Appendix B. Scenario B—Simulation of 2002 Average Conditions without Savannah River Site Pumping

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Appendix B. Scenario B—Simulation of 2002 Average Conditions without Savannah River Site Pumping

Purpose of Scenario

The purpose of Scenario B was to evaluate the effect of Savannah River Site (SRS) pumping in addition to adjustments in specified heads in the source-sink layer and along lateral boundaries. The most influential factors controlling particle movement are vertical and lateral head gradients and pumping distribution within the active layers of the model. The 5.3 Mgal/d of SRS pumping (R.A. Hiergesell, Westinghouse Savannah River Company, written commun., 2002) was eliminated to measure the effects of pumping on particle movement and potential migration of contaminants in the event of closure of the SRS. In Scenario B, the specified heads in the source-sink layer A1 and along lateral boundaries (layers A2–A7) of the model were averaged between long-term average (1987–92) and dry (2002) hydrologic conditions. A comparison was conducted with Scenario A to document how the elimination of SRS pumpage affected simulated ground-water flow, aquifer heads, and particle movement.

Water Budget Changes

Total projected ground-water pumpage in Scenario B (layers A2–A7) during this period was 61.9 million gallons per day (Mgal/d) of which 29 percent was from the lower Midville aquifer (layer A7), 20 percent was from the lower Dublin aquifer (layer A5), and 17 percent was from the Gordon aquifer (layer A2, fig. B1). The remaining 34 percent of ground-water pumpage in Scenario B was apportioned to the upper Midville aquifer (layer A6), Millers Pond aquifer (layer A3), and the upper Dublin aquifer (layer A4; table 11). Most of the 5.3 Mgal/d pumpage at the SRS is withdrawn from layers A5–A7 (lower Dublin and upper and lower Midville aquifer) with the pumping rates of layers A2 and A3 remaining the same as 2002 and Scenario A (fig. B1; table 11). Simulated water budget for Scenario B indicates that major components of flow were similar to the Scenario A simulation, with the exception that decreased pumpage at the SRS induced 2.1 Mgal/d less recharge from the source-sink layer A1 into layer A2 (Gordon aquifer; fig. B1). In general, inflows to the lower layers of the model (layers A3–A7) through the confining units decreased from 0.6 to 2.2 Mgal/d (fig. B1). The decreased inflows to each of the active layers of the model, however, were balanced by increased outflows to overlying confining units ranging from 1.3 to 2.4 Mgal/d. Also, the decrease in SRS pumpage allowed an additional 1.9 Mgal/d to discharge to streams in layer A2 (Gordon aquifer, fig. B1).

Pumpage in the A/M Area of SRS has the most influence on ground-water movement and depth of penetration. Ground-water withdrawals from this area were 3.3 Mgal/d during 2002 (R.A. Hiergesell, Westinghouse Savannah River Company, written commun., 2002) and were eliminated for Scenario B. For the period from the 1987 to 1992, the pumping rate was slightly less at 2.6 Mgal/d (Clarke and West, 1998).

Water-Level Changes

The elimination of pumping at the SRS (5.3 Mgal/d) resulted in simulated water-level changes that rebounded by more than 4 feet (ft) near SRS production wells (layers A4–A7). The area of influence of SRS pumping generally was limited within the site boundaries with some water-level declines extending further to the northwest (figs. B2–B7). Substantial water-level recovery also was observed in layer A2 (Gordon aquifer), which does not have any active SRS production wells. On the SRS, the simulated water-level changes ranged from +0.5 to +4 ft as a result of the localized effects of pumping (figs. B2–B7). In layer A2 (Gordon aquifer, fig. B2), water-level changes indicate steep vertical gradients in proximity to the A/M Area and the Separations and Waste Management Area that existed as a result of pumping from SRS production wells screened in the Dublin and Midville aquifer systems (layers A4–A7). In layer A2 (Gordon aquifer), the water-level changes are affected by pumping in the lower layers, but extend only as far as Upper Three Runs Creek because assigned river stages remained constant for each of the simulations (fig. B2; fig. 1*B*). In the Midville aquifer system (layers A6 and A7), the +0.5 ft-water-level change is located in close proximity to the SRS boundaries with the exception of a lobe that extends to the northwest (figs. B6 and B7). The area influenced by SRS pumping outside the boundaries is limited to a relatively small part of land between Hollow Creek and the northern boundary of SRS (figs. B2, B4–B7).

Ground-Water Flowpaths

Simulated ground-water flowpaths for Scenario B generally were limited to areas within the SRS boundary (figs. B8–B12). Flowpaths were evaluated using MODPATH in forward-tracking mode from five zones in which particles placed at the were allowed to migrate to discharge areas. Downward vertical gradients exist that allow depth of penetration into the Dublin aquifer system, but flowpaths inside the boundaries of the SRS are eventually upward toward discharge areas within the Gordon aquifer (layer A2). General ground-water discharge areas or sinks include Upper Three Runs Creek (layer A2) and the alluvial valley of the Savannah River (source-sink layer A1 and layer A2). General ground-water movement from zone 1 is south toward discharge areas along Upper Three Runs Creek, with a southwesterly component moving away from the A/M Area (fig. B8). General ground-water flow directions from zones 2 and 3 are west toward Upper Three Runs Creek, with another flow component moving south toward discharge areas along Pen Branch (figs. B9–B10). Ground-water movement from zones 4 and 5 generally is south toward discharge areas located on the South Carolina side of the Savannah River near Steel Creek (figs. B11–B12). Most of the ground-water flowpaths indicate movement is limited to areas within the boundaries of the SRS. Exceptions to the preceding statement include: (1) ground-water discharge to areas east of Eagle Point (layer A2, fig. B8), located west of the SRS boundary in Aiken County, S.C., from zone 1; (2) trans-river flow zones near Flowery Gap Landing (layer A2), located in Burke County, Ga., originating from zones 2 and 3; and (3) discharge areas located in Allendale County, S.C., migrating from zones 4 and 5.

Time-of-Travel

Simulated time-of-travel for Scenario B from the five zones of recharge on the SRS to discharge areas ranged from 20 year (yr) to about 27,300 yr (figs. B8–B12; table B1). Fastest mean travel times occurred from zone 1; slowest travel times occurred from zone 5 (table B1). All simulated travel times are for particle movement from the top of the Gordon confining unit (C1) forward toward discharge areas and does not include time-of-travel within the source-sink layer A1 (Upper Three Runs aquifer). According to Flach and others (1999b), model simulations indicate time-of-travel downward through the Upper Three Runs aquifer approximating several decades. The time-of-travel data shown in table B1 indicate travel times from initial placement at the top of the Gordon confining unit (C1) to points of discharge along local streams or the Savannah River floodplain. For example, the statistics indicate that at 64 yr about 10 percent of the particles (98 particles) placed in zone 1 have reached discharge areas along Upper Three Runs Creek. Mean time-of-travel from zone 1 to discharge areas was 249 yr, with values ranging from 20 yr to about 1,290 yr. Mean time-of-travel from zone 2 to discharge areas was 866 yr, with values ranging from 29 yr to about 27,300 yr. Mean time-of-travel from zone 3 to discharge areas was 947 yr, with values ranging from 63 yr to about 5,920 yr. Mean time-of-travel from zone 4 to discharge areas was 494 yr, with values ranging from 143 yr to about 3,020 yr. Mean time-of-travel from zone 5 to discharge areas was about 1,490 yr, with values ranging from 36 yr to about 11,400 yr.

At the 100-yr time-of-travel interval (figs. B8–B9), about 18 percent of the particles have discharged along Upper Three Runs Creek from zone 1, and several groups of particles have moved short distances from zone 2 to discharge areas along Fourmile Branch, Pen Branch, and Upper Three Runs Creek near the Separations and Waste Management Area. Also, several particles have migrated beyond the western boundary of the SRS from zone 1 to areas south of the town of Jackson, S.C. In zone 1, the 200-yr time-of-travel interval (fig. B8) indicates additional particles have discharged to areas along Upper Three Runs Creek and the alluvial valley of the Savannah River. All particles released from zone 1 terminate within South Carolina and have a maximum travel time of 1,294 yr. In zone 2, the 200-yr time-of-travel interval (fig. B9) indicates from about 15 to 20 percent (table B1) of the particles applied have migrated toward discharge areas along Upper Three Runs Creek and Pen Branch, with one particle moving toward trans-river areas on the Georgia side of the Savannah River. In zones 4 and 5, the 500-yr time-of-travel interval (figs. B11–B12) shows general ground-water movement to the south, with discharge areas located to the north of the Savannah River on the South Carolina side. The final endpoints from particles placed in zones 1 through 3 indicate that most of the particles discharge to areas along Upper Three Runs Creek, and in zones 4 and 5 most of the particles discharge to alluvial areas on the South Carolina side of the Savannah River.

Trans-River Flow

Simulated trans-river flow for Scenario B was limited to ground water moving to discharge areas located near Flowery Gap Landing along the Savannah River (fig. B13). For these trans-river flow areas, recharge occurred between D Area and K Area on the SRS. Of the 300 particles released near Flowery Gap Landing, 110 particles (37 percent) backtracked to recharge areas on the SRS. The remaining 190 particles backtracked to areas along the western model boundary on the Georgia side of the Savannah River. For the particles that backtracked toward the SRS, the mean travel time was 460 yr with a median value of 366 yr. The cross-sectional view indicates that shorter travel times ranged from 110 to 170 yr within layer A2 (Gordon aquifer), and longer travel times ranged from 530 to 810 yr within layers A4 and A5 (upper and lower Dublin aquifers). Also, the cross section shows layer A3 (Millers Pond aquifer) has minimal thickness in this area and has minor effects on particle movement. The 100-yr time-of-travel intervals denoted on the flow lines indicate slow movement through layers A4 and A5 (upper and lower Dublin aquifers). Two particles backtracked to recharge cells located near R Area with a simulated travel times of 1,440 and 1,830 yr, respectively (fig. B13). The Gordon confining unit (C1) generally is 20 to 30 ft thick between D Area and K Area and time-of-travel from the base of the Upper Three Runs aquifer (source-sink layer A1) into the Gordon aquifer (layer A2) is about 10 yr.

Table B1. Time-of-travel for particles seeded in recharge areas (five zones) on Savannah River Site, South Carolina, and forward tracked through time to discharge areas.

Zone number	Number of particles applied		[1]1987–92	2002	Scenario A	Scenario B	Scenario C	Scenario D
			Boundary conditions					
			Wet	Dry	Average	Average	Average	Dry
				Time-of-travel, in years				
Zone 1	984	Mean	301	294	294	249	293	293
		90th percentile	545	561	552	440	550	560
		75th percentile	404	412	407	335	408	417
		Median	264	231	228	217	228	234
		25th percentile	166	164	163	150	163	149
		10th percentile	92	94	91	64	91	94
		Maximum	2,121	1,113	2,481	1,294	1,393	1,284
		Minimum	19	22	21	20	21	22
Zone 2	1,148	Mean	823	917	848	866	861	928
		90th percentile	1,289	1,554	1,364	1,524	1,384	1,587
		75th percentile	828	874	813	819	827	875
		Median	543	591	561	524	564	593
		25th percentile	367	408	388	323	388	407
		10th percentile	212	218	222	144	220	213
		Maximum	6,715	9,425	6,703	27,276	6,699	11,426
		Minimum	28	30	29	29	29	30
Zone 3	1,161	Mean	1,051	1,100	1,095	947	1,085	1,120
		90th percentile	1,553	1,740	1,804	1,764	1,773	1,856
		75th percentile	1,275	1,419	1,375	1,339	1,373	1,429
		Median	1,020	1,146	1,105	834	1,084	1,142
		25th percentile	442	523	470	411	469	518
		10th percentile	178	207	183	181	183	207
		Maximum	58,102	9,724	11,778	5,916	14,658	9,916
		Minimum	61	80	63	63	63	79
Zone 4	882	Mean	522	505	508	494	495	502
		90th percentile	961	969	949	926	940	967
		75th percentile	624	595	600	592	595	594
		Median	402	404	398	395	397	402
		25th percentile	324	335	329	327	327	335
		10th percentile	225	238	233	232	229	236
		Maximum	2,870	1,589	5,741	3,015	1,560	1,647
		Minimum	123	125	124	143	122	123
Zone 5	668	Mean	1,570	1,553	1,532	1,491	1,532	1,552
		90th percentile	2,296	2,218	2,391	2,303	2,453	2,207
		75th percentile	1,575	1,609	1,628	1,596	1,612	1,626
		Median	1,340	1,337	1,349	1,307	1,348	1,354
		25th percentile	1,132	966	1,052	998	1,138	1,108
		10th percentile	672	444	510	460	463	434
		Maximum	13,217	16,045	12,874	11,443	12,071	19,304
		Minimum	38	34	36	36	36	34

[1]Clarke and West (1998)

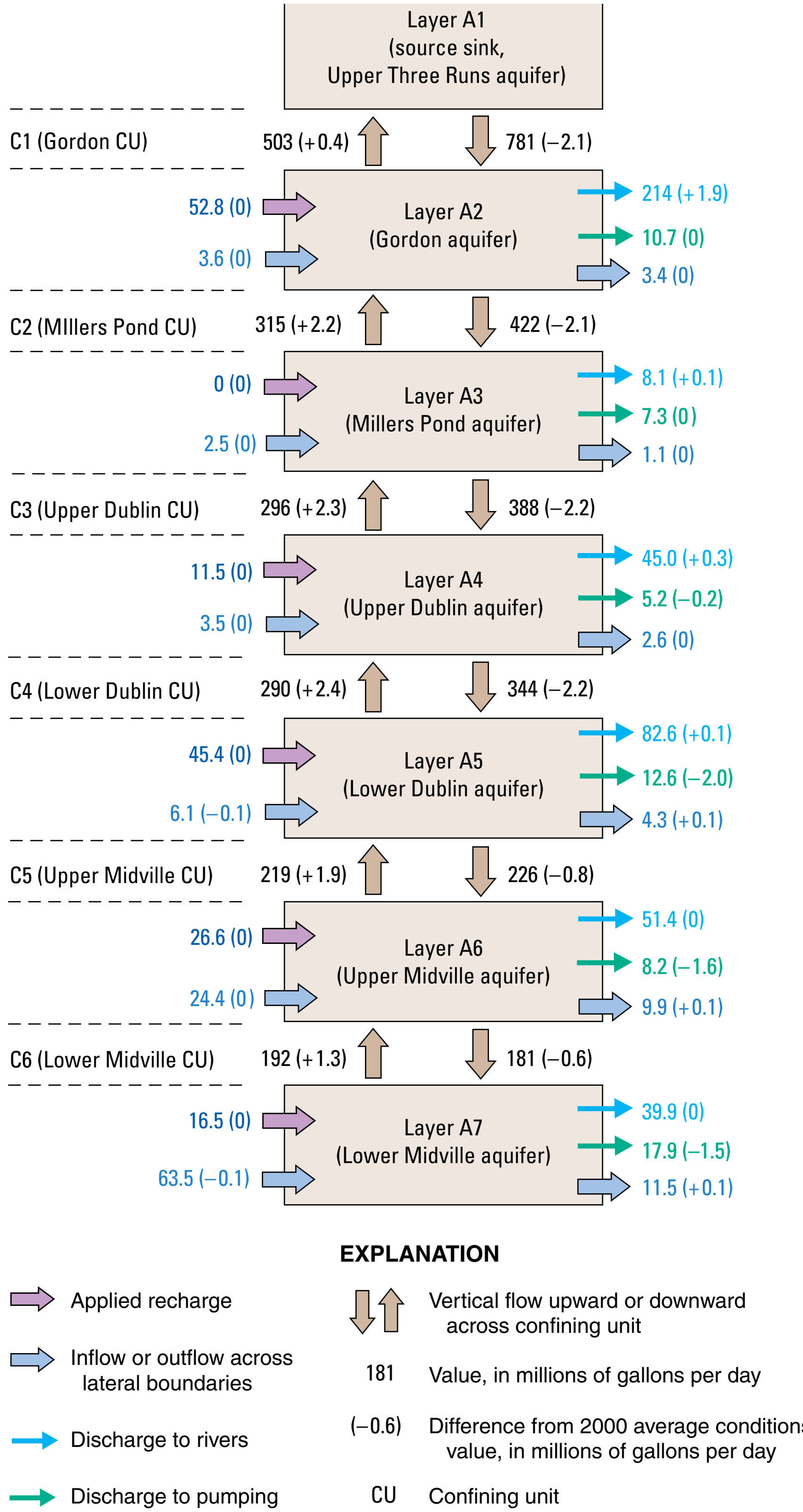


Figure B1. Simulated 2002 average conditions without Savannah River Site pumping (Scenario B) water budget by layer and comparison of budget terms with simulated 2002 average conditions (Scenario A).

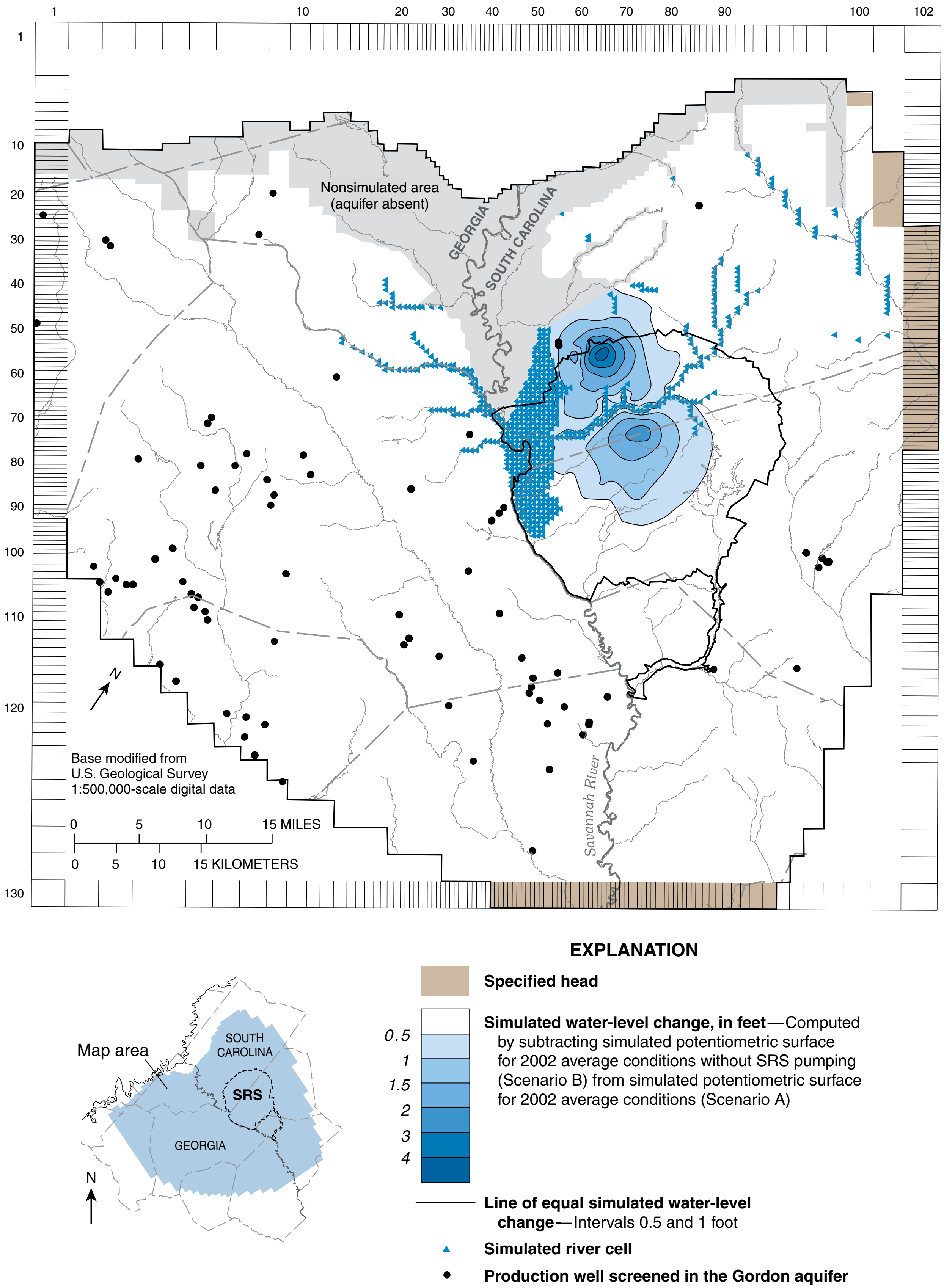


Figure B2. Simulated water-level change between 2002 average conditions (Scenario A) and 2002 average conditions without Savannah River Site (SRS) pumping (Scenario B), and locations of simulated pumpage in the Gordon aquifer (layer A2) in the SRS area, South Carolina.

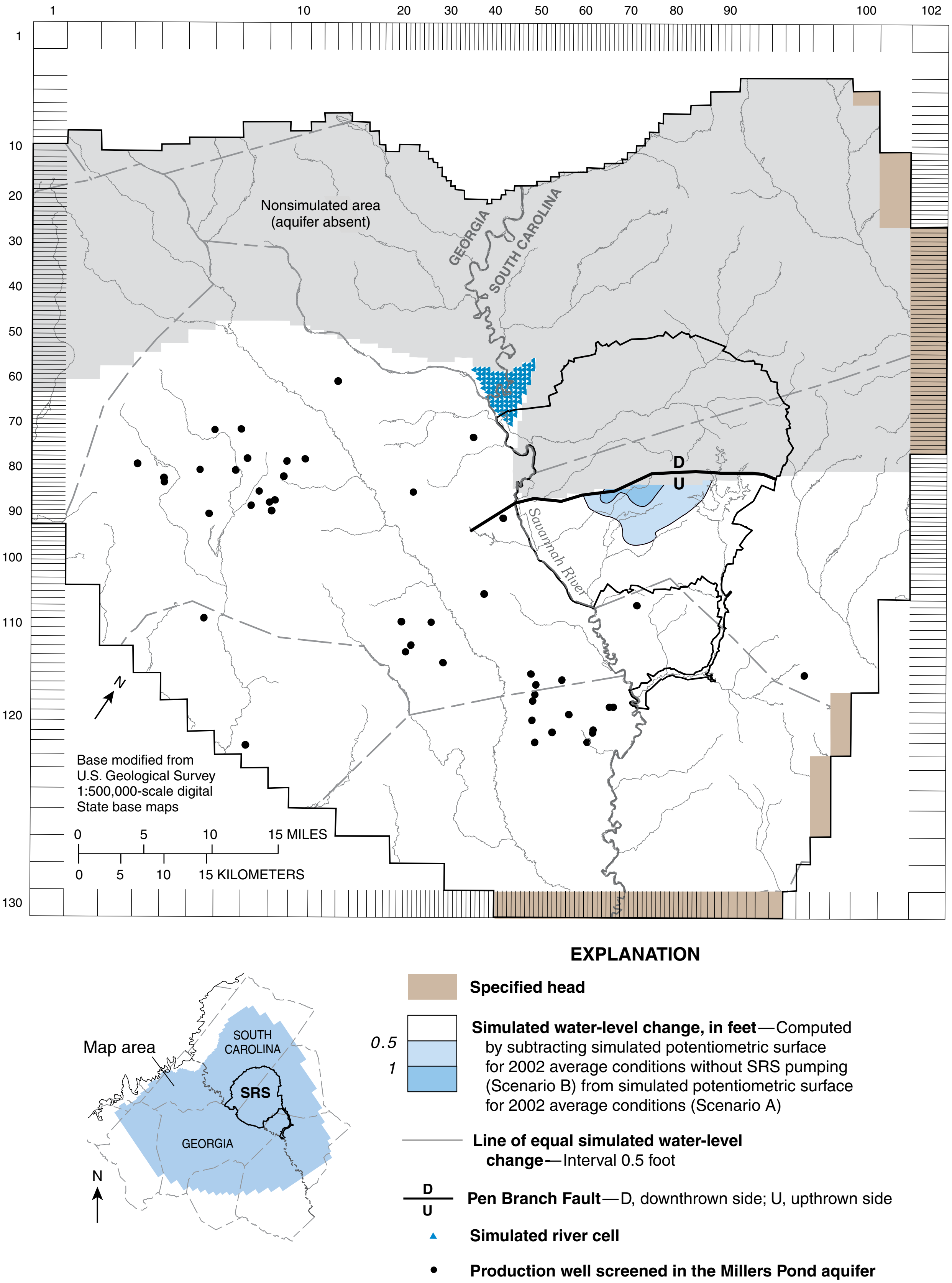
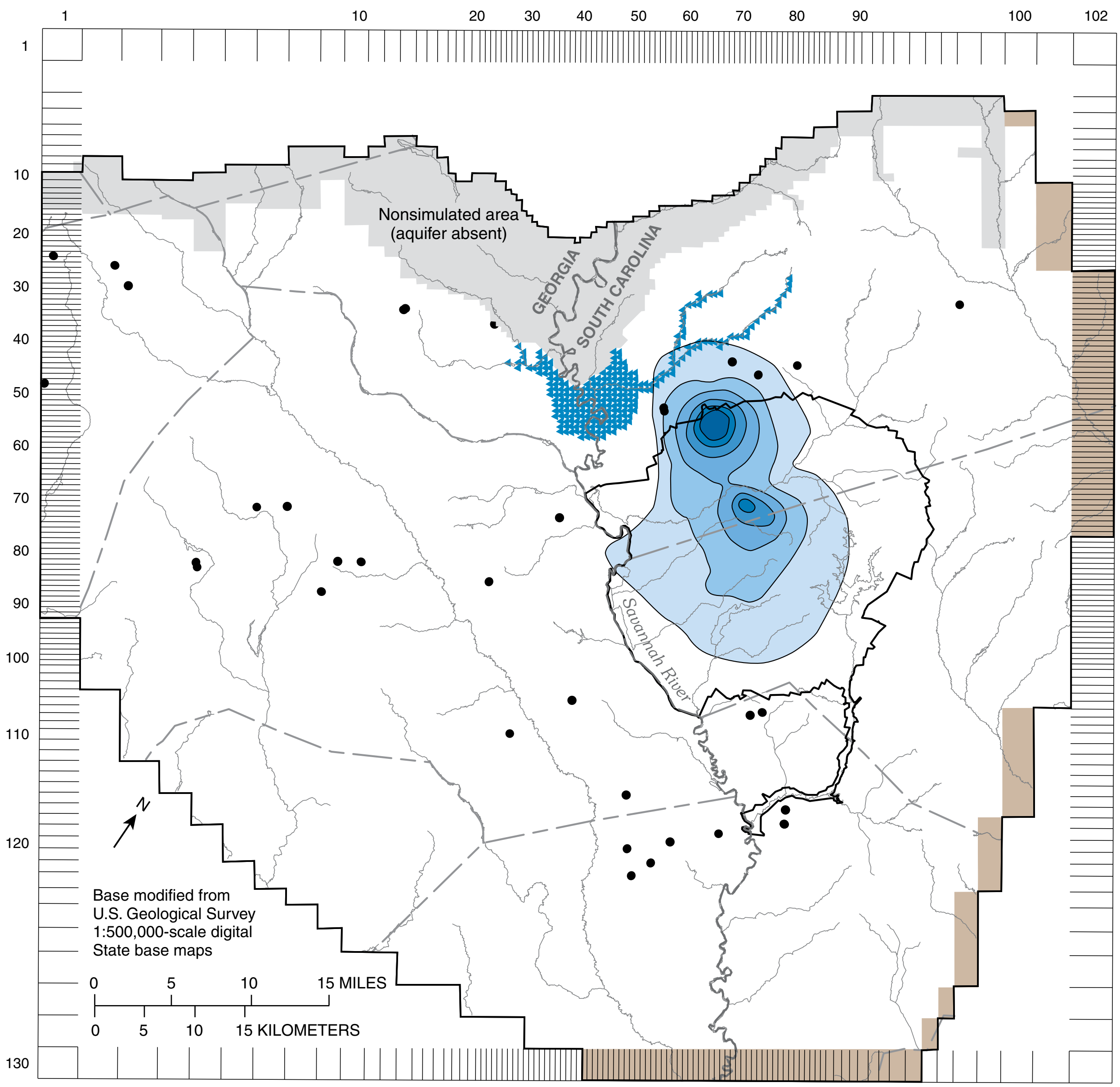
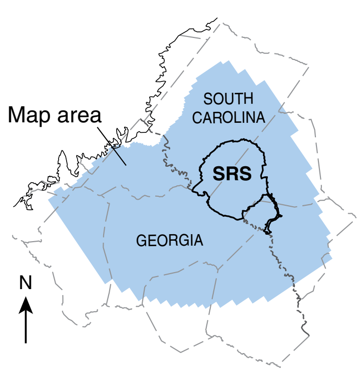


Figure B3. Simulated water-level change between 2002 average conditions (Scenario A) and 2002 average conditions without Savannah River Site (SRS) pumping (Scenario B), and locations of simulated pumpage in the Millers Pond aquifer (layer A3) in the SRS area, South Carolina.





EXPLANATION

Specified head

Simulated water-level change, in feet—Computed by subtracting simulated potentiometric surface for 2002 average conditions without SRS pumping (Scenario B) from simulated potentiometric surface for 2002 average conditions (Scenario A)

0.5
1
1.5
2
3
4

Line of equal simulated water-level change—Intervals 0.5 and 1 foot

Simulated river cell

Production well screened in the upper Dublin aquifer

Figure B4. Simulated water-level change between 2002 average conditions (Scenario A) and 2002 average conditions without Savannah River Site (SRS) pumping (Scenario B), and locations of simulated pumpage in the upper Dublin aquifer (layer A4) in the SRS area, South Carolina.

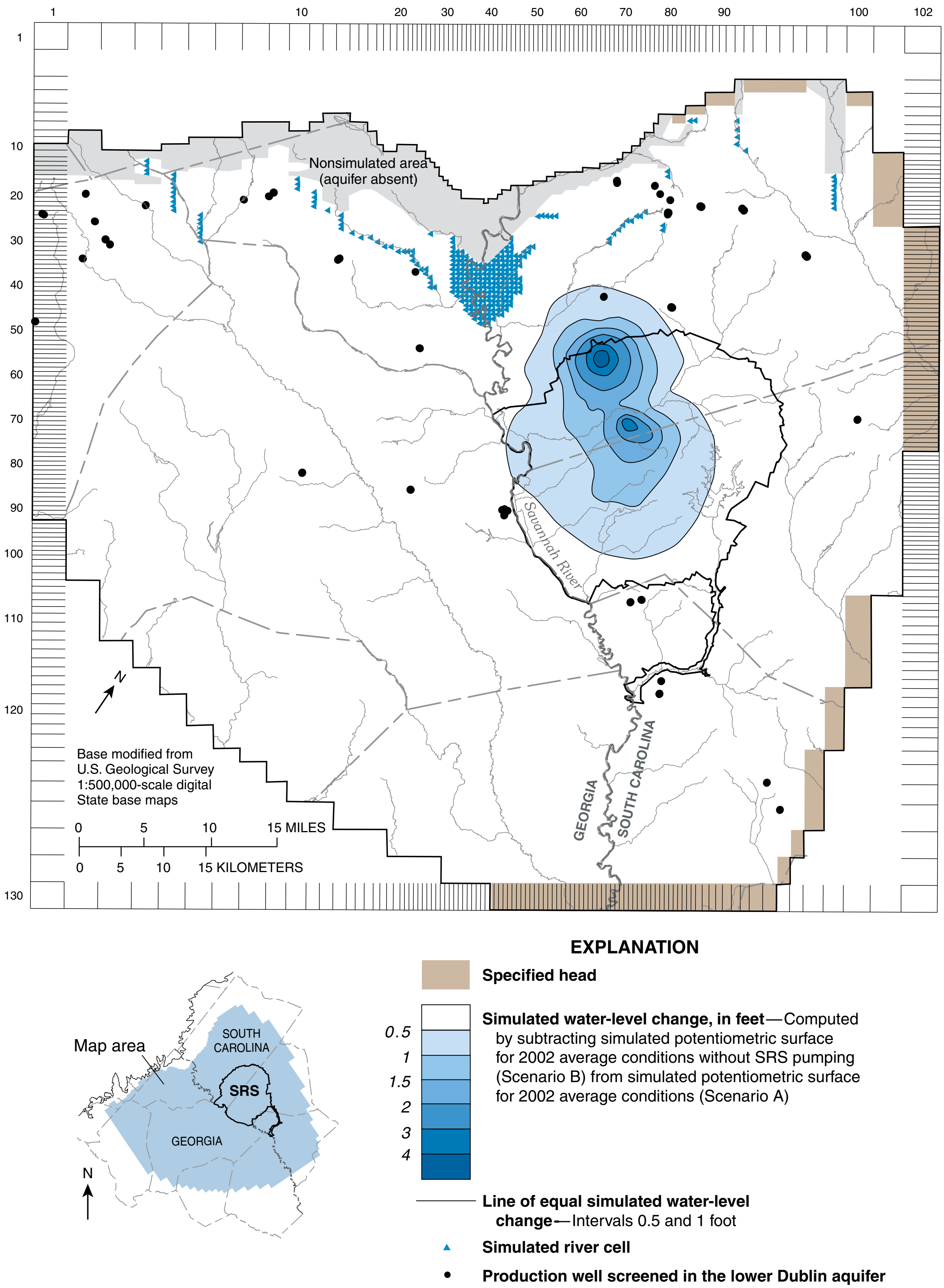


Figure B5. Simulated water-level change between 2002 average conditions (Scenario A) and 2002 average conditions without Savannah River Site (SRS) pumping (Scenario B), and locations of simulated pumpage in the lower Dublin aquifer (layer A5) in the SRS area, South Carolina.

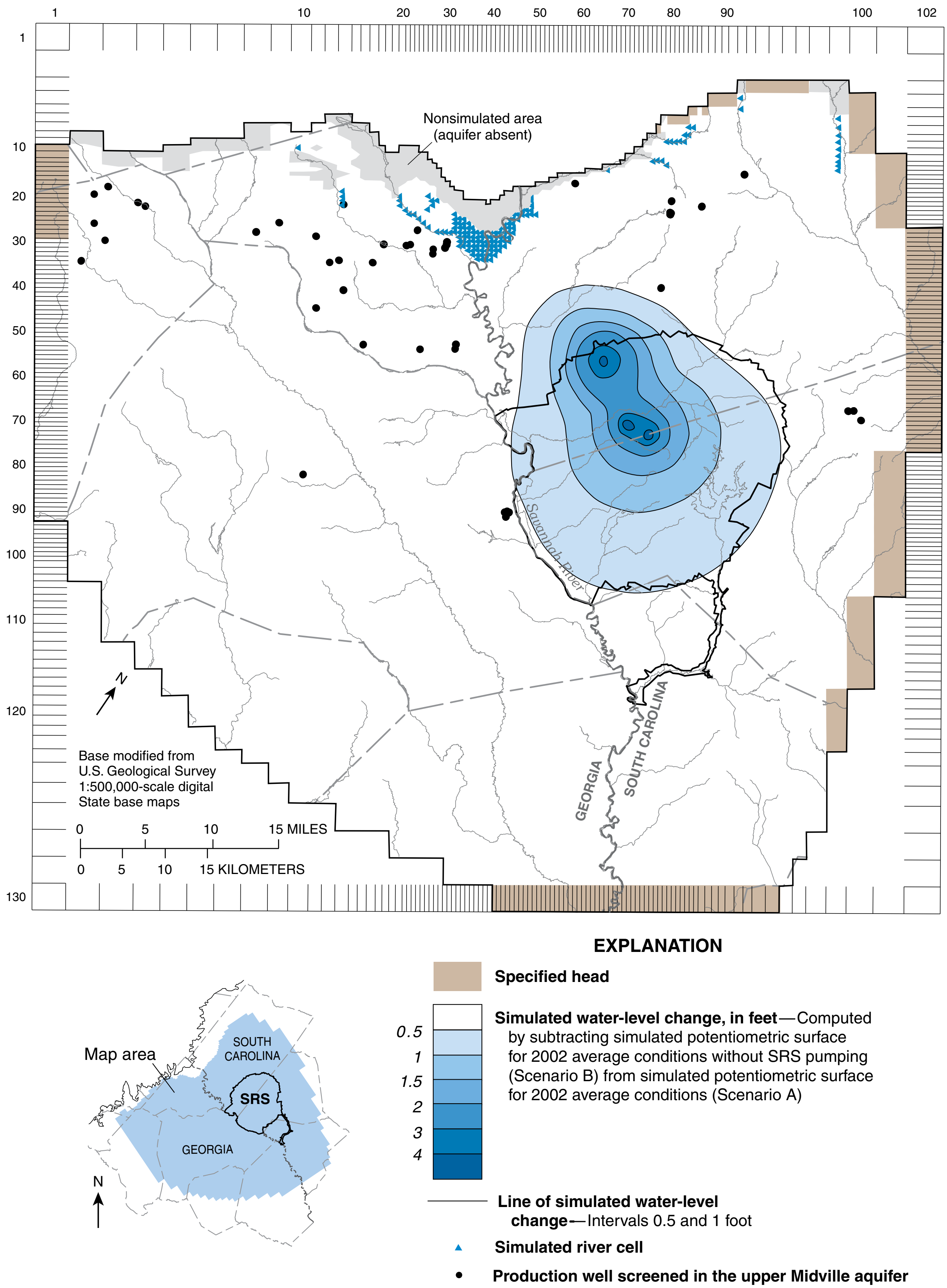


Figure B6. Simulated water-level change between 2002 average conditions (Scenario A) and 2002 average conditions without Savannah River Site (SRS) pumping (Scenario B), and locations of simulated pumpage in the upper Midville aquifer (layer A6) in the SRS area, South Carolina.

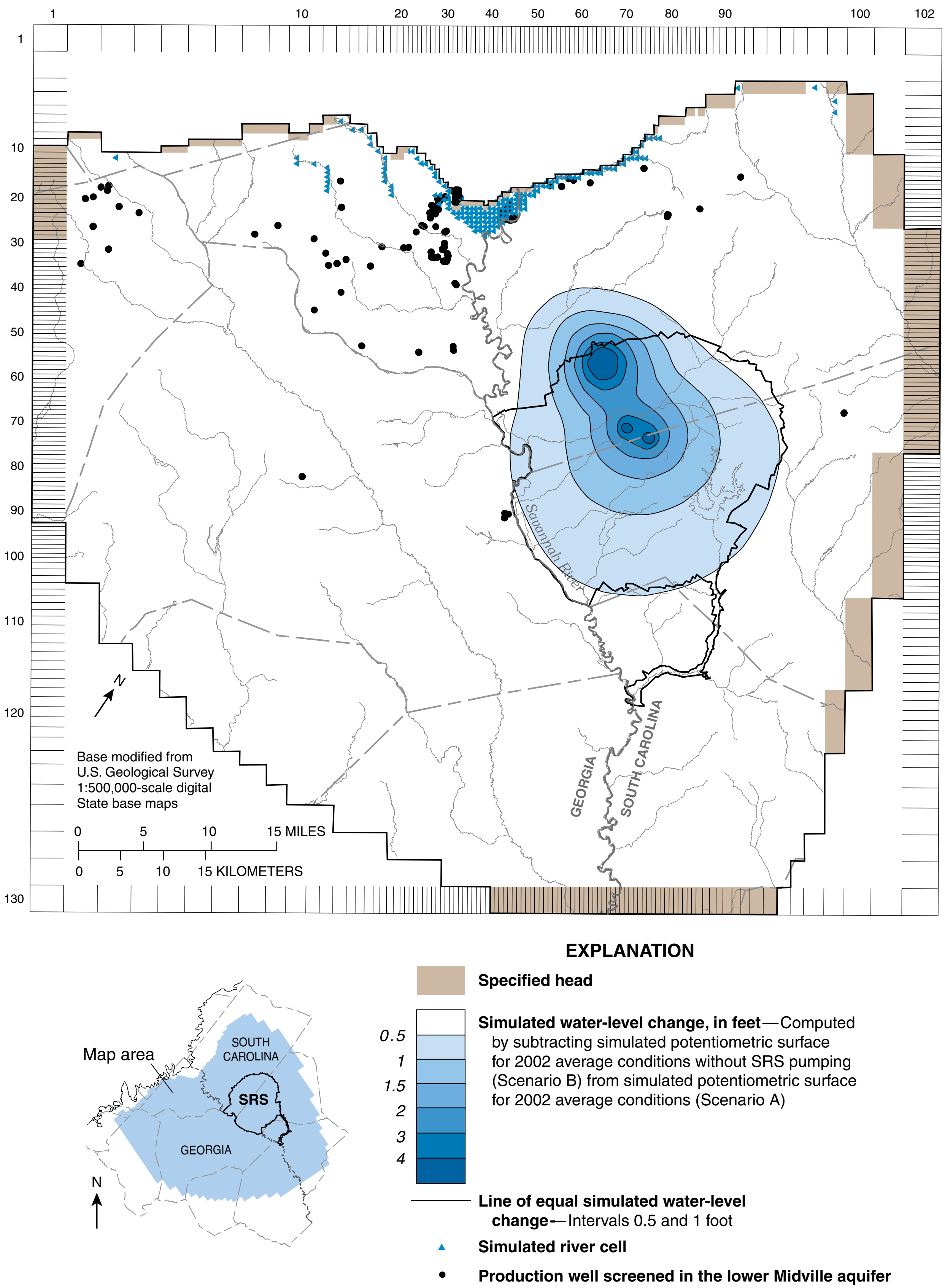


Figure B7. Simulated water-level change between 2002 average conditions (Scenario A) and 2002 average conditions without Savannah River Site (SRS) pumping (Scenario B), and locations of simulated pumpage in the lower Midville aquifer (layer A7) in the SRS area, South Carolina.

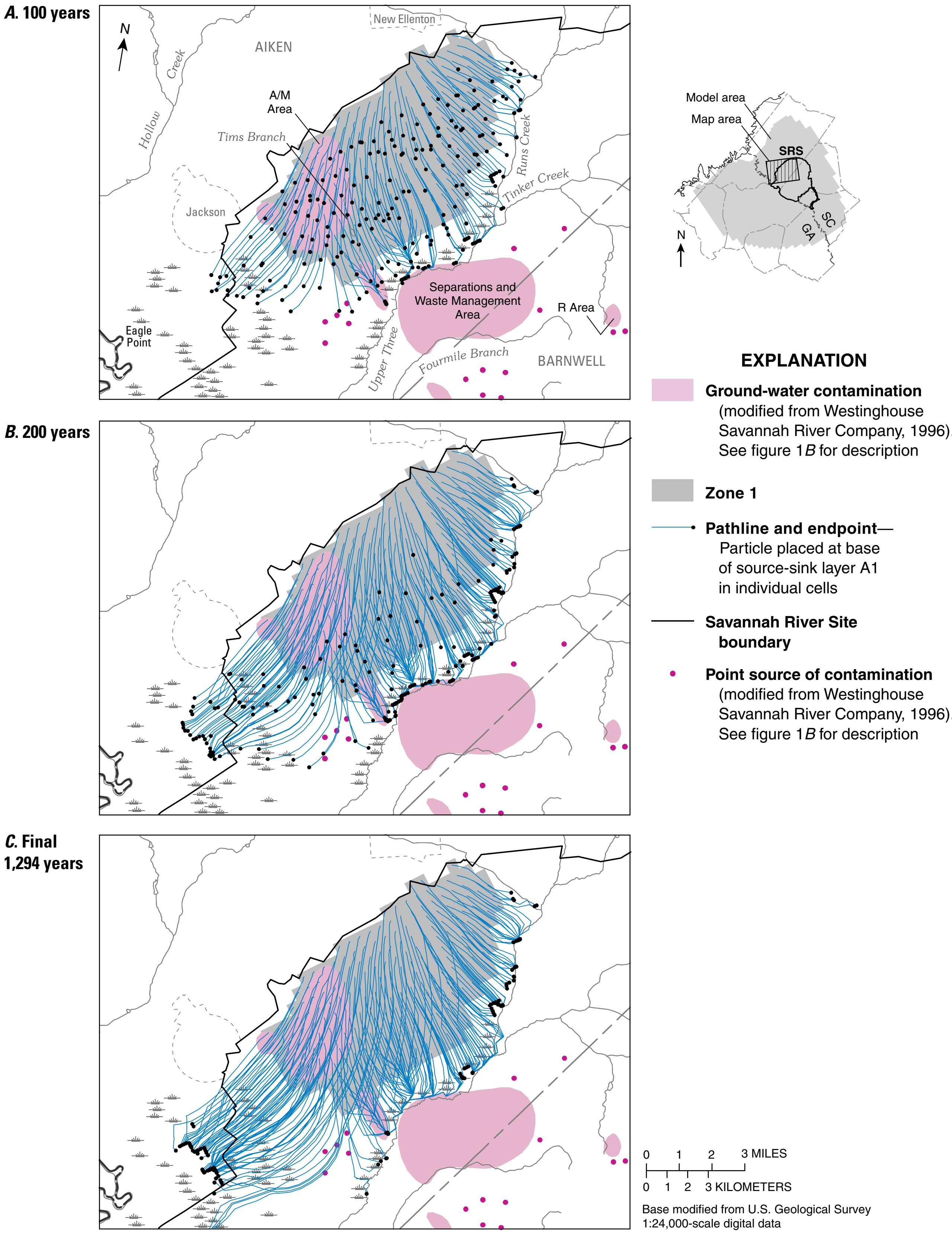


Figure B8. Particle-tracking results from the simulation of 2002 average conditions without Savannah River Site (SRS) pumping (Scenario B) at selected time intervals in zone 1 located in the northwestern part of the SRS, South Carolina.

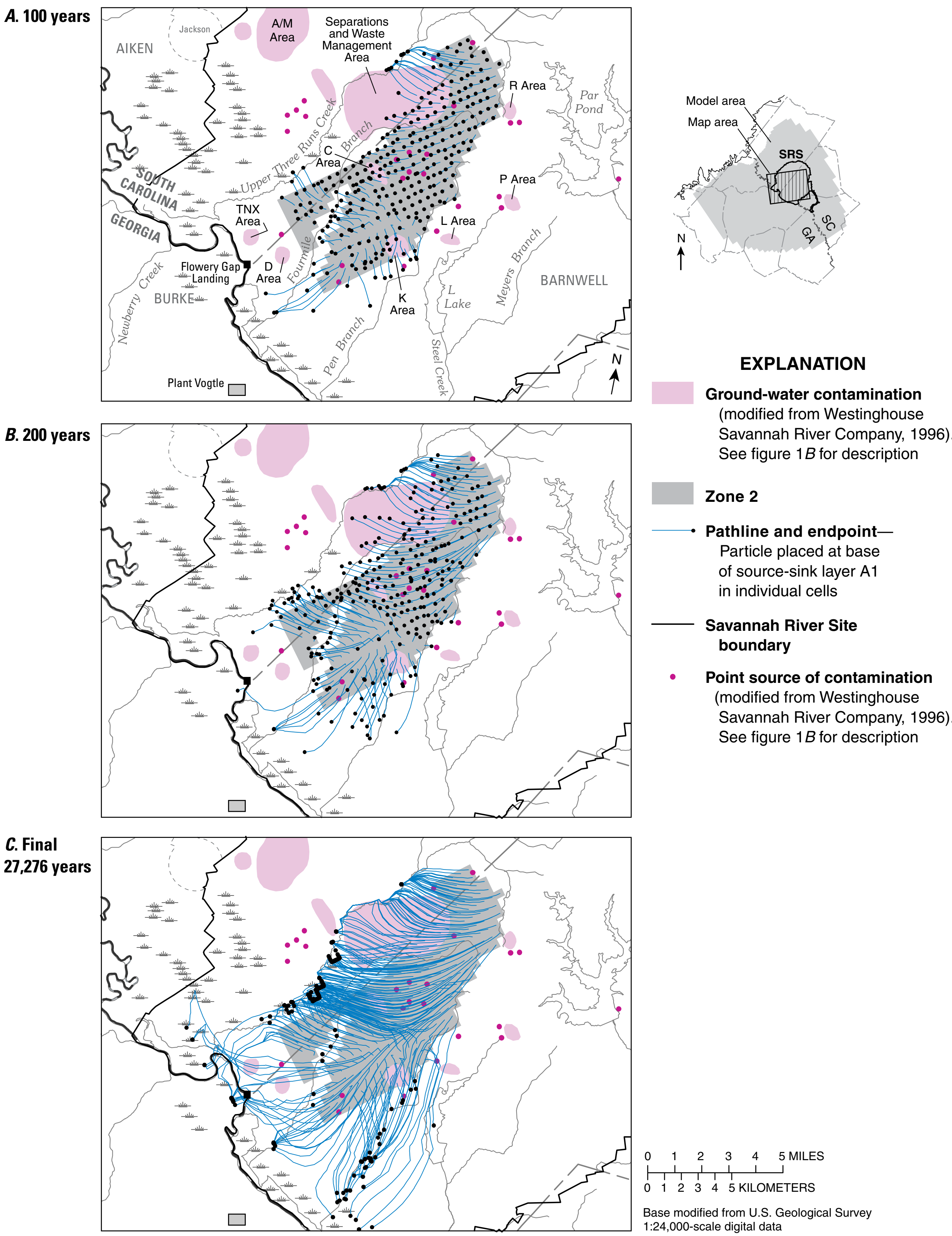


Figure B9. Particle-tracking results from the simulation of 2002 average conditions without Savannah River Site (SRS) pumping (Scenario B) at selected time intervals in zone 2 located in the central part of the SRS, South Carolina.

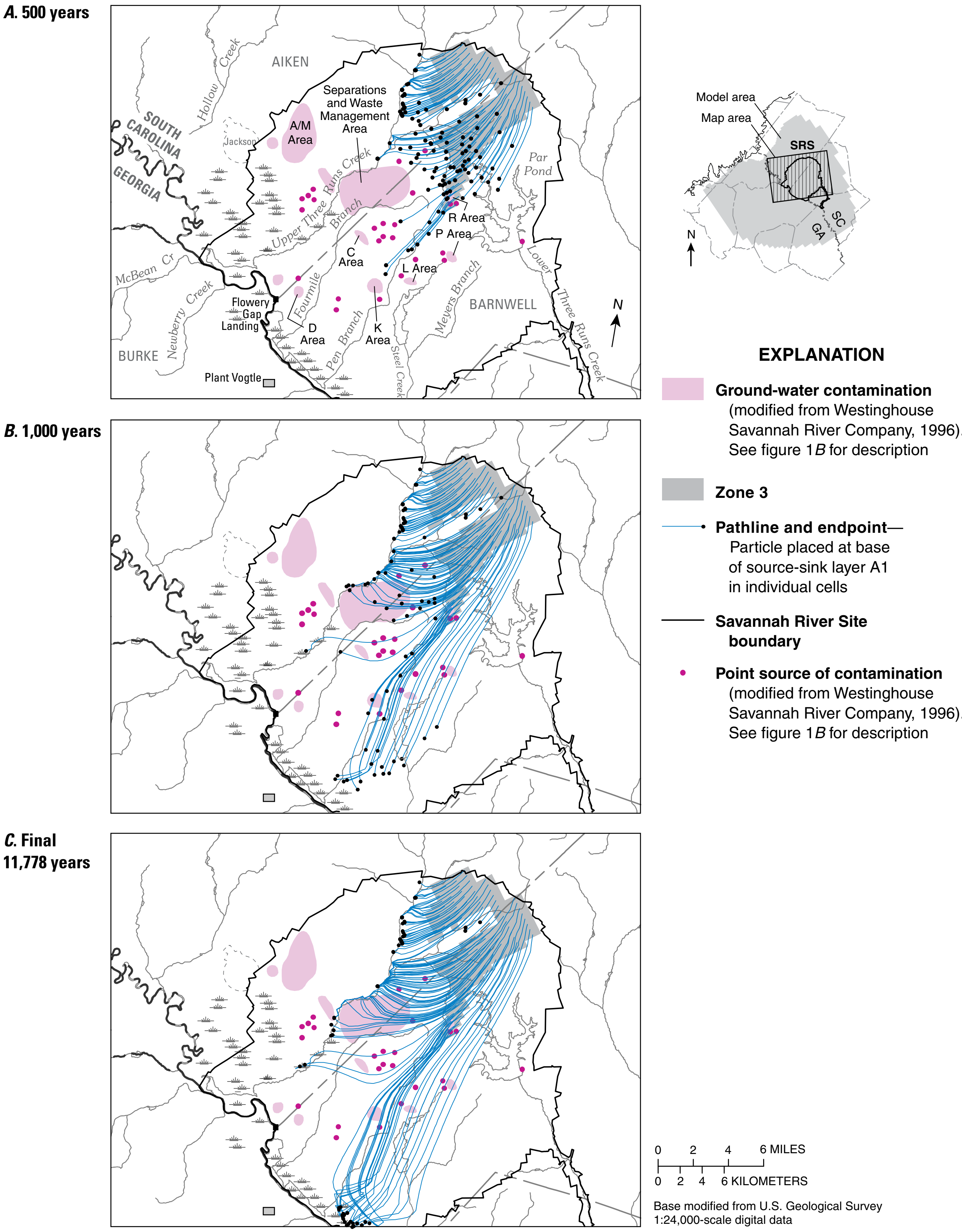


Figure B10. Particle-tracking results from the simulation of 2002 average conditions without Savannah River Site (SRS) pumping (Scenario B) at selected time intervals in zone 3 located in the northeastern part of the SRS, South Carolina.

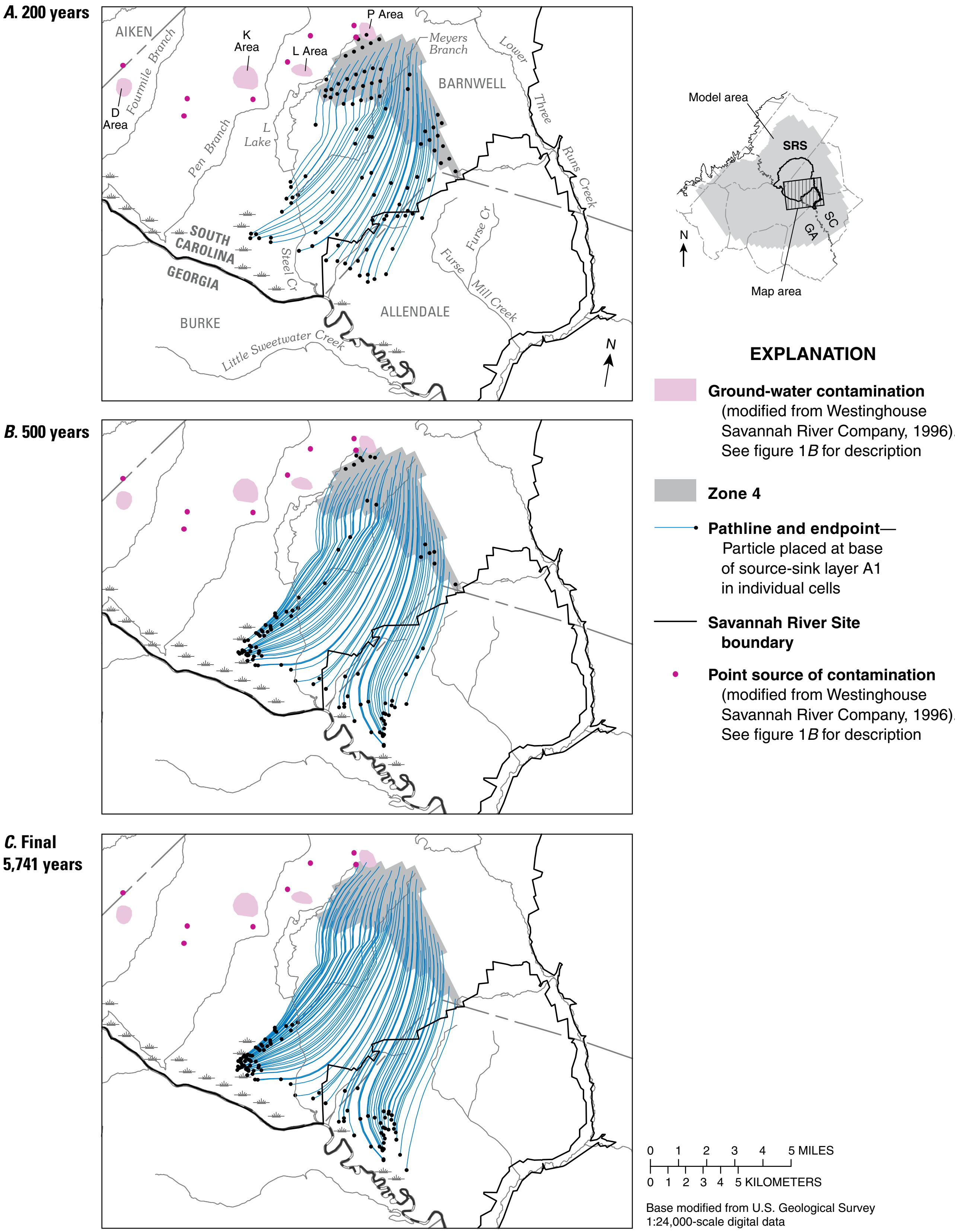


Figure B11. Particle-tracking results from the simulation of 2002 average conditions without Savannah River Site (SRS) pumping (Scenario B) at selected time intervals in zone 4 located in the south-central part of the SRS, South Carolina.

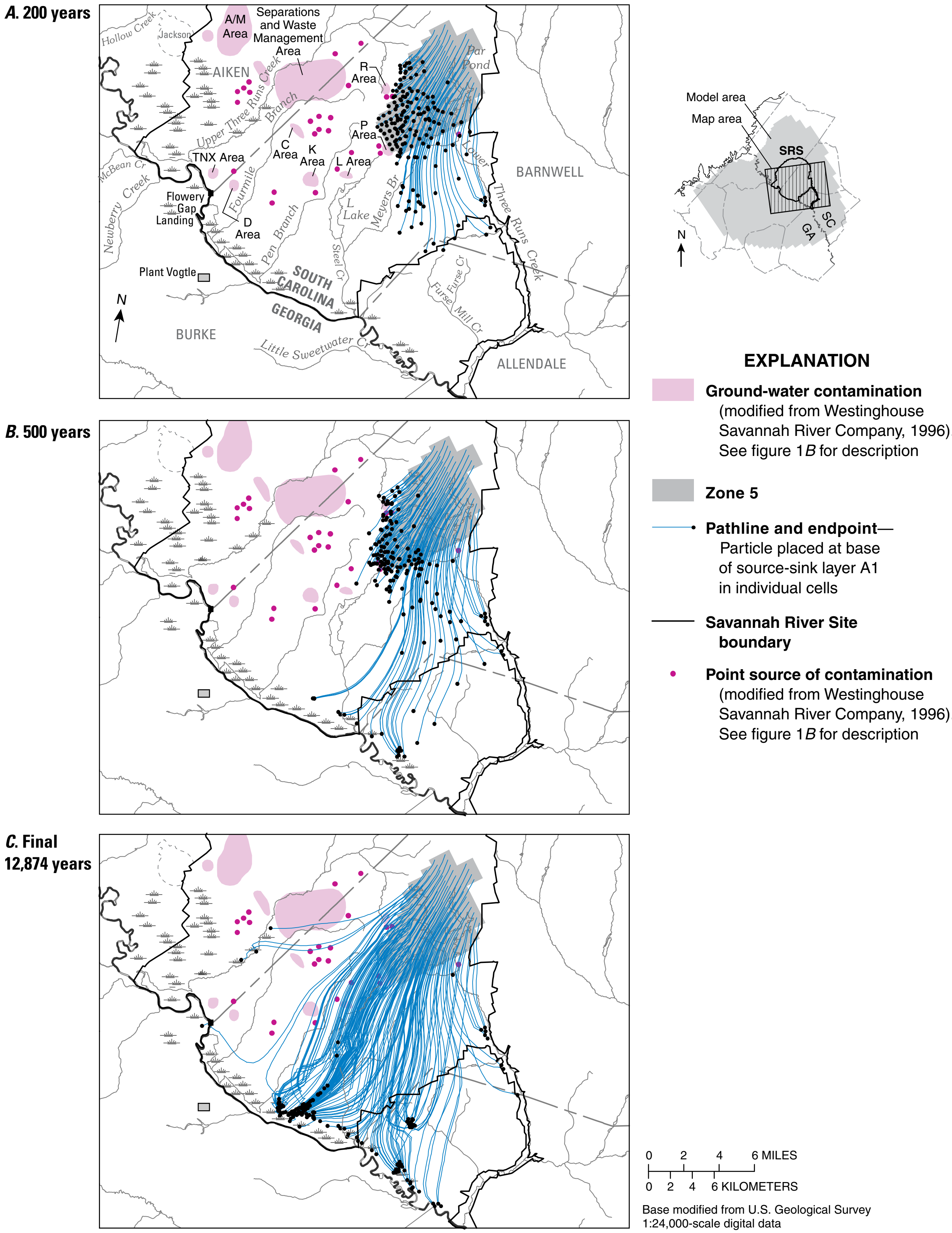
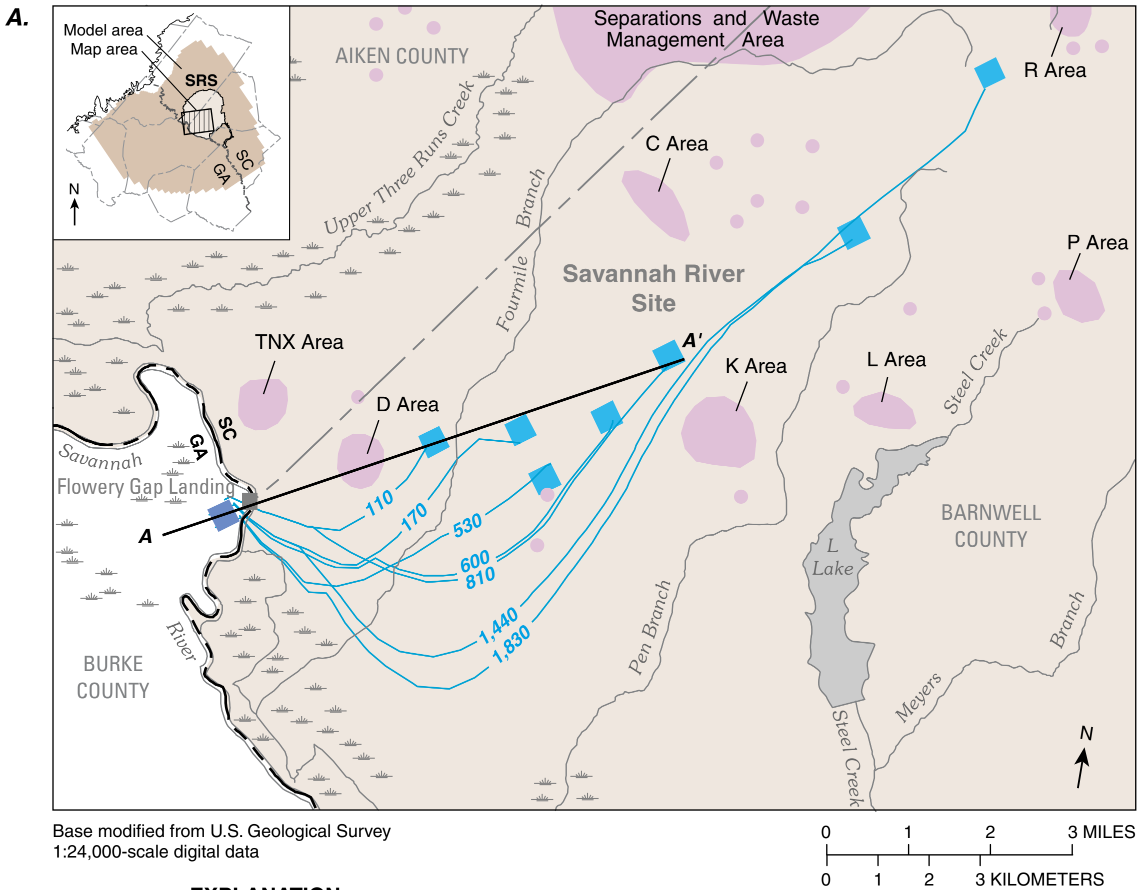


Figure B12. Particle-tracking results from the simulation of 2002 average conditions without Savannah River Site (SRS) pumping (Scenario B) at selected time intervals in zone 5 located in the eastern part of the SRS, South Carolina.



EXPLANATION

Map

Ground-water contamination

Recharge cell

Selected discharge cell

A —— A' Line of section

— 110 — Particle path and total years of travel

Cross section

Savannah River alluvial valley

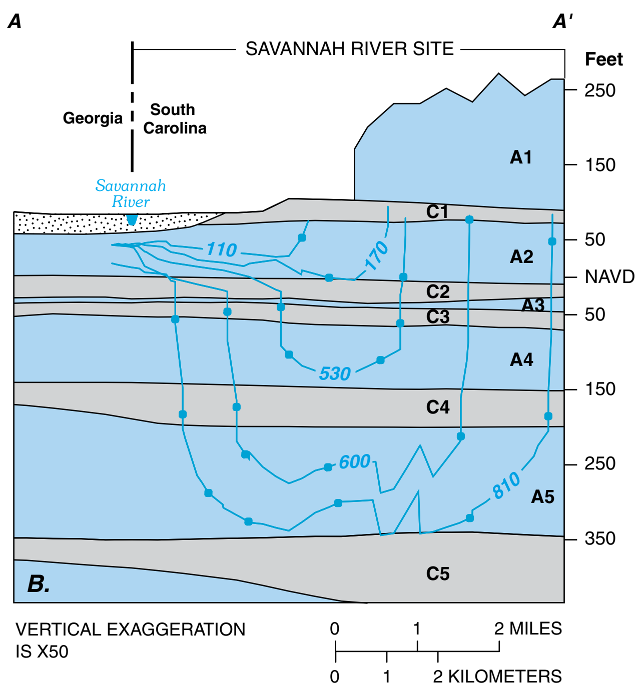
Aquifer

Confining unit

Hydrogeologic contact

100-year time-of-travel interval

A1 Active model layer



	Simulation		
	[1]1987–92	2002 Scenario A	2002 without SRS pumping Scenario B
Boundary conditions	Long-term average	Average	Average
Particles released	300	300	300
Recharge on SRS	93	89	110
Time-of-travel, in years			
Mean	534	516	460
90th percentile	978	934	904
75th percentile	753	736	722
Median	486	462	366
25th percentile	140	145	120
10th percentile	102	103	110
Maximum	2,356	2,299	2,572
Minimum	80	81	79

[1]Clarke and West, 1998

Figure B13. (A) Simulated trans-river flow for 2002 average conditions without Savannah River Site (SRS) pumping (Scenario B) and selected ground-water pathlines in map view, and (B) selected ground-water pathlines in cross-sectional view along row 82 (see figure 8) at the SRS, South Carolina.