5.1 EFFECTS OF OPERATION OF HEAT DISSIPATION SYSTEM

The CRBRP will employ a closed recirculating condenser cooling system with heat dissipation via mechanical draft evaporative cooling towers. 6
Potential environmental concerns associated with heat dissipation system operation include discharge of a small fraction of the plant waste heat load through the cooling tower blowdown, withdrawal of makeup cooling water from the Clinch River, formation of water vapor plumes, drift deposition and noise. (Effects of chemicals present in the cooling tower blowdown are discussed in Section 5.4.)

5.1.1 PLANT THERMAL DISCHARGE

During normal operation, the CRBRP will discharge waste heat to the Clinch River through the blowdown flow of the cooling tower. As the cooling system is of the recirculating type, the amount of heat discharged is very small -- less than 0.1 percent of the heat load rejected to the circulating water system by the condenser. A discharge plume study, discussed in the Appendices to Section 10.3, has been developed to examine the temperature distribution and plume configuration resulting from plant thermal discharges. This study is based on physical thermal-hydraulic and mathematical modeling investigations performed by the University of Iowa, Institute of Hydraulic Research (Iowa Institute). The Iowa Institute's 6
report of findings is presented in Appendix B to Section 10.3

5.1.1.1 MIXING CASES

As the Clinch River is a regulated stream controlled by TVA dams, conditions of flow and pool elevation uncommon to free flowing rivers are experienced. Consideration of these circumstances has resulted in the identification of both typical (average) and extreme (worst case) modeling events for the characterization of thermal discharge effects. These cases are described in detail in Appendix A to Section 10.3 and are summarized below:

1. Typical Winter Case -- average of river and discharge parameter (pool elevation, flow rate, temperature, etc.) values for January, February and March.

2. Typical Summer Case -- average of parameter values for July, August and September.

3. Hypothetical Winter Extreme Case -- arbitrary assumption of simultaneous occurrence of minimum recorded river water temperature and maximum air (wet bulb) temperature for same month (January) to produce a maximum initial temperature differential (between cooling tower blowdown and ambient river).

4. Hypothetical Summer Extreme Case -- assumption of simultaneous occurrence of maximum recorded river water temperature and maximum air (wet bulb) temperature for same month (June) to produce a maximum water temperature in the river.

5. Extended No Flow Winter Extreme Case -- occurrence of a prolonged period of zero river flow during the winter months resulting from shutdown of Melton Hill Dam; no flow event sufficiently long for quasi-steady state thermal equilibrium conditions to be achieved. 6

6. Extended No Flow Summer Extreme Case -- prolonged period of zero river flow occurring during the summer.

Numeric values for the key mixing parameters are given in Table 10.3A-4 for the typical and hypothetical cases and Table 10.3A-10 for the extended no flow cases.

Hypothetical extreme cases are examined to determine plant environmental performance under conditions more severe than those that would be anticipated during the lifetime of the facility. In addition to assumptions regarding air and water temperatures which tend to maximize thermal effects, the hypothetical extreme cases are assumed to occur during periods of minimum river pool elevation and zero river flow to minimize dilution potential. Evaluations of the two hypothetical extreme cases provides upperbound estimates of adverse environmental impact without recourse to consideration of the innumerable combinations of mixing conditions that may be postulated to occur. (Two such conditions are thermal stratification and flow reversal. The rationale for not including these in the extreme case analysis is presented in Additional Worst Case Considerations, Appendix A to Section 10.3.)

Extended periods of no flow in the Clinch River at the Site are considered as a response to past operating experience at Melton Hill Dam (see
Table 2.5-2). While prolonged periods of zero flow from the dam are 6
not anticipated in the future, the extended no flow cases could potentially be limiting from an environmental perspective and are, therefore, included in the thermal plume analysis.

5.1.1.1.1 COOLING SYSTEM DESIGN EVOLUTION

The Amendment VI revisions to the ER (1976) include the identification of
new design parameters for the CRBRP cooling system which have arisen as a 9
consequence of selection of the turbine-generator. At the time of the environmental evaluation of the thermal effects of the plant discharge, a previous set of cooling system design values were in use. Comparisons
of system performance for both sets of values are presented in 6
Table 10.3A-1 and Figure 10.3A-2. The differences in performance characteristics are not substantial and indicate, by virtue of lower cold water (discharge) temperature and blowdown flowrate, a reduced level of
thermal impact for the 1976 cooling system design. The staff of the 9
Iowa Institute has reviewed these design changes and determined that

the differences between the 1976 values and those utilized by the physical 9
modeling studies are not significant (see Appendix I to Appendix 10.3B). Accordingly, no attempt has been made to either re-perform the modeling investigations or rewrite the environmental analysis presented in this section. Note that the extended no flow analysis was conducted after the adoption of the revised cooling system design parameters and, therefore, is based on the 1976 performance data. 6 9

To facilitate differentiation between values based on the old and 1976 9
cooling tower performance data, numbers derived from the original data (environmental analysis values in Table 10.3A-1 and Figure 10.3A-2) are underlined in this section.

As an example of the effect of the 1976 cooling system design values 9
on the environmental analysis, Table 5.1-1 has been modified to include an estimate of plume temperature reductions which would occur if the new performance data are utilized. 9

Further refinements in cooling tower design are included in Amendment IX (1980) revisions to Section 3.4. The 1980 design data results in increased cooling tower blowdown temperatures and volumes on the order of 5% or less over the 1976 data (see Table 10.3A-1). This places the newest 9
design intermediate between the original and the 1976 design. Therefore, the impact analysis presented here is considered to be still valid, although it is understood that small (less than 5%) increases in the size of the extended no flow plumes would be expected.

In general, CRBRP thermal plumes will be characterized by temperature increases above ambient and spatial extents of a smaller magnitude than 6
that described in this section. The environmental impact associated with these plumes will be similarly reduced.

Another revision incorporated with Amendment 7 is the recessing of the 7
discharge pipe into the river bank (see Figure 3.4-8). This was done to

ensure that the CRBRP single-port submerged discharge structure does not present a hazard to navigation on the river. The new placement neither adversely affects the mixing of plant effluents in the river nor 7 produces any significant changes in the thermal and chemical plume formations as projected by the Iowa Institute of Hydraulics modeling studies (see Appendix III to Appendix 10.3B). Accordingly, the validity of the discharge plume analyses, as presented, is not compromised.

5.1.1.2 THERMAL PLUMES

Temperature distributions and geometric configurations of thermal plumes anticipated to result in the Clinch River as a consequence of CRBRP waste heat discharges are described in detail in Appendix 10.3A. In 6 general, these plumes may be characterized as modest in both temperature rise and spatial extent. The plant effluent, which is released to the river through a submerged single port discharge, rapidly mixes from top to bottom in the water column. Excess temperature is, accordingly, quickly diluted so that the initial isotherms which may be identified as encompassing measurable areas of the river are on the order of a degree or two above ambient water temperatures.

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Thermal plume development for the typical and hypothetical cases is
predicted on the basis of the Iowa Institute physical model of the CRBRP
discharge as reported in Appendix 10.3B. The model results are presented
in Figures 10.3A-4 through 10.3A-7. Maximum temperature rises at the 6
river surface and bottom for the typical and hypothetical case plumes
are recorded in Table 5.1-1. It should be noted that such temperature
differential maxima essentially occur at a single point and would not 9
extend over any noticeable area of the river. The isotherms predicted
from the modeling study are superimposed on surface and bottom plan views
of the Clinch River in the vicinity of the discharge point in Fig-
ures 5.1-1 through 5.1-4. Areas of the river encompassed by these iso-
therms are identified in Tables 5.1-2 and 5.1-3 for the surface and river
bottom, respectively. Only for the hypothetical winter extreme case is
the full river width affected by temperatures in the order of one F degree
above ambient. For all other cases, regions of excess temperatures down
to one F degree are confined to the immediate area of the discharge point.

5.1.1.2.1 EXTENDED NO FLOW

Characterization of the thermal plumes for extended no flow episodes
is based on a mathematical modeling study performed by the Iowa Institute 6
and described in Appendix II to Appendix 10.3B. Recall that the most
recent (1980) cooling system design may result in plumes slightly (less 9
than 5%) larger than those described here.

Thermal plume development during extended periods of no river flow at
the Site is initiated with the shutdown of the Melton Hill Dam turbines
at which time the plume configurations depicted in Figures 5.1-1 and
5.1-2 are in evidence. With the cessation of flow at the discharge point, 6
these typical case plumes begin to spread out across the river surface
from the zone of near-field mixing. As this spreading proceeds, the
amount of ambient fluid available for entrainment in the discharge jet
diminishes and near-field dilution is reduced. Initially, plume temper-
ature rises; however, as the surface area encompassed by the plume in- 6

creases, heat loss to the atmosphere becomes an important transport mechanism. Eventually, with the plumes extending across the full width of the channel for several miles up and downstream, a point is reached at which the surface area occupied is sufficiently large that the rate of heat loss through surface cooling is equal to the rate of heat addition at the discharge. A steady-state condition is thus attained and no further 6 increases in either temperature or spatial extent are realized. As the plume exists as a buoyant surface layer of roughly one-third of pool depth in thickness, ambient fluid flows beneath it throughout its length.

For the case of extended no flow in the winter, a steady-state condition
is reached in approxmately 5 days. At this point in time, the maximum
plume temperature rise is 3.4F° and is associated with a transitional
zone of several channel widths (600 ft. increments) in length which extends
from the near-field mixing zone to the point of shore-to-shore spreading.
The maximum plume half-length is 1.0 mile and is defined as the distance
either up or downstream from the discharge to the boundary of the iso-
therm which represents one percent of the initial temperature rise or 6
0.034F°. As 0.034F° is not biologically significant, the thermal plume
half-length may more appropriately be considered from an environmental
viewpont to be the distance to the 0.5F° isotherm or 0.7 mile (see
Figure A-3, Appendix 10.3B). Isotherm boundaries for the winter case
are depicted in Figure 5.1-5.

In the summer no flow case, the time to achieve steady-state conditions
is approximately 10 days. Maximum plume temperature rise in the tran- 9
sitional zone is 1.3F° and the plume half-lengths are 3.0 and 2.0 miles
for the one percent and 0.5F° isotherms, respectively. Isotherm bound-
aries are illustrated in Figure 5.1-6.

5.1.2 THERMAL STANDARDS FOR DISCHARGE TO CLINCH RIVER

The DRAFT NPDES Permit imposes the following thermal requirements on the common plant discharge:

"The receiving water shall not exceed (1) a maximum water tem- 9
perature change of 3°C (5.4°F) relative to an upstream control
point, (2) a maximum temperature of 30.5°C (86.9°F) and (3) a

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maximum rate of change of 2°C (3.6°F) per hour as measured outside the
mixing zone (66 ft from the point of discharge) at a depth of five feet 9 16
or mid-depth which ever is less.

An examination of the data presented in the Appendices to Section 10.3
and Figures 5.1-1 through 5.1-6 indicates that the CRBRP thermal dis-
charge will not produce temperature regimes in the Clinch River that would 6
exceed the above limits. Temperatures in the plumes are within the 9
NPDES Permit requirements. Note that allowance will be made for a
reasonable zone of mixing (see Appendix to Section 2.5); accordingly,
temperature measurements for compliance certification purposes would not
be expected to be taken in the emerging jet core -- i.e., prior to plume
surfacing.

Thermal discharges from the CRBRP will not affect the water quality in 6
any other state.

5.1.3 EFFECT OF HEATED PLUME ON AQUATIC LIFE IN THE CLINCH RIVER

Temperature affects all organisms. Temperature not only defines the 9
distribution of organisms, but it is an important controlling factor in reproduction and growth. The range of temperatures at which life can exist is enormous; however, most animals are confined to a range of 32 to 104 degrees F (0 to 40°C)[2] and even then, few species can survive the entire range of these temperatures since their range of survival temperatures is still smaller. Even small, well defined temperature ranges for each species can be further subdivided. For example, an adult aquatic species may survive at temperatures between 35 to 90 degrees F, but may spawn only at temperatures between 45 to 55 degrees F. Similarly, the eggs may develop only at temperatures between 45 to 55 degrees F. Since the survival of a species is dependent on completion of all phases of the life cycle, failure of any one phase will result in reduced populations.

An examination of the temperatures at which an animal can develop should focus on the particular phase of the life cycle (spawning, egg or larval development, etc.) which is the least resistant to thermal alteration of its normal temperature regime. This type of information is exceedingly sparse and the complete thermal requirements are known for very few organisms.

From analyses discussed in the following sections it can be concluded that aquatic life in the Clinch River would not be seriously impacted by the thermal effluent from the CRBRP. This conclusion is based on a number of known facts and projected results which are itemized for various types of aquatic life as follows:

1. Fish - The temperature which fish prefer is dependent upon the previous acclimation temperature (previous thermal history). Fish not acclimated to, yet exposed to, higher temperatures would be expected to move away to lower temperature regions. Fish migrations will not be impeded in the vicinity of the Site and spawning habits should not be disrupted because the thermal plume which will result from the cooling tower blowdown for typical and hypothetical cases is relatively small when compared to the total cross-sectional area of the river at the point of effluent discharge. During the extended no flow case maximum surface plume temperature is predicted to be 3.4 F° above ambient and to extend across the river. This plume will spread over the surface while there is no river flow but the lower two-thirds of the river depth will be at ambient temperatures. Since the river surface is only several degrees above ambient and ambient temperature exists below the surface, fish movement will not be significantly affected by the thermal plume. 6

2. Benthos - Results of thermal-hydraulic modeling studies (Appendix B to Section 10.3) indicate that the plant

discharge will scour a small area of the river bottom, less than 100 square feet, and the thermal plume isotherms of 1 to 3 F degrees above ambient river temperatures will impinge on less than 0.01 acre of the bottom. For the hypothetical winter extreme case, the bottom area bounded by the 2.3 F degree isotherm will be 0.01 acre. Though temperatures on the bottom will be greater during the extended no flow conditions a similar area of the bottom will be affected by the discharge plume.

3. Periphyton - Thermal discharges are not expected to cause changes in the periphyton communities from autotrophic to heterotrophic organisms in the immediate area of the discharge because the plant effluent mixes rapidly so that within a short distance from the discharge nozzle, resultant temperatures are only 2 to 3 F degrees above ambient temperatures. Use of cooling towers, as proposed for the CRBRP, was shown to reduce thermal stress in the periphyton community and to aid in maintaining normal autotrophic-heterotrophic relationships in the Green River.[3] Even the extreme cases of extended no flow periods should not significantly alter species composition of the the periphyton community because the smallest temperature rise occurs in the summer when bluegreen species are naturally favored by higher summer temperatures. Winter ambient temperatures are low so that even the 3.4 F° rise in river temperature is still within the thermal range of diatoms. 6

4. Planktonic species (phytoplankton, zooplankton, fish eggs and larvae) - Temperature increases in the plume are small and within the thermal tolerance limits of the dominant

species of river plankton. Even under extended no flow conditions, the highest winter plume temperatures are within the thermal tolerance limits of the dominant species and summer temperature increases are similar to normal diurnal variations. Plume volumes are small when compared to the river volume and during typical flow conditions, only a small portion of the plankton population will experience a short exposure to the small temperature increase associated with the plume. 6

5.1.3.1 THERMAL EFFECTS ON FISH

Effects of temperature have been reported for several of the more common species of fish collected at the Clinch River Site. Lists of fish collected are presented in Tables 5.1-4 and 5.1-5. Lethal temperature 6 characteristics of selected fish, where previous acclimation temperatures were known, are presented in Table 5.1-6. Extensive literature reviews of thermal relationships have been prepared in recent years by Coutant and Pfuderer,[4] and Coutant and Goodyear.[5] While the data presented in Table 5.1-6 are not exhaustive, they are considered adequate to permit evaluation of thermal impacts on fish from CRBRP blowdown. Results from several experiements have been reported for some of the species. Differences in lethal temperatures for similar acclimation temperatures may occur because different experimenters conducted the research under different laboratory conditions, used different criteria for determining lethal conditions, or used different populations of a test species. Information on preferred temperatures, when fish were held at different acclimation temperatures, is presented in Table 5.1-7.

Lethal and preferred temperatures of fish species generally increase significantly with an increase in acclimation temperatures. Data in Table 5.1-6 suggest that, at least to an upper limit where the acclimation temperature equals the lethal temperature, as acclimation temperature increases, so does the temperature at which fish die. For example, bluegill acclimated at 45 degrees F have a lethal temperature (where 50 percent of the fish were observed to die in a 24-hour period) of 89 degrees F. Acclimation at 52 degrees F raises the lethal temperature to 95 degrees F and when acclimated at 79 degrees F the lethal temperature increased to 103 degrees F. Data in Table 5.1-7 indicate that preferred temperatures also increase as the acclimation temperature is increased. As shown in Table 5.1-7, carp acclimated at 50 degrees F, when offered a gradient of temperatures, preferred 61.3 degrees F; those acclimated at 77 degrees F preferred 87.8 degrees F. Bluegill and channel catfish acclimated at 48.2 degrees F preferred 67.3 degrees F, but temperature preferences after acclimation at 75.2 degrees F increased to 88.2 degrees F for bluegill and 84.9 degrees F for channel catfish. 6

For the typical summer case, the acclimation temperature would be that of the ambient river water temperature of 65.7 degrees F. For example, bluegill acclimated at 59 degrees F could possibly experience some lethal effects at temperatures above 87.8 degrees F. Largemouth bass population acclimated at 68 degrees F may experience 50 percent mortality if in 90.7 degrees F water for several hours. However, these lethal temperatures would only be experienced if these species were able to position themselves in the undiluted effluent at the discharge nozzle for an extended period of time. Such an occurrence is not likely to happen because the effluent exists the discharge nozzle as a high velocity (>20 fps) jet and plume temperatures rapidly fall below the lethal levels cited, well before jet velocities are reduced to a point where fish could remain within the developing plume. Under typical summer conditions at approximately 18 feet from the discharge point, sufficient mixing has been achieved so that maximum plume temperatures are less than 2 F degrees above ambient. Studies of game fish in Lake Monona in Wisconsin,[(6)] have shown that certain species of fish tend to position themselves in a discharge plume according to their temperature preferences and would not be expected to approach the region of substantially undiluted temperature directly in front of the discharge nozzle.

Bush[7], estimating the effects of increased temperature on fish species in the Tennessee River, concluded that only 5 percent of the species, mainly trout, would be lost from the river if the temperature increased to 86°F. This temperature is several degrees higher than values that will be experienced by fish in the thermal plume under the modeled river 6
condition. Since trout were not collected during the baseline survey and plume temperatures will be well under 86 degrees F, it can be concluded that discharge plumes in the area of the Site will not alter Clinch River fish populations. 9

Preferred temperatures presented in Table 5.1-7 were derived from observations in which a range of temperatures were available to the fish. Without exception, all of the preferred temperatures reported in this table are below the typical summer case blowdown temperature of <u>89.3 degrees F</u> (31.8 degrees C). On the basis of these data and the results of the thermal regulation study,[6] it is expected that within the plume of the CRBRP, fish would remain in or near their preferred temperatures. If the temperature at the discharge were above the preferred temperature, it would be expected that they would move out of the plume into cooler waters.

It has recently been discovered that mature striped bass from the main body of Watts Bar Lake are attracted to the cool temperatures of the Clinch River during the summer (Section 2.7.2.5). These fish prefer temperatures in the range of 64 to 71 degrees F (18-22 degrees C), centering on 68 degrees F (20 degrees C),[7a,7b,7c] and avoided temperatures above 77 degrees F (26 degrees C). When the oxygenated epilimnion (surface layer) in the main reservoir reaches 75 degrees F or more (around mid-July), these fish move into the Clinch River, where summer temperatures during the baseline survey averaged 67-74 degrees F (19.8-23.3 de- 9
grees C). The fish stay in the river until falling temperatures allow them to return to the reservoir in October. A preferred location in the river is the west and south side of the channel from miles 15 to 17 (the proposed CRBRP discharge is on the northeast bank at mile 16).[7a,7b,7c] As discussed in previous paragraphs, typical summer thermal plume temperatures are less than 2 F degrees above ambient within 20 feet of the discharge point, and temperatues exceeding ambient by more

than 0.7 degrees F occur in less than 0.07 surface acres. Under extreme ambient conditions, less than 0.02 acres would be more than 0.7 degrees F above ambient. These very small plumes would not have any effect on striped bass use of the Clinch River.

Only when an extended period of zero release from Melton Hill Dam (modeled in Figure 5.1-6) occurs concurrently with extreme ambient temperatures (74 degrees F or more), might the thermal discharge have a small deleterious effect on striped bass. Under these conditions, the surface one meter near the southwest bank of river mile 16 would be elevated approximately 1.3 F degree above ambient. The 1 F degree isotherm would extend for over 3/4 mile in either direction, affecting a large area preferred by striped bass. Thus, under these very unlikely worst case conditions, the top one meter of water in 1 1/2 to 2 miles of the river may be avoided by striped bass. Since these fish typically avoid the surface waters during the day,[7a] the thermal effect suggested here might not be experienced by the fish. It is therefore concluded that the potential impact of the CRBRP thermal plume on striped bass use of the Clinch River as a coolwater refuge would be very small even under worst case conditions. 9

The critical points in this discussion are that, while the lethal temperatures of some species will be exceeded by the maximum summer blowdown temperature at the point of discharge: (1) discharge velocities will prevent fish from entering the area of lethal temperature; (2) 6 mixing will be rapid, hence thermal decay will be rapid; (3) the area of initial mixing and temperature increase will be small and, hence, passage time through the zone by fish will be small; and (4) fish can and will avoid this mixing zone, as Neill and Magnuson[6] and Gammon[8], among others, have shown. 6

5.1.3.1.1 MIGRATION

The thermal plume which enters the Clinch River is not expected to interfere with the migration or movement of local fish. Only in the hypothetical winter extreme and the unexpected extended no flow cases does the 6

thermal plume, as indicated in Figures 5.1-3, 5.1-5 and 5.1-6 extend more than 12 percent of the way across the river. A plume of 3 F° or less across the river should not interfere with normal migration patterns of Clinch River fish because the plume will rise and only affect the surface. Extreme conditions in which the 3 F degree and 1 F degree plumes 9
extend a significant distance across the channel should not produce a 6
barrier to fish populations because the warm water species identified in the Clinch River would not be migrating under conditions of winter water temperature and summer no flow regimes associated with the development of these plumes. Seasonal factors which are most important in controlling fish migrations and breeding, are day-length, temperature and river discharge. 9
These three factors would be most favorable for the warm water species in the Clinch River during typical spring conditions when only 10 percent of the river width would be affected by the 1 F degree isotherm. Considerable river width is left under these favorable migration conditions to allow fish movements. Those fish which do encounter the plume would be expected to move around it if preferred temperatures are exceeded.

5.1.3.1.2 SPAWNING

Spawning temperature data that are available for Clinch River fish species 9
in the vicinity of the Site are listed in Table 5.1-8. Additional spawning data are presented in the Appendix to Section 2.7. 6
Dominant fish species in the Clinch River, as identified by the aquatic baseline survey, spawn mainly in the spring and early summer. Most of the species collected lay adhesive, demersal eggs which would only be affected by elevated temperatures in the small area where thermal plumes reach the bottom. 9
Average blowdown temperatures during the spawning months, as shown in Table 10.3A-1, are 80.7 degrees F in April, 84.6 degrees F in May and 89.5 degrees F in June. 6
Maximum temperatures at the discharge pipe in April would probably not be great enough to prohibit spawning of bluegill and channel catfish right at the opening of the pipe if this were

physically possible. Blowdown temperatures of 84.6 degrees F in May are
above the reported spawning temperatures for all the species in Table
5.1-8 except channel catfish. June blowdown temperatures at the opening
of the discharge nozzle would be above the spawning temperature of most
fish. The large plumes, which develop during extended no flow con-
ditions, would not significantly affect fish eggs and larvae because 6
plumes do not reach the bottom and there would be no current to carry 9
eggs and larvae into the plume.

Excess temperatures that would have the potential to influence spawning
areas would be plume temperature that impinge on the bottom. Maximum
plume temperatures that would be experienced on a small area of the
bottom are indicated in Table 5.1-1. These bottom temperatures are only
2 F degrees above ambient for typical summer conditions and are 5 F
degrees above ambient for winter worst case conditions. Bottom area
bounded by the 1 F degree isotherm, as shown in Table 5.1-3, is less
than 700 square feet under typical river conditions. The small size of
the thermally affected bottom area, as discussed in Section 10.3, should
preclude any adverse effects on fish spawnings. Factors, as discussed
in Section 4.1.3.1.1, that influence fish migrations also control
spawning activities so that winter hypothetical worst case and extended 6
no flow case conditions would not be experienced by spawning populations.

As indicated in Section 2.7.2.5, there is some evidence indicating that
sauger, an important game fish species, may spawn in the Clinch River in
the vicinity of the CRBRP Site. Sauger in reproductive condition have
been collected in the vicinity of CRM 14 to CRM 17 during April and early
May at water temperatures ranging from 53 to 58 degrees F (12 to 14.5 de-
grees C).[8a] Based on temperature tolerance data for embryos, spawning 9
may be possible up to 68 degrees F (20 degrees C),[8b] so increased
temperatures of a few degrees Farenheit should have no effect. The ther-
mal plumes expected to occur in the spring have not been modeled, but
they are not anticipated to be substantially different from the winter
and summer plumes presented in Appendix A to Section 10.3 (Section 14.6).
These plumes indicate a maximum of 0.06 acres (0.024 hectares) of river

surface affected by temperature rises of 2.3 F degrees or more. Therfore, spawning of sauger might be inhibited only if the fish stayed in the immediate vicinity of the discharge, where the blowdown temperature could reach 75-80 degrees F, for an extended period of time. Sauger eggs at first adhere to the substrate, but after hardening become non-adhesive and drift with the current. Modeled thermal plumes (Secton 14.6) indicate a maximum bottom area of less than 0.01 acres (0.004 hectares) to be elevated 2.3 F degrees or more above ambient. At water velocities sufficient to carry drifting eggs, transit through
this small plume would occur in a matter of seconds, which is not 9
expected to adversely affect the developing embryos. Spawning habitat for sauger has been described as sand and gravel or gravel to rubble shoals,[8c] although fish collected in the Clinch River tended to be in 15 to 20 feet of water over a bottom of fine sand and silt.[8a] Sand to rubble bottoms are common in the Clinch River between river miles 14.4 and 18.0 (Section 2.7.2.3.18 and Reference 8d), and probably to Melton Hill Dam above river mile 23. Since less than 0.06 acres of several miles of similar river bottom may be affected by temperatures of 2.3 F degrees above ambient, impact of the thermal discharge on potential sauger spawning is expected to be negligible. Studies
to determine the locations of sauger spawning in the vicinity of 16
the project site were initiated in March 1982 (See Section 2.7.2.5).

Entrainment of fish eggs and larvae in the heated plume during July and August when temperatures are highest, as shown in Table 10.3A-1, is not expected to be a serious problem for the following reasons: (1) the very small size of the plume and rapid thermal mixing, even during the hypothetical summer extreme case as shown in Figure 5.1-4; (2) the short time of entrainment in the plume (if entrained); (3) the fact that most of the major fish in the vicinity of the Site either lay adhesive eggs in well-defined nests or scatter semi-buoyant eggs over the bottom and therefore, fish eggs are not expected to predominate in the plankton and few would be entrained; and (4) by July and August, many of the

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young fish would have developed to an actively swimming stage and thus should be more capable of avoiding a heated plume.

5.1.3.2 THERMAL EFFECTS ON BENTHOS

Benthic organisms are considered to be excellent indicators of environmental changes because of their relatively long life cycle and immobility. Environmental impacts on river bottom communites by thermal discharges may include both scouring of bottom materials and elevated temperatures. Table 5.1-9 is a listing and classification of benthic macroinvertebrates collected from the Clinch River Site. Relative abundance of those benthic macroinvertebrate species collected from March 1974 through April 1975 is presented in Table 5.1-10.

No significant effect of the thermal plume on the benthos in the Clinch River is expected because results of the thermal-hydraulic modeling study discussed in Appendices to Section 10.3 indicate that scouring by the plume is limited to a small area of the bottom, about 100 square feet as shown in Figure 5.1-6 and Table 5.1-11, and typical bottom temperatures are predicted to be 1.2 F degrees above ambient over less than 0.01 acre of the bottom, Table 5.1-3. In the extended no flow case the thermal plume will still only increase the temperature of a small area of the bottom. Daily ambient temperature variation in the water column may be as great as 2 to 3 F°. The small area of the plume and the temperatures which impinge on the bottom during the extreme case should have an insignificant effect on the Clinch River benthos. 6

Data on macroinvertebrates collected in the Clinch River between miles 15.0 and 18.0 for March 1974 through April 1975 have been reviewed in Section 2.7.2.4.5. The benthic population is dominated by a variety of chironomid larvae, oligochaetes and clams with a small number of mayflies and caddisflies. Curry[9] has reviewed the distribution of chironomid larvae and has presented data on the temperature ranges for several species which have been collected in the Clinch River during the study period. Such common genera of the Clinch River as Cricotopus, Cryptochironomus, Glyptotendipes, Paratendipes and Polypedilum, Table 5.1-10, have been reported from areas with an ambient temperature greater than 89.6 degrees F (32°C). Cricotopus and Polypedilum, which are dominant in terms of relative abundance, have been reported from areas with a temperature of 102.2 degrees F (39°C). The larvae of Cricotopus and Paratendipes have been reported from water of 103.1 degrees F (39.5°C).[10] Walshe's work[11] on seven species of larval midge flies shows a range of LD_{50} (the temperature which is lethal to 50 percent of a test group of organisms) from 84 to 102 degrees F. 6

Few studies have been able to detect a major impact of power plants on river benthos. Twenty-six species of stoneflies (Plecoptera) and mayflies (Ephemeroptera) were taken above and below a power plant on the Severn River in Great Britain.[12] Mean weekly temperatures were 0.4 degrees F to 7.2 degrees F higher below the plant and maximum fluctuation was 13 F degrees above ambient. There was no evidence of a decrease in abundance or size of organisms collected below the plant. Coutant studied the riffle fauna above and below a power station on the upper Delaware River.[13] The study showed that the Delaware River invertebrate fauna, sampled chiefly during summer months, had a tolerance limit of 90 to 95 degrees F.[13] A similar investigation was conducted above and below a heated discharge on the Schuylkill River near Philadelphia.[14] The faun 1/4-mile below the discharge was similar to that above it. Temperatures at the downstream station often exceeded 95 degrees F. At the CRBRP Site temperature increases of 2.5 F degrees would only be expected to occur on a limited area of the bottom during the hypothetical winter extreme case. The highest predicted bottom temperature for the winter case will be only 5 F degrees above ambient. These predicted temperature values are well within the thermal tolerance range of species collected in the Clinch River.

Several general conclusions can be drawn concerning the effects of temperature on benthic macroinvertebrates. Most species can tolerate temperature fluctuations of 10 degrees F without lethal effects provided some ultimate upper incipient lethal temperature is not exceeded. This upper limit has not been determined but field studies conducted around power plants suggest that it is between 90 and 95 degrees F for some river systems. Highest blowdown temperature discharge, 89.6°F, will be below the proposed upper temperature limit for groups of macroinvertebrates in the area of the Site. 6

It is unlikely that the thermal plume will have much effect on the Clinch River benthos because of the small area impinged and the resistance of species in the impacted area to the small temperature increase. Scouring produced by the discharge structure will remove populations in the immediate scour area but will not cause a shift in Clinch River benthic community species dominance.

5.1.3.3 THERMAL EFFECTS ON PERIPHYTON

Only in the immediate vicinity of the discharge point does the thermal plume have the potential to influence the periphyton species of the Clinch River and this influence will not alter population structure in the remainder of the river. In TVA studies made at the Paradise Steam Plant on the Green River in Kentucky, before and after installation of cooling towers, it was demonstrated that the cooling towers aided in restoring normal autotrophic-heterotrophic relationships below the plant.(3)

Baseline aquatic survey data from March 1974 through April 1975 has shown that Chrysophyta (mainly diatoms) are the dominant species in the Clinch River periphyton. 6 Patrick's(15) study of the effect of temperature increase on diatom species has shown that proximity of the temperature experienced to the upper limit of tolerance is more important in determining lethal conditions than the actual interval of temperature change. She states that thermal tolerance is a function of a particular species' upper temperature limit and its duration of exposure. As the upper limit is approached, diatom species exhibit a slowing of division rate and begin to assume a resting state. Three genera of diatoms which have been identified as dominant in the Clinch River community, Table 2.7-69 and for which thermal tolerance limits have been studied are Melosira, Synedra and Gomphonema. These species have been reported by Wallace[15] to be able to withstand a temperature of 93.2 to 95 degrees F (34-35°C) for periods of several days duration. 6

Thermal plume effects on periphyton species will be minimal because the upper limit for thermal tolerance for diatoms would only be experienced after several days exposure within the immediate area of the discharge during maximum blowdown at summer temperatures, as shown in Figure 5.1-5. Periphyton species attached to bottom substrates would experience lower temperatures than periphyton species at the discharge nozzle. In the summer extended no flow case plume temperatures in the upper layer of the river would be only 1.3 F° above ambient. Ecological factors other than temperature, such as available substrate, light and current, are important in controlling periphyton populations[9] and will probably have a more significant effect on Clinch River populations than will the small, rapidly mixed discharge from the CRBRP. 6

5.1.3.4 THERMAL EFFECTS ON PHYTOPLANKTON

Large discharges of heated water can significantly alter the character of phytoplankton communities, but the small discharge volumes and small area of the plume in the Clinch River should not significantly affect the Clinch River phytoplankton community in the area of the Site.

The phytoplankton community identified by the monitoring program from March 1974 through April 1975 is dominated by diatom species with seasonal increases in the green and blue-green algae. These three classes of algae are important in a consideration of thermal discharges because they have somewhat different temperature tolerances. Under experimental 6 conditions diatoms dominate at temperatures between 68 and 86 degrees F, green algae between temperatures of 86 and 95 degrees F and blue-green algae at temperatures above 95 degrees F.[17] Shifts in abundance from diatoms to blue-greens would be a major change in the phytoplankton community because blue-green algae are considered nuisance species which often impart a disagreeable odor to the water and are a poor food source for other organisms.

Patrick states that the results of several studies show that there are fewer species in the heated discharges areas and that they are represented by more individuals.[17] When the temperature was greater than 94.1 degrees F for three months during the summer, an increase in blue-green algae occurred in the discharge area. A similar study was conducted on the Delaware River at a power plant with a temperature rise of 14.4 degrees F.[17] Downstream temperatures seldom exceeded 94.1 degrees F and no significant differences were found in either the numbers or types of species between the upstream and downstream areas.

Thermal discharges from the CRBRP are not expected to cause an increase in blue-green algae downstream from the plant because the maximum blow-down temperature of <u>89.6 degrees F</u> will be reduced rapidly by mixing after discharge. Hypothetical worst case winter conditions will be a <u>1 F degree</u> plume extending across the entire river. The highest tempera- 6 ture for the largest surface plume will occur during an extended no flow period in the summer and will be only 1.3 F° above ambient. Effluent effects on the composition and division rates of species in the phytoplankton community are not expected to be significant for the following reasons: (1) the plume volume is small when compared to the volume of the river; (2) species entrained in the plume will have only short exposures to increased temperatures; and (3) the increase in water temperature is small compared to daily fluctuations in ambient temperatures.

5.1.3.5 THERMAL EFFECTS ON ZOOPLANKTON

The zooplankton population of the Clinch River in the vicinity of the CRBRP Site has been characterized in Section 2.7.4.3. This population is composed of cladocerans, copepods and rotifers. Rotifers were the most abundant and diverse group with peak abundance in May and August. Cladocerans were abundant in all the samples collected. Bosmina longirostris, with its greatest density in May and June 1974 and April 1975, was one of the dominant cladocerans during the March 1974 through April 1975 sampling period. 6

Thermal effects can cause mortality of zooplankton species when an upper lethal temperature limit is maintained for a sufficient period or can cause population changes by increasing the division rate of selected species. Studies of a power plant on a British Lake where plant discharge increased winter water temperature by 21 degrees F and summer temperatures by 10 degrees F thereby causing a horizontal temperature gradient, showed no significant difference in the species of crustaceans or rotifers collected from the warm and cool parts of the lake. Seasonal changes from a winter dominance of Bosmina to a summer dominance of Daphnia and Diaphanosoma took place simultaneously in both the warm and cool parts of the lake.[18] Lethal temperature results for various species of Daphnia (a cladoceran commonly collected and similar to Bosmina) ranged from 86 to 111 degrees F. At the latter temperature, death occurred within one minute.[19]

Results of the effect of temperature and food supply on the rate of reproduction have been reported for two species of rotifer which are common in the Clinch River. Polyarthra cochlearis was abundant in surface tows in September. Studies of these species collected from British Lakes[20] suggest that if rotifers are entrained in a large thermal discharge plume for a sufficient period their reproductive rate may increase provided some lethal limit is not exceeded.

In view of the lethal temperature tolerance of crustaceans, and the three characteristics of the plume summarized in Section 5.1.3.4, it is felt that no significant thermal impact should occur to the zooplankton population.

5.1.4 POTENTIAL FISH MORTALITY AT INTAKE STRUCTURES

Fish mortality at intake structures is a function of many factors such as: (1) intake velocity; (2) intake sturcture design; (3) fish species; (4) health of the fish; and (5) season. Additional unknown factors make quantitiative and qualitative predictions of mortality from intake structures difficult.

Several general remarks concerning the fish resources of the Clinch River at the Site can be made from aquatic baseline survey data collected from March 1974 through January 1975. As discussed in Section 2.7.2.4.7, 6
forage and rough fish dominate in both numbers and biomass. The most common forage fish are the threadfin shad and gizzard shad. Game fish make up 12.4 percent of the total fish collected and include sauger, white bass and bluegill. Bluegills are the most abundant game fish. No unique or rare and endangered fish species are known to inhabit this portion of the Clinch River.

Extremely important among the factors which determine impingement rates are intake velocity and intake structure design. Because the design and effects of intake structures are discussed in detail in Section 10.2, only salient and applicable features of this Section will be presented here.

A perforated pipe intake system is depicted in Figure 10.2-4. As described in Section 3.4, the entire filtering function of the intake is 6
accomplished by perforated pipes submerged in the waterway several feet above the bottom. The pipes will be positioned parallel to the flow

direction so that debris and fish are assisted past the intake by the natural river currents. Two effects of the intake design will combine to minimize fish entrapment: (1) fish encountering the pipe have clear escape paths in all directions except directly into the perforations and (2) low approach velocities, as shown in Figure 10.2-15, and internal sleeving to produce uniform velocity fields, as shown in Figure 10.2-14, are incorporated into the perforated pipe intake design to enhance its fish protection capabilities.

Significance of fish impingement is determined by the impact that losses might have on the natural populations in the Clinch River in the vicinity of the Site. Pounds of fish impinged per unit time and, more importantly, the impact of this effect on the local fish populations cannot be definitively determined at this time. However, with consideration of the design of the intake structures, environmental impacts from fish mortalities at the intake structures should not be significant.

5.1.5 EFFECT OF CONDENSER PASSAGE (ENTRAINMENT) ON PLANKTON AND NEKTONIC FORMS

Changes occur in the plankton and larval fish population taken into the plant and passed through the condenser system. Plankton is affected directly by pressure difference and mechanical damage in pumping, changes in temperature (both increases and decreases) and chemicals added during plant operation.

Effect of plant entrainment on the Clinch River planktonic population is controlled by the CRBRP's cooling water demand. The design flow rate
of 9,000 gpm represents a maximum potential intake of 20.7 cfs. Com- 9
parison of this to the average monthly discharges of the Clinch River
from Melton Hill Dam, which varies from an average monthly summer discharge 9
of 5,066 cfs to an average monthly winter discharge of 6,772 cfs, shows that the total intake represents less than 0.5 percent of the lowest

total average flow. Hence, the potential quantity of plankton, fish eggs and larvae lost in transit through the plant will not be significant.

Estimates of the fish eggs and larvae which may be entrained by the CRBRP have been made during the aquatic baseline survey. Results of this sampling are shown in Table 5.1-12. Eggs were most abundant in collections from mid-May through early June and were evenly distributed among the transects. Most of the dominant fish at the Site lay adhesive demersal eggs in shallow water and these eggs would not normally be entrained. Field observations and sampling results do not indicate that important concentrations of eggs or larvae occur in the area of the proposed plant intake. 7

Though entrainment may have only sublethal effects on plankton organisms, the most conservative estimate of 100 percent entrainment mortality is considered in this section. Using this estimate the quantity of plankton lost would be proportional to their concentration in the makeup water. 7 Based on the design flow presented above, entrainment would effect ≤0.5 percent of the population at any time during the year. This is such a small portion of the total population, it can be assumed that entrainment of plankton, fish eggs and larvae through the condenser will have negligible effects on the river populations.

Additional information on the effects of entrainment are presented in Section 10.2.4.1.

5.1.6 IMPACTS FROM INDUCED CIRCULATION EFFECTS

Potential environmental effects resulting from the motion and displacement of water in conjunction with the operation of power plant intake and discharge systems include scouring and sedimentation, alteration of dissolved oxygen and nutrient contents and disruption of thermal stratification.

Scouring and sedimentation will not occur to any substantial
degree as a result of the water flows of the CRBRP intake and
dischrge systems. Approach velocity of water at 0.75 inch from
the surface of the perforated pipe intake is less than 0.2 fps
when both pipes are operating. As the minimum distance from the
pipe surface to the river bottom is 5 feet and 9 inches, no 13
induced movement of bottom material will occur. Although the
discharge structure is supported on piles and elevated above the
bottom, maximum discharge velocities may exceed 20 fps, as shown 6
in Table 10.3A-4, and some bottom scouring will occur. Benthic
populations will be reduced in the small area of scouring but the
dominant benthic organisms in the river community will not be
altered.

Initial scouring of bottom material may suspend organic material from sediments that will reduce dissolved oxygen and increase nutrient levels in a small area downstream from the discharge. After the initial removal of bottom sediment, scouring will only resuspend those sediments that have been transported into the discharge area by the river and will not cause alteration of the downstream dissolved oxygen or nutrient content.

The Clinch River is regulated stream and experiences daily and
seasonal fluctuations in flow and pool elevation as a result of
the operational procedures of various upstream and downstream TVA
dams. The intake and discharge flows at full power (13.6 and 5.4 6 16
cfs, respectively, based on Table 3.3-1) are small in relation to
the typical seasonal flows of the river. Further, the discharge

5.1.7 IMPACT FROM STOPPING BLOWDOWN FLOW

Biocide system design will provide the capability for automatically stopping the blowdown flow during chlorine applications and for maintaining zero release from the cooling tower basin until the residual concentration has fallen to .14 mg/l. During normal plant operation, such 16 stoppages of blowdown flow will occur several times daily and will cause the thermal plume to diminish in both temperature and spatial extent during the interval preceding renewal of the blowdown flow.

An environmental concern associated with rapid changes in thermal plume temperatures and spatial extent is the potential for thermal shock to aquatic life that may have become acclimated to conditions within the plume. Thermal shock is generally associated with the winter months when certain species are attracted by the warmer plume temperatures. Important parameters to be considered in evaluating the impact to aquatic life from plume dissipation include the magnitude of the temperature increase or decrease and extent of the plume.

Predicted thermal plumes for the CRBRP are presented in Figures 5.1-1 through 5.1-6. The maximum temperature rise of any significant size isotherm occurs in the winter extended no flow case, Figure 5.1-5, when the 3.4 F degree isotherm extends to the other bank of the river. The heated water forms a layer at the surface so fish could position themselves in the plume in terms of their preferred temperature ranges. 6

Data from available literature on fish tolerance to abrupt temperature changes indicates that no adverse effects will be produced by a 3.4 F degree fluctuation in ambient Clinch River temperatures.[21,22] During the extended no flow winter case, when the 3.4 F degree plume extends across the river, plume temperature changes that will occur when blowdown is stopped will be gradual and non-lethal. Further, the volume of the Clinch River included within the typical and hypothetical thermal plumes is very small, as indicated in Tables 5.1-2 and 5.1-3. Temperature increases of 1.5 F degrees are limited to 0.01 acre of the river surface during typical case conditions and only in the winter worst case does the area bounded by the 2.3 F degree isotherm increase to 0.06 acre of the river surface. Consequently, stoppages of cooling system blowdown flow do not present a hazard to aquatic life in the thermal plume.

Plant shutdowns for reactor refueling or SCRAM conditions will also result in termination of the blowdown flow. However, as these operations involve a gradual reduction in blowdown temperatures rather than an abrupt stoppage and are not expected to be daily occurrences, there will be no adverse impact to aquatic life in the thermal plumes.

5.1.8 EFFECTS OF HEAT DISSIPATION SYSTEM ON TERRESTRIAL ENVIRONMENT

Potential effects of the heat dissipation system on the terrestrial environment include cooling tower plume formation, ground fog and ice, drift and noise. A complete evaluation of the atmospheric effects of the CRBRP mechanical draft wet cooling tower, linear array, is presented in the Appendix to Section 10.1.

As discussed in Section 5.1.1.1, design parameter changes for the cooling system were added to the ER in Amendment XVI Table 5.1-13 includes both 16
old and new design features for the cooling tower.

Review of the new modifications in the cooling system indicates that most of the critical parameters used in the evaluation of potential atmospheric impact associated with the operation of the cooling system changed slightly 6
in value. These critical parameters are heat rejection, total air flow, evaporation rate, drift rate, number of concentrations and tower size. In fact, moisture discharge in the form of vapor and drift have decreased slightly in value.

It is anticipated that the net effect upon the potential atmospheric impact would be to slightly reduce extent of visible plume, ground fogging and icing potential as well as the drift deposition rate.

The changes in the magnitude of the aforementioned parameters associated with any potential impact of the cooling system amount only to a few percent and can be considered to be well within the realm of accuracy of the calculations made. Therefore, it is felt that the original analysis is still applicable to the slight modifications made in the new design. Further experience indicates that the analysis conducted is conservative in nature. 6

5.1.8.1 VISIBLE PLUMES

Under certain meteorological conditions, visible water vapor plumes will be produced by the mechanical draft wet tower. Plumes attaining lengths greater than 300 feet are predicted to occur approximately 58 percent of the hours in a year. Plume length, as a function of stability class and relative humidity is given in Table 5.1-14. The longest plumes occur 6 at 100 percent relative humidity and under stable atmospheric conditions.

Frequency distribution of visible plumes varies with wind direction and is presented in Table 10.1A-6. Plumes will extend to the northeast (NNE-ENE) and southwest (SSW-WSW) during 55 percent of the year, as indicated in Table 2.8-18.

Visual impact from CRBRP cooling tower plumes will be limited by terrain, cloud cover when it exists and low population density. The Site vicinity is characterized by a series of parallel ridges and valleys which will act as a natural barrier to uninterrupted observations of the full extent of tower plumes. Areas frequented by the public, such as Interstate 40, Gallaher Bridge, ORNL and Melton Hill Lake, are effectively screened by these terrain features. Natural cloud cover would be anticipated during the periods of high relative humidity and stable atmospheric conditions that produce the longest plumes. Presence of cloud cover would tend to diminish the visual impact of cooling tower plumes. The region surrounding the CRBRP is rural in character with a low population density (less than 40 people/mi^2 within five miles of the Site), as indicated in Table 2.2-3. Therefore, the number of local residents who might see the plume will be small.

As the maximum predicted visible plume lengths do not extend appreciably beyond 10 miles, no significant impact on the operations of either Meadow Lake Air Park (the closest sport airport, 10 miles SW of plant) of McGhee-Tyson Airport (the nearest commercial airport, 28 miles SE of plant) are anticipated.

5.1.8.2 GROUND FOG AND ICE

Mechanical draft wet tower plumes originate at low elevations and are characterized by a high degree of initial turbulence and low buoyancy. This high initial turbulence and low buoyancy combine to cause the plume to approach ground level during periods of 100 percent relative humidity and unstable atmospheric conditions; refer to Table 10.1A-7 for further clarification. The result is formation of ground fog. Ground fog potential for all directions from the Site is given in Table 5.1-15. | 6

Fogging and icing become important environmental concerns when sensitive areas such as highways, bridges and building complexes are affected. For the CRBRP Site vicinity, three such areas may be identified: Interstate 40 at Caney Creek, Gallaher Bridge and ORNL. Predicted fogging hours due to tower operation for these points of interest are presented in Table 5.1-15. Also included are hours each year of natural fogging which have been recorded at the Oak Ridge City Office and Melton Hill Dam. In comparison to the extent of natural fogging typical for this region, the amount of additional fog that may be contributed by the cooling tower is not significant.

Occurrences of fog along the Clinch River will be limited, in any one direction, to values similar to those given in Table 5.1-16 for Gallaher | 6
Bridge and I-40 at Caney Creek. As natural fogging is common in this region, see Tables 2.6-9 and 2.6-10, and the volume of river traffic is

small, see Table 2.2-15, no significant impact on the Clinch River is anticipated due to cooling tower induced fog.

The major portion of the potential ground fog hours listed in Table 5.1-15 will occur in the valleys northeast and soutwest of the plant. The northeast section encompasses an AEC restricted area and is largely unoccupied. Poplar Springs Valley to the southeast contains few settlements and one minor roadway. Interstate 40, at its juncture with Poplar Springs Valley, is beyond the range of tower induced fogging. 6

Approximately seven percent of the potential ground fog hours indicated in Table 5.1-15 will occur at temperatures below freezing, as shown in Table 10.1A-7. A thin layer of rime ice will form on objects within the fogging area during these periods. 6

5.1.8.3 DRIFT DEPOSITION

During the operation of the CRBRP mechanical draft wet cooling tower droplets of water, which contain chemicals in concentrations similar to the cooling tower basin, will be entrained in the exhausted air and carried out of the tower. These water losses are known as drift and will be deposited downwind of the plant under certain meteorological conditions. Drift rates are given as a percentage of the circulating cooling water flow and are estimated to be 0.05 percent for the CRBRP tower. As the current state of drift eliminator technology indicates that far lower drift rates are achievable,[23] this value may be considered high. Predicted drift deposition for the CRBRP cooling tower is given in Table 5.1-17. 6

Environmental concern relative to drift deposition include chemical changes to soils, salt damage to foliage and corrosion of structures. Impacts on soils, vegetation, fauna, groundwater and surface water are examined in Section 5.4-6. Drift deposition will have no significant 6
effect on agriculture or structures because the concentrations of harmful

chemicals in the circulating water flow are very small, as shown in Table 5.4-5. For example, the chloride concentrations of the Clinch River are relatively low and drift deposition of chlorides in the compass sector that will experience the highest amounts of deposition, SSW, as shown in Table 5.1-17 are on the order of two lb/acre-month or 10^{-6} lb/ square foot-day. This amount of deposition is below the levels of chloride salts that are known to damage the most sensitive plants,[24] as discussed in Section 5.4 Total dissolved solids (TDS) content of circulating cooling water, assuming the conservative case of an average makeup water TDS of 150 mg/l, is 375 mg/l. This anticipated TDS concentration in the CRBRP cooling tower drift droplets is within the permissible range established by the Public Health Service for drinking water.[25] 6

5.1.8.4 COOLING TOWER NOISE

Operation of the CRBRP mechanical draft wet cooling tower will produce an approximate noise level of 68 dBA at a distance of 500 feet. Allowing for sound attenuation from hemispherical spreading and atmospheric absorption, the sound level would be about 55 dBA perpendicular to one of the open louvered faces of the tower at a minimum exclusion distance of 2,200 feet. 6 Noise levels will diminish toward the ends of the tower. A further reduction of 2 dB to 5 dB will occur because of ground attenuation, depending on the season of the year. A sound level of 50 dBA to 53 dBA is less than the noise from the average room air conditioner on low fan speed.[25]

TABLE 5.1-1

MAXIMUM RIVER SURFACE AND BOTTOM TEMPERATURE DIFFERENTIALS RECORDED IN THERMAL-HYDRAULIC MODEL OF DISCHARGE PLUME

Modeling Case	Temperature Above Ambient*		Temperature Reduction Associated With New Coding System Performance Data (%)
	Surface °F(°C)	Bottom °F(°C)	
Typical Cases			
Winter	1.92 (1.07)	2.33 (1.29)	23
Summer	1.27 (0.71)	2.15 (1.19)	18
Hypothetical extreme cases			
Winter	4.77 (2.39)	5.05 (2.81)	21
Summer	0.79 (0.44)	1.18 (0.66)	34

*Temperature differences determined from physical model study performed by the Iowa Institute (see Figures 10.3A-4 through 10.3A-7).

TABLE 5.1-2

SURFACE AREA OF CLINCH RIVER AFFECTED BY THERMAL PLUMES*

Mixing Conditions	Area (acres)				
Isotherms (F°):	0.7	1.0	1.2	1.5	2.3
Typical Cases					
Winter		0.05	0.01	0.01	
Summer	0.07	0.02	<0.01		
Hypothetical Extreme Cases					
Winter		3.92**			0.06
Summer	0.02				

*As determined from the Iowa Institute physical model study (see Table 10.3A-5).

**Estimated based on extrapolation of model plume boundaries to achieve closure of isotherm (see Figure 10.3A-10).

TABLE 5.1-3

BOTTOM AREA OF CLINCH RIVER AFFECTED BY THERMAL PLUMES

	Area (acres)				
Isotherms (F°):	0.7	1.0	1.2	1.5	2.3
Mixing Conditions					
Typical Cases					
Winter		0.01	<0.01		
Summer		0.01	<0.01		
Hypothetical Extreme Cases					
Winter					0.01
Summer		<0.01			

TABLE 5.1-4

FISH OF THE CLINCH RIVER*

Common Name	Scientific Name
Walleye	(*Stizostedion vitreum vitreum*)
Sauger**	(*Stizostedion canadense*)
White bass**	(*Morone chrysops*)
Carp**	(*Cyprinus carpio*)
Quillback	(*Carpoides cyprinus*)
River carpsucker	(*Carpiodes carpio*)
Golden redhorse	(*Moxostoma erythrurum*)
Black redhorse	(*Moxostoma duquesnei*)
Silver redhorse	(*Moxostoma anisurum*)
Smallmouth buffalo**	(*Ictiobus bubalus*)
Gizzard shad**	(*Dorosoma cepedianum*)
Skipjack herring**	(*Alosa chrysochloris*)
Freshwater drum	(*Aplodinotus grunniens*)
Channel catfish	(*Ictalurus punctatus*)
Minnows++	(*Cyprinidae*)
Bluegill	(*Lepomis macrochirus*)
Black buffalo	(*Ictiobus niger*)
Mooneye	(*Hiodon tergisis*)
Longnose gar	(*Lepisosteus osseus*)
Emerald shiner	(*Notropis atherinoides*)
Largemouth bass	(*Micropterus salmoides*)
Hogsucker+	(*Hypentelium* sp.)
Threadfin shad**	(*Dorosoma petenense*)

* Extracted from TVA data. Jaco, B. B., and Sheddan, T. L., TVA Fish Population Monitoring - LMFBR Demonstration Project, Unpublished Report, January 11, 1974. Scientific names extracted from American Fisheries Society Special Publication No. 6, A List of Common and Scientific Names of Fishes from the United States and Canada, Third Edition, Bailey, R. M., Editor. 1970.

** Most abundant species in CRBRP Site vicinity, according to results of first reference cited above.

\+ Specific determinations cannot be made due to insufficient information.

++ Generic and specific determinations cannot be made due to insufficient information.

TABLE 5.1-5

ENUMERATION OF FISH SPECIES* COLLECTED IN THE CLINCH RIVER - MARCH 28, 1974 - JANUARY 17, 1975

General Category	Family	Genus and Species	Common Name	Total No. Collected	No. Collected Electroshocking	No. Collected Gill Netting
Game	Centrarchidae	Ambloplites rupestris	Rock bass	13	13	0
		Lepomis auritus	Redbreast sunfish	5	4	1
		Lepomis macrochirus	Bluegill	79	71	8
		Lepomis megalotis	Longear sunfish	2	2	0
		Lepomis microlophus	Redear sunfish	4	4	0
		Micropterus punctulatus	Spotted bass	14	14	0
		Micropterus salmoides	Largemouth bass	20	19	1
		Pomoxis annularis	White crappie	3	2	1
	Percidae	Perca flavescens	Yellow perch	2	2	0
		Stizostedion canadense	Sauger	18	1	17
	Percichthyidae	Morone chrysops	White bass	19	7	12
		Morone saxatilis	Striped bass	1	0	1
Forage	Atherinidae	Labidesthes sicculus	Brook silverside	8	8	0
	Clupeidae	Dorosoma cepedianum	Gizzard shad	128	119	9
		Dorosoma petenense	Threadfin shad	383	103	280
	Cottidae	Cottus carolinae	Banded sculpin	7	7	0
	Cyprinidae	Hybopsis storeriana	Silver chub	4	0	4
		Notemigonus crysoleucas	Golden shiner	6	6	0
		Notropis ardens	Rosefin shiner	1	1	0
		Notropis atherinoides	Emerald shiner	154	154	0
		Pimephales notatus	Bluntnose minnow	17	17	0
	Percidae	Etheostoma blennioides	Greenside darter	1	1	0
		Percina caprodes	Logperch	5	5	0
Rough	Catostomidae	Carpiodes cyprinus	Quillback carpsucker	14	3	11
		Hypentelium nigricans	Northern hogsucker	2	0	2
		Ictiobus bubalus	Smallmouth buffalo	11	8	3
		Moxostoma carinatum	River redhorse	6	1	5
		Moxostoma duquesnei	Black redhorse	2	1	1
		Moxostoma erythrurum	Golden redhorse	50	39	11
	Clupeidae	Alosa chrysochloris	Skipjack herring	74	2	72
	Cyprinidae	Cyprinus carpio	Carp	33	21	12
	Hiodontidae	Hiodon tergisus	Mooneye	16	7	9
	Ictaluridae	Ictalurus punctatus	Channel catfish	12	0	12
	Sciaenidae	Aplodinotus grunniens	Freshwater drum	20	12	8
			TOTAL	1,134	654	480

*Classification is based on Bailey, R. M., et al, A List of Common and Scientific Names of Fishes from the United States and Canada, third edition, American Fisheries Society Special Publication No. 6, Washington, 1970.

TABLE 5.1-6

ACCLIMATION AND LETHAL TEMPERATURES OF SELECTED CLINCH RIVER FISH

Genus and Species	Common Name	Acclimation Temperature °F (°C)	Lethal Temperature °F (°C)	Reference Number
Lepomis macrochirus	Bluegill	45 (7.2)	89 (31.7)	26
		52 (11.1)	95 (35.0)	26
		59 (15.0)	*87.8 (31.0)	27
		70 (21.1)	101.5 (38.6)	26
		76 (24.4)	97-99 (36.1-37.2)	26
		79 (26.1)	103 (39.4)	28
		86 (30.0)	*93.2 (34.0)	27
Cyprinus carpio	Carp	68 (20.0)	87.8-93.2 (31.0-34.0)	29
		78.8 (26.0)	96.3 (35.7)	29
Ictalurus punctatus	Channel catfish	45 (7.2)	91 (32.8)	26
		52 (10.0)	95 (35.0)	26
		71.6 (22.0)	95 (35.0)	30
		86 (30.0)	>95 (>35.0)	30
Dorosoma cepedianum	Gizzard shad	77 (25.0)	94 (34.3)	31
		77 (25.0)	*95 (35.0)	27
		86 (30.0)	96.6 (35.9)	31
		95 (35.0)	98.6 (37.0)	27
Micropterus salmoides	Largemouth bass	45 (7.2)	87 (30.6)	26
		52 (11.1)	95 (35.0)	26
		68 (20.0)	90.5 (32.5)	31
		77 (25.0)	99 (37.2)	28
		77 (25.0)	94.1 (34.5)	31
		80 (26.7)	100-102 (37.8-38.9)	28
		86 (30.0)	97.5 (36.4)	31

*Lethal temperature refers to the temperature at which mortality was first observed. Other lethal temperatures are reported as LD_{50} - temperature which is lethal to 50 percent of a test group of organisms. Duration of temperature trials for LD_{50} values varied from 10-43 hours.

TABLE 5.1-7

PREFERRED TEMPERATURES OF SELECTED CLINCH RIVER FISH

Common Name	Acclimation Temperature °F	(°C)	Mean Preferred Temperature °F	(°C)	Reference Number
Carp	50	(10)	61.3	(16.3)	32
	59	(15)	75.9	(24.4)	
	68	(20)	78.8	(26.0)	
	77	(25)	87.8	(31.0)	
	86	(30)	87.1	(30.6)	
	95	(35)	90.1	(32.3)	
Channel catfish	42.8	(6)	66.0	(18.9)	33
	48.2	(9)	68.7	(20.4)	
	53.6	(12)	67.8	(19.9)	
	64.4	(18)	73.2	(22.9)	
	75.2	(24)	84.9	(29.4)	
	86.0	(30)	86.9	(30.5)	
Bluegill	42.8	(6)	65.7	(18.7)	33
	48.2	(9)	67.3	(19.6)	
	53.6	(12)	75.0	(23.9)	
	64.6	(18)	84.6	(29.2)	
	75.2	(24)	88.2	(31.2)	
	86.0	(30)	89.1	(31.7)	

TABLE 5.1-8

SPAWNING TEMPERATURES OF SELECTED CLINCH RIVER FISH

Genus and Species	Common Name	Spawning Temperatures	Reference Number	
Lepomis macrochirus	Bluegill	80°F (26.7°C)	34	
Cyprinus carpio	Carp	60-68°F (15.6 - 20°C) 59°F (15°C)	35 36	
Ictalurus punctatus	Channel catfish	70-85°F (21.1 - 29.4°C)	35	9
Dorosoma cepedianum	Gizzard shad	73.4 -84.2°F (23 - 29°C)	37	
Micropterus salmoides	Largemouth bass	60.7°F (15.9°C)	36	
Percina caprodes	Logperch	71.6 - 80.6°F (22 - 27°C)	36	
Ictiobus bubalus	Smallmouth buffalo	57.2 - 69.8°F (14 - 21°C)	38	9
Dorosoma petenense	Threadfin shad	62.6°F (17°C)	39	
Stizostedian canadense	Sauger	53 - 58°F (12 - 14.5°C)	8a	9

TABLE 5.1-9

BENTHIC MACROINVERTEBRATE SPECIES* COLLECTED IN THE CLINCH RIVER BY ARTIFICIAL SUBSTRATES - JUNE 3, 1974 THROUGH MAY 28, 1975

Phylum	Class	Family	Genus and Species
Annelida			
	Oligochaeta		
		Lumbriculidae	
			Lumbriculus sp.
		Naididae	
			Naidium sp.
			Nais sp.
			Pristina sp.
			Stylaria sp.
		Tubificidae	
			Limnodrilus sp.
Arthropoda			
	Crustacea		
	(Order - Copepoda)		
	(Suborder - Calanoida)		
		Diaptomidae	
			Diaptomus sp.
	(Order - Cladocera)		
		Daphnidae	
			Daphnia sp.
		Sididae	
			Sida sp.

(Continued)

TABLE 5.1-9 (Continued)

Phylum	Class	Family	Genus and Species
Arthropoda			
	Insecta		
	(Order - Diptera)		
		Ceratopogonidae	
			<u>Palpomyia</u> sp.
		Chironomidae	
			<u>Calopsectra</u> sp.
			<u>Chironomus</u> sp.
			<u>Corynoneura</u> sp.
			<u>Cricotopus</u> sp.
			<u>Cryptochironomus</u> sp.
			<u>Dicrotendipes</u> cf. <u>neomodestus</u>
			<u>Dicrotendipes</u> cf. <u>nervosus</u>
			<u>Dicrotendipes</u> sp.
			<u>Diplocladius</u> sp.
			<u>Endochironomus</u> sp.
			<u>Eukiefferiella</u> sp.
			<u>Glyptotendipes</u> sp.
			<u>Heterotrissocladius</u> sp.
			<u>Labrundinia</u> sp.
			<u>Larsia</u> sp.
			<u>Microcricotopus</u> sp.
			<u>Micropsectra</u> sp.
			<u>Orthocladius</u> sp.
			<u>Parachironomus</u> sp.
			<u>Parametriocnemus</u> sp.
			<u>Pentaneura</u> sp.
			<u>Phaenopsectra</u> sp.

(Continued)

TABLE 5.1-9 (Continued)

Phylum	Class	Family	Genus and Species
Arthropoda			
	Insecta		
	(Order - Diptera)		
		Chironomidae	
			Polypedilum (scalaenum type)
			Polypedilum sp.
			Procladius sp.
			Psectrocladius sp.
			Pseudochironomus sp.
			Rheotanytarsus sp.
			Stictochironomus sp.
			Tanypus sp.
			Tanytarsus sp.
			Thienemannimyia (series)
			Trissocladius sp.
			Xenochironomus sp.
		Empididae	
			Hemerodromia sp.
	(Order - Ephemeroptera)		
		Caenidae	
			Tricorythodes sp.
		Heptageniidae	
			Stenonema sp.
		Leptophlebiidae	
			Leptophlebia sp.
	(Order - Odonata)		
		Aeshnidae	
			Boyeria sp.

(Continued)

TABLE 5.1-9 (Continued)

Phylum	Class	Family	Genus and Species
Arthropoda			
	Insecta		
	(Order - Plecoptera)		
		Capniidae	
			Allocapnia sp.
	(Order - Trichoptera)		
		Hydropsychidae	
			Cheumatopsyche sp.
			Hydropsyche sp.
			Smicridea sp.
		Hydroptilidae	
			Agraylea sp.
			Hydroptila sp.
			Oxyethira sp.
		Leptoceridae	
			Athripsodes sp.
		Psychomyiidae	
			Cyrnellus sp.
			Polycentropus sp.
			Psychomyiid Genus A
Bryozoa			
	Ectoprocta		
		Lophopodidae	
			Pectinatella sp.
Coelenterata			
	Hydrozoa		
		Clavidae	
			Cordylophora sp.

(Continued)

TABLE 5.1-9 (Continued)

Phylum	Class	Family	Genus and Species
Coelenterata			
	Hydrozoa		
		Hydridae	
			Hydra sp.
Mollusca			
	Gastropoda		
		Ancylidae	
			Ferrissia sp.
		Planorbidae	
			Gyraulus sp.
	Pelecypoda		
		Corbiculidae	
			Corbicula sp.
Nematoda			
	Secernentea		
		Diplogasteridae	
			Diplogaster sp.
Nemertea			
	--		
		--	
			Prostoma rubrum
Platyhelminthes			
	Turbellaria		
		Planariidae	
			Curtisia sp.
			Phagocata sp.

*Classification of macroinvertebrates is based primarily on Ward, H. B. and Whipple, G. C., Fresh-Water Biology, second edition, John Wiley & Sons, Inc., New York, 1959.

TABLE 5.1-10

RELATIVE ABUNDANCE OF BENTHIC MACROINVERTEBRATE SPECIES COLLECTED BY DREDGING ON EACH SAMPLING TRIP AT THE CLINCH RIVER FROM MARCH 25, 1974 THROUGH APRIL 16, 1975

Species	Relative Abundance (%)								
	March 25 and March 29	June 1	June 26	July 25	August 26 and August 28	September 25	November 21	January 14	April 16
ANNELIDA									
Aeolosoma sp.	--	--	--	0.5	--	--	--	4.8	--
Branchiura sp.	1.0	0.1	1.1	--	--	0.7	0.1	0.7	0.2
Chaetogaster sp.	--	--	--	--	--	--	--	--	1.3
Limnodrilus sp.	--	8.5	10.9	13.8	4.9	31.3	11.6	19.6	8.9
Lumbriculus sp.	2.0	--	--	7.8	--	--	--	--	--
Naidium sp.	--	8.4	--	--	--	0.7	--	0.4	0.2
Nais sp.	41.6	--	27.2	1.4	--	0.2	0.2	1.2	0.6
Tubifex sp.	--	--	--	--	--	--	--	--	1.4
ARTHROPODA									
Allocapnia sp.	--	--	--	--	--	--	--	0.1	--
Athripsodes sp.	--	--	--	--	--	--	--	--	0.1
Bezzia sp.	--	--	--	--	--	--	--	--	0.3
Calopsectra sp.	--	--	--	--	--	0.2	--	0.1	--
Cheumatopsyche sp.	--	--	--	--	--	0.5	--	0.7	--
Chironomini sp.	--	--	--	--	--	0.2	--	--	--
Chironomus sp.	--	--	1.1	--	--	--	0.3	0.5	0.1
Cladotanytarsus sp.	--	--	--	--	--	0.9	--	--	--
Corynoneura sp.	--	--	--	1.8	--	--	--	--	--
Cricotopus sp.	--	0.8	12.0	3.7	0.3	0.7	0.3	0.3	0.9
Cryptochironomus sp.	--	0.7	4.3	5.5	1.6	0.9	1.0	1.8	0.4
Cyrnellus sp.	--	--	--	--	--	--	--	--	3.5
Dicrotendipes sp.	1.0	0.5	9.2	2.8	3.2	--	2.4	5.0	0.2
Dubiraphia sp.	--	--	--	--	--	--	0.1	--	--
Epiococladius sp.	--	--	--	--	--	--	--	0.3	--
Eukiefferiella sp.	--	--	--	--	--	--	--	--	0.1
Glyptotendipes sp.	1.0	--	--	--	--	1.2	0.5	0.7	0.1
Harnischia sp.	--	--	0.5	--	--	--	--	--	--

TABLE 5.1-10 (Continued)

Species	Relative Abundance (%) March 25 and March 29	June 1	June 26	July 25	August 26 and August 28	September 25	November 21	January 14	April 16
ARTHROPODA (Continued)									
Heterotrissocladius sp.	--	--	--	--	--	--	--	--	0.2
Hexagenia sp.	1.0	--	2.2	1.4	0.6	0.5	2.5	4.3	1.4
Hyalella sp.	--	--	--	--	--	0.2	--	--	--
Hydroptila sp.	--	--	--	--	--	--	0.2	0.1	--
Isotomurus sp.	--	--	--	--	--	--	0.2	--	--
Larsia sp.	--	--	--	--	--	--	0.1	0.2	--
Lirceus sp.	--	--	--	--	--	--	0.1	--	--
Microcricotopus bicolor	1.0	--	--	--	--	--	--	--	--
Microcricotopus sp.	--	2.0	1.1	2.3	0.3	--	--	0.1	--
Micropsectra sp.	--	--	--	--	--	0.2	--	--	0.2
Microtendipes sp.	--	0.1	0.5	--	--	--	0.3	0.5	--
Mystacides sp.	--	0.1	--	--	--	--	--	--	--
Natarsia sp.	--	--	--	--	--	0.2	--	--	--
Neumania sp.	--	--	--	--	--	--	--	0.1	--
Nilothauma sp.	--	--	--	--	--	--	--	0.1	--
Orthocladius sp.	--	0.7	--	--	--	--	--	0.7	0.1
Oxyethira sp.	--	--	--	--	--	--	--	0.2	--
Palpomyia sp.	--	--	--	--	--	--	--	1.0	0.7
Parachironomus sp.	--	--	--	--	--	--	0.1	2.1	0.2
Paralauterborniella sp.	1.0	--	--	--	--	--	0.7	--	0.2
Paratanytarsus sp.	1.0	--	--	--	--	--	--	--	--
Paratendipes sp.	2.0	--	--	--	0.6	--	--	--	0.4
Pentaneura sp.	--	--	--	--	--	--	--	0.2	--
Phenopsectra sp.	--	--	--	0.5	--	--	--	--	--
Polypedilum (*scalaenum* type)	17.8	--	--	4.1	--	--	4.5	--	6.1
Polypedilum sp.	--	0.3	1.6	0.5	--	0.2	0.3	3.9	0.2
Procladius sp.	--	--	--	--	--	--	0.2	--	--

TABLE 5.1-10 (Continued)

Species	Relative Abundance (%) March 25 and March 29	June 1	June 26	July 25	August 26 and August 28	September 25	November 21	January 14	April 16
ARTHROPODA (Continued)									
Psectrocladius sp.	--	0.1	--	--	0.3	--	--	--	0.6
Pseudochironomus sp.	--	0.7	1.1	--	0.3	--	0.1	1.0	--
Psychomyiid Genus A	--	--	--	--	0.3	0.5	3.0	2.1	--
Rheotanytarsus exigus	--	--	--	--	--	--	0.2	--	--
Rheotanytarsus sp.	--	5.6	1.6	0.9	3.6	0.5	0.4	0.2	0.6
Sialis sp.	--	--	--	--	--	--	--	0.1	--
Simulium sp.	--	--	--	--	--	--	0.1	--	--
Stenochironomus sp.	--	--	--	--	--	--	0.1	--	--
Stenonema sp.	--	--	--	--	--	--	--	0.2	--
Stictochironomus sp.	1.0	--	--	1.8	--	--	0.1	0.1	--
Synclita sp.	--	--	--	--	--	--	--	--	--
Tanypus sp.	--	--	--	--	--	--	--	0.2	--
Tanytarsus sp.	--	0.5	2.2	4.1	0.6	--	--	0.8	0.6
Tetragoneuria sp.	--	--	--	--	--	--	--	--	0.1
Thiennemannimyia sp.	--	--	--	--	--	--	--	0.6	--
Tribelos sp.	--	--	--	--	--	--	--	--	0.1
Xenochironomus (*Anceus* group)	1.0	--	--	--	--	--	--	--	--
Xenochironomus sp.	--	--	--	0.9	1.9	--	0.4	--	0.2
COELENTERATA									
Cordylophora sp.	--	*	*	--	*	*	*	*	*
Hydra sp.	--	55.9	--	0.5	31.4	0.5	4.0	1.6	3.7
MOLLUSCA									
Corbicula sp.	26.7	14.8	22.8	44.5	48.5	56.8	64.0	42.1	65.3
Quadrula sp.	--	--	--	0.5	--	--	--	--	--
Ferrissia sp.	--	--	--	--	--	0.9	0.3	--	--
Gyraulus sp.	--	--	--	--	--	--	--	--	0.1

TABLE 5.1-10 (Continued)

Species	March 25 and March 29	June 1	June 26	July 25	August 26 and August 28	September 25	November 21	January 14	April 16
	Relative Abundance (%)								
NEMATODA									
Diplogaster sp.	--	0.3	--	0.9	0.6	0.5	0.1	1.2	0.6
NEMERTEA									
Prostoma rubrum	--	--	--	--	--	--	1.0	0.2	0.1
PLATYHELMINTHES									
Curtisia sp.	--	--	--	--	0.6	--	0.1	--	--
Dugesia sp.	--	0.1	--	--	--	--	--	--	--
Phagocata sp.	1.0	--	--	--	--	0.2	--	--	--
Number of organisms	101	744	184	218	309	428	914	1,218	1,247

*Colonial organisms present but not enumerated, so relative abundance could not be determined.

TABLE 5.1-11

BOTTOM AREA OF CLINCH RIVER AFFECTED BY SCOURING*

Mixing Conditions	Area (ft^2)	Area (acres)
Typical Cases		
Winter	71	<0.01
Summer	85	<0.01
Hypothetical Extreme Cases		
Winter	59	<0.01
Summer	54	<0.01

*Based on actual scouring of model flume bottom material. Areas computed assuming elliptical-shaped scour hole.

TABLE 5.1-12

FISH EGGS AND LARVAE - STATIONARY NETTING*
ENUMERATION PER FIELD TRIP - CLINCH RIVER
COLLECTED JUNE 17 - AUGUST 29, 1974

Collection Date	June 17		June 25-26		July 12		July 25		August 9		August 29	
	No. Counted	No./m^3	No. Counted	No./m^3	No. Counted	No./m^3	No. Counted	No./m^3	No. Counted	No./m^3	No. Counted	No./m^3
EGGS												
Fertilized	3	< 0.10	7	< 0.02	1	0.01	1	< 0.01	--	--	--	--
Unfertilized	--	--	1	< 0.01	--	--	--	--	--	--	--	--
LARVAE	--	--	13	< 0.03	--	--	--	--	--	--	--	--

*Samples were collected one foot above the bottom using a 1,000 micron mesh, one-half meter diameter plankton net with attached inside and outside flow meters. For each sample the net was placed in a stationary position facing upstream for ten minutes.

(Continued)

TABLE 5.1-12 (Continued)

FISH EGGS AND LARVAE - STATIONARY NETTING*

ENUMERATION - CLINCH RIVER

COLLECTED MARCH 28 - JUNE 2, 1974

Collection Date	March 28		April 18		May 1		May 16		June 2	
	No. Counted	No./m^3	No. Counted	No./m^3	No. Counted	No./m^3	No. Counted	No./m^3	No. Counted	No./m^3
EGGS										
Fertilized	1	<0.01	--	--	5	0.02	106	0.48	169	0.48
Unfertilized	1	<0.01	--	--	--	--	1	<0.01	--	--
LARVAE										
	1	<0.01	--	--	--	--	--	--	--	--

*Samples were collected one foot above the bottom using a 1,000 micron mesh, one-half meter diameter plankton net with attached inside and outside flow meters. For each sample the net was placed in a stationary position facing upstream for 10 minutes.

TABLE 5.1-13

OLD AND NEW DESIGN PARAMETERS FOR THE COOLING SYSTEM

Parameter	Old Design	New Design	
Total No. of Towers	1	2	
Total No. of Cells	10	10	
Tower Size	400 ft x 60 ft x 55 ft	247 ft x 76 ft x 41 ft	
Heat Rejection	2.650×10^9 Btu/hr	2.26×10^9 Btu/hr	13
Circulating Water Flow Rate	212,000 gpm	212,200 gpm	
Approach to Wet Bulb	15°F	11°F	
Range	25°F	21.34°F	13
Total Air Flow	17.0×10^6 ft^3/min	16×10^6 ft^3/min	
No. of Concentrations	2.5	2.5	
Total Dissolved Solids (Avg)	375 mg/l	355 mg/l	13 16
Blowdown (Annual Avg)	2700 gpm	2326 gpm	
Drift (Annual Avg)	110 gpm	106 gpm	
Evaporation (Annual Avg)	4240 gpm	3623 gpm	
Makeup (Annual Avg)	7050 gpm	6109 gpm	16

TABLE 5.1-14

MEAN LENGTH OF VISIBLE PLUME* FOR CRBRP COOLING TOWER**

	Relative Humidity (percent)			
Stability Class	100	95	85	75
A	1.6	0.6	0.4	0.2
B	3.4	1.1	0.8	0.7
C	5.1	1.8	1.3	0.9
D	6.0	3.7	2.9	2.2
E	8.3	5.5	5.0	4.1
F	10.3	8.0	6.9	6.4

*Plume length in miles

**From Table 10.1A-5

TABLE 5.1-15

GROUND FOG POTENTIAL FOR CRBRP COOLING TOWER

Horizontal Visibility Through Fog (miles)	Ground Fog (hrs/yr)*
<1/2	146
<1/4	146
<1/10	100

*Ground fog values from Table 10.1A-7

TABLE 5.1-16

GROUND FOG FOR POINTS OF INTEREST IN CRBRP SITE VICINITY

Point of Interest	Distance From CRBRP (miles)	Direction From CRBRP	Horizontal Visibility Through Fog (miles)	Naturally Occurring Ground Fog (occurrences/yr)*	Predicted Fogging Due to Cooling Tower (hrs/yr)**
Interstate 40 at Caney Creek	1.1	SSE	<1/2		0.1
			<1/4		0.1
			<1/10		0
Gallaher Bridge	1.6	NW	<1/2		0.8
			<1/4		0.8
			<1/10		0.7
ORNL	4.5	NE	<1/2		0.1
			<1/4		0.1
			<1/10		<0.1
Melton Hill Dam	4.5	E	<5/8	119	
			<5/16	106	
Oak Ridge City Office	9.0	NE	<1/4	34	

*Ground fog values from Tables 2.6-10 and 2.6-11.

**Ground fog values from Table 10.1A-12

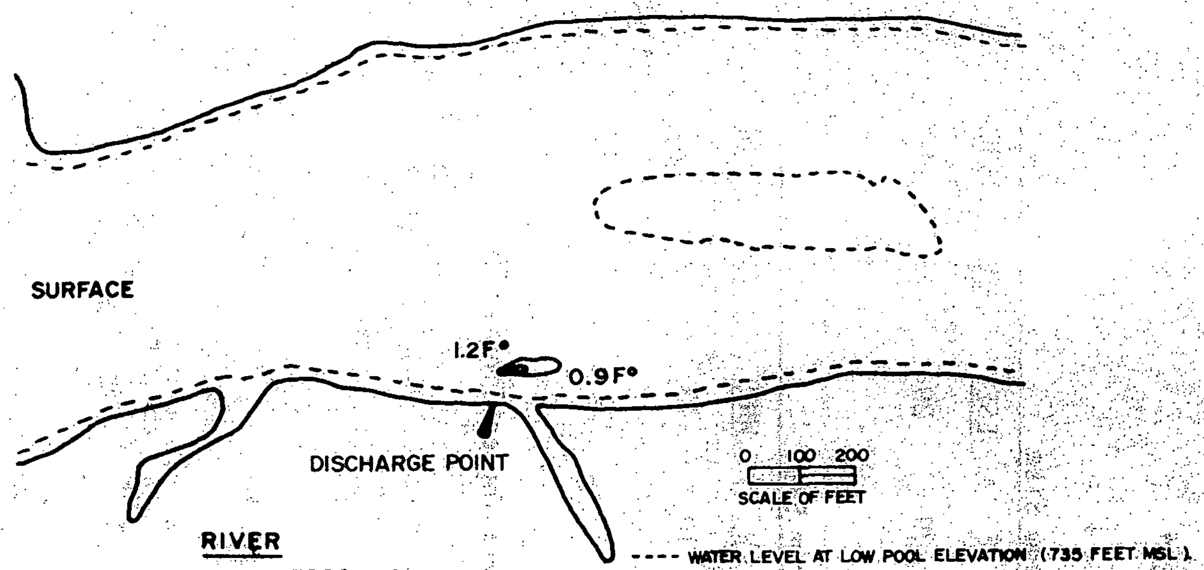
TABLE 5.1-17

DRIFT DEPOSITION FOR CRBRP COOLING TOWER*

	Direction from Site							
	N	NNE	NE	ENE	E	ESE	SE	SSE
Typical Drift Deposition (lb/acre-month)	34	84	43	59	29	29	13	6

	Direction from Site							
	S	SSW	SW	WSW	W	WNW	NW	NNW
Typical Drift Deposition (lb/acre-month)	26	89	42	39	10	13	7	23

*Based on Table 10.1A-16 with assumption of 375 mg/l TDS in circulating cooling water (equivalent to 150 mg/l TDS in Clinch River)



RIVER

flow = 5338 cfs
velocity = 1.39 fps (0.87 fps)*
pool elevation = 736 ft MSL

DISCHARGE JET

flow = 5.57 cfs
velocity = 15.96 fps
temp. diff. = 31.0F°

*Prototype velocity based on hydraulic model velocity. Reflects physical limitations of the flume.

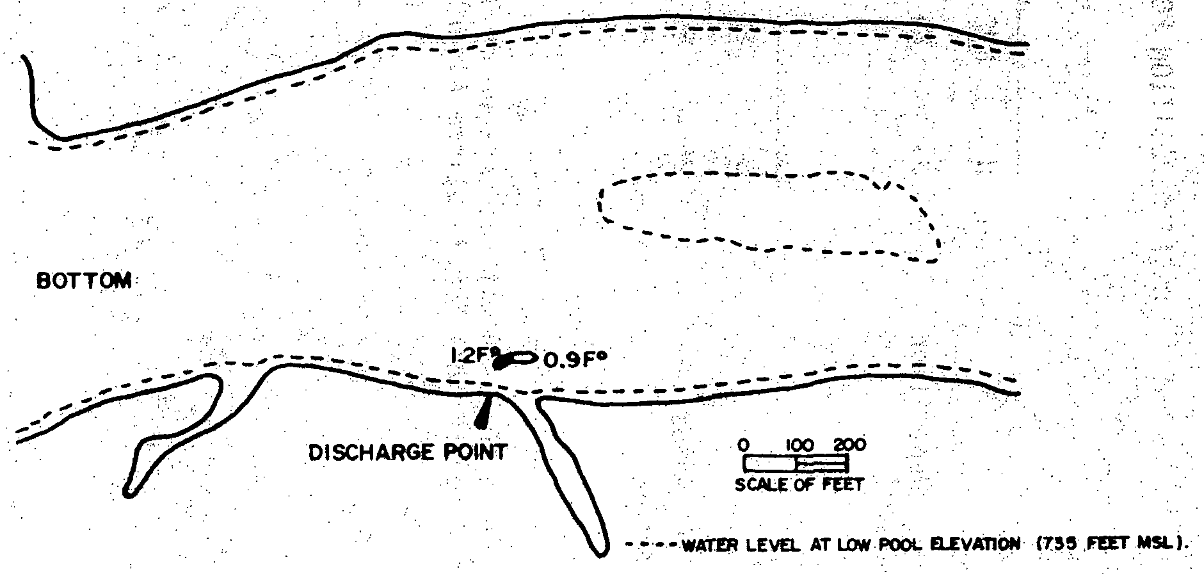
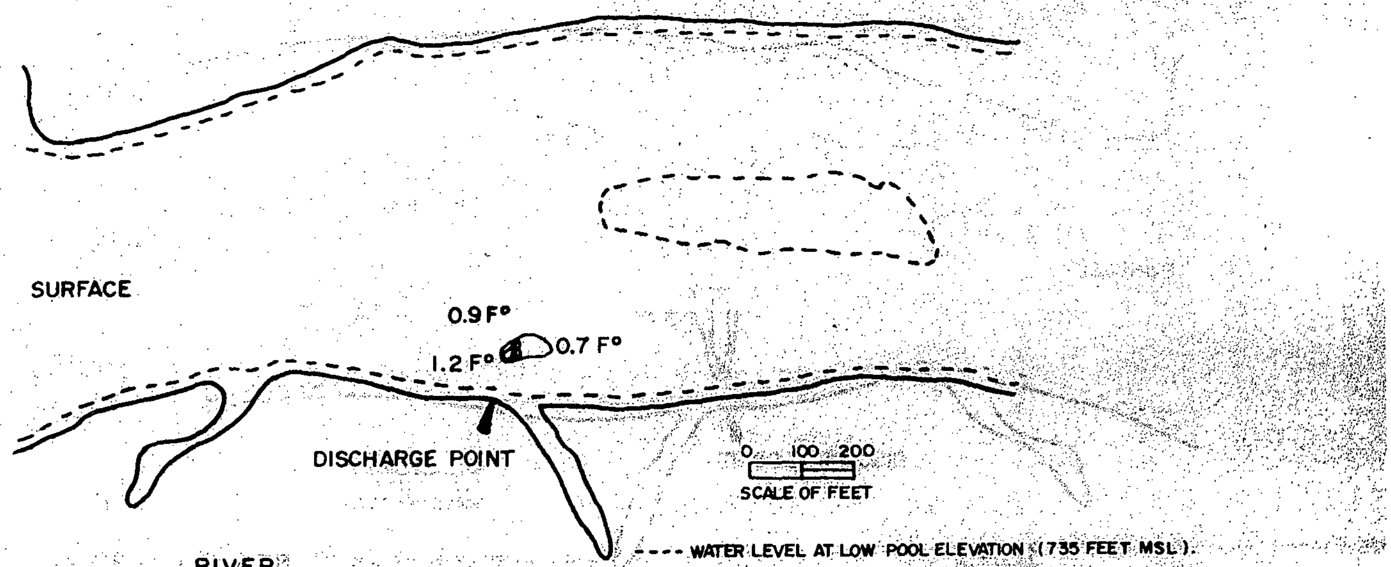


Figure 5.1-1 TYPICAL CASE-WINTER (based on Iowa Institute physical model study)



RIVER

flow = 4777 cfs
velocity = 0.63 fps (0.50 fps)*
pool elevation = 741 ft MSL

DISCHARGE JET

flow = 7.22 cfs
velocity = 20.68 fps
temp. diff. = 23.6F°

*Prototype velocity based on hydraulic model velocity. Reflects physical limitations of the flume.

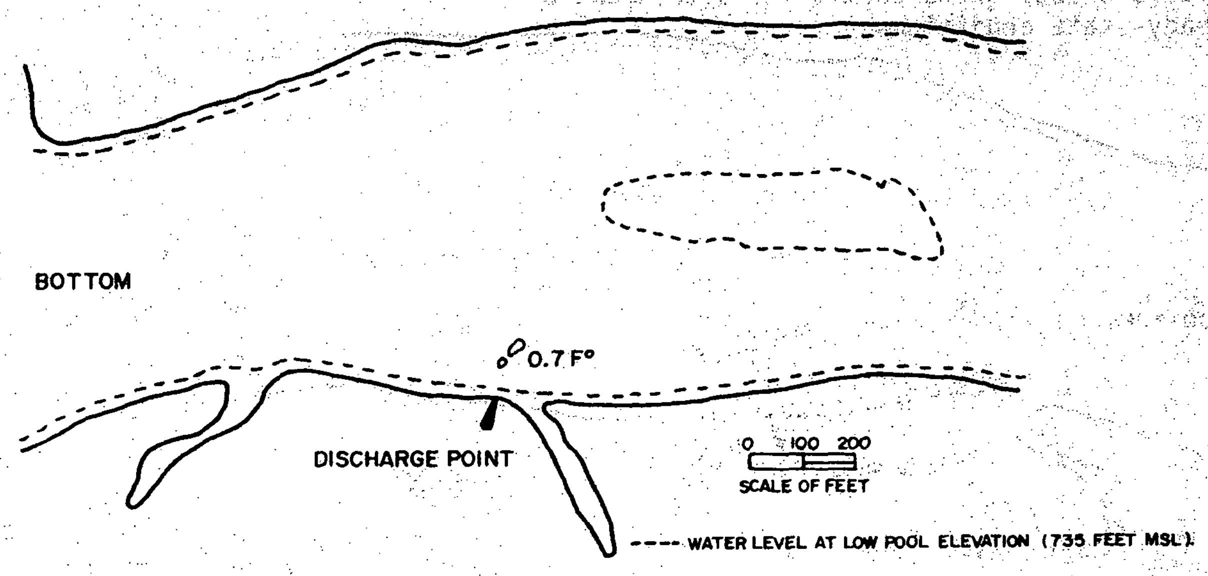
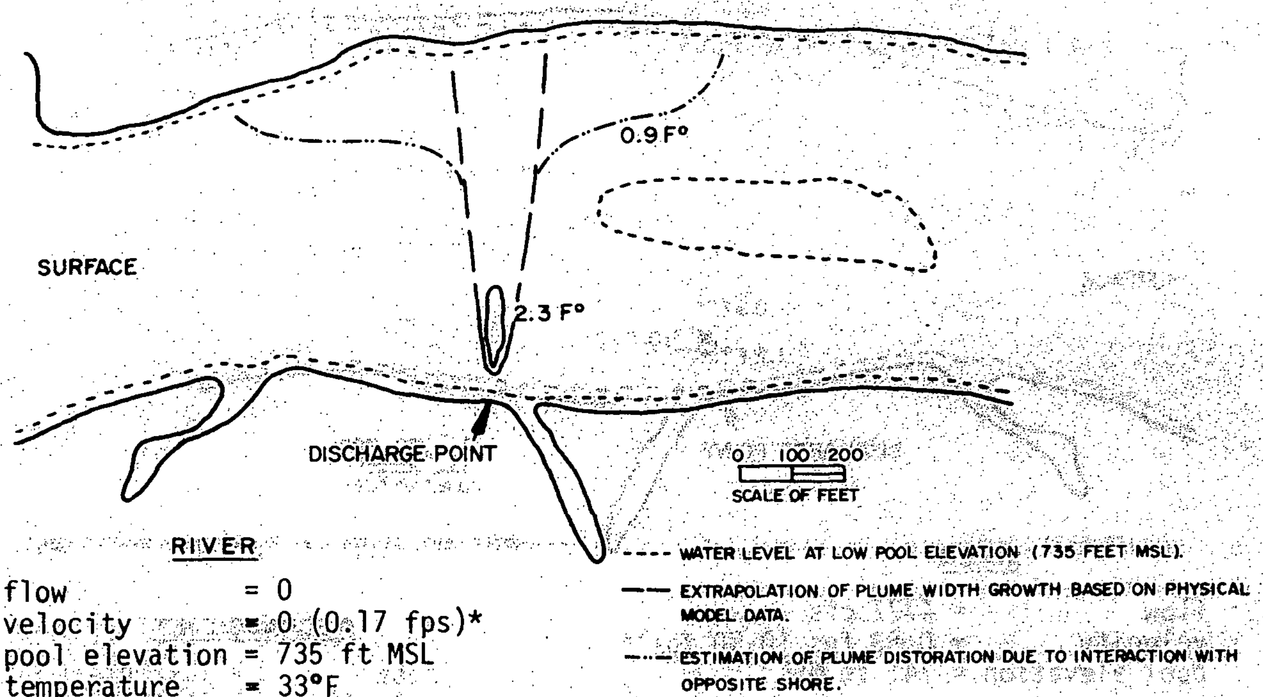


Figure 5.1-2 TYPICAL CASE-SUMMER (based on Iowa Institute physical model study)



RIVER

flow = 0
velocity = 0 (0.17 fps)*
pool elevation = 735 ft MSL
temperature = 33°F

DISCHARGE JET

flow = 6.26 cfs
velocity = 17.93 fps
temp. diff. = 46.8F°

*Prototype velocity based on hydraulic model velocity. Reflects necessity of maintaining a flume crossflow to permit the attainment of steady-state conditions.

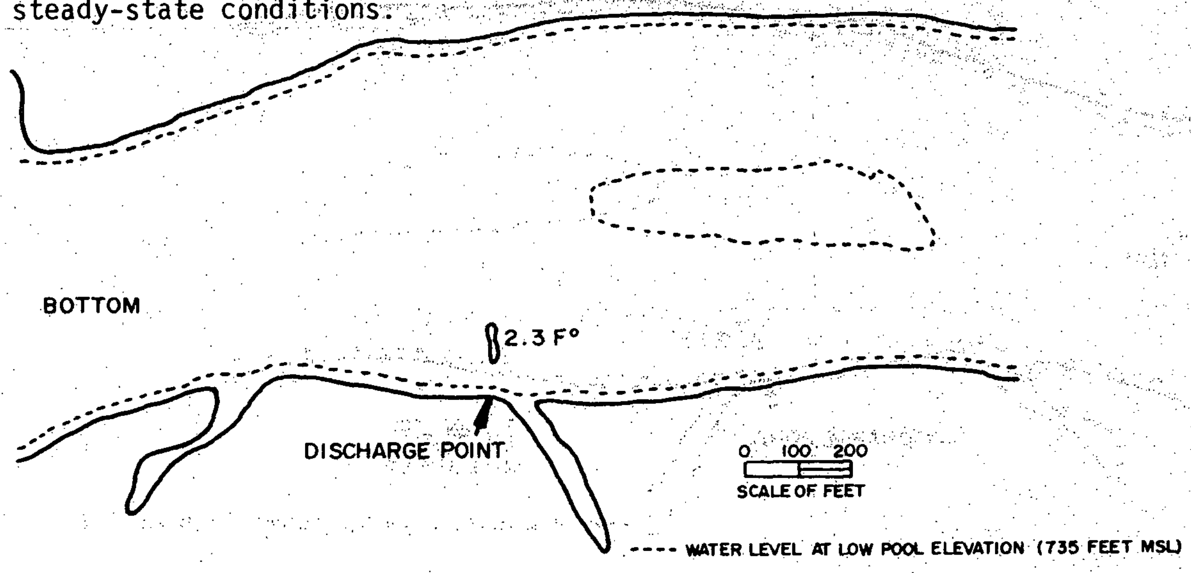
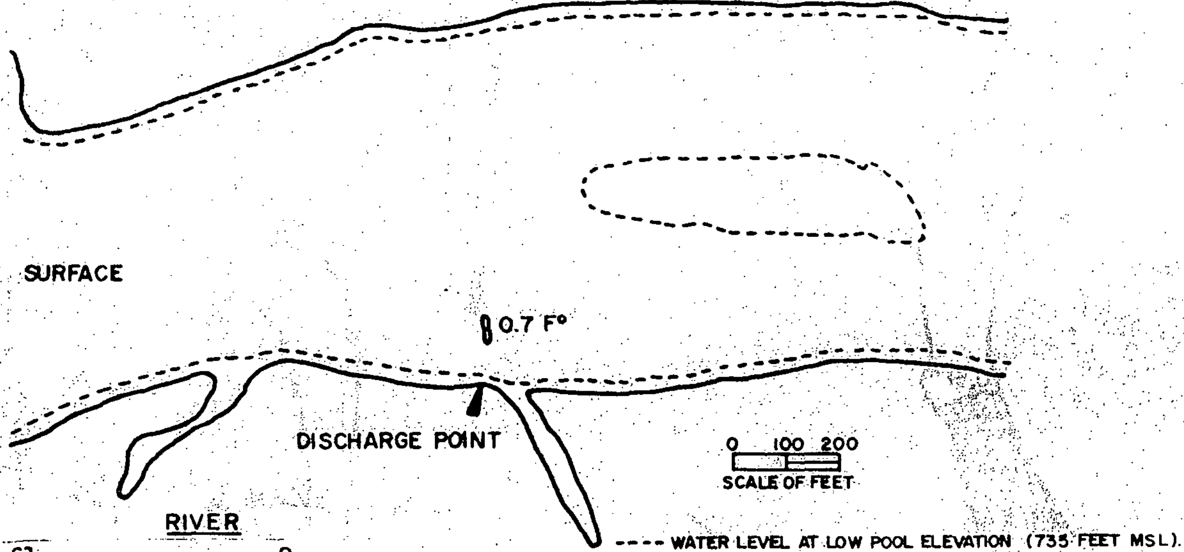


Figure 5.1-3 HYPOTHETICAL WORST CASE-WINTER (based on Iowa Institute physical model study)



RIVER

flow = 0
velocity = 0 (0.17 fps)*
pool elevation = 739 ft MSL
temperature = 78°F

DISCHARGE JET

flow = 7.31 cfs
velocity = 20.94 fps
temp. diff. = 11.6F°

*Prototype velocity based on hydraulic model velocity. Reflects necessity of maintaining a flume crossflow to permit the attainment of steady-state conditions.

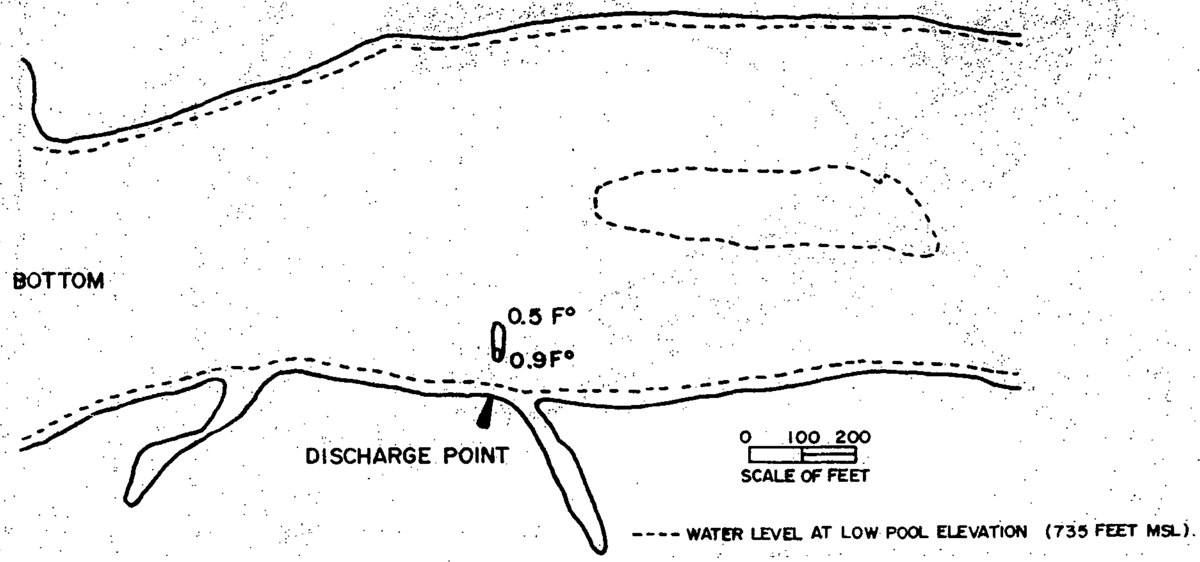


Figure 5.1-4 HYPOTHETICAL WORST CASE-SUMMER (based on Iowa Institute physical model study)

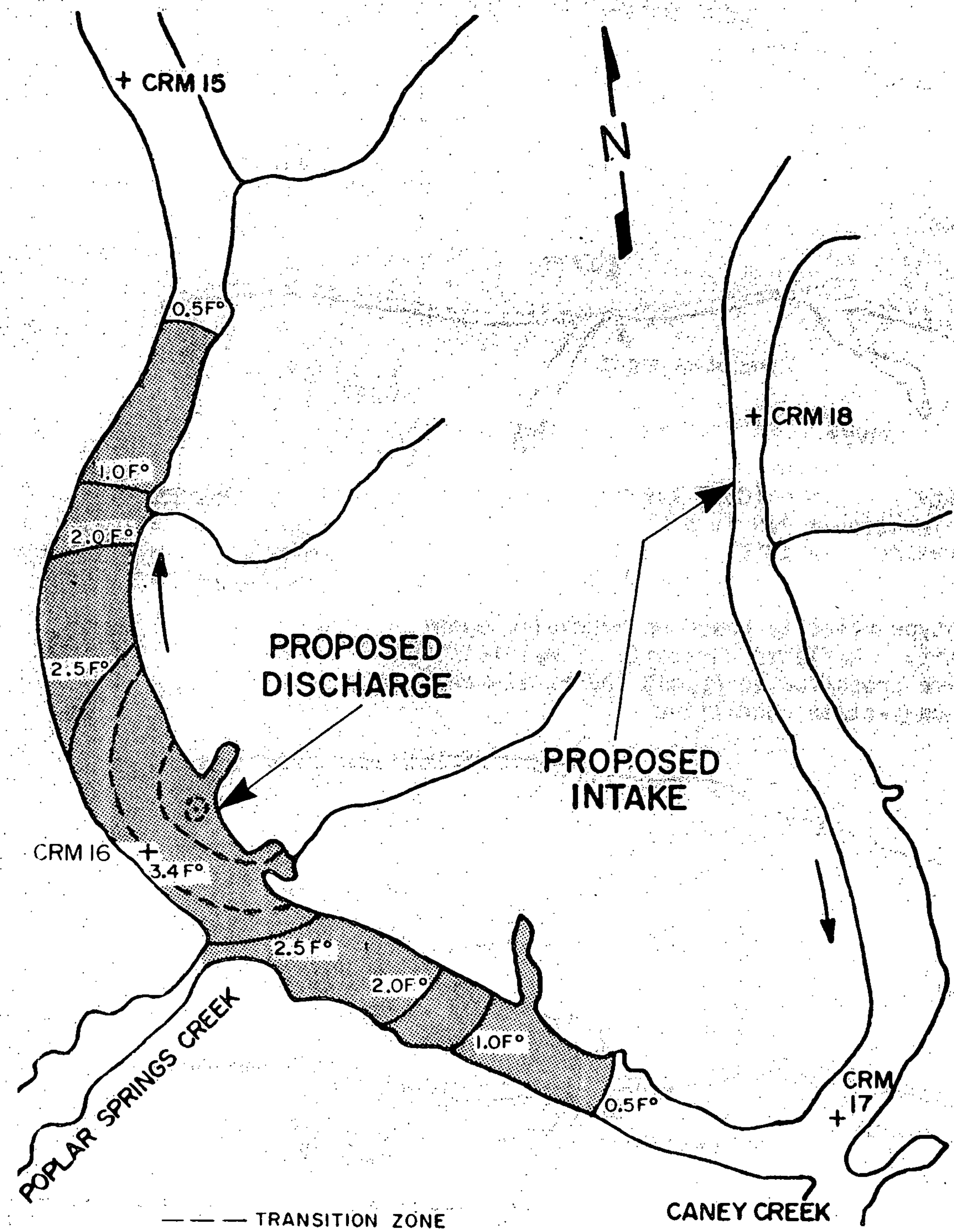


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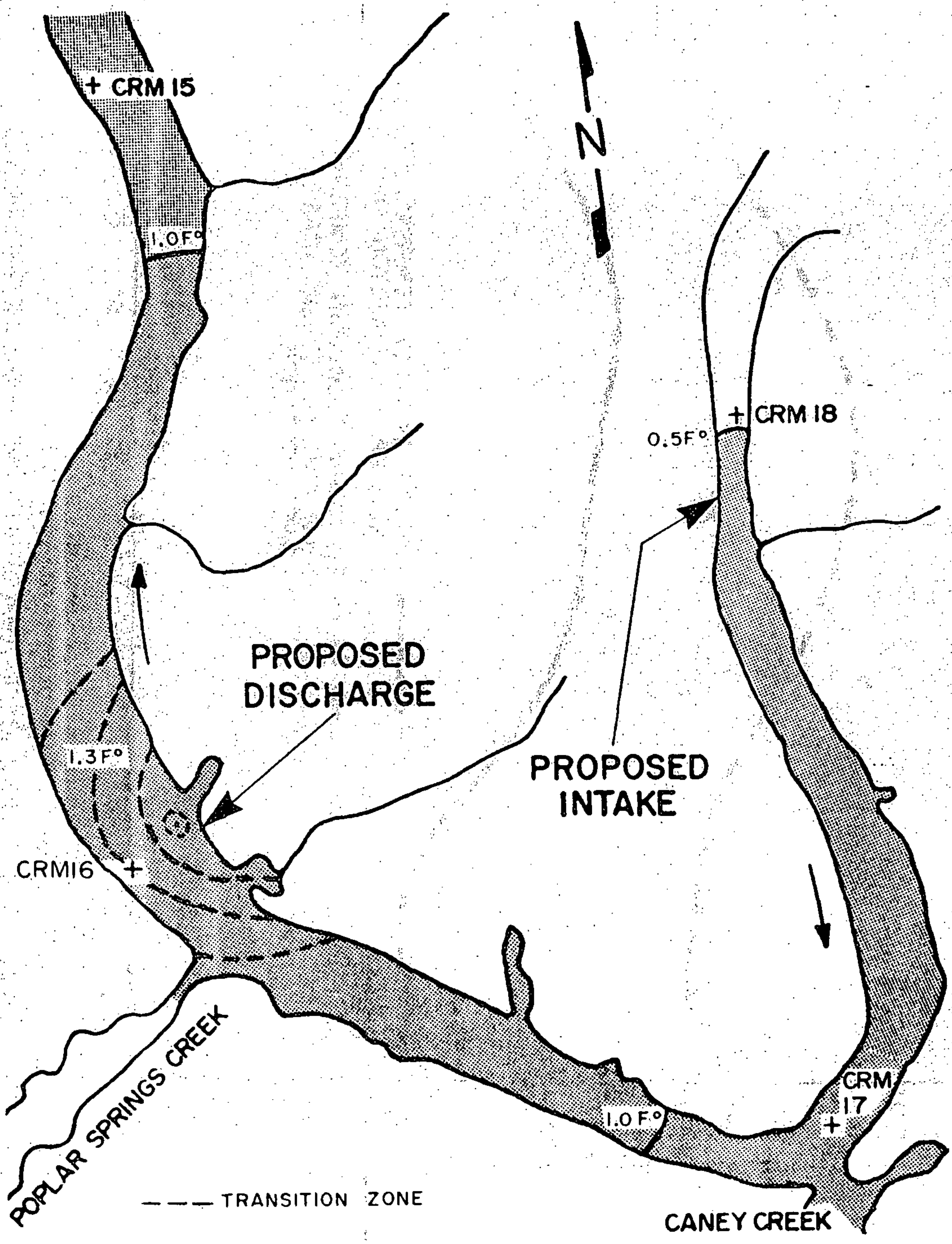
Figure 5.1-5 SURFACE ISOTHERMS FOR WINTER EXTENDED NO FLOW CASE



7

Figure 5.1-6 SURFACE ISOTHERMS FOR SUMMER EXTENDED NO FLOW CASE

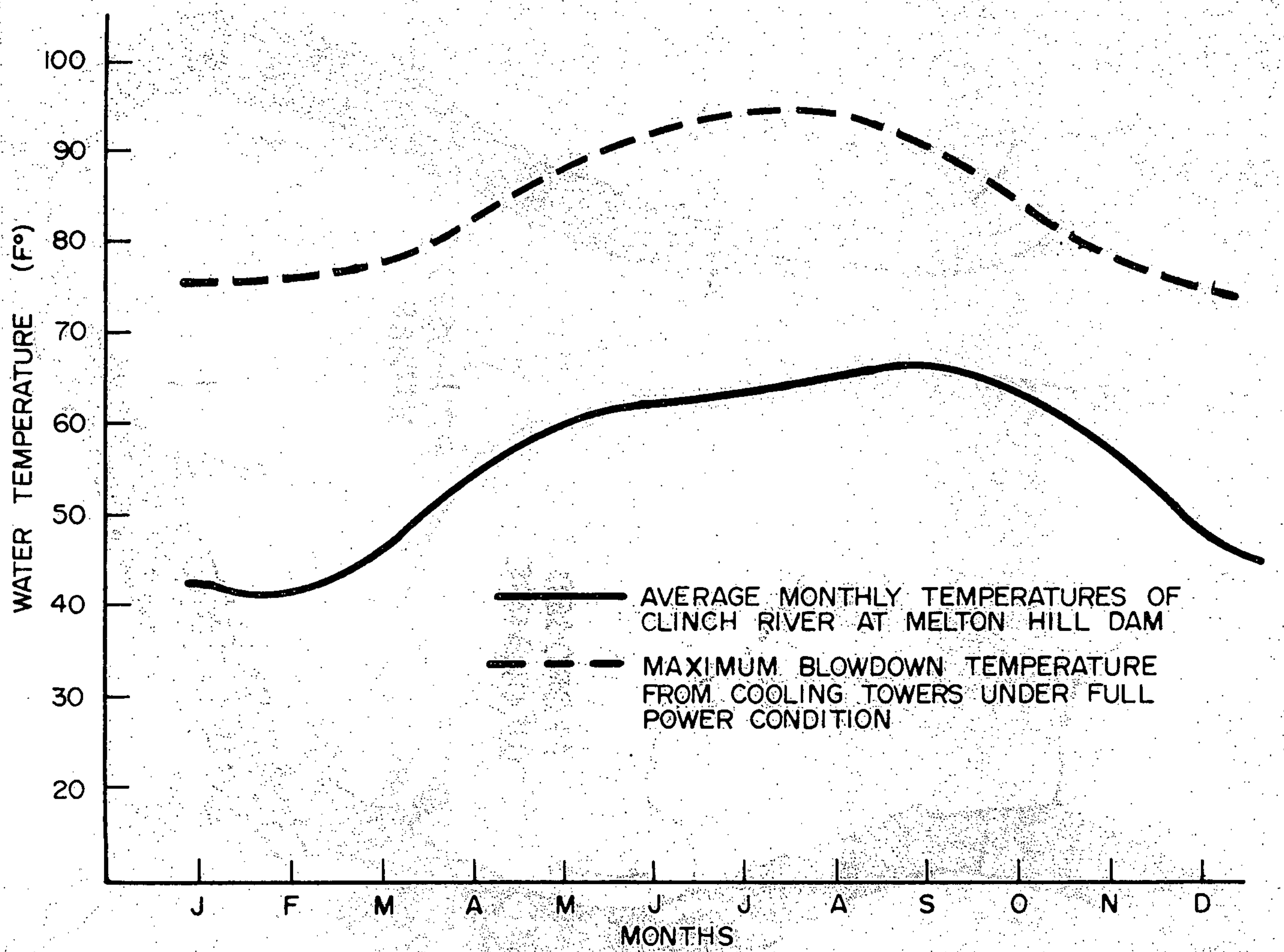


Figure 5.1-7 CLINCH RIVER TEMPERATURES AND BLOWDOWN TEMPERATURES

AMENDMENT II
July 1975

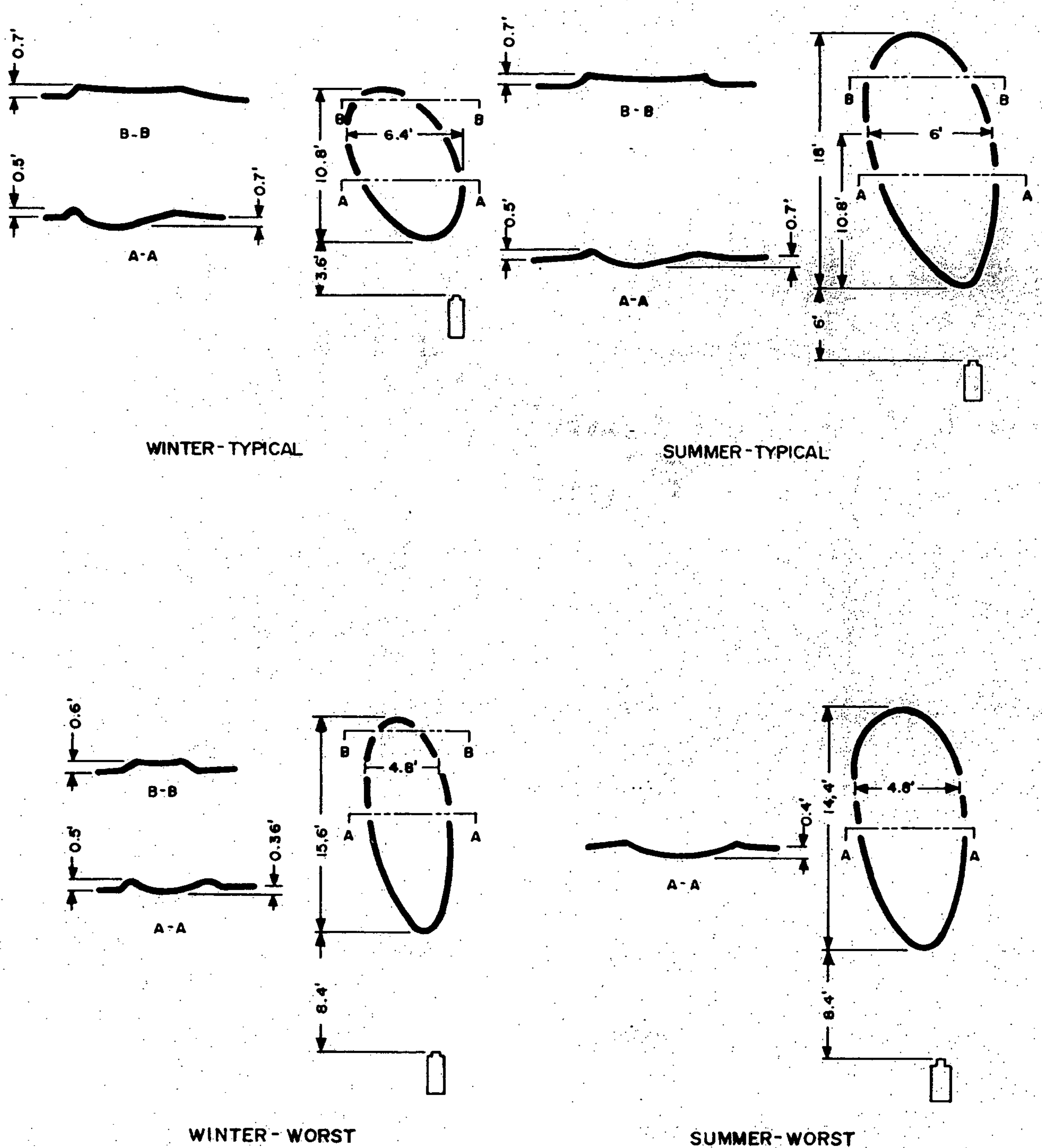


Figure 5.1-8 AREAS OF BOTTOM SCOURING (based on Iowa Institute physical model study)

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5.2 RADIOLOGICAL IMPACT FROM ROUTINE OPERATION

This section includes both the Radiological impact on biota other than man and the Radiological impact on man which had previously been discussed separately in Sections 5.2 and 5.3, respectively. The radiological impact from routine releases, previously discussed in Section 14.4, is also presented in this section.

5.2.1 EXPOSURE PATHWAYS

Extensive waste treatment systems included in the CRBRP design will assure that the amounts of radioactivity released to the environs during normal operation of the plant will be as low as reasonably achievable. Potential doses to man, and biota other than man, from both external and internal sources have been estimated for routine releases and are presented in this Section.

5.2.1.1 EXPOSURE PATHWAYS FOR ORGANISMS OTHER THAN MAN

These pathways originate with either liquid or gaseous effluent release and result in doses from external and internal routes. 13
External pathways include submersion in air and water and exposure to soil and sediment. Internal exposure results from the ingestion of food or water and the inhalation of air. The primary exposure pathways for organisms other than man are shown in Figure 5.2-1.

Doses to aquatic organisms from radionuclides deposited internally are generally of greater magnitude than the doses they receive from external sources of radiation. Radionuclides are incorporated into tissues of aquatic organisms either through the assimilation of food or through the direct penetration of dermal tissue. External radiation exposures to aquatic organisms are due primarily to radioactivity in solution or associated with suspended particulates. Benthos receive an additional external dose from radionuclides adsorbed onto or concentrated in the benthic substrate.

Internal doses to terrestrial animals are generally of greater magnitude than the doses they receive from external sources. These internal exposures result primarily from radionuclides ingested with food and water and from the inhalation of airborne radioactivity. Terrestrial organisms and plants receive an external exposure from submersion in air containing concentrations of radionuclides. Radionuclide concentrations in soil and vegetation, due to deposition from the atmosphere and to radionuclides entering through the water supply, are minor contributors to the external dose. An additional external exposure is attributable to direct radiation from radioactivity 13
contained within the plant.

5.2.1.2 EXPOSURE PATHWAYS TO MAN

The most significant exposure pathways to man are diagrammed in Figure 5.2-2.

5.2.1.2.1 LIQUID EFFLUENTS

Radiation exposures from liquid effluents generally arise from recreational activities or dietary intake. External exposures occur as a result of swimming, boating, and fishing in waters containing radioactivity; and persons involved in shoreline activities may be exposed from radionuclides accumulated in sediment. These external doses are proportional to radionuclide 15
concentrations in water and sediment. Internal doses result from the ingestion of water, the consumption of fish that contain radionuclides, and ingestion of waterfowl which feed on aquatic organisms. Swimmers receive an internal dose from tritium accumulated in the body as a result of exchange processes.

5.2.1.3 ENDANGERED OR THREATENED SPECIES

Unusual vegetation present within 10 miles of the Site which may be exposed to radioactivity released from the CRBRP includes a nearly pure stand of sassafras near the DOSAR (Dosimetry Application Research Facility) reactor at X-10 and a stand of eastern red cedar near the University of Tennessee Agricultural Farm. Also within 10 miles are 40 acres of plants used for biological research located on Jones Island and the University of Tennessee Arboretum

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5.2.1.2.2 GASEOUS EFFLUENTS

Individuals are exposed to gaseous effluents via the following pathways: (1) external radiation from radioactivity in the air and on the ground; (2) inhalation; (3) ingestion of beef, vegetables, and milk; and (4) tritium transpiration. No other additional exposure pathway has been identified which would contribute ten percent or more to either individual or population doses.

External air exposures are evaluated at points of potential maximum exposure (i.e., points at the site boundary and sector peaks given in Table 5.2-1). External skin exposure, total body exposure and the internal dose from tritium are calculated at the site boundary and sector peak locations.

13

The contribution to the internal dose from tritium includes inhalation, milk ingestion (with cow assumed to obtain 100% of feed from pasture), beef ingestion and vegetable ingestion.

It is assumed that enough fresh vegetables are produced at each residence to provide for annual consumption by all members of that household. Data on annual meat production are not available for a 50-mile radius from the plant center. It is assumed that enough milk and meat is produced in each sector annulus to supply the needs of that region. The CRBRP population distribution is given in Table 5.2-2.

5.2.1.2.3 DIRECT RADIATION

The shielding design criteria for the CRBRP specifies that, during normal operation, the dose rate at the surface of that part of the containment vessel which is above grade will be no more than 0.2 mrem/hr. An estimated 90 percent of the containment building that is above grade is shielded from the Site boundary by buildings and is enclosed by the Reactor Confinement Structure consisting of four feet of concrete.

Radwaste tanks are housed in buildings protected with concrete 15
walls. In addition, sodium storage tanks, the Radioactive Argon 13
Processing System (RAPS) and the Cell Atmosphere Processing System (CAPS) are located below grade.

As described in Section 3.2, the probability of radioactive sodium leaking from the primary to the intermediate loop of the Heat Transport System is very small.

Because of the above design and shielding characteristics, direct radiation doses at the site boundary are calculated to be much less than 1% of natural background. Therefore, these doses have not been included in the summary tables.

5.2.2 RADIOACTIVITY IN THE ENVIRONMENT

5.2.2.1 LIQUID EFFLUENTS

Estimated average annual quantities of radionuclides released in liquid effluents are listed in Section 3.5. The assumption is made that aquatic biota are exposed to radionuclide concentrations in the river near the liquid effluent discharge port. These concentrations are calculated assuming one part of liquid effluent is diluted by nineteen equal parts of river water. The average blowdown rate from the plant is assumed to be 2,306 gallons per minute. To calculate the exposure to man, the assumption is made that the liquid effluents from the plant are mixed with 1/5 of the river flow in the section of the Clinch River between the CRBRP and the Clinch River mouth. Water from the Clinch River is assumed to be mixed with 1/5 of the Tennessee River flow for a 10 mile reach of the Tennessee River starting at the mouth of the Clinch River. Downstream from this section of the river, the effluent is assumed to be mixed into the entire Tennessee River flow. Dilution of the radionuclide concentrations in the Clinch and Tennessee Rivers is calculated using mean flow data (see Table 5.2-3). The resulting average annual concentrations of radionuclides which would be contributed by the CRBRP plant at locations on the Clinch and Tennessee Rivers are listed in Table 5.2-4. For comparison purposes, average annual radionuclide concentrations in the plant effluent prior to mixing in the Clinch River are also listed.

As discussed in Section 2.5, the area of the Clinch River encompassing the point of the CRBRP discharge acts as a groundwater sink. Therefore exposure to liquid containments through seepage into aquifers is highly unlikely. 13

The assumptions and equations used to calculate the cumulative buildup of radionuclides in sediment are listed in NRC Regulatory Guide 1.109.

5.2.2.2 GASEOUS EFFLUENTS

Calculations of atmospheric transport, dispersion, and ground deposition are based on the straight-line airflow model discussed in NRC Regulatory Guide 1.111 (Revision 1, July 1977). Because of the small magnitude of doses predicted from routine operation of the facility, it was not considered appropriate to use a more sophisticated model. Therefore terrain correction factors as applied in Section 2.6 were not used in this assessment. All releases are assumed to be continuous.

All gaseous releases from the plant are treated as ground-level releases. The joint frequency distribution (JFD) used in the assessment may be found in Section 2.6.2.2 (Tables 2.6-5 through 2.6-11).

Air concentrations and deposition rates were calculated considering radioactive decay and buildup during transit. Plume depletion was calculated using the figures provided in Regulatory Guide 1.111.

Estimates of normalized concentration (X/Q) and normalized deposition rates (D/Q) for releases from the plant at points where potential dose pathways exist are listed in Tables 5.2-1 and 5.2-6.

5.2.3 DOSE RATE ESTIMATES FOR BIOTA OTHER THAN MAN

Analyses for the following representative organisms and pathways are performed to determine the potential radiological impact of the CRBRP.

Aquatic Organisms	- external exposure from water
	- external exposure from sediment
	- internal exposure
Terrestrial	
Vertebrates	- external exposure from air
	- external exposure from ground or water
	- external exposure from direct radiation
	- internal exposure from ingestion or inhalation
Plants	- external exposure from air
	- external exposure from ground
	- external exposure from direct radiation

Because of the complexity of biological functions and the interrelationships between organisms and their environment, simplified dose models have been developed to predict doses resulting from the more significant exposure pathways. Conservative assumptions are chosen because these models cannot predict the detailed variances of a system and because the results of an analysis cannot be applied equally to all members of a population. A brief outline of the models, methods of calculation, and basic assumptions is provided in this section. Dose estimates are based on the average annual activities of radionuclides expected to be released during normal operation of the CRBRP (Section 3.5). 13

5.2.3.1 LIQUID EFFLUENTS

The assumption is made that aquatic biota are exposed to radionuclide concentrations in the river near the liquid effluent discharge port. Dilution in the river near the plant is calculated using an average plant blowdown rate of 2327 gpm and mixing with nineteen parts river water. Average annual radionuclide concentrations in the plant effluent prior to mixing in the Clinch River are listed in Table 5.2-4. 16

TERRESTRIAL VERTEBRATES

Waterfowl and muskrats feed on aquatic plants which concentrate trace elements to a greater extent than do fish and invertebrates.[1] Therefore, maximum potential internal dose estimates for terrestrial mammals are computed for muskrats with diets consisting entirely of green algae from algal masses growing near the water discharge structure. This same analysis is also performed for ducks as a pathway to man. Equation 5.2-1 is used for estimating the annual internal total body dose to ducks and muskrats.

$$D_i = \frac{51.2 \times 10^3}{m} I_i f_{wi} \varepsilon_i (1 - \exp(-\lambda_i T))/\lambda_i \text{, mrad} \quad (5.2\text{-}1)$$

where 13

$51.2 \times 10^3 = (1.6 \times 10^{-8}$ g-rad/meV) $(3.20 \times 10^9$ dis/Ci-d) $(10^3$ mrad/rad),

I_i = 330 g/d x C_{wi} x F_{pi} x 365 d, μCi,

C_{wi} = water concentration, μCi/g,

F_{pi} = concentration factor for aquatic plants, dimensionless,

f_{wi} = fractional uptake, dimensionless,

ε_i = effective energy absorbed per disintegration of the i^{th} radionuclide including daughter products, MeV/dis,

λ_i = effective decay constant, $days^{-1}$,

T = 1,825 days,

m = 1,000 g.

The duck and muskrat are assumed to have a mass of 1,000 g, an effective radius of 10 cm, and a daily intake of 330 g of

green algae. Long-lived radionuclides such as Cs-137 can deliver significant portions of the total dose commitment long after the time of ingestion. Therefore, a life span of five years is assumed for the integration interval T. In the absence of data applicable specifically to ducks and muskrats, International Commission on Radiological Protection (ICRP) data[2] are used for 15
the fractional uptake and for the biological half-life of parent radionuclides. The use of human data for biological half-lives is considered to be conservative because warm-blooded vertebrates smaller than man exhibit more rapid elimination rates.[3]

The duck and muskrat are assumed to be exposed continuously by full immersion in the water. External dose rates are estimated using the equation:

$$R_i = 51.2 \times 10^3 \, C_{wi} E_i, \text{ mrad/d,} \qquad (5.2\text{-}2)$$

where 13

E_i = average effective energy emitted by the i^{th} radionuclide per disintegration, MeV/dis.

Doses to this hypothetical mammal (muskrat) are given in Table 5.2-9.

AQUATIC PLANTS, INVERTEBRATES, AND FISH

Radioactivity desposited internally in these organisms is estimated by multiplying the average water concentration contributed from the CRBRP releases in the Clinch River near the point of discharge by the applicable concentration factors[1, 3, 4, 12, 13] listed in Table 5.2-7. Internal doses are estimated (Table 5.2-8) for organisms having effective radii of 3 cm and 30 cm. In the absence of detailed knowledge of the dynamic behavior of radioactive daughter products that are produced internally, all daughter products are assumed to be bound permanently in the organisms; and every daughter in a decay chain is assumed to decay at an equilibrium disintegration rate equal to the disintegration rate of the parent nuclide. The annual dose from i^{th} radionuclide is calculated using the equation:

$$D_i = 51.2 \times 10^3 C_{fi} \varepsilon_i \times 365, \text{ mrad/yr} \qquad (5.2\text{-}3)$$

where 13

C_{fi} = radioactivity concentration in the organism
= $C_{wi} \times F_i$, μCi/g,
F_i = concentration factor, dimensionless.
ε_i = effective energy absorbed per disintegration of the i^{th} radionuclide including daughter product, Mev/dis.

External doses for organisms immersed in water (Table 5.2-7) are calculated using Equation 5.2-2. Benthic organisms such as mussels, worms, and fish eggs receive additional external doses from radioactivity associated with bottom sediments. Accurate prediction of the accumulation of radioactivity in sediment and the resultant doses to benthic organisms requires detailed knowledge of a number of factors, including mineralogy, particle size, exchangeable calcium in the sediment, channel geometry, waterflow patterns, chemical form of the radiocompounds, and behavioral characteristics of the organism. In the absence of this detailed knowledge, external doses from radioactivity associated with bottom sediment are calculated assuming a 4-π geometry for beta doses and a 2-π geometry for gamma doses.

5.2.3.2 GASEOUS EFFLUENTS

In the evaluation of the potential impact of gaseous effluents on terrestrial organisms, biota are assumed to be located at the point of maximum offsite exposure. External doses to terrestrial organisms from air submersion and ground contamination are 13
estimated using dose factors derived for humans. It is assumed that total body dose factors for humans are applicable to terrestrial vertebrates and that skin dose factors for humans are applicable to terrestrial plants and small fauna.

Internal exposures vary for each type of organism and tissue. For this estimate, biota are assumed to be located at the point of maximum offsite exposure. The equation used to calculate the annual total body dose to an animal from the inhalation and ingestion exposure pathway is:

$$D_i = (C_{ai} \times DF_{ai}) + (C_{gi} \times DF_{gi}), \text{ mrad/yr} \qquad (5.2\text{-}4)$$

where

C_{ai} = average air concentration, $\mu Ci/cm^3$,
C_{gi} = average ground concentration, $\mu Ci/m^2$. 15
DF_{ai} = dose factor for inhalation, mrad per year per $\mu Ci/cm^3$,
DF_{gi} = dose factor for ingestion, mrad per year per $\mu Ci/m^2$. 15

Dose estimates for biota which could result from CRBRP plant released radioactivity are listed in Table 5.2-9. These estimated doses are less than the dose limits established for occupational workers in the nuclear industry.[5, 6] In the "BEIR" report,[7] it is stated that ". . . probably no other living organisms are very much more radiosensitive than man, so that if man as an individual is protected, then other organisms as populations would be most unlikely to suffer harm."

5.2.4 DOSE RATE ESTIMATES FOR MAN

5.2.4.1 LIQUID PATHWAYS

Estimated average annual activities of radionuclides released in liquid effluents are listed in Section 3.5. Data listed in Table 5.2-5 for potable water supply systems [17] and appropriate ingestion dose factors [11,12,13] are combined to calculate dose commitments from the ingestion of Tennessee River water (Table 5.2.10). Dilution of the radionuclide concentrations in the Clinch and Tennessee Rivers is calculated using flow data listed in Table 5.2-3. The plant effluent is assumed to be mixed with one-fifth of the Clinch River flow in the reach between the CRBRP plant and the river mouth. Water from the Clinch River is 13 assumed to mix with 1/5 of the Tennessee River flow in a 10 mile reach of the Tennessee River starting at the mouth of the Clinch River. Beyond this section, mixing into the entire Tennessee River flow is assumed.

Fish harvest data[14, 15] provided in Table 5.2-11 are used to calculate population doses resulting from the ingestion of fish.[1, 2, 11, 12, 13] Maximum expected population and individual doses resulting from fish consumption are presented in Table 5.2-10. The types of fish in the Clinch and Tennessee Rivers are discussed in Section 2.7.

Data[16] provided in Table 5.2-12 and appropriate dose factors[11, 12, 13] are used to calculate population doses resulting from recreation activities on or near the Tennessee River. Maximum individual doses for above-water use of the river 13
are estimated for a fisherman exposed for 100 days per year at 5 hours per day. The maximum individual doses for in-water activities are estimated for a person who swims 500 hours per year at a location in the river just below the CRBRP site. Maximum tritium doses to a swimmer are calculated for continuous immersion for 5 months in the Clinch River just below the CRBRP site. The visitation data listed in Table 5.2-11 were developed by multiplying the actual above-water, in-water, and shoreline visits to each stream reach by the average length of stay (in hours) along each reach and then dividing the resultant total visitor hours by the assumed lengths of stay. This process of extrapolation does not change the total visitor-hour values for each reach but simply puts the recreation use data in a comparable and suitable form for application of dosimetric analyses.

An individual adult is assumed to participate in shoreline activities for 500 hours per year. Population doses can be calculated using the recreational data provided in Table 5.2-12 and assuming an average recreational visit lasts 5 hours. The maximum annual individual and population doses expected from the use of the Clinch and the Tennessee Rivers for water sports during operation of the CRBRP are shown in Table 5.2-10.

It is assumed that the maximum exposed individual consumes one duck each year which has been contaminated as outlined in Section 5.2.3.1. The predicted doses are given in Table 5.2-10.

5.2.4.2 GASEOUS PATHWAYS

Doses are calculated using the dose factors and methodology contained in NRC Regulatory Guide 1.109 with certain exceptions as follows: 13

1. Inhalation doses are based on average individual inhalation rates[8] of 1,400; 5,500; 8,000; and 8,100 m^3/year for infant, child, teen, and adult respectively.

2. Doses to air are calculated using average beta and gamma energies per decay from the TVA nuclide data library.

3. The milk ingestion pathway has been modeled to include the assumption of 100% pasture grazing by milk animals.

4. The stored vegetable and beef ingestion pathways have been modeled to reflect more accurately the actual dietary characteristics of individuals. For stored vegetables the assumption is made that home grown stored vegetables are consumed when fresh vegetables are not available, i.e., during the 9 months of fall, winter, and spring. Rather than use a constant storage period of 60 days, radioactive decay is accounted for explicitly during the 275-day consumption period. The radioactive decay correction is calculated by:

$$\frac{1}{275}\int_{0}^{275} \exp(-\lambda_i t)\,dt = \frac{1-\exp(-\lambda_i 275)}{275\,\lambda_i}$$ 13

This replaces the term exp $(-\lambda_i t_h)$ in equation C-7 of Regulatory guide 1.109.

5. The beef consumption pathways can be divided into either commercial sales or home use pathways. Dose calculations are made for individuals consuming meat produced for home use.

The normal processing route is for an individual to slaughter the beef animal, package and freeze the meat, and then consume the meat during the next 3-month period. Radioactive decay is calculated during the 3-month period 15
by

$$\frac{1}{90}\int_{0}^{90} \exp(-\lambda_i t)\,dt = \frac{1 - \exp(-\lambda_i\, 90)}{90\,\lambda_i}$$

This term is multiplied into equation C-14 in Regulatory Guide 1.109. If the beef animals are sold commercially, then individuals would not be exposed continuously to meat containing radioactivitiy from the same farm. It is 13
expected that this pathway will not cause significant individual exposures.

Calculations of wet deposition based on a washout model and recommendations of Engelmann[9] indicate that wet deposition is not a significant portion of total deposition. All doses related to deposition pathways (ground exposure and food ingestion) are estimated using dry deposition.

The basic data for individual and population dose calculations are contained in Tables 5.2-1 and 5.2-2. Included are distances and elevations at the site boundary and sector peaks; and population distribution and maximum elevations. Population doses were based on a U.S. population distribution of:

Category	Ages(A)*	Fraction
Infant	$A<2$	.034
Child	$2\leq A<13$	.211
Teen	$13\leq A<19$	.134
Adult	$19\leq A$	.621

*e.g., someone who is 1 year, 11 months is an infant, while someone who is exactly two years old is a child.

Tables 5.2-13 and 5.2-14 provide the doses estimated for 13
individuals and the resident population within 50 miles of the plant site.

5.2.4.3 DOSES VIA EXPOSURE TO RADIOACTIVE MATERIALS IN TRANSIT

5.2.4.3.1 NEW FUEL

Dose estimates have been made based upon transportation of fuel and blanket assemblies to the plant from the Hanford Site. These doses have been calculated based upon NUREG-0170[10].

Assuming an average of 14 shipments of fresh fuel for the core and axial blankets per year and 12 shipments of fresh fuel for the inner and radial blankets per year over a distance of 2500 miles per shipment, the annual dose to the general public is estimated and presented in Table 5.2-15.

5.2.4.3.2 IRRADIATED FUEL

Population doses from transport of irradiated fuel to fuel reprocessing plants have also been estimated based upon NUREG 0170[10] with shipment by rail. Assuming 14 shipments per year for spent fuel plus axial blanket assemblies and 12 shipments per year for inner and radial blankets assemblies and a transit distance of 2500 miles for each shipment, the population dose 13
presented in Table 5.2-15 was calculated.

5.2.4.3.3 RADIOACTIVE WASTES

Approximately one-hundred eighty-one (181) 55-gallon drums of solidified liquid wastes will be shipped from the Site to an NRC-licensed burial ground each year. An estimated 112 drums of non-compactible solids and 28 drums of compactible solids will also be shipped from the Site each year. An estimated four shipments per year will be made for irradiated control assemblies and radial shield assemblies. The estimated population dose to the general population would be 0.43 man-rem/yr, as shown in Table 5.2-15. These estimates assume a shipping distance of 2500 miles per shipment.

5.2.5 SUMMARY OF ANNUAL RADIATION DOSES

The radiological impact to regional population groups in the year 2020 from the normal operation of the CRBRP are estimated. Table 5.2-15 summarizes these population doses. The total body dose from background to individuals within the United States ranges 13
from approximately 100 mrem to 250 mrem per year. The annual total body dose due to background for a population of 921,200 persons expected to live within a 50-mile radius of the CRBRP in the year 2020 is calculated to be approximately 128,968 man-rem assuming 140 mrem/year/individual. By comparison, the same population will receive a total body dose of approximately 0.03 15
man-rem from effluents released from the CRBRP. Based on these results, it is concluded that the normal operation of the CRBRP will present minimal risk to the health and safety of the public.

TABLE 5.2-1

DATA ON POINTS OF INTEREST NEAR THE CRBRP

	POINT	SECTOR	DISTANCE (m)	ELEVATION* (m)	CHI-OVER-Q** (s/m^3)	D-OVER-Q** ($1/m^2$)
1	LAND SITE BOUNDARY	N	2060.	87.	1.01E-06	1.31E-09
2	LAND SITE BOUNDARY	NNE	2440.	87.	6.43E-07	8.11E-10
3	LAND SITE BOUNDARY	NE	880.	-5.	5.06E-06	1.25E-08
4	LAND SITE BOUNDARY	ENE	820.	20.	8.33E-06	1.80E-08
5	LAND SITE BOUNDARY	E	820.	2.	9.69E-06	1.46E-08
6	LAND SITE BOUNDARY	ESE	980.	-5.	7.45E-06	1.42E-08
7	LAND SITE BOUNDARY	SE	1200.	-23.	3.83E-06	6.20E-09
8	LAND SITE BOUNDARY	SSE	820.	-23.	5.65E-06	7.35E-09
9	LAND SITE BOUNDARY	S	700.	-23.	6.08E-06	8.04E-09
10	LAND SITE BOUNDARY	SSW	670.	-23.	6.66E-06	9.38E-09
11	LAND SITE BOUNDARY	SW	670.	-23.	8.10E-06	1.34E-08
12	LAND SITE BOUNDARY	WSW	700.	-23.	1.10E-05	1.71E-08
13	LAND SITE BOUNDARY	W	750.	-23.	1.57E-05	1.57E-08
14	LAND SITE BOUNDARY	WNW	810.	-23.	9.77E-06	8.38E-09
15	LAND SITE BOUNDARY	NW	820.	-23.	1.80E-05	1.31E-08
16	LAND SITE BOUNDARY	NNW	1000.	-23.	1.00E-05	1.10E-08
17	SECTOR PEAK	N	1900.	93.	1.14E-06	1.51E-09
18	SECTOR PEAK	NNE	1900.	93.	9.16E-07	1.24E-09
19	SECTOR PEAK	NE	6500.	123.	2.78E-07	4.20E-10
20	SECTOR PEAK	ENE	6500.	166.	4.24E-07	5.39E-10
21	SECTOR PEAK	E	1700.	99.	3.20E-06	4.45E-09
22	SECTOR PEAK	ESE	2700.	93.	1.71E-06	2.65E-09
23	SECTOR PEAK	SE	3300.	117.	9.07E-07	1.14E-09
24	SECTOR PEAK	SSE	1000.	75.	4.14E-06	5.31E-09
25	SECTOR PEAK	S	1200.	93.	2.70E-06	3.33E-09
26	SECTOR PEAK	SSW	1300.	105.	2.40E-06	3.17E-09
27	SECTOR PEAK	SW	2700.	93.	9.95E-07	1.34E-09
28	SECTOR PEAK	WSW	1400.	69.	3.77E-06	5.53E-09
29	SECTOR PEAK	W	1400.	75.	5.85E-06	5.68E-09
30	SECTOR PEAK	WNW	1200.	69.	5.25E-06	4.41E-09
31	SECTOR PEAK	NW	7500.	93.	8.22E-07	3.02E-10
32	SECTOR PEAK	NNW	6900.	81.	6.87E-07	4.09E-10

* reference with respect to plant grade (Plant grade has been established at 816 feet above mean sea level)

** normalized air concentrations and deposition rates were generated using a constant wind direction model and the joint frequency distributions of meteorological data given in Section 2.6.2.2 (Tables 2.6-5 through 2.6-11)

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TABLE 5.2-2

CRBRP - POPULATION DISTRIBUTION AND SECTOR ELEVATIONS (Year 2020)*

POPULATION WITHIN EACH SECTOR ELEMENT

SECTOR**	1305.	2414.	4023.	5633.	7242.	12070.	24140.	40234.	56327.	72420.
N	0.	0.	0.	0.	0.	2100.	3600.	1100.	4300.	8400.
NNE	0.	0.	0.	0.	0.	8300.	10800.	4000.	20700.	7400.
NE	0.	0.	0.	0.	0.	5900.	26200.	1900.	10400.	5500.
ENE	20.	20.	0.	0.	0.	5100.	21000.	124100.	44600.	14900.
E	50.	80.	140.	30.	40.	3400.	33000.	125800.	29500.	22200.
ESE	20.	30.	70.	170.	150.	1500.	7600.	73200.	5500.	5700.
SE	0.	30.	70.	170.	70.	11500.	4700.	4700.	2400.	2400.
SSE	0.	30.	50.	110.	210.	1300.	4900.	1800.	2500.	5700.
S	0.	70.	60.	150.	200.	900.	5200.	10500.	4300.	4300.
SSW	10.	40.	70.	100.	110.	900.	1500.	2900.	6100.	12700.
SW	30.	100.	100.	130.	170.	800.	3300.	12800.	32900.	11700.
WSW	20.	80.	100.	170.	410.	5500.	2300.	4000.	4900.	5600.
W	0.	150.	120.	130.	620.	6600.	8700.	1600.	22500.	4700.
WNW	10.	100.	210.	10.	50.	3400.	6000.	2100.	3400.	3700.
NW	30.	30.	0.	10.	40.	1400.	2100.	1800.	3300.	8200.
NNW	10.	0.	0.	0.	100.	900.	3700.	1300.	4100.	3700.

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MAXIMUM ELEVATIONS ABOVE PLANT GRADE (Meters)

SECTOR**	1305.	2414.	4023.	5633.	7242.	12070.	24140.	40234.	56327.	72420.
N	56.	93.	69.	99.	93.	239.	727.	635.	514.	514.
NNE	38.	93.	93.	93.	99.	56.	696.	818.	605.	666.
NE	26.	38.	56.	123.	123.	117.	117.	148.	239.	666.
ENE	20.	99.	56.	117.	166.	87.	148.	148.	392.	483.
E	62.	99.	38.	117.	111.	117.	56.	148.	635.	696.
ESE	50.	93.	87.	99.	99.	87.	56.	209.	818.	1428.
SE	-5.	117.	123.	75.	133.	87.	148.	575.	1245.	1306.
SSE	75.	105.	123.	105.	123.	87.	117.	148.	1062.	1336.
S	99.	87.	93.	123.	117.	56.	87.	209.	361.	514.
SSW	99.	93.	105.	99.	130.	87.	87.	87.	56.	56.
SW	14.	93.	111.	111.	105.	87.	117.	87.	87.	270.
WSW	69.	62.	75.	87.	87.	87.	87.	239.	681.	529.
W	81.	56.	81.	62.	87.	87.	331.	453.	635.	361.
WNW	69.	44.	38.	93.	93.	87.	422.	453.	361.	544.
NW	38.	44.	38.	87.	117.	209.	514.	514.	270.	300.
NNW	26.	50.	14.	56.	93.	209.	696.	696.	300.	239.

* Resident population distribution 0-10 and 10-50 miles from the CRBRP site for the year 2020 are taken from ER tables 2.2-2E and 2.2-3E

** Distance in meters from the center of the plant site to the center of the sector annulus

TABLE 5.2-3

MEAN RIVER FLOW

Location* (River Mile)	Mean Flow (ft^3/sec)
585.7	4580
568.0	20,500
568.0	27,500
500.0	28,800
500.0	34,200
469.0	35,100
469.0	35,800
423.0	36,600
423.0	37,700
361.0	39,700
361.0	40,500
344.0	40,800
344.0	41,800
339.0	41,800
339.0	42,700
333.0	42,800
284.0	45,200
284.0	49,000
264.0	50,100
264.0	50,900
256.0	51,100
225.0	52,100
225.0	53,500
189.0	54,300
136.0	55,600
136.0	56,000
110.0	56,400
110.0	61,800
100.0	62,000
67.0	62,700
67.0	63,500
22.0	64,000
4.0	64,100
4.0	64,700
0.0	64,800

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* River mile locations are for the Clinch - Tennessee River System. (River mile 585.7 is at CRBRP site.) A repeated river mile location indicates tributary inflow.

TABLE 5.2-4

AVERAGE RADIONUCLIDE CONCENTRATIONS IN WATERS FROM CRBRP RELEASES (μ Ci/ml)

NUCLIDE	PLANT EFFLUENT AT DIFFUSER	CLINCH RIVER BELOW CRBRP	TENNESSEE RIVER ABOVE KINGSTON	TENNESSEE RIVER BELOW KINGSTON
H-3	2.85E-9	1.46E-11	3.60E-12	5.27E-13
Na-22	4.48E-14	2.29E-16	5.66E-17	8.26E-18
Na-24	6.74E-16	2.89E-17	8.51E-19	0.0
Cr-51	1.69E-13	9.07E-16	2.14E-16	2.90E-17
Mn-54	1.27E-12	6.50E-15	1.60E-15	2.33E-16
Co-58	1.14E-11	5.90E-14	1.43E-14	2.04E-15
Co-60	3.24E-12	1.66E-14	4.10E-15	5.99E-16
Fe-59	8.18E-14	4.31E-16	1.04E-16	1.45E-17
Sr-89	3.39E-15	1.78E-17	4.29E-18	6.03E-19
Sr-90	2.61E-15	1.33E-17	3.30E-18	4.83E-19
Y-90	2.61E-15	1.33E-17	3.30E-18	4.83E-19
Y-91	1.00E-15	5.22E-18	1.26E-18	1.78E-19
Zr-95	8.32E-13	4.34E-15	1.05E-15	1.49E-16
Nb-95	8.46E-13	4.34E-15	1.07E-15	1.56E-16
Mo-99	1.29E-16	1.07E-18	1.63E-19	1.12E-20
Ru-103	1.09E-12	5.74E-15	1.37E-15	1.90E-16
Ru-106	1.72E-14	8.78E-17	2.17E-17	3.15E-18
Rh-106	1.72E-14	8.78E-17	2.17E-17	3.15E-18
Ag-111	5.67E-17	3.47E-19	7.17E-20	0.0
Sb-125	6.09E-16	3.11E-18	7.69E-19	1.12E-19
Te-127m	7.10E-15	3.67E-17	8.97E-18	1.29E-18
Te-127	7.10E-15	3.67E-17	8.93E-18	1.28E-18
Te-129m	2.06E-14	1.09E-16	2.59E-17	3.56E-18
Te-129	1.32E-14	1.09E-16	1.66E-17	2.28E-18
Te-132	1.09E-14	8.45E-17	1.38E-17	1.05E-18
I-131	3.96E-13	2.39E-15	5.00E-16	5.63E-17
I-132	1.12E-14	2.61E-16	1.42E-17	1.08E-18
Cs-134	2.15E-14	1.10E-16	2.72E-17	3.97E-18
Cs-136	1.98E-14	1.11E-16	2.49E-17	3.13E-18
Cs-137	7.37E-13	3.77E-15	9.33E-16	1.36E-16
Ba-140	5.54E-13	3.13E-15	6.98E-16	8.66E-17
La-140	5.95E-13	3.13E-15	7.51E-16	9.75E-17
Ce-141	2.30E-15	1.22E-17	2.90E-18	3.98E-19
Ce-143	1.47E-15	2.00E-17	1.87E-18	5.90E-20
Pr-143	3.78E-15	2.00E-17	4.78E-18	6.18E-19
Ce-144	1.73E-15	8.89E-18	2.19E-18	3.18E-19

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TABLE 5.2-4 (continued)

AVERAGE RADIONUCLIDE CONCENTRATIONS IN WATERS FROM CRBRP RELEASES (μCi/ml)

NUCLIDE	PLANT EFFLUENT AT DIFFUSER	CLINCH RIVER BELOW CRBRP	TENNESSEE RIVER ABOVE KINGSTON	TENNESSEE RIVER BELOW KINGSTON
Pr-144	1.73E-15	8.89E-18	2.19E-18	3.18E-19
Nd-147	3.86E-16	2.22E-18	4.87E-19	5.89E-20
Pm-147	4.36E-16	2.22E-18	5.50E-19	8.04E-20
Eu-155	8.86E-17	4.54E-19	1.12E-19	1.63E-20
Ta-182	5.43E-13	2.80E-15	6.85E-16	9.84E-17
Pu-238	1.30E-16	6.60E-19	1.63E-19	2.39E-20
Pu-239	3.45E-17	1.76E-19	4.35E-20	0.0
Pu-240	5.08E-17	2.59E-19	6.41E-20	0.0
Pu-241	3.71E-15	1.89E-17	4.68E-18	6.84E-19
Pu-242	9.81E-18	5.00E-20	1.24E-20	0.0
Np-238	0.0	0.0	0.0	0.0
Np-239	4.08E-18	3.48E-20	0.0	0.0
Am-241	1.34E-17	6.81E-20	1.69E-20	0.0
Am-242	1.40E-19	0.0	0.0	0.0
Am-243	5.32E-19	0.0	0.0	0.0
Cm-242	9.40E-18	4.82E-20	1.18E-20	0.0
Cm-243	1.31E-19	0.0	0.0	0.0
Cm-244	2.73E-18	1.39E-20	0.0	0.0
Nb-95m	5.08E-15	0.0	6.41E-18	1.84E-18
Tc-99m	1.41E-16	0.0	1.78E-19	1.23E-20
Rh-103m	1.09E-12	0.0	1.37E-15	1.91E-16
I-129	0.0	0.0	0.0	0.0
Ba-137m	7.37E-13	0.0	9.33E-16	1.36E-16
Sm-147	0.0	0.0	0.0	0.0

An entry of 0.0 indicates a concentration of less than 1×10^{-20} μCi/ml.

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TABLE 5.2-5

POTABLE WATER SUPPLIES DOWNSTREAM FROM THE CLINCH RIVER BREEDER REACTOR PLANT PROJECT (ref 17)

Public Water Supply	Location (TRM)	2020 Population Served
CRBRP Discharge	585.7 (a)	
Bear Creek Water Supply	584.2 (b)	5,600
Kingston Steam Plant	572.3 (c)	790
Kingston	568.2	7,900
Harriman	561.2 (c)	6,800
Camp John Knox	553.0	200
Watts Bar Resort	529.9	300
Dayton	503.8	12,300
ICI America, Inc (VAAP)	473.0	2,000
C.F. Industries	473.0	900
E.I. DuPont, Co.	470.5	4,000
Chattanooga	465.3	610,700
South Pittsburg	418.0	4,400
Bridge Port	413.6	3,400
Widows Creek Steam Plant	407.6	500
Mead Paper Board	405.2	500
Scottsboro	385.8	38,700
Sand Mountain Water Authority	382.1	18,600
Christian Youth Camp	368.2	125
Guntersville	358.0	14,900
N.E. Morgan Co. Water & Fire	334.5	4,500
Huntsville	334.2	168,600
Redstone Arsenal	330.2	10,000
Decatur	306.0	84,600
U.S. Plywood-Champion Paper	283.0	500
Wheeler Dam	274.9	50
Muscle Shoals	259.6	14,100
TVA-NFDC	259.5	2,700
Sheffield	254.3	21,100
Colbert Steam Plant	245.0	520
Cherokee	239.3	3,900
U.S. Steel AGRI-Chemicals, Inc.	238.7	350
Hardin County Water District	206.8	2,400
Tri-County Utility District	193.5	1,900
Clifton	158.0	1,100
Foote Mineral Company	101.9	170
New Johnsonville	100.5	6,100
Camden	100.4	13,300
Johnsonville Steam Plant	100.0	375
E.I. DuPont Co.	98.5	900

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TABLE 5.2-5 (continued)

POTABLE WATER SUPPLIES DOWNSTREAM FROM THE CLINCH RIVER BREEDER REACTOR PLANT PROJECT (ref 17)

Public Water Supply	Location (TRM)	2020 Population Served
Consolidated Aluminum Corp.	95.5	700
Inland Container Corporation	94.5	250
Bass Bay Resort	79.5	120
Johnathan Creek Water District	39.3	4,300
North Marshall Water District	28.5	9,100
Grand Rivers	23.6	650
B.F. Goodrich Chemical Co.	17.8	600
AIRCO Carbide	17.4	106
AIRCO Alloys	16.8	592
Air Products and Chemicals	16.7	510
Paducah	0.1	69,800

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(a) Clinch River Mile (CRM) 16.0
(b) CRM 14.5
(c) Water intake on the Emory River, a tributary of the Clinch River. Included to account for the possibility of water from the Clinch River backing up the Emory River.

TABLE 5.2-6

CRBRP - NORMALIZED CONCENTRATIONS AND DEPOSITION RATES AT SECTOR ANNULI+

AVERAGES ANNUAL CHI-OVER-Q VALUES (s/m^3)

SECTOR*	1305.	2414.	4023.	5633.	7242.	12070.	24140.	40234.	56327.	72420.
N	2.03E-6	8.10E-7	4.07E-7	2.60E-7	1.87E-7	9.51E-8	3.87E-8	2.01E-8	1.31E-8	9.53E-9
NNE	1.61E-6	6.52E-7	3.29E-7	2.10E-7	1.51E-7	7.73E-8	3.15E-8	1.64E-8	1.07E-8	7.83E-9
NE	2.76E-6	1.09E-6	5.36E-7	3.37E-7	2.40E-7	1.20E-7	4.80E-8	2.46E-8	1.60E-8	1.16E-9
ENE	4.09E-6	1.64E-6	8.10E-7	5.13E-7	3.66E-7	1.85E-7	7.43E-8	3.83E-8	2.49E-8	1.81E-8
E	4.76E-6	1.93E-6	9.71E-7	6.20E-7	4.46E-7	2.27E-7	9.27E-8	4.82E-8	3.15E-8	2.30E-8
ESE	4.89E-6	1.99E-6	9.93E-7	6.31E-7	4.52E-7	2.29E-7	9.28E-8	4.81E-8	3.14E-8	2.29E-8
SE	3.40E-6	1.40E-6	6.93E-7	4.40E-7	3.14E-7	1.59E-7	6.43E-8	3.33E-8	2.17E-8	1.58E-8
SSE	2.80E-6	1.14E-6	5.69E-7	3.62E-7	2.59E-7	1.31E-7	5.33E-8	2.76E-8	1.80E-8	1.31E-8
S	2.39E-6	9.79E-7	4.81E-7	3.03E-7	2.16E-7	1.08E-7	4.33E-8	2.23E-8	1.45E-8	1.05E-8
SSW	2.39E-6	9.63E-7	4.80E-7	3.05E-7	2.18E-7	1.10E-7	4.47E-8	2.31E-8	1.51E-8	1.10E-8
SW	2.88E-6	1.16E-6	5.79E-7	3.68E-7	2.64E-7	1.34E-7	5.41E-8	2.80E-8	1.83E-8	1.33E-8
WSW	4.19E-6	1.69E-6	8.48E-7	5.40E-7	3.88E-7	1.97E-7	7.99E-8	4.15E-8	2.70E-8	1.97E-8
W	6.52E-6	2.61E-6	1.34E-6	8.66E-7	6.27E-7	3.24E-7	1.34E-7	7.01E-8	4.60E-8	3.37E-8
WNW	4.62E-6	1.87E-6	9.62E-7	6.23E-7	4.51E-7	2.34E-7	9.67E-8	5.08E-8	3.34E-8	2.44E-8
NW	8.66E-6	3.50E-6	1.82E-6	1.18E-6	8.60E-7	4.48E-7	1.87E-7	9.83E-8	6.48E-8	4.75E-8
NNW	6.69E-6	2.69E-6	1.38E-6	8.93E-7	6.46E-7	3.34E-7	1.38E-7	7.22E-8	4.74E-8	3.47E-8

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AVERAGE ANNUAL D-OVER-Q VALUES ($1/m^2$)

SECTOR*	1305.	2414.	4023.	5633.	7242.	12070.	24140.	40234.	56327.	72420.
N	2.78E-9	1.00E-9	4.16E-10	2.30E-10	1.46E-10	6.02E-11	1.84E-11	7.51E-12	4.07E-12	2.47E-12
NNE	2.29E-9	8.26E-10	3.42E-10	1.89E-10	1.20E-10	4.95E-11	1.52E-11	6.18E-12	3.35E-12	2.03E-12
NE	6.58E-9	2.37E-9	9.84E-10	5.43E-10	3.46E-10	1.42E-10	4.35E-11	1.78E-11	9.62E-12	5.84E-12
ENE	8.44E-9	3.04E-9	1.26E-9	6.97E-10	4.43E-10	1.83E-10	5.59E-11	2.28E-11	1.23E-11	7.50E-12
E	6.83E-9	2.46E-9	1.02E-9	5.64E-10	3.59E-10	1.48E-10	4.52E-11	1.84E-11	9.99E-12	6.07E-12
ESE	8.90E-9	3.21E-9	1.33E-9	7.35E-10	4.68E-10	1.93E-10	5.89E-11	2.40E-11	1.30E-11	7.91E-12
SE	5.41E-9	1.95E-9	8.10E-10	4.47E-10	2.84E-10	1.17E-10	3.58E-11	1.46E-11	7.92E-12	4.81E-12
SSE	3.44E-9	1.24E-9	5.15E-10	2.85E-10	1.81E-10	7.45E-11	2.28E-11	9.30E-12	5.04E-12	3.06E-12
S	2.91E-9	1.05E-9	4.35E-10	2.40E-10	1.53E-10	6.29E-11	1.92E-11	7.84E-12	4.25E-12	2.58E-12
SSW	3.15E-9	1.14E-9	4.72E-10	2.60E-10	1.66E-10	6.82E-11	2.09E-11	8.51E-12	4.61E-12	2.80E-12
SW	4.51E-9	1.63E-9	6.74E-10	3.72E-10	2.37E-10	9.75E-11	2.98E-11	1.22E-11	6.59E-12	4.00E-12
WSW	6.19E-9	2.23E-9	9.26E-10	5.11E-10	3.25E-10	1.34E-10	4.10E-11	1.67E-11	9.06E-12	5.50E-12
W	6.36E-9	2.30E-9	9.52E-10	5.26E-10	3.34E-10	1.38E-10	4.21E-11	1.72E-11	9.31E-12	5.65E-12
WNW	3.85E-9	1.39E-9	5.76E-10	3.18E-10	2.02E-10	8.32E-11	2.55E-11	1.04E-11	5.63E-12	3.42E-12
NW	6.12E-9	2.21E-9	9.15E-10	5.05E-10	3.21E-10	1.32E-10	4.05E-11	1.65E-11	8.95E-12	5.43E-12
NNW	7.14E-9	2.58E-9	1.07E-9	5.90E-10	3.75E-10	1.54E-10	4.73E-11	1.93E-11	1.04E-11	6.34E-12

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* Distance in meters from the center of the plant site to the center of the sector annulus

\+ Normalized air concentrations and deposition rates were generated using a constant wind direction model and the joint frequency distributions of meteorological data given in Section 2.6.2.2 (Tables 2.6-5 through 2.6-11)

TABLE 5.2-7

CONCENTRATION FACTORS FOR AQUATIC ORGANISMS

NUCLIDE	RADIOLOGIC HALF-LIFE (DAYS)	RADIONUCLIDE CONCENTRATION FACTORS		
		FISH	BIOTA	PLANT
H-3	4.48E3	1.00	1.00	1.00
C-14	2.09E6	4.55E3	9.09E3	4.55E3
Na-22	9.50E2	1.00E2	2.00E2	5.00E2
Na-24	6.33E-1	1.00E2	2.00E2	5.00E2
P-32	1.43E1	1.00E5	2.00E4	5.00E5
K-40	4.60E11	2.50E3	8.33E2	6.70E2
Cr-51	2.78E1	2.00E2	2.00E3	4.00E3
Mn-54	3.03E2	4.00E2	1.40E5	3.50E4
Mn-56	1.07E-1	4.00E2	1.40E5	3.50E4
Fe-55	9.50E2	1.00E2	3.20E3	1.00E3
Fe-59	4.56E1	1.00E2	3.20E3	1.00E3
Co-57	2.71E2	3.65E1	1.93E2	6.20E3
Co-58	7.13E1	2.08E1	1.75E2	6.20E3
Co-60	1.92E3	4.75E1	1.99E2	6.20E3
Ni-65	1.07E-1	1.00E2	1.00E2	5.00E1
Cu-64	5.31E-1	5.00E1	4.00E2	2.00E3
Zn-65	2.45E2	1.42E3	9.61E3	2.00E4
Zn-69m	5.75E-1	1.14E1	5.44E2	2.00E4
Zn-69	3.96E-2	7.92E-1	3.94E1	2.00E4
Br-82	1.48	4.20E2	3.33E2	5.00E1
Br-83	1.00E-1	4.20E2	3.33E2	5.00E1
Br-84	2.21E-2	4.20E2	3.33E2	5.00E1
Br-85	2.08E-3	4.20E2	3.33E2	5.00E1
Kr-83m	7.75E-2	1.00	1.00	1.00
Kr-85m	1.83E-1	1.00	1.00	1.00
Kr-85	3.93E3	1.00	1.00	1.00
Rb-86	1.87E1	2.00E3	1.00E3	1.00E3
Rb-88	1.24E-2	2.00E3	1.00E3	1.00E3
Rb-89	1.07E-2	2.00E3	1.00E3	1.00E3
Sr-89	5.27E1	1.04E1	3.99E3	3.00E3
Sr-90	1.01E4	2.97E1	4.00E3	3.00E3
Sr-91	4.03E-1	1.20E-1	3.20E3	3.00E3
Sr-92	1.13E-1	3.39E-2	2.12E3	3.00E3
Sr-93	5.56E-3	1.67E-3	2.11E2	3.00E3
Y-90	2.67	2.50E1	1.00E3	5.00E3
Y-91m	3.47E-2	2.50E1	1.00E3	5.00E3
Y-91	5.88E1	2.50E1	1.00E3	5.00E3
Y-92	1.47E-1	2.50E1	1.00E3	5.00E3
Y-93	4.29E-1	2.50E1	1.00E3	5.00E3

TABLE 5.2-7 (Continued)

CONCENTRATION FACTORS FOR AQUATIC ORGANISMS

NUCLIDE	RADIOLOGIC HALF-LIFE (DAYS)	RADIONUCLIDE CONCENTRATION FACTORS		
		FISH	BIOTA	PLANT
Zr-95	6.55E1	3.33	6.70	1.00E3
Zr-97	7.08E-1	3.33	6.70	1.00E3
Nb-95m	3.75	3.00E4	1.00E2	8.00E2
Nb-95	3.50E1	3.00E4	1.00E2	8.00E2
Nb-97m	6.25E-4	3.00E4	1.00E2	8.00E2
Nb-97	5.00E-2	3.00E4	1.00E2	8.00E2
Mo-99	2.78	1.00E1	1.00E1	1.00E3
Tc-99m	2.52E-1	1.50E1	5.00	4.00E1
Tc-99	7.74E7	1.50E1	5.00	4.00E1
Tc-101	9.93E-3	1.50E1	5.00	4.00E1
Ru-103	3.96E1	1.00E1	3.00E2	2.00E3
Ru-106	3.68E2	1.00E1	3.00E2	2.00E3
Rh-103m	3.96E-2	1.00E1	3.00E2	2.00E2
Rh-105	1.48	1.00E1	3.00E2	2.00E2
Rh-106	3.46E-4	1.00E1	3.00E2	2.00E2
Ag-111	7.48	2.00	7.69E2	2.00E2
Ag-110m	2.53E2	2.00	7.69E2	2.00E2
Sb-124	6.02E1	1.00	1.00E1	1.50E3
Sb-125	9.96E2	1.00	1.00E1	1.50E3
Sb-127	3.80	1.00	1.00E1	1.50E3
Te-125m	5.80E1	4.00E2	1.00E3	1.00E3
Te-127m	1.09E2	4.00E2	1.00E3	1.00E3
Te-127	3.92E-1	4.00E2	1.00E3	1.00E3
Te-129m	3.41E1	4.00E2	1.00E3	1.00E3
Te-129	4.77E-2	4.00E2	1.00E3	1.00E3
Te-131m	1.25	4.00E2	1.00E3	1.00E3
Te-131	1.72E-2	4.00E2	1.00E3	1.00E3
Te-132	3.24	4.00E2	1.00E3	1.00E3
Te-134	2.92E-2	4.00E2	1.00E3	1.00E3
I-129	6.21E9	5.00E1	1.00E3	2.00E2
I-130	5.17E-1	1.70E1	1.00E3	2.00E2
I-131	8.05	4.45E1	1.00E3	2.00E2
I-132	9.42E-2	4.30	1.00E3	2.00E2
I-133	8.46E-1	2.29E1	1.00E3	2.00E2
I-134	3.61E-2	1.74	1.00E3	2.00E2
I-135	2.78E-1	1.09E1	1.00E3	2.00E2
Xe-133m	2.26	1.00	1.00	1.00
Xe-133	5.27	1.00	1.00	1.00
Xe-135m	1.08E-2	1.00	1.00	1.00
Xe-135	3.83E-1	1.00	1.00	1.00

TABLE 5.2-7 (Continued)

CONCENTRATION FACTORS FOR AQUATIC ORGANISMS

NUCLIDE	RADIOLOGIC HALF-LIFE (DAYS)	RADIONUCLIDE CONCENTRATION FACTORS		
		FISH	BIOTA	PLANT
Cs-134	7.47E2	2.00E3	9.87E3	2.50E4
Cs-135	1.10E9	2.00E3	1.00E4	2.50E4
Cs-136	1.37E1	1.86E3	5.78E3	2.50E4
Cs-137	1.10E4	2.00E3	9.99E3	2.50E4
Cs-138	2.24E-2	4.38E1	2.23E1	2.50E4
Ba-137m	1.77E-3	4.00	2.00E2	5.00E2
Ba-139	5.76E-2	4.00	2.00E2	5.00E2
Ba-140	1.28E1	4.00	2.00E2	5.00E2
La-140	1.68	2.50E1	1.00E3	5.00E3
La-141	1.63E-1	2.50E1	1.00E3	5.00E3
Ce-141	3.25E1	2.50E1	1.00E3	4.00E3
Ce-143	1.38	2.50E1	1.00E3	4.00E3
Ce-144	2.84E2	2.50E1	1.00E3	4.00E3
Pr-143	1.36E1	2.50E1	1.00E3	5.00E3
Pr-144	1.20E-2	2.50E1	1.00E3	5.00E3
Nd-147	1.11E1	2.50E1	1.00E3	5.00E3
Pm-147	9.57E2	2.50E1	1.00E3	5.00E3
Pm-149	2.21	2.50E1	1.00E3	5.00E3
Pm-151	1.16	2.50E1	1.00E3	5.00E3
Sm-147	3.90E13	2.50E1	1.00E3	5.00E3
Sm-151	3.18E4	2.50E1	1.00E3	5.00E3
Sm-153	1.95	2.50E1	1.00E3	5.00E3
Sm-156	3.92E-1	2.50E1	1.00E3	5.00E3
Eu-155	6.61E2	2.50E1	1.00E3	5.00E3
Eu-156	1.54E1	2.50E1	1.00E3	5.00E3
Ta-182	1.15E2	3.00E4	6.67E2	8.00E2
W-187	9.96E-1	1.20E3	1.00E1	1.20E3
Pb-210	8.15E3	3.00E2	1.00E2	2.00E2
Pb-212	4.43E-1	3.00E2	1.00E2	2.00E2
Pb-214	1.86E-2	3.00E2	1.00E2	2.00E2
Bi-212	4.21E-2	1.50E1	1.00E5	1.00E5
Bi-214	1.38E-2	1.50E1	1.00E5	1.00E5
Po-212	3.50E-12	5.00E1	2.00E4	2.00E3
Po-214	1.90E-9	5.00E1	2.00E4	2.00E3
Po-216	1.74E-6	5.00E1	2.00E4	2.00E3
Po-218	2.12E-3	5.00E1	2.00E4	2.00E3
Ra-224	3.64	5.00E1	2.50E2	2.50E3
Ra-226	5.85E5	5.00E1	2.50E2	2.50E3
Ra-228	2.10E3	5.00E1	2.50E2	2.50E3
Ac-228	2.56E-1	3.00E1	5.00E2	1.50E3

TABLE 5.2-7 (Continued)

CONCENTRATION FACTORS FOR AQUATIC ORGANISMS

NUCLIDE	RADIOLOGIC HALF-LIFE (DAYS)	RADIONUCLIDE CONCENTRATION FACTORS		
		FISH	BIOTA	PLANT
Th-228	6.99E2	3.00E1	5.00E2	1.50E3
Th-230	2.81E7	3.00E1	5.00E2	1.50E3
Th-232	5.20E12	3.00E1	5.00E2	1.50E3
Th-234	2.41E1	3.00E1	5.00E2	1.50E3
U-234	8.91E7	2.00	6.00E1	5.00E-1
U-238	1.60E12	2.00	6.00E1	5.00E-1
Np-238	2.12	1.00E1	4.00E2	3.00E2
Np-239	2.35	1.00E1	4.00E2	3.00E2
Pu-238	3.21E4	3.50	1.00E2	3.50E2
Pu-239	8.91E6	3.50	1.00E2	3.50E2
Pu-240	2.40E6	3.50	1.00E2	3.50E2
Pu-241	5.48E3	3.50	1.00E2	3.50E2
Pu-242	1.41E8	3.50	1.00E2	3.50E2
Am-241	1.58E5	2.50E1	1.00E3	5.00E3
Am-242	6.68E-1	2.50E1	1.00E3	5.00E3
Am-243	2.70E6	2.50E1	1.00E3	5.00E3
Cm-242	1.63E2	2.50E1	1.00E3	5.00E3
Cm-243	1.02E4	2.50E1	1.00E3	5.00E3
Cm-244	6.54E3	2.50E1	1.00E3	5.00E3

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TABLE 5.2-8

ANNUAL DOSES TO AQUATIC ORGANISMS LIVING IN THE CLINCH RIVER NEAR THE CRBRP

Organism	Dose Estimates: Internal (mrad/yr) 3-cm	30-cm	External (mrad/yr)	
Plants	2.6E-2*	1.1E-1	3.4E-5	
Invertebrates	1.7E-2	9.6E-2	3.4E-5	suspended
			3.0E-1	benthic
Fish	1.3E-2	3.3E-2	3.4E-5	

*2.6E-2 = 2.6×10^{-2}

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TABLE 5.2-9

ANNUAL DOSES TO TERRESTRIAL ORGANISMS NEAR THE CRBRP SITE

Organism	Dose Estimates Internal (mrad/yr)	External (mrad/yr)	Total (mrad/yr)
Terrestrial Mammal			
Gaseous Pathway	0.006	0.069	0.075
Liquid Pathway	0.027	<0.001	0.027
Total	0.033	0.070	0.10
Plants		1.4	1.4

TABLE 5.2-10

ANNUAL DOSE TO MAN FROM LIQUID EFFLUENT RELEASES

	Bone	GI Tract	Thyroid	Total Body	Skin
I. Ingestion					
a. Water					
Individual at Nearest public supply	1.3E-6	2.6E-6	4.1E-6	1.3E-6	1.3E-6 mrem
Population	5.5E-5	1.0E-4	9.9E-5	5.4E-5	5.4E-5 man-rem
b. Fish					
Maximum Individual	1.4E-5	1.6E-4	1.8E-5	1.3E-5	1.3E-5 mrem
Population	2.6E-4	2.6E-3	2.6E-4	2.4E-4	2.4E-4 man-rem
c. Duck					
Maximum Individual	1.7E-4	3.6E-5	1.1E-4	1.1E-4	1.1E-4 mrem/duck
II. External					
a. Immersion					
Maximum Individual				6.2E-8	4.8E-7 mrem
Population				5.7E-8	3.4E-7 man-rem
b. Above water					
Maximum Individual				4.5E-8	4.5E-7 mrem
Population				5.4E-8	4.2E-7 man-rem
c. Shoreline					
Maximum Individual				3.5E-5	4.1E-5 mrem
Population				6.2E-5	7.3E-5 man-rem
III. Total*					
a. Maximum Individual	2.2E-4	2.3E-4	1.7E-4	1.6E-4	1.7E-4 mrem
b. Population	3.8E-4	2.8E-3	4.3E-4	3.6E-4	3.7E-4 man-rem

* total organ doses include total body component due to external radiation

TABLE 5.2-11

2020 CLINCH AND TENNESSEE RIVER FISH HARVEST DATA (14,15)

Reach (TRM)[1]	Commercial Harvest (lbs/acre)	Sport Harvest (lbs/acre)	Area (acres)
17.4-0.0 (CRM)	23.8	64.9	2,100
568-528	23.8	64.9	26,100
528-471	23.8	64.9	34,900
471-425	23.8	64.9	10,900
425-349	23.8	64.9	67,800
349-275	23.8	64.9	67,000
275-259	23.8	64.9	16,000
259-207	23.8	64.9	43,600
207-165	23.8	64.9	16,000
165-121	23.8	64.9	16,000
121-76	23.8	64.9	48,100
76-22	23.8	64.9	80,200

1. TRM = Tennessee River Mile.   CRM = Clinch River Mile

TABLE 5.2-12

USE OF CLINCH AND TENNESSEE RIVER SYSTEM IN 2020 FOR RECREATIONAL PURPOSES (REF. 16)

Reach (TRM)	Above Water* Visits	In-Water* Visits	Shoreline* Visits
17.4-0.0 (CRM)	2.0E5**	2.0E5	2.0E5
568-528	2.0E6	2.0E6	2.0E6
528-471	3.4E6	6.5E5	3.1E6
471-425	1.2E5	2.6E4	1.1E5
425-349	6.4E6	1.2E6	5.6E6
349-275	3.6E6	6.9E5	3.2E6
275-259	1.5E6	2.9E5	1.4E6
259-207	1.5E6	3.0E5	1.8E6
207-165	2.2E5	1.7E4	1.9E6
165-121	4.7E5	3.8E4	4.3E6
121-76	8.8E5	5.6E5	1.0E7
76-22	8.7E6	6.3E6	1.2E8

* These are the number of visits assuming five hours per visit. The actual estimates have different times per visit for each activity and reach of river.

** 2.0E5 = 2.0×10^5

TABLE 5.2-13

CRBRP - INDIVIDUAL DOSES FROM GASEOUS EFFLUENTS

Noble Gas Exposures 15

Pathway	Point	Dose
Gamma air dose	Max. Exp.[1]	0.076 mrad/yr
Beta air dose	Max. Exp.[1]	1.4 mrad/yr
Total Body	Max. Exp.[1]	0.069 mrem/yr
Skin	Max. Exp.[1]	0.55 mrem/yr

Particulate Exposures - Total Body 15

Tritium	Max. Exp.[1]	5.3E-4 mrem/yr

Breakdown of Particulate Exposures - Total Body (mrem/yr) 15

	Child	Adult	
Vegetable Ingestion	2.6E-4	1.9E-4	
Beef Ingestion	2.7E-5	4.8E-5	
Inhalation	8.3E-5	1.6E-4	
Ground Contamination	1.6E-5	1.6E-5	
Milk Ingestion	1.4E-4	8.4E-5	
Total	5.3E-4	5.0E-4	13

1. Maximum exposure point is at 820 meters in the NW sector.

TABLE 5.2-14

CRBRP - POPULATION DOSES FROM GASEOUS EFFLUENTS

	Thyroid					Total Body				
	Infant	Child	Teen	Adult	Totals	Infant	Child	Teen	Adult	Totals
Submersion	9.94E-4	6.19E-3	3.94E-3	1.83E-2	2.94E-2	9.94E-4	6.19E-3	3.94E-3	1.83E-2	2.94E-2
Ground	3.76E-7	2.34E-6	1.49E-6	6.91E-6	1.11E-5	3.76E-7	2.34E-6	1.49E-6	6.91E-6	1.11E-5
Inhalation	3.00E-6	4.86E-5	2.35E-5	1.39E-4	2.15E-4	3.00E-6	4.86E-5	2.35E-5	1.68E-4	2.43E-4
Cow Milk	9.88E-6	4.07E-5	1.59E-5	5.13E-5	1.18E-4	9.88E-6	4.07E-5	1.59E-5	5.13E-5	1.18E-4
Beef Ingestion	0.0	1.43E-5	7.57E-6	7.14E-5	9.32E-5	0.0	1.43E-5	7.57E-6	7.14E-5	9.32E-5
Veg Ingestion	0.0	9.57E-6	5.14E-6	4.58E-5	6.05E-5	0.0	9.57E-6	5.14E-6	4.58E-5	6.05E-5
Total Man-Rem	1.01E-3	6.31E-3	4.00E-3	1.86E-2	2.99E-2	1.01E-3	6.31E-3	4.00E-3	1.86E-2	2.99E-2

TABLE 5.2-15

SUMMARY OF ANNUAL RADIATION DOSES TO POPULATION FROM CRBRP

	Thyroid (man-rem/yr)	Total Body (man-rem/yr)	
I. Internal			
Ingestion (water)	9.9E-5	5.4E-5	
(fish)	2.6E-4	2.4E-4	
(milk)	1.2E-4	1.2E-4	
(meat)	9.3E-5	9.3E-5	
(vegetables)	6.1E-5	6.1E-5	
Inhalation	2.1E-4	2.4E-4	13
II. External			
In-water sports	5.7E-8	5.7E-8	
Above-water sports	5.4E-8	5.4E-8	
Shoreline activities	6.2E-5	6.2E-5	
Submersion in air	2.9E-2	2.9E-2	
Ground contamination	1.1E-5	1.1E-5	15
III. Transportation of radioactive material			
Unirradiated fuel	0.45	0.45	
Irradiated fuel	0.92	0.92	
Wastes	0.43	0.43	
Total	1.83	1.83	

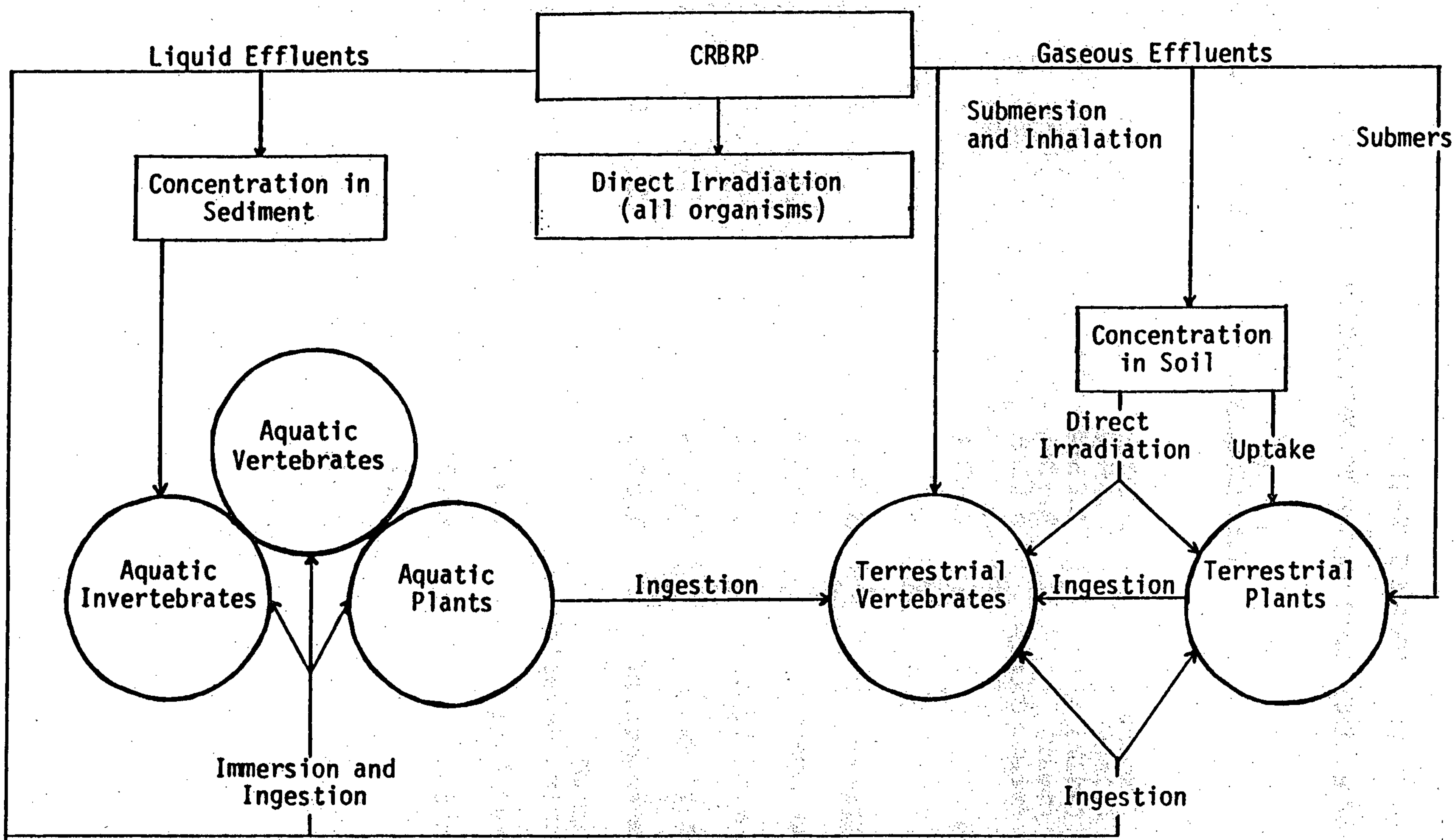

Figure 5.2-1

EXPOSURE PATHWAYS TO ORGANISMS OTHER THAN MAN

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| 13

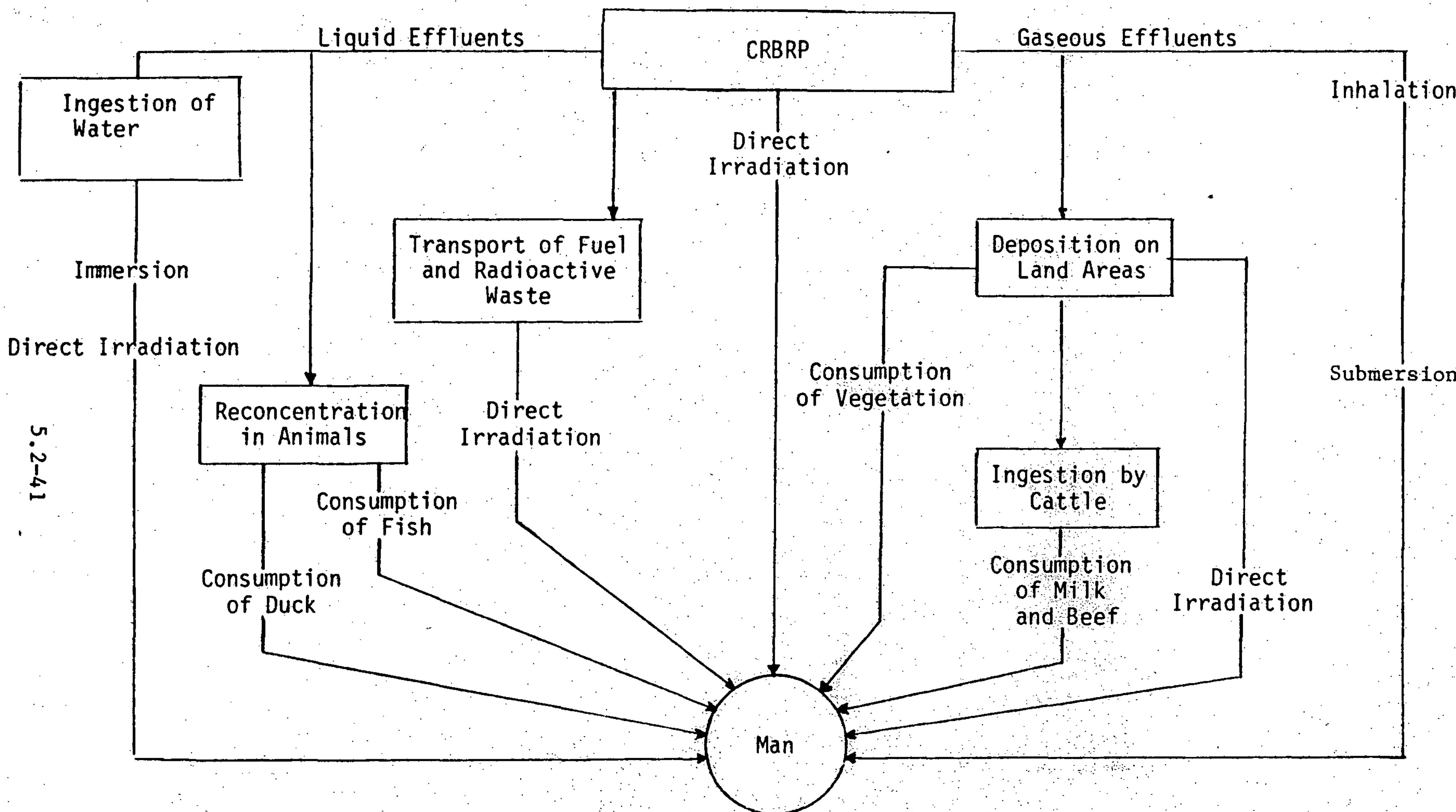

Figure 5.2-2

EXPOSURE PATHWAYS TO MAN

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5.3 RADIOLOGICAL IMPACT ON MAN

This section has been combined with Section 5.2 in Amendment XIII.

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The maximum permissible whole body burden for tritium is 66 times that for Cs-137,[1] and the maximum permissible drinking water concentration is 150 times that of Cs-137.[3] The reduced hazard for tritium results from the fact that its disintegration energy is the lowest of any radionuclide (a maximum energy of 0.018 MeV and an average energy of 0.006 MeV) and decay is solely by beta emission.[4] Because of this, it poses no external radiation hazard to organisms. Secondly it is released to the environment almost exclusively in the form of tritiated water. As such, in an aquatic system, the dilution by normal water molecules is enormous, producing an exceedingly low specific activity (ratio of radioactive molecules of a compound to total molecules of the compound). 8

More significantly, tritiated water behaves like normal water in any organism. It is quickly and uniformly distributed throughout the body following ingestion.[5] Furthermore, it is rapidly excreted with a biological half-life of only 12 days in man. Some tritium atoms will exchange with stable hydrogen atoms of biochemical compounds in body tissues. Thus, chronic exposure to tritiated water results in a small percentage of organically bound tritium in body tissues.[6] Such organically bound tritium normally is distributed rather evenly in the body, not selectively concentrated in any tissues.[7]

As shown in Table 5.3A-12, Appendix to Sections 5.2 and 5.3, the bioaccumulation factor for tritium for all organisms is one. Therefore, algae, crustacea, mollusks and fish living in the Clinch River will attain body concentrations of tritium no higher than the river water concentration. 8

Undue concern as to genetic effects has been occasioned when it was learned that tritium may be incorporated into DNA molecules in body cells. Several key experiments have been performed to evaluate the relative radiobiological effects of tritium in cells as water and as a portion of DNA (introduced as tritiated thymidine).[8,9] Bond summarizes the results: "All experiments of this type to date, on somatic and genetic effects in mammals, showed approximately the same degree of biological effect whether or not the tritium was incorporated into DNA; i.e., the tritium showed no additional effect by virtue of its having been incorporated into DNA."(5)

5.3.1.2 LIQUID EXPOSURE PATHWAYS

A discussion of the pathways by which radioactivity can be released to the Clinch River can be found in Section 3.5. The pathways whereby the public will be exposed to the low-level radioactivity released to the Clinch River are determined by the various public uses made of the river water. In Section 2.2.3, it was noted that no public water supplies 8
located downstream of the CRBRP Site withdraw surface water from the Clinch River to supplement the groundwater drinking supply. An industrial water supply is taken approximately 1.5 miles downstream from the Site. As discussed in Section 2.5, the area of the Clinch River encompassing the point of the CRBRP liquid discharge acts as a groundwater sink. Therefore, exposure to liquid contaminants through seepage into aquifers used as sources of drinking water is very unlikely.

Recreational uses of the Clinch River include fishing, boating and swimming. Public exposure to radioactivity in the Clinch River during fishing and boating activities would generally be restricted to the extremely small amount of radiation escaping from a small area of the river surface. The closest swimming area is located approximately one mile upstream of the point of liquid effluent discharge. Therefore, under normal circumstances, immersion in effluent water should not be an important exposure pathway. Uptake of radioactivity from a contaminated aquatic environment is possible through increasing trophic levels beginning with phytoplankton (such as algae) which in turn are assimilated by zooplankton, small fish and larger fish.

Since there is no usage of the Clinch River water for irrigation of crops, the only pathway for radiation exposure of the public through the aquatic food chain is the consumption of fish caught by sport fishermen in the general vicinity of the blowdown discharge. No other aquatic biota is considered edible in this area. The Corbicula clam, used for human consumption in some parts of the world, can be found in the Clinch River. However, it is used primarily as bait and is not generally part of the local diet.[10] No quantitative data is currently available on the amount of fish caught from this region by sport fishermen for human consumption.[11] Approximately 100 tons of non-game fish are taken annually from Watts Bar Reservoir by commercial fishermen.[12] However, a breakdown on the utilization of the catch is not available.

Doses are presented for relatively significant liquid exposure pathways 8
that exist. These include external doses received while swimming, boating and fishing and internal doses from ingestion of fish. However, it must be pointed out that these doses are not expected under normal circumstances due to the small radioactive plume associated with the CRBRP liquid discharge design. Concentrations of liquid effluents in the Clinch River beyond 60 feet from the point of discharge in most instances are at near 8
ambient levels. Therefore, drinking water taken from the Clinch River more than 60 feet downstream of the point of discharge will not contain measurable amounts of radioactivity and no significant internal doses can be expected. As discussed in Section 5.3.1.2, the doses calculated for exposure to liquid effluents are not expected under normal conditions. 8

5.3.1.3 DIRECT RADIATION FROM FACILITY

The shielding design criteria for the CRBRP specifies that, during normal operation, the dose rate at the surface of that part of the containment vessel which is above grade will be no more than 0.2 mr/hr. An estimated 90 percent of the containment building that is above grade is shielded from the Site boundary by buildings and is enclosed by the Reactor Confinement Structure consisting of four feet of concrete. 8

Radwaste tanks are housed in buildings protected with concrete walls. In addition, sodium storage tanks, the Radioactive Argon Processing System (RAPS) and the Cell Atmosphere Processing System (CAPS) are located below grade.

As described in Section 3.2, the probability of radioactive sodium leaking from the primary to the intermediate loop of the Heat Transport system is very small. Therefore, it is assumed that the only radioactive contaminant in the stream is tritium, a low energy beta-emitter (0.006 MeV) which presents no direct radiation hazard.

5.3.1.4 TRANSPORTATION OF RADIOACTIVE MATERIALS

5.3.1.4.1 NEW FUEL

Transfer of non-irradiated fuel between fuel-fabrication plants and the CRBRP Site will result in a small external dose to the general population along the routes and to the personnel involved in the shipping process (see Section 3.8 for details
concerning transportation of core fuel). The core fuel will be 6
fabricated at DOE's Secure Automated Facility being built at the 12
DOE Hanford Site in the State of Washington. The blanket fuel will be fabricated at an existing commercial facility.

5.3.1.4.2 IRRADIATED FUEL

Transfer of irradiated fuel from the CRBRP to a fuel reprocessing plant will expose the general public along the route and the shippers to direct radiation. The irradiated fuel
assemblies at the CRBRP will be loaded into shielded casks. 8
These casks are DOT-NRC approved shipping containers for
transportation of spent fuel assemblies (see Section 3.8 for 6

details concerning transportation of irradiated fuel). The spent fuel from the CRBRP will be transported to a yet to be determined facility for interim storage and reprocessing. Since 12
the actual Government facility has not yet been selected, the transportation impacts in Section 3.8 assume a distant facility.

5.3.1.4.3 RADIOACTIVE WASTES

Transportation of the radioactive wastes can also present a radiation hazard to the general public and shippers. Section
3.8 describes the type of radioactive waste package to be 8
shipped off-site for disposal. The CRBRP will use an NRC-licensed burial site for disposal of all packaged radioactive waste. As yet, the location of this site has not been determined.

5.3.2 DOSE RATE ESTIMATES

5.3.2.1 DOSES FROM AIRBORNE EXPOSURES

Doses received from exposure to gaseous effluents from the CRBRP were evaluated using equations 1 through 11 presented in the Appendix to Sections 5.2 and 5.3. Maximum external whole body and skin doses at the site boundary were calculated using the highest annual average χ/Q which occurs at the Site boundary.
Using a method similar to the method used in Section 5.2.2.1 to 8
obtain the maximum χ/Q at the exclusion boundary, the maximum site boundary χ/Q was found to occur in the northwest sector. Site boundary distance occurs in this sector at 2500 feet from

the plant and the annual average value for χ/Q of 5.10×10^{-5} sec/m^3 was obtained by interpolating the data in Table 2.6-39 for this radial distance. Values of 0.023 mrem/yr and 0.073 mrem/yr gamma whole body dose rate and beta plus gamma skin dose rates were obtained at this location assuming no protection from buildings or clothing. 8

As can be seen in Table 5.3A-1 of the Appendix to Sections 5.2 and 5.3, all of the radioisotopes present in the gaseous effluent contribute to an external gamma dose except Argon-39 and tritium which decays by beta emission only. On the basis of the population distribution expected near 8 the end of plant life in 2010, presented in Table 2.2-12, and the annual gamma dose distribution within 50 miles of the Site as determined by the annual average values of χ/Q, presented in Table 2.6-39, the external population dose (whole body) from CRBRP atmospheric releases is estimated to be 0.027 man-rem/yr. It should be noted that the dose to personnel exposed to CRBRP atmospheric releases at the nearby Oak Ridge Gaseous Diffusion Plant and Oak Ridge National Laboratory does not impact the total dose to the population. 8

A comparison of the external dose resulting from the operation of the CRBRP to the dose received from natural radioactivity assists in evaluating the impact of the CRBRP. Near the plant site the average annual dose from naturally occurring external sources of radiation is approximately 100 mrem, as discussed in Section 2.8. Therefore, on the basis of projected population for 2010, the population dose within 50 miles of the CRBRP from naturally occurring radioactivity is estimated to be 98,700 man-rem/yr. The calculated contribution from the CRBRP (which is based on conservative assumptions) is 0.00004 percent of the population dose from naturally occurring radioactivity. 8

Internal doses via the various exposure pathways to gaseous effluents (inhalation and ingestion of milk, vegetables and meat) will be due almost exclusively to the presence of tritium. The noble gases are relatively inert and result in practically no internal exposure. These doses are presented in Table 5.3-1.

The growing season for leafy vegetables in the Eastern Tennessee region is assumed to be 90 days. All other variables used in the calculation of dose from ingestion of leafy vegetables, such as total daily intake and yield per unit area of cultivated land, are provided in Table 5.3A-13 8

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of the appendix to Sections 5.2 and 5.3. Maximum dose to an individual from eating vegetation contaminated with gaseous fallout is 3.5×10^{-2} mrem/yr. 8

Average effective grazing area of beef cattle and dairy cows is assumed to be 45 m^2. Assuming that 100 percent of the tritium ingested is evenly distributed within the meat and the average weight of a steer is 500 kg, the total cumulative fraction of tritium transferred per kg of beef is 1.0/500 kg or 0.002/kg. Although some grains produced outside of the immediate area are used to supplement their diet, dairy cows on the farm nearest the CRBRP Site are allowed to graze outside all year around.(13) Therefore, it was assumed that 100 percent of the annual diet of both cows and cattle comes from the fields in order to obtain maximum dose rates. All other variables, such as total daily intake of beef or milk and elapsed time between butchering and ingestion, are provided in Table 5.3A-13 of the Appendix to Sections 5.2 and 5.3.

Maximum total annual whole body internal dose from exposure to gaseous effluents to the hypothetical individual who eats only leafy vegetables grown in the closest home garden to the Site, eats only the meat from beef cattle grazing in the closest field to the Site, drinks one liter of milk per day taken only from the closest known farm to the Site with dairy cows and lives in the closest house to the Site is 0.56 mrem/yr. 8 The estimated annual internal dose from natural radiation to an individual is 18 mrem/yr.(14) Therefore, the maximum internal dose to an individual from exposure to CRBRP gaseous effluents is approximately 1.3 percent of 8 his internal dose from naturally occurring radiation. External and internal doses resulting from exposure to daughter products of gaseous effluents have been included in the dose evaluations.

Depth of the reservoir from which water is taken for the industrial facility downstream of the plant site was conservatively calculated as 4.8 m based on winter low water pool conditions as given in Section 2.5.1.4. 8 It was assumed that 0.5 days are required for processing the Clinch River water into potable water. Internal whole body dose to persons body dose to persons drinking water at the industrial facility is calculated with the assumption that total daily intake during an eight-hour working day is 1,100 cc.[2] Period of exposure is 260 days per year. A dilution factor for gaseous releases to the river due to flow of fresh water into the reservoir and flow of contaminated water out of the reservoir during typical summer conditions (4,777 cfs) is 0.09. Therefore, maximum whole body internal dose to an individual from ingestion of water is 0.0022 mrem/yr. Based on an average daily worker population of 4,600, the man-rem due to ingestion of drinking water at the ORGDP containing activity from fallout of airborne effluent is calculated to be 0.01 man-rem/yr. 8

5.3.2.2 DOSES FROM EXPOSURE TO LIQUID EFFLUENTS

Doses received from exposure to the liquid effluents released from the CRBRP were calculated using equations 18 to 27 found in the Appendix to Sections 5.2 and 5.3. A dilution factor of 20 was assumed based on the 8 analysis that under typical summer conditions the concentration of radionuclides in the discharge plume are reduced to 5.0 percent and initial 8 levels within less than 60 feet of the discharge point.

Due to lack of definitive data, no credit is taken for removal of activity from the water through adsorption on solids and sedimentation, by deposition in the biomass, or by processing within water treatment systems. Dose rates via the various exposure pathways to liquid effluents are presented in Table 5.3-2.

Evaluation of dose via exposure to shoreline deposits (river sediment) assumes an exposure time to 500 hr/yr. Times of exposure for swimming (immersion) of 100 hrs/yr and above-water activities (boating, fishing and skiing) of 600 hrs/yr were assumed. Time between release of the isotope and exposure is assumed to be 0.5 days. Expected total body gamma 8

and beta skin doses from all isotopes to an individual from the above sources are 7.2×10^{-7} mrem/yr and 8.9×10^{-7} mrem/yr, respectively. These 8
doses are much less than one-millionth of a percent of natural background radiation and are essentially undetectable. A breakdown of the dose contribution from each pathway is presented in Table 5.3-2.

Population doses for exposure from immersion in water and from above-water activities were calculated assuming:

1. 90 persons (as projected in Section 2.2 for the year 2010) were immersed for 100 hrs/yr (see Table 5.3A-13 of the 8
Appendix to Sections 5.2 and 5.3); and
2. 45 persons spent 600 hr/yr in above-water activities (100 hrs/yr boating and 500 hrs/yr fishing).

Total population dose from all aquatic activities is 3.7×10^{-8} man-rem/yr. 8

Doses to humans from ingestion of aquatic foods (50 g of fish/day) were evaluated using the bioaccumulation factors listed in Table 5.3A-12 of 8
the Appendix to Section 5.2 and 5.3 and are tabulated in Table 5.3-2. Most of the whole body internal dose results from ingestion of tritium.

The population dose from ingestion of aquatic foods, based on a daily catch of 23,000 grams, is 3.9×10^{-3} man-rem/yr. It is assumed that 50 percent of the catch is edible and the equivalent of 2,300 persons would be supplied by this harvest based on an average daily consumption of 5 grams/day. 8
An additional pathway to humans is the ingestion of small game such as a raccoon or duck which may have fed on fish from the Clinch River. In view of the low doses resulting from ingestion of aquatic foods, no significant exposure via this pathway can be expected.

Plutonium isotopes are present in low concentrations in the CRBRP liquid 8
effluent described in Section 3.5. Although fairly high concentration factors have been evidenced by lower trophic level species (2,600 for zooplankton and 1,600 for phytoplankton in sea water off the

southern California coast)[15] the lower concentration factors in fish (~4) indicate some possible discrimination takes place at the higher trophic levels. Furthermore, the concentration which does occur in fish occurs principally in nonedible portions such as bone.[16] Thus, it appears that biological concentration does not occur to a very large extent in edible aquatic food products. Furthermore, the fractional uptake by ingestion for humans is extremely low (~0.003%)[2] thus providing an additional safety margin for this pathway.

Total dose to the bone from the plutonium isotopes via ingestion of 50 grams of fish per day is 5.2×10^{-9} mrem/yr. This dose is 0.02 percent of the total dose to the bone (2.9×10^{-5} mrem/yr) resulting from exposure to all radioisotopes in the CRBRP liquid effluent. The estimated total dose to the bone from natural radiation is 87 mrem/yr.[17] Therefore, the dose contributions from plutonium isotopes and from all radioisotopes in the liquid effluent are very much smaller than the dose from natural sources. No detectable health effects can be expected as a result of these low doses.[18,19] Population doses to bone via exposure to plutonium and to all radioactive liquid effluents are estimated to be 1.2×10^{-9} man-rem/yr and 6.7×10^{-6} man-rem/yr, respectively. Assumptions for estimation of the population dose are an average intake of five grams of fish per day and a daily catch of 23,000 grams of which 50 percent is edible.

A potentially important daughter product resulting from decay of the plutonium isotopes present in the liquid effluent is Am-241, which may also contribute to bone dose principally through alpha-emission. An estimate of the build-up concentration of Am-241 as a result of radioactive decay of Pu-241 is presented in Table 5.3-3. As can be seen in Table 5.3-3, secular equilibrium will not be reached until 30 to 80 years after initial release of the parent. Dose conversion factors, mrem/yr per μCi/cc, for exposure via ingestion of water to Am-241 are 5.0×10^{7} for whole body,

6.0×10^8 for bone, 5.0×10^7 for the GI Tract and 3.8×10^8 for the kidney. Dose conversion factors for exposure via ingestion of Am-241 are not significantly higher than those dose conversion factors for the plutonium isotopes presented in Table 5.3A-5 of the Appendix to Sections 5.2 and 5.3. Therefore, doses from exposure to americium are not expected to be significant and will be less than the minimal dose from the plutonium isotopes. 4

5.3.2.3 DOSE FROM EXPOSURE TO DIRECT RADIATION FROM THE FACILITY

Because the containment building is 90 percent shielded by buildings constructed of concrete walls and because the four feet of concrete from the confinement structure has not been accounted for in the analysis, the population dose from direct radiation presented in Table 5.3-4 is highly conservative. The dose is calculated with the assumption that the radiation field is caused by an isotropic point source at the center of containment having an energy of 3.0 MeV. The inverse square law was used to calculate the dose at several points beyond the Site. Build-up and attenuation in air was accounted for in the calculations. Sky-shine was not considered since the closest point to the center of containment is not shielded by additional buildings. 8 8

The calculated dose rate to an individual (0.6 mrem/yr at the Site boundary) is 0.6 percent of the external dose received from natural radiation in the Eastern Tennessee region. 8

5.3.2.4 DOSES VIA EXPOSURE TO RADIOACTIVE MATERIALS IN TRANSIT

5.3.2.4.1 NEW FUEL

Dose estimates have been made based upon transportation of fuel and blanket assemblies to the plant from the Hanford Site. These doses have been calculated based upon NUREG-0170[20]. 12

Assuming an average of 14 shipments of fresh fuel for the core 6 9
and axial blankets per year and 12 shipments of fresh fuel for
the inner and radial blankets per year over a distance of 2500
miles per shipment, annual doses to the general public are
estimated and presented in Table 5.3-5.

5.3.2.4.2 IRRADIATED FUEL

Population doses from transport of irradiated fuel to fuel
reprocessing plants have also been estimated based upon NUREG
0170 with shipment by rail. Assuming 14 shipments per year for 6 9
spent fuel plus axial blanket assemblies and 12 shipments per
year for inner and radial blankets assemblies and a transit 12
distance of 500 miles for each shipment, the population doses
presented in Table 5.3-6 were calculated.

5.3.2.4.3 RADIOACTIVE WASTES

Approximately one-hundred thirty-five (135) 55-gallon drums of 9
solidified liquid wastes will be shipped from the Site to an 4 8
NRC-licensed burial ground each year. An estimated 112 drums of
non-compactible solids and 28 drums of compactible will also be 9
shipped from the Site each year. An estimated four shipments
per year will be made for irradiated control assemblies and
radial shield assemblies. The estimated population doses to the
general population would be 0.165 man-rem/yr, as shown in Table
5.3-6. These estimates assume a shipping distance of 500 miles
per shipment.

5.3.3 SUMMARY OF DOSE RATE ESTIMATES AND EVALUATION OF RADIOLOGICAL IMPACT ON MAN

A summary of expected doses resulting from exposure to the CRBRP is presented in Table 5.3-7. Both individual and population doses are projected.

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These doses are believed to reflect the "as low as reasonably achievable" philosophy applied to light water reactors. The limiting external dose is from exposure to direct radiation from the plant. As discussed in the text, this dose was calculated using very conservative assumptions and will undoubtedly be much lower under normal operating conditions. Total individual dose from all exposure pathways is only 1.0 percent of the total exposure from natural radiation. Therefore, it is concluded that the CRBRP will have no detectable effect upon the general population residing near the plant site. 8

TABLE 5.3-1

MAXIMUM INTERNAL WHOLE BODY DOSE RECEIVED BY AN INDIVIDUAL VIA EXPOSURE TO CRBRP GASEOUS EFFLUENTS

Pathway	Location of Exposure	χ/Q (sec/m^3)	Dose (mrem/yr)
Inhalation	Near side of river 2,500 feet NW of the Plant	5.0×10^{-5}	8.4×10^{-3}
Ingestion of milk	Closest dairy cow, 2 miles, WNW	4.67×10^{-6}	4.4×10^{-1}
Ingestion of leafy vegetables	Closest home garden, 0.6 mile, SSW	9.69×10^{-6}	3.5×10^{-2}
Ingestion of beef	Closest forage area 0.3 mile, S	1.88×10^{-5}	7.4×10^{-2}
Total			5.6×10^{-1}

8

TABLE 5.3-2

DOSE RATES RECEIVED BY AN INDIVIDUAL VIA
EXPOSURE TO CRBRP LIQUID EFFLUENTS

mrem/yr

Pathway

	Contaminated River Sediment	Immersion	Above-Water Activities	Ingestion of Aquatic Food
Total Body Gamma	7.20×10^{-8}	1.62×10^{-7}	4.87×10^{-7}	--
Total Skin	8.48×10^{-8}	2.01×10^{-7}	6.04×10^{-7}	--
Whole Body Internal	--	--	--	1.69×10^{-2}
Bone	--	--	--	2.89×10^{-5}
GI Tract	--	--	--	2.00×10^{-4}
Thyroid (Adult)	--	--	--	6.51×10^{-7}
Kidney	--	--	--	3.41×10^{-5}

8

TABLE 5.3-3

BUILD-UP ACTIVITY OF AM-241 FROM PU-241 RELEASED FROM CRBRP LIQUID RADWASTE SYSTEM*

No. of Years After Pu-241 is Initially Released	Activity Am-241 (μCi/cc)	
1	7.11×10^{-17}	
30	2.11×10^{-15}	
80	5.38×10^{-15}	
200	1.23×10^{-14}	6
1,000	3.66×10^{-14}	

*Initial activity of Pu-241 is 4.76×10^{-14} μCi/cc

TABLE 5.3-4

ESTIMATED RADIATION DOSE TO THE PUBLIC VIA DIRECT RADIATION FROM THE CRBRP

Distance From Plant (miles)	Estimated Dose Rate (mrem/yr)
0.4	6.3×10^{-1}
0.6	9.0×10^{-2}
1.0	2.6×10^{-3}
2.0	7.6×10^{-7}
3.0	2.8×10^{-10}
4.0	1.6×10^{-13}
5.0	6.8×10^{-17}

Population Dose within 5 miles of Site = 0.02 man-rem/year

TABLE 5.3-5

ESTIMATED EXTERNAL TOTAL BODY DOSES TO THE GENERAL PUBLIC FROM SHIPPING UNIRRADIATED MATERIALS TO CRBRP SITE

Material*	Total Miles Per Year	Man-rems Received Per Year General Population
Fresh fuel Radial blanket	30,000	0.007
Fresh fuel Core and axial blanket	35,000	0.762
Total		0.769

12

*These packages meet all DOT limits on external dose rates

TABLE 5.3-6

ESTIMATED EXTERNAL TOTAL BODY DOSES TO THE GENERAL PUBLIC FROM SHIPPING IRRADIATED MATERIALS FROM THE CRBRP SITE

Material	Total Miles Per Year	Man-rems Received Per Year General Population
Spent fuel		
Core and axial blanket	7,000	.105
Radial blanket	6,000	.090
Radwaste	10,000	.165
Total		.360

12

TABLE 5.3-7

SUMMARY OF INDIVIDUAL AND POPULATION DOSES

FROM EXPOSURE TO THE CRBRP

Exposure Pathway	Individual (mrem/y) External Total Body	Individual (mrem/y) Internal Whole Body	Population* (man-rem/yr) External Total Body	Population* (man-rem/yr) Internal Whole Body	
Gaseous Effluents	2.3×10^{-2}	5.6×10^{-1}	2.7×10^{-2}		
Liquid Effluents	7.2×10^{-7}	1.9×10^{-2}	3.7×10^{-8}	3.9×10^{-3}	8
Direct Radiation	6.3×10^{-1}	—	2.0×10^{-2}	—	
Transportation of Fuel and Radwaste	—	—	1.1×10^{0}	—	
Total	6.5×10^{-1}	5.8×10^{-1}	1.1×10^{0}	3.9×10^{-3}	12
Percent of Natural Radiation**	6.5×10^{-1}	3.2×10^{0}	1.1×10^{-3}	2.2×10^{-5}	8

*Population is 987,314 as projected for 2010 in Section 2.2.

**External natural background for Eastern Tennessee is 100 mrem/yr. Internal natural background is 18 mrem/yr.

+This value is very conservatively calculated since it does not include allowance for shielding provided by the four-foot thick concrete confinement structure. 8

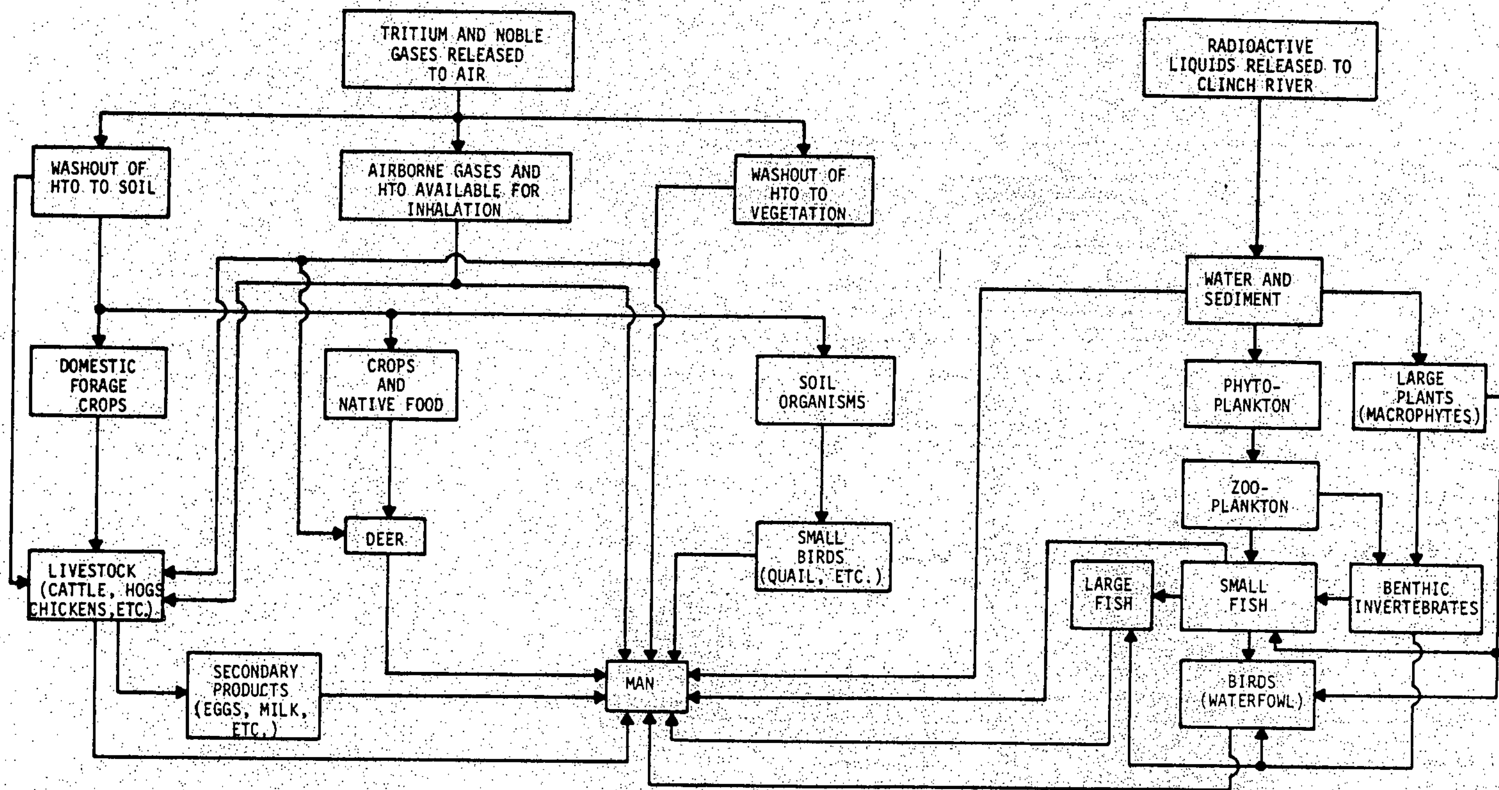

Figure 5.3-1 POTENTIAL RADIATION EXPOSURE PATHWAYS TO MAN FROM THE CRBRP RADWASTE SYSTEMS

5.4 EFFECTS OF CHEMICAL AND BIOCIDE DISCHARGES

The Clinch River will be the source of makeup water for the CRBRP and also will be the recipient of discharges from the plant. River water is presently used for industrial and public water supplies, livestock watering and recreation, including whole body contact as noted in Section 2.2. To properly maintain and preserve all water uses, the CRBRP is designed to prevent the occurrence of significant adverse impact on water quality as a result of chemical and biocide discharges.

As described in Section 3.6, Chemical and Biocide Wastes, all chemical effluent streams will be combined prior to discharge to the river. Discharges will be mixed with the river by the common plant discharge diffuser. The cooling towers are designed to discharge a blowdown that will contain only a 2.5 fold concentration of chemicals already present in the Clinch River. The contribution from other plant waste streams will be a relatively insignificant addition to the blowdown concentration. 16
The effluents' discharge to the river will have a minimum of 14 fold reduction in concentration within the mixing zone. The rapid dilution achieved by the 14 fold reduction in effluent concentration will limit the incremental concentrations to small areas and approach the ambient water quality levels well within the mixing zone.

Only small amounts of trace metals are expected to be in the discharge. For conservatism, no distinction has been made of the elements' state or form. It is considered that all forms are equally available to the biota. In actuality, this is not true as discriminatory limits are determined by the state or form of the element as presented to an organism. A study will be 16
conducted, indicated in EPA's proposed NPDES permit conditions, to both qualitatively and quantitatively establish the form or state of a trace metal such as copper. There are no planned uses

of any materials that would result in normal discharge of "added"
trace metals to the aquatic environment. An acid feed system has
been provided to treat the cooling tower water with sulfuric
acid. Its use would adjust pH for control of scaling and to 16
ensure that the blowdown is in compliance with the NPDES permit
limits. The CRBRP will not use corrosion inhibitors in the
circulating water. The biocide system design provides the
capability of automatically stopping the cooling tower blowdown
flow if the chlorine is excessive. Excessive chlorine 9
concentration is a concentration that exceeds 0.14 mg/L at any 16
time.

Considering the present water uses of the Clinch River, Tables
5.4-1 through 5.4-5 contain lists of the U.S. Environmental
Protection Agency (EPA) regulations for drinking water, the EPA
and State of Tennessee surface water criteria for public water 9
supplies, guides for evaluating the quality of water used by
livestock, trace element tolerances for irrigation water and EPA
and State criteria for freshwater aquatic life. Water quality 9
criteria of the State of Tennessee are listed in the Appendix to
Section 2.5. The permissible concentrations of free chlorine for
new sources are listed in Table 5.4-6.

This section contains an evaluation of the anticipated effects that chemical and biocide discharges may have on the water quality of the Clinch River.

5.4.1 IMPACTS OF CHEMICAL DISCHARGES ON SURFACE WATER

Discharges from the CRBRP will enter the Clinch River through a submerged single port discharge system, as described in Sections 3.4 and 10.3 and illustrated in Figure 3.4-8.

Water quality of the Clinch River at the CRBRP Site is described in detail in Section 2.7.2, Aquatic Ecology. Average and maximum values for some chemical constituents in the Clinch River, as found in the field surveys conducted during 1974-1975 are listed in Table 5.4-7 and, in 6
this section, serve as a reference for any possible impact from the CRBRP.

A discharge plume study, discussed in the Appendices to Section 10.3, has 9
been developed to examine plume formation in the Clinch River resulting from plant discharges of waste heat and chemicals. This study is based on physical and mathematical modeling studies of the thermal component of the cooling tower blowdown flow performed by the University of Iowa, Institute of Hydraulic Research (Iowa Institute). The Iowa Institute's 6
report of findings is presented in Appendix B of Section 10.3. The analysis of chemical discharge effects is developed from the results of the thermal study as described in the <u>Chemical Mixing</u> section of Appendix A to Section 10.3.

Average and maximum values of the important chemical parameters found in the discharge used in the chemical model are listed in Table 5.4-8. Values based on modifications of cooling system design are identical to these except for sodium (which increased 15-20%), sulfate (which increased 5-10%) and 9
total solids (1-5% increase), as seen in Table 3.6-1. These increases have an insignificant effect on impact as discussed below.

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5.4.1.1 MIXING CASES

As the Clinch River is a regulated stream controlled by TVA dams, conditions of flow and pool elevation uncommon to free flowing rivers are experienced. Consideration of these circumstances has resulted in the identification of both typical (average) and extreme (worst case) modeling events for the characterization of chemical discharge effects. These cases are described in detail in Appendix A to Section 10.3 and are summarized below:

1. Typical Winter Case -- average of river and discharge parameter (pool elevation, flow rate, temperature, etc.) values for January, February and March.
2. Typical Summer Case -- average of parameter values for July, August and September.
3. Short Duration No-Flow Extreme Cases -- periods of up to several days during which the portion of the river in the Site vicinity is essntially a quiescent body of water; evaluated for the mixing parameter conditions associated with the thermal hypothetical extreme cases for winter (January) and summer (June); chemicals assumed to be discharged at their maximum concentrations (see Table 10.3A-2). 6
4. Extended No-Flow Extreme Cases -- no flow episodes based on historical occurrences of prolonged zero flow at the Site (see Table 10.3A-3), which are not anticipated to occur in the future; evaluated for the mixing parameter conditions associated with the typical winter and summer cases; chemicals assumed to be discharged at their average concentrations (see Table 3.6-1). 6

Numerical values for the key parameters for each of the mixing cases cited above are given in Table 10.3A-4 for the typical and short duration no flow cases and Table 10.3A-10 for the extended no flow cases. 6

Extreme cases are examined to determine plant environmental performance under conditions more severe than those that would be anticipated during the lifetime of the facility. The worst case analyses provide conservative 6 estimates of adverse environmental impact. Evaluation of the no flow extreme cases documents anticipated environmental performance without recourse to consideration of the innumerable combinations of mixing conditions that may be postulated to occur. (Two such conditions are thermal stratification and flow reversal. The rationale for not including these in the extreme case analysis is presented in <u>Additional Worst Case Considerations</u>, Appendix A to Section 10.3). 6

5.4.1.1.1 COOLING SYSTEM DESIGN EVOLUTION

The Amendment VI revisions to the ER include the identification of 1976 9 design parameters for the CRBRP cooling system which have arisen as a consequence of selection of the turbine-generator. At the time of the environmental evaluation for the typical and short duration no flow mixing cases, a previous set of cooling system design values were in use. Comparisons of system performance for both sets of values are presented in Table 10.3A-1 and Figure 10.3A-2. The differences in performance characteristics are not substantial and indicate, by virtue of lower water discharge temperature and blowdown flow rate, a reduced level of environmental impact for the 1976 cooling system design. The 9 staff of the Iowa Institute has reviewed these design changes and 6 determined that the differences between the 1976 values and those utilized 9 in the physical modeling studies are not significant (see Appendix I to Appendix 10.3B). Accordingly, no attempt has been made to either reperform the modeling investigations or rewrite the environmental analysis presented in this section.

As the reduction in cooling tower blowdown flowrate has altered the relative contributions of the various plant effluent streams to the total discharge, chemical concentrations for certain constituents have changed. The concentrations utilized in the environmental analyses are given in Table 10.3A-2. Reference to Table 3.6-1 provides a means of comparing the two sets of concentration values.

The mathematical modeling effort to describe chemical plume formation during extended no-flow events was undertaken after the revisions to 6
the cooling system were adopted; accordingly, this analysis is based on the new cooling tower performance data presented in Section 3.4.

Further modifications to the cooling system in 1980 resulted in no change of chemical concentrations in the discharge, although total volume in- 9
creased slightly. This increase (< 5%) does not significantly affect the impact analyses presented here.

To facilitate differentiation between values based on the original and revised cooling tower performance data, numbers derived from the original
data (Environmental Analysis values in Table 10.3A-1 and Figure 10.3A-2) 6
are underlined in this section.

Another revision incorporated with Amendment VII is the recessing of the 9
discharge pipe into the river bank (see Figure 3.4-8). This was done to
ensure that the CRBRP single-port submerged discharge structure does not
present a hazard to navigation on the river. The new placement neither
adversely affects the mixing of plant effluents in the river nor produces 7
any significant changes in the thermal and chemical plume formations as
projected by the Iowa Institute of Hydraulics modeling studies (see Ap-
pendix III to Appendix 10.3B). Accordingly, the validity of the discharge
plume analyses, as presented, is not compromised.

5.4.1.2 CHEMICAL PLUMES

5.4.1.2.1 TYPICAL CASES

Chemical constituents of the blowdown for a typical winter condition will
be detectable within the effluent shown in Figure 5.4-1. Surface areas
affected by the chemical plumes and the expected increases in concentra-
tions in these areas of the Clinch River are listed in Table 5.4-9. The
increase in chemical constituents within the plume will be approximately
five percent of the difference between the ambient and the blowdown con-
centrations over a surface area of 0.01 acre. Areas of approximately
0.01 and 0.05 acre, respectively, will experience increases of four and 9
three percent of the difference between the ambient and the blowdown con-
centrations. Maximum chemical increases are within the applicable State
and Federal Criteria; therefore, adverse conditions are not expected to 9
occur in the Clinch River under these mixing conditions.

Chemical constituents of the blowdown for the typical summer case will
be detectable within the effluent shown in Figure 5.4-2. Surface areas
affected by the chemical plumes and the expected increases in concentra-
tions in these areas of the Clinch River are listed in Table 5.4-9. The
increase in chemical constituents of the plume will be approximately
five percent of the difference between the ambient and the initial blow-
down concentration over a surface area of less than 0.01 acres. The
maximum chemical increases within this zone should be small, and within

the applicable State and Federal standards; therefore, adverse conditions are not expected to occur in the Clinch River under these mixing conditions.

Use of the Clinch River from CRM 15 to CRM 17 by striped bass as a summer refuge (Section 2.7.2.5) produces the possibility of extended exposure of these fish to the chemical plume. The plume concentration of discharged chemicals will fall to less than five percent of the difference between ambient and initial blowdown concentration within a surface area of 0.01 acres, and to less than three percent within 0.07 surface acres (Table 5.4-9) very close to the discharge (Figure 5.4-2). Since the striped bass appear to spend most of their time well away from this small area,(A,B,C) the potential for adverse effects of chronic exposure to the CRBRP chemical discharge is negligible. 9

5.4.1.2.2 SHORT DURATION NO FLOW EXTREME CASES

Short periods of zero flow past the Site occur as a result of peaking power operation of the Melton Hill Dam turbines. As a means of assessing the environmental performance of the CRBRP during such no flow events, two extreme cases are postulated for which the combinations of key mixing parameters (pool elevation, discharge flow, etc.) chosen tend to minimize the potential for dilution in the river. The mixing parameters for these two cases are the same as those for the hypothetical winter and summer thermal extreme cases (see Table 10.3A-4).

Surface area affected by the chemical plumes and increases in chemical concentrations for the short duration no flow extreme cases are tabulated in Table 5.4-9 and are graphically depicted in Figures 5.4-3 and 5.4-4. 6
The highest increase in chemical concentrations is associated with the summer extreme case. Under these mixing conditions, an area of 0.02 acre could experience chemical concentration increases of six percent above the difference between the initial blowdown and the levels in ambient river water. Chemical concentrations anticipated within this 0.02 acre area for the various plant effluent constituents under both average and maximum discharge levels are listed in Table 5.4-8. 6

Examination of Table 5.4-8 indicates that even under these
extreme mixing conditions, the water within the six percent 6
isopleth still generally meets the drinking water quality
regulations, the water quality criteria for surface waters in the 9
State of Tenessee and required criteria for freshwater aquatic
life. Effluents from the CRBRP are expected to be consistent
with applicable criteria and standards prior to reaching the 16
nearest potable water intake downstream of the site (the ORGDP
intake at CRM 14.4).

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5.4.1.2.3 EXTENDED NO FLOW CASES

Since the closure of Melton Hill Dam in 1963, there have been three periods of zero release that have lasted for over one week. On each occasion, these were associated with biological control programs on the reservoir. Since such programs are coordinated with other uses of the waterway, extended periods of zero release are not expected in the future. However, the anticipated environmental effects of prolonged no flow episodes are discussed in Appendix A to Section 10.3 and summarized below. 6

During periods of no flow lasting beyond the time interval required to achieve steady-state thermal conditions (5 and 10 days for the winter and summer cases, respectively), sections of the Clinch River extending 1.0 mile in winter and 3.0 miles in summer up and downstream of the discharge point will be subjected to chemical levels above ambient values. For those chemical constituents which are detectable in the CRBRP discharge, the concentrations in the river produced during no flow episodes of up to 29 days duration are given in Table 5.4-10. The values presented in this table are based on the computational approach described under Chemical Plumes in the SUPPLEMENTARY ANALYSIS OF NO FLOW EVENTS section of Appendix 10.3A. Basically, this approach conservatively assumes that all of the discharged chemicals will be contained within that stretch of the river occupied by the thermal plume. Additionally, it is assumed that chemicals will migrate outward from the discharge point to the plume leading edge and then transverse this distance in the opposite direction as part of the return flow of ambient water to the discharge. Consequently, a cycling process is established through which the emerging chemical plume experiences incremental concentration increases once each cycle as progressively higher than ambient chemical levels become the diluting fluid for the discharge jet. For the summer no flow case, the plume half-length is sufficiently large that recirculation of discharged chemicals occurs at the plant intake. This factor is accounted for in the computations. 6

Comparison of the concentrations given in Table 5.4-10 with the U.S.
Environmental Protection Agency's drinking water limits (Table 5.4-1), 9
the permissible surface water criteria for public water supplies
(Table 5.4-2) and the aquatic life water quality criteria (Table 5.4-5) 9
indicates that, for most of the chemical constituents in the plant dis-
charge, these limits will not be exceeded during periods of extended no 6
flow. The only consituents for which compliance is not indicated are
iron and manganese (above permissible surface water criteria) and copper 9
(above aquatic life criterion). For iron and manganese the reason for
non-conformity is not the plant discharge <u>per se</u> but rather the existence
of ambient river levels at or above the cited criteria. Although copper
levels would exceed criteria in these cases, the likelihood of extended 9
no-flow periods is remote.

As the U.S. EPA's and State criteria are complied with for all applicable 9
discharged chemicals, no adverse impact would be anticipated on the
downstream K-25 potable water intake from either the winter or summer
extended no flow plumes.

5.4.2 EFFECTS FROM BIOCIDES ON SURFACE WATERS

Chlorine, in the form of sodium hypochlorite, will be used as the biocide
to control biological growth within the cooling system. An intermittent
mode of application will be employed consistent with the requirements of
40 CFR 423 which limit chlorine discharges to two hours per day, as noted
in Table 5.4-6. The biocide system design provides the capability of
automatically stopping the cooling tower blowdown flow if the chlorine
concentration is excessive. Excessive chlorine concentration is a con-
centration that exceeds .14 mg/l at any time. 9 16

Once discharged to the river, residual chlorine will be diluted by ambient river water in accordance with the information presented in Appendix A to Section 10.3. Further dissipation of chlorine will result from oxidation and complexation. However, as a conservative assumption, no credit is taken from either of these two processes in the calculations of plume concentrations presented below.

Based on an ambient river chlorine concentration of zero (from Table 5.4-7), the resulting maximum residual chlorine concentrations produced in the river for both the typical winter and summer mixing cases will be 0.01 mg/l for the highest concentration isopleth identified in Table 5.4-9. This chlorine level will be associated with river surface areas of approximately 0.01 acre for each case. During short duration no flow conditions, the maximum chlorine level within the highest concentration isopleth will be 0.03 mg/l for the summer case. The surface area of the river affected at this concentration is 0.02 acre. 6

The values cited above for the typical and short duration no flow mixing cases are termed maximum concentrations because residual chlorine will not be discharged on a continuous basis. While these values will be approached during the two hour period of release, chlorine concentrations in the chemical plumes identified in Figures 5.4-1 through 5.4-4 will begin to dissipate once its discharge is terminated. After several hours, it may be anticipated that the chlorine residual within the plumes will be completely dissipated. 6

During an extended period of zero river flow past the Site, the concentrations of chlorine in the winter and summer plumes are as given in Table 5.4-10. It must be noted, however, that these values are based on the assumptions of continuous discharge and no dissipation in the plume. Consequently, the actual chlorine levels anticipated would be substantially lower. 6

The following conclusions may be drawn concerning the environmental impact of chlorine discharges: 6

1. Considering the conservatism of the calculations and the intermittent mode of application, chlorine levels within the chemical plumes would not be expected to exceed the water quality criterion for Cl_2 identified in Table 5.4-5.

2. No significant adverse impact on the aquatic life in the river is anticipated to result from plant chlorine discharges.

A potential environmental concern for aquatic life in the river is the formation of chloramines from the free chlorine and ammonia. Chloramines can be formed according to the following reactions:[1]

$$NH_4^+ + HClO \rightleftarrows H^+ + H_2O + NH_2Cl \text{ (monochloramine)}$$

$$NH_2Cl + HClO \rightleftarrows H_2O + NHCl_2 \text{ (bichloramine)}$$

$$NHCl_2 + HClO \rightleftarrows H_2O + NCl_3 \text{ (trichloramine)}$$

The formation of monochloramine is instantaneous and takes precedence over the other two possible chloramines. The source of ammonium ions (NH_4^+) could be any ammonium salts or ammonia in water:

$$NH_3 + H_2O \rightleftarrows NH_4^+ + OH^-$$

The source of the hypochlorite ions (ClO^-) could be hypochlorite or chlorine as it reacts in water:

$$Cl_2 + H_2O \rightleftarrows HClO + HCl$$

Chloramines are relatively more stable than chlorine, have about half the oxidation potential of chlorine and are toxic to aquatic life.

Effluent streams containing chlorine are combined with other plant effluents containing ammonia prior to being discharged. Ammonia sources are the 8,000 gpd of the sewage effluents with an ammonia-N concentration of 0.5 mg/l, as shown in Table 3.7-1 and the decomposition product of hydrazine from the auxiliary steam generator (when operating) of 480 gpd with an ammona-N concentration of 0.5 mg/l. In addition, the Clinch River in 1974-1975, contained an average of 0.28 mg/l and a maximum of 1.00 mg/l of ammonia-N as shown in Table 5.4-7.

The small concentrations of chloramines formed or the excess residual chlorine are not expected to persist in the water due to three main reasons: (1) the nonchlorinated circulating waters probably contain bacteria which will dissipate one portion; (2) another portion will be lost by evaporation; and (3) another portion will react with reducing agents found in the waters such as $S^{=}$, Fe^{++} and Mn^{++}. Thus, it is not expected that chloramines or excess chlorine will persist at significant levels in the river. Given that zero free chlorine is present in the Clinch River water (Table 5.4-7), the ambient concentration of chloramines may also be considered to be zero. Assuming that the total discharged chlorine (no dissipation or oxidation) is complexed with the available ammonia, estimates of chloramine concentrations are the following: 6

1. 0.015 mg/l of chloramine in the five percent isopleth for the typical winter condition;
2. 0.015 mg/l of chloramine in the five percent isopleth for the typical summer condition;
3. 0.018 mg/l of chloramine in the six percent isopleth for the summer short duration no flow extreme case; and
4. 0.079 mg/l of chloramine in the winter extended no flow plume. 6

Concentrations given above are below reported acutely toxic levels.(2) 6
While long terms exposure of an amphipod and one minnow species (15 and 21 weeks, respectively) at concentrations greater than 0.0034 and 0.0165 mg/l, respectively, have shown some sublethal effects such as a reduction in the number of young amphipods and minnow eggs produced,(2) the intermittent nature of chlorine discharges effectively precludes the potential for chronic exposure of organisms in the plumes to sublethal chlorine concentrations. Consequently, the chloramine concentrations

that may be produced from CRBRP residual chlorine discharges are not expected to present significant hazards to the aquatic ecosystem. 6

Another potential environmental concern for aquatic life and human health is the formation in the river of trihalomethanes (THMs). These substances can be formed by the reaction of chlorine with natural humic and fulvic acids which are probably present in the Clinch River.[2a] In addition, some algae, tannic acids and nitrogen-containing compounds have also been shown to produce THMs on chlorination.[2b,2c] The United States Environmental Protection Agency (EPA) has promulgated final Primary Drinking Water regulations setting a Maximum Contaminant Level (MCL) for THMs of 0.1 mg/l which should not be exceeded in finished drinking water (see Table 5.4-1). 9

Organic precursors of THMs, in particular humic and fulvic acids, are likely to occur in the Clinch River, although no specific information is available on the concentrations of these substances. Pretreatment of sanitary wastes by aeration and settling prior to chlorination will reduce the organic levels in the sanitary effluent and remove some THM precursors. Considering the low level of chlorine in the wastewater, THM concentrations in excess of MCL levels are not expected in the Clinch River discharge and should have no effect at the nearest potable water intake, 1.5 miles downstream. Even so, the sanitary discharge will be monitored for these substances in both the construction and operation phases.

5.4.3 EFFECTS FROM OIL AND STORED CHEMICALS ON SURFACE WATER

Oil and chemicals will be required for operation of the CRBRP and will be stored on-site. Section 7.2 contains a list of the quantities to be stored and the methods of storage. Both oil and chemicals are potentially hazardous to aquatic biota as well as biomass.

Oil will be stored in accordance with the Environmental 9
Protection Agency Regulations on Oil Pollution Prevention [3] which will minimize the potential impacts of oil contamination on the local surface and groundwater systems. Chemicals will be stored in accordance with the Environmental Protection Agency Proposed Hazardous Substance Pollution Prevention
Regulations.[3a] A list of the on-site chemical storage tanks 11
and a description of the Secondary Containment Systems are found in Section 7.2. No environmental impact is anticipated under normal conditions form the stored chemicals.

Storm water collected from the permanent parking facility is sent 16
via the storm drainage system to a runoff treatment pond for 15
settlement. Runoff treatment pond effluents are filtered and 6
released from a controlled pond discharge and are transported to
the Clinch River via existing natural water courses. A portable 11
oil skimmer will be available should a visible oil slick appear
on the surface of the runoff treatment pond. Any collected oil 15
would be disposed of off-site by a licensed contractor.

5.4.4 EFFECTS ON GROUNDWATER

A total of 110 wells and springs are located within a 2-mile radius of the Site. Nearly all of the wells are of limited capacity and serve as small domestic wells as shown in Figure 2.5 -12. All of these wells are located to the south of the Clinch River which services as a "barrier" between the Site and these wells. There are no wells or springs on the Site. Within
a 20-mile radius of the Site there are 13 public water supplies 11
that use groundwater as listed in Table 2.2-14.

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Determination of any possible impact on the local groundwater quality and quantity is of great environmental concern. The local groundwater system, as described in Section 2.5, could be affected by plant operation in five ways: (1) contamination from liquid or solid wastes, such as holding ponds, sanitary lagoons or solid waste disposal areas; (2) seepage from contaminated bodies of surface water; (3) deposition from cooling tower drift; (4) accidental leakage from storage facilities of chemicals and fuel; and (5) depletion of the water source by over-withdrawal. However, the CRBRP will be designed so that none of these will affect the local groundwater.

As described in Sections 3.6 and 3.7, the facility will have no liquid or solid sanitary waste disposal areas on the Site. The sludge from the extended aeration package will be trucked off-site 8
for disposal. Recharge to the aquifers is through surface soils and joints in the rock strata. Discharge from aquifers is through soil and rock joints, and the Clinch River is a groundwater sink into 6
which the discharge from the aquifers flow. Cooling tower drift will have no effect on groundwater, shown in Section 5.4.6.5. Storage facilities of chemicals and oil will be constructed to prevent leaks and spills to the surrounding soils. The plant will not use groundwater for industrial or drinking purposes. Thus, the operation of the CRBRP is not anticipated to have any impact on the quality or quantity of the local groundwater system.

5.4.5 EFFECTS FROM COOLING TOWER DRIFT

Drift from the CRBRP cooling towers will become deposited in the surrounding vicinity. Whether this deposited material will have any impact on the local soils, vegetation or waters of the Clinch River is of environmental concern. Calculated drift depositions are given in

Table 10.1A-16 of the Appendix to Section 10.1, and serve as the basis for evaluating any impacts on the local terrestrial and aquatic ecosystem.

Amendment VI revisions to the ER include new design parameters for the CRBRP cooling system. Table 5.1-13 includes both old and new design features for the cooling tower. A review of these changes indicates that most of the critical parameters (evaporation rate, drift rate) have decreased slightly in value. It is anticipated that the net effect upon potential atmospheric impact would be to slightly reduce the extent of visible plume, ground fogging and icing potential as well as the drift deposition rate.

The changes in the magnitude of the critical parameters associated with any potential impact of the cooling system amount only to a few percent and can be considered to be well within the realm of accuracy of the calculation made. Therefore, it is felt that the original analysis based upon the original design parameters is still applicable to the slight modification made in the new design. Since the original analysis in Appendix 10.1 of the ER is considered to be on the conservative side, drift deposition values were not computed for the new cooling system design. 6

5.4.5.1 CHEMICAL COMPOSITION OF DRIFT

Examination of Table 5.4-7 which lists the composition of the Clinch River waters that will serve as makeup water for the cooling towers and will be the source of the drift, indicates that the major anionic constituents of this river are bicarbonate ions and the major cations are calcium and magnesium. The drift will probably consist mainly of calcium and magnesium carbonates, some calcium and magnesium sulfates and smaller quantities of sodium and potassium chloride. The drift will also contain 2.5 fold of the trace element concentration of these waters.

5.4.5.2 IMPACT ON SOIL

An examination of Table 10.1A-16 in the Appendix to Section 10.1 indicates that the maximum drift deposition from the mechanical draft wet cooling tower with linear array will be 88.75 lb/acre-month of total dissolved solids. Because most of this deposited material will be calcium and magnesium carbonate, no impact on the local soils is anticipated.

Calculations of drift depositions from typical 1,000 MWe natural and mechanical draft cooling towers utilizing salt water have demonstrated that there are no significant impacts on soils.(4) Thus, the minor quantities of sodium and potassium chloride, less than three percent by weight of the total dissolved solids content in the CRBRP drift, and calcium sulfate from the river water will be too small to cause any significant impact on these soils.

Regarding the accumulation of drift deposits over long periods of time, field loss parameter data for a few elements have been documented. Field loss rate can be best expressed as the time required for one-half of the deposited material to be weathered away and is called the chemical half-life. For the reported elements in the river water, strontium, manganese and others, the chemical half-life time ranged between two to five weeks.(5,6,7) Field loss of mercury from bare soils is reported to be from 2 to 11 percent in three days and between 35 to 40 percent in 11 days,(8) which suggests a half-life of approximately two weeks for mercury on soil.

Assuming a half-life of four weeks for the trace elements deposited with the drift, each trace element containing an average concentration of 0.01 ppm in the water will comprise 0.007 percent of the maximum deposited drift, reported in lb/acre-month in the Appendix to Section 10.1. The mechanical draft wet cooling tower, linear array, will deposit up to 700 feet from the cooling towers a maximum of 0.006 lb/acre-month 6

(4.5×10^{-9} lb-ft^2-day) of each of these elements. Maximum deposits of this magnitude should not have any significant impact on the local soils. 6

5.4.5.3 IMPACT ON VEGETATION

Typical drift from cooling towers may affect vegetation in two main ways: (1) any effect on the local soils may affect the vegetation these soils support; and (2) deposits on leaves may reduce photosynthesis and/or cause burns to these leaves. Both possible impacts are of environmental concern; however, the drift from the CRBRP cooling towers will not cause either of these impacts.

As described in Section 5.4.5.2, the CRBRP cooling towers are not expected to have any impact on the local soils. Thus, the vegetation supported by these soils should not be affected either. Most of the drift will be composed of calcium or magnesium carbonate, which is essentially one of the main components of calcareous soils. Drift of such composition does not cause burns to leaves and the small quantity that will be deposited on green leaves will reduce the rate of photosynthesis by a small amount (an amount that can be comparable to blowing dust). The frequent rains in this area will wash down these small quantities and no significant accumulations will occur.

Sodium chloride is known to cause burns to plants. However, the small amount to be found in the drift from the CRBRP cooling towers is not expected to cause any damage. Examination of Table 5.4-5 indicates that approximately three percent of the drift will be composed of chloride salts. Thus, from the mechanical draft wet tower with linear array a maximum of 2.7 lb/acre-month of chloride salts will be deposited. Such small quantities of chloride salts are not expected to cause damage even to the most sensitive plants.[9]

5.4.5.4 IMPACT ON FAUNA

Impact on soils or vegetation could have an impact on the local wildlife. However, since no impact on the local soils or on the vegetation is anticipated, no impact on the local fauna is expected.

5.4.5.5 IMPACT ON GROUNDWATER

Since the local aquifers are mainly recharged through the surface area, any impact on the local soils could result in impacts of the local groundwater system. However, since the drift deposition from the CRBRP cooling towers is not expected to contaminate the soils, no impact on the local groundwater should occur.

5.4.5.6 IMPACT ON THE WATERS OF THE CLINCH RIVER

Whether drift deposits will affect the water quality of the Clinch River is of environmental concern. Assuming that the maximum deposited drift shown in the Appendix to Section 10.1, enters approximately three miles of the river, during the worst possible no-flow conditions of one month, the increases in concentrations of total dissolved solids at the end of such a month will be approximately 3 mg/l for the mechanical draft wet cooling tower with the linear array. Such small increases should not have any impact on the aquatic community of the Clinch River or any impacts on the present water usage of the river.

Another possible source of water contamination that could be attributed to the cooling tower drift is runoff from drift deposits on the local soils. However, no such runoffs are anticipated, as explained in Section 5.4.6.2; thus, no contamination of the Clinch River water quality from this source should occur.

TABLE 5.4-1

U.S. ENVIRONMENTAL PROTECTION AGENCY NATIONAL INTERIM PRIMARY[10] AND SECONDARY[10a] DRINKING WATER REGULATIONS

Substance	National Interim Primary Drinking Water Regulations*	Secondary Drinking Water Regulations*	
Arsenic	0.05 mg/l		
Barium	1.0 mg/l		
Cadmium	0.01 mg/l		
Chloride		250 mg/l	
Chromium	0.05 mg/l		
Color		15 units	
Copper		15 mg/l	
Endrin	0.0002 mg/l		
Fluoride		1 mg/l	
Iron		0.3 mg/l	
Lead	0.05 mg/l		
Lindane	0.004 mg/l		
Manganese		0.05 mg/l	
Mercury	0.002 mg/l		9
Methylene-Blue Activated Substances		0.5 mg/l	
Methoxychlor	0.1 mg/l		
Nitrates (as Nitrogen)	10 mg/l		
Selenium	0.01 mg/l		
Silver	0.05 mg/l		
Sulfate		250 mg/l	
Total Dissolved Solids		500 mg/l	
Toxaphene	0.005 mg/l		
Total trihalomethanes	0.1 mg/l		
Zinc		5 mg/l	
2,4-D	0.1 mg/l		
2,4,5 TP (Silvex)	0.01 mg/l		

*Primary regulations set health-related limits; secondary set limits to control other attributes of drinking water, such as taste, odor, etc.

TABLE 5.4-2

SURFACE WATER CRITERIA FOR DOMESTIC WATER SUPPLIES* 9

Constituent or Characteristic	Criteria	
Arsenic**	zero; 0.022 μg/l+	9
Barium**	1.0 mg/l	
Boron**	1.0 mg/l	
Cadmium**	0.01 mg/l	
Chromium,** hexavalent	0.05 mg/l	
trivalent	170 μg/l	
Color**	75 color units	9
Copper**	1.0 mg/l	
Cyanide	0.2 mg/l	
Iron	0.3 mg/l	
Lead**	0.05 mg/l	
Manganese**	0.05 mg/l	
Mercury**	0.144 μg/l	9
Nickel	0.0134 mg/l	
Nitrates plus nitrates**	10 mg/l (as N)	
pH (range)	6-9 units	
Phenol	0.3 mg/l	9
Selenium**	0.01 mg/l	
Silver**	0.05 mg/l	
Sulfate and chloride**	250 mg/l	
Total dissolved solids** (filterable residue)	250 mg/l	9
Zinc**	5 mg/l	
Oil and grease	Virtually absent	
Coliform	1,000 colonies per 100 ml, geometric mean, 5,000 colonies per 100 ml maximum	9
2,4,5-TP**	0.01 mg/l	

(Continued)

TABLE 5.4-2 (Continued)

Constituent or Characteristic	Criteria	
2-4-D**	0.3 μg/l	9
Endrin**	0.001 μg/l	
Lindane**	0.004 mg/l	
Methoxychlor**	0.1 mg/l	9
Toxaphene**	zero, 0.0071 μg/l+	

* The more stringent of applicable Federal[11,11a] or State[11b] water quality criteria. 9

** The defined treatment process has little effect on this constituent.

\+ The first value is the absolute safe level for carcinogens. The second value represents the concentration calculated to cause one additional cancer per 100,000 individuals. 9

TABLE 5.4-3

GUIDES FOR EVALUATING THE QUALITY OF WATER USED BY LIVESTOCK[12]

Quality Factor	Threshold Concentration* (mg/l)	Limiting Concentration** (mg/l)
Total Dissolved Solids (TDS)	2,500	5,000
Cadmium	5	--
Calcium	500	1,000
Magnesium	250	500+
Sodium	1,000	2,000+
Arsenic	1	
Bicarbonate	500	500
Chloride	1,500	3,000
Fluoride	1	6
Nitrate	200	400
Nitrite	None	None
Sulfate	500	1,000+
Range of pH	6.0 - 8.5	5.6 - 9.0

*Threshold values represent concentrations at which poultry or sensitive animals might show slight effects from prolonged use of such water. Lower concentrations are of little or no concern.

**Limiting concentrations based on interim criteria, South Africa. Animals in lactation or production might show definite adverse reactions.

+Total magnesium compounds plus sodium sulfate should not exceed 50 percent of the total dissolved solids.

TABLE 5.4-4

TRACE ELEMENT TOLERANCES FOR IRRIGATION WATER[13]

Element	For Water Used Continuously on All Soils (mg/l)	For Short-Term Use on Fine Textured Soils Only (mg/l)
Aluminum	1.0	20.0
Arsenic	1.0	10.0
Beryllium	0.5	1.0
Boron	0.75	2.0
Cadmium	0.005	0.05
Chromium	5.0	20.0
Cobalt	0.2	10.0
Copper	0.2	5.0
Lead	5.0	20.0
Lithium	5.0	5.0
Manganese	2.0	20.0
Molybdenum	0.005	0.05
Nickel	0.5	2.0
Selenium	0.05	0.05
Vanadium	10.0	10.0
Zinc	5.0	10.0

TABLE 5.4-5

CRITERIA FOR WATER QUALITY: FRESHWATER CONSTITUENTS FOR AQUATIC LIFE 9

Parameter	Criterion*
pH	6.5 - 8.5 units
Alkalinity	Not less than 20 mg/l
NH_3	0.02 mg/l un-ionized ammonia
Cl_2	10 µg/l, 2 µg/l salmonids
Dissolved Oxygen	5.0 mg/l
Gases, total dissolved	110% of saturation at existing atmospheric pressure
Be	11 µg/l in soft water, 1.1 µg/l in hard water
Cd	0.025 µg/l (24-hour average),** 3.0 µg/l (maximum),**
Cr (hexavalent)	0.29 µg/l (24-hour average), 21 µg/l (maximum)
Cu	5.6 µg/l (24-hour average), 22 µg/l (maximum)**
Fe	1.0 mg/l
Pb	3.8 µg/l (24-hour average),** 170 µg/l (maximum)**
Hg	0.00057 µg/l (24-hour average), 0.0017 µg/l (maximum)
Ni	96 µg/l (24-hour average),** 1800 µg/l (maximum)**
Se	35 µg/l (24-hour average), 260 µg/l (maximum)
Ag	0.01 of 96-hour LC_{50} for sensitive resident species.+ Approximately 1.5 mg/l for fathead minnows.
H_2S	2 µg/l
Zn	47 µg/l (24-hour average), 320 µg/l (maximum)**
CN	3.5 µg/l (24-hour average), 52 µg/l (maximum)
Oil and Grease	1. No visible oil on surface 2. No deleterious amounts in sediment 3. <0.01 of 96-hour LC_{50} of several sensitive species in flow-through tests.+
Aldrin	0.003 µg/l
Chlordane	0.0043 µg/l (24-hour average), 2.4 µg/l (maximum)

9

(Continued)

TABLE 5.4-5 (Continued)

Parameter	Criterion
Demeton	0.1 μg/l
Dieldrin	0.0019 μg/l (24-hour average), 2.5 μg/l (maximum)
Endosulfan	0.056 μg/l (24-hour average), 0.22 μg/l (maximum)
Endrin	0.0023 μg/l (24-hour average), 0.18 μg/l (maximum)
Guthion	0.01 μg/l
Heptachlor	0.0038 μg/l (24-hour average), 0.52 μg/l (maximum)
Lindane	0.08 μg/l (24-hour average), 2.0 μg/l (maximum)
Malathion	0.1 μg/l
Methoxychlor	0.03 μg/l
Mirex	0.001 μg/l
Parathion	0.04 μg/l 9
Toxaphene	0.013 μg/l (24-hour average), 1.6 μg/l (maximum)
Phthalate Esters	3 μg/l (24-hour average), 910 μg/l (maximum)
Polychlorinated Biphenyls (PCB)	0.014 μg/l (24-hour average)
Color	<10% increase in seasonally established normal
Turbidity	<10% increase in seasonally established normal
Coliform (fecal)	1,000 colonies per 100 ml, geometric mean 5,000 colonies per 100 ml, maximum
Suspended Solids	<10% increase in seasonally established normal

* The more stringent of applicable Federal[11,11a] or State[11b] water quality criteria.

** Assumes total hardness = 100 mg/l (as $CaCO_3$).

\+ LC_{50} = lethal concentration to 50% of the tested animals.

TABLE 5.4-6

PERMISSIBLE CHLORINE CONCENTRATIONS IN CRBRP EFFLUENTS* 16

Effluent Characteristic	Inst. Maximum	Average Concentration
Free available chlorine	0.5 mg/l	0.2 mg/l

16

16

*CRBRP draft NPDES Permit 16

TABLE 5.4-7

AVERAGE AND MAXIMUM VALUES OF SOME CHEMICAL CONSTITUENTS IN CLINCH RIVER*

	Avg. Conc. (mg/l)	Max. Conc. (mg/l)
Total Alkalinity (as $CaCO_3$)	96	116
Ammonia Nitrogen (as N)	0.28	1.00
BOD	2.1	6.0
Calcium	34	43
Chloride	4.7	13.0
Chlorine Residual	**	**
COD	6.7	16.0
Copper+	<0.005	<0.01
Total Dissolved Solids (TDS)	142	174
Total Iron+	0.38	0.68
Lead+	<0.03	<0.03
Magnesium	7.8	8.5
Manganese+	0.05	0.07
Nickel+	<0.01	<0.01
Nitrate (NO_3)	1.3	2.2
pH	8.1	8.3
Total Phosphate	0.05	0.4
Potassium	1.4	1.9
Silica (SiO_2)	3.9	6.1
Sodium	2.1	2.5
Sulfate (SO_4)	15	23
Total Suspended Solids (TSS)	13	46
Zinc+	0.02	0.03

*Based on Aquatic Baseline Survey Data (March, 1974-April, 1975)

**Field measurements using the orthotolidine calorimetric method repeatedly showed the chlorine residual concentration to be below the limits of detection (<0.05 mg/l). As there are no nearby sources of chlorine additions to the river, it can be assumed that the ambient level is zero. 6 15 16

+Includes contribution to effluent quantities from condenser erosion/corrosion.

TABLE 5.4-8 6

CONCENTRATIONS OF CHEMICAL CONSTITUENTS IN THE CRBRP DISCHARGE AND THE SIX PERCENT ISOPLETH OF THE SUMMER SHORT DURATION NO-FLOW PLUME* 6

	Concentrations in CRBRP Discharge**		Concentrations in Six Percent Isopleth	
	Average (mg/l)	Maximum (mg/l)	Average (mg/l)	Maximum (mg/l)
Total Alkalinity (as $CaCO_3$)	239.0	286.0	104.58	126.20
Ammonia Nitrogen (as N)	0.7	2.5	0.31	1.09
BOD	5.3	15.0	2.29	6.54
Calcium	85.0	108.0	37.06	46.90
Chloride	11.8	32.3	5.13	14.16
Chlorine Residual	0.14	0.14	0.01	0.03
COD	16.8	40.0	7.31	17.44
Copper+	0.2	0.93	0.02	0.07
Total Dissolved Solids (TDS)	373.0	582.0	155.86	198.48
Total Iron+	0.95	1.72	0.41	0.74
Lead+	<0.03	<0.03	<0.03	<0.03
Magnesium	19.6	21.4	8.51	9.27
Manganese	0.13	0.18	0.05	0.08
Nickel	0.02	0.11	0.01	0.02
Nitrate (NO_3)	3.4	5.6	1.43	2.40

(Continued)

TABLE 5.4-8 (Continued) 6

	Concentrations in CRBRP Discharge**		Concentrations in Six Percent Isopleth	
	Average (mg/l)	Maximum (mg/l)	Average (mg/l)	Maximum (mg/l)
pH	6.5 - 8.5	6.5 - 8.5		
Total Phosphate	0.14	1.0	0.06	0.44
Potassium	3.5	4.8	1.53	2.07
Silica (SiO_2)	9.8	15.3	4.25	6.65
Sodium	13.2	107.3	2.77	8.79
Sulfate (SO_4)	48	106	16.98	27.98
Total Suspended Solids (TSS)	33	114	14.20	50.08
Zinc+	0.05	0.08	0.02	0.03

6

*Based on Iowa Institute physical model study

**From Table 10.3A-2

+Includes contribution to effluent quantities from condenser erosion/corrosion. 6

TABLE 5.4-9 6

SURFACE AREA AFFECTED BY CHEMICAL PLUMES AND INCREASES IN CHEMICAL CONCENTRATIONS*

Mixing Conditions	Chemical Isopleth** (%)	Area (acres)	6
Typical Cases			
Winter	3	0.05	
	4	0.01	
	5	0.01	
Summer	3	0.07	
	4	0.02	
	5	<0.01	
Extreme Case-Short Duration No Flow			
Winter	2	3.92+	6
	5	0.06	
Summer	4	0.07	
	6	0.02	

*Based on Iowa Institute physical model study

**Percent difference between initial blowdown and ambient concentrations in river

+Estimated, based on extrapolations of model plume boundaries to achieve closure of 0.9 °F isotherm (see Figures 10.3A-6 and 10.3A-10). 6

TABLE 5.4-10

CONCENTRATION OF DISCHARGED CHEMICALS IN THE EXTENDED NO FLOW PLUMES

	Average Ambient River Concentration* (mg/l)	Average Plant Discharge Concentration* (mg/l)	Extended No Flow Maximum Plume Concentrations — Winter Case: @ End of 15 Days (mg/l)	Winter Case: @ End of 30 Days (mg/l)	Summer Case: @ End of 18 Days (mg/l)	Summer Case: @ End of 31 Days (mg/l)
Total Alkalinity	96	239	117	135	106	107
Ammonia Nitrogen (as N)	0.28	0.70	0.34	0.39	0.31	0.31
BOD	2.1	5.3	2.6	3.0	2.3	2.3
Calcium	34	85	41	47	37	38
Chloride	4.7	11.8	5.7	6.6	5.2	5.3
Chlorine Residual	**	0.2+	0.03	0.05	0.01	0.01
COD	6.7	16.8	8.2	9.5	7.4	7.5
Copper	<0.005	0.20	0.03	0.05	0.02	0.02
Total Dissolved Solids (TDS)	142	377	176	205	158	160
Total Iron	0.38	0.95	0.46	0.53	0.42	0.43
Lead	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Magnesium	7.8	19.6	9.5	11.0	8.6	8.7
Manganese	0.05	0.13	0.06	0.07	0.06	0.06
Nickel	<0.01	0.02	0.01	0.01	0.01	0.01
Nitrate	1.3	3.4	1.6	9.9	1.4	1.5
pH	7.9	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5
Total Phosphate	0.05	0.14	0.06	0.07	0.06	0.06
Potassium	1.4	3.5	1.7	2.0	1.5	1.6
Silica (SiO_2)	3.9	9.8	4.8	5.5	4.3	4.4
Sodium	2.1	15.0	4.0	5.6	3.0	3.0
Sulfate	15	50	20	24	17	18
Total Suspended Solids (TSS)	13	33	16	18	14	14
Zinc	0.02	0.05	0.02	0.02	0.02	0.02

*From Table 5.4-7

**Field measurements using the orthotolidine calorimetric method repeatedly showed the chlorine residual concentration to be below the limits of detection (<0.05 mg/l). As there are no nearby sources of chlorine additions to the river, it can be assumed that the ambient level is zero.

+Continuous discharge assumed

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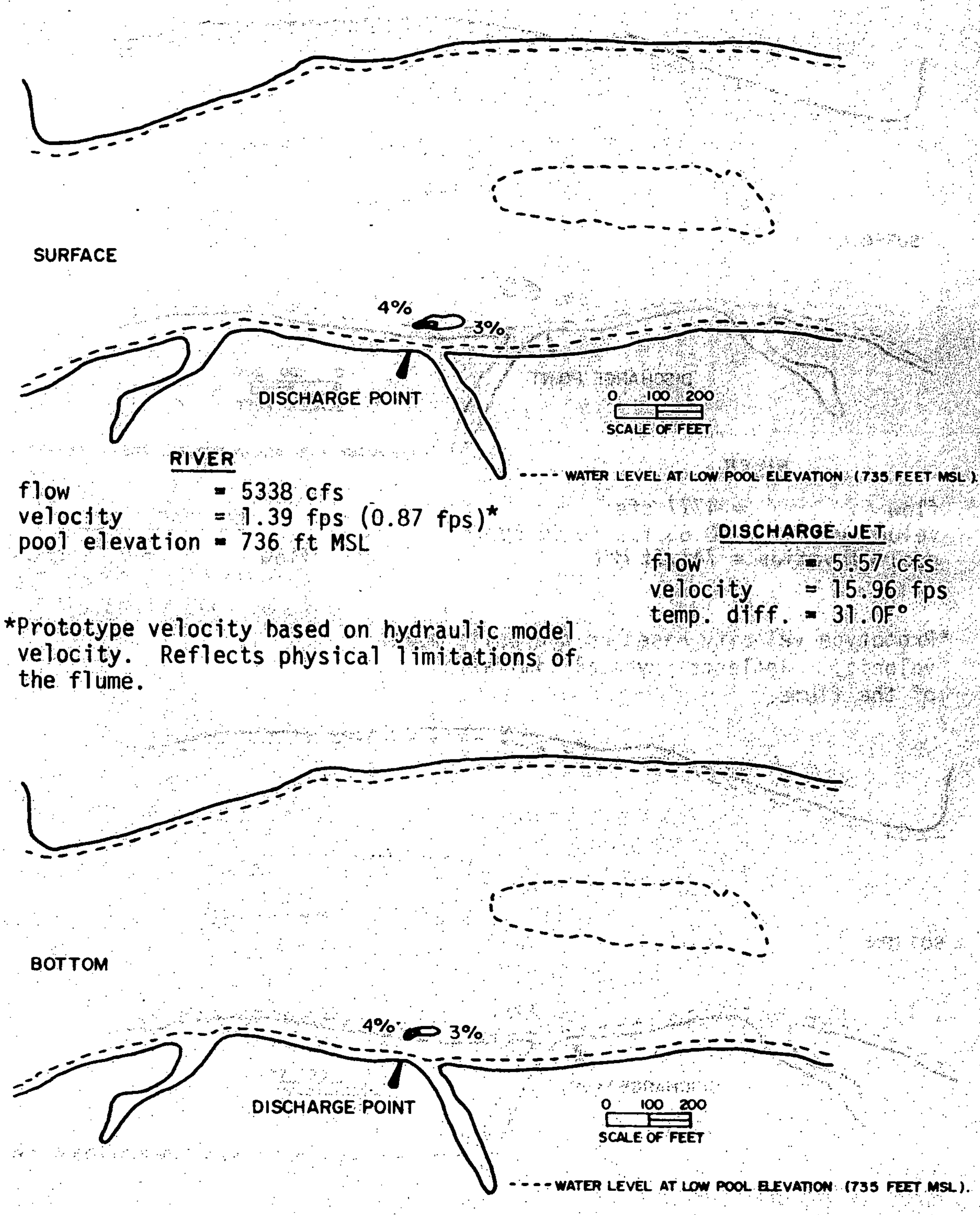
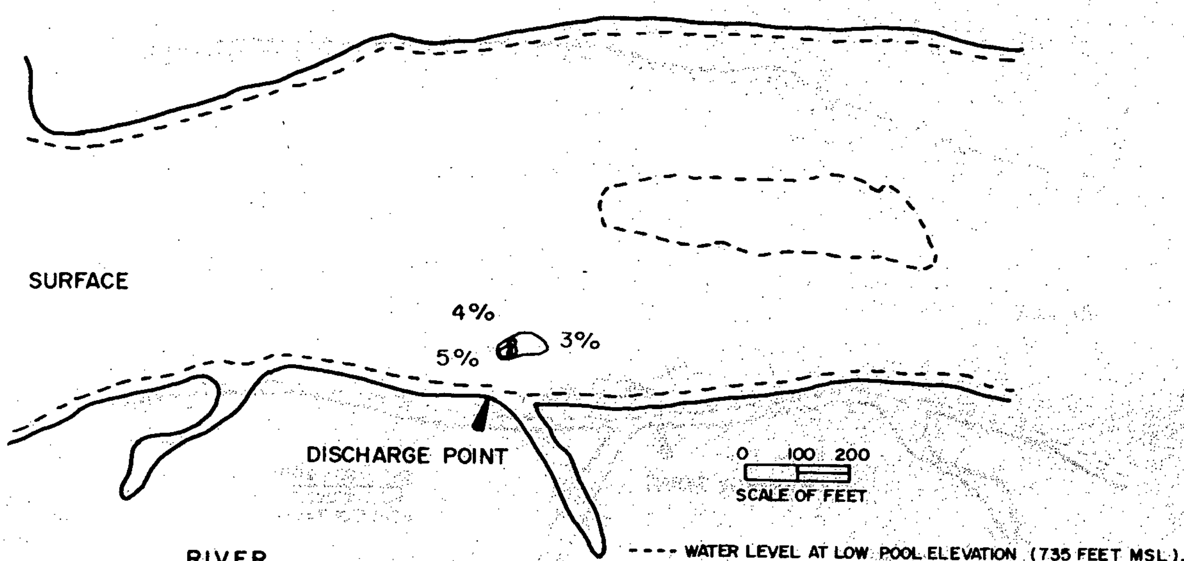


Figure 5.4-1 CHEMICAL PLUMES FOR TYPICAL CASE-WINTER
(Based on Iowa Institute physical model study) 6



RIVER

flow = 4777 cfs
velocity = 0.63 fps (0.50 fps)*
pool elevation = 741 ft MSL

DISCHARGE JET

flow = 7.22 cfs
velocity = 20.68 fps
temp. diff. = 23.6F°

*Prototype velocity based on hydraulic model velocity. Reflects physical limitations of the flume.

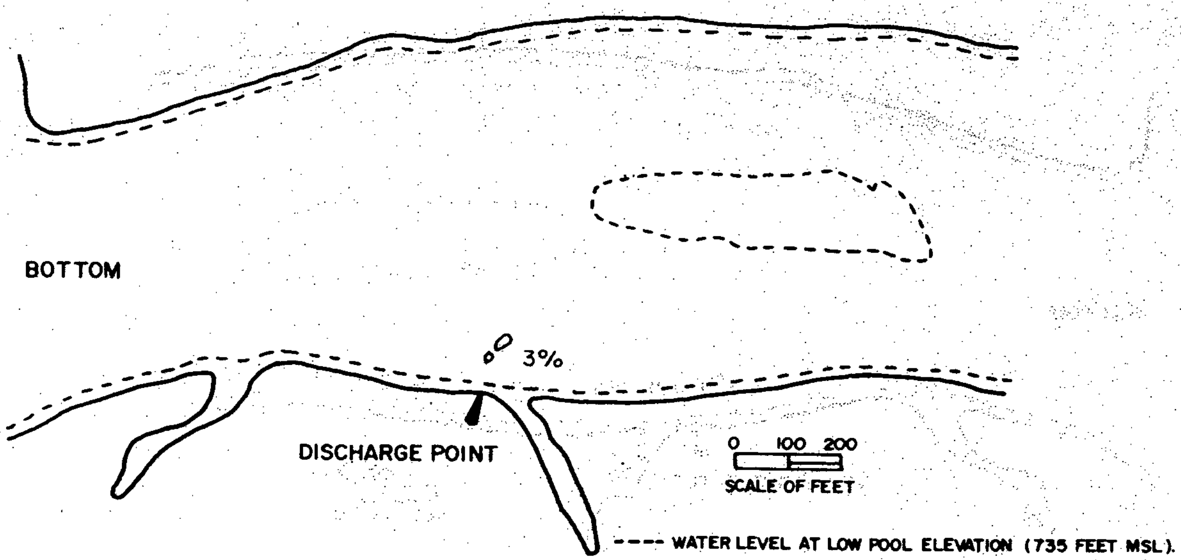
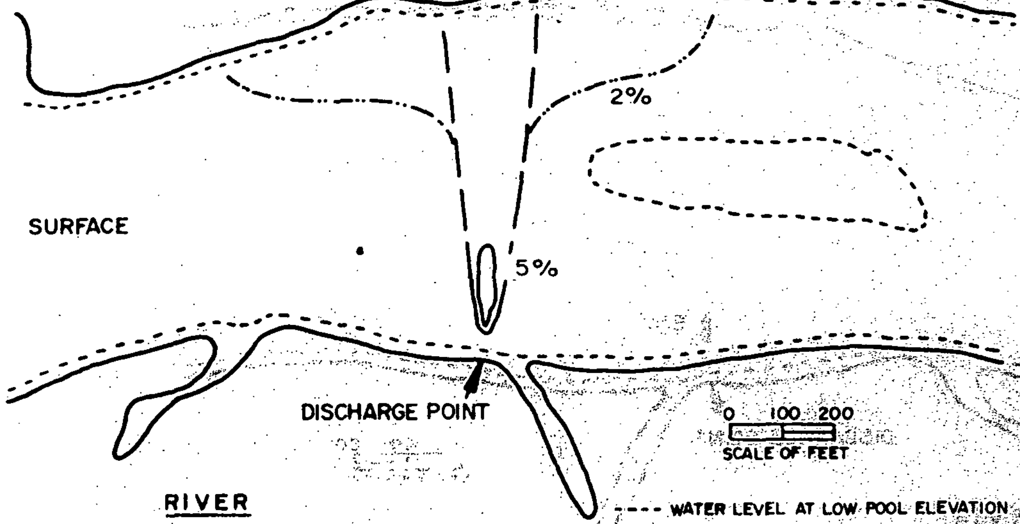


Figure 5.4-2 CHEMICAL PLUMES FOR TYPICAL CASE-SUMMER (Based on Iowa Institute physical model study) 6



---- WATER LEVEL AT LOW POOL ELEVATION (735 FEET MSL)

—— EXTRAPOLATION OF PLUME WIDTH GROWTH BASED ON PHYSICAL MODEL DATA.

—··— ESTIMATION OF PLUME DISTORATION DUE TO INTERACTION WITH OPPOSITE SHORE.

RIVER

flow = 0
velocity = 0 (0.17 fps)*
pool elevation = 735 ft MSL
temperature = 33°F

DISCHARGE JET

flow = 6.26 cfs
velocity = 17.93 fps
temp. diff. = 46.8F°

*Prototype velocity based on hydraulic model velocity. Reflects necessity of maintaining a flume crossflow to permit the attainment of steady-state conditions.

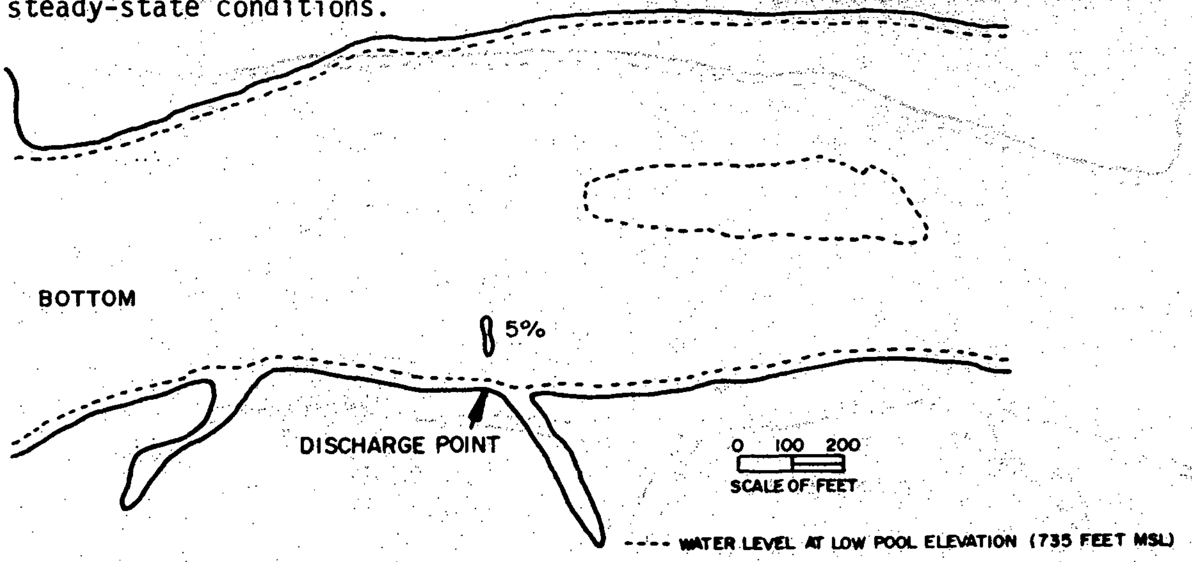
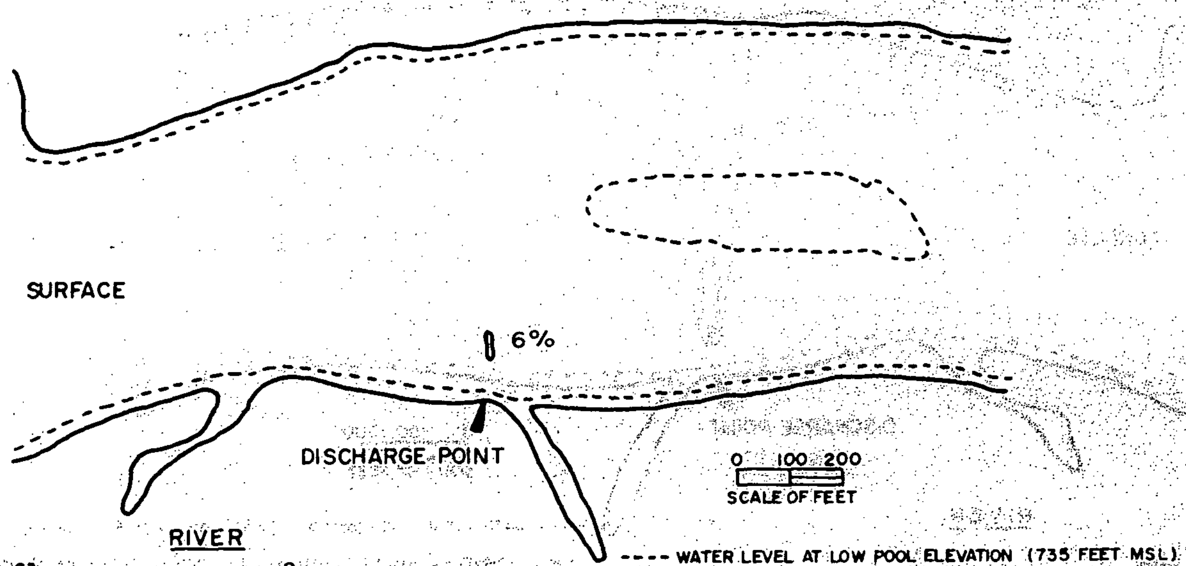


Figure 5.4-3 CHEMICAL PLUMES FOR SHORT DURATION NO FLOW (Hypothetical Winter Worst Case - Thermal Mixing) (Based on Iowa Institute physical model study) 6

SURFACE



RIVER

flow = 0
velocity = 0 (0.17 fps)*
pool elevation = 739 ft MSL
temperature = 78°F

DISCHARGE JET

flow = 7.31 cfs
velocity = 20.94 fps
temp. diff. = 11.6F°

*Prototype velocity based on hydraulic model velocity. Reflects necessity of maintaining a flume crossflow to permit the attainment of steady-state conditions.

BOTTOM

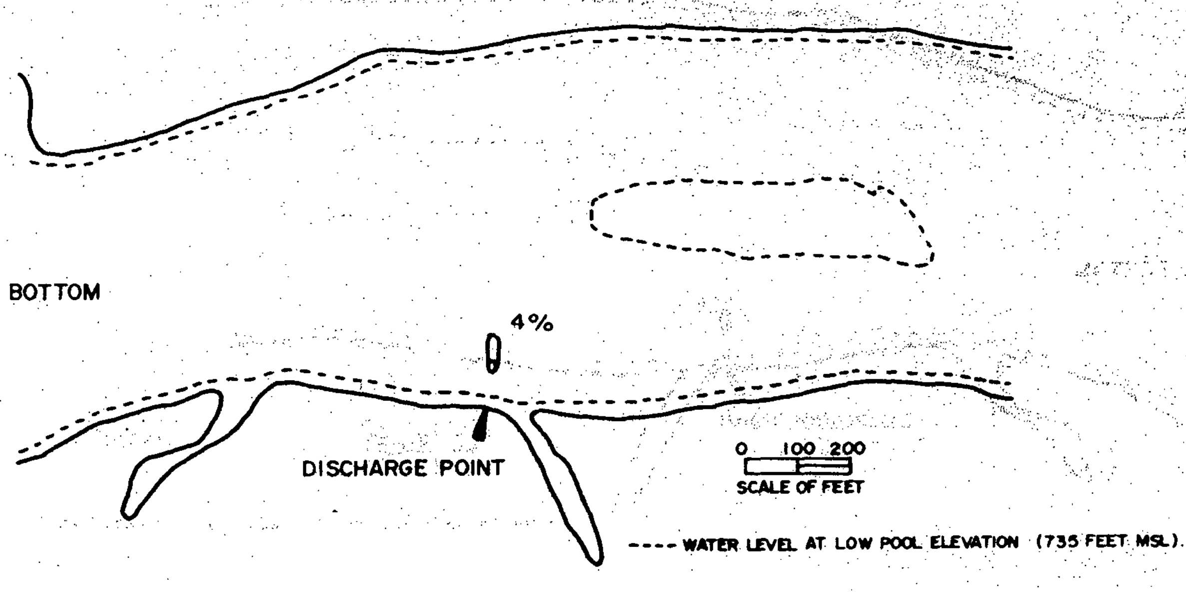


Figure 5.4-4 CHEMICAL PLUMES FOR SHORT DURATION NO FLOW (Hypothetical Summer Worst Case - Thermal Mixing) (Based on Iowa Institute physical model study) 6

5.5 EFFECTS OF SANITARY AND OTHER WASTE DISCHARGES

In this section effects from sanitary wastes on the Clinch River as well as effects from gaseous effluents from the emergency diesel generator and the diesel fire pump are discussed and evaluated.

5.5.1 EFFECTS FROM SANITARY WASTES

Sanitary wastes are described in Section 3.7. These wastes, comparable to normal domestic sanitary waste, will enter a Sewage Disposal System consisting of an extended aeration package treatment plant. The operating 9
period (permanent) plant will include a slow sand filter that will be installed following the CRBRP construction period.

The sanitary system for the construction period is designed for a peak manning of 2,450 persons. Maximum daily sanitary wastewater design flow will be 61,250 gallons, or 25 gal/person/day. During construction, a unit of 13,000 gal/day and a large unit of 52,000 gal/day capacity will be 8
installed to give a total treatment capacity of 65,000 gal/day.

9

The average daily sanitary wastewater flow during normal operation will be 7,000 gallons. This is based upon 200 plant personnel, or 35 gal/person/day for normal plant operation. Present projected number of plant personnel is 179 persons with a peak manning of 300 men anticipated for annual shutdown. The permanent plant design flow of 13,000 gallons per 8
day will be adequate for this loading.

9

waste systems will be designed in accordance with the Tennessee Department of Public Health Design Criteria.[1,2] Treated effluent discharges will meet NPDES Permit limits. 9

Cooling tower blowdown is approximately 2,650 gpm or 5.9 cfs in the summer and approximately 1,955 gpm or 4.3 cfs in winter. 9
Sanitary effluents during normal operation at full load will become diluted by the cooling tower blowdown 530 fold in the summer and 390 fold in the winter. The small concentration of pollutants (listed in Table 3.7-1) in the sanitary effluent will become further diluted in the Clinch River waters (6,772 cfs, average winter flow and 4,339 cfs average spring flow). The 13
concentration of pollutants in the sanitary effuent before dilution will meet the NPDES Permit discharge criteria and are not anticipated to have any effect on the water quality of the Clinch River or on its aquatic biota at the mixing zone or beyond it, even for the worst case of no-flow conditions discussed in Section 5.4.

Sludge from the sewage treatment facility (the aeration package) will be trucked off-site by a contractor for ultimate disposal, as discussed in Section 3.7.

5.5.2 EFFECTS FROM GASEOUS EMISSIONS FROM EMERGENCY DIESEL GENERATOR AND DIESEL FIRE PUMP

Emission rates of gaseous pollutants from the emergency diesel generator units (quantity-3) and the diesel fire pumps (quantity-2) are given in Table 3.7-2. Emission regulations for 13
the State of Tennessee for NO_x apply only if the total heat input to all the units exceeds 250 million Btu per hour.[5] Heat input is 159.11 million Btu/hr; thus, these diesel units are not regulated for NO_x emissions. Emission regulations for Roane

County limit SO_2 emissions to 5.0 pounds of SO_2 per million Btu per hour heat input.[6] Emissions of SO_2 are 0.547 pounds per million Btu per hour heat input and comply with the standards. Particulate standards limit emissions to 0.13 pounds per million Btu per hour heat input for total plant size of 159 million Btu heat input.[7] Emissions of particulate matter as found in Table 5.5-1 are 0.0076 pounds per million Btu per hour and comply with the standards. Carbon monoxide emissions for stationary sources are not regulated. The limit placed on organic compound emissions will be determined at the time of the permit application review by the Technical Secretary of the Tennessee Department of Public Health, Division of Air Pollution Control.[8] Because the emission rates of the gaseous pollutants are within the limits cited in the governing regulations and the source of these gaseous emissions is the emergency equipment which operates infrequently, the gaseous emissions do not constitute any hazard to the local environment. 13

TABLE 5.5-1

PRINCIPAL PARAMETERS AND EXHAUST EFFLUENTS FROM PLANT DIESEL ENGINES OPERATION (DURING NORMAL OPERATIONS)

	DIVISION 1 & 2 DIESEL GENERATOR (DG) UNITS	DIVISION 3 DIESEL GENERATOR (DG) UNITS	DIESEL FIRE PUMPS
1. Quantity	2	1	2
2. Test			
a. Frequency, per Unit	1 start test per month & at least 1 full loading test every 18 months	Same as Division 1 & 2 DG units	1 start test per week
b. Duration, per Unit	2 hours & 24 hours, respectively	Same as Division 1 & 2 DG units	30 min.
3. Fuel consumption rate, gal/hr	1,012	187.22	26.2
4. Heat input, 10^6 Btu/hr (Fuel Heating Value of 130,000 Btu/gal)	131.4	24.31	3.4
5. Maximum emission rates of pollutants released to atmosphere:			
a. Particulates, lbs/hr	1	0.185	0.026
(lbs/10^6 Btu/hr)	(0.0076)	(0.0076)	(0.0076)
b. Sulfur dioxide (SO_2), lbs/hr	71.8	13.28	1.87
(lbs/10^6 Btu/hr)	(0.547)	(0.547)	(0.547)

13

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TABLE 5.5-1
(Continued)

PRINCIPAL PARAMETERS AND EXHAUST EFFLUENTS FROM PLANT DIESEL ENGINES OPERATION
(DURING NORMAL OPERATIONS)

	DIVISION 1 & 2 DIESEL GENERATOR (DG) UNITS	DIVISION 3 DIESEL GENERATOR (DG) UNITS	DIESEL FIRE PUMPS
5. (Continued)			
c. Nitrogen oxides (NO_X), lbs/hr	402	74.37	10.45
($lbs/10^6$ Btu/hr)	(3.06)	(3.06)	(3.07)
d. Organic compounds, lbs/hr	7	1.295	0.182
($lbs/10^6$ Btu/hr)	(0.053)	(0.053)	(0.053)
e. Carbon monoxide (CO), lbs/hr	14.4	2.664	0.374
($lbs/10^6$ Btu/hr)	(0.109)	(0.109)	(0.110)

13

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5.6 EFFECTS OF OPERATION AND MAINTENANCE OF THE TRANSMISSION SYSTEM

No significant adverse environmental impacts are expected to occur during normal operation of the transmission lines. Maintenance of the right-of-way (ROW) will involve regular clearing operations which will cause a disturbance to plant and animal communities within the corridor.

5.6.1 ELECTRICAL EFFECTS

Electrical effects such as corona, audible noise, radio and television interference, ozone production and electrostatic induction may be associated with the operation of transmission lines. These effects and the associated environmental impacts are discussed in the following subsections.

5.6.1.1 VISIBLE LIGHT

Corona has been described as a luminous discharge caused by the ionization of the air in the vicinity of a conductor. It is a partial breakdown of the dielectric constant of the air caused by a concentration of electrical stresses at the edge of an electrode in an electrical field or by increased stress across a low dielectric strength material in series with other insulated materials. Electric corona along a transmission line conductor occurs when the potential of the conductor in air is raised to such a value that the dielectric strength of the surrounding air is exceeded. Corona manifests itself by bluish tufts or streamers appearing around the conductor particularly where abrasions, foreign particles and sharp points are located along the conductor. Under fair weather conditions, corona will not be visible along the 161-kV lines. Under foul weather conditions and on a dark night, a glow may be visible. Corona, however, will be minimal and will cause no adverse environmental effects or inconvenience.

5.6.1.2 AUDIBLE NOISE

Audible noise is measured with an acoustical sound level meter (SLM). During fair weather, audible noise emanating from transmission lines of any voltage is not usually measurable above normal ambient sounds. During inclement weather and unusual atmospheric conditions, a light humming may be heard directly under transmission lines. In its operating experience thus far, TVA has not experienced problems with audible noise from either the 161-kV or the 500-kV transmission lines; no problems are expected with this transmission line.

5.6.1.3 RADIO AND TELEVISION INTERFERENCE

Measurements of radio noise (RN) were made in the vicinity of several 161-kV transmission lines on the TVA system more than a year before the first 500-kV line was energized. As the 500-kV network began to grow, a fairly comprehensive RN measurement program was initiated and since that beginning, measurements have been made beneath and near every 500-kV transmission line constructed by TVA. Because of the low noise levels found initially, the possibility of problems with 161-kV lines was discounted and few subsequent measurements were made.

During all of TVA's radio noise program, the selection of measuring sites, instrumentation and measuring techniques have conformed to the recommendations of the IEEE Radio Noise Subcommittee. Measurements at a lateral distance of 50 feet from a point directly beneath the outer phase and at a frequency near 1.0 megahertz (MHz), the approximate center of the broadcast band, are preferred. Noise meters should have quasipeak (QP) detector characteristics. The units usually preferred for expressing RN are decibels above one microvolt per meter (dB above 1.0 μV/m); this is also frequently used to express field intensity of a broadcast radio signal. The average of a substantial number of measurements, taken 50 feet from typical 161-kV lines, is about 29 dB above 1.0 μV/m during fair weather.

The numerical value of measured RN alone is not sufficient to determine the quality of radio reception at a given location. It is also necessary to know the received radio signal strength so that a comparison can be made. The quality of reception depends solely upon the signal-to-noise ratio (S/N) generally expressed as the difference in level (in dB) between the signal strength and the noise. For example, if a radio antenna is receiving a signal at a level 80 dB above 1.0 μV/m, and the RV at the antenna location is 35 dB above 1.0 μV/m, the S/N will be 45 dB.

In rural areas, the primary coverage of a radio station includes the area within which the signal strength is 500 μV/m (54 dB above 1.0 μV/m) or more. With average RN levels, a "fairly satisfactory" S/N[1] of 22 dB or more is available at distances of 120 feet or more from the line even in "fringe" areas. It should be emphasized that antennas located 300 feet or more from the line are essentially free from its influence. There will be no antennas associated with this plant.

Despite a narrower right-of-way, the 161-kV line permits a minimum S/N of 25 to 26 dB even at the edge of its right-of-way during average fair-weather conditions. Reception under these conditions has been classified as "very good".

As a final observation, distribution lines and transformers frequently located immediately adjacent to residences, in general, radiate higher RN levels than transmission lines--even 500-kV.

Noise generated by corona and radiated from a transmission line generally is much lower in intensity at FM and TV frequencies than at broadcast radio frequencies.

Noise energy within a given bandwidth decreases with increasing radio frequency. A rule of thumb for close approximation is that the noise level (in microvolts per meter) varies inversely as the frequency. For example, if measured RN is 100 μV/m at a frequency 1.0 MHz, it would be approximately 10 μV/m at 10 MHz--a drop of 30 dB.

This relationship has been borne out by measurements which indicate that the noise levels directly under a transmission line at television frequencies are usually comparable with ambient levels. Numerically, these levels fall in the range between 0.5 and 2.0 μV/m at 100 MHz when referenced to the same bandwidth as the 1.0 MHz readings. With the aid of portable TV receivers, it has been demonstrated that noise from the transmission line has no noticeable effect on reception.

In other parts of the country, it has been found that substantial TV interference is sometimes radiated from extra-high voltage power lines during severe snow storms or icing conditions. Severe storms or icing conditions occur so infrequently in the area of the CRBRP that this potential problem is almost nonexistent.

The proposed transmission lines are located in a secluded area away from the general public except for the tap point in the vicinity of White Wing Road. No residences or businesses are close to the proposed lines; therefore, there will be no effect.

5.6.1.4 OZONE PRODUCTION

Under some conditions, ozone may be produced in small amounts from corona discharges (ionization of the air) in the operation of transmission lines and substations, particularly at the higher voltages. Though it can be harmful if breathed in sufficient concentrations over prolonged periods, it is not considered to be injurious to vegetation, animals and humans unless concentrations exceed about 50 ppb. Preliminary studies conducted by Oak Ridge National Laboratory indicate that concentration directly beneath transmission lines may approach 1 to 2 ppb.[2]

Extensive field tests to detect ozone in the vicinity of 765-kV lines were conducted by the Battelle Memorial Institute under a variety of meteorological conditions.[3] From these tests, it was concluded that no significant adverse effects on vegetation, animals or humans are to be expected from levels of ozone that may be produced in the operation of transmission facilities at voltages up to 765-kV.

In view of the design and construction standards employed by TVA in building its transmission facilities, corona discharges are minimal or nonexistent. Accordingly, any ozone which could possibly be generated by the proposed transmission line (161-kV nominal voltage) would be environmentally inconsequential and harmless to vegetation, animals and humans.

5.6.1.5 ELECTROSTATIC INDUCTION

High-voltage lines and equipment terminals can, under certain conditions, also cause mild static charges to develop on ungrounded objects nearby. These charges are similar to the harmless common static charges formed while walking on certain types of carpeting. Induced or conducted ground currents are insignificant under most operating conditions.

High-voltage power lines and equipment operating in close proximity to telephone and signaling equipment can produce undesirable effects on the communication circuits through induced voltages. For the proposed transmission line connections, there are no nearby communications facilities, fences or other ungrounded objects that will be affected. Since there are no residences or businesses close to the proposed line, radio or television interference is not considered to be a problem.

5.6.2 MAINTENANCE EFFECTS

The right-of-way (ROW) will be inspected annually by helicopter, and by ground patrol when necessary, to insure that the equipment is in a safe and reliable condition.

5.6.2.1 VEGETATION

Vegetation in the ROW will be allowed to reach a maximum height of 15 feet, the highest allowable under a 161-kV line, by TVA maintenance specifications. Corridor vegetation will, therefore, probably be cut back every four to five years. Clearing is done by a farm tractor with a bushhog attachment. This treatment will leave a standing cover of approximately one foot in height. A TVA field supervisor makes the decision and instructs the clearing crew foreman on specific methods to be used. Protective vegetation will be retained along the streambanks to minimize siltation. Outside of the ROW, trees or limbs in danger of falling across a line will be trimmed or removed. Clearing operations, with the objective of maintaining herbaceous and shrub cover and repressing tree growth, will inhibit natural plant succession along the ROW. Each clearing operation will destroy the plant growth which has occurred since the last clearing and will have a significant effect.

5.6.2.2 WILDLIFE

As the plant communities in the ROW change from low herbaceous to shrubby cover with the invasion of local plant species, the animal species which use the ROW will also change. The growth of shrubs and saplings will provide a diverse habitat, more suitable for the many species considered edge species, as discussed in Section 2.7. Songbirds, especially, show an increase in number as natural succession alters the corridor vegetation. Increased plant growth means more food and cover available to such species as deer, rabbits and woodchucks, among others. As the corridor cover changes from grassland to heavy brush, such species as the bobwhite quail will decline in numbers. Clearing will return the area to shrubby habitat areas. This cycle will continue as long as the area is maintained by regular clearing operations.

The presence of 85-foot high transmission towers, approximately 15 feet taller than the bordering forest, is not expected to effect the Canada goose migration across the CRBRP site.

5.6.2.3 ACCESS ROADS

Existing area roads will suffice for maintenance work; the majority of these roads are presently surfaced with gravel, regularly maintained and restricted to the public. Any rutting caused by maintenance vehicles on these roads will be repaired by grading and reseeding or graveling as necessary. Some routine maintenance work or emergency work will require vehicular traffic on the ROW. Rutting will be repaired by hand or machine, and any drainage disturbed will be restored.

5.6.2.4 AESTHETICS

Visual impacts considered during plant operation included views of the site, containment building, and cleared transmission line corridors. The CRBRP site will be visible from various vantage points near the plant site. Both the site and the containment building will be visible from portions of both I-40 and S.R. 58. Both the site and the containment building will be visible from recreation sites 1 and 2 listed on Table 2.2-8. The site will not be visible from any housing development within the study area but will be easily seen from many of the single-family homes from across the Clinch River. Neither the containment building nor the plant site will be visible from any significantly offsite historical site or structure within the study area. 15

Cleared rights-of-way can also have a profound visual impact on the environment. Usually this impact is most noticeable when the lines pass through scenic, recreational or historical areas or where the public is afforded extensive views of the facilities. Only a short expanse of the proposed corridor is visible from White Wing Road and it is visible for only a few seconds to 15
motorists, as discussed in Section 4.2. Although a newly cleared transmission line is not generally an aesthetically pleasing sight, public viewing of corridors in this condition will be insignificant in terms of time and amount of line observable. Natural buffers of vegetation will be maintained where public viewing of such maintenance conditions would be possible. The remainder of the proposed transmission facilities are out of sight of public view as access to the ROW is controlled by locked gates at all times. In summary, aesthetic impacts during plant operation are considered insignificant because of the limited 15
amount of time when either the site, containment building, or transmission line corridors are visible to the observers during each year.

5.7 OTHER EFFECTS OF PLANT OPERATION

Operation of the CRBRP should institute no changes in land use
not already abrogated during the construction phase. Comparison
of the construction phase to the operational phase should, in
fact, result in relief of some of the man-induced stresses due to
significant reductions in the motion and noise of heavy equipment
and vehicular traffic at the plant site. Stabilization of
routing should result in greater tolerance of the installation by
the terrestrial population. The effects of plant operation are
discussed in Sections 5.1 through 5.6. Because of the plant
design and the distance of the Site from other industrial or
power plants in the area (ORGDP is three miles north-northwest)
the CRBRP should not have significant thermal or radioactive 16
waste interaction with effluents released by other plants in the
area. No wastes from the plant are anticipated to be disposed of
by means other than those discussed in Sections 5.2 through 5.5.

5.7.1 FUEL CYCLE REVISION 16

The CRBRP fuel cycle includes mixed oxide (MOX) fuel fabrication,
blanket element fabrication, reprocessing, management of the
wastes generated by facilities in the fuel cycle and
transportation of wastes and products among the various
facilities. Some of the facilities required to support the CRBRP
fuel cycle are not yet available. Notable examples are a fuel 14
reprocessing plant capable of handling CRBRP fuel, and a federal
repository for radioactive waste disposal. The environmental 16
impacts estimated herein use existing information regarding the
most likely design of these facilities for those that are not yet
available. This assessment also assumes that appropriate
facilities will be available in time to support the CRBRP fuel
cycle such that interim measures like away from reactor fuel
storage and product storage are not required.

A simplified schematic diagram of the CRBRP fuel cycle is shown in Figure 5.7-1. The mass flow parameters are characteristic of those for the CRBRP under pseudo-average equilibrium-cycle conditions (where the cycle-to-cycle variations in the batch CRBRP fuel management have been averaged out). At equilibrium, approximately 0.9 MT of plutonium and 11 MT of depleted uranium are fabricated into mixed-oxide fuel and blanket assemblies per year. One half of one percent heavy metal has been assumed to be unrecoverable in the fabrication process. In the reactor core, irradiation at 975 MW(th) for 274 equivalent full power days destroys approximately .28 MT of plutonium and 0.38 MT of uranium per year through fission and nuclear transmutation reactions. 0.27 MT of fission product isotopes are produced per year. Because of the breeding characteristics of the CRBRP, plutonium is both produced and destroyed in the core and the discharge fuel and blankets contain approximately 1.00 MT of plutonium. This spent fuel is chemically reprocessed, where once again 1/2% of the heavy metal isotopes are assumed to be unrecoverable. Fission products, irradiated structural material and other wastes are shipped to a waste disposal facility. The recovered plutonium (0.99 MT/year), and perhaps the uranium as well, is recycled as fresh fuel input to the fuel fabrication facilities. The net gain of approximately 0.10 MT of plutonium per year can be stored for later use. The contribution of the plant fuel cycle to the environmental impacts is in Table 5.7-1, "CRBRP Summary of Environmental Considerations for Fuel Cycle." Below is a description of the facilities and methods used to estimate the Table 5.7-1 impacts. 16 16 14 16 16

DOE will supply plutonium to startup and operate CRBRP during the five-year demonstration period. The plutonium will come from existing DOE inventories, processed domestic nuclear power reactor spent fuel and, if necessary, foreign sources. A simplified schematic diagram of the CRBRP fuel cycle with Pu recycle is given in the Appendix to Section 5.7 (Section 14.4A). 16

No impacts are included in the estimate in Table 5.7-1 for production of this material. These impacts have been addressed in other environmental impact documents.

Table 5.7-1 includes estimates of environmental impacts from reprocessing of CRBRP spent fuel, including oxide conversion. Reprocessing of CRBRP spent fuel would produce adequate plutonium to fuel the CRBRP.

The DOE-supplied plutonium may require conversion to an oxide form at a yet to be determined facility prior to fuel fabrication. Oxide conversion is planned as a step at the reprocessing plant. The impacts of conversion are bounded by the impacts of operating the reprocessing plant given in Table 5.7-1.

5.7.1.1 CRBRP FUEL FABRICATION

Fabrication of the mixed oxide core fuel is planned to be performed at the Secure Automated Fabrication (SAF) line, to be installed in the Fuels and Materials Examination Facility (FMEF) at DOE's Hanford reservation. CRBRP fuel fabrication will require about 65 percent of the SAF line operational schedule (15 of every 24 months). The data presented in Table 5.7-1 for mixed oxide fuel fabrication are based on the impacts in DOE/EA-0116 "Environmental Assessment for the Fuels and Materials Examination Facility," July 1980, and supplement.(6),(7) 14

The Secure Automated Fabrication (SAF) Program has as its objective to develop and demonstrate an advanced manufacturing line (SAF) for plutonium oxide breeder reactor fuel pins. This line will be the source of fuel for the FFTF and the CRBRP. The SAF line will utilize technology that focuses on improved safety features for plant operating personnel, the public, and the environment.

Fabrication of fuel on the SAF line in the fully automated and remotely operated mode results in the following important advances over current manual fuel fabricaton technology:

- o Reduced radiation exposure to plant personnel
- o Reduced access to Special Nuclear Materials (SNM)
- o Improved containment of SNM
- o Near real-time accountability of SNM
- o Improved product cost and quality
- o Increased protection of the public and the environment from radiation or contamination

The basic fabrication process includes receiving and assaying nuclear ceramic powders, blending of the powders, pelletizing and sintering the powders into fuel pellets, and loading these pellets into finished fuel pins. The SAF line will include necessary support systems for nondestructive assay, SNM accountability, rapid chemical analysis, waste and scrap handling, maintenance, and material handling. All processing equipment and support systems will be combined to form an interdependent, fully integrated, automated and remotely operated fuel fabrication system. 14

Prior to introduction of feed materials to the fabrication line, an analysis and characterization of the feed will be performed. As the feed material progresses, automatic measurements of the quantity of SNM will be conducted and recorded in the process control and safeguards computers to maintain a continuous record for process monitoring and for safeguards and accountability purposes.

The SAF line is designed to minimize the spread of contamination and the threat of diversion. Process enclosures are designed for each subsystem. Glove ports and windows will be incorporated to allow for "hands-on" maintenance. All containment structures will have built-in shielding, and the process equipment will incorporate supplemental shielding as necessary to meet radiation exposure criteria.

SAF equipment is within contamination control enclosures physically located behind isolation walls that function as a secondary confinement barrier. Plant operating personnel are normally located in an operating corridor that is on the opposite side of the isolation wall or in the operations computer center where all process operations are monitored and coordinated. Under normal operating conditions, plant personnel located in the operating corridor can control and monitor the performance of process equipment. There will be no penetrations in the isolation walls that would provide direct access to the process equipment by the operators. Under abnormal conditions, the operator can utilize local controls that can be activated to control operation of the process equipment while visually monitoring its performance. If tooling changes must be made or when routine maintenance must be performed that requires the presence of an operator at the working face of the containment, the fuel material will be removed from the equipment as necessary to maintain personnel exposure limits and to minimize SNM access. 14

The mechanical assembly of the welded fuel pins produced by the SAF line into fuel assemblies will be performed in Building 308 on the Hanford Reservation. This is an existing, multi-purpose, plutonium facility that is safeguarded as described in 5.7.1.5. The first four cores of the FFTF were assembled into driver fuel assemblies here. The CRBRP assembly operation will produce no gaseous, solid or liquid radioactive or toxic effluents and will have no significant environmental impact.

Uranium dioxide feed material for the SAF line will be obtained by having existing UF_6 at DOE's diffusion plants converted at a to be determined commercial facility. For the purpose of estimating environmental impacts in Table 5.7-1, conversion is assumed to take place at the blanket fuel fabrication facility. The total uranium conversion capacity required to support the CRBRP fuel cycle, including blanket fabrication, on an annual average basis is 11MT.

Blanket fuel fabrication for the CRBRP will be carried out at a yet to be selected commercial facility. An average of approximately 70 blanket fuel assemblies will be required per year. There will be about 100 kg of uranium per assembly. Thus, a conservative throughput of about 7.5 MT/yr of uranium is assumed. For the purpose of estimating the environmental impacts in Table 5.7-1, the impacts of the model UO_2 fuel fabrication facility in WASH-1248 were apportioned to a 7.5 metric ton/year throughput. 14

5.7.1.2 CRBRP FUEL REPROCESSING

Demonstration of technology for reprocessing and recycle of LMFBR fuels is planned to begin a few years after the planned initial criticality of the CRBRP. The Department of Energy plans to demonstrate technology for commercial reprocessing of LMFBR fuels by reprocessing of CRBRP (and other) fuels in the Developmental Reprocessing Plant (DRP) (formerly called the Hot Experimental Facility). There has been some preliminary conceptual design of the DRP, sufficient for preliminary environmental analysis which 16
indicates that such a facility can be operated within existing and proposed environmental guidelines[8]. A description of the DRP design follows.

Study and plans to date for the DRP have focused on a new stand-alone facility at a new site. However, some preliminary thought has been given to constructing a "breeder head-end" (fuel receipt and storage, shearing, dissolution, feed clarification, first cycle solvent extraction, and waste processing) at an existing reprocessing plant, (e.g. at Savannah River, Hanford or Barnwell). Final decision on a "stand-alone," "breeder head-end," or alternative DRP will consider cost, environmental impact, impact on existing reprocessing plant programs, and importance of a reliable demonstration.

Reprocessing capacity for the DRP has been set at about 1/2 metric ton of heavy metal (MTHM) per day. This capacity is a compromise between the minimum that will permit scale-up to a production-scale operation with reasonable assurance of success, and the maximum that will permit a meaningful demonstration of reliable reprocessing systems with the limited quantities of LMFBR type fuels that will be available during the demonstration period. In order to provide economical operation during the early periods of operation and in order to have a full reprocessing load to provide an adequate demonstration of operability (300 day-per-year operation is contemplated), reprocessing of LMFBR fuels will be supplemented by reprocessing of LWR fuels in the DRP. 14

The DRP design is based on the following philosophy:

- The DRP will be a U.S. Government owned developmental fuel reprocessing demonstration facility
- Public and worker health and safety are of fundamental concern

- o Safety and safeguards-related features will be designed and will be constructed and operated in accordance with industrial standards applicable to nonreactor nuclear facilities. Nationally recognized codes such as the ASME, ANSI, and similar codes will be followed. The NRC Regulatory Guides, which provide guidelines in meeting those requirements, will be utilized.

- o The DRP will be operated and maintained within the constraints of 10 CFR 20 for radioactive effluents and personnel exposure, and of 40 CFR 190 for environmental standards for exposure of the general public to LWR generated radioactive material. The DRP is also designed to guidelines equivalent to the 10 CFR 100 accidental release limits for power reactors. Nonradioactive effluents will meet applicable state and local air and water quality standards. In addition, the ALARA principle 14
will be applied to this facility and its emissions.

- o The DRP will be a developmental facility. Operating flexibility, including the ability to change equipment, is needed to meet U.S. Government program objectives.

<u>DRP Support Facilities</u>. The DRP conceptual design includes all 16
of the facilities and services necessary for routine operation and maintenance of fuel storage and processing activities. The services include water supply, sanitary waste disposal, electrical supply, steam and compressed gas supply, access roads, rail spurs, etc. Support facilities include on-site maintenance shops, mockup areas, laboratory and routine analytical services, cooling services, warehouses, and offices. For reference the following capabilities have been included in the DRP conceptual 16
design.

DRP Fuel Receiving and Storage The DRP is capable of receiving and storing currently conceived types of spent oxide fuel assemblies from plutonium breeder reactors as well as from light-water reactors. The specific reactors and fuels that the DRP currently has capability for reprocessing are listed in Table 5.7-2. 16

The DRP is capable of receiving fuel assemblies that have cooled a minimum of 150 days. For purposes of calculating transportation impact however, the spent fuel and blanket was assumed to be shipped after 100 days, which is conservative.

DRP Fuel Shipping Cask Handling The DRP is capable of (1) unloading casks that have been shipped by either truck or rail, (2) removing road dirt and external surface contamination from casks upon receipt, and (3) decontaminating casks prior to shipment from the DRP. The DRP is capable of removing fuel from all of the casks which will be used to ship fuel from the reactors listed in Table 5.7-2. 16

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Capability is also provided to identify fuel assemblies for verification and inventory control, and to assay fuel assemblies for fissile material content.

DRP Fuel Storage A water-filled pool is provided with capacity to store enough fuel for 100 days of operations at 0.5 MT/day capacity with CRBRP-type fuel assemblies. The storage facility has provisions for detecting, handling, and canning (if necessary) suspect or known failed-fuel assemblies.

<u>DRP Cask Maintenance</u>. The capability to perform limited maintenance operations on shipping casks is provided. This capability is limited to removal and disposal of contaminated 16 coolant from casks and canisters; decontaminating the internal surfaces of casks; and limited repair of cask internals and externals.

<u>DRP Fuel Reprocessing</u>. The reprocessing facility initially provides equipment to reprocess fuel assemblies containing uranium, plutonium, and radioactive fission products, clad in either stainless steel or zirconium alloy. The process functions, as shown in Figure 5.7-2 are:

- Fuel receiving, cleaning, non-destructive assay and storage 16
- Mechanical processing and shearing
- Dissolution, feed clarification, and feed adjustment 14
- Solvent extraction for purification of uranium and plutonium
- Uranium oxide production
- Plutonium oxide production 16
- Reagent makeup and distribution
- Rework of off-specification process liquids 16
- Waste concentration and solidification
- Off gas treatment 16
- Recovery and recycle of water and nitric acid

<u>DRP Type of Process</u>. Separation of the fission products from the fissile and fertile material is based upon liquid-liquid solvent extraction. The conventional Purex process, modified as required for specific nuclear fuels, is the basic process. The Purex process utilizes a tributylphosphate (TBP) extractant in a normal paraffinic hydrocarbon (NPH) solvent. The uranium and plutonium products are converted to oxides in a form to be used directly in fuel fabrication.

Storage capacity for all oxide products is provided for 100 days of operation at the maximum production rate for the two oxide products stated above. Capacity to store liquid products temporarily for 30 days of operation is also provided. The design for storage and shipment of uranium and plutonium is in accordance with the requirements of 10 CFR 70, 10 CFR 73, and applicable Department of Energy Orders. 14

<u>DRP Process Liquid Recycle and Disposition</u>. Contaminated water 16
and acid used in the processes will be recovered, purified, and recycled to the extent practical. Water additions to the process will thus be minimized, and excess water will be decontaminated prior to release from the stack as a vapor. Radioactivity limits in the vaporized water are consistent with the design objectives for fission product emission. There are no radioactive liquid releases.

<u>DRP Waste and Effluents</u>. The DRP will be capable of being operated and maintained within the environmental constraints imposed by Federal, state, and local regulations. This specifically includes consideration of the provisions of 10 CFR 20 and 40 CFR 190 for routine operations, and 10 CFR 100 for accident conditions. Consistent with these regulations, effluent control systems were designed to provide overall plant confinement factors when processing typical breeder reactor fuel as shown in Table 5.7-3. The annual effluent releases from the DRP as a result of processing CRBRP fuel after 150 days of decay are also shown in Table 5.7-3. 16

<u>DRP Waste Management Systems</u>. The high-level liquid waste system 16
is designed to accommodate the wastes resulting from the liquid 14
reprocessing of 150 metric tons per year of heavy metal. The liquid waste storage capacity is designed for two years' processing capacity, concentrated to 200 gallons per metric ton 16
of heavy metal.

High-level liquid wastes are concentrated, solidified, and packaged for subsequent transfer to a Federal repository accordance with the requirements of Appendix F, 10 CFR 50.

16

Transuranic wastes and radioactive metal scrap originating from 16
the fuel, blanket and shield assemblies, process operations, and nonrepairable in-cell equipment will be consolidated and packaged for shipment to a Federal repository.

The overall size, weight, capacity, etc., of waste shipping casks to be handled by the DRP are not yet established.

Nonprocess, potentially contaminated wastes, such as change room showers, sink effluents, and fire-protection water discharges, are routed to a collection system for monitoring (and processing if required) to assure compliance with the effluent release
requirements. All liquid wastes discharged to the environment 14
will meet Federal and State requirements.

All solid wastes that are potentially contaminated are inspected,
processed or packaged, as required, and low level wastes will be 16
shipped to a suitable burial site.

Combustible wastes, including waste process organics, are treated by a suitable combustion process to reduce them to a noncombustible material for disposal. The remaining wastes will be packaged as required and sent to a suitable disposal site.

Environmental Impacts

The fuel reprocessing plant presented in the PFES (WASH-1535) was assumed to have a processing capability of five metric tons of heavy metal (uranium plus plutonium) per day, which would permit the plant to serve about eighty LMFBR power plants, each having a capacity of 1000MWe.

Environmental impact and public health effects, due to radiological emissions that would result from normal as well abnormal (accidents) operations of the DRP, having a throughput capacity of 1/2 metric tons of heavy metal per day, will be significantly less than those impacts from the much larger capacity reprocessing plant (five metric tons per day) described in the PFES. However, impacts on a unit capacity basis (i.e., per MWe) would be essentially the same as those given in the PFES.

For the purpose of estimating atmospheric radiological releases from reprocessing CRBRP fuel, gaseous radioactive effluents were calculated by applying the confinement factors of the model reprocessing plant in WASH-1535 to the average annual CRBRP fuel 14
source term (see Table 5.7-3). For comparison, we have also estimated the environmental impacts which would result where the CRBRP spent fuel reprocessed in the Development Reprocessing Plant (DRP).

Table 5.7-3 shows that the radiological releases from reprocessing CRBRP fuel in the DRP are similar to those for the model reprocessing plant. The bounding reprocessing impacts, those from the DRP, are included in Table 5.7-1. Other effluents from the reprocessing plant, provided in Table 5.7-1, were estimated by apportioning the effluents of the model plant in WASH-1535 to the 12 metric ton/year throughput required for CRBRP. These are expected to bound the actual CRBRP reprocessing impacts regardless of what reprocessing alternative is eventually used. 16

5.7.1.3 RADIOACTIVE WASTES FROM THE CRBRP FUEL CYCLE

Radioactive wastes are a by-product of the CRBRP fuel cycle. Table 5.7-4 summarizes the types, quantities, key constituents, and disposition of the wastes from the CRBRP fuel cycle. Table 5.7-5 compares the quantities of wastes expected to be produced in the CRBRP fuel cycle with those of the once-through and uranium-only recycle fuel cycles for LWR's. The following discusses the waste generated at each step in the fuel cycle and the environmental impacts from disposing of these wastes.

Adequate supplies of depleted uranium in the form of UF_6 are currently available at DOE enrichment plants to supply material for the CRBRP indefinitely. The depleted UF_6 is left over from production of enriched uranium for LWR's. No incremental waste generation nor environmental impacts are attributed to the CRBRP for production of this material. 14

Operation of the CRBRP does not require the use of enriched uranium for fuel material. This is an important difference between the LWR fuel cycle and the CRBRP fuel cycle. As such, the CRBRP fuel cycle generates no radioactive wastes nor environmental impacts from uranium production or enrichment.

Conversion of depleted UF_6 to UO_2 for CRBRP blankets is planned to be performed at the blanket fuel fabrication facility. As noted in section 5.7.1.1, both UO_2 for blanket fabrication and for fabrication of core fuel would be converted in this facility. 16
During UF_6 conversion, CaF_2 will be formed. This is the most significant waste generated at the blanket fuel fabrication plant.

The CaF_2 will be contaminated with about 0.01 μCi/gm of uranium. The 11 MT/year of CaF_2 generated by the CRBRP fuel cycle is based on the production rate of one metric ton for each metric ton of uranium processed as given in section 3.2.5, NUREG-0116[9]. The CaF_2 is expected to be disposed of at the blanket fabrication facility in bulk form. Based on the solubility of CaF_2, any uranium leached out would be present in the leachate at concentrations of about 10^{-3} of MPC, which is so low as to be insignificant as a potential radiation hazard (see WASH-1248, page E-16).

Operation of the SAF line is expected to produce about 200 m^3 of transuranic contaminated wastes per year[6]. As CRBRP requires about 65 percent of the SAF line capacity, about 130 m^3 of transuranic wastes will be generated from fabrication of the annual CRBRP core fuel. These wastes will be contaminated with uranium, plutonium, and daughter products to levels in excess of 10 nanocuries per gram. The CRBRP wastes will be partially compacted and packaged into about 145, 55 gallon drums annually. 14

The transuranic wastes generated from operation of the SAF line will be transported to an existing DOE transuranic waste storage site on the Hanford Reservation. Environmental impacts from operation of the Hanford Reservation are addressed in ERDA-1538, "Waste Management Operations, Hanford Reservation," December 1975. CRBRP transuranic waste (about 30 m^3 annually) will be a 16
small addition to over 155,000 m^3 of transuranic waste already in storage at the Hanford facility and will result in an insignificant incremental environmental impact compared with the totality of Hanford waste management.

As the LWR fuel cycle does not involve plutonium recycle, as yet, a key difference between the LWR and CRBRP fuel cycle is the generation of transuranic contaminated wastes from fuel fabrication. This difference is evident from Table 5.7-5. For the purpose of estimating the environmental impacts from this unique CRBRP fuel cycle waste stream, it was assumed that these wastes would be ultimately disposed of in a Federal respository. The environmental impacts from disposing of about 85,000 m^3 of transuranic waste in the proposed Waste Isolation Pilot Plant[10] were apportioned to the 130 m^3 annual generation rate for CRBRP, and included in Table 5.7-1.

Wastes generated at the CRBR plant are addressed in section 3.5. Low-level wastes from the plant will be transported to a shallow land burial site for disposal. An estimate of the environmental impacts from disposal of these wastes is based on section 4.7.3.4 of NUREG-0116[9]. Disposal of this waste will require the commitment of about 0.006 acres of land annually. As indicated in the reference, the routine atmospheric effluents from disposal of low-level wastes are insignificant.

Appropriate fuel reprocessing capability is expected to be available in time to support the CRBRP fuel cycle. No need to supplement the approximately 4 years of spent fuel storage capacity at CRBRP with away from reactor storage is anticipated. Thus, no wastes are identified from operation of such a facility to support the CRBRP fuel cycle. 14

The types and quantities of waste in Table 5.7-5 from reprocessing were estimated based on the conceptual DRP design. The DRP is expected to generate about 25 m^3 of miscellaneous low-level wastes annually in support of the CRBRP fuel cycle. These wastes will be generated from fuel storage, handling and cleaning operations prior to reprocessing. The key contaminants are short lived fission and activation products with a total activity level typically of 10Ci/m^3. The low-level wastes will contain less than 10 nanocuries per gram of transuranic contaminants.

For the purpose of estimating environmental impacts, it is assumed that the low-level wastes will be fixed in concrete, packed in about 120, 55 gallon drums annually, and shipped to a shallow land burial facility for disposal. Based on the analysis in section 4.7.3 of NUREG-0116, the reprocessing plant low-level wastes will require the commitment of approximately 0.0025 acres of land annually and result in insignificant routine atmospheric effluents.

Metal scrap waste is generated at the DRP consisting of hulls and hardware from fuel element and in-vessel component disassembly and nonrepairable in-cell equipment. The bulk of this waste, that from fuel element disassembly, will be contaminated with about 0.05 percent of residual fuel material and with activation products formed during irradiation. The metal scrap is expected to have a total activity of about 4×10^5 Ci/m^3. For the purpose 14
of estimating environmental impacts, the metal scrap is assumed to be partially compacted, packaged into about 102, 10 inch diameter by 10 feet high stainless steel cylinders annually and shipped to a Federal repository for disposal.

Operation of the DRP also produces some transuranic contaminated wastes. Essentially all wastes produced from operation of the plant, except for fuel storage and handling, are assumed to be contaminated with greater than 10 nanocuries per gram of transuranics as well as fission and activation products. These wastes range from 1000 Ci/m^3 to 10^6 Ci/m^3 in total activity. For the purpose of estimating environmental impacts, these wastes are assumed to be fixed in concrete, packaged in 50, 55 gallon drums annually, and shipped to a federal repository for disposal.

Approximately 1 m^3 of solidified high-level waste is expected to 16
be generated from reprocessing CRBRP fuel on an annual average

basis. The high-level waste will be fixed in a matrix with a very low leach rate (such as borosilicate glass) and packaged in 12-inch diameter by 10 feet long stainless steel cylinders for disposal at a Federal repository. When overpacked for disposal, these cylinders occupy about 0.55 m^3 each. About six cylinders of high-level waste will be produced annually from CRBRP fuel reprocessing. The volume for disposal is, therefore, about 3.3 m^3 annually. A typical 2000 acre (800 hectare) repository could contain about 100,000 such cylinders. 14 16

The key constituents of CRBRP high-level waste are in Table 5.7-6. These were assumed to contain 10% of the tritium, 0.5% of the uranium and plutonium, and all of the non-volatile fission products and other transuranic elements. The fuel was conservatively assumed to be reprocessed 150 days after reactor discharge and the waste is stored as a liquid until solidification 1 year after discharge from the reactor.

NUREG-0116 estimates the environmental impacts from disposal of the transuranic and high-level wastes from reprocessing LWR spent fuel in a uranium only recycle mode. For this NRC study, the plutonium produced in the LWR is assumed to be disposed of with the high-level wastes in a geologic repository. The constituents of this high-level waste are shown for comparison to those generated from reprocessing CRBRP fuel in Table 5.7-6. These constituents were assumed to contain all of the non-volatile fission products and transuranic elements, 0.5 percent of the uranium and all of the plutonium for spent fuel 1 year after reactor discharge given in NUREG-0116, Appendix A. 16 16

It is evident from Table 5.7-6 that most CRBRP high-level waste constituents are enveloped by the constituents of LWR high-level wastes from U-only recycle. There are two exceptions. Cm-242 has a relatively short half life and can be expected to decay to negligible levels before any significant release would be anticipated from the waste package. The second is 16 16

Am-241. Am-241 is a daughter product of the much shorter half-life Pu-241, of which the LWR waste has much more than that from CRBRP. As such, the Am-241 in LWR wastes will surpass that in CRBRP wastes in less than 1 year. The environmental impacts of disposal of CRBRP high-level wastes are therefore expected to be similar to those from the LWR high-level wastes given in NUREG-0116. 14

Similarly, the environmental impacts from geologic disposal of transuranic contaminated and metal scrap waste from LWR fuel reprocessing envelope the impacts from disposal of similar CRBRP wastes. The impacts included in Table 5.7-1 for geologic disposal of fuel reprocessing plant wastes are those calculated in section 4.4 of NUREG 0116.

The DRP does not vent all of the Kr-85 and I-129 in the CRBRP spent fuel to the atmosphere. Instead, Kr-85 is captured and implanted in a metal (nickel-lanthanum alloy) matrix by a sputtering process.(11) The metal matrix containing the krypton is loaded into 9 inch diameter by 65 inch high steel cylinders. Approximately one cylinder will be generated for every 28 years of CRBRP operation. These cylinders are expected to be disposed of at a federal geologic repository. 16

I-129 will be fixed in concrete as barium iodate and packaged in about 0.05, 55 gallon drums annually. This waste stream will be sent to a Federal repository for disposal.

For the purpose of estimating the environmental impacts of waste management in Table 5.7-1, the captured Kr-85 is assumed to be retained within the metal matrix for a period of 100 years. After this time, the remaining krypton (about 55 curies) is assumed to escape to the atmosphere. 16

Disposal of the very long half-life (1.72 x 10^7 years) but low specific activity I-129 should not result in a significant incremental environmental impact over those estimated from 14 disposal of other wastes in the Federal repository.

The nonradiological environmental effects of the shipment of materials from the CRBRP fuel cycle are similar to those characteristic of the trucking industry in general. The CRBRP fuel cycle and waste transportation has been estimated to add 450,000 miles of transportation, including the return shipments of empty casks, shipping containers, and protective overpacks. Based upon NUREG-0116, the emissions from transportation are presented in Table 5.7-1.

5.7.1.4 DOSES FROM CRBRP FUEL CYCLE

Doses from Facility Operations CRBRP core fuel fabrication is planned for the SAF line. The SAF line is a portion of the FMEF. For the purpose of estimating atmospheric releases and doses from CRBRP core fuel fabrication, those resulting from operation of the entire FMEF were conservatively used. Actual releases and doses due to CRBRP core fuel fabrication would be a portion of those from the SAF line, which are a portion of those from FMEF operation.

Routine atmospheric releases of plutonium from FMEF are given in the following table.

Isotope	Annual Release[(6)] (Ci/yr)	Isotopic[(6)] Composition (%)	14
Pu-236	2.0×10^{-9}	8×10^{-6}	
Pu-238	4.3×10^{-6}	0.5	
Pu-239	2.2×10^{-6}	72.	
Pu-240	2.2×10^{-6}	20.	
Pu-241	3.0×10^{-4}	6.	
Pu-242	3.0×10^{-9}	1.5	

These releases are based on the above isotopic composition, release factors (from the SAF line) of 10^{-3}, and release factors 16
of 1.25×10^{-8}* (for 3 HEPA filters in series, where each HEPA filter would have a separate tested efficiency of 99.95%). The plutonium throughput used was 4 MT/yr, the total FMEF capacity. There are no liquid radioactivity releases associated with SAF line operation.

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*This is a conservative assumption. Actual release factors would range from 10^{-9} to 1.25×10^{-10}.

Routine atmospheric releases of uranium (total FMEF throughput of 6.0 MT/yr of uranium) and other radionuclides from the SAF line were calculated on essentially the same basis and are given below. Note that although depleted uranium is expected to be used for CRBRP fuel, natural uranium was conservatively used for those calculations.

Isotope	Annual Release(6) (Ci/yr)	Isotopic(6) Composition (%)
U-232	-	-
U-234	$5.8x10^{-11}$	$5x10^{-3}$
U-235	$2.5x10^{-12}$	0.72
U-236	-	-
U-238	$5.4x10^{-11}$	99.27
Th-231	$<2.5x10^{-12}$	-
Th-234	$<5.4x10^{-11}$	-
Pa-234	$<5.4x10^{-11}$	-

Accidental releases of radioactivity and resulting consequences are given in Reference 7. 14

The FMEF annual 50-year dose commitments to maximum individuals and the general population within 50 miles of the FMEF are as follows:

Organ	Maximum Individual Dose (millirem)	Population Dose (Man-rem)
Whole Body	$1.5x10^{-3}$	$4.6x10^{-3}$
Thyroid	$2.2x10^{-4}$	$9.0x10^{-4}$
Lung	$2.9x10^{-3}$	$1.1x10^{-2}$
Bone	$9.5x10^{-3}$	$4.0x10^{-2}$
Liver	$5.3x10^{-3}$	$2.1x10^{-2}$

Natural background and medical exposures would give an annual average exposure to individuals of about 150 millirem. The annual whole body population doses due to natural radioactivity would be about 25,000 man-rem for the year 2000 population within 50 miles of the FMEF.

Blanket fuel fabrication for the CRBRP will be carried out at a yet-to-be selected commercial facility. For purposes of this assessment, it is assumed that the commercial facility selected will have three stages of HEPA filters (with an efficiency of 99.9% per stage), yielding an overall confinement factor of 10^9. Atmospheric releases for blanket fuel fabrication calculated on this basis are given in the following table. 14

Isotope	Annual Release (Ci/yr)
U-234	-
U-235	3.2×10^{-11}
U-236	-
U-238	2.5×10^{-9}
Th-231	$<3.2 \times 10^{-11}$
Th-234	$<2.5 \times 10^{-9}$
Pa-234	$<2.5 \times 10^{-9}$

The releases are based on a 7.5 MT/yr throughput and isotopic composition of 0.2% U-235 and 99.8% U-238. This 7.5 MT/yr throughput is less than 1% of the annual throughput of the model fuel fabrication plant described in WASH-1248 (900 MT/yr), which could handle the fuel fabrication requirements of 26 light water reactors annually. Thus, CRBRP blanket fuel fabrication environmental impacts, on an annual basis, would be about 1/4 of the comparable impacts normalized to the model LWR fuel requirement given in WASH-1248.

The 7.5 MT/yr throughput provides the CRBRP radial blanket requirements. Although not fabricated into fuel rods at the blanket fabrication facility, an additional 3.5 MT/yr of uranium dioxide would be converted from UF_6 to UO_2 at this facility to supply the core fuel and axial blanket requirements. The total UO_2 conversion throughput would therefore be 11 MT annually. 14

The higher required capacity for UO_2 conversion would increase the land used, the gaseous release of F^-, the liquid chemical releases, and the liquid radiological releases of the blanket fuel fabrication facility. These impacts in Table 5.7-1 were calculated to be 1/3 of the comparable impacts normalized to the model LWR fuel requirement given in WASH-1248.

16

The 50-year dose commitments to maximum individuals and the general population within 50 miles of the model LMFBR fuel reprocessing plant in WASH-1535 for atmospheric releases given in Table 5.7-3 would be as follows per year of reprocessing of CRBRP fuel: 16

Organ	Maximum Individual Dose (millirem)	Population Dose (Man-rem)
Whole Body	0.06	1.01
Thyroid	0.87	9.0
Lung	0.10	1.02
Bone	0.15	2.33
Liver	0.08	1.38

Natural background exposures would give an annual average exposure to individuals in the vicinity of the model plant site of about 102 millirem.[12] The annual whole body population dose due to natural radioactivity for the population within a 50 mile radius of the model plant is estimated to be 1.02×10^5 man-rem.[12]

It should be noted that there would be no liquid releases of radioactivity from the model plant. The C-14 released would produce a world-wide population dose commitment, over all time, of 37 man-rem, based on a constant world population of 6×10^9 people.[13] 14

The doses associated with reprocessing spent CRBRP fuel in the DRP were calculated assuming the model fuel reprocessing plant site described in WASH-1535. Conservative confinement factors were chosen to estimate radioactivity releases. Table 5.7-3 gives information on confinement factors and atmospheric releases of radioactivity associated with reprocessing CRBRP fuel in the DRP.

The 50-year dose commitments to maximum individuals and the general population within 50 miles of the DRP at the model LMFBR fuel reprocessing plant site for these atmospheric releases would be as follows: 16

Organ	Maximum Individual Dose (millirem)	Population Dose (Man-rem)
Whole Body	0.06	1.01
Thyroid	3.9	81.2
Lung	0.10	1.02
Bone	0.15	2.33
Liver	0.08	1.38

Natural background exposures would give an annual average exposure to individuals in the vicinity of the model plant site of about 102 millirem.[12] The annual whole body population dose due to natural radioactivity for the population within a 50 mile radius of the DRP is estimated to be 102,000 man-rem.[12]

It should be noted that there would be no liquid releases of radioactivity from the DRP. The C-14 released would produce a world-wide population dose commitment, over all time, of $3.7x10^3$ man-rem, based on a constant world population of $6x10^9$ people.[13]

Note that the DRP doses differ only slightly from those resulting from the model reprocessing plant, primarily due to use of different confinement factors for C-14 and I-129.

Impacts from high level waste product solidification are included within the total impact from operation of the reprocessing facility. 14

Doses from Transportation Impacts from transportation of new core assemblies (based on 84/yr of fuel and 72/yr of blanket) to CRBRP, from operation of CRBRP and from transportation of spent core assemblies from CRBRP are identified in Section 5.3.

This dose impact conservatively assumes that no partial shipments occur, and that all shipments contain 6 assemblies. Hence, the number of assemblies assumed in calculating the radiation impact is greater than that described in Section 3.8. 16

The transportation of irradiated fuel assemblies by rail, as described in Section 3.8, has been selected over shipment by truck as a result of a cost/benefit analysis. The comparison has been made between a multiple-assembly, rail-car transported cask and a single-assembly, truck transported cask. Shipment using a single-assembly, truck-transported cask was eliminated from consideration due to the higher number of shipments required. This higher number of shipments increased (1) the operational costs of mating the cask both to CRBRP and to the fuel reprocessor, (2) the radiation exposure to the personnel handling the cask at both the CRBRP and the fuel reprocessing site, and (3) the transportation radiation exposure. Furthermore, weight limitations imposed on a truck, with resultant limits on shield thicknesses, would require decay of the irradiated fuel assemblies beyond 100 days.

The doses from transportation of wastes from reprocessing are given in Table 5.7-7.

The transuranic wastes from core fuel fabrication are to be stored at the DOE's Hanford Reservation. Transportation from the fuel fabrication plant to the waste management site occurs over a route completely within the Hanford Reservation. As there are no permanent inhabitants along this route, there will be only minimal public exposure from this transportation phase. However, to be conservative, doses from transportation of the transuranic wastes from the core fuel fabricator to a repository have been calculated and are presented in Table 5.7-7. 14

The calculational approach identified in NUREG-0170 was used to determine the population doses due to all different phases of the fuel cycle. The assumptions made for these calculations are as follows:

Shipment of New Fuel from Fabricator by Truck (SST)

Shipment Parameters	High Population Areas	Med. Population Areas	Low Population Areas
Average Speed (MPH)	30	50	55
Population Density (person/mile^2)	10,000	2,000	15
Fraction of distance traveled	0.05	0.05	0.90
One way traffic per hr.	3,000	800	500

14

Additional Assumptions:

- Fuel/food stops in population areas of 200/mile^2, 4 hr/day.
- 14 shipments/year, 2500 miles
- Shielding of new fuel gives same external dose as for spent fuel shipping cask. Dose Rate Factor - $K = 10^3$
- Four lane traffic exists only in high population zones. This contributes 2% of high-population traffic.
- Shipment duration 2.5 days.

Shipment of New Blanket from Fabricator by Truck

Shipment Parameters	High Population Areas	Med. Population Areas	Low Population Areas
Average Speed (MPH)	30	50	55
Population Density (person/mile^2)	10,000	2,000	15
Fraction of distance traveled	0.05	0.05	0.90
One way traffic per hr.	3,000	800	500

Additional Assumptions: 14

- o All stops in low population areas for rest.
- o Fuel/food stops in med-population areas, 1 hr/day
- o 14 hr/day lay over
- o 12 shipments/year, 2500 miles
- o Dose Rate Factor K=10
- o Four lane traffic exists only in high population zones. This contributes 2% of high-population zones.
- o Shipment duration 5 days

Shipment of TRU from Fuel Fabrication Plant by Truck

Shipment Parameters	High Population Areas	Med. Population Areas	Low Population Areas
Average Speed (MPH)	30	50	55
Population Density (person/mile^2)	10,000	2,000	15
Fraction of distance traveled	0.05	0.05	0.90
One way traffic per hr.	3,000	800	500

14

Additional Assumptions:

- o All stops in low population areas for rest.
- o Fuel/food stops in med-population areas, 1 hr/day
- o 14 hr/day layover
- o 5 shipments/year, 2500 miles
- o Dose Rate Factor $K=10^3$
- o Four lane traffic exists only in high population zones. This contributes 2% of high-population traffic.
- o Shipment duration 5 days.

Shipment of Spent Fuel from CRBRP by Rail

Shipment Parameters	High Population Areas	Med. Population Areas	Low Population Areas
Average Speed (MPH)	15	25	25
Population Density (person/mile^2)	10,000	2,000	15
Fraction of distance traveled	0.05	0.05	0.90
Stop Duration (hrs)	0	0	36

14

Additional Assumptions:

- o 14 shipments/year, 2500 miles
- o Dose Rate Factor $K=10^3$
- o Per NUREG-0170, on-link persons dose considered negligible.

Shipment of Spent Blanket from CRBR by Rail

Shipment Parameters	High Population Areas	Med. Population Areas	Low Population Areas
Average Speed (MPH)	15	25	25
Population Density (person/mile^2)	10,000	2,000	15
Fraction of distance traveled	0.05	0.05	0.90
Stop Duration (hrs)	0	0	36

14

Additional Assumptions:

- 12 shipments/year, 2500 miles
- Dose Rate Factor - no credit taken for reduction in source strength compared to spent fuel. ($K=10^3$)
- Per NUREG-0170, on-link persons dose considered negligible.

Shipment of Irradiated Control and Removable Radial Shield Assemblies from CRBRP by Rail

Shipment Parameters	High Population Areas	Med. Population Areas	Low Population Areas
Average Speed (MPH)	15	25	25
Population Density (person/mile^2)	10,000	2,000	15
Fraction of distance traveled	0.05	0.05	0.90
Stop Duration (hrs)	0	0	36

14

Additional Assumptions:

- 4.5 shipments/year, 2500 miles
- Dose Rate Factor K=10
- Per NUREG-0170, on-link persons dose considered negligible.

Shipment of PuO_2 from Reprocessing Plant by Truck (SST)

Shipment Parameters	High Population Areas	Med. Population Areas	Low Population Areas
Average Speed (MPH)	30	50	55
Population Density (person/mile^2)	10,000	2,000	15
Fraction of distance traveled	0.05	0.05	0.90
One way traffic per hr.	3000	800	500

14

Additional Assumptions:

- Fuel/food stops in population areas of 200/mile^2, 4 hr/day
- 14 shipments/yr, 3000 miles
- Dose Rate Factor $K=10^3$
- Four lane traffic exists only in high population zones. This contributes 2% of high-population traffic.
- Shipment duration 3 days

Shipment of HLW from Reprocessing Plant by Rail

Shipment Parameters	High Population Areas	Med. Population Areas	Low Population Areas	
Average Speed (MPH)	15	25	25	
Population Density (person/mile^2)	10,000	2,000	15	
Fraction of distance traveled	0.05	0.05	0.90	14
Stop Duration (hrs)	0	0	36	

Additional Assumptions:

- 3 shipments/year, 2500 miles
- Assume 36 hour layover in train yards, 65 person/mile^2

Shipment of TRU and Metal Scrap from Reprocessing Plant by Truck

Shipment Parameters	High Population Areas	Med. Population Areas	Low Population Areas	
Average Speed (MPH)	30	50	55	
Population Density (person/mile^2)	10,000	2,000	15	
Fraction of distance traveled	0.05	0.05	0.90	
One way traffic per hr.	3000	800	500	14

Additional Assumptions

- o 24 shipment/year, 2500 miles
- o Dose Rate Factor $K=10^3$
- o 7 containers/shipment for TRU, 6 containers/shipment for metal scrap
- o All stops in low population areas for rest.
- o Fuel/food stops in med-population areas, 1 hr/day
- o 14 hrs/day layover
- o Four lane traffic exists only in high population zones. This contributes 2% of high-population traffic.
- o Shipment duration 5 days

Shipment of LLW from Reprocessing Plant by Truck

Shipment Parameters	High Population Areas	Med. Population Areas	Low Population Areas
Average Speed (MPH)	30	50	55
Population Density (person/mile^2)	10,000	2,000	15
Fraction of distance traveled	0.05	0.05	0.90
One way traffic per hr.	3000	800	500

14

Additional Assumptions:

- All stops in low population areas for rest
- Fuel/food stops in med-population areas, 1 hr/day
- 14 hr/day layover
- 2 shipments/year, 2500 miles
- Dose Rate Factor $K=10^3$
- Four lane traffic exists only in high population zones. This contributes 2% of high-population traffic.
- Shipment duration 5 days
- 882 ft^3 of material/year @ 0.3 Ci/ft^3
- 60 drums per truck

Doses to maximum individuals were calculated for the two different modes of transportation, truck and rail shipment. For truck shipments, the maximum allowable dose in the cab of an exclusive-use truck is 2 mrem/hr. The dose rate at 3 feet from the surface of a cask containing spent fuel is 10 mrem/hr. Assuming a crew member spends 9 hrs. per day in the truck cab and 1/2 hr. per day inspecting the shipment, the dose is calculated per trip as:

(trip/yr)(day/trip)[(9 hrs/day)(2 mrem/hr)+(0.5 hr/day)(10 mrem/hr)]

For rail shipment, it is assumed that the maximum individual would be a person in the yard where the train stops for rest. Assuming this person was three feet from the cask for the full duration of the stop, the maximum individual dose would be calculated as: 14

(10 mrem/hr)(stop duration)

The results of the calculations are presented in Table 5.7-7.

5.7.1.5 SAFEGUARDS AND SECURITY

The principal fuel cycle operations that will support the CRBRP* are fabrication of mixed-oxide fuel for the reactor core, fabrication of depleted uranium fuel for the radial blanket, reprocessing of spent fuel, transportation between the facilities and storage or disposal of radioactive wastes. The safeguards/security measures to be employed at the supporting facilities and during transportation are individually described.

The CRBRP must meet NRC requirements specified in the Code of Federal Regulations, 10CFR 50, 70 and 73. Each licensee is required to submit written plans and procedures for meeting these requirements to NRC. Upon approval, these become conditions of the specific license.

It is assumed that the mixed-oxide fuel for the CRBRP will be fabricated in DOE facilities and the spent fuel will be reprocessed in a DOE facility, subject to the safeguards/security requirements specified in DOE Orders 5630, 5631 and 5632. PuO_2 and fresh mixed-oxide fuel will be transported using DOE's Safe Secure Transport System. 14

The objectives of both NRC and DOE are "to provide high assurance that activities involving special nuclear material are not inimical to the common defense and security and do not constitute an unreasonable risk to the public health and safety." In 10CFR73.1(a), NRC describes, in broad terms, design basis threats for sabotage, theft and diversion. Performance requirements are further explained in 10CFR73.25 and 45.

*Safeguards for the CRBRP itself are described in Section 13.7 of the CRBRP PSAR

DOE material control, accounting and physical protection are required by the Energy Reorganization Act of 1974 to provide safeguards and security comparable to that required by NRC. DOE Order 5632.2, paragraph 5 states: "Policy and Objectives: It is the DOE policy to physically protect all special nuclear material against theft. This order is designed to facilitate effective safeguards and security systems through graded, performance-evaluated physical protection requirements for special nuclear material. The minimum standards have been so designed as to satisfy the policy requirements that the effectiveness of nuclear safeguards and security systems in DOE activities provide comparable effectiveness with that required of licensees by the Nuclear Regulatory Commission".

DOE facility operators, like NRC licensees, are required to maintain updated safeguards and security procedures manuals. These procedures and actual performance are reviewed and monitored by DOE safeguards and security personnel. Design basis 14
threats are useful for the drafting of procedures and for preliminary assessment of performance. DOE conducts on-going studies of potential adversary motivations, characteristics, and capabilities and supports a substantial program of research on and implementation of safeguards/security techniques and of assessment methodology.

Material access and vital areas are located within buildings of substantial construction. Except during processing, fuel containing plutonium is to be stored in vaults or vault-like rooms. The buildings that contain material access and vital areas are located within a protected area that is surrounded by two chain-link fences, surmounted with barbed wire. The entrances for personnel and vehicles to the protected area are under the control and supervision of security personnel in a hardened security post. A second hardened security post is located within the protected area. Outside the fence and the protected area is an isolation zone, so that activities outside of the fence can be observed, and a controlled area that is posted as Government Property. The protected and isolation zone are provided with intrusion detectors, lights, and CCTV or other means to detect intruders.

DOE employees will have "Q" clearances. Contractor employees will have "L" or "Q" clearances, depending on task assignments and responsibilities. Only authorized personnel are to be permitted to enter the protected area and only those having assignments within material access or vital areas can enter them. Persons, vehicles and packages entering the protected and inner areas are to be searched for contraband and similarly, on leaving, for concealed SNM.

Redundant communications are provided between the security posts, 14
security personnel on assignment elsewhere, and with off-site
security forces. At the DOE facilities under construction, there
will be other DOE or contractor security personnel, as well as
local law enforcement agency and state police personnel, nearby.

The material control and accounting systems for the proposed mixed-oxide fuel fabrication and reprocessing facilities will exploit the latest advances in remotely controlled, automated processing and near-real-time accounting techniques in the interest of quality control, safety, radiation protection, and safeguards. Personnel will only have access to the fuels when feeding materials into the process or loading out the products or when small samples are handled for chemical analysis. Special procedures and surveillance will be employed to deter and detect diversion (exit searches provide redundancy). The on-line nondestructive assay instrumentation will provide timely detection of any abrupt, or more protracted, loss of SNM. Items such as containers of PuO_2 or fresh or spent fuel assemblies will have identifying symbols. Seals will be employed where appropriate. Process lines will be shut down and cleaned out for physical inventories periodically, at which time any nuclear material, which may remain as "hold-up" in the equipment, will be confirmed by NDA measurements.

Fabrication of CRBRP Fuel

Two general types of fuel will be employed, driver fuel rods which contain plutonium in mixed-oxide pellets in the center section and depleted uranium-oxide pellets in both end sections and the blanket rods containing only depleted uranium-oxide pellets. The former will be fabricated at DOE facilities on the Hanford, Washington reservation. The latter will be fabricated at commercial facilities. Safeguards concerns pertain only to the fuel rods and fuel assemblies which contain mixed-oxide (MOX). 14

The DOE supplied plutonium may require conversion to stoichiometric plutonium dioxide (PuO_2) in an as yet undetermined DOE facility. A candidate facility for PuO_2 conversion is the Purex Reprocessing facility at the 200 East site of the Hanford reservation.

The PuO_2 will be mechanically blended with uranium-dioxide (UO_2), and processed into pellets. The pellets will be inserted into fuel rods and the rods will be sealed and examined in the Secure Automated Fabrication (SAF) line, which is located within the Fuel and Materials Examination Facility (FMEF).

The finished MOX fuel rods are to be transported to a third facility, the Fuel Development Laboratory (Building 308), where the rods may be examined by NDA, and mechanical operations will be performed to produce fuel assemblies. 16

The contract guard forces at all of the Hanford sites are managed by the Rockwell Hanford contractor. The whole reservation is posted Government Property. Guard posts and patrols communicate with each other and with the security office in the DOE Richland Operations Office, so that reactions to threats will be efficiently coordinated. 14

Significant amounts of SNM are frequently transported between buildings and between the security areas. Such transfers are made in dedicated vehicles with armed patrol escorts to meet or exceed the security requirements of DOE Order 5632.

Since the exact location and design of the conversion process are not determined at this time, the material control and accounting activities can only be described generically. Like the pellet fabrication equipment, which has been designed and is under construction, the chemical conversion stages and calcine oven will be designed for remote operation and control and equipped with instrumentation for unit process material accounting. Whenever operators have access to the materials, they will be accompanied by material control and health physics personnel. The feed and products will be measured by weight, and samples will be analyzed for SNM concentration. Feed, product, scrap and waste will also be measured by non-destructive analysis (NDA).

Probably the process area will be treated as one material balance area, with an item control storage vault for items not being processed. The equipment will be shut down and cleaned out periodically for physical inventory.

Items (feed, product, scrap) will be counted and verified by NDA as frequently as may be desired. The on line unit process accountancy data and bulk/chemical analysis data will be continuously fed to a computer and analyzed for abrupt and protracted losses. For an annual throughput of 1500 kg or less of plutonium, the daily throughput would be about 5 kg. 14

An often quoted study[14] of 1975, based on achievable measurement accuracies and frequent draindowns, rather than the use of on-line NDA, suggested that the limit of error of the material unaccounted for (LEMUF) should be approximately:

LEMUF

	% of throughput	kilograms
1 week	1.5%	0.5 kg
1 month	0.5	0.7 kg
6 months	0.3	2.25 kg
1 year	0.2	3 kg

Many simulated studies of the DYMAC system, and experience at a somewhat similar instrumented process at Los Alamos, suggest that the shorter time sensitivities for loss or diversion may be rather more sensitive than this.

The fabrication of CRBRP Mixed Oxide (MOX) fuel is planned for the Secure Automated Fabrication (SAF) line which will be installed in the Fuels and Materials Examination Facility. Welded fuel pins from the SAF line will then be assembled into fuel assemblies in Building 308 at DOE's Hanford Reservation.

The SAF process line will be fully automated from the blending of powders through the sintering and examination of pellets, and equipped with sensors so that material balances can be drawn about individual processes and for the whole material balance area every day. Whenever operators have access to the materials, they will be accompanied by material control and health physics personnel. 14

It is planned to analyze the PuO_2 containers received from the conversion facility using a calorimeter and a gamma-ray neutron instrument. Finished rods will be scanned, using active interrogation, to measure the plutonium content and the location and quality of the MOX pellets. Scrap and waste containers will be measured by NDA. Samples of the PuO_2 feed, intermediate products, pellets and recoverable scrap will also be measured by weight and analysis of samples. The equipment will be shut down and cleaned out for physical inventory periodically. At that time, the plutonium which remains trapped in the pipes and vessels will be analyzed by NDA survey instruments.

The previously referenced study[14] predicted sensitivities to loss or diversion for a MOX fuel fabrication facility which are very similar to those given previously for a conversion facility. Again, simulation studies and experience with DYMAC at a similar process area at Los Alamos suggest that the short and intermediate time (1 day to 1 month) sensitivity of the system being installed at the SAF line should be somewhat superior to this. Actual measurement data and material balance calculations for an operating MOX fuel fabrication facility indicate that the LEMUF for one year of operation was 0.2% or less of the annual throughput.(15) This suggests the capability to detect diversion of 3 kg of plutonium in one year.

The SAF line will incorporate provisions for safeguards and accountability of SNM throughout the fabrication process. The following features will be included: 14

- One Material Balance Area (MBA) will be established on the 70-ft. level of FMEF containing the SAF line.

- The SAF Line MBA shall generate data that details the quantity of SNM received into the MBA, shipped from the MBA or remaining in the MBA. All SNM entering and leaving the MBA shall be measured by both the shipper and receiver, unless the SNM is in a container sealed with a Tamper Indicating Device (TID).

- SNM will be carefully characterized before it enters the SAF Line MBA. SNM will travel through the processing operations using item identification and weight as the primary accountability measurements.

- In instances where weight and item identification do not sufficiently identify the SNM (i.e., scrap and waste), nondestructive examination of the material will be required.

- Unit Process Accountability areas (UPAAs) will be established around each processing step within the SAF Line MBA. Generally, these will coincide with boundaries established for the purpose of criticality control.

- All SNM entering and leaving UPAAs will be measured. When SNM leaving a UPAA enters another UPAA through a common point, only a single measurement is required.

- Data on all SNM movement within the SAF Line MBA will be available such that a material balance can be drawn around each UPAA within 24 hours.

Transportation of Fresh MOX Fuel

Under contract with Project Management Corporation for the CRBRP, DOE maintains ownership of the fuel for the initial core and first four reloads, and is responsible for delivery of the fuel to the plant. Since October 1976, DOE has required that all shipments of more than two kilograms of plutonium or uranium-233, or five kilograms of uranium-235 in high-enriched uranium, should be made in Safe Secure Transport vehicles with armed escorts and monitored by the DOE radio-communication system. The vehicles are similar to those being used for secure transport of nuclear weapons, and provide a level of assurance in excess of that associated with commercial shipment (10CFR 73.25 - .37). The CRBRP fresh fuel shipments will use the DOE system, which includes the following security measures: 14

1. The fresh fuel will be carried in a special penetration-resistant vehicle. The vehicle includes active and passive barriers to protect the cargo, crew compartment armor, and means to immobilize the vehicle.

2. The cargo vehicle itself contains two reliable and trustworthy armed couriers (both drivers) and will be accompanied by a minimum of one escort vehicle carrying three additional armed couriers (all drivers).

3. Couriers are carefully selected for reliability, trustworthiness and physical fitness, and are specially trained, equipped, and armed.

4. Shipments are under the direct control of a central dispatcher. A system for redundant, all-weather communication between shipments anywhere in the continental United States and the dispatcher is in operation. It provides for 2-way communications, and for emergency signaling under duress. Communication is by means of an 14
array of widely-spaced transmitter-receiver stations connected by land lines to the central dispatcher, with automatic switching and acknowledgement. Both escort and cargo vehicles can communicate with the dispatcher, and routine reports are submitted at frequent intervals.

5. Specific standing arrangements are in effect with state police and certain other local law-enforcement agencies to provide timely response in emergencies. Studies have been made to determine expected response times at various locations; operations have been geared to realistic response-time estimates. Liaison is maintained with other Federal agencies to facilitate further support in extreme emergencies.

Spent Fuel Transportation

Irradiated (spent) fuel removed from CRBRP represents a small incremental risk over other fuel cycle operations. The spent fuel is hot, both radiologically and thermally, and therefore requires special equipment for even the simplest handling operations. The material is highly unattractive as a target for diversion, since chemical and mechanical operations requiring expensive complex facilities and equipment are required to reduce it to a usable form. Spent fuel assemblies would be transported and protected in large casks weighing many tons. Irradiated fuel assemblies would be contained in a removable canister inserted in the cask. The fuel casks will be designed to be transported on a 100-ton capacity railroad flatcar. The cask/car combination will be designed in accordance with DOT and NRC regulations, which include provision for crash protection and passive cooling capability. Specific elements which will serve to protect the spent CRBRP fuel while in transit in the cask include multiple heavy steel shells, a thick, dense gamma (radiation) shield, a liquid jacket and sacrificial impact absorbers. These protection elements, while designed to enable the irradiated fuel to withstand crash, also provide substantial protection against sabotage. 14

Even though the CRBRP casks would be very massive and difficult targets for sabotage, the threat of sabotage still exists. The diversion of CRBRP spent fuel for conversion of its plutonium to weapons-grade material is not considered a likely scenario since complex, chemical and mechanical equipment and facilities would be required for this conversion.

Casks designed to carry LWR spent fuel have been shown through experiment to provide significant protection from credible, intentional destructive acts. Experiments have shown that these casks do limit consequences of intentional acts to levels considerably less than those that had been estimated using conservative engineering judgment and to levels that are less than the consequences of the explosive blast associated with the intentional act, itself.

It is likely that the CRBRP spent fuel casks will be even more massive and difficult to penetrate than LWR casks. In any case, since the spent fuel will be owned and shipped by the Department of Energy, the CRBRP spent fuel shipments will be subject to physical protection requirements equivalent to those of the NRC found in 10CFR73.37. The purpose of these requirements is to minimize the chances of a successful, intentional destructive act.

Radioactive Wastes

14

Because of the low concentration of plutonium and uranium in radioactive wastes, wastes are not considered attractive for diversion purposes. However, there are certain inherent safeguards features within radioactive waste handling and management procedures.

High level radioactive waste (HLW) will be stored within the physical security bounds of the reprocessing plant prior to shipment. Due to the relatively high radioactivity and thermal generation associated with HLW, transport to a repository will be accomplished in a similar fashion to spent fuel. At the repository, the physical security of the site as well as the remote location of the wastes deep underground should effectively deter diversion. Similarly, transuranic and low level wastes will be packaged in DOT approved shipping containers and transported from points of origin to disposal facilities, where they will be handled within exisiting physical security systems.

Chemical Reprocessing

The safeguards provisions of the reprocessing facility are expected to be similar to those for the model facility in WASH-1535 or those included in the design of the Developmental Reprocessing Plant (DRP) described below. 16

The safeguards system for the DRP will provide both physical protection and nuclear material control and accounting capabilities to satisfy Federal (NRC and DOE) regulatory requirements. In addition to traditional safeguards capabilities, the system will provide for the protection and control of classified matter and information, and the DRP plant and property (i.e., Government property). The system includes mechanisms and provisions for deterrence, detection, delay, communications, assessment, accounting, control, and response as 14
required to meet the above regulations plus anticipated future requirements. The DRP physical protection system includes security zones, facility architectural and design features, personnel and vehicle access control, intrusion detection and assessment, automated alarm reporting, surveillance, communications, and computer security.

Physical security zones include an isolation zone, a protected zone, a hardened area, no access areas, material access areas, vital areas and limited access areas. The isolation zone is an open area surrounding the protected zone except where support facilities for personnel/vehicle/rail egress and ingress control are provided. It will ensure that only authorized entry is made to the protected zone and will detect unauthorized entry attempts. This zone will be bounded by two chain link fences and will be clear of all objects that could conceal or shield an individual.

The isolation zone will be equipped with intrusion detection equipment and closed-circuit television (CCTV) to allow rapid reviewing and assessment of this zone. This zone also has a vehicle barrier, exterior to the outer of the two zone fences, designed to prevent forced entry with automobiles or light trucks.

The protected zone is the area totally enclosed by the isolation zone that contains the Process Building (the hardened Process Building shell included), the open area between the Process Building and the isolation zone boundary fence and any other support structures within the area surrounded by the isolation zone.

The protected zone is further subdivided by the hardened area. The hardened area is the portion of the Process Building enclosed within a tornado missile barrier. This includes the hardened 14 shell of the main Process Building and the hardened control centers. Normal and routine entry is restricted through a hardened guard station, at the hardened shell perimeter.

The facility architectural and design features assure that significant quantities of SNM are physically separated from all personnel during normal operations, and access control to the security areas is provided. The natural phenomena barrier that encloses most of the Process Building is a major barrier of the safeguards system. The limited number of entrances to this hardened area controls access to the Process Building.

The entry-control system will allow surveillance, monitoring and control of personnel, vehicles and materials to and from the controlled zone, the protected zone, the Process Building, and the hardened areas. Vehicle inspection portals exist at entries to the protected zone to allow search of vehicles prior to entry and upon exit. Personnel access portals exist at entry and exit ways of security areas.

A defense-in-depth concept for physical security depends on the use of electronic devices to detect intruders at each level of defense. Alarms given by the system are both audible and visual and all are received at the safeguards control center and the secondary alarm station. The intrusion detection system consists of exterior and interior intrusion detectors and CCTV cameras, secure signal transmission, alarm assessment and display equipment and alarm and CCTV recording equipment. This system will be used to detect unauthorized entry into the controlled zone, isolation zone, and protected zone. Interior alarms will annunciate in the continuously-manned safeguards control center 14
and at the secondary alarm station.

To ensure immediate reporting and assessment of possible attempts at intrusion, the intrusion detection sensors and key-card access control system will report through a computer-initiated automatic-alarm switching system. This system includes the computer, intrusion detection devices, key-card alarms, response action instructions and outline maps with closed-circuit television (CCTV) surveillance and alarm assessment system display.

Security surveillance of activities and processes involving special nuclear materials and/or impacting on security of these processes is a fully integrated safeguards system. Primary forms of surveillance used in the DRP will include:

- Guard force (fixed, vehicular and foot patrols)
- Management and supervisory observation
- Closed-circuit television (CCTV) surveillance, monitored and managed at the safeguards control center (SCC) and the secondary alarm station (SAS).

Full-time surveillance is employed for security barrier fencelines, the isolation zone cleared areas and entry/exit-ways through primary barriers.

The communications network for the DRP physical protection system will allow rapid and continuous communication among on-site security force personnel and between on-site and off-site response forces. Off-site communications needs are met using telephones for routine communications and a radio link for emergency communications. Similarly, a radio communication system consisting of base stations, mobile radios and hand-carried portable transceivers will meet on-site communication needs under most conditions. 14

Since the efficiency and effectiveness of the entry control and intrusion detection systems depend on automatic data processing, computer security will have a high priority in the overall safeguards system. Access to the computer facilities (the SCC or SAS) requires a key-card reader and digital code operated locking system. Safeguards computer transmission lines will be under constant line supervision and all panel boxes, connectors, etc., will be affixed with tamper-indicating devices or switches.

In addition to physical security, the DRP Safeguards System includes material control and accounting capabilities. Both passive and active material control features are included. Passive material control is accomplished by placing barriers or impediments between SNM and an inside adversary. All significant quantities of SNM are processed and stored in remotely operated cells which limit direct personnel access during routine operation. Active material control is accomplished by monitoring cell penetrations from sensitive process equipment to occupied areas for the presence of nuclear materials.

The DRP material accounting system will be based on a series of Material Balance Areas (MBA). The MBA is an identifiable physical area around which accurate SNM balances can be performed. The material balance areas will consist of a small
pool to store spent fuel assemblies, the chemical separation 14
equipment area, storage vessels for the uranium and plutonium nitrate products of the extraction-purification stages, the chemical processing equipment used to convert plutonium nitrate to plutonium oxide, product storage vault and the analytical laboratory.

All of the process equipment will be contained within massive shielding, operated under remote control, and with provision for remote repair and maintenance. Material control is achieved primarily by this containment. Where spent fuel, products or samples are handled, guards and/or materials control personnel will provide continuous surveillance. In addition, personnel and packages entering or leaving the operations areas will be subject to search for contraband and nuclear materials.

Material accounting will be on a near-real-time basis. Spent fuel assemblies will be accounted for as discrete, numbered items. After disassembly and dissolution of the pellets, an accurate measurement will be made of the volume of solution, the concentration of uranium and plutonium in the solution, and the isotopic compositions of both. For process control and accounting, the quantities of uranium and plutonium in the process vessels and intermediate buffer vessels will be continuously monitored. Intermediate nitrate products. oxide products and all waste streams will be measured.

Spent fuel assemblies are received and accounted for on an item identity basis. The plutonium content is booked at the values calculated by reactor operations until assemblies are dissolved and the actual U and Pu amounts are determined on the basis of solution volume and U and Pu concentration. PuO_2 products are measured by bulk and by concentration when the product containers are filled. The plutonium in product containers can also be measured reasonably accurately by NDA. 14

The chemical reprocessing and conversion processes will incorporate precise bulk/analytical measurements at the input, transfer and product output points. Combinations of NDA. process instrumentation. flow indicators and chemical analysis of samples from between process stages will provide the information for near-real-time accounting on a unit-process basis. The U and Pu content of wastes will be measured in various ways, e.g., NDA of hulls, bulk/sample analysis of hot liquid wastes, alpha counting for discharged reagents, etc. These measures will provide for timely detection of loss or diversion.

Based on their reprocessing plant experience and knowledge of traditional material accounting and measurements, McSweeney. et al[14] estimated in 1975 that the LEMUF could be expected to be about 1.4 percent of the throughput for 1 week, 0.8 percent for 1 month, 0.75 percent for 6 months and 0.7 percent for 1 year.

Since then there have been several developments which should improve the sensitivity, and which would be employed at the DRP. One is to improve the measurement of the volume of solution in the major liquid accountability vessels by design of the vessels themselves and by the use of modern instrumentation to measure bubbler pressures and to analyze this data with on-line computers. Such systems have been installed and used in the United States and Japan. The systematic error in such measurements should be 0.1 percent or less. The most difficult chemical concentration measurement has been that of the U and Pu concentration of the highly radioactive solution in the input accountability vessel. There have been significant advances in the quality of analysis of such samples for concentration and for the isotopic composition of the U and Pu.[16] Experience with near-real-time accounting techniques at the Tokai Reprocessing Plant in Japan and in "cold runs" at the AGNS, Barnwell, S.C. facility give confidence that the combination of improved input-output measurements with unit-process monitoring, real-time computer data analysis, and process simulation should substantially improve on the sensitivity for detection of shorter or longer term loses. 14

The LEMUF on 900 kg of Pu would be about 7 kg of plutonium for 6 months, using the McSweeney estimate. The improved measurement capabilities, along with improved data analysis methods, suggest that the short term and longer term diversion sensitivities should be substantially better than the 1975 estimates. Ellis[17] concluded that 5-day balances should have a limit of error (LE) of 2 percent. Over a period of a year, the random errors of individual measurements cancel out and the important factors are the systematic errors involved in calibrations of the accountability vessels and the accuracy of the standards used for sample analysis. It is anticipated that annual LEMUF would be substantially smaller than the McSweeney estimate.

It should be noted that it would be very difficult for any domestic adversary to divert any plutonium from the remotely operated, remotely maintained equipment or the storage areas in this facility. The near-real-time accounting system may have importance for international safeguards. For domestic purposes, the measuring and accounting system is more important for efficient operations. It serves to provide assurance that the physical isolation and protection systems continue to function effectively.

The 6-month or annual inventory balances and error limits referred to assume the shutdown and cleanout of the entire system at 6 month or 1 year intervals. At such a time, all material that it is possible to remove is transferred to vessels where it can be accurately measured. Some of the nuclear material will remain on the surface of pipes and tanks and in crevices. This 14
"hold-up" could be of the order of 0.1 percent of throughput.

Safeguards Costs

The incremental cost of safeguarding the facilities in the fuel cycle, apportioned to reflect the part of the facility operations dedicated to the CRBRP fuel cycle, are shown in Table 5.7-8. Costs are included for safeguarding facilities for fuel fabrication, fuel reprocessing, the CRBRP plant, and transportation of special nuclear materials (SNM) among the facilities. Both initial investment and annual operating costs are given in constant FY 1982 dollars. It is evident from the totals in Table 5.7-8 that the costs of safeguarding SNM in the CRBRP fuel cycle are a small portion of the total facility costs.

Costs are given separately for physical security of the facilities, the materials control and accounting (MC&A) provisions, and the guard forces. Physical security costs include such things as perimeter and entry controls, video surveillance and internal security systems. MC&A costs are those incremental costs of upgrading normal process control and monitoring instrumentation for safeguards application, non-secure software and communications systems, and the maintenance thereof. The guard force costs include salaries, benefits, overhead and equipment. The assumptions and bases for these costs are described below for each facility.

Fuel Fabrication

The CRBRP fuel pins are planned to be fabricated at the Secure Automated Fabrication (SAF) line, located within the Fuels and Materials Examination Facility (FMEF) at DOE's Hanford Reservation. The resulting fuel pins will be transported a short distance on the Hanford site to the 308 Building where they are formed into final fuel assemblies. The safeguards provisions at these facilities are described above. 14

The SAF line is an addition to the FMEF. Only the incremental costs for securing the SAF line are attributable to the CRBRP fuel cycle. The SAF line will share the FMEF perimeter security system, guard force center, display consoles, guard forces, etc.

The initial costs of installing the SAF physical security system include:

$0.5M - entry control portals, hand geometry controls, key card controlled doors, map displays, TV monitors, alarm processors, TV switchers, video recording equipment, electrically locked doors, sensors and closed circuit TV cameras.

$0.4M - installation of the above equipment
0.2M - software development
$1.1M

The annual cost of operating the SAF physical security system is estimated at 15 percent of the hardware costs for repair and maintenance, plus one additional guard per shift over that required for FMEF. The guard force operates on a 5 shift operation. Therefore, the additional guard per shift is expected to cost $250,000 per year. The annual cost for repair and maintenance is estimated to total $165,000. 14

The initial investment for the SAF MC&A system is estimated as:

$0.5M - computer
$1.0M - software development
$0.5M - upgraded measurement capability for safeguards purposes
$2.0M

The annual cost of operating the SAF MC&A system assumes one shift operation, except the sintering furnace will continuously operate.

$150K - repair and maintenance at 15 percent
$150K - computer software improvement
$200K - 2 supervisors
$480K - 8 technicians
<u>$100K</u> - analytical services
$1080K

As the CRBRP fuel cycle utilizes about 65 percent of SAF's operational schedule, only that portion of the above costs are included in Table 5.7-8.

The 308 Building is located within the 300 area at DOE's Hanford reservation. Based on discussions with the Hanford Engineering and Development Laboratory staff that operate the 308 Building, the physical security system costs for the 300 area are: a) initial investment - $7.5 million, b) annual repair and maintenance expense at 15 percent of the hardware cost - $1.1 million, and c) annual guard force expense - $3.2 million. The 300 area is manned by a staff of 70 guards. 14

Support of the CRBRP fuel cycle requires about 20% of the 300 area activities, and only that portion of the security costs are included in Table 5.7-8. The 20% figure is based on the 308 Building being about 1/3 of the major facilities in the 300 area requiring physical security (in addition to the 324 and 325 Buildings) and that CRBRP fuel cycle support requires about 65% of the fuel assembly capacity of Building 308.

The 308 Building MC&A system accounts for discrete, numbered items only. No liquid or powder process steps are involved and no volume, density or concentration measurements are required. As such, no costs are estimated for upgraded measurement capability. The initial investment for the 308 Building MC&A system is estimated at $0.5 million for MC&A equipment.

The annual cost of operating the 308 Building MC&A system is estimated as follows:

$75K - repair and maintenance at 15 percent of hardware
$100K - 1 MC&A supervisor
<u>$180K</u> - 3 MC&A technicians
$355K

Support of the CRBRP fuel cycle requires about 65 percent of the 308 Building fuel assembly capacity, and only that portion of the MC&A costs are included in Table 5.7-8.

The total fuel fabrication safeguards system costs in Table 5.7-8 are a summation of the appropriate portions of the costs for the SAF and 308 Building. 14

Reprocessing

The safeguards provisions for the reprocessing plant where CRBRP fuel is eventually processed will be similar to those described earlier for the DRP. Only very preliminary design information is available for the DRP. Detailed estimates of the DRP costs, including the safeguards provisions, have not been made. The following estimates of the costs of the DRP safeguards provisions are the best now available.

The initial cost of the DRP physical security system is expected to cost about $35 million. Maintenance and repair of this system is expected to cost approximately $1.5 million annually. The guard force is expected to consist of about 75 personnel at an annual cost of about $3.5 million.

The DRP MC&A system is estimated to cost $15 million initially. Operation and maintenance of this system is estimated to cost $5 million annually.

Support of the CRBRP fuel cycle will require about 8 percent of the DRP 150 tonne annual capacity. Thus, 8 percent of the above costs are included in Table 5.7-8.

Plant

The CRBRP safeguards provisions are described in PSAR Section 13.7. The following is a breakdown of the physical security system costs.

	Initial Investment	Maintenance and Operating	
Electronic Security System (includes CCTV, alarms, computers, access control electronics)	$ 1.80 M	$ 90 K	14
Gate House (less access control electronics) and Central Alarm Station	0.42 M	8 K	
Fencing and Related Items Such As Sewer Pipe Grating and Derailers	0.19 M	4 K	
Electrical (wiring, conduit, uninterruptible power supply, batteries)	1.33 M	66 K	
Communications	0.12 M	6 K	
	$ 3.86 M	$174 K	

Accountability of fissile and fertile material is inherent in the design of the CRBRP refueling system for reasons other than security. After inspection at receipt, the assemblies are not visually identified again until shipment of the irradiated assemblies. The assemblies are mechanically identified prior to insertion into the core and subsequent to removal from the core as part of the refueling controls. All movements of fuel within the plant are monitored and/or recorded on the refueling system computer for inventory purposes and to insure proper configuration changes. No incremental cost is assumed for safeguards accountability at the plant.

The CRBRP security force consists of:

1 -	Unit Chief
1 -	Operations Captain
1 -	Administration Captain
1 -	Training Officer
5 -	Shift Supervisors
5 -	Alarm System Monitors
55 -	Public Safety Officers
3 -	Clerk-Typists
72	Personnel

14

The initial investment of hiring, training and equipping this force is estimated to cost $47,000. The bulk of the security force will be onsite when the fuel arrives, approximately 9 months prior to fuel loading. The cost of guards during the year prior to criticality is estimated at $1.1 million. From the year of criticality onward, the guard force is estimated to cost about $2.1 million annually.

Transportation

The number of shipments per year for the different materials in the CRBRP fuel cycle are given on Table 5.7-7. Special safeguards measures are provided for the shipment of fresh fuel, PuO_2, spent fuel and spent blanket assemblies. The other materials transported within the CRBRP fuel cycle do not contain sufficient quantities of SNM to warrant special safeguards measures.

Transportation of new fuel and PuO_2 is planned using DOE's Safe Secure Transport (SST) system. As this system will have sufficient capacity and communications capability to accommodate CRBRP transportation requirements, no initial investment costs are anticipated. Operating costs for SST shipments are estimated to cost $18,000 per 2500 mile shipment, round trip.

Transportation of spent fuel and spent blanket assemblies require two escorts and appropriate communications devices. The incremental cost per escort for these provisions is estimated to be $50,000 per year. 14

The safeguards cost of transportation within the CRBRP fuel cycle is summarized below:

Material	Shipments/Yr.	Cost/Shipment	Annual Cost
PuO_2	14	18,000	252,000
Fresh Fuel	14	18,000	252,000
Spent Fuel	14	N/A	100,000
Spent Blankets	12	N/A	100,000
			$704,000

CRBRP Fuel Cycle - Socioeconomic Impacts

Fuel fabrication and fuel reprocessing are two key elements of the fuel cycle for the CRBRP. Since both activities involve utilization of facilities separate from the CRBRP, a generalized assessment of their potential socioeconomic impact is appropriate. Both of these facilities are intended to support the DOE Liquid Metal Fast Breeder Program by demonstrating those technologies and to serve the CRBRP during its operation.

The Secure Automated Fabrication (SAF) facility will be built as part of the Fuels and Materials Examination Facility (FMEF) which is currently under construction on DOE's Hanford Reservation near Richland, Washington. Construction of the SAF facility will take
about 20 months and have a peak employment of about 250 persons. 14
Employment at full operation will be about 100. Currently, employment at the Hanford Reservation is about 10,000, and the population of the metropolitan Richland area is about 125,000. Given the small magnitude of the project and its work force and the relatively large population of the Richland area, there are no adverse socioeconomic impacts expected from construction or operation of the facility. The number of construction workers moving into the area, if any, would be a small fraction of the peak work force and would not be expected to cause a strain on services in such an urbanized area.

The Developmental Reprocessing Plant (DRP) would reprocess light 16
water reactor fuel in addition to serving the breeder program by demonstrating reprocessing technology and by reprocessing CRBRP fuel. The location for the DRP has not been selected although the likelihood is great that it will be a federally owned site. The Oak Ridge and Hanford Reservations are both under consideration. Construction of the facility is currently

scheduled to begin in late 1987 and be completed by 1996. The
peak construction force is projected to be about 3,700 and the
full operations work force about 750. A significant proportion
of the work force would be expected to move into the area and
create the potential for a temporary strain on community services
and facilities. A projection of the magnitude of any influx
cannot be made until a site is selected. However, over a decade
of surveys of TVA nuclear plant construction forces in rural
areas indicate that between 20 percent and 40 percent of the work
force could be expected to inmigrate. The likelihood for adverse 16
impacts is less likely if the facility is built in a relatively
urbanized area. For example, if the DRP were built on the Oak
Ridge Reservation, significant impacts would not be expected
because of the availability of local labor and the capacity of an
urbanized area's services and facilities to absorb additional
temporary population. Since the CRBRP construction force would
be decreasing as the DRP construction force is increasing, the 14
potential for cumulative impacts should not be great.

Based on TVA's experience, a higher proportion of the operations work force would move into the plant area, compared to that for the construction force. However, the actual number of inmoving workers and dependents would still be relatively small. Also, the construction force should be decreasing while the operations force is increasing. Thus, any increases in the capacity of local services and facilities to accommodate construction movers would be available to accommodate operations movers. After a site is selected, a more detailed analysis of potential construction and operations impacts will be conducted as part of the facility's Environmental Impact Statement.

5.7.2 POWER PLANT OPERATIONAL NOISE AND IMPACT

The CRBRP will contain a large number of sound sources, most of which will be well enclosed in thick concrete structures and will, thus, pose no noise problems. There are, however, several external sources of noise whose effect on the surrounding area is described in this section. Estimated ambient noise level, predicted CRBRP noise levels and impact assessment are discussed in subsequent subsections.

5.7.2.1 ESTIMATED AMBIENT NOISE LEVEL 6

The area on and around the plant site has an ambient noise level characteristic of a sparsely populated rural area. The only consistent source of non-natural noise is traffic on Interstate 40 which is about 1-1/4 miles from the center of the CRBRP Site at its closest approach. At the nearest dwelling to the CRBRP Site center, trucks passing on the interstate highway can be heard, but not cars. Based on measurements made in other similar rural areas, the average A-weighted ambient noise level is estimated to be 40-45 dBA. Traffic on the interstate is believed to be a major contributor to the ambient noise level.

5.7.2.2 PREDICTED NOISE LEVELS

The major sources of noise from the plant site will be the mechanical draft cooling towers, the turbine generator building and the main power output transformer. Arrangement of main plant structures is shown in Figure 2.1-4, and the location of these structures on the Site is shown in Figure 2.1-3. Cooling tower sound levels were determined from published references (also see Section 5.1.8.4). The transformer sound level estimates were based on the National Electrical Manufacturers Association (NEMA) transformer ratings. The sound levels from the turbine-generator building were based on estimates of the internal machinery noise level corrected for the transmission loss of the metal panel walls.

The radiated noise levels were determined by assuming that the 6
total sound power emitted by the plant, suitably corrected for directivity (geometry, location and orientation), is radiated hemispherically from the center of the plant site. The sound levels in the surrounding area were calculated by summing the contribution from each of the sources at each point of interest. Corrections were made for the shielding effect of the plant on the cooling tower noise and of the turbine-generator building on the transformer noise.

A correction for the molecular absorption of sound in air also has been included.[1] The magnitude of this correction was determined by assuming a sound spectrum for the cooling tower noise.[2] Because most of the area surrounding the plant site is and will remain heavily wooded, a correction for the ground attenuation was estimated and included in the calculated sound levels.[3] A significant change in the ground attenuation is anticipated with a seasonal change from summer to winter because of the loss of foliage from the woods.

The nearest dwellings to the CRBRP Site are located approximately 3,100 feet south-southwest of the plant site and approximately 3,200 feet west-southwest of the plant site. Both dwellings are at an elevation of about 800 feet MSL, one on each side of Poplar Springs Creek. The predicted sound level, due to normal plant operation alone, at both of these locations is 42 dBA in the summer and 45 dBA in the winter.

At radial distances greater than several thousand feet, contours of equal sound level are almost circular. At a radial contour one mile from the plant site center the predicted summer noise level from the plant is 37 dBA; the corresponding predicted winter level from the plant is 41 dBA. Ambient levels may be higher than these values particularly for locations nearer Interstate 40. The one-mile contour and the two nearest dwellings are shown in Figure 5.7-3. 6

5.7.2.3 IMPACT OF OPERATIONAL NOISE

The U.S. Department of Housing and Urban Development[4] has provided outdoor noise exposure guidelines for non-aircraft noise. Three categories of external noise exposure are defined. The categories and their respective noise limits are listed in Table 5.7-9.

Since the noise from the power plant is essentially constant, the "acceptable" category corresponds to sound levels below 65 dBA, the "normally unacceptable" category levels between 65 and 75 dBA and the "unacceptable" category corresponds to levels above 75 dBA.

Based on the predicted levels and contours described in Section 5.7.2.2, the population distribution from Table 2.2-2F and the peak resident and transient population from Table 2.2-9 and 14
Figure 2.2-7F, there will be no exposure of the permanent population or of the transient population including nearby recreation areas to noise levels above 65 dBA.

At many locations, particularly a recreation area at Caney Creek, the ambient noise from the interstate highway will exceed the noise produced by the plant.

The State of Tennessee and Roane County do not have any 6
regulations or zoning restrictions related to noise that are applicable to the CRBRP Site. The City of Oak Ridge has a zoning ordinance[5] which specifies that sound shall not exceed the decibel levels given in Table 5.7-10 when adjacent to the uses listed. The ordinance does not indicate whether the sound level limits are linear or A-weighted sound levels. The specified levels are assumed to be A-weighted values since the A-weighting simulates the response of the human ear and is thus used in most such ordinances.

To the north, the CRBRP Site property line adjoins the Clinch River Consolidated Industrial Park. The sound level contour shown in Figure 5.7-3 shows that the sound level at this property line will be significantly less than the specified limit in Table 5.7-10. The remainder of the area adjoining the Site is rural in character and separated from the Site by the Clinch River. The Oak Ridge ordinance does not specifically address this type of area. However, based on the predicted noise levels, the impact of the noise produced by the plant on the surrounding area will be negligible. 6

TABLE 5.7-1

CRBRP - SUMMARY OF ENVIRONMENTAL CONSIDERATIONS FOR FUEL CYCLE

Natural Resource Use	Fuel Fabrication: Mixed Oxide (Core Fuel)	Fuel Fabrication: Uranium Dioxide*** (Blanket)	Reprocessing****	Waste Management	Transportation	Total	
Land (acres)							
Temporarily Committed	—	0.07^{+}	10.0	1.3	—	11.37	
Undisturbed Area	—	0.05^{+}	9.0	—	—	9.05	
Disturbed Area	—	0.01	1.0	—	—	1.01	
Permanently Committed	—	—	—	2.3	—	2.3	
Water (gallons/day)							
Discharged to air	—	—	1.0×10^{3}	2.7×10^{2}	—	1.27×10^{3}	16
Discharged to water bodies	—	1.3×10^{4}	—	—	—	1.3×10^{4}	14
Discharged to ground	7.5×10^{2}	—	—	2.2×10^{3}	—	2.95×10^{3}	
Total Water	7.5×10^{2}	1.3×10^{4}	1.0×10^{3}	2.47×10^{3}	—	1.72×10^{4}	16
Fossil Fuel							
Electrical Energy (MW-hr/yr)	9.0×10^{3}**	4.2×10^{2}	—	5.3×10^{2}	—	9.9×10^{3}	
Equivalent Coal (MT/yr)	3.6×10^{3}**	1.6×10^{2}	1.3×10^{3}	2.0×10^{2}	—	5.26×10^{3}	
Effluents							
Chemicals							
Gases* (MT/yr)							
SO_x	133	5.8	0.4	6×10^{-2}	1.2	140	
NO_x	35.2	1.5	3.9	9.1×10^{-2}	15.4	56.1	
Hydrocarbons	0.36	1.5×10^{-2}	—	5.1×10^{-3}	1.6	1.98	
CO	0.86	3.8×10^{-2}	0.13	2.7×10^{-2}	9.4	10.5	
Particulates	35.2	—	—	6.5×10^{-2}	0.6	35.9	
F^{-}	—	$1.7 \times 10^{-3+}$	—	—	—	1.7×10^{-3}	

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TABLE 5.7-1 (Continued)

Effluents	Fuel Fabrication: Mixed Oxide (Core Fuel)	Fuel Fabrication: Uranium Dioxide*** (Blanket)	Reprocessing****	Waste Management	Transportation	Total
Liquids (MT/yr)						
H_2SO_4	$1.0x10^{-1}$	--	--	--	--	$1.0x10^{-1}$
HNO_3	$1.0x10^{-1}$	7.7^{+}	--	--	--	7.8
NH_3	--	2.8^{+}	--	--	--	2.8
F^{-}	--	1.4^{+}	--	--	--	1.4
PO_4^{3-}	$1.0x10^{-2}$	--	--	--	--	$1.0x10^{-2}$
PO_4^{3-} (after degrading)	$1.0x10^{-3}$	--	--	--	--	$1.0x10^{-3}$
Radiological (Curies/yr)						
Airborne						
Pu-236	$2.0x10^{-9}$	--	$1.36x10^{-9}$	--	--	$3.36x10^{-9}$
Pu-238	$3.4x10^{-6}$	--	$8.45x10^{-5}$	--	--	$8.8x10^{-5}$
Pu-239	$2.2x10^{-6}$	--	$2.14x10^{-5}$	--	--	$2.34x10^{-5}$
Pu-240	$2.2x10^{-6}$	--	$2.20x10^{-5}$	--	--	$2.42x10^{-5}$
Pu-241	$3.0x10^{-4}$	--	$2.55x10^{-3}$	--	--	$2.85x10^{-3}$
Pu-242	$3.0x10^{-9}$	--	$4.70x10^{-8}$	--	--	$5.0x10^{-8}$
U-232	--	--	$6.22x10^{-11}$	--	--	$6.22x10^{-11}$
U-234	$5.8x10^{-11}$	--	$1.62x10^{-9}$	--	--	$1.68x10^{-9}$
U-235	$2.5x10^{-12}$	$3.2x10^{-11}$	$7.84x10^{-11}$	--	--	$1.13x10^{-10}$
Cm-242	---	--	$5.42x10^{-4}$	--	--	$5.42x10^{-4}$
Cm-244	---	--	$7.16x10^{-7}$	--	--	$7.16x10^{-7}$

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TABLE 5.7-1 (Continued)

Effluents	Fuel Fabrication: Mixed Oxide (Core Fuel)	Fuel Fabrication: Uranium Dioxide*** (Blanket)	Reprocessing****	Waste Management	Transportation	Total
Radiological (Curies/yr)						
Airborne						
U-236	--	--	1.58×10^{-10}	--	--	1.58×10^{-10}
U-238	5.4×10^{-11}	2.5×10^{-9}	7.36×10^{-9}	--	--	9.9×10^{-9}
Th-228	--	--	1.20×10^{-12}	--	--	1.20×10^{-12}
Th-231	2.5×10^{-12}	3.2×10^{-11}	7.84×10^{-12}	--	--	4.23×10^{-11}
Th-234	5.4×10^{-11}	2.5×10^{-9}	2.36×10^{-10}	--	--	2.79×10^{-9}
Am-241	--	--	2.06×10^{-5}	--	--	2.06×10^{-5}
Np-237	--	--	2.08×10^{-10}	--	--	2.08×10^{-10} 14
Pa-234	5.4×10^{-11}	2.5×10^{-9}	7.36×10^{-10}	--	--	3.29×10^{-9}
H-3	--	--	5.51×10^{3}	6.8×10^{-6}	--	5.51×10^{3}
Kr-85	--	--	4.75×10^{3}	5.5×10^{1}	--	4.80×10^{3}
C-14	--	--	1.44×10^{1}	--	--	1.44×10^{1}
I-129	--	--	3.26×10^{-4}	--	--	3.26×10^{-4}
I-131	--	--	3.61×10^{-2}	--	--	3.61×10^{-2}
Ru-103	--	--	1.84×10^{-3}	--	--	1.84×10^{-3}
Ru-106	--	--	7.09×10^{-3}	--	--	7.09×10^{-3}
Cs-134	--	--	5.60×10^{-5}	--	--	5.60×10^{-5}
Cs-137	--	--	1.60×10^{-4}	--	--	1.60×10^{-4}
Rn-220	--	--	--	3.0×10^{-4}	--	3.0×10^{-4}
Rn-222	--	--	--	8.2×10^{-3}	--	8.2×10^{-3}
Particulate Fission Products	--	--	6.16×10^{-4}	1.1×10^{-3}	--	1.72×10^{-3}

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TABLE 5.7-1 (Continued)

Effluents	Fuel Fabrication: Mixed Oxide (Core Fuel)	Fuel Fabrication: Uranium Dioxide*** (Blanket)	Reprocessing****	Waste Management	Transportation	Total
Radiological (Curies/yr)						
Liquids						
U-Total	--	$6.7x10^{-3+}$	--	--	--	$6.7x10^{-3}$
Th-234	--	$3.3x10^{-3+}$	--	--	--	$3.3x10^{-3}$
Pa-234	--	$3.3x10^{-3+}$	--	--	--	$3.3x10^{-3}$
Solids (Ci/yr)						
Other than high level						
Alpha	$1.0x10^{5}$	--	$7.0x10^{5}$	--	--	$8.0x10^{5}$
Beta-Gamma	34.	--	40	--	--	74
High Level	--	--	$3.8x10^{6}$	--	--	$3.8x10^{6}$
Thermal Generation (Btu/yr)	Not Available	$2.2x10^{9}$	$1.6x10^{10}$	$5.9x10^{10}$	$8.50x10^{7}$	$7.72x10^{10}$ 14

*Based upon combustion of equivalent coal for power generation
**Total for FMEF operation
***Non-radiological estimates from WASH-1248, Table E-1 (divided by 4)
****Non-radiological estimates from WASH-1535, Vol. II, Section 4.4 (1500 MT/yr divided by 100, or 3 days of plant operation).
+ WASH 1248, TABLE E-1 (divided by 3), increased to include conversion of UF_6 to UO_2 to be used in core fuel fabrication.

Table 5.7-2

DRP ANTICIPATED THROUGHPUT

(per 24 hour day)

Reactor	Spent fuel, %	Element/ton	Fuel available, tons/yr	Fuel receiving, elements	Head-end, kg	Solvent extraction, kg	Pu conversion, kg	U conversion kg
FFTF	U 72 Pu 28	31.7	3 (30 total by 1991)	24	500	U 360 Pu 140	60	360
CRBRP core	U 83 Pu 17	17	4.7	24	500	U 415 Pu 85	60	415
CRBRP blanket	U 97.5 Pu 2.5	10	6.8	24	500	U 488 Pu 12	12	488
BWR	U 99 Pu 1	5.3	Unlimited	24	500	U 495 Pu 5	5	495
PWR	U 99 Pu 1	2.2	Unlimited	10	500	U 495 Pu 5	5	495
LDP core	U 78 Pu 22	7.8	18	10	500	U 390 Pu 110	60	390
LDP blanket	U 97 Pu 3	5.5	12	10	500	U 485 Pu 15	15	485
CRBRP core with Pu recycle	U 82 Pu 18	17	4.7	24	500	U 410 Pu 90	60	410

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TABLE 5.7-3

Atmospheric Releases from Reprocessing CRBRP Spent Fuel

Radionuclide	Input (Ci/yr)*	Model Reprocessing Plant Confinement Factor	Model Reprocessing Plant Release (Ci/yr)	DRP Confinement Factor	DRP Release (Ci/yr)	
H-3	5.51×10^{3}	1	5.51×10^{3}	1	5.51×10^{3}	
C-14	1.44×10^{1}**	10^{2}	1.44×10^{-1}	1	1.44×10^{1}	
Kr-85	4.75×10^{4}	10^{2}	4.75×10^{2}	10	4.75×10^{3}	
Sr-90	3.70×10^{5}	5×10^{9}	7.4×10^{-5}	5×10^{9}	7.4×10^{-5}	
I-129	3.26×10^{-1}	10^{4}	3.26×10^{-5}	10^{3}	3.26×10^{-4}	
I-131	3.61×10^{1}	10^{4}	3.61×10^{-3}	10^{3}	3.61×10^{-2}	
Ru-103	1.84×10^{6}	10^{9}	1.84×10^{-3}	10^{9}	1.84×10^{-3}	
Ru-106	7.09×10^{6}	10^{9}	7.09×10^{-3}	10^{9}	7.09×10^{-3}	
U-232	3.11×10^{-2}	5×10^{8}	6.22×10^{-11}	5×10^{8}	6.22×10^{-11}	
U-234	8.12×10^{-1}	5×10^{8}	1.62×10^{-9}	5×10^{8}	1.62×10^{-9}	
U-235	3.92×10^{-2}	5×10^{8}	7.84×10^{-11}	5×10^{8}	7.84×10^{-11}	
U-236	7.91×10^{-2}	5×10^{8}	1.58×10^{-10}	5×10^{8}	1.58×10^{-10}	
U-238	3.68	5×10^{8}	7.36×10^{-9}	5×10^{8}	7.36×10^{-9}	14
Pu-236	3.07	2×10^{9}	1.53×10^{-9}	2×10^{9}	1.53×10^{-9}	
Pu-238	1.69×10^{5}	2×10^{9}	8.45×10^{-5}	2×10^{9}	8.45×10^{-5}	
Pu-239	4.27×10^{4}	2×10^{9}	2.14×10^{-5}	2×10^{9}	2.14×10^{-5}	
Pu-240	4.40×10^{4}	2×10^{9}	2.20×10^{-5}	2×10^{9}	2.20×10^{-5}	
Pu-241	5.10×10^{6}	2×10^{9}	2.55×10^{-3}	2×10^{9}	2.55×10^{-3}	
Pu-242	9.40×10^{1}	2×10^{9}	4.70×10^{-8}	2×10^{9}	4.70×10^{-8}	
Cs-134	2.80×10^{5}	5×10^{9}	5.60×10^{-5}	5×10^{9}	5.60×10^{-5}	
Cs-137	7.99×10^{5}	5×10^{9}	1.60×10^{-4}	5×10^{9}	1.60×10^{-4}	
Th-228	5.98×10^{-3}	5×10^{9}	1.20×10^{-12}	5×10^{9}	1.20×10^{-12}	
Th-231	3.92×10^{-2}	5×10^{9}	7.84×10^{-12}	5×10^{9}	7.84×10^{-12}	
Th-234	3.68	5×10^{9}	7.36×10^{-10}	5×10^{9}	7.36×10^{-10}	
Am-241	1.03×10^{5}	5×10^{9}	2.06×10^{-5}	5×10^{9}	2.06×10^{-5}	
Np-237	1.04	5×10^{9}	2.08×10^{-10}	5×10^{9}	2.08×10^{-10}	
Pa-234	3.68	5×10^{9}	7.36×10^{-10}	5×10^{9}	7.36×10^{-10}	
Cm-242	2.71×10^{6}	5×10^{9}	5.42×10^{-4}	5×10^{9}	5.42×10^{-4}	
Cm-244	3.58×10^{3}	5×10^{9}	7.16×10^{-7}	5×10^{9}	7.16×10^{-7}	

* 150 days after discharge; fission products calculated with RIBD code; actinides calculated with ORIGEN code.

** 200 ppm N in fuel.

Table 5.7-4

Radioactive Wastes from the CRBRP Fuel Cycle

Facility	Waste/Form Containers	Annual Generation Volume(m^3)/# of Containers	Key Constituents	Disposition
Fuel Reprocessing Plant				
Low-Level	concrete/drums	25/120	Fission & Activation Products, 10. Ci/m^3	Shallow land burial
Misc. TRU	concrete/drums	10/50	Fission Products & >10 nCi/g TRU, 10^3-10^6 Ci/m^3	Repository
Metal Scrap	metal/cylinders	14/102	Fuel Material, Fission & activation products, $4x10^5$ Ci/m^3	Repository 14
High-Level	glass/cylinders	3.3/6	Fission Products, TRU, 1.5 x 10^7 Ci/m^3	Repository
Kr-85	metal matrix/cylinders	0.01/0.035	Kr in metal matrix $3.4x10^6$ Ci/m^3	Repository
I-129	concrete/drums	0.01/0.05	Barium Iodate $1.4x10^2$ Ci/m^3	Repository
Core Fuel Fabrication Plant				
TRU	solid/drums	130/145*	U, Pu, TRU 64 Ci/m^3	Store at Hanford
Blanket Fuel Fabrication Plant				
LLW	CaF_2/bulk	11 MT	Uranium 0.01 uCi/g	Onsite disposal
CRBR Plant				
LLW	solid-concrete/drums	67/321	Fission, activation products <10^2 Ci/m^3	Shallow land burial 16

*Volume stated is prior to compaction.

Table 5.7-5

COMPARISONS OF QUANTITIES OF WASTES

Fuel Cycle Operation	Waste Type	Waste Volume per Year (m^3) CRBRP	1000 MWe LWR* No Recycle	1000 MWe LWR* U Recycle
UF_6 Conversion (dry)	CaF_2 Chem Waste	--	92	95
(wet)	CaF_2 Sludge, Chem Wastes	--	41	35
Enrichment	Low-Level Misc.	--	28	30
Fuel Fabrication	CaF_2, Misc.	11 (MT)	29	29
	TRU	130	--	--
Reactor	Low-Level	67	620	620
	Spent Fuel	--	35	--
Spent Fuel Storage	Low-Level	--	<3	<1
Fuel Reprocessing	Low-Level Misc.	25	--	7
	High-Level	3.3	--	8
	Misc. TRU and Scrap	24	--	44
	Plutonium	--	--	6
	Kr-85 Cylinders	0.01	--	--
	I-129 Cylinders	0.01	--	--

* NUREG-0116, Table 3.3

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TABLE 5.7-6

Comparison of Annual High-Level Waste Constituents (Ci)

Nuclide	Half-life	CRBRP	1000 Mwe LWR(1)
H-3	12.26Y	5.33×10^{2}	2.3×10^{3}
Sr-90	28Y	3.65×10^{5}	2.7×10^{6}
Ru-103	40D	4.28×10^{4}	7.18×10^{4}
Ru-106	1.0Y	5.28×10^{6}	9.6×10^{6}
I-129	1.72×10^{7}Y	3.26×10^{-1}	1.31
I-131	8.05D	3.29×10^{-7}	6.97×10^{-7}
Cs-134	2.19Y	2.32×10^{5}	6.2×10^{6}
Cs-137	30Y	7.88×10^{5}	3.7×10^{6}
Ce-144	285D	3.95×10^{6}	1.6×10^{7}
Th-228	1.91Y	4.83×10^{-3}	1.18×10^{-1}
U-234	2.48×10^{5}Y	4.06×10^{-3}	2.66×10^{1}
U-235	7.13×10^{8}Y	1.96×10^{-4}	5.99×10^{-1}
U-236	2.39×10^{7}Y	3.96×10^{-4}	1.10×10^{1}
U-238	4.51×10^{9}Y	1.84×10^{-2}	1.01×10^{1}
Np-237	2.2×10^{6}Y	1.04	1.19×10^{1}
Pu-236	285Y	1.53×10^{-2}	9.63
Pu-238	89Y	8.41×10^{2}	1.0×10^{5}
Pu-239	2.44×10^{4}Y	2.14×10^{2}	1.1×10^{4}
Pu-240	6.58×10^{3}Y	2.20×10^{2}	1.7×10^{4}
Pu-241	13Y	2.47×10^{4}	3.5×10^{6}
Pu-242	3.79×10^{5}Y	4.70×10^{-1}	4.83×10^{1}
Am-241	458Y	1.04×10^{5}	8.8×10^{3}
Cm-242	163D	1.09×10^{6}	2.5×10^{5}
Cm-244	17.6Y	3.5×10^{3}	8.2×10^{4}

(1) "Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle," NUREG-0116, Appendix A; 10% of H-3, 100% of others, multiplied by 35 MTHM/annual LWR charge; 1 year after discharge. This evaluation assumes that all of the LWR plutonium is disposed of in the waste.

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Table 5.7-7

Transportation Radiological Impact

Fuel Cycle Element	Shipment/ yr	Distance (Miles)	Pop. Dose (Person-Rem)	Max. Individual Dose* (Rem)	
New Fuel	14	2500	0.449	1.40	
New Blanket	12	2500	0.0065	0.013	
Plant Radwaste	8	2500	0.430	0.878	
Spent Fuel	14	2500	0.489	0.160	
Spent Blanket	12	2500	0.432	0.160	
Irradiated Control, RRS	4.5	2500	<0.001	0.004	
PuO_2	14	3000	0.536	1.64	
Reproc. Radwaste					14
HLW	3	2500	0.0817	0.360	
TRU & Metal Scrap	24	2500	1.296	2.640	
LLW	2	2500	0.109	0.220	
Fuel Fabricator Radwaste					
TRU	5	2500	0.270	0.550	

*To transportation workers

TABLE 5.7-8
CRBRP Fuel Cycle Security Costs By Plant Type
($ in millions)

Item	CRBRP Plant Capital	CRBRP Plant Annual Operating	Fuel Fabrication Plant Capital	Fuel Fabrication Plant Annual Operating	Reprocessing Plant Capital	Reprocessing Plant Annual Operating
Physical Security System	3.86	0.17	2.2	0.3	2.8	0.12
Material Control and Accounting	-	-	1.6	0.9	1.2	0.4
Security Force	0.05	2.1	-	0.8	-	0.28
	3.91	2.27	3.8	2.0	4.0	0.8

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HUD'S SITE ACCEPTABILITY STANDARD (Ref. 4)

	Day-night average sound level (in decibels)	Special approvals and requirements
Acceptable	Not exceeding 65 dB([1])	None
Normally Unacceptable	Above 65 dB but not exceeding 75 dB	Special Approvals (2) Environmental Review (3) Attenuation (4)
Unacceptable	Above 75 dB	Special Approvals (2) Environmental Review (3) Attenuation (5)

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Notes (1) Acceptable threshold may be shifted to 70 dB in special circumstances pursuant to 51.105(a).

(2) See 51.104(b) for requirements

(3) See 51.104(b) for requirements

(4) 5 dB additional attenuation required for sites above 65 dB but not exceeding 70 dB and 10 dB additional attenuation required for sites above 70dB but not exceeding 75db (See Section 51.104(a)).

(5) Attenuation measures to be submitted to the Assistant Secretary for CPO for approval on a case-by-case basis.

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TABLE 5.7-10

CITY OF OAK RIDGE NOISE LIMITS[5]

Sound Level, dB	Adjacent Uses	Where Measured
50	All Residential Districts	Common Lot Line
55	Neighborhood Business District	Common Lot Line
60	General Business District	Common Lot Line
65	Industrial District	Common Lot Line
75	Major Street	Lot Line at Street
60	Secondary Residential Street	At Street Lot Line

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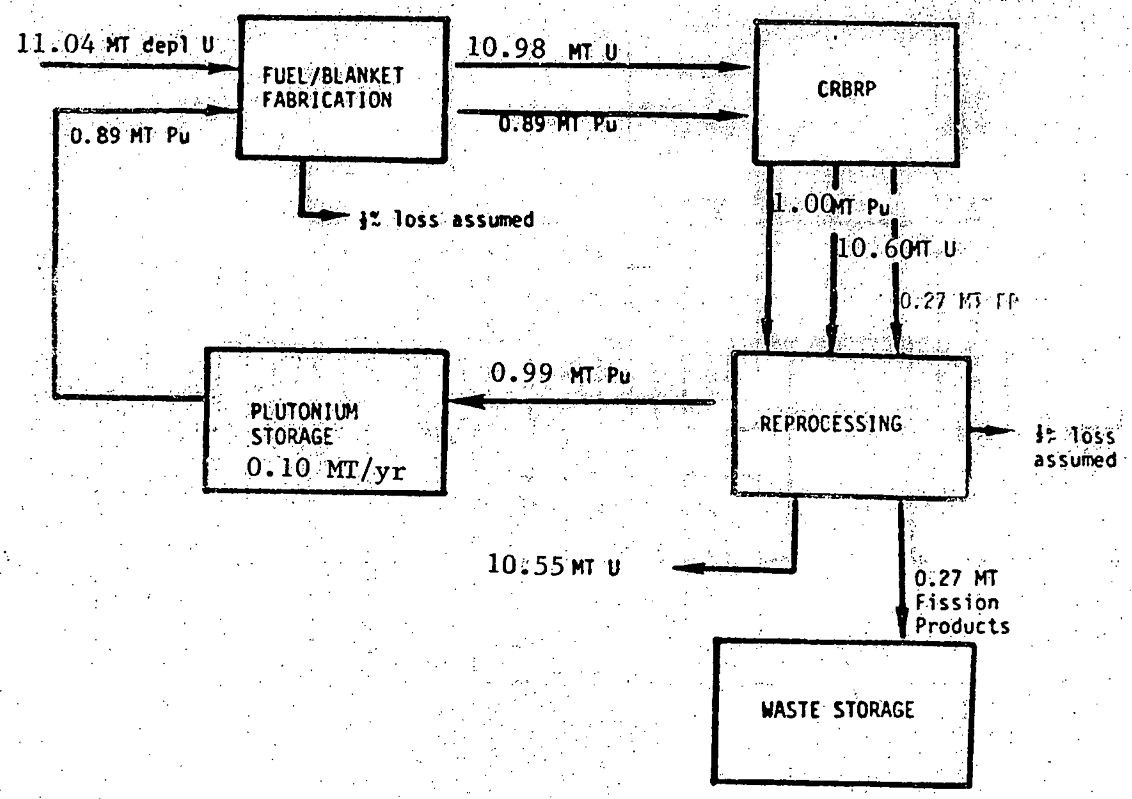
FIGURE 5.7-1

CRBRP EQUILIBRIUM FUEL CYCLE

PLUTONIUM AND URANIUM MASS FLOW

(MT/year, average)



12

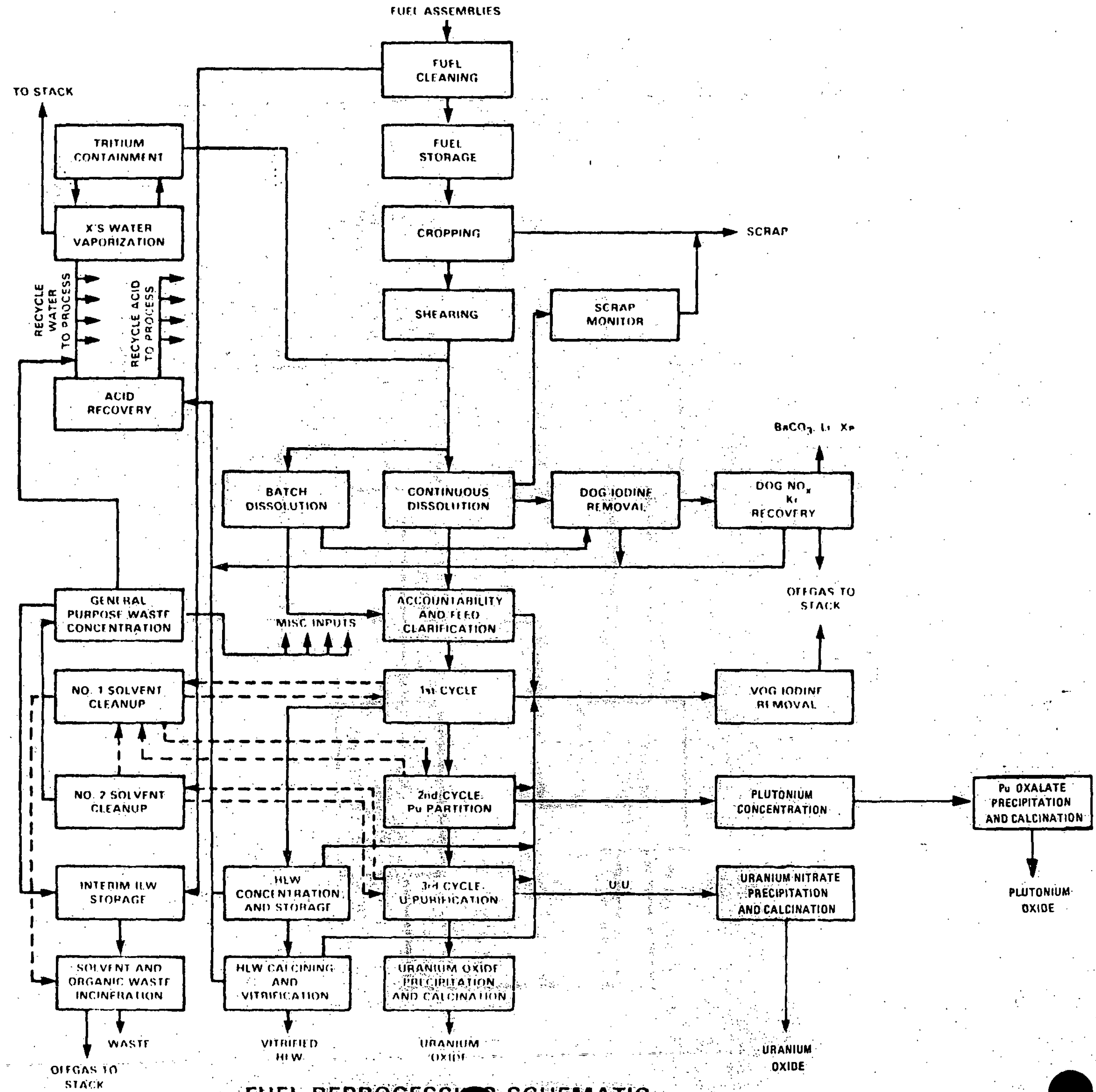


FIGURE 5.7-2 FUEL REPROCESSING SCHEMATIC

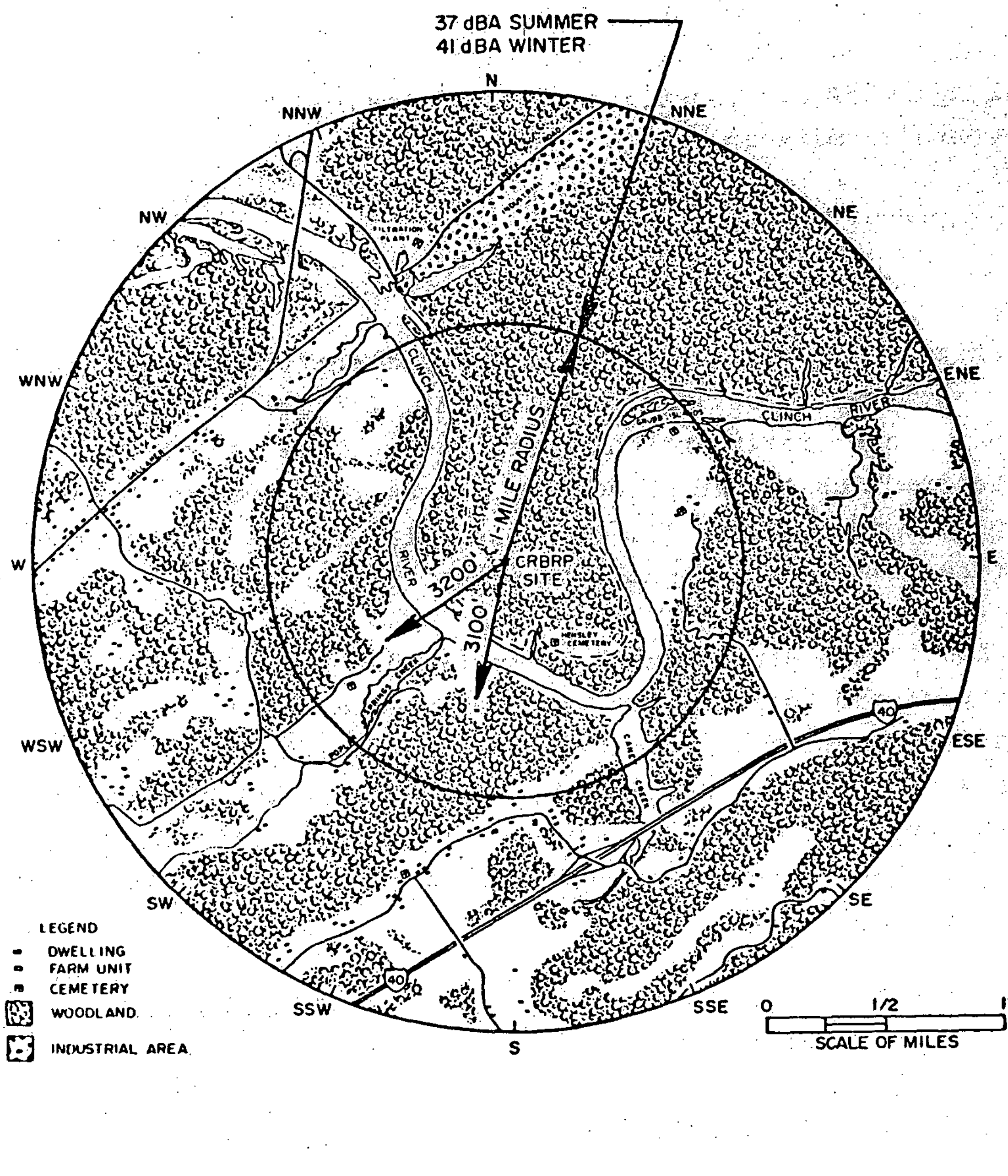


Figure 5.7-3. One-Mile CRBRP Sound Level Contour and Nearest Dwellings

5.8 RESOURCES COMMITTED

The commitment of resources ascribed to the construction of the CRBRP was discussed in Section 4.3. This section is concerned with the commitment of resources during the expected life of the plant. Commitments of the various types of resources are not all of equal consequence. During operation of the plant, resources are utilized in amounts that, relative to their general availability, will not constitute an irreversible or irretrievable commitment.

5.8.1 COMMITMENT OF LAND RESOURCES

Approximately 135 acres of primarily forested land area (on-site plus off-site) have been committed for permanent plant facilities 13 and the transmission corridor for the CRBRP and its related facilities. This commitment, however, does not represent a measurable fraction of the productive forest resources of the region. The commitment of 135 acres is only 0.27 percent of the total acreage within a five-mile radius of the plant.

The Site has little agricultural potential due to the poor suitability of the soil and has been designated as an area for industrial development as discussed in Section 2.7. Should it be desirable at the end of the facility's expected life, the land can be returned to a condition suitable for future industrial development. Decommissioning and dismantling of the facility are discussed in Section 5.9.

No further alteration or destruction of wildlife habitats should occur during plant operation.

5.8.2 COMMITMENT OF WATER RESOURCES

One of the major resources committed during plant operation will be water from the Clinch River. Flow rate of the river varies from an average low flow of 4339 cfs in the spring to an average high flow of 6,772 cfs in the winter. For maximum power operation, the anticipated average water makeup requirement is 13.6 cfs. An average of 5.4 cfs will be returned to the river and approximately 8.3 cfs will be consumed during plant operation. The consumptive use of 8.3 cfs is only 0.15% of the annual average Clinch River flow rate of about 5,380 cfs. The amount of water lost to the atmosphere through evaporation is not actually an irretrievable loss, however, as the water eventually will be returned to the earth as precipitation. 10 13 9 16 10

Considering aquatic life as a resource, the loss of fish, zooplankton, benthos, macrophytes and the like will be a commitment of resources directly attributable to operation of the CRBRP. Discharges to the Clinch River will be continuously monitored to prevent introduction of deleterious effects to the aquatic life by excessive temperature, chemicals or turbulence. 9 A preconstruction survey conducted on the Clinch River will establish a reference framework for assessing the degree to which this resource is committed.

5.8.3 COMMITMENT OF FUEL RESOURCES

Initial fuel assembly loading of the Clinch River Breeder Reactor will consist of approximately 5.2 Metric Tons (MT) of uranium and plutonium metal in a 36-inch high core. The fuel consists of sintered mixed-oxide pellets of PuO_2 and UO_s encapsulated in the sealed stainless steel tubing (rods). Plutonium enrichment is 33.2 weight percent. In later cycles the plutonium enrichment will be approximately 33 weight percent. Each of the 156 fuel subassemblies in the reactor core contains 217 fuel rods. The reactor core fuel contains 20.7 MT of stainless steel. 9 9 9 15

The isotopic composition of the feed plutonium metal in the core is 0.1 percent Pu-238, 86.0 percent Pu-239, 11.7 percent Pu-240, 2.0 percent Pu-241 and 0.2 percent Pu-242. The isotopic split is similar to FFTF-grade plutonium.

An additional 25.2 MT of depleted uranium metal is committed in 14
the inner radial and axial blankets. Inner and radial blankets,
consisting of 208 assemblies, each containing 61 rods, contain 14
21.0 MT of depleted uranium metal and 26.8 MT of stainless steel.
Each of the two axial blankets, which are an integral part of the
fuel assemblies, contains 2.1 MT of depleted uranium metal.

An estimated 2427 fuel assemblies and 2106 blanket assemblies 14
will be committed during the 30-year life of the plant. Operated
on the once-through fuel cycle, the total requirement of the
plant could be as high as 27 MT of plutonium metal, 332 MT of 14
uranium and 595 MT of stainless steel over 30 years. However, it
is expected that the burned fuel will be recycled to the plant
after reprocessing and refabrication so that the actual heavy 9
metal commitment to the plant from virgin ore (natural uranium)
will be only a fraction of the aforementioned values.

If one assumes recycle with CRBRP operating by itself, requiring one full core load in the reactor and an additional reload core in reprocessing and fabrication, then the commitment from resources is only on the order of 3.5 MT of plutonium plus 58.0 MT of uranium.

The isotopic composition for the case where CRBRP spent fuel is
reprocessed and recovered Pu is recycled as feed is discussed in 16
the appendix to Section 5.7 (Section 14.4A).

Uranium burnup and an assumed one percent heavy metal loss of 9
each batch through the reprocessing-refabrication cycle raises
the plant lifetime total heavy metal commitment to 72.2 MT of 14
uranium. The 3.5 MT plutonium commitment, which is required for 9
initial startup, does not increase since the plutonium burnup is
more than made up by the reactor breeding. An additional net of
3.2 MT of plutonium, in excess of that originally committed, will 9 14
be produced over the life of the plant.

At the time of decommissioning, 2.1 MT of plutonium and 27.6 MT 14
of uranium can be recovered from the core, leaving a total
irreversible consumption of depleted uranium reserves of 14.2 MT 14
and a net gain of 3.2 MT of bred plutonium. All of the stainless 15
steel in the burned fuel and in the blanket assemblies (nominally 14
595 MT over the life of the plant) must be considered as
permanently consumed due to radioactive contamination which 9 14
precludes its reuse.

5.8.4 IRRETRIEVABLE COMMITMENT OF OTHER RESOURCES

Irretrievable commitments of resources include those resources consumed during plant operation. Operation of the CRBRP will involve the direct use of substantial quantities of consumable supplies including: (1) chemicals for treatment of water for the cooling and sanitary systems; (2) oils and lubricants; (3) decontamination and cleansing agents; (4) minor quantities of sodium; and (5) other consumable items such as paper supplies, spare parts, etc. The amount consumed during plant operation is only a fraction of the supply available and therefore would not constitute a major commitment.

5.9 DECOMMISSIONING AND DISMANTLING

The Clinch River Breeder Reactor Plant (CRBRP) is being designed for a 30-year operating life, thereby placing the plant's final operation at about the year 2020, assuming no premature termination. At that time, 9
a detailed plan to decommission will be prepared for approval by the appropriate licensing agency with criteria comparable to Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors". A number of alternative approaches will be evalutaed in terminating the operating license of the plant; the approach chosen will not affect use of the remaining portions of the Site in any more adverse manner than continued operation of the plant would have. Length of operating history, after some initial activation, will not significantly affect the approach chosen. The final condition will provide for protection of the public safety and will be environmentally suitable.

A wide choice of experience in decommissioning reactors is available from the AEC civilian power program and civilian reactors.[1-8] These experiences range from removal of fuel and minor decontamination to total removal, including some subgrade structures. None of the approaches to date have presented safety or environmental problems of substantative difference than those which have occurred during normal operation of a plant.

The land committed to the CRBRP plant buildings, inside the security fence, occupies 8.6 acres as seen on Figure 2.1-4. The sludge lagoon equalization basin, sewage treatment plant and river water pump house 9
occupy an additional 2.7 acres outside the security fence. Depending upon the chosen plan, the termination of the plant could commit up to 11.3 acres of the Site. It is noteworthy that the less extensive 10
approaches to termination do not irretrievably commit the Site; that is, should a decision be reached at some date after termination that justification exists to reduce the land commitment, the cost of recover versus the initial decommissioning cost would be negligible. If the decision

were made to dispose of the CRBRP by partial or total demolition, disposal site resources would be committed.

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Based on estimated 1000 MWe LWR decommissioning costs,[9] the costs for the CRBRP decommissioning are expected to range from about one to five percent of the original capital investment for the plant. This level of cost is not significant when compared to the total of the lifetime fuel and capital costs.

The environmental impact of decommissioning is not expected to be significant. Environmental impacts associated with construction and operation of the plant will have already occurred. After the removal of irradiated and unirradiated fuel from the Site, the possibility of adverse environmental impacts will be virtually eliminated. Radioactivity releases and waste heat discharges would be considerably less than those that occurred during operation of the plant. It is anticipated that noise and chemical discharge impacts would also be less than those associated with construction and operation. Decommissioning may involve the shipment of all contaminated or irradiated material off-site for entombment.

In summary, the termination of operation and decommissioning of the CRBRP can be accomplished with complete safety provisions for the general public and the workers at a reasonable cost and in an environmentally acceptable manner.

6.0 EFFLUENT AND ENVIRONMENTAL MEASUREMENTS AND MONITORING PROGRAMS

The purpose of the effluent and environmental measurements and monitoring programs is: (1) to establish a baseline (reference) framework of information on the environment in the vicinity of the Clinch River Breeder Reactor Plant (CRBRP) and (2) to assess the effects on the environment resulting from construction and operation of the CRBRP. Specific aspects of the environment to be monitored in varying degrees of detail are physical and chemical parameters, and radiological, terrestrial, limnological and fisheries components. Information relating to geology and soils, land use and demographic surveys is also included.

Many details of the environmental monitoring program are closely related to final plant design; therefore, present monitoring program plans are tentative. When final details of the plant design are available, the respective components of the monitoring program will be reevaluated and modified accordingly.

As a basis for designing the environmental monitoring program, a number of potential environmental impacts which often are a result of construction and operation of nuclear power generating facilities have been identified. The monitoring program will be reviewed periodically and various elements may be added, altered or deleted if further study and data collection indicate a need to consider different or additional impacts. A quality assurance program will verify the adequacy of the sampling procedures and various analyses.

The programs discussed in this section are divided into the following categories: (1) preoperational (including preconstruction and construction periods) and (2) operational.

6.1 APPLICANT'S PREOPERATIONAL ENVIRONMENTAL PROGRAM

The preoperational environmental monitoring program serves to establish
baseline data for ecological, radiological, meteorological and water
quality conditions in the vicinity of the CRBRP prior to start of con-
struction and operation, and to assess the environmental impact of con- 6
struction. The aquatic and terrestrial baseline monitoring programs
discussed in this section were conducted from March 1974 through May 1975
to gather information required for Section 2.7 for identification of
important ecological characteristics of the Site area. TVA conducted a
preconstruction monitoring program during 1975-1978. Information 9
from these monitoring programs will be used to provide background infor-
mation for impact assessment during plant construction. Once construction
begins, the TVA program and one to be instituted by Stone and Webster
Engineering Corporation (SWEC), the construction contractor, will monitor
those areas which may be affected by construction activities.

6.1.1 SURFACE WATERS

6.1.1.1 BASELINE MONITORING PROGRAM

Most of the previous aquatic studies of the Clinch River were conducted in the early 1960's or earlier. With reference to the Clinch River in the vicinity of the Site, two factors suggested collection of current data: (1) the tendency for most rivers in the United States to change chemically, and therefore ecologically, because of ever-increasing contributions of nutrients and other chemicals from man's activities and (2) the installation in 1963 of Melton Hill Dam at Clinch River mile 23.1. Also, many of the previous aquatic studies of the Clinch River were concerned with qualification ("naming") and not quantification ("counting") of data.

In order to have a current picture of the Clinch River aquatic environ-
ment in the vicinity of the Site, an aquatic baseline program was
conducted from March 1974 through May 1975 to supply information pre- 9
viously not available and to update existing information. The purpose of
this program was to identify and characterize: (1) physical and chemical
parameters; (2) existing biological communities; and (3) endangered
species, if any, and their spawning habits. This program was used to 9
identify the important ecological parameters in the Site area which might
reasonably be expected to be affected by the CRBRP.

Selection of locations for the sampling transects in the Clinch River
used in this program was determined largely by a consideration of those
areas of the plant which will have the greatest potential for impact
during plant construction and operation. These sampling transects are
shown in Figure 6.1-1. Basically, the major aquatic impacts may occur 9
at three areas: (1) at the plant intake; (2) in the circulatory cooling
water system; and (3) in the vicinity influenced by the plant discharge.
Based on these considerations, Transects 1 and 5 were established as
control areas. Transect 1 should be completely free of any mechanical,
chemical or thermal effects from the plant, whereas Transect 5 might
show some slight effects. Transects 2 and 3 were placed at the mouths 9
of Caney and Poplar Springs Creeks, respectively. These transects
were established to help determine to what extent, biologically, chemi-
cally and physically these creeks may modify the main river. Transect 4,
by its close proximity to the downstream path of the proposed plant dis-
charge, would be a key sampling area in evaluating the effects of the 9
discharge. Specific sampling stations for the variety of parameters
surveyed are shown in Figures 6.1-2 through 6.1-9. 9

The arrangement of sampling stations was based around the general plan of
having three stations numbered 3, 5 and 7, along each transect. Locations
of these three stations were as follows: Station 5 was located in the
middle of the river; Station 3 was located halfway between the center 9

station and the right shore; and Station 7 was located halfway between the center station and the left shore. Right and left shores were oriented as facing downstream. This general station plan is used in tables and figures pertaining to the following parameters: 9

1. Biological Communities

   bacteria (Figure 6.1-2)
   phytoplankton (Figure 6.1-2)
   zooplankton tows (Figure 6.1-2)
   zooplankton pumping (Figure 6.1-2)
   fish eggs and larvae (Figure 6.1-8)

2. Physical and Chemical Parameters

   routine lab analyses (Figure 6.1-2)
   additional analyses (Figure 6.1-9)

For benthos dredging, physical and chemical field measurements and sediment analyses, the three station plan per transect was utilized at Transects 1, 4 and 5 as shown in Figure 6.1-4. However, at Transects 2 and 3, Station 7 was located closer to shore, immediately at the mouths of Caney and Poplar Springs Creek, respectively. 9

Sampling locations for periphyton, benthos artificial substrates, macrophytes, fish population and fish food preference did not comply with the general three station plan. For periphyton sampling, floating samplers were placed approximately 30 feet from the right shore at Transects 1, 4 and 5 as shown in Figure 6.1-3. Placement of nearshore benthos artificial substrates at Transects 1, 4 and 5 was 30 to 50 feet from the right shore as shown in Figure 6.1-5 and was also dependent upon the water depth. Mid-river benthos artificial substrates were placed 50 to 100 feet from the right shore at Transects 1, 4 and 5. Collection of macrophytes extended approximately 200 feet both up and downstream of each transect and along left and right shores as shown in Figure 6.1-6. Sampling for 9 9 9 9

fish population and fish food preference was done by setting 150 foot 9
gill nets perpendicular to both shores at Transects 1 and 5. On the
right side of the river at Transect 4, one gill net was set perpendicular
to the shore and another gill net was set along the north shore of the 9
mid-river sand bar perpendicular to the right side of the river. On
the right side of the river at Transects 2 and 3, gill nets were set 9
perpendicular to the right shore; on the left side of the river, on
alternate field trips, gill nets were set either directly across the 9
mouths of Caney and Poplar Springs Creeks or perpendicular to the left
shore. Figure 6.1-7 illustrates the locations of these sampling
stations.

The sampling schedule for the aquatic baseline program is shown in
Table 6.1-1. Since the first major sampling trip was not initiated
until March 1974, the data for the month of January were collected 9
in 1975. Sampling methods, frequency and analysis procedures and location of sampling stations for each parameter are presented in
Table 6.1-2. A summary of the total number of samples collected 9
and analyzed during the year survey is indicated in Table 6.1-3.

6.1.1.1.1 PHYSICAL AND CHEMICAL PARAMETERS

Bathymetry

Bottom profiling of the study area was done using a recording fathometer. Thirty river transects (left to right shore as facing downstream) were made on February 27, 1974. Thirty additional transects were made on June 4, 1974. Bathymetric charts and cross-sectional profiles for the areas in the vicinity of the intake and discharge have been prepared from data collected during field trips. The bathymetric charts, Figures 2.5-5 and 2.5-6, and the cross-sectional profiles, Figures 2.5-7 and 2.5-8, are in Section 2.5, Hydrology.

River Height

Water level of the Clinch River in the study area is highly variable because of various operations of dams in the vicinity; therefore, measurement of water levels was incorporated into the regular field measurement and sampling schedule. A stadia staff, from which water level could be measured, was established along the north shore at approximately CRM 16.0 and 16.5. Markings in feet and inches on the staffs were correlated by surveying to the known elevation of 781 feet (bench mark CD81 near Hensley Cemetery) on February 24, 1974. Water levels were recorded several times during each day of a field 9
trip.

Field Measurements

Field measurements were taken nine times during the study period in 9
accordance with the baseline program sampling schedule shown in Table 6.1-1. Locations of the sampling stations used for field measurements are shown in Figure 6.1-4.

Measurements indicated as "surface" were taken one foot below the water surface and those as "bottom" were one foot above the river bottom. Measurements made in profile were made one foot below the 9
water surface, then at one meter intervals until one foot above the bottom.

In addition to the 15 regular sampling stations shown in Figure 6.1-4, field measurements were made on May 29, 1974, at single stations within Caney and Poplar Springs Creeks. Location of each of these stations was 50 to 60 yards from the mouth of each creek.

Routine Laboratory Analyses

Twenty-three physical and chemical parameters sampled nine times 9
during the study period and analyzed in the laboratory are listed in
Table 6.1-2.

Surface water samples were taken at three locations, shown in 9
Figure 6.1-2, nine times during the survey period in accordance
with the schedule in Table 6.1-1. Sampling frequency, methods
and analysis procedures are shown in Table 6.1-2. Water samples
were preserved in accordance with EPA recommended procedures[1] and
analysis for perishable items was started within six to eight hours 9
from the time of collection.

Additional Analyses

Chemical analyses for 29 additional parameters, listed in Table 6.1-2,
part C, were done in the laboratory. Water samples for these addi-
tional analyses were collected in March and September, 1974, at the 9
single location shown in Figure 6.1-9.

9

For each parameter a single analysis was made from a surface water 9
sample. The methods used for analysis and for expressing results
are indicated in Table 6.1-2. Water samples were preserved in ac- 9
cordance with EPA recommended procedures,[1] and analysis for
perishable items was started within six to eight hours after col- 9
lection of water samples.

Sediment Analyses

Analyses of sediment, in terms of particle size composition and total volatile (organic) solid content, were done six times 9
during the survey period in accordance with the survey sampling schedule indicated in Table 6.1-1 and at the 15 locations shown in Figure 6.1-4. Each sample was a composite of two Ponar dredge hauls 9
per station.

On March 25, 1974, five additional composite samples representing the five sampling transects were taken. Each composite (transect) 9
sample consisted of one Ponar grab collected at each of three stations and composited. Samples were sieved (0.25 in. mesh) in the field 6
and kept cold until returned to the laboratory. Samples were analyzed for total phosphate and heavy metal content.

On April 16, 1975, three more composite samples, collected as above, were taken at Transects 1, 4 and 5. These samples were analyzed 9
for total phosphate, heavy metals, other trace metals, polychlorinated biphenyls, and several insecticides.

Sediment sampling frequency, methods and analysis procedures are indicated in Table 6.1-2. A summary of the number of samples col- 9
lected for the year survey is shown in Table 6.1-3.

6.1.1.1.2 ECOLOGICAL PARAMETERS

Bacteria

Bacterial composition of river water often reflects the response of the decomposer community to organic materials from agricultural, industrial and domestic sources. This bacterial utilization of organic material for energy plays an important role in the energy flow of a river ecosystem.

Enumeration of bacteria by the "standard plate count" is used to determine the bacterial density of waters.[2] Coliform bacteria occurring in a river are often used as an indicator of sanitary water quality. Fecal coliforms in water specifically indicate fecal waste contamination by warm-blooded animals.[3] Non-fecal coliforms commonly occur in the soil, on plants and insects, in old sewage and in waters polluted in the past.[4] Coliform bacteria in a river respond uniquely to changes in water level. In a clean river the number of coliforms per unit volume of water tends to increase with a rise in water level, but in a river polluted by sewage, coliform concentrations decrease because of dilution.[5]

The presence of fecal streptococcus bacteria in water is also indicative of fecal contamination by warm-blooded animals. Although levels of acceptability for these bacteria have not been established by State or Federal agencies, they have been used in conjunction with fecal coliform levels to determine the specific nature of the contributing sources.[3]

In human feces, fecal coliforms markedly outnumber fecal stretococci while in the feces of most common farm animals the opposite is true. Consequently, waters which show a higher fecal coliform count than fecal streptococcus most likely contain wastes of human origin. The ratio (fecal coliform/fecal streptococcus) in this case tends to be significantly greater than two. When waters show a higher fecal streptococcus count than fecal coliform, it most likely contains wastes of animals, particularly livestock origin. Ratios are less than one in such instances. Interpretation of these ratios must be cautiously done because of such influencing factors as age and pH of the water.

Surface water samples for bacterial analysis were collected at 9
the three locations indicated in Figure 6.1-2. Single samples from
each of these stations were collected nine times during the 9
survey period on a schedule as indicated in Table 6.1-1. Sampling
frequency, methods and analsis procedures are shown in Table 6.1-2;
total number of samples analyzed are shown in Table 6.1-3. 9

Analysis includes determination of standard plate, total coliform, 9
fecal coliform and fecal streptococcus bacteria counts. Inoculations
for bacterial analysis were done within 24 hours of sample 9
collection. Physical and chemical water measurements and sampling
were done concurrently with the water sampling for bacteria. 9

Phytoplankton

Phytoplankton forms an important link in the flow of nutrients and energy in many aquatic ecosystems. Because of the importance of phytoplankters as primary producers, it is necessary to determine their composition and abundance. Phytoplankters may also be significant as indicator organisms in pollution studies (especially organic pollution). In most aquatic ecosystems, the dominant groups of freshwater phytoplankton consist of diatoms, green and blue-green algae.

The proportional distribution of these groups may be considered as indicative of the relative health of a water body. While the proportions of these groups may normally fluctuate greatly with the season, the dominance and diversity of diatoms and green algae is usually considered as "healthy"; whereas, the increased abundance of blue-green algae is often considered as an indication of increased pollution or ecosystem imbalance. In larger rivers, however, the indicator value of phytoplankton may be limited.[5] In moving water, the origin of the phytoplankton may be unknown.

At each of the three locations shown in Figure 6.1-2, four one-liter
surface water samples were collected. Two of the one-liter samples
were fixed in five percent formalin and were used for phytoplankton 9
identification and enumeration using settling tubes to concentrate
the organisms and a Sedgwick-Rafter cell for counting. The two
other one-liter samples were kept cold and in the dark until they
were filtered later in the same day. Biomass estimation was done 9
using

chlorophyll a analysis on these filtered (0.45 membrane filters)
samples. Residue on the filters was kept cold and in the dark until
returned to the laboratory. Chlorophyll a, b and c analyses were 9
done using extraction with 90 percent acetone and the trichromatic
procedure.[6] Pheophytin a content ratio was measured by determining 9
optical density 663 ratios before and after acidification.[6] The
pheophytin a content ratio enables determination of the physiological
condition of the phytoplankton by comparison of chlorophyll a and
its degradation product pheophytin a. Physical and chemical water
measurements and sampling were done on the same day as the phyto- 9
plankton sampling. Sampling for phytoplankton was done nine times
during the survey period. Total number of samples collected for the 9
survey is indicated in Table 6.1-3. Sampling frequency, methods and
analysis procedures are shown in Table 6.1-2. The diversity index
employed was the Shannon-Wiener species diversity index. 9

Zooplankton

Zooplankters, as primary consumers, constitute a distinct and important part of an aquatic ecosystem. They are an important trophic link between primary producers (phytoplankton) and carnivores (fish). Zooplankters can be entrained by the cooling system of a power plant. They may also act as indicators of water quality. Sampling for zooplankton needs to take into account not only the seasonal development but also the possible vertical distribution of this group.

Location of the three zooplankton sampling stations used in
this survey is indicated in Figure 6.1-2. Sampling was done
nine times during the course of this survey following the schedule 9
shown in Table 6.1-1. Total number of samples collected
during the survey are shown in Table 6.1-3.

Sampling was done with a plankton net towed vertically on all oc-
casions and horizontally at the surface beginning in September 1974.
A submersible pump was also used from March through July 1974. 9
Sampling methods, frequency and analysis procedures are listed in
Table 6.1-2.

Two samples were taken at each station by the towing methods; each 9
sample consisting of a single tow. In the vertical (bottom
to surface) towing a No. 20 (0.076 mm mesh) one-half meter diameter
plankton net, with attached inside and outside flow meters, was used;
the same equipment was used for horizontal surface tows. 9
Three composite samples were taken at each station by pumping; each
composite sample consisted of two 2-minute pumpings taken at the
surface, middle and bottom (one foot from the bottom) of the water
column. The rate of pumping was 14.8 gallons per minute; therefore,
approximately 59.2 gallons (224 liters) were pumped for each 4-minute 9
composite sample. By pumping, a specific portion of the water
column can be sampled. Drawbacks to this procedure are that only a
small volume of water is sampled, some zooplankton forms are destroyed
mechanically and larger zooplankters may actively evade the pump.
Vertical towing is a more effective sampling procedure in that
approximately 100 times more water is sampled; however, the depth
from which zooplankters are collected cannot be ascertained by this
method. Because of the rough bottom of the Clinch River horizontal
bottom tows were not feasible. A decision was made after four field 9
trips to eliminate sampling by pumping, based on comparative analysis
of the two methods, and to substitute horizontal surface tows. 9

Zooplankton were first narcotized with a one-percent neosynephrin
then fixed in five-percent formalin. Enumeration was done by strip 9
counts using a Sedgwick-Rafter counting chamber.[2] Composite
biomass estimates were obtained by measurement of the lengths 9
of zooplankters and conversion to biomass by comparison with works

in the literature, or by determining the dimensions of the organisms and converting these to biomass. The diversity index employed 9
here was the Shannon-Wiener index. Measurement and sampling of the 9

physical and chemical water parameters was done on the same day as the sampling for zooplankton. 9

Periphyton

Periphyton is variously defined by different authors. In a broad sense the periphyton community can be considered as the "entire assemblage of organisms (mostly microscopic) on submerged objects in aquatic environments; such organisms do not penetrate into the substrate and may or may not be sessile".(7) Photosynthetic components of this community include many species of algae that colonize nearly every type of substrate available in a river.

Periphyton can also be a very good indicator of water quality. Diatom composition(8,9) and biomass-chlorophyll ratio of periphyton have previously been used for this purpose.(8,9,10,11,12) Autotrophic index values greater than 100 may be a good indication of organic pollution. The ratio of periphyton chlorophyll a and biomass has been mentioned as an indicator of thermal addition to the aquatic ecosystem.(10)

In the present baseline program, periphyton was sampled at the three locations shown in Figure 6.1-3. Seven major periphyton samplings were done during the survey period according to the schedule shown in Table 6.1-1, with the total number of samples collected and analyzed as shown in Table 6.1-3. 9 9

Because of the fluctuating water levels at the study area, surface-floating periphyton samplers were used. Design of the samplers was similar to that used by TVA.(10) Each sampler was kept buoyant by two styrofoam floats and had five or six plexiglass plates mounted on a submerged bracket. Each plate had an exposure area of 144 cm^2 and was maintained in a vertical position 18 inches below the floats 9

(water surface). Two samplers were maintained approximately 50 yards 9
apart at each of the three sampling stations; sampling was done
primarily from one sampler with the other sampler acting as a "back-
up" in the event the first sampler was lost. After an exposure 9
period of two to four weeks the plexiglass plates coated with peri-
phyton were placed in individual plastic bags, kept on ice and in
the dark; upon return to the laboratory they were kept in a freezer 9
until they were analyzed.

Prior to June 18, 1974 periphyton analysis procedure used in the baseline study was as follows:

1. Two plates from each station were used for identifi-
cation and enumeration of periphyton organisms. At
first, freezing and placement of plates in five-percent
formalin were used as a preservation technique; later
only the five-percent formalin preservation was con-
tinued. Items of analysis are listed in Table 6.1-2.
Acid digestion was used for diatom identification.
The Shannon-Wiener diversity index was employed. 9

2. Two plates from each station were used for determination of biomass-chlorophyll ratios. This was done in the following manner:

   a. Periphyton was scraped from a plate with a neoprene policeman and washed with a 95-percent solution of alcohol. Residue was then placed in 75 ml of 95-percent ethyl alcohol and refrigerated in the dark for 48 hours. The sample was then filtered through a 0.45 μm glass filter; the filter and residue then placed in a crucible;

   b. volume of filtrate was adjusted to 100 ml by dilution or evaporation, and optical density of the filtrate determined for chlorophyll *a* and pheophytin *a* using the trichromatic method;[6]

c. Ash-free dry weight of the residue on the filter in the crucible was determined;[6] and

d. Autotrophic index was calculated using the EPA formula:[5]

$$\text{Autotrophic Index} = \frac{\text{Ash-free Wgt } (mg/m^2)}{\text{Chlorophyll } a\ (mg/m^2)}$$

Starting with June 18, 1974, periphyton analysis was as follows:

1. Two plates from each station were used for identification, enumeration and species diversity in the same manner as described previously; 9

2. Periphyton was scraped from two plates from a station and ash-free dry weight determinations were made;[6] 9

3. Periphyton was scraped from two other plates from the same station and chlorophyll *a*, *b*, *c* and pheophytin *a* determinations were made and autotrophic index was determined. 9 Procedures used were identical to those described by the EPA[6] except that grinding of periphyton was not done; and

4. Autotrophic index was calculated using the EPA[6] formula as previously mentioned. 9

Benthos (Macroinvertebrates)

All animals and plants living in or upon the bottom of a lake, river or ocean are collectively termed as benthos. Macroinvertebrates constitute the animal portion of the benthos which are capable of being detected with the unaided eye. The major groups constituting freshwater benthic macroinvertebrates are insects, annelids, crustaceans, mollusks, flatworms and roundworms. Because benthic macroinvertebrates, by their diet, can be classified as omnivores, carnivores or herbivores, they are not able to be placed at any one trophic level.[6] This group constitutes a key link in the food web of fish.

Benthic macroinvertebrates are good indicators in an aquatic ecosystem because of their limited mobility, slow turnover rates and differential tolerances to environmental stresses. This group has been divided by the EPA[6] into tolerant, facultative and intolerant members on the basis of tolerances to decomposable organic wastes. Presence of even a few intolerant members at a particular location can be a significant indication of low organic waste content of that area. Collection of benthic macroinvertebrates from the bottom by dredging, when possible, is a good sampling technique. However, in making comparisons between different sampling locations it must be kept in mind that the composition, abundance and distribution of these organisms is very much dependent on bottom type (particle size, organic content), water depth and water velocity.[6] Because of the uniformity of sampler substrate, the use of suspended artificial substrate samplers is extremely useful in making water quality comparisons among different areas, especially if the bottom cannot be effectively penetrated by a sampling dredge. However, artificial substrates are selective and do not necessarily reflect the actual bottom community.

Sampling for benthic macroinvertebrates in the present baseline
program was done by dredging and by use of artificial substrates. 9
Locations of dredging and artificial substrate sampling stations are
indicated in Figures 6.1-4 and 6.1-5, respectively. Sampling schedule
for the survey is shown in Table 6.1-1 and the total number of samples
collected and analysed as shown in Table 6.1-3. Sampling 9
frequency, methods and analysis procedures used are shown in
Table 6.1-2.

Dredging was done using a 9" x 9" x 9" Ponar dredge. Four grabs were 9
taken at each location; two for identification and enumeration 9
of organisms and two for biomass determination. Volume of each grab
was recorded and the entire sample placed in jars and preserved 9
with 10-percent formalin. At the laboratory the samples were sieved
using a number 30 sieve (0.52 mm mesh) and sorted organisms placed
in 70-percent ethanol. Identification of organisms was done and
results expressed as number organisms/meter2 and number of
organisms/liter. Composite biomass was determined by measurement of 9
blotted weights and ash-free dry weight.(6) Biomass of mollusks was
determined separately from that of all other organisms because
molluscan biomass (primarily the Asiatic clam, <u>Corbicula manilensis</u>)
was considerably greater than that of all other organisms. Sampling 9
using artificial substrates was done at a mid-channel and a 9
near-shore location at each of the three transects shown in
Figure 6.1-5. Samplers were of the Hester-Dendy type(13) consist- 9
ing of multiple, hardboard plates. Each sampler was maintained
one to two feet above the river bottom by use of a cinder block
and a styrofoam float for a six-week exposure period. Analysis
procedures for identification, enumeration and composite biomass
determinations were basically the same as those used for the
dredged samples. 9

Prior to June 4, 1974, a single sampler was placed at each sampling
location. The plates used were evenly spaced, were square cut and

each sampler had a total exposure area of 0.0939 m^2. Identification and enumeration of organisms was done from one half of the plates and biomass determination from the remaining plates of the same samples. Because the rods supporting the plates in each sampler were of nylon, they could not withstand current velocity. As a result of supporting rod breakage most of the samplers put out prior to June 4 were lost.

After June 4, 1974 metal rods were substituted for nylon rods and
flotation was reduced; thus, the problem of sampler loss was rectified.
Plates were variously spaced and had a circular cut so that the en-
tire sampler could be placed in a jar with preservative. Total
exposure area of one sampler was 0.092 m^2. Two samplers were 9
placed at each location; one was used for identification and enumer-
ation of organisms and the other for biomass determination.

Corbicula clams were found to be plentiful in the study area and appear 9
to constitue the major part of the benthic macroinvertebrate biomass in
this part of the river. Because of their abundance and possible impor-
tance to the ecology of the survey site, additional attention was 9
paid to them. Corbicula is of special importance to CRBRP because
it is a pest which has caused clogging problems in the circulating
cooling water systems at TVA steam plants.[14] Larvae entrained with-
in the cooling system cause clogging by attaching and growing in the
system. To determine the potential clogging problem, extensive Cor-
bicula population data were collected in the area of the Site. Lengths 9
of all clams collected were measured to determine clam spawning periods 6
and present population structures in the Clinch River at the Site.

Macrophytes

Macrophytes are multi-cellular aquatic plants whose cells are differentiated into specialized tissue. They range in size from microscopic to massive forms and in species composition from mosses to flowering plants. Macrophyte communities occur naturally in the majority of aquatic ecosystems and a variety of community types exist due to various environmental conditions which may affect plant growth. Some of these influencing environmental conditions are nutrients, substrate, water velocity, temperature and light. In studies of macrophyte communities, emphasis is usually placed primarily on the herbaceous plants.

Use of the macrophyte community as an indicator of water quality has received very little attention. However, such pollution factors as sludge deposits, turbidity, inorganic and organic nutrients and herbicidal compounds may stimulate or prevent the growth of macrophytes.[6]

During the baseline program, extensive search and sampling 9
for macrophytes was carried out along both shores, approximately 9
200 feet upstream and downstream of the five transects indicated in Figure 6.1-6. Sampling for macrophytes was done three times during the survey period according to the schedule shown in Table 6.1-1. In Table 6.1-3 the total number of samples collected has been left blank because the occurrence of macrophytes was expected to be a variable factor. The density of growth encountered was in fact so low that quantitative 9
sampling was not performed.

During the March field trip, river water level was low and much of the shoreline was exposed. This enabled a rather thorough investigation for macrophytes to be carried out. Search for macrophytes was done by visual inspection of shoreline, wading and raking by hand and occasional dredging using the Ponar dredge. During the May and July field trips water level was high. Search for macrophytes during 9
these field trips was carried out by wading and raking at about one-third of the stations and by raking from a boat at the other stations.

No precise quantitative sampling was done during these trips because macrophyte growth was almost non-existent. Only an occasional strand of Eurasian water milfoil, liverwort (Scaponia sp.) or occasional moss growth (Fontinalis) on submerged branches were found. 9

9

Fish Populations (Adult and Juvenile)

Fish represent the highest trophic level in most aquatic ecosystems and as such hold a conspicuous position as indicators of the general condition of the ecosystem. Environmental stresses on lower trophic levels may eventually be reflected in the fish population structure. In some situations fish may be more sensitive to pollutants than lower animals and plants.

Methods of collecting fish are often selective with respect to species and size of individuals. In most methods of capture, the fish collected represent only a very small portion of the total population because of behavioral differences among the fish species. These differences may exist in accordance with sex, size, habits and time of day or season.

Sampling of fish in the present baseline program was done by 9
electroshocking and gill netting at approximately the locations
indicated in Figure 6.1-7. Sampling schedule is listed in Table 6.1-1
and the number of samples which were collected during the year 9
study can be found in Table 6.1-3. An outline of sampling frequency,
methods and analysis procedures is presented in Table 6.1-2.

Gill netting was done using nets 150 feet long and six feet high; each
net contained six panels with bar mesh sizes of 3/4, 1, 1-1/4, 1-1/2,
2 and 3 inches. During a field trip all nets were set at each location 9
for one to two hours or overnight (12 to 14 hours). Nets were usually
attached to shore and set perpendicular to the shore. In the case of
Transect 4 one net was attached to the mid-river sand bar and set
perpendicular to the shore in the direction of the north shore. At
the sampling stations immediately at the mouths of Caney and Poplar
Springs Creeks the nets were sometimes set directly across the mouths 9
of the creeks.

Electroshocking was done using a 240 Volt (3,000 Watt) AC generator.
AC current was converted to pulsating DC by a half-wave rectifying 9
bridge. Sampling for a station consisted of electroshocking approx-
imately 300 feet upstream and downstream from the locations indicated
in Figure 6.1-7.

Analysis of captured fish included species composition, relative 9
species abundance, percentage of game, rough and forage fish and

determination if any fish found belong to the endangered species category. Species diversity was computed. Length (standard length) and weight measurements were made on all fish immediately after capture. 9

Additional attention was given to the following seven species of fish: Stizostedion canadense (sauger), Morone chrysops (white bass), Alosa chrysochloris (skipjack herring), Dorosoma cepedianum (gizzard shad), Dorosoma petenense (threadfin shad), Cyprinus carpio (carp) and Ictiobus bubalus (smallmouth buffalo). In a TVA survey[15] of fish at the baseline program site, these seven species were found to be considerably more abundant than all other species which were collected and identified. The sauger and white bass are highly prized game fish by fishermen in the area. 9 9 9

From the length and weight measurements a condition factor "K", as an estimate of the state of health or well-being, was calculated for each of the seven species. K is calculated from the equation:[16] 9

$$K = W\,10^5/L^3$$

where,

W = Weight in grams

L = Standard length in millimeters

Length by age growth curves were determined for these seven species using best fit curves. Age determinations, including back-calculations, were made for 30 fish of each of these species. Information derived from this analysis was used to describe the growth and condition of each of these populations. 9 9

Fish Eggs and Larvae

By condenser entrainment and exposure to thermal effluents of a power plant, heat-sensitive fish eggs and larvae may be destroyed and fish populations of an area thus impacted. It is important to know if fish eggs and larvae are present in the region of the power plant intake structure or in an area that would be influenced by an appreciable thermal plume. Proper assessment of fish eggs and larvae requires frequent, quantitative sampling during and immediately after the general spawning season. Quantitative sampling is difficult because many of the fish eggs are attached to the bottom or shores of a river and may be very spotty in distribution.

Locations of the five sampling stations at which fish eggs and larvae were collected are shown in Figure 6.1-8. These samples were collected bi-weekly from May through August as indicated in Table 6.1-1. Total number of samples collected during the period of the survey is shown in Table 6.1-3. 9

Fish eggs and larvae samples were collected at each station by netting and by pumping. 9 Net samples were collected using a 1/2-meter diameter, 1,000 μ mesh ichthyoplankton net placed in a stationary upstream position one to two feet above the bottom. Sampling time was 9 10 minutes at each station with flow volumes recording using TSK meters attached to the inside and outside of net frame. Pump samples were col- 9 lected using a submersible pump placed one to two feet above the bottom. Pumping was done for 10 minutes at each station at the rate of 48 gallons per minute. Pumped water was strained also through an ichthyoplankton net. 9 All fish eggs and larvae samples were placed in polyethylene containers and preserved in 10-percent formalin. Analysis procedures for collected samples are indicated in Table 6.1-2.

Fish Stomach Contents 6

Food preference of fish, as determined by analysis of stomach content, gives an indication of which organisms in the aquatic ecosystem are important foods for the fish. Organisms such as phytoplankton, zooplankton, periphyton, macrophyton and benthos are often found in stomach analysis of fish.

Sampling frequency for fish stomach contents is given in Table 6.1-1. 6
Ten sampling locations where fish used for stomach analysis
were captured are shown in Figure 6.1-7. Both gill netting and 9
electroshocking were used as methods of fish capture. As noted in
Table 6.1-3, individuals of each of the seven most abundant 9
species were collected for stomach analysis. All fish were injec- 9
ted with 100-percent formalin in the peritoneal cavity in the field
and kept frozen.

In the laboratory the entire alimentary canal of each fish was then 9
dissected and preserved in 70-percent alcohol. During examinations of
the alimentary canal, any extraneous fat, liver and pyloric caeca, 6 9
were trimmed away from the stomach and the weight of the stomach
determined. An incision was made which completely circumscribed the
stomach, and the percent fullness of the stomach estimated. After
all food items had been picked from the walls of the stomach, the net
weight of stomach contents was determined by the difference be-
tween gross weights before and after removal of food items. When the 9
case arose where no food was found in the stomach, the alimentary
canal then was further dissected and the intestinal region examined
for food items. All food items were then identified to the most spe-
cific taxon practical and counted; the percent abundance was calculated.

Species Diversity

Diversity indices are mathematical expressions which describe community structure and permit the summarization of large amounts of information about numbers and kinds of organisms.[17] Diversity is also related to community stability, since a community with a highly diverse assemblage of organisms, possesses more potential trophic pathways along which density-dependent population control mechanisms can operate.

A variety of different diversity indices have been suggested by ecologists interested in community structure. These indices differ in the assumptions made about the relative abundance of species in natural communities, in their sensitivity to change in community structure and their degree of independence of sample size.

Of the variety of diversity indexes available, the one 9
selected for use in this study was the information theory function 9
derived independently by both Shannon and Wiener and defined by the equation:[18]

$$H^1 = -\Sigma \, p_i \; \log p_i$$

where,

H^1 = Measure of diversity = information content of sample

p_i = Decimal fraction of total individuals belonging to the i species

This diversity index has been widely used in the past by numerous authors.[17,19,20,21] However, this index assumes that a random sample is taken from an infinitely large population and that all the species in the community population are represented in the sample.[22]

Although the Shannon-Wiener index is perhaps the most common diversity index currently in use, as indicated by the literature, some concern
has arisen that it is not as widely applicable to field data 9
as it seems.[22,23] Reevaluation of this index is currently being undertaken by a variety of investigators to either confirm its validity or to propose a more suitable index to be utilized in conjunction with field collections.

6.1.1.2 PRECONSTRUCTION-CONSTRUCTION AQUATIC ENVIRONMENTAL MONITORING PROGRAM

Preconstruction effects monitoring was initiated in March 1975. 9
This program was based primarily on a continuation of many of the
features of the comprehensive baseline aquatic monitoring program 6
conducted during the period March 1974 through May 1975, which is 9
discussed in detail in Section 6.1.1.1.

The initial preconstruction program, which was conducted during
the period March 1975 through October 1975, included the
monitoring of Clinch River water quality, phytoplankton,
periphyton, zooplankton, and benthic macroinvertebrate 9
communities. Also, special surveys were conducted to monitor the
impact of runoff from the site on Clinch River water quality.
The composite program is summarized in tabular form in Table
6.1-4 and the sampling stations are shown in Figures 6.1-9a and
6.1-9b.

The preconstruction monitoring program was reviewed and revised 9
in January 1976 to reflect a more comprehensive site-specific 6
monitoring program. This program was not designed to be a
continuation of the baseline monitoring program or as a 9
preoperational monitoring program, but was based on the knowledge
and experience of TVA's technical staff with respect to the
hydrodynamic and aquatic conditions of the Clinch River in the
vicinity of the site and the results of the Aquatic Baseline 6
Monitoring Report, Section 2.7. This site-specific monitoring 9
program is summarized in tabular form in Table 6.1-4a and the
sampling stations are shown in Figures 6.1-9a and 6.1-9c.

In January 1978, ERDA (now DOE) requested that all aquatic
monitoring at the site be discontinued except for the peripheral 9
storm water runoff, which was to continue through October 1978.

Initially, preconstruction monitoring was to be followed by 16
construction effects monitoring once site preparation was

started. Data from construction effects monitoring were to be compared with preconstruction data to assess effects of siltation and increased turbidity related to runoff and construction of instream facilities (i.e., intake, discharge, and barge-unloading facility).

In accordance with an agreement with the Environmental Protection Agency (EPA) and the State of Tennessee, in lieu of an instream monitoring plan for assessing construction effects, Best Management Practices (BMP) will be applied for sediment and erosion control in order to reduce impacts to the aquatic environment.[22a] BMP for this wastewater will consist of 16
sedimentation control ponds large enough to contain the runoff resulting from a 10 year, 24-hour storm event and slow sand filtration to remove finer particles. Filtering capability will be designed to limit discharge from these basins into the Clinch River to 50 mg/l TSS. Therefore, construction monitoring will concentrate on monitoring performance of these treatment systems as required by the NPDES Permit. In addition, all construction activities associated with instream facilities will be within enclosures, thus minimizing siltation in immediate and downstream areas.

As needed, instream construction will be scheduled to avoid periods of fish spawning in this area of the Clinch River. A study to locate sauger spawning areas in the vicinity of the project has been initiated such that potential construction impacts to suitable spawning areas can be minimized.

A preoperational monitoring program will be designed and implemented two years prior to scheduled date of initial fuel loading as required by the NPDES Permit. This program will be 6 9 16
based on the details of the final plant design and the existing environmental conditions at the time the program is to be implemented.

9

Physical, chemical, and biological water quality data collected by TVA during the preconstruction monitoring program are available (23a) and on file in the TVA's Water Quality Branch offices. 16

6.1.1.2.1 MONITORING PROGRAM DESCRIPTION

This section outlines the monitoring program performed from March 1975 through October 1978, summarized in Tables 6.1-4 and 6.1-4a. 9

<u>River Substrate</u>

Single sediment samples were collected at CRM 14.4, CRM 15.4, CRM 17.9, and CRM 19.0 on a monthly basis from March to October 1975 and on a seasonal basis in 1976 (March, May, July, September) and 1977 (March, May, and July). A Ponar dredge was used to collect the samples.(23b) Sediment particle size composition was determined.

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Physical and Chemical Parameters 9

Instream monitoring stations were located at CRM's (Clinch River Miles)
23.1 (1975 only), 19.0 and 17.9, upstream from the Site and at CRM's 15.4
and 14.4, both downstream from the Site. Samples were collected monthly 9
from March through October 1975, and January and March through October 6
during 1976-1977. All water quality sampling conducted during these
surveys was coordinated with and conducted concurrently with the limno-
logical preconstruction monitoring program. 9

Samples were also collected at the mouths of Caney Creek, Poplar Springs
Creek, Grassy Creek and a tributary at CRM 14.6, monthly from March 9
through October 1975.

Samples collected during the general water quality (and biological sup-
port) surveys were analyzed for temperature, dissolved oxygen, pH,
conductance, alkalinity, nitrogens (organic, ammonia and nitrite plus
nitrate), phosphorus (total and filterable), chemical oxygen demand, 6
total organic carbon, solids (dissolved and suspended), turbidity and
color (true and apparent). At all stations, the temperature,
dissolved oxygen, pH and conductance data were collected at depths of
0.3, 1, 1.5, 3, 5 and 6 m; all other parameters were collected at 1, 3 9
and 5 m depths. In addition to the analysis above, during 1975 and the
months of January, April, July and October of 1976 and 1977, biochemical
oxygen demand, fecal coliform (surface samples only), sulfate, silica,
chlorides, cadmium, chromium, copper, lead, mercury, nickel, zinc, iron 6
(total and filterable), sodium, potassium, calcium, magnesium and 9
manganese (total and filterable) were analysed. Soluble organic carbon 9
was also measured in 1975.

Perimeter monitoring was also conducted in the creeks and sloughs that
drain the construction area. Sample collections were made monthly from 9
March 1975 through October 1978 and supplemented by additional sample 6
collections during selected periods of heavy rainfall (0.3 inch or more

per hour or 1.0 inch or more over a 24-hour period). Samples collected during this portion of the monitoring program were analyzed for pH, suspended solids and turbidity. 9 9

Sample collection and analysis procedures for all water quality phases of the preconstruction monitoring program were in accordance with the "Handbook of Standard Procedures for the Collection of Water Samples"(1R) and "Handbook of Standard Laboratory Operating Procedures."(24) 6 9 16

Ecological Parameters 9

Fish and Fish Habitat

Construction activities potentially present two main types of aquatic impacts: long-term commitments of small areas of aquatic habitat due to instream construction and short-term increase in turbidity and localized siltation. 6

Acreages of aquatic habitat lost due to construction (dredging or filling) of intake, discharge and barge facilities will be documented. 16

Because of the potential for sauger to spawn in the vicinity of the CRBRP site, a study to identify sauger spawning areas in the reach of the Clinch River between CRM 9.0 and Melton Hill Dam (CRM 23.1) was initiated in March 1982. 16

Limnological

The results of the baseline aquatic monitoring program
previously described and summarized in Section 2.7, reflect a
comprehensive baseline assessment of the limnological
communities in the vicinity of the Site. The number of
monitoring stations and the sampling frequency in the 9
preconstruction program were considerably reduced from that 16
of the baseline assessments. Primary emphasis was placed on
those portions of the aquatic community that reside in the 9
potential impact areas (i.e., the benthos) rather than
detailed enumeration of that portion of the aquatic community
(plankton) which simply pass through the potential impact
area. 6

Artificial benthos substrates (in triplicate) were placed at
four stations located at CRM 19.0, 17.9, 15.4 and 14.4, 9
monthly from March through October 1975 and during the months
of May, July, September and November of 1976 and 1977. These
substrates were retrieved following an approximate two-month
exposure and enumerated to determine benthos fauna, biomass,
numbers and species diversity.

The benthic communities were further monitored by the
collection of ten replicate Ponar dredge samples at each of 9
the four stations during the months of March, May, July and
September for the years 1976 and 1977. These samples were

enumerated to determine benthos biomass, numbers and species 6
diversity. 9

16

Zooplankton and periphyton samples were also collected during 1975. These were analyzed for taxonomic composition, diversity (zooplankton), biomass (periphyton) and autotrophic index (periphyton). 16

6.1.1.2.2 RESULTS OF PRECONSTRUCTION MONITORING PROGRAM 9

The results of the preconstruction monitoring program, suspended in 1977, are described in detail in Reference 23a, and are summarized below.

Clinch River Substrate

The substratum in the area of the CRBRP is predominantly coarse with the majority of the sediment being classified as rocky.

The sediments collected in 1975 indicated a similarity between CRM 14.4 and CRM 17.9. They also indicated a similarity between CRM 15.4 and CRM 19.0. However, in 1976 and 1977 the similarity between these stations was not as definable and was attributed to the collection of sediment samples at different locations.

Clinch River Water Quality

Observed temperatures in the Clinch River were well below the State of Tennessee standard of 30.5°C. The river was well mixed with thermal gradients normally below 1°C. During periods of reverse flow warmer water from Poplar Springs Creek appears to flow upstream elevating river water temperatures.

Dissolved oxygen concentrations of the Clinch River were greater than or equal to 5.0 mg/l. The water was well mixed in the vertical direction, with dissolved oxygen gradients normally less than 0.5 mg/l. Isolated low concentrations of dissolved oxygen, ranging from 3.2 to 4.7 mg/l, were measured at Melton Hill Dam tailrace. But there appears to be sufficient reaeration capacity in the river to increase levels to 5.0 mg/l within a short distance. Dissolved oxygen percent saturation levels did not indicate any areas of unusual oxygen production which would be attributed to widespread photosynthetic activity or areas of serious reduction in dissolved oxygen concentrtions. 9

Measured concentrations of nutrients, most metals, and sanitary-chemical constituents were normally low. Elevated concentrations of mercury and COD were observed on isolated occasions. Concentrations of iron and manganese were above levels identified for finished drinking water. The water is considered to be moderately hard.

During rainfall events the river contained high total coliform densities. The high nonfecal ratio would indicate that the source of the bacteria is soil and vegetation.

Site Stormwater Runoff Water Quality

Rainfall intensity rather than the total amount of rainfall had a more significant impact on physical water quality in the drainageways. Surveys performed in conjunction with periods of intense rainfall resulted in the highest levels of suspended solids and turbidity measured in the drainage ways. An evaluation of suspended solids and turbidity data show that the observed values varied considerably and did not plot as a normal distribution.

In 1975 five special rainfall surveys of the Clinch River were performed. Neither the total amount of rainfall nor rainfall intensity could be clearly correlated to Clinch River physical water quality due to time delays between the rainfall events and surveys. In addition, a determination of whether the site was the source of the suspended solids and turbidity could not be 9 made. Therefore, the data resulting from this activity are useful only for background determinations in the Clinch River after rainfall events. It is clearly shown by this evaluation that (1) rainfall intensity is significant to stormwater runoff quality, and (2) the timing of stormwater runoff surveys is 16 critical. 16

Benthic Macroinvertebrates

The data obtained both by artificial substrates and by Ponar dredges indicated a macroinvertebrate population that is not very diverse and also low in numbers. In general, the fauna collected indicate a habitat that is substantially "rocky" in nature. This term implies a range from gravel to pebble sized substrate.

The taxa collected differed extensively from those reported in the baseline study (Section 2.7). However, this was attributed to different station locations and habitat types.

Biomass and quantitative estimates indicate a selectivity for artificial substrates by non-molluscan macroinvertebrates.

Phytoplankton

The most common phytoplankton genera found throughout the sampling reach were Melosira, Synedra, Stephanodiscus, Chlamydomonus, Scenedesmus, Dactylococcopis, Anacystis, and Trachelomonas. Generally the Chrysophytes were dominant mostly during the spring, the Chlorophyta during the summer, and the Cyanophytes during the fall.

Numbers of phytoplankton generally start increasing during May with the 9
largest peaks occurring in October. Highest concentrations were over 3,700,000 cells/ℓ at CRM 14.4 during October. Concentrations of less than 100,000 cells/ℓ only occurred during March at CRM's 17.9 and 19.0.

Chlorophyll a and productivity rates generally followed the same pattern, especially with relatively lower values during the months of March, April, and May of each year during the monitoring period. May was an exceptional month during 1977 for productivity rates with higher than usual values. The comparisons of 1976 and 1977 productivity rates show similarity with normal annual variations caused by seasonal temperature and turbidity differences in the water.

All three phytoplankton parameters (standing crop, chlorophyll a, and productivity) indicated a patchy distribution primarily controlled by a continuous moving flow pattern of the Clinch River with increases observed downstream from CRM 19.0 as the water mass velocity decreased and the retention time became longer. Productivity was also greater in the channel areas than in the overbank areas for surface area measurements due to deeper waters, but similar for per unit area measurements.

Periphyton

The data indicated that Chrysophytes (diatoms) were the dominant algal group at each station. They also indicated that the genus Achnanthes comprised the majority of the Chrysophyta and, as such, a majority of the entire periphyton community at times. The autotrophic index data were highly variable both temporally and spatially.

Zooplankton

Samples revealed a diverse and abundant fauna throughout the study area
with seasonality a major influencing factor on species occurrence and 9
abundance. Rotifers were the predominant zooplankton at all stations with the exception of April when the Cladocera were the dominant group.

Seasonal effects on rotifers are quite dramatic with large abundances occurring in 1975 during the months of May and October for some species and May, August, and September for others. Five species were primarily responsible for rotifer abundance throughout the year.

One species of Cladocera, Bosmina longirostris, was found on all sampling dates and was the dominant Cladoceran at most stations throughout the year.

Diversity indices changed seasonally.

There were no dramatic differences between the four stations with respect to the zooplankton population.

6.1.2 GROUNDWATER

A network of six manually sampled groundwater observation wells
was established on the site early in 1973, as shown in Figure
6.1-10. Monthly observations of water levels have been made 6
since May 1973; periodic water-level observations will continue 9
throughout the life of the plant. In addition, a monitor well
equipped with an automatic sampling device was installed in
October 1975, in one of the main areas of groundwater movement 6 8
from the plant to the river (Figure 6.1-10). Water levels are 9
measured in this well on the same schedule as the other wells. A
weekly composite of periodic samples is available from this well. 8 9

During the preconstruction monitoring program (1976-1977),
composite groundwater samples were analyzed for chemical quality 9
on a quarterly basis. These samples were analyzed for the
following parameters: temperature, pH, conductivity, alkalinity, 9
total dissolved solids, phosphorus (soluble and total), copper, 8
nickel, zinc, chromium, boron, sodium, sulfate, manganese,
cadmium, and lead. During the life of the plant, chemical 16
quality analyses for the listed parameters will be made on a
quarterly basis on composite samples from the monitor well.

6.1.2.1 PRECONSTRUCTION GROUNDWATER QUALITY MONITORING RESULTS

An evaluation of all groundwater data showed a quality variation with differing sampling techniques. The sampling technique utilized for the nonpumped observation wells did not allow for the removal of the standing water in the casing and resulted in
contaminated samples. The source of contamination would most 9
likely be solids entering the casing from the host formation and corrosion of the metal casing. Additionally, acidification of a contaminated sample to a pH of 2.0 would dissolve suspended solids in the water and solubilize most metals contained in these solids. These solids normally would not be present in a sample obtained from a well properly flushed prior to sampling.

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Therefore, the data obtained from the unpumped wells did not properly represent the quality of water in the formation at the Site.

An evaluation of the data obtained from the pumped well showed that at the site groundwater quality was good. Concentrations of dissolved solids were low, averaging 230 mg/l. Concentrations of analyzed nutrients and metals were normally low and on many occasions below detectable limits. 9

6.1.3 AIR

6.1.3.1 METEOROLOGY

Meteorological data for the CRBRP area are referenced in Section 16
2.6 and include data extracted from local and regional climatological records; hourly wind direction, wind speed and stability data from the CRBRP on-site permanent meteorological tower (110-meter), and information on severe weather phenomena. 9 11 16
Local climatological data are drawn from the National Weather Service records, primarily for Knoxville and Oak Ridge, 16
Tennessee, and from TVA fog observation stations along Melton Hill Lake on Clinch River upstream from the Site. Regional information on low-leel inversion frequency, mixing depths, wind speed, and air pollution potential is taken from publications by Hosler[25] and Holzworth[26,27].

16
Hourly dry-bulb temperature and dew point data for 1970 thru 1973 from the Bull Run meteorological facility (15 miles northeast of the Site and based at 1,042 feet MSL) were used to obtain the results in Section 5.1, Effects of Operation of Heat Dissipation System.

Tornado occurrence statistics are taken from publications by the NOAA Climatologist for Tennessee [28,29]. Tornado occurrence probability at the Site is calculated by Thom's method and based on his frequency data[30]. Information on hail damage potential at the Site is based on Changnon[31]. Extreme rainfall for 9
periods ranging from 5 minutes to 24 hours are from Knoxville records[32]. Historical data on glaze storms are from the U.S. Army Technical Report EP-105[33] and information on passage of tropical cyclones through the eastern Tennessee area is drawn from a U.S. Department of Commerce publication on North Atlantic hurricanes[34]. 10

6.1.3.1.1 TEMPORARY MONITORING SYSTEM

Collection of on-site meteorological data at the temporary meteorological facility (Fig. 6.1-12) located about one-fourth mile west-southwest of the plant reactor site began on April 11, 1973 and ended March 2, 1978. Data were collected by the 16
"Pulse-O-Matic" system during the period April 11, 1973 to June 21, 1977. Data were collected by the "Nova" System during the 16
period February 11, 1976 to March 2, 1978. The facility was also equipped with backup analog strip-chart recorders for both wind and temperature data. Data from the 200-foot tower (based at 772 ft. MSL) initially included temperature, wind direction, and wind speed at the 75- and 200-foot levels and temperature difference (delta-T) between these two levels. The 75- and 200-foot levels were selected as representative heights for identifying the low-level wind and stability patterns over the heavily wooded, irregular terrain. Had the general site area been relatively level and without heavy timber, 33 feet and 150 feet aboveground would have been considered the more representative levels as suggested in Regulatory Guide 1.23 and based on past meteorological experience. 16

A number of modifications were made to the temporary meteorological facility during the period of operation. 8 9

A hygrothermograph was installed in May 1973. In April 1974, dry bulb temperature, wind speed and wind direction sensors were added at the 33-foot level. Also at this time the delta-T system was converted to a direct measurement system between the 75- and 200-foot levels.

As of February 11, 1976, an additional data acquisition system 16
was installed. This system utilized a Nova minicomputer to 9
collect the meteorological data for further analysis. The 9
Pulse-O-Matic system was left in operation to assure optimum data

recovery. At the same time, the temperature system was upgraded 8
so that the 33-foot temperature could be included in delta-T
measurements within the accuracy requirement of NRC Regulatory
Guide 1.23.

A dew-point system based on an optical dew-point sensor was
installed at the 33-foot level and became operational in May 9
1976.

6.1.3.1.2 PERMANENT MONITORING SYSTEM 9

The terrain on and around the CRBRP site is complex and wooded. 9 16
In order to provide for assurance that requirements for
acceptable exposure under all meteorological conditions would be
satisfied, two meteorological sites were selected: a 110-meter
tower at site B (800 ft. MSL) and a 10-meter pole (852 ft. MSL) 16
at site A. The locations for these sites are indicated on Figure
6.1-12. Collection of onsite meteorological data by a NOVA
System began on February 16, 1977, and was suspended after March
6, 1978. On March 25, 1982, monitoring at both sites was 16
restarted. Measurements obtained at site B are those normally 9
carried out at the permanent meteorological facility supporting
the operation of TVA nuclear plants. Measurements at site A are 16
wind direction and wind speed only. Planned construction 16
activities are not expected to conflict with meteorological
measurements at the permanent locations.

The instrumentation at site A consists of wind speed and wind
direction sensors at 10 meters. Site B is instrumented for (1) 8 16
wind speed and wind direction at 10, 60 and 110 meters; (2) 9
temperature at 10, 60, and 110 meters; (3) dew point at 10 11
meters; and (4) solar radiation, and rainfall at 1 meter.

The data collection and processing high speed digital computer
system is located at site B with the 10-meter wind measurements
at site A telemetered to site B for processing.

The following is a more detailed description of the meteorological sensors used and their levels on the meteorological tower. 9

Site A

Sensor	Height (Meters)	Description
Wind Direction	10	Climet Instruments, Inc. Model 012-10*, horizontal only; calibrated range, electrical, 0-539o, mechanical, 0-360o continuous: data recording range, 0-540o, linearity ± 0.5 percent; accuracy ±3o; damping ratio 0.6 standard. Starting threshold, 0.75 mph. 8
Wind Speed	10	Climet Instruments, Inc., Model 011-1*; starting threshold, 0.6 mph; operating range, 0-110 mph, calibrated range, 0.6-90 mph; data recording range, 0-99.9 mph; accuracy within ±1 percent or 0.15 mph, whichever is greater from 0.6 to 90 mph.

Site B

Sensor	Height (Meters)	Description
Wind Direction	10, 60 and 110	Climet Instruments, Inc. 012-10*, horizontal only; calibrated range, electrical, 0-539o, mechanical, 0-360o, continuous; data recording range, 0-540o; linearity ± 0.5 percent; percent ±3o; damping ratio 0.6 standard. Starting threshold 0.75 mph.

* A replacement sensor of a different manufacturer or model will meet or exceed NRC Regulatory Guide 1.23. 9

Wind Speed	10, 60 and 110	Climet Instruments, Inc. Model 011-1*; starting threshold, 0.6 mph; operating range, 0-110 mph; calibrated range, 0.6-90 mph; data recording range, 0-99.9 mph; accuracy within ±1 percent or 0.15 mph, whichever is greater from 0.6 to 90 mph.	8 16
Temperature**	10, 60 and 110	Aerodet (ARI Industries, Inc.) Model R-22.3-E100*; 100 ohms, RTD (Platinum Wire Resistance Temperature Detector); mounted in motorfan aspirated solar radiation shield, Climet Instruments, Inc., Model 016-1 at the 60- and 110-meter levels and Model 016-2 at the 10-meter level. Data recording range, $-9.9^{\circ}F$ to $99.9^{\circ}F$; RTD accuracy	16

* A replacement sensor of a different manufacturer or model will meet or exceed NRC Regulatory Guide 1.23. 9

**Temperature difference (ΔT) is calculated in the mini-computer, from the temperature values provided by these sensors. 8

Sensor	Height (Meters)	Description
Temperature (Continued)		±0.06° F; aspirated shield maximum radiation error, 0° F to +0.2° F. 8
Dew Point	10	EG & G, Inc., Model 220 Dew-point Hygrometer*; 16 thermo-electrically cooled stainless steel mirror cooled to dew point, optically sensed, controlled to the dew point; mirror surface temperature sensed by a platinum RTD; sensor range, -50°F to +140°F; data recording range 0°F to 100°F; accuracy ±0.5°F; sensitivity, ±0.1°F.
Solar Radiation	1	Epply Laboratories, 180° Pyranometer, Model 8-48*; 16 calibrated range, 0 to 2 gm-cal cm^{-2} min^{-1}; linearity ± percent from 0 to 2 gm-cal cm^{-2} min^{-1}; response time 4 seconds; cosine response, ±2 percent from 10° to 90°; sensitivity, near 7.5 mv per gm-cal cm^{-2} min^{-1}; typical output, 0-14 mv.
Rainfall	1	Belfort Instrument Co. Model 5915-12* spring 16 weighing and potentiometer output type; calibrated range 0 to 9.9 inches; data recording range 0 to 9.99 inches; accuracy +_0.5% (±0.06 inch); sensitivity, 0.01 inch.

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*A replacement sensor of a different manufacturer or model will meet or exceed NRC Regulatory Guide 1.23. 9

Data Acquisition System

The mini-computer controlled data acquisition system is located 16
in the Environmental Data Station at site B and consists of the
signal conditioners, read-relay scanner, DVM (analog voltage and
ohms to digital converter), mini-computer (NOVA 1200 by Data
General Corporation) with 32K words of memory, high speed paper
tape reader, ASR33 teletypewriter with paper-tape punch, and
various interface and telemetry devices. The system at site A
includes a signal conditioner and interface and telemetry 16
equipment to transmit data to the site B system. All
meteorological sensor outputs are measured periodically during 16
each hour, controlled and printed out by the site B data system.
Strip-chart recorders are provided for wind speed and direction
at both sites. Horizontal wind direction is read each five 16
seconds (720 per hour); wind speed and solar radiation are read
each 15 seconds (240 per hour); temperature and dew point are 16
read each minute (60 per hour); rainfall, and wind sensor supply
voltage is read each hour. 16

Sigma-Y (horizontal), the standard deviation of the wind
direction fluctuations, is calculated for every 5-minute 16
interval, using the respective horizontal wind-sensor output
values (720 per hour). Sigma-Y values computed from the standard 16
statistical formula:

$$\sigma_y = \sqrt{[\Sigma X^2 - (\Sigma X)^2/N]/(N-1)}$$ 16

where X = the instantaneous wind direction and N = the number of 8
valid readings during the 5-minute interval. The twelve 5-minute
values are then used to compute the 1-hour average value,
σ average (1 hour) = ($\sigma_1 + \sigma_2 + \ldots \sigma_{12}$)/12.

Prevailing horizontal wind direction for each hour is computed as the average direction in the 23-degree sector (among 360 overlapping sectors) that has the highest number of valid readings during the hour. 8 16

The data collected on punched paper tapes are transferred offsite to magnetic tapes for validation, storage, and use in analysis of onsite meteorological conditions. 8

The following is a description of the major components of the data acquisition system. 9

Wind Translator -- Climet Company Model 025-2 is a solid state signal conditioner with integral power supplies with a frequency-to-voltage wind speed signal converter and a wind direction signal amplifier. Signal outputs are 0-10 ma to strip-chart recorder and 0-4.8v to the DVM input. 9

The following is a description of the data collection hardware utilized in the mini-computer data acquisition system at the CRBRP site.

NOVA 1200 Minicomputer -- the Nova 1200 is a general purpose computer system with a 16 bit word length. It executes arithmetic and logical instructions within 1 cycle time of 1350 nanoseconds. The central processor is the control unit for the entire system: It controls all peripheral input-output (I/O) equipment, performs all arithmetic, logical, and data-handling operations, and sequences the program. It is connected to the memory bus and to the peripheral equipment by an I/O bus. The memory has a maximum capacity of 32,768 words.

<u>High-Speed Paper Tape Reader</u> -- Data General's high speed paper 9
tape reader, model 6013 photoelectrically reads one inch wide, eight channel, fanfold perforated mylar or paper tape at speeds up to 400 characters per second. The reader is interfaced to the Nova 1200 computer by the reader I/O control, a part of the basic I/O control board.

<u>33 ASR Teletypewriter</u> -- The automatic Send-Receive 9
Teletypewriter is an electromechanical device that provides I/O 16
terminal facilities for the mini-computer. The reader senses the code punched in tape which can then be transmitted to the system computer. The unit prints messages and data on paper (hardcopy) and the tape punch perforates paper tape.

<u>Computer Interface</u> -- The computer interface is the interface
equipment between the Nova computer and the remainder of the data 16
acquisition system. The basic computer interface furnishes computer control signals and/or data input from the following: (1) TTY Power - On Control; (2) Battery Real-Time Clock; (3) Computer Interface Front Panel Axuiliary, Real-Time Clock; (4) DEVICE 40--Control HSDL; and (5) DEVICE 60--DVM/MET Type II.

<u>Battery Real-Time-Clock</u> -- The BRTC, (Battery Real-Time Clock), is an alternate system clock. Its purpose is to provide a time reference for the computer in the event of a system power failure. The BRTC is powered by a 12 VDC "gel cell" battery. System 120 VAC powers an AC "float" charger which holds the battery voltage constant and powers the unit under normal operation. Should a system power failure occur, the battery supplies the unit power until system power is restored. When a return of system power occurs, the computer's clock is updated with the BRTC's time including seconds, minutes, and hours. Battery life without charging is approximately 45 hours.

DVM/MET Type II -- The purpose of the DVM/MET Type II is to acquire meteorological data upon computer request. The DVM/MET is interfaced to a Hewlett-Packard HP 3405B programmable multifunction meter (DVM). The DVM/MET is capable of measuring various meteorological parameters which are definable by either an analog input or a 4-wire resistance measurement. The measured parameter is displayed digitally on the DVM display readouts and in binary logic levels at the digital output jack. 9

The DVM/MET parameter computer controlled addressing is by means of a parallel digital mux point address and two DVM programs words. The DVM/MET logic provides the trigger signal to the DVM. Data from the DVM is sent to the computer in two 16-bit words.

Digital Voltmeter -- The Hewlett-Packard model 3405B Multifunction Meter is a five-digit integrated digital voltmeter/ohmmeter. A dual-slope integrating technique and fully guarded measurement circuitry provide

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excellent immunity from noise and common-mode voltages. DC measurement is basic to the instrument, with the ohms function added by optional plug-in assembly.

Five dc ranges from 100 mV to 1000 V full scale provides 15 measurements per second, with 20 percent overranging on all ranges. A one μV resolution is achieved on the 100 mV range. An input resistance of greater than 10^{10} ohms is achieved on the 100 mV through 10 V ranges, and 10 megohms on the 100 V and 1000 V ranges.

The Ohms Option has a six range capabiltiy of 100 Ω to 10 MΩ full scale, with 20 percent overranging on all ranges. A 1 mΩ sensitivity is offered on the 100 Ω range which has the maximum 1 mA signal current. A four-terminal technique allows measurements without lead resistance errors on non-Ratio. 9

Other options added to the Standard instrument are Digital Output, Remote Control and Rear Input. Digital output provides a digital output of the measurement data, function, range, polarity, limit-test decisions and some timing signals. Remote Control allows complete control of the instrument with coded voltages or switch closures to ground. Rear Input supplements the front panel terminals.

<u>Recorder</u> -- The servo/riter recorder is a self-balancing potentiometric strip-chart recorder, for accurate recording of dc signals. The signal input leads are floating aboveground and the circuit makes use of a guard shield to accurately record signals that have ac longitudinal and dc common-mode interference. The recorder uses a low-pass input filter to provide transverse interference rejection.

The electronic circuitry is solid state, including a photoconductive chopper. A zener reference unit is standard on all servo/riter II recorders. The flushmount recorder is designed to fit a standard 19-inch rack without special adapters and is available in one to six channels with many options and accessories.

System Accuracies

The system is designed so that the data meet or exceed the accuracy requirements of Regulatory Guide 1.23. More detailed information on total system and system component accuracies are given in the station manual, which will be updated as necessary (rather than the following discussion) to reflect system component and accuracy estimate changes. Replacement components will be compatible with the total system and will be chosen so that the total system accuracy will meet or exceed Regulatory Guide 1.23 specifications.

Wind Speed Error

Component	Units: / Wind Speed:	mph 10	mph 30	mph 100	
Sensor, ± 1% of true value or ± 0.15 mph, whichever is greater		± 0.15	± 0.30	± 1.00	9
Translator, linearity plus drift, total error		± 0.21	± 0.21	± 0.21	
DVM, total error, full scale		± 0.03	± 0.03	± 0.03	
Software, total error, full scale		0	0	0	
Total maximum error		± 0.39	± 0.54	± 1.24	
Root sum square error		± 0.26	± 0.37	± 1.02	
Regulatory Guide 1.23 specification		± 0.5	± 0.5	± 0.5	

The instantaneous error for wind speed measurements, assuming the individual component errors are additive and independent (root sum square error), is within the Regulatory Guide 1.23 specifications for all wind speeds less than 45 mph.

The error of time averaged wind speeds will be less than the instantaneous root sum square error (this statement is applicable for all other parameters in this discussion). Therefore, for wind speeds considered to be most critical for dispersion calculations, the estimated error is well within the Regulatory Guide 1.23 specifications.

Wind Direction Error

Component	Degrees
Sensor	±3
DVM, total error, full scale	±0.160
Software, total error, full scale	-0.674
Total maximum error	-3.834
Root sum square error	+3.08
Regulatory Guide 1.23 specification	±5.0

Dry-Bulb Temperature Error 9

Component		°F
Sensor, RTD		±0.06
DVM, total error		±0.08
Radiation error, maximum		+0.20
Software, total error		
	- 10°F	-0.35
	50°F	0.00
	110°F	-0.26
Total maximum error	- 10°F	-0.49
	50°F	+0.34
	110°F	-0.40
Root sum square error	- 10°F	±0.42
	50°F	±0.22
	110°F	±0.34
Regulatory Guide 1.23 specification		±0.9 (±0.5°C)

Vertical Temperature Difference Error

Component	°F
Sensor 1	±0.06
Sensor 2	±0.06
DVM (Sensor 1 reading)	±0.08
DVM (Sensor 2 reading)	±0.08
Radiation	0.0
Software	0.0
Total maximum error	±0.28
Root sum square error	±0.14
Regulatory Guide 1.23 specification	±0.18 (±0.1°C)

The assumption is made that the radiation and software errors are identical for both sensors and therefore cancel. 9

Dewpoint Temperature Error

Component	°F
Sensor EG & G Model 440	±0.7
Mirror contamination	+0.3
Loss of water in sample lines	-0.2
Sample line contamination	±0.1
Pressure change correction	±0.1
Frost point conversion (dewpoints below 32°F)	±0.05
DVM, total error, full scale	±0.04
Software, total error	0.0
Total maximum error	+1.29
Root sum square error	±0.80
Regulatory Guide 1.23 specification	±0.90 (±0.5°C)

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Refer to Table 6.1-6 for data sample rates and scaling calculations.

Pages 6.1-32k through
6.1-32m are deleted
in Amendment IX

<u>Instrument Servicing, Maintenace and Calibration</u>

The permanent meteorological facility is serviced by engineering 9 16
aides, instrument technicians, or engineers. Maintenance and
calibrations are performed by instrument technicians, electrical 16
engineering associates, or electrical engineers. Prior to plant
operation, operational checks of the system will be made twice 16
weekly or more frequently as necessary to achieve the required 90
percent recovery of data. The calibration status of each
component of the meteorological facility (sensors, recorders,
electronics, DVM, data logger, etc.) is checked and the component 16
field calibrated or removed and replaced by a laboratory
calibrated component, at least every six months. More frequent
calibration intervals for individual components may be specified
in the station manual, on the basis of the operational history of
that component type, in order to ensure the maximum practicable
recovery rate. Detailed, standardized procedures are included in
the station manual and/or the laboratory calibration procedures
document. 16

6.1.3.2 MODELS

The mathematical model used to estimate atmospheric dilution factors (χ/Q values) for gaseous effluets released from the CRBRP is give in Section 2.6.7. Models used to assess reactor accidents are covered in Section 2.6.6. 8

6.1.4 LAND

6.1.4.1 GEOLOGY AND SOILS

The purpose of the foundation investigations and related geological studies at the Clinch River Site was to develop the regional and Site geology, establish the sub-surface geological profile, select the optimum location and bearing elevation for the Category I structures and determine the static and dynamic foundation design parameters for the supporting rock matrix.

6.1.4.1.1 REGIONAL INVESTIGATION PROGRAM

A regional investigation program was conducted which encompassed the area within a 200-mile radius of the Site, with major emphasis placed on the Valley and Ridge Physiographic Province. This investigation contained the following elements:

1. Literature review - a comprehensive review of available data including published and unpublished reports and maps and interviews with recognized authorities, was made to evaluate the geologic conditions of the region and Site;

2. Aerial photographic studies - these studies included thermal imagery, infra-red, color and black and white stereography;

3. U.S.G.S. topographic map studies - maps of the region were reviewed and surface features which were possible indicators of anomalous sub-surface activity were noted for subsequent investigation; and

4. Field Reconnaissance - planning and investigation of specific surface features considered pertinent to the development and understanding of the regional geology was performed.

6.1.4.1.2 SITE INVESTIGATION PROGRAM

A Site investigation program was conducted consisting of the following primary elements: seismic refraction survey, core borings, surface reconnaissance and mapping, geophysical logging, terrace borrow and residual soil investigation, test grouting program and laboratory testing. 9

A seismic refraction survey was conducted at the Site covering approximately 6,940 linear feet. This survey permitted preliminary evaluation of the sub-surface conditions based on measurements of compressional wave velocities of the in-situ material. Conditions investigated included depths to the various sub-surface horizons and the presence of 9
seismic discontinuities. 9

The total investigative program for Category I structures consisted of 9
129 borings of which 66 were directed to defining the Site geology, checking potential anomalies in the seismic refraction data, understanding the nature, extent and significance of sinkholes which have occurred in the limestone formations occurring at the Site and selecting the optimum location and bearing elevation for the Nuclear Island. 9
Sixty-three borings were included in the final investigation phase which permitted the detailed evaluation of foundation design parameters at the selected location of the structures.

Borings were advanced utilizing truck-mounted rotary drills and samples were obtained from both the soil and rock strata. 9 In general, the holes were drilled four inches in diameter through the overburden soils to the top of rock, with standard penetration test samples being taken at five foot intervals. This penetration test consists of driving a sampling device into the undisturbed soil under standard conditions - the sampler size, distance driven and energy used are all predetermined. The resistance to penetration encountered by the sampler was used to determine pertinent engineering properties. In rock,

continuous, NX, NQ and HQ-sized core was extracted from the borings by rotating a conventional discharge diamond-studded bit mounted on either an NX, double-tubed, swivel-type core barrel or an NQ or HQ 9
wire line core barrel. The core was geologically logged, which included a description of the rock based on visual examination, degree of weathering, presence and orientation of joints and partings and any anomalous features.

To aid in the determination of the Site geology, detailed mapping of exposed rock outcrops was conducted by field geologists. Among the 9
features noted were rock types, degree of weathering, orientation of strike and dip, location of sinkholes and lines of demarcation between the different rock units. A Site geological map was subsequently prepared from this data.

Selected borings were logged for natural gamma-ray emission, electrical resistivity and spontaneous potential, to assist in identification and confirmation of lithologic changes. Borings were also logged by additional in-hole techniques, which consisted of gamma density determinations, caliper measurements and compressional wave velocity measurements. 9
Separate cross-hole and up-hole seismic surveys were conducted to permit the determination of various in-situ dynamic rock properties.

Residual soils and terrace deposits encountered at the Site were investigated by means of backhoe trenches, soil sampling and testing to evaluate their potential use as sources of borrow material. Bulk samples were obtained from test pits, protected against loss of moisture and retained for laboratory testing.

A test grouting program was conducted on the west side of the Nuclear Island to confirm the adequacy of the bearing capability of the foundation rocks. The program was performed in an area where the Unit A Limestone is overlain by the shallowest depth of siltstone and conse- 9
quently was considered to be most susceptible to development of solutioning within the bearing influence of the Category I structures.

A comprehensive laboratory testing program was conducted on soil and rock samples obtained from test pits and core borings to determine the engineering properties of these materials. These properties included unit weight, moisture content, compactibility, compressibility, strength and chemical composition.

6.1.4.1.3 RESULTS OF INVESTIGATION

Results of the investigation program are summarized below:

1. The Site is covered by a mantle of residual clay and weathered rock derived from the decomposition of the underlying parent formations which generally occur at shallow depths and consist of sedimentary rocks of Ordovician age. Deformation of the rock strata occurred during the Paleozoic Era (more than 230 million years ago) and are now tilted to the southeast at an angle of about 30 degrees. The Chickamauga Formation consisting of interbedded limestones and siltstones comprises the foundation bedrock in the general vicinity of the plant structures.

2. An upper siltstone band approximately 400 feet in horizontal width was selected as the optimum bearing stratum for the Nuclear Island based on shallow 9
depth of weathering, inherent resistance to development of solution activity and satisfactory engineering characteristics.

3. There is no geological evidence for any capable faulting within 200 miles of the Clinch River Breeder Reactor Plant Site.

4. In conformance with relationships accepted by the 8
Nuclear Regulatory Commission (NRC) for nuclear power plants located in the Southern Appalachian Tectonic 9
Province, and as directed by NRC, the maximum horizontal ground motion for the Safe Shutdown Earthquake 8
(SSE) was established at 0.25 g.

5. Instability of foundation material is not considered a problem.

6.1.4.2 LAND USE AND DEMOGRAPHIC SURVEYS

There are two steps in presenting the population data in the circle and sector format:

1. Distribution of the 1980 population into sectors.

2. Projection of the population for 1990, 2000, 2010, 2020, and 2030.

Although the two steps link together, they have separate approaches.

6.1.4.2.1 DISTRIBUTION OF THE 1980 POPULATION

The preliminary results of the 1980 U.S. Census of Population were used in the existing population estimate and placed in the appropriate sectors within the circle. The circle format is an intersection of rays and radius 10
circles centered at the reactor. There are 16 rays, each 22-1/2 degrees apart. One of the sectors created by two rays is centered on North such that the rays are 11-1/4 degrees east or west of North. Radius circles are at distances of 1, 2, 3, 4, 5, 10, 20, 30, 40, and 50 miles. There are 160 separate sectors in the circle. Figures 2.2-1 and 2.2-2 are examples of the population circles.

The 1980 population was allocated to the population wheel sector using aerial photography for the area within 5-miles of the site and using Census County Division maps (CCD) for the area from 5- to 50-miles of the site.

<u>0- TO 5-MILE ALLOCATION OF POPULATION</u>

The 1980 population within 5-miles of the site was estimated by counting structures, identified on an aerial photograph, which fell within a population wheel sector. The steps were as follows:

- A mosaic of aerial photography was prepared. The photography was at a scale of 1 inch equals 1,000 feet. Aerial photographs were taken on February 25, 1981.

- A clear overlay with the circle and sector figure inscribed on it was placed over the mosaic. The center of the figure was placed on the reactor site.

- Within each sector, structures which were houses or apartments were identified and counted. Apartments were distinguished from houses by identifying apartment parking lots from the photographs followed by a field check to 10 identify the actual number of apartments when necessary. In cases where the structure could not be identified, it was assumed that the structure was a dwelling.

- Using the 1980 Preliminary Population and Housing Unit Counts,[34a] an average number of persons per housing unit was 11 obtained for Roane and Loudon Counties.

- The persons per housing unit calculated above was applied to the structures counted.

This procedure provided a sector by sector estimate of the people within 5-miles of the site.

5- TO 50-MILE ALLOCATION OF POPULATION

The allocation of population between 5- and 50-miles of the site was performed using Census County Division (CCD) maps (CCD's) and assuming that the population is, geographically, evenly distributed within the county divisions. The steps in the allocation process were:

- Obtain the CCD maps. The 1980 maps were unavailable at the time of the study. As a consequence, 1970 CCD maps were used. The Bureau of the Census reported that only Knox County of the study area counties had changes from 1970 to 1980 in the CCD boundaries.[34b] These changes were 11
incorporated into the CCD map.

- A composite of the CCD maps of Tennessee, North Carolina, and Kentucky was prepared.

- The circle and sector figure was placed on the CCD composite map.

- The areal proportion of a Census County Division or town which lies in a sector is calculated.* 10

- The 1980 population for the CCD or town is multiplied by the proportion calculated above. This process is repeated for each CCD or town which lies totally or partially within a wheel sector.

- The sector population estimates are calculated by summing the separate CCD or town estimates.

This method's assumption that the population is evenly distributed over the area of the CCD or town is realistic for Tennessee. Except for national parks and national forests, the state has a relatively dense rural population.

6.1.4.2.2 POPULATION PROJECTIONS

Population projections for the study area for 1990, 2000, 2010, 2020, and 2030 were generated using the Greenberg and Krueckeberg

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*The Census County Division maps provides boundaries for the county, its county divisions, towns of 100 or more persons, and unincorporated towns of 2,500 persons or more. For each of these entities, the census provides a population estimate.

ratio-trend methodology.[34c] In this methodology, U.S. Census Bureau Projections[34d] corrected for the 1980 census performance were used as controlled totals. Projections for Tennessee, Kentucky, and North Carolina were available only to year 2000.[34e] Historical data, the ratio-trend methodology, and the U.S. control totals were used to extend these projections to 2010, 2020, and 2030. 11 11

State projections were "stepped-down" to county and census civil division (CCD) levels. Ratios of county to state populations were obtained from the Tennessee State Planning Office[34f] or by the ratio-trend methodology using historical data for Kentucky and North Carolina. Census civil division projections were "stepped-down" from the county level using CCD to county ratios obtained from the Tennessee State Planning Office or by the ratio-trend methodology. 10 11

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6.1.4.3 ECOLOGICAL MONITORING

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The terrestrial monitoring program is designed to evaluate the impact of operational and construction activities on the structure and function of the terrestrial ecosystem.

6.1.4.3.1 BASELINE STUDIES

A terrestrial baseline study program was conducted on the Clinch River Site to document preexisting conditions and stresses and to identify food chains. Preexisting conditions and stresses are those presently existing on the Site, whether naturally occuring or man-made.

Purpose of the baseline study program was to evaluate, both qualitatively and quantitatively, the specific aspects of the terrestrial environment that will be affected by the construction of the breeder reactor facility. Three major study objectives have been identified:

1. Evaluation of the biotic components of areas subject to construction activity for the plant and associated facilities and assessment of possible environmental effects of plant construction and operation;

2. Observation of seasonal fluctuations in the biological diversity represented within the Site area; and

3. Identification of significant parameters to be measured or monitored in later studies which will provide a more precise estimate of real and potential impact.

The study period included seasonal surveys, shown in Table 6.1-5, which began in the winter of 1974 and ended with the completion of the fall survey of 1975. 6

A two-day reconnaissance field survey was conducted August 27 and 28, 1980 to evaluate site changes since the 1974 baseline surveys and to sample a shortleaf pine plantation that was established in 1976. Results of this reconnaissance survey are reported in Section 2.7. 9

6.1.4.3.2 METHOD FOR ACQUIRING BASELINE DATA - SITE AND ENVIRONS

Terrestrial ecology field investigations of the Clinch River Site included four seasonal surveys conducted during 1974 as indicated in Table 6.1-5. Investigations involved floristic, vegetation, mammal, avifauna and herpetofauna evaluations in 12 communities as discussed below and in Section 2.7. Vegetation types and sampling communities are shown in Figure 2.7-6. Vegetation sampling plot locations, mammal sampling grids and transects and avifauna quantitative transects are shown in Figures 2.7-7, 2.7-A and 2.7-B, respectively. Sampled communities were chosen to include major forest cover types on the site to adequately characterize the site. Sampled communities included mixed hardwood, successional pine, pine plantation, cedar-pine and hardwood-cedar-pine forest cover types. In addition to surveys on plots, general observations of flora, migratory wildlife and herpetofauna were made when traveling from one 9 sampling location to another, systematically driving site roads in early morning and late evening times and searching in suitable habitat. Simultaneous surveys were conducted whenever possible.

The floristic sampling program was designed to determine the presence or absence of plant species that were either listed as rare or that were eligible for listing as threatened or endangered by the U.S. Fish and Wildlife Service. Discussions with Dr. A. J. Sharp of the University of Tennessee had indicated that flora of the Site area was poorly known so an intensive specimen collection and preservation program was conducted. Mounted specimens were deposited at the University of Tennessee Herbarium.

Vegetative sampling, in coordination with the floristic sampling program, was designed to (a) determine the presence or absence of plant species in various forest types, especially rare or potentially threatened or endangered species, (b) provide data to compute density, cover, frequency and abundance of ground cover and shrub species and (c) provide data to compute importance values, annual growth increments and successional trends for tree species. Merchantable tree volume and management procedures were available from Oak Ridge National Laboratory (ORNL). Substantial timber acreages on the Site were thinned or harvested to control forest diseases and pests during and following the field sampling program. The ORNL forest management program is described briefly in Section 2.7.

Wildlife surveys were conducted as indicated in Table 6.1-5 with sampling locations indicated in Figures 2.7-A and 2.7-B. Special attention was given to fauna that were either listed or eligible for listing as rare, threatened or endangered. On-going wildlife studies at nearby ORNL 9
were utilized as indicated in Section 2.7.

Mammal live-trapping grids and snap-trapping transects were established so that traps could be located at the same stations during each survey. Sherman live traps (50 per grid) were placed in grids covering approximately one acre. Household snap traps (50 per transect) were spaced at approximately 20 foot intervals along a marked transect line. A wooden surveyors stake was placed at each trap station in the grid and at each end of the transect. Traps were baited with a mixture of peanut butter and lard to attract both herbivorous and carnivorous small mammals. Each trap was visited in the early morning for five consecutive days. Captured animals were examined to determine age (adult or juvenile), sex, reproductive condition and overall condition. Live captured animals were toe clipped for identification purposes and released. General site searches were also conducted for tracks, scats and other evidence of mammal presence. An early morning and late evening survey was conducted during each survey period. During the summer survey, an endangered bat expert searched known site caves for the presence of bat species, mistnetted in likely bat habitat along Grassy Creek and the Clinch River and searched for other site caves. Results of mammal surveys are discussed in Section 2.7.1.

Avifauna surveys included both quantitative and qualitative investiga-
tions. Quantitative avifauna surveys were conducted for seven days in
late May to early June and in mid-December using a modified Emlen tech-
nique discussed in Section 2.7.1. Sampling transects and stations are
indicated in Figure 2.7-B. Breeding populations were estimated from the 9
late spring survey, while winter resident populations were estimated
from the December survey. Migratory and resident species in other
habitats and on the sampling transects were evaluated during all four
seasonal surveys.

Systematic searches were conducted for herpetofauna species in likely habitat throughout the site during late spring and summer surveys. Herpetofauna aestivate during the dry, hot fall and hibernate during the winter and are not consistently observable.

6.1.4.3.3 METHODS FOR ACQUIRING BASELINE DATA - TRANSMISSION LINE RIGHTS OF WAY

Communities along the transmission corridor were visually examined and the various types identified and described. A summary of the community descriptions, major species observed and species expected may be found in Section 2.7.

6.1.4.3.4 CONSTRUCTION MONITORING

Construction impacts can be thought of as primary and secondary. Primary
impacts include modification and alteration of habitat by blasting, drill- 6 9
ing, excavating and clearing. These impacts will occur during develop-
ment of access corridors (roads, railroads and transmission lines),
clearing and excavation for all construction (intake and discharge areas,
holding ponds, cooling towers and other buildings), noise and vibrations

from construction equipment, exhaust emissions, atmospheric particulates, fuel leaks and spills, mud and activity of men and machines. Associated with these primary impacts are secondary impacts such as increases in housing developments, trailer courts, energy use, recreation and use of recreation facilities (camping, hunting, boating, hiking, etc.), household pets and transportation of all types (automobile, truck, railroad, barge and air).

Monitoring for primary construction impacts on the Site will concentrate on vegetation and vertebrate parameters. Primary and secondary construction impacts that will occur regionally (other than on-site) will be related to construction of power lines and other changes in land use. When power line corridors are developed, habitats will be altered, land cover will change and species composition will change. The major impacts associated with the power lines will be to deciduous and coniferous forest communities and the biota associated with them. 6

A draft program for on-site environmental monitoring during construction
has been prepared by Stone & Webster.[35] Critical ecological elements
will be identified from baseline survey data, and the plant construction 9
manager will be provided with maps and photographs of the locations of
these critical elements so that they may be avoided during construction.
Semi-annual inspections of species and community locations will be per-
formed to monitor the status of the critical elements.

6.1.5 RADIOLOGICAL SURVEYS

Preoperational radiation levels at the Site and environs are discussed in Section 2.8. The preconstruction-construction environmental radiological monitoring program described here has the objective of establishing the extent to which construction activities in the Clinch River disturb the existing bottom sediment, resuspending part of it in the river. This is important at this plant site because radionuclides have been released to the environment in this area by other facilities for approximately 30 years. Full development of the preoperational-operational radiological monitoring program is given in Section 6.2.

6.1.5.1 PRECONSTRUCTION-CONSTRUCTION PHASE ENVIRONMENTAL RADIATION MONITORING PROGRAM

The purpose of this monitoring program is to determine the effect of construction activities on the reservoir environment. To achieve this, a routine program was initiated in 1975 for monitoring radioactivity levels in ground and surface waters and in bottom sediment in the vicinity of the CRBRP. This program was discontinued in December 1977. The construction monitoring program will resume 6 months prior to start of construction. Approximately two years prior to plant operation, it will be replaced by a more extensive preoperational-operational monitoring program.

All samples were analyzed in TVA's Radioanalytical Laboratory in Muscle Shoals, Alabama. Gross alpha and gross beta content were determined by use of a low background proportional counter. Total alpha content was determined by alpha counting heavy metals separated along with strontium. Gamma-emitting radionuclides were identified and quantified by gamma spectral analysis employing a Ge (Li) detector. All sediment samples 9
were dried, pulverized, and thoroughly mixed prior to analysis.

Sediment sampling began in March 1975. Samples were taken quarterly by TVA's Water Quality and Ecology Branch at Clinch River Miles (CRM) 14.4, 15.4, 17.9, 19.0, and 24.0 (Figure 6.1-11). Replicate samples were taken from the right overbanks (horizontal location -- 99 percent from the left bank looking in a downstream direction) at CRM's 14.4, 15.4, 17.9, and 19.0 and midchannel at CRM 24.0 by Ponar dredge hauls.

River water samples were taken automatically by a sequential-type sampling device at CRM's 14.4, 15.4, 18.6, and 23.1. The sampler at CRM 14.4 was located immediately upstream of the Department of Energy (DOE) potable water intake and is considered representative of the raw potable water supply.

The samplers were placed in operation in October 1975, and the initial samples were collected in November. Composite samples from each location were forwarded monthly to the radiological laboratory for analysis.

Ground water monitoring was also begun in October 1975, with the first sample being taken in November. The same type of automatic sampler used in the river water monitoring was employed at a well located down gradient from the proposed plant site (Figure 6.1-10). Water from this well was collected automatically and forwarded monthly to the radiological laboratory for analysis.

The results obtained in these monitoring studies and in three short-term special studies indicate that radioactivity levels in the bottom sediment vary widely with the depth from which the sample is taken, with the river mile cross section, and with time at specific locations.[36] Radioactivity levels found in the over-bank regions near the proposed locations of the barge unloading facility, the water intake, and the discharge site were not significantly different from background levels found in the Tennessee River. However, samples of sedimentary material deposited farther off the bank showed radioactivity levels up to 100 times these levels. 9

Other than gross beta concentrations approximately three to five times background and tritium concentrations approximately 10 times background (measured at Melton Hill Dam), no significant radioactivity levels were found in the water from the Clinch River. Although initial indications are that dredging operations in the river will not produce significant increases in the radioactivity concentrations in the river water due to the resuspension of radionuclides in the bottom sediment, further sampling will be conducted during dredging in order to determine if this is true.

TABLE 6.1-1

CLINCH RIVER AQUATIC BASELINE SURVEY SAMPLING SCHEDULE

	1974										1975				
	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Biological Parameters															
Bacteria	X		X	X	X	X	X		X		X			X	
Phytoplankton	X		X	X	X	X	X		X		X			X	
Zooplankton (tows)	X		X	X	X	X	X		X		X			X	
Zooplankton (pumping)	X		X	X	X*										
Periphyton	X		X	X		X		X			X				X
Benthos (dredging)	X		X	X	X	X	X		X		X			X	
Benthos (artificial substrate)	X**		X**	X**	X	X	X		X		X				X
Macrophytes	X		X		X										
Fish Populations	X		X	X	X	X	X		X		X			X	
Fish Eggs and Larvae	X+	X+	X+	X+	X+	X+									
Fish Stomach Contents	X		X	X		X	X		X		X				
Physical and Chemical Parameters															
Field Measurements	X		X	X	X	X	X		X		X			X	
Routine Lab. Analyses	X		X	X	X	X	X		X		X			X	
Additional Analyses	X						X								
Sediment Analyses															
Particle Size and Organic Content	X		X		X		X				X			X	
Heavy Metal Content	X													X	
Total Phosphate Content	X													X	
Trace Elements														X	
Polychlorinated Biphenyls (PCB's)														X	
Insecticides														X	

* Pump sampling was discontinued after this trip.

** Most samplers were damaged in river.

+ Once every two weeks.

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TABLE 6.1-2

SAMPLING METHODS FOR THE CLINCH RIVER AQUATIC BASELINE SURVEY

Parameter	Sampling/Frequency	Sampling Method	Analyses	Sampling Location	
BIOLOGICAL					
Bacteria Standard plate count Total coliform count Fecal coliform count Fecal strep. count	Once each month in March, May-Sept. and Nov. (1974); and Jan. and April (1975)	surface collection (one foot below surface) using sterilized glass containers	(1) concentration expressed as colonies/100 ml (2) analyses according to "Standard Methods"*	Figure 6.1-2	9
Phytoplankton	Once each month during March, May-Sept. and Nov. (1975); and Jan. and April (1975)	(1) Van Dorn bottle (2) surface collection	(1) identification to the specific level, when practical (2) number/liter (3) species diversity (4) percent composition--major groups (5) biomass (chlorophyll a method including measurement of chlorophyll b, c and pheophytin a content ratio)	Figure 6.1-2	9
Zooplankton tows	Once each month during March, May-Sept. and Nov. (1974); and Jan. and April (1975)	(1) vertical tows, (2) 0.5 meter diameter, 0.76μ mesh plankton net with TSK outside and inside flow meters (3) horizontal surface tows beginning in September	(1) identification to the specific level, when practical (2) number/liter (3) species diversity (4) composite biomass (volume by displacement or measurement of cells depending on abundance)	Figure 6.1-2	9 9
Zooplankton pumping	Once each month during March, May, June and July (1974)	(1) submersible pump (2) filtered through a 0.76μ mesh plankton net (3) surface, mid and bottom collections	(1) identification to the specific level, which practical (2) number/liter (3) species diversity (4) composite biomass (volume by displacement or measurement of cells depending on abundance)	Figure 6.1-2	9
Periphyton	Once each month during May, June, Aug., and Oct. (1974); and Jan. and May (1975)	(1) plexiglass slides on floating racks (2) 2-4 week exposure period	(1) identification to the specific level, when practical, of species of all groups of algae (2) species diversity (3) autotrophic index	Figure 6.1-3	9

(Continued)

TABLE 6.1-2 (Continued)

Parameter	Sampling/Frequency	Sampling Method	Analyses	Sampling Location	
Benthos dredging	Once each month during March, May-Sept. and Nov. (1974); and Jan. and April (1975)	Ponar dredge	(1) identification to the (specific level, when practical (2) number/m^2 and number/liter (3) size ranges of larger mollusks (4) species diversity (5) composite biomass (blotted wet weight and ash free dry weight)	Figure 6.1-4	9
Benthos artificial substrate	Once each month during March, May-Sept. and Nov. (1974); and Jan. and May (1975)	(1) hardboard, multi-plate sampler suspended 1 to 2 feet above bottom	(1) identification to the specific level, when practical (2) number/m^2 (3) species diversity (4) composite biomass (blotted wet weight and ash free dry weight)	Figure 6.1-5	9 9
Macrophytes	Once each month during March, May and July	(1) collection by hand (2) quantitative sampling within quadrates if substantial growth encountered	(1) identification to the specific level, when practical (2) composite biomass (blotted wet weight and ash free dry weight) (3) construction of vegetation map if substantial growth encountered	Figure 6.1-6	9
Fish populations	Once each month during March, May-Sept. and Nov. (1974); and Jan. and April (1975)	(1) electoshocking (2) gill nets (3) scale collection of 7 most abundant species	(1) species composition (2) relative species abundance (3) percentage game, rough and forage fish (4) species diversity (5) length and weight determinations (6) condition factor of 7 most abundant species (7) length by age-growth curves of 7 most abundant species	Figure 6.1-7	9
Fish eggs and larvae	Once every two weeks during March through August.	(1) stationary bottom 1,000μ ichthyoplankton net with TSK inside and outside flow meters (2) pumping using submersible pump 1 to 2 feet from bottom	(1) density (number/m^3) (2) stage of development (3) species identification, when practical	Figure 6.1-8	

(Continued)

TABLE 6.1-2 (Continued)

Parameter	Sampling/Frequency	Sampling Method	Analyses	Sampling Location	
Fish stomach contents	Once each month during March, May, June, Aug., Sept. and Nov. (1974) and Jan. (1975)	collecton of stomachs from each of the 7 most abundant fish species	(1) identification of food items to the most specific taxon practical (2) number and percent abundance of food items (3) percent fulness of stomach (4) net weight of stomach contents	Figure 6.1-7	6 9
PHYSICAL AND CHEMICAL					
A. Field measurements - Temperature (profile) - Dissolved oxygen (profile) - Water velocity and current direction (profile) - pH (surface, mid, bottom) - Specific conductivity (surface, mid, bottom) - Light penetration (profile) - Water depth	Once each month in March, May-Sept. and Nov. (1974); and Jan. and April (1975)	(1) temperature, pH, DO and conductivity measured by Hydrolab unit and additional electronic recording units (2) light penetration measured by submarine photometer (3) velocity measured by Gurley and Savonium meters; current direction by internal compass (4) water depth measured by recording fathometer	(1) temp. in degrees centigrade (2) pH in pH units (3) dissolved oxygen in mg/l (4) conductivity in μmho (5) light penetration in foot-candles and percent transmittance; determination of 1% light incidence (6) water depth in meters (7) water velocity in feet per second (fps)	Figure 6.1-4	9 6
B. Routine Laboratory Analyses Total alkalinity ($CaCO_3$) Hardness ($CaCO_3$) Turbidity Color (true) BOD COD TOC (total organic carbon) Chloride Chlorine residual (field method) Sulfate Sodium Potassium Solids Dissolved Settleables Suspended Volatile Fixed (by difference) Total Volatile Fixed (by difference)	Once each month in March, May-Sept. and Nov. (1974); and Jan. and April (1975)	"Standard Methods"*	(1) concentration expressed in parts per million (2) turbidity in Jackson turbidity units (3) color in color units (4) "Standard Methods"* used in all analyses except for sodium and potassium in which case "Methods for Chemical Analysis"** is used	Figure 6.1-2	9

(Continued)

Parameter	Sampling/Frequency	Sampling Method	Analyses	Sampling Location	
Nitrogen					
NO_2					
NO_3					
NH_3					
Phosphate					
Total - PO_4					
Ortho - PO_4					
C. Additional Analyses	Once during March and	"Standard Methods"*	Analyses were done using	Figure 6.1-9	9
Chlorine demand	Sept. 1974		"Standard Methods"* except		
Fluoride			for: (a) mercury, molybdenum		
Nitrogen gas			and nickel in which case		
Silicate			"Methods for Chemical Analy-		
Calcium			sis"** was used (b) nitrogen		9
Magnesium			gas in which case the Van		
Molybdenum			Slyke method+ was used		9
Selenium			(c) selenium in which case		
Tin			"Proposed Tentative Method"++		
Alumium			was used		9
Manganese					
Zinc					
Copper					
Mercury					
Silver					
Arsenic					
Cadmium					
Chronium					
Lead					
Nickel					
Cobalt					
Iron (total)					
Organic compounds					
Cyanide					
Detergents-surfactants (MBAS)					
Oil and grease (solvent extraction)					
Phthalate esters					
Pesticides					
Organochlorines (insecticide)					
Atrazine (herbicide)					
2-4-D (herbicide)					

(Continued)

TABLE 6.1-2 (Continued)

Parameter	Sampling/Frequency	Sampling Method	Analyses	Sampling Location	
SEDIMENT					
Particle size and total volatile (organic) solid content	Once each month during March, May, July and Sept. (1974); and Jan. and April (1975)	collection by dredge	(1) particle size determination as in "Shore Protection"∇ (2) total volatile solid content by combustion according to "Standard Methods"*	Figure 6.1-4	9
Total Phosphate Content Heavy Metal Content Molybdenum Selenium Tin Aluminum Manganese Zinc Copper Mercury Silver Arsenic Cadmium Chromium Lead Nickel Cobalt Iron (total)	Once at the beginning of the study and once at the end of the study March 1974 and April 1975	collection by dredge	acidification, then procedure as in "Standard Methods"* for metal analysis	Five composite samples in 1974, three composite samples in 1975 with each sample consisting of the three sampling stations per transect. Figure 6.1-4 in 1974; Transects 1, 4 and 5 in 1975	9
Trace Elements Polychlorinated Biphenyls Insecticides Beryllium Fluoride Mangesium Antimony Vanadium Bromine Bismuth Calcium Strontium Potassium Sodium Niobium	Once in April 1975	collection by dredge	(1) metals: acidification, then procedure as in "Standard Methods"* (2) other: "Standard Methods"* or "Methods for Chemical Analysis"**	Three composite samples with each sample consisting of three sampling stations per Transect 1, 4 and 5.	9

(Continued)

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TABLE 6.1-2 (Continued)

Parameter	Sampling/Frequency	Sampling Method	Analyses	Sampling Location
Silica				
Titanium				
Zirconium				
Barium				
Lithium				
Scandium				
Germanium				
PCB's				
Chlordane (α and γ)				
DDE				
DDD				
DDT				

9

* Standard Methods for the Examination of Water and Waste Water, American Public Health Association, Washington, D.C., 1971.

** Methods for Chemical Analysis of Water and Wastes, EPA, Water Quality Office, Analytical Quality Control Laboratory, Cincinnati, Ohio, 1971.

\+ Van Slyke, Donald D., and Neil, J. H., Journal of Biological Chemistry, 61:523, 1924.

++ Proposed Tentative Method of Test for Selenium in Water, American Society of Testing Materials, November 1970.

∇ Shore Protection, Planning and Design, Technical Report No. 4, U.S. Army Corps of Engineers, 1966.

TABLE 6.1-3

CLINCH RIVER - SUMMARY OF AQUATIC BASELINE SURVEY PROGRAM

Parameter	Number of Transects	Stations/ Transect	Samples/Station	Field Visits	Total No. Samples
BIOLOGICAL					
Bacteria	3	1	4 parameters	9	108
Phytoplankton	3	1	4 (2 for identification; 2 for chlorophyll determination*)	9	108
Zooplankton (vertical tows)	3	1	2	9	54
Zooplankton (Pumping)	3	1	3 (each a composite of 2 pumpings)	4**	36
Zooplankton (surface tows)	3	1	2	4**	24
Periphyton	3	1	6+ (2 for identification; 4 for autotrophic index)	7	126
Benthos (dredging)	5	3	2 (each of composite of 2 dredges) (1 composite sample for identification; 1 composite sample for biomass)	9	270
Benthos (artificial substrates)	3	2	2 (1 sample for identification; 1 sample for biomass)	9	108++
Macrophytes	5	2	--	3	--
Fish Population	5	2	1 (for identification, length and weight)	9	90
	5	2	30 scale readings (fish), where possible, of each of the 7 most abundant species taken from fish collected over the 9 field trips		210 fish maximum
Fish Eggs & Larvae	5	1	2 (1 sample by collecting net; 1 sample by pumping)	12	120
Fish Food Pref.	5	2	Variable, depending on numbers of seven most abundant species collected	7	--
PHYSICAL AND CHEMICAL					
Field Measurements	5	3	7 parameters	9	945
Routine Lab. Analyses	3	1	23 parameters	9	621
Additional Analyses	1	1	29 parameters	2	58
SEDIMENT					
Particle Size and Organic Content	5	3	1	6	90
Total Phosphate Content Heavy Metal Content	Five composite samples with each sample consisting of three sub-samples per transect			1	5
Total Phosphate Content Trace Elements PCB's Insecticides	Three composite samples consisting of three subsamples per transect			1	3

* 6 additional samples were taken on May 29, 1974 for chlorophyll analysis because of early problems encountered in previous chlorophyll analysis procedures.

** Pumped samples were discontinued after July 1974; surface tows were substituted beginning in September 1974.

\+ 10 additional samples were taken for identification and autotrophic index analysis because of early problems encountered in analysis.

++ Total number of samples less than indicated as a result of damage of samplers prior to June 1, 1974.

TABLE 6.1-4

PRECONSTRUCTION AQUATIC (NONFISH - NONRADIOLOGICAL) ENVIRONMENTAL MONITORING PROGRAM
CLINCH RIVER BREEDER REACTOR PLANT SITE
(Monthly March Through October 1975)

	Physical-Chemical				Biological						
Station Location	Horizontal Location[1]	In Situ[2] (meters)	Laboratory[3] (meters)	Stormwater Runoff[4]	Coliform[3] (meters)	Phytoplankton and Chlorophyll[5] (meters)	Submarine Photometer (meters)	Zooplankton[6]	Autotrophic-Heterotrophic (Indices) (Periphyton)[7]	Benthos (Artificial Substrate)[8]	Benthos (Dredge)[9]
CRM 23.1	20			X							
CRM 19.0	50	0.3,1,1.5,3,5,6	1,3,5	X	1,3,5	0.1,1,3,5	0.1,1,3,5	X	X	X	X
CRM 17.9	50	0.3,1,1.5,3,5,6	1,3,5	X	1,3,5	0.1,1,3,5	0.1,1,3,5	X	X	X	X
	5,25,75,95			X							
CRM 15.4	50	0.3,1,1.5,3,5,6	1,3,5	X	1,3,5	0.1,1,3,5	0.1,1,3,5	X	X	X	X
	5,25,75,95			X							
CRM 14.4	50	0.3,1,1.5,3,5,6	1,3,5	X	1,3,5	0.1,1,3,5	0.1,1,3,5	X	X	X	X
Caney Creek 0.01 (CRM 16.9L)	50			X							
Poplar Springs Creek 0.01 (CRM 16.2L)	50			X							
Grassey Creek 0.01 (CRM 14.5R)	50			X							
Tributary 0.01 (CRM 14.6L)	50			X							

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[1] Percent from the left bank, facing the downstream direction.
[2] Measurements made In situ for dissolved oxygen, pH, temperature, and conductivity.
[3] Measurements made for alkalinity (field), solids, colors, turbidity, coliform, BOD, COD, Carbon (TOC and SOC), nitrogens, phorphorus, Fe, Na, K, Ca, Mg, Cl, SO_4, SiO_2, Cd, Cr, Cu, Mn, Pb, Hg, Ni, and Zn.
[4] Samples collected at surface for pH (field), turbidity, and suspended solids determination. Additional samples collected in March, May, June, September, and October during rainfall events.
[5] Phytoplankton collected for cell enumeration and percentage composition by major taxonomic group. Chlorophyll a estimate of biomass standing crop.
[6] Zooplankton sampled by vertical tows for species identification and composite biomass determination.
[7] Artificial periphyton substrates (4-week exposure) for autotrophic index and percentage composition of major taxonomic groups.
[8] Artificial substrates for benthos, samples used to quantify biomass, numbers, and diversity.
[9] Dredge for benthos and particle size analysis, samples used to quantify biomass, numbers, diversity, and substrate type.

TABLE 6.1-4a

PRECONSTRUCTION AQUATIC (NONFISH-NONRADIOLOGICAL) ENVIRONMENTAL MONITORING PROGRAM CLINCH RIVER BREEDER REACTOR PLANT SITE (1976-1978)

Station Location	Horizontal Location[1]	Physical-Chemical: In Situ[2] Meters	General[3] Meters	Comprehensive[4] Meters	Biological: Fecal Coliforms[4] Meters	Primary Productivity (In Situ C^{14})[5] Meters	Submarine Photometer[5] Meters	Benthos (Artificial Substrates)[6]	Benthos (Dredge)[7]
CRM 19.0	50								X
	95							X	
CRM 17.9	50	0.3,1,1.5,3, 5,6	1,3,5	1,3,5	0.1	0.1,1,3,5	0.1,1,3,5		X
	5	(0.3,1,1.5,3)[8]				0.1,1,3	0.1,1,3		
	95	(0.3,1,1.5,3)[8]				0.1,1,3	0.1,1,3,5	X	
CRM 15.4	50	0.3,1,1.5,3, 5,6	1,3,5			0.1,1,3,5	0.1,1,3,5		X
	5	(0.3,1,1.5,3)[8]				0.1,1,3	0.1,1,3		
	95	(0.3,1,1.5,3)[8]				0.1,1,3	0.1,1,3	X	
CRM 14.4	50	0.3,1,1.5,3, 5,6	1,3,5	1,3,5	0.1	0.1,1,3,5	0.1,1,3,5		X
	5	(0.3,1,1,5,3)[8]				0.1,1,3	0.1,1,3		
	95	(0.3,1,1.5,3)[8]				0.1,1,3	0.1,1,3	X	
Peripheral Stormwater Runoff									
CRM 15.5	0.4[9]			S[10]					
CRM 15.95	0.1			S					
CRM 16.10	0.2			S					
CRM 16.50	2.4			S					
Groundwater									
Well A-58				X[11]					
Well E-60				X					
Well R-62				X					
Well G-68				X					
Well A-70				X					
Well N-70				X					
Well-Auto Sampled				X					

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[1]Percent from the left bank, facing the downstream direction.
[2]Measurements made in situ for dissolved oxygen, pH, temperature, and conductivity once during months of January, and March through October.
[3]Measurements made for alkalinity (field), nitrogens, phosphorus, COD, TOC, solids, turbidity, and colors once during months of January and March through October.
[4]Measurements made for BOD, fecal coliform, Cd, Ca, Cl, Cr, Cu, Fe, Pb, Mg, Mn, Hg, Ni, K, SiO_2, Na, SO_4, and Zn once during months of January, April, July, and October.
[5]Primary productivity (in situ C_{14} uptake) and submarine photometer (percent light perbiastion) measurements made once during months of March through October.
[6]Artificial Substrates for Benthos - two month exposures. Placed in during months of March, May, July, and September and removed in May, July, September, and November. Samples used to quantify biomass, numbers, and diversity.
[7]Dredge for Benthos and particle size anlaysis once during months of March, May, July, and September. Samples used to quantify biomass, numbers, diversity, and substrate type.
[8]Initiated in June 1977.
[9]Kilometers from mouth of drainage ways all located at 100 percent from left bank, facing the downstream direction.
[10]Samples analyzed for pH and temperature in the field, and suspended solids and turbidity in the laboratory. Sampling initiated in June 1976 on a monthly basis.
[11]Samples analyzed for pH and temperature in the field and conductivity, alkalinity, P, solids, Na, SO_4, B, Cd, Cr, Cu, Pb, Mn, Ni, and Zn in the laboratory. Sampling initiated in June 1976 on a quarterly basis.

TABLE 6.1-5

CLINCH RIVER SITE TERRESTRIAL BASELINE SURVEY SUMMARY

Parameters	Sampling Frequency	Sampling Method	Sampling Location	Statistics and Analyses
Floristic Survey	Monthly surveys (March through September)	General floristic survey.	Entire site	Presence or absence of species in various habitat types.
Vegetative Ground Cover	Three surveys (Spring, summer and fall)	Point-centered circular 0.001 acre quadrats	Twelve communities	Identification of ground cover and shrubs. Calculations to determine relative frequency, density and importance values.
Woody Vegetation	One survey (Summer)	Nested circular plots (0.1, 0.05 and 0.05 acre) for trees, saplings and woody understory, respectively.	Twelve communities	Identification of overstory species. Calculations to determine relative density, basal area and frequency. and importance values. 6
Mammal Survey	Four times per year (March, May, August, and November	Live trapping and snap trapping of small mammals. Direct observation and secondary signs such as dens, scats and tracks.	5 grids and 7 transects	Species identification, vigor, sex, weight, species fluctuation and habitat preference. Calculations to determine relative population estimates or trap night indices.

(Continued)

TABLE 6.1-5 (Continued)

Parameters	Sampling Frequency	Sampling Method	Sampling Location	Statistics and Analyses
Avifauna Survey	Quantitative (Late May and mid-December) Qualitative (March, May August and November)	Direct observations, calls and songs while conducting walking surveys during migratory periods and systematic observations on permanent transects.	Eleven communities and edge areas	Species seasonal utilization, annual fluctuations, relative abundance and species diversity of residents.
Herpetofauna Survey	Two surveys (late spring and mid-summer)	Direct observations	General search of entire site	Species identification and relative abundance.

TABLE 6.1-6

LOCAL METEOROLOGICAL PARAMETERS MONITORED

Chan. No. (Octal)	Parameter	Period Between Scans	Scaling Calculations (x = value of measurement)
1	61m Temperature	60 sec.	$\frac{x \text{ ohms} - 92.97 \text{ ohms}}{\text{ohms}/°F} = \frac{x - 92.97}{.22}$ °F
2	23m Temperature	60 sec.	$\frac{x \text{ ohms} - 92.97 \text{ ohms}}{\text{ohms}/°F} = \frac{x - 92.97}{.22}$ °F
3	10m Temperature	60 sec.	$\frac{x \text{ ohms} - 92.97 \text{ ohms}}{\text{ohms}/°F} = \frac{x - 92.97}{.22}$ °F
4	Spare		
5	Spare		
6	Spare		
10	61m Wind Speed	2 sec.	$\frac{x \text{ mv}}{\text{mv/mph}} = \frac{x}{48}$ mph
11	61m Hor. Wind. Dir.	2 sec.	$\frac{x \text{ mv}}{\text{mv/degree}} = \frac{x}{8.9}$ degrees
12	61m Wind Voltage	1 hr.	
13	23m Wind Speed	2 sec.	$\frac{x \text{ mv}}{\text{mv/mph}} = \frac{x}{48}$ mph
14	23m Hor. Wind. Dir.	2 sec.	$\frac{x \text{ mv}}{\text{mv/degree}} = \frac{x}{8.9}$ degrees
15	23m Wind Voltage	1 hr.	
16	10m Wind Speed	2 sec.	$\frac{x \text{ mv}}{\text{mv/mph}} = \frac{x}{48}$ mph
17	10m Hor. Wind Dir.	2 sec.	$\frac{x \text{ mv}}{\text{mv/degree}} = \frac{x}{8.9}$ degrees

8

(CONTINUED)

Chan. No. (Octal)	Parameter	Period Between Scans	Scaling Calculations (x = value of measurement)
20	10m Wind Voltage	1 hr.	
21	Spare		
22	Spare		
27	Dew Point 10m	60 sec.	

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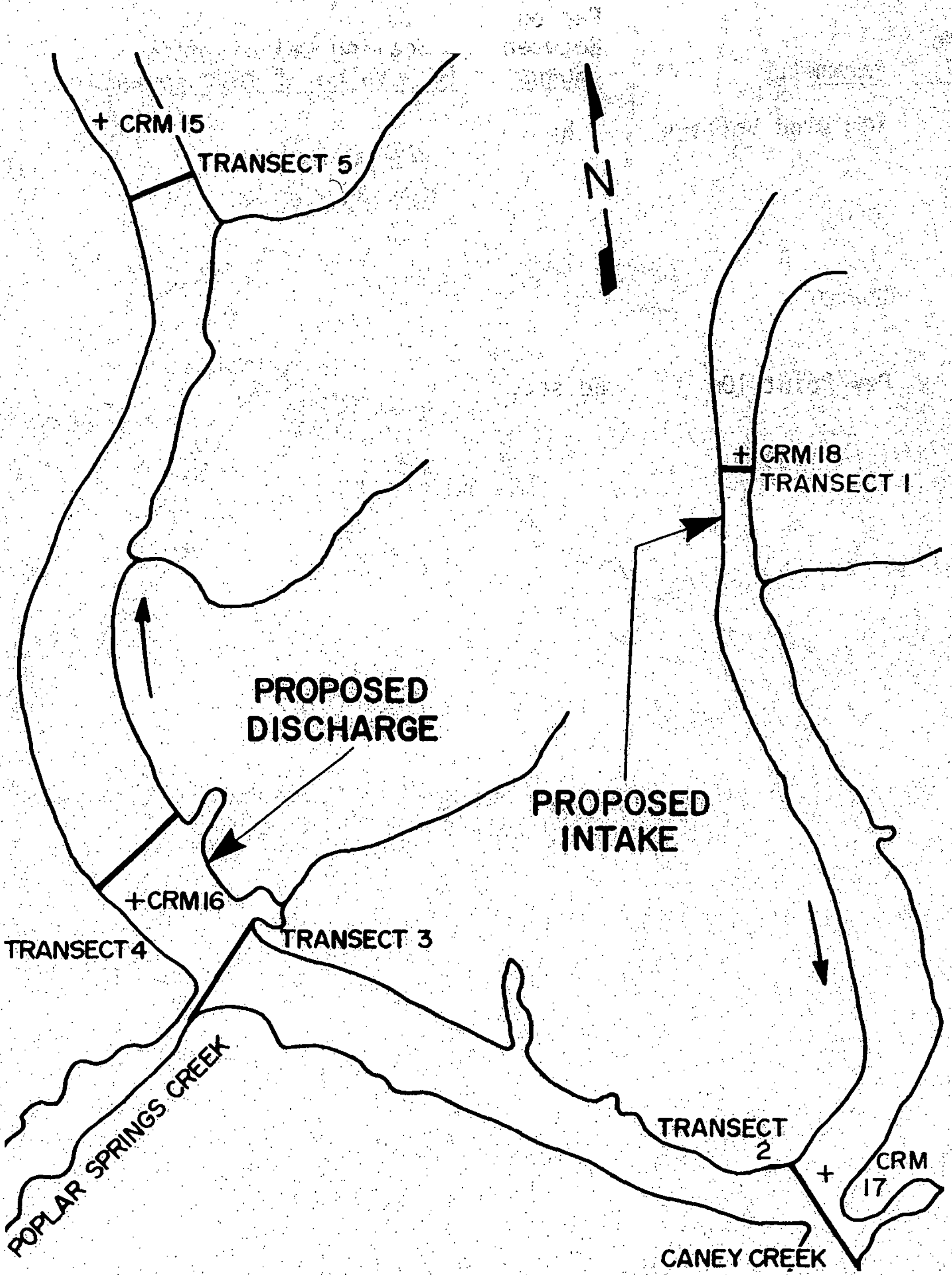

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Figure 6.1-1 LOCATION OF SAMPLING TRANSECTS ON THE CLINCH RIVER FOR THE BASELINE MONITORING PROGRAM

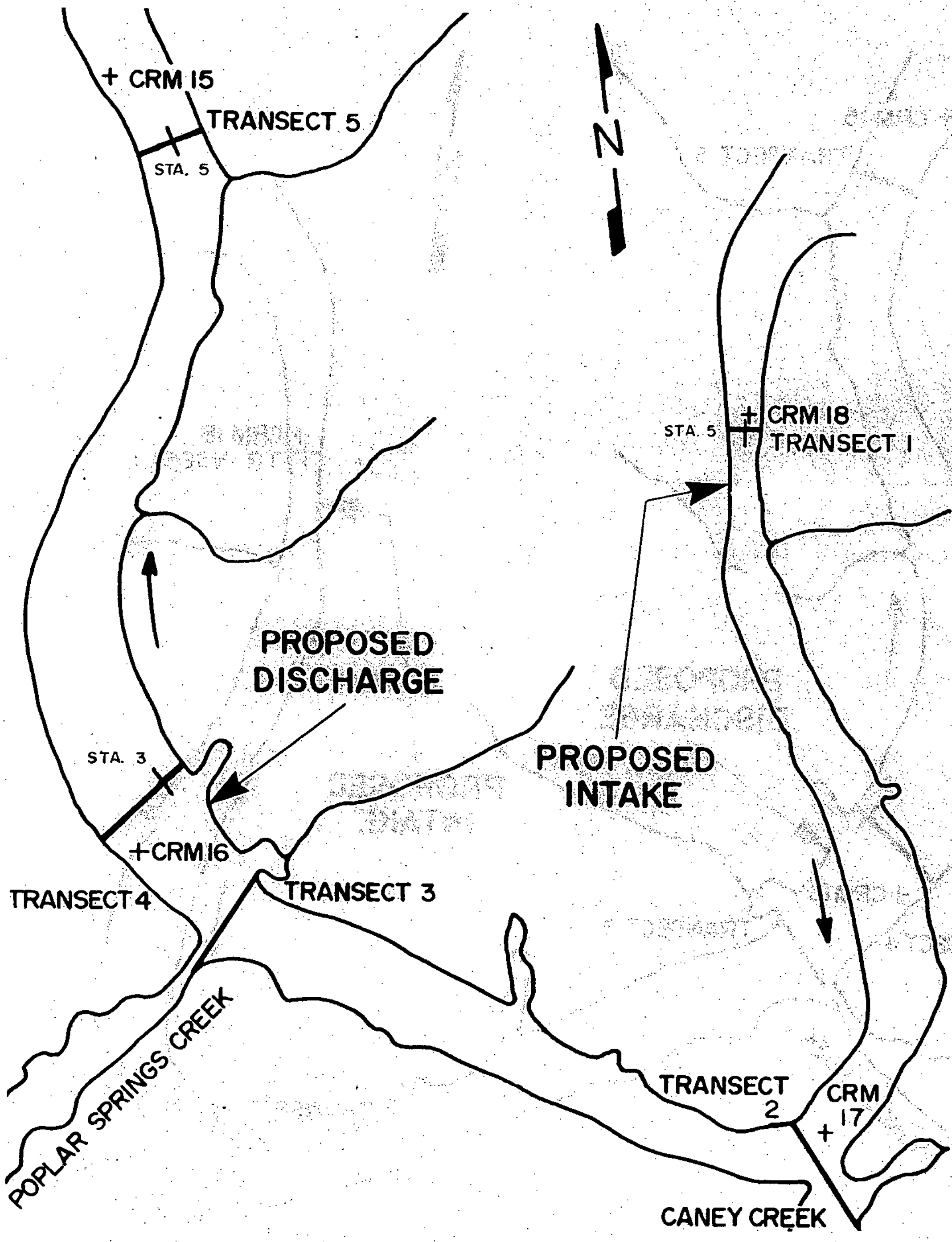

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Figure 6.1-2 LOCATION OF SAMPLING STATIONS FOR ZOOPLANKTON (PUMPING AND TOWING), PHYTOPLANKTON AND WATER SAMPLES FOR PHYSICAL AND CHEMICAL ROUTINE LABORATORY ANALYSES AND BACTERIOLOGICAL ANALYSES FOR THE BASELINE MONITORING PROGRAM

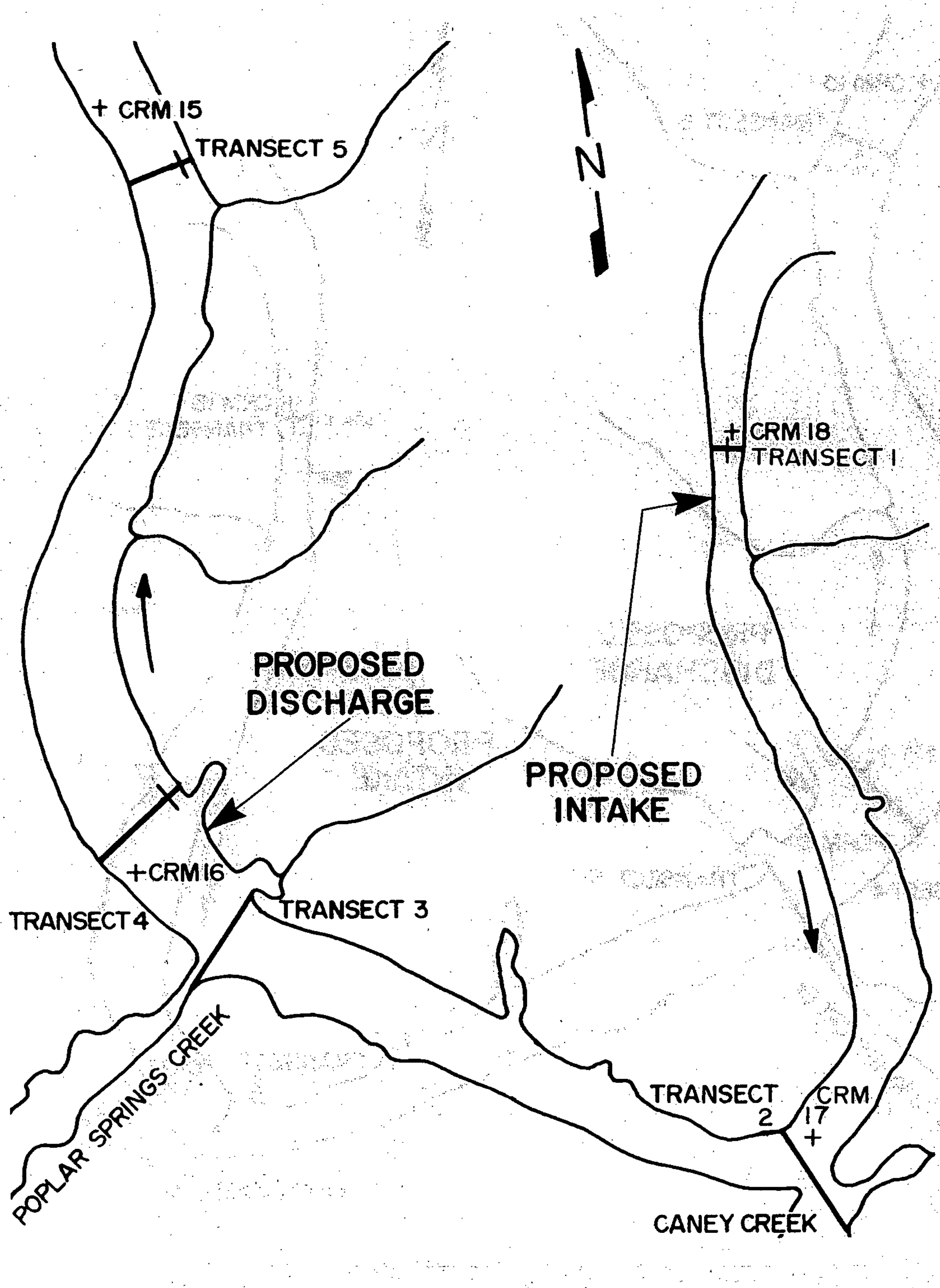

Figure 6.1-3 PERIPHYTON SAMPLERS LOCATED APPROXIMATELY 30 FEET FROM RIGHT SHORE FOR THE BASELINE MONITORING PROGRAM

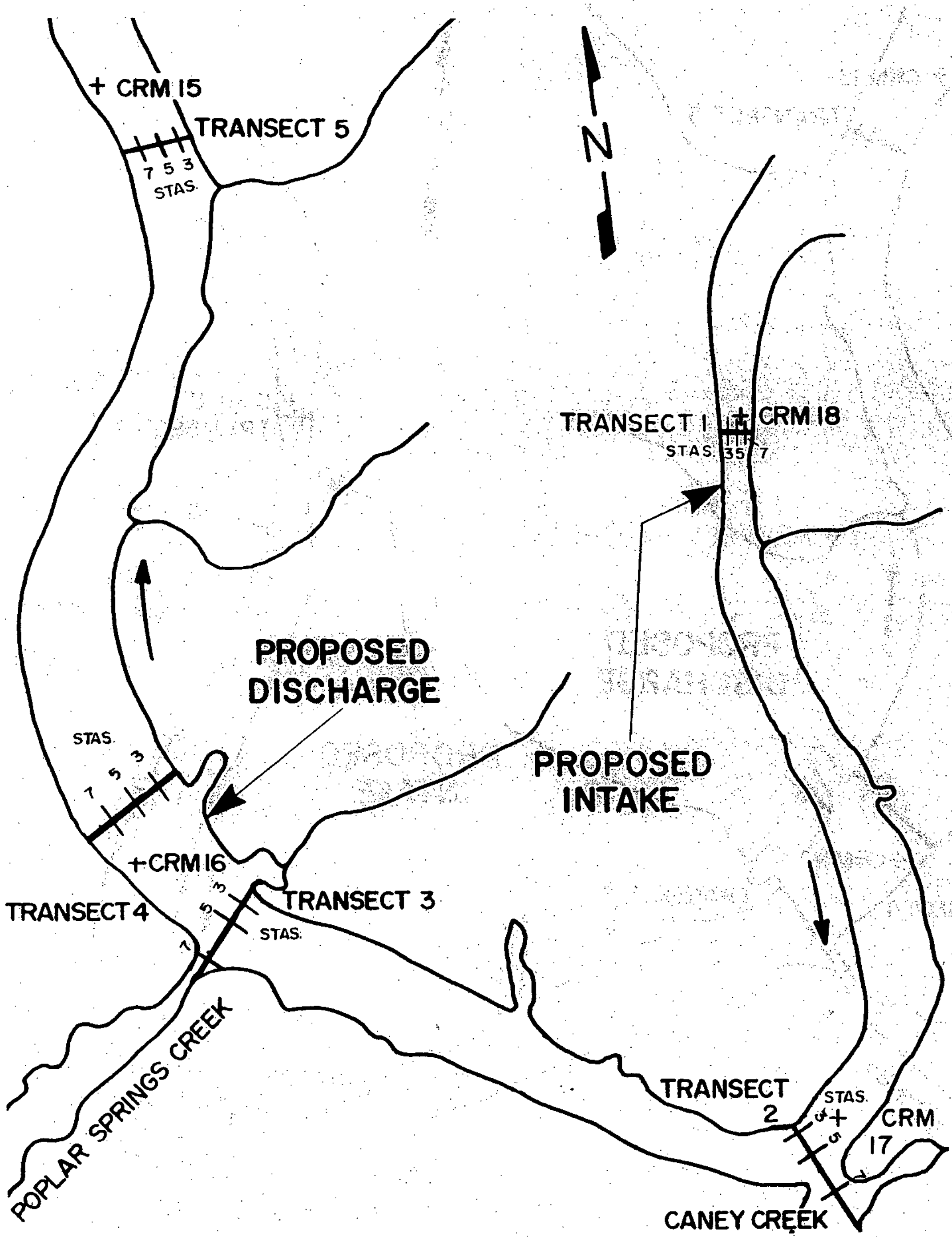

Figure 6.1-4 SAMPLING LOCATIONS FOR (A) BENTHOS BY DREDGING, (B) PHYSICAL AND CHEMICAL FIELD MEASUREMENTS, (C) SEDIMENTS, FOR THE BASELINE MONITORING PROGRAM

6

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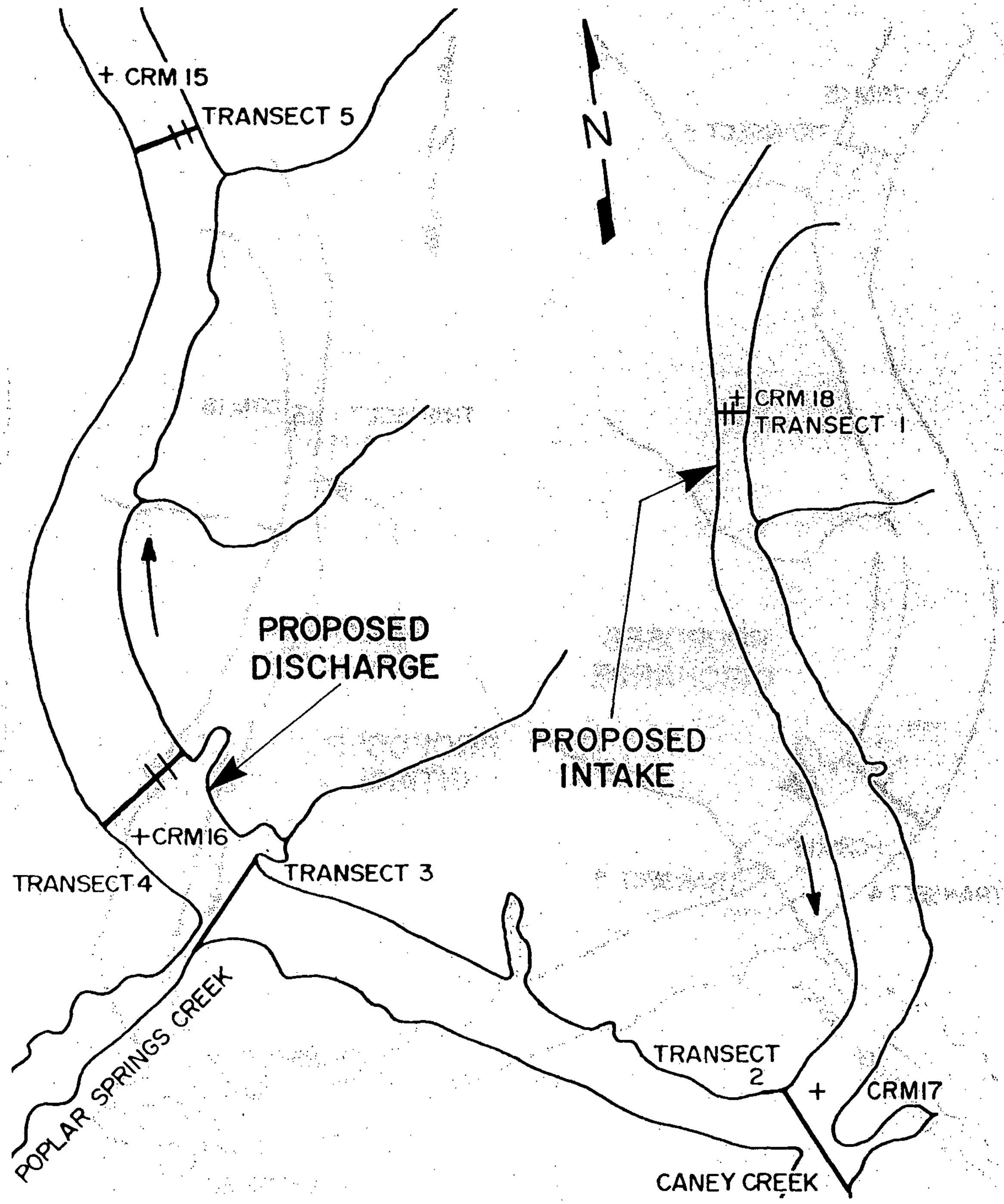

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Figure 6.1-5 NEARSHORE BENTHIC ARTIFICIAL SUBSTRATES ARE LOCATED 30 TO 50 FEET FROM RIGHT SHORE. MID-RIVER SUBSTRATES ARE LOCATED 50 TO 100 FEET FROM RIGHT SHORE, FOR THE BASELINE MONITORING PROGRAM

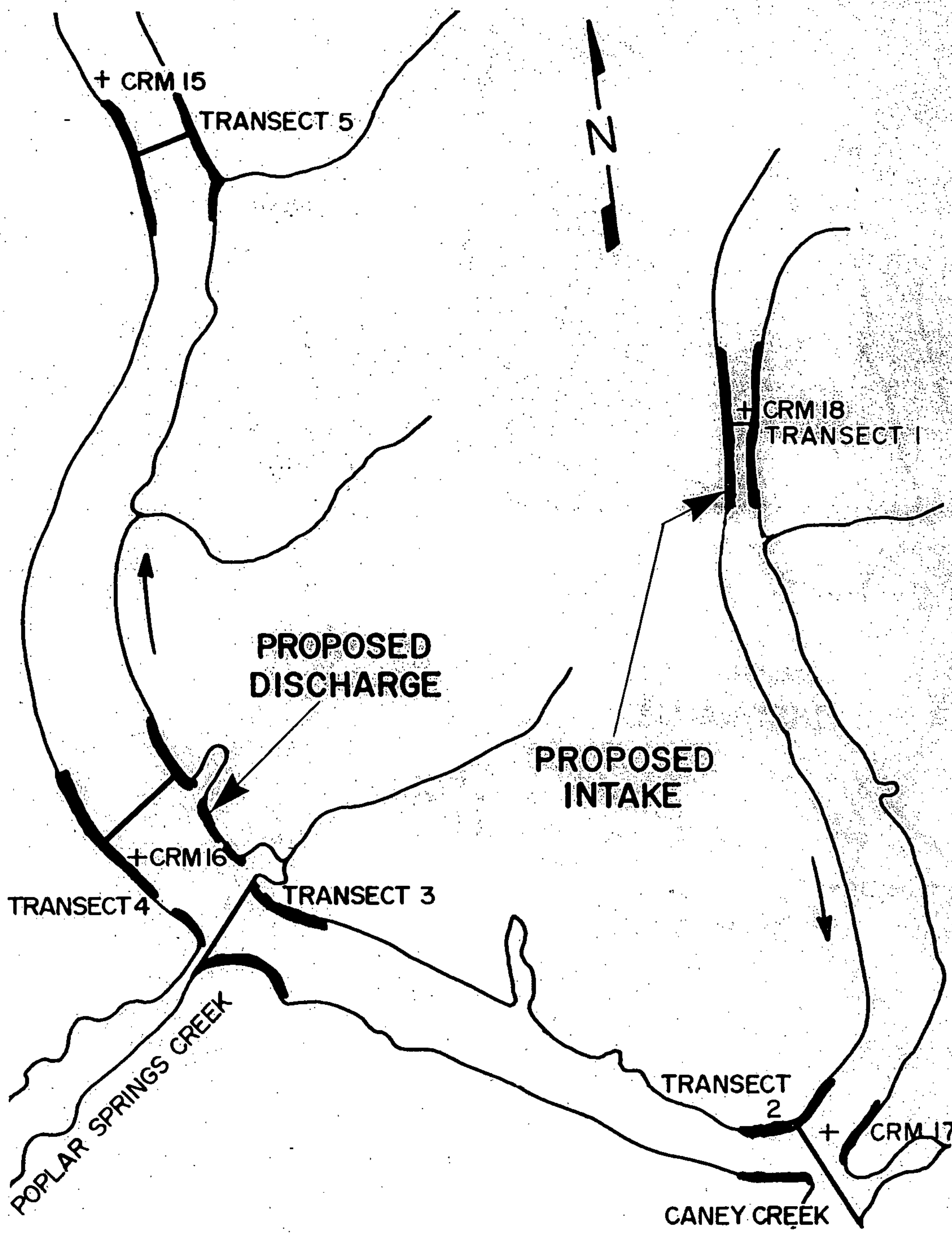

Figure 6.1-6 SAMPLING LOCATIONS FOR MACROPHYTES. SAMPLING WAS DONE APPROXIMATELY 200 FEET BOTH UP AND DOWNSTREAM TO THE TRANSECTS INDICATED FOR THE BASELINE MONITORING PROGRAM

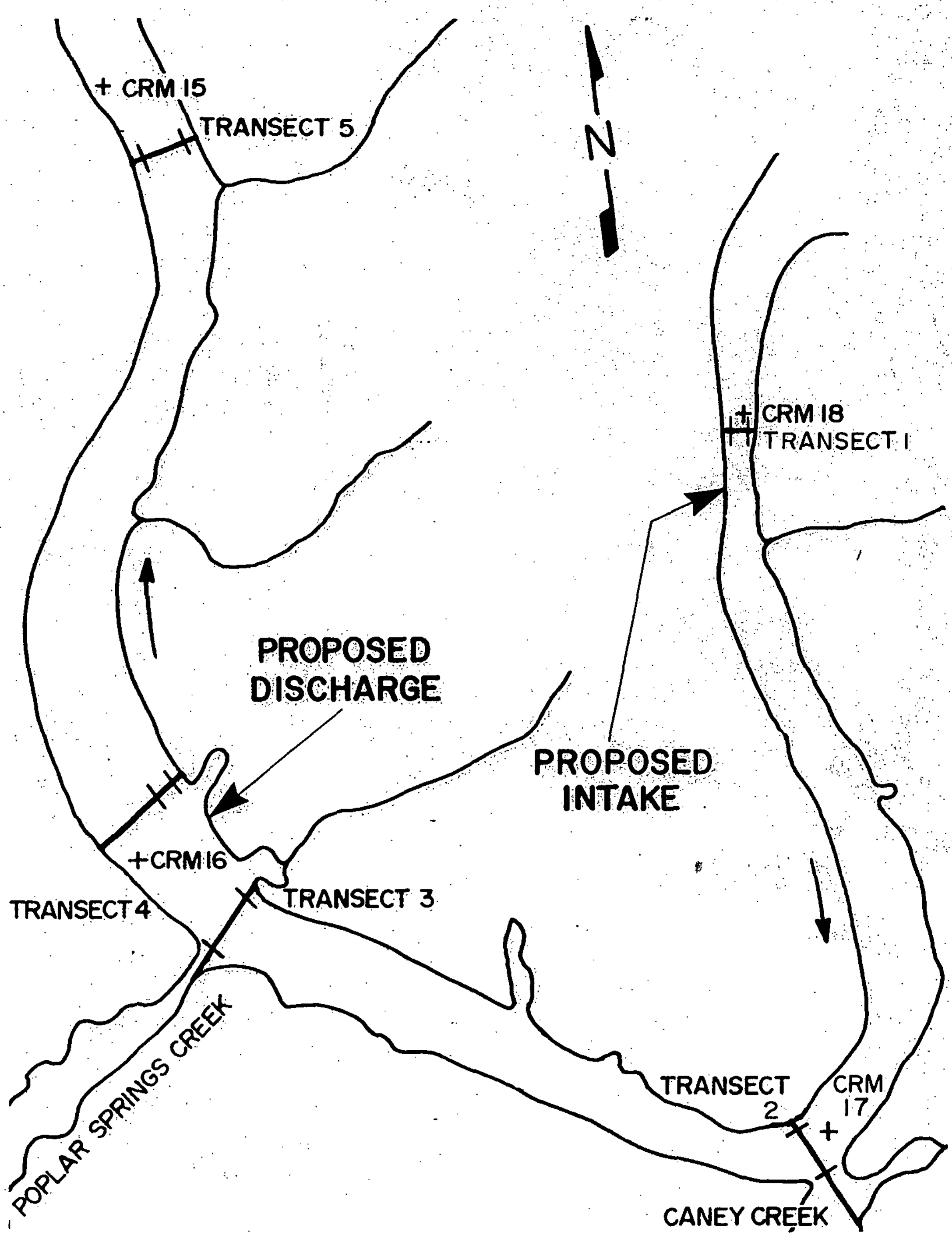

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Figure 6.1-7 SAMPLING STATIONS FOR FISH POPULATIONS AND FISH STOMACH CONTENTS FOR THE BASELINE MONITORING PROGRAM

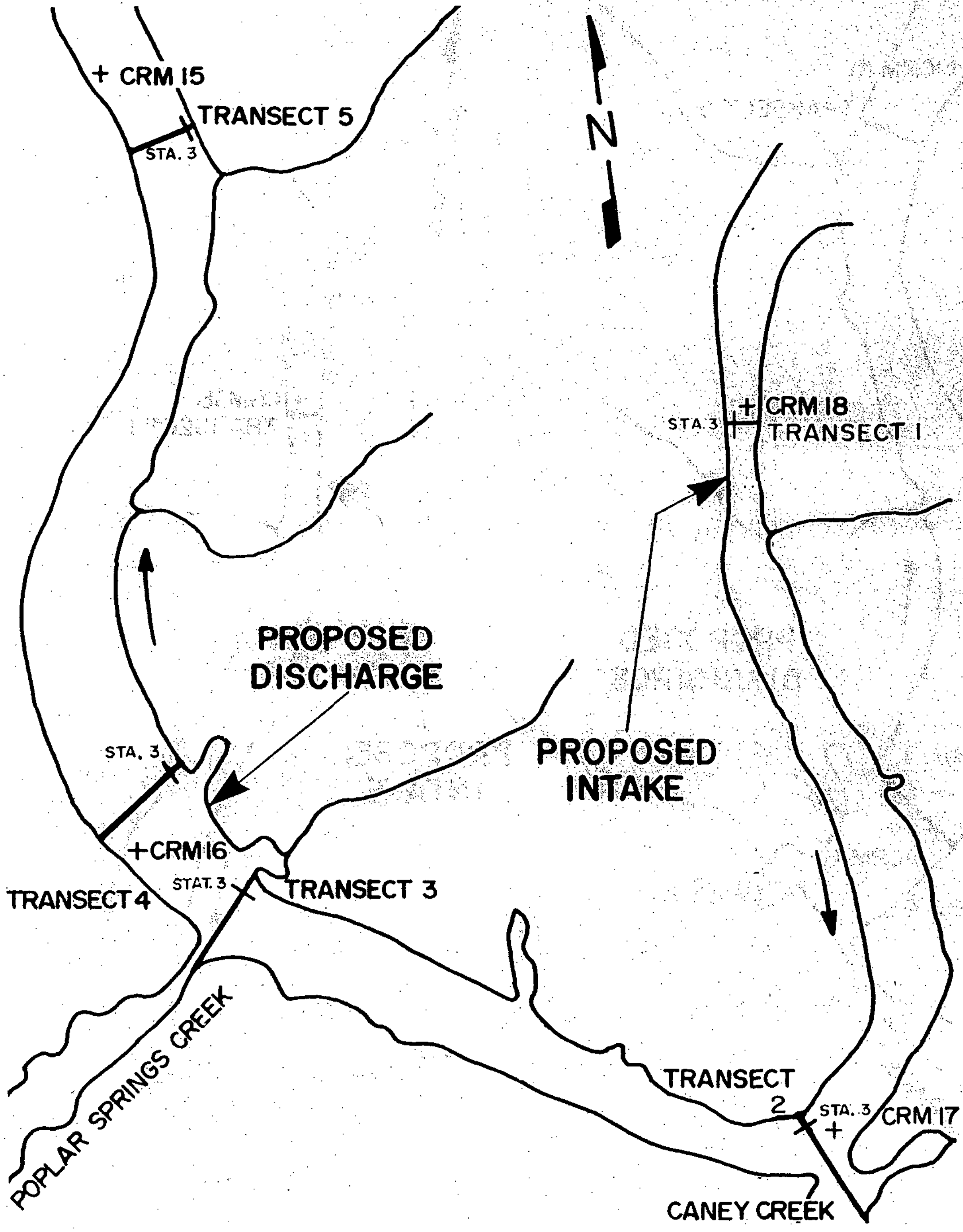

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Figure 6.1-8 LOCATION OF SAMPLING STATIONS FOR THE COLLECTION OF FISH EGGS AND LARVAE FOR THE BASELINE MONITORING PROGRAM

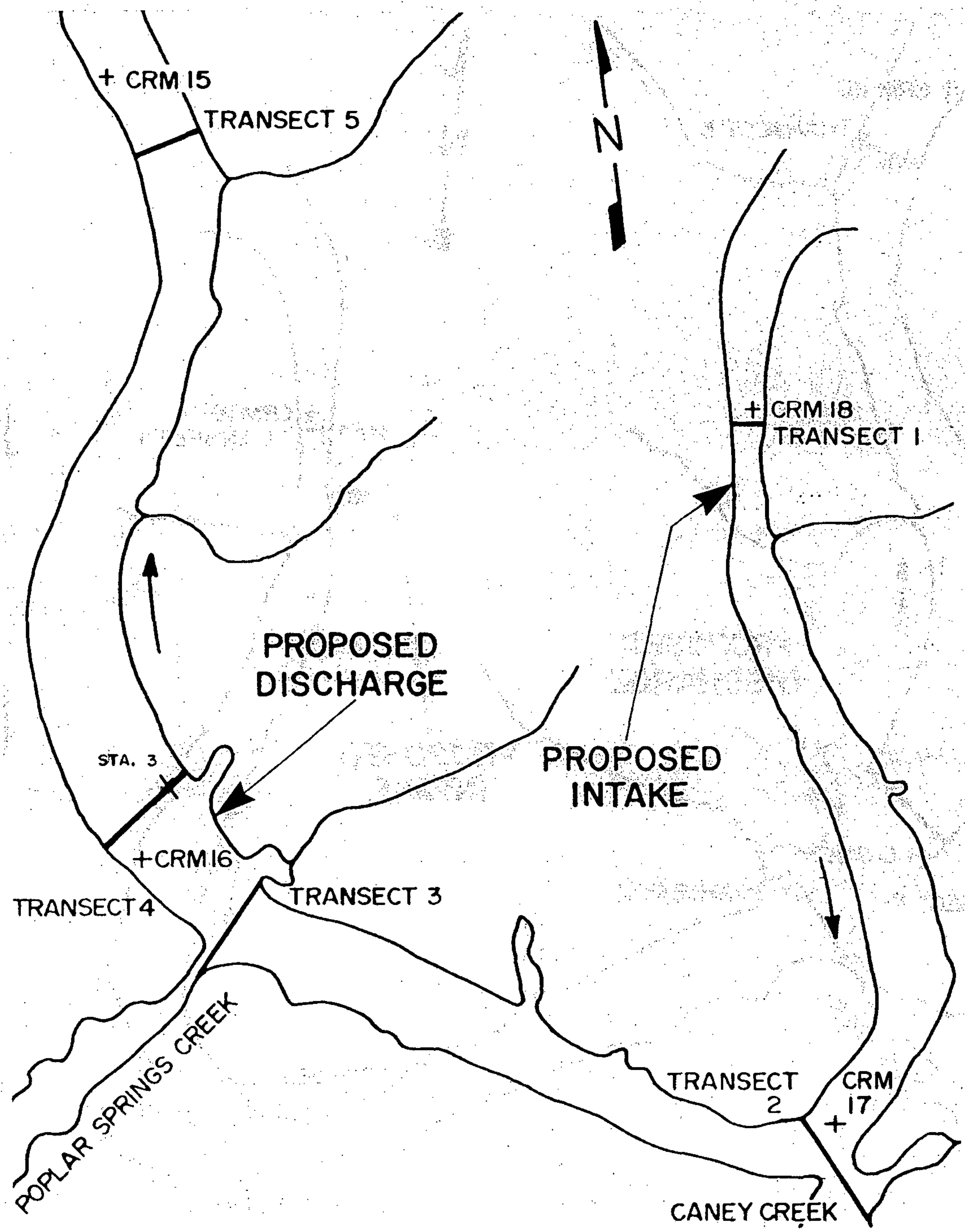

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Figure 6.1-9 SAMPLING LOCATION FOR PHYSICAL AND CHEMICAL ADDITIONAL ANALYSES FOR THE BASELINE MONITORING PROGRAM

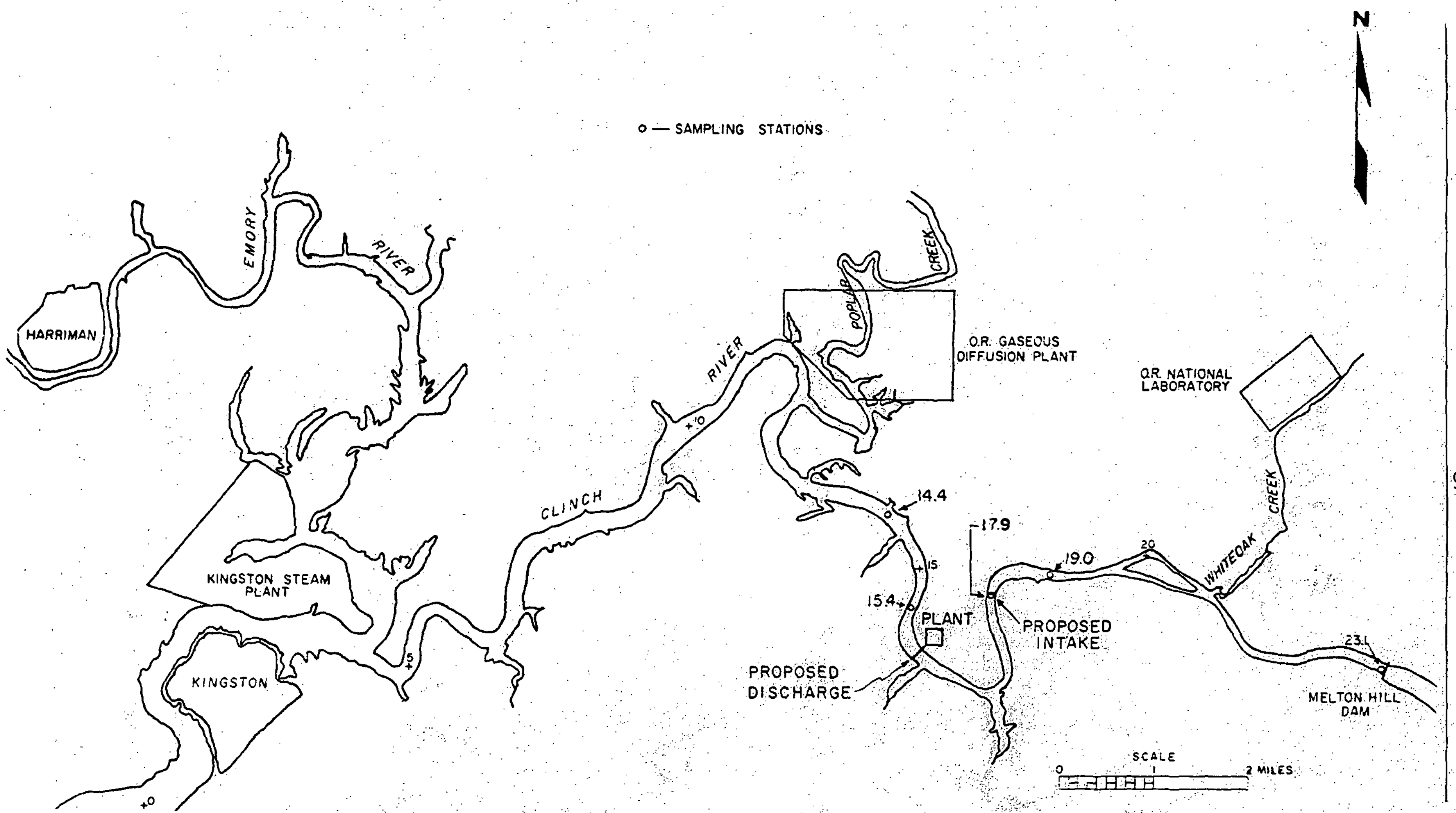

FIGURE 6.1-9a SAMPLING LOCATIONS FOR WATER QUALITY AND AQUATIC BIOLOGICAL MONITORING CLINCH RIVER BREEDER REACTOR PLANT PRECONSTRUCTION-CONSTRUCTION PHASE (1975-1977)

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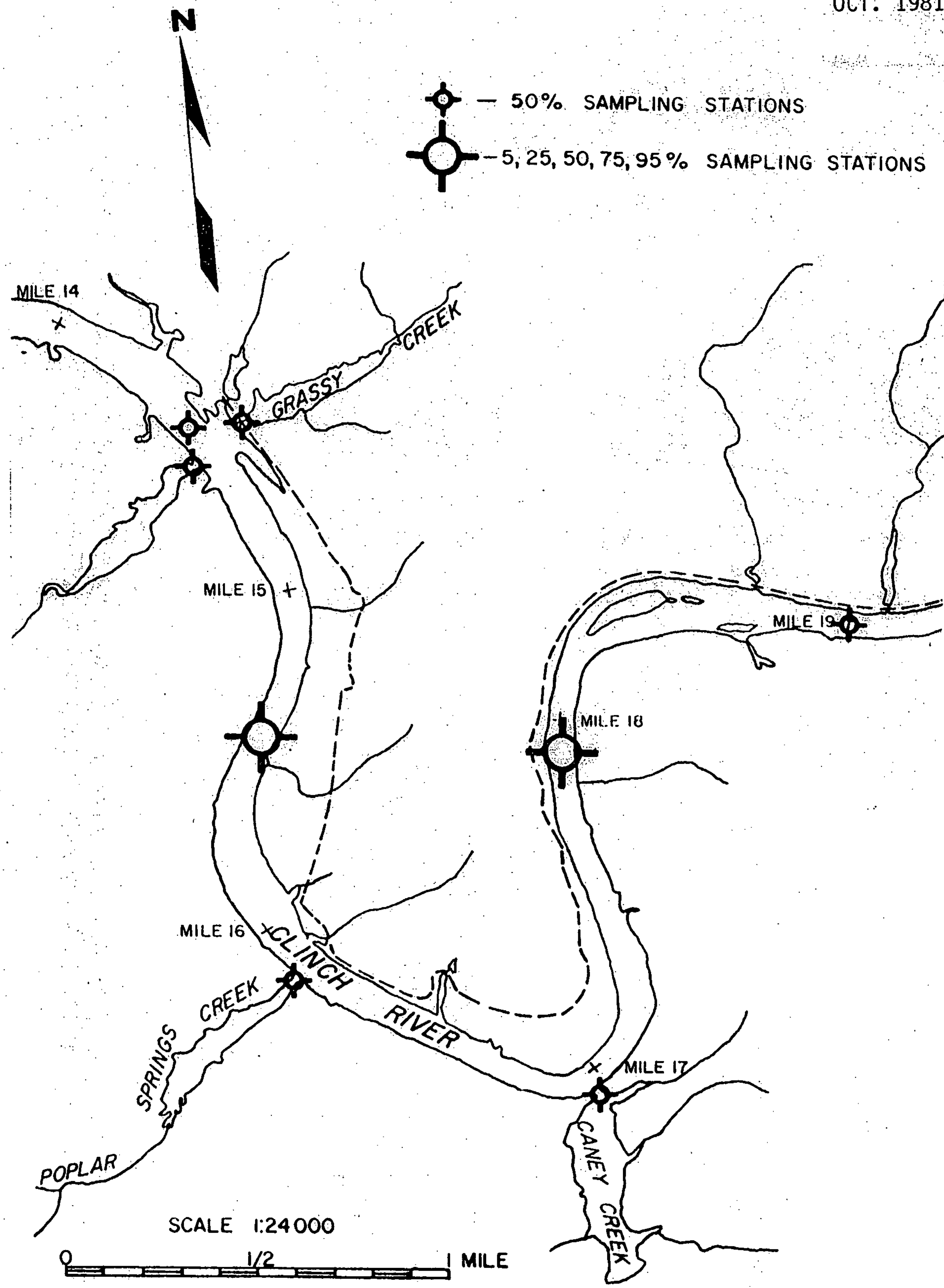

FIGURE 6.1-9b CLINCH RIVER SAMPLING STATIONS FOR SITE STORMWATER RUNOFF, CRBRP - 1975

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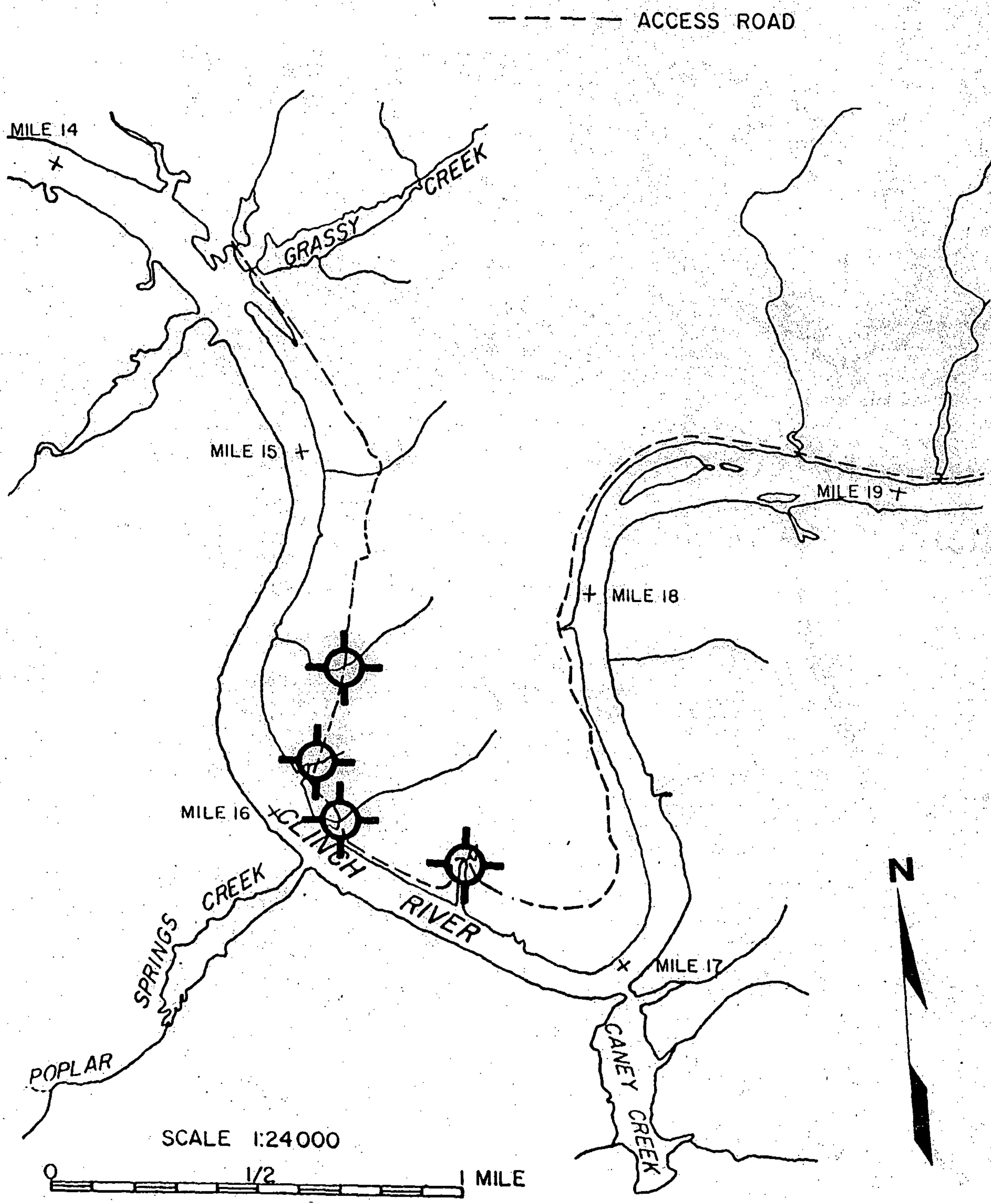

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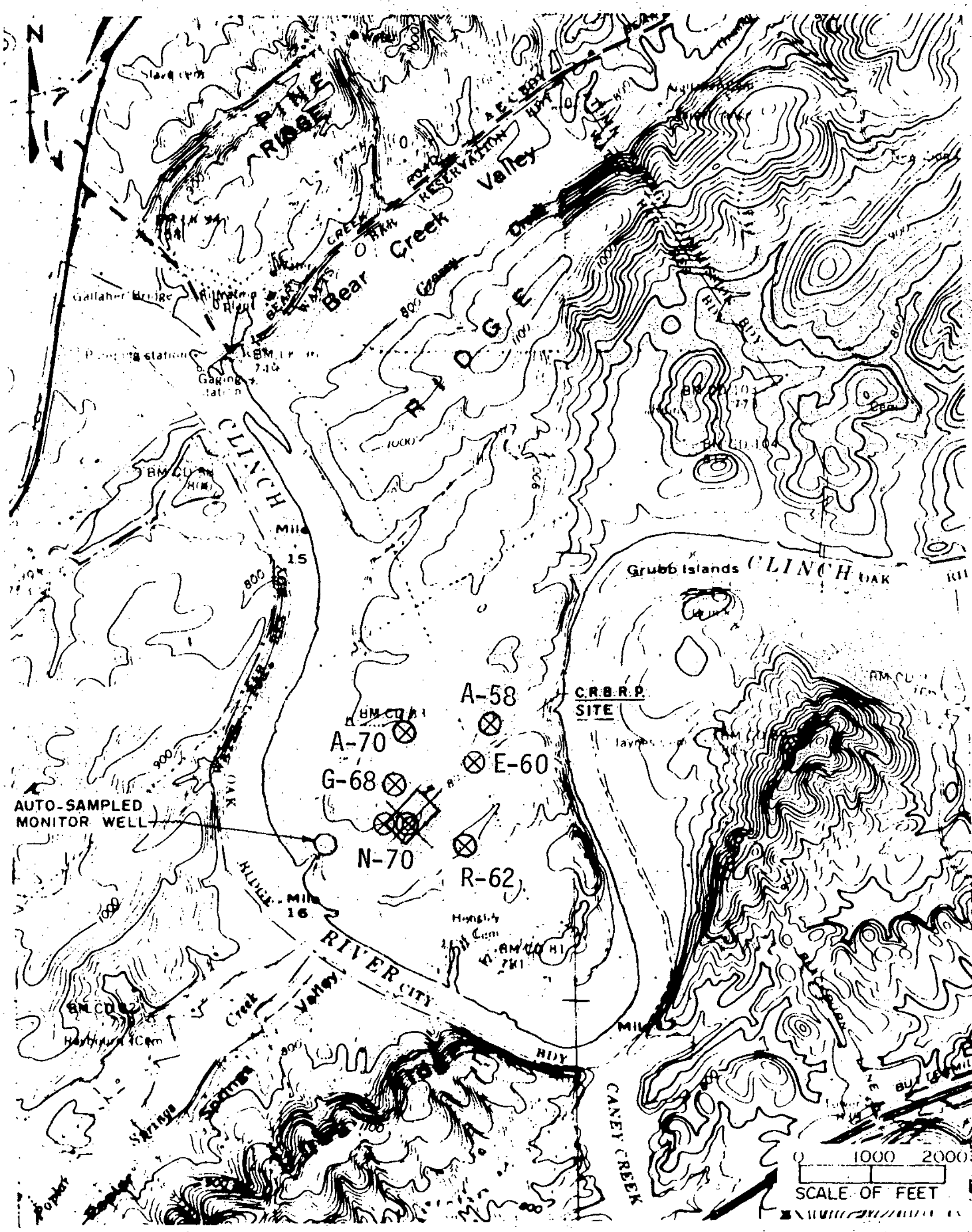
FIGURE 6.1-9c PERIPHERAL SAMPLING STATIONS FOR SITE STORMWATER RUNOFF, CRBRP - (1976-1978)



9

⊗ Manually sampled observation wells 9

FIGURE 6.1-10 LOCATION OF GROUND WATER OBSERVATION WELLS, CRBRP (1976-1977)

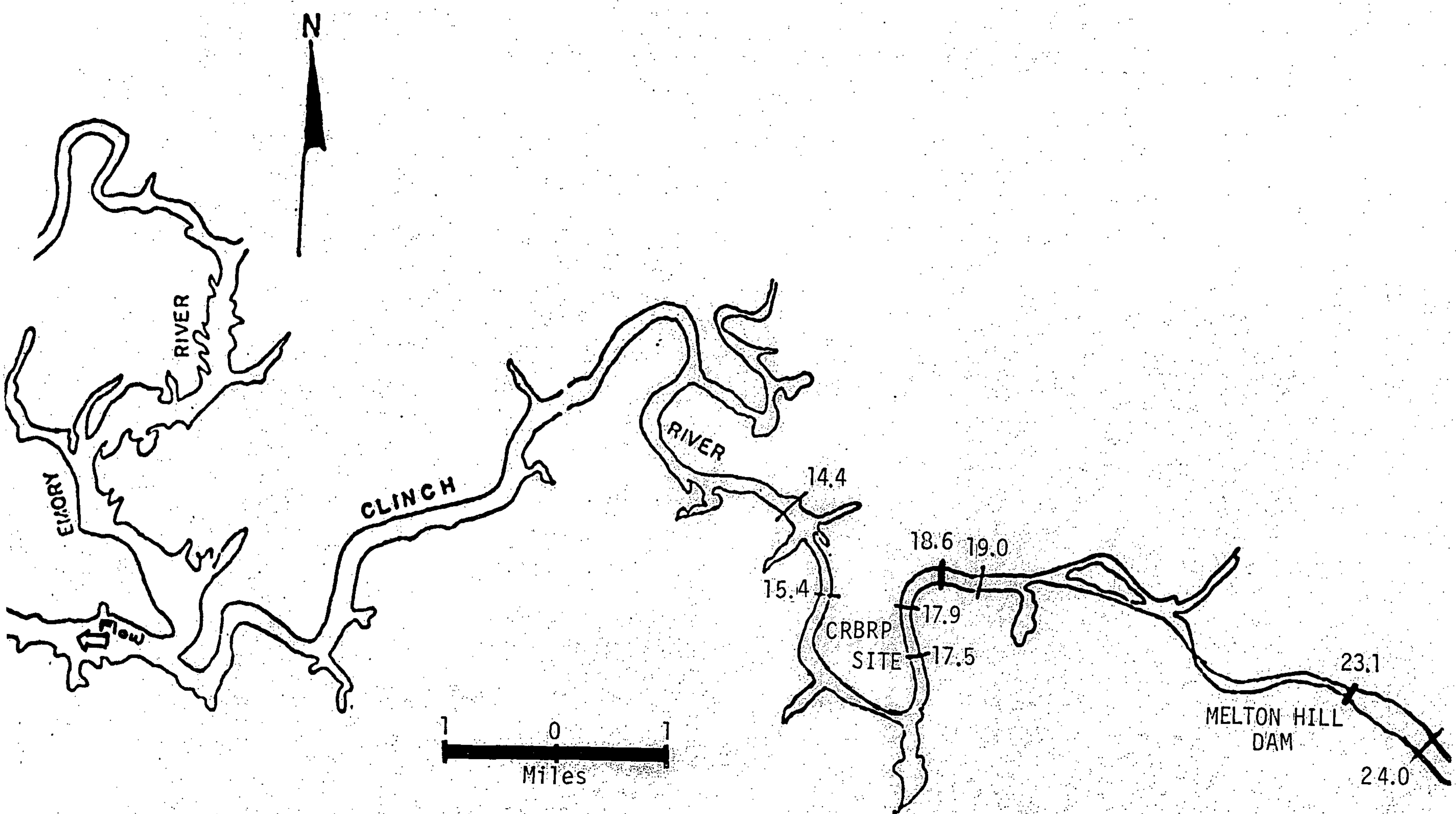


FIGURE 6.1-11 RESERVOIR ENVIRONMENTAL RADIATION MONITORING NETWORK,
PRECONSTRUCTION-CONSTRUCTION PHASE

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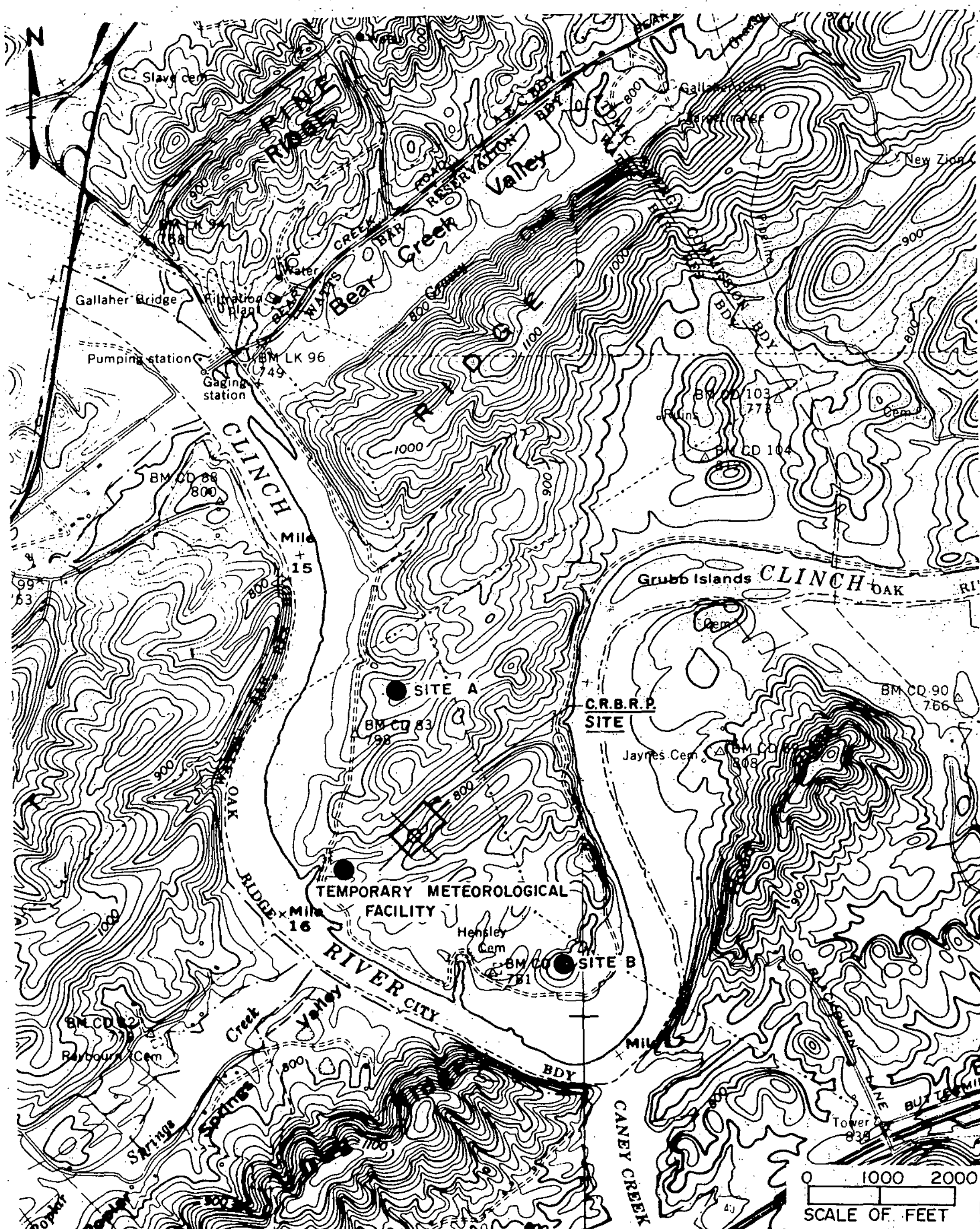

Figure 6.1-12 METEOROLOGICAL FACILITY LOCATOR CHART

8

6.2 APPLICANT'S PROPOSED OPERATIONAL MONITORING PROGRAM

The operational monitoring program outlined here will monitor the postulated impacts resulting from operation of the facility. The program covers radiological, chemical, thermal, meteorological and ecological considerations. In some cases the operational program is merely an extension of the preoperational program. However, the operational program may be modified as a result of information gained during either the preoperational or operational phase of the program. In some cases more specific operational monitoring will be performed in order to assess the impact of a particular aspect of plant operation such as operation of cooling towers.

6.2.1 RADIOLOGICAL MONITORING

6.2.1.1 PLANT EFFLUENT MONITORING SYSTEMS

6.2.1.1.1 GASEOUS EFFLUENTS

The radioactive effluent monitoring system will be designed to sample and/or continuously monitor and record radiation levels and concentrations of radioactivity from thirty-four (34) exhaust
points (thirty-two building ventilation and two equipment 13
exhaust) from which radioactive gaseous releases may emanate; one located in the Intermediate Bay (SGB-IB), nine located near the
top of the Reactor Confinement Building (RCB) dome, two located 9 13
in the Reactor Service Building (RSB), one located in the Radwaste Area (Bay) (RWA), one located in the Plant Service Building (PSB), fourteen in the Turbine Generator Building (TGB),
and six located in the Steam Generator Building (SGB). 13

Continuous monitoring will be performed at those exhaust points which conceivably undergo a significant increase in detectable levels of radioactivity. The remaining exhausts will be samlped periodically, on an as-necessary basis.

The exhaust plenum located in the Intermediate Bay (IB) receives ventilation exhaust air from the Steam Generator Building Intermediate Bay (SBG-IB) area. A continuous air monitor (CAM) will be provided to detect gaseous activity in the effluent stream. The air sample will be obtained isokinetically from the exhaust, on a continuous basis. Sampled air will first flow through a particulate filter which will be viewed for beta activity, then through an iodine retention element for radioiodine detection, and finally through a 4π geometry shielded chamber for gas detection. 13

9

The exhaust plenum located on the Radwaste Building receives ventilation exhaust air from the Radwaste Area. A continuous air monitor (CAM) will be provided to detect particulate and gaseous activity in the effluent stream. The air sample will be obtained isokinetically from the exhaust, on a continuous basis.

The two Reactor Service Building (RSB) exhausts will be continuously monitored for radioactivity releases. Exhaust plenums located on the RSB roof which receive ventilation exhaust from the RCB and exhaust from the RSB via RSB clean-up filtration units will be continuously monitored for particulate, gaseous, and radioiodine activity in the effluent stream. 13

13

The exhaust plenum located near the top of the RCB dome, which receives exhaust from the containment clean-up and annulus pressure maintenance and filtration system (located in the RSB), will be continuously monitored for particulate, radioiodine, gaseous, and plutonium activity in the effluent stream.

The eight exhausts located at the top of the RCB dome for the RCB annulus cooling air become potential radioactivity release points only in the event of very low probability accidents beyond the design basis (Thermal Margin Beyond the Design Base Scenario). The annulus air cooling system may be required to be initiated 24 to 36 hours after the accident. No on line radioactivity monitor will be provided for these exhausts and off site/emergency monitoring techniques will be adopted.

The six Steam Generator Building (SGB) exhausts receive 9 13
ventilation exhausts from the individual steam generator cells. Each exhaust will be sampled for tritium activity using silica-gel dessicants; and analysis of samples will be performed by liquid scintillation techniques. The exhaust sample flow through the silica-gel column will be maintained constant by a regulated pump assembly.

The twelve (12) exhaust fans in the Turbine Generator Building (TGB) receive ventilation exclusively from the various TGB operating areas and could potentially contain some tritium activity. This potential contribution would not alter the values 13
reported for BOP gaseous tritium release. The condenser vacuum pump discharge is connected to the exhaust duct serving the lube oil areas of the TGB.

A continuous gas sample will be withdrawn from each of the deaerator exhaust, and turbine steam packing exhaustor, into the tritium samplers. The samplers will be comprised of a silica gel dessicant column for determination of tritium activity, in order to indicate unacceptable tritium diffusion into the steam generators. The sample will be analyzed using liquid scintillation techniques in the counting room. 13

In addition, the other TGB areas will be periodically grab sampled and samples will be analyzed for tritium activity.

The exhaust in the Plant Service Building (PSB) receives ventilation from the combined laboratory. Samples will be collected isokinetically by a particulate (and iodine, if required) filter and analyzed for isotopic content in the counting room. 9

The recorded activity levels, based on Counting Room analysis and recorded effluent flow rates out of the vents, provide a record of airborne activity release. Continuous monitoring provides an indication of off-normal conditions or changes in release levels, warranting a manual sample and counting room analysis. The reporting of effluent radioactivity released will be consistent with the guidelines established in Regulatory Guide 1.21. Detailed descriptions of the continuous monitoring/sampling equipment are given in Table 6.2-5, "Continuous Effluent Monitoring/Sampling".

The three Steam Generator Building (SGB) exhausts receive ventilation exhausts from the individual steam generator cells. Each exhaust will be sampled for tritium activity using silica-gel dessicants; and analysis of samples will be performed by liquid scintillation techniques. The exhaust sample flow through the silica-gel column will be maintained constant by a regulated pump assembly.

The exhaust fans in the Turbine Generator Building (TGB) receive ventilation from the various TGB operating areas. These exhaust points will also be sampled for tritium activity. A continuous gas sample will be withdrawn from each of the condenser vacuum pump airs, deaerator exhausts, and turbine steam packing exhauster airs into tritium samplers comprised of a silica gal dessicant column for determination of tritium activity in order to indicate unacceptable tritium diffusion in the steam generators. The sample will be analyzed using liquid scintillation techniques in the counting room. 9

In addition, the other TGB areas will be periodically grab sampled and samples will be analyzed for tritium activity.

The exhaust in the Plant Service Building (PSB) receives ventilation from the combined laboratory. Samples will be collected isokinetically by a particulate (and iodine if required) filter and analyzed for isotopic content in the counting room.

The recorded activity levels, based on Counting Room analysis and recorded effluent flow rates out of the vents, provide a record of airborne activity release. Continuous monitoring provides an indication of off-normal conditions or changes in release levels, warranting a manual sample and counting room analysis. The reporting of effluent radioactivity released will be consistent with the guidelines established in Regulatory Guide 1.21. Detailed descriptions of the continuous monitoring/sampling equipment are given in Table 6.2-5, "Continuous Effluent Monitoring/Sampling".

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6.2.1.1.2 LIQUID DISCHARGE POINTS

The location of the plant liquid effluent discharge into the Clinch River is shown in Figure 3.4-9. The plant discharge consists of effluents from the Liquid Radwaste Disposal System, Waste Water Disposal System, and Sewage Disposal System, all diluted by the cooling tower blowdown. 9 9

Effluents from the Liquid Radwaste Disposal System are discharged into the cooling tower blowdown. A liquid radioactivity detector will continuously monitor, record, and control the activity released from the radwaste system to the cooling tower blowdown stream. The blowdown flow rate available for liquid waste dilution and compliance with applicable federal regulations will be considered in establishing a high radiation set-point for this monitor. A high radiation signal will automatically close the isolation 4 9 valve in the radwaste discharge line and trigger an alarm in the control room.

Frequent composite samples of the common plant discharge, taken downstream of the radioactive liquid input, will be taken for radionuclide determination, including tritium. The problem associated with continuous monitoring of low level beta activity of tritium in water is recognized; therefore, a composite sample will be taken and analyzied in the laboratory. 9 9

Building storm drains are normally non-radioactive and will not be monitored, but will be periodically sampled for radioactivity analysis. 4 9

6.2.1.2 ENVIRONMENTAL RADIOLOGICAL MONITORING

Preoperational-operational environmental radiological surveillance programs proposed for the CRBRP are described in this section. The types of samples to be collected, sampling locations, frequency and the analyses 6 to be performed on each sample are discussed. The discussion also includes rationale for the choice of sampling locations, types of samples to be collected and the collection frequency.

The detection capabilities for environmental sample analyses will be presented in the FSAR. The nominal lower limit of detection (LLD) for the various analytical techniques will be based on the method discussed in HASL-300.[1] Nominal LLD values are expected to approximate the values 9
recommended in Regulatory Guide 4.8; however, the LLD's will vary depending on the activities of the various components in the samples.

6.2.1.2.1 PREOPERATIONAL-OPERATIONAL PHASE ENVIRONMENTAL RADIATION MONITORING PROGRAM - GENERAL

The preoperational environmental radiological monitoring program has the objective of establishing a baseline of data on the distribution of back- 9
ground radioactivity in the area near the CRBRP. With this background information and that obtained from the preconstruction-construction program, it will then be possible to determine, after the plant becomes operational, the earliest possible indications of the accumulation or buildup of radionuclides attributable to plant operation. During the life of the plant this accumulation should not exist in quantities greater than trace amounts. The preoperational environmental radiological monitoring 9
program will be initiated approximately two years prior to plant operation. 9

The environmental monitoring program outlined in this section is based on current regulatory guidelines and monitoring philosophy. At such time as any monitoring program is implemented, it may be revised to reflect 9
changes in regulatory requirements and monitoring philosophy.

9

The program as outlined includes measurements of direct gamma radiation and 9
sampling of airborne radioactivity, fallout particulate matter, rainfall,
well and public water supplies, soil, vegetation, milk, fish, clams 6
(if available), bottom sediment and river water. The extent to which various 9
aspects of the program will be carried out takes into account data available from other sources; however, the program as outlined is self-sufficient. It will be continually evaluated to insure that the most sensitive vectors are being sampled for the proper evaluation of exposure of the population. Continual evaluation permits the planning of an effective system with respect to sampling frequencies, locations and laboratory analyses.

6.2.1.2.2 PREOPERATIONAL-OPERATIONAL PHASE ENVIRONMENTAL RADIATION MONITORING PROGRAM - ATMOSPHERIC MONITORING

Fifteen atmospheric monitoring stations are planned for the CRBRP. 9
Four of these monitors will be located on or adjacent to the plant Site in the sectors having the greatest wind frequency. Nine other stations will be located at perimeter areas within ten miles of the plant Site.
The four site monitors and four of the nine perimeter area monitors
will be instrumented and may telemeter data into the control room. 6 9
Eight of these nine stations will be located within seven miles of the plant in the sectors having the greatest wind frequency on an annual basis, see Figure 6.2-1. These stations will be positioned in the valley in which the plant is located and in the two adjacent valleys. In addition, two of these nine monitors will bracket the Oak Ridge National Laboratory to aid in the determination of the origin of any increase in radioactivity levels and one will be in a more densely populated area
approximately ten miles from the plant. Two monitors will be used as 6

control or baseline stations. Samples of air, rainwater and heavy particle fallout will be collected routinely as indicated in Table 6.2-1.

The atmosphere around the CRBRP will be sampled for tritium. A sampling apparatus will be incorporated into the four local monitors and one of the remote monitoring stations.

6.2.1.2.3 PREOPERATIONAL-OPERATIONAL PHASE ENVIRONMENTAL RADIATION MONITORING PROGRAM - TERRESTRIAL MONITORING

Samples of milk, vegetation, pasturage grass, soil, well water, drinking 9
water supplies and food crops will be collected within a ten-mile 9
radius of the plant. Environmental gamma radiation levels will be
measured utilizing thermoluminescent dosimeters near the plant boundaries 6
and at each off-site atmospheric monitoring station. At least two dosimeters will be placed at the locations of highest predicted ground level concentrations. All dosimeters will be left in the field for three months. 6

Milk from dairy farms near the plant will be sampled on a monthly basis. After the plant begins operation, samples of fresh milk will be obtained at least once every two weeks (during the seasons when cows producing 9
milk for human consumption are on pasture) and analyzed for ^{131}I content.

Vegetation (grass, weeds, leaves, etc.) and soil samples will be collected quarterly from the vicinity of the atmospheric monitoring stations. The same rationale used for locating the atmospheric monitors is applicable to this program. The sampling and analysis schedule is shown in Table 6.2-1.

Pasturage grass will be collected quarterly from the dairy farms. This 9
vector would be the first indicator in the food chain to man through
animal. If a statistically significant increase above the natural back- 6
ground established during the preoperational monitoring program is detected, the program will be expanded to include other vectors in the food chain such as beef cattle.

Well water in the vicinity of the plant will be sampled monthly
and automatic water samplers will be installed on all potable surface
water supply intakes within 10 miles downstream from the plant. These 6
samples will be analyzed monthly. Food crops grown by subsistence
farmers in the area will be sampled during the growing season.

6.2.1.2.4 PREOPERATIONAL-OPERATIONAL PHASE ENVIRONMENTAL RADIATION MONITORING PROGRAM - RESERVOIR MONITORING

Samples will be collected from five river stations in Watts Bar and
Melton Hill Reservoirs. All samples except reservoir water will be
collected semi-annually. Reservoir water samples will be collected 9
by automatic sequential-type samplers and analyzed monthly.
The stations will be located approximately as indicated in Figure 6.2-2
near Clinch River Miles (CRM) 14.4, 15.4, 17.9, 18.6 and 24.0. Proposed 6 9
discharge point for the CRBRP is at approximately CRM 16. Samples col-
lected for radiological analysis will include water from four stations
and fish from two stations. Bottom fauna (Asiatic clams) and sediment 9
samples will be taken semi-annually from four stations when sufficient 9
quantities are available. Further sampling information can be found in
Tables 6.2-1 and 6.2-2. 9

Gamma, gross alpha and gross beta activity will be determined in water,
sediment, clams and fish. Whole fish, the shells of clams and sedi- 9
ment samples will be analyzed for strontium and plutonium. Water 9
samples will be analyzed for tritium. The activity of at 9
least ten gamma-emitting radionuclides will be determined with a multi-
channel gamma spectrometer. This program will sample those vectors which

will give the first indication of increased radioactivity levels in the environment. If statistically significant increases above natural pre-operational background are seen in those vectors being sampled, consideration will then be given to expansion of the sampling program to include other biological parameters.

Consideration has been given to sampling waterfowl; however, about 95 percent of ducks hunted in eastern Tennessee are migratory, moving great distances in the winter and spring. It would be impossible to make an accurate determination of the particular source of radionuclides found in migratory waterfowl. Therefore, it seems more logical to sample other vectors in the environment which the waterfowl might inhabit for short periods of time.

Water

Water samples will be collected for determination of radioactivity 6
from four stations. Samples will be collected by automatic water 9
samplers with composite samples analyzed monthly.

9

Fish

Radiological monitoring will be accomplished by analyses of composite samples of adult fish taken from the Clinch River above and below Melton Hill Dam.

No permanent sampling stations have been established within each reservoir because of the movement of fish species within the reservoirs.

This movement has been determined by TVA data from the Browns Ferry Nuclear Plant preoperational monitoring program. Samples of a predominate commercial and game species, to be determined in the CRBRP preoperational survey, will be collected semi-annually and anal-
yzed for gamma, gross alpha and gross beta activity. Concentrations 9
of Sr-89, Sr-90 and Pu will be determined on a commercial species. Sufficient amounts of each species of fish will be collected in each reservoir to yield a composite sample containing from 250 to 300 grams oven-dry weight for analytical purposes. The composite samples will contain approximately the same quantity of flesh from each of the fish. For each composite a subsample of material will be drawn for counting.

9

Sediment

Deposited sediment samples will be collected semi-annually from 9
Ponar dredge hauls when sufficient quantities are available. Gamma, 6
gross alpha and gross beta activity, and Sr-89, Sr-90 and Pu content
will be determined in samples collected from four stations. Each 6
sample will be a composite obtained by combining equal volumes of sediment from at least three dredge hauls collected from each station at a single point.

Asiatic Clams

Asiatic clams may be collected from in-place bimonitoring units at 9
four stations. The in-place bimonitoring units are used to identify 6
the source of radionuclides released to the river. These samples will be analyzed for gamma, gross alpha and gross beta activity. The Sr-89, Sr-90 and Pu content will be determined on the shells only.

Drinking Water Supply Monitoring

Drinking water supplies, such as small surface streams and wells, 9
will be sampled and analyzed. Groundwater will be obtained from at least two wells located near the plant. All public water supplies within ten miles downstream of the plant discharge will be sampled automatically and analyzed monthly for gross beta, gross alpha,
tritium and at least ten specific gamma-emitting radionuclides, and 6
quarterly for Pu. 9

Quality Control

A quality control program will be established and administered by TVA. TVA has similar programs in effect with the Tennessee Department of Public Health Radiological Laboratory and the Eastern Environmental Radiation Facility, Environmental Protection Agency,
Montgomery, Alabama. Samples of air, water, milk and soil col- 6
lected around the plant will be submitted for analysis. Results will be exchanged for comparison.

6.2.1.2.5 PREOPERATIONAL-OPERATIONAL PHASE ENVIRONMENTAL RADIATION MONITORING PROGRAM - GROUNDWATER

The types of sampling, sampling frequency and radiation parameters
described for the automatically sampled well in Section 6.1.5.1 will 6
continue throughout the plant life. A monthly composite sample will be 8

analyzed for gross alpha, gross beta and tritium activities. 8
If any significant increase in gross alpha or gross beta activity is detected, an analysis will be made to identify the specific radionuclide.

6.2.2 CHEMICAL EFFLUENT MONITORING

All point source discharges originating from the plant during the operating phase will be monitored in accordance with the terms of the operational NPDES permit. Applicable effluent limitations and related monitoring programs, including frequency and parameter coverage will be separately identified for each such discharge in the permit.

Instream water quality monitoring programs will be implemented as necessary to correspond with the requirements of the operational NPDES permit[(2)] and the results of the preoperational monitoring program. The preoperational monitoring program, which will be implemented two years prior to the initiation of fuel loading, will be designed to reflect both the best information available regarding final plant design and the environmental conditions existing at the time it is to be implemented. 6

6.2.3 THERMAL EFFLUENT MONITORING

The thermal effluent temperature monitoring program, as presently envisioned, will consist of stream temperature monitors situated upstream 6
and downstream of the discharge to the Clinch River which is located at river mile 16.0. By taking into consideration the results of effluent dispersion studies described in the Appendix to Section 10.3, an estimate of the number and location of the monitors can be made at this time. There will be a total of four monitors used for thermal effluent monitoring. Two will be placed upstream of the discharge just below the location of the intake at CRM 17.6 and the other two will be placed approximately one-half mile downstream of the discharge. The exact locations will be made after further considerations of river bottom topography, influent tributaries and barge channel locations.

In all cases, multiple temperature sensors will be located in the vertical at each monitoring location. Sensors will be mounted at the one-half foot, two and one-half foot and five-foot depths and at other depths depending upon the channel depth at the monitor location. The monitoring system will be designed to operate during periods of both normal and reverse flow conditions in the Clinch River.

The water temperature monitoring system will be automatically scanned by radiotelemetry and data will be transmitted to the plant for storage on paper tape and subsequent transfer to automatic data processing systems. Selected key water temperature data used for plant operational control will be relayed directly to the plant control room.

This program will be designed to ensure compliance with the thermal standards of the State of Tennessee Water Quality Control Board.[3] 6
This program will be subject to review and revision as appropriate to ensure compliance with the terms of the operational NPDES permit.[2]

6.2.4 METEOROLOGICAL MONITORING

After fuel loading begins, and continuing throughout the operation of the plant, the permanent meteorological facility will provide the base for prediction of dispersion in the event of an accidental release of radioactive gaseous materials. 8
Selected meteorological data, along with other environmental data will be remoted from the meteorological facility to the reactor control room for operational display.

The operational meteorological program will be a continuation of the permanent preoperational program. A detailed description of this program is included in section 6.1.3. 8

A program for observation of fogging and icing (rime and glaze) will be initiated in the vicinity of the Site during the plant construction phase. Fog observed in the immediate vicinity of the Site will be compared to that observed at the TVA fog observation station established in early 1964 at the Melton Hill Dam, located about 4.5 miles to the east (upriver). 8

6.2.5 ECOLOGICAL MONITORING

This program is designed to evaluate the impact of plant operation on the structure and function of the terrestrial and aquatic ecosystems.

6.2.5.1 MONITORING OF MOISTURE IMPACTS

Operation of a cooling tower will result in water vapor releases to the atmosphere. In nearby plant communities the moisture regime may be altered resulting in less soil moisture stress and higher relative humidity in the canopy. If changes in the water budget occur due to cooling tower operation, the following effects may be noted:

1. Incidence of plant diseases which depend on moist conditions may increase;
2. Growth rates of plant species favored by moist conditions may increase; and

3. Plant community characteristics may change resulting in greater density or frequency of species responding to more moist conditions.

Elements of the final plant design and studies at other facilities will indicate whether monitoring of these effects is necessary at the CRBRP. The following is an outline for such a study if it is needed.

Moisture indices for vegetation plots will be calculated by using relative humidity, soil moisture stress and air temperature data. Plots will be located proportionally to the wind rose or where significant impingement is expected. This will be coordinated with meteorological monitoring.

Plant disease incidence will be determined by examination of vegetation by a plant pathologist once each year during the peak period of expected disease occurrence. Transects will be permanently established to enable the subsequent evaluation of the same area.

Annual growth rates of selected plant species will be determined by measuring ring increment on hardwood trees and ring and height increment on conifer trees. Species will be chosen which are relatively common to the Site. Growth measurements will be made on the same plots for which moisture indices are developed.

Plant community characteristics of herbs, seedlings and saplings (DBH 4") will be determined by treating each plot as a stand and determining importance values for species annually during the monitoring period.

6.2.5.2 MONITORING OF ICING DAMAGE

During cold weather, operation of cooling towers may result in formation of ice (rime or glaze) on exposed vegetation. In turn, some vegetation may be damaged or destroyed.

If major icing occurs, aerial photography will be used to establish the extent of the accumulation and damage. Plots will be subsequently established in the affected area and periodically evaluated.

6.2.5.3 MONITORING OF DRIFT IMPACT

During operation, chemical constituents in cooling water will be discharged as drift along with water vapor. Normal constituents of water may be concentrated because of evaporation losses and other chemical constituents may be present because they are used during the plant operation. Accumulation of chemical constituents on leaves and in soil may increase uptake and may, in extreme cases, cause necrosis of leaf tissue. Chemical constituents may be retained in the soil or may be cycled by plants and animals on the Site. Elements of final plant design and studies at other facilities will indicate whether monitoring of these effects is necessary at the CRBRP. The following is an outline of such a study if it is needed.

Soil and litter samples will be obtained on each plot once each year in August for determination of chemical constituents. Litter samples will be a composite of the 01 and 02 horizons which are defined in the Walker Branch Watershed Study.[4,5] Surface soil samples one cm thick will be compared to preoperational data.

Subsoil samples from 10 cm depth (2 cm thick) will also be obtained and composited. Vegetation samples will be obtained on each plot during August of each year to determine chemical constituents. At each plot location individuals will be selected and marked for sampling. Leaves obtained will be composited by plot and by species. These samples will be coordinated with other monitoring programs such as radiological, etc., where possible.

Individuals of (1) seed-eating resident mammals, (2) insect-eating resident mammals and (3) forage-eating resident mammals will be collected for determination of chemical constituents. Samples will be collected once each year in autumn and will be obtained in the vicinity of the cooling towers.

Materials to be sampled and number of samples to be obtained annually are given in Table 6.2-4. Soil and vegetation sampling will be attempted during relatively dry periods.

6.2.5.4 LIMNOLOGICAL MONITORING

An instream limnological monitoring program will be implemented as necessary to correspond with the requirements of the operational NPDES permit[2] and the results of the preoperational monitoring program. The preoperational monitoring program, which will be implemented two years prior to the initiation of fuel loading, will be designed to reflect both the best information available regarding final plant design and the environmental conditions existing at the time it is to be implemented. 6

6.2.5.5 MONITORING OF CIRCULATING WATER IMPACTS 6

Operation of the circulating cooling water system will result in four main categories of nonradiological impact: heated water discharges, impingement of organisms on intake structures, entrainment of biota and discharge of chemicals. Final plant design details may modify the programs detailed in the following subsections. Most of the monitoring will be done in the area near the plant where any impacts should be most pronounced. No reservoir-wide monitoring is contemplated.

The monitoring program will show the changes in the distribution of fish in response to heated water. Certain species of fish may be attracted to heated water during winter or repelled during summer; hence, species composition may change while numbers remain relatively constant. Sampling for species composition and numerical abundance will be concentrated in the overbank areas influenced by the heated discharge. Other effects of heated water can be hypothesized; however, these effects would be less obvious than changes in the distribution of fish. Monitoring of these more subtle effects is not planned.

Because of the design of the perforated pipe intake structure, no impingement monitoring will be done. Larval fish entrainment monitoring may be done by sampling along the condenser lines although such sampling is usually difficult. If such samples cannot be taken, entrainment losses will be monitored by comparison of samples taken upstream and downstream from the plant.

6.2.5.5.1 FISH

Operation of power plants may produce three main categories of nonradiological impacts on fish: thermal effects, impingement of postlarval fish on the perforated pipe intake and entrainment of eggs and larval fish. The majority of fish sampling will be conducted in the area near the plant where any impacts should be most pronounced. Preoperational monitoring will begin two years prior to plant operation and will establish baseline data for comparison with operational data. Preoperational monitoring procedures are discussed below and operational monitoring will follow generally these same procedures. Sampling methods may be changed (preoperational and operational monitoring) when field sampling experience and/or data analysis indicate the necessity. 6

6.2.5.5.2 HEATED DISCHARGES

This phase of the monitoring program is designed to show any changes in the distributions, species composition and abundance of fish in the immediate vicinity of the plant that result from responses to heated water. Sampling will be concentrated in the area immediately downstream of the discharge which should be most influenced by heated water (preoperational-operational and upstream-downstream comparisons will be made).

Changes in the distributions of postlarval fish will be assessed by rotenone sampling, gill netting, hoop netting and electrofishing. Sampling will be conducted at three stations: (1) a control upstream from the proposed discharge, (2) immediately below the discharge and (3) approximately one mile downstream. Netting and electrofishing samples will be taken monthly to provide seasonal measurements at the three stations. Rotenone samples will be taken once a year during the late summer or early fall if suitable locations are found in close proximity to the site.

Fish collected will be identified to species, counted and individual lengths and weights recorded for selected species. Where large numbers of a single species are collected, subsample methods may be utilized. 6

6.2.5.5.3 ENTRAINMENT (FISH EGGS AND LARVAE)

The objective of this monitoring program is to provide a data base from which an impact assessment of condenser and thermal plume entrainment can be accomplished. Estimated numbers of larval fish entrained will be compared to the estimated total larval population passing the plant. In addition, the relative impact of entrainment on each species will be assessed by comparisons of estimated entrainment losses of each species versus estimated abundance or standing stock of adults and juveniles of the same species in this area of the Clinch River. Localized impacts on resident species living near the plant will also be studied.

Entrainment will be assessed by weekly sampling during the approximate time period March 15 - September 15 and preoperational sampling will provide information on the abundance, species composition and distribution of fish eggs and larvae in the vicinity of the plant.

Samples will be taken at three reservoir transects: (1) near the plant intake, (2) near the plant discharge and (3) downstream of the plant discharge. Three stations will be sampled along each transect: a station at each shoreline and a midtransect (midchannel) station. Also, samples will be taken along the shoreline at four stations in both the Poplar Springs Creek and Caney Creek embayments. Both day and night reservoir (river channel) samples will be taken at the transect locations. Embayment samples will be taken at night.

Samples will be collected at each reservoir transect location using a 1 m, square, 505 micron mesh ichthyoplankton net. Depth-discrete samples will be taken at surface and bottom at each of the reservoir stations; and, where depth allows, a discrete midlevel sample will be taken. Passive, stationary samples will be taken at each level during periods of high flow; and active, moving samples will be taken during periods of low flow. At least 100 m^3 of water will be strained by each sample. 6
Flow will be recorded using a T.S.K. No. 313 flowmeter mounted in the center of the net.

Collections of fish eggs and larvae at the stations in Poplar Springs Creek and Caney Creek embayments will be taken using a Model 120TP3-1 Homelite trash pump. Pump samples will be strained through a 505 micron mesh net. Samples will be taken at a boat speed of roughly 0.3 m/s; a 10-minute sample will strain approximately 10 m^3 of water. The intake hose will be manipulated to sample the entire water column at each station.

Samples will be preserved in the field in 10 percent formalin and returned to the laboratory for sorting, enumeration, mensuration and identification to the lowest possible taxon.

6.2.5.5.4 IMPINGEMENT

Because the perforated pipe intake structure of the CRBRP is designed to minimize impingement and is located approximately nine feet deep in usually swift water, no regularly scheduled impingement monitoring is planned. Periodic observations of the intake structure may be conducted by divers.

TABLE 6.2-1

PREOPERATIONAL-OPERATIONAL ENVIRONMENTAL RADIOLOGICAL SUREILLANCE PROGRAM

	Criteria and Sampling Locations	Collection Frequency	Analysis/Counting
I. Atmospheric			
A. Air			
1. Particulate	Filter paper at 12-15 locations	Weekly	Gross beta; gross alpha; gamma scan monthly; Pu, Sr and U quarterly
2. Radioiodine	Charcoal filter at 12-15 locations	Weekly	^{131}I
3. Tritium	Atmospheric moisture samplers at 2-5 locations	Weekly*	^{3}H
B. Fallout	Gummed acetate at 12-15 locations	Monthly	Gross beta, gross alpha
C. Rainwater	Rainwater collection trays at 12-15 locations	Monthly	Gross beta, gamma scan, ^{89}Sr, ^{90}Sr, ^{3}H
II. Reservoir			
A. Water			
1. Municipal (public supplies)	All public water supply intakes within 10 miles upstream and downstream of the plant	Monthly**	Gross beta, gross alpha, gamma scan, ^{3}H monthly, Pu quarterly
2. River	Timed sequential samplers at 4-8 locations	Analyzed Monthly	Gross beta, gross alpha, gamma scan, ^{3}H monthly, ^{89}Sr, ^{90}Sr, Pu, U quarterly
B. Aquatic Biota			
1. Fish	Two locations	Semi-annually	Gross beta, gross alpha, gamma scan, ^{89}Sr, ^{90}Sr, Pu
2. Shellfish (if available)	Four to six locations	Semi-annually	Gross beta, gross alpha, gamma scan (^{89}Sr, ^{90}Sr, Pu shell only)

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(Continued)

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TABLE 6.2-1 (Continued)

	Criteria and Sampling Locations	Collection Frequency	Analysis/Counting
C. Sediment	Four to six locations	Semi-annually	Gross beta, gross alpha, gamma scan, ^{89}Sr, ^{90}Sr, Pu
III. Terrestrial			
A. Soil	Atmospheric monitoring locations	Annually	Gross beta, gross alpha, gamma scan, Pu, U
B. Vegetation			
1. Pasturage grass	Selected dairy farms within 10-mile radius of plant	Quarterly	Gross beta, gross alpha, gamma scan, ^{89}Sr, ^{90}Sr, Pu
2. Grass	Collected at atmospheric monitoring stations	Quarterly	Same as pasturage grass
3. Food crops	Within 10-mile radius of plant	Annually	Gross beta, gross alpha, gamma scan, ^{89}Sr, ^{90}Sr, Pu
C. Milk	Selected dairy farms within 10-mile radius of plant	Monthly+	Gamma scan, ^{89}Sr, ^{90}Sr, ^{131}I 9
D. Well water	Selected farms within 5 miles of plant and 1-5 wells on site	Monthly	Gross beta, gross alpha, gamma scan monthly, Pu quarterly
E. Direct radiation	TLD's on site and at atmospheric monitors	Quarterly	Dose determination

* Every other week during preoperational monitoring.

** All public water supplies within 10 miles downstream of the plant will be collected automatically and analyzed monthly.

\+ After the plant begins operation milk samples will be taken at least once every two weeks for ^{131}I analysis when cows are on pasture.

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TABLE 6.2-2

RESERVOIR WATER AND BIOLOGICAL SAMPLING SCHEDULE (RADIOLOGICAL) - CLINCH RIVER BREEDER REACTOR PLANT, WATTS BAR AND MELTON HILL RESERVOIRS

Station or CRM	Reservoir Water*	Asiatic Clams**	Sediment	Fish+	
14.4	1	1	1	--	
15.4	1	1	1	--	
17.9		1	1	--	9
18.6	1				6
24.0	1	1	1	--	

* Timed sequential samples, analyzed monthly

** If available 9

\+ Fish samples will be taken from the Clinch River above and below Melton Hill Dam.

Information originally contained in Table 6.2-3 has been incorporated into Table 6.2-1 in Amendment IX

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TABLE 6.2-4

NUMBER OF SAMPLES/YEAR FOR CHEMICAL CONSTITUENTS*

Material	Composite or Replicated Sample	Sample
Litter	Composite x 20 locations	20
Surface soil	Composite x 20 locations	20
Subsoil	Composite x 20 locations	20
Hardwood leaves	Composite x 10 locations	10
Conifer needles	Composite x 10 locations	10
Broom sedge	Composite x 10 locations	10
Ragweed	Composite x 10 locations	10
Kentucky 31 fescue	Composite x 10 locations	10
Virginia creeper	Composite x 10 locations	10
Lawn grass	3 replications x 40 locations	120
Insectivorous small mammal	3 replications x 5 locations	15
Seed-eating small mammal	3 replications x 5 locations	15
Forage-eating small mammal	3 replications x 5 locations	15
		285

*Tentative sampling schedules subject to modification

TABLE 6.2-5

CONTINUOUS EFFLUENT MONITORING/SAMPLING

Description	Bldg.	Elev.	Monitor Type	Detector Type	Sensitivity µCi/cc	Remarks
Raps and Caps Exhaust	RSB	884'	Gaseous	Scint.	10^{-6} Kr^{85}	(Continuous)
Radwaste Ventilation Exhaust	RSB	867'	Particulate	Scint.	10^{-10} Cs^{137}	
			Gaseous	Scint.	10^{-6} Kr^{85}	(Continuous)
RCB Ventilation Exhaust	RSB	861'	Particulate	Scint.	10^{-10} Cs^{137}	
			Gaseous	Scint.	10^{-6} Kr^{85}	
			Radioiodine	Scint.	10^{-10} I^{131}	(Continuous)
Steam Generator Loop Cells (3)	SGB	806'	Tritium Sampler	-	-	Sample Analyzed in Counting Room by Liquid Scintillation Techniques (Sample)
Turbine Generator Building Ventilation	TGB	915'	Tritium Sampler	-	-	Sample Analyzed in Counting Room by Liquid Scintillation Techniques (Sample)
Decontamination Area Ventilation	PSB	830'	Particulate Sampler	-	-	Sample Analyzed in Counting Room Using Proportional Counter and Spectroscopy System (Sample)
Hot Lab and Counting Room Ventilation	PSB	830'	Particulate Sampler	-	-	Sample Analyzed in Counting Room Using Proportional Counter and Spectroscopy System (Sample)
Plant Discharge Canal	YRD	830'	Composite Liquid Sampler	-	-	Sample Analyzed in Counting Room Using Proportional Counter and Spectroscopy System (Sample)
SBG-IB Exhaust	SGB	836'	Gaseous	Scint.	10^{-6} Kr^{85}	

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(Continued)

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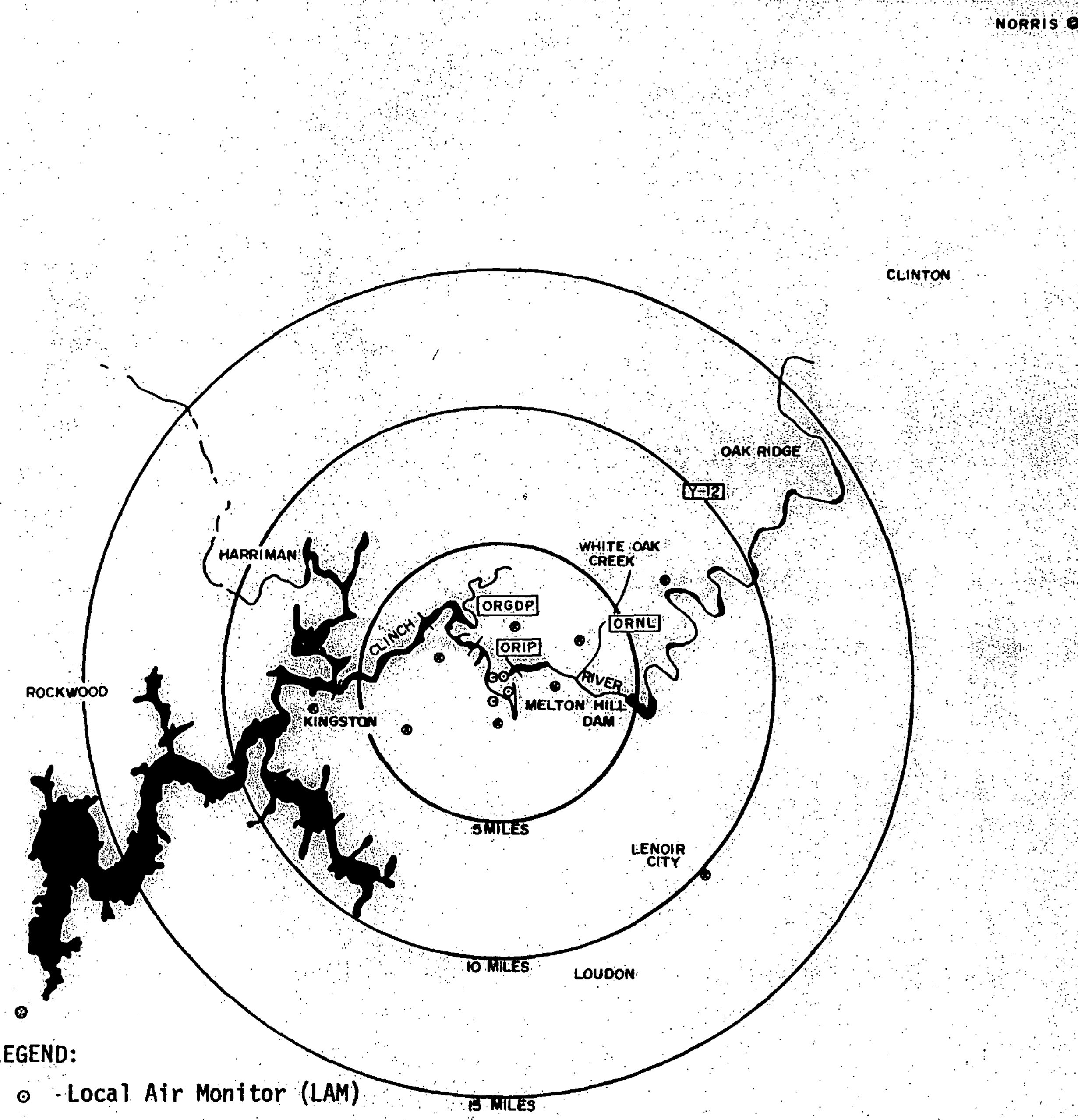
TABLE 6.2-5 (Continued)

Description	Bldg.	Elev.	Monitor Type	Detector Type	Sensitivity µCi/cc	Remarks
Annulus Filter	RSB	861'	Particulate	Scint.	10^{-10} Cs^{137}	
Discharge (A) 861'		840'	Gaseous	Scint.	10^{-6} Kr^{85}	
(B) 840'			Radioiodine	Scint.	10^{-10} I^{131}	(Continuous)
RCB Annulus/TMBDB	RSB	840'	Particulate	Scint.	10^{-10} Cs^{137}	
Effluent (A)			Gaseous	Scint.	10^{-6} Kr^{85}	
			Radioiodine	Scint.	10^{-10} I^{131}	(Continuous)
Annulus Filter	RSB	861	Particulate	Scint.	10^{-10} Cs^{137}	
Inlet (A) 861'		840'	Gaseous	Scint.	10^{-6} Kr^{85}	
(B) 840'			Radioiodine	Scint.	10^{-10} I^{131}	(Continuous)
RSB Clean Up Filter	RSB	816'	Particulate	Scint.	10^{-10} Cs^{137}	
Discharge (A) 816'		794'	Gaseous	Scint.	10^{-6} Kr^{85}	
(B) 794'			Radioiodine	Scint.	10^{-10} I^{131}	(Continuous)
RCB Annulus/THBDB	RSB	861'	Particulate	Scint.	10^{-10} Cs^{137}	
Effluent (B)			Gaseous	Scint.	10^{-6} Kr^{85}	
			Radioiodine	Scint.	10^{-10} I^{131}	(Continuous)
RCB Annulus/TMBDB Effluent	RSB	861'	Plutonium	Scint.	10^{-12} Pu^{239}	
Pu Activity (A) 861'		840'				(Continuous)
(B) 840'						
RSB Exhaust	RSB	840'	Gaseous	Scint.	10^{-6} Kr^{85}	(Continuous)

9



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LEGEND:

⊙ - Local Air Monitor (LAM)

⊗ - Perimeter Air Monitor (PAM)

⊖ - Remote Air Monitor (RAM)

ORGDP - Oak Ridge Gaseous Diffusion Plant

ORNL - Oak Ridge National Laboratory

ORIP - Oak Ridge Industrial Park

NOTE: The following samples are collected at each monitoring site:

Air Particulates	Rainwater
Radioiodine	Soil
Heavy Particles	Vegetation
Fallout	

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Figure 6.2-1. ATMOSPHERIC AND TERRESTRIAL MONITORING NETWORK FOR CRBRP

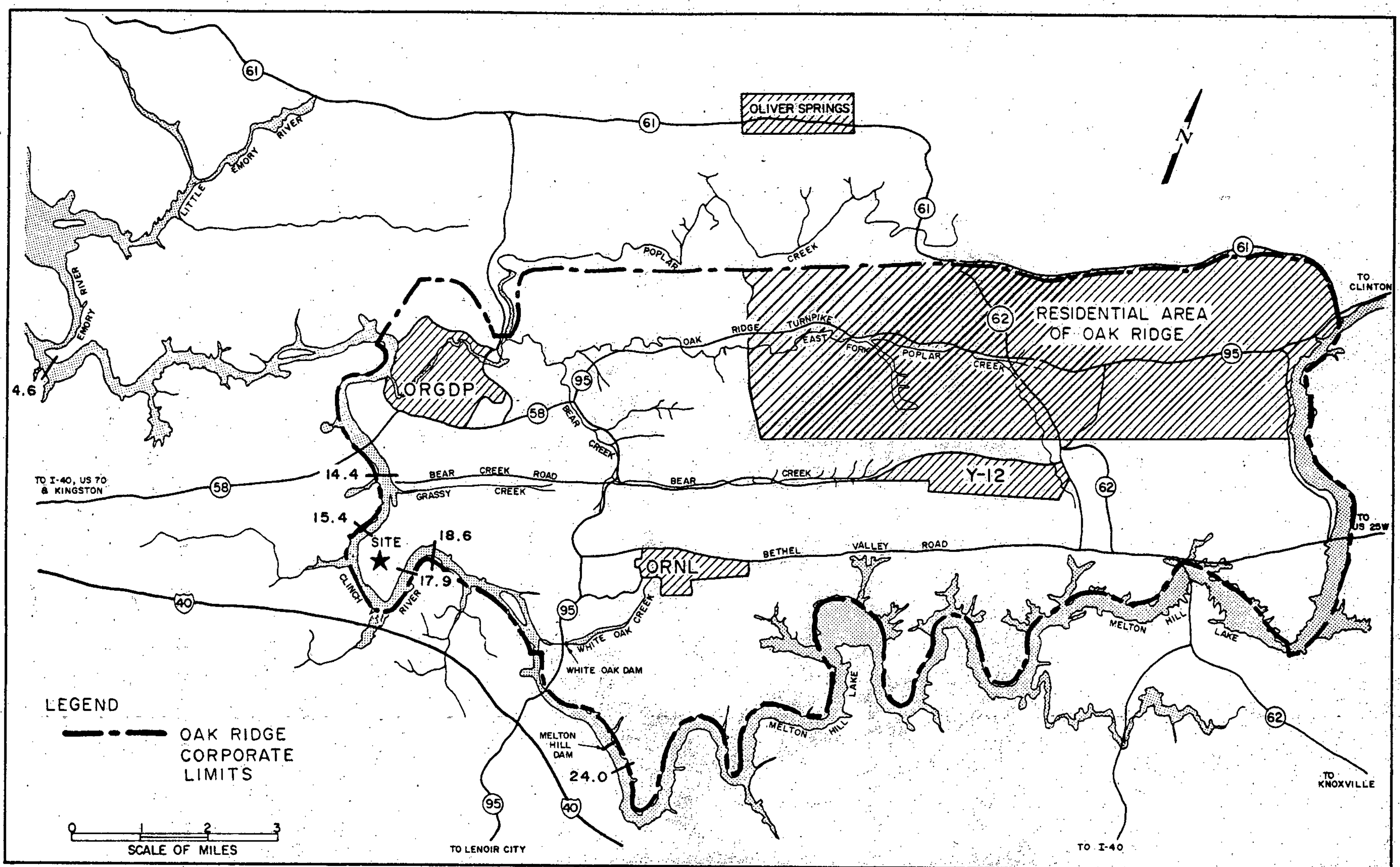

Figure 6.2-2 RESERVOIR MONITORING NETWORK

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6.3 RELATED ENVIRONMENTAL MEASUREMENTS AND MONITORING PROGRAMS

Various biological, water, air, radiological and ecological programs are in process in the general area of the CRBRP. Some of these programs are being conducted by the Oak Ridge National Laboratory operated by Union Carbide Corporation for the Energy Research and Development Administration. The scope and nature of these programs are outlined in the ORNL Annual Progress Report[1] and the ERDA Environmental Monitoring Report.[2]

The TVA Water Quality Branch maintains a network of routine water quality monitoring stations throughout the Tennessee Valley. Closest of these stations to the CRBRP Site is at CRM 23.1 (Melton Hill Dam tailrace). Grab samples are taken weekly for temperature and dissolved oxygen concentration.

Other temperature and dissolved oxygen sampling stations in the general area of the CRBRP Site include TRM 529.9 (Watts Bar Dam tailrace), TRM 602.3 (Fort Loudoun Dam tailrace) and CRM 79.8 (Norris Dam tailrace).

The U. S. Geological Survey has a water quality monitoring station at TRM 529.9 (Watts Bar Dam tailrace) which complements TVA's program. Temperature, conductivity and streamflow are measured and recorded continuously. Monthly grab samples are collected and analyzed for chemical and biological parameters. Quarterly grab samples are also collected and analyzed for additional parameters.

A monthly composite sample is collected at the Union Carbide water intake at TRM 593.3. Company personnel collect this sample in cooperation with the Tennessee Water Quality Control Division. 6

NRC QUESTIONS ABOUT SECTION 7

NRC Letter November 19, 1974 - Giambusso

Item 000.16 (7.1) - Amendment I, Part I, pages AI-2 and 3
Item 000.1 (7.1) - Amendment II, Part I, pages AII-2 and 3
Item 000.2 (7.1) - Amendment II, Part I, pages AII-4 to 6
Item 000.3 (7.1) - Amendment II, Part I, pages AII-7 and 8
Item 000.4 (7.1) - Amendment II, Part I, pages AII-9 and 10
Item 000.5 (7.1) - Amendment II, Part I, pages AII-11 and 12
Item 000.6 (7.1) - Amendment II, Part I, pages AII-13 to 15
Item 000.7 (7.1) - Amendment II, Part I, pages AII-16 to 19
Item 000.8 (7.1) - Amendment II, Part I, pages AII-20 and 21
Item 000.9 (7.1) - Amendment II, Part I, pages AII-22 and 23
Item 000.10 (7) - Amendment II, Part I, pages AII-24 and 25
Item 000.11 (7.1) - Amendment II, Part I, pages AII-26 and 27
Item 000.12 (7.1) - Amendment II, Part I, pages AII-28 to 32
Item 000.13 (7.1) - Amendment II, Part I, pages AII-33 and 34
Item 000.14 (7) - Amendment II, Part I, pages AII-35 to 37
Item 000.15 (7.1) - Amendment II, Part I, pages AII-38 and 39

NRC Letter June 11, 1975 - Speis - Amendment IV, Part I, page AIV-3

NRC Letter June 27, 1975 - Dicker

Item 000.17 (7.1.2.2.1) - Amendment IV, Part I, page AIV-8
Item 000.18 (7.1.2.3) - Amendment IV, Part I, page AIV-9
Item 000.19 (7.1.2.3.3) - Amendment IV, Part I, page AIV-10
Item 000.20 (7.1.2.4) - Amendment IV, Part I, page AIV-11
Item 000.21 (7.1.2.5.1) - Amendment IV, Part I, pages AIV-12 and 13
Item 000.22 (7.1.2.5.1) - Amendment IV, Part I, page AIV-14
Item 000.23 (7.1.2.5.2) - Amendment IV, Part I, page AIV-15 to AIV-19 7
Item 000.24 (7.1.2.6.1) - Amendment IV, Part I, page AIV-20
Item 000.25 (7.1.2.6) - Amendment IV, Part I, pages AIV-21 and 22
Item 000.26 (7.1.2.8.1) - Amendment IV, Part I, pages AIV-23 and 24
Item 000.27 (7.1.2.8.2) - Amendment IV, Part I, pages AIV 25 to 28
Item 000.28 (7.1) - Amendment IV, Part I, pages AIV 29 to 36
Item 000.29 (7.1) - Amendment IV, Part I, pages AIV-37 and 38
Item 000.30 (7.1) - Amendment IV, Part I, pages AIV-39 to 42
Item 000.31 (7.1) - Amendment IV, Part I, pages AIV-43 to 45

7.1 PLANT ACCIDENTS

Eight classes of postulated accidents are examined in this section. The NRC, in Regulatory Guide 4.2, has defined a spectrum of accident 8
classes with potential impact ranging from trivial to serious for light water reactors. To the extent possible, Regulatory Guide 4.2 was used for selecting and classifying postulated accidents for the CRBRP. 8

Consequences of most of the postulated accidents are dependent on the activity levels of the primary sodium coolant and/or the reactor cover gas system. The CRBRP design basis for these activity levels is continuous plant operation with one percent failed fuel. However, the maximum expected fuel failure rate is lower by a factor of 10. Consequences of the postulated accidents were determined based on continuous plant operation with 0.5 percent failed fuel. Use of this value provides an adequate measure of potential radiological impact, without introducing undue conservatism.

Atmospheric dispersion was based on the assumption of ground level release. This type of release assumption results in higher concentrations at the Site boundary compared to elevated releases and thus provides a conservative assessment of environmental impact.

For each postulated accident, the environmental consequences are evaluated in terms of the maximum individual whole body and organ doses at the nearest Site boundary. Doses at a number of other downwind distances of interest are also presented. An estimate of the whole body population dose resulting from each accident is made. A summary of all the individual doses computed for each accident, as well as the appropriate 10 CFR 20 and 10 CFR 100 limits for 11
comparison, are provided in Tables 7.1-5 to 7.1-12. Population dose 8
estimates are summarized in Table 7.1-13.

7.1.1 COMPUTATIONAL MODELS

7.1.1.1 METEOROLOGY

Diffusion calculations for the accident analyses were performed
using the meteorological data provided in Section 2.6. A
statistical analysis of dilution factors (x/Q) computed from hourly
on-site data was performed to define the 50 percent probability x/Q
values as a function of downwind distance from the plant. These
values represent median atmospheric dilution conditions; dilution
will be poorer (less dispersion) 50 percent of the time and better
(more dispersion) 50 percent of the time. The x/Q's as a function 8
of downwind distance from the plant are listed in Table 7.1-1.

11

Use of these 50 percent x/Q values, representative of the median atmospheric dilution conditions, is consistent with the realistic approach to the evaluation of accidents as required for Environmental Reports.

7.1.1.2 DOSE CALCULATIONAL METHODOLOGY

For each of the accidents evaluated, the following doses were
considered: 11

- o Whole body dose = Sum of the external whole body gamma dose and the whole body dose from the inhalation of radioactive material;
- o Lung dose;
- o Bone dose;
- o Thyroid dose; and
- o Population dose

Not all of the accidents evaluated resulted in releases leading to bone, lung or thyroid doses. The radionuclides released for each accident determined which of the doses itemized above were non-zero.

Doses were based on an exposure time equal to the duration of the accident. Doses to an individual (whole body, lung, bone and thyroid) were computed at each of the following locations: 11

1. 2,200 feet, minimum exclusion distance;
2. 0.6 miles, nearest residence;
3. 1 mile, nearest recreational area;
4. 2.5 miles, low population zone radius 8
5. 4 miles, nearest dairy;
6. 7 miles, nearest population center >2,500 (Kingston);
7. 21 miles, nearest population center >100,000 (Knoxville); and
8. 50 miles.

11

Whole body gamma dose was computed based on a semi-infinite spherical cloud model as follows:

$$D_\gamma = 0.25\ (\chi/Q) \sum_i (A)_i\ (E_\gamma)_i$$

where,

D_γ = Whole body gamma dose, rem

$(E_\gamma)_i$ = Average gamma energy of isotope, i, per disintegration, MeV, Table 7.1-2

$(A)_i$ = Activity of isotope, i, released to the environment, over time interval considered, Curies

χ/Q = Dilution factor appropriate for time interval and downwind distance, sec/m^3, Table 7.1-1.

Doses to the whole body and various organs from the inhalation of radionuclides were computed as follows:

$$D_{Inh} = (\chi/Q)\ B \sum_i (A)_i\ (F)_i$$

where,

D_{Inh} = Dose to organ under consideration, rem

B = Reference man-breathing rate, for 8 hour period, 3.47×10^{-4} m^3/sec

$(F)_i$ = Dose conversion factor of isotope, i, for organ under consideration, rem/Ci inhaled, Table 7.1-3

$(A)_i$ = Activity of isotope, i, released to the environment, over time interval considered, Curies

χ/Q = Dilution factor appropriate for time interval and downwind distance, sec/m^3, Table 7.1-1

Average gamma energies employed in this analysis were taken from several sources.(2,3,4) Gamma energies include x-rays. No allowance for attenuation in tissue was included. Thus, the energies provide a conservative estimate of the actual absorbed energy. 11

Conversion factors for internal doses from the inhalation of radionuclides were taken from Regulatory Guide 1.109.(5)

An estimate of the whole body population dose that could result from each accident was made. The model used is as follows:

$$DP = \sum_{(r)_j\ (min)}^{50\ miles} [0.25 \sum (A)_i\ (E_\gamma)_i + B \sum_i (A)_i\ (F_{WB})_i]\ (\chi/Q)_j (P)_{jk}$$

where,

DP = Whole body population dose, man-rem

$(\chi/Q)_j$ = Dilution factor appropriate for time interval and downwind distance $(r)_j$, sec/m^3

$(A)_i$ = Activity of isotope, i, released to environment over time interval considered, Curies

$(E_\gamma)_i$ = Average gamma energy of isotope, i, per disintegration, MeV

B = Reference man breathing rate, 3.47 x 10^{-4} m^3/sec

$(F_{WB})_i$ = Whole body dose conversion factor of isotope, i, rem/Ci inhaled

$(P)_{jk}$ = Population in radial increment r_j to r_{j+1} and azimuthal sector k

$(r)_j$ = Downwind distance at midpoint of radial increment r_j to r_{j+1}

The model for calculation of whole body population dose includes both the contribution of the internal whole body dose due to inhalation of radioactive material and the external gamma dose.

To provide an estimate of the maximum and minimum population dose that could result from each accident, depending on the wind direction during the accident, two azimuthal sectors were used in the evaluation. The maximum population dose was determined assuming that the wind was persistent (constant direction) for the duration of the accident and towards the E, the sector with the highest 11 $\sum_j (\chi/Q)_j (P)_{jk}$. Minimum population dose was determined by assuming wind persistence towards the NNW, the sector with the lowest $\sum_j (\chi/Q)_j (P)_{jk}$. A measure of the probability that either of these situations exists is the respective annual average wind frequency, $(f)_k$, for each sector. Both the minimum and maximum population doses are based on sector centerline doses and thus are conservative since meandering of the wind within the sector is neglected.

Wind frequency and population distribution per radial increment for both the E and NNW sectors are shown in Table 7.1-4. The 50 percent 11
$^{X}/Q$ values defined at the midpoint of each radial increment are included in Table 7.1-1. Population distribution is the projected distribution for census year 2010.

7.1.1.3 SODIUM FIRE ANALYSIS

The pressure-temperature history of inerted cells following postulated sodium spills is computed using the SOFIRE II and SPRAY-3 computer codes. SOFIRE II and SPRAY-3 calculations have been 8
compared favorably to experimental results.[6] Two versions of SOFIRE II have been written to simulate fires in a single 11
containment volume and in an interconnected double cell. In air-filled cells, the pressure-temperature histories are calculated using the SPRAY-3B and SPCA codes.

Time behavior of aerosols generated during sodium combustion was computed using the HAA-3 computer code.[7] The code provides for 8
both one and two compartment modeling. Effects of Brownian agglomeration, gravitational agglomeration, settling, wall plating and leakage are included in the program. In addition to predicting a number of time-dependent parameters descriptive of the aerosol, the program computes, as a function of time, the plated, settled, suspended and leaked masses. The latter is of particular interest in determining potential environmental impact resulting from postulated sodium spills.

7.1.2 ACCIDENT ANALYSES

7.1.2.1 ACCIDENT 1.0 - TRIVIAL INCIDENTS

These incidents are included and evaluated in Sections 5.2 and 5.3 under routine releases in accordance with Regulatory Guide 4.2.

7.1.2.2 ACCIDENT 2.0 - SMALL RELEASES OUTSIDE CONTAINMENT

To demonstrate the minimal environmental impact resulting from small tritium releases outside containment, two postulated releases are evaluated in the following sections.

7.1.2.2.1 ACCIDENT 2.1 - TRITIUM RELEASE THROUGH SGAHRS VENT CONTROL VALVES 11

The event which would result in the largest release of steam from the Steam Generator System (SGS) due to operation of the Steam 11 Generator Auxiliary Heat Removal System (SGAHRS) Vent Control Valves has been identified as the loss of the main condenser during full power operation. Design basis frequency for the loss of main condenser is 10 over the life of the plant. However, it is expected that the actual frequency is lower than the design basis.

Following the postulated loss of a main condenser, heat removal would be accomplished by venting the steam in the SGS to the atmosphere through the SGAHRS Vent Control Valves. Venting 11 continues until the heat load is reduced to 45 MWT at which time (~1.0 hour) the SGAHRS is capable of removing heat in a closed loop 11 fashion. For the accident postulated, release of all the available steam/water in the SGS and the normal feedwater deaerator tank is assumed. This assumption is a conservative estimate of the maximum 6 water volume released during steam venting.

Approximately 353,000 pounds of water is assumed to be released to 11 the atmosphere. 6 The only radioactive material present in the water is tritium which has entered the system by diffusion through the heat exchanger tubes in the steam generators and superheaters. The

calculated level of tritium in the SGS at the end of plant life (30 11
years) is 0.62 μCi/g resulting in a tritium release to the
atmosphere of 99 Curies during the steam dump.

Maximum off-site whole body dose from this postulated release is
5.50 mrem. Doses at specific downwind distances and estimates of 4 8 11
the potential population dose are provided in Tables 7.1-5 to
7.1-13.

7.1.2.2.2 ACCIDENT 2.2 - CONDENSATE STORAGE TANK LEAK

For this accident, a leak in a condensate storage tank containing 11
tritiated water was postulated. The following conservative
assumptions and conditions were used to evaluate potential
environmental impact;

1. The condensate has attained the same equilibrium tritium concentration as is found in the steam generator 11
(0.62μci/cc);
2. The storage tank releases water via a valve leak at a rate of 10 gpm to a drain which empties directly into the river, and
3. The flow rate of the Clinch River at the point of discharge
is 4,339 cfs (Low flow - spring average). 11

This postulated accident leads to a release rate of 23.5 mCi/minute
to the river and a downstream concentration of 3.18 x 10^{-6} μCi/cc of 11
tritium. This concentration is about three orders of magnitude
below the limits set forth in 10 CFR 20, Appendix B and will be of
limited duration; as such, no adverse environmental impact would
result from this postulated leak.

7.1.2.3 ACCIDENT 3.0 - RADWASTE SYSTEM FAILURES

Intermediate activity level liquid process streams and storage tanks are located in concrete cells below grade in a non-hardened portion of the Reactor Service Building. Floors and walls of the cells are painted with an epoxy coating to prevent leakage of contaminated 11
water to the outside groundwater and to facilitate decontamination, if necessary. Floors of all cells in the basement are protected with a pliable undercoat to prevent in-leakage of ground water to 11
the cells. Each cell is provided with a floor drain whose effluents are routed to a sump. Sump pumps are then used to transfer spilled fluids to any desired tank.

Because the cleaning process used to remove contaminated sodium from components yields salts which are expected to remain stable during processing in the radwaste system, the liquid radwaste tanks contain no gaseous radioactive species. In the event of tank failure, malfunction or operator error, resulting in a spill, the only mechanism for radioactivity release is the evaporation of water containing tritium as HTO.

The CRBRP gaseous radwaste system consists of two subsystems that process radioactive gases; the Cell Atmosphere Processing Subsystem (CAPS) and the Radioactive Argon Processing Subsystem (RAPS). RAPS processing components are located in the RCB, and CAPS components 11
are located in the RSB.

CAPS processes gas streams that normally contain low level radioactivity prior to their discharge from the plant. RAPS processes the more highly radioactive cover gases from the primary 11
sodium system.

Because RAPS receives and processes gases of much higher activity 11
levels than CAPS its process components are located in the RCB.
Rupture of the Noble Gas Storage Vessel (NGSV) is included in the
accidents in the subsequent sections since it is the limiting
gaseous radwaste system accident.

7.1.2.3.1 ACCIDENT 3.1 - LIQUID SYSTEM TANK MALFUNCTION

A malfunction or equipment leakage of a liquid storage tank
releasing 25 percent of the average inventory of the tank is
postulated. The liquid release, 5,000 gallons of water, would
contain 13,000 μCi of tritium as HTO. The floor area of the cell 6
housing the storage tank is 1,000 square feet and the cell volume is
39,000 cubic feet. Spilled fluid would be transferred to an
unfaulted tank by a sump pump, designed for a flow capacity of 50 11
gpm. Time required for spill cleanup is 1.7 hours. Evaporation
rate of the liquid tritium during the time period when the liquid is
being pumped into an unfaulted tank was assumed to be constant.
Rate of tritium evaporation was computed using the experimental
results of Horton, et al.[8] The total tritium release from the 8
pool by evaporation during the 1.7 hour cleanup time is 25 μCi.
Direct release of the evaporated tritium to the atmosphere via the 6
Reactor Service Building ventilation system was assumed.

The maximum off-site whole body dose resulting from this event is 11
1.4×10^{-6} mrem. Doses at specific downwind distances, based on 6
exposure for the duration of the accident, are presented in Tables
7.1-5 through 7.1-12. Estimates of the potential population dose 8
are presented in Table 7.1-13.

As the above analysis indicates, a realistic assessment of this
postulated fault results in exposure orders of magnitude less than
10 CFR 20 limits. To further demonstrate the minimal environmental 11
impact of this postulated event, an upper bound limit to potential
off-site exposure was computed by unrealistically assuming that the
total HTO inventory, 13,000 μCi, of the spilled fluid was evaporated
and released directly to the atmosphere. In this case, the maximum
whole body dose would be 7.2×10^{-4} mrem. Even for this upper-bound
unrealistic evaluation, the doses are well below 10 CFR 20 limits. 11

7.1.2.3.2 ACCIDENT 3.2 - LIQUID SYSTEM TANK FAILURE

This event is similar to ACCIDENT 3.1 except complete release, 100
percent, of the average inventory of the tank is postulated. In
this case, 20,000 gallons of water containing 50,000 μCi of liquid
HTO are assumed spilled. Spill cleanup time is 6.7 hours. The
total tritium evaporated during this time is 95 μCi. Direct release 6
of the evaporated tritium to the atmosphere through the Reactor 11
Service Building ventilation system was assumed.

The maximum off-site whole body dose resulting from this event is
5×10^{-6} mrem. Summaries of the whole body doses at specific downwind 6 8
distances, based on exposure for the duration of the accident, are
presented in Tables 7.1-5 through 7.1-12. Estimates of the
potential population dose are presented in Table 7.1-13. 8

As was done for ACCIDENT 3.1, an upper bound limit to off-site
exposure was computed for this event by assuming complete
evaporation and release of the 50,000 μCi of HTO contained in the 6 11
spilled fluid. This was done only to demonstrate the minimal
environmental impact of this unlikely fault because the assumption
of complete tritium release as vapor is unrealistic. Even for this
worst case assessment, the resultant whole body dose, 2.8×10^{-3} mrem, 6 8
is well below 10 CFR 20 limits. 11

7.1.2.3.3 ACCIDENT 3.3 - RUPTURE OF THE RAPS NOBLE GAS STORAGE VESSEL

The RAPS noble gas storage vessel (NGSV) normally contains radioactive gas which is off-loaded annually from the RAPS cryostill. It contains mainly argon (including argon-39) but also krypton and xenon isotopes, both stable and radioactive. The gas is bled slowly from the vessel into CAPS so that its pressure normally decreases over the annual period. A rupture of this vessel or of associated piping and components could release radioactive gas at above-ambient pressure into the NGSV cell. Although such a rupture is not expected, it is assumed to occur. For the purpose of the accident analysis, it is conservatively assumed that the reactor has been operating sufficiently long with gaseous fission products from 0.5% failed fuel for steady-state isotopic composition to exist in the cover gas system and that 1 years' accumulation by the cryostill of noble gas isotopes, under that condition, has been off-loaded to the NGSV. Furthermore, it is assumed that some unspecified maintenance operation has required that the new fresh cryostill charge also be off-loaded to the storage vessel, this in quick sequence, so that the storage vessel contains two charges and is approximately at maximum pressure. 11

Assuming the vessel (260 actual cubic feet volume) is at 1 atmosphere pressure absolute before the two cryostill off-loadings (1.5 cubic feet of liquid argon each), it will contain 2640 scf of gas prior to the accident.

Following the assumed storage vessel rupture, the NGSV cell H&V radiation monitor will sense the presence of radioactivity, sound an alarm, and initiate a signal which will cause the cell vent line to close. The cell (whose net volume is 3560 actual cubic feet including the vessel volume) pressure will then increase to 9.8 psig, assuming instant temperature equilibration to ambient. The initial radioactivity inventory and amount leaked to the environment are shown in Table 7.1-15.

The accident scenario assumes the RAPS NGSV cell leaks at a rate consistent with its design leak rate of 1%/day at 3 psig. This is a 11
reasonable assumption since the cell will be periodically tested to insure that its design leak rate is met.

The off-site doses are further limited by the low leakage rate of the RCB, which is assumed to isolate immediately following the event. The design leak rate of the RCB is 0.1%/day at 10 psig. Also, for the analysis, a constant 1 psig containment pressure was assumed. This 1 psig pressure is a conservative allowance for building heatup following containment isolation.

The maximum off-site whole body dose resulting from this event is 7.71×10^{-1} mrem. Summaries of the whole body doses at specific downwind distances, based on exposure for the duration of the accident, are presented in Tables 7.1-5 through 7.1-12. Estimates of the potential population dose are presented in Table 7.1-13. As these Tables indicate, large margins exist between the potential doses and the applicable regulatory limits. It is concluded that the postulated Noble Gas Storage Vessel rupture will not result in unacceptable environmental consequences.

To further demonstrate the minimal environmental impact of this postulated event, an upper bound limit to potential off-site exposures was computed by also assuming that the NGSV cell is not a leakage barrier, which is an extremely conservative assumption. For this assumption, the radioactivity is assumed to be released directly to the RCB. The off-site doses still are limited by the low leakage rate of the RCB, which is assumed to isolate immediately 11
following the event.

The maximum off-site whole body dose resulting from this exaggerated event is 4.46 mrem.

7.1.2.4 ACCIDENT 4.0 - SODIUM FIRES DURING MAINTENANCE

Postulated sodium fires could possibly result in the dispersion of some radioactive materials to the atmosphere. Fires involving primary sodium coolant are of most concern since this sodium circulates through the reactor core and accumulates radioactivity due to neutron activation and entrainment of fission products leaking from defective fuel. Postulated fires involving sodium used in the Ex-Vessel Storage Tank (EVST) cooling system could also result in radiological releases. The EVST sodium is essentially non-radioactive at the beginning of plant life. However, during refueling a small quantity of primary sodium is transferred to the EVST along with each irradiated assembly, resulting in a slow buildup of radioactivity in the EVST sodium.

Accidents discussed in this section involve postulated sodium spills during maintenance. Detailed maintenance procedures for the CRBRP are not yet completely defined. However, recognizing the potential hazard associated with postulated sodium fires, a set of design guidelines have been established to limit the consequences of postulated sodium fires during maintenance by limiting residual sodium content and equipment being maintained as follows:

1. The maximum inventory of primary sodium in an open, de-inerted cell, able to communicate with the environment, shall not exceed 130 pounds;

2. The maximum allowable spill of EVST sodium in an open, de-inerted EVST cooling system cell shall not exceed 250 pounds.

If during maintenance inside containment, the potential exists for a postulated primary sodium spill exceeding 130 pounds into an open de-inerted cell, the RCB/RSB Hatch will be closed, insuring containment integrity. Large sodium spills inside containment during maintenance and large sodium spills during operation are extremely unlikely events and are discussed in ACCIDENT 8.0.

To determine the potential radiological impact of sodium fires during maintenance, two accidents, one involving primary sodium and the other EVST sodium, have been postulated. Consequences of these fires, presented in the following sections, have been conservatively evaluated taking no credit for the fire protection systems, fallout of combustion products during transit downwind, or aerosol plateout and settling within buildings.

7.1.2.4.1 ACCIDENT 4.1 - FAILURE OF EX-CONTAINMENT PRIMARY SODIUM DRAIN PIPING DURING MAINTENANCE

The ex-containment primary sodium storage vessels are located in a cell on the lowest level of the Intermediate Bay of the Steam Generator Building (SGB). Vessels are connected to process systems within containment by fill and drain headers. Headers are valved off at the containment penetrations. During normal plant operation the vessels are essentially empty; the drain lines are also expected to be empty. It is postulated that the storage vessel cell is opened by pulling a plug in the cell ceiling and is entered for tank inspection. The cell atmosphere is then open to the atmosphere of the Intermediate Bay of the SGB above the cell. Maximum potential sodium spill under these conditions is limited to 130 pounds* and for the postulated accident it is assumed that this quantity of sodium is instantaneously spilled to the cell floor. Although postulated, it should be noted that a spill of this magnitude is not expected because operational procedures dictate that the system will be drained before permitting access.

It is assumed that the cell is opened for inspection or maintenance after the sodium has undergone radioactive decay for 10 days. Actual decay time before entry to the cell is expected to be longer. It is further assumed that the accident occurs near the end of plant life (30 years) when the activity of the sodium has reached its peak. The radioactive content of the sodium under these conditions is shown in Table 7.1-18.

The radiological impact of this postulated spill was determined as follows:

1. Complete combustion of the spilled sodium is assumed to occur in less than 2 hours. It is assumed that 27% of the burned sodium is released from the surface of the

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*For purposes of this analysis, it is postulated that the drain piping between the containment isolation valve and the storage vessels is filled and the drain piping ruptures at the worst location.

burning pool to the cell atmosphere[10]. This results in the release of 47 pounds of Na_2O aerosol containing 35 pounds of sodium. 11

2. Radioisotope concentrations in the aerosol are proportional by elemental weight to the initial concentrations in the sodium; 11

3. The aerosol is released directly to the atmosphere via the Steam Generator Building ventilation system;

4. Radioactive decay during the accident is neglected; and

5. No credit for plateout or settling of the aerosol in the Intermediate Bay of the SGB or in the ventilation system was taken.

Rapid combustion (< 2 hours) of the spilled sodium results because it was assumed that the spilled sodium spreads evenly over the entire floor area (2,400 ft^2) of the storage tank cell. 11 This assumption results in the maximum possible sodium pool area and therefore, the maximum burning rate. A more realistic assumption would be a much smaller pool in the vicinity of the postulated leak and consequently, a slower burning rate.

Using the above assumptions, the total Na_2O aerosol released to the atmosphere is 47 pounds. The maximum off-site whole body dose is 2.37×10^{-2} rem. Doses at specific downwind distances 4 8 11 and estimates of the population dose are provided in Tables 7.1-5 through 7.1-13.

7.1.2.4.2 ACCIDENT 4.2 - FAILURE OF THE EX-VESSEL STORAGE TANK (EVST) SODIUM COOLING SYSTEM DURING MAINTENANCE

There are three EVST sodium cooling circuits, two normal and a
backup. The normal cooling circuits are used alternately to cool
sodium circulated to and from the Ex-Vessel Storage Tank (EVST).
Each circuit is located in a separate cell, inerted with nitrogen 11
during circuit operation. For the accident postulated it is
assumed that a normal cooling circuit cell is de-inerted to
permit personnel access for maintenance. During maintenance, the
sodium loop will be isolated from the EVST and will be drained 6
prior to opening the cell. Consequently, a major spill involving
a siphoning of the EVST, as described in ACCIDENT 8.4, is not
considered a credible event when the cell is de-inerted and open.
A shielded door or plug, approximately seven feet high by three
feet wide, is opened, permitting the cell atmosphere to
communicate with the atmosphere of the Reactor Service Building. 11
For the purpose of the analysis it is assumed that the loop is
not drained, and during this time, a leak in the isolated sodium
loop is assumed to occur. The maximum potential sodium spill
under these conditions is 250 pounds and for the postulated
accident it is assumed that this quantity of sodium is 6
instantaneously spilled to the cell floor. Although postulated,
it should be noted that a spill of this magnitude is not expected
because the system will be drained before de-inerting the cell.

For conservatism it was assumed that the postulated spill occurs near the end of plant life when the EVST sodium activity has reached its maximum value. It was further assumed, for conservatism, that the postulated accident occurs shortly after initiating of a refueling operation before Na-24, transferred to the EVST along with irradiated assemblies, has had sufficient time to decay. The EVST sodium activity content for this condition is shown in Table 7.1-19. 8 11

The radiological impact of this postulated spill was determined as follows: 11

1. Spilled sodium burns releasing Na_2O aerosol. It is assumed that complete sodium combustion occurs in less than 2 hours resulting in the release of 91 pounds of Na_2O aerosol containing 68 pounds of sodium; 11

2. Radioisotope concentrations in the aerosol are proportional by elemental weight to the initial concentrations in the sodium; 11

3. The aerosol is released directly to the atmosphere via the Reactor Service Building ventilation system;

4. Radioactive decay during the accident is neglected; and

5. No credit for plateout or settling of the aerosol in the Reactor Service Building or in the ventilation system was taken.

Rapid combustion (< 2 hours) of the spilled sodium results because it was assumed that the spilled sodium spreads evenly over the entire floor area (280 ft^2) of the cell. This assumption results in the maximum possible sodium pool area and therefore, the maximum burning rate. A more realistic assumption would be a much smaller pool in the vicinity of the postulated leak and consequently, a slower burning rate. 11

The total Na_2O aerosol released to the atmosphere is 91 pounds. The maximum off-site whole body dose is 8.75 x 10^{-3} rem. Doses 4 8 11
at specific downwind distances and estimates of the population dose are provided in Tables 7.1-5 through 7.1-13.

7.1.2.5 ACCIDENT 5.0 - FISSION PRODUCTS TO PRIMARY AND SECONDARY SYSTEMS

Environmental consequences of plant operation with cladding defects (failed fuel) were considered in Sections 5.2 and 5.3 of this report. The assesssment was conducted realistically assuming continuous plant operation with 0.1 percent failed fuel. The environmental impact of tritium, produced in the reactor core during normal operation, and diffused through the fuel and control rod cladding to the primary and secondary systems to the 11
steam generator, was also considered in Sections 5.2 and 5.3.

Environmental consequences of transient-induced fuel failures coupled with a steam generator leak are typically addressed in light-water reactor environmental reports. However, the design of the CRBRP Heat Transport System (HTS) is such that radioactivity released to the primary coolant is effectively isolated from the steam generators. Primary sodium coolant removes heat from the reactor core and blanket and transfers this heat to the intermediate sodium through the Intermediate Heat Exchanger (IHX). Primary sodium then returns to the reactor vessel. In the intermediate system, sodium, heated in the IHX, is circulated to the Steam Generator (SG) where its heat is transferred to a water-steam mixture which drives a conventional turbine-generator unit. This configuration provides a double barrier, the IHX and SG tube wall/tube sheets between the primary sodium and the steam system. In addition to the double barrier inherent in the HTS design, the operating pressure of the intermediate sodium is slightly higher than that of the primary sodium. As a result, leakage of primary sodium into the intermediate system is avoided, further reducing the possibility of radioactivity release through the Steam Generator.

Significant fuel failures resulting from off-design transients are not anticipated in the CRBRP. As discussed above, even if some unexpected fuel failures are postulated, release of radioactivity through the steam generator is avoided. Environmental release of radioactivity following a postulated fuel failure would be limited to noble gas leakage. The release of noble gases through this system during normal operation with 8
0.1 percent failed fuel was considered in Sections 5.2 and 5.3. A postulated fuel failure would result in an incremental surge of noble gas activity into the reactor cover gas space. This surge of activity would be subject to normal processing and leakage. Potential environmental impact of this event is discussed in the following section.

The possibility of non-radioactive intermediate sodium interacting with water/steam via a Steam Generator tube rupture has also been investigated. Environmental consequences of this event are discussed below.

7.1.2.5.1 ACCIDENT 5.1 - OFF-DESIGN TRANSIENTS THAT INDUCE FUEL FAILURES ABOVE THOSE EXPECTED

Significant fuel failures resulting from off-design transients are not anticipated in the CRBRP. However, potential environmental consequences associated with a postulated transient-induced fuel failure have been evaluated. The evaluation is based on the following assumptions:

1. 0.02 percent of the end-of-cycle equilibrium core inventory of noble gases and halogens instantaneously released to the primary coolant;

2. Cover gas and primary coolant activity prior to the postulated transient based on continuous operation with 0.5 percent failed fuel; and

3. Normal operation of CAPS and RAPS prior to and following the postulated transient.

Assuming no decay time for the noble gases as they rise through the sodium coolant, this postulated accident results in an instantaneous release of noble gases to the reactor cover gas volume. Because of the strong chemical affinity of liquid sodium for halogens, release of halogens from solution to the cover gas can be neglected. Radioactive argon, neon and tritium concentrations in the reactor cover gas are unaffected by this postulated fault. These isotopes principally arise from neutron activation and no additional activity from these isotopes will be introduced to the reactor cover gas as a result of the postulated accident. Therefore, the postulated accident results in an incremental surge of radioactive xenon and krypton to the reactor cover gas.

Normal steady-state radioactive cover gas inventory for
continuous operation with 0.5 percent failed fuel, due to xenon
and krypton, totals 19,500 Curies. The postulated surge of xenon 8 11
and krypton into the cover gas adds 37,100 Curies. Total cover
gas radioactive inventory due to xenon and krypton immediately
following the postulated transient is, therefore, 56,600 Curies. 11
This surge activity, as well as the normal steady-state activity,
is subject to normal processing and cleanup through RAPS and is
also subject to normal cover gas leakage.

The accident was evaluted in terms of the total excess cover gas
activity released to the environment as a result of the transient
compared to that normally released, assuming continuous plant
operation with 0.5 percent failed fuel. Excess activity leakage 11
will continue until the cover gas system returns to its normal
steady-state condition. The inventory of each xenon and krypton
isotope will asymptotically approach a steady-state condition.
For the evaluation, the recovery time required for the inventory
of each isotope to reach a value within one percent of its
steady-state value was determined. The recovery time for each
isotope is dependent on the isotope's half-life, the purge rate
of the reactor cover gas to RAPS and the decontamination factor
for the isotope in RAPS. The longest recovery time for any of
the xenon or krypton isotopes is 15 hours (for Kr-85).

Total excess cover gas leakage during the 15-hour recovery time 11
is only 0.0014 Curies (see Table 7.1-17). More than 75 percent
of this activity leaks in the first two hours following the
postulated transient. Major leak paths from the cover gas system
are reactor head seal leakage and leakage of recycle cover gas
through buffer seals in the reactor head. For conservatism, no
delay factors in the movement of gases to or through these seals
were included in the analysis. Delays in gas movement through
these seals resulting in radioactive decay and reduced releases
are expected. Further, all seal leakage was assumed released
directly to the atmosphere via the Reactor Containment Building
ventilation system.

The maximum off-site whole body dose from this postulated 4 8 11
accident is 8.4 x 10^{-5} mrem. Doses at specific downwind
distances and estimates of the potential population dose are
provided in Tables 7.1-5 through 7.1-13.

7.1.2.5.2 ACCIDENT 5.2 - STEAM GENERATOR TUBE FAILURE

The steam generator modules are designed and will be manufactured to the highest quality industrial standards. Furthermore, a broad base DOE development program supported the design and manufacture of the CRBRP units and the water-sodium boundary has been designed and will be fabricated to have a high degree of integrity. Consequently, probability of failure of the boundary is expected to be small. However, over the plant lifetime, the possibility of leaks of water into sodium must be considered. to address this potential condition, the steam generators are continuously monitored by a leak detection system which provides early detection of water-to-sodium leaks to allow subsequent operator corrective action to limit their consequences while they are still small.

The water-to-sodium leak detection system is designed to alert the operator to the existence of a leak rate as small as approximately 2×10^{-5} lb. water/sec. For initial leak sizes which can be realistically expected (up to about 10^{-2} lb. water/sec.) the alarm is given in sufficient time for the operator to take action to prevent a significant increase of the leak rate.

For these small leaks, the reactor will be shut down followed by a controlled cooldown and depressurization of the affected steam generator. The affected IHTS loop would then be drained to allow repair of the steam generator. However, as a limiting case it is assumed that the leak indication is such that the operator elects to manually scram the reactor and isolate and blowdown all three steam generator modules in the affected loop. The operator would then drain the affected IHTS loop resulting in flow stoppage in the loop.

Under these conditions, the radiological release will be insignificant even if it is assumed that this event occurs following operation with the maximum undetected intermediate-to-primary sodium leak rate. Leakage of primary sodium into the IHTS is prevented by pressurizing the IHTS such that a pressure differential across the IHX (intermediate-to-primary) of at least 10 psi exists during plant operation. This pressure differential could be lost during the sodium dumping process and it is possible that small quantities of primary sodium could enter the IHTS. Leak rates of approximately 6 gph will be detected during normal operation and, therefore, only a small amount of primary sodium could be introduced into the IHTS during the pump coast down. This small amount of primary sodium would mix with the intermediate sodium and either remain in the non-drainable sections of the IHTS, steam generators, and IHX, or be drained to the sodium dump tank. Over-pressurization of this tank is prevented by either the equalization line or the pressure relief valve. The gases vented through this system will be the inert gas displaced by the sodium entering the dump tank. No sodium will be released in this process and, accordingly, there are no associated radiological consequences with this event.

There is a small probability that a leak may progress rapidly into the intermediate size range (greater than 0.1 lb/sec of water) before operator corrective actions could be implemented. In this event, the expansion tank vent line duplex rupture disk assembly will burst. Sodium flow through the disc assemblies will initiate automatic isolation and blowdown of the water and steam from the steam generator modules in the affected loop.

In the unlikely event that a larger leak occurs, the sodium/ water reaction (SWR) will generate sodium compounds as well as hydrogen gas. To provide protection for this event with its 15 attendant hydrogen gas generation, each of the three heat transport loops include rupture disks and a Sodium/Water Reaction Pressure Relief Subsystem (SWRPRS) which acts as an overpressure protection system and also stores SWR products.

The operation of the SWRPRS is initiated by the rupturing of one or more of the duplex rupture disk assemblies. These assemblies are located adjacent to the superheater sodium inlet nozzle, and each evaporator sodium outlet nozzle. A rupture releases sodium into the SWRPRS piping and the reaction products separator tanks. Following this sodium is a mixture of sodium, solid reaction products and gaseous hydrogen. Within the reaction products separator tanks, separation of the liquid sodium and solid reaction products from the gases takes place. The gases are exhausted through an atmospheric seal, to the flare stack and igniter, which ignites any combustible hydrogen/air mixture as it discharges to the atmosphere.

When the pressure in the isolated evaporators and superheater has been reduced to 300 psig, the plant operator then controls the opening of four sets of double isolation valves in the affected IHTS loop, which initiates draining of the residual sodium in the affected loop to the sodium tank. The other two loops, which were not subjected to a large sodium/water reaction, will then provide for shutdown heat removal. In this manner the reactor decay heat and the primary and intermediate sodium systems' sensible heat will be removed.

The SWRPRS is designed to accommodate steam generator leaks whose consequences cannot be limited by operator action. The design basis leak (DBL) for the system is a postulated equivalent double-ended guillotine break (EDEG) of a single tube that is followed by two additional EDEG tube failures. The basis for the selection of DBL is presented in detail in PSAR Section 5.5.3.6. 15

As a result of this postulated DBL, approximately 669 pounds of reaction products and entrained sodium would be carried into the reaction products separator tank where the gaseous products are separated and vented. During the short time period (28 seconds) while the SWRPRS is venting to the atmosphere during the design basis leak (DBL) and the SGS is blowing down, small amounts of primary sodium might leak into the intermediate sodium. However, this sodium would not be transported to the superheater inlet during the period of time that this steam generator system is being blown down, due to the length of the piping between the IHX and the superheater inlet and the reduced sodium flows during this event. Therefore, no allowance has been made for venting of primary sodium to the atmosphere. 15

The dose resulting from the Tritium within the IHTS sodium that 13 is released with the reaction products has been evaluated. The Tritium concentration in the Steam Generator System at the end of plant life (30 years) is 0.62 uCi/g and the Tritium concentration in the IHTS sodium is 0.13 uCi/g for a hydrogen background level 11 in the IHTS of 200 ppb of hydrogen. During a DBL, 204 pounds of water combines with 465 pounds of sodium and the conservative assumption is made that all the sodium-water reaction products are discharged to the atmosphere.

Depressurization of the isolated loop by opening the Power Relief Valves will result in the release of all water/steam in the loop to the atmosphere. The total mass released is 5,040 pounds. Using the end of life (30 years) tritium concentration, 0.62 uCi/g for the steam system, the total tritium release through the 11 Power Relief Valves for this postulated accident is 1.417 Curies.

Thus, the total radioactivity released to the atmosphere as a result of the postulated steam generator tube failure is 1.50 11 Curies of tritium, 0.083 released through SWRPRS and 1.417 8 released through the Power Relief Valves.

The maximum off-site whole body dose for this postulated release is 8.3 x 10^{-2} mrem. Doses at specific downwind distances and 4 11 estimates of the potential population dose are provided in Tables 8 7.1-5 through 7.1-13.

7.1.2.6 ACCIDENT 6.0 - REFUELING ACCIDENTS

In accordance with Regulatory Guide 4.2, the refueling accident evaluations used in connection with light-water reactor environmental reports are generally analyses of radioactivity releases caused by dropping a spent fuel bundle into the open reactor vessel or the open spent fuel storage pool, dropping a heavy object onto the core when the reactor head is removed for refueling or onto the open spent fuel storage pool and dropping of an open loaded spent fuel shipping cask. These incidents are mechanistically related to the fuel handling system for light-water reactor plants. The refueling system to be used on the CRBRP does not use an open reactor vessel, an open fuel storage pool or a removable reactor head. Hence, the CRBRP refueling system is not realistically subject to these same kinds of accidents.

An alternative set of three postulated events, more representative of the CRBRP refueling system, has been defined. These events, selected after careful review of the CRBRP refueling procedure, represent the most severe radioactivity releases associated with postulated refueling system faults. Each postulated fault, although none of them is expected to occur during the life of the plant, was evaluated and then potential radiological consequences determined.

The three postulated faults, discussed fully in the following sections, are:

1. Spent fuel cladding failure while in the Ex-Vessel Transfer Machine (EVTM) resulting in the release of one percent of the noble gases and iodines contained in the irradiated assembly to the interior of the EVTM;

2. This event is similar to (1) above except that the total inventory, 100 percent, of the noble gases and iodines contained in the irradiated assembly, are assumed released to the interior of the EVTM. This represents an extremely conservative upper limit; and

3. Inadvertent opening of a floor valve while a reactor port plug is removed. Complete release of the radioactive reactor cover gas through the resulting opening is assumed.

7.1.2.6.1 ACCIDENT 6.1 - SPENT FUEL CLADDING FAILURE IN EVTM - ONE PERCENT NOBLE GAS AND IODINE RELEASE

The earliest scheduled time for the handling of any fuel assembly 11
with the EVTM is 8 days after shutdown (based on anticipated fuel handling efficiency). At that time, the noble gas and iodine fission product inventories of an average powered fuel assembly, based on end-of-cycle equilibrium core (peak fission product 8
inventories), are shown in Table 7.1-20.

The postulated accident is the instantaneous release of one percent of the noble gases and iodines from the fuel assembly to the interior of the EVTM. 11
This represents a possible consequence of a loss of cooling of the EVTM cold wall.

Radioactive gases released to the EVTM interior can then slowly diffuse through the seals of the EVTM to the Reactor Containment Building (RCB)/Reactor Service Building (RSB) atmosphere. During refueling the large equipment hatch connecting the RCB and RSB is 11
open. Based on the 47 cubic feet of EVTM gas space being filled with reactor cover gas prior to the fuel cladding failures, the 8
isotopic concentrations of the noble gases and iodines within the EVTM immediately following the assumed one percent release are 8
shown in Table 7.1-21.

All seals in the EVTM are double seals. All dynamic or movable seals are, in addition, supplied with a pressurized buffer gas between the seals that is monitored for leakage. Thus, leakage

of EVTM gases due to physical defects in the seals is unlikely. The mechanism for leakage through these seals is by diffusion of the material (radioactive gases in particular) through the elastomer. Based on the EVTM seal materials, dimensions, operating temperature and the experimentally determined seal permeation rates,[9], the diffusion rate for the radioactive 11
isotopes released to the EVTM interior was determined. Iodine isotopes were included in the list because it was assumed possible for bubbles caused by the release of fission gas to rise through the sodium and be released inside the EVTM without the sodium totally absorbing the iodine. Since no permeation data for iodine through the elastomer seals are available, the seal permeability for iodine was taken to be the same as for xenon. However, it is expected that the permeation will actually be much lower since iodine may react with the elastomer. This would effectively prevent its release.

Diffusion rates and isotopic concentrations were used to compute leakage rates from the EVTM for each isotope; these are shown in 8
Table 7.1-22.

Leakage rates itemized in the table are initial leakage rates at 11
8 days after reactor shutdown. Actual activity leakage of the isotopes decreases subsequently with time, based on their radioactivity decay constants.

The normal time required to transfer spent fuel from the reactor vessel to the EVTM and from the EVTM to the ex-vessel storage tank is approximately one hour. In the event of the postulated accident considered here, within three hours after the initiation of the accident the EVTM would be moved to a location where the released radioactive gases would be purged to the gas cleanup system. This purging operation could be conducted at either the

reactor vessel or the ex-vessel storage tank. Normally the EVTM 8
is not purged. However, following the postulated accident, a
purge would be provided to achieve rapid cleanup. The purge
results in an exponential removal factor in addition to the
leakage rates and radioactive decay. 11

Using the leakage rates itemized in Table 7.1-22, release of 8 11
radioactivity from the EVTM to the RCB/RSB atmosphere was
determined assuming that the EVTM is connected to a purging line
and the radioactivity is purged in eight hours. No credit is
taken for the reduced leakage rate during purging. Off-site
exposure was conservatively computed assuming the RCB and RSB 11
ventilation systems continue to exhaust to the atmosphere.
Actually, both systems are designed to reduce the exhaust flow 8 11
rate upon detecting high activity in the exhaust.

The maximum off-site whole body dose is 2.13×10^{-2} mrem. 8
Summaries of potential doses from this event at specific downwind
distances are provided in Tables 7.1-5 through 7.1-12. Estimates 11
of the potential population dose are provided in Table 7.1-13.

7.1.2.6.2 ACCIDENT 6.2 - SPENT FUEL CLADDING FAILURE IN THE EVTM - 100 PERCENT NOBLE GAS AND IODINE RELEASE

This postulated acccident is identical to ACCIDENT 6.1, except
the total inventory, 100 percent, of the noble gases and iodines
contained in the spent fuel assembly is assumed to be released 11
instantaneously to the interior of the EVTM. This assumed
release represents an extremely conservative upper limit.

Initial isotopic concentrations in the EVTM and the initial
activity leakage rates from the EVTM for this assumed release are
itemized in Tables 7.1-21 and 7.1-22, respectively. Again, 8

conservatively assuming continuous ventilation exhaust to the
atmosphere, the maximum off-site whole body dose is 2.13 mrem. 4 8 11
Doses at specific downwind distances and estimates of the
potential population dose are provided in Tables 7.1-5 through
7.1-13.

7.1.2.6.3 ACCIDENT 6.3 - INADVERTENT OPENING OF A FLOOR VALVE WHILE A REACTOR PORT PLUG IS REMOVED

During refueling a port plug is removed from the reactor vessel
head to allow transfer of fuel and other core assemblies between 11
the reactor vessel and refueling machines. Radiation shielding
and isolation of the reactor cover gas from the containment
atmosphere is provided by a Floor Valve (FV) mounted over the
transfer port prior to port plug removal. When the FV is in
position over the transfer port, without a refueling machine
mated and sealed to its upper surface, the FV is closed and
sealed providing containment between the reactor cover gas and
the containment atmosphere. With a refueling machine (EVTM for
example) mounted and sealed to the upper surface of the FV, the
valve is opened to permit transfer of core components between the
reactor vessel and the refueling machine. Inadvertent opening of
the FV when it is not mated and sealed to a refueling machine is
prevented by proper sequencing of refueling actions, electrical 11
interlocks, and disconnection of the electrical power cable from
the EVTM to the motor that opens the floor valve. However, to
assess the radiological consequences resulting from the
inadvertent opening of a FV, this event is arbitrarily
postulated.

The earliest time for normal port plug removal is 30 hours after 11
shutdown (based on anticipated refueling preparation efficiency).
The reactor cover gas inventory, at this time, is shown in Table 8
7.1-23.

With the port plug removed and the FV inadvertently opened, the majority of this activity would remain in the reactor vessel because of Argon's high density and the low cover gas pressure. For evaluation purposes all the reactor cover gas activity was assumed to be released instantaneously to the RCB/RSB atmosphere. (During refueling the large equipment hatch connecting the RCB and RSB is open.) To determine off-site radiological exposure it was further assumed that the RCB and RSB exhaust systems vent this activity directly to the atmosphere. 11

The maximum off-site whole body dose is 1.08 mrem. Summaries of potential doses at specific downwind distances are provided in Tables 7.1-5 through 7.1-12. Estimates of the potential population dose are provided in Table 7.1-13. 4 8 11

7.1.2.7 ACCIDENT 7.0 - SPENT FUEL HANDLING ACCIDENTS

As discussed in Section 7.1.2.6, REFUELING ACCIDENTS, the design of the CRBRP refueling system does not employ an open fuel storage pool. Therefore, dropping a fuel assembly into a fuel storage pool or dropping a heavy object onto a fuel rack in a fuel storage pool, postulated events normally evaluated in light-water reactor environmental reports, are not realistic occurrences in the CRBRP.

Inadvertent dropping of a loaded spent fuel shipping cask during fuel handling is considered to be a hypothetical event. The radiological consequences of this postulated event are discussed in the following section. 11

7.1.2.7.1 ACCIDENT 7.1 - SPENT FUEL SHIPPING CASK DROP

The spent fuel shipping cask is normally raised and lowered in the 72-foot-deep cask access shaft using the Reactor Service Building bridge crane, which is a double-reeved crane with two 11 independent hooks, each capable of supporting the entire spent fuel shipping cask load. Failure of one will not result in cask drop. With a double failure needed to initiate a drop and a low handling frequency (about 20 times a year), it is not expected that inadvertent dropping of a spent fuel shipping cask in the cask access shaft will occur. As a precaution against a release of radioactive material in the event a drop should occur, however, the cask is designed to withstand a 30-foot drop onto an unyielding surface without leakage. This is sufficient to meet the requirement of 10 CFR 71. (A 72-foot drop onto the concrete floor is less severe than the design drop.) Nevertheless, for purposes of accident analysis, it is postulated that a cask drop occurs which results in loss of cask integrity. The radiological consequences are evaluated using the source given in Table 7.1-24, which is based on the following conditions. 11

1. The fission gas inventory from one fully loaded spent fuel cask (80-days cooling) is assumed released into the inner containment of the cask. It leaks at the design leak rate of the inner containment seals to the RSB and then to the atmosphere via the RSB ventilation system. No credit is taken for outer containment seals.

2. The cask holds nine assemblies (six fuel assemblies and three blanket assemblies).

The maximum off-site whole body dose resulting from this postulated failure is 2.830 x 10^{-4} mrem. Summaries of potential 4 8
doses from this event at specific downwind distances are provided in Tables 7.1-5 through 7.1-12. Estimates of the potential population dose are provided in Table 7.1-13.

7.1.2.8 ACCIDENT 8.0 - ACCIDENT INITIATION EVENTS CONSIDERED IN DESIGN BASIS EVALUATION IN THE SAFETY ANALYSIS REPORT

7.1.2.8.1 ACCIDENT 8.1 - PRIMARY SODIUM IN-CONTAINMENT STORAGE TANK FAILURE DURING MAINTENANCE 11

The primary sodium in-containment storage tank is located below the containment operating deck in a normally inerted cell. Cell 11 volume is approximately 45,000 cubic feet and the floor area 8 beneath the tank is 850 square feet. Cell walls are concrete, nominally six feet thick. Interior surfaces of the cell are protected with Engineered Safety Feature steel liners.

8

During normal operation, the drain tank is essentially empty and the cell atmosphere is inerted.In the event that major plant maintenance requires complete draining of one of the primary 11 loops, the storage tank will be used to store the sodium coolant. Maximum volume of sodium stored in the tank will be 35,000 gallons and the sodium temperature will be maintained at approximately 400 degrees F. The cell atmosphere will remain inerted.

Prior to deinerting and entry into the tank cell for maintenance of cell equipment, the cell will be prepared in order to reduce radiation exposure to maintenance personnel. The preparation will include allowing the Na-24 to decay and draining the sodium in the tank to a minimum level (<500 gal). Any sodium in excess 11 of this minimum level will be transferred to an ex-containment storage tank. The off-site doses for a storage tank failure following deinerting for maintenance as stated above, are enveloped by the following evaluation which characterizes an accident which conservatively assumes failure of the storage tank when full. For the accident evaluation it was assumed that the primary sodium stored in the tank has decayed for 10 days after reactor shutdown. It was further assumed that the accident occurs near the end of plant life (30 years) when the primary sodium coolant activity has reached its peak value. Radioactivity content of the sodium for these conditions is shown in Table 7.1-18. 8

This source term would result in personnel radiation exposure in excess of CRBRP ALARA guidelines and therefore prohibits personnel entry. However, the calculations of this accident have been performed based upon not draining the tank. 11

After de-inerting the cell atmosphere, manned access to the cell is via a 21 ft^2 shielded door. The evaluation assumes that the cell environment connects directly with the upper containment atmosphere via a hypothetical passageway equivalent in area to the cell door. At this time the total tank capacity, 35,000 gallons, is assumed instantaneously drained to the cell floor. 11

The radiological impact of this postulated event was determined as follows:

1. Spilled sodium burns, releasing Na_2O as aerosol;

2. Radioisotope concentrations in the aerosol are proportional by elemental weight to the initial concentrations in the sodium; 11

3. Radioactive decay during the accident is conservatively neglected; 8

4. The RCB ventilation system is automatically shut down, isolating containment from the outside atmosphere. 8

5. Leakage from the RCB to the confinement annulus was computed based on the design leak rate of the RCB (0.1% vol/day at 10 psig) and the containment overpressure due to sodium burning; and

6. Release from the confinement annulus to the environment would be through the annulus filtration system. 8

GESOFIRE analyses of the postulated spill and resultant fire indicate a peak containment pressure of approximately 0.8 psig. This peak pressure occurs about 40 hours following the postulated spill. Containment pressure then decreases to ~ 0 psig 11
approximately 75 hours after the start of the fire. The long duration of the accident results since no credit for fire fighting action was taken.

Using the pressure/time history computed by GESOFIRE, HAA-3 analyses were used to determine the behavior of the aerosol generated during sodium combustion. The results of the analysis indicate a total release of 3.4 kg of Na_2O aerosol, containing 8 11
2.5 kg of sodium, to the atmosphere over the 140-hour overpressure period.

The maximum off-site whole body dose is 3.7×10^{-3} rem. Doses at specific downwind distances and estimates of the population dose 8 11
are provided in Tables 7.1-5 through 7.1-13.

7.1.2.8.2 ACCIDENT 8.2 - LARGE PRIMARY COOLANT SODIUM SPILL DURING OPERATION

A large spill of primary sodium into an inerted Heat Transport System (HTS) cell during operation is arbitrarily postulated for purposes of this evaluation. For evaluation of cell integrity, an upper bound limit of approximately 35,000 gallons of primary 8 11 sodium at 1015 degrees F is arbitrarily assumed discharged to the HTS cell. It is further conservatively assumed that the primary sodium has reached its peak activity level at the end of plant life (30 years) and that no decay of sodium activity has occurred prior to the spill.

During operation the HTS cell is inerted and closed to the upper containment atmosphere. The RCB/RSB Hatch is closed, insuring containment integrity. The HTS cell walls are concrete, nominally six feet thick, and all interior surfaces of the cell are steel lined.

The radiological impact of this postulated event was determined as follows:

1. Sodium reacts with the available oxygen in the inerted HTS cell (2% O_2). The resultant fire releases Na_2O as an aerosol; 8

2. Radioisotope concentrations in the aerosol are proportional by elemental weight to the initial concentrations in the sodium; 11

3. Radioactive decay during the accident is conservatively neglected;

4. Twenty seven (27) percent of the airborne aerosols are assumed to be instantaneously released to the upper containment atmosphere. 11

5. Leakage from the RCB to the confinement annulus was completed based on the design leak rate of the RCB (0.1% vol/day at 10 psig) and the containment pressure due to sodium burning. 11

6. Fallout (cloud depletion) of radioactive material during downwind transit is conservatively neglected. 8

SPRAY analysis of the postulated spill and resultant fire indicates a peak cell pressure of 14 psig. This peak pressure 8 11 occurs about five minutes after the beginning of the postulated spill. The sodium combustion rate decreases to zero within 2 hours.

SPRAY and HAA-3 analyses were used to determine the time behavior of the aerosol generated during sodium burning. The analyses indicate that if no measures are taken to mitigate sodium burning, approximately 3.6 grams of Na_2O would leak over a 30-day period. 8

The maximum off-site whole body dose is 3.26×10^{-5} rem. Doses at specific downwind distances and estimates of the population dose are provided in Tables 7.1-5 through 7.1-13. 4 8 11

7.1.2.8.3 ACCIDENT 8.3 - GROSS FAILURE OF EX-CONTAINMENT PRIMARY SODIUM STORAGE TANK

The ex-containment primary sodium storage tanks are located in a cell on the lowest level of the Intermediate Bay of the Steam Generator Building. 8 The tanks will be used to store primary sodium only in the event maintenance requires drainage of a a large volume of reactor vessel sodium. The accident postulated 11 is an assumed failure which results in the complete spill of the contained sodium to the cell floor. 4 This postulated accident is extremely unlikely.

For conservatism, the postulated accident is assumed to occur
near the end of plant life (30 years) when the radioactive
content of the primary sodium has reached its peak. It is
further assumed that the sodium has undergone radioactive decay
for 10 days prior to charging the tank. The actual decay time is
expected to be longer to allow for complete Na-24 decay. The
radioactive content of the sodium for these conditions is shown 8
in Table 7.1-18.

When an ex-containment sodium tank is full, access to the tank
cell is prohibited and the cell is closed. The cell floor area
is approximately 2,400 square feet. The floor of the cell is 11
protected with a steel catch pan, 3/8-inch thick, which extends
vertically upward to a minimum height such that the maximum
potential sodium spill can be safely contained within the steel-
lined volume.

The postulated accident results in the spill of 45,000 gallons 11
(~300,000 lbs.) of 400 degrees F sodium to the cell floor. This 8
spill represents 100 percent of the contained volume in one of
the two storage vessels in the cell and is an extremely
conservative upper bound. The postulated spill covers the entire
floor of the cell. 8

The radiological impact of this postulated spill was determined
as follows:

1. Spilled sodium reacts with the available oxygen in the
cell (inerted, 2% O_2), burns and releases Na_2O as 4
aerosol;

2. Radioisotope concentrations in the aerosol are proportional by elemental weight to the initial concentrations in the sodium; 11

3. Radioactive decay during the accident is conservatively neglected;

4. Leakage of aerosol from the cell to the Intermediate Bay of the Steam Generator Building (SGB) was computed based on a design cell leak rate of 0.6 percent vol/day at 3.9 psig, and the cell overpressure due to sodium burning; 11

5. It was conservatively assumed that the SGB ventilation system continues to operate for the duration of the accident and that all aerosol leaked to the SGB vents directly to the atmosphere; and 11

6. No credit for plateout or settling of the aerosol in the SGB ventilation system was taken.

Sodium fire analyses indicate a peak cell pressure of 4.0 psig approximately 10 minutes after the postulated spill. The cell pressure then decreases to atmospheric pressure roughly eight days after the spill. SOFIRE II and HAA-3 analyses were used to determine the time behavior of the aerosol generated during sodium burning. With the conservative assumption of continuous SGB venting, approximately 0.1 kg of Na_2O aerosol would be released to the atmosphere over the eight-day overpressure period. 4 8 11

The maximum off-site whole body dose is 4.2×10^{-5} rem. Doses at specific downwind distances and estimates of the population dose are provided in Tables 7.1-5 through 7.1-13. 4 8 11

7.1.2.8.4 ACCIDENT 8.4 - RUPTURE OF THE EX-VESSEL STORAGE TANK SODIUM COOLING SYSTEM DURING OPERATION

There are three Ex-Vessel Storage Tank (EVST) sodium cooling
circuits, two normal and a backup. The normal cooling circuits
are used alternately to cool sodium circulated to and from the
EVST. Each is located in a separate cell adjacent to the EVST.
The pump suction line for each normal cooling circuit exits from
the EVST at an elevation above the normal sodium level in the
tank. There is an internal downcomer within the EVST which
extends down below the sodium level. An isolation valve in the
pump suction line is located approximately at the tank outlet 11
elevation.

The postulated accident is a rupture of the pump suction line in
the operating normal cooling circuit. In the event of this
postulated accident, the other normal cooling circuit would be
brought on line to permit continued EVST cooling. The rupture is
assumed to occur at the low point of the pump suction line,
resulting in the siphoning of sodium down to the level of the
internal downcomer within the EVST. This postulated rupture
results in the maximum possible quantity of sodium discharged 6 11
from the system during operation. Approximately 7,500 gallons
(~57,000 lbs.) of 475-degree F sodium would be spilled into the
cell. For conservatism, it is assumed that the accident occurs
near the end of the plant life (30 years) and shortly after a
refueling operation when the EVST sodium activity has reached its
peak. Radioactive content of the EVST sodium under these 4 8
conditions is shown in Table 7.1-19.

The maximum spill postulated would require a simultaneous major
piping failure plus failure of the remotely operated isolation
valve. As such, the accident postulated is extremely unlikely
and is not expected to occur over the life of the plant.

During operation, the sodium cooling circuit cell is inerted (2% O_2) and closed. Interior surfaces of the cell are protected with a steel liner approximately 3/8-inch thick. Cell walls are nominally two-foot thick concrete. The free volume of the cell is approximately 14,960 cubic feet and the cell floor area is 680 square feet. 8 11

The radiological impact of this postulated event was determined as follows:

1. Sodium reacts with the available oxygen in the inerted cell (2% O_2). The resultant fire releases Na_2O as aerosol; 8

2. Radioisotope concentrations in the aerosol are proportional by elemental weight to the initial concentrations in the sodium; 11

3. Radioactive decay during the accident is conservatively neglected;

4. Leakage of airborne aerosol from the cell to the Reactor Service Building (RSB) was computed based on a design cell leak rate of 0.36 percent vol/day at 12 psig; 11

5. It was conservatively assumed that the RSB ventilation system continues to operate for the duration of the accident and that the aerosol leaked to the RSB vents directly to the atmosphere; and

6. No credit for plateout or settling of the aerosol in the RSB ventilation system was taken.

SOFIRE II analyses of the postulated spill and resultant fire indicate a peak cell pressure of 3.78 psig. This peak pressure occurs two hours following the postulated spill. The cell

pressure then decreases to approximately 1.4 psig after 96 hours. 8 11
After one day, the burning rate is less than 10^{-6} lb/hr-ft^2, and only 56 pounds of the spilled sodium has reacted with the available oxygen in the cell.

SOFIRE II and HAA-3 analyses were used to determine the time behavior of the aerosol generated during sodium burning. With
the conservative assumption of continuous RSB venting, 2.0 grams 11
of Na_2O would be released to the atmosphere. Total release time 8
is four days.

An accident in the backup cooling circuit would be less severe than the one described above, since this is a "raised" circuit which prevents a major spill involving siphoning of the EVST. The total amount of sodium that could be spilled from the backup cooling circuit is ~35,000 lbs.

The maximum off-site whole body dose is 4.3×10^{-4} mrem. Doses at 4 8 11
specific downwind distances and estimates of the population dose are provided in Tables 7.1-15 through 7.1-13.

7.1.2.8.5 ACCIDENT 8.5 - LARGE STEAM LINE BREAK

The consequence of a large steam line break has been analyzed for rupture of the main steam line between the main steam line isolation valves and the manifold which joins the three main steam lines. For this case the superheater isolation valves
close in each loop and reactor trip occurs on high steam- 8
feedwater ratio. After the isolation valves close, the system is depressurized and the sensible and decay heat from the core is removed by operation of the pressure relief valves until the heat load reaches 45 MWT at which time the SGAHRS is capable of removing the heat without venting.

Main steam line rupture is a transient emergency event for which the plant is designed. Thus, no other system in the plant will

experience conditions which exceed the design specifications and
no other plant damage will result. The only radiological
consequence of the failure will be the release of a large amount
of steam-water which contains a low concentration of tritium.
The level of tritium in the steam system at end of plant life (30 11
years) is 0.62 uCi/cc.

The amount of water released as a result of a main steam line
break is approximately 312,000 pounds. Of this amount, about 11
9,000 pounds are released from the pipe break before the
isolation valves close and 303,000 pounds are vented from the
Power Relief Valves to remove heat from the system. This 303,000
pounds of water will contain 85 Curies of tritium which will be 11
released over a 5.7 hour period.

The maximum off-site whole body dose is 4.7 mrem. Doses at 4 11
specific downwind distances and estimates of the potential
population dose are provided in Tables 7.1-5 through 7.1-13. 8

7.1.3 SUMMARY OF PLANT ACCIDENT DOSES

Potential doses for each postulated accident at a number of
downwind distances of interest are summarized in Tables 7.1-5 8
through 7.1-12. This summary indicates that all potential doses
fall well within the limits of 10 CFR 100. A large margin also 11
exists between the potential doses and the 10 CFR 20 limits.

The whole body population dose for each accident is shown in
Table 7.1-13. This dose includes both the external gamma dose 8
and the internal whole body dose due to inhalation of radioactive
material. Two whole body population doses were estimated for
each accident. The maximum prediction assumes that the wind
persists towards the E for the duration of the accident, while 11

the minimum estimate assumes wind persistence towards the NNW for the duration of the accident. These two directions correspond, respectively, to the most and least populated azimuthal sectors, based on the projected population distribution for the year 2010.

TABLE 7.1-1

ATMOSPHERIC DILUTION FACTORS
50 PERCENT PROBABILITY χ/Q VALUES (sec/m^3)*

Distance (miles)	2-hr	8-hr	16-hr	72-hr	624-hr
0.42	1.01E-3	1.55E-4	1.23E-4	7.69E-5	9.06E-5
0.5	8.25E-4	1.27E-4	9.28E-5	5.78E-5	6.76E-5
0.6	7.16E-4	1.07E-4	6.91E-5	4.30E-5	5.02E-5
0.7	6.19E-4	9.29E-5	5.43E-5	3.36E-5	3.93E-5
1.0	4.29E-4	6.51E-5	2.70E-5	1.67E-5	1.93E-5
1.5	2.81E-4	4.30E-5	1.07E-5	6.69E-6	7.73E-6
2.0	2.08E-4	3.03E-5	5.61E-6	3.50E-6	4.06E-6
2.5	1.59E-4	2.30E-5	3.58E-6	2.29E-6	2.60E-6
3.0	1.26E-4	1.83E-5	2.58E-6	1.60E-6	1.85E-6
3.5	1.03E-4	1.49E-5	1.96E-6	1.19E-6	1.40E-6
4.0	8.69E-5	1.24E-5	1.55E-6	9.35E-7	1.11E-6
4.5	7.49E-5	1.09E-5	1.26E-6	7.66E-7	9.06E-7
5.0	6.58E-5	9.46E-6	1.06E-6	6.42E-7	7.64E-7
7.0	4.21E-5	6.04E-6	5.87E-7	3.66E-7	4.32E-7
7.5	3.90E-5	5.57E-6	5.28E-7	3.30E-7	3.88E-7
9.0	3.07E-5	4.44E-6	4.27E-7	2.65E-7	3.10E-7
10.0	2.73E-5	3.99E-6	3.77E-7	2.31E-7	2.72E-7
15.0	1.70E-5	2.46E-6	2.28E-7	1.36E-7	1.63E-7
20.0	1.21E-5	1.76E-6	1.56E-7	9.47E-8	1.14E-7
21.0	1.14E-5	1.66E-6	1.47E-7	8.91E-8	1.07E-7
25.0	9.26E-6	1.34E-6	1.17E-7	7.22E-8	8.67E-8
35.0	6.43E-6	9.33E-7	7.98E-8	4.89E-8	5.82E-8
45.0	4.88E-6	7.60E-7	5.89E-8	3.71E-8	4.37E-8
50.0	4.32E-6	6.25E-7	5.16E-8	3.29E-8	3.90E-8

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*See Section 2.6

TABLE 7.1-2

AVERAGE ENERGY PER DISINTEGRATION

Isotope	Beta (MeV)	Gamma (MeV)
H-3	0.006	0
C-14	0.052	0
Na-22	0.182	2.195
Na-24	0.463	4.123
Ne-23	1.460	0.160
Ar-39	0.188	0
Ar-41	0.406	1.280
Mn-54	0.00021	0.835
Co-58	0.0237	0.977
Co-60	0.105	2.51
Kr-83m	0.036	0.00248
Kr-85m	0.277	0.158
Kr-85	0.230	0.002
Kr-87	1.324	0.793
Kr-88	0.376	1.950
Sr-89	0.488	0.000082
Sr-90	0.182	0.0
Y-90	0.930	0.0
Y-91	0.515	0.0036
Zr-95	0.130	0.725
Nb-95	0.0532	0.765
Ru-103	0.077	0.474
Ru-106	0.013	0.0
Sb-125	0.335	0.121
Te-129m	0.621	0.0414
Te-129	0.407	0.108
Te-132	0.10	0.216

(Continued)

TABLE 7.1-2 (Continued)

Isotope	Beta (MeV)	Gamma (MeV)
I-131	0.197	0.371
I-132	0.448	2.40
Xe-131m	0.143	0.02
Xe-133m	0.189	0.042
Xe-133	0.135	0.045
Xe-135m	0.095	0.432
Xe-135	0.316	0.247
Xe-138	0.612	1.183
Cs-134	0.166	1.59
Cs-136	0.139	2.23
Cs-137	0.246	0.563
Ba-140	0.284	0.236
La-140	0.397	2.12
Ce-141	0.315	0.0695
Ce-144	0.101	0.0163
Pr-143	0.310	0.0
Nd-147	0.335	0.122
Pm-147	0.070	0.0

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TABLE 7.1-3

INHALATION DOSE CONVERSION FACTORS, F_i

rem/Ci Inhaled*

Isotope

Isotope	Lung	Bone	Thyroid	Whole Body	
H-3	1.58 E2	-	1.58 E2	1.58 E2	
Na-22	1.30 E4	1.30 E4	1.30 E4	1.30 E4	
Na-24	1.28 E3	1.28 E3	1.28 E3	1.28 E3	
Mn-54	1.75 E5	-	-	7.87 E2	
Co-58	1.16 E5	-	-	2.59 E2	
Co-60	7.46 E5	-	-	1.85 E3	
Sr-89	1.75 E5	3.80 E4	-	1.09 E3	11
Sr-90	1.20 E6	1.24 E7	-	7.62 E5	
Y-90	2.12 E4	2.61 E2	-	7.01	
Y-91	2.13 E5	5.78 E4	-	1.55 E3	
Zr-95	2.21 E5	1.34 E4	-	2.91 E3	
Nb-95	6.31 E4	1.76 E3	-	5.26 E2	
Ru-103	6.31 E4	1191 E2	-	8.23 E1	
Ru-106	1.18 E6	8.64 E3	-	1.09 E3	
Sb-125	2.18 E5	6.67 E3	6.75	1.58 E3	
Te-129m	1.45 E5	1.22 E3	4.30 E2	1.98 E2	
Te-129	2.42 E2	6.22 E-3	4.87 E-3	1.55 E-3	
Te-132	3.60 E4	3.25 E1	2.37 E1	2.02 E1	
I-131	-	3.15 E3	1.49 E6	2.56 E3	
I-132	-	1.45 E2	1.43 E4	1.45 E2	
I-133	-	1.08 E3	2.69 E5	5.65 E2	
I-134	-	8.06 E1	3.73 E3	7.69 E1	
I-135	-	3.35 E2	5.60 E4	3.21 E2	

*From NUREG-0172

TABLE 7.1-3 (Continued)

INHALATION DOSE CONVERSION FACTORS, F_i

rem/Ci Inhaled*

Isotope

Isotope	Lung	Bone	Thyroid	Whole Body	
Cs-134	1.22 E4	4.66 E4	-	9.10 E4	
Cs-136	1.50 E3	4.88 E3	-	1.38 E4	
Cs-137	9.40 E3	5.98 E4	-	5.35 E4	
Ba-140	1.59 E5	4.88 E3	-	3.21 E2	
La-140	1.70 E4	4.30 E1	-	5.73	
Ce-141	4.52 E4	2.49 E3	-	1.91 E2	
Ce-144	9.72 E5	4.29 E5	-	2.30 E4	11
Pr-143	3.51 E4	1.17 E3	-	5.80 E1	
Pr-144	1.27 E2	3.76 E-3	-	1.91 E-4	
Nd-147	2.76 E4	6.59 E2	-	4.56 E1	
Pm-147	6.60 E4	8.37 E4	-	3.19 E3	
Pu-238	1.82 E8	2.74 E9	-	6.90 E7	
Pu-239	1.72 E8	3.19 E9	-	7.75 E7	
Pu-240	1.72 E8	3.18 E9	-	7.73 E7	
Pu-241	1.52 E5	6.41 E7	-	1.29 E6	
Pu-242	1.65 E8	2.95 E9	-	7.46 E7	

*From NUREG-0172

TABLE 7.1-4

POPULATION DISTRIBUTION FOR THE E AND NNW SECTORS*

Radial Interval (miles)	Population Within Radial Interval E	NNW
0-1	40	10
1-2	70	0
2-3	110	0
3-4	30	0
4-5	40	100
5-10	3400	1100
10-20	32,600	3,600
20-30	124,000	1,400
30-40	29,500	4,200
40-50	21,700	3,700

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*Population distribution is the projected distribution for census year 2010

TABLE 7.1-5

SUMMARY OF POTENTIAL DOSES FROM PLANT ACCIDENTS
MINIMUM EXCLUSION DISTANCE - 2200 FEET*
mrem/event

ACCIDENT	WHOLE BODY	BONE	LUNG	THYROID
2.1	5.50	0.	5.50	5.50
3.1	1.37E-6	0.	1.37E-6	1.37E-6
3.2	5.18E-6	0.	5.18E-6	5.18E-6
3.3	7.71E-1	0.	5.92-2	0.
4.1	2.37E1	3.15E2	1.77E1	8.74E1
4.2	8.75	2.36E2	1.16E1	7.45
5.1	8.40E-5	0.	2.10E-6	0.
5.2	1.30E-2	0.	1.30E-2	1.30E-2
6.1	2.13E-2	2.06E-2	1.46E-5	9.64
6.2	2.13	2.06	1.46E-3	9.64E2
6.3	1.08	0.	1.98E-2	1.88E-4
7.1	2.83E-4	3.11E-4	2.86E-6	1.42E-1
8.1	3.68	4.93E1	2.77	1.37E1
8.2	3.26E-2	2.38E-2	1.03E-2	1.89E-2
8.3	4.22E-2	5.63E-1	3.16E-2	1.56E-1
8.4	4.29E-4	1.16E-2	5.67E-4	3.65E-4
8.5	4.71	0.	4.71	4.71
10CFR20 (mrem/yr)	5.00E2			1.50E3
10CFR100 (mrem/event)	2.50E4	1.50E5**	7.50E4**	3.00E5

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*Shortest distance from containment to the far bank of the Clinch River (Far bank is site boundary)

**Not covered in 10CFR100; used as guideline values

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TABLE 7.1-6
SUMMARY OF POTENTIAL DOSES FROM PLANT ACCIDENTS
DOWNWIND DISTANCE - 0.6 MILE*
mrem/event

ACCIDENT	WHOLE BODY	BONE	LUNG	THYROID	
2.1	3.90	0.	3.90	3.90	
3.1	9.71E-7	0.	9.71E-7	9.71E-7	
3.2	3.67E-6	0.	3.67E-6	3.67E-6	
3.3	5.47E-1	0.	4.19E-2	0.	
4.1	1.68E1	2.23E2	1.25E1	6.20E1	
4.2	6.20	1.67E2	8.22	5.28	
5.1	5.96E-5	0.	1.49E-6	0.	
5.2	9.22E-3	0.	9.22E-3	9.22E-3	
6.1	1.51E-2	1.46E-2	1.04E-5	6.83	
6.2	1.51	1.46	1.04E-3	6.83E2	
6.3	7.66E-1	0.	1.40E-2	1.33E-4	
7.1	2.01E-4	2.20E-4	2.03E-6	1.01E-1	11
8.1	2.61	3.49E1	1.96	9.69	
8.2	2.31E-2	1.69E-2	7.32E-3	1.34E-2	
8.3	2.99E-2	3.99E-1	2.24E-2	1.11E-1	
8.4	3.04E-4	8.22E-3	4.02E-4	2.59E-4	
8.5	3.34	0.	3.34	3.34	
10CFR20 (mrem/yr)	5.00E2			1.50E3	
10CFR100 (mrem/event)	2.50E4	1.50E5	7.50E4	3.00E5	

*Nearest Residence

TABLE 7.1-7

SUMMARY OF POTENTIAL DOSES FROM PLANT ACCIDENTS

DOWNWIND DISTANCE - 1 MILE*

mrem/event

ACCIDENT	WHOLE BODY	BONE	LUNG	THYROID	
2.1	2.34	0.	2.34	2.34	
3.1	5.82E-7	0.	5.82E-7	5.82E-7	
3.2	2.20E-6	0.	2.20E-6	2.20E-6	
3.3	3.28E-1	0.	2.51E-2	0.	
4.1	1.01E1	1.34E2	7.52	3.71E1	
4.2	3.72	1.00E2	4.93	3.17	
5.1	3.57E-5	0.	8.93E-7	0.	
5.2	5.53E-3	0.	5.53E-3	5.53E-3	
6.1	9.05E-3	8.76E-3	6.21E-6	4.10	
6.2	9.05E-1	8.76E-1	6.21E-4	4.10E2	
6.3	4.59E-1	0.	8.42E-3	7.99E-5	
7.1	1.20E-4	1.32E-4	1.22E-6	6.04E-2	
8.1	1.56	2.09E1	1.18	5.81	11
8.2	1.38E-2	1.01E-2	4.39E-3	8.04E-3	
8.3	1.79E-2	2.39E-1	1.34E-2	6.63E-2	
8.4	1.82E-4	4.93E-3	2.41E-4	1.55E-4	
8.5	2.00	0.	2.00	2.00	
10CFR20 (mrem/yr)	5.00E2			1.50E3	
10CFR100 (mrem/event)	2.50E4	1.50E5	7.50E4	3.00E5	

*Nearest Recreational Area

TABLE 7.1-8

SUMMARY OF POTENTIAL DOSES FROM PLANT ACCIDENTS
DOWNWIND DISTANCE - 2.5 MILES*
mrem/event

ACCIDENT	WHOLE BODY	BONE	LUNG	THYROID
2.1	8.64E-1	0.	8.64E-1	8.64E-1
3.1	2.16E-7	0.	2.16E-7	2.16E-7
3.2	8.15E-7	0.	8.15E-7	8.15E-7
3.3	1.21E-1	0.	9.31E-3	0.
4.1	3.72	4.95E1	2.78	1.37E1
4.2	1.37	3.71E1	1.82	1.17
5.1	1.32E-5	0.	3.30E-7	0.
5.2	2.04E-3	0.	2.04E-3	2.04E-3
6.1	3.34E-3	3.23E-3	2.29E-6	1.51
6.2	3.34E-1	3.23E-1	2.29E-4	1.51E-2
6.3	1.70E-1	0.	3.11E-3	2.95E-5
7.1	4.44E-5	4.88E-5	4.49E-7	2.23E-2
8.1	5.80E-1	7.76	4.36E-1	2.15
8.2	5.13E-3	3.75E-3	1.63E-3	2.98E-3
8.3	6.63E-3	8.84E-2	4.96E-3	2.45E-2
8.4	6.74E-5	1.82E-3	8.90E-5	5.73E-5
8.5	7.39E-1	0.	7.39E-1	7.39E-1
10CFR20 (mrem/yr)	5.00E2			1.50E3
10CFR100 (mrem/event	2.50E4	1.50E5	7.50E	3.00E5

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*Low Population Zone (LPZ)

TABLE 7.1-9
SUMMARY OF POTENTIAL DOSES FROM PLANT ACCIDENTS
DOWNWIND DISTANCE - 4 MILES*
mrem/event

ACCIDENT	WHOLE BODY	BONE	LUNG	THYROID	
2.1	4.73E-1	0.	4.73E-1	4.73E-1	
3.1	1.18E-7	0.	1.18E-7	1.18E-7	
3.2	4.46E-7	0.	4.46E-7	4.46E-7	
3.3	6.63E-2	0.	5.09E-3	0.	
4.1	2.04	2.71E1	1.52	7.52	
4.2	7.53E-1	2.03E1	9.98E-1	6.41E-1	
5.1	7.22E-6	0.	1.81E-7	0.	
5.2	1.12E-3	0.	1.12E-3	1.12E-3	
6.1	1.83E-3	1.77E-3	1.26E-6	8.29E-1	11
6.2	1.83E-1	1.77E-1	1.26E-4	8.29E1	
6.3	9.29E-2	0.	1.70E-3	1.62E-5	
7.1	2.43E-5	2.67E-5	2.46E-7	1.22E-2	
8.1	3.17E-1	4.24	2.38E-1	1.18	
8.2	2.80E-3	2.05E-3	8.88E-4	1.63E-3	
8.3	3.63E-3	4.84E-2	2.72E-3	1.34E-2	
8.4	3.69E-5	9.98E-4	4.88E-5	3.14E-5	
8.5	4.05E-1	0.	4.05E-1	4.05E-1	
10CFR20 (mrem/yr)	5.00E2			1.50E3	
10CFR100 (mrem/event)	2.50E4	1.50E5	7.50E4	3.00E5	

*Nearest Dairy

TABLE 7.1-10
SUMMARY OF POTENTIAL DOSES FROM PLANT ACCIDENTS
DOWNWIND DISTANCE - 7 MILES*
mrem/event

ACCIDENT	WHOLE BODY	BONE	LUNG	THYROID	
2.1	2.31E-1	0.	2.31E-1	2.31E-1	
3.1	5.71E-8	0.	5.71E-8	5.71E-8	
3.2	2.16E-7	0.	2.16E-7	2.16E-7	
3.3	3.21E-2	0.	2.47E-3	0.	
4.1	9.95E-1	1.32E1	7.43E-1	3.67	
4.2	3.68E-1	9.91	4.87E-1	3.13E-1	
5.1	3.53E-6	0.	8.82E-8	0.	
5.2	5.46E-4	0.	5.46E-4	5.46E-4	
6.1	8.95E-4	8.65E-4	6.13E-7	4.05E-1	
6.2	8.95E-2	8.65E-2	6.13E-5	4.05E1	
6.3	4.54E-2	0.	8.32E-4	7.90E-6	
7.1	1.19E-5	1.31E-5	1.20E-7	5.96E-3	
8.1	1.53E-1	2.05	1.15E-1	5.70E-1	11
8.2	1.36E-3	9.92E-4	4.30E-4	7.89E-4	
8.3	1.77E-3	2.36E-2	1.33E-3	6.55E-3	
8.4	1.80E-5	4.87E-4	2.38E-5	1.53E-5	
8.5	1.98E-1	0.	1.98E-1	1.98E-1	
10CFR20 (mrem/yr)	5.00E2			1.50E3	
10CFR100 (mrem/event)	2.50E4	1.50E5	7.50E4	3.00E5	

*Nearest Population Center > 2500 (Kingston)

TABLE 7.1-11
SUMMARY OF POTENTIAL DOSES FROM PLANT ACCIDENTS
DOWNWIND DISTANCE - 21 MILES*
mrem/event

ACCIDENT	WHOLE BODY	BONE	LUNG	THYROID
2.1	6.05E-2	0.	6.05E-2	6.05E-2
3.1	1.55E-8	0.	1.55E-8	1.55E-8
3.2	5.85E-8	0.	5.85E-8	5.85E-8
3.3	8.70E-3	0.	6.68E-4	0.
4.1	2.61E-1	3.47	1.95E-1	9.61E-1
4.2	9.63E-2	2.60	1.28E-1	8.20E-2
5.1	9.24E-7	0.	2.31E-8	0.
5.2	1.43E-4	0.	1.43E-4	1.43E-4
6.1	2.34E-4	2.27E-4	1.61E-7	1.06E-1
6.2	2.34E-2	2.27E-2	1.61E-5	1.06E1
6.3	1.19E-2	0.	2.18E-4	2.07E-6
7.1	3.11E-6	3.42E-6	3.15E-8	1.56E-3
8.1	4.16E-2	5.56E-1	3.13E-2	1.54E-1
8.2	3.68E-4	2.69E-4	1.17E-4	2.14E-4
8.3	4.64E-4	6.19E-3	3.48E-4	1.72E-3
8.4	4.72E-6	1.28E-4	6.24E-6	4.02E-6
8.5	5.18E-2	0.	5.18E-2	5.18E-2
10CFR20 (mrem/yr)	5.00E2			1.50E3
10CFR100 (mrem/year)	2.50E4	1.60E5	7.50E4	3.00E5

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*Nearest Population Center > 100,000 (Knoxville)

TABLE 7.1-12

SUMMARY OF POTENTIAL DOSES FROM PLANT ACCIDENTS

DOWNWIND DISTANCE - 50 MILES

mrem/event

ACCIDENT	WHOLE BODY	BONE	LUNG	THYROID
2.1	2.20E-2	0.	2.20E-2	2.20E-2
3.1	5.86E-9	0.	5.86E-9	5.86E-9
3.2	2.22E-8	0.	2.22E-8	2.22E-8
3.3	3.30E-3	0.	2.53E-4	0.
4.1	9.48E-2	1.26	7.08E-2	3.50E-1
4.2	3.50E-2	9.44E-1	4.64E-2	2.98E-2
5.1	3.36E-7	0.	8.40E-9	0.
5.2	5.20E-5	0.	5.20E-5	5.20E-5
6.1	8.52E-5	8.24E-5	5.84E-8	3.86E-2
6.2	8.52E-3	8.24E-3	5.84E-6	3.86
6.3	4.32E-3	0.	7.92E-5	7.52E-7
7.1	1.13E-6	1.24E-6	1.14E-8	5.68E-4
8.1	1.57E-2	2.11E-1	1.18E-2	5.85E-2
8.2	1.39E-4	1.02E-4	1.42E-5	8.10E-5
8.3	1.69E-4	2.25E-3	1.26E-4	6.24E-4
8.4	1.72E-6	4.64E-5	2.27E-6	1.46E-6
8.5	1.88E-2	0.	1.88E-2	1.88E-2
10CFR20 (mrem/yr)	5.00E2			1.50E3
10CFR100 (mrem/event)	2.50E4	1.50E5	7.50E4	3.00E5

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TABLE 7.1-13

SUMMARY OF POTENTIAL WHOLE BODY POPULATION DOSES FROM PLANT ACCIDENTS

Whole Body Population Dose

Accident Number	Minimum Estimate (Man-rem)	Maximum Estimate (Man-rem)
2.1	1.41E-1	1.75E+0
3.1	3.52E-8	4.35E-7
3.2	1.33E-7	1.65E-6
3.3	1.98E-2	2.45E-1
3.4	1.67E-2	2.06E-1
4.1	6.09E-3	7.53E-2
4.2	2.25E-1	2.78
5.1	2.16E-6	2.67E-5
5.2	3.34E-4	4.13E-3
6.1	5.47E-4	6.77E-3
6.2	5.47E-2	6.77E-1
6.3	2.77E-2	3.43E-1
7.1	7.27E-6	8.99E-5
8.1	9.46E-2	1.17
8.2	8.38E-4	1.04E-2
8.3	1.08E-3	1.34E-2
8.4	1.10E-5	1.36E-4
8.5	1.21E-1	1.50

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TABLE 7.1-14

HAS BEEN DELETED

TABLE 7.1-15

RUPTURE OF THE NOBLE GAS STORAGE VESSEL

Cell Leak Tightness Assumed

Isotope	Initial Inventory in the NGSV (Ci)	Total Radioactivity Released From the Plant (Ci)
Xe-133	2.34E5	1.07E2
Xe-135	4.40E4	0.19
Kr-88	8.30E2	3.4E-4
Total	2.79E5	1.07E2

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No Cell Leak Tightness Assumed

Isotope	Initial Inventory in the NGSV (Ci)	Total Radioactivity Released From the Plant (Ci)
Xe-133	2.34E5	5.6E2
Xe-135	4.40E4	7.7
Kr-88	8.30E2	4.4E-2
Total	2.79E5	5.7E2

TABLE 7.1-16

HAS BEEN DELETED

TABLE 7.1-17
TOTAL EXCESS COVER GAS LEAKAGE
FOR ACCIDENT 5.1

Isotope	Leakage (Curies)
Xe131m	1.3E-6
Xe133m	1.1E-5
Xe133	3.8E-4
Xe135m	2.1E-5
Xe135	3.7E-4
Xe138	5.4E-5
Kr83m	1.5E-5
Kr85m	4.3E-4
Kr85	8.6E-7
Kr87	4.3E-5
Kr88	7.0E-5
Total	1.4E-3

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TABLE 7.1-18
RADIOACTIVE CONTENT OF PRIMARY SODIUM COOLANT*

	μCi/gm Days After Shutdown	
ISOTOPE	0	10
Na-24	2.94	4.32E-1
Na-22	3.49	3.46
Cs-137	42.1	4.21E1
Cs-136	8.7	5.25
Cs-134	5.35	5.30
Sb-125	.241	2.40E-1
I-131	24.8	1.05E1
Te-132	1.76	2.08E-1
I-132	16.7	1.98
Te-129M	.359	2.93E-1
Te-129	.359	2.93E-1
Sr-89	.055	4.80E-2
Sr-90	.034	3.40E-2
Y-90	.034	3.40E-2
Y-91	.0156	1.40E-2
Zr-95	.0292	2.60E-2
Nb-95	.0292	2.60E-2
Ru-103	.0415	3.50E-2
Ru-106	.0287	2.80E-2
Rh-106	.0287	2.80E-2
Sb-127	1.82	2.93E-1
Te-127M	.104	9.80E-2
Te-127	.124	9.80E-2
Ba-140	.0327	1.90E-2

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TABLE 7.1-18 (Continued)
RADIOACTIVE CONTENT OF PRIMARY SODIUM COOLANT*

	µCi/gm		
	Days After Shutdown		
ISOTOPE	0	10	
La-140	.0327	1.90E-2	
Ce-141	.0387	3.10E-2	
Ce-144	.0229	2.20E-2	
Pr-144	.0229	2.20E-2	
Pr-143	.0274	1.70E-2	
Nd-147	.0128	7.00E-3	
Pm-147	.0128	1.30E-2	
Pu-238	8.0E-3	8.00E-3	11
Pu-239	2.12E-3	2.10E-3	
Pu-240	2.77E-3	2.80E-3	
Pu-241	.23	2.30E-1	
Pu-242	5.9E-6	5.90E-6	
Np-238	2.45E-6	9.00E-8	
Np-239	7.9E-3	4.12E-4	
Am-241	8.2E-4	8.20E-4	
Am-242m	3.23E-5	3.23E-5	
Am-242	3.69E-5	3.23E-5	
Am 243	1.32E-5	1.32E-5	
Cm-242	6.0E-4	5.75E-4	
Cm-243	7.95E-6	7.95E-6	
Cm-244	1.66E-4	1.66E-4	
H-3	2.34	2.34	
Rb-86	1.00	.69	

*30 years of plant operation, 0.5 percent failed fuel

TABLE 7.1-19
RADIOACTIVE CONTENT OF EVST SODIUM*

Isotope	Sodium (μCi/g)
H-3	1.40E-2
Na-22	5.8E-1
Na-24	1.47E-1
I-131	4.45E-1
Cs-134	3.5E-1
Cs-136	2.2E-1
Cs-137	3.55
Pu-238	3.5E-3
Pu-239	9.3E-4
Pu-240	1.21E-3
Pu-241	8.1E-2
Pu-242	2.59E-6

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*30 years plant operation, 0.5 percent failed fuel, maximum value during refueling.

TABLE 7.1-20
FUEL ASSEMBLY NOBLE GAS AND IODINE INVENTORIES
8 DAYS AFTER SHUTDOWN 11

Isotope	Inventory (Curies)	Half-Life	
Kr-85m	2.07E-9	4.4	hr.
Kr-85	6.07E2	10.76	yr.
I-130	7.42E-1	12.6	hr.
I-131	9.10E4	8.1	d.
I-132	4.39E4	2.4	hr.
I-133	5.03E2	20.3	hr.
I-135	6.61E-4	6.68	hr.
Xe-131m	1.06E3	11.8	d.
Xe-133m	2.16E3	2.26	d.
Xe-133	1.29E5	5.27	d.
Xe-135m	2.24E-4	15.7	min.
Xe-135	5.33E-1	9.14	hr.

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TABLE 7.1-21
EVTM GAS ACTIVITY 8 DAYS AFTER SHUTDOWN

Isotope	1% Release From Fuel Assembly (μCi/cc)	100% Release From Fuel Assembly (μCi/cc)
H-3	2.6E-4	2.6E-4
Ar-39	7.8E-1	7.8E-1
Kr-85m	1.24E-11	1.24E-9
Kr-85	3.64	3.64E2
I-130	4.44E-4	4.44E-2
I-131	5.45E2	5.45E4
I-132	2.63E2	2.63E4
I-133	3.01	3.01E2
I-135	3.96E-6	3.96E-4
Xe-131m	6.33	6.33E2
Xe-133m	1.29E1	1.29E3
Xe-133	7.71E2	7.71E4
Xe-135m	1.34E-6	1.34E-4
Xe-135	3.19E-3	3.19E-1
Total	1.60E3	1.60E5

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TABLE 7.1-22

INITIAL LEAKAGE RATE THROUGH EVTM SEALS TO RCB/RSB ATMOSPHERE

8 DAYS AFTER SHUTDOWN | 11

Isotope	1% Release From Fuel Assembly (μCi/sec)	100% Release From Fuel Assembly (μCi/sec)
H-3	1.82E-6	1.82E-6
Ar-39	1.13E-3	1.13E-3
Kr-85m	2.36E-14	2.36E-12
Kr-85	6.92E-3	6.92E-1
I-130	1.04E-6	1.04E-4
I-131	1.28	1.28E2
I-132	6.18E-1	6.18E1
I-133	7.07E-3	7.07E-1
I-135	9.31E-9	9.31E-7
Xe-131m	1.49E-2	1.49
Xe-133m	3.04E-2	3.04
Xe-133	1.81	1.81E2
Xe-135m	3.15E-9	3.15E-7
Xe-135	7.50E-6	7.50E-4
Total	3.77	3.77E2

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TABLE 7.1-23

REACTOR COVER GAS INVENTORY 30 HOURS AFTER SHUTDOWN

Isotope	Inventory (Curies)	
H-3	3.4E-3	
Ar-39	10.0	
Xe-131m	0.11	
Xe-133m	0.23	
Xe-133	4.2	11
Xe-135m	8.0	
Xe-135	2.5	
Total	25.0	

TABLE 7.1-24
FUEL ASSEMBLY INVENTORY AND RELEASE RATES OF LONG-LIVED VOLATILE FISSION-GAS ISOTOPES WITH SIGNIFICANT ACTIVITIES FOR SFSC DROP FROM MAXIMUM POSSIBLE HEIGHT

Isotope	Total Activity in One F/A at 80-Day Decay Time (Ci)	Specific Activity in Cask Gas at 80-Day Decay Time (Ci/sec)(1)	Leak Rate From Dropped Cask (Ci/sec)
Kr-85	599	1.076E-3	1.23E-7
Xe-131m	29.7	5.33E-5	6.08E-9
Xe-133	10.1	1.81E-5	2.06E-9
I-131	184	3.31E-4	3.77E-8
Cs-134	3600	1.89E-7(2)	2.15E-11
Cs-136	219	1.38E-10(2)	1.57E-14
Cs-137	9950	5.24E-7(2)	5.97E-11
Rb-86	41.5	1.05E-9(2)	1.20E-13

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(1) Specific activity for six fuel assemblies.

(2) Based on vapor pressure of Cs and Rb at the maximum SFSC seal temperature of 350°F.

7.2 OTHER ACCIDENTS

Accidents of a non-radioactive nature have been postulated for
all areas where potentially hazardous chemicals are stored. In
almost all cases, the chemicals are concentrated acids and bases
although some other materials present special problems. It
should be noted that chlorine gas will not be present on-site
because sodium hypochlorite will be utilized for cleaning 11
purposes in place of chlorine.

7.2.1 FIRES AND EXPLOSIONS

Minimum environmental impact is expected from fires and
explosions. The only significant explosion hazard exists in the
hydrogen gas storage area, located outside opposite the southeast 11
corner of the Maintenance Shop Warehouse. The total volume of
hydrogen stored on site will be 28,000 scf. An explosion will 4
not produce any hazardous gases or any significant damage to
nearby buildings; thus, such an explosion will have no effect on
the environment.

The largest potential source of fire is from the two emergency 4
diesel fuel storage tanks, located below grade adjacent to the
Diesel Generator Building. Elevation of the tanks is 796 feet
± 3 feet base, with plant grade at 815 feet MSL. As this fuel is 11
stored below grade, the chance of an accident is reduced. There
is also a concrete mat positioned below the tank. Any leakage is
collected in a sump and periodically pumped to the surface
through a pipe. The leakage will then be collected and
transported off-site by a licensed contractor. There is no 11
environmental impact anticipated as a result of leakage from this
tank.

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A list of chemical storage tanks is provided in Table 7.2-1. Two
of the chemicals, hydrazine and liquid ammonia, require special
consideration. Hydrazine, in pure form, presents an inhalation
hazard and is potentially explosive. The hydrazine on the Site
will be stored as a 35 percent solution; in this form it is not 11
volatile, so both problems are eliminated. Liquid ammonia
vaporizes upon release and therefore, presents an inhalation
hazard. It will be stored in a separate room with its own
ventilation system; any leakage will be released to the exhaust
of the Turbine Generator Building and diluted there. Ammonia
fires are not possible below a temperature of 1,500 degrees F[1]
so further protection is not necessary. Neither hydrazine nor
ammonia will have an impact on the Site and the surrounding area.

In the Nuclear Island, the postulated accidents could involve 11
cryogenic materials or DOWTHERM. There are two cryogenic
materials, liquid nitrogen and liquid argon, located in the
Reactor Service Building (RSB). Any leakage will quickly
evaporate and the ventilation system will be designed such that
concern over such releases is eliminated. o11

The Nuclear Island of the CRBRP will utilize a limited amount of
DOWTHERM in several secondary cooling loops for cooling the Fuel 6
Handling Cells and Primary Sodium Cold Traps. In this
application, Dowtherm serves as an intermediate cooling medium
for separating the sodium associated with the Fuel Handling Cells
and Primary Cold traps from the chilled water used as primary
heat exchanging medium. The entire Dowtherm inventory will be
contained in closed piping systems; no Dowtherm will be stored in
the Nuclear Island.

Each cooling line containing Dowtherm will utilize remote shutoff
valves positioned on the lines to isolate and limit any leakages

that might be postulated to occur. In addition, the cooling lines will be sloped to assure collection into small pools and reduction in surface area of any leakages.

Fire prevention measures will provide additional guarantees that postulated leakage of Dowtherm will be limited and accommodated.

7.2.1.1 SODIUM FIRES - NON-RADIOLOGICAL EFFECTS

Sodium fires may occur at the CRBRP Plant. The main combustion products of sodium are Na_2O, Na_2O_2, NaOH, NaH and Na_2CO_3. Such
compounds as Na_2O and NaOH could be released into the atmosphere 8
as a smoke plume originating from a sodium fire.

Several sources(1-5) have identified the currently acceptable 8
guideline for human exposure to NaOH as the threshold limit value (TLV) of two milligrams per cubic meter of air recommended by the
American Congress of Governmental Industrial Hygienists (ACGIH). 8
A threshold limit value is defined as an eight-hour time-weighted
average concentration level under which continuous exposure will 8
not adversely affect an average human for an integrated exposure over a working lifetime.

Because of the high affinity of sodium oxide (Na_2O) for water, it 8
is reasonable to assume that sufficient contact with atmospheric moisture would have occurred when the airborne plume reaches the Site boundary to allow the sodium oxide to convert to other chemical forms such as sodium hydroxide or carbonate. The assessment presented assumes the hydroxide form is present at the site boundary. Laboratory experiments have suggested a value of 80 mg/m^3 as a limit for unprotected short-term exposure to sodium hydroxide[5].

Evaluation of the three most limiting potential sodium fire accidents occurring at the CRBRP in terms of expected sodium hydroxide releases and associated concentration levels at the closest Site boundary are presented in Table 7.2-2.

Cases considered in the overall evaluation include both radioactive and non-radioactive sodium releases. Site boundary NaOH concentrations calculated for the non-limiting postulated accidents are quite low, ranging in magnitude from about 10^{-3} mg/m^3 to about 10^{-8} mg/m^3. These levels are well below the suggested TLV of 2.0 mg/m^3. The higher NaOH concentration values estimated for the shorter time duration accidents given in Table 7.2-2 are also at tolerable levels, as is seen by comparison to the short term exposure suggested limit ranges for short duration events. Specifically, potential Accidents 4.1 and 8.1 both have expected sodium hydroxide levels of about 1.7 mg/m^3 for durations of two minutes each, and Accident 5.2 has an expected concentration level of 8.0 mg/m^3 for a 15-second duration.

The chemical form of the sodium combustion product before reaching the Site boundary can be expected to be in a less toxic, carbonate form due to reaction with carbon dioxide in the atmosphere. A method has been developed for predicting this conversion.[6] For the time scale involved before a postulated release would reach the Site boundary, essentially complete 8
conversion to the carbonate form would be expected. In addition, the travel from release to arrival at the Site boundary is expected to involve some fallout of the cloud. A depletion factor of 100 has been applied for sodium hydroxide in its transit from release to arrival at the Site boundary. This factor will conservatively account for the expected chemical conversion and fallout effects and has been applied to the non-radiological impacts of sodium releases.

Expected off-site sodium hydroxide concentrations resulting from the potential accidents, such as those evaluated in Table 7.2-2, are considered to be compatible with the suggested long term and short term exposure limit guidelines. There is expected to be no long-term adverse impacts to off-site public based upon the assumed releases of sodium combustion products at CRBRP. 8

7.2.2 OIL AND HAZARDOUS MATERIAL SPILLS

Minimal environmental impact is expected from spills of oil and hazardous materials. In the Balance of Plant (BOP), consequences of accidents such as tank rupture or leakage are controlled by secondary containment systems. Secondary containment, sufficient to contain the capacity of the largest single tank in the drainage system shall be provided for all on-site tanks containing potentially hazardous materials. When the tank storage is outside, the capacity of the secondary containment will be increased to allow for the additional accumulation of liquid from rainfall. 11

In the Nuclear Island, acid and caustic will be stored in the Radwaste Area of the RSB. The cells storing these tanks are designed to handle the leakage and are equipped with drains to the collection tank in the Radwaste System. No environmental effects are anticipated due to any accidental release from these tanks. A list of chemical storage tanks is provided in Table 7.2-1.

As was discussed in Section 7.2.1, the largest potential source of an oil spill is from the two emergency diesel fuel storage tanks. These tanks are located below grade and anchored to a reinforced concrete mat which is founded on and surrounded by

compacted Class A backfill. This mat will serve as a catchment in the event that an oil leak occurs in either of the two tanks. Any percolated rainfall runoff or tank leakage will be collected in a sump and periodically pumped to the surface through a pipe. Any leakage will be collected and transported offsite by a licensed contractor. There is no environmental impact anticipated as a result of leakage of these tanks. Lube oil is stored in a single tank in the Turbine Generator Building. This tank is comprised of 2 compartments; 10,000 gallons each. Secondary containment, sufficient to contain the capacity of the entire tank is provided within the building. Switchyard and transformer yard equipment 11
containing oil, i.e., transformers, circuit breakers, and the neutral ground reactor, will have secondary containment systems capable of handling and containing any oil spills associated with this equipment without adverse environmental impact. A list of oil storage facilities is provided in Table 7.2-3.

All outside fill stations are provided with secondary containment in the form of a sloped concrete pad, capable of holding the largest tank truck served at that station. If a spill should occur, the material will be contained at the fill station until it can be disposed of offsite by a licensed contractor.

TABLE 7.2-1

CRBRP Chemical Storage Tanks

LOCATION	MAX. STORAGE	STORAGE VESSEL
Turbine Generator Building		
Sulfuric Acid	5,500 gal.	1 tank
Sodium Hydroxide	5,500 gal.	1 tank
Ammonium Hydroxide	3,300 gal.	1 tank
Hydrazine	TBD	55 gal. drum
Circulating Water Pumphouse		
Sulfuric Acid	12,000 gal.	1 tank
Sodium Hypochlorite	15,000 gal. ea.	2 tanks
Radwaste Area of Reactor Service Building		
Sulfuric Acid	150 gal.	1 tank
Sodium Hydroxide	2,500 gal. 150 gal.	2 tanks
Waste Disposal Bldg.		
Sulfuric Acid	4,000 gal.	1 tank
Sodium Hydroxide	4,000 gal.	1 tank
Aluminum Sulfate (Alum)	TBD	Paper Bag

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TABLE 7.2-2

ESTIMATED* SODIUM HYDROXIDE RELEASES FOR REPRESENTATIVE POTENTIAL FIRE ACCIDENTS

Accident No.**	Description	Duration	Average Concentration (mg/m3)	Peak Concentration (mg/m3)	
4.1	Failure of ex-containment primary sodium drain pipe during maintenance	2 minutes	1.73	2.54	
5.2	Steam generator tube rupture	15 seconds	7.95	--	4 8
8.1	Primary sodium in-containment drain tank failure during maintenance	145 hours	3×10^{-7}	7.3×10^{-5}	

*Estimated sodium hydroxide levels at the closest Site boundary 8

**Refer to accident numbering in Section 7.1

TABLE 7.2-3

CRBRP Oil Storage Facilities

LOCATION	MAX. STORAGE
[illegible]tor Building	
[illegible]nk	20,000 gallons
[illegible]rator Building	
[illegible] Fuel Storage Tanks	68,000 gallons/each 11
Main Transformer Yard	
1 Main Transformer	12,000 gallons
1 USS Transformer	6,000 gallons
1 Ground Reactor	2,500 gallons
Reserve Switchyard and Transformer Area	
2 Reserve Transformers	8,000 gallons/each
2 Oil Circuit Breakers	5,000 gallons/each
Generating Switchyard	
5 Circuit Breakers	5,000 gallons/each