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CHAPTER 11.0

RADIOACTIVE WASTE MANAGEMENT

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11.1.1 Radioactive Concentrations and Releases

Estimated radioactive liquid effluent concentrations for Callaway Plant are provided in Section 11.1 of the Standard Plant.

11.2.3.2 Release Points

The Callaway Plant normal effluent releases as calculated per the guidance in Section 11.1.1, were considered for evaluating the local surface-water environment in dispersing, diluting, or otherwise concentrating radioactive effluents as related to existing or potential future water users. Since routine plant releases will be discharge directly to the Missouri River by pipeline, there will be no impact on the local ground-water system(s) from this source.

11.2.3.3 Dilution Factors

11.2.3.3.1 Description of Surface-Water Analytical Model

A steady-state stream tube model was utilized for evaluating the transport of radionuclides in the Missouri River downstream from the Callaway Plant effluent release point. This model, based on Equation 17 in Regulatory Guide 1.113 (NRC, 1977), applies to nontidal river/stream systems.

For evaluating radionuclide transport in the Missouri River from plant effluent releases, flow was assumed to be steady and uniform. Application of the steady-state stream tube model for evaluating plant effluent releases was based on simplifying assumptions of idealized rectangular stream channel geometry and velocity in the Missouri River under assumed steady and uniform flow conditions. The Missouri River is gauged and streamflow in the immediate vicinity of the Callaway Plant site, and only channel velocity distributions are known several miles downstream at the USGS gauging station at Hermann.

For steady open-channel flow, K_y can be determined from hydrodynamic properties of the channel by using Elder's empirical formula (NRC, 1977):

$$K_y = \beta u^* d \qquad (11.2\text{-}1)$$

where:

d = River depth;

u^* = Shear velocity; and

β = A dimensionless constant.

The dimensionless constant, β, has a value of approximately 0.23 for straight natural stream channels (NRC, 1977). For curved channels, however, secondary flows can lead to increased lateral mixing, and the value of β is larger (Fischer, 1969; Yotsukura et al., 1970; Sayre and Yeh, 1973). Fischer (1969) has demonstrated that the lateral mixing coefficient can be increased in bending streams, varying inversely as the square of the

radius of curvature. The dimensionless parameter, β, as determined by field investigations, is reportedly 0.6 to 0.7 for a gradually curving reach of the Missouri River near Blair, Nebraska (Yotsukura et al., 1970). Another field investigation conducted near Brownsville, Nebraska for a test reach containing a very sharp bend reported average and maximum values of β equal to 3.3 and 10, respectively (Sayre and Yeh, 1973).

The certified computer program, DISPERN, was used for performing the routine effluent analysis. This program is based on the steady-state stream tube model.

11.2.3.3.2 Selection of Surface-Water Model Parameters

A summary of parameters used in the routine effluent analysis is presented in Table 11.2-1. Representative channel geometry parameters of the Missouri River for 50 miles downstream of the Callaway Plant effluent discharge pipeline are noted for the estimated average flow conditions. Average flow conditions are discussed in Section 2.4 and are based on stage-discharge relationships developed for the Missouri River at the Hermann gauging site (see Figure 2.4-10) and near the Callaway Plant site (see Figure 2.4-12), hydrographic survey data from the U.S. Army Corps of Engineers (1978), and hydrologic analysis for river channel variables.

In the analysis, methods for evaluating the lateral turbulent diffusion coefficient, K_y, were reviewed. The minimum value of β, 0.23 for determining K_y, was not considered appropriate to use since it applies specifically to straight natural stream channels and ignores secondary flows which have been experimentally found (as in the Missouri River) to lead to increased lateral mixing. A value of β equal to 0.65 for determining K_y was adopted, as found experimentally for a gradually curving reach of the Missouri River upstream of the Callaway Plant site.

11.2.3.3.3 Results of Analysis

In the analysis for radionuclide transport in the Missouri River from the estimated Callaway Plant annual liquid effluent releases (see Section 11.1.1 of Standard Plant), dilution factors and transit times were predicted from the plant effluent discharge to a distance 50 miles downstream. These are presented in the computer output summary in Table 11.2-2 and 11.2-3. Values are indicated at various cross-stream distances from the near shore for incremental distances beginning at 1 foot.

In tables 11.2-2 and 11.2-3, the dilution factors are presented at the given cross-stream distances from the near shore out to within 50 feet of where the farthest influence of radionuclide transport is estimated.

11.2.3.3.4 Water Usage

For noting liquid pathways to man and for evaluating potential impacts from effluent releases from the Callaway Plant on man and other biota (Section 11.2.3.4), Missouri

River water users were identified along its entire length (115 river miles) downstream from the Callaway Plant site. Dischargers were also identified. These are discussed in Section 2.4 and are identified in Tables 2.4-18 and 2.4-19. Locations of these water withdrawals and water discharge points are shown on Figure 2.4-8. The closest municipal user of Missouri River water downstream from the Callaway Plant site is St. Louis City (Howard Bend), and its water intake is located at Missouri River mile 36.8, some 78 river miles downstream of the Callaway Plant site. The cities of Hermann, New Haven, and Washington, all within 50 miles downstream of the plant effluent discharge pipeline, are the major dischargers to the Missouri River; however, these communities derive their municipal water suppliers from deep wells only. Two known irrigation users that utilize Missouri River water downstream of the Callaway Plant site have intakes located at Missouri River miles 64.5 and 61.4, the nearest of which is located 51 river miles downstream from the plant effluent discharge pipeline. The Union Electric Company also withdraws water from the Missouri River at river mile 58.1 and discharges downstream at river mile 57.9, just below the city of Washington.

Since water users upstream of the Callaway Plant site can alter flows at and downstream of the site and because relocation of contaminated and potentially contaminated materials upstream in the physical environment (such as occurs in dredging operations) could potentially affect the conditions near the site (NRC, 1977 and 1976), Missouri River water users and dischargers upstream from the site were also sufficiently identified to the best extent possible. These are shown on Figure 2.4-9. No potential contaminant source areas were identified. Also, NRC Regulatory Guide 1.113 (1977) suggests identification of the following features in relation to a nuclear plant site:

> (1) surface water usage [Use types include water, irrigation, process water (consumed by such users as breweries and soft drink manufacturers), recreation areas, and fisheries. Ground-water users with wells whose zones of influence extend to streams should also be included (NRC, 1977).] upstream and downstream of the plant site, (2) major tributaries and their junctions, (3) streamflow gauging stations (including their periods of record), and (4) major reservoirs and diversions upstream and downstream of the plant site. Approximate contributing drainage areas and types of water use for all points identified should be shown on the diagram or tabulated separately.

Section 2.4.1 presents a description of surface and ground-water uses in the region surrounding the Callaway Plant site, based on the best available data, both published and unpublished. Descriptions of the Missouri River and its major tributaries, streamflow gauging stations, major reservoirs, and ground-water characteristics in this region are discussed in Section 2.4.1. All of the above were considered for modeling the Missouri River under present conditions and for evaluating the impacts on man and other biota from effluent releases from the Callaway Plant (refer to Section 11.2.3.4).

11.2.3.3.5 Ground-Water Models

Since routine plant releases will be discharged directly to the Missouri River by pipeline, there will be no impact on the local ground-water regime from this source. Therefore, effluent releases were not considered in evaluating the local ground-water environment in dispersing, diluting, or otherwise concentrating radioactive effluents as related to existing or potential future ground-water users.

11.2.3.4 Estimated Doses

11.2.3.4.1 Dose Rate Estimates for Biota Other than Man

From considerations of the exposure pathways and the distribution of facility-derived radioactivity, dose rate estimates to local biota have been formulated through the use of the LADTAP II computer code. This code is based on the methodology presented in Regulatory Guide 1.109, which uses the standard ICRP model for computation of effective radionuclide decay energies and resultant dose factors.

Doses to aquatic flora and fauna can be calculated from a knowledge of concentrations of radionuclides in the Missouri River 0.05 miles downstream of the discharge. Based on radionuclide concentrations present and bio-accumulation factors in Table A-8 in Regulatory Guide 1.109, doses to fish and shellfish living continuously in the section of the Missouri River 0.05 miles downstream of the discharge of the plant were calculated to be 2.19 mrad/yr and 3.95 mrad/yr respectively.

Doses to terrestrial and semi-aquatic animals from the radionuclides in the gaseous and liquid effluent and direct radiation from the plant are expected to be less than or equal to those calculated for man. Dose rates due to liquid radioactive effluents from the Callaway Plant were calculated for the muskrat and raccoon, a semi-aquatic herbivore and a terrestrial omnivore, respectively. Total exposures were 7.10 mrad/yr and 0.845 mrad/yr for the muskrat and raccoon, respectively. It was assumed that the animals obtained all of their food and water from the shore and waters of the Missouri River 0.05 miles downstream of the Callaway discharge. The doses to such animals as migrating ducks, bald eagles, etc. whose presence within 50 miles of the site is on a sporadic or seasonal basis is expected to be considerably less than doses to animals which inhabit the area on a continuous basis.

The dose to organisms other than man will be a very small percentage of that resulting from naturally occurring radiation.

11.2.3.4.2 Dose Rate Estimates for Man

Dose rates to individuals were calculated for drinking water, fish consumption, and recreational activity pathways. Assumptions, including point of exposure, are described for each pathway in the following paragraphs; the calculated liquid pathway doses are

summarized in Table 11.2-4. Releases calculated using the guidance presented in Section 11.1.1 were used.

Crop irrigation is not considered a potential pathway of liquid effluents to man. This is because most water used for irrigation by local farmers comes from small streams in the vicinity rather than the Missouri River.

No drinking water is drawn from the Missouri River within 50 miles downstream of the Callaway Plant discharge. Nevertheless, the dose to an individual obtaining his entire annual water requirements from the Missouri River 0.05 miles downstream of the plant discharge was calculated. The maximum calculated dose to a single organ from this pathway was calculated to be 9.39×10^{-2} mrem/yr to an infant's liver; maximum total-body dose was calculated to be 7.27×10^{-2} mrem/yr to an infant.

Radionuclides released from the plant were assumed to be immediately available for uptake by fish. In lieu of site specific fish consumption data the values recommended by the NRC for use with the LADTAP II program were used. The maximum predicted dose of 0.573 mrem/yr to an adult liver was calculated from the fish consumption pathway due to fish caught 0.05 miles downstream of the plant discharge. The maximum total-body dose calculated was 0.434 mrem/yr to an adult.

The Missouri River has been designated unsuitable for swimming by the State of Missouri but of suitable quality for wading or boating. Potential recreational use of the Missouri River does, however, justify calculation of shoreline activity doses. The maximum calculated dose to a single organ from shoreline recreation 0.05 miles downstream of the plant discharge was 1.78×10^{-3} mrem/yr to the skin on a teenager. A maximum total body dose of 1.53×10^{-3} mrem/yr was calculated at the same location.

Examination of Table 11.2-4 reveals that, based on the dose calculation assumptions described above, the liquid pathway of primary importance in individual total-body exposure is ingestion of fish caught in the Missouri River downstream of the discharge structure. Exposure from shoreline activities will generally be of less importance. No drinking water pathway exists within 50 miles of the plant.

11.2.3.4.3 Estimated Population Doses

Population doses were calculated for fish ingestion, shoreline, and boating exposure pathway. As explained in Section 11.2.3.4.2, the drinking water, swimming, and crop irrigation exposure pathways are not expected to contribute a measurable percentage to the population doses within 50 miles downstream of the Callaway Plant on the Missouri River.

The dose to the population from fish ingestion was based upon a fish harvest of 4.58×10^{-6} kg/yr from the Missouri River from the plant discharge structure to 50 miles downstream, and includes both commercial and sport fish harvest.

Calculation of population doses from recreational exposure was based on usage rates taken from data compiled by the Army Corp or Engineers (Recreational Development Missouri River Rulo, Nebraska, to the Mouth, June 1978).

Fish ingestion accounts for more than 95 percent of the total man-rem dose from the Missouri River. Exposure from recreational activity is expected to contribute the other 5 percent of the total man-rem dose.

TABLE 11.2-1 PARAMETER VALUES USED IN SURFACE-WATER TRANSPORT OF RADIONUCLIDES IN MISSOURI RIVER FROM CALLAWAY PLANT ANNUAL LIQUID EFFLUENT RELEASES

Parameter	Average Annual Flow Condition
Average Width of River, B (feet)	1,100
Average Depth of River, D (feet)	14
Discharge in River, Q (cfs)	69,000
Average River Bed Slope, S (ft/ft)	0.000165
Distance from Near Shore for Source, YS (feet)	0
β for determining K_y	0.65

Values noted are for regulated flow conditions.

TABLE 11.2-2 RESULTS OF ROUTINE EFFLUENT ANALYSIS
Incremental Distance: 264 feet

AVERAGE WIDTH OF RIVER = 1100.0 FEET
AVERAGE DEPTH OF RIVER = 14.0 FEET
AVERAGE DISCHARGE OF RIVER = 69000.0 CFS
AVERAGE SLOPE OF RIVER BED = .000165 FT/FT
POINT SOURCE DISTANCE FROM NEAR SHORE = 0.0 FEET
FACTORS TO INCREASE DISPERSION COEFFICIENT FOR INCREASED MIXING DUE TO CHANNEL CURVATURE

TRANVERSE FACTOR = 2.8
INCREMENTAL DISTANCE AT WHICH TO PERFORM CALCULATIONS = 264.0 FEET
MAXIMUM DOWNSTREAM DISTANCE TO PERFORM CALCULATIONS = 5280.0 FEET
A VALUE OF 11.14 CFS HAS BEEN POSTULATED AS THE DISCHARGE RATE.

DISTANCE DOWNSTREAM (FT)	264.0									
TRANSIT TIME (SECS)	58.9									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	59.8	0.	0.	0.	0.	0.	0.	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	528.0									
TRANSIT TIME (SECS)	117.8									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	84.5	0.	0.	0.	0.	0.	0.	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	792.0									
TRANSIT TIME (SECS)	176.8									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	103	0.	0.	0.	0.	0.	0.	0.	0.	0.

TABLE 11.2-2 (Continued)

DISTANCE DOWNSTREAM (FT)	1056.0									
TRANSIT TIME (SECS)	235.7									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	119	9420	0.	0.	0.	0.	0.	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	1320.0									
TRANSIT TIME (SECS)	294.6									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.134E+03	.440E+04	0.	0.	0.	0.	0.	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	1584.0									
TRANSIT TIME (SECS)	353.5									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.146E+03	.269E+04	0.	0.	0.	0.	0.	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	1848.0									
TRANSIT TIME (SECS)	412.5									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.158E+03	.192E+04	0.	0.	0.	0.	0.	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	2112.0									
TRANSIT TIME (SECS)	471.4									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.169E+03	.150E+04	0.	0.	0.	0.	0.	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	2376.0									
TRANSIT TIME (SECS)	530.3									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.179E+03	.1250E+04	0.	0.	0.	0.	0.	0.	0.	0.

TABLE 11.2-2 (Continued)

DISTANCE DOWNSTREAM (FT)	2640.0									
TRANSIT TIME (SECS)	589.2									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.189E+03	.108E+04	0.	0.	0.	0.	0.	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	2904.0									
TRANSIT TIME (SECS)	648.1									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.198E+03	.969E+03	0.	0.	0.	0.	0.	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	3168.0									
TRANSIT TIME (SECS)	707.1									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.207E+03	.887E+03	0.	0.	0.	0.	0.	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	3432.0									
TRANSIT TIME (SECS)	766.0									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.215E+03	.825E+03	0.	0.	0.	0.	0.	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	3696.0									
TRANSIT TIME (SECS)	824.9									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.223E+03	.778E+03	0.	0.	0.	0.	0.	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	3960.0									
TRANSIT TIME (SECS)	883.8									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.231E+03	.741E+03	.244E+04	0.	0.	0.	0.	0.	0.	0.

TABLE 11.2-2 (Continued)

DISTANCE DOWNSTREAM (FT)	4224.0									
TRANSIT TIME (SECS)	942.7									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.239E+03	.712E+03	.188E+05	0.	0.	0.	0.	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	4488.0									
TRANSIT TIME (SECS)	1001.7									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	246E+03	.688E+03	.150E+05	0.	0.	0.	0.	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	4752.0									
TRANSIT TIME (SECS)	1060.6									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.253 E+03	.669E+03	.123E+05	0.	0.	0.	0.	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	5016.0									
TRANSIT TIME (SECS)	1119.5									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.260E+03	.653E+03	.103E+05	0.	0.	0.	0.	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	5280.0									
TRANSIT TIME (SECS)	1178.4									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.267E+03	.640E+03	.879E+04	0.	0.	0.	0.	0.	0.	0.

TABLE 11.2-3 RESULTS OF ROUTINE EFFLUENT ANALYSIS

Incremental Distance: 1 Mile

AVERAGE WIDTH OF RIVER = 1100.0 FEET
AVERAGE DEPTH OF RIVER = 14.0 FEET
AVERAGE DISCHARGE OF RIVER = 69000.0 CFS
AVERAGE SLOPE OF RIVER BED = .000165 FT/FT
POINT SOURCE DISTANCE FROM NEAR SHORE = 0.0 FEET
FACTORS TO INCREASE DISPERSION COEFFICIENT FOR INCREASED MIXING DUE TO CHANNEL CURVATURE
TRANVERSE FACTOR = 2.8
INCREMENTAL DISTANCE AT WHICH TO PERFORM CALCULATIONS = 5280.0 FEET
MAXIMUM DOWNSTREAM DISTANCE TO PERFORM CALCULATIONS = 264000.0 FEET
A VALUE OF 11.14 CFS HAS BEEN POSTULATED AS THE DISCHARGE RATE.

DISTANCE DOWNSTREAM (FT)	5280.0									
TRANSIT TIME (SECS)	1178.4									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.267E+03	.640E+03	.879E+04	0.	0.	0.	0.	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	10560.0									
TRANSIT TIME (SECS)	2356.9									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.378E+03	.584E+03	.217E+04	.192E+05	0.	0.	0.	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	15840.0									
TRANSIT TIME (SECS)	3535.3									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.462E+03	.619E+03	.148E+04	.636E+04	0.	0.	0.	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	21120.0									
TRANSIT TIME (SECS)	4713.7									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.534E+03	.664E+03	.128E+04	.381E+04	.176E+05	0.	0.	0.	0.	0.

TABLE 11.2-3 (Continued)

DISTANCE DOWNSTREAM (FT)	26400.0									
TRANSIT TIME (SECS)	5892.2									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.597E+03	.711E+03	.120E+04	.288E+04	.977E+04	0.	0.	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	31680.0									
TRANSIT TIME (SECS)	7070.6									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.654E+03	.756E+03	.117E+04	.242E+04	.672E+04	.249E+05	0.	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	36960.0									
TRANSIT TIME (SECS)	8249.0									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.706E+03	.800E+03	.116E+04	.217E+04	.520E+04	.160E+05	0.	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	42240.0									
TRANSIT TIME (SECS)	9427.5									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.755E+03	.842E+03	.117E+04	.202E+04	.433E+04	.116E+05	0.	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	47520.0									
TRANSIT TIME (SECS)	10605.9									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.801E+03	.883E+03	.118E+04	.192E+04	.379E+04	.907E+04	.264E+05	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	52800.0									
TRANSIT TIME (SECS)	11784.3									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.844E+03	.921E+03	.120E+04	.185E+04	.342E+04	.750E+04	.196E+05	0.	0.	0.

TABLE 11.2-3 (Continued)

DISTANCE DOWNSTREAM (FT)	58080.0									
TRANSIT TIME (SECS)	12962.8									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.885E+03	.959E+03	.122E+04	.181E+04	.316E+04	.645E+04	.154E+05	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	63360.0									
TRANSIT TIME (SECS)	14141.2									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.925E+03	.995E+03	.124E+04	.178E+04	.296E+04	.571E+04	.127E+05	0.	0.	0.
DISTANCE DOWNSTREAM (FT)	68640.0									
TRANSIT TIME (SECS)	15319.7									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.963E+03	.103E+04	.126E+04	.176E+04	.282E+04	.517E+04	.108E+05	.259E+05	0.	0.
DISTANCE DOWNSTREAM (FT)	73920.0									
TRANSIT TIME (SECS)	16498.1									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.999E+03	.106E+04	.128E+04	.175E+04	.271E+04	.475E+04	.944E+04	.213E+05	0.	0.
DISTANCE DOWNSTREAM (FT)	79200.0									
TRANSIT TIME (SECS)	17676.5									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.103E+04	.110E+04	.131E+04	.175E+04	.263E+04	.443E+04	.842E+04	.179E+05	0.	0.
DISTANCE DOWNSTREAM (FT)	84480.0									
TRANSIT TIME (SECS)	18855.0									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.107E+04	.113E+04	.133E+04	.175E+04	.256E+04	.418E+04	.762E+04	.155E+05	0.	0.

TABLE 11.2-3 (Continued)

DISTANCE DOWNSTREAM (FT)	89760.0									
TRANSIT TIME (SECS)	20033.4									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.110E+04	.116E+04	.135E+04	.175E+04	.250E+04	.398E+04	.700E+04	.137E+05	0.	0.
DISTANCE DOWNSTREAM (FT)	95040.0									
TRANSIT TIME (SECS)	21211.0									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.113E+04	.119E+04	.138E+04	.175E+04	.246E+04	.381E+04	.650E+04	.122E+05	0.	0.
DISTANCE DOWNSTREAM (FT)	100320.0									
TRANSIT TIME (SECS)	22390.3									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.116E+04	.122E+04	.140E+04	.176E+04	.243E+04	.367E+04	.609E+04	.111E+05	0.	0.
DISTANCE DOWNSTREAM (FT)	105600.0									
TRANSIT TIME (SECS)	23588.7									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.119E+04	.125E+04	.142E+04	.177E+04	.240E+05	.356E+05	.575E+05	.101E+05	0.	0.
DISTANCE DOWNSTREAM (FT)	110880.0									
TRANSIT TIME (SECS)	24747.1									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.122E+04	.128E+04	.144E+04	.178E+04	.238E+04	.346E+04	.547E+04	.939E+04	0.	0.
DISTANCE DOWNSTREAM (FT)	116160.0									
TRANSIT TIME (SECS)	25925.6									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.125E+04	.130E+04	.147E+04	.179E+04	.236E+04	.338E+04	.523E+04	.876E+04	.303E+05	0.

TABLE 11.2-3 (Continued)

DISTANCE DOWNSTREAM (FT)	121440.0									
TRANSIT TIME (SECS)	27104.0									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.128E+04	.133E+04	.149E+04	.180E+04	.235E+04	.331E+04	.502E+04	.822E+04	.268E+05	0.
DISTANCE DOWNSTREAM (FT)	126720.0									
TRANSIT TIME (SECS)	28282.4									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.131E+04	.136E+04	.151E+04	.181E+04	.234E+04	.325E+04	.485E+04	.777E+04	.240E+05	0.
DISTANCE DOWNSTREAM (FT)	132000.0									
TRANSIT TIME (SECS)	29460.9									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.133E+04	.138E+04	.154E+04	.183E+04	.233E+04	.320E+04	.469E+04	.738E+04	.216E+05	0.
DISTANCE DOWNSTREAM (FT)	137280.0									
TRANSIT TIME (SECS)	30639.3									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.136E+04	.141E+04	.156E+04	.184E+04	.233E+04	.315E+04	.456E+04	.704E+04	.197E+05	0.
DISTANCE DOWNSTREAM (FT)	142560.0									
TRANSIT TIME (SECS)	31817.7									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.139E+04	.143E+04	.158E+04	.186E+04	.233E+04	.311E+04	.444E+04	.675E+04	.180E+05	0.
DISTANCE DOWNSTREAM (FT)	147840.0									
TRANSIT TIME (SECS)	32996.2									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.141E+04	.146E+04	.160E+04	.187E+04	.233E+04	.308E+04	.434E+04	.649E+04	.166E+05	.308E+05

TABLE 11.2-3 (Continued)

DISTANCE DOWNSTREAM (FT)	153120.0									
TRANSIT TIME (SECS)	34174.6									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.144E+04	.148E+04	.162E+04	.189E+04	.233E+04	.305E+04	.425E+04	.626E+04	.154E+05	.275E+05
DISTANCE DOWNSTREAM (FT)	158400.0									
TRANSIT TIME (SECS)	35353.0									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.146E+04	.151E+04	.164E+04	.190E+04	.233E+04	.303E+04	.417E+04	.606E+04	.144E+05	.246E+05
DISTANCE DOWNSTREAM (FT)	163680.0									
TRANSIT TIME (SECS)	36531.5									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.149E+04	.153E+04	.166E+04	.192E+04	.233E+04	.301E+04	.409E+04	.587E+04	.134E+05	.225E+05
DISTANCE DOWNSTREAM (FT)	168960.0									
TRANSIT TIME (SECS)	37709.9									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.151E+04	.155E+04	.168E+04	.193E+04	.234E+04	.299E+04	.403E+04	.571E+04	.126E+05	.205E+05
DISTANCE DOWNSTREAM (FT)	174240.0									
TRANSIT TIME (SECS)	38888.3									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.153E+04	.157E+04	.170E+04	.195E+04	.234E+04	.297E+04	.397E+04	.556E+04	.119E+05	.189E+05
DISTANCE DOWNSTREAM (FT)	179520.0									
TRANSIT TIME (SECS)	40066.8									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.156E+04	.160E+04	.173E+04	.196E+04	.235E+04	.296E+04	.391E+04	.542E+04	.113E+05	.174E+05

TABLE 11.2-3 (Continued)

DISTANCE DOWNSTREAM (FT)	184800.0									
TRANSIT TIME (SECS)	41245.2									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.158E+04	.162E+04	.175E+04	.198E+04	.235E+04	.294E+04	.386E+04	.530E+04	.107E+05	.162E+05
DISTANCE DOWNSTREAM (FT)	190080.0									
TRANSIT TIME (SECS)	42423.7									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.160E+04	.164E+04	.177E+04	.199E+04	.236E+04	.293E+04	.382E+04	.519E+04	.102E+05	.151E+05
DISTANCE DOWNSTREAM (FT)	195360.0									
TRANSIT TIME (SECS)	43602.1									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.162E+04	.166E+04	.178E+04	.201E+04	.237E+04	.292E+04	.378E+04	.509E+04	.977E+04	.141E+05
DISTANCE DOWNSTREAM (FT)	200640.0									
TRANSIT TIME (SECS)	44780.5									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.165E+04	.168E+04	.180E+04	.202E+04	.238E+04	.292E+04	.374E+04	.499E+04	.936E+04	.133E+05
DISTANCE DOWNSTREAM (FT)	205920.0									
TRANSIT TIME (SECS)	45959.0									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.167E+04	.170E+04	.182E+04	.204E+04	.238E+04	.291E+04	.371E+04	.490E+04	.898E+04	.125E+05
DISTANCE DOWNSTREAM (FT)	211200.0									
TRANSIT TIME (SECS)	47137.4									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.169E+04	.173E+04	.184E+04	.205E+04	.239E+04	.291E+04	.368E+04	.482E+04	.864E+04	.119E+05

TABLE 11.2-3 (Continued)

DISTANCE DOWNSTREAM (FT)	216480.0									
TRANSIT TIME (SECS)	48315.8									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.171E+04	.175E+04	.186E+04	.207E+04	.240E+04	.290E+04	.365E+04	.475E+04	.833E+04	.113E+05
DISTANCE DOWNSTREAM (FT)	221760.0									
TRANSIT TIME (SECS)	49494.3									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.173E+04	.177E+04	.188E+04	.209E+04	.241E+04	.290E+04	.362E+04	.467E+04	.804E+04	.107E+05
DISTANCE DOWNSTREAM (FT)	227040.0									
TRANSIT TIME (SECS)	50672.7									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.175E+04	.179E+04	.190E+04	.210E+04	.242E+04	.290E+04	.360E+04	.461E+04	.778E+04	.102E+05
DISTANCE DOWNSTREAM (FT)	232320.0									
TRANSIT TIME (SECS)	51851.1									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.177E+04	.181E+04	.192E+04	.212E+04	.243E+04	.289E+04	.357E+04	.455E+04	.753E+04	.979E+04
DISTANCE DOWNSTREAM (FT)	237600.0									
TRANSIT TIME (SECS)	53029.6									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.179E+04	.183E+04	.193E+04	.213E+04	.244E+04	.289E+04	.355E+04	.449E+04	.731E+04	.938E+04
DISTANCE DOWNSTREAM (FT)	242880.0									
TRANSIT TIME (SECS)	54208.0									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	181E+04	.184E+04	.195E+04	.215E+04	.245E+04	.289E+04	.353E+04	.444E+04	.710E+04	.901E+04

TABLE 11.2-3 (Continued)

DISTANCE DOWNSTREAM (FT)	248160.0									
TRANSIT TIME (SECS)	55886.4									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.183E+04	.186E+04	.197E+04	.216E+04	.246E+04	.289E+04	.352E+04	.438E+04	.690E+04	.868E+04
DISTANCE DOWNSTREAM (FT)	253440.0									
TRANSIT TIME (SECS)	56564.9									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.185E+04	.188E+04	.199E+04	.218E+04	.247E+04	.289E+04	.350E+04	.434E+04	.672E+04	.837E+04
DISTANCE DOWNSTREAM (FT)	258720.0									
TRANSIT TIME (SECS)	57743.3									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.187E+04	.190E+04	.201E+04	.219E+04	.248E+04	.289E+04	.348E+04	.429E+04	.656E+04	.808E+04
DISTANCE DOWNSTREAM (FT)	264000.0									
TRANSIT TIME (SECS)	58921.7									
CROSSTREAM DISTANCE (FT)	1.	100.	200.	300.	400.	500.	600.	700.	900.	1100.
DILUTION OF ALL NUCLID	.189E+04	.192E+04	.202E+04	.220E+04	.249E+04	.289E+04	.347E+04	.425E+04	.640E+04	.782E+04

TABLE 11.2-4 SUMMARY OF CALCULATED LIQUID PATHWAY DOSES - CALLAWAY PLANT

			Organ Receiving Maximum Dose		
Pathway	Location	Age Group	Organ	Dose (mrem/yr)	Total Body Dose (mrem/yr)
Fish Ingestion	Missouri River - 0.05 miles downstream of discharge	Adult	Liver	5.73E-1	4.34E-1
		Teen	Liver	5.86E-1	2.52E-1
		Child	Liver	5.06E-1	1.01E-1
Shoreline Activity	Recreational access points on the Missouri River within 50 miles downstream of the discharge	Adult	Skin	3.19E-4	2.73E-4
		Teen	Skin	1.78E-3	1.53E-3
		Child	Skin	3.72E-4	3.19E-4

11.3.3.4.1 Diffusion Models

Annual average dilution factors (χ/Q's) utilized in evaluating the releases of gaseous effluents were calculated according to the straightline method set forth in Regulatory Guide 1.111, based on three years of on-site meteorological data acquired during the periods of May 4, 1973, through May 4, 1975, and March 16, 1978, through March 16, 1979. A detailed discussion of the applicable methodology appears in Sections 2.3.4 and 2.3.5 with the results of the calculation of annual χ/Q values listed in Table 2.3-61 through 2.3-86.

11.4.2.4 Packaging, Storage, and Shipment

See FSAR Standard Plant,Section 11.4.1.2 and11.4.2.5.