Table F-1. Hydrostratigraphic units in the vicinity of SRP[a,b,c] (continued)

Formation	Recharge	Discharge	Confining layers	Other characteristics
CONGAREE (continued)				
		Almost no leakage downward through basal clay and upper Ellenton clay to Ellenton sands, or upward through green clay.	Top of Ellenton	Water yields to wells moderate to high: Central SRP: 2.5 m^3/min with 15-meter drawdown; A/M-Areas: 0.11 m^3/min with 9-meter drawdown. Water levels shown on Figs. 3-8, F-5, F-10, F-11, F-16, F-17, F-18, F-28, F-29, and F-33. $K_V = 1.8 \times 10^{-4}$ m/day (of basal clay) Hydraulic conductivity: F/H-Areas: $K_L = 1.5$ m/day (Table F-7; Fig. F-14). C/P-Areas: $K_L = 40$ m/day. A/M-Areas: $K_L = 0.7$ to 1.0 m/day. Effective porosity: F/H-Areas: $j = 0.20$. A/M-Areas: $j = 0.14$. $I = 0.0015$ to 0.005. $V_L = 365IK_L/j =$ F/H-Areas: 13.7 m/year. A/M-Areas: 3.2 m/year.

Table F-1. Hydrostratigraphic units in the vicinity of SRP[a,b,c] (continued)

Formation	Recharge	Discharge	Confining layers	Other characteristics
ELLENTON				
Upper Cretaceous (Period) or Paleocene Epoch of Tertiary Period 18 m thick in Separations Area No surface exposure	From underlying Tuscaloosa and offsite areas.	Upper clay layer of Tuscaloosa *may be discontinuous* or or contain sandy zones which permit communication.	Lower pisolitic clay of Congaree *Upper clay layer* of Ellenton Upper clay layer of Tuscaloosa; usually not effective confining layer	Upper 3-5 m thick lignitic clay, silty and sandy clay layer, *becoming thicker toward* northwest (10 m in A/M-Areas). Lower layer of medium-to-coarse clayey quartz sand. Permeable portion of Ellenton and upper Tuscaloosa considered to be single aquifer. Water levels shown on Figs. 3-8, F-5, F-10, F-12, F-27, and F-33. $K_v = 9.8 \times 10^{-5}$ m/day (of upper clay unit).
TUSCALOOSA				
Upper Cretaceous (Period) 180 m thick in Separations Area	Principally from offsite areas - outcrop area 15-50 km wide in South Carolina near the Fall Line and in major stream valley (see Figs. F-7 and F-31).	Upper Tuscaloosa to lower unit of Ellenton. Ground water beneath SRP flows to sink along Savannah River.	Upper clay layer of Ellenton Upper clay layer of Tuscaloosa; usually not effective confining layer Basal clay layer	Two aquifer units within Tuscaloosa separated by clay layer: Upper layer of clay, sandy clay, and clayey sand 18 m thick allows communication with Ellenton aquifer. Upper aquifer of well-sorted medium to coarse sand 46 m thick. Middle layer 12 m thick with one or more clay units. Lower aquifer of well-sorted medium to coarse sand 92 m thick.

AW-1,
FE-2

Table F-1. Hydrostratigraphic units in the vicinity of SRP[a,b,c] (continued)

Formation	Recharge	Discharge	Confining layers	Other characteristics
TUSCALOOSA (continued)				
				Basal clay layer 12 m thick overlying saprolitic basement.
				Water yields to wells are large with 3.5-4.0 m^3/min wells having drawdowns of 6-12 meters at center of core of depression and during pumping tests. Drawdowns are typically 0.3 m 490-700 m from pumping well.
				Water levels shown on Figs. 3-8, F-5, F-6, F-7, F-8, F-9, F-10, F-11, F-12, F-16, F-22, F-27, F-28, F-29, and F-33.
				In central SRP, heads in Tuscaloosa are higher than Congaree heads; opposite is true in A/M-Areas. Differences beneath seepage basins are currently about: Area — Upward differential (m) L — 3.7 F — 7.6 H — 3.0 M — -5.5
				Transmissivity (11 values): Mean is 1.5 x 10^6 ℓ/day/m^2. Mean is 1.4 x 10^6 ℓ/day/m^2.
				Storage coefficient (mean of 7 values) is 4.5 x 10^{-4}.

AW-1,
FE-2

Table F-1. Hydrostratigraphic units in the vicinity of SRP[a,b,c] (continued)

Formation	Recharge	Discharge	Confining layers	Other characteristics
TUSCALOOSA (continued)				
				K_L = 40.8 m/day. j = 0.2 - 0.30. I = 0.0007. $V_L = 365IK_L/j$ = 52.2 m/year.

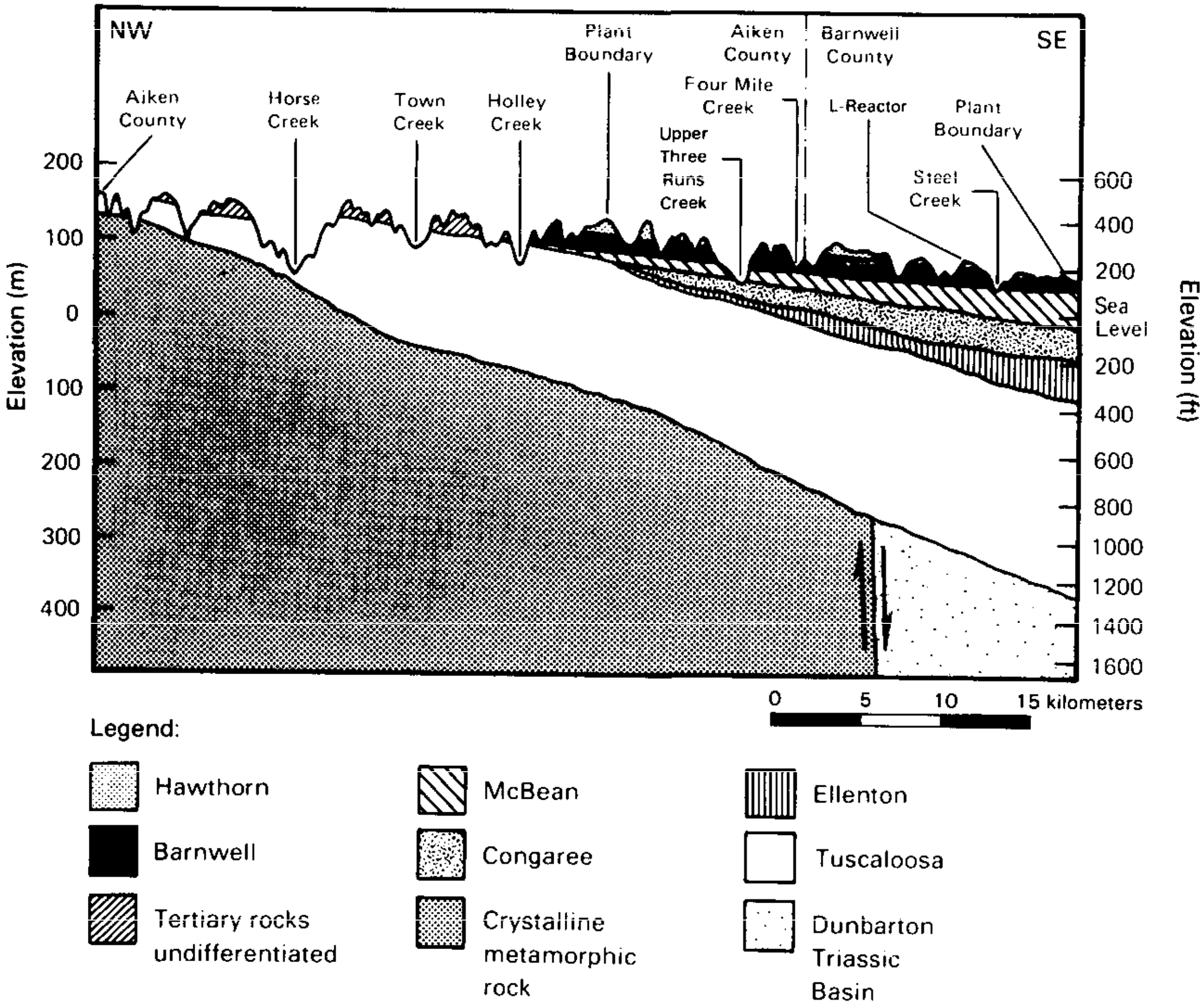
AW-1,
FE-2

[a] Additional descriptive information is presented in Table 3-8.

[b] Abbreviations:

K_L = Lateral hydraulic conductivity
K_V = Vertical hydraulic conductivity
I = Hydraulic gradient (decimal)
j = Effective porosity (decimal)
V_L = Lateral ground-water velocity
V_V = Vertical ground-water velocity

[c] Sources: Du Pont (1983c); Root (1983)

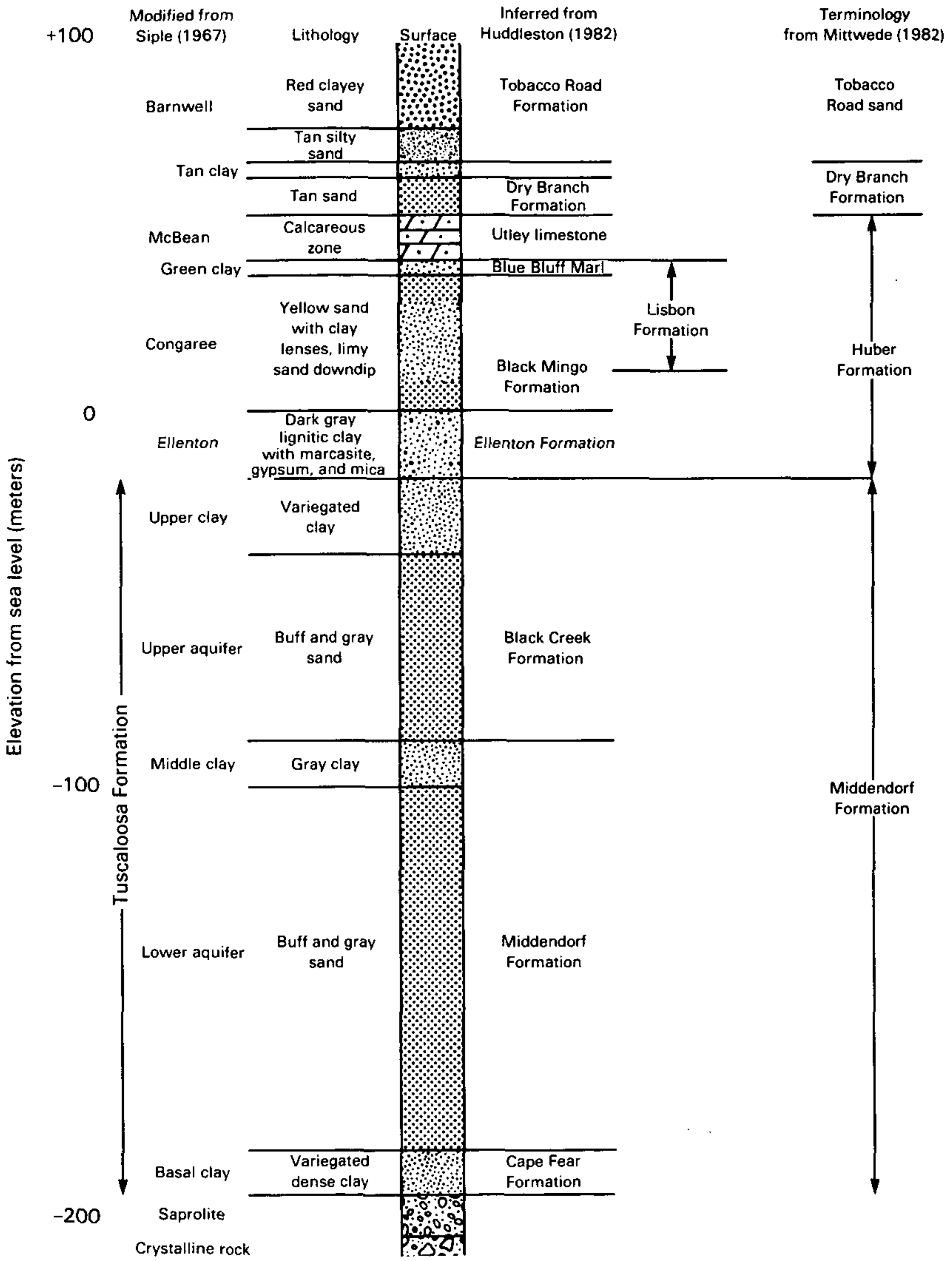


Note: Figure F-6 shows the location of this geologic profile.

Source: Siple (1967).

TC

Figure F-3. **Generalized northwest to southeast geologic profile across the Savannah River Plant.**



Source: Du Pont (1983).

Figure F-4. Tentative correlation of stratigraphic terminology of the southwestern South Carolina Coastal Plain.

F.2 DESCRIPTION OF THE HYDROSTRATIGRAPHIC UNITS

Three distinct geologic and hydrologic systems exist in the SRP vicinity (Figure F-3):

- The coastal plain sediments where water occurs in porous, unconsolidated to semiconsolidated sands and clays
- The buried crystalline metamorphic basement rock consisting of chlorite-hornblende schist, hornblende gneiss, and lesser amounts of quartzites, where water occurs in small fractures
- A buried Triassic basin consisting mostly of red consolidated mudstone with some poorly sorted sandstones, where water occurs in the intergranular space but is very restricted in movement by the extremely low permeability

Figure F-5 shows the depth and thickness of the hydrostratigraphic units in the coastal plain sediments and the water levels associated with each unit near the center of SRP (H-Area).

F.2.1 Crystalline metamorphic rock

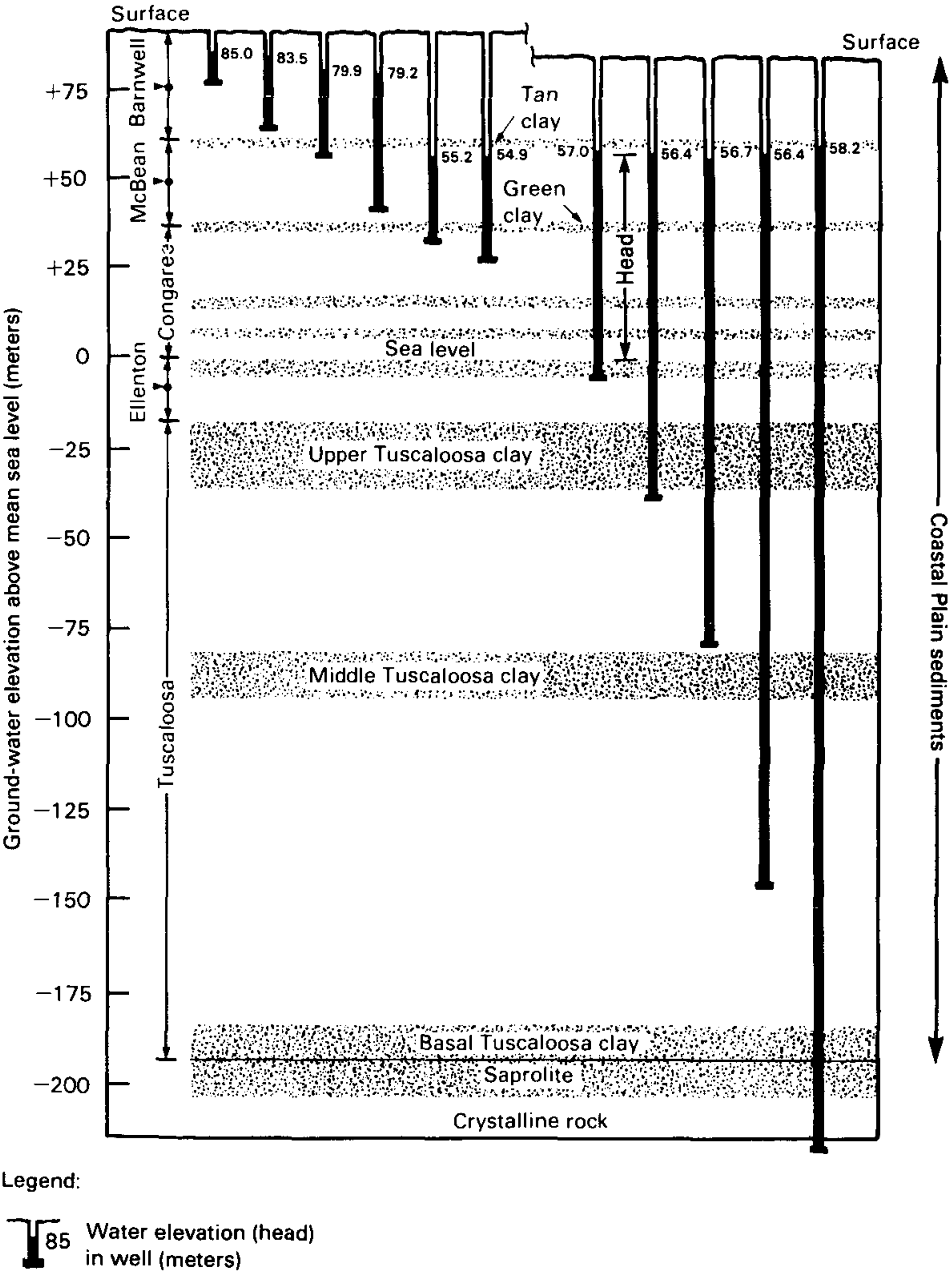
Near the center of SRP the crystalline and metamorphic rock is buried beneath about 280 meters of unconsolidated-to-semiconsolidated coastal plain sediments (Marine, 1967). The surface of the rock dips to the southeast at a gradient of about 6.8×10^{-3} (Siple, 1967), and the rock crops out at the Fall Line about 40 kilometers northwest of SRP.

Water injection and removal tests on packed-off sections of rock indicate that there are two types of fractures in the crystalline rock (Marine, 1966). The first type consists of minute fractures that pervade the entire rock mass but transmit water extremely slowly. Rock that contains only this type of fracture is called "virtually impermeable rock." The other type of fracture is restricted to definite zones that are vertically restricted but laterally correlatable and have larger openings that transmit water faster. Rock that includes this type of fracture is called "hydraulically transmissive rock."

Representative values of the hydraulic conductivity are 1.2×10^{-2} liters per day per square meter for virtually impermeable rock and 33 liters per day per square meter for hydraulically transmissive rock (Marine, 1975). Analysis of a two-well tracer test with tritium indicated a fracture porosity of 0.08 percent in a hydraulically transmissive fracture zone (Webster et al., 1970). Laboratory analyses of cores indicated an average intergranular porosity of 0.13 percent.

Immediately overlying the crystalline rock is a layer of clay (saprolite), which is the residual product of weathering of the crystalline rock. The combined saprolite and basal-Tuscaloosa clay (Figure F-5) at the top of the metamorphic rock form an effective seal that separates water in the coastal plain sediments from water in the crystalline metamorphic rock.

TC



TC Note: Figure F-6 shows well locations.

Sources: ERDA (1977), Du Pont (1983).

Figure F-5. Geology and hydrostatic head in ground water near the center of the *Savannah River Plant (H-Area) in 1972.*

Except for testing programs, there is no pumpage from the metamorphic rock until the Fall Line is approached. From there westward in the Piedmont Province, the metamorphic rock provides water for domestic use. Because of the prolific aquifer in the overlying coastal plain sediments and the saprolite/clay seal, it is unlikely that the hydrologic regimen of the metamorphic rock will be impacted by Savannah River Plant in this area.

Table F-2 shows a typical chemical analysis of water from the crystalline metamorphic rock. The water has a total dissolved solids content of about 6,000 milligrams per liter, which is largely calcium (500 milligrams per liter), sodium (1,300 milligrams per liter), sulfate (2,500 milligrams per liter), and chloride (1,100 milligrams per liter).

F.2.2 Triassic sedimentary rock

A groben-like basin of mudstone (the Dunbarton Basin), formed by downfaulting of the crystalline metamorphic rock during the Triassic Period, is buried beneath about 370 meters of coastal plain sediments (Figure F-3). The northwest boundary of the basin has been well defined by seismic traverses and by a well that penetrated 490 meters of Triassic rock and then passed into the crystalline metamorphic rock below. The southeast margin is not as well defined because there is no well similarly placed to the one that defines the northwest margin (Marine, 1976a).

The upper surface of the Triassic rock is beveled by the same erosional cycle that created a peneplain on the crystalline rock surface. This surface is now tilted at a gradient of about 6.8 x 10^{-3} (Siple, 1967), but after correcting for this dip, the surface is extremely flat and featureless. |TC

The depth to the bottom of the Dunbarton Basin is not known from well penetration except along the northwest border. A well near the center of the basin was drilled to a depth of 1,300 meters and did not penetrate crystalline rock.

The Triassic sediments consist of poorly sorted, consolidated gravel, sand, silt, and clay. The coarser material is found near the northwest margin where fanglomerates are abundant. Nearer the center, sand, silt, and clay predominate; however, the sorting is always extremely poor (Marine and Siple, 1974), which causes an extremely low primary permeability in the Triassic rocks. Ground water occurs in the primary porosity of the Triassic clastic rock. However, the hydraulic conductivity is extremely low, and water movement is almost nonexistent.

The hydraulic conductivity of the Triassic sedimentary rock as determined from field tests ranged from 4 x 10^{-3} to 4 x 10^{-6} liters per day per square meter (Marine, 1974). The average total porosity was 8.0 percent for sandstones and 3.3 percent for mudstones. The average effective porosity was 7.0 percent for sandstones and 0.53 percent for mudstones.

Table F-2. Chemical analyses of water from metamorphic and Triassic rock at Savannah River Plant

	Mineral content, mg/ℓ									
Well	SiO_2	Fe	Ca	Mg	Na	K	HCO_3	SO_4	Cl	Total dissolved solids
DRB8 Crystalline Rock	7.6	0.03	467	15	1,200	16	18	2,590	900	5,660
DRB9										
Triassic	1.0	0.00	518	83	1,120	30	72	420	2,620	5,950
Crystalline Rock	6.1	0.09	461	38	1,440	11	29	2,460	1,260	5,990
P12R	--	0.05	22	7.6	262	9.3	157	<1	330	800
DRB11 Triassic	--	<1	3,845	8.5	2,710	22.1	1	1	11,600	18,500
DRB10	3.5	0.04	1,990	53	2,100	44	85	110	6,720	11,900
54P Coastal Plain	12	0.18	5.0	0.9	1.2	1.0	10.5	14.1	1.4	38

Adapted from Du Pont (1983).

Table F-2 lists some chemical analyses of water samples from the Dunbarton Basin of Triassic age. Samples from the deeper wells (DRB 10 and DRB 11) near the center of the basin had total dissolved solids contents (almost entirely sodium chloride) of 12,000 and 18,000 milligrams per liter.

No water is pumped from the Dunbarton Triassic Basin, nor is there likely to be in the future because of the poor water quality and the low permeability of the rocks.

F.2.3 Tuscaloosa Formation

F.2.3.1 Hydrostratigraphy

The Tuscaloosa Formation consists primarily of fluvial and estuarine deposits of cross-bedded sand and gravel with lenses of silt and clay. It rests directly on saprolite, a residual clay weathered from the crystalline metamorphic rock. The Tuscaloosa is overlain conformably by the Ellenton Formation, but near the Fall Line, where the Ellenton is absent, it is overlain unconformably by sediments of Tertiary and Quaternary age (Siple, 1967). The Tuscaloosa crops out in a belt that extends from Western Tennessee to North Carolina. In South Carolina, this belt is from 15 to 50 kilometers wide. The thickness of the Tuscaloosa ranges from zero at the Fall Line to about 230 meters beneath the L-Reactor site at Savannah River Plant (Figure F-3). The thickness remains fairly constant in the SRP area.

In this region, the Tuscaloosa consists of light gray to white, tan, and buff colored cross-bedded quartzitic to arkosic coarse sand and gravel, with lenses of white, pink, red, brown, and purple silt and clay (Siple, 1967). Ferruginous sandstone concretions, siderite nodules, and lenses of kaolin 0.5 to 12 meters thick are present in the Tuscaloosa. The chief minerals in the sediments are quartz, feldspar, and mica, which were derived from weathering of the igneous and metamorphic rocks of the Piedmont province to the northwest.

In areas of the South Carolina Coastal Plain within about 40 kilometers of the Fall Line, sand beds in the Tuscaloosa Formation form one of the major supplies of ground water. Industrial wells in this aquifer commonly yield more than 3,800 liters per minute of good quality water.

The Tuscaloosa Formation is the thickest (170-250 meters) of the coastal plain formations in this area (Figures F-3 and F-5). Near the center of the SRP area, the units of the Tuscaloosa Formation from top to bottom (Figure F-5) are (1) a unit of clay, sandy clay, or clayey sand about 20 meters thick; (2) an aquifer unit of well-sorted medium to coarse sand about 45 meters thick; (3) a unit, about 12 meters thick, in which one or more clay lenses occur; (4) an aquifer unit of well-sorted medium-to-coarse sand about 90 meters thick; and (5) a basal unit of sandy clay about 12 meters thick. The two aquifer units (2 and 4) combined are about 135 meters thick and are used singly and together to supply water-production wells at SRP. For many purposes, they are treated as one aquifer; however, they are hydraulically separated at Savannah River Plant, except near wells that take water from both units.

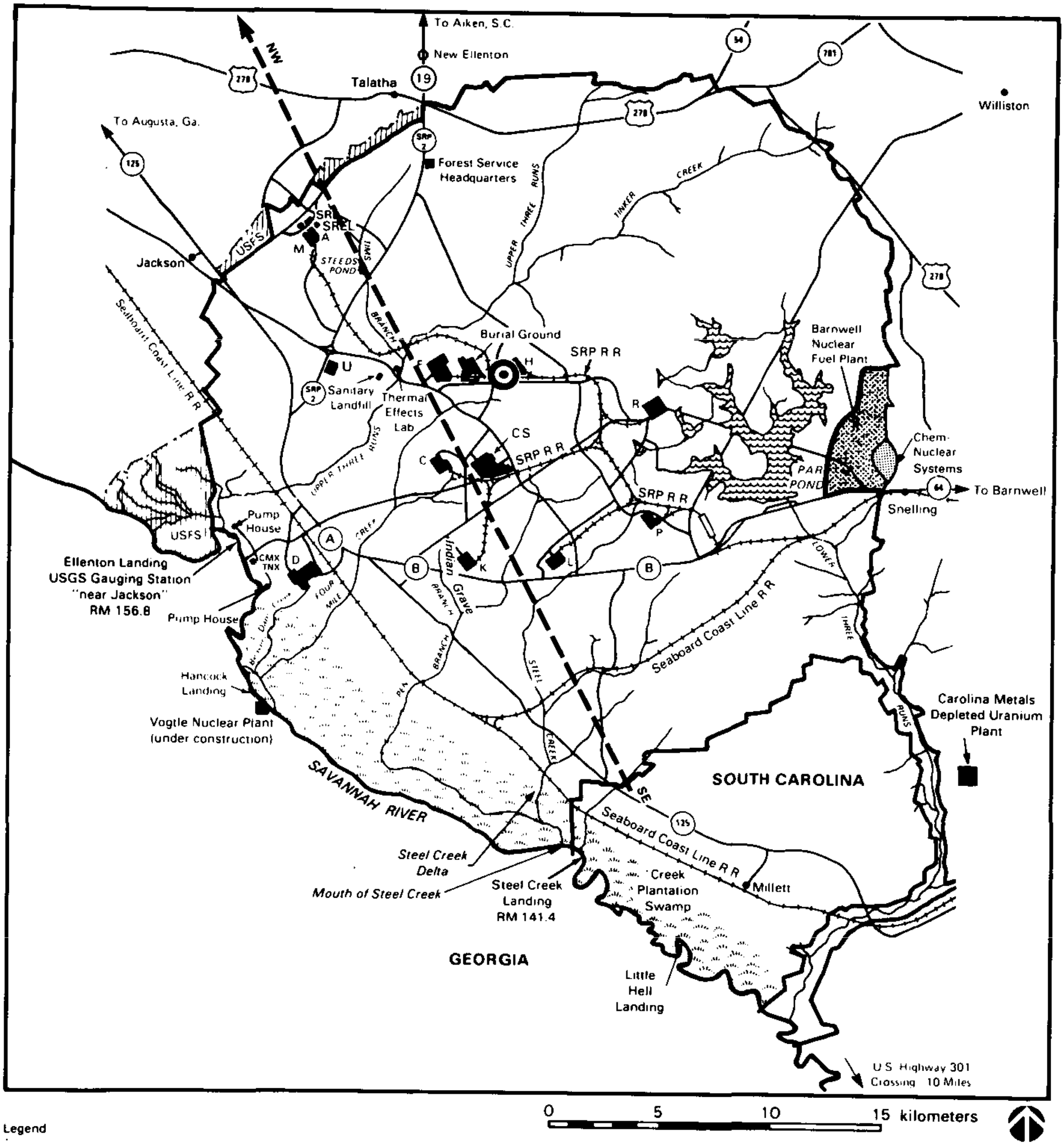
F.2.3.2 Hydrologic characteristics

Field tests of the transmissivity of the Tuscaloosa Formation were made when the original wells were drilled during the construction of Savannah River Plant (Siple, 1967). A representative value of transmissivity is listed in Table F-3 for each area at Savannah River Plant shown on Figure F-6 (Marine and Routt, 1975). The average of these 11 transmissivity values is 1.5 x 10^6 liters per day per square meter; the median is 1.4 x 10^6 liters per day per square meter. Storage coefficients were determined for seven regions of the Tuscaloosa Formation (Siple, 1967); the average value is 4.5 x 10^{-4}. Effective porosities were reasonably assumed to be 20 percent to 30 percent (Siple, 1967).

The location of Savannah River Plant and the outcrop area of the Tuscaloosa Formation are shown together with a piezometric map of the formation in Figure F-7. Where the outcrop area is high in elevation, such as on the Aiken Plateau in the northeast sector (Figure F-7), water recharged to the Tuscaloosa Formation exceeds the water discharged to local streams, and this excess water moves southeastward through the aquifer. Where the outcrop area is low in elevation, such as along the Savannah River Valley in the northwest sector (Figure F-7), water discharges from the formation to the river. Thus, the pattern of flow is arcuate.

Recently (1982) two independent piezometric maps of the Tuscaloosa aquifer have been published. The first of these (Figure F-8) was prepared by Faye and Prowell (1982) based on data from 1945 to 1981. The general piezometric pattern presented on this map is the same as that presented by Siple (1967), and the map shows an arcuate flow pattern toward a sink along the Savannah River. Another piezometric map of the Tuscaloosa Formation was prepared in a study for Georgia Power Company (1982) using only data from May to June 1982. This map (see Figure F-32) also shows a ground-water sink along the Savannah River. All of these maps indicate that ground water in the Tuscaloosa Formation does not cross from South Carolina into Georgia or from Georgia into South Carolina.

The term "Tuscaloosa Formation" has been applied to geologic deposits from North Carolina to Louisiana. This formation is a prolific aquifer in parts of North Carolina, South Carolina, and Georgia. However, the water in the formation that passes beneath Savannah River Plant recharges and discharges from the formation only in Aiken, Barnwell, and Allendale Counties of South Carolina. In general, these three piezometric maps do not distinguish between wells in upper and deeper aquifers of the Tuscaloosa Formation; yet it is known at Savannah River Plant that wells screened near the base of the lower Tuscaloosa that are away from centers of pumpage have a higher water level than those in the upper part of the Tuscaloosa. Figure F-9 is a piezometric map of the Tuscaloosa aquifer on Savannah River Plant. Water-level data from wells screened only at the bottom of the aquifer were not used. Although the data for this map are sparse, flow in the Tuscaloosa toward the Savannah River is confirmed.



Legend

- C, K, R, L, P Reactor Areas (C, P, K are operating)
- F, H Separations Areas
- M Fuel and Target Fabrication
- D Heavy Water Production
- A Savannah River Laboratory and Administration Area
- U Temporary construction area
- RM River Mile

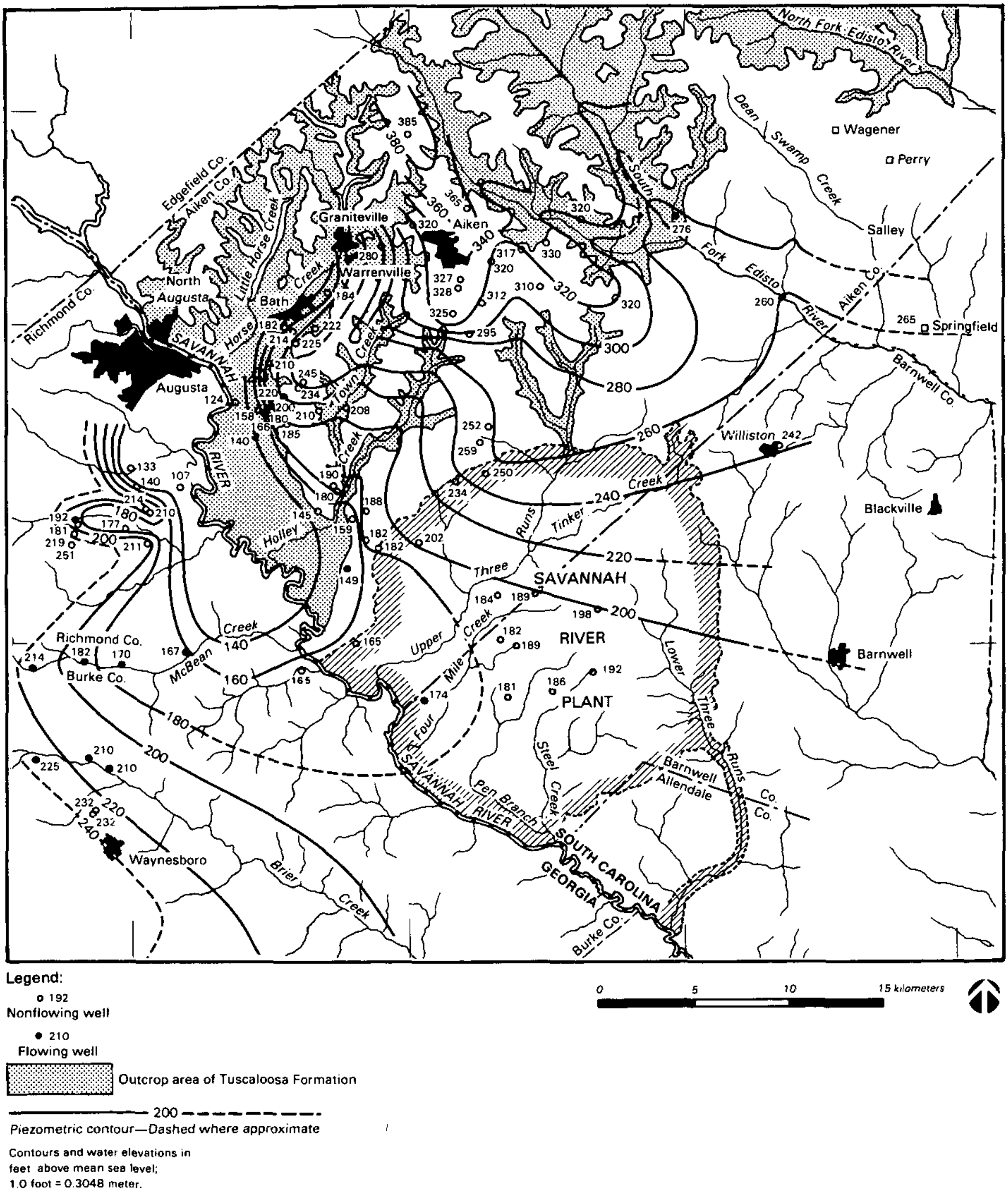
Road A = Highway 125

◎ Cluster of wells (See Figure F-5)

NW ⟵ — — SE Location of geologic profile shown in Figure F-3.

TC

Figure F-6. Areas for which the transmissivity of the Tuscaloosa Formation is given in Table F-3 and the location of the cluster of wells shown in Figure F-5.



TC

Figure F-7. Piezometric surface and outcrop area of the Tuscaloosa Formation reproduced from Siple (1967).

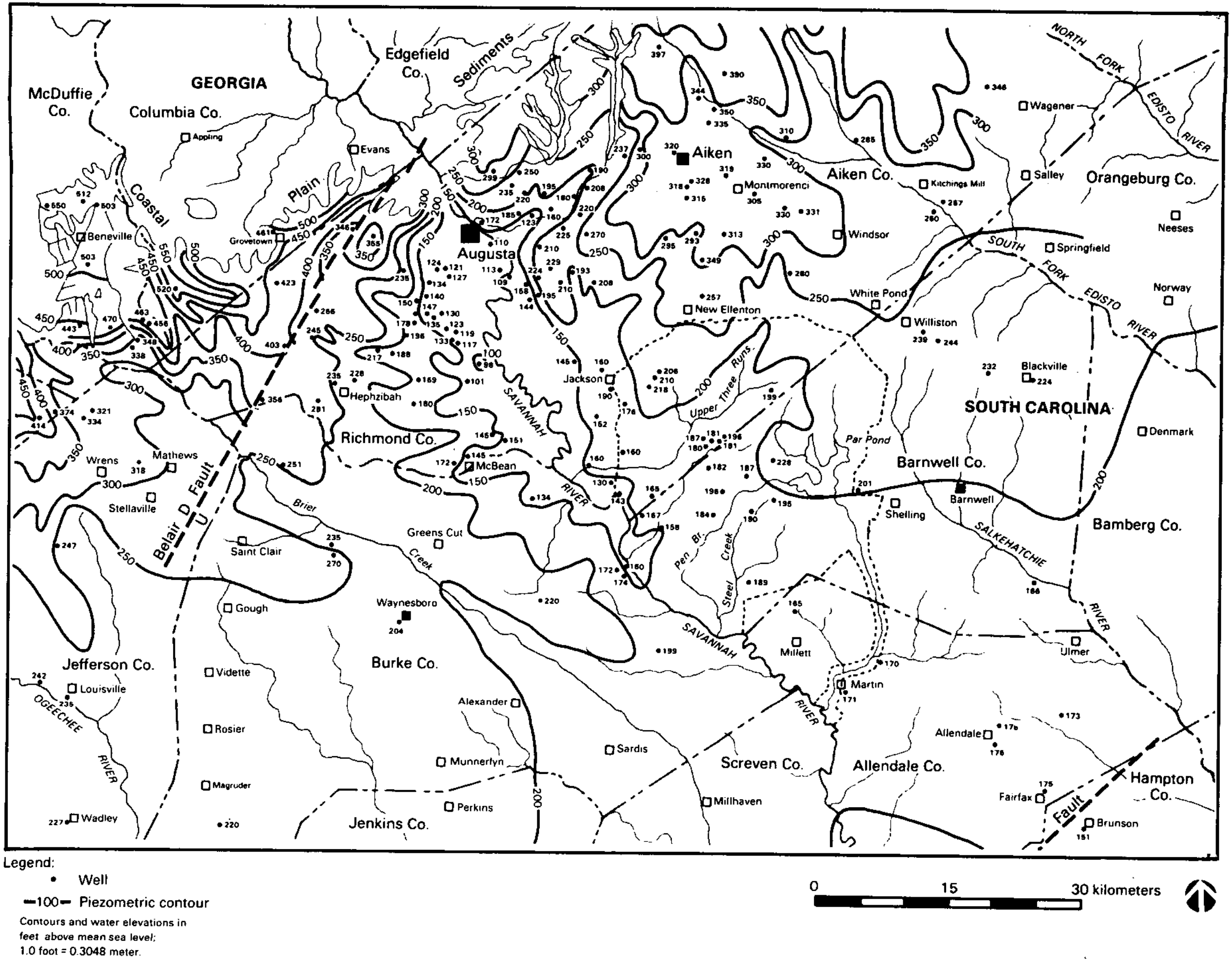
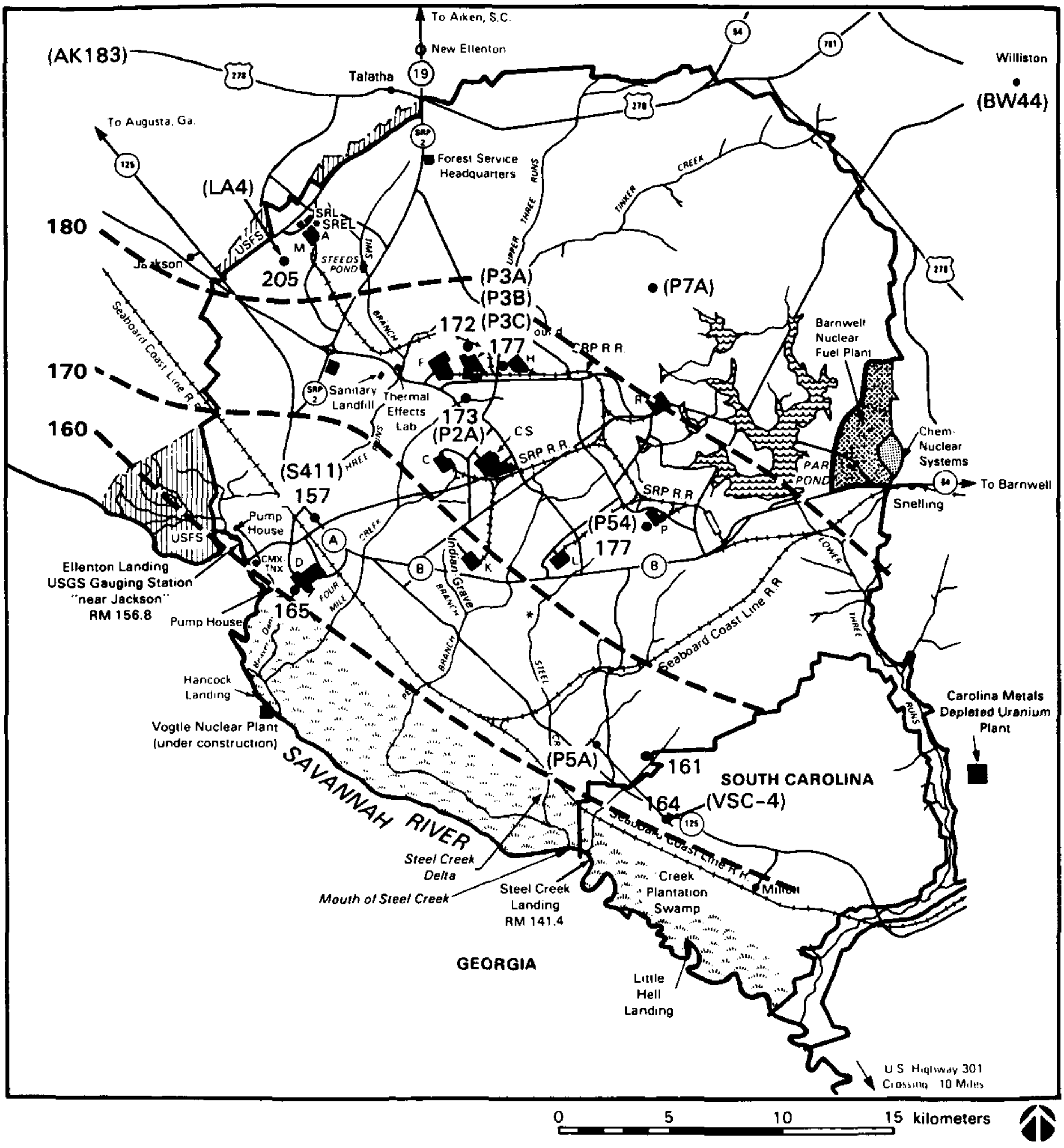


Figure F-8. Piezometric surface of Tuscaloosa Formation (based on Faye and Prowell, 1982).

TC



TC

Note: Contours and water elevations in feet above mean sea level.
1.0 foot = 0.3048 meters.
P5A VSC-4
●————● Location of profile shown on Figure F-10.
*Abandoned well S329, which could be flooded by a cooling lake on Steel Creek.

Figure F-9. Piezometric map of Tuscaloosa Formation at Savannah River Plant (May 11, 1982) and locations of Tuscaloosa wells (parentheses) for which hydrographs are given in Figures F-12 and F-27.

The relationship of water levels in the Tuscaloosa Formation to those in overlying formations at H-Area in 1972 is shown in Figure F-5. The head in the upper Tuscaloosa is about 1.2 to 1.8 meters above those in the Congaree; however, these particular Tuscaloosa observation wells are within the influence of the cone of depression caused by the continuous pumpage from nearby wells in H-Area. A single water-level measurement in the Tuscaloosa in 1952, before pumping began, indicates a head difference in H-Area 2 meters greater than that measured in 1972.

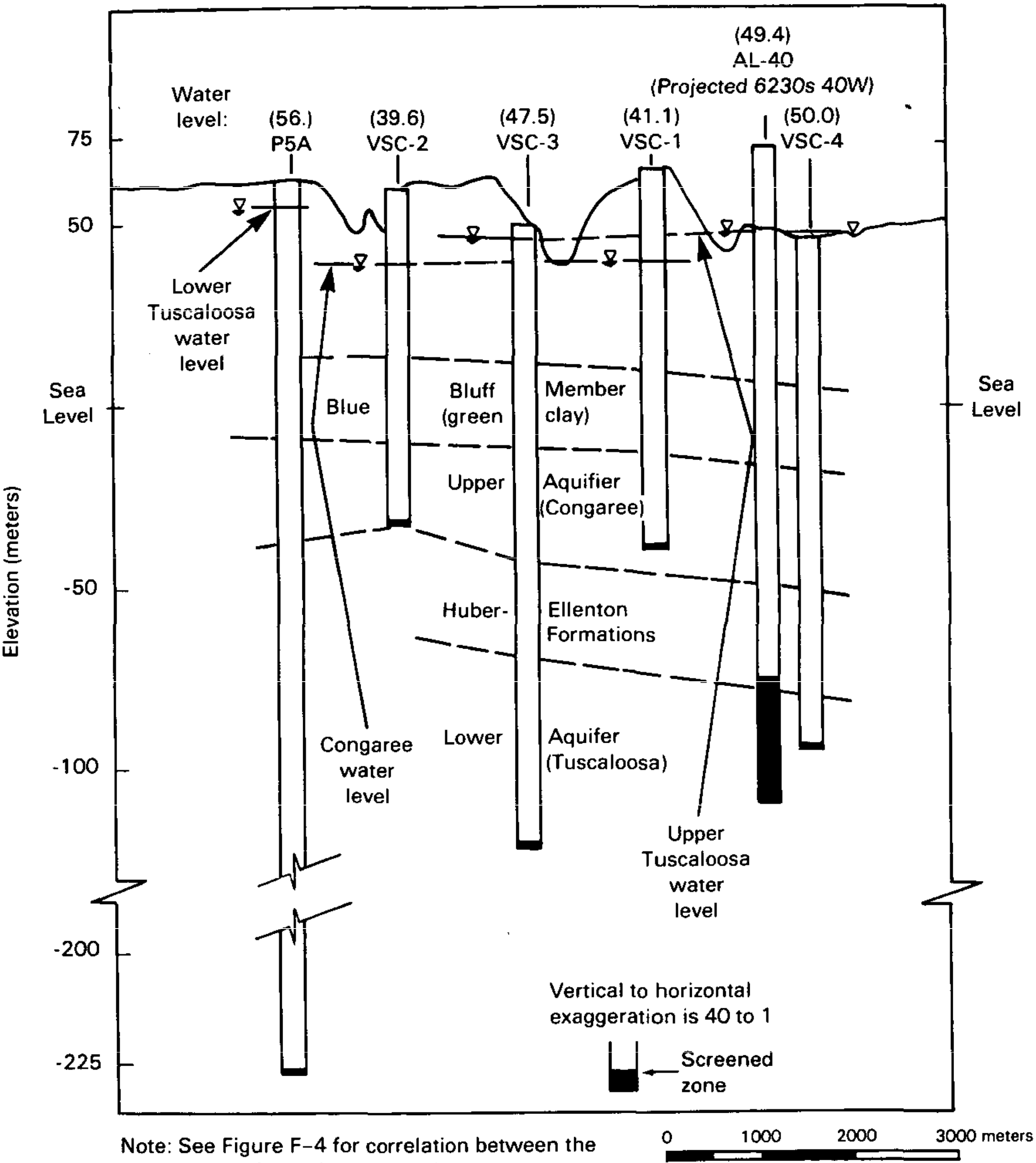
TC

Table F-3. Transmissivity of the Tuscaloosa Formation (Area locations shown on Figure F-6)[a]

Location	Transmissivity ℓ/day/m
Savannah River Plant	
A-Area	1.2×10^6
C-Area	1.4×10^6
F-Area	2.5×10^6
H-Area	2.5×10^6
K-Area	1.4×10^6
L-Area	8.7×10^5
P-Area	6.2×10^5
R-Area	1.1×10^6
Aiken	1.2×10^6
Williston	1.5×10^6
Barnwell Nuclear Fuel Plant	1.8×10^6
Average	1.5×10^6
Median	1.4×10^6

[a] Adapted from Marine and Routt (1975).

In addition to showing more detailed stratigraphy at Savannah River Plant, Figure F-5 also shows that the water head in the coastal plain formations in the vicinity of H-Area generally decreases with increasing depth down to the Congaree Formation. This trend indicates some downward movement of water in addition to its horizontal movement. The Congaree Formation crops out in the more deeply incised stream valleys on the plant site, and the water head in this aquifer is controlled in part by the elevation of these on-plant streams. The water head in the Tuscaloosa and Ellenton Formations is higher than in the Congaree Formation (Figure F-5), showing that the Tuscaloosa and Ellenton Formations at SRP are separated from the Congaree Formation by an effective confining layer. Figure F-10 shows the vertical head relationships near the southern boundary of the plant where the water elevation in the Tuscaloosa Formation is also higher than in the Congaree.



Note: See Figure F-4 for correlation between the various formation nomenclature.
Figure F-9 shows the location of this profile.

Source: Du Pont (1983).

Figure F-10. Comparison of ground-water elevations in the Congaree Formation to those in the Tuscaloosa Formation in the southern part of Savannah River Plant (1982).

Figure F-10 also shows that the water elevation in the deep Tuscaloosa aquifer (Middendorf) is higher than that in the shallower Tuscaloosa aquifer (Black Creek) by at least 6 meters. This difference means that care must be exercised in constructing a Tuscaloosa piezometric map. Each aquifer must be mapped separately. Figure F-9 is a piezometric map of the Upper Tuscaloosa aquifer; the water elevations in P5A and P7A (both screened in the deep aquifer) are not shown (they are 7.6 meters and 3.0 meters higher than the shallower Tuscaloosa water elevations at those locations).

|TC

Figure F-11 shows the vertical head relationships near M-Area where the Tuscaloosa water elevation is below that of the Congaree. At this location there is a continuous decline of head with depth indicating that this is a recharge area for the Tuscaloosa similar to much of the area of the Aiken Plateau northwest of Savannah River Plant.

In the outcrop area of the Tuscaloosa Formation, hydraulic gradients are steep (0.003) and ground-water velocities are correspondingly high. Downdip where the Tuscaloosa is overlain by a significant thickness of other coastal plain sediments, the gradients are gentler (0.0007) and the velocities are lower. Siple (1967) calculated the horizontal velocity of water of 52.2 meters per year using the hydraulic constants: hydraulic conductivity 4 x 10^4 liters per day per square meter (40.8 meters per day), a gradient of 0.0007, and an effective porosity of 20 percent.

|TC

|TC

Ground water is naturally discharged from the Tuscaloosa where the outcrop area is low in elevation, as in the Savannah River and Horse Creek valleys. In these regions, the base flow of streams is supported by discharge from the Tuscaloosa. As shown in Figure F-12, 22 years of pumping about 17 cubic meters per minute at the Savannah River Plant caused no progressive decline in water elevations in the prolific regional Tuscaloosa Formation. Tuscaloosa ground water use and development is discussed in Section F.3.

F.2.3.3 Water quality

Water from the Tuscaloosa Formation is low in dissolved solids (Table F-4). Specific analyses of water from the Tuscaloosa are given in Table F-5. Locations of the sampled wells are shown in Figure F-13. Because the water is soft and acidic, it has a tendency to corrode most metal surfaces (Siple, 1967). This is especially true where the water contains appreciable amounts of dissolved oxygen and carbon dioxide. The dissolved oxygen content of water from the Tuscaloosa Formation around the separations areas is very low (Marine, 1976b), and the sulfate content is about 13 milligrams per liter. The dissolved oxygen content is inversely related to the sulfate content of the water. In the northwest part of SRP nearer the outcrop area, water in the Tuscaloosa is near saturation with dissolved oxygen while the sulfate content is very low.

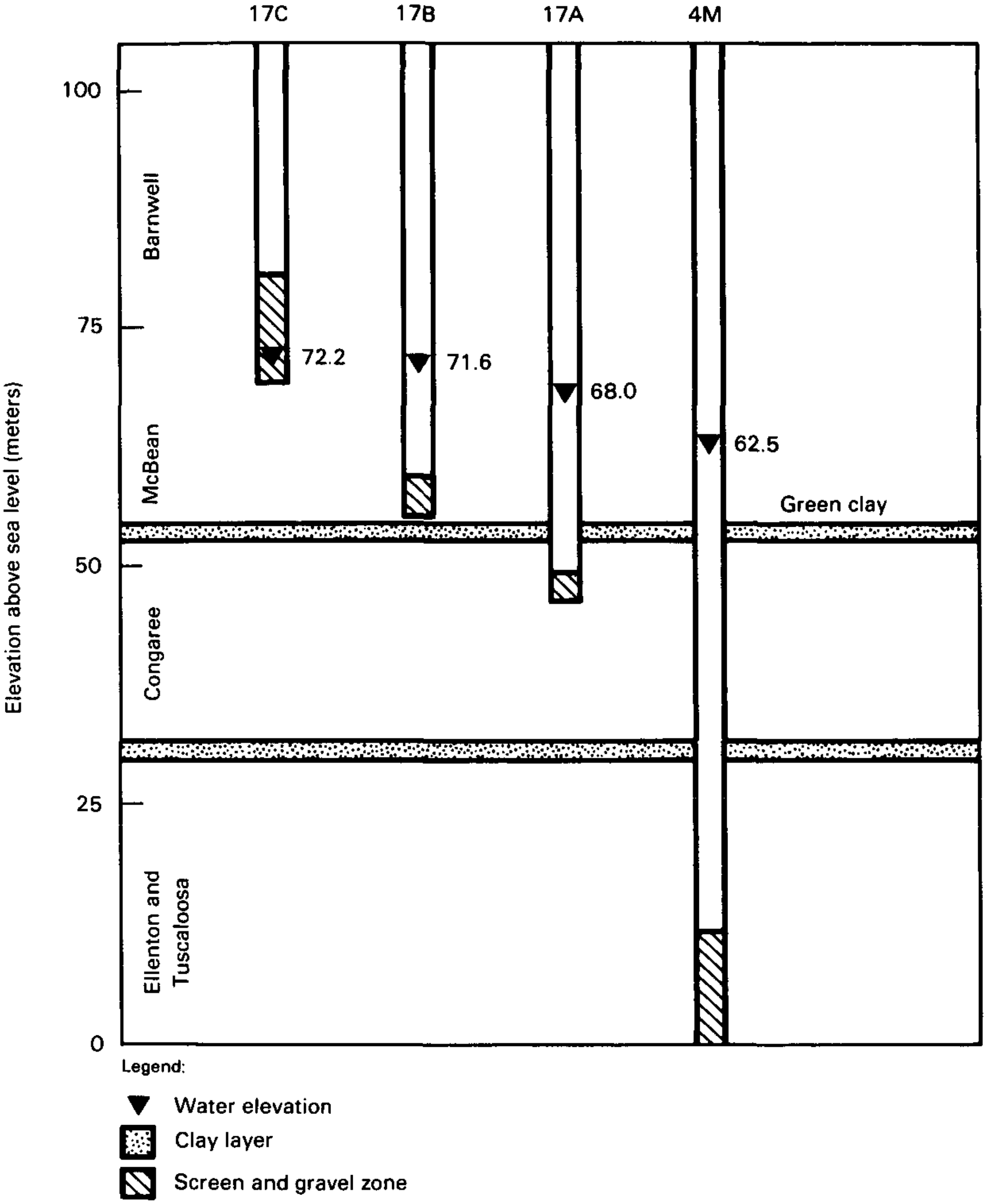
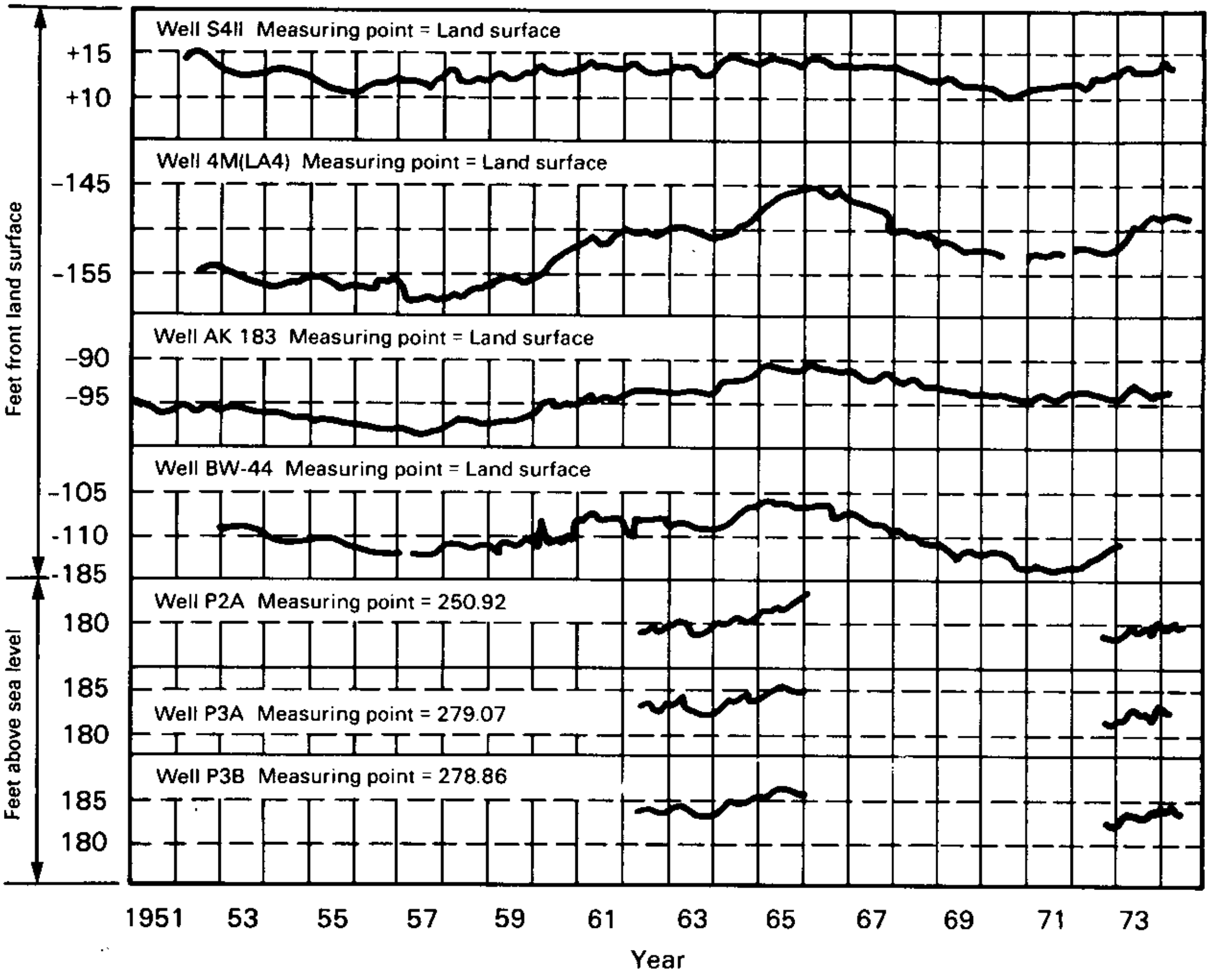


Figure F-36 shows the location of well cluster

Source: DuPont (1983).

Figure F-11. Vertical head relationships near M-Area in 1982.



Note: 1.0 foot = 0.3048 meter.
Figure F-9 shows well locations.

TC

Source: Du Pont (1983).

Figure F-12. Long-term hydrographs of water elevations in the Tuscaloosa and Ellenton Formations.

Table F-4. Chemical analyses of ground water from four major sources in the vicinity of SRP[a]

Source of water	Number of analyses	Range and median	pH	Constituents, mg/ℓ										
				Fe	Ca^{2+}	Mg^{2+}	$Na^{+}+K^{+}$	CO_3^{2-}	SO_4^{2-}	Cl^{-}	F^{-}	NO_3^{-}	Dissolved solids[b]	Hardness[c]
Tuscaloosa Formation	13	Maximum	6.9	0.77	1.4	0.9	6.7	17	4.8	4.0	0.1	8.8	28	7
		Minimum	4.4	0.00	0.3	0.0	0.9	0	0.5	0.8	0.00	0.0	14	2
		Median	5.4	0.16	0.9	0.5	2.1	3	1.4	2.2	0.0	0.6	19	5
Ellenton Formation	16	Maximum	6.8	4.1	8.7	1,3	4.2	23	27	6.0	0.2	0.9	54	30
		Minimum	4.4	0.10	3.9	0.4	1.5	4	7.4	1.5	0.0	0.0	36	10
		Median	5.9	1.1	6.4	1.0	2.7	12	11	2.1	0.1	0.0	41	19
Eocene[d] Limestone	15	Maximum	7.6	1.0	47	9.4	19	17.1	14	4.5	0.5	6.2	192	132
		Minimum	6.8	0.00	17	0.3	0.4	55	0.8	0.4	0.0	0.0	75	50
		Median	7.1	0.25	27	2.0	1.7	94	4.3	2.8	0.1	0.2	95	72
Eocene[d] Sand	9	Maximum	6.1	1.84	8.7	4.2	2.4	17	9.3	4.0	0.3	2.3	29	15
		Minimum	4.2	0.04	0.5	0.3	0.4	1	0.8	1.5	0.00	0	20	4
		Median	5.5	0.16	1.5	0.7	2.1	5.5	1.9	2.7	0.1	1.3	21	8

[a] Adapted from Siple (1967).

[b] Residue after evaporation at 180°C.

[c] As $CaCO_3$.

[d] McBean and Congaree Formations.

Table F-5. Analyses of ground water from coastal plain formations at Savannah River Plant[a]

	Source of water			Properties[b]			Chemical constituents, mg/ℓ[b]														
Date sampled	Well number[c]	Screen depth, ft	Formation	Temp. °C[d]	pH[d]	Specific conductance, micromhos	Ca^{+2}	Mg^{+2}	K^{+}	Na^{+}	Fe	Si	Al	Mn	HCO_3^-	Cl^-	SO_4^{-2}	NO_3^-	PO_4^{-3}	F^-	TDS
12/16/66	HC1E	43 to 48	Barnwell Upper Zone	21.7	5.8	48	3.3	0.3	1.6	TR[c]	.52	6.8	TR	0.02	12	6.0	1.0	3.8	0.0	0.0	34
10/25/77	HC2F	74 to 79	Barnwell	23.0	5.04	NM	0.42	0.05	0.10	3.96	<0.2	3.9	<1	<0.02	NM	3.7	0.25	5.8	.32	.01	20
08/01/74	HC3F	55 to 60	Barnwell	NM	5.2	15	1.7	0.43	0.25	2.9	<0.1	2.9	NM	NM	4.0	3.3	1.0	0.78	NM	NM	15
10/18/77	HC6B	85 to 90	Barnwell	22.0	6.30	NM	3.72	0.03	1.91	2.20	<0.2	4.6	<1	<0.03	18.3	1.5	0.62	5.1	.01	0.01	30
07/25/74	HC3E	93 to 98	Barnwell	NM	5.7	18	5.4	0.25	0.54	2.5	<0.1	4.6	NM	NM	16.3	3.0	1.8	<0.0001	NM	NM	26
07/23/74	HC3D	121 to 126	McBean	NM	4.8	11	0.8	0.37	0.22	1.7	<0.1	5.5	NM	NM	2.1	3.0	1.0	<0.0001	NM	NM	14
04/28/66	HC2H	134 to 144	McBean Calcareous Zone	23.2	7.1	103	11	0.4	3.0	TR	0.02	12	0.1	0.00	45	4.1	5.8	0.2	0.78	0.01	66
11/23/77	HC6A	139 to 144	McBean	21.2	6.93	NM	13.8	0.02	0.64	2.57	<0.2	5.4	<1	<0.02	49.3	2.3	0.62	0.05	0.01	0.01	51
02/21/72	905-72G	110 to 160	McBean	NM	7.0	NM	7.0	9.2	0.90	12.5	0.012	0.60	NM	0.05	27.5	1.6	10.2	0.11	0.18	NM	56
07/19/74	HC3A	230 to 235	Congaree	NM	6.4	130	28	0.54	0.55	1.5	<0.1	9.4	NM	NM	72	2.8	2.2	0.001	NM	NM	81
01/19/78	FC2A	231 to 235	Congaree	19.6	6.15	NM	11.1	0.07	0.94	1.45	<0.2	10.7	<1	<0.03	42.7	3.92	10.5	0.05	0.12	0.01	61
02/21/72	905-31A	440 to 536	Tuscaloosa	NM	5.5	17	0.11	1.7	NM	1.75	0.01	0.56	NM	<0.05	5.4	0.8	2.3	2.3	0.06	NM	10
02/29/72	905-41D	335 to 490	Tuscaloosa	NM	6.6	NM	1.4	3.5	4.3	11.0	<0.05	0.6	NM	<0.05	9.9	0.59	15.0	15.0	0.3	NM	42
02/21/72	905-43H	660 to 850	Tuscaloosa	NM	4.3	54	0.82	1.52	1.15	1.82	0.14	0.9	NM	0.05	0.97	0.60	11.3	11.3	--	NM	22
02/21/72	905-67U	615 to 725	Tuscaloosa	NM	5.15	19	0.22	1.5	0.43	1.6	0.05	0.44	NM	0.05	0.97	0.71	3.5	3.5	--	NM	10

[a] Adapted from Du Pont (1983).

[b] NM = not measured; TR = trace.

[c] Figure F-13 shows well locations.

[d] Measured at well head.

TC

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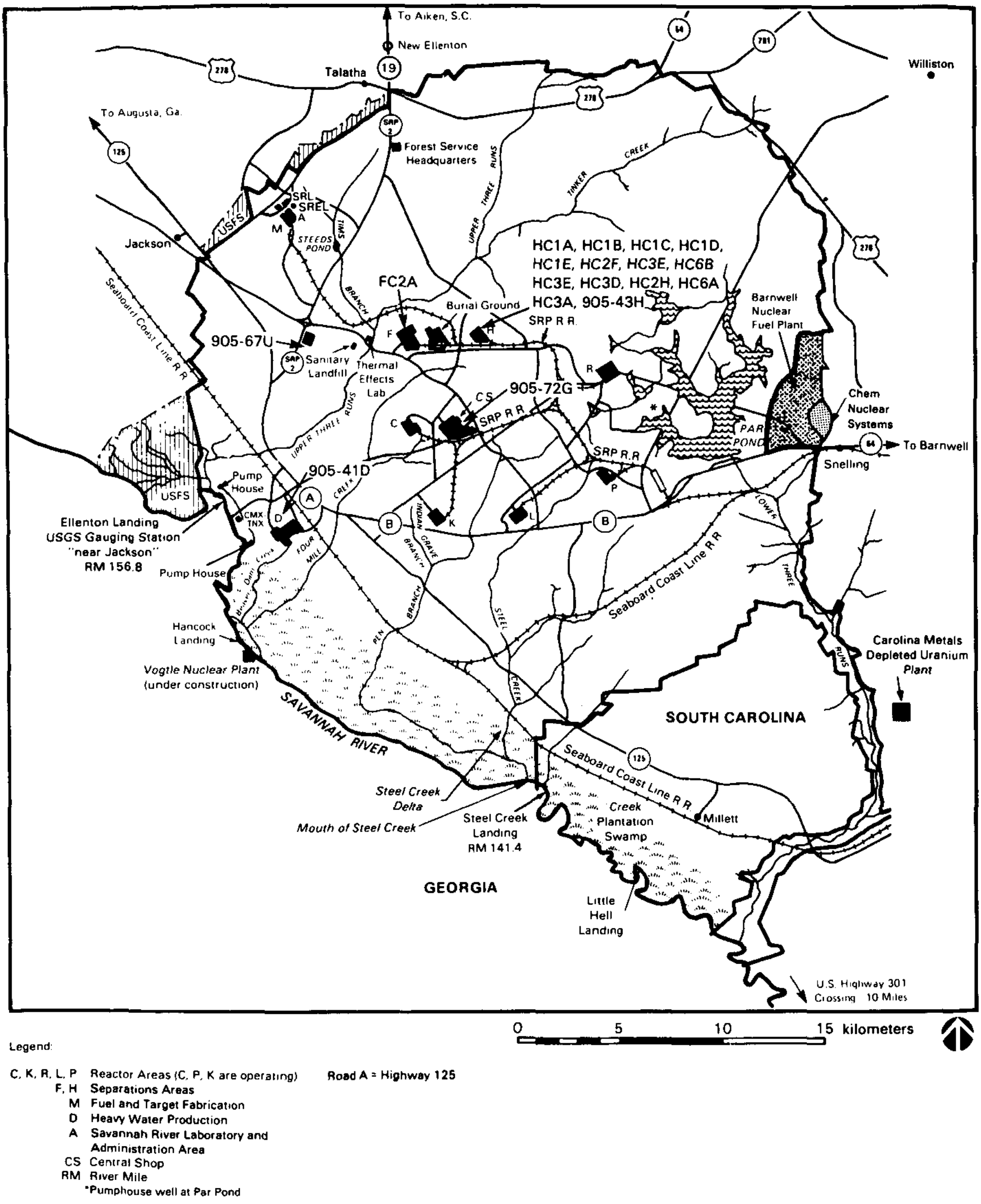

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Figure F-13. Locations of wells sampled for chemical analyses of ground water.

F.2.4 Ellenton Formation

F.2.4.1 Hydrostratigraphy

The Ellenton Formation overlies the Tuscaloosa Formation and consists of dark lignitic clay with coarse sand units. It is thought to be Late Cretaceous or Paleocene in age and is unconformably overlain by the Congaree Formation (of the Eocene Epoch). The known Ellenton sediments are entirely within the subsurface; they range in thickness from 0 near the northwest boundary of SRP to about 30 meters southwest of Savannah River Plant.

The Ellenton Formation was described and named by Siple from subsurface studies on the Savannah River Plant (Siple, 1967). The formation was not correlated outside of this area, but Siple speculated that it might be equivalent to the Black Creek Formation of Late Cretaceous age or the Black Mingo Formation of Paleocene or early Eocene age (Siple, 1967).

The lignitic clay is dark gray to black, sandy, and micaceous. It is interbedded with medium quartz sand, and contains pyrite and gypsum. The upper part of the formation is characterized by gray silty-to-sandy clay with which gypsum is associated. This clay is about 3 to 5 meters thick in the central part of SRP; it thickens to 10 meters in the A- and M-Areas, where laboratory measurements indicate that its vertical hydraulic conductivity is 9.8×10^{-5} meters per day. The lower part consists generally of medium-to-coarse clayey quartz sand, which is very coarse and gravelly in some areas (Siple, 1967).

TC

In many places in the vicinity of SRP, there is a thick clay at the top of the Tuscaloosa (Figure F-5) which apparently separates the aquifers of the Ellenton and the Tuscaloosa. However, this clay contains lenses of sand that apparently connect the two aquifers. Although the Tuscaloosa Formation can be differentiated from the Ellenton Formation, the permeable or water-bearing zones within the two formations are not completely separated by an intervening confining bed (Siple, 1967). Since ground water is free to move from one formation into the other where the two formations are hydraulically connected, the permeable zones in the Tuscaloosa and Ellenton Formations are considered to constitute a single aquifer over a large part of the area including Savannah River Plant. The water levels shown in Figure F-5 indicate that this is the case.

F.2.4.2 Hydrologic characteristics

Some of the sand lenses in the Ellenton may be as permeable as sands in the Tuscaloosa, but they are not as thick as the Tuscaloosa sands, and are therefore not developed by wells as commonly as those of the Tuscaloosa. Pumping tests to determine hydraulic constants are rare in the Ellenton Formation. In general, Siple (1967) did not distinguish between the Ellenton and the Tuscaloosa formations in reporting the results of pumping tests. No piezometric map exclusively of the Ellenton Formation exists. Thus, little is known about the lateral flow path of water within the formation. Because it is apparently hydraulically connected to the Tuscaloosa Formation, its flow pattern is probably similar.

Figure F-5 shows the relationship at H-Area of the water elevation in the Ellenton to water elevation in the formations above and below. The water elevation in the Ellenton is above that in the Tuscaloosa in Figure F-5 because the Tuscaloosa wells are all within the cone of depression of the continuous pumping in H-Area. These Tuscaloosa observation wells are probably more responsive to the hydraulic effects of this local pumping than is the Ellenton well.

The hydraulic heads shown on Figure F-5 indicate that there is not a direct hydraulic connection between the Ellenton and the overlying Congaree Formation. Although the clays that separate the Ellenton and the Congaree are not thick, they are apparently extensive and continuous enough to impede the hydraulic connection. A pisolitic clay at the base of the Congaree appears to be extensive and may constitute the principal confining bed that separates that Congaree and the deeper hydrologic system (Siple, 1967). The upper part of the Ellenton is a sandy clay, which may also function as a confining bed between the Ellenton and the Congaree.

The poor hydraulic connection of the Ellenton with the Congaree and the apparent good connection with the Tuscaloosa can be explained on the basis of the sedimentary environments of these formations. The Tuscaloosa was deposited under nonmarine conditions, and therefore the sands and clays might be discontinuous. The Ellenton was deposited under both nonmarine and estuarine conditions. However, the Congaree was deposited under marine conditions, which would be conducive to deposition of extensive continuous layers of clay and layers of sand.

Because the Ellenton is entirely a subsurface formation, there is no natural discharge to the surface. Water passing through the Ellenton is principally recharged by and discharged to the Tuscaloosa Formation.

Although few wells pump exclusively from the Ellenton Formation, some wells that are screened in the Tuscaloosa are also screened in the Ellenton. Accordingly, the course of future well development in the Ellenton will parallel the development of the Tuscaloosa Formation. It is, however, difficult to estimate the quantity pumped from the Ellenton alone.

F.2.4.3 Water quality

A summary of chemical analyses of water from the Ellenton Formation is given in Table F-4. Its dissolved solids content is somewhat higher than that of water from the Tuscaloosa, but it is still very low at less than 50 milligrams per liter.

F.2.5 Congaree Formation

F.2.5.1 Hydrostratigraphy

The Congaree Formation was included in the McBean Formation by Cooke (1936), and this usage was followed by the U.S. Army Corps of Engineers (COE, 1952) during the original foundation studies for the construction of the Savannah River Plant (Marine and Root, 1978). The lower part of the original McBean was raised to formational status and called the Congaree Formation and the Warley Hill Marl by Cooke and McNeil (1952). In discussing geology and ground water at Savannah River Plant, Siple (1967) used the term "McBean" both to include all deposits of Claiborne age (see Table F-1) and to include only the upper part of these deposits. In much of the area studied by Siple, the two formations could not be distinguished, either where exposed or in well logs (Marine and Root, 1978).

Subsequent investigations at Savannah River Plant have shown that for hydrologic studies, it is desirable to distinguish the McBean Formation (as used in the restricted sense, rather than as used by Siple, 1967) from the Congaree Formation, because in the central part of Savannah River Plant the water elevation in the Congaree is about 24 meters lower than that in the McBean (restricted sense), and the Congaree is more permeable (Marine and Root, 1978). These two hydrostratigraphic units are separated by a clay layer informally called the "green clay" in studies at Savannah River Plant. This clay occupies the same stratigraphic position as the Warley Hill Marl of Cooke and McNeil (1952).

In discussing the geohydrology, the term McBean Formation will be used only in the restricted sense. The term "deposits of Claiborne age" will be used to refer to the broad sense in which the term "McBean Formation" was previously used (Cooke, 1936).

The deposits of Claiborne age strike about N 60°E and dip at a gradient of about 1.5×10^{-3} to 1.7×10^{-3} toward the south or southeast (Siple, 1967). Their thickness ranges from zero near the Fall Line to about 76 meters in southeastern Allendale County. In the central part of Savannah River Plant, the Claiborne deposits are about 61 meters thick (Figure F-5), of which about 37 meters is Congaree Formation.

In the central part of Savannah River Plant, the Congaree Formation consists of gray, green, and tan sand with some layers of gray, green, or tan clay (Marine and Root, 1978). In the northwest part of Savannah River Plant, it consists primarily of tan clayey sand. It is slightly glauconitic in some places, slightly calcareous in others. In some locations in Calhoun County, South Carolina, it consists of well to poorly sorted sand, fuller's earth, brittle siltstone, and light gray to green shale, alternating with thin-bedded fine-grained sandstone. Elsewhere in Lexington and Calhoun Counties, it includes tan, white, and reddish-brown cross-bedded sand very similar to that in the McBean Formation (Siple, 1967).

Although subdivision of the Claiborne group may be warranted in the SRP area and in other parts of South Carolina and Georgia, such subdivision appears less warranted toward the Fall Line because the shoreward facies of each unit grades into a comparatively thin zone, and criteria for distinguishing them become doubtful (Siple, 1967). That this is so is confirmed by drilling in the northwestern part of Savannah River Plant (M-Area), where the green clay is thin and discontinuous and the sediments of both McBean and Congaree are very similar in appearance.

A pisolitic clay zone at the base of the Claiborne deposits is the base of the Congaree Formation (Siple, 1967). If this characteristic clay is correlative with a similar pisolitic clay zone at the base of the Claiborne deposits on the Gulf Coast, then it is likely that the clay is continuous within the SRP area. This may be the effective confining bed that hydrologically separates the aquifer in the Congaree Formation from that of the Ellenton Formation. In A- and M-Areas, laboratory tests indicate a vertical hydraulic conductivity of 1.8×10^{-4} meters per day.

The green clay layer at the top of the Congaree Formation appears to be continuous in the central SRP area. In the northwest SRP area (i.e., updip) it becomes discontinuous. This clay is hydrologically significant because it supports a large head differential between water in the McBean Formation above and water in the Congaree Formation below. In the northwest SRP area where the clay is discontinuous, the head differential is not as large. To the south it appears that the green clay thickens to about 7 meters in L-Area and 18 meters in the southeastern portions of the SRP to become what is referred to in Georgia as the Blue Bluff Marl of the Lisbon Formation (Figure F-4). It is encountered at the Vogtle Nuclear Power Station in Georgia, in wells in the southern part of the Savannah River Plant, and offsite to the south. However, intermediate wells that confirm the tentative correlation of the green clay with the Blue Bluff Marl do not exist. The green clay is herein considered to be part of the Congaree Formation even though there is no faunal support for this assignment. This clay consists of gray-to-green, dense, occasionally indurated clay (Marine and Root, 1978). The indurated nature of the clay is commonly caused by dense compaction and siliceous cement. Calcareous cement is usually absent from this indurated zone. Farther south calcareous cement may be more common.

The sand beds of the Congaree Formation constitute an aquifer in this region that is second only to the Tuscaloosa aquifer in productivity. Maximum yields of 2.5 cubic meters per minute with 15 meters of drawdown have been reported from wells in Claiborne deposits on SRP (Siple, 1967). Much of the water produced by high-yielding wells reported to be pumping from the McBean Formation (Siple, 1967) in the broad sense, i.e., Claiborne deposits, probably comes from the Congaree Formation. Another well in these deposits yielded only 0.66 cubic meters per minute with 15 meters of drawdown. Wells in the municipal well field at Barnwell, South Carolina, have yielded as much as 1.5 cubic meters per second with 12 meters of drawdown. However, in other areas such as northwestern SRP (M-Area), the yield may be as low as 0.11 cubic meters per minute with 9 meters of drawdown.

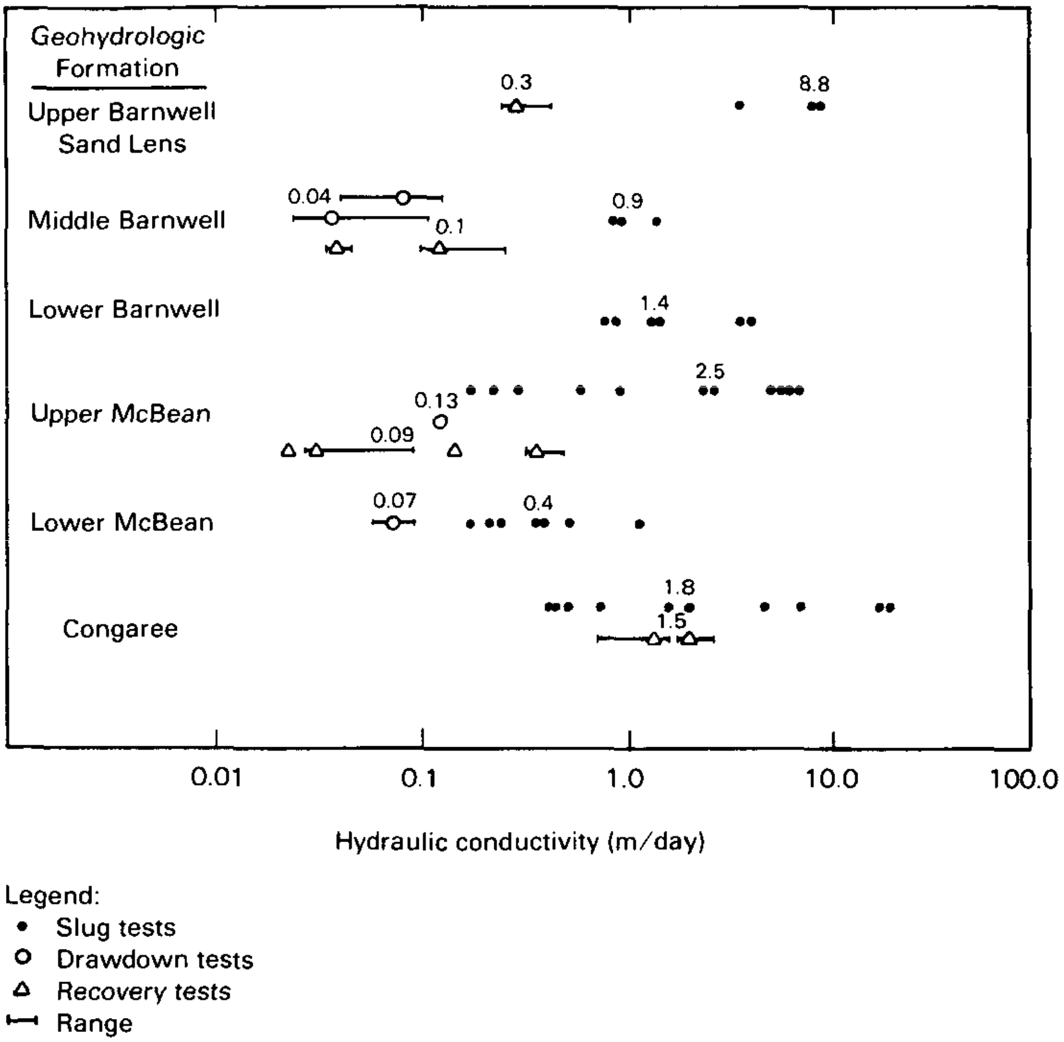
F.2.5.2 Hydrologic characteristics

Table F-6 lists hydraulic constants for the Claiborne deposits. Two of the tests, which were located near the central part of SRP, indicated a hydraulic conductivity of nearly 40,000 liters per day per square meter, whereas one of the values (730 liters per day per square meter) in M-Area is 50 times less than this. The median conductivity value for 10 slug tests (decay of an instantaneous head change) in sandy zones of the Congaree Formation in the separations areas of Savannah River Plant was 1800 liters per day per square meter (Root, 1977a, 1977b). The median conductivity of two water-level recovery tests was 1500 liters per day per square meter. Values for the median hydraulic conductivities for the Tertiary hydrostratigraphic units (Table F-1) in the separations areas determined from aquifer tests are shown in Table F-7. The results of pumping tests, recovery tests, and slug tests on Tertiary units in the separations areas are shown in Figure F-14.

Table F-6. Summary of pumping-test data on the McBean and Congaree Formations[a]

Pumping well	Observation well	Date of test	SRP area[b]	Pumping rate (ℓpm)	Aquifer thickness, (m)	Transmissibility (ℓ/day/m)	Hydraulic conductivity (ℓ/day/m^2)	Hydraulic conductivity Meters per day	Storage coefficient
10 TCA	9 TCA	04-16-51	Near C	1540	18	7.3×10^5	4.0×10^4	40	0.0001
14 TSC	14 TC	04-20-51	CS	660	15	8.9×10^4	5.7×10^3	5.8	(c)
26 CY	26 CY	10-18-51	Near P	1550	32	1.2×10^6	3.9×10^4	39	(c)
MPTW-1	MSB11C	06-21-82	Near M	110	18	1.4×10^4	7.3×10^2	0.7	0.14

[a] First three tests from Siple (1967).
[b] Areas are shown on Figure F-6.
[c] Not determined.



Note: Median value represented by numbers.

Source: Du Pont (1983).

Figure F-14. Hydraulic conductivity values from selected hydrostratigraphic units.

Table F-7. Median hydraulic conductivities of Tertiary hydrostratigraphic units as determined by pumping tests

Formation	Conductivity[a] (m/day)
Barnwell sand lens	0.3
Barnwell clayey sand	0.04
Barnwell silty sand	--
Upper McBean	0.13
Lower McBean	0.07
Congaree	1.5

[a] Adapted from Marine and Root (1976).

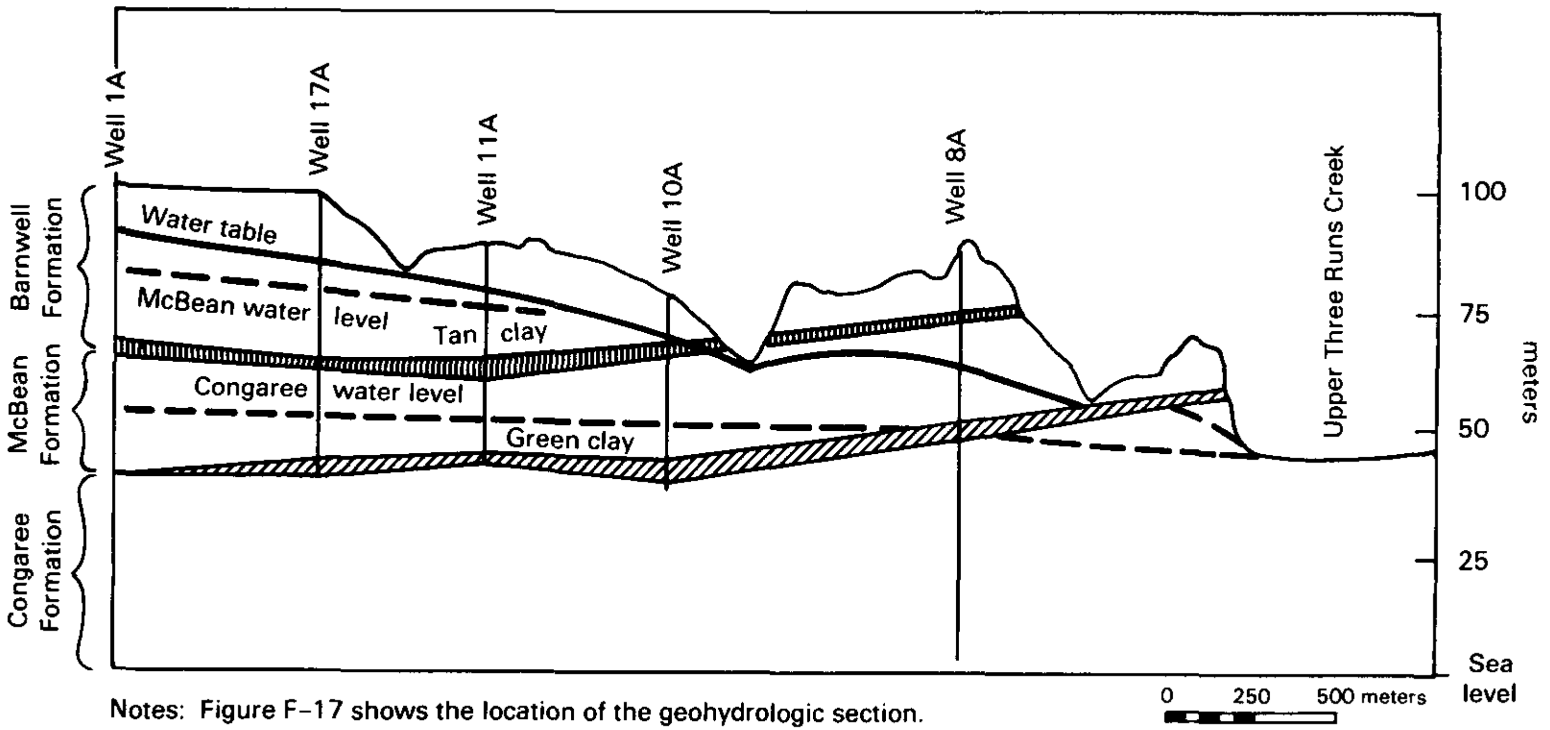
Laboratory tests by the U.S. Army Corps of Engineers (COE, 1952) indicated a median value of 43 percent for the total porosity of the upper part of the Congaree Formation. A reasonable effective porosity (used in calculating ground-water velocity) is estimated as 20 percent. A pumping test in northwest Savannah River Plant gave a value of 14 percent.

Figure F-5 shows the water elevation in the Congaree Formation and its relationship to that in the hydrostratigraphic units above and below. These data are for one location in the separations areas where water-level differences are probably at their maximum. Near the discharge areas of creek valleys, water elevations of the several Tertiary aquifers converge (Figure F-15).

The natural discharge areas for the Congaree Formation at Savannah River Plant are the swamps and marshes along Upper Three Runs Creek and along the Savannah River Valley. Although springs do occur, most of the discharge occurs along the valley bottoms in swamps, making it difficult to measure flow rates of the discharge.

On a regional basis, the dissecting creeks divide ground water in the Congaree Formation into discrete subunits. Thus, even though the hydraulic characteristics of the formation may be similar throughout the area, each subunit has its own recharge area and its own discharge area. If dissection is through most of the formation thickness, then no water moves from one subunit to another.

The fluctuation of water elevations in the Congaree Formation and their relationship to those in other hydrostratigraphic units is shown in Figure F-16. The spatial variation of water elevations in the Congaree Formation in the separations areas is shown in Figure F-17. This piezometric map indicates a northwestward movement of water across the separations areas. This direction of movement is governed by the discharge of the water in the Congaree Formation to Upper Three Runs Creek, where the green clay, is breached. Because Four Mile Creek does not breach the green clay, the piezometric map is unaffected by its valley.

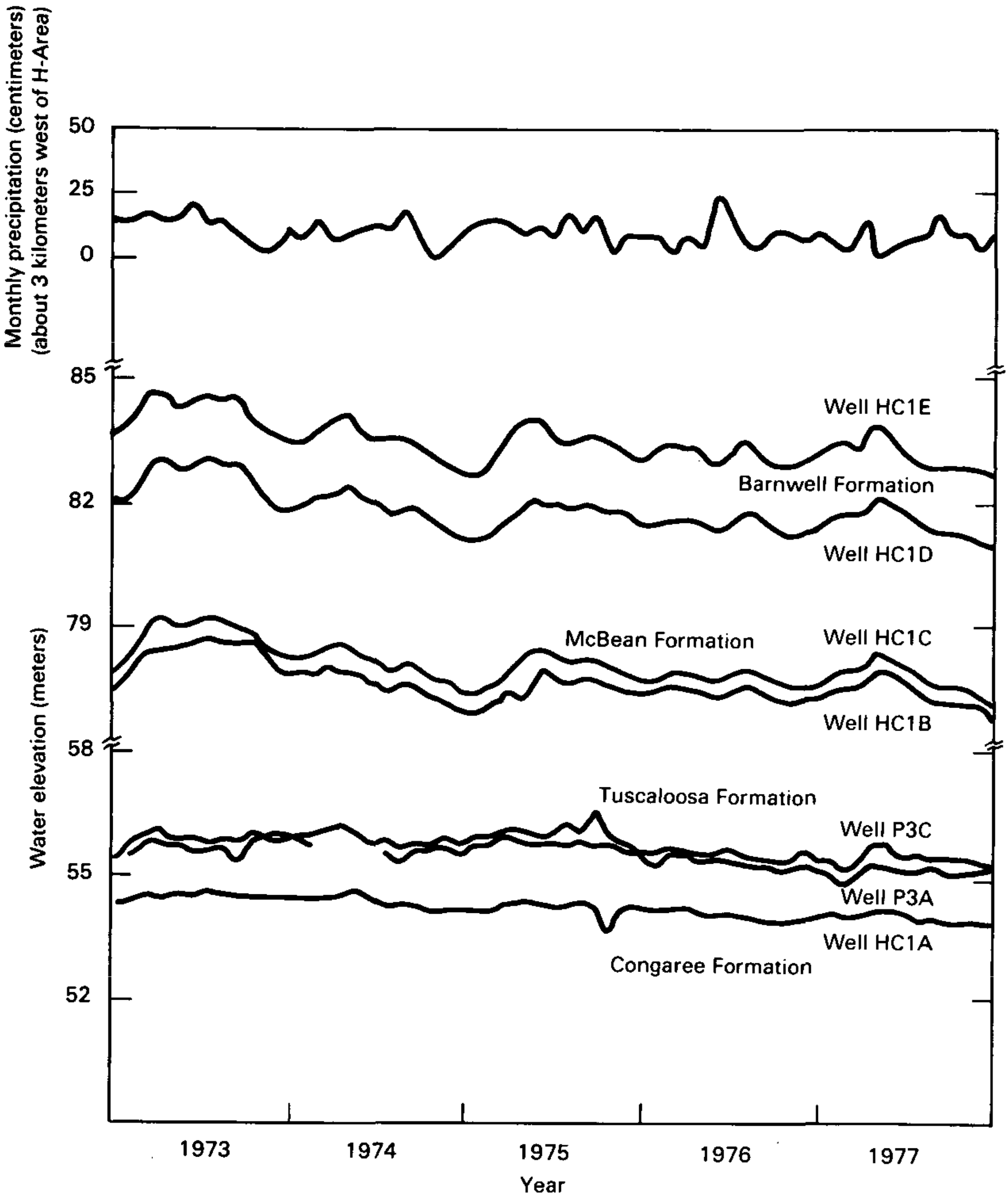


Notes: Figure F-17 shows the location of the geohydrologic section.
Water elevations were measured on August 29, 1977.

Source: Du Pont (1983).

TC

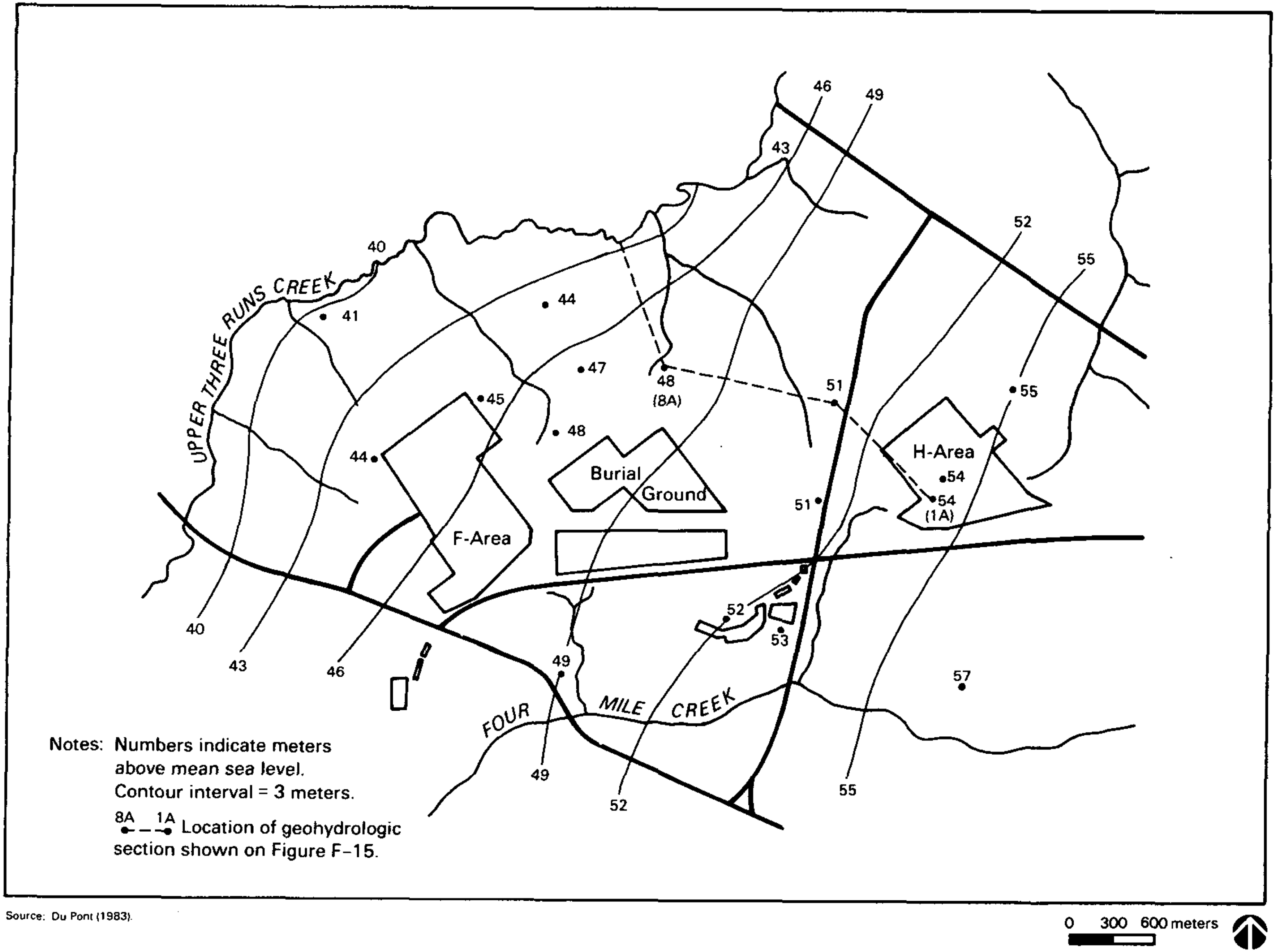
Figure F-15. Geohydrologic section in central part of Savannah River Plant.



Note: Well locations shown on Figures F-9 (P3A, P3C) and F-13 (HC1A-HC1E). | TC

Source: Du Pont (1983).

Figure F-16. Hydrographs of selected wells and monthly precipitation.



Notes: Numbers indicate meters above mean sea level.
Contour interval = 3 meters.
8A — — 1A Location of geohydrologic section shown on Figure F-15.

Source: Du Pont (1983).

Figure F-17. Piezometric map of the upper part of the Congaree Formation in the separations areas of Savannah River Plant (August 29, 1977).

As shown in Figure F-18 the water elevations in the Congaree Formation are significantly drawn down by the ground-water discharge to the Savannah River and to Upper Three Runs Creek. Two regional piezometric maps of the Congaree have been recently published (Faye and Prowell, 1982; Georgia Power Company, 1982), but neither reflects the significant drawdown due to the incision of the formation by Upper Three Runs Creek.

The vertical head relationships of the Congaree to the units above and below are shown in Figures F-5, F-15, and F-16. These figures show that the head in the Congaree Formation in the separations areas is the lowest of any hydrostratigraphic unit in the coastal plain system. This is brought about by two factors: (1) the low permeability of the green clay through which recharge must take place, and (2) the high hydraulic conductivity of the Congaree sands below the green clay, which enhances lateral movement and discharge to the deeper creek valleys. Upward recharge of water to the Congaree from the Ellenton-Tuscaloosa systems is also impeded by clay layers at the base of the Congaree and at the top of the Ellenton.

The lateral hydraulic gradient, I, in the Congaree Formation (Figure F-18) ranges from about 0.003 to 0.005. Using a hydraulic conductivity, K, of 1.5 meters per day (Table F-7) and an effective porosity, j, of 20 percent, the flow velocity (Darcy's Law) is

$$V = \frac{IK}{j} = \frac{365 \text{ days/yr} \times 0.005 \times 1.5 \text{ m/day}}{0.20} = 13.7 \text{ m/yr}$$

In the A- and M-Areas, the lateral flow velocity is about 3.2 to 7.6 meters per year; in the southern part of the Plant, the velocity is calculated to be 160 meters per year. TC

The Congaree Formation provides water to Savannah River Plant (tens to hundreds of liters per minute) and to the rural population around Savannah River Plant. In the M-Area vicinity the Congaree Formation is clayey sand rather than sand as it is farther downdip. Thus well yields in this area are not nearly as high as in the downdip areas. For example, a hydraulic conductivity value of 730 liters per day per square meter in M-Area (Table F-6) is only 2 percent of the value of 40,000 liters per day per square meter obtained from pumping tests near C-Area and P-Area. In the future, pumpage will increase from both the Congaree and Tuscaloosa Formations, but increases are expected to occur more rapidly in the Tuscaloosa.

F.2.5.3 Water quality

Summary of chemical analyses of water from deposits of Eocene age (McBean and Congaree Formations) is given in Table F-4 as reported by Siple (1967). These analyses are grouped into those from Eocene limestone, which would be primarily for water from the McBean Formation but might include some analyses of water from the Congaree Formation, and those of water from Eocene sand, which would include the Barnwell, McBean, and Congaree Formations.

The analyses of water from the Eocene sands are similar to those from the Tuscaloosa Formation, which is also predominantly sand. The water is low in

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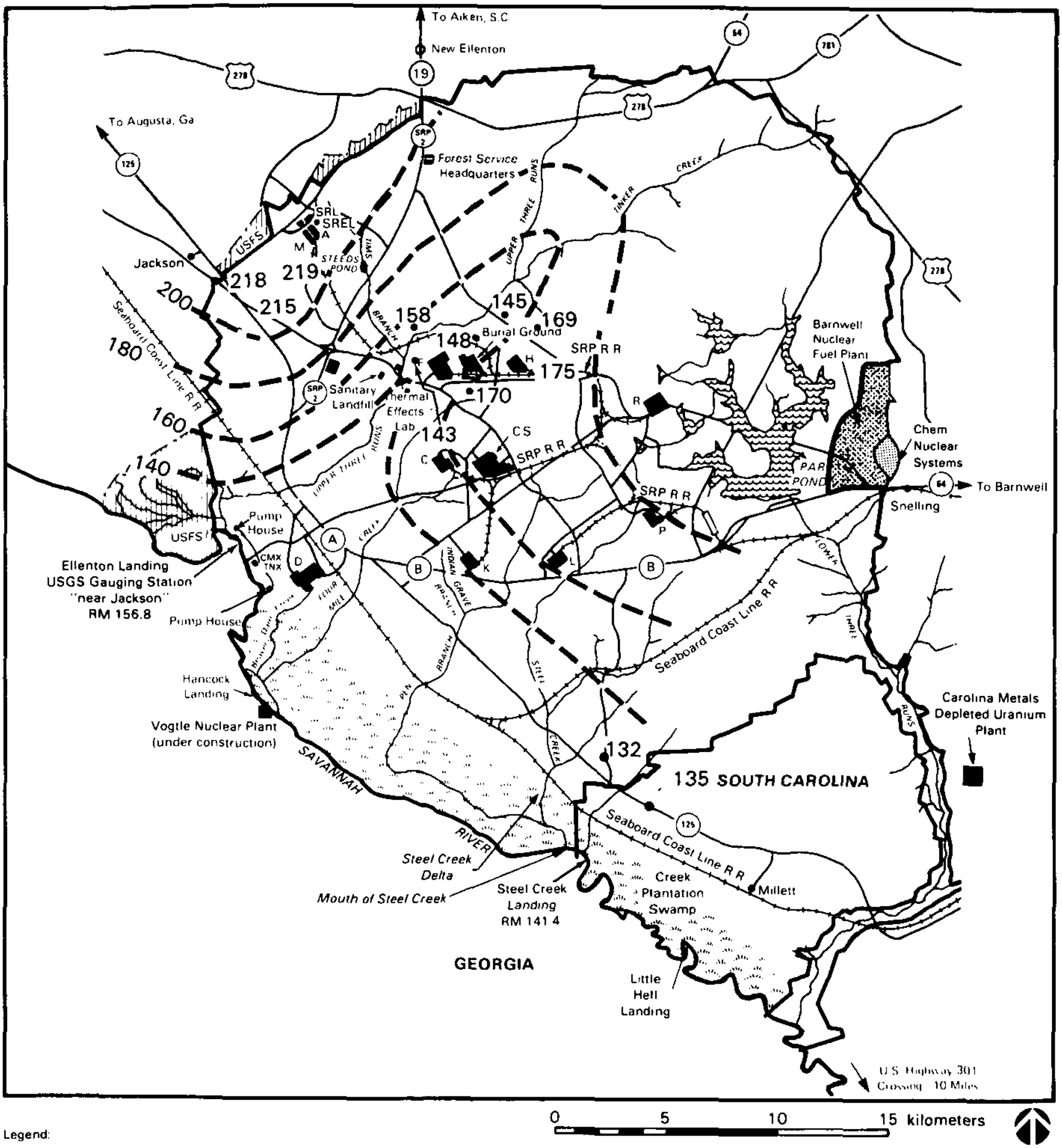


Legend:

C, K, R, L, P	Reactor Areas (C, P, K are operating)
F, H	Separations Areas
M	Fuel and Target Fabrication
D	Heavy Water Production
A	Savannah River Laboratory and Administration Area
CS	Central Shop
RM	River Mile

Road A = Highway 125

Note: Contours and water levels in feet above mean sea level.
1.0 foot = 0.3048 meter.

Source: Du Pont (1983).

Figure F-18. Piezometric map of the Congaree Formation (May 11, 1982) at Savannah River Plant.

dissolved solids (about 20 milligrams per liter) and is acidic (pH about 5.5). In comparison, the water from the Eocene limestone is much higher in dissolved solids (about 100 milligrams per liter) and is nearly neutral (pH about 7). Most of the increase in dissolved solids is due to increases in calcium and bicarbonate ions, as would be expected from sediments high in calcium carbonate.

Two analyses of water from sands in the Congaree Formation are shown in Table F-5. The analyses are similar to those reported for Eocene limestone by Siple (1967), including a high calcium and bicarbonate content. These zones in the Congaree Formation probably contained some calcareous cement, giving rise to the ionic content of this water.

F.2.6 McBean Formation

F.2.6.1 Hydrostratigraphy

As previously discussed, the term McBean was originally used to designate all deposits of Claiborne age in this area, but it is now used to designate only the upper part of these sediments. Even though this distinction was originally made on a stratigraphic basis, the distinction is even more significant on a hydrologic basis. Hydraulic head differences between the McBean and Congaree Formations are large in many places, and the Congaree is about 10 times more permeable than the McBean.

The McBean Formation may be divided into two subunits, an upper unit consisting of tan clayey sands and occasionally red sand (Marine and Root, 1978), and a lower unit consisting of light tan-to-white calcareous clayey sand. This lower unit is locally referred to as the "calcareous zone"; in some places, it contains void spaces that could result in rod drops or lost circulation during drilling operations (COE, 1952). To the northwest these void spaces appear to decrease so that no calcareous zone exists in the northwest part of Savannah River Plant (M-Area). However, to the southeast the lime content of the zone increases as do void spaces. Southeast of Savannah River Plant the zone becomes a limestone with only small amounts of sand; and its water yielding potential increases.

The McBean Formation is considered to be the shoreward facies of the Santee limestone, which occurs to the southeast (Siple, 1967). In the SRP area, the "calcareous zone" may represent a tongue of the Santee limestone. Toward the Fall Line to the northwest of SRP, it becomes more difficult to distinguish the several Eocene formations, and Siple (1967), maps the Eocene deposits undifferentiated. In the northwest SRP area (M-Area), the calcareous zone is replaced by a clayey sand unit.

Ground water occurs in both the upper sandy unit and in the calcareous zone, but neither are prolific aquifers in the central part of SRP. Farther to the southeast, where the calcareous content as well as the number and size of the voids in the calcareous zone increase, well yields are moderate.

As with the Congaree Formation, creeks in the region dissect the McBean Formation, and divide the hydrogeologic unit into separated subunits, each having its own recharge and discharge area. Because the McBean is a shallower formation than the Congaree, smaller creeks with less deeply incised valleys make these divisions. The subunits of the McBean are therefore smaller than those of the Congaree. In the separations areas, the only stream that cuts into the Congaree is Upper Three Runs Creek, whereas the McBean is incised by Upper Three Runs Creek, several of its larger tributaries, and Four Mile Creek. Thus, ground water that enters the McBean Formation in the separations areas cannot migrate to other subunits of the McBean.

F.2.6.2 Hydrologic characteristics

The median hydraulic conductivity of the upper sand of the McBean Formation is 130 liters per day per square meter (0.13 meters per day) and that of the calcareous zone is about half that of the upper sand (Table F-7). Figure F-14 shows the median and range of hydraulic conductivity as measured in the field by slug tests, recovery tests, and drawdown tests. Figure F-19 shows the range and median of laboratory measurements of hydraulic conductivity. An effective porosity of 20 percent is presumed reasonable.

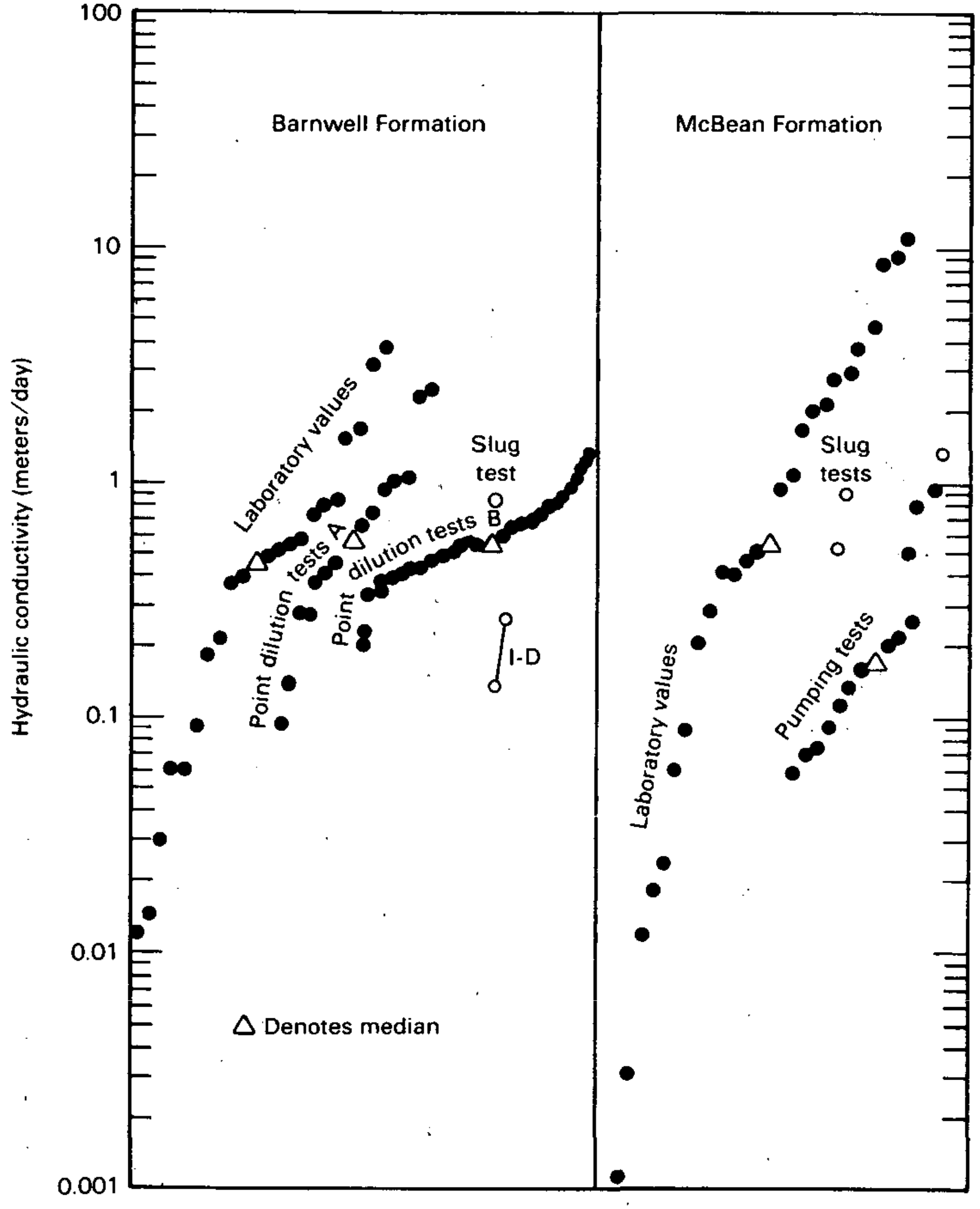
Fluid losses in the calcareous zone during drilling operations make it appear very permeable. However, pumping tests on the calcareous zone indicate a low hydraulic conductivity (Table F-7, Figure F-14). Apparently zones of higher permeability do not connect over large distances, and the regional permeability of the calcareous zone is lower than it appears from drilling experience.

Water elevations in both the upper sand unit and in the calcareous zone are shown in Figures F-5 and F-16. These data, based on wells in the recharge area, indicate a difference of about 0.6 meter in hydraulic head between the top of the McBean and its base. This indicates a better hydraulic connection between the sandy unit of the McBean and the calcareous zone than between the McBean and the Congaree Formations below or the Barnwell Formation above.

Figure F-20 shows the piezometric surface of the upper part of the McBean Formation in the separations areas. This map indicates lateral flow in the upper part of the McBean Formation toward Upper Three Runs Creek to the north and toward Four Mile Creek to the south. Because of the hydraulic connection between the upper sandy zone and the calcareous zone, Figure F-20 can also be used to determine the approximate flow path of water in the calcareous zone.

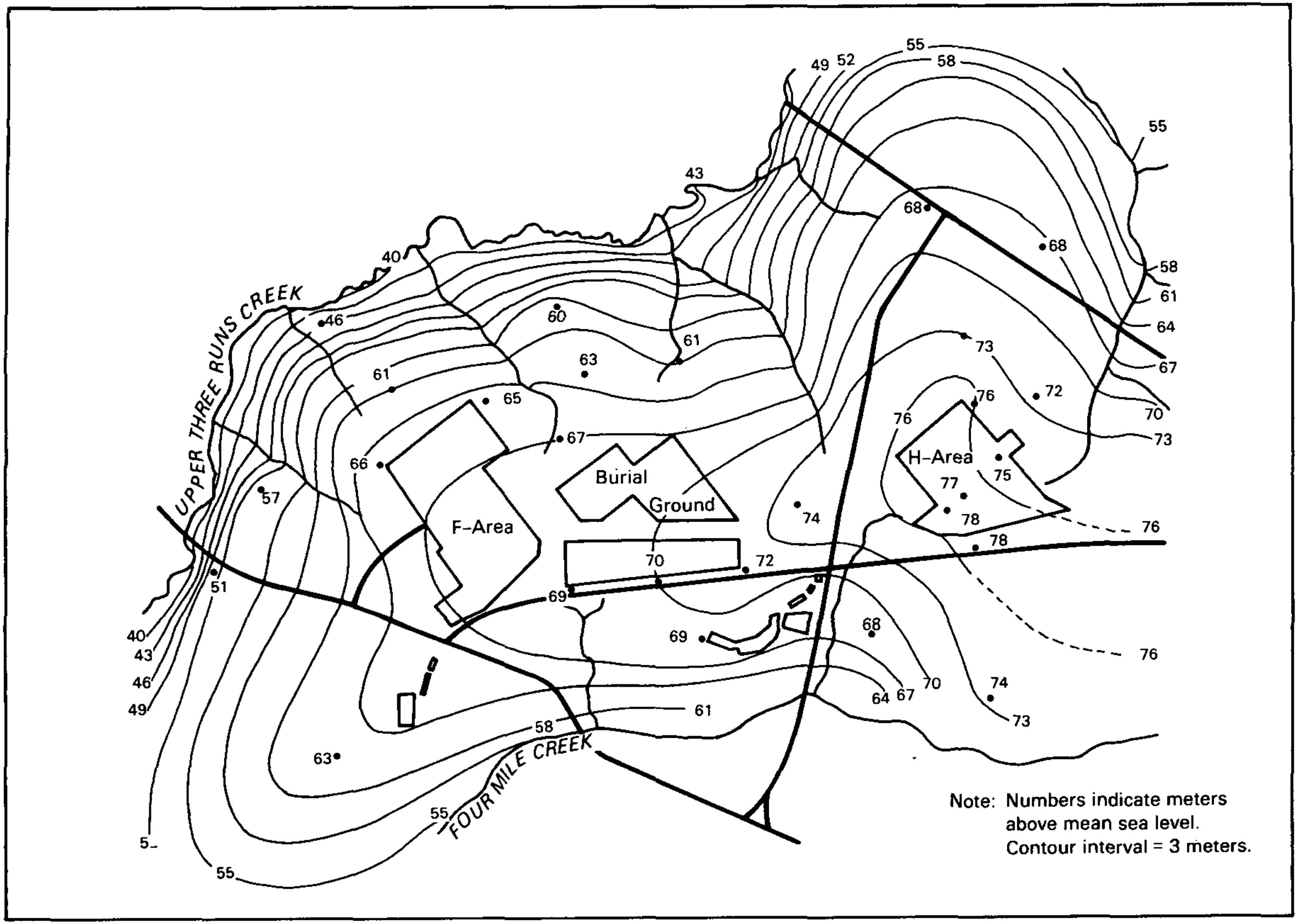
As previously described, the green clay impedes downward movement of water from the McBean to the Congaree Formation in the central part of Savannah River Plant, thereby contributing to a hydraulic head differential of about 24 meters (Figure F-5). In the Barnwell Formation just above the McBean Formation, a tan clay impedes vertical movement of water from the Barnwell Formation into the McBean. This tan clay is not as continuous as the green clay, and it has a higher hydraulic conductivity. The McBean Formation is less permeable than the Congaree; thus, the head differential between the Barnwell and the McBean Formation is only about 4 meters (Figure F-5).

Using the previously given hydraulic conductivity, and effective porosity along with an appropriate hydraulic gradient of 0.017, the average horizontal velocity of the McBean in the central part of Savannah River Plant is calculated (by Darcy's Law, as was done for the Congaree) as 4.0 meters per year. Assuming



Source: Du Pont (1983).

Figure F-19. Horizontal hydraulic conductivities of the Barnwell and McBean Formations in the separations areas at Savannah River Plant.



Note: Numbers indicate meters above mean sea level. Contour interval = 3 meters.

Source: Du Pont (1983).

Figure F-20. Piezometric surface of the upper part of the McBean Formation in the separations areas at Savannah River Plant (August 29, 1977).

|TC

the same gradient as for the Upper McBean, the regional ground-water velocity in the calcareous zone is 2.2 meters per year.

In the northwest part of Savannah River Plant (M-Area) the average hydraulic conductivity of the McBean and Congaree Formations together, as determined from a pumping test, is 0.75 meter per day and the average velocity is about 6.1 meters per year. The main body of the chlorinated hydrocarbon plume in the A- and M-Areas is moving at a rate of 7.6 meters per year; the outer fringe is moving at 76 meters per year. TC

Water from the McBean Formation is not used for industrial or municipal purposes. Larger wells producing from the Claiborne deposits probably derive most of their water from the Congaree. The McBean is, however, sufficiently permeable in some places to supply water for domestic use.

Because the McBean Formation is not used for large supplies of water, it is not anticipated that there will be much future change from water use in the hydrologic regimen of this formation. The head differential between the McBean and Congaree is about 24 meters at present, and even if the Congaree were subjected to additional drawdown, it is unlikely that there would be much effect on the McBean hydrology. Dissection of the McBean by local creeks also divides the formation into subunits whose hydrologic regimen is unaffected by adjacent subunits. Thus, increased development in one of the subunits would have little effect on the regional hydrology of this formation.

F.2.6.3 Water quality

Samples of water from Eocene sand and Eocene limestone probably include some water from both the upper sand and the calcareous subunits of the McBean Formation. The median and range of chemical analyses are listed in Table F-4. The water from both subunits is low in dissolved solids, but water from the upper sand subunit is much lower. The differences in the chemical characteristics of water from the two subunits of the McBean are readily apparent in Table F-5. Well HC3D in the upper sandy unit has a total dissolved solids content of 14 milligrams per liter with all constituents being very low. The other two wells are screened in the calcareous zone and have a dissolved solids content of more than 50 milligrams per liter with higher calcium and bicarbonate contents. The pH of the water from the calcareous zone is near 7, while that of water from the upper sandy zone is generally less than 5.

F.2.7 Barnwell Formation

F.2.7.1 Hydrostratigraphy

The Barnwell Formation directly overlies the McBean Formation and is exposed over a considerable area in the uplands of Aiken and Barnwell Counties. The formation thickens to the southeast from zero in the northeastern part of Aiken County to about 27 meters at the southeast boundary of Barnwell County. The Barnwell Formation is overlain by the Hawthorn Formation, from which it is usually difficult to distinguish from the Barnwell. In the separations areas, these two units together are usually about 30 meters thick (Figure F-5).

The Barnwell Formation consists mainly of deep red fine-to-coarse clayey sand and compact sandy clay. Other parts of the formation contain beds of mottled-gray or greenish-gray sandy clay and layers of ferruginous sandstone that range in thickness from 0.03 to 1 meter. Although fossils at some places indicate a marine origin, material identified as Barnwell may have been deposited in other places as alluvium during Pliocene to Pleistocene time (Siple, 1967). Beds of limestone occur in the Barnwell Formation in Georgia, but none have been recognized in South Carolina.

These factors indicate that a considerable part of the Barnwell Formation was deposited as a sandy limestone in a near-shore or estuarine environment. Some evidence of the remnant calcareous nature of the formation is indicated by the comparatively high proportion of calcium carbonate found in ground water circulating in this unit (Siple, 1967).

In the separation areas, the Barnwell Formation appears divisible into three parts:

1. The lowest unit, the tan clay, commonly consists of two thin clay layers separated by a sandy zone. The entire unit is about 3 to 4.5 meters thick and is semicontinuous over the area.

2. Above the tan clay is a silty sand unit, 0 to 12 meters thick.

3. Above the silty sand is a unit of clayey sand (that may include beds of silty clay or lenses of silty sand) to 30 meters thick. This sand is slightly less permeable than the underlying silty sand.

Because of the large amount of clay and silt mixed with the sands, the Barnwell Formation does not generally yield water to wells. However, an occasional lens of sand may be relatively free of clay and can provide adequate quantities of water for domestic use.

F.2.7.2 Hydrologic characteristics

Laboratory measurements of hydraulic conductivities of many undisturbed Barnwell samples, as well as results of point-dilution tracer tests, are shown in Figure F-19. The median conductivity was 0.04 meter per day for the clayey sand unit (Table F-7 and Figure F-15). Although no pumping tests were made on the silty sand unit, a pumping test in a sand lens within this unit indicated a hydraulic conductivity of 0.3 meter per day (Table F-7).

The relationship of water elevations in different zones within the Barnwell, as well as the relationship of these levels to those in the formations below, are shown in Figures F-5 and F-15. The variations of water levels in the Barnwell over a period of five years are shown in Figure F-16. This figure indicates that the amplitude of water elevation fluctuation is greater in the Barnwell than in the formations below.

Figures F-5 and F-15 show a hydraulic head that decreases with depth within the Barnwell Formation. Although the tan clay impedes the downward movement of water, the McBean Formation is recharged by water that passes through this hydrostratigraphic unit.

The water table is commonly within the Barnwell Formation, although in the creek valleys it successively occupies positions in the lower formations (Figure F-15). A map of the elevation of the water table is shown in Figure F-21. The surface drainage and topography strongly influence the flow path at any point. Even small tributaries to the larger creeks cause depressions in the water table, diverting ground-water flow towards them.

Using an overall average gradient for the water table of 0.018, a hydraulic conductivity for the clayey sand unit of 0.04 meter per day (Table F-7), and an effective porosity of 20 percent, the ground-water velocity through Barnwell material is calculated as 1.3 meters per year. If a sand lens with a hydraulic conductivity of 0.3 meter per day (Table F-7) existed for the entire flow path, the velocity would be 9.7 meters per year. A series of tracer dilution tests and tracer injection detection tests yielded velocities ranging from 0.7 to 21 meters per year (Fenimore, 1968).

Natural discharge from the water table, which is predominantly in the Barnwell Formation, is to the creeks and their tributaries on Savannah River Plant. The areas of perennial creek drainage are shown by the solid lines representing creeks in Figure F-21.

The Barnwell Formation supplies water for domestic purposes in some places in the region, but it is not used by industry or municipalities. Total pumpage has not been estimated, but is small. The future ground-water levels of the Barnwell Formation will mainly depend on natural conditions such as rainfall.

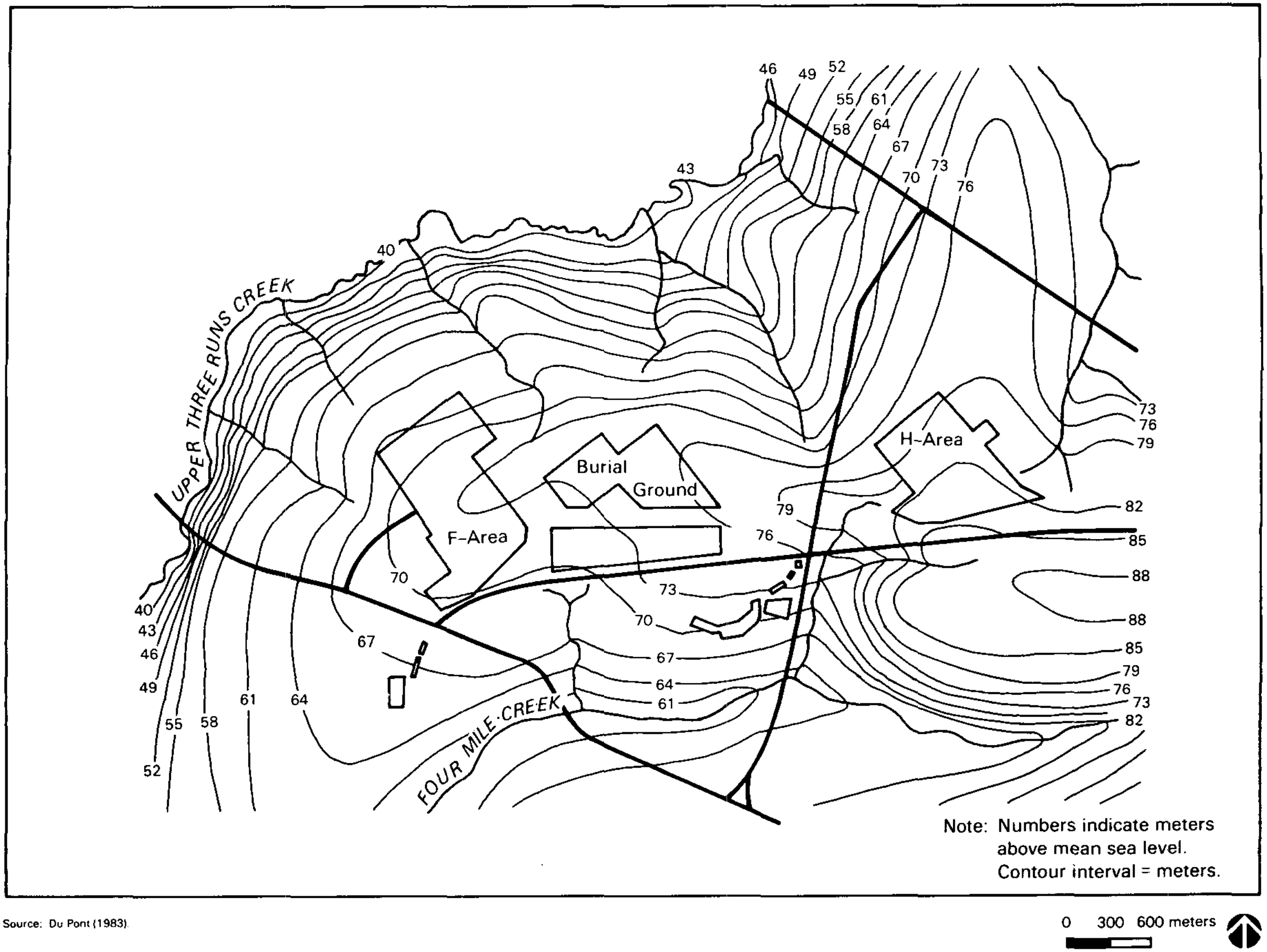
F.2.7.3 Water quality

Five analyses of water from the Barnwell Formation in the separations areas are given in Table F-5. The dissolved solids content is low, and the calcium and bicarbonate ions are not as high as in the McBean and Congaree Formations. The pH of water from the Barnwell Formation is as low as that of water from other formations in the area.

F.2.8 Hawthorn Formation

F.2.8.1 Hydrostratigraphy

The Hawthorn Formation crops out over a very large area of the Atlantic Coastal Plain and is perhaps the most extensive surficial deposit of Tertiary age in this region (Siple, 1967). It is bounded on top and bottom by erosional unconformities, and is present at the surface in the higher areas of Aiken County. It ranges in thickness from zero in northwestern Aiken County to about 25 meters near the Barnwell-Allendale County Line.



Note: Numbers indicate meters above mean sea level. Contour interval = meters.

Source: Du Pont (1983).

Figure F-21. Average elevation of the water table in the separations areas at Savannah River Plant during 1968.

Typical Hawthorn Formation is fine, sandy, phosphatic marl or soft limestone and brittle shale resembling silicified Fuller's earth. Updip, however, in the vicinity of Aiken and Barnwell Counties, it is characterized by tan, reddish-purple, and gray sandy, dense clay that contains coarse gravel, limonitic nodules, and disseminated flecks of kaolinitic material.

The fine-grain materials within the Hawthorn Formation, consisting of compact silt and clay, are incapable of yielding water and are therefore not suitable for wells (Siple, 1967). The Hawthorn Formation is above the water table throughout much of the SRP area. However, where low permeability beds are overlain by more permeable beds, perched water bodies may occur.

F.2.8.2 Hydrologic characteristics

Because the Hawthorn Formation in the SRP area is usually unsaturated, no pumping tests have been performed. There is no piezometric map of the Hawthorn Formation in this area. Flow paths are predominantly vertical, with only short horizontal flow paths.

Within the Hawthorn there are numerous clastic dikes that criss-cross the clayey sand of the formation. These dikes are generally filled with greenish-gray silty-to-sandy clay (Du Pont, 1980). The dike wall, 0.5 to 2.5 centimeters thick, is generally indurated and consists of an iron oxide-cemented quartz sand (Siple, 1967). Thus, the dike filling is generally finer grained than the surrounding sediments. The origin of the dikes is uncertain. Possible explanations include (1) shrinkage resulting from weathering, (2) seismic activity, and (3) relief of compressional stresses by upward movement of plastic material (Siple, 1967).

F.2.8.3 Water quality

No water samples from the unsaturated zone have been analyzed.

F.2.9 Surficial formations

F.2.9.1 Tertiary alluvium

Alluvial deposits of Late Tertiary age occur irregularly and discontinuously on the interstream divides or plateaus. They are composed of coarse gravel and poorly sorted sand and were tentatively classified by Siple (1967) as Pliocene in age. Their thickness ranges from 1.5 to 6 meters. These deposits are generally considerably above the water table and are therefore unimportant as a source of ground water for wells. Nevertheless, they are fairly permeable, and are capable of storing and transmitting water. Their presence therefore enhances recharge to underlying formations.

F.2.9.2 Terrace deposits

Cooke (1936) recognized seven marine terraces of Pleistocene age on the Atlantic Coastal Plain of South Carolina. He indicated that the four highest terraces are present in the Savannah River Valley. The deposits that may be associated with these terraces are on the order of 10 meters thick or less (Cooke, 1936). Because of their near-surface location, they are not important as sources of well water.

F.2.9.3 Holocene alluvium

Alluvium of Holocene age occurs in the tributary and main channels of the Savannah River. These deposits, which are generally cross-bedded and heterogeneous in composition, range in thickness from 1.5 to 9 meters (Siple, 1967). The poorly sorted sand, clay, and gravel have little potential for ground-water development except along the larger streams where infiltration galleries might be possible.

F.2.10 Hydrostratigraphy at L-Area

The hydrostratigraphy at L-Area can be developed from the regional hydrostratigraphy as well as geological investigations and well logs at L-Area. Figure F-22 shows a hydrostratigraphic section from Pen Branch to Steel Creek developed from foundation borings (COE, 1952) and the driller's log from one of the water wells (29-L). Figure F-23 shows two cross sections through L-Area down to an elevation of about 12 meters above sea level. The tan clay is not readily evident from foundation borings, drillers logs, or geophysical well logs; however, even in other areas of the Savannah River Plant where it supports a significant head difference, this clay is not always apparent in soil cores alone. The calcareous zone is quite evident as it should be in this downdip location where the original lime content of the zone was greater. The green clay is recognizable in the water well driller's log, but cores might indicate that it is thicker than shown in the driller's log. Based on self-potential, resistivity, and gamma-ray geophysical well logs of wells 104L and 55-2, the green clay is 7 meters thick. (Figure F-24 shows the areas of the well field.) The Congaree Formation is not distinctive on the driller's log, but the upper aquifer of the Tuscaloosa Formation is noted in logs. TC TC

Figure F-24 is a water table map in the vicinity of L-Area. The water table in this area is unaffected by plant pumpage and is subject only to variation in local precipitation. The water table is between 3 and 6 meters below the surface (60 to 75 meters above sea level). The water table has a gradient of approximately 0.0188 (including the head of water in the seepage basin), resulting in lateral flow from the seepage basin toward Steel Creek. If the hydraulic conductivity of the Barnwell (water table) Formation at L-Area was 0.6 meter per day (Section F.2.6.2), the lateral ground-water velocity would be about 21 meters per year. Root (1983) suggests that a lateral ground-water velocity of 14.5 meters per year per percent gradient is appropriate for the EN-44 EN-44

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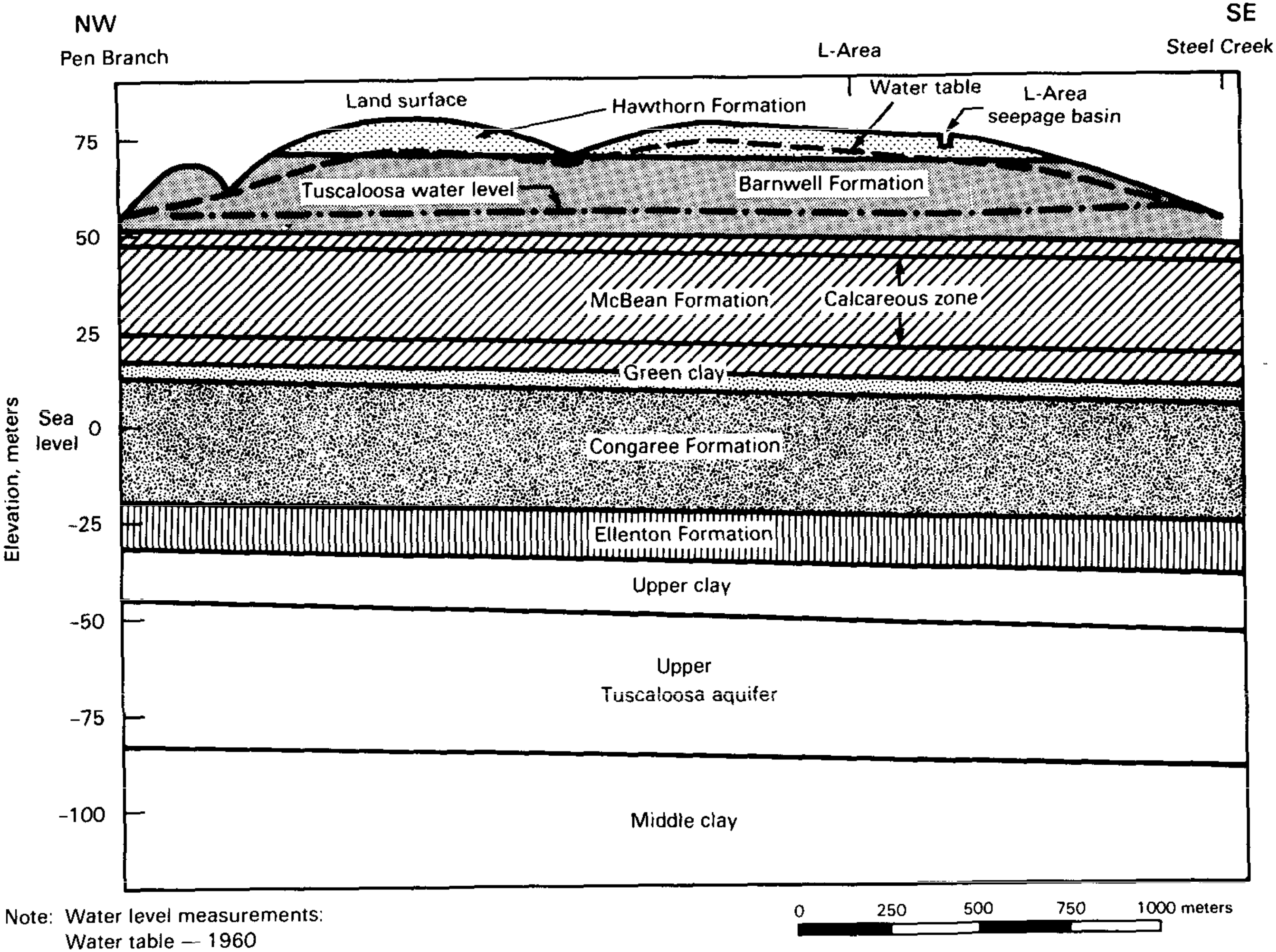

Note: Water level measurements:
Water table — 1960
Tuscaloosa — Feb. 2, 1982

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Figure F-22. Hydrogeology at L-Area.

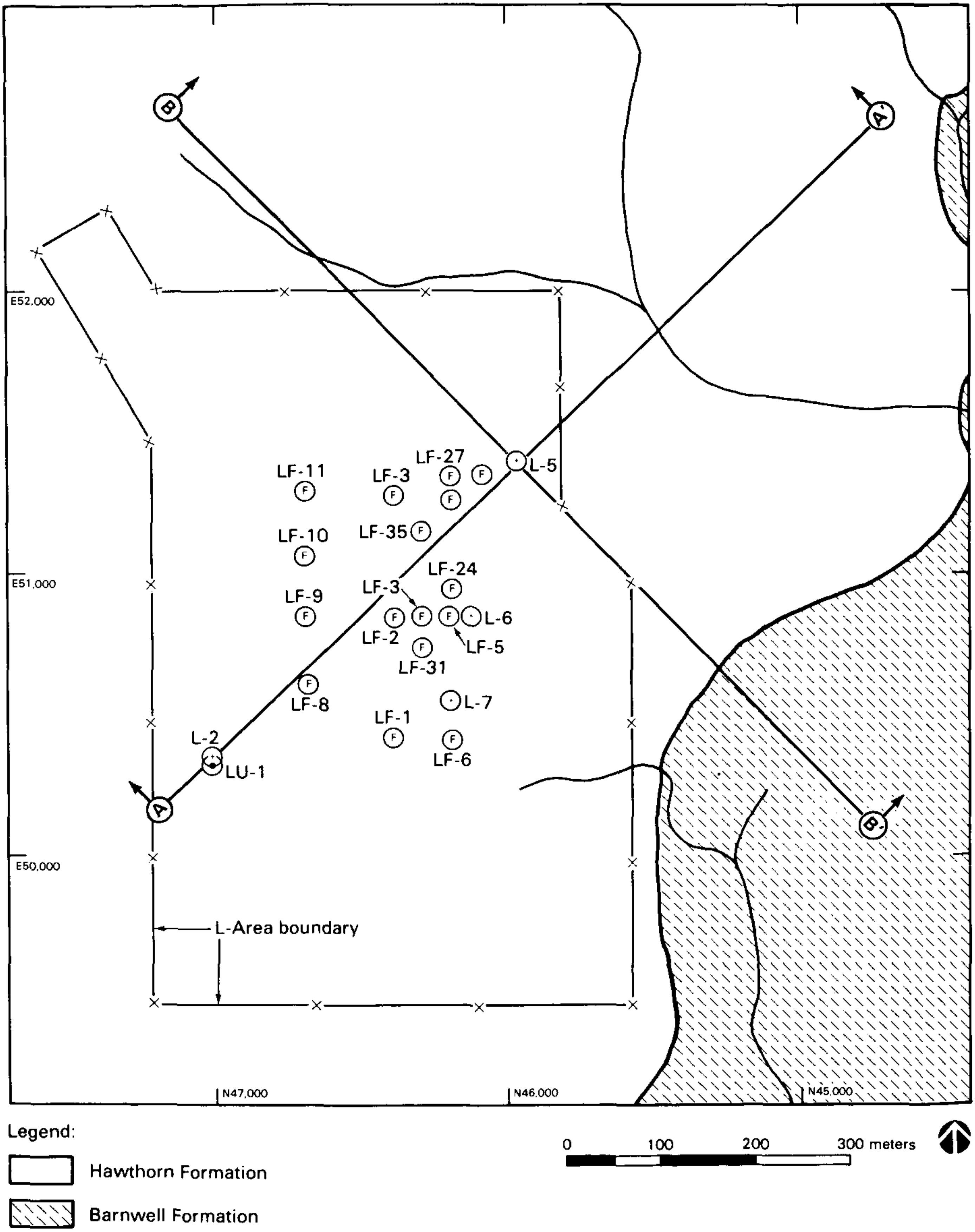
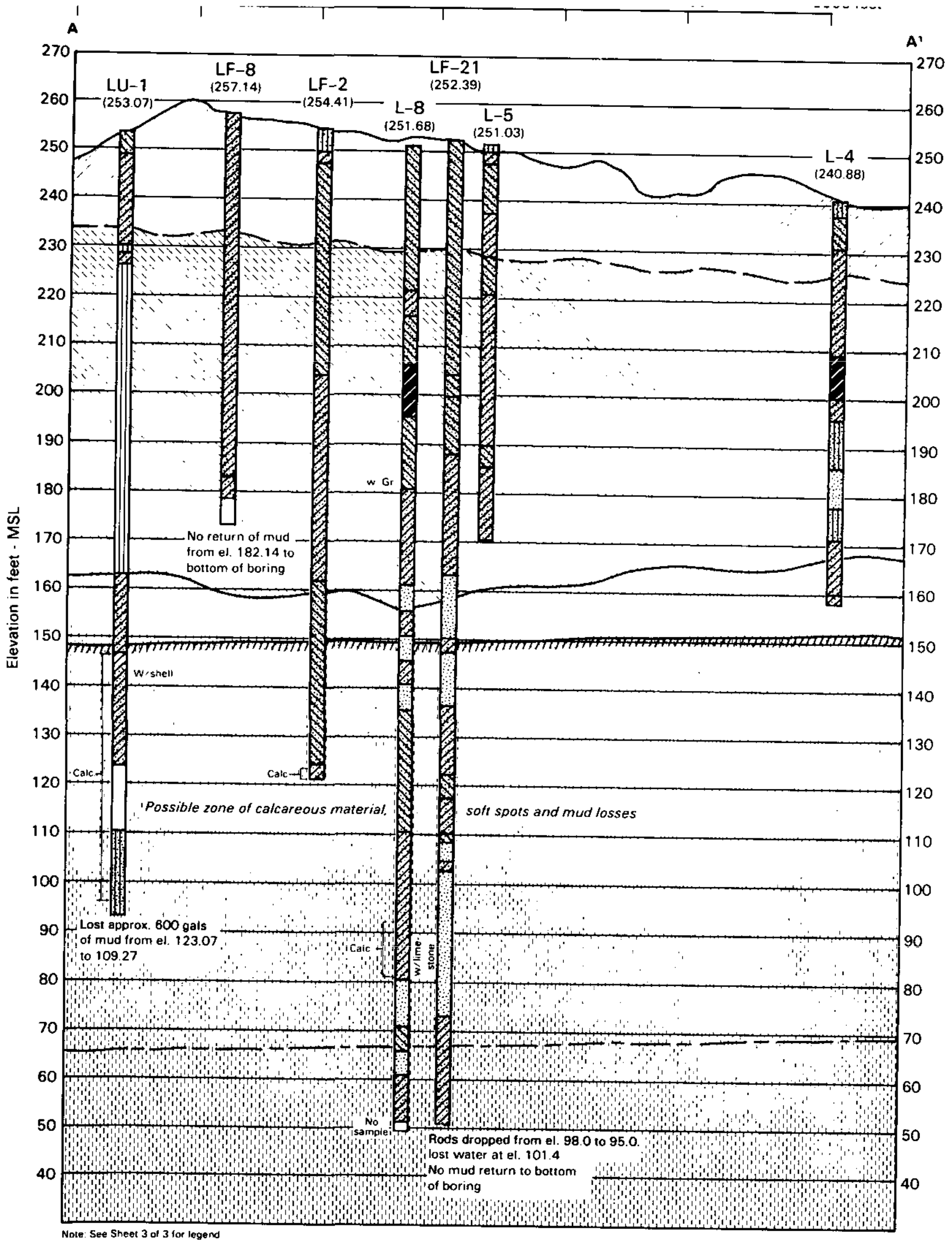
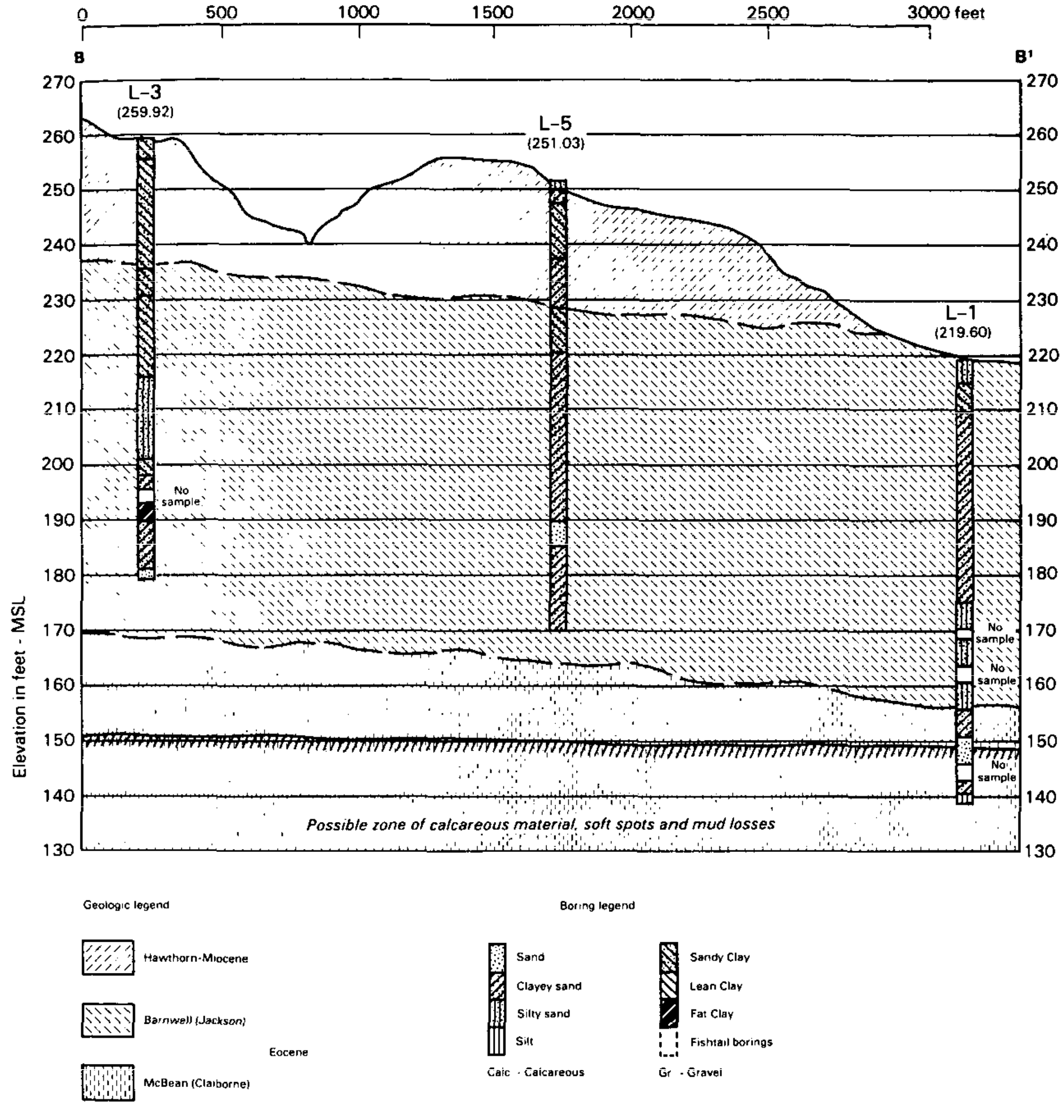


Figure F-23. Geologic sections across L-Area (Sheet 1 of 3).



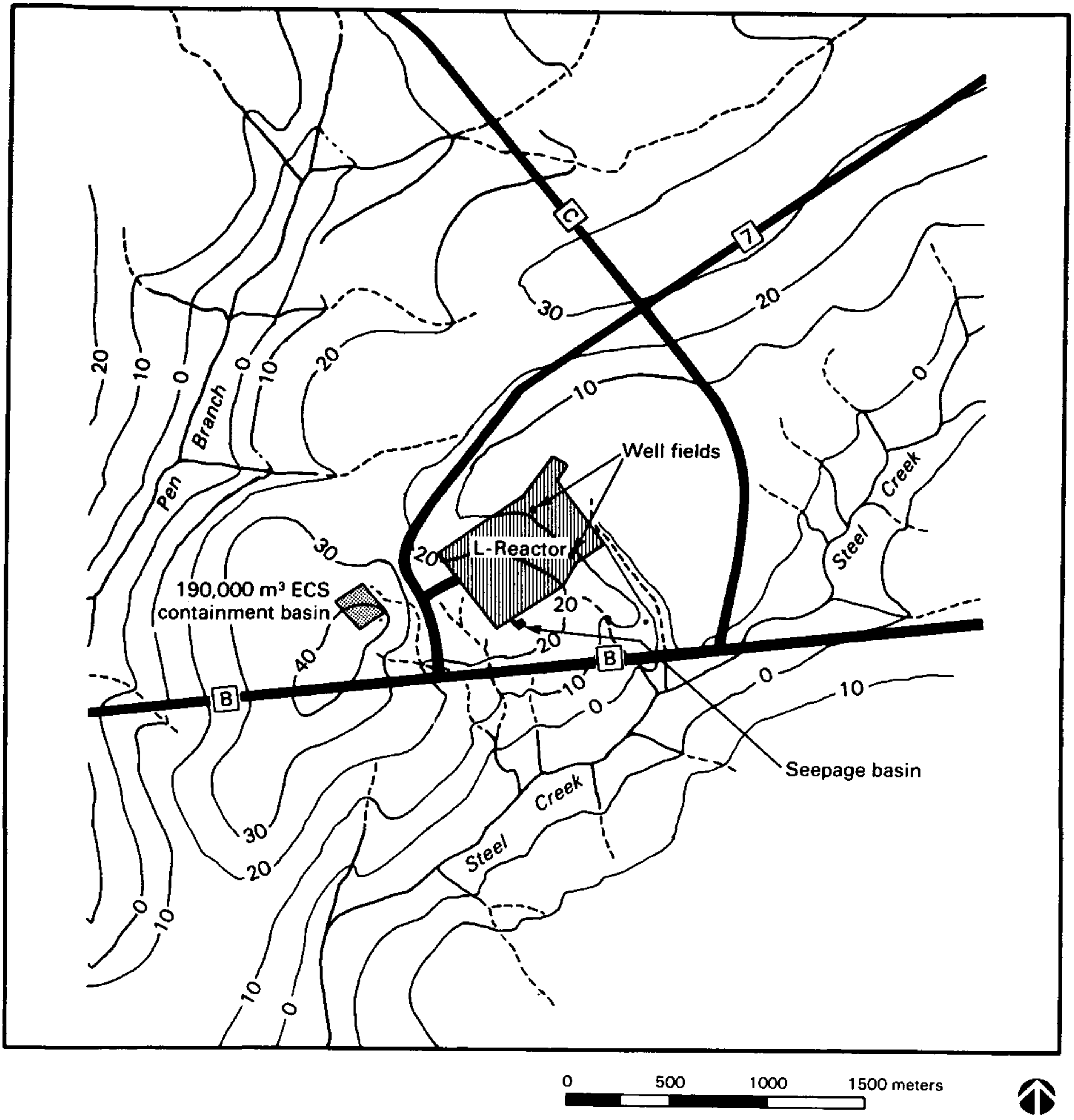
Note: See Sheet 3 of 3 for legend

Figure F-23. Geologic sections across L-Area (Sheet 2 of 3).



Note: Hawthorn and Barnwell Formations may be alluvial deposits of Pleistocene or Pliocene Age

Figure F-23. Geologic sections across L-Area (Sheet 3 of 3).



Note: Contours shown in feet; 1.0 feet = 0.3048 meter.

Source: Langley and Marter (1973).

Figure F-24. Depth to the water table in the vicinity of L-Area (1965).

TC

EN-44 Barnwell Formation. This relationship yields a lateral velocity of about 27 meters per year between the L-Reactor seepage basin and Steel Creek. Because the L-Reactor seepage basin will not receive continuous discharges of low pH wastewater that enhance seepage (as in F- and H-Areas), a travel time of at least 18 years is expected for the 600-meter path between the basin and the creek.

Water levels have not been measured in the McBean or Congaree Formations at L-Area, but Figure F-18 indicates that the water level in the Congaree Formation should be about 50 meters above sea level. The water elevation in the Tuscaloosa Formation (Well 29-L) was 57 meters in 1951 before pumpage began. In 1982 the static Tuscaloosa water level was 55 meters in elevation. Thus, the heads decrease with depth to the Congaree Formation and then increase with depth in the Ellenton and Tuscaloosa Formations.

F.3 GROUND-WATER DEVELOPMENT

F.3.1 Use of ground water

Ground-water users within a 32-kilometers radius of the center of SRP were surveyed. Information was obtained from the South Carolina Department of Health and Environmental Control (SCDHEC), the South Carolina Water Resources Commission (South Carolina Water Resources Commission, 1971; Dukes, 1977), from files at the Savannah River Plant, and from Siple (1967).

Most municipal and industrial water supplies in Aiken County are developed from the Tuscaloosa Formation, which occurs at shallower depths as the Fall Line is approached. Domestic water supplies are primarily developed from the Barnwell, McBean, and Congaree Formations. In Barnwell and Allendale Counties, the Tuscaloosa Formation occurs at increasingly greater depths; some municipal users are therefore supplied from the shallower Congaree and McBean Formations or from their limestone equivalent. In these counties, domestic supplies are developed from the Barnwell and the McBean Formations.

The survey identified 44 municipalities and industries that use more than 18.9 cubic meters per day from ground-water sources. The total pumpage for these users is about 106,300 cubic meters per day. The locations of these users are shown in Figures F-25 and F-26, together with ground-water flow paths for the Tuscaloosa and Congaree Formations, respectively. Pertinent data are listed in Tables F-8 and F-9. TC

F.3.1.1 Municipal use

TC Twenty municipal users, with a combined withdrawal rate of about 39,000 cubic meters per day, were identified (Table F-8). Talatha community (in Aiken County), the municipal user nearest to the center of the Savannah River Plant (about 11 kilometers away), uses about 150 cubic meters per day. The largest

Table F-8. Ground-water pumpage for municipal supplies[a]

Map location[b]	User	Distance from center of SRP (km)	Population served	Average daily use m^3/day	Water-bearing formation	Type of source
		AIKEN COUNTY, SOUTH CAROLINA				
1	City of Aiken	34	28,000	7,570	Tuscaloosa	Springs
2	Town of Jackson	16	3,152	660	Tuscaloosa	2 wells
3	Town of New Ellenton	13	4,000	1,135	Tuscaloosa	2 wells
4	Town of Langley	31	1,330	490	Tuscaloosa	2 wells
5	College Acres	21	1,264	245	Tuscaloosa	3 wells
6	Bath Water District	31	1,239	1,230	Tuscaloosa	2 wells
7	Beech Island	27	4,500	1,135	Tuscaloosa	3 wells
8	Talatha	11	1,200	150	Tuscaloosa	2 wells
9	Breezy Hill	32	4,500	880	Tuscaloosa	4 wells
10	Burnettown	31	1,200	570	Tuscaloosa	2 wells
11	Montmorenci	23	4,232	1,600	Tuscaloosa	2 wells
12	Warrenville	31	788	1,135	Tuscaloosa	4 wells
13	Johnstown	31	1,560	545		
	Howlandville	31	1,232	380	Tuscaloosa	1 well
	Gloverville	31	1,440	545		
14	Belvedere	39	6,300	1,370	Tuscaloosa	5 wells

Table F-8. Ground-water pumpage for municipal supplies[a] (continued)

Map location[b]	User	Distance from Center of SRP (km)	Population served	Average daily use m^3/day	Water-bearing formation	Type of source
		BARNWELL COUNTY, SOUTH CAROLINA				
15	Barnwell	26	6,500	15,140	Congaree	11 wells
16	Williston	19	3,800	2,650	McBean-Tuscaloosa	4 wells
17	Blackville	32	2,975	1,135	Tuscaloosa	3 wells
18	Hilda	35	315	35	Tuscaloosa	1 well
19	Elko	23	315	40	McBean	1 well
		BURKE COUNTY, GEORGIA				
40	Girard	32	210	75	Tuscaloosa	3 wells

[a] Adapted from Du Pont (1983).
[b] See Figure F-25.

Table F-9. Ground-water pumpage for industrial supplies

Map location[a]	User	Distance from center of SRP (km)	Population served	Average daily use (m^3/day)	Water-bearing formation	Type of source
			SAVANNAH RIVER PLANT			
20	A/M-Area	10	2,131	9,805[b]	Tuscaloosa	4 wells
21	F-Area	3	800	9,275[c]	Tuscaloosa	6 wells
22	H-Area	0	825	10,035[b]	Tuscaloosa	5 wells
23	U-Area	6	110	490	Tuscaloosa	3 wells
24	Central Shops (CS)	11	600	820	Tuscaloosa	3 wells
25	CMX-TNX	13	50	1,630	Tuscaloosa	1 well
26	Class. Yd.	10	35	30	(d)	1 well
38	DWPF[e]	1	530	1,080	Tuscaloosa	2 wells
39	FMF[f]	1	280	290	Tuscaloosa	(d)
41	C-Area	5	(b)	1,900	Tuscaloosa	2 wells
42	K-Area	9	(b)	1,630	Tuscaloosa	2 wells
43	P-Area	9	(b)	1,900	Tuscaloosa	2 wells
44	L-Area	9	(b)	1,355[b]	Tuscaloosa	2 wells
			AIKEN COUNTY, SOUTH CAROLINA			
27	U.S. Forest Service	11	70	20	Tuscaloosa	1 well
28	Graniteville Company	32	2,156	525	Tuscaloosa	1 well
29	J. M. Huber Company	29	(b)	8,440	Tuscaloosa	1 well
30	Augusta Sand & Gravel	35	(b)	3,595	Tuscaloosa	1 well
31	Cyprus Mines Corp.	32	(b)	1,420	Tuscaloosa	1 well
32	Florida Steel Corp.	32	(b)	75	Tuscaloosa	1 well
33	Valchem	29	(b)	410	Tuscaloosa	1 well
			ALLENDALE COUNTY, SOUTH CAROLINA			
34	Sandoz Co.	29	(b)	10,900	Tuscaloosa	1 well

TC

Table F-9. *Ground-water pumpage for industrial supplies* (continued)

Map location[a]	User	Distance from center of SRP (km)	Population served	Average daily use (m^3/day)	Water-bearing formation	Type of source
			BARNWELL COUNTY, SOUTH CAROLINA			
35	E. T. Barwick Ind.	26	400	945	Tuscaloosa	2 wells
			FUTURE INDUSTRIAL SUPPLIES			
36	Barnwell NFP[g]	18	450	1,100	Tuscaloosa Congaree	1 well
37	A. W. Vogtle NPS[h]	24	(b)	950	Tuscaloosa Congaree	2 wells 3 wells

[a] See Figure F-25; adapted from Du Pont (1983).

[b] Usage is not expected to increase when L-Reactor operation is resumed.

[c] In September 1984, usage is expected to decrease to 4905 cubic meters per day when the F-Area powerhouse is placed in standby status; usage is then expected to increase to 6540 cubic meters per day as the result of L-Reactor operation.

[d] Data not available.

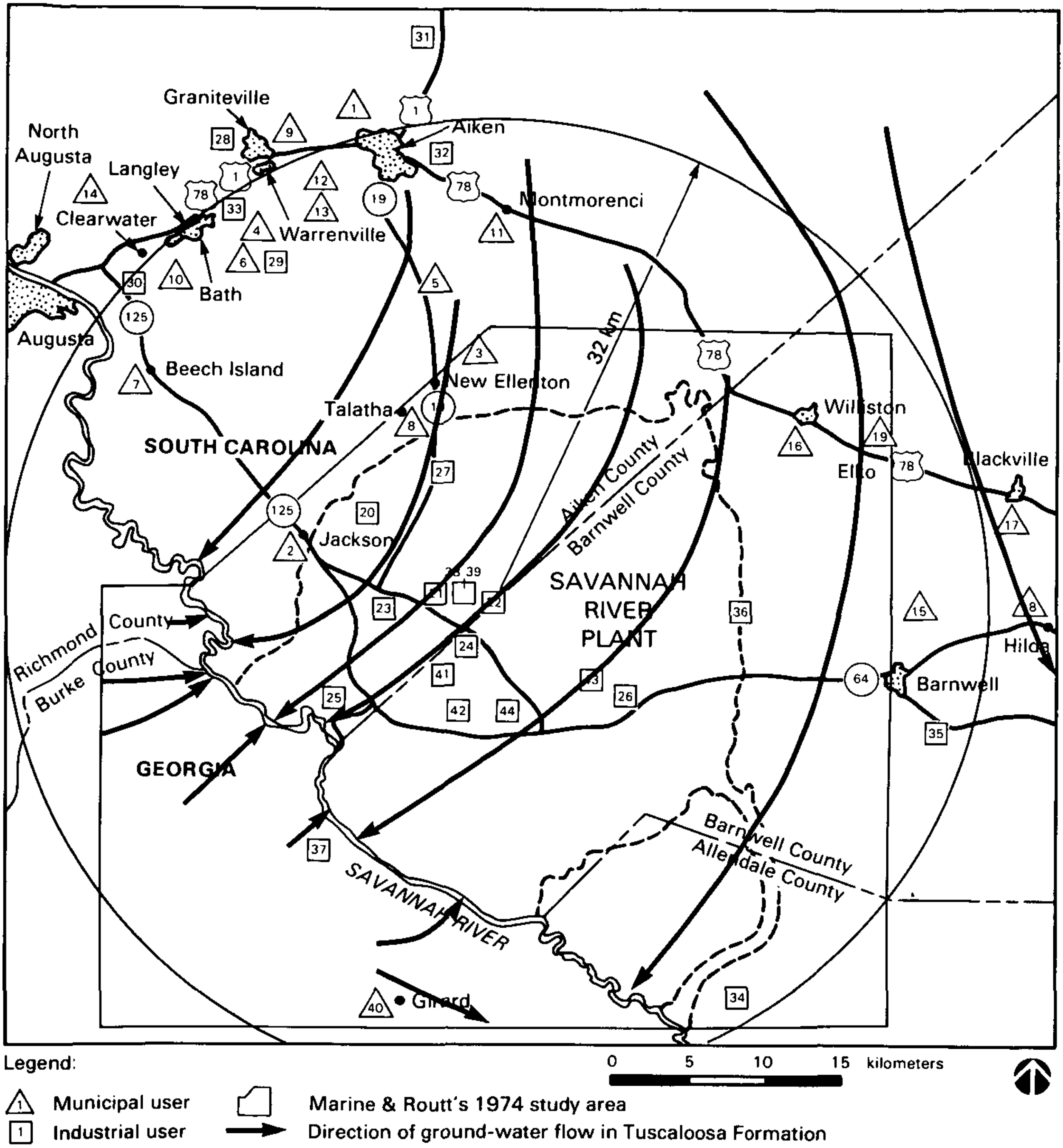
[e] The Defense Waste Processing Facility (DWPF) is under construction; the exact number of water wells and pumping requirements are not firmly established. Current plans (December 1983) indicate a usage of less than 1080 cubic meters per day supplied by one or two wells, each with a capacity of 5450 cubic meters per day.

TC

[f] The Naval Fuel Materials Facility (FMF) is under construction; the pumping requirements are not firmly established.

[g] The Barnwell Nuclear Fuel Plant has not processed and is not expected to process nuclear fuel.

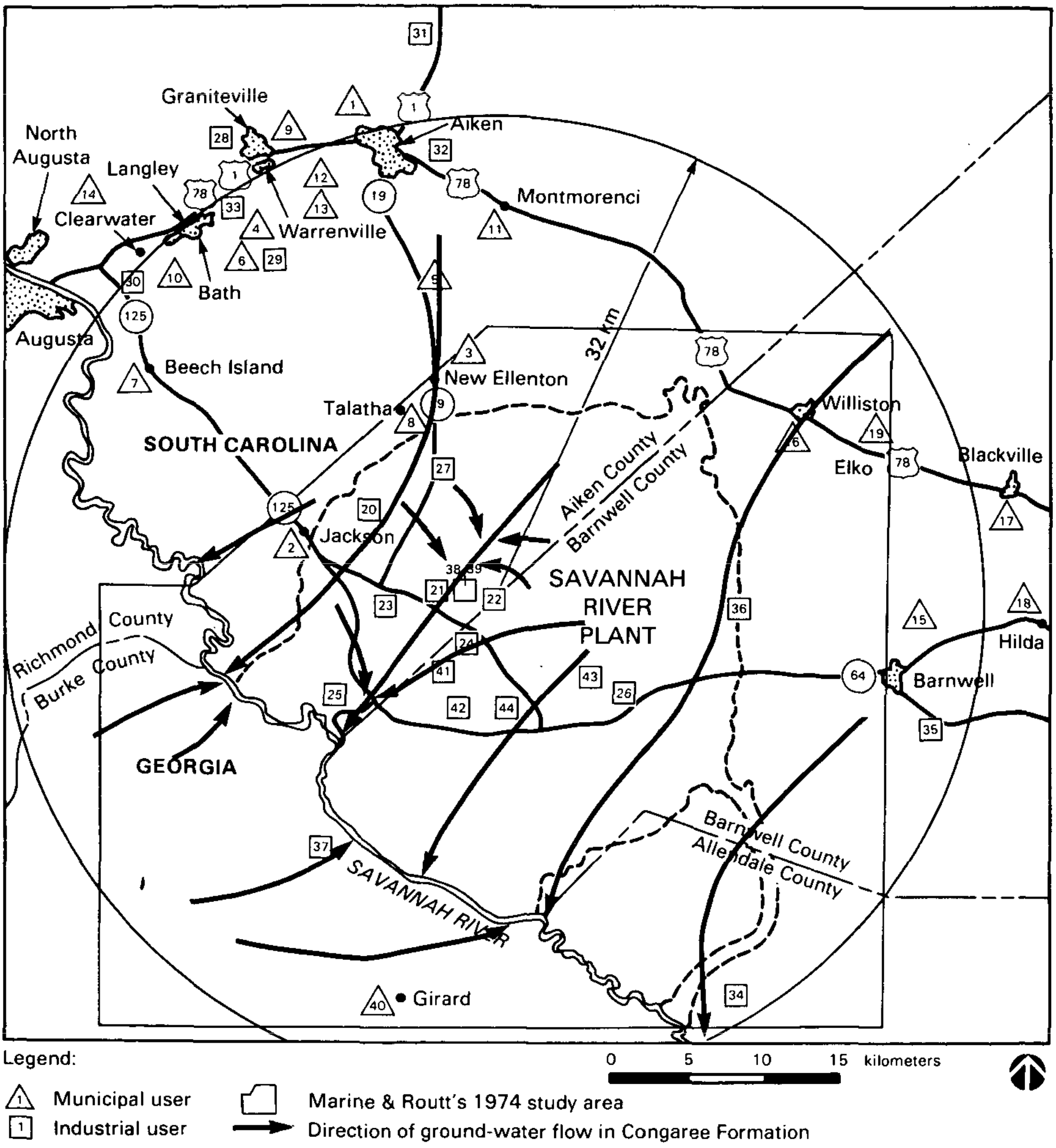
[h] The Vogtle Nuclear Power Station is under construction; its total ground-water requirements are not available.



Note: Users are identified in Tables F-8 and F-9; flow directions are developed from Figures F-8 and F-9.

Source Du Pont (1983)

Figure F-25. Locations of municipal and industrial ground-water users within a 32-kilometer radius of the center of Savannah River Plant, showing the direction of ground-water flow in the Tuscaloosa Formation.



Note: Users are identified in Tables F-8 and F-9; flow directions are developed from Figure F-18 and *Figure 3-21 in Du Pont, 1983.*

Source Du Pont (1983)

Figure F-26. **Locations of municipal and industrial ground-water users within a 32-kilometer radius of the center of Savannah River Plant, showing the direction of ground-water flow in the Congaree Formation.**

municipal user is the town of Barnwell (in Barnwell County), about 26 kilometers away; it uses 15,140 cubic meters per day, some of which is supplied to local industry.

Total municipal pumpage from the Tuscaloosa Formation is about 23,500 cubic meters per day. Total municipal pumpage is 38 cubic meters per day from the McBean Formation and 15,000 cubic meters per day from the Congaree Formation. TC

F.3.1.2 Industrial use

Twenty-four industrial users were identified as shown in Table F-9, including 13 SRP users. Total industrial pumpage from the Tuscaloosa Formation, including the Savannah River Plant, is about 67,300 cubic meters per day. TC

The Barnwell Nuclear Fuel Plant has not, nor is it currently expected to operate and the only pumpage (for domestic purposes, boiler make-up, and wash water) is estimated to be about 0.76 cubic meter per minute from one Tuscaloosa well and one Congaree well. The Sandoz Plant, about 29 kilometers south of the center of Savannah River Plant, is the largest offsite industrial user and pumps about 10,900 cubic meters per day from one Tuscaloosa well. This pumpage began about 1978.

Construction work at the Vogtle Nuclear Power Plant, across the Savannah River from Savannah River Plant restarted in 1977. Water is supplied from two Tuscaloosa wells about 260 meters deep and three shallower wells about 73 meters deep, probably in the Congaree Formation. The average pumping rate for the total five-well system was 950 cubic meters per day in 1982. This pumpage also began about 1978.

F.3.1.3 Agricultural use

In 1980 irrigation from ground-water sources in Allendale County amounted to an average annual pumping rate of 15,000 cubic meters per day. In Barnwell County this amounted to 4100 cubic meters per day. Most of the growth of irrigation systems in these two counties has taken place over the last several years. Some of these irrigation systems are in the Tuscaloosa, but some are in the limestone equivalent of the McBean or Congaree Formations.

F.3.1.4 Domestic use

In addition to the large municipal and industrial users, 25 small communities and mobile home parks, 4 schools, and 11 small commercial interests are listed in the files of the South Carolina Department of Health and Environmental Control as using ground water. Wells serving these users are generally equipped with pumps of 54 to 325 cubic meters per day capacity and do not draw large

TC quantities of water. Most produce from shallow aquifers. The estimated total withdrawal from these 40 users is about 1000 cubic meters per day. However, incomplete State records provide little information on screened zone, formation, or actual usage. Two South Carolina State Parks are within the survey area: (1) Aiken State Park, with seven wells, and (2) Barnwell State Park, with two wells. The Edisto Experimental Station at Blackville pumps an average of 70 cubic meters per day from the Congaree Formation. Several shallow wells produce TC small quantities (pump capacity of less than 40 liters per minute) of water for guardhouses at the Savannah River Plant.

There are a large number of shallow drilled and dug wells in the survey area outside of Savannah River Plant. Pumpage from these wells is not included in this survey.

F.3.2 SRP ground-water usage

Table F-10 shows the pumping rates from 1968 to 1983 for individual areas at SRP. The location of most of these areas is shown in Figure F-25. The centers for greatest ground-water pumpage at Savannah River Plant are in A-, F-, and H-Area. The total pumpage at Savannah River Plant is shown in graphical form in Figure F-27. In 1983 annual ground-water usage was 27.0 cubic meters per minute. Siple (1967) concluded that (1) the Tuscaloosa aquifer can supply about 37.8 cubic meters per minute for the operation of Savannah River Plant TC with no adverse effects on pumping capabilities in existing 1960 wells; and (2) potentially, the aquifer could produce more water if well fields were properly designed. In 1960 the SRP pumpage from the Tuscaloosa was about 18.9 cubic meters per minute.

F.4 HYDROLOGIC INTERRELATIONSHIPS AT SRP

F.4.1 Natural interrelationships

Although a number of hydrologic interrelationships between the various hydrogeologic units at Savannah River Plant have been discussed in Section F.2, which describes the hydrostratigraphic units, the purpose of this section is to summarize and amplify these relationships.

Precipitation at Savannah River Plant averages about 121 centimeters per year with a maximum of 187 centimeters in 1964 and a minimum of 73 centimeters in 1954 (for the period 1952 through 1982). Table F-11 shows the monthly precipitation at Savannah River Plant near the administration area since 1952. Although there may be both spatial and temporal variations in the fraction of this precipitation that recharges the ground water, the overall average annual recharge is about 30 percent of the total or 38 centimeters. This value varies with slight variations in the hydraulic conductivity of the shallow layers of sediment, the proportion of the rainfall that falls in the nongrowing season, the antecedent wet or dry conditions, and drainage patterns.

Table F-10. Ground-water pumping rates by area at Savannah River Plant, 1968 to 1983 (average continuous pumping rate in cubic meters per minute)

Area	Wells	1968-1973 (average)	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1985[a]
A/M	4	5.1	4.3	4.3	4.2	4.4	4.0	4.1	4.4	5.1	5.03	6.81	6.81
F	6	6.3	5.3	3.9	4.5	4.6	4.5	5.0	5.2	5.3	5.87	6.44	4.54
H	5	5.9	6.1	5.8	6.5	6.3	6.7	6.8	6.9	7.4	7.19	7.19	7.19
CS	3	0.25	0.34	0.36	0.44	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.74
D	(b)	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U	3	0.48	0.38	0.38	0.28	0.28	0.28	0.28	0.28	0.28	0.34[c]	0.34[c]	0.34[c]
C	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	1.13	1.13	1.13
K	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	1.13	1.13	1.27
L	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.28[d]	0.94	0.94
P	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	1.13	1.32	1.32
CMX-TNX	3	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.61	1.13	1.13	1.13
Total		18.8	16.6	14.9	16.1	16.3	16.2	16.9	17.5	20.4	23.8	27.0	25.4

[a] Projected use with L-Reactor operating. In September 1984, the pumping rate in F-Area is expected to decrease to 3.41 cubic meters per minute because ground water will no longer be used by the F-Area powerhouse (to be placed in standby status). The L-Reactor increment is 1.13 cubic meters per minute.

[b] Wells are no longer in use.

[c] Includes temporary construction area.

[d] Currently about 0.28 cubic meter per minute; 0.94 projected in NPDES Permit SC0000175 (Du Pont, 1981) application.

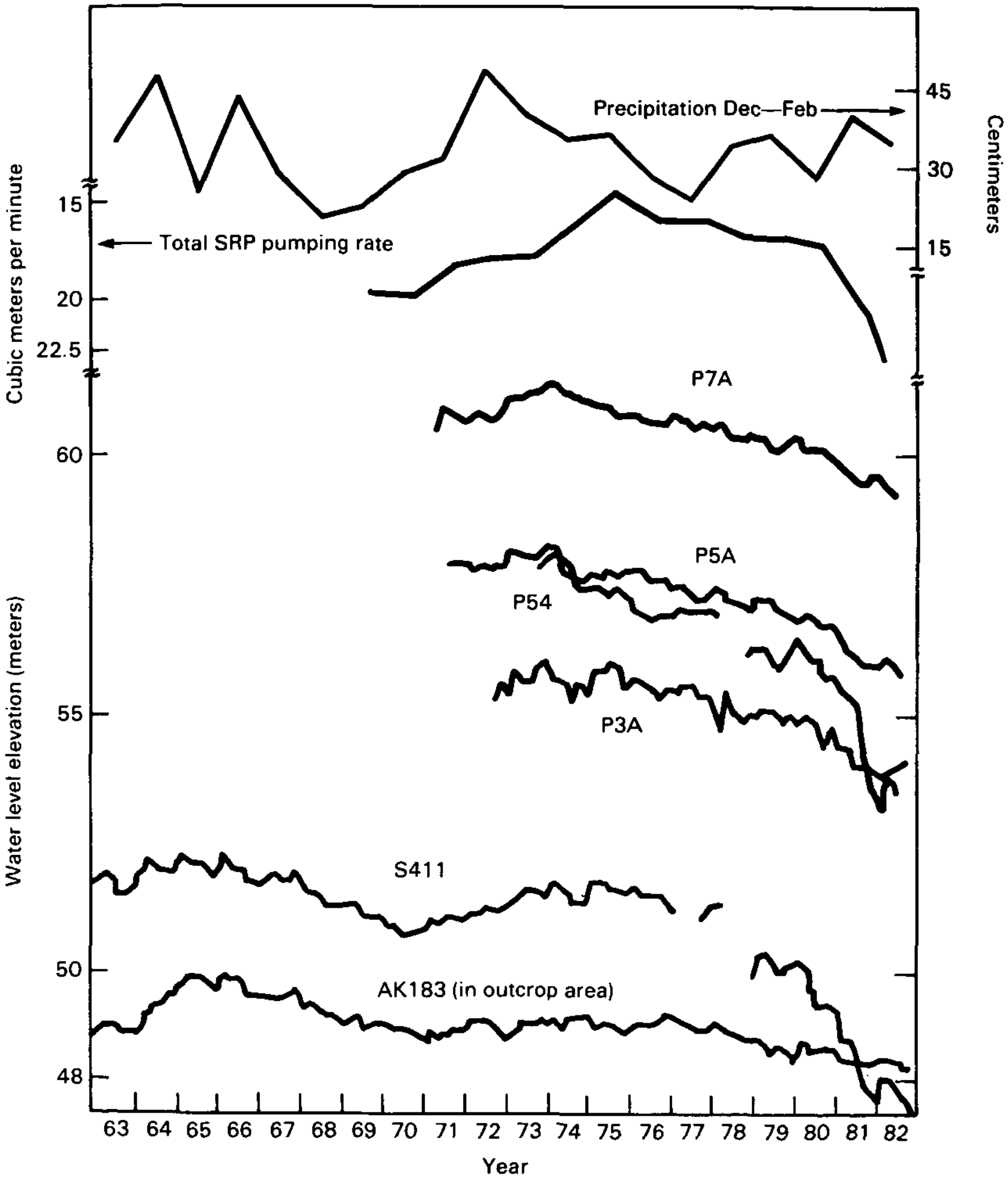
Table F-11. Savannah River Plant precipitation by month and year, 1952 through 1982 (in centimeters)[a]

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Departure from average
1952	5.3	8.2	16.6	7.9	14.1	14.4	7.2	15.2	8.5	3.5	7.3	10.1	118.2	-3.1
1953	6.8	13.9	9.7	7.5	11.2	13.7	9.2	9.2	21.7	0.3	2.6	19.1	124.9	3.6
1954	3.2	4.2	7.5	6.4	7.3	7.4	5.2	10.4	3.6	3.3	7.5	7.3	73.2	-48.2
1955	12.1	6.7	5.6	14.1	11.5	8.4	10.0	12.9	8.7	3.4	7.4	1.2	101.9	-19.4
1956	4.2	20.2	12.3	8.2	7.8	5.9	11.0	8.1	11.6	4.6	2.4	5.2	101.5	-19.9
1957	5.2	4.0	10.9	7.0	20.4	10.6	8.9	6.1	12.8	15.5	16.4	5.7	123.5	2.2
1958	10.2	11.1	12.6	14.3	5.3	6.4	13.5	7.0	2.8	2.4	0.5	11.2	97.4	-24.0
1959	9.0	15.4	16.4	5.2	9.7	10.3	14.7	7.4	22.1	27.6	5.0	9.0	151.8	30.4
1960	17.6	14.8	14.6	12.9	5.0	9.3	13.4	7.1	12.3	2.5	2.1	7.4	118.9	-2.4
1961	9.1	14.6	18.4	20.8	9.9	7.6	7.8	18.2	2.5	0.2	4.6	16.8	130.6	9.2
1962	11.8	13.1	16.6	10.2	8.9	11.2	6.5	8.7	14.1	5.8	8.9	5.6	121.3	-0.1
1963	15.1	9.2	8.5	9.4	7.6	21.4	8.1	2.6	13.6	0.0	9.3	11.4	116.3	-5.1
1964	19.8	15.2	14.7	15.1	9.2	11.4	26.5	31.3	14.4	15.6	2.2	11.1	186.6	65.3
1965	5.1	16.2	22.0	6.2	3.4	12.8	20.4	4.9	7.2	6.6	5.5	3.6	113.9	-7.5
1966	18.2	15.1	11.3	6.4	14.0	11.8	10.4	13.3	9.2	3.2	2.7	8.6	124.3	3.0
1967	9.3	9.7	14.4	7.2	12.7	9.5	19.1	18.6	4.3	1.6	6.4	8.0	120.7	-0.6
1968	10.1	2.4	3.8	5.4	8.8	15.7	9.9	10.8	5.7	7.6	8.6	6.9	95.8	-25.6
1969	5.1	6.2	8.6	10.4	7.7	10.0	6.9	13.8	11.6	2.9	1.0	10.6	94.8	-26.5
1970	7.1	6.8	18.7	3.5	10.6	8.8	12.3	9.6	4.3	12.7	4.3	12.5	111.3	-10.1
1971	13.0	10.6	22.0	7.4	7.6	15.0	26.7	22.3	9.7	15.1	5.9	7.3	162.6	41.2
1972	22.6	11.2	7.2	1.4	12.0	16.7	6.7	15.4	3.7	3.0	9.0	13.3	122.3	1.0
1973	13.6	13.4	16.2	11.6	8.9	27.7	15.3	9.7	9.4	3.1	0.8	11.8	141.5	20.1
1974	6.6	17.9	7.3	7.4	10.5	7.1	10.4	15.9	8.2	0.2	5.6	9.7	106.7	-14.6
1975	12.6	16.9	15.0	11.2	13.1	9.8	21.7	9.7	13.2	4.4	8.7	5.2	141.4	20.1
1976	10.6	2.7	9.7	6.4	27.7	11.0	5.0	4.2	13.9	12.5	10.6	12.9	127.3	5.9
1977	9.4	4.1	17.4	3.2	4.5	6.3	8.7	18.5	14.0	10.8	4.1	9.8	111.0	-10.3
1978	25.5	3.4	7.8	9.0	9.2	8.7	10.5	13.0	10.3	0.2	9.0	4.8	111.2	-10.2
1979	9.1	19.7	7.8	16.5	22.7	3.9	19.9	5.4	15.6	3.4	10.0	5.5	139.6	18.2
1980	13.0	8.8	27.8	4.3	8.9	7.6	2.3	5.2	14.9	5.4	6.4	4.9	109.4	-12.0
1981	2.3	12.8	12.0	5.3	17.5	10.9	10.1	14.7	1.4	7.1	2.5	24.3	120.8	-0.6
1982	10.0	11.3	6.4	14.4	6.9	10.8	29.2	12.7	11.7	9.8	6.1	12.3	141.6	20.3

Table F-11. Savannah River Plant precipitation by month and year, 1952 through 1982 (in centimeters)[a] (continued)

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Departure from average
Average	10.7	11.0	12.9	8.9	10.8	11.0	12.5	11.7	10.2	6.3	5.9	9.5	121.4	
Maximum	25.5	20.2	22.8	20.8	27.7	27.7	29.2	31.3	22.1	27.6	16.4	24.3	186.6	
Year	1978	1956	1980	1961	1976	1973	1982	1964	1959	1959	1957	1981	1964	
Minimum	2.3	2.4	3.8	1.4	3.4	3.9	2.3	2.6	1.4	0.0	0.5	1.2	73.2	
Year	1981	1968	1968	1972	1965	1979	1980	1963	1981	1963	1958	1955	1954	

[a] Adapted from Du Pont (1983).



Notes: Well S411 is screened in the Ellenton Formation; the remaining wells are screened in the Tuscaloosa Formation.
Figure F-9 shows well locations.

Source: Du Pont (1983).

Figure F-27. Hydrographs of Tuscaloosa and Ellenton wells.

Infiltrating water moves vertically through the unsaturated zone at a rate of about 2 meters per year in the central part of Savannah River Plant to recharge the water table which is commonly in the Barnwell Formation. This rate varies spatially and temporally. Upon reaching the water table, the recharging water travels on a path that has both vertical and horizontal components. The magnitude of these two components depends on the vertical and horizontal components of the hydraulic conductivity. Clay layers of low hydraulic conductivity tend to impede vertical flow and enhance horizontal flow. If the horizontal hydraulic conductivity is low, recharging water will tend to "pile up" above the clay, and the water table will be high, or perched. On the other hand, if the hydraulic conductivity is high, the recharging water will be conducted more quickly away from the recharge area, and the water table will be low.

Figure F-5 shows the head relationship of the various hydrostratigraphic units in the central part of Savannah River Plant (which includes F-, H-, and L-Area), and Figure F-15 shows how these relationships change as Upper Three Runs Creek is approached. The water table is high in this area because the tan clay inhibits the downward movement of water and the low horizontal hydraulic conductivity of the Barnwell Formation does not permit rapid removal of the water in a horizontal direction. The head builds in the Barnwell Formation sufficiently to drive the water through the material of low hydraulic conductivity--some going vertically through the tan clay and some moving laterally to the nearby tributary streams. Although there are temporal variations in the elevation of the water table, there is an overall equilibrium of the water table that depends on hydraulic conductivity, the geometry of the system, and its discharge points.

Water that enters the McBean Formation also moves on a path that has both vertical and horizontal components. The water recharging this formation through the tan clay is the difference between 38 centimeters per year and the amount of water that is removed from the Barnwell by lateral flow. Also, compared to the Barnwell Formation, the discharge points for the deeper McBean Formation are more distant from their respective ground-water divides.

The green clay has a lower hydraulic conductivity than the tan clay. As a result, recharge to the Congaree through this clay is less than the recharge to the McBean. Most of the recharge is from offsite areas. In addition, the Congaree has a higher hydraulic conductivity than the material above and as a result lateral flow is enhanced making the water levels in the Congaree much lower than those above (Figures F-5 and F-15). The discharge areas for the Congaree are the valleys of the Savannah River and Upper Three Runs Creek. Even though these discharge areas are more distant from the central part of Savannah River Plant than the discharge areas for the Barnwell and McBean Formations, the hydraulic conductivity is sufficiently high so that the natural discharge from the Congaree makes its water level much lower in this area than the formations above.

Tuscaloosa Formation water elevations in the central part of Savannah River Plant are above those in the Congaree (Figure F-5) showing that in this area, the Tuscaloosa is not naturally recharged from the Congaree. However, this upward head differential has been decreasing at about 0.16 meter per year over the AW-1

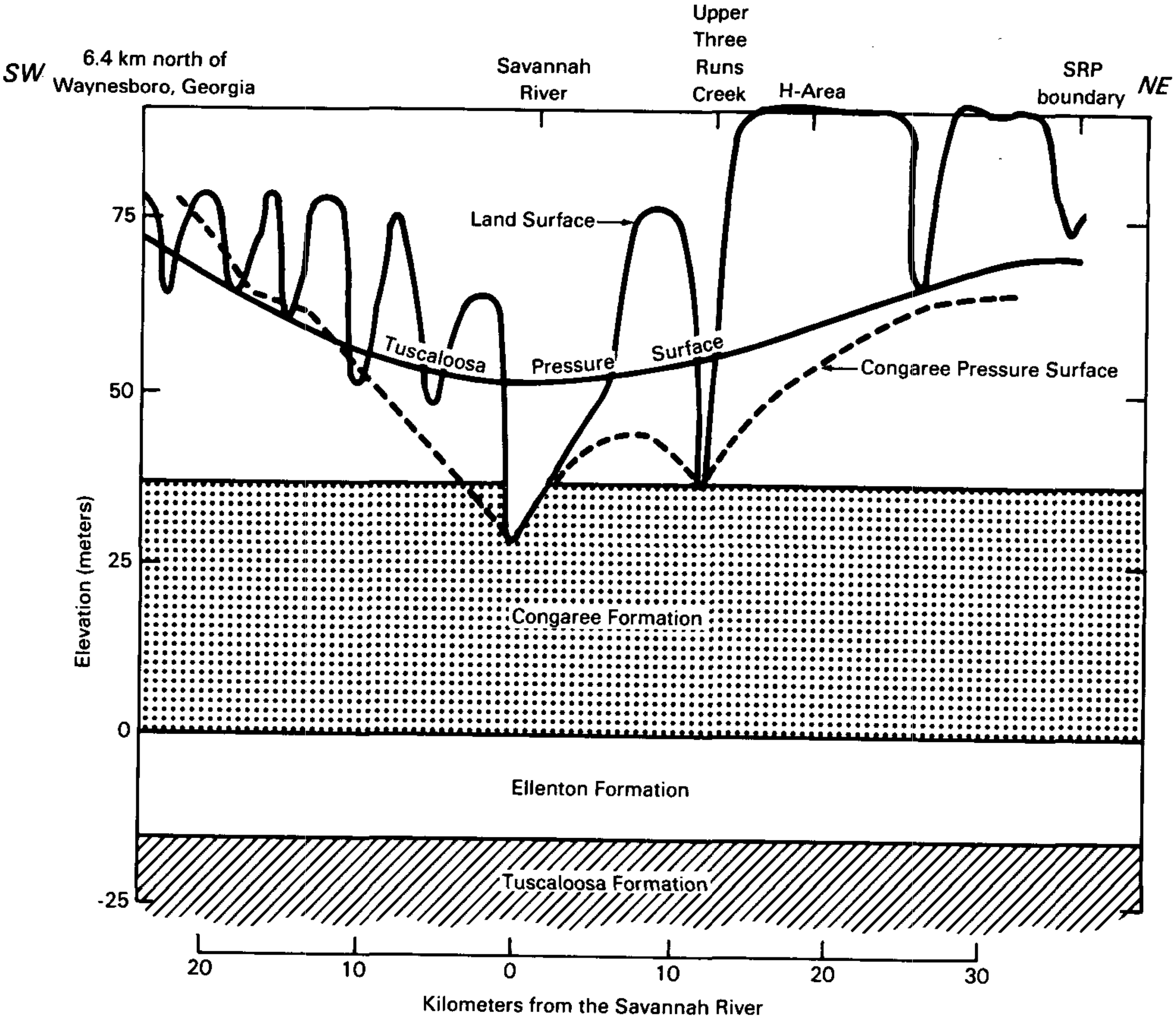
AW-1 past 10 years, primarily because of increased SRP pumping (Section F.4.2). Water in the Tuscaloosa passing beneath this area is recharged through the Tertiary sediments to the north of Savannah River Plant (Figure F-7). Water is discharged from the Tuscaloosa upward into the overlying sediments in the Savannah River Valley. This relationship is shown on Figure F-28 which is a hydrologic section through H-Area approximately perpendicular to the Savannah River. This diagram shows that in the Savannah River Valley and Upper Three Runs Valley, the head in the Tuscaloosa is consistently above that of the Congaree. Water levels in the Tuscaloosa in the Savannah River Valley are commonly above land surface and wells in these areas flow naturally. This figure also shows that water from either the Tuscaloosa or the Congaree does not naturally flow from South Carolina to Georgia or vice versa. Piezometric maps prepared in 1982 confirm these facts (Georgia Power Company, 1982).

Figure F-10 shows the vertical head relationships between the Congaree, shallow Tuscaloosa, and deep Tuscaloosa in the southern part of Savannah River Plant. The head relationship between the Congaree water level and higher Tuscaloosa water elevation is the same here as in H-Area but the head difference is greater. This area is greatly influenced by the drawing down of the head in the Congaree due to the nearness of the Savannah River Valley.

The head relationships in the northwest part of Savannah River Plant (M-Area) are quite different as shown on Figure F-11. In this updip area, the green clay is discontinuous and is thinner than it is farther downdip. The tan clay has disappeared entirely. Thus, there is little impedance to downward vertical flow within the Tertiary sediments and the water levels are deeper below land surface. The sands of the Congaree Formation are not as well sorted and the hydraulic conductivity in the Congaree near M-Area is lower than that in the central part of Savannah River Plant. As a result, the lateral flow of water in the Congaree is insufficient to draw its water elevation down below that of the Tuscaloosa, thereby creating a downward head differential from the Congaree to the Tuscaloosa. Closer to the Savannah River, the discharge from the Congaree draws its water level down below that of the Tuscaloosa (Figure F-29).

The Congaree and Tuscaloosa Formations are separated in M-Area even though this area is near the updip termination of the Ellenton Formation. In places, the Ellenton consists of 18 meters of sandy clay of low hydraulic conductivity, but it appears not to be this thick continuously. Thus there may be discontinuous recharge from the Congaree to the Tuscaloosa through the Ellenton in this area.

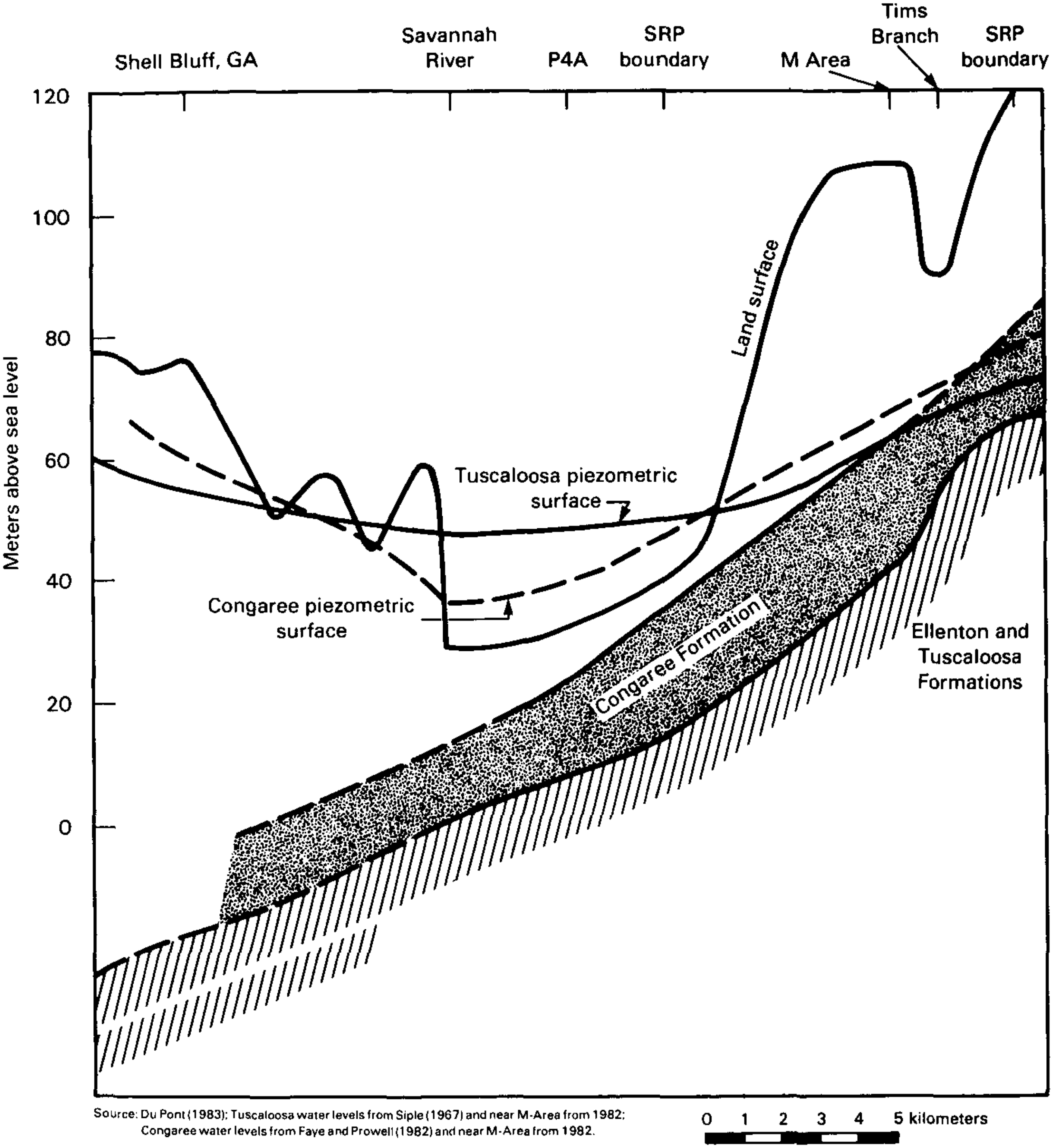
An indication of the location of areas where there is a head reversal between the Congaree and the Tuscaloosa (higher head in the Tuscaloosa), and areas where there is not, may be obtained by constructing a map showing the difference between the Tuscaloosa piezometric map (Figure F-9) and the Congaree piezometric map (Figure F-18). This head difference map (Figure F-30) shows that the head in the Tuscaloosa is higher than the head in the Congaree in a broad area within about 10 kilometers of the Savannah River and Upper Three Runs Creek. The head in the Congaree is higher in an area around M-Area, as discussed previously, and in the vicinity of Par Pond. It must be emphasized that this map is constructed by subtracting two piezometric maps for which data are somewhat sparse. Thus it should not be used to predict detailed head relationships but only to indicate general areas of expected relationships.



Source: Du Pont (1983); Tuscaloosa water levels from Siple (1967); Congaree water levels from Faye and Prowell (1982).

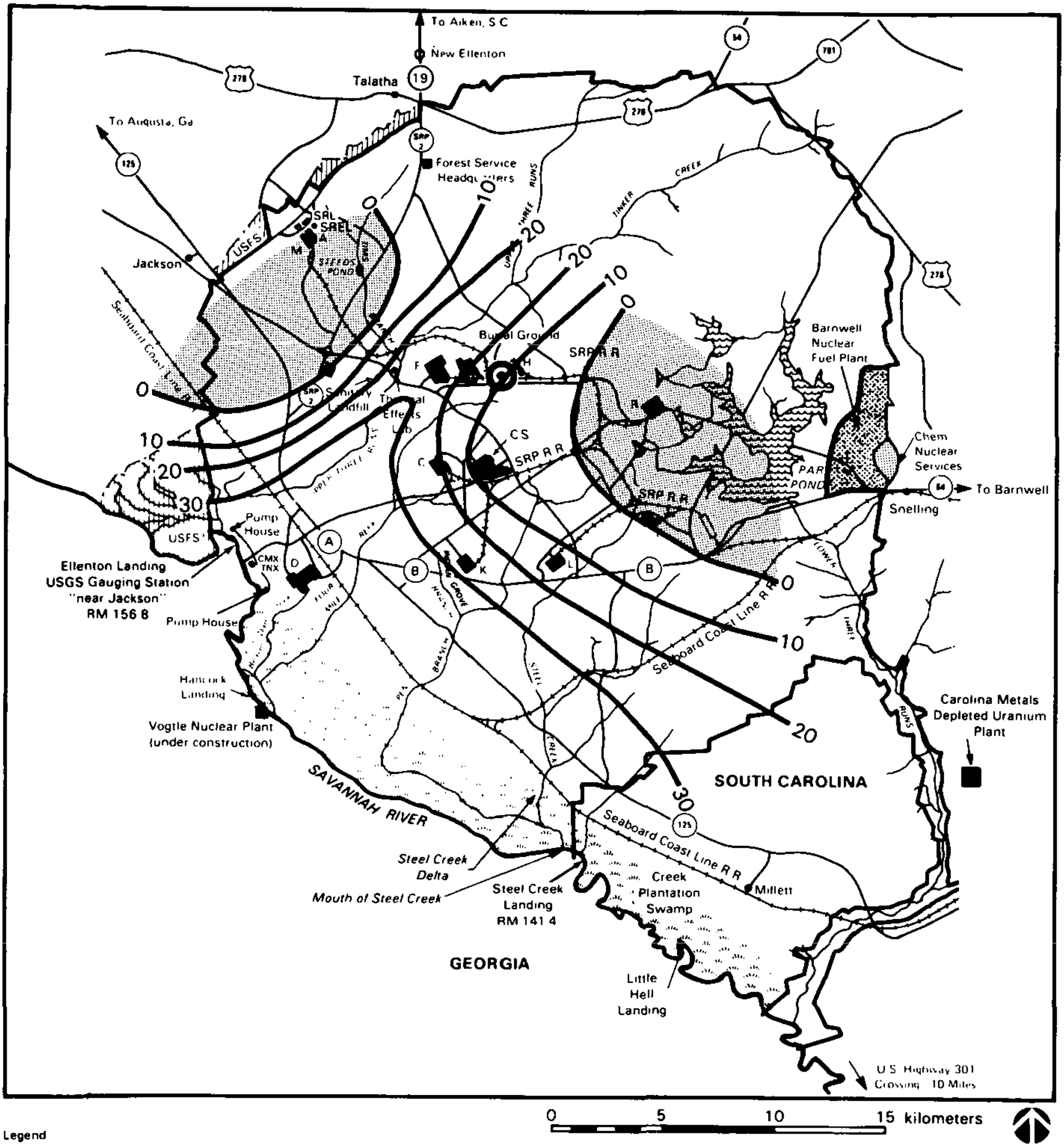
Figure F-28. Hydrogeologic section perpendicular to the Savannah River through H-Area.

EL-18



Source: Du Pont (1983); Tuscaloosa water levels from Siple (1967) and near M-Area from 1982; Congaree water levels from Faye and Prowell (1982) and near M-Area from 1982.

Figure F-29. Hydrologic section perpendicular to the Savannah River through M-Area.



AW-1

Legend

C, K, R, L, P	Reactor Areas (C, P, K are operating)
F, H	Separations Areas
M	Fuel and Target Fabrication
D	Heavy Water Production
A	Savannah River Laboratory and Administration Area
U	Temporary construction area
RM	River Mile

Road A = Highway 125

▨ Area where the Congaree head exceeds the Tuscaloosa head.

Contour showing locations where the head in the Tuscaloosa is 10 feet (1.0 foot = 0.3048 meter) above the head in the Congaree. Developed from Figures F-9 and F-10.

Developed from Figures F-9 and F-10.

Figure F-30. Head difference between upper Tuscaloosa and Congaree Formations at SRP (May 11, 1982).

F.4.2 Relationship of ground-water use to water levels

TC

In 1974 Marine and Routt (1975) made a numerical model study of the Tuscaloosa Formation in the vicinity of Savannah River Plant to assess the impact of additional planned water withdrawals from the Tuscaloosa Formation on water elevations at the Plant. The model focused on the water flux through the Tuscaloosa beneath the Plant and excluded water in the outcrop area that is recharged and discharged to the Tuscaloosa in very short distances (Figure F-31). Marine and Routt calculated a flux of 110 cubic meters per minute as being representative of conditions in the Tuscaloosa Aquifer beneath the Savannah River Plant and vicinity. However, for this EIS, a flux of 51 cubic meters per minute is conservatively chosen (the lower bound estimate of Marine and Routt). This conservative flux better reflects the fact that Tuscaloosa heads have declined since the study was performed in 1974.

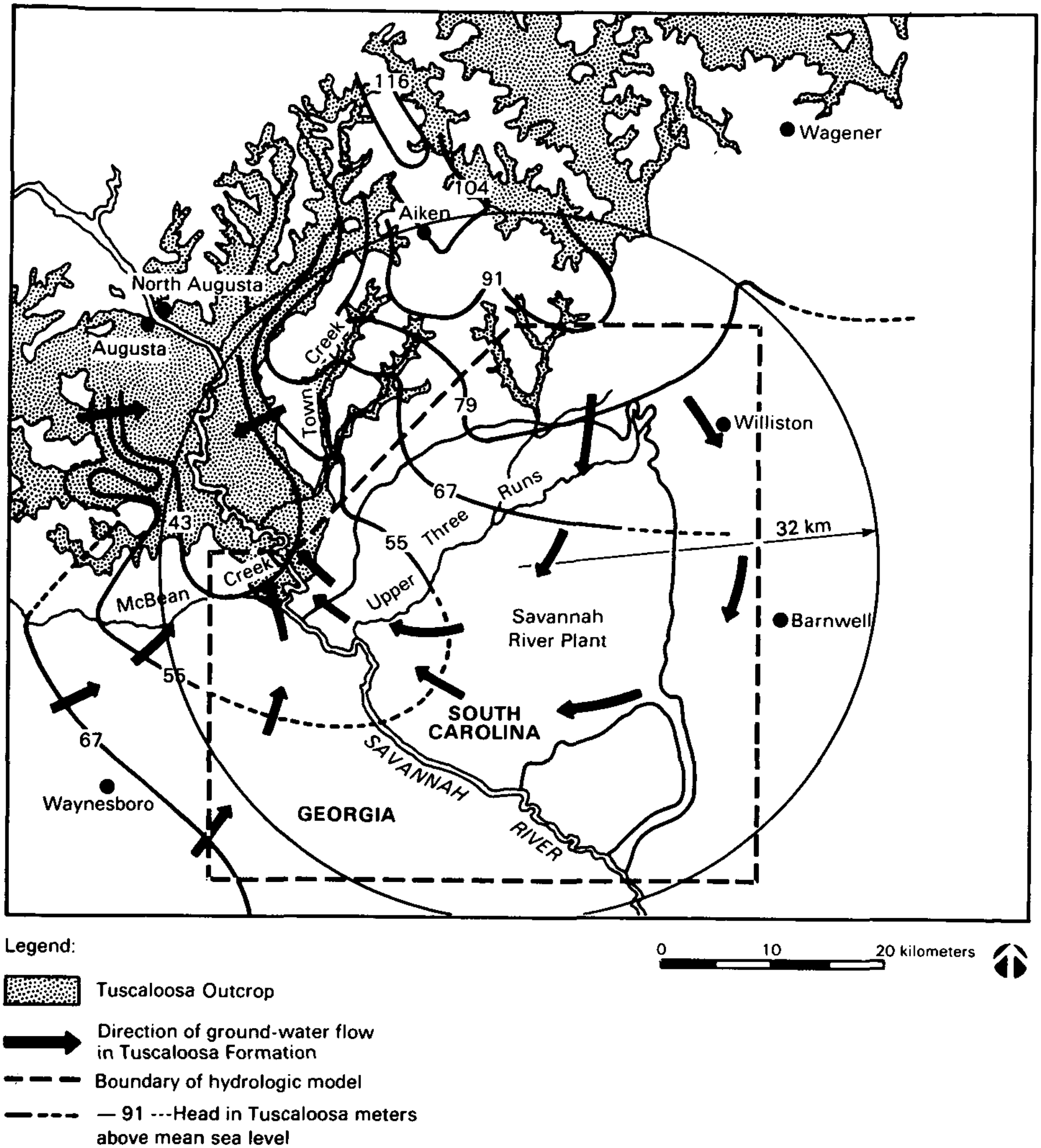
TC

For this EIS, drawdowns of water levels in the Tuscaloosa Aquifer were calculated using the procedure for a leaky artesian aquifer (Siple, 1967). The recommended drawdown-versus-distance curve was used in this analysis. Chapters 4 and 5 describe the onsite and offsite effects in the study area shown in Figure F-32.

TC

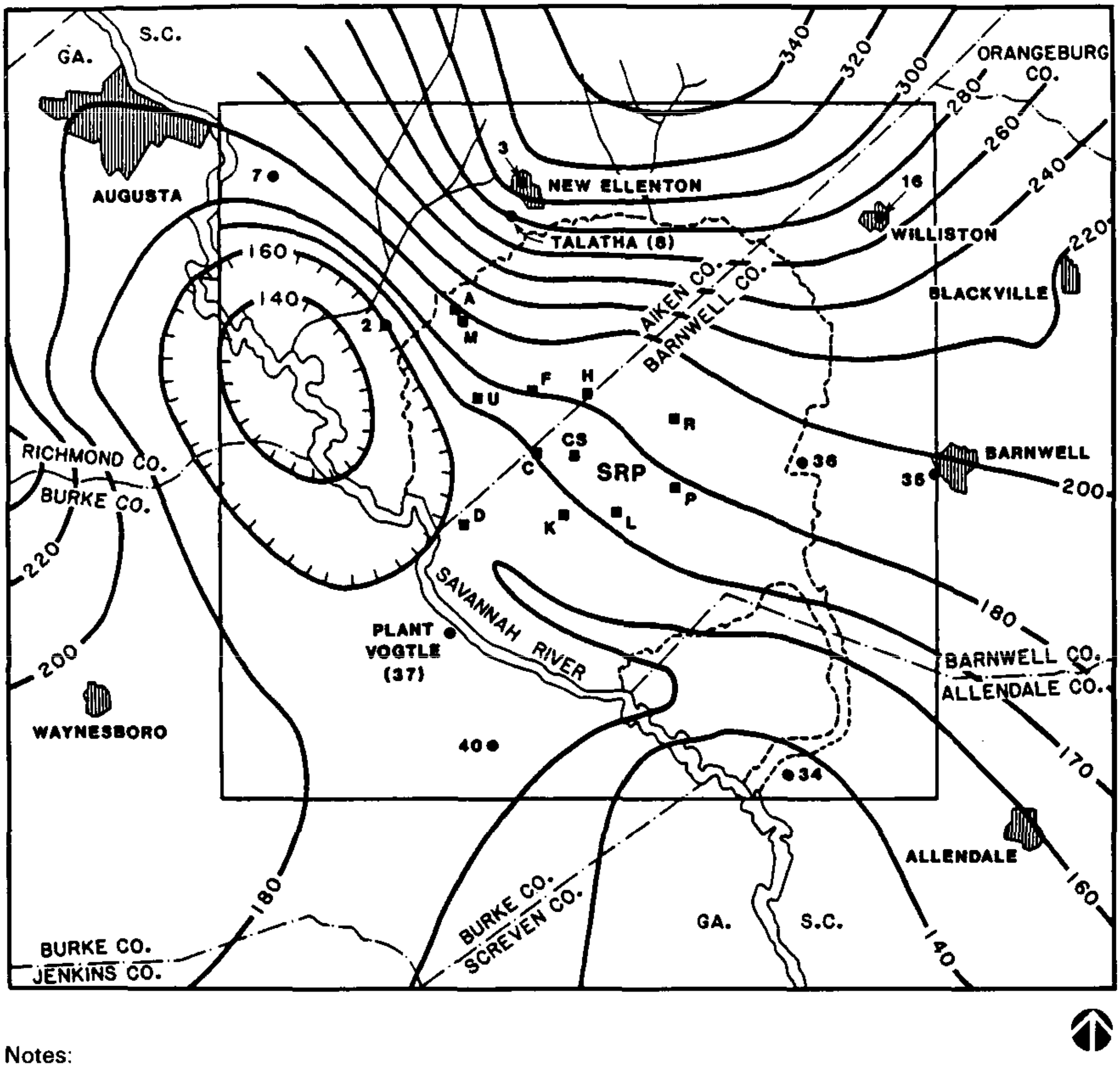
Figure F-27 shows the hydrographs of five Tuscaloosa wells. The location of these wells except for AK-183 is shown in Figure F-9. Well AK-183 is located 29 kilometers northwest of the center of Savannah River Plant in the Tuscaloosa outcrop area and should be uninfluenced by pumpage in the vicinity of Savannah River Plant. The winter (December to February) precipitation is plotted at the top of Figure F-27 because ordinarily, it is the precipitation in this period, which is not intercepted by growing plants, that recharges the ground water. However, abundant precipitation of about twice the annual mean caused recharge during the summer of 1964. Thus, as a result, record high-water levels occurred in 1965 and 1966. A low in winter precipitation occurred in 1968, and this resulted in low-water levels in 1970. Generally high Tuscaloosa water levels occurred in 1974, but from that point on, to the present, Tuscaloosa water levels have declined. From 1972 to 1981 there has been a general decline in the winter precipitation that may partially account for the declining water levels. However, since 1975, SRP pumping has increased by about 80 percent, from 14.9 to 27.0 cubic meters per minute in 1983. Calculations show that the decline in water levels exhibited at monitoring wells P7A, P54, and P3A is related primarily to increased ground-water withdrawal at SRP. The drawdowns at these monitoring wells reflect adjustments in equilibrium levels rather than aquifer depletion. Near-equilibrium water levels are expected to occur quickly (within about 100 days) in response to changes in pumping rates (Mayer et al., 1973).

The current total pumpage from the Tuscaloosa Formation within 32 kilometers of the Savannah River Plant is estimated to be 63 cubic meters per minute in 1983, including pumpage from wells outside the area used by Marine and Routt (1975) to estimate the flux in the Tuscaloosa Formation (see Figures F-25 and F-31). This total should not be sufficient to exceed the ground-water flux through the area as determined by the computer model. However, the incremental pumpage might be sufficient to affect local water levels as new equilibrium piezometric surfaces are attained. Siple (1967) suggested that pumpage from the Tuscaloosa at Savannah River Plant could exceed 37.8 cubic meters per minute if wells were drilled and spaced to minimize interference between wells. Current (1983) usage at SRP is about 27.0 cubic meters per minute.



Sources: Siple (1967); Marine and Routt (1975).

Figure F-31. Boundary of numerical model of ground-water flux in the Tuscaloosa Formation beneath Savannah River Plant.



TC

Notes:
Offsite ground-water users include (see Tables F-8 and F-9): Jackson (2), New Ellenton (3), Beech Island (7), Talatha (8), Sandoz Co. (34), Barwick Ind. (35), Barnwell NFP (36), Vogtle NPS (37), and Girard (40).
1982 onsite ground-water pumping listed in Table F-10.

Piezometric map adapted from Georgia Power Company (1982); water levels measured in feet during May-June 1982; 1.0 foot = 0.3048 meter.

Figure F-32. Study area for calculations of drawdown within Tuscaloosa Aquifer from withdrawal at end near SRP.

The decline of water levels in the Tuscaloosa Formation since the mid-1970s has reduced but not eliminated the head reversal at the Congaree Formation that occurs southeast of Upper Three Runs. The map of the head difference between the Tuscaloosa and Congaree Formations at Savannah River Plant (Figure F-30) shows that in 1982 the head reversal was still a general situation in the Savannah and Upper Three Runs Creek valleys.

To illustrate the present vertical head relationship in the central part of Savannah River Plant, Figure F-33 repeats Figure F-5, which shows water levels in 1972, but with the addition of water levels measured November 7, 1982. Heads in the Barnwell, McBean, and Congaree are from 1 to 1.5 meters below the level of 1972, but the Tuscaloosa water levels are 3 to 3.5 meters lower. Even though the head reversal at the Congaree is still present, it is reduced. Farther southeast, the current head reversal is about 7.9 meters as shown in Figure F-10 (compare Well VSC 2 to Well VSC 3).

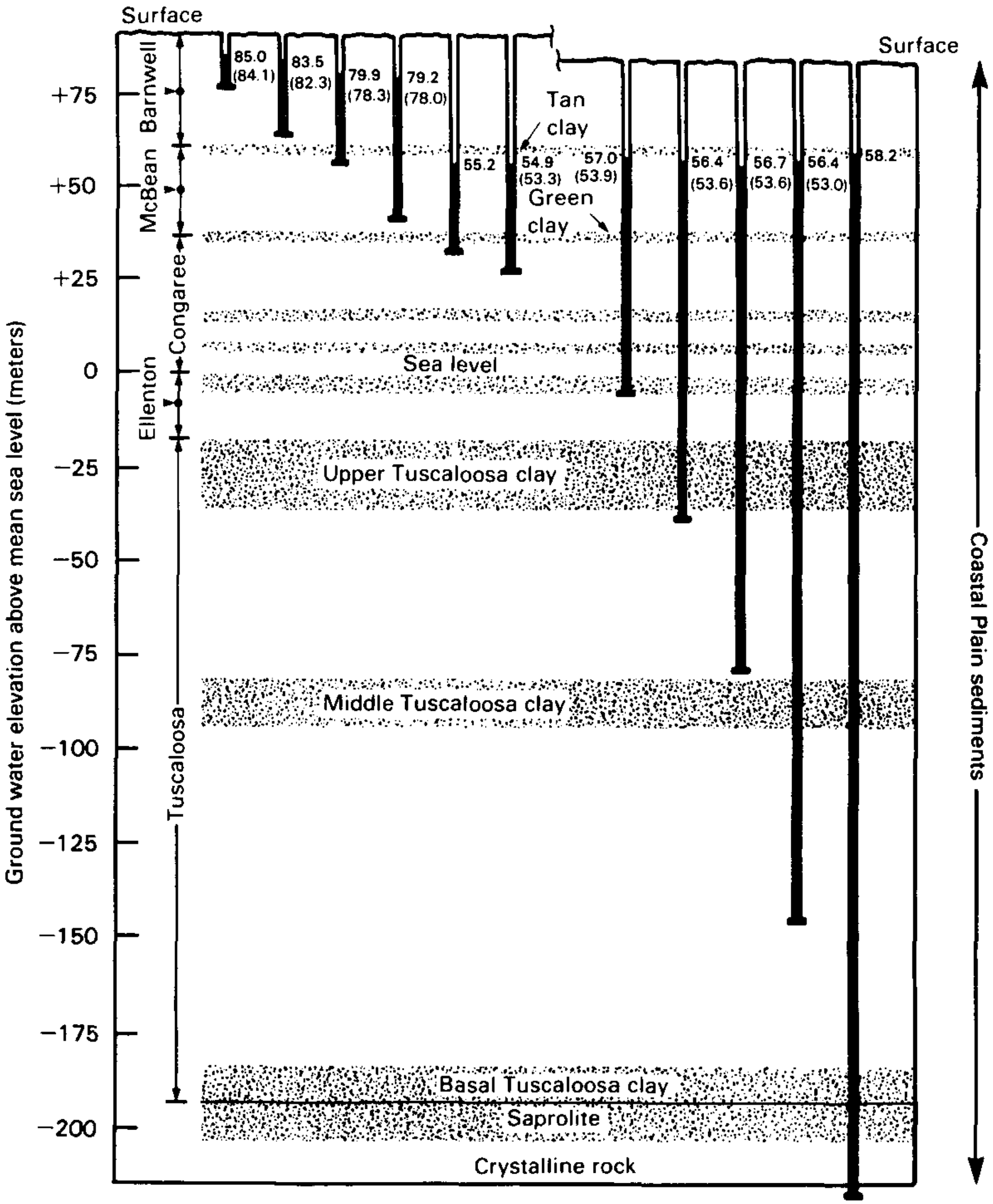
F.4.3 Water-level depression around water supply wells

To pump water from an aquifer, the water level in the vicinity of the well must be depressed. The amount of head depression to obtain a given pumping rate is dependent on the transmissivity of the aquifer. The transmissivity of the Tuscaloosa is very high as shown in Table F-3. Thus the cones of depression at the pumping centers for the Tuscaloosa are not very deep. Drawdowns at most 5000 cubic-meter-per-day wells in the Tuscaloosa are between 6 and 12 meters. Although specific measurement of the radii of the cones of depression have not been made at every pumping center, that these cones are not extensive is shown by the facts that when Well 20A, near M-Area (see Figure F-37), was pumped at 4900 cubic meters per day only 0.3 meter of drawdown was recorded 490 meters away and that a 5000 cubic-meters-per-day well in H-Area made a drawdown change of about 0.3 meter 700 meters away during short-term tests.

During a 60-day pumping test performed at the Barnwell Nuclear Fuel Plant (Mayer et al., 1973), water was withdrawn from the Tuscaloosa Aquifer at a rate of 10,900 cubic meters per day. A drawdown of about 0.15 meter was observed at SRP monitoring well P54 (see Figure F-9), about 9 kilometers from the pumping well. TC

Even though these cones of water level depression are not areally extensive, drawdowns of 6 to 12 meters are adequate to negate the head reversal between the Congaree and Tuscaloosa Formation where it exists. In areas where the head reversal does not exist, such as M-Area, the drawdowns increase the natural downward gradient in the area immediately surrounding the pumping wells. Because the cones of depression are not areally extensive, they probably have little hydrologic influence over waste facilities that are even moderate distances (kilometers) from the center of pumpage such as seepage basins and waste pits.

TC



Legend:

85 Water elevation (head) in meters. Values are those existing in 1972 with 1982 measurements given in parentheses.

Note: Figure F-6 shows well locations.

Sources: ERDA (1977), Du Pont (1983).

Figure F-33. Hydrostatic head in ground water near H-Area comparing water levels in 1972 to those in 1982.

F.4.4 Effects of L-Reactor operation

As shown on Table F-10 in 1982 the pumpage at L-Area averaged only about 0.28 cubic meter per minute. When L-Area is operating, the pumping rate will be about 0.94 cubic meter per minute, slightly less than at the other operating reactors because there is no powerhouse located in L-Area. On two tests of pumping 2.8 cubic meters per minute one well (104L) had a drawdown of 8.2 meters and the other well (105L) had a drawdown of 12.2 meters; thus the average specific capacity is 0.27 cubic meter per minute per meter of drawdown. Thus, for a pumping rate of 0.94 cubic meter per minute a short-term drawdown of 3.5 meters would be expected in the pumping well (including well entrance losses). Calculated drawdowns in L-Area and in other SRP areas supporting L-Reactor operation are discussed in Sections 4.1.1.3, 5.1.1.4, and 5.2.3.

F.5 GROUND-WATER QUALITY

F.5.1 Natural ground-water quality

A detailed discussion of the natural ground-water quality of the hydrostratigraphic units is contained in previous sections of this appendix (F.2.1 to F.2.10). Chemical analyses are given in Tables F-2, F-4, and F-5. In general, the water in the coastal plain sediments is of good quality, suitable for industrial and municipal use with minimal treatment. It is generally soft, slightly acidic, and low in dissolved and suspended solids.

F.5.2 L-Area

Previous activities in L-Area have resulted in the discharge of radioactive and nonradioactive wastes into 10 basins and pits in and adjacent to the area. Currently only one of these sites is active (a rubble pit receiving solid waste that is neither radioactive nor hazardous).

Some contamination of the shallow ground water between the L-Area seepage basin and Steel Creek (about 600 meters to the southeast) is expected from the tritium previously discharged to the basin (about 3300 curies). Similarly minor amounts of strontium-90 are expected to have reached the ground water beneath the basin, but confirmation is presently lacking. Monitoring data from around the basin are not yet available; however, monitoring wells have recently been installed.

F.5.3 F- and H-Area seepage basins

Intensive ground-water monitoring studies around the F- and H-Area seepage basins have detected only tritium, strontium-90, and uranium in concentrations greater than 10 times the natural background. Companion studies have shown nitrate and mercury are also present.

Approximately 30 percent of the tritium discharged to the separations areas seepage basins evaporates to the atmosphere. The remaining tritium moves rapidly to the water table (at a depth of about 3 meters in H-Area and 15 meters in F-Area), and then moves at the same velocity as the ground water. In F-Area, the average flow rate of tritium from the basins to Four Mile Creek is estimated TC to be 0.15 meter per day (a travel time of 8.9 years to move 600 meters). Approximately 40 percent of the tritium decays before emerging in Four Mile Creek. Concentrations at seepline springs range from 40 to 60 microcuries per liter.*

In H-Area, the flow rate of tritium from the seepage basins to Four Mile Creek is estimated to be 0.3 meter per day (a travel time of 1.1 to 3.8 years). Approximately 10 to 20 percent of the tritium decays before emerging in Four Mile Creek. Concentrations at the seepline springs range up to 40 microcuries per liter.

The maximum vertical penetration of tritium into the ground is about 15 to 20 meters, and throughout most of the distance from the basins to the seepline springs, the highest concentrations are 3 to 6 meters below the water table.

Strontium, unlike tritium, does not move at the same rate as ground water; its transport is retarded by the clay minerals in the Formation. Thus, it has been emerging into Four Mile Creek from F-Area only since about 1964, and from TC H-Area since 1959. The amount entering the creek annually is 2 percent of the ground-water load in F-Area and 0.19 percent of the load in H-Area. Under current conditions, F-Area is contributing about 40 times as much strontium to the creek as H-Area because of differing soil retention characteristics. Maximum concentrations of strontium-90 in ground water and emergent seep-lines range up to 0.34 microcurie per liter in F-Area, and 1.8×10^{-3} microcurie per liter in H-Area.

Cesium is retained well by soils at Savannah River Plant, and none has migrated far enough to be detected in ground water between the separations areas seepage basins and Four Mile Creek. Alpha activity in ground water between the F- and H-Area basins and Four Mile Creek is attributed mostly to uranium discharged to the basin plus a small amount of natural radioactivity (plutonium is even more highly immobilized in SRP soils than cesium). Alpha concentrations in ground water and seepline springs range up to 6.5×10^{-3} microcurie per liter in F-Area and 7.5×10^{-6} microcurie per liter in H-Area.

Although most of the mercury released to the separations areas seepage basins is accounted for in the basin soil, studies made in 1971 on soils from the swampy outcrop along Four Mile Creek, bottom sediments, and of suspended solids from the creek show that mercury is slowly migrating into the creek (approximately 0.4 gram per day from both areas).

Nitrate and hydrogen ions are also migrating from the basins. Nitrate concentrations in the ground water measured in 1968 and 1969 ranged to 300 milligrams per liter in F- and H-Area. The pH of ground water in the vicinity of the

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*The EPA drinking water standard for tritium is 0.02 microcurie per liter.

basins is 4 to 6 compared to a pH range of 5 to 7 for natural ground water at Savannah River Plant.

Results of 1982 chemical analyses of ground-water samples from monitoring wells at F- and H-Area seepage basins are presented in Tables F-12 and F-13. The locations of these wells are shown in Figure F-34. TC

F.5.4 M-Area

The M-Area settling basin was constructed in 1958 to settle out and contain uranium discharged in process streams from fuel fabrication facilities. The water discharged to the basin can best be characterized as a metal finishing-type process waste. The process discharges contain, among other things, uranium, aluminum, nitrate, nickel, and chlorinated organics; they can be classified as hazardous only because of the low pH. Waste effluents from M-Area operations have been drained to two process sewers. In May 1982 discharges to Tims Branch were discontinued and diverted instead to the M-Area basin, which now receives all process sewer flows except noncontact cooling water. Some of the process water released to this basin seeps into the ground, but most overflows the basin and seeps into the ground at Lost Lake (shown in Figure F-35). EN-51

Extensive ground-water monitoring studies around M-Area have been conducted since volatile organics were discovered in the ground water beneath the M-Area basin in June 1981. The distribution of contaminants has been vertically and horizontally determined. A plume of chlorinated hydrocarbons extends about 1 kilometer southwest of the M-Area in 1983. The main body of this plume is moving slowly to the southwest (Figure F-35) at about 7.6 meters per year. Those studies establish that no volatile organics have migrated to the Plant boundary.

Contaminants in the soil beneath the M-Area basin have been characterized by the analyses of cores from coreholes drilled to a depth of about 5 meters below the bottom of the basin. Soil concentrations of lead and mercury ranged up to 125 and 0.16 milligram per kilogram (dry weight), respectively. In all cores, metal concentrations decreased with increasing depth beneath the basin and reached background values in the soil cores at or before 4 feet below the bottom of the basin.

Downward migration rates for metals were calculated using the corresponding depths at which the metal concentrations were equal to background values and a 24-year operation period since startup of the basin in 1958. The calculated migration rates were 0.04 meter per year for lead and 0.05 meter per year for uranium. At these migration rates and under the present operating conditions of the basin, these metals do not pose a significant problem for future contamination of the surrounding ground water. At the present rate of downward movement, it will take the uranium 700 years to travel the 37-meters distance to the ground water.

Soil concentrations of 1,1,1-trichloroethane, trichloroethylene ("triclene") and tetrachloroethylene ("perclene") ranged to 11, 90, and 2000 milligrams per kilogram (dry weight), respectively. However, migration rates could not be calculated because of wide variations in concentrations across the M-Area seepage basin.

Table F-12. Results of monitoring well analyses for F-Area seepage basin[a]

FSB-76 Upgradient N76137.97 E51386.73 Elev = 294.2

Parameter	Units	DWS	2QR 82	3QR 82	4QR 82	1QR 83
Water Table Elevation	Ft		218.2	218.2	218.4	218.7
Coliform B	#/100 ml		0	2	20	5
Color	CU	15	3	30	3	2
Corrosion			No	No	No	No
Odor		3	0	1.4	1	1
pH	pH	6.5-8.5	4.6	4.9	5.0	4.8
Specific Conductivity	µmho/cm		50	56	64	63
TDS	mg/L	500	62	119	42	56
Temp	°C		19.2	19.4	19.7	17.2
Turbidity	1/TU		3.9	1.29	5.1	.2
Ag	mg/L	.05	<.001	<.001	<.001	<.001
As	mg/L	.05	<.002	<.002	<.002	.004
Ba	mg/L	1.0	.112	.44	.07	.12
Be	mg/L		<.010	<.005	<.005	<.005
Cd	mg/L	.01	<.001	.001	<.001	.003
Cr	mg/L	.05	.002	.003	.011	.005
Cu	mg/L	1.0	.004	.005	.012	.011
Fe	mg/L	.3	1.170	12.97	12.01	14.59
Hg	mg/L	.002	<.0002	<.0002	.0004	<.0002
Mn	mg/L	.05	.029	.056	.13	.06
Na	mg/L		11.24	8.74	10.99	14.35
Ni	mg/L		.004	.008	.027	.043
Pb	mg/L	.05	.106	.007	.011	.014
Se	mg/L	.01	<.002	<.002	<.002	<.002
Zn	mg/L	5	.052	.065	<.010	.100
Cl	mg/L	250	3	3	5.1	3.4
CN	mg/L		<.005	<.005	<.005	<.005
F	mg/L	1.6	.11	<.10	<.10	<.01
Foaming agents	mg/L	.5	<.01	<.01	<.01	.01
H_2S	mg/L		<1.0	<1.0	<1.0	<1.0
NO_3	mg/L	10	.05	3.13	4.51	4.81
SO_4	mg/L	250	<5	35	<5	<5
Gross Alpha	pCi/L	15	.6±.6	1.1±.7	0.4±6.2	1.7
Gross Beta	pCi/L		2±8	8.7±8.1	10.5±8.6	9.3
Ra	pCi/L	5	<.42	.27	.45	.51
DOC	mg/L		7	1.5	4	5.5
GC	µg/L		<40	<40	<40	<40
Phenols	mg/L		<.002	<.002	<.006	<.002
TOC	mg/L		<1	2.5	4	9.5
TOH	mg/L		.360	.830	.009	.012
Endrin	µg/L	.2	<.009	<.04	<.04	<.04
Lindane	µg/L	4	<.005	<1	<1	<1
Methoxychlor	µg/L	100	<.06	<20	<20	<20
Toxaphene	µg/L	5	<1.04	<1	<1	<1
24D	µg/L	100	<.41	<20	<20	<20
245TP	µg/L	10	<.13	<2	<2	<2

Table F-12. Results of monitoring well analyses for F-Area seepage basin (continued)[a]

FSB-77 Downgradient N75128.39 E50716.25 Elev = 273.3

Parameter	Units	DWS	2QR 82	3QR 82	4QR 82	1QR 83
Water Table Elevation	Ft		215.0	214.9	215.3	215.3
Coliform B	#/100 ml		16	0	00	2
Color	CU	15	10	>5	>5	50
Corrosion			No	No	No	No
Odor		3	0	1.4	0	1
pH	pH	6.5-8.5	3.8	3.7	3.8	3.8
Specific Conductivity	µmho/cm		707	620	104	13200
TDS	mg/L	500	896	796	829	648
Temp	°C		28	28	28	28
Turbidity	1/TU		1.0	.53	.4	.1
Ag	mg/L	.05	<.001	<.001	<.001	<.001
As	mg/L	.05	<.002	<.002	.004	<.002
Ba	mg/L	1.0	.106	.05	<.05	.08
Be	mg/L		<.010	<.005	<.005	<.005
Cd	mg/L	.01	.060	.049	<.023	.057
Cr	mg/L	.05	.001	.001	.012	.009
Cu	mg/L	1.0	.022	.013	.027	.026
Fe	mg/L	.3	3.239	15.72	21.27	23.6
Hg	mg/L	.002	<.0002	<.0002	.0003	<.0002
Mn	mg/L	.05	1.395	1.442	1.55	1.19
Na	mg/L		76.75	70.5	126.7	95.8
Ni	mg/L		.018	.020	.037	.034
Pb	mg/L	.05	.422	.008	.013	.019
Se	mg/L	.01	<.002	<.002	<.002	<.002
Zn	mg/L	5	.167	.093	<.065	.067
Cl	mg/L	250	4	3	5.6	3.1
CN	mg/L		<.005	<.005	<.005	<.005
F	mg/L	1.6	.19	<.10	.13	.01
Foaming agents	mg/L	.5	<.02	<.01	.02	<.01
H_2S	mg/L		<1.0	<1.0	<1.0	<1.0
NO_3	mg/L	10	81.5	60.2	159.05	91.6
SO_4	mg/L	250	<5	26	<5	<5
Gross Alpha	pCi/L	15	4.8±1.3	2.5±1	2.22±1.09	8.2
Gross Beta	pCi/L		2003±36	1660±32	2577±41	2829
Ra	pCi/L	5	10.10	14.16	18.95	20.10
DOC	mg/L		4	2.5	4	9.0
GC	µg/L		<40	<40	<40	<40
Phenols	mg/L		.004	.006	.009	<.002
TOC	mg/L		6	5.0	1	23.0
TOH	mg/L		.051	.042	.34	.018
Endrin	µg/L	.2	<.009	<.04	<.04	<.04
Lindane	µg/L	4	<.005	<1	<1	<1
Methoxychlor	µg/L	100	<.06	<20	<20	<20
Toxaphene	µg/L	5	<1.04	<1	<1	<1
24D	µg/L	100	<.41	<20	<20	<20
245TP	µg/L	10	<.13	<2	<2	<2

Table F-12. Results of monitoring well analyses for F-Area seepage basin (continued)[a]

FSB-78 Downgradient N74750.0 E50150.00 Elev = 272.5

Parameter	Units	DWS	2QR 82	3QR 82	4QR 82	1QR 83
Water Table Elevation	Ft		210.9	210.7	210.7	211.0
Coliform B	#/100 ml		0	0	0	0
Color	CU	15	10	>5	>5	20
Corrosion			No	No	No	No
Odor		3	0	1.4	6	4
pH	pH	6.5-8.5	3.1	2.9	2.8	2.7
Specific Conductivity	µmho/cm		1551	1700	1834	15500
TDS	mg/L	500	946	1183	964	1187
Temp	°C		22.2	22.0	23.0	19.6
Turbidity	1/TU		.66	.70	.8	.3
Ag	mg/L	0.05	<.001	<.001	<.001	<.001
As	mg/L	0.05	<.002	<.002	.034	.011
Ba	mg/L	1.0	.157	.34	<.05	.10
Be	mg/L		<.010	<.005	<.005	<.005
Cd	mg/L	0.01	.150	.100	<.047	.044
Cr	mg/L	0.05	.015	.023	.053	.030
Cu	mg/L	1.0	.098	.096	.071	.074
Fe	mg/L	0.3	2.379	5.362	44.02	79.64
Hg	mg/L	0.002	.0015	<.0002	.0340	.0536
Mn	mg/L	0.05	1.714	1.356	.845	.74
Na	mg/L		113.30	102.4	153.6	195.0
Ni	mg/L		.045	.085	.109	.065
Pb	mg/L	0.05	.080	.068	.017	.014
Se	mg/L	0.01	<.002	<.002	.008	<.002
Zn	mg/L	5	.259	.178	.196	.226
Cl	mg/L	250	2	2	5.6	2.3
CN	mg/L		<.005	.013	.006	<.005
F	mg/L	1.6	.73	<.10	.44	.51
Foaming agents	mg/L	0.5	.03	<.01	.04	.01
H_2S	mg/L		<1.0	1.0	<1.0	<1.0
NO_3	mg/L	10	198	159.46	262.4	235.2
SO_4	mg/L	250	10	7	20	10
Gross Alpha	pCi/L	15	41.3±3.7	35±3.4	19.06±3.14	37.7
Gross Beta	pCi/L		7969±69	6426±68	1116±27	799
Ra	pCi/L	5	14.70	23.23	23.94	15.60
DOC	mg/L		<1	1.5	<1	8.0
GC	µg/L		<40	<40	<40	<40
Phenols	mg/L		<.002	.017	.011	.022
TOC	mg/L		<1	1.0	1	18.0
TOH	mg/L		.024	.016	.007	.007
Endrin	µg/L	0.2	<.009	<.04	<.04	<.04
Lindane	µg/ℓ	4	<.005	<1	<1	<11.3
Methoxychlor	µg/L	100	<.06	<20	<20	<20
Toxaphene	µg/L	5	<1.04	<1	<1	<1
24D	µg/L	100	<.41	<20	<20	<20
245TP	µg/L	10	<.13	<2	<2	<2

Table F-12. Results of monitoring well analyses for F-Area seepage basin (continued)[a]

FSB-79 Downgradient N73660.00 E50145.00 Elev = 217.7

Parameter	Units	DWS	2QR 82	3QR 82	4QR 82	1QR 83
Water Table Elevation	Ft		203.0	202.8	202.9	203.2
Coliform B	#/100 ml		0	0	0	0
Color	CU	15	0	1.4	0	0
Corrosion			No	No	No	No
Odor		3	3.5	4.2	4.6	4.1
pH	pH	6.5-8.5	4.5	5.1	5.4	4.5
Specific Conductivity	μmho/cm		56	29	20	0.63
TDS	mg/L	500	37	110	10	-
Temp	°C		17.8	20.5	21.4	15.9
Turbidity	1/TU		0.49	0.43	1.0	0.6
Ag	mg/L	0.05	<0.001	<0.001	<0.001	<0.001
As	mg/L	0.05	<0.002	<0.002	<0.002	<0.002
Ba	mg/L	1.0	0.092	0.16	0.07	<0.05
Be	mg/L		<0.010	<0.005	<0.005	<0.005
Cd	mg/L	0.01	0.002	0.001	<0.001	0.003
Cr	mg/L	0.05	0.003	0.002	0.003	0.002
Cu	mg/L	1.0	0.006	0.009	<0.002	0.002
Fe	mg/L	0.3	0.499	3.15	2.40	2.57
Hg	mg/L	0.002	0.0003	<0.0002	0.0004	<0.0002
Mn	mg/L	0.05	0.035	0.020	<0.02	0.04
Na	mg/L		4.11	2.05	2.45	8.95
Ni	mg/L		0.002	0.006	0.008	0.008
Pb	mg/L	0.05	0.020	0.003	0.005	0.002
Se	mg/L	0.01	<0.002	<0.002	<0.002	<0.002
Zn	mg/L	5	0.016	0.025	<0.010	0.019
Cl	mg/L	250	3	3	3.4	2.6
CN	mg/L		<0.005	<0.005	<0.005	<0.005
F	mg/L	1.6	0.10	0.50	<0.10	<.01
Foaming agents	mg/L	0.5	0.02	0.02	<0.01	<0.01
H_2S	mg/L		<1.0	<1.0	<1.0	<1.0
NO_3	mg/L	10	4.31	0.39	0.69	3.71
SO_4	mg/L	250	<5	21	<5	<5
Gross Alpha	pCi/L	15	0.8±0.6	3.9±1.2	0.74±0.66	0.9
Gross Beta	pCi/L		25±9	51.2±95	7.5±8.4	57
Ra	pCi/L	5	2.63	0.47	0.50	0.26
DOC	mg/L		5	<1.0	1	9.0
GC	μg/L		<40	<40	139	<40
Phenols	mg/L		<0.002	<0.002	0.007	<0.002
TOC	mg/L		3	<1.0	2	9.0
TOH	mg/L		0.120	0.850	0.026	0.012
Endrin	μg/L	0.2	<0.009	<0.04	<0.04	<0.04
Lindane	μg/L	4	<0.005	<1	<1	<1
Methoxychlor	μg/L	100	<0.06	<20	<20	<21
Toxaphene	μg/L	5	<1.04	<1	<1	<1
24D	μg/L	100	<0.41	<20	<20	<20
245TP	μg/L	10	<0.13	<_	<2	<2

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[a] Adapted from Du Pont, 1983.

Table F-13. Results of monitoring well analyses for H-Area seepage basin[a]

HSB-65 Upgradient N72424.25 E58433.00 Elev = 271.9

Parameter	Units	DWS	2QR 82	3QR 82	4QR 82	1QR 83
Water Table Elevation	Ft		237.1	236.4	237.5	236.9
Coliform B	#/100 ml		0	0	0	0
Color	CU	15	3	3	5	2
Corrosion			No	No	No	No
Odor		3	1.4	1.4	0	2
pH	pH	6.5-8.5	3.9	5.4	4.8	4.3
Specific Conductivity	μmho/cm		48	48	54	45
TDS	mg/L	500	64	19	43	22
Temp	°C		18.0	17.6	19.9	16.3
Turbidity	1/TU		1.7	1.2	0.6	0.3
Ag	mg/L	0.05	<0.001	<0.001	<0.001	<0.001
As	mg/L	0.05	<0.002	<0.002	0.005	0.021
Ba	mg/L	1.0	0.218	0.05	<0.05	0.24
Be	mg/L		<0.010	0.31	<0.005	0.012
Cd	mg/L	0.01	0.002	<0.001	<0.001	0.009
Cr	mg/L	0.05	0.021	0.062	0.031	0.043
Cu	mg/L	1.0	0.022	0.046	0.024	0.075
Fe	mg/L	0.3	19.89	8.07	24.54	90.98
Hg	mg/L	0.002	<0.0002	<0.0002	0.0003	<0.0002
Mn	mg/L	0.05	0.177	0.560	0.15	0.56
Na	mg/L		3.08	2.78	3.54	6.09
Ni	mg/L		0.018	0.054	0.029	0.025
Pb	mg/L	0.05	0.027	0.048	0.047	0.062
Se	mg/L	0.01	<0.002	<0.002	<0.002	<0.002
Zn	mg/L	5	0.095	0.283	0.075	0.278
Cl	mg/L	250	5	4	4.4	3.3
CN	mg/L		<0.005	<0.005	<0.005	<0.005
F	mg/L	1.6	<0.10	0.12	<0.10	<0.01
Foaming agents	mg/L	0.5	<0.01	0.02	<0.01	<0.01
H_2S	mg/L		<1.0	<1.0	<1.0	<1.0
NO_3	mg/L	10	2.36	2.39	2.63	3.21
SO_4	mg/L	250	<5	26	<5	<5
Gross Alpha	pCi/L	15	3.4±1.1	1.8±0.7	1.27±0.84	-
Gross Beta	pCi/L		18±8	52±45	21.2±8.9	-
Ra	pCi/L	5	<0.38	0.20	0.41	0.50
DOC	mg/L		8	1.5	2	9.0
GC	μg/L		<40	<40	<40	<40
Phenols	mg/L		0.004	<0.002	0.006	<0.002
TOC	mg/L		6	2.0	4	9.5
TOH	mg/L		0.010	0.026	0.017	0.007
Endrin	μg/L	0.2	<0.009	<0.04	<0.04	<0.04
Lindane	μg/L	4	<0.005	<1	<1	<1
Methoxychlor	μg/L	100	<0.06	<20	<20	<20
Toxaphene	μg/L	5	<1.04	<1	<1	<1
24D	μg/L	100	<0.41	<20	<20	<20
245TP	μg/L	10	<0.13	<2	<2	<2

Table F-13. Results of monitoring well analyses for H-Area seepage basin (continued)[a]

HSB-66 Upgradient N72429.63 E56928.59 Elev = 280.1

Parameter	Units	DWS	2QR 82	3QR 82	4QR 82	1QR 83
Water Table Elevation	Ft		230.9	230.1	231.4	229.4
Coliform B	#/100 ml		5	0	0	5
Color	CU	15	10	3	5	2
Corrosion			No	No	No	No
Odor		3	50	2	0	0
pH	pH	6.5-8.5	4.0	6.3	5.4	4.1
Specific Conductivity	µmho/cm		24	26	25	22
TDS	mg/L	500	32	19	36	5
Temp	°C		19.6	19.5	20.8	16.3
Turbidity	1/TU		0.59	0.86	1.1	0.7
Ag	mg/L	0.05	<0.001	<0.001	<0.001	<0.001
As	mg/L	0.05	<0.002	<0.002	<0.002	<0.002
Ba	mg/L	1.0	<0.05	<0.05	0.7	<0.05
Be	mg/L		<0.010	0.014	<0.005	<0.005
Cd	mg/L	0.01	0.001	0.001	<0.001	0.032
Cr	mg/L	0.05	0.002	0.002	0.007	0.002
Cu	mg/L	1.0	0.002	0.006	0.006	0.004
Fe	mg/L	0.3	0.140	0.12	0.70	0.94
Hg	mg/L	0.002	<0.0002	<0.0002	0.0003	<0.0002
Mn	mg/L	0.05	0.020	0.020	<0.02	0.03
Na	mg/L		2.68	2.17	2.87	5.35
Ni	mg/L		0.002	0.009	0.010	0.020
Pb	mg/L	0.05	0.857	0.005	0.010	0.028
Se	mg/L	0.01	<0.002	<0.002	<0.002	<0.002
Zn	mg/L	5	0.078	0.078	0.080	0.060
Cl	mg/L	250	3	3	3.7	2.8
CN	mg/L		<0.005	<0.005	<0.005	<0.005
F	mg/L	1.6	<0.15	0.11	<0.10	<0.01
Foaming agents	mg/L	0.5	0.02	<0.01	0.02	0.03
H_2S	mg/L		<1.0	<1.0	<1.0	<1.0
NO_3	mg/L	10	1.19	3.01	0.95	0.91
SO_4	mg/L	250	<5	22	<5	<5
Gross Alpha	pCi/L	15	1.2±0.7	0.5±0.4	0.37±0.5	1.2
Gross Beta	pCi/L		5±8	1.7±6.5	6.2±8.4	6.8
Ra	pCi/L	5	<0.43	0.40	2.83	0.33
DOC	mg/L		8	1.5	3	6.5
GC	µg/L		<40	-	<40	<40
Phenols	mg/L		<0.002	<0.002	0.003	<0.002
TOC	mg/L		4	4.0	3	11.5
TOH	mg/L		0.013	0.025	19.0	0.011
Endrin	µg/L	0.2	<0.009	<0.04	<0.04	<0.04
Lindane	µg/L	4	<0.005	<1	<1	<1
Methoxychlor	µg/L	100	<0.06	<20	<20	<20
Toxaphene	µg/L	5	<1.04	<1	<1	<1
24D	µg/L	100	<0.41	<20	<20	<20
245TP	µg/L	10	<0.13	<2	<2	<2

Table F-13. Results of monitoring well analyses for H-Area seepage basin (continued)[a]

HSB-67 Downgradient N71499.98 E58409.98 Elev = 237.6

Parameter	Units	DWS	2QR 82	3QR 82	4QR 82	1QR 83
Water Table Elevation	Ft		228.6	228.1	228.6	228.6
Coliform B	#/100 ml		0	0	0	0
Color	CU	15	2	3	7	2
Corrosion			No	No	No	No
Odor		3	0	0	12	0
pH	pH	6.5-8.5	3.6	4.4	4.2	4.2
Specific Conductivity	µmho/cm		180	54	80	87
TDS	mg/L	500	156	54	52	52
Temp	°C		17.8	20.4	21.5	13.5
Turbidity	1/TU		56	0.89	0.4	3.9
Ag	mg/L	0.05	<0.001	<0.001	<0.001	<0.001
As	mg/L	0.05	<0.002	<0.002	<0.002	<0.002
Ba	mg/L	1.0	0.080	0.08	<0.05	<0.05
Be	mg/L		<0.005	<0.005	<0.005	<0.005
Cd	mg/L	0.01	0.002	<0.001	<0.001	<0.002
Cr	mg/L	0.05	0.004	0.002	0.007	0.004
Cu	mg/L	1.0	0.004	0.002	0.003	0.002
Fe	mg/L	0.3	2.548	2.91	1.61	1.75
Hg	mg/L	0.002	0.0458	0.0092	0.0074	0.0067
Mn	mg/L	0.05	0.056	<0.020	<0.02	0.05
Na	mg/L		33.75	6.13	12.91	16.40
Ni	mg/L		0.004	<0.002	0.005	0.015
Pb	mg/L	0.05	0.008	0.002	0.011	0.004
Se	mg/L	0.01	<0.002	<0.002	<0.002	<0.002
Zn	mg/L	5	0.072	0.066	0.048	0.042
Cl	mg/L	250	5	3	4.2	4.6
CN	mg/L		<0.005	<0.005	<0.005	<0.005
F	mg/L	1.6	<0.10	<0.10	<0.10	<0.01
Foaming agent	mg/L	0.5	0.03	<0.01	<0.01	<0.01
H_2S	mg/L		<1.0	<1.0	<1.0	<1.0
NO_3	mg/L	10	19.5	4.26	7.89	8.71
SO_4	mg/L	250	<5	16	<5	<5
Gross Alpha	pCi/L	15	4.9±1.3	1.2±0.6	1.11±0.79	1.2
Gross Beta	pCi/L		1009±26	93.5±9.1	96.2±11.2	154
Ra	pCi/L	5	3.81	1.38	<0.39	0.97
DOC	mg/L		7	1.5	2	6.0
GC	µg/L		<40	70	<40	<40
Phenols	mg/L		<0.002	<0.002	0.007	<0.002
TOC	mg/L		6	3.5	5	9.0
TOH	mg/L		0.100	0.068	0.110	0.047
Endrin	µg/L	0.2	<0.009	<0.04	<0.04	<0.04
Lindane	µg/L	4	<0.005	<1	<1	<1
Methoxychlor	µg/L	100	<0.06	<20	<20	<20
Toxaphene	µg/L	5	<1.04	<1	<1	<1
24D	µg/L	100	<0.41	<20	<20	<20
245TP	µg/L	10	<0.13	<2	<2	<2

Table F-13. Results of monitoring well analyses for H-Area seepage basin (continued)[a]

HSB-68 Downgradient N73660.00 E50145.00 Elev = 217.7

Parameter	Units	DWS	2QR 82	3QR 82	4QR 82	1QR 83
Water Table Elevation	Ft		226.4	226.0	226.3	226.5
Coliform B	#/100 ml		0	0	0	1800
Color	CU	15	2	>5	>5	2
Corrosion			No	No	No	No
Odor		3	0	1.4	0	4
pH	pH	6.5-8.5	3.1	4.2	4.0	5.1
Specific Conductivity	µmho/cm		160	170	174	418
TDS	mg/L	500	148	141	116	39
Temp	°C		12.6	20.1	19.9	15.5
Turbidity	1/TU		100	8.5	0.5	0.3
Ag	mg/L	0.05	<0.001	<0.001	<0.001	<0.001
As	mg/L	0.05	<0.002	<0.002	0.005	<0.002
Ba	mg/L	1.0	<0.05	0.78	<0.05	0.14
Be	mg/L		<0.010	0.035	<0.005	<0.005
Cd	mg/L	0.01	0.002	<0.001	0.001	0.010
Cr	mg/L	0.05	0.017	0.008	0.047	0.051
Cu	mg/L	1.0	0.004	0.004	0.016	0.017
Fe	mg/L	0.3	45.78	172	139.6	231.6
Hg	mg/L	0.002	0.0048	0.0058	0.0039	0.0087
Mn	mg/L	0.05	0.762	1.277	0.51	1.19
Na	mg/L		60.10	50.4	27.53	101.6
Ni	mg/L		0.009	0.015	0.019	0.021
Pb	mg/L	0.05	0.025	0.018	0.043	0.029
Se	mg/L	0.01	<0.002	<0.002	<0.002	<0.002
Zn	mg/L	5	0.074	0.120	0.180	0.219
Cl	mg/L	250	4	2	3.6	3.5
CN	mg/L		<0.005	<0.008	<0.005	<0.005
F	mg/L	1.6	0.10	<0.10	<0.10	<0.01
Foaming agents	mg/L	0.5	0.02	<0.01	<0.01	<0.01
H_2S	mg/L		<1.0	<1.0	<1.0	<1.0
NO_3	mg/L	10	18.8	30.1	68.5	65.31
SO_4	mg/L	250	<5	27	<5	<5
Gross Alpha	pCi/L	15	3.2±1.1	6.1±1.3	4.54±1.55	3.2
Gross Beta	pCi/L		1280±29	1502±28	1824±35	14.9
Ra	pCi/L	5	5.37	12.18	1.06	6.06
DOC	mg/L		5	<1.0	3	11.5
GC	µg/L		<40	<40	<40	<40
Phenols	mg/L		<0.002	0.010	0.016	<0.002
TOC	mg/L		7	8.5	10	20.0
TOH	mg/L		0.280	0.018	<0.005	0.012
Endrin	µg/L	0.2	<0.009	<0.04	<0.04	<0.04
Lindane	µg/L	4	<0.005	<1	<1	1.8
Methoxychlor	µg/L	100	<0.06	<20	<201	<20
Toxaphene	µg/L	5	<1.04	<1	<1	<1
24D	µg/L	100	<0.41	<20	<20	<20
245TP	µg/L	10	<0.13	<2	<2	<2

Table F-13. Results of monitoring well analyses for H-Area seepage basin (continued)[a]

HSB-69 Downgradient N72550.00 E56400.00 Elev = 235.8

Parameter	Units	DWS	2QR 82	3QR 82	4QR 82	1QR 83
Water Table Elevation	Ft		222.3	216.9	222.8	222.7
Coliform B	#/100 ml		0	0	0	20
Color	CU	15	5	3	7	2
Corrosion			No	No	No	No
Odor		3	0	2	0	0
pH	pH	6.5-8.5	3.6	4.5	4.4	4.1
Specific Conductivity	µmho/cm		80	18	25	86
TDS	mg/L	500	68	22	18	81
Temp	°C		16.3	18.9	21.2	14.6
Turbidity	1/TU		1.4	1.2	1.0	0.1
Ag	mg/L	0.05	<0.001	<0.001	<0.001	<0.001
As	mg/L	0.05	<0.002	<0.002	<0.002	<0.002
Ba	mg/L	1.0	<0.05	0.24	0.06	0.18
Be	mg/L		<0.010	0.014	<0.005	<0.005
Cd	mg/L	0.01	0.001	<0.001	<0.001	<0.005
Cr	mg/L	0.05	0.009	0.002	0.004	0.006
Cu	mg/L	1.0	0.007	0.002	0.002	0.006
Fe	mg/L	0.3	9.55	24.65	7.30	16.35
Hg	mg/L	0.002	0.006	<0.003	0.006	0.006
Mn	mg/L	0.05	0.048	0.081	0.12	0.05
Na	mg/L		18.04	102.1	4.16	17.40
Ni	mg/L		0.005	0.010	0.009	0.016
Pb	mg/L	0.05	<0.001	0.006	0.008	0.009
Se	mg/L	0.01	<0.002	<0.002	<0.002	<0.002
Zn	mg/L	5	0.101	0.095	<0.010	0.131
Cl	mg/L	250	3	2	3.4	2.1
CN	mg/L		<0.005	0.005	<0.005	<0.005
F	mg/L	1.6	0.10	<0.10	<0.10	<0.01
Foaming agents	mg/L	0.5	0.01	<0.01	<0.01	<0.01
H_2S	mg/L		<1.0	<1.0	<1.0	<1.0
NO_3	mg/L	10	8.83	1.13	0.51	9.11
SO_4	mg/L	250	<5	16	<5	<5
Gross Alpha	pCi/L	15	1.2±0.7	1.6±0.7	0.69±0.64	0.8
Gross Beta	pCi/L		36±9	16.3±7.0	19.1±8.9	21.4
Ra	pCi/L	5	1.32	0.91	<0.46	1.61
DOC	mg/L		7	1.5	3	6.0
GC	µg/L		<40	<40	<40	<40
Phenols	mg/L		<0.002	<0.002	0.004	<0.002
TOC	mg/L		8	2.0	3	12.0
TOH	mg/L		0.009	0.022	5.3	0.010
Endrin	µg/L	0.2	<0.009	<0.04	<0.04	<0.04
Lindane	µg/L	4	<0.005	<1	<1	<1
Methoxychlor	µg/L	100	<0.06	<20	<20	<20
Toxaphene	µg/L	5	<1.04	<1	<1	<1
24D	µg/L	100	0.41	<20	<20	<20
245TP	µg/L	10	<0.13	<2	<2	<2

Table F-13. Results of monitoring well analyses for H-Area seepage basin (continued)[a]

HSB-70 Upgradient N72600.00 E55760.00 Elev = 242.5

Parameter	Units	DWS	2QR 82	3QR 82	4QR 82	1QR 83
Water Table Elevation	Ft		229.9	231.0	231.0	231.2
Coliform B	#/100 ml		0	0	8	32
Color	CU	15	5	2	10	0
Corrosion			No	No	No	No
Odor		3	50	0	10	0
pH	pH	6.5-8.5	3.9	4.5	4.7	4.7
Specific Conductivity	µmho/cm		36	40	31	35
TDS	mg/L	500	35	101	18	38
Temp	°C		17.8	23.1	21.2	13.2
Turbidity	1/TU		1.2	1.4	2.0	0.7
Ag	mg/L	0.05	<0.001	<0.001	<0.001	<0.001
As	mg/L	0.05	<0.002	<0.002	<0.002	<0.002
Ba	mg/L	1.0	<0.05	0.10	<0.05	0.32
Be	mg/L		<0.010	<0.010	<0.005	<0.005
Cd	mg/L	0.01	<0.001	<0.001	<0.001	0.002
Cr	mg/L	0.05	<0.004	0.10	0.002	0.008
Cu	mg/L	1.0	0.008	0.004	<0.002	0.002
Fe	mg/L	0.3	11.64	8.452	0.75	3.56
Hg	mg/L	0.002	<0.0002	<0.0002	0.0004	<0.0002
Mn	mg/L	0.05	<0.02	0.023	<0.02	0.06
Na	mg/L		1.66	1.04	1.48	2.98
Ni	mg/L		0.003	<0.001	0.007	0.039
Pb	mg/L	0.05	0.004	0.002	0.003	0.001
Se	mg/L	0.01	<0.002	0.002	<0.002	<0.002
Zn	mg/L	5	0.044	0.016	0.057	0.090
Cl	mg/L	250	2	2	2.8	1.4
CN	mg/L		0.006	<0.005	<0.005	<0.005
F	mg/L	1.6	<0.10	0.10	<0.10	<0.01
Foaming agents	mg/L	0.5	0.02	<0.01	<0.01	<0.01
H_2S	mg/L		<1.0	<1.0	<1.0	<1.0
NO_3	mg/L	10	0.13	0.29	0.12	0.31
SO_4	mg/L	250	<5	7.5	10	<5
Gross Alpha	pCi/L	15	0.7±0.6	0.7±0.7	0.74±0.66	0.9
Gross Beta	pCi/L		5±8	6.5±8.2	10.3±8.6	12.5
Ra	pCi/L	5	<0.33	<0.20	<0.41	0.57
DOC	mg/L		7	1	3	10.0
GC	µg/L		<40	<40	<40	<40
Phenols	mg/L		<0.002	<0.002	0.004	<0.002
TOC	mg/L		5	4	5	17.5
TOH	mg/L		0.037	0.046	0.013	0.006
Endrin	µg/L	0.2	<0.009	<0.04	<0.04	<0.04
Lindane	µg/L	4	<0.005	<1	<1	<1
Methoxychlor	µg/L	100	<0.06	<20	<20	<20
Toxaphene	µg/L	5	<1.04	<1	<1	<1
24D	µg/L	100	<0.41	<20	<20	<20
245TP	µg/L	10	<0.13	<2	<2	<2

Table F-13. Results of monitoring well analyses for H-Area seepage basin (continued)[a]

HSB-71 Downgradient N73660.00 E50145.00 Elev = 217.7

Parameter	Units	DWS	2QR 82	3QR 82	4QR 82	1QR 83
Water Table Elevation	Ft		226.1	225.8	226.3	226.1
Coliform B	#/100 ml		0	2	0	3
Color	CU	15	3	2	5	2
Corrosion			No	No	No	No
Odor		3	0	0	0	0
pH	pH	6.5-8.5	4.2	4.4	4.6	4.4
Specific Conductivity	µmho/cm		69	41	34	18
TDS	mg/L	500	86	113	13	28
Temp	°C		17.1	20.4	21.4	13.5
Turbidity	I/TU		1.1	1.86	3.6	7.9
Ag	mg/L	0.05	<0.001	<0.001	<0.001	<0.001
As	mg/L	0.05	<0.002	<0.002	<0.002	<0.002
Ba	mg/L	1.0	0.148	0.18	<0.05	0.13
Be	mg/L		<0.010	<0.010	<0.005	<0.005
Cd	mg/L	0.01	<0.001	<0.001	<0.001	0.005
Cr	mg/L	0.05	0.005	0.014	0.003	0.003
Cu	mg/L	1.0	0.011	0.007	0.004	0.003
Fe	mg/L	0.3	0.987	1.008	0.59	1.33
Hg	mg/L	0.002	<0.0002	<0.0002	0.0003	<0.0002
Mn	mg/L	0.05	<0.02	0.053	0.06	<0.02
Na	mg/L		11.34	12.04	4.34	6.53
Ni	mg/L		<0.001	0.016	0.009	0.011
Pb	mg/L	0.05	<0.001	0.016	0.005	0.010
Se	mg/L	0.01	<0.002	<0.002	<0.002	<0.002
Zn	mg/L	5	0.067	0.115	0.049	0.077
Cl	mg/L	250	4	3	3.9	1.2
CN	mg/L		0.005	<0.005	<0.005	<0.005
F	mg/L	1.6	0.10	0.11	<0.10	<0.01
Foaming agents	mg/L	0.5	0.02	<0.01	<0.01	<0.01
H_2S	mg/L		<1.0	<1.0	<1.0	<1.0
NO_3	mg/L	10	5.31	2.51	1.07	0.21
SO_4	mg/L	250	<5	7.5	<5	<5
Gross Alpha	pCi/L	15	0.9±0.7	0.5±0.6	0.37±0.5	0.4
Gross Beta	pCi/L		18±8	3.3±8.1	7.4±8.4	0.9
Ra	pCi/L	5	<0.43	<0.32	<0.37	0.18
DOC	mg/L		7	6	3	6.5
GC	µg/L		<40	<40	<40	<40
Phenols	mg/L		<0.002	<0.002	0.005	<0.002
TOC	mg/L		6	4	3	11.5
TOH	mg/L		0.037	0.270	0.011	0.011
Endrin	µg/L	0.2	<0.009	<0.04	<0.04	<0.04
Lindane	µg/L	4	<0.005	<1	<1	<1
Methoxychlor	µg/L	100	<0.06	<20	<20	<20
Toxaphene	µg/L	5	<1.04	<1	<1	<1
24D	µg/L	100	<0.41	<20	<20	<20
245TP	µg/L	10	<0.13	<2	<2	<2

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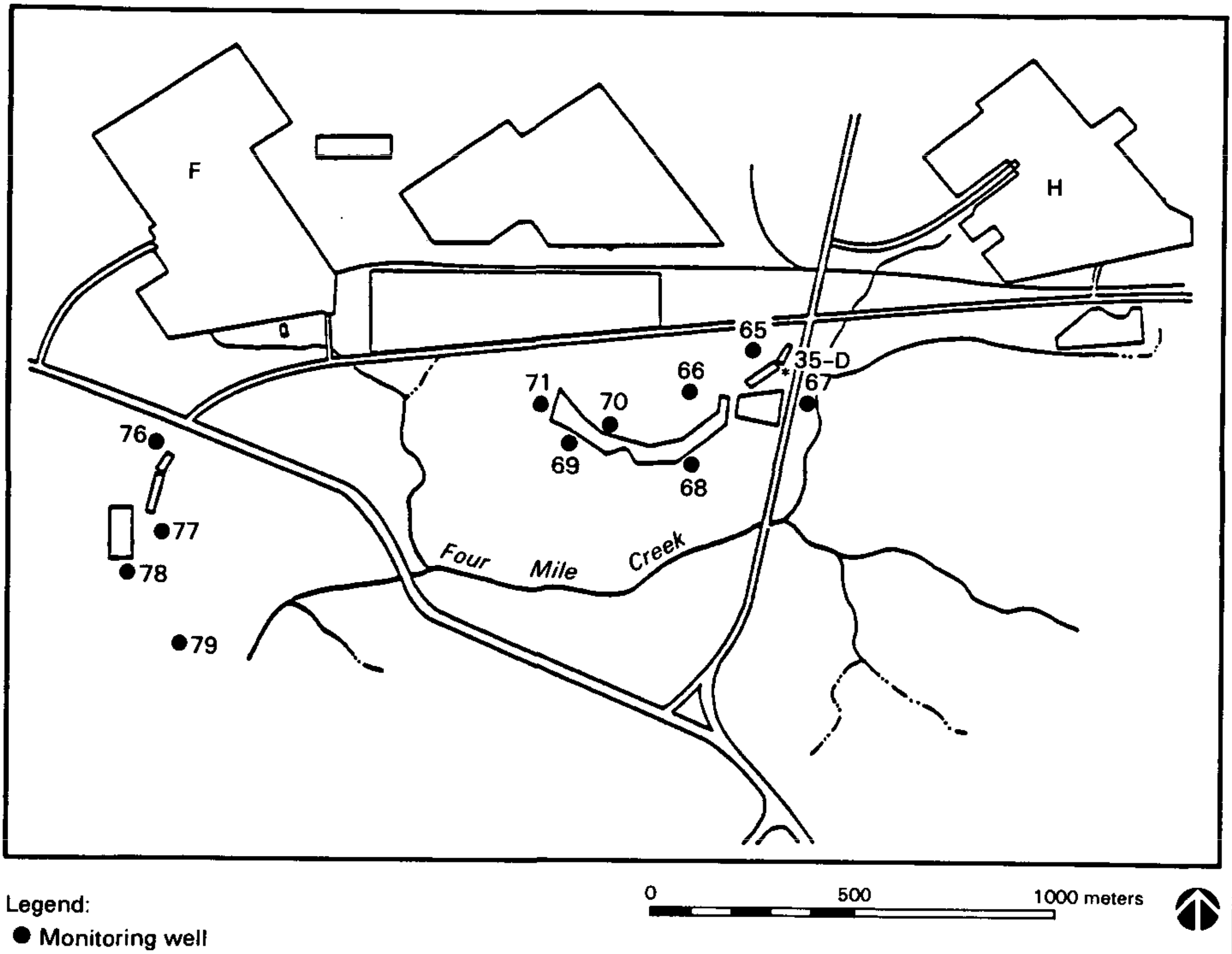
[a] Adapted from Du Pont, 1983



Legend:

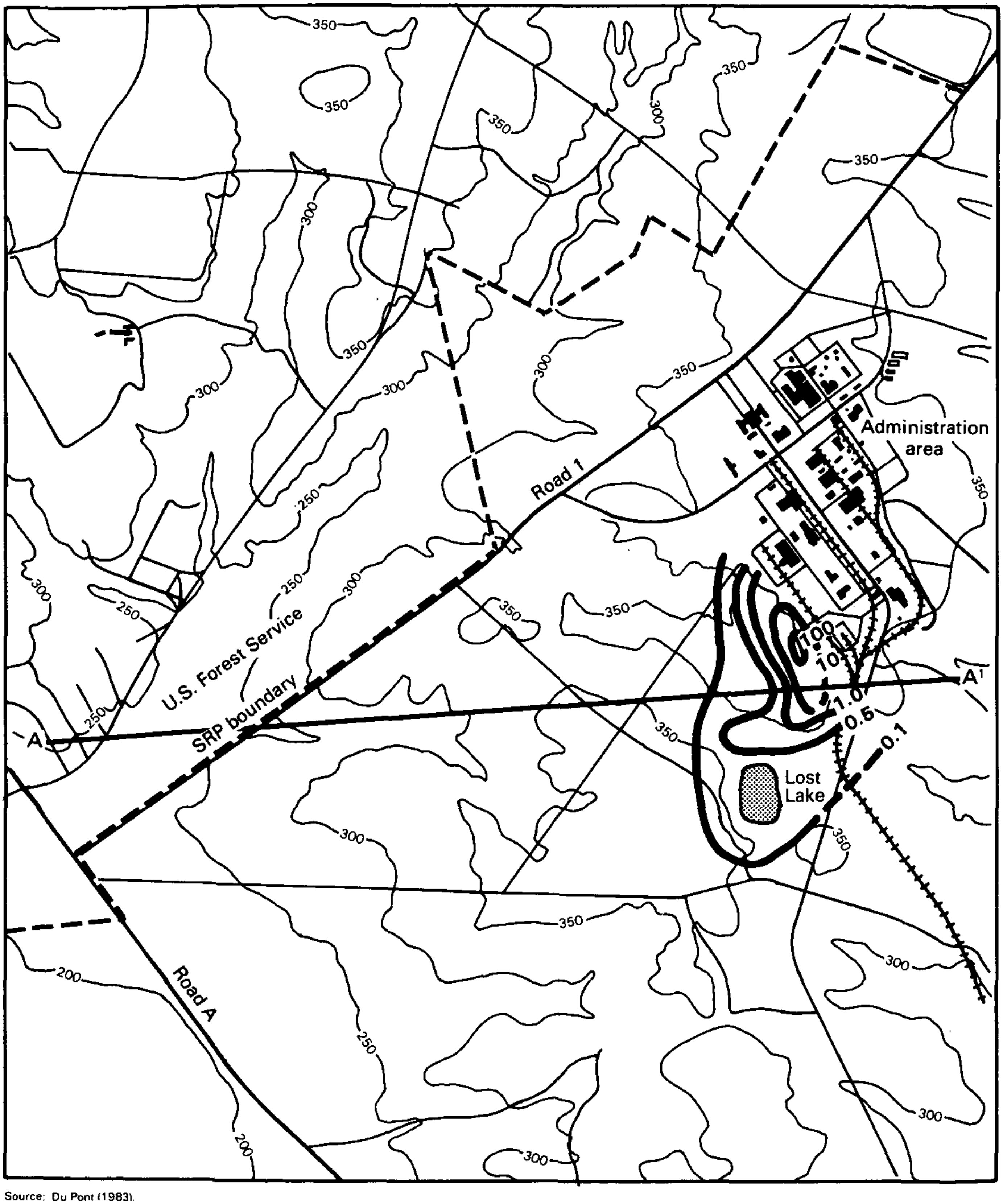
- ● Monitoring well

  See Tables F-12 and F-13 for monitoring results.

*Monitoring well 35-D (Marine, 1965)

TC

Figure F-34. Location of FSB (F-Area) and HSB (H-Area) hazadous-waste monitoring wells.



Source: Du Pont (1983).

Figure F-35. Contours of total organic degreaser concentrations from ground-water analyses (mg/l).

Trichloroethane, the last of the three chlorinated organics discharged to the settling basin, was detected at the 15-foot depth and is known to be present in the ground water; perclene was also detected in the bottom sections of all five cores and has been found in high concentrations in the ground water near the basin.

Figure F-35 shows the distribution of total organic degreasers in the horizontal dimension west of the M-Area settling basin and process effluent sewer. Figure F-36 shows the extent of the contamination in a vertical section. Using the contours and from the investigation of the basin and discharge pipeline, the quantity of volatile organics in the ground water in this area is estimated at about 27,000 kilograms. From soil cores an additional 24,000 kilograms is estimated to reside in the unsaturated zone beneath the surface sources of contamination. (See Du Pont 1982, for additional details.) EN-51

Tables F-14 and F-15 give analyses of other constituents in the ground water from the Tertiary aquifers in M-Area. Figure F-37 shows the locations of these monitoring wells. A high nitrate content is characteristic of the center of the organics plume and exceeds drinking water standards. Other ground-water constituents are within drinking water limits. EN-51

Wells in neighboring A-Area (Figure F-37) that draw from the Tuscaloosa Formation (especially wells 53A and 20A) were found to have small quantities of chlorinated hydrocarbons, in concentrations from a few to about 27 micrograms per liter (Du Pont, 1983; Geraghty and Miller, 1983). The entry of chlorinated hydrocarbons into these wells might have resulted from the migration of the contaminants from Tertiary (shallow) aquifers down the well annuli to the well screens, and not from any M-Area-related contamination of the Tuscaloosa that has migrated through the overlying basal Congaree and upper Ellenton clay units. This hypothesis is being investigated through geophysical examinations of old production wells and through the monitoring of the water quality of new wells. Chlorinated hydrocarbons above the limit of detection (1 microgram per liter) have not been found in recent M- and A-Area wells drilled to monitor Tuscaloosa water quality and water levels. One of these new wells is within 80 meters of the A-Area production well (53A) that exhibited the highest concentrations of chlorinated hydrocarbons. Recent analysis of water from well 53A showed no evidence of such volatile organics as chlorinated hydrocarbons (Steele, 1983). A cement bond log of well 53A indicated extensive areas where the cement sheath around the casing was not bound to the casing. Such areas of poor bond would provide avenues for contaminated water from the Tertiary to migrate directly to the screen sections of the Tuscaloosa (Geraghty and Miller, 1983). These determinations lend support to the hypothesis that A-Area wells received contamination from ground water that entered from the shallow aquifers and not from the Tuscaloosa Aquifer. EN-51

F.5.5 Burial ground

Ground-water quality at the SRP burial ground is being extensively studied with monitoring wells located inside and adjacent to the burial site. Monitoring for radionuclides and mercury has shown that only tritium has reached the ground water in significant amounts after 30 years of operations. Average

Table F-14. Inorganic chemistry of ground water in the vicinity of M-Area basin[a]

Constituent	Concentration (mg/ℓ) Average background (6 wells)	Concentration (mg/ℓ) Average downgradient[b] (6 wells)
K	5.6	7.7
Na	7.2	33.7
Ca	40.7	68.5
Mg	.38	8.3
Cl	2.1	4.7
SO_4	2.5	2.2
P	37	34
N (NO_2 + NO_3 as N)	.9	56
Fe[b]	1.4	.7
Zn[b]	.35	4.0
Ni[b]	<.01	.06
Al[b]	3.7	1.8
Cu[b]	.07	.04
Property		
Conductivity (µmho/cm)	337	554
pH	9.2	8.76

[a] PVC wells only (background, 4 wells; downgradient, 5 wells); adapted from Du Pont (1983).

[b] Wells within 300 meters of basin.

Table F-15. Results of monitoring well analyses for M-Area[a]

MSB-1 Background N101824.23 E48468.50 Elev = 352.53 (83)
N101824.2 E48486.1 Elev = 353.4 (82)

Parameter	Units	DWS	2QR 82	3QR 82	4QR 82	1QR 83
Water Table Elevation	Ft		244.4	243.9	243.6	242.0
Coliform B	#/100 ml		0	0	0	4
Color	CU	15	3	3	5	2
Corrosion			No	No	No	No
Odor		3	0	0	0	0
pH	pH	6.5-8.5	7.6	8.6	6.0	4.5
Specific Conductivity	µmho/cm		153	112	118	60
TDS	mg/L	500	107	71	87	20
Temp	°C		18.7	21.6	18.9	17.8
Turbidity	1/TU		7.5	3.4	0.1	0.2
Ag	mg/L	0.05	<0.001	<0.001	<0.001	<0.001
As	mg/L	0.05	0.003	<0.002	<0.002	<0.002
Ba	mg/L	1.0	<0.05	<0.05	0.49	<0.05
Be	mg/L		<0.005	<0.010	<0.005	<0.005
Cd	mg/L	0.01	0.004	0.008	0.004	0.006
Cr	mg/L	0.05	0.010	0.003	0.024	0.039
Cu	mg/L	1.0	0.011	0.008	0.025	0.008
Fe	mg/L	0.3	1.20	1.185	16.86	93.42
Hg	mg/L	0.002	0.0002	<0.0002	0.0002	<0.0002
Mn	mg/L	0.05	0.016	0.033	0.25	0.16
Na	mg/L		14.30	15.70	9.32	6.49
Ni	mg/L		0.010	0.009	0.020	0.014
Pb	mg/L	0.05	0.158	0.082	0.152	0.015
Se	mg/L	0.01	<0.002	<0.002	<0.002	<0.002
Zn	mg/L	5	20.28	11.46	18.08	0.751
Cl	mg/L	250	4	4.6	3.5	2.3
CN	mg/L		0.012	<0.005	<0.005	<0.005
F	mg/L	1.6	0.14	0.15	0.13	0.01
Foaming agents	mg/L	0.5	<0.01	<0.01	<0.01	<0.01
H_2S	mg/L		<1.0	<1.0	<1.0	<1.0
NO_3	mg/L	10	0.8	3.29	3.75	3.01
SO_4	mg/L	250	<5	<5	5	<5
Gross Alpha	pCi/L	15	0.3±0.4	0.7±0.6	0.74±0.59	2.2
Gross Beta	pCi/L		4±8	10.1±8.1	0.45±7.51	3.1
Ra	pCi/L	5	<0.18	<0.45	0.51	0.77
DOC	mg/L		5	4	2	5.5
GC	µg/L		<40	56	<40	129
Phenols	mg/L		<0.002	<0.002	0.003	<0.002
TOC	mg/L		4	2	5	21.3
TOH	mg/L		0.970	0.400	216	0.21
Endrin	µg/L	0.2	<54	<0.04	<0.04	<0.04
Lindane	µg/L	4	<0.17	<1	<1	<1
Methoxychlor	µg/L	100	<2.5	<20	<20	<20
Toxaphene	µg/L	5	<6.0	<1	<1	<1
24D	µg/L	100	<0.31	<20	<20	<20
245TP	µg/L	10	<0.14	<2	<2	<2

Table F-15. Results of monitoring well analyses for M-Area (continued)[a]

MSB-2 Downgradient N102021.39 E487545.98 Elev = 351.72
N101999.2 E48741.9 Elev = 352.3

Parameter	Units	DWS	2QR 82	3QR 82	4QR 82	1QR 83
Water Table Elevation	Ft		240.8	241.9	241.8	241.7
Coliform B	#/100 ml		0	0	100	33
Color	CU	15	5	5	5	2
Corrosion			No	No	No	No
Odor		3	2	1	0	4
pH	pH	6.5-8.5	5.6	7.1	6.3	3.4
Specific Conductivity	µmho/cm		181	202	209	
TDS	mg/L	500	104	136	157	38
Temp	°C		19.0	20.3	19.2	17.5
Turbidity	1/TU		13.6	14.4	0.1	0.1
Ag	mg/L	0.05	<0.001	<0.001	<0.001	<0.001
As	mg/L	0.05	0.003	<0.002	0.006	<0.002
Ba	mg/L	1.0	<0.05	0.21	0.18	0.06
Be	mg/L		<0.005	<0.010	<0.005	<0.005
Cd	mg/L	0.01	0.014	0.019	0.022	0.011
Cr	mg/L	0.05	0.075	0.022	0.115	0.031
Cu	mg/L	1.0	0.010	0.044	0.107	0.011
Fe	mg/L	0.3	18.24	12.34	111.4	56.72
Hg	mg/L	0.002	0.0002	<0.0002	0.0006	<0.0002
Mn	mg/L	0.05	0.424	1.615	3.09	0.08
Na	mg/L		18.74	19.42	24.49	6.32
Ni	mg/L		0.042	0.039	0.032	0.018
Pb	mg/L	0.05	0.026	0.032	0.065	0.021
Se	mg/L	0.01	<0.002	<0.002	<0.002	<0.002
Zn	mg/L	5	2.815	1.316	5.25	0.276
Cl	mg/L	250	3	5.8	3.4	30.6
CN	mg/L		0.013	<0.005	0.007	<0.005
F	mg/L	1.6	<0.10	0.20	0.13	0.05
Foaming agents	mg/L	0.5	<0.01	0.20	0.04	<0.01
H_2S	mg/L		<1.0	<1.0	<1.0	<1.0
NO_3	mg/L	10	0.30	3.16	3.01	6.23
SO_4	mg/L	250	<5	<5	5	90
Gross Alpha	pCi/L	15	3.2±1.1	2.0±0.9	1.98±0.9	4.8
Gross Beta	pCi/L		7±8	10.4±8.1	9.53±8.52	2.2
Ra	pCi/L	5	1.17	1.08	0.97	4.14
DOC	mg/L		19	6	6	7.0
GC	µg/L		280	206	197	1217
Phenols	mg/L		<0.002	0.014	0.003	<0.002
TOC	mg/L		16	14	39	36.8
TOH	mg/L		0.190	4.7	50	2.1
Endrin	µg/L	0.2	<0.54	<0.04	<0.04	<0.04
Lindane	µg/L	4	<0.17	<1	<1	<1
Methoxychlor	µg/L	100	<2.5	<20	<20	<20
Toxaphene	µg/L	5	<6.0	<1	<1	<1
24D	µg/L	100	<0.31	<20	<20	<20
245TP	µg/L	10	<0.14	<2	<2	<2

Table F-15. Results of monitoring well analyses for M-Area (continued)[a]

MSB-3	Downgradient	N102181.57	E48552.08	Elev = 359.03
		N102181.6	E48530.7	Elev = 359.6

Parameter	Units	DWS	2QR 82	3QR 82	4QR 82	1QR 83
Water Table Elevation	Ft		242.6	243.1	243.2	242.0
Coliform B	#/100 ml		0	0	0	0
Color	CU	15	7	5	70	5
Corrosion			No	No	No	No
Odor		3	2	2	165	128
pH	pH	6.5-8.5	4.9	5.7	5.8	3.8
Specific Conductivity	µmho/cm		206	496	300	1248
TDS	mg/L	500	147	507	355	877
Temp	°C		19.8	22.7	19.4	18.9
Turbidity	1/TU		7.4	2.1	2.6	0.3
Ag	mg/L	0.05	<0.001	<0.001	<0.001	<0.001
As	mg/L	0.05	<0.002	<0.002	<0.002	<0.002
Ba	mg/L	1.0	0.07	0.35	<0.05	0.05
Be	mg/L		<0.005	<0.010	<0.005	<0.005
Cd	mg/L	0.01	0.008	0.090	0.258	0.026
Cr	mg/L	0.05	0.100	0.029	0.052	0.025
Cu	mg/L	1.0	<0.002	0.014	0.015	0.030
Fe	mg/L	0.3	33.42	29.17	34.74	49.10
Hg	mg/L	0.002	0.0010	<0.0002	0.003	<0.0002
Mn	mg/L	0.05	0.674	1.331	0.74	0.56
Na	mg/L		11.70	12.04	93.79	230.0
Ni	mg/L		0.084	0.079	0.179	0.042
Pb	mg/L	0.05	0.043	0.039	0.051	0.008
Se	mg/L	0.01	<0.002	<0.002	<0.002	<0.002
Zn	mg/L	5	5.020	7.566	3.71	0.373
Cl	mg/L	250	4	7.7	13.8	16.3
CN	mg/L		0.028	<0.005	0.011	0.077
F	mg/L	1.6	0.13	<0.10	0.14	0.63
Foaming agents	mg/L	0.5	<0.01	<0.01	<0.01	0.09
H_2S	mg/L		<1.0	<1.0	<1.0	<1.0
NO_3	mg/L	10	10.62	4.18	54.35	129.4
SO_4	mg/L	250	<5	<5	10	<5
Gross Alpha	pCi/L	15	5.3±1.4	0.2±0.4	2.8±1.04	1.7
Gross Beta	pCi/L		32±9	7.3±8.3	19.7±8.9	8.3
Ra	pCi/L	5	3.07	7.99	4.61	9.96
DOC	mg/L		11	9	10	4.2
GC	µg/L		81070	70835	41882	85870
Phenols	mg/L		0.056	0.031	0.040	0.024
TOC	mg/L		27	23	1100	100.5
TOH	mg/L		6.200	16.0	64	78.0
Endrin	µg/L	0.2	<1.4	<0.04	<0.04	<0.04
Lindane	µg/L	4	<0.2	<1	<1	<1
Methoxychlor	µg/L	100	<7.3	<20	<20	<20
Toxaphene	µg/L	5	<60.0	<1	<1	<1
24D	µg/L	100	<0.31	<20	<20	<20
245TP	µg/L	10	<0.14	<2	<2	4.5

Table F-15. Results of monitoring well analyses for M-Area (continued)[a]

MSB-4 Downgradient N101982.66 E48312.57 Elev = 354.05
N102010.4 E48313.8 Elev = 355.1

Parameter	Units	DWS	2QR 82	3QR 82	4QR 82	1QR 83
Water Table Elevation	Ft		242.6	242.7	243.6	242.0
Coliform B	#/100 ml		0	0	500	27
Color	CU	15	-	3	3	5
Corrosion			No	No	No	No
Odor		3	4	2	1	32
pH	pH	6.5-8.5	-	-	5.3	4.3
Specific Conductivity	µmho/cm		-	147	186	116
TDS	mg/L	500	-	98	109	110
Temp	°C		-	-	19.1	17.0
Turbidity	1/TU		-	3.1	2.2	0.4
Ag	mg/L	0.05	0.001	<0.001	<0.001	<0.001
As	mg/L	0.05	<0.002	<0.002	0.004	<0.002
Ba	mg/L	1.0	0.21	0.17	0.06	<0.05
Be	mg/L		0.017	<0.010	<0.005	<0.005
Cd	mg/L	0.01	0.040	0.042	0.024	0.012
Cr	mg/L	0.05	0.649	0.096	0.179	0.041
Cu	mg/L	1.0	0.240	0.477	0.109	0.019
Fe	mg/L	0.3	201.0	80.35	92.8	104.1
Hg	mg/L	0.002	0.0002	0.1025	0.0136	<0.0002
Mn	mg/L	0.05	0.963	0.950	0.88	0.40
Na	mg/L		0.99	1.04	15.77	11.03
Ni	mg/L		0.301	0.297	0.090	0.024
Pb	mg/L	0.05	0.639	0.265	0.437	0.010
Se	mg/L	0.01	<0.002	<0.002	<0.002	<0.002
Zn	mg/L	5	43.0	11.24	21.78	0.293
Cl	mg/L	250	-	4.0	3.5	4.8
CN	mg/L		0.018	<0.005	0.006	<0.005
F	mg/L	1.6	<0.1	0.17	0.27	0.01
Foaming agents	mg/L	0.5	<0.01	0.02	0.22	<0.01
H_2S	mg/L		<1.0	<1.0	<1.0	<1.0
NO_3	mg/L	10	0.61	0.43	3.63	10.11
SO_4	mg/L	250	<5	<5	5	<5
Gross Alpha	pCi/L	15	12.9±2.1	0.5±0.5	1.9±0.86	5.7
Gross Beta	pCi/L		59±10	3.9±8.2	10.6±8.6	16.7
Ra	pCi/L	5	1.80	1.66	1.32	1.83
DOC	mg/L		7	15	32	5.3
GC	µg/L		170	166	126	177
Phenols	mg/L		0.035	<0.002	<0.002	<0.002
TOC	mg/L		28	14	140	96.0
TOH	mg/L		0.170	0.520	0.17	0.74
Endrin	µg/L	0.2	<0.014	<0.04	<0.04	<0.04
Lindane	µg/L	4	<0.002	<1	<1	<1
Methoxychlor	µg/L	100	<0.073	<20	<20	<20
Toxaphene	µg/L	5	<0.61	<1	<1	<1
24D	µg/L	100	<0.31	<20	<20	<20
245TP	µg/L	10	<0.14	<2	<2	<2

Table F-15. Results of monitoring well analyses for M-Area (continued)[a]

MSB-5 Downgradient N101948.21 E46998.81 Elev = 343.63 (83)
N101768.7 E46983.8 Elev = 339.1 (82)

Parameter	Units	DWS	2QR 82	3QR 82	4QR 82	1QR 83
Water Table Elevation	Ft		240.1	240.9	234.1	238.1
Coliform B	#/100 ml		0	0	16	79
Color	CU	15	30	7	10	2
Corrosion			No	No	No	No
Odor		3	6	4	14	1
pH	pH	6.5-8.5	5.2	5.9	6.1	5.0
Specific Conductivity	µmho/cm		134	185	69	173
TDS	mg/L	500	100	143	175	137
Temp	°C		18.1	21.0	17.4	15.3
Turbidity	1/TU		12.0	79	10.0	0.4
Ag	mg/L	0.05	<0.001	<0.001	<0.001	<0.001
As	mg/L	0.05	<0.002	<0.002	0.002	<0.002
Ba	mg/L	1.0	<0.05	<0.050	0.06	<0.05
Be	mg/L		<0.010	<0.010	<0.005	<0.005
Cd	mg/L	0.01	0.017	0.004	0.002	0.006
Cr	mg/L	0.05	0.004	0.037	0.027	0.027
Cu	mg/L	1.0	0.021	0.048	0.007	0.007
Fe	mg/L	0.3	7.68	29.04	53.04	49.64
Hg	mg/L	0.002	<0.0002	<0.0002	0.0003	<0.0002
Mn	mg/L	0.05	0.536	0.791	0.13	0.21
Na	mg/L		25.74	24.07	40.2	34.0
Ni	mg/L		0.010	0.009	0.022	0.018
Pb	mg/L	0.05	0.034	0.080	0.013	0.019
Se	mg/L	0.01	<0.002	0.002	<0.002	<0.002
Zn	mg/L	5	4.120	8.78	0.139	0.134
Cl	mg/L	250	5	8.1	4.1	4.6
CN	mg/L		<0.005	<0.005	<0.005	<0.005
F	mg/L	1.6	<0.10	<0.10	0.10	0.03
Foaming agents	mg/L	0.5	<0.01	<0.01	<0.01	<0.01
H_2S	mg/L		<1.0	<1.0	<1.0	<1.0
NO_3	mg/L	10	5.252	7.76	8.57	18.31
SO_4	mg/L	250	<5	10	12	<5
Gross Alpha	pCi/L	15	3.7±1.2	3.9±1.2	1.5±0.8	1.1
Gross Beta	pCi/L		14±9	4.2±8.2	9.0±8.2	2.6
Ra	pCi/L	5	0.46	0.82		0.90
DOC	mg/L		4	5	4	5.3
GC	µg/L		<40	<40	<40	<40
Phenols	mg/L		0.004	0.002	0.003	<0.002
TOC	mg/L		6	16	11	16.0
TOH	mg/L		0.280	0.180		0.11
Endrin	µg/L	0.2	<0.54	<0.04	<0.04	<0.04
Lindane	µg/L	4	<0.17	<1	<1	<1
Methoxychlor	µg/L	100	<2.5	<20	<20	<20
Toxaphene	µg/L	5	<6.0	<1	<1	<1
24D	µg/L	100	<0.31	<20	<20	<20
245TP	µg/L	10	<0.14	<2	<2	<2

Table F-15. Results of Monitoring Well Analyses for M-Area (continued)[a]

MSB-6 Downgradient N101105.06 E46328.28 Elev = 336.1 (83)
N101080.1 E46462.6 Elev = 339.7 (82)

Parameter	Units	DWS	2QR 82	3QR 82	4QR 82	1QR 83
Water Table Elevation	Ft		237.0	237.2	231.8	228.1
Coliform B	#/100 ml		0	0	>16	33
Color	CU	15	10	5	15	5
Corrosion			No	No	No	No
Odor		3	17	17	16	8
pH	pH	6.5-8.5	5.3	6.0	5.2	4.3
Specific Conductivity	µmho/cm		88	146	71	35
TDS	mg/L	500	76	100	64	30
Temp	°C		18.9	20.7	16.6	16.4
Turbidity	1/TU		2.5	7.5	3.5	0.6
Ag	mg/L	0.05	<0.001	<0.001	<0.001	<0.001
As	mg/L	0.05	<0.002	<0.002	<0.002	<0.002
Ba	mg/L	1.0	0.104	0.19	0.24	0.47
Be	mg/L		<0.010	<0.010	<0.005	<0.005
Cd	mg/L	0.01	0.004	0.007	0.001	0.016
Cr	mg/L	0.05	0.005	0.017	0.014	0.016
Cu	mg/L	1.0	0.014	0.043	0.013	0.008
Fe	mg/L	0.3	5.89	16.93	13.98	18.79
Hg	mg/L	0.002	<0.0002	<0.0002	0.0003	<0.0002
Mn	mg/L	0.05	0.483	0.836	0.42	0.34
Na	mg/L		25.96	37.56	12.92	6.93
Ni	mg/L		0.011	0.014	0.046	0.031
Pb	mg/L	0.05	0.042	0.085	0.030	0.013
Se	mg/L	0.01	<0.002	0.002	<0.002	<0.002
Zn	mg/L	5	2.595	14.87	0.196	0.152
Cl	mg/L	250	4	4.7	5.2	4.4
CN	mg/L		<0.005	<0.005	<0.005	<0.005
F	mg/L	1.6	<0.10	<0.18	<0.10	0.06
Foaming agents	mg/L	0.5	0.02	0.30	0.02	<0.01
H_2S	mg/L		<1.0	<1.0	<1.0	<1.0
NO_3	mg/L	10	0.33	0.23	0.46	0.61
SO_4	mg/L	250	<5	<5	<5	<5
Gross Alpha	pCi/L	15	0.8±0.6	1.6±0.8	1.4±0.8	1.8
Gross Beta	pCi/L		4±8	15.3±8.6	2.1±8.0	4.8
Ra	pCi/L	5	0.57	0.88		0.27
DOC	mg/L		6	6	5	7.5
GC	µg/L		110	<40	<40	<40
Phenols	mg/L			<0.002	0.002	<0.002
TOC	mg/L		2	3	16	15.3
TOH	mg/L		0.530	0.250	0.37	0.008
Endrin	µg/L	0.2	<0.54	<0.04	<0.04	<0.04
Lindane	µg/L	4	<0.17	<1	<1	<1
Methoxychlor	µg/L	100	<2.5	<20	<20	<20
Toxaphene	µg/L	5	<6.0	<1	<1	<1
24D	µg/L	100	<0.31	<20	<20	<20
245TP	µg/L	10	<0.14	<2	<2	<2

Table F-15. Results of monitoring well analyses for M-Area (continued)[a]

MSB-7 Downgradient N100563.73 E46737.06 Elev = 343.93 (83)
N100730.7 E46785.9 Elev = 340.7 (82)

Parameter	Units	DWS	2QR 82	3QR 82	4QR 82	1QR 83
Water Table Elevation	Ft		238.7	239.2	234.3	237.4
Coliform B	#/100 ml		0	0	>16	79
Color	CU	15	5	3	15	2
Corrosion			No	No	No	No
Odor		3	2	2	16	4
pH	pH	6.5-8.5	5.4	5.9	5.4	4.5
Specific Conductivity	µmho/cm		166	136	89	47
TDS	mg/L	500	117	94	95	36
Temp	°C		18.6	19.9	16.7	16.4
Turbidity	1/TU		2.2	1.7	6.2	0.5
Ag	mg/L	0.05	<0.001	<0.001	<0.001	<0.001
As	mg/L	0.05	<0.002	<0.002	<0.002	<0.002
Ba	mg/L	1.0	<0.050	<0.05	0.26	0.46
Be	mg/L		<0.010	<0.010	<0.007	<0.005
Cd	mg/L	0.01	0.007	0.016	0.002	0.025
Cr	mg/L	0.05	0.025	0.017	0.046	0.040
Cu	mg/L	1.0	0.001	0.014	0.010	0.009
Fe	mg/L	0.3	6.240	21.20	62.98	48.14
Hg	mg/L	0.002	<0.0002	<0.0002	0.0003	<0.0002
Mn	mg/L	0.05	0.620	0.963	0.31	0.17
Na	mg/L		8.14	4.02	12.48	5.45
Ni	mg/L		1.051	0.937	0.024	0.023
Pb	mg/L	0.05	0.143	0.031	0.025	0.020
Se	mg/L	0.01	<0.002	0.002	<0.002	<0.002
Zn	mg/L	5	2.110	1.964	0.173	0.121
Cl	mg/L	250	4	6.7	3.8	2.6
CN	mg/L		<0.005	<0.005	<0.005	<0.005
F	mg/L	1.6	0.16	0.36	<0.10	<0.01
Foaming agents	mg/L	0.5	0.07	<0.01	0.02	<0.01
H_2S	mg/L		<1.0	<1.0	<1.0	<1.0
NO_3	mg/L	10	0.04	0.06	1.01	1.11
SO_4	mg/L	250	<5	10	<5	<5
Gross Alpha	pCi/L	15	0.7±0.6	1.2±0.7	5.9±1.4	3.0
Gross Beta	pCi/L		12±9	11.3±8.6	9.9±8.3	10.0
Ra	pCi/L	5	0.79	0.83		0.78
DOC	mg/L		6	6	5	7.5
GC	µg/L		<40	<40	<40	<40
Phenols	mg/L		<0.002	<0.002	0.002	<0.002
TOC	mg/L		2	9	28	26.0
TOH	mg/L		0.079	0.210	0.39	0.031
Endrin	µg/L	0.2	<0.54	<0.04	<0.04	<0.04
Lindane	µg/L	4	<0.17	<1	<1	<1
Methoxychlor	µg/L	100	<2.5	<20	<20	<20
Toxaphene	µg/L	5	<6.0	<1	<1	<1
24D	µg/L	100	<0.31	<20	<20	<20
245TP	µg/L	10	<0.14	<2	<2	<2

Table F-15. Results of monitoring well analyses for M-Area (continued)[a]

MSB-8	Downgradient		N100796.20 N100944.0	E47302.80 E47145.4	Elev = 343.72 (83) Elev = 339.4 (82)	
Parameter	**Units**	**DWS**	**2QR 82**	**3QR 82**	**4QR 82**	**1QR 83**
Water Table Elevation	Ft		241.4	240.9	236.8	241.2
Coliform B	#/100 ml		0	0	>16	120
Color	CU	15	30	5	15	2
Corrosion			No	No	No	No
Odor		3	2	0	16	4
pH	pH	6.5-8.5	5.6	6.0	5.4	4.9
Specific Conductivity	µmho/cm		195	194	82	31
TDS	mg/L	500	141	151	116	39
Temp	°C		17.7	18.8	16.9	15.4
Turbidity	1/TU		31	59	5.1	0.4
Ag	mg/L	0.05	<0.001	<0.001	<0.001	<0.001
As	mg/L	0.05	<0.002	<0.002	<0.002	<0.002
Ba	mg/L	1.0	<0.050	<0.05	0.12	0.70
Be	mg/L		<0.010	0.052	<0.005	0.006
Cd	mg/L	0.01	0.010	<0.001	<0.001	0.005
~~Cr~~	~~mg/L~~	~~0.05~~	~~0.001~~	~~0.010~~	~~0.040~~	~~0.046~~
Cu	mg/L	1.0	0.005	0.030	0.012	0.038
Fe	mg/L	0.3	7.925	9.05	90.8	299.4
Hg	mg/L	0.002	<0.0002	<0.0002	0.0007	0.0002
Mn	mg/L	0.05	0.226	0.262	0.32	0.54
Na	mg/L		27.76	24.48	14.92	5.06
Ni	mg/L		0.412	0.391	0.052	0.036
Pb	mg/L	0.05	0.101	0.043	0.007	0.024
Se	mg/L	0.01	<0.002	0.002	<0.002	<0.002
Zn	mg/L	5	0.742	0.072	0.071	0.208
Cl	mg/L	250	6	9.5	2.5	1.3
CN	mg/L		<0.005	<0.005	<0.009	<0.005
F	mg/L	1.6	0.10	0.20	<0.10	0.01
Foaming agents	mg/L	0.5	0.03	<0.01	<0.01	<0.01
H_2S	mg/L		<1.0	<1.0	<1.0	<1.0
NO_3	mg/L	10	7.00	10.39	4.39	2.11
SO_4	mg/L	250	<5	<5	<5	<5
Gross Alpha	pCi/L	15	2.4±1	3.5±1.1	5.6±1.4	13.9
Gross Beta	pCi/L		6±8	18.2±8.7	9.3±7.8	14.3
Ra	pCi/L	5	0.23	1.14		0.68
DOC	mg/L		5	14	4	4.2
GC	µg/L		<40	<40	<40	43
Phenols	mg/L		0.004	<0.002	0.002	<0.002
TOC	mg/L		6	11	24	31.5
TOH	mg/L		0.074	0.270	0.48	0.20
Endrin	µg/L	0.2	<0.54	<0.04	<0.04	<0.04
Lindane	µg/L	4	<0.17	<1	<1	<1
Methoxychlor	µg/L	100	<2.5	<20	<20	<20
Toxaphene	µg/L	5	<6.0	<1	<1	<1
24D	µg/L	100	<0.31	<20	<20	<20
245TP	µg/L	10	<0.14	<2	<2	<2

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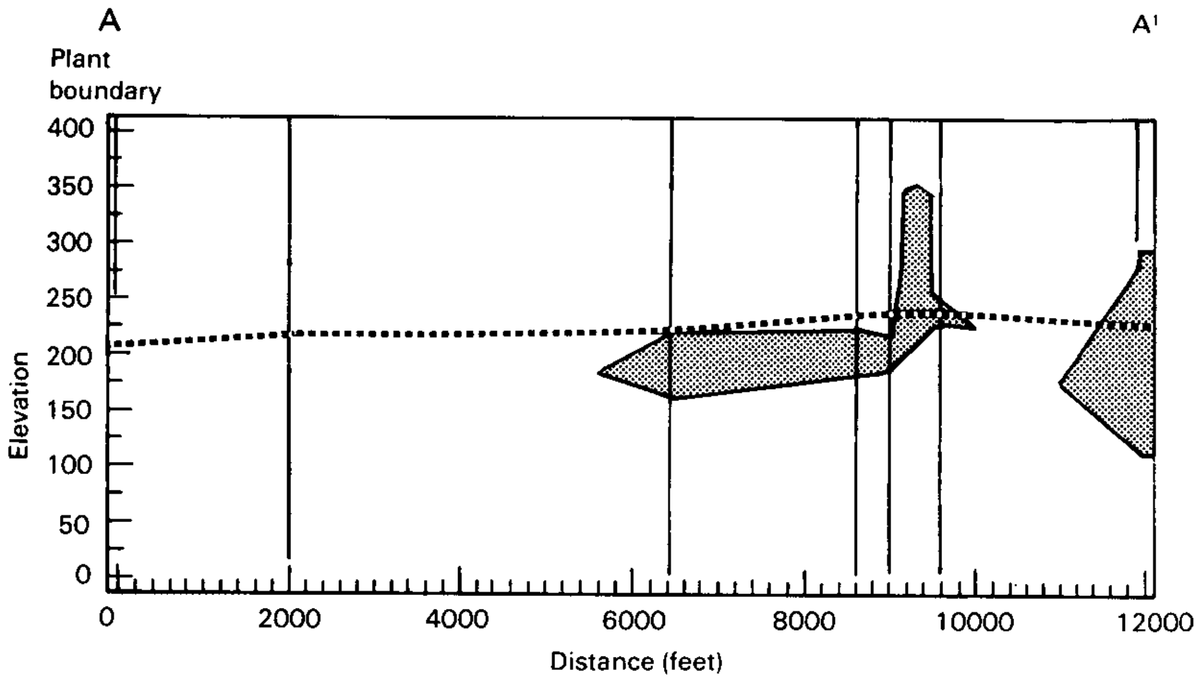
[a] Adapted from Du Pont, 1983



Legend:

▨ Triclene and perclene above detectability between 1 and 10 μg/kg.

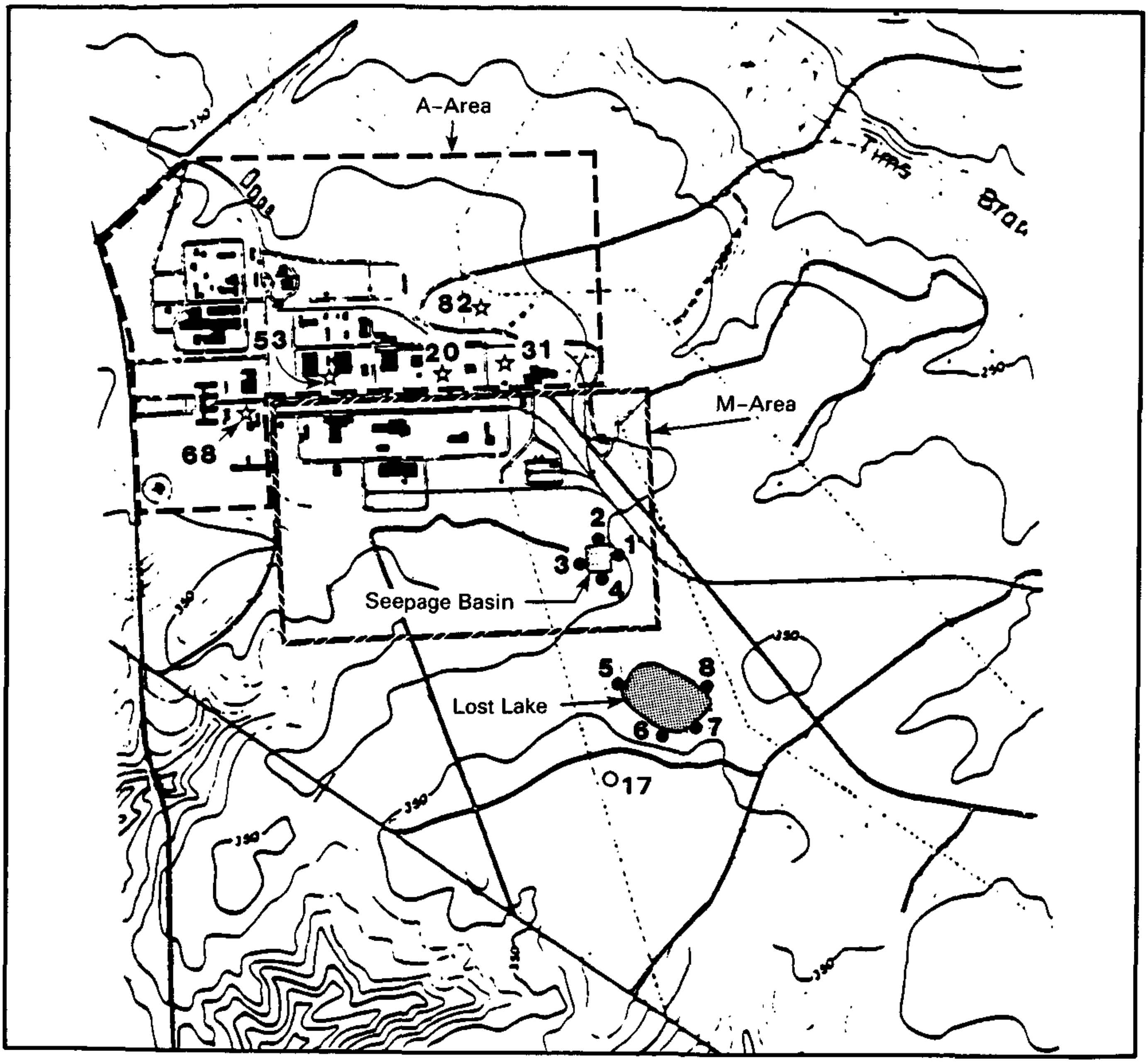
▪▪▪▪▪▪▪ Water table (1982)

Note: 1.0 foot = 0.3048 meter.
Figure F-37 shows the location of cross section AA'.

Source: Du Pont (1983).

Figure F-36. M-Area plumes of triclene and perclene from soil samples.

EN-51



Legend:

- ● Monitoring Well
  See Table F-15 for
  monitoring results.
- ○ See Figure F-11 for location of
  well cluster section.
- ☆ A-Area production wells
  A-A¹ Location of cross-section shown in Figure F-36.

Figure F-37. Location of MSB (M-Area) hazardous-waste monitoring wells and A-Area production wells.

annual concentrations range up to 3300 microcuries per liter, but are typically less than 100 microcuries per liter. Traces of alpha and beta-gamma emitters have moved only short distances (up to a few hundred meters) from the point of entry.

F.6 SRP GROUND-WATER PROTECTION PLAN

The Department of Energy is committed to the protection of ground-water quality at SRP. Specifically, DOE is committed to (1) an expanded program of sitewide ground-water monitoring and study; (2) the continued involvement of the State of South Carolina in ground-water monitoring activities at and in the vicinity of SRP; and (3) taking mitigative actions at SRP to reduce pollutants released to the ground water and to establish with the State of South Carolina a mutually agreed-on compliance schedule for these actions. Current plans call for discontinuing the use of the M-Area seepage basin by April 1985 and constructing a process wastewater-treatment facility for M-Area liquid effluents (see Section 5.1.1.2). These commitments have been formalized by the Memorandum of Understanding between DOE and the State of South Carolina (Congressional Record, July 14, 1983, p. S1000) and by the FY 1984 Supplemental Appropriations Bill (Public Law 98-191, signed November 30, 1983).

A draft "SRP Groundwater Protection Implementation Plan" was developed recently (September 1983) to examine strategies and schedules to implement mitigative actions required to protect the quality of the ground waters beneath SRP. In addition to the commitment for M-Area, this sitewide plan considers other remedial actions, including discontinuing the use of seepage basins in F- and H-Areas and the continued use of the present SRP Burial Ground. It has been reviewed by the State of South Carolina and the U.S. Environmental Protection Agency--Region IV; responses to review comments are being prepared. Implementation of mitigative actions would be accomplished under DOE's Hazardous Waste and Radioactive Mixed Waste Management Program, which is comparable to the design and performance criteria, other technical requirements, and recordkeeping and reporting requirements of the regulations (40 CFR 260-266 and 270) that EPA has adopted to implement RCRA (42 USC 6901 et seq.) (Memorandum of Understanding between DOE and EPA dated February 22, 1984). These mitigative actions would also be compatible with the State of South Carolina's hazardous waste management regulations. The draft "SRP Groundwater Protection Implementation Plan" has been incorporated in the "SR RCRA Program Management Plan" of January 23, 1984, approved by G. K. Oertel, Acting Manager. Chapter 7 contains additional information on RCRA. DA-2

The sitewide ground-water protection plan described above will be the subject of a separate NEPA review. Topics to be discussed in this review will include the sitewide use of seepage basins, disposal pits and the burial ground; mitigation and remedial measures; decommissioning of currently operating facilities receiving hazardous and radioactive mixed wastes; occupational and offsite exposures; and effects of research and development activities.

A two-volume technical document (Du Pont, 1983) supports the draft "SRP Groundwater Protection Implementation Plan." Volume I covers the site geohydrology and solid/hazardous waste; Volume II is concerned with radioactive waste at SRP. In addition, the "SRP Groundwater Protection Policy" has been approved by G. K. Oertel, Acting Manager (January 23, 1984). This policy states that:

> It is the goal of this Operations Office that all operations conducted at the SRP will not adversely affect the quality of any of the groundwater resources.
>
> - An extensive monitoring program, including sampling for both indicator and specific parameters, shall be conducted on a continuing basis.
> - All new facilities shall be designed utilizing groundwater protection concepts; new seepage basin facilities shall not be constructed.
> - All waste disposal sites on the SRP shall be fully assessed for their impacts on groundwater, utilizing an integrated, interdisciplinary approach.
> - Site utilization of groundwater resources shall be reviewed to assure compatibility with regional needs.
> - Appropriate government requirements and agencies shall be consulted where improvements in groundwater quality are desirable.
> - DA-2 Mitigative actions shall be taken, where necessary, in a timely manner to protect groundwater quality.
>
> This Operations Office will continue to cooperate with other Federal and State agencies on matters concerning groundwater protection and utilization.

In compliance with this policy, an SRP baseline hydrogeologic investigation program plan and a ground-water modeling program plan have been formulated (Bledsoe, 1984; Stephenson, 1984). Under this plan, 17 clusters of six to eight wells each will be drilled at strategic SRP locations to further define the hydrostratographic units and their geohydraulic properties. The wells will provide additional data on ground-water levels and quality for each of the major Coastal Plain hydrostratigraphic units on a sitewide basis. Information obtained from this network and from other monitoring wells will be used in computer modeling of the SRP ground-water regime.

Two other projects have been initiated recently to protect SRP ground waters. One is the design and construction of a wastewater-treatment plant to process the liquid effluent presently being discharged to the M-Area seepage basin. Treated wastewater from this plant will be discharged to an onsite stream under an NPDES permit. Current plans call for the completion of this facility by April 1985, about 6 months before the date required by the FY 1984 Supplemental Appropriations Bill (Public Law 98-181, signed November 30, 1983).

The high concentrations of chlorinated hydrocarbons found in the A- and M-Area shallow ground-water system (Tertiary ground-water system) are being removed by both a pilot and a prototype air stripper units, with capacities of

0.075 and 0.18 cubic meter per minute, respectively. Project S-2583 (Steele, 1983) will establish a 1.5-cubic-meter-per-minute production interceptor/recovery well-air stripper system in A- and M-Areas. This system, scheduled to start operating in August 1984, has been designed to prevent chlorinated hydrocarbon contaminants in the shallow (Tertiary) M-Area ground-water system from reaching the drinking water of any offsite well or the Tuscaloosa Aquifer. Specifically, it will consist of nine 200-foot-deep interceptor/recovery (I/R) wells and an air stripper capable of removing about 30 tons of chlorinated hydrocarbons per year during the first few years of operation; thereafter, the removal rate will decrease as the concentrations of contaminants decrease. Liquid effluent from the air stripping column will either be routed to the A-Area powerhouse process-water system or used as non-process cooling water in M-Area; in either case, the wastewater would be discharged through an NPDES-permitted outfall. This I/R-well-and-air-stripping system will be constructed and operated under permits issued by the State of South Carolina. Both the EPA and SCDHEC have reviewed the initial project plans, and have agreed that the planned program is technically sound.

DOE is planning an effluent-treatment facility to treat the wastewaters that are currently discharged to the F- and H-Area seepage basins, so they can be released to an NPDES-permitted outfall. The Department of Energy will submit for approval to Congress a Fiscal Year 1986 funding request for this treatment facility; operation is scheduled for October 1988. DOE also plans to install additional monitoring wells and to take cores within the basins to provide basic data for decommissioning plans. Currently, the basins are scheduled for decommissioning by the end of 1990. DA-2

Section 4.4.3 identifies the periodic disposal of radioactively contaminated water to the L-Area seepage basin as DOE's preferred alternative for the disposal of disassembly-basin purge water. The Department will continue, however, to study and evaluate the practicability of moderator detritiation. Contingent on feasibility and approval of Congressional funding, the moderator detritiation concept will be implemented. As part of a separate NEPA review of the SRP Groundwater Protection Implementation Plan, the Department will evaluate alternative cleanup and remedial-action measures for the L-Area seepage basin.

F.7 WELL DATA FILE

In December 1983, the computerized Well Data File (WDF) at SRP contained records for 6404 wells and borings. Most of these wells are sealed and abandoned. The WDF provides a central source of information on well and boring construction, geology, and water quality. As many as 66 variables can be entered for each well. There are currently 620 monitoring wells and 70 production wells, in the WDF. The remainder are engineering and test borings, grout wells, and miscellaneous wells; this last category includes about 600 old wells, the exact location and status of which are unknown (locations are known within 100 meters). EL-25

Based on pre-SRP well-drilling practices, many of these old wells are believed to have been shallow hand-dug domestic wells. Some probably penetrated the Tuscaloosa, including some drilled flowing wells discovered on SRP in the

Savannah River valley. Any open holes, rusted-out casings, or otherwise defective wells can provide a direct route for contaminated surface water or shallow ground water to contaminate deeper aquifers, even the Tuscaloosa. Contamination of lower aquifers cannot occur from flowing wells. No hand-dug or abandoned wells are known to exist at or adjacent to either L-Reactor or any waste disposal sites of its support facilities. In addition, no contamination of the Tuscaloosa aquifer by radionuclides and chlorinated hydrocarbons has been noted in the central portion of the SRP. Abandoned well S329 in the Steel Creek floodplain, which is reported to be 20 centimeters in diameter and 33 meters deep, could be flooded if a cooling lake is selected as the alternative cooling-water system (see Section 4.4.2). This well is believed to have drawn from the calcareous zone in the McBean Formation. Additional information on abandoned wells is contained in Appendix L.

EL-25

Contamination of well water by chlorinated hydrocarbons (used as degreasers in M-Area) from A-Area wells producing from the Tuscaloosa was confirmed earlier in 1983. This contamination now appears to have resulted from chlorinated hydrocarbons that entered the well annuli from the contaminated shallow (Tertiary) aquifer in A- and M-Areas, and not from any generalized contamination of the Tuscaloosa aquifer itself (Geraghty and Miller, 1983).

Geophysical surveys of well 53A, which exhibited the highest contamination, indicated there were no gross casing breaks. However, packer tests indicated that the casing might leak, and a cement bond log showed that there were extensive areas where the cement sheath around the casings was not bound to the casing. Such areas of poor bond would provide avenues for contaminated water from the Tertiary to migrate directly to screened sections of the Tuscaloosa aquifer. Additional details are provided in Geraghty and Miller (1983).

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APPENDIX G

ENVIRONMENTAL IMPACT OF POSTULATED PLANT ACCIDENTS

This appendix provides supplementary information for Section 4.2.1, Reactor Accidents. This appendix describes (1) the general characteristics of accidents; (2) the actual experience with SRP reactor incidents; (3) safety features of the L-Reactor and of the site that act to mitigate the consequences of accidents; (4) all postulated transients considered for the safety evaluation of L-Reactor; (5) radiological consequences of four hypothetical accidents that cover a spectrum of significant events postulated to release radioactivity above normal operating limits; and (6) input considerations for a CRAC2 analysis of a hypothetical 10-percent core-melt accident (Section 4.2.1.5).

G.1 GENERAL CHARACTERISTICS OF ACCIDENTS

The term "accident," as used in this section, refers to any postulated event that could result in a release of radioactive materials into the environment. The predominant focus is on events that can lead to releases substantially in excess of permissible limits for normal operation.

Several features combine to reduce the risk associated with accidents at nuclear plants. Safety features in the design, construction, and operation, comprising the first line of defense, are devoted to the prevention of the release of radioactive materials from their normal places of confinement within the plant. Also, a number of additional lines of defense are designed to mitigate the consequences of failures in the first line. The most important mitigative features for L-Reactor are described in Section G.3.1. Detailed descriptions of these features may be found in the Safety Analysis Report (SAR) (Du Pont, 1983).

The L-Reactor is designed to produce plutonium by the absorption of neutrons in uranium. The reactor uses heavy water (D_2O) as a moderator and as the primary coolant to remove heat generated by the nuclear fission process. L-Reactor operates at significantly lower temperatures and pressures than light-water commercial nuclear power plants designed for electric power generation. This feature in itself tends to reduce the consequences of many types of accidents. In addition, the absence of a turbine load eliminates a whole range of accidents possible with conventional nuclear power plants.

The transients considered for evaluation of L-Reactor safety are listed in Table G-1. The reactor will operate at a power limit that is determined separately for each charge and each fuel and target cycle so that for any anticipated transient, operation at or below the operating limit would prevent release of radioactivity to the environment. Major safety systems, listed in Table G-2, have been incorporated into the design and operation of the reactor to shut down the reactor and limit the release of radioactivity if necessary.

Four hypothetical accidents are evaluated that cover a spectrum of events postulated to release radioactivity. These four hypothetical accidents, which

Table G-1. Postulated accidents

No.	Accident description	Condition of reactor	Has initiating event occurred at SRP	Main effect
		REACTIVITY ADDITION ACCIDENTS		
1	Single rod withdrawal	Full power	Yes	Local power increase
2	Partial rod insertion	Full power	Yes	Local power increase
3a	Gang rod withdrawal	Full power	No	Reactor power increase
3b	Gang rod withdrawal	Low power	No	Rapid power rise
4	Control rod melting	Full power	No	Local power increase
5	Target melting	Full power	No	Local power increase
6	Fuel melting	Full power	No	Fission products in moderator
7	Reloading error	Shutdown-charge-discharge	No	Inadvertent criticality
		FLOW REDUCTION ACCIDENTS		
8	Loss of D_2O coolant pump power	Full power	No	Increased assembly temperature
9	Loss of H_2O pump power	Full power	No	Increased assembly temperature
10	Loss of both D_2O and H_2O pump power	Full power	No	Increased assembly temperature
11	Pump shaft break	Full power	No	Increased assembly temperature
12	Rotovalve closure	Full power	Yes[a]	Increased assembly temperature
13	Flow reduction in single assembly	Full power	Yes	Increased assembly temperature
14	Loss of control-rod cooling	Full power	Yes	Increased control rod temperature
15	Loss of blanket-gas pressure	Full power	No[b]	Decreased saturation temperature
16	Loss of coolant (leak)	Full power	No	Decreased moderator level; increased temperature; release of radioactivity
17	Loss of D_2O circulation	Full power	No	Increased assembly temperature
18	Loss of cooling during or after discharge	Discharge operations	No	Possible melting of fuel

[a] Two rotovalves closed in one system only one time; closure of all rotovalves in two systems has not occurred.

[b] Slow leaks of blanket gas have occurred.

Table G-2. Major safety systems

Reactor shutdown and safety systems	Engineered safety systems
1. Safety rods	1. Emergency cooling system (ECS)
2. Control rods	2. Water removal and storage
3. Scram instruments and alarms	3. Activity confinement system
4. Supplementary safety systems (SSS)	4. Confinement heat removal system
5. Automatic backup shutdown--safety computer (ABS-S/C)	5. Reactor room spray system
6. Automatic backup shutdown--gang temperature monitor (ABS-GTM)	6. Discharge assembly cooling

have never occurred at SRP, include (1) a total moderator spill, (2) a discharge mishap in which an irradiated assembly is dropped and melts; (3) a misloading accident during charge-discharge operations resulting in melting less than 3 percent of the reactor core; and (4) a loss-of-coolant accident resulting in the melting of 1 percent of the reactor core. No credible accident sequences have been identified that will cause a reactor accident resulting in core damage greater than 3 percent. FG-3

The probabilities reported in this document are based on more than 115 reactor-years of operating experience at Savannah River Plant, conservative engineering judgment, and failure modes and effects analyses (Church, 1983). The probabilistic and risk assessment discussion contained in this document has been based in part on the methodology presented in the Reactor Safety Study (NRC, 1975). In addition, a probabilistic risk assessment (PRA) of the SRP reactors is being performed.

No accidents occurred during the previous operation of the L-Reactor that resulted in the release of radioactivity to the public above DOE standards for normal operations. Safety-system improvements made to other SRP reactors, as a result of years of operating experience, have reduced the probability of an accident. These improvements have also been made on the L-Reactor.

G.2 ACCIDENT EXPERIENCE AND OBSERVED IMPACTS

This section describes the actual experience with SRP reactors. No significant reactor accidents have occurred at the SRP in its 30 years of operation. The following sections describe reactivity addition, flow reduction, and other events that might have led to substantial release of radioactive material if the safety systems or automatic backup systems had failed to function properly.

G.2.1 Reactivity addition

G.2.1.1 Single control-rod withdrawal

An average of two to three unwanted control-rod movements (Jones, 1972) has occurred per reactor year since 1954, and half of the movements were withdrawals that resulted in the addition of reactivity. The incidents were caused by either personnel errors or control-rod drive system malfunctions. However, these events never caused damage to the fuel or release of radioactivity into the environment, because an unwanted rod motion was usually stopped and rod position corrected immediately after the unwanted movement was recognized. Only about 1 percent of these events persisted long enough to actuate the control-rod reversal system. Safety rod scram action has never been required for inadvertent control-rod action. TC

G.2.1.2 Partial control-rod insertion

Approximately half of the two to three control-rod movements that have occurred per reactor year since 1954 were applicable to partial control rods. Fewer than half of these unwanted partial control-rod movements were insertions that resulted in an addition of reactivity. However, these events never caused damage to the fuel or any release of radioactivity to the environment.

G.2.1.3 Gang-rod withdrawal at full power

No unwanted continuous gang-rod withdrawal has occurred at SRP. There were cases when the control computer attempted to raise power because of an erroneous input signal (Jones, 1972). Such incidents occurred at the rate of about 0.34 per reactor year. In one such incident in 1976, a spurious signal withdrew Gang I rods 0.2 foot in 15 seconds. The withdrawal by the control computer is not continuous and is terminated when the temperature signal reaches the operating limit. In all of these incidents, no damage to the fuel and no radioactivity release has occurred.

G.2.1.4 Gang-rod withdrawal at low power

TC No unwanted continuous gang-rod withdrawal has occurred during low-power operation at the Savannah River Plant.

G.2.1.5 Control-rod melting

No control-rod melting has ever occurred at SRP. There have been several cases where the control-rod housing was not seated which reduced the cooling of the rods (Du Pont, 1983), but no rods were damaged.

G.2.1.6 Fuel assembly melting

Fuel melting has never occurred in the SRP reactors. During irradiation of the Californium-I high-flux charge in 1969 and early 1970, several fuel assemblies experienced cladding failures that resulted in releases of activity to the moderator (Du Pont, 1983). An estimated 40,000 curies of fission products entered the moderator and were subsequently removed by the moderator purification system. The failures were caused by improper allowance for assembly rib effects in heat transfer calculations. A small amount of noble gases was released into the blanket gas and subsequently discharged to the atmosphere. The release created no undue safety hazard. Noble gas monitors were installed in each operating reactor in 1972; any releases would now be recorded.

G.2.1.7 Target-assembly melting

No target-assembly has melted at SRP. While reductions in assembly coolant flow have been observed, all such reductions have been slow enough to enable shutting down the reactor without melting the assembly.

G.2.1.8 Fuel-reloading error

No reloading errors have occurred that have caused significant approach to criticality. One misloaded assembly was detected and corrected before reactor operations began.

G.2.2 Flow reduction

G.2.2.1 Loss of D_2O coolant pumps

The abrupt and total loss of offsite (commercial) a.c. power has occurred only four times in the history of Savannah River Plant, the longest being 38 minutes in duration. There are 11 onsite generators that normally supply about half of the electrical power to the 115-kilovolt grid. The complete loss of all 11 onsite generators has never occurred. Loss of a.c. power to the D_2O pump motors has been experienced at Savannah River Plant (Du Pont, 1983). The protective systems, including the independent backup d.c. motors, prevented any potentially damaging accidents.

A project currently underway will provide automatic load shedding following a loss of offsite power. This will prevent the resultant loss of the onsite generators so that power will continue to be supplied to the 115-kilovolt grid and to associated vital equipment.

G.2.2.2 Loss of H_2O pumps

Loss of all a.c. power to the H_2O pump motors has never been experienced at Savannah River Plant (Du Pont, 1983); however, a partial loss has occurred. The protective systems, including gravity flow backup cooling, prevented potentially damaging effects.

G.2.2.3 Pump shaft break

A drive shaft break between the D_2O pump impeller and the flywheel has never occurred at SRP. D_2O pump shafts are inspected during periodic overhaul of the pumps.

G.2.2.4 Rotovalve closure

Rotovalves are installed in the six external loops of D_2O circulation system between each of the 12 heat exchangers and the reactor plenum. Spontaneous closure of rotovalves has occurred on several occasions (Du Pont, 1983). On one occasion both rotovalves in a single system closed simultaneously at full power. However, a closure involving more than one external loop has not occurred, nor has any significant loss of D_2O circulation occurred due to rotovalve closures. No core damage or release of radioactive material occurred in any of the above incidents.

G.2.2.5 Flow reduction in a single assembly

The gradual reduction in flow could occur to a single coolant channel of a fuel or target assembly caused by cladding failure. Such failures accompanied by flow reduction have occurred at Savannah River Plant: five target failures in the last 3 years of operation of three reactors. The protective system was adequate to mitigate the consequences of this accident and prevent fuel melting and the release of radioactivity.

G.2.2.6 Loss of control-rod cooling

Control-rod cooling is accomplished by D_2O upflow through the septifoil (control-rod housing) from a header supplied by lines from the heat exchangers. The header pressure (and therefore flow) decreased on rare occasions, and the header pressure scram circuit operated properly to shut down the reactor. There were two cases of septifoils being unseated for long periods of time resulting in boiling of the coolant in the septifoils (Du Pont, 1983). Even then the control rods were not damaged and no radioactivity was released.

G.2.2.7 Loss of blanket gas pressure

Slow leaks of blanket gas have occurred without damage to the reactor or release of radioactivity. No rapid drop in blanket gas pressure has ever occurred.

G.2.2.8 Loss-of-coolant accident

No loss-of-coolant accident (LOCA) has ever occurred at Savannah River Plant. Furthermore, no fuel melting is anticipated in any credible LOCA. Small leaks from seals, flanges, and valves occasionally occur. The D_2O makeup system can replace D_2O at rates up to 15 liters per minute, and it is planned to increase these capabilities to 75 liters per minute. Most of the leak rates experienced at Savannah River Plant have been less than 2 liters per minute and only two leaks have approached 75 liters per minute (Joseph et al., 1970; Nomm, 1983).

G.2.2.9 Loss of D_2O circulation

Loss of a.c. power to the D_2O pump motors has occurred in the past (Du Pont, 1983). A complete loss of D_2O circulation has never occurred due to the backup d.c. motors operated by the independent diesel generator for each system.

G.2.2.10 Loss of cooling during and after assembly discharge

The discharge machine cooling systems have always worked when required. In about 300,000 assembly discharge operations, there have been instances in which the discharge operation was interrupted and emergency cooling was required. No fission products have been released because of failure of the cooling system during assembly discharge operations. In 1969, 100,000 curies of antimony and tellurium isotopes were released to the reactor building of which 0.003 curies were released to the environment, when an antimony-beryllium source rod melted while being held in air (Olliff, 1970; Brown, 1971; AEC, 1973). This accident was the result of administrative error; appropriate procedural controls have been implemented. This was the only time that the confinement system was required to function at SRP. No irradiated assembly has been dropped at SRP during discharge operations.

G.2.3 D_2O moderator spill

A sizable spillage of D_2O moderator occurred once during the early stages of operation. In July 1954, over a 12-hour period, an estimated 45,000 liters TC

TC of D_2O moderator overflowed seal leakage collection pots in the motor room in L-Area because two valves inadvertently were left open. An estimated 38,000 liters were recovered from sumps in the building. The moderator lost contained insignificant amounts of tritium because the reactor had achieved initial criticality only 15 days before the spill. In more recent history, spills of 380 to 3800 liters have occurred at a rate of about once per year.

G.2.4 Summary

The evidence of accident frequency is a useful indicator of future probabilities. As shown in the preceding sections, there have been no significant reactor accidents at SRP.

G.3 MITIGATION OF ACCIDENT SEQUENCES

A summary of safety features of the L-Reactor and of the SRP site that act to mitigate the consequences of accidents are provided in the following subsections.

G.3.1 Design features

L-Reactor is essentially identical to the other SRP reactors currently in operation. Each unit contains features designed to prevent accidental release of fission products from the fuel and targets and to lessen the consequences should such a release occur. These accident-preventive and mitigative features are referred to as shutdown systems, engineered safety systems, support systems, and a unique reactor power limit system. To establish design and operating specifications for L-Reactor, postulated events referred to as anticipated transients and accidents are analyzed.

Ward et al. (1980) studied the effects of neutron irradiation on the stainless-steel SRP reactor vessels and concluded that the vessels have experienced no significant deleterious effects. Furthermore, no deleterious metallurgical effects are expected in the future because neutron fluence has been accumulating very slowly since operations with lithium-blanketed charges began in 1968. At the temperatures and neutron fluences experienced by SRP reactors, yield strength and tensile strength increase; ductility and impact strength decline with increasing neutron fluence. The temperature of the SRP reactor tank walls is too low for significant swelling to occur from voids or gas bubbles resulting from neutron irradiation. In addition, experimental evidence has demonstrated that a relaxation of preirradiation stresses also results from fast neutron fluence. The reactor tanks are not expected to be affected by fatigue damage because the stresses encountered in the low-temperature, low-pressure system are well below endurance limits, and vibration from process-water circulation has been reduced to a low level. CU-3

G.3.1.1 Limit system

L-Reactor will operate at limits which are determined by a number of accident analyses for each reactor charge. These limits define the conditions at which the reactor can operate and still allow the protective instrument system to terminate any anticipated transient without exceeding prescribed damage criteria (for example, an approach to fuel melting). Three such limits are established, and the reactor is operated at the lowest of them.

1. The first limit is defined by assuming that the safety-rod scram--the primary emergency shutdown system--works on demand. This is the "transient protection" limit.

2. The second limit is defined by assuming that the safety-rod system fails and that an automatic backup system (called the automatic backup shutdown--safety computer, or ABS-S/C) is required to terminate the transient. This second limit defines the confinement protection limit, which is based on the criterion that the airborne activity confinement system not be damaged.

3. The third limit, the emergency cooling system (ECS) limit, is established by assuming a minimal level of emergency cooling system operability.

In principle, any of the three limits could be most restrictive; however, in practice and by design, the transient protection limit is usually the most restrictive. A more complete description of the SRP Limit System is given in the SAR.

Each plutonium-producing reactor charge is moderated and cooled by D_2O and has the same spacing between fuel and target assemblies. But changes in moderator and coolant temperature coefficients during the charge exposure time and changes in the average and relative fissile content of the fuel assemblies, among others, require that an accident analysis be made for each charge. Some of the analyses can be generic in nature (such as confinement protection limits), but the more important analyses, which generally fix the operating limits for the charge, are charge-specific. A summary of the analyses required for a charge is given in Table G-3.

The range of operating variables experienced during the 30 years of reactor operation at Savannah River Plant are given in Table G-4. The large ranges shown here demonstrate the flexibility available in a charge design. L-Reactor is currently scheduled to operate with a mixed-lattice, plutonium-producing charge, as shown in Table G-5.

G.3.1.2 Reactor shutdown systems

Several redundant systems operate to rapidly shut down the reactor, if necessary. The primary reactor shutdown mechanism is safety and control rod insertion, activated by the scram instruments or manually; the secondary shutdown

Table G-3. Summary of data and analyses for each reactor charge

Data and analysis	Analysis required
Technical limits and transient-protection limits for assembly effluent temperature	Yes
Technical limits and transient-protection limits for film-boiling burnout risk	Yes
Technical limits and transient-protection limits for reactor effluent temperature	Yes
Confinement protection limits for accidents with assumed inoperative safety rods	Yes
Criticality during withdrawal of safety rods	Yes
Shutdown system worths	Yes
Primary and secondary scram circuit designation	Yes
Natural convection cooling	Yes
Mechanical and metallurgical properties during discharge	Yes
Protection against criticality during charge-discharge operations	Yes
Storage and handling of enriched uranium assemblies	Yes
Shield heat loads	Yes
Emergency cooling of irradiated fuel	Yes
Heat removal from safety and control rods	Yes
Temperature and void coefficients	Yes
Startup accident analysis	Yes
Xenon oscillations	Yes
Compliance with Technical Standards and safety analyses	Yes

system is the supplementary safety system (injection of gadolinium nitrate), activated automatically by the gang temperature monitor and the safety computers, or manually.

Safety rods

The safety rods provide a primary rapid-shutdown mechanism for the reactor and thus prevent core damage. Upon receipt of a scram signal, the safety rods drop into the reactor core in about one second. L-Reactor has 66 safety rods made of cadmium, an effective neutron absorber.

Control rods

When a shutdown (scram) signal is received, in addition to the safety-rod drop, the 61 clusters of control rods are automatically driven into the reactor. The control rod system is designed such that the reactor is subcritical

Table G-4. Range of operating variables in SRP reactor charges

Variable	Range
Thermal neutron flux (full power)	5×10^{13} to 7×10^{15a} n/(cm^2)(sec)
Reactor power (full power)	650[a] to 2915 MW (thermal)
Assembly power	Up to 21 MW (thermal)
Prompt coefficient	$+2 \times 10^{-5}$ to -15×10^{-5} k/°C[b]
Moderator coefficient	-1×10^{-5} to -35×10^{-5} k/°C
Reactivity in control rods	Up to 30% k at cycle beginning; to 0.5% k at cycle end
Reactivity in xenon after shutdown	Up to 60% k
Irradiation cycle length	4[a] to 400 days
Fuel heat flux	Up to 914 watts/cm^2
Total D_2O flow	341 to 619 m^3/min
D_2O flow per assembly	Up to 66.2 ℓ/sec
Assembly coolant velocity	Up to 22 m/sec

[a] Special high-flux charge.

[b] Overall temperature coefficient (prompt plus moderator) is always negative. k is the multiplication factor of the reactor--effectively the number of neutrons present at the end of a neutron generation for each neutron present at the start of that generation.

Table G-5. Nominal values of operating parameters for typical L-Reactor charge

Operating parameter	Plutonium producer (mixed-lattice)
Principal fuel	Enriched uranium
Principal target	Depleted uranium
D_2O flow (m^3/min)	
Per fuel	1.59
Per target	0.89
Total reactor	587
D_2O velocity (m/sec)	
Fuel	5.8
Target	7.6
H_2O flow (m^3/min)	672
Power, MW (thermal)	
Per fuel	7.4
Per target	2.5-4.8
Total reactor	2350
Fuel surface heat flux, watts/cm^2	220
Assembly effluent D_2O temperature, °C	
Fuel	113
Target	85-110

when the control rods are inserted and the safety rods are withdrawn. The control rods can be driven in singly, or by a gang drive; the rate of insertion is less rapid than that for the safety rods.

Scram instruments

The scram circuits monitor reactor operation and will cause the safety rods to fall and the control rods to drive in. The scram instruments for a particular variable (e.g., neutron flux, coolant pressure, etc.) are set to produce a scram at the operating limit imposed for safe operation. A reactor scram at the setpoint will prevent damage to the fuel and the reactor. The scram, or shutdown instruments, installed in L-Reactor are listed in Table G-6.

Table G-6. Automatic scram circuits

Variable measured	Number provided[a]
Neutron flux (High-level flux monitor)	Four
Operability of neutron flux monitors	One
Rate of change of neutron flux (period)	Two
D_2O plenum pressure	Two
Blanket gas pressure	Two
H_2O supply header flow	One for each of two H_2O headers
Individual heat exchanger H_2O flow	One for each of 12 heat exchangers
Control rod coolant supply pressure	One
Moderator level	One
D_2O pump a.c. power supply	One for each of six pump motors
Assembly coolant flow	600 in L-Reactor
Assembly average effluent temperature[b]	600 in L-Reactor
Control system power supply	One
Seismic activity	Two of three coincidence
Operability of safety computers	One

[a] A manual scram circuit is also provided.

[b] Four thermocouples in each of 600 monitor pins provide maximum and average assembly effluent temperature. Monitoring and scram signals are provided for each of the 2400 monitoring thermocouples.

Supplementary safety system

The supplementary safety system (SSS) is a fully independent system that acts as a backup shutdown system. The SSS can be actuated manually or automatically if safety rods fail to shut down the reactor. When the system is activated, gadolinium nitrate, an effective neutron absorber, is injected into the moderator. The SSS is designed such that the reactor will be subcritical even if all safety and control rods are in the fully withdrawn condition. The system has redundant tanks, piping, and valves.

Automatic backup shutdown-safety computer (ABS-S/C)

The ABS-S/C is a backup system that consists of two computers, each of which monitors an average of 300 assembly effluent temperatures and flow every 0.36 second, and which will actuate the SSS to shut down the reactor if the safety rods fail to reduce reactor power in the event of a scram. It will terminate all identified transients for which the primary shutdown mechanism, safety-rod insertion, fails.

Automatic backup shutdown-gang temperature monitor (ABS-GTM)

The ABS-GTM is a second automatic backup shutdown system that is independent of the safety-rod scram system. The sensors are dual monitor pin thermocouples in three fuel assembly positions associated with each of the three gangs of control rods. The sensors are set to actuate the SSS when monitored assembly effluent temperatures approach specified limits.

G.3.1.3 Engineered safety and support system

In addition to the systems discussed above, there are a number of other engineered reactor safety and support systems which help mitigate the consequences of an accident. Several of these systems are described below.

Emergency cooling system (ECS)

The ECS is designed to remove decay heat following a reactor shutdown by the direct addition of light water to the reactor core in case of loss of heavy-water coolant or circulation. Four sources of light water are available, at least two of which have to be online for reactor operation.

1. A diesel-driven booster pump which supplies H_2O from the 95-million-liter 186-L basin.
2. A header with a diameter of 107 centimeters pressurized by five pumps drawing H_2O from the 95-million-liter basin.
3. Another header with a diameter of 107 centimeters pressurized by five additional pumps.
4. A line directly from the river water supply line, pressurized by the river water pumps.

The ECS is actuated automatically as liquid level decreases in the reactor tank or manually as abnormal conditions dictate. When the ECS is actuated, the diesel-driven booster pump starts, and valves are automatically opened or closed to couple the reactor with the primary sources of light water. Borated water from the storage header will be injected into the reactor first, to prevent a reactivity transient when the light water displaces D_2O in the reactor core.

Water removal and storage

If the heavy-water system ruptures, the heavy-water and light-water emergency cooling water would flow to sump pumps in the basement of the reactor building. The sump pumps deliver the water first to a 225,000-liter underground tank; the flow is then diverted to a 1.9-million-liter tank that sits in the 190-million-liter emergency earthen basin. Some of the water on the 0-level process room floor would drain directly to the 1.9-million-liter tank. If this tank should become full, the additional water bypasses the tank and flows into the emergency basin. The 1.9-million-liter tank is vented to the activity confinement system in the reactor building. Because the volume of the 1.9-million-liter tank represents about 10 times the reactor D_2O volume, no moderator is expected to reach the emergency basin. Hence, no tritium or fission product is expected to be carried into this basin.

Airborne activity confinement systems

L-Reactor has an airborne activity confinement system. In the event of an accident, airborne fission products may be released into the reactor room, and possibly into the heat-exchanger bay or the pump room. As shown in Figure G-1, the air from these areas is exhausted through a set of confinement filters before it is released to the stack. During normal operation, the process areas are maintained at a pressure that is lower than the pressure of the external atmosphere to ensure that all air from the process areas is exhausted through the activity confinement system.

Three large centrifugal fans exhaust the air from the process areas. Two of these fans normally are online, but only one is necessary to maintain the negative pressure. The air flow from a single fan is enough to prevent the overheating of carbon filters that might be caused by high retention of radioactivity after a severe accident. The three fan motors can be powered simultaneously by two electric sources:

1. The normal building power through at least two substations
2. The emergency building power from diesel generators.

In addition, each of the three fans has a backup motor, any two of which can be powered by dedicated diesel generators. Exhaust filters remove moisture, particulates, and halogens. The filter banks are enclosed in five separate compartments; three to five of these compartments are normally online at one time. Each compartment can be isolated for maintenance and testing; each contains the following filter banks, in the order of air-flow treatment:

1. Moisture separators, designed to remove about 99 percent of entrained water (spherical particles measuring 1 to 5 microns) to protect against a significant blinding of the particulate filters.

2. Particulate filters, designed to retain more than 99 percent of all particles with diameters of 0.3 micron or larger.

3. Activated carbon beds that use an impregnated carbon to retain halogen activity if an accident were to occur. Special impregnants have been developed to improve the retention of organic iodide compounds. The effectiveness of these filters is discussed in Section G.5.1.2.

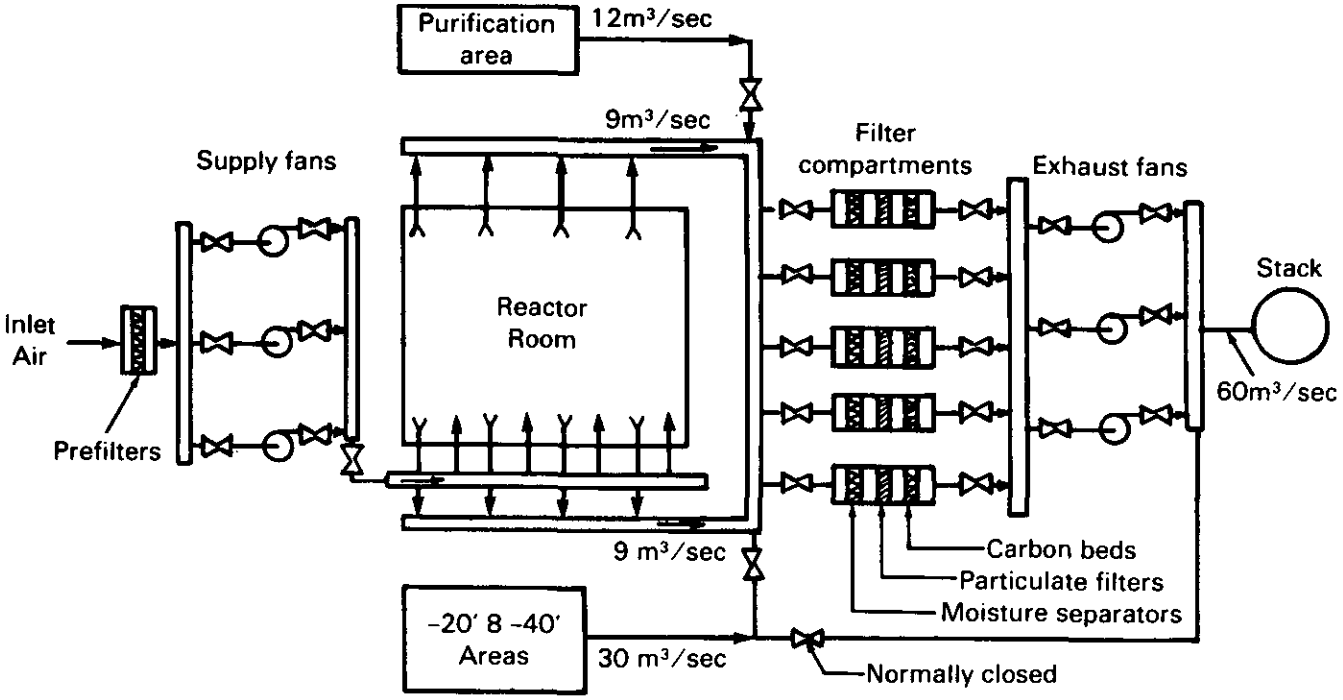

Figure G-1. Reactor activity confinement system.

Confinement heat removal system

A confinement heat removal system (CHRS) is provided to prevent failure of the confinement system in the event of a postulated meltdown of a reactor core. Such a meltdown could occur from the nuclear decay heat if both normal cooling and emergency cooling fail. The CHRS provides limited water flooding on the 40-foot-level floor to cool any molten core material that may penetrate the reactor tank or process pipes.

The source of water for the CHRS is the disassembly basin. Only the top 1.4 meters of disassembly basin water can be drained onto the 40-foot-level floor. The remaining basin water still maintains adequate shielding and cooling for fuel elements stored in the basin. There is a system to provide makeup water to the disassembly basin from two sources.

Reactor room spray system

A system is provided in the reactor room to spray water on an irradiated assembly if one is accidentally dropped during unloading operations. This system consists of a header with twelve groups of fixed spray nozzles mounted on the reactor room wall. The spray pattern from these nozzles covers the area traversed by the discharge machine. Each spray nozzle group has its own actuation valve.

Component handling-cooling during discharge operations

During the interval between removal of irradiated fuel (or targets or other heat-producing assemblies) from the reactor and insertion in the cooling basin, the irradiated assemblies are cooled by water. Five sources of water are available to the discharge machine through four independent paths. Except at the final point of discharge to the assembly, each system has separate hoses, pipes, and actuation valves.

In normal practice, primary H_2O cooling is started automatically as soon as the assembly is withdrawn from the reactor and the water pan swings under the assembly. If primary H_2O flow stops, a secondary H_2O source is switched on automatically. Primary and secondary D_2O cooling is automatically available if the assembly is partially in the reactor, or if the assembly is over the reactor and the water pan does not move under the assembly.

The reactor room spray system is available if an assembly is dropped onto the floor of the reactor room. Assemblies are not discharged unless the maximum decay heat generation rate is less than could be dissipated by the discharge machine cooling water or by natural convective cooling in the disassembly basin if the assembly is dropped and lies in a horizontal position.

G.3.1.4 Electric power

Electric power from the SRP power grid is supplied to L-Area by two 115-kilovolt transmission lines. These lines enter L-Area from two directions. There are also three 30,000-kilovolt-ampere transformers in the area that are connected to the 115-kilovolt grid. Each transformer can carry the L-Area load.

Emergency power for the reactor building is furnished by diesel generators. Two 1000-kilowatt a.c. generators supply emergency power to the reactor building if normal power fails. Eight 103-kilowatt d.c. generators supply power to the process pump motors that maintain the cooling-water flow to the shutdown reactor if the normal a.c. power fails; six of these generators are normally operated at all times, and the remaining two are on standby. Four other diesel generators are located throughout L-Area and provide backup power for ventilation fans, street lights, and other equipment.

G.3.1.5 Process and effluent monitoring

All gaseous radioactive releases through the stack are monitored continuously by gamma spectrometry. Stack-effluent tritium is monitored by two ion chambers that operate in parallel. Moisture is removed from the air to one of the chambers to provide a differential current between the chambers. A continuous sampling technique with daily quantitative analysis is also used. All other air and water samples are monitored routinely; quantitative release records are kept. Above-normal activity levels are investigated to locate the source so the condition can be corrected.

Samples are analyzed routinely to quantify the key surveillance radionuclides from the following sources:

1. The moderator
2. The stack exhaust air
3. The effluent heat-exchanger cooling water
4. The disassembly-basin effluent purge water

G.3.2 Site features

G.3.2.1 Site location

The Savannah River Plant occupies an approximately circular area of about 800 square kilometers. The L-Reactor site is located in the south-central portion of the Savannah River Plant.

G.3.2.2 Site description

The predominant site feature that would mitigate the consequences of an accident at the L-Reactor is the distance of 9 kilometers to the nearest SRP boundary. Although South Carolina Highway 125 is only 5 kilometers from L-Reactor, there are procedures for stopping traffic and clearing all personnel off the highway within a short time of any incident at the SRP.

G.3.3 Emergency preparedness

G.3.3.1 Emergency planning - onsite

An onsite Emergency Operating Center (EOC) is maintained at SRP to provide immediate and informed response to any site accidents. The responsibility for emergency response at the plant facilities (including L-Reactor) within the Savannah River complex is clearly defined (DPSOP 67 and 129). Adequate staffing to provide initial facility accident response in key functional areas is maintained at all times. Timely augmentation of response capabilities is available and the interface among various onsite response activities is clearly specified (DPSOP 129).

Patrol EOC personnel operate from the communications room 24 hours a day, 7 days a week, using radio and telephone equipment that links all patrol installations throughout the plant. During emergencies, specialized communications equipment is operated to contact production control rooms, local law enforcement agencies, state and Federal radiological agencies, state and local government officials and others, as required by the specific emergency.

Accident emergency classifications and action-level schemes have been established (DPSOP 129 and 175). There are provisions for prompt communications among principal response organizations and emergency personnel (DPSOP 129).

The EOC is equipped with self-contained power and service facilities and a shelter capable of housing 20 persons for 30 days under emergency conditions. The center has blast doors, air locks, and an emergency escape hatch. The EOC will withstand blast pressures to 15 psi and provides a radiation protection factor of up to 6000. It can be completely isolated from the outside environment in about 5 minutes. The EOC is also equipped with air filters for emergency use. A sand filter system is underground in a blast-resistant concrete structure. There are also two carbon filters in series. The first unit will absorb chemical warfare gases; the second unit will absorb radioactive iodine.

The EOC shift crew and meteorological operations center contains radio and telephone equipment for all necessary communications in handling response to an emergency condition (DPSOP 129 and 307). Equipment is also available for monitoring a release from the reactor areas and obtaining critical data from instrumentation in an uninhabited reactor building. The Weather Information and Display (WIND) system terminal provides facilities to accurately predict downwind hazards from chemical and radioactive releases. Maps and plotting equipment allow a visual organized presentation of the data for EOC staff personnel. Equipment is also available for monitoring radiation and chemical hazards to personnel occupying the EOC.

The EOC staff room contains a comprehensive communications network permitting the DOE-SR and Du Pont staff to monitor communications on the patrol and emergency radio networks and also to monitor telephone conversations between the Area Emergency Coordinator at the incident site and Production and Technical Management personnel in the EOC. Copies of Emergency Procedures, pictures of vital process equipment and process schematics, maps, television monitors and a number of other visual aids are available for use by EOC staff liaison personnel in keeping the EOC staff informed concerning the status of an emergency. Future information and communications improvements, either authorized or planned, include a remote detection and control (REDAC) terminal from the reactor areas and a plantwide cable television network that will provide video and audio communications between the Plant Production areas and the EOC.

During an emergency situation the organizational and emergency procedures and responsibilities are clearly defined and shared between Du Pont and the Department of Energy (DOE). Procedures for notification of emergency occurrences to state and county officials exist through current memoranda of understanding.

An Offsite Communications Center (OCC-A) is also maintained in Aiken, South Carolina. The purpose of the OCC-A is to assure a communications link with Savannah River Plant if (1) highways to SRP are impassable, (2) telephone lines are inoperative due to overloads, or (3) the Emergency Operating Center is not accessible. The OCC-A also provides an offsite location for EOC staff members or key personnel during a national or local emergency.

In the event of emergency assignment to OCC-A, Du Pont and DOE-SR management representatives would serve as liaison between the EOC staff and offsite personnel, using a direct telephone line from OCC-A to the Emergency Operating Center. A monthly check of this line is made to ensure operability. The OCC-A also contains a radio with SRP Patrol, SRP Emergency, and DOE-SR net channels. Maps, copies of emergency procedures, and other visual and briefing material are also located in the OCC-A.

As required, the OCC-A can serve as a location for use by DOE-SR Office of External Affairs personnel to brief media representatives. It could also be employed as a temporary office location for a small number of representatives from state and Federal agencies, or for local government officials.

The Dwight D. Eisenhower Army Medical Center, Ft. Gordon, Georgia, is also on call to respond to the medical requirements of the SRP (DPSOP 129). All other facilities, communications, and emergency resources are maintained within the Savannah River complex (DPSOP 129 and 175).

A minimum of four emergency training exercises are conducted annually to test and evaluate the performance of EOC personnel and equipment.

G.3.3.2 Emergency planning - offsite

South Carolina and Georgia, and their respective counties of Aiken, Allendale, Barnwell, and Burke and Richmond have existing Emergency Response Plans in varying degrees of completeness. State and county officials are being assisted by DOE in fully developing their respective Emergency Response Plans. These plans are discussed further in Appendix H.

G.3.3.3 WIND system

The Weather Information and Display (WIND) system is an automated emergency response system for real-time predictions of the consequences of liquid and atmospheric releases from the Savannah River Plant (Garrett, 1981). The WIND System has been developed over the last 10 years specifically for use at Savannah River Plant. Site-specific features of the system include meteorological towers at each production area that are instrumented at the stack height, computer terminals at each production area that can be used to run the emergency response codes remotely, codes which use empirical information on atmospheric diffusion and deposition gathered at Savannah River Plant (Carlson et al., 1982; Buckner et al., 1975), and stream transport and diffusion codes that have been calibrated with dye tests in the SRP streams (Garrett and Murphy, 1981).

The SRP Health Protection Department staffs all production areas 24 hours a day with technicians who are trained to run the WIND system emergency response codes in addition to the four meteorologists, a computer system manager, a field engineer and 3 technicians who comprise the basic team that operates the WIND system.

Computer codes have been developed which allow display of latest or archived meteorological data from the SRP towers or Automatic Forecasting and Observation System (AFOS); trajectory, concentration, deposition, and dose calculations for atmospheric releases; concentration calculations for releases to SRP streams; and estimates of reactor core melt based on stack monitor data. Dose calculations include inhalation doses and whole-body doses caused by gamma radiation from noble gases and iodine. Atmospheric transport and diffusion codes range in complexity from Gaussian trajectory models (Cooper and Rusche, 1968) that can be run in less than 5 minutes, to two- and three-dimensional codes that require about 1 hour of computations.

G.4 ACCIDENT AND IMPACT ASSESSMENT

As a means of assuring that L-Reactor features meet acceptable design and performance criteria, the potential consequences of a number of postulated transients have been evaluated. These postulated transients or accidents are used to help establish system design characteristics and operating limits. They are described in the following subsections. These subsections also describe the results of analyses used to estimate the possible impacts and risks associated with a group of four postulated severe accident sequences--with a low probability of occurrence--that could release significant radioactivity to the environment. The consequences to persons offsite are described in Section G.5. The potential radiological consequences for all of these postulated incidents cover a considerable range of values depending on the particular course taken by the accident and the conditions, including meteorology, prevalent during the accident.

G.4.1 Postulated transients and accidents

The postulated transients and accidents considered in the safety analysis and evaluation of L-Reactor include all incidents listed in Table G-1. Four hypothetical severe accidents are specified to cover a spectrum of credible events postulated to release significant quantities of radioactivity. |TC

All reactor-related accidents share the common characteristic of too much power for too little cooling. Accident analyses can be grouped into three broad classes.

1. Reactivity addition (equivalent to removal of neutron absorber) that increases reactor power or power in a local region of the reactor.

2. Flow reduction, caused by loss of pumping power, reduction of circulation, or loss of coolant, that reduces the cooling capacity of the reactor or individual heat-producing assemblies. The loss of moderator will be considered in this class.

3. Non-nuclear types of accidents that are not directly related to rapid changes in the reactor conditions.

For all of the accidents analyzed, the reactor would be shut down by the primary or redundant shutdown systems before:

1. Reactor tank is damaged, or the
2. Confinement system is breached.

The radiological consequences of incidents often called anticipated operational occurrences, fall within limits of normal operational releases of radioactivity. The key postulated transients in this class are all incidents listed in Table G-1 with the possible exceptions of incidents 4 through 7, 16, and 18. Many are credible but have a very low likelihood of occurrence. Incidents 1, 2, 7, 12, 13, 14, and 15 have a nontrivial occurrence record among all of the SRP reactors.

The following discussion addresses each transient in Table G-1.

G.4.1.1 Single control-rod withdrawal

The reactor is assumed to be operating at full power at operating limits. The control rod withdrawn is adjacent to the hottest assembly in the reactor. Withdrawal is at the maximum rate possible requiring two minutes to move from the full-in to the full-out position. The hypothesized withdrawn rod is near the edge of the reactor, thus causing a radial power tilt as well as an increase of local reactor power.

Occasional unwanted control rod motion is expected to occur at L-Reactor. Reactor and hottest assembly powers would increase until scram or cessation of rod motion. In a limiting case, the reactor power increases almost linearly at a rate of 0.4 percent per second, while the hottest assembly power increases at about 1.9 percent per second. Primary scram is based on the assembly coolant |TE temperature monitor in the hottest assembly. Secondary scram is based on nearby assembly coolant temperature monitors or high-level flux monitors. The accident is analyzed for every reactor charge to establish normal operating limits and is analyzed generically to establish confinement protection limits. The operating limit on assembly coolant flow and coolant temperatures is set so that a reactor scram would prevent the coolant from reaching the saturation temperature. Under this condition there would be no damage to fuel or reactor, and radioactivity would not be released to the environment.

G.4.1.2 Partial control-rod movement

The partial rod is assumed to be centered axially in the reactor at the position of maximum absorption. The rod drives in or out at the maximum speed of 0.136 and 0.118 foot per second, respectively. The partial rod is in a control cluster near the side of the reactor, thus causing radial power tilting. Axial power distribution changes as well as radial power distribution changes will occur.

Unwanted partial rod motion is expected to occur occasionally. The scram bases are the same as for single control-rod withdrawal. Reactor and local power increases are less than or equal to those caused by unwanted full rod withdrawal. Analysis considerations are the same as for full rod withdrawal (Section G.4.1.1).

G.4.1.3 Gang-rod withdrawal at full power

Groups of control rods called gangs are moved together in normal reactor operation. Gang I consists of the inner 19 clusters of control rods, Gang II the next ring of 18 control clusters, and Gang III the outer ring of 24 clusters. The reactor is assumed to be at full power at operating limits. A gang of control rods moves out continuously at maximum speed. Significant radial power perturbation cannot occur.

Unwanted continuous gang withdrawal is not expected to occur. Short-term withdrawal, because of spurious signals in the control computer, might occur. Reactor power and hottest assembly powers would increase until scram or cessation of rod motion. Reactor power would increase at a rate of 1.2 percent per second, while the hottest assembly power would increase at 1.7 percent per second. Primary scram is based on assembly coolant temperature monitors. Secondary scram is based on high-level flux monitors (can be the primary instrument). The gang-rod-withdrawal accident is analyzed for both transient protection limits and confinement protection limits. This accident is often the most restrictive in setting reactor operating limits.

G.4.1.4 Gang-rod withdrawal at low power

It is assumed that inadvertent gang withdrawal occurs three decades (a factor of 1000) below full power (at 1 to 3 megawatt thermal). The inventory of xenon-135, which has a very large neutron cross section, is at or near maximum. At full power, xenon-135 absorbs about 3 percent of all neutrons produced in the reactor, but when the reactor is shut down, the inventory of xenon-135 increases by decay of iodine-135 to several times its full power inventory. If the reactor were restarted with a large inventory of xenon-135, its burnup would add reactivity that could exceed that caused by control rod withdrawal. Temperature coefficients do not provide sufficient negative feedback to prevent a rapid power rise until the reactor power reaches levels within a decade of full power.

This gang rod withdrawal at low power is expected to have the same frequency of occurences at full power. Reactor power would increase at rates greater than for gang withdrawal at full power, becuase of the xenon-135 burnup. Primary scram is based on high-level flux monitors and period (rate of flux increase) monitors. Secondary scram is based on assembly coolant temperature monitors at about 50-percent full power. The accident is analyzed for each type of charge. For certain high-level flux charges, restrictions are placed on the time for xenon to decay before the reactor can be restarted.

G.4.1.5 Control-rod melting

If, based on control-rod heat flux, control-rod melting is possible for the reactor charge design being analyzed, it is postulated that:

1. Control-rod heating and melting occur adiabatically
2. The neutron-absorbing material disappears from the reactor as soon as melting occurs
3. Partially inserted rods are severed at the midplane by melting, allowing the lower part to drop
4. The control rods melt in clusters on the outside of the reactor

Control rods can melt because of possible reduced cooling, provided they have sufficiently high power density. Reactor power increases are similar to those for single-rod withdrawal accidents, although the rate of reactivity addition is different. Effluent temperature monitors for assemblies in the affected control cluster would cause a scram. For a septifoil with no forced flow (unseated), control-rod melting has been analyzed to begin with film-boiling burnout at a heat flux of 102 watts per square centimeter. Typical maximum heat flux values for current charges are 57 to 74 watts per square centimeter. The control-rod melting accident is not considered in establishing limits if the maximum heat flux in the charge is less than the 102 watts per square centimeter value calculated to be required for control-rod melting.

G.4.1.6 Loss of target

The analysis of a loss-of-target accident is an effort to conceive of all possible means by which reactivity could be added to the core. The postulated loss of target is the consequence of an extremely improbable loss of cooling to only a single target and should be considered in that context. It is assumed that an abrupt reduction in coolant flow occurs in a high-power target. No known mechanism exists to cause such a reduction in flow. The target assembly is assumed to melt, whether the reactor is shut down immediately or not. The target material disappears from the reactor as soon as the target melts, which increases reactivity. If a high-power target assembly should melt, reactivity could be added at a rate greater than that for control rod or gang rod withdrawal. The flow monitor for the afflicted target assembly would be the first scram instrument to respond. The secondary scram circuit would be the assembly coolant temperature monitor. The course of the accident would be trivial if the safety-rod scram system performed as designed. If the safety-rod scram should fail, core damage would be prevented by the automatic backup systems.

Loss-of-target accidents are not considered in deriving transient protection limits because the postulated large, and abrupt, loss of flow is considered so improbable. More realistic reductions in flow to individual assemblies are considered for operating limits. The loss-of-target accident is considered for conservatism in establishing confinement protection limits.

G.4.1.7 Loss of fuel

The analysis of a loss-of-fuel accident, like the loss-of-target accident, is an effort to identify all conceivable reactivity addition transients independent of currently accepted credibility arguments. Again, the assumption is made that a sudden, abrupt loss of flow (for which no initiating mechanism has been identified) occurs to a fuel assembly. The fuel assembly melts, and some of the molten debris from the uranium-aluminum alloy fuel may be entrained and reach the moderator where it would then be exposed to a higher neutron flux than in its usual pre-melt condition. The exposure would cause a temporary increase in reactivity, until the debris is swept from the reactor core. Simultaneously, steam voids formed in the moderator around the fuel particles would decrease reactivity.

The primary scram instrument is the assembly flow monitor. Secondary scram instruments are the high-level flux monitors and assembly temperature monitors. Even with the conservative assumptions used for this accident, the calculations to assess this accident indicate that the primary and backup shutdown systems provide adequate protection.

G.4.1.8 Reloading error

A reloading error is the basis for one of four hypothetical events postulated to cover the spectrum of accidents that could have a significant impact on the environment.

The reactor is shut down and the charge-discharge operation is in progress in a mixed-lattice charge. It is assumed that an error is made when irradiated targets are discharged from adjacent positions without charging fresh targets to these positions, or in spite of mechanical interlocks, fuel assemblies are charged to target positions. It is further assumed that charge design constraints have failed, and the reactor becomes supercritical.

The result of the postulated accident could be fuel melting and radioactivity release to the reactor building. The scram system is ineffective because the safety and control rods are already in the reactor. The Supplementary Safety System is much less effective than at full power because of the reduced moderator and coolant circulation rate required during charge-discharge operations. The neutron flux changes caused by reloading errors are highly localized and therefore the two fission counters external to the reactor core might not detect the error.

To help avoid this potentially serious accident, each reactor charge is analyzed to search for the worst possible reloading error. The charge is designed such that it does not become critical during this error. An improved monitoring system, consisting of six internal fission chambers, has been designed, tested, and installed in L-Reactor.

The course of a postulated power excursion caused by reloading errors has been calculated. The highly localized damage involves less than 3 percent of the core.

Reloading accidents are not considered in establishing normal operating limits because full-power parameters are not involved. Nor are they weighed against the conventional criterion for confinement protection because the reactor coolant system is open to the atmosphere during reloading. However, calculations have shown that the confinement system integrity is not seriously challenged by this accident.

G.4.1.9 Loss of D_2O coolant pump power

Loss of all offsite a.c. power is a credible event. The onsite a.c. power generation is insufficient for simultaneous full-power operation of all SRP reactors. Thus, it is assumed that loss of a.c. power could occur for any reactor, and further that a.c. power to the six D_2O coolant pumps is lost simultaneously. The d.c. motors to the pumps continue to supply power and would maintain flow at 29 percent of full flow. Flywheels between the pumps and motors slow the flow decay transient.

As the flow decreases, fuel and target assembly effluent temperatures increase. The increased water temperature produces a negative reactivity, which causes reactor power to drop slightly in the first 2 seconds. The first scram instruments to respond would be the two plenum pressure monitors. These are backed up almost immediately by the assembly coolant flow monitor.

The accident analysis is used to set both transient protection and confinement protection limits. The safety-rod scram would limit the maximum coolant temperature to a value at least 7°C lower than the saturation temperature. If the safety rods are ineffective, the ABS-S/C would limit coolant temperatures to about 5°C less than the saturation temperature. If both a.c. and d.c. power were lost (for which no mechanism has been identified), flow would continue to decay until either some pumping power is restored or emergency coolant is introduced. This accident is considered separately as the loss of D_2O circulation accident.

G.4.1.10 Loss of H_2O pump power

The loss of H_2O pump power is a credible event. It is assumed that electrical power is lost to the pumps supplying H_2O directly to the reactor heat exchangers. The H_2O flow decreases to 25 percent of normal sustained by gravity flow. Gravity flow is assured by the difference in elevation of the cooling water basin and the heat exchangers at -20 ft.

As a result of the decrease in H_2O flow, the temperature of the D_2O TE| leaving the heat exchangers and entering the reactor would increase. This would increase the D_2O outlet and fuel assembly effluent temperatures. Reactor power would decrease because of the negative temperature coefficient of the reactor charges. The fuel coolant temperatures change more slowly than for a loss of D_2O pump power. The scram instruments to respond first would be the 12 heat exchanger flow monitors, followed by the two H_2O header flow monitors and the fuel assembly effluent temperature monitors.

The accident is not used to establish reactor operating limits because the transients are slow compared to other flow reduction accidents. The temperature of the hottest assembly would be 19°C below the saturation temperature (coolant boiling) at shutdown caused by the ABS-S/C. The accident is used in establishing confinement protection limits.

Alternative forms of this accident have been postulated. Clearly, a partial loss of pumping power would yield a less severe flow transient than the total loss of power considered here. Plugging or breaking a line to an individual heat exchanger would be still less of a perturbation. A break in an H_2O supply header could, if the break were large enough, cause a more severe flow transient than loss of pumping power. The response of D_2O temperature to such an improbable abrupt and total loss of H_2O cooling has been calculated. It was found that effluent temperatures hardly change before a safety-rod scram (triggered by H_2O flow monitors) shuts down the reactor. If H_2O cooling is not restored, then the assembly and reactor effluent temperatures would eventually increase because of fission product decay heat. Manual actuation of the ECS would then be required, but the accident would be less severe than the loss-of-circulation accident. No melting would occur.

G.4.1.11 Loss of both D_2O and H_2O pumps

The possibility of simultaneous loss of a.c. power to both D_2O and H_2O pumps has been considered as an extreme extension of either of the accidents considered singly. However, analysis shows that the accident of D_2O flow reduction increases coolant temperatures so much more quickly than H_2O flow reduction that the two accidents are essentially independent. In the event of loss of both D_2O and H_2O pumps, coolant temperatures increase at the same rate as for loss of D_2O pumps only. Thus, the combined case is not considered in establishing operating or confinement protection limits.

G.4.1.12 Pump shaft break

This accident is conceivable but not likely to occur because of over 600 pump years of operation without failure and because of frequent inspections. It is assumed that a pump drive shaft breaks between the D_2O pump impeller and the flywheel when the reactor is at full power. The impeller is left free to rotate, which allows a reversal of flow through the pump.

If a shaft breaks, the fluid momentum drops to zero (and reverses) much more quickly than if a D_2O pump should lose power (because the energy stored in the flywheel would reduce the rate of decrease in flow). The resulting flow changes in the reactor are asymmetric--the fuel and target assemblies in the affected coolant sector have a greater flow reduction than other assemblies in the reactor. Some assembly flows reduce to 75 percent of normal in 2 seconds, while average assembly flows reduce to slightly greater than 80 percent normal. The primary scram instruments are the plenum pressure monitors, followed by the assembly flow monitors.

Analysis of the pump shaft break accident is used in deriving operating and confinement protection limits. The safety-rod scram would prevent the assemblies from melting. The maximum assembly temperature can exceed the boiling point if the safety rods fail to drop. Reactor limits are set such that if this happens, the steam generated does not produce a force great enough to lift the plenum. The steam generation lasts for too short a time to cause any assemblies to melt and release radioactivity.

Analysis of the case in which the broken pump shaft freezes and prevents the impeller from turning has been compared with the analysis in which the impeller is left free to rotate. The latter case produces the more restrictive limits.

G.4.1.13 Rotovalve closure

Although spurious rotovalve closure is possible and has occurred, the combination of closures specified for the postulated transient has never occurred and there is no known mechanism for an occurrence. Rotovalves are installed in the six external loops of the D_2O circulation system between each of the 12 heat exchangers and the reactor plenum. During normal, full-power operation, the rotovalves are fully open. During maintenance work, the rotovalves are fully closed to prevent loss of D_2O. It is assumed that the two rotovalves in each of two external loops close simultaneously when the reactor is at full power.

The flow reductions have been calculated for simultaneous closure of the four rotovalves. Flow in the minimum flow assembly after 2 seconds is about 97 percent of normal, compared with 75 percent of normal flow at 2 seconds for a pump shaft break accident. The difference between the maximum expected assembly effluent temperature and the saturation temperature is large compared with the difference for a pump shaft break accident.

The primary scram instruments are the plenum pressure monitors and the assembly flow monitors. Postulated rotovalve closure incidents are not used to set transient protection limits, because this incident always yields higher limits than the pump shaft break incident. Postulated rotovalve closure incidents are used to set confinement protection limits.

G.4.1.14 Flow reduction in a single assembly

It is assumed that a gradual reduction in flow occurs to a single coolant channel within an assembly. This could be caused by the swelling that accompanies a cladding failure in a uranium fuel or target assembly. Fuel failures resulting in flow reduction have occurred at SRP.

As assembly flow gradually decreases, the assembly channel effluent temperature gradually increases. The assembly coolant flow monitor would be the first to scram the reactor. The scram setpoint for the monitor is required to be at the point that would prevent coolant boiling in the hot channel. The assembly effluent temperature monitors are also set to prevent boiling in the hottest channel. This flow reduction incident is used to determine transient protection limits for the reactor. One other case is considered in establishing confinement protection limits. This is the abrupt and complete flow reduction that is postulated to lead to the loss of assembly accidents already discussed. No specific initiating mechanisms have been identified for this abrupt flow reduction.

G.4.1.15 Loss of control-rod cooling

Flow reduction or blockage in the header supplying cooling to the control rods, or in the individual septifoil housing the control rods is unlikely because there are strainers in the headers and because heat exchangers with much smaller flow passages are upstream. Instead of a flow blockage, it is assumed that the septifoil housing is unseated in the reactor, thus reducing the flow to zero.

For this transient, calculations show that for current charges control-rod temperatures increase, but damage or melting does not occur because the calculated control-rod heat flux is not in excess of a high specific limit. If the heat flux exceeds the limit, then a control-rod melt accident is considered.

A reduction in header flow would cause a reactor shutdown within 2 seconds and prevent any damage. If a control rod should melt because of very high heat flux and septifoil unseating, then the assembly effluent temperature monitors around the affected cluster would shut down the reactor. No fuel or target assembly damage would result.

G.4.1.16 Loss of blanket-gas pressure

Slow leaks of blanket gas have occured at Savannah River Plant, but not a sudden rapid drop in pressure. It is assumed that a blanket-gas leak reduces the blanket-gas pressure linearly from 0.136 to 0 MPa in 2 seconds. This loss |TC of blanket-gas pressure would reduce the saturation temperatures in the reactor and cause evolution of the helium gas dissolved in the D_2O. Other secondary results follow. Cavitation may occur in the external cooling loops, which would reduce reactor coolant flow and increase coolant temperatures. A second consequence of losing pressure is that the dissolved gaseous helium would appear as bubbles in the D_2O, which would cause a negative reactivity effect and drive reactor power down. The lower power would produce a positive reactivity feedback and the power would rise again. A safety-rod scram would occur after 1 second. Power and temperature oscillation could occur because of evolution of helium if the scram did not occur. Oscillations in currently operating charges would be small. However, the ABS-S/C would shut down the reactor after 5 seconds, so that realistically, no oscillation would occur.

The primary and secondary scram instruments are the two blanket-gas pressure monitors and the assembly effluent temperature monitors. Analysis of this accident is used to set transient protection limits. The assembly coolant temperature monitor is required to have its scram setpoint set low enough to ensure that the saturation temperature of the channel exit is not exceeded at a blanket-gas pressure of 0.129 MPa (normal operating pressure is 0.136 MPa). |TC This ensures no reactor damage and thus no release of radioactivity.

G.4.1.17 Loss-of-coolant accident

It is postulated that a leak occurs somewhere in the D_2O coolant system when the reactor is at power. There are two classes of leaks: credible small leaks and a hypothetical, very large, sudden leak.

If a leak rate greater than 15 liters per minute should occur, the moderator level in the reactor tank, the blanket-gas pressure, and the plenum pressure would all decrease. The response would be as follows:

1. Automatically shut down the reactor.
2. Isolate the leak as much as possible.
3. Activate the Emergency Cooling System, if needed, to replace the lost D_2O with H_2O.
4. Maintain circulation to cool the fuel and target assemblies. (One other result of a large leak, the release of radioactivity to the reactor building and the environment, will be discussed in following sections.)

The scram instruments that would be activated are the moderator level, blanket-gas pressure, or plenum-pressure circuits, followed by the individual assembly flow and temperature monitors.

A large effort has been expended on the analysis of credible and hypothetical leaks. An ECS supplied from four independent sources of water can be activated manually or by logic circuits connected to the reactor scram instruments. Analysis shows that no fuel melting would occur for any credible loss-of-coolant accident. Of the credible accidents, the most likely would be a break in one of the smaller pipes in the auxiliary cooling systems. An example would be a break in a pipe supplying D_2O coolant to the septifoil system. The leak rate from this system would be 14 cubic meters per minute; no fuel damage would occur after the ECS was actuated.

The analysis is also made for a hypothetical maximum leak rate--an abrupt, double-ended break of a large pipe accompanied by other circumstances that render two of the three ECS supply systems ineffective. The worst of the accidents analyzed is a break in a line that also serves as one of the lines that would supply emergency H_2O coolant. The accident is not considered credible in the SRP system of stainless steel pipe operating at relatively low pressures of approximately 100 psi. For this hypothetical large leak, the ECS would limit the accident to 1 percent core damage if the ECS were degraded by a valve failure in another ECS supply line.

Shutdown would begin about 1 second after the pipe break. Analysis of the accident indicates that fuel damage does not occur in this 1-second interval. The longer term flow transient analysis indicates that damage may occur later. The factors that enter into the analysis are reactor power, power distribution, reactor flow, flow distribution, ratio of fission product decay power to normal operating power level, the ECS supply rate, and finally the degree of fuel damage established as a function of assembly flow and power. Reactor power is limited to a value that would produce less than 1 percent core damage if this hypothetical maximum leak rate should occur and only one of the three ECS systems were operable. The releases for this accident are discussed in Section G.5.

No fuel melting is anticipated in any credible LOCA. But some radioactivity will be released to the environment in any LOCA. The main contributor to offsite dose is tritium in the moderator (formed from neutron capture by deuterons). The tritium is released mainly by evaporation. The amount released depends on the size of the leak and on the disposition of D_2O leaking from the reactor to the reactor building.

Unless the leak were stopped, the entire inventory of D_2O could be released to the reactor building. This is the basis for the large moderator spill accident which is one of the four hypothetical events postulated to cover the spectrum of accidents that could release radioactivity to the environment. Almost all of the D_2O would be contained in two closed tanks outside the reactor building. Because the only vent path for the tanks is back to the reactor building, any tritium released by evaporation would eventually be discharged through the 61-meter stack. The releases for this accident are discussed in Section G.5.

G.4.1.18 Loss of D_2O circulation

The complete loss of D_2O circulation is considered highly improbable. It is assumed that a complete loss-of-D_2O circulation occurs by loss of all pumping power or some obstruction. Loss of pumping power could occur if all electrical power were lost and the motor room were flooded so as to stop the d.c. motors. Obstruction could occur if all rotovalves were closed, or if the D_2O became frozen.

The loss of circulation would cause a reactor scram, but the ECS system would have to be activated to prevent melting fuel by the remaining decay heat. The addition of H_2O from the ECS would force a moderator-H_2O mixture out of the three pressure relief systems in the reactor tank. As a result of this accident radioactive moderator is released to the reactor building through the pressure relief ports. Even if one of the three ECS lines is inoperable, no fuel melting will occur. The reactor is shut down by numerous flow sensors. The ECS is activated manually by procedural response.

The pre-accident reactor power is adjusted to limit fuel melting to 1 percent of the reactor core. In this sense, the loss-of-circulation accident is considered in deriving reactor power limits. However, detailed analysis of this accident shows that the reactor power that would limit fuel damage to 1 percent is higher than the reactor power prescribed by other limits. Thus, no melting may occur, but radioactive moderator would be released to the reactor building and the environment. The analysis of this accident is also used to define function specifications for the operation of the ECS.

Emergency sump pumps and dams are provided to minimize the possibility of flooding of the motor room.

Another postulated mechanism for losing D_2O circulation is freezing of D_2O in the heat exchanger due to extremely low cooling-water temperature. Operating procedures specify recirculating effluent water if the river water temperature should drop to 5°C. The D_2O freezing point is 3.8°C, and on one occasion (over 30 years of operation), the temperature of the Savannah River came close to this value. But if the water temperature drops below 5°C, some of the hot-water effluent is recirculated to the water in the basin to keep the inlet temperature from falling below 5°C.

G.4.1.19 Loss of cooling during and after discharge

Irradiated fuel and target assemblies are discharged in air and transported by crane to the discharge canal. If the crane becomes disabled, emergency cooling would be required to prevent melting and release of fission products. It is assumed that the crane becomes disabled. This accident is considered credible but improbable. If all four addition paths of emergency cooling to the discharge machine should fail at the same time a discharge machine interruption occurs, melting of fuel could take place.

G.4.2 Disassembly-basin accidents

The melting of irradiated fuel or target components in the disassembly basin is considered to be highly unlikely. Assemblies are not discharged from the reactor until the calculated heat generation rate is low enough to assure adequate cooling, even if the assembly is dropped to a horizontal position. In most cases, the heat generation in fuel and target assemblies immediately after reactor shutdown is sufficiently low that no cooling-off period is required. Should some unexpected assembly damage occur, the radioactivity would be released under about 10 meters of water. The affected basin section would be isolated and the water in that section would be circulated through deionizers and sand filters. Although the disassembly area is not part of the confinement system, most of the airborne release would be filtered by the confinement system as the air from personnel areas is drawn into the lower-pressure process areas and exhausted. In addition the high partition coefficient for iodine in water would cause the majority of the iodine released from the assembly to remain in the water, and no particulates would escape to the atmosphere.

A criticality accident is also an unlikely possibility in the disassembly area; such an accident is strongly guarded against by mechanical and administrative controls. If such a criticality did occur, it would typically involve from 10^{15} to 10^{20} fissions and occur under 10 meters of water. Offsite effects would not be expected to be measurable.

G.5 RADIOLOGICAL CONSEQUENCES OF REACTOR ACCIDENTS

The range of accidents considered for L-Reactor safety has been discussed in Sections G.1 and G.4.1. This section discusses how radioactivity released by accidents may affect the public. The sources of a radioactivity release are discussed first. Then the calculation techniques and finally the results of the calculations are presented.

The spectrum of conceivable SRP reactor accidents covers the range from trivial to severe. Four specific accident cases are cited to illustrate a range of accidents (up to 3 percent damage of the core).

G.5.1 Sources of a radioactive release

G.5.1.1 Isotopes released and manner of release

The sources of radioactivity considered in this section are tritium in the heavy-water moderator and fission products in the fuel. Potential offsite doses from nonfission product isotopes (cobalt-60, plutonium-239, etc.) are considered in Section G.5.5.

G.5.1.1.1 Moderator radioactivity

This report uses a conservative value of 5,000,000 curies of tritium present in the moderator. This is 30 to 40 percent higher than actual present values in currently operating reactors. The tritium is a natural consequence of neutron capture by deuterium. This tritium could be partially released to the confinement system following ECS actuation or any LOCA.

Any tritium becoming airborne in the confinement system would be discharged from the stack, because the confinement system has no mechanism for tritium removal.

It is quite unlikely that the full moderator inventory of tritium would evaporate and diffuse into the confinement system following any accident because the moderator would flow into the two holding tanks of the liquid activity confinement system. It is estimated that no more than about 3 percent of the tritium would evaporate during the initial 2-hour period after the postulated accident.

G.5.1.1.2 Radioactivity available for release from core melting

If any fuel or target assemblies melt, fission products become available for release. Depending on the type of assemblies melting and other circumstances the radioactivity release would include noble gases (xenon, krypton), iodine, and radioactive particulates (fission products, cobalt-60, plutonium-239, etc.). The concentration of these isotopes in the core is a function of reactor power that might reach a maximum of 3000 megawatts. Table G-10 lists the total inventory of fission products. Most of these isotopes decay rapidly following shutdown; and depending on the expected accident sequence, some isotopes may not contribute significantly to potential offsite doses.

The inventory of noble gases and iodine contributing to offsite dose is shown in Table G-7 and Figure G-2. Tritium is present in lithium-containing assemblies and control rods; up to 12 megacuries of tritium may be present in plutonium-producing charges. The radioactive particulates include several different isotopes and would be captured by the HEPA filters. The amount of particulates that would penetrate the filters would not contribute significantly to the offsite dose (Cooper and Rusche, 1968; Durant et al., 1966).

Table G-7. Iodine and noble gas inventory of 3000-MW core (major contributors to 2-hour offsite dose)

Isotope	Inventory (MCi)	Isotope	Inventory (MCi)
I-131	75	Kr-87	35
I-132	115	Kr-88	75
I-133	175	Xe-133	165
I-134	180	Xe-133m	25
I-135	165	Xe-135	20
		Xe-135m	30

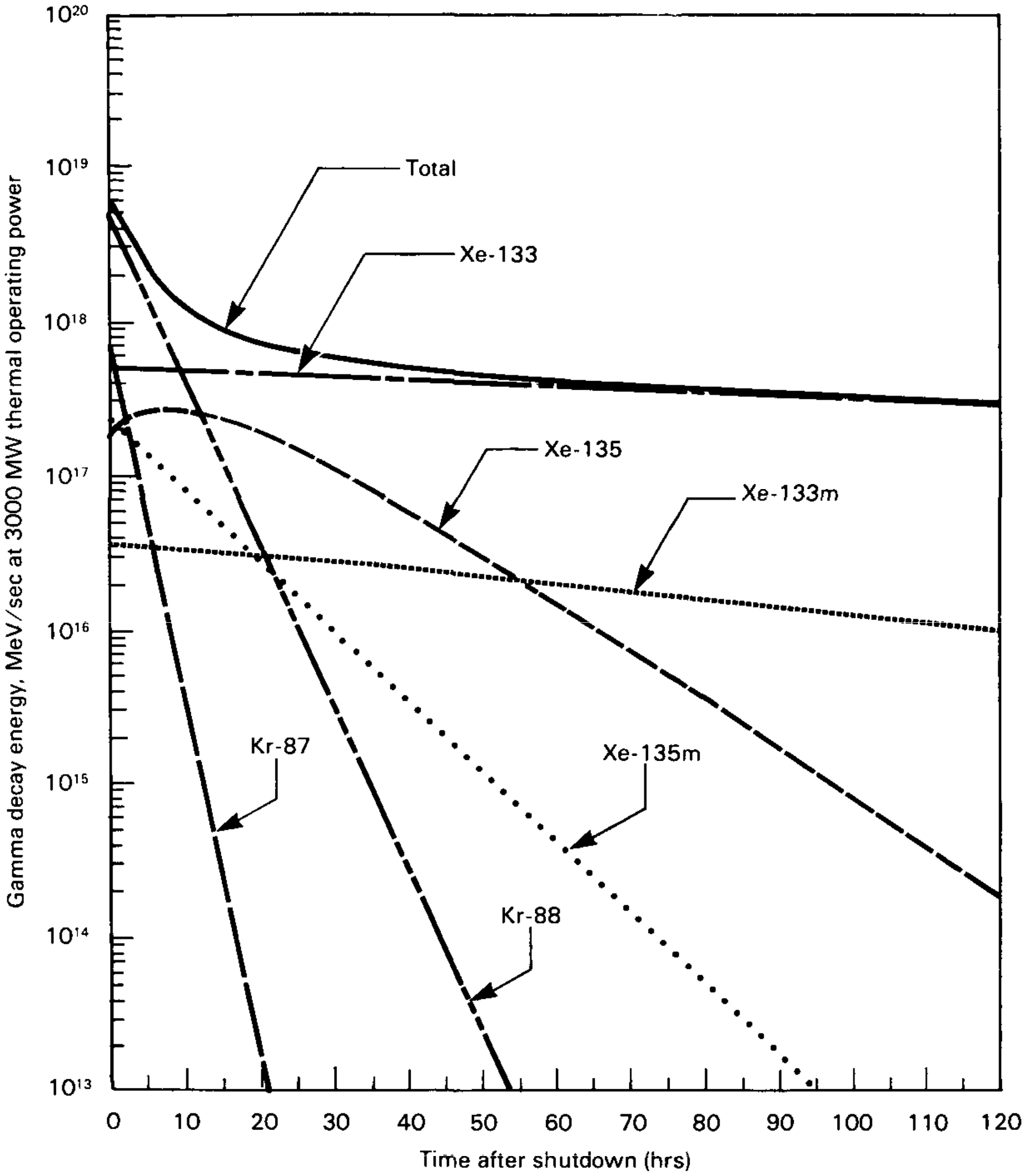

Figure G-2. Gamma decay energy of noble gases.

Three releases of radioactivity from the core are considered as credible in this EIS; they involve melting of a single fuel assembly, 3 percent damage of the core during a reloading accident, and 1 percent damage of the core during a LOCA. |TC

Melting of a single assembly during discharge

The fission products in the assembly would have decayed significantly between shutdown of the reactor and the discharge operation. Fourteen hours of decay of fission products is assumed as the minimum time to satisfy other discharge constraints as discussed in Section G.4.1.19.

The reactor room emergency spray system would be used to cool a hot assembly that drops to the reactor room floor to prevent melting. If melting occurred, the spray water would keep much of the iodine and particulates from becoming airborne. No credit is taken for this, however, and 50 percent of the iodine and 100 percent of the noble gases available for release are assumed to escape the assembly and become airborne. The iodine that reaches the carbon bed is assumed to be all elemental iodine because of the high air flow and rapid transport of iodine to the carbon beds (Durant et al., 1966). These parameters are also assumed for all accidents described in the following sections.

Core melting during a reloading accident

A criticality resulting from a reloading accident is postulated to cause some melting of the core (Section G.4.1.8). Core damage would be less than 3 percent for this accident. The melting could release fission products into the moderator. For purposes of analysis, it is assumed that 50 percent of the iodine and all the noble gases become airborne. Prior to the accident, the fission products would have decayed for a minimum of 14 hours. To be conservative, no credit is taken for decay prior to the accident.

Core melting during a loss-of-coolant accident (LOCA)

The LOCA is described in detail in Section G.4.1.17. If the worst conceivable D_2O pipe break were to occur, the emergency cooling and confinement systems would control offsite doses well within the 10 CFR 100 reference values, even with failure of a single active component in the emergency cooling system. No more than 1 percent core damage is expected in the worst-case LOCA. This accident is analyzed assuming 1 percent of the core inventory of noble gases and tritium and 0.5 percent of the iodine (50 percent of that available for release from the core) becomes airborne.

G.5.1.2 Release of radioactivity

In the moderator spill accident, tritium is released to the confinement system and then discharged from the 61-meter stack. This is assumed to occur over a 2-hour period. Only a small part of the tritium would actually be released; the rest would remain in solution in the two (225,000-liter and 1.9-million-liter) holding tanks. It is conservatively assumed that about 3 percent of the tritium evaporates.

For the accidents in which assemblies are assumed to melt, the amount of fission products released is proportional to the fraction of the core that melts. Noble gases and iodine are assumed to be released into the process room. Any gases vented to the blanket-gas system would eventually be released into the confinement system. It is estimated that 1 percent of the particulates (fission products, plutonium isotopes, etc.) would be released into the building, and half of that would reach the filters (Cooper and Rusche, 1968; Durant et al., 1966). Some 99.95 percent of the iodine and 99 percent of the remaining particulates would be captured by the activity confinement system. In the event of a dropped assembly, the reactor room spray system could remove much of the airborne iodine (and particulates) and some of the tritium before they left the process room, but this was not considered in the accident analyses.

Following a postulated melting accident, all noble gases are assumed released from the stack. In comparison with other doses, the released solids are considered insignificant (Cooper and Rusche, 1968). Some of the iodine trapped on the carbon bed would be desorbed as the result of the high radiation field generated by the decay of radioactive iodine. The desorption rates, shown in Figure G-3, are used to calculate potential offsite doses as discussed in Section G.5.2.

G.5.2 Calculation of offsite dose

This section describes the techniques used to calculate offsite doses resulting from reactor accidents. The calculations and data are consistent with NRC guidelines for accident analysis (NRC, 1972; 1979). The methods discussed were used for analysis of all accidents, including the moderator spill and fuel melting accidents.

G.5.2.1 Dose calculational method and criteria

There are three parameters necessary to compute the offsite doses. First, the radioactive source term must be specified, including the release rate and isotope type. Second, the transport of the isotope to the receptor location by the wind must be computed, based on appropriate calculational models and meteorological data. Third, the external and internal doses to an individual assumed to be at the plant boundary are computed based on parameters of a standard man (including breathing rates) and additional parameters related to absorption of energy from a particular isotope.

Individual characteristics, time of exposure, and meteorological behavior are important variables that are generalized in computing a maximum individual dose. In an actual accident, the WIND computer system of SRP would predict the release path and indicate appropriate action to minimize exposure to people offsite (Garrett et al., 1981). Evacuation procedures, which would reduce the actual dose to an individual, are not considered in these dose calculations (Garrett and Murphy, 1981).

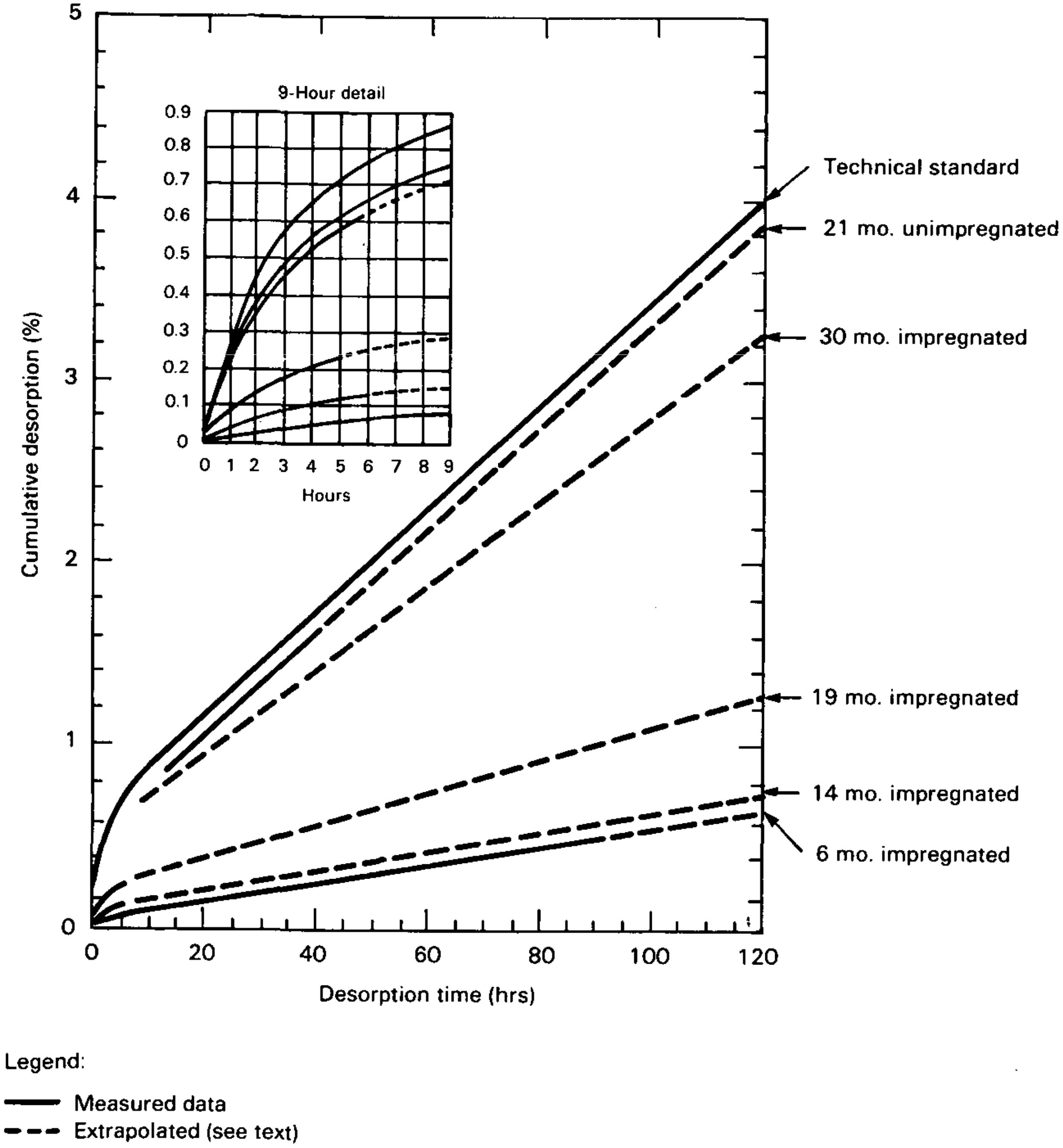

Figure G-3. Extrapolated radiolytic desorption of iodine from several service aged carbons.

The doses are reported both for 2-hour exposures and for 120-hour exposures. The 120-hour exposure represents a time after which further exposure would not significantly change the overall dose.

The dose calculation uses median meteorology. This and other parts of the calculation are discussed in the following subsections.

G.5.2.2 Source terms for radioactivity releases

The maximum amount of radioactivity available for release following the postulated moderator spill or assembly melting accidents was described in Section G.5.1.

The release from the stack is assumed to propagate over a 2-hour period in one direction as a Gaussian plume, and the exposure of an individual is treated as a time-integrated calculation. This is very conservative because measurements at the SRP site show that the probability of wind persistence for a 2-hour period is, for some directions, only about 20 percent (Langley and Marter, 1973).

The 2-hour irradiation period begins when the radioactive material reaches the Plant boundary. Both the noble gas and iodine source terms are assumed to decay during transport.

The source terms for iodine are the amount that would penetrate (or bypass) the filters and desorb from the charcoal in the first 2 hours and the first 120 hours following the incident. The average iodine retention efficiency assumed for the carbon is that for carbon aged 19 months, typical of normal operation. Carbon beds are replaced on a staggered schedule, so some beds have relatively fresh carbon, some have carbon of intermediate age, and some have carbon approaching its service limit of 30 months.

G.5.2.3 Transport of release and dose calculation

The downwind concentrations of iodine, tritium, and noble gases were calculated according to an integral technique using the computer code NRC145-2 (Pendergast, 1982a,b). This code was developed at Savannah River Plant and uses a Gaussian plume model based on NRC Regulatory Guide 1.145 (1979).

The meteorological data used in the dose calculations were collected from January 1975 through December 1979 (Garrett and Hoel, 1982). The data were obtained at towers near P-, K-, and C-Reactors. Calculations for L-Reactor used data from the closest tower (K-Area). The meteorological data from each tower were averaged for 2-hour periods and sorted into 16 direction sectors, 6 wind speeds, and 7 stability classes. (Stability classes were based on the standard deviation of the mean wind direction).

Median meteorological conditions (50th percentile) were assumed in these calculations. The effects of other less probable meteorological assumptions are shown in Figure 4-9.

Corrections for topography and jet rise of the released plume are applied. The topography correction is prescribed by the regulatory guide (NRC, 1972) and reduces the effective stack height when the downwind terrain is higher than the ground level elevation at the point of release. The jet rise of the plume occurs because the high volume exhaust fans (continuously online) impart a momentum to the gases going up the stack and increase the effective height of the release point. The model for jet rise that is included in NRC145-2 is described in Huber (1981).

The effect of fumigation, a condition that depresses downwind plume elevation to below the release height, was not included. The long distance from the release point to the site boundary makes local fumigation insignificant. Wind shear had no effect on atmospheric mixing at a distance corresponding to the plant boundary.

Interpolation between 2-hour doses and annual average doses was used to obtain the dose for an extended exposure period of 120 hours, using a method recommended in the NRC guidelines, incorporated into NRC145-2 and independently verified (Pendergast, 1982c).

The thyroid dose and the whole-body dose are each composed of an inhalation component from iodine and tritium and a shine component from the gamma emission of the noble gases. The inhalation component was computed by multiplying the isotopic relative concentration by the source strength and dose conversion factors. The shine component integrated the gamma dose from the entire (finite) radioactive plume (Pendergast, 1982a; Cooper, 1972).

G.5.2.4 Dose conversion

The transport of the radioactive release to the plant boundary is calculated using the above techniques. At the boundary the diluted radioactive material is assumed to expose a standard man. To determine the dose received, calculational methods and parameters were used that were consistent with techniques described in Pillinger and Marter (1982). For iodine and tritium, a standard man's breathing rate was used to calculate an inhalation dose. The dose conversion factor considers skin absorption as well as inhalation in the case of tritium.

G.5.3 Results of calculations

The bases and assumptions for both the radioactive source terms and the methods for computing the transport to the plant boundary were described in Sections G.5.1 and G.5.2, respectively. The doses for the four accidents considered are discussed below.

G.5.3.1 Dose from moderator spill

As discussed in Section G.5.1.1.1, this accident considers the tritium dose when moderator is displaced from the reactor (e.g., due to actuation of the ECS). The calculation assumes a release of 0.15 megacurie (about 3 percent of the assumed 5-megacurie tritium inventory in the moderator) over a 2-hour period. The calculated dose to an individual at the plant boundary is shown in Table G-8.

G.5.3.2 Dose from core melting

As discussed in Section G.5.1.1.2, three melting accidents are considered.

G.5.3.2.1 Dose from melting a single assembly during discharge

This accident, discussed in Section G.5.1.1.2, assumes an irradiated fuel assembly, having decayed for 14 hours after shutdown, melts while being discharged. The calculated dose to an individual at the plant boundary is shown in Table G-8.

Table G-8. Calculated radiation dose to a person at the SRP site boundary following four specific accidents (50-percent meteorology and 3000 Mw power)

Accident	Calculated dose (rem)		
	Whole body-2 hr[a]	Thyroid-2 hr	Thyroid-120 hr
D_2O spill	0.006	--	--
Discharge mishap (one fuel assembly melts)	0.003	0.004	0.01
Reloading error (about 3% core damage)	0.39	0.51	1.5
LOCA (1% core damage)	0.13	0.17	0.50

[a] A 2-hour whole-body dose is essentially the same as the accident-duration whole-body dose.

G.5.3.2.2 Dose from core melting during reloading accident

As discussed in Section G.4.1.8, calculations indicate that the maximum hazard would involve less than 3 percent core damage. It is assumed that the fission product content of the core is the equilibrium concentration that would be obtained at full power. Even with this assumption, the computed dose at the plant boundary is small relative to the DOE radiation standards for normal operation (see Table G-8).

G.5.3.2.3 Dose from 1 percent core damage during a loss-of-coolant accident

As discussed in Section G.4.1.17, this accident assumes that a massive double-ended pipe break occurs. For conservatism, the break is assumed to be in one of the lines used by the ECS addition system, so that one of the ECS addition systems is incapacitated. It is further assumed that a valve does not open in one of the remaining ECS addition systems. Thus, only one of the three ECS addition systems is assumed to work as designed. The doses (Table G-8) are below the DOE radiation standards for normal operation.

G.5.4 Summary of dose calculations

In summary, the offsite doses listed in Table G-8 were calculated in accordance with accepted methods and assumptions for environmental impact statements (in contrast to the more conservative analyses employed in Safety Analysis Reports). The whole-body and thyroid doses for these postulated accidents are less than the DOE annual radiation protection standards for normal operation. TC

G.5.5 Particulates (both fission product and nonfission product isotopes)

The potential offsite dose from nonfission product isotopes (e.g., cobalt-60, polonium-210, and plutonium-238) that may be present in large quantities in the mixed-lattice charges has also been considered. Few, if any, of these isotopes will be present in sufficient concentrations to generate sufficient heat to melt the target. Hence, major releases of the product materials in mixed-lattice charges would be expected to occur only in conjunction with a major reactor accident.

For calculational purposes, it is assumed that in an accident the fractional release of the nonfission product isotopes to the building environment, transport in the reactor building, and removal by the activity confinement system will be identical to the behavior of particulate fission products discussed in Brown (1971), namely, 1 percent of the inventory in the damaged portion of the core is released to the building, 50 percent of the released fraction is deposited in the building before reaching the activity confinement units, and 99 percent of the remainder is collected by the units. For the maximum credible core damage of 3 percent, the assumed net release fraction from the damaged core portion is thus 5×10^{-5}.

To provide an estimate of the relative magnitude of the potential offsite effects of several isotopes, full-charge inventories of several possible products have been calculated. The core inventory of several typical isotopes is shown in Table G-9. The inventories are based on the production capability in a single reactor (except plutonium-238 inventory, which is based on the availability of intermediates as feed material). Lesser amounts would be present in mixed lattices involving the production of several isotopes simultaneously.

Table G-9. Potential offsite doses from nonfission product isotopes[a] (50-percent meteorology)

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Isotope	Maximum inventory (megacuries)	Amount inhaled[b] during 2-hour exposure at plant boundary (µCi)	50-year dose commitment (rem)	Critical organ
Co-60	230	2×10^{-1}	1×10^{-1}	Lung
Po-210	38	3×10^{-2}	8×10^{-1}	Lung
U-233	0.0005	3×10^{-7}	2×10^{-5}	Lung
Pu-238	0.45	3×10^{-4}	8×10^{-1}	Bone
Pu-239	0.022	2×10^{-5}	4×10^{-2}	Bone
Cm-244	0.25	2×10^{-4}	1×10^{-1}	Bone

[a] These numbers generally are based on reactor charge producing a single product (the exception is plutonium-238). If two or more products are being produced simultaneously in the same reactor, the maximum inventory of any one would be lower.

[b] Release fraction of 5×10^{-5} for all isotopes.

Values of potential doses from a postulated accident releasing 3 percent of the core inventory were computed for each isotope by multiplying the curies released by the relative concentration (χ/Q) and an appropriate dose conversion factor. The calculation was similar to the inhalation dose calculations described in Section G.5.3. The assumed breathing rate was 3.47×10^{-4} cubic meter per second.

The quantity of each isotope that might be inhaled by a receptor at the plant boundary was calculated using the method described in Section G.5.2. Fallout, deposition, and decay in transit to the plant boundary were neglected. The calculated amount of each isotope inhaled is shown in Column 3 of Table G-9, assuming all of the aerosols reaching the boundary are of respirable size. The fractional release for all isotopes is based on 3 percent damage.

There are no official guidelines related to the inhalation of isotopes in a short time (as in a reactor accident). The dose conversion factors for chronic inhalation (Pillinger and Marter, 1982) were used to compute the potential 50-year dose commitments shown in Table G-9. The most restrictive dose conversion factors were used to determine the critical organ that received the highest dose. Thus the insoluble form of cobalt-60, polonium-210, and uranium-233 was assumed with the lung as the critical organ. The soluble form of plutonium-238, plutonium-239, and curium-244 was assumed with the bone as the critical organ.

The whole-body dose from noble gases present in the fuel in the same reactor charge is not included in Table G-9. The whole-body irradiation from exposure to gamma emitters would be added to the doses received from inhalation of particulates.