Appendix C. Scenario C— Simulation of 2020 Average Conditions

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Appendix C. Scenario C—Simulation of 2020 Average Conditions

Purpose of Scenario

The purpose of Scenario C was to evaluate the effects of adjustments to specified heads in the source-sink layer and along lateral boundaries. Scenario C also represents a redistribution of pumpage with a general decrease in ground-water withdrawals for irrigation and an increase in well production for public supply in areas of projected population growth for the year 2020. In Scenario C, 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 made with 2002 average hydrologic conditions (Scenario A) to document how these adjustments to pumping distribution affected simulated ground-water flow, water levels, and particle movement.

Water Budget Changes

Total projected ground-water pumpage in Scenario C (layers A2–A7) during this period was 55.3 Mgal/d, of which 35 percent was for lower Midville aquifer (layer A7), 22 percent was for the lower Dublin aquifer (layer A5), and 14 percent was for the upper Midville aquifer (layer A6). The remaining 29 percent of ground-water pumpage in Scenario C was apportioned to the upper Midville aquifer (layer A6), Millers Pond aquifer (layer A3), and the upper Dublin aquifer (layer A4; table 11). The overall estimated pumpage for the 2020 projection is substantially less than the 2002 simulation, which indicates the severity of the 1998–2002 drought and above-average well use for irrigation. Simulated water budget for Scenario C indicates that major components of flow were similar to the Scenario A simulation (2002 simulation with averaged boundary conditions), with the exception that decreased overall pumpage in the active layers of the model (layers A2–A7) induced 4.2 Mgal/d less recharge from the source-sink layer A1 into layer A2 (Gordon aquifer; fig. C1). In general, inflows to the lower layers of the model (layers A3–A6) through the confining units decreased ranging from 0.9 to 3.4 Mgal/d (fig. C1). The decreased inflows to each of the active layers of the model, however, were balanced by increased outflows ranging from 0.4 to 3.6 Mgal/d. The simulated outflow to streams was similar to Scenario A with the greatest changes being an increase in layer A2 (Gordon aquifer) of 0.9 Mgal/d and a decrease of 0.3 Mgal/d in layer A4 (upper Dublin aquifer, fig. C1).

Water-Level Changes

The adjustments made to specified heads in the source-sink layer A1 and along lateral boundaries of the active layers of the model (layers A2–A7) for Scenario C resulted in simulated water-level changes that ranged from declines of as much as 0.1 feet (ft) in the Gordon aquifer (layer A2), to rises greater than 4 ft in the Gordon aquifer and Dublin and Midville aquifer systems (layers A2, A4–A7). Simulated water-level changes for Scenario C are shown in figures C2–C7. The most pronounced changes were near production wells for the city of Aiken, S.C., where pumping rates were unusually high during the 2000–2002 period. The water-level changes in this area generally range from 1 to 4 ft with only minor changes (+0.1 ft) extending south into the Savannah River Site (SRS). The relatively small simulated changes on the SRS also are due in part to SRS production wells being simulated at a constant 2002 pumping rate of 5.3 Mgal/d. The exception is the Millers Pond aquifer (layer A3) with simulated water-level changes on the SRS ranging from +0.5 to +1 ft (fig. C3).

Ground-Water Flowpaths

Simulated ground-water flowpaths for Scenario C generally were limited to areas within the SRS boundary (figs. C8–C12). Flowpaths were evaluated using MODPATH in forward-tracking mode from five zones in which particles placed at the base of the Upper Three Runs aquifer (source-sink layer A1) 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 eventually are 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. C8). 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. C9–C10). 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. C11–C12). 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. C8), 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; (3) discharge areas located in Allendale County, S.C., migrating from zones 4 and 5; and (4) discharge area located in Screven County, Ga., migrating from zone 5.

Time-of-Travel

Simulated time-of-travel for Scenario C from the five zones of recharge on the SRS to discharge areas ranged from 21 years (yr) to about 14,700 yr (figs. C8–C12, table C1). Fastest mean travel times occurred from zone 1; slowest travel times occurred from zone 5 (table C1). 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 C1 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 91 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 293 yr, with values ranging from 21 yr to about 1,390 yr. Mean time-of-travel from zone 2 to discharge areas was 861 yr, with values ranging from 29 yr to about 6,700 yr. Mean time-of-travel from zone 3 to discharge areas was 1,085 yr, with values ranging from 63 yr to about 14,700 yr. Mean time-of-travel from zone 4 to discharge areas was 495 yr, with values ranging from 122 to 1,560 yr. Mean time-of-travel from zone 5 to discharge areas was about 1,530 yr, with values ranging from 36 yr to about 12,100 yr.

At the 100-yr time-of-travel interval (figs. C8–C9), about 10 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. C8) 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 1,393 yr. In zone 2, the 200-yr time-of-travel interval (fig. C9) indicates about 10 percent of the particles applied have migrated to 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. C11–C12) shows general ground-water movement to the south with particle discharge areas located to the north of the Savannah River on the South Carolina side. One particle exhibited trans-river flow from zone 5, originating in a recharge area northeast of Par Pond with a discharge area located near the confluence of Lower Three Runs Creek and the Savannah River in Screven County, Ga. (fig. C12). The particle penetrates the lower Dublin aquifer (layer A5) before migrating laterally toward the Savannah River with discharge occurring within the source-sink layer A1 (Upper Three Runs aquifer). The time-of-travel for this particle is 2,720 yr.

The final endpoints from particles placed in zones 1–3 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. In general, the time-of-travel for particles originating in zones 3 and 5 is substantially longer than particles placed in zones 1, 2, and 4 (figs. C8–C12; table C1).

Trans-River Flow

Simulated trans-river flow for Scenario C was primarily from ground water moving to discharge areas located near Flowery Gap Landing along the Savannah River (fig. C13). 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, 88 particles (29 percent) backtracked to recharge areas on the SRS. The remaining 212 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 541 yr with a median value of 454 yr. The cross-sectional view indicates shorter travel times ranged from 110 to 170 yr within layer A2 (Gordon aquifer), and longer travel times ranged from 530 to 820 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 line indicate slow movement through layers A4 and A5 (upper and lower Dublin aquifers). In map view, one particle has backtracked to a recharge cell located near R Area with a simulated travel time of 1,680 yr (fig. C13). 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 C1. 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)

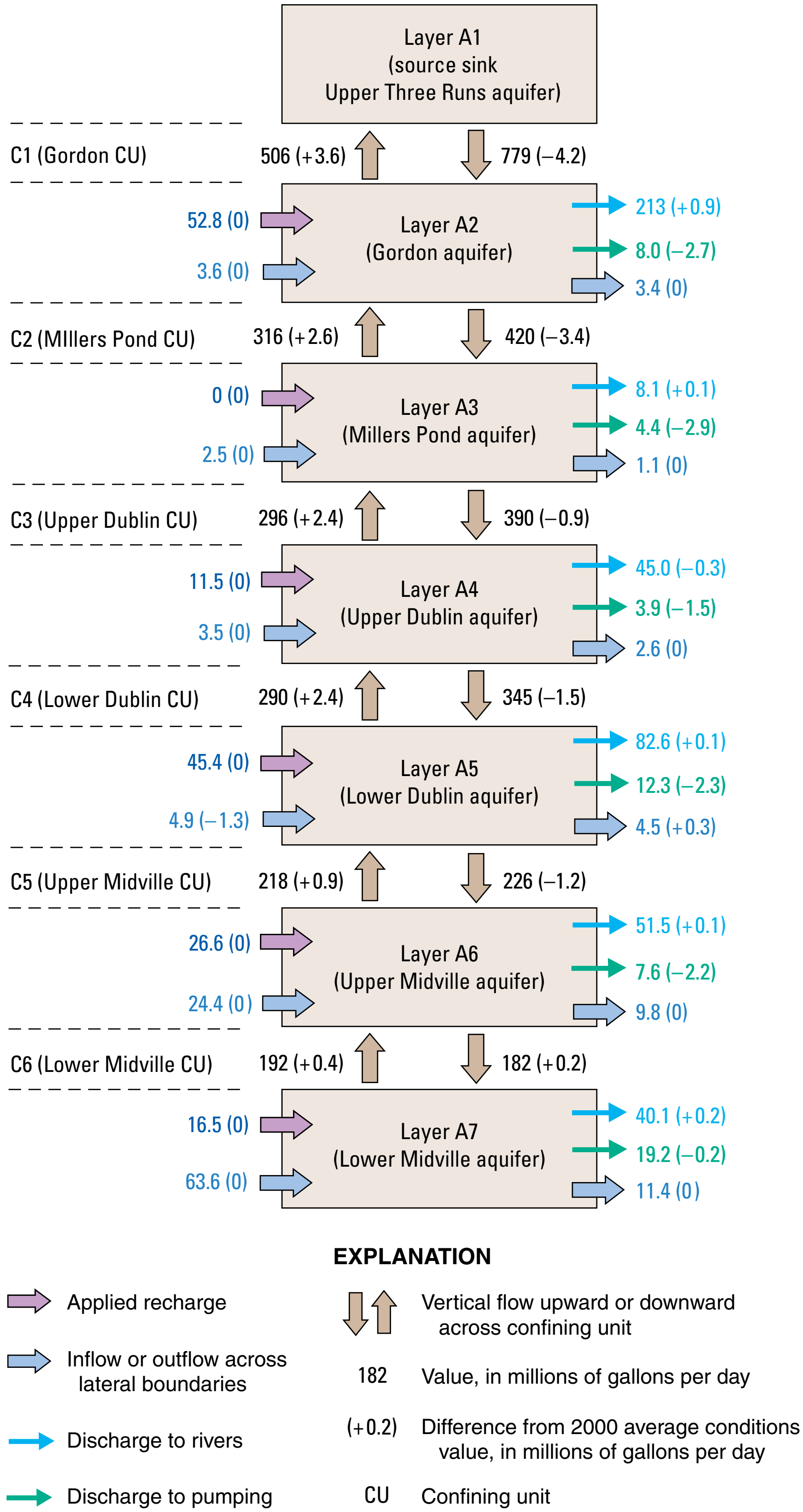


Figure C1. Simulated 2020 average conditions (Scenario C) water budget by layer and comparison of budget terms with simulated 2002 average conditions (Scenario A).

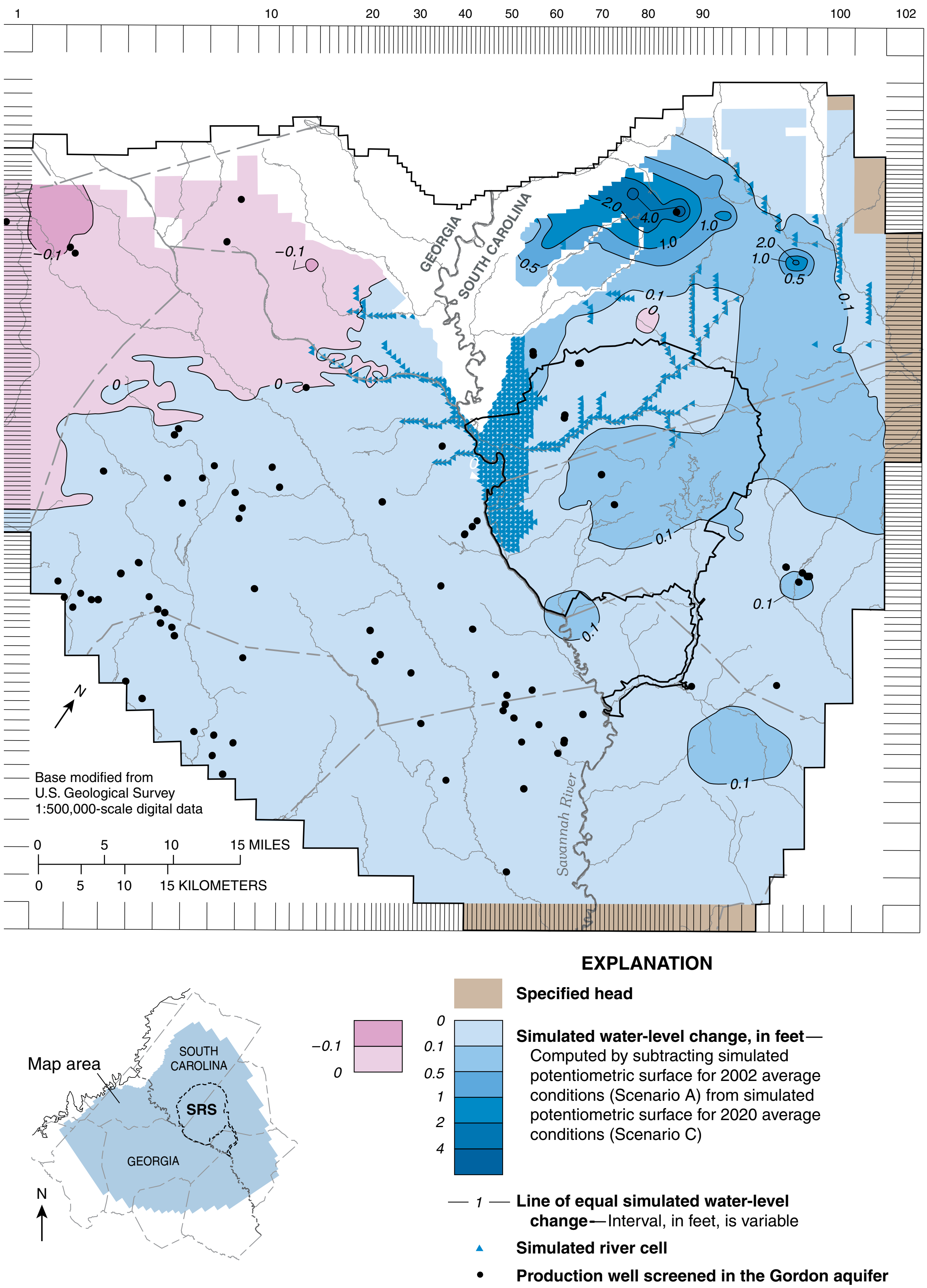


Figure C2. Simulated water-level change between 2002 average conditions (Scenario A) and 2020 average conditions (Scenario C), and locations of simulated pumpage in the Gordon aquifer (layer A2) in the Savannah River Site (SRS) area, South Carolina.

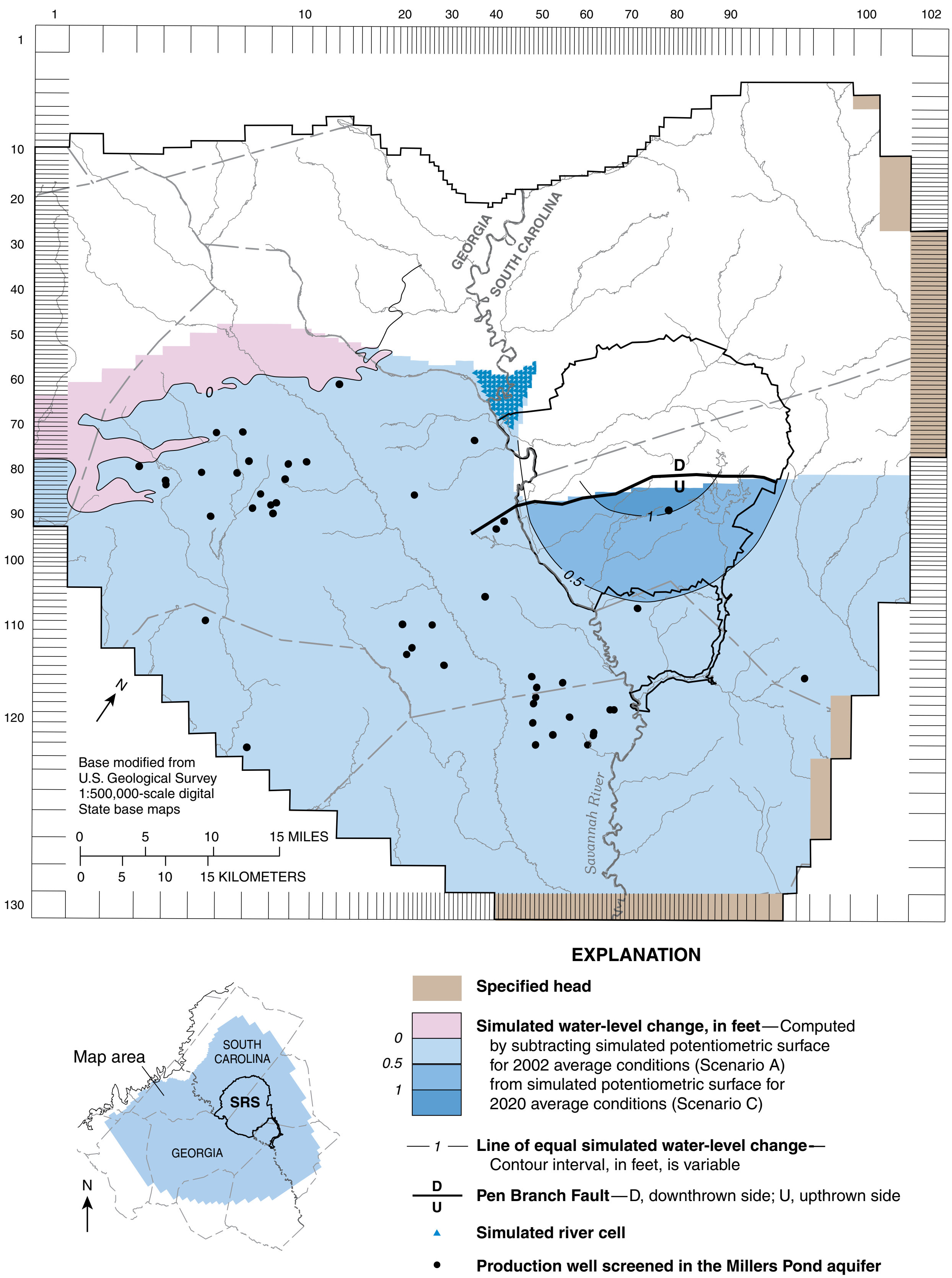


Figure C3. Simulated water-level change between 2002 average conditions (Scenario A) and 2020 average conditions (Scenario C), and locations of simulated pumpage in the Millers Pond aquifer (layer A3) in the Savannah River Site (SRS) area, South Carolina.

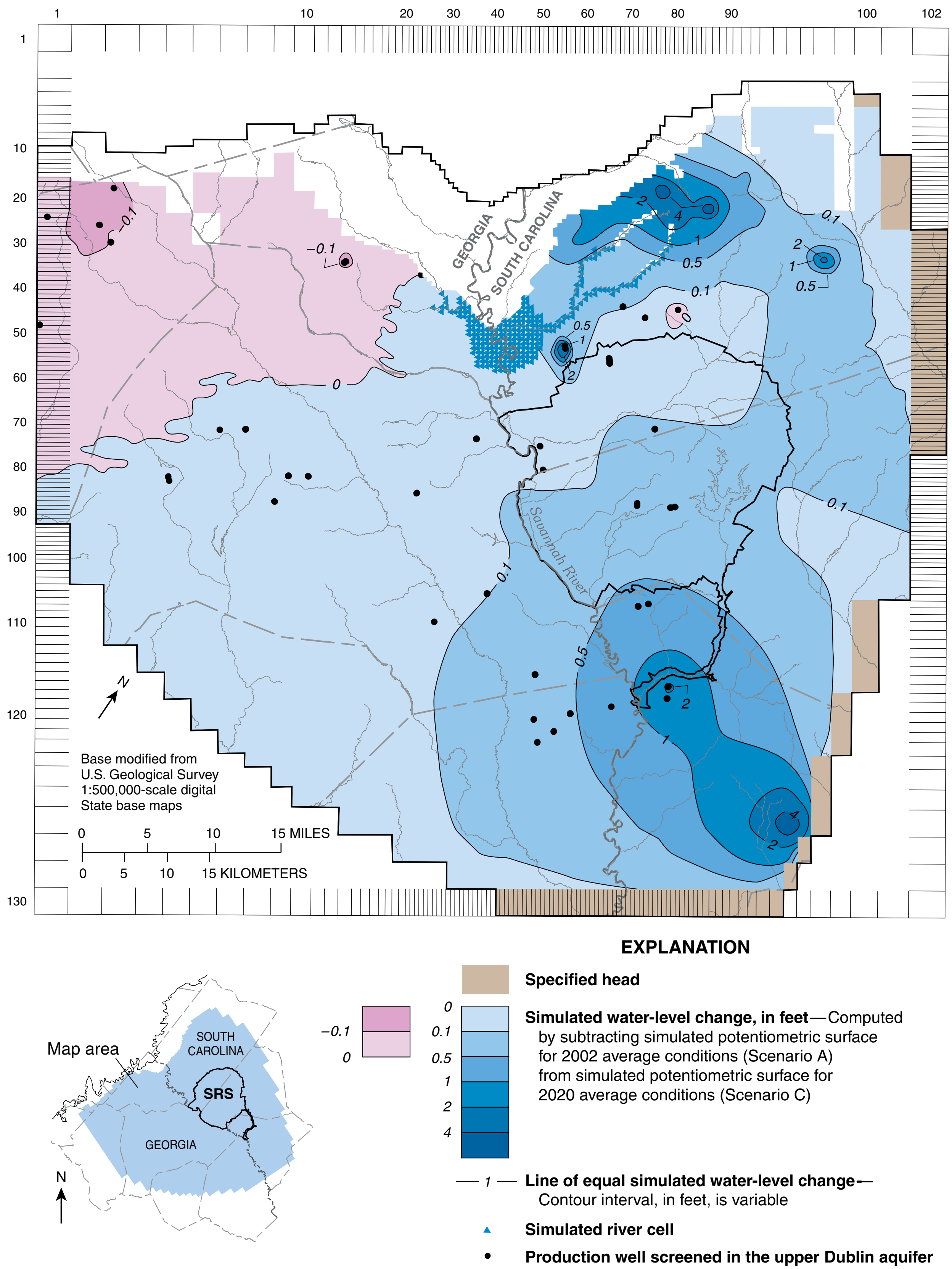


Figure C4. Simulated water-level change between 2002 average conditions (Scenario A) and 2020 average conditions (Scenario C), and locations of simulated pumpage in the upper Dublin aquifer (layer A4) in the Savannah River Site (SRS) area, South Carolina.

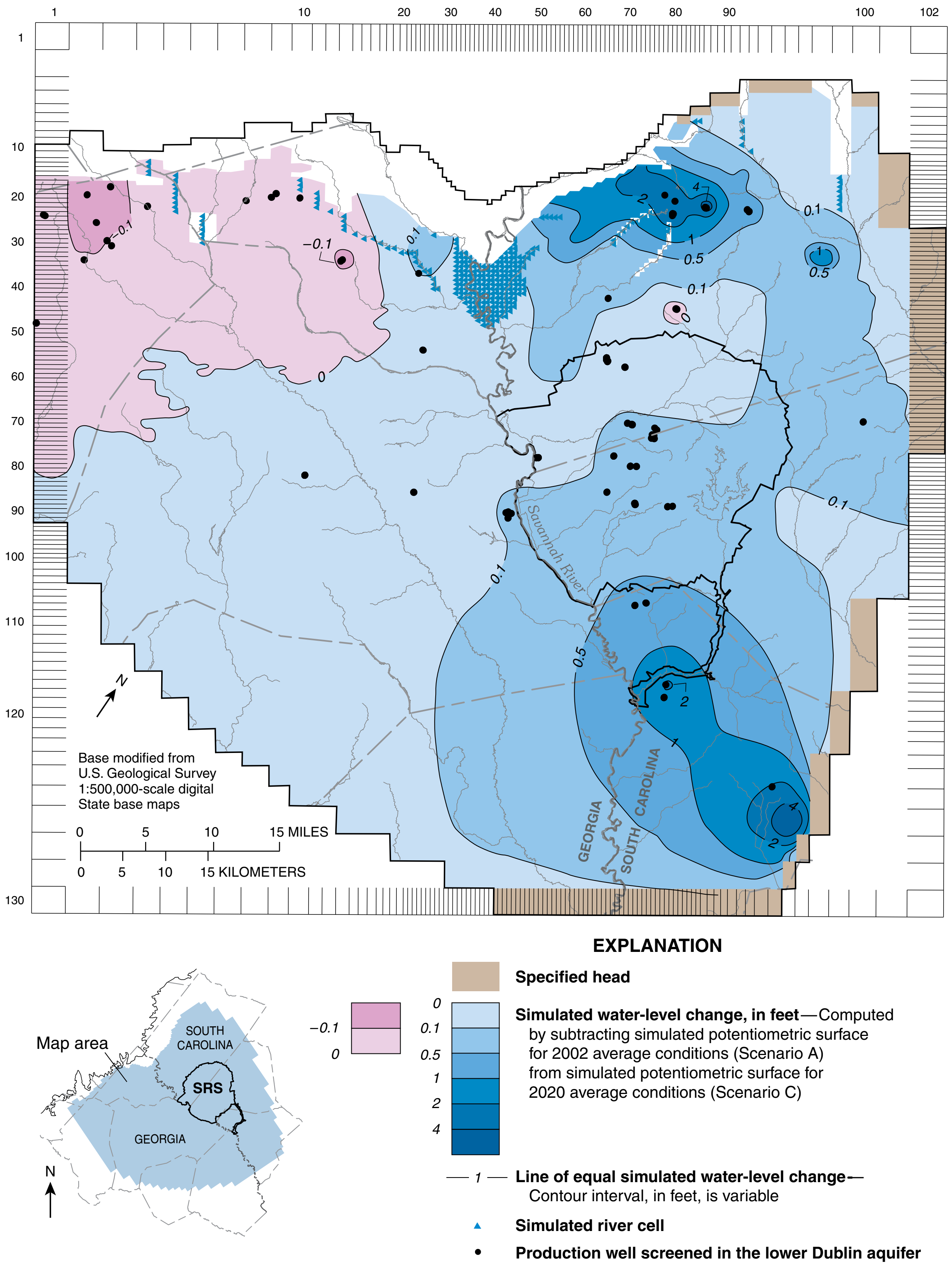


Figure C5. Simulated water-level change between 2002 average conditions (Scenario A) and 2020 average conditions (Scenario C), and locations of simulated pumpage in the lower Dublin aquifer (layer A5) in the Savannah River Site (SRS) area, South Carolina.

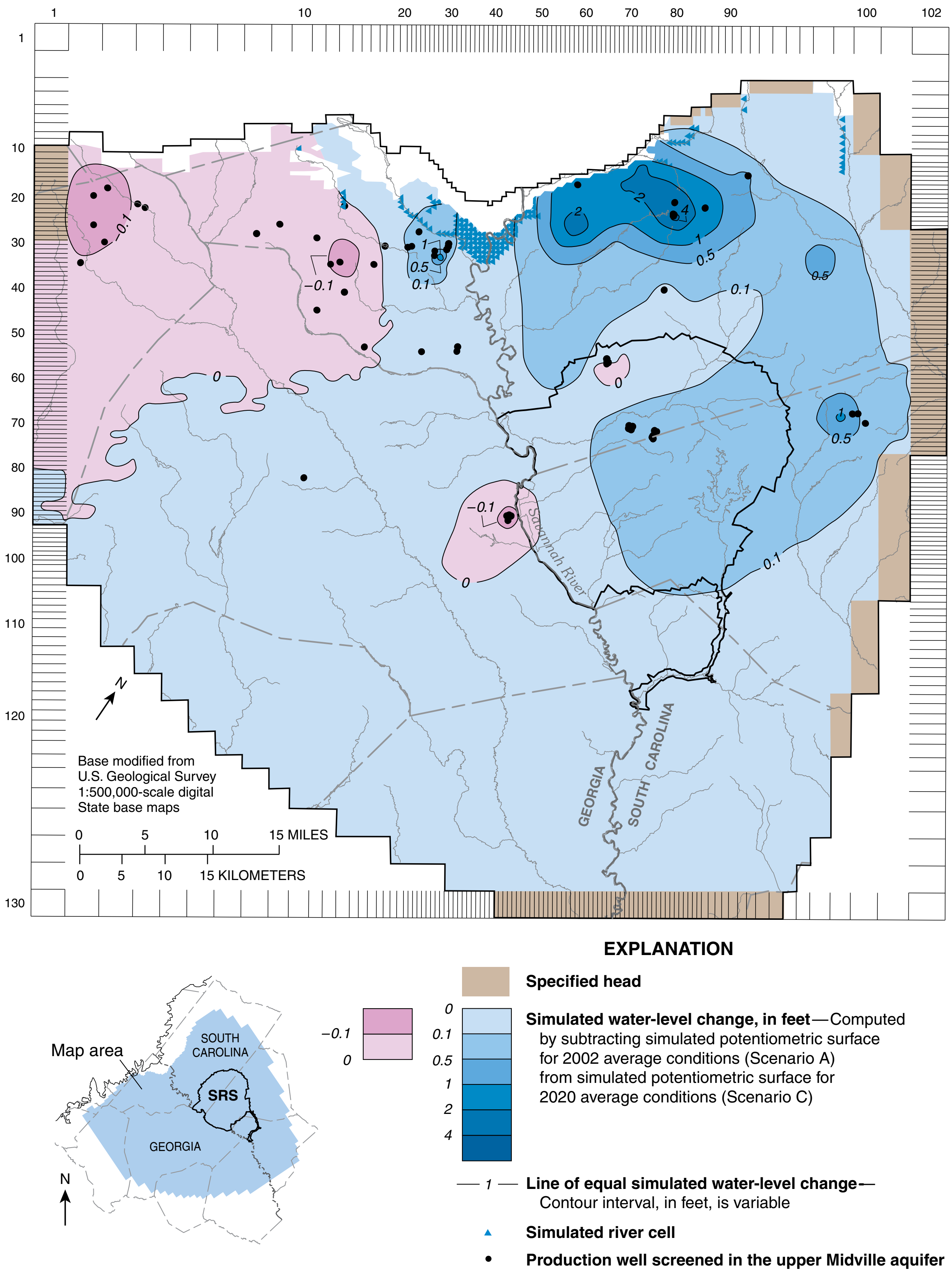


Figure C6. Simulated water-level change between 2002 average conditions (Scenario A) and 2020 average conditions (Scenario C), and locations of simulated pumpage in the upper Midville aquifer (layer A6) in the Savannah River Site (SRS) area, South Carolina.

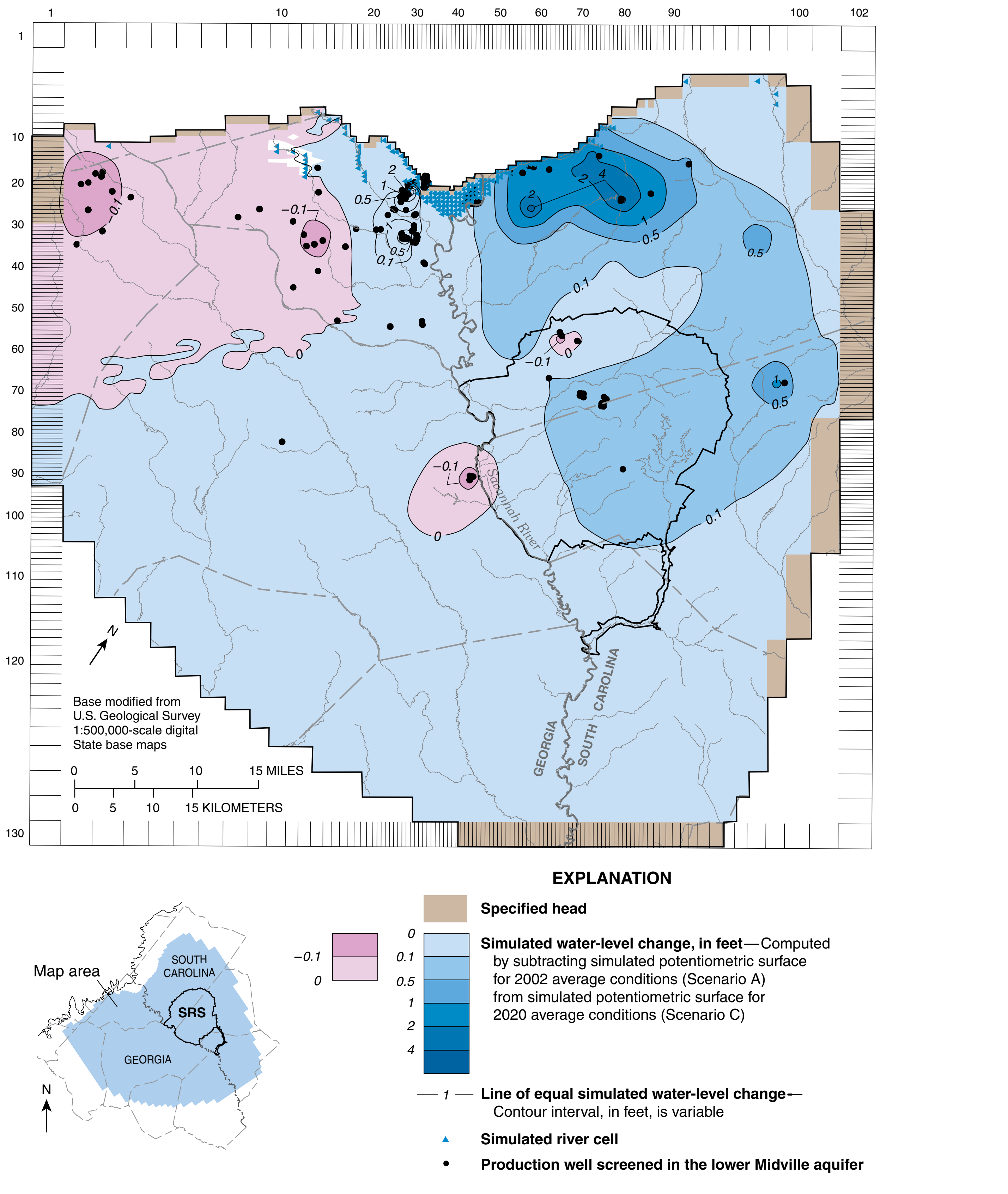


Figure C7. Simulated water-level change between 2002 average conditions (Scenario A) and 2020 average conditions (Scenario C), and locations of simulated pumpage in the lower Midville aquifer (layer A7) in the Savannah River Site (SRS) area, South Carolina.

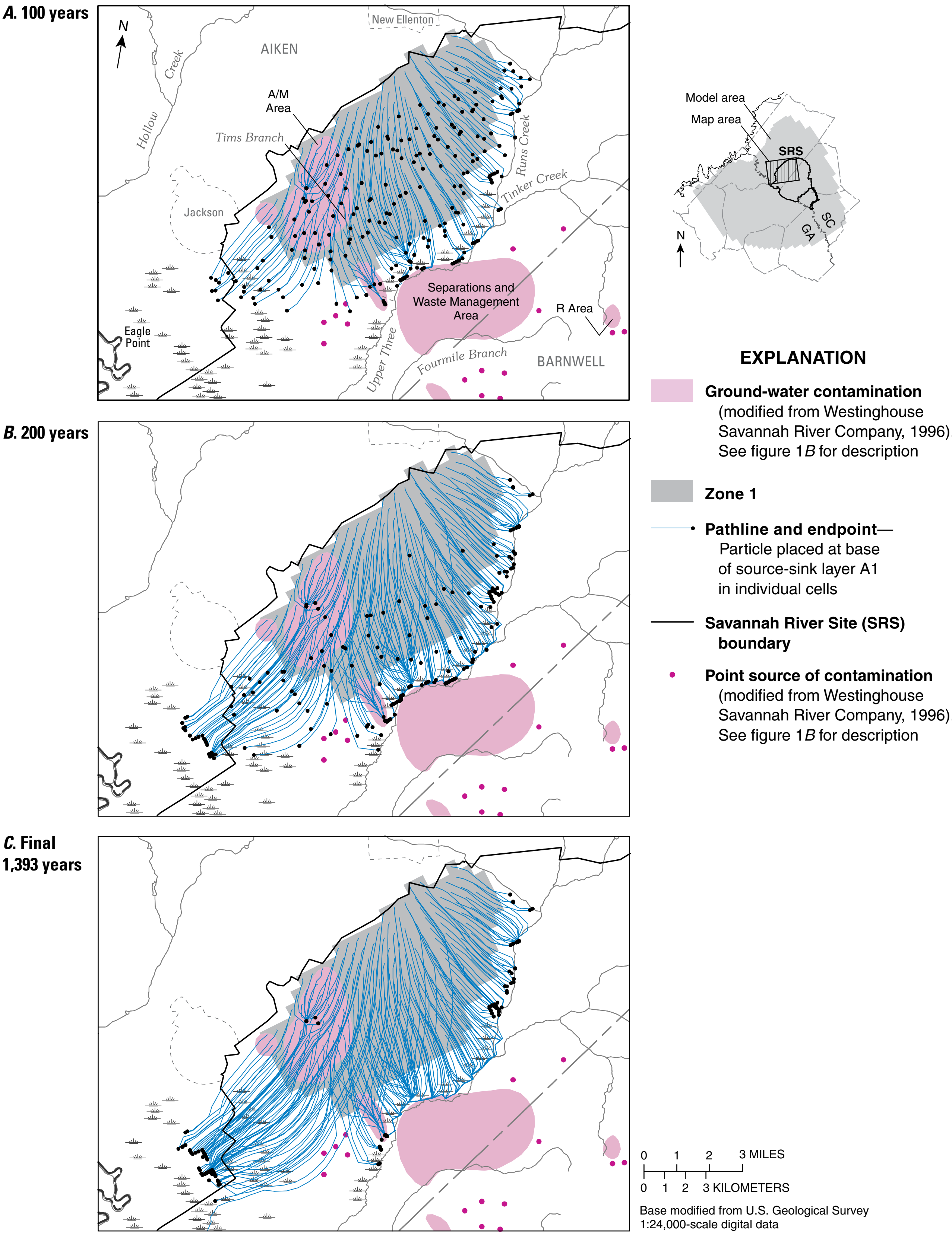


Figure C8. Particle-tracking results from the simulation of 2020 average conditions (Scenario C) at selected time intervals in zone 1 located in the northwestern part of the Savannah River Site, South Carolina.

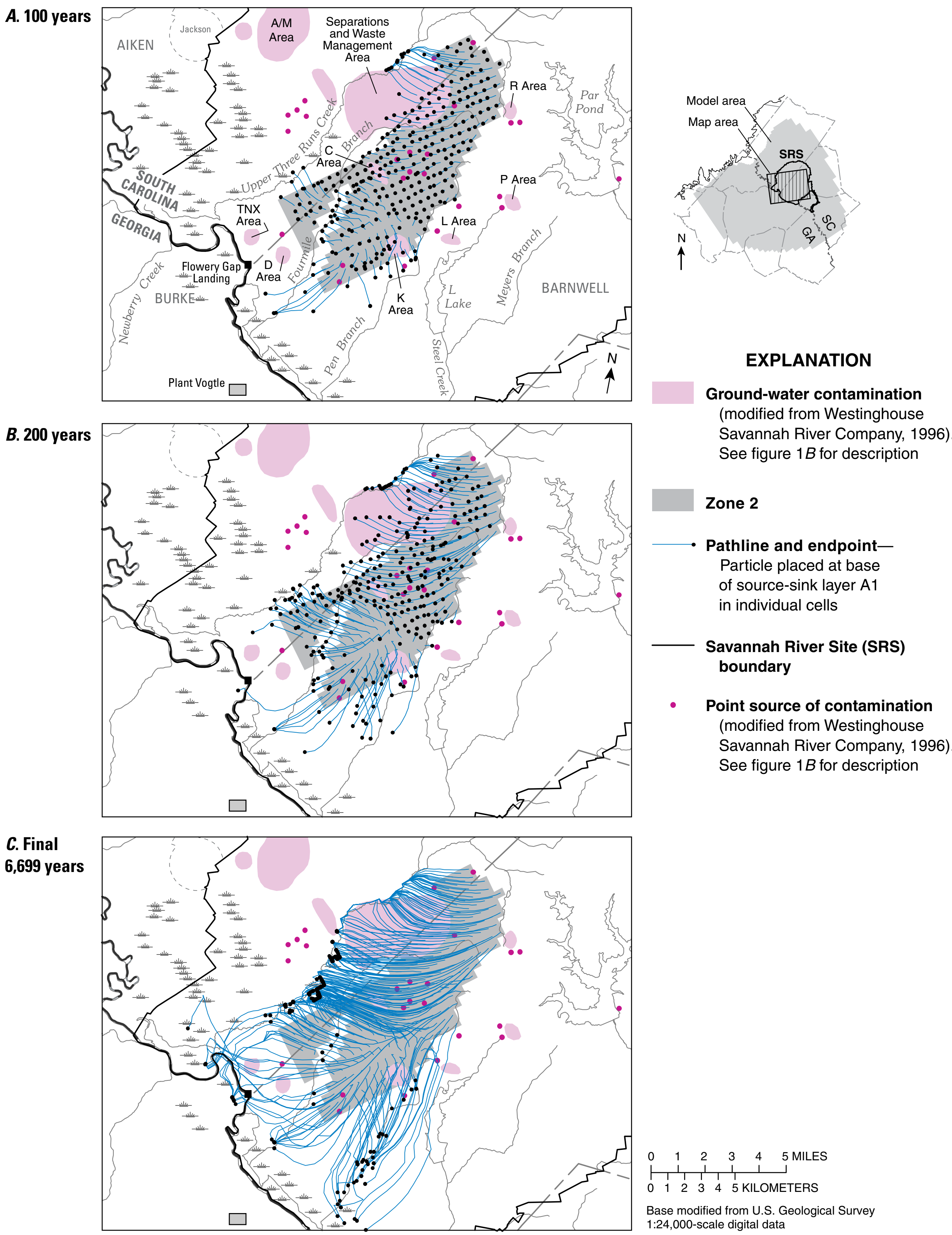


Figure C9. Particle-tracking results from the simulation of 2020 average conditions (Scenario C) at selected time intervals in zone 2 located in the central part of the Savannah River Site, South Carolina.

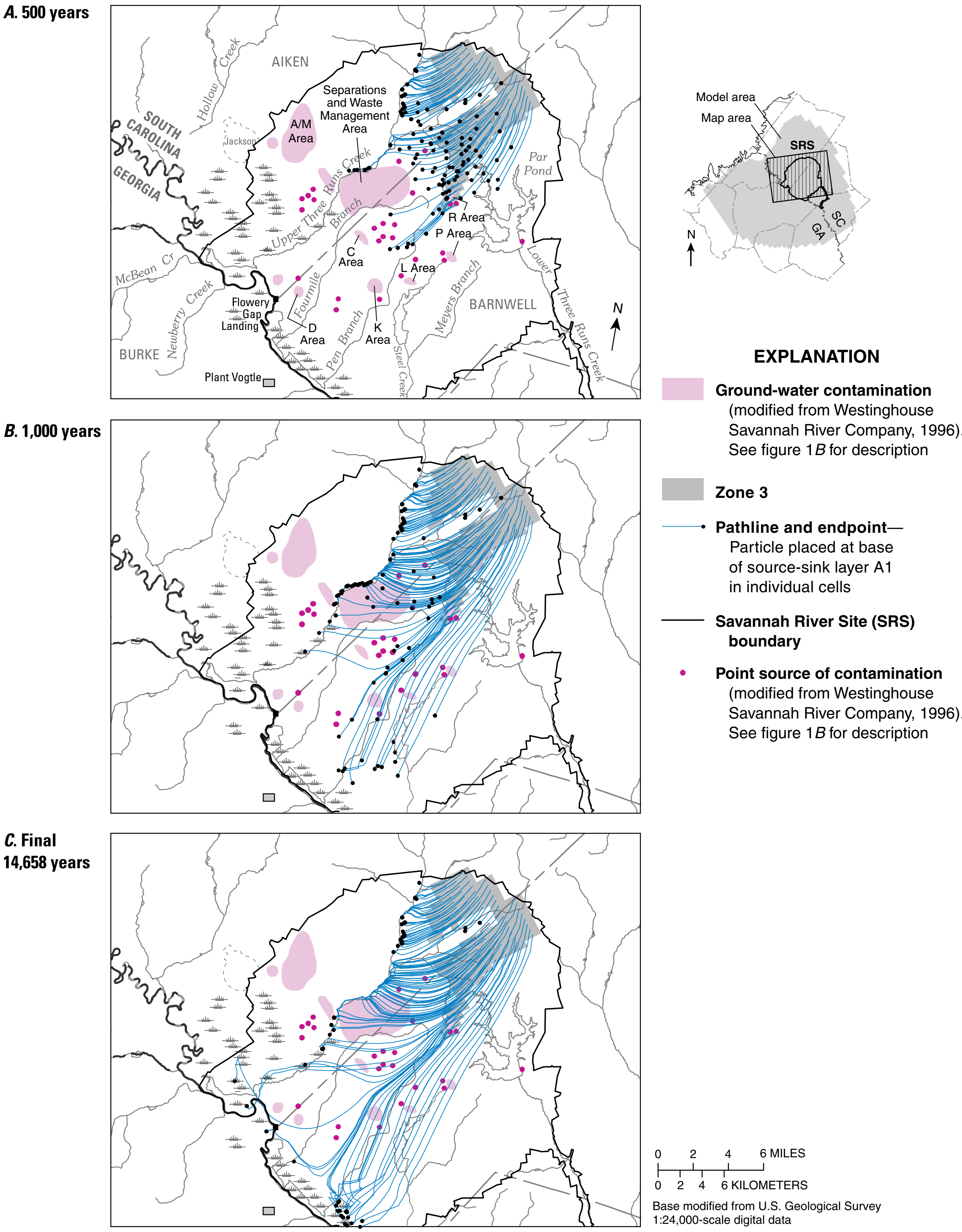


Figure C10. Particle-tracking results from the simulation of 2020 average conditions (Scenario C) at selected time intervals in zone 3 located in the northeastern part of the Savannah River Site, South Carolina.

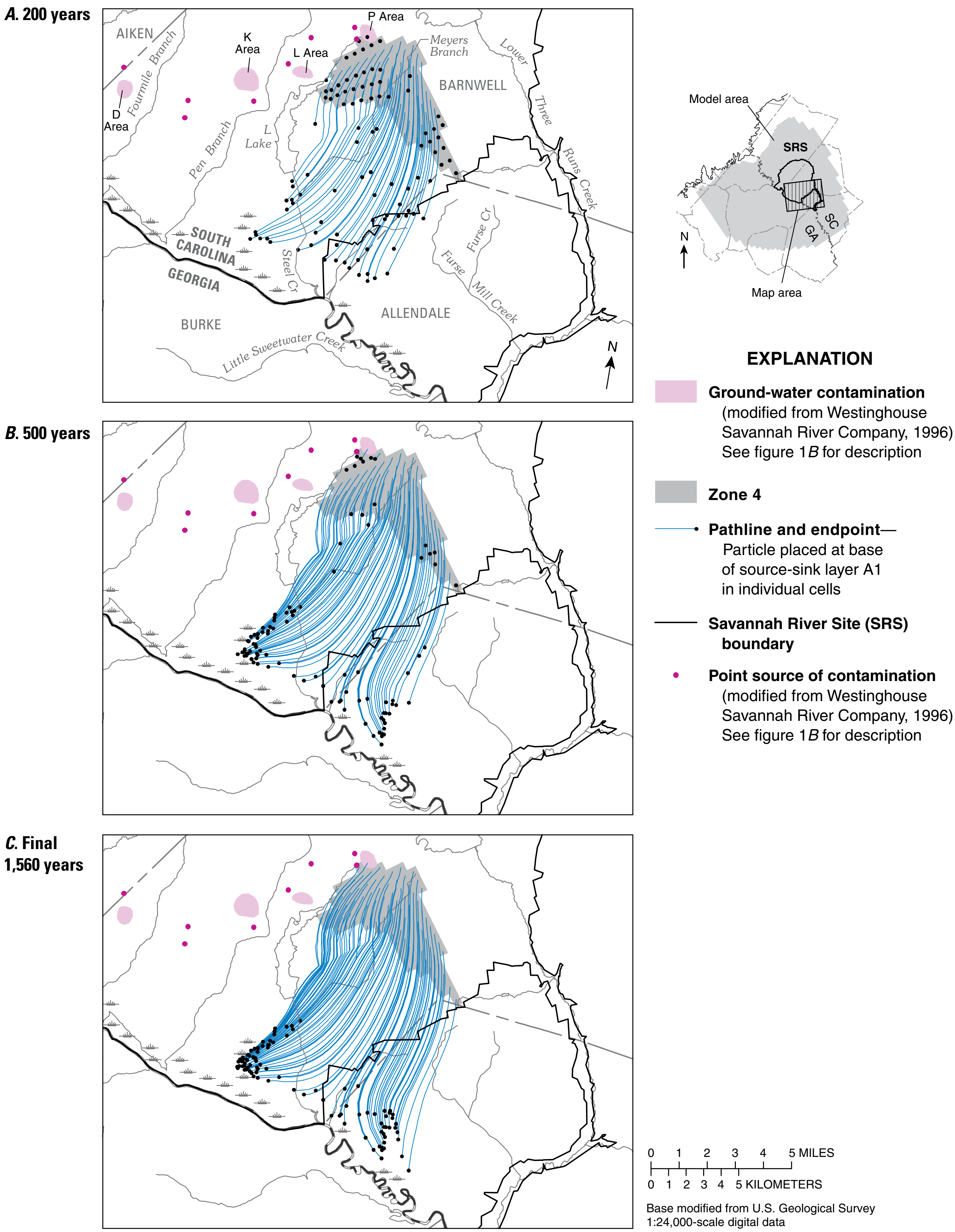


Figure C11. Particle-tracking results from the simulation of 2020 average conditions (Scenario C) at selected time intervals in zone 4 located in the south-central part of the Savannah River Site, South Carolina.

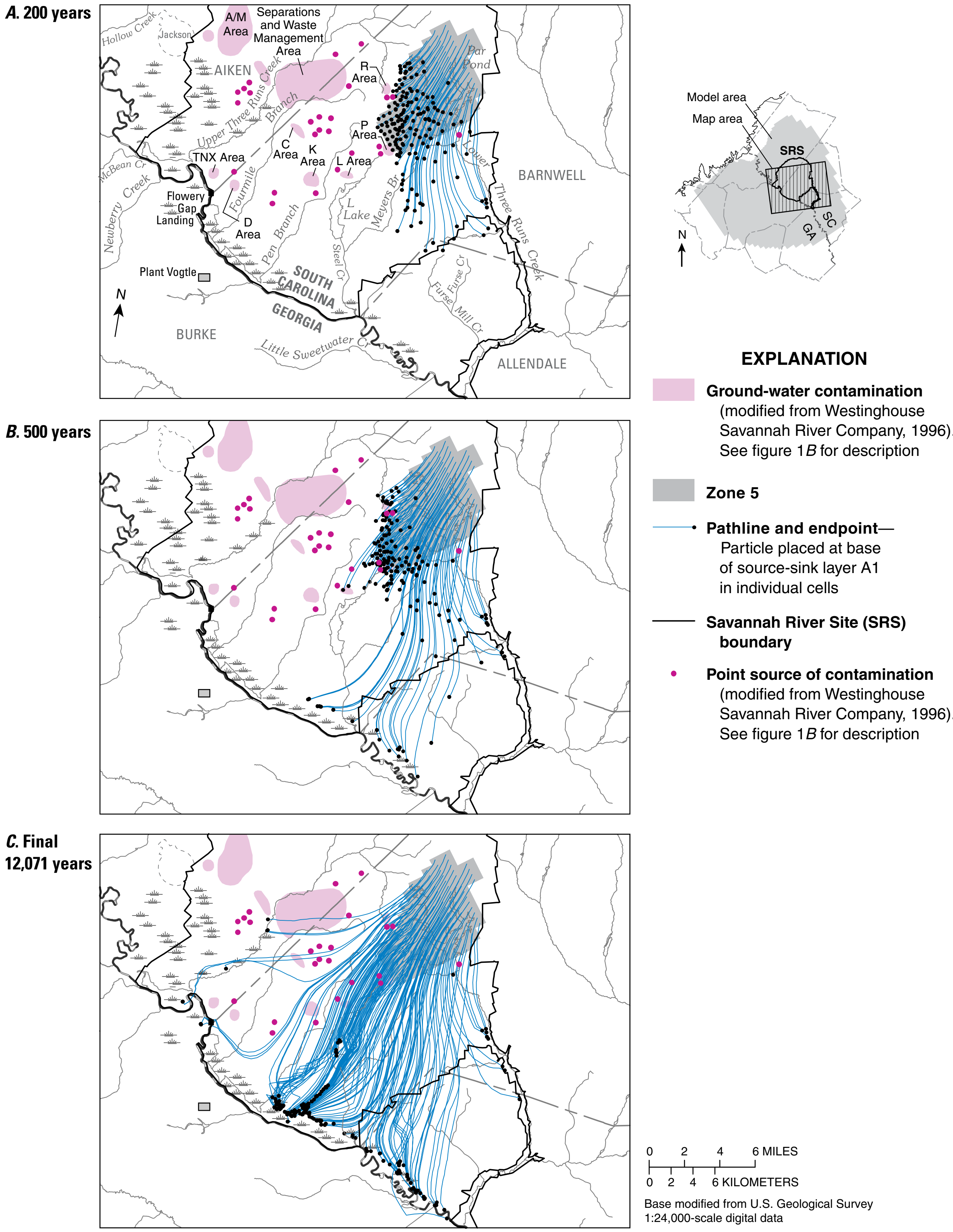
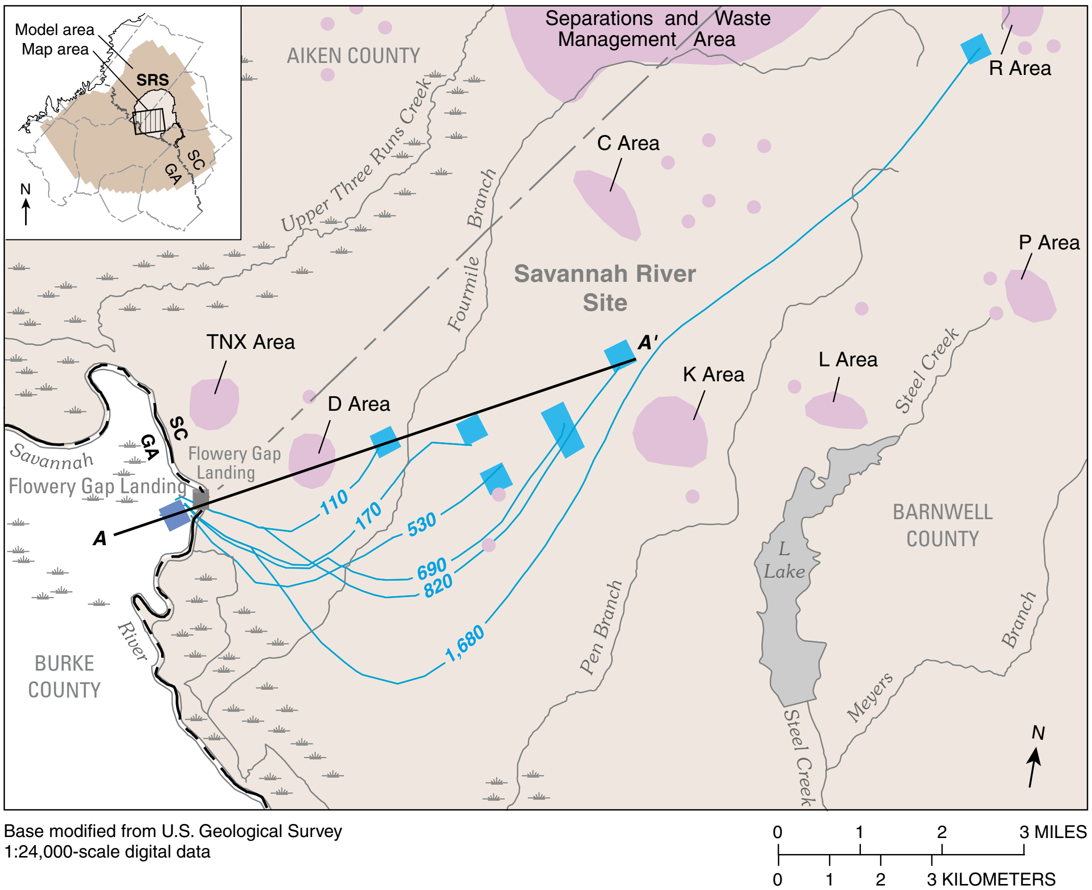
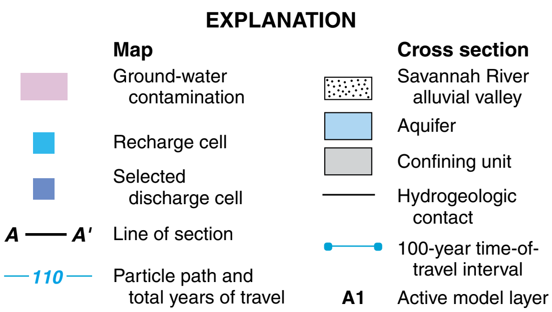


Figure C12. Particle-tracking results from the simulation of 2020 average conditions (Scenario C) at selected time intervals in zone 5 located in the eastern part of the Savannah River Site, South Carolina.

A.





	Simulation		
	1987–92[1]	2002 Scenario A	2020 Scenario C (projected pumping rates)
Boundary conditions	Long-term average	Average	Average
Particles released	300	300	300
Recharge on SRS	93	89	88
Time-of-travel, in years			
Mean	534	516	541
90th percentile	978	934	940
75th percentile	753	736	757
Median	486	462	454
25th percentile	140	145	148
10th percentile	102	103	103
Maximum	2,356	2,299	2,305
Minimum	80	81	81

[1]Clarke and West, 1998

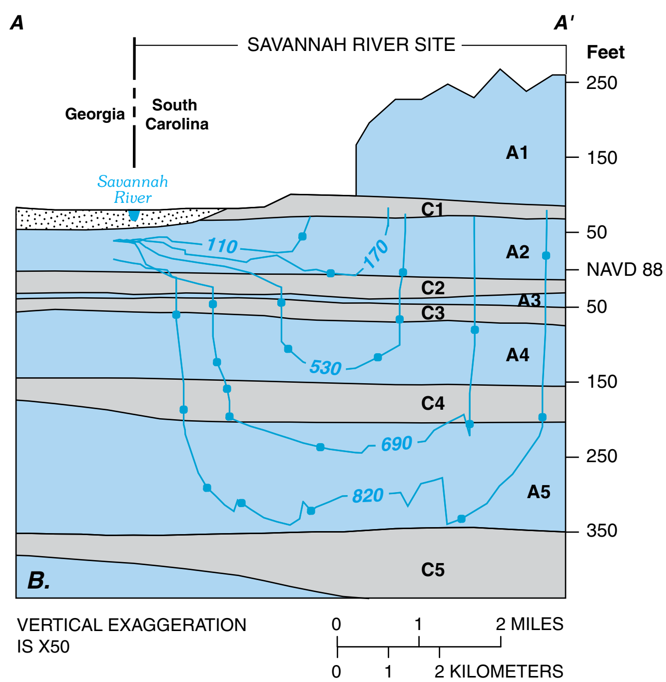


Figure C13. (*A*) Simulated trans-river flow for 2020 average conditions (Scenario C) and selected ground-water pathlines in map view, and (*B*) selected ground-water pathlines in cross-sectional view along row 82 (see figure 8) at the Savannah River Site (SRS), South Carolina.