CASE STUDY 9

Introduction

The following case study is a permutation of Case Study 8 leading to a Class I - Ecologically Vital Classification. Although the preliminary information remains the same, the location of the endangered species habitat has changed (see Figure C9-1). Relevant issues addressed in this case include ecologically vital areas and vulnerability.

Ecologically Vital Areas

The State Endangered Species Coordinator reports that the banks of the Logan River provide wetland habitat for an endangered species. This area serves as a ground-water discharge area for the Caldor Formation. (Figure C9-2).

Vulnerability

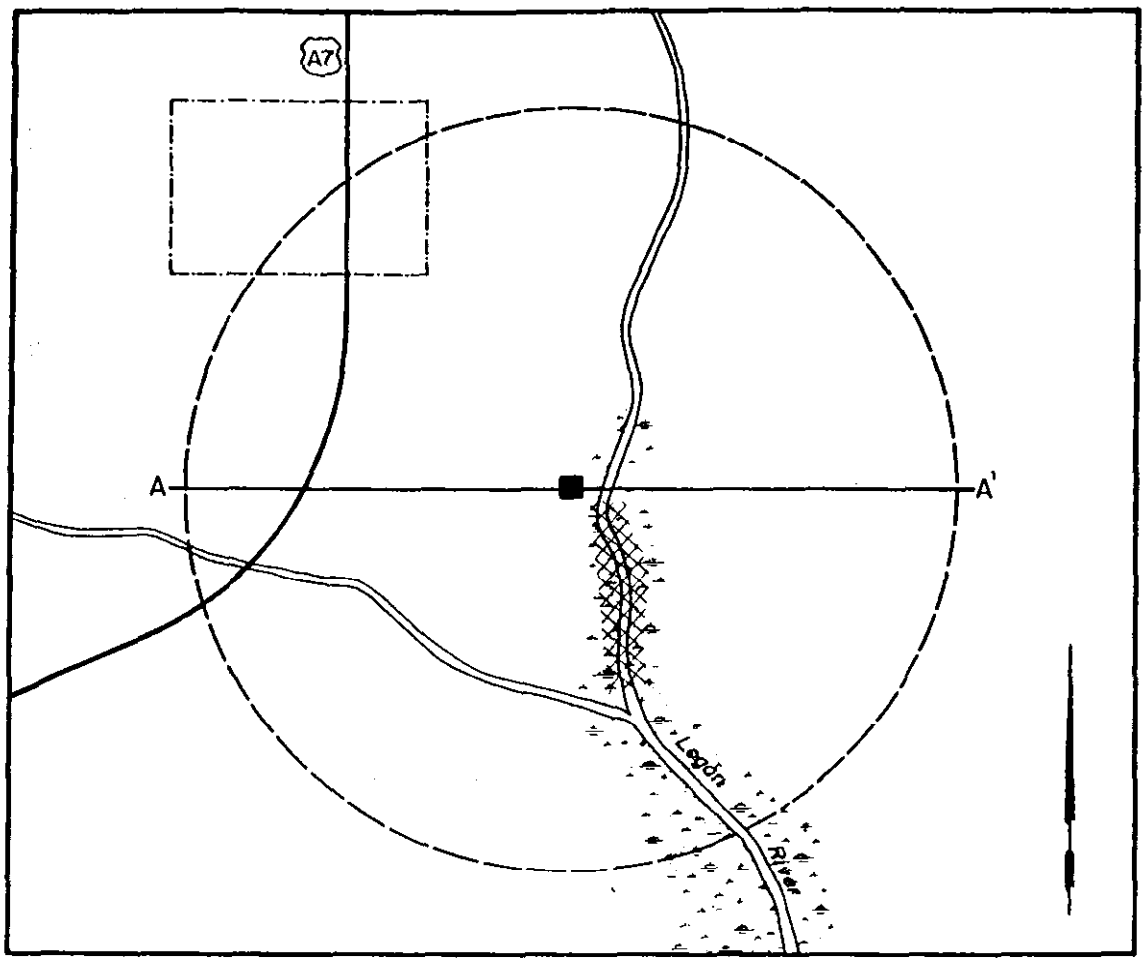
A vulnerability analysis is the next step in the ground-water classification process upon determining that an endangered species habitat is present within the Classification Review Area and the habitat can be shown to be a discharge area for the proposed activity. This is necessary in order to establish whether the area is highly vulnerable to ground-water contamination. (See Section 4.4 and Appendix D for procedural information.)

Under Option A for determining vulnerability, DRASTIC is utilized with the following results:

CALDOR FORMATION	Rating	Weight	Number
. Depth to water - 5 to 10 feet	9	5	45
. Net recharge - approximately 10-15 in/year	9	4	36
. Aquifer media - sand with silt, clay, and lignite	7	3	21
. Soil media - sandy loam	6	2	12
. Topography - less than 2%	10	1	10
. Impact of vadose zone media - interbedded sand with silt, clay and lignite	6	5	30
. Hydraulic conductivity - highly permeable (approximately .16 ft/sec)	10	3	30
		DRASTIC Index (TOTAL)	164

A DRASTIC score of 150 or more constitutes a highly vulnerable hydrogeologic setting under Option A.

FIGURE C9-1
BASE MAP ENCOMPASSING THE CLASSIFICATION REVIEW AREA

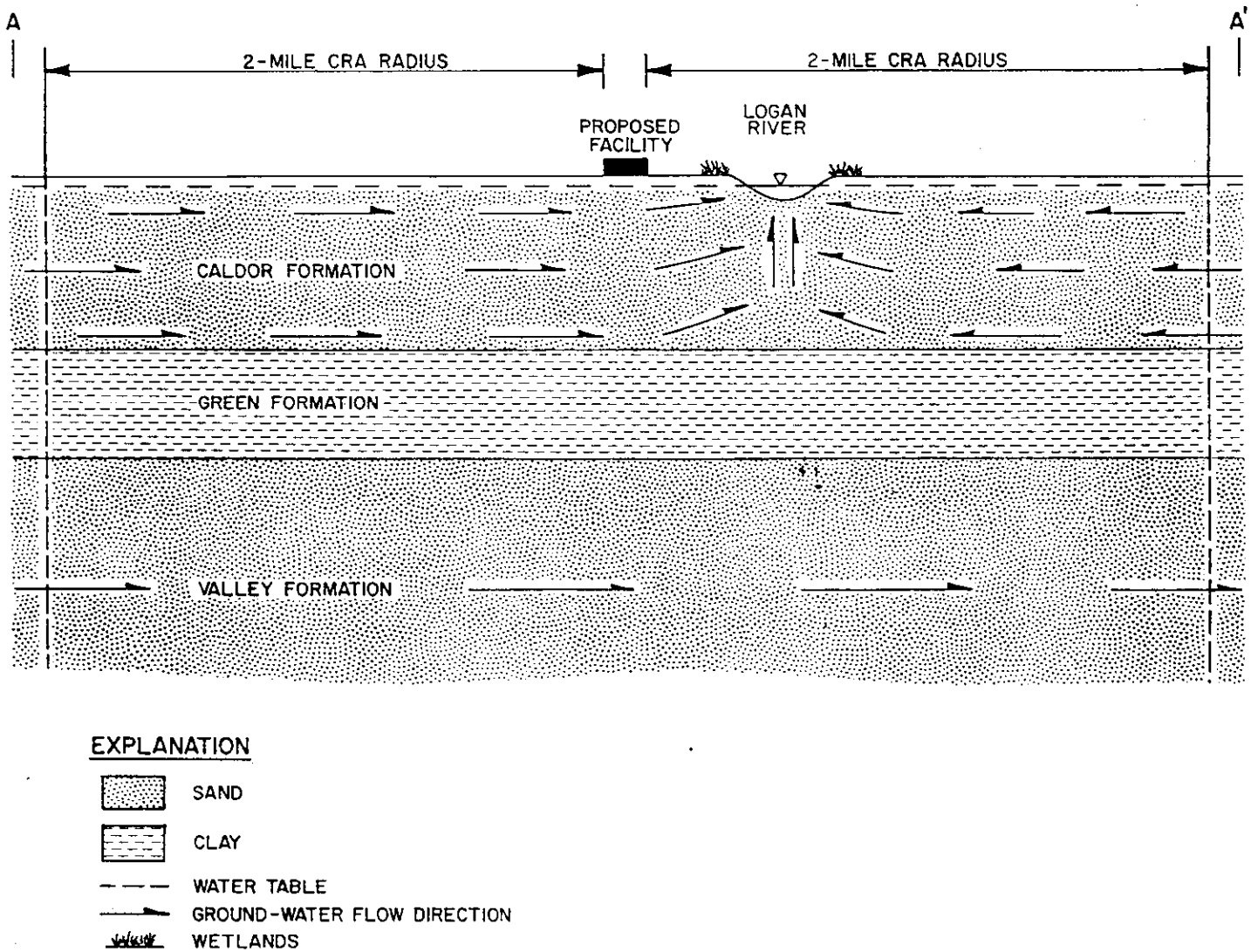


EXPLANATION

0 1 2 MILES

- PROPOSED FACILITY
- CLASSIFICATION REVIEW AREA BOUNDARY
- WETLANDS
- ECOLOGICALLY VITAL AREA
- CITY LIMITS
- ROADWAY

FIGURE C9-2
GENERALIZED CROSS-SECTION OF THE HYDROGEOLOGY WITHIN THE CLASSIFICATION REVIEW AREA



Under Option B for determining vulnerability, two expert hydrogeologists were consulted. These experts disagree on whether the hydrogeologic conditions present constitute a "highly vulnerable" setting as they have differing professional opions regarding the hydrologic properties of the aquifer media. This situation under Option B was resolved by making the conservative assumption that the setting is highly vulnerable.

Referring to the Procedural Chart shown in Figure 4-1 and associated worksheet in Table 4-1, the ground water is classified using the following steps:

Step	Question/Direction	Response/Comment
1	Establish Classification Review Area (CRA) and collect preliminary information. Optional - Demonstrate subdivision(s) of the CRA.	The CRA is defined by a two-mile radius from the proposed facility and has been subdivided into various shallow flow systems due to the presence of a ground-water divide.
2	Locate any ecologically vital areas in the CRA. Does the CRA or appropriate subdivision overlap an ecologically vital area? . Yes, go to next step . No, go to Step 4	Yes, an ecologically vital area is present in the CRA.
3	Perform vulnerability analysis. Is the CRA or appropriate subdivision a highly vulnerable hydrogeologic setting? . Yes, then the ground water is CLASS I - ECOLOGICALLY VITAL . No, go to next step	Yes, under Option A, a DRASTIC score of 150 or more constitutes a highly vulnerable setting. Under Option B, differing expert professional opinions exist, therefore, it is conservatively assumed that the hydrogeologic setting is highly vulnerable.

FINAL CLASS DETERMINATION: CLASS I - ECOLOGICALLY VITAL

CASE STUDY 10

Introduction

Case Study 10 is another example of a CLASS IIA replaceable drinking-water source. An analysis determined that the ground-water supply was replaceable.

Preliminary Information with Respect to the Classification Review Area

General

A permit application is being submitted for a site which would overlie a highly transmissive aquifer, serving as the major water-supply aquifer for the area. A two-mile Classification Review Area (shown in Figure 10-1) was employed.

Geology/Hydrogeology

Based on U.S. Geological Survey field work, the aquifer is divided into two, approximately 50-foot thick, highly interconnected zones (Figure C10-2). The upper zone consists of dense, sandy limestones and soft, fine-grained, quartz sandstones. The lower zone is made of hard, medium-grained, quartz sandstones and sandy limestones which exhibit extensive dissolution features. Underlying the aquifer is a limestone formation of low permeability.

Well/Reservoir Survey

The Classification Review Area contains a well field comprised of large-capacity wells that produce 8 million gallons-per-day for 75,000 area residents (Figure C10-1). The wells are screened in the lower sandy limestone formation where dissolution features have greatly enhanced aquifer permeability.

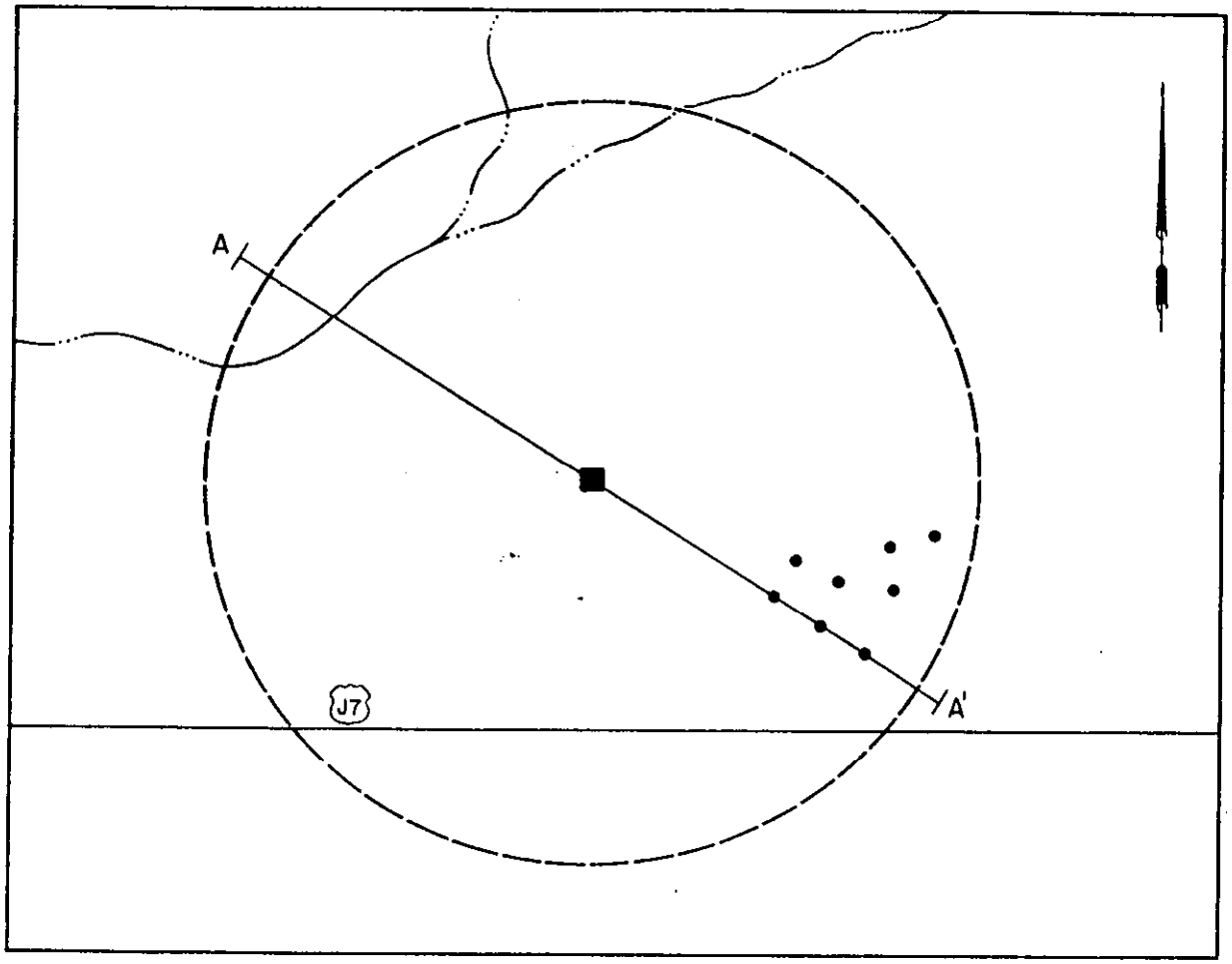
No water-supply reservoirs are present.

The above information was verified by the county public health agency.

Demography

The Classification Review Area is well populated. Based on U.S. Census Bureau information, an estimated 75,000 persons live within the two-mile-wide radius. All persons, as well as industries, utilize ground-water resources for their drinking water supply. This site population constitutes a substantial population under irreplaceability Option A.

FIGURE C10-1
BASE MAP ENCOMPASSING THE CLASSIFICATION REVIEW AREA

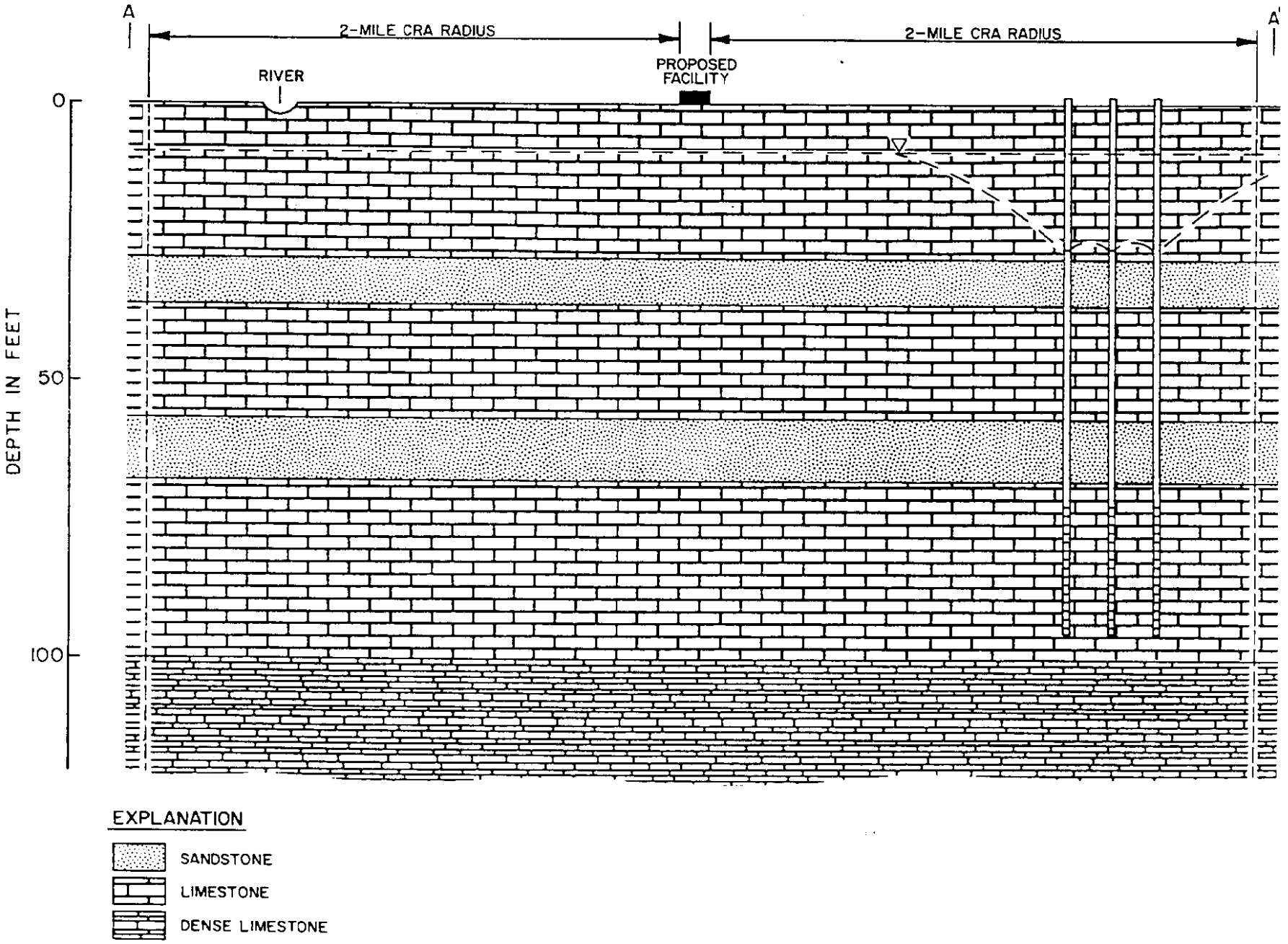


EXPLANATION

- PROPOSED FACILITY
- CLASSIFICATION REVIEW AREA BOUNDARY
- MUNICIPAL WELL
- STREAM
- INTERMITTENT CREEK
- ROADWAY

0 1 2 MILES

FIGURE C10-2
GENERALIZED CROSS SECTION OF THE HYDROGEOLOGY WITHIN THE CLASSIFICATION REVIEW AREA



Ecologically Vital Areas

No ecologically vital areas are present within the Classification Review Area. The State Endangered Species Coordinator confirmed that the Classification Review Area does not contain any ecologically vital areas or provide a habitat to any endangered species.

Irreplaceability Analysis

The well/reservoir survey in the Classification Review Area indicates a municipal well field producing 8 mgd and serving 75,000 area residents and it is determined that the substantial population criterion is met under both Options A and B. Subsequently, a Class I, irreplaceability analysis is performed. In determining irreplaceability, the following factors are addressed:

- Uncommon pipeline distance
- Comparable quality
- Comparable quantity
- Institutional constraints
- Economic infeasibility

The notion of uncommon pipeline distance creates a manageable boundary within which alternative water supplies can be identified. According to Table 4-3, a distance of 100 miles would be appropriate in this case. Use of surface-water resources in the area is precluded due to tidal influences requiring desalination. However, a review of local geological reports, indicates the continuity of lower sandy limestones tapped by the existing municipal well field. To the south, urbanization and agriculture is limited indicating that production of the required volume of water may be possible. An alternative well field could be located four miles south of the facility and five miles from the existing water plant.

Local geological reports include extensive data on ground-water quality, particularly for the lower sandy limestone unit. Throughout the region, this unit is used as a water-supply aquifer, and background water quality parameters have limited variation. Elevated total dissolved solids levels have been observed 15 miles to the southeast. However, as far as five miles south, the TDS levels average less than 100 mg/l, only 25 mg/l higher than the existing municipal wells to the north. As a result, water quality is anticipated to be of comparable quality to the existing source, and treatment in addition to that received by the existing source will not be required.

Although water-quality data is well characterized, the quantity of water that can be produced or the aquifer's sustainable yield is not specically known in the proposed area. However, data from a local USGS observation well indicates fairly constant water levels in the proposed area. The data also indicates the sandy limestone formation to be slightly thicker near the USGS observation well than in the vicinity of the municipal well field. Additionally, the composition of the sandy limestone formation in each area is similar. In this region, aquifer transmissivities correlate closely with thickness, indicating fairly homogeneous permeability of materials. Although a pump test was not conducted, productivity would appear to be between 7 and 12 mgd, and should be adequate to replace the existing source.

Planning and zoning maps and tax maps indicate that lands in the proposed area are privately owned and are zoned for agriculture. Also, no other supply wells are recorded within a 3-mile radius of the proposed alternative supply. As a result, it is likely that an adequate property could be acquired to establish the new well field. The easement required for the 5-mile pipeline should also not represent a constraint as a power utility easement already exists between the two points.

The final step in evaluating the alternative supply is to determine if the additional cost of water-supply development and delivery would be economically infeasible to the community. The additional cost to be borne would include:

- Land aquisition
- Well-field development
- Pipeline construction

According to the local economic development agency, the average cost of agricultural land in the area is $2500/acre, resulting in a cost of $50,000 for a 20-acre property suitable for a well field. In order to develop 8 mgd, four 100-foot deep, 16-inch wells are required, including high capacity pumps and testing. This system would cost about $500,000 according to cost information provided by the municipality from construction of the existing system. The 10-year old cost data was escalated using appropriate construction cost indices. Operation and maintenance costs for the well field were also provided and average $200,000/year, mainly for power and well maintenance. Construction costs for a five-mile, 30-inch diameter pipeline was estimated from previous sewerage transmission lines constructed in the area. A local engineering firm constructed the line and indicated the cost at approximately $30/foot or about $750,000. As the power utility is providing the easement for no charge, this is the total capital cost. Operation and

maintenance of the line is estimated at an annual cost of $100,000. Other cost components such as the water plant, distribution lines and treatment facility will not require replacement.

In order to compute the total annual cost of the new water-supply components, capital costs are annualized as indicated in Section 4.3 or in Appendix E.

Total Capital Cost ($1,300,000) x
Annualization Factor (.1) =
Annualized Capital Cost ($130,000)

The annualized capital cost of $130,000 is added to the $300,000 in operation and maintenance costs resulting in an average annual cost of $430,000 as the incremental increase in water-supply cost. This figure expressed on a per household basis results in $15 per household (e.g., 75,000 people/2.7 people/household = 28,000). Using Option A for assessing irreplaceability, the figure of $15 is compared to the average annual household income for the state. Average household income for the state is $20,000 according to the 1980 census figures. As $15 is less than 1 percent of that figure ($200), the ground water is considered replaceable and not Class I under Option A.

Under Option B, expert socioeconomists in the area were consulted. These experts agree that the cost of replacing the ground water does not exceed the community's ability to pay. Thus, under Option B, as under Option A, the ground water would be considered replaceable and not Class I.

Referring to the Procedural Guide shown in Figure 4-1 and associated worksheet in Table 4-1, the ground water is classified using the following steps:

Step	Question/Direction	Response/Comment
1	Establish Classification Review Area (CRA) and collect preliminary information. Optional - Demonstrate subdivision(s) of the CRA.	The CRA is defined by a two-mile radius from the proposed facility. No CRA subdivision has been performed.
2	Locate any ecologically vital areas in the CRA. Does the CRA or appropriate subdivision overlap an ecologically vital area? . Yes, go to next step . No, go to Step 4	No ecologically vital areas are present in the CRA.
4	Determine location of well(s) within the CRA or appropriate subdivision. Does the CRA or appropriate subdivision contain well(s) used for drinking water? . Yes, go to next Step . No, go to Step 8	Yes, a well field comprised of large-capacity wells that provide 8 mgd for 75,000 area residents is present in the CRA.
5	Inventory population served by well(s). Does the well(s) serve a substantial population? . Yes, go to next step . No, then the ground water is CLASS IIA-CURRENT SOURCE OF DRINKING WATER	Yes, drinking-water wells within the CRA serve a population of 75,000. Under Option A, the population served exceeds the 2500-person threshold. Under Option B, the population served is considered substantial given the demographics of the region.

Step	Question/Direction	Response/Comment
6	Unless proven otherwise, the drinking water source is assumed to be irreplaceable. Optional - perform irreplaceability analysis. Is the source of drinking water irreplaceable? . Yes, go to next step . No, then the ground water is CLASS IIA-CURRENT SOURCE OF DRINKING WATER	No, under Option A, the ground water is considered replaceable. Under Option B, the ground water is considered replaceable.

FINAL CLASS DETERMINATION: CLASS IIA-CURRENT SOURCE OF DRINKING WATER

CASE STUDY 11

Introduction

This case study details the problems associated with karst hydrogeology and the need for an expanded Classification Review Area. The hypothetical facility setting is first examined using the standard two-mile Classification Review Area and second using an expanded review area to demonstrate the disparity of results and limitations of a two-mile radius to this particular setting.

Preliminary Information with Respect to the Classification Review Area

General

A permit application is being submitted for a site located in Central Kentucky near the Little Blue River. Planning and zoning maps indicate land use in the area is primarily rural farmland. Several population centers exist at distances greater than two miles which are served solely by ground water.

Regional Physiography/Geology

The area under consideration is within the Central Kentucky Karst terrain which is characterized by sinkholes, infrequent streams and an integrated system of subsurface drainage conduits within a carbonate bedrock complex. Directly west of the facility, streams drain an upland area, flowing eastward to the sinkhole plain. At the plain, the streams intersect sinkholes and surface water is diverted to the underground network of solution conduits within the karst bedrock. This zone where surface water is re-routed to the subsurface represents the termination of the eastwardly extent of the more resistant sandstone formation overlying limestone and dolomites. Without the resistant sandstone, surface water has reworked the carbonate bedrock into a network of vertical and horizontal solution cavities and conduits that drain the sinkhole plain eastward to the Little Blue River (Figure C11-1).

Hydrogeology

The hydraulic characteristics of a karst aquifer are far different from the Darcian principles of flow through a granular media. Instead, ground-water circulation occurs through a system of conduits having a variety of shapes and capacities. The spatial position and relationship of these

conduits and the temporal hydraulic heads within the voids determine the geometry of ground-water flow paths. Regional investigations including dye tracer tests, field mapping, exploratory drilling, spelunking, and geochemical reconnaissance sampling have been performed by county hydrogeologists. The flow system is characterized as dynamic and undergoes major changes depending upon the magnitude of a precipitation recharge event. Extending our view eastward past the two-mile Classification Review Area radius to the Little Blue River during two distinct precipitation/recharge events will help in understanding the intricacies of karst groundwater circulation (Figure C11-1).

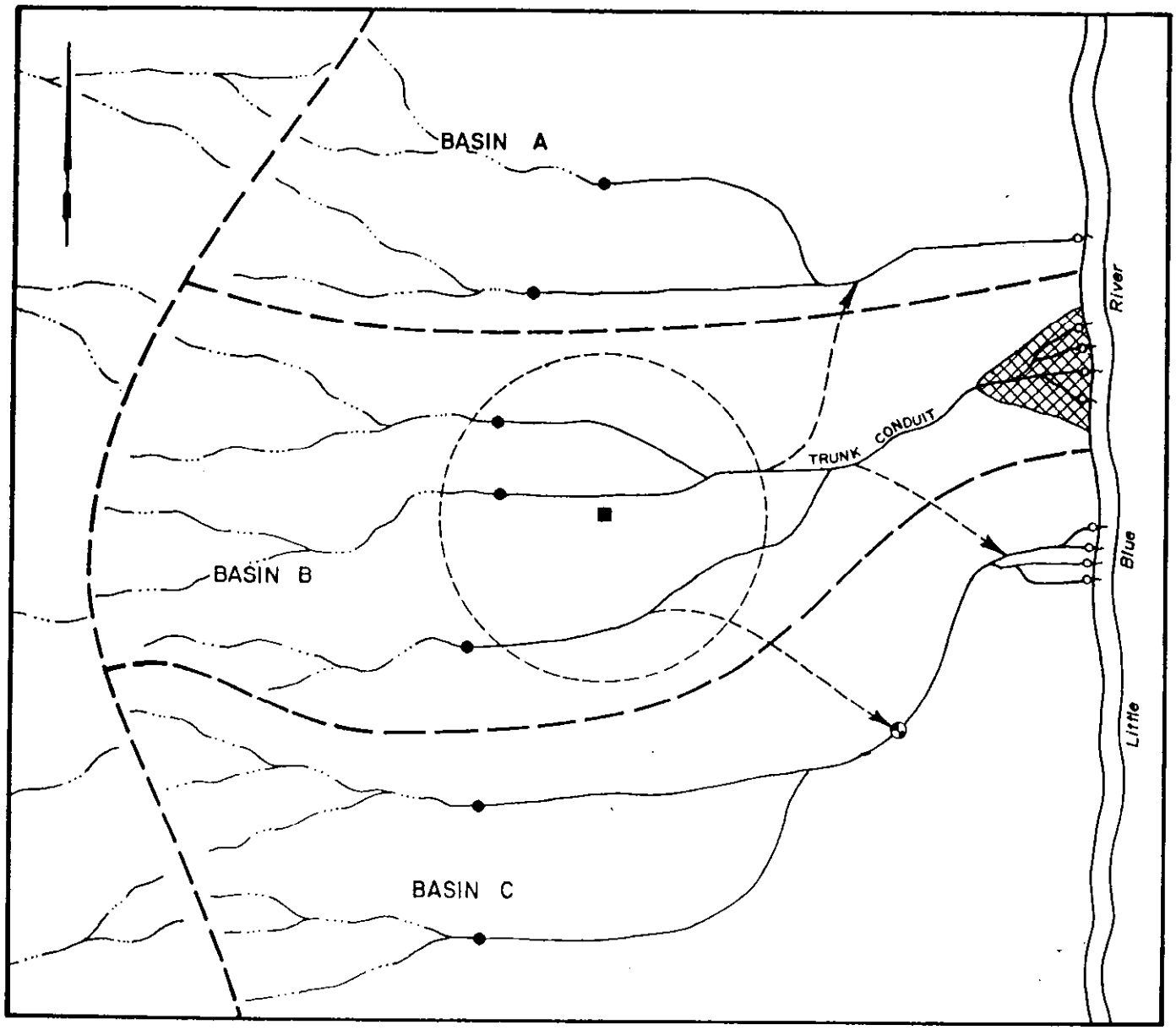
During periods of low flow (little or no precipitation), surface-water recharges the carbonate aquifer at the sinkhole plain and travels through a series of solution cavities to the ground-water Basin B trunk conduit (Figure C11-2 and Figure C11-3). Under these conditions, each ground-water basin hydraulically operates as a separate entity. The general direction of flow in Basin B (although tortuous) is directly toward the Little Blue River.

During peak rainfall events, recharge to the aquifer via sinkholes and swallets causes ground-water levels within the Basin B trunk conduit to increase to the point where upper cavity transverse conduits are intersected and ground-water migrates into the trunk conduits of Basins A and C. This process is termed "ground-water piracy". The consequence of this process can be severe. In the example setting, a substantial population within Basin C is served by ground water from the trunk conduit. During high intensity recharge events, ground water from Basin B which could potentially contain contaminants from the proposed facility will travel to all three ground-water basins. In effect, disposal activities in one distinct basin could potentially affect both the substantial population and the ecologically vital area.

Well Survey

Within the two-mile Classification Review Area radius, several domestic wells exist on the sinkhole plain as well as domestic spring houses along the sandstone upland region. Within the expanded review area there is a small city that relies on ground water taken from a cave stream.

FIGURE C11-1
FEATURES OF THE EXAMPLE KARST SETTING



EXPLANATION

- PROPOSED FACILITY
- CLASSIFICATION REVIEW AREA BOUNDARY
- 3000 POPULATION WELL CENTER
- ECOLOGICALLY VITAL AREA
- SPRING/SEEP
- FLOW ROUTE
- HIGH-LEVEL OUTFLOW ROUTE
- GROUND-WATER BASIN BOUNDARY
- SWALLET OF SINKING STREAM

FIGURE C11-2
GENERALIZED CROSS-SECTION OF A KARST HYDROGEOLOGIC SETTING

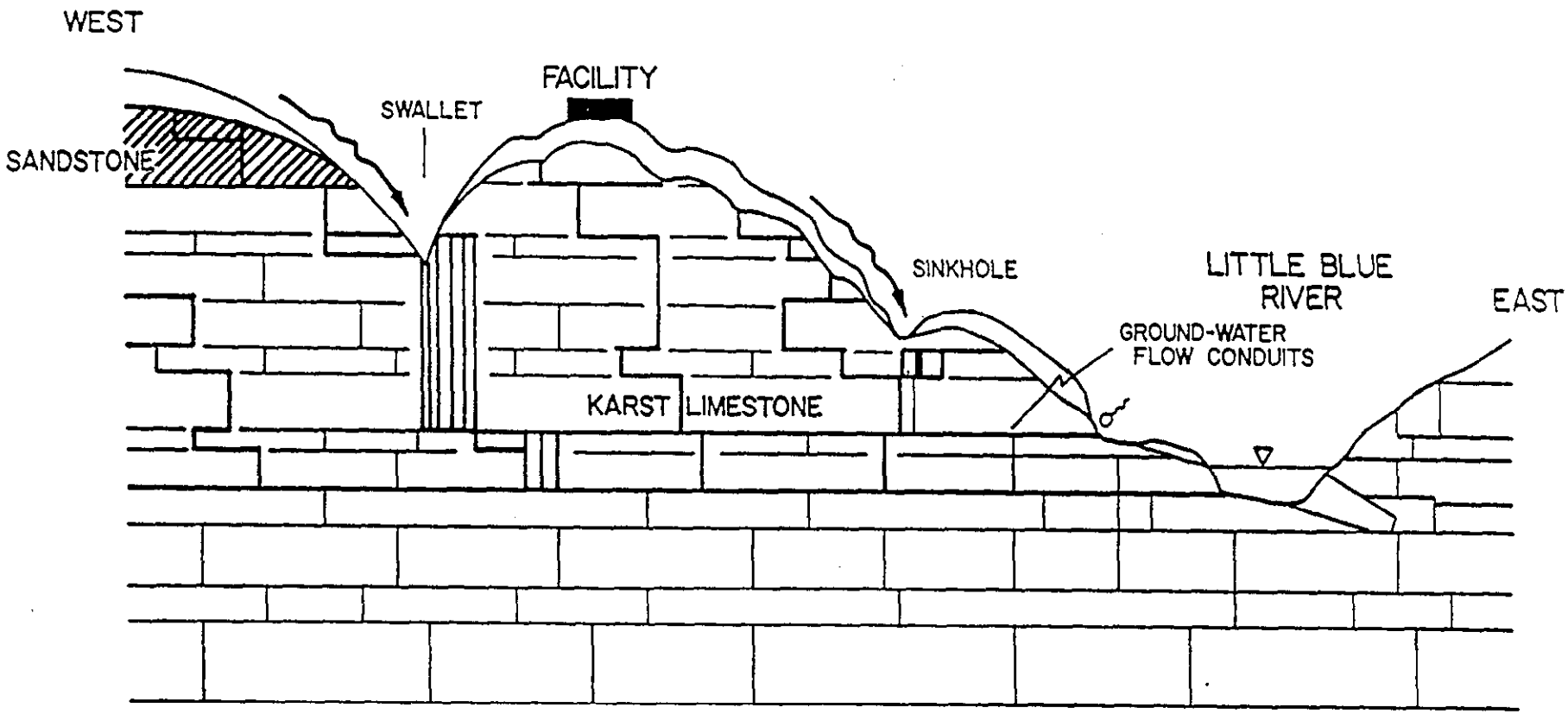
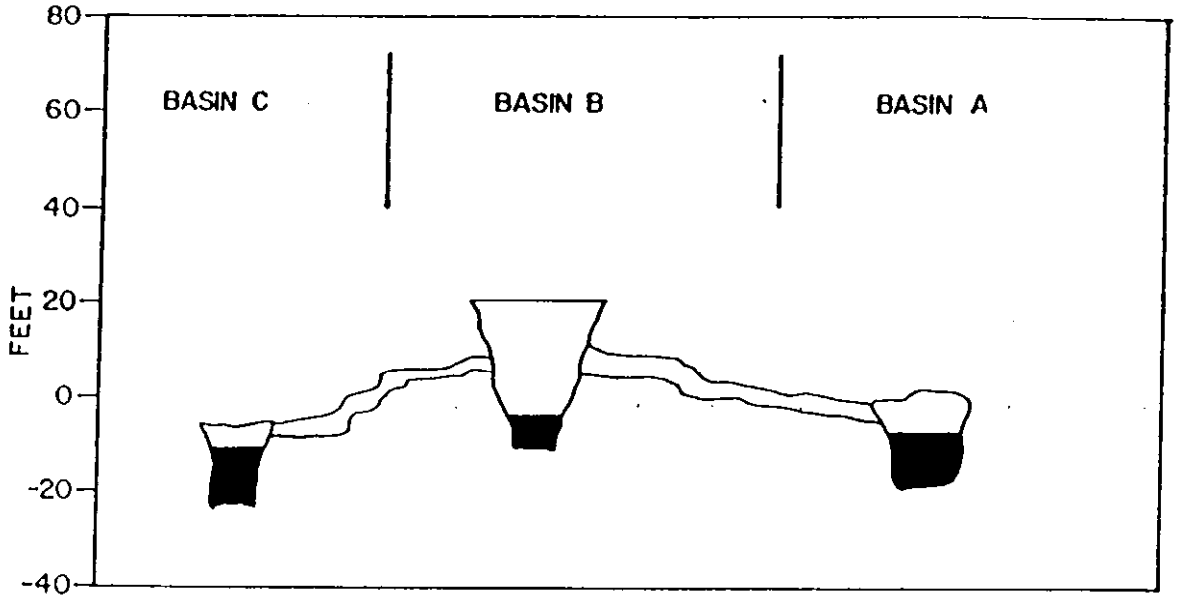
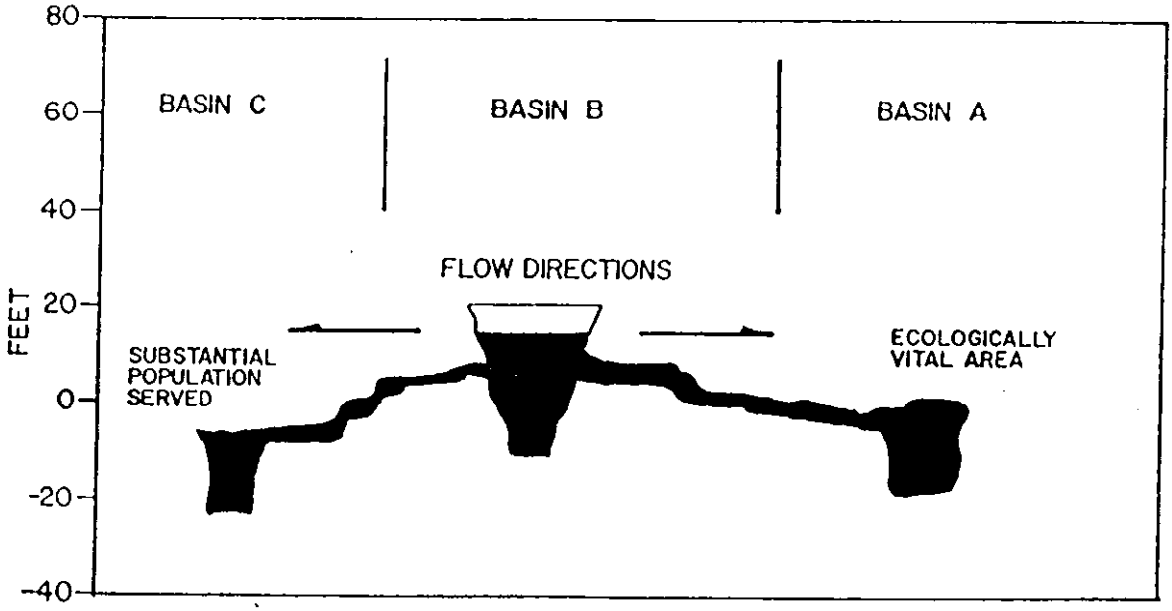


FIGURE C11-3
EXAMPLE OF OVERFLOW ACROSS GROUND-WATER BASINS



BASE FLOW CONDITIONS
(A)



HIGH INTENSITY FLOW CONDITION
(B)

Demography

Several small cities exist nearby but do not fall within the two-mile Classification Review Area. Two population centers each having populations around 3500 to 4000 individuals are found within the expanded review area. Rural residents in the two-mile Classification Review Area number approximately 100. The population is small enough, however, not to involve the issue of substantial population.

Ecologically Vital Areas

The two-mile Classification Review Area does not encompass any Federal lands designated for ecological protection or ecologically vital areas. To the northeast, within the expanded review area and along the Little Blue River, several cave streams have been designated as critical habitats for a rare and endangered aquatic species. Given that the cave stream is a discharge area for ground water, this habitat qualifies as an ecologically vital area.

Vulnerability to Contamination

Under Option A for assessing vulnerability, the DRASTIC methodology yields the following results (averaged over the review area):

	Range	Rating	Weight	Number
Depth to Water	30-50	5	5	25
Net Recharge	10+	9	4	36
Aquifer Media	Karst limestone	10	3	30
Soil Media	Thin to absent	10	2	20
Topography	6-12	5	1	5
Vadose Zone Media	Karst limestone	10	5	50
Hydraulic Conductivity	2000^{+}	10	3	30
			DRASTIC Index (TOTAL)	196

A DRASTIC Index of 196, exceeds the 150 criterion and, therefore, the area is determined to be highly vulnerable to contamination under Option A.

Under Option B for assessing vulnerability, expert hydrogeologists in the area were consulted. Given the substantial lack of soil media and the high permeability of the aquifer, these experts agree that the area is "highly vulnerable."

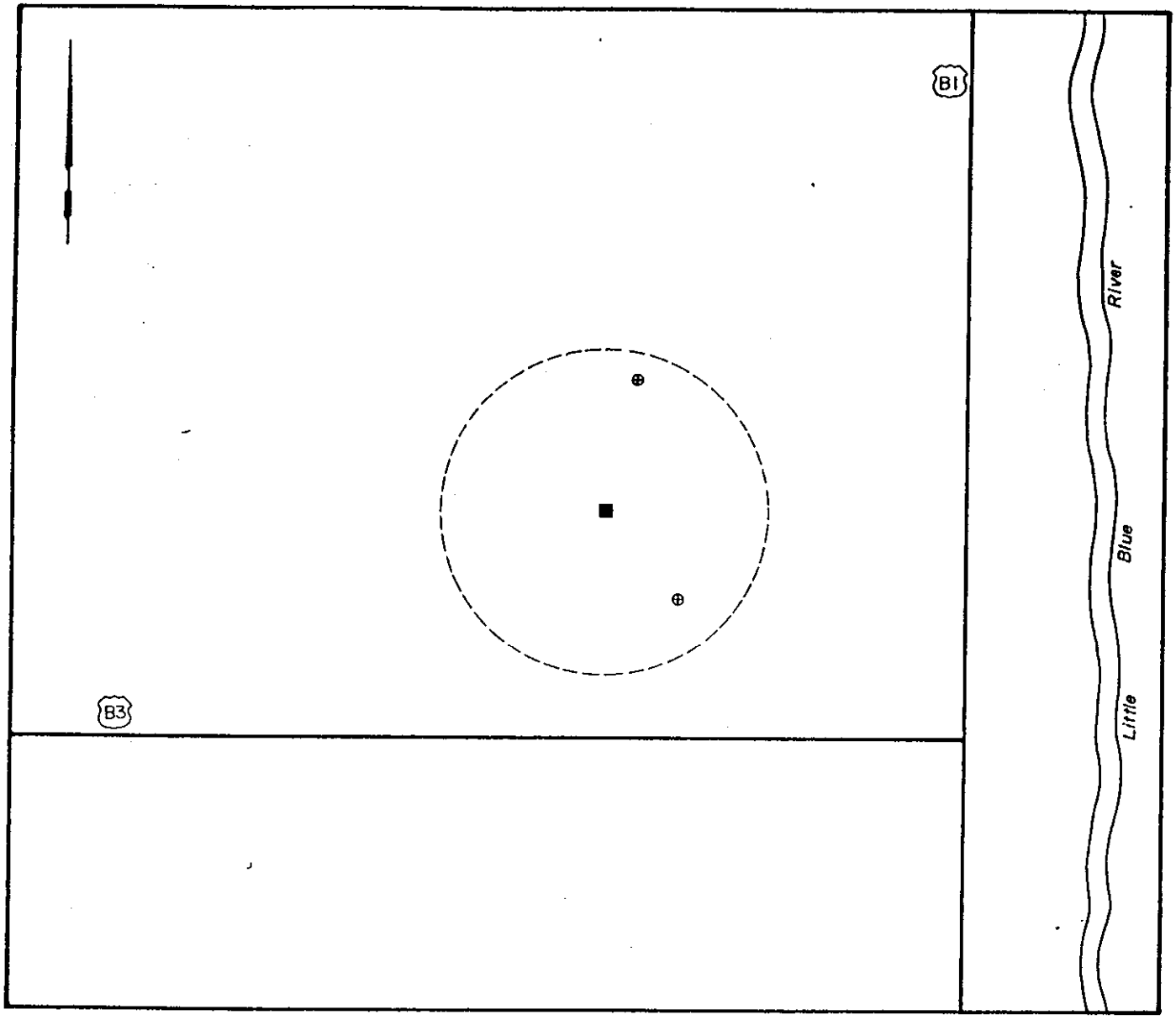
Classification Based on Two-Mile Classification Review Area

Referring to the procedural chart shown in Figure 4-1 and the associated worksheet in Table 4-1, the following classification was performed using a two-mile Classification Review Area as shown in Figure C11-4.

Step	Question/Direction	Response/Comment
1	Establish Classification Review Area (CRA) and collect preliminary information. Optional - Demonstrate subdivision(s) of the CRA.	The CRA is defined by a two-mile radius from the proposed facility. No CRA subdivision has been performed.
2	Locate any ecologically vital areas in the CRA. Does the CRA or appropriate subdivision overlap an ecologically vital area? . Yes, go to next step . No, go to Step 4	No ecologically vital areas are present in the two-mile CRA.
4	Determine location of well(s) within the CRA or appropriate subdivision. Does the CRA or appropriate subdivision contain well(s) used for drinking water? . Yes, go to next Step . No, go to Step 8	Yes, several domestic wells exist on the sinkhole plain as well as domestic spring houses along the sandstone upland region.
5	Inventory population served by well(s). Does the well(s) serve a substantial population? . Yes, go to next step . No. then the ground water is CLASS IIA-CURRENT SOURCE OF DRINKING WATER	No substantial populations are present in the CRA as determined by Option A.

FINAL CLASS DETERMINATION: CLASS IIA-CURRENT SOURCE OF DRINKING WATER

FIGURE C11-4
BASE MAP ENCOMPASSING THE TWO-MILE CLASSIFICATION REVIEW AREA



EXPLANATION

- ■ PROPOSED FACILITY
- ---- CLASSIFICATION REVIEW AREA BOUNDARY
- ⊕ SPRING HOUSE FOR DOMESTIC USE
- ━━ ROADWAY

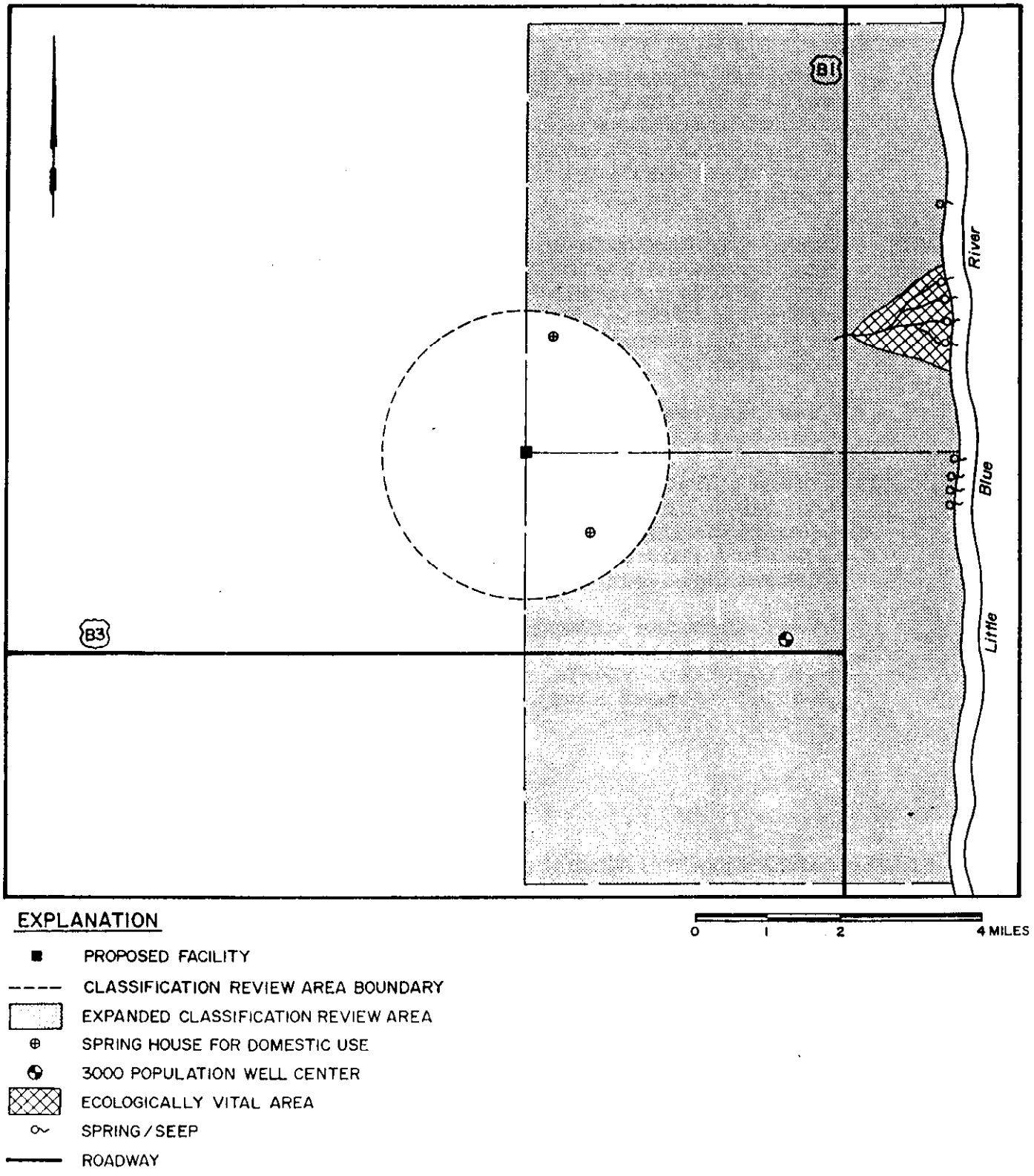
0 1 2 4 MILES

Classification Based on Expanded Classification Review Area

The expanded Classification Review Area is shown in Figure C11-5. The following work sheet explains the classification decisions. Note that Figure C11-5 does not show the location of the cave stream network nor the location of ground-water basin divides as shown in Figure C11-1. In the majority of Karst areas, this information will not be known.

Because this karst setting is composed of carbonate rocks having a well developed system of enlarged solution openings an expanded Classification Review Area is allowed. It will be assumed that the true location of ground-water basins and karst streams is not known. The dimensions of the expanded review area are then determined by the distance to the nearest spring-fed perennial stream; in this case the Little Blue River. The topographic high between the Little Blue River and the next stream to the east is further east of the facility. Therefore, it can be assumed under the rules of Classification Review Area expansion that ground water beneath the facility will move toward the Little Blue River. The expanded review area is shown in Figure C11-5.

FIGURE C11-5
BASE MAP ENCOMPASSING THE EXPANDED CLASSIFICATION REVIEW AREA



Step	Question/Direction	Response/Comment
1	Establish Classification Review Area (CRA) and collect preliminary information. Optional - Demonstrate subdivision(s) of the CRA.	The CRA has been expanded because of the karst setting. No CRA subdivision has been performed.
2	Locate any ecologically vital areas in the CRA. Does the CRA or appropriate subdivision overlap an ecologically vital area? . Yes, go to next step . No, go to Step 4	Yes, ecologically vital areas are present in the CRA.
3	Perform vulnerability analysis. Is the CRA or appropriate subdivision a highly vulnerable hydrogeologic setting? . Yes, then the ground water is CLASS I-ECOLOGICALLY VITAL . No, go to next step	Yes, under Options A and B, the expanded CRA is a vulnerable hydrogeologic setting.

FINAL CLASS DETERMINATION: CLASS I-ECOLOGICALLY VITAL

Note: It is possible that the ground water may also be an irreplaceable source of drinking water, however, there was no need to perform an irreplaceability analysis because the ground water qualified as Class I under the ecological vital criteria.