WNP-2
ER

AMENDMENT 3, JANUARY 1979

INSTRUCTIONS

The following is furnished as a guide for insertion of Amendment 3 sheets into the WPPSS Nuclear Project No. 2 Environmental Report - Operating License Stage. After inserting Amendment 3, place the letter of transmittal and instruction sheets in the front of the Environmental Report to maintain a record of the changes.

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LIST OF ILLUSTRATIONS
(continued)

LIST OF ILLUSTRATIONS
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Figure No.

TABLE 1.1-6

PUBLIC AGENCY - BPA ENERGY RESOURCES AND REQUIREMENTS
(Average Megawatts)

		Probable Energy Date				Scheduled Date			
Year Ending June 30	Estimated Requirements (1)	Estimated Resources (1)	Unsatisfied Requirements	WPPSS No. 2	Unsatisfied Requirements w/o WPPSS No. 2	Estimated Resources (Adjusted) (2)	Unsatisfied Requirements (3)	WPPSS No. 2	Unsatisfied Requirements w/o WPPSS No. 2
1977	10,675	10,416	259		259	10,416	259		259
1978	11,200	9,477	1,723		1,723	9,477	1,723		1,723
1979	11,786	10,225	1,561		1,561	10,225	1,561		1,561
1980	12,162	10,897	1,265	550	1,815	10,402	1,760	55	1,815
1981	12,868	11,142	1,726	798	2,524	11,018	1,850	674	2,524
1982	13,010	11,243	1,767	825	2,592	11,868	1,142	825	1,967
1983	13,245	11,773	1,472	825	2,297	12,367	878	825	1,703
1984	13,542	13,023	519	825	1,344	12,973	569	825	1,394
1985	13,946	13,792	154	825	979	13,976	(30)	825	795
1986	14,356	14,306	50	825	875	14,361	(5)	825	820
1987	14,786	14,414	372	825	1,197	14,414	372	825	1,197

(1) - Blue Book Table 2 adjusted for duplication in BPA & Public Agency values occasioned by CSPE - Centralia resource, contracts between BPA and Public Agencies and exports to California.

(2) - Column 3 (Estimated Resources) adjusted for the difference in added resources between probable energy date and scheduled date of commercial operation adjusted to WPPSS significant Project events status as of 8-26-76.

(3) - ( ) denotes surplus resource over requirements.

TABLE 1.1-7

WEST GROUP ENERGY RESOURCES AND REQUIREMENTS
(Average Megawatts)

Year Ending June 30	Estimated Requirements (1)	Probable Energy Date: Estimated Resources (2)	Unsatisfied Requirement with WPPSS No. 2	WPPSS No. 2	Unsatisfied Requirement without WPPSS No. 2	Scheduled Date: Estimated Resources Adjusted (3)	Unsatisfied Requirement with WPPSS No. 2	WPPSS No. 2	Unsatisfied Requirement without WPPSS No. 2
1977 . . .	15,736	14,971	765		765	14,971	765		765
1978 . . .	16,593	15,158	1,435		1,435	15,158	1,435		1,435
1979 . . .	17,533	15,236	2,297		2,297	15,236	2,297		2,297
1980 . . .	18,331	15,955	2,376	550	2,926	15,754	2,577	55	2,632
1981 . . .	19,250	16,733	2,517	798	3,315	17,047	2,203	619	2,822
1982 . . .	19,876	17,284	2,592	825	3,417	18,026	1,850	151	2,001
1983 . . .	20,540	17,844	2,696	825	3,521	18,471	2,069	825	2,894
1984 . . .	21,331	20,068	1,263	825	2,088	19,871	1,460	825	2,285
1985 . . .	22,251	21,136	1,115	825	1,940	21,334	917	825	1,742
1986 . . .	23,148	22,507	641	825	1,466	22,570	578	825	1,403
1987 . . .	24,132	23,511	621	825	1,446	23,511	621	825	1,446

(1) - From 1976 Blue Book Table 1, Line 3.
(2) - From 1976 Blue Book Table 1, Line 26.
(3) - Blue Book Table 1, Line 26 Adjusted from Probable Energy Date to Scheduled Date of Commercial Operation as adjusted to WPPSS Significant Project Events Status as of 8-26-76.

TABLE 1.1-8

WEST GROUP CAPACITY (PEAK) RESOURCES AND REQUIREMENTS
(Megawatts)

		Probable Energy Date				Scheduled Date			
Year Ending June 30	Estimated Requirements (1)	Estimated Resources (2)	Unsatisfied Requirement with WPPSS No. 2	WPPSS No. 2	Unsatisfied Requirement without WPPSS No. 2	Estimated Resources (Adjusted) (3)	Unsatisfied Requirement with WPPSS No. 2 (4)	WPPSS No. 2	Unsatisfied Requirements without WPPSS No. 2 (4)
1977 . . .	25,181	26,325	(1,144)		(1,144)	26,325	(1,144)		(1,144)
1978 . . .	26,759	27,467	(708)		(708)	27,467	(708)		(708)
1979 . . .	28,251	30,276	(2,025)		(2,025)	30,276	(2,025)		(2,025)
1980 . . .	29,561	32,069	(2,508)	1,100	(1,408)	31,459	(1,898)		(1,898)
1981 . . .	31,019	32,585	(1,566)	1,100	(466)	33,075	(2,056)	1,100	(956)
1982 . . .	31,947	32,834	(887)	1,100	213	34,084	(2,137)	1,100	(1,037)
1983 . . .	33,361	33,659	(298)	1,100	802	33,659	(298)	1,100	802
1984 . . .	34,634	36,848	(2,214)	1,100	(1,114)	36,848	(2,214)	1,100	(1,114)
1985 . . .	36,161	36,360	(199)	1,100	901	37,600	(1,439)	1,100	(339)
1986 . . .	37,754	38,420	(666)	1,100	434	38,420	(666)	1,100	434
1987 . . .	39,450	39,496	(46)	1,100	1,054	39,496	(46)	1,100	1,054

(1) - From 1976 Blue Book Table 1, Line 3.
(2) - From 1976 Blue Book Table 1, Line 26.
(3) - Blue Book Table 1, Line 26 Adjusted from Probable Energy Date to Scheduled Date of Commercial Operation as adjusted to WPPSS Significant Project Events Status as of 8-26-76.
(4) - () Indicates surplus resources over requirements.

The natural recharge due to precipitation over the low lands
of the Hanford Reservation is not measurable. The major
artificial recharge of groundwater to the unconfined aquifer
occurs near the 200 East and 200 West Areas. As is clearly
shown in Figure 2.4-15, the large volumes of process water
disposed to ponds at this site have caused the formation of
significant mounds in the water table. The points of signifi-
cant withdrawals at the present time are for construction
purposes at the FFTF site (400 Area) and the WNP-1, -2
and -4 sites (see Figure 2.1-3). These are temporary withdrawals 1
of groundwater and affect only the local groundwater flow
patterns.

Upon reaching the water table, chemical and radioactive contaminants from the 200 Area disposal sites are convected in the direction of groundwater movement. Nitrate (NO_3) and tritium (^3H) ions had reached the project site in 1972.[29,30] However, the plume of gross beta emitters calculated as (^{106}Ru) does not reach the site at the present time and is not likely to do so in the future.[25]

East of the Columbia River is a very intensive 500,000 acre irrigated farming area (Columbia Basin Project area). The water table in that region is 40 to 60 ft higher than the river elevation. The water table in the region between Eltopia and Pasco has risen 40 to 60 ft since 1960[22] due to an increase in irrigation in the area. Although no specific studies have been conducted, it is apparent from the water table elevations that the flow of water is into the Columbia River. It is believed that there is a hydraulic connection between the unconfined aquifers under the Hanford Reservation and under the Columbia Basin project area. Groundwater east of the Columbia River may be contaminated by the agricultural activities. However, the Columbia River acts as a discharge boundary for the unconfined aquifers.

An underground disposal site for radioactive wastes is located immediately adjacent to the northwest corner of the WNP-2 site (Figure 2.1-3). The disposal site covers an area of 8.6 acres and was used between 1962 and 1967 to dispose of a broad spectrum of low- to high-level radioactive wastes, primarily fission products and plutonium.[31] Cartoned low-level waste was buried in trenches, and mediumto high-level waste was buried in caissons or pipe facilities. The buried wastes are approximately 45 ft above the water table.

Two standby wells with a combined maximum pumping rate of
500 gpm can provide potable and service water to WNP-2 1
during outages and in emergencies should the river water
supply fail or be insufficient. The wells are 234 and
244 ft deep and obtain their water from the unconfined
aquifer in the Ringold formation.

Amendment 1
May 1978

TABLE 2.4-1

COLUMBIA RIVER MILE INDEX

Description	River Mile
River Mouth	0.0
Bonneville Dam	146.1
The Dalles Dam	191.5
John Day Dam	215.6
McNary Dam	292.0
Snake River	324.2
Yakima River	335.2
WNP-2 Intake and Discharge	351.75
Proposed WNP-1 and 4 Intake and Discharge	351.85
Existing Hanford Generating Plant	380.0
Priest Rapids Dam	397.1
Wanapum Dam	415.8
Rock Island Dam	453.4
Wenatchee River	468.4
Rocky Reach Dam	473.7
Chelan River	503.3
Wells Dam	515.6
Chief Joseph Dam	545.1
Grand Coulee Dam	597.6
Spokane River	638.9
United States-Canadian Boundary	745.0

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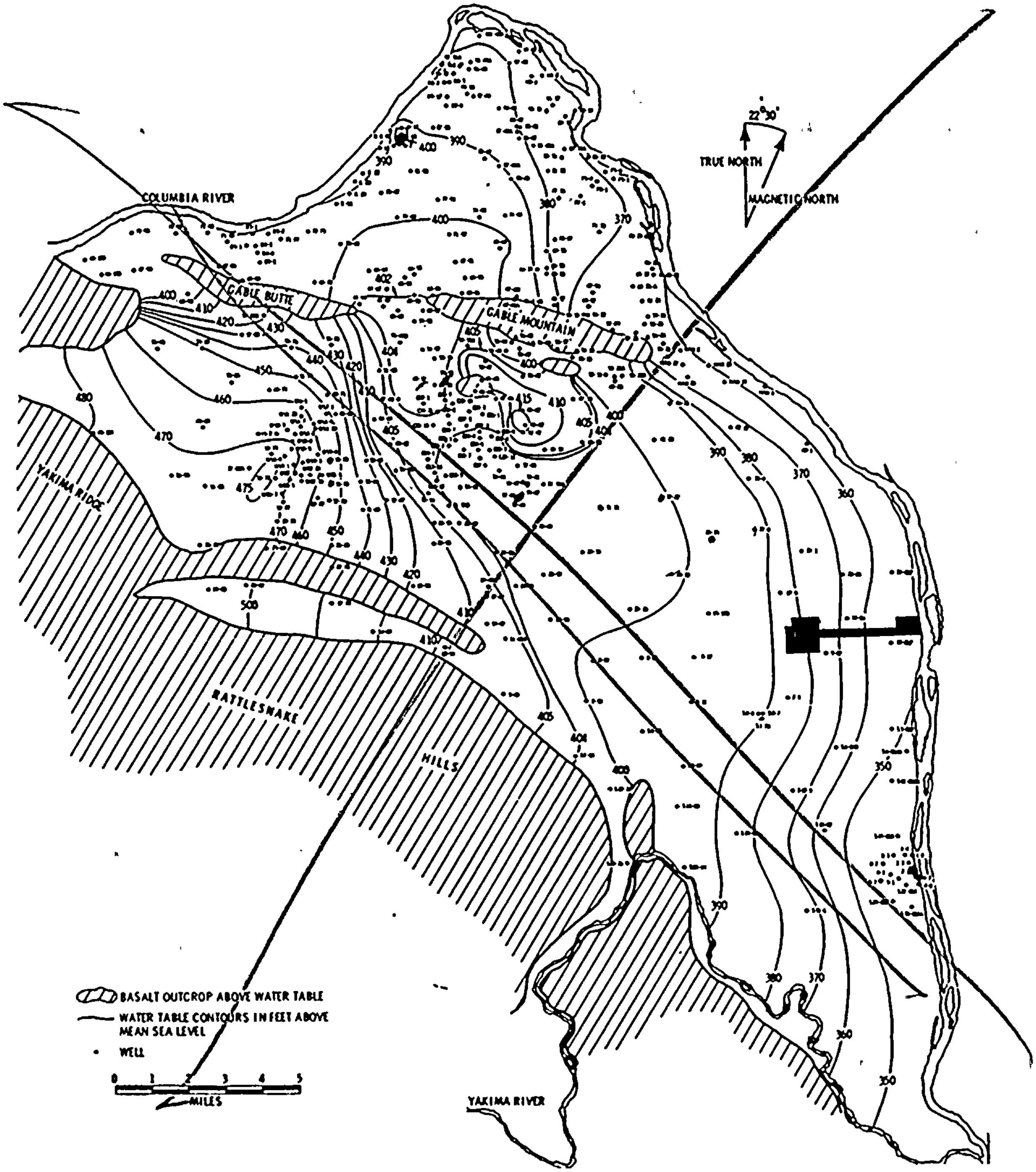


WASHINGTON PUBLIC POWER SUPPLY SYSTEM WPPSS NUCLEAR PROJECT NO. 2 Environmental Report	GROUNDWATER CONTOURS AND LOCATIONS OF WELLS FOR THE HANFORD RESERVATION, WASHINGTON SEPTEMBER, 1973
	FIG. 2.4-15

2.5 GEOLOGY

The basic geology of the site and region was described in the AEC Final Environmental Statement (December 1972). Additional geologic and seismic studies of the site area have been conducted in support of construction and safety studies for WNP-1 and WNP-4. Applicable results are reported in the WNP-2 FSAR. These additional studies have not indicated any need to further evaluate the interface between the plant and its operation, and the geologic environment.

Chlorine dosage will be automatically controlled so that a concentration of about 0.5 ppm will be present after the condenser, in the water going to the cooling tower, during periods of chlorinator operation. A small portion of this will be dispersed to the atmosphere and the remainder effectively consumed by the small quantities of organic matter present in the circulating water. During the time the chlorine is added, the cooling tower blowdown valve will closed. It will remain closed until the total residual chlorine concentration has been at or below 0.1 mg/l for 15 minutes. 1
The total cumulative operating time of the chlorination system will not exceed 2 hrs/day. Interrupting the blowdown flow during periods of chlorinator operation and for a short period afterwards, assures compliance with 40 CFR Part 423, "Effluent Limitations, Guidelines and Standards for the Steam Electric Power Generating Source Category,: issued by the Environmental Protection Agency October 8, 1974.

The anticipated composition of the cooling tower blowdown is given in Table 3.6-1. This discharge flow will be essentially continuous during normal operation, except during periods of chlorinator operation and for a brief period afterwards.

A small portion of the circulating water will be lost from the cooling towers in the form of small droplets. This "drift" is of the same composition as the circulating water containing some dissolved and suspended solids (Table 3.6-1). Drift eliminators are incorporated in the design of the cooling towers so as to limit the drift to a maximum of 285 gpm, as discussed in Section 3.4. The total solids contained in the drift will amount to about 520,000 lbs per year, under full load conditions. The deposition of drift in the vicinity of the cooling towers is discussed in Section 5.1.4.

TABLE 3.6-1

WATER COMPOSITION
COLUMBIA RIVER, DEMINERALIZER WASTE, COOLING TOWER BLOWDOWN

	A	B	C	D	E	F	G
	Columbia River			Demineralizer Waste	Cooling	Tower	Blowdown
	Avg.	Max.	Min.		Avg.	Max.	Min.
Calcium, Ca^{++} ppm	23	32	18	309	116	160	90
Magnesium, Mg^{++} ppm	4	7	2	52	21	34	10
Sodium, Na^{+} ppm	2	5	0	1466	12	24	0
Bicarbonate, HCO_3^- ppm	72	80	50	514	92	92	92
Carbonate, $CO_3^=$ ppm	2	6	0	-	0	0	0
Sulfate, $SO_4^=$ ppm	15	28	10	3495	236	415	109
Chloride, Cl^- ppm	1	2.6	0.2	56	5	13	1
Nitrate, NO_3^- ppm	0.24	0.62	0	32	1.24	3.1	0
Phosphate, $PO_4^=$ ppm	0.03	0.13	0	5	0.06	0.63	0
Total Hardness ppm $CaCO_3$	74	88	64	988	375	540	265
Total Alkalinity ppm $CaCO_3$	63	76	41	422	150	150	150
pH	8.7	9.1	8-8.5	8.3	7.5	8.5	6.5
Silica, SiO_2 ppm	6	9	3	76	30	45	15
Dissolved Soilds, ppm	87	115	72	6022	435	600	360

The construction site is in the early state of recovery from the fire and provides limited food and cover for resident wildlife. Construction activities, destroying the habitats of small mammals (of which the pocket mouse is the dominant species), has not had any measurable effect on the transitory wildlife of the large shrubsteppe. The pocket mouse population near the construction site has been monitored for three 1
years as part of the monitoring program for WNP-1/4.[6,7] There has been virtually no change in the population during that time. It appears that the pocket mouse is impacted only if directly within the disturbed construction area. The major disturbance and displacement of fauna in the area occured as a result of the fire. The more productive shrub-steppe and riparian habitats are remote from the site, and construction appears to have had little influence on the wildlife associated with these habitats.

Following the range fire in 1970, the construction site had a sparse cover of annual vegetation in early successional stages, which has partially stabilized the soil and provides only a marginal habitat for resident wildlife. The exposed area is subjected to wind erosion and consequently blowing dust occurs frequently. Since the construction activities are not visible to the general public, they have no aesthetic impact with the possible exception of an incremental dust burden to the air.

Rainfall at the Hanford Reservation averages 6.25 inches per year. The surface soils are very permeable and minimal natural surface runoff occurs. Erosion control has been successfully accomplished by proper grading and terracing.

No known historical or archaeological sites are located within the WNP-2 site or the transmission corridors.

During the construction period a competent archaeologist is employed and his expertise has been utilized during excavation activities. Archaeological sites south of the WNP-2 lease area along the river bank were roped off to avoid disturbance. A discussion of findings is presented in Section 2.6.

Sanitary wastes have been and will continue to be disposed of through septic tanks and tile fields supplemented by temporary chemical toilets. The chemical toilets are serviced, when necessary, by an outside contractor. This is in compliance with State of Washington Department of Labor and Industries Safety Standards for Construction Work, WAC 296-40-055 - Sanitary Facilities.

Separate wash facilities are housed in a heated building, and the waste water is disposed of through a drainage tile field. Waste flow from these facilities is estimated at 15-30 gallons per day per person. No adverse affects on the environment have been experienced.

Combustible construction scraps were initially burned in a burn pit approximately 1/4 mile east of the main plant but are currently being buried. Petroleum wastes are not drained to the ground but have been accumulated in drums and disposed of off-site. Chemical wastes have been and will be accumulated in drums and returned to the manufacturer for disposal or otherwise disposed of in a manner determined to adequately protect the environment.

4.1.2.1.2 Future Construction Effects

Future work, off of WPPSS's property, includes the completion and erection of the transmission lines and their associated access roads. Section 4.2 describes their construction effects. Major construction still to be completed at the site includes those major items listed in Figure 4.1-1. Future work at the WNP-2 site will continue to be controlled by the Construction Impact Control Program (see section 4.5) to ensure mitigation of possible environmental impacts.

4.1.2.2 Water Use

4.1.2.2.1 Past and Present Impacts

In accordance with the site certification agreement with the Thermal Power Plant Site Evaluation Council (TPPSEC), construction activities involving work in the Columbia River was to be limited to the period from July 31 thru October 15, 1975. The reasoning being that during those months the river level and velocity and migrant fish levels were low and construction impacts would be minimal. However, additional work to return the river bed to its natural contours required TPPSEC notification and rip rap repair in the vicinity of the intake "T"'s and the cooling tower blowdown line. This repair was performed during February 11 to March 15, 1976.

Some turbidity and sedimentation during excavation is inevitable, however mitigation of construction impacts was accomplished with a large backhoe and the placing of excavated material just downstream of the trench. To further reduce possible biotic and water quality impacts during initial work and repair work, the small gravel used for pipeline bedding was screened and rip rap was placed via use of a clam shell.

The water used during construction has been pumped from onsite wells at a combined maximum withdrawal rate of approximately 350 gpm. This withdrawal rate has had no measurable effect on the ground-water profile, since ample recharge of the aquifer is available.

4.1.2.2.2 Future Construction Effects

There is no further construction or excavation scheduled to take place in the Columbia River. Well water withdrawal is not expected to exceed 5000 gallons per day, and as experience has shown, no adverse environmental effects are expected. 1

4.1.3 Final Site Construction and Restoration

Landscaping will serve both a functional and an aesthetic purpose. Suitable grasses and hedges will be planted to facilitate erosion and dust control plus the added benefits of the aesthetic appeal. Landscaping will integrate excess excavated materials (spoils) with the site contours to ensure runoff away from all buildings and auxiliary structures. In compliance with the WNP-2 security program, no landscaping is to be provided within an isolation area extending 20 feet on either side of the perimeter security line. 1 Figures 3.1-2 and 3.1-5 are an artist's conception of the finished plant and makeup water pumphouse showing the landscaping and plant facilities.

Where required, clearing will be by bulldozer; no spraying will be used to clear the rights-of ways. Section 4.2.4.3 discusses the effects of construction on identified endangered species, and Section 4.1 gives an estimate of land requirements during construction.

The corridors do not cross any streams or come near the Columbia River and the substation will be located approximately 3000 feet north of WNP-2 and 3 miles east of the Columbia River. Therefore, no environmental impacts on the river or streams will occur.

Clearing the transmission routes and the substation site will not create noise noticeable to the general public.

Erosion is discussed in Subsection 4.2.4.

4.2.2 Method for Erecting Transmission Line Structures

Construction of transmission lines involves establishment of temporary construction access roads for movement of materials and heavy erection machinery to construction areas; clearing vegetation, structures, and other obstructions on the rights-of-way that might interfere with construction of the transmission lines; burning or otherwise disposing of cleared vegetation; leveling areas necessary for tower sites and tower steel storage and staging areas; excavating for and installing tower footings; erecting transmission towers; stringing and tensioning conductors; construction of permanent maintenance access roads on and off the rights-of-way as dictated by terrain and other factors; and reseeding or otherwise revegetating disturbed soil areas where appropriate.

4.2.3 Access and Service Roads

A total of 16.4 miles of new access and service roads will be constructed. Ten and one-half miles of access roads will be on the rights-of-way, 5.5 miles will be off the rights-of-way, and 0.4 miles will be for the substation.

With the total length of the corridors being 20.9 miles, the remainder of the access roads will be comprised of existing access roads from other transmission lines and service roads from existing telephone lines. For example, through the sand dunes area, approximately 3 miles of an existing gravelled telephone access road will be utilized. Short spur roads to the individual tower sites will be necessary.

4.2.4 Environmental Effects

4.2.4.1 Erosion

Wind erosion potential of the sandy loam soil in this dry

climate is extremely high. When vegetative cover is removed and soil is disturbed during construction and clearing of access roads and tower sites, wind erosion can be severe. In most areas, the fall germination of cheatgrass will restabilize the area in a few years. Blowouts, dunes, and other wind produced features found widely scattered across the area, however, attest to the chronic erosion potential in the absence of control measures.

The lines cross 3 miles of sand dunes. Some sand dunes are not stable due to lack of vegetation cover and construction will impact on these as well as on stabilized dunes with a high potential for additional erosion. Sand dunes are up to 30 feet high and capable of moving eastward at a rate of up to 1 foot per year.

In order to minimize wind erosion caused by construction as many existing roads as possible will be used and gravel will be used to cover the principal new access roads. If possible, spur roads will not be graded. Existing roads that are well gravelled seem to be very stable with little wind erosion. It has also been found that in a disturbed area such as temporary access roads, grass will establish itself within 1 to 2 years and again be capable of minimizing wind erosion.

Several temporary vegetation recovery study areas near WNP-2 are under investigation for grass and sagebrush regrowth. (Nineteen thousand acres of its vegetative cover was burned in July 1970.) These study areas (two burned and three unburned plots) are located approximately within a mile of the site in west, south, and east quadrants (see Figure 6.1-2). Knowledge from these studies applies to construction
1 impacts because the 1970 fire was extremely hot, destroying virtually all plant life and all seeds which would have normally germinated the next year. As with construction areas, revegetation of these areas depends on new seeds blowing in from unburned areas. Information on these plots is contained in Section 6.1.4.3.

4.2.4.2 Loss of Agricultural Productivity

The Hanford Reservation is owned and controlled by the Energy Research and Development Administration. The 500 KV and 230 KV transmission lines will be entirely within the boundaries of the Reservation. Most of the land (excepting Gable Mountain) is a shrub steppe with no other productive (agricultural and other) uses planned by ERDA. Therefore construction activities will have no foreseeable affect on agricultural productivity.

4.5 CONSTRUCTION IMPACT CONTROL PROGRAM

4.5.1 Controls

WNP-2 is located in a shrub steppe region, consisting of several shallow rolling hills, with the eastern extremity having a general slope to the river. Surface drainage is good due to the open and dry nature of the area (average rainfall is 6.25 inches per year) and sandy soil types.

During construction, contractors are required to maintain proper drainage and erosion control around the construction areas and especially in areas of excavation or fill. Controls are being employed to insure proper embankment slopes. These slopes were further recommended not to be cut steeper than one vertical on one and one half horizontal(1).

Borrow pits are prepared by grading to minimize wind and water erosion and to conform, where possible, to the natural topography. Any accumulation of precipitation within the excavation area are allowed to infiltrate into the permeable soils.

WNP-2 is located on the Hanford Reservation and the vast land area serves as a natural barrier to inhibit the impact of dust and noise upon major population centers. Public use of the reservation is currently limited to several highways which have further helped to mitigate any indesirable effects of dust and noise upon the public. Truck traffic, due to construction activities, is largely restricted to the reservation, except for the transportation of supplies to WNP-2.

Throughout the construction period stockpiles, site roadways, and storage areas are watered down by special sprinkler trucks as necessary to decrease the impact of windblown debris.

Combustible construction scraps were initially burned in a burn pit approximately 1/4 mile east of the main plant, but are currently being buried. Petroleum wastes are not drained to the ground but are accumulated in drums and returned to the manufacturer for disposal. Non-combustible wastes (scrap metal, etc.) are accumulated in a pit and removed periodically from the site for recycling.

Sanitary wastes are disposed of through septic tanks and tile fields supplemented by temporary chemical toilets. The chemical toilets are serviced, when necessary, by an outside contractor. This is in compliance with State of Washington Department of Labor and Industries Safety Standards for Construction Work, WAC 296-40-055 - Sanitary Facilities.

The water used during construction is pumped from two on-
site wells with an average withdrawal rate of approximately
1 5000 gpd. This withdrawal rate has no measurable effect on
the ground water profile, since ample recharge of the aquifier
is available.

In accordance with the site certification agreement with the Thermal Power Plant Site Evaluation Council, initial construction activities, in the river, were limited to the period of July 31, 1975 through October 15, 1975. During these months river flow and velocity, and fish migration were at a minimum and construction activities had little effect upon aquatic life forms or the river flow. No blockage to the river or flooding occurred at any time during the construction period.

Landscaping and final site construction will serve both a functional and an aesthetic purpose. Suitable grasses and hedges will be planted to facilitate erosion and dust control plus the added benefits of the aesthetic appeal. Landscaping will integrate excess excavated material (spoils) with the site contours to ensure runoff away from all buildings and auxiliary structures.

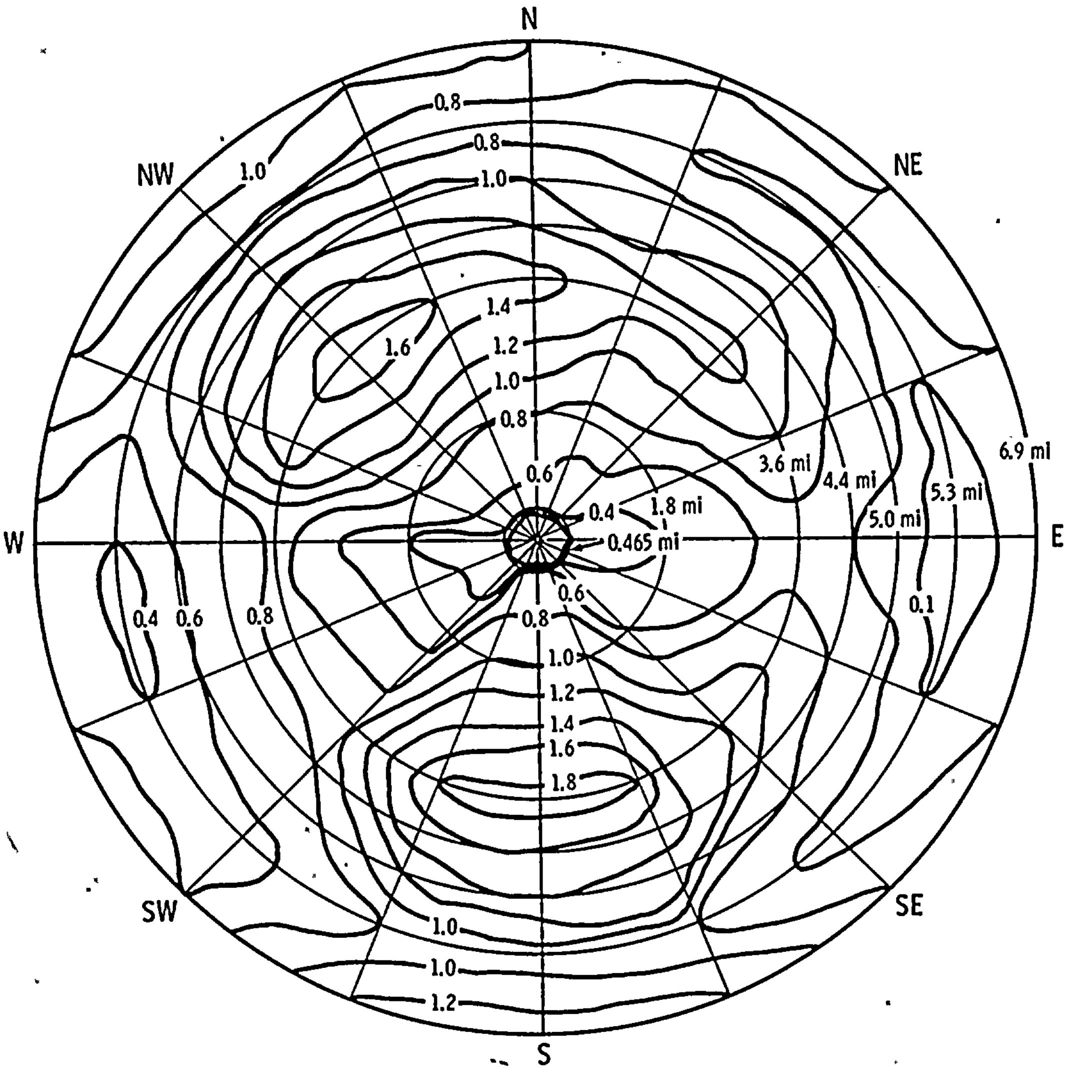
4.5.2 Nature of Control Implementation

Control of the environmental quality protection requirements are implemented and maintained via two main methods:

a. written direction to contractors through specifications and correspondence; and

b. routine inspection of the site by an A.E. representative.

Construction activity impacts are controlled by the Site Certification Agreement between the State of Washington and WPPSS, the U. S. Army Corps of Engineers Construction Permit, the U. S. Atomic Energy Commission Construction Permit (No. EPPR-93), the Energy Research and Development Administration, and the State Environmental Policy Act. The requirements of these legal entities and documents are implemented by the Supply System through auditable contractual agreements between WPPSS and contractors. A.E. personnel who represent the Supply System, inspect construction activities to ensure contract adherence, and the Supply System in turn audits the A.E. through routine on-site inspection.



WASHINGTON PUBLIC POWER SUPPLY SYSTEM WPPSS NUCLEAR PROJECT NO. 2 Environmental Report	SALT DEPOSITION PATTERNS OUT TO 6.9 MILE (lb/acre/yr) FIG. 5.1-12

5.2 RADIOLOGICAL IMPACT FROM ROUTINE OPERATION

During normal operation of any nuclear plant, radioactive material is generated. Regardless of the effectiveness of the advanced liquid and gas treatment systems it is a prudent design practice and an NRC design requirement that potential release paths be identified and any offsite effects evaluated. Details of the radwaste system and design assumptions regarding overall plant performance are described in Section 3.5 based on conservative[a] assumptions regarding fuel failures and system leakage. The system is designed to meet the requirements of Appendix I to 10 CFR 50 and applicable sections of 10 CFR 20. Radiological impact calculations have been performed in accordance with Regulatory Guide 1.109.

5.2.1 Exposure Pathways

The potential release paths considered in the design of this nuclear plant include releases to the atmosphere as a gas or vapor and release to the river. Radionuclides released to the atmosphere would be primarily noble gases, which would not be taken up by vegetation or animals. However, any radioiodine and particulates released may be deposited on or taken up by vegetation, from which they may enter into a food chain ending in man or other biota.

Radionuclides in liquid effluents would be available for uptake in algae and other water plants, fish, clams, and crustaceans living in the river. Radionuclides may be accumulated by these organisms to concentrations greater than in the surrounding water. Predators of the more simple organisms, such as small animals, fish and birds, may concentrate these nuclides still further. In addition, some radionuclides may be deposited with the silt on the river bottom and shoreline and lead to external exposure of biota; Figure 5.2-1 shows the exposure pathways to biota from WNP-2.

Radionuclides released into the plant liquid effluents reach man through a variety of pathways, involving both external exposure and internal exposure. Pathways of external exposure include such activities as swimming, boating and skiing on waters downstream from the plant, also hiking, fishing, etc., along the river shore. Pathways leading to internal exposure include the consumption of drinking water, fish and waterfowl from the river, produce from gardens irrigated

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(a) In this context, "conservative" assumptions are those which will increase the expected release of radioactive material.

with river water, and animal products such as meat, eggs and milk from animals who eat irrigated feed or pasture grass.

Exposure via the airborne pathways includes both external exposure to skin and total body from the noble gases and internal exposure from inhalation of tritium, radioiodines and particulates released from the plant. Also, internal exposures may be received from the consumption of foods produced from vegetation on which radionuclides of plant origin may be deposited. Such foods include fresh leafy vegetables from local gardens and milk from cows foraging on pasture grass. In addition, direct exposure may be received from the transportation of fuel and radioactive wastes outside the plant boundary and from the plant itself. Figure 5.2-2 shows the exposure pathways to man from WNP-2.

5.2.2 Radioactivity in the Environment

Table 5.2-1 lists the amounts of radio-nuclides and the associated concentrations in a blowdown flow of 5.76 cfs. 1
A few feet downstream from the discharge point, the effluent will be diluted to 10% of its original concentration, while a few miles downstream the effluent will be entirely mixed in the river with a dilution of 1:20,000, assuming an average river flow of 120,000 cfs.

Table 5.2-2 lists the amounts of radionuclides that may be released to the atmosphere from WNP-2. Also listed in Table 5.2-2 are the associated concentrations in the effluent of WNP-2 which are discharged to the atmosphere. The effluent is then diluted further by prevailing meteorological conditions. Table 5.2-3 lists the annual average atmospheric dilution factors ($\overline{\chi}/Q'$) derived from 1 year of meteorological data collected at the site (see Section 6.1 for a discussion of the methodology and release point assumptions used to determine the χ/Q values).

Effluents from WNP-1 and -4 used to calculate radiation doses from those plants in this report were taken from Section 5.2 of the Environmental Report for WNP-1 and -4.

Table 5.2-4 lists concentrations of several radionuclides in various environmental media and foodstuffs. The nuclides listed were chosen because they may be important in terms of radiation dose to man.

Assumptions used in the calculations of radiation dose to biota and to man are given in Tables 5.2-5, 5.2-6 and 5.2-7. The models used are outlined in Appendix II.

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5.2.3 Dose Rate Estimates for Biota Other Than Man

Using the source terms and assumptions noted above and models in Appendix II, doses were estimated for organisms living in or close to the water such a fish, clams, and crustacea which derive an internal dose from sorption of the water in which they live and from consumption of plankton.

External doses are received from the surrounding water and sometimes from the mud on the river bottom. Animals and birds, which prey on these smaller creatures, derive an internal dose from the radionuclides contained in their diet and external doses from air, water, and shoreline. Some geese reside near the Hanford Reservation most of the year. These birds do not consume aquatic food and so receive most of their radiation dose from external exposure to contaminated water or shoreline. Animals such as deer, coyotes, and field mice that do not consume aquatic food or spend much time at the river bank, will receive their dose through direct radiation from the plant's gaseous effluent plume, ingestion of terrestrial vegetation and external doses due to exposure to contaminated ground. The dose from inhalation of radionuclides and consumption of terrestrial vegetation will be small. Animals such as deer may receive an external dose rate of less than 1 mrad/yr from WNP-2 if near the plant boundary 50% of the time. A slight additional dose may be received by such animals due to grazing. Table 5.2-8 lists dose rates to biota associated with airborne and waterborne releases of radioactive material from WNP-2.

Numerous investigations have been made on the effects of radioactivity on biota. No effects have been observed at dose rates as low as those associated with the proposed WNP-2 effluents. Investigations of Chironomid larvae, bloodworms, living in bottom sediments near Oak Ridge, Tennessee, where they were irradiated at the rate of about 230 to 240 rad/yr for more than 130 generations, have shown no decrease in abundance, even though a slightly increased number of chromosome aberrations have occurred.[1]

Studies have shown that irradiation of salmon eggs and larvae from the Columbia River at a rate of 500 mrad/day did not affect the number of adult fish returning from the ocean or their ability to spawn.[2] Previously, when all the Hanford reactors were operating, studies were made on the effect of their released radionuclides on spawning salmon. These studies have shown that these salmon have not been affected by dose rates in the range of 100 to 200 mrad/week.[3]

Since the estimated doses to Columbia River biota from the radioactive effluents released by WNP-2 will be many times less than those mentioned in the above studies, no perceptible effect on the biota in the environs is expected.

5.2.4 Dose Rate Estimates for Man

Using the source terms and assumptions noted above and the models in Appendix II, doses were estimated for individuals living near the plant and for the population within 50 miles of the plant. Tables 5.2-9 and 5.2-10 summarize the annual radiation doses to an individual which could be attributed to WNP-2 only and in combination with WNP-1 and WNP-4.

5.2.4.1 Liquid Pathway

People may be exposed to the radioactive material released in the liquid effluent from WNP-2 by drinking water, eating fish, eating irrigated farm products and by participating in recreational activities on or along the Columbia River.

Drinking Water

The population within 50 miles of the site utilizing Columbia River water for drinking includes the cities of Pasco and Richland. The city of Kennewick utilizes groundwater drawn from collectors placed along the Columbia River. Historically, the Kennewick city water has contained significantly lower concentrations of radionuclides of Hanford origin that the water in the Pasco municipal system immediately across the river. The water table slopes toward the river from the Kennewick highlands, channeling uncontaminated water into the aquifers adjacent to the river.

The cities of Richland and Pasco have efficient alum-floc water treatment plants capable of removing a significant fraction of the radionuclides in the incoming water. Samples of the water entering and leaving these two water treatment plants were collected and analyzed for several years under the AEC environmental monitoring program at Hanford. Results of these measurements have been used to define the removal efficiencies for specific radionuclides during the years 1960 through 1968. These data, which represent the fraction passing through the treatment plant, are summarized in Table 5.2-11 along with estimated values for chemically similar nuclides not measured.[4]

When estimating radiation doses, the radionuclide content of drinking water in the cities of Pasco and Richland was

calculated from the annual releases (given in Table 5.2-1) diluted in the average river flow. The resulting concentrations in the river were then reduced by the factors in Table 5.2-11 and decayed for 24 hours travel time from the effluent discharge point downriver and through the water plant to the consumer.

Assuming a consumption rate of 2.0 ℓ/day of water, a typical adult living in Richland or Pasco would receive a total-body dose rate of 1.8×10^{-5} mrem/yr from this source. The total estimated population of consumers in 2020 (75,000) drinking an average of 1.2 ℓ/day would receive an integrated total-body dose rate 2.1×10^{-3} man-rem/yr. The radiation dose rate to the individual adult thyroid from consumption of 2.0 ℓ/day of drinking water was estimated to be 1×10^{-4} mrem/yr.

When WNP-1 and WNP-4 begin operation, the calculated radiation dose to a typical adult in Richland or Pasco would be 1.8×10^{-3} mrem/yr to the total-body. The calculated population total-body dose would be 8.3×10^{-2} man-rem/yr.

Fish and Waterfowl

Because fish will concentrate most radionuclides from the water they inhabit, the potential radiation dose from consumption of Columbia River fish was estimated for both the individual and the population within 50 miles of the plant. There is some waterfowl hunting around the perimeters of the Hanford Reservation. Some of these waterfowl could conceivably derive part of their diet from fish or aquatic plants from water downstream of the plant, but most waterfowl eaten by people (i.e., ducks and geese) consume primarily grains.

Based on the assumptions found in Table 5.2-6[5] the internal dose rate to the individual fisherman would be 2.2 mrem/yr to his total body due to effluents from WNP-2. Integrated dose rate to the population would be 3.9×10^{-4} man-rem/yr from fish consumption. After WNP-1 and WNP-4 have begun operation, the fisherman would receive a total-body dose of 2.3 mrem/yr. The total-body dose rate to the population would be 4.3×10^{-4} man-rem/yr. The radiation dose to an individual on the population due to consumption of waterfowl will be insignificant.

Water Recreation

Aquatic recreation is a popular pastime in the stretch of the Columbia River below the plant site. Swimming, boating, water skiing and picnicking along the shore or on islands

could result in small incremental doses to the local population.[6] Using the assumptions listed in Table 5.2-6 the total-body dose rate to an individual from external exposure would total about 9.3 x 10^{-2} mrem/yr. The population dose received during water recreation activities[6] can be estimated on the basis of the assumptions listed in Table 5.2-6. Under these conservative assumptions, the integrated population dose rate from water sports would be 3.0 x 10^{-4} man-rem/yr, principally from exposure to the contaminated shoreline.

No detectable increase in radiation dose will result from this pathway when WNP-1 and WNP-4 begin operation.

Irrigated Farm Products

Estimates were made of doses derived from consuming food products produced on farms and gardens downstream from the plant using irrigation water from the river. It was assumed the individual will eat food that will be grown directly under such irrigation plus eggs, milk, and meat from animals consuming feed grown under irrigation. Table 5.2-12 lists the food paths considered along with some typical parameters used in the calculation of the dose to the individual. The dose to the population was estimated using these assumptions, except that the consumption rates were reduced by one-half. The holdup is the period between the release of the radionuclides and deposition on the ground or on plants plus any time periods between harvest and consumption.[a] In the case of eggs, beef or pork, when the animal will eat grain, the holdup also includes the time

(a) Consumption is the amount of the food eaten per year by an individual.

Irrigation rate is the amount of water applied by a sprinkler to the crop per unit area in 1 month; typical rates for the Columbia Basin were used.

Yield is the amount grown per surface area of ground. In the case of animal products the yield refers to the pasture or feed of the animal.

Growing period is the period during which plant leaves are presented to the air. In the case of milk, it is the time elapsed until the cow returns to the same part of the pasture to graze.

between the grain harvest and its consumption by the animal as well as the time between the slaughter of the animal (or egg laying) and consumption of the animal product by an individual. For the forage-milk pathway, the holdup includes the time between deposition on plants and consumption by the cow as well as the time between milking and consumption of milk by an individual. The total dose rate estimated from this pathway will be very small, 5.9×10^{-5} mrem/yr to the total-body of an individual from the consumption of all 13 food types which are irrigated.

At the present time, the nearest point at which Columbia River water is withdrawn for irrigation of farm products downstream of the site is at the Riverview District. Other irrigation water used either adjacent to the site or in the Kennewick area comes from the Grand Coulee Dam area or the Yakima River. The total land available for irrigation in the Riverview District is about 5300 acres.(7) It is doubtful that this amount of land could produce food for more than a few thousand people. Since some additional irrigation occurs near Burbank using Columbia River water, it was conservatively assumed that a maximum of 10,000 persons could consume irrigated food products for this population dose estimate. The point at which water is taken from the river for irrigation in the Riverview District is about 12 miles from the plant outfall. This coupled with the fact that there are several islands between the outfall and the point of withdrawal will give complete mixing of all effluents in the river. From these assumptions the annual whole-body dose to the population from irrigated food products is estimated to be 1.6×10^{-4} man-rem. When WNP-1 and WNP-4 begin operation, the radiation dose to an individual from this pathway will be 2.3×10^{-3} mrem/yr to the total-body. The annual total-body population dose would be 8.0×10^{-3} man-rem/yr.

5.2.4.2 Gaseous Pathways

People may be exposed to radioactive material released to the atmosphere by WNP-2 via inhalation, air submersion and ingestion of farm products.

Air Submersion

The maximum exposure at the site boundary line occurs at a location approximately 0.5 mile southeast of the WNP-2 where the average atmospheric dilution factor is 3.8×10^{-6} sec/m^3. The estimated total-body dose rate to an individual at this location would be 6.7×10^{-4} mrem/hr while his skin

dose would be 1.2×10^{-3} mrem/hr. However, since the location is now on Federally-owned land (the Hanford Reservation), the general public would not ordinarily be allowed access. A more probable location for occupancy by the general public would be a point just offshore from the plant about 2.5 miles ESE, where a fisherman might fish from a boat. Here the atmospheric dilution factor at the shoreline is the greatest, 4.6×10^{-7} sec/m^3. The external total-body dose rate to the fisherman at this point is estimated to be 8.2×10^{-5} mrem/hr. An avid fisherman remaining here 500 hr/yr would receive an annual total-body dose of 4.1×10^{-2} mrem; his skin dose would be approximately 7.3×10^{-2}.

At present the closest point to the plant at which people reside is across the river at Ringold Flat, approximately 4 miles ENE of WNP-2. However, the atmospheric dilution factor is greater at the second closest residence across the river at Taylor Flat, approximately 4.2 miles ESE of the plant. Airborne radiation doses were estimated for an individual occupying this location (Taylor Flat) all year. The atmospheric dilution factor was estimated to be 3.0×10^{-7} sec/m^3 at this location. The total-body and skin dose rates from external radiation were estimated to be 0.16 mrem/yr and 0.32 mrem/yr, respectively. When WNP-1 and WNP-4 begin operation, the individual at Taylor Flat would receive 0.18 mrem/yr to the total-body and 0.72 mrem/yr to the skin.

The annual total-body air submersion dose to the estimated 2020 population residing within a 50-mile radius of the plant was estimated. Table 5.2-13 shows that the estimated 270,000 persons living within the region in 2020 would receive an annual external dose of only 1.6 man-rem from the radioactive gaseous effluents released into the atmosphere by WNP-2. With the later addition of WNP-1 and WNP-4, a total-body dose would increase to 2.1 man-rem/yr.

Inhalation

An individual residing at Taylor Flat would receive a dose to the total-body of 9.4×10^{-4} mrem/yr due to inhalation of radioiodines and particulates and absorption of tritium through the skin. The radiation dose to the thyroid of this individual would be 9.0×10^{-2} mrem/yr. The fisherman located 2.5 miles from the plant for 500 hours during the year would receive a total-body dose of 7.9×10^{-5} mrem/yr via this pathway. The annual total-body radiation dose to the population within 50 miles of WNP-2 due to inhalation/transpiration would be 2.3×10^{-2} man-rem.

When WNP-1 and WNP-4 begin operation, an individual at Taylor Flat would receive a total-body dose of 4.4×10^{-3} and a thyroid dose of 0.11 mrem/yr. At that time, the annual total-body radiation dose to the population would be 0.11 man-rem/yr.

Farm Products

Estimates were made of radiation doses received from consuming farm products produced in the vicinity of the plant which might be affected by airborne effluents. Table 5.2-12 lists the 14 food items considered along with some typical parameters used in the calculation of dose to the individual. The dose to the population within 50 miles of the site was estimated using these same assumptions, except that the consumption rates were reduced by one-half. The dose rate from this pathway for an individual residing at Taylor Flat would be 1.0×10^{-2} mrem/yr to the total-body and 2.1 mrem/yr to the thyroid.

For the population dose estimate, it was assumed that all land not on the Hanford Reservation or in an urban area could be used for agriculture and that the entire population within 50 miles (270,000) might eat food grown in this area. Using these assumptions, the annual total-body dose to the population from this pathway would be 7.0×10^{-2} man-rem/yr.

When WNP-1 and WNP-4 begin operation, an individual at Taylor Flat would receive a dose rate to the total body of 4.5×10^{-2} mrem/yr and 2.5 mrem/yr to the thyroid. The total-body dose rate to the population at that time would be 0.27 man-rem/yr.

Milk

The air→grass→cow→milk pathway, which for some nuclear plants is quite critical because of milk cows actually pastured on or near the fenceline, is of less importance for these projects because cows are not pastured very close to the plant. Since the plant is on ERDA property and natural pasture is sparse, it is very unlikely that milk cows would be pastured at the fenceline in the foreseeable future.

The closest point at which a milk cow is now pastured is across the river 5 miles southeast of the site at Taylor Flat. The atmospheric dilution factor at this location is estimated to be 2.6×10^{-7} sec/m^3. The estimated thyroid dose rate to a child consuming 1 ℓ of milk each day from cows pastured

9 months of the year at this farm would be 9.0 mrem/yr. The dose rate to an adult consuming the same amount of milk would be 1.6 mrem/yr.

When WNP-1 and WNP-4 begin operation, these doses would increase to 11 mrem/yr to a child's thyroid and 1.9 mrem/yr to an adult's thyroid.

5.2.4.3 Direct Radiation From Facility

Radiation From Facility

Wastes from WNP-2 will be stored in tanks within concrete buildings so that radiation levels to workers within the plant boundaries will be below applicable standards. In addition, tanks containing low levels of activity will be situated and shielded to reduce dose rates at the site boundary to very small levels. Since the plant is located inside the Hanford Reservation it is not expected that the general public will be close to the plant site long enough to receive any measurable radiation exposure from turbine shine.

Transportation of Radioactive Materials

Since the locations of fuel facrication plants, reprocessing plants and waste disposal facilities have not been determined, transportation routes have not been decided. However, a generic study[8] has estimated that radiation dose rates to the general public from transportation of radioactive materials will not exceed 5 man-rem/yr per unit. Therefore, until transportation routes are chosen for plant radioactive materials, this average value will be used. It is expected that the value estimated from the actual routing of the plant's radioactive material transport will be lower than this since much of the route will be through low populated regions of the western United States or the waste may not be transported outside of the Hanford Reservation.

5.2.4.4 Conformance With Appendix I Design Objectives

Radiation dose calculations were made to demonstrate compliance with 10 CFR 50 Appendix I. The analytical models used to calculate radiation doses consider the cumulative effect of all sources and pathways from the plant. The potential land use, water use and food pathways which could exist during the life of the plant were used to calculate radiation doses to an individual living near the site. Assumptions used to calculate these radiation doses have been discussed in the

preceding sections. A discussion of the models used for these calculations is included in Appendix II. The doses calculated for this report include the effect of possible environmental accumulation during the life of the plant.

The radiation dose from all exposure pathways due to liquid effluents could result in a radiation dose to an individual of 2.3 mrem/yr to the total body, 0.34 mrem/yr to the thyroid and 1.7 mrem/yr to the bone.

The annual radiation dose to air from noble gases was computed at a location approximately 0.5 miles southeast of WNP-2 where the average atmospheric dilution factor is 3.8×10^{-6} sec/m^3. At this location, the annual air dose due to releases from WNP-2 are 1.9 mrad/yr from beta radiation and 2.9 mrad/yr from gamma radiation. The radiation dose to an individual located on the shoreline 2.5 miles ESE of WNP-2 would be 0.71 mrem/yr to the total body and 1.3 mrem/yr to the skin.

The highest radiation dose to an individual due to release of radioiodine and particles to the atmosphere would be 9.2 mrem/yr to a child's thyroid. This infant was assumed to drink 1 ℓ/day of milk from the nearest cow and live at the nearest residence.

These radiation doses all comply with limits specified in 10 CFR 50 Appendix I, Section II, A, B, and C.

5.2.5 Summary of Annual Radiation Doses

Table 5.2-14 lists the annual radiation doses received by individuals residing near the site from the major pathways. It is conceivable that one individual residing at Taylor Flat could be exposed simultaneously via several pathways. If this individual were an avid fisherman, drank milk from the nearest cow and ate farm products affected by plant effluents (liquid and airborne), he might receive a total-body radiation dose of 2.5 mrem/yr, a thyroid dose of 2.7 mrem/yr and a bone dose of 1.9 mrem/yr.

The estimated annual doses to the population affected by the operation of the WNP-2 and the combined operation of WNP-2, WNP-1 and WNP-4 are given in Table 5.2-15. The total population dose estimate includes the transportation of radiomaterials (spent fuel and wastes) from the plants as well as the doses received via the air and water pathways. The dose to the population from the direct radiation from the plants is assumed negligible, since the closest point to

the site continuously occupied is more than 3 miles away from any one plant, and the point occupied intermittently by a fisherman is more than 2 miles.

The annual population dose from all sources attributable to all three plants operating simultaneously is 18 man-rem. By comparison the background radiation dose rate from natural sources in this region is approximately 105 mrem/yr,[a] resulting in an annual dose of 28,000 man-rem to the same population. Therefore, routine operations of the WNP-1, WNP-2 and WNP-4 operating simultaneously at this site, will contribute a very small increment to the total-body dose already received as a result of the natural background radiation.

Construction workers at WNP-1 and WNP-4 will receive some radiation dose due to the operation of WNP-2. If an individual were to work 0.5 mile from WNP-2, he would receive a total-body dose of 2.5 mrem/yr from N-16 turbine shine.[10] This worker would also receive about 0.7 mrem/yr due to the airborne release of radioactive material from WNP-2. When WNP-2 begins operation, approximately 3200 construction workers will be building WNP-1 and WNP-4. If these workers are located an average of 1 mile from WNP-2, the total-body radiation dose to those workers would be 4.4 man-rem/yr.

(a) Approximately 80 mrem/yr from external sources and 25 mrem/yr from internal sources (mostly K-40)[8]

TABLE 5.2-1

RELEASE RATES AND CONCENTRATION OF RADIONUCLIDES IN LIQUID EFFLUENTS FROM WNP-2

Isotope	Release (Ci/y)	Concentration in Plant Effluents (pCi/ℓ)
H-3	12.0	2.3E+3
Na-24	6.6E-3	1.3
P-32	2.6E-4	5.1E-2
Cr-51	6.7E-3	1.3
Mn-54	8.0E-5	1.6E-2
Mn-56	7.1E-3	1.4
Fe-55	1.4E-3	2.7E-1
Fe-59	4.0E-5	7.8E-3
Co-58	2.7E-4	5.2E-4
Co-60	5.5E-4	1.1E-1
Ni-65	4.0E-5	7.8E-3
Cu-64	2.0E-2	3.9
Zn-65	2.7E-4	5.2E-2
Zn-69m	1.4E-3	2.7E-1
Zn-69	1.5E-3	2.9E-1
Br-83	3.7E-4	7.2E-2
Br-84	3.0E-5	5.8E-3
1 Rb-89	2.1E-4	4.1E-2
Sr-89	1.4E-4	2.7E-2
Sr-90	7.0E-5	1.4E-2
Sr-91	2.2E-3	4.3E-1
Sr-92	1.5E-3	2.9E-1
Y-90	7.0E-5	1.4E-2
Y-91m	1.4E-3	2.7E-1
Y-91	7.0E-5	1.4E-2
Y-92	3.1E-3	6.0E-1
Y-93	2.3E-3	4.5E-1
Mo-99	2.3E-3	4.5E-1

TABLE 5.2-3

ANNUAL AVERAGE ATMOSPHERIC DILUTION FACTORS ($\overline{X}/Q'$)

Direction from Source	Range (mile) .5 MI	1.5 MI	2.5 MI	3.5 MI	4.5 MI	7.5 MI	15 MI	25 MI	35 MI	45 MI	TOTALS
N	3.04E-06	8.04E-07	4.30E-07	2.83E-07	2.07E-07	1.08E-07	4.40E-08	2.22E-08	1.40E-08	9.92E-09	4.97E-06
NNE	2.65E-06	6.72E-07	3.54E-07	2.31E-07	1.67E-07	8.65E-08	3.45E-08	1.72E-08	1.08E-08	7.59E-09	4.23E-06
NE	2.10E-06	5.47E-07	2.90E-07	1.90E-07	1.38E-07	7.16E-08	2.85E-08	1.41E-08	8.82E-09	6.18E-09	3.39E-06
ENE	2.04E-06	5.36E-07	2.85E-07	1.86E-07	1.36E-07	6.99E-08	2.78E-08	1.38E-08	8.60E-09	6.03E-09	3.31E-06
E	1.98E-06	5.10E-07	2.69E-07	1.75E-07	1.27E-07	6.48E-08	2.54E-08	1.25E-08	7.79E-09	5.45E-09	3.17E-06
ESE	3.33E-06	8.73E-07	4.63E-07	3.03E-07	2.20E-07	1.13E-07	4.45E-08	2.20E-08	1.37E-08	9.58E-09	5.39E-06
SE	3.82E-06	1.03E-06	5.50E-07	3.38E-07	2.64E-07	1.37E-07	5.50E-08	2.75E-08	1.72E-08	1.21E-08	6.24E-06
SSE	3.61E-06	9.58E-07	5.13E-07	3.38E-07	2.47E-07	1.29E-07	5.21E-08	2.61E-08	1.64E-08	1.16E-08	5.90E-06
S	3.11E-06	8.33E-07	4.49E-07	2.98E-07	2.18E-07	1.15E-07	4.68E-08	2.35E-08	1.48E-08	1.04E-08	5.12E-06
SSW	2.38E-06	6.52E-07	3.55E-07	2.37E-07	1.74E-07	9.25E-08	3.79E-08	1.91E-08	1.21E-08	8.49E-09	3.97E-06
SW	2.13E-06	6.01E-07	3.31E-07	2.22E-07	1.64E-07	8.75E-08	3.62E-08	1.83E-08	1.16E-08	8.17E-09	3.61E-06
WSW	1.85E-06	5.08E-07	2.77E-07	1.84E-07	1.36E-07	7.19E-08	2.94E-08	1.48E-08	9.32E-09	6.56E-09	3.08E-06
W	1.38E-06	3.81E-07	2.08E-07	1.30E-07	1.02E-07	5.39E-08	2.20E-08	1.10E-08	6.92E-09	4.87E-09	2.30E-06
WNW	1.66E-06	4.33E-07	2.30E-07	1.50E-07	1.10E-07	5.69E-08	2.27E-08	1.12E-08	7.01E-09	4.91E-09	2.69E-06
NW	1.75E-06	4.47E-07	2.36E-07	1.54E-07	1.12E-07	5.74E-08	2.28E-08	1.13E-08	7.08E-09	4.97E-09	2.80E-06
NNW	2.65E-06	7.11E-07	3.82E-07	2.52E-07	1.84E-07	9.67E-08	3.92E-08	1.98E-08	1.25E-08	8.82E-09	4.36E-06
TOTALS	3.95E-05	1.05E-05	5.62E-06	3.67E-06	2.71E-06	1.41E-06	5.69E-07	2.85E-07	1.79E-07	1.26E-07	6.45E-05
CUM TOTL	3.95E-05	5.00E-05	5.56E-05	5.93E-05	6.20E-05	6.34E-05	6.39E-05	6.42E-05	6.44E-05	6.45E-05	6.45E-05

TABLE 5.2-4

CONCENTRATIONS OF IMPORTANT RADIONUCLIDES IN VARIOUS ENVIRONMENTAL MEDIA

Nuclide	River Water at Point of Irrigation (pCi/ℓ)	Air at Taylor Flats (pCi/m^3)	Sediment at outfall (pCi/kg)	Soil at Taylor Flats (pCi/kg)	Fish at Outfall (pCi/kg)	Coots (pCi/kg)	Drinking Water at Richland (pCi/ℓ)	Vegetation at Taylor Flats (pCi/kg)	Milk from Nearest Cow (pCi/ℓ)	Eggs at Taylor Flats (pCi/kg)	Meat at Taylor Flats (pCi/kg)
H-3	1.1E-1	6.5E-1	--	8.1E+0	2.1E+3	2.1E+3	--	7.4E+1	3.6E+1	1.5E+1	3.5E+1
Na-24	--	0	--	--	1.3E+2	1.3E+2	5.5E-5	--	--	--	--
P-32	2.4E-6	0	--	0	1.5E+1	1.5E+1	--	0	0	0	0
Mn-56	--	0	--	--	5.5E+2	5.5E+2	3.3E-5	--	--	--	--
Co-60	5.1E-6	1.3E-4	1.9E+0	1.3E-1	5.4E+0	5.4E+0	1.0E-7	3.6E-2	--	--	--
Kr-87	0	1.9E+0	0	0	0	0	0	0	0	0	0
Kr-88	0	2.2E+0	0	0	0	0	0	0	0	0	0
Sr-89	1.3E-6	5.8E-5	--	1.6E-3	8.2E-1	8.2E-1	2.6E-7	1.4E-2	1.1E-3	--	--
Sr-90+D	6.5E-7	2.7E-7	--	8.1E-4	4.1E-1	4.1E-1	1.3E-7	2.3E-4	--	8.5E-6	3.3E-6
I-131	6.0E-5	4.4E-3	--	2.0E-1	1.9E+1	1.9E+1	4.8E-5	4.3E+0	2.4E+0	1.7E-1	1.4E-1
I-132	--	0	--	--	1.0E+1	1.0E+1	2.6E-5	--	--	--	--
I-133	--	1.6E-2	--	7.7E-2	5.0E+1	5.0E+1	1.3E-4	1.3E+0	3.6E-1	2.4E-2	--
I-135	--	0	--	--	2.3E+1	2.3E+1	5.9E-5	--	--	--	--
Xe-135	0	1.0E+1	0	0	0	0	0	0	0	0	0
Xe-138	0	1.4E+1	0	0	0	0	0	0	0	0	0
Cs-134	6.9E-5	4.2E-5	9.6E+0	1.7E-2	2.9E+3	2.9E+3	6.3E-5	1.2E-2	3.0E-3	--	1.8E-3
Cs-136	4.4E-5	--	--	--	1.8E+3	1.8E+3	3.9E-5	--	--	--	--
Cs-137	1.6E-4	6.0E-5	1.4E+2	1.8E-1	6.6E+3	6.6E+3	1.4E-4	1.7E-2	4.4E-3	3.1E-4	3.5E-3
Cs-138	--	--	--		2.8E+3	2.8E+3	6.1E-5	--	--	--	--
Ba-140	4.9E-6	1.1E-4	--	7.7E-4	4.1E-1	4.1E-1	2.0E-6	1.5E-2	--	--	--

TABLE 5.2-5

ASSUMPTIONS USED FOR BIOTA DOSE ESTIMATES

Fish, Clam, Crustacea

- In equilibrium with 10% plant effluent
- Effective radius = 2 cm
- Bioaccumulation factors listed in Appendix II

Muskrat

- Spends 33% of time in 10% plant effluent; 33% in riverbank den; 33% on land
- Effective radius = 6 cm
- Body mass = 1 kg
- Consumes 100 g/day aquatic vegetation growing in 10% plant effluent

Raccoon

- Spends 25% of time on shoreline washed with 10% plant effluent
- Effective radius = 14 cm
- Body mass = 12 kg
- Consumes 20 g/day fish living in 10% plant effluent (10% of total diet). (The other 90% of his diet is assumed to be free of radionuclides of WNP-2 origin.)

Coot

- Spends 50% of time floating in 10% plant effluent and 50% of time on shoreline washed with 10% plant effluent
- Effective radius = 5 cm
- Body mass = 1 kg
- Consumes 100 g/day aquatic vegetation living in 10% plant effluent

Heron

- Spends 33% of time standing in 10% plant effluent; 33% on riverbank washed with 10% plant effluent
- Effective radius = 11 cm
- Body mass = 4.6 kg
- Consumes 600 g/day fish living in 10% plant effluent

Goose

- Spends 50% of time floating in 10% plant effluent and 50% of time on shoreline washed with 10% plant effluent
- Effective radius = 10 cm
- Body mass = 3 kg
- Consumes 500 g/day of grain

External dose to muskrat, coot and heron from gaseous effluents are received at shoreline 2.4 mi ESE of the containment building.

External dose to raccon from gaseous effluents are received at shoreline (25%) and at closest plant boundary located 0.5 mi SE (75%).

TABLE 5.2-6

ASSUMPTIONS USED IN ESTIMATING DOSES FROM THE LIQUID PATHWAY

Drinking Water

- Liquid effluent diluted by annual average river flow (120,000 cfs)
- 24 hours delay between release of radionuclides and consumption of water (plus holdup in water plant)
- Fractions of radionuclides passing through water plant were those given in Table 5.2-11
- Consumption rate of 2.0 ℓ/day (730 ℓ/yr) for maximum individual and 1.2 ℓ/day (440 ℓ/yr) for the average individual.
- Total population consuming drinking water downstream from the plant is approximately 75,000

Fish

- Fish caught in waters containing plant effluent diluted by a factor of 0.1 for maximum individual and by annual average river flow for population average.
- One-day delay between harvest of fish and consumption for population and 1 hour for maximum individual.
- Consumption rate of 40 kg/yr for maximum individual[3] and 1.4×10^4 kg/yr (edible weight) for population living in the 50-mile radius of the plant. (The approximate edible weight of sportfish harvested from the river between Ringold and Boardman.[5])
- No losses in preparation of fish.

RECREATIONAL ACTIVITIES

Maximum Individual

- Recreation in or near waters containing 10% effluent.
- 0.1 hour delay between release and location of shoreline activity, swimming and boating.
- 500 hrs/yr shoreline activities.[b][6]
- 100 hrs/yr swimming (complete immersion)[6]
- 100 hrs/yr boating or water skiing (surface)[6]

Average Individual Members of the Population

- Recreation in or near waters containing plant effluent fully diluted in the annual average river flow.[a]
- 4 hours delay between release of radionuclides and location of recreation.
- 17 hrs/yr shoreline activities[b][6]
- 10 hrs/yr swimming (complete immersion)[6]
- 5 hrs/yr boating and water skiing (surface)[6]
- Total population using Columbia River downstream from the plant for recreation is approximately 193,000.[c]

Irrigated Food Products

- Irrigation water contains effluent nuclides diluted with annual average river flow.
- Radionuclide buildup period in soil is 30 years.
- 25% of radionuclide which falls out is retained on crops.
- All radioiodine released is in inorganic form.
- Environmental half-life of deposition on plants is 14 days.
- Holdups, Individual Consumptions, Irrigation Rates, Yields, and Growing Periods are listed in Table 5.2-12
- Average member of population is assumed to eat 1/2 of consumptions listed in Table 5.2-12
- Population consuming irrigated foods assumed to be 10,000.

(a) The dilution offered by the Snake River below Pasco, and the decay during river travel time to southwest Benton County was ignored. The majority (over 50%) of the exposed population resides in the vicinity of the Tri-Cities, (Pasco, Kennewick, and Richland).

(b) Receptor assumed 3 ft above infinite plane. Resulting dose decreased by factor of 0.2 to account for finite width of shoreline.

(c) The population within 50 miles of the site in the sectors between the NNE and the SW directions, inclusive, are the persons who travel to the Columbia River downstream of the plant for their aquatic recreation. This population is estimated to total 192,710 persons in 2020.

TABLE 5.2-9

ESTIMATED ANNUAL DOSES TO AN INDIVIDUAL FROM THE LIQUID AND GASEOUS EFFLUENTS OF WNP-2

Pathway	Annual Exposure	Location	Dilution Factor or χ/Q	Annual Doses (mrem) to an Adult				
				Skin	Total Body	GI-LLI	Thyroid	Bone
LIQUID								
Drinking Water	730 ℓ	Richland	1/20,000	--	1.8E-5	1.2E-5	1.1E-4	7.9E-6
Fish	40 kg	Near Outfall	1/10	--	2.2	2.0E-1	2.5E-1	1.6
Water Recreation	(a)	Near Outfall	1/10	1.1E-1	9.3E-2	(9.3E-2)[c]	(9.3E-2)	(9.3E-2)
Irrigated Food Products:								
Produce	(b)	Riverview Area	1/20,000	--	2.7E-5	1.1E-5	6.5E-5	2.5E-5
Eggs	(b)	Riverview Area	1/20,000	--	5.4E-7	4.1E-7	2.7E-6	5.4E-7
Milk	(b)	Riverview Area	1/20,000	--	2.4E-5	5.0E-6	1.6E-4	1.9E-5
Meat	(b)	Riverview Area	1/20,000	--	7.6E-6	1.6E-6	4.9E-6	6.3E-6
Ground Contamination	4,400 h	Riverview Area	1/20,000	2.2E-4	1.9E-4	(1.9E-4)	(1.9E-4)	(1.9E-4)
AIR								
Air Submersion	8,766 h	Taylor Flat	3.0×10^{-7}	3.2E-1	1.6E-1	(1.6E-1)	(1.6E-1)	(1.6E-1)
Inhalation/Transportation	7,300 m^3	Taylor Flat	3.0×10^{-7}	--	9.4E-4	9.9E-4	9.0E-2	2.7E-4
Food Products:								
Produce	(b)	Taylor Flat	3.0×10^{-7}	--	6.5E-3	6.1E-3	6.9E-1	2.0E-3
Eggs	(b)	Taylor Flat	3.0×10^{-7}	--	6.8E-5	6.0E-5	1.0E-2	2.4E-5
Milk	(b)	Taylor Flat	2.6×10^{-7}	--	3.4E-3	2.4E-3	1.4	3.1E-3
Meat	(b)	Taylor Flat	3.0×10^{-7}	--	3.1E-4	2.7E-4	1.9E-2	6.5E-5
Ground Contamination	4,400 h	Taylor Flat	3.0×10^{-7}	4.9E-3	3.9E-3	(3.9E-3)	(3.9E-3)	(3.9E-3)

(a) See Table 5.2-6 for exposure rates for water recreation.
(b) See Table 5.2-12 for consumption rates for farm products.
(c) Parentheses around a number indicate that the radiation dose to an internal organ is due to an external source and is estimated to be equal to the external total-body dose.

TABLE 5.2-10

ESTIMATED ANNUAL DOSES TO AN INDIVIDUAL FROM THE LIQUID AND GASEOUS EFFLUENTS OF WNP-2, WNP-1 and WNP-4

Pathway	Annual Exposure	Location	Annual Doses (mrem) to an Adult				
			Skin	Total Body	GI-LLI	Thyroid	Bone
LIQUID							
Drinking Water	730 ℓ	Richland	--	1.8E-3	1.8E-3	1.9E-3	7.9E-6
Fish	40 kg	Near Outfall	--	2.3	2.6	3.1E-1	1.6
Water Recreation	(a)	Near Outfall	1.1E-1	9.3E-2	(9.3E-2)[c]	(9.3E-2)	(9.3E-2)
Irrigated Food Products:							
Produce	(b)	Riverview Area	--	1.3E-3	1.3E-3	1.3E-3	2.5E-5
Eggs	(b)	Riverview Area	--	6.9E-5	6.9E-5	6.9E-5	5.4E-7
Milk	(b)	Riverview Area	--	6.6E-4	6.5E-4	8.1E-4	1.9E-5
Meat	(b)	Riverview Area	--	2.3E-4	2.2E-4	2.3E-4	6.3E-6
Ground Contamination	4,400 h	Riverview Area	2.2E-4	1.9E-4	(1.9E-4)	(1.9E-4)	(1.9E-4)
AIR							
Air Submersion	8,766 h	Taylor Flat	7.2E-1	1.8E-1	(1.8E-1)	(1.8E-1)	(1.8E-1)
Inhalation/Transportation	7,300 m^3	Taylor Flat	--	4.4E-3	4.5E-3	1.1E-1	3.0E-4
Food Products:							
Produce	(b)	Taylor Flat	--	3.4E-2	3.2E-2	8.3E-1	2.2E-3
Eggs	(b)	Taylor Flat	--	3.2E-4	3.1E-4	1.3E-2	2.8E-5
Milk	(b)	Taylor Flat	--	9.2E-3	7.9E-3	1.6	3.4E-3
Meat	(b)	Taylor Flat	--	1.6E-3	1.5E-3	2.3E-2	7.2E-5
Ground Contamination	4,400 h	Taylor Flat	5.1E-3	4.0E-3	(4.0E-3)	(4.0E-3)	(4.0E-3)

(a) See Table 5.2-6 for exposure rates for water recreation.
(b) See Table 5.2-12 for consumption rates for farm products.
(c) Parentheses around a number indicate that the radiation dose to an internal organ is due to an external source and is estimated to be equal to the external total-body dose.

TABLE 5.2-11

FRACTION OF RADIONUCLIDE PASSING THROUGH WATER TREATMENT PLANTS(4)

Element	Fraction	Element	Fraction
H	1.0	Mo	0.9
Na	0.9	Tc	0.7
P	0.4	Ru	0.5
Cr	0.9	Rh	0.5
Mn	0.5	Te	0.8
Fe	0.2	I	0.8
Co	0.2	Cs	0.9
Ni	0.2	Ba	0.4
Cu	0.6	La	0.2
Zn	0.4	Ce	0.2
Br	0.8	Pr	0.2
Rb	0.9	W	0.9
Sr	0.2	Np	0.7
Y	0.2		

TABLE 5.2-12

ASSUMPTIONS FOR ESTIMATING DOSES FROM CROPS AND ANIMAL FODDER SUBJECT TO DEPOSITION OF RADIOACTIVE MATERIALS RELEASED BY THE PLANT

Food Types	Holdup (day)	Consumption[(a)] (kg/yr or ℓ/yr)	Irrigation[(b)] Rate (ℓ/m²/mo)	Atmospheric Dilution (s/m³)	Yield (kg/m²)	Growing Period (day)
Produce						
Leafy Vegetables	1	30	200	3.0×10^{-7}	1.5	70
Beans, Peas, Asparagus	1	30	160	3.0×10^{-7}	0.4	70
Potatoes	10	110	180	3.0×10^{-7}	5	100
Other Root Vegetables	1	72	150	3.0×10^{-7}	5	70
Berries	1	30	180	3.0×10^{-7}	2.7	60
Melons (water)	1	40	180	3.0×10^{-7}	1.4	100
Orchard Fruit	1	265	180	3.0×10^{-7}	2.1	90
Wheat	10	80	0[(c)]	3.0×10^{-7}	0.72	70
Other Grain (sweet corn)	1	8.3	150	3.0×10^{-7}	1.4	100
Eggs	2	30	150	3.0×10^{-7}	0.66	130
Milk	2	274	200	2.6×10^{-7}	1.3	30
Meat						
Beef	15	40	160	3.0×10^{-7}	2.0	130
Pork	15	40	150	3.0×10^{-7}	0.69	130
Poultry	2	18	140	3.0×10^{-7}	0.66	130

(a) Consumptions are for maximum individual. Average population member is assumed to eat one-half of those quantities.
(b) Typical irrigation rates for the region.
(c) No irrigation of wheat.

TABLE 5.2-13

CUMULATIVE POPULATION, ANNUAL POPULATION DOSE, FROM SUBMERSION IN AIR CONTAINING RADIONUCLIDES FROM THE WNP-2 AND COMBINED RELEASES OF WNP-2 AND WNP-1 AND -4

Radius (miles)	Cumulative Population (2020)	Cumulative Annual Population Dose (man-rem)		Annual Average Dose (mrem)	
		WNP-2	Combined	WNP-2	Combined
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0
5	130	0.0086	0.010	0.066	0.078
10	12,650	0.44	0.56	0.035	0.045
20	108,060	1.3	1.8	0.012	0.016
30	157,760	1.5	2.1	0.0093	0.013
40	201,270	1.5	2.1	0.0075	0.010
50	267,790	1.6	2.2	0.0058	0.0081

TABLE 5.2-14

ANNUAL DOSES RECEIVED VIA MAJOR PATHWAYS FOR WNP-2 AND FOR WNP-2, WNP-1 AND -4 COMBINED

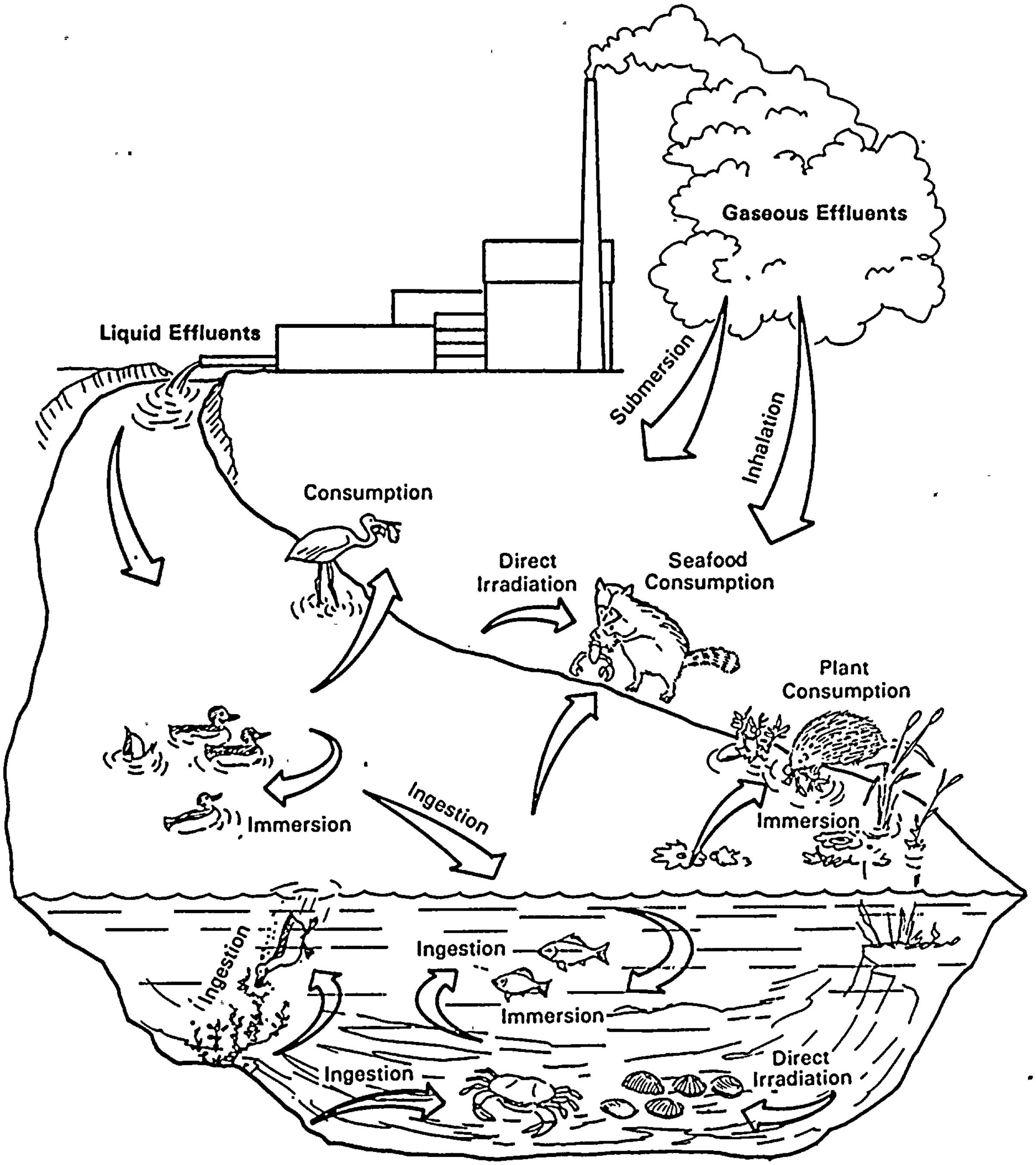
	Annual Dose (mrem)			
	WNP-2	WNP-1 & -4	Combined	Appendix I Limits per Reactor
AIR PATHWAY				
Air Submersion[a]				
Total Body	0.71	0.38	1.1	5
Skin	1.3	0.60	1.9	15
Child's Thyroid[b]	9.2	1.6	11	15
Nearest Resident[c]				
Thyroid	2.4	0.37	2.8	15
Total Body	0.18	6-8E-2	0.24	10
LIQUID PATHWAY				
Drinking Water				
Total Body	1.8E-5	1.8E-3	1.8E-3	3
Fish Consumption				
Total Body	2.2	6.2E-2	2.3	3
Bone	1.6	4.0E-8	1.6	10
Nearest Resident[d]				
Total Body	0.10	2.9E-2	0.13	3
All Others	<0.10	<3.0E-3	~0.1	10
AIR DOSE (mrad/yr)[e]				
Gamma Air Dose	2.9	-	-	10
Beta Air Dose	1.9	-	-	20

(a) Located 2.5 miles ESE of the plant.
(b) Milk and inhalation at nearest residence.
(c) Inhalation, air submersion, ingestion of farm products, contaminated ground.
(d) Swimming, boating, shoreline, ground contamination, ingestion of farm products.
(e) At the site boundary 0.5 miles southeast of the plant.

TABLE 5.2-15

ESTIMATED ANNUAL POPULATION DOSES ATTRIBUTABLE TO WNP-2 AND COMBINED RADIONUCLIDE RELEASES OF WNP-1, WNP-2 AND WNP-4

Pathway	Total Body Dose Man-Rem WNP-2	Total Body Dose Man-Rem Combined	Remarks
AIR			
Submersion in Cloud	1.6	2.1	No credit taken for shielding.
Direct Radiation	--	--	
Inhalation/Transpiration	2.3E-2	1.1E-1	
Farm Products	7.0E-2	2.7E-1	
WATER			
Fish Consumption	3.9E-4	4.3E-4	Complete mixing in river was assumed.
Drinking Water	2.1E-3	8.3E-2	Complete mixing in river was assumed.
Water Recreation	3.0E-4	3.0E-4	Complete mixing in river was assumed.
Irrigated Farm Products	1.8E-4	8.0E-3	
TRANSPORTATION OF RADIOACTIVE MATERIALS	5	15	From reference 7.



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EXPOSURE PATHWAYS FOR ORGANISMS OTHER THAN MAN

FIG. 5.2-1