Land-use Planning Scenarios for Contaminated Land: Comparing EPA, State, and Tribal Scenarios – 15642

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ABSTRACT

Land-use planning focusing on future disposition of public lands, forests and, former agricultural or industrial land, must take into account demographic and economic factors as well as future needs and availability of recreational open space, arable land, and water for growing populations. Planning requires the balancing of competing interests for "growth" , open space, and preservation of cultural, ecological and natural resources   Landscapes with soil, surface water, and groundwater contaminated by former military, industrial, mining or agricultural uses, pose special challenges, many of which have been addressed under the rubric of "brownfields". Land-use decisions or recommendations can be based mainly on economic/social interests taking into account projected demographic changes, or they can be based mainly on environmental issues taking into account contamination levels, remediation costs and technologies, and health risk issues.

Future land-use is interwoven with cleanup goals. Where unrestricted future land-use is anticipated or desired, cleanup levels for soil and groundwater must be low enough to allow such uses without unacceptable health risks. Where such cleanup levels are unattainable for fiscal or technological reasons, residual contamination will remain, and future uses, particularly for groundwater, must be restricted, requiring engineered barriers and institutional controls to interdict future exposure pathways from contaminated environmental media to receptors (residents, recreationists, employees). Although contamination and hazard may persist for centuries, planning beyond a generation or two incurs great uncertainties in demographics, policies, economic, and climate-related changes.

The Environmental Protection Agency and various states have established categories of clean-up levels corresponding to future industrial, recreational and residential use, with variations on these themes. This paper examines the spectrum of land-uses, and emphasizes a distinctions between "residential" and "unrestricted" as applied to future land-uses, particularly involving groundwater. Land-use determinations can be proposed and evaluated by a myriad of regulatory policies, guidance documents, and processes, including comprehensive land-use planning documents, Baseline Risk Assessments, Remedial Investigation/Feasibility documents and Records of Decision – which are not the focus of this study. This study instead focuses on gradations in different residential, recreational and industrial land-use scenarios and their relation to contamination of soil and groundwater. The Consortium for Risk Evaluation with Stakeholder Participation (CRESP) instituted this study to help understand the varying land-use versus clean-up decisions at the Department of Energy's environmental management sites, particularly Hanford (Washington State).

INTRODUCTION

Land-use planning for future uses of public or private lands accounting for projected economic, demographic, and recreational changes is on ongoing process. Planning requires the balancing of competing interests for "growth", open space, and preservation of cultural, ecological and natural resources Landscapes with soil, surface water, and groundwater contaminated by former military, industrial, mining or agricultural uses, pose special challenges. In general, the Environmental Protection Agency has two major land-use visions, either industrial or residential [1], but EPA allows many variations on these themes, including a variety of recreational uses. For each category (residential, recreational, and industrial) there are various scenarios, each associated with assumptions about potential exposure to the current contamination or future residual contamination of water, soil, foods, or air. Many default values have been published representing different scenarios of land-use. EPA guidance recommends that site-specific information be used to define appropriate recreational scenarios [1]. Each scenario can be identified with frequency and duration metrics and by the exposure pathways that may be completed (i.e. inhalation of airborne contaminants, ingestion of soil, particularly by toddlers, or drinking contaminated water). Residential scenarios assume that residents may occupy a site almost 365 days a year and almost 168 hours a week for a lifetime (up to 70 years). Industrial scenarios assume that future site workers will be on site only 40 hours a week for a working lifetime, typically 25 years. Recreational scenarios designate the number of days per year or hours per day a recreationist may be on site, as well as what extractive activities they may perform (i.e. hunting, fishing, and gathering).

Much of the thinking and writing on this topic occurred in the 1990s, a rich period for EPA's development of risk assessment guidance under the Clinton Administration [1, 2]. "Brownfields" redevelopment was a high profile area [3, 4], with a focus on both the health risks and the economics and liability issues. Brownfields discussions focused mainly on contamination in the soil, for in the urban former industrial areas, site-based groundwater use was usually not a consideration due to availability of public water supplies from offsite wells or surface water.

Exposure assessment focuses on the identification of potential exposure pathways (see Table I). Contaminants may be present in air, soil, water, or food, and may enter the body through inhalation, ingestion, or in some cases through the skin (dermal absorption). Direct exposure to radiation is an additional route, often ignored in chemical hazard risk assessments. Exposure assessments based on average values underestimate risks to special groups such as subsistence farmers or American Indian tribes [5].

Major clarification on the relation of contaminated environments and future land-use comes from the Environmental Protection Agency documents related to the *Comprehensive Environmental Response, Compensation and Liability Act* (CERCLA) with regard to future land-uses for sites on the National Priorities List (NPL or "Superfund)[1], and by extension to other contaminated lands. EPA identifies that land-use decisions are in the hands of local authorities and stakeholders, and are governed by current conditions and future projections for each region. Exposure to contaminants may be current, or might occur in the future. EPA may vet local land-use decisions and preferences in comparison with what is known about extent of contamination as well as projected cleanup. Where the future land-use is uncertain, a range of land-use alternatives may be linked to remediation options [2].

Groundwater quality is a major consideration in land-use and remediation planning. Groundwater is both a primary receptor in itself and a potential exposure source for human and ecological receptors. Both CERCLA [1] and the EPA National Contingency Plan [7] have the expectation to "return useable groundwater's to their beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site".

Although there is no official time horizon for land-use planning, a generation seems reasonable. Indeed, a 20 year horizon is incorporated in EPA Guidance [2] and in the State of Washington's *Growth Management Act* [8]. This time period should not be confused with the exposure "lifetimes" that the EPA incorporates into its Reference Dose calculations or which the Agency for Toxic Substances and Disease Research (ATSDR) incorporates into its Minimal Risk Level (MRL) which are typically based on 30 to 70 years of exposure. Additional longer-term time horizons which may justify much longer-term land-use planning, derive from: The projected efficacy of pump and treat programs in rendering groundwater suitable for drinking over few decades or in the decay of medium-life radionuclides such as strontium-90 and cesium-137 (half-lives circa 30 years) rendering an area "safe" after about three centuries.

TABLE 1. Generalized exposure matrix. Each cell in the matrix represents a potential exposure pathway. Very few chemicals are taken up through intact skin (dermal route). Direct exposure to radiation is mainly from soil, although naturally occurring radon can be present in groundwater.

		POTENTIALLY CONTAMINATED ENVIRONMENTAL MEDIA			
		AIR	**WATER**	**SOIL**	**FOOD**
U P T A K E	**Inhalation**	Major pathway for air pollutants, soil particulates and dusts, and vapors.	Showering and sweat lodges release volatiles	Fine dusts during excavation or along dirt roads. Vapor intrusion from underground volatiles & radon	Not applicable
	Ingestion	airborne deposition on soil, gardens, and	major pathway for surface or	toddlers are the main concern and "drive" most exposure	Major pathway for crops, herbs, berries, fish,

R O U T E S		crops	groundwater	assessments Tribal scenarios also emphasize soil ingestion	wildlife & domestic meat, eggs, milk, and medicinal plants
	Dermal	s	Rare pathway. May occur in sweat lodges or swimming	Rare pathway for slurries & muds	Not applicable
	Direct radiation		Natural radon	Natural radon or Radiation plumes	Contaminated fish and game

METHODS

We reviewed land-use plans, soil cleanup levels, and associated exposure scenarios from documents obtained from websites of the EPA, the States of Washington and New Jersey, the Department of Energy, the City of Richland, and Tribal sources.

Conceptual Site Model

The development of a conceptual site model (CSM) is the starting point for site assessments – large or small [1]. The CSM should be constructed in a geospatial framework that clarifies the relationships between sources (for one or more contaminants of concern), the potential receptors (at least residents, workers), the potential pathways from air, water, soil, or food chain, and the existing or planned barriers or controls to interdict those pathways [9]. The CSMs are needed for current conditions, for conditions during remediation where additional receptors (remediation workers) and sources (disrupted soils, contaminated facilities) occur, and post-remediation when the planned land-use is in place. Even then, the time dimension is important both for the sustainability of barriers/controls and the possibility of eventual cleanup of groundwater.

Industrial Scenarios

The basic industrial scenario assumes that following clean-up and closure of a site where residual contamination precludes unrestricted uses, the site can be developed for industrial or commercial purposes, maintaining it as an economic asset rather than a liability [10]. There is an assumption that residual soil contamination is under some engineered barrier or cap that cannot or should not (deed restriction) be breached. There is an assumption that groundwater cannot be used for human consumption (groundwater with or without treatment may be used for industrial purposes).

Construction workers building the future factories or malls may have special exposure potential during disturbance of soil and potential disruption of caps. However, once built the employees of the future industrial or commercial facilities are assumed to be present for only 40 hours a week. Although there may be a potential for exposure to offsite “dust”, it is assumed that the cap and cover will prevent direct radiation exposure (above some health based standard) or generation of contaminated dust. The future employees will be served by offsite water sources, will not consume food grown on site, and will not ingest contaminated surface soil[1]. Direct radiation exposure or vapor intrusion from soil are either not present at levels sufficient to yield unacceptable health risk to a 40 hour per week worker, or have been interdicted by distance, physical barriers, or vapor extraction systems.

Institutional controls prevent disruption of the barriers or digging (perhaps below a specified level) and a permit system (restricting access) may be in place. Untreated groundwater is not used for drinking or showering, but may be used for industrial processes depending on contaminants. Drinking water is provided from external sources. Industrial workers are required to have training for the hazards they may encounter at their jobs, and this training can include a basic orientation to the historic contamination, thereby introducing and reinforcing institutional controls.

EPA also uses an industrial/commercial scenario which diversifies the types of people who will be present. A default assumption of an industrial scenario is that the “public” is not generally allowed site. However, commercial sites will have public visitors to stores and offices [1]. Office workers on site 40 hours a week will have the same exposure opportunity as their industrial counterparts. However, public access to stores is allowed. The public is not likely to have prior training or orientation into the particular features of the site. However, members of the public accessing stores are unlikely to use the site for more than a few hours a week, and there are no completed exposure pathways, hence this receptor is usually not considered in industrial scenarios

Future site workers may also differ in whether their activities are mainly indoors or outdoors [10]. Indoor workers have greater potential for exposure to vapor intrusion while outdoor workers are more likely to have direct contact with or to ingest soil or inhale dust. Remedial measures (like contaminated soil removal) preceding occupancy should reduce these potential exposure risks.

Residential Scenarios

The terms “residential” and “unrestricted” are sometimes used interchangeably. The State of Washington defines "’Unrestricted site use conditions’ means restrictions on the use of the site or natural resources affected by releases of hazardous substances from the site are not required to ensure continued protection of human health and the environment.”[11] This includes consumption of groundwater by future site users. Soil cleanup levels must be based on the reasonable maximum exposure expected to occur under both current and future site use conditions [11], particularly soil ingestion by small children.

A default assumption of residential scenarios is the nearly full-time occupancy (almost 24 hrs/day and 365 days/yr) for a lifetime. The present paper emphasizes the importance of distinguishing the term "Residential" from "Unrestricted" land-use. "Unrestricted" [11] includes the maximum beneficial use of groundwater, including for drinking, cooking, showering, swimming pools, gardens, livestock and agriculture. We identify "unrestricted" with Tribal/residential land-use and rural subsistence agricultural land-uses. For many urban and suburban areas, particularly in industrial parts of the United States, where groundwater aquifers historically contaminated by industry, agriculture, mining, or urban development are not used for drinking, huge residential areas do not and cannot rely on their own groundwater. Land-use in these areas is "residential", but not" unrestricted". This distinction hinges on several important dimensions or pathways. There is a hierarchy of groundwater uses from none, to public lawns, private lawns and gardens, livestock, swimming pools, showers, and drinking/cooking.

Where alternative external sources of water are provided, risk management focuses on surface soil contamination. Ingestion of contaminated soil by toddlers is often the driver of risk assessments. This pathway is easily interdicted by some combination of removal and/or capping (including lawns and pavement). As one moves from rural to suburban to urban communities, the opportunity for contact with soil diminishes. Other land-use considerations include whether raising livestock, consuming garden crops, or local fishing is allowed. Tribal scenarios, such as those developed for the Hanford Site [5,12] include daily use of sweat lodges, and large scale consumption of fish, game, and traditional plant material. Tribal members have an expectation of "unrestricted" access and use.

Based on the above considerations, this paper identifies and names several subsets of "residential" land-use scenarios (Table II) that differ by their potential access to ground or surface water, soil, and various foods. We identify a "high rise scenario" with no childhood exposure to soil, an "urban scenario" where children can play in a yard, but garden crops are not consumed, and a "suburban scenario" where consumption of garden crops is allowed. All of these may rely on external sources of water.

There are numerous modifications possible. Most residential scenarios include children of any age, including toddlers who may have the highest exposure to surface soil contamination. The Hanford *River Corridor Baseline Risk Assessment* [RCBRA 13] includes a "resident monument worker receptor" who "is assumed to live in a residence constructed on a remediated waste site and work outdoors…." It appears that this scenario does not allow for children. By contrast the "subsistence farmer" scenario, includes children [14] and would correspond to the "unrestricted rural residential" in Table II. .

Implications of Industrial vs. Residential Designation

The EPA and states have established various soil screening levels for a large number of chemical contaminants for either residential or industrial designations. About 750 chemicals have both residential and industrial screening values [10]. The ratio of the latter to the former averages 10.6. For most metals the ratio between of the industrial to the residential screening level is in the 13 to 15 range (for example for uranium soluble salts. 350 vs 23 milligrams/kilogram (mg/kg) or parts per million (ppm). For most volatile organics the ratio is in the 4 to 5 range (for example, trichloroethylene 1.9 vs 0.41 mg/kg). Soil screening levels are not necessarily cleanup levels although they are often used that way. EPA [10] makes it clear that screening levels can be modified on a site specific basis depending on the future land-use.

Recreational Scenarios

Cleanup to unrestricted levels may not be necessary to allow a variety of recreational uses of partially contaminated sites. Non-extractive recreational activities (hiking, biking, bird watching) entail minimal disruption of soil. Extractive recreation including consumption of fish, game or plant material, results in higher exposure, and may be conducted without accessing groundwater [13]. Boating and swimming entail potential exposure to surface water contamination. The conservation/preservation designation of large areas of the Hanford Site [15], may allow recreational access, while areas specifically identified for recreation may involve construction of limited facilities (low-intensity), or extensive facilities (high intensity-recreation), unrelated to contamination level. EPA recommends that recreational exposure be based on local practices. Examples of EPA recreational exposure scenarios, include use of a park on a formerly contaminated site for one day per week [16] or of a beach along the Columbia River [17]. For the latter, four activities were identified; playing in sand, swimming, camping, and boating, as part of a two week camping trip repeated annually for thirty years. In each case, small children were the drivers of the exposure and risk estimates, and contaminant concentration levels deemed protective of children were assumed to be protective of adults [17].

The DOE's *River Corridor Baseline Risk Assessment* for Hanford [13] identified an "avid angler" scenario (60 days/year, with a fish consumption of 227 g/day (8 ounces), an avid hunter (30 days/year, 454 g/week of meat), and a casual user (30 days/year, non-extractive).

Soil Screening Guidance and Scenarios

EPA's soil screening level guidance [10] addresses exposure assessment scenarios for five receptors, applicable to brownfields redevelopment. That document includes a construction worker category in addition to onsite resident, offsite resident and indoor vs outdoor future site workers. Outdoor workers have potential soil contact and ingestion, but air pollutants are diluted. Indoor workers have exposure potential for vapor intrusion. Offsite residents, are defined as fence line neighbors, potentially exposed to dust from the site. Exposure could be heavy during remediation and construction, with some post-remediation exposure potential to dust. Urban yards adjacent to paved industrial properties (active or abandoned), may receive direct rainwater runoff from the adjacent contaminated site, posing an additional source for fence line neighbors

Table II. Examples of future land-use scenarios for a contaminated site with respect to direct radiation exposure, consumption of fish and game, ingestion of soil, and use of groundwater.

SCENARIO **(days/year)**	**Radiation Hazards**	**Fish and Wildlife Consumption**	**Soil Hazards**	**Groundwater uses (GW)**
Highly hazardous (0 days)	Remote handling and remote monitoring only	fish and wildlife not part of the scenario	No contact with soil	No use of GW
Restricted access No public use allowed (1-12 days for monthly or yearly monitoring)	Direct surface hazardous conditions, only trained & protected workers	fish and wildlife not part of the scenario	No contact with soil	No use of GW
Industrial (225 days)	Direct surface hazards blocked by paving	fish and wildlife not part of the scenario	No contact with soil. Digging requires permit & monitoring	Limited use of untreated GW
Recreational (non-extractive) (30 days)	No or slight direct surface hazardous conditions	fish and wildlife not safe to consume	No or slight soil consumption	No use of GW
Recreational (extractive)(30 days) “avid hunter	No direct surface hazardous conditions	fish and wildlife and plants safe to consume. Consumes 454g/wk of game	No or slight soil hazard. Shallow digging may be allowed	No use of GW
Recreational (avid angler/fisher) 60 days	No direct surface hazardous conditions	Consumes large amounts of fish (227 g/d). Major part of	No or slight soil hazard. Shallow digging may be allowed	No use of GW

		diet		
Residential Urban high rise(365 days)	No direct surface hazardous conditions	fish and wildlife not part of the scenario	Potential soil hazard requires paving	No use of GW
Residential Urban (365 days)	No direct surface hazardous conditions	fish and wildlife not part of the scenario	Potential soil hazard in backyard requires cover.	No use of GW
Residential Suburban (365 days)	No direct surface hazardous conditions	fish and wildlife not part of the scenario	No surface soil risk. Flower gardening allowed	GW may be used for gardensBUT NOT DW
Suburban gardens on public water system (365 days)	No direct surface hazardous conditions	fish and wildlife not part of the scenario	No soil hazard for crops, gardners, toddlers Gardening allowed	GW can be used for gardens BUT NOT DW
Unrestricted rural residential agricultural (365 days)	No direct surface hazardous conditions	fish and wildlife safe for consumption	No soil hazard for crops, gardners, toddlers	GW can be used for irrigation and drinking water
Unrestricted tribal (365 days)	No direct surface hazardous conditions	fish and wildlife safe for high level, up to 450 g/d of fish consumption	No soil hazard for crops, gardners, toddlers	GW can be used for irrigation and drinking water and sweat lodge

Construction workers are usually ignored at the land-use planning scale. These workers will be remediating soil or digging the basements and foundations of the future industrial structures. Over the period of months, the construction workers will have the highest potential exposure to contaminants in soil and water. Workers designated as hazardous waste workers are required to have extensive training, and work under a formalized Health and Safety Plan. Construction workers are less likely to have HAZWOPR training. Therefore, site specific training should include appropriate recognition of hazards and use of personal protective equipment. The potential for ingestion, inhalation, dermal contact, and direct radiation exposure are significant [10]. Although construction worker exposures at one site may be short term (months), the workers will then move on to other sites [18] so that their cumulative exposures to contaminated sites, may approach residential duration. Although EPA has many documents with various exposure scenarios we selected EPA [10] for Table III to illustrate some examples. Additional scenarios are developed for non-residential, daycare settings, children visiting a site for a season, and intermittent non-residential exposure for adults [16].

Table III. Exposure assessment parameters for selected residential and industrial scenarios. Modified from Exhibit 1-2 in Soil screening guidance [8].

	Residential	Non- residential Commercial/Industrial		Construction worker	Offsite-resident
		INDOOR	OUTDOOR		
Frequency (days/year)	350	225	250	months	
Duration (yrs) for exposure	30	25	25		
Soil ingestion rate(mg/d)	child 200 adult 100	100	50	330	not applicable
Ground water ingestion rate liters/day	2	2	2	not applicable	not applicable
Inhalation rate (m^3/d)	20	20	20	20	20
Body surface area exposed (cm^2)	child 2800 adult 5700	3300	not applicable	3300	not applicable
Lifetime (yrs) for outcome	70	70	70	70	70

EPA's Risk Assessment Guidance [14] provides a different depiction of exposure pathways to distinguish residential, commercial/industrial and residential exposures.

Land-use Controls

Except for truly unrestricted sites, the potential for exposure does not cease after remediation and the onset of the future land-use. Both the engineered barriers and institutional controls must be in place to assure that continuance of the planned use and to protect future generations. Engineered controls include barriers and security forces. Institutional controls include transmission of knowledge, communication of hazards, sign posting, and deed restrictions. These controls may be protective for a generation or two with appropriate maintenance. Restricted and highly restricted areas require security fences, patrols, and monitoring. Recreational uses may be governed by access controls, permits, patrols by park police, and inspections. Permits may limit the duration of a visit and the kinds of activity allowed. Recreationists are accustomed to signs designating what is and is not allowed on a particular site, including “no hunting” and “no fishing” signs. Many bodies of water contaminated by PCBs and mercury are under Advisories ranging from “do not fish” and “do not eat” to “eat no more than one meal per month”. Fish advisories, a form of institutional controls are not always followed, and the health consequences of exceeding recommendations are not well-established [19].

For residential and industrial land-uses, the architecture constructed on a site, may adequately control future exposures. Piped municipal water supplies preclude use of site-related groundwater. Pavement precludes soil contact. Commercial buildings preclude residential uses on the site. High rise buildings with paved parking lots and paved playgrounds preclude children’s exposure to soil and water contamination. Structures may shield radiation, interdict exposure to direct soil contamination or vapor intrusion, and prevent accessing contaminated groundwater (although poor maintenance of such structures incurs its own environmental health hazards). Deed restrictions may specify “do not dig” or “do not dig below this barrier”, at which point a geotextile membrane may be encountered bounding the contaminated soil below. However, suburban dwellers, particularly in communities where a groundwater well is available for lawns and gardens, but public water is used for drinking, may forget or ignore of the restriction against drinking groundwater, even if specified in deed restrictions.

Institutional controls require maintaining a “memory” of the former contamination to avoid inadvertent exposures during residential or construction activities. Reliance on institutional controls does not take into account that some communities prefer to shed their historic industrial toxicology image. Hence the waning of institutional controls in the community surrounding the Love Canal Superfund Site in Niagara Falls, New York. After remediation of the contaminated canal and surrounding areas, “Love Canal” warning signs came down; the area was re-named, Black Creek Village, and homes were sold. Within a decade, contamination resurfaced impacting a new generation of residents [20].

Tribal Scenarios

Exposure assessments conducted by an for the Confederated Tribes of the Umatilla [12]and the Yakama Nation [5], demonstrate that traditional Indian subsistence rights and uses of the land result in higher estimates of exposure through daily sweat lodge use, and consumption of large quantities of fish, game, plant materials and groundwater. Risk assessments conducted by EPA and tribal scientists demonstrate unacceptable cancer risk and non-cancer hazard if institutional and engineered controls for some contaminated areas of Hanford fail prior to cleanup [5]. The Yakama exposure “scenario describes the maximum exposure reasonably expected to occur in the Yakama population, who currently subsist on natural resources in the vicinity of Hanford.”[5], and represent the extreme condition for unrestricted land-use, including drawing groundwater for sweat lodge use. DOE has incorporated the tribal exposure assessments into its EIS for the River Corridor [13], but has also developed a non-residential tribal scenario (RCBRA) in which the soil ingestion and food ingestion pathways predominate. Tribal exposure values exceed EPA's usual default assumptions, for most pathways. For example, daily sweat lodge use results in a drinking water consumption estimate of 4 L/day rather than the 2 L/day often used. Similarly the mean tribal fish consumption (451 g/day in the Yakama exposure assessment), lies above the 90th percentile assumed in EPA documents, and may itself underestimate risk to outliers among tribal members[5].

Case Study: Hanford

A variety of future land-use scenarios have been envisioned for the Hanford Site. The Department of Energy (DOE) considers the *Comprehensive Land-use Plan* (CLUP) embodied in the 1999 Environmental Impact Statement [15] and reaffirmed in subsequent documents as its guide to future uses of the 1518 square kilometer (586 square mile) site.. The several categories of use included industrial-exclusive for long-term storage and management of hazardous waste, industrial (which included research and development), conservation/preservation, and recreation (both low intensity and high intensity). The largest area was designated conservation/preservation, for which recreational access might be allowed to certain portions [15]. Much of the conservation/preservation area of the CLUP is part of the Hanford Reach National Monument administered by the U.S. Fish and Wildlife Service, with recreation, including hunting and fishing, as part of its mission [21]. The Columbia River is accessible to the public, although occasional signs along the River identify 'no access" areas. Parts of the Monument are closed except under research permits [21]. In December 2014 Congress established the Manhattan Project National Historic Park, including several areas on the Hanford Site [22]. The CLUP land-use designation allows for some levels of public access, but assumes no residential use anywhere on the Hanford Site.

By contrast, the DOE's baseline risk assessment [13] and remedial investigation/feasibility study (RI/FS) for the Hanford 300 area, [23] which includes land along the Columbia River, defines five future land-use scenarios: industrial, casual recreation, resident monument worker, residential, and tribal, thus conflicting with the Department's own CLUP. The RI/FS recognizes that the River Corridor and National Monument will include "recreational users, tribal users, and monument workers", the latter of whom are site residents.

The RI/FS [23] does not provide a timeframe for restoration of groundwater. The City of Richland's *Comprehensive Land-use Plan* [24] developed in 1997 and amended in 2005 reclassifies the "Hanford 300 Area from Industrial and Business Research Park designations to a Mix of Land-use Designations Including Developed and Natural Open Space, Commercial, Residential, Business Research Park and Industrial" [24]. Richland's residential population draws most of its water supply from the Columbia River [24], and the land-use plan does not address the quality of groundwater or the source of drinking water for future residents of the 300 Area. Although groundwater pump and treat systems are in place, an urban residential or suburban scenario, relying on municipal rather than local groundwater is feasible.

Risk assessments conducted by EPA and tribal scientists demonstrate unacceptable cancer risks and non-cancer hazards if institutional and engineered controls for some previously remediated areas of Hanford were to fail [13]. Integral to any consideration relating land-use to risks or vice-versa, is the assumption that the sources of contamination have been adequately characterized, that plumes have been discovered, and potential future pathways identified. After cleanup, a fair balance between any residual contamination and the allowable land-use should result in no more than *de minimus* risks for the future site users. Risk assessments based upon mean exposures or common defaults, of necessity underestimate the risk to outliers (90^{th} percentile of exposure) who may represent a large number of people at risk [6], leading us to conclude that *outliers matter*.

CONCLUSION

The reciprocal relationship between future land-use and clean-up levels must be considered in any future land-use planning. Not every site can or will be cleaned up to completely unrestricted status in a 50 year time horizon, or perhaps, ever. "Maximal beneficial use of groundwater" is often the obstacle to unrestricted designation, since treatment of contaminated groundwater to eliminate contamination to a drinking water standard is likely to take decades and sources of ongoing contamination to groundwater are not always defined. Many urban and suburban residential areas of the United States have gone for decades without accessing their contaminated aquifers, so that residential land-uses, barring access to groundwater, can be a reasonable locally beneficial land-use. This paper describes gradations in recreational and residential land-use along with their accompanying scenarios. The terms "suburban residential", "urban residential" and "high rise residential" exemplify partially restricted residential land-uses. The Hanford case study illustrates disagreements in projected land-uses that may have major implications for remedy selection.

In many brownfields situations, recreational access of varying intensities may an acceptable compromise solution. The DOE's CLUP designation of conservation/preservation as the largest areal land-use for Hanford, the establishment of the Hanford Reach National Monument (in 2000)[21], and designation of the Manhattan Project National Historic Park (in 2014) [22] indicate that tourism and recreation are important components of a vision for Hanford, while remediation of contamination in the former industrial areas of the site continues. After cleanup, a fair balance between any residual contamination and the allowable land-use should result in no unacceptable health risk for the future industrial, commercial, recreational residential and Tribal users.

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