Traditional Tribal Subsistence Exposure Scenario and Risk Assessment Guidance Manual

Three Rivers, Idaho (Courtesy of Barbara Harper)

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A BACKGROUND AND CONSIDERATIONS

A.1 PURPOSE AND NEED

This document provides a framework for evaluating risks in Indian Country. Under the paradigm used by the federal government (NRC 1983) human health risk derives from the combination of human exposure to contaminants and the toxicity of the contaminants. In the risk assessment process, contaminant data is gathered to estimate present or future exposures to determine if resources are, or could become, harmful to the health and well-being of a community.

Environmental contact rates are used to estimate contamination doses to exposed individuals via inhalation, ingestion of food and water, and dermal absorption during a defined set of activities in particular locations (Figure 1). Conversely, the degree of allowable contamination required to keep human health risks below a specified risk level can also be calculated.

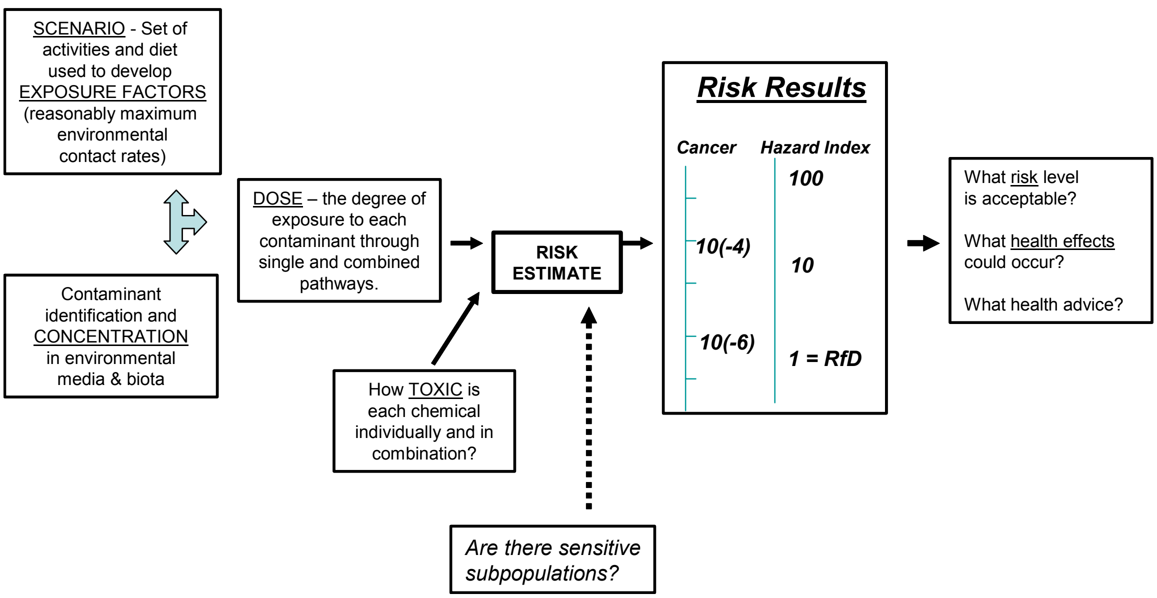

Figure 1. Schematic of the Risk Assessment Process

Exposure scenarios are used in the risk assessment process to describe how people come into contact with natural resources through direct exposure pathways (e.g., air, water, soil) and indirect pathways (food) (Figure 2). The risk assessment estimates doses of each contaminant, then estimates the health risks for each contaminant. Risks are summed is a variety of ways (EPA 2003).

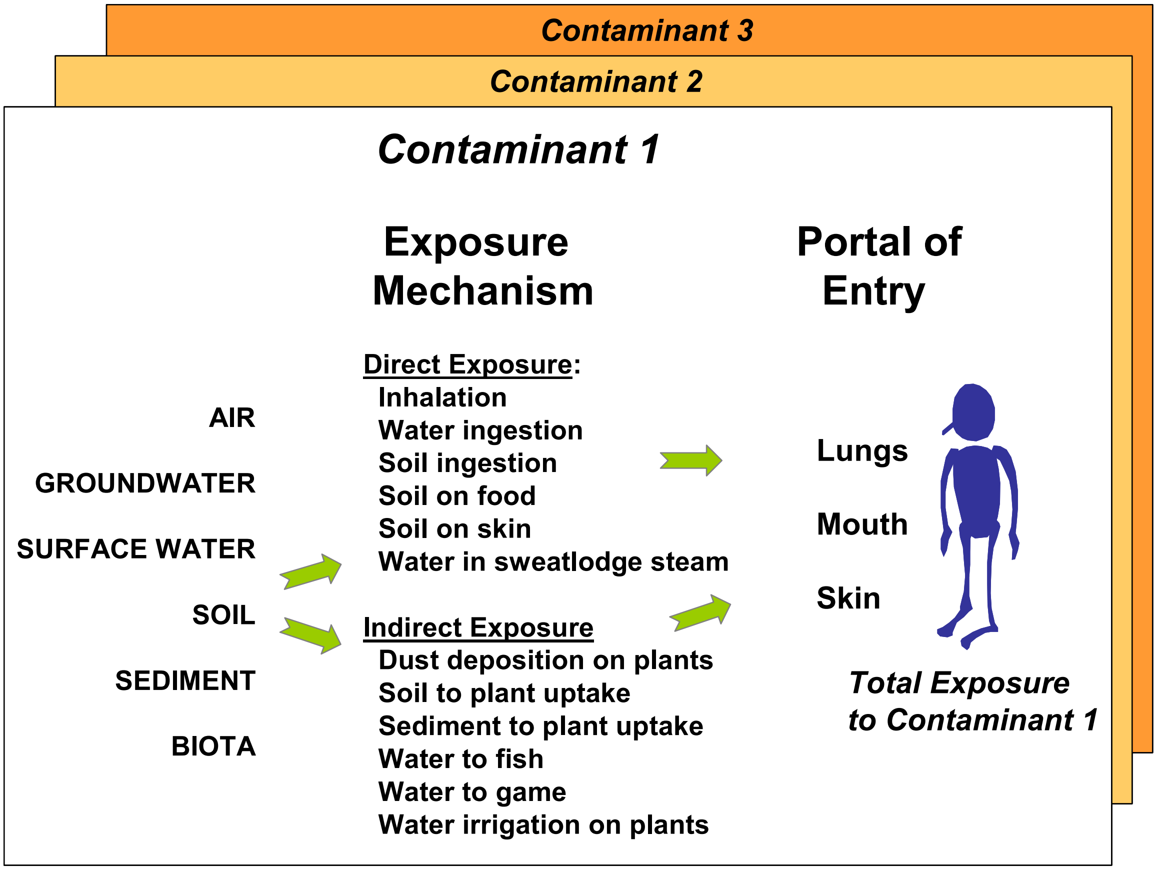

Figure 2. Exposure Pathways Evaluated in the Risk Assessment Process

In order to estimate doses and risks, we must understand how people interact with the environment. All cultures depend on environmental quality for their survival, but the health of tribal communities and their individual members is so intertwined with their environment as to be inseparable. This leads to quite different perspectives on the risk assessment process and the role of risk in making environmental and health decisions (Figure 3). Nevertheless, the conventional perspective and the tribal perspective must be brought together in order to make risk-based decisions that protect tribal health and the environment. In most cases conventional methods can be modified to a greater or lesser extent.

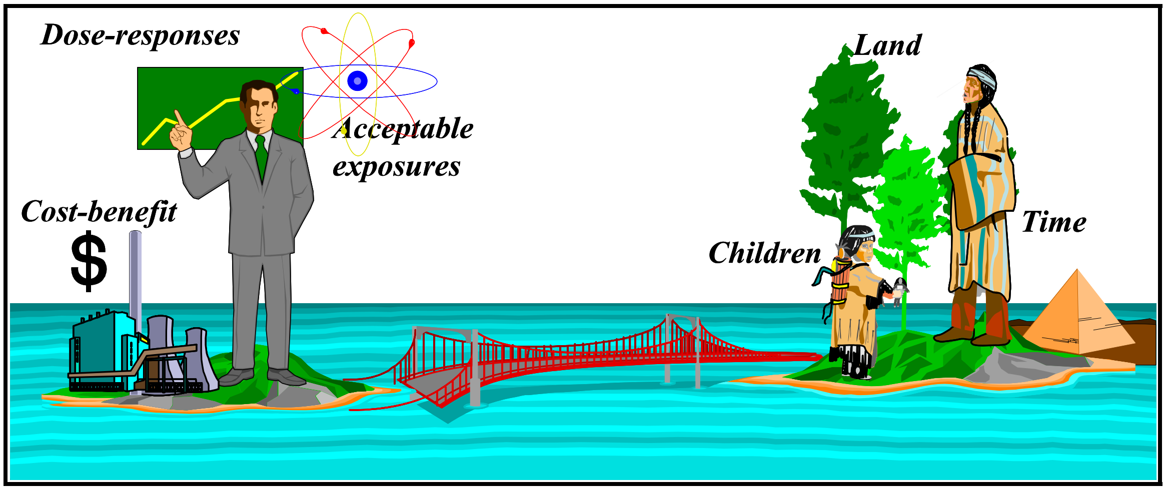

Figure 3. Bridging Perspectives

In the conventional assessment of risk, exposures to contaminants are the focus of the process. The doses of each contaminant are estimated by assuming daily ingestion rates (in units of grams/day or gpd) of a particular biotic or abiotic resource, such as fish, for a particular exposure period. Risks for each contaminant, including mercury, are calculated using conventional equations. The Average Daily Doses (ADD) of each contaminant incurred through each exposure pathway is calculated using the following equation:

$$ADD = (C \times IR \times EF \times ED) / (AT \times BW)$$

where:

C	=	concentration of chemical in the sample (mg/kg)
IR	=	ingestion rate of each sample (mg or grams per day)
EF	=	exposure frequency (days per year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time (days)

The factors of ingestion rate, frequency, and duration are paramount to estimating risks. Because exposure evaluation methods were developed to reflect exposures received in urban or suburban situations (Figure 4), tribal exposure pathways may not be recognized at all and/or not understood well enough to realize the diversity and intensity of environmental contact, and therefore the frequency and duration of exposure (Figure 5). The first question, then, is how to recognize whether tribal members use the affected area or resources.

How does a federal agency know when tribal resources and health are affected?

The first question is, “Are tribal resources affected?” The second question is, “Are tribal members exposed?”

- Do tribal members use resources from the impacted zone?
- Do tribal members live in or visit the impacted zone?
- Is a tribe a Natural Resource Trustee of the affected resource, are there lands held in trust for tribes, or are there public lands which tribal members use?
- Is the affected area within a tribal historic area, a traditional cultural property, or a tribally important landscape?
- Is the affected area linked ecologically, culturally, visually, or hydrologically to tribal resources or uses?

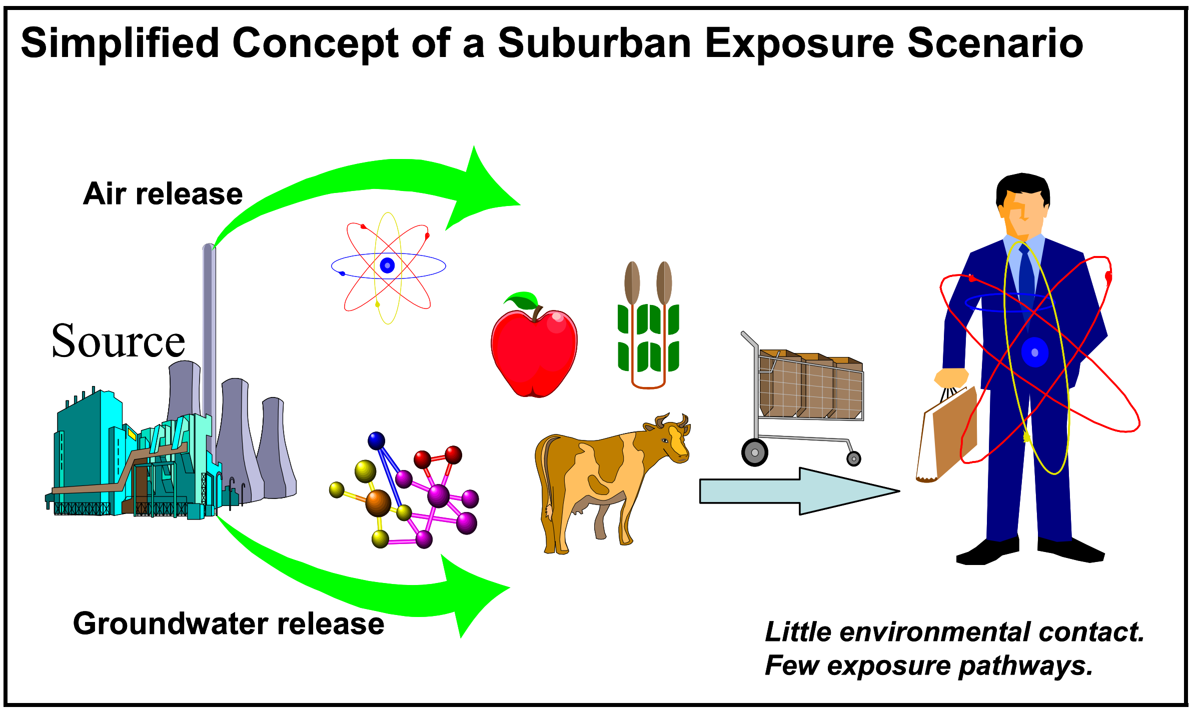

Figure 4. Conventional Exposure Pathways Based on an Urban or Suburban Lifestyle

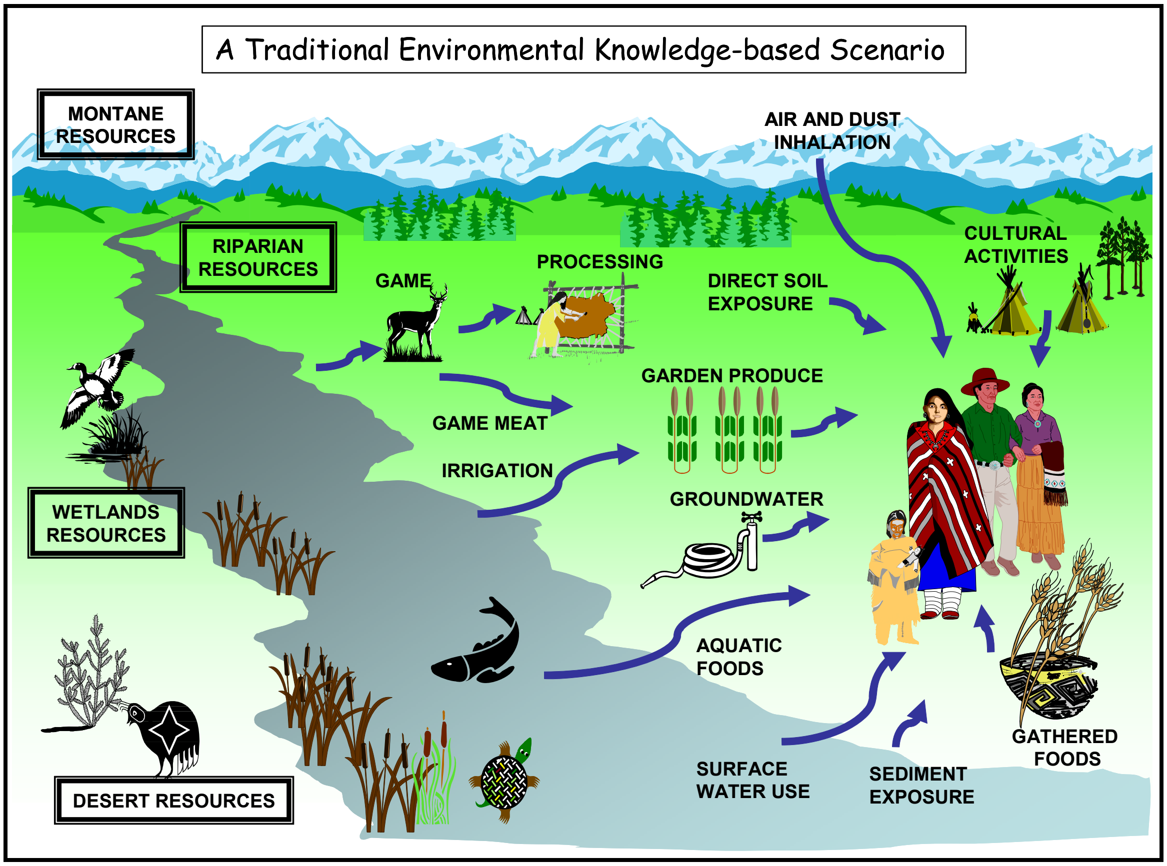

Figure 5. Tribal Exposure Pathways Based on a Subsistence Lifestyle

A.2 VALUES, QUALITY ASSURANCE, AND INFORMED CONSENT

Native American ties to the environment are much more complex and intense than is generally understood by risk assessors (Harris 1998, Oren Lyons[1]). Many tribal cultures are essentially synonymous with and inseparable from the land and its resources. The quality of the socio-cultural and eco-cultural landscapes is very important, as is the quality of individual natural resources or ecosystem integrity. To many American Indians, individual and collective well being is derived from membership in a healthy community that has access to, and utilization of, ancestral lands and traditional resources. This wellness stems from and is enhanced by having the opportunity and ability to live within traditional community activities and values. Tribal elders draw upon an ancient storehouse of environmental knowledge that has been built over thousands of years using involved environmental observation and teaching younger generations how to live and behave.

This lifestyle is resilient and has persisted through floods, droughts, cataclysms, upheavals, and warfare. This environmental management science has long been

[1] http://www.ratical.org/many_worlds/6Nations/OLatUNin92.html; http://www.youtube.com/watch?v=hDF7ia23hVg.

codified into traditional tribal laws for daily living and for religious practice. The traditional environmental management science, which guided this eco-cultural system, was eminently practical. Language and ethics were highly developed, laws were codified, governmental structures were strong yet flexible, crime and disease were low, and food was adequate. The lifestyle evolved with a confidence that through wise environmental management there would always be enough resources and food for the community over time, even if there were lean years. Generosity to the community was held in the highest esteem. A person's failure to take care of the people and the environment was considered wrong, and the accumulation of excess resources was seen as antisocial, especially if it was at the expense of others through waste, displacement, theft of property, or rights of ownership, access or use. These traditions, each of which is unique to a particular tribe and its homeland, are woven into complex tapestries that extend from far in the past to long into the future. All of the foods and implements gathered and manufactured by the traditional American Indian are interconnected in at least one way, but more often in many ways. Therefore, if the link between a person and his/her environment is severed through the introduction of contamination or physical or administrative disruption, the person's health suffers, and the well being of the entire community is affected.

After this continent became populated by Indo-European people and their form of infrastructure, many native governments which had survived slavery, kidnapping of children, epidemics, and federal biological and military extermination and sterilization policies signed treaties with the United States government. In these treaties the tribes ceded the title to almost all of their homelands to the United States but reserved guaranteed rights to hunt, fish, gather plants, and pasture livestock "for as long as the grass shall grow and the rivers flow." The intent of the treaties was, in part, to protect the natural resources on which the native lifestyles and religion depend, although the right to religious freedom has only recently been reestablished and is still only partially protected. Although every treaty has been broken to a greater or lesser extent by the United States, treaties are still the supreme law of the land under the United States Constitution.

Additionally, a long history of case law has upheld the obligations of the federal government as a Natural Resource Trustee to protect natural resources for all citizens. Under CERCLA and the Clean Water Act, tribes are specifically identified as trustees of natural resources both on reservations and throughout their homeland areas. The federal government is also a trustee of lands held in trust for tribal use.

In order to protect tribal uses of natural resources, risk assessments must be designed and scaled appropriately. While tribal risk assessments have an ecological focus, performing a tribally relevant risk assessment means more than simply performing an ecological risk assessment with culturally important species and/or using a human exposure scenario that includes exposures received during cultural activities. It means developing an exposure scenario that reflects the lifestyle treaties (or their equivalent) were designed to protect.

This document presents some generic risk assessment methods while recognizing that they do not substitute for intergovernmental consultation and meaningful participation in the decision process. Several cautionary notes are as follows:

- Every tribe is different, and generalizations cannot be made from one tribe to another or from one exposure scenario to another.
- Government to government protocol means that the agency must to talk to individual tribes. Intertribal groups do not substitute for individual tribal consultation and do not represent or speak for individual tribes.
- Treaties and trusteeship are federal obligations that precede more recent environmental regulations. These obligations do not fade with time.
- Environmental standards were not set with tribes in mind, and may not be adequately protective.
- There is a balance between maintaining confidentiality of tribal information and having access to data for verification. Tribes have the right to protect proprietary information and to give only summary information to the assessor.
- Human subjects protocols as well as tribal cultural resource or research codes apply equally to cultural data. Neither human health nor cultural information should be published without permission of the tribe.

Our experience in developing tribal subsistence-based exposure scenarios has led to a set of technical, ethical, and procedural rules (Figure 6, adapted from Harper et al. 2002):

- Each parameter must be able to be tested or verified (documented, modeled, measured, or elicited from acknowledged experts) to enable each assumption to be systematically validated. This validation can rely on ethnographic data and open peer-reviewed literature, and on verbal representations from subsistence practitioners and tribally recognized cultural experts. Ethnographic experts are recognized by their standing in the academic community, while cultural experts are recognized by their traditional or indigenous environmental knowledge and their standing in the tribal community.
- Pursuant to Rule 702, "a witness is qualified as an expert by knowledge, skill, experience, training, or education" to testify when his or her "scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue." In response to two U.S. Supreme Court cases holding trial judges responsible for excluding unreliable expert testimony, Rule 702 recently was qualified by amendment. To be admissible, the rule now requires federal courts to find: "(1) the testimony is based upon sufficient facts or data, (2) the testimony is the product of reliable principles and methods, and (3) the witness has applied the principles and methods reliably to the facts of the case." Another risk assessor should be able to repeat the same steps and construct essentially the same scenario. Multiple lines of evidence should lead to the same general conclusion. The scenario should be accepted by colleagues as reasonable

and factual rather than eccentric, unreliable, or mere opinion. It should meet the "general acceptance" test set forth in *Frye v. United States*, 293 F. 1013 (App. D.C. 1923), the predecessor case to *Daubert*. This criterion should ideally be satisfied by obtaining peer review from qualified colleagues ("the relevant scientific community") even beyond the editorial peer review process that occurs during publication in peer-reviewed journals.

- The scenario must be relevant and reliable both scientifically and culturally. The process must be culturally sensitive, respectful, draw on traditional environmental knowledge (such as the observational expertise of elders), and must be developed from within the tribe by a risk assessor in partnership with tribal cultural and technical experts. This interaction may take several forms and results in a community-based participatory process. It is based on the principles of meaningful consultation, in which all players come to the table and have equal parts in the decision-making process. It establishes cultural credibility, obtains truly informed consent, and reflects the local the knowledge system and customary means of exchanging materials and information.
- The methodology used to reach the conclusions of this study incorporated information from a variety of disciplines, including cultural and traditional environmental knowledge. These lifeway scenarios for indigenous Native Americans were developed, as much as possible, using general scientific criteria adopted from the *Daubert* case.[2] To ensure the highest quality of reliability for the process used to develop these scenarios, an internal and external peer review process was followed by cultural and technical experts during and after preparation.

Informed consent is required when conducting federally funded research. It is our contention that, whether or not a university is involved, the risk assessor is ethically bound to surpass minimal informed consent guidelines (Figures 7 and 8).

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[2] *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579 (1993).

Tribal Data must be Credible & Pedigreed

Technical Credibility

- ***Must be scientifically relevant and reliable***
- ***Must use both statistical and ethnographic survey methods***
- ***Rules of Evidence – based on sufficient facts; reliable methods; each assumption validated….. (Rule 702; Frye; Daubert).***
- ***Importance of multiple peer reviews and data quality validation; often must have higher data quality standards and more documentation because we are challenging convention.***

Cultural Credibility

- ***Must be culturally relevant and reliable.***
- ***Culturally sensitive, respectful, draw on TEK, developed from within the Tribe. Must be TRUE informed consent.***
- ***Must protect confidential information.***

Figure 6. Cultural and Technical Credibility

Ethics & Informed Consent

Try It. You'll like it.

TRUST ME.
I want to help

I know just what you need

Federal Institutional Review Board rules require extra effort to explain benefits and disadvantages of collecting different kinds of data, using various methods, participating in various studies.
This should be a discussion at multiple levels of Tribal authority, not a sales pitch.
The Tribe must have ownership of the project & data.

Figure 7. Ethics and Informed Consent

OFFICE OF HUMAN SUBJECTS RESEARCH

Informed consent is obtained from research subjects or their legally authorized representatives.
(a) Does the informed consent document include the eight required elements?
(b) Is the consent document understandable to subjects?
(c) Who will obtain informed consent (PI, nurse, other?) & in what setting?

Additional safeguards required for subjects likely to be vulnerable to coercion or undue influence.
(a) Are appropriate protections in place for vulnerable subjects, e.g., pregnant women, fetuses, socially- or economically-disadvantaged, decisionally-impaired?

Subject privacy & confidentiality are maximized.
(a) Will personally-identifiable research data be protected to the extent possible from access or use?
(b) Are any special privacy & confidentiality issues properly addressed, e.g., use of genetic information?

Figure 8. Informed Consent

A.3 LARGER GOALS OF A HEALTHY TRIBAL COMMUNITY

One of the premises of this guidance manual is that an individual is not healthy unless the entire tribal community is healthy. John M. Last defines individual human health as

> a state characterized by anatomic integrity, ability to perform personal, family, work, and community roles; ability to deal with physical, biological, and social stress; a feeling of well-being; and freedom from the risk of disease and untimely death (Last 1998).

This definition is broader than the risk-based regulatory approach, which tends to equate good health with lack of excessive exposure. More broadly, definitions of health and functionality from the public health literature include a variety of medical and functional measures. However, they may not emphasize the fact that the survival and well-being of individuals and indigenous cultures depend on a healthy environment. Indigenous cultures and their environs are intertwined to a degree that is usually not accounted for by Western society and scientists when developing risk metrics. The environment constitutes a cultural homeland where the people (and their genetics) co-evolved with the ecology over thousands of years. The concepts of health and culture can be combined into a concept of cultural health (healthy individuals functioning in healthy social and cultural systems).

Culture is collective knowledge and systematic unity that gives members a sense of personal identity and cultural anchorage (Greaves 1996). Various definitions of “culture” include social behavior systems, religion, art, material goods, individual and collective health, a land ethic, ways of relating to the environment, and other elements. A culture includes time from the past to the future; religious, economic, political, communication, and kinship systems, as it is the whole set of learned behavior patterns common to a group of people; interactive behavior systems; art; material goods; individual and collective health, and the natural resources and environment on which all of this depends (Harris 1998). Figure 9 illustrates this concept.

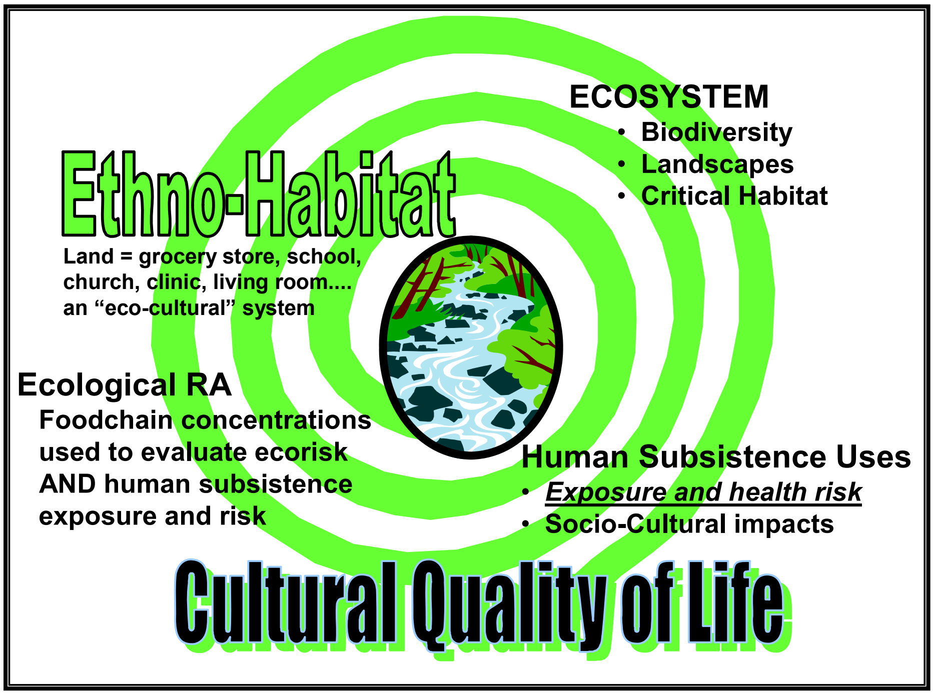

Figure 9. Cultural Quality of Life

Tribal elders have explained that traditional indigenous lifestyle and behavior is a conscious response to environmental observation and that traditional teachings are a product of rigorous and proven methodology that has guaranteed survival through all types of natural cycles. That lifestyle is resilient and has persisted through floods, droughts, cataclysms, upheavals, and warfare. Ancestors understood the value of systematic observation and used inductive reasoning to determine the most probable reactions of very complex, interrelated ecosystem functions. The application of this science has been distilled into daily practice. This knowledge is still transferred between generations. Education of each generation is not simply a matter of teaching survival skills, but of teaching an entire way of living.

If we think about where people go to fulfill their daily needs for individual and community health, upon which the culture survives and thrives, the difference between subsistence and suburban lifestyles becomes more apparent (Figure 10). The suburban lifestyle is geared toward traveling to various specialists and structures to obtain medical care, education, groceries, and so on. The ecology is often seen as something to be appreciated from a distance or by weekend camping, sightseeing, or other recreation. Conversely, indigenous communities turn to the environment for their medicine, spiritual health care, education, food, and so on. The environment is not a place to visit; but a place to be comfortable in. Tribal members look on their environs and landscape as the home, kitchen, living room, grocery store, pharmacy, place of spiritual renewal, role model, advisor, and teacher.

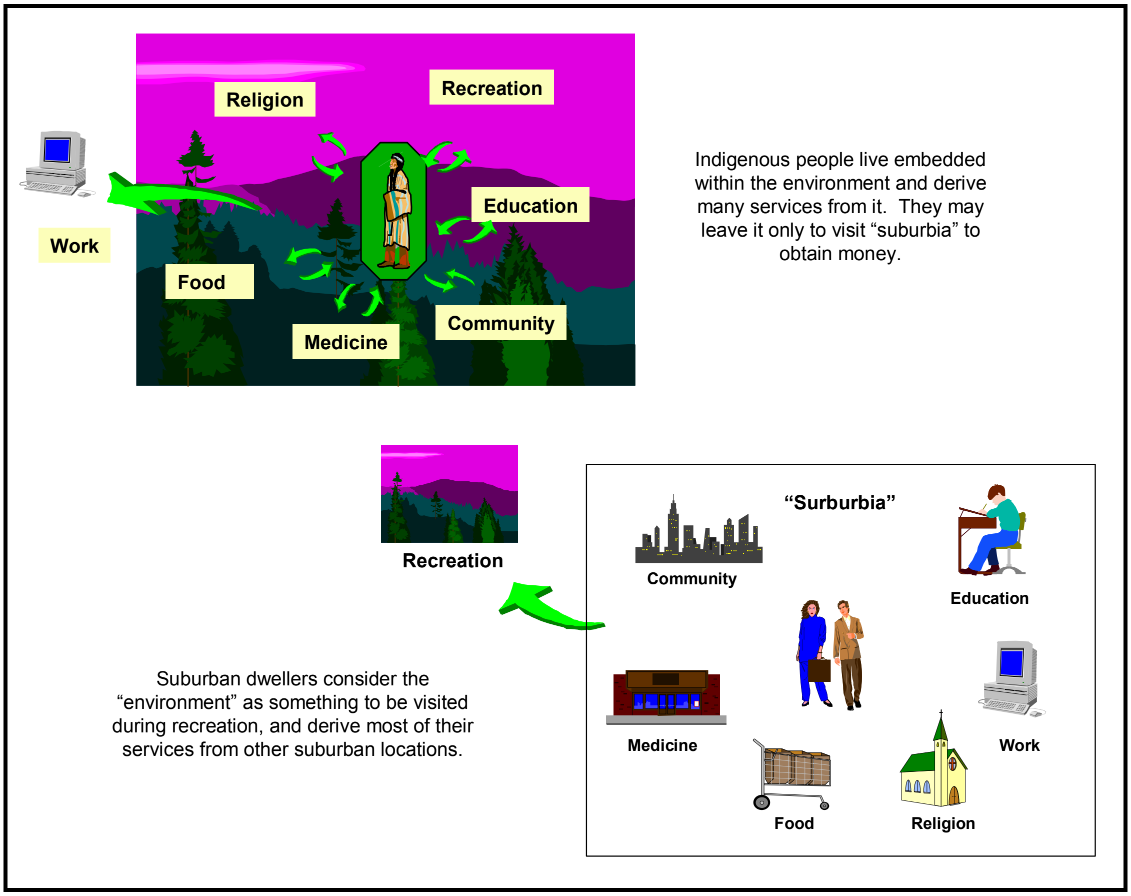

Figure 10. Where People Go to Fulfill Elements of their Lifestyles

Over the years, we have tried to find various analogies to illustrate the unitary and indivisible character of tribal members and their environment. The tendency of Western-trained scientists is to divide the problem into its smallest identifiable units, study them individually, and then try to reconstruct the meaning and functionality of the entire system. Figure 11 is one illustration of concepts that are missed if the analysis jumps too quickly to isolated studies. One can study each patch on a soccer ball, its shape, its composition, and its relation to its neighboring patches; yet parameters at the scale of the soccer ball, its inflation pressure, its role in a contest, and the meaning of the contest to the contestants cannot be discerned. Without tribal guidance, the selection of surrogate indicators and the relation of the indicators to the overall culture might be misconstrued (Figure 12).

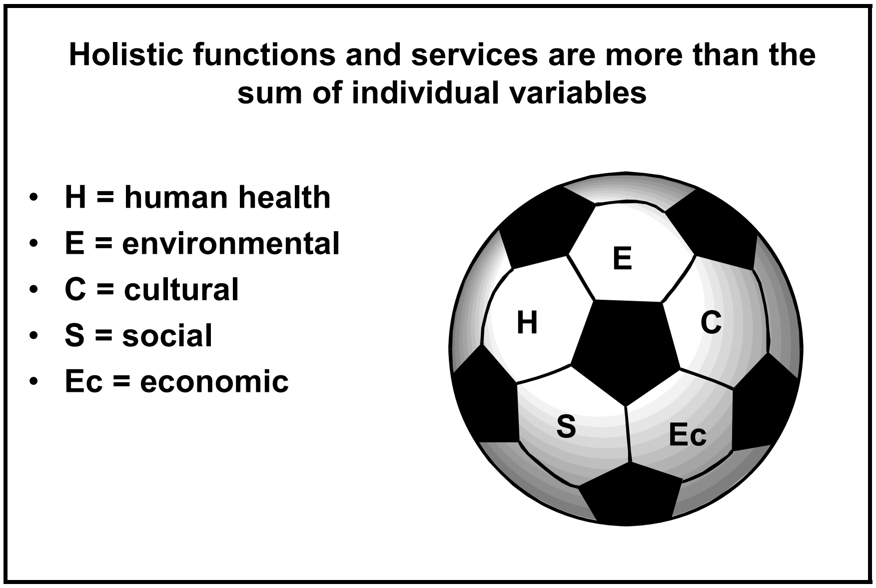

Figure 11. Example of Holistic versus Fragmented Analysis

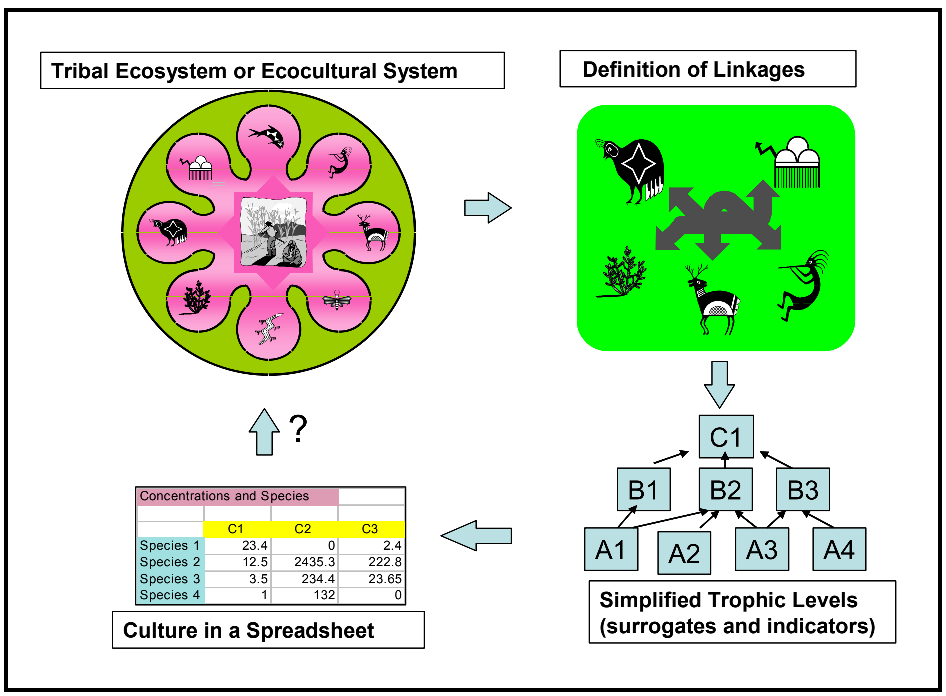

Figure 12. Deconstructing and Reconstructing

One of the first issues we grappled with when we started working on tribal risk assessment methods in 1995 was the obvious fact that if salmon are contaminated, more is at stake than simply a risk of excess exposure to humans or fish (Figure 13). Social, educational, and religious activities are also affected.

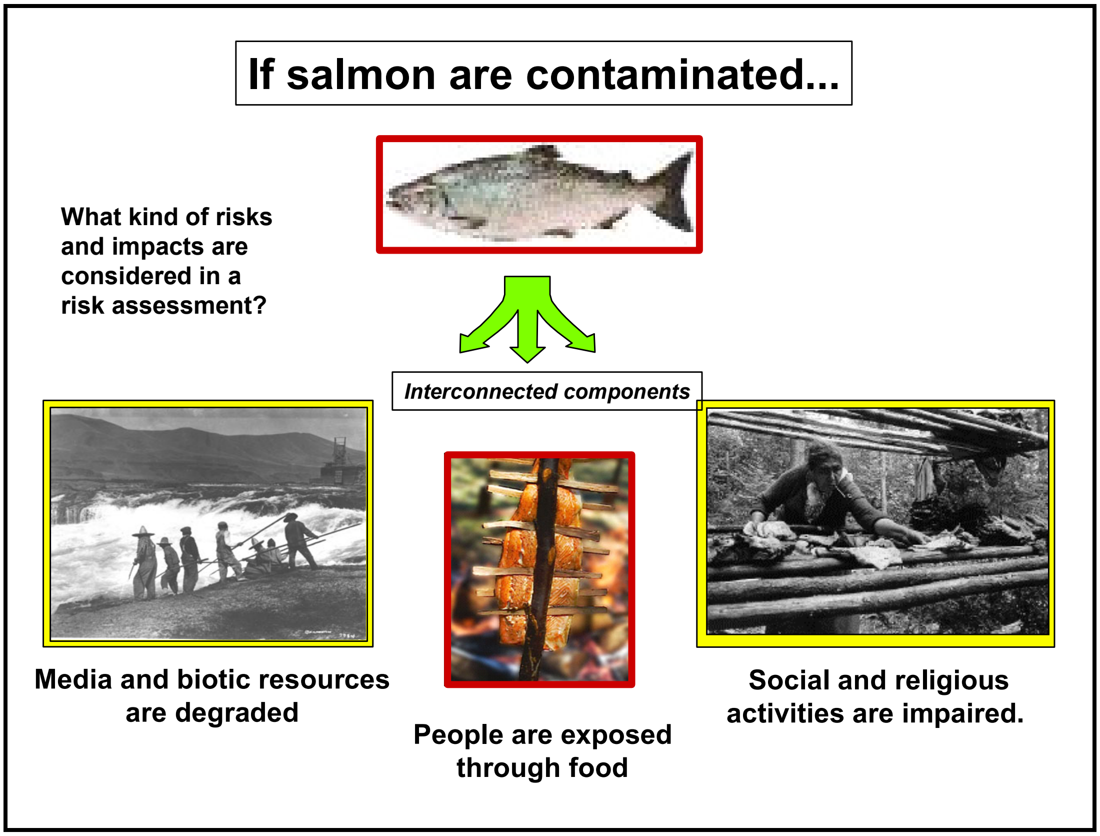

Figure 13. Impacts of Contaminated Salmon

With this realization, it was immediately evident that conventional risk assessment methods do not address all of the things that are *at risk* in communities and do not provide enough information to tell the complete story or answer the questions that people ask about risks to their community, health, resource base, and way of life. The full span of risks and impacts needs to be evaluated within the risk assessment framework in order for cumulative risks to be adequately characterized. This is in contrast to a more typical process of evaluating risks to human health and ecological resources within the risk assessment phase and deferring the evaluation of risks to socio-cultural and socioeconomic resources until the risk management phase (National Research Council 1994, 1996; President's Commission 1997).

Figure 14 illustrates the conventional method for evaluating risks to human health and additional steps that we believe are beneficial. Because many communities need such additional information, the Environmental Protection Agency developed a Comparative Risk method over a decade ago for adding a community welfare or quality of life component (EPA 1993). We have modified this concept to reflect traditional tribal cultural values as well as secular or social community aspects that apply to suburban communities, as well as to tribal communities (Harper et al. 1995, Harper and Harris 2000). We envisioned three or four components to the risk assessment process: human health (using appropriate exposure scenarios), ecological health, and socio-cultural/socioeconomic health, all of which are elements of the overall eco-cultural system (Figures 14 and 15).

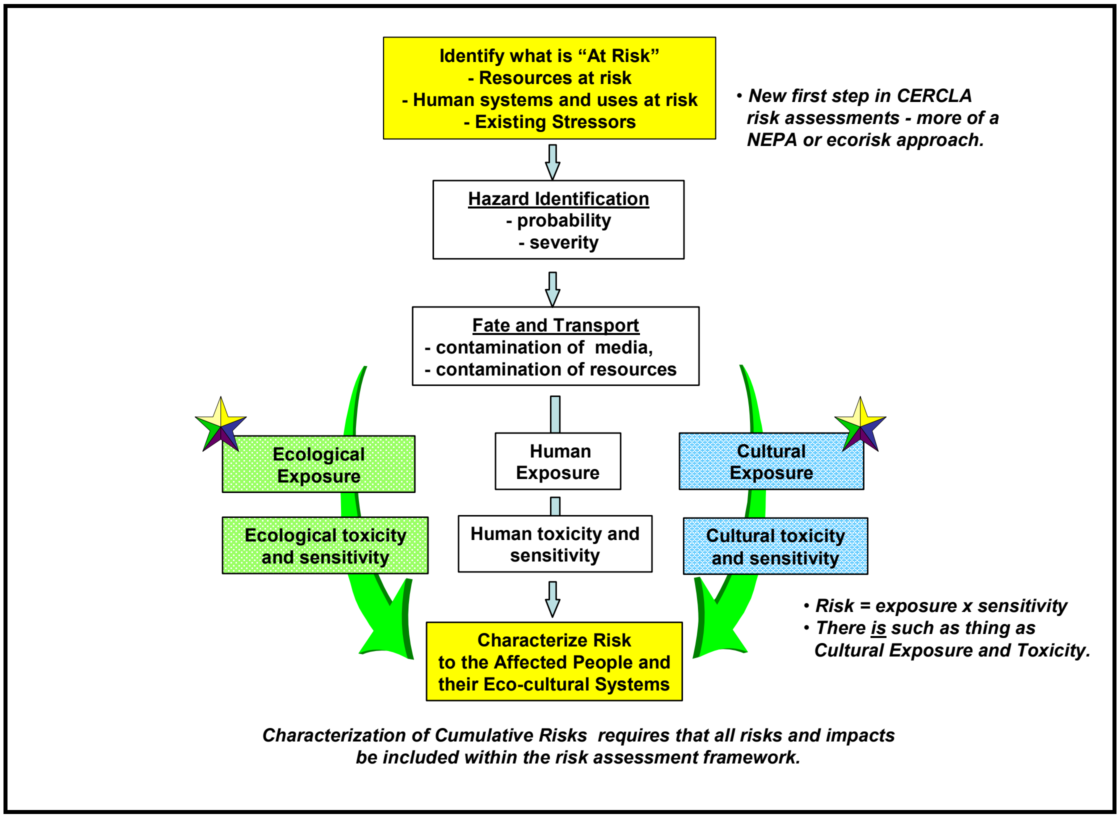

Figure 14. The Broader View of Risk Assessment with Three Components

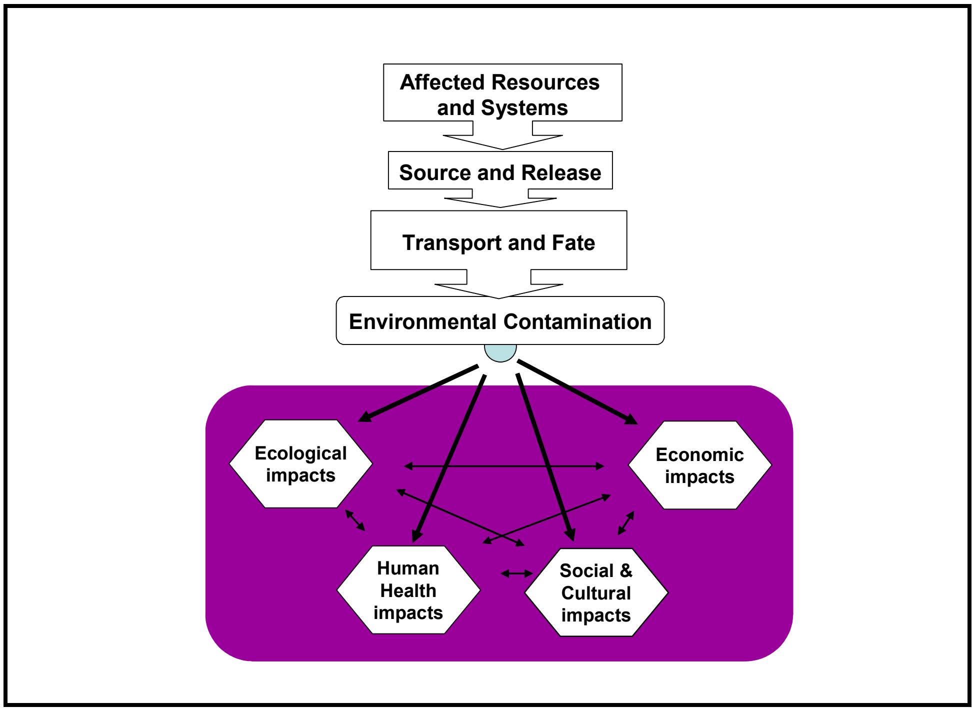

Figure 15. The Broader View of Risk Assessment with Four Components

Figures 15 and 16 show four categories of functions provided by an original undisturbed environment, functions that contribute to individual and community health. Impacts to any of these functions can adversely affect health. Metrics associated with impacts within each of these categories are presented in Harper and Harris (1999).

- **Human Health-Related Goods and Services:** This category includes the provision of water, air, food, and native medicines. In a tribal subsistence situation, the land provided all the food and medicine that was necessary to enjoy long and healthy lives. From a risk perspective, those goods and services can also be exposure pathways.
- **Environmental Functions and Services:** This category includes environmental functions such as soil stabilization and the human services that this provides, such as erosion control or dust reduction. Dust control in turn would provide a human health service related to asthma reduction. Environmental functions such as nutrient production and plant cover would provide wildlife services such as shelter, nesting areas, and food, which in turn might contribute to the health of a species important to ecotourism. Ecological risk assessment includes narrow examination of exposure pathways to biota as well as examination of impacts to the quality of ecosystems and the services provided by individual biota, ecosystems, and ecology.
- **Social and Cultural Goods, Functions, Services, and Uses:** This category includes many things valued by suburban and tribal communities about

particular places or resources associated with intact ecosystems and landscapes. Some values are common to all communities, such as the aesthetics of undeveloped areas, intrinsic existence value, environmental education, and so on.

- **Economic Goods and Services:** This category includes conventional dollar-based items such as jobs, education, health care, housing, and so on. There is also a parallel non-dollar indigenous economy that provides the same types of services, including employment (i.e., the functional role of individuals in maintaining the functional community and ensuring its survival), shelter (house sites, construction materials), education (intergenerational knowledge required to ensure sustainable survival throughout time and maintain personal and community identity), commerce (barter items and stability of extended trade networks), hospitality, energy (fuel), transportation (land and water travel, waystops, navigational guides), recreation (scenic visitation areas), and economic support for specialized roles such as religious leaders and teachers.

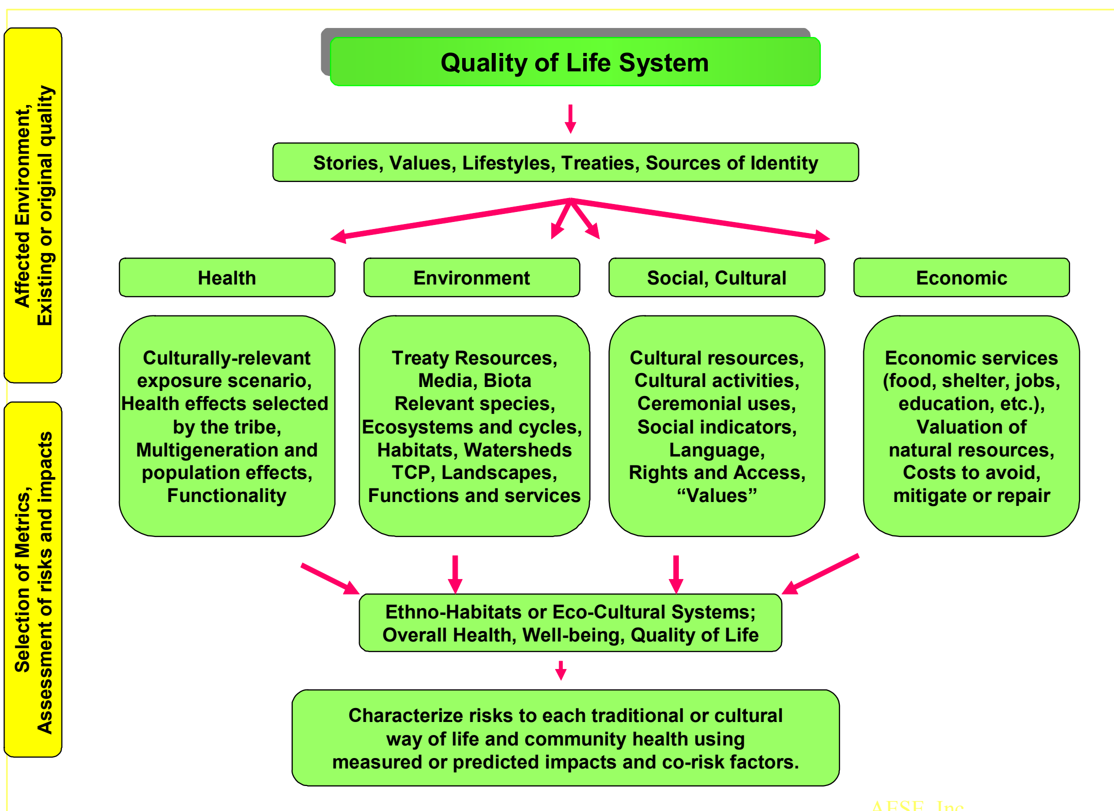

Figure 16. Categories of Environmental Functions Contributing to Individual and Community Health

B SCENARIO METHODS

B.1 GENERAL DESCRIPTION OF SCENARIO AND APPROACH

In order to evaluate risks to environmental contamination, the amount of exposure to potentially contaminated air, water, soil, and food must be known. The core component of exposure assessment is the exposure scenario.

An exposure scenario describes a set of activities and diet(s) that compose a lifestyle and its frequency, intensity, and duration of environmental contact. When developing a cross-cultural scenario, and tribal subsistence scenarios in particular, several misunderstandings can arise. Risk assessors who are unfamiliar with tribes may think that everyone lives a suburban lifestyle with extra game and fish, and cultural activities or ceremonies on the weekend (Figure 17). As we have discussed, this is incorrect. However, if this is the mental model that the risk assessor has, then the development of the scenario will be from a perspective of making minor modifications to a conventional scenario and conventional diet.

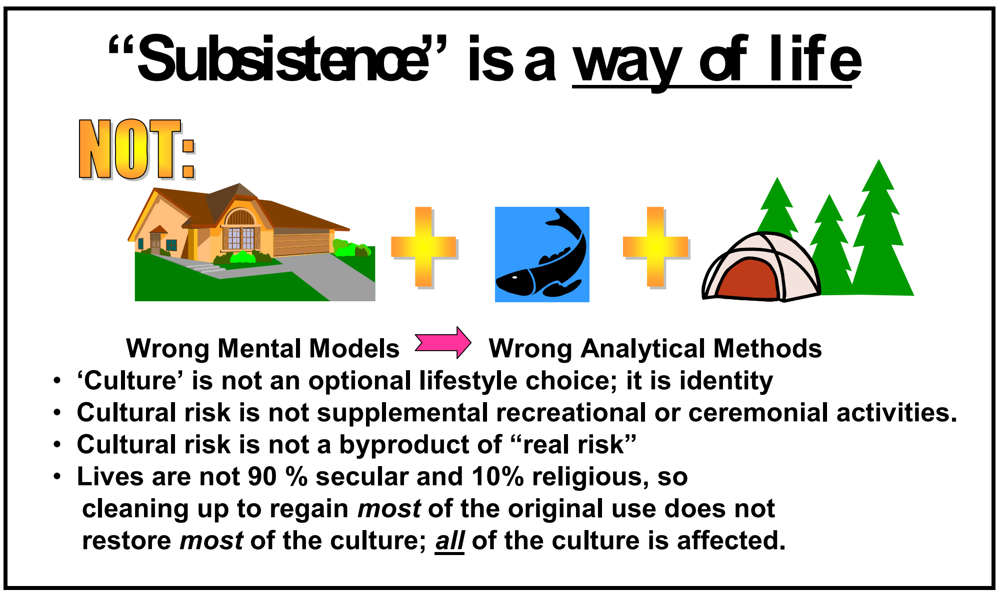

Figure 17. Misunderstandings Common to Tribal Risk Assessment

The scenarios we are presenting in this document lie at the intersection of conventional risk assessment, ecological settings, and the anthropological or ethnographic literature (Figure 18).

The ethnographic literature is not generally accessed by risk assessors, but is essential to the development of tribal eco-cultural scenarios. The basic premise is that we want to develop the scenario to reflect traditional, subsistence, and/or contact-era lifestyles that match environmental protection and restoration goals and support traditional uses of the natural resources.

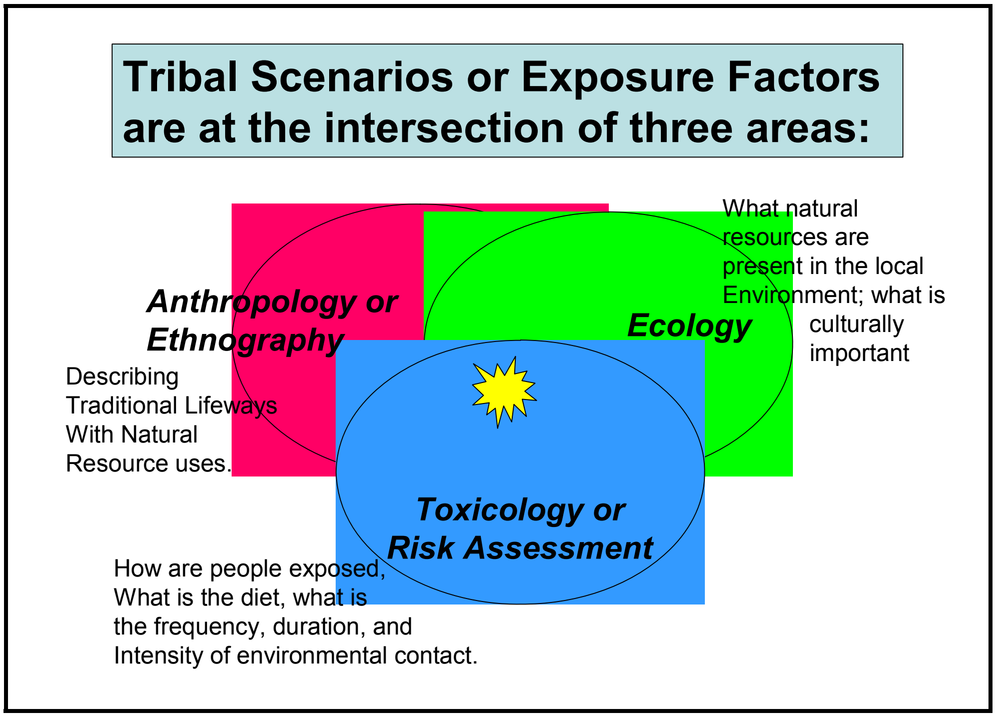

Figure 18. Information for Building a Tribal Scenario

The overall methods include using information from all these types of literature. The general sequence of steps is

1. Describing eco-cultural zones (the environmental setting);
2. Determining general resource use and unique tribal exposure pathways, such as hunting, gathering, fishing, making material items, and engaging in other cultural activities;
3. Reconstructing an original subsistence diet using multiple lines of evidence;
4. Identifying direct exposure factors (frequency, intensity, duration) and resource use, and
5. Quantifying exposure factors into metrics that can be used in CERCLA risk assessments.

Note that we are not trying to describe a contemporary lifestyle with a food consumption survey. Rather, we are trying to help tribes regain their original natural and healthier lifestyles by describing them accurately.

When developing an exposure scenario for the general U.S. population, there are national databases available for exposure factors (e.g., diet and human activity data) that have been summarized in the EPA guidance.[3]

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[3] U.S. EPA. Exposure Factors Handbook (1997) http://www.epa.gov/ncea/efh/ *and* Guidelines for Exposure Assessment. U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, DC, 600Z-92/001 (1992) http://cfpub.epa.gov/ncea/raf/recordisplay.cfm?deid=15263

In the case of tribal exposure scenarios, there are no tribal-specific databases of subsistence activities, resources, or diets as there are for the general United States population. Cross-sectional surveys of most contemporary tribal populations will not generate that data because much resource use is currently suppressed due to loss of land and access, awareness of contamination, and other reasons. Further, tribal communities often include people who rely largely on the natural environment and others who participate in the Western economic system. This means that large statistical distributions for true subsistence exposure factors are not available and cannot be developed. Rather, an ethnographic and eco-cultural approach was taken to describe these lifestyles (Figure 19).

The amount of information extracted from the literature and from interviews with tribal members can be overwhelming. One of the first questions is the level of detail that is needed to (a) completely represent major components of the lifestyle and a calorically complete diet, yet (b) match the level of detail that is used in the risk assessment process. We feel that it is difficult to reconstruct the entire diet by asking questions about every food item, or to reconstruct an entire average lifestyle by learning about everywhere people go and everything they do.

Catalog or Inventory Approach:	***Holistic Overview Approach:***
Lists of every plant eaten with amounts of each;	**Major food groups with total calorie estimates**
Lists of "important" species (typically >200);	**Indicators & Surrogates, start with ecological web.**
Lists of every place visited;	**General understanding of cultural activities for development of exposure factors**
Statistical surveys and "real" tribal data.	
Intrusive, data-intensive, always incomplete.	**Less probablistic but more complete and accurate.**

Figure 19. Two Approaches to Tribal Risk Assessment

B.2 ETHNOGRAPHIC AND ANTHROPOLOGICAL METHODS

B.2.1 Ethnohistory, Anthropology, and Multiple Lines of Evidence

Even though tribal lands have been lost and resources degraded, the objective of many tribes is to regain land, restore resources, and encourage more members to practice healthier (i.e., more traditional) lifestyles and eat healthier (i.e., more native and local whole) food. Therefore, the objective of subsistence exposure scenarios is to describe *original* lifestyles and resource uses. It is not to present a snapshot of *contemporary restricted* or *suppressed* uses, because the intent is to restore the ecology so that the original pattern of resource use is both possible (after resources are restored) and safe (after contamination is removed). Thus, the use of historical, archaeological, and ethnological data is required to identify the exact nature of these past resource uses.

The exposure scenario reflects a traditional subsistence lifestyle. “Subsistence” refers to the hunting, fishing, and gathering activities that are fundamental to the way of life of many indigenous peoples. Subsistence utilizes traditional and modern technologies for harvesting and preserving foods as well as for distributing the produce through communal networks of sharing and bartering.

In general our steps for reconstructing subsistence diets have been to:

1. Review ecological and foraging information specific to the tribe, and the local ecosystem(s);
2. Review interviews and other archaeological and ethnographic sources for supporting information of species and abundance, habitat types, human activity levels, and methods of obtaining, preparing, and using resources;
3. Develop overall percentages of major food categories and major staples within the total diet;
4. Estimate calories provided by the diet, and compare estimates of percentages of quantities and percentages of calories, and
5. Refine estimates of major staples and food categories after considering information about medicines, sweeteners, other often-overlooked food/medicine types, and other factors.

Steps 1 and 2 require engaging different forms of anthropology, ethnohistory, and archaeology. In particular, ethnohistorical approaches, when combined with other forms of data, some of which are geographic, offer the most insight into past subsistence lifestyles. While ethnohistory was originally founded as a discipline to write the history of peoples without their own documentary past, it has since evolved into a way of critiquing documentary histories and supplanting them with fuller, more accurate accounts (see Krech 1991). As noted historian Richard White (1998) points out, ethnohistorical approaches, when done correctly, are hybrid in nature—they confront documents that preserve complementary perspectives based on different cultural premises, represent conflicting realities, rooted in different epistemologies, and bring these two types of data together for a fuller picture of history. See Figures 20, 21, 22, 23, and 24 for visualizations of how cultural uses reflect the underlying ecological setting.

http://www.epa.gov/wed/pages/ecoregions/na_eco.htm

Figure 20. Level I EPA Ecoregions

Figure 21. Culture Areas (after Waldman 2000)

Figure 22. Dominant Materials Used for Non-cooking Containers (after Driver and Massey 1957)

Figure 23. Dominant Subsistence Food Categories (after Driver and Massey 1957)

Figure 24. Important Subsistence Foods (after Driver and Massey 1957)

One exciting challenge for us has been to combine the various forms of data (from faunal analyses and bone isotopes to first hand explorer accounts, documentary history, and ethnography) into one cohesive, verifiable whole, and there have been great rewards in our methodology.

Our approach is similar to the methods defined by renowned historian Patricia Galloway (2006), who sees that archaeology, ethnohistory, oral tradition, first hand accounts, and ethnography can come together in a "convergence of several lines of evidence" (Galloway 2006). We are influenced by predecessors in ethnohistory, because we believe, like Bruce Trigger, that succeeding "ethnohistorians have pioneered the use of more recent ethnographic data to reveal biases and inaccuracies in the historical record and to make possible the interpretation of native behavior in the absence of any independent documentation of native viewpoints" (Trigger 1986). Thus, we have often combined more recent (usually late 19th century and early 20th century) ethnographic accounts of subsistence lifestyles with contact period first-hand accounts and late pre-contact and contact period archaeological data. This approach is slightly more difficult when the first-hand accounts are distant in time from the ethnographic data, as is the case in much of the eastern part of North America. But first-hand accounts can still be valuable sources of information, since the colonial documents are often more sustained and diverse (from many different national sources) in this geographic area.

Of course, creating this convergence is not simple, and requires a way of contextualizing each of these forms of knowledge, including the documents of first-hand accounts and ethnography. As Galloway points out, this convergence is best done when we come to the "understanding of the [historical] document as an artifact of a process…and that archaeology itself is going to help judge its truth" (Galloway 2006). Thus, when using archaeological evidence with first hand accounts, oral tradition, and ethnography we must be cognizant of the context of production—why a document was preserved or a study performed in the first place, and what the motivations were in recording the facts. This is not to say that the evidence in these documents is not true or accurate, but that when they are brought together they can paint a deeper and more verifiable picture of past cultures.

One key question of our scenarios is what period to focus on for the subsistence diet, because Native cultures, like other cultures, are dynamic, creative, and respond to changes in climate and environment as well as internal preferences. In general, we usually focus on the early treaty period, which usually happens near the time of initial contact with Europeans (of course this can be anywhere from the 17th century to the 19th century, depending on the Native group). The reasons for this are many—rights to resources are usually guaranteed in these agreements, first-hand accounts are generally available, allowing for multiple lines of evidence, and the resources themselves are usually not degraded at this time in history.

Our uses of archaeological data have been heavily influenced by approaches in ethno-archaeology that use community-based experts to comment on sites and previously published reports (see Kelly 1986)—this approach has also influenced our research protocol (see section on research ethics below). We find this method meshes well with our use of ethnohistory, in that each has its own strengths and weaknesses. As Bruce Trigger points out, "archaeology is not merely a deficient or denatured copy of ethnology, as many ethnologists have assumed it to be, but a complementary discipline that is capable of providing information about cultural change that ethnology cannot" (Trigger 1986).

Each geographic and cultural context requires a different mixture of data, and we recommend that researchers understand not only the resource and cultural history of a particular tribal group, but also the history of research in that area. In one example we found that the amount of hunting and fishing gear in archaeological evidence, the seasonal round as identified in ethnography and archaeology, the settlement pattern relative to known resources, human bone isotope ratios, pollen profiles over time, and so on gave a fairly accurate structure of a diet (Sanger 1988). This information was then supplemented with early first-hand and ethnological accounts on the amount of food needed to feed a certain number of men for a winter season, with the relative abundance of certain wild foods that were brought in for trade. Whatever the mixture of data, we maintain that the highest standards of science are used, and this is most ensured by obtaining multiple lines of evidence.

B.2.2 Research Ethics, Indigenous People, and Ground-Truthing

Using multiple lines of evidence not only creates better knowledge for environmental managers to protect subsistence lifestyles; it also creates and maintains better relations between scientists (both Native and non-Native) and Native communities. While our studies aim to protect traditional lifestyles, it is arrogant to ignore our part in a colonial history in which scientific study has harmed indigenous people and their ways of life. In fact, even when researchers work for tribal communities, local indigenous citizens often worry about the research and question why it is being done, who it is for, and how it has been designed (Smith 1999). As Maori scholar and activist Linda Tuhiwai Smith points out, "anthropology made the study of Others, colonized peoples, its primary area, but other disciplines were employed in the practices of imperialism in less direct but far more devastating ways" (Smith 1999). The use of research in the colonization of indigenous peoples is understood in most Native communities, but it can be overcome by being more collaborative and inclusive—in these contexts, stakeholder input into scientific production will result in more accurate and more sustainable science. Again, as Smith points out, "decolonization does not mean and has not meant a total rejection of all theory or research or Western knowledge. Rather, it is about centering our concerns and world views and then coming to know and understand theory and research from our own perspectives and for our own purposes" (Smith 1999).

Ideally, therefore, our findings on subsistence lifestyles have impacts for environmental managers beyond their immediate reports. We acknowledge that historical reports are often irrelevant to indigenous people because "history does not usually deal with what they really value about their native cultures: their language, religions, oral traditions, arts, and kin networks” (Ortiz 1988). Moreover, we realize that our reports will not be seen as discreet academic products with specific means and ends by tribal community members. As Angela Wilson points out,

> Our role as historians should be to examine as many perspectives as possible. But, the greatest lessons of these stories are to the young people, the children, and the grandchildren of the elders and storytellers, who will gain an understanding of where they come from, who they are, and what is expected of them as a Dine, as an Apache, as a Laguna, as a Choctaw, and as a Dakota (Wilson 1998).

Therefore, as researchers, we do not pretend our research exists in a vacuum of academic or scientific protocol. Our work has potential political impacts, and we believe, following anthropologist Peter Whitely (1997), that we consider and address the effects of disseminating our studies and attend to and conform to the interests of the local communities in constructing our research projects. By doing this, we can make sustainable research connections with Native communities as well as meet their specific needs in both the short and long term (Ranco 2006).

Most of our work has not involved sustained, direct interviews regarding cultural knowledge about resources (due to time and resource issues, we have focused on scientific evidence already in the public domain), but this has not prevented us from engaging community members, from gaining their input on the scientific evidence that founds the exposure scenario. Our self-conscious approach to collaboration (in consideration of science’s role in colonization) has meant that we create many opportunities for feedback in the scientific process. One example of such a feedback loop can be seen below (Figure 25).

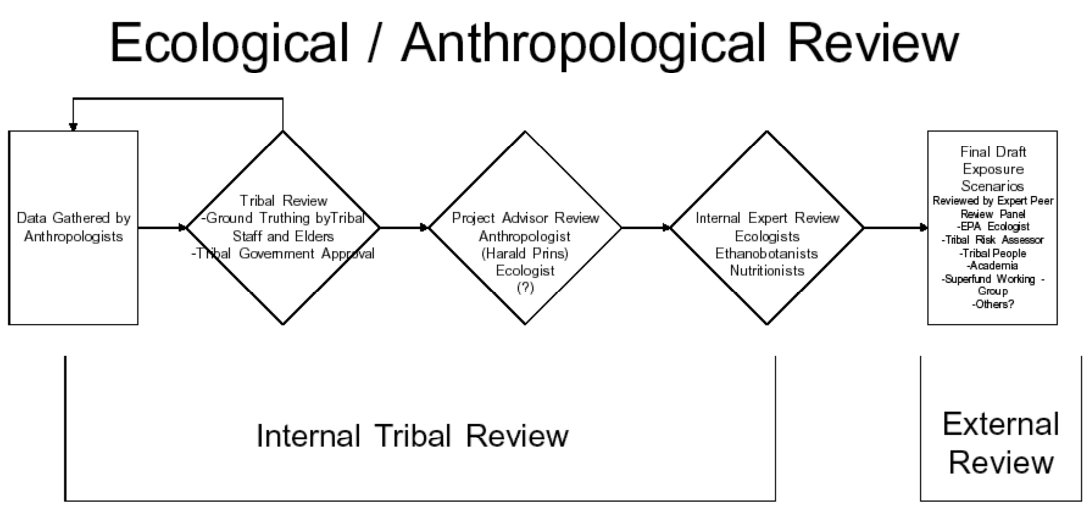


Figure 25. Ecological and Anthropological Review Process (Fred Corey, Aroostook Band of Micmacs)

Figure 25 shows our concern for tribal input and review, especially in the data gathering part of the exposure scenario process. We are committed to the notion that all cultural and historical evidence be at least commented on by tribal cultural and natural resource personnel and elders. We also believe that tribal governmental approval endorsing the study happen early on in the process, so that tribal personnel will have a mandate to engage the research as it occurs, not after-the-fact. Again, this process allows for better science, as community-based experts have the opportunity to critique scientific evidence already in the public domain—this is captured by the feedback loop between "Data Gathered by Anthropologists" and "Tribal Review" in Figure 25. For quality control purposes, we also have opportunities, depending on the community and funding, for project advisors and internal review before we submit the exposure scenario to a formal, external peer review. This process ensures both internal tribal validation as well as validation from the scientific community.

B.3 ECOREGION METHODS

One of the objectives of this project was to develop traditional tribal subsistence exposure scenarios based on particular eco-cultural zones or ecoregions. Thus, one of our initial tasks was to explore existing literature and various Websites to examine the perspective and approach accepted by federal agencies and other research organizations to describe ecoregions or ecological zones for the continental U.S. We sought a common developed framework that had been validated by the scientific community upon which to apply our work. We were also interested in a framework that was Internet accessible and compatible with GIS applications, which would allow us to layer cultural and other types of maps.

B.3.1 Development of a Common Framework of Ecoregions

We discovered early on there is much discussion among federal agencies and researchers on the subject of developing a common framework of ecoregions (Omernik 2004). Historically, earth science and resource management agencies that manage land and resources within a common geographic area have worked independently. Activities of each agency center on an individual agency's mission and areas of expertise, and these differences have been reflected in the spatial frameworks that agencies use in the planning, design, implementation, and evaluation of their work.

The recent impetus to develop a common scheme for identifying and mapping ecoregions came about in 1994 when the U.S. Government Accounting Office (U.S. GAO) produced a report that stipulated a need for a common geographic framework that would allow management to be conducted by ecological rather than political or administrative regions (U.S. GAO 1994).

The second recent effort to develop a common ecological framework occurred in 1996, when nine federal agencies signed a Memorandum of Understanding, "Developing a Spatial Framework of Ecological Units of the United States"

(McMahon et al. 2001). The group formed to address the problem was called National Interagency Technical Team (NITT), and it agreed to develop a spatial framework to provide the basis for interagency ecosystem management. The following agencies participated on the NITT:

- Natural Resources Conservation Service (NRCS)
- US Department of Agriculture Forest Service (USFS)
- Agricultural Research Service
- Bureau of Land Management (BLM)
- US Geological Survey (USGS)
- National Park Service
- Fish and Wildlife Service
- National Biological Service (currently known as Biological Resources Division of USGS)
- US Environmental Protection Agency (EPA)

The NITT did not include tribal representatives or non-profit organizations. The task faced by the NITT was difficult because of lack of agreement over the definition of ecoregions and how they should be mapped. Definitions were shaped not only by agencies or programs from which these members came, but also by educational backgrounds and experiences. For example, geographers, biologists, soil scientists, regional planners, foresters, conservationists, etc. bring their bias to the meaning of the term “ecology” and how ecoregions should be defined. Geologists start with geology and use other characteristics as they relate to geology; plant ecologists probably base their regions more heavily on patterns of potential and existing vegetation, climatologists on climate, etc.

The greatest impediment to agreeing on how to define ecoregions occurs because: (1) of the inherent complexity of ecosystems, in that they are dynamic; features change and constantly shift, and they are not closed systems; (2) although the framework is hierarchical, boundaries are not precise and regions at different levels of detail do not nest perfectly, and (3) humans affect the stability of ecosystems and the identity of ecological regions by fragmenting the spatial structure of the landscape, changing the physical and chemicals conditions within which ecological systems operate (McMahon et al. 2001). In fact, ecoregion boundaries are areas, rather than lines, where the predominant characteristics of one region meet the predominant characteristics of another.

The goal of the NITT was to develop a map of common ecological regions for the conterminous U.S. (areas that share a common boundary) (McMahon et al. 2001). They established a working definition of an ecoregion to read: areas of similarity regarding patterns in the mosaic of biotic, abiotic, aquatic, and terrestrial ecosystem components, with humans being considered part of the biota (McMahon et al. 2001, Omernik 2004). The intent of developing the common definition and framework is that this effort will foster an ecological understanding of the landscape rather than an understanding based on a single resource, scientific discipline, or agency perspective. The new framework was not intended to replace individual agency frameworks that will continue to be used when they serve a specific purpose. However, the new framework was deemed to be useful for agency activities that are ecologically oriented and involve interests of several participating agencies.

It was decided that the spatial framework was to be hierarchical, with ecological regions defined at two map scales:

1. small-map scale, with less resolution and greater extent (overall area), dividing the U.S. into 80–90 regions for state-level and broad regional and national assessment
2. large-map scale, with higher resolution and less extent, subdividing the U.S. into coarser regions

Map compilation relies on appropriately scaled information about factors that affect ecological potential, such as soils, vegetation, geology, physiography, hydrology, climate, land use, and wildlife. Finally, regions defined at the larger map scale will nest into smaller map scale framework (1:7,500,000-scale)

Currently, much progress has been made in developing this common framework, first exploring areas of agreement and disagreement in three federal natural-resource spatial frameworks:

1. Major Land Resource Areas of the USDA,
2. National Hierarchy of Ecological Units of the USDA Forest Service, and
3. Level III Ecoregions of the USEPA.

The common framework effort is ongoing work and not yet completed. Ecoregions resulting from this effort may fit within, and potentially may be used to revise, the framework of ecological regions of North America developed by the Commission for Environmental Cooperation (CEC). The CEC is an international, interagency supported by the North American Free Trade Agreement. The Commission developed and published maps of two broad levels of ecological regions for N. America (rather than just the U.S.) in 1997, which are described in *Ecological Regions of North America: Toward a Common Perspective* (CEC 1997). The most holistic framework to date, however, is that of the CEC, which may also be the dominant framework eventually adopted by the NITT. The CEC effort, formed with a trilateral working group from the U.S., Mexico, and Canada, was the first attempt at holistically classifying and mapping ecological regions across all three countries of the North American continent. The working group hoped to foster cooperative work to protect the environment, to insure the sustainability of resources, and to study the effect of human activities on ecosystems.

For these reasons we have chosen *Ecological Regions of North America: Toward a Common Perspective* (CEC 1997) as the framework for identifying and describing the components of the major ecological regions in developing the exposure scenarios. A large contribution to this framework came from Jim Omernik (U.S. EPA), author of the ecoregions used in National Nutrient Strategy Approach (Omernik 1995). However, the CEC ecoregions are those listed on the USEPA Website for reference and downloading. See http://www.epa.gov/wed/pages/ecoregions/na_eco.htm.

B.3.2 Our Choice of Framework: CEC Hierarchical Spatial Framework of Ecoregions

Ecological Regions of North America: Toward a Common Perspective has been chosen as the classification system for identifying the major ecological regions. The approaches used to develop the classification include: (1) opinions from ecologists and other scientists on relevant features for each region and (2) a data matrix that could be used to build each ecological level (CEC 1997). This ecological framework was developed by federal, state, provincial, and territorial agencies, and represented a shift towards a more comprehensive, continental scale approach—one that includes not only assessments of trade, but also strives to foster cooperative work to protect the environment, to insure the sustainability of resources, and to study the effect of human activities on ecosystems (CEC 1997).

Ecoregions denote areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources. They are designed to serve as a spatial framework for the research, assessment, management, and monitoring of ecosystems and ecosystem components. By recognizing the spatial differences in the capacities and potentials of ecosystems, ecoregions stratify the environment by its probable response to disturbance (Bryce et al. 1999). These general purpose regions are critical for structuring and implementing ecosystem management strategies across federal agencies, state agencies, and nongovernment organizations that are responsible for different types of resources within the same geographical areas. The most immediate needs by the states are for developing regional biological criteria and water resource standards, and for setting management goals for nonpoint-source pollution. Explanation of the methods used to delineate the ecoregions are given in Omernik (1995) and Gallant et al. (1989). This series of maps has been produced as part of a regional interagency collaborative project aimed at obtaining consensus between the EPA, the NRCS, and the USFS regarding alignments of ecological regions.

Diagnostic criteria for the mapped areas are based on *enduring* ecosystem components (CEC 1997). The term “enduring” means the components are relatively stable and do not change appreciably over ecological time. This includes components such as soil, landform, or major vegetation types. Climate is considered but is unique because it must be assessed by looking at long term records.

The approach used to compile ecoregion maps is based on the premise that ecological regions can be identified through the analysis of the patterns and the composition of biotic and abiotic phenomena that affect or reflect differences in ecosystem quality and integrity (Wiken 1986, Omernik 1987, 1995). These phenomena include geology, physiography, vegetation, climate, soils, land use, wildlife, and hydrology. A hierarchical scheme has been adopted for different levels of ecological regions, and is being used by the U.S. Environmental Protection Agency (EPA 2004). The relative importance of each characteristic varies from one ecological region to another regardless of the hierarchical level. Because of possible confusion with other meanings of terms for different levels of ecological regions, a Roman numeral classification scheme has been adopted for this effort. Level I is the coarsest level, dividing North America into 15 ecological regions, whereas at Level II the continent is subdivided into 52 classes (CEC 1997). Level III represents further detail. Level IV ecoregions are under construction, with significant number of states having been completed at this level; see Figure 26.

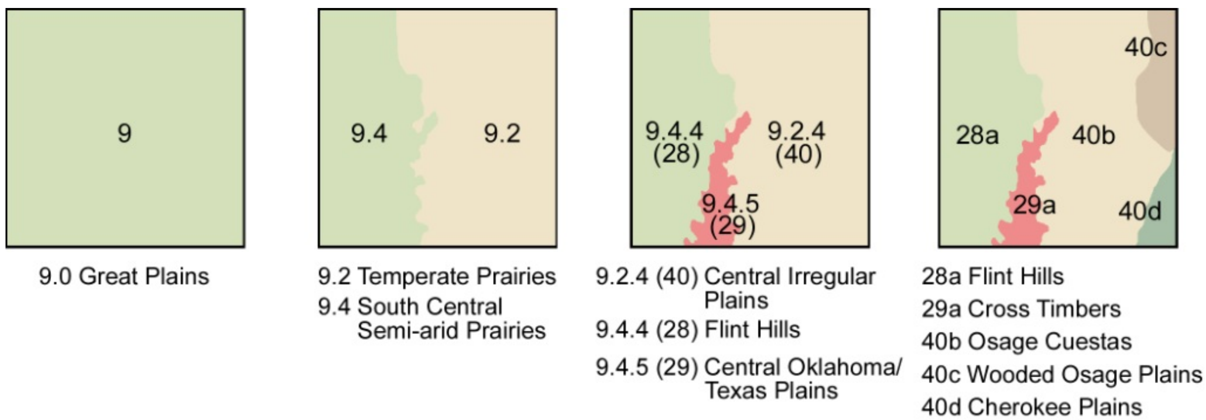


Figure 26. Example of the Hierarchical Form of EPA Ecoregions

In describing the characteristics of ecoregions in the Guidance Manual, references from other frameworks have been made. These include: *Terrestrial Ecoregions of North America* (Ricketts et al. 1999)*, Freshwater Ecoregions of North America: A Conservation Assessment* (Abell et al. 2000)*,* and *the USDA Description of the Ecoregions of the United States* (Bailey 1995)*.* Although the literature cites similarities between *Ecological Regions of North America: Level I and Level II* and the mentioned resources, additional information is needed to determine whether additional frameworks can be used for describing the major ecological regions.

B.3.3 Description of Ecoregion Levels

Level I: North America has been divided into 15 broad, Level I ecological regions (Figure 21). Determination of the areas composing the regions has been made through satellite imagery and appropriate natural resource source maps at broad scales (1:40–1:50 million-scale presentation). These ecoregions highlight major ecological areas and provide the broad backdrop to the ecological mosaic of the continent, putting it in context at global or intercontinental scales. Viewing the ecological hierarchy at this scale provides a context for seeing global or intercontinental patterns. Level I ecological regions are: Arctic Cordillera, Tundra, Taiga, Hudson Plains, Northern Forests, Northwestern Forested Mountains, Marine

West Coast Forests, Eastern Temperate Forests, Great Plains, North American Deserts, Mediterranean California, Southern Semi-Arid Highlands, Temperate Sierras, Tropical Dry Forests, and Tropical Wet Forests.

Brief narrative descriptions of each level I region can be found in Section III of the CEC's (1997) publication, *Ecological Regions of North America: Toward a Common Perspective*. These descriptions—each of which is divided into sections describing the physical setting, biological setting, and human activities therein—provide an overview of the principal attributes of each region. The intent is to provide a sense of the ecological diversity, the human interactions taking place, and how each region differs from adjacent ones.

Level II: The 52 Level II ecological regions (shown in Figure 27) that have been delineated are intended to provide a more detailed description and national/regional perspective of the large ecological areas nested within the Level I regions. For example, the Tropical Wet Forests of Level I is the region covering coastal portions of the United States and Mexico, and is composed of six Level II regions. Level II ecological regions are useful for national and subcontinental overviews of ecological patterns. Three Level I regions (Hudson Plains, Marine West Coast Forest, and Mediterranean California) have no subdivisions at Level II. The Temperate Sierras, Tropical Dry Forests, and Tropical Wet Forests Level I regions, on the other hand, each have six Level II subdivisions. This level is useful for national and subcontinental overviews of physiography, wildlife, and land use. Level II determination of the areas is made through satellite imagery and appropriate natural resource source maps at broad scales (approximately 1:20–1:30 million-scale presentation).

http://www.epa.gov/bioindicators/html/usecoregions.html

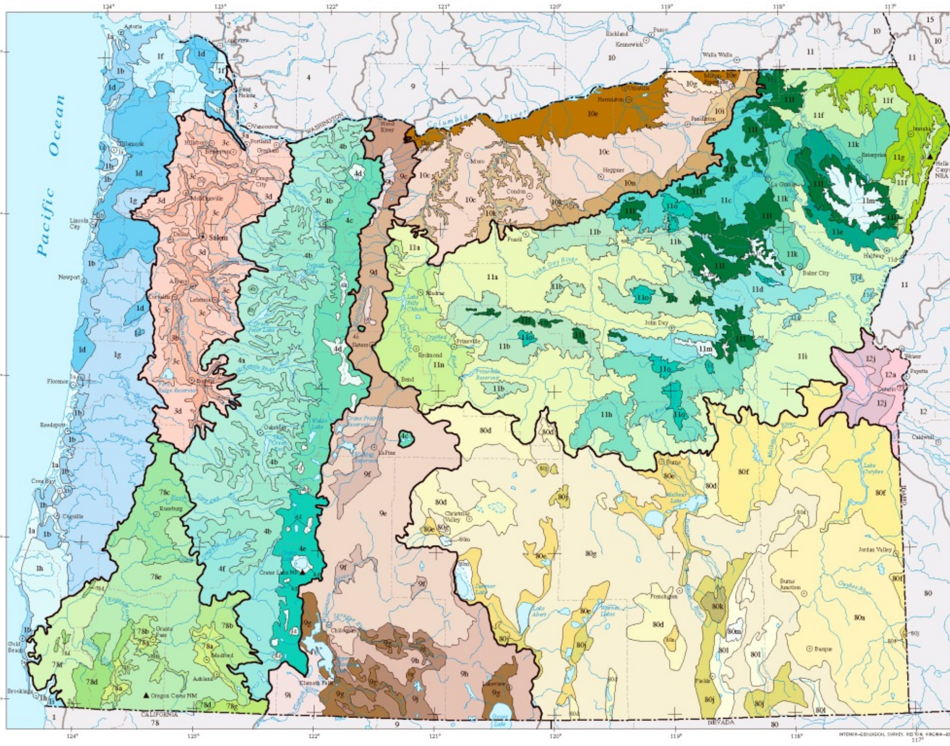
Figure 27. Level I and II Ecoregions of North America

Level III: Level III mapping describes smaller ecological areas nested within Level II regions. At Level III, shown in Figure 28, the continental United States contains 104 ecoregions and the conterminous United States has 84 ecoregions (U.S. EPA 2003). These smaller divisions enhance regional environmental monitoring, assessment, and reporting, as well as decision-making. Because Level III regions are smaller, they allow locally defining characteristics to be identified and more specific management strategies to be formulated (CEC 1997). Level III ecoregion determinations are made through remote sensing techniques and appropriate regional natural resource source maps (1:2–1:4 million-scale presentation)

http://www.epa.gov/bioindicators/html/usecoregions.html

Figure 28. Level III Ecoregions of the Continental U.S.

Level IV: The Level IV state projects depict revisions and subdivisions of ecoregions, that were compiled at a relatively small scale. Level IV is a further subdivision of Level III ecoregions. Explanations of the methods used to define the USEPA's ecoregions are given in Omernik (1995), Griffith et al. (1994), and Gallant et al. (1989). Compilation of the Level IV maps, performed at the larger 1:250,000 scale, has been a part of collaborative projects between United States Environmental Protection Agency, National Health and Environmental Effects Laboratory (NHEERL)—Corvallis, OR, the U.S. Forest Service, Natural Resources Conservation Service, and a variety of other state and federal resource agencies. Level IV ecoregions, currently under development, will aid in localized monitoring, reporting, and decision-making. Level IV ecoregions of Oregon are presented below for an example (Figure 29).



ftp://ftp.epa.gov/wed/ecoregions/or/or_eco_pg.pdf

Figure 29. Level III and IV Ecoregions of Oregon

B.4 DIET

Kelly (1995) described the concept of systematic evaluation of eco-cultural lifestyles for efficiency and resource use patterns, also known as foraging theory. This concept includes labels for people such as hunter-gatherers and foragers, which unfortunately leads to mental images of people barely surviving by randomly foraging around the landscape for something to eat. In reality, these labels describe people living within an informed educational system based on traditional environmental knowledge, systematic observation, rich languages, exquisite crafts, and adaptability.

In the 1960s to 1980s the “Man the Hunter” concept of subsistence lifestyles (with males providing most of the provender) prevailed due to a previous archaeological emphasis on hunting and warfare artifacts (Lee and Devore 1968). This gave way in the 1990s to a more balanced foraging model that recognized the importance of plants as much as meat (and equality of genders in contributing to survival) and a relatively peaceful and secure “original affluent society” (Sahlins 1972). The latter concept is supported by data (Kelly 1995, Winterhalder 1981, Steegman 1983) on the amount of time required to obtain survival necessities and to raise children, and the typically abundant amount of time available for socializing, education, ceremonies, material items, leisure, oratories, and so on. Winterhalder (1981) further elaborated this view by evaluating information about ecotypes, biodiversity, abundance, patchiness, species abundance, and travel times to various resources in the boreal zone to confirm that indigenous traditional environmental knowledge is intimately informed through general knowledge and constant observation for efficient recovery of resources.

In foraging theory, efficiency or return rate for specific resources obtained from specific habitats is estimated by evaluating the amount of calories expended in getting food (search costs) by means of hunting, gathering, or fishing relative to time spent or calories obtained. Foraging information is typically presented as return rates, or net calories obtained per hour of effort. Depending on the evaluation methods used in a study, this return rate data may include (1) time and calories spent in preparing to hunt, fish, or gather (e.g., making nets), (2) time and/or calories spent in the actual activity, and (3) time spent in the processing of the resource after obtaining it. Several submodels have been proposed:

- **Diet Breadth:** In this model, resources are ranked by their value to the forager. Foraging is divided into two phases: search costs (time or energy) to encounter each unit of potential resource species and the pursuit costs for each unit. An optimal diet is one that adds resources to those pursued in decreasing rank order until search costs for a resource start to exceed energy return.
- **Patch Selectivity:** Since most resources are unevenly distributed, the forager must randomly move over the environment and allocate time and effort to travel to various patches of various quality, according to which resources are needed, until the travel time exceeds the value of the resource gained.
- **Movement among Habitats:** The marginal value model assumes that the forager pre-selects the patches to be visited, first using the resources that are closest and best, and gradually moving to lower quality patches farther away until the travel time is so great that the residence is moved and/or hi switches to different resources.

The drawback of oversimplifying foraging solely to caloric efficiency is that micronutrients (vitamins, minerals, specific amino acids, and fatty acids), medicinal or pharmacologically active compounds, other nutritional requirements, and non-nutritional attributes, such as aroma or dye or material uses may not be considered (Lindstrom 1992). Similarly, many plants and animals have multiple uses or are co-located with other resources; therefore, caloric calculations must not ignore the way that people actually make decisions about where to go or what to gather, or the reasons they seek to obtain particular resources.

Sanger (1988) points out that developing a foraging picture based solely on archaeological evidence is inadequate because the ratio between marine and terrestrial remains in sites and the ratio between plants and fish and bone among middens is not equal. Supplementary information would include the known technology and the amount of biomass and phytomass that could have been provided by the particular habitat association types and biodiversity (Winterhalder 1981).

Together, the amount of hunting and fishing gear in evidence, the seasonal round, the settlement pattern relative to known resources, human bone isotope ratios, pollen profiles over time, and so on give a fairly accurate picture of the overall diet (Sanger 1988).

The dietary input for the risk assessment is typically somewhat less complex than a food pyramid (due to intrinsic limitations of the risk methods). Nevertheless, the risk assessment must consider the totality of species and calories. Therefore, the food pyramids consider the number of species and the foraging studies with their dietary estimates, and identify potential toxins.

As noted in Section B.2.1, the steps developed to reconstruct an ecologically based diet are:

1. Review ecological and foraging information specific to the tribe, and the local ecosystem(s);
2. Review interviews and other archaeological and ethnographic sources for supporting information of species and abundance, habitat types, human activity levels, and methods of obtaining, preparing, and using resources;
3. Develop overall percentages of major food categories and major staples within the total diet;
4. Estimate calories provided by the diet, and compare estimates of percentages of quantities and percentages of calories;
5. Refine estimates of major staples and food categories after considering information about medicines, sweeteners, other often-overlooked food/medicine types like macronutrients, and other factors.

B.4.1 Nutritional Analysis

The basis for subsistence diets is an assumption of 2000 to 2500 kcal/day. The amount of 2000 kcal is much less than athletes in training, but is adequate for a mix of 2 hours of high activity, 6 hours of moderate activity, 8 hours of low and sedentary activity, and 8 hours of rest. Basic nutritional and energy requirements (Stipanuk 2000) were compared to information on resource abundance to evaluate overall adequacy of the initial diets. The initial estimates are then refined based on information on paleonutrition (Wing and Brown 1979, Sobolik 1994) and exercise physiology (McArdle et al. 1996, 1999). Additionally, methods from other authors was also evaluated for relevance and compared to the results in this report (Delorimer and Kuhnlein 1999, Egeland 2004, Kuhnlein et al. 1996, Kuhnlein et al. 2006, White 1999).

The diets reflect foods obtained solely from each of the major habitat types. All of the caloric information is from the USDA database[4] for either the exact species or a member of the same or nearest plant or animal family. The data for fresh or cooked foods matches the form of native plants eaten as closely as possible. The USDA derived this data from recent studies on contemporary domesticated and wild foods, including some information on different methods of food preparation. Some of the information was obtained by USDA in response to requests from Indian tribes and is appropriate as to species and cooking method (e.g., roasted beaver). In other cases nutrient data are not available (such as for wild tubers or bulbs), so data for the most natural domesticated species was used. In most cases this would probably not alter the high-level food pyramid or food circle, even though native peoples recognize that flavor, texture, and "strength" differ between wild species and domesticated cultivars.

An example of a diet adapted to Maine coastal environments is shown in Table 1. Figure 30 displays the Maine coastal diet estimate as a food wheel. Figure 31 shows estimated diets for the Confederated Tribes of the Umatilla Indian Reservation (CTUIR).

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[4] http://www.ars.usda.gov/main/site_main.htm?modecode=12354500

Table 1. Maine coastal diet.

Representative 2000 kcal Diet—Coastal (Islands, Estuary)			
Food Category	**% of 2000 kcal**	**kcal per 100g (Representative Species)***	**Daily Amount (grams per day)**
Resident fish and other aquatic	5% or 100 kcal	Mixed trout, cooked—190 kcal Crayfish, wild cooked—82 Turtle, raw—89	100 kcal x 100g/175 kcal = 57gpd
Anadromous and marine fish and shellfish	40% or 800 kcal	Salmon, cooked—180 Shad, cooked—252 Herring, dry cooked—200 Pollock, dry cooked—118 Eel, dry cooked—236 Oyster, dry cooked—70 Clam, moist cooked—148 Lobster, moist heat cooked—98 Seal, raw—142 Beluga, raw—111	800 kcal x 100g/175 kcal = 457gpd
Game, large and small	25% or 500 kcal	Deer, roasted—158 Moose, roasted—134 Moose liver, braised—155 Rabbit, wild, roasted—173 Beaver, roasted—212 Muskrat, roasted—236	500 kcal x 100g/175kcal = 286gpd
The items below are the same for all Maine subsistence diets (25% of calories)			
Fowl and eggs	12% or 240 kcal	Quail, cooked—234 Duck, cooked—200 Duck eggs—185 Pheasant (for wild turkey) —247	240 kcal x 100g/200 kcal = 120gpd
Roots, tubers, rhizomes	2% or 40 kcal	Raw Chicory root—73 Boiled burdock root—88 Potato, baked (tuber) —200	40 kcal x 100g/100 kcal = 40gpd
Bulbs	2% or 40 kcal	Leek, onions and bulbs (bulb & leaf)—31	40 kcal x 100g/30 kcal = 133gpd
Berries, fruits	2% or 40 kcal	Raw elderberries—73 Raw strawberries—70	40 kcal x 100g/100 kcal = 40gpd
Other vegetables (above-ground)	2% or 40 kcal	Beans, cooked pinto, kidney or white—143 Peas, boiled pigeon or split—120 Squash, cooked winter—37 Squash, cooked Navajo—16	40 kcal x 100g/100 kcal = 40gpd
Greens, tea**	2% or 40 kcal	Raw dandelion greens—45 Raw watercress—11 Fiddleheads, raw—34	100 kcal x 100g/30 kcal = 133gpd
Seeds, nuts, grain	6% or 120 kcal	Corn, Navajo steamed—386 Raw dried sunflower seeds—570 Chia seeds—490 Hazelnut, dry roast—646 Butternuts, dried—612	120 kcal x 100g/500 kcal = 24gpd
Honey, maple syrup, other	2% or 40 kcal	Honey—304 Maple syrup—261	40 kcal x 100g/275 kcal = 15gpd
* All USDA data ** Greens include watercress, and the leaves, stems, shoots of other species for food, medicine, tea, flavor			

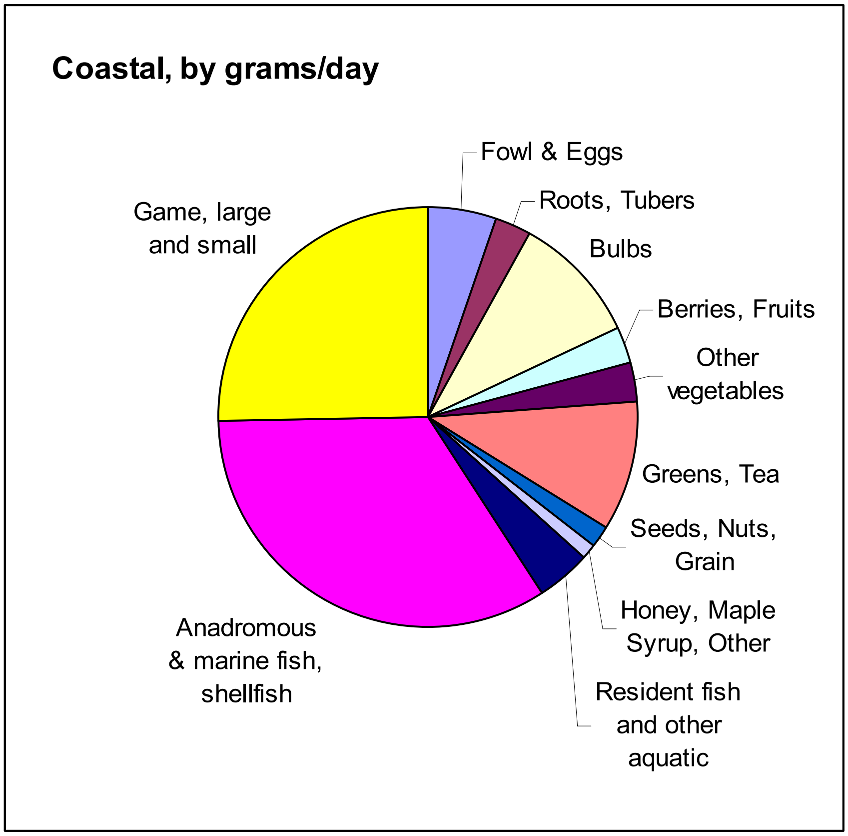
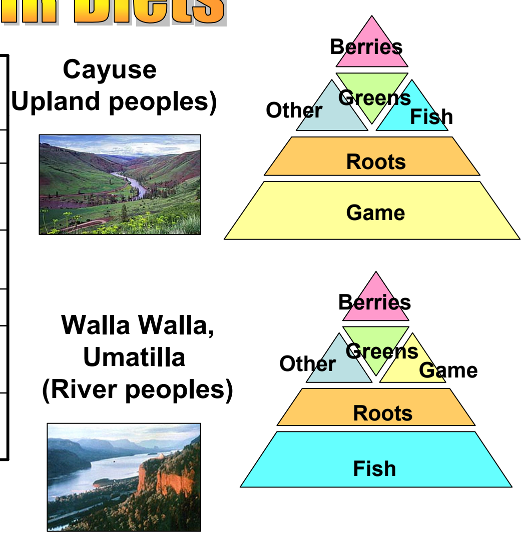


Figure 30. Food Wheel—Coastal Maine

CTUIR Diets

Food Category	Grams Per Day	Kcal per day	% of 2500 kcal
Fish	620	1000	40%
Game, fowl, eggs (reversed for upland Tribes)	125	150	6
Roots	800	800	32
Berries, fruits	125	125	5
Greens, medicinal leaves, tea, stems, pith…	300	300	12
Other: sweeteners, mushrooms, etc.	125	125	5%



Edible and/or materially useful resources includes 200 plant and animal species – a rule of thumb for any ecoregion.

Harper & Harris 2006

Figure 31. Two CTUIR Diets (Columbia River Basin)

B.5 DIRECT EXPOSURE FACTORS AND PATHWAYS

This section focuses on direct pathways: inhalation, dermal exposure, and ingestion of water, sediment, and soil (including soil on the outside of food). Default exposure factors have been developed for conventional suburban, urban, occupational, and recreational scenarios based on national statistics and assumptions about the activity patterns that compose those situations. The approach for developing a tribal scenario is similar, except that large statistical databases are not available. The basic assumption is that traditional Native American lifeways continue to be active outdoor lifestyles that are moderately physically demanding, even with some modern conveniences. Information about especially active individuals is considered; for example, young Indian bachelors ("pure men" or "runners") would run down game and serve as messengers (Speck 1979). Not everyone is considered to be this athletic, but this kind of information is used to confirm a moderately active lifestyle.

The conceptual steps in this process are:

1. Understand the lifestyle and the activities that comprise the lifestyle, and are required to obtain necessities and engage in the community culture;
2. Describe the day, the year, and the lifetime of Maine Indian men and women to identify any significant differences in activity levels between genders or ages;
3. Cross-walk activities with exposure pathways on the basis of frequency and duration of major activities, activity levels, and degree of environmental contact, and
4. Estimate cumulative exposure factors.

B.5.1 Major Activities

Indigenous subsistence foragers (both genders) perform a combination of aerobic (high pulse and ventilation rates), strength, endurance, and stretching-flexibility activities daily, as well as performing more sedentary work and resting. Tables 2 and 3 and Figure 26 show the thought process for considering the wide range and numerous activities associated with the major activity categories (hunting, fishing, gathering, and sweat lodge purification). In actuality, many activities are sequential—for example, a resource might be gathered in one location, used in a second location to make an implement or basket, and taken to a third location for use in hunting or fishing.[5] The activities shown in Figure 32 and Table 2 are so interconnected that it is virtually impossible to separate a lifestyle into distinct categories, but they are presented as separate for illustration.

[5] This is similar to the Cultural Ecosystem Stories concept developed Terry Williams (Tulalip Tribes) with the associated software, ICONS (see, for example, http://www.epa.gov/owow/watershed/wacademy/ wam/comresource.html).

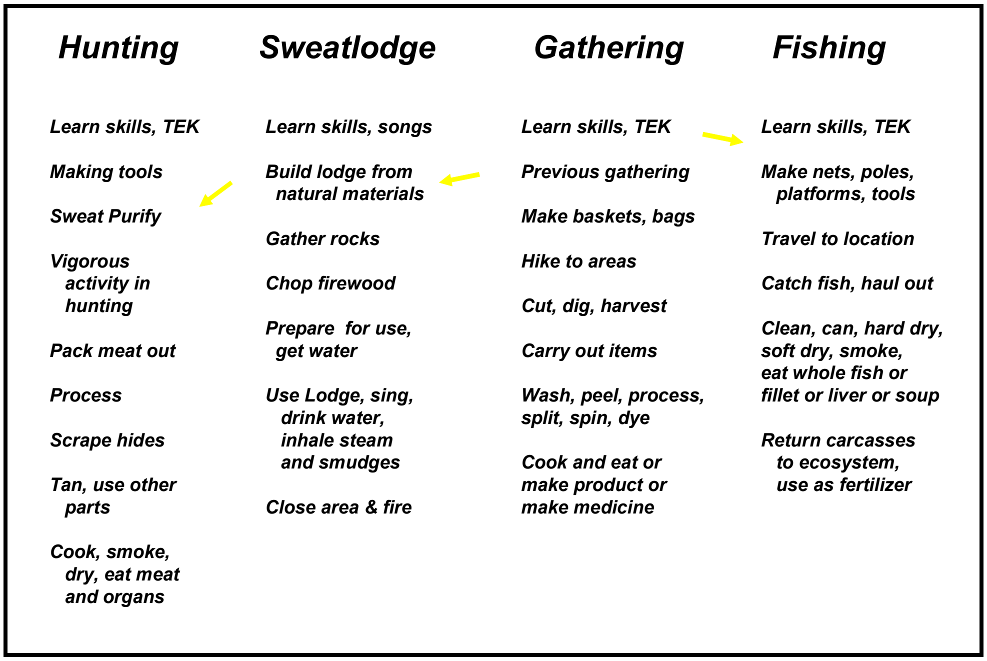


Figure 32. Activities within Major Activity Categories

Table 2. Major activity categories.

Activity Type	General Description
Hunting	Hunting includes a variety of preparation activities of low to moderate intensity. Hunting occurs in terrain ranging from flat and open to steep and rugged. It may also include setting traplines, waiting in blinds, climbing, etc. After the capture or kill, field dressing, packing or hauling, and other very strenuous activities occur, depending on the species. Subsequent activities include cutting, storing (e.g., smoking or drying), and returning the remains to the ecosystem.
Fishing	Fishing includes building weirs, hauling in lines and nets, gaffing or gigging, wading (for shellfish), followed by cleaning the fish and carrying them to the place of use. Activities associated with smoking and constructing drying racks may be involved. Remains are returned to aquatic ecosystems.
Gathering	Women gathered plants, bark, and firewood up to a day or two distant from the camp or village using a digging stick, knife, and basket or other means for carrying resources back to camp. A variety of activities is involved, such as hiking, bending, stooping, wading (marsh and water plants), digging, bundling, carrying, and climbing over a wide variety of terrains.
Ritual purification (sweat lodge)	Sweat lodge building and repairing is intermittent, but collecting firewood is a constant activity. Willoughby (1906) and McBride and Prins (1983, citing Denys) suggest that the sweat lodge was used weekly or monthly, either in a cave or in a small structure covered with mats or skins.
Materials use and food preparation	Many activities of low to high intensity are involved in preparing materials for use or food storage. This category includes basket making, which is an example of a very important activity with its own set of prescribed activities, meanings, and cultural ethics.

Table 3 shows the cross-walk between tribal activity categories and exposure pathways, showing how exposure factors are derived from knowledge about activities, and interlinked resources and ecosystem stories, and the technical literature. This is an iterative process that relies on multiple lines of evidence. This is not intended to be a complete listing of activities. It shows an example of the thought process used to iteratively cross-walk exposure pathways and categories of subsistence activities. The last column, “Totals for major exposure factory categories,” shows how exposure pathways (such as soil ingestion) are evaluated by estimating across activity categories. This is not a statistical summation but rather a judgment based on multiple lines of evidence such as ethnohistorical, archaeological, nutritional, and experimental information.

Table 3. Example exposure considerations for major activity categories.

	Hunting and associated activities	**Fishing and associated activities**	**Gathering and associated activities**	**Ritual purification and associated activities**	**Material and food use and processing**	**Totals for major exposure factor categories**
Food, medicine, tea, other biota ingestion (diet)	*n* deer /yr diet; Total large-small game, fowl; Organs eaten	*n fish* /yr diet; Total pounds or meals/day-wk-yr; Organs eaten	Includes foods, medicines, teas, etc.	No food, but herbal particulates are inhaled	Both as-gathered and as-eaten forms; cleaning and cooking methods	Must account for all calories, breadth of plant species; parts eaten
Soil, sediment, dust, and mud ingestion	Terrain types such as marsh with more mud contact	Sediment contact, dust and smoke if drying; Weir construction, tide flats	External soil on plants; Cooking method	Includes building the sweat lodge and getting materials	Includes incidental soil remaining on foods	Must consider living area, unpaved roads, regional dust and mud
Inhalation rates	Days per terrain type; Exertion level; Hide scraping; Load & grade	Exertion level—nets and gaffing methods; Cleaning effort	Exertion level for load and grade, or gardening; Include making items	Includes building the lodge, chopping firewood, singing	Exertion level for pounding, grinding, smoke from fires	Must account for exertion levels, smokes and smudges
Groundwater and surface water pathways	Ritual bathing, Drinking water; Wash water; Water-to-game and plant pathways	Drinking water; Incidental ingestion; Washing and cooking	Drinking water; Cooking water; Soaking in mud or water	Steam in lodge; Drinking water during sweat	Soaking; Washing; Leaching tannins; Other uses	Must account for climate, sweat lodge, ritual bathing
Dermal exposure	Soil, air, and water pathways, plus pigments, etc.	Immersion considerations	Same as hunting	Immersion with open skin pores	Includes basket making, wounds	Must consider skin loading and habitat types

Seasonality: The changes in activity patterns over the annual seasonal cycle has been modified in modern times, but the ecological cycle has not, so people must still gather plants according to when they are ripe, hunt according to game and fowl patterns, and fish when the spawning runs occur. Many items are gathered during one season for year-round use. While specific activities change from season to season, they are replaced by other activities with a similar environmental contact rate. For instance, a particular plant may be gathered during one month, while another month may be spent hunting, and a winter month may include cleaning and using the items obtained previously.

We generally assume that all activities are roughly equal, that there is no decrease in environmental contact rates during winter months. The main winter foods were fresh, dried, and frozen meats and fish, dried berries, seeds, dried root and seed cakes, and teas and medicines. Gathering firewood was required year-round. There was also winter fishing and hunting, as well as an emphasis on making tools, baskets, and other material items. Food and material preparation were constantly required regardless of the season.

B.5.2 Exposure Factors for Direct Exposure Pathways

For the purposes of developing these exposure factors, the description of tribal activities focused on:

Frequency of activity:
- Daily, weekly, monthly

Duration of activity:
- Hours at a time
- Number of years

Intensity of environmental contact and intensity of activity

Drinking Water:

The Spokane and Umatilla scenarios (Harper et al. 2000, Harris and Harper 1997) recommended 3L/d for the hot arid climate of the Columbia Basin. However, other climates are cooler and moister. Two liters might be appropriate elsewhere.

Soil and Sediment Ingestion:

Soil ingestion includes consideration of direct ingestion of dirt, mud, or dust, swallowing inhaled dust, mouthing of objects, ingestion of dirt or dust on food, and hand-to-mouth contact. We recommend an indigenous soil ingestion rate of 400mg/day based on a review of EPA guidance, soil ingestion studies in suburban and indigenous settings, and dermal adherence studies (see Appendix for more detail). It is also based on knowledge about tribal subsistence lifestyles with their higher environmental contact rates and local climatic and geologic conditions. It reflects a variety of soil exposure pathways such as cooking, gardening or wild foods harvesting and/or gathering, residual soil or dust on foods and medicine, holding natural materials in the mouth while processing or using the materials. It also considers many *1-gram days and 1-gram events*, such as sports, powwows, days in wetlands or marshes, and similar activities. There are also likely to be many intermediate-contact days, depending on the occupation (e.g., wildlife field work, construction or road work, cultural resource field work).

The soil ingestion rate of 400mg/d for all ages is the published upper bound for suburban children (EPA 1997), and is within the range of outdoor activity rates for adults but lower than the typical 480mg/d applied to intermittent outdoor occupations. Tribal subsistence lifestyles were not considered by the EPA guidance, but are generally considered to be similar in soil contact rates to construction, utility worker or military soil contact levels. The U.S. military assumes 480mg per exposure event[6] or per field day. The UN Balkans Task Force assumes that 1 gram of soil can be ingested per military field day.[7] Anecdotally, U.S. forces deployed in Iraq report frequent grittiness in the mouth and food. Haywood and Smith (1990) also considered sensory reports of grittiness in their estimate of 1–10g/d in aboriginal Australians.

Simon (1998) reviewed soil ingestion studies from a perspective of risk and dose assessment. Because of their high dependence on the land, indigenous peoples are at highest risk for inadvertent ingestion, along with professions that may bring workers into close and continual contact with the soil. Simon recommends using a soil ingestion rate for indigenous people in hunter/food gathering/nomadic societies of 1g/d in wet climates and 2g/d in dry climates. He recommends using 3g/d for all indigenous children. This is higher than the prior EPA default value of 200mg/day (USEPA 1989). This rate reflects both indoor dust and continuous outdoor activities analogous to gardening or camping (van Wijnen 1990), but it is less than a single-incident sports or construction ingestion rate (Boyd 1999). After considering all of the exposure pathways and activities, this report recommends the use of 400mg/d per day.

Inhalation Rate:

The inhalation rate in indigenous scenarios reflects the active, outdoor lifestyle of traditional tribal members. Traditional tribal communities have no sedentary members except the frail elderly, whereas one-quarter of modern American adults of all ages report no leisure time physical activity at all.[8] The activity levels associated with the traditional lifestyle and diet based on published anthropological studies, ethnographic literature on foraging theory, hunting-gathering lifestyles, and interviews with tribal members were evaluated (see Appendix). Using EPA guidance on hourly inhalation rates for different activity levels, a reasonable inhalation rate for an average tribal member's active lifestyle is a *median* rate of 26.2m^3/d. This rate is

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[6] http://www.gulflink.osd.mil/pesto/pest_s22.htm, citing US Environmental Protection Agency, Office of Research and Development, "Exposure Factors Handbook," Volume I, *EPA/600/P-95/002a*, August 1997 as the basis for the 480mg/d.

[7] UNEP/UNCHS Balkans Task Force (BTF) (1999). The potential effects on human health and the environment arising from possible use of depleted uranium during the 1999 Kosovo conflict. http://www.grid.unep.ch/btf/missions/september/dufinal.pdf.

[8] http://www.cdc.gov/brfss/pdf/ 2001prvrpt.pdf and http://www.cdc.gov/brfss/pubrfdat.htm.

based on 8 hours sleeping at 0.4m^3/hr, 2 hours sedentary at 0.5m^3/hr, 6 hours light activity at 1m^3/hr, 6 hours moderate activity at 1.6m^3/hr, and 2 hours heavy activity at 3.2m^3/hr. Unlike most other exposure factors, which are upper bounds, the inhalation rate is a median rate. This is rounded down to 25m^3/day based on the relation of oxygen utilization to caloric intake.

Dermal Exposures:

The dermal pathway has not been fully researched for this scenario, but EPA methods[9] for dermal exposure can be used. Two relevant papers are summarized here. Kissel et al. (1996) included reed gatherers in tide flats in a study of dermal adherence. The category of “kids in mud” at a lakeshore had by far the highest skin loadings, with an average of 35mg/cm^2 for 6 children and an average of 58mg/cm^2 for another 6 children. Reed gatherers were next highest at 0.66mg/cm^2 with an upper bound of >1mg/cm^2. This was followed by farmers and rugby players (approximately 0.4mg/cm^2) and irrigation installers (0.2mg/cm^2). Holmes et al. (1999) studied 99 individuals in a variety of occupations. Farmers, reed gatherers, and kids in mud had the highest overall skin loadings. The next highest skin loadings on the hands were for equipment operators, gardeners, construction, and utility workers (0.3mg/cm^2), followed by archaeologists, and several other occupations (0.15–0.1 mg/cm^2). In the future, a more refined approach that considers numbers of days or hours in various habitats and activities and matches that information with soil ingestion rate could be used. For example, the soil ingestion rate and dermal adherence rate should both consider the number of mud-event days and the proportion of wetlands present in the region of the location where the scenario is being applied.

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[9] http://www.epa.gov/superfund/programs/risk/ragse/

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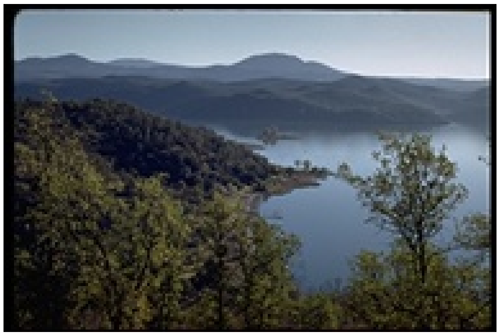
Elem (Pomo)
Human Health Risk Assessment
Exposure Scenario



Clear Lake[1]

Clear Lake Pomo Hunter on a Tule Raft[2]

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[1] Photos by Charles Webber, posted at http://calphotos.berkeley.edu/cgi/img_query?where-genre=Landscape&query_src=photos_landscape_index&rel-location=like&where-location=clear+lake&rel-plant_comm=like&where-plant_comm=&where-continent=any&where-country=any&where-state=California+%282716%29&rel-county=eq&where-county=any&where-collectn=any&rel-photographer=eq&where-photographer=any&rel-kwid=equals&where-kwid=
[2] CURTIS, Edward Sheriff, The Hunter—Lake Pomo; http://www.donaldheald.com/browse18.html

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1 INTRODUCTION

This document presents the Elem (Southeastern Pomo) Exposure Scenario at Clear Lake, California. An exposure scenario is a narrative and numerical representation of the interactions between human receptors and their immediate environment. Exposure scenarios include media-specific and pathway-specific exposure factors that reflect the degree of environmental contact for each medium and each exposure pathway, expressed as the frequency, duration, and intensity of contact. If environmental contamination is present, the exposure factors are used to estimate human exposure, expressed as the dose of each contaminant to the person for whom the exposure scenario is developed. The dose of each contaminant is combined with its toxicity to develop and estimate of health risk to the person. Exposure factors can also be used to develop environmental standards to ensure that natural resources are safe to use.

Even though many tribal lands have been lost and resources degraded, there are generally more traditional or subsistence practices followed by tribal members than the general non-native population realizes. Additionally, the objective of many tribes is to regain land, restore resources, and encourage more members to practice healthier (i.e., more traditional) lifestyles. Therefore, the objective of subsistence exposure scenarios is to describe the original lifestyles and resource uses, not to present a current snapshot of restricted or suppressed uses, because the intent is to restore the ecology so that the original pattern of resource uses is both possible (after resources are restored) and safe (after contamination is removed). This is a different situation than for the general American population, where the intent of remediation is to allow people to continue their *current* (and portable) lifestyle in a newly cleaned location.

For the general United States population, an exposure scenario is typically designed to describe an upper bound (generally around the 75th percentile) of the population being assessed. Some individual exposure factors are the 90th or 95th percentile; others are mean values. In the case of tribal exposure scenarios, there are no tribal-specific databases of subsistence activities, resources, or diets as there are for the general United States population. Cross-sectional surveys of current tribal populations will not generate that data because much resource use has been suppressed due to loss of land and access, awareness of contamination, prosecution by the dominant society, and other reasons. This means that large and accurate statistical distributions for subsistence exposure factors are not available and cannot be developed unless only a fully subsistent subset of the tribe is studied, and this is not possible because the traditional subsistent members resist being studied and measured. Therefore, ranges of exposures, or specified percentiles of exposure are not possible to calculate. The Elem Scenario is reconstructed as a reasonable representation of the traditional subsistence lifestyle, equivalent to a central tendency of this lifestyle rather than a statistical upper bound.

For the general suburban population the exposure scenario is well defined in EPA guidance (Exposure Factors Handbooks). The Elem tribal scenario is based on the lifestyle and baseline conditions of the regional natural resources.

This scenario identifies general exposure pathways specific to Elem lifestyles and key resources that the Elem people use. It starts with a general description of baseline natural resources that are (or should be) present in the study area. A general understanding of what people do (or would do in the absence of contamination) and what resources are available for their use provides the basis for developing preliminary exposure factors. Then the scenario describes the activities that traditional people undertake to survive and thrive in that local ecosystem, including hunting, gathering foods and medicines, fishing, making material items, farming or gardening, raising livestock, irrigating, and various cultural and domestic activities.

As mentioned, the exposure scenario reflects a traditional subsistence lifestyle. Subsistence refers to the hunting, fishing, and gathering activities that are fundamental to the way of life of many indigenous peoples. Today's subsistence economies utilize traditional and modern technologies for harvesting and preserving foods and for distributing the produce through communal networks of sharing and bartering. The following is a useful explanation of "subsistence," taken from the National Park Service:

> While non-natives tend to define subsistence in terms of poverty or the minimum amount of food necessary to support life, native people equate subsistence with their culture. Among many tribes, maintaining a subsistence lifestyle has become the symbol of their survival in the face of mounting political and economic pressures. It defines who they are as a people. To Native Americans who continue to depend on natural resources, subsistence is more than eking out a living. While it is important to the economic well-being of their communities, the subsistence lifestyle is also the basis of cultural existence and survival. It is a communal activity. It unifies communities as cohesive functioning units through collective production and distribution of the harvest. Some groups have formalized patterns of sharing, while others do so in more informal ways. Entire families participate, including elders, who assist with less physically demanding tasks. Parents teach the young to hunt, fish, and farm. Food and goods are also distributed through native cultural institutions. Most require young hunters to distribute their first catch throughout the community. Subsistence embodies cultural values that recognize both the social obligation to share as well as the special spiritual relationship to the land and resources. This relationship is portrayed in native art and in many ceremonies held throughout the year.[3]

In economic terms, a subsistence economy is one in which a dollar currency is limited because many goods and services are produced and consumed by the same

[3] National Park Service: http://www.cr.nps.gov/aad/cg/fa_1999/Subsist.htm

families or bands. Today, currency (symbols of specified quantities of useful resources) is limited, but important, so many indigenous families include members whose role is to acquire various types of wealth. The subsistence economy does include currencies of goods, services, knowledge, obligation, and respect, as well as ‘money’ or symbols of work that are used to ‘buy’ goods or services whose use is displaced in time and space from their production. Examples of money include wampum and, today, dollars. Wealth can be measured in other ways, including the security that comes from an abundance of respect that ensures that resources will be provided to the family even in lean times, as well as from community well-being and sensory loading from the beautiful and aromatic natural surroundings. For example, subsistence in an Arctic community includes the following:

> The modern-day subsistence family depends on the tools of the trade, most of which are expensive. Snowmobiles, gasoline, guns, fishing nets, and sleeping bags are necessities. Subsistence households also enjoy many of the modern conveniences of life, and are saddled with the economic demands which come with their acquisition. Today’s subsistence family generates much-needed cash as wage-labourers, part-time workers and trappers, professional business people, traditional craftmakers, and seasonal workers. A highly-integrated interdependence between formal (cash-based) and informal (barter and subsistence-based) economic sectors has evolved.[4]

Once the activities composing a particular subsistence lifestyle are known, they are translated into a form that is used for risk assessment. This translation captures the degree of environmental contact that occurs through activities and diet, expressed as numerical *exposure factors*. Exposure factors for direct exposure pathways include exposure to abiotic media (air, water, soil, and sediment), which can result in inhalation, soil ingestion, water ingestion, and dermal exposure. Indirect pathways refer to contaminants that are incorporated into biota and subsequently expose people who ingest or use them. There are many unique exposure pathways that are not accounted for in scenarios for the general public, but may be significant to people with certain traditional specialties such as basket making, flint knapping, or using natural medicines, smoke, smudges, paints, and dyes. These activities may result in increased dust inhalation, soil ingestion, soil loading onto the skin for dermal exposure, or exposure via wounds, to give a few examples. While the portals of entry into the body are the same for everyone (primarily via the lungs, skin, mouth), the amount of contaminants may be increased and the relative importance of some activities (e.g., basket making, wetlands gathering), pathways (e.g., steam immersion or medicinal infusions), or portals of entry (e.g., dermal wounding) may be different than for the general population.

Foraging theory data from the anthropological literature is particularly useful for developing exposure scenarios because the major dietary and resource staples may be described, as well as how much time and effort is needed to obtain them.

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[4] http://arcticcircle.uconn.edu/NatResources/subsistglobal.html

Together, this information is then used for the food-chain portion of the scenario and to calculate the direct exposure factors.

This process is laid out in the following sections according to the general sequence:

1. Environmental setting—what resources are available;
2. Lifestyle description—activities and their frequency, duration and intensity, and resource use;
3. Diet;
4. Exposure pathways, and
5. Exposure factors—iterative cross-walk between pathways and direct exposure factors: cumulative soil, water, air, and dietary exposures.

Because the method for developing exposure factors is derived from an understanding of lifestyle rather than from large statistical databases (national drinking water rates, or USDA databases of national average food intakes) and is unfamiliar to many readers, it is described briefly here (more detail is presented below).

Because large databases are not available and cannot be constructed, we take a top-down approach. For example, we do not attempt to develop a complete diet based on surveys of the uses of the typical 200+ natural resources available and used with an ecoregion. Rather, we develop a calorically complete estimate of a 2000kcal/day diet that identifies the major staples and their rough percentages in the original diet. Similarly, we do not develop an average day by tracking hundreds of individual activities from many people. The basic process is to:

1. Start with an understanding of the major categories of subsistence activities (such as hunting, fishing, gathering, basket making, and sweat lodge purification),
2. Describe enough of the sub-activities that the complexity and interconnection of resources and activities can be understood,
3. Identify the major activities that contribute to exposure, and then
4. Iteratively cross-walk between activities and conventional exposure factors to develop cumulative exposure factors.

To illustrate, each of the major activity categories includes activities that result in exposure to soil, and therefore soil ingestion. By estimating the relative amount of time spent in activities that result in high, medium, or low soil exposure for each activity category, an overall soil-ingestion rate can be estimated. However, we do not attempt to be overly quantitative in enumerating the myriad activities and resources in each category—this requires more precision than is warranted and is likely to require proprietary information that cannot be released.

Finally, a review of existing literature (biomedical, anthropological, and so on) enables us to double-check whether multiple lines of evidence leads us to a similar conclusion for each exposure factor.

2 ENVIRONMENTAL SETTING

This section provides a general introduction to habitats and plant communities present in Elem territory. Baseline environmental conditions are approximated. This is not a fixed year, but rather a condition of natural resources. In the case of Elem, baseline conditions refer to the early-contact time period when there were still ample resources and minimal land loss. This time period extends to as recently as 100–200 years ago, before the era of the large California irrigation projects and development of the California interior and the Clear Lake region.

The overall territory of the Pomo peoples is north of San Francisco Bay approximately 130 miles north to south and 100 miles east to west. Pomo environments include the coastal and redwood belts, river valleys, and the Clear Lake area where Elem is located. It reaches from the coast to the Sacramento River in the interior California central valley (Baumhoff 1978, Barrett 1908).

Habitation around Clear Lake began at least 10,000 to 12,000 years ago (Willig et al. 1988, McLendon and Lowry 1978). Each cluster of village communities (or 'tribelet') was slightly different from the next, resulting in a wide range of cultures and seven languages. The Elem people were located in Elem, the largest of the southeastern Pomo villages, on Rattlesnake Island (or Sulphur Bank Island) in Clear Lake, and in two other smaller villages on Clear Lake (McLendon and Lowry 1978, Brown and Andrews 1969, Willig et al. 1988).

The Clear Lake area is shown in a map of the continental US in Figure 1.

Figure 1. Continental US with Clear Lake Location

2.1 CLEAR LAKE ECOSYSTEM

Many tribal homelands are defined in terms of watershed boundaries with the water source in the center (unlike the Western habit of using rivers as peripheral boundaries). This is because native peoples use entire river valleys with their ranges of elevation from the river bottoms to the boundary ridges or mountains, and utilized the associated seasonal patterns of resource availability. Figures 2–6 show the Elem area within its watersheds, beginning with California's greater watersheds below.

http://cwp.resources.ca.gov/browser/

Figure 2. California Watersheds

Figure 3 indicates the location of the Sacramento River watershed. Figures 4 and 5 show the Clear Lake region (Cache Creek).

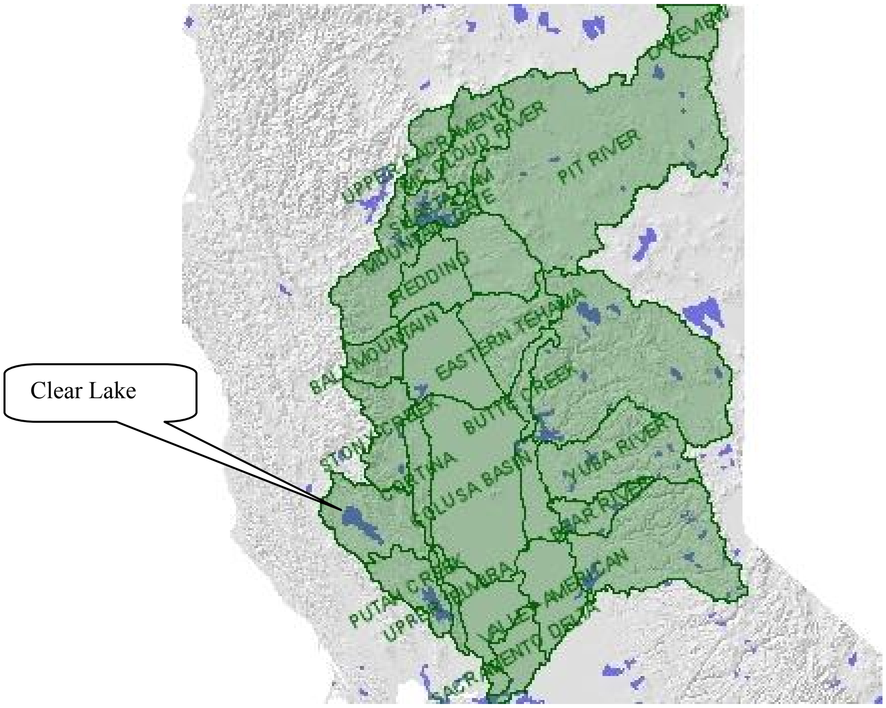

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Figure 3. Sacramento River Basin

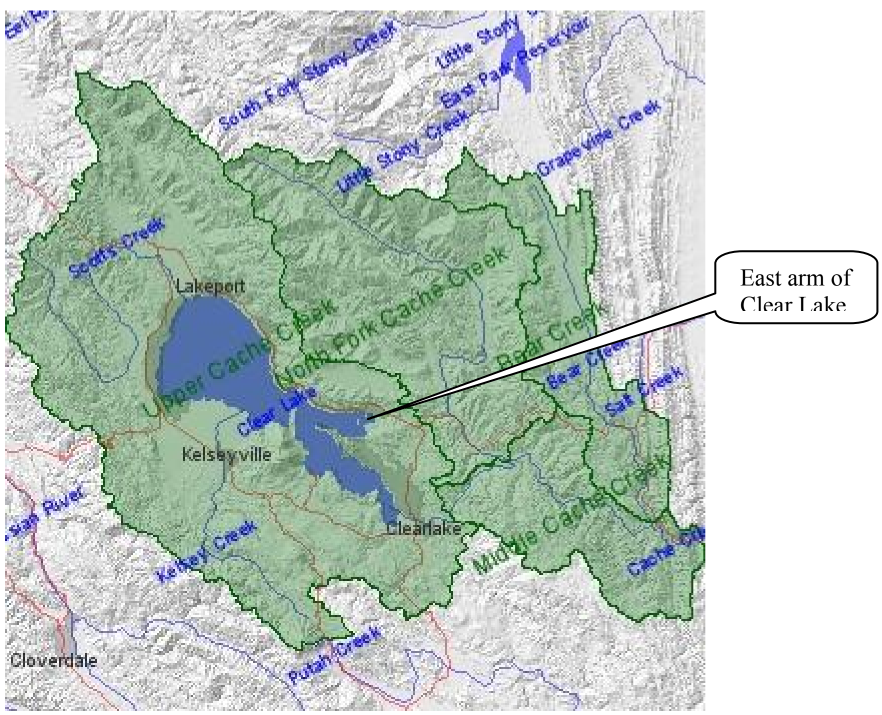

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Figure 4. Cache Creek Subregion

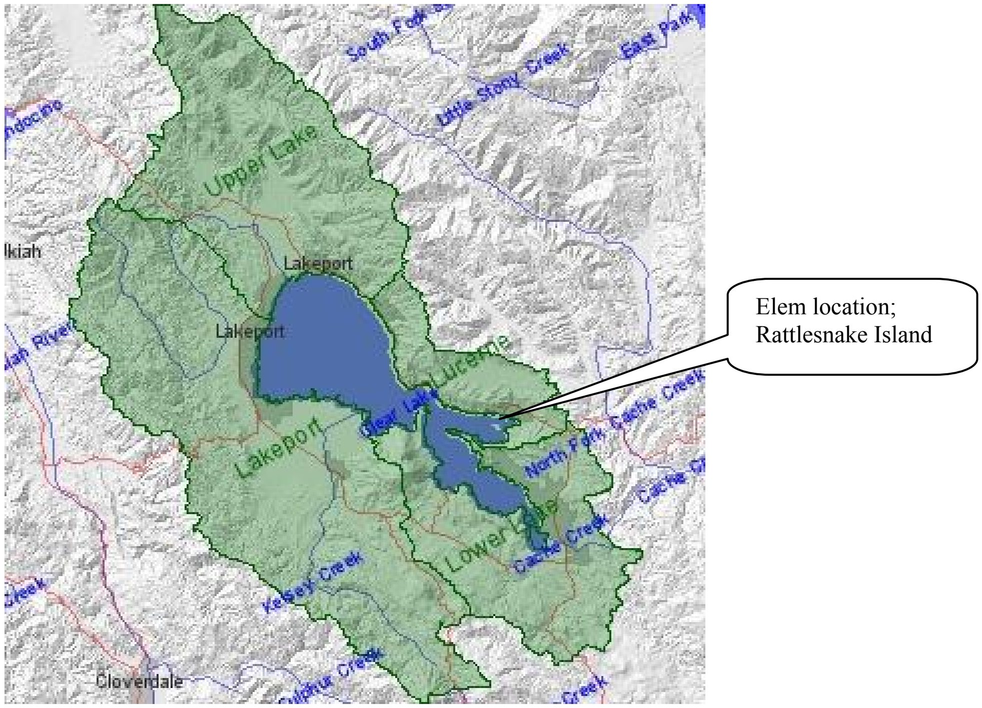

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Figure 5. Upper Cache Creek Subregion

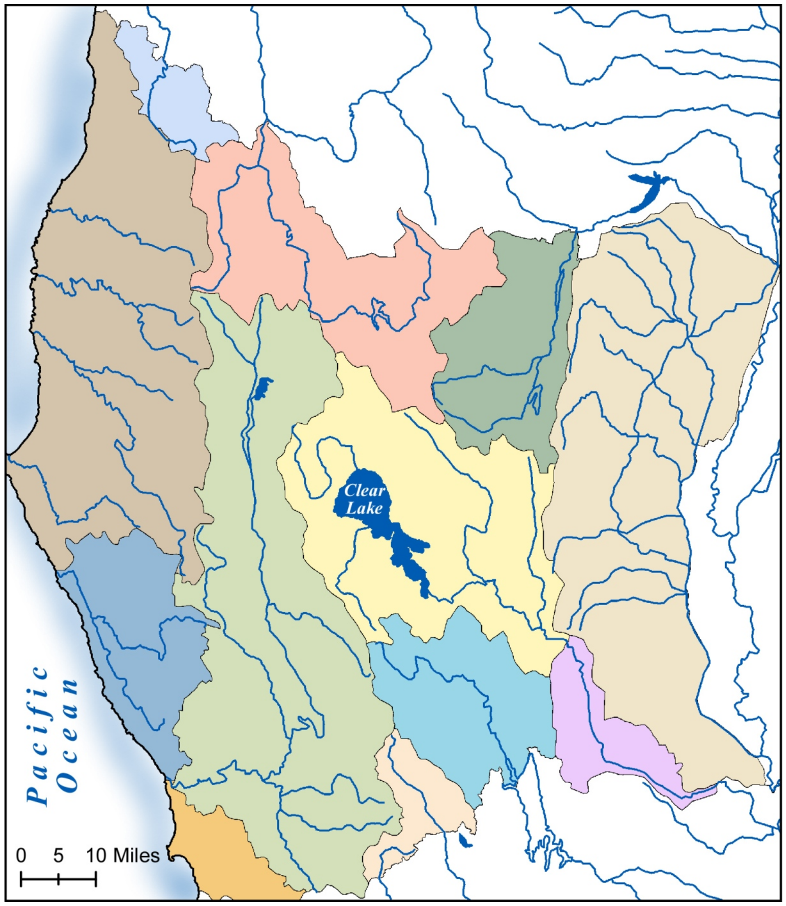

Figure 6. Clear Lake Area Watersheds

Clear Lake is located in an area of California characterized by Mediterranean climate, considerable rainfall in winter, and a long, hot, dry period in summer (McLendon 1977). The vegetation in the Elem area includes a few square miles of pine-fir forest, 150 square miles of oak woodland, and 53 square miles of chaparral types, as well as lake-marsh-riparian zones with gallery forests of oak, cottonwood, and willow along streams (Baumhoff 1963, White et al. 2002, Anderson et al. 1997). The Elem area has two streams with Clear Lake cyprinid runs in spring (chi or Clear Lake hitch,[5] pike minnow, and sucker), and midsummer lakeshore runs of tule perch, Sacramento perch and blackfish.

Briefly, the vegetation types and major species around Clear Lake follow (Goodrich 1980, White et al. 2002).

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[5] Clear Lake Hitch, *Lavinia exilicauda chi*, are a "Species of Special Concern" in California. Clear Lake hitch are in the minnow family. Adults reach lengths of up to 14 inches and exceed one pound in weight. Clear Lake hitch are a unique subspecies; the word "chi" acknowledges the name given to this species by Pomo Indians, the native people of the Clear Lake basin. http://www.nativefish.org/articles/hitch.php

2.1.1 Lake, Marsh, and Riparian Habitat

Originally there were very large marshes of willows and tule on Clear Lake, with large nesting and spawning areas. The margins of the lake were almost completely surrounded by a fringe of tules, which have an “impressive number of uses,” including houses, boats, clothing, plates, mats, diapers, beds, and food (Brown and Andrews 1969).

Along the streams, the pepperwood or California laurel (*Umbellularia californica*) is much used. The willow (*Salix argyrophylla)* is particularly important as a basket material. Groves of alder (*Alnus rhombifolia*) are found near mountain streams and near springs. The wild grape (*Vitis californica*) occurs in the alder groves.

2.1.2 Uplands

Dry slopes and hills typically have patches of mixed evergreen—oak, madrone (*Arbutus menzeii*), Douglas fir, pepperwood, with chestnut, other oaks, maple, and hazelnut in lesser quantities. The understory is manzanita, berries, other browse, plus grasses and forbs, with meadows with bulbs and clover.

Oak Woodland: Oak woodlands are dominated by black oak, often with ponderosa pine, Douglas fir, canyon live oak, madrone, scrub oak, manzanita, maple, and buckeye. The understory is mostly grass. One of the most common and striking trees is the white oak (*Quercus lobata*), which provided a great amount of food, both because of abundance and because of the “excellent flavor of the acorns.” Other oaks of importance include the California black oak (*Q. california*), the Pacific post oak (*Q. garryana*), the tan-bark oak (*Q. densiflora*), and the maul oak (*Q. chrysolepis*).

Oak Grassland: Oak grassland contains blue oak (*Q. douglassi*), with gray pine, California buckeye, toyon, poison oak, and various grasses: *Bromus* spp., wild oats, fescue, filaree (*Erodium*), bluegrass (*Poa spp*), three-awn (*Aristida*), and needlegrass (*Stipa*).

Chaparral: Chaparral is a patchy composite of scrub oak, chamise-dominated brush, and ceanothus-dominated brush.

- Oak chaparral includes scrub oak, leather oak, and live oak, with whiteleaf manzanita, California buckeye, Jepson ceanothus, chamise, and sargent cypress.
- Chamise-dominated chaparral contains chamise, with wedgeleaf ceanothus, Eastwood manzanita, creeping sage, toyon, Stanford manzanita, and Fremont silktassel.
- Ceanothus-dominated chaparral contains ceanothus, common manzanita, hoary manzanita, bracken, foothill ash, and chamise.

2.2 RARE SPECIES

Rare species identified by the California Department of Fish and Game presently occurring in the Clearlake Oaks and Clearlake Highlands quads are shown below, tables 1 and 2, preceded by a corresponding map, Figure 7. The information was taken from the following Web site, http://cwp.resources.ca.gov/browser/cnddbQuery.epl?quadcode=3912216&quadname=Clearlake%20oaks.

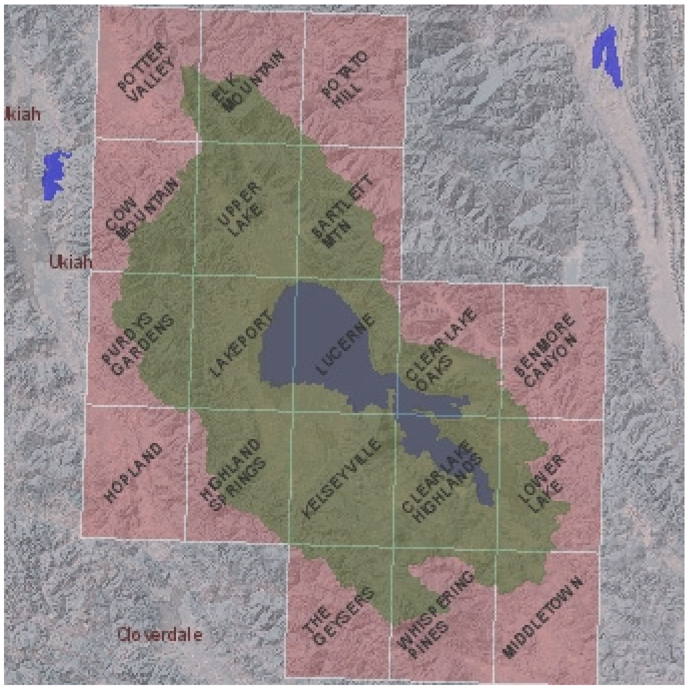


Figure 7. Clear Lake Area USGS Quad Maps

Table 1. Clearlake Oaks quad rare species.

Scientific Name	Common Name	Federal Status	California Status	Sensitive
Archoplites interruptus	Sacramento perch	None	None	N
Arctostaphylos manzanita ssp. elegans	Konocti manzanita	None	None	N
Great Valley Mixed Riparian Forest	Great Valley Mixed Riparian Forest	None	None	N
Lavinia exilicauda chi	Clear Lake hitch	None	None	N
Layia septentrionalis	Colusa layia	None	None	N
Potamogeton zosteriformis	Eel-grass pondweed	None	None	N

Table 2. Clearlake Highlands quad rare species.

Scientific Name	Common Name	Federal Status	California Status	Sensitive
Archoplites interruptus	Sacramento perch	None	None	N
Arctostaphylos manzanita ssp. elegans	Konocti manzanita	None	None	N
Clear Lake Drainage Resident Trout Stream	Clear Lake Drainage Resident Trout Stream	None	None	N
Coastal and Valley Freshwater Marsh	Coastal and Valley Freshwater Marsh	None	None	N
Coccyzus americanus occidentalis	Western yellow-billed cuckoo	Candidate	Endangered	N
Dubiraphia brunnescens	Brownish dubiraphian riffle beetle	None	None	N
Emys (=Clemmys) marmorata marmorata	Northwestern pond turtle	None	None	N
Eriastrum brandegeeae	Brandegee's eriastrum	None	None	N
Eryngium constancei	Loch Lomond button-celery	Endangered	Endangered	N
Harmonia hallii	Hall's harmonia	None	None	N
Hedychridium milleri	None	None	N	
Hesperolinon bicarpellatum	Two-carpellate western flax	None	None	N
Horkelia bolanderi	Bolander's horkelia	None	None	N
Lasthenia burkei	Burke's goldfields	Endangered	Endangered	N
Lavinia exilicauda chi	Clear Lake hitch	None	None	N
Navarretia leucocephala ssp. bakeri	Baker's navarretia	None	None	N
Navarretia leucocephala ssp. pauciflora	Few-flowered navarretia	Endangered	Threatened	N
Navarretia leucocephala ssp. plieantha	Many-flowered navarretia	Endangered	Endangered	N
Northern Basalt Flow Vernal Pool	Northern Basalt Flow Vernal Pool	None	None	N
Northern Volcanic Ash Vernal Pool	Northern Volcanic Ash Vernal Pool	None	None	N
Potamogeton zosteriformis	Eel-grass pondweed	None	None	N
Rana boylii	Foothill yellow-legged frog	None	None	N
Sedella leiocarpa	Lake County stonecrop	Endangered	Endangered	N

2.3 CLEAR LAKE ECOREGIONS

"The entire region abounds in oaks of many kinds, and it is from these that the chief supply of vegetable food of the Indians was derived."

The basic premise of understanding ecologically-based lifeways is that people adapt their activities and diets to their local ecological region in order to survive and prosper. Therefore, the description of environmental setting must identify natural ecological zones, or ecoregions. Ecoregions denote areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources. They are designed to serve as a spatial framework for the research, assessment, management, and monitoring of ecosystems and ecosystem components (Bryce et al. 1999). These general purpose regions are critical for structuring and implementing ecosystem management strategies across federal and state agencies and nongovernmental organizations responsible for different types of resources in the same geographical areas (Omernik 2000).

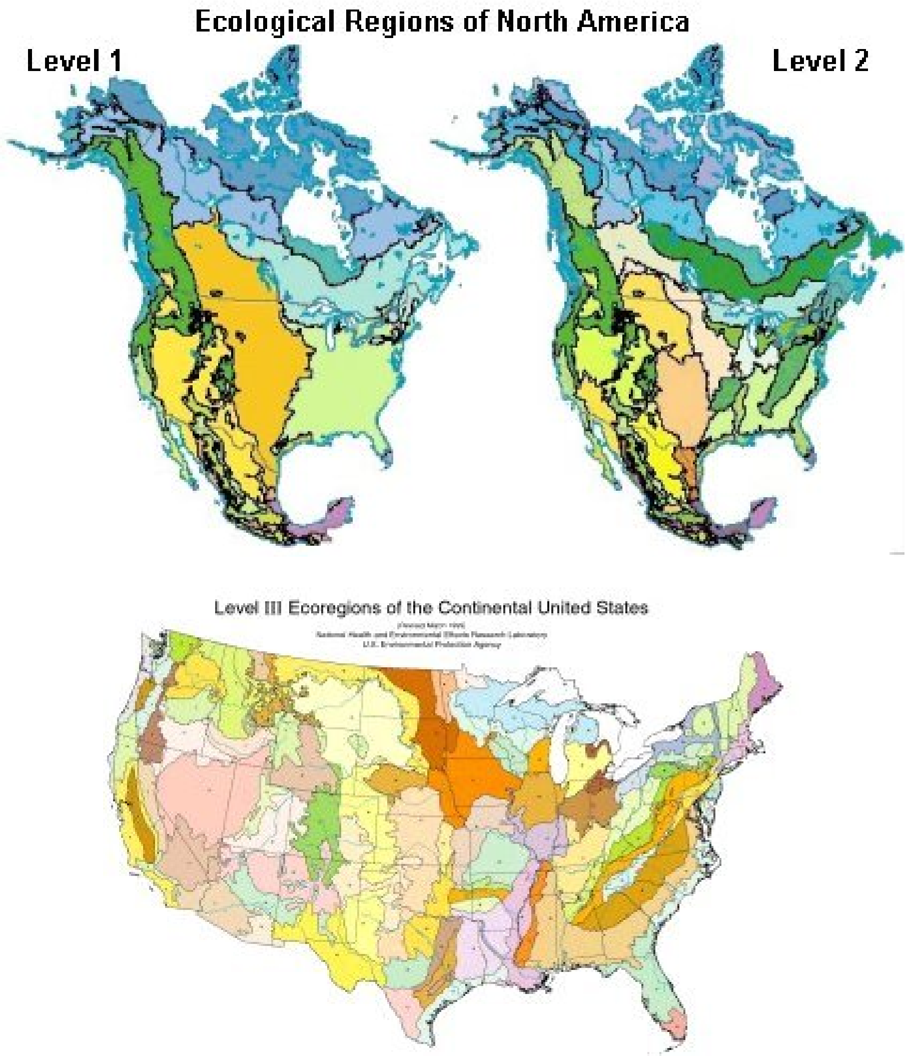
Ecological diversity is strongly related to its varied climate, terrain, geology, and soil, and largely tracks the watersheds and physiographic regions shown in Section 2.1. In North America, several broad climatic zones are recognized, roughly corresponding to temperature and moisture gradients. North American vegetation types roughly track these zones. Of these zones, the marine west coast, Mediterranean California, and northwestern forested mountains are relevant to the Elem Scenario. Because the zones are defined by dominant vegetation types, the composition of plant and animal species is fairly predictable for the dominant species. Local differences in geology (soils and deeper substrates), elevation, aspect, and climate (light, temperature, precipitation and wind), and water (streams and wetlands) affect individual plant associations.

A hierarchical scheme has been adopted for different levels of ecological regions, and is being used by the US Environmental Protection Agency (USEPA)[6]. Level I is the coarsest level, dividing North America into 15 ecological regions. Level II divides the continent into 52 regions. At Level III, the conterminous United States has 84 (USEPA 2005). Methods used by the USEPA to define the ecoregions are explained in Omernik (1995, 2004), Omernik (2000), Gallant et al. (1989), and Bailey (US Forest Service)[7]. The approach used to compile these ecoregion maps is based on the premise that ecoregions can be identified through the analysis of the spatial patterns and the composition of biotic and abiotic characteristics that affect or reflect differences in ecosystem quality and integrity (Wiken 1986, Omernik 1987, 1995). These characteristics include physiography, geology, climate, soils, land use, wildlife, fish, hydrology, and vegetation, including “potential natural vegetation,” defined by Kuchler as vegetation that would exist today if human influence ended and the natural vegetation were restored (including the earlier fire regime of mixed natural and indigenous origin, and natural flooding).

Figure 8 shows the Level I and II ecoregions of North America and the Level III ecoregions of the United States.

[6] http://www.epa.gov/wed/pages/ecoregions.htm and http://www.cec.org/files/PDF/BIODIVERSITY/eco-eng_EN.pdf

[7] USFS Bailey province ecology: http://www.fs.fed.us/land/pubs/ecoregions/intro.html



http://www.epa.gov/bioindicators/html/usecoregions.html

Figure 8. Level I, II, and III Ecoregions

Ecoregion Delineations and Vegetation Types:

Within the general Pomo territory ecoregions have been refined to Level III detail. The ecoregions that exist in this area are listed below from coarsest description (Level I) to a more precise description (Level III):

- 6 Northwestern Forested Mountains (Level I)
- 6.2 Western Cordillera (Level II)
- 6.2.11 Klamath Mountains (Level III)

- 7 Marine West Coast (Level I)
- 7.1 Marine West Coast (Level II)
- 7.1.8 Coast Range (Level III)

- 11 Mediterranean California (Level I)
- 11.1 Mediterranean California (Level II)
- 11.1.1 Southern and Central Chaparral and Oak Woodlands (specific to the Clear Lake area) (Level III)
- 11.1.2 Central California Valley (Level III)

Figure 9 shows the Clear Lake area and its Level III ecoregions.

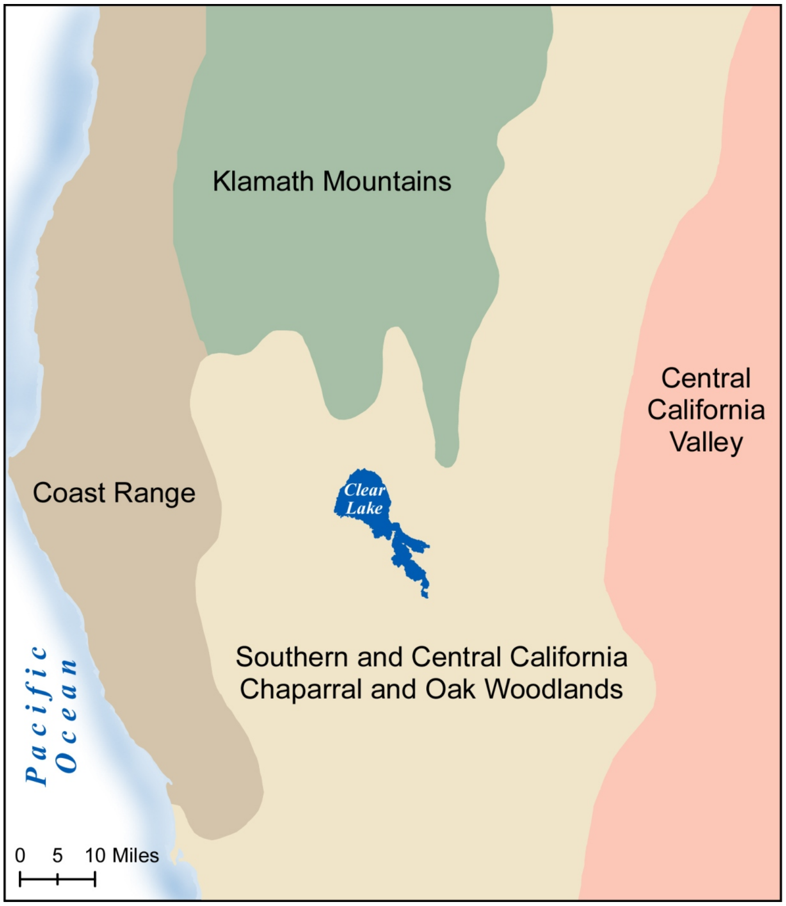


Figure 9. Clear Lake Level III Ecoregions

2.3.1 Northwestern Forested Mountain and Western Cordillera Ecoregion: Klamath Mountains (6.2.11)

Level I Ecoregion 6, Northwestern Forested Mountains, and Level II Ecoregion 2, Western Cordillera, cover the mountainous regions of the West from southern Alaska into California, Utah, and New Mexico (CEC 1997). For more information on the Western Cordillera Ecoregion please refer to *Ecological Regions of North America: Toward a Common Perspective*, online at http://www.cec.org/files/PDF/BIODIVERSITY/eco-eng_EN.pdf. The most specific Level III ecological description of the Western Cordillera relevant to the Elem Pomo territory is the Klamath Mountains Ecoregion 11. The area is physically and biologically diverse. Highly dissected, folded mountains, foothills, terraces, and floodplains occur and are underlain by igneous, sedimentary, and some metamorphic rock. The climate of the Klamath Mountains is subhumid and mild, with a lengthy summer drought. The region supports a mix of northern Californian and Pacific Northwest conifers (USEPA 2006b).

The rugged coastal mountains give this region the nickname “the Klamath Knot.” Within the ecoregion, habitat ranges from wet coastal temperate rain forests to moist inland forests and includes the largest concentration of wild and scenic rivers in the United States. These diverse habitats are filled with unusual communities and many truly unique species. An estimated 3,500 native plants species are found here (National Geographic 2005). The extraordinary biodiversity may be due to the lack of extensive glaciation during recent ice ages, which would have provided both a refuge for many species and long periods of relatively favorable conditions for species to adapt to specialized conditions. The mosaic of habitats includes highly toxic serpentine soils, hosting many specialized plants. Rivers and streams contain freshwater mussels, nine species of native salmon and trout, and many species of snails and salamanders that are restricted to small areas.

2.3.2 Marine West Coast Ecoregion: Coast Range (7.1.8)

The Level II Ecoregion 7.1, Marine West Coast, includes mainland and offshore islands of the Pacific Coast from Alaska south to central California (CEC 1997). For more information on the Marine West Coast Ecoregion please refer to *Ecological Regions of North America: Toward a Common Perspective*, online at http://www.cec.org/files/PDF/BIODIVERSITY/eco-eng_EN.pdf. The most specific Level III ecoregion relevant to the Elem Pomo is the Coast Range Ecoregion 8. Highly productive, rain-drenched coniferous forests cover the low mountains of the Coast Range. Sitka spruce forests originally dominated the fog-shrouded coast, while a mosaic of western red cedar, western hemlock, and Douglas fir blanketed inland areas. A distinguishing feature of the Northern California Coastal Forests ecoregion is its redwood trees, generally found within 40 miles (65 kilometers) of the coast. They are among the biggest, tallest, and oldest trees in the world. Only a few other forests in the world can compare with the complex structure and biodiversity of the redwoods. From the moss and fungi on the forest floor to the rare marbled murrelets that nest only in the ancient trees, the ecosystem supports communities of plants and animals much more diverse than those of younger forests. On uplands where fire disturbance was once more common, redwoods mix with other big trees, such as Douglas fir, grand fir, western red hemlock, Sitka spruce, western red cedar, tanoak, bigleaf maple, California bay, and Port Orford cedar. These forests contain a rich understory of herbaceous plants, shrubs, treelets, ferns, and fungi, as well as a great diversity of animal life.

2.3.3 Mediterranean California Ecoregions: Southern and Central Chaparral and Oak Woodlands (11.1.1) and Central California Valley (11.1.2)

Level II Ecoregion 11.1, Mediterranean California, extends 1,300km from Oregon in the north to Baja California Norte in the south. It abuts the Pacific Ocean on the west and the Sierra Nevada and deserts to the east. For more information on the Mediterranean California Ecoregion please refer to *Ecological Regions of North America: Toward a Common Perspective*, online at http://www.cec.org/files/PDF/BIODIVERSITY/eco-eng_EN.pdf. The most specific ecological descriptions of the Elem Pomo territory are the Southern and Central Chaparral and Oak Woodlands Ecoregion 1 and the Central California Valley Ecoregion 2.

Southern and Central Chapparal and Oak Woodlands: The distinguishing characteristic of this ecological region is its Mediterranean climate of hot dry summers and cool moist winters, and the associated vegetative cover: mainly chaparral and oak woodlands, with grasslands occurring in some lower elevations and patches of pine found at higher elevations. Most of the region consists of open low mountains or foothills, with occasional areas of irregular plains in the south and near the border of the adjacent Central California Valley ecological region that this region encircles.

Many species of oaks are native to this area: blue, scrub, coast live, canyon live, golden-cup, valley, interior live, and maul. In several areas, a base of serpentine rock supports plants which thrive in its presence, including several species of pines and cypresses (such as Sargent and McNab cypress), leather oak, interior silktassel, milkwort streptanthus, and Muir's hairstreak.

Mammals are diverse here, making up 10 percent of the 60 endemic species—the largest number of endemic mammals in any ecoregion in the United States or Canada. Sonoma chipmunks, Suisun shrews, salt marsh harvest mice, and many species of kangaroo rats call the area home. A variety of plethodontid, or lungless, salamanders also live here, including five endemics. Scrub jays, acorn woodpeckers, and wrentits are three of the area's 100 species of birds. Unusual invertebrates found here include army ants, ancient bristletails, and land snails.

This ecoregion supports over 2000 species of plants in addition to trees. This is probably due to the fact that the area is a mosaic of grasslands, chaparral shrublands, open oak savannas, oak woodlands, serpentine communities, closed-cone pine forests, pockets of montane conifer forests, wetlands, salt marshes, and riparian forests. The area also ranges in elevation from 300 feet (90m) to 3,000 feet (900m). Oak woodland and chaparral are the most common plant communities. Valleys contain foothill pines, California buckeye, manzanita, redbud, and chamise.

Central California Valley: The long, hot, dry summers and cool, moist winters of this flat-plained ecological region distinguish it from neighboring regions that are either hilly or mountainous, forested or shrub covered. California's Central Valley was once a large temperate grassland with bunch grasses, the California Central Valley grasslands ecoregion, on which herds of pronghorn and elk grazed; some writers referred to it as “America’s Serengeti.” The area supported incredibly diverse habitats, including desert areas, prairies, savannas, woodlands, marshes, vernal pools (seasonal wetlands), and an immense river delta.

The grasslands once provided plentiful food for pronghorn, elk, mule deer, California ground squirrels, and kangaroo rats. Their predators included coyotes, mountain lions, ringtails, bobcats, and San Joaquin Valley kit foxes, now a federally endangered species found only in southern foothills. River areas were lined by a wide swath of trees such as willows, western sycamores, box elders, Fremont cottonwoods, and valley oaks. These riparian forests provided stopover points and breeding areas for huge flocks of migrating birds from as far as the tropics, and a home for the elderberry longhorn beetle, now a federally endangered species. In winter, the delta marshes provided food and shelter for thousands of waterfowl. Some vernal pools still support the rare Delta green ground beetle.

3 OVERVIEW OF GENERAL ELEM ECOLOGICAL LIFESTYLE

This section describes the ecologically-based lifeways and traditional resource uses that compose the traditional Elem subsistence lifestyle. The Elem culture exploits a wide range of resources and ecological niches. The Elem territory includes several vegetation zones, which allows the people to take advantage of seasonal diversity of resources (Heizer and Elasser 1980). Clear Lake basin was characterized by unusual resource abundance which allowed or encouraged a complex social structure and artisanship (White 1998, McLendon 1977, Brown and Andrews 1969). The interior valley which included the lake was originally filled with grass over 6 feet tall and large game "so abundant like flocks of sheep" (Barrett 1952). People did not have to travel far to obtain all they needed (McLendon 1977). Travel between Clear Lake villages was invariably by balsa (tule stems bound together into boats).

Subsistence activities included traditional and modern technologies for harvesting and preserving foods, as well as for distributing produce and cash through communal networks of sharing and bartering. Stored foods included dried fish, seeds, acorns, buckeyes, pepperwood nuts, with seasonal supplementation of fresh vegetal foods, such as berries, clover, roots, and bulbs. Everyone participated in subsistence activities, and most had additional specialties, such as knowing all the uses of a particular resource (Gifford 1926).

The Clear Lake culture was centered on resources of acorns, fish, game, and tule. Staples (foods that are abundant, reliable, and/or storable) in the area were acorns, large game mammals, roots, seeds, and fish (Baumhoff 1963). The stored foods were acorns (56%), fish (28%), and small seeds (14%). Acorns, seeds and nuts were most often made into two forms of food, atole and pinole,[8] used throughout California. A "typical meal was dried fish and acorn mush," and the components were available year-round in fresh and stored forms. This was supplemented with fresh meat or waterfowl when available, and fresh greens, roots, bulbs, berries, and fruits in season (McLendon and Lowy 1978, McLendon 1977). Cultivation was common among all the Pomo tribes, and fire management was practiced throughout the California region.

3.1 HISTORICAL SEASONAL PATTERNS OF THE ELEM

The Elem year was structured around major resources. The annual natural cycle started with fish runs in February and March. The lake was "teeming with fish," although fishing occurred primarily during spawning runs, when each fish species in succession moved close to shore or into streams to spawn (McLendon 1977). After the first fish runs, the first greens were ready, followed by young tule shoots, and then angelica shoots and other early greens. In May or June the first tubers were ready for digging. A third tuber, Indian carrot, was ready in June or July. Manzanita berries ripened in late June or July, and were eaten fresh or dried and stored to be

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[8] *Atole* is a thick souplike food (mush) made from ground parched acorns or many other nutlike seeds. *Pinole* is the fine flour made from parched seeds. *Balanophagy* is acorn eating.

eaten in pinole during the winter. In July gooseberries and blackberries ripened, and freshwater clams were boiled and eaten. In July and August tule roots were collected, peeled, and eaten. In spring and summer traps were set for various birds and small animals, such as ground squirrels. Rabbits, deer, and squirrels were hunted year round. In August and September, wild cherries and grapes were ripe, and the grains for pinole were collected and stored. In the fall honey was collected. In October the acorns were ready. Buckeyes were gathered in November, then peppernuts, Indian tobacco, and dried milkweed stems (for twine). During the winter, stored food, plus fresh birds, rabbits, deer, and waterfowl were eaten (McLendon 1977).

3.2 GENERAL RESOURCE USE

A detailed list of natural resources used can be found in Appendix A, at the end of this report.

3.2.1 Fishing and Hunting

“While considerable fishing was done by the Pomo on the rivers, such as the Russian and Gualala, and off the rocks of the ocean shore, this profession reached its greatest complexity and perfection among the Clear Lake Pomo, who extensively used the rafts made out of bound tules, and developed elaborate nets and fish traps.” At Clear Lake, fishing was more clearly a specialized profession where certain men did nothing but fish and traded their catch for other necessities. Often they fished all night when fish fed. Fish were grilled, baked, and dried and smoked (Brown and Andrews 1969). Large game included mule and black-tailed deer, Roosevelt and tule elk, and pronghorn antelope (Baumhoff 1963).

3.2.2 Gathering

About 230 plant species are documented as used by Pomo bands in edible, medicinal, or material forms (Goodrich 1980, Heizer and Elasser 1980, Holmes 1975). Almost every kind of nut, berry, seed, bulb, and root was utilized, as well as many kinds of leaves and young sprouts consumed as greens, flavorings, teas, or medicines (Barrett 1952, Stewart 1943, Bibby 1992, Loeb 1926, McLendon 1977). Goodrich documents that various Pomo bands used 11 species of plants for bread, 19 for fruits, 11 for greens, and around a dozen for pinole and/or atole. Many plants have pharmacologically active compounds for a wide range of ailments, including diabetes (black huckleberry leaves, *Vaccinium ovatum*), and many plants have both nutritional and medicinal qualities. Many species have material uses, including 14 materials used in baskets, 3 for fish poison, 4 for glue, and 5 for rope.

Acorns were the primary plant food, followed by roots and bulbs, seeds and nuts, berries, and greens (in that order), plus teas, medicines, sweets, salt and pepper, and tobacco (McLendon and Lowry 1978). With the exception of the poisonous *Zygadenes,* all the bulbous plants were used for food. A dozen kinds of bulbs were used (*Calochortus, Brodiaea, Allium, Hookera,* others), and the bulbs of various species of lilies were important and more abundant in this region than in almost any other part of the state (Barrett 1908). Seeds included *Chenopodium* (chia), *Clarkia*, *Gallium* (bedstraw), *Madia* (tarweed), *Marah* (wild cucumber), *Pinus sabiana*, *Quercus*, *Scirpus* (tule), *Trifolium* (clover), *Umbellularia* (bay), *Vulpia* (fescue grasses), and the Helianthae tribe of sunflowers. Berries include manzanita, strawberry, gooseberry, raspberry, thimbleberry, blackberry, elderberry, toyon, salmonberry, salal berry, and currant. Greens include clover, angelica, anise, poppy, fiddlehead, tule shoots and roots (3 species), and many others. Condiments included salt, pepper (pepper balls gathered from the pepper or bay tree, roasted, hulled and ground), and anise roots.

The Elem were the primary bead-makers in central California. Bead (money) makers were a partly specialized class of men who obtained the raw materials and made it into various items (McLendon and Lowry 1978). Beads were used for ceremonial donation, money, funerary donations, trade, debts, trespass, payment for work done, and payment of fines (Barrett 1952). Clamshell (*Saxidonus nuttalli*) and magnesite money-beads were regarded as small change and strung on strings, while magnesite cylinders were counted individually. Clam shell discoid beads were made by rubbing the outer surface down to the white inner layer, then breaking the shell into fragments. A fragment was chipped into a rough-edged disc, which was drilled with a snowberry shaft fitted with a chert point. Magnesite discs were made essentially the same, with the addition that the magnesite was buried under a fire to impart a pleasing color that ranged from pink to brick red to chocolate brown, or variegated. Discs were strung on wire grass for final shaping by sandstone as a strand. Magnesite cylinders were ¼ inch to 2 inches in diameter and 1 to 3 inches long. Silica exposure associated with this occupation is unknown.

Everyone used obsidian from abundant local sources (Mt. Konocti on the southern shore of Clear Lake) to make arrowheads and other tools. Chert, jasper, flint, steatite, chalcedony, petrified wood, and quartz crystals were also used for various purposes. Chert is harder and used for drills and harder arrowheads. Steatite (soap stone), magnesium mica, and talc were used. Pumice was used as an abrasive, such as for softening deer hides. Cinnabar was used for body paint.

Pomo baskets are elaborate, with different styles of basket for different uses, some water tight. Materials included willow used as the warp (shaped, sorted and dried). Woof was sedge root (dried, split down the middle, hung up for a year), redbud bark, bulrush root, often dyed black, and digger pine root fibers (Brown and Andrews 1969). Black color in baskets roots of carex (razor grass) were buried in black oak ashes. One medium grass basket required 3750 grass stalks from previously burned or pruned plants; 5 *Apocynum* stalks make one foot of cordage; a 40-foot deer net used fibers from 35,000 plants.

Acorns: Acorns furnished the main article of diet and are the most characteristic California staple. Preference of acorn species depends on specific use. In order of preference, the oaks are tan oak (*Lithocarpus densiflora*), black oak (*Quercus kellogii*), blue oak (*Q. douglasii*), valley oak (*Q. lobata*), coast live oak (*Q. agrifolia*), oregon oak (*Q. garryana*), Englemann oak (*Q. engelmannii*), maul oak (*Q. chrysolepis*), interior live oak (*Q. wislizenii*), and scrub oak (*Q. dumosa*) (Baumhoff 1978).

Certain oak trees or patches of trees belonged to individuals (Barrett 1952). A family could easily collect several ton of acorns. During an actual collection period, 100 pounds of acorns could be gathered in an hour, producing 50 pounds of kernels. The tan oak and black oak seed crop is about 125 pound per tree. The Oregon oak (*Q. garryana*) can produce 200 pounds or more per tree. Other species are also prolific, but some tend to have irregular crops (Baumhoff 1963).

Every old photograph of Elem villages shows multiple granaries on stilts (Baumhoff 1963). The smallest granaries were roughly the size of a 50-gallon barrel. A typical granary for a family of 6 measures 5 by 12 feet, holding 2440kg (Heizer and Elasser 1980). Acorn granaries were lined with wormwood or bay leaves to repel insects and worms (Fagan 2003). Acorns in the shell could be stored up to 2 years. Because relying on acorns as a staple requires intense activity at harvest and large storage capacity, granaries were located at permanent settlements located near oak forests (Fagan 2003). Processing involved labor-intensive shelling, winnowing (to remove the skin), and pounding, taking much longer than grass seeds. It takes 3 hours to convert 6 pounds of shelled acorns into 5.3 pounds of flour. A day’s hard pounding provided enough flour for a family for several days. After pounding, the tannic acid is leached out, and the leached meal can be boiled as mush or baked as bread (Baumhoff 1963).

Other Nuts and Seeds: Grass seeds, though abundant, also require intensive processing—hulling (breaking shells if large), milling (coarse grinding), and grinding into flour (Fagan 2003). Pinole was the fine flour or meal made from parched, ground seeds from tansy-mustard, chia, or other grasses and flowering annuals; this was eaten dry, pinch by pinch, or made into a mush with water. The meal also can be dampened, made into balls, and eaten raw or cooked (Balls 1962, Barrett 1952).

Ground buckeye balls were also leached, but much more thoroughly, often for months. Pine nuts (of digger and sugar pines) were eaten raw or roasted. California Bay nuts were picked in the spring, roasted, shelled, ground, and stored for winter. Hazelnuts (and shoots for baskets) were gathered from carefully-managed patches.

Salt: Various inland seepages occur where salt-bearing water (percolating upward through salt beds) evaporates and leaves crystallized salt on the surface of the soil. Often the crude salt is dissolved and recrystallized, which by chemical analysis is 99.2% NaCl. The crude salt is 28% insoluble material, still used raw, and still palatable (Mauldin 1975). Sea salt was obtained during trips to the coast.

Clay Used in Bread: It was a common culinary practice to mix ferruginous clay with acorn meal (one pint of clay to 3 quarts flour). The clay is referred to as “Indian baking powder” (masil), is somewhat sweet, and helps the cake stick together. This clay is 10% FeO_2 by weight. The purpose of the clay was to convert the tannic acid of the acorn meal into an insoluble compound formed at the baking temperature, by reaction of the tannic acid with iron oxide (Mauldin 1975, Stewart 1943, Holmes 1975, Selinus et al. 2005).

3.2.3 Resource Management

Early settlers who arrived in central California saw a verdant carpet of grass with scattered live oaks and manzanita bushes that reminded them of a well tended garden. This is because California was not *wilderness* but many carefully managed habitats and plant communities that supported large populations through exceptionally effective extractive and storage technology (Blackburn and Anderson 1993). Throughout the state, many areas were cared for by families and knowledge was passed on to each generation. Individual families took care of individual oak trees. Mosaic vegetation and biodiversity were deliberately encouraged. Cultivating favored plants in different patches was common among all of the Pomo tribes, as well as weeding, pruning, irrigation, sowing, selective harvesting, and tilling. Methods for gathering mimic natural disturbance; for example, the root harvest tool (digging stick) does not harm the resource, but loosens the soil. Pomo women also weeded sedge beds to loosen the soil and remove impediments to rhizomes radiating from each plant, promoting the untangled, long underground stems desirable for basketry material (Anderson 1973, Anderson et al. 1997). Coppicing (encouraging annual shoots of basket materials) was also practiced.

Natural fire caused by summer lightning strikes not associated with rain is an important component of the Mediterranean climate. Until suppression policies around 1900, late summer and early fall fires were an expected natural event, with a natural fire interval of 10–50 years in each location (in addition to more frequent fire regimes employed by the native peoples). Thus, intense destructive fires were rare. California plants not only evolved with fire, but some require fire. Without fire, brush can become dominant. With fire, grasses and young shoots provide deer browse. Without fire, chaparral becomes dense and reduced in browseability, and forbs are inhibited. Certain species were known to better with annual burning, others did better with burning every several years, and so on (Anderson et al. 1997, Lewis 1993). Native people understood the relation of plant and fire cycles and employed fire to maintain browse, reduce catastrophic fire hazard, and encourage germination of native plants and growth of native forbs. Undergrowth was controlled so forests were more open, meadows were kept clear, and marshes were deliberately fired to clear out dead plants, control disease and insects, and increase breeding areas and diversity.

4 HUMAN ACTIVITIES AND EXPOSURE SCENARIO

The approach used in describing an overall diet is to use the information about major resources present in the study area, foraging theory information, and information from the existing literature and interviews. An overall total caloric diet with rough proportions of different food groups in a typical traditional diet is shown in Section 4.3 (Figure 10). This diet is reconstructed from information about what the traditional diet actually was, rather than what it might be today if USDA recommendations about daily intakes were followed substituting wild for domesticated foods.

The steps for reconstructing the Elem diet are:

1. Review foraging theory information presented above specific to the Tribe, the local ecosystem, and, if available, for the specific location under consideration;
2. Review ecological information for a rough estimate of resource abundance of natural resources under baseline conditions;
3. Review interviews and other ethnographic sources for supporting information of species and abundance, habitat types, human activity levels, and methods of obtaining, preparing, and using resources;
4. Develop overall percentages of major food categories and major staples within the total diet;
5. Estimate calories provided by the diet, and compare estimates of percentages of quantities and percentages of calories;
6. Refine estimates of major staples and food categories after considering information about medicines, sweeteners, and other often-overlooked food/medicine types; macronutrients, and other factors.

4.1 METHODS FOR DESCRIBING THE DIET

Kelly (1995) describes the concepts of eco-cultural lifestyles, also known as foraging theory. In the 1960s to 1980s the “Man the Hunter” concept (with males providing most of the provender) prevailed due to a previous archaeological emphasis on hunting and warfare artifacts (Lee and Devore 1968). This gave way in the 1980s and 1990s to a more balanced foraging model that emphasized plants as much as meat (and equality of genders in contributing to survival), and a relatively peaceful and secure “original affluent society” (Sahlins 1972). The latter concept is supported by data (Kelly 1995, Winterhalder 1981) on the amount of time required to obtain survival necessities and to raise children, and the typically abundant amount of time available for socializing, education, ceremonies, material items, leisure, recreation, oratories, and so on. However, hunter-gatherers are not over-nourished, and face seasonal or cyclical shortages even though outright starvation is rare. The lifestyle is also “physically demanding” (Kelly 1995), giving rise to discussions about the number of calories available or required and the activity levels used to develop exposure factors.

Efficiency or return rate for specific resources in specific habitats is estimated using foraging theory by evaluating the amount of calories expended in getting food (search costs) by means of hunting, gathering, or fishing relative to time spent or calories obtained. Foraging information is typically presented as return rates, or net calories obtained per hour of effort. Additional factors such as biodiversity, abundance, and patchiness or continuity of resources result in time allocation decisions that are intentionally or unintentionally made by foraging societies, such as optimal diet breadth, optimal foraging area, and optimal foraging group size for a particular ecosystem (Winterhalder 1981). Depending on the evaluation methods used in a study, this return rate data may include (1) time and calories spent in preparing to hunt, fish, or gather (e.g., making nets), (2) time and/or calories spent in the actual activity, and (3) time spent in the processing of the resource after obtaining it. The drawback of oversimplifying foraging solely to caloric efficiency is that micronutrients (vitamins, minerals, specific amino acids, and fatty acids), medicinal or pharmacologically active compounds, other nutritional requirements, and non-nutritional attributes, such as aroma or dye or material uses, are often not considered (Lindstrom 1992). Similarly, many plants and animals have multiple uses or are co-located with other resources; therefore, caloric calculations must not ignore the way that people actually make decisions about where to go or what to gather, or the reasons they seek to obtain particular resources.

4.2 FORAGING STUDIES FOR CENTRAL CALIFORNIA

Broughton (1988) evaluated the fauna of the Sacramento Valley, and developed a diet breadth model. White (2002) reviewed this approach and identified problems with this and other foraging models. For example, seasonal competition affects choices if two resources are ready at the same time. Also, the *lonely forager* assumption is not generally applicable since resources are gathered by groups with different people procuring different resources. The Broughton model was modified by White to be suitable to the Clear Lake area (by omitting salmon and pronghorn), although it still includes only animal resources. White’s modification of Broughton’s animal-based acquisition estimates are shown in Table 3.

Table 3. Acquisition estimates.

Rank	Resource	Total kcal/indiv per animal	Pursuit hrs/kg	Processing hrs/kg	NAR* kcal/hr
1	Tule elk	10,7248	0.0015	0.012	35749
2	Deer	42,900	0.0015	0.04	24710
3	Jackrabbit	1,103	0.025	0.05	14437
4	Cottontail	637	0.04	0.083	9391
5	Squirrel	309	0.085	0.1	5865
6	Duck	630	0.095	0.32	2342
7	Freshwater fish (slow water)	160	0.2	0.05	816

* Net acquisition rate.

White critiques these figures in several ways:

- He concludes that they do not hold for the Clear Lake Basin. In particular, fish were greatly underestimated because they were not evaluated as they would be taken during spawning runs. Fish (hitch, blackfish, pike) were actually one of the highest ranked resources, at least during the various spawning seasons.
- Turtles were not included, whereas they actually comprise a substantial fraction of small game bones in sites in appropriate locales, and more common in some assemblages than lagomorphs.
- Over time, the ratios of fish to large game can change considerably for many reasons, including uses of non-edible parts such as bones for tools, etc.
- Mollusks were not included, whereas they were used widely (western ridge mussel, *Gonidea angulata*, and California floater mussel, *Anodonta californiensis*). Clear Lake mussels were gathered by feeling them with bare feet.

Baumhoff (1963) estimated acorn and game production from vegetation maps, which showed 22 vegetation types (in 1945). He reconstructed a pre-contact resource map from vegetation information, original soil maps, and historic range land studies. He identified vegetation types and rated them for acorn and game production, and identified stream miles and rated them for fish production. He then determined the size of each vegetation type and stream miles available to individual tribes, and weighted them according to productivity of game, acorns, and fish. For example, 60 square miles of chaparral, which ranks as a secondary acorn source, gives an index of 30 for acorns (60 mi^2 x ½). However, it ranks very high in game production, which is weighted double, giving a game index of 120. Therefore, the total index for 60 acres of chaparral for both game and acorns is 150. For individual tribes, Baumhoff estimated the acreage of each vegetation type, as well as the number of stream miles suitable for primary, secondary, or tertiary fish production.

Clear Lake is immediately surrounded primarily by oak woodland and chaparral, with nearby grassland and pine-fir forest. Oak woodlands rank at the highest level for the combination of game and acorn production, while grassland ranks at the highest level for game but lower for acorn density. Baumhoff ranks production of Clear Lake fisheries as equivalent to a secondary salmon stream in terms of total poundage. The southeastern Pomo had 200 square miles of upland available, primarily oak woodland. He concludes that the ranking of resource availability for the southeastern Pomo was as follows: game ranked slightly ahead of acorns, which ranked ahead of fish in terms of overall productivity. Baumhoff estimated that tribes living on primary salmon rivers relied on acorn, game, and fish in an estimated ratio of 3:2:3.

4.3 THE ELEM DIET

This section uses the information from the previous sections to derive and rank estimates of major categories of food types. It considers the number of species, the foraging studies with their dietary estimates, and recent interview data. This information is combined to reconstruct a diet that was obtained from the Clear Lake area. It is intended to describe what the diet actually was before contamination altered the natural resources. Figures 11 and 12 illustrate the derived diet by percent of calories and by grams per day. The latter illustration is more comparable to conventional food pyramids, which are shown by number of servings.

Baumhoff (1963) estimated a ratio for intake of acorn, game, and fish for central California tribes on salmon-bearing rivers of 3:2:3. Those tribes generally used acorns and game more than fish; however, the tribes immediately around Clear Lake used all three. We extrapolate from Baumhoff's ratio a Clear Lake ratio for acorns, game, and fish of 3:2:2, which accounts for fish being of secondary rather than primary quantity.

The general order of vegetal resources used, in order, are acorns, roots and bulbs, seeds and nuts, berries, greens, and a general category for teas, medicines, sweets, salt and pepper, and tobacco (McLendon and Lowry 1978). The general order of animal resources is fish, large game, fowl, small game, shellfish, insects, and turtles. Heizer and Elasser (1980) combined vegetal and animal resource use into an approximate overall diet (Figure 10) based on earlier work, particularly from Baumhoff, but also from earlier authors who measured what was being stored.

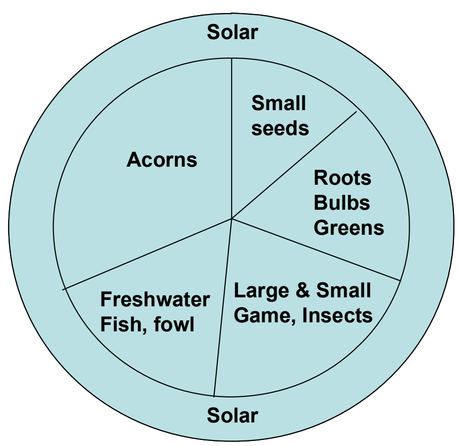

Figure 10. Diet Estimate

Based on interviews and existing literature, foraging theory, dietary calories, and related information, the traditional Elem diet is estimated as:

- Acorns (30% of total calories);
- Fish (20%);
- Game (large and small, and fowl) (15%);
- Roots, tubers, rhizomes, corms (10%);
- Bulbs (5%);

- Seeds (5%);
- Fruits, berries (5%);
- Greens, shoots (5%);
- Teas, medicines, sweeteners (5%).

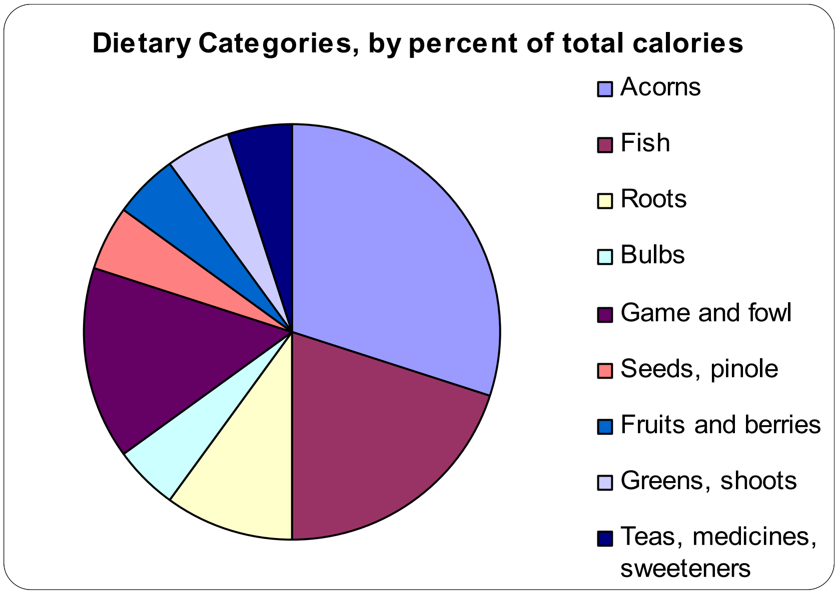

Figure 11. Percentage of Dietary Category Ingested per Day

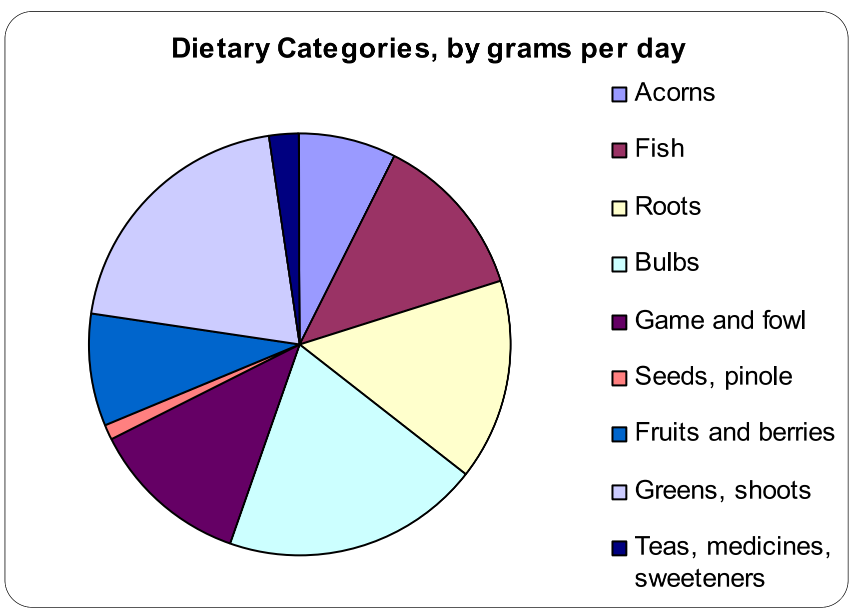

Figure 12. Grams of Dietary Category Ingested per Day

4.4 NUTRITIONAL ANALYSIS

A brief nutritional analysis is presented here in order to cross-check the amounts eaten with an estimate of macronutrients that would be provided. This is done to ensure that a full amount of calories is accounted for, and the diet is roughly balanced within the ranges of other foraging diets. Based on the discussion above, an estimate of the complete diet is shown below in Table 4. Each food category is converted to calories, and then to grams per day. It is impossible to be more quantitative than a rough estimate of overall percentages given the lack of data on native foods—nutritional data on native foods are almost totally lacking. Therefore, all of the information in Table 4 is from the USDA database (except where noted) for an average member of the same or nearest plant or animal family (the "Representative Species" column in Table 4). Wherever specific information is available from the USDA database, such as for game species, it is used (http://www.nal.usda.gov/fnic/foodcomp/search/). Where possible, the data for fresh or cooked foods matches the form of native plants eaten. We recognize that domesticated species of plants have been bred for certain characteristics such as low fiber content, more sweetness, and other characteristics. Tribal members often refer to wild varieties as "stronger" than domesticated varieties, but the actual nutritional or biochemical attributes that this refers to are not known. This is a well-known data gap.

Table 4. Summary of estimated relative proportions of dietary foods.

Representative 2000 kcal Diet			
Resource	**% of 2000 kcal**	**kcal per 100g (Representative Species)***	**Daily Amount (grams/day)**
Acorns	30% or 600 kcal	Dried acorns & acorn flour—500	120 grams
Fish	20% or 400 kcal	Mixed trout, cooked—190	200
Game (large and small) and waterfowl, other animal species	15% or 300 kcal	Deer, roasted—158 Rabbit, wild, roasted—173 Quail, cooked—234	200
Roots, tubers, rhizomes, corms	10% or 200 kcal	Raw Chicory root—73 Potato (baked tuber)—93	250
Bulbs	5% or 100 kcal	Leek, onions and bulbs (bulb & leaf)—31	360
Seeds, pinole, atole	5% or 100 kcal	Raw dried sunflower seeds—570; Sesame seed flour—526	20
Fruits and berries	5% or 100 kcal	Raw elderberries—73	140
Greens, shoots	5% or 100 kcal	Raw dandelion greens—45 Raw watercress—11	333
Teas, medicines, sweeteners	5% or 100 kcal	Honey—304	36
Totals	**100%**	**-**	**1660g (3.6 lbs)****
* Calorie estimates are from the USDA nutrient database. ** 1 pound = 454g.			

A closer examination of a primary food, acorns, illustrates some issues in estimating food group totals. Many investigators have evaluated the nutritional quality of acorns, but early reports in the anthropological literature frequently did not report whether their estimates were based on unshelled nuts (a stored form), the flour (stored for shorter periods), or fresh nuts versus parched or dried. Dried acorn whole nuts (without the shell) and ground acorn flour have 500 kcal/100g. Raw acorn nuts (without the shell but fresh) contain 387 kcal/100g.[9]

Tables 5, 6, and 7 show three nutritional analyses: Baumhoff (1963), Heizer and Elasser (1980), and the USDA (http://www.nal.usda.gov/fnic/foodcomp/Data/SR14/sr14.html), respectively. The difference in water content between the Baumhoff and Heizer analyses, compared to the USDA data, suggests that the Baumhoff analysis (Table 5) was done with dried acorns, while the Heizer and Elasser analysis (Table 6) was done with fresh acorns. Table 7 shows nutritional values for both raw, dried, and flour forms.

Table 5. Nutritional content of hulled acorns.

Species	Water %	Protein %	Fats %	Fiber %	CHO %	Ash %
Lithocarpus	9	2.9	12.1	20.1	54.4	1.4
Q. lobata	9	4.9	5.5	9.5	69	2.1
Q. garryana	9	3.9	4.5	12.0	68.9	1.8
Q. douglasii	9	5.5	8.1	9.8	65.5	2.1
Q. chrysolepis	9	4.1	8.7	12.7	63.5	2.0
Q. agrifolia	9	6.3	16.8	11.6	54.6	1.8
Q. kellogii	9	4.6	18.0	11.4	55.5	1.6
For comparison:						
Barley	10.1	8.7	1.9	5.7	71.0	2.6
Wheat	12.5	12.3	1.8	2.3	69.4	1.7

Table 6. Nutritional content of acorns.

Species	Water %	Protein %	Fats %	Fiber %	CHO %
Q kellogii	31.4	3.44	13.55	8.6	41.81
Q lobata	40.8	3.2	3.6	6.15	44.9
Q douglasii	33.6	4.0	5.9	7.15	47.8

Table 7. USDA information on raw acorns, dried acorns, and acorn flour, *Quercus* spp.

Form	Water %	Protein %	Total Lipid %	CHO %	Ash %
Raw nuts	27.90	6.15	23.86	40.75	1.35
Dried nuts	5.06	8.10	31.41	53.66	1.78
Full fat flour	6.00	7.49	30.17	54.65	1.69

[9] USDA database (http://www.nal.usda.gov/fnic/foodcomp/search/)

5 EXPOSURE FACTORS AND PATHWAYS

5.1 APPROACH

Exposure factors reflect the activity levels and resource use of the lifestyle scenario under evaluation.[10] Exposure factors for both direct and indirect pathways are developed. Indirect pathways include exposure via the oral ingestion of food and medicine (see previous section). This section focuses on direct pathways: direct inhalation, dermal exposure, and ingestion of water, air, dust, sediment, and soil (including soil on the outside of food or added through cooking).

Default exposure factors have been developed for conventional suburban, urban, occupational, and recreational scenarios based on national statistics. Our approach to developing a tribal scenario is not to inventory every activity and every resource, but to provide an overall estimate of the general activity levels, anchored with specific information as available. The basic assumption is that traditional lifeways are active outdoor lifestyles that are somewhat physically demanding, even with some modern conveniences. Subsistence foragers (both genders) perform a combination of aerobic (high heart and ventilation rates), strength, endurance, and stretching-flexibility daily activities, as well as performing more sedentary work and resting.

The exposure factors here are general to traditional subsistence lifestyles, regardless of their location. The conceptual steps in this process are:

1. Understand the lifestyle and the activities that comprise the lifestyle, and are required to obtain necessities and engage in the community culture;
2. Describe the day, the year, and the lifetime of men and women to identify any significant differences in activity levels between genders or ages;
3. Cross-walk activities with exposure pathways on the basis of frequency and duration of major activities, activity levels, and degree of environmental contact, and
4. Estimate cumulative direct exposure factors.

5.2 MAJOR ACTIVITIES

Tables 8–10 show the thought process for considering the range and number of activities associated with major activity categories (hunting, fishing, gathering, and sweat-lodge purification). Tables 8 and 9 list a number of individual activities within each major category; this is included because most non-Indians have not learned much about traditional lifestyles and the complexity of daily life. Table 10 shows the connection between activity categories. In actuality, many activities are sequential—for example, a resource might be gathered in one location, used in a second location to make an implement or basket, and taken to a third location for use in hunting or

[10] http://cfpub2.epa.gov/ncea/cfm/recordisplay.cfm?deid=85843

fishing.[11] The activities shown in Table 8 are so interconnected that it is virtually impossible to separate a lifestyle into distinct categories, but they are presented as separate for illustration. The number of sub-activities in each column displays the complexity of each major activity, as well as interconnections between categories. The category of gathering includes both vegetal food procurement and basket making.

Table 8. Traditional lifeways—typical activities in the activity categories.

Hunting	Purification	Gathering	Fishing
Learn skills	Learn skills, songs	Learn skills	Learn skills, TEK
Making tools	Build lodge from natural materials	Previous gathering	Make nets, poles, platforms, tools
Ritual bathing	Gather rocks	Make baskets, bags	Travel to location
Vigorous activity in hunting	Chop firewood	Hike to areas	Catch fish, haul out
Pack meat out	Prepare for use, get water	Cut, dig, harvest	Clean, can, hard dry, soft dry, smoke, eat whole fish or fillet or liver or other parts or soup
Process	Use Lodge, sing, drink water, inhale steam and smudges	Carry out items	Return carcasses to ecosystem, use as fertilizer
Scrape hides	Close area & fire	Wash, peel, process, split, spin, dye	
Tan, use other parts		Cook and eat or make product or medicine	
Cook, smoke, dry, eat meat and organs			

[11] This is similar to the Cultural Ecosystem Stories concept developed Terry Williams (Tulalip Tribes) with the associated software, ICONS (see, for example, http://www.epa.gov/owow/watershed/wacademy/ wam/comresource.html).

Table 9. Major activity categories.

Activity Type	General Description
Hunting	Hunting includes a variety of preparation activities of low to moderate intensity. Hunting occurs in terrain ranging from flat and open to very steep and rugged. It may also include setting traplines, waiting in blinds, digging-out small game, climbing, etc. After the capture or kill, field dressing, packing or hauling, and other strenuous activities may occur, depending on the species. Subsequent activities include cutting, and storing (e.g., smoking or drying).
Fishing	Fishing includes building weirs, scooping minnows, hauling in lines (we assume that large nets are not used in small drainages), gaffing or gigging, wading (for shellfish), followed by cleaning the fish and carrying them to the place of use. Activities associated with smoking and constructing drying racks may be involved.
Gathering	A variety of activities is involved, such as hiking, bending, stooping, wading (marsh and water plants), digging, bundling, carrying, and climbing over a wide variety of terrains.
Ritual purification (sweat lodge)	Sweat-lodge building and repairing is intermittent, but collecting firewood is a constant activity. Cold and hot springs were used for therapeutic healing.
Materials use and food preparation	Many activities of low to high intensity are involved in preparing materials for use or food storage. Some are quite vigorous such as pounding or grinding seeds and nuts into flour, preparing meat, and tanning hides. This category includes basket making, which is an example of a very important activity with its own set of prescribed activities.

Table 10 shows the cross-walk between activity categories and exposure pathways, with examples of how exposure factors are derived from knowledge about activities, interlinked resources, and ecosystem stories, and the technical literature. Again, this is an iterative process that relies on multiple lines of evidence. This is not a complete listing of activities. It shows an example of the thought process used to perform the iterative cross-walk. In each case a gap identification step may be necessary, and greater uncertainty may require placeholder values until data are obtained. The last column, "Totals for major exposure factor categories," shows exposure pathway totals (such as soil ingestion) that are estimated across activity categories. This is not a statistical summation but rather a judgment based on multiple lines of evidence. Each estimate has been checked against technical literature for confirmation.

Table 10. Example exposure considerations for major activity categories.

	Hunting and associated activities	**Fishing and associated activities**	**Gathering and associated activities**	**Ritual purification and associated activities**	**Material and food use and processing**	**Totals for major exposure factor categories**
Food, medicine, tea, other biota ingestion (diet)	*n* deer /yr diet; Total large-small game, fowl; Organs eaten	*n fish* /yr diet; Total pounds or meals/day-wk-yr; Organs eaten	Includes foods, medicines, teas, etc.	No food, but herbal particulates are inhaled.	Both as-gathered and as-eaten forms; cleaning and cooking methods.	Must account for all calories. Extra factor for 100–200 plant species; parts eaten
Soil, sediment, dust, and mud ingestion	Terrain types such as marsh with more mud contact; Degree of dermal contact;	Sediment contact, dust and smoke if drying; Weir construction in mud	External soil on plants; Cooking method such as pit cooking; Ingestion when gathering	Includes building the sweat lodge and getting materials	Includes incidental soil remaining on foods, pit cooking	Must also include living area, unpaved roads, regional dust, local dust-generating activities
Inhalation rates	Days per terrain; Exertion level; Hide scraping; Load & grade.	Exertion level—nets and gaffing methods; cleaning effort.	Exertion level for load and grade, or gardening; Include making items	Includes building the lodge, chopping firewood, singing	Exertion level for pounding, grinding, etc.	Must account for exertion levels, Smokes and smudges
Groundwater and surface water pathways	Drinking water; Wash water; Water-to-game pathways	Drinking water; Incidental ingestion	Drinking water; cooking water; etc.	Steam in lodge; Drinking water during sweat	Soaking, possibly other uses	Must account for climate, sweat lodge, ritual bathing
Dermal exposure	Soil, air and water pathways, plus pigments, etc.	Immersion considerations	Same as hunting	Immersion with open skin pores	Includes basket making, wounds	Must consider skin loading and habitat types

5.3 THE FAMILY, THE DAY, AND THE LIFETIME

5.3.1 Activity Patterns

Adult Hunter/Fisher/Gatherer: Each adult hunts (male), fishes (male), or gardens and gathers plants (female). Because these activities are roughly analogous with respect to environmental contact, they are assumed to result in the same amount of soil or sediment ingestion for males and females. General levels of exertion, relative to inhalation rate, are also assumed to be the same for males and females. The inland Pomo would make several trips to the coast each year during low tide. On the way back from gathering clamshells, etc., conical baskets are filled, weighing about 130 pounds; "yet the Pomo not only average this amount per pack, but also carry strings of dried fish, kelp, and lighter articles, over precipitous trains, making only four camps along the 80 mile journey home to Clear Lake" (Hudson 1975).

Elder (ages 56–75): The elder gathers plants and medicines, prepares them, uses them (e.g., making medicines or baskets, etc.), and teaches a variety of indoor and outdoor traditional activities. The elder also provides child care in the home. "Even old people carried immense loads gracefully and tirelessly" (Brown and Andrews 1969). Boy chiefs were 40 or under. Between 40 and 60 a chief was considered a young man, and at 60 or older was a man.

5.3.2 Specific Cultural Activities

Sweat House Purification: Each village had a sweat house. "It was the custom for every Pomo man to take a sweat bath each day" (Barrett 1975). Other authors also report frequent or daily use of the sweat house (Gifford 1926, Barrett 1952, Brown and Andrews 1969, Heizer and Elasser 1980).

Cultural Activities: All persons participate in day-long outdoor community cultural activities once a month, such as powwows and seasonal ceremonial and private cultural activities (averaging about 0.5 hours/day). These activities tend to be large gatherings with a greater rate of dust resuspension and particulate inhalation. Individuals also tend to be active, resulting in a greater inhalation and water ingestion rates: "the exertion of the dance was so great that perspiration showed freely on their fine looking bodies" (Brown and Andrews 1969).

Basket Making: Exposure pathways specific to basket makers are well-recognized,[12] but it has not been fully researched with respect to environmental contact rates. Gathering of some plants (e.g., willows, cattails, reeds, and rushes) can be very muddy, and river shore or lakeshore activities with sediment exposure may be underestimated. Washing, peeling, weaving rushes, and other activities results in additional exposure, such as dust deposited on leaves or soil adhered to roots. Some of the materials are held in the mouth for splitting, and cuts on the fingers are common. As more information becomes available, it will be evaluated to

[12] http://www.cdpr.ca.gov/docs/envjust/documents/basketweaver.pdf

ensure that the exposure factors for each route of exposure account for this particular activity.

Other Special Activities: It is recognized that there are special circumstances when some people may be highly exposed to individual natural resources or media. For instance, some men hunt or fish for the general community, and many people provide roots and fish and game to elders in addition to their own families. Beadmakers may receive additional exposure through obtaining and working with their materials.

Seasonality: The changes in activity patterns over the annual seasonal cycle has been modified in modern times, but the ecological cycle has not, so people must still gather plants according to when they are ripe, hunt according to game and fowl patterns, and fish when the spawning runs occur. Many items are gathered during one season for year-round use. While specific activities change from season to season, they are replaced by other activities with a similar environmental contact rate. For instance, a particular plant may be gathered during one month, while another month may be spent hunting, and a winter month may include cleaning and using the items obtained previously. Therefore, since activity levels are roughly equal throughout the seasons, there is no decrease in environmental contact rates during winter months.

5.4 EXPOSURE FACTORS FOR DIRECT EXPOSURE PATHWAYS

A description of activities for the purposes of developing exposure factors focuses on:

Frequency of activity:
- Daily, weekly, monthly

Duration of activity:
- Hours at a time
- Number of years

Intensity of environmental contact and intensity of activity:
- For soil ingestion and dermal exposure, is the activity more than, less than, or equal to gardening, camping, construction/excavation, or sports?
- For inhalation rates and calorie needs, is the activity level more than, less than, or equal to standard EPA activity levels for specific activities with known respiration rates and caloric expenditure?

The following table (Table 11) includes two adult scenarios: the suburban resident and the subsistence forager. The scenario is typically used in risk assessments, and the second reflects the set of activities that compose the Elem lifestyle. Each scenario is intended to be physiologically *coherent*, which means that the dietary intake, activity levels, and inhalation rates are physiologically linked. For instance, the more sedentary suburban scenario is based on national data on typical lifestyles (light occupational activities sitting or standing, with some moderate activity at home). The subsistence forager is more active, with a proportionally higher inhalation rate, as well as a higher soil ingestion rate, due to a higher degree of soil contact.

The following table shows adult values, as does the dietary discussion above. Children's exposure factors are scaled from the subsistence forager rates, as is conventionally done in risk assessment (from the Children's Exposure Factors Handbook), with the exception of the soil ingestion rate, which is left at 400mg/d throughout the lifetime. Body weight is a consistent 70kg because that is the standard EPA assumption used in risk assessments.

Table 11. Major exposure factors for direct pathways.

Direct Pathway	Exposure Factors (Adult)	
	Default Suburban Lifestyle	**Subsistence Forager Lifestyle**
Inhalation	$20m^3$	$25m^3$/day: This rate is based on a lifestyle that is an outdoor active lifestyle, based on EPA activity databases, foraging theory and ethnographic description of the activities undertaken to obtain subsistence resources as well as allotment-based food (livestock and garden). It is higher than the conventional $20m^3$/day because the respiration rates associated with typical activities are higher than those of suburban activities.
Drinking water ingestion	2L/d	3L/d plus 1L for each use of the sweat lodge during ritual purification, or 4L/day total.
Soil ingestion	100mg/d (conventional suburban); 50mg/d (manicured suburban; less outdoor time).	400 mg/d: This rate is based on indoor and outdoor activities, a greater rate of gathering, processing, and other uses of natural resources, as well as on residual soil on grown and gathered plants. Episodic events (1 gram each) are considered, such as wetland gathering, cultural activities with higher soil contact, and so on. But this might be underestimated. It does not specifically include geophagia or pica.
Dermal exposure	Must be included in the risk assessment. Greater environmental contacts must be factored in; however, suburban defaults may be used until data for traditional lifeways are developed, although a greater fraction of the skin surface and a higher dermal loading rate should be considered.	
Other parameters		
Exposure frequency	Up to 365 days per year, but varies. Hours per day varies; typically 24 hrs/d.	365 days per year. Hours per day varies; typically 24 hrs/d.
Exposure duration	30 years	70–75 years

Drinking Water: Harper et al. (2002) estimated an average water ingestion rate of 3L/day for adults, based on total fluid intake in an arid climate. In addition, each use of the sweat lodge requires an additional 1L for rehydration (24L per year). It should be noted that water intake in an arid environment may be more than 3L per day. For example, the Army assumes that the maximum individual daily amount of drinking water required by military personnel to remain combat-effective ranges from 5–15L/day, depending on the climate, season, and intensity of work.[13] The Army Quartermaster assumes that military personnel in hot climates require 3 gallons per day as drinking water.[14]

Soil and Sediment Ingestion: Soil ingestion includes consideration of direct ingestion of dirt, mud, or dust, swallowing inhaled dust, mouthing of objects, ingestion of dirt or dust on food, and hand-to-mouth contact. The tribal soil ingestion rate of 400mg/day is based on a review of EPA guidance, soil ingestion studies in suburban and indigenous settings, pica and geophagia, and dermal adherence studies (a small portion of which is summarized here). The Elem soil ingestion rate also considers many *1-gram days and events*, such as root gathering days, tule and wapato gathering days, powwows, rodeos, horse training and riding days, sweat-lodge building or repair days, grave digging, and similar activities. However, this might result in an underestimation of soil ingestion. It reflects a variety of soil pathways such as pit cooking, gathering and gardening, residual soil or dust on foods and medicine, localized soil-generating activities, holding natural materials in the mouth while processing or using, driving on unpaved roads, and similar considerations. For the Elem, the underground oven was very important. "A large percentage of their food, roots, berries, seeds, and even a large portion of meats [were] eaten in an uncooked state" (Barrett 1952).

The soil ingestion rate of 400mg/d for all ages is the published upper bound for suburban children (EPA 1997), and is within the range of outdoor activity rates for adults but lower than the typical 480mg/d applied to outdoor work to allow for some low-contact days. Subsistence lifestyles were not considered by the EPA guidance, but are generally considered to be similar in soil contact rates to construction, utility work or military exercise. The US military assumes 480mg per exposure event[15] or per field day. The UN Balkans Task Force assumes that 1 gram of soil can be ingested per military field day.[16] Anecdotally, US forces deployed in Iraq report frequent grittiness in the mouth and food. Haywood and Smith (1990) also considered sensory reports of grittiness in their estimate of 1–10g/d in aboriginal Australians.

Simon (1998) reviewed soil ingestion studies from a perspective of risk and dose assessment. Because of their high dependence on the land, indigenous peoples are at highest risk for inadvertent ingestion, along with professions that may bring

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[13] http://www.nap.edu/execsumm/NI000954.html Guidelines for Chemical Warfare Agents in Military Field Drinking Water (1995).
[14] http://www.pasols.org/energy/water2.pdf
[15] http://www.gulflink.osd.mil/pesto/pest_s22.htm, citing US Environmental Protection Agency, Office of Research and Development, *Exposure Factors Handbook, Volume I*, EPA/600/P-95/002a, August 1997 as the basis for the 480mg/d.
[16] UNEP/UNCHS Balkans Task Force (BTF) (1999). The potential effects on human health and the environment arising from possible use of depleted uranium during the 1999 Kosovo conflict. www.grid.unep.ch/btf/missions/september/dufinal.pdf

workers into close and continual contact with the soil. Simon recommends using a soil ingestion rate for indigenous people in hunters/food gathering/nomadic societies of 1g/d in wet climates and 2g/d in dry climates. He recommends using 3g/d for all indigenous children.

For the Clear Lake climate and lifestyle, the soil ingestion rate for young children (0–6 years) is assumed to be 400mg/day for 365 days/year. This is higher than the prior EPA default value of 200mg/day (USEPA 1989). This rate reflects both indoor dust and continuous outdoor activities analogous to gardening or camping (Van Wijnen 1990), but it is less than a single-incident sports or construction ingestion rate (Boyd 1999).

Inhalation Rate: The inhalation rate in the Elem scenario reflects the active, outdoor lifestyle of traditional tribal members. Their fitness was comparable to that of long distance runners. In the late 1800s, 20 mile round trips were "regarded as so commonplace a performance as to be worth but two dollars" (Heizer and Elasser 1980). Traditional tribal communities have no sedentary members except the frail elderly, whereas one-quarter of modern American adults of all ages report no leisure time physical activity at all.[17] An inhalation rate of 25m^3/d is more accurate for the Tribe's active, outdoor lifestyle than the EPA default rate of 20m^3/d (USEPA 1997). Using EPA guidance, a *median* rate of 26.2m^3/d is obtained from 8 hours sleeping, 2 hours sedentary, 6 hours light activity, 6 hours moderate activity, and 2 hours heavy activity. This represents minimal heavy activity (construction, climbing hills, etc.). Most other exposure factors are upper bounds, so the use of a median rate for inhalation is inconsistent with the reasonable maximum exposure (RME) approach typically used in Superfund risk assessments, and could result in under-protection of children, the elderly, athletes, asthmatics, and the half of the population with above-average inhalation rates.

Dermal Exposures: The dermal pathway has not been fully researched for this scenario, but EPA methods[18] for dermal exposure can be used. However, a greater surface area and a greater skin loading of soil (soil adhered to skin) should be used. Two relevant papers are summarized here. Kissel et al. (1996) included reed gatherers in tide flats in a study of dermal adherence. The category of "kids in mud" at a lakeshore had by far the highest skin loadings, with an average of 35mg/cm^2 for 6 children and an average of 58mg/cm^2 for another 6 children. Reed gatherers were next highest at 0.66mg/cm^2 with an upper bound of >1mg/cm^2. This was followed by farmers and rugby players (approximately 0.4mg/cm^2) and irrigation installers (0.2mg/cm^2). Holmes et al. (1999) studied 99 individuals in a variety of occupations. Farmers, reed gatherers and kids in mud had the highest overall skin loadings. The next highest skin loadings on the hands were for equipment operators, gardeners, construction, and utility workers (0.3mg/cm^2), followed by archaeologists, and several other occupations (0.15–0.1 mg/cm^2).

[17] http://www.cdc.gov/brfss/pdf/ 2001prvrpt.pdf and http://www.cdc.gov/brfss/pubrfdat.htm.
[18] http://www.epa.gov/superfund/programs/risk/ragse/

Children's Exposure Factors: Children's exposure factors are based on "Child-Specific Exposure Factors Handbook"[19] but scaled from the adult subsistence values for the inhalation rate. The diet is scaled for children from the food categories indicated above for adults. The soil ingestion rate for children is a constant 400mg/day, without age stratification. If age stratification is done for other exposure factors, the Elem can be contacted for recommendations.

[19] U.S. Environmental Protection Agency (EPA). (2002) Child-specific exposure factors handbook. National Center for Environmental Assessment, Washington, DC; EPA/600/P-00/002B. Available from: National Information Service, Springfield, VA; PB2003-101678 and http://www.epa.gov/ncea.

6 CONCLUSION

This report has presented the Elem scenario and supporting information for use in human health risk assessments. This report is intended to describe enough about the traditional subsistence lifestyle that a risk assessor who is familiar with developing exposure scenarios can understand the derivation of the exposure factors even if she does not have an in-depth familiarity with the Elem lifestyle. Where information is not presented, it is assumed that conventional parameters are suitable (e.g., skin surface area).

The report describes the Elem environment in the Klamath Mountains, Coast Range, Southern and Central Chaparral and Oak Woodlands, and Central California Valley ecoregions, and the available resources. An ecological lifestyle is presented, one centered on traditional resources of acorns, fish, game, and tule. An overall diet is developed by reviewing previous foraging studies, and considering available resources, with major food-type categories estimated as percentages and presented by percent of calories and by grams per day. The most prevalent food source is the acorn. Exposure factors are developed based on traditional subsistence lifestyles, with attention to the activity patterns and specific activities of the Elem. Rates of inhalation, water ingestion, and soil ingestion are higher than those of the general population, due in part to the Elem people's increased outdoor activity. Increased soil ingestion is partly attributable to the gathering and processing of food and material resources, at times in wetlands.

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APPENDIX A

Table A.1 presents additional information on natural resource use from Brown and Andrews (1969), and Barrett (1952).

Table A.1. Supplemental resource information.

Resource	Use or Knowledge
Miscellaneous	
Salt	From seaweed and coastal trading; also from saltlicks in the interior. Miner's lettuce leaf ash is a substitute for salt.
Soap plant (*Chlrogalum pomeridianum*)	Soap and fish poison. Soaproot grows plentifully on rocky and hills. The roasted bulb is high in saponin and low in alkali, making a very good lathery but gentle soap for delicate fabrics and dandruff. It is also antiseptic and, as a saponin, a laxative, and diuretic. It also stupefies fish (along with turkey mullein, *Croton setigerus*).
Pine pitch	Gum
Seaweed—kelp and sea palm	Porphyra cakes were letting the seaweed dry in the sun and layering the leaves. The kelp bulb can be eaten raw, dried, or cooked into cakes.
Tea	Many species of leaves and berries
Sugar	From sugar pine, honeycombs, rose hips.
Tobacco (*Nicotiana*, with balsam and willow)	Smoked in ordinary daily life, mostly by men. Also used ceremonially.
Army worm (caterpillar)	Not every year. Eats ash leaves. Caught by digging small moats around trees; the caterpillars let go of the tree when the leaves are eaten and crawl to the next tree. They fall in the moats and are scooped up. They are drowned quickly in water and roasted in hot ashes or boiled and eaten in great quantities there; the rest are sun-dried (Barrett 1936).
Bulbs and Roots	
***Brodiaea* or Blue Dicks**, *Tritelia laxa* (*Brodiae laxa*). Other Brodiaea were also widespread and eaten.	The most abundant and widespread of all the Indian potatoes, known as highland potato, grows in fields and hills; eaten raw or roasted.
Yellow Pond Lily	Baked, and seeds used for bread and soup.
Yampah roots	Washed, mashed, washed again, and cooked as potatoes. One kind was boiled until mealy.
Cowparsnips roots	Cooked like rutabagas.
Arrowroot tubers	Baked
Indian potatoes, anise, tule	Roots, bulbs, tubers, corms. In aboriginal times, they were "superabundant." Inexhaustible supply. Many were eaten raw, others were cooked or baked. Around 20 different species.
Camas (*Qamasia leichtlinii*)	An abundant camas in high damp meadows (more northerly than Clear Lake), blue flowers open only at night, largest and best of all the Indian potatoes. Generally pit cooked.
Lilies/Onions (a dozen kinds of bulbs)	Nowhere in the world is there a more characteristic abundance and variety of bulbous-rooted liliaceous plants than in California, a provision of nature by which the inhabitants have long been benefited. All are highly nutritious when cooked, and many, especially the species of *Calochortus*, have a very agreeable nut-like flavor when raw

	and are the primary below-ground food in the region.
Brodiaea (*Brodiaea grandiflora*). Small bulbs, eaten raw, June or July	*Dichelostemma capitatum* (*Brodiae capitatum*), very common on rocky hillsides, eaten raw but sweeter when cooked in ashes. *Hesperoscordum lacteum* (probably *Brodiae hyacinthina*), abundant in valleys, raw or cooked.
Allium (*Allium bolanderi)*	Abundant along streams, small but easily gathered corms. *Allium unifolium*: The wild or Indian onion, grows in high damp meadows; bulb and base of the leaves are fried.
The *Calochortus* genus (Mariposa lilies)	*Calochortus maweanus*: Grass and open hillsides, corms are sweetish and eaten by children. *C. pulchellus*: Very common, small corms but easily gathered; raw or roasted. *C. venustus*: Commonest Mariposa lily, corms are sweet; called sweet potatoes.
Squaw root (*Carum garnderi*)	Thick roots are eaten raw, gathered in fall, not stored
Berries	
Berries: strawberry, gooseberry, raspberry, thimbleberry, blackberry, elderberry, toyon, salmon berry, salal merry, currant, raspberry, huckleberry, wild grape, chokecherry	Eaten fresh, dried, or as beverage. Several species (*Ribes*, *Vaccinium*, other). Variety of habitats.
Manzanita	Pulverized and mixed with water or used for flavor in other foods. Also made into a drink. *Arctostaphylos manzanita* (and *A. tomentosa* at higher elevaitons). Found universally. Berries are ground and molded into small flat cakes, no cooking necessary. Can also be used as flour (Barrett 1952).
Cerasus demissa (*Prunus d.*)	
Greens	
Leaves of Miner's lettuce, *Mimulus guttatus,* miner's lettuce Grows near springs, substitutes for lettuce; leaf ash is a substitute for salt.	Early spring cowparsnip, some clovers, and others were eaten raw. *Trifolium* spp., clovers. Many kinds. Regarded as essential to the diet.
Ferns	The fiddleheads (young curled tops of the bracken fern) were eaten raw, or roasted for a day and a half.
Flowers	Several species were eaten raw.
Greens: Many species including clover, angelica, anise, poppy, tule shoots, some lupine leaves, hedge mustard, goosefoots	Eaten raw or cooked like spinach. "The people moved out into the fields and reveled in the abundance of these greens, eating great quantities as they gathered then, and bringing them back into the village by the burden-basketful." "So greedily did the people devour these greens that it was not unusual for them to be afflicted by bloating... the eating of pepperwood cakes was said to help serve as a preventative..." The people of the lake region used several species of tule and cattails "in so many ways that it is no surprise to find them on their list of foods." The roots and tender shoots were eaten as greens. The men go out swimming in May or June when the shoots are emerging from the lake bottom (Barrett 1952).

Nuts, Acorns	
Acorns	White oak or valley oak. *Q. lobata*—most common, main acorn supply, best kind for bread. Can be 80 feet high, acorns can be over 2 inches long. Black oak or California oak. *Q. californica*, Considered second best for bread and soup because they are especially rich in oil Tan oak or tan-bark oak *Q. densiflora*. Very rich and oily. The best kind for soups and mushes. Shell, spread out to dry, remove thin papery covering, grind. Leaching is most often done with flour, but sometimes of the whole acorn (takes a day or more). Sand lined pits, careful not to get sand in the meal. Black bread is made from ground meal without leaching. The red earth eliminated the bitterness and makes the bread black and sweet. It keeps very well.
Peppernut: Pepperwood (California laurel)	Cakes and edible husk. Dry whole fruits until hull splits; husks can be eaten raw. Kernels are covered with a thin hard shell and can be stored. Shell, wash thoroughly, grind into oily meal, made into cakes and stored dry. Also eaten whole as condiment with clover and other greens, with buckeye meal, or with acorn bread and mush. Also eaten with seaweed in coastal areas (Barrett 1952).
Buckeyes (horse chestnut) is fairly abundant. Poisonous if not leached.	Char, hull, leach, or roasted then leached, or shell, bake, mash, dry, soaked to leach and squeezed dry again, leach thoroughly then ready to eat. Hull, peel, boil, ground, sift, leach, with coarser parts molded into balls, then leach for days.
Chestnut, cinquapin, nutmeg, hazelnuts	
Conifers	Digger pine (*P. sabiniana*) and sugar pine (*P. lambertiana*). Fairly widespread; large cones with large nuts. Sugar pine: nuts used as food, sugar as medicine. Other pine nuts were also used (Barrett 1952). Digger pine—One of the most characteristic trees. Very large and heavy cones, sweet and oily nuts—51% oil and 28% crude protein; cones opened by fire; cambium also eaten as a starvation food. Pitch used as healing cover for burns and sores, glue for feathers; gum that accompanies the pitch is chewed as gum and as a cure for rheumatism; roots used for large baskets; bark infusion drunk for consumption; pine oil steam as tonic.
Seeds, Grain, Pinole	
Pinole: made from grass seeds, meal, cakes. Pinole is meal made from parched, ground seeds. The meal can be dampened and made into balls; no further cooking is required. Pinole can also be made into mush.	Seeds used as pinole. (“Pinole” is Spanish for cereal meal.) Any parched seeds of grains and flowers ground into flour (does not apply to nut flour). 32 different species of seeds have been identified. An important but secondary food. Seed types were kept separate and mixed according to the desired flavor (Barrett 1952).

Manzanita berry pinole and biscuits	Wild oats (*Avena fatus* or *Danthonia californica*, probably the latter since the former may not be native to the US). Gathered by elderly ladies. Hairs are singed, seeds parched and ground. Salt or the ash from "certain plants" added. Pinole is any meal made from parched seeds. But the Pomo had different names for different grains and carefully mixed grains for particular flavors.
Pogogyne parviflora	Seed is gathered in surprisingly large quantities and values as a sweet aromatic ingredient of wheat and barley pinole.
Blepharipappus platyglossus, tidy-tips.	A yellow daisy, seeds prized for pinole.
Achillea millefolium, yarrow. ***Hemizonia luzulaefolia***	Seeds used for pinole. The most common kind of tarweed (several different plants are called tarweed due to their exudation). Important for pinole.
Madia dissitiflora	A typical tarweed, also used for pinole. Note that tarweed oils appear to be important for pinole texture or cookability also.
Madia densifolia	Another tarweed, also important for pinole and even more aromatic than Hemizonia.
Salvia columbariae	Seeds are mucilaginous and used for thickening soup.
Other Food Information	
Hunting. Do not eat right before hunting. 4-day sweats before group hunting. Different sets of songs for each animal, fish or bird. Hunting methods—noting unique. Around Clear Lake, frequent use of large nets to rake water birds, as well as slings with clay balls, tule boats. At Clear Lake, different portions of the lake were used by individual families (Barrett 1952).	
Methods of cooking: rock boiling in basket, baking bread and fish in underground ovens, roasting in ashes, broiling on hot coals, parching with coals in basket (put seeds or bird eggs in basket with coals and shake them together). Underground oven, lined with leaves (grape, madrone, grass).	
Very small mammals were singed to get rid of the hair, eviscerated, and pounded to a pulp before being broiled (bones as calcium source). Larger animals such as rabbits were skinned before being pounded and broiled.	
Spoons made with mussel and freshwater clam (for eating mush or soups).	
Non-Food (basket, cordage, other)	
Tule. In addition to food and several specific kinds of baskets, tule was used for mats, padding, clothing, floats, slings, swaddling clothes, balsa. Two species are found in Clear Lake, *Scirpus lacustris*, *robustus*, and cattails (*Typha latifolia*) There are also words for different maturities. Tules were eaten. Shoots up to a foot tall were eaten by taking the outer part off; the outer portion was shredded until fluffy and used for diapers. Tule tubers (new growth only) were peeled and eaten (Barrett 1952).	
Cordage—dogbane (*Apocynum cannabinum*), milkweed (*Asclepias criocarpa*), Iris (*Iris douglasiana*, and (*Psoralea macrostachya*). Also sinew (Barrett 1952). Hemp (*Apocynum androssemifoluem*). Gows in marshy areas or damp soil. Stalk gathered in the fall. Stalks split and dried, then the woody part id broken away form the fiber. Fiber made into string by rolling on the leg.	
Cattail (flag tule; Lewis & Clark called them flags; *Typha latifolia*), roots and shoots used as food; pollen eaten. Mats and baskets.	
Sedge. *Carex* spp. Roots used for baskets, since they spread by root runners. The most important roots used in baskets; strongest and most durable baskets. Sedge root baskets are made by splitting the roots into fine strands by holding one part of the root in the mouth and pulling 1/3 with each hand, so the root is split into thirds. Each stand is split into smaller thirds. Used in 3-rod coiled baskets.	
Salix argyrophylla. A shrubby white-leaved willow, common along some rivers, shoots are the best for large coarse baskets. Roots are highly prized for other kinds of baskets. Tough fibrous inner bark can be made into rope and woven. Inner bark widely used as medicine.	
Cercocarpus betuloides, mountain mahogany. Common on dry brushy hillsides. Very hard wood.	

Symphoricarpos racemosus or *albus*, snowberry. Grows in great abundance on level land. White waxy berries, prized for light strong wood, especially for pipestems and revolving drills.	
Iris douglasiana. The common wild iris, edges of the leaves are fine and strong as silk.	
Byracea—Alsia abietins. A moss used for baby bedding.	
Maidenhair fern (*Adiantum emerginatum*). Keeps ear holes open.	
Lonicera interrupta, honeysuckle. Vines used for baskets.	
Multi-Use and Medicinal Uses	
California Nutmeg (*Tumicon californicum*). Roasted nuts; roots used in baskets. *Juniperus californica*. Berries sometimes boiled and eaten. *Trillium sessile giganteum*. The common trillium in damp shade, tuber-like rhizomes used in medicine, but are intensely bitter. *Artemesia heterophylla*, wormwood. Bitter taste but aromatic aroma. Highly esteemed as medicine for colic and colds. Used in sweat bath for rheumatism. *Wyethia longicaulis*, sunflower. The most common sunflower. Lower part of young leaves and stems are edible; seed is very much used for pinole. Resinous root used as an emetic. *Escholtzia douglasii*, California poppy. Fresh root is placed in the cavity of a tooth to stop toothache; extract used for headache. Leaves are edible. *Thysanocarpus elegans*. Lacepod. Seeds are used in pinole; concoction of whole plant used for stomach ache. *Heteromeles arbutifolia* (*Photina a.*) Common toyon or Christmas berry. Evergreen, berries are eaten raw but generally cooked first. Decoction of leaves and bark used for stomach ache and various aches and pains.	*Trichostema lanceolatus*, vinegar weed or tar weed. Pungent aroma like vinegar and turpentine. Known as a fish poison. *Sambucus glauca*, pale alder. Very abundant. Berries are acidic but eaten raw or dried; now used with sugar in pies and jelly. Dried flowers are used for fever, lotion, antiseptic, anti-itch, and sores. Wood pith for tinder; hollow shaft after pith is removed used for wistles, straws. *Micrampelis marah*, big root. A vine common along streams, large spherical fleshy root like a man's head, acrid and poisonous. Douglas fir (*Pseudotsuga menziesii*). Long small roots used in baskets; balsamic odor valued as a tea. *Alnus rhombifolia*, mountain alder. Common, large tree in moist places, often marking springs. The bark is astringent, used as a dye, decoction used to stop diarrhea and induce sweating; fresh bark colors deerskin and basket materials when smoking. Yellwo pond lily, *Nymphaea polysepsis*. Grows profusely in shallow lakes and winter ponds in the coast region, but not very common in the interior. The fleshy roots are a favorite browse of deer, and the nutritious seeds are eaten whenever available. *Butneria occidentalis* (or *Calycanthus o.*), western spice bush, fairly common in shady places, fragrant and used for baskets. *Umbellularia californica*, California laurel, grows in canyons and damp woods. Thin-shelled nuts, pungent, and sparsely used. Many uses of the leaves (the volatile oil). *Cercis occidentalis*, redbud. Bark and thin shoots used for baskets; not as durable as sawgrass or sedge.

Sanicule tuberose. Small bulb but one of the best Indian potatoes, generally eaten raw. *Arstostaphyles manzanita*. Very common. The ripe fruit is dry, mealy, and very nutritious. The green berries can be eaten in small amounts to quench thirst. Ripe berries can also be soaked for a cider.	*Croton setigerus*, turkey mullein (not the tall introduced mullein). Dainty mat with bristly hairs. Small seeds in great abundance are a favorite of mourning dove. Bruised leaves are a substitute for soaproot for stupefying fish. *Rhus diversiloba*, poison oak. Full-blood Indians said to be impervious. Used to remove warts and ringworm. Fresh juice used for black coloration.
Dodecatheon hendersoni, shooting star. Roots and leaves can be roasted and eaten.	*Vitis californica*. Wild grape. Used for basket rims by soaking vines in water and hot ashes, then splitting into strands.
Apocynum cannabinum, Indian hemp. Moist soil. Inner bark is soft, silky, and exceedingly strong. *Eriodictyon californicum*, yerba santa. Grows profusely on dry bushy hillsides, also known as mountain balm, wild balsam, gum leaves, tar weed. Found in every household; no plant is more highly valued as medicine. Leaf is used for many things.	*Heracleum lanatus*, cow parsnip. *Umbelliferous*, tender leaf and flower stalks are agreeably aromatic, and are eaten as early greens after peeling away the outer covering. The basal portion of the plant is a substitute for salt. *Pagio bothrys campestris*, snowdrops. Crimson color at base of leaves used on cheeks; shoots and flowers are eaten, seeds gathered in large quantities for pinole. *Monardells sheltonii*, horsemint or pennyroyal. Aromatic leaves are used as tea for beverage, colic, and blood purifier.
Amsinokia lycopsoides. Juicy shoots are eaten.	*Cynoglossum grande*, hound’s tongue. Grated roots are anti-inflammatory for burns.

Washoe Tribe
Human Health Risk Assessment
Exposure Scenario

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1 INTRODUCTION

This document presents the Washoe Exposure Scenario. This scenario applies to the pinyon-juniper ecosystem between the Sierra Nevada Mountains and the Great Basin. An exposure scenario is a narrative and numerical representation of the interactions between human and/or ecological receptors and their immediate environment. Exposure scenarios include media-specific and pathway-specific exposure factors required to estimate a dose to the target receptor as they pursue a defined set of activities in particular locations.

Even though many tribal lands have been lost and resources degraded, there are generally more traditional or subsistence practices followed by tribal members than the general non-native population realizes. However, the objective of many tribes is to regain land, restore resources, and encourage more members to practice healthier (i.e., more traditional) lifestyles. Therefore, the objective of subsistence exposure scenarios is to describe the original lifestyles and resource uses, not to present a current snapshot of restricted or suppressed uses, because the intent is to restore the ecology so that the original pattern of resource uses is both possible (after resources are restored) and safe (after contamination is removed). This is a different situation than for the general American population, where the intent of remediation is to allow people to continue their *current* (and portable) lifestyle in a newly cleaned location. The intent of the Washoe Scenario is to reconstruct what the lifestyle and diet would have been in the affected area prior to contamination.

For the general United States population, an exposure scenario is typically designed to be an upper bound (generally around the 75^{th} percentile) of the population being assessed. Some individual exposure factors are the 90^{th} or 95^{th} percentile; others are mean values. In the case of tribal exposure scenarios, there are no specific databases of subsistence activities, resources, or diets as there are for the general United States population. Cross-sectional surveys of current tribal populations will not generate that data because much resource use has been suppressed due to loss of land and access, awareness of contamination, persecution by the dominant society, and other reasons. This means that large and accurate statistical distributions for subsistence exposure factors are not available and cannot be developed. Therefore, ranges of exposures or specified percentiles of exposure are not possible to calculate. The Washoe scenario is intended to be a reasonable representation of a traditional subsistence lifestyle, equivalent to a central tendency rather than to an upper bound.

For the general suburban population the exposure scenario is well defined in EPA guidance (Exposure Factors Handbooks). The Washoe tribal scenario is based on the lifestyle and baseline conditions of the regional natural resources.

This scenario identifies general exposure pathways specific to Washoe lifestyles and key resources that the Washoe people use. It starts with a general description of baseline natural resources that are (or should be) present in the region. A general understanding of what people do (or would do in the absence of contamination) and what resources are available for their use provides the basis for developing preliminary exposure factors. Then the scenario describes the activities that traditional people undertake to survive and thrive in the local ecosystem, including hunting, gathering foods and medicines, fishing, making material items, farming or gardening, raising livestock, irrigating, and various cultural and domestic activities.

As mentioned, the exposure scenario reflects a traditional subsistence lifestyle. "Subsistence" refers to the hunting, fishing, and gathering activities that are fundamental to the way of life of many indigenous peoples. Today's subsistence economies utilize traditional and modern technologies for harvesting and preserving foods and for distributing the produce through communal networks of sharing and bartering. The following is a useful explanation of "subsistence," taken from the National Park Service:

> While non-natives tend to define subsistence in terms of poverty or the minimum amount of food necessary to support life, native people equate subsistence with their culture. Among many tribes, maintaining a subsistence lifestyle has become the symbol of their survival in the face of mounting political and economic pressures. It defines who they are as a people. To Native Americans who continue to depend on natural resources, subsistence is more than eking out a living. While it is important to the economic well-being of their communities, the subsistence lifestyle is also the basis of cultural existence and survival. It is a communal activity. It unifies communities as cohesive functioning units through collective production and distribution of the harvest. Some groups have formalized patterns of sharing, while others do so in more informal ways. Entire families participate, including elders, who assist with less physically demanding tasks. Parents teach the young to hunt, fish, and farm. Food and goods are also distributed through native cultural institutions. Most require young hunters to distribute their first catch throughout the community. Subsistence embodies cultural values that recognize both the social obligation to share as well as the special spiritual relationship to the land and resources. This relationship is portrayed in native art and in many ceremonies held throughout the year.[1]

In economic terms, a subsistence economy is one in which currency is limited because many goods and services are produced and consumed by the same families or bands. Today, currency (symbols of specified quantities of useful resources) is limited, but important. For example, subsistence in an Arctic community includes the following:

> The modern-day subsistence family depends on the tools of the trade, most of which are expensive. Snowmobiles, gasoline, guns, fishing nets, and sleeping bags are necessities. Subsistence households also enjoy many of the modern conveniences of life, and are saddled with the economic

[1] National Park Service: http://www.cr.nps.gov/aad/cg/fa_1999/Subsist.htm

> demands which come with their acquisition. Today's subsistence family generates much-needed cash as wage-labourers, part-time workers and trappers, professional business people, traditional craftmakers, and seasonal workers. A highly-integrated interdependence between formal (cash-based) and informal (barter and subsistence-based) economic sectors has evolved.[2]

Once the activities composing a particular subsistence lifestyle are known, they are translated into a form that is used for risk assessment. This translation captures the degree of environmental contact that occurs through activities and diet, expressed as numerical *exposure factors*. Exposure factors for direct exposure pathways include exposure to abiotic media (air, water, soil, and sediment), which can result in inhalation, soil ingestion, water ingestion, and dermal exposure. Indirect pathways refer to contaminants that are incorporated into biota and subsequently expose people who ingest or use them. There are many unique exposure pathways that are not accounted for in scenarios for the general public, but may be significant to people with certain traditional specialties such as basket making, flint knapping, or using natural medicines, smoke, smudges, paints, and dyes. These activities may result in increased dust inhalation, soil ingestion, soil loading onto the skin for dermal exposure, or exposure via wounds, to give a few examples. While the portals of entry into the body are the same for everyone (primarily via the lungs, skin, mouth), the amount of contaminants may be increased and the relative importance of some activities (e.g., basket making, wetlands gathering), pathways (e.g., steam immersion or medicinal infusions), or portals of entry (e.g., dermal wounding) may be different than for the general population.

Foraging theory data from the anthropological literature is particularly useful for developing exposure scenarios, because the major dietary and resource staples may be described, as well as how much time and effort is needed to obtain them. Together, this information is then used for the food-chain portion of the scenario and to calculate the direct exposure factors.

This process is laid out in the following sections according to the general sequence:

1. Environmental setting—what resources are available;
2. Lifestyle description—activities and their frequency, duration and intensity, and resource use;
3. Diet;
4. Exposure pathways, and
5. Exposure factors—iterative cross-walk between pathways and direct exposure factors: cumulative soil, water, air, and dietary exposures.

Because the method for developing exposure factors is derived from an understanding of lifestyle rather than from large statistical databases (national drinking water rates, or USDA databases of national average food intakes) and is

[2] http://arcticcircle.uconn.edu/NatResources/subsistglobal.html

unfamiliar to many readers, it is described briefly here (more detail is presented below).

Because large databases are not available and cannot be constructed, we take a top-down approach. For example, we do not attempt to develop a complete diet based on surveys of the uses of the typical 200+ natural resources available and used with an ecoregion. Rather, we develop a calorically complete food pyramid that identifies the major staples and their rough percentages in the original diet. Similarly, we do not develop an average day by tracking hundreds of individual activities from many people. The basic process is to:

1. Start with an understanding of the major categories of subsistence activities (such as hunting, fishing, gathering, basket making, and sweat lodge purification),
2. Describe enough of the sub-activities that the complexity and interconnection of resources and activities can be understood,
3. Identify the major activities that contribute to exposure, and then
4. Iteratively cross-walk between activities and conventional exposure factors to develop cumulative exposure factors.

To illustrate, each of the major activity categories includes activities that result in exposure to soil, and therefore soil ingestion. By estimating the relative amount of time spent in activities that result in high, medium, or low soil exposure for each activity category, an overall soil-ingestion rate can be estimated. However, we do not attempt to be overly quantitative in enumerating the myriad activities and resources in each category—this requires more precision than is warranted and is likely to require proprietary information that cannot be released.

Finally, a review of existing literature (biomedical, anthropological, and so on) enables us to double-check whether multiple lines of evidence leads us to a similar conclusion for each exposure factor.

2 ENVIRONMENTAL SETTING

This section provides a general introduction to habitats and plant communities present in Washoe territory. General resource use throughout the Washoe territory is described, with reference to the Leviathan-Bryant Creek drainage or similar drainages as data are available.

The Washoe culture, which evolved around Lake Tahoe, exploits a wide range of resources and ecological niches. The Washoe territory includes the boreal lakes and Sierra crest conifer zone (including Lake Tahoe, Honey Lake, and Topaz Lake), the transition zone with pinyon pines, and the Sonoran or sagebrush zone. Permanent settlements were located primarily near rivers and springs on the high ground of larger valleys. The distribution of resources was largely the same in all major valleys, with some north-to-south gradations.

Many authors have described the general environmental setting of the Sierra Nevada, Pinyon-Juniper, and Great Basin ecosystems (Barbour and Major 1977, Brown 1986, Foster and Hobbs 1992, Holland and Kiel 1995, Lanner 1981, Moore 2000, Muir 1988a, b, Schaffer 1998, Smith 2000, Tilford 1997, Tingley and Pizarro 2000, Winnett 1987). There are two distinct ecosystem types in the original Washoe territory—the heavily timbered and well-watered Sierra Nevada and the semi-desert Great Basin.

The elevation of the Sierra Nevada causes saturated westerly winds to drop most of their moisture on the western slope. The moister western side has more ecological zones than the eastern side, with more gradual transitions from one to the next. The western slopes mostly contain chaparrals and ponderosa pine-oak woodlands, while the rain-shadowed eastern slopes, stretching from the peaks to the Great Basin floor, mostly contain pinyon-juniper and sagebrush-steppe plant communities.

A general sequence of vegetation types from higher to lower elevation is described by Walker (2003), Hammett et al. (2004), and references cited therein, and is summarized in the following sections.

The area is shown on a map of the continental US in Figure 1 below.

Figure 1. Continental U.S. with Washoe Tribe Location

2.1 BOREAL ZONES

2.1.1 Upper Montane Zone

This boreal zone typically contains Jeffrey pine, white fir, and incense cedar (on gravelly dry slopes at higher elevations and moister north slopes at lower elevations) with understories of greenleaf and pinemat manzanita, tobacco brush and/or snow bush, depending on soil type, moisture, canopy cover, and aspect. Oaks are shrubs at this elevation (huckleberry oak and bush chinquapin). This zone may include white and lodgepole pine if the water table is high, and red fir in flats with deep soils. This broad zone includes several subzones: the alpine and subalpine belts at higher elevations, and the lodgepole-fir belt.

2.1.2 Lower Montane Zone

This boreal zone typically contains pines, red fir, and western or Sierra juniper with chaparral understories of manzanitas, deer brush, whiteleaf, snowberry, serviceberry (*Amelanchier*), tobacco brush (*Ceanothus velutinus*), mountain mahogany (*Cercocarpus lidifolius*), mountain misery, or sagebrush, depending on soil type, moisture, canopy cover, and aspect. There are also some black oaks, western white pine, and sugar pine. Where fires have been suppressed, white fir and incense cedar overtake ponderosa and black oaks; regular fires promote ponderosa, oaks, and ceanothus (deer forage). In higher meadows or sand flats formed on pumice flats, a ring of water-tolerant lodgepole pines may surround the moist flat. In drier areas, the understory may be characteristic of Basin sagebrush, with mountain mahogany, rabbitbrush, grasses, mule ear (*Wyethia mollis*), squirrel tail (*Elymus elymoides*), Great Basin wild rye, and forbs such as yarrow (*Achillea millefolium*), sulfur flower (*Eriogonum umbellatum*), and lupine (*Lupinus argenteus*). These latter species are also being used for revegetation at the mine site.[3]

2.1.3 Mountain Meadows, Springs, and Creeks

These habitats occur throughout the boreal and transition zones. Riparian species change somewhat with elevation, and may include dogwood, alder, elderberry, currants, other berries, quaking aspen, willow, coffeeberry, birches, cottonwood, rushes, sedges, grasses, horsetail, ferns, and a variety of bulbs and tubers. Springs and associated marshes and riparian habitats are extremely important to the Pine Nut Mountains' wildlife and to the Washoe people. They are widely scattered over the Pine Nut Mountains. While some wet areas are saline and alkaline marshes, most are small pools with warm to cool water sources. Where the water table is highest (mesic soils), mountain meadows are present, with willows, alders, huckleberries, wild rose, aspen, and cottonwood at lower elevations (a sign of water). Meadows have the highest plant diversity, with up to a hundred species in a single meadow. Mule ears (an aromatic large-leafed sunflower) can form colonies in dry meadows that are tens of acres in size. Berries, swamp onions, fern, wild spinach, wild lettuce, and various bulbs and tubers, such as lilies, wild potatoes, and Indian sweet potatoes, may be present. Tule, cattail, sedges, and other rushes can be present if moist enough. On river bottomlands, wild rye, western wheatgrass, Nevada bluegrass, sedges, rushes, silver buffaloberry, rubber rabbitbrush, Basin big sagebrush, Fremont cottonwood, and willow can be found.

2.2 TRANSITION ZONES

2.2.1 Pinyon-Juniper Habitat (*Pinus monophylla*-*Juniperus osteosperma*)

This habitat covers slopes of the eastern Sierra in areas with gravelly, well-drained soils, which transition into the lower sagebrush belt. This community is closely associated with sagebrush scrub, often with pinyons on upper slopes and sage just below them on flatter drier areas. The understory is most often sage, bitterbrush, rabbitbrush, green ephedra (Mormon tea), and mountain mahogany, with a variety of perennial wildflowers and grasses.

2.2.2 Sagebrush Steppe

Intermountain grassland and Basin sagebrush plant associations occur at lower and drier elevations with sage (*Artemesia tridendata*), rabbitbrush (*Chrysothamnus nauseosus*), and a variety of grasses and flowers. In the Basin (by the East Fork of the Carson River around Dresslerville), the vegetation on the bench lands includes Wyoming big sagebrush, rabbitbrush, bitterbrush, greasewood, spiny hopsage, green ephedra (Mormon tea), Anderson peachbush, balsamroot, Thurber needlegrass, bottlebrush squirreltail, a variety of grass seeds, mustard, pigweed,

[3] Lahontan Regional Water Quality Control Board, State of California (2003). 2002 Year-End Report for Leviathan Mine, Alpine County, California, p.24, http://www.swrcb.ca.gov/rwqcb6/Leviathan/PDFs/2002_year_end_report_FINAL.pdf.

saltbrush, rabbitbrush, sand grass, and other grasses. It also includes the sego lily, a food source that sustained Washoe people and Anglo settlers during times of scarcity.

2.2.3 Mountain Meadows, Springs, and Creeks

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2.3 GREAT BASIN VALLEY FLOOR

The valley floor is included because contamination from the mine may have traveled to the lower reaches of the East Fork of the Carson River. The lowest zone in the Great Basin is the shadscale zone, named after its most abundant shrub, and typically includes also green rabbitbrush, sagebrush, four-winged saltbrush, Bailey's greasewood, and littleleaf horsebrush. The more saline areas may be dominated by big greasewood, along with desert blite and green molly.

2.3.1 Desert Marshlands

The Great Basin has no river outlets, but exhibits high evaporation rates; therefore, some wet areas can contain alkaline waters and soils/sediments. Depending on the alkalinity, these waterlogged areas may contain salt-tolerant sedges and rushes. For example, the Stillwater Marsh (near to but not in the affected area) has four lakes that drain from one to another, causing the salinity to increase sequentially. The first lake receives the freshest water (still potable) and contains cattails, bulrush, willow, and sago pondweed. The next lake is more saline and contains muskgrass, sago pondweed, and wigeongrass. The third basin contains alkali saltbrush or nutgrass. The final basin is the most saline (similar and up to twice as saline as seawater) and contains few plants but many brine shrimp and brine flies.

2.4 WATERSHEDS

Many tribal homelands are defined in terms of watershed boundaries with the water source in the center (unlike the Western habit of using rivers as peripheral boundaries). This is because native peoples use entire river valleys with their ranges of elevation from the river bottoms to the boundary ridges or mountains, and utilized the associated seasonal patterns of resource availability. Figure 2 shows the Washoe area watersheds.

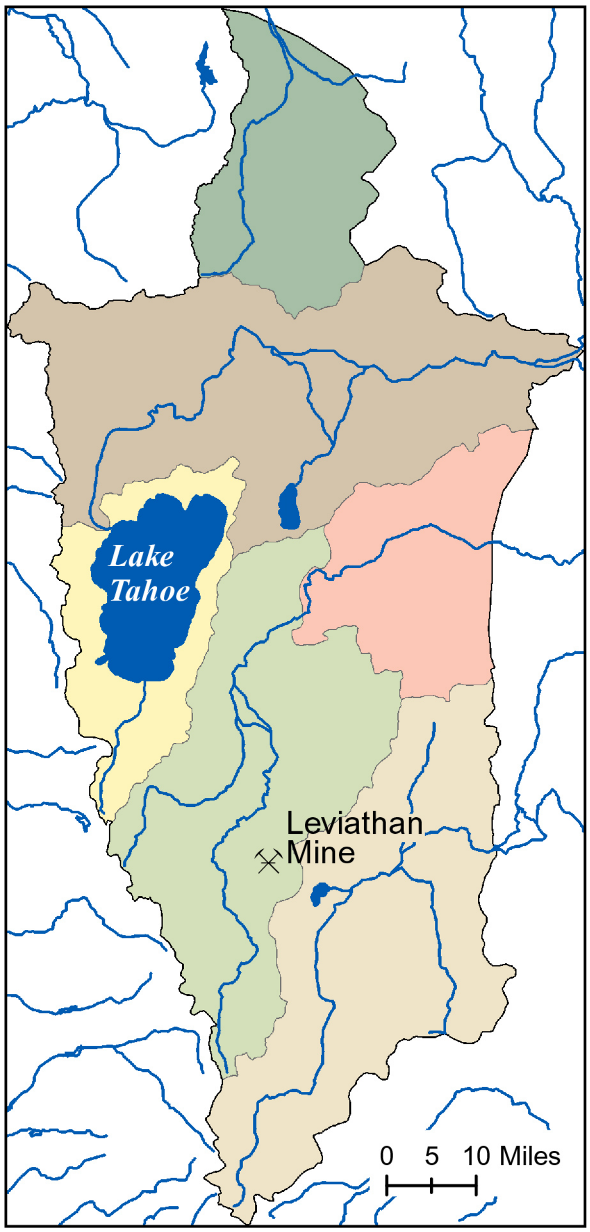

Figure 2. Washoe Area Watersheds

2.5 WASHOE ECOREGIONS

The basic premise of understanding ecologically-based lifeways is that people adapt their activities and diets to their local ecological region in order to survive and prosper. Therefore, the description of environmental setting must identify natural ecological zones, or ecoregions. Ecoregions denote areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources. They are designed to serve as a spatial framework for the research, assessment, management, and monitoring of ecosystems and ecosystem components (Bryce et al. 1999). These general purpose regions are critical for structuring and implementing ecosystem management strategies across federal and state agencies and nongovernmental organizations responsible for different types of resources in the same geographical areas (Omernik 2000).

Ecological diversity is strongly related to its varied climate, terrain, geology, and soil, and largely tracks watersheds and physiographic regions. In North America, several broad climatic zones are recognized, roughly corresponding to temperature and moisture gradients. North American vegetation types roughly track these zones. Of these zones, the Northwestern Forested Mountains and North American Deserts are relevant to the Washoe Scenario. Because the zones are defined by dominant vegetation types, the composition of plant and animal species is fairly predictable for the dominant species. Local differences in geology (soils and deeper substrates), elevation, aspect, and climate (light, temperature, precipitation and wind), and water (streams and wetlands) affect individual plant associations.

A hierarchical scheme has been adopted for different levels of ecological regions, and is being used by the US Environmental Protection Agency (USEPA).[4] Level I is the coarsest level, dividing North America into 15 ecological regions. Level II divides the continent into 52 regions. At Level III, the conterminous United States has 84 (USEPA 2005). Methods used by the USEPA to define the ecoregions are explained in Omernik (1995, 2000, 2004), Gallant et al. (1989), and Bailey (1995).[5] The approach used to compile these ecoregion maps is based on the premise that ecoregions can be identified through the analysis of the spatial patterns and the composition of biotic and abiotic characteristics that affect or reflect differences in ecosystem quality and integrity (Wiken 1986, Omernik 1987, 1995). These characteristics include physiography, geology, climate, soils, land use, wildlife, fish, hydrology, and vegetation, including "potential natural vegetation," defined by Kuchler as vegetation that would exist today if human influence ended and the natural vegetation were restored (including the earlier fire regime of mixed natural and indigenous origin, and natural flooding).

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[4] http://www.epa.gov/wed/pages/ecoregions.htm and http://www.cec.org/files/PDF/BIODIVERSITY/eco-eng_EN.pdf

[5] USFS Bailey province ecology: http://www.fs.fed.us/land/pubs/ecoregions/intro.html

Below, Figure 3 shows the traditional Level III ecoregions of the Washoe.

Figure 3. Washoe Level III Ecoregions

3 OVERVIEW OF GENERAL WASHOE ECOLOGICAL LIFESTYLE

The Washoe did not have to travel very far to obtain all the resources they needed and to access trade across the Sierras into California (Cook 1941). The Washoe economy focused on plant gathering, fishing, and hunting (Price 1980, Kelly 1995, Tucker et al. 1992). The predominant staples included fish and pinyon nuts, both of which were zealously defended (Downs 1966). There is evidence that Washoe families had a form of ownership interest of pinyon plots, which is rare in hunting and gathering societies. Additional staples included rabbits, acorns (obtained from northern Washoe areas or by trade from across the Sierras into California), large game, small game, fowl, and many bulbs, roots, seeds and berries (Walker 2003, Hammett et al. 2004). An abundance of basket weaving and rabbit-skin robes indicates that a considerable amount of time was available for the material aspects of the culture. In the words of one Tribe member, water was a culturally esteemed resource,

> Water has always had a special significance to the Washoe people. All life is derived from water in Washoe beliefs, and water is considered sacred. There are legends and mythologies related to water. The many uses of water range from spiritual, medicinal, and ceremonial uses, to everyday uses such as drinking, bathing, cooking, and cleaning with water. Water—whether in springs, streams, rivers, or lakes—has such a defining and profound role in the culture of the Washoe people that it could be described as the essence of the Washoe people.[6]

The number of people who still know and practice traditional ways (or remember them) is high, based on the number of people available for interviews by Walker and Hammett.

3.1 HISTORICAL SEASONAL PATTERNS OF THE WASHOE

This section describes both the historical cycles and the modern adaptations that still follow seasonal resource availability. Although this description often refers to past practices, it is important to understand that a resource-oriented lifestyle must still conform to the natural environment. Thus, even if people do not physically move their homes seasonally, they still pursue original seasonal activities in original locations from a permanent home base, with modern conveyances and tools enabling them to reach these areas quicker and process resources faster. Also, pine nut camps, hunting camps, fishing camps, or other resource-based camps are still used by many native peoples.

The Washoe year includes annual cycles for fishing, gathering, and hunting (Downs 1966, Kelly 2001). Fishing occurs all year long, but begins in earnest as soon as the snow begins to leave the lower foothills. Whitefish from Lake Tahoe and the rivers

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[6] Darrel Cruz, Washoe Tribal member and Washoe Tribe Environmental Specialist, March 10, 2005.

provided welcome fresh food, along with game and early spring plants. By June, people had moved from the lake to winter camps in the pinyon belt or lowlands, to harvest spring migrations of trout and suckers from the lakes to the tributaries. Fish were dried and lasted most but not all of the year, supplemented by smaller fish fresh from streams and rivers (the Carson River, Truckee River, Bryant Creek, and their tributaries). When the spring spawning runs were over, families moved to higher lakes, where mountain meadows provided an increasing amount and diversity of food and more fish and animals became available. By late summer, the many ripening lowland grasses spurred a round of seed gathering. In the fall, the pinyon nut harvest occurred, as well as its associated ceremonies, large assemblages, and other events. Tremendous amounts of nuts were gathered, parched, and stored for winter and year-round use.

Washoes were active during all seasons, although less so during the winter due to weather conditions (Downs 1966, Kelly 1995, Hammett et al. 2004, Walker 2003, Price 1980, Tucker et al. 1992). At that time, watercress was the primary fresh green plant available for gathering. The main winter foods were pine nuts, dried and frozen meats, dried berries, fish, fowl, seeds, dried root and seed cakes, and teas and medicines. Some of the pine nuts were partially processed, but grinding, winnowing, skinning, and other activities were still required. The Tribe had to gather firewood year-round. Whitefish were sought in the winter and hunting continued, and there was an emphasis on making tools, baskets, and other material items. Food and material preparation were constantly required regardless of weather. The full range of plant and animal processing was constant, including hulling, grinding, pounding, scraping, roasting, excavating cooking pits, carrying loads of food and materials and firewood, and building smoking racks, hearths, caches, and shelters. Similarly, people always scouted, tracked game, monitored where to harvest the next ready resources, or looked for good stands. Downs noted that, “Plant foods were gathered intensively from early spring until late fall” (1966). A longer list of activities is presented in Hammett et al. (2004).

3.2 GENERAL RESOURCE USE

A wide variety of species use by the Washoe is documented. Fowler (1986) lists over 200 species used throughout the Great Basin, many of which are in the Washoe areas, and Tilford (1997) notes that around 150 edible and medicinal species, including berries are in the general area, with 75% of those species (or at least 100) expected to be present in the Washoe territory. D’Azevedo (1986) describes “a large variety of predictable resources close at hand.”

Hammett et al. (2004) and Walker (2003) analyzed information on plant and animal use from historical and contemporary ethnographic sources, including interviews with tribal members. The interviews focused on the resources of the Leviathan-Bryant Creek watershed that are or were used by Washoe tribal members. The Walker report identifies many resources used. The Hammett report identifies and quantifies some of the resources of the overall diet, and also determines an activity level needed to develop exposure factors for traditional activities.

3.2.1 Fishing and Hunting

Fishing was a highly important vocation. In the higher mountain section of the Washoe country, notably at Lake Tahoe, fishing was of similar importance as pine nut gathering. The Bryant Creek drainage has been a primary fishing area for the Washoe, and also has contained some of the best hunting grounds. Fish of various kinds were abundant in the Bryant Creek drainage. Several native species of fish (Lahontan cutthroat trout, whitefish, suckers, and minnows) and introduced species (brown trout, brook trout, rainbow trout, golden trout, and carp) are now present, although diminished.

> We depended on that creek [Leviathan and Bryant] before [mining]; we used to fish in it. There were big fish in it, and we fished it all the time (Walker 2003).

Game resources collected by the Washoe in the higher elevations, the Bryant Creek drainage, and the East Fork of the Carson River include but are not limited to deer, antelope, marmot, ground squirrels,[7] rabbits, crayfish, clams, waterfowl, quail, sage hens, grouse, and grasshoppers. The annual deer migration from high to lower elevations through the Leviathan Creek corridor was a predictable event and the people relied upon it as a source of deer meat. However, as interviewees noted, the deer do not come over Monitor Pass or through the Leviathan Creek area any more, indicating disrupted migration patterns (Walker 2003).

3.2.2 Gathering

Price (1980) writes that “the average [Washoe] woman was comparable to a botanist in her medical knowledge of plants,” and that “about 100 species of plants were used in some way as food, medicine, fiber, or construction.” Hammett et al. (2004) also lists about 100 plant species used. Downs (1966) describes the variety and amounts of plant foods as “almost infinite,” but widely dispersed.

The semi-arid portion of the general Washoe territory provides a variety of grasses with edible seeds, as well as the pinyon pine whose nuts, commonly referred to as “pine nuts,” constitute such an important article of food throughout much of the Great Basin area.

Leviathan Creek was one of the best sources for gathering plant to eat and willow branches for basket making (Walker 2003). Many Leviathan-Bryant Creek plant resources are cited in the Walker and Hammett interviews. In the spring and early summer numerous bulbs and roots were historically available, such as wild onions,

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[7] Different authors and interviewees use the terms gopher, woodchuck, marmot, prairie dogs, ground squirrel, and small or large ground squirrel without indicating species. We assume that woodchucks and large ground squirrels are actually marmots *(Marmota flaviventri)*, and gophers and prairie dogs are actually ground squirrels *(Spermophilus beldingi)*.

watercress, sego lily, camas, bitterroot, several other types of wild lilies, several types of wild potatoes, cattail, tule, and many medicines. One Walker (2003) interviewee noted of the mine site, “There is a lot of *busdi* [wild onions] up there.” Among the most common kinds of berries were western chokecherry, elderberry*,* buckberry*,* Saskatoon serviceberry, desert and golden currants, Sierra plum, and Sierra gooseberry. Varieties of wild strawberries were also traditionally gathered in the area and highly prized. Another Tribe member spoke of the abundance of edible plants (Walker 2003), “There were a lot of strawberries, spinach, and we had a lot of greens, like watercress. Mama knew a lot of the plants, like wild spinach. There were currants and strawberries, lots of them. There were very sweet. Chokecherries, as well.”

The leafy and/or tender parts of many plants gathered from the Bryant Creek drainage and the East Fork of the Carson River were often eaten raw, although many were cooked or dried. Several species of watercress grow along many streams; some varieties are available throughout the winter months and were eaten fresh as picked. Several types of mushrooms were gathered under trees after spring rains, and ephedra tea was used as a stimulating tea and for medicinal purposes (Walker 2003).

The Washoe were especially noted for their basketry: “Washoe baskets are the finest in the world” (Sprout and Sprout 1999, Mason 1904, Cahodas 1979). Today, the Washoes continue to make twined or coiled baskets, primarily out of willow. Inner bark is used for the white twining and sewing elements, and browned from sun exposure (Barrett 1988). The other primary colored materials are the bracken root (*Pteridium aquilinum)*, black when soaked in mud, and the brown or red redbud bark (*Cercis occidentalis*). The latter was historically obtained by trade from the western Maidu (Garey-Sage 2003). Softer basket materials include cattails and a variety of grasses and sedges. Tules are used for rafts and mats. Most cordage is made from dogbane (*Apocynum*), as well as milkweed (*Asclepias*), sagebrush, or iris (Lindstrom 1992).

3.2.3 Sampling and Analysis Priorities

Some of the major plant resources are shown in Table 1, as well as some of the animal species that could be a priority to sample and include in both the human and ecological risk assessments. Higher trophic levels than those in the table would also be included in both the human and ecological risk assessments, but are not recommended for sampling (they should be modeled instead). This table is not an exhaustive list of edible species, but includes representative edible and materially important species. Some categories contain multiple plant families, genera, and species. Some indication as to what season a resource is gathered in (and therefore when the sampling should be done) is provided. Note that many of these categories include multiple species. In every case, co-located water, soil and/or sediment should also be sampled.

One major data gap is the distinction between the as-gathered and as-eaten forms. Some species are merely brushed off before eating, some are ground, and some are pit-cooked. Residual soil on the outside of plants is known to be an exposure pathway, but there is very little data on this point. Laboratory analysis should ideally test both what is internal to plants and what is left on the surface after being treated by tribal members in their usual way; otherwise the contaminant load will be underestimated.

Table 1. Priority species for sampling and contaminant analysis.

Species or Class	Habitat Type	Rationale
Pine nuts	Pinyon-Juniper	Major food item; ripe in the fall.
Berries (different classes) —elderberry, chokecherry, currant, gooseberry, strawberry, other	Riparian or hillside	Berries from different plant families are used; some are eaten as picked without washing (dust pathway) or with washing (in contaminated water); some may contain contaminants in the fruit. Species should be varied and kept separate.
Seeds—mustard or sunflower/Balsamroot	Sagebrush steppe	Some *Brassica* and *Helianthus* hyperaccumulate metals.
Bracken fern	Riparian	Roots and fiddlenecks—bracken hyperaccumulates arsenic; edible fiddlenecks and basket material.
Willow shoots	Aquatic-Riparian	Multiple uses, particularly baskets, high water uptake; stems chewed and held in mouth for splitting. Sample in spring growth cycle.
Tule (*Scirpus*), **cattail** (*Typha*), **sedge** (*Carex*)	Aquatic-Riparian	Multiple uses; edible. Collect shoots in spring (eaten), leaves (baskets), pollen (eaten), tubers (eaten, fall is the high starch storage season). The 3 species should each be sampled.
Watercress	Aquatic-Riparian	In-stream; edible, eaten especially in winter.
Edible bulbs and tubers—wild potato, wild onions, wild sweet potato, yampah, Sego lily, others	Riparian or hillside-meadow	Below-ground edible foods can uptake and retain internal contaminants and/or external residual soil when eaten. Sample riparian areas as a priority. Keep plant families separate.
Greens—miner's lettuce, nettle, others	Hillside-meadow	Above-ground plants may have deposited dust and translocated contaminants; keep plant families separate.
Mushrooms	Various	Some species hyperaccumulate metals
Honey	Widespread	Bees forage, and honey can be a sentinel for localized contamination.
Burrowing rodent—marmot or ground squirrel	Riparian or hillside-meadow	Grooming of fur can be a major exposure pathway; some are pit-cooked.
Shellfish—crawfish, snail, mussel	Aquatic	Mollusks are filter feeders; crayfish are eaten. Also sample co-located sediment.
Aquatic insects	Aquatic	Ensure that testing for contaminants occurs as far downstream as the scenario is applied. Should be tested along with sediment as an aquatic food-chain base.
Resident fish—minnow or larger fish if present	Aquatic	Bottom feeders and predators should be sampled.

4 HUMAN ACTIVITIES AND EXPOSURE SCENARIO

4.1 METHODS FOR DESCRIBING THE DIET

The approach used in describing an overall diet is to use the information about major resources present in the study area, foraging theory information, and information from existing literature and interviews. An overall total caloric food pyramid with rough proportions of different food groups has been developed to show a typical traditional diet (Figure 4). This food pyramid is reconstructed from information about what the traditional diet actually was, rather than what it might be today if USDA recommendations about daily intakes were followed substituting wild foods for domesticated ones. In particular, the traditional Washoe diet was based on fish and game rather than grains.

The steps for reconstructing the Washoe diet are:

- Review foraging theory information specific to the Tribe, the local ecosystem, and, if available, for the specific location under consideration;
- Review ecological information for a rough estimate of resource abundance of natural resources under baseline conditions;
- Review interviews and other ethnographic sources for supporting information of species and abundance, habitat types, human activity levels, and methods of obtaining, preparing, and using resources;
- Develop overall percentages of major food categories and major staples within the total diet;
- Estimate calories provided by the diet, and compare estimates of percentages of quantities and percentages of calories, and
- Refine estimates of major staples and food categories after considering information about medicines, sweeteners, other often-overlooked food/medicine types like macronutrients, and other factors.

The dietary input for the risk assessment is typically somewhat less complex than the food pyramid (due to intrinsic limitations of the risk methods). Nevertheless, the risk assessment must consider the totality of species and calories. As noted in Section 3.2 on general resource use, the amount and variety of species used by the Washoe is wide and abundant.

4.1.1 Foraging Theory

Kelly (1995) describes the concepts of eco-cultural lifestyles, also known as foraging theory. In the 1960s to 1980s the “Man the Hunter” concept (with males providing most of the provender) prevailed due to a previous archaeological emphasis on hunting and warfare artifacts (Lee and Devore 1968). This gave way in the 1990s to a more balanced foraging model that emphasized plants as much as meat (and equality of genders in contributing to survival) and a relatively peaceful and secure “original affluent society” (Sahlins 1972). The latter concept is supported by data (Kelly 1995, Winterhalder 1981) on the amount of time required to obtain survival necessities and to raise children, and the typically abundant amount of time available for socializing, education, ceremonies, material items, leisure, recreation, oratories, and so on. However, hunter-gatherers are not over-nourished, and face seasonal shortages even though outright starvation is rare. The lifestyle is also "physically demanding" (Kelly 1995), giving rise to discussions about the number of calories available or required and the activity levels used to develop exposure factors.

Efficiency or return rate for specific resources in specific habitats is estimated using foraging theory by evaluating the amount of calories expended in getting food (search costs) by means of hunting, gathering, or fishing relative to the time spent or calories obtained. Foraging information is typically presented as return rates, or net calories obtained per hour of effort. Additional factors such as biodiversity, abundance, and patchiness or continuity of resources result in time allocation decisions that are intentionally or unintentionally made by foraging societies, such as optimal diet breadth, optimal foraging area, and optimal foraging group size for a particular ecosystem (Winterhalder 1981). Depending on the evaluation methods used in a study, this return rate data may include (1) time and calories spent in preparing to hunt, fish, or gather (e.g., making nets), (2) time and/or calories spent in the actual activity, and (3) time spent in the processing of the resource after obtaining it. The drawback of oversimplifying foraging solely to caloric efficiency is that micronutrients (vitamins, minerals, specific amino acids, and fatty acids), medicinal or pharmacologically active compounds, other nutritional requirements, and non-nutritional attributes, such as aroma or dye or material uses, are often not considered (Lindstrom 1992). Similarly, many plants and animals have multiple uses or are co-located with other resources; therefore, caloric calculations must not ignore the way that people actually make decisions about where to go or what to gather, or the reasons they seek to obtain particular resources.

4.2 STUDIES ON WASHOE DIET

4.2.1 Foraging Studies

Three major foraging theory studies have been identified for the Washoe: (1) Lindstrom (1992) focused on fishing in the Truckee River, (2) Tucker et al. (1992) evaluated a more generalized area and diet, and (3) Kelly (2001) focused on Great Basin wetlands resources. While these studies did not specifically focus on the Leviathan-Bryant Creek drainage, they provide relevant information due to similarity of resources and uses. Each author's results are presented separately even if they included the same resources since there were some differences in methods and assumptions.

Lindstrom (1992) evaluated Truckee River fishing and Great Basin aquatic and terrestrial resources for caloric return rate efficiency associated with traditional methods, i.e., including the time needed to make fish nets and other implements and processing costs for storage compared to fresh consumption. She evaluated the hours spent obtaining and preparing resources (during their peak availability times).

She also gathered information from interviews with Washoe members skilled at making and using traditional implements, and information from the archaeological record. She concluded that the Truckee River-based economy would have emphasized fish, grasshoppers (during peak years and seasons), big game, rabbits, small game, pinyon nuts (from the foothills), cattail pollen, and various individual seeds and roots, in that approximate order. Lindstrom writes that "a high level of energy efficiency suggests fish were used as a principal resource whenever they were available." This assumes a certain efficiency of capture or abundance, especially during schooling or spawning, and ratios of specific capture methods. As she notes, her ranking of resources from most to least preferred is not entirely consistent with notes from anthropologists, settlers, and visitors, or with tribal traditional environmental knowledge. For instance, rabbits and pine nuts (from the pinyon pine) are ranked lower than their actual importance, primarily because her analysis focused on a single resource area rather than on the overall Washoe territory. This also suggests that a number of factors are not included in typical equations used to rank resources, such as possible high seasonal abundance, group hunts, storability, and multiple uses of resources (e.g., rabbits hunted for both food and skins, willows gathered for baskets as well as medicine, and many other material items made from mountain and foothill resources).

Tucker et al. (1992) describe an "idealized pre-contact Washoe diet" based on a diet breadth model using ethnographic and archaeological data, such as frequency and location of bones and implements commonly found in excavations. The diet is also based on known resource abundance and caloric return rates per hour, but it underestimates soft matter such as plants and fish bones that decompose and leave less of a physical trace. Tucker et al. do not include energy expended in chasing or the efficiency of gathering co-located resources (other than indirectly through overall abundance of the resource), the energy expended in processing the resources, or other uses that might alter the preferential sequence. The approximate order in which individual resources would be preferred using only the caloric, seasonal abundance and archaeological information is:

1. Deer (return rate = 24,000 kcal/hr; assumes one kill per 8 hours of effort),
2. Antelope (return rate = 23,000 kcal/hr),
3. Jackrabbit (return rate = 14,000 kcal/hr),
4. Fish (return rate = 12,000 kcal/hr)
5. Ground squirrels (return rate = 10,000 kcal/hr),
6. Large ground squirrels[8] (return rate = 5,000 kcal/hr),
7. Honey (return rate = 3,000 kcal/hr),
8. Small ground squirrel (return rate = 3,000 kcal/hr),
9. Duck (return rate = 2,000 kcal/hr),
10. Pine nuts (return rate = 1,000 kcal/hr, including roasting, grinding, and cooking),
11. Sunflower seeds (return rate = 500 kcal/hr),
12. Great Basin wild rye seeds (return rate = 400 kcal/hr), and

[8] Probably the marmot.

13. Indian rice grass seeds (return rate = 300 kcal/hr).

This list only partially accounts for co-locational or localized abundance. Therefore, as noted by Tucker et al. (1992), small seeds and greens as combined categories of resources (rather than individual species) are efficient resources to gather if they are sufficiently abundant and if gathered concurrently with higher ranked resources. This list also completely overlooks the many important greens, roots, bulbs, tubers, and rhizomes that were gathered in abundance, as well as basket materials and non-food items. Some of the listed resources would also rank higher if they store well or if they provide specific nutrients. The Washoes knew to expend extra energy in gathering storable resources as a hedge against famine, and are also well aware of nutritional or medicinal benefits of specific plants. For example, spinach and watercress were considered essential foods. A Hammett et al. (2004) interviewee noted, "[Washoe] people craved this food [watercress]; must have been something in it people need because parents insisted that children eat it." Thus, broad categories of plants (greens, fruits, roots, bulbs, tubers) are not represented at all in the above ranking. Even seeds, some of which are recovered archaeologically, are probably underestimated, especially native grasses "from which tons of seed were gathered" (Cook 1941).

Kelly (1995) evaluated Great Basin foraging in his discussion of many foraging societies around the world. Animals, including waterfowl, are all more efficient to gather than plants as long as they are relatively easy to catch. Return rates for a few resources (based on kcal/hr of effort, but not indicating how strenuous the effort is; on known abundance locally, and showing rates for worst to best years based on available data) were estimated as:

- Deer = 17,000–31,000 kcal/hr (poor year to best year),
- Jackrabbit = 14,000,
- Gopher = 10,000,
- Cattail = 300, and
- Pine nuts = 800–1,400.

Kelly (1995) estimated that the overall Washoe diet was obtained 30% from hunting, 40% from gathering, and 30% from fishing. This was based on estimates of abundance, density of resources, seasonality, and harvesting or cooking technology. Unlike the list in Tucker et al. (1992), plant resources are very prominent. For example, cattail roots harvested in the summer have a poor return rate, because they have expended their energy into the leaves. But when harvested in the late fall or winter when energy is being stored, they have a much higher return rate and would be a preferred food choice. Lower caloric return rates are provided by cattail pollen, squirrels, ducks, gambel oak acorns, tansy mustard seeds, pine nuts (low overall calorie return due to the time required to roast the cones, gather seeds, and grind them into meal), bitterroot roots, wild rye seeds, minnows (caught with nets), saltbush seeds, bulrush seeds, other grasses, sunflowers, and roots. Among plant resources, cattail pollen was estimated to have the densest caloric content, with acorns, pine nuts, and tansy mustard seeds next, followed by all other roots and seeds. However, although cattail pollen is calorically dense, it takes time and effort to obtain; therefore, its return rate is lower than cattail roots, which is a poorer food but easier to obtain in quantity. However, cattail pollen can be eaten right off the stalk, and thus may have no processing costs (although it was typically ground into flour before use).

Kelly (2001) focused on the level of resources obtained from Great Basin wetlands (Stillwater Marsh near Carson Lake, southeast of Pyramid Lake), based on foraging theory and a caloric balance that includes walking to a resource, carrying a load back, and harvesting and processing costs. Based on all costs, Kelly estimated that a typical family's foraging area is 6km in radius until resources are reduced beyond a certain abundance (hunting areas might be larger). A large amount of storable resources, such as dried fish or game or pine nuts, allows a family to maintain a central residence such as a winter home (which was always by springs or streams). Thus, "fish, large game, seeds, and pinyon appear to have been particularly important." Kelly concluded that the rates of return were greatest for grasshoppers (collected en masse after they periodically washed up on lake shores and formed windrows, then roasted), followed by local large game, small game, waterfowl, a variety of seeds and nuts, and winter-gathered cattail and tule roots.

Kelly (2001) also estimated return rates for foraging away from home and included an estimate of kcal expended during the foraging activity. Foraging in a marsh from a residential base near the marsh (camps were generally ¼ to ½ mile from a marsh due to mosquitoes) was based on an assumption of moderate walking at 300 kcal/hr on the way out, plus 30% more carrying a 32 liter load back, all in an 8 hour day and with an average return rate of 1830 kcal/hr (not including processing). After taking the return rate and subtracting the energy cost of walking there and collecting and returning with a load, the species which have the most effective return rates are (more examples appear in Kelly 2001; Table 3-8):

- Cattail pollen = 4500 kcal/hr (the highest return rate kcal/hr),
- Chub = up to 4000,
- Rodents, waterfowl, bulrush seeds = around 1000, and
- Many other seeds ranging from 100 to 800.

It is important to note that the effective return rate for large game is more difficult to estimate, since the time spent in finding it is so variable. Here is a list of similar more variable return rates are:

- Pine nuts = 800 to 9600 (depending on distance and other conditions),
- Large game = up to 4,500 at 8 hours per kill,
- Small game = up to 2500,
- Bitterroot = 1250, and
- Ricegrass and wild rye seeds = 350.

Kelly (2001) also compared the most efficient caloric return rates for plants in several habitats. These are presented as examples of methodology and species identification. Within each habitat, examples of species preferences are as follows (in order of preference with the most preferred at top; the original reference has longer lists):

Wetlands:

- Tule bulrush (*Scirpus acutus, americanus*, or spp) shoots in spring, pollen in summer, seeds in fall, tubers in fall
- Nutgrass (*Scirpus or Carex* and spp) seeds, tubers in the fall
- Cattail (*Typha latifolia* and spp) shoots in spring, seeds in fall, and tubers in fall
- Sago pondweed (*Potamogeton* spp) tubers in summer, corms in winter or spring
- Chufa fatsedge (*Cyperus esculentus*) tubers in spring
- Water plantain (*Alisma geyeri*) seeds in fall
- Spikerush (*Elercharis palustris*) seeds in fall
- Seepweed (*Suaeda depressa*) seeds
- Pickleweed (*Allenrolfea occidentalis*) seeds
- Mollusks (*Anadonta* spp) all year, referred to as both clams and mussels.
- Brine fly (*Ephydra*)

Lowlands and Riparian:

- Onion (*Allium anceps, nevadense*) corms and leaves in spring
- Wild potatoes, several species
- Sego lily (*Calochortus nuttali* and other lily spp) bulbs
- Many seeds, berries, stems, leaves, and bark

Uplands:

- Nevada desert parsley (*Lomatium nevadense*) roots in spring, summer
- Yampah (*Perideridia bolanderi*) roots in summer
- Bitterroot (*Lewisia rediviva*) roots in spring
- Spring beauty (*Claytonia umbellata*) roots in spring
- Other bulbs and tubers
- Balsamroot (*Balsamorhiza* spp) roots, shoots, seeds
- Many berries

4.2.2 Interview Data

Qualitative information from the interviews in Hammett et al. (2004) on resources gathered from the Leviathan-Bryant Creek drainage is presented for approximate relative importance of some of the resources. This is not a total amount consumed per person per year, but it does identify many of the most important representative species gathered from the affected area and gives a rough idea of abundance or availability. The numbers indicate how much could be gathered by one or more people in a season for personal use, family use, and/or sharing or trading.

Nuts:

- Pine nuts—up to 1500 lbs of nuts

Note: Price (1980) indicates consumption of 300 pounds of pine nuts per person per year, eaten at a rate of 1 pound of pine nuts per person per day, or one-half of the total food consumption. At roughly 600 kcal per 100g after shelling and winnowing (USDA database), and 454g/pound, this means that 2700 kcal per pound of pine nuts could have been available per person per day. If pine nuts comprised half the diet, this would mean that 5,000 kcal/day was consumed, which is double the typical forager dietary intake (Kelly 1995). On the other hand, pine nuts are a well-known staple. “At certain seasons [the Washoe] have fish... for the remainder of the year they live upon the pine nuts, which form their greater winter subsistence” (Lindstrom 1992, citing Nevins 1956).

Cook (1941) interviewed Washoe families regarding current pine nut availability. Families could gather up to twenty 100-pound sacks in good years, although they typically sold up to half. Some families got far less, presumably depending on their access to pine nut allotments, whether it was a good year, or other reasons. A 100 pound sack yields 60 pounds of meat after shelling and winnowing (which Price, above, may not have considered). Cook also discussed fresh pine nuts versus the dried nuts (after parching for storage), which could reduce the weight by 15%. This would mean that 100 pounds of fresh nuts yields about 50 pounds of ground meal at approximately 2100 kcal per pound of nut flour, which is one of the forms eaten.

Berries:

Blueberry—not quantitative
Buckberry—not quantitative
Chokecherry—up to 20 gallons
Currants—not quantitative
Serviceberry—not quantitative
Strawberry—2 gallons
Elderberry—up to 100 gallons
Gooseberry—up to 20 gallons

Bulbs and Roots:

- Green onions—5 lbs
- Lily—400–1200 bushels
- Sego Lily—300 lbs
- Arrowroot—not quantitative
- Sweet potato—25 lbs
- Wild garlic—12 bushels
- Indian potatoes—up to 75 lbs

- Wild onions—up to 460 gallons; 7.5 gunny sacks (225 gallons)
- Swamp onion—12 grocery sacks

Greens:
- Tops of wild onion—not quantitative
- Wild rhubarb—up to 100 lbs
- Watercress—3–10 gallons; 15 gunny sacks (450 gallons)
- Tule shoots—60 plants
- Wild mustard—20 lbs

Other:
- Mustard seeds—6–9 lbs
- Mushrooms—24 gallons
- Lomatium tea—not quantitative
- Wyethia stems—up to 48 stems
- Ephedra—1 grocery sack

Fowl:
- Chukkar—20–60 birds
- Dove—20–60 birds
- Goose—32 birds
- Quail (both mountain and valley)—20–60 individual birds each
- Sagehen—20–60 birds

Game:
- Deer—up to 2250 lbs of meat
- Jackrabbit—up to 420 lbs of meat
- Marmot—12 lbs of meat
- Porcupine—1 animal at 30 lbs
- Prairie dogs—up to 33 animals or 25 lbs of meat
- Rabbit—up to 240 animals or 616 lbs of meat

Fish and Shellfish:
- Trout (various species)—up to 168 fish per year per person

4.3 WASHOE DIET

This section uses the information from the previous sections to derive estimates of major categories of food types as percentages. It considers the number of species, the foraging studies with their dietary estimates, and recent interview data. This information is combined to reconstruct a diet that was obtained from stream-river drainages such as the Leviathan-Bryant Creek system. It is intended to describe what the diet actually was before contamination altered the natural resources. This diet is presented below as percentages and as a food pyramid (Figure 4).

Kelly (1995) estimated the traditional Washoe diet to be obtained 30% by fishing, 30% by hunting, and 40% by gathering. Kelly's estimate included the large spawning runs in Lake Tahoe, whereas the present scenario is centered on smaller drainages, such as Leviathan-Bryant Creek, that have lower carrying capacities. Therefore, fish are ranked lower in the diet shown below. It does not include acorns from the northern part of the Washoe territory.

Based on interviews and existing literature, foraging theory, dietary calories, and related information, the traditional Washoe diet for foothill drainage systems such as the Leviathan-Bryant Creek system is estimated as:

- Pine nuts (20% of total calories);
- Fish and shellfish (15%);
- Game (large and small, and fowl) (15%);
- Roots, bulbs, tubers, rhizomes (15%);
- Greens (10%);
- Berries (10%);
- Seeds (10%), and
- Honey, rose hips, medicines, teas (5% combined).

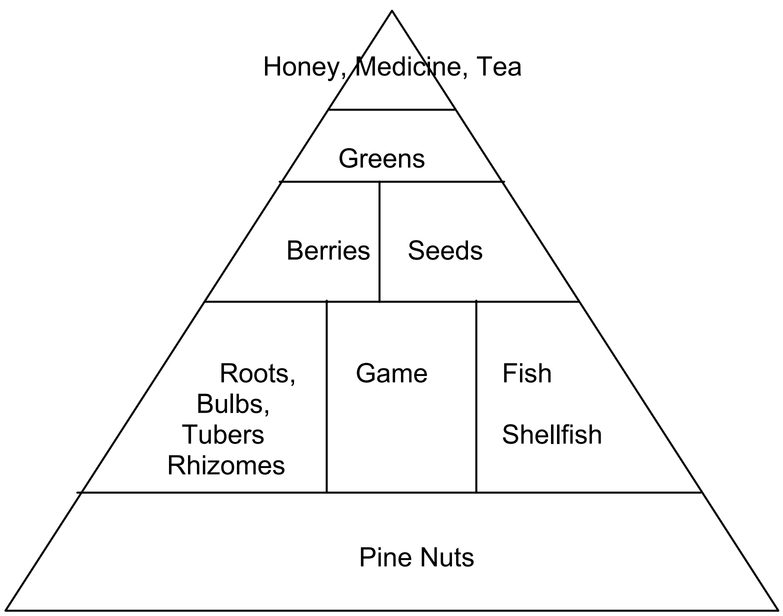

Figure 4. Washoe Traditional Food Pyramid

4.4 NUTRITIONAL ANALYSIS

A brief nutritional analysis is presented here in order to cross-check the amounts eaten with an estimate of macronutrients that would be provided. This is done to ensure that a full amount of calories is accounted for, and that the diet is roughly balanced within the ranges of other foraging diets. It is impossible to be more quantitative than this given the lack of data on native foods—nutritional data on the specific resources available to the Washoe are almost totally lacking. Therefore, all of the information in Table 2 is from the USDA database (except where noted) for an average member of the same or nearest plant or animal family (the “Representative Species” column in Table 2). Specific information from the USDA database, such as for game species, is used when available. Where possible, the data for fresh or cooked foods matches the form of native plants eaten. We recognize that domesticated species of plants have been bred for certain characteristics, such as low fiber content and more sweetness. Tribal members often refer to wild varieties as being “stronger” than domesticated varieties. This is a well-known data gap.

Table 2 indicates macronutrient content for representative species, Table 3 estimates calories for the major food categories, and Table 4 estimates macronutrients for the major food categories. We are assuming, as other authors have, that 2500 kcal is adequate for foraging activity levels in a 70kg person; however, higher calorie levels may also be appropriate. For this analysis, we are conservatively assuming the lower calorie rate.

Table 4 estimates a Washoe daily diet in which 26% of calories come from protein, 170 grams per day (gpd); 36% from lipid, 102gpd, and 38% from carbohydrate (CHO), 244gpd. (Due to the lipid content of the nuts and seeds, this diet is higher in lipid than many foraging diets.) Protein and carbohydrate provide roughly 4 kcal/g. Fats and oils provide roughly 8–9 kcal/g. Therefore, the estimated daily macronutrients ingested yield:

> 170g protein x 4 kcal/g = 680 kcal,
> 102g lipid x 9 kcal/g = 918 kcal, and
> 244g CHO x 4 kcal/g = 976 kcal,

providing a total of 2574 kcal.

For comparison, Hunn (1990) described a typical daily Columbia Plateau diet that included 1300gpd roots (providing 1330 kcal), 100gpd berries (62 kcal), 500gpd salmon (850 kcal), and 240gpd venison (302 kcal). The total intake is 2140gpd (2543 kcal), or roughly 4 to 5 pounds of food per day. The Columbia Plateau diet provides 168gpd protein, 334gpd carbohydrate, and 55.4gpd lipid (30% protein, 60% carbohydrate, and 10% lipid). However, Walker (1998) believes that Hunn overestimates roots and underestimates fish in that particular Plateau diet.

Table 2. Macronutrient content based on dietary proportion.

Representative 2500 kcal Diet					
Food Category*	**% of 2500 kcal**	**Nutrients per 100 grams**			
		kcal per 100g (Representative Species)	**Protein per 100g**	**Lipid per 100g**	**CHO per 100g**
Pine nuts**	20% or 500 kcal	630 kcal	12 grams	61 grams	21 grams
Fish	15% or 375 kcal	Mixed trout, cooked—190	27	8.5	0
Roots, tubers, rhizomes, bulbs	15% or 375 kcal	Raw chicory root—73 Potato (baked tuber) —93 Bitterroot, fresh—90 Camas bulb, fresh—113 Leek, onions and bulbs (bulb & leaf) —31	1 2 0.7 0.7 1	0.2 0.1 0.1 0.2 0.2	17 15 22 27 8
Game & fowl	15% or 375 kcal	Deer, roasted—158 Rabbit, wild, roasted—173 Quail, cooked—234	30 33 25	3 3.6 14	0 0 0
Berries	10% or 250 kcal	Raw elderberries—73	0.7	0.5	19
Greens†	10% or 250 kcal	Raw dandelion greens—45 Raw watercress—11	3 2.3	1 0.1	9 1.3
Seeds	10% or 250 kcal	Raw dried sunflower seeds —570 Sesame seed flour—526	23 31	50 31	19 27
Honey, tea, sweeteners, misc.	5% or 125 kcal	Honey—304	0.3	0	82

* All USDA data except bitterroot and camas (Hunn 1990).

** Pine nuts (*Pinus edulis* and *Pinus pinea*) are in the USDA database; *Pinus monophylla* is not, but there is no indication of major differences between pine species, even though *monophylla* nuts are meatier and less greasy than other pine nuts, so there is less rancidity upon prolonged storage.

† Greens include watercress and the leaves, stems, shoots of other species.

Table 3. Estimated caloric content.

Food Category	Assumption	Estimate of Daily Quantity
Pine nuts	500 kcal	500 kcal x 100g/630 kcal = 80gpd*
Fish	375 kcal	375 kcal x 100g/190 kcal = 200gpd
Roots, tubers, rhizomes	275 kcal	275 kcal x 100g/90 kcal = 300gpd
Bulbs	100 kcal Allium family	100 kcal x 100g/30 kcal = 300gpd (Allium bulbs)
Game	300 kcal game and	300 kcal x 100g/165 kcal = 180gpd
Fowl	75 kcal fowl	75 kcal x 100g/200 kcal = 40
Berries	250 kcal	250 kcal x 100g/75 kcal = 333gpd
Greens	250 kcal	250 kcal x 100g/30 kcal = 833gpd **
Seeds	250 kcal	250 kcal x 100g/550 kcal = 50gpd
Honey, teas, etc.	125 kcal	125 kcal x 100g/300 kcal = 40gpd

* The original diet had 450gpd of pine nuts available per person per day (Price 1980); a lower estimate considers the lack of clarity in the forms (fresh or parched; whole or ground) analyzed by prior authors.

** Greens include watercress, leaves, stems, and shoots. This estimate includes a consideration that a home garden would include above-ground garden vegetables and may be part of the exposure scenario.

Table 4. Estimated macronutrients of major food categories.

Food Category	Assumption of Grams per Day	Protein (grams per 100g)	Lipid (grams per 100g)	CHO (grams per 100g)
Pine nuts	80	80 x 12/100 = 9.6	80 x 61/100 = 48.8	80 x 21/100 = 16.8
Fish	200	200 x 27/100 = 54	200 x 8.5/100 = 17	0
Roots, tubers	300	300 x 1/100 = 3	300 x 0.2/100 = 0.6	300 x 20/100 = 60
Bulbs	300	300 x 1/100 = 3	300 x 0.2/100 = 6	300 x 6/100 = 18
Game *	180	180 x 30/100 = 54	180 x 3/100 = 5.4	0
Fowl **	40	40 x 25/100 = 10	40 x 14/100 = 5.6	0
Berries	333	333 x 0.7/100 = 2.3	333 x 0.5/100 = 1.7	333 x 19/100 = 63
Greens†	833	833 x 2.5/100 = 21	833 x 0.5/100 = 4.2	833 x 5/100 = 42
Seeds	50	50 x 25/100 = 12.5	50 x 40/100 = 12.5	50 x 23/100 = 11.5
Honey, teas . . .	40	40 x 0.3/100 = 0.1	0	40 x 82/100 = 32.8
Total	**2356g**	**170g protein**	**102g lipid**	**244g CHO**

* Livestock that are substituted for game are assumed to be grass fed, not grain finished.

** Ducks and geese would have a higher lipid content

† Greens are estimated somewhat high due to potential substitution with conventional vegetables

5 EXPOSURE FACTORS AND PATHWAYS

5.1 APPROACH

Exposure factors reflect the activity levels and resource use of the lifestyle scenario under evaluation.[9] Exposure factors for both direct and indirect pathways are developed. Indirect pathways include exposure via the oral ingestion of food and medicine (see previous section). This section focuses on direct pathways: direct inhalation, dermal exposure, and ingestion of water, air, dust, sediment, and soil (including soil on the outside of food or added through cooking).

Default exposure factors have been developed for conventional suburban, urban, occupational, and recreational scenarios based on national statistics. Our approach to developing a tribal scenario is not to inventory every activity and every resource, but to provide an overall estimate of the general activity levels, anchored with specific information as available. The basic assumption is that traditional lifeways are active outdoor lifestyles that are moderately physically demanding, even with some modern conveniences. Subsistence foragers (both genders) perform a combination of aerobic (high heart and ventilation rates), strength, endurance, and stretching-flexibility daily activities, as well as performing more sedentary work and resting.

The exposure factors here are general to traditional subsistence lifestyles, regardless of their location. However, they may not be identical to the site-specific RME (reasonably maximally exposed) individual, which will be tailored to the habitats and resources found in the affected area once baseline and current ecological and environmental conditions are defined.

The conceptual steps in this process are:

1. Understand the lifestyle and the activities that comprise the lifestyle, and are required to obtain necessities and engage in the community culture;
2. Describe the day, the year, and the lifetime of men and women to identify any significant differences in activity levels between genders or ages;
3. Cross-walk activities with exposure pathways on the basis of frequency and duration of major activities, activity levels, and degree of environmental contact, and
4. Estimate cumulative exposure factors.

5.2 MAJOR ACTIVITIES

Tables 5–7 show the thought process for considering the range and number of activities associated with major activity categories (hunting, fishing, gathering, and sweat-lodge purification). Tables 5 and 6 list a number of individual activities within each major category; this is included because most non-Indians have not learned

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[9] http://cfpub2.epa.gov/ncea/cfm/recordisplay.cfm?deid=85843

much about traditional lifestyles and the complexity of daily life. Table 5 shows the connection between activity categories. In actuality, many activities are sequential—for example, a resource might be gathered in one location, used in a second location to make an implement or basket, and taken to a third location for use in hunting or fishing.[10] The activities shown in Table 5 are so interconnected that it is virtually impossible to separate a lifestyle into distinct categories, but they are presented as separate for illustration. The number of sub-activities in each column displays the complexity of each major activity, as well as interconnections between categories. The category of gathering includes both vegetal food procurement and basket making.

Table 5. Traditional lifeways—Typical activities in the activity categories.

Hunting	Purification	Gathering	Fishing
Learn skills	Learn skills, songs	Learn skills	Learn skills
Making tools	Build lodge from natural materials	Previous gathering	Make nets, poles, platforms, tools
Ritual bathing	Gather rocks	Make baskets, bags	Travel to location
Vigorous activity in hunting	Chop firewood	Hike to areas	Catch fish, haul out
Pack meat out	Prepare for use, get water	Cut, dig, harvest	Clean, can, hard dry, soft dry, smoke, eat whole fish or fillet or liver or other parts or soup
Process	Use Lodge, sing, drink water, inhale steam and smudges	Carry out items	Return carcasses to ecosystem, use as fertilizer
Scrape hides	Close area & fire	Wash, peel, process, split, spin, dye	
Tan, use other parts		Cook and eat or make product or medicine	
Cook, smoke, dry, eat meat and organs			

[10] This is similar to the Cultural Ecosystem Stories concept developed Terry Williams (Tulalip Tribes) with the associated software, ICONS (see, for example, http://www.epa.gov/owow/watershed/wacademy/ wam/comresource.html).

Table 6. Major activity categories.

Activity Type	General Description
Hunting	Hunting includes a variety of preparation activities of low to moderate intensity. Ritual bathing occurs before the hunt. Hunting occurs in terrain ranging from flat and open to very steep and rugged. It may also include setting traplines, waiting in blinds, digging-out small game, climbing, etc. After the capture or kill, field dressing, packing or hauling, and other strenuous activities may occur, depending on the species. Subsequent activities include cutting, storing (e.g., smoking or drying), and returning the remains to the ecosystem.
Fishing	Fishing includes building weirs, scooping minnows, hauling in lines (we assume that large nets are not used in small drainages), gaffing or gigging, wading (for shellfish), followed by cleaning the fish and carrying them to the place of use. Activities associated with smoking and constructing drying racks may be involved. Remains are returned to aquatic ecosystems.
Gathering	Women gathered plants "perhaps within a day's walk from camp" using a digging stick, knife, and basket for carrying resources back to camp (Downs 1966, Hammett et al. 2004). A variety of activities is involved, such as hiking, bending, stooping, wading (marsh and water plants), digging, bundling, carrying, and climbing over a wide variety of terrains.
Ritual purification (sweat lodge)	Sweat-lodge building and repairing is intermittent, but collecting firewood is a constant activity. D'Azevedo (1986) lists 6 citations for Washoe ritual purification. Cold and hot springs were used for therapeutic healing. Today, every Washoe community has a purification lodge (Washoe Tribe, personal communication).
Materials use and food preparation	Many activities of low to high intensity are involved in preparing materials for use or food storage. Some are quite vigorous such as pounding or grinding seeds and nuts into flour, preparing meat, and tanning hides. This category includes basket making, which is an example of a very important activity with its own set of prescribed activities, meanings, and cultural ethics.

Table 7 shows the cross-walk between activity categories and exposure pathways, with examples of how exposure factors are derived from knowledge about activities, interlinked resources and ecosystem stories, and the technical literature. Again, this is an iterative process that relies on multiple lines of evidence. Rather than a complete listing of activities, Table 7 presents an example of the thought process used to perform the iterative cross-walk. In each case a gap identification step may be necessary, and greater uncertainty may require placeholder values until data are obtained. The last column, “Totals for major exposure factor categories,” shows exposure pathways totals (such as soil ingestion) are estimated across activity categories. This is not a statistical summation but rather a judgment based on multiple lines of evidence. Each estimate has been checked against technical literature for confirmation.

Table 7. Example exposure considerations for major activity categories.

	Hunting and associated activities	**Fishing and associated activities**	**Gathering and associated activities**	**Ritual purification and associated activities**	**Material and food use and processing**	**Totals for major exposure factor categories**
Food, medicine, tea, other biota ingestion (diet)	*n* deer/yr diet; Total large/small game, fowl; Organs eaten	*n* fish/yr diet; Total pounds or meals/day-wk-yr; Organs eaten	Includes foods, medicines, teas, etc.	No food, but herbal particulates are inhaled	Both as-gathered and as-eaten forms; Cleaning and cooking methods	Must account for all calories; Extra factor for 100–200 plant species, parts eaten
Soil, sediment, dust, and mud ingestion	Terrain types such as marsh with more mud contact	Sediment contact, dust and smoke if drying; Weir construction in mud	External soil on plants; Cooking method such as pit cooking; Ingestion when gathering.	Includes building the sweat lodge and getting materials	Includes incidental soil remaining on foods, pit cooking	Must also include living area, unpaved roads, regional dust, local dust-generating activities
Inhalation rates	Days per terrain; Exertion level; Hide scraping; Load & grade	Exertion level—nets and gaffing methods, cleaning effort	Exertion level for load and grade, or gardening; Include making items	Includes building the lodge, chopping firewood, singing	Exertion level for pounding, grinding, etc.	Must account for exertion levels; Smokes and smudges
Groundwater and surface water pathways	Ritual bathing; Drinking water; Wash water; Water-to-game pathways	Drinking water; Incidental ingestion, washing and cooking	Drinking water, Cooking water, Soaking in mud or water	Steam in lodge; Drinking water during sweat	Soaking; Washing; Leaching tannins; other uses	Must account for climate, sweat lodge, ritual bathing
Dermal exposure	Soil, air and water pathways, plus pigments, etc.	Immersion considerations	Same as hunting	Immersion with open skin pores	Includes basket making, wounds.	Must consider skin loading and habitat types.

5.3 THE FAMILY, THE DAY, AND THE LIFETIME

This section describes a family-based exposure scenario based on a traditional Washoe lifestyle and diet. It is based on habits of tribal members who live in a house in a sparsely populated riparian corridor with a home garden, and who have a high rate of subsistence activities, a regular schedule of other cultural activities and are seasonally occupied as field workers monitoring natural and cultural resources, taking environmental samples, and doing reclamation or restoration work. The lifestyles are moderately active outdoor lifestyles.

5.3.1 Lifestyle of a Representative Washoe Tribal Family

The families are intended to be reasonable maximum composites, and were constructed with the guidance of the Washoe Tribal Cultural Resources Coordinator. Each family includes (1) an infant/child (age 0–2 years) who breast-feeds for two years and crawls and plays; (2) a child (age 2–6) who plays in the house and outdoors; (3) a youth (age 7–16) who attends school, plays outdoors near his/her residence, and is learning traditional practices; (4) two adult workers (one male, one female, age 17–55; the female breast-feeds the infant) who work outdoors on reclamation and environmental and cultural activities, and engage in subsistence activities, and (5) an elder (age 56–75) who is partly at home and partly outdoors teaching and demonstrating traditional cultural practices. All members (except the infant from 0–2 years) partake in cultural activities throughout the year.

Location and Type of Residence: The residence is located at the furthest upstream available allotment in the Leviathan-Bryant Creek drainage. The family lives in a house with no landscaping other than the natural vegetation, no air conditioning, and wood-burning heat in the winter. The house has its own well for domestic use and a garden irrigated with groundwater or surface water (whichever is more contaminated). The road and driveway are not paved.

5.3.2 Activity Patterns of Each Family Member

Infant: The infant breast-feeds for 2 years, and crawls on the floor (a source of house dust exposure) from age 6 months to 2 years. Infants ingest more fluid per body weight than children do, and toddlers (6 months to 2 years) are likely to have the highest of the children’s exposures due to crawling and mouthing behaviors, and their food and water per capita ingestion rates.

Child (ages 2–6 years): Beginning at age 2, the child eats the same food as everyone else, and spends some time accompanying the mother as she gardens and gathers.

Youth (ages 7–16): The adolescent is learning to hunt, gather, and fish (and spends equal time in each activity in their respective locations), plays outdoors, and attends school.

Adult Worker (ages 17–55): Workers are assumed to work for the Tribe collecting environmental samples, engaging in restoration/remediation or construction work, and caring for natural and cultural resources and tribal property. This type of activity is dusty in the summer and muddy in the winter. Both males and females are currently employed in this type of activity. Workers could be exposed to surface soil and dust, vegetation, surface water, sediments, and seeps. These workers have an average 8-hour workday. While in the field, the worker eats lunch brought from home, possibly supplemented with native foods gathered near the workplace, and does not have a place to wash food (dust ingestion).

Adult Hunter/Fisher/Gatherer: Each adult also hunts (male), fishes (male), or gardens and gathers plants (female). These activities are roughly analogous to each other with respect to the degree of environmental contact, and therefore are assumed to result in the same amount of soil or sediment ingestion for males and females. The additional time and contact during game processing, plant washing and preparation are also roughly equal. The location of hunting small game or fowl is in the same area as the residence, and the location of big game hunting covers a larger area. The garden is at the place of residence and uses the same water as the household, while the gathering occurs in a larger area. All of the hunters, gatherers and fishers spend some time near water, if it is present in the area, on activities such as washing plants or game, gathering aquatic plants and mollusks/crustaceans, and so on, with concomitant exposure to mud or sediment.

Elder (ages 56–75): The elder gathers plants and medicines, prepares them, uses them (e.g., making medicines or baskets, etc.) and teaches a variety of indoor and outdoor traditional activities. The elder also provides child care in the home.

5.3.3 Specific Cultural Activities

This section considers activities that are engaged in at varying levels by the Tribe and by varying age-groups, and other factors that affect exposure.

Ritual Purification (Sweat Lodge) (ages 10–75): A sizeable fraction of Washoe youth and adults participate in purification ceremonies in private or community ceremonial (sweat) lodges. The basic mechanics of lodge construction and use have been described in the open literature. The size of Washoe sweat lodges is roughly 5 feet high and 12 feet wide. The duration is generally about 2 hours per ceremony. The frequency is calculated based on 8 months of participation in one 2-hour ceremony plus 4 months of participation in a four-sweat series, for a total of 24 2-hour sweats per year. This frequency is an average for Washoes who participate in purification ceremonies, but may somewhat underestimate the frequency for ceremonial leaders. During the ceremony, approximately 4 gallons of water is poured on heated rocks, forming steam (one gallon per half hour). Either groundwater or surface water may be used. Inhalation and heart rates and inhalation rates may be higher depending on activities that occur during the sweat-lodge ceremony (e.g., singing).

Cultural Activities: All age-groups participate in day-long outdoor community cultural activities once a month, including seasonal ceremonial and private cultural activities (averaging about 0.5 hours/day). These are often gatherings which consist of activities that result in a greater rate of dust resuspension and particulate inhalation, as well as greater personal inhalation and water ingestion rates. If this scenario is applied in other locations, additional activities such as powwows could be considered.

Basket Making: Exposure pathways specific to basket makers are well-recognized,[11] but data useful for exposure assessment are almost totally lacking. Gathering of some plants (e.g., willows, cattails, reeds, and rushes) can be very muddy, and therefore river-shore or lakeshore sediment exposure may be underestimated. Washing, peeling, weaving rushes, and other activities result in additional exposure to dust deposited on leaves or soil adhered to roots. Some of the materials are held in the mouth for splitting, and cuts on fingers are common. As more information becomes available, it will be evaluated so that exposure factors for each route of exposure account for these particular activities.

Other Special Activities: It is recognized that there are special circumstances when some people may be highly exposed (and their exposure would be underestimated). For instance, some men hunt or fish for the general community, and many people provide roots and fish and game to elders in addition to their own families. Flint knappers may receive additional exposure through obtaining and working with their materials. Elders with special traditional environmental knowledge may spend more time in the field teaching.

As with the exposure pathways of basket making, other pathways unique to traditional practices also lack data and are therefore sources of uncertainty. For example, pharmacologically active medicinal plants may have differential uptake of contaminants into the plant as well as affecting the metabolism of the person and/or interacting with contaminants. Alkaloids in ephedra tea and other plants affect metabolism in various ways. Materials released from firewood, smokes, and smudges may contain contaminants or affect physiological parameters of the person. We have tried to consider these and other pathways in the cumulative roll-up of exposure factors, but they remain as potential exposure pathways or can potentially affect the way that a person reacts to single or multiple contaminants.

Seasonality: The changes in activity patterns over the annual seasonal cycle has been modified in modern times, but the ecological cycle has not, so people must still gather plants according to when they are ripe, hunt according to game and fowl patterns, and fish when the spawning runs occur. Many items are gathered during one season for year-round use. While specific activities change from season to season, they are replaced by other activities with a similar environmental contact rate. For instance, a particular plant may be gathered during one month, while another month may be spent hunting, and a winter month may include cleaning and

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[11] http://www.cdpr.ca.gov/docs/envjust/documents/basketweaver.pdf

using the items obtained previously. We assume that all activities are roughly equal, so there is no decrease in environmental contact rates during winter months.

5.3.4 Time Allocation throughout the Day

This section describes the time allocation that is reflected in daily exposure factors. The locations at which these activities occur will be defined in the RME report.

Identical Activities: From the age of 2 to 75 years, 15 hours of every day are similar: 8 hours sleep, 3.5 hours in other indoor activities, some time in the sweat lodge (averaged), 2 hours in nearby outside activity, such as small game hunting, 0.5 hour in community cultural activities, and 1 hour traveling on unpaved roads. These activities are referred to as *common time*.

Infant: Standard infant exposure parameters are used. House dust is assumed to have similar concentrations of contaminants as outside soil. The infant is breast-fed for 2 years. The risk assessment may be performed assuming two different scenarios: (1) the mother has received 25 years of prior exposure from a contaminated area; and (2) the mother has not received such exposure. In situations where exposure has been occurring, a new mother may have been exposed as she was growing up and may carry a body burden or heritable mutation that she might pass on to a fetus during gestation, as well as during lactation. If contamination remains on site into the future, then future mothers could be exposed as children, and then through pregnancy. In other situations, a female might not return to the site until after the baby is born, so the infant's exposure would not start until birth, and would not have been exposed in utero.

Child: The child, through age 6, spends the same amount of common time in the same activities, and 4 hours indoors and 5 hours outdoors with the mother as she gardens and gathers.

Youth: Common time plus 6 hours at school 5 days/week (averaging 4.5 hours/day), 2.5 hours indoors, and 3 hours outdoors playing or accompanying an adult or elder, learning traditional activities. It is assumed that the school is uncontaminated unless there is data about chemical usage or contamination, and it is also assumed that his or her near-residence outdoor time results in a higher amount of soil contact than at other ages; therefore, the youth's average contact rates are the same as those of the child and the adult.

Adult: Common time plus 8 hours working 5 days/week (about 5.5 hours/day), 0.5 hour at home, and 3 hours in one of the subsistence activities.

Elder: Common time plus 3 hours at home providing child care, 3 hours outdoors teaching, 1 hour gardening or gathering, and 2 hours at home processing materials and making items.

5.3.5 The Lifetime

Traditionally, daily tasks were somewhat different for males and females: males tend to hunt and fish, while females gather and cook. However, even where activity patterns show gender dimorphism, the rates of environmental contact were and are probably similar. In addition, both women and men are employed as environmental and construction workers, as well. Therefore, for the purposes of the exposure scenario, the genders have identical exposure factors.

Male Lifetime: The male lifetime consists of the standard infancy, childhood, and youth. At age 17 he specializes in either hunting or fishing and begins working as a reclamation/restoration/environmental worker. These activities are specified solely to determine their locations, which may have different contaminant concentrations. As an elder he changes his activity patterns to teaching and demonstrating, as described above.

Female Lifetime: The female lifetime consists of the standard infancy, childhood, and youth. At age 17 she engages in gathering and gardening and also works the same job as the male. During motherhood, the woman may remain at home, which is located in the same sparsely populated area, and she continues to garden and gather, so her exposure does not diminish. Her earlier exposure may result in a dose to the fetus and breast-feeding infant.

5.4 MEDIA, PATHWAYS, AND DIRECT EXPOSURE FACTORS

As described previously, exposure factors are developed by cross-walking the activities described above with specific media-based exposure pathways. The identification of media pathways begins to sum exposures; for instance, all the soil exposures from hunting, gathering, household activities, processing and using materials, food processing, and other activities are summed qualitatively. At a later step in the RME, the time spent in various locations will be defined so location-specific exposure point concentrations can be determined.

Ground Water and/or Surface Water Pathways: The importance of bathing in Washoe ritual life makes access to clean and uncontaminated water particularly important. As mentioned previously, water is central to Washoe identify and life. Ritual bathing and/or steam purification occurs before hunting and other cultural activities. Water is also important for general cleanliness (which has always been very important to tribal members), soaking plant materials, and processing foods and materials. For purposes of evaluating risk, both ground water and/or surface water are directly ingested as drinking water. Both are also used to create steam in the sweat lodge. Other uses of these resources include typical household use (e.g., cooking, bathing, showering), irrigation of crops and/or garden, and livestock watering.

Air and Dust Pathways: As a general rule, the air pathway can result in exposure to any present volatiles, aerosols, and resuspended dust. Dust resuspension from unpaved roads and other unvegetated surfaces should be included as part of the inhalation exposure pathway. If there is a potential for exposure, inhalation of fire smoke or smudge should be included because some of these pathways can be frequent and significant.

Soil and Sediment Pathways: This pathway includes soil ingestion from hand to mouth activities associated with daily activities, gathering (e.g., digging roots) and gardening, food and material processing (e.g., grinding, scraping, pit cooking). Several foods are prepared by pit cooking: fish, ground squirrels, wild garlic, wild onions, acorns, pine nuts, and marmots (Hammett et al. 2004, Walker 2003).

This pathway also includes direct ingestion resulting from residual soil on roots and bulbs. The as-gathered and as-eaten conditions of plants are important. Many vegetable foods were eaten raw and on the spot. Hammett et al. (2004) describes such eating of lily bulbs, with the only preparation being brushing the dirt off. Grinding seeds and nuts also adds rock dust to the flour.

Gathering of willows, bracken fern, and other basket and cordage materials results in soil ingestion. Further exposure is received when one splits shoots into weaving strips by holding one end in the mouth while pulling strips off with each hand.

5.5 EXPOSURE FACTORS FOR DIRECT EXPOSURE PATHWAYS

A description of activities for the purposes of developing exposure factors focuses on:

Frequency of activity:
- Daily, weekly, monthly

Duration of activity:
- Hours at a time
- Number of years

Intensity of environmental contact and intensity of activity:
- For soil ingestion and dermal exposure, is the activity more than, less than, or equal to gardening, camping, construction/excavation, or sports?
- For inhalation rates and calorie needs, is the activity level more than, less than, or equal to standard EPA activity levels for specific activities with known respiration rates and caloric expenditure?

The following table (Table 8) includes three adult scenarios: the suburban resident, the rural residential farmer-gardener, and the subsistence forager. The first two scenarios are typically used in risk assessments, and the third reflects the set of activities that compose the Washoe lifestyle. Each scenario is intended to be physiologically *coherent*, which means that the dietary intake, activity levels, and inhalation rates are physiologically linked. For instance, the more sedentary suburban scenario is based on national data on typical lifestyles (light occupational activities sitting or standing, with some moderate activity at home), while the rural residential farmer has a higher activity level, higher inhalation rate, and higher soil ingestion rate due to his farming activity pattern. The subsistence forager is still more active, with a proportionally higher inhalation rate, as well as a higher soil ingestion rate, due to a higher degree of soil contact.

The table shows adult values, as does the dietary discussion above. Children's exposure factors are scaled from the subsistence forager rates, as is conventionally done in risk assessment (from the Children's Exposure Factors Handbook), with the exception of the soil ingestion rate, which is left at 400mg/d throughout the lifetime. Body weight is a consistent 70kg because that is the standard EPA assumption used in risk assessments.

Table 8. Exposure factors for direct pathways.

Direct Pathway	Exposure Factors (Adults)		
	Default Suburban Lifestyle	**Rural Residential Farmer Lifestyle**	**Subsistence Forager Lifestyle**
Inhalation	$20m^3$	$25m^3$: While EPA does not have official exposure factors for this lifestyle, it is reasonable to assume that a person who farms, gardens, irrigates, and cares for livestock has an intermediate inhalation rate.	$30m^3$/day: This rate is based on a lifestyle that is an outdoor active lifestyle, based on EPA activity databases, foraging theory, and ethnographic description of the activities undertaken to obtain subsistence resources as well as allotment-based food (livestock and garden). It is higher than the conventional $20m^3$/day because the activities with associated respiration rates are higher than suburban activities.
Drinking water ingestion	2L/d	3L/day: This rate is based on water requirements in an outdoor moderately arid environment.	3L/d plus 1L for each use of the sweat lodge during ritual purification: at 24 uses per year, this is 3.065L/d, which we are rounding down to 3L.
Soil ingestion	100mg/d (conventional suburban); 50mg/d (manicured suburban; less outdoor time)	300mg/d	400mg/d: This rate is based on indoor and outdoor activities, a greater rate of gathering, processing, and other uses of natural resources, as well as on residual soil on grown and gathered plants. Episodic events (1 gram each) are considered, such as wetland gathering, cultural activities with higher soil contact, and so on. It does not specifically include geophagia or pica.
Dermal Pathways	Must be included in the risk assessment. Greater environmental contacts must be factored in; however, suburban defaults may be used until data for traditional lifeways are developed, although a greater fraction of the skin surface and a higher dermal loading rate should be considered.		
Other parameters			
Exposure frequency	Up to 365 days per year, but varies; Hours per day varies, typically 24 hrs/d	Up to 365 days per year, but varies; Hours per day varies, typically 24 hrs/d	365 days per year; Hours per day varies, typically 24 hrs/d
Exposure duration	30 years	30 or 70–75 years	70–75 years

Drinking Water: Harper et al. (2002) estimated an average water ingestion rate of 3L/day for adults, based on total fluid intake in an arid climate. In addition, each use of the sweat lodge requires an additional 1L for rehydration (24L per year). It should be noted that water intake in an arid environment may be more than 3L per day. For example, the Army assumes that the maximum individual daily amount of drinking water required by military personnel to remain combat-effective ranges from 5–15L/day, depending on the climate, season, and intensity of work.[12] The Army Quartermaster assumes that military personnel in hot climates require 3 gallons per day as drinking water.[13]

Soil and Sediment Ingestion: Soil ingestion includes consideration of direct ingestion of dirt, mud, or dust, swallowing inhaled dust, mouthing of objects, ingestion of dirt or dust on food, and hand-to-mouth contact. The Washoe soil ingestion rate of 400mg/day is based on a review of EPA guidance, soil ingestion studies in suburban and indigenous settings, and dermal adherence studies (a small portion of which is summarized here). It is also based on knowledge about subsistence lifestyles with their higher environmental contact rates and local climatic and geologic conditions. It reflects a variety of soil pathways such as pit cooking, gathering and gardening, residual soil or dust on foods and medicine, localized soil-generating activities, holding natural materials in the mouth while processing or using, driving on unpaved roads, and similar considerations. It also considers many *1-gram days and events*, such as root gathering days, tule and reed gathering days, horse training and riding days, sweat-lodge building or repair days, grave digging, and similar activities. There are also likely to be many high or intermediate-contact days, depending on the occupation (e.g., wildlife field work, construction or road work, cultural resource field work). A baseline number of these events is incorporated, but this would need to be reconsidered in the RME if a large number of such events becomes evident.

The soil ingestion rate of 400mg/d for all ages is the published upper bound for suburban children (EPA 1997), and is within the range of outdoor activity rates for adults but lower than the typical 480mg/d applied to outdoor work, to allow for some low-contact days. Subsistence lifestyles were not considered by the EPA guidance, but are generally considered to be similar in soil contact rates to construction, utility work, or military exercise. The US military assumes 480mg per exposure event[14] or per field day. The UN Balkans Task Force assumes that 1 gram of soil can be ingested per military field day.[15] Anecdotally, US forces deployed in Iraq report frequent grittiness in the mouth and food. Haywood and Smith (1990) also

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[12] http://www.nap.edu/execsumm/NI000954.html Guidelines for Chemical Warfare Agents in Military Field Drinking Water (1995).

[13] http://www.pasols.org/energy/water2.pdf

[14] http://www.gulflink.osd.mil/pesto/pest_s22.htm, citing US Environmental Protection Agency, Office of Research and Development, "Exposure Factors Handbook," Volume I, EPA/600/P-95/002a, August 1997 as the basis for the 480mg/d.

[15] UNEP/UNCHS Balkans Task Force (BTF) (1999). The potential effects on human health and the environment arising from possible use of depleted uranium during the 1999 Kosovo conflict. http://www.grid.unep.ch/btf/missions/september/dufinal.pdf

considered sensory reports of grittiness in their estimate of 1–10g/d in aboriginal Australians.

Simon (1998) reviewed soil ingestion studies from a perspective of risk and dose assessment. Because of their high dependence on the land, indigenous peoples are at highest risk for inadvertent ingestion, along with professions that may bring workers into close and continual contact with the soil. Simon recommends using a soil ingestion rate for indigenous people in hunter/food gathering/nomadic societies of 1g/d in wet climates and 2g/d in dry climates. He recommends using 3g/d for all indigenous children.

For the Washoe climate and lifestyle, the soil ingestion rate for young children (0–6 years) is assumed to be 400mg/day for 365 days/year. This is higher than the prior EPA default value of 200mg/day (USEPA 1989). This rate reflects both indoor dust and continuous outdoor activities analogous to gardening or camping (van Wijnen 1990), but it is less than a single-incident sports or construction ingestion rate (Boyd 1999).

Inhalation Rate: The inhalation rate in the Washoe scenario reflects the active, outdoor lifestyle of traditional tribal members. Traditional tribal communities have no sedentary members except the frail elderly, whereas one-quarter of modern American adults of all ages report no leisure time physical activity at all.[16] We have documented the activity levels associated with the traditional lifestyle and diet with published anthropological studies, ethnographic literature on foraging theory, hunting-gathering lifestyles, and interviews with tribal members. Using EPA guidance on hourly inhalation rates for different activity levels, a reasonable inhalation rate for an average tribal member's active lifestyle is a *median* rate of $26.2m^3/d$. This rate is based on 8 hours sleeping at $0.4m^3/hr$, 2 hours sedentary at $0.5m^3/hr$, 6 hours light activity at $1m^3/hr$, 6 hours moderate activity at $1.6m^3/hr$, and 2 hours heavy activity at $3.2m^3/hr$. Most other exposure factors are upper bounds, so the use of a median rate for inhalation is inconsistent with the usual RME approach used in Superfund risk assessments, and could result in under-protection of children, the elderly, athletes, asthmatics, and the half of the population with above-average inhalation rates. Due to a tribal desire to protect more than just the average traditional person, the inhalation rate is rounded up, from $26.2m^3/d$ to $30m^3/day$.

Dermal Exposures: The dermal pathway has not been fully researched for this scenario, but EPA methods[17] for dermal exposure can be used. However, a greater surface area and a greater skin loading of soil (soil adhered to skin) should be used. Two relevant papers are summarized here. Kissel et al. (1996) included reed gatherers in tide flats in a study of dermal adherence. The category of "kids in mud" at a lakeshore had by far the highest skin loadings, with an average of $35mg/cm^2$ for 6 children and an average of $58mg/cm^2$ for another 6 children. Reed gatherers were next highest at $0.66mg/cm^2$ with an upper bound of $>1mg/cm^2$. This was followed by

[16] http://www.cdc.gov/brfss/pdf/ 2001prvrpt.pdf and http://www.cdc.gov/brfss/pubrfdat.htm.
[17] http://www.epa.gov/superfund/programs/risk/ragse/

farmers and rugby players (approximately 0.4mg/cm^2) and irrigation installers (0.2mg/cm^2). Holmes et al. (1999) studied 99 individuals in a variety of occupations. Farmers, reed gatherers, and kids in mud had the highest overall skin loadings. The next highest skin loadings on the hands were for equipment operators, gardeners, construction, and utility workers (0.3mg/cm^2), followed by archaeologists, and several other occupations (0.15–0.1mg/cm^2).

Children's Exposure Factors: Children's exposure factors are based on "Child-Specific Exposure Factors Handbook"[18] but scaled from the adult subsistence values for the inhalation rate. The diet is scaled for children from the food categories indicated above for adults. The soil ingestion rate for children is a constant 400mg/day, without age stratification. If age stratification is done for other exposure factors, the Washoe Tribe can be contacted for recommendations.

[18] U.S. Environmental Protection Agency (EPA). (2002) Child-specific exposure factors handbook. National Center for Environmental Assessment, Washington, DC; EPA/600/P-00/002B. Available from: National Information Service, Springfield, VA; PB2003-101678 and http://www.epa.gov/ncea.

6 CONCLUSION

This report has presented the Washoe scenario and supporting information for use in human health risk assessments. This report is intended to describe enough about the traditional subsistence lifestyle that a risk assessor who is familiar with developing exposure scenarios can understand the derivation of the exposure factors even if she does not have an in-depth familiarity with the Washoe lifestyle. Where information is not presented, it is assumed that conventional parameters are suitable (e.g., skin surface area).

The report describes the Tribe's environment in the Sierra Nevada and Great Basin ecosystems, and the available resources. An ecological lifestyle is presented, one that traditionally followed seasonal areas for fishing and food and material gathering, and placed cultural significance on water for use in ritual and day-to-day activity. An overall diet is developed by reviewing previous foraging studies and ethnographic data, and considering available resources, with major food-type categories estimated as percentages and presented in a food pyramid. The most prevalent food source is the pine nut, which corresponds to a diet higher in lipids than the typical forager diet. Exposure factors are developed based on traditional subsistence lifestyles, with attention to the lifestyle, activity patterns, specific activities, daily time allocation, and lifetime of the Washoe. Rates of inhalation, water ingestion, and particularly soil ingestion are higher than those of the general population, due in part to the Tribe's increased outdoor activity in an arid climate. Increased soil ingestion is partly attributable to the gathering and processing of food and material resources, at times in wetlands.

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Confederated Tribes of the Umatilla Indian Reservation Human Health Risk Assessment Exposure Scenario

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1 INTRODUCTION

This document presents the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) Exposure Scenario. An exposure scenario is a narrative and numerical representation of the interactions between human and/or ecological receptors and their immediate environment. Exposure scenarios include media-specific and pathway-specific exposure factors required to estimate a dose to the target receptor as they pursue a defined set of activities in particular locations.

Even though many tribal lands have been lost and resources degraded, there are generally more traditional or subsistence practices followed by tribal members than the general non-native population realizes. However, the objective of many tribes is to regain land, restore resources, and encourage more members to practice healthier (i.e., more traditional) lifestyles. Therefore, the objective of subsistence exposure scenarios is to describe the original lifestyles and resource uses, not to present a current snapshot of restricted or suppressed uses, because the intent is to restore the ecology so that the original pattern of resource uses is both possible (after resources are restored) and safe (after contamination is removed). This is a different situation than for the general American population, where the intent of remediation is to allow people to continue their *current* (and portable) lifestyle in a newly cleaned location. The intent of the CTUIR Scenario is to reconstruct what the lifestyle and diet would have been in the affected area prior to contamination.

For the general United States population, an exposure scenario is typically designed to be an upper bound (generally around the 75th percentile) of the population being assessed. Some individual exposure factors are the 90th or 95th percentile; others are mean values. In the case of tribal exposure scenarios, there are no specific databases of subsistence activities, resources, or diets as there are for the general United States population. Cross-sectional surveys of current tribal populations will not generate that data because much resource use has been suppressed due to loss of land and access, awareness of contamination, persecution by the dominant society, and other reasons. This means that large and accurate statistical distributions for subsistence exposure factors are not available and cannot be developed. Therefore, ranges of exposures or specified percentiles of exposure are not possible to calculate. The CTUIR scenario is intended to be a reasonable representation of a traditional subsistence lifestyle, equivalent to a central tendency rather than to an upper bound.

For the general suburban population the exposure scenario is well defined in EPA guidance (Exposure Factors Handbooks). The CTUIR scenario is based on the lifestyle and baseline conditions of the regional natural resources.

This scenario identifies general exposure pathways specific to CTUIR lifestyles and key resources that the CTUIR people use. A general understanding of what people do (or would do in the absence of contamination) and what resources are available for their use provides the basis for developing preliminary exposure factors. Then the scenario describes the activities that traditional people undertake to survive and thrive in the local ecosystem, including hunting, gathering foods and medicines, fishing, making material items, farming or gardening, raising livestock, irrigating, and various cultural and domestic activities.

As mentioned, the exposure scenario reflects a traditional subsistence lifestyle. “Subsistence” refers to the hunting, fishing, and gathering activities that are fundamental to the way of life of many indigenous peoples. Today’s subsistence economies utilize traditional and modern technologies for harvesting and preserving foods and for distributing the produce through communal networks of sharing and bartering. The following is a useful explanation of “subsistence,” taken from the National Park Service:

> While non-natives tend to define subsistence in terms of poverty or the minimum amount of food necessary to support life, native people equate subsistence with their culture. Among many tribes, maintaining a subsistence lifestyle has become the symbol of their survival in the face of mounting political and economic pressures. It defines who they are as a people. To Native Americans who continue to depend on natural resources, subsistence is more than eking out a living. While it is important to the economic well-being of their communities, the subsistence lifestyle is also the basis of cultural existence and survival. It is a communal activity. It unifies communities as cohesive functioning units through collective production and distribution of the harvest. Some groups have formalized patterns of sharing, while others do so in more informal ways. Entire families participate, including elders, who assist with less physically demanding tasks. Parents teach the young to hunt, fish, and farm. Food and goods are also distributed through native cultural institutions. Most require young hunters to distribute their first catch throughout the community. Subsistence embodies cultural values that recognize both the social obligation to share as well as the special spiritual relationship to the land and resources. This relationship is portrayed in native art and in many ceremonies held throughout the year.[1]

In economic terms, a subsistence economy is one in which currency is limited because many goods and services are produced and consumed by the same families or bands. Today, currency (symbols of specified quantities of useful resources) is limited, but important. For example, subsistence in an Arctic community includes the following:

> The modern-day subsistence family depends on the tools of the trade, most of which are expensive. Snowmobiles, gasoline, guns, fishing nets, and sleeping bags are necessities. Subsistence households also enjoy many of the modern conveniences of life, and are saddled with the economic demands which come with their acquisition. Today’s subsistence family generates much-needed cash as wage-labourers, part-time workers and

[1] National Park Service: http://www.cr.nps.gov/aad/cg/fa_1999/Subsist.htm

trappers, professional business people, traditional craftmakers, and seasonal workers. A highly-integrated interdependence between formal (cash-based) and informal (barter and subsistence-based) economic sectors has evolved.[2]

Once the activities composing a particular subsistence lifestyle are known, they are translated into a form that is used for risk assessment. This translation captures the degree of environmental contact that occurs through activities and diet, expressed as numerical *exposure factors*. Exposure factors for direct exposure pathways include exposure to abiotic media (air, water, soil, and sediment), which can result in inhalation, soil ingestion, water ingestion, and dermal exposure. Indirect pathways refer to contaminants that are incorporated into biota and subsequently expose people who ingest or use them. There are many unique exposure pathways that are not accounted for in scenarios for the general public, but may be significant to people with certain traditional specialties such as basket making, flint knapping, or using natural medicines, smoke, smudges, paints, and dyes. These activities may result in increased dust inhalation, soil ingestion, soil loading onto the skin for dermal exposure, or exposure via wounds, to give a few examples. While the portals of entry into the body are the same for everyone (primarily via the lungs, skin, mouth), the amount of contaminants may be increased and the relative importance of some activities (e.g., basket making, wetlands gathering), pathways (e.g., steam immersion or medicinal infusions), or portals of entry (e.g., dermal wounding) may be different than for the general population.

Foraging theory data from the anthropological literature is particularly useful for developing exposure scenarios, because the major dietary and resource staples may be described, as well as how much time and effort is needed to obtain them. Together, this information is then used for the food-chain portion of the Scenario and to calculate the direct exposure factors.

This process is laid out in the following sections according to the general sequence:

1. Environmental setting—what resources are available;
2. Lifestyle description—activities and their frequency, duration and intensity, and resource use;
3. Diet;
4. Exposure pathways, and
5. Exposure factors—iterative cross-walk between pathways and direct exposure factors: cumulative soil, water, air, and dietary exposures.

Because the method for developing exposure factors is derived from an understanding of lifestyle rather than from large statistical databases (national drinking water rates, or USDA databases of national average food intakes) and is unfamiliar to many readers, it is described briefly here (more detail is presented below).

[2] http://arcticcircle.uconn.edu/NatResources/subsistglobal.html

Because large databases are not available and cannot be constructed, we take a top-down approach. For example, we do not attempt to develop a complete diet based on surveys of the uses of the typical 200+ natural resources available and used with an ecoregion. Rather, we develop a calorically complete food pyramid that identifies the major staples and their rough percentages in the original diet. Similarly, we do not develop an average day by tracking hundreds of individual activities from many people. The basic process is to:

1. Start with an understanding of the major categories of subsistence activities (such as hunting, fishing, gathering, basket making, and sweat lodge purification),
2. Describe enough of the sub-activities that the complexity and interconnection of resources and activities can be understood,
3. Identify the major activities that contribute to exposure, and then
4. Iteratively cross-walk between activities and conventional exposure factors to develop cumulative exposure factors.

To illustrate, each of the major activity categories includes activities that result in exposure to soil, and therefore soil ingestion. By estimating the relative amount of time spent in activities that result in high, medium, or low soil exposure for each activity category, an overall soil-ingestion rate can be estimated. However, we do not attempt to be overly quantitative in enumerating the myriad activities and resources in each category—this requires more precision than is warranted and is likely to require proprietary information that cannot be released.

Finally, a review of existing literature (biomedical, anthropological, and so on) enables us to double-check whether multiple lines of evidence leads us to a similar conclusion for each exposure factor.

1.1 BASIS

Information on the CTUIR eco-cultural lifestyle has been presented previously, and is summarized as follows.

> The CTUIR culture, which has co-evolved with nature through thousands of ecological education, has provided its people with their traditional environmental knowledge. Throughout the year, when the CTUIR traditional American Indian participates in activities such as hunting and gathering for foods, medicines, ceremonies, and subsistence, the associated activities are as important as the end product. All of the foods and implements gathered and manufactured by the traditional American Indian are interconnected in at least one, but more often in many ways. The people of the CTUIR community follow cultural teachings brought down through history from the elders. Our individual and collective well-being is derived from membership in a healthy community that has access to ancestral lands and traditional resources and from having the ability to satisfy the personal responsibility to participate in traditional community activities and to help maintain the spiritual quality of our

> resources. This is an ancient oral tradition of cultural norms. The material or fabric of this tradition is unique, and is woven into a single tapestry that extends from far in the past to long into the future. In order to encompass the wide range of factors [directly] tied to the traditional American Indians of the CTUIR, a risk assessment has to be designed and scaled appropriately (Harris 1998).

EPA is required to identify populations who are more highly exposed; for example, subsistence populations and those who practice subsistence consumption of natural resources (Executive Order 12898[3]). EPA is also required to protect sensitive populations.[4] Some of the factors known to increase sensitivity include developmental stage, age (very young and very old), gender, genetics, and health status,[5] and this is part of EPA's human health research strategy.[6]

> The Superfund law requires cleanup of the site to levels which are protective of human health and the environment, which will serve to minimize any disproportionately high and adverse environmental burdens impacting the EJ community.[7]

CERCLA ARARs include treaties such as the Migratory Bird Treaty Act of 1918, 16 U.S.C. § 703 et seq. Therefore, CTUIR believes that other treaties, including the Treaty of 1855, are ARARs as well. In addition, the situation that existed when Hanford was established included CTUIR members living in permanent fishing villages along the Hanford Reach. This scenario reflects that fact.

> Section 120(a)(2) of CERCLA provides that all guidelines, rules, regulations, and criteria for preliminary assessments, site investigations, National Priorities List (NPL) listing, and remedial actions are applicable to federal facilities to the same extent as they are applicable to other facilities. No federal agency may adopt or utilize any such guidelines, rules, regulations, or criteria that are inconsistent with those established by EPA under CERCLA.[8]

CTUIR believes that this CERCLA language means that DOE and USFWS cannot abrogate the Treaty of 1855 by developing land use plans that do not include the exercise of treaty rights where they existed before Hanford was established, or do not recognize case law such as fishing and hunting rights cases.

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[3] White House, 1994. Federal Actions To Address Environmental Justice In Minority Populations And Low income Populations: Feb. 11, 1994; 59 FR 7629, Feb. 16, 1994.
[4] *Superfund Exposure Assessment Manual*. EPA/540/1-88/001 OSWER directive 9285.5-1. U.S. Environmental Protection Agency Office of Remedial Response, U.S. Environmental Protection Agency, Washington, D.C. 1988.
[5] http://www.epa.gov/nheerl/research/childrens_health.html
[6] EPA/600/R-02/050, September 2003 (posted at http://www.epa.gov/nheerl/publications/).
[7] http://www.epa.gov/region02/community/ej/superfund.htm
[8] 40CFR300 National Oil and Hazardous Substances Pollution Contingency Plan, Preamble http://www.epa.gov/superfund/action/guidance/remedy/pdfs/ncppreamble61.pdf

1.2 LOCATION

The CTUIR area is shown in a map of the continental US in Figure 1.

Figure 1. Continental U.S. with CTUIR Location

2 HUMAN ACTIVITIES AND EXPOSURE SCENARIO

2.1 METHODS FOR DESCRIBING THE DIET

The approach used in describing an overall diet is to use the information about major resources present in the study area, foraging theory information, and information from existing literature and interviews. An overall total caloric food pyramid with rough proportions of different food groups has been developed to show a typical traditional diet (Figure 2). This food pyramid is reconstructed from information about what the traditional diet actually was, rather than what it might be today if USDA recommendations about daily intakes were followed substituting wild foods for domesticated ones. In particular, the traditional CTUIR river-based diet was based on fish.

The dietary input for the risk assessment is typically somewhat less complex than the food pyramid (due to intrinsic limitations of the risk methods). Nevertheless, the risk assessment must consider the totality of species and calories.

2.2 CTUIR RIVER-BASED DIET

Approximately 135 species of plants are used as foods, flavorings, or beverages; approximately 125 species are used in traditional technologies; nearly 120 species of medicinal plants are used by the southern Columbia Plateau tribes and up to 200 by northern tribes (Hunn 1990). This wide variety of plants is typical of foraging societies. For risk assessment, however, this is collapsed into a few food categories. This is because the simple risk equations cannot handle more detailed information, and data on species-specific soil-to-plant uptake is lacking. Further compounding this problem is the tendency of game to be treated like livestock, and native plants like domesticated plants. Many pathways such as medicines and teas are typically ignored altogether. For this reason, the upper bounds for food categories are evaluated in the same way that direct exposure factors are rounded up to account for the myriad of small and otherwise ignored pathways.

There are two distinct diets within the Umatilla Tribes: the game-focused diet and the fish-focused diet. Because this scenario is applied to Hanford and the Columbia River, only the fish-based diet is presented here. The estimated diet is shown below as a food pyramid (Figure 2). The percentages of each food category in the diet are:

- Fish (40% of total calories);
- Roots (including tubers, corms, and bulbs) (32%);
- Greens (including medicinal leaves, tea, stems, pith, and cambium) (12%);
- Game (including fowl) (6%);
- Berries and fruits (5%), and
- Sweeteners, mushrooms, lichens (5%).

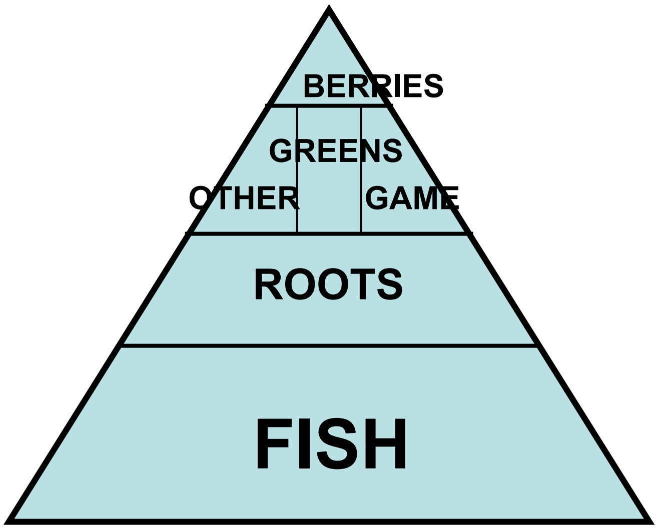

Figure 2. Traditional CTUIR River-Based Food Pyramid

2.3 NUTRITIONAL ANALYSIS

After making appropriate simplifying assumptions, the general CTUIR 2500 kcal subsistence diet that is focused on rivers is estimated in Table 1 (based on references by Hunn and Walker, see also DOE[9]). CTUIR can be contacted if more detail is needed (for instance, the ratio between tubers and bulbs, from different plant families, and so on). Related information on the CTUIR fish consumption rate can be found in Appendix A of this report.

[9] www.hanford.gov/doe/culres/mpd/toc.htm

Table 1. Summary of estimated relative proportions of dietary foods.

Representative 2500 kcal Diet			
Food Category	**% of 2500 kcal**	**Daily Amount (grams/day)**	**Comments**
Fish - 75% anadromous - 25% resident	40% or 1000 kcal	620 grams	Consumption of parts with higher lipid content needs to be added to this total. The lipid content will vary with species; the ratio of species can be provided on request.
Game, fowl	6% or 150 kcal	125	Consumption of organs with higher contaminant concentration (10x) needs to be added to this total. If 10% is organ meat with 10x bioconcentration, the total is *250gpd* equivalents.
Roots (unspeciated, including tubers, corms, bulbs)	32% or 800 kcal	800	Depending on the habitat, this needs to allocated among tubers and bulbs (different plant families) and terrestrial or aquatic species.
Berries, fruits	5% or 125 kcal	125	
Greens, medicinal leaves, tea, stems, pith, cambium	12% or 300 kcal	300	Above-ground plants may have contaminants translocated from the roots as well as dust deposited on the leaves.
Other: sweeteners, mushrooms, lichens	5% combined or 125 kcal	125	General assumption of 1 kcal per gram.
Total	**100%**	**2095g**	This is 4.6 pounds of food per day; this includes a much higher fiber content than domesticated varieties, which were bred for lower fiber and easier commercial processing.

3 EXPOSURE FACTORS AND PATHWAYS

3.1 APPROACH

Exposure factors reflect the activity levels and resource use of the lifestyle scenario under evaluation.[10] Exposure factors for both direct and indirect pathways are developed. Indirect pathways include exposure via the oral ingestion of food and medicine (see previous section). This section focuses on direct pathways: direct inhalation, dermal exposure, and ingestion of water, air, dust, sediment, and soil (including soil on the outside of food or added through cooking).

Default exposure factors have been developed for conventional suburban, urban, occupational, and recreational scenarios based on national statistics. Our approach to developing a tribal scenario is not to inventory every activity and every resource, but to provide an overall estimate of the general activity levels, anchored with specific information as available. The basic assumption is that traditional lifeways are active outdoor lifestyles that are somewhat physically demanding, even with some modern conveniences. Subsistence foragers (both genders) perform a combination of aerobic (high heart and ventilation rates), strength, endurance, and stretching-flexibility daily activities, as well as performing more sedentary work and resting.

The exposure factors here are general to traditional subsistence lifestyles, regardless of their location. The conceptual steps in this process are:

5. Understand the lifestyle and the activities that compose the lifestyle, and are required to obtain necessities and engage in the community culture;
6. Describe the day, the year, and the lifetime of men and women to identify any significant differences in activity levels between genders or ages;
7. Cross-walk activities with exposure pathways on the basis of frequency and duration of major activities, activity levels, and degree of environmental contact, and
8. Estimate cumulative direct exposure factors.

This scenario reflects an active, outdoor lifestyle with a subsistence economic base. Subsistence food sources include gathering, gardening, hunting, pasturing livestock, and fishing. The forager relies all or in part on native foods and medicines, while the residential farmer relies on domesticated but self-produced foods. Thus, the CTUIR scenario is at the foraging end of the subsistence spectrum, while the residential farmer is at the domesticated end of the subsistence spectrum. Both are active, outdoor lifestyles, and are consistent with the reasonable maximum exposure (RME) approach to baseline risk assessment.

This is a full-time multipathway scenario, to be applied within each area being assessed, consistent with EPA guidance on performing baseline risk assessments.

[10] http://cfpub2.epa.gov/ncea/cfm/recordisplay.cfm?deid=85843

The purpose of CERCLA baseline risk assessments is to evaluate the risks that would occur to a person engaging in defined sets of activities *absent* land use restrictions. It reflects the activities that the person would engage in if the site were not contaminated. Therefore, a baseline risk assessment is applied irrespective of possible institutional controls or other restrictions that may be needed as part of the remedy in order to protect human health.

Unrestricted access is the typical baseline risk assessment “no action” scenario. This includes CTUIR residence, because permanent year-round fishing villages with resident CTUIR members were present along the Hanford Reach when Hanford was established. This scenario is not a visiting scenario like a recreational scenario. It is a full-time scenario. This means that the forager may obtain a site-specific percentage of his and her food from an irrigated garden to supplement the native plants in his or her diet. The ratio of gathered to grown plants will vary with the size and resources of the assessment area, as will the ratio of game to livestock, upland to riparian resources, and so on. The forager also uses a well and/or seep and/or river for drinking water, sweat lodge water, and irrigation, also consistent with the general CERCLA principles of evaluating reasonable maximum exposures.

Exposure factors for the traditional CTUIR lifestyle are presented below. One of the key misunderstandings is how a subsistence lifestyle can be applied to a constrained area. The risk assessment methodology uses an interface between lifestyle and contamination termed an exposure point concentration. The guidance for risk assessment is to assume that the RME individual is constrained to the area being assessed (for subsistence or residential scenarios), or receives exposures only during visits to the area being assessed (for recreational or occupational scenarios). The subsistence scenario is not to be divided into partial scenarios, such as upland hunting or localized gathering, unless those are also complete scenarios, accounting for a full life but with emphasis on a specialized activity (e.g., the subsistence person who specializes in fishing for himself and others and trades fish for game and plants, or the subsistence person who specializes in gathering food and medicinal plants and materials and trades those items for fish and game).

3.2 MAJOR ACTIVITIES

Tables 2–4 show the thought process for considering the range and number of activities associated with major activity categories (hunting, fishing, gathering, and sweat-lodge purification). Tables 2 and 3 list a number of individual activities within each major category; this is included because most non-Indians have not learned much about traditional lifestyles and the complexity of daily life. Table 2 shows the connection between activity categories. In actuality, many activities are sequential—for example, a resource might be gathered in one location, used in a second location to make an implement or basket, and taken to a third location for use in hunting or fishing.[11] At times, a hide must be brain-tanned to make a drum head to sing the songs required for ceremonies in preparation for fishing. The activities shown in Table 2 are so interconnected that it is virtually impossible to separate a lifestyle into distinct categories, but they are presented as separate for illustration. The number of sub-activities in each column displays the complexity of each major activity, as well as interconnections between categories. The category of gathering includes both vegetal food procurement and basket making.

Table 2. Traditional lifeways—Typical activities in the activity categories.

Hunting	Purification	Gathering	Fishing
Learn skills, TEK	Learn skills, songs	Learn skills, TEK	Learn skills, TEK
Making tools	Build lodge from natural materials	Previous gathering	Make nets, poles, platforms, tools
Ritual bathing	Gather rocks	Make baskets, bags	Travel to location
Vigorous activity in hunting	Chop firewood	Hike to areas	Catch fish, haul out
Pack meat out	Prepare for use, get water	Cut, dig, harvest	Clean, can, hard dry, soft dry, smoke, eat whole fish or fillet or liver or other parts or soup
Process	Use Lodge, sing, drink water, inhale steam and smudges	Carry out items	Return carcasses to ecosystem, use as fertilizer
Scrape hides	Close area & fire	Wash, peel, process, split, spin, dye	
Tan, use other parts		Cook and eat or make product or medicine	
Cook, smoke, dry, eat meat and organs			

[11] This is similar to the Cultural Ecosystem Stories concept developed Terry Williams (Tulalip Tribes) with the associated software, ICONS (see, for example, http://www.epa.gov/owow/watershed/wacademy/ wam/comresource.html).

Table 3. Major activity categories.

Activity Type	General Description
Hunting	Hunting includes a variety of preparation activities of low to moderate intensity. Hunting occurs in terrain ranging from flat and open to very steep and rugged. It may also include setting traplines, waiting in blinds, digging, climbing, etc. After the capture or kill, field dressing, packing or hauling, and other very strenuous activities may occur, depending on the species. Subsequent activities include cutting, storing (e.g., smoking or drying), etc.
Fishing	Fishing includes building weirs and platforms, hauling in lines and nets, gaffing or gigging, wading (for shellfish), followed by cleaning the fish and carrying them to the place of use. Activities associated with smoking and constructing drying racks may be involved.
Gathering	A variety of activities is involved in gathering, such as hiking, bending, stooping, wading (marsh and water plants), digging, and carrying.
Ritual purification (sweat lodge)	Sweat lodge building and repairing is intermittent, but collecting firewood is a constant activity.
Materials and food use	Many activities of varying intensity are involved in preparing materials for use or food storage. Some are quite vigorous such as pounding or grinding seeds and nuts into flour, preparing meat, and tanning hides. Many others are semi-active, such as basket making, flint knapping, construction of storage containers, cleaning village sites, sanitation activities, home repairs, and so on.

Table 4 shows the cross-walk between activity categories and exposure pathways, with examples of how exposure factors are derived from knowledge about activities, interlinked resources and ecosystem stories, and the technical literature. Again, this is an iterative process that relies on multiple lines of evidence. Rather than a complete listing of activities, Table 4 presents an example of the thought process used to perform the iterative cross-walk. In each case a gap identification step may be necessary, and greater uncertainty may require placeholder values until data are obtained. The last column, "Totals for major exposure factor categories," shows exposure pathways totals (such as soil ingestion) are estimated across activity categories. This is not a statistical summation but rather a judgment based on multiple lines of evidence. Each estimate has been checked against technical literature for confirmation.

Table 4. Example exposure considerations for major activity categories.

	Hunting and associated activities	**Fishing and associated activities**	**Gathering and associated activities**	**Ritual purification and associated activities**	**Material and food use and processing**	**Totals for major exposure factor categories**
Food, medicine, tea, other biota ingestion (diet)	*n* deer /yr diet; Total large-small game, fowl; Organs eaten	*n* fish /yr diet; Total pounds or meals/day-wk-yr; Organs eaten	Includes foods, medicines, teas, etc.	No food, but herbal particulates are inhaled.	Both as-gathered and as-eaten forms; cleaning and cooking methods	Must account for all calories and 100–200 plant species; parts eaten
Soil, sediment, dust, and mud ingestion	Terrain types; Degree of dermal contact; How much dirt and mud	Sediment contact, dust and smoke if drying; Weir construction in mud	External soil on plants; Cooking method such as pit cooking; Ingestion when gathering	Includes building the sweat lodge and getting materials.	Includes incidental soil remaining on foods, pit cooking.	Must consider living area, roads, and gap identification.
Inhalation rates	Days per terrain; Exertion level; Hide scraping; Load & grade	Exertion level—nets and gaffing methods; cleaning effort.	Exertion level for load and grade, or gardening; Include making items.	Includes building the lodge, chopping firewood, singing.	Exertion level for pounding, grinding, etc.	Must account for exertion levels; Smokes and smudges.
Groundwater and surface water pathways	Drinking water; Wash water; Water-to-game pathways	Drinking water; Incidental ingestion	Drinking water, Cooking water, etc.	Steam in lodge; Drinking water during sweat	Soaking, possibly other uses	Must account for climate, sweat lodge, ritual bathing.
Dermal exposure	Soil, air and water pathways, plus pigments etc.	Immersion considerations	Same as hunting	Immersion with open skin pores.	Includes basket making, wounds.	Must consider skin loading and habitat types.

3.3 THE FAMILY, THE DAY, AND THE LIFETIME

This section describes a family-based exposure scenario based on traditional CTUIR lifestyles and diets. Only the fish-based diet is discussed here, since it is to be applied within 20 miles of a major fishing river. It is based on habits of members who live in the sagebrush steppe, gather native foods supplemented with a home garden, have a high rate of subsistence activities, have a regular schedule of other cultural activities, and work as field workers monitoring natural and cultural resources, taking environmental samples, and doing reclamation or restoration work. The lifestyles are moderately active outdoor lifestyles, with daily sweat lodge use.

3.3.1 Lifestyle of a Representative Traditional CTUIR Family

The families are intended to be reasonable composites. Each family includes an infant/child (age 0–2 years) who breastfeeds for two years and crawls and plays; a child (age 2–6) who plays in the house and outdoors, a youth (age 7–16) who attends school, plays outdoors near his/her residence, and is learning traditional practices; two adult workers (one male, one female, age 17–55; the female breast-feeds the infant) who work outdoors on reclamation and environmental and cultural activities and who also engage in subsistence activities; and an elder (age 56–75) who is partly at home and partly outdoors teaching and demonstrating traditional cultural practices. All members (except the infant from 0–2 years) partake in family sweat lodge use and in cultural activities throughout the year.

Location and Type of Residence: The residence is located within the assessment area. The family lives in a house with little or no landscaping other than the natural vegetation. Each house has its own well for domestic use and a garden irrigated with groundwater or surface water (whichever is more contaminated). This is not a fully traditional pit house or tule mat house, but a typical reservation-quality house, with seasonally open windows. The road and driveway are not paved.

3.3.2 Activity Patterns of Each Family Member

Infant: The infant breast-feeds for 2 years, and crawls on the floor (with house-dust exposure) from age 6 months to 2 years. Infants ingest more fluid per body weight than children do, and toddlers (6 months to 2 years) are likely to have the highest of the children’s exposures due to crawling and mouthing behaviors, and their higher food and water per capita ingestion rates.

Child (ages 2–6 years): Beginning at age 2, the child eats the same food as everyone else, participates in family sweat lodge, and spends some time accompanying the mother as she gardens and gathers.

Youth (ages 7–16): The adolescent is learning to hunt, gather, and fish (and spends equal time in each activity in their respective locations), plays outdoors, and attends school.

Adult Worker (ages 17–55): Workers are assumed to work for the Tribe collecting environmental samples, engaging in restoration/remediation or construction work, and caring for natural and cultural resources and tribal property. This type of activity is dusty in the summer and muddy in the winter. Both males and females are currently employed in this type of activity. Workers could be exposed to external irradiation, surface soil and dust, vegetation, surface water, sediments, seeps, and radon and daughter products in outdoor air and water. These workers have an average 8-hour workday.

Adult Hunter/Fisher/Gatherer: Each adult also hunts (male), fishes (male), or gardens and gathers plants (female). These activities are roughly analogous with respect to environmental contact, and therefore are assumed to result in the same amount of soil or sediment ingestion for males and females. The additional time and contact during game processing and plant washing and preparation are also roughly equal. The location of hunting small game or fowl is in the same area as the residence, and the location of big game hunting covers a larger area, although the livestock are located in the same area as the residence. The time spent hunting or fishing versus livestock tending is proportional to the diet and the size of the assessment area. The garden is at the place of residence and uses the same water as the household, while the gathering occurs in a larger area, also proportional to the size of the assessment area. All of the hunters, gatherers, and fishers spend some time near water, if it is present in the area, on activities such as washing plants or game, gathering aquatic plants and mollusks/crustaceans, and so on, with concomitant exposure to mud or sediment.

Elder (ages 56–75): The elder gathers plants and medicines, prepares them, uses them (e.g., making medicines or baskets, etc.) and teaches a variety of indoor and outdoor traditional activities. The elder also provides child care in the home.

3.3.3 Specific Cultural Activities

This section considers activities that are engaged in at varying levels by the Tribe and by varying age-groups, and other factors that affect exposure.

Ritual Purification (Sweat Lodge) (ages 2–75): The daily use of the sweat lodge is an integral part of the lifestyle that starts at age 2. Sweat lodge construction has been described in the open literature. Although the details vary among Tribes and among individual families, they are generally round structures (6 feet in diameter for single-family use) constructed of natural materials (i.e., branches, moss, leaves with a dirt floor covered with mats or cedar boughs) near a source of surface or groundwater. A nearby fire is used to heat rocks that are brought into the sweat lodge. Water (4L) is poured over the rocks to form steam (a confined hemispheric space with complete evaporation of the water which is available for inhalation and dermal exposure over the entire skin area). Either groundwater or surface water may be used. Inhalation and heart rates may be higher depending on activities that occur during the sweat lodge ceremony (e.g., singing).

Cultural Activities: All age-groups participate in day-long outdoor community cultural activities once a month, such as powwows, horse races, and seasonal ceremonial and private cultural activities (together averaging about 0.5 hours/day). These activities tend to be large gatherings with a greater rate of dust resuspension and particulate inhalation. Individuals also tend to be active, resulting in a greater inhalation and water ingestion rates.

Basket Making: Exposure specific to basket makers is a well-recognized problem[1], but data useful for exposure assessment are almost totally lacking. Gathering of some plants (e.g., willows, cattails, tules, reeds, and rushes) can be very muddy, and river shore or lakeshore activities with sediment exposure may be underestimated. Washing, peeling, weaving rushes, and other activities results in additional exposure, such as dust deposited on leaves or soil adhered to roots. Some of the materials are held in the mouth for splitting, and cuts on the fingers are common. As more information becomes available, it will be evaluated so that exposure factors for each route of exposure account for these particular activities.

Other Special Activities: It is recognized that there are special circumstances when some people may be highly exposed (and their exposure would be underestimated). For instance, some men hunt or fish for the general community, and many people provide roots and fish and game to elders in addition to their own families. Flint knappers may receive additional exposure through obtaining and working with their materials. Healers handle pharmacologically active plants, some of which may uptake contaminants differentially. Materials released from firewood, smokes, and smudges may contain contaminants or affect physiological parameters of the person. These types of activities may require special consideration with respect to exposures.

Seasonality: The changes in activity patterns over the annual seasonal cycle has been modified in modern times, but the ecological cycle has not, so people must still gather plants according to when they are ripe, hunt according to game and fowl patterns, and fish when the spawning runs occur. Items are gathered during a harvest season for year-round use. While specific activities change from season to season, they are replaced by other activities with a similar environmental contact rate. For instance, a particular plant may be gathered during one month, while another month may be spent hunting, and a winter month may include cleaning and using the items obtained previously. Therefore, since we are assuming that all activities are roughly equal, there is no decrease in environmental contact rates during winter months.

3.3.4 Time Allocation throughout the Day

This section describes the time allocation that is reflected in daily exposure factors. The time adds up to slightly more than 24 hours per day, as is typical for any exposure scenario, in order to allow specific pathways to drive the risk should they

[1] http://www.cdpr.ca.gov/docs/envjust/documents/basketweaver.pdf

be contaminated. This also accounts for specialization by the person who spends more than an average amount of time in particular activities.

Identical Activities: From the age of 2 to 75 years, 15 hours of every day are similar: 8 hours sleep, 2.5 hours in other indoor activities, 2 hours in the sweat lodge, 1 hour in nearby outside activity, such as small game hunting, 0.5 hour in community cultural activities, and 0.5 hour traveling on unpaved roads. These activities are referred to as *common time*.

Infant: Standard infant exposure parameters are used. House dust is assumed to have similar concentrations of contaminants as outside soil. The infant is breast-fed for 2 years, assuming two different scenarios: (1) the mother has received 25 years of prior exposure from a contaminated area; and (2) the mother has not received such exposure. The issue of fetal exposure remains to be determined.

Child: The child, up through age 6, spends the same amount of common time in the same activities, and 4 hours indoors and 5 hours outdoors with the mother as she gardens and gathers.

Youth: Common time plus 6 hours at school 5 days/week (averaging 4.5 hours/day over a full week), 2.5 hours indoors, and 3 hours outdoors playing or accompanying an adult or elder, learning traditional activities. It is assumed that the school is uncontaminated unless there is data about chemical usage or contamination, and it is also assumed that his or her near-residence outdoor time results in a higher amount of soil contact than at other ages; therefore, the youth's average contact rates are the same as the child and adult's.

Adult: Common time plus 8 hours working 5 days/week (about 5.5 hours/day), 0.5 hour at home, and 3 hours in one of the subsistence activities (hunting = 1 hour plus 2 hours processing, smoking, etc.; fishing = 2 hours plus 1 hour processing; gathering/gardening = 1 hour gathering in the assessment area, 1 hour gardening at home, and 1 hour washing, processing, etc.).

Elder: Common time plus 3 hours at home providing child care, 3 hours outdoors teaching, 1 hour gardening or gathering, and 2 hours at home processing materials and making items.

3.3.5 The Lifetime

Traditionally, daily tasks were somewhat different for males and females: males tend to hunt and fish, while females gather and cook. However, even where activity patterns show gender dimorphism, the rates of environmental contact were and are probably similar. In addition, both women and men are employed as environmental and construction workers, as well. Therefore, for the purposes of the exposure scenario, the genders have identical exposure factors.

Male Lifetime: The male lifetime consists of the standard infancy, childhood, and youth. At age 17 he specializes in either hunting or fishing and begins working as a reclamation/restoration/environmental worker. These activities are specified solely to determine their locations, which may have different contaminant concentrations. As an elder he changes his activity patterns to teaching and demonstrating as described above.

Female Lifetime: The female lifetime consists of the standard infancy, childhood, and youth. At age 17 she engages in gathering and gardening and also works the same job as the male. During motherhood, the woman may remain at home, which is located in the same sparsely populated area, and she continues to garden and gather, so her exposure does not diminish. Her earlier exposure may result in a dose to the fetus and breast-feeding infant.

3.4 MEDIA, PATHWAYS, AND EXPOSURE FACTORS

As described previously, exposure factors are developed by cross-walking the activities described above with specific media-based exposure pathways. The identification of media pathways begins to sum exposures; for instance, all the soil exposures from hunting, gathering, household activities, processing and using materials, food processing, and other activities are summed qualitatively.

Ground Water and/or Surface Water Pathways: Ground water and/or surface water are directly ingested as drinking water. Both are used to create steam in the sweat lodge. Other uses of these resources include typical household use (e.g. flushing, cooking, bathing, and showering), irrigation of crops and/or garden, and livestock.

Air and Dust Pathways: As a general rule, the air pathway can result in exposure to any present volatiles, aerosols, and resuspended dust. Dust resuspension from unpaved roads and other unvegetated surfaces should be included as part of the inhalation exposure pathway. If there is a potential for exposure, inhalation of fire smoke or smudge should be included because some of these pathways can be frequent and significant.

Soil and Sediment Pathways: This pathway includes soil ingestion from hand to mouth activities associated with daily activities, gathering (e.g., digging roots) and gardening, food and material processing (e.g. grinding, scraping, pit cooking). This pathway also includes direct ingestion resulting from residual soil on roots and bulbs. The as-gathered and as-eaten conditions of plants are important. Some vegetable foods are eaten raw on the spot after being brushed off. Grinding seeds and nuts also adds rock dust to the flour.

3.5 EXPOSURE FACTORS FOR DIRECT EXPOSURE PATHWAYS

A description of activities for the purposes of developing exposure factors focuses on:

Frequency of activity:
- Daily, weekly, monthly

Duration of activity:
- Hours at a time
- Number of years

Intensity of environmental contact and intensity of activity:
- For soil ingestion and dermal exposure, is the activity more than, less than, or equal to gardening, camping, construction/excavation, or sports?
- For inhalation rates and calorie needs, is the activity level more than, less than, or equal to standard EPA activity levels for specific activities with known respiration rates and caloric expenditure?

The following table (Table 5) includes three adult scenarios: the suburban resident, the rural residential farmer-gardener, and the subsistence forager. The first two scenarios are typically used in risk assessments, and the third reflects the set of activities that compose the CTUIR lifestyle. Each scenario is intended to be physiologically *coherent*, which means that the dietary intake, activity levels, and inhalation rates are physiologically linked. For instance, the more sedentary suburban scenario is based on national data on typical lifestyles (light occupational activities sitting or standing, with some moderate activity at home), while the rural residential farmer has a higher activity level, higher inhalation rate, and higher soil ingestion rate due to his farming activity pattern. The subsistence forager is still more active, with a proportionally higher inhalation rate, as well as a higher soil ingestion rate, due to a higher degree of soil contact. We have included the rural residential farmer-gardener information for consideration, since it describes an intermediate lifestyle between that of the suburban resident and subsistence forager.

The following table shows adult values, as does the dietary discussion above. Children’s exposure factors are scaled from the subsistence forager rates, as is conventionally done in risk assessment (from the Children’s Exposure Factors Handbook), with the exception of the soil ingestion rate, which is left at 400mg/d throughout the lifetime. Body weight is a consistent 70kg because that is the standard EPA assumption used in risk assessments.

Table 5. Exposure factors for direct pathways.

Direct Pathway	Exposure Factors (Adults)		
	Default Suburban	**Rural Residential Gardener**	**Subsistence Forager**
Inhalation	20m^3	25m^3: While EPA does not have official exposure factors for this lifestyle, it is reasonable to assume that a person who farms, gardens, irrigates, and cares for livestock has an intermediate inhalation rate.	30m^3/day: This rate is based on a lifestyle that is an outdoor active lifestyle, based on EPA activity databases, foraging theory, and ethnographic description of the activities undertaken to obtain subsistence resources as well as allotment-based food (livestock and garden). It is higher than the conventional 20m^3/day because the activities with associated respiration rates are higher than suburban activities.
Drinking water ingestion	2L/d	3L/day: This rate is based on water requirements in an outdoor moderately arid environment.	3L/d plus 1L for each use of the sweat lodge.
Soil ingestion	100mg/d (conventional suburban); 50mg/d (manicured suburban; less outdoor time).	300mg/d	400mg/d: This rate is based on indoor and outdoor activities, a greater rate of gathering, processing, and other uses of natural resources, as well as on residual soil on grown and gathered plants. Episodic events (1 gram each) are considered, such as very muddy gathering, cultural activities with higher soil contact, and so on. It does not specifically include geophagy or pica.
Other parameters			
Exposure frequency	Up to 365 days per year, but varies. Hours per day varies; typically 24 hrs/d.	Up to 365 days per year, but varies. Hours per day varies; typically 24 hrs/d.	365 days per year. Hours per day varies; typically 24 hrs/d.
Exposure duration	30 years	30 or 70–75 years	70–75 years

Drinking Water: Harper et al. (2002) estimated an average water ingestion rate of 3L/day for adults, based on total fluid intake for an arid climate. In addition, each use of the sweat lodge requires an additional 1L for rehydration, for a total of 4L per day. It should be noted that water intake in an arid environment may be more than 3L per day. For example, the Army assumes that the maximum individual daily amount of drinking water required by military personnel to remain combat-effective ranges from

5–15L/day, depending on the climate, season, and intensity of work.[2] The Army Quartermaster assumes that military personnel in hot climates require 3 gallons per day as drinking water.[3]

Soil Ingestion: Soil ingestion by young children (0–6 years) is assumed to be 400mg/day for 365 days/year. This is higher than the prior EPA default value of 200mg/day (USEPA 1989), and is the children's upper bound value. This rate reflects both indoor dust and continuous outdoor activities analogous to gardening or camping, but it is less than a single-incident sports or construction ingestion rate. For adults, the soil ingestion value is also 400mg/day, reflecting an unspecified upper percentile (EPA 1997).

Inhalation Rate: An inhalation rate of 30m^3/d is more accurate for the active outdoor lifestyle than the EPA default rate of 20m^3/d (EPA 1997). Using EPA guidance, an average rate of 26.2m^3/d is obtained from 8 hours sleeping, 2 hours sedentary, 6 hours light activity, 6 hours moderate activity, and 2 hours heavy activity. This represents minimal heavy activity (construction, climbing hills, etc.), and is an average rather than a reasonable maximum. Most other exposure factors are upper bounds, so the use of a median rate for inhalation is inconsistent with the reasonable maximum exposure (RME) approach typically used in Superfund risk assessments, and could result in under-protection of children, the elderly, athletes, asthmatics, and the half of the population with above-average inhalation rates.

Sweat Lodge: Inhalation and dermal exposure in the sweat lodge are evaluated by assuming: (1) one hour of use daily; (2) 4 liters of water is poured on heated rocks resulting in instant vaporization; (3) the sweat lodge is a hemisphere 6 feet in diameter; and (4) dermal exposure is over the entire body surface area. More detail is given in Appendix B.

Children's Exposure Factors: Children's exposure factors are based on "Child-Specific Exposure Factors Handbook"[4] but scaled from the adult subsistence values for inhalation rate. The soil ingestion rate for children is a constant 400mg/day, without age stratification.

3.6 SUMMARY OF EXPOSURE FACTORS

A summary of primary exposures are presented in Table 6. Further documentation is provided in appendices for the three major exposure factors: inhalation rate, soil ingestion rate, and fish consumption rate. Additional detail on exposure factors or

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[2] http://www.nap.edu/execsumm/NI000954.html Guidelines for Chemical Warfare Agents in Military Field Drinking Water (1995).
[3] http://www.pasols.org/energy/water2.pdf
[4] U.S. Environmental Protection Agency (EPA) (2002). Child-specific exposure factors handbook. National Center for Environmental Assessment, Washington, DC; EPA/600/P-00/002B. Available from: National Information Service, Springfield, VA; PB2003-101678 and http://www.epa.gov/ncea.

guidance on the application of the scenario to particular locations will be provided on request. This summary draws on the 1997 and 2004 references. All exposure duration and averaging times are daily for 70 years unless otherwise noted. Children's factors are scaled from adults except where noted.

Table 6. Summary of exposure factors.

Medium	Exposure Pathway	Exposure Factor	Value
Soil	Ingestion	Ingestion rate	400mg/d (all ages)
	Dermal	Adherence rate (<150 um particle size)	1mg/cm^2 (all ages)
		Skin surface area (head, hands, forearms, lower legs)	5700cm^2 (adult) 2800cm^2 child)
Air	Inhalation	Inhalation rate	30m$^{3/}$/day (adult)
Water	Dermal	Skin surface area	18,000cm^2 (adult) 14,900cm^2 (child)
	Dermal and Ingestion	Swimming	13 days/yr, 2.6 hrs/event, 50ml/event
	Ingestion	Ingestion rate	4L/d
Biota	Foodchain	Fish ingestion rate	500 lbs per capita per year, or 620gpd
		Game, meat, fowl	125gpd
		Fruit, greens (unprotected)	Berries—125gpd Greens—300gpd Other—125gpd
		Below-ground roots	800gpd
		Milk	Use children's rate (children only)

Notes

- Soil adherence rate is correlated to grain size; soil samples must be sieved, and data for particle size <0.044cm (RAGSe, App. C, Table C-4) should be used for dose estimation. Inhalation is also related to particle size, so the dust resuspension estimate must also include particle size. The adherence rate of 1mg/cm^2 is higher than most commercial rates but lower than the kid-in-mud rate (RAGSe, Ch.3, Table C-3) to account for longer events and more wet soil (riparian, wetlands) contact.
- Animal meats include organs, which have a bioconcentration potential. Assume that 10% of animal food is organs with 10x higher concentration.
- Sweat lodge parameters are included in the attached appendix.

4 CONCLUSION

This report has presented the CTUIR scenario and supporting information for use in human health risk assessments. This report is intended to describe enough about the traditional subsistence lifestyle that a risk assessor who is familiar with developing exposure scenarios can understand the derivation of the exposure factors even if she does not have an in-depth familiarity with the CTUIR lifestyle. Where information is not presented, it is assumed that conventional parameters are suitable (e.g., skin surface area).

The report describes the Tribes' environment. An overall river-based diet is developed, with major food-type categories estimated as percentages and presented in a food pyramid. The most prevalent food source is fish. Exposure factors are developed based on traditional subsistence lifestyles, with attention to the lifestyle, activity patterns, specific activities, daily time allocation, and lifetime of a CTUIR person. Rates of inhalation, water ingestion, and particularly soil ingestion are higher than those of the general population, due in part to increased outdoor activity in an arid climate.

5 REFERENCES

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APPENDIX A

FISH CONSUMPTION RATE

CTUIR Fish Consumption Rate = 620g/d or 500 pounds per year (adult).

A.1 INTRODUCTION

Although many indigenous peoples living along coasts or major waterways originally had very high fish consumption rates, most are now suppressed due to destruction of fisheries, lost access to aboriginal lands, or awareness of contamination. Therefore, studies that assess the current fish consumption rates are not measuring the true subsistence rate, but a modern suppressed rate. Even so, a subset of tribal members remains heavily fish-dependent, creating a bimodal distribution that is missed in most conventional survey methods.

The Confederated Tribes (Cayuse, Umatilla, Walla Walla) have relied on resident and anadromous fish in the Columbia River and its tributaries for at least 10,000 years. Salmon and the people are inseparable, and people will and must continue to partake in the circle of life with salmon as a partner. We regard current fish numbers as a temporary decline, with continued improvement through concerted efforts in watershed restoration. Therefore, since Hanford cleanup must remain protective for thousands of years, we are using our subsistence consumption rate, not the current average suppressed consumption rate.

The subsistence consumption rate is an average of 620 grams per day for adults. This is known through anthro-historical data, anecdotal information by early observers such as Lewis & Clark, nutritional analysis, and documentation from the era of dam construction (1920–1950), interviews of current subsistence fishers, and literature review. Table A.1 shows examples of the range of consumption rates that were reviewed.

Table A.1. Summary of selected fish ingestion rates.

Fish Ingestion Rate	Derivation
6.5g/day	Previously used in federal promulgations based on national food consumption surveys of the general non-tribal population; now superceded by 17.5g/d.
17.5g/day	EPA's new recommendation for the general non-tribal population and recreational fishers
48.5g/day	EPA and FDA recommendations for adults to eat two 6-ounce meals per week
54g/d	Model Toxics Control Act (Washington State) and OSWER (Combustor risk assessment guidelines).
63.2g/day (about 1 pound/week)	CRITFC (1994) average for current tribal fish consumers, excluding subsistence fishers; see commentary below
142.4g/day	EPA proposed average rate for tribal subsistence fishers and 99th percentile of the general non-tribal population
389g/day	CRITFC 99th percentile of *non*-subsistence fish consumers plus non-consumers, minus 7 *outliers*. The 90th percentile was between 97 and 130g/day, and the 95th percentile was between 170 and 194g/day.
454g/day (1 pound/day)	Anecdotal subsistence estimate, commonly cited during interviews with traditional and subsistence people
540g/day	Harris & Harper (1997), based on averages for traditional CTUIR fishing families, and the lower end of the Treaty-based range; approved by BOT for use at Hanford and Columbia River. The authors sought out and interviewed traditional and subsistence fishing members.
620g/day	Cited in the Boldt decision ("Salmon, however, both fresh and cured, was a staple in the food supply of these Indians. It was annually consumed by these Indians in the neighborhood of 500 pounds per capita"). U.S. District Judge George Boldt, U.S. v. Washington, February 12, 1974, note 151. *Note: Boldt was referring to Columbia mainstem fishers when he wrote this. This does not include resident fish.*
650g/day	Walker (1999), mid-range of top third of Yakama members using the Columbia River during the 1950s and 1960s (both resident and anadromous fish). This is based on interviews of tribal fishermen, fish market records, nutritional analysis, archaeological and ethnographic evidence, and literature reviews. Walker cites other studies that support this number. Walker estimated that minimal river users ate 80g/d, and the median river user ate 350g/d. The BOT endorsed the numbers in this paper.
1000g/day	Walker (1985) estimate of pre-dam rates for Columbia Plateau tribes, accounting for calorie loss as fish migrate upriver and other documentation.
Notes	
To convert from ounces to grams, multiply by 28.35. There are 3.53 ounces in 100 grams. To convert from pounds to grams, multiply by 453.6. There are 16 ounces in a pound. 100 grams or 3.5 ounces is about the size of a deck of cards. Meal sizes are generally assumed to be 8 ounce portions for adults.	

A.2 APPROACH AND ASSUMPTIONS

Within the Confederation of Cayuse, Walla Walla, and Umatilla tribes, there are different family natural resource uses according to the specific area that a family is from. Nevertheless, while the Cayuse Tribe emphasized hunting more than fishing and the Walla Walla and Umatilla Tribes emphasized fishing more than hunting, both diets are “subsistence” diets because they provide all the food and medicine that a family needs to survive and thrive. However, in this scenario we are using the term “subsistence fisher” to refer to original consumption rates along the Columbia River and its major tributaries, which the Treaty of 1855 was intended to protect.

The development of the CTUIR fish consumption rate was based on the following premise:

- Subsistence consumption rates were practiced by many or all members of a tribe, but today are practiced by a subset of tribal members;
- Within tribes or confederations of tribes there may be distinct patterns of natural resource use that are obscured by statistical cross-sectional surveys. Therefore, cross-sectional fish consumption surveys in tribal communities may not be able to identify subsistence fishers, and
- In order to develop a subsistence consumption rate, subsistence fishers must be specifically identified and interviewed, and existing studies must be reviewed to determine whether they are suitable for developing true subsistence rates, or combined/suppressed consumption rates.

Our goal was to identify the subsistence consumption rate, because that is the rate that the Treaty of 1855 was designed to protect and which is upheld by case law. It also reflects tribal fish restoration goals and healthy lifestyle goals.

As other investigators have done (Walker, in particular), the CTUIR fish consumption rate was developed using multiple lines of evidence: literature review of ethnohistorical evidence, review of cross-sectional fish consumption surveys (a combination of subsistence and non-subsistence fishers), interviews of current subsistence fishers, and caloric and nutritional analysis.

A.3 CURRENT FEDERAL AND STATE GUIDANCE

The EPA Office of Water provides guidance for setting ambient water quality standards for surface water, and includes a consideration of fish consumption rates. The prior national fish consumption rate for the general population, 6.5gpd, was based on the mean national per capita (for both consumer and non-consumers) consumption rate of freshwater and estuarine finfish and shellfish from 3-day diary results that were reported in the 1973–74 National Purchase Diary Survey (Javitz 1980).

The EPA Office of Water[5] now recommends a default fish intake rate of 17.5 grams/day to adequately protect the general population of fish consumers including sport fishers, and 142.4 grams/day for subsistence fishers. The basis for the fish

[5] Estimated Per Capita Fish Consumption in the United States. (EPA-821-C-02-003) (August 2002). http://www.epa.gov/waterscience/fish/consumption_report.pdf; *and* Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000) EPA-822-B-00-004, October 2000. http://www.epa.gov/waterscience/humanhealth/method/chapter4.pdf

intake rates is the 1994–96 Continuing Survey of Food Intake by Individuals and 1998 Continuing Survey of Food Intakes by Individuals (CSFII) conducted by the U.S. Department of Agriculture.

When tribes develop ambient water quality standards, EPA[6] recommends using either an upper percentile of a cross-section or an average rate specific for a higher fishing group, according to the policies of the tribe. EPA says that the two numbers should be compared to ensure that the higher fishing group (if one is present within a general tribal population) is protected. In the case of the CTUIR, these two numbers are quite different (see discussion below), so the CTUIR rate is based on the average rate specific to the higher fishing group rather than the average for the whole Tribe.

The U.S. EPA Office of Solid Waste and Emergency Response (OSWER) also considers fish consumption in the Superfund program. OSWER's policy is to assume an ingestion rate of 54g/day for high recreational consumers of locally caught fish (OSWER directive 9285.6-03). This number is based on recreational, not Native American data. Region 10 of the U.S. EPA recommends the use of results from local or regional seafood-intake surveys for use in the regional Superfund program.[7] If tribal-specific or local information is not available, EPA-OSWER recommends using the U.S. EPA Exposure Factors Handbook, which recommends a mean and 95th percentile for the general U.S. population of 20.1g/day and 63g/day, respectively (USEPA 1997). For Native American subsistence populations the recommended value for mean intake is 70g/day and the recommended 95th percentile is 170g/day.

The Washington State Department of Ecology recently recommended a *draft* statewide default of 177g/day to protect all Washington residents including the highest consumers, subsistence fishers. The draft report recommends,

> final default consumption values of approximately 178 and 175 g/day for marine and freshwater areas, respectively. These values represent approximately the 90th percentile of the fish consumption rate distribution from the Toy et al. study and the 95th percentile from the CRITFC study, respectively.[8] State-wide criteria may use the mid-point between these values, or 177 g/day as a reasonably protective default. Shellfish may be separated out from the marine values. Shellfish estimates are recommended as 68 g/day based on the Toy et al. study.

[6] www.epa.gov/ost/standards/tribal/tribalfact2004.html or www.epa.gov/ost/standards/tribal/tribalfact2004.pdf.

[7] Currently being revised: http://yosemite.epa.gov/r10/oea.nsf/af6d4571f3e2b1698825650f0071180a/db6a5cf0b287291c88256c55006cd81e?OpenDocument

[8] Washington Department of Ecology, Analysis and selection of fish consumption rates for Washington State risk assessments and risk-based standards, external review draft, March 1999. http://www.ecy.wa.gov/biblio/99200.html

The Washington Department of Ecology's 1997 standards for surface water refer to WAC 173-340-730 (Model Toxics Control Act), which includes a *placeholder* for fish consumption of 54gpd.

A.4 FISH CONSUMPTION SURVEYS OF CURRENT SUPPRESSED RATES

Several studies have evaluated current tribal fish consumption rates in the Pacific Northwest in order to evaluate current exposures and risks (Table A.2). None of them addressed the issue of original fish consumption rates which are protected by treaty or by judicial decisions, and none addressed the current tribal conditions which forced many people off the river and away from their hereditary or usual and accustomed fishing sites. Additionally, none of them specifically consider the range of lifestyles within tribal communities, but assumed that tribes are all composed of a homogeneous population, even if tribes with different histories, homelands, and languages were forced onto the same reservation. This results in bimodal or more distributions within many tribes. In the case of the Confederated Umatilla Tribes, there is a subset of tribal members who maintain high fishing rates and consumption rates (see next section). The studies summarized in Section A.4 assumed that tribes were homogeneous in their activities and lifestyles, and therefore took a statistical cross-section approach. In contrast, the studies summarized in Section A.5 specifically focused on the subset of tribal members who maintain a true subsistence lifestyle, and on documenting original consumption rates.

Table A.2. Major Pacific Northwest cross-sectional studies of current suppressed fish consumption rates.

Survey	Mean (converted to g/person/d)			95th	99th
	Finfish	Shellfish	Combined	Fish and Shellfish	
CRITFC	63.2	-	63.2	170–194	389
Suquamish	81.8	132.7	213.9	798	ND
Toy—Tulalip/Squaxin	48.8	22.3	72.9	177	ND
Sechena—Asian/Pac Isl.	-	-	119.3	?	?

CRITFC—outliers were eliminated from the database (implies a presumption of not valid).
Suquamish—no labeling of high end consumers as outliers; says they were assumed to be accurate reports.
Tulalip—recoded outliers (implies a presumption that these were valid but mistaken).

A.4.1 CRITFC (1994)

CRITFC (1994). "A Fish Consumption Survey of the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin." CRITFC Technical Report No. 94-3, Portland, OR.

The CRITFC fish consumption survey was designed in a way that is conventionally used in typical suburban populations. It used statistical rather than ethnographic research methods. Both methods are *scientific* in that they are systematic, repeatable, and verifiable, but they are suitable for different populations and situations. The CRITFC survey was a random cross-section of tribal members (names were randomly selected from enrollment lists), with ultimate surveys of 126 Warm Springs, 133 Nez Perce, 131 CTUIR, and about 130 Yakama members. The mean age of respondents was 39 years old (less than 10% were elders 60 years old or older). Tribal members were contacted by phone, mail, or in person. They were asked to drive to a central location on a particular day, and answer a lengthy set of questions read from a script (for consistency) by an interviewer. The overall response rate was 69% (31% of selected people either refused, could not be located, or did not participate for unknown reasons). It is likely that traditional members were under-represented due to refusal, lack of a phone, car, or permanent address, or inability to respond for the small amount of payment ($40).

Seven individuals reported that they ate more than 389g/day, or more than 99% of the amount eaten by fish consumers (4 people ate 486g/day, and one person each ate 648g/d, 778g/d, and 972g/d). These values were treated as statistical outliers and were eliminated from the database. No follow-up was done to find out whether these higher rates were accurate or not, but we assume that these people are true subsistence fishers. Because these numbers are based on a reported meal frequency and size, we assume that the underlying answers by the interviewees were accurate, because people can provide information about meal frequency more easily than poundage.

During the research for the Harris & Harper paper (1977) traditional members who had been included in the CRITFC survey were asked if they gave accurate information, and several said no. Some traditional fishers said they simply refused to participate, or reported lower consumption rates than reality, due to a fear of law enforcement or fear of being accused of knowingly eating contaminated fish. Other factors are unknown, such as whether traditional members were away from home during a fishing season, or otherwise engaged in activities that prevented them from participating. The personal experiences of the people we are most interested in (elders and subsistence fishing families) make them less likely to answer questions, even when posed by a member of the community. Fishing families often have a family history of having to fish clandestinely and being persecuted by authorities or jailed as a result of fishing in their own rivers to feed their families.

The point of this discussion is that the makeup and history of the community must be understood before conducting a conventional survey. In addition to the above items, we know that elders tend to eat more traditionally (including people who return to traditional ways as they get older). Within the Umatilla and Walla Walla membership there are people who lost access to their hereditary fishing sites, or who have full-time day jobs or other family circumstances that prevent them from designating a family member as a fish provider.

Arithmetic mean = 63.2 grams/day
50th percentile = 38.9 to 40.5gpd
90th percentile = 127gpd (Table 10 says the weighted 90th = 97–130gpd).

95th percentile = 182 (Table 10 says the weighted 95th = 170–194gpd. The 95th percentile is also cited as 175 from Table 18 by the same author in her discussion of the Portland Harbor workplan)
98th percentile = 317gpd
99th percentile = 389gpd
Average serving size = 8.42 oz +/- 0.13 oz.

A.4.2 Toy et al. (1996)

Toy, K.A., Polissar, N.L., Liao, S., and Mittelstaedt, G.D. (1996). "A Fish Consumption Survey of the Tulalip and Squaxin Island Tribes of the Puget Sound Region." Tulalip Tribes, Department of the Environment, 7615 Totem Beach Road, Marysville, WA 98721.

This survey was designed to focus on frequency (daily, weekly, monthly, annually) and portion size of fish and shellfish, both fresh and frozen. Commercial fishing and shellfishing is an important source of income for both tribes, but for the Tulalip, "at present, the consumption of shellfish is limited to a personal-use activity." Sample size goals were developed by assuming a homogeneous (not bimodal) population and a certain standard deviation. Random names were generated, and children were evaluated if a parent was included (limited to one child per family). The final sample sizes were 73 Tulalip and 117 Squaxin adults over 18 and 68 children. A scripted questionnaire with food models was used.

52 edible species were divided into anadromous, pelagic, bottom fish, shellfish, and other (canned tuna or trout) categories. Consumption per body weight was recorded (average weight = 81kg). Participants were paid $25. There was no correlation of consumption with income (i.e., low income did not drive people to eat more fish; high income did not allow more fish as a luxury purchase; or the two factors balanced each other).

Outliers were recoded to the 3 SD value. "The distribution of consumption rates was skewed toward large values." At least 25 people (out of 190, or 13% of participants) ate more than the 95th percentile of total finfish. This suggests that there is an underlying bimodal distribution of higher consumers, rather than a single homogeneous population.

The weighted means of total finfish and shellfish consumption rates for both tribes combined were:

Shellfish = 0.272g/kg/d,
Finfish = 0.596g/kg/d, and
Total fish = 0.890g/kg/d.

Table A.3, adapted from the Toy et al.'s table A2, shows consumption rates in grams per kg body weight per day and grams per person (assumed to weigh 70kg) per day.

Table A.3. Combined Tulalip and Squaxin Island results.

	Finfish (g/70kg/d)	Shellfish (g/70kg/d)	Total fish (g/70kg/d)
50th percentile	22.2	8.1	37.2
90th	122.5	58.8	161.8
95th	153.2	91.6	205.5
99th	Not calculated	Not calculated	Not calculated

A.4.3 Suquamish (2000)

Suquamish Tribe (2000). "Fish Consumption Survey of the Suquamish Indian Tribe of the Port Madison Indian Reservation, Puget Sound Region." Suquamish Tribe, Fisheries Department, PO Box 498, Suquamish, WA.

This study used a questionnaire with food models, as well as maps, pictures, and interviews. The study used scripted statistical methods for the questionnaire and ethnographic methods for oral history and elders' interviews. There were 3 special interest groups: children under 6, women between 16 and 42, and elders 55 and over. According to the study,

> Despite degraded water quality and habitat, tribal members continue to rely on fish and shellfish as a significant part of their diet. All species of seafood are an integral component of the cultural fabric that weaves people, the water, and the land together in an interdependent linkage which was been experienced and passed on for countless generations.

Given a SD of 1.26 (from the span of ingestion rates for the Toy study), and a target precision of +/-20%, the target sample size was *n = 150*, indicating that one-quarter of the adults should be sampled. The final sample size was 92 adults (out of 425 eligible) and 31 children. Participants were paid $25. The participation rate was 65%.

Consumption rates "have very little correlation with body weights among adults," but people did not want to report their weights or be weighed. The average weight (males and females combined) was 79kg. As with the Tulalip study, some people report eating more for health benefits, but twice as many people ate less now than 20 years ago due to contamination and restricted access.

Outliers were not recoded because high values were believed to reflect actual high consumption. When tested, it was found that recoding outliers had "virtually no effect" on results. The distribution graph again appears bimodal, with a group of people eating 9–10g/kg/d (750g/d), but the *best fit* line obscures this. One respondent reported an ingestion of 1kg/d, which is nutritionally possible, although it may also have reflected a short-term seasonal availability—it is known that people tend to overestimate whatever is seasonally available and underestimate whatever is out of season.

Adults total mean finfish and shellfish = 2.7g/kg/d
Average finfish = 1.03g/kg/d; shellfish = 1.68g/kg/d
90th percentile = 2.5 finfish, 4.6 shellfish, 6.2 total (all in g/kg/d)
(or 175, 322, 434 in g/70kg/d)
95th percentile = 3.4 finfish, 7.75 shellfish, 10.1 total (all in g/kg/d)
(or 238, 542.5, 707 in g/70kg/d)
99th percentile = not calculated

A.4.4 Sechena et al. (1999)

Sechena, R., Nakano, C., Liao, S., Polissar, N., Lorenzana, R., Truong, S., and Fenske, R. (1999). "Asian and Pacific Islander Seafood Consumption Study," (EPA 910/R-99-003). Seattle: EPA Region 10; http://www.epa.gov/r10earth/offices/oea/risk/a&pi.pdf.

Sechena, R., Liao, S., Lorenzana, R., Nakano, C., Polissar, N., and Fenske, R. (2003). "Asian American and Pacific Islander seafood consumption—a community-based study in King County, Washington." ***J Expo Anal Environ Epidemiol*** **13(4): 256–66.**

This paper describes and quantifies seafood consumption rates and acquisition and preparation habits of 202 first- and second-generation Asian-American and Pacific Islanders (API) from 10 ethnic groups (Cambodian, Chinese, Filipino, Hmong, Japanese, Korean, Laotian, Mien, Samoan, and Vietnamese) in King County, Washington, in 1997.

A sample size of 200 fish consumers was the target, and 202 people participated, with 5–30 interviews per ethnic group. Because it was not possible to pre-identify first and second generation API for random name generation, half the participants were invited to participate from rosters provided by community leaders for random contact, and half were volunteers who had previously been recruited for a Dietary Habits Study. The interviewee pool was adjusted to reflect age and gender of the populations (from census and other information), so the participants had to fit the ethnic, age, and gender profiles before inclusion in the study. If groups were still too small, relatives of participants were actively recruited. The sample size of some ethnicities was deliberately larger than others, according to a judgment about how well established that group was in the Seattle area (e.g., they knew where and how to get fish, etc.). The majority of the 202 respondents (89%) were first generation (i.e., born outside the United States). There were slightly more women (53%) than men (47%), and 35% lived under the 1997 Federal Poverty Line. Participants were paid $25 or given a store voucher

In general, the API members consumed seafood at a very high rate. The average overall consumption rate for all seafood combined was 1.891 grams/per kilogram body weight/day (g/kg/day), with a median consumption rate of 1.439g/kg/day (or a mean of 117.2 and a median of 89g/70kg/day). Seafood consumption based on gender, age, income, and *fishermen* status did not differ significantly. However, mean consumption rates varied significantly between ethnic groups with Vietnamese (2.63g/kg/day) and Japanese (2.18g/kg/day) having the highest average consumption rates, and Mien (0.58g/kg/day) and Hmong (0.59g/kg/day) the lowest.

The predominant seafood consumed was shellfish (46% of all seafood). The most frequently consumed finfish and invertebrates were salmon (93% of respondents), tuna (86%), shrimp (98%), crab (96%), and squid (82%). Fish fillets were eaten with the skin 55% of the time, and the head, bones, eggs, and/or other organs were eaten 20% of the time. Crabmeat including the hepatopancreas was consumed 43% of the time.

Outliers (more than 3 SD from the mean) had “large but uncertain” ingestion rates. They were recoded to 3 SD. Again, fish consumption rates were skewed considerably for all fish groups. The skewed distribution indicates that a few respondents had a larger consumption rate than other respondents. Because outliers had already been recoded within each fish group, these large consumption rates reflected the fact that some API members were, indeed, higher consumers of seafood.

People over 55 ate more fish (131gpd) than younger people (111gpd). There was no correlation with income. Volunteer participants ate very slightly more than roster recruits (random contact from lists). Fishermen and non-fishermen did not show any statistical difference, and there was little or no difference between first generation (foreign born) and second generation (bore here).

Below, Table A.4, adapted from Sechena et al.'s table R-1, presents the consumption rates found.

Table A.4. Consumption Rates of Asian/Pacific Islanders in King County.

Category	N	Median g/kg/d	Mean g/kg/d	Percentage of Consumption	S.E.	95% LCI* g/kg/d	95%UCI** g/kg/d	90% g/kg/d
Anadromous fish	202	0.093	0.201	10.6%	0.008	0.187	0.216	0.509
Pelagic fish	202	0.215	0.382	20.2%	0.013	0.357	0.407	0.829
Freshwater fish	202	0.043	0.110	5.8%	0.005	0.101	0.119	0.271
Bottom fish	202	0.047	0.125	6.6%	0.006	0.113	0.137	0.272
Shellfish Fish	202	0.498	0.867	45.9%	0.023	0.821	0.913	1.727
Seaweed/ kelp	202	0.014	0.084	4.4%	0.005	0.075	0.093	0.294
Miscellaneous seafood	202	0.056	0.121	6.4%	0.004	0.112	0.130	0.296
Totals								
All finfish	202	0.515	0.818	43.3%	0.023	0.774	0.863	1.638
All fish	202	1.363	1.807	95.6%	0.042	1.724	1.889	3.909
All seafood	202	1.439	1.891	100.0%	0.043	1.805	1.976	3.928
All seafood, converted to g/70kg person/d		100.7	132.4			126.4	138.3	274.5
* LCI= lower confidence interval ** UCI = upper confidence interval								

A.5 STUDIES OF SUBSISTENCE FISHERS AND TREATY-BASED CONSUMPTION RATES

In order to document original fish consumption rates, as well as to evaluate the subset of tribal members who maintain a subsistence level of fish consumption, a combination of historical documentation, literature review, and additional ethnographic interviews were used. These three lines of evidence indicate that the range of original rates (also referred to as a treaty-protected rate) is 540 to 1000gpd. Interviews confirm that there are quite a few people who consume fish two to three times a day in various forms (whole filet, soup, powdered thickener or flavoring, dried or smoked as snacks). Some of the primary references are summarized below, with citations of other literature included. It should be noted that these rates persist to the present despite the decimation of salmon runs by canneries and dams, and knowledge of contamination.

A.5.1 Harris and Harper (1997)

Harris, S.G., and Harper, B.L. (1997). "A Native American Exposure Scenario." *Risk Analysis* 17(6): 789–795.

Harris interviewed 75 people in order to identify members of the special interest group (the higher fishing group). A subset of 35 traditional fishers, including many elders, was then interviewed in detail using ethnographic methods. The ethnographic interview is actually a process (Schensul et al. 1999a, b, Spradley 1979, Emerson et al. 1995, Fetterman 1998, Thornton 1998, Mihesuah 1998). It involves establishing community standing and personal credibility, and demonstrating cultural sensitivity and an understanding of what information is proprietary. Without this process, information collected from interviews or questionnaires with Native Americans risks being inaccurate. Interviewees were asked how the accuracy of their responses compared to other studies, including the CRITFC study, and many stated that they do not try to provide accurate information (or actively seek to avoid revealing information) unless they know the person and know how the information could be used or misused. The authors consider this to be an essential part of the bioethics and informed consent safeguards, even if this takes considerably more time than simply asking people to answer questions.

Interviewees reported eating fish daily, with fresh and dried fish in equal weights. This amount reflects one 4-ounce portion of fresh fish and 4 ounces of dried fish, which is equivalent to 12 ounces of wet weight. Since these interviews, more research has been done which indicates that several forms of fish consumption were overlooked, including use of thickeners and flavorings, and the use of whole fish and eggs were probably underestimated. In addition, the CRITFC (1994) results indicate that half of the interviewees ate less than they did twenty years previously. The resulting rate is 540 grams per day.

Anecdotally, people are now eating more fish as the salmon runs are being restored in the Umatilla and Walla Walla rivers. The Umatilla tribes have invested a large amount of money, time, and effort to restore these runs, with the goal of regaining subsistence fishing capabilities.

A.5.2 Walker (1967)

Walker, D.E. (1967). "Mutual Cross-Utilization of Economic Resources in the Plateau: from aboriginal Nez Perce Fishing Practices." Washington State University Laboratory of Anthropology, Report of Investigations, No. 21, Pullman WA.

Walker estimated that fish consumption rates before dam construction ranged from 365 to 800 pounds per year.

A.5.3 Walker (1985)

cited in: **Scholtz, A., O'Laughlin, K., Geist, D., Peone, D., Uehara, J., Fields, L., Kleist, T., Zozaya, I., Peone, T., and Teesatuskie, K. (1985). "Compilation of information on salmon and steelhead total run size, catch, and hydropower related losses in the Upper Columbia River Basin, above Grand Coulee Dam." Fisheries Technical Report No. 2., Upper Columbia United Tribes Fisheries Center, Eastern Washington University, Department of Biology, Cheney, WA 99004.**

Walker reviewed the ethno-historical and scientific literature to estimate the pre-dam fish consumption rates of tribes along the Columbia River. He estimated that total fish consumption (not harvest) was 1000 lbs per capita for lower Columbia tribes, of which 75% was salmon (Umatilla and Yakama estimates), and the Nez Perce also ate 1000 lbs per capita, of which 90% were salmonids (including trout and whitefish). Other early estimates are very close to this. Hewes (1947, 1973) originally estimated from 50 to 900 pounds per year for Plateau tribes by estimating a total catch, subtracting an estimate of the amount of salmon that was traded, used as dog food or otherwise, and adding an additional 1/3 of the weight of the salmon to account for resident fish consumption during the 1/3 of the year that salmon are not running (considering the dried, pounded (pemmican or powder) fish that are eaten in the winter).

Walker improved on Hewes' estimate by using historical observational counts of the Indian catch, rather than a global estimate of a tribe's entire catch for a season. The median annual per capita consumption of salmonids for the Columbia Plateau tribes derived by Walker was 585 pounds per capita. "Walker's figures provide a more accurate picture of the catch...based on direct observation and ethnographic fieldwork."

Other authors were also cited in this reference:

> Schalk (1985) pointed out that the early caloric estimates were for salmon flesh in the ocean. Since salmon lose calories as they migrate upstream, tribes living upriver would actually have to take more fish than tribes living downriver to obtain an equivalent amount of calories.

He estimated that 1.5 pounds of wet weight are equivalent to 1 pound dried, and that 20% of a whole fish is entrails. Schalk estimated that a family needs 250 to 500 dried fish per family, or 2000 pounds per family.

Walker also cited Swindell (1942), who interviewed 55 family heads from Yakama, Umatilla, and Warm Springs (not specifically fishing families) for an average of 322 pounds/yr in 1941 (the time when the canneries were taking a large percentage of the fish, leaving fewer for the Indians). Hewes estimated that Cayuse ate 365 pounds per capita, while Umatilla and Walla Walla ate 500 pounds per capita.

Yakama, Klickitat, Wanapum, and Palus were estimated to eat 400 lbs, and Nez Perce were estimated to eat 300 lbs.

Hudson Bay records from 1827, 1829, and 1830 indicated that the company supplemented the regular supplies that were shipped to them by purchasing about 535 lbs of fish per person (about 30 people were housed at the Colville Post), as well as around 100 lbs dried venison (for the 30 men), 1500 pounds of fresh venison, 10 beavers, 275 ducks, 200 geese, 10 cranes, 75 dogs, 50 grouse, and a few swans, beaver tails, and small fish.

A.5.4 Walker (1992)

Walker, D.E. (1992). "Productivity of Tribal Dipnet Fishermen at Celilo Falls: Analysis of the Joe Pinkham Fish Buying Records." *Northwest Anthropol. Res. Notes* 26(2): 123–135.

Walker reviewed an earlier reference (Anastasio 1972), who reviewed historical accounts of early explorers, as well as thoroughly reviewing ethnographic and ethnohistoric research. Archaeological research indicates that this region has been the scene of relatively continuous anadromous fishing activity for at least 10,000 years. Walker reviewed fish buying records in 1945, a time when fish runs were declining rapidly, continuing a trend begun with the canneries. Over the years, packing house and cannery records support statements that salmon runs have been 99% decimated.

A.5.5 Walker (1999)

Walker, D.E., and Pritchard, L.W. (1999). "Estimated Radiation Doses to Yakama Tribal Fishermen: An Application of the Columbia River Dosimetry Model for the Hanford Environmental Dose Reconstruction Project." Boulder, CO: Walker Research Group.

This study relied on the use of officially recorded fishing sites along the Columbia River mainstem, and interviews with the individuals who actually used those sites between 1950 and 1971. Fishermen were grouped as maximum, median, or minimum river users according to how many fishing sites they held. Minimum river users used between 1 and 9 fishing sites, and ate 64 pounds per year (29kg/yr or 80gpd). Median river users used between 10 and 19 sites and ate 282 pounds per year (128kg or 350gpd). Maximum river users "would be considered subsistence fishermen," and used 20 or more fishing sites. They ate 522 pounds per year (237kg or 650gpd). 75% of fish were caught between April 1 through October 31; of this 75%, 90% was anadromous and 10% was resident. Between November 1 and March 31, 25% of the annual catch was caught; of this 75% were resident and 25% anadromous.

A.5.6 Hunn (1990)

Hunn, E.S. (1990). *Nch'i-Wana, The Big River: Mid-Columbians and Their Land*. Seattle: University of Washington Press.

Hunn estimated that 30–40% of caloric needs supplied by salmon. Table 13 (Hunn 1990, page 150) provides estimates of salmon consumption per capita from Hewes (not including resident fish during the winter quarter): Wishram Tribe (400 pounds per year), Tenino Tribe (500 pounds), Umatilla Tribe (500 pounds), and Nez Perce Tribe (382 pounds from Hewes's estimate and 582 pounds from Walker's estimates), including the adjustment for caloric loss as fish move upstream.

A.5.7 Ray (1977)

Ray, V.E. (1977). "Ethnic Impact of the Event Incident to Federal Power Development on the Colville and Spokane Indian Reservations." Prepared for the Confederated Tribes of the Colville Reservation and the Spokane Tribe of Indians, Port Townsend, WA. Available at Eastern Washington State Historical Society, Spokane WA.

Ray provided expert testimony of the amount of fish consumption of the upper Columbia River tribes during the discussions of the impact of the Grand Coulee Dam. Ray estimates 1.25 pound per person per day based on 50 years of observation and research, including fish counts, catch rates, early observers. This is also supported by contemporaneous observations at Celilo during the late 1940s:

> The salmon and other fish taken from the rivers provided around half of the native subsistence, and the lands immediately adjacent to the rivers supplied a significant part of the game which was taken.
>
> Apart from fish and game, the most important component of the Indian diet was roots.
>
> Salmon was the staple food for both the Colvilles and the Spokanes. The fish were taken during the long fishing seasons—May to October—but during the same period great quantities were dried to serve and the basic item of subsistence during the winter.

A.5.8 Boldt (1994), case law

Judge Boldt stated that "Salmon, however, both fresh and cured, was a staple in the food supply of these Indians. It was annually consumed by these Indians in the neighborhood of 500 pounds per capita."[9] Boldt was referring to Columbia mainstem fishers when he wrote this. This does not include resident fish.

[9] U.S. District Judge George Boldt, U.S. v. Washington, February 12, 1974, note 151.

A.5.9 Bimodality in Tribal Communities

In the above discussion, we have suggested that the cross-sectional tribal surveys summarized in Section A.4 revealed a bimodal distribution, with a cluster of people consuming high amounts of fish. We believe that these are accurate reports from members of a distinct group of subsistence consumers, and that most of this group is missed in cross-sectional surveys because they decline to participate in conventional surveys. However, this raises the question of how a tribe or tribal confederation should be stratified, and whether this reflects simply a high end tail of a normal distribution defined by an arbitrary upper percentile or standard deviation, or whether there is a discernible subset of tribal members with a distinct lifestyle and/or a statistically detectable consumption rate.

- In the Sechena study, respondents were divided into low (<75th percentile) or higher (>75th percentile) consumers; the basis for this is not given.
- In the Walker (1999) study, Columbia River mainstem fishers were divided into three groups according to how many fishing sites were used by a fisherman; the basis for this was not given.
- In the three tribal cross-sectional studies, there appear to be clusters of high consumers; since no follow-up was done to investigate the characteristics or accuracy of these individuals, we conclude (as others have concluded) from indirect evidence that these people are members of a subsistence subset that is otherwise obscured by poor study design, and that their reports were indeed accurate.
- In our review of subsistence and cross-sectional studies, we have concluded that a threshold for subsistence consumption rates is roughly 1 pound per day, without regard to the shape of a distribution curve.

The Confederated Umatilla Tribes have distinct subsets of natural resource use according to the original tribe's homeland; Cayuse emphasized upland hunting more than fishing, while Walla Walla and Umatilla tribes emphasized fishing more than hunting. During ethnographic interviews, several subsistence consumers confirmed our supposition that traditional subsistence fishers generally decline to participate in surveys by people they don't know, or give information that they assume is *correct* rather than information that is accurate.

A.6 CONCLUSION

We conclude that the subsistence consumption rate for the Confederated Tribes is in the range of 540 to 650gpd or more (particularly at permanent fishing villages such as Celilo). Within this range, we have concluded that the best estimate is 500 pounds per year (or 620gpd) as the central tendency of subsistence fish consumption, as well as being recognized in a widely cited legal decision.

- The CRITFC study (1994) is judged to reflect the median river user (350gpd from Walker) and minimum river users (80gpd from Walker). This is comparable to the CRITFC 95th and 99th percentiles (175–182gpd and

389gpd) and the CRITFC median (63gpd), further indicating that the CRITFC study captured data for the minimum and median river users, not the maximum river users.

- The CRITFC "outliers" (reporting a consumption rate of 486–972gpd) are comparable to Walker's maximum river users (650gpd), which reflect subsistence use.
- Most per capita estimates of fish consumption rates for subsistence fishers are approximately 500 pounds per year, or 620gpd as a mean value. These results are based on direct observation of early observers, fish buying records, interview with current members, caloric and nutritional calculations, and ecological and archaeological information.
- Salmon supplied 30 to 40% of the total calories in the river-based subsistence diet. At an average of 175 kcal per 100g of raw fish weight, 620gpd would provide roughly 1000 kcal daily, which is 40% of a 2500 kcal diet. This conforms with the estimates of Hunn and others that salmon provide 30–40% of the subsistence diet.
- The number of people in the high consumer or maximum river user group diminished as runs were decimated, dams were constructed, and awareness of contamination increased. However, the existence of the subsistence or maximum river user clearly persists to this day, and in fact may be increasing recently as runs are restored and health benefits of eating fish are emphasized.

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APPENDIX B

NATIVE AMERICAN SWEAT LODGE EXPOSURE SCENARIO—EXPOSURE EQUATIONS

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B.1 INHALATION IN SWEAT LODGE

In this analysis it is assumed that the internal temperature of the sweat lodge is maintained at a constant 150 °F (339 °K) (personal communication). It is further assumed that the geometry of the lodge can be estimated as a hemisphere of radius r so that the internal volume is equal to:

$$V_{lodge} = \frac{2}{3} \cdot \pi \cdot r^3 \qquad (1)$$

where:

V_{lodge} = internal volume of the sweat lodge (m^3)
r = radius of sweat lodge (m)
π = the constant *pi* (unitless); $\pi \approx 3.14159$

Finally, contaminants, termed Compounds of Potential Concern (COPC), are assumed to be introduced into the sweat lodge predominately through the water used to create steam.

B.1.1 Volatile and Semi-Volatile Compounds

For the purpose of the following analysis, volatile and semi-volatile compounds are defined as those with a boiling point less than, or equal to, 339 °K. Intake of COPCs via inhalation is typically estimated as:

$$I_{inh} = \frac{C_v \cdot IR \cdot ET \cdot EF \cdot ED}{BW \cdot AT \cdot CF} \qquad (2)$$

where:

I_{inh} = inhalation exposure to COPCs in the sweat lodge (mg/kg-day)
C_v = vapor phase COPC concentration (mg/m^3)
IR = inhalation rate (m^3/hr)
ET = exposure time (hr/event)
EF = exposure frequency (events/yr)

ED = exposure duration (yr)
BW = body weight (kg)
AT = averaging time for carcinogens (AT_C) or noncarcinogens (AT_N) (yr)
CF = units conversion factor of 365 (day/yr)

For compounds that preferential partition to the air phase, it is assumed that a negligible quantity deposit on surfaces or partition into condensed liquid. Thus, the bulk of contaminants added in the water will remain in the vapor phase throughout the sweat. The vapor concentration of an individual COPC is given by:

$$C_v(t) = C_{dw}\left(\frac{V_w(t)}{V_{lodge}}\right) \tag{3}$$

where:

C_{dw} = dissolved surface water concentration of the COPC (mg/L); calculated according to EPA 1998a, Appendix B
$C_v(t)$ = time dependent vapor phase concentration of the COPC in the sweat lodge (mg/m^3)
$V_W(t)$ = cumulative volume of water used in the sweat at time t; see the discussion of $V_W(t)$ below (L)

Combining equations 1 through 3 and recognizing that the total inhalation exposure for a single sweat requires integration of the volume function over the duration of the sweat results in the following equation for inhalation exposure:

$$\int_0^{ET} I_{inh}(t)\cdot dt = I_{inh} = \frac{C_{dw}\cdot\left(\dfrac{1}{\frac{2}{3}\cdot\pi\cdot r^3}\right)\cdot IR\cdot EF\cdot ED}{BW\cdot AT\cdot CF}\cdot\int_0^{ET} V_w(t)\cdot dt \tag{4}$$

If it is assumed that water is poured over heated rocks at a constant rate throughout the sweat, then the volume function would be described by the following linear equation:

$$V_w = \frac{V_{w,total}}{ET}\cdot t \tag{5}$$

Where $V_{w,total}$ is the total amount of water that will be used in the sweat to create steam in units of liters (L).

Noting that:

$$\int_0^{ET} V_w(t) \cdot dt = \frac{V_{w,total}}{ET} \cdot \int_0^{ET} t \cdot dt = \frac{V_{w,total}}{2} \cdot ET \qquad (6)$$

then the intake by inhalation is described by the following equation:

$$I_{inh} = \frac{C_{dw} \cdot \left(\frac{V_{w,total}}{2} \right) \cdot \left(\frac{1}{\frac{2}{3} \cdot \pi \cdot r^3} \right) \cdot IR \cdot ET \cdot EF \cdot ED}{BW \cdot AT \cdot CF} \qquad (7)$$

If more water is poured over the heated rocks during the first part of the sweat, then the following form would be more appropriate:

$$V_w(t) = \frac{V_{w,total} \cdot t}{k + t} \qquad (8)$$

where $V_{w,total}$ is the maximum amount of water poured over the heated rocks during a sweat and k indicates the time when half of the water has been used. Integration of the above equation between the limits of 0 and ET results in the following expression for intake via inhalation:

$$I_{inh} = \frac{C_{dw} \cdot \left(\frac{V_{w,total}}{\frac{2}{3} \cdot \pi \cdot r^3} \right) \cdot \left(ET + k \cdot \ln\left(\frac{k}{ET + k} \right) \right) \cdot IR \cdot EF \cdot ED}{BW \cdot AT \cdot CF} \qquad (9)$$

The assumptions regarding the mathematical representation of water volume in the sweat lodge are an uncertainty in estimating intake via inhalation for the Native American adult. For simplicity, the linear assumption represented by equations 5 and 7 is a reasonable approximation for intake via inhalation of volatile and semi-volatile compounds in the sweat lodge. Table B.1 provides a list of typical values for the parameters used in Equation 7.

Table B.1. Typical parameter values for calculating intake via inhalation (I_{inh}) for volatile and semi-volatile compounds.

Parameter	Typical Value	Unit
Volume of water used in a sweat ($V_{w,total}$)	4	L
Radius of a hemispherical sweat lodge (r)	1	m
Inhalation rate (IR)	30	m^3/day
Length of a sweat event (ET)	1	hr/event
Number of sweats per year (EF)	365	events/yr
Number of years a person sweats in a life time (ED)	64	yr
Average body weight (BW)	70	kg
Averaging time (AT)	70 (carcinogen) ED (noncarcinogens)	yr
Conversion factor (CF)	365	day/yr

B.1.2 Nonvolatile Compounds

For the purpose of the following analysis nonvolatile compounds are defined as those with a boiling point greater than 339 °K. The sweat lodge vapor concentration for nonvolatile compounds can be estimated by assuming that:

- Nonvolatile COPC become airborne as an aerosol as the water they were carried in vaporizes.
- Once airborne, nonvolatile compounds deposit onto solid surfaces with aqueous condensation.
- The ideal gas law can be applied to air and water vapor at the temperature and pressure of the sweat lodge.

With these assumptions the quantity of nonvolatile constituents in the air phase is limited to that which is carried into the air phase by the volume of liquid water needed to create saturated conditions in the lodge. Numerically this can be expressed as:

$$C_v = \left(\frac{V_{w,sat}}{V_{lodge}}\right) \cdot C_{dw} \tag{10}$$

where $V_{w,sat}$ represents the volume of liquid water needed to create a saturated vapor in the sweat lodge in units of liters (L). From the ideal gas law and the properties of liquid water, $V_{w,sat}$ can be determined from:

$$V_{w,sat} = \left(\frac{p \cdot V_{w,air}}{R \cdot T}\right)\left(\frac{MW_w}{\rho_w}\right) \tag{11}$$

where:

$V_{w,air}$ = volume of air space in sweat lodge occupied by water vapor (m^3)

p = ambient pressure (mmHg)
ρ_w = density of liquid water (g/L)
T = temperature of the sweat lodge (K)
R = ideal gas law constant (0.06237 (mmHg·m^3)/(gmole·K))
MW_w = molecular weight of water (AMU)

The volume of water vapor in the sweat lodge air can be estimated from the vapor pressure of water at the temperature of the sweat lodge (assumed constant at 339 °K), the ambient pressure, and the internal volume of the lodge.

$$V_{w,air} = \left(\frac{p^*}{p}\right) \cdot V_{lodge} \tag{12}$$

where $p*$ represents the vapor pressure of water at temperature T (mmHg). The vapor pressure of water as a function of temperature is given by the Antoine equation as follows (Himmelblau 1982):

$$\ln(p^*) = 18.3036 - \frac{3816.44}{T - 46.13} \tag{13}$$

Combining equations 10 through 13 allows the concentration of nonvolatile COPC in the air to be determined as follows:

$$C_v = C_{dw} \cdot \left(\frac{MW_w}{R \cdot T \cdot \rho_w}\right) \cdot EXP\left(18.3036 - \frac{3816.44}{T - 46.13}\right) \tag{14}$$

Application of Equation 14 to the definition of vapor inhalation exposure given in Equation 2 yields the following result for nonvolatile compounds:

$$I_{inh} = \left(\frac{IR \cdot ET \cdot EF \cdot ED}{BW \cdot AT \cdot CF}\right) \cdot C_{dw} \cdot \left(\frac{MW_w}{R \cdot T \cdot \rho_w}\right) \cdot EXP\left(18.3036 - \frac{3816.44}{T - 46.13}\right) \tag{15}$$

Table B.2 provides a list of typical values for the parameters used in Equation 15.

Table B.2. Typical parameter values for calculating intake via inhalation (I_{inh}) for nonvolatile compounds.

Parameter	Typical Value	Unit
Temperature of the sweat lodge (T)	339 (150)	K (F)
Ideal gas law constant (R)	0.06237	(mmHg·m^3)/(gmole·K)
Inhalation rate (IR)	30	m^3/day
Length of a sweat event (ET)	1	hr/event
Number of sweats per year (EF)	365	events/yr
Number of years a person sweats in a life time (ED)	64	yr
Average body weight (BW)	70	Kg
Averaging time (AT)	70 (carcinogen) ED (noncarcinogens)	yr
Conversion factor (CF)	365	day/yr
Molecular weight of water (MW_w)	18	g/gmole
Density of liquid water (ρ_w)	1000	g/L

B.2 DERMAL EXPOSURE IN SWEAT LODGE

Dermal exposure to COPC in a sweat lodge can come from skin contact with contaminates in both the air and water that condense on the skin. Calculation of dermal exposure to COPC from water contacting the skin is typical represented by the following equations:

$$I_{d,l} = \frac{C_{dw} \cdot SA \cdot f_{SA,l} \cdot Kp_l \cdot ET \cdot EF \cdot ED \cdot CF_3}{BW \cdot AT \cdot CF_2} \qquad (16)$$

where:

- $I_{d,l}$ = intake of COPCs from dermal absorption to liquid within the sweat lodge (mg/kg-day)
- C_{dw} = dissolved-phase surface water concentration (mg/L); calculated according to EPA 1998a, Appendix B
- SA_l = body surface area available for contact (m^2)
- $f_{SA,l}$ = fraction of skin area (SA) in contract with liquid (unitless)
- Kp_l = COPC-specific water-to-skin permeability constant (cm/hr)
- ET = exposure time (hr/event)
- EF = exposure frequency (events/yr)
- ED = exposure duration (yr)
- CF_2 = units conversion factor of 365 (day/yr)
- CF_3 = units conversion factor of 10 (L/m^2-cm)
- BW = body weight (kg)
- AT = averaging time for carcinogens (AT_C) or noncarcinogens (AT_N) (yr)

Dermal exposure resulting from skin contact with contaminants in the air is calculated as:

$$I_{d,v} = \frac{C_v \cdot SA \cdot f_{SA,v} \cdot Kp_v \cdot ET \cdot EF \cdot ED \cdot CF_1}{BW \cdot AT \cdot CF_2} \qquad (17)$$

where:

- $I_{d,v}$ = intake of COPCs from dermal absorption to vapor within the sweat lodge (mg/kg-day)
- C_v = vapor-phase concentration for a COPC (mg/m^3)
- $f_{SA,v}$ = fraction of skin area (SA) in contract with vapor (unitless)
- Kp_v = COPC-specific vapor to skin permeability constant (cm/hr)
- CF_1 = units conversion factor of 0.01 (m/cm)

B.2.1 Volatile and Semi-Volatile Compounds

Dermal exposure should be calculated using the same assumptions described for inhalation exposure. For volatile and semi-volatile compounds (defined as those with a boiling point less than or equal to 339 °K), 100% volatilization with a hemispherical sweat lodge was assumed. Hence, the primary exposure pathway will be from vapor and exposure from condensed water can be neglected. The vapor concentration of COPC causing dermal exposure is identical to the inhalation concentration and is given by equations 3 and 5. Combining equations 3 and 5 with Equation 17 and integrating between the limits of 0 and ET results in the following prediction from dermal exposure to volatile and semi-volatile compounds:

$$I_{d,total} = I_{d,v} = \frac{C_{dw} \cdot \left(\frac{V_{w,total}}{2}\right) \cdot \left(\frac{1}{2/3 \cdot \pi \cdot r^3}\right) \cdot SA \cdot f_{SA,v} \cdot Kp_v \cdot ET \cdot EF \cdot ED \cdot CF_1}{BW \cdot AT \cdot CF_2} \qquad (18)$$

where $I_{d,total}$ is the total dermal exposure rate for volatile and semi-volatile compounds. Table B.3 provides a list of typical values for the parameters used in Equation 18.

Table B.3. Typical parameter values for calculating total dermal exposure rate ($I_{d,total}$) for volatile and semi-volatile compounds.

Parameter	Typical Value	Unit
Volume of water used in a sweat ($V_{w,total}$)	4	L
Radius of a hemispherical sweat lodge (r)	1	m
Body surface area available for contact (SA)	1.8	m^2
Fraction of skin area (SA) in contact with vapor ($f_{SA,v}$)	0.0–1.0	unitless
COPC-specific permeability constant for vapor exposure (Kp_v)	1 to 1E-5	cm/hr
Length of a sweat event (ET)	1	hr/event
Number of sweats per year (EF)	365	events/yr
Number of years a person sweats in a life time (ED)	64	yr
Average body weight (BW)	70	kg
Averaging time (AT)	70 (carcinogen) ED (noncarcinogens)	yr
Conversion factor (CF_1)	0.01	m/cm
Conversion factor (CF_2)	365	day/yr

B.2.2 Nonvolatile Compounds

For non-volatile compounds (defined as those with a boiling point greater than 339 °K), the dermal exposure assumptions would result in a concentration in condensed water equal to that of the water added to the heated rocks and a vapor concentration as described by Equation 14. Thus, exposure through dermal contact resulting from water condensing on the skin would be calculated using the following equation:

$$I_{d,l} = \frac{C_{dw} \cdot SA \cdot f_{SA,l} \cdot Kp_l \cdot ET \cdot EF \cdot ED \cdot CF_3}{BW \cdot AT \cdot CF_2} \tag{19}$$

The dermal exposure to COCP in the vapor phase is represented by combining equations 17 and 14 as follows:

$$I_{d,v} = \left(\frac{(SA \cdot f_{SA,v} \cdot Kp_v \cdot ET \cdot EF \cdot ED \cdot CF_1}{BW \cdot AT \cdot CF_2} \right) \cdot C_{dw} \cdot \left(\frac{MW_w}{R \cdot T \cdot \rho_w} \right) \cdot \ldots$$
$$\ldots EXP\left(18.3036 - \frac{3816.44}{T - 46.13} \right) \tag{20}$$

In this equation $f_{SA,v}$ and Kp_v represent the fraction of skin area (SA) in contact with vapor and the COPC-specific permeability coefficient for a contaminant from vapor to the skin.

The total dermal exposure for nonvolatile compounds is thus represented by the sum of $I_{d,v}$ and $I_{d,l}$. That is:

$$I_{d,total} = I_{d,v} + I_{d,l} \quad (21)$$

It should be noted that at the temperature conditions assumed for a sweat lodge it is acceptable to neglect the vapor component of dermal exposure, since it will always be less than 0.2% of the liquid exposure value. This can be demonstrated by computing the ratio of the vapor to liquid exposure rates. In this calculation it should be recognized that, in a sweat lodge, more of the body surface area will be covered with a layer of liquid water (condensation and perspiration) than would be dry and so available for only vapor contact (i.e., $f_{SA,l} > f_{SA,v}$). In addition the vapor permeability coefficient is generally within an order of magnitude of the corresponding liquid coefficient (EPA 1992). With these assumptions the ratio of vapor to liquid dermal exposure is given by:

$$\frac{I_{d,v}}{I_{d,l}} = \frac{CF_1 \cdot MW_w}{CF_3 \cdot \rho_w \cdot R \cdot T} \cdot \frac{f_{SA,v}}{f_{SA,l}} \cdot \frac{Kp_v}{Kp_l} \cdot EXP\left(18.3036 - \frac{3816.44}{T - 46.13}\right) \leq 1.6 \times 10^{-3} \quad (22)$$

Hence, for the purposes of this evaluation the dermal exposure to nonvolatile compounds can be represented by:

$$I_{d,total} = I_{d,l} \quad (23)$$

Table B.4 provides a list of typical values for the parameters used in Equations 19 through 23.

Table B.4. Typical parameter values for calculating total dermal exposure for nonvolatile compounds ($I_{d,total}$).

Parameter	Typical Value	Unit
Volume of water used in a sweat ($V_{w,total}$)	4	L
Radius of a hemispherical sweat lodge (r)	1	m
Body surface area available for contact (SA)	1.8	m^2
Fraction of skin area (SA) in contact with liquid ($f_{SA,l}$)	0.0–1.0	unitless
Fraction of skin area (SA) in contact with vapor ($f_{SA,v}$)	1.0–$f_{SA,l}$	unitless
COPC-specific permeability constant from vapor contact with skin (Kp_v)	1 to 1E-5	cm/hr
COPC-specific permeability constant from water contact with skin (Kp_l)	1 to 1E-5	cm/hr
Length of a sweat event (ET)	1	hr
Number of sweats per year (EF)	365	events/yr
Number of years a person sweats in a life time (ED)	64	yr
Average body weight (BW)	70	kg
Averaging time (AT)	70 (carcinogen) ED (noncarcinogens)	yr
Molecular weight of water (MW_w)	18	g/gmole
Density of liquid water (ρ_w)	1000	g/L
Temperature of the sweat lodge (T)	389 (150)	K (F)
Ideal gas law constant (R)	0.06237	$(mmHg \cdot m^3)/(gmole \cdot K)$
Conversion factor (CF_1)	0.01	m/cm
Conversion factor (CF_2)	365	day/yr
Conversion factor (CF_3)	10	L/m^2-cm

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The Spokane Tribe's Multipathway Subsistence Exposure Scenario and Screening Level RME

by

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ABSTRACT

Exposure scenarios are a critical part of risk assessment; however, representative scenarios are not generally available for tribal communities where a traditional subsistence lifestyle and diet are relevant and actively encouraged. This article presents portions of a multipathway exposure scenario developed by AESE, Inc. in conjunction with the Spokane Tribal Cultural Resources Program. The scenario serves as the basis for a screening-level reasonable maximum exposure (RME) developed for the Midnite Uranium Mine Superfund site. The process used in developing this scenario balances the need to characterize exposures without revealing proprietary information. The scenario and resulting RME reflect the subsistence use of original and existing natural resources by a hypothetical but representative family living on the reservation at or near the mine site. The representative family lives in a house in a sparsely populated conifer forest, tends a home garden, partakes in a high rate of subsistence activities (hunting, gathering, fishing), uses a sweat lodge daily, has a regular schedule of other cultural activities, and has members employed in outdoor monitoring of natural and cultural resources. The scenario includes two largely subsistence diets based on fish or game, both of which include native plants and home-grown produce. Data gaps and sources of uncertainty are identified. Additional information that risk assessors and agencies need to understand before doing any kind of risk assessment or public health assessment in tribal situations is presented.

Key Words: Native American; subsistence diet; multipathway; exposure scenario

1 INTRODUCTION

Exposure assessment has been termed the "wasteland of risk assessment"[4] because so much information is lacking with regard to exposure patterns and rates, and this is especially true for specific populations such as Native American communities. The need to address a tribe's subsistence exposure is based on fundamental considerations of the tribe, as a people, and the role the reservation and its natural resources play in supporting them. The United States recognizes that Indian reservations were, and are, intended to provide permanent homelands for members of the particular tribes. As such, those members possess the inherent right to use reservation natural resources for subsistence, religious, and other cultural purposes. The Spokane Tribe's effort to preserve its culture and environmental quality has, on numerous occasions, been formally memorialized by pronouncements of the Tribe's official governing body. The immediate impetus for developing this tribal scenario is the Midnite Uranium Mine Superfund Site, an inactive open-pit uranium mine located on the Spokane Reservation, that has contaminated various media with radionuclides and heavy metals. The exposure scenario described herein is an effort to ensure the proper evaluation of risk to Spokane Tribal members who engage in traditional practices in areas affected by the mine. While this scenario attempts to include as many activities related to Spokane cultural practices as possible, there undoubtedly exist unintended omissions and instances of understated exposure. It is important for readers to understand that this scenario is designed to reflect traditional lifestyles whose practice has been and remain the long-term intent of the tribal council, rather than a current snapshot of statistical cross-sectional surveys. While the latter may be more "quantitative," they would not provide the level of protection needed for safe practice of traditional ways.

The scenario relies on existing ethnographic information about traditional Spokane lifestyles identified by the Tribe as accurate(1-3) as well as confirmatory interviews with elders. The Spokane Tribe has determined that information regarding cultural activities, gathering areas, and resources is a cultural resource, and restricts access to that information (Spokane Tribal Resolution 1996-0018); therefore, details regarding specific species, locations, uses, or activities that are deemed proprietary have been omitted.

The scenario also serves as the basis for a screening-level reasonable maximum exposure (RME) developed for the Midnite Uranium Mine Superfund site. This paper presents portions of a multipathway exposure scenario developed by AESE, Inc.(4) in conjunction with the Spokane Tribal Cultural Resources Program. It includes dietary factors specific to the Spokane Tribe and builds on previous work(5), refines some of the exposure factors used in earlier work, and demonstrates how a complex scenario can be used to develop a screening-level RME under CERCLA. It should be noted that the term "subsistence" has been used in this article as a short-hand

[4] Carol Henry, American Chemistry Council, quoted in Wakeland, 2001 *EHP 108*(12): A559.

term which encompasses a broader range of activities than those necessary to sustaining human life such as eating and drinking. It includes other cultural and religious practices as well, such as medicinal and ceremonial uses of natural resources.

Our experience in developing tribal subsistence-based exposure scenarios has led to a set of technical, ethical, and procedural rules:

- To be most useful to regulators and others seeking to protect the health of subsistence users, the information should be developed with an eye toward satisfying appropriate court rules for admissibility of expert testimony. While both state and federal courts have such rules, Federal Rule of Evidence 702, on which many state court rules are modeled, is the most widely applied and interpreted. Rule 702 permits "a witness qualified as an expert by knowledge, skill, experience, training, or education" to testify when his or her "scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue." In response to two U.S. Supreme Court cases holding trial judges responsible for excluding unreliable expert testimony, Rule 702 recently was qualified by amendment. To be admissible, the rule now requires federal courts to find: "(1) the testimony is based upon sufficient facts or data, (2) the testimony is the product of reliable principles and methods, and (3) the witness has applied the principles and methods reliably to the facts of the case." The subsistence scenario incorporates information from a variety of disciplines, including cultural and traditional environmental knowledge. To prevent a challenge to the admissibility of the subsistence scenario as being unreliable, we wish to ensure that the subsistence scenario has been developed as much as possible using general scientific criteria adopted from the *Daubert* case:[5]

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[5] See *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579 (1993) (holding trial courts responsible for excluding unreliable scientific expert testimony); *Kumho Tire Co. v. Carmichael*, 526 U.S. 137 (1999) (holding trial courts responsible for excluding unreliable nonscientific expert testimony). An authoritative discussion of *Daubert* and the reliability tests for expert testimony is contained in the Federal Rules of Evidence Advisory Committee Notes, which accompany Rule 702. They include a "nonexclusive" list of considerations for reliability of scientific expert testimony under *Daubert*:

(1) whether the expert's technique or theory can be or has been tested—that is, whether the expert's theory can be challenged in some objective sense, or whether it is instead simply a subjective, conclusory approach that cannot reasonably be assessed for reliability;
(2) whether the technique or theory has been subject to peer review and publication;
(3) the known or potential rate of error of the technique or theory when applied;
(4) the existence and maintenance of standards and controls; and
(5) whether the technique or theory has been generally accepted in the scientific community.

Kumho found that depending on the particular circumstances of the case, these factors may also apply to nonscientific testimony. Other factors considered by post-*Daubert* courts include: whether the expert's opinions were developed independent of litigation or for the purpose of testifying; whether there exists too great an analytical gap between data and opinion; whether obvious alternative explanations have been accounted for; and whether the same level of intellectual rigor is applied in

- That each parameter can be tested or verified (documented, modeled, measured, or elicited from acknowledged experts), and that each assumption has been systematically validated. Risk assessors can rely on ethnographic data, verbal representations from subsistence practitioners, and so on. We relied on (1) open peer-reviewed literature on exposures through different but analogous pathways and caloric content of foods, (2) ethnographic documents and reports concerning traditional lifestyles and practices, and (3) statements from tribally recognized cultural experts. This latter expertise derives from their traditional environmental knowledge, and is based on confidential information, so we cannot verify it in the sense of reanalyzing raw numerical data, but we can verify the expertise of the cultural experts who summarized their knowledge of resources and activity patterns for us.
- That another risk assessor could repeat the same steps and would construct essentially the same scenario, because the approach for developing an exposure scenario is fairly standardized.
- That the scenario is accepted by colleagues as reasonable and factual rather than eccentric, unreliable, or mere opinion, or that it meets the "general acceptance" test set forth in *Frye v. United States*, 293 F. 1013 (App. D.C. 1923), the predecessor case to *Daubert.* We satisfy this criteria by obtaining peer review from qualified colleagues ("the relevant scientific community") even beyond the editorial peer-review process. Does this mean that exposure scenarios for over 500 tribes must be peer reviewed and published in *Risk Analysis* in order to be admissible in court should they be challenged during a CERCLA or NEPA process? We believe that if a standardized process is followed and the scenario is reviewed by an advisory board of qualified peers that actual publication is not necessary, even though publication in a peer-reviewed journal is a commonly accepted standard for peer review.

- The scenario must be both scientifically relevant and reliable, and culturally relevant and reliable. The process must be culturally sensitive, respectful, draw on traditional environmental knowledge (such as the observational expertise of elders), and must be developed from within the tribe by a toxicologist/risk assessor in partnership with tribal cultural and technical experts. Collaboration with the Cultural Resources Program provided the cultural assurance.
- Policy-level approval must be obtained. The process must meet Institutional Review Board rules or their equivalent for conducting human research (which we believe includes cultural or anthropological research) such as informed consent, benefit to the tribal community, disclosure of the risk of adverse consequences, and confidentiality. Repeated conversations with tribal program managers and/or policy makers ensured that there was an understanding of the way that the risk information was to be used, the potential adverse consequences of developing a scenario from a risk acceptance perspective or precedent, and related concerns.

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the testimony as would be required in field practice. In addition to reliability, courts will require a testifying expert to be "qualified," and the testimony must be relevant and helpful to the trier of fact. Thus, the emphasis is on testimony being relevant and reliable more than on whether there is a strict litmus test of generating a theory and statistically testing a null hypothesis.

- Identifying resources and activities on a base map overlain by ecological habitats, and constructing a dependency web (culturally relevant natural history diagrams)[6] as a pictorial representation of the ethnohabitat proved helpful. A subsistence food pyramid is another useful tool.

2 THE SPOKANE TRIBE AND ITS ECOCULTURAL LANDSCAPE

The Spokane Indians are part of the Interior Salish group, which has inhabited northeastern Washington and northern Idaho since time immemorial.[1] The Spokane Reservation lies at the confluence of the Spokane and Columbia Rivers in northeastern Washington. Salmon was the most important commodity in the early economy of the Tribe. Since the construction of Columbia River dams the anadromous salmon are no longer available. Instead, Kokanee (landlocked sockeye salmon) and resident trout and other species have been substituted. Abundant game also supports an alternative game diet, along with a wide variety of roots, berries, and other plants. Because the reservation is still fairly pristine and undeveloped, it provides enough resources for some members to continue a traditional subsistence dietary lifestyle, and for all members to obtain traditional foods.

The ecology of the reservation area is characteristic of the arid montane areas of the northern Columbia Basin transitioning into the Okanagon highlands to the north. Annual precipitation is approximately 16 inches. The Spokane lands include the two major rivers (the Columbia River and one of its tributaries, the Spokane River) including the waters to their far banks, and various other large and small tributaries, springs, ponds, and wetlands. Mount Spokane is a central feature of the reservation landscape. A Douglas fir zone exists at the highest elevations, with Ponderosa pine and Western juniper zones with a variety of understories at lower elevations, and grassland-sagebrush shrub steppe and riparian areas along the waterways.[7-9] Areas affected by activities at the Midnite Mine include the mined area on Mount Spokane and adjacent upland habitats, several seeps and springs with riparian habitats, and a major creek (Blue Creek) which empties into the Spokane River arm of Lake Roosevelt, the reservoir created in the Columbia River by the Grand Coulee Dam.[10]

The Spokane traditional lifestyle is governed by ecological seasons and the activities that people undertake in response. A significant portion of the population follows this lifestyle in full or in part. Hunting, fishing, and gathering are essential to support nutritional, cultural, spiritual, and medicinal needs of tribal members. Hunting and gathering on the reservation is allowed based on the needs of the family. Typically, all family members work in the field on a regular basis to keep the extended family unit stocked with a wide variety of plants and wildlife. While in the field, tribal members live off the land by consuming surface and spring water, wild plants, and wildlife. In addition to the time spent in hunting, fishing, or gathering, time is also spent cleaning, processing, and preserving hides, drying vegetal food or medicines, and making a wide variety of items. The Spokane people use over 200 varieties of plants.[11] Huckleberries are gathered, as are a wide variety of roots, shoots, moss, leaves, stems, cambium, seeds, and flowers. Most natural resources have several human uses[12,13] as well as providing multiple ecological functions and services. A more complete description of edible plants, ethnographic information, plant technology, ethnobotany, and ethnopharmacology is found in AESE.[4]

The location of the Spokane Reservation is shown in Figure 1.

Figure 1. Continental U.S. with Spokane Reservation Location

3 GENERALIZED LIFESTYLE OF A REPRESENTATIVE COMPOSITE SPOKANE TRIBAL FAMILY

This section describes a family-based exposure scenario founded on traditional Spokane lifestyles and diets (one fish-based diet and one game-based diet). This hypothetical but representative family lives in a house in a sparsely populated conifer forest, tends a home garden, pursues a high rate of subsistence activities and a regular schedule of other cultural activities. The lifestyle is moderately active, with daily sweat lodge use and outdoor employment. The family composition was determined with the guidance of the Spokane Tribal Culture Program and current tribal demographics. Each family includes an infant/child (age 0–2 years) who breastfeeds for two years and crawls and plays; a child (age 2–6), a youth (age 7–16) who attends school, plays outdoors near his/her residence, and is learning traditional practices; two adult workers (one male, one female, age 17–55; the female breastfeeds the infant) who work outdoors on reclamation and environmental and cultural activities and who also engage in subsistence activities, and an elder (age 56–75) who is partly at home and partly outdoors teaching and demonstrating traditional cultural practices. All members (except the infant) partake in family sweat lodge use and in cultural activities throughout the year. In actuality, a family typically includes members who are employed conventionally and members who are full-time subsistence providers.

3.1 RESIDENCE

A conventional suburban scenario would identify a person living at home and growing a garden. The subsistence family is superficially similar to this, but they live in a more open house, spend more time outdoors in cultural and subsistence activities, eat both garden and native foods, and are fully interactive with the environment. The family spends its entire lifetime on the reservation, rather than the suburban default assumption of 30 years. The house has no landscaping other than the natural Ponderosa and understory, some naturally bare soil, a gravel driveway, no air conditioning, and a wood-burning stove in the winter for heat. Each house has its own well for domestic use and a garden irrigated with groundwater and/or surface water. Each house has a nearby sweat lodge. The amount of indoor dust is not known, but is likely to be higher than in suburban communities with manicured lawns, air conditioning, and paved streets.

3.2 GENERALIZED DAILY ACTIVITY PATTERNS OF EACH FAMILY MEMBER

Due to space limitations, the average daily activity pattern is not described for each age range and each gender, but in the full scenario, such information would be included in this section.(6) While activities of Spokane males and females are different, they likely result in a similar frequency and duration of environmental contact, so the genders may be separated or combined. The daily activity patterns can also be combined into entire lifetimes for the evaluation of cumulative risk.

3.3 SWEAT LODGE USE (AGES 2–75)

The daily use of the sweat lodge is an integral part of the lifestyle that starts at age two. Sweat lodge construction has been described in the open literature.[14,15] Although the details vary among tribes and among individual families, sweat lodges are generally round structures (6 feet in diameter for single-family use). A nearby fire is used to heat rocks that are brought into the sweat lodge. Water (4L) is poured over the rocks to form steam (a confined hemispheric space with complete evaporation of the water, which is available for inhalation and dermal exposure over the entire skin area). Water is ingested (1L is included in the total drinking water ingestion rate) and medicinal plants are used (not specifically included).

3.4 CULTURAL ACTIVITIES

All persons participate in day-long outdoor group cultural activities once a month, such as pow-wows, horse races, and seasonal ceremonial as well as private family cultural activities. These activities tend to be large gatherings with a greater rate of dust resuspension and particulate inhalation. Individuals also tend to be more active during the ceremonies, resulting in greater inhalation and water ingestion rates. These activities are folded into the higher soil ingestion, water ingestion, and inhalation rates rather than being estimated on a single-event basis.

3.5 DIET

The Spokane food pyramid looks markedly different from the USDA food pyramid. Caloric needs are generally cited in the range of 2,000 to 4,000 kcal per day for adult males, depending on the level of activity. We use 2,500 kcal/day for the Spokane Tribe, based on a moderately active outdoor lifestyle and renowned athletic prowess (as did Scholz[3]). The original diet of the Spokane Indians was based on salmon and included large and small game, roots, berries, and many other plants.[2, 3,11] Hunn[16] estimated that 45% of the native Columbia Plateau dietary calories came from protein (fish and game), with higher estimates for upriver tribes such as the Spokane.[3] Historically, the Spokane Tribe consumed roughly 1,000 to 1,500 grams of salmon and other fish per day.[2,3] The most robust upper bound estimate of original (predam) salmon intake by the Spokane Tribe is the Walker estimate (cited in Reference 3) of 1,200 pounds per year of salmon per adult, or 1,426 gpd (about 3 pounds/day), yielding 2,566 kcal/day before migration (i.e., if caught in the estuary) and 2566 x 0.64 = 1643 kcal/day after migration from the ocean to the Spokane area. With the construction of the Grand Coulee Dam, the anadromous salmon runs were destroyed, so there was a shift to big game and to Kokanee and resident trout. Because the intent of this scenario is to evaluate exposures that traditional members currently receive and that more members will receive as they regain a traditional diet, two diets were evaluated: a high fish diet and a high game diet. Eighty percent of each diet is native, augmented with vegetables grown in a household garden. The current realistic high fish diet based on availability, percentage of the diet, and caloric content consists primarily of fish (885 g/d, somewhat lower than historical levels), supplemented by big game, aquatic amphibian/crustacean/mollusks, small mammals, and upland game birds. The high game diet reverses the fish-game quantities, and both diets include identical amounts of native and domestic plants. Both forms of the diet are approximately 40% protein, 25% fat, and 35% carbohydrate (given the limited data available for native foods), which is comparable to other hunter-gatherer diets.(17) Until recently, this diet was even higher in fish-derived protein, and was stable for at least 5,000 years (based on archaeological evidence of salmon runs). The carbohydrates are largely unprocessed and include many roots but little grain. The fats are from fish, game, nuts, and seeds.

3.6 DRINKING WATER

Daily replacement water needs are approximately 2L/100 pounds body weight (more during exercise or pregnancy).[6] Athletic activity can result in a loss of 1.5 L/hour; replacement volumes are recommended as 1 to 1.5 ml/kcal of energy expended.(18) Harris and Harper(5) estimated an average water ingestion rate of 3 L/day for adults, based on total fluid intake for the Confederated Tribes of the Umatilla Indian Reservation. However, that number did not account for all uses. This scenario includes adult water ingestion of 1L while at home (from the household water supply), 1L taken from home to the worksite, 1L consumed from worksite sources, and 1L from the household or spring to rehydrate during use of the sweat lodge, for a total of 4 L/d.

3.7 SOIL INGESTION

Soil ingestion by young children (0–6 years) is assumed to be 400 mg/day for 365 days/year. This is higher than the prior EPA default value of 200 mg/day.(19) It reflects both indoor dust and continuous outdoor activities analogous to gardening or camping,(20) but is less than a single-incident sports or construction ingestion rate.(21,22,23) For adults, the soil ingestion value is also 400 mg/day, reflecting an unspecified upper percentile.(21) This value also better reflects the environmental setting, the typical residential situation, gardening and gathering activities, the preparation and consumption of native and garden plants, the consumption of other natural foods, and a variety of additional outdoor activities (work, play, cultural activities). However, it may still substantially underestimate the amount of soil and sediment on garden produce and gathered plant foods. In particular, episodic events such as gathering in wetlands or road work could result in 1 gram of soil ingested per event,(21,22,23) which may be over and above the 400 mg ingested daily. If there is geophagy (eating dirt for micronutrients or salt), the ingestion would be higher yet. In fact, the intentional presence of some Mother Earth in food may be beneficial medically(23) and spiritually.

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[6] U.S. Air Force at http://www.capnhq.gov/nhq/cp/ encampments/AETC.htm#AETC.; Coyle at http://www.veggie.org/veggie/fluid.exercise.shtml.

3.8 INHALATION RATE

We believe that an inhalation rate of 30 m^3/d is more accurate for the Spokanes' active, outdoor lifestyle than the EPA default rate of 20 m^3/d.[(21)] EPA[(21)] reviewed several extensive studies that examined ventilation rates based on direct measurement and activity diaries in developing the default rate of 20 m^3/day. EPA recognizes that special populations, such as athletes or outdoor workers, have higher average rates and recommends calculating their inhalation rates using the following median hourly intakes for various activity levels (in m^3/hr): resting = 0.4, sedentary = 0.5, light activity = 1, moderate activity = 1.6, heavy activity = 3.2. For outdoor workers, a median rate is 1.3, with an upper percentile of 3.3, depending on the ratio of light, moderate, and heavy activities during the observation time. "Inhalation rates may be higher among outdoor workers/athletes because levels of activity outdoors may be higher, therefore, this subpopulation group may be more susceptible to air pollutants and are considered a 'high risk' subgroup."[(21)] Using this EPA guidance, a median rate of 26.2 m^3/d is obtained from eight hours sleeping, two hours sedentary, six hours light activity, six hours moderate activity, and two hours heavy activity. This represents minimal heavy activity (construction, climbing hills, etc.), and is a median rather than a reasonable maximum. The California Air Resources Board[(25)] also reviewed daily breathing rates based on activity levels and concluded that 20 m^3/d represents an 85th percentile of typical American adult lifestyle (eight hours sleeping and 16 hours of light to moderate activity), a lifestyle that is less active than an outdoor lifestyle in a topography that includes steep slopes, as on the Spokane Reservation.

4 A SCREENING-LEVEL COMPOSITE RME

Due to the number of age groups, daily activities, and limited EPA funds for determining both media-specific exposure point concentrations as well as developing and subsequently running the risk model, EPA requested that the Tribe condense the scenario into a screening-level composite RME application for use in the Midnite Mine risk assessment (Table 1). The principle of developing a screening scenario is to reduce the number of calculations by combining (not eliminating) pathways and age groups, and maximizing exposure factors to a reasonable degree. The screening-level risk assessment then generally employs the composite RME and the upper 95th percentile exposure point concentrations in each medium, wherever they occur throughout the site, so that any location, activity, diet, or water source has the chance to drive risk. This means that the result of the screening level risk assessment is not strictly location, pathway, age, or activity specific. It only indicates whether unacceptable site-wide risk is possible and shows the spatial aspects of the risk profile if plotted on a base map. In the future, EPA or the Tribe will need to use the full scenario and location-specific exposure point concentrations to assess risk attributable to location, pathway, age, or activity. Such information will be required to evaluate the remedial alternative during the feasibility study and to quantify residual risk once remediation has been completed.

The full scenario was condensed as follows. The daily time allocation is 12 hrs/d indoors, 2 hours in the sweat lodge, 7 hours outdoors working, playing, and other non-subsistence activities, and 3 hours of subsistence activities in *each* contaminated area where these activities might occur. This will result in more than a 24-hour day, but is necessary to reduce the number of calculations. Alternately, the person can live and subsist at the single most contaminated location. Soil ingestion remains at 400 mg/d for 365 days/year (100 mg from indoor sources and 300 from outdoor sources; for multiple contaminated sub-sites, each contributes 300 mg, which could result in more than 400 mg/d; alternately, the single most contaminated soil location can serve as the sole source of soil-based exposure). For application to other areas, such as wetlands, 1 gram per visit may be used.[21,22] Drinking water remains at 4 L/d, which is derived from the most contaminated source (this is duplicated for surface and groundwater if both are contaminated). This results in an upper bound sitewide risk estimate. Risks for an actual individual who specializes in certain activities (i.e., the hunter or the fisher), spends more time in fewer locations or a single location, or fully utilizes a contaminated medium such as groundwater, could be as high as but no higher than this upper bound estimate. Subsequent analyses using either the complete scenario or the composite RME can examine particular pathways and locations, or can be used to support risk management decision such as remedial goals, subsistence soil and water remedial screening levels, or tribal regulatory standards.

Table 1. The Spokane subsistence composite RME scenario.

Medium	Description (Not All Routes of Exposure are Listed)
Groundwater	Each family has their own well for drinking/household, watering the garden, sweat lodge
Surface water	Each family uses surface water (seep and creek) for domestic and garden use, washing locally gathered materials, and the worker uses surface water during fieldwork and sweat lodge
Air	Indoor radon, sweat lodge radon, outdoor radon daughters, inhalation of resuspended dust, inhalation of aerosols
Soil	Direct ingestion, deposition on plants, as-gathered conditions, and indirect (uptake from soil to plant)
Sediment	Duplicates the soil; gathering may include high rates of sediment exposure that may be underestimated
Sweat lodge	Daily for 2 hours, using groundwater (springs) or surface water
Pathway	**Description (Not All Routes of Exposure are Listed)**
Inhalation	$30m^3$/d to accommodate indoor and outdoor activities; the inhalation rate for strenuous outdoor activities may actually be underestimated (can be discussed as a source of uncertainty)
Drinking water	4 L/d; this is duplicated for surface and groundwater if both are contaminated; fluid replacement needs for strenuous activity may be underestimated
Other water uses	Garden irrigation, dermal and inhalation while showering, other standard routes of exposure
Sweat lodge	Steam, inhalation, immersion
Soil ingestion	400 mg/d (100 mg/d from indoor sources and 300 mg/d from outside sources); outdoor sources may vary in concentration; indoor dust is equal to local outside soil; this is duplicated if sediment is included; episodic events 1 gram each
Other	Other factors are as reported previously (dermal, etc.; Harris and Harper, 1997)

High Fish Diet—About 2500–3000 kcal/d (Moderate Adult Level)		High Game Diet—About 2500–3000 kcal/d (Moderate Adult Level)	
Fish (10% of which is organ meat with 10x concentrations; sockeye and mixed trout are used for calorie estimates)	885 g/d = 1300 kcal	**Big game** (10% of which is organ meat with 10x concentrations; deer and elk are used for calorie estimates, not beef)	885 g/d = 1000 kcal
Big game	100 g/d = 110 kcal	**Fish**	75 g/d = 180 kcal
Local small game, fowl	50g/d = 75 kcal (or 25g birds, 25g rabbits)	**Local small game, fowl**	50g/d = 75 kcal (or 25g birds, 25g rabbits)
Aquatic foods (mussels and crayfish are nutritionally similar)	175 g/d = 120 kcal	**Aquatic foods**	175 g/d = 120 kcal
Vegetal calories 10% garden (above ground); 10% garden (below ground); 40% gathered terrestrial below ground; 20% gathered terrestrial above ground; 20% aquatic	1600 gpd = about 1000 kcal (mixed species)	**Vegetal calories** 10% garden (above ground); 10% garden (below ground); 40% gathered terrestrial below ground; 20% gathered terrestrial above ground; 20% aquatic	1600 gpd = about 1000 kcal (mixed species)
Other calories (medicines, etc.)	Not determined	**Other calories** (medicines, etc.)	Not determined
Dairy (children only)	0.5 L/d milk	**Dairy** (children only)	0.5 L/d milk

Notes

- The best estimate of original (predam) salmon intake by the Spokane Tribe is the Walker estimate (cited in Scholz et al., 1985) of 1,200 pounds per year of salmon per adult, or 1,426 gpd (about 3 pounds), yielding 2,566 kcal before migration and 2566 x 0.64 = 1643 kcal after migration from the ocean to the Spokane area. The current 885 gpd is based on a combination of calories estimates, availability, interviews, and dietary balance. The current Spokane diet relies on Kokanee (landlocked sockeye) and trout (bull or Dolly Varden, rainbow), suckers, whitefish, other species. Salmon and steelhead are obtained whenever possible. Mussels and crayfish were also eaten regularly.
- Both fish and game are eaten fresh, smoked, or dried, but there are no data on calories or contaminant concentrations according to method of preparation. No contaminant loss during preparation is assumed, since contaminants could become more concentrated as well as being lost with fat loss.
- The dietary data are not adequate to distinguish fruit, berries, greens, roots, bulbs, fungi/moss, seeds/nuts, medicines, or sweeteners on a caloric basis, nor domesticated from wild plants. If data for uptake from soil/sediment or dust/sediment load for a native species becomes available, the intake of that species will be estimated. The proportion of above and below ground plants is based on reliance on tubers and bulbs, using USDA caloric information on domesticated plants from the same plant families. Intake of other plants (medicines, rose hips, etc.) occurs but was not determined.
- Dairy may be underestimated (cheese, milk), and eggs are not specifically included, but should be included depending on the information supplied by tribal members.
- While many animal species are similar with respect to how much nutrition they provide to people, their contaminant concentration will vary according to their habitat and ecological niche, as well as their location and size of home range. This is estimated through the ecological food web or actual sampling data.
- All of the exposure factors are constant through the year (i.e., they apply 365 days/year).

Table 2 shows some of the major differences between EPA default exposure factors and our subsistence scenario. We are not presenting a sensitivity analysis in this article because the relative contribution of various exposure factors will depend on the concentration of contaminants in various media and their physical parameters, and specific human activity patterns at the contaminated site. This will be the subject of another article. However, we expect that the major factors for subsistence lifestyles or lifestyles with high environmental contact rates will be soil ingestion, drinking water, exposure duration, and diet. We should note that the dietary factors in the *Exposure Factors Handbook* reflect major categories of the diet rather than a necessarily complete diet—adding average caloric content for the categories identified in the *Handbook* totals about 2000 kcal/d for the general population, which is lower than actual national average caloric intakes by up to one-third. That other third of the diet is not likely to come from the contaminated site, so from an exposure perspective this does not detract from suburban dietary exposure estimates. The subsistence diet in this paper, however, yields a full day's calories (~2500 kcal). If one tried to construct a subsistence diet solely from the *Handbook*, the caloric intake would fall short of an adequate amount even if the intake factors for Native Americans were used. One could erroneously equate "subsistence" with a modern diet supplemented with fish, game, and wild plants using intake rates that are given in the *Handbook*. This could be due to several factors: whether reservation dwellers were specifically sampled during the three-day recall surveys (versus urban or suburban dwellers who happened to be Native American), the difference between current reservation conditions (with USDA commodity foods) and a truly subsistence lifestyle, socioeconomic factors, and so on. Thus, developing a subsistence exposure scenario with a traditional diet and cultural practices specific to reservation living needs to rely primarily on ethnographic data and cultural information, and only secondarily on national dietary survey data.

Table 2. Examples of differences in exposure factors for a 70 kg adult.

Parameter	Default Value[1]	Subsistence Value[2]
Drinking water ingestion	2 L/day	4 L/d (includes 1L during sweat lodge use)
Soil ingestion	200 mg/d (children) 50 mg/d (adult)	400 mg/d for all ages
Inhalation tate	20 m^3/d	Varies by average activity level; 30 m^3/d
Meat & fish ingestion[3]	21.1 g/d (general population) and 70–170 (subsistence); 17.5 g/d (general population) and 142.4 g/d (subsistence)	885–1000 g/d fish and 100 g/d meat (high fish diet), or 885 g/d meat and 75 g/d fish (high game diet); 50 g/d small game for each, 175 g/d shellfish for each; no dairy for adults is included in this total
Vegetable ingestion	Fruit and vegetable totals: 539 g/d; grain: 287 g/d[4]	1600 g/d; fraction obtained locally = 1, both gathered and home-grown
Exposure frequency	Varies according to climate and activity	365 d/yr unless documented otherwise
Exposure duration	30 yrs (assumes retirement elsewhere) or less (average time spent in a home)	70 yrs (a full lifetime)

[1] EPA *Exposure Factors Handbook*, in totals per day assuming 70 kg body weight.
[2] These values apply only to the Spokane Tribe unless verified specifically for other tribes. Dietary factors are specific to the Spokane Tribe. Total caloric intake is assumed to be the same for both scenarios but in fact may be higher for the more athletic outdoor lifestyle.
[3] *Exposure Factors Handbook*, Volume II, Section 10.10 recommends using 21.1 g/d total fish and shellfish as the mean value for the general population and 70 g/d for Native American subsistence populations (mean value) or 170 g/d (95th percentile). EPA Office of Water (Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health 2000, EPA-822-B-00-004 and Water Quality Standards for Indian Country at www.epa.gov/ost/standards/tribal/tribalfact.html) uses 17.5 g/d as the 90th percentile for the general population and 142.4 g/d for subsistence populations as the 99th percentile, all in uncooked weight. These values are all for adults and are all based on current cross-sectional surveys that likely omit traditional tribal members. The Spokane value reflects existing documentation on historical subsistence consumption rates with caloric evaluation, confirmatory interviews with the tribal cultural staff, and tribal policy goals for regaining traditional healthy cultural lifestyles, not on dietary surveys.
[4] *Exposure Factors Handbook*, Volume II (mean values).

5 DATA GAPS AND SOURCES OF UNCERTAINTY ASSOCIATED WITH THE SCREENING-LEVEL RME

An incomplete list of data gaps and uncertainties are briefly discussed below. The relative error caused by each uncertainty cannot be ascertained at this time. We believe that the overall uncertainty and variability are greater in tribal communities than in suburban communities due to the greater number of risk factors and the potential for several risk factors to cluster in particular communities and individuals. Because tribal members could be at greater risk due to both greater exposure and greater sensitivity, an additional safety factor or precautionary approach may be warranted in these types of situations.

5.1 MOBILE VERSUS STATIONARY RME

The typical suburban RME for members of the general population is a house-bound individual with a local garden, or a residential farmer who is largely self-sufficient. In these cases, the house and garden are assumed to be located at the contaminated site and available for unrestricted use. The subsistence family also lives where the contamination occurs if this is physically possible, but may spend more time away from the immediate residence during subsistence activities. However, a subsistence RME should not assume that exposure is diluted by spending significant amounts of time in uncontaminated areas. For large sites with variable contaminant concentrations, problems arise when trying to perform a single risk assessment to evaluate multiple hot spots (as not-to-exceed concentrations), even if the risk assessment assumes that the person moves around from hot spot to hot spot or if all subsistence activities are assumed to occur where the upper 95th concentration limit occurs. Additionally, the problem of spatially integrating widespread contamination still remains because, conceptually, 10 acres of contamination poses a greater risk than 1 acre with the same contaminant concentration. Temporally, persistent contaminants pose a longer risk, and therefore a greater total risk, than degradable contaminants. Unfortunately, the present regulatory framework does not use spatial or temporal risk metrics (such as risk acre-years, or dose per community gene pool across several generations) to account for this cumulative exposure over time and space and people.

5.2 SPECIAL ACTIVITIES

There are special circumstances when some people may be highly exposed that have not included in the complete scenario or the screening-level RME. For instance, some men hunt or fish for the general community, and many people provide roots and fish and game to elders in addition to their own families. Gathering of some plants (e.g., cattails, water potatoes, reeds and rushes) is a very muddy activity, and rivershore or lakeshore activities may underestimate sediment exposure (soil ingestion can be 1 gram per event[21,22,23]). Washing, peeling, weaving rushes, and other activities results in additional exposure. For example, basketmakers clean and wash their materials, incur cuts on their hands, and hold materials in their mouth. Flintknappers may receive additional exposure through obtaining and working with their materials. In addition, there are potential pathways that are not specifically identified but which might contribute additional exposure, such as contaminated firewood used for smoking food, plants used for teas, flavoring, smudging, or medicine, contact with contaminated animal parts (paints, bone ornaments, clothing), sitting on the ground for long periods of time while processing or during ceremonial activities, and so on. Even though the composite activity patterns are intended to reflect reasonable maximum exposures, there is a potential for underestimating some pathways (i.e., this is not a worst-case scenario).

5.3 COMMUNITY EXPOSURE BURDENS

An entire community exposure burden estimate or population dose estimate may be needed that includes people who do not reside in but occasionally visit the contaminated area (this includes inadvertent intruders onto the site). If a resource is contaminated, the entire community is exposed. The assumption that protecting the RME adequately protects everyone else may result in a failure to provide all the information that the tribe's governing body needs for informing its members. There may be sensitive individuals (children, elders, the sick, the occupationally exposed) who, arguably, may or may not be protected by using standard reference doses and other factors. Also, tribal leaders often make decisions at the community rather than the individual level (i.e., the survival of the individual may not be as important as the survival of the family or community, so the community is also an appropriate unit of analysis). Therefore, decisions where everyone is exposed to a low level of contamination may be different from and more stringent than decisions where a few individuals are at high risk or decisions where risks are distributed over time, space, and populations rather than localized. We believe this to be an important but understated element of real risk and risk-based decision making (not to be dismissed as perceived risk, or cultural amplification of real risk, or a risk management determination). The nature and extent of community exposure can be estimated over time and space by estimating the number of people and the number of generations that could live in each area or concentration isopleth and be exposed (a community chemical effective dose equivalent). The total number of generations and the number of people per generation need to be described in terms of the total number of people exposed, total dose for the community (or the gene pool), proportion of each generation exposed, and so on. Even more broadly, the total dose for a small community's combined gene pool or neuronal pool could be estimated. Finally, the proportion of each generation that is affected, rather than simply the number of people (in a small population), can be determined.

5.4 BACKGROUND EXPOSURE AND COMMUNITY-WIDE EXPOSURE FROM OTHER SOURCES

Under the National Contingency Plan and subsequent EPA guidance, EPA is charged with evaluating incremental risk to humans caused by a release from the subject site. This means that when evaluating a Superfund site, EPA is not charged with evaluating risk associated with high concentrations of naturally occurring substances, such as arsenic measured in background soil, water, or food, if the concentrations were not increased by on-site activity, nor risk associated with releases of contaminants from another site. When there is background contamination (however that is defined), or widespread low-level contamination, this contamination contributes to cumulative exposure to many or all people in the community. From a human health standpoint, the origin of the contaminant is irrelevant. However, from a liability-based regulatory standpoint such as CERCLA, the origin is paramount. In the case of the Spokane scenario, it is known that Columbia River fish are contaminated with PCBs and metals (there are existing fish advisories for Lake Roosevelt and for an upriver portion of the Spokane River), but cleanup at the mine site is proceeding as if this contamination is not present or that people are not exposed to it. When an entire community is exposed to non-site contaminants, we believe that this should be included as part of the total risk burden, and that the clean-up goals for the incremental risk posed by the site itself may need to be modified (see, for instance, OSWER Environmental Justice Action Agenda, EPA 540/R-95/023, which states that “OSWER supports Agency-wide efforts to develop scientifically valid standards to measure cumulative risk.”). Other EPA approaches are more cumulative in nature, such as the Guidance on Cumulative Risk Assessment (http://www.epa.gov/ORD/spc/cumrisk2.htm); Toward Integrated Environmental Decision Making (EPA-SAB-EC-00-011; http://www.epa.gov/science1/ecirp011.pdf); and various permitting programs based on total toxicant burdens in a watershed or airshed. As another example, the EPA approach to arsenic or other substances in drinking water is to require treatment to safe levels even if these are lower than natural background levels.

5.5 INDIVIDUAL EXPOSURE FACTORS

The exposure assessment literature is lacking relevant information for subsistence activities. For instance, gardening or camping are typically used by risk assessors as an analogue for hunting and gathering activities, athletic physiological factors are used as an analogue for the more vigorous outdoor activities, sports nutrition information is used in checking diet, and so on. Several pathways are simply unknown, such as the use of medicinal plants (further, certain of these pathways need to be included in a way that does not violate confidentiality). We believe that some factors, particularly soil ingestion, are still underestimated. The amount of exposure obtained as a person consumes wild foods (often without being able to wash them first as is assumed in a typical suburban scenario) is unknown, as is the amount of soil remaining on gathered vegetation even if it is washed, because environmental samples are generally not analyzed in an as-gathered or as-consumed condition.

5.6 ECOLOGICAL FOOD WEB AS AN INPUT TO HUMAN EXPOSURE

At present, the Tribe does not know if the ecological risk assessments being prepared by EPA for the Midnite Mine will provide the appropriate information for estimating human subsistence dietary information. Existing ecological and human health risk models are generally incompatible. Ecological models typically have more species but fewer pathways, while human health models have many more pathways but generally less trophic-level capability. The lack of transfer factors (soil to plant, and dispersion through the food web) may also pose a problem. EPA is attempting to address this nationally; it is especially important to include tribal considerations during these discussions.

5.7 SEASONALITY AND ACUTE EXPOSURES

Some of the original activity patterns over the annual seasonal cycle have been modified in modern times, but the ecological cycles have not. Therefore, people must still gather plants according to when they are ripe, hunt according to game and fowl patterns, and fish when the spawning runs occur. The Spokane Tribe Cultural Resources Program confirmed that although specific activities change from one season to the next throughout the year, these activites are replaced by other activities with a similar environmental contact rate. This scenario assumes that exposure is fairly homogeneous because even in winter months materials are gathered, cleaned, and used, and native foods are eaten (i.e., all factors are applied 365 days per year). However, it is possible that excessive acute exposures occur, over and above the annually averaged exposure rates included in this scenario.

5.8 CO-RISK FACTORS

Many co-risk factors cluster in tribal communities, including poverty, higher rates of existing health conditions (such as diabetes), poorer access to health care, inadequate infrastructure, 500 years of cumulative psychological stress, employment in occupations with more chemical exposures, and so on. Data on other factors such as enzyme polymorphisms related to detoxification or disease susceptibility are simply absent. Each of these factors is known to influence the health response to chemicals, although data are lacking about their combined effect as well as their prevalence in any particular tribal community.

6 CONCLUSION

Although the scenario discussed in this article greatly improves the accuracy of risk-based decision making in Indian Country, much still remains to be done in order for tribes to achieve the same proportional degree of risk reduction that suburban communities have enjoyed for many decades. Existing human-health-based regulatory standards were not developed with subsistence in mind, so tribes are always less protected because they are always more exposed. This is not meant to indict standards as intentionally ignoring certain populations, simply that there are situations and populations that did not receive attention when the regulations were written many years ago. The inequity of this situation has not been fully explored, but is the topic of current research. Additionally, this scenario is not generalizable to other tribes, particularly the diet section, although the soil and drinking water exposure factors may prove to be fairly similar for many tribal settings.

The true worth of any risk assessment is measured by whether its results are used, even if the ultimate decision is based more on other factors such as economics, technical feasibility, or precaution. One of the goals of a project manager is to achieve a stable decision, or one that is durable over time, even if this is not explicitly stated. Decision stability is not merely due to compromise or consensus, but also to whether a community's expectations are met regarding the specific metrics and impacts to be assessed. Decisionmakers or community leaders have certain information needs that can help design a truly useful risk assessment, even if the assessment takes form somewhat differently from the norm. We believe that deliberately incorporating community concerns into both the risk assessment and the risk management decision makes decisions more stable and robust, not less scientific. It is a matter of opinion whether responding to community issues within the risk assessment itself, rather than deferring these items until a later risk management phase, improves the assessment and makes it more useful by tailoring it to the specific situation, or merely results in inconsistency by making results less useful for comparing risks between sites.

We would also like to raise the bar for risk ethics. The traumatic history of federal actions against tribes is still recent history for many tribal nations and tribal members experience remnants of federal extermination and assimilation policies literally every day. This is a strong and discomforting statement, but it is a reality that risk assessors and project managers must recognize if they work on tribal risk issues. It might even be said that tribes are still at war, a war that is being fought in the courts on a daily basis to preserve their rights, jurisdiction, resources, religion, homeland, and way of life. We do not want risk assessors to underestimate how serious this is to tribal members and tribal staff. Many or most tribal members can name ancestors who died defending their rights and homelands, and the current generation of tribal scientists honors this by vigilantly protecting the rights and resources on which their culture and identity and existence depend. Mistrust of the federal government and its risk assessment tools can be extremely high and pervasive. Particularly in tribal communities, risk assessors or public health assessors typically run afoul of tribal perspectives because they do not understand the community and its history. There is a tendency to want to get the details right first, then step back and look at the implementation or consequences (i.e., to keep risk assessment separate from risk management). We do not intend to introduce bias into the risk assessment that might come from knowing so much about the community that unconscious judgments are made about how to tailor the assessment (for instance, making a subconscious determination that remediation might take dollars away from other visibly urgent needs). We simply want the assessor to be more aware of the subjects of his or her assessment from the start so as to avoid pitfalls, missteps, and negative community reactions. Currently, tribes and regulators still operate from two different decision paradigms. We wish to recognize the tremendous progress made in recent years by various federal agencies in increasing the attention paid to these issues, but we recognize how much remains to be done.

DISCLAIMER

This exposure scenario has been approved for publication by the Spokane Tribal Council and for use in the Midnite Mine risk assessments. It should not be viewed as a release or waiver of any claims or rights concerning the protection of human health and the environment, the injury of natural resources, or any other claim or right.

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APPENDIX A

INHALATION RATE

Inhalation Rate = 25m^3/d (adult)

A.1 SUMMARY

The inhalation rate in the indigenous scenarios reflects the active, outdoor lifestyle of traditional tribal members, including youth who are learning traditional subsistence skills, adult outdoor workers who also hunt, gather, and fish, and elders who gather plants and medicines, and prepare and use them (e.g., making medicines or baskets, etc.) and who teach a variety of indoor and outdoor traditional activities. Traditional tribal communities have no sedentary members except the frail elderly, whereas one-quarter of modern American adults of all ages report no leisure time physical activity at all.[1] We have estimated the activity levels associated with this lifestyle and diet using published anthropological studies, ethnographic literature on foraging theory, hunting-gathering lifestyles, and interviews with tribal members. Using EPA guidance on hourly inhalation rates for different activity levels, a reasonable inhalation rate for an average tribal member's active lifestyle is an average rate of 26.2m^3/d, based on 8 hours sleeping at 0.4m^3/hr, 2 hours sedentary at 0.5m^3/hr, 6 hours light activity at 1m^3/hr, 6 hours moderate activity at 1.6m^3/hr, and 2 hours heavy activity at 3.2m^3/hr. Unlike most other exposure factors, which are upper bounds, the inhalation rate is an average rate. This could result in under-protection of children, the elderly, athletes, asthmatics, and the half of the population with above-average inhalation rates. However, to be consistent with national methodology, we have rounded the rate to 25m^3/day.

A.2 POPULATION-SPECIFIC PHYSIOLOGY

Perhaps the most relevant factors associated with ethnic specificity of metabolic and inhalation rates are the thrifty genotype(s), insulin use, and oxidation and adiposity patterns (Goran 2000, Fox et al. 1998, Muzzin et al. 1999, Rush et al. 1997, Saad et al. 1991, Kue Young et al. 2002), as well as ethnic differences in spirometry (Crapo et al. 1988, Lanese et al. 1978, Mapel et al. 1997, Aidaraliyev et al. 1993, Berman et al. 1994). Research on the thrifty genotype suggests that there may be several stress response genes that enable indigenous populations to respond to environmental stresses and to the rapid transition between extremes, including feast and famine, heat and cold, disruption in circadian rhythms, dehydration, seasonality, and explosive energy output or rapid transitions between minimum and maximum exercise and $VO2_{max}$ (Kimm et al. 2002, Snitker et al. 1998). These genes "uncouple" several energy expenditure parameters (Kimm et al. 2002) and generally

[1] http://www.cdc.gov/brfss/pdf/ 2001prvrpt.pdf and http://www.cdc.gov/brfss/pubrfdat.htm.

support the logic of using a higher inhalation rate for active outdoor lifestyles, especially in Native American populations.

A.3 SHORT-TERM VERSUS LONG-TERM INHALATION RATES

Most federal and state agencies either use the EPA default value of $20m^3/d$ or use activity levels to estimate short-term and long-term inhalation rates. For these exposure scenarios, activity levels were evaluated through anthropological data (foraging theory and activity descriptions in the anthropological literature) and confirmatory interviews with tribal elders, and used the CHAD-based EPA recommendations for ventilation rates for the different activity levels. Several examples of similar approaches are:

- EPA's National Air Toxics Assessment (homepage: http://www.epa.gov/ttn/atw/nata/ natsa3.html) uses the CHAD database in its HAPEM4 model to estimate national average air toxics exposures, even though "the lack of activity pattern data that extend over longer periods of times presents a challenge for HAPEM4 to predict the long-term (yearly) activity patterns that are required to determine chronic exposures." Therefore, "an approach of selection of a series of single day's patterns (from CHAD) to represent an individual's activity pattern for a year was developed."
- The California Air Resources Board (CARB 2000) reviewed daily breathing rates based on activity levels and measured ventilation rates for many activities in the CHAD database. The average hourly rate for sleeping was $0.5m^3/hr$, light activities at $0.55m^3/hr$, moderate activities at $1.4m^3/hr$, and heavy rates of activity levels at $3.4m^3/hr$. The CARB concluded that $20m^3/d$ represents an 85th percentile of typical adult sedentary/light activity lifestyles. This is based on 8 hours sleeping and 16 hours of light activity with no moderate or heavy activity, or 1 hour per day of moderate and heavy activity each.
- In their technical guidance document, "Long-term Chemical Exposure Guidelines for Deployed Military Personnel," the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) recommended an inhalation rate of $29.2m^3/d$ for U.S. service members. Deployed personnel were assumed to spend 6 hours sleeping at an inhalation rate of $0.4m^3/hr$, 4 hours in sedentary activities (at $0.5m^3/hr$), 6 hours in light duties (at $1.2m^3/hr$), and 8 hours in moderate duties (at $2.2m^3/hr$).[2]
- EPA used $30m^3/day$ for a year-long exposure estimate for the general public at the Hanford Superfund site in Washington state, based on a person doing 4 hours of heavy work, 8 hours of light activity, and 12 hours resting.[3]

[2] http://www.gulflink.osd.mil/particulate_final/ particulate_final_s06.htm and http://www.gulflink.osd.mil/pm/pm_en.htm.

[3] "Report of Radiochemical Analyses for Air Filters from Hanford Area"; Memorandum from Edwin L. Sensintaffar, Director of the National Air and Radiation Environmental Laboratory, to Jerrold Leitch, Region 10 Radiation Program Manager (http://yosemite.epa.gov/R10/AIRPAGE.NSF/webpage/Hanford+Environmental+Perspective)

- The DOE's Lawrence Berkeley Laboratory also used 30m^3/d: "the working breathing rate is for 8 hours of work and, when combined with 8 hours of breathing at the active rate and 8 hours at the resting rate, gives a daily equivalent intake of 30m^3 for an adult."[4]
- The Rocky Flats Oversight Panel recommended using 30m^3/d.[5]

A.4 THE USE OF POPULATION-SPECIFIC INFORMATION RATHER THAN NATIONAL AVERAGES

EPA instructs risk assessors to identify the receptor population and their activities or land use.[6] "Assessors are encouraged to use values which most accurately reflect the exposed population."[7] The OSWER Land Use Directive[8] requires the identification of land uses for the baseline risk assessment; when the affected resources are on reservations or areas where tribes retain usory rights, a subsistence/residential land use must be assumed if the tribe so indicates. Executive Order 12898[9] requires the identification of subsistence consumption of natural resources, and for Indian tribes this includes the activities required to obtain those resources.

EPA recognizes that inhalation rates may be higher in certain populations, such as athletes or outdoor workers, because levels of activity outdoors may be higher over long time periods. "If site-specific data are available to show that subsistence farmers and fishers have higher respiration rates due to rigorous physical activities than other receptors, that data may be appropriate."[10] Such subpopulation groups are considered *high risk* subgroups.[11] EPA (1997) recommends calculating their inhalation rates using the following *average* hourly intakes for various activity levels (in m^3/hr): resting = 0.4, sedentary = 0.5, light activity = 1, moderate activity = 1.6, heavy activity = 3.2. EPA's average rate for outdoor workers is 1.3m^3/hr, with an upper percentile of 3.3m^3/hr, depending on the ratio of light, moderate, and heavy activities during the observation time. Other EPA risk assessments typically use 2.5m^3/hr for groundskeepers.[12]

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[4] www.lbl.gov/ehs/epg/tritium/TritAppB.html
[5] RAC (Risk Assessment Corporation). 1999. *Task 1: Cleanup Levels at Other Sites. Rocky Flats Citizens Advisory Board, Rocky Flats Soil Action Level Oversight Panel.* RAC Report No. 3-RFCAB-RFSAL-1999' http://www.itrcweb.org/Documents/RAD-2.pdf
[6] http://www.epa.gov/superfund/programs/risk/ragsd/table4instructions.pdf.
[7] "Exposure Factor Handbook," Volume 1, page 5-23
[8] OSWER Directive 9355.7-04, "Land Use in the CERCLA Remedy Selection Process" (May 25, 1995)
[9] White House, 1994. Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations: Feb. 11, 1994; 59 FR 7629, Feb. 16, 1994.
[10] EPA (OSWER) "Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities, Support Materials Volume 1: Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities," page 6-4, at http://www.epa.gov/earth1r6/6pd/rcra_c/protocol/volume_1/chpt6-hh.pdf
[11] "Exposure Factors Handbook," 1997, Volume 1. page 5-24
[12] For outdoor workers, see U.S. EPA 1991a. U.S. Environmental Protection Agency (U.S. EPA). Human health evaluation manual, supplemental guidance: "Standard default exposure factors."

Using EPA guidance on hourly inhalation rates for different activity levels, a reasonable inhalation rate for an average tribal member's active lifestyle is an average rate of 26.2m^3/d, based on 8 hours sleeping at 0.4m^3/hr, 2 hours sedentary at 0.5m^3/hr, 6 hours light activity at 1m^3/hr, 6 hours moderate activity at 1.6m^3/hr, and 2 hours heavy activity at 3.2m^3/hr. The resultant 26.2m^3/d is rounded to 25 m^3/day.

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APPENDIX B

SOIL INGESTION RATE

Indigenous Soil Ingestion Rate = 400mg/d (all ages)

B.1 SUMMARY

Soil ingestion includes consideration of direct ingestion of dirt, mud, or dust, swallowing inhaled dust, mouthing of objects, ingestion of dirt or dust on food, and hand-to-mouth contact. The indigenous soil ingestion rate is based on a review of EPA guidance, soil ingestion studies in suburban and indigenous settings, pica and geophagia, and dermal adherence studies. It is also based on Columbia Plateau subsistence lifestyles with their higher environmental contact rates, and local climatic and geologic conditions.

The soil ingestion rate of 400mg/d for all ages is the upper bound for suburban children (EPA 1997) and within the range of outdoor activity rates for adults. Subsistence lifestyles were not considered by the EPA guidance, but are generally considered to be similar in soil contact rates to construction, utility worker, or military soil contact levels. However, it is lower than 480mg/d to allow for some low-contact days and balanced with many 1-gram days and events, such as root gathering days, tule and wapato gathering days, powwows, rodeos, horse training and riding days, sweat lodge building or repair days, grave digging, and similar activities. There are also likely to be many high or intermediate-contact days, depending on the occupation (e.g., wildlife field work, construction or road work, cultural resource field work).

B.2 EPA GUIDANCE

EPA has reviewed the studies relevant to suburban populations and has published summaries in its “Exposure Factors Handbook” (1989, 1991, and 1997). In the current iteration of the “Exposure Factors Handbook”[1], EPA reviewed the available scientific literature for children and identified seven key studies that were used to prepare recommended guidelines for evaluating the amount of soil exposure. The mean daily values in these studies ranged from 39mg/day to 271mg/day with an average of 146mg/day for soil ingestion and 191mg/day for soil and dust ingestion. Based on these studies, EPA originally recommended a value of 200mg/day. EPA now recommends 100mg/d as a mean value for children in suburban settings, 200mg/day as a conservative estimate of the mean, and a value of 400mg/day as an

[1] Environmental Protection Agency. 1997. Exposure Factors Handbook. Volumes I, II, III. U.S. Environmental Protection Agency, Office of Research and Development. EPA/600/P-95/002Fa.

upper bound value (exact percentile not specified). Most state and federal guidance uses 200mg/d for children.

For adults, the USEPA now suggests a mean soil ingestion rate in suburban settings of 50mg/day for adults (USEPA 1997), which has been decreased from 100mg/d as recommended in earlier guidance. However, EPA says that this rate is still highly uncertain and has a low confidence rating due to lack of data. An adult soil ingestion rate of 100mg/day is most commonly used for residential or agricultural settings.

Other EPA guidance such as the Soil Screening Level Guidance[2] recommends using 200mg/d for children and 100mg/d for adults, based on RAGS HHEM, Part B (EPA 1991), or an age-adjusted rate of 114mg-y/kg-d.

A value for an ingestion rate for adult outdoor activities is no longer given in the 1997 "Exposure Factors Handbook" for adults as it is "too speculative." However, the soil screening guidance still recommends 330mg/d for a construction worker or other outdoor worker, and risk assessments for construction workers typically use a rate of 480mg/d (EPA 1997, Hawley 1985).

Other soil ingestion rates are also used by risk assessors. For example, some states recommend the use of 1 gram per acute soil ingestion event[3] to approximate a non-average day for children, such as an outdoor day.

B.3 MILITARY GUIDANCE

The US military assumes 480mg per exposure event[4] or per field day. For military risk assessment, the US Army uses the Technical Guide 230 (TG) as the tool to assist deployed military personnel when assessing the potential health risks associated with chemical exposures.[5] No database is available to estimate incidental soil ingestion for adults in general or for military populations either during training at continental US facilities or during deployment. Department Of Defense (2002)[6] recommendations for certain activities, such as construction or landscaping which

[2] EPA (1996) Soil Screening Guidance: Technical Background Document, EPA/540/R-95/128, July 1996 (http://www.epa.gov/superfund/resources/soil/toc.htm#p2), and EPA (2002) Supplemental Guidance For Developing Soil Screening Levels For Superfund Sites. OSWER 9355.4-24 (http://www.epa.gov/superfund/resources/soil/ssg_main.pdf).

[3] MADEP (1992). Background Documentation For The Development Of An "Available Cyanide" Benchmark Concentration. http://www.mass.gov/dep/ors/files/cn_soil.htm

[4] http://www.gulflink.osd.mil/pesto/pest_s22.htm, citing US Environmental Protection Agency, Office of Research and Development, "Exposure Factors Handbook," Volume I, EPA/600/P-95/002a, August 1997 as the basis for the 480mg/d.

[5] USACPPM TG 230A (1999). Short-Term Chemical Exposure Guidelines for Deployed Military Personnel. U.S. Army Center for Health Promotion and Preventive Medicine. Website: http://www.grid.unep.ch/btf/missions/september/dufinal.pdf

[6] Reference Document (RD) 230, "Exposure Guidelines for Deployed Military." A Companion Document to USACHPPM Technical Guide (TG) 230, "Chemical Exposure Guidelines for Deployed Military Personnel," January 2002. Website: http://chppm-www.apgea.army.mil/desp/; and http://books.nap.edu/books/0309092213/html/83.html#pagetop.

involve a greater soil contact rate, is a soil ingestion rate of 480mg/day. This value is based on the assumption that the ingested soil comes from a 50μm layer of soil adhered to the insides of the thumb and the fingers of one hand. DOD assumed that the deployed military personnel would be exposed at both the high ingestion rate and a mean ingestion rate throughout the year. The two ingestion rates were averaged (half the days were spent at 480 and half at 50mg/d) for a chronic average rate of 265mg/d.

The UN Balkans Task Force assumes that 1 gram of soil can be ingested per military field day.[7]

B.4 STUDIES IN SUBURBAN OR URBAN POPULATIONS

Written knowledge that humans often ingest soil dates back to the classical Greek era. Soil ingestion has been widely studied from a perspective of exposure to soil parasite eggs and other infections. More recently, soil ingestion was recognized to be a potentially significant pathway of exposure to contaminants, and risk assessments initially used a high inadvertent, based on studies of pica children (e.g., Kimbrough 1984). This triggered a great deal of research with industry (e.g., the Calabrese series) or federal funding (e.g., the DOE-funded studies of fallout and bomb test contamination).

Some of the key studies are summarized here. Other agencies (including the EPA[8] and California OEHHA) have reviewed more studies and provide more detail. To quote form OEHHA:

> There is a general consensus that hand-to-mouth activity results in incidental soil ingestion, and that children ingest more soil than adults. Soil ingestion rates vary depending on the age of the individual, frequency of hand-to-mouth contact, seasonal climate, amount and type of outdoor activity, the surface on which that activity occurs, and personal hygiene practices. Some children exhibit pica behavior which can result in intentional ingestion of relatively large amounts of soil.[9]

In general, two approaches to estimating soil ingestion rates have been taken. The first method involves measuring the presence of (mostly) non-metabolized tracer elements in the feces of an individual and in the soil with which an individual is in contact, generally in controlled (largely indoor) situations. The other method involves measuring the dirt adhered to an individual's hand and observing hand-to-mouth activity. Results of these studies are associated with large uncertainty due to their

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[7] UNEP/UNCHS Balkans Task Force (BTF) (1999). The potential effects on human health and the environment arising from possible use of depleted uranium during the 1999 Kosovo conflict. www.grid.**un**ep.ch/btf/missions/september/dufinal.pdf

[8] http://www.epa.gov/ncea/pdfs/efh/sect4.pdf.

[9] California Office of Environmental Health Hazard Assessment, Technical Support Document for Exposure Assessment and Stochastic Analysis, Section 4: Soil Ingestion. http://www.oehha.ca.gov/air/hot_spots/pdf/chap4.pdf

somewhat qualitative nature, but some studies include specific activities relevant to outdoor lifestyles.

B.4.1 Studies in Children

Early studies in children focused on pica (see below) and unique food-related events. In particular, one study of soil ingestion from “sticky sweets” was estimated at 10mg to 1g/d (Day et al. 1975).

Hawley (1985) estimated that the amount ingested by young children during outdoor activity between May and October is 250mg/d. For outdoor activities from May through October, Hawley estimated the ingestion amount as 480mg per active day, assuming that 8 hours is spent outdoors per day, 2 d/week.

Other early tracer studies in American children (Binder et al. 1986) resulted in large ranges of estimates of soil ingestion for several reasons. In the Binder study (as in all subsequent studies), the particular tracer element makes a large difference in soil ingestion estimates. Clausing et al. (1987) followed basically the same approach for Dutch rather than American children. Neither study included the trace minerals from food or medicine. A third study (van Wijnen et al. 1990) used the same approach, and was the first to include a consideration of camping and the presence or absence of gardens.

Thompson and Burmaster (1991) reanalyzed the original data on children from Binder et al. (1986) to characterize the distribution of soil ingestion by children. In studies with large numbers of children, pica children may be present, but most studies did not try to diagnose pica. On the other hand, not all children with high ingestion rates are pica children, so caution must be exercised when identifying pica children merely on the basis of high soil ingestion. The reanalysis indicates a mean soil ingestion rate of 91mg/d, and a 90^{th} percentile of 143mg/d.

Davis et al. (1990), in Calabrese’s laboratory, included an evaluation of food, medicine, and house dust as a better approximation of a total mass balance. As with the earlier studies, using titanium as the tracer results in estimates of large soil ingestion rates, while Al and Si tracers resulted in a narrower range of soil ingestion rates. However, Ti is problematic because of its variability in food, Al is difficult to control since it is the third most abundant soil mineral and present in many household products, and Si is widespread and an essential trace element for plants and animals (although apparently not for humans). This illustrates the difficulty of using mineral tracers to calculate mass balance and soil ingestion, but trace studies provide the most quantitative estimates.

Calabrese et al. (1989) based estimates of soil ingestion rate in children in a home and university daycare setting on measurements of eight tracer elements (aluminum, barium, manganese, silicon, titanium, vanadium, yttrium, and zirconium). The study population consisted of 64 children between one and four years old in Amherst, Massachusetts. They used a method similar to Binder et al. (1986) but included an improved mass balance approach. They evaluated soil ingestion over eight days rather than three days, and collected duplicate samples of food, medicine, and house dust. In addition, the children used tracer-free toothpaste and ointment. The adult (n = 6) validation portion of the study indicated that study methodology could adequately detect soil ingestion at rates expected by children. Recovery data from the adult study indicated that Al, Si, Y, and Zr had the best recoveries (closest to 100%). Zirconium as a tracer was highly variable, and Ti was not reliable in the adult studies. The investigators conclude that Al, Si, and Y are the most reliable tracers for soil ingestion. This was also the first study to evaluate whether pica children were present in the sampled population; one diagnosed pica child was found.

Stanek and Calabrese (1995a) adjusted their 1989 data for the 64 children. The primary adjustment was related to intestinal transit time, which allowed an adjustment for clearance of minerals on days when fecal samples were not collected. They concluded that daily intake based on the “overall” multi-tracer estimates is 45mg/day or less for 50% of the children and 208mg/day or less for 95% of the children. When extended to an annual estimate, the range of average daily soil ingestion in the 64 children was 1–2268mg/d; the median (lognormal) was 75mg/d, the 90th percentile was 1190mg/d, and the 95th percentile was 1751mg/d. The known pica child was not included, and individual “outlier” results for individual tracers were also omitted. Even so, the range of rates is so large that it is evident that there are still methodological difficulties.

Stanek and Calabrese (1995a) also evaluated the number of days a child might have excessive soil ingestion events. An estimated 16% of children are predicted to ingest more than 1 gram of soil per day on 35–40 days of the year. In addition, 1.6% would be expected to ingest more than 10 grams per day for 35–40 days per year.

Stanek and Calabrese (1995b) published a separate reanalysis combining the data from their 1989 study with data from Davis et al. (1990) and using a different methodology. This methodology, the Best Tracer Method (BTM), is designed to overcome intertracer inconsistencies in the estimation of soil ingestion rates. The two data sets were combined, with estimates as follows: 50th percentile = 37mg/d, 90th = 156mg/d, 95th = 217mg/d, 99th = 535mg/d, mean = 104mg/d □758. Even with this method, they conclude that the large standard deviation indicates that there are still large problems with “input-output misalignment.” They also write that soil ingestion cannot even be detected, in comparison to food, unless more than 200mg/d is ingested, rather than at the lower rates they indicated in 1989.

Stanek et al. (2000) conducted a second study of 64 children aged 1–4 at a Superfund site in Montana, using the same methods from their earlier study, with three additional tracers. Soil, food, and fecal samples were collected for a total mass balance estimate. The home or daycare settings were not described, nor were the community conditions or the typical daily activities of the children, and 32% of the soil ingestion estimates were excluded as outliers. In addition, only soil with a grain size of 250μm or less was used; no explanation of concentration differences between large and small grain sizes were given (see discussion on dermal adherence), and no concentration data were included.

B.4.2 Studies in Adults

Only a few soil ingestion studies in adults have been done because the attention has been focused on children, who are known to ingest more soil and are more vulnerable to toxicity of contaminants. Stanek, Calabrese, and co-authors (1997) conducted a second adult pilot study (n = 10) to compare tracers. This study was done as a method validation, and was “not designed to estimate the amount of soil normally ingested by adults.” Each adult was followed for 4 weeks. The median, 75^{th} percentile, and 95^{th} percentile soil ingestion estimates were 1, 49, and 331mg/day, with estimates calculated as the median of the three trace elements Al, Si, and Y.

B.5 STUDIES IN INDIGENOUS POPULATIONS

Studies of soil ingestion in indigenous populations have largely centered on estimates of past exposure (or dose reconstruction) of populations affected by atomic bomb tests, such as the Marshall Islands (tropical island) and Maralinga (Australian desert) evaluations.

Haywood and Smith (1992) evaluated potential doses to aboriginal inhabitants of the Maralinga and Emu areas of South Australia, where nuclear weapons tests in the 1950s and 1960s resulted in widespread residual radioactive contamination. Annual doses to individuals following an aboriginal lifestyle could result in annual effective dose equivalents of several mSv within contours enclosing areas of several hundred square kilometers. The most significant dose pathways are inhalation of resuspended dust and ingestion of soil by infants. Haywood and Smith constructed a table showing hours per week spent sleeping, sitting, hunting or driving, cooking or butchering, and other activities. The authors state that in this climate

> virtually all food, whether of local origin or purchased, has some dust content by the time of consumption due to methods of preparation and the nature of the environment. A total soil intake in the region of 1gpd was estimated based on fecal samples of nonaboriginals during field trips. This must be regarded as a low estimate of soil ingestion by aboriginals under camp conditions. In the absence of better information, a soil intake of 10gpd has been assumed in the assessment for all age groups.

They noted a “very high occurrence of cuts and scratches with a high percentage being classified as dirty...puncture wounds on the feet were frequent.”

The Marshall Island indigenous peoples have also been studied. In a study of the gastrointestinal absorption of plutonium, Sun and Meinhold (1997) assumed a soil ingestion rate of 500mg/d. This was based on the primary work of Haywood and Smith who “reported an average soil intake of 10,000mg/d in dose assessments for the Emu and Maralinga nuclear weapons testing sites in Australia." The authors state that:

> Haywood and Smith specifically discussed the effects of lifestyle on plutonium ingestion for the Australian aboriginal people: an average soil intake of 1,000mg/d was established from the fecal samples of the investigators who made field trips to the affected areas.
>
> It is difficult to quantitatively compare the amount of soil ingested by the Marshall Islanders and the Aboriginal people because of their different lifestyles. However, both societies live in close contact with their natural environment, although the Australian aboriginal people are nomadic, while the Marshallese have a lifestyle nearly like to that of industrial nations. LaGoy (1987) reported a maximum intake of 500mg/d for adults in developed nations who do not exhibit habitual pica. This value, then, was taken to be a reasonably conservative average for the Marshallese people. Therefore, this work adopts 500mg/d as the average life-time intake of soil by the Marshallese.

Simon (1998) reviewed soil ingestion studies from a perspective of risk and dose assessment. Certain lifestyles, occupations, and living conditions will likely put different individuals or different groups at risk to inadvertent soil ingestion. Because of their high dependence on the land, indigenous peoples are at highest risk for inadvertent ingestion, along with professions that may bring workers into close and continual contact with the soil. Most of the studies that Simon reviewed were related to geophagia (intentional soil ingestion; see below), which is relatively common worldwide. Simon recommends using a soil ingestion rate for indigenous people in hunting/food gathering/nomadic societies of 1g/d in wet climates and 2g/d in dry climates. He recommends using 3g/d for all indigenous children. Geophagia is assumed not to occur; if geophagia is common, Simon recommends using 5g/d. These are all geometric means (lognormal) or modes (triangular distribution), not maxima.

These estimates are supported by studies of human coprolites from archaeological sites. For instance, Nelson (1999) noted that human coprolites from a desert spring-fed aquatic system included obsidian chips (possibly from sharpening points with the teeth), grit (pumice and quartzite grains from grinding seeds and roots), and sand (from mussel and roots consumption). Her conclusions are based on finding grit in the same coprolites as seeds, and sand in the same coprolites as mussels and roots. She concludes that "the presence of sand in coprolites containing aquatic root fibers suggests that the roots were not well-cleaned prior to consumption. Charcoal was present in every coprolite examined."

B.6 GEOPHAGIA

Despite the limited awareness of geophagia in western countries, the deliberate consumption of dirt, usually clay, has been recorded in every region of the world both as idiosyncratic behavior of isolated individuals and as culturally prescribed behavior (Abrahams 1997, Callahan 2003, Johns and Duquette 1991, Reid 1992). It also routinely occurs in primates (Krishnamani and Mahaney 2000). Indigenous peoples have routinely used montmorillonite clays in food preparation to remove toxins (e.g., in acorn breads) and as condiments or spices (in the Philippines, New Guinea, Costa Rica, Guatemala, the Amazon and Orinoco basins of South America). Clays are also often used in medications (e.g., kaolin clay in Kaopectate). But the most common occasion for eating dirt in many societies, especially kaolin and montmorillonite clays in amounts of 30g to 50g a day, is pregnancy. In some cultures, well-established trade routes and clay traders make rural clays available for geophagy even in urban settings. Clays from termite mounds are especially popular among traded clays, perhaps because they are rich in calcium (Callahan 2003, Johns and Duquette 1991).

> There are two types of edible clays, sodium and calcium montmorillonite[10]. Sodium montmorillonite is commonly known as bentonite; the name is derived from the location of the first commercial deposit mined at Fort Benton, Wyoming, USA. Bentonite principally consists of sodium montmorillonite in combination with 10 to 20% of various mineral impurities such as feldspars, calcite, silica, gypsum, and others. Calcium montmorillonite, the second type of montmorillonite, is also known as “living clay” for it principally consists of nutritionally essential minerals.

Geophagia has long been viewed as pathological by the Western medical profession. However, this practice is so widespread and physiologically significant that is presumed to be important in the evolution of human dietary behavior due to its antidiarrheal, detoxification, and mineral supplementation potentials (Reid 1992, Krishnamani and Mahaney 2000).

Krishnamani and Mahaney (2000) propose several hypotheses that may contribute to the prevalence of geophagy:

1. Soils adsorb toxins.
2. Soil ingestion has an antacid action.
3. Soils act as an antidiarrheal agent.
4. Soils counteract the effects of endoparasites.
5. Geophagy may satiate olfactory senses.
6. Soils supplement nutrient-poor diets. Some clays release calcium, copper, iron, magnesium, manganese, or zinc in amounts of nutritional significance (Johns and Duquette 1991). This is especially important in pregnancy and at high altitudes.

Several studies of geophagia in pregnancy have been done. In countries such as Uganda, where modern pharmaceuticals are either unobtainable or prohibitively expensive, ingested soils may be very important as a mineral supplement,

[10] http://www.the-vu.com/edible_clay.htm

particularly iron and calcium during pregnancy (Abrahams 1997). One widely held theory suggests that iron deficiency is a major cause of geophagia[11]. Several reports have described an extreme form of geophagy (pica) in individuals with documented iron deficiency, although there has been uncertainty as to whether the iron deficiency was a cause of pica or a result of it. Because some substances, such as clay, are believed to block the absorption of iron into the bloodstream, it was thought that low blood levels of iron could be the direct result of pica. Some studies have shown that pica cravings in individuals with iron deficiency stop once iron supplements are given to correct the deficiency, suggesting that iron deficiency induces pica (and other) cravings during pregnancy. In addition, low blood levels of iron commonly occur in pregnant women and those with poor nutrition, two populations at higher risk for pica.

Edwards et al. (1994) studied 553 African American women who were admitted to prenatal clinics in Washington, D.C. Serum ferritin concentrations of pica women were significantly lower during the second and third trimesters of pregnancy; the average values for three trimesters of pregnancy for both ferritin and mean corpuscular hemoglobin were significantly lower in pica women than their nonpica counterparts. Although not significantly different, the iron (66 vs. 84% RDA) and calcium (60 vs. 75% RDA) contents of the diets of pica women were less than those of nonpica women. Again, low ferritin and hemoglobin are hypothesized to result in pica.

A further hypothesis is presented by Callahan (2003). Regular consumption of soil might boost the mother's secretory immune system. Monkeys that regularly eat dirt have lower parasite loads. In some cultures, clays are baked before they are eaten, which could boost immunity from previous exposures. For decades aluminum salts, like those found in clays, have been used as adjuvants in human and animal vaccines. Adjuvants are compounds that nonspecifically amplify immune response. Aluminum compounds make effective adjuvants because they are relatively nontoxic; the charged surfaces of aluminum salts absorb large numbers of organic molecules. Note that Al was one of Calabrese's preferred tracers due to the assumption that it is inert at trace levels and not adsorbed (it is quite toxic at high levels).

B.7 ACUTE SOIL INGESTION AND PICA

There is a gradient between geophagy and pica, and there is not a clear distinction between the conditions. Pica is an obsessive-compulsive eating disorder typically defined as the persistent eating of nonnutritive substances for a period of at least 1 month at an age in which this behavior is developmentally inappropriate. The definition also includes the mouthing of nonnutritive substances. Individuals presenting with pica have been reported to mouth and/or ingest a wide variety of nonfood substances, including, but not limited to, clay, dirt, sand, stones, pebbles, hair, feces, lead, laundry starch, vinyl gloves, plastic, pencil erasers, ice, fingernails,

[11] http://www.ehendrick.org/healthy/001609.htm

paper, paint chips, coal, chalk, wood, plaster, light bulbs, needles, string, and burnt matches.

Pica is generally thought of as a pediatric condition, but pica diagnoses include psychiatric conditions like schizophrenia, developmental disorders including autism, and conditions with mental retardation. These conditions are not characterized by iron deficiency, which supports a psychological component in the cause of pica.

Pica is seen more in young children than adults; 10–32% of children aged 1 to 6 may exhibit pica behavior at some point[12]. LaGoy (1987) estimated that a value of 5gpd is a reasonable maximum single-day exposure for a child with habitual pica. In June 2000, the U.S. Agency for Toxic Substances and Disease Registry appointed a committee to review soil pica. The committee settled on a threshold of pathological levels as consumption of more than 5000mg of soil per day but cautioned that the amount selected was arbitrary[13]. With this criterion, studies in the literature estimate that between 10 and 50% of children may exhibit pica behavior at some point. While this threshold may be appropriate in relatively clean suburban settings, it may not be appropriate for defining the pica threshold in rural settings where average soil ingestion is likely to be higher.

The occurrence of pica has been discussed with respect to risk assessment, especially for acute exposures. Calabrese et al. (1997) recognized that some children have been observed to ingest up to 25–60g soil during a single day. When a set of 13 chemicals were evaluated for acute exposures with a pica exposure rate, four of these chemicals would have caused a dose approximating or exceeding the acute human lethal dose.

Regulatory guidance recommends 5 or 10g/d for pica children. Some examples are:

1. EPA (1997) recommends a value of 10g/d for a pica child.
2. Florida recommends 10g per event for acute toxicity evaluation[14].
3. ATSDR uses 5g/day for a pica child[15].

B.8 DATA FROM DERMAL ADHERENCE

Dermal adherence of soil is generally studied in relation to dermal absorption of contaminants, but soil on the hands and face can be ingested, as well. Although this

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12 http://www.nlm.nih.gov/medlineplus/ency/article/001538.htm#Causes,%20incidence,%20and%20risk%20factors

13 Summary report for the ATSDR Soil-Pica Workshop, Atlanta, Georgia, 2000. Available from: URL: http://www.atsdr.cdc.gov/NEWS/soilpica.html

14 Proposed Modifications To Identified Acute Toxicity-Based Soil Cleanup Target Level, December 1999, www.dep.state.fl.us/waste/quick_topics/ publications/wc/csf/focus/csf.pdf.

15 For Example: El Paso Metals Survey, Appendix B, www.atsdr.cdc.gov/HAC/PHA/**elpaso**/epc_toc.html.

body of literature is not typically used to estimate a quantitative contribution to soil ingestion, it can give relative estimates of soil contact rates between activities.

Two relevant papers from Kissel's laboratory are summarized here. Kissel et al. (1996) included reed gatherers in tide flats. The category of "kids in mud" at a lakeshore had by far the highest skin loadings, with an average of 35mg/cm^2 for 6 children and an average of 58mg/cm^2 for another 6 children. Reed gatherers were next highest at 0.66mg/cm^2 with an upper bound of >1mg/cm^2. This was followed by farmers and rugby players (approximately 0.4mg/cm^2) and irrigation installers (0.2mg/cm^2). Holmes et al. (1999) studied 99 individuals in a variety of occupations. Farmers, reed gatherers, and kids in mud had the highest overall skin loadings, up to 27mg/cm^2. The next highest skin loadings on the hands were for equipment operators, gardeners, construction, and utility workers (0.3mg/cm^2), followed by archaeologists, and several other occupations (0.15–0.1mg/cm^2). The higher skin loadings of reed gatherers, farmers, and gardeners are supporting evidence that these activities also have higher than average soil ingestion rates.

One factor that has not received enough attention is the grain size of adhering and ingested soil. Stanek and Calabrese (2000) said that variability in estimating soil ingestion rates using tracer elements was reduced when grain sizes of less than 250µm were excluded in order to reduce variability. Driver et al. (1989) found statistically significant increases in skin adherence with decreasing particle size, with particles above the sand-silt size division (0.075mm) adhering less than smaller sizes. Average adherences of 1.40mg/cm^2 for particle sizes less than 150µm, 0.95mg/cm^2 for particle sizes less than 250µm, and 0.58mg/cm^2 for unsieved soils were measured (see EPA 1992[16] for more details). Soil samples should be sieved and concentrations should be evaluated for sizes below 0.075mm.

A consideration of grain size could affect the estimation of soil ingestion rates because the mineral and organic composition within a particular soil sample can vary with particle size and pore size. If soil adherence studies are conducted in a manner wherein sand is brushed off the hands while smaller grain sizes remain adhered, then tracer ratios could be altered, and would be different from the original unsieved soil. Soil loading on various parts of the body is collected with wipes, tape, or rinsing in dilute solvents, which would generally collect the smaller particle sizes[17]. Soil adherence rate is correlated to grain size; soil samples must be sieved, and data for particle size <0.044cm (RAGSe, App. C, Table C-4) should be used for dose estimation. Inhalation is also related to particle size, so the dust resuspension estimate must also include particle size.

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[16] EPA (1992). Interim Report: Dermal Exposure Assessment: Principles And Applications. Office of Health and Environmental Assessment, Exposure Assessment Group. /600/8-91/011B

[17] Soils are classified according to grain size (1mm = Very coarse sand; 0.5mm = Coarse sand; 0.25mm = Medium sand; 0.10mm = Fine sand; 0.05mm = Very fine sand; 0.002mm = Silt; <0.002mm = Clay). The Wentworth scale classifies particle sizes as ranges: sand = 1/16 to 2mm; silt = 1/256 to 1/16 mm; clay = <1/256mm.

B.9 DATA FROM WASHED OR UNWASHED VEGETABLES

Direct soil ingestion also occurs via food, for example from dust blowing onto food (Hinton 1992), residual soil on garden produce or gathered native plants, particles on cooking utensils, and so on. However, there is very little quantitative data about soil on vegetation as-gathered, as-prepared, or as-eaten, which is a separate issue from root uptake of soil contaminants into edible materials. However, there is information on interception rate of dust particles deposited onto leafy surfaces, and information on soil ingestion by pasture animals. For example, Beresford and Howard (1991) found that soil adhesion to vegetation was highly seasonal, being highest in autumn and winter, and is an important source of radionuclides for grazing animals. Palacios et al. (2002) evaluated lead levels in the aerial part of herbage near a Superfund site. A water washing pre-treatment of the vegetal samples considerably diminished the concentration of lead.

Kissel et al. (2003) evaluated concentrations of arsenic and lead in rinsed, washed, or peeled garden vegetables. He found that concentrations of lead and arsenic in washed or peeled potatoes or lettuce were generally lower, as expected, although the concentration of lead in peeled potatoes was higher than in rinsed or washed potatoes.

B.10 SUBSISTENCE LIFESTYLES AND RATIONALE FOR SOIL INGESTION RATE

The derivation of the soil ingestion rate is based on the following points:

- The foraging-subsistence lifestyle is lived in close contact with the environment.
- Columbia Plateau winds and dust storms are fairly frequent, and incorporated into overall rate, rather than trying to segregate ingestion rates according to number of high-wind days per year, because low-wind days are also spent in foraging activities.
- The original Columbia Plateau lifestyle—pit houses, caches, gathering tules and roots—includes processing and using foods, medicines, and materials. This is considered but not as part of today's living conditions.
- An average house is assumed to have little landscaping other than the natural conditions or xeriscaping, some naturally bare soil, a gravel driveway, no air conditioning (more open windows), and a wood burning stove in the winter for heat.
- All persons participate in day-long outdoor group cultural activities at least once a month, such as powwows, horse races, and seasonal ceremonial, as well as private family, cultural activities. These activities tend to be large gatherings with a greater rate of dust resuspension and particulate inhalation. These are considered to be 1-gram events or greater.

- 400mg/d is based on the following:

1. 400mg/d is the upper bound for suburban children (EPA); traditional or subsistence activities are not suburban in environs or activities.
2. This rate is within the range of outdoor activity rates for adults (between 330 and 480); the soil contact levels of subsistence activities are more like those of construction, utility work, or military activity. However, the rate is lower than 480 to allow for some low-contact days. The consideration of the number of windy-dusty days does not further quantify air particulates.
3. The low soil-contact days are balanced with many 1-gram days and events (as suggested by Boyd et al. 1999), such as root gathering days, tule and wapato gathering days, powwows, rodeos, horse training and riding days, sweat-lodge building or repair days, grave digging, and similar activities. There are also likely to be many high or intermediate-contact days, depending on the occupation (e.g., wildlife field work, construction or road work, cultural resource field work).
4. This rate is lower than Simon's (1998) estimate of 500mg/d and lower than the recommendations of 3g/d for indigenous children and 2g/d for indigenous adults in arid environments. It is also lower than the 5 or 10 grams he estimated for purely aboriginal lifestyles. For original housing conditions, a higher rate would be clearly justified; for today's housing conditions, a lower rate is adequate.
5. This rate does not account for pica or geophagy
6. Primary data is supported by dermal adherence data in gatherers and *kids in mud*. Tule and wapato gathering are kid-in-mud activities
7. This rate includes a consideration of residual soil on roots (a major food category) through observation and anecdote, but there is no quantitative data.

B.11 REFERENCES

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