CHAPTER 3

Effects of Changing Land Use on the Aquifer and Water Supply

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Trends in land use have directly affected the ground-water resource in and around Albuquerque. The urbanization of the area and increased pumping of ground water for municipal and industrial needs has been accompanied by a reduction in aquifer recharge potential due to modification of the Rio Grande, declines in irrigated acreage, and abandonment of segments of the drainage and irrigation delivery system. These trends have resulted in ground-water pumping exceeding recharge capacity and in an unsustainable resource outlook for the future. Land uses and land use trends also affect water quality in the aquifer. Contamination of the ground water continues to occur largely as a result of urbanization.

While this discussion dwells mainly on conditions adversely impacting ground-water supplies and on the potential for mitigating these impacts in the immediate vicinity of Albuquerque, it is important to recognize that urban growth trends are now emerging or are well underway from Bernalillo to Belen and beyond (Summers, 1995). The water supply problems now of concern in Albuquerque can be expected to follow urban development up and down the valley.

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This chapter is based on data and information contained in four technical reports which, in turn, are based on other Assessment component studies. These four reports are:

(1) "Land Use Trend Analysis" (Bell et al., 1993 and 1994), which provides land use trend interpretations of aerial photography for the years 1935, 1955, 1975, and 1993.

(2) "Middle Rio Grande Basin Surface Water Budgets for 1935, 1955, 1975 and 1993" (Gould, 1995), which integrates and tests the validity of water use estimates associated with the land use trends identified and quantified in the "Land Use Trend Analysis."

(3) "1993 Paired-Sample Water Budget for the Albuquerque Reach of the Middle Rio Grande" (Hansen, in press[a]), which partitions surface water losses to the various water use budget components in order to isolate and quantify ground-water recharge contributions in the Albuquerque area.

(4) "Land-Use Trends and Their Effect on Water Use and the Hydrologic Budget in the Albuquerque Basin, New Mexico" (Summers, 1995), which provides interpretation of and conclusions reached about the hydrologic impacts of land use changes.

The appendix contains more detailed summaries of these reports.

Impact of Historic Land Use Trends on Ground-Water Recharge

The water table in the Albuquerque area has been dropping since ground-water pumping for municipal supplies began to exceed system recharge capacity. Even before that time, aquifer recharge potential had been significantly reduced by engineering modifications to the hydrologic system that began around 1930.

The water table in the Albuquerque area has been dropping since ground-water pumping for municipal supplies began to exceed system recharge capacity probably in the 1960's. Even before that time, aquifer recharge potential had been significantly reduced by engineering modifications to the hydrologic system that began around 1930. Since then, the continued modification of the hydrologic system, due to urbanization and other influences, has resulted in further reduced recharge.

The following discussions address several types of changing land use, related modifications to the hydrologic system, and the resulting reductions in potential or actual ground-water recharge that have occurred in the greater Albuquerque metropolitan area over the past 65 years. Most of these changes have been well chronicled through design and planning documents, historic water records, photographs, etc. This data and information allows us to evaluate impacts on the water supply, develop workable mitigation measures, and identify additional untapped resources.

Effect of Changes to the Rio Grande and Riparian Zone

The most obvious and well recognized ground-water recharge asset in the Albuquerque Basin is the Rio Grande. Surface water budgets developed for the reach between Bernalillo and Isleta that cover 1993 and 1994 estimate the recharge contributions from the river and riverside drains at about 33,000 acre-feet annually (Hansen, in press[a]). It appears that this source of recharge has been reduced in some areas to about half of the natural recharge potential prior to human alteration of the river channel and riparian corridor (Hansen, in press[b]). These reductions are, to some degree, reversible.

The river was the source of life for agrarian societies occupying the valley even before arrival of the Spaniards. It was also a source of frequent destructive floods. Commonly occurring droughts inhibited economic development and poor drainage due to sediment accumulation in the river channel reduced the productivity of irrigable lands (Summers, 1995). Increasing diversion of water from the Rio Grande in Colorado and northern New Mexico during the late 19th century further reduced the river's ability to carry its sediment load and contributed to increasing sediment deposition in the river channel through the Middle Valley. Problems caused by flooding and high ground-water levels continued to worsen.

The Middle Rio Grande Conservancy District was formed in the late 1920's to drain and reclaim saturated agricultural lands, improve the irrigation system, and make the river more manageable and reliable. To accomplish these purposes, the District initiated a program of engineering works to provide better water control and management in the Rio Grande Valley between Cochiti and the Bosque del Apache. Later, as local resources proved inadequate for the needs, Reclamation and the U.S. Army Corps of Engineers built additional flood control and river channel stabilization works. These activities have had significant impacts on the river and riparian corridor.

Some of the works that were constructed to solve the problems of the 1920's, 1930's, 1940's, and 1950's are now acting to inhibit recharge.

Training the river with levees and jetties stabilized the channel and made the valley floor a safer and more profitable place to farm and live. Narrowing and deepening of the river channel has reduced open water evaporation, increased sediment transport efficiency, and promoted better valley drainage. In many areas, drainage and bank stabilization were factors in allowing riparian forests to become established, approximately doubling bosque area in the vicinity of Albuquerque between 1935 and 1993 (Summers, 1995). Attaining these benefits has been achieved at a cost to ground-water recharge. Along the river between Paseo Del Norte and Rio Bravo Boulevard, some of the works that were constructed to solve the problems of the 1920's, 30's, 40's, and 50's are now acting to inhibit recharge of the shallow ground-water system (Hansen, in press[b]). Reduced wetted perimeter in the river channel and interception and removal of water leaking from the river by the riverside drains are significant factors reducing aquifer recharge.

Potential groundwater recharge from the Rio Grande is now reduced by as much as half because the riverside drains intercept water seeping from the river before it can enter the deeper groundwater system.

The District constructed the riverside drains in the 1920's and 1930's to drain lands near the river and prevent them from becoming waterlogged. They were designed to drain away the valley's high ground water and intercept water seeping from the river. Where high ground-water tables persist, the riverside drains continue to perform their intended function. However, in many areas, pumping of ground water by City wells has now lowered the water table below the level of the drains. In these dewatered areas, potential ground-water recharge from the Rio Grande is now reduced by as much as half because the riverside drains intercept water seeping horizontally from the river before it can enter the deeper ground-water system. Water intercepted by the drains is returned to the river downstream or diverted to the irrigation system. As illustrated in figure 3-1, the riverside drains also slow the rate of shallow ground-water movement away from the river by lowering the adjacent water table and flattening its gradient.

Assessment investigations showed that in many areas, the valley fill alluvium in the Albuquerque Reach between Bernalillo and Isleta has potential for high rates of horizontal hydraulic conductivity. Horizontal conductivity rates as high as 350 feet per day per unit gradient have been measured (Cummins, 1993). Steady state analysis shows that water seeping

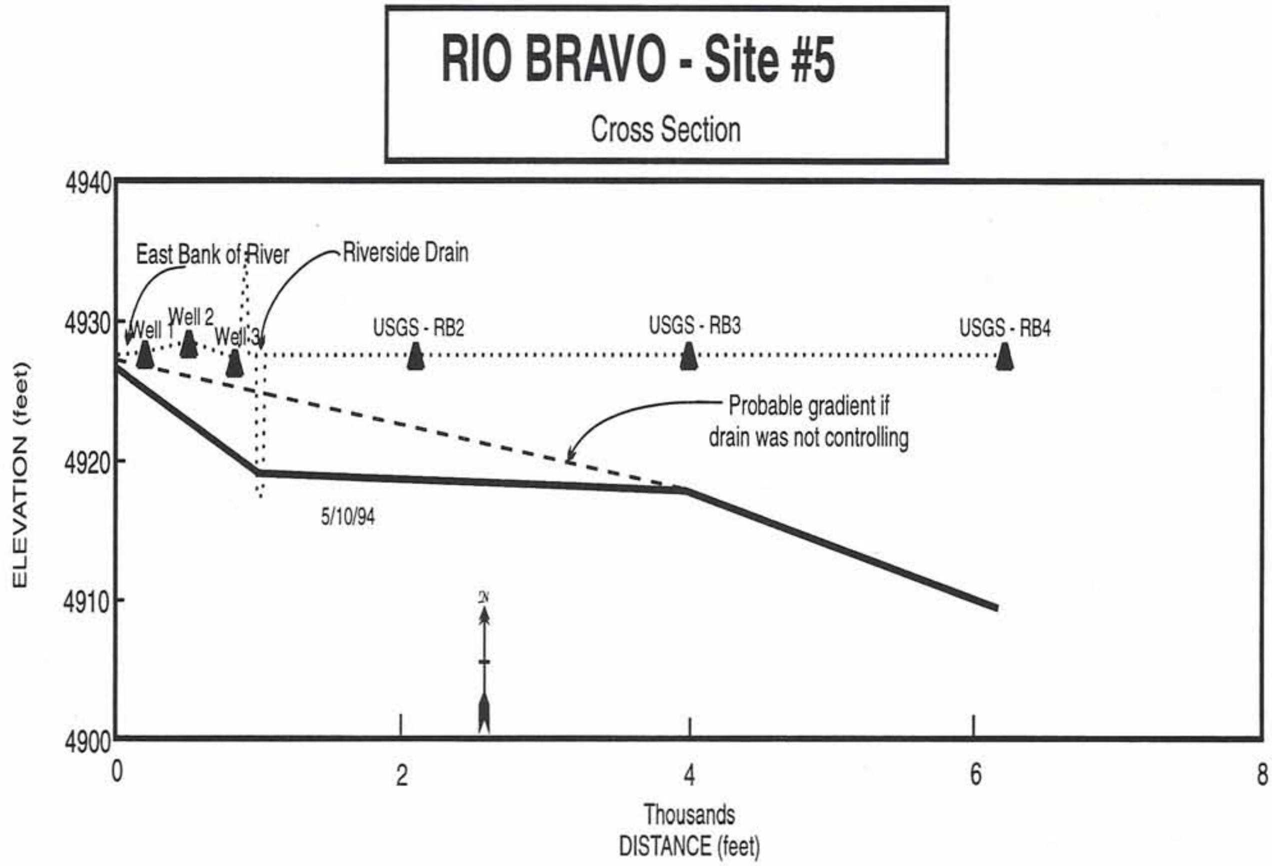

Figure 3-1.—Effects on water table and gradient (ground-water profile across drain).

from the river moves toward the riverside drains at rates ranging from about 1.6 to 21 cubic feet per second (cfs) per mile, averaging about 7 cfs per mile (Hansen, in press[b]). Mass balance analysis at three sites shows that the drains capture and remove between 75 percent and 86 percent of this ground-water flow. Therefore shallow ground water moving toward City wells between Paseo del Norte and Rio Bravo Boulevard can be estimated to range from 0.9 to 2.5 cfs per mile, averaging about 1.7 cfs per mile.

Flood wave testing and transient ground-water analysis (Pruit and Bowser, 1994) showed results similar to the steady state analysis indicating that, at most, only 13 percent of the river seepage recharges the deep aquifer in the Santa Fe Group deposits.

River permeameter studies (Gould, 1994) showed that potential rates for vertical infiltration through the riverbed is about three orders of magnitude smaller than horizontal infiltration through the river channel's banks. These findings indicate that water seeping from the Rio Grande moves horizontally more easily than vertically. Apparently, river seepage moving toward deep aquifer recharge moves out from the river horizontally to cover a wide area as it seeps more slowly into the less permeable Santa Fe Group aquifer materials below. Interception of horizontal seepage near the river by the riverside drains reduces the infiltration area and thereby diminishes recharge.

Water seeping from the Rio Grande moves more easily horizontally than vertically.

In summary, a number of the Assessment investigations provide a basic picture of natural recharge limitations, the mechanics and magnitude of human caused recharge reductions, and potential for mitigation or even enhancement of recharge within the riparian corridor. Most importantly, it appears that reductions in recharge due to the effects of the riverside drains are recoverable and that there may be some potential for enhancement over natural conditions. Specific methods for enhancing recharge by changing the management of the riverside drains will be discussed in chapter 5.

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Effect of Changes in Irrigated Agriculture

Recharge benefits associated with irrigated agriculture often go unrecognized, though they are quite substantial. In fact, water budgets calculated for 1994 show that irrigated agriculture and associated water distribution facilities contribute about half, or 31,000 acre-feet, of the annual recharge presently occurring in the Albuquerque Reach between Bernalillo and Isleta (Hansen, in press[a]). The budgets estimate that deep percolation from irrigated fields contributed about 8,000 acre-feet to recharge in 1994, while seepage from canals contributed about 23,000 acre-feet. However, these current levels of recharge are declining and may be lost as urbanization continues.

Land use trend analysis shows that irrigated acreage between Bernalillo and Belen has declined from a maximum of nearly 20,400 acres in 1955 to its present level of about 11,500 acres. Conversion of agricultural lands to urban uses has been the primary cause of this decline. A number of the Assessment studies provide a basis for estimating that the average annual deep percolation from irrigated lands is about 0.7 acre-foot per acre (Cummins, 1994). Consequently, since 1955, the annual recharge potential due to this source in the Albuquerque metropolitan area has been reduced by as much as 6,000 acre-feet or about 43 percent.

Agriculture and associated water distribution facilities contribute about half of the annual recharge presently occurring between Bernalillo and Isleta. These current levels of recharge are declining.

Loss in annual recharge due to reduced irrigation in the valley since 1975 is equivalent to the annual water use needs of more than 13,000 people.

About 60 percent of the loss of irrigated acreage since 1955 has occurred in the 20 years since 1975, and the trend appears to be accelerating. South of Albuquerque to Belen, the trend is particularly rapid. The cumulative loss in annual recharge potential due to reduced irrigation in the valley since 1975 is equivalent to the annual water use needs of more than 13,000 people at a per capita use rate of 200 gallons per day.

If we assume that average trends since 1975 hold constant, it will take less than 35 years before irrigation is totally eliminated between Bernalillo and Albuquerque. Although the likelihood of this prospect is debatable because of the number of large estates and hobby farms in the valley, even approaching this scenario with further significant reductions of remaining agricultural lands could have far-reaching consequences.

Even before irrigated agriculture disappears entirely due to development pressures, dwindling irrigation may make the costs of operating and maintaining the irrigation system unjustifiable for the District. Increasing costs to the District include providing public protection, liability, and compensation for damages along conveyance facilities in increasingly developed areas. The difficulty of maintaining the irrigation delivery system could ultimately force the District to abandon some facilities.

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Traditionally, canal seepage has been perceived as wasteful and a burden to downslope landowners. Ironically, canal seepage now plays an increasingly major role in recharging the shallow ground-water system in the Albuquerque Reach, in spite of declining irrigated acreage. A worst case scenario, involving complete abandonment of the canal system in the Albuquerque area, would eliminate about 23,300 acre-feet of annual recharge from canal seepage.

A number of Assessment studies, including measurements from canal seepage ponding tests (Hansen and Gould, 1994), are used in developing water budgets that quantify and validate estimates of canal seepage recharge contributions. Although irrigated acreage has been reduced substantially in the Albuquerque Reach to date, only about 20 miles of irrigation conveyance system has been abandoned, amounting to a loss of about 1,800 acre-feet of recharge potential. About 71 percent of this loss has occurred between Corrales and Central Avenue in Albuquerque.

The canal system has potential to provide significant recharge enhancement, requiring nothing more than some management and operational changes. The system also has capability to deliver water for other recharge enhancement projects throughout the valley. Later discussions in chapter 5 will explore these possibilities in more detail.

Effect of Changes on the Interior Drainage System

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The interior drains are the only surface water features dramatically showing the effects of municipal pumping on the shallow ground-water system. With ever greater municipal pumping has come progressive drying up of drains at increasing distances from the pumping centers. The easternmost drains were the first to dry up, and many are no longer acting as ground-water drains because of the general lowering of the water table. The Alameda Drain along North Second Street exemplifies this condition. These drains still function as surface water channels for routing irrigation water and storm runoff, and they do provide some incidental recharge as a consequence.

Ground-water drains are normally thought to provide the inverse function of recharge. That is, they collect ground water and remove it from the area. However, interior drains can also redistribute ground water, collecting and removing it from an area of surplus ground-water and carrying it into dewatered areas where it can again enter the ground-water system. The amount of ground water redistributed through the drains in this manner is unknown.

The interior drain system has good potential for use in enhancing ground-water recharge. It remains largely intact even though it is becoming increasingly less needed for controlling the shallow ground-water elevation. However, as of 1986, about 2 miles of the interior drainage system had already been abandoned (Thompson, 1986).

Land Use Factors Related to Contamination of Ground Water and Aquifer Recharge

The Albuquerque-Bernalillo County Ground-Water Protection Policy and Action Plan describes the nature and extent of shallow ground-water contamination that is estimated to cover over 30 square miles.

A number of past and present land use practices are responsible for contamination of the shallow ground-water system which is the principal source of recharge for the deeper aquifer. The nature of this problem has been recognized, and the Albuquerque/Bernalillo County Ground-Water Protection Policy and Action Plan (Albuquerque/Bernalillo County, 1993-1994) has been formulated to address it. The plan describes the nature and extent of shallow ground-water contamination that is estimated to cover over 30 square miles. Contamination due to both localized sources (such as industrial sites) and more widespread sources (such as septic systems) is shown relative to important recharge areas and ground-water levels for the year 1994-95 in figure 3-2. To date, the primary emphasis of the Groundwater Protection Plan has been on recognition, prevention, and containment of damages.

Industrial Pollution Sources

Until recently, life along the Rio Grande has been centered in the valley, where there is easy access to water. Development in the valley occurred first near the river, then along the railroad, and later along the highways. Finally, development occurred more on the mesas. Yet the valley floor remains a primary center of domestic, agrarian, urban, and industrial activities.

Industrial and commercial activities have historically contributed to the shallow ground-water pollution problems in the valley. Contamination from these sources has caused the abandonment of several of Albuquerque's municipal wells, most notably in the San Jose well field. Retail gas stations have also been a significant source of ground-water pollution. With increasing regulation, new problems will be likely to abate, but they will be difficult to eliminate. Discovery of previously contaminated but unidentified sites will also continue.

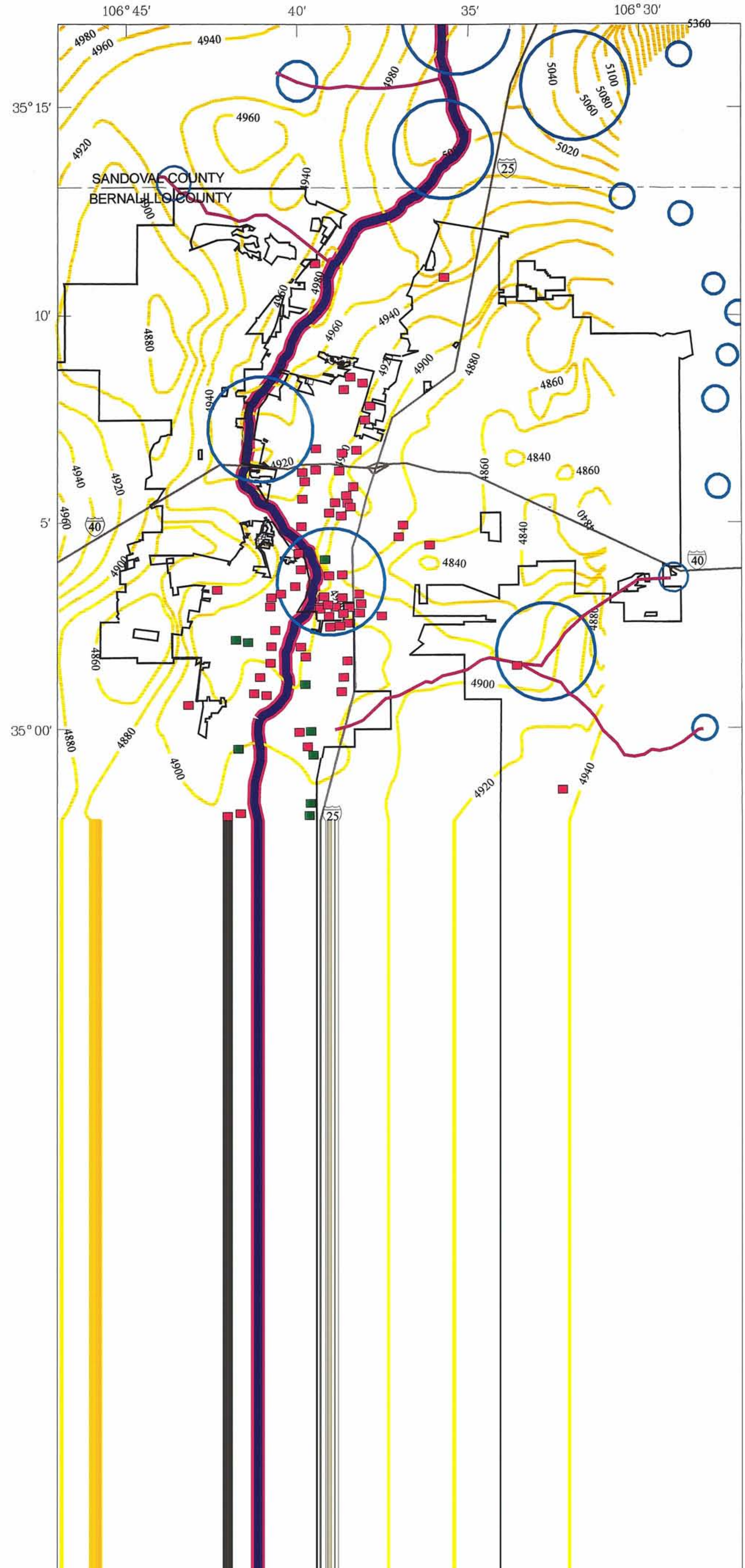
Ground-water contamination in the vicinity of recharge windows and corridors merits particular concern. Vigorous upfront protection of water quality in recharge areas is a critical element in overall water resource management for Albuquerque and surrounding communities.

Ground-water contamination in the vicinity of recharge windows and corridors merits particular concern. Migration of contaminants into the aquifer can occur most easily and rapidly in these areas. Trichloroethylene contamination associated with the Sparton Technology facility on Coors Road (Bitner, Halloran, and Minchak, 1996) is apparently being drawn into the Calabacillas Recharge Window. Heavy pumping of wells serving southeastern Rio Rancho, Paradise Hills, and Albuquerque's west side will increasingly induce movement of the contaminant plume toward the deep aquifer. The contamination may eventually be widely dispersed through the ground-water trough under the west mesa.

Remedial activities for industrial contamination are costly and take time. In many cases, responsible parties cannot be found or proven. Vigorous upfront protection of water quality in recharge areas is a critical element in overall water resource management for Albuquerque and surrounding communities.

Septic Tanks and Leach Fields

The widespread use of septic systems for waste water disposal in the valley is causing extensive aquifer contamination. Nevertheless, septic systems continue to be an accepted and sanctioned waste water disposal practice in many areas. Problems associated with use of septic systems include degradation of the shallow ground water with nitrates and, occasionally, coliform bacteria from systems which are not properly maintained. The oxidation and reduction process which breaks down these contaminants can also cause precipitation of iron and manganese in the aquifer and within shallow domestic water systems rendering them unusable as sources of potable water.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There are no easy or cheap answers to this extensive problem which is becoming more prevalent in the entire Middle Rio Grande Valley. Albuquerque continues to replace individual septic systems by expanding central sewer service. However, the process is slow, costly, and politically sensitive. In the meantime, increasing drawdown of the shallow ground water by municipal pumping is drawing more and more contaminated shallow ground water toward municipal pumping centers.

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Agricultural Contamination

Although irrigated agriculture has been shown to be relatively clean in the Middle Rio Grande Valley (Ong, O'Brien, and Rucker, 1991) compared to other parts of the country where salinity, selenium, pesticides, and herbicides pose major concerns, there are locations where problems have been identified.

General sampling of surface water, ground water, bottom sediments, and biota associated with irrigation and drainage in the Middle Rio Grande Valley show no evidence of impairment to drinking water or wildlife related water quality standards. This includes consideration of herbicides, pesticides, fertilizers, and metals. However, recent investigations have shown that past farming practices at an old truck farm location south of Albuquerque left evidence of excessive fertilizer application which substantially elevated nitrate concentrations in the shallow ground water (McQuillan and Space, 1995).

A potential for problems justifies continued concern, awareness, and education. This is especially true for urban homeowners, who often use amounts of chemicals exceeding the economic production levels that would normally be used in commercial agriculture.

Location of Landfills in High Potential Aquifer Recharge Zones

Solid waste disposal in landfills can present ground-water contamination problems in a number of ways. Not only can landfills pollute recharge sources with many types of contaminants, but they are often located in the best recharge locations and must be completely removed to remediate contamination problems. Figure 3-3 shows the locations of landfill sites in relation to 1994-95 ground-water contours and important recharge features (Groundwater Threat Characterization Report, CH_2M Hill, 1990).

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The fact that so many dumps ended up in prime recharge areas is not accidental. Until recently, it was common practice to locate dumps and landfills in pits left over from sand and gravel mining operations. Clean sand and gravel deposits containing little or no fine material or organic matter are most desirable for production of construction materials. Because these deposits are highly permeable, they also characterize the best natural ground-water recharge zones. In general, the higher the quality of the sand and gravel as a construction material, the better the conductivity as an aquifer material or as a recharge conduit.

The existence of old landfills in highly permeable deposits will continue to pose concerns over contaminant migration, and these sites will require costly long-term monitoring.

Sand and gravel operations leave holes in the ground which are often considered to be eyesores and public safety problems. A seemingly practical solution is to fill the hole with unwanted refuse, cover it with soil, and reclaim the land for some other useful purpose. In Albuquerque, for example, the Balloon Fiesta Park and Tingley Beach are located on former landfill sites. This practice was a result of practical considerations and went without question for generations because the consequences were not well understood. We now recognize a serious danger of contamination of the aquifer posed by the location of dumps and landfills in sand and gravel pits and similar sites. Toxic leachates from landfills located in sand and gravel deposits easily find their way into the ground-water system through the highly permeable materials. Modern landfill design requires impermeable barriers to contain these leachates. The existence of old landfills in highly permeable deposits will continue to pose concerns over contaminant migration, and these sites will require costly long-term monitoring.

It is important to recognize that sand and gravel mining occurring in valuable recharge zones is not necessarily a cause of aquifer contamination. Properly managed sand and gravel pits may actually offer some recharge enhancement opportunities.

Land Use Management and Water Resources

Land use categories pertaining to water supply considerations are a relatively new development.

Management of land uses for protection of public values is usually approached through a planning process. Traditionally, land use planning has sought to assure compatible uses of adjacent lands and to assure the "highest and best" use of the land. Zoning ordinances are the common manifestation of land use planning. Typically, the process results in the adoption of land use maps which are used to guide future development. Planning methods focus on designating areas suitable for particular uses as defined by commercial, residential, agricultural, and industrial needs. Open space and similar needs may also be addressed. Transportation design and esthetic considerations are the focus of traditional planning processes. Land use categories pertaining to water supply considerations, such as well head protection zones and sole source aquifer protection zones, are a relatively new development.

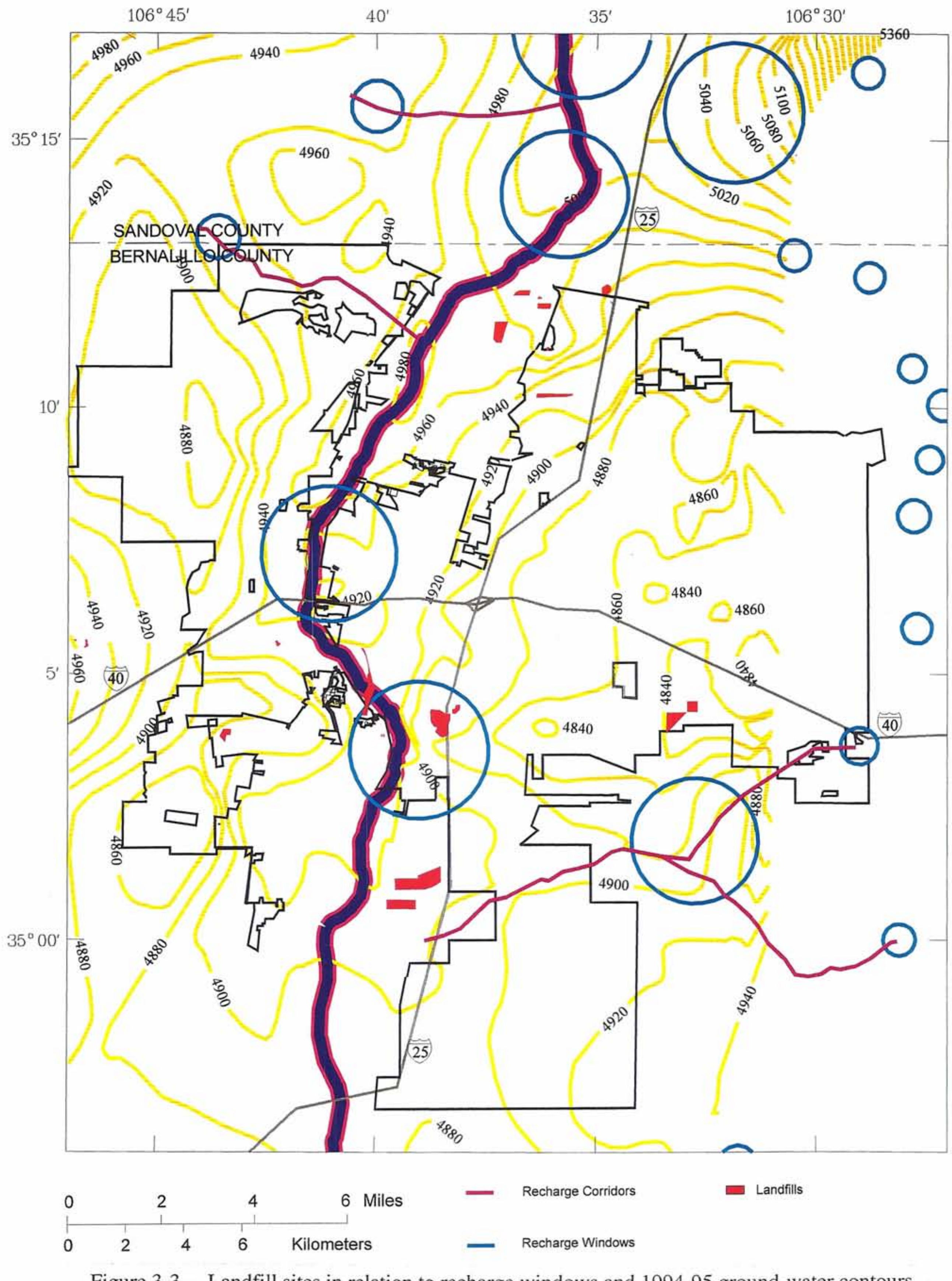

Figure 3-3.—Landfill sites in relation to recharge windows and 1994-95 ground-water contours.

Many water resource management needs can be addressed in the context of traditional land use planning by defining categorical designations and allocating land use types accordingly. Aquifer recharge zones, aquifer protection zones, shallow aquifer use zones, and water resource management zones are all examples of zoning categories that could be established to preserve or protect water resources or important hydrologic features. Land use categories pertaining to water resource needs could overlay traditional land use categories requiring special precautions or restrictions on the encompassed traditional use.

The planning process begins with the public establishment of goals and objectives. An example of a goal would be to assure sustainable use of the deep aquifer beneath the City. Objectives are finite, near-term actions which lead to goal accomplishment, such as the establishment of a technical advisory team. After setting of goals and objectives comes an inventory of existing conditions. Assessment component studies could provide much of the data required for an inventory of current land use and water resource conditions. Once an inventory is complete, the need for additional data can be determined. Some needs for additional data collection have already been identified in component studies of the Assessment.

A planning process can and should be used by the various political subdivisions in the Middle Rio Grande Valley at the local and regional level to protect and enhance water resources.

Alternatives are formulated that provide various ways of contributing to achievement of the original goal. Once they are formulated and evaluated, alternatives are presented to a decisionmaking body. Implementation follows the decisionmaking process.

A planning process can and should be used by the various political subdivisions in the middle Rio Grande Valley at the local and regional level to protect and enhance water resources. If sustainable aquifer use were established as a planning goal, then the following items might be appropriate objectives:

- Determine the sustainable level of consumptive water use for the region so that the limitations of the resource can be understood.
- Establish per capita consumptive use guidelines as a basis for allocating consumptive uses among users.
- Establish target piezometric surface elevations for affected aquifers so that their conditions can be adequately monitored.
- Promote conjunctive water use through land use planning or infrastructure development.

Objectives specifically applying to land use planning might be:

- Protect and maintain the irrigation distribution and drainage infrastructure (diversions, canals, drains, etc.). These facilities contribute significantly to aquifer recharge. Potential exists for enhancing this contribution through structural modifications or operational changes.
- Promote low-density agrarian uses of the valley. Irrigation provides ground-water recharge and water quality benefits.
- Encourage industry to locate in areas away from shallow ground water or important recharge zones to protect recharge potential and minimize ground-water contamination.
- As far as possible, extend sewer service with required hookup to all housing to protect or improve ground-water quality.
- Impose requirements for regular maintenance of septic systems to minimize a major source of ground-water pollution.
- Establish a recharge zone land use category restricting certain uses or requiring special protections and management in areas with high aquifer recharge potential.
- Establish flood water management regulations that would promote recharge and protect water quality, especially for new development.
- Restrict further development in important recharge areas such as mountain front sites to protect the important function of these areas in the hydrologic system.

Other ways to achieve planning objectives may include providing various types of incentives to promote desirable land uses or disincentives for undesirable uses. Incentives and disincentives can be applied through taxes, utility rate structures, user fees, or subsidies. Taxes and disincentives carry obvious political liabilities, so positive incentives should be used to the greatest possible extent.

Public awareness and education are key requirements for successful planning and implementation.

Public awareness and education are key requirements for successful planning and implementation. Without widespread awareness, understanding, and support, it is doubtful that land use management or other programs to protect and manage water resources will be accepted by the public.

To be successful, planning must also be supported by all affected political entities within the geographic area. There are currently so many jurisdictional subdivisions within the Basin that

Regional planning is needed to protect water resources that are shared across jurisdictional boundaries.

decisions affecting water resources are frequently fragmentary or haphazard and are sometimes conflicting and counterproductive. Cities, counties, the District, Middle Rio Grande Council of Governments, the State of New Mexico, the Albuquerque Metropolitan Arroyo Flood Control Authority, various Federal agencies, and Native American communities all have some measure of control over projects and regulations that influence regional water resources. Regional planning is needed to protect water resources that are shared across jurisdictional boundaries.

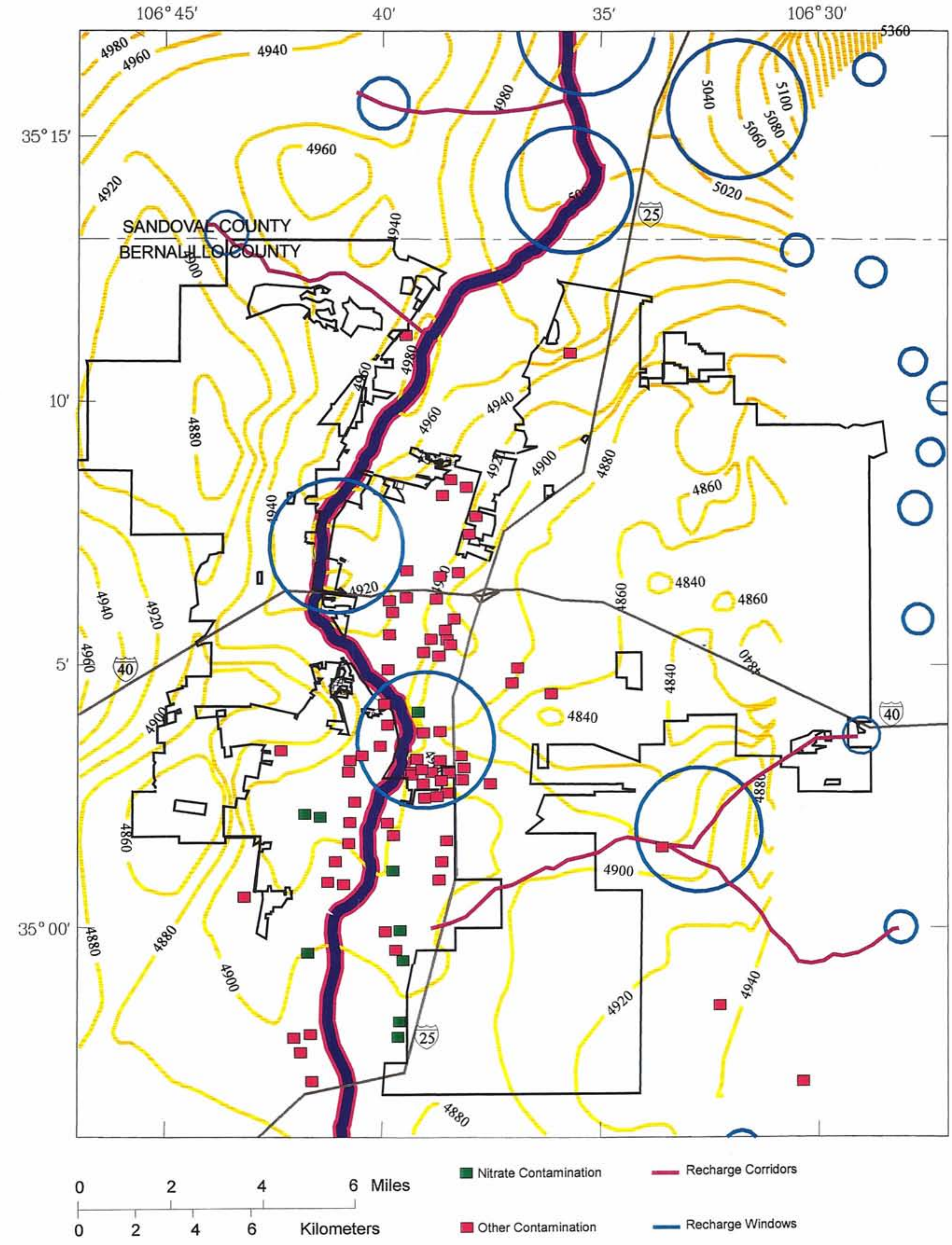

Figure 3-2.—Nitrate and industrial contamination sites shown in relation to recharge windows and 1994-95 ground-water contours.