Title

Appropriate Technologies in the Traditional Native American Smokehouse: Public Health Considerations in Tribal Community Development

Journal
American Indian Culture and Research Journal , 24(4)

ISSN
0161-6463

Authors
Flanagan, Mary Ellen
Zaferatos, Nicholas C.

Publication Date
2000-09-01

DOI
10.17953

AMERICAN INDIAN CULTURE AND RESEARCH JOURNAL 24:4 (2000) 69–93

Appropriate Technologies in the Traditional Native American Smokehouse: Public Health Considerations in Tribal Community Development

MARY ELLEN FLANAGAN AND NICHOLAS C. ZAFERATOS

The long suppression of traditional Indian spiritual practices was, in part, overcome when the Swinomish Indian Tribal Community of Washington State constructed its long-anticipated ceremonial smokehouse. The celebrated resumption of smokehouse activities, however, presented new environmental health threats that were not adequately anticipated and that required remediation. This article examines how the community was able to reduce the associated health risks by adapting appropriate technologies that respected the importance of privacy in ceremonial practice.

In sharp contrast to historic federal Indian policies that disrupted the fabric of Native American communities, current federal policies now encourage tribal governments to reconstruct their political systems, economies, and cultures to achieve sustainable community improvement. Beginning in the late 1960s and early 1970s, tribes began programs of political and community reconstruction. As a result, their once-suppressed spiritualism quickly rebounded from the effects of federal assimilation that sought to diminish Indian identity by prohibiting the use of traditional languages and spiritual practice. For many Coast Salish Indians, the reconstruction of the traditional smokehouse, also called longhouse—the ceremonial place of worship—

Mary Ellen Flanagan is a research industrial hygienist in the Field Research and Consultation Group, Department of Environmental Health, University of Washington.

Nicholas C. Zaferatos is an assistant professor of planning at Huxley College of Environmental Studies, Western Washington University, and formerly served for two decades as the general manager and director of planning for the Swinomish Indian Tribal Community.

became a centerpiece of their community redevelopment. The Swinomish Indian Tribal Community sought to reestablish its ceremonial smokehouse to stimulate the revival of cultural and traditional spiritualism known as Seowyn.

Following years of searching for funding, construction of the traditional smokehouse on the Swinomish Indian Reservation began in the early 1990s. Adhering to stringent traditional design criteria while simultaneously complying with newly adopted tribal sanitary and structural building codes, the smokehouse design provided for two open fires which are central to Seowyn ceremonial practice. While the new building promised to revive the community's spiritual tradition, it also raised new concerns—the burning fires within the structure were expected to contribute airborne pollution that could present a public health threat to smokehouse occupants.

TRIBAL COMMUNITY REDEVELOPMENT

Tribes have been active in reestablishing their primary role as governments since the earliest introduction of tribal community redevelopment programs under the federal Great Society initiatives of the 1960s. Tribal community development began on many reservations as a three-pronged effort that involved (1) the strengthening and application of political sovereignty; (2) the development and protection of reservation homelands; and (3) the advancement of cultural priorities. The early period of tribal community development emphasized political reorganization as well as the provision of basic governmental services and social programs, public housing, reservation infrastructure development, and the defense of treaty rights.

The self-determination era beginning in 1970 fostered advances in tribal political sovereignty. The effects of the federal strategy, however, also promoted new forms of tribal dependency on nontribal forms of development, including a reliance on external technical assistance, that were often inconsiderate of tribal cultural priorities. The Indian Self Determination and Education Assistance Act of 1975 was the first major legislation that sought to transfer federal programs to tribal administration. As the development of reservation communities progressed with growth in tribal, political, and administrative institutions, attention began to focus on the internal priorities of the cultural community to meaningfully ensure that tribal traditional and spiritual values were protected, enhanced, and integrated within the tribes' overall development strategies.

Traditional culture and religion are viewed as inseparable from tribal identity. For many tribal communities, reservation lands and natural resources are viewed as elements of the larger cultural community objective rather than as an end to itself. This community norm often assigns to a natural resource a social-use value superior to that of its economic exchange value, emphasizing a traditional concern for the finiteness of natural resources and the community's ability to survive. Traditional tribal views are the foundation of tribal planning approaches that seek to protect reservation lands and natural resources for future generations. However, as tribes expand their political authority by enacting new forms of laws and regulations that often mirror federal or state standards, tribes must carefully determine how those standards might impede traditional values.

PHOTO 1. *Carvings on structural building posts in ceremonial room.*

THE SUPPRESSION OF INDIAN RELIGIOUS AND CULTURAL TRADITIONS

The normative belief systems that underlie modern Indian societies are distinct from the predominant social values of non-Indian society. Fundamental to a tribal community's development goals are the consensual belief systems that reflect the collective community and the preservation of its cultural identity. Notwithstanding the experience of tribal acculturation and the subsequent acceptance and incorporation of many non-Indian values, important normative differences prevail, contributing to the maintenance of an Indian ethnic identity.[1] Indian people have long objected to the Anglo assumption that the loss of Native culture is either inevitable or desirable. Biculturation, a concept that has emerged to promote positive models of cultural identity, refers to the process of dual cultural competence. This occurs when an original culture is positively valued and its activity maintained while concurrently achieving a competency in a mainstream or dominant culture. A bicultural

Photo 2. *Smokehouse interior.*

community retains its original cultural traditions, identities, beliefs, and sets of values while participating constructively within a mainstream society.

Northwest coastal tribal communities, like other Indian communities, continue to place a high value on the practice of traditional activity. In many Coast Salish communities, generosity continues to bring greater esteem than does the accumulation of personal wealth.[2] Northwest coastal tribes also continue to have a greater reverence for spiritual knowledge gained through transcendental experiences than do most non-Indians. Even those tribal members who may no longer directly participate in traditional religious activities continue to acknowledge a strong personal association with traditional practices.

Early Anglo contact with Indian communities resulted in misunderstanding about Indian tradition and evoked ethnocentric assumptions about the superiority of non-Indian culture.[3] The presumption of Anglo cultural dominance over Indian values eventually led to the persecution of Indian religious practices. Non-Indian society used institutional mechanisms, including the passage of laws prohibiting religious practices, to disrupt tribal cultural cohesion. During the late 1800s it was declared illegal for Indians to practice any aspect of traditional religion, spiritual dance, or healing practices. Courts of Indian Offenses were established to punish those practicing traditional beliefs.

As a result of persecution, Indians were forced to practice traditional spiritualism in secrecy. The suppression of Indian religion eventually led to a diminished knowledge of valuable traditions.[4] Indians who preserved spiritual knowledge became reluctant to reveal their knowledge and, as a form of self- and community-preservation, would often deny an association to that knowledge.[5] While the legal persecution of traditional religion abated following the passage of the Indian Reorganization Act of 1934,[6] prohibition of the practice was not formally repudiated until passage of the Indian Freedom of Religion Act of 1978.[7]

SWINOMISH TRIBAL COMMUNITY

The Swinomish Indian Reservation occupies the southeastern portion of Fidalgo Island in Skagit County, Washington. Promised to four related Indian bands, the area was set aside by the 1855 Treaty of Point Elliott and further redefined under Executive Order in 1873. The reservation was to be exclusively used as the Swinomish Tribal Community's homeland. Swinomish ancestors have inhabited the reservation area for several thousand years. Numerous known archaeological sites are located within reservation boundaries, and several historic villages and shell midden sites have been identified along the reservation coastline. At the site of the Swinomish Indian Village (the present location of tribal governmental services, tribal residences, and several religious buildings) was Twiwok, an Indian settlement continuously inhabited for more than 3,500 years.

The Swinomish Tribal Community was severely shaken by the effects of federal assimilation and the Allotment Act, which resulted in the subdivision of communally owned reservation lands and the eventual loss of almost one-half of the land base to non-Indian ownership. The conditions in which the tribe finds itself today is the consequence of the imposition of alien cultural values promoted by past federal Indian policies. Despite notable recent political gains in many areas, social and economic conditions on the reservation continue to be depressed. Consequently, reestablishing a viable, self-sustaining reservation community is the primary challenge facing the Swinomish, a challenge complicated by a wide variety of cultural, organizational, and historic obstacles.

WINTER TRADITIONS AND SEOWYN CEREMONIAL PRACTICE

Members of the modern Swinomish Indian Tribal Community are descendants of the Swinomish, Kikiallus, Samish, and Lower Skagit tribes. The ancestors of these groups lived in the Skagit River Valley and on the coastline and islands near the river's mouth. Each shared the Coast Salish language. The culture and economy of the inhabitants of the Skagit region were centered around natural resources, including salmon, shellfish, and upland resources such as cedar, camus, berries, and wildlife. Resource gathering activities, in response to seasonal availability of the various resources, resulted in a fluctuation of village demography in which families dispersed to seasonal locations. During aboriginal times, the most salient unit of social organization in the Skagit region was the winter village community.[8]

Three institutions formed the social basis of the Skagit region villages: marriages, summer exchange visits, and winter ceremonials. The winter ceremonials included both invitational feasts and the spirit dance. The spirit dance was a gathering of different village communities each winter, usually in

PHOTO 3. *Interior roof in main ceremonial room showing smoke hole.*

the house of a young person who had recently acquired a guardian spirit following years of training, spiritual questing, fasting, and wilderness solitude. The spirit provided protection and special knowledge. In return, the individual was expected to perform a spirit dance that involved ceremonial costuming and the singing of a particular song.

The other winter ceremonial, the invitational feast, related to the winter spirit dance but was a larger affair that included bathing and fasting in order to attract spiritual guardians. The feast, occurring in large smokehouse structures, included games, gambling, trading, singing, dancing, and masked performances.[9] Also called potlatches, these feasts were important economic institutions, allowing wealthy communities to convert accumulated stores of food and other wealth into higher social status and prestige.

Smokehouse practices were abruptly interrupted in the late eighteenth century. The devastating smallpox epidemic of 1782 and 1783 reduced the Native population by almost one-half, and resulted in the destruction of many of the infected smokehouses throughout the area.[10] The reservation village contained a large smokehouse that burned down before 1900 during a smallpox epidemic. Furthermore, one of the most devastating rules imposed by the Bureau of Indian Affairs (BIA) during the early reservation period of the nineteenth century outlawed the practice of traditional spirit dancing as well as the practice of Indian medicine. The federal government viewed the elimination of Native religion as a politically important strategy since traditional religion served to strengthen tribal cohesiveness that fostered resistance to federal intrusion.

The Swinomish responded to the oppression by taking their spirit dance underground, operating a large smokehouse off the reservation on Guemes

Island, which at the time was isolated from the Anglo community. Between 1906 and 1912 the Swinomish along with other tribes appealed to the superintendent of the BIA to lift the ban on traditional Indian spiritual practices. The BIA consented on the condition that the ceremonies be limited to a public display of dance. Hence, the revived dances were referred to as "show dances" and open to the public. After the public left, however, traditional spiritual dances would occur in private. A large smokehouse, more than one hundred feet long and forty feet wide was built on the northern end of the reservation between 1912 and 1913 to house the event. The traditional smokehouse building contained bleacher-seating along the interior walls surrounding an area of open fires. Two or more fires would be constructed during ceremonies and the roof contained an opening that permitted exhaust smoke to escape the building. The building, however, was later lost in a fire.[11]

Despite the restrictions placed on their ceremonial practices, the people of the Swinomish Indian Tribal Community have retained many aspects of their traditional culture. A growing number of the current tribal membership now practices Seowyn. The importance of spiritual practice and its members' continuous connection to it are integral parts of the tribe's cultural identity.[12]

REBUILDING TRIBAL CEREMONIAL SMOKEHOUSES

Funds to construct the ceremonial smokehouse were secured during the late 1980s when the tribe entered into a cultural mitigation agreement with the city of Seattle. The city sought to renew its Federal Energy Resources Commission (FERC) license in order to continue to operate hydroelectric facilities on the Skagit River. During the process of applying for renewal of the FERC license, the city agreed to address environmental impacts to Swinomish fisheries and cultural resources that would result from the continued operation of its dams on the river. The settlement agreement provided for a sum of money to be allocated among the Swinomish and the two other tribes of the Skagit for purposes of mitigating the impacts to cultural resources.

With funding in place under the terms of the agreement, the Swinomish Indian Senate, the governing body of the Swinomish tribe, authorized project planning to commence for the construction of the smokehouse. An oversight committee was established that included representation from the Swinomish Smokehouse Organization, a nonprofit independent religious organization separate and distinct from the tribal government. A site was selected and dedicated within Swinomish Village, and proposals were solicited for architectural services. Project design objectives sought to incorporate the architectural principles of the Northwest longhouse, emphasizing the use of traditional building materials and construction techniques, and the employment of tribal members in each phase of project construction.

The design process revealed several potential problems that required reconciliation. Under the building standards that are typically enforced in most jurisdictions, it would be difficult, if not impossible, for the traditional smokehouse to meet strict building regulations. Because the building was intended to serve traditional spiritual practices, the design required, among other considerations, that the ceremonial floor be composed of earthen clay material with open fire pits. The tribe sought to achieve its traditional design goals while reasonably complying with building codes adapted from standard state building regulations. Those regulations were written without any consideration to traditional Native American ceremonial activities.

Project architects were careful to design the structure in a manner that cloaked many of the code-compliant structural features, including the installation of a system of lateral bracing hidden between the building's rough-sawn cedar-planked interior and exterior walls. Regulatory code variances were issued that permitted the structure to be constructed with an earthen floor necessary for the ceremonial dances. While the facility's public restrooms, kitchen, and dining areas were designed to comply with standard public safety and health regulations, the provision of two large open fire pits in the main ceremonial room presented a more difficult design challenge. After considering and rejecting an imposing chimney system, it was determined that fire protection could be adequately addressed by providing water standpipes and pressure hoses, fire extinguishers, and fire-suppression training for the smokehouse firemen responsible for maintaining the spiritually important burning of the fires.

A related concern were the potential health risks associated with the open burning of wood fires in the center of a ceremonial room that would accommodate more than 600 individuals. To address this concern, the project architects examined the design of other operable smokehouse structures in the region and consulted the literature on historic smokehouse structures in order to anticipate the probable air movement characteristics from the open flame and resulting exhaust smoke.

The structure was designed with a large roof-opening overhead that would permit escapement of smoke from the building. Several small openings were constructed beneath the bleacher seating to provide an exterior air supply source to the open fires. Since the building shell was not enclosed in an air tight vapor barrier, air intake through the building's walls was also thought to provide an adequate source of fresh air to the building's occupants.

FEATURES OF THE SWINOMISH SMOKEHOUSE

The Swinomish smokehouse is a two-hundred-foot long by seventy-foot wide cedar-planked frame structure and is divided into two sections by an open breezeway. The northern section contains the main ceremonial room. The southern section contains a kitchen, dining area, restrooms, and a "local room," used for private ceremonial activity. The main ceremonial area, a seventy-by-one-hundred-foot open meeting room with seven rows of bleachers around all four sides, was the focus of this study. There are exterior exit doors on the north, south, and east walls (see fig. 1). Smoke from the fires is vented at the roof peak. The roof is designed with a second, higher peak, which is situated three feet above the lower peak. The three-foot-high east and west vertical walls of the second peak are open to the outside and provide 400 square feet of roof area for ventilation of combustion products.

Floor Plan of Main Ceremonial Room

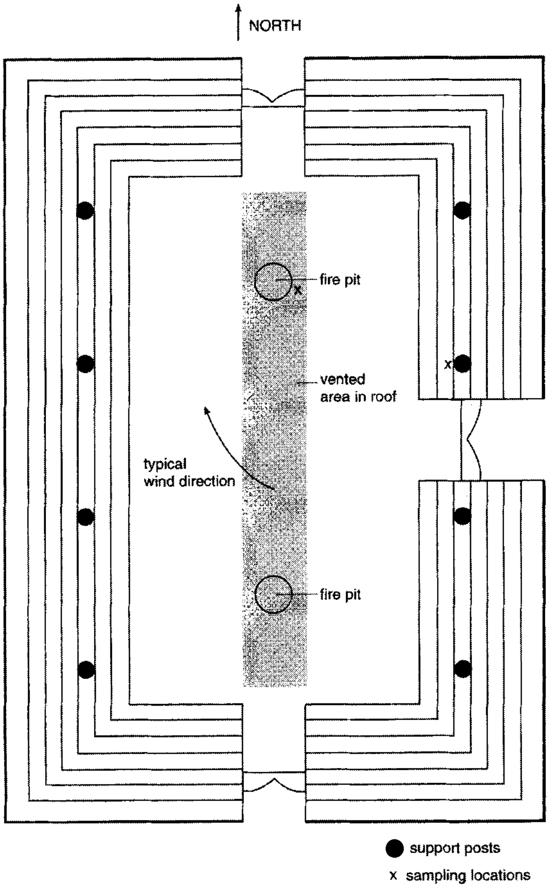

FIGURE 1.

The open fires play a vital role in the ceremony and provide the sole source of heat for winter gatherings. Two and occasionally three open fires are burned on the main floor during a ceremony. Traditionally, the fires were built on the clay dirt floor. Wood burned is usually Douglas fir and is sometimes seasoned depending on availability and cutting schedules. Approximately three cords of wood are burned for each ceremony, and ceremonies typically last about twelve hours. Wind direction is usually from the southeast during the winter ceremonial season.

ASSESSING HEALTH RISKS ASSOCIATED WITH COMBUSTION PRODUCTS IN SMOKEHOUSE CEREMONIES

The smokehouse construction commenced in the spring of 1991 and was substantially completed in 1992. The building was informally conveyed to the

Swinomish Smokehouse Organization for limited community use during the winter ceremonial season of 1993. During the first two winters of ceremonial events, several tribal members indicated the presence of a large amount of visible smoke that remained present throughout the evening's ceremony. Members complained of burning irritation in their eyes, and expressed concern for the health of occupants, particularly tribal elders suffering from respiratory health problems.

Recognizing that air quality data would be needed to determine whether a health risk existed, the Tribal Planning Department requested technical assistance to evaluate the risk potential from open fire emissions. The tribe called upon the resources of several agencies and the University of Washington to address their concern with smoke and carbon monoxide emissions from fires during smokehouse ceremonies.

To assess whether there was a basis for health concern, tribal staff obtained assistance from the Northwest Air Pollution Agency, a regional air pollution agency, and the Washington State Department of Labor and Industries, a state Occupational Safety and Health Administration (OSHA) agency, to sample indoor air for carbon monoxide, particulate, and polynuclear aromatic hydrocarbons (PAHs) during a ceremony in March 1997. Over a four-hour period, carbon monoxide was measured at 67 parts per million (ppm) parts of air. Respirable particulate was measured in three locations over the course of a twelve-hour ceremony at 3.9, 3.4, and 2.8 milligrams per cubic meter (mg/m^3) of air. No PAHs were detected. These measurements indicated that there was reason for concern about carbon monoxide and particulate exposure.

Potential adverse health effects from carbon monoxide exposure include reduced exercise tolerance, recurring heart pain (people with heart problems are more susceptible), headache, dizziness, light-headedness, and concentration, memory, and vision problems. During pregnancy, carbon monoxide poses a greater risk for the fetus than to the mother. With exposure to wood smoke particulate, health studies have found evidence of more shortness of breath and reduced lung capacity and greater chance of respiratory diseases such as bronchitis, pneumonia, and asthma. Adverse health effects from wood smoke can be more severe for children.[13]

Concerned that the direct application of air quality standards might disrupt the traditional Seowyn practices, the tribe sought nonregulatory technical assistance to assess the public and occupational health risk and to devise solutions that would not visibly interfere with the building's traditional features. The tribe requested assistance from the University of Washington's Environmental Health Department, which offers applied research to nonprofit and small businesses in matters of public health, to provide advice for improving air quality and test the effectiveness of implemented solutions. The tribe sought to improve air quality and to make the best use from heat generated from the fires to provide a safe and comfortable ceremonial environment. A criterion for any smoke control alteration to the building required that the appearance of the fire not be altered and that the installation of any mechanical equipment not be visible or audible in the ceremonial space.

The evaluation began by examining how wood combustion is likely to behave inside an enclosed building. This led to the development of a smoke emissions and air movement theory, which was later tested within the Swinomish smokehouse. The successful simulation test of the concept led to the design and permanent construction of smokehouse improvements, which were then tested for efficacy in reducing harmful exposures to occupants.

BACKGROUND ON WOOD COMBUSTION PRODUCTS

A fire that achieves complete combustion will produce less harmful combustion products. Combustion is dependent on the availability of oxygen to feed the chemical reaction and the type and water content of the fuel source. When adequate oxygen is available, the chemical reaction primarily produces carbon dioxide (CO_2). The absence of sufficient oxygen produces more carbon monoxide (CO). In low concentrations, carbon dioxide is considered to be a nontoxic compound. Carbon monoxide, on the other hand, may pose serious detrimental health effects.[14]

The temperature of the fire is dependent on oxygen supply and the water content of the wood. A fire with adequate oxygen will burn hot. Wet wood will burn at a lower temperature because a large amount of energy is expended to evaporate the water before the wood can burn. A fire burning at a lower temperature will smolder, producing more smoke. Complete combustion from a hotter fire will result in smaller amounts and sizes of particles. Different wood species have different chemical compositions depending upon their resin content. A wood with a high resin content will produce more smoke. Alder, for example, has a considerably lower resin content than Douglas fir and would therefore burn with less smoke.[15]

The movement characteristics of the combustion products within the smoke plume as well as the movement that occurs when the plume reaches the roof are both important considerations for effective smoke removal. As the column rises it expands as it mixes with the cooler ambient air of the larger room.[16] As it reaches the roof, it will exit through the vent openings if there are no conflicting air or temperature patterns to interfere with that movement. Interfering air patterns can be caused by several factors: (1) wind entering at the roof vent openings; (2) mixing of the plume with colder room air, resulting in a wider, cooler plume and cooling of the plume as it mixes with colder outside air near the roof vents; or (3) air currents produced by replacement air entering the building at the roof vents.

SMOKE CONTROL CONCEPT—SIMULATION TEST

If additional oxygen is provided to a fire, it will burn more efficiently. One way to add oxygen could be to feed air to the fire by installing a duct below the fire. The heat from the fire would create suction within the duct to pull air from outside the building. This concept was independently suggested by University of Washington staff and by tribal community members who were aware that this approach had been used in other smokehouses. To test this

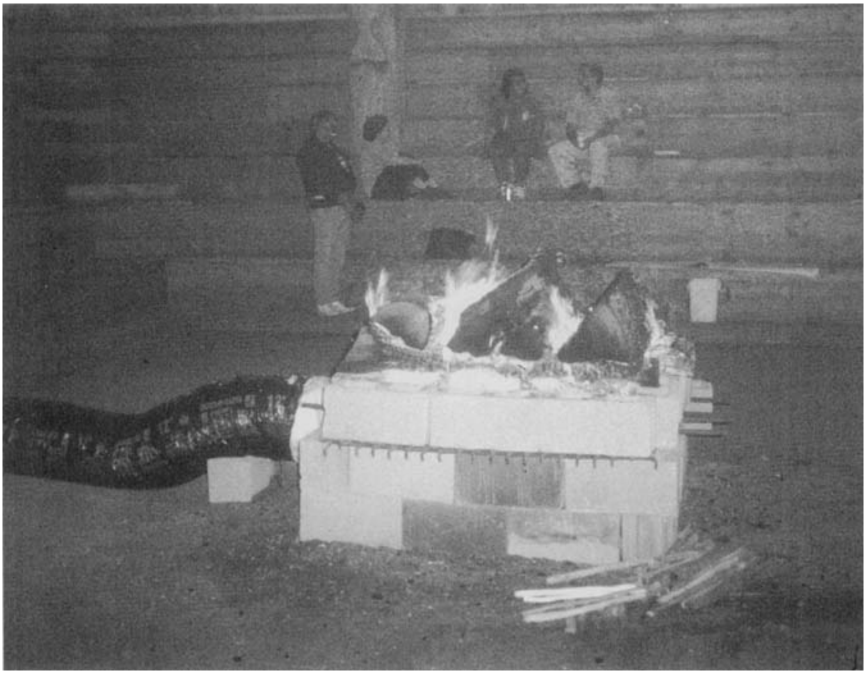

PHOTO 4. *Test fire pit with outdoor air supply.*

concept, a temporary fire pit was built on the clay floor using a concrete block base covered by a metal grate and located at the northern-most fire pit location. A one-foot-diameter duct ran from the base of the pit to the north building entrance. Plastic sheeting covered the north entrance, blocking outside air from entering the building except through the duct.

A series of tests were conducted to determine the concentrations of smoke and CO produced by the single open fire with the air supply duct in place (measure 1) and without the duct in place (measure 2). The testing was next completed with two fires burning without the duct (measure 3). The fourth test monitored emissions with the duct in place for one of the two fires (measure 4). Area samples for respirable particulate and area samples for carbon monoxide were collected using data logging instrumentation. Air velocity within the duct was measured to determine the volume of air that was naturally pulled through the duct.

The wood burned for this test was seasoned, dry fir. The fire was smaller than what is typically burned, containing two and occasionally three layers of four-foot long split logs. A typical ceremonial fire contains three to four layers of split logs.

Carbon Monoxide Measurements

Carbon monoxide concentration was measured in three locations: (1) five feet south of the fire pit, three feet above the floor; (2) on the east wall sitting on the bleacher at support post; and (3) hanging from the support post ten feet above the bleacher. All carbon monoxide concentrations measured were markedly lower than concentrations measured during the March 1997 ceremony when a four-hour time-weighted average of 67 ppm was recorded. Test results were compared to the allowable Environmental Protection Agency (EPA) air concentration of 9 ppm averaged over eight hours.

Concentrations varied over the course of each test as shown in figure 2. Carbon monoxide concentrations close to the fire remained relatively stable. Carbon monoxide concentrations were the lowest ten feet above the bleacher area on the building's posts, while concentrations at the bleacher built to the highest levels. If the duct had not been added to one fire, the buildup, which reached a high of 9 ppm, may have gone significantly higher. The bleacher location may be experiencing the greatest buildup because the gas plume rises toward the roof vents, but as it begins to mix with the room air it widens and cools. Smoke on the perimeter of the plume follows the cold air along the exterior wall. In the March 1997 test the monitor was located on the wall directly above the bleachers.

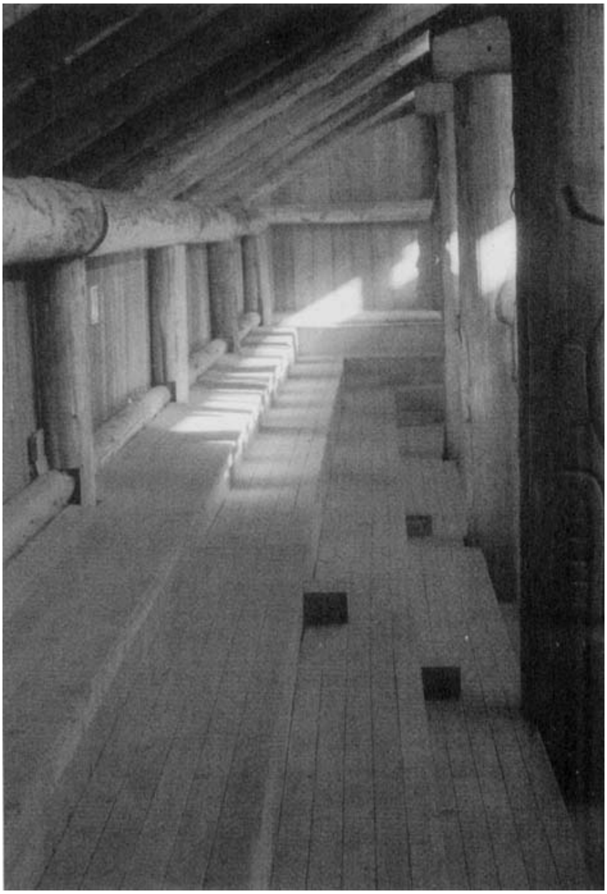

PHOTO 5. *Interior of the main room: upper bleacher seating area.*

Figure 2 illustrates the effect of the four different tests on carbon monoxide exposure. With one fire connected to the air supply duct (measure 1), carbon monoxide concentration was found to be low and stable. When one fire was burned without connection to the air supply duct (measure 2) the concentration began to rise, particularly at the bleacher location. When a second fire without connection to the duct was added (measure 3), CO levels rose at both the bleachers and at the high post locations. When the duct was reintroduced to the north fire (measure 4) (samples were collected on the north side of the building), levels immediately began to drop. CO concentrations averaged over the testing period (time-weighted average or TWA) were 2.6 ppm at the fire and 1.1 ppm high on the post. Both were below the EPA standard of 9 ppm.[17]

Carbon Monoxide Concentrations During Smoke Control Concept Simulation Test

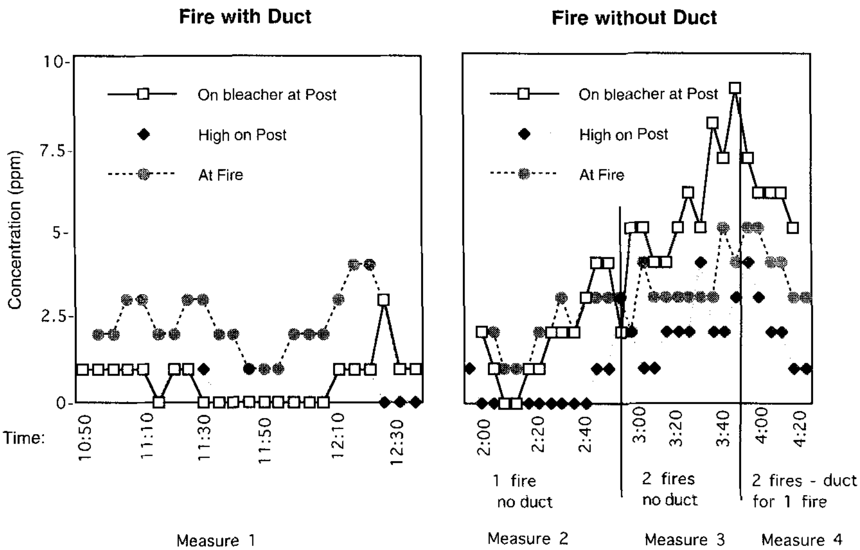

FIGURE 2.

Particulate Measurement

Respirable particulate samples were collected at six locations on the west, north, and east bleachers and on four individuals participating in the testing. Some samples were below the EPA respirable particulate (PM10) standard of 0.15 mg/m^3. Table 1 shows a comparison of samples taken at two different locations for a ducted and nonducted fire. When the air supply duct was not used, particulate levels were two times higher. There was a marked difference in concentrations between the east and west bleachers. It was suspected that this may be due to wind through the vents blowing smoke into the northwest corner of the building.

The particulate samples collected during concept testing were an average of ten times lower than samples collected during the March ceremony where the mean concentration was 3.4 mg/m^3. The March samples were collected on the support posts, approximately eight feet above the bleachers, while the September samples were all collected on the bleachers, the location where most people would be exposed.

Table 1
Respirable Particulate Concentration During Concept Tests (September 1997)

Location	Concentrationin mg/m^3 without Duct	Concentration in mg/m^3 with Duct
West area—top bleacher	1.1	0.6
East area—top bleacher	0.04	0.02

Observation of Smoke Plume

Smoke emanating from the fire and its rise to the peak of the roof was visually observed. On the day of the test, the wind direction was primarily from the north, according to weather data gathered at the tribe's rooftop weather station. The fire connected to the air supply duct burned clear and hot. Very little smoke could be seen coming from the edges of the flame. The combustion product column moved quickly to the roof peak. At the peak, the smoke became turbulent and swirled around at the peak rather than exiting immediately. Initially, a small vent hole at the north end of the roof peak was open. There was a particularly turbulent area at the north end of the peak. When the north vent hole was covered, the turbulence disappeared.

Without the air duct, the fire did not burn as clearly. More smoke could be observed at the edges of the flame. The smoke column moved more lethargically toward the peak, and there appeared to be a larger turbulent area at the peak, extending at times below the second peak. The observed difference between fires was dramatic when two fires were burning at once, with only one of the fires connected to the air supply duct.

The fire connected to the air supply duct burned hotter and its smoke column appeared to maintain enough heat to move directly upward toward the roof vents. This condition contrasted with the fire that was not connected to the air supply duct whose smoke column tended to mix with ambient room air and was carried back down along the cool exterior walls along the bleachers (fig. 3). As a result of the observation of the turbulent area at the peak and the tribe's concern about the effect of wind blowing through the vents, it was concluded that operable shutters should be installed and tested.

Makeup Air Flow

On the day of testing, airflow was also measured at the east entrance during typical fire burning. An average airflow to support each fire was calculated at approximately 1,000 cubic feet per minute from these measurements. It was also observed that the airflow tended to increase significantly during the period when wood was added to the fire when the fire was raging. When the fire was burning hotter and faster, more ambient room air would be pulled into the very hot smoke column and be drawn out of the building at the roof vent. The phenomenon of drawing ambient room air into the smoke column is known as *entrainment*. This entrained air must also be factored into the airflow calculations since air will otherwise be drawn into the building from open cracks or crevices and doors to replace the air exiting through the smoke vents. Test participants reported noticing cold air coming through crevices in the east bleachers and noticed strong drafts whenever the fire was burning hottest when wood was added.

POSTCONSTRUCTION FIRE PIT TEST

The fire pit simulation test results were presented to the tribe and to members of the smokehouse organization. Tribal members understood the potential health risks from continued exposure and strongly urged the tribe to install permanent air supply ducts at both fire pits. With funding secured from an EPA air quality demonstration grant, fire pits with permanent air supply ducts to the exterior of the building were constructed at both the north and south

Smoke Dispersion—A Portion of Cooler Plume Follows Roofline into Bleachers

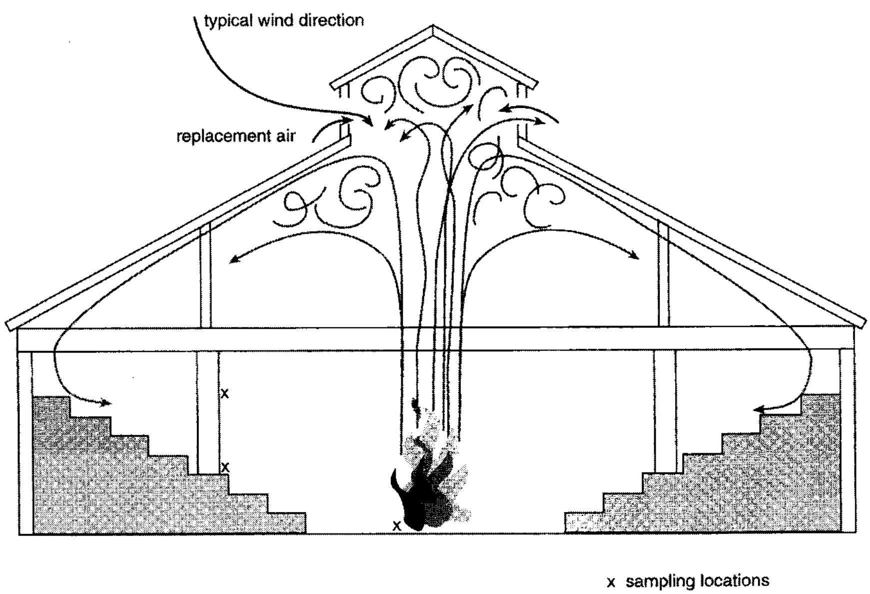

FIGURE 3.

fire pit locations. Fire pits are six-foot-diameter precast concrete vaults that extend three feet below ground level in order to accommodate falling ash and a two-foot-diameter concrete air duct. A six-foot-diameter metal grate placed at floor level covers the top of the concrete vault and provides a surface for firewood while allowing direct air feed to the fire from the duct extending outside the building. Each fire's duct extends to the exterior of the building below the floor and is protected from rainfall by roof extensions. An exterior metal grate covers each duct's air intake vault. The sunken fire pits and ducting infrastructure are not visible from public view, except for the grates over the pits and the exterior air supply vaults. Upward swinging shutters were also installed on all opening portals for the east roof vents and on two of the six portals for west roof vents. Some roof vents on the leeward (west) side were left opened to ensure that some venting will always occur. The shutters can be opened or closed by the firemen from the upper bleachers via a simple rope-and-pulley system.

After completion of construction during the autumn of 1998, a second air monitoring session was conducted to evaluate the effect of the new fire pits and shutter system on reducing air pollutants in the smokehouse. Carbon monoxide and respirable particulate levels, and air velocity at the duct entrances were measured. The shutter system was evaluated by visual observation of smoke movement at the roof peak. The wood used for the fire on this day was wet but cured and had been stored outside unprotected from the rain. Over

Photo 6. *Installation of air inflow pipe to fire pit*

the test period of approximately four hours, one cord of wood was burned at both fires. This would be equivalent to the size of a typical fire during a twelve-hour ceremony when three cords are normally consumed.

Carbon Monoxide Measurement

Carbon monoxide was measured in two of the same locations measured during the September tests: (1) five feet from the north fire pit; and (2) on the east bleacher at the support post. Carbon monoxide direct-reading instruments with data loggers were used.

Carbon monoxide airborne concentrations at the two sample locations are shown in figure 4. Early in the test period an incident occurred that demonstrated the effectiveness of the ducting in reducing CO. Air testing began when the north fire was burning and the duct grate outside the north door was open, allowing airflow to the fire. At 11:15 A.M. staff conducting the test went outside and found that the wind had blown a section of plywood over the duct grate to block the air supply to the north fire. The plywood was removed. The blocking of the air supply to the north fire caused the high peak seen in figure 4 early in the test. When the air supply duct was unblocked, CO concentrations dropped quickly. It is unknown how high the carbon monoxide concentration may have gone if the duct had remained blocked.

Another noteworthy observation from figure 4 is that the addition of new wood affected CO concentrations. When wood was first added to the fire, the

Carbon Monoxide Concentration During Postconstruction Fire Pit Test

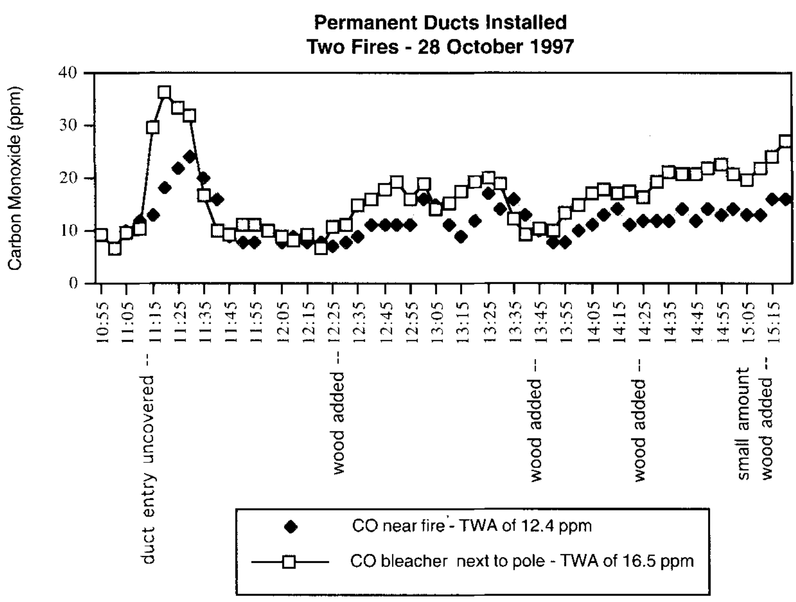

FIGURE 4.

testing staff observed that the smoke seemed to clear out immediately. Because of this observation, the time when wood was added to the fire was noted to see if there was a relationship to carbon monoxide levels. When wood was added, the fire burned vigorously, the fire temperature rose, and the smoke column rushed to the roof. One explanation may be that more ambient room air became entrained in the hotter smoke column thereby pulling more of the smoky air out of the building as the hotter air plume sought the cooler, lower-pressure air outside the roof vents. The carbon monoxide concentrations gradually rose at the end of the test (fig. 4). Without the addition of more wood, the fire smoldered, possibly producing more CO.

To understand how the carbon monoxide dispersed within the smokehouse, a direct-reading CO monitor was carried throughout the bleachers to identify areas where the CO concentration built up. In the upper portion of the bleachers the concentration was higher than at lower portions of the bleachers and the northwest corner and north end generally showed higher concentrations. This spatial dispersion was observed several times throughout the postconstruction test and helped determine how best to balance the openings of the shutters.

Particulate Measurement

Respirable particulate was measured on the bleachers and at eight feet above the bleachers at three different support posts so that results could be compared to the March ceremony test. Many of the respirable particulate samples exceeded the EPA respirable particulate limit of 0.15 mg/m^3.

Samples eight feet up on the support posts had higher particulate concentrations than samples taken on the bleachers during the same time period (Table 2). The bleacher samples would be more representative of the exposure received by persons sitting in the bleachers. Samples collected during September concept tests were considerably lower than the initial March or post-construction October tests. In September, dry, seasoned wood was used and smaller fires were burned. Although it is not possible to conclude whether dry wood or small fires were more important in reducing the exposure concentration, it was observed that the dry wood used in September appeared to burn cleaner than the wetter wood used during the October test when the wood was exposed to rain.

Table 2
Respirable Particulate Mean Concentration (mg/m^3)

Test	Concentration at Bleacher	Concentration at Support Post
March: ceremony	NS	3.4
September: concept test	0.4	NS
October: installation test	1.3	2.6
NS=no sample		

Observation of Smoke Plume

For the October test the outside temperature was cooler and the prevailing wind stronger than during the September test. The wind was from the southeast—the typical wind direction for the winter season. The air seemed smokier during the October test than during the September test. Firemen and other observers who had not seen the September test reported reduced smoke over typical ceremonial conditions. The smoke plume did not appear to move with as much speed as during the September test. The wet wood probably caused a cooler fire, producing smoke that would not rise as quickly.

At the beginning of the October test, the same turbulent smoke pattern was seen at the roof as during the September test. All shutters were open. The wind from the southeast appeared to blow some of the smoke plume below the second peak and into the northwest corner of the building. Various shutters were closed to determine which shutters should be closed to remove the turbulent smoke at the roof and reduce the CO levels in the bleachers. The shutter configuration most effective in eliminating the turbulent pattern and movement of smoke into the northwest corner was to close all but the middle two shutters on the east wall and leave all the west roof vents open.

FINDINGS AND RECOMMENDED ACTION

The air ducting to the fire pit notably reduced carbon monoxide concentrations in the smokehouse by providing more oxygen to feed the fire. CO concentrations were higher at the bleacher level than at the fire level. With dry, well-seasoned wood, CO levels were below the EPA standard for CO. With seasoned wood damp from rain exposure that resulted in cooler fire temperatures, CO levels were above the EPA standard. The upper north bleachers have somewhat higher levels of carbon monoxide than other parts of the building. This may be due to the direction of the wind entering through roof smoke vent openings.

Airborne particulate levels were also reduced with the introduction of additional air supply through the ducting system, although the reduction was not as great as the carbon monoxide reduction. Concentrations were often above the EPA standard. During the first testing session with dry, seasoned wood and one fire, levels were lower than for the second test using wetter wood and two fires.

Better control of particulate may be achieved by warming the air above the bleachers to discourage the hot air plume from mixing with the cold air above the bleachers. With warmer air above the bleachers, the hot air plume will tend to seek colder outside air. Stringent control of particulate will not be achievable in a large building with open fires. The only way to strictly control particulate is to install a chimney. The shutters were effective in eliminating turbulent air patterns at the peak, which interfere with movement of the smoke plume out of the roof vents.

Great improvements were achieved in air quality with the addition of the ducting system and shutters. Two areas where additional improvements would enhance air quality and comfort in the smokehouse are through the consistent use of dry, well-seasoned wood and through the introduction of a heated makeup air supply to replace the air volume exiting the building with the smoke plume.

Use of Dry Wood

The difference in air quality measurements between the September and October tests is partially due to the difference in dryness of the wood used on those two test days. Carbon monoxide is approximately four times higher in October and particulate is approximately two-and-a-half times higher than during September tests. The September firewood was very dry and well-seasoned. Swinomish Smokehouse Organization volunteers have since built a firewood shelter outside the smokehouse to protect cut wood from the rain.

Addition of Makeup Air

A prewarmed makeup air supply would encourage the quicker exhaust of the smoke plume through the roof vents. A heating/ventilation system could be installed out of sight below the bleachers. The effects of improved ventilation

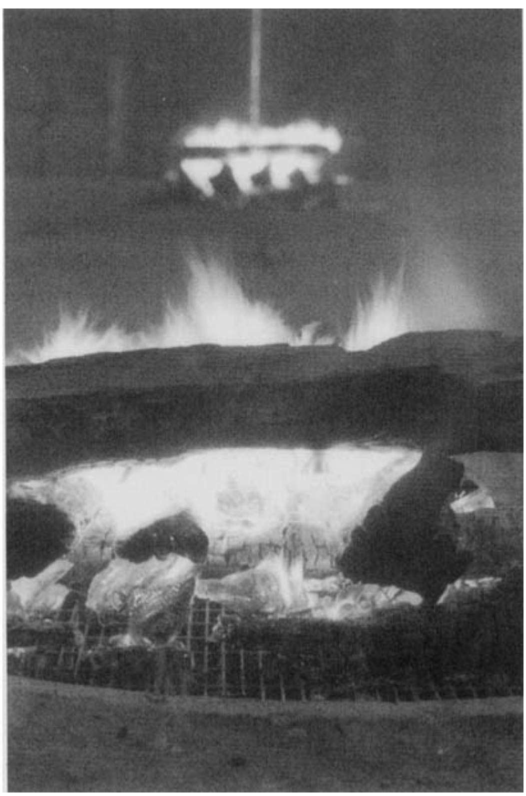

Photo 7. *Fire over air supply grate*

should reduce the presence of smoke in the bleachers and on the main floor, and improve temperature comfort for smokehouse ceremony participants and observers.

CONCLUSIONS

Tribal governments are quickly advancing their own development by constructing new facilities intended to meet community needs, and by enacting their own regulations to control the standards of development. While relying on building codes and environmental quality standards that are often adapted from federal or state agencies, tribes should carefully anticipate the potential

Chronology of Project Activities

Date	Event/Result
June 1991	Construction of smokehouse building commences financed with cultural mitigation funds under FERC relicensing procedure
November 1993	Smokehouse is formally conveyed to the smokehouse organization; first winter ceremonial season occurs
March 1995	Smokehouse members report persistence of visible smoke from open fires and concern about respiratory health risks
June 1996	Tribe requests technical agency assistance to evaluate indoor air quality conditions
March 1997	High levels of carbon monoxide and polynuclear aromatic hydrocarbons (PAHs) detected due to incomplete combustion from wood fires
May 1997	Tribe requests technical assistance from University of Washington to develop solutions to improve indoor air quality
August 1997	Experimental fire pits constructed with direct air supply to open fires; simulation tests measure markedly lower concentrations of carbon monoxide, airborne particulate, and improved exhaust plume
September 1997	Permanent air inflow pipes installed to underground fire vaults; roof vent shutters installed over portals in roof to control exhaust air flow
October 1997	Carbon monoxide and particulate levels fall within acceptable federal and tribal standards

FIGURE 5.

for conflict when applying contemporary development standards to traditional reservation activities—in particular when they may impair the attainment of cultural priorities. In the example of the Swinomish Tribal Community, the construction of the smokehouse not only resulted in the successful resurgence of community cultural traditions, but also introduced a new form of public health risk to its community. Successful tribal community development can be measured by a tribe's ability to attain its community's objectives without compromising other health, social, environmental, or cultural objectives.

The Swinomish sought technical knowledge from outside experts from the University of Washington and federal and state agencies. The successful outcome from the interagency partnership was largely attributed to the willingness of each participant to respect the necessity to avoid any disruption of the traditional ceremonial activities. In this example (see fig. 5), the use of sophisticated air-quality monitoring equipment and air movement theory helped the community better understand the health risks associated with the use of open fires during the winter ceremonies. The corrective improvements were designed jointly by technical advisors and community members as an acceptable low-technology solution based on traditional smokehouse design concepts. The process also fostered a greater sense of community self-reliance by involving the community in each phase of the project.

The Swinomish experience demonstrates how a community can successfully take self-help actions to improve its own environmental conditions. Provided with new information about the risks associated with their traditional ceremonial activities, the smokehouse organization quickly mobilized its members to fully participate in the community improvement project. Their expanded understanding about fire-burning dynamics fostered a strong working relationship with tribal officials and technical experts that resulted in acceptable alterations to the smokehouse building. Members participated in monitoring air quality during the testing periods, agreed upon alternative corrective measures, and comprised the work crew that constructed the permanent improvements. Smokehouse members responsible for the ceremonial fires also instituted new procedures for building and maintaining the open fires and managing air current dynamics by adjusting the roof shutter system to correspond to conditions inside and outside the smokehouse. Finally, the understanding about the importance of a well-seasoned, dry firewood supply prompted other smokehouse members to construct an exterior wood storage facility and secure a long-term supply of suitable fuel material.

ACKNOWLEDGMENTS

The authors wish to extend their appreciation to the Swinomish Indian Tribal Community, the Swinomish Smokehouse Organization, and the several agencies that cooperated in this project. Our appreciation is especially extended to Swinomish Senate leaders Chester Cayou Sr., Robert Joe Sr., Barbara James, and Brian Cladoosby, tribal chairman. Swinomish Smokehouse Organization members Maxine Williams, Mike Porter, Chester Cayou Jr., Greg Topaum, Grover Topaum, and Bruce James supported the effort from initial planning through construction. Tribal planning staff included Larry Campbell, Ken Edwards, and Lauren Rich. Technical assistance was received from Bob Parker, Washington State Department of Labor and Industries, Dave Blake, Northwest Air Pollution Authority, Steve Guffey, University of Washington, and MaryBell Austin and Regional Thompson, United States Environmental Protection Agency Region Ten Air Program.

NOTES

1. See Alexandra Harmon, *Indians in the Making: Ethnic Relations and Indian Identities around Puget Sound* (Berkeley: University of California Press, 1998).

2. Natalie Roberts, "A History of the Swinomish Tribal Community" (Ph.D. diss., University of Washington, 1975), 338.

3. See Robert A. LeVine and Donald T. Campbell, *Ethnocentrism: Theories of Conflict, Ethnic Attitudes, and Group Behavior* (New York: John Wiley and Sons, Incorporated, 1972).

4. Traditional spiritualism also continued through the rise of the Shaker movement beginning around 1881 or 1882. See G. P. Castile, "The Half-Catholic Movement: Edwin and Myron Eells and the Rise of the Indian Shaker Church," *Pacific Northwest Quarterly* 73 (1982): 165–174.

5. Roberts, "History of the Swinomish Tribal Community."

6. 25 USC sec. 461-479. Also known as the Wheeler-Howard Act, this act represented a new approach to tribal sovereignty and a commitment to protect Indian cultures.

7. 92 Stat. 469, 1978 (codified in part 42 USC sec. 1996). This act explicitly recognizes the importance of traditional Indian religious practices and directs all federal agencies to ensure that their policies will not abridge the free exercise of Indian religions.

8. Roberts, "History of the Swinomish Tribal Community"; and Marian W. Smith, "The Coast Salish of Puget Sound," *American Anthropologist* 43 (1941): 197–211.

9. Wayne Suttles, "PostContact Culture Changes among the Lummi Indians" *British Columbia Historical Quarterly* 18 (1951): 29–103.

10. For a broader review of the effect of smallpox and other introduced diseases, see George M. Guilmet et al., "The Legacy of Introduced Disease: The Southern Coast Salish" *American Indian Culture and Research Journal* 15:4 (1991): 1–32.

11. For a complete review of the history of oppression to Swinomish traditional spiritualism, see Roberts, "History of the Swinomish Tribal Community."

12. Larry Campbell, member of the Swinomish Smokehouse Organization and community liaison with the Swinomish Planning Office, conversations with authors, LaConner, Washington, June–September 1998.

13. K. Morris et al., "Wood-Burning Stoves and Lower Respiratory Tract Infection in American Indian Children," *American Journal of Diseases of Children* 144 (1990): 105–108; US National Library of Medicine, Hazardous Substances Data Bank (HSDB) 903: Carbon Monoxide, 97:2 (May 1997); and T. Larson and J. Koenig, "Wood Smoke Emissions and Noncancer Respiratory Effects," *Annual Review of Public Health* 0163-7525/94/0510-0133 (1994): 133–56.

14. National Fire Protection Association, "Wood and Wood-Based Products," sec.

4, chap. 2 in *Fire Protection Handbook* (Quincy, Mass.: National Fire Protection Association, 1981); US National Library of Medicine, Hazardous Substances Data Bank 903.

15. National Fire Protection Association, *Fire Protection Handbook.*

16. See E. G. Butcher and A. Parnell, *Smoke Control in Fire Safety Design* (London: E. and F. N. Spon., 1979); National Fire Protection Association, *Fire Protection Handbook.*

17. Code of Federal Regulations 40, parts 50.6 "Particulate Matter" and 50.8 "Carbon Monoxide" (July 1997).