerhouses, as well as data from weather stations and interconnected utilities" (BPA 1967:7; BPA 1970a:31).

The microwave communication facilities would transmit the data necessary for these functions, and BPA relocated five microwave terminals from Portland to Dittmer (BPA 1972:24). In addition to its standard functions, the microwave communication system would operate in conjunction with the new computer system to provide "electronic paths for gathering vast new quantities of data" (BPA 1971:23). BPA's 1970 annual report further underscored the importance role that microwave communications would play in centralized controls, recognizing that its new $5 million computer control system "will be no better than the communications network which is an integral part of it (BPA 1970a:31).

Another motivation for BPA to move the control center back to Ross was for security, which had become increasingly critical as the Intertie project progressed. BPA's 1966 annual report expressed concern about the vulnerabilities of microwave communication equipment mounted atop the Portland headquarters building: "Because the present [Portland control] center is above ground and its microwave antennae clustered on the roof, it is somewhat of a security risk" (BPA 1966:27). At Ross, sufficient space existed for an underground facility "that would be protected from blast, fallout and other hazards" (BPA 1966:27).

After completion of Dittmer, BPA expanded system controls facilities with relocation of the Eastern Control Center (ECC) from Pasco to Moses Lake, Washington. The center's computer-directed supervisory control and data acquisition system (SCADA II) linked to 35 microwave units at remote substations throughout BPA's eastern service area, including northern Idaho, western Montana, and east of the Cascade Mountains in Oregon and Washington. The SCADA II System provided remote control of substation equipment, telemetering of voltage, power and reactive data, and automatic reporting of failures or vulnerabilities on the subgrid (subgrid transmission lines carry voltages reduced from the main system to regional distribution stations) (BPA 1973:17). The ECC began operations around July 1976, using about $6 million in telecommunications and control equipment housed in a remodeled Air Force building. During emergencies, ECC could provide backing for critical functions at Dittmer (BPA 1975:13). The ECC, including its microwave communications facilities, was retired in 2015 (BPA 2016).

3.2.10 BPA's Pioneering Engineers in Microwave Communication Technology

Although numerous individuals contributed to the development and expansion of BPA's microwave communication system, three BPA engineers warrant special mention: Sol E. Schultz, Richard F. Stevens, and Theodore W. Stringfield.

Sol E. Schultz (1900-1990)

Figure 30. Sol E. Schultz, 1950 press photograph (Amazon.com 2019).

Sol E. Schultz, born Solomon Elijah Schultz, served as BPA's chief engineer from 1939 to 1954, and played a significant role in implementation of BPA's original microwave radio communication system (*Corvallis Gazette-Times* 1952). Schultz was born on December 23, 1900 in Oil City, Pennsylvania, to Russian-born parents. As a young man, he began working as a streetcar electrician before earning his degree in electrical engineering (Ancestry.com 2002a, 2006, 2010, 2012). When BPA's microwave radio communication system was placed into operation, Schultz described it as "the largest of its type in the world" (*Union-Bulletin* 1950). Completion of the system's initial Ross – Snohomish microwave link coincided with Schultz winning the Milton H. McGuire achievement award for "outstanding engineering work" from the Northwest Public Power Association in September 1950 (*Mail Tribune* 1950). During Schultz's tenure as chief engineer, BPA added 6,000 miles of power transmission lines, 150 power substations, and dozens of radio stations (*Bend Bulletin* 1954).

Schultz resigned from BPA in July 1954 to manage the Seattle office of H. Zinder and Associates, and continued to play an important role in West Coast power development. During the 1960s, while at H. Zinder, Schultz completed a feasibility study that strongly, and successfully, advocated for construction of the Pacific Northwest – Southwest Intertie (*Bend Bulletin* 1954; *Seattle Times* 1960). In 1962, Schultz became a regional H. Zinder vice president (*Seattle Times* 1962a), and was named “Engineer of the Year” by the Washington Society of Professional Engineers (Seattle Chapter) (*Seattle Times* 1962b). Schultz served on the Bonneville Regional Advisory Council for the Seattle area through the 1960s and 1970s (BPA 1968:59; BPA 1976:43). Schultz died on May 27, 1990 in Washington State (Ancestry.com 2002b).

Figure 32. Richard F. Stevens (Seattle Times 1950b).

Richard F. Stevens (1902-1996)

Richard Francis Stevens joined BPA in 1938, and worked with BPA engineers to design and implement the microwave radio communication system. Stevens was born in Columbus, Ohio, on June 5, 1902 (Ancestry.com 2011). Before working at BPA, Stevens served as chief of electrical design for Seattle City Light’s Diablo installation (*Seattle Times* 1950a). After BPA hired Stevens as a technical assistant in 1938, he helped design the system’s first transmission lines, which were completed in 1939. As a Navy officer during WWII, Stevens supervised electronic installations for the military (*Seattle Times* 1950a).

Beginning in 1946, and through the 1950s, Stevens worked as chief engineer for BPA’s Branch of Design. He authored numerous technical papers, including those on implementing microwave technology into the BPA communication system (*Oregonian* 1964). In January 1949, Stevens presented on microwave radio application to power systems at a meeting of the AIEE and the Institute of Radio Engineers (*Oregonian* 1949b). In February 1964, Stevens received the Distinguished Service Award and Gold Medal, the U.S. Department of the Interior’s highest award (*Oregonian* 1964). Stevens died on October 7, 1996 (Ancestry.com 2002b).

Figure 32. Theodore W. Stringfield (Oregonian 1968).

Theodore W. Stringfield (1909-1975)

Theodore William Stringfield was born on March 28, 1909 in New York City. He graduated from Renselaer Polytechnic Institute in Troy, New York, with a degree in electrical engineering, and completed a master’s degree in electrical engineering at Brooklyn Polytechnic. Stringfield joined BPA in 1939, and worked as chief of electronics and communication for BPA’s Design and Construction Branch (*Seattle Times* 1950b). During WWII, Stringfield took leave from BPA to serve in the U.S. Navy (*Oregonian* 1958b).

In collaboration with other BPA engineers, including Richard F. Stevens, Stringfield developed and patented methods for transmission lines fault location (*Sunday Oregonian* 1975). Stringfield also worked to design and install BPA’s microwave communication system, and played an important part in development of the Intertie (*Sunday Oregonian* 1975). In November 1958, Stringfield was made a fellow of the AIEE, a distinction he earned for "contributions to power system communications and protections" (*Oregonian* 1958b). In July 1959, BPA awarded Stringfield for "outstanding resourcefulness and technical skill in planning a Pacific Northwest radiological defense monitoring system and training personnel" (*Oregonian* 1959). In 1968, Stringfield was promoted to BPA's new branch of Power System Control, which used high-speed digital computers to schedule and control release of power over BPA transmission lines (*Oregonian* 1968). When Stringfield retired from BPA in 1970, he was awarded the Distinguished Service Award and Gold Medal, the U.S. Department of the Interior's highest award (*Sunday Oregonian* 1975). Stringfield passed away on February 19, 1975 (*Sunday Oregonian* 1975; Ancestry.com 2014). The Clackamas County Park adjacent to his former home on SE Naef Road was dedicated as Stringfield Family Park in 2009.

4. Microwave/Radio Stations and their Characteristic Features

Although BPA’s two principal property types are transmission lines and substations, the microwave radio stations provide communications functions that are critical to grid operations. BPA currently owns and operates 117 microwave radio station sites, 53 of which were built prior to 1975 and retain historic features (VFA 2019). The sites contain three fundamental elements: line of sight to other communication sites, station buildings, and antenna towers. The antennas relay transmissions between radio facilities at control centers and substations, and with mobile field units. Station buildings house microwave equipment, power-generating units, and other station equipment. Another communication system feature, the passive repeater, helps close microwave links where obstacles in the signal path block direct line-of-sight transmission between radio station antennas. The passive repeater is a reflective panel mounted on a steel or wood structure located intermittently between microwave/radio station sites.

4.1 Microwave/Radio Station Sites

Microwave radio station sites typically consist of an access road for construction and maintenance, cleared site surrounded by chain-link fencing, radio station building, transmission line for site power, generator housing, and fuel storage for backup site power, and antenna tower (BPA 1977:VII-52). The sites are generally located on “high ground,” such as ridges and hilltops to enable line-of-sight reception and transmission between the antenna tower and adjacent station towers (BPA 1977:V-26 – V-28). The geography and vegetation vary from forest environments to sage steppe, to above tree line elevations.

The sites were planned in circuits to link communication between microwave radio stations, substations, and central communications at Ross Complex, and later Dittmer Control Center. The sites are inter-connectedly linked through line of sight to other microwave radio stations, to substations, central controls, and to mobile VHF units. A comparison of historic system maps to the current system data indicates how line of sight has been retained or modified since the historic period. Although new microwave sites have been introduced to the system since 1975, all of the sites retain line of sight to at least one adjacent facility, and most retain all aspects of their line of sight. The tables in the following subsections show the sites associated with BPA’s initial microwave communication system; the expanded system through 1957; the Northwest – Southwest Intertie; and the “Q” system extending to Idaho and Montana.

Microwave antennas are installed at several of BPA’s substations that contribute to BPA’s communication system and circuits. BPA’s historic substations were previously evaluated as a separate effort and are not included in this study.

Sites Excluded from this Study

Sites shown on the historic maps and diagrams were not evaluated for NRHP eligibility as part of this study for the following reasons: lack of historic features (station buildings and antennas); sold or demolished sites no longer in BPA’s system; substations that were previously evaluated; and passive repeater sites that lack station buildings. The sites excluded from the evaluation are included for reference in the subsection tables below.

Some sites in BPA’s system no longer retain any historic features (station buildings or antennas). Although these sites are not considered historic resources, they maintain their line of sight to other adjacent sites and are listed in the findings. Those sites include Alvey Hill, Bald Mountain, Cape Blanco, Capitol Peak, Lines Creek, Naselle Ridge, Odell Butte, Patrick’s Knob, Pomeroy, Seattle, Stampede Pass, and Wolf Mountain.

The following sites built during the historic period have been sold, moved, or demolished, and are no longer part of BPA's microwave radio communication system: Heybrook Lookout (VHF Site), Kittitas, Mount Vernon (VHF Site), Portland, and Winchester Bay.

4.1.1 Initial Construction (1950)

The initial construction in 1950 included six stations between Ross and Snohomish Substation, with spurs to Longview, Chehalis Substation, and Seattle. Additional circuits were planned for subsequent construction between Snohomish and Spokane, and between Ross and Columbia; all of which were built between 1953 and 1955.

Table 1. Initial Microwave Radio Station Historic Sites

Microwave Radio Station	Built Date	Retains Line of Sight
Chehalis	1950	Yes
Olympia	1951	Yes
Rainier	1950	Yes
Ross	1950	Yes
Squak Mountain	1950	Yes

Table 2. Initial Microwave Sites Excluded from Study

Site	Reason Excluded from Study
Chehalis Substation	Substation (Eligible)
Longview Substation	Substation (Not Eligible)
Seattle	No remaining historic features
Snohomish Substation	Substation (Not Eligible)

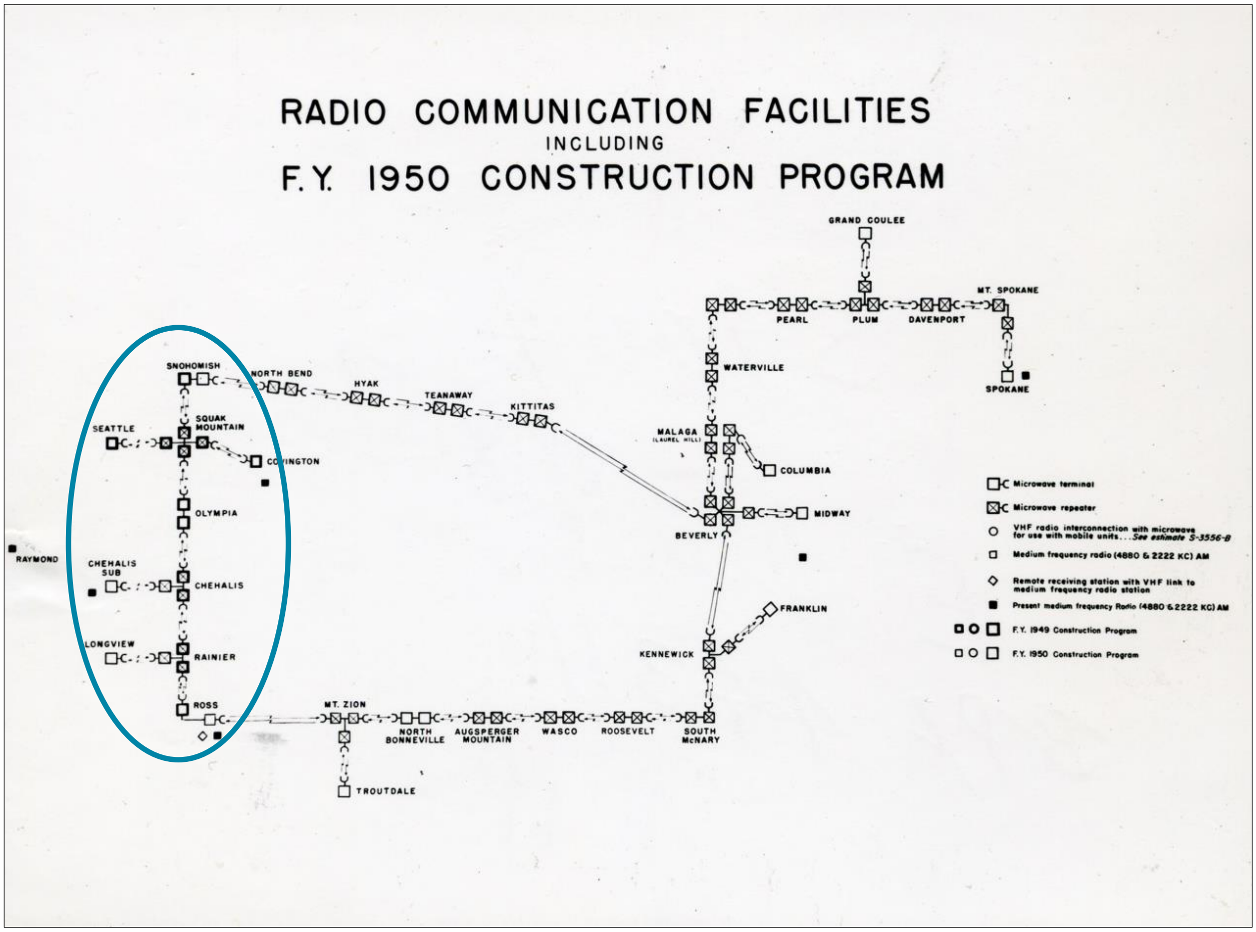


Figure 33. Diagram showing BPA's Microwave Radio System Plan in 1950, highlighting the initial construction period.

4.1.2 Microwave System Expansion (1950-1957)

A map from 1957 shows BPA's expanded system, with communication loops extending to southern Oregon, including the interconnection to Oregon's southern coast (Figure 35). More than half of BPA's historic microwave radio stations were in operation by 1957. Of the microwave radio stations established by 1957, the Kittitas and Winchester Bay microwave radio stations are no longer in the BPA system, and the original communication center in Portland was moved to the Ross Complex. Line of sight is generally retained for all the sites, although it is considered partially retained for those sites adjacent to those no longer in BPA's operation. In these situations, the site has lost line of sight in one direction, but not both directions.

Table 3. Historic Microwave Radio Station Sites Established by 1957

Microwave Radio Station	Built Date	Retains Line of Sight
Augspurger Mountain	1953	Yes
Beverly	1953	Partial
Biddle Butte	1953	Yes
Chehalis	1950	Yes
Coburg	1954	Yes
Davenport	1955	Yes
Foster Creek	1953	Yes

Goodwin Peak	1953	Partial
Grand Coulee	1953	Yes
Hyak (Easton? Rockdale?)	1954	Yes
Kennewick	1955	Yes
Leneve	1953	Partial
Malaga	1955	Yes
Mt. Spokane	1953	Yes
North Bend	1954	Yes
North Bonneville (Bradford Island)	1953	Yes
Noti	1954	Yes
Olympia	1951	Yes
Pearl (Del Rio)	1953	Yes
Plum	1953	Yes
Prospect Hill	1953	Yes
Rainier	1950	Yes
Roosevelt	1953	Yes
Ross	1950	Yes
Squak Mountain	1950	Yes
Teanaway	1954	Partial
Troutdale	1953	Yes
Wasco	1953	Yes
Waterville	1953	Yes
West Portland	1954	Partial

Table 4. Sites Established by 1957 Excluded from Study

Site	Reason Excluded from Study
Bell Substation	Substation (Not Eligible)
Big Eddy Substation	Substation (Eligible)
Cape Blanco Microwave Radio Station	No remaining historic features
Chehalis Substation	Substation (Eligible)
Chemawa Substation	Substation (Eligible)
Columbia Substation	Substation (eligible)
Covington Substation	Substation (Eligible)
Franklin Substation	Substation (Not Eligible)
J.P. Alvey Substation	Substation (Eligible)
Keeler Substation	Substation (Eligible)
Kittitas Microwave Radio Station	No longer in BPA's System
Longview Substation	Substation (Not Eligible)
McNary Substation	Substation (Eligible)
Midway Substation	Substation (eligible)
Oregon City Substation	Substation (Eligible)
Portland	Moved
Salem Substation	Substation (Eligible)

Site	Reason Excluded from Study
Santiam Substation	Substation (Not Eligible)
Seattle Microwave Radio Station	No remaining historic features
Snohomish Substation	Substation (Not Eligible)
Tacoma (South Tacoma) Substation	Substation (Eligible)
Winchester Bay Microwave Radio Station	No longer in BPA's operation

Figure 34. Map of BPA's Microwave Communication System in 1957

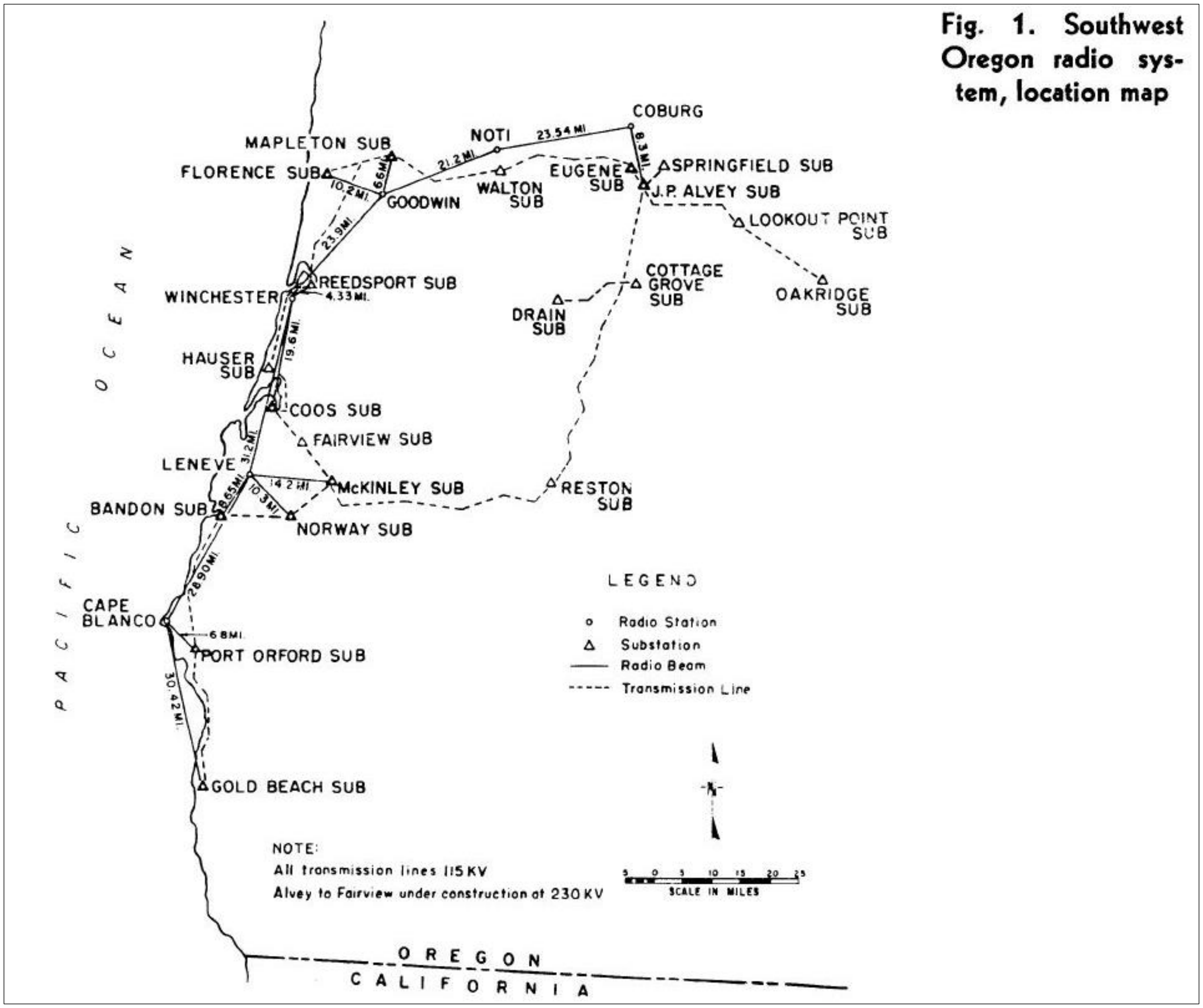


Figure 35. Southwest Oregon Microwave Radio System in 1956.

4.1.3 Pacific Northwest – Southwest Intertie (1968)

BPA's microwave communication system upgrade was critical to the Intertie.

The circuit of microwave radio stations constructed to support the Intertie is generally intact. Microwave communication equipment was installed at several substations as part of the Intertie effort. The sites associated with this theme are generally intact, with the exception of two microwave radio stations that no longer retain historic features. Line of sight is retained for most sites.

Table 5. Historic Northwest – Southwest Intertie Microwave Radio Communication Station Sites

Microwave Radio Station	Built Date	Retains Line of Sight
Applegate Butte	1968	Yes
Augspurger	1953	Yes
Biddle Butte	1953	Partial
Buck Butte	1968	Yes
Grizzly Mountain	1968	Yes

Microwave Radio Station	Built Date	Retains Line of Sight
Haystack Butte	1968	Yes
Indian Mountain	1968	Yes
Pine Mountain	1968	Yes
Prospect Hill	1953	Yes
Shaniko	1968	Yes
Swan Lake Point	1969	Partial
West Portland	1954	Partial
Wasco	1953	Yes

Table 6. Northwest - Southwest Intertie Sites Excluded from Study

Site	Reason Excluded from Study
Big Eddy Substation	Substation (Eligible)
Grizzly Substation	Substation (Not Eligible)
John Day Substation	Substation (Eligible)
Malin Substation	Substation (Not Eligible)
Odell Butte Microwave Radio Station	No remaining historic features
Portland	Moved
Wolf Mountain Microwave Radio Station	No remaining historic features

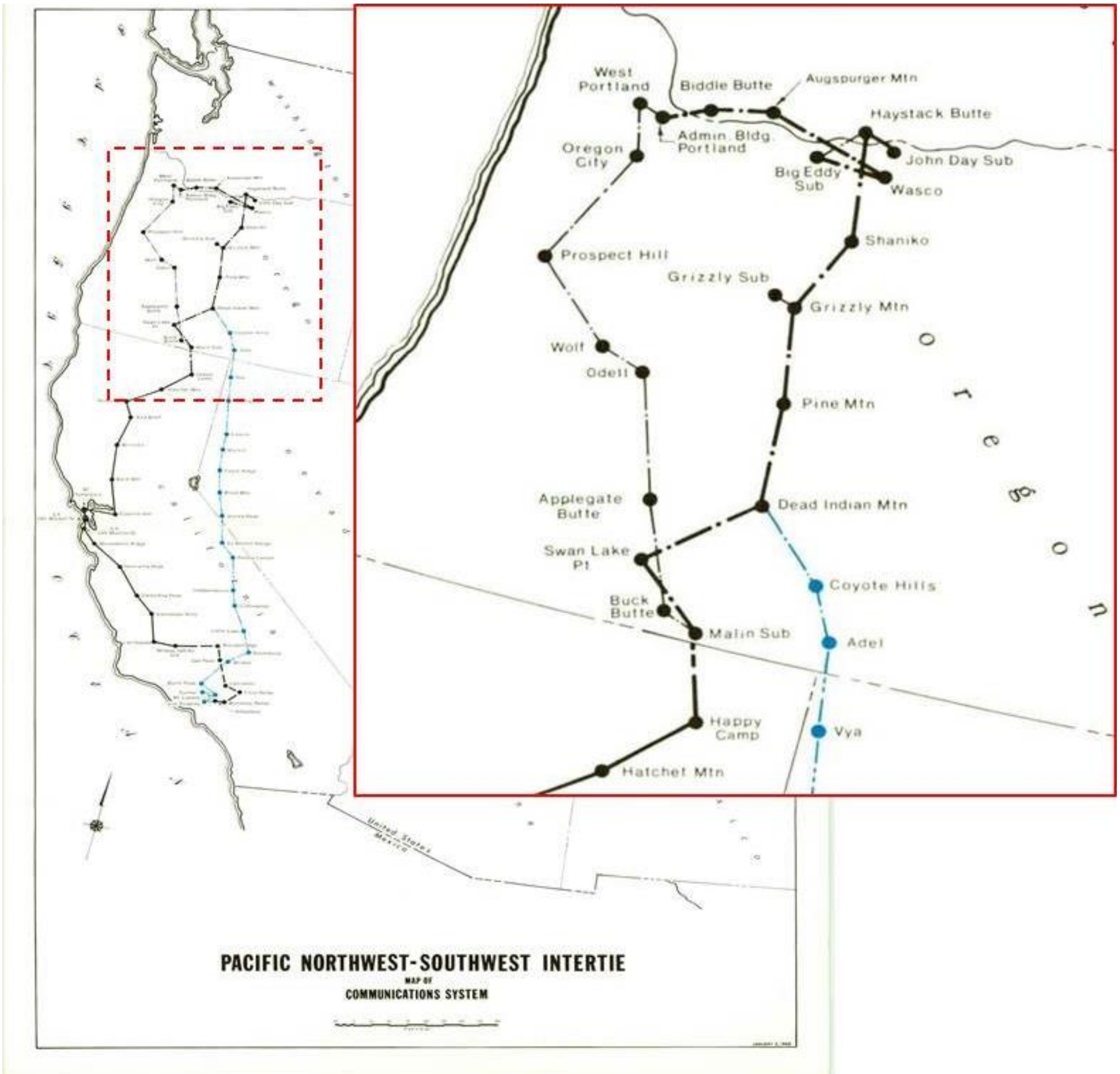


Figure 36. Pacific Northwest - Southwest Intertie map with inset showing BPA's microwave radio sites

4.1.4 BPA "Q" Microwave System Extension to Idaho and Montana (1968-1971)

BPA's "Q" Microwave System Extension provided communications to Idaho and Montana. Of the microwave radio stations associated with this extension, only three retain historic features, and two are passive repeaters; however, line-of-sight is retained.

Table 7. Historic "Q" System Extension Microwave Radio Station Sites

Microwave Radio Station	Built Date	Retains Line of Sight
Blacktail Peak	1968	Yes
Hungry Horse	1971	Yes
Teakean Butte	1971	Yes

Table 8. "Q" System Extension Sites Excluded from Study

Site	Reason Excluded from Study
Bald Mountain Microwave Radio Station	No remaining historic features
Conkelley Substation	Substation (Eligible)
Dworshak Dam	Not a BPA Resource
Dworshak Substation	Substation (Eligible)
Hot Springs Passive Repeater	Passive Repeater
Hot Springs Substation	Substation (Eligible)
Kalispell Substation	Substation (Not Eligible)
Libby Substation	No remaining historic features
Lines Creek Microwave Radio Station	No remaining historic features
Patrick's Knob Microwave Radio Station	No remaining historic features
Pomeroy Microwave Radio Station	No remaining historic features
Teakettle Passive Repeater	Passive Repeater

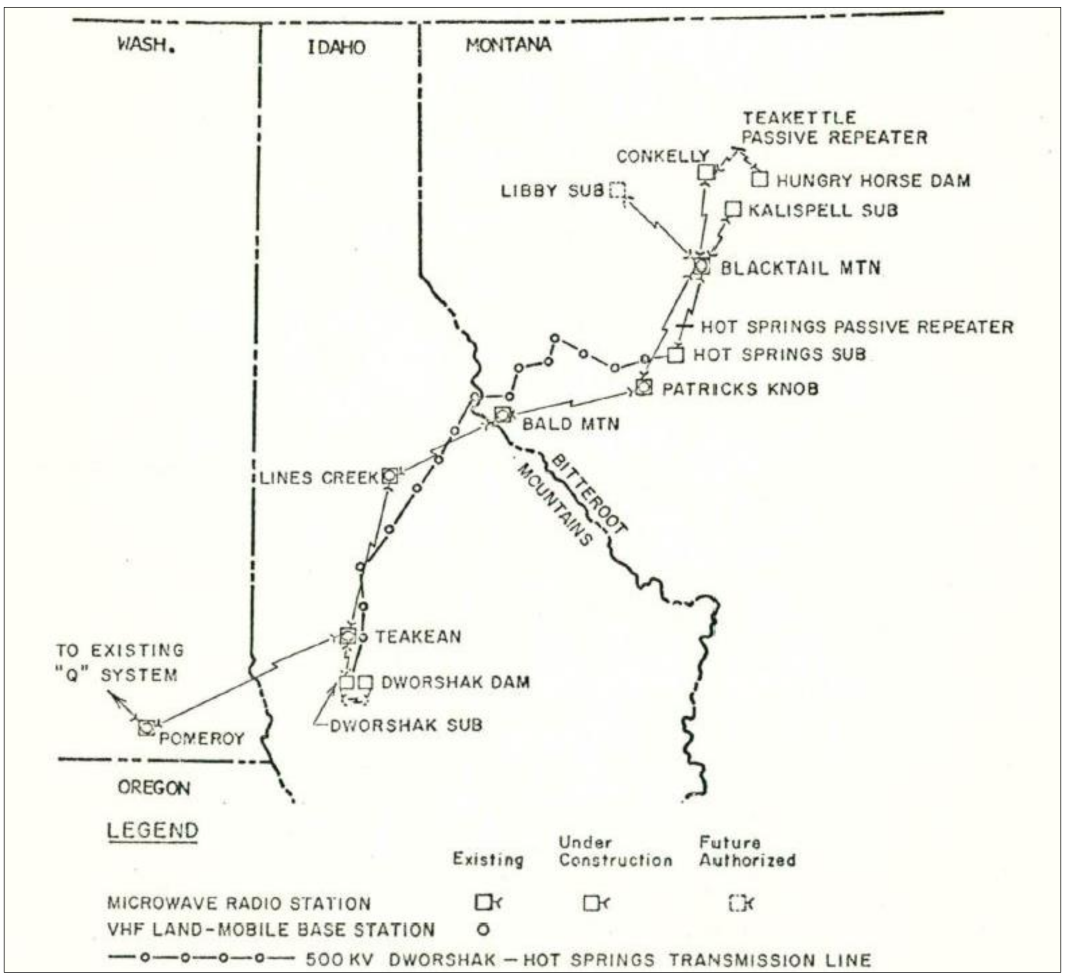


Figure 37. BPA's "Q" Microwave System Extension to Idaho and Montana

4.1.5 Sites Not Shown on Identified Historical System Maps and Diagrams

The historic microwave radio station sites in Table 9 were not shown on the identified historical system maps and diagrams. Historic line of sight was assessed by comparing the existing connections to historic built dates and current BPA operation of associated sites. All of the microwave radio stations shown below retain their historic line of sight.

Table 9. Historic Microwave Radio Station Sites Not Shown on Identified Historical Maps and Diagrams

Microwave Radio Station	Built Date	Likely Historic Function	Retains Line of Sight
Hall Ridge	1973	Spur branch from Marion Substation and Prospect Hill	Yes
Hampton Butte	1968	Spur branch from Pine Mountain	Yes
Kahlotus	1968	Connection between Kennewick and Pomeroy to provide branch spur to Little Goose Substations	Yes
Kenyon Mountain	1961	Connection between Fairview Substation and Scott Mountain	Yes
Lookout Mountain	1966	Connection between Custer and Intalco substations	Yes
Marys Peak	1961	Spur branch from Prospect Hill	Yes
Metaline	1968	Spur branch from Mt. Spokane connecting to Boundary Substation	Yes
Mt. Hebo	1958	Spur Branch from Prospect Hill	Yes
Scott Mountain	1959	Connection to Kenyon Mountain	Yes
Sunnyside	1956	Connection between Moxee and Grandview substations	Yes
Tacoma	1956	Connection between Capitol Peak, Tacoma Substation, Covington, Squak Mountain, and North Bend	Yes

4.2 Station Buildings

Most of BPA's building assets fall under specific design types developed as part of BPA's architecture program. In general, BPA's historic microwave radio station buildings follow a standardized architectural design, or were prefabricated by a manufacturer and installed on site. The following descriptions, historic photographs, and original drawings (when available) illustrate the stylistic characteristics and building design types found at BPA's microwave radio station sites.

4.2.1 Early Modern Concrete-Block Buildings (1950)

The earliest microwave radio stations, built in 1950, are constructed of concrete block, and display exterior features representative of an early Modern architectural style common during the 1950s. These style elements include an emphasis on clean lines, basic low-slung forms, rectangular plans, flat roofs, and cantilevered canopies.

Type 1600 1-Story Building

The Type 1600 design, used by BPA in 1950, is a single-story concrete-block building with a symmetrically located entrance. The entrance consists of a single two-panel metal door covered by a cantilevered flat canopy. The buildings were originally constructed with glass-block windows flanking the entrance; however, these have been infilled with concrete. The secondary elevations lack fenestration, but contain metal vents, vent hoods, and exhaust pipes. The flat roof is finished with built-up roofing material and includes an exhaust fan and an aluminum gutter system. Two Type 1600 buildings were constructed; one at the Chehalis Microwave/Radio Station (20-foot by 30-foot building) and the other at the Rainier Microwave/Radio Station (18-foot by 18-foot building).

Table 10. Type 1600 Buildings

Microwave Radio Station	Built Date	Site Retains Integrity
Chehalis	1950	Yes
Rainier	1950	Yes

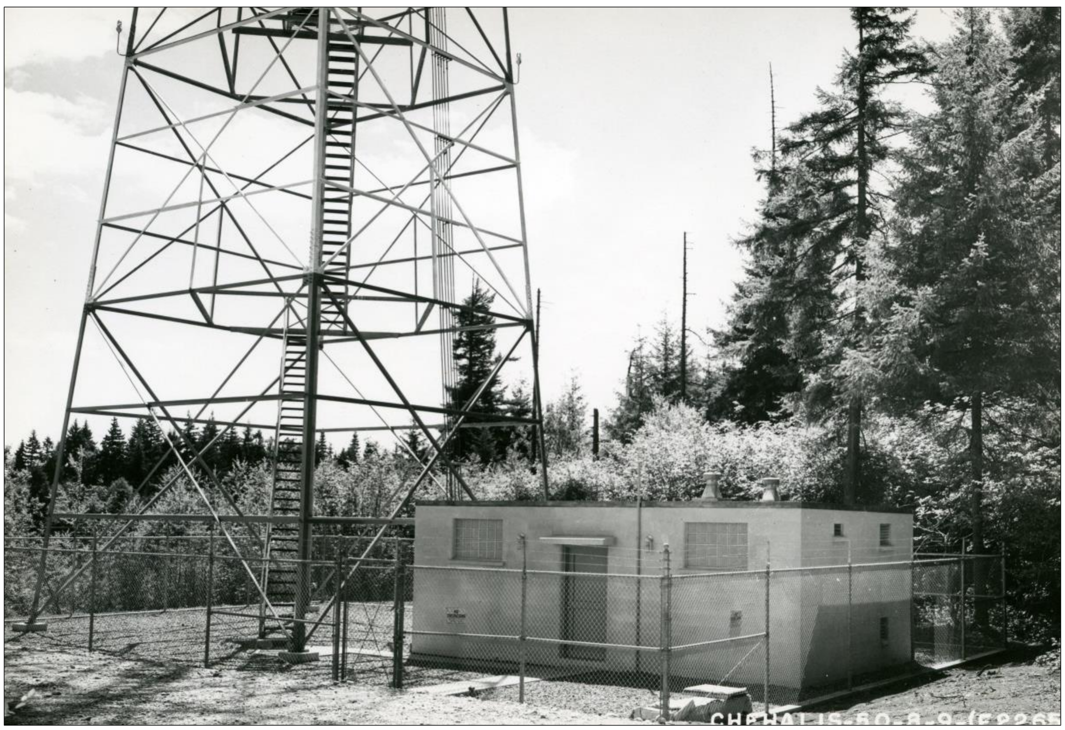


Figure 38. Type 1600 Chehalis Microwave Radio Station Building, 1950 (NARA:ChehalisMWNARABox17-008)

Type 1602 2-Story Building

The Type 1602 design, used by BPA in 1950, displays similar features to BPA’s Type 1600 buildings, but features two stories and measures 21 feet by 25 feet. The concrete-block building’s primary façade originally had two entrances and two glass-block windows on the ground floor, and a central single glass-block window at the second floor. One entry contains a two-panel metal door with a concrete cantilever canopy, and the other has a louvered door with a canopy to provide ventilation for the generator. The rear elevation had a central glass-block window at the second floor. BPA’s only example of this building type, at Squak Mountain Radio Station, is altered from its original design. The concrete-block exterior is covered with sprayedon insulation, and the windows are infilled with concrete and air conditioning equipment. The flat roof is finished with built-up roofing material and includes an aluminum gutter system.

Microwave Radio Station	Built Date	Site Retains Integrity
Squak Mountain	1950	Yes

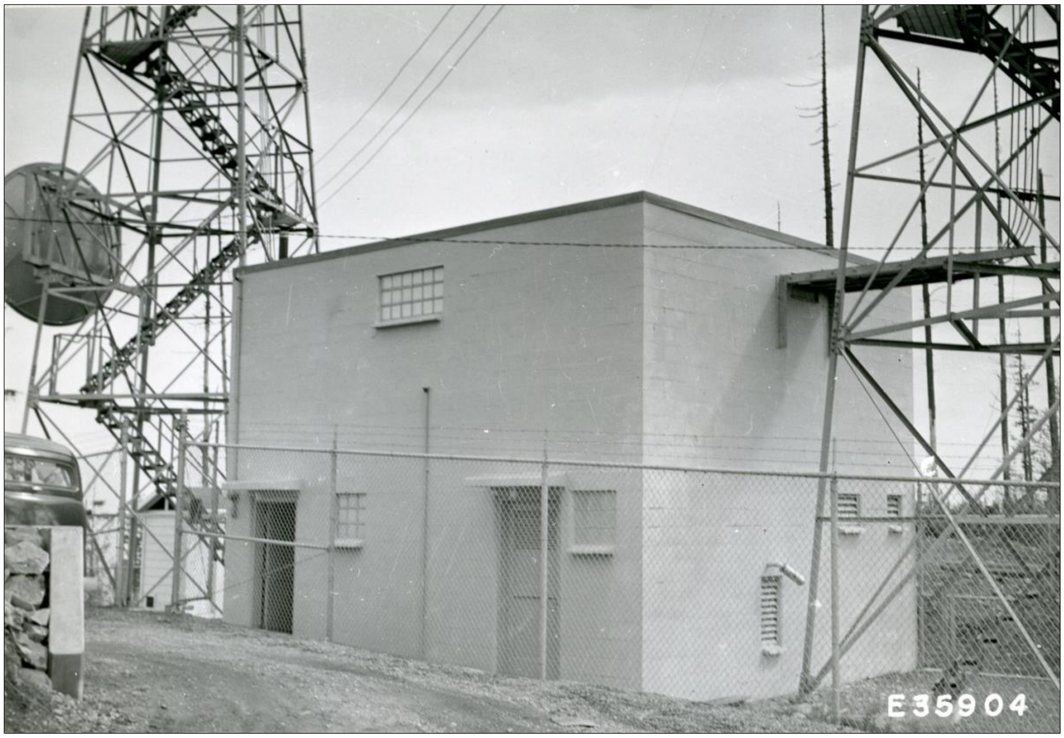


Figure 39. Type 1602 Squak Mountain Microwave Radio Station Building, 1951 (NARA:Squak2NARAbox27of52-014)

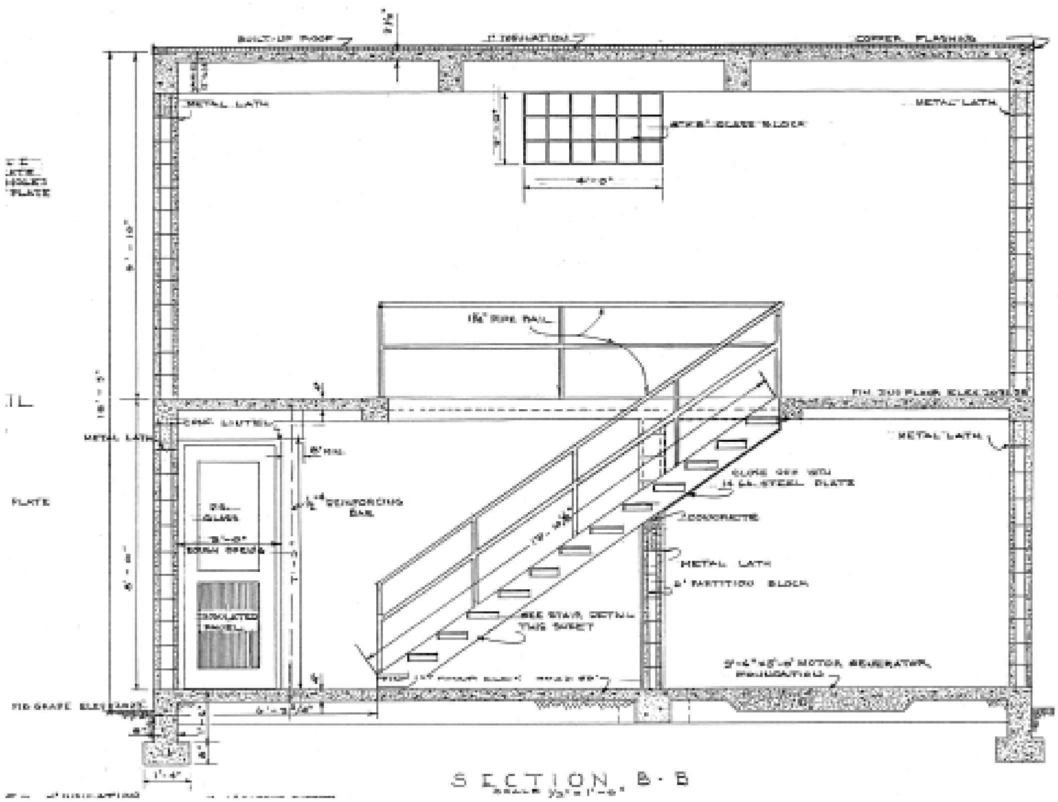


Figure 40. Section drawing for Type 1602 Squak Mountain Radio Station Building, 1949 (BPA)

4.2.2 Modern Concrete Buildings (1953-1956)

The largest trend in BPA's microwave radio buildings is concrete buildings that display features that reflect the Modern architectural style, such as an emphasis on clean lines, basic forms, rectangular shapes, and flat roofs.

Constructed between 1953 and 1956, these buildings are similar to, but smaller than, BPA's substation control houses built during the same time period. Architectural drawings show that the buildings featured walls of concrete block and/or poured concrete covered with a smooth concrete and plaster finish scored to display an approximate 3-foot- by 3-foot-square grid pattern. The nearly flat roof is finished with built-up roofing material and includes metal flashing. Most of the buildings have two asymmetrically located doors to provide separate entrances to the control and engine generator rooms, although some variations have one door. Concrete canopies supported by metal poles shelter the entries. The size and entrance placement sometimes varies, but the buildings otherwise share the same characteristics.

Common alterations include the infill of one of the doors, covering the exterior grid with a flat stucco finish, or installing new vents, air conditioning units, or other equipment on the exterior walls.

Type 1605 – 2 doors (left)

The Type 1605 design (Troutdale) measures 22 feet by 35 feet, and displays two doors at the left end of the primary façade.

Table 11. Type 1605 Buildings

Microwave Radio Station	Built Date	Site Retains Integrity

Troutdale	1953	Yes

Figure 41. Type 1605 Troutdale Microwave Radio Station Building, under construction, 1952 (NARA:TroutdaleMWNARAbox28of52-004)

Type 1606 – 2 doors (right)

Larger than the Type 1605 buildings, the Type 1606 design measures 23 feet by 40 feet, with two doors at the right end of the primary façade. This design type, built entirely in 1953, reflects the largest single group of station buildings. The Plum microwave radio station building is also identified as a Type 1606 design, even though the entrances are at the left.

Table 12. Type 1606 Buildings

Microwave Radio Station	Built Date	Site Retains Integrity
Beverly	1953	Yes
Davenport	1955	Yes
Del Rio	1953	No (Antenna tower replaced)
Foster Creek	1953	Yes
Plum	1953	Yes
Roosevelt	1953	Yes
Waterville	1953	Yes

Figure 42. Type 1606 Beverly Microwave Radio Station Building, 1954 (NARA:BeverlyMWNARAbox10-007)

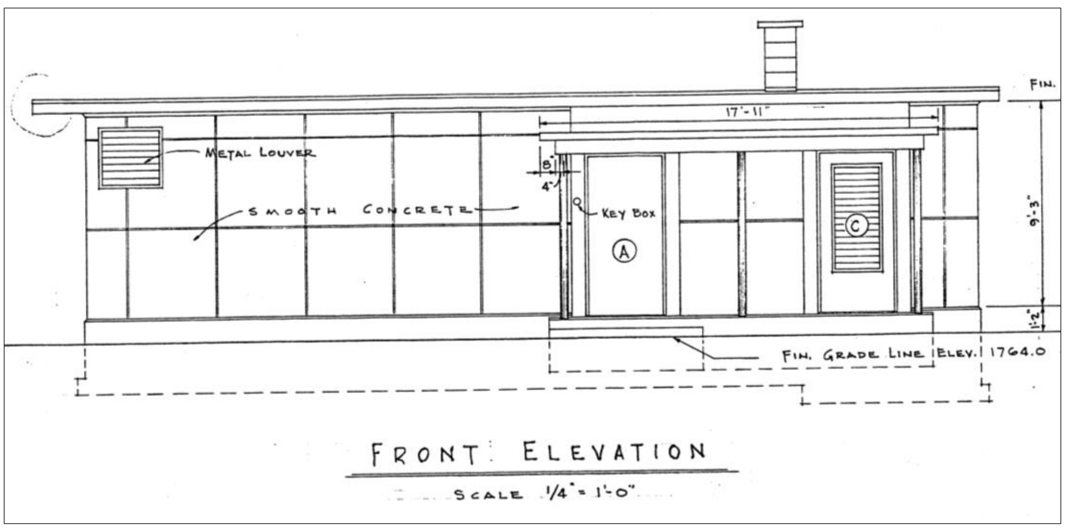


Figure 43. Elevation drawing for Type 1606 Roosevelt Microwave Radio Station, 1952 (BPA)

Type 1607 – 2 doors (left)

Essentially a mirror image of the Type 1606 building, but larger, the Type 1607 design measures 28 feet by 32 feet, with two doors at the left end of the primary façade. BPA's Type 1607 station buildings were constructed in 1953 and 1955.

Table 13. Type 1607 Buildings

Microwave Radio Station	Built Date	Site Retains Integrity
Grand Coulee	1953	Yes
Kennewick	1955	No (Antenna tower replaced)
Malaga	1955	Yes

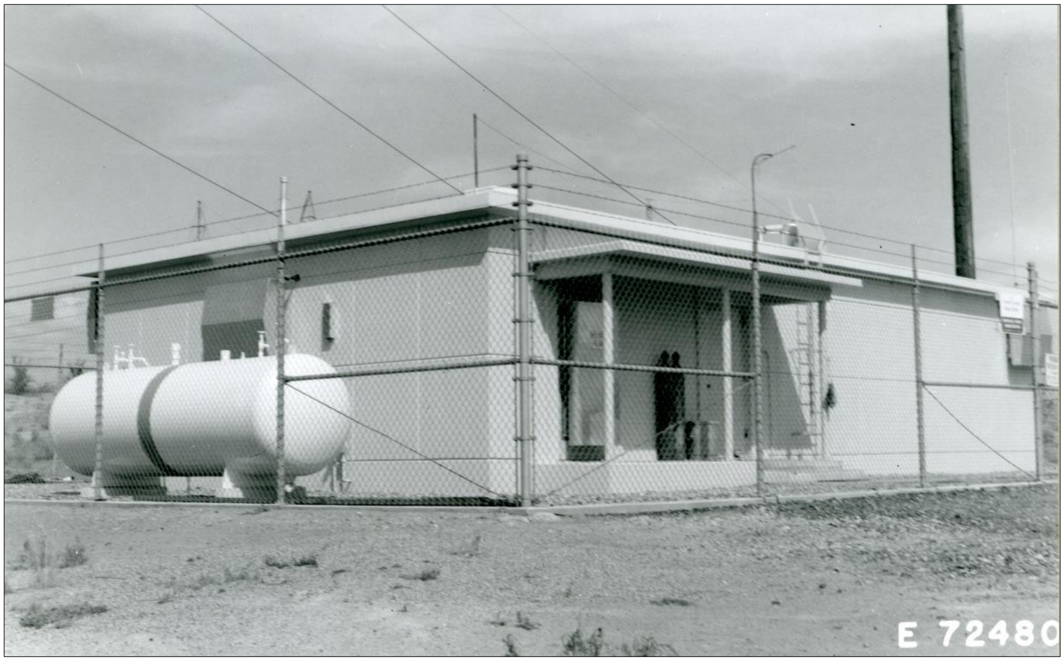


Figure 44. Type 1607 Grand Coulee Microwave Radio Station Building, 1954 (NARA:GrandCouleeMWNARAbox33-003)

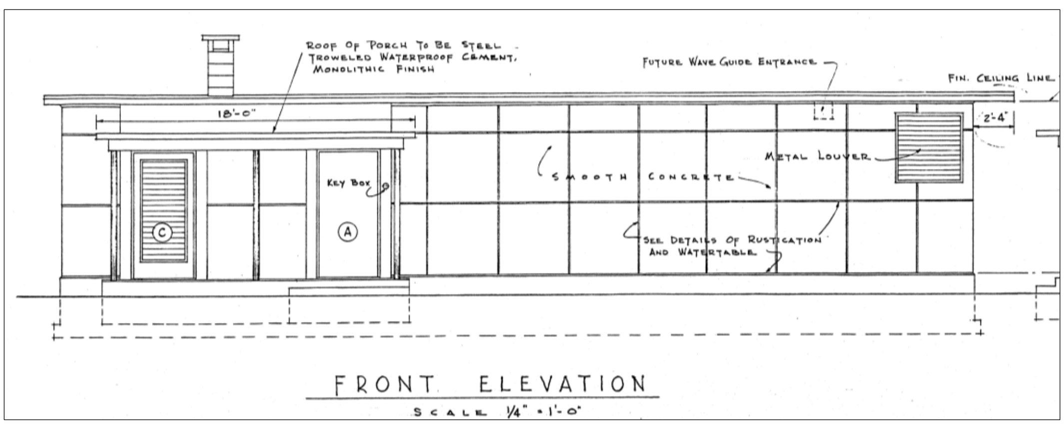


Figure 45. Elevation Drawing for Type 1607 Kennewick Microwave Radio Station, 1952 (BPA)

Type 1610 – 2 doors (right)

The Type 1610 design measures 28 feet by 32 feet, with two doors at the right end of the primary façade.

Table 14. Type 1610 Buildings

Microwave Radio Station	Built Date	Site Retains Integrity
Coburg	1954	No (Antenna tower replaced)
Prospect Hill	1953	No (Antenna tower replaced)
Teanaway	1954	Yes
West Portland	1954	No (Antenna tower replaced)

Figure 46. Type 1610 Teanaway Microwave Radio Station Building, 1964 (NARA:TeanawayNARAbox27of52-001)

Unknown Type – 2 doors (center)

The Tacoma Microwave/Radio Station building does not have a known design type, but the rectangular concrete building with a nearly flat roof measures 22 feet by 26 feet, with the two doors centrally located on the primary façade. Vent hoods cover the louvered vents.

Table 15. Unknown Design Type

Microwave Radio Station	Built Date	Site Retains Integrity
Tacoma	1956	No (Antenna tower replaced)

Figure 47. Tacoma Radio Station, 1956 (NARA:TacomaMWNARAbox27of52-007)

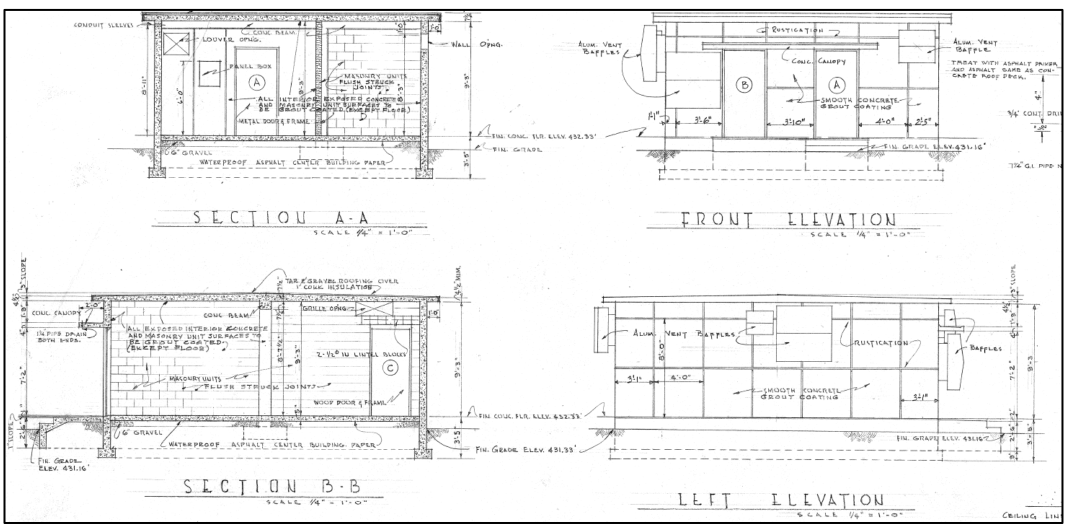


Figure 48. Elevation and drawings for Tacoma Microwave Radio Station Building, 1954 (BPA)

Types 1603, 1604, 1608 – Single Door Variations

Some of the buildings only have one asymmetrically located entrance with a metal door that leads to the communications and engine generator rooms. The Type 1603 design (Wasco) measures 27 feet by 42 feet, with a door on the left. The Type 1604 design (Bradford Island) measures 23 feet by 40 feet, with a door on the right. The Type 1608 design (Biddle Butte) measures 23 feet by 42 feet, with a door on the left.

Table 16. Type 1603, 1604, and 1608 Buildings

Microwave Radio Station	Built Date	Site Retains Integrity

Biddle Butte	1953	No (Antenna tower replaced)
Bradford Island	1953	No
Wasco	1953	Yes

Figure 49. Type 1603 Wasco Microwave Radio Station Building, 1954 (NARA:WascoMWNARAbox30of52-005)

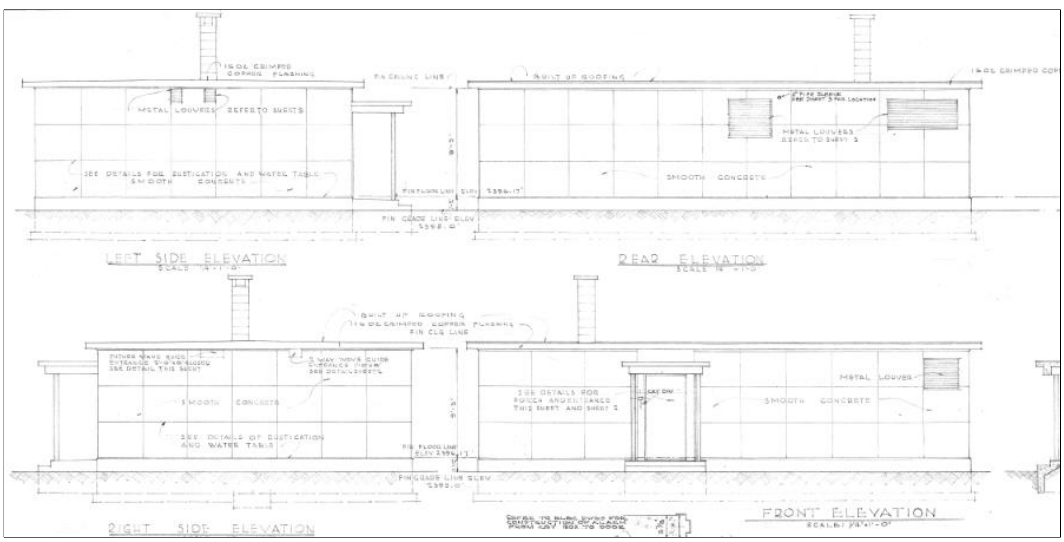


Figure 50. Elevation drawings for Type 1603 Wasco Microwave Radio Station Building, 1951 (BPA)

Figure 51. Type 1604 Bradford Island (formerly North Bonneville) Microwave Radio Station Building, 1960 (NARA:NorthBonn1MWNARAbox18of52-001)

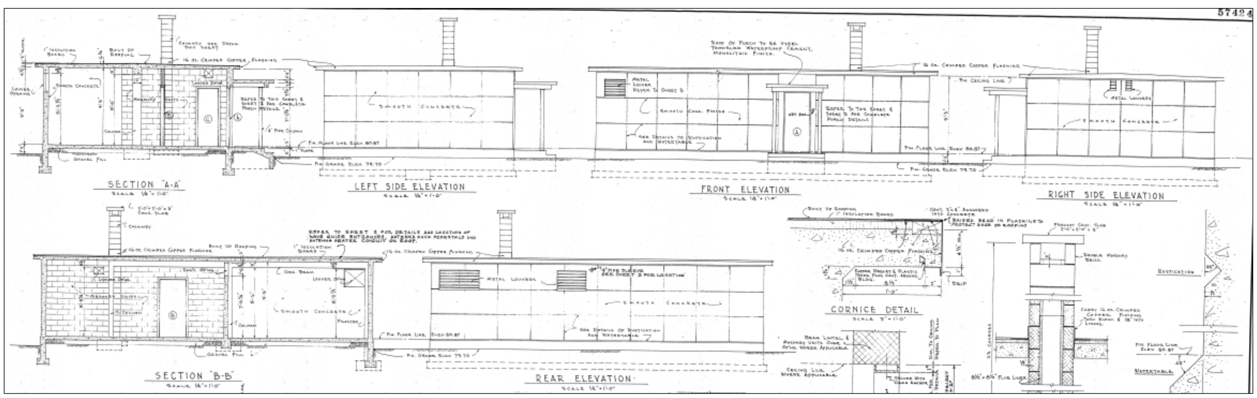


Figure 52. Elevation and section drawings for Type 1604 Bradford Island Microwave Radio Station Building, 1951 (BPA)

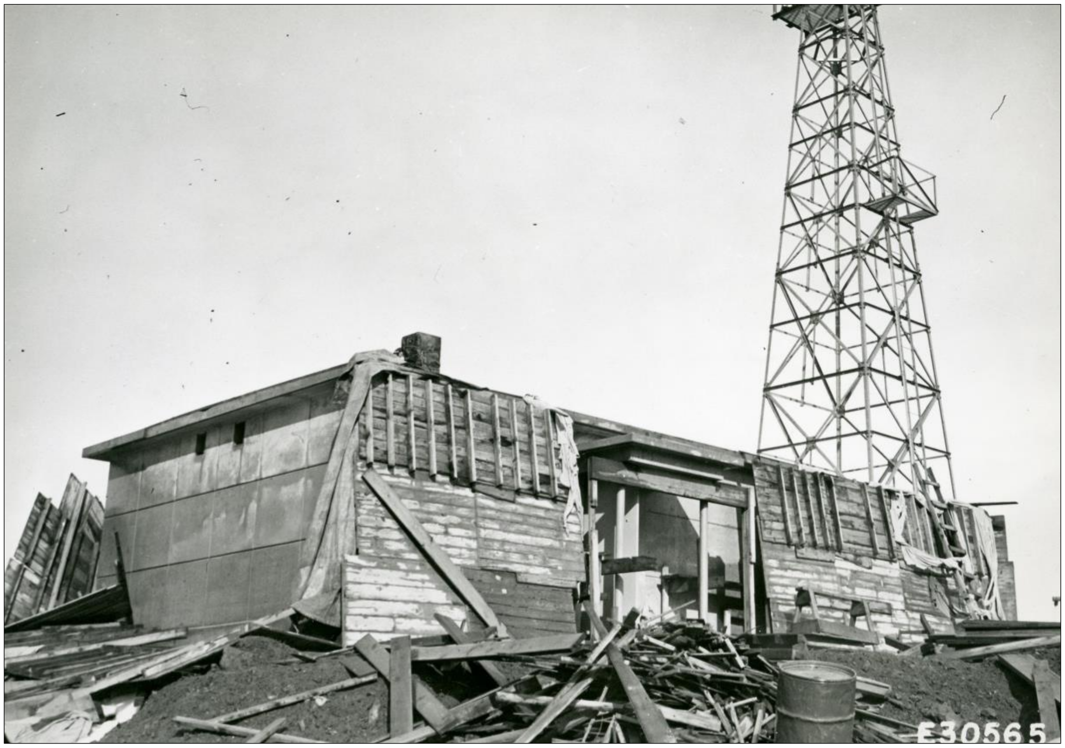


Figure 53. Type 1608 Biddle Butte Microwave Radio Station Building under Construction, 1952 (NARA:BiddleBNARAbox10-015)

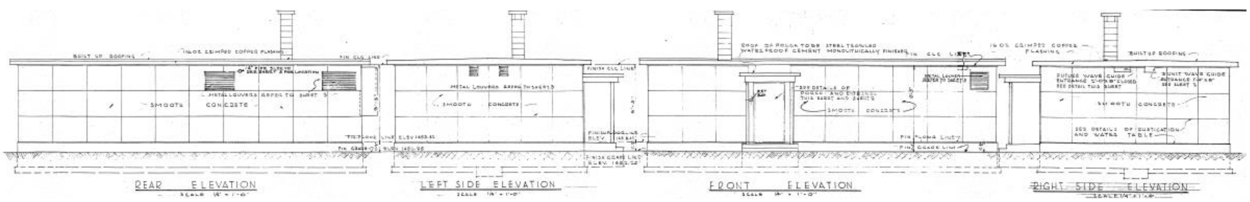


Figure 54. Elevation drawings for Type 1608 Biddle Butte Microwave Radio Station Building,1951 (BPA)

Type 1612 2-Story Building

BPA's Type 1612 two-story design was used at high-elevation sites constructed between 1953 and 1955 to allow entrance via the second floor, because the typical snow fall could prevent first-floor entry. Constructed of concrete block with a 24 foot by 24-foot plan, the main power panels and emergency power equipment was originally located on the first floor; and microwave and VHF mobile-radio equipment on the second floor. The primary façade consists of an asymmetrically located first- and second-floor entrance. The first-floor entrance includes two single door openings with flush-panel metal doors and a flat concrete canopy supported by three metal poles; or when modified, a storm entrance. The two doors lead to the separate communications and engine generator rooms. A metal access ladder is attached to the side of the canopy and provides access to the second-floor entrance, which includes a single-door opening.

Table 17. Type 1612 Buildings

Microwave Radio Station	Built Date	Site Retains Integrity
Augspurger Mountain	1953	Yes
Easton	1954	Yes
North Bend	1954	Yes
Mt. Spokane	1953	No (Antenna Tower Replaced)
Rockdale	1955	Yes

Figure 55. Type 1612 Rockdale Microwave Radio Station Building, 1954 (NARA:Rockdale2NARAbox21of52-008)

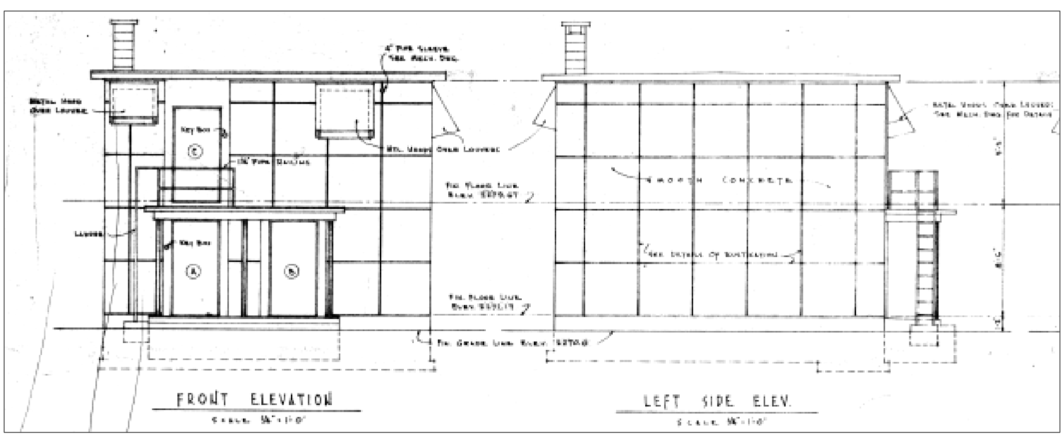


Figure 56. Elevation drawings for Type 1612 Rockdale Microwave Radio Station Building, 1953 (BPA)

4.2.3 Utilitarian Concrete Buildings (1961, 1968)

Utilitarian design elements applicable to BPA's concrete microwave radio station buildings include an emphasis on function over design, limited applied detail, one-story form, simple entrances, and lack of fenestration.

Type 1530

The Type 1530 design, used by BPA from 1959 to 1961, employs a concrete-block construction, but conveys a more utilitarian appearance than the early Modern style concrete-block buildings (Type 1600 and Type 1602). Measuring 16 feet by 20 feet, the rectangular building's primary façade consists of an asymmetrically located entrance with a metal door with an upper louvered panel (replaced at the Mary's Peak Microwave/Radio Station). The secondary elevations are absent of fenestration, but contain a metal vent, vent hood, and a wall-mounted air conditioning unit. The building has a nearly flat roof finished with built-up roofing material and includes metal coping and roof ventilators.

Table 18. Type 1530 Buildings

Microwave Radio Station	Built Date	Site Retains Integrity
Kenyon Mountain	1961	No (Antenna tower replaced)
Marys Peak	1961	Yes
Scott Mountain	1959	No (Antenna tower replaced)

Figure 57. Type 1530 Scott Mountain Microwave Radio Station Building, 1960 (NARA:ScottMtNARAbox25of52-005)

Shared Facility

The Blacktail Peak Microwave/Radio Station, built in 1968 by a non-BPA agency, shares its radio building with a local television service. The concrete-block building's primary façade consists of two entrances, originally designed to provide separate access points for BPA and a local television station that shared the building. The eastern entrance consists of a single-door opening with a single-lite flush-panel metal door and a concrete step in front of it. The western entrance consists of a block-shaped concrete masonry unit (CMU) vestibule with a double-door opening and a flat roof with metal coping and built-up roofing material. The entrance includes two flush-panel metal doors and a concrete step in front of it. A metal vent hood is positioned between the two entrances. Original windows on the southwestern elevation are infilled. An 8-foot by 16-foot metal-clad addition with a gable roof was constructed in 2002 for a PSC Battery Bank. Around this time, a 7-foot by 16-foot snow entry was also installed (BPA 2016).

Table 19. Shared Buildings

Microwave Radio Station	Built Date	Site Retains Integrity
Blacktail Peak	1968	Yes

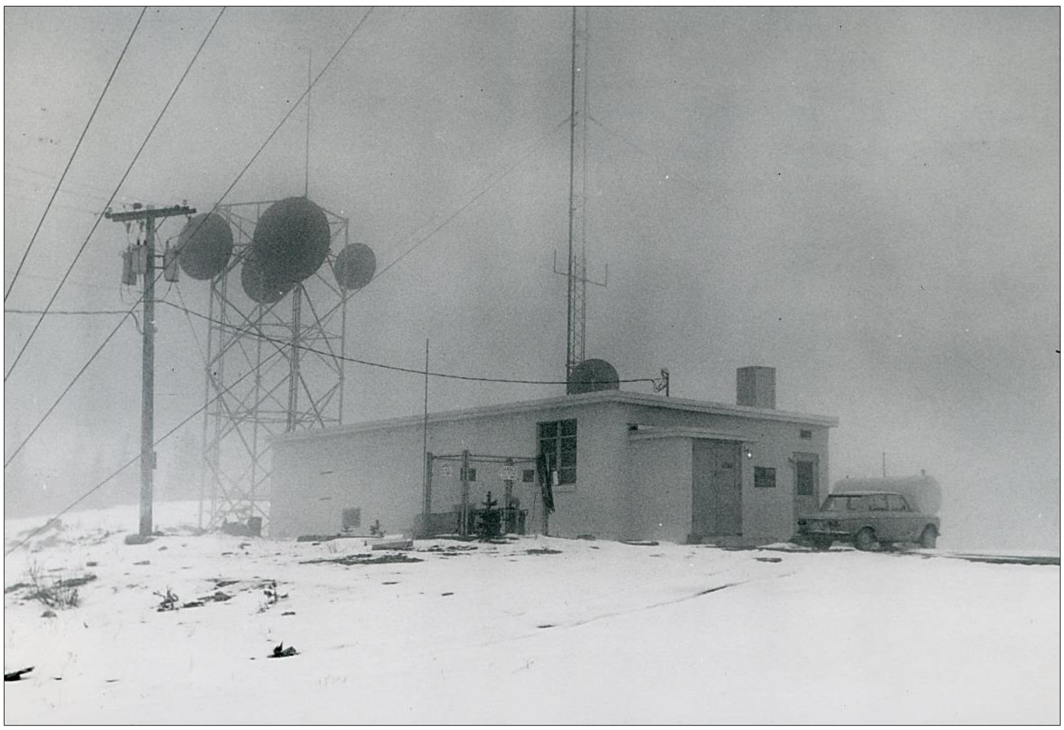


Figure 58. Shared Building at Blacktail Peak Microwave Radio Station, 1971 (BPA Library)

4.2.4 Utilitarian Aluminum Buildings (1950-1973)

Utilitarian aluminum microwave radio station buildings were built throughout the historic period and continue to be constructed today. The utilitarian design emphasizes function over design, limited applied detail, one-story form, and simple entrances. These small rectangular buildings are constructed of metal panels with a nearly flat roof finished with standing-seam metal panels and metal coping.

The buildings generally have two flush-metal doors on the front elevation, providing access to separate rooms for emergency power and radio equipment. They are similar in style and construction to the smallest and most utilitarian aluminum control houses built at BPA’s substations during the 1960s. The buildings lack fenestration, but the exterior may contain vents, vent hoods, exhaust pipes, wall-mounted heating, ventilation, and air conditioning units, utility boxes, or other equipment.

Although historical documentation states that some of BPA's earliest radio buildings were made of aluminum, none of these buildings dating to the late 1940s or early 1950s appear to remain.

Type 1502

The Type 1502 design built at the Sunnyside Microwave Radio Station in 1956 originally measured 10 feet by 16 feet, with two slightly asymmetrically located doors at the left end of the primary façade. This building has been altered with an addition that dominates the original building's scale and form.

Table 20. Type 1502 Buildings

Microwave Radio Station	Built Date	Site Retains Integrity
Sunnyside	1956	No (Antenna tower replaced)

Figure 59. Type 1502 Sunnyside Microwave Radio Station Building, 1956 (NARA:Sunnyside4X-001)

Type 1503

The Type 1503 design measures 10 feet by 18 feet, with two asymmetrically located entrances at the left end of the primary façade. The Goodwin Peak and Noti buildings were constructed in 1953 and 1954, respectively; while the Hampton Butte building was built in 1968. Only the Hampton Butte building retains the two entrances, while the others have been modified and only retain one entrance.

Table 21. Type 1503 Buildings

Microwave Radio Station	Built Date	Site Retains Integrity
Goodwin Peak	1953	Yes
Hampton Butte	1968	No (Antenna tower replaced)
Noti	1954	Yes

Figure 60. Type 1503 Noti Microwave Radio Station Building, 1956 (NARA:NotiMWNARAbox19of52-003)

Type 1504

The Type 1504 aluminum building design built between 1953 and 1958 measures 10 feet by 20 feet but is otherwise identical to the Type 1502 and 1503 designs. The Mt. Hebo building retains the two entrances, while the Leneve building has been modified and only retains one entrance.

Table 22. Type 1504 Buildings

Microwave Radio Station	Built Date	Site Retains Integrity
Leneve	1953	Yes
Mt. Hebo	1958	No (Antenna tower replaced)

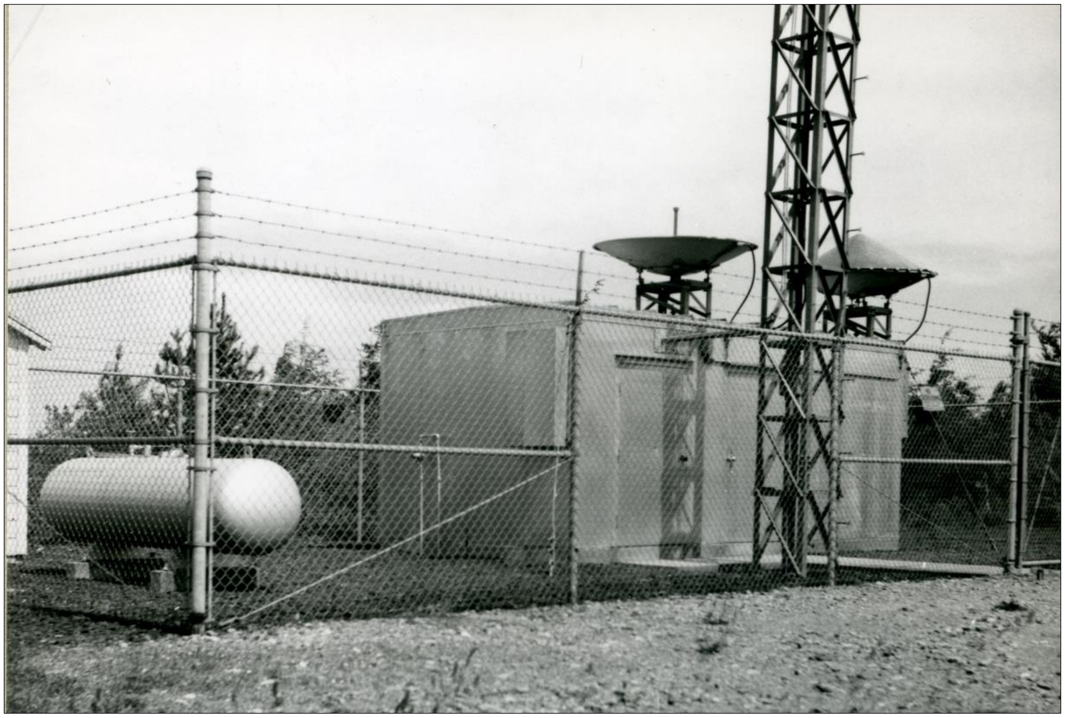


Figure 61. Type 1504 Leneve Microwave Radio Station Building, 1963 (NARA:LeneveNARAbox15of52-002)

Type 1136-1

The Type 1136-1 aluminum building design is reflected only at the Hall Ridge microwave radio station. Constructed in 1973, the building measures 6 feet by 10 feet, and contains one door.

Table 23. Type 1136-1 Buildings

Microwave Radio Station	Built Date	Site Retains Integrity
Hall Ridge	1973	Yes

Figure 62. Type 1136-1 Hall Ridge Microwave Radio Station Building, 2016 (BPA)

Type 190

The Type 190 design used for microwave radio station buildings is different than the Type 190 design commonly used for substation control houses. The Ross Complex displays BPA's only Type 190 design at a microwave radio station site. Constructed in 1950, the building measures 8 feet by 20 feet, and contains a single flush-metal door.

Table 24. Type 190 Microwave Radio Station Buildings

Microwave Radio Station	Built Date	Site Retains Integrity
Ross	1950	No (Antenna tower replaced)

Figure 63. Type 190 Ross Microwave Radio Station Building, ca. 2016 (VFA)

4.2.5 Fiberglass "Armadillo" Buildings (1968-1971)

From 1968 to 1971, BPA installed prefabricated insulated metal and fiberglass radio buildings manufactured by Armadillo Manufacturing Company. The rectangular buildings with flat roofs range in size from 10 feet by 20 feet to 10 feet by 28 feet and were constructed specifically for heavy snow and wind loading. The buildings include a thermostatically controlled refrigeration-type air conditioner with the capability to maintain an inside temperature of 85 degrees Fahrenheit, with an outside temperature of 100 degrees. All outside air entering the building is filtered, and the air conditioner snow shield prevents snow and ice from blocking the air intake grill. Characteristic of the buildings is an engine intake snorkel and door snow shield at sites that typically receive significant snowfall (Myers 1971:3). The Hungry Horse Microwave/Radio Station building, constructed in 1971, is the only fiberglass building that does not have the snorkel.

Most of BPA's Armadillo buildings have been replaced by new radio control buildings, even when the original building remains onsite.

Table 25. Fiberglass "Armadillo" Buildings

Microwave Radio Station	Built Date	Site Retains Integrity
Applegate Butte	1968	No (New station building)
Buck Butte	1968	No (New station building, antenna tower replaced)
Grizzly Mountain	1968	No (New station building)
Haystack Butte	1968	Yes

Microwave Radio Station	Built Date	Site Retains Integrity
Hungry Horse	1971	No (Previously determined)
Indian Mountain	1968	No (New station building)
Kahlotus	1968	No (New station building)
Metaline	1968	No (New station building)
Pine Mountain	1968	No (New station building)
Shaniko	1968	No (New station building)
Swan Lake Point	1969	No (New station building)
Teakean Butte	1971	No (New station building)

Figure 64. Armadillo Manufacturing Co. Haystack Microwave Radio Station Building, 1968 (NARA:HaystackNARAbox13of52-002)

4.2.6 Other/Unknown Aluminum Building Types (1966)

Two aluminum buildings, both constructed at Lookout Mountain Microwave Radio Station, are not associated with identified design types. These small utilitarian buildings have nearly flat roofs; are clad in vertical corrugated metal siding; and have a single door on the primary façade. Some of the evaluated microwave radio station sites contain aluminum engine generator buildings, but only one was built during the period of significance.

The Lookout Mountain station building, constructed in 1966, measures 8 feet by 16 feet. It contains a metal structure with an aluminum exterior. The building is clad in corrugated metal siding and has a single door near the right end of the primary façade.

The Lookout Mountain engine generator building, also constructed in 1966, is clad in corrugated metal siding with a nearly flat roof finished with standing-seam sheet-metal roofing. The building lacks windows but has a single door on the primary façade next to a large vent hood.

Table 26. Other/Unknown Buildings Types

Microwave Radio Station	Built Date	Site Retains Integrity
Lookout Mountain	1966	No (Antenna tower replaced)

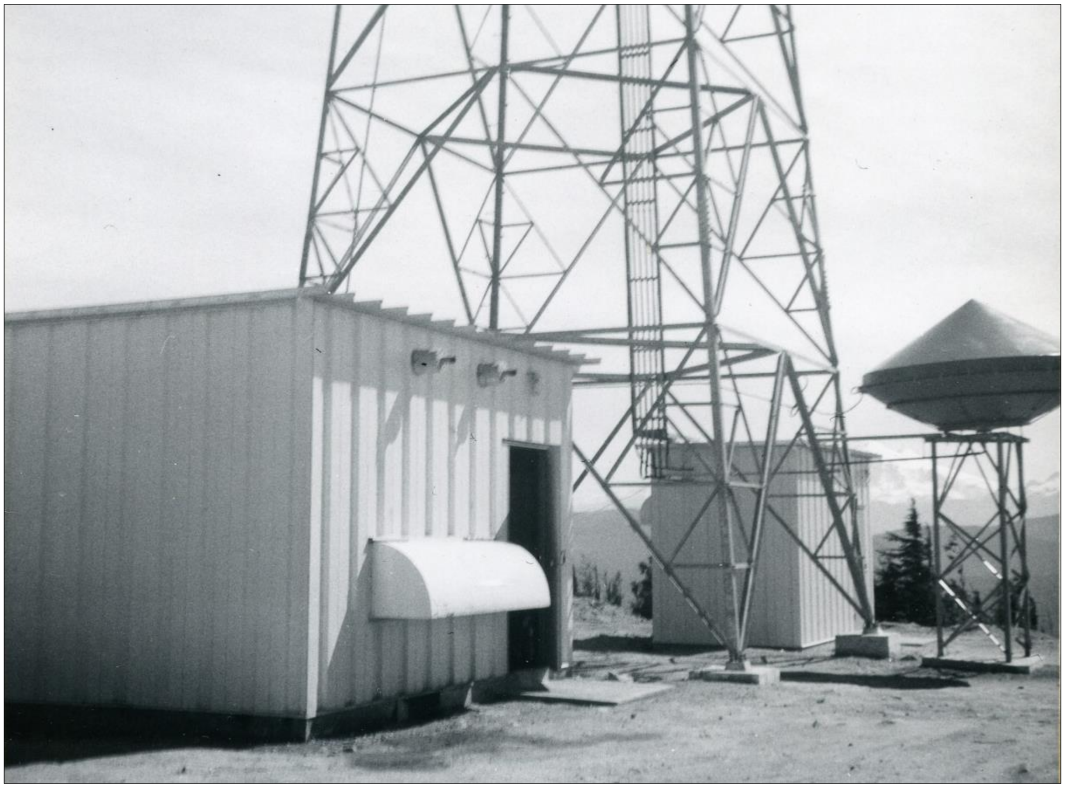


Figure 65. Lookout Mountain Microwave Radio Station, Engine Generator Building on left, Station Building on right, 1966 (BPA Library)

4.3 Antenna Towers

BPA's first microwave radio link, between Ross and Snohomish, transmitted and received microwave impulses using parabolic antennas measuring 6 to 10 feet in diameter. They were configured directionally, and at elevations to provide line-of-sight transmission (BPA 1950:4). VHF whip antennas were also used for mobile-unit communications. In exceptional cases, like the Easton radio station, BPA mounted microwave antennas on a transmission line tower instead of erecting a dedicated antenna tower (Strong et al. 1957:660).

BPA initially mounted the antennas on standard prefabricated U.S. Forest Service lookout towers measuring 50 to 150 feet high. The self-supporting steel towers were designed to bend less than one degree in 100-mph winds, and withstand 0.5 inch of ice. The original tower stairways were soon replaced with ladders equipped with protective guards (Stevens and Stringfield 1950:12; *Oregonian* 1949).

By 1957, BPA's radio station network included 33 standard, 8 guyed, 4 specially designed, and 3 heavy-duty antenna towers (Strong et al. 1957:661). As the towers became more specialized, they were either monopole (wood or metal) construction, with heights ranging up to 80 feet, or three- and four-leg lattice steel construction, ranging up to 175 feet in height. Many towers fell within the 25- to 30-foot range, which was often sufficient to keep the antennas above nearby obstructions (BPA 1977:V-26).

4.3.1 Three-leg Steel Lattice (1953-1973)

BPA erected three-leg steel lattice towers throughout the historic period, with the largest concentration built in the late 1960s.Three-leg steel lattice towers are composed of triangular steel structures positioned on three concrete footings. Steel poles join to form each corner of the structure and are interconnected by repetitive horizontal and diagonal steel cross braces that form the lattice framework. Multiple antennas can be attached to these structures at varying heights and angles to optimize communications and ensure line of sight for microwave antennas. Steel access ladders are typically attached to one side of the structure.

Table 27. Microwave Radio Stations with Three-Leg Steel Lattice Towers

Microwave Radio Station	Built Date	Site Retains Integrity
Applegate Butte	1968	No (New station building)
Buck Butte	1968	No (New stationbuilding, antenna tower replaced)
Coburg	1954	No (Antenna tower replaced)
Grizzly Mountain	1968	No (New station building)
Hall Ridge	1973	Yes
Hampton Butte	1968	No (Antenna tower replaced)
Haystack Butte	1968	Yes
Indian Mountain	1968	No (New station building)
Mt. Hebo	1958	No (Antenna tower replaced)
Pine Mountain	1968	No (New station building)
Prospect Hill	1953	No (Antenna tower replaced)
Shaniko	1968	No (New station building)
Swan Lake Point	1969	No (New station building)

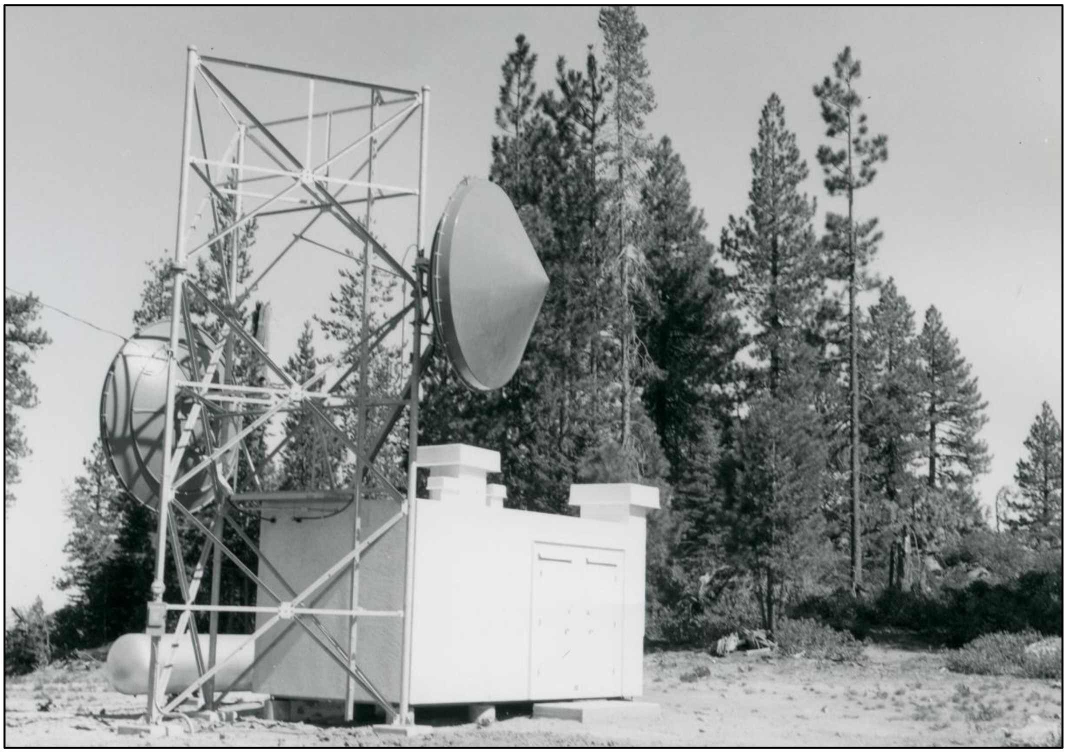


Figure 66. Three-leg Antenna Tower at Applegate Butte Microwave Radio Station, 1967 (NARA:ApplegateX-001)

4.3.2 Four-leg Steel Lattice (1950-1973)

BPA erected four-leg steel lattice towers at microwave radio stations throughout the historic period, making it the most prevalent antenna tower type. Four-leg steel lattice towers are steel structures with square bases positioned on four concrete footings. In general, the structures taper towards the top to provide a broader base for support. Steel poles join to form each corner of the structure and are interconnected by repetitive horizontal and diagonal steel cross braces that form the lattice framework. Multiple antennas can be attached to these structures at varying heights and angles to optimize communications and ensure line-of-sight for microwave antennas. Steel access ladders are typically attached to one side of the structure.

Table 28. Microwave Radio Stations with Four-leg Steel Lattice Towers

Microwave Radio Station	Built Date	Site Retains Integrity
Augspurger Mountain	1953	Yes
Biddle Butte	1953	No (Antenna tower replaced)
Blacktail Peak	1968	Yes
Davenport	1955	Yes
Del Rio	1953	No (Antenna tower replaced)
Easton	1954	Yes
Foster Creek	1953	Yes
Goodwin Peak	1953	Yes
Hungry Horse	1971	No (Previously determined)
Indian Mountain	1968	No (New station building)
Kahlotus	1968	No (New station building)

Microwave Radio Station	Built Date	Site Retains Integrity
Kennewick	1955	No (Antenna tower replaced)
Kenyon Mountain	1961	No (Antenna tower replaced)
Lookout Mountain	1966	No (Antenna tower replaced)
Malaga	1955	Yes
Metaline	1968	No (New station building)
North Bend	1954	Yes
Noti	1954	Yes
Olympia	1951	No (Microwave equipment removed)
Plum	1953	Yes
Rainier	1950	Yes
Rockdale	1955	Yes
Roosevelt	1953	Yes
Ross	1950	No (Antenna tower replaced)
Scott Mountain	1959	No (Antenna tower replaced)
Squak Mountain	1950	Yes
Sunnyside	1956	No (Antenna tower replaced)
Tacoma	1956	No (Antenna tower replaced)
Teakean Butte	1971	No (New station building)
Teanaway	1954	Yes
Troutdale	1953	Yes
Wasco	1953	Yes
Waterville	1953	Yes
West Portland	1954	No (Antenna tower replaced)

Figure 67. Four-leg Steel Lattice Antenna Tower at Wasco Microwave Radio Station, 1953 (BPA Library)

4.3.3 Four-leg Steel Lattice with Internal Staircase (1950-1953)

Four-leg steel lattice towers with internal staircases are generally the tallest and widest towers in the BPA radio network. Nearly identical to other four-leg steel-lattice towers in terms of materials and design, these structures feature a series of staircases and platforms within the framework of the tower to provide access at varying heights. Multiple antennas can be attached at varying heights and angles to optimize communications and ensure line of sight for microwave antennas. The towers were utilized in environments that required additional strength due to wind loads or additional height to reach the line-of-sight requirement.

Table 29. Microwave Radio Stations with Four-leg Steel Lattice Towers and Staircase

Microwave Radio Station	Built Date	Site Retains Integrity
Beverly	1953	Yes
Chehalis	1950	Yes

Figure 68. Four-leg Steel Lattice Antenna Tower with Internal Staircase at Rainier Microwave Radio Station, 1951 (NARA:Rainier4X-002)

4.3.4 Steel Lattice with Guyed Wires (1953, 1968)

BPA used steel lattice towers with guy wires to provide diagonal tension support and extra stability to withstand lateral loads from high winds. Steel lattice towers with guy wires consist of tall and narrow lattice steel structures with square bases positioned on concrete foundations and supported by a series of diagonal tension cables (guy wires) securing the tower to the ground. Steel poles join to form each corner of the structure and are interconnected by repetitive horizontal and diagonal steel cross braces that form the lattice framework. Multiple antennas can be attached to these structures at varying heights and angles to optimize communications and ensure line of sight for microwave antennas.

Table 30. Microwave Radio Stations with Steel Lattice Towers with Guy Wires

Microwave Radio Station	Built Date	Site Retains Integrity
Blacktail Peak	1968	Yes
Leneve	1953	No (Microwave equipment removed)

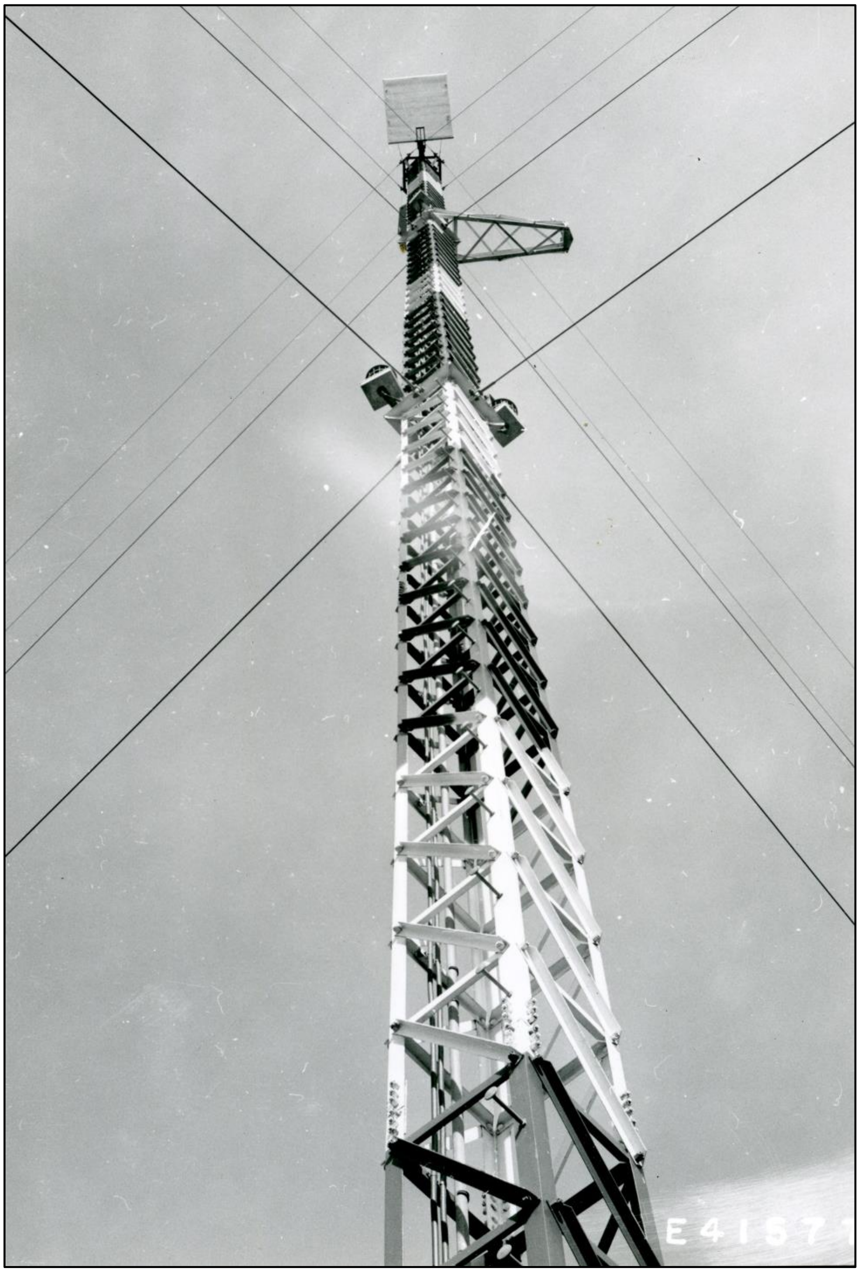


Figure 69. Steel Lattice Antenna Tower with Guyed Wires at Leneve Microwave Radio Station, 1956 (NARA:LeneveNARAbox15of52-009)

4.3.5 Wood Monopole (1961)

Wood monopole towers consist of single wood poles set into the ground to secure their position. Wood poles used for BPA transmission line structures were typically positioned to a depth of

10 percent of its aboveground height plus 2 feet (BPA Drawings 1946). Multiple antennas can be attached to these structures at varying heights and angles to optimize communications and ensure line of sight for microwave antennas. Only one microwave radio station retains its wood monopole tower.

Table 31. Microwave Radio Stations with a Wood Monopole Tower

Microwave Radio Station	Built Date	Site Retains Integrity
Marys Peak	1961	Yes

Figure 70. Wood Monopole Antenna Tower at Kenyon Mountain Microwave Radio Station, 1960 (NARA:KenyonNARAbox14of52-001)

4.3.6 Roof-Mounted Antennas (1953)

Two microwave radio stations historically used roof-mounted antennas. The antennas at the Bradford Island Microwave Radio Station are mounted to a transmission tower that crosses the site, and the antennas at the Grand Coulee Microwave Radio Station are mounted to the station building roof.

Table 32. Microwave Radio Stations with Roof-Mounted Antennas

Microwave Radio Station	Built Date	Site Retains Integrity
Bradford Island	1953	No
Grand Coulee	1953	Yes

Figure 71. Roof-Mounted Antenna on Grand Coulee Microwave Radio Station Building, 1964 (NARA:GrandCouleeMWNARAbox33-002)

4.4 Fuel Distribution Tanks

Due to the isolated nature of several of the microwave radio stations, some contain fuel distribution tanks to power the generators and station equipment. Many have been removed or replaced, but seven tanks installed during the historic period remain. The steel tanks are considered secondary features in the sites.

Table 33. Microwave Radio Stations with Fuel Tanks Installed during the Historic Period

Microwave Radio Station	Built Date	Site Retains Integrity
Augspurger Mountain	1953	Yes
Chehalis	1950	Yes
Coburg	1954	No (Antenna tower replaced)
Leneve	1953	No (Microwave equipment removed)
Marys Peak	1961	Yes
Scott Mountain	1959	No (Antenna tower replaced)
Tacoma	1956	No (Antenna tower replaced)

Figure 72. Propane Fuel Distribution Tank at Augspurger Mountain Microwave Radio Station, 1952 (NARA:AuspurgerMW1NARAbox7-007)

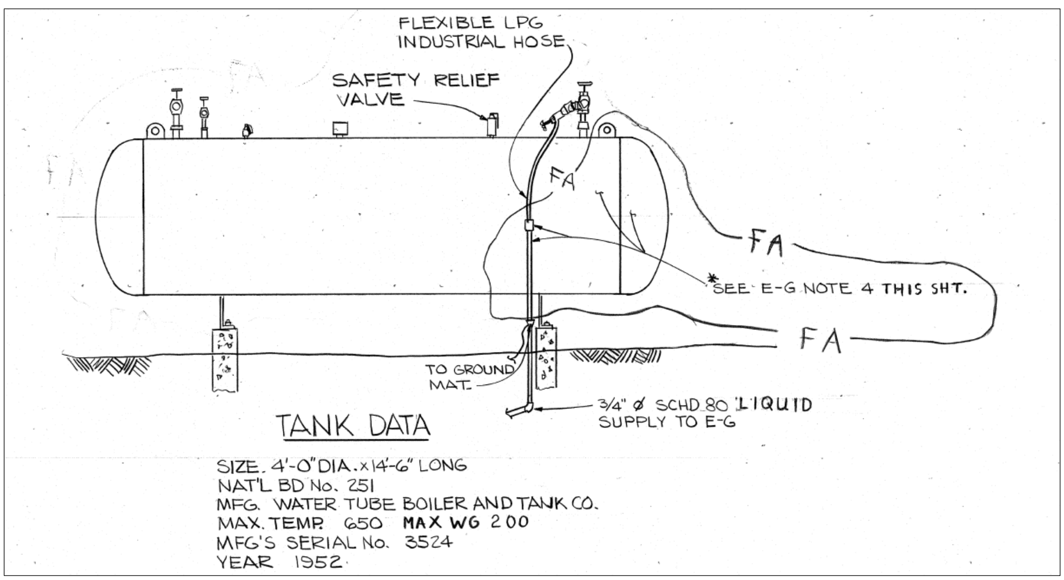


Figure 73. Tank Drawing, Teanaway Microwave/Radio Station, redrawn in 1956 from 1953 original drawing (BPA)

4.5 Passive Repeaters

Passive repeaters are aluminum-panel reflectors mounted on steel or wood structures that help close microwave links where obstacles in the signal path block direct line-of-sight transmission. Passive repeaters do not require proximity to a power source for operations, such as a transmission line or generator, and there are generally no buildings at these sites. Passive repeater sites typically include about 625 square feet, and may encompass up to 2,500 square feet. Passive repeaters required infrequent maintenance, approximately every 2 years, thereby reducing the degree of accessibility required, and making access roads generally unnecessary (BPA 1977:V-26-V29).

BPA owns numerous passive repeaters. Due to their limited features and geographic distance from the microwave radio station sites, passive repeaters are not considered historic resources, and were not evaluated as contributing or non-contributing features to the sites.

BPA records indicate that only one passive repeater site, Olympia, contains a building asset constructed during the historic period. Historic newspapers and photographs indicate the station was originally constructed as a microwave radio station. The Olympia Microwave Radio Station was converted to a passive repeater site circa 1970-1971. The parabolic antennas atop the antenna tower were replaced with a passive reflector (BPA Personal Communication). Built in 1951, the 8-foot by 16-foot aluminum panel building has a symmetrically located flush-metal door and is similar to the Type 190 design employed for substation control houses and the Ross Complex microwave radio building. The building currently houses electrical power equipment associated with the Federal Aviation Administration-mandated tower lights attached to the antenna tower.

Table 34. Passive Repeaters

Microwave Radio Station	Built Date	Site Retains Integrity
Olympia	1951/c.1971	No (Microwave equipment removed)

Figure 74. Olympia Microwave Radio Station Building, ca. 2016 (VFA)

5. Historic Significance

BPA's microwave/radio stations are potentially eligible for the NRHP under Criterion A in the areas of Communications and Community Planning and Development. Microwave radio stations are significant for their association with the design, construction, and operation of the BPA transmission system in the Northwest between 1938 and 1974 (Kramer 2012). The period of significance for each site begins with its initial date of construction, and ends in 1974, BPA's period of significance for historic resources outlined in the MPDF. Significant historic themes include:

- Initial establishment using Philco and Federal Telecommunications Laboratories equipment in early 1950s.
- Enhanced integration with the Northwest Power Pool members.
- Environmental adaptations to function in harsh and isolated conditions.
- Southwest Oregon system installed in 1953.
- System upgrades using Lenkurt equipment in 1963.
- Pacific Northwest – Southwest Intertie connection in 1968.
- Service extensions to Idaho and Montana regions 1968-1971.
- Applications of BPA's "Beautility" principles in late 1960s and early 1970s.
- System monitoring and support to computer-based Dittmer control center (1974).

BPA pioneered the Pacific Northwest's first large-scale microwave radio communication system, which greatly enhanced the power grid's capacity, reliability, and cost-effectiveness; and facilitated operations for the region's interconnected power pool. The new system reflected advances in microwave-based technology gained during the WWII era.

As BPA expanded its communication system during the 1950s and 1960s, "[T]he result was what amounted to a secondary region-wide network that worked in parallel with the transmission system throughout BPA's service area" (Kramer 2012:E-22). The Pacific Northwest – Southwest Intertie, the nation's largest single transmission project, incorporated the construction of 22 new radio stations to provide coverage for the area. By 1974, the entire microwave radio station was connected to BPA's central Dittmer Control Center.

To support community planning and development, BPA's microwave-based network substantially enhanced the power grid's capacity, reliability, and cost-effectiveness, which supported regional community development and industrial expansion. Microwave communication service correlated with BPA's system expansion, including significant extensions to remote areas in Southwest Oregon, and east to Idaho and Montana.

BPA's microwave-based communication system operated in conjunction with the power transmission system, to provide advanced system communication and remote operational control (Kramer 2012:F-67). The MPDF classifies BPA's radio stations as "key operational elements within the BPA Transmission System" that are "integral to the centralized operation of the BPA Transmission System" (Kramer 2012:F-67). The radio stations "reflect the development of an interconnected, centrally controlled, transmission network and, as such, are associated with the development of the BPA Transmission system and have strong association with its significance" (Kramer 2012:F-68).

Microwave Radio Stations are generally modest in design and character, and are generally limited to significance under NRHP Criterion A. Sites eligible under Criterion C are exemplary of a particularly significant technology or key design, and retain a high level of integrity to relate that technology or design (Kramer 2012:67-69). BPA engineered customized equipment and adapted building and tower designs to withstand the extreme weather conditions typical at high-ground radio station sites. The sites containing two-story buildings are potentially eligible under Criterion C in the area of Architecture as a rare building type in a system with small utilitarian buildings with limited features. Because all microwave equipment has been upgraded since its initial construction, no sites retain sufficient integrity to convey Criterion C significance in the area of Engineering, as the sites no longer retain the distinctive characteristics of the technologies used during the period of significance, do not reflect the work of a master engineer, or possess high artistic values.

In general, BPA's Microwave Radio Stations are not considered eligible under NRHP Criteria B and D. For Criterion B, the Stations were conceived of and developed by BPA administrators and teams of engineers and builders and operated by dozens of BPA field personnel. These individuals and groups, however, were not necessarily considered significant in the past and so the Stations would not convey historical significance under Criterion B. Under Criterion D, the Stations' physical appearance are readily visible and the existing documentary sources on the resources do not indicate that the properties retain any information potential that would be historically significant and that are otherwise not observed from the surface. They therefore could not convey historical significance under Criterion D.

Figure 75. North Bend Microwave Radio Station, 1964 (NARA:NorthBendMWNARAbox18of52-001).

6. Microwave Radio Station NRHP Evaluations

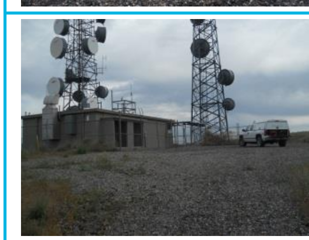
BPA's current microwave communication network consists of 117 microwave radio stations (VFA 2019). Of these, 53 were built between 1950 and 1974, and are evaluated in this study. Overall, 31 sites are recommended as eligible for the NRHP, and 21 are recommended as not eligible. The evaluated microwave radio stations are located in Washington (27 sites), Oregon (22 sites), Idaho (1 site), and Montana (2 sites). The following subsections provide the NRHP evaluations for each state. Eligibility maps are provided in Appendix A. Site forms that comply with the recordation requirements for each SHPO are provided in Appendix B.

6.1 Historic Microwave/Radio Stations in Washington

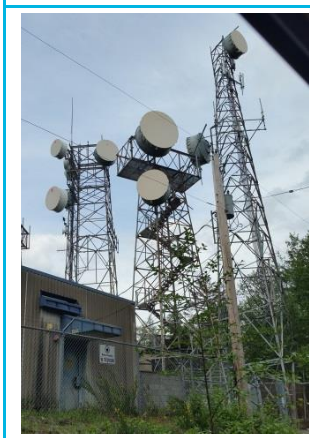
In Washington, BPA owns 28 historic period microwave radio station sites constructed during the historic period. Table 357 lists the NRHP eligibility findings of BPA's Microwave Radio Station sites in Washington.

Table 35. Historic Microwave Radio Stations in Washington

WASHINGTON						
Photograph	Microwave Radio Station	Year Built	Building Type	Tower Type	BPA District	NRHP Eligibility
	Augspurger Mountain	1953	Type 1612	4-Leg Lattice Steel	Longview	Eligible Criterion A
	Beverly	1953	Type 1606	4-Leg Lattice Steel with Staircase	Wenatchee	Eligible Criterion A
	Biddle Butte	1953	Type 1608	4-Leg Lattice Steel	Longview	Not Eligible (Antenna tower replaced)
	Bradford Island (North Bonneville)	1953	Type 1604	Mounted to Transmission Tower	Longview	Not Eligible (Antenna tower replaced)
	Chehalis	1950	Type 1600	4-Leg Lattice Steel with Staircase	Olympia	Eligible Criterion A
	Davenport	1955	Type 1606	4-Leg Lattice Steel	Spokane	Eligible Criterion A

WASHINGTON						
Photograph	Microwave Radio Station	Year Built	Building Type	Tower Type	BPA District	NRHP Eligibility
	Del Rio	1953	Type 1606	4-Leg Lattice Steel	Wenatchee	Not Eligible (Antenna tower replaced)
	Easton	1954	Type 1612	4-Leg Lattice Steel	Wenatchee	Eligible Criterion A
	Foster Creek	1953	Type 1606	4-Leg Lattice Steel	Wenatchee	Eligible Criterion A
	Grand Coulee	1953	Type 1607	No tower (roof-mounted)	Wenatchee	Eligible Criterion A
	Haystack Butte	1968	Armadillo	3-Leg Lattice Steel	The Dalles	Eligible Criterion A
	Kahlotus	1968	Armadillo	4-Leg Lattice Steel	Tri-Cities	Not Eligible (New station building)
	Kennewick	1955	Type 1607	4-Leg Lattice Steel	Tri-Cities	Not Eligible (Antenna tower replaced)

WASHINGTON						
Photograph	Microwave Radio Station	Year Built	Building Type	Tower Type	BPA District	NRHP Eligibility
	Lookout Mountain	1966	Utilitarian	4-Leg Lattice Steel	Snohomish	Not Eligible (Antenna tower replaced)
	Malaga	1955	Type 1607	4-Leg Lattice Steel	Wenatchee	Eligible Criterion A
	Metaline	1968	Armadillo	4-Leg Lattice Steel	Spokane	Not Eligible (New station building)
	Mt. Spokane	1953	Type 1612	4-Leg Lattice Steel	Spokane	Not Eligible (Antenna tower replaced)
	North Bend	1954	Type 1612	4-Leg Lattice Steel	Covington	Eligible Criterion A
	Olympia	1951	Utilitarian	4-Leg Lattice Steel	Olympia	Not Eligible (Microwave equipment removed)
	Plum	1953	Type 1606	4-Leg Lattice Steel	Spokane	Eligible Criterion A

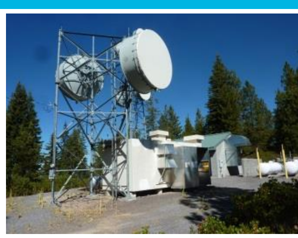
WASHINGTON						
Photograph	Microwave Radio Station	Year Built	Building Type	Tower Type	BPA District	NRHP Eligibility
	Rockdale	1955	Type 1612	4-Leg Lattice Steel	Covington	Eligible Criterion A
	Roosevelt	1953	Type 1606	4-Leg Lattice Steel	Tri-Cities	Eligible Criterion A
	Ross	1950	Type 190	4-Leg Lattice Steel	Longview	Not Eligible (Antenna tower replaced)
	Squak Mountain	1950	Type 1602	4-Leg Lattice Steel	Covington	Eligible Criterion A
	Sunnyside	1956	Type 1502	4-Leg Lattice Steel	Tri-Cities	Not Eligible (Antenna tower replaced)
	Tacoma	1956	Modern	4-Leg Lattice Steel	Covington	Not Eligible (Antenna tower replaced)

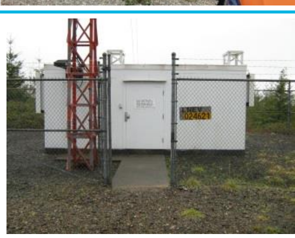
WASHINGTON						
Photograph	Microwave Radio Station	Year Built	Building Type	Tower Type	BPA District	NRHP Eligibility
	Teanaway	1954	Type 1610	4-Leg Lattice Steel	Wenatchee	Eligible Criterion A
	Waterville	1953	Type 1606	4-Leg Lattice Steel	Wenatchee	Eligible Criterion A

6.2 Historic Microwave Radio Stations in Oregon

In Oregon, BPA owns 22 historic period microwave radio station sites constructed during the historic period. Table Table 3618 lists the NRHP eligibility findings of BPA's Microwave Radio Station sites in Oregon.

Table 36. Historic Microwave Radio Stations in Oregon

OREGON						
Photograph	Microwave Radio Station	Year Built	Building Type	Tower Type	BPA District	NRHP Eligibility
	Applegate Butte	1968	Armadillo	3-Leg Lattice Steel	Redmond	Not Eligible (New station building)
	Buck Butte	1968	Armadillo	3-Leg Lattice Steel	Redmond	Not Eligible (New station building and antenna tower replaced)
	Coburg	1954	Type 1610	3-Leg Lattice Steel	Eugene	Not Eligible (Antenna tower replaced)

OREGON						
Photograph	Microwave Radio Station	Year Built	Building Type	Tower Type	BPA District	NRHP Eligibility
	Goodwin Peak	1953	Type 1503	4-Leg Lattice Steel	Eugene	Eligible Criterion A
	Grizzly Mountain	1968	Armadillo	3-Leg Lattice Steel	Redmond	Not Eligible (New station building)
	Hall Ridge	1973	Type 1136-1	3-Leg Lattice Steel	Salem	Eligible Criterion A
	Hampton Butte	1968	Type 1503	3-Leg Lattice Steel	Redmond	Not Eligible (Antenna tower replaced)
	Indian Mountain	1968	Armadillo	4-Leg and 3-Leg Lattice Steel	Redmond	Not Eligible (New station building)
	Kenyon Mountain	1961	Type 1530	4-Leg Lattice Steel	Eugene	Not Eligible (Antenna tower replaced)
	Leneve	1953	Type 1504	Guyed Lattice Steel	Eugene	Not Eligible (Microwave equipment removed)

OREGON						
Photograph	Microwave Radio Station	Year Built	Building Type	Tower Type	BPA District	NRHP Eligibility
	Marys Peak	1961	Type 1530	Wood Monopole	Eugene	Eligible Criterion A
	Mt. Hebo	1958	Type 1504	3-Leg Lattice Steel	Salem	Not Eligible (Antenna tower replaced)
	Noti	1954	Type 1503	4-Leg Lattice Steel	Eugene	Eligible Criterion A
	Pine Mountain	1968	Armadillo	3-Leg Lattice Steel	Redmond	Not Eligible (New station building)
	Prospect Hill	1953	Type 1610	3-Leg Lattice Steel	Salem	Not Eligible (Antenna tower replaced)
	Rainier	1950	Type 1600	4-Leg Lattice Steel	Longview	Eligible Criterion A
	Scott Mountain	1959	Type 1530	4-Leg Lattice Steel	Eugene	Not Eligible (Antenna tower replaced)

OREGON						
Photograph	Microwave Radio Station	Year Built	Building Type	Tower Type	BPA District	NRHP Eligibility
	Shaniko	1968	Armadillo	3-Leg Lattice Steel	The Dalles	Not Eligible (New station building)
	Swan Lake Point	1969	Armadillo	3-Leg Lattice Steel	Redmond	Not Eligible (New station building)
	Troutdale	1943	Type 1605	4-Leg Lattice Steel	Longview	Eligible Criterion A
	Wasco	1953	Type 1603	4-Leg Lattice Steel	The Dalles	Eligible Criterion A
	West Portland	1954	Type 1610	4-Leg Lattice Steel	Longview	Not Eligible (Antenna tower replaced)

6.3 Historic Microwave Radio Stations in Idaho

Table 19 lists the NRHP eligibility finding of BPA's lone Microwave Radio Station site in Idaho.

Table 37. Historic Microwave/Radio Stations in Idaho

IDAHO						
Photograph	Microwave Radio Station	Year Built	Building Type	Tower Type	BPA District	NRHP Eligibility
	Teakean Butte	1971	Armadillo	4-Leg Lattice Steel	Spokane	Not Eligible (New station building)

6.4 Historic Microwave Radio Stations in Montana

Table 20 lists the NRHP eligibility findings of BPA's Microwave Radio Station sites in Montana.

Table 38. Historic Microwave Radio Stations in Montana

MONTANA						
Photograph	Microwave Radio Station	Year Built	Building Type	Tower Type	BPA District	NRHP Eligibility
	Blacktail Peak	1968	Modern (shared facility)	3-Leg Lattice Steel & Guyed Lattice Steel	Kalispell	Eligible Criterion A
	Hungry Horse	1971	Armadillo	4-Leg Lattice Steel	Kalispell	Previously Determined Not Eligible (Lack of integrity)

7. References

AFCA (Armed Forces Communications Association).

1953 “Philco is the World’s Leading Manufacturer of Microwave Equipment” [advertisement], *Signal* 7(5). May-June.

1966 “Armadillo pre-packaged electronic systems offer permanent protection” [advertisement]. *Signal* 21(4). December.

Amazon.com. 2019. Press Photo, 1950, Sol E. Schultz, BPA Engineer.https://www.amazon.com/Vintage-Photos-Press-Schultz-Engineer/dp/B077914VBD (accessed February 19, 2019).

Ancestry.com

2002a 1930 United States Federal Census [database on-line]. Provo, UT, USA: Ancestry.com Operations Inc.

2002b Washington, Death Index, 1940-2014 [database on-line]. Provo, UT, USA: Ancestry.com Operations, Inc.

2006 1910 United States Federal Census [database on-line]. Lehi, UT, USA: Ancestry.com Operations Inc.

2010 1920 United States Federal Census [database on-line]. Provo, UT, USA: Ancestry.com Operations, Inc.

2011 U.S. WWII Draft Cards Young Men, 1940-1947 [database on-line]. Lehi, UT, USA: Ancestry.com Operations, Inc.

2012 1940 United States Federal Census [database on-line]. Provo, UT, USA: Ancestry.com Operations, Inc.

2014 U.S., Social Security Death Index, 1935-2014 [database on-line]. Provo, UT, USA: Ancestry.com Operations Inc.

Baker, Herbert C. 1953. “BPA to Build Microwave Link.” *Eugene Register-Guard* [Eugene, Oregon]. February 5.

Bellingham Herald [Bellingham, Washington].

1965a “Communication System.” Business Notes. August 2.

1965b “BPA Lets $420,000 Contract For Area Microwave Radios.” Business Notes. December 1.

Bend Bulletin [Bend, Oregon]. 1954. “Sol E. Schutz To Quit BPA.” June 11.

BPA (Bonneville Power Administration)

1939 Second Annual Report of the Administrator of the Bonneville Power Administration. U.S. Department of the Interior.

1940 Third Annual Report of the Bonneville Power Administration. U.S. Department of the Interior.

1941 Annual Report of the Administrator of the Bonneville Power Administration. U.S. Department of the Interior.

1943 Annual Report of the Administrator of the Bonneville Power Administration to The Secretary of the Interior. U.S. Department of the Interior.

1948 Communication Requirements for the Advanced Program (1948-1954) of the Bonneville Power Administration (BPA library document BPA566_1948-1950).

1949 Report on the Columbia River Power System. U.S. Department of the Interior.

1950a *BPA Currents* V(4) [BPA employee publication]. “Microwave Award Announced.” February 16 (BPA Library document BPA68_1950-02-16).

1950b *BPA Currents* V(4) [BPA employee publication]. "Radio Sleuth." February 16 (BPA Library document BPA68_1950-02-16).
1950c *BPA Currents* V(18) [BPA employee publication]. "Microwave Radio Communications Net Links Bonneville System." October 12 (BPA Library document BPA68_1950-10-12).
1950d Report on the Columbia River Power System. U.S. Department of the Interior.
1951 Report on the Columbia River Power System. U.S. Department of the Interior.
1954 Report: U.S. Columbia River Power System. U.S. Department of the Interior.
1955 Report: U.S. Columbia River Power System. U.S. Department of the Interior.
1966 Report, U.S. Columbia River Power System. U.S. Department of the Interior.
1967 Report, U.S. Columbia River Power System. U.S. Department of the Interior.
1968 Annual Report. Federal Columbia River Power System. U.S. Department of the Interior.
1969 Annual Report. Federal Columbia River Power System. U.S. Department of the Interior.
1970a Annual Report. Federal Columbia River Power System. U.S. Department of the Interior.
1970b Environmental Statement: Fiscal Year 1972 Proposed Program. Attachment C: Environmental Criteria for Electric Transmission System. III. Microwave VHF & UHF Radio Station. December.
1971 Annual Report, Federal Columbia River Power System. U.S. Department of the Interior.
1972 Annual Report, Federal Columbia River Power System. U.S. Department of the Interior.
1973 Annual Report, Federal Columbia River Power System. U.S. Department of the Interior.
1975 Annual Report, Federal Columbia River Power System. U.S. Department of the Interior.
1976 Annual Report. Federal Columbia River Power System. U.S. Department of the Interior.
1977 The Role of the Bonneville Power Administration in the Pacific Northwest Power supply System: Including Its Participation in the Hydro-Thermal Power Program. Appendix B, BPA Power Transmission. U.S. Department of the Interior (DES-77-21). June 22.
2012 *Power of the River: The Continuing Legacy of the Bonneville Power Administration in the Pacific Northwest*. Bonneville Power Administration. Printed Through the Government Printing Office. November.
2016 "BPA Bids Farewell to the Eastern Control Center." News & Us. January 11. https://www.bpa.gov/news/newsroom/Pages/BPA-bids-farewell-to-the-Eastern-Control-Center.aspx (accessed February 20, 2019).
2018 Pacific Intertie Map. The Oregon History Project. Last updated March 17. https://oregonhistoryproject.org/articles/historical-records/pacific-intertie-map/#.XGWkuJXrvZN (accessed February 14, 2019).

BPA ECDU (Bonneville Power Administration, Electronics and Communications Design Unit). 1951. VHF Radiation Survey, Progress Report No. 2. Upper Columbia Area, North Central Washington Area, Mid-Columbia Area, Lower Columbia Area. Substation Design Section, Branch of Design. November 26 (BPA library document BPA414_1951).

BPA.gov. 2017. About Us. Electronic Document, https://www.bpa.gov/news/AboutUs/Pages/default.aspx (accessed March 29, 2017).BPA. N.d. Comments. https://www.energy.gov/sites/prod/files/gcprod/documents/BonnevillePower_Comments_CommsReqs.pdf

BPA.gov. 2018. Intertie (1969) [film]. News & Us. https://www.bpa.gov/news/AboutUs/History/Pages/Intertie.aspx (accessed February 20, 2019).

Cantelon, Philip L. 1995. "The Origins of Microwave Telephony – Waves of Change." *Technology and Culture* 36(3):560-582. Published by The Johns Hopkins University Press and the Society for the History of Technology. July.

Charitz, Gladys (ed.). 1963. “Communications System to Serve Northwest.” Industrial Notes. *Electrical Engineering*. September.

Coffman, Larry. 1967. “Bonneville Flexes Its Muscles On its 30th Birthday.” *Seattle Times* [Seattle, Washington]. August 20.

Corvallis Gazette-Times [Corvallis, Oregon]
1952 “Bonneville Engineer Assistant Administrator.” February 13.

Curran, Christine Ann. 1998. Master’s Thesis. A Historic Context for the Transmission of Hydroelectricity by the Bonneville Power Administration, 1939-1945. University of Oregon.

Currey, Al. 1951. “Large-Size Flying Saucers Due in Valley.” *Eugene Register-Guard* [Eugene, Oregon]. February 20.

Eugene Register-Guard [Eugene, Oregon]
1941 “Bonneville Radio Station Here Is Ready For Testing.”
1963 “Contract Awarded For Radio System.” June 30.

Fussell, E.B. 1951. “Two-Cushion Shot for Microwaves on the Skagit.” *Seattle Times* [Seattle, Washington]. March 4.

Horgan, John. 2010. “Remembering San Carlos’ Lenkurt Electric Co. *Mercury News* [San Jose, California]. https://www.mercurynews.com/2010/12/08/john-horgan-remembering-san-carlos-lenkurt-electric-co/ (accessed January 23, 2019).

Intertie (Pacific Northwest – Southwest Intertie, Design and Construction Task Force). 1968. Final Report. January 3 (BPA library document BPA676_1968).

Jaques, Tom. 1954. “Wheels, Gauges Keep Tab on EWEB Operation: Telemetering Device Permits Remote Control.” *Eugene Register-Guard*. February 23.

Kershner, Jim. 2016. "Northwest Power Pool." HistoryLink.org. March 29. http://www.historylink.org/File/11199 (accessed February 12, 2019).

Komen, Jr., Peter J. and George H. Smith. 1951. “Microwave Radio Site Location.” *Electric Light and Power*: 110-111. August.

Kramer, George. 2010. Corridors of Power: The Bonneville Power Administration Transmission Network. Historic Context Statement. For the Bonneville Power Administration, Portland, Oregon under Master Agreement #38010. April.

Kramer, George. 2012. Bonneville Power Administration [BPA] Pacific Northwest Transmission System. National Register of Historic Places, Multiple Property Documentation Form. United States Department of the Interior, National Park Service.

Mail Tribune [Medford, Oregon]
1949 “Power Dispatching Station In Service.” December 18.
1950 “Bonneville Engineer Honored By Award.“ September 15.

Marihart, D.J. 1972. “Microwave System Design, Fade Problems and Solutions. Bonneville Power Administration. Portland, Oregon (BPA Library document BPA431_1972_Marihart_02).

Marihart, D.J. and D.L. Wylie. 1956. “Southwest Oregon Radio System for the Bonneville Power Administration.” November (BPA library document BPA431_1956_Marihart).

Myers, Walter E. 1971. Telecommunications Facilities for the Dworshak, Idaho to Hot Springs, Montana 500 KV Transmission System. Bonneville Power Administration, Portland, Ore. A paper recommended by the IEEE Power System Communications Committee of the IEEE Power Engineering Society for presentation at the IEEE Winter Power Meeting, New York, N.Y., January 31 – February 5.

NARA (National Archives and Records Administration). Seattle, Washington.

NASEM (The National Academies of Sciences, Engineering, Medicine). 1994. Microwave Processing of Materials. The National Academies Press. https://www.nap.edu/read/2266/chapter/4#10 (accessed January 31, 2019).

NPS (National Park Service). 1997. “How to Apply the National Register Criteria for Evaluation,” National Register Bulletin. U.S. Department of the Interior, National Park Service.

Observer [La Grande, Oregon]. 1955. “Bonneville Builds Radio Stations.” June 24.

Oregonian [Portland, Oregon]
1949a “Bonneville Ready to Cut In Power Dispatching Center.” December 17.
1949b “BPA Man to Talk.” January 5.
1950a “BPA to Have Radio System.” February 10.
1950b “World’s Largest Microwave Radio Center To Speed Repairs on Bonneville Lines.” October 6.
1951 “Millions Spent in N.W. On Power, Reclamation.” December 30.
1954 “Bonneville Power Administration Budgets $35,000,000 for Facilities, Improvements in 1955.” December 19.
1955 “BPA Plots Line Project.” June 12.
1958a “Bonneville Adds Robot Controller.” May 29.
1958b “2 Engineers Get Awards.” November 13.
1959 “BPA Honors 3 Employees.” July 17.
1964 “BPA Engineer Wins Medal.” February 6.
1968 “Employe [*sic*] Gets new Position.” September 27.
1969 “Former Official of BPA Dies.” May 22.

OSHA (Occupational Safety & Health Administration). 2019. Power-line Carrier. United States Department of Labor. https://www.osha.gov/SLTC/etools/electric_power/illustrated_glossary/substation_equipment/power_line_carrier.html (accessed February 1, 2019).

Radiocom, Inc. 1954. ‘Taking the Shackles Off Microwave.” [Lenkurt Electric Co. advertisement]. *Communication Engineering* 54(1). January – February.

Science News Letter.1950. “Radio Sleuth Detects Powerline Trouble.” *Science News Letter* 57(6). Published by the Society for Science and the Public. February 11.

Seattle Times [Seattle, Washington]
1950a “New Bonneville Installation Will Be Discussed Here.” March 19.
1950b “Electrical –Engineer Group to Meet.” March 19.
1960 “Calif., N.W. Power Tie-In Advocated.” August 23.
1962a “Business-Industrial Digest – The Election of Sol E. Schultz.” June 17.

1962b “Sol Schultz Is ‘Engineer of Year.’” February 24.

Shank, K. and R. Lawrence. 1965. “Multipurpose Microwave System Takes Over at BPA.” *Electric Light and Power*:42-47. January (BPA library document BPA431_1965_Shank).

Stanton, Boles (Stanton, Boles, Maguire and Church). 1966. A Report on Appearance Planning for BPA. May.

Stevens, Richard F.

1949 “Microwave Supplements Present Channels.” *Electrical World*:39-42. January 1.

1950 “BPA Completes 200-mile Microwave Link.” *Electrical West* 105(4):82-83. October (BPA library document BPA431_1950_Stevens_02).

Stevens, Richard F. and Theodore W. Stringfield. 1950. Microwave Applications to Bonneville Power Administration System. AIEE Technical Paper 50-170. A paper recommended by the AIEE Committee on Carrier Current and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General meeting, Pasadena, Calif., June 12-16, 1950. Manuscript submitted March 15, 1950; made available for printing May 8, 1950 (BPA library document BPA431_1950_Stevens_03).

Stevens, Richard F. and Theodore W. Stringfield. 1951. “Microwave Applications to Bonneville Power Administration System.” Electrical Engineering. January.

Strong, E.M., E.J. Warchol, and S.E. Benson. 1957. “Microwave Radio Communication Under Severe Winter Conditions on the Bonneville Power Administration System.” Transactions of the American Institute of Electrical Engineers, Part I: Communication and Electronics 76(5): 655-662. November. https://ieeexplore.ieee.org/document/6372359 (accessed January 29, 2019).

Sunday Oregonian. 1975. T.W. Stringfield – Obituaries. February 23.

Union-Bulletin [Walla Walla, Washington]. 1950. “Microwave Radio Links Bonneville Centers of Power.” October 6.

VFA. 2019. Bonneville Power Administration.

Walz Frank C., Jr., Stacey F. Pickup, and Clyde A. Kratochvil. 1968. Prefabricated portable building, Armadillo Mfg. Co., United States Patent 3415025.

Westby, Ken. 2019. Personal communication with BPA. June 12.

Appendix A – BPA Microwave Radio Stations NRHP Eligibility Spreadsheet

BPA Microwave Radio Stations NRHP Eligibility

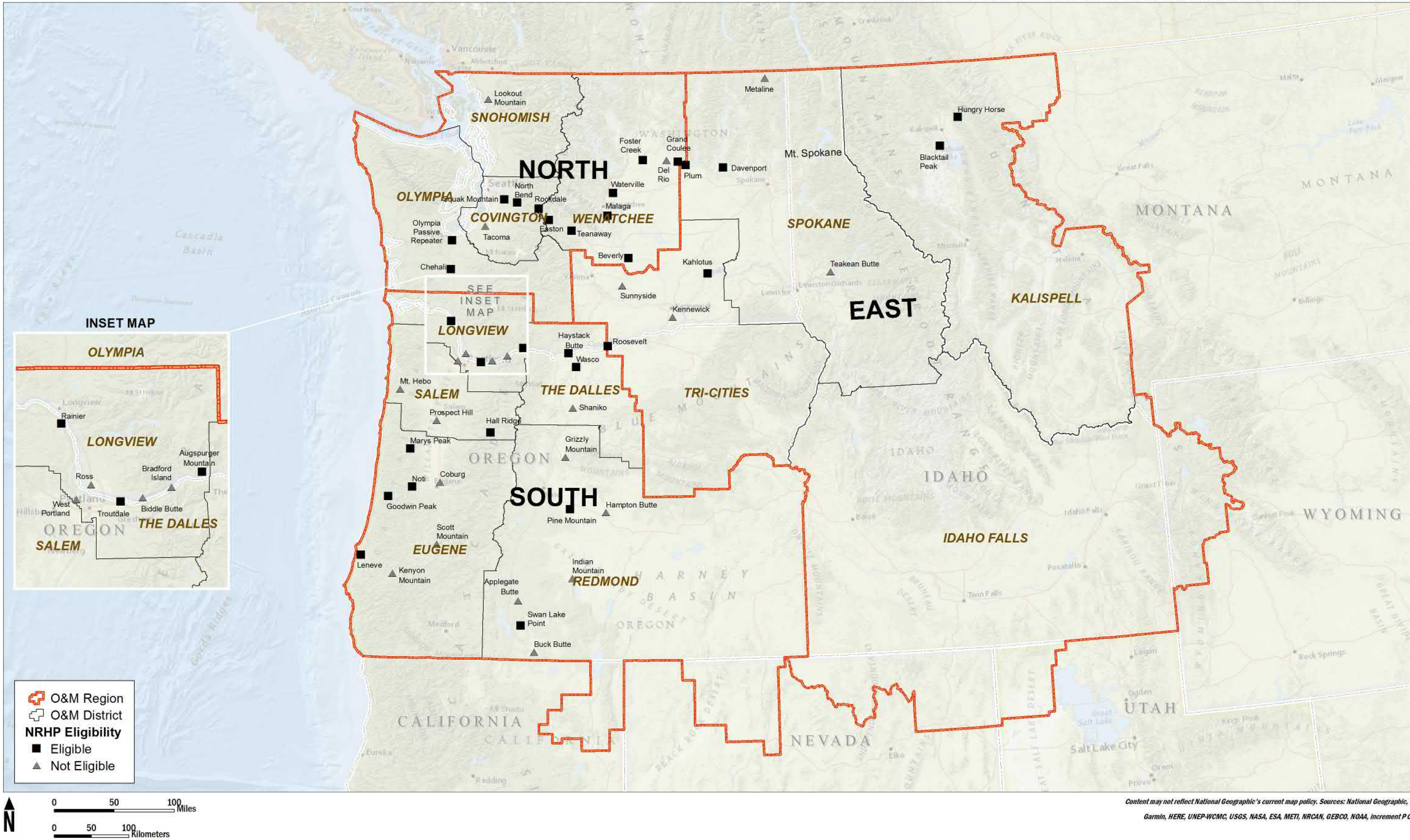
Station Name	YearBuilt	Circuit	BPA Design/Type	Tower Type	Line of sight retained	Site Retains Integrity	NRHP_Eligibility	District	Region	State
Applegate Butte Radio Station	1968	PNW-PSW Intertie	Armadillo	3-Leg Lattice Steel	yes	No (building replaced)	Not Eligible	REDMOND	SOUTH	OR
Augspurger Mountain Radio Station	1953	Ross-Spokane	Type 1612	4-Leg Lattice Steel	yes	Yes	Eligible	LONGVIEW	SOUTH	WA
Beverly Radio Station	1953	Ross-Spokane; Snohomish-Beverly	Type 1606	4-Leg Lattice Steel with Staircase	Partial	Yes	Eligible	WENATCHEE	NORTH	WA
Biddle Butte Radio Station	1953	Ross-Spokane	Type 1608	4-Leg Lattice Steel	Partial	No (tower replaced)	Not Eligible	LONGVIEW	SOUTH	WA
Blacktail Peak Radio Station	1968	Montana/Idaho Expansion	Modern (shared facility)	3-Leg Lattice Steel & Guyed Lattice Steel	yes	Yes	Eligible	KALISPELL	EAST	MT
Bradford Island Radio Station	1953	Ross-Spokane	Type 1604	Mounted to Tranmission Tower	yes	No (rooftop antenna tower replaced)	Not Eligible	LONGVIEW	SOUTH	WA
Buck Butte Radio Station	1968	PNW-PSW Intertie	Armadillo	3-Leg Lattice Steel	yes	No (building and tower replaced)	Not Eligible	REDMOND	SOUTH	OR
Chehalis Radio Station	1950	Ross-Snohomish	Type 1600	4-Leg Lattice Steel with Staircase	yes	Yes	Eligible	OLYMPIA	NORTH	WA
Coburg Radio Station	1954	SW Oregon; Ross-Alvey	Type 1610	3-Leg Lattice Steel	yes	No (tower replaced)	Not Eligible	EUGENE	SOUTH	OR
Davenport Radio Station	1955	Ross-Spokane	Type 1606	4-Leg Lattice Steel	yes	Yes	Eligible	SPOKANE	EAST	WA
Del Rio Radio Station	1953	Ross-Spokane	Type 1606	4-Leg Lattice Steel	yes	No (tower replaced)	Not Eligible	WENATCHEE	NORTH	WA
Easton Radio Station	1954	Snohomish-Beverly	Type 1612	4-Leg Lattice Steel	yes	Yes	Eligible	WENATCHEE	NORTH	WA
Foster Creek Radio Station	1953	Ross-Spokane	Type 1606	4-Leg Lattice Steel	yes	Yes	Eligible	WENATCHEE	NORTH	WA
Goodwin Peak Radio Station	1953	SW Oregon	Type 1503	4-Leg Lattice Steel	Partial	Yes	Eligible	EUGENE	SOUTH	OR
Grand Coulee Radio Station	1953		Type 1607	No tower (roof-mounted)	yes	Yes	Eligible	WENATCHEE	NORTH	WA
Grizzly Mountain Radio Station	1968	PNW-PSW Intertie	Armadillo	3-Leg Lattice Steel	yes	No (building replaced)	Not Eligible	REDMOND	SOUTH	OR
Hall Ridge Radio Station	1973		Type 1136-1	3-Leg Lattice Steel	yes	Yes	Eligible	SALEM	SOUTH	OR
Hampton Butte Radio Station	1968		Type 1503	3-Leg Lattice Steel	yes	No (tower replaced)	Not Eligible	REDMOND	SOUTH	OR
Haystack Butte Radio Station	1968	PNW-PSW Intertie	Armadillo	3-Leg Lattice Steel	yes	Yes	Eligible	THE DALLES	SOUTH	WA
Hungry Horse Radio Station	1971	Montana/Idaho Expansion	Armadillo	4-Leg Lattice Steel	yes	No (building substantially altered)	Not Eligible (previously determined)	KALISPELL	EAST	MT
Indian Mountain Radio Station	1968	PNW-PSW Intertie	Armadillo	4-Leg and 3-Leg Lattice Steel	yes	No (building replaced)	Not Eligible	REDMOND	SOUTH	OR
Kahlotus Radio Station	1968		Armadillo	4-Leg Lattice Steel	yes	No (new building)	Not Eligible	TRI-CITIES	EAST	WA
Kennewick Radio Station	1955	Ross-Spokane	Type 1607	4-Leg Lattice Steel	yes	No (tower replaced)	Not Eligible	TRI-CITIES	EAST	WA
Kenyon Mountain Radio Station	1961		Type 1530	4-Leg Lattice Steel	yes	No (tower replaced)	Not Eligible	EUGENE	SOUTH	OR
Leneve Radio Station	1953	SW Oregon	Type 1504	Guyed Lattice Steel	Partial	No (station equipment removed)	Not Eligible	EUGENE	SOUTH	OR
Lookout Mountain Radio Station	1966		Utilitarian	4-Leg Lattice Steel	yes	No (tower replaced)	Not Eligible	SNOHOMISH	NORTH	WA
Malaga Radio Station	1955	Ross-Spokane	Type 1607	4-Leg Lattice Steel	yes	Yes	Eligible	WENATCHEE	NORTH	WA
Marys Peak Radio Station	1961		Type 1530	Wood Monopole	yes	Yes	Eligible	EUGENE	SOUTH	OR
Metaline Radio Station	1968		Armadillo	4-Leg Lattice Steel	yes	No (building replaced)	Not Eligible	SPOKANE	EAST	WA
Mt. Hebo Radio Station	1958		Type 1504	3-Leg Lattice Steel	yes	No (tower replaced)	Not Eligible	SALEM	SOUTH	OR
Mt. Spokane Radio Station	1953	Ross-Spokane	Type 1612	4-Leg Lattice Steel	yes	Yes	Eligible	SPOKANE	EAST	WA
North Bend Radio Station	1954	Snohomish-Beverly	Type 1612	4-Leg Lattice Steel	yes	Yes	Eligible	COVINGTON	NORTH	WA
Noti Radio Station	1954	SW Oregon	Type 1503	4-Leg Lattice Steel	yes	Yes	Eligible	EUGENE	SOUTH	OR
Olympia Passive Repeater Site	1951	Ross-Snohomish	Utilitarian	4-Leg Lattice Steel	yes	No (MW equipment removed)	Not Eligible	OLYMPIA	NORTH	WA
Pine Mountain Radio Station	1968	PNW-SW Intertie	Armadillo	3-Leg Lattice Steel	yes	No (new building)	Not Eligible	REDMOND	SOUTH	OR
Plum Radio Station	1953	Ross-Spokane	Type 1606	4-Leg Lattice Steel	yes	Yes	Eligible	SPOKANE	EAST	WA
Prospect Hill Radio Station	1953	Ross-Alvey	Type 1610	3-Leg Lattice Steel	yes	No (tower replaced)	Not Eligible	SALEM	SOUTH	OR
Rainier Radio Station	1950	Ross-Snohomish	Type 1600	4-Leg Lattice Steel	yes	Yes	Eligible	LONGVIEW	SOUTH	OR
Rockdale Radio Station	1955	Snohomish-Beverly	Type 1612	4-Leg Lattice Steel	yes	Yes	Eligible	COVINGTON	NORTH	WA
Roosevelt Radio Station	1953	Ross-Spokane	Type 1606	4-Leg Lattice Steel	yes	Yes	Eligible	TRI-CITIES	EAST	WA
Ross Complex	1950	Ross-Snohomish; Ross-Spokane; Ross-Alvey	Type 190	4-Leg Lattice Steel	yes	No (tower replaced)	Not Eligible	LONGVIEW	SOUTH	WA
Scott Mountain Radio Station	1959		Type 1530	4-Leg Lattice Steel	yes	No (tower replaced)	Not Eligible	EUGENE	SOUTH	OR

BPA Microwave Radio Stations NRHP Eligibility

Station Name	YearBuilt	Circuit	BPA Design/Type	Tower Type	Line of sight retained	Site Retains Integrity	NRHP_Eligibility	District	Region	State
Shaniko Radio Station	1968	PNW-SW Intertie	Armadillo	3-Leg Lattice Steel	yes	No (building replaced)	Not Eligible	THE DALLES	SOUTH	OR
Squak Mountain Radio Station	1950	Ross-Snohomish	Type 1602	4-Leg Lattice Steel	yes	Yes	Eligible	COVINGTON	NORTH	WA
Sunnyside Radio Station	1956		Type 1502	4-Leg Lattice Steel	yes	No (tower replaced)	Not Eligible	TRI-CITIES	EAST	WA
Swan Lake Point Radio Station	1969	PNW-PSW Intertie	Armadillo	3-Leg Lattice Steel	Partial	No (building replaced)	Not Eligible	REDMOND	SOUTH	OR
Tacoma Radio Station	1956		Modern	4-Leg Lattice Steel	yes	No (tower replaced)	Not Eligible	COVINGTON	NORTH	WA
Teakean Butte Radio Station	1971	Montana/Idaho Expansion	Armadillo	4-Leg Lattice Steel	yes	No (building replaced)	Not Eligible	SPOKANE	EAST	ID
Teanaway Radio Station	1954	Snohomish-Beverly	Type 1610	4-Leg Lattice Steel	Partial	Yes	Eligible	WENATCHEE	NORTH	WA
Troutdale Substation	1953	Ross-Spokane Branch Spur	Type 1605	4-Leg Lattice Steel	yes	Yes	Eligible	LONGVIEW	SOUTH	OR
Wasco Radio Station	1953	Ross-Spokane, PNW-SW Intertie	Type 1603	4-Leg Lattice Steel	yes	Yes	Eligible	THE DALLES	SOUTH	OR
Waterville Radio Station	1953	Ross-Spokane	Type 1606	4-Leg Lattice Steel	yes	Yes	Eligible	WENATCHEE	NORTH	WA
West Portland Radio Station	1954	Ross-Alvey	Type 1610	4-Leg Lattice Steel	Partial	No (tower replaced)	Not Eligible	LONGVIEW	SOUTH	OR

Appendix B – BPA Microwave Radio Stations NRHP Eligibility Maps

UPDATED: 6/14/2019 USER robin.lium PATH C:\Users\robin.lium\Documents\ActiveProjects\BPA_RadioStations_Copied20190613\02_Maps\02_Map_Production_and_Reports\BPA_RadioStations_OverviewMap_20190614.mxd



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Bonneville Power Administration

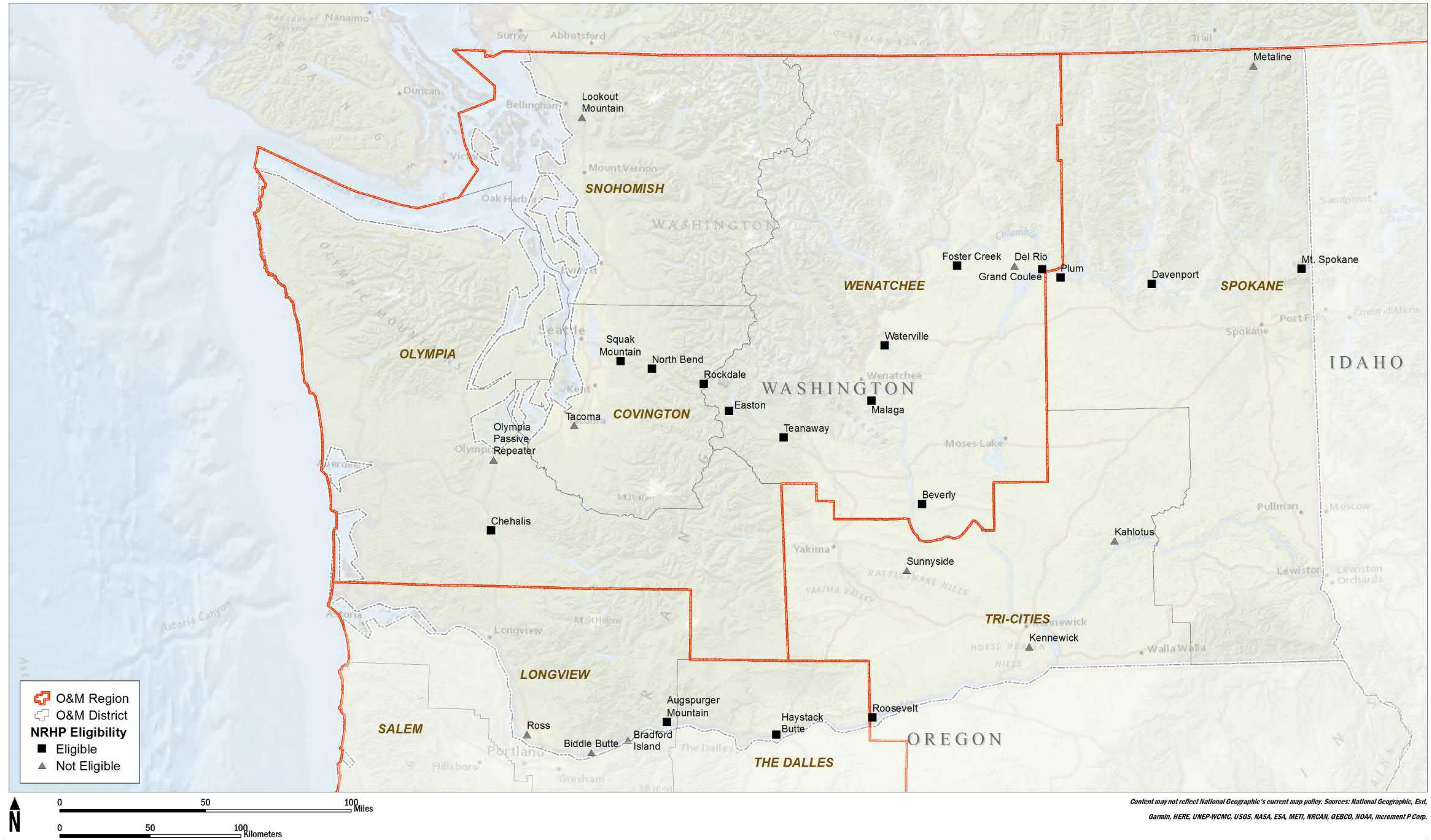
Project No: 60539520 Date: January 2019

Bonneville POWER ADMINISTRATION

HISTORIC MICROWAVE RADIO STATION OVERVIEW MAP

NATIONAL REGISTER OF HISTORIC PLACES (NRHP) EVALUATIONS

BONNEVILLE POWER ADMINISTRATION



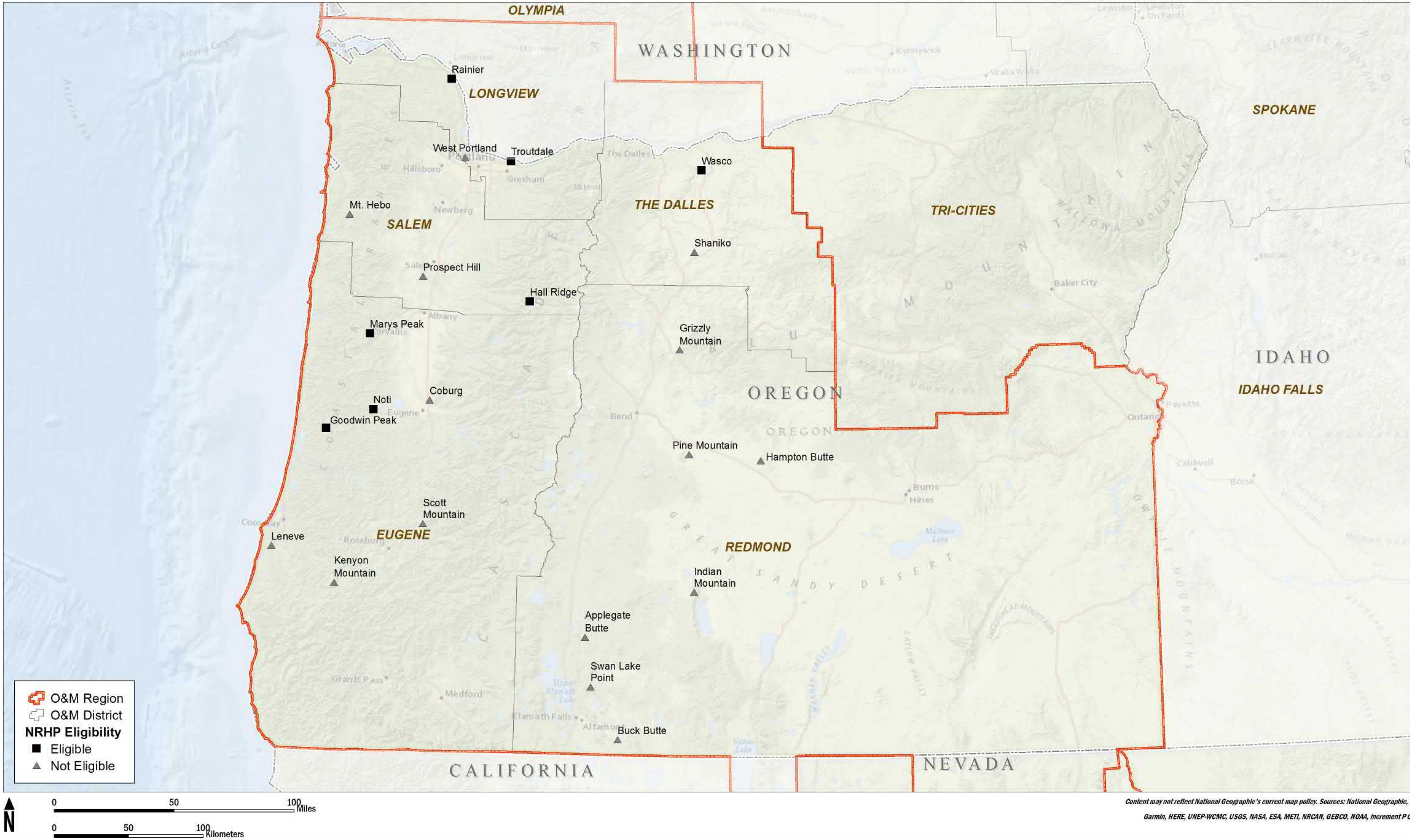
AECOM
Bonneville Power Administration
Project No: 60539520 Date: April 2019

Bonneville
POWER ADMINISTRATION

HISTORIC MICROWAVE RADIO STATIONS IN WASHINGTON

NATIONAL REGISTER OF HISTORIC PLACES (NRHP) EVALUATIONS

BONNEVILLE POWER ADMINISTRATION



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Project No: 60539520 Date: April 2019

Bonneville POWER ADMINISTRATION

HISTORIC MICROWAVE RADIO STATIONS IN OREGON

NATIONAL REGISTER OF HISTORIC PLACES (NRHP) EVALUATIONS
BONNEVILLE POWER ADMINISTRATION

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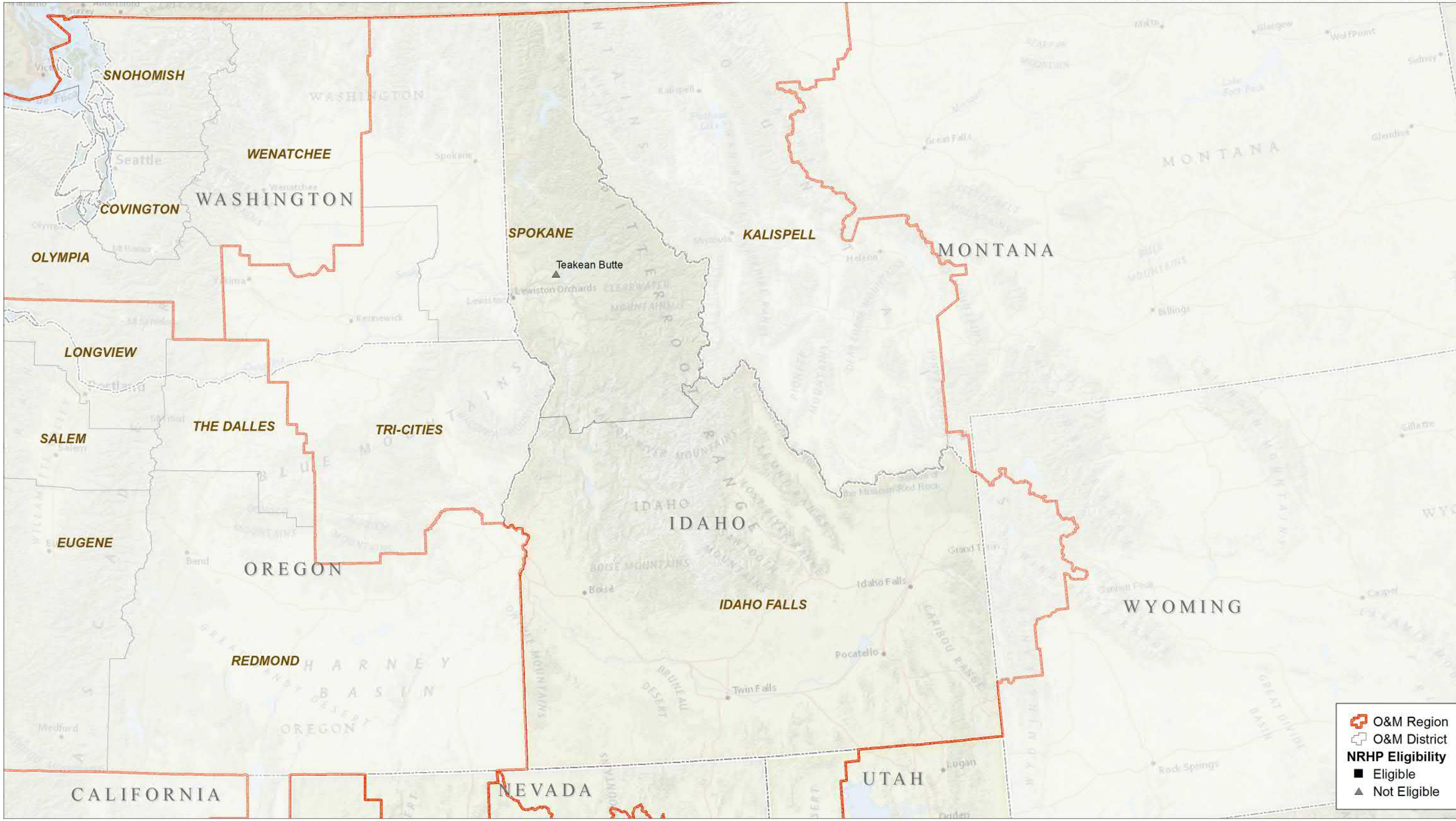

0 50 100 Miles

0 50 100 Kilometers

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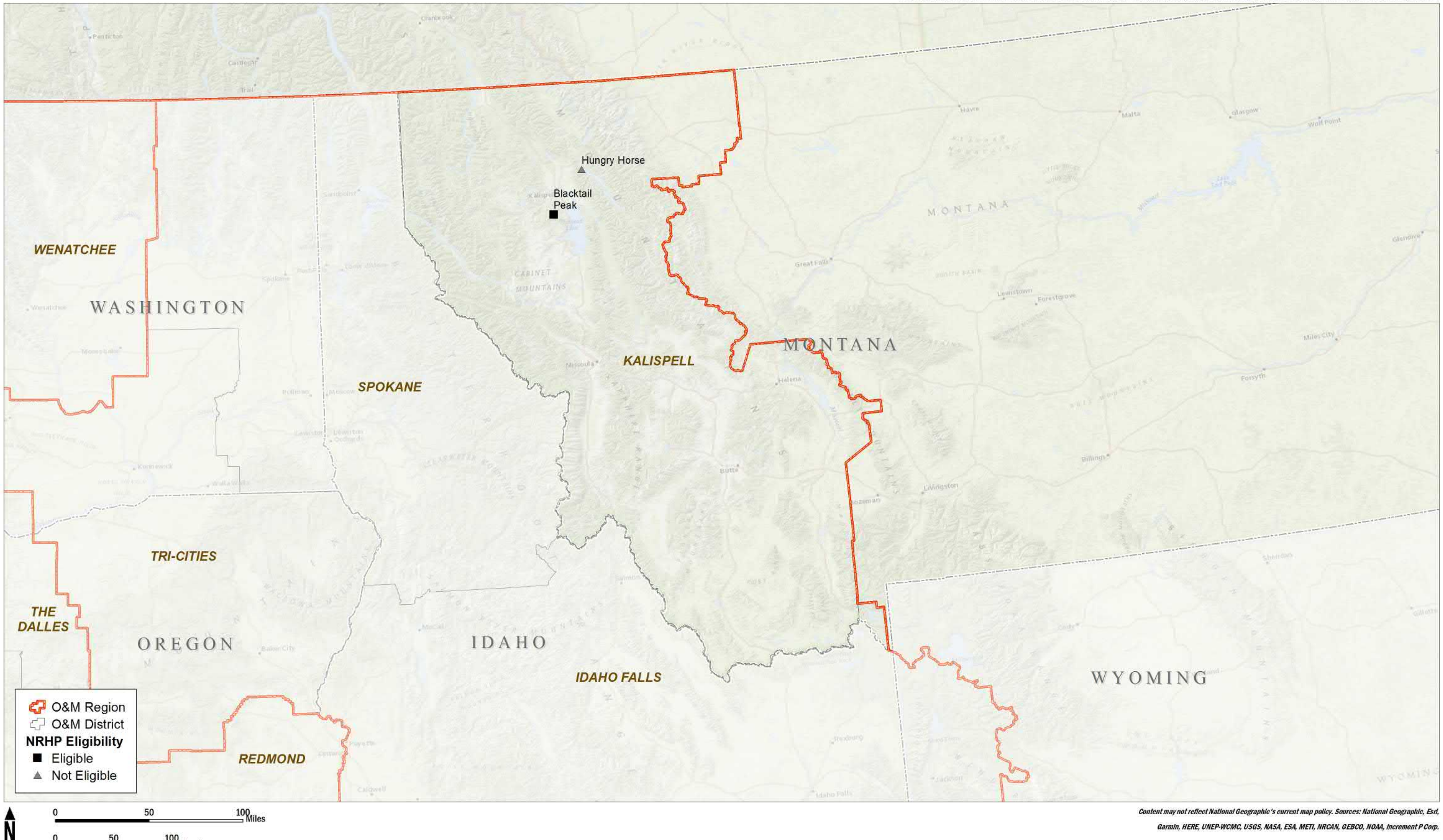
Project No: 60539520 Date: April 2019

Bonneville POWER ADMINISTRATION

HISTORIC MICROWAVE RADIO STATIONS IN IDAHO

NATIONAL REGISTER OF HISTORIC PLACES (NRHP) EVALUATIONS

BONNEVILLE POWER ADMINISTRATION



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HISTORIC MICROWAVE RADIO STATIONS IN MONTANA

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Appendix C – BPA Microwave Radio Stations SHPO Site Forms

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