NRC QUESTIONS ABOUT SECTION 9

NRC Letter November 19, 1974 - Biambusso

Item 340.1 (9.2) - Amendment I, Part I, page IA-54

Item 350.14 (9.2.4) - Amendment I, Part I, page A1-85

NRC Letter February 13, 1975 and April 23, 1975 - Dicker

Question F6 (T9.2-5) - Amendment I, Part II, Page A1-276

Question F7 (T9-2-5) - Amendment I, Part II, Pages A1-277 to 280

NRC Letter April 10, 1975

Question 1 (9.1 and 9.2) - Amendment I, Part III, Pages A1-312 and 313

Question 5 5 (9.2) - Amendment I, Part III, Page A1-317

NRC Letter October 15, 1976

Amendment VIII, Part I, Pages AVIII-2 to AVIII-9, and ER Appendix D.

NRC Letter December 22, 1976

Question 1 - Amendment VIII, Part I, Pages AVIII-11 to AVIII-15

Question 2 - Amendment VIII, Part I, Pages AVIII-16 to AVIII-22

Question 3 - Amendment VIII, Part I, Page AVIII-23

Question 4 - Amendment VIII, Part I, Pages AVIII-24 and AVIII-25

Question 5 - Amendment VIII, Part I, Page AVIII-26

9.0 ALTERNATIVE APPROACHES AND SITES

9.1 ALTERNATIVE APPROACHES

The LMFBR Program is a key part of DOE's overall long-range energy research and development activities.[1,2] Alternative energy sources have been discussed and analyzed in the ERDA LMFBR Program Environmental Statement[3] and the DOE Supplemental Environmental Impact Statement for the LMFBR Program.[4] These statements and their analyses of alternative energy sources amply demonstrate the need for vigorous pursuit of the LMFBR Program. Since the CRBRP is a necessary step in the LMFBR Program, alternative energy sources for the CRBRP are not again considered in this report. The need for a demonstration plant as part of the LMFBR program is summarized in Section 1 of this report. 13
Since the primary purpose of the CRBRP is broader than the production of electrical power, the treatment of the alternative of not creating new generating capacity, although usually provided in accordance with Regulatory guide 4.2, is not appropriate here.

The operation of the CRBRP supports the overall LMFBR Program and provides the necessary technological base leading to development of larger commercial-sized liquid metal fast breeder reactors. Moreover, the CRBRP represents the development of technology with predicted performance, industrial support, a broad base of technological experience, and proven basic feasibility. The CRBRP is needed as soon as possible in order to demonstrate the technical performance, reliability, maintainability, safety, environmental acceptability, and economic feasibility of an LMFBR power plant on a utility system. The role of CRBRP in the LMFBR Program is discussed in detail in Section 1 and elsewhere.[4]

9.2 ALTERNATIVE SITES AND PLANT ARRANGEMENTS

In late 1971, the AEC appointed a Senior Utility Steering Committee and Senior Utility Technical Advisory Panel to assist them in selecting a utility partner to design, build and operate the demonstration plant. Proposals were submitted to the Liquid Metal Fast Breeder Reactor (LMFBR) Committee and AEC, by groups of utilities interested in participating in the demonstration plant program. Each of the principal sites advanced in the four proposals that were received appeared to meet the general requirement: The proposed site should require "no unusual design features or special consideration in licensing."[1] The Steering Committee noted "that increased siting flexibility could be associated with the Commonwealth/TVA arrangement . . . ."[2]

The Tennessee Valley Authority (TVA) and Commonwealth Edison Company (CE) proposal was subsequently accepted by the Committee and the AEC. This joint proposal by TVA and CE for building and operating the Nation's first large-scale (300 to 500 MWe) LMFBR demonstration plant included guidelines for selecting the site of the LMFBR demonstration plant. Guidelines included building the plant on the TVA system preferably at an existing electric generating plant which would utilize the steam from the LMFBR Nuclear Steam Supply System (NSSS). The proposal specifically named the John Sevier plant as a potentially suitable plant for this hook-on arrangement and indicated that other existing plants on the TVA system might also be suitable. As an alternate to the hook-on arrangement, the provision was made in the proposal to build an entirely new plant on the TVA system, where TVA would provide links from its transmission system to the switchyard at no cost to the project. A site on the Clinch River, which is in the custody of TVA, was named as one possible location which could be made available at no cost to the project.[2]

TABLE 9.1-1

COSTS AND URANIUM AND SEPARATIVE WORK REQUIREMENTS WITH AND WITHOUT A BREEDER[1]
(Most Likely Projections for Energy, Uranium and Breeder Development)

	With Breeder	Without Breeder
Cumulative Requirements		
U_3O_8 1970-2020 (tons)	2,450,000	6,300,000
Separative Work Duty 1970-2020 (1000s of SWUs)	1,820,000	6,500,000
Maximum Annual Requirements		
U_3O_8 (tons)	105,000 (1998)*	280,000 (2020)*
Separative Work Duty (1000s of SWUs)	81,000 (2000)*	436,000 (2020)*
Energy Costs ($ billions)		
Undiscounted	6598.2	8322.4
Discounted at 7.5%	464.1	524.0
Benefits, discounted at 7.5%	59.9	
Fuel Cycle Costs in Year 2020 (mills/Kwhr)		
LWR	2.5	6.4
LMFBR	0.2	

* Year of maximum requirement.

PURPOSELY BLANK

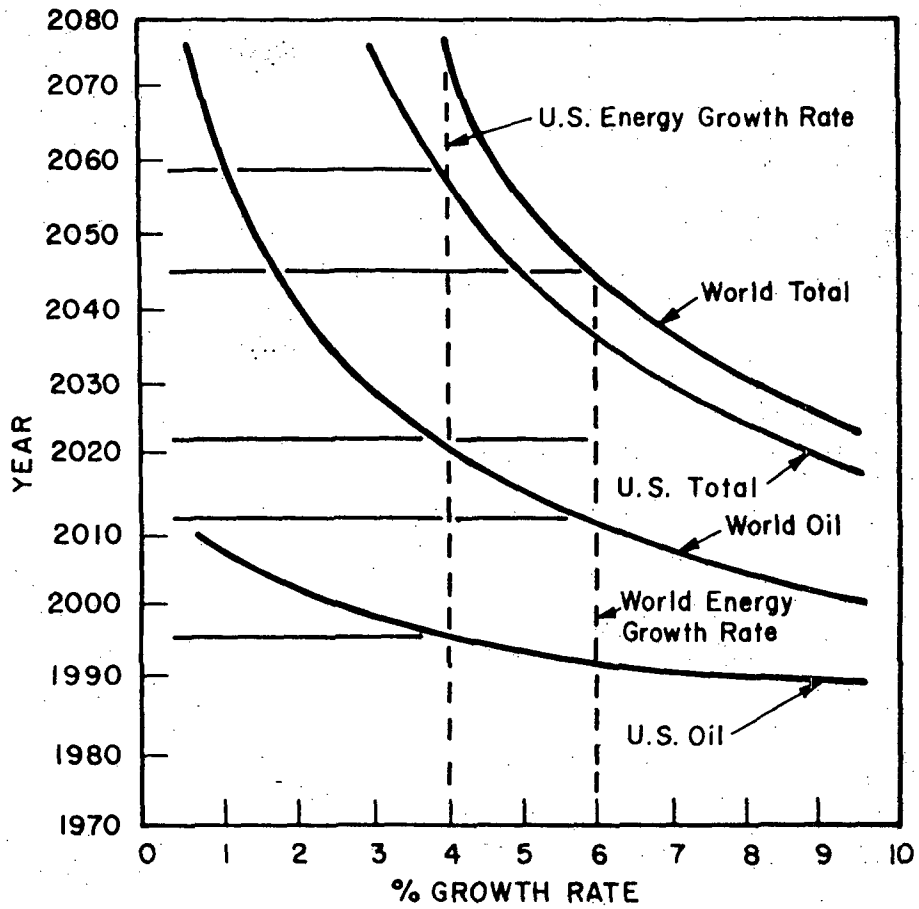

Figure 9.1-1 YEAR OF DEPLETION FOR NATURAL OCCURRING FOSSIL FUEL SOURCES (INCLUDING URANIUM ORE RESERVES) VS. PROJECTED ENERGY CONSUMPTION RATES[4,5]

9.2 ALTERNATIVE SITES AND PLANT ARRANGEMENTS

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In arriving at a preferred site location for the LMFBR Demonstration Plant on the TVA grid, TVA carried out a series of screening studies of potential sites. In addition, extensive engineering, environmental and economic studies were made by TVA, CE, AEC and three reactor manufacturers for two hook-on alternative sites (John Sevier and Widows Creek) and a new site on the Clinch River. 8 8

9.2.1 SITE SELECTION CRITERIA

Selection of a site for the LMFBR Demonstration Plant was based on siting criteria established by considering the joint TVA-CE proposal, the AEC's request for proposals and other applicable requirements. Site selection criteria were established in recognition of the developmental nature of the LMFBR concept. Also, immediate availability of a site for the demonstration plant was highly desirable. In addition, it had been determined that any potential site must not require unusual design features or special licensing considerations and should permit the construction of a plant that would conform in every respect with applicable environmental standards. 8

An important consideration in selecting the site was to assure that the demonstration plant would not have an adverse effect on TVA's ability to provide an adequate supply of electricity to the region it serves. While there was no basis to assume that the plant would not be a reliable producer of electric energy, it was not considered to be an integral part of TVA's power system capacity. Additionally, because of the scarcity of suitable new sites for commercial nuclear power plants, preference was given to those sites which were not expected to be used in the near future for commercial generating plants.

The criteria used in the search for a suitable site for the demonstration plant are summarized as follows:

1. The demonstration plant size will be in the 300 to 500 MWe range;
2. The site must meet physical and environmental requirements;
3. A hook-on plant is preferable to a new plant provided adequate incentives exist;
4. Concerning the hook-on criteria:
   a. The project should not adversely affect TVA's power system operation or system reliability and should permit the use of existing boilers during periods when the LMFBR NSSS is not available for operation; and
   b. Steam conditions and unit sizes of existing steam plant should closely match requirements of the LMFBR demonstration plant;
5. Concerning new site criteria:
   a. The site should be available immediately; and
   b. The site should be one which is not expected to be used for a commercial generating plant in the near future.

Additional justification of the plant size is contained in Section 1.

9.2.2 SELECTION OF CANDIDATE SITE(S) - HOOK-ON ARRANGEMENTS

In the site selection process for hook-on arrangements, all TVA plants which were expected to be operational on a time schedule consistent with the planned operations of the LMFBR demonstration plant were considered, as shown in Figure 9.2-1. Factors such as plant size, steam condition, seismic region and population centers ruled out a number of sites

without any need for further consideration. Table 9.2-1 lists the plants and summarizes the important factors used in judging the suitability of these sites. Based on the size requirement, the plants which had turbogenerator units judged to be acceptable were: Colbert 1-4, Gallatin 1-4, John Sevier, Johnsonville, Kingston, Shawnee, Allen and Widows Creek 1-6.

The Widows Creek 1-4 units are nonreheat; units 5 and 6 use reheat. The combined capacity of reheat units 5 and 6 is less than the 300 MWe minimum demonstration plant size. Since it would introduce unnecessary complications in the plant design to mix reheat and nonreheat unit types, only units 1-4 were considered at Widows Creek.

The extreme western end of the TVA system is in close proximity to an area in which major seismic activity has occurred as recently as the early 1800's. TVA had submitted a report, "Relationship of Earthquakes and Geology in West Tennessee and Adjacent Area,"[4] to AEC's Director of Regulation for consideration in determining the extent to which nuclear plants can be located in the western end of the TVA system. Since a determination by AEC had not yet been made, the Allen, Shawnee and Johnsonville Steam Plant locations were eliminated from further consideration. 8

The remaining candidate sites are located in tectonic provinces where sufficient studies have been made to assure that nuclear plants can be adequately designed without sustaining major cost penalties.

The remaining candidate hook-on plants were examined from the standpoint of importance of these units to the TVA power system. While each unit's generating capacity contributes directly to TVA's ability to serve present and future loads, the capacity factor is a measure of the importance of the unit from the standpoint of power system economics and other

requirements. The capacity factors of these units for fiscal years 1970-71 (July 1, 1969 to June 30, 1971) were as follows:

Units	FY 1970 and 1971 Capacity Factor
Gallatin 1-4	63.6
Colbert 1-4	63.2
Kingston 1-9	61.2
John Sevier 1-4	54.8
Widows Creek 1-4	50.8

As indicated, the Gallatin, Colbert and Kingston units are utilized at a relatively higher capacity factor on the TVA system. Similar utilization patterns were expected in the future. TVA believed it to be prudent to exclude these plants from further consideration as hook-on candidates provided the Widows Creek or John Sevier units are otherwise suitable for the demonstration plant.

At John Sevier, units 3 and 4 were selected as best fitting the needs of the demonstration plant since adequate space is available immediately adjacent to these units to accommodate the LMFBR Nuclear Steam Supply System (NSSS). These units have normal steam conditions of 1,800 psig at 1,050 degrees F with 1,050 degrees F reheated steam. For the demonstration plant, the initial steam temperature and reheat steam temperature would hereto be reduced to about 900 degrees F. This would result in a capacity loss of about 36 MW and the net electrical output of the demonstration plant would be about 346 MW. Consideration of John Sevier as a site for a hook-on plant requires that reheat steam to the turbine be provided.

Units 1 to 3 were selected as the best Widows Creek units for a hook-on plant. Normal steam condition for these units is 1,450 psig

at 1,000 degrees F. Reducing steam temperature to 900 degrees F to accommodate the demonstration plant would result in a loss in net electrical output of about 27 MW, resulting in a demonstration plant net electrical output of about 342 MW.

9.2.3 TECHNICAL EVALUATIONS OF ALTERNATIVE HOOK-ON ARRANGEMENTS

Studies to evaluate the feasibility, economics and hook-on plant requirements were carried out under the direction of a technical committee which included the TVA, Commonwealth Edison, Atomic Energy Commission and the AEC's Project Definition Phase contractors, General Electric, Westinghouse and Atomics International along with their respective Architect-Engineering subcontractors, C. F. Braun, R. M. Parsons and Bechtel. This committee reviewed demonstration plant hook-on considerations at TVA's John Sevier and Widows Creek steam plants. The study concluded "there is no known physical or engineering reason why locating an LMFBR at either John Sevier or Widows Creek to use existing power-producing equipment is not feasible."[1]

9.2.3.1 REHEAT SELECTION ALTERNATIVE FOR JOHN SEVIER

Because John Sevier was one of the prime candidates for the site and because it requires reheat steam to the turbine, an extensive study was carried out on the means of supplying the reheat steam.[5] These were use of the existing coal-fired boilers for reheat, modification of the turbines to nonreheat, steam reheat, separate oil-fired reheaters and sodium reheat. The first two methods were considered to be impractical. Steam reheat might be possible but would pose some difficult design problems. From an engineering standpoint, the most promising alternatives appeared to be separate oil-fired reheaters or sodium reheat.

While sodium reheat is technically feasible and does improve the plant heat rate, there are many technical problems and additional development

costs associated with the use of sodium reheat on the first demonstration plant. By increasing the number of sodium and steam components and control requirements, the potential for operating limitations and reduced plant availability would be introduced. Furthermore, the development and testing of sodium reheat technology on a high technical assurance and reliability basis would not be practical on a schedule compatible with the demonstration plant design.

A sodium reheat task force was formed to conduct a study on the use of sodium reheat. The task force consisted of representatives from the AEC, TVA, Commonwealth Edison, PMC, GE, Westinghouse, AI, ANL and the Liquid Metal Engineering Center. The task force prepared a preliminary draft report in March of 1972[6] and studied the status of sodium reheat development in Europe in June 1972. Their report, "Status of LMFBR Reheat in Western Europe--1972,"[7] along with United States' studies indicated that no clear technical and economic advantages for sodium reheat could be shown at this stage of LMFBR development. Therefore, it was not thought in the best interest of the project to include sodium reheat in the first demonstration plant and only separate oil-fired reheaters were considered for the hook-on at John Sevier. However, the future use of sodium reheat on large-scale commercial LMFBR's has not been precluded and present planning on long-range use of sodium reheat is continuing.

9.2.3.2 COMBINED CYCLE POWER PLANT

The possibility of building an oil-fired, combined cycle power plant which could accommodate an LMFBR NSSS hook-on was also considered as one of the alternatives for the demonstration plant. TVA's Office of Engineering Design and Construction performed a preliminary engineering and feasibility study of such an arrangement for the Clinch River site.[8] A wide range of combinations of conventional components is possible in such an arrangement. The arrangement selected for study consisted of 12 gas turbines with a combined base-load rating of 615 MW, which exhausted

into heat-recovery boilers, using supplemental oil firing, to provide steam to three steam turbine generators with a combined base rating of 435 MW. The 1,050-MW combined cycle plant would have a net plant heat rate of about 8,300 Btu/kWh at steam conditions of 1,250 psig and 950 degrees F. With a steam temperature of 900 degrees F, the steam turbine plant could accommodate an LMFBR NSSS and have a net electrical output in the range of about 400 to 450 MW. The incremental cost of modifying the plant to accommodate the NSSS was estimated to be about 16 million dollars. This study and independent studies by General Electric and Westinghouse indicated that this type of arrangement is feasible and would not represent a significant compromise in the design of the NSSS for the demonstration plant.

TVA performed system expansion studies of alternative capacity additions to the TVA system within the time frame to accommodate the demonstration plant schedule to see if the combined cycle plant could be economically justified as a part of TVA's power program. The analysis indicated that such a plant could not be economically justified on TVA's system by a margin of about 75 million dollars.[9]

9.2.4 SELECTION OF CANDIDATE SITE(S) - NEW

Without regard to the possession and commercial plant use criteria, TVA conducted a survey of potential new sites for the LMFBR Demonstration Plant and identified eleven potential sites. These sites were under various stages of investigation by TVA. Eleven sites, considered in the survey, and some of the major characteristics of each site are listed in Table 9.2-2 (See Appendix A for additional information). It was concluded from this study that a comparison of site features and environmental factors showed no apparent overall advantage of these sites over the Clinch River site. Since there were no known physical, engineering or environmental reasons that would preclude consideration of a new plant at the Clinch River site and, because only it satisfied the new site selection criteria, it was decided that the Clinch River site would be considered as a potential 8

site for an entirely new plant as an alternate to the two hook-on sites previously discussed.

9.2.5 CANDIDATE SITES STUDIES

Each of the three principal candidate sites, John Sevier, Widows Creek and Clinch River, are discussed in the following subsections in terms of site location, access, population, geology, seismology, hydrology, flood features, meteorology, land and land use, ecology, public water supplies and historic sites.[9] Major points of comparison of the above site-sensitive factors among the three sites are summarized in Table 9.2-3. Based upon a preliminary analysis, each site represents a feasible location to build the plant.

9.2.5.1 JOHN SEVIER

9.2.5.1.1 SITE LOCATION

The John Sevier site,[10] which occupies 717 acres, is located in Hawkins County, Tennessee, on the south bank of Cherokee Reservoir approximately three miles southeast of Rogersville, Tennessee, as shown in Figure 9.2-2.

9.2.5.1.2 ACCESS

The John Sevier site already has both road and railroad access and only short additions or spurs would be needed to extend these to the NSSS. Barge transportation is not available and the site is approximately 60 miles from the Tri-Cities Airport.

9.2.5.1.3 POPULATION

The area within a 50-mile radius of the John Sevier site includes portions of northeast Tennessee, northwest North Carolina, southwest Virginia

and southeast Kentucky. The population within this area was estimated to be 694,295 in 1970. This represents an increase of 1.9 percent over the 1960 population as compared with a gain of 13 percent for the Nation. The average population density within 50 miles of the site is 88.5 people per square mile. The distance from the plant to the nearest continuously occupied domestic structure is 3,400 feet. Resident population is sparsely settled throughout the area within 10 miles of the site except at the town of Rogersville, located three miles northwest of the plant. The population of Rogersville in 1970 was 4,076 and is projected to be 7,000 by the year 1980 and 1,3000 by the year 2010. The population within 10 miles of the site was estimated from 1970 census statistics to be 18,955 and is projected to be 21,760 by the year 1980 and 27,560 by the year 2010. There are only 725 people within two miles of the site.

The nearest population center as defined in 10 CFR Part 100 is Kingsport, Tennessee, approximately 25 miles away with a population of 61,487 according to the 1970 census.

9.2.5.1.4 GEOLOGY

The initial geologic investigations at John Sevier were conducted in 1952.[11] In March 1972, four additional holes were drilled in the proposed area where the demonstration plant would be located. A relatively even bedrock surface is overlain by approximately 40 feet of fill and terrace material at the site. Experience during prior construction indicates that approximately three feet of slightly weathered rock would have to be removed from the rock surface to obtain sound, unweathered material suitable for foundation of the structures. Additional studies and investigations are required before a detailed geologic evaluation could be made. However, it was anticipated that adequate foundations could be designed.

9.2.5.1.5 SEISMOLOGY

Because of the very similar seismological characteristics of the three candidate sites, all three will be treated here to avoid repetition. The seismic history of the southeastern United States suggests that the earthquake hazard is negligible at the John Sevier, Widows Creek and Clinch River sites. There are no active faults in the vicinity of the sites and there is no physical evidence of any recent seismic activity at any of the sites. The maximum seismic intensity to have been felt at any of the sites in the recorded history of the area is of moderate intensity. The nearest known epicenters of damaging earthquakes at each of the sites were 45 miles southwest of the John Sevier site, 60 miles south of the Widows Creek site and 45 miles northeast of the Clinch River site.

There is no known correlation between earthquakes observed in the region and any superficial tectonic structures. The sites lie in the southern Appalachian tectonic province as defined in TVA's "Sequoyah Nuclear Plant Final Safety Analysis Report."

There are two known major faults in close proximity to the Clinch River site. There is no evidence that these or any other known faults in the region are still potentially active. In the vicinity of all these sites, there is no physiographic evidence, such as stream offsets, displacement of Plio-Pleistocene terrace deposits or displacement of alluvial deposits, to indicate current or geologically recent movement along any of these faults. Therefore, faults in the region are considered to be inactive and detailed faulting investigation is not required.

9.2.5.1.6 HYDROLOGY

The Cherokee Reservoir is a large storage impoundment on the Holston River covering an area of 30,300 acres extending from the Cherokee Dam

to the John Sevier plant. A concrete spillway dam at the plant site creates a water supply impoundment for the plant. This impoundment has a nearly constant surface elevation of 1,080 feet and a volume of 5,500 acre-feet. Condenser cooling water flowrate of 1,012 cubic feet per second (cfs) is withdrawn from the storage impoundment, increased in temperature 15 degrees F and discharged to the Cherokee Reservoir. When operating at full load, the four existing John Sevier generating units reject a total of 3.5 billion Btu per hour to Cherokee Reservoir. As a hook-on plant, the total level of heat rejection at the John Sevier site would be essentially unchanged from the present loads.

Since 1955, TVA has been observing the distribution of heated waters discharged from TVA's power plants, including John Sevier. Studies have not identified any environmental damage resulting from the heat rejection at John Sevier.

The nearest stream gage to the John Sevier site is located at Surgoinsville, Tennessee. This gage has been in operation since 1941. Based on information gathered at this station and gaging stations at Big and Beech Creeks, the average discharge at the John Sevier site is 3,680 cfs. The minimum flow has occurred at those time periods when there has been no flow over the plant water supply dam.

9.2.5.1.7 FLOOD FEATURES

The Holston River watershed, at the John Sevier site, has an area of 3,007 square miles and includes four major dams: Watauga, South Holston, Boone and Ft. Patrick Henry. The estimated maximum possible flood level elevation, based on a flood discharge of 520,000 cfs and including wave runup, is 1,125 feet which is 16 feet above the existing site grade elevation of 1,109 feet.

A feasible method of flood protection at John Sevier is the use of an elevated fill to avoid the potential of water reaching Class I structures. The slopes of this filled area would be suitably protected against rushing waters and floating debris. This method of protection would provide plant access above the computed flood elevation.

9.2.5.1.8 METEOROLOGY

The John Sevier site is located in a well-defined valley in the foothill region of the Appalachian Mountains. The low-level wind at John Sevier tends to be slightly higher than at either Widows Creek or Clinch River. This would result in an augmenting area-wide upvalley and downvalley wind regime which would likely strengthen the local wind in the plant site area. The preliminary meteorological evaluation of the John Sevier site was made using 1954 data from a TVA station one mile southwest of the power plant. The station included a wind sensor 320 feet aboveground and no temperature gradient measurement. Based on a preliminary assessment of atmospheric dispersion characteristics, the most restrictive condition most likely corresponds to Pasquill Type G condition.

9.2.5.1.9 LAND AND LAND USE

Most development surrounding the John Sevier site is very sparse, with farming and forestry being the major land uses. Rogersville is the only exception to this dispersed development. There is some evidence that a new residential development is imminent about 1.5 miles north-northeast, upstream and across the river. The John Sevier hook-on site is already committed to power plant use; thus, no change in land use of the plant site would be experienced by construction of the demonstration plant.

The site can accommodate an exclusion area radius of over 2,000 feet. Based upon work by the reactor manufacturers during the Project Definition

Phase (PDP) of the demonstration plant program, this exclusion area radius appears to be adequate.

No additional off-site transmission lines would be required with only some tie-in equipment necessary.

9.2.5.1.10 ECOLOGY

The resident aquatic organisms are found in two thermal environments at the John Sevier site. First, in the thermal effluent which moves along the left shoreline and then out to midstream. Second, the water flowing over the dam, which creates a water supply impoundment for the plant, affects the immediate area above the thermal effluent and along the right shore, as well as under the heated water addition. Rooted aquatic macrophytes dominate the river above John Sevier. The Cherokee Reservoir downstream from the plant has an oxygen depletion problem which affects the ecological characteristics downstream.

9.2.5.1.11 PUBLIC WATER SUPPLIES

There are four public water supplies taken from other surface water sources within 20 miles of the John Sevier site. Also, there are 24 public ground water supplies within this same area. There is only one public water supply, Morristown, Tennessee, taken from the Holston River between Cherokee Dam and the confluence of the north and south forks of the Holston River. The intake for this supply is located 31.4 miles downstream from the site and, in conjunction with ground water supplies, serves an estimated population of 37,540 with a daily capacity of 3,460,000 gallons.

9.2.5.1.12 HISTORIC SITES

The Andrew Johnson National Historical Site is located approximately 25 miles from the John Sevier site. No other historical sites listed in the "National Register of Historic Places" or the "State Register of Historic Places" have been identified.

9.2.5.2 WIDOWS CREEK

9.2.5.2.1 SITE LOCATION

The Widows Creek site[12] is located on 809 acres in Jackson County, Alabama, on the west bank of the Guntersville Reservoir between Tennessee River Miles 407 and 408, five miles southwest of Bridgeport, Alabama, as shown in Figure 9.2-3.

9.2.5.2.2 ACCESS

The Widows Creek site already has both road and railroad access and only short additions or spurs would be needed to extend these to the NSSS. However, tie-in may require some rerouting of existing lines. Barge transportation is available via a nine-foot-deep navigable channel which connects with the Inland Waterway System. The airport at Chattanooga is approximately 50 miles away by highway.

9.2.5.2.3 POPULATION

Within a 50-mile radius of the Widows Creek Steam Plant are portions of northeast Alabama, northwest Georgia and southern Tennessee. The population within this area was estimated to be 783,760 in 1970. The area has generally experienced a loss of population over the 1960-70 period with no indication that this trend will change dramatically in the future. The population density within this 50-mile radius is about 100 people

per square mile. Resident population is sparsely scattered throughout the area within 10 miles of the plant with only 360 people within two miles of the site. The nearest community is Stevenson, located 4-1/2 miles west of the plant, with a 1970 population of 2,390. The population within 10 miles of the site based upon 1970 census statistics is 15,105 and is projected to be 16,245 by the year 1980 and 24,985 by the year 2010.

The nearest population center as defined in 10 CFR Part 100 would be Chattanooga, Tennessee, approximately 23 miles away with a population of 223,580.

9.2.5.2.4 GEOLOGY

The initial geologic investigations at Widows Creek were conducted in 1949[13,14,15] in anticipation of constructing a fossil-fired plant. Additional investigations were conducted during the construction of the plant. In March 1972, six additional holes were drilled in proposed areas (three areas were considered) where the demonstration plant might be located. The presence of an ancient shear zone was encountered which would require additional investigation to establish the exact extent of this relatively minor structure. The most important relationship between the shear zone and the character of the foundation is the increase in weathering effects in the rocks surrounding the shear. Depending on the extent of the weathering, some foundation treatment may be required. Also, the presence of a meta-bentonite seam was encountered in one of the six exploratory holes. The significance of the presence of the meta-bentonite seam is that this material, on immersion in water will slake and disintegrate and is a potential zone of weakness that could permit settlement if not under a sufficient rock cover. If there is a significant presence of meta-bentonite, then it would be necessary to excavate to a depth where the overlying rock is sufficiently thick to carry the superimposed

loads without relying on the strength of the meta-bentonite. However, it was anticipated that adequate foundations can be designed for the Widows Creek site.

9.2.5.2.5 SEISMOLOGY

Seismology for the Widows Creek site has been discussed in Section 9.2.5.1.5.

9.2.5.2.6 HYDROLOGY

The Guntersville Dam forms TVA's second largest reservoir by area at a normal pool elevation of 595 feet. At this elevation the reservoir is 75.7 miles long, covering an area of 67,900 acres, with a volume of 1,018,000 acre-feet. At the site the reservoir is about 1,500 feet wide, with cross-sectional depths ranging up to 20 feet at normal pool elevation. When operating at normal full load, the existing Widows Creek plant rejects a total of 8.2 billion Btu per hour to Guntersville Reservoir. A condenser cooling water flowrate of 2,434 cfs is withdrawn, heated 15 degrees F and returned to the reservoir. As a hook-on plant, the total level of heat rejection at the Widows Creek site would be essentially unchanged from the present level.

Since 1955, TVA has been observing the distribution of heated waters discharged from TVA's power plants, including Widows Creek. Studies have not identified any environmental damage resulting from the heat rejection of the Widows Creek Steam Plant.

The nearest stream gage to the plant is at South Pittsburg, Tennessee, at Tennessee River Mile 418.1. This gage was moved to its present location in 1965 from a point 11.7 miles upstream, where it was established in 1930. The average discharge for the 40 years of record (1931 to 1970) is 35,330 cfs. The maximum discharge was 241,000 cfs. The

average water flow at Guntersville Dam for the period 1951 to 1965 is 38,875 cfs. Based on these flows and those at South Pittsburg, the long-term average flow at the site was estimated to be 38,200 cfs.

9.2.5.2.7 FLOOD ELEVATION

The Tennessee River at Widows Creek Steam Plant drains 22,820 square miles. The drainage area at Nickajack Dam is 21,870 square miles. There are 22 major dams in the TVA system upstream from Widows Creek Steam Plant, 10 of which have substantial reserved detention capacity during the flood season and lesser amounts at other times of the year. In addition, there are six major dams owned by the Aluminum Company of America (ALCOA) which often contribute to flood reductions but do not have dependable reserved flood detention capacity. Estimation of the maximum possible flood at Widows Creek is based on the flood analysis made for TVA's Browns Ferry Nuclear Plant. When translated to Widows Creek with a three-foot wave runup, the estimated maximum possible flood elevation is 649 feet, which is about 24 feet above the nominal site grade elevation of 625 feet. The use of dikes or elevated land fill could be used to provide flood protection.

9.2.5.2.8 METEOROLOGY

The Widows Creek plant lies in a slightly more pronounced valley than the other two sites. The area experiences upvalley and downvalley wind and stability regimes similar to the other two sites. The pronounced valley produces a slightly lower average wind speed and a higher relative frequency of stable low wind speed conditions, with less favorable meteorological dispersion characteristics in comparison with the other two sites. The preliminary meteorological evaluation of the Widows Creek site was made using 1967-70 data from a TVA station 3.8 miles north-northeast of the plant. The wind sensor is located 44 feet

aboveground with no temperature gradient measurement. Based on a preliminary assessment of atmospheric dispersion characteristics, the most restrictive condition most likely correspond to Pasquill Type G conditions.

9.2.5.2.9 LAND AND LAND USE

The area within a 50-mile radius of the Widows Creek plant is used primarily for agriculture and forest. Forest is the predominant land use within 10 miles of the plant. The exception is the Sequatchie Valley extension, which contains three small communities, the steam plant and agricultural activities. Some of the land near the site has been identified for potential industrial use. The Widows Creek hook-on site is already committed to power plant use. Therefore, no change in land use of the plant site would be experienced by construction of the demonstration plant.

The site can accommodate an exclusion area radius of over 2,000 feet. Based upon work by the reactor manufacturers during the Project Definition Phase (PDP) of the LMFBR demonstration plant program, this exclusion area radius appears to be adequate.

No additional off-site transmission lines would be required with only some tie-in equipment necessary.

9.2.5.2.10 ECOLOGY

At one time, the Guntersville Reservoir near Widows Creek was a commercial source of mussels. However, in the three-year period from 1969 through 1971, only a few mussels have been harvested by commercial mussel fishermen from Guntersville Reservoir. Biological samples collected in 1967 below the plant consisted of bryozoans, limpets (Ferrissia) and Asiatic clams (Corbicula). Further downstream a diversity of bryozoans, caddis flies, limpets and Asiatic clams were found. Upstream from the

plant flatworms (Dugesia), sponges, oligochaetes, bryozoans, limpets and Asiatic clams were found. Hexagenia, Chronomidae, Heleidae, oligochaetes and fingernail clams (Sphaeriidae) were common on the nearly uniform bottom substrate in Widows Creek embayment.

9.2.5.2.11 PUBLIC WATER SUPPLIES

There are nine public water supplies taken from Guntersville Reservoir and its tributary embayments downstream from the Widows Creek site. The nearest downstream surface water supply is the Scottsboro, Alabama, water supply. Its intake is located 21.7 river miles downstream of the plant. The Scottsboro supply serves an estimated 10,000 persons and has an average daily water use of 1,190,000 gallons. There are 20 public ground water supplies within a 20-mile radius of the site.

9.2.5.2.12 HISTORIC SITES

Russell Cave national monument is located about 15 miles from the Widows Creek site. No other historical sites listed in the "National Register of Historic Places" or the "State Registry of Historic Places" have been identified.

9.2.5.3 CLINCH RIVER

9.2.5.3.1 SITE LOCATION

The Clinch River site[16] is on a peninsula located in Roane County, Tennessee, on the north bank of Watts Bar Lake between Clinch River Miles (CRM) 15 and 18 as shown in Figure 9.2-4. The site borders the U. S. Atomic Energy Commission's Oak Ridge Reservation and consists of a portion of a 1,364-acre tract.

9.2.5.3.2 ACCESSIBILITY

Access to the Clinch River plant location would necessitate improving or building about two miles of road. Railroad access is not presently available on the site but can be provided by a spur of approximately two miles in length. Barge transportation could be made available to the site. The nearest commercial airport is the Knoxville airport, about 40 miles away.

9.2.5.3.3 POPULATION

Virtually all the area within 50 miles of the Clinch River site is within Tennessee. Only a small portion of North Carolina and a very small portion of Kentucky are included. The population within this 50-mile radius was estimated to be 678,800 in 1970. This was an increase of only 5.9 percent over 1960 as compared with an increase of 13 percent for the Nation. The population density within a 50-mile radius of the site was 86.5 people per square mile. Within 10 miles of the Clinch River site are the municipalities of Kingston, Lenoir City, Harriman and Oak Ridge. Kingston with a 1970 population of 4,142 is nearest and about seven miles west of the site. The population within 10 miles of the site was estimated from the 1970 census statistics to be 41,895 and is projected to be 46,570 by the year 1980 and 52,145 by the year 1990.

Within five miles of the site there are no significant concentrations of population. Approximately one-third of the area is in either AEC or TVA custody. The land in AEC and TVA custody (including the site) is within the city limits of Oak Ridge. Oak Ridge is the nearest population center as defined in 10 CFR Part 100. Using the present AEC boundary as the limit of residential development of the city, such development could come within about five miles of the plant. Nevertheless, at least two-thirds of Oak Ridge's 28,319 resident population in 1970 were located beyond the 10-mile radius.

9.2.5.3.4 GEOLOGY

Geology of the Clinch River site has been discussed in Section 2.4. 15

9.2.5.3.5 SEISMOLOGY

Seismology for the Clinch River site has been discussed in Section 9.2.5.1.5.

9.2.5.3.6 HYDROLOGY

Watts Bar Dam on the Tennessee River at TRM 529.9 is located 55 river miles downstream from the Clinch River site. In the vicinity of the site the reservoir ranges in width from about 300 feet to 600 feet with depths between 22 and 24 feet at the Watts Bar normal full-pool elevation of 741 feet. Based upon stream gage measurements by the U. S. Geological Survey at three locations near the site area, the average discharge is estimated to be 4,600 cfs. The Melton Hill Dam, located about five miles upstream of the site, was closed in May 1963. Since the closure of the dam, there has been an average of 50 days per year during which there were no releases from the dam, resulting in practically zero flow at the Clinch River site. The drainage area between Melton Hill Dam and the

plant site is 25 square miles. The longest period with no release from the dam occurred in February and March 1966 when there was no flow below the dam for 29 consecutive days. These conditions resulted from special reservoir operations in an effort to reduce the growth of Eurasian water milfoil in the reservoir.[17] Such extended periods of zero flow from Melton Hill Dam are not anticipated in the future. During days when there are no releases from Melton Hill Dam, upstream flow at the site is possible, depending upon the operation of Watts Bar and Fort Loudoun Reservoirs.

Use of the Clinch River site would require the installation of supplemental cooling facilities. Makeup water requirements from the reservoir for cooling towers are expected to be approximately 14 cfs with discharges from the cooling facilities to the reservoir of about 7 cfs. Adequate treatment of this limited amount of water can be provided to meet applicable Federal and state water quality standards. State water quality standards are in Section 2.5.

9.2.5.3.7 FLOOD ELEVATION

The maximum flood levels expected at the Clinch River site were determined using preliminary estimates. The maximum possible hydraulic conditions without dam failure could cause the river to reach an elevation of 785 feet. Nonconcurrent seismic failure of Norris Dam could result in an estimated flood elevation of 800 feet at the Clinch River site. The possible contribution from the potential failure of Melton Hill Dam which is located between Norris Dam and the site was not taken into account due to its relatively small size compared to Norris Dam. AEC recommended procedures for considering concurrent flooding and seismic failure of Norris Dam give an estimated elevation of 810 feet.

The Clinch River site plant grade was expected to be at an elevation of approximately 810 feet. Due to the topography at this site, the plant

elevation can be increased by minor relocation if required. Consequently adequate flood protection could be provided without making special provisions at this site.

9.2.5.3.8 METEOROLOGY

The Clinch River site is located in a well-defined valley with an upvalley and downvalley wind stability regime similar to John Sevier and Widows Creek. The physiological features of the site are very much like the John Sevier site, both having less pronounced features than the Widows Creek site. The preliminary evaluation of meteorology at the Clinch River site was based primarily on 1963-68 data from Oak Ridge area Station X-10, located 4.5 miles northeast of the plant site. The station includes wind sensors 140 feet aboveground and temperature sensors 5 and 140 feet aboveground.

Based on a preliminary assessment of atmospheric dispersion characteristics, the most restrictive condition corresponds to Pasquill Type G condition.

9.2.5.3.9 LAND AND LAND USE

The area within a 50-mile radius of the Clinch River plant site is mostly rural and used mainly for agriculture and forest except for the urban areas of Knoxville, Oak Ridge, Maryville-Alcoa and Athens. Within five miles of the site, there are two major industrial activities. These are the Oak Ridge Gaseous Diffusion Plant and the Oak Ridge National Laboratory. In addition, three small industrial operations will be commencing operation in the near future between Chesthut Ridge and the road which forms the northern boundary of the tract. These plants are expected to have from 6 to 25 employees. The AEC's Y-12 Plant is located approximately nine miles from the site and TVA's Kingston Steam Plant is 7-1/2 miles west of the site. While location of the plant at the Clinch River site will commit the land to power plant use, the land is already

committed to industrial development. The site can accommodate an exclusion area radius of over 2,000 feet. Based upon work by the reactor manufacturers during the Project Definition Phase (PDP) of the LMFBR Demonstration Plant Program, this exclusion area radius appears to be adequate.

No additional off-site transmission lines would be required, but a tie-in to an existing 161-kV line and a switchyard will be needed. Further study after the site was selected has shown that some off-site transmission lines will be required; see Section 3.9.

9.2.5.3.10 ECOLOGY

Benthic data near the Clinch River site were available from ORNL investigations conducted in the early and mid-1960's and from TVA studies in the 1960's. The Clinch River is not greatly enriched with organic matter. An estimate of productivity in the river is 10 $g/m^2/yr$ in terms of midge adults. The addition of heat to the river at the site should not have a significant effect on presumably limited biota.

9.2.5.3.11 PUBLIC WATER SUPPLIES

There are ten public surface water supplies within a 20-mile radius of the Clinch River site. Three of these water supplies are located where they would be influenced by the plant's water discharges. There are also 17 public water supplies withdrawing water from wells and springs within a 20-mile radius of the plant site.

The city of Rockwood, Tennessee, has an auxiliary public water supply intake located on the King Creek embayment of Watts Bar Reservoir where the potential for reverse flow exists. Under certain conditions, Clinch River waters could flow upstream in the Emory River.

There are 16 industrial water supplies within a 20-mile radius of the site of which five are located where they would be influenced by the plant's discharges. The closest of these is an AEC water intake located 1.6 miles downstream from the site at CRM 14.4. This supply has an average daily use of 2.5 million gallons. The second is an AEC supply at CRM 11.5 and the third is TVA's Kingston Steam Plant. A. B. Long Quarries, Incorporated and Mead Corporation are both located on the Emory River arm of Watts Bar Reservoir and could receive upstream flows from the Clinch River, but neither of these supplies is used for potable or sanitary purposes.

9.2.5.3.12 HISTORIC SITES

The Museum of Atomic Energy and the ORNL Graphite Reactor are within 10 miles of the Clinch River site. No other historical sites listed in the "National Register of Historic Places" or the "State Registry of Historic Places" have been identified.

9.2.6 ECONOMIC COMPARISON

9.2.6.1 BASIS OF COMPARISON

In this subsection, the differential costs of the three alternatives are compared. Using a new plant at the Clinch River site as the base case, the hook-ons at John Sevier and Widows Creek are examined for cost savings and penalties. The costs are presented in 1972 dollars. A re-examination of these costs is described at the end of subsection 9.2.6.2.

The economic comparison is based on: (1) the use of two reheat units at John Sevier; (2) the use of three non-reheat units at Widows Creek; and (3) the Clinch River site adjacent to the AEC's Oak Ridge Reservation for

a new plant site.[9] Principal plant parameters utilized in this comparison are briefly summarized in Table 9.2-4. Plant cost information is based on the following three sources:

1. A draft report entitled "LMFBR Hook-On Considerations at John Sevier and Widows Creek," dated April 1, 1972.[18]
2. Proposals received by the Project Management Corporation (PMC) on April 21, 1972, from General Electric, Westinghouse and Atomics International to design and furnish the nuclear steam supply system for the LMFBR demonstration plant. The PMC request for proposals specified two alternatives. One was an 810-MW thermal NSSS at John Sevier with separate oil-fired reheaters. The other was a 950-MW thermal NSSI at Widows Creek.[19,20,21]
3. A preliminary cost estimate by TVA for the balance of a new plant at the Clinch River site assuming that the NSSS specified for the Widows Creek site would be used at the new site.

The reference turbine plant design for an entirely new demonstration plant at the Clinch River site is based on an adaptation of a design proposed by Westinghouse after a study of various alternatives. The reference design utilizes a turbine with throttle conditions of 2,400 psig and 900 degrees F in conjunction with moisture separation and steam reheat with six stages of feedwater heating. The proposed 3,600-RPM tandem compound machine would have three casings and a four-flow exhaust end with 25-inch last stage blading. The demonstration plant net heat rate for the above conditions is estimated to be about 8,950 Btu per kilowatt hour corresponding to a net thermal efficiency of 38 percent. With a 950-MW thermal NSSS, the net electrical output would be 361 MW. The use of this configuration for the turbine plant did not provide an optimized arrangement. However, it did provide a reasonable basis for comparison.

9.2.6.2 COST COMPARISON

The cost comparison made in terms of 1972 dollars is summarized in Table 9.2-5. Normal overheads and appropriate contingencies for each cost component were included; however, interest during construction is not included.

The estimates indicate a potential savings of about $42 and $38 million in plant first costs for Widows Creek and John Sevier, respectively, over an entirely new demonstration plant at the Clinch River site. The difference of $4 million in the first cost at John Sevier and Widows Creek is well within the uncertainties associated with these estimates. An extensive detailed engineering study would be required to reduce the uncertainty in the estimates.

Site development cost of approximately $21 million for the new plant at the Clinch River site is shown as a credit for the hook-on sites. Site cost associated with additions and modifications required for the hook-on is much smaller and is included in the hook-on cost. Less than $2 million difference exists for alternative NSSS costs; and, therefore, it is not a major factor in the comparison. The difference is attributed to the difference in plant size.

The cost of a new turbine plant is approximately $46 million (shown as a credit) compared to the hook-on cost at Widows Creek of about $32 million and the hook-on cost including oil reheaters at John Sevier of about $38 million. It was assumed that cooling towers would be used for the new plant at the Clinch River site. The cooling towers together with the new switchyard represent about $7 million in new facilities that were not required at Widows Creek or John Sevier.

Demonstration period operating cost is based on a five-year demonstration period after completion of operational testing of the plant. It was

assumed AEC would provide all nuclear fuel and fuel services for the project during the demonstration period at no cost to the project. The nuclear fuel cost included fuel fabrication but does not include cost of nuclear materials, use charges, spent fuel shipping and reprocessing. The credit of $6 million at John Sevier is due to its smaller nuclear fuel requirements. Fuel oil costs for the oil-fired reheater more than offset the savings from the smaller core. There is no significant difference in the non-fuel operation and maintenance cost, which includes nuclear liability insurance, staff training and plant preoperational testing. Based on this comparison, Widows Creek would be about $1 million lower in cost and John Sevier about $5 million more expensive to operate over the demonstration period than a new plant at the Clinch River site. Taking credit for the value of the output of the demonstration plant, the net operating cost difference would be less than $1 million more for Widows Creek than for a new plant due to Widows Creek's smaller net electric rating and the disadvantage for John Sevier would be about $6.4 million.

The John Sevier plant is located in a higher fuel cost area than Widows Creek. In the past TVA has had difficulty in obtaining an adequate supply of coal at John Sevier and in the future the outlook is not expected to improve. Therefore, location of the LMFBR demonstration plant at John Sevier could partly alleviate the coal supply problem and possibly result in increased revenue to the project from the NSSS output which is not considered in this comparison.

The economic comparison including the effects of 30-percent escalation to the end of the demonstration period, indicates an advantage of about $54 million and $41 million, respectively, for Widows Creek and John Sevier over a new plant. Widows Creek has about a $13 million advantage over John Sevier which is largely attributed to the use of fuel oil for the reheaters at John Sevier.

Because of the changes in the national economy since the cost comparison was made, it was decided to review the results. Changes in the plant cost components should be similar for each of the alternatives. The cost of fuel oil for John Sevier was estimated as $1.00 per million Btu in the 1972 estimate. Based upon current projections, there would be a substantial increase in the cost of fuel for the oil-fired reheaters. These changes indicate the plant capital costs would be about the same and that the operating cost at John Sevier would increase; thus, giving less economic incentive for John Sevier as compared with the 1972 estimate. Within the limits of accuracy in the analysis, these changes would not significantly change the conclusions made in the 1972 study.

The differential costs of the alternative approaches are best estimates and are further subject to relatively large uncertainty. The evaluation of this uncertainty and hence, the detailed application of the results is a major problem in itself. However, in view of the project costs given in Section 8, the cost differentials are felt to be relatively small and do not provide a clear incentive to select any of the three sites based on cost considerations.

9.2.7 OTHER FACTORS CONSIDERED IN COMPARING THE CANDIDATE SITES

In addition to the information provided on the three candidate sites in the description of the sites and the economic evaluation, there were several other important factors considered in selecting the site for the demonstration plant project. Most of these focus upon the relative advantages and disadvantages and effectiveness of the hook-on concept versus an all-new plant in meeting project and programmatic objectives.

With respect to the plant design in general, the Clinch River Site offers a distinct advantage inasmuch as an all-new plant could be designed in an integrated fashion to accommodate the LMFBR nuclear steam supply system. Technical risk associated with design would thereby be minimized. In contrast, a hook-on plant would be constrained in terms of design flexibility since the nuclear steam supply system design must accept the 8

existing balance-of-plant parameters. Although from an engineering standpoint, it is not infeasible to design within the existing balance-of-plant parameters, and the loss of design flexibility is not in itself a compelling disadvantage, the hook-on concept offers a substantially less effective means for satisfying project and programmatic objectives.

In the first instance the hook-on concept would result in the expenditure of substantial design and development efforts and the assumption of significant technical risk without a commensurate benefit in terms of project and programmatic objectives. Since the benefits of the project are measured in terms of the information which it will provide for the LMFBR research, development and demonstration program, it would follow that the information obtained from the demonstration plant should have application to the LMFBR program. In this respect, the hook-on concept presents a significant disadvantage. Design of the hook-on plant would require substantial developmental efforts on continuous analog-type control functions in order that the turbine system would withstand plant design transients imposed on the nuclear steam supply system. Moreover, substantial efforts from a design and development standpoint would be required to apply nuclear standards and quality assurance requirements on existing hook-on plant equipment. While these efforts are not infeasible from a purely technical standpoint, there is a finite risk that design and development efforts would not be successful. More importantly, the expenditure of resources and assumption of risks on control system technology and the application of nuclear standards and quality assurance for the turbine system would represent one-time expenditures which would have virtually no return for future LMFBR demonstration plants. In short, the solution of turbine control system and standards/quality assurance problems would not demonstrate anything of value to the project or program.

As a corollary point, the use of a hook-on arrangement would result in a mismatch in steam conditions leading to degradation of turbine performance. Moreover, the relative age of the turbine system as compared with the nuclear island, when coupled with this degraded turbine performance, would

suggest that the reliability of the nuclear island and turbine system are potentially incompatible and would operate as a source of indeterminant, and perhaps substantial, risk to the fulfillment of project reliability objectives. Based upon prior experience in AEC developmental programs and more recent experience with commercial light water reactors, the risk associated with a reliability mismatch would present significant uncertainties as to the capacity of the hook-on arrangement to meet the reliability objectives of the Project. This finds support in the fact that unavailability of commercial LWR's has been as frequently caused by turbine island problems as by nuclear island problems. Although the risk associated with this reliability mismatch could be amenable to solution by design, the engineering and developmental efforts to upgrade the reliability of the relatively aged turbine machinery and to minimize this risk would have little value in terms of future LMFBR technology.

The hook-on concept carries with it an additional disadvantage in terms of impact upon utility system generating capacity. Under the hook-on concept the nuclear island would be merged with an existing turbine island and made interchangeable with an existing fossil fired boiler. As a result, the location of the demonstration plant as a hook-on unit on the utility generating system does not result in a net addition of system capacity. In fact, the use of a hook-on arrangement, with the resultant degradation of steam conditions and turbine performance, would result in a net decrease in system capacity. 8

Moreover, the need to shut down the facility during installation of the nuclear island with the turbine system would result in loss of generating capacity and incur a cost for replacement energy. The impact and cost associated with shutdown to tie in the NSSS would vary greatly with the circumstances and season of the year in which the shutdown occurs. The cost would be minimal if the outage occurred in an off-peak period and adequate system reserves were available. Under less favorable conditions, the cost to TVA could be substantial ($2 - 3 million) for a three month outage.

The implications of system capacity impacts are even more significant when viewed in terms of the project program objectives. Since the hook-on concept would not result in a net capacity addition, and owing to the higher operating costs (particularly of John Sevier with its oil fired re-heaters) associated with a hook-on nuclear island arrangement, there is a strong disincentive for TVA to offer to purchase the demonstration plant at its value to TVA on the TVA system following the demonstration period. If TVA does not elect to purchase the plant, it will be at ERDA's option and expense to decommission the plant or continue to operate the plant for ERDA. The continued operation of the demonstration plant beyond the demonstration period would allow for extended research and development on the LMFBR concept and advanced fuels. On the other hand, an all-new plant located at the Clinch River site might have sufficient economic value that continued operation could be justified, beyond the demonstration period and thus would maintain programmatic options open and viable beyond the demonstration period and assure greater flexibility in terms of the future course of the LMFBR program. Moreover, the all-new plant located at the Clinch River site offers the ancillary but not insubstantial benefit of providing flexibility for satisfying the power requirements of the Oak Ridge Gaseous Diffusion Plant in the future. 8

Table 9.2-6 includes some other somewhat intangible considerations which played a part in the overall site selection decision. Though the intangible considerations are difficult to quantify, the results indicate more advantages for the Clinch River site than for the other two sites, with Widows Creek being the least desirable.

9.2.8 SITE SELECTION CONCLUSION

Analyses of relevant siting, environmental and direct economic cost factors for the three candidate sites disclose no clear-cut or overriding advantages for any single site. From a siting and environmental standpoint, the analyses disclose nothing which would preclude use of either the Widow's Creek, John Sevier, or Clinch River sites for the LMFBR 8

demonstration plant. There are no significant differences in relevant siting and environmental factors between the three candidate sites, and such differences as do exist are amenable to treatment by the design within the limits of existing technology. As a practical matter, the three candidate sites are equivalent from a site characteristic and environmental standpoint.

From an economic cost standpoint, comparisons of direct economic cost estimates for demonstration plants at the three candidate sites have suggested a slight advantage to the two hook-on sites in relation to a new plant sited at Clinch River. However, the differences in direct cost estimates for the three candidate sites are within the range of uncertainties inherent in the cost analysis methodology, and cannot be characterized as dispositive.

There being no distinct siting, environmental or economic cost advantage to any particular candidate site, analyses of the relative merits of the candidate sites was carried out in terms of their comparative effectiveness as alternatives for meeting project and programmatic objectives. Upon such analysis, it is apparent that an all-new plant located at the Clinch River site offers decisive advantages from the standpoints of minimizing technological and developmental risk, and maximizing the potential for fulfilling project and programmatic objectives.

In summary, the all-new concept offers a substantial advantage in terms of design flexibility, information of value to the LMFBR program, reliability, and maximum flexibility for satisfaction of project and programmatic objectives. Thus, on the basis of the foregoing analysis, it was concluded that the all-new plant located at the Clinch River site is the preferred candidate plant/site alternative.

TABLE 9.2-1

TVA STEAM PLANT CHARACTERISTICS FOR DEMONSTRATION PLANT SITING ADAPTABILITY

Plant	Units	Unit Nameplate Capacity-MWe	Throttle Steam Pressure $16/in^2$ gage	Throttle/ Reheat Steam Temp. °F	Meets Size Criteria	Acceptable Seismology	Candidate Site
Allen	3	330.00	2400	1050	Yes	No	
Browns Ferry*	3	1152.00	950	540	No	--	
Bull Run	1	950.00	3500	1000/1000	No	--	
Colbert	1&2	200.00	1800	1050/1050	Yes)	]	]
	2-4	223.25	1800	1050/1050	Yes)	] Yes	] Yes
	5	550.00	2400	1050/1000	No	--	
Cumberland	1&2	1300.00	3500	1000/1000	No	--	
Gallatin	1&2	300.00	2000	1050/1050	Yes)	] Yes	] Yes
	3&4	327.60	2000	1050/1050	Yes)	]	]
John Sevier	1	223.25	1800	1050/1050	Yes)	] Yes	] Yes
	2-4	200.00	1800	1050/1050	Yes)	]	]
Johnsonville	1-4	125.00	1450	1000	Yes)	]	
	5-6	147.00	1450	1000	Yes)	] No	
	7-10	172.80	2000	1050/1000	Yes)	]	
Kingston	1-4	175.00	1800	1000/1000	Yes)	]	]
	5-9	200.00	1800	1050/1050	Yes)	] Yes	] Yes
Paradise	1-2	704.00	2400	1050/1000	No	--	
	3	1150.20	3500	1000/1000	No	--	
Sequoyah*	1-2	1220.58	765	515	No	--	
Shawnee	1-10	175.00	1800	1000/1000	Yes	No	
Watts Bar	1-4	60.00	850	900	No	--	
Watts Bar Nuclear Plant	1-2	1269.90			No	--	
Widows Creek	1-4	140.63	1450	1000	Yes	Yes	Yes
	5-6	140.63	1800	1000/1000	No	--	
	7	575.01	2400	1050/1000	No	--	
	8	550.00	2400	1050/1000	No	--	
X-14 & X-15*	1-2	1332.00			No	--	

*Nuclear Plants

TABLE 9.2-2

SITE DATA FOR CANDIDATE SITES - NEW

NO.	SITE	RIV MI	PLT GR EL	MAX POSS FL EL	COND COOLING	ACCESS FACILITIES HWY	ACCESS FACILITIES RAIL	ACCESS FACILITIES BARGE	FDN CONDITIONS	DIST FROM POPULATED AREAS	TRANS LINES 161 KV
	TENN RIVER										
1.	Spring Creek (Wheeler Res)	283L	580	573	Auxiliary Cooling Req'd	7±mi (A1a20)	7±mi (SOU)	Yes	Not investigated	18±mi to Athens Ala (pop 14,000±) 19±mi to Decatur Ala (pop 37,800±)	1-3 mi SW
2.	Murphy Hill (Guntersville Res)	370L	618	618	Auxiliary Cooling Req'd	16±mi (US431)	27±mi (L&N)	Yes	Core drilling indicates top of rock 21 to 61 ft below general site grade	11±mi to Guntersville Ala (pop 6,500±) 15±mi to Scottsboro Ala (pop 9,300±)	1-Just across reservoir. Proposed line and substation 3 mi S
3.	Blythe Ferry (Chickamauga Res)	499L	730	725	Auxiliary Cooling Req'd	0.3±mi Tenn 80	22±mi (SOU)	Yes	Seismic determinations indicate top of rock at favorable depth below plant grade	6±mi to Dayton Tenn. (pop 4,400±)	1-6 mi SE
4.	Caney Creek (Watts Bar Res)	562R	820	775	Auxiliary Cooling Req'd	1.5±mi (US70 & 27)	6±mi (L&N)	Yes	Not investigated*	4.5±mi to Rockwood Tenn (pop 5,300±) 5.5 mi to Kingston Tenn (pop 4,200±)	1±mi NW 1-4 mi SE across reservoir

(Continued)

TABLE 9.2-2 (Continued)

NO.	SITE	RIV MI	PLT GR EL	MAX POSS FL EL	COND COOLING	ACCESS FACILITIES HWY	RAIL	BARGE	FDN CONDITIONS	DIST FROM POPULATED AREAS	TRANS LINES 161 KV
	CLINCH RIVER										
5.	Clinch River (Watts Bar Res)	16R	800	785	Auxiliary Cooling Req'd	2±mi (Oak Ridge Turnpike)	2±mi Spur of SOU	Yes	Core drilling indicates lime stone and silt stone underlies site Geologists believe adequate foundation is available	8±mi to Kingston Tenn (pop 4,200±) 10 mi to Oak Ridge Tenn (pop 28,000±)	1-passes through site 1±mi N
	FR. BROAD RIVER										
6.	Taylor Bend (Douglas Res)	64R	1055	1016	Auxiliary Cooling Req'd	2±mi (US 25E)	4±mi (SOU)	No	Currently under investigation	7±mi to Newport Tenn (pop 7,300±) 12±mi to Morristown Tenn (pop 20,300±)	1-6±mi N 2-9±mi N
	HOLSTON RIVER										
7.	Buck Hollow	39L	1050	950	Auxiliary Cooling Req'd	4±mi (US 11E)	4±mi (SOU)	No	Currently under investigation	5±mi to Jefferson City (pop 5,100±)	1-passes through site 1-2±mi S
8.	Lee Valley (Cherokee Res)	88L	1120	1089	Auxiliary Cooling Req'd	2±mi (Tn 66A)	6±mi (SOU)	No	Geologists say site is underlain by limestone and shale	10±mi to Rogersville Tenn (pop 4,000±) 11±mi to Morristown Tenn (pop 20,300±)	3-passes just north of the site

(Continued)

TABLE 9.2-2 (Continued)

NO.	SITE	RIV MI	PLT GR EL	MAX POSS FL EL	COND COOLING	ACCESS FACILITIES HWY	RAIL	BARGE	FDN CONDITIONS	DIST FROM POPULATED AREAS	TRANS LINES 161 KV
9.	Phipps Bend	122R	1195	1152	Auxiliary Cooling Req'd	2±mi (US 11 W)	1.5±mi (SOU)	No	Currently under investigation	11.5±mi to Rogersville Tenn (pop 4,000±) 16±mi to Kingston Tenn (pop 32,000±)	2-9±mi SW
	CUMBERLAND RIVER										
10.	Johntown (Old Hickory Res)	285R	536	514	Auxiliary Cooling Req'd	1±mi (Tn 25)	5.5±mi (L&N)	Yes	Extensive core drilling indicates satisfactory foundation available	8±mi to Harrisville Tenn (pop 2,200±) 18±mi to Carthage Tenn (pop 2,500±)	2-5±mi S
	DUCK RIVER										
11.	Rieves Bend (Proposed Columbia Res)	146L	700	644	Auxiliary Cooling Req'd	3±mi (Tn 50)	4±mi (L&N)	No	Core drilling indicates satisfactory foundation available	5±mi to Columbia Tenn (pop 21,500±)	1-10±mi S

TABLE 9.2-3

A SUMMARY OF COMPARISONS BETWEEN THE JOHN SEVIER, WIDOWS CREEK, AND CLINCH RIVER SITES

	JOHN SEVIER	WIDOWS CREEK	CLINCH RIVER
A. FEASIBILITY CONSIDERATIONS			
Based upon a preliminary analysis, each site represents a feasible location to build the plant.			
Foundation Conditions	Probably the best foundation conditions of the three sites.	Several potential problems have been identified. Adequate foundation could be designed.	Similar to TVA's Bull Run Steam Plant. Adequate foundation could be designed.
Seismology	Seismology is similar for all the sites. No active faults in vicinity of any of the sites and no physical evidence of any recent seismic activity at any of the sites.		
Flooding	Site grade lies below maximum possible flood (MPF) level elevation which would require special flooding protection.	Site grade lies below MPF level elevation which would require special flooding protection.	Plant grade can be established above MPF level elevation. Best site from this standpoint.
Cooling Water	Adequate based on John Sevier Steam Plant operations.	Most acceptable site from standpoint of cooling water availability throughout the year.	Will require supplemental cooling.
Meteorology	Slightly better than Clinch River site.	Least desirable site from standpoint of overall meteorology.	Slightly less favorable than John Sevier site.

(Continued)

TABLE 9.2-3 (Continued)

	JOHN SEVIER	WIDOWS CREEK	CLINCH RIVER
Available Land	All three plant sites can accommodate the facilities and an exclusion area radius of 2,000 feet.		
Access	Highway and rail facilities available. Must tie into facilities at the plant.	Highway, rail and barge facilities available. Tie into facilities may require some rerouting of existing lines plus additional track to the NSSS.	Highway, rail and barge facilities can be added. Two miles of rail track and two miles of improving or building of roads is required.
Transmission Facilities	No additonal off-site transmission lines required with only some tie-in equipment needed.		No additional off-site transmission lines required.* Tie-in to 161-kV line and switchyard needed.
Steam Conditions	Degraded from existing conditions. Considered feasible but will have increased turbine erosion and associated maintenance.	Degraded from existing conditions. Considered feasible but moisture may be more of a problem.	Set by plant design.

(Continued)

TABLE 9.2-3 (Continued)

	JOHN SEVIER	WIDOWS CREEK	CLINCH RIVER
Plant Control	Three sodium loops supplying two steam turbines considered feasible, but a difficult control problem. Reheat control adds complexity. Potential for decreased reliability.	Less of control problem than John Sevier.	Simplest scheme with one turbine. More prototypical of large commercial plants.
Plant Size	Set by turbine.	Set by turbine.	Set by program needs.
Safety	No question that plant can be made safe at each site. There is a possible question on the extent to which Nuclear Standards and Quality Assurance requirements can be applied to existing hook-on plant equipment.		
Licensability	Considered licensable.	Considered licensable.	Considered licensable.

B. ENVIRONMENTAL FACTORS

Based upon these preliminary analyses, it is concluded that the demonstration plant could be located at any of the three proposed sites without significant adverse impacts to the environment and none of the sites offer significant siting advantage.

(Continued)

TABLE 9.2-3 (Continued)

	JOHN SEVIER	WIDOWS CREEK	CLINCH RIVER
Population			
Total Population within 50 miles (1970)	694,295	783,760	678,800
Total Population within 10 miles			
1970	18,955	15,105	41,895
2010	27,560	24,985	65,089
Total population within 2 miles	725	359	No significant concentration.
Land Impact			
Additional Land Committed - Acres	None	None	Some (to be determined)
Land Use Designation	Industrial	Industrial	Industrial
Proximity to National Monuments or Historic Sites	Andrew Jackson historical site within 25 miles.	Russel Cave within 15 miles.	Museum of Atomic Energy and ORNL Graphic Reactor within 10 miles.

(Continued)

TABLE 9.2-3 (Continued)

	JOHN SEVIER	WIDOWS CREEK	CLINCH RIVER
Water Impact			
Distance to Nearest Surface Water User	31.4 miles	21.7 miles	1.6 miles
Potable Water Intake	3.46 MGD	1.19 MGD	2.5 MGD
Additional Heat Rejection to Reservoir from LMFBR	Essentially none	Essentially none	Small with the cooling towers.
Air Quality Impact	SO_2 emissions from operation of oil-fired reheater of 1.4 tons/hr. However, operation of LMFBR will decrease SO_2 emission levels when plant would otherwise be required.	Reduces overall system emission levels when LMFBR is in operation. In comparison to John Sevier, these sites have less emission levels by amount contributed by operation of oil-fired reheater during operation of LMFBR.	

*Further study after the site was selected showed some additional off-site transmission lines would be needed (see Section 3.9).

TABLE 9.2-4

PRINCIPAL PLANT PARAMETERS FOR THE DEMONSTRATION PLANT ALTERNATIVES

Type	New Plant	Hook-on Non-Reheat	Hook-on Reheat
Site	Clinch River	Widows Creek	John Sevier
Steam Cycle	Steam reheat	Non-reheat	Oil-fired reheat
No. of Turbine-generator Units	1	3	2
Reactor Thermal Rating (MW)	950	950	810
Oil Thermal Input (MW)	-	-	156
Net Electrical Output (MW)	361	342	346
Net Capacity Derating (MW)*	-	27	36

* From normal net full-load capacity when operated on fossil boilers.

TABLE 9.2-5

SUMMARY OF ECONOMIC COMPARISON OF DIFFERENTIAL COSTS OF ALTERNATIVES TO THE CLINCH RIVER BREEDER REACTOR

	Millions of Dollars	
Plant Cost	Widows Creek	John Sevier
Site Development	-20.8	-20.8
Nuclear Plant (NSSI)*	0	- 1.7
Turbine Plant	-46.2	-46.2
Hook-on	+31.9	+37.7
Cooling Facilities	- 4.5	- 4.5
Switchyard	- 2.7	- 2.7
Subtotal (1972 $)	-42.3	-38.2
Five-Year Demonstration Period Operation Costs		
Nuclear Fuel Fabrication**	0	- 6.0
Fuel Oil	0	+12.8
Non-fuel O&M	- 1.2	- 1.9
Subtotal	- 1.2	+ 4.9
Potential Power Credit at 3.5 mils	+ 1.9	+ 1.5
Net Operating Costs (1972 $)	+ 0.7	+ 6.4
Subtotal Differential Cost	-41.6	-31.8
Escalation Allowance at 30%	-12.5	- 9.5
Total Differential Costs (1972 $)	-54.1	-41.3

* Based on nominal preliminary estimates provided by PMC derived largely from proposals submitted to PMC by reactor manufacturers.

** Nuclear fuel fabrication cost does not include the cost of other fuel cycle materials and services that will be provided by AEC; the difference in cost indicated is due to the smaller reactor size at John Sevier.

TABLE 9.2-6

INTANGIBLE CONSIDERATIONS

	John Sevier	Widows Creek	Clinch River
The following considerations cannot be easily quantified but may have some bearing on the decision:			
Apparent public acceptance (as judged from inquiries and responses from public and civic organizations)	Excellent	Questionable	Good to excellent
Ability to accommodate construction force without major impact on community	Poor	Fair	Good
Possible impact on construction forces for other TVA projects	Minimal	Could cause some problems	Minimal
Interference with other announced TVA R&D projects	None	Possible interference with stack gas cleaning program	None
Effect on power supply capability	Possible slight disadvantage	Greatest potential for disruption	Possible slight advantage
Availability of public facilities and convenience as a show place	Fair	Poor	Good
Access to special purpose nuclear facilities and technical capability at AEC facilities	Fair	Poor	Excellent
Convenience to AEC operations offices in Oak Ridge	Fair	Poor	Excellent

TABLE 9.2-6 (Continued)

	John Sevier	Widows Creek	Clinch River
Convenience to TVA Power offices	Poor	Good	Fair
Convenience to TVA Knoxville offices	Fair	Poor	Good
Accommodations for PMC offices	Poor	Poor	Good

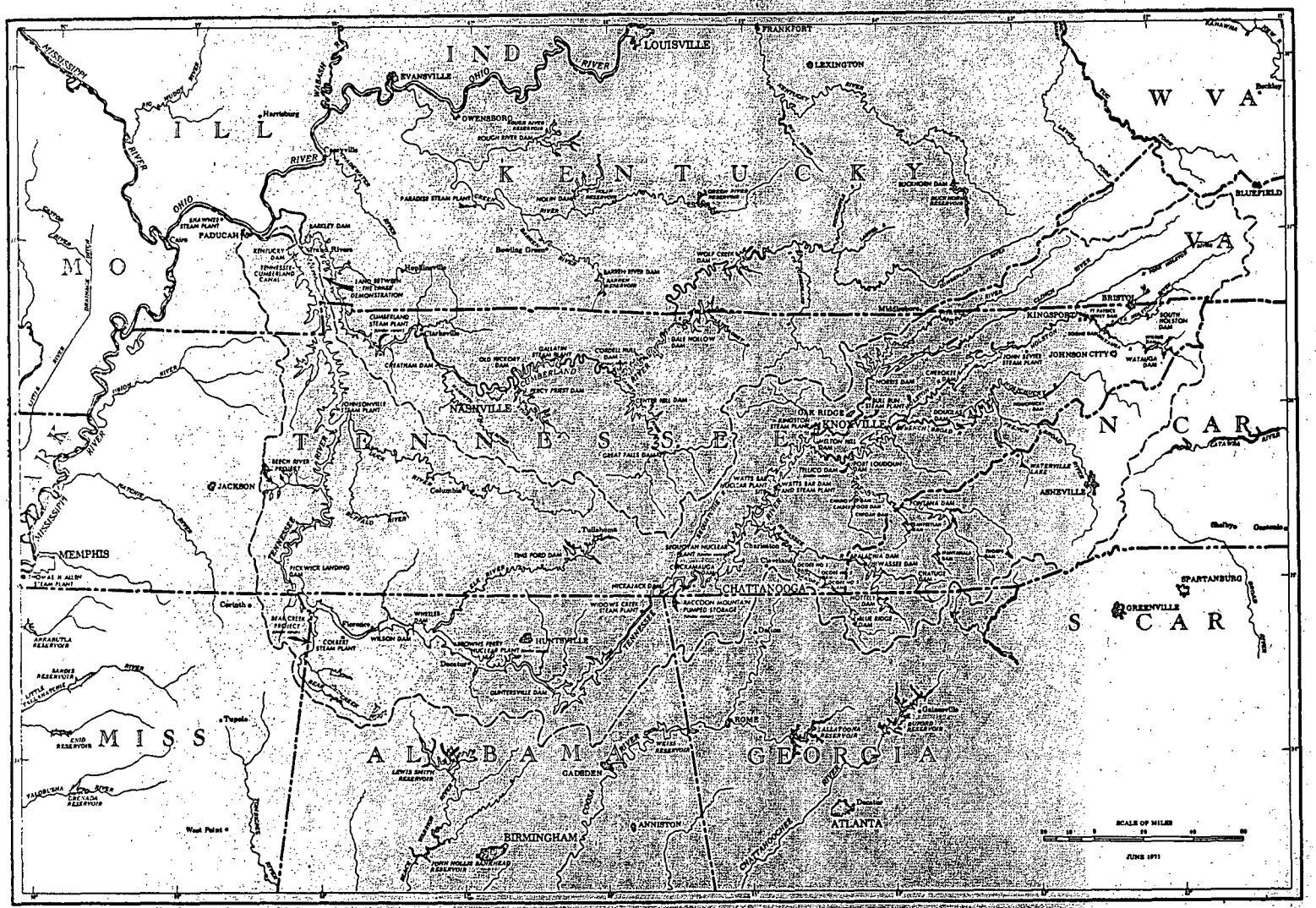

Figure 9.2-1 TVA CANDIDATE PLANTS FOR A HOOK-ON ARRANGEMENT

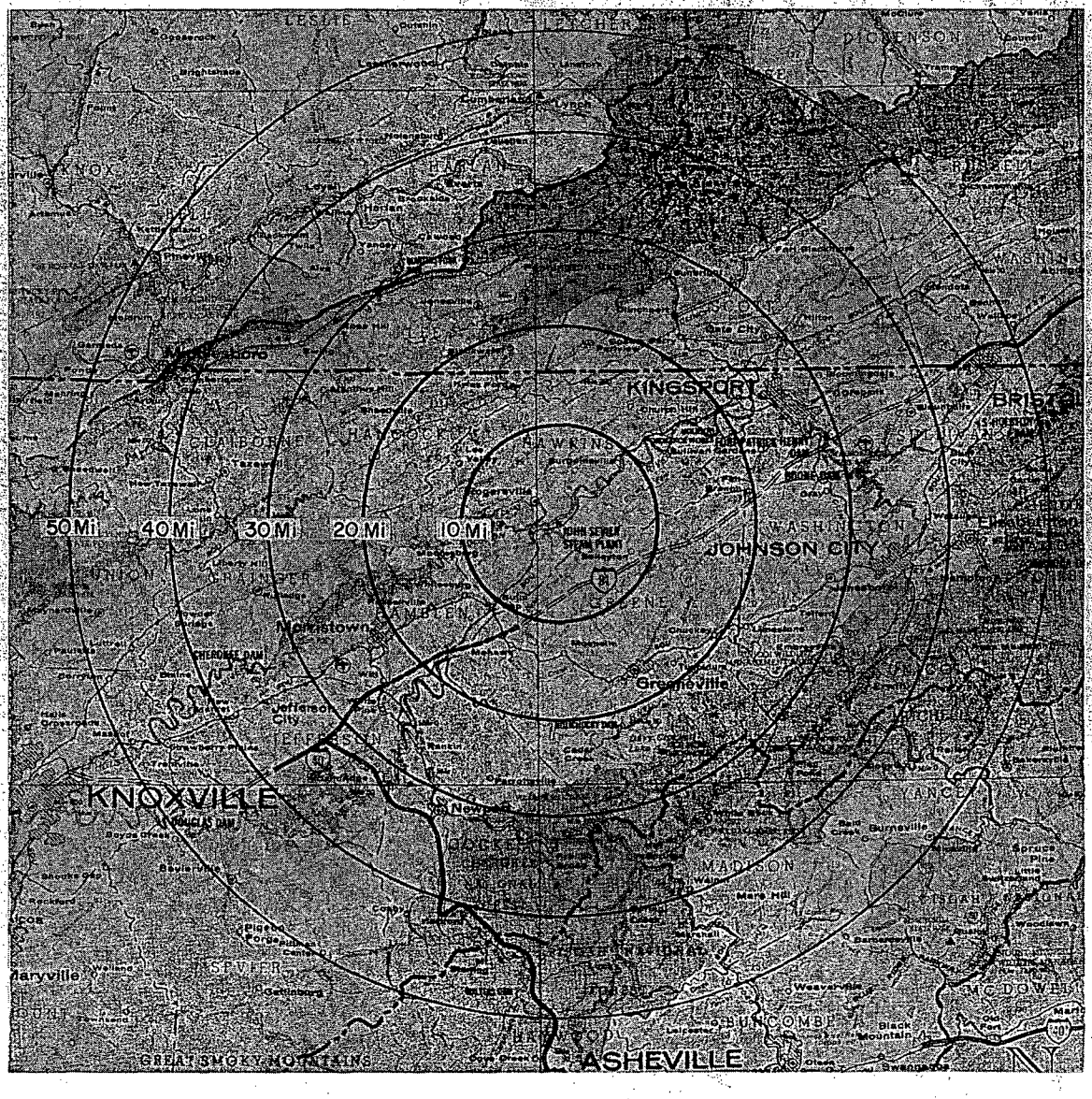

Figure 9.2-2 JOHN SEVIER SITE

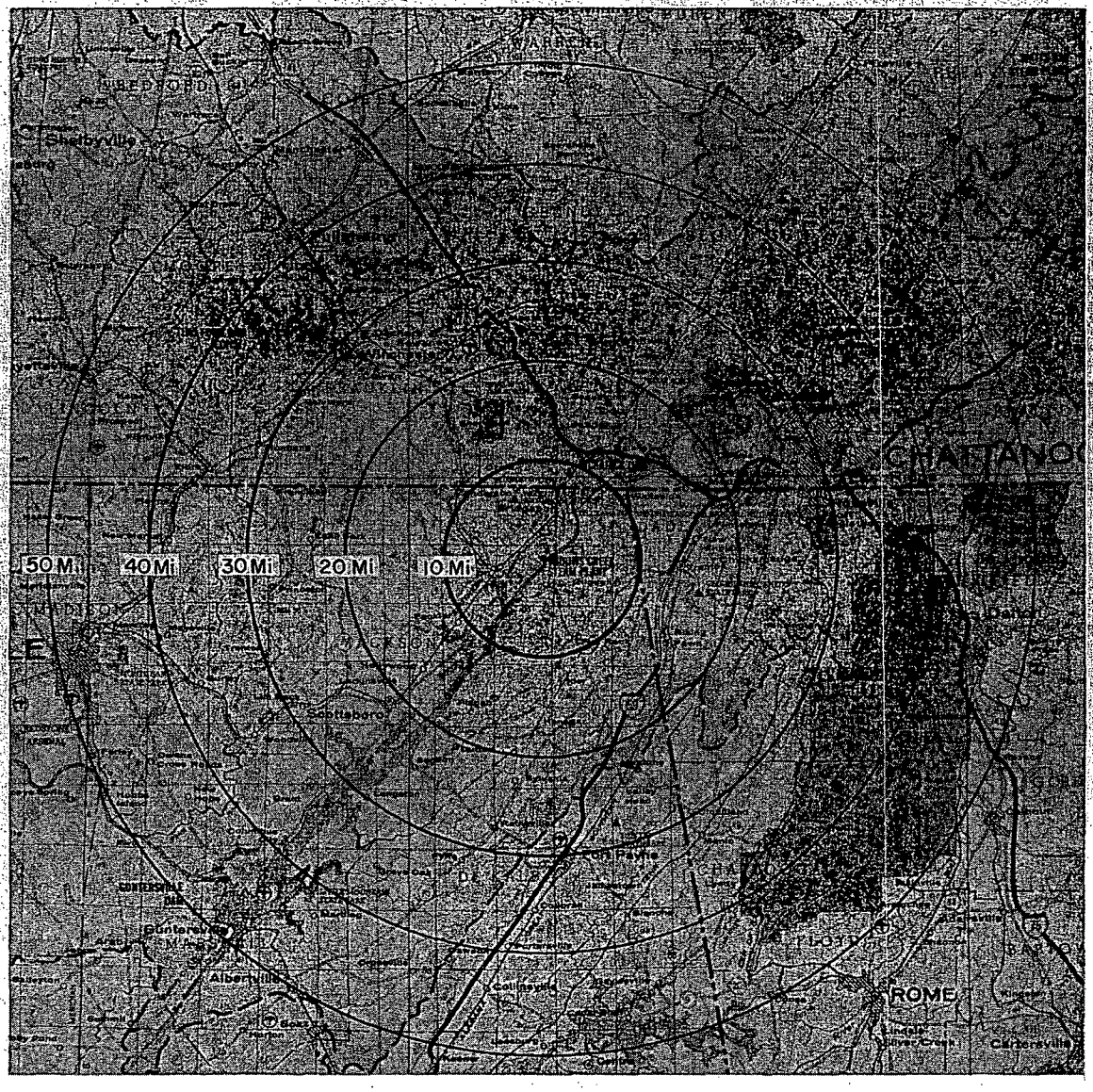

Figure 9.2-3 WIDOWS CREEK SITE

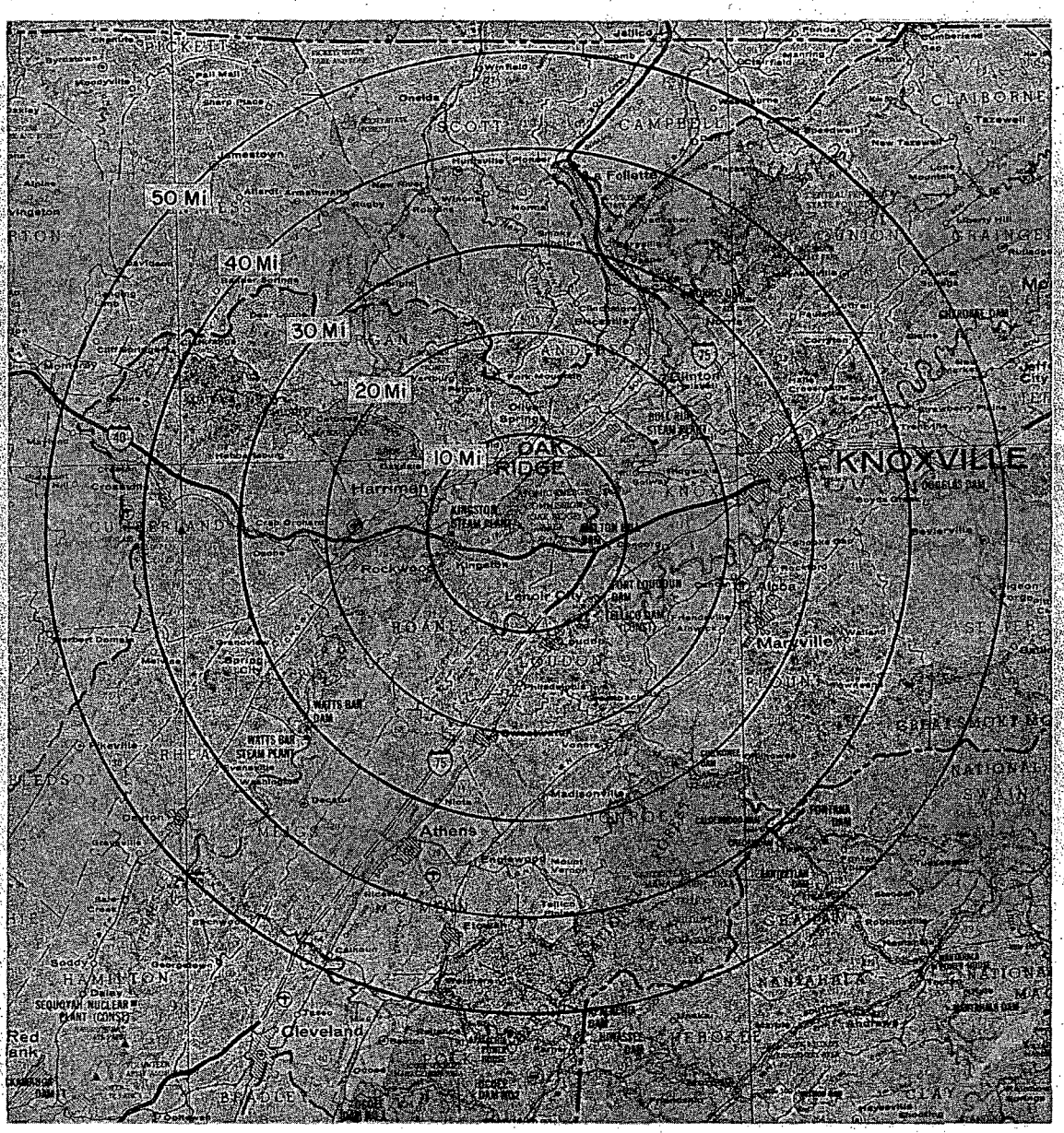

Figure 9.2-4 CLINCH RIVER SITE

10.0 PLANT DESIGN ALTERNATIVES

This section of the ER discusses the alternative systems designs as they were presented over the period October, 1974 through February, 1977, which resulted in the acceptable findings published in the NRC's FES (NUREG-0139). Since the publication of the FES in February 1977, there have been no significant technological breakthroughs which would alter the relative effectiveness ranking of the various candidate systems. Similarly, the cost rankings would remain the same, since the effects of inflation would increase costs approximately equally. Therefore, a detailed update to the ER which discusses the various alternatives and their costs is not necessary nor is it justified. The various sections have been revised to update the descriptions of the chosen alternative systems so that these descriptions are consistent with information appearing in other Sections of the ER and in the PSAR. 13

The following discussions of alternatives provides the information upon which the 1977 FES (NUREG-0319) was based.

It must be recognized that any act of man or nature has some impact upon the environment. It is also important to note that although adverse impact can be reduced by the allocation of additional resources for environmental protection, the law of diminishing returns applies to the resources expended. This point was recognized by the U.S. Congress in enacting the National Environmental Policy Act of 1969 and was further reinforced by the U.S. Court of Appeals for the District of Columbia in 1971 in the Calvert Cliffs Decision. A benefit-cost analysis of the proposed project (the cost-effectiveness portion in particular) brings into account the environmental aspects of the proposed project and, therefore, assists in the implementation of both the letter and spirit of the National Environmental Policy Act of 1969.

The benefit-cost analysis of the Clinch River Breeder Plant requires a discussion of the proposed nuclear power station and a comparison of the proposed station and its feasible alternatives.

The environmental effects of a nuclear power station can be associated with the operation of certain identifiable systems, each of which has been selected, through evaluation of environmental, economic and other costs, as the optimal choice for its category. 13

In some instances, the interaction of these systems may be such as to require their selection on the basis of an optimal combination rather than on the basis of individual optimal systems. The weak point in this form of analysis is not the logic but (1) the availability of realistic data on many of the parameters associated with each of the systems and (2) meaningful quantitative estimates on the importance of environmental changes and the extent of change assignable to a particular alternative. Although energy requirements, hardware costs and economic considerations are relatively easy to predict, social benefits and costs, such as the impact upon human health and safety and preservation of the biological ecosystem, are not well defined and are therefore, by necessity, more subjective.

Whenever there is no objective method of determining benefits or costs, or when effects are highly uncertain because of the lack of basic understanding and knowledge they shall, nonetheless, be identified and discussed. All relevant knowledge must be included in attempting to come to a reasonable judgement. Hence, "benefits" and "costs" as used herein are defined on a broad scope. This approach is in agreement with the philosophy of the Calvert Cliffs Decision and U.S.A.E.C. guidelines.

To provide continuity and uniformity to the logic process through which the alternatives study for each plant system is conducted, a single general format for Section 10 is employed. A guide to its structure appears in Table 10.0-1.

TABLE 10.0-1

GENERAL OUTLINE FOR SECTION 10.0

10.X System

Purpose of System
Identification of Selected System
Identification of Alternatives

10.X.1 Description of Alternatives

[All alternatives identified above are described generically.]

10.X.2 Elimination of Impractical Alternatives

[Any alternatives that lack feasibility on the basis of technical, economic, or plant/site-adaptability considerations are identified and the reasons for their elimination given. No further environmental or economic evaluations are performed for these alternatives.]

10.X.3 Specifications for Reasonable Alternatives

[Those alternatives not eliminated in 10.X.2 are identified and their site/plant-specific design and operational characteristics are presented.]

10.X.4 Environmental Costs

[The potential environmental costs are identified and each reasonable alternative evaluated.]

10.X.5 Economic Costs

[The economic costs involved are identified and each reasonable alternative evaluated.]

10.X.6 Comparison of Alternatives

10.X.6.1 Direct Comparison of All Reasonable Alternatives

10.X.6.2 Reasons for Selection of Chosen System

10.1 COOLING SYSTEM

During the operation of any fossil or nuclear-fueled power plant, a large portion of the thermal energy of the steam is not converted into useful mechanical energy and must be removed as waste heat. Dissipation of this excess heat is the function of the cooling system. The environmental significance of heat rejection and the influence of the processes governing it upon the design of other plant systems make the selection of the cooling system one of the most important and comprehensive of the alternative studies.

Potential mechanisms for heat rejection from the CRBRP include open and recirculating systems involving total and partial use of the Clinch River as a heat sink, and evaporative and non-evaporative cooling through the creation of artificial waterbodies and employment of cooling towers. Environmental concerns associated with these approaches include the effects of thermal discharges on Clinch River aquatic life, condensed vapor plume formation, ground fog and ice, drift, energy and water consumption, land use and aesthetics. Selection of a system that reduces the adverse environmental effects to that degree consistent with the results of benefit-cost analysis is the desired goal of the cooling system alternative study.

A mechanical draft wet cooling tower, is the selected cooling system for the CRBRP. Final selection of a linear cell array or circular cell array will be made based on economic cost. For purposes of description and environmental analysis in other sections of the ER, the mechanical draft wet cooling tower linear cell array is used. This choice provides a slightly conservative estimate of the environmental impacts, since a comparison of linear versus circular cell array shows the environmental impact from ground fogging and drift deposition to be slightly greater for the linear array. 6

Alternative cooling systems considered for the CRBRP are: (1) Once through cooling; (2) Cooling lake; (3) Spray pond; (4) Natural draft wet cooling tower; (5) Mechanical draft wet cooling tower; (6) Mechanical draft dry cooling tower; and (7) Mechanical draft wet/dry cooling tower.

10.1.1 DESCRIPTION OF ALTERNATIVES

10.1.1.1 ONCE THROUGH COOLING

Although current apprehension over the effects of thermal discharges and EPA regulations[1] will severely limit its use, once through cooling remains the simplest, most economic and most effective means of dissipating condenser thermal energy. Once through cooling employs a natural surface water source to provide cooling water on a non-recirculatory basis. Ultimate rejection of the total heat load extracted from the condenser is to this water source. The large quantities of cooling water required necessitate the availability of a surface source of such size and character that sufficient year-round supply and assimilative capacity are assured.

10.1.1.2 COOLING LAKE

When once through use of a natural surface water source is not practical but ample land suitable for impoundment is available, a cooling lake is an attractive alternative. A cooling lake serves as a heat sink and reservoir by providing for the bulk of the dissipation of condenser thermal energy and permitting recirculation of cooling water. In this manner, the cooling lake and plant form a nearly closed water cycle. Interface with a natural water body is needed because blowdown of a portion of the cooling lake water is required to prevent excessive accumulations of chemicals in the lake. This action necessitates withdrawal of makeup water from the natural source as well.

Heat discharged to the cooling lake is ultimately rejected to the atmosphere through the natural processes of convection, evaporation and

radiation. As these energy transfer modes are relatively slow acting in a lentic environment, the size of cooling lakes must be large, on the order of $\geq$ 1 acre per MWe.

Cooling lakes are usually man-made impoundments created by damming existing streams or pumping water into suitable basins. Environmentally, they offer the advantages of reduced impact on the natural water body, multiple use potential such as boating or fishing and aesthetic attractiveness.

10.1.1.3 SPRAY POND

A modification of the cooling lake that may be employed to enhance heat dissipation or reduce land requirements is the spray pond. Spraying atomizes the warm water increasing its effective surface area and the relative velocity between the water and air. The amount of heat dissipated through evaporation is significantly increased producing more rapid cooling and higher water consumption.

In conventional spray ponds, the heated effluent is pumped from the condenser directly through spray nozzles into the pond. A recent innovation utilizes modular spray units mounted on floating platforms. Each modular unit is equipped with a pump for drawing water from beneath the platform. Any number of modules can be employed. This system produces better mixing within the pond and better cooling by continual respraying of the heated effluent.

Current studies indicate that a spray pond requires only about five percent of the land needed for an equivalent cooling lake. Thus, it is an environmentally attractive alternative where land use is limited. However, the use of a spray pond increases the rate of water consumption and the potential for fogging and introduces drift to the cooling lake system.

10.1.1.4 NATURAL DRAFT WET COOLING TOWER

A natural draft cooling tower is designed so that a natural draft is created upward through the tower because of the difference in density of the warmed air inside the tower and the exterior surrounding air. The flow rate is proportional to the density difference and to the tower height. Air drawn through the tower is contacted with the cooling water, which is continually redistributed into fine droplets while falling through the tower packing (fill) to provide a large air-water surface contacting area. Heat is transferred from the water to the air by sensible convective transport and evaporation. Heat transfer occurs as a result of direct contact between the naturally drafted air and the recirculating cooling water; thus, the name -- natural draft wet cooling tower.

Much of the cooling in a wet tower is achieved by the evaporation of a portion of the water. The exit air stream, warmed and saturated with water vapor, leaves the tower and mixes with the atmospheric air. Excess water vapor in this air mixture is condensed, forming a plume. In addition to the water vapor, droplets of water in the exit air stream can be blown out of the tower as drift. Tower height is increased as much as possible to achieve the greatest air flow; typical natural draft cooling tower heights for large commercial plants are as much as 500 feet. Base diameter for these structures are almost equal to the height.

Formation of a condensed vapor plume under certain meteorological conditions is one of the environmental concerns associated with the natural draft wet tower. Typically, the tower height reduces the potential for ground fogging. The high level plume, however, does represent a possible hazard for local air traffic and an aesthetic intrusion. Other environmental concerns for the natural draft tower include salt damage to foliage as a result of drift deposition, water consumption due to the evaporative cooling process and the aesthetic impact of the structure itself.

Because of the massiveness of the structure, the natural draft cooling tower is expensive to construct. However, the operating costs are relatively low because natural forces are used to move the air. The necessity to warm the air to get drafting causes temperatures in the tower to be greater than might otherwise be desirable. Thus, the degree of cooling is reduced and the relative performance of the turbine generator is correspondingly decreased due to back pressure. This introduces a capability (electrical generating capacity) penalty into the cost of the tower.

10.1.1.5 MECHANICAL DRAFT WET COOLING TOWER

Cooling in a mechanical draft wet tower proceeds by the same heat transfer modes described in the previous section on the natural draft wet tower. Air flow, however, is mechanically induced by electrically powered fans. Natural drafting is not required and the massive tower size and attendant structural configuration problems are reduced. Mechanical draft towers can be built in a relatively compact and standardized fashion.

In a manner similar to the natural draft tower, the mechanical draft wet cooling tower consumes large volumes of water, creates a plume and has drifting of water droplets. Because of construction features, the mechanical draft tower is less expensive to purchase initially than the natural draft tower but the power used to drive the fans causes a significant increase in the operational cost. Individual plumes are created for each fan cell and are exhausted at heights of 60 to 80 feet above ground level, creating a potential for localized ground fogging.

10.1.1.6 MECHANICAL DRAFT DRY COOLING TOWER

In areas where water consumption is a critical environmental concern, dry cooling becomes a competitive alternative system. The mechanical

draft dry cooling tower is designed for 100 percent closed cycle cooling with no requirement for makeup from a natural water body.

Dry cooling towers dissipate heat by conduction and convection. Heated cooling water from the plant's condensers is pumped through banks of finned-tube heat exchanger surfaces. Heat in the water is transferred to the metal walls of the tubing, then to air which flows up through the cooling tower, past the tubing and out of the tower. Water and air do not come into direct contact; therefore, water is not lost by evaporation. Because the heat transfer does not include the latent heat of evaporation, dry cooling towers require both greater air flows and larger air temperature increases in order to dissipate the same amount of heat as a comparable evaporative cooling system.

Wet towers rely on an overall enthalpy driving force between water and air to transfer heat between phases; dry towers rely on a temperature driving force between the water inside the tubes and the air flowing outside. Therefore, the dry bulb temperature of the air is the theoretical limit of cooling which can be accomplished by dry towers.

In addition to eliminating water consumption, the dry cooling tower does not produce drift, condensed vapor plumes or thermal discharges. However, the non-utilization of evaporative cooling that results in the above benefits imposes several environmental and economic costs. More cells are required to dissipate the same heat load by dry cooling than are needed for wet cooling. Land use and energy requirements (for fan power) are increased. Dry cooling tower cold water temperatures are considerably higher than those produced by wet towers; therefore, higher capability penalties must be assessed and plant efficiency is reduced.

10.1.1.7 MECHANICAL DRAFT WET/DRY COOLING TOWER

An effective way of reducing cooling tower plume formation and, particularly, the hazards of fogging and icing without resorting to dry cooling is the employment of a standard wet evaporative cooling tower in combination with a dry heat exchanger system. This hybrid design -- the wet/dry cooling tower -- modifies the exhaust air condition by utilizing nonevaporative heat transfer to handle part of the cooling requirement. In this way, supersaturation of the exhaust air stream is prevented and a visible plume is not created.

In the wet/dry tower, finned-tube heat exchangers (dry section) are installed along with the packing (wet section) of a typical wet cooling tower, as shown in Figure 10.1-1. Hot water serves as the tube side heat exchanger. Dry section cooling is inherently less efficient than wet section cooling. When the system is operated totally dry, or at some combination of wet/dry, the overall cold water temperature returned to the plant will be higher than it would be for the totally wet mode operation. It is usually not economical, practical or necessary from a fog control standpoint to design the system for totally dry operation.

Plant operation and fog control requirements make it practical and economical to operate at water temperatures above the level that a totally wet section will produce during cold weather when fog becomes a major concern. Usually a design level combination of wet/dry cooling with a stated maximum system cold water temperature can be selected which will eliminate fog plume problems without raising the cold water temperature above a level that reduces plant operating efficiency.

Current technology favors a combination wet/dry system for controlling plume formation. Flexibility in the wet/dry system allows for efficient evaporative cooling in the warmer months, combined with a variable controlled dry heat exchange section for fog control during cold months.

The quantity of air flow through the wet and dry sections can be controlled by a feedback system which senses cold water temperature. In this manner, cold water temperature can be maintained at an upper limit, while evaporation, and thus fogging, is kept to a minimum.

In addition to its environmental advantage of plume control, the wet/dry tower offers reductions in water consumption and drift rate compared to all-wet cooling. However, winter cold water temperatures are higher due to the utilization of the dry sections resulting in a warmer blowdown and reduced generating capability.

10.1.2 ELIMINATION OF IMPRACTICAL ALTERNATIVES

10.1.2.1 ONCE THROUGH COOLING

The Committee on Power Plant Siting of the National Academy of Engineering has established the following criterion: "Plants sited on large streams and using once-through cooling should not use more than 20% of the low water flow of the stream".[2] Due to the unique hydrology of the Clinch River described in Section 2.5, the low water flow condition is actually one of no flow, as shown in Figure 10.1-2. Under such a condition, the condenser heat load could not be adequately dissipated and the discharge water temperatures would cause significant impact to aquatic life. Once through cooling is not, therefore, a viable alternative for the CRBRP.

10.1.2.2 COOLING LAKE

Use of a cooling lake requires sufficient land suitable for impoundment. Noting that an efficient lake system in regions of moderate humidity must be sized to $\geq$ 1 acre per MWe, a 350 to 400 acre lake would be needed for the CRBRP. Due to the uneven topography of the Site, a lake of this size would be subject to extensive fingering with attendant reduction in heat dissipation capability and probable off-site land loss. Thus, a lake cooling system is not an applicable alternative.

10.1.3 SPECIFICATIONS FOR REASONABLE ALTERNATIVES

10.1.3.1 SPRAY POND

The spray pond cooling system considered for the CRBRP consists of two rectangular channels 80 feet wide and 2,175 feet long and occupies approximately eight acres of land. A floating platform spray system consisting of 54 modular cells is used. Each module is self-contained and includes pump, water intake and four spray nozzles. Design conditions for the spray pond are given in Table 10.1-1.

10.1.3.2 NATURAL DRAFT WET COOLING TOWER

A single natural draft wet cooling tower is required for the CRBRP. Dimensions for this tower are a 310-foot base diameter and a 385-foot height. Range and approach are both 20 degrees F. Design parameters for the natural draft tower are presented in Table 10.1-1. Exhaust conditions are depicted in Figure 10.1-3.

10.1.3.3 MECHANICAL DRAFT WET COOLING TOWER

Two alternative mechanical draft wet cooling towers are identified for the CRBRP. They are the same in all respects except in tower configuration. One design utilizes the standard linear arrangement of tower cells and the other design incorporates the recent innovation of circular cell configuration. Circular design permits a greater plume rise with attendant reductions in ground fog potential and recirculation of the exhausted air stream.

Both mechanical draft towers have a 25 degree F range and 15 degree F approach and utilize 5 cells in a single tower. Exhaust conditions and evaporation rate for these towers are depicted in Figure 10.1-4 and 10.1-5, respectively. The linear tower is 400

feet long, 55 feet wide and 60 feet high. The circular tower has a 250-foot diameter base and a 60-foot height, as shown in Table 10.1-1.

10.1.3.4 MECHANICAL DRAFT DRY COOLING TOWER

The mechanical draft dry cooling system considered for the CRBRP is a four tower unit utilizing a total of 82 cells. Each circular tower has a base diameter of 245 feet and a height of 78 feet. Required circulating water flow for the dry cooling alternative is nearly twice that of the mechanical draft wet tower, as seen in Table 10.1-1. A Heller cycle dry tower,[3] shown in Figure 10.1-6, is employed. Cold water temperatures and exhaust conditions for the dry tower are depicted in Figures 10.1-7 and 10.1-8, respectively. 13

10.1.3.5 MECHANICAL DRAFT WET/DRY COOLING TOWER

Two mechanical draft wet/dry towers are considered for the CRBRP; a 30 percent plume severity tower and a zero percent severity tower. Plume severity is defined in Figure 10.1-9 and is used to indicate the design conditions for which no visible plumes are produced. The zero percent severity tower provides the greater level of plume control. Both of the wet/dry towers utilize a circular configuration. Design conditions for the towers are given in Table 10.1-1.

10.1.4 ENVIRONMENTAL COSTS

10.1.4.1 PLUME FORMATION

Environmental concerns relating to the formation of vapor plumes from evaporation cooling towers include ground fog and ice, plume interference with air traffic and aesthetic impact. To predict the magnitude of these potentially adverse effects, a vapor plume study has been performed and is included as an appendix to this section.

10.1.4.1.1 GROUND FOG AND ICE

Occurrences of ground fog and ice are predicted for the five alternative cooling towers in Appendix 10.1. A summarization of the potential total hours per year of ground fog attributable to each of the alternatives is given in Table 10.1-2. Plumes for the natural draft wet tower are sufficiently elevated that interception with the terrain will not occur; hence, no ground fogging is expected. Potential fogging hours are the highest for the mechanical draft wet tower, linear array, and are the lowest for the zero percent plume severity wet/dry tower.

System selection cannot be determined solely by fogging potential, as a major consideration relates to the fogging of highways, bridges and water ways. These are areas of concern where the local population may be most severely affected. For the CRBRP vicinity, three points of interest are identified for which the effects of fogging pose potentially significant environmental costs. These are Interstate Highway 40 at Caney Creek, Gallaher Bridge and the Oak Ridge National Laboratory (ORNL). Each is within the predicted areas of plume interception with the ground as shown in Tables 10.1A-7 through 10.1A-10. Ground fog hours per year for these three points of interest are presented in Table 10.1-3. For all four mechanical draft wet-type towers, ground fog occurrences are limited to one hour or less per year. Compared to the occurrences of natural fog indicated in Tables 2.6-26 and 2.6-27, the small quantities of cooling tower induced fogging at Interstate Highway 40, Gallaher Bridge and ORNL are insignificant. Consequently, no substantial environmental advantage would be gained by any of the alternatives from the viewpoint of fog control. 13

The valleys located along a SW-NE line passing through the Site will experience the largest portion of the potential fog hours identified in Table 10.1-2 due to the predominance of wind action in these two directions as shown in Table 2.6-20. As these valleys are lightly populated (particularly to the northeast which is DOE restricted area), fogging is not expected to present a significant environmental concern. Ground fog caused by any of the alternative cooling systems will not extend to regional airports and will not significantly affect navigation on the Clinch River, as indicated in Section 5.1.8.2.

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10.1.4.1.2 AESTHETIC IMPACT OF PLUMES

Mean lengths of visible plumes for the five cooling tower alternatives are given in Table 10.1A-5. These values represent maximum plume extents as the effects of changing weather conditions that would tend to dissipate the plumes are not considered. The longest plumes are produced by the natural draft tower while the zero percent plume severity wet/dry tower produces the shortest plumes. In general, extensive plumes occur during days of high relative humidity when natural cloud cover is to be expected. Merger of cooling tower plumes with the cloud cover would be likely, particularly for the natural draft tower plumes which rise higher than those of the mechanical draft towers.

As the Site is located in a sparsely populated area, significant aesthetic impact is not anticipated. The uneven topography of the Site area will tend to obscure the full extent of cooling tower plumes from the local populace.

10.1.4.2 DRIFT

Drift deposition for the five cooling tower alternatives are presented in Table 10.1-4. Highest drift deposition occurs for the mechanical draft wet tower, linear array, while the lowest deposition occurs for the zero percent plume severity tower. (No drift is produced by the dry tower.) Drift deposition for the spray pond would be similar to that of the mechanical draft tower, linear array. The drift calculations in Table 10.1-4 are based on highly conservative assumptions; notable is

the disregard for the diluting effects of rainfall. Given these assumptions, the drift depositions calculated are extremely small. Drift deposition is the highest for the mechanical draft wet tower, linear array; however, it is equivalent to less than 0.00007 pounds per square foot per day. Drift deposition of this magnitude does not pose a significant environmental concern, as indicated in Section 5.1.8.3.

10.1.4.3 WATER USE

Potential environmental concerns relating to cooling system water use include entrainment and impingement of aquatic life due to withdrawal from the Clinch River, consumption via evaporation and drift losses and changes to river water quality and impact on aquatic life arising from the blowdown of waste heat and chemicals. None of these concerns are applicable to the mechanical draft dry tower as it is designed for a 100 percent closed water cycle.

10.1.4.3.1 WITHDRAWAL

The cooling system utilizes the largest portion of the CRBRP makeup water flow and is primarily responsible for the entrainment of aquatic life. As discussed in Section 5.1, entrainment losses for the mechanical draft wet tower are not significant due to the small size of the makeup flow in relation to the Clinch River. Although the natural draft wet tower requires a greater makeup flow (0.3% above that of the mechanical draft wet towers) and the wet/dry towers use less water (~8% below the mechanical draft wet towers makeup flow), only marginal differences in the magnitude of entrainment effects would exist among the alternative cooling systems (except for the dry tower).

Impingement of fish and other aquatic life is not directly a function of the cooling system water requirements but depends primarily on the design

of the intake system. No measurable differences in the magnitude of impingement losses would be anticipated among any of the cooling system alternatives that require a flow of makeup water.

10.1.4.3.2 WATER CONSUMPTION

In arid regions of the country, notably the southwest, water use is a critical environmental concern. However, in the southeast and, in particular, the Oak Ridge Tennessee area, ample rainfall and a highly developed system of storage reservoirs ensure abundant freshwater supplies.[4] Hence, the deployment of evaporative cooling systems does not in general constitute a significant environmental cost in regard to water consumption.

For the CRBRP recirculating cooling system, water consumption is a very small quantity in comparison to the total annual flow of the Clinch River. The per day sum of evaporation, drift and associated water losses for the mechanical draft wet tower cooling system represents only 0.2 percent of the average daily discharge of Melton Hill Dam (average value for operating life of dam to date can be seen in Table 2.5-3). In the context of the above description of regional water availability, this amount may be considered negligible. However, conditions of no flow occur in the river at the Site during Melton Hill Dam zero release periods. At these times, the relative consequence of cooling system water consumption will increase; however, when compared to the storage capacity of the Melton Hill Reservoir, the water consumption attributable to the reference cooling system represents a negligible percentage of the reservoir capacity.

Cooling system water consumption can be eliminated by the use of dry cooling towers and decreased slightly by the deployment of a wet/dry tower. However, the foregoing discussion indicates that the environmental advantage to be gained by a water use savings is not significant.

10.1.4.3.3 BLOWDOWN

All of the alternative cooling systems operate on a recirculating mode and, with the exception of the mechanical draft dry tower, utilize evaporative cooling which consumes water. Water lost through evaporation drift and blowdown must be replaced to maintain circulating flow. Blowdown prevents excessive accumulations of chemicals which cause scale formation and corrosion of pipes and equipment. For the CRBRP, a chemical concentration factor of 2.5 will be utilized. The cooling system blowdown will contain essentially river water with all chemical constituents concentrated 2.5 times.

Thermal Characteristics

Thermal discharges are a major environmental concern associated with power production. The CRBRP utilizes a recirculating or closed loop cooling system that shifts primary heat dissipation responsibilities from the natural water body (the Clinch River) to a specifically designed external device. Heat load to the river and, consequently, thermal impact are significantly reduced. Each of the cooling system alternatives operates in this fashion with the exception of the dry cooling tower which is a completely closed-loop system with no blowdown of heated water.

Blowdown (cold water) temperatures for the alternative cooling systems are presented in Figure 10.1-10. The mechanical draft wet tower produces the coldest blowdown throughout the year. Winter temperatures for the natural draft wet tower are nearly as low but summer temperatures are considerably higher. The spray pond blowdown is approximately five degrees warmer than the mechanical draft wet tower blowdown. Cold water temperatures for the zero percent plume severity wet/dry tower are equivalent to that of the reference system in summer

but deviate in winter as the utilization of the dry section reduces cooling efficiency. The same is true for the 30 percent plume severity wet/dry tower although its blowdown is uniformly warmer than the zero percent tower.

As previously noted, the primary environmental concern associated with the discharges of waste heat is the formation of thermal plumes. A discharge plume study has been performed to estimate the size and character of the anticipated CRBRP thermal mixing zones. This study is based on the performance of the selected cooling system and appears as an Appendix to Section 10.3. Figures 10.3A-8 through 10.3A-11 of this appendix illustrate the extent of the thermal plume formation under various mixing conditions. As discussed in Sections 5.1 and 10.3, these plumes are sufficiently small both in size and temperature differential that no significant impact on aquatic life is anticipated. Thermal plumes that would result from the alternative cooling systems would be expected to be of similar size as those produced by the mechanical draft wet tower blowdown but of slightly higher temperature in accordance with the information presented in Figure 10.1-10. 6

Chemical Composition

Chemical discharges from all of the cooling system alternatives (with the exception of the dry tower) will be nearly identical as all have the same chemical concentration factor and produce similar blowdown flow rates. As indicated in Section 5.4, chemical discharges by the selected cooling system will not significantly affect either water quality or aquatic life in the Clinch River.

10.1.4.4 LAND USE

The CRBRP Site comprises over 1,300 acres of woodland. It is not at present, nor has it been recently, inhabited or utilized (for farming, forestry, etc). Use of a portion of the 1,300 acres for plant structures does not represent a significant land use concern as the area has for many years been in government custody and unavailable to the general public.

Land requirements for various alternative cooling systems range from one-half acre for the mechanical draft wet tower (both linear and circular configurations) to eight acres for the spray pond. Land requirements for each alternative both in terms of acres needed and percent of Site area utilized are presented in Table 10.1-5. When viewed in the latter perspective, the land requirement of even the spray pond (0.6% of Site acreage) appears small.

Although the development of the CRBRP Site does not represent loss of publicly-utilized land, the acreage required by the cooling system becomes a valid land use concern insofar as additional undisturbed woodland area within the Site boundaries must be committed. The results, shown in Table 10.1-5, indicate that this potential increase in land consumption is quite small for any of the alternative systems.

10.1.4.5 AESTHETIC IMPACT OF STRUCTURES

The Oak Ridge, Tennessee area in which the CRBRP Site is located is characterized by undulating topography. The region's many ridges will form a natural barrier to visual encounters with plant structures. Except for several residences on the south shore of the Clinch River across from the Site, observation of the plant will be limited.

Compared to the tallest plant structure, the Reactor Containment Building measuring 179' above plant grade, only the natural draft

tower cooling alternative presents a greater visual attraction. To evaluate its potential aesthetic impact, four regional points of relatively high population use are considered: Melton Hill Dam, Oak Ridge National Laboratory (ORNL), Interstate 40 and the Gallaher Bridge. A measure of visual impact at each of these four locations of the natural draft tower compared to the reactor dome is presented in Table 10.1-6. (All of the other cooling system alternatives are sufficiently low in profile that they are not visible from any of these points.) Figure 10.1-11 depicts the actual view of the plant (with natural draft tower cooling system) from two of the locations.

At two of the locations, Interstate 40 and Melton Hill Dam, the reactor dome is not visible; only the natural draft tower rises above the horizon. For the other locations, the height of plant above the horizon is increased by over 200 feet due to the presence of the tower. Clearly, the natural draft tower would have a significant effect on plant visibility as seen in Figure 10.1-11. The translation of this effect into a measure of adverse aesthetic impact is, of necessity, a subjective process heavily dependent on value judgements that are not well known. It is possible that a natural draft tower could be viewed as a desirable landmark. However, in view of hilly terrain and generally rural flavor of the region, the projection of concrete structures above tree-lined ridges must be considered an environmental intrusion rather than asset.

Only the natural draft cooling tower poses a significant aesthetic concern. The visibility of the remaining alternatives is limited to the area across the river from the Site. For the few people living there the spray pond might present a more attractive sight than cooling towers; however, this advantage for the spray pond is lost when regional points of higher population utilization are considered.

10.1.5 ECONOMIC COSTS

10.1.5.1 EFFECTS ON PLANT POWER PRODUCTION

In a recirculating cooling system, economics prevent the attainment of turbine back pressures similar to that of once through systems. As a consequence, losses in generating capability are incurred.

Auxiliary power requirements by the cooling system can be quite high, as seen in Table 10.1-7. This is true for mechanical draft towers where large horsepower fans are utilized to induce air movement. Modular spray ponds are also high energy users as electrical pumps are employed to force water through the banks of nozzles.

The combined effects of capability losses and energy requirements produce variations in plant net output of electricity among the alternative cooling systems. Annual average net output for each of the alternatives is presented in Table 10.1-7. Differentials among all alternatives except the dry tower are within a range of 3 MW. Compared to the reference mechanical draft wet tower, dry cooling imposes a 13.6 MW deficit on the CRBRP.

10.1.5.2 MONETARY COSTS

The determination of monetary costs is based on the economic factors listed in Table 10.1-8. Monetary costs for the cooling system alternatives are presented in Table 10.1-9. These are present worth values and are expressed in incremental fashion with the mechanical draft wet tower, as the base. 6

A comparison of total cost for each system shows the mechanical draft wet tower, to be the least expensive cooling system alternative. 6
The natural draft tower, both wet/dry towers and the spray pond

are within a range of $2.0 to 2.5 million higher in cost. By far the most expensive system is dry cooling with a $15.5 million price increase over that of the mechanical draft wet tower.

10.1.6 COMPARISON OF ALTERNATIVES

10.1.6.1 DIRECT COMPARISON OF REASONABLE ALTERNATIVES

A summary of the environmental and economic costs for the cooling system alternatives is presented in Table 10.1-10. The lowest economic costs are realized by the mechanical draft wet tower. As capsulized in the Table 10.1-10 and detailed in Section 5.1, differences in environmental costs are not significant. 6

Improved control over atmospheric releases is the primary environmental advantage offered by the natural draft wet tower and both wet/dry towers. Although the natural draft tower eliminates ground fogging and produces the least drift of the wet-type systems, greater plume lengths, higher blowdown temperatures and increased plant visual impact counterbalance these positive features. Consequently, the $2.19 million additional system's cost is not offset by a clear environmental advantage over the mechanical draft wet tower. Reductions in both ground fogging and plume extent are offered by the wet/dry tower alternatives; however, winter blowdown temperatures are substantially increased. As the predicted ground fog hours for the mechanical draft wet tower are not significant in relation to regional occurrences of natural fogging, there is no overriding incentive to absorb the offsetting environmental disadvantage and higher economic costs associated with the wet/dry towers. 6

Spray pond performance is similar to the mechanical draft wet tower. Its environmental costs are roughly equivalent with a potential advantage in plume formation counterbalanced by higher blowdown temperatures 6

and a larger land area requirement. Economic cost for the two systems is the deciding factor as a $2.52 million price increase and 3 MWe capability penalty are assessed against the spray pond alternative.

The lowest environmental costs are realized by the mechanical draft dry tower. As this system is designed for closed cycle operation, no makeup water is normally required and no vapor plumes, drift or blowdown are produced. Land requirements are increased, however, as many more cells are required to dissipate the plant heat load by dry mechanisms than are needed for the wet towers. Economic costs for the dry tower are substantial as a 13.6 MWe capability penalty and $15.5 million price increase over the mechanical draft wet tower are incurred. The burden of these economic costs would have to be offset by significant reductions in environmental impact. However, as the mechanical draft wet tower does not represent a significant environmental concern, the dry tower economic costs are not justified. 6

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10.1.6.2 REASONS FOR SELECTION OF CHOSEN SYSTEM

The selected cooling system for the CRBRP is the mechanical draft wet tower like that shown in Figure 10.1-12. In contrast to once through cooling, it provides significant protection from the adverse environmental effects of thermal discharges. It is economically preferable to, and environmentally competitive with, other recirculating mode cooling systems and will not have any significant environmental costs associated with its operation. 6

6

TABLE 10.1-1

DESIGN CONDITIONS FOR THE COOLING SYSTEM ALTERNATIVES

	Spray Pond	Natural Draft Wet Tower	Mechanical Draft Wet Tower: Line Array	Mechanical Draft Wet Tower: Circle Array	Mechanical Draft Dry Tower	Mechanical Draft Wet/Dry Tower: 30% Plume Severity	Mechanical Draft Wet/Dry Tower: 0% Plume Severity
Circ. Water Flow (1,000 gpm)	212	265	212	212	400	265	212
Range (°F)	25	20	25	25	13.25	20	25
Approach (°F)	20	20	15	15	28 to dry bulb	20	15
Evaporation (gpm)	4,240	4,240	4,240	4,240	0	3,900*	3,900*
Drift (gpm)	110	130	110	110	0	120*	100*
Makeup (gpm)	7,050	7,070	7,050	7,050	**	6,520*	6,500*
Blowdown (gpm)	2,700	2,700	2,700	2,700	**	2,500*	2,500*
Total Heat Duty $\left(\frac{10^6\ Btu}{hr}\right)$	2,650	2,650	2,650	2,650	2,650	2,650	2,650
No. of cells	54	1	10	10	82	14	17
Heat duty/cell $\left(\frac{10^6\ Btu}{hr}\right)$	49.1	2,650	265	265	32.3	189	155.9
No. of towers	NA+	1	1	1	4	1	1
Tower size (feet)	Channel size 2 passes each 80' wide, 2,175' long	385 high 310 base	400 long 60 high 55 wide	240 diam 60 high	245' diam 78' high	340 diam 65 high	425 diam 65 high
No. of concentrations	2.5	2.5	2.5	2.5	NA+	2.5	2.5
Airflow, 10^6 cfm	NA+	14	17	17	110	14	17

*Annual average quantities. Summer operation will have the same values as the wet tower. Winter operation will have lower values.

**Almost zero during normal operation; does not include periodic cleaning

+Not applicable

TABLE 10.1-2

GROUND FOG POTENTIAL FOR COOLING TOWER ALTERNATIVES*

(Fog in hrs/yr)

Horizontal Visibility Through Fog (miles)	Natural Draft Wet Tower	Mechanical Draft Wet Tower		Mechanical Draft Wet/Dry Tower		Mechanical Draft Dry Tower
		Linear Array	Circular Array	30% Plume Severity	0% Plume Severity	
≤1/2	0	146	146	138	138	0
<1/4	0	146	146	138	138	0
<1/10	0	100	92	0	0	0

*Based on Tables 10.1A-7 through 10.1A-10

TABLE 10.1-3

GROUND FOG FOR THREE POINTS OF INTEREST IN THE CRBRP SITE VICINITY*

Point of Interest	Distance from CRBRP (miles)	Direction from CRBRP	Horizontal Visibility Through Fog (miles)	Ground Fog (in hours/year)			
				Mechanical Wet Tower		Mechanical Wet/Dry Tower	
				Linear Array	Circular Array	30% Plume Severity	0% Plume Severity
Interstate 40 @ Caney Creek	1.1	SSE	1/2	0.1	0.1	0	0
			1/4	0.1	0	0	0
			1/10	0	0	0	0
Gallaher Bridge	1.6	NW	1/2	0.8	0.8	0.1	0
			1/4	0.8	0.8	<0.1	<0.1
			1/10	0.7	0.5	0	0
ORNL	4.5	NE	1/2	0.1	<0.1	<0.1	<0.1
			1/4	0.1	<0.1	0	0
			1/10	<0.1	0	0	0

*Based on Table 10.1A-12

TABLE 10.1-4

DRIFT DEPOSITION FOR COOLING TOWER ALTERNATIVES

	Natural Draft Wet Tower	Mechanical Draft Wet Tower		Mechanical Draft Wet/Dry Tower	
		Linear Array	Circular Array	30% Plume Severity	0% Plume Severity
Drift Deposition* (lbs/acre-month)	3	89	74	44	37

*Drift for compass direction having highest deposition (from Tables 10.1A-15 through 10.1A-19)

TABLE 10.1-5

LAND REQUIREMENTS FOR ALTERNATIVE COOLING SYSTEMS

	Spray Pond	Natural Draft Wet Tower	Mechanical Draft Wet Tower		Mechanical Draft Dry Tower	Mechanical Draft Wet/Dry Tower	
			Linear Array	Circular Array		30% Plume Severity	0% Plume Severity
Land required (in acres)	8.0	1.7	0.5	1.0	4.3	2.1	3.3
Fraction of Site Area (as %)	0.57	0.12	0.03	0.07	0.31	0.15	0.24

TABLE 10.1-6

VISUAL IMPACT OF NATURAL DRAFT WET COOLING TOWER COMPARED TO REACTOR DOME

Regional Points of High Population Use	Distance from CRBRP (miles)	Visual Impact (%)* Reactor Dome (179 feet)	Visual Impact (%)* Natural Draft Tower (385 feet)
Gallaher Bridge	1.8	20	53
I-40 W**	2.6	0	11
ORNL	4.0	9	23
Melton Hill Dam	4.5	0	9
		29	96

*Visual Impact: degree of impact varies directly with height of structure above horizon (h) and inversely with viewing distance from plant site (d)

$$I(\%) = \frac{h/385}{(d/2)/0.7} \times 100$$

**An approximate one mile long section of I-40 located SE of plant site in which the driver of a vehicle traveling in the westbound lane will have a portion of the natural draft wet tower in the center of his vision.

TABLE 10.1-7

EFFECTS OF ALTERNATIVE COOLING SYSTEMS ON PLANT POWER PRODUCTION

	Spray Pond	Natural Draft Wet Tower	Mechanical Draft Wet Tower		Mechanical Draft Dry Tower	Mechanical Draft Wet/Dry Tower	
			Linear	Circular		30% Plume Severity	0% Plume Severity
Auxiliary Power, kW	1,310	(521)	Base	Base	14,431	1,034	666
Net Output, MWe	(2.9)	0.2	Base	Base	(13.6)	(2.2)	(1.4)
Total Annual Generation 10^6 kW-hrs	(16)	3	Base	Base	(80)	(12)	(7)

TABLE 10.1-8

ECONOMIC FACTORS

Annual Fixed Charge	11 Percent
Capability Cost	$338/kw
Plant Life	30 years
Fuel Cost	$0.00161/kw Hr.
Average Capacity Factor	68.5 Percent

TABLE 10.1-9

ECONOMIC COSTS FOR THE COOLING SYSTEM ALTERNATIVES

ALL COSTS ARE MILLIONS OF DOLLARS ON A DIFFERENTIAL BASIS

	Spray Pond	Natural Draft Wet Tower	Mechanical Draft Wet Tower Linear or Circular	Mechanical Draft Dry Tower	Mechanical Draft Wet/Dry Tower 30% Plume Severity	Mechanical Draft Wet/Dry Tower 0% Plume Severity
Fixed Costs						
Condenser Tube Cost and Installation	0.0	0.16	Base	0.47	0	0.16
Condenser Shell and Erection	0.0	0.18	Base	--	0	0.18
Circulating Water Pumps and Motors	0.0	0.17	Base	0.58	0	0.17
Cooling Tower	(1.32)	2.02	Base	8.57	1.86	1.05
Excavation	2.32	0.0	Base	0.0	0.0	0.0
Total Fixed Costs	0.91	2.53	Base	9.62	1.56	1.86
Variable Costs						
Capitalized Fuel Costs	0.23	(0.05)	Base	1.17	0.10	0.17
Total Capability Cost	1.38	(0.29)	Base	4.70	0.23	0.33
Total Variable Costs	1.61	(0.34)	Base	5.87	0.33	0.50
Total Fixed and Variable Costs	2.52	2.19	Base	15.49	2.06	2.19

TABLE 10.1-10

SUMMARY OF ENVIRONMENTAL AND ECONOMIC COSTS FOR THE ALTERNATIVE COOLING SYSTEMS

	Report Section	Unit of Measure	Spray Pond	Natural Draft Wet Tower	Mechanical Draft Wet Tower: Linear Array	Mechanical Draft Wet Tower: Circular Array	Mechanical Draft Dry Tower	Mechanical Draft Wet/Dry Tower: 30% Plume Severity	Mechanical Draft Wet/Dry Tower: 0% Plume Severity
Environmental Costs									
Plume Formation									
Ground Fog	10.1.4.1.1	Percent of natural fog*	NA	0	2.3	2.2	--	0.1	<0.1
Visible Plume Extent	10.1.4.1.2	Mean length in miles (95% R.H., C stability: Table 10.1A-5)	NA	2.9	1.8	1.9	--	1.5	1.6
Drift Deposition	10.1.4.2	Lbs/sq foot-day (from Table 10.1-4)	~7×10^{-5}	0.2×10^{-5}	6.8×10^{-5}	5.7×10^{-5}	--	3.4×10^{-5}	2.8×10^{-5}
Water Use									
Entrainment	10.1.4.3.1	Percent/yr**	0.33	0.33	0.33	0.33	0	0.30	0.30
Impingement	10.1.4.3.1	Qualitative	Same	Same	Same	Same	0	Same	Same
Water Consumption	10.1.4.3.2	Percent of Melton Hill Dam releases+	0.20	0.20	0.20	0.20	0	0.19	0.19
Heat Rejection	10.1.4.3.3	Heat load to river in winter as percent of total plant heat duty	0.052	0.049	0.048	0.048	0	0.055	0.052
Initial Temperature Difference	10.1.4.3.3	Blowdown temperature minus river ambient (in winter), °F	36	31	30	30	--	48	43
Effect of Chemicals	10.1.4.3.3	Qualitative	Negligible	Negligible	Negligible	Negligible	None	Negligible	Negligible
Land Use	10.1.4.4	Percent of Site acreage required	0.57	0.12	0.03	0.07	0.31	0.15	0.24
Visual Impact	10.1.4.5	See Table 10.1-6	0	96	0	0	0	0	0
Economic Costs									
Plant Net Output	10.1.5.1	MWe differential	(2.9)	0.2	Base	Base	(13.6)	(2.2)	(1.4)
Total System Cost	10.1.5.2	Present worth in millions of $	2.52	2.19	Base	Base	15.49	2.06	2.19

*Maximum induced fog for <1/4-mile visibility (Gallaher Bridge: Table 10.1A-12) as percent of natural fog at Oak Ridge City Office (Table 2.6-9)

**Makeup flow (Table 10.1-1) as a percentage of annual releases (from Table 2.5-3); density of entrainable organisms assumed uniform

+Evaporation and drift losses as percentage of annual releases

6

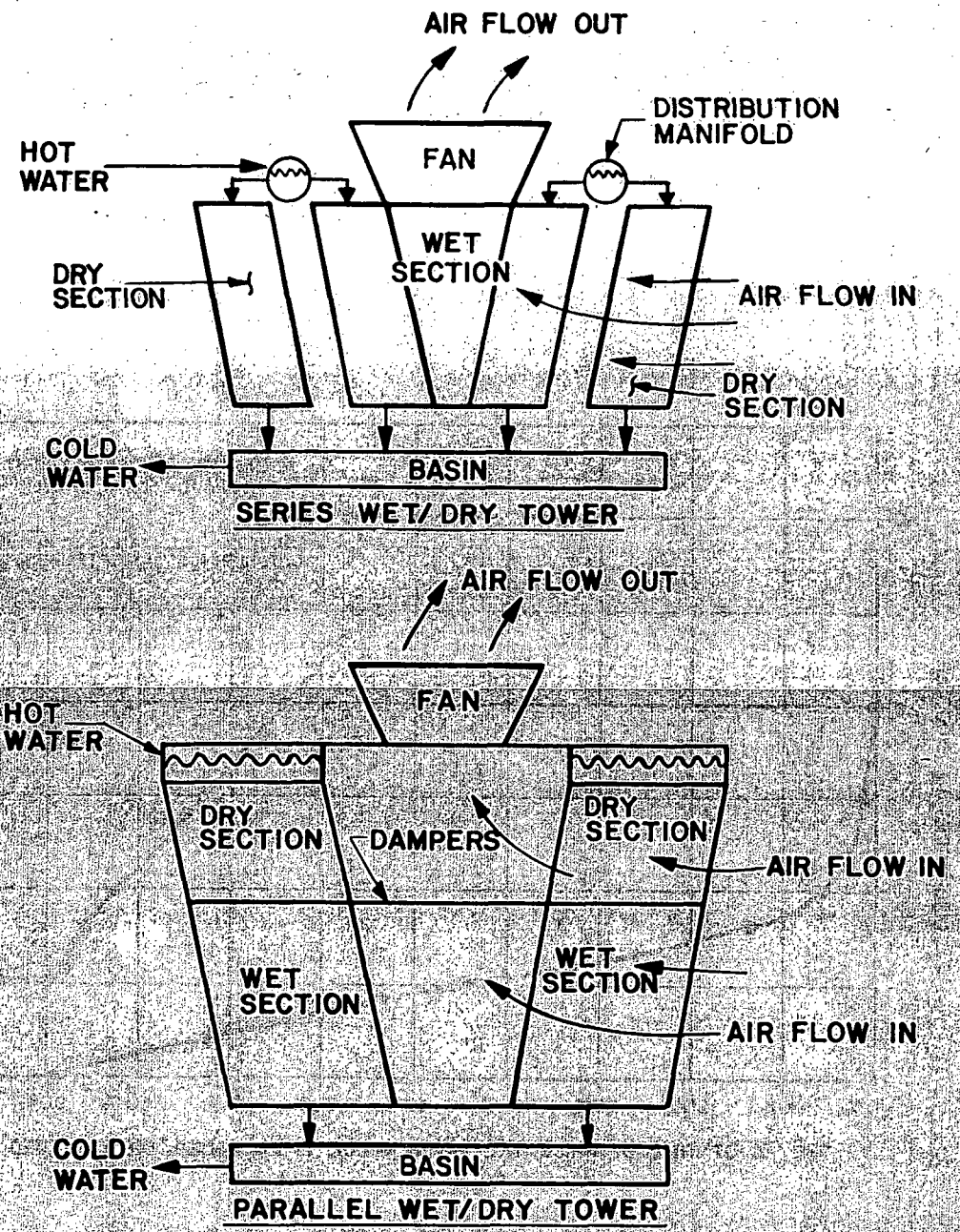


Figure 10.1-1 THE MECHANICAL DRAFT WET/DRY COOLING TOWER

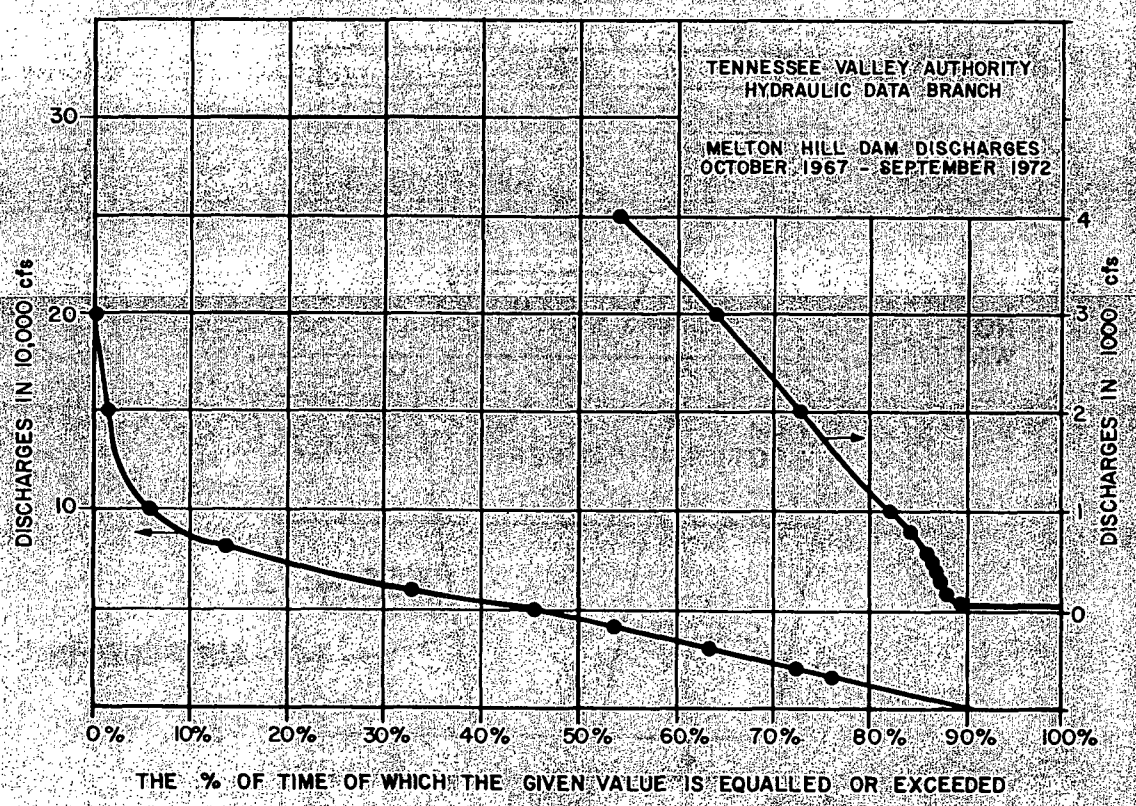


Figure 10.1-2 FLOW CONDITIONS IN CLINCH RIVER

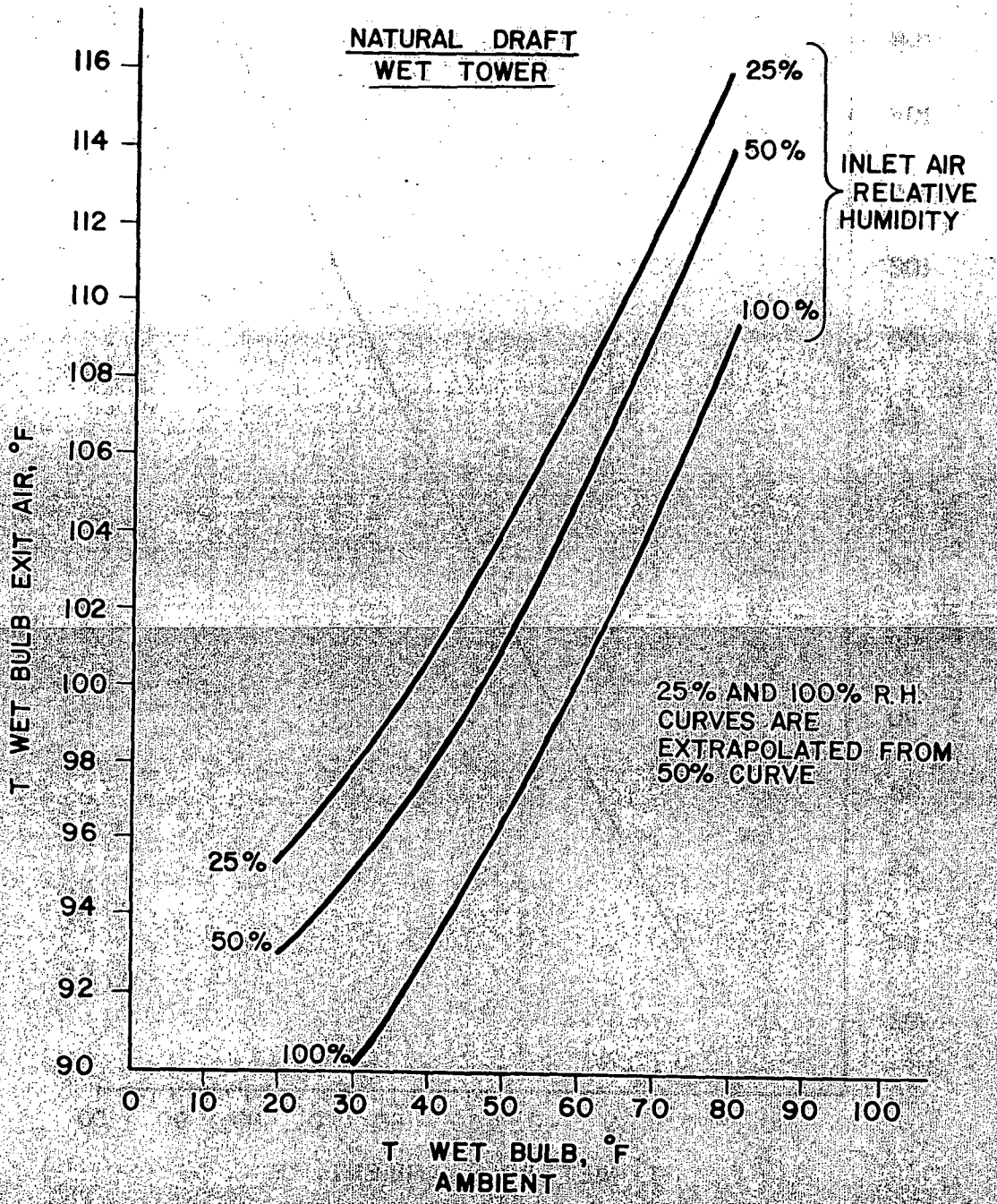


Figure 10.1-3 EXHAUST CONDITIONS FOR THE NATURAL DRAFT WET TOWER

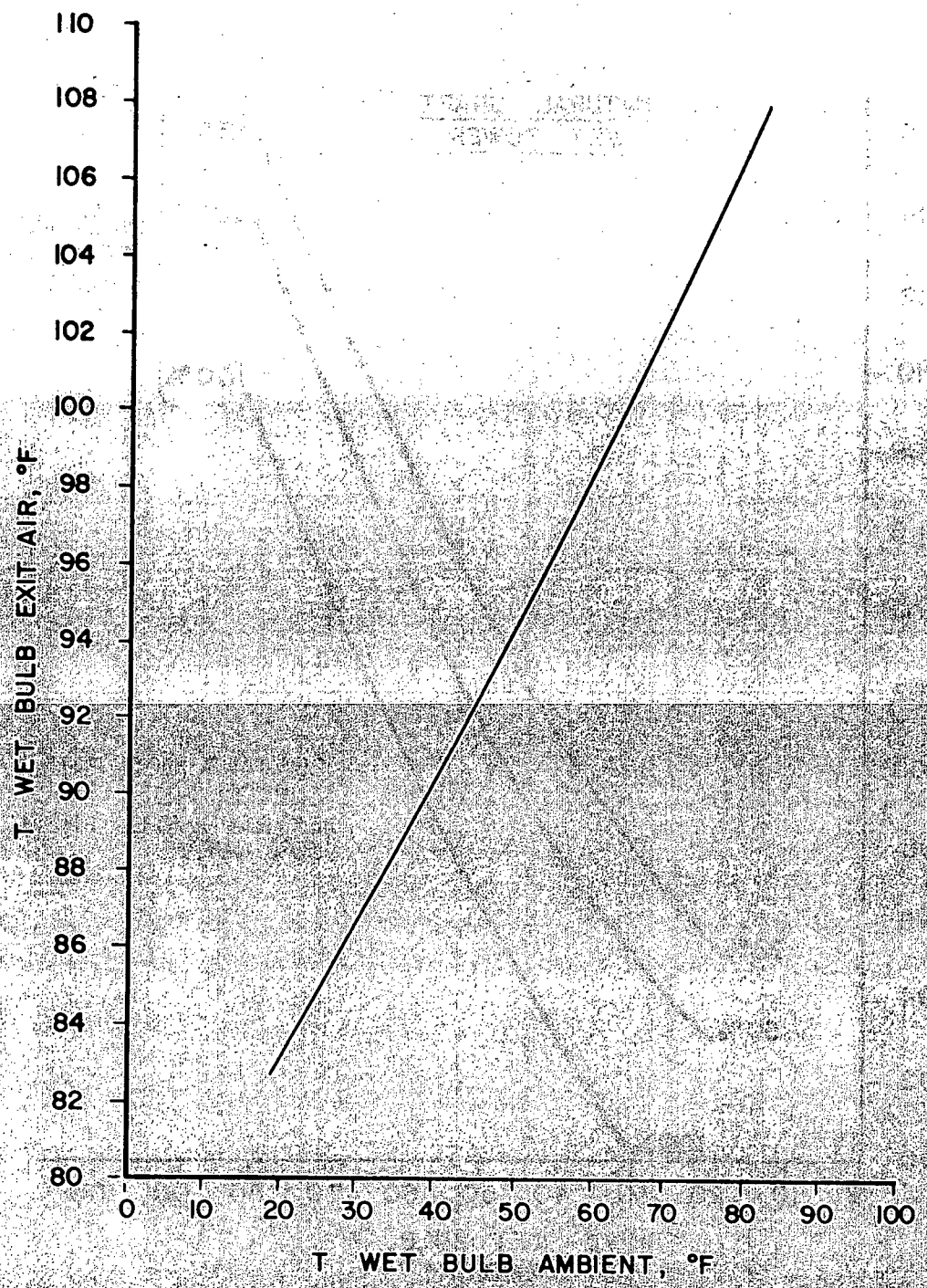


Figure 10.1-4 EXHAUST CONDITIONS FOR THE MECHANICAL DRAFT WET TOWER

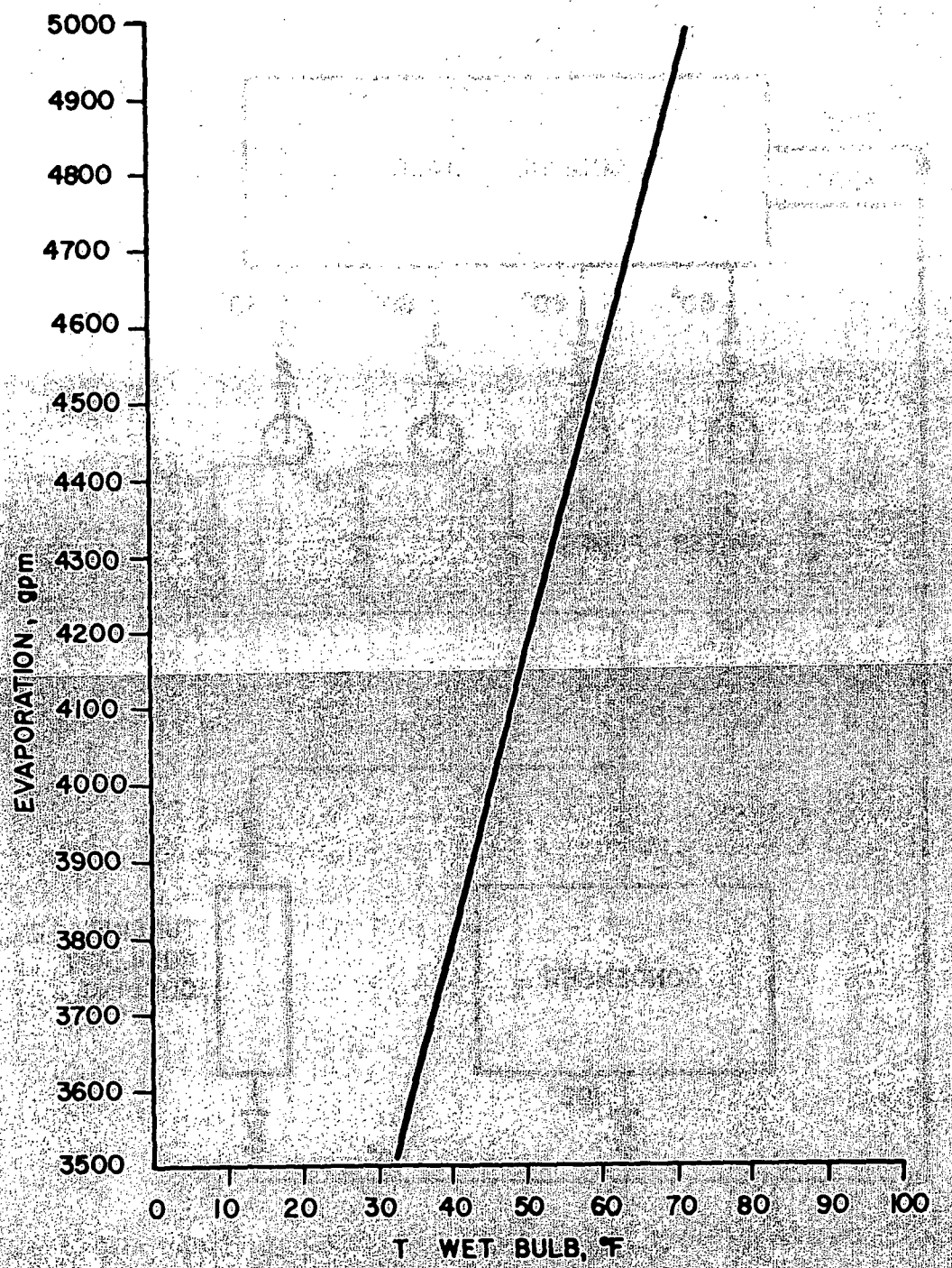


Figure 10.1-5 EVAPORATION RATES FOR THE MECHANICAL DRAFT WET TOWER

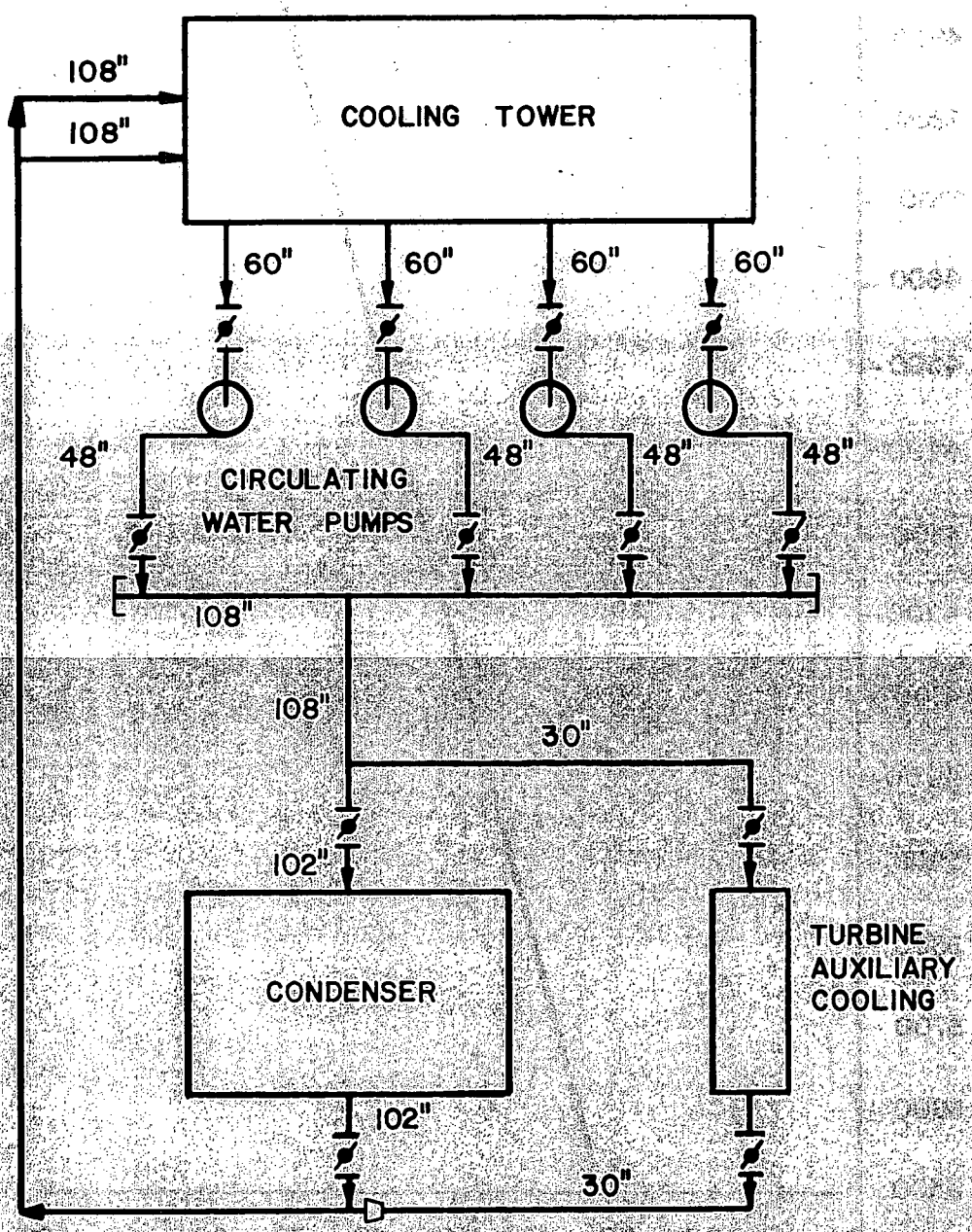


Figure 10.1-6 HELLER CYCLE DRY COOLING TOWER[3]

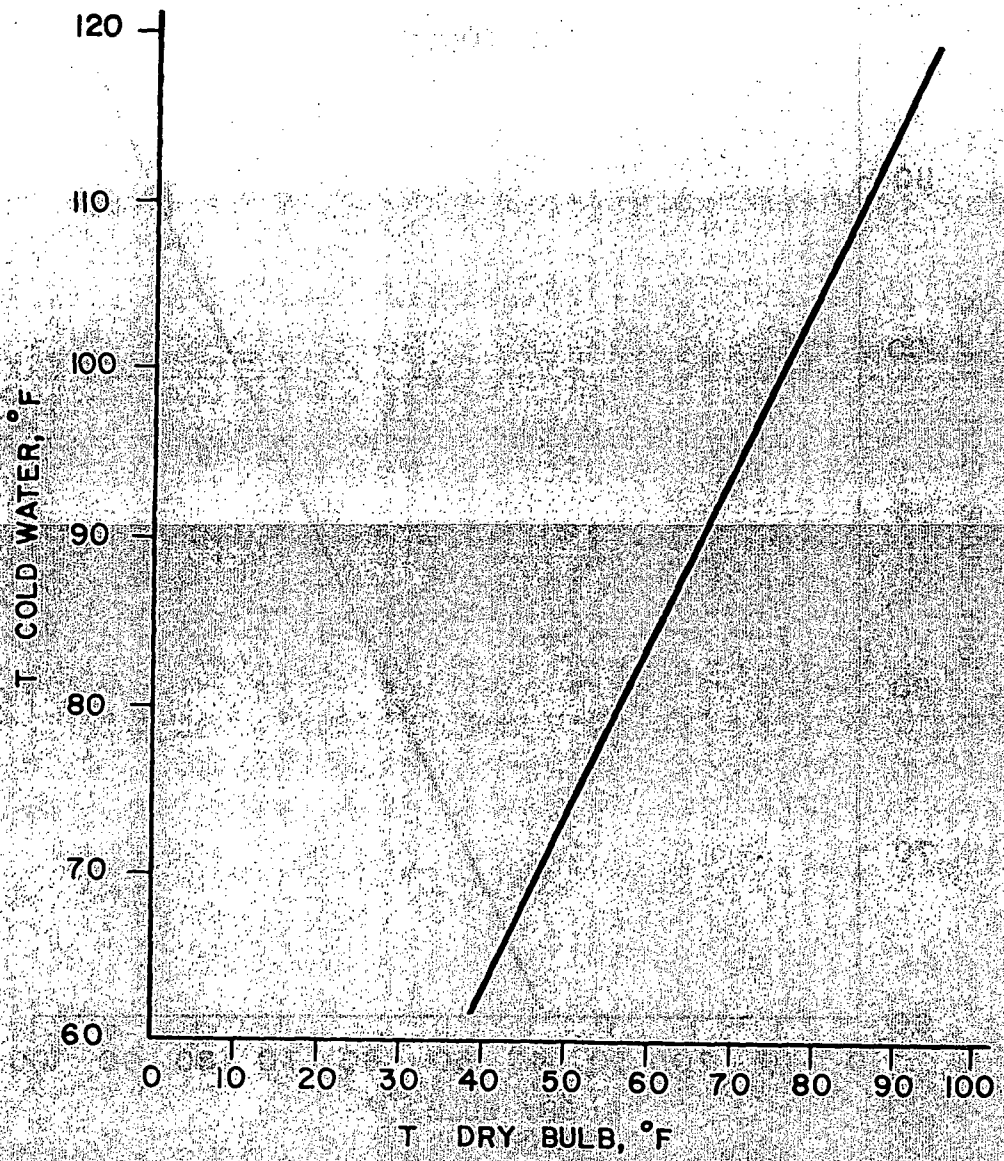


Figure 10.1-7 COLD WATER TEMPERATURE FOR THE MECHANICAL DRAFT DRY TOWER

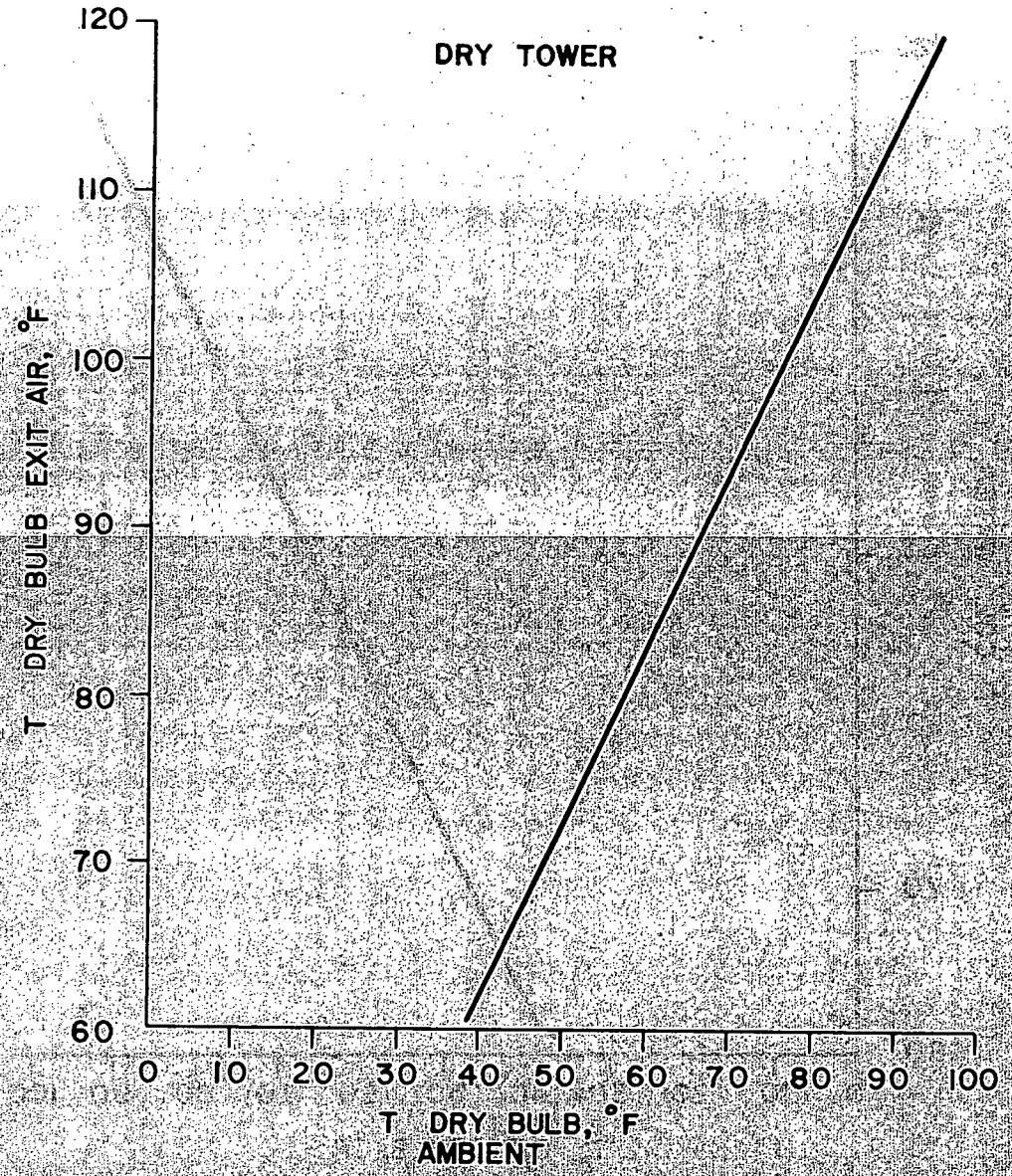
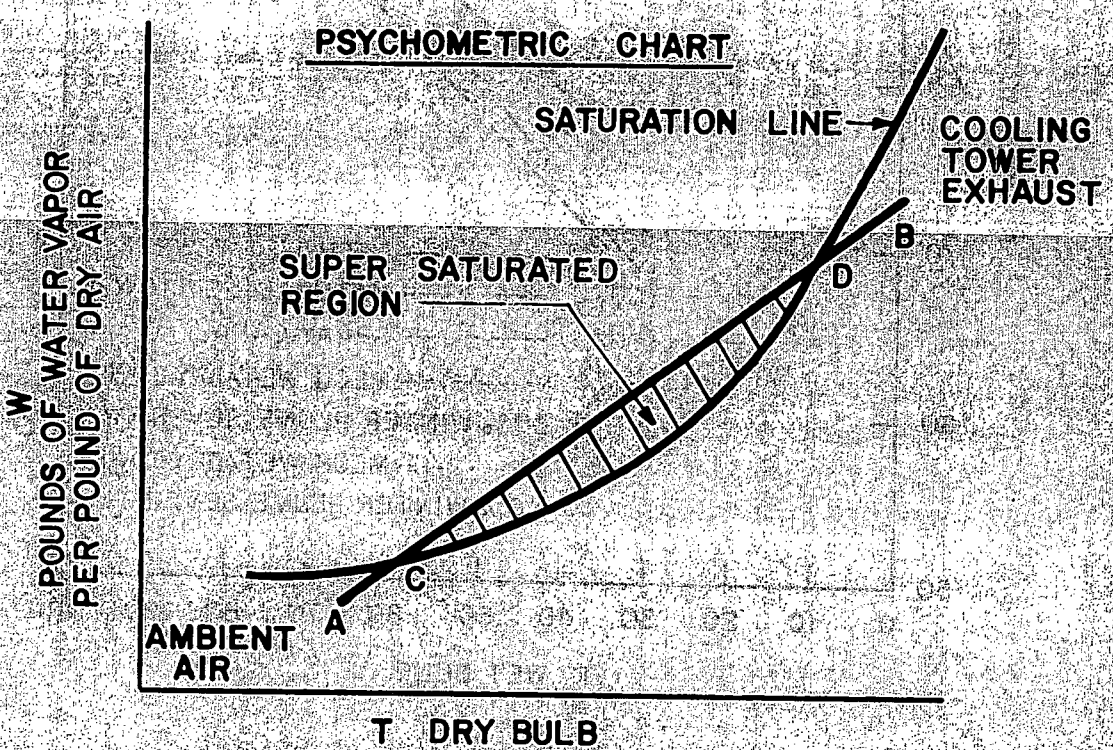


Figure 10.1-8 EXHAUST CONDITIONS FOR THE MECHANICAL DRAFT DRY TOWER



$$\text{PLUME SEVERITY} = \frac{T_D - T_C}{T_B - T_A} = \frac{W_D - W_C}{W_B - W_A}$$

Figure 10.1-9 DEFINITION OF PLUME SEVERITY

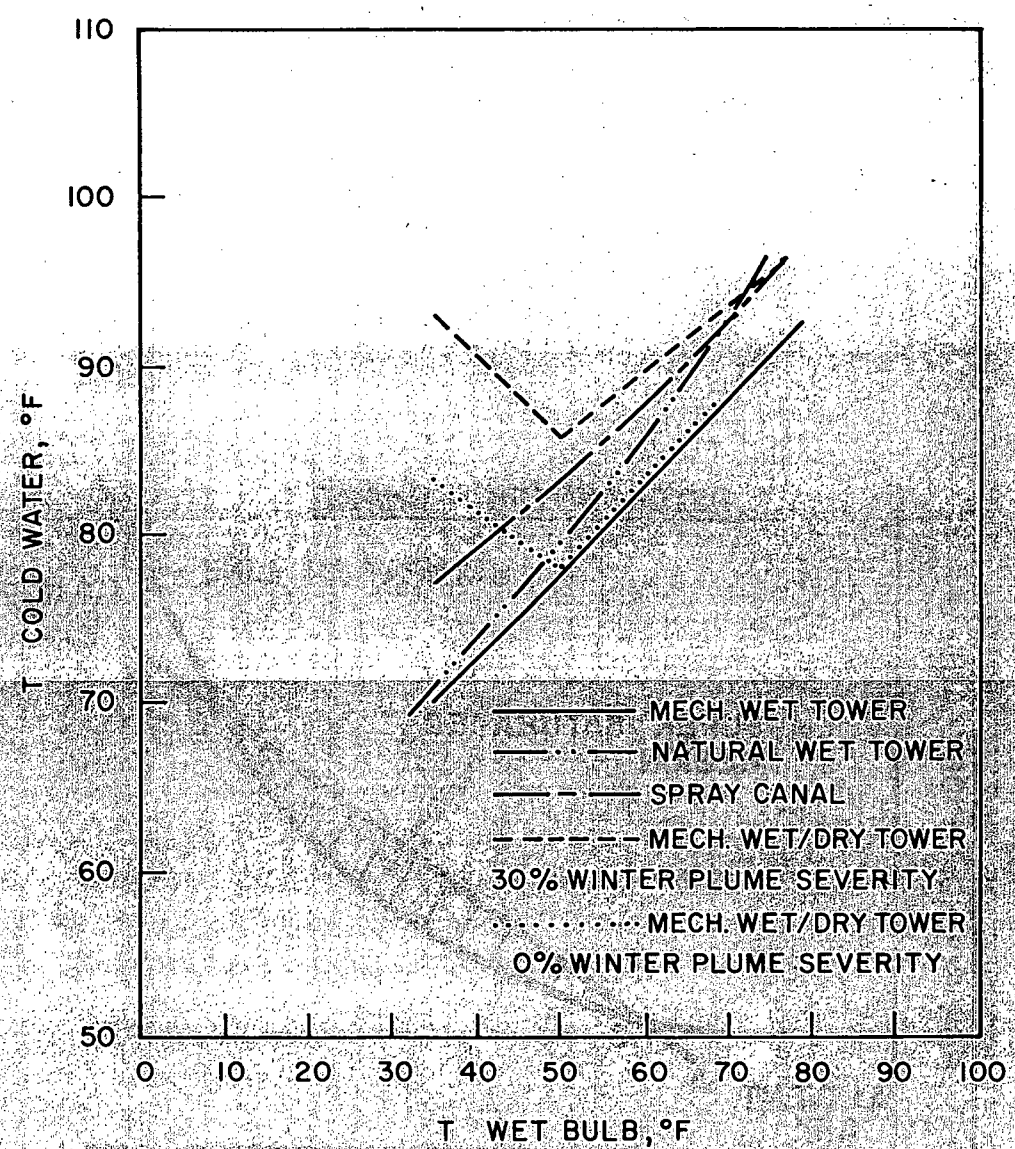


Figure 10.1-10 BLOWDOWN TEMPERATURES FOR THE EVAPORATIVE COOLING SYSTEM ALTERNATIVES

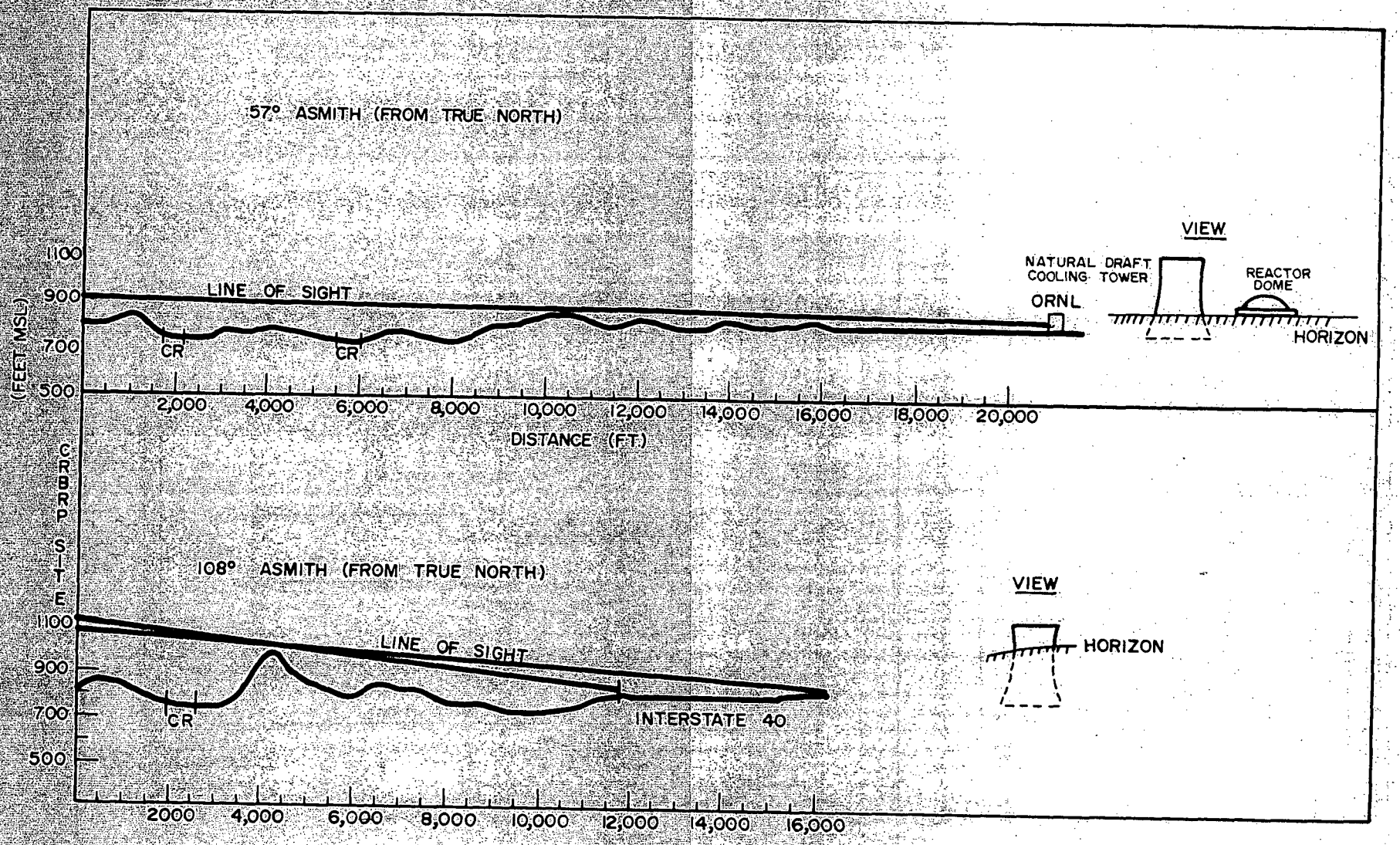


Figure 10.1-11 GROUND PROFILES AND DEPICTION OF CRBRP VISIBILITY FOR THE NATURAL DRAFT TOWER

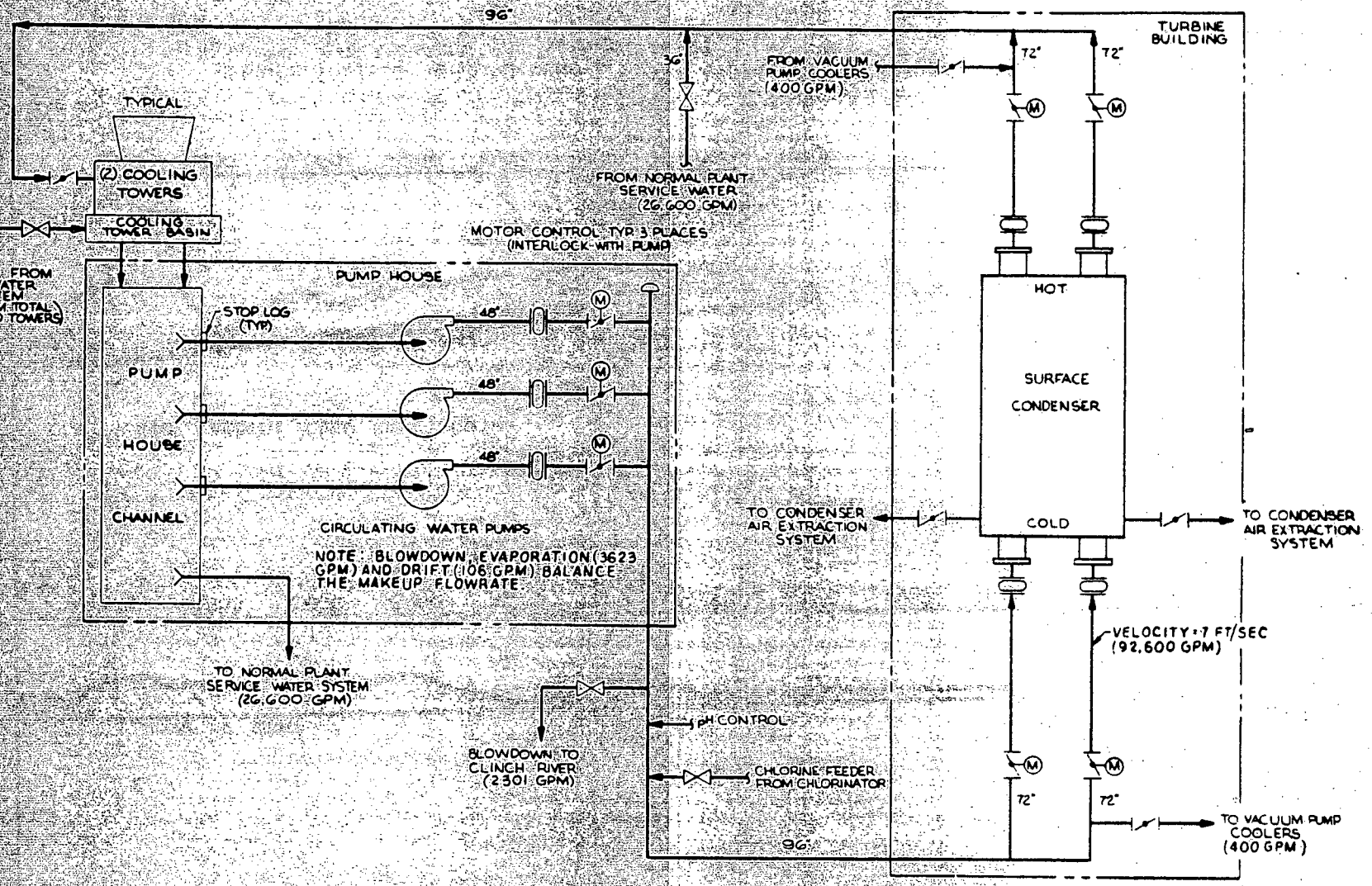


Figure 10.1-12 SELECTED COOLING SYSTEM--MECHANICAL DRAFT WET TOWER

10.2 INTAKE SYSTEM

Makeup water from the Clinch River will be required on a continuous basis during normal operation of the CRBRP. It is the function of the intake system to transport river water to the plant proper and to perform such pretreatment as may be required for the protection of equipment. This latter function is accomplished by screening devices that prevent the passage of large objects that could damage cooling system components.

It is this screening requirement that is responsible for the most important environmental concern associated with the intake system -- entrapment and impingement of fish. Other environmental effects of the intake system include entrainment of aquatic organisms (although this is primarily controlled by the design and water requirements of the cooling system), construction effects and the aesthetic impact of the structure itself.

The intake system for the CRBRP has been selected to reduce adverse environmental impact to that degree consistent with the need for an uninterrupted water supply and the results of benefit-cost analysis.

A perforated pipe is the selected system for the CRBRP.

Alternatives considered for the CRBRP intake system are:

1. Conventional traveling screens;
2. Traveling screens mounted at angle to flow;
3. Single entry-double exit traveling screens;
4. Horizontal screens;
5. Louver system;
6. Electric screens;

7. Bubble, sound and light barriers;

8. Perforated pipe; and

9. Infiltration bed.

10.2.1 DESCRIPTION OF ALTERNATIVES

10.2.1.1 CONVENTIONAL TRAVELING SCREENS

The most commonly employed mechanical screening device in use today is the conventional traveling screen. This intake system is highly reliable, applicable to a wide variety of screening situations, fairly insensitive to fluctuating water levels and well standardized in terms of components. It does not, however, provide any mechanisms specifically directed at fish protection. It is included in this alternative study to represent the basic traveling screen concept that is also utilized by intakes that do possess fish protection modifications and to provide a readily identifiable base system to which the other alternatives can be compared.

A typical conventional traveling screens intake is depicted in Figure 10.2-1. Makeup water pumps located in bays at the rear of the structure draw water first through trash bars and then through the traveling screens. The trash bars prevent the passage of large objects such as logs and cans that might damage the screens. A mechanical rake is usually provided to periodically remove debris from the bars. The screens are positioned directly behind the bars and perpendicular to the incoming flow of water. Mounted on sprockets at the bottom and top (deck level) of the structure, the screens form a continuous band which rotates vertically. Only the bottom half of the screen is usually submerged. Objects greater in size than the screen mesh (normally 3/8 inch) are retained on the front face. Debris removal is accomplished by rotating the screens until the affected portion is at deck level where high pressure water jets cleanse the screen and deposit the debris

in troughs for land disposal. Traveling screens can be operated intermittently or continuously with either manual or automatic control.

10.2.1.2 TRAVELING SCREENS MOUNTED AT ANGLE TO FLOW

A modification of the conventional intake that does provide fish protection mechanisms is the traveling screens mounted at an angle to the flow. This intake system is illustrated in Figure 10.2-2.

Trash bars and rakes for the angle-mounted screens intake are identical in function and location with those of the conventional system. The vertical traveling screens, however, are positioned at an angle to the flow of incoming water. At one end of the screens, a fish escape channel with assist pump and return pipe to the river is provided.

The angle-mounting innovation causes the water flow to change direction at the screens. This creates a velocity component parallel to the screen face which assists in directing fish in imminent danger of impingement into the escape channel where the fish pump can transfer them safely back to the waterway.

10.2.1.3 SINGLE ENTRY-DOUBLE EXIT (PASSAVANT) SCREENS

A more advanced fish protection mechanism is a by-pass system incorporated into the standard single entry-double exit (Passavant) traveling screen. As shown in Figure 10.2-2, fish entering the intake can proceed without change in direction into an escape passage located directly behind the screens. This sytem permits lethargic fish (such as might be encountered during the winter months) to be carried to safety as a swimming response is not required by the fish.

The key to the Passavant intake is the screen mounting position. Screen faces are parallel to the incoming flow and water passes from the inside

of the screen band to the outside. The fish escape channel lies directly ahead of any fish approaching the screens. A fish pump and return pipe safely transport the fish to the waterway.

The Passavant screening concept has had wide application in Europe although it is rare in the United States; however, the particular design described above has not been previously used but can be built using proven and available components.

10.2.1.4 HORIZONTAL TRAVELING SCREENS

One of the most promising screening concepts designed specifically for fish protection is the horizontal traveling screen. It functions by inducing a swimming response in the fish which will directly lead to their removal from the intake and safe return to the waterway.

Fish protection features of the horizontal traveling screen are illustrated in Figure 10.2-2 and resemble those of the vertical screens mounted at an angle to the flow, see Section 10.2.1.2, with one important exception. The screens travel horizontally in the direction of the fish bypass channel. In operation, fish encountering the screen orient themselves perpendicular to it and attempt to escape. The screens, rotating at much higher speeds than conventional ones, create a strong velocity component parallel to their faces which sweeps the fish into the bypass channel. Fish that do become impinged on horizontal screens are not subject to as great a holding force as that typical to vertical screens and are more likely to free themselves.

Horizontal traveling screens were developed in the Pacific Northwest and have proven very effective in reducing impingement losses. To date their use has been limited to experimental applications as the high degree of component reliability required for commercial introduction has not as yet been demonstrated.

10.2.1.5 LOUVER SYSTEM

The next three systems to be described in Sections 10.2.1.5, 10.2.1.6 and 10.2.1.7 are not intakes but barriers that are placed ahead of conventional intake structures to dissuade fish from entering them. Each utilizes an external stimulus to induce a behavioral response in the fish. The louver system is based on the well demonstrated tendency of fish to avoid abrupt changes in flow direction and velocity.

The principle of the louver behavioral barrier is illustrated in Figure 10.2-3. Louver panels are positioned perpendicular to the water flow and form a line at a sharp angle across the intake entrance channel. As the water flow strikes the barrier, its speed and direction changes. Fish will not willingly pass across such a barrier; instead they orient themselves at right angles to it. The velocity component parallel to the louvers assists in directing the fish to the bypass channel and safely away from the intake.

Incoming water velocity, water level and the size of the fish are critical parameters to the success of the louver system. As such, the design of the barrier is not standardized but must be custom-tailored to each application. Conventional trash bars and screens are required as the louver system performs no debris retention or filtering function.

10.2.1.6 ELECTRIC SCREENS

The use of electricity to influence fish behavior is well known. The electric screen produces a current field which repels fish and can be utilized to prevent their entrance into an intake structure.

An electric fish fence behavioral barrier is shown in Figure 10.2-3. Fish swimming towards the screen are repulsed and retreat. Several attempts to reapproach the barrier may be made before the fish begin to move along the edge of the current field and into the bypass channel.

To date, the electric screen has been utilized primarily for the diversion of upstream migrating fish such as salmon. In this mode, danger of electrocution is reduced because stunned fish will float back downstream rather than pass through the electric field. The employment of electric barriers at power plant intakes would, in most instances, constitute a reversal of this pattern as the fish would be traveling in the flow direction. Fish response to the electric field varies with size and species requiring that the screen voltage and pulse be preselected for a particular age group of a single key species. Electrical effect also depends upon the conductivity of the water which can fluctuate substantially at any one site.

10.2.1.7 BUBBLE, LIGHT AND SOUND BARRIERS

The addition of air bubble, light and sound barriers ahead of intake structures to reduce impingement losses has been attempted with varying degrees of success. In each case the effectiveness of the system depends on the magnitude of the repelling response elicited in the fish.

Air bubble screens are produced by forcibly ejecting compressed air through perforations in a pipe lying along the bottom. Active fish will generally avoid swimming through the curtain of air bubbles; however, lethargic fish (encountered during cold winter water temperatures) often do not respond to the barrier and will passively drift through it.

Light barriers depend on a negative response of fish to visible light. Experiments with light diversion have revealed that fish tend to become acclimated to the light and after several minutes its effectiveness as a barrier is negated.

Although fish can become accustomed to continuous noises, pulsating, multi-frequency sound does apparently have a repelling effect. However, the response of fish to sound varies considerably among different species.

10.2.1.8 PERFORATED PIPE

The perforated pipe intake system was originally developed to improve debris removal, but it appears to possess significant fish protection potential. It is one of the simplest intake designs in that trash bars and traveling screens are not required.

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 accomplished by perforated pipes submerged in the waterway several feet above the bottom. In flowing water application, the pipes are positioned parallel to the flow direction so that debris and fish are assisted past the intake by the natural currents. Fish encountering the pipe have clear escape paths in all directions except directly into the perforations. Low approach velocities and internal sleeving to produce uniform velocity fields can be incorporated into the perforated pipe intake design to enhance its fish protection capabilities.

Out of six known installations of perforated pipe inlets in the United States, response to inquiries on operational experience was obtained from five. These have been in satisfactory operation for a period of 3 to 14 years without any serious problems involving algae growth, clogging or fish intake even though they all have a non-uniform velocity inflow through the perforations. Four of these installations have provisions for backwashing (forcing air or water backwards through the perforations to remove adhering debris). In one case this provision has not been used since installation six years ago. In the other three cases, it has been used as necessary without any difficulty.[1]

10.2.1.9 INFILTRATION BEDS

Theoretically, the infiltration bed intake represents the maximum possible protection for fish and floating organisms. Piping buried beneath the

waterway draws water through either natural pervious material or an artificial filter medium. Approach velocities can be made extremely low resulting in zero impingement.

Where suitable water bearing permeable material exists, supply pipes can be inserted into sand and gravel aquifers beneath the water body. These are connected to a central pumping well and are termed radial well intake systems. A level of natural filtering is provided which is far superior to that of mechanical screens and capable of greatly reducing entrainment as well as eliminating impingement.

In waterways lacking sufficiently permeable beds, artificial filtering substrates can be employed. Usually built of concrete or stone, these substrates require an extensive construction effort with attendant impact on benthic life.

10.2.2 ELIMINATION OF IMPRACTICAL ALTERNATIVES

10.2.2.1 HORIZONTAL TRAVELING SCREENS

Although it represents a significant advance in mechanical screening technology with respect to fish protection, the horizontal traveling screen has not proceeded beyond the experimental stage and is still beset by major design problems. Important among these are the need to develop reliable long-life components that can withstand the stresses imposed by the screens' high rotational speeds, the danger of screen collapse due to clogging, the requirement for bypass facilities that can separate fish to be returned to the waterway from debris to be removed and the sensitivity of the screens to water level fluctuations on the order of six feet such as are common in the Clinch River at the Site. For these reasons, the horizontal traveling screen cannot be considered a reasonable alternative for the CRBRP intake system.

10.2.2.2 LOUVER SYSTEM

The louver system is technically feasible at this time. However, certain features of the system render it non-adaptable to the CRBRP Site.

Louver barrier efficiency in reducing impingement losses is highly dependent upon the water velocity through the louvers. This is a function of water level and flow rate. Only small variations in these two parameters can be tolerated. At the Site, the Clinch River regularly experiences six-foot water level differentials on a seasonal basis.

In addition to seasonal fluctuations, daily fluctuations can vary by about three feet at summer operational level to about eight feet during winter operational level. Hourly rate of flow can vary from zero to Melton Hill turbine capacity (approximately 22,000 cfs) at any time during the year. As presently conceived, the louver system could not function successfully under these conditions and does not constitute a viable alternative for the CRBRP intake system.

10.2.2.3 ELECTRIC SCREENS

While it has been shown effective for diverting upstream migrating fish in several cases, the electric screen does not appear practical for use in the CRBRP intake system. No unique or regular migration of a key species is evident in the Clinch River. Selection of the proper voltage and pulse for the screen would be difficult as the river contains a variety of species, no one of which is of dominating importance. Because fish entering the intake structure are moving with the flow of water, any that become stunned by the electrical barrier will be drawn directly through it and impinged on the intake screens. Additionally, the electric screen presents a hazard to other wildlife and to humans due to the high voltages used. For these reasons, the electric fish fence cannot be considered a reasonable alternative for the CRBRP intake system.

10.2.2.4 BUBBLE, LIGHT AND SOUND BARRIERS

The success of bubble, light and sound behavioral barriers has been far from dramatic. They have not adequately demonstrated degrees of reliability or effectiveness that would permit their consideration as viable alternatives for the CRBRP intake system.

Of the three types, the air bubble screen has shown the most promise;[2] however, it suffers from an inability to repel fish during the cold winter months. Light barriers have had poor success owing to the rapid acclimation response of fish to them. Sound barriers must be directed at one particular species to be effective. This is not practical for the Clinch River Site.

10.2.2.5 INFILTRATION BEDS

The composition of the Clinch River bottom in the Site vicinity is rock; no permeable material is present that would permit the use of a radial well intake. The employment of an artificial filtering medium would impose a potentially severe construction impact on aquatic life in the river. Additionally, currently operating artificial media have been prone to clogging and cannot guarantee an uninterrupted water supply. Infiltration beds, either natural or artificial, do not, therefore, represent reasonable alternatives for the CRBRP intake system.

10.2.3 SPECIFICATIONS FOR REASONABLE ALTERNATIVES

10.2.3.1 MODIFIED CONVENTIONAL TRAVELING SCREENS

The modified conventional traveling screens intake structure for the CRBRP would be located along the shore of the Clinch River at the position indicated in Figure 10.2-5. The entire facility is approximately 18 feet wide, extends 42 feet back from the shoreline and rises 38 feet above the river bed.

Trash racks, located at the shoreline parallel with the river flow, are 3/8-inch bars at approximately three inch centers. A mechanical trash rake removes impinged debris from the bars and carries it to deck level where it is collected for on-land disposal.

Two traveling water screens, each five feet wide with 3/8-inch square mesh openings, impede any debris which passes through the trash racks. The screens are rotated either on a periodic or continuous basis depending upon the amount of debris impinging the screens.

Debris is washed from the screen at deck level by high pressure sprays, collected in a trough and removed for on-land disposal. Wash water drains back to the river.

Screens are "flush mounted", meaning that the front face of the screen is flush with its supporting wall and parallel with the river flow as shown in Figure 10.2-6. Openings in both outer walls permit fish to escape from the screen face by swimming to the left or to the right. The combined "flush mounted" screens and interior wall openings eliminate the closed end channel which results from placing the screens in a conventional concrete channel.

Maximum approach velocity to the traveling screens, measured at minimum river water level, does not exceed 0.5 feet per second (fps).

Two 100-percent capacity makeup water pumps are located behind the traveling screens in separate bays. The total operating flow of the intake is 10,000 gpm.

10.2.3.2 TRAVELING SCREENS MOUNTED AT ANGLE TO FLOW

The angle-mounted traveling screens intake alternative for the CRBRP is identical in design to the conventional intake with the exceptions indicated in Figure 10.2-7. The portion of the structure containing the

traveling screens and circulating water pumps is positioned at a 45 to 60 degree angle to the flow of incoming water. The fish passages with trash bars utilized in the conventional screens design are replaced with a single escape channel. A fish pump and return pipe connect the escape channel to the river.

Angle-mounting adds approximately 13 feet to the overall length of the structure compared to the modified conventional intake. Operationally, the two systems are the same with the addition of the fish pump for the angle-mounted screen intake.

10.2.3.3 SINGLE ENTRY-DOUBLE EXIT (PASSAVANT) SCREENS

The single entry-double exit (Passavant) screens intake system is illustrated in Figure 10.2-8. It is 2 feet wider and 17 feet longer than the conventional intake and utilizes the same trash bars and rake design.

Two 4.5-foot wide Passavant vertical traveling screens are mounted with their faces parallel to the flow of incoming water. In the back of each screen is an escape channel leading to a collection chamber containing a fish pump and inlet for the return pipe to the river.

10.2.3.4 PERFORATED PIPE

In the perforated pipe inlet design illustrated in Figure 10.2-9, both the trash racks and the traveling screens are replaced by two submerged perforated pipes, positioned approximately 70 feet from shore, parallel to the river flow and supported off the river bottom as shown in Figures 10.2-10 and 10.2-11. Perforations will be 3/8-inch diameter maximum.

Maximum average velocity of entering water measured 0.75 inch from the face of the perforated pipe is estimated to be less than 0.4 fps. Uniform entering velocity is produced by design features noted below.

Fish have a clear escape passage in all directions except directly into the perforations.

Two 100-percent capacity perforated pipes are provided, to permit backwashing one while the other is in operation. Normal maximum inlet water velocity with both inlets in operation will thus be less than 0.2 fps.

Uniform inlet velocity through the perforations is produced by an internal perforated sleeve. Details of the inlet pipe for this specific design concept have been developed through extensive model tests.[3] Water velocity profiles at the point of intake are described in Section 10.2.4.2.2.

Removal of debris from the inlet pipe is accomplished by flow reversal in the intake piping. It is anticipated that because of the low inlet velocities associated with the perforated pipe, backwashing should be an infrequent operation. When backwashing is required, makeup water supply to the plant is interrupted and the water discharged through the plugged perforated pipe.

The pumphouse structure is located near the river bank, similar to the conventional intake design. It is, however, substantially smaller due to elimination of the racks and screens.

10.2.4 ENVIRONMENTAL COSTS

10.2.4.1 ENTRAINMENT

As the intake system draws water from the Clinch River for plant use, certain aquatic organisms in the vicinity of the intake's velocity field and small enough in size to pass through the screens will become entrained in the water supply. These organisms will be primarily composed of floating plankton but will also include (during the spawning season) fish eggs that are not laid in nests or attached to vegetation and larvae.

Numbers of aquatic organisms that become entrained are not principally a function of the intake system. Heat Dissipation System water requirements determine to the largest extent the degree of entrainment. Additionally, the fate of the organisms carried into the plant water supply system is a function of the Heat Dissipation System design. Although survival of some life forms discharged from a once through cooling system does occur, a closed cycle system such as that employed by the CRBRP causes nearly 100 percent entrainment mortality.

The influence of the intake system with reference to entrainment is limited to the effects of its location. An intake that draws water from a region of the waterway that serves as a fish spawning area or is characterized by dense plankton populations will cause an additional amount of entrainment. It is, therefore, important to avoid such unique areas for the intake location.

The location of the CRBRP intake structure is shown in Figure 10.2-5. The aquatic baseline and preconstruction monitoring programs as described in section 2.7 and 6.1 have been completed. This area of the river does not possess any unique abundance of aquatic life that would disfavor its selection. Entrainment effects may be considered substantially the same for the traveling screens intake options. Due to its off-shore location near the river bottom, the perforated pipe may have a lower level of entrainment (particularly in regard to fish eggs and larvae) associated with its operation. 13

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10.2.4.2 ENTRAPMENT AND IMPINGEMENT

The principal environmental concern that is the direct responsibility of the intake system is entrapment and impingement. Entrapment occurs when dead water areas in which fish can congregate exist within the intake structure (such as behind curtain walls). (4) Impingement refers to the physical attachment of aquatic organisms (primarily fish) on the intake

screens caused by the force exerted by the flowing water. The magnitude of the entrapment and impingement losses that occur is a function of intake water passage design, screen type, water velocity at screen face, velocity distribution along screen cross-section, fish escape features employed and the position of the intake relative to the distribution of fish.

10.2.4.2.1 FISH ESCAPE PASSAGES

Each of the four intake system alternatives utilizes some type of fish escape passage to reduce impingement losses. Further, all of the alternative intakes employ design features such as flush mounted screens to eliminate dead areas that result in fish entrapment.

The modified conventional traveling screen intake has an escape passage located at each end of the screens, as shown in Figure 10.2-6. Fish that enter the intake can, upon approaching the screens, move to either the left or right and proceed into the escape channel and back to the river. These passages, however, are simply openings in the sidewalls of the structure and as such probably function to some degree as secondary water entrance passages with subsequent water flow direction that would oppose the progress of escaping fish.

A single fish escape passage at one end of the screen face is employed with the angle-mounted traveling screen intake as shown in Figure 10.2-7. This passage, however, contains a fish pump to provide a positive force in directing fish away from the screens and back to the river. Angle-mounting is an additional feature of the escape mechanism that produces a velocity component parallel to the screen face to assist fish towards the escape passage.

The single entry-double exit traveling screen utilizes screens positioned with their faces parallel to the water flow and escape passages in the

rear of the screen areas as is illustrated in Figure 10.2-8. Fish entering the intake are not required to change direction to be drawn to safety. The escape passage lies directly in front of the fish as they enter the intake. A fish pump is employed to assist the fish through the escape channel and back to the river. Lethargic (wintering) fish that will not actively respond to currents are more likely to escape impingement with this intake design.

Fish approaching the perforated pipe intake can escape by swimming in any direction except directly into the perforations.

10.2.4.2.2 WATER VELOCITY AT THE SURFACE OF INTAKE SCREEN

One of the most important aspects of the intake system that pertains to impingement is the magnitude and distribution of the water velocity at the surface of the screens. The greater the velocity, the stronger the impingement force, and thus, the more difficult escape from the screen becomes.

There has been considerable effort expended to quantify the relation between fish impingement and screen approach velocity. The results have generally shown that the potential for impingement is significantly reduced when the screen approach velocity does not exceed 0.5 fps.[4] All four of the intake system alternatives are designed for a $\leq$ 0.5 fps approach velocity.

Although a 0.5 fps velocity has been designated, the three vertical traveling screens intake alternatives suffer from the poor velocity distribution that is generally recognized as common to traveling screens.[4] This causes localized regions of the screen face with higher than design approach velocities. Figure 10.2-12 is a velocity profile for a traveling screen similar to that required for the CRBRP. Uneven velocity distribution is evident and the occurrence of equivalent conditions with the CRBRP traveling screen intakes is to be expected.

The perforated pipe alternative utilizes a unique internal sleeve design that produces essentially uniform velocity through all perforations. Extensive model testing has been employed to verify this effect and to optimize the pipe design.[3] Figure 10.2-13 shows the velocity profile of a perforated pipe without internal sleeving. Velocity varies considerably along the screen length rising to as much as 60 percent above the design condition. In Figure 10.2-14, the velocity profile for the perforated pipe with internal sleeve modification is presented. In this case, the design velocity is not exceeded except for a small segment at the screen ends and the velocity field is nearly 100 percent uniform.

Figure 10.2-15 is a graph of approach velocity versus distance from the surface for the perforated pipe intake. It shows that the field of accelerating flow for this intake design does not extend beyond 1/4 inch from the pipe surface. Thus, a fish must pass extremely close to the surface itself to be affected by suction force. As both perforated pipes represent only 0.4 percent of the cross-sectional area of the river at the proposed intake location, the potential for impingement is confined to a very small region of the river.

Two 100-percent capacity pipes are employed by the perforated pipe intake. During normal operation, both will be functioning resulting in a screen approach velocity of less than 0.2 fps.

10.2.4.2.3 FISH RESOURCES IN CLINCH RIVER

The degree to which consideration is given to intake systems that provide extensive fish protection features is to a certain extent a function of the significance of the fish resources of the waterway. An important game or commercial fish production area or residence of a unique or rare and endangered fish species should quite naturally receive greater attention in reference to intake design than a water body for which no such conditions exist.

Only three game fish species are well represented, the sauger, striped bass, and white bass. Forage and rough fish dominate in both numbers and biomass.[5] Although Watts Bar Reservoir produced a commercial fish harvest of nearly 95,000 pounds in 1973, catches within a 10-mile radius of the Site amounted to only one percent of this total.[6] No unique or rare and endangered fish species live in this portion of the Clinch River, as discussed in Section 2.7.

10.2.4.3 CONSTRUCTION EFFECTS

Construction of the CRBRP intake systems will cause temporary dislocation of some aquatic life and produce potential silt and turbidity additions to the river. Specific practices and techniques used to minimize the construction impact are examined in Section 4.1.

The three traveling screen intake alternatives are similar in design and will have essentially identical construction effects. Although substantially different in design, the perforated pipe intake should not cause a construction impact dissimilar to the other three as the additional adverse effect of installing the submerged pipes will be balanced by the smaller amount of work required at the shoreline for the perforated pipe pumphouse. Consequently, none of the intake system alternatives offers any significant decrease in construction impact.

10.2.4.4 AESTHETIC IMPACT OF INTAKE STRUCTURE

At present the portion of the Clinch River in the vicinity of the intake location may be characterized as a natural setting. The shoreline is relatively undisturbed. As such, the CRBRP intake structure represents an aesthetic intrusion, although its individual impact will be lessened by the presence of the plant itself.

The three traveling screen intake alternatives will present large, open concrete structures rising from the river bed at the shoreline.

Their aesthetic impact will be considerable with the angle-mounted screens intake the most imposing due to its angled posture.

The perforated pipe intake will present the least visual impact of the intake alternatives. The pipes themselves will be submerged and hidden from view. The only visible structure will be the enclosed pumphouse along the shoreline which is much smaller than the other three intake structures.

10.2.5 ECONOMIC COSTS

Monetary costs (capital and operating) for the CRBRP intake system alternatives are presented in Table 10.2-1. Due to its simple design which eliminates the need for trash rakes and traveling screens and subsequent large shoreline structure, the perforated pipe intake is the lowest cost alternative as shown in Table 10.2-1. The modified conventional traveling screens intake is nearly two and one-half times as costly and the angle-mounted and single entry-double exit traveling screens intakes are approximately three and four times, respectively, the cost of the perforated pipe alternative.

There are fewer moving parts associated with the perforated pipe and no debris disposal is required. System maintainability for the four alternatives will be influenced by the presence of Asiatic clams in the Clinch River; however, no significant differences among the system designs would be anticipated.

10.2.6 COMPARISON OF ALTERNATIVES

10.2.6.1 DIRECT COMPARISON OF ALL REASONABLE ALTERNATIVES

A comparative summary of the economic and environmental costs for the four CRBRP intake alternatives is presented in Table 10.2-2. The results indicate that the perforated pipe intake is the

economically preferable system and for two environmental costs, entrainment and construction effects, the four alternatives are equivalent. The aesthetic impact of the perforated pipe system is moderate when compared to travelins screen alternatives. Therefore, the benefit-cost analysis revolves about a balancing of fish impingement against the economic costs. 13

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The intake system chosen for the CRBRP should be designed to reduce fish mortality to that degree consistent with the value of the fish resource of the river and the constraints of economics. These constraints dictate that the additional monetary cost incurred by the employment of an intake system equipped with extensive fish protection features be matched by an equivalent reduction in its environmental cost. In view of this, the modified conventional traveling screens intake alternative is eliminated from further consideration because of its failure to produce environmental improvement in proportion to its higher monetary costs (in comparison to the base case perforated pipe intake). In fact, in terms of

the effectiveness of its fish escape features, the conventional intake is the least desirable alternative.

Three remaining alternative systems each offer certain advantages and limitations in reference to impingement effects. The angle-mounted traveling screens intake produces a velocity vector parallel to the screen face to assist fish into the escape passages; however, a positive swimming response by the fish is required. The single entry-double exit traveling screens intake employs escape passages directly in the path of fish entering the intake; therefore, no swimming response is needed. Both of these intakes utilize fish pumps to transfer fish to safety, but the velocity distribution across the screen faces is non-uniform and subject to local regions of higher than desired speeds. The perforated pipe alternatives requires fish approaching the intake to swim away to escape; however, the escape field is very large (all directions except directly into the perforations) and the intake field of accelerating flow is very small (extending only 0.25 inch above the pipe surface).

Comparing these three intake systems, the above enumerated features tend to balance one another resulting in fish impingement losses that should not substantially differ among the alternatives. Of the three, the single entry-double exit intake is potentially the most effective in reducing impingement due to its capability to better protect lethargic (wintering) fish. The angle-mounted traveling screens and perforated pipe intakes can be considered approximately equal with the fish pump and screen angle features of the angle to flow intake balanced by the superior approach velocity characteristics of the perforated pipe. When the monetary cost differential and aesthetic impact are considered, the perforated pipe intake is preferable overall to the angle-mounted traveling screens.

The foregoing analyses have now reduced the number of competing alternatives to the single entry-double exit traveling screens and perforated pipe. The traveling screens intake possesses a small advantage in fish

protection but is considerably more costly economically and is less desirable aesthetically. In view of the nature of the fish resource of the Clinch River near the Site as described in Secion 10.2.4.2.3, the impingement reduction advantage offered by the single entry-double exit intake fails to outweigh its burden of economic and aesthetic costs.

10.2.6.2 REASONS FOR SELECTION OF CHOSEN SYSTEM

The perforated pipe intake system has been selected for the CRBRP. It offers the advantages of a simple design that eliminates the need for costly trash rakes and traveling screens, a unique internal sleeve modification to produce very desirable approach velocity characteristics that provide significant protection against fish impingement, a small enclosed shoreline structure that reduces the aesthetic impact associated with conventional intakes and no debris disposal requirements.

TABLE 10.2-1

ECONOMIC COSTS FOR INTAKE ALTERNATIVES

	Conventional Traveling Screens	Angle-Mounted Traveling Screens	Single Entry Double Exit Traveling Screens	Perforated Pipe
Substructure	$ 81,000	$117,000	$174,000	BASE
Superstructure	22,000	BASE	6,000	2,000
Trash Rake	24,000	24,000	24,000	NA*
Traveling Screen	48,000	48,000	60,000	NA*
Perforated Pipe	NA*	NA*	NA*	46,000
CAPITAL COST DIFFERENTIAL	$127,000	$141,000	$216,000	BASE
EQUIVALENT INVESTMENT OPERATING COST DIFFERENTIAL	1,000	1,000	1,000	BASE
TOTAL DIFFERENTIAL COST	$128,000	$142,000	$217,000	BASE

*Not applicable

TABLE 10.2-2

SUMMARY OF ENVIRONMENTAL AND ECONOMIC COSTS FOR INTAKE ALTERNATIVES

	Conventional Traveling Screens	Angle-Mounted Traveling Screens	Single Entry Double Exit Traveling Screens	Perforated Pipe
Environmental Costs				
Entrainment	Same	Same	Same	Same
Impingement				
Fish escape passages	Fair	Good	Excellent	Good
Water velocity at screens	0.5 fps @ 1.0 inch	0.5 fps @ 1.0 inch	0.5 fps @ 1.0 inch	0.2 fps @ 0.75 inch*
Velocity distribution	Poor	Poor	Poor	Excellent
Construction Effects	Same	Same	Same	Same
Aesthetic Impact	Considerable	Considerable	Considerable	Moderate
Economic Costs				
Monetary Costs ($)	127,000	141,000	216,000	Base
Maintainability	Same	Same	Same	Same

*With both pipes operating

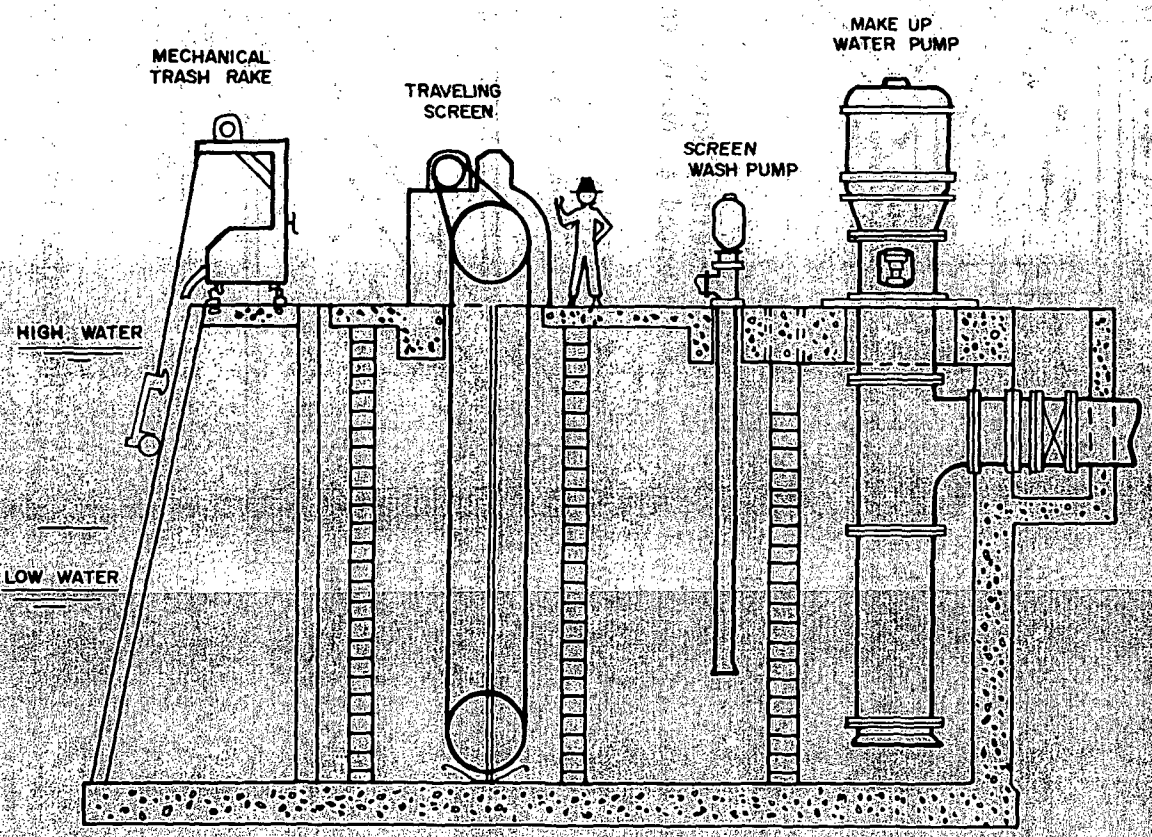
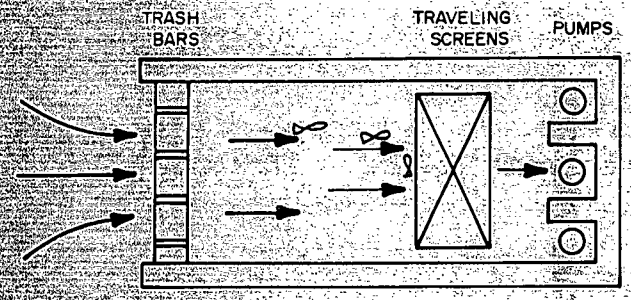
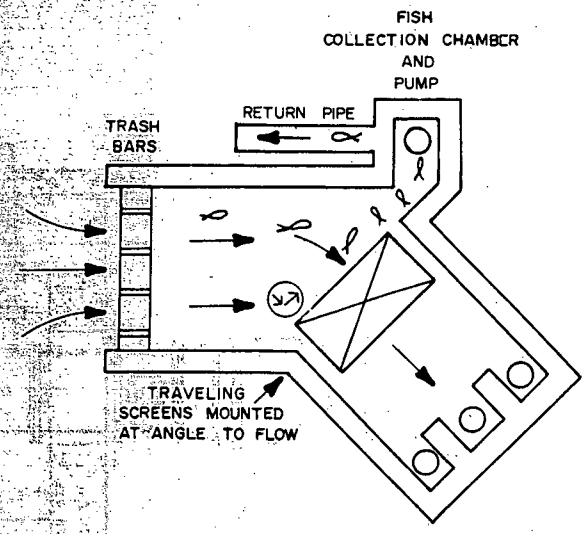


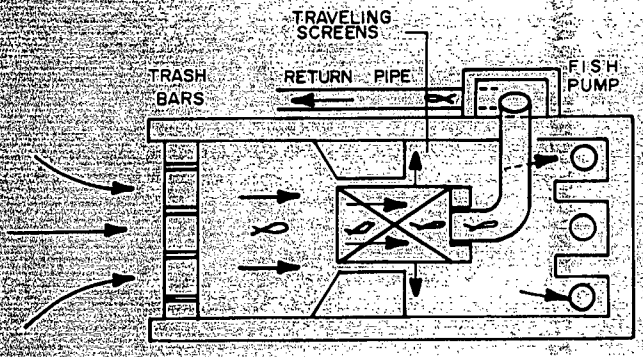
Figure 10.2-1 CONVENTIONAL TRAVELING SCREENS INTAKE STRUCTURE



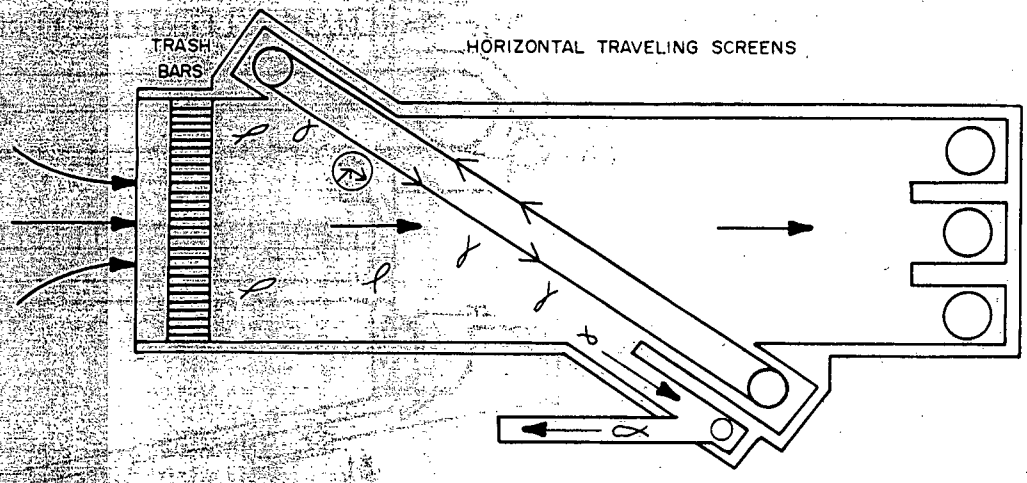
Conventional Traveling Screens



Traveling Screens
Mounted at Angle to Flow



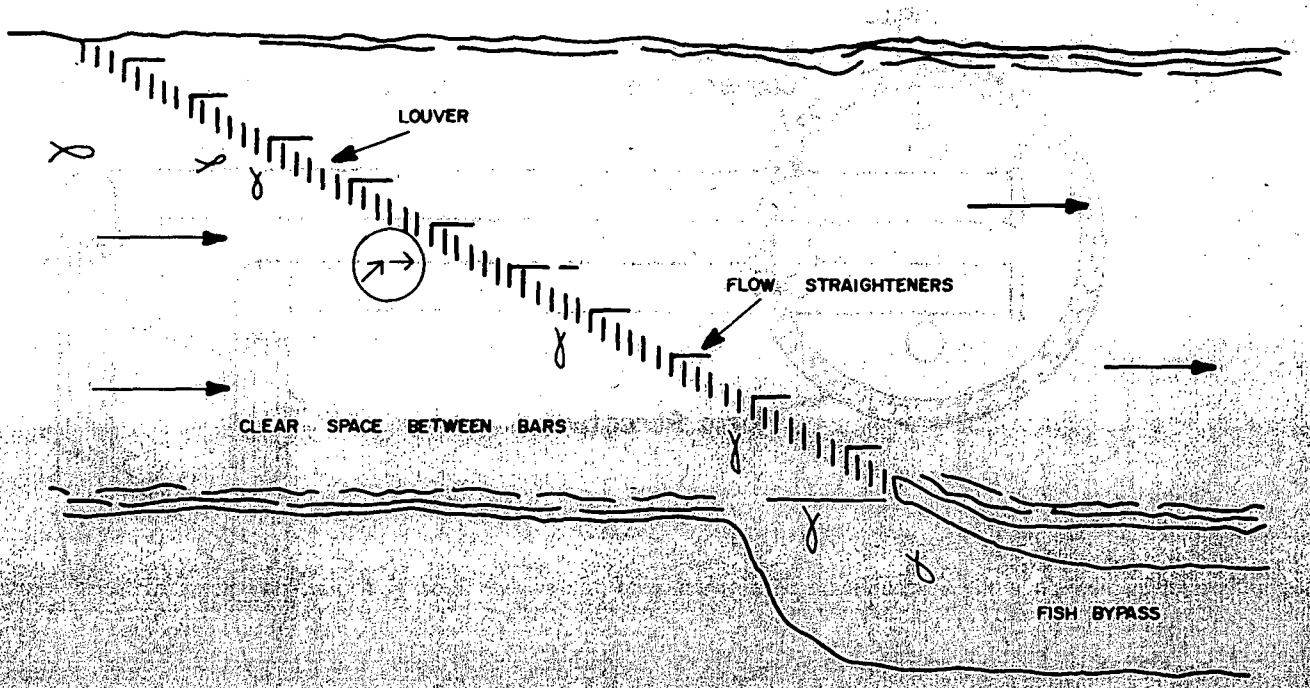
Single Entry-Double Exit Screens



Horizontal Traveling Screens

Figure 10.2-2 FISH PROTECTION FEATURES OF TRAVELING SCREENS INTAKE ALTERNATIVES

LOUVER BARRIER



ELECTRIC FISH FENCE

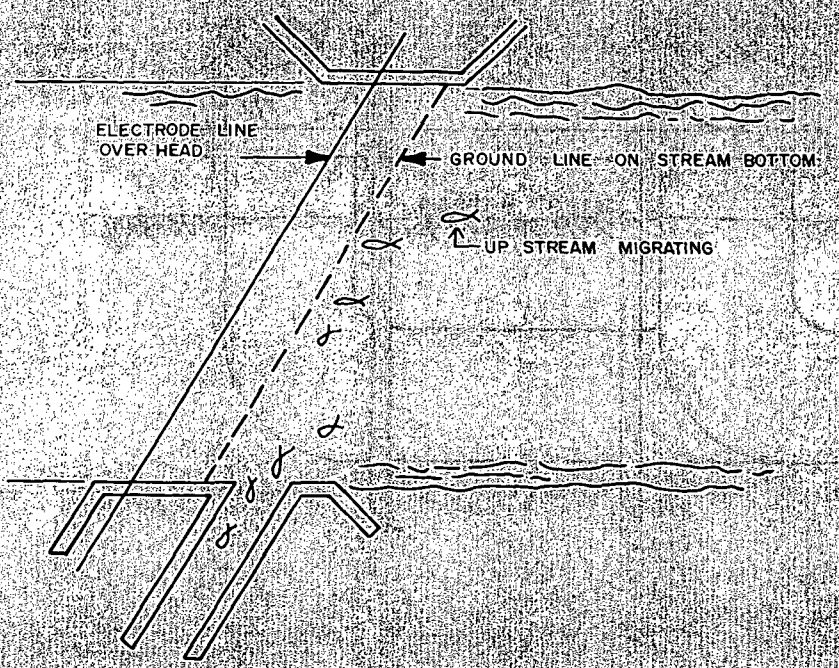


Figure 10.2-3 BEHAVORIAL BARRIERS

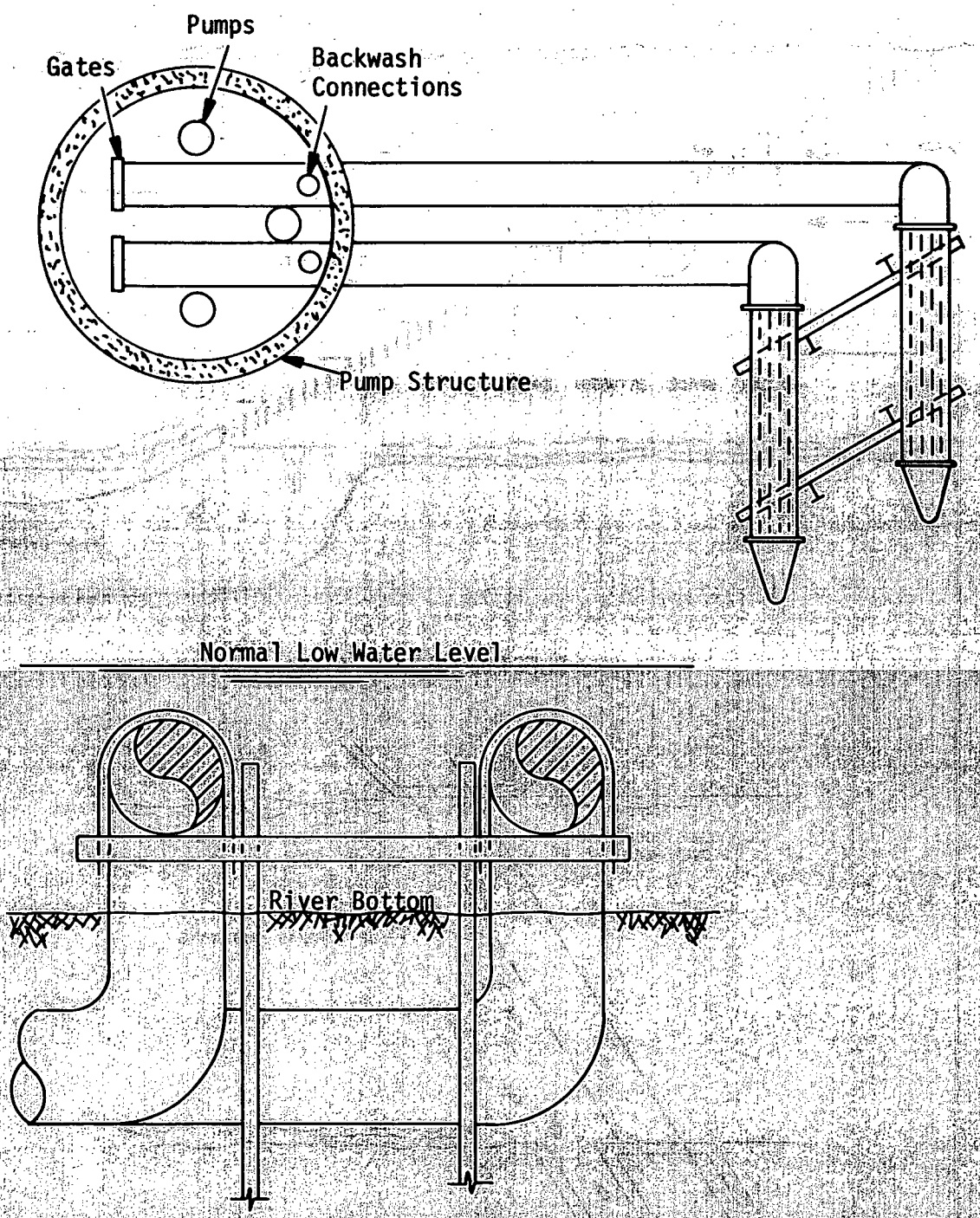


Figure 10.2-4 PERFORATED PIPE INTAKE SYSTEM

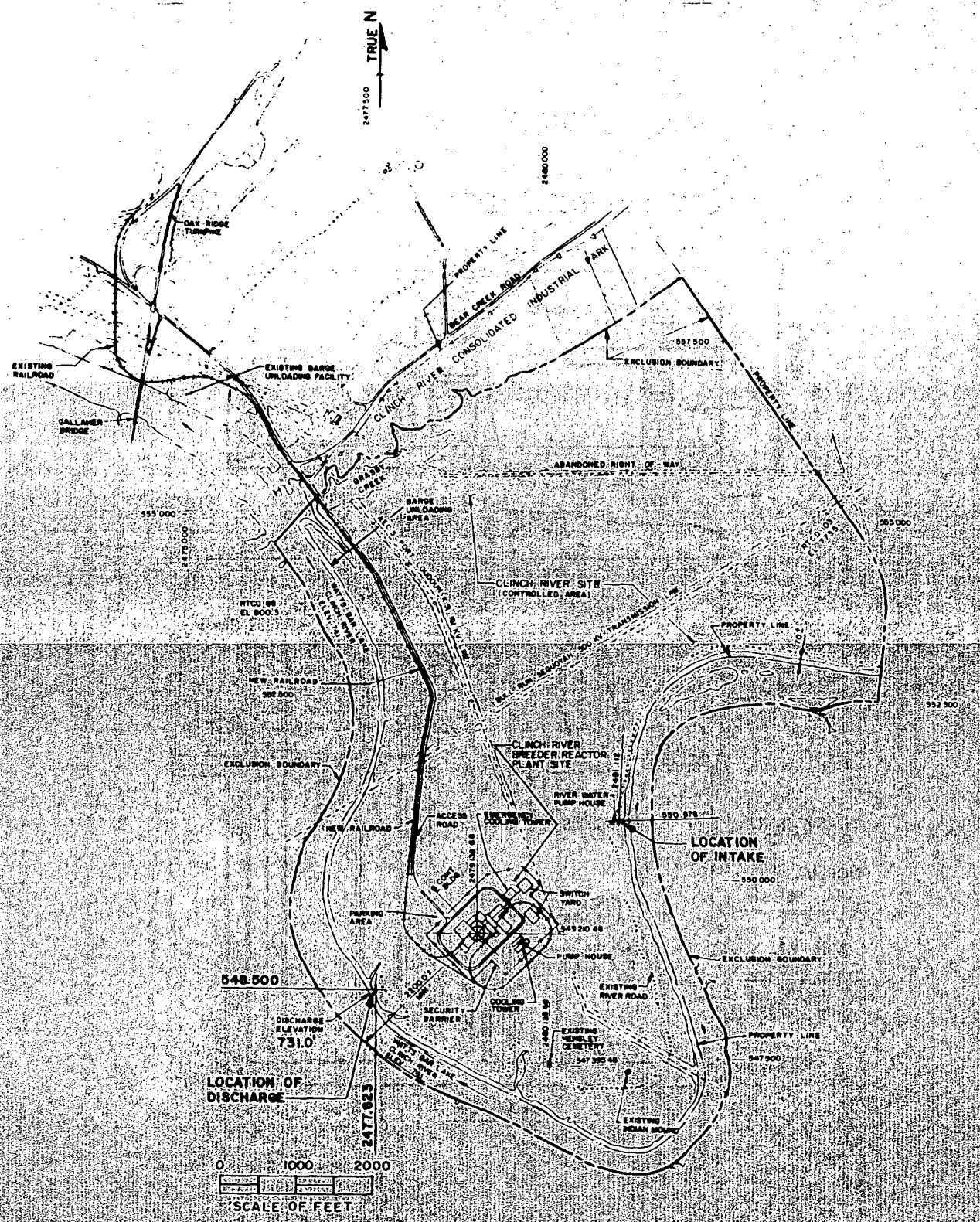


Figure 10.2-5 LOCATION OF CRBRP INTAKE

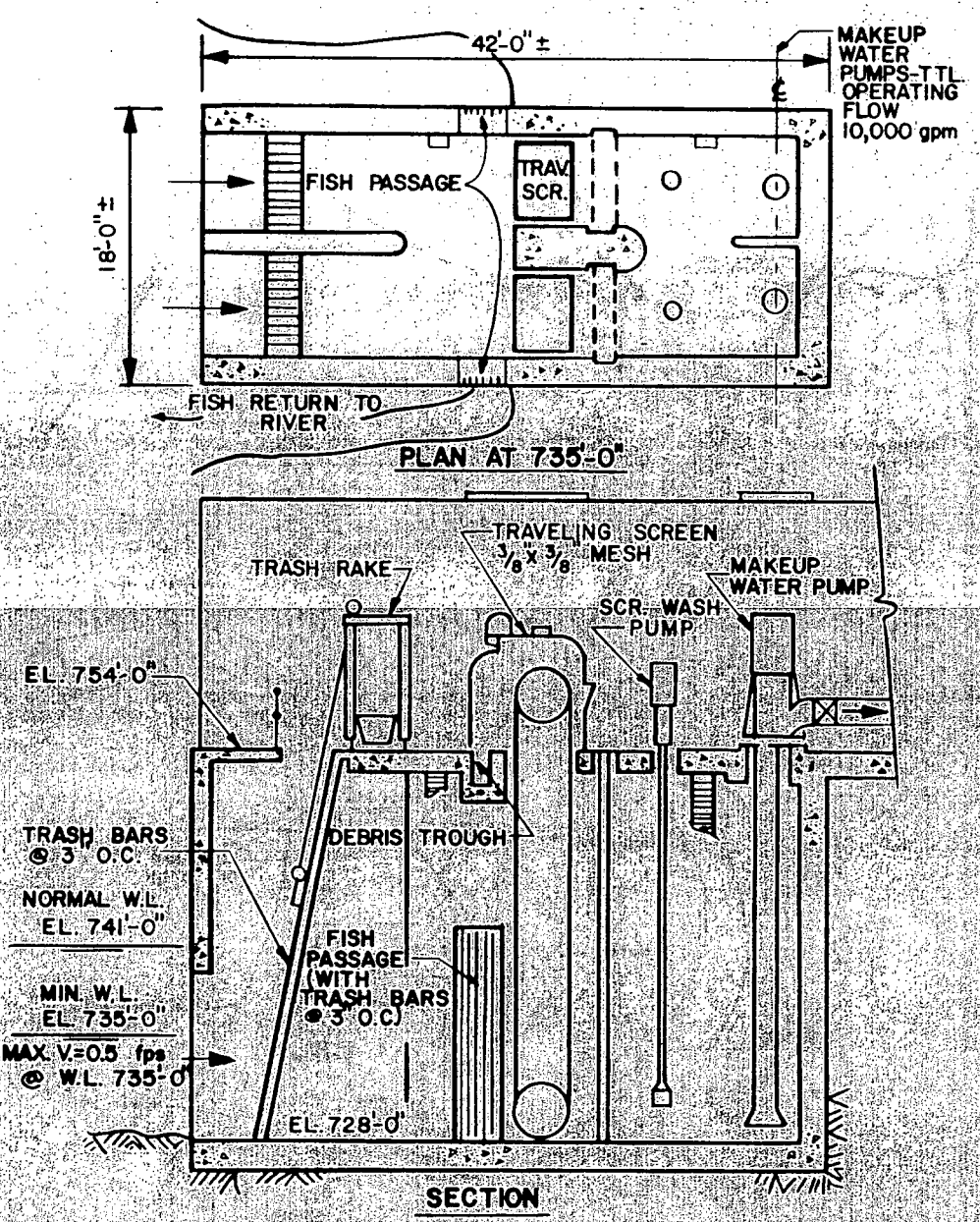


Figure 10.2-6 CONVENTIONAL TRAVELING SCREENS INTAKE SYSTEM

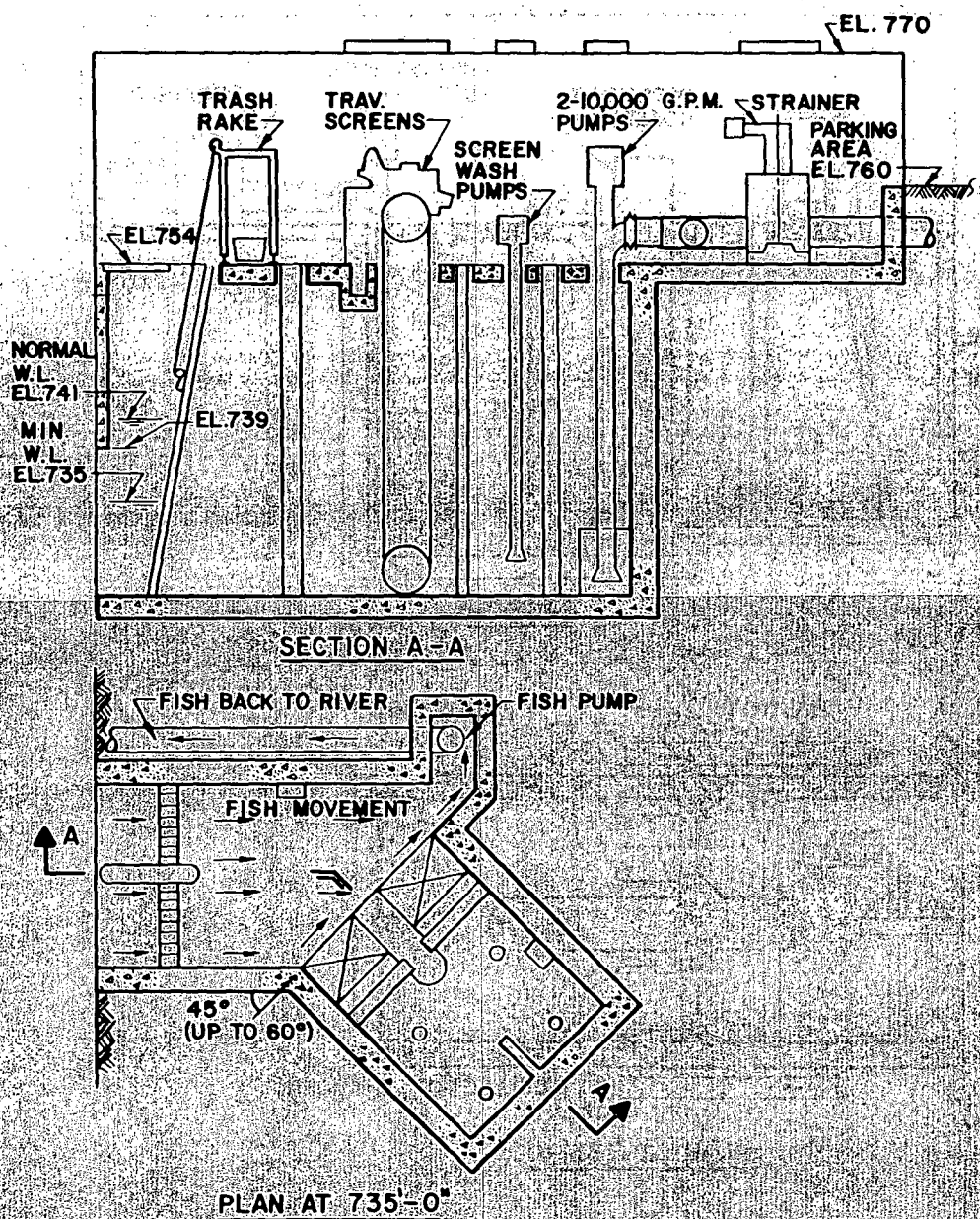
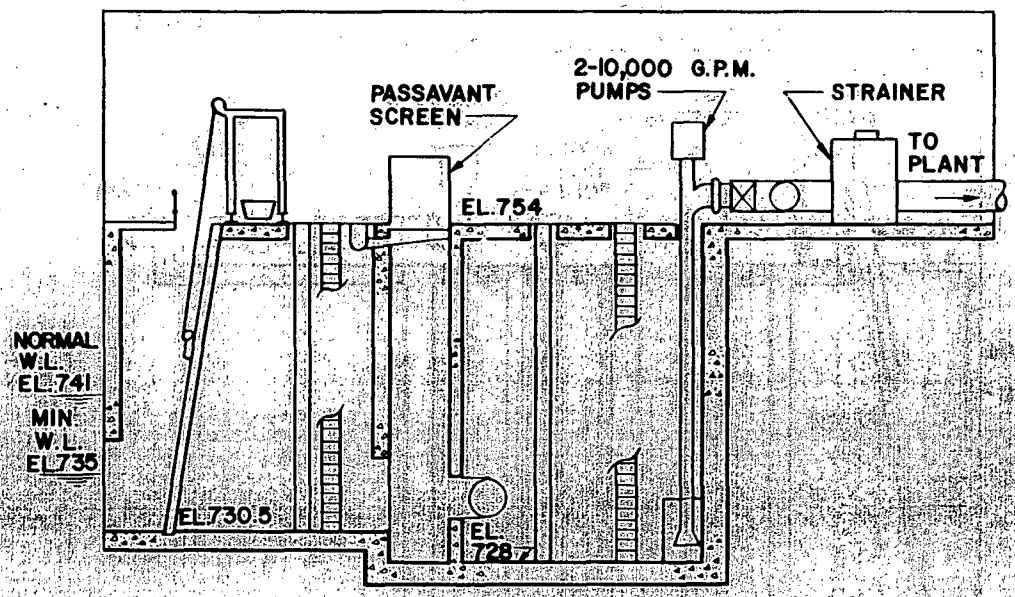
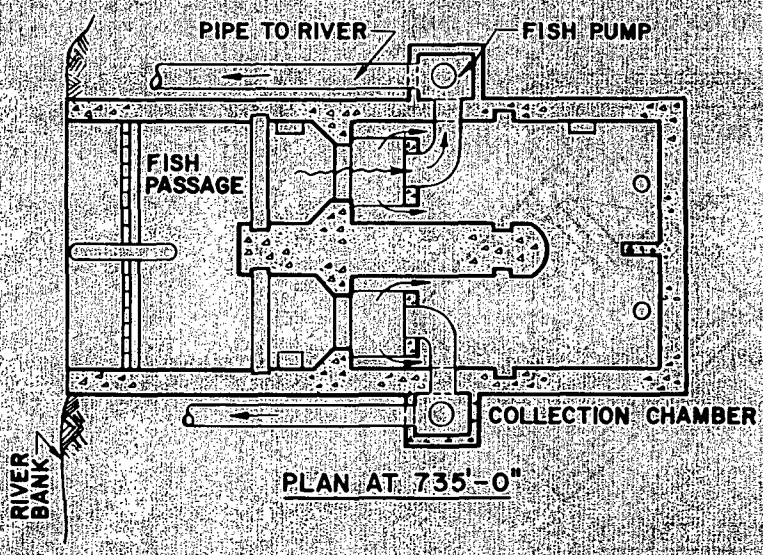


Figure 10.2-7 TRAVELING SCREENS MOUNTED AT ANGLE TO FLOW

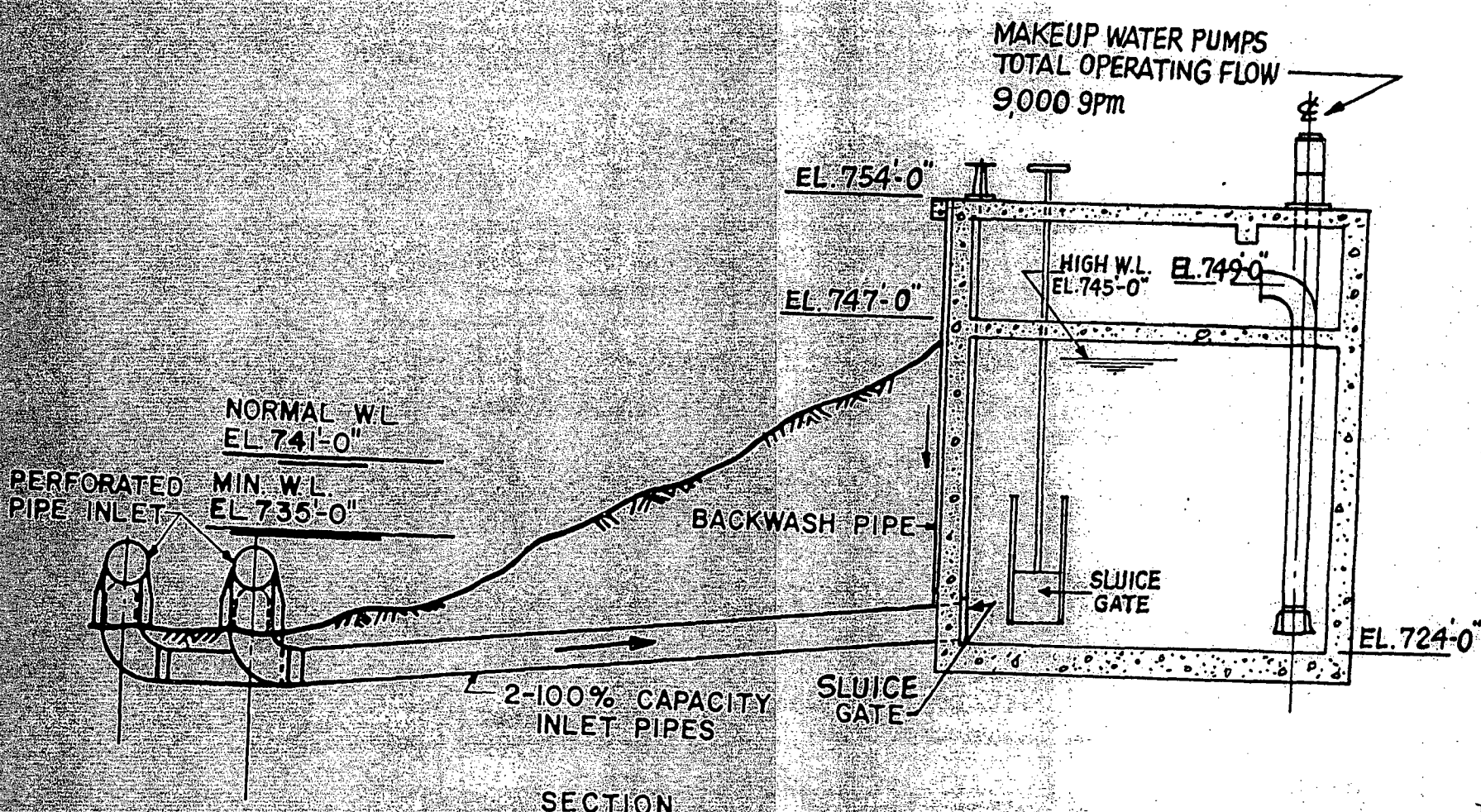


SECTION



PLAN AT 735'-0"

Figure 10.2-8 SINGLE ENTRY-DOUBLE EXIT (PASSAVANT) SCREENS



SECTION

Figure 10.2-9 PERFORATED PIPE INTAKE SYSTEM

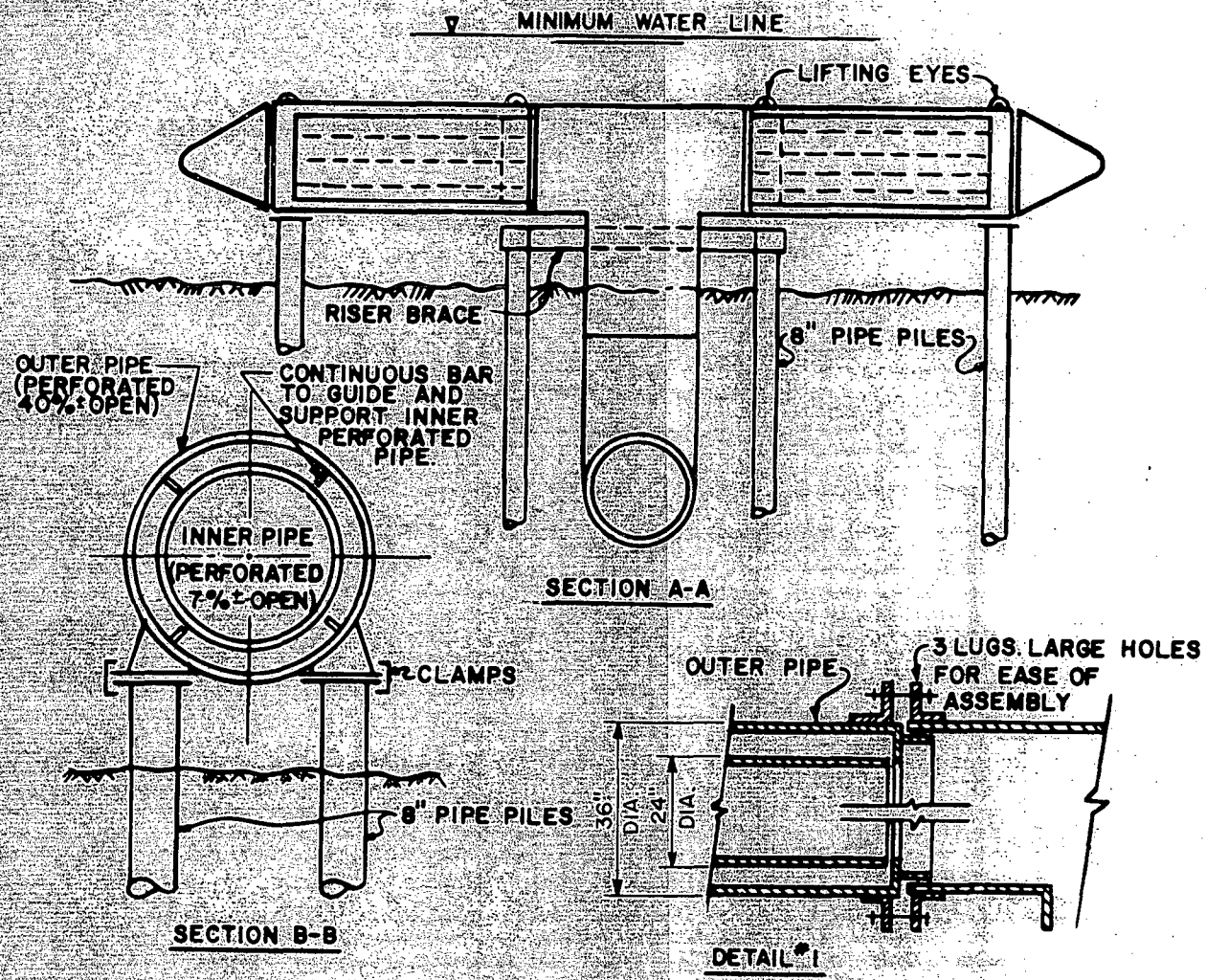


Figure 10.2-10 PERFORATED PIPE SUPPORTING FRAMEWORK

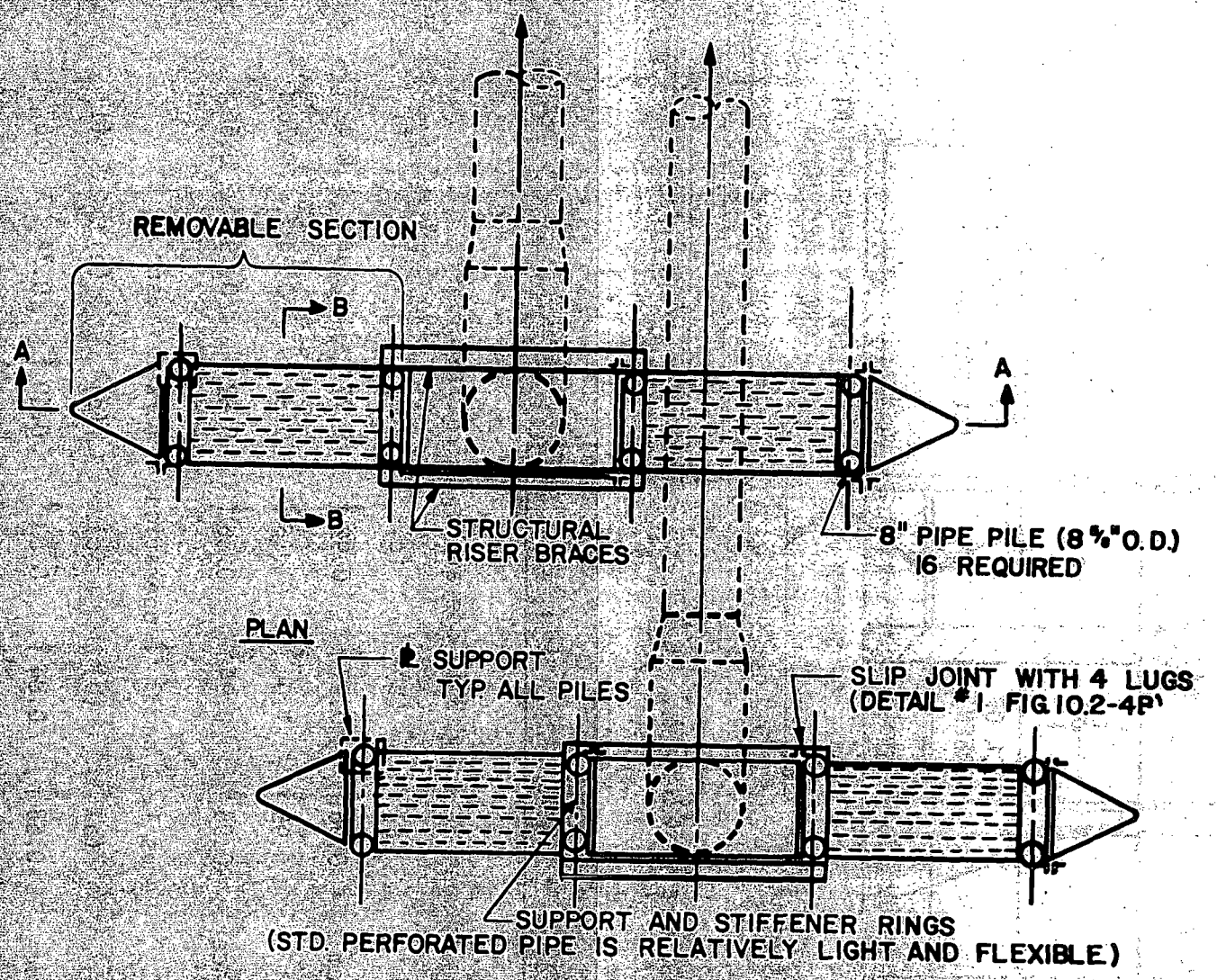
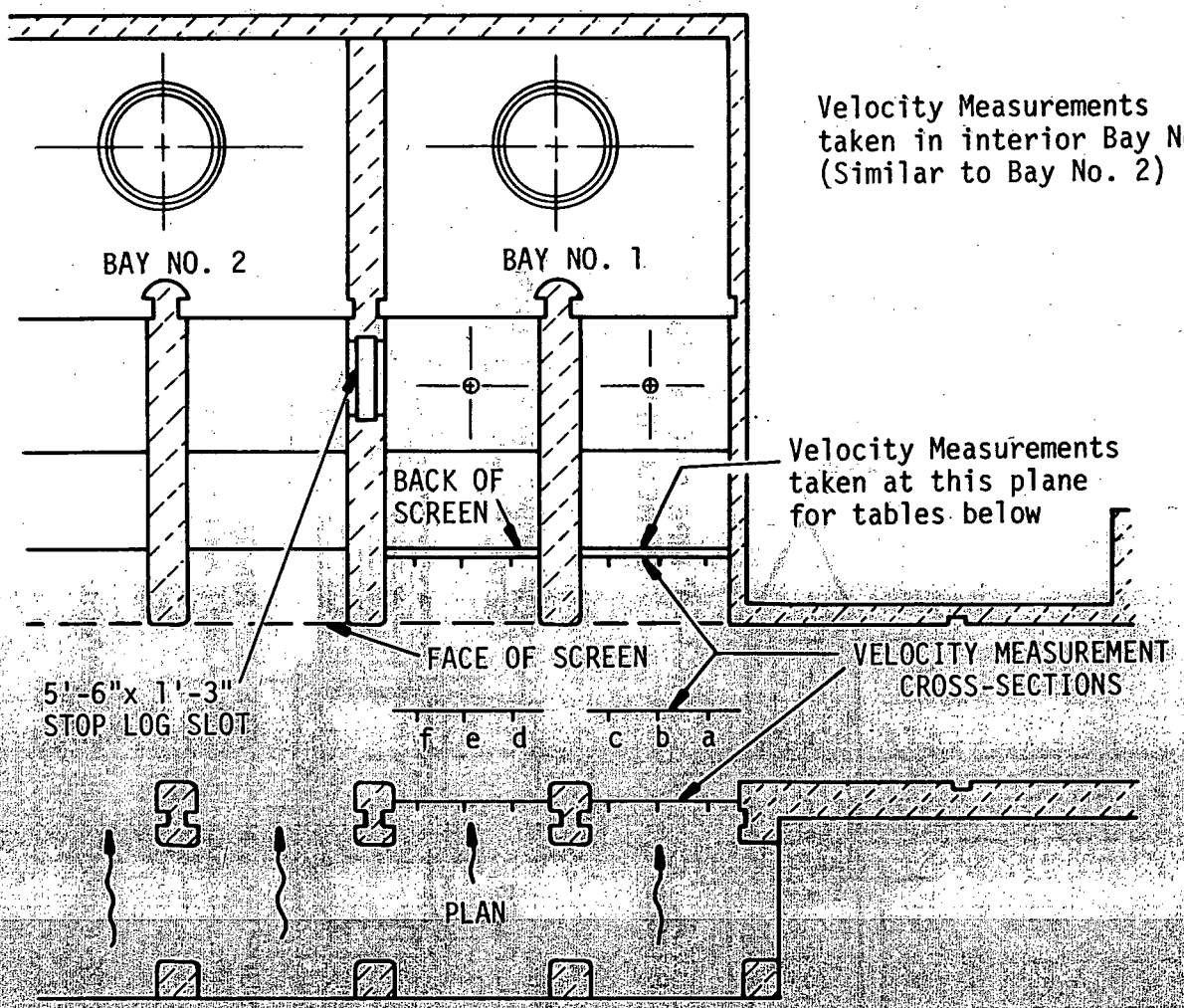


Figure 10.2-11 PERFORATED PIPE CONNECTIONS TO PUMPHOUSE



Pumps 1, 2 and 3 in operation; 0.5 ft/sec river

	(a)	(b)	(c)	(d)	(e)	(f)
Near Bottom	0.96 ↑	0.97 ↑	0.92 ↑	0.77 ↑	0.84 ↑	0.42 ↑
Mid-Depth	0.95 ↑	1.04 ↑	1.06 ↑	0.87 ↑	0.84 ↑	0.76 ↑
Near Surface	0.96 ↑	0.94 ↑	0.86 ↑	0.82 ↑	0.79 ↑	0.65 ↑

Pumps 1, 2 and 3 in operation; 2 ft/sec river

	(a)	(b)	(c)	(d)	(e)	(f)
Near Bottom	0.68 ↑	0.84 ↑	0.80 ↑	0.60 ↑	0.74 ↑	0.67 ↑
Mid-Depth	0.80 ↑	0.95 ↑	1.06 ↑	0.67 ↑	0.80 ↑	0.81 ↑
Near Surface	1.20 ↑	1.01 ↑	0.47 ↑	0.63 ↑	0.63 ↑	(nil) ↑

Figure 10.2-12 TRAVELING SCREEN VELOCITY PROFILE[7]

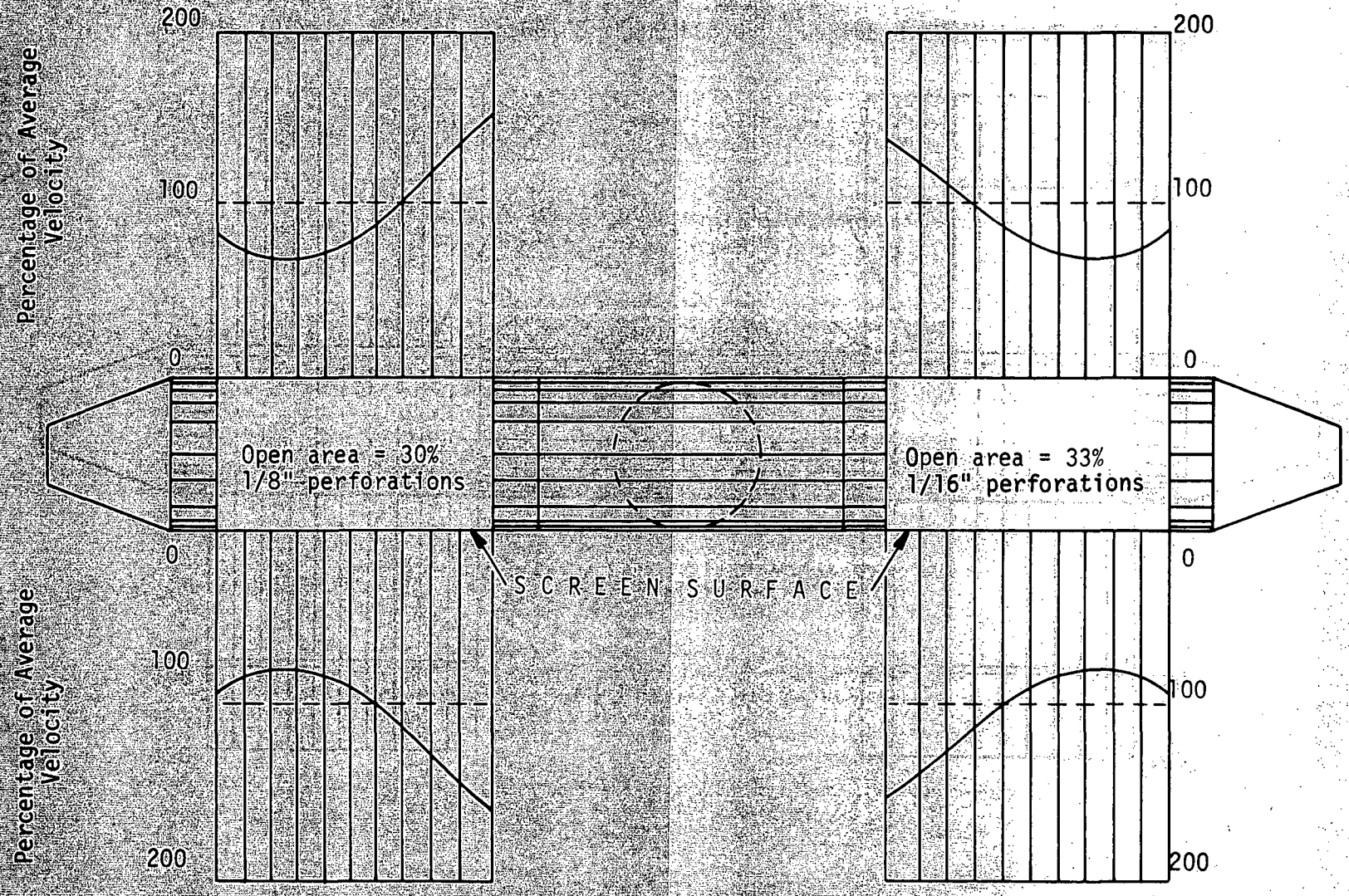


Figure 10.2-13 VELOCITY PROFILE ALONG PERFORATED PIPE WITHOUT INTERNAL SLEEVE (3)

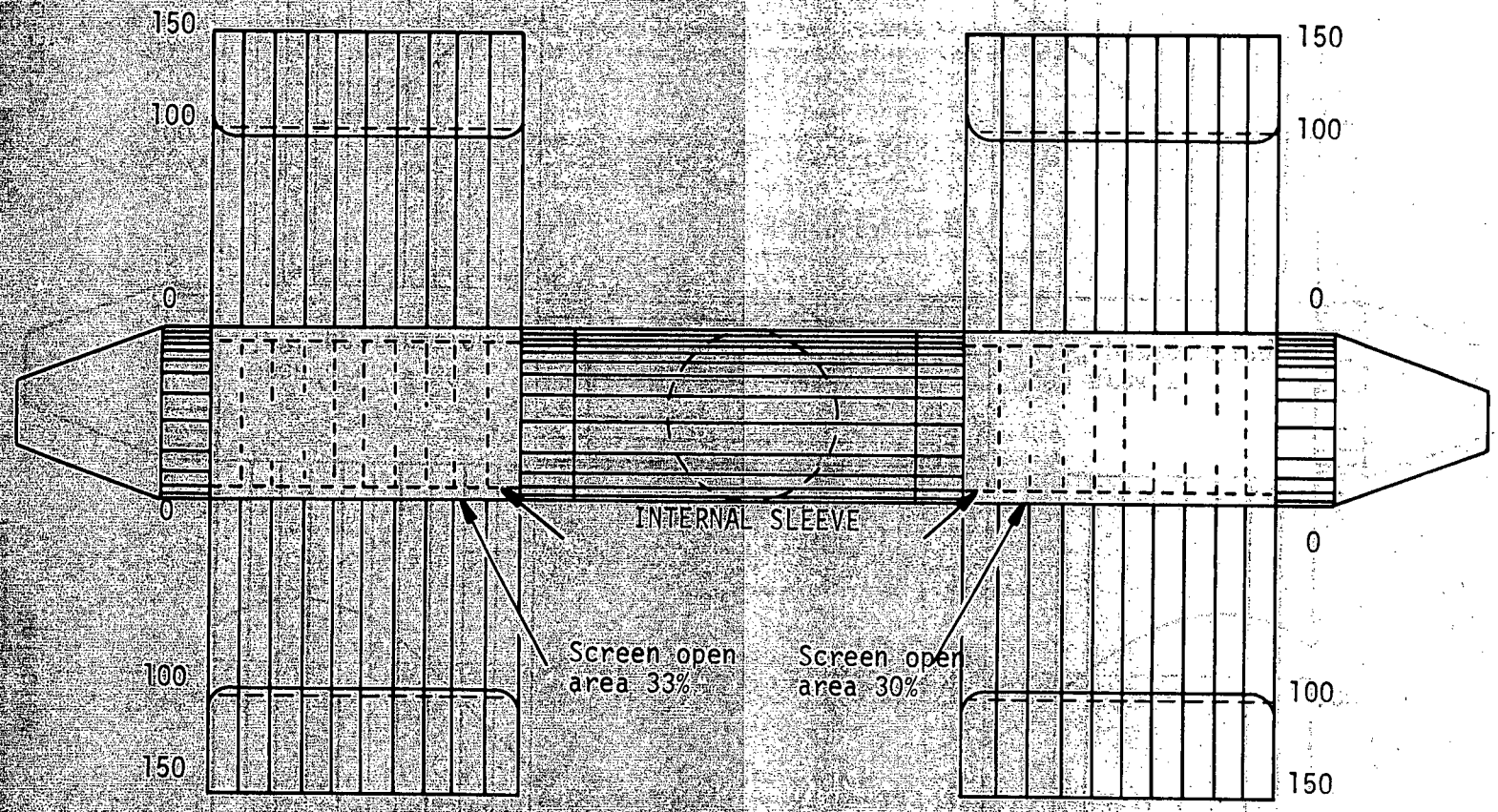


Figure 10.2-14 VELOCITY PROFILE ALONG PERFORATED PIPE WITH INTERNAL SLEEVE[3]

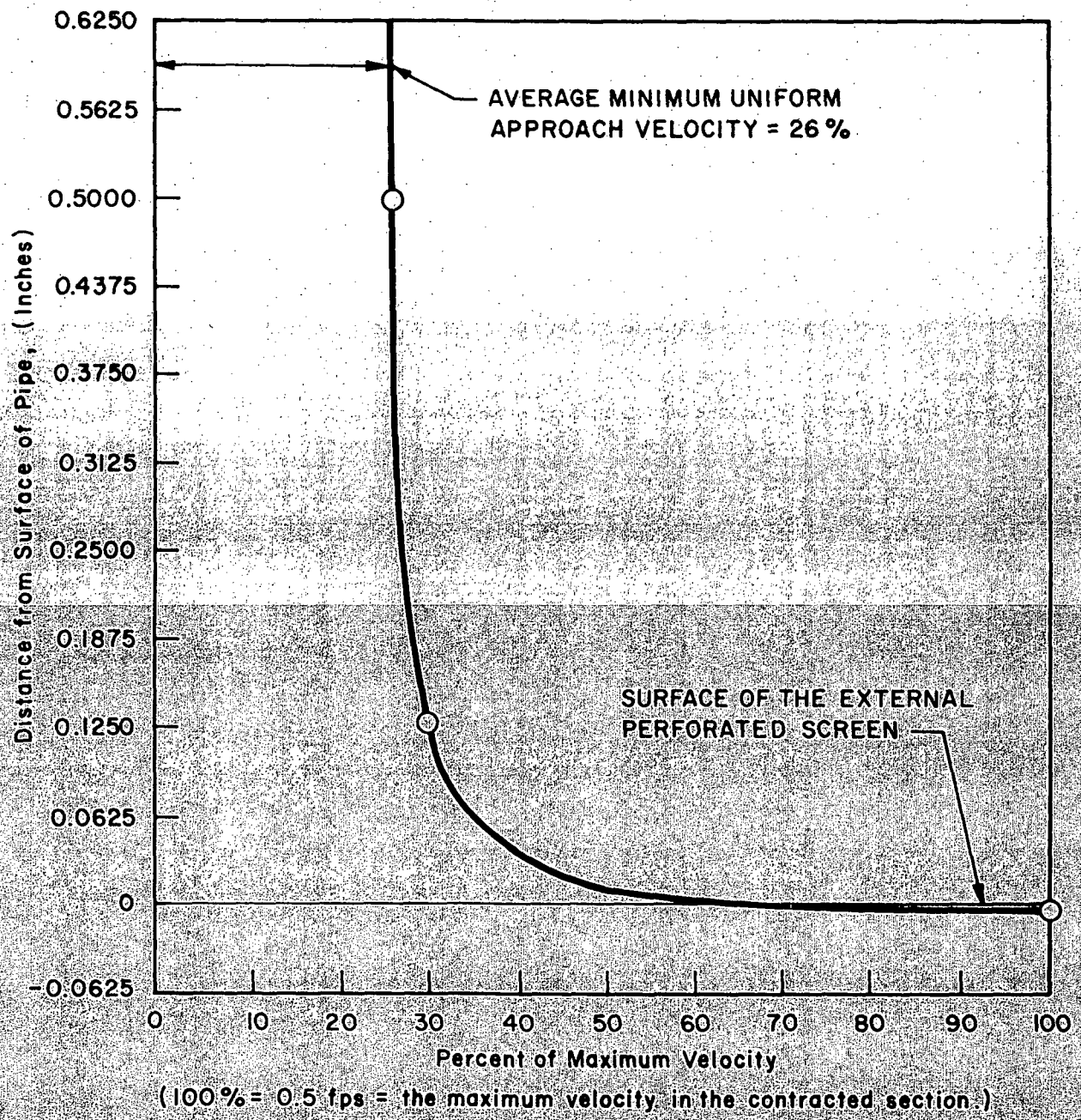


Figure 10.2-15 APPROACH VELOCITY VERSUS DISTANCE FROM SURFACE OF A PERFORATED PIPE[3]