DWR EXHIBIT Q

Final Report on Recharge Demonstration Project
Submitted with December 16, 2003 Response Letter

Final Report on the Equus Beds Groundwater Recharge Demonstration Project

Prepared for

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

April 2000

92-195-4-016

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April 25, 2000

Mr. H. Douglas Yoder
Special Programs Manager
U.S. Department of Interior
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Denver Federal Center, Bldg. 67
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Denver, CO 80225-0007

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WICHITA
Interim Report on the Equus Beds
Groundwater Recharge Demonstration Project
B&McD Project 92-195-4-016

Dear Mr. Yoder:

Presented herewith is the *Final Report on the Equus Beds Groundwater Recharge Demonstration Project* as delineated in the City of Wichita's demonstration project proposal submitted to the Bureau in 1995. The proposal set forth the completion of a final report on the project after the 3rd year of operation. This report is organized according to your outline as requested in late 1998. Part II of the report on *Water Quality Analysis* was prepared by Region 7 USEPA. The demonstration project now has about 3-years of operating experience and findings to date indicate that the concept of full-scale aquifer recharge, storage and recovery is feasible.

This demonstration project reflects a collaborative effort by many individuals and agencies at the local, state and federal levels. The Bureau's participation is truly appreciated.

Sincerely,

Frank L. Shorney, P.E. for	David H. Stous, P.E.	L. Jeffrey Klein, P.E.
Project Manager	Project Hydrogeologist	Project Engineer

FLS/DHS/LJK/le276dv.doc

cc: Ms. Shirley J. Shadix, Program Coordinator, Bureau of Reclamation
Mr. Michael T. Dealy, Manager, Equus Beds Groundwater Mgmt District No. 2
Mr. David Warren, Director, Wichita Water and Sewer Department
Mr. Jerry Blain, Superintendent of Production and Pumpage

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U.S. DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION

FINAL REPORT ON THE EQUUS BEDS GROUNDWATER RECHARGE DEMONSTRATION PROJECT

92-195-4-016

INDEX AND CERTIFICATION PAGE

REPORT INDEX

Recognition is given to the following additional people who assisted in completing this report:

Fred Pinkney, PhD, Environmental Specialist
David Vallejo, Water Supply Engineer

CERTIFICATION(S)

FRANK LAVERN SHORNEY
LICENSED
6011
KANSAS
PROFESSIONAL ENGINEER

Frank L. Shorney
4/25/00

Note: The above certification does not apply to Part II of the report (Water Quality Analysis), which was completed by USEPA Region 7.

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PROJECT BACKGROUND AND DEVELOPMENT

PART I

PROJECT BACKGROUND AND DEVELOPMENT

A. INTRODUCTION

1. HISTORICAL DEVELOPMENT AND BACKGROUND

The Equus Beds Aquifer and Well Field has supplied water to the City of Wichita since the 1940's and is a key component of the City's water supply system. The well field includes 55 wells with a groundwater delivery capacity of 78 million gallons per day and has traditionally provided 60 percent of the City's total raw water supply. After years of municipal and agricultural use, the volume of water stored in the aquifer has been reduced by approximately 70 to 100 billion gallons with groundwater levels lowered by as much as 30 feet. This decrease in groundwater level is allowing migration of chlorides into the well field with the potential for significant water quality degradation over an extended period of time.

Aquifer storage and recovery (ASR) of the City's Equus Beds Wellfield is proposed to assure the continued use of the aquifer to meet the City's long-term water demands. ASR involves the capture of water in the Little Arkansas River, the transfer of captured water to the Equus Beds for recharge and storage, and the recovery of water from the recharged aquifer for use when needed. Recharging the well field area assures future water availability, specially during extended dry weather periods, and will reduce future deterioration of the aquifer's water quality by slowing migration of high chloride water into the well field from nearby sources.

The City of Wichita (City) and the U.S. Bureau of Reclamation (Reclamation) are sponsoring the Equus Beds Groundwater Recharge Demonstration Project (Project) to study the feasibility of full-scale recharge operations. The Wichita's manager for the Project is Jerry Blain, Superintendent of Production and Pumping, Wichita Water and Sewer Department. The City's engineers for the Project are Burns & McDonnell in Kansas City, Missouri and Mid-Kansas Engineering Consultants in Wichita, Kansas. Maintenance and operation of the recharge facilities are performed by the City of Wichita.

Other Project participants and contributors include the U.S. Geological Survey in Lawrence, Kansas and Groundwater Management District No. 2 (GMD2) in Halstead, Kansas (agency sponsoring the demonstration project environmental assessment and full-scale project environmental impact statement). Participating agencies with regulatory overview include:

- U.S. EPA - Region VII
- U.S. Fish & Wildlife Service
- Kansas Board of Agriculture, Division of Water Resources
- Kansas Department of Health and Environment
- Kansas Department of Wildlife and Parks
- State Historic Preservation Office

Major historical events leading to the implementation of the Project are shown in Table I-1. The Project began operation in mid-1997 and is scheduled to operate through year 2000.

Table I-1

Major Historical Events Leading to Implementation of the Project

Date	Event
June 30, 1992	Initiate a Water Supply Study for the City of Wichita including determination of water needs through year 2050.
July 23, 1993	Original submittal of Equus Beds Groundwater Recharge Demonstration Proposal sent to U.S. Bureau of Reclamation, Great Plains Region, Billings, Montana.
June 30, 1993	City's Water Supply Study completed with recommendations to implement the Integrated Local Water Supply Plan with Groundwater Recharge Component.

Table I-1 - continued

Date	Event
August 31, 1993	Wichita City Council approves Integrated Local Water Supply Plan with Groundwater Recharge Component.
May 6, 1994	Report titled *Equus Beds Groundwater Recharge Demonstration Project Feasibility Study (Phase 1, Part 1 - Preliminary Data Review and Concept Development)* submitted to City.
October 6, 1994	Kickoff meeting of the Equus Beds Groundwater Recharge Demonstration Project with Reclamation and project participants; notice of anticipated federal funding of 50% for the project and funding of $0.5 million for FY 1995; demonstration project noted to require NEPA compliance.
November 2, 1994	Notice from Reclamation that an Environmental Assessment of the Demonstration Project is needed by end of month in order to protect federal funding.
November 29, 1994	Submitted draft of *Environmental Assessment, Equus Beds Groundwater Recharge Demonstration Project* to Reclamation and project participants for review.
August, 1995	Received term permit for test well at Halstead from GMD2.
September, 1995	Distributed final *Environmental Assessment and "Findings-Of-No-Significant Impact" (FONSI) for the Demonstration Project.*
July 9, 1996	Presented findings of 30-day pump test to GMD2 Board. Board reaffirmed their support for the groundwater recharge project.

Table I-1 - continued

Date	Event
September 12, 1996	Conducted state and federal agency meeting in Topeka to update project participants on project status. Received general indication that the groundwater recharge demonstration project could proceed.
October, 1996	Initiated fast-track design of demonstration facilities with the objective of getting facilities under construction and in operation in preparation for FY 1997 runoff events and Reclamation's tour in April, 1997.
December 12, 1996	Report titled *Equus Beds Groundwater Recharge Project (Phase I, Part II - Engineering Study Involving Water Quality, Testing, Facility Siting, Test Well Construction and Aquifer Test)* submitted to City.
December 13, 1996	Opened bids on the Groundwater Recharge Demonstration Project.
December 17, 1996	Recommended award of demonstration facility construction contract to Utility Contractors, Inc. of Wichita, Kansas in the amount of $2,267,700.
May 23, 1997	Began recharge operations in basins and trench at the Halstead Test Facility.
June 13, 1997	Opened bids for the supervising control and data acquisition (SCADA) contract for the demonstration project. Recommended award to Southwestern Electric of Wichita, Kansas.

Table I-1 - continued

Date	Event
August 26, 1997	Completed Halstead Recharge System recharge well and started recharge testing.
October 17, 1997	Started testing of the Sedgwick Recharge System.
December 3, 1997	Presented project results for fiscal year 1997 at state and federal update meeting in Topeka.
February 24, 1998	Project received recognition through the Dr. Lennel I. Wright Conservation Award presented by the Sedgwick County Conservation District and the 1997 Public Works Project Award presented by the Kansas Contractors Association.
March 25, 1998	SCADA System became operational at both Halstead and Sedgwick groundwater recharge sites.
November, 1998	Began public access to the Equus Beds Recharge Project web page on the USGS Kansas District home page. The address is http://www.ks.cr.usgs.gov/kansas/ eqqus.
November, 1998	The Equus Beds Recharge Project received honorable mention in the 1998 National Groundwater Project Award Program.
November 27, 1998	Presented findings to date on the Project to state and federal agencies in Topeka.
February 13, 1999	Received honorary award for Equus Beds Recharge Project from Consulting Engineers' Council of Missouri at the 25th Annual Engineering Excellence Awards Reception/Banquet.

Table I-1 - continued

May, 1999	Delivered to the City the plans and specifications for passive recharge well option for the Halstead Recharge Site.
June, 1999	Closed out the SCADA contract with Southwestern Electric.
August, 1999	Awarded construction of the passive recharge system at the Halstead Recharge Site to Clarke Well & Equipment Company of Great Bend Kansas.
August 31, 1999	City conducted a tour of the recharge facilities with the Little Arkansas River Basin Watershed Coalition.
September, 1999	SCADA system for the demonstration project was incorporated into the City's overall water monitoring system.
November, 1999	Completed construction of the passive recharge well system at the Halstead Recharge Site. Began testing of the passive recharge well system.
November 23, 1999	Made project status report to City Council on the Equus Beds Groundwater Recharge Demonstration Project and the Integrated Local Water Supply Plan.
March 31, 1999	Submitted draft of the *Concept Design Study of the Equus Beds Aquifer Recharge, Storage and Recovery Project* to City. This report was the result of three years of engineering and hydrogeologic investigations including the operation of the demonstration project.

2. OBJECTIVES AND APPROACH

The Project is a phased, small-scale test or trial project used to determine the feasibility of a full-scale $150 million groundwater recharge, storage and recovery project. The full-scale ASR project is a key part of Wichita's Integrated Local Water Supply (ILWS) Plan which proposes to provide additional water supply to the City and surrounding communities through year 2050. During this period, average day water demands are projected to increase from 62 million gallons per day (MGD) in 1998 to 112 MGD in 2050.

The ILWS Plan was adopted by Wichita in 1993 and has been modified slightly over the years as additional hydrogeological data, test results and regulatory issues develop. This plan currently includes major components as shown in Figure I-1 and listed below:

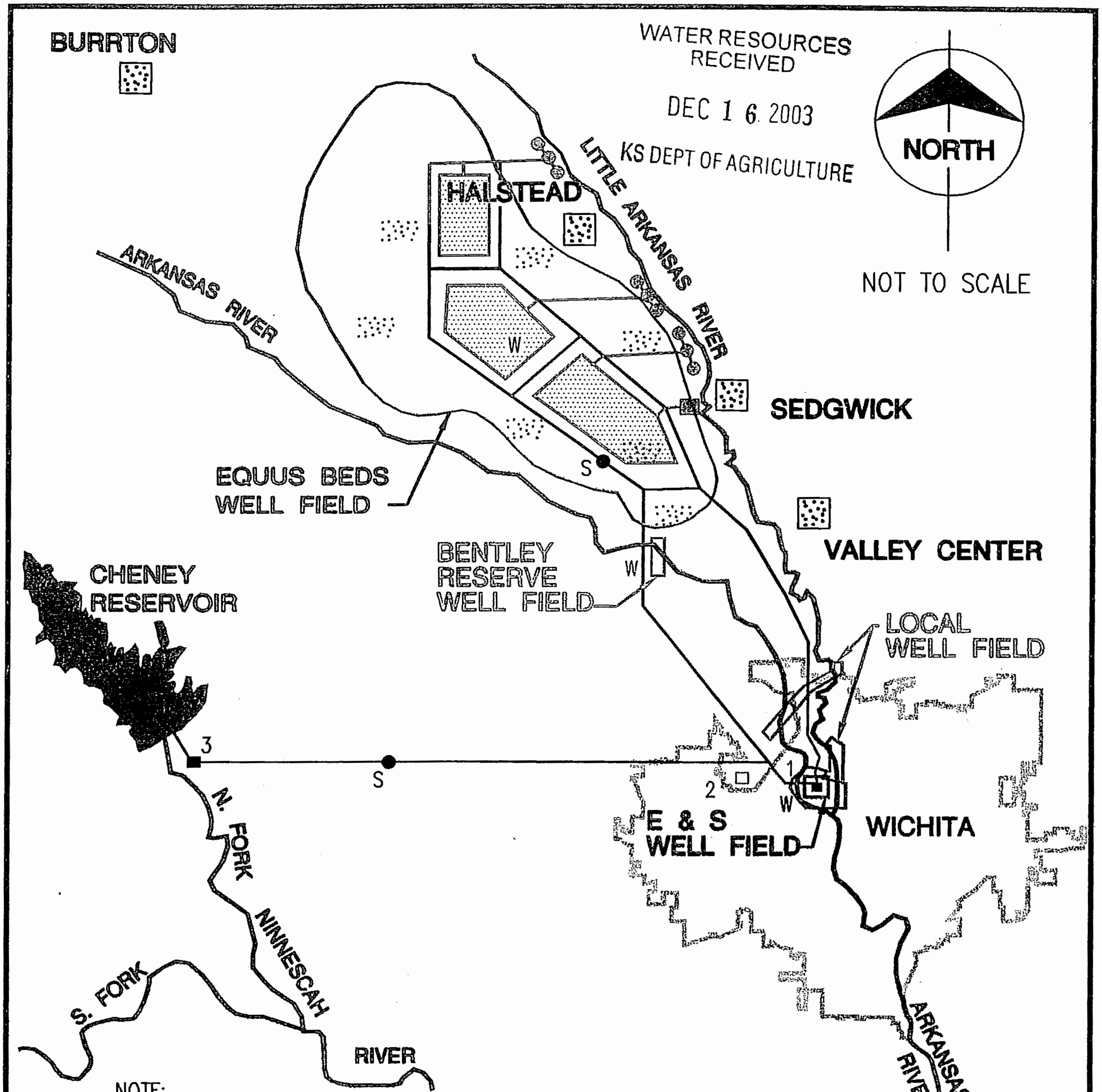
- Capture of "above-base" flow from the Little Arkansas River - captured water will be used for aquifer recharge or for direct supply to water treatment facilities. Above-base flow water is defined as water which is generated from rainfall runoff above the base river flow as established by the Kansas Division of Water Resources.

- Recharge of the Equus Beds Aquifer - captured water will be stored in the aquifer until needed during extended dry weather conditions.

- Recovery of Stored Water in the Aquifer - the Equus Beds Well Field will be used to deliver stored water to water treatment facilities during extended dry weather conditions. During normal weather conditions the well field will have low usage to conserve water in aquifer storage.

- Greater use of Cheney Reservoir - when available, greater amounts of surface water will be used to offset groundwater usage to conserve water in aquifer storage.

- Expansion of the Local Well Field - capture of "above-base" water from the Little Arkansas River and "leakage water" from the recharged Equus Beds Well Field with water delivered directly to water treatment facilities. Pumpage will be controlled to reduce



NOTE:

1. PLAN ALSO INCLUDES WATER CONSERVATION.
2. GENERALIZED LAYOUT OF PROPOSED FACILITIES DEPICTED.

LEGEND

- EXISTING RAW WATER PIPELINE
- RIVER AND LAKES
- S — SURGE TANK
- W — WELL FIELD
- 1 ■ CENTRAL WATER TREATMENT PLANT
- 2 □ PROPOSED WATER TREATMENT PLANT
- 3 ■ CHENEY RESERVOIR PUMP STATION
- PROPOSED PIPELINE
- PROPOSED SURFACE WATER INTAKE
- PROPOSED DIVERSION WELLS, RECHARGE WELLS/BASINS, RECOVERY WELLS

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Figure I–1

INTEGRATED LOCAL WATER SUPPLY PLAN SCHEMATIC potential for high-salt migration towards the well field from the Arkansas River.

- Redevelopment of the Bentley Reserve Well Field - high salt water from this old well field will be used in a water blending operation with other higher quality water sources to meet short-term peak water demands during extended dry weather conditions.

- Water conservation - conservation water rates and public education will continue to be used to influence water demands by all customer classes.

As part of the City's ILWS Plan, the full-scale ASR project will benefit all users of the Equus Beds as follows:

- By adding about 65 billion gallons (200,000 acre-feet) of water to aquifer storage for use to meet City demands during dry weather or drought conditions.

- By reducing power costs for pumping because of higher groundwater levels.

- By helping to protect the aquifer from water quality deterioration from intrusion of natural and man-made sources of salt water.

The Project is providing pertinent data to design the full-scale facilities and meet Wichita's goal of short-term and long-term water supply for the area. The Project has shown that recharge in the Equus Beds Well Field is feasible. The main objectives of the Equus Beds Groundwater Recharge Demonstration Project are as follows:

- Determine ultimate ASR project feasibility.

- Develop design criteria for ASR facilities.

- Develop operating criteria for ASR facilities.

- Refine construction and operating requirements and costs.

- Use findings to site and size ASR facilities.
- Obtain approvals and permits of full-scale ASR facilities from local, state and federal agencies.

In addition to providing information needed for design, construction and operation the ASR system for the Equus Beds Wellfield, the Project is also developing and testing concepts that could potentially be applied at other recharge facilities facing similar problems. The completion schedule for the Project is shown in Figure I-2.

B. SITE CONDITIONS

1. AREA DESCRIPTION

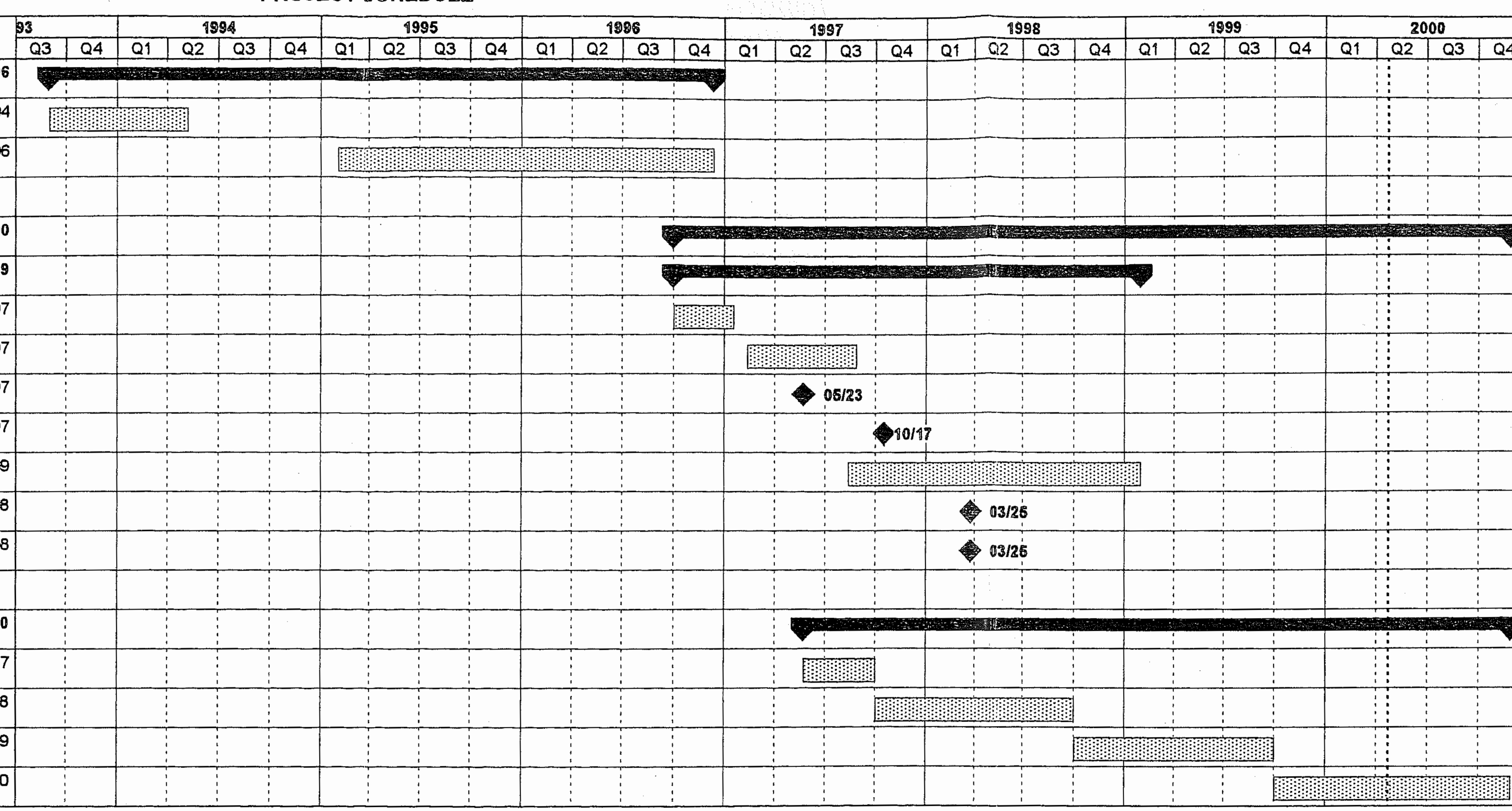
a. Location

The Project area is located in south-central Kansas within the Little Arkansas River Watershed. It includes the western portion of Harvey County, Kansas and the northwestern portion of Sedgwick County, Kansas. The major cities in the region include Wichita to the south and Newton to the north. The small communities of Halstead and Sedgwick lie within the central portion of the project area. Numerous county roads are located throughout the area. U.S. Highway 50 runs east-west across the northern portion of the Project area. Interstate 135 is located a few miles east of the Project area and runs north-south.

The Equus Beds Aquifer underlies portions of Sedgwick, Harvey, McPherson and Reno Counties and covers an area of about 900,000 acres. The aquifer is located within the boundaries of Groundwater Management District No.2 (GMD2). A general map of the area, which includes the existing Equus Beds Well Field and other relevant site features, is shown in Figure I-3.

Figure I-2
EQUUS BEDS GROUNDWATER RECHARGE DEMONSTRATION
PROJECT SCHEDULE

ID	Task Name	Duration	Start	Finish
1	PROJECT 1	858 days	08/31/93	12/12/96
2	Feasibility Study	179 days	08/31/93	05/06/94
3	Engineering Study	487 days	02/01/95	12/12/96
4				
5	PROJECT 2	1408 days	10/01/96	11/28/00
6	PHASE I - DESIGN & CONSTRUCTION	799 days	10/01/96	01/29/99
7	Design	79 days	10/01/96	01/17/97
8	Contract 1 Construction (facilities)	183 days	02/11/97	08/26/97
9	Halstead Start-up	1 day	05/23/97	05/23/97
10	Sedgwick Start-up	1 day	10/17/97	10/17/97
11	Contract 2 Construction (SCADA)	536 days	08/12/97	01/29/99
12	Halstead Start-up	1 day	03/25/98	03/25/98
13	Sedgwick Start-up	1 day	03/25/98	03/25/98
14				
15	PHASE II - OPERATIONS	1226 days	05/23/97	11/28/00
16	FY1997 Operations	131 days	05/23/97	09/30/97
17	FY1998 Operations	365 days	10/01/97	09/30/98
18	FY1999 Operations	365 days	10/01/98	09/30/99
19	FY 2000 Operations	365 days	10/01/99	11/28/00



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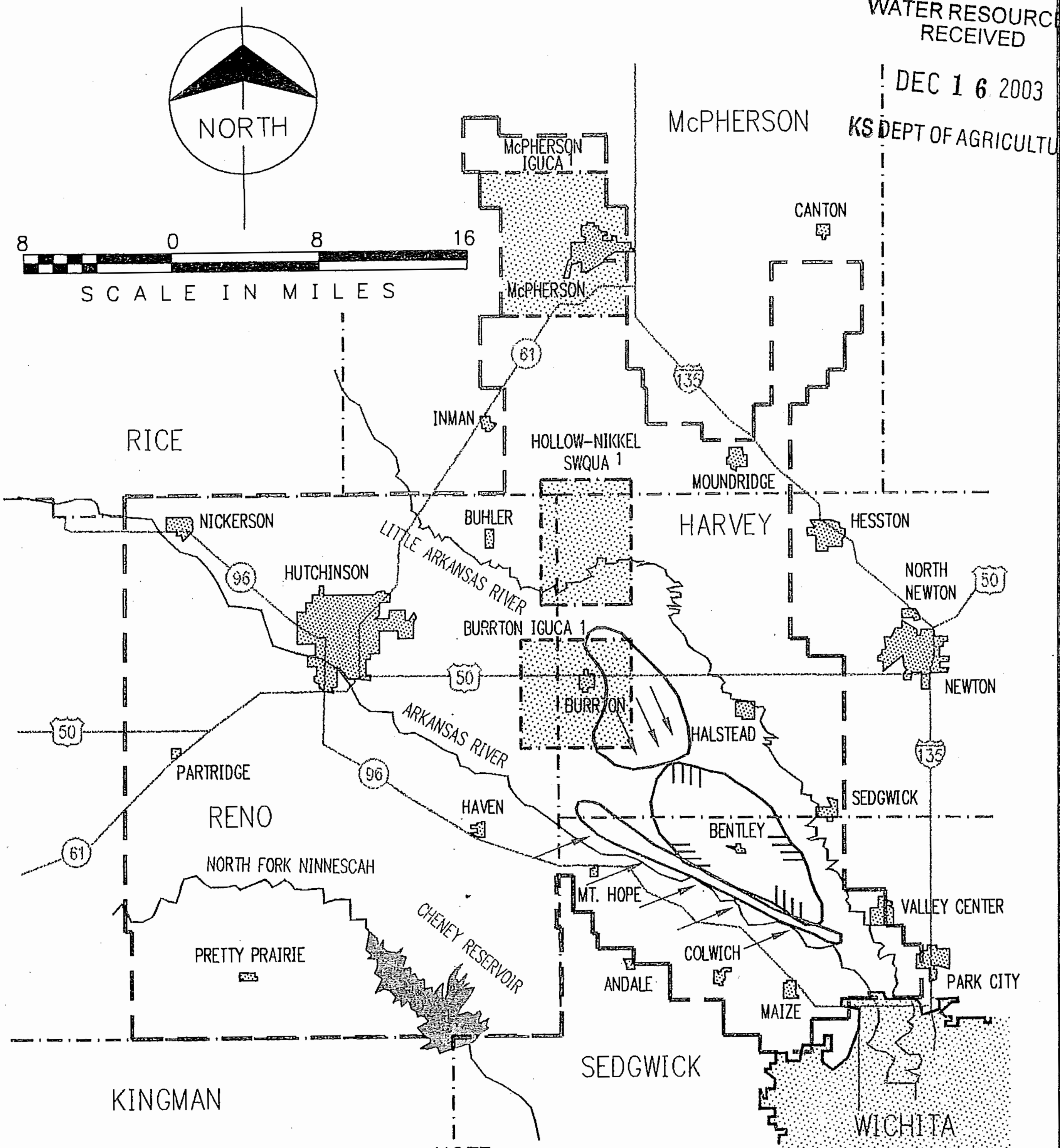
Project: schedule Date: 04/21/00	Task	Milestone	Rolled Up Task	Rolled Up Progress	Project Summary	Rolled Up Split	
	Progress	Summary	Rolled Up Milestone	External Tasks	Split		

schedule.MPP



LEGEND

- CHLORIDE PLUMES
- DISTRICT BOUNDARY
- EQUUS BEDS WELL FIELD
- SPECIAL MANAGEMENT AREA BOUNDARY
- COUNTY LINE

NOTE:

[1] DENOTES SPECIAL WATER QUALITY USE AREA. AREAS CONTAIN GROUND WATER WITH HIGH CHLORIDE LEVELS.

Burns & McDonnell

Figure I-3

EQUUIS BEDS AQUIFER REGIONAL MAP

J:\WICHITA\921954.014\NEWFIG\FIG-I-3.dwg 05-05-1999 15:44 MJC

b. Geologic and Geographic Description

The Project area is located near the boundary of the Great Bend Prairie physiographic region and the High Plains region of the Central Lowlands physiographic province. Based on aquifer characteristics, the Great Bend Prairie area and western areas of Kansas underlain by the Ogallala Formation have been grouped into one groundwater region and is considered to be part of the Great Bend region. The Great Bend Prairie physiographic province (also known as the Wellington and McPherson Lowlands) is characterized by large areas of low topographic relief. This featureless plain is disrupted by a belt of sand dunes trending northwest-southeast along the northeast side of the Arkansas River Valley, and several major rivers, including the Ninnescah and Arkansas Rivers and their tributaries, (Williams and Lohman, 1949 and Hathaway et al, 1981).

The Little Arkansas River watershed drains an area of approximately 1,342 square miles with land surface elevations ranging from a high of 1,738 feet above mean sea level (MSL) to a low of 1,295 feet MSL. The Equus Beds Aquifer area is part of this watershed and is therefore drained by the Little Arkansas River and its tributaries. Land surface elevations in the Equus Beds Aquifer area range from a high of 1,441 ft. MSL north of Alta Mills to a low of 1,344 feet (MSL) south of Valley Center. Tributaries to the Little Arkansas River are the Kisiwa, Blaze Fork, Turkey, Black Kettle, Emma, Sand, Jester, and Gooseberry Creeks. The Little Arkansas River joins the Arkansas River at Wichita. Although an area from Burrton north to the Little Arkansas River does not have an established drainage pattern, its soils are sandy and rapidly absorb the precipitation that falls. Most of the area south of Kisiwa Creek lacks a well defined drainage pattern. The topography is nearly level and several intermittent lakes are scattered throughout this area (Hoffman and Dowd, 1974).

The study area is underlain by 4,000 to 4,500 feet of limestone, sandstone, shale, clay, silt, sand and gravel, and small amounts of salt and gypsum. Ancient seas and rivers deposited and eroded the rock-forming materials. The bedrock underlying the unconsolidated deposits in the study area consists primarily of early Permian age (approximately 240 million years old) shales of the Wellington Formation and Ninnescah Shale. Unconsolidated deposits are highly variable with clays, silts, sands, and gravels in depths ranging from 0 to 250 feet. The Little Arkansas River serves to divide soils in the study area into two broad groups. Soils north and east of the river are predominately clayey and loamy with well-developed surface drainage features. South and west of the river, soils tend to be sandy and loamy with poorly defined surface drainage features. Detailed descriptions of the study area physiography, geology and soils were presented in the Equus Beds Groundwater Recharge Feasibility Study (Burns & McDonnell, 1994).

c. **Climate Conditions**

The climate of the area is classified as temperate continental (warm summer subtype). Average annual precipitation is approximately 30 inches. Most of the precipitation occurs during the summer months with high-intensity thunderstorms. Prevailing wind direction is from the south with the windiest period from March to April. Wind speed averages 12 m.p.h. The average annual evaporation rate for the region is 54 inches a year. The relatively high mean wind speed enhances evaporation during the summer.

d. **Predominant Flora and Fauna**

The project area is composed of croplands, warm season pasture, and riparian woodlands. Small amounts of cool season pasture, native grassland, road right-of-way, woodlots, fencerows, shelterbelts, and residential areas compose the remainder of the area. Cropland is the most abundant land use in the project area. Fields are generally large. Some fields contain drainage swales planted in cool season grass. However, most are near monocultures of seeded crops. Primary crops are wheat, soybeans, milo, and corn.

The Little Arkansas River and its perennial tributaries support a warm water fishery. Habitat within the streams includes undercut banks, fallen trees, log jams, brush piles, small riffles, small beaver dams and pools. Common fish species expected to occur include: green sunfish, orange spotted sunfish, white crappie, largemouth bass, black bullhead, channel catfish, flathead catfish, common carp, red shiner, sand shiner, gizzard shad, and mosquito fish. Seasonal low flows, limited amounts of habitat and high sediment loads due to runoff from agricultural lands combine to reduce fish species deversity and the overall quality of stream fisheries.

Croplands provide waste grain which is utilized by area wildlife as forage. Species expected to use croplands include whitetailed deer, bobwhite quail, ring-necked pheasant, mourning dove, western meadowlark, wild turkey, common crow, brown-headed cowbird, common grackle, a variety of other songbirds, eastern cottontail, mice and voles. Warm season pasture generally provides low overall habit for area wildlife due to low plant species diversity and sparse growth. Species which likely use these areas include those previously mentioned as well as fox, coyote, redtailed hawk, American kestrel, scissortailed flycatcher, bull snake, prairie kingsnake, yellow-bellied racer, great plains rat snake, six lined racerunner, and western box turtle. Riparian areas, particularly those which are wooded, provide cover for area wildlife, especially during the winter. Species expected to utilize riparian areas include those previously mentioned as well as raccoon, opossum, beaver, muskrat, mink, striped skunk, great blue heron, wood duck, great horned owl, common flicker, red-bellied woodpecker, blue jay, northern cardinal, American robin, northern water snake, plains garter snake, western ribbon snake, painted turtle, and bullfrog.

Threatened or endangered species potentially found within the project area include the Federally threatened piping plover and the Arkansas River shiner and the Federally endangered bald eagle, least tern, peregrine falcon, and the whooping crane.

2. LAND AND WATER

a. Local Land Uses

The project area is located in portions of Harvey and Sedgwick Counties in south-central Kansas. The Project area itself is primarily rural agricultural. Homes are generally widely separated. Small clusters of residences are present, but contain only a few homes or mobile homes. Most of the land in the Project area is either row-crops (75%) or pasture (25%). The principal crops include wheat, soybeans, milo, and corn, which are typically irrigated with flood irrigation or via a center pivot.

a. Ownership Issues

Land ownership throughout the Project area can be divided into private, county, and City.

Private lands make up the majority of land ownership. They include croplands, pastures, residences, and small commercial areas. Lands under ownership by either Harvey or Sedgwick Counties include road rights-of-way and the Harvey County Park. The City owns lands in the Project area and has easements and lease agreements with private land owners for wells and existing water pipelines. Numerous public utility easements also cross private land.

The primary problem for the Project was obtaining rights of entry, easements and land for the Project. However, all land issues were resolved. New pipelines were located within the existing utility easement along county roadways whenever possible. Easements for additional right-of-way were acquired from the adjacent landowners. For those soil borings, wells and facilities located on private lands, lease agreements or easements were negotitated with the land owner. Recharge facilities were constructed on property currently owned by the City.

b. **Cultural Resources**

Cultural resources are expected to potentially exist along the Little Arkansas River, since prehistoric and historic occupations are known to occur along the river. Consequently, the areas to be disturbed by access routes, recharge basins, pipelines, and wells were surveyed for cultural resources eligible to or in the National Register. Survey results showed that Project facilities do not affect any cultural resources.

c. **Current Water Use and Limitations**

The City has historically used two principal raw water sources: Cheney Reservoir, located 20 miles west of the City and the Equus Beds Aquifer, located 16 miles northwest of the City. The Local Well Field (or E&S Well Field), located in the City around the water treatment plant, is also used to help supply peak demands, specially during the summer months. In the past, the City has used about 60% groundwater from the Equus Beds Well Field and about 40% surface water from Cheney Reservoir at its water treatment plant for municipal water supply.

The Equus Beds Aquifer totals about 900,000 acres in size with an average annual withdrawal of 157,000 acre-feet, including approximately 55% for irrigators, 39% for municipalities (Wichita, Halstead, Newton, Hutchinson, McPherson, Valley Center and others) and 6% for industry. Since the 1950's, water levels in the aquifer have dropped 20 to 40 feet as a result of heavy pumpage. At the present time, water rights and pumpage exceed the aquifer's natural recharge estimated by the State to be six inches per year in the area of interest. Because of this overdevelopment, static water levels have been lowered and the Equus Beds Aquifer is currently being threatened by migration of natural saltwater from the Arkansas River to the southwest and by oil field brine from the Burrton area to the northwest, as shown in Figure I-3.

Water currently obtained from the Equus Beds is of adequate quality for municipal water supply; however, groundwater modeling by the U.S. Bureau of Reclamation indicates that, as a result of saltwater migration, the average chloride concentration in the well field, which is an indicator of salinity, will increase from about 60 mg/L to 95 mg/L in year 2010 and 145 mg/L in year 2050. At that time, maximum chloride levels could exceed 300 mg/L in some areas, which would exceed maximum recommended levels for agricultural and municipal uses.

d. <u>Source Water Characteristics</u>

Raw and finished water quality are important concerns associated Wichita's ILWS Plan. This plan must provide a raw water that can be treated by conventional processes to produce an economic, quality finished water that meets all regulations of the Safe Drinking Water Act and Amendments. Additionally, recharge water must not adversely impact the water quality in the Equus Beds Aquifer.

Two types of source water were used for the Project, surface water from the Little Arkansas River and bank storage water obtained from a well drilled adjacent to the Little Arkansas River.

Preliminary water quality data for the Little Arkansas River indicated that the above-base flow water to be used for recharge water varies with flow and is also generally of good quality. A summary of surface water quality data, as reported by Burns & McDonnell, 1994, as compared to existing Maximum Contaminant Levels (MCLs) and Secondary Maximum Contaminant Levels (SMCLs), follows in Table I-2.

The main water quality concerns associated with the recharge of the Equus Beds Aquifer include:

- Quality of the source water for recharge. This water may carry phosphorous, nitrates and pesticides into the aquifer.

- Atrazine, an agricultural herbicide, has consistently been found in the Little Arkansas River at background levels of approximately 0.1 µg/L to a high of 50 µg/L. The potential for the intermittent clay layers in the riverbed, riverbank and aquifer to adsorb the herbicide needs more investigation.

- Chlorides from the river and aquifer vary with location and streamflow. Concentrations range from approximately 10 mg/L to a high of 300 mg/L.

- Quality of bank storage recovery water. The sands, gravels, silts and clay along the river drastically reduce the turbidity and suspended solids levels of bank storage water and improve other aspects of the water quality, such as reduction of atrazine and other triazine herbicides when present in river water. However, the plugging potential of

Table I-2

Summary of Surface Water Quality Data

Parameter	Recharge Water (Mean)	MCL	SMCL
Chloride (mg/l)	78	NA	250
Sulfate (mg/l)	37	NA	250
Nitrate as N (mg/l)	1.3	10	NA
Hardness (mg/l as $CaCO_3$)	161	NA	NA
Specific Conductance (micro-mhos)	509	NA	NA

NA = not applicable

the river bank deposits by long-term, full-scale operation of an induced infiltration system needs more investigation.

3. HYDROGEOLOGIC CONDITIONS

a. Major Aquifer Characteristics

The Equus Beds Aquifer is the eastern-most part of the aquifer system known as the High Plains Aquifer in Kansas, which includes the Ogallala. The Equus Beds are named for the Equine fossils (Pleistocene) found in the unconsolidated sediments in this area. Three general hydrogeologic units are generally recognized in the area; an upper sand and gravel unit; a middle fine grained (fine sand, silt, and clay) unit; and a lower coarse grained unit. These units are not consistent and vary throughout the area. Typical cross sections are shown in Figures I-4 (Burns & McDonnell, 1996) and I-5 (Burns &McDonnell, 1994). Figure I-4 shows the cross-section along the Little Arkansas River from Alta Mills to Wichita, Kansas. Figure I-5 shows an east-west cross section perpendicular to the Little Arkansas River about one mile south of Halstead, Kansas. Locations of soil borings, monitoring wells and reference points shown on the above cross-sections are indicated in Figure 1-6.

Variations in bedrock elevations cause large variations in the saturated thickness of the Equus Beds Aquifer in the Wichita well field area. The distribution of the saturated thickness for the area is shown in Figure I-7. Saturated thickness ranges from over 200 feet to less that 30 feet.

Predevelopment depth to water, before 1940, in the Equus Beds Aquifer was relatively shallow, ranging from 10 to 20 feet below land surface. After many years of municipal and irrigation pumping, current depth to water ranges from 10 to 50 feet. The increased gradient toward the areas of heavier pumping from the Arkansas River and Burrton area have raised concerns about migration of saline water from these areas into the Equus Beds Well Field.

WATER RESOURCES
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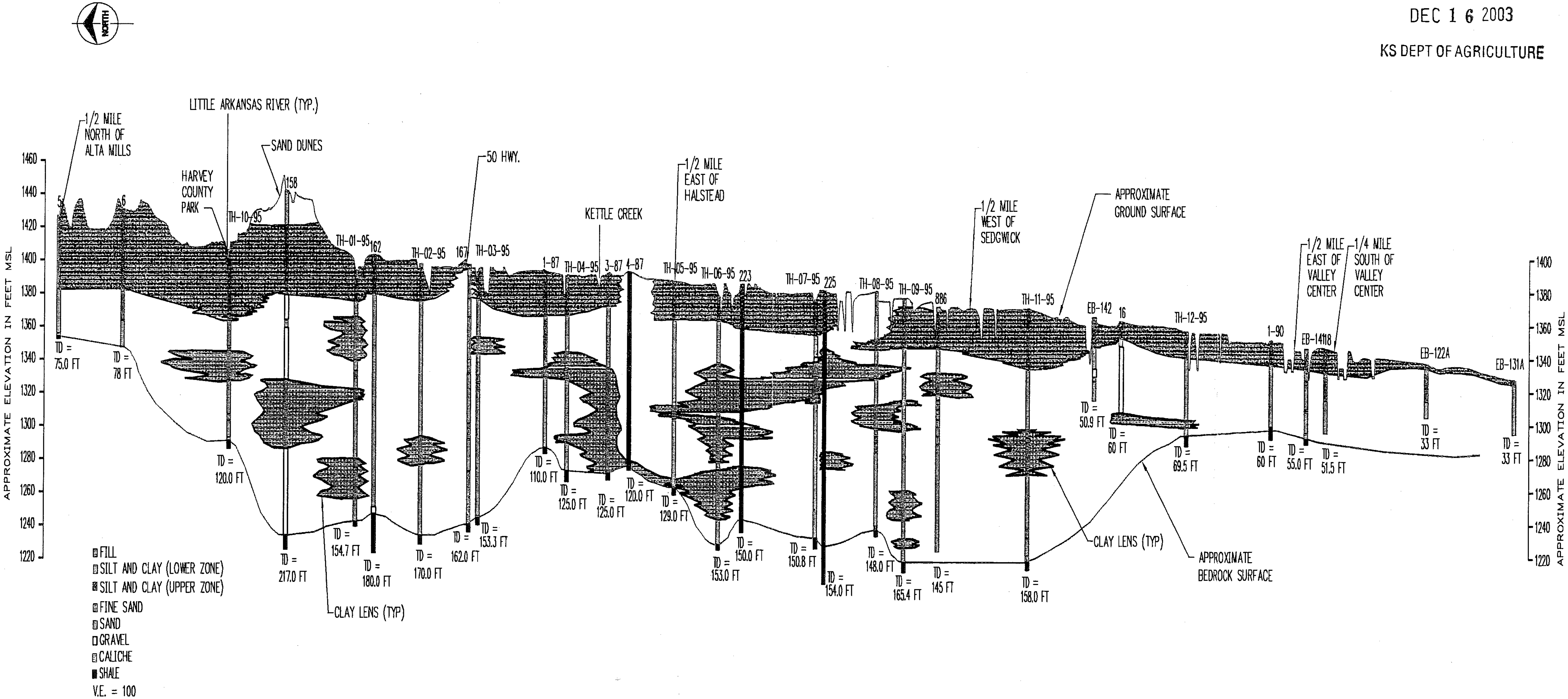

NOTE:
THE NUMEROUS CROSSINGS OF THE LITTLE ARKANSAS RIVER (AS DEPICTED BY THE INCISED FEATURES ON THE PROFILE) ARE A RESULT OF THE MEANDERING NATURE OF THE RIVER AND THE CONTINUOUS CHANGE IN DIRECTION ALONG THE LINE OF PROFILE (SEE BASE MAP).

Burns & McDonnell

Figure I-4

LITTLE ARKANSAS RIVER GEOLOGIC PROFILE ALTA MILLS TO WICHITA

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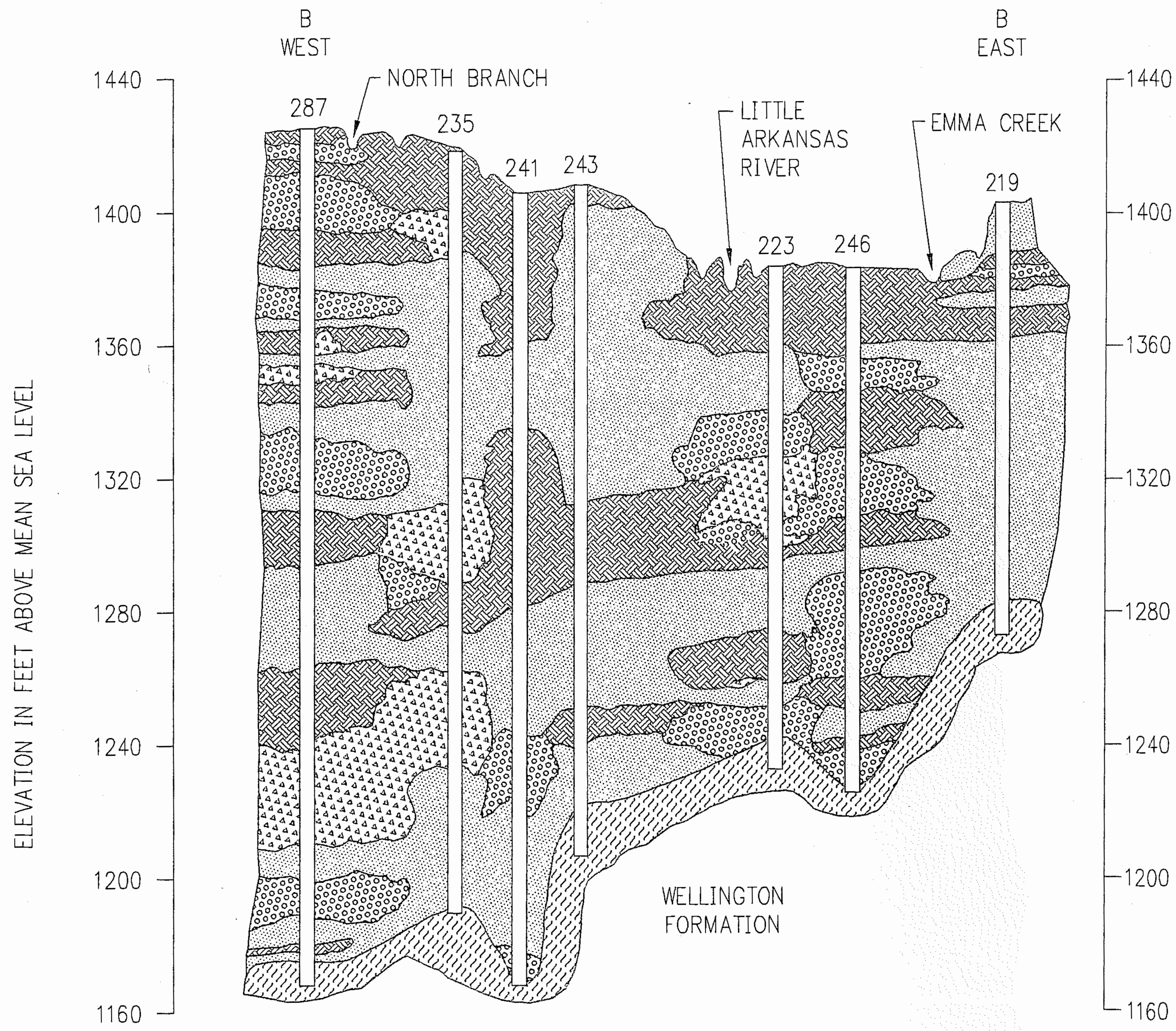


LEGEND

- CLAY AND SILT
- SILT AND SAND
- SAND
- SAND AND GRAVEL
- SHALE

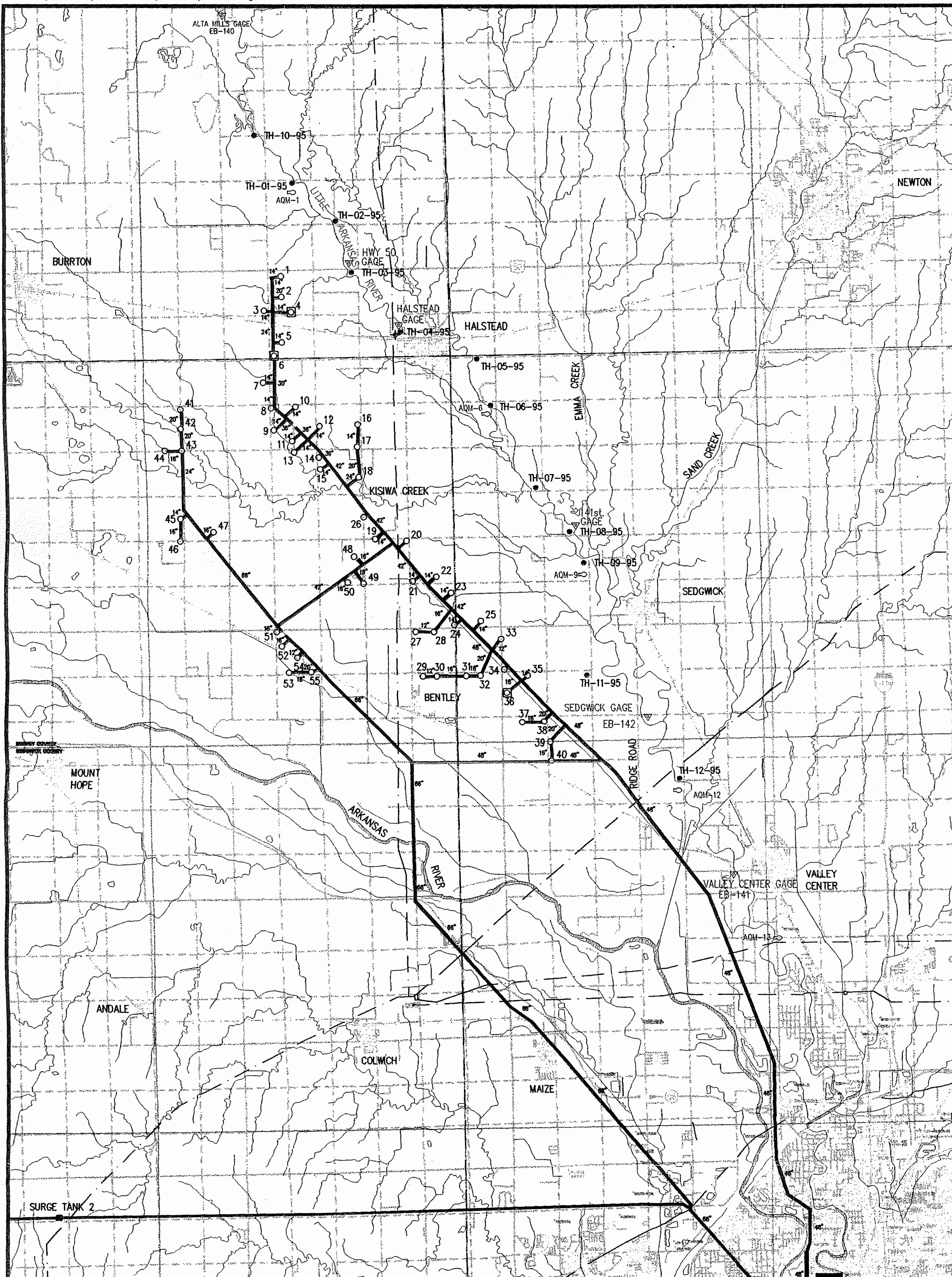
HOR. 1 0 1 2 SCALE IN MILES

VERT. 40 0 40 80 SCALE IN FEET

Burns & McDonnell

Figure I – 5

GEOLOGIC PROFILE
1.5 MILES SOUTH OF HALSTEAD
EAST AND WEST OF
LITTLE ARKANSAS RIVER



LEGEND

- PIEZOMETER OR BORING LOCATION
- ▽ USGS DCP
- ○ CITY OF WICHITA SUPPLY WELL
- EXISTING PIPELINE
- RAILROAD
- XXX MONITORING WELL STRING
- SURFACE WATER INTAKE
- TEST WELL
- RECHARGE SITE AT CITY WELL

12000 0 12000 22000

SCALE IN FEET

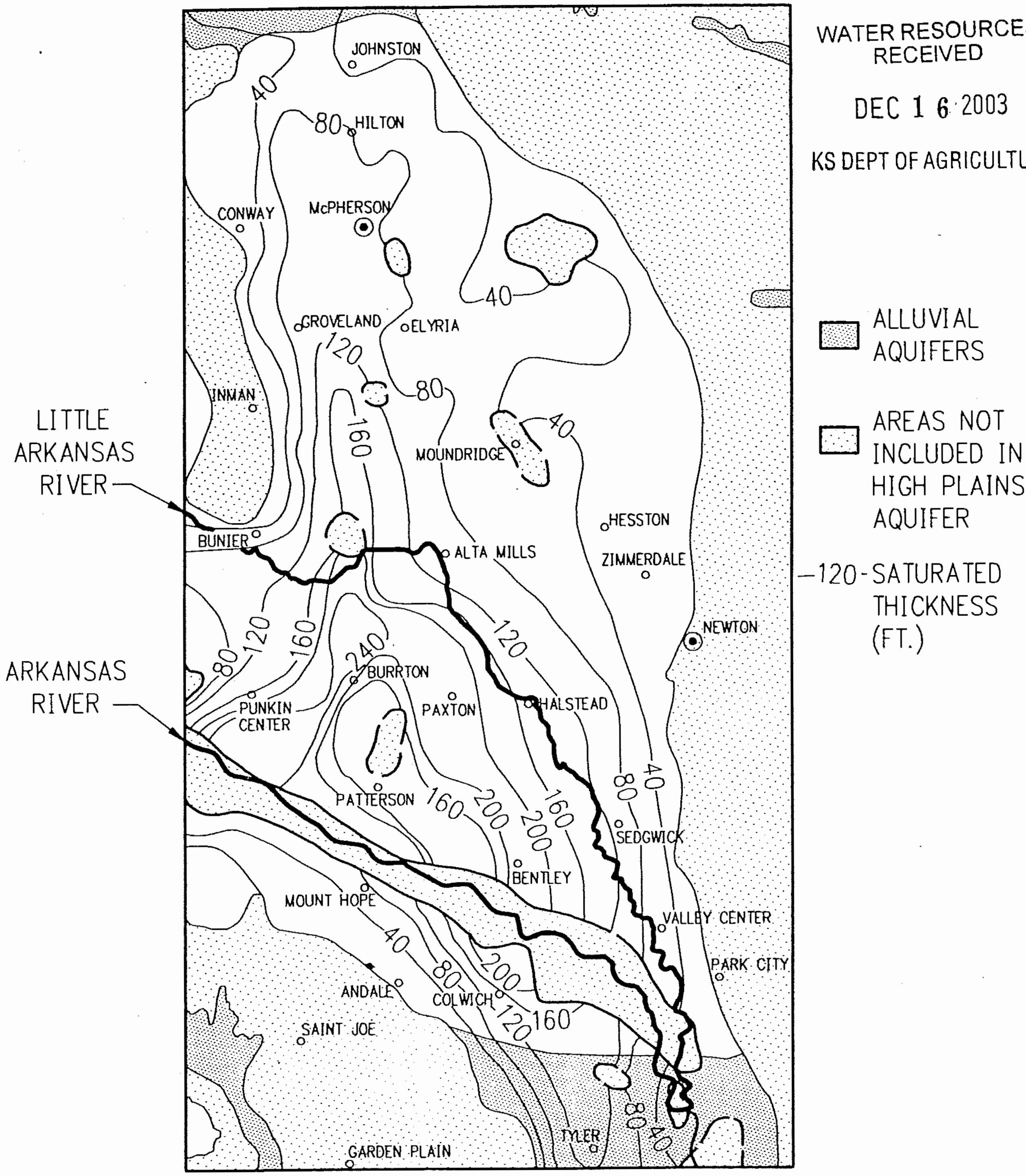
NORTH

NOTE:
DISTANCES SHOWN BETWEEN MONITORING WELLS IN WELL STRING ARE NOT TO SCALE.

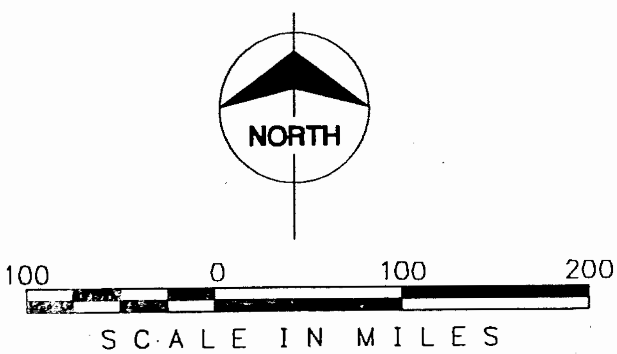
Burns & McDonnell

Figure I-6

DEMONSTRATION PROJECT AREA MAP



NOTE:
1. ADAPTED FROM HANSEN, 1987



Burns & McDonnell

Figure I-7

SATURATED THICKNESS MAP

b. Permeability and Percolation Characteristics

A number of aquifer pumping tests have been collected by the USGS from wells constructed in the Equus Beds Well Field and evaluated to determine hydrogeological parameters throughout the aquifer. Aquifer parameters summarized from the USGS Open-File Report 85-200 are as follows:

	Average	Range
Transmissivity (ft^2/day)	13,100	34,000-7,300
Storage Coefficient (dimensionless)	0.03	0.16-.0008

The upper materials generally act as an unconfined aquifer and materials below the intermediate fine grained materials, where present, act in a confined or semi-confined manner. In areas that fine grained materials influence the aquifer to react as a confined system, such as the northern end of the Equus Beds (or Wichita) Well Field area, large changes in water levels are readily noted with changing conditions (either pumping or recharge).

c. Subsurface Flow Characteristics

The Equus Beds Aquifer in our study area is underlain by shales of the Wellington Formation and bound by the Arkansas River to the west and the Little Arkansas River to the east. The original water table had a southeast gradient at about 6 feet per mile. Today pumping modifies the groundwater gradient; however, there is still a southeasternward gradient allowing flow toward the Little Arkansas River.

The high bedrock north and east of the Little Arkansas River generally prevent underflow out of the Equus Beds in that direction. Some underflow loss occurs to the southeast into the alluvium of the Arkansas and Little Arkansas River near the confluence of the two rivers. Where the groundwater levels are higher than stream levels, water is lost from the aquifer to the stream as base flow. Base flow in the Little Arkansas River is provided by discharge from the Equus Beds Aquifer. However, as more water is removed by pumping, less water is available for seepage into the river as baseflow. Computer modeling suggests that pre-development base flow to the Little Arkansas River was about 60 cubic feet per second (cfs). The model's simulation of current conditions indicates the base flow to be about 27 cfs, a 33 cfs reduction over 50 years.

The Equus Beds Well Field is recharged by underflow from aquifer materials from the west and stream losses in areas where groundwater is lower than the surface water levels. The Arkansas River is currently believed to be a losing stream between Hutchinson and Wichita. Recent groundwater modeling estimates an average of approximately 50 cfs of high chloride water is moving from the Arkansas River into the Equus Beds Aquifer in the reach from Hutchinson to Wichita.

Groundwater and river flow interact and move depending on water levels of the groundwater and river. The interaction is influenced to some extent by the conductivity of the riverbed materials. Sediments in the Arkansas and Little Arkansas Rivers are relatively coarse, allowing rapid infiltration of water into the riverbank or rapid exfiltration of water to the stream.

d. <u>Groundwater Characteristics; General Quality, Uses, Limitations</u>

Water from the Equus Beds Well Field is generally recognized as being of good quality for the beneficial uses of municipal water supply and irrigation. A summary of groundwater quality data follows in Table I-3.

Table I-3

Summary of Well Field Water Quality Data

Parameter	Equus Beds Well Field (Average)	MCL	SMCL
Chloride (mg/l)	55	NA	250
Sulfate (mg/l)	72	NA	250
Nitrate as N (mg/l)	1.5	10	NA
Hardness (mg/l as $CaCO_3$)	201	NA	NA
Specific Conductance (micro-mhos)	690	NA	NA

NA = not applicable

C. DEVELOPMENT AND CONSTRUCTION

1. REGULATORY, ENVIRONMENTAL, AND PUBLIC HEALTH CONSIDERATIONS

a. Applicable Regulatory Statutes

Section 404 permits were obtained for the surface water diversion at the Sedgwick facility and for the pipeline alignments through which waters would be transported to both the Halstead and Sedgwick recharge facilities.

b. NEPA Compliance Activities

Numerous activities were conducted in conjunction with preparation of environmental studies for the Project. Activities included the development of an environmental assessment (EA), field surveys for two testing, monitoring, and construction activities, public information meetings, and fisheries and instream flow surveys on the Little Arkansas River. A brief summary and description of the field visits, meetings, and EA activities, associated with completion and agency approval of the EA for the Project, and activities required for agency approval of construction activities is provided below.

(1) Environmental Assessment

The EA was prepared to fulfill the requirements of the National Environmental Policy Act (NEPA) of 1969. The EA was needed as a result of the participation of Reclamation in the Project, both from the financial and technical stand points. Such participation constituted a Federal action, as defined by NEPA and Reclamation policy, and mandated that environmental documentation assessing the federal action be prepared.

A preliminary draft EA was prepared in late 1994 and submitted to Reclamation's Regional office in Billings, Montana. Submittal of the EA was necessary to insure continued Reclamation cooperation and financial support of the Project with the City and GMD2. Regional comments provided guidance on the scope of the EA and the extent of coverage the Reclamation would require for EA approval. Comments were received from Reclamation in January 1995.

The EA analyzed the potential impacts of the Project on the natural resources of the area, specifically wetlands, fish and wildlife habitat, and threatened and endangered species. Project impacts were associated with construction of a test well, several monitoring wells, pipelines, and infiltration pits and basins, with groundwater recharge at existing well sites and reduced surface water flows in the Little Arkansas River. After identifying the existing natural resources and evaluating the Project's potential impacts, no significant impacts were determined to result from implementation of the Project.

Several coordination meetings with the City, Reclamation, USGS, Kansas Department of Health and Environment (KDHE), GMD2, the Environmental Protection Agency (EPA) and other cooperating agencies followed through the spring of 1995. These meetings served to refine the scope and contents of the EA as well as define areas needing more detailed data collection. A revised preliminary draft EA was submitted to the cooperating and other agencies for review on May 25, 1995. Several comments were subsequently received. A draft EA was prepared and submitted for public review and comment on July 7, 1995.

On July 16 and 17, 1995, Reclamation and Burns & McDonnell personnel met and revised the draft EA according to public and agency comments received. Responses to comments received were prepared and incorporated into the final EA. The final EA was prepared and submitted to Reclamation. A "Finding of No Significant Impact" (FONSI) was determined to be appropriate for the Project. The EA and the FONSI were approved by Reclamation on September 11, 1995.

(2) Environmental Field Activities

Environmental field reviews were conducted during the preparation of the draft EA. These reviews involved soil test borings, installation of infiltration test pits, drilling and construction of monitoring wells and the test well as shown in Figure I-6. Environmental and cultural resource assessments where conducted to minimize environmental impacts and insure adherence to environmental commitments included in the 1995 FONSI.

On January 30, 1995, Burns & McDonnell personnel participated with representatives from the City, Reclamation, USGS, GMD2, and Mid-Kansas Engineering Consultants (MKEC) in a field inspection of twelve (12) sites proposed for soil borings. Burns & McDonnell biologists evaluated each site for the presence of wetland, wildlife, and threatened and endangered species habitats and impacts. Soil borings were sited at locations that would have no impact on any environmental resources. A Reclamation archaeologist performed cultural resource surveys for the 12 proposed soil boring test sites. No cultural resources were reported in the immediate vicinity of 11 of the 12 proposed borings. Additional archeological investigation at the remaining site revealed only a light scatter of historic material, none of which appeared to date beyond the 1940s. Reclamation therefore determined the proposed work would have no impact on cultural resources.

On April 4, 1995, Burns & McDonnell personnel visited the sites proposed for monitoring wells and well strings. These sites differed from the original soil boring sites and monitoring well string locations and were evaluated for potential impacts to wetlands, wildlife, and threatened and endangered species. The evaluation for cultural resources was conducted by Reclamation. No impacts to any environmental resources would result form these construction activities.

Burns & McDonnell biologist and archaeologist conducted two additional investigations. A survey of four soil boring sites located near Wichita Well Nos. 36, 37, 38 and 39 in Sedgwick County was conducted in June 1995. The results of the survey were negative. The second survey involved 8 small sites intended for test infiltration basins. No significant aquatic, terrestrial or cultural resources were found. A telephone conversation with Mr. Barry Williams of the State Historic Preservation Office (SHPO) indicated that no cultural resource report to the state would be required. However, letters detailing all archaeological investigations have been forwarded to the SHPO in compliance with a letter dated November 19, 1993.

(3) Fisheries Surveys

Due to the lack of recent data on the fisheries resources of the Little Arkansas River, Kansas Department of Wildlife and Parks (KDWP) suggested fishery stream habitat studies be conducted to characterize the existing condition within the Little Arkansas River. This data would be beneficial in describing the existing conditions of the river during the anticipated preparation of the environmental impact statement (EIS) for the full-scale project. This work would help to determine potential project impacts and to establish mitigative measures for any adverse impacts caused by the full-scale project.

Burns & McDonnell coordinated with KDWP personnel to develop a fishery sampling plan in September 1995. The purpose of the plan was to establish baseline data on the aquatic resources, including fisheries, macroinvertebrates, and mussels, present within the Little Arkansas River. A preliminary plan was developed based on methods used by KDWP. Stream habitat studies using Instream Flow Incremental Methodology (IFIM) studies were initiated in the Spring of 1996. KDWP personnel were again involved in the selection of IFIM sites and location of stream habitat transects.

Following approval of the aquatic sampling plan by KDWP, Burns & McDonnell coordinated with GMD2 and the City to obtain landowner permission for potential stream locations determined appropriate for aquatic sampling. Potential sample sites were evaluated in the field following acquisition of landowner access. Six sample sites on the Little Arkansas River and one site on the Arkansas River were determined acceptable for sampling activities as shown on Figure I-6.

The first fishery sampling effort was conducted from September 12 through 18, 1995 and represented the summer season. KDWP personnel were present during the first day of sampling to insure sampling procedures and methods were acceptable to

KDWP. Sites were sampled for fish populations by seining[1] and electrofishing2 (see Photograph I-1), for macroinvertebrates using a D-frame kick net (see Photograph I-2), and for mussels by visual inspection of riffles and bank areas. Fishery habitat at each site was also measured.

Following the September sampling, KDWP was consulted regarding modifications to the sampling procedure. With their approval, the number of sampling sites was reduced from a total of seven sites to five sites. The Arkansas River site and one site along the Little Arkansas River were dropped. The Little Arkansas River site was dropped since the other five sites adequately represented the aquatic habitats present. The Arkansas River site would be sampled one time per year assuming flow conditions permit. Additionally, minor modifications to the seining methodology were discussed and approved. Fishery surveys were conducted seasonally through November 1997. Following each survey, macroinvertebrates and mussels were identified. Fisheries data were incorporated into a database for both qualitative and quantitative analysis.

An aquatic monitoring report summarizing the surveys for the Little Arkansas River was finalized September 8, 1998. The results of the monitoring have shown that both the aquatic macroinvertebrate and the fish communities within the Little Arkansas River are typical of other sandy bottom streams in Kansas.

A draft report of the Instream Flow Incremental Modeling (IFIM) investigation, which was conducted, on the Little Arkansas River from 1996 to 1998 is currently under review. Preliminary results of the modeling showed that the required discharges for maximum weighted useable habitat and the peak modeled flow both

[1] Seining is conducted in riffle, run and shallow pool habitats using a 30-foot bag seine. The seine is shortened as necessary, depending upon the width of the stream.

[2] Electrofishing was conducted as a quantitative means of sampling in-stream habitat that could not be sampled with a seine, such as deep pool habitat, woody debris, etc. A Smith-Root Model 15A backpack electrofisher was used in electrofishing efforts. Electrofishing was conducted in all habitat types, but focused on stream bank cover and in-stream cover provided by woody cover and miscellaneous debris.

Photograph I-1: Electrofishing along the Little Arkansas River during the September 1995 aquatic survey

Photograph I-2: Sampling macroinvertebrates from the Little Arkansas River in September, 1995 fell far below historic peak flows. Therefore, the removal of an estimated 5% of the discharge during peak flow periods would not greatly impact fish species found in the Little Arkansas River.

c. **Other Permits/Regulatory Requirements**

A number of permits were required for Project development and construction by local and state regulations. The main permits obtained prior to implementing the demonstration facilities are the following:

- Permit for levy modification at the Halstead Intake Site from the Kansas Department of Agriculture, Division of Water Resources (DWR).
- Two permits for construction in the floodplain from DWR. Both the Halstead Recharge Site and the Sedgwick Intake Site required this type of permit as the facilities at both places are subject to flooding.
- Permit to construct an obstruction in the Little Arkansas River at the Sedgwick Intake Site from DWR. This permit was necessary since an intake screen was installed in the river bed at this site.
- Construction permits from the County (Sedgwick County).
- Term permits to "Appropriate Water for Beneficial Use" from DWR. Copies of those permits are attached in the Appendix.
- Class 5 Letter of Authorization from KDHE for operation of the recharge well at the Halstead Recharge Site.

2. INITIAL FEASIBILITY INVESTIGATIONS

This section of the report describes investigations performed to confirm Project feasibility and to determine locations and design criteria for Project facilities. The study area for these investigations is bounded by the Little Arkansas River on the east, Valley Center on the south, the Arkansas River on the west and Alta Mills on the north, as shown in Figure I-6. Investigations performed include facility siting, environmental and cultural resource evaluations (discussed above in Section C.1.), stream flow monitoring, water level monitoring of the Little Arkansas River and adjacent groundwater levels, geologic testing, aquifer infiltration tests, aquifer pump tests, water quality sampling and analysis and evaluation of

Arkansas River impacts.

a. **Planning to Provide Source Water Supply**

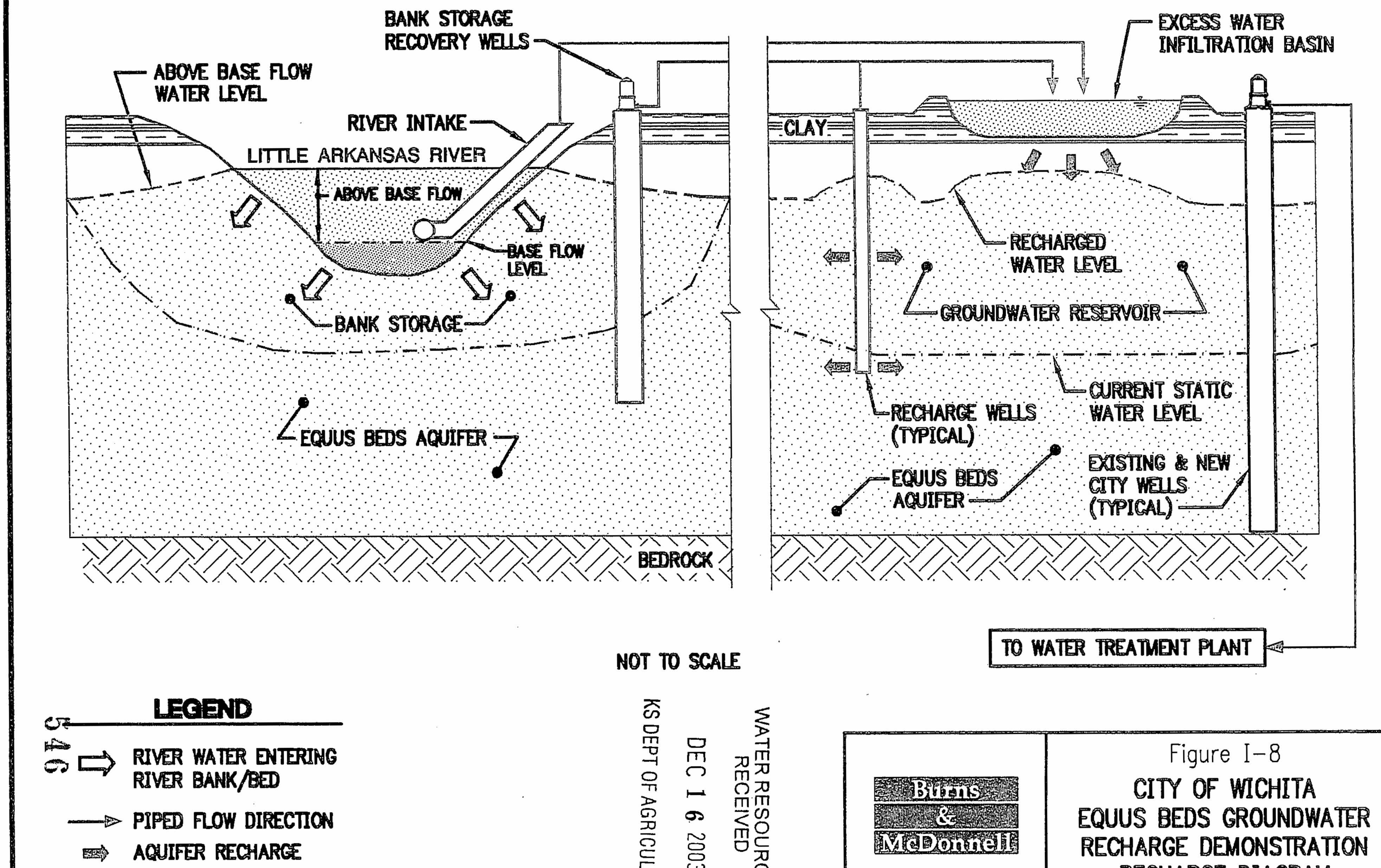
The Project is based on the concept of diverting above-base flow from the Little Arkansas River between Alta Mills and Valley Center to the Equus Beds Well Field for recharge, as shown in Figure I-8. Although the details of this concept have been refined over the years from those originally developed in the 1993 Water Supply Study (Burns & McDonnell, 1993), feasibility investigations were based on the following plan:

- Conduct an engineering study to confirm the feasibility of the Project and to refine project concepts. This stage included initial hydrogeological data collection, construction of a limited number of monitoring wells, collection of water quality data, preliminary groundwater modeling, plan development, public involvement and state review. Findings of this study were described on the the report *Equus Beds Groundwater Recharge Demonstration Project Feasibility Study (Phase 1, Part I - Preliminary Data Review and Concept Development* (Burns & McDonnell, 1994).

- Conduct a field testing program to monitor groundwater, surface water, and water quality and to further demonstrate feasibility of the Project. These investigations included installation of additional soil borings and monitoring wells as well as construction of infiltration test pits and one 1,000-gpm pumping well (or test well) near the Little Arkansas River for infiltration and aquifer testing, respectively. Findings of these investigations were reported on the document *Equus Beds Groundwater Recharge Demonstration Project (Phase I, Part II - Engineering Study Involving Water Quality Testing, Facility Siting, Test Well Construction and Aquifer Test)* (Burns & McDonnell, 1996).

- If the recharge demonstration facilities appear to be feasible, construct a riverbank storage transfer system that would convey water from the test well to new recharge facilities. Additionally, a surface water intake would be built and water would be conveyed to the recharge facilities. Recharge facilities would include a combination of recharge basins, recharge well, and recharge trench.

J:\WICHITA\921954.014\NEWFIG\FIG-II-8.dwg 07-07-1999 08:25 MJC



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Burns & McDonnell

Figure I-8

CITY OF WICHITA
EQUUS BEDS GROUNDWATER
RECHARGE DEMONSTRATION
RECHARGE DIAGRAM

b. **Facility Site Selection**

Project facility sites were selected based on existing geologic data available from various existing information sources and from the additional geologic, stream flow and water quality data collected during more detailed investigations. Other site selection factors included availability of land and distance from the river to potential recharge sites. Data used on these investigations are shown on Figure I-6 and include the following:

- Existing soil borings from various information sources by others.
- Twelve soil borings for Sites TH-01 through TH-12 (five holes completed as monitoring wells).
- Twenty-one additional shallow soil borings at city wells.
- Existing USGS stream flow gages at Alta Mills, Sedgwick and Valley Center.
- Additional USGS stream flow or stage gages at Highway 50, Site TH-04 (near Halstead) and Site TH-08.
- Three existing monitoring wells in the river bank at Alta Mills, Sedgwick and Valley Center.
- Three monitoring well strings of five wells each at Site TH-04 (near Halstead), Site TH-08 and the Sedgwick gage.
- Two surface water collection locations at Highway 50 and Sedgwick gage.
- A 1,000-gpm pumping well (or test well) adjacent to the Little Arkansas River at Site TH-04 (near Halstead).
- Seven shallow and nine deep piezometers for the aquifer test at Site TH-04 (near Halstead).

A geologic cross-section of the aquifer was developed based on geologic boring data along the Little Arkansas River, as shown in Figure I-4. This cross-section shows the aquifer along the river to be non-homogeneous with intermittent, lenticular clay layers, generally occurring between upper and lower sandy zones. The cross-section was updated throughout the Project with new soil boring data to help site the well strings, test well and proposed Project facilities.

Facilities at Site TH-04, near Halstead at the north end of the Project area, include a monitoring well string, a test well and 16 piezometers. This site was selected because of an excellent river-aquifer connection at this location, availability of land, and the short distance of about 3 miles to several city wells for recharge. Review of specific conductance and triazine herbicide (atrazine) water quality data for this site shows an excellent connection exists between the upper portion of the river bank aquifer and the river. During a flood event, on April 24 and 25, 1995, specific conductance for the river and aquifer were very close, respectively, 1750 µs/cm and 1350 µs/cm. Atrazine was detected in the river and the adjacent shallow monitoring well at respective concentrations of about 3 µg/L and 1 µg/L.

Land at Site TH-04 is owned by the City of Halstead and is in the floodplain, on the river side of the recently-constructed levee. Several nearby monitoring wells are located on land recently purchased by Harvey County. The City of Wichita reached lease agreements with Harvey County and the City of Halstead for use of land for the Project.

Another monitoring well string is located at Site TH-08 at the approximate mid-point of the Project study area. The site is between Site TH-04 and the Sedgwick gage and has been purchased by the City.

A monitoring well string is also located at the south end of the Project study area near the Sedgwick gage. A surface water intake was planned for installation near this site because of cooperative landowners. This intake location was selected based on the following:

- Higher stream flow than at Sites TH-04 and TH-08 and more frequent above-base flow events, allowing more demonstration testing without impacting other water rights.

- Triazine herbicide (atrazine) concentrations typically range from non-detect (or >0.1 µg/L) to approximately 31 µg/L with a mean of 3.7 µg/L and a median of 1.91 µg/L at Sedgwick compared to non-detect (or >0.1µg/L) to approximately 49 µg/L with a mean of 2.4 µg/L and a median of 1.1 µg/L at Site TH-04. This allows the Project to address the potential for aquifer contamination by triazine herbicides. Concentrations are based on sampling conducted during periods of high flow (above-base flow) and scheduled monthly sampling.

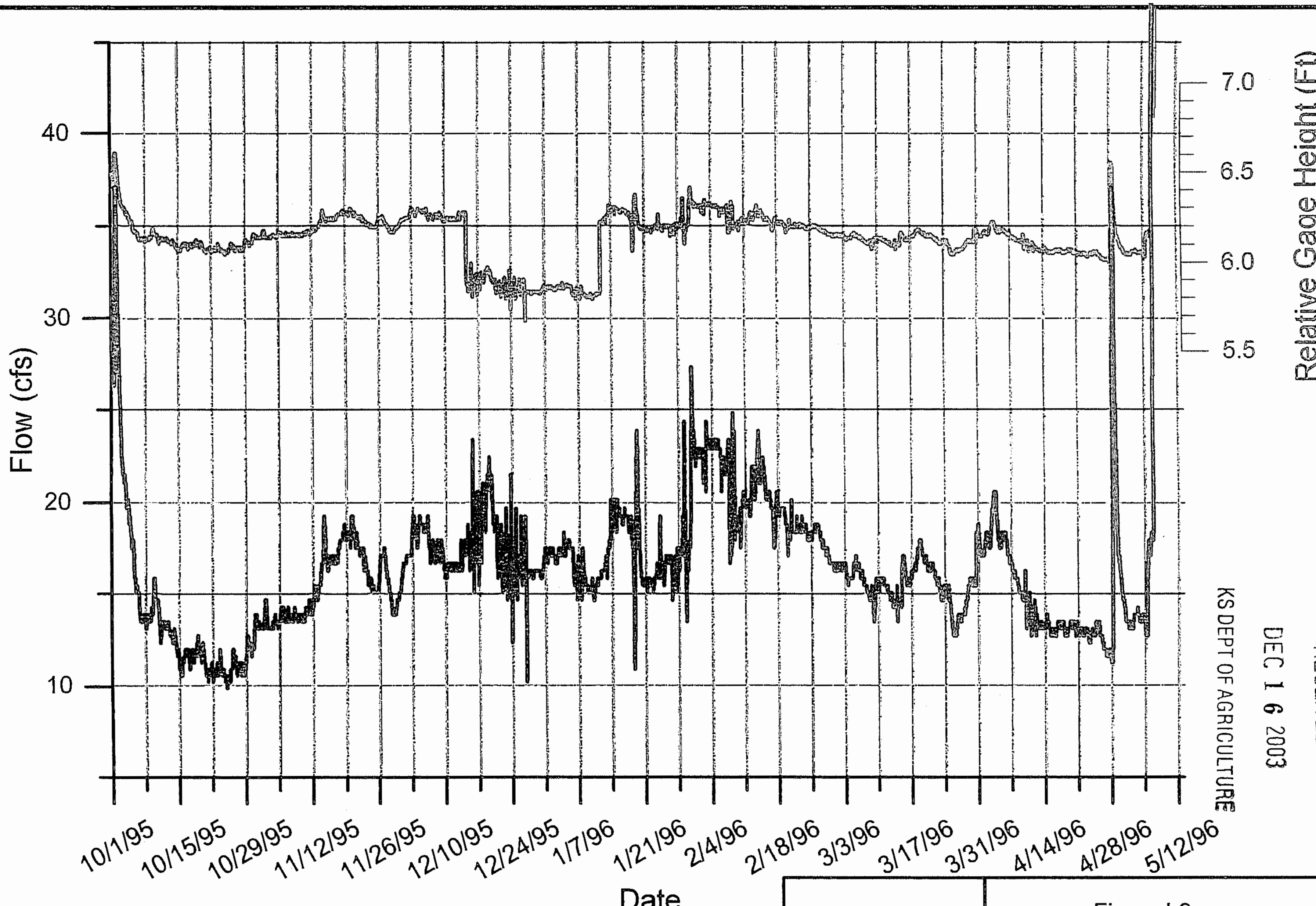
- Distance of about 3 miles to several city well locations which show potentially high recharge rates.

c. **Stream Flow and Water Level Data**

USGS flow and stage gages exist at Alta Mills, Sedgwick, and Valley Center on the Little Arkansas River. A new flow and stage gage was installed as part of the Project at Highway 50, north of Halstead and two stage-only gages were installed near Sites TH-04 (Halstead gage) and TH-08. Locations of these gages are shown in Figure I-6. These gages, in addition to existing gages at Alta Mills, Sedgwick and Valley Center, are all connected to the USGS Data Collection Platform (DCP) which records data every 15 minutes. The gages used in this Project are at Highway 50, Site TH-04, Site TH-08 and Sedgwick. These gages are located between the north and south operating limits of the Project's study area and at specific test sites. Monitoring well strings located adjacent to the gages at Site TH-04, Site TH-08 and the Sedgwick gage record groundwater levels near the river. Monitoring wells at both Site TH-04 and the Sedgwick gage are also connected to the adjacent USGS gage DCP.

The Alta Mills and Valley Center gages at the fringe of the study area were used in the 1993 Water Supply Study (Burns & McDonnell, 1993) and 1994 Feasibility Study (Burns & McDonnell, 1994). The Alta Mills and Valley Center gages are useful when evaluating operating scenarios due to their respectively long periods of record (from 1973 to present and from 1922 to present).

Average daily stream flow data for the Highway 50 and Sedgwick gages from October 1, 1995 through August 26, 1996 are respectively shown in Figures I-9 and I-10. Review of the flow data shows the stream flow in the Little Arkansas River is highly variable, ranging approximately from 7 cubic feet per second (cfs) to more than 3,000 cfs at Highway 50 and 8 cfs to more than 3,300 cfs at Sedgwick. Average streamflow at the Sedgwick gage was typically greater than the flow at the Highway 50 gage due to inflow from Emma and Sand Creeks. The Little Arkansas River has a mean annual flow of 284 cubic feet per



Note: Gage Datum = 1370.55 ft (above MSL)

Burns & McDonnell

Figure I-9

FLOW AND RIVER STAGE AT THE HIGHWAY 50 GAGING STATION

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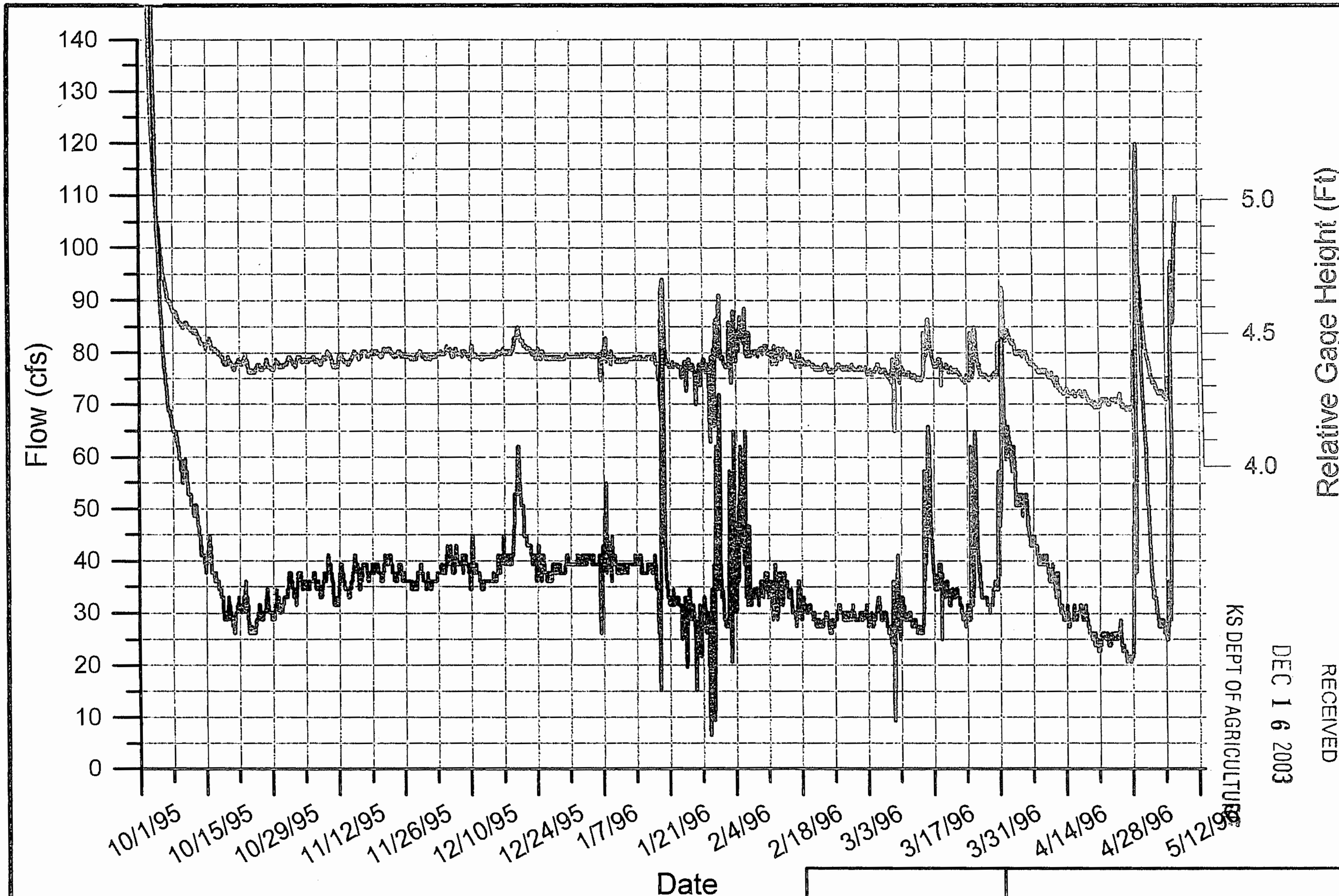


Note: Gage Datum = 1340.00 ft (above MSL)

Burns & McDonnell

Figure I-10

FLOW AND RIVER STAGE AT THE SEDGWICK GAGING STATION

05/13/99 J:\wichita\921954\absr\download\flows\sedflstg.grf second (205,600 acre-feet/year) at Valley Center, Kansas, based on 69 years of histori :al record.

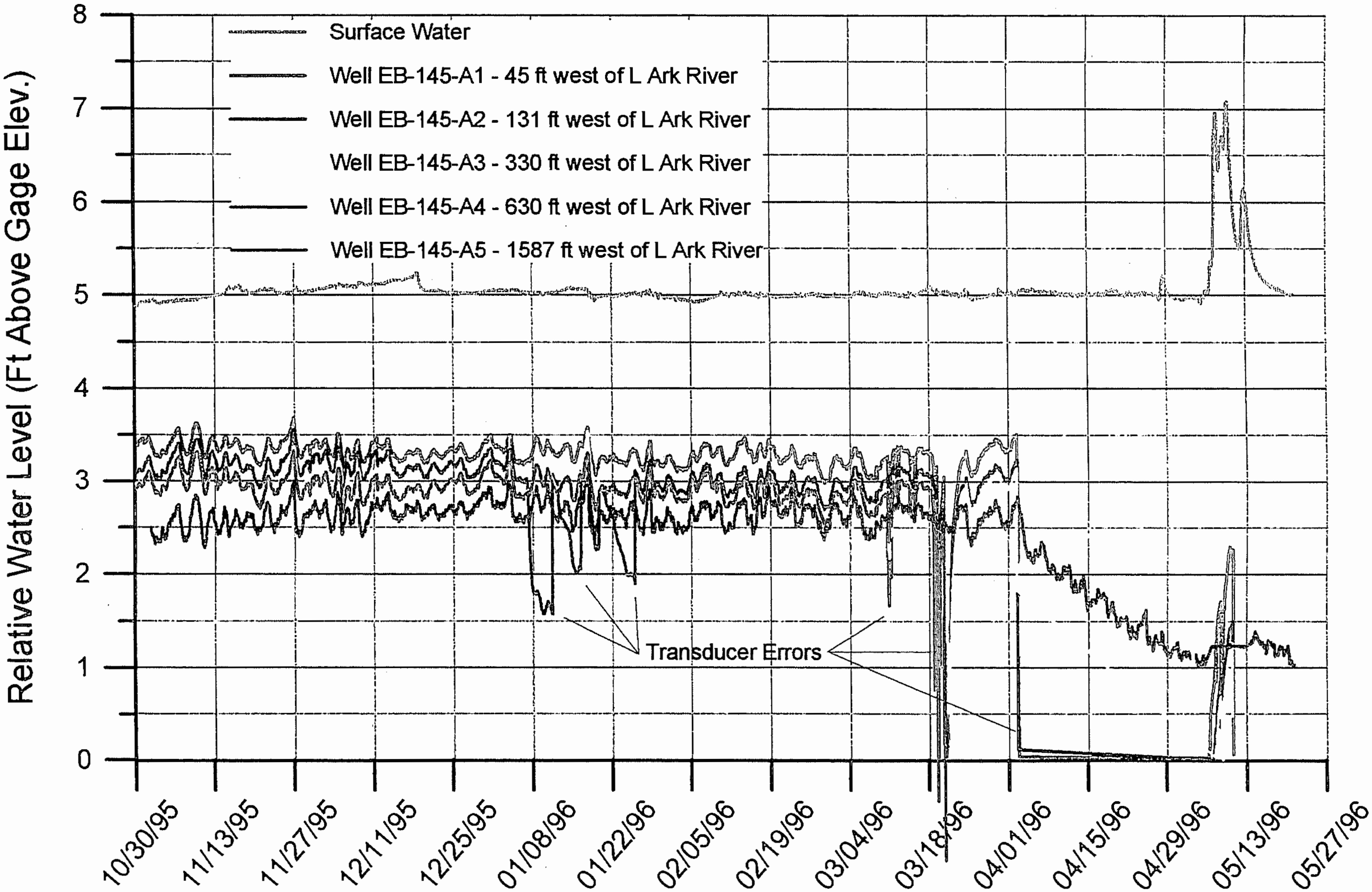
River stage data collection for Site TH-04, Site TH-08 and the Sedgwick gages and groundwater levels in the associated monitoring well strings began on October 30, 1995, December 12, 1995 and December 12, 1995, respectively, and continued through the end of the feasibility test period as shown in Figures I-11, I-12 and I-13. Review of the stage data for the river and the monitoring wells show the river bank water levels quickly increasing with the rise of river level and rapidly decreasing with the recession of river level. Data for Site TH-04 shows water levels are typically higher in the river than the monitoring wells due to the influence of the low head dam on the Little Arkansas River about 3/4 miles downstream of the site. Data gaps in for some of the monitoring wells in Figures I-12 and I-13 were caused by temporary malfunction of the transducers.

During wet weather conditions, flow in the Little Arkansas River exceeds base flow and is available for aquifer recharge. Based on 71 years of record at Valley Center and 20 years of record at Alta Mills, the frequency of recovery water availability is shown in Table I-4. Based on that information and minimum study stream flows for water recovery (5.6 cfs for Alta Mills and 24.8 cfs for Valley Center), the total annual average flow available for use was estimated to be about 115,200 acre-feet per year at Alta Mills and 176,300 acre-feet per year at Valley Center.

Table I-4

Frequency of Recovery Water Availability

	Stream Flow (cfs)	Average No. of Periods	Median Length (days)	Days per Year
Alta Mills	5.6	3.3	9	316
	189.0	9.0	3	43
Valley Center	24.8	4.1	7	306
	30.0	4.4	7	277
	60.0	7.4	6	171
	284.0	7.8	4	47



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Note: Gage datum elevation is 1371.00 ft. MSL

Burns & McDonnell

Figure I-11

RIVER STAGE AND STRING WELL GROUNDWATER LEVELS SITE TH-04

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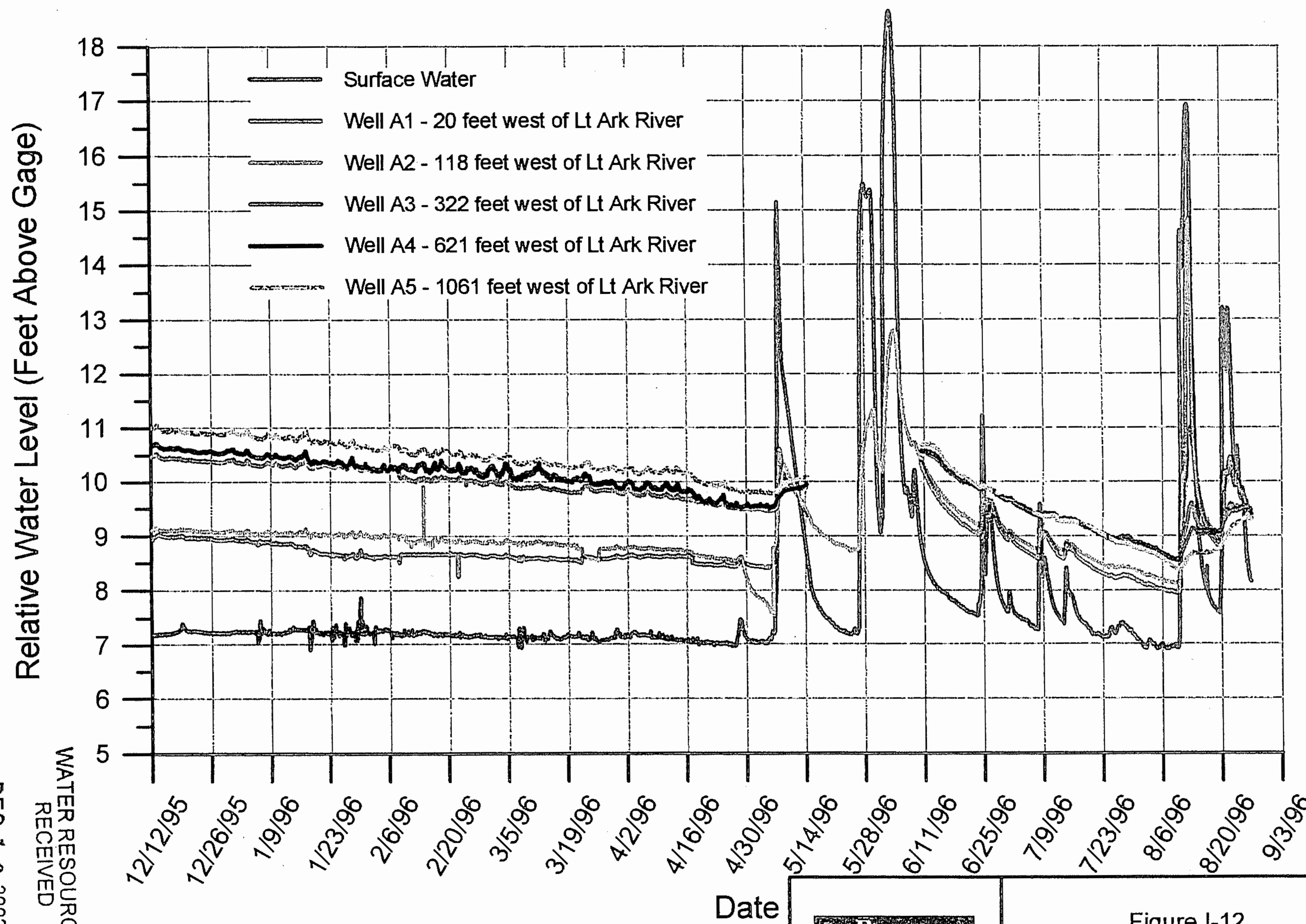

Note: Gaging station on Little Arkansas River at SW 84th Street near Sedgwick
Gage Datum is 1,345 feet above sea level.

Burns & McDonnell

Figure I-12

RIVER STAGE AND LEVELS STRING WELLS SITE TH-O8

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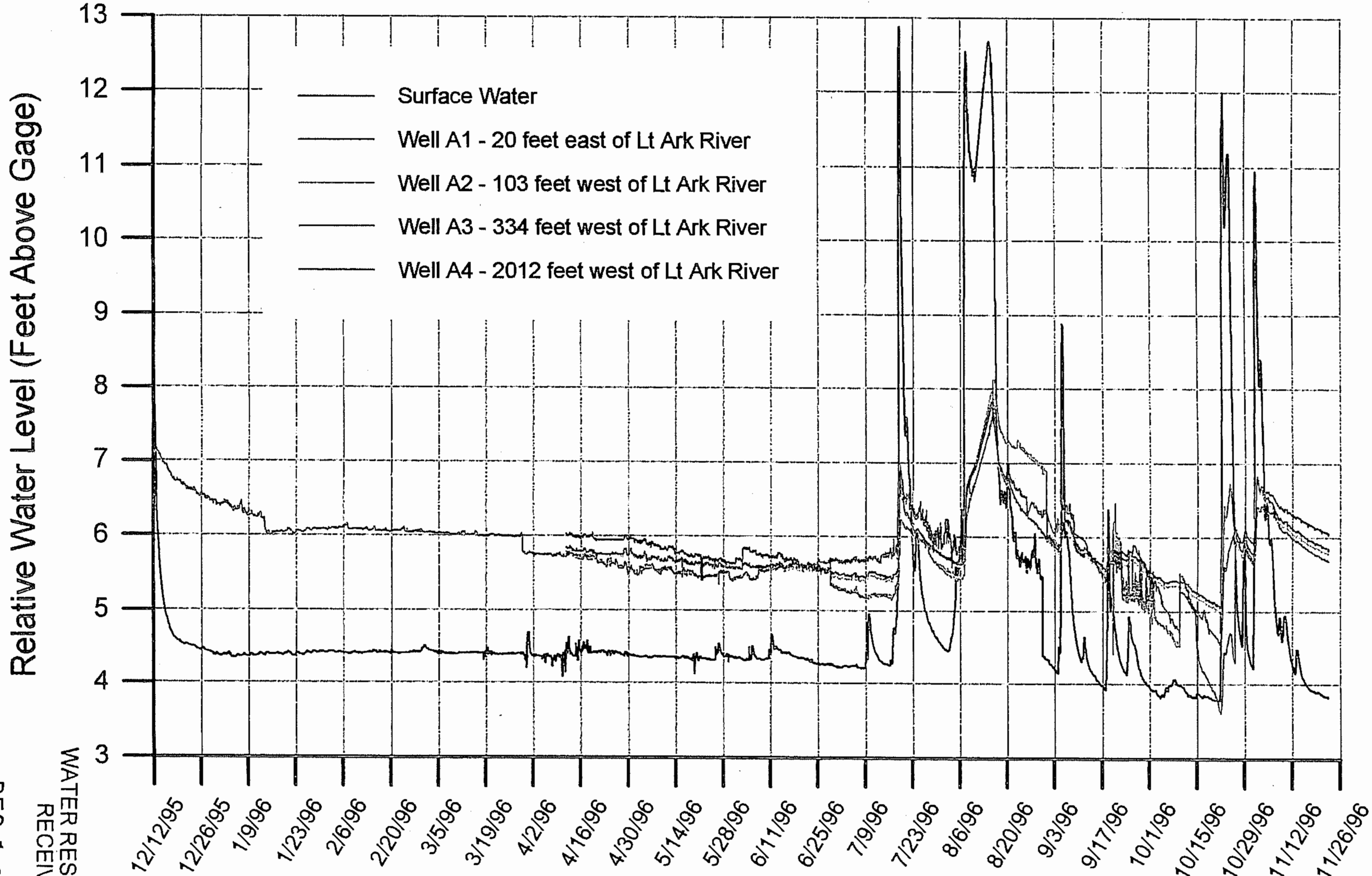

Note: Gaging station on Little Arkansas River at Fry Bridge near Sedgwick
Gage Datum is 1,340 feet above mean sea level

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Figure I-13

RIVER STAGE AND LEVELS STRING WELLS SEDGWICK

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(1) Monitoring Well String Site Selection

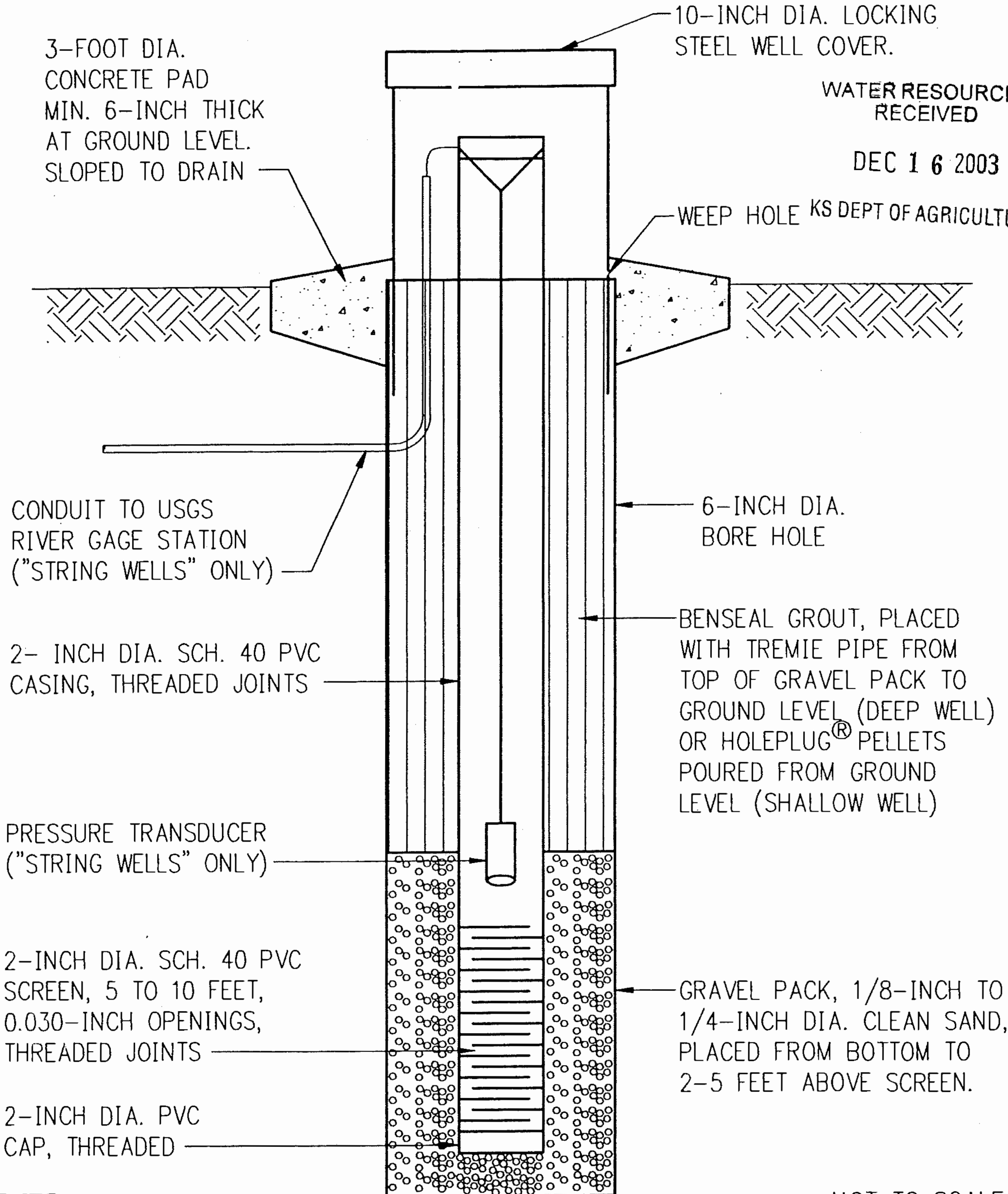
Subsurface conditions at 12 test hole locations (TH-01-95 through TH-12-95), as shown in Figure I-6, were evaluated for geologic data to select three monitoring well string sites. Five of the test holes were completed as monitoring wells to provide initial estimates of river bank water quality and additional information about river-aquifer interaction.

Borings were spaced along the Little Arkansas River between Harvey County Park on the north side of the study area and just north of Valley Center on the south side of the study area as shown in Figure I-6. The borings were designated TH-01-95 through TH-12-95. The five borings converted to monitoring wells included TH-02-95, TH-04-95, TH-06-95, TH-08-95 and TH-12-95. Those wells were incorporated into the monitoring system operated by GMD2. A schematic of a typical monitoring well is shown in Figure I-14. Data collected from each drilling location was evaluated to help select locations for placement of the monitoring well strings and a high-capacity test well near the river.

(2) Monitoring Well String Installation

Monitoring well strings were installed at Site TH-04, Site TH-08 and the Sedgwick gage, as shown in Figure I-6, to evaluate river-aquifer interaction through water levels and water quality monitoring. Each well string consists of five wells placed along a line perpendicular to the river with the last well approximately 1400 to 1800 feet from the river. Layouts and spacing of the well strings are respectively shown for the TH-04, TH-08 and Sedgwick gage sites in Figures I-15, I-16 and I-17. The well strings were installed between October 10 to 28, 1995. Additional information on the three well string sites follows:

- Halstead Site: Four additional wells installed at the location of Boring TH-04-95 (a preliminary phase installation, renamed Monitoring Well EB-145-A1). Well EB-145-A1, installed during the drilling of the 12 test holes, was utilized as the first well in the string at the Halstead site.



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NOTES:

1. SHALLOW MONITORING WELLS RANGE FROM 37 TO 68 FEET DEEP.
2. DEEP MONITORING WELLS RANGE FROM 115 TO 140 FEET DEEP.

Burns & McDonnell

Figure I-14

TYPICAL MONITORING WELL

J:\WICHITA\921954.014\NEWFIG\FIGI-14.dwg 05-06-1999 09:14 MJC

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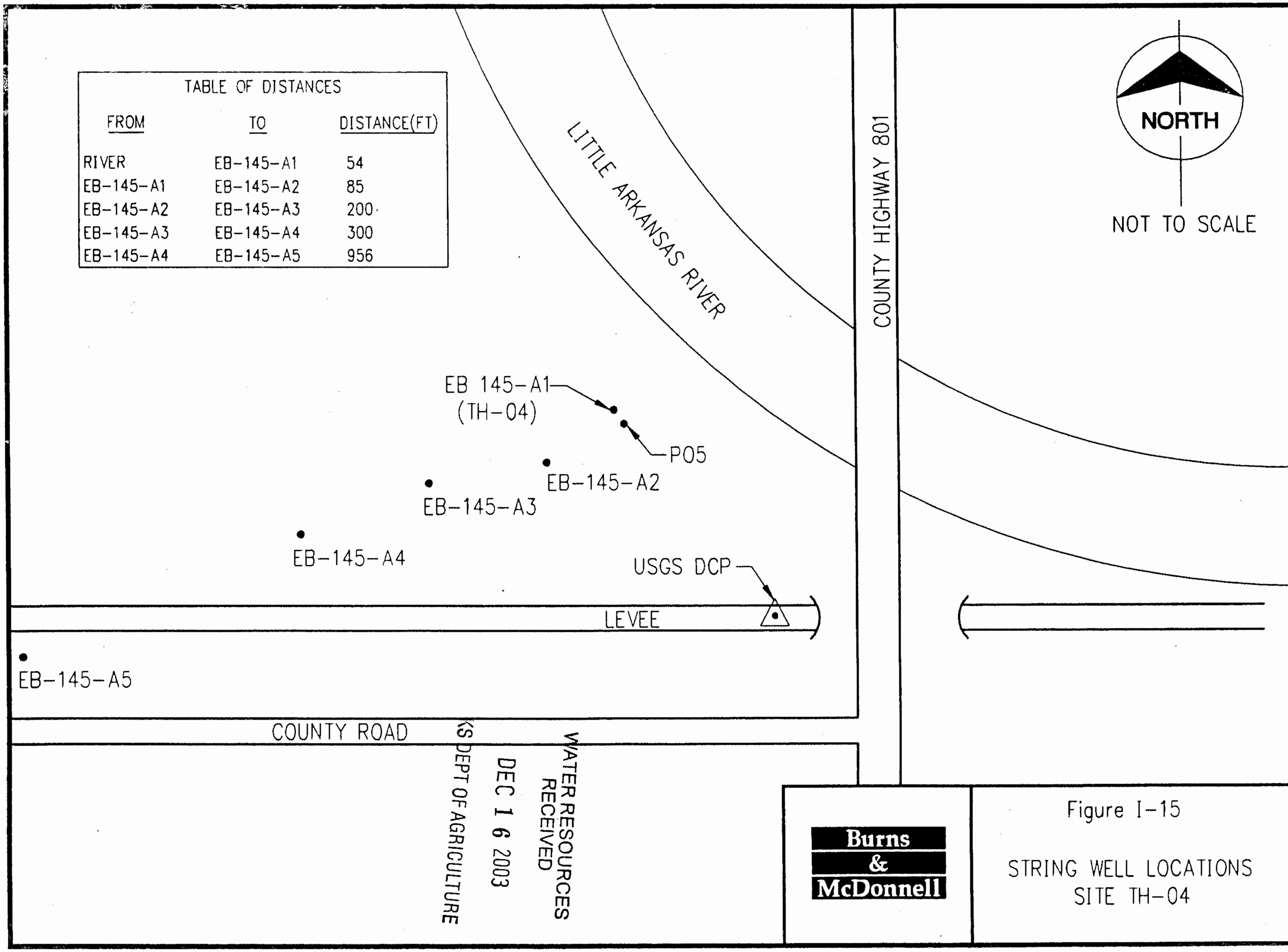

TABLE OF DISTANCES

FROM	TO	DISTANCE(FT)
RIVER	EB-145-A1	54
EB-145-A1	EB-145-A2	85
EB-145-A2	EB-145-A3	200
EB-145-A3	EB-145-A4	300
EB-145-A4	EB-145-A5	956

Figure I-15

STRING WELL LOCATIONS
SITE TH-04

558

J: \WICHITA\921954.014\NEWFIG\Figi-16.dwg 05-06-1999 16:12 MJC

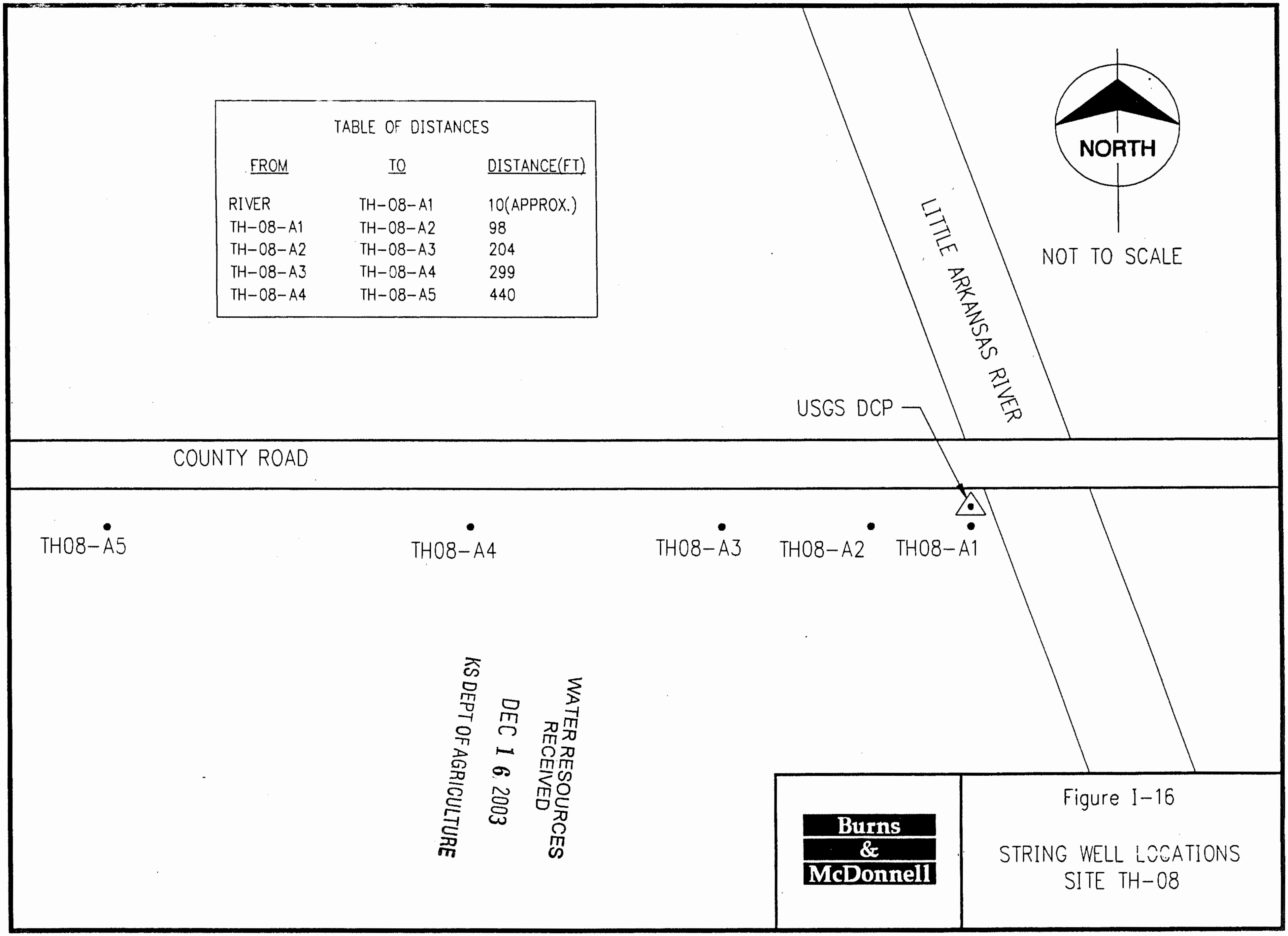

TABLE OF DISTANCES

FROM	TO	DISTANCE(FT)
RIVER	TH-08-A1	10(APPROX.)
TH-08-A1	TH-08-A2	98
TH-08-A2	TH-08-A3	204
TH-08-A3	TH-08-A4	299
TH-08-A4	TH-08-A5	440

Figure I-16

STRING WELL LOCATIONS
SITE TH-08

J: \WICHITA\921954.014\NEWFIG\Figi-17.dwg 05-06-1999 16:11 MJC

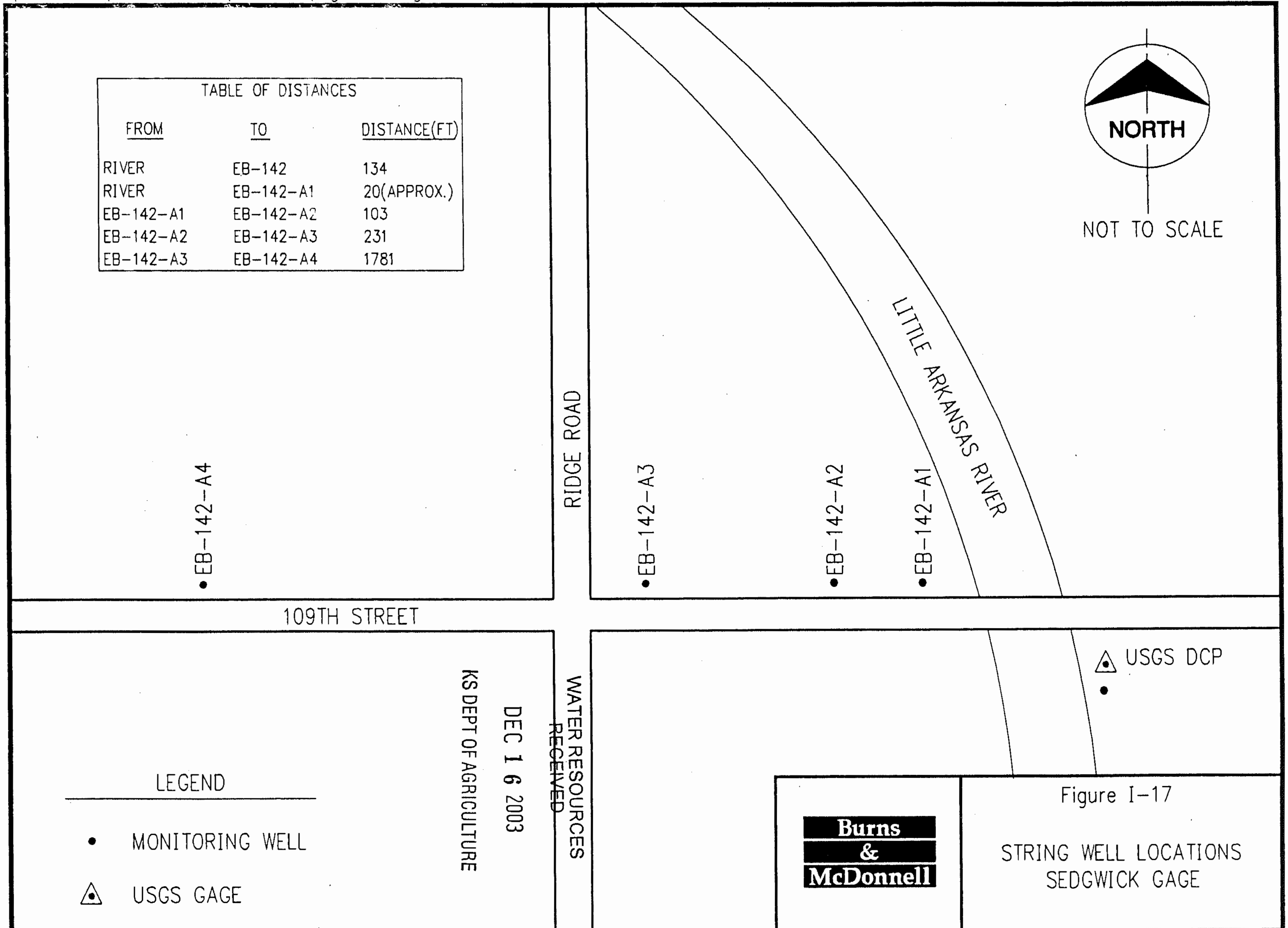

TABLE OF DISTANCES

FROM	TO	DISTANCE(FT)
RIVER	EB-142	134
RIVER	EB-142-A1	20(APPROX.)
EB-142-A1	EB-142-A2	103
EB-142-A2	EB-142-A3	231
EB-142-A3	EB-142-A4	1781

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Figure I-17

STRING WELL LOCATIONS
SEDGWICK GAGE

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- Northern Sedgwick County Site: Five wells installed at the location of Boring TH-08-95 (a preliminary phase boring).

- Sedgwick Site: Four additional wells installed near the USGS Sedgwick river gage (and the location of Monitoring Well EB-142, drilled and installed during a preliminary phase of the investigation).

(3) Instrumentation

The USGS supplied instrumentation for the monitoring well strings. Pressure transducers connected directly to an assigned DCP were installed in all monitoring well strings except Well EB-142-A4 (near Sedgwick). The DCPs collect water level measurements at 15-minute intervals and periodically transmit stored data via satellite to a USGS database in Lawrence, Kansas. Well EB-142-A4 was located too far from the DCP to allow reliable transmission of the signal from the transducer to the DCP. Automated water level data collection was provided in Well EB-142-A4 with an InSitu Well Sentinel data logger.

e. <u>Infiltration Testing</u>

Test drilling was performed at 11 City of Wichita wells to collect geologic data to site project infiltration test pits. One boring was drilled and logged at City of Wichita Wells 4, 5, 20, 26, 35, 36, 37, 38, 39, 42, and 51 (City Well locations are shown in Figure I-6). Based on review of the test drilling data, Wells 4, 6, 36, and 38 were selected for further investigation. Ten additional borings were installed to obtain data for final evaluation of those sites. A piezometer was also installed at each site for monitoring groundwater levels adjacent to the infiltration test pit.

Drilling conducted at the City wells for the test pit infiltration basin siting showed the soils have a variable fine-grained topsoil thicknesses that will affect design and construction of recharge basins. The fine-grained topsoil layer showed to be thicker at the northern City wells (12 to 14 feet) and thinner in the southern and middle wells (5 to 7 feet). A clay layer was locally present at some City wells at depths of 15 to 25 feet. These clay layers, where present, where anticipated to inhibit the vertical percolation of recharge water, reducing the overall recharge rate.

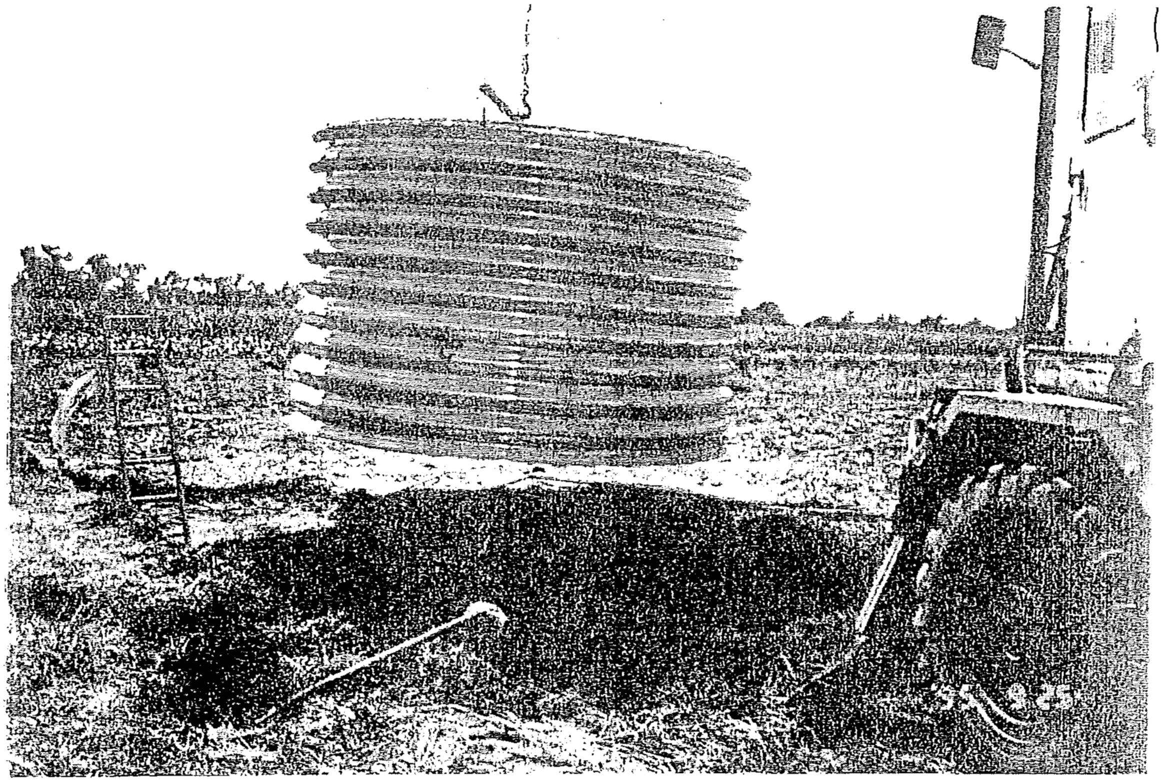
Infiltration tests were conducted at each of the four selected sites to collect data for further evaluation of the sites as potential locations for Project recharge basins. Test pits were installed at City Wells 6, 36, and 38 in October 1995 by City of Wichita staff. Testing for the infiltration test pit at Well No. 38 was terminated on January 12, 1996, and its structure moved to Well No. 4. Typical installation of the test pits is shown in Photographs I-3 through I-6. A schematic of a typical infiltration test pit is shown in Figure I-18. Water for the infiltration testing was supplied by the City's well field piping system. Each test facility was located adjacent to an existing well.

Infiltration testing was performed by filling the pit with water and recording daily flow, depth of water in the pit and water level in the piezometer. A shallow piezometer was installed adjacent to each test pit to observe any mounding of groundwater that may occur during the infiltration testing. The results of the infiltration testing, including soil bottom materials description, test pit depth, and initial and long-term infiltration rates, are listed in Table I-5. City Wells Nos. 4, 36 and 38 demonstrated high infiltration rates. Locations near Wells No.4 and 36 were selected to be used for recharge sites during the demonstration project.

f. **Aquifer Testing**

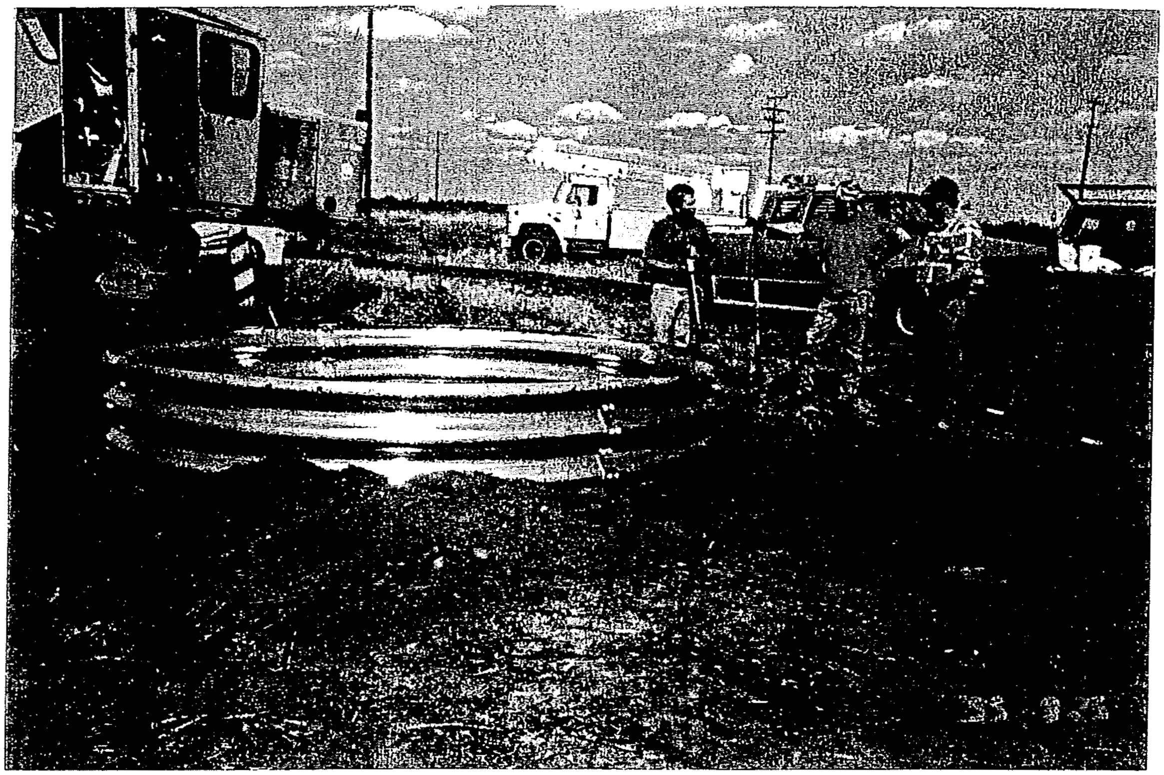
Aquifer testing was conducted to prove that the test well induced infiltration from the Little Arkansas River and that the water quality was acceptable for recharge through surface recharge basins and recharge wells. The test well provides the supply of induced infiltration water for the Project testing phase at Site TH-04 (or Halstead site) scheduled from April 1997 through September 1999.

Prior to well construction, the City submitted an "Application to Appropriate Water for Beneficial Use" to the Kansas Department of Agriculture, Division of Water Resources (DWR). Prior to acting on the application, DWR requested review and approval from GMD2.

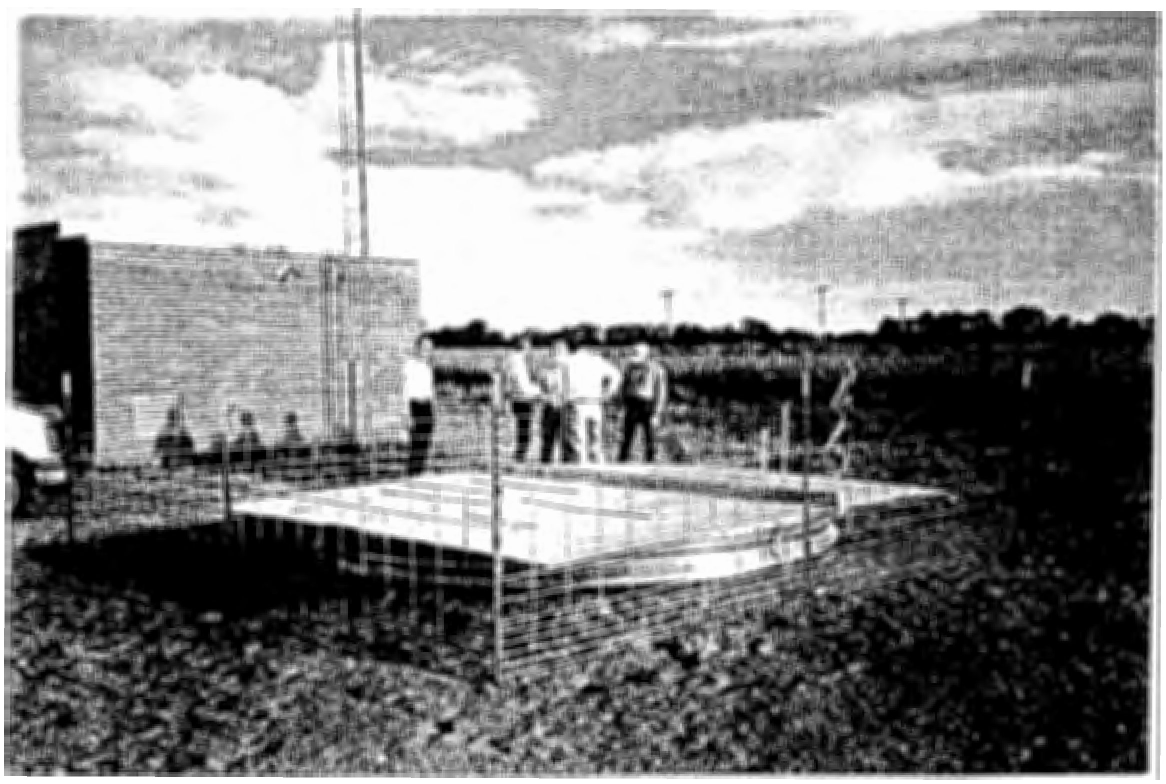


Photograph I-3: Infiltration Test Pit Construction

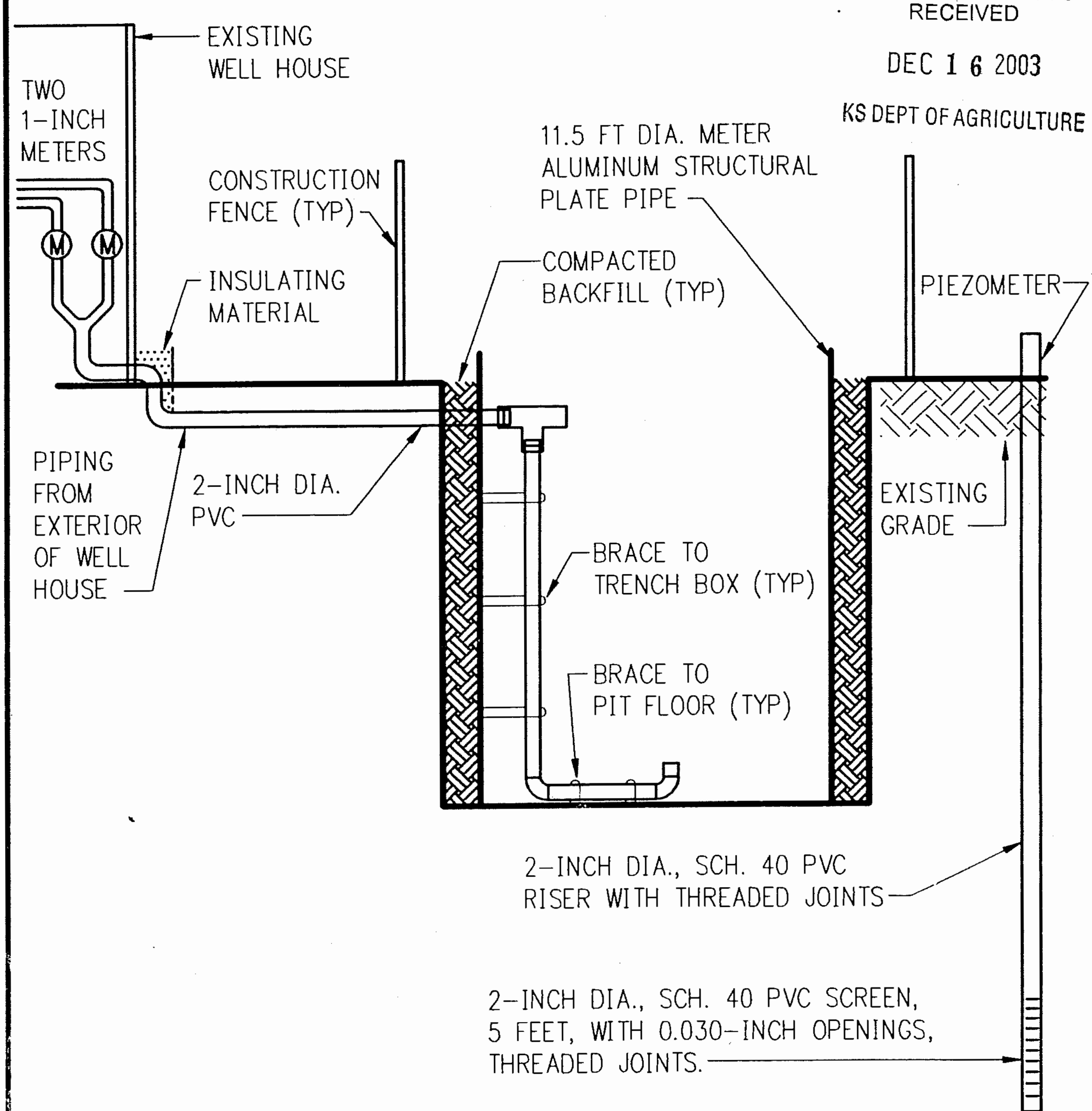
Photograph I-4: Infiltration Test Pit Construction



Photograph I-5: Infiltration Test Pit Construction



Photograph I-6: Infiltration Test Pit Construction



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J:\WICHITA\921954.014\NEWFIG\FIG-I-18.dwg 05-04-1999 14:42 MJC

Burns & McDonnell	Figure I-18 INFILTRATION TEST PIT SCHEMATIC

Table I-5
Infiltration Test Results

Well No.	Sand Bottom Materials	Pit Depth (feet)	Initial Infil-tration Rate (ft/day)	Long Term Infiltration Rate (ft/day)
4	Fine sand, some medium	11.5	60 to 80	6 to 10
6	Fine silty sand, trace clay	12	< 1.0	< 1.0
36	Fine to very coarse sand, some fine gravel	7.5	80 to 100	10
38	Fine to medium sand, some coarse, some gravel	6	30 to 40	12

Several provisions of the application were contrary to established policies of the GMD2 and the City requested a hearing with the GMD2 Board of Directors to ask for a variance so the Project could continue. The City met with the GMD2 Board of Directors on July 11, 1995, the application was approved by the Board of Directors, with inclusion of a list of "Additional Conditions."

Subsequent to approval of the Application by GMD2, DWR examined and approved the application, with conditions, as Term Permit 959087, valid for a period of 4 years. The effective dates of the Term Permit are February 1, 1996 to February 1, 2000. The Term Permit, and "Additional Conditions," are included in the Appendices. The letter of approval is dated October 10, 1995.

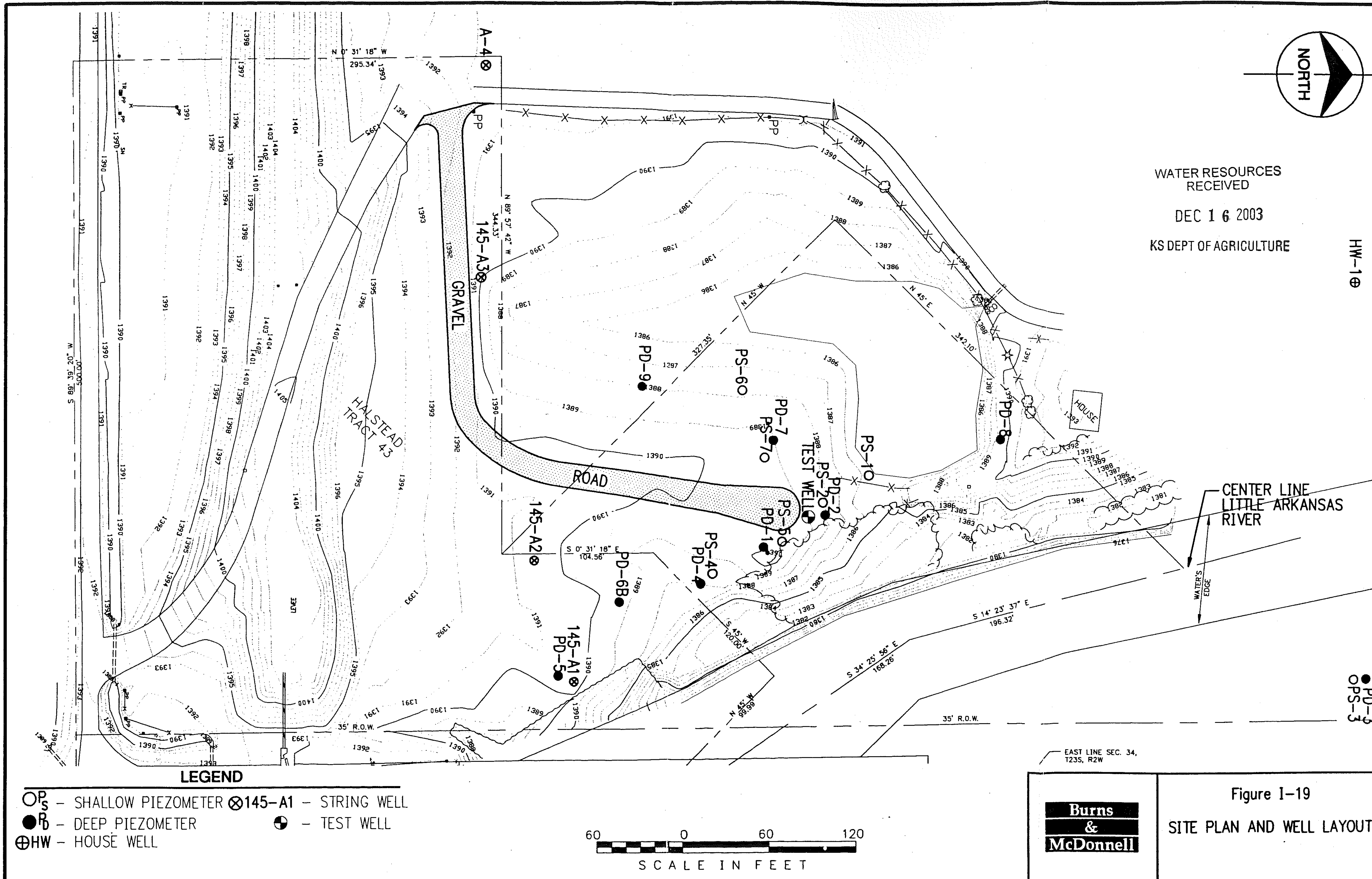
Primary concerns addressed in the term permits' "Additional Conditions" include:

- Concern about hydraulic communication between aquifer zones and preventing the Project from using deep zone groundwater.
- Concern for no impairment of existing water rights or contamination of the aquifer.
- Provisions that the installation meet GMD2 and state rules and policy requirements.

To address these concerns, the scope of the aquifer test was increased to include the installation of additional shallow and deep piezometers with additional water quality monitoring, groundwater modeling, and data evaluations.

Field work was conducted at Site TH-04 (Halstead site) from October 11, 1995 to May 2, 1996, as shown in Figure I-19, and the following tasks were completed:

- Drilled and sampled pilot hole (PH-1) and conducted analysis of soil samples for siting and design of the test well.
- Drilled and installed nine deep monitoring wells for aquifer testing (P_D1 through



J:\WICHITA\921954.014\NEWFIG\FIGI19.dwg 05-06-1999 09:57 MJC

P_D9).

- Drilled and installed seven shallow monitoring wells for aquifer testing (P_S1 through P_S7).

- Drilled and installed the test well (Well EBRP-1). The well was constructed as shown in Figure I-20.

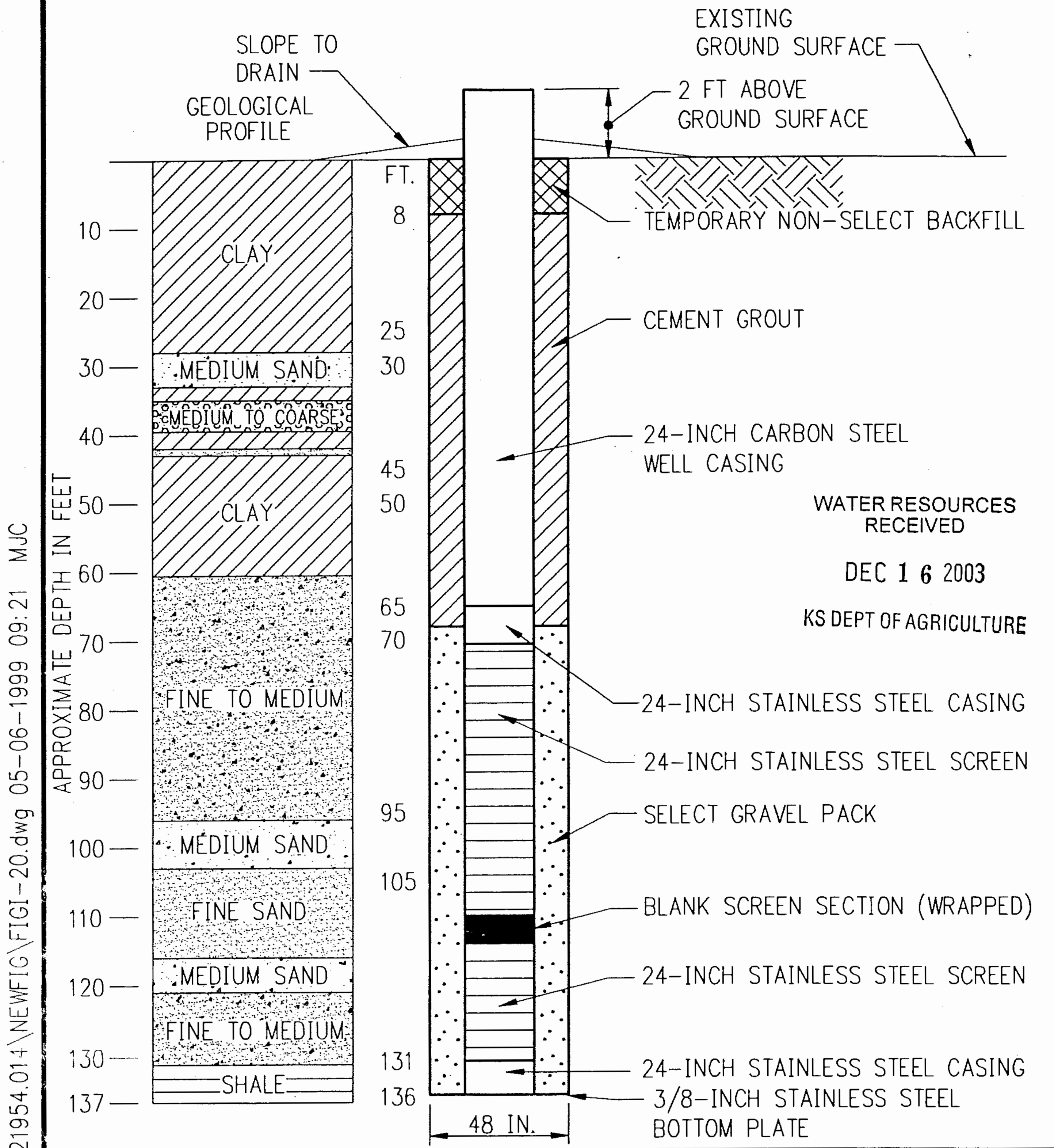
- Conducted a 24-hour well acceptance test.

- Conducted a 30-day aquifer pumping test.

- Conducted a 75-day aquifer pumping test for water quality.

A 24-hour well acceptance test was conducted to determine well efficiency and to determine the optimum pumping rate for a 30-day test. The test was conducted on March 20-21, 1996. Based on totalizer readings, the well was pumped at an average flow rate of approximately 923 gallons per minute (gpm) during the test. The 24-hour specific capacity was 31.3 gallons per minute per foot of drawdown (gpm/ft-dd).

The 30-day test was conducted to collect hydraulic and water quality data on the river and the aquifer to determine if the aquifer is confined, if test well water quality is acceptable for recharge and if the provisions of the term permit can be met by the test well. This test was conducted from April 2, 1996 to May 2, 1996. The well was pumped at an average flow rate of approximately 860 gallons per minute (gpm) during the test. Results from the test showed that groundwater levels in both deep and shallow monitoring wells responded very quickly to the pumping stress by the test well, which indicated good hydraulic communication between aquifer zones, thus meeting the provisions in the term permit. Drawdown (difference between groundwater static level and test level) for the upper and lower zone during the 30-day test is shown in Figure I-21. This figure shows two cones of drepression; one in the shallow zone and one in the deep zone. The greatest drawdown in the deep zone occurred, as expected, at the test well. The greatest drawdown in the

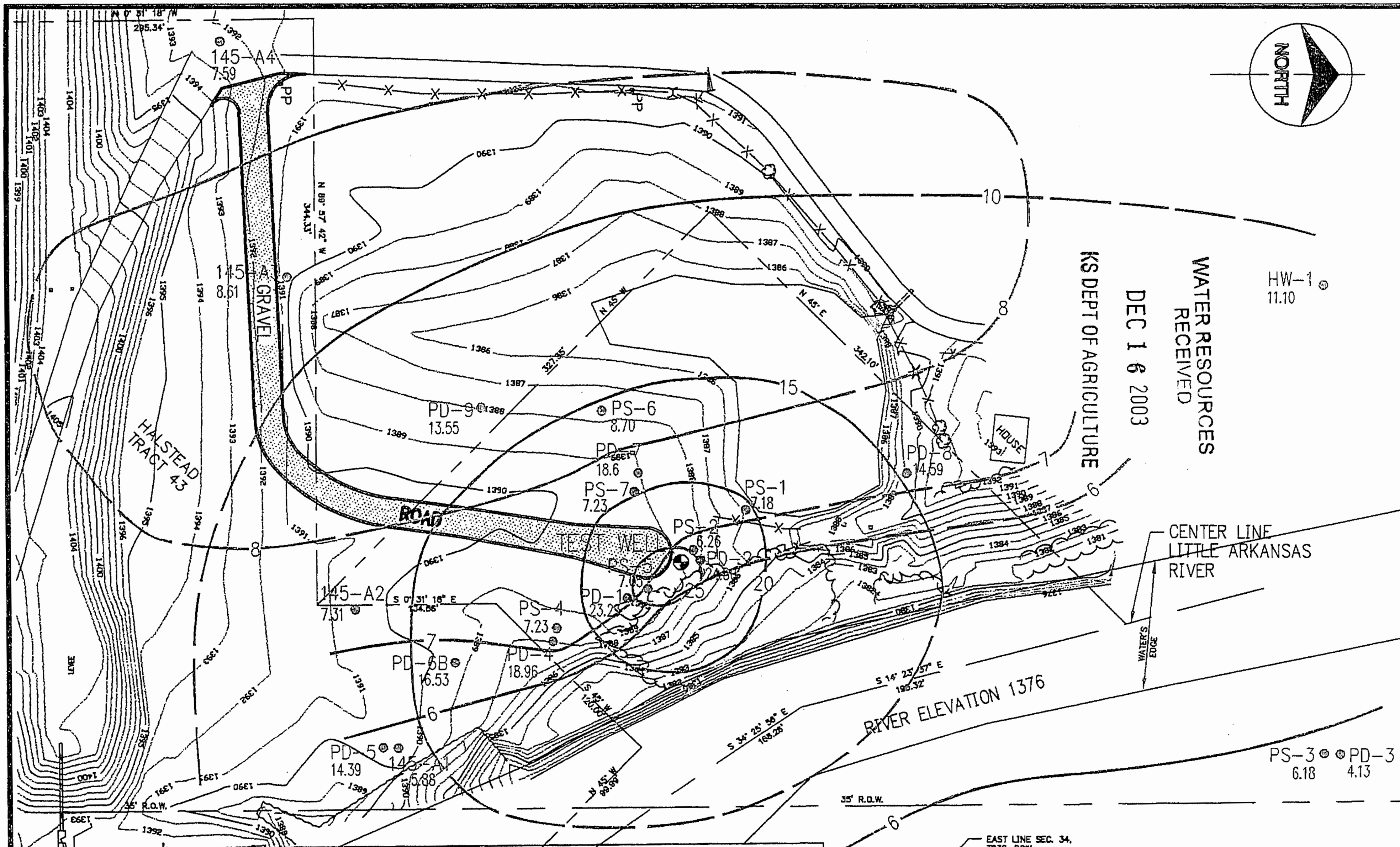


NOTE: SURFACE WATER LEVEL ABOUT 17 FEET BELOW EXISTING GRADE.

Burns & McDonnell

Figure I-20

AS-CONSTRUCTED TEST WELL AT SITE TH-04.



LEGEND

- P_S – SHALLOW PIEZOMETER
- —7.0— SHALLOW ZONE – DRAWDOWN
- P_D – DEEP PIEZOMETER
- —20— DEEP ZONE – DRAWDOWN
- 145-A1 – STRING WELL
- ⊕ – TEST WELL
- HW – HOUSE WELL

80 0 80 160

SCALE IN FEET

NOTE:

DRAWDOWN AFTER 24 DAYS OF PUMPING
Q = 863 GPM (APRIL 26, 1996)

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Figure I-21

DRAWDOWN
UPPER AND LOWER ZONES
SITE TH-04

J:\WICHITA\971954.014\NEWFIG\Fig1-21.dwg 07-15-1999 16:06 MJC shallow zone is displaced west of the pumping well and occurs due to river influence and geologic conditions at the site. River water enters the shallow aquifer zone but must flow west of the test well to flow around a clay layer which separates the upper and lower aquifer zones at the test well. West of the test well, in the area around EB-145-A3, the clay layer is absent and water can migrate downward. This observation confirmed the good connection between upper and lower aquifer zones at the test area.

The 75-day aquifer test was conducted to evaluate the impacts of atrazine and other water quality concerns for an extended pumping scenario. The test was started on May 6, 1996 and was completed on July 24, 1996. The average discharge rate for the test was 978 gallons per minute (gpm). During the 75-day test, two major stream flow events of about 1,500 cfs and 2,600 cfs occurred as well as other lower flow events. Hydrographs revealed that water levels in shallow and deep piezometers were directly affected by increases in river stage further proving a good connection between the river and shallow and deep portions of the aquifer. The deep aquifer zone showed a delayed response to flow changes in the river, which suggested a hydraulic flow response rather than a pressure transfer to a confined aquifer.

Estimates of aquifer parameters analyzed by distance-drawdown analysis are as follows:

Test	Transmissivity (ft^2/day)	Storativity (Dimensionless)
24-hour (parallel to river)	7,240	0.0013
30-day (parallel to river)	6,768	0.0057
30-day (perpendicular to river)	4,007	0.0230

A subregional groundwater flow model of the Equus Beds Aquifer in the vicinity of the pumping well site was developed for the Project. The model was used to predict aquifer reaction to stresses induced by pumping. The subregional model was adapted from a regional groundwater flow model originally developed by the U.S. Geological Survey (USGS), modified by the Bureau of Reclamation and further refined by Burns and McDonnell during the 1994 Feasibility Study (B&McD, 1994). The regional model was created utilizing MODFLOW, a modular three-dimensional finite-difference groundwater flow model developed by the USGS, and the subregional model was extracted from this regional model using techniques published by the USGS. Water level data developed in the 30-day aquifer test was used to calibrate the subregional groundwater model for current conditions.

g. **Water Quality and Potential Water Chemistry Interactions**

An extensive water quality sampling and analysis plan was developed and followed throughout the feasibility investigations of the Project to develop baseline water quality data. Samples were collected by the USGS and analyzed by the USGS and the City's laboratory using approved methodologies. Analyses for pesticides and organics were conducted by USGS and analyses for inorganics, metals and microbiology were conducted by the City.

From February 27, 1995 through July 24, 1996, a total of 1,258 samples were collected and analyzed. The samples were collected at Little Arkansas River sample locations for surface water (Alta Mills, Highway 50, Sedgwick and Valley Center), Emma Creek and Sand Creek, monitoring wells, and the test well. The parameters detected in either the Little Arkansas River surface water or the groundwater included 2,4 D acetochlor, alachlor, ametryne, triazine screen, atrazine, deisopropyl atrazine, diethyl atrazine, bromacil, butylate, carbaryl, carbofuran, cyanazine, DCPA, diazinon, dicamba, 2,6-diethylaniline, EPTC, diuron, ethoprop, methylparathion, metolachlor, metribuzin, picloram, prometon, propazine, simazine, tebuthiuron, terbacil, and trifluralin. Review of the data revealed these parameters to have concentrations slightly above the detection limit and less than 20 percent of EPA's MCLs, except for higher readings for atrazine and cyanazine.

Based on dectection limits, triazine herbicides (atrazine and cyanazine) were found to be the only major organic water quality parameters requiring evaluation for possible water quality impacts to the aquifer. Chloride appeared to be the only inorganic parameter of concern. Atrazine concentrations in the river water at the Highway 50 gage ranged from non-detect (ND) to 46 µg/L with a mean of 2.3 µg/L compared to a range of ND to 33 μg/L with a mean of 3.5 μg/L at Sedgwick. Higher atrazine concentrations at Sedgwick are the result of higher atrazine loading from Sand and Emma Creek or the east side of the Little Arkansas River watershed. At high river flows atrazine can be high depending on timing of agricultural applications. Cyanazine was detected in 19 of 40 samples at a maximum of 1.82 μg/L and a mean of 0.099 μg/L including the non-detects at the detection limit concentration (0.1 μg/L). Chloride concentrations in the river at Highway 50 ranged from less than 10 to 380 mg/L with a mean of 171 mg/L compared to a range of less than 10 to 218 mg/L with a mean of 70 mg/L at Sedgwick. Chlorides typically decrease with flow with high chloride concentrations, 100 to 400 mg/L, ocurring at low stream flow and low chloride concentrations, 10 to 100 mg/L occurring at high stream flows.

Atrazine was anticipated to be a potential problem due to past positive detections in the Little Arkansas River water. Therefore, this herbicide was extensively sampled and analyzed at monitoring wells near the Little Arkansas River and throughout the area of interest during the feasibility studies leading to the implementation of the Project. Although atrazine was detected in the shallow portions of the river bank, results showed that no atrazine occurred above the detection limit in the deep monitoring wells near the river or in the aquifer at distances of 200 to 300 feet from the river. Adsorption to the river bank soils and natural degradation seem to prevent triazines from reaching the aquifer.

The test well ran for 105 days with minimal interruption during April, May, June, and July of 1996. Based on the collected water quality data, pumped water from the test well (or recharge water) was not anticipated to negatively impact aquifer water quality. Chloride concentrations in the test well pumpage ranged from 22 to 66 mg/L which is similar to the average aquifer chlorides concentration of about 55 mg/L. After 105 days of nearly continuous pumping during aquifer tests and daily triazine sampling, triazine herbicides were found above the detection limit of 0.1 μg/L in only 2 of the 105 well water samples collected. However, no level triazine herbicide occurred above the MCL (3 μg/L).

h. <u>Conclusions of Preliminary Investigations</u>

Based on the findings of the preliminary studies, the Project was recommended to continue through pilot facility operation. Primary concerns stated in the Term Permit and "Additional Conditions" were addressed by these studies with positive results as follows:

- Good hydraulic communication between the river and the upper and lower aquifer zones near the river was shown to exist, which would prevent the use of deep zone groundwater by the Project.

- Negative impacts on the water quality of the aquifer as a result of recharge operations were not anticipated. Chloride concentrations in the test well pumpage were similar to the background aquifer chloride concentration, whereas atrazine concentration in the test well water was always below the established MCL.

Geologic investigations showed the complex and non-homogeneous nature of the unconsolidated materials in the areas of interest, even on a local scale. A clay layer was found to exist at several locations at depths of 15 to 25 feet. These clay layers, where present, may inhibit the vertical percolation of recharge water, reducing the overall recharge rate. Detailed drilling and analysis of the subsurface conditions was anticipated to be required at each potential recharge site to help determine specific geology and recharge design criteria.

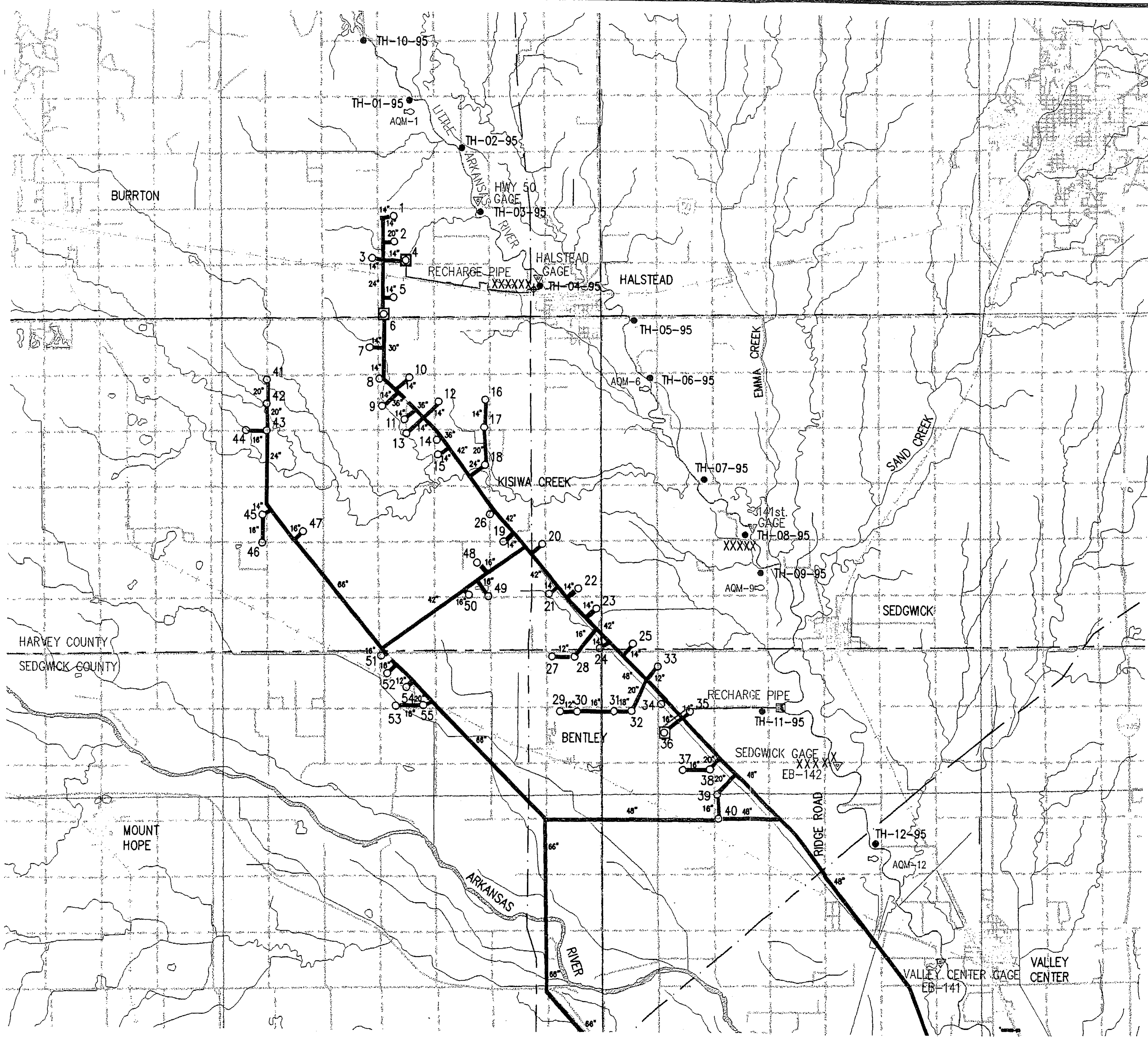
i. Public Involvement

Three project information meetings were held on September 26, 1995. The first two involved a slide presentation to the Wichita City Council and Wichita Chamber of Commerce. Question and answer periods followed each meeting. During the evening, a public information workshop was held in Halstead, Kansas. An introductory presentation was made, exhibits were presented, and Project questions and discussions were encouraged.

3. FACILITIES DESIGN AND CONSTRUCTION

Based on the work completed in the feasibility studies, two locations were selected for construction of the groundwater recharge demonstration facilities, as shown in Figure I-22.

J:\WICHITA\921954.014\NEWFIG\FIG-I-22.dwg 07-09-1999 11:07 AAO



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10000 0 10000 20000
SCALE IN FEET

LEGEND

- PIEZOMETER OR BORING LOCATION
- USGS DCP
- CITY OF WICHITA SUPPLY WELL
- RECHARGE PIPELINE
- PROPOSED PIPELINE
- RAILROAD
- XXX MONITORING WELL STRING
- SURFACE WATER INTAKE
- TEST WELL

NOTE:

DISTANCES SHOWN BETWEEN MONITORING WELLS IN WELL STRING ARE NOT TO SCALE.

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Figure I-22

DEMONSTRATION PROJECT FACILITIES LOCATION

The first system, referred to as the Halstead Recharge System, involves the capture of induced river water during periods of above-base flow from a diversion (or test) well near the Little Arkansas River at Halstead, Kansas. The main components of the Halstead System, as shown in Figure I-23, include the test well constructed during the feasibility studies, a water conveyance pipeline, two recharge basins, a recharge well, and a recharge trench.

The second system, referred to as the Sedgwick Recharge System, includes the capture of above-base flow surface water during periods of high river flow from a surface water intake in the Little Arkansas River near Sedgwick, Kansas. The main components of the Sedgwick System, as shown in Figure I-23, include a surface water intake, a packaged pre-sedimentation unit, water conveyance pipelines, a pre-sedimentation basin, and three infiltration basins.

Chemical treatment systems will be used at each recharge system. Chlorine can be fed as needed (during shutdown sequence) to control biological growths at the Halstead Recharge System. At the Sedgwick facility, polymer can be used to reduce turbidity in the river water as it passes through a parallel plate separator and powdered activated carbon (PAC) can be fed to remove atrazine and other herbicides. Chlorine can be used upstream of the parallel plate separator to oxidize minerals and downstream of the separator, when the PAC unit is off (during shutdown sequence), to control biological growth. Polymer may also be used at an earthen pre-sedimentation basin located near the recharge basins.

a. **Conveyance of Source Water Supply**

(1) Halstead Recharge System

The Halstead Recharge System is located at two sites connected by a pipeline. The diversion well site is located along the Little Arkansas River near Halstead as shown in Figure I-22. The main system components included at this site, as shown in Figure I-24, are the diversion (or test) well, a chlorine feed system, monitoring wells, and water conveyance pipeline.

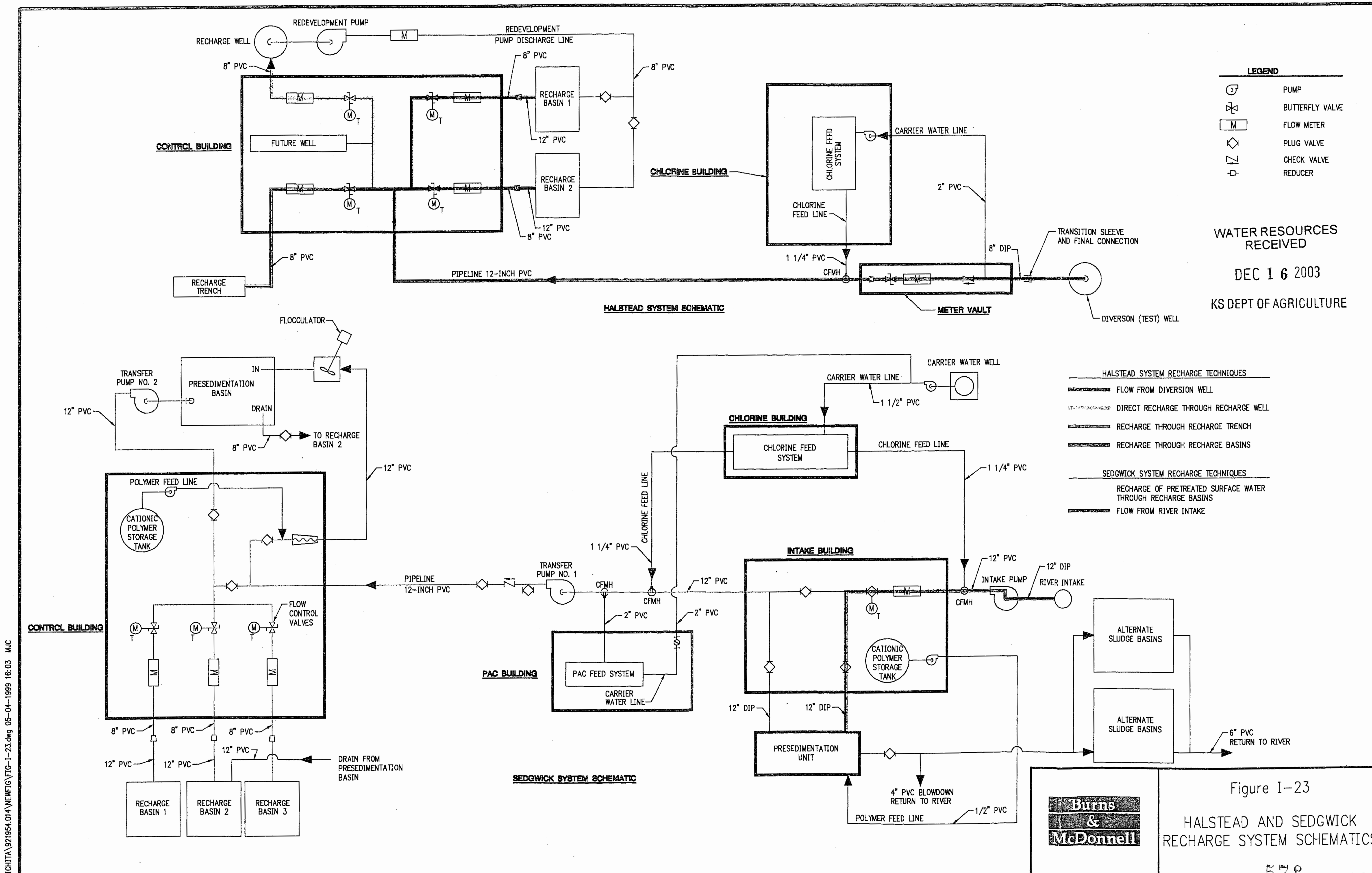
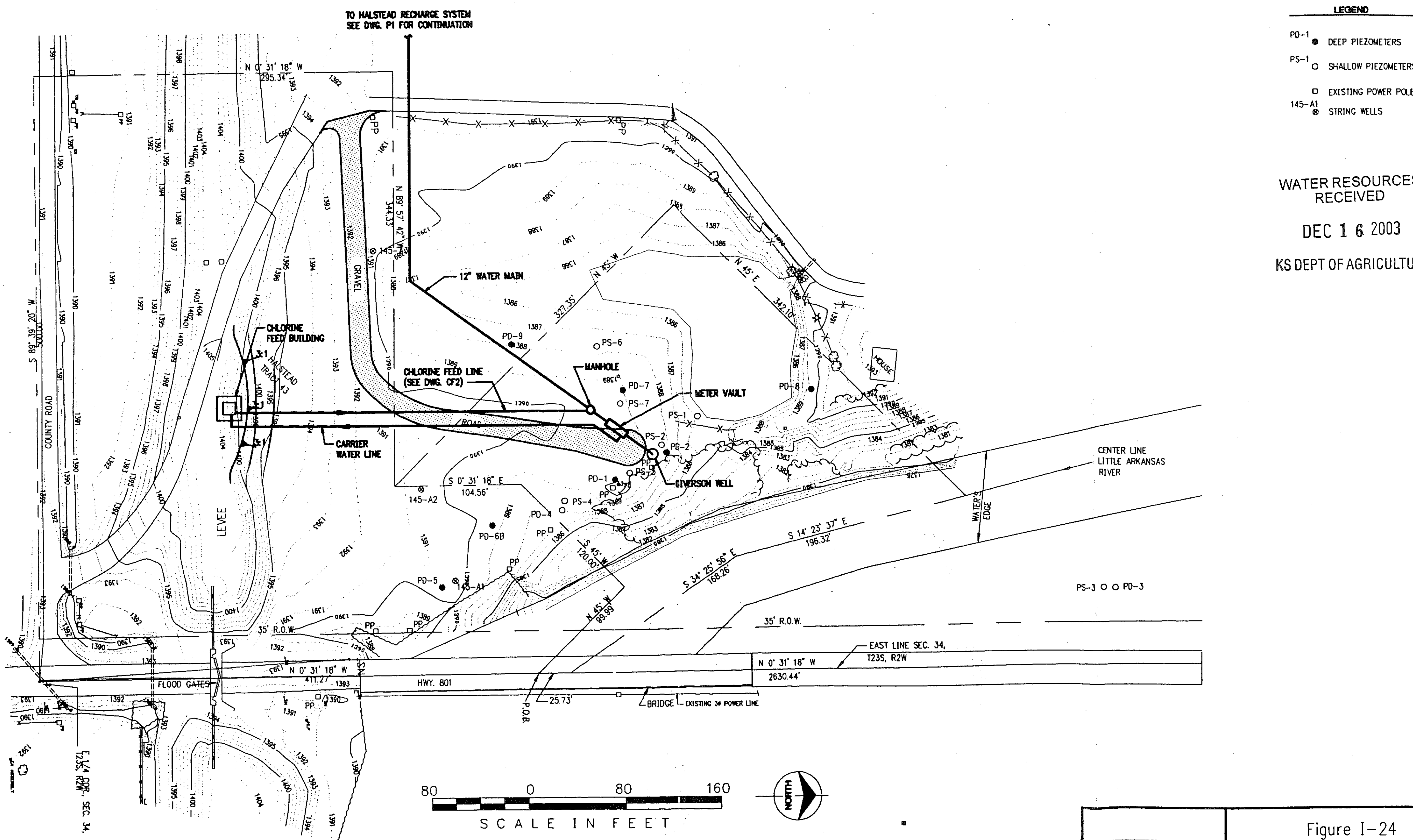


Figure I-23
HALSTEAD AND SEDGWICK RECHARGE SYSTEM SCHEMATICS

J:\WICHITA\921954.014\NEWFIG\FIG-I-24.dwg 07-09-1999 11:14 AAO



Burns & McDonnell

Figure I-24

HALSTEAD RECHARGE SYSTEM DIVERSION

Diversion Well

The diversion well shown in Figure I-20 conveys up to 1,000 gpm of induced infiltration water to the recharge facilities (recharge well, recharge basins, and recharge trench) located adjacent to City Supply Well No. 4. A submersible pump was installed in the well and a meter vault was installed adjacent to the test well, as shown in Figure I-24. The submersible pump and motor allow operation during flooding of the riverbank.

Chlorine System

The chlorine system is located in a building (Chlorine Feed Building) on the levee at the Halstead diversion well site. Chlorine is added to the system during the shutdown sequence. This minimizes degradation of the water quality in the pipeline between recharge events due to biological growth.

Monitoring Wells

There are seven shallow and nine deep monitoring wells located at the Halstead Recharge System diversion site. The location of these monitoring wells is shown in Figure I-19. A schematic of a typical monitoring well is shown in Figure I-14. Shallow monitoring wells range from 37 to 68 feet deep. The deep monitoring wells range from 115 to 140 feet deep. The string wells at this site were installed with pressure transducers and connected to the USGS data collection platform (DCP) for monitoring water levels. The string wells at this site are EB-145-A1 through EB-145-A5 and PD5.

Pipeline

Recharge water is conveyed through a 12-inch diameter PVC (C900) pipeline from the diversion well to the recharge site. The pipeline routing plan is shown in Figure I-25.

(2) Sedgwick Recharge System

The Sedgwick Recharge System is located at two sites connected by a pipeline as shown in Figure I-22. The surface water intake site is located on the Little Arkansas

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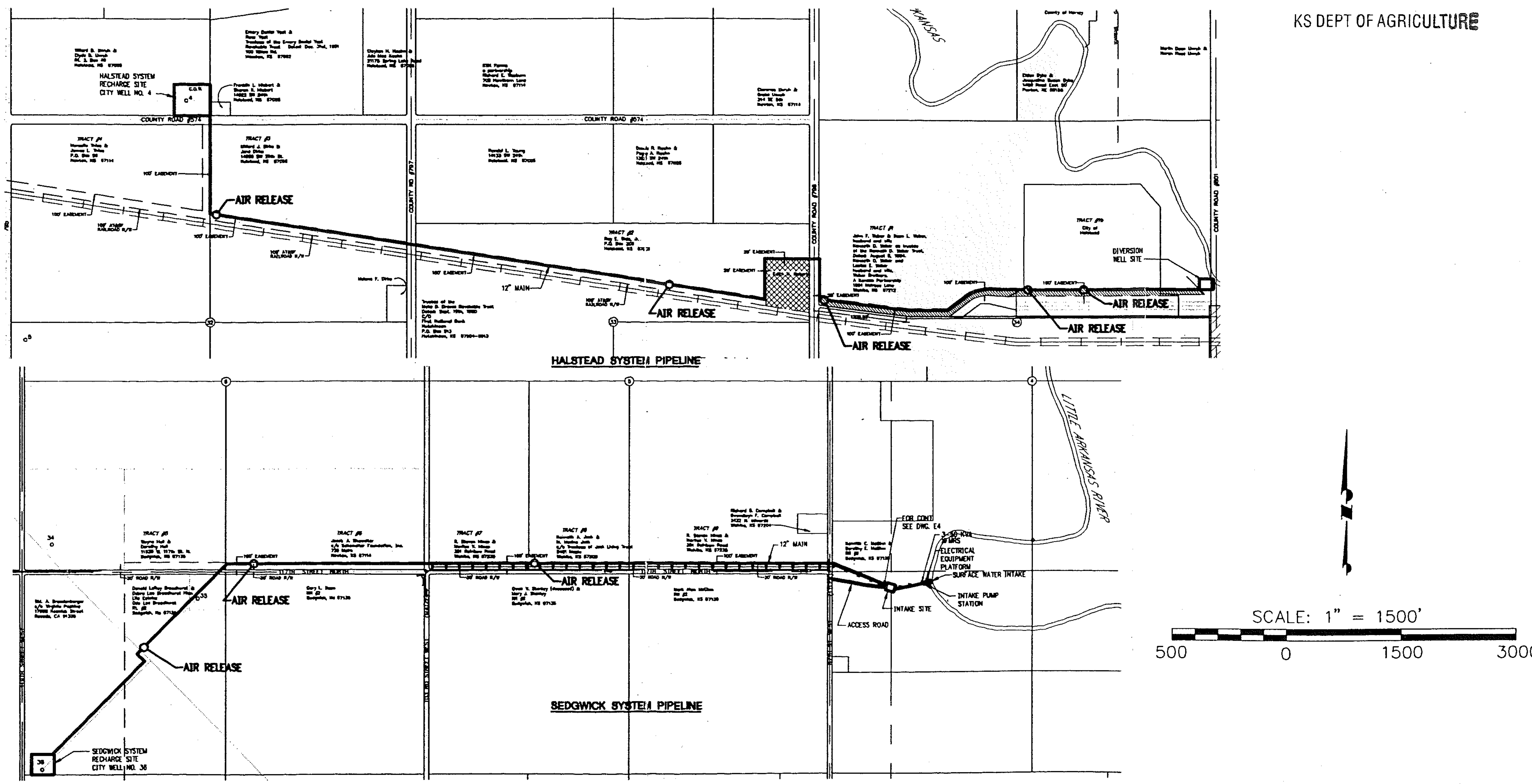

LEGEND

o AIR RELEASE

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Figure I-25

PIPELINE ROUTING PLANS

WICHITA\921954.014\NEWFIG\ FIGI-25.dwg 05-06-1999 15:52 MJC

River near Sedgwick. The main system components included at this site, as shown in Figure I-26, are a surface water intake, an intake building, a pretreatment unit (parallel plate separator), a carrier well, a polymer feed system, a powdered activated carbon (PAC) feed system, a chlorination system, a transfer pump, and a water conveyance pipeline.

Surface Water Intake

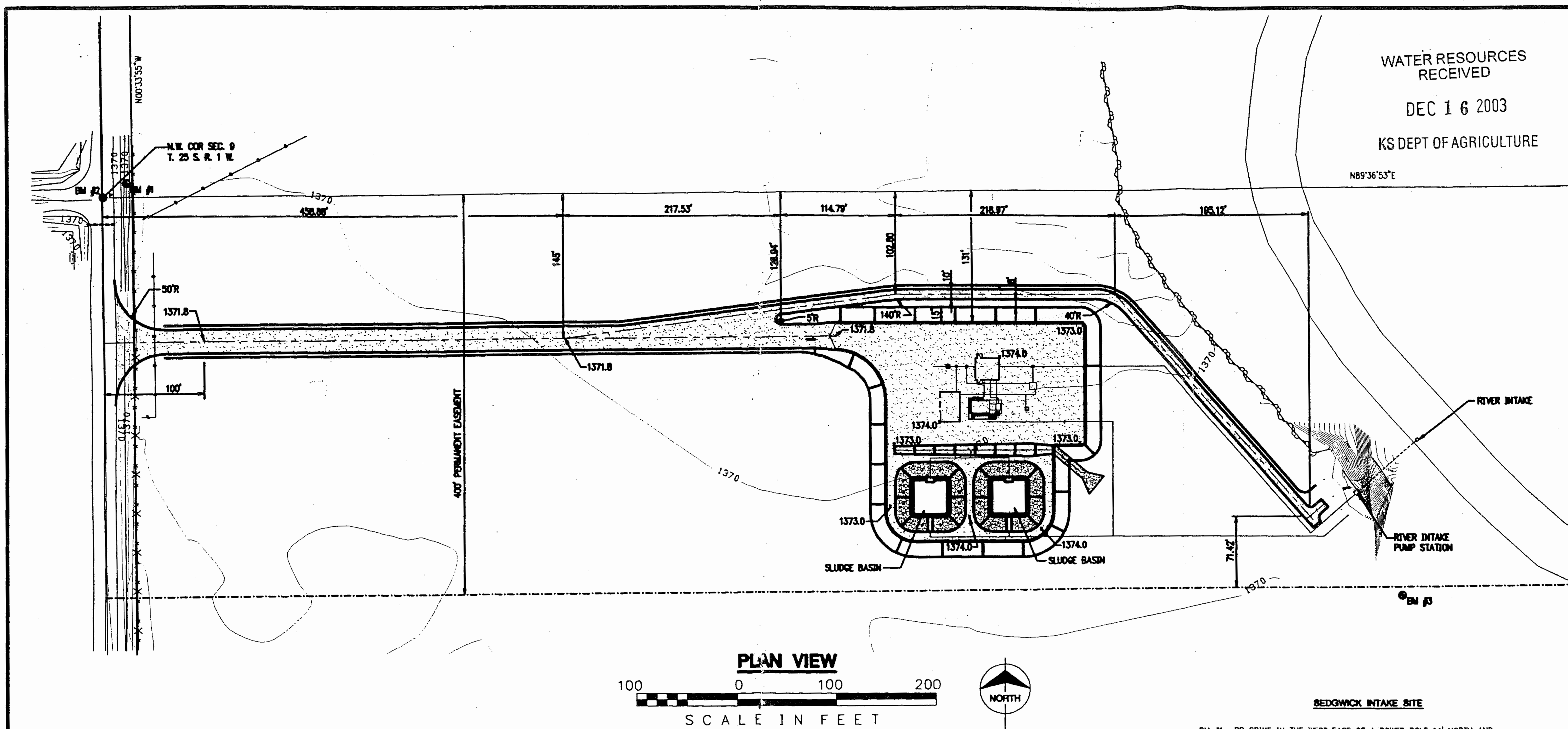
A cross-section of the Surface Water Intake and Pump Station is shown in Figure I-27. The intake diverts water from the Little Arkansas River at rates of up to 1,000 gpm. The water is conveyed through the water intake station through the pretreatment units. The intake screen is located in the river approximately 10 feet from the river's edge. A submersible pump is located approximately 60 feet from the intake screen.

Intake Building

Water is pumped from the Surface Water Intake to the Intake Building where the flow is measured. The layout of the Intake Building is shown in Figure I-28. Flow may be diverted to a packaged pretreatment unit or continue directly to the recharge site. Also contained within the building is the storage tank for polymer and a sampling facility composed of sample piping, sink, and table.

Pretreatment Unit (Parallel Plate Separator)

The pretreatment unit is shown in Figure I-28 with the Intake Building. This unit is a Lamella Gravity Settler and includes rapid mix and flocculation chambers. These units improve coagulation and removal of river water turbidity to less than 30 NTU for efficient recharge. Polymer will be added to the surface water at the rapid mixer. Low doses of chlorine can also be added ahead of the rapid mixer to oxide the minerals and improve settling characteristics. The water will then be flocculated and settled and flow by gravity to Transfer Pump 1 for conveyance to the City Supply Well No. 36 site (recharge site). Residuals will be blown down to sludge lagoons on intermittent basis to maintain a sludge blanket in the unit which improves particle removal.



SEDGWICK INTAKE SITE

BM #1 RR SPIKE IN THE WEST FACE OF A POWER POLE 14' NORTH AND 24' EAST OF THE NORTHWEST CORNER OF SECTION 9, T 25 S, R 1 W. ELEVATION 1371.27

BM #2 TOP OF 3/4" PIPE AT THE NORTHWEST CORNER OF SECTION 9, T 25 S, R 1 W. ELEVATION 1370.38

BM #3 TOP OF GALVAVIZED PIPE WITH MID-KANSAS ID CAP SET 400' SOUTH AND 1294' EAST OF THE NORHTWEST CORNER SECTION 9, T 25 S, R W 1. ELEVATION 1369.86

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Figure I-26

SEDGWICK RECHARGE SYSTEM
INTAKE SITE PLAN

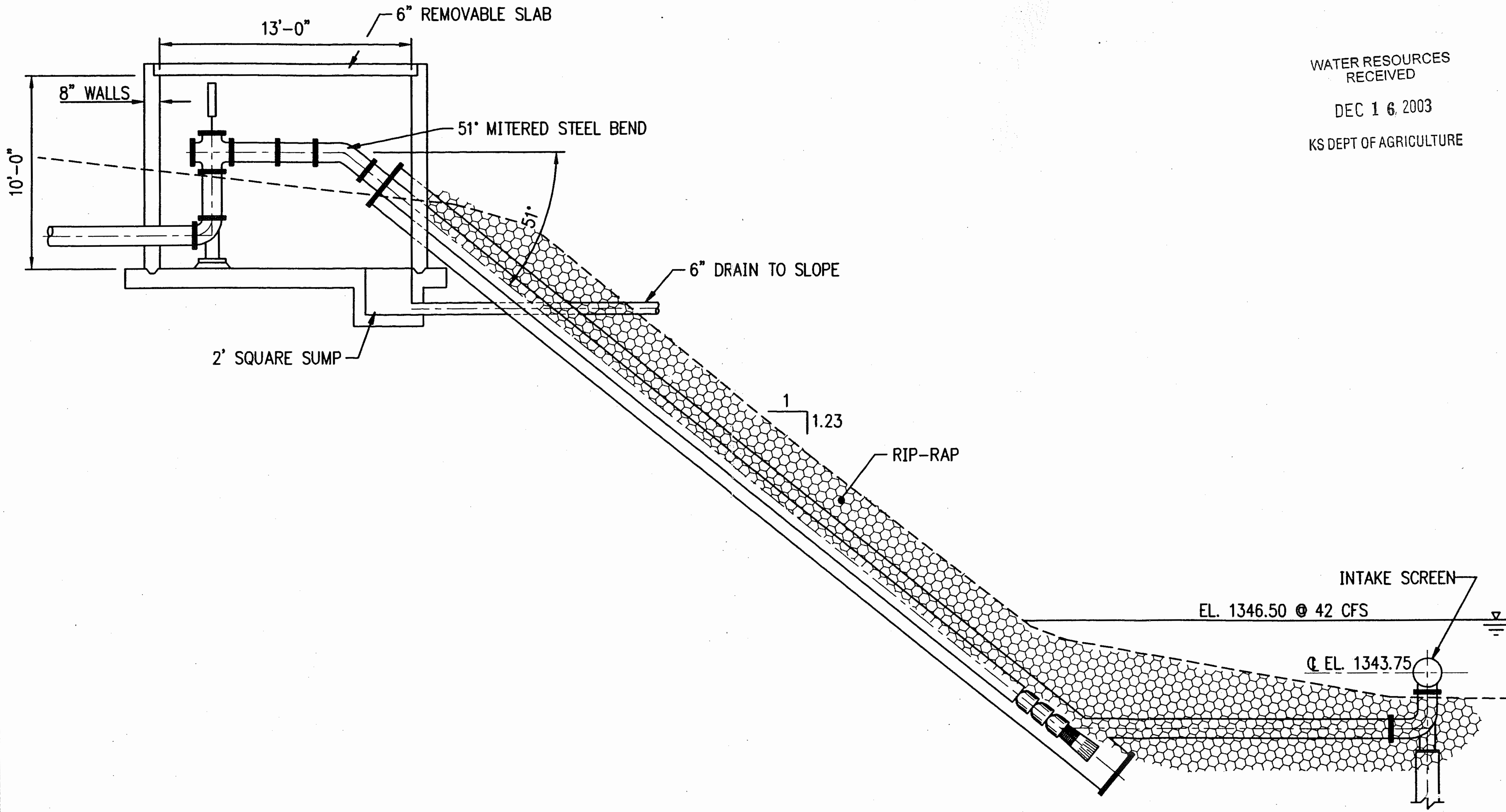

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Figure I-27

SEDGWICK RECHARGE SYSTEM
INTAKE FACILITY

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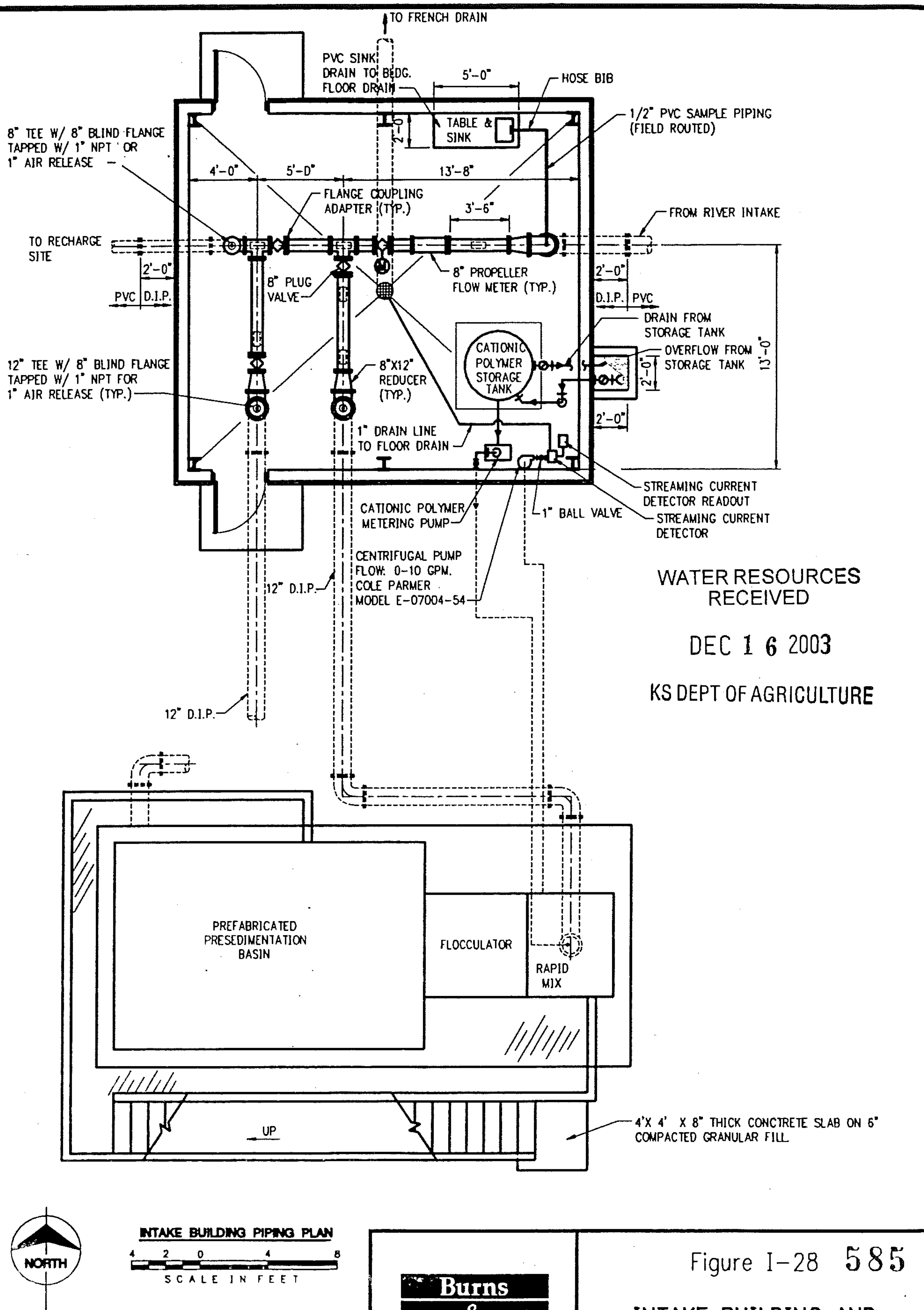

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Figure I-28 585

INTAKE BUILDING AND PRESEDIMENTATION BASIN

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Carrier Well

One carrier well is installed at the Sedgwick Recharge System diversion site. This well conveys up to 30 gpm of water that is used to mix chlorine and/or PAC for the treatment process.

Polymer Feed System

Polymer is added to the pretreatment unit to help settle the river solids. Cationic polymer addition will be paced off a streaming current detector. A non-ionic polymer may also be added at low doses with the cationic polymer to improve solids removal.

Chlorine System

Chlorine can be fed upstream of the parallel plate separator to oxidize minerals and downstream of the separator, when the PAC unit is off (during shutdown sequence), to control biological growth.

PAC System

PAC is added upstream of Transfer Pump 1 to absorb atrazine that may be in the river water. The PAC utilizes the 1.5 hours of travel time in the 12-inch pipeline to the recharge site to maximize adsorption.

Transfer Pump 1

Transfer Pump 1 is located at the Sedgwick surface water diversion site. Water is conveyed at a rate of about 1,000 gpm via this submersible pump to City Supply Well No. 36 site for additional treatment and recharge.

Pipeline

Recharge water is conveyed through a 12-inch diameter PVC C900 pipeline from the intake to the recharge site. The pipeline routing plan is shown in Figure I-24.

b. Description of Recharge System Components

(1) Halstead Recharge System

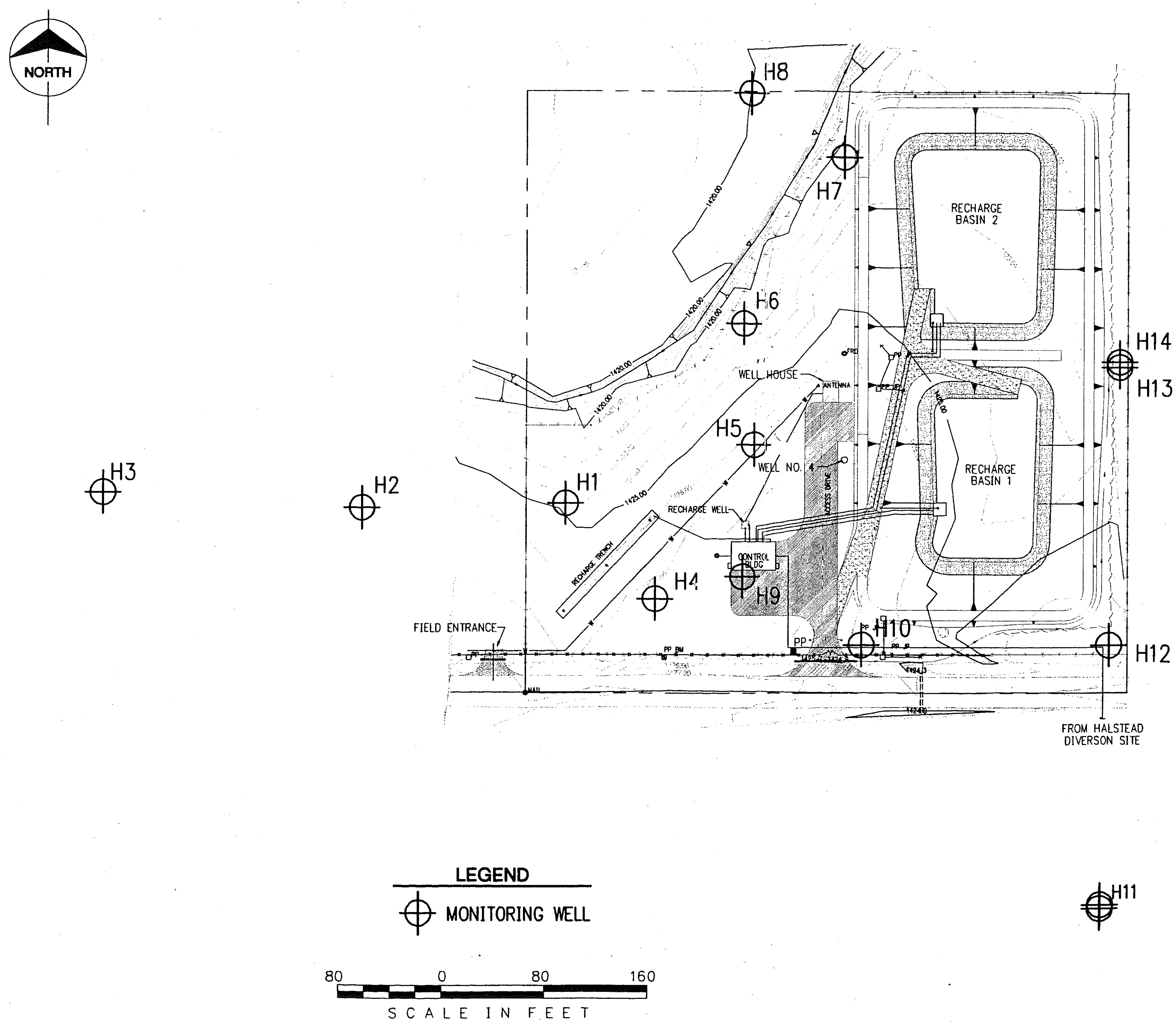
The Halstead recharge site is located at City (Wichita) Supply Well No. 4 and is shown in Figure I-29. The facilities located at this site include a recharge well with redevelopment pump, two recharge basins, a recharge trench, a control building, and monitoring wells.

Recharge Well

One recharge well (or test well) is installed at Wichita City Well No. 4 property. Water is introduced to the recharge well through three different size recharge tubes embedded in three 4" casing pipes, as shown in Figure I-30. The tubes are designed to maintain full pipe flow so that water will not cascade, causing oxidation of the minerals resulting in plugging of the screens. The three separate pipe sizes will allow a range of recharge flow rates. Pipes may be used in combination or individually to maintain a specified flow rate. The tested recharge tubing rates are shown below; however, these rates may vary with changing ground water levels or when flow is partly diverted to the trench or basins.

Tube Size (inches)	Minimum Flow (gpm)	Maximum Flow (gpm)
2	190	295
2-1/2	270	420
3	430	600

The well is designed to recharge approximately 1,000 gpm. A cross-section of the recharge well is shown in Figure I-31. Instrumentation for water level monitoring enters the well through a fourth 4" casing pipe, as shown in Figure I-31. The well is equipped with a 1,500-gpm redevelopment pump which is used to periodically remove sediment and deposits that accumulate during recharge operations to maintain high recharge efficiency.



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J:\WICHITA\921954.014\NEWFIG\FIGI29.dwg 07-09-1999 11:16 AAO

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Figure I-29

HALSTEAD RECHARGE SYSTEM
RECHARGE SITE PLAN

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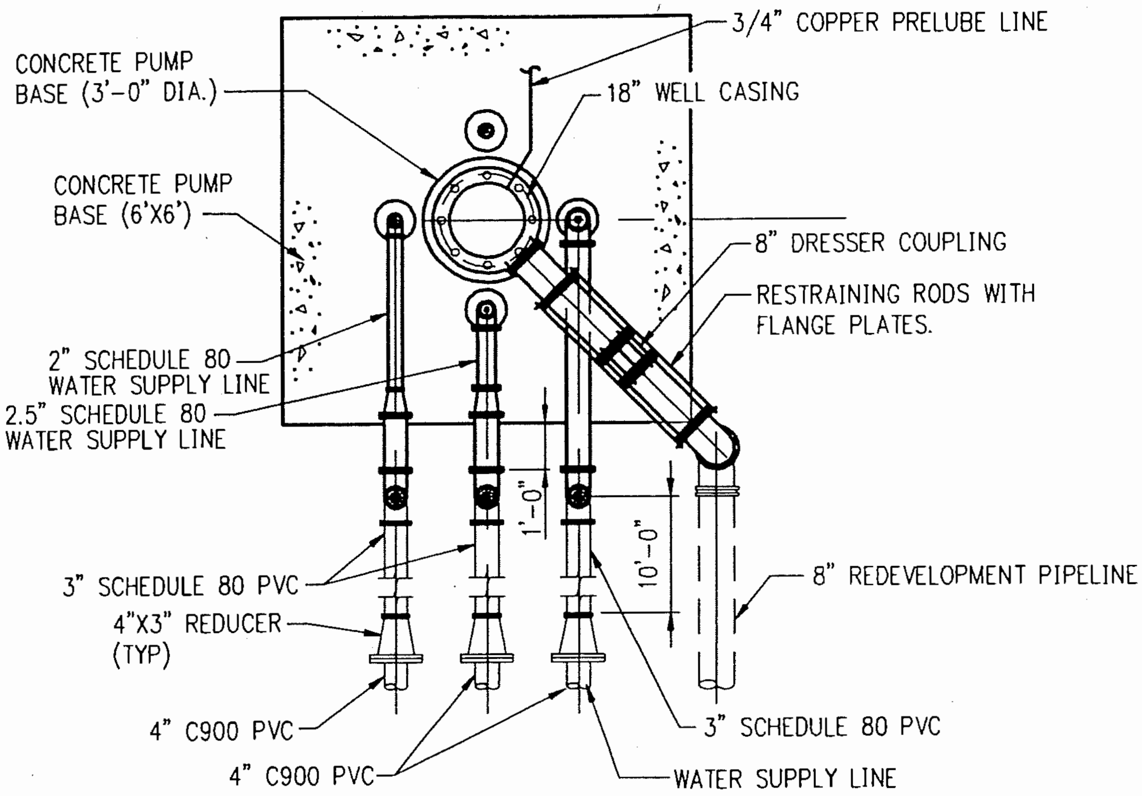

J:\WICHITA\921954.014\NEWFIG\FIGI-30.dwg 05-06-1999 15:58 MJC

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Figure I-30

PLAN VIEW OF RECHARGE WELL

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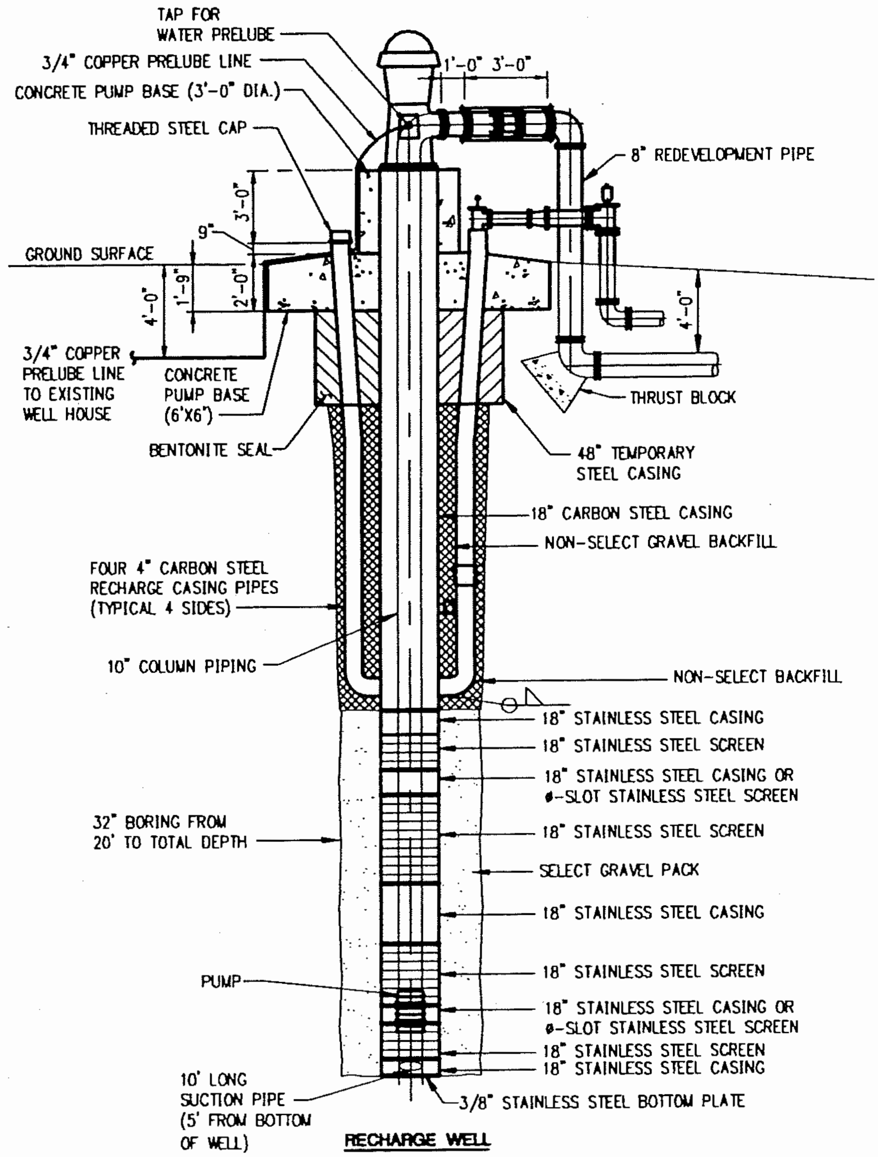

J:\WICHITA\921954.014\NEWFIG\FIGI-31.dwg 05-06-1999 09:09 MJC

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Figure I-31

CROSS SECTION OF RECHARGE WELL

Recharge Basins

The north and south recharge basins at the Halstead site have respective bottom areas of 0.35 and 0.20 acres. The recharge basins have natural sand bottoms and riprap side slope protection. Each basin has a gravel access ramp to allow maintenance of the bottom surface.

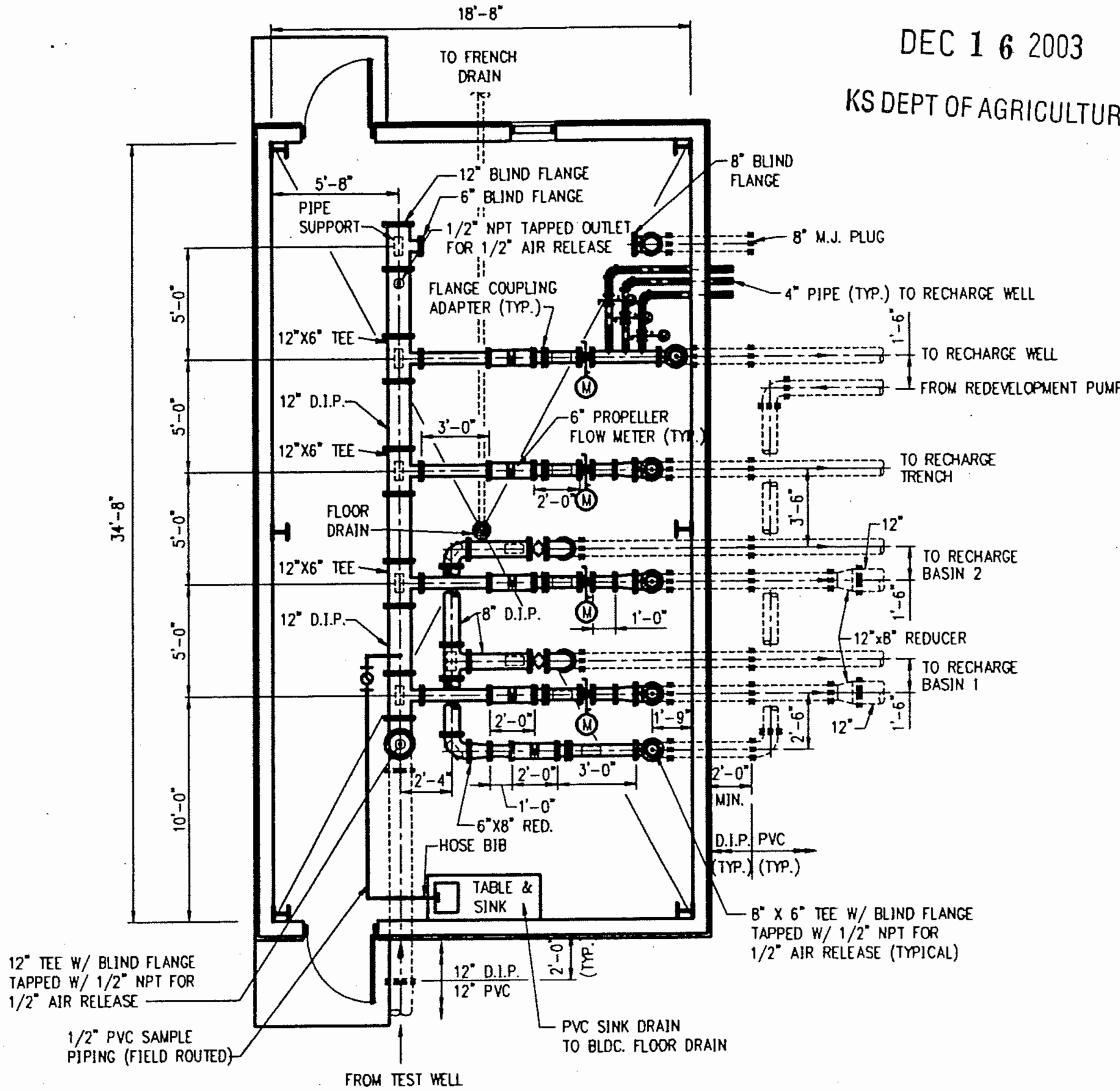
Initial testing showed the total recharge rate for the two basins to be about 150 gpm or 1 to 2 feet per day. Initial recharge rates could be higher than long-term event recharge rates due to a combination of saturation of the upper aquifer zone, biofouling, and physical plugging. Periodic drying of the basins is expected to provide primary control of the biofouling by killing the algae and allowing shrinkage to reestablish desirable infiltration rate. When recharge rates decrease to an unacceptable rate, the basins are taken out of service for drying. Flow can be directed to the other basin or the other recharge facilities. Typically, recharge events last no longer than 7 to 14 days, depending on availability of above-base flow in the Little Arkansas River. Periods between recharge allow basin drying, restoring infiltration rates.

Recharge Trench

The trench is 3-foot wide and 100-foot long and is constructed of coarse sand covered with a filter fabric to allow high infiltration rates through the surface clay layer. It is designed for a flow rate of approximately 120 gpm. A cover is installed over the trench to reduce potential for algal growth and to secure the facility.

Control Building

The layout of the Halstead Recharge Site Control Building is shown in Figure I-32. Water piped from the diversion site enters the building from the east. Within this structure, control valves can direct the water to the recharge well, recharge trench, or to recharge basins 1 and 2. As shown in the drawing, there are 4 pipelines to the recharge well. The pipe or pipes used depend on the flow rate diverted to the well. Also included in the building is a sampling line, sink, and table. Monitoring equipment located in the building are a turbidimeter, conductivity meter, and water



CONTROL BUILDING PIPING PLAN

J:\WICHITA\921954.014\NEWFIG\figi-32.dwg 05-06-1999 16:19 MJC

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Figure I-32

HALSTEAD RECHARGE SITE CONTROL BUILDING

temperature gage. Displays of system status and operation conditions are l.)cated on the south wall.

Monitoring Wells at the Halstead Recharge Site

There are 15 monitoring wells and piezometers at or near the Halstead Recharge Site as shown in Figure I-29. Six monitoring wells (four deep and two shallow) are instrumental with the SCADA system for continuous monitoring. These wells are included in the Water Quality Sampling plan. There are seven additional off-site piezometers provided to obtain manual depth to water measurements.

(2) Sedgwick Recharge System

The Sedgwick recharge site is located at City Supply Well No. 36 and is shown in Figure I-33. The facilities located at this site include a pre-sedimentation basin (earthen basin), Transfer Pump 2, three recharge basins, a control building and monitoring wells.

Pre-sedimentation Basin

The earthen basin, as shown in Figure I-33, is used to allow the PAC to settle out of the recharge water. Due to the small size of the PAC, less than 45 microns, it must be allowed to settle and be removed as to prevent clogging of the recharge basins.

This unit is also equipped with a static mixer, flocculator and polymer feed to remove river solids if the pretreatment unit at the intake is bypassed. The polymer feed can be paced off by a streaming current detector.

Transfer Pump 2

This submersible-type pump transfers pre-sedimentation basin effluent to the recharge basins.

Recharge Basins

The northeast, southeast, and southwest recharge basins at the Sedgwick Recharge Site have bottom respective areas of about 0.42, 0.42 and 0.49 acres. The basins have

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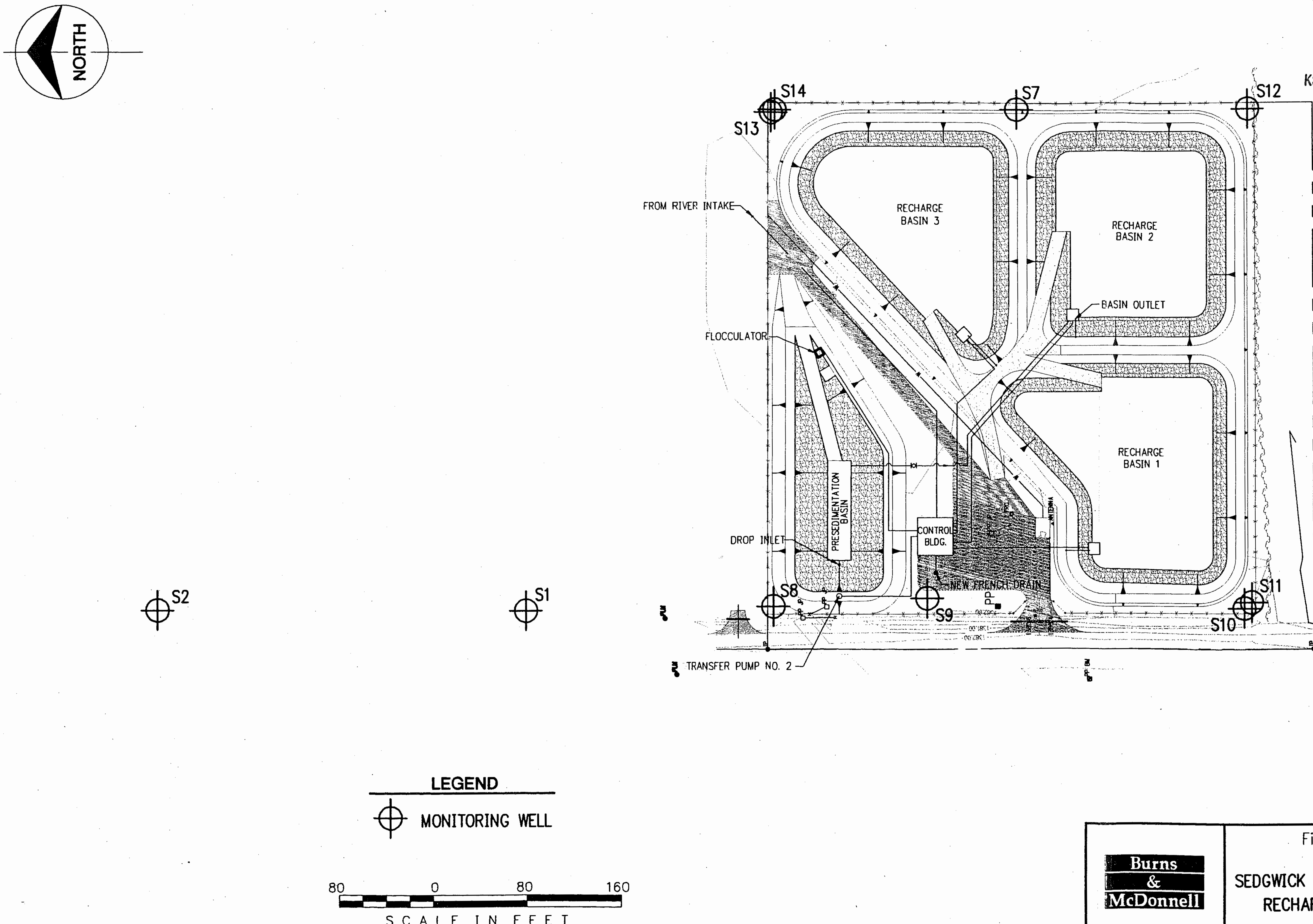

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Figure I-33

SEDGWICK RECHARGE SYSTEM
RECHARGE SITE PLAN

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natural sand bottoms and side slope protection, which consists of a geotextile fabric and riprap lining. Each basin has a gravel access ramp to allow maintenance of the bottom.

Control Building

The layout of the Sedgwick Recharge Site Control Building is shown in Figure I-34. Water piped from the diversion site enters the building from the east. Within this structure, the water can be diverted to the pre-sedimentation basin or directly to any of the three recharge basins. Also included in the building is the polymer storage tank, sampling line, sink, and table. Monitoring equipment located in the building are a turbidimeter, conductivity meter, and water temperature gage. Displays of system status and operation conditions are located on the west wall.

Monitoring Wells

There are 10 monitoring wells and piezometers at or near the Sedgwick recharge site, as shown in Figure I-33. Some of these monitoring wells are instrumental with the SCADA system for continuous monitoring. These wells are included in the Water Quality Sampling Plan. The other piezometers are provided to obtain manual depth to water measurements.

D. OPERATIONS AND MONITORING

1. RECHARGE OPERATIONS

Recharge operations at the Halstead Recharge System began on May 23, 1997 with the two basins and the recharge trench and on August 26, 1997 with the recharge well. Subsequently, operational tests of all three recharge components of the Halstead Recharge System were conducted through the remainder of 1997 and continued through the end of 1999.

The term permit from the Kansas Division of Water Resources for the diversion (test) well at the Halstead System establishes minimum flow in the Little Arkansas River for operation of 42 cfs or 20 cfs, depending on the season. A graph of Little Arkansas River stage at Highway 50

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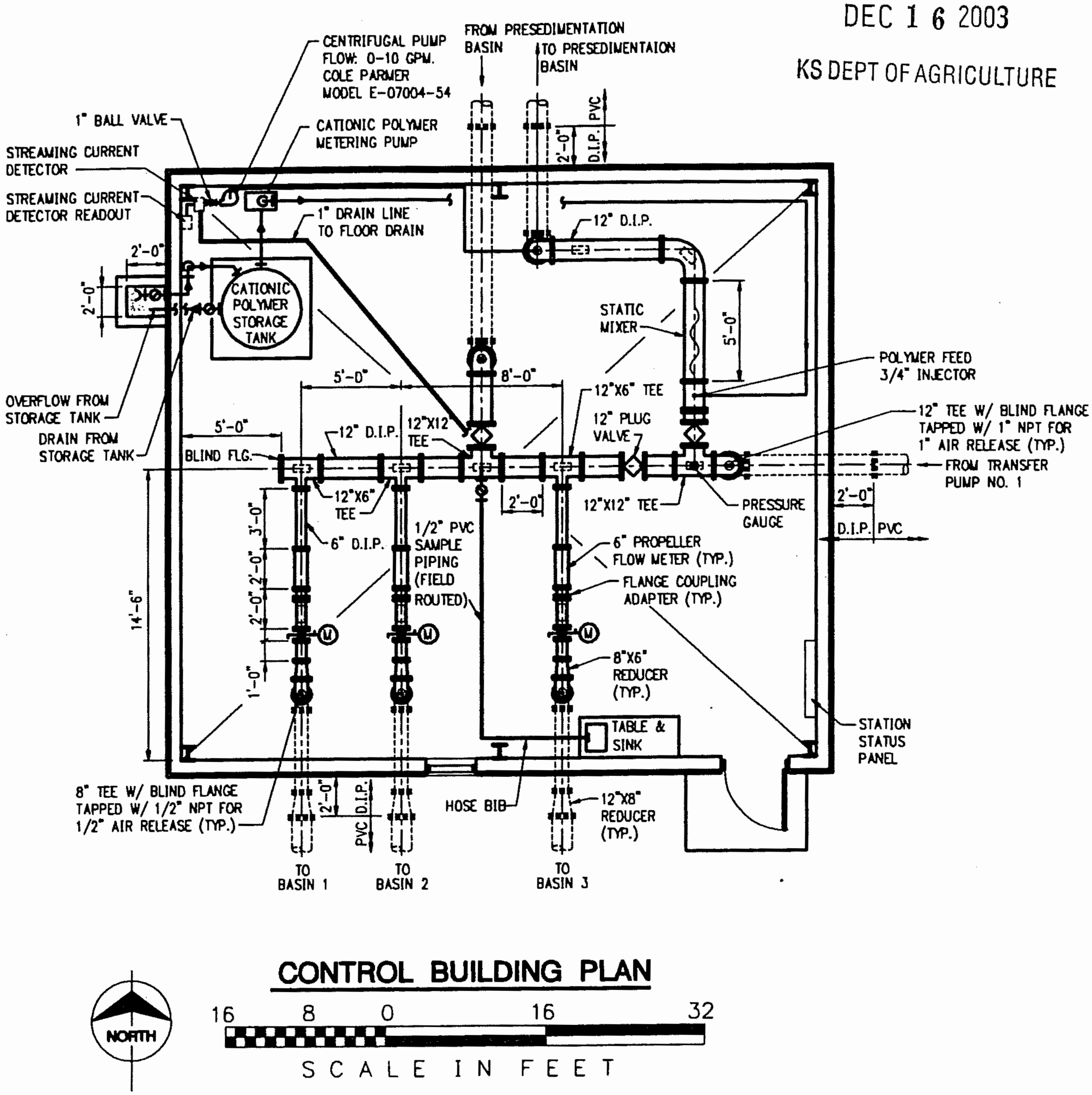

CONTROL BUILDING PLAN

WICHITA\921954.014\NEWFIG\ Figi-34.dwg 05-06-1999 09:24 MJC

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Figure I-34

SEDGWICK RECHARGE SITE
CONTROL BUILDING

from the start of system operation through the end of 199) is shown in Figure I-35. The graph also shows the minimum stage limit for operation. Stages for the summer and winter flow limits according to the 1999 USGS rating table for the gage are as follows:

	Flow (cfs)	River Stage (feet)
Summer minimum (April - September)	42	6.49
Winter minimum (October - March)	20	6.07

Current stage information can be obtained by use of a telephone connection to the gage and from the Kansas USGS "real-time" Internet web page (http://www-ks.cr.usgs.gov/kansas/equus.). The Equus Recharge Project web page also provides historic and current water quality information.

Figure I-36 shows groundwater levels in selected monitoring wells and the river stage near the diversion well near Halstead. The river stage at Highway 50 is also shown on this figure, as this gage dictates the minimum stage for system operation. The monitoring wells are part of the line of monitoring wells perpendicular to the river that were installed to evaluate river-aquifer interaction. River stage and groundwater level data is collected by the USGS data collection platform (DCP) at the site and transmitted by satellite to the main computer database in Lawrence, Kansas. The "hydrologic connection" between the river and aquifer is clearly shown by the response of groundwater levels to storm events. Operation of the diversion well is clearly shown by drawdowns in the monitoring well data. Additionally, good communication between the upper and lower aquifer zones near the river is indicated by the parallel movement of gage levels in both shallow and deep monitoring wells.

The term permit from the Kansas Division of Water Resources for the diversion (test) well at the Sedgwick System establishes minimum flow in the Little Arkansas River for operation of 40 cfs. River stage for this flow limit according to the 1999 USGS rating table for the gage is 3.62 ft. Operation of the Sedgwick Recharge System was initiated in October 1997. The system was operated on a limited basis during that year before being shutdown for the winter. Recharge operations and system testing at the Sedgwick Recharge System was continued in

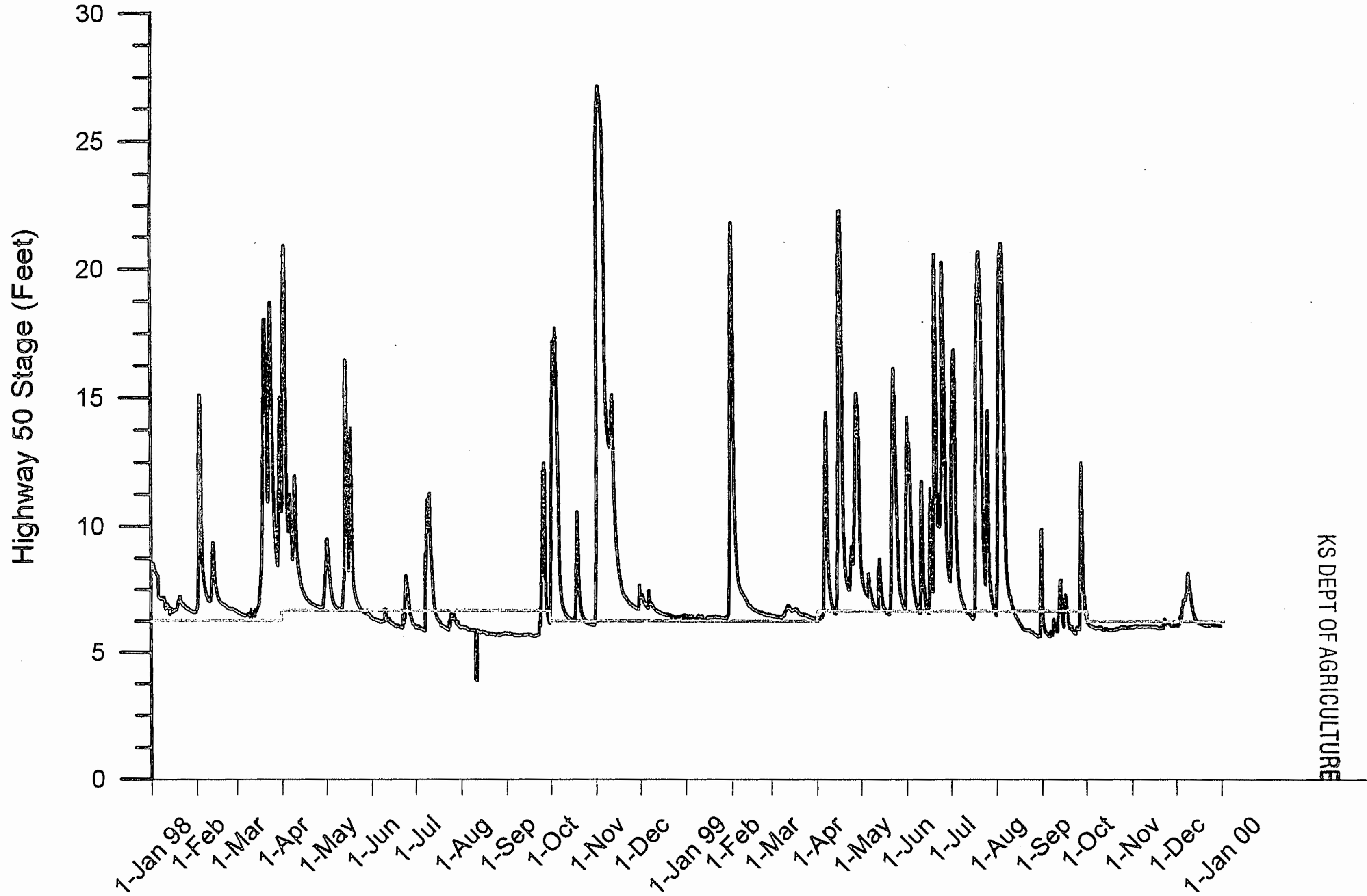

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Figure I-35
RIVER STAGE AND PERMIT LIMITS

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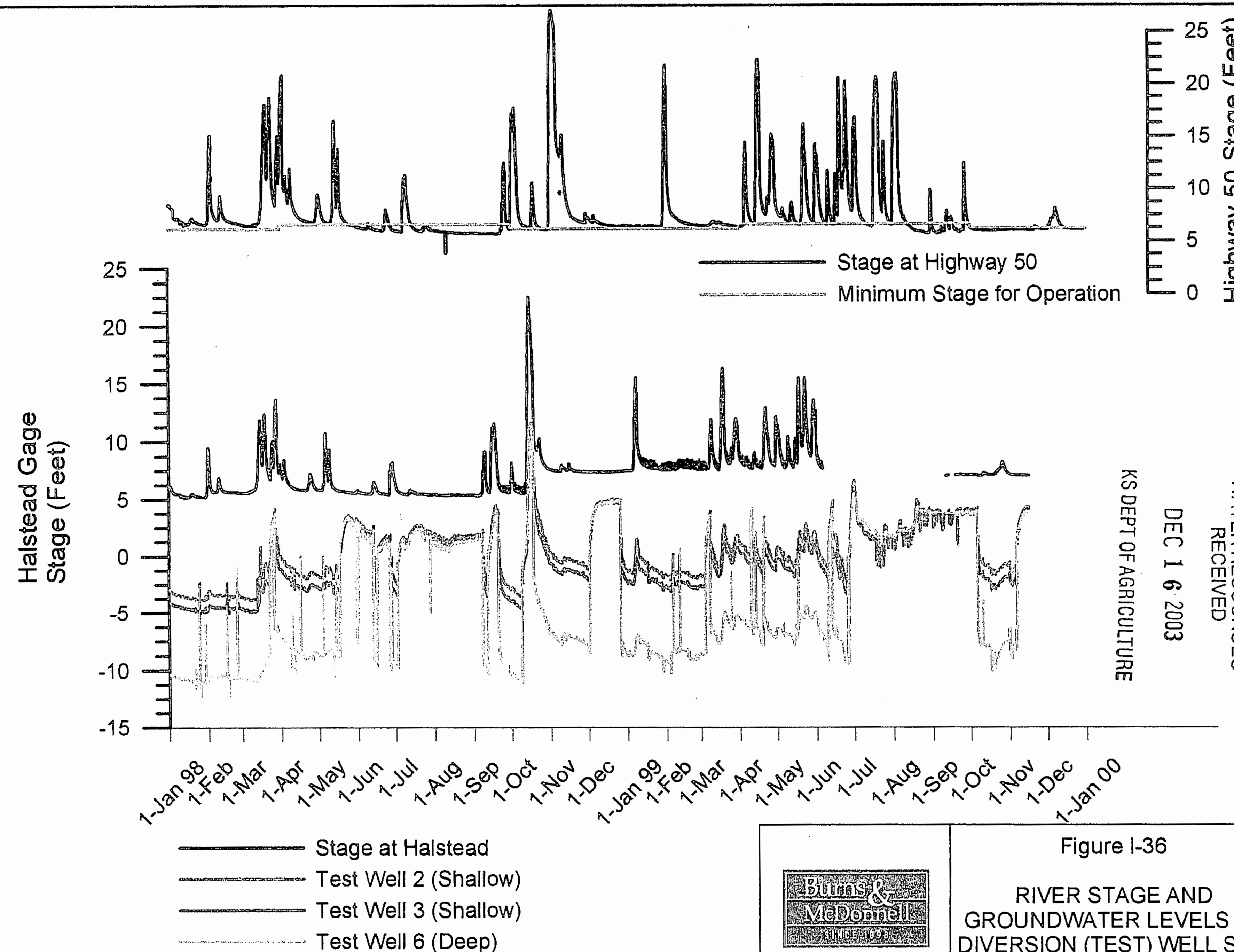

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Figure I-36

RIVER STAGE AND GROUNDWATER LEVELS AT DIVERSION (TEST) WELL SITE NEAR HALSTEAD

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J:\WICHITA\921954.016\DATA\STG98_99.GRF 04/12/00 years 1998 and 1999 when the river stage was above 40 cfs at the Sedgwick gage. Figure I-37 shows a graph of Little Arkansas River stage at Sedgwick from the start of system operation through the end of 1999.

A summary of system recharge operations through the end of 1999 for both systems is shown in Table I-6. The amount of recharge water lost due to evaporation at the recharge basins is estimated to be negligible at both sites. Based on an average annual evaporation rate of 54 inches and an average annual basin operation time of 4 to 5 months, the water volume lost due to evaporation through the end of 1999 is estimated in approximately 0.7 to 0.8 million gallons at the Halstead Site and 1.2 to 1.5 million gallons at the Sedgwick site. This evaporation volume represents less than one percent of the total volume recharged.

Table I-6

Equus Beds Recharge Demonstration Project

Recharge Volume through 1999

Halstead Recharge System	
North Basin	9,496,000
South Basin	39,898,700
Recharge Trench	5,802,100
Recharge Well	579,707,600
Total	634,904,400 gallons
Sedgwick Recharge System	
Southwest Basin	60,138,900
East Basin	44,696,200
North Basin	19,639,400
Pre-sedimentation Basin	23,859,800
Total	148,334,300 gallons
Total through Dec. 1999:	783,238,700 gallons (2,404 acre-feet)

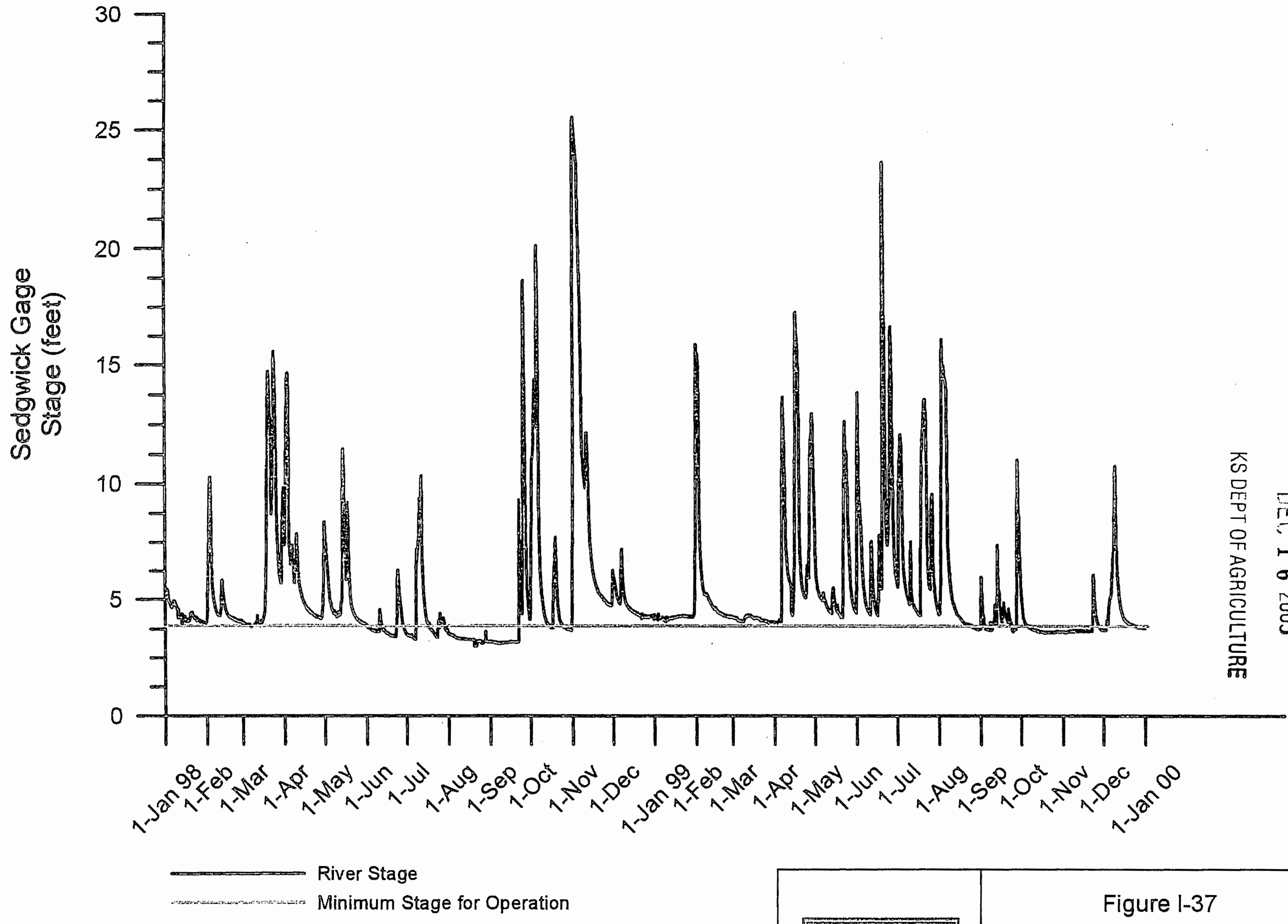

Figure I-37

RIVER STAGE AND
PERMIT LIMITS
SEDWICK INTAKE SITE

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Recharge tests were conducted by manual (non-automated) operation of the system by Wichita wellfield personnel in coordination with the Engineer and Contractor through February 1998. Efforts included system startup and shutdown, daily water level measurements, installation of temporary high level alarms, and 24-hour monitoring during specific operations. Since March 1998, the supervisory control and data acquisition (SCADA) system with associated instruments and controls became operational and allowed automated operation of the recharge systems during the rest of the demonstration period.

Figures I-38 and I-39 show the cumulative recharge volume through the end of 1999 at the respective Halstead and Sedgwick sites. Average daily recharge rates for the Halstead and Sedgwick recharge facilities, respectively, are approximately 670,000 gallons per day and 180,000 gallons per day for the entire period of project operation.

2. MONITORING PROGRAM

a. Description of Program Development

The Recharge Monitoring Program is based on the concept of diverting water from the Little Arkansas River to the Equus Beds Well Field for recharge only when the river is at "above-base" flow stages. The rate and quantity of recharge for all the different units must be monitored by maintaining a water balance in each component of the recharge facilities and by periodically determining the addition to groundwater storage through observation and piezometer water level measurements. The collection of water-balance data includes volumetric determination of system inflow and outflow amounts.

At the Halstead and Sedgwick Systems, respectively, the diversion well pump and the river intake pump are activated by the control system when an above-base flow event occurs, as measured by the respective USGS gaging station. The diversion well and the river intake pumps are shut down when the event ends. The total volume of surface water diverted at the Sedgwick Site is metered at the surface water intake, while the volume of groundwater diverted at the Halstead Site is metered at the recharge units. Each recharge unit at both recharge sites have a separate water meter and water level indicator so that detailed information about basin, well or trench inflow and change of storage can be determined.

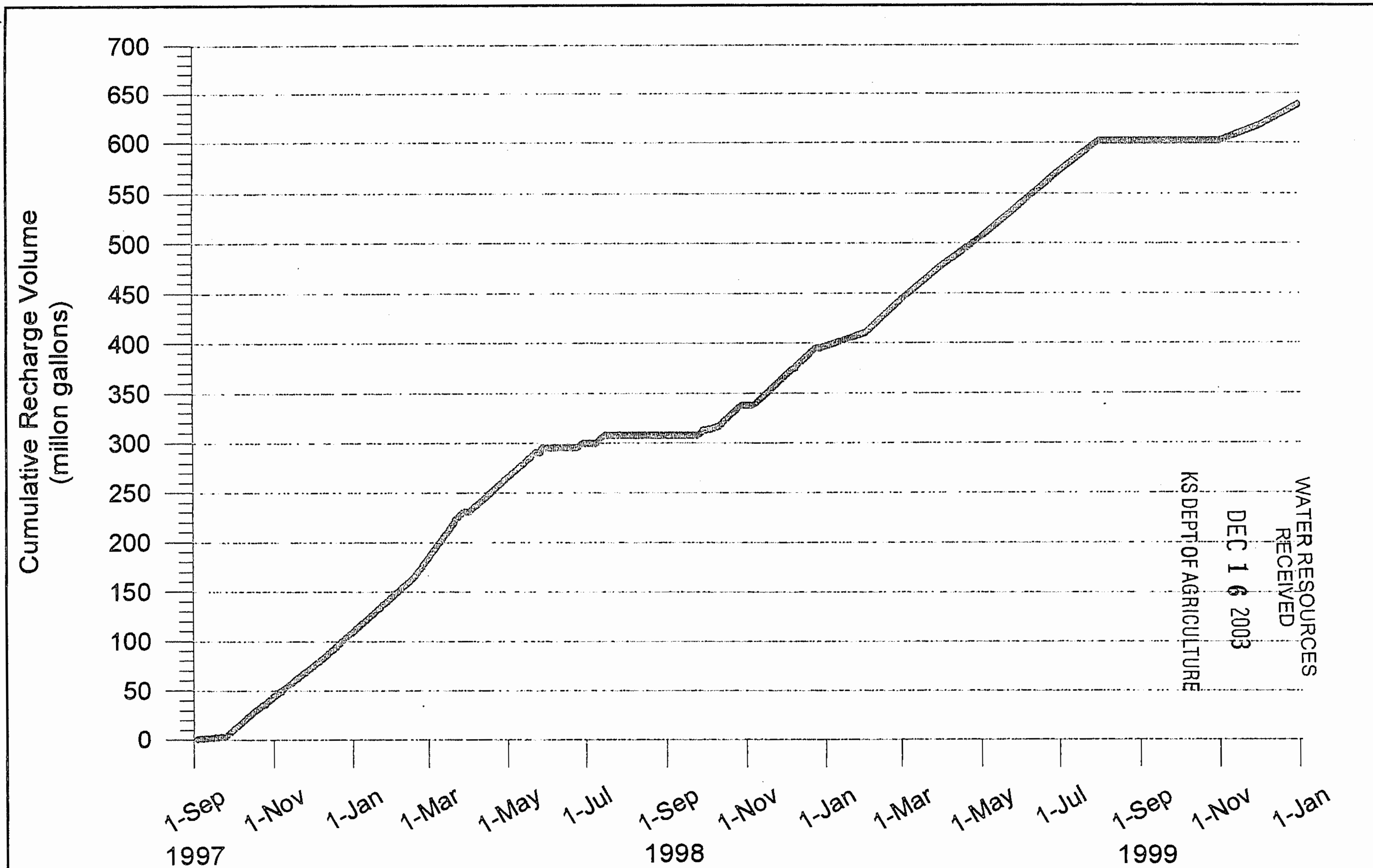

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Figure I-38

HALSTEAD RECHARGE SITE CUMULATIVE RECHARGE VOLUME

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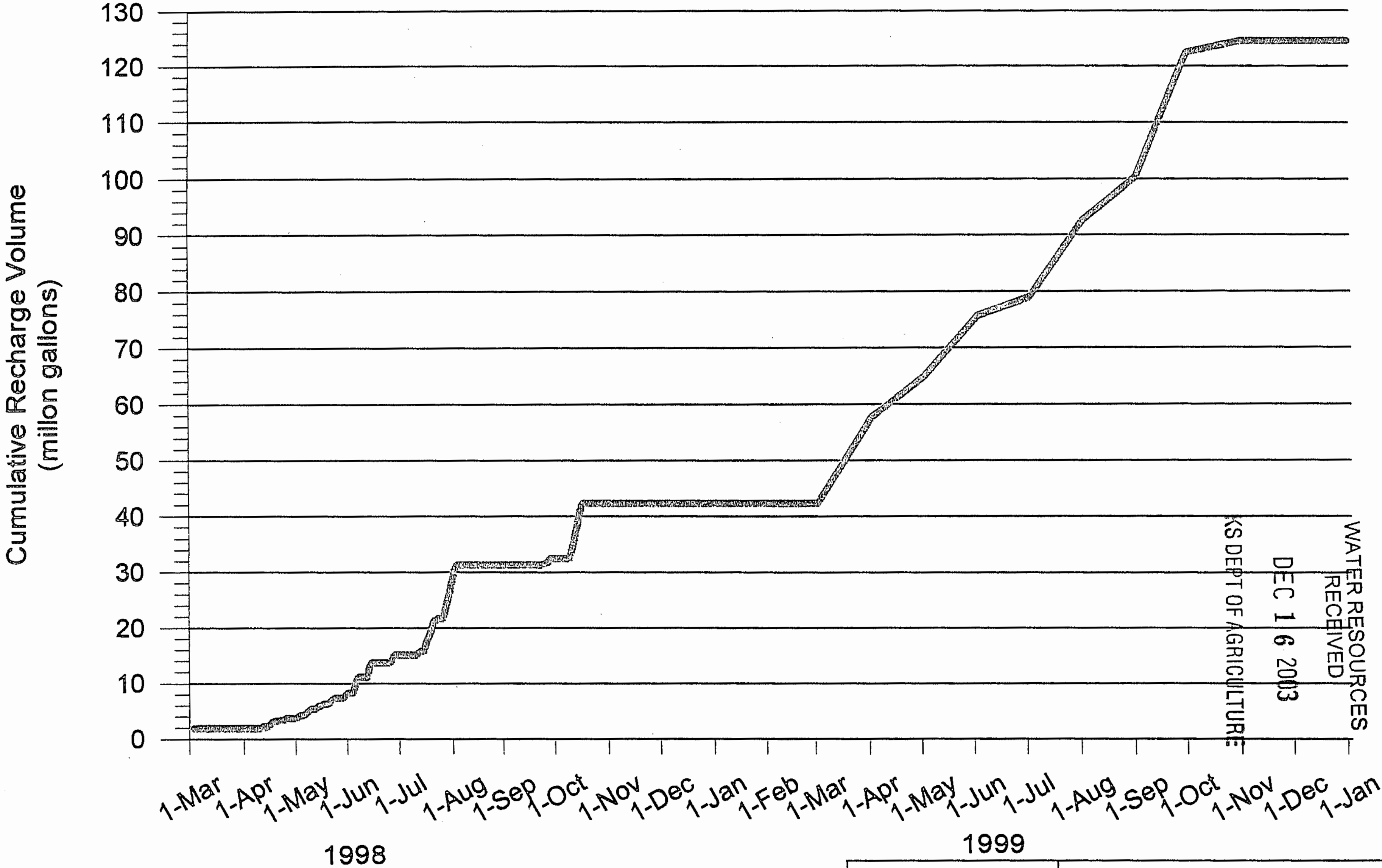

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Figure I-39

SEDGWICK RECHARGE SITE CUMULATIVE RECHARGE VOLUME

Instrumentation is connected to Wichita's existing well field computer control system for data acquisition, storage and transfer for analysis. The amount of water that is added to underground storage in the depleted parts of the aquifer is evaluated by metering, periodic measurements of groundwater levels and groundwater modeling.

b. Water Quality

Refer to Part II (by EPA) for detailed water quality monitoring information.

c. Monitoring of Recharge Activities and Storage

The demonstration facilities have been equipped with a supervisory control and data acquisition (SCADA) system with associated instruments and controls for use in operating and monitoring the Equus Beds groundwater recharge demonstration system. There is a computer controlled, Master Programmable Logic Controller (PLC) located at the City Hall. Operator workstations are located at the Water Treatment Plant and Equus Beds Wellfield Headquarters. The Halstead Recharge Site, Sedgwick Intake Site, and Sedgwick recharge sites are equipped with remote PLCs. The PLCs interact through a SCADA radio communications network and are equipped with an uninterruptible power system (UPS). The master radio and antenna are located at City Hall.

(1) Operator Workstations

The PLCs monitor and control the field equipment and transmit status information to and receive control commands from the operator workstations through the SCADA communications network. The operator workstations are equipped with an animated graphical Windows software which is used to view the status of and interact with the recharge system. The process and control capabilities include:

- Start/stop motors
- Open/close valves.
- Auto/manual control of analog loops
- Change setpoints for control loops

The operator workstation located at the Water Treatment Plant is a desktop unit located in the Plant Control Room. The operator workstation located at the Wellfield Headquarters is a laptop computer.

(2) PLCs

The PLCs communicate by a polling SCADA radio system using Modbus protocol. The master PLC polls the remote PLCs with an internal polling table. The master PLC also has a backup CPU. The master PLC has the following alarms:

- Power failure
- UPS active
- UPS alarm
- Master radio alarm
- Intrusion
- CPU low battery alarm
- Primary CPU switched to backup CPU

(3) Uninterruptible Power System

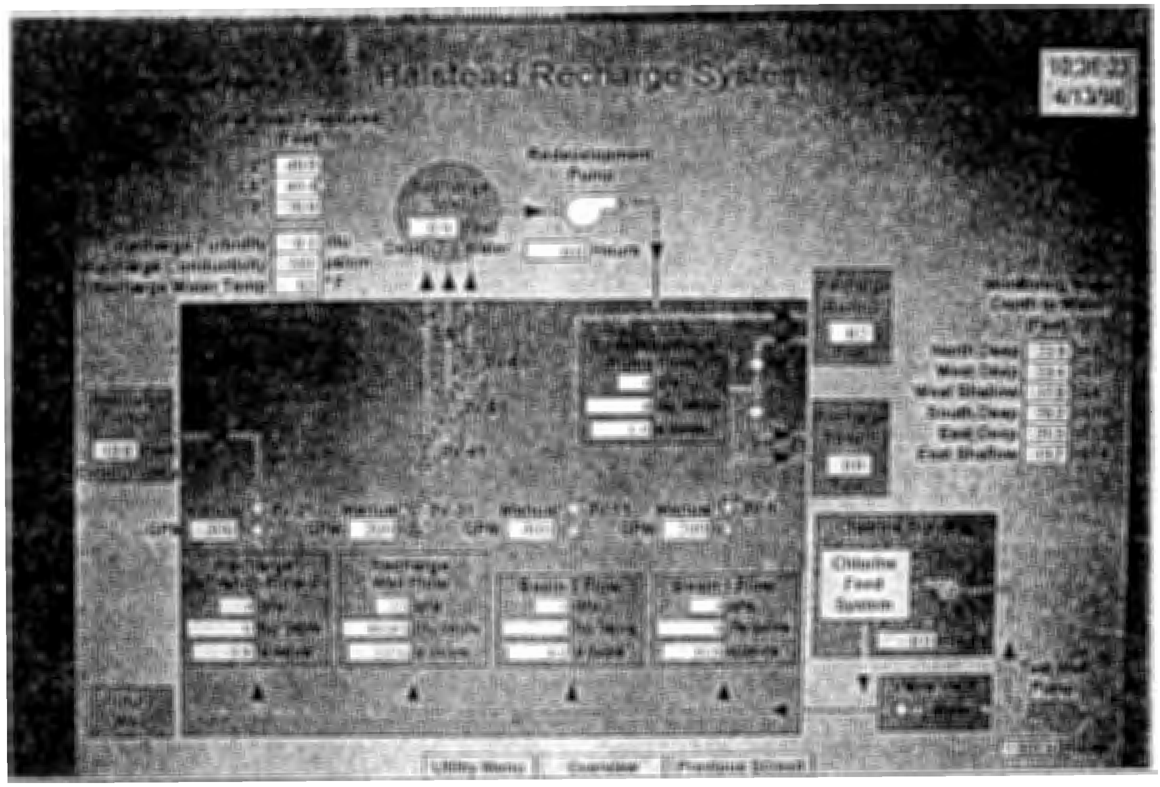
The master PLC and radio at City Hall and the remote PLCs and radios at the demonstration sites are equipped with uninterruptible power systems (UPS). These units automatically switch to battery inverter backup when normal power is lost. When normal power is restored, these systems automatically switch back.

(4) Software Control Package

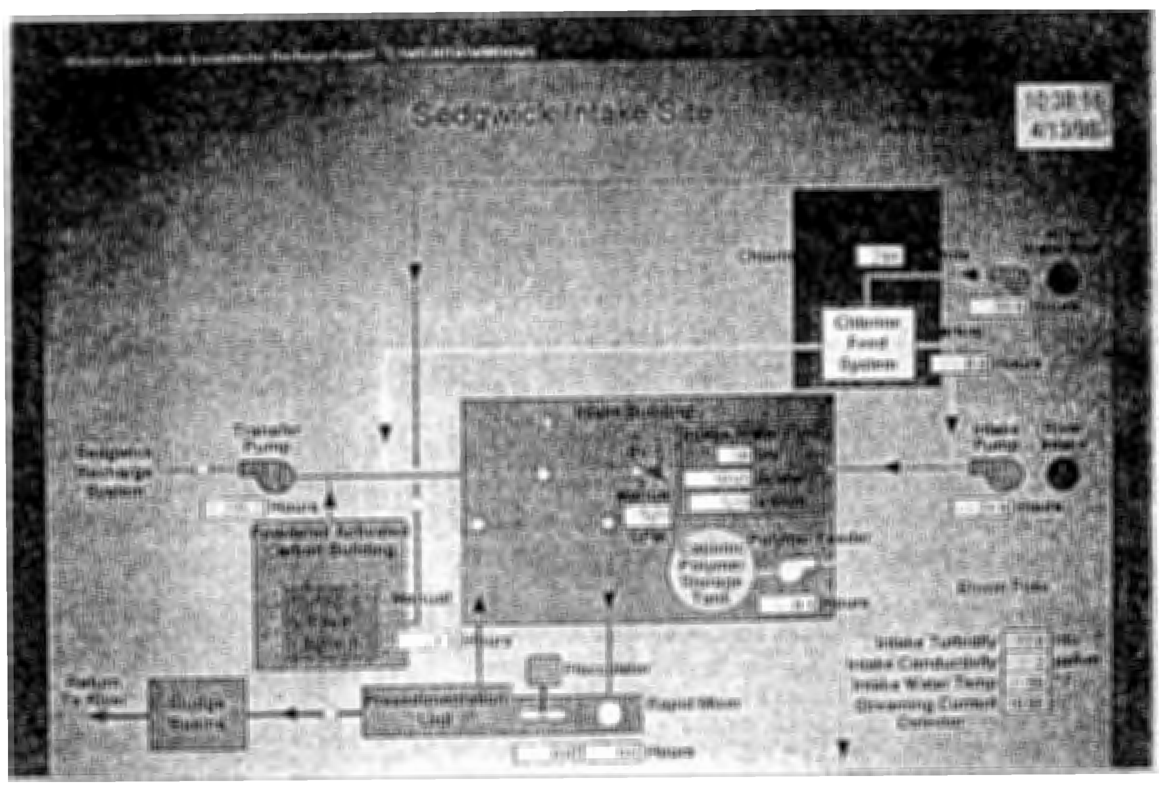
The operator workstations are equipped with a software control package for control, display, monitoring alarms, data storage, and communication. These software packages include detailed documentation and are Wonderware InTouch 6.0 Runtime, Microsoft Windows NT 4.0, and Microsoft Excel 97. Wonderware InTouch is the animated graphical Windows software. The windows designed for this project are shown in Photographs I-7 and I-8.

c. Response Actions

If the MCL for atrazine or other monitored parameters are exceeded in the shallow or deep monitoring well samples at the recharge sites, the nearest City well (No. 4 at the Halstead



Photograph I-7: Halstead Recharge System SCADA Computer Screen



Photograph I-8: Sedgwick Recharge System SCADA Computer Screen

Site and No. 36 at the Sedgwick Site) will be turned on to create a cone of depression and pump the groundwater to the Wichita water plant for treatment. The well is anticipated to be operated for a minimum of seven days. Water quality sampling and analysis for triazines will then be repeated. If atrazine is still detected above the MCL in the monitoring well, the above pumping and sampling procedure will be repeated until the atrazine concentration decreases below the MCL. However, based on extensive water quality sampling of the test well recharge water at the Halstead Site, no atrazine is anticipated to be detected in the test well recharge water. At the Sedgwick Site, powdered activated carbon is added to the surface water to reduce atrazine concentrations to levels substantially below the MCL (3 μg/L).

3. DATA MANAGEMENT

The purpose of this section is to describe the data collection protocols and procedures used in the collection of baseline and recharge data at the recharge facilities for the Equus Beds Groundwater Recharge Demonstration Project from summer 1997 through the end of the Project (mid 2000). This section describes, in conjunction with the *"Baseline Data-Collection and Quality Control Protocols and Procedures for the Equus Beds Ground-Water Recharge Demonstration Project Near Wichita, Kansas, 1995-1996"* by the U.S. Geological Survey, Open-File Report 97-235, (Ziegler and Combs, 1997) (Data-Collection/QC Report), water level and discharge measurements, on-site water quality measurements, instrument calibration, water quality sample collection, identification, preservation, and chain of sample custody, and references the analytical techniques used. Quality control protocols and procedures are incorporated for each data collection activity as referenced in the Data-Collection/QC Report. The Data-Collection/QC Report is available on the Internet at http://www-ks.cr.usgs.gov/kansas/ pubs/reports/ofr.97-235.html.

a. <u>Data Collection and Compilation</u>

The overall objective of the data collection activities is to document and quality assure sufficient water level, discharge, and water quality data to determine the hydrologic and water quality conditions in the surface water and test well pumpage along the Little Arkansas River and in the adjacent Equus Beds Aquifer to demonstrate and quantify the potential impacts on the aquifer and assure compliance with federal and state regulations. These data describe and quantify the effects of the small-scale recharge demonstration project on the aquifer and will be used to determine the technical, economic, and environmental validity of the full-scale aquifer storage, recharge and recovery project. The goals for analytical precision, accuracy, comparability, representativeness and completeness are described in the Data-Collection/QC Report.

(1) Stream Flow and Water Levels

Stream water-surface elevation (stage) is determined at six streamflow-gaging stations along the Little Arkansas River (see Fig. I-6) with non-submersible, pressure transducers and was measured to the nearest 0.01 foot. The stage is recorded relative to an arbitrary datum, which has been referenced to the elevation of the gage datum (see Table I-7). Stage data is electronically recorded and transmitted by a data-collection platform (DCP). The data then is transmitted by satellite to a downlink site and then to the computer at the USGS office in Lawrence, Kansas. These data are recorded every 15 minutes and transmitted at least every 4 hours.

Four of the six streamflow-gaging stations (Alta Mills, Highway 50, Sedgwick and Valley Center) are operated as continuous streamflow or discharge stations, and stage-discharge ratings are developed and maintained for these sites. The remaining two gaging stations (near Halstead and Site TH-08) continuously record the water elevation or stage of the stream.

Water levels in monitoring wells are recorded to the nearest 0.01 foot at 15-minute intervals and transmitted from the same DCP as the colocated streamflow-gaging stations at all of the sites listed in Table I-7, except sites TH-10-95, TH-02-95, TH-06-95, and TH-12-95, which are measured only at the time of sampling. Water-level sensing equipment consists of submersible transducers that transmit the water level to the DCP. Water levels are recorded and then transmitted every 4 hours to the USGS office in Lawrence, Kansas.

Table I-7

Data-collection sites used during baseline data collection for the Equus Beds Ground-Water Recharge Demonstration Project (Ziegler and Combs, 1997)

[S, streamflow-gaging station; W, monitoring well; Q, surface-water sampling site; T, test well; –, information not available]

Data-collection site	U.S. Geological Survey site identification no.	Site Name	Type of site	Legal description	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Gage or well datum (feet above sea level)	Approx. well depth (feet)	Approx. screened interval (feet)
07143665	071443666	Little Arkansas River at Alta Mills, Kansas	S	22S-02W-30BBC	38°06'44"	97°35'30"	1,391.40	–	–
Monitoring well at 07143665	380644097353001	Well at Alta Mills Gage	W	22S-02W-30BBC	38°06'44"	97°35'30"	1,391.40	–	–
TH-10-95	380424097343801	Well TH-10 near Alta Mills, Kansas	W	23S-02W-06DDD	38°04'24"	97°34'38"	–	59.10	48.7-58.7
TH-02-95	380237097324401	Well TH-02	W	23S-02W-16CDD	38°02'37"	97°32'44"	–	54.00	43.6-53.6
07143672	07143673	Little Arkansas River at Highway 50 near Halstead, Kansas	S,Q	23S-02W-28AABB	38°01'43"	97°32'25"	1,370.55	–	–
07143680	07143680	Little Arkansas River at Halstead, Kansas	S	23S-02W-34ADDD	38°00'27"	97°30'52"	1,371.00	–	–
EB-145-A1	380028097311001	Well #1 at TH-04-95	W	23S-02W-34ADDA	38°00'28"	97°30'52"	1,371.00	48.00	37.6-47.6
PD-5	380028097311002	Piezometer well	W	23S-02W-34ADDA	38°00'28"	97°31'07"	1,371.00	120.00	112-117
EB-145-A2	380028097310901	Well #2 at TH-04-95	W	23S-02W-34ADDA	38°00'28"	97°31'09"	1,371.00	47.00	37-47
EB-145-A3	380028097311101	Well #3 at TH-04-95	W	23S-02W-34ADDB	38°00'28"	97°31'11"	1,371.00	70.00	60-70
EB-145-A4	380027097311401	Well #4 at TH-04-95	W	23S-02W-34ADCD	38°00'27"	97°31'14"	1,371.00	60.00	50-60
EB-145-A5	380025097312701	Well #5 at TH-04-95	W	23S-02W-34ACDC	38°00'25"	97°31'27"	1,371.00	43.00	32-42
Test well		Test well at TH-04-95	T	23S-02W-34ADDA	38°00'31"	97°31'10"	–	136.50	75.9-136.5
07143770	07143770	Black Kettle Creek near Halstead, Kansas	Q	24S-01W-21CCC	38°01'43"	97°31'13"	–	–	–
TH-06-95	375304097291301	Well TH-06 near Halstead, Kansas	W	24S-02W-01DCC	37°53'04"	97°29'13"	–	41.00	30.6-40.6
07143930	07143930	Kisiwa Creek near Halstead, Kansas	Q	24S-02W-14DDD	30°57'25"	97°30'05"	–	–	–
07144050	07144050	Emma Creek near Sedgwick, Kansas	Q	24S-01W-21CCC	37°56'28"	97°26'39"	–	–	–
07143950	07143950	Little Arkansas River at SW 84th Street near Sedgwick, Kansas	S,Q	24S-01W-29ABAB	37°56'28"	97°27'04"	1,345.00	–	–

Table I-7 (continued)

Data-collection sites used during baseline data collection for the Equus Beds Ground-Water Recharge Demonstration Project (Ziegler and Combs, 1997)

[S, streamflow-gaging station; W, monitoring well; Q, surface-water sampling site; T, test well; --, information not available]

Data-collection site	U.S. Geological Survey site identification no.	Site Name	Type of site	Legal description	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Gage or well datum (feet above sea level)	Approx. well depth (feet)	Approx. screened interval (feet)
TH-08-A1	375628097270201	Well #1 at TH-08-95	W	24S-01W-29ABAA	37°56'28"	97°27'02"	1,345.00	40.00	30-40
TH-08-A2	375628097270401	Well #2 at TH-08-96	W	24S-01W-29ABAB	37°56'28"	97°27'04"	1,345.00	53.00	43-53
TH-08-A3	375628097270801	Well #3 at TH-08-97	W	24S-01W-29ABAB	37°56'28"	97°27'08"	1,345.00	59.00	48-58
TH-08-A4	375628097271001	Well #4 at TH-08-98	W	24S-01W-29ABBA	37°56'28"	97°27'10	1,345.00	58.00	46-56
TH-08-A5	375628097271701	Well #5 at TH-08-98	W	24S-01W-29BAAA	37°56'28"	97°27'17"	1,345.00	53.00	42-52
7144090	07144090	Sand Creek near Sedgwick, Kansas	Q	24S-01W-34BCB	37°55'19"	97°25'36"	--	--	--
7144100	07144100	Little Arkansas River at Fry Bridge near Sedgwick, Kansas	S,Q	25S-01W-15BBAA	37°52'59"	97°25'27"	1,340.00	--	--
EB-142	375259097252701	Well #1 at 07144100	W	25S-01W-15BBAA	37°52'59"	97°25'27"	1,340.00	--	--
EB-142-A1	375300097253101	Well #2 at 07144100	W	25S-01W-10CCCD	37°53'00"	97°25'31"	1,340.00	--	--
EB-142-A2	375300097253301	Well #3 at 07144100	W	25S-01W-10CCCC	37°53'00"	97°25'33"	1,340.00	--	--
EB-142-A3	375300097253501	Well #4 at 07144101	W	25S-01W-10CCCC	37°53'00"	97°25'35"	--	57.50	47.2-57.2
EB-142-A4	375300097254201	Well #5 at 07144102	W	25S-01W-9DDDC	37°53'00"	97°25'42"		--	--
TH-12-95	375140097243301	Well TH-12 near Valley Center, Kansas	W	24S-01W-23BCC	37°51'40"	97°24'33"	--	50.30	39.9-49.9
7144200	07144200	Little Arkansas River at Valley Center, Kansas	S	25S-01W-36CBA	37°49'56"	97°23'16"	1,325.66	--	--
Monitoring well at 07144200	3754956097231600	Well at Valley Center gage	W	25S-01W-36CBA	37°49'56"	97°23'16"	1,325.66	--	--

(2) Recharge Flow and Water Levels

Halstead Recharge Site

At the Halstead Recharge Site, water flowrate and water levels were monitored at the recharge basins, recharge well, and recharge trench with the SCADA System. Flowrate and water-level sensing equipment consisted of flow meters and level-indicating transmitters, respectively, at the North and South recharge basins, recharge well and recharge trench. Monitoring wells H-1, H-4, H-7, H-10, H-13, and H-14 at the Halstead Recharge Site (see Figure I-29) are also equipped with level-indicating transmitters. Flow and level data are transmitted by the Halstead Recharge Site remote PLC through the SCADA radio communications network to the Master PLC located at the City Hall, where they are recorded.

Sedgwick Intake and Recharge Sites

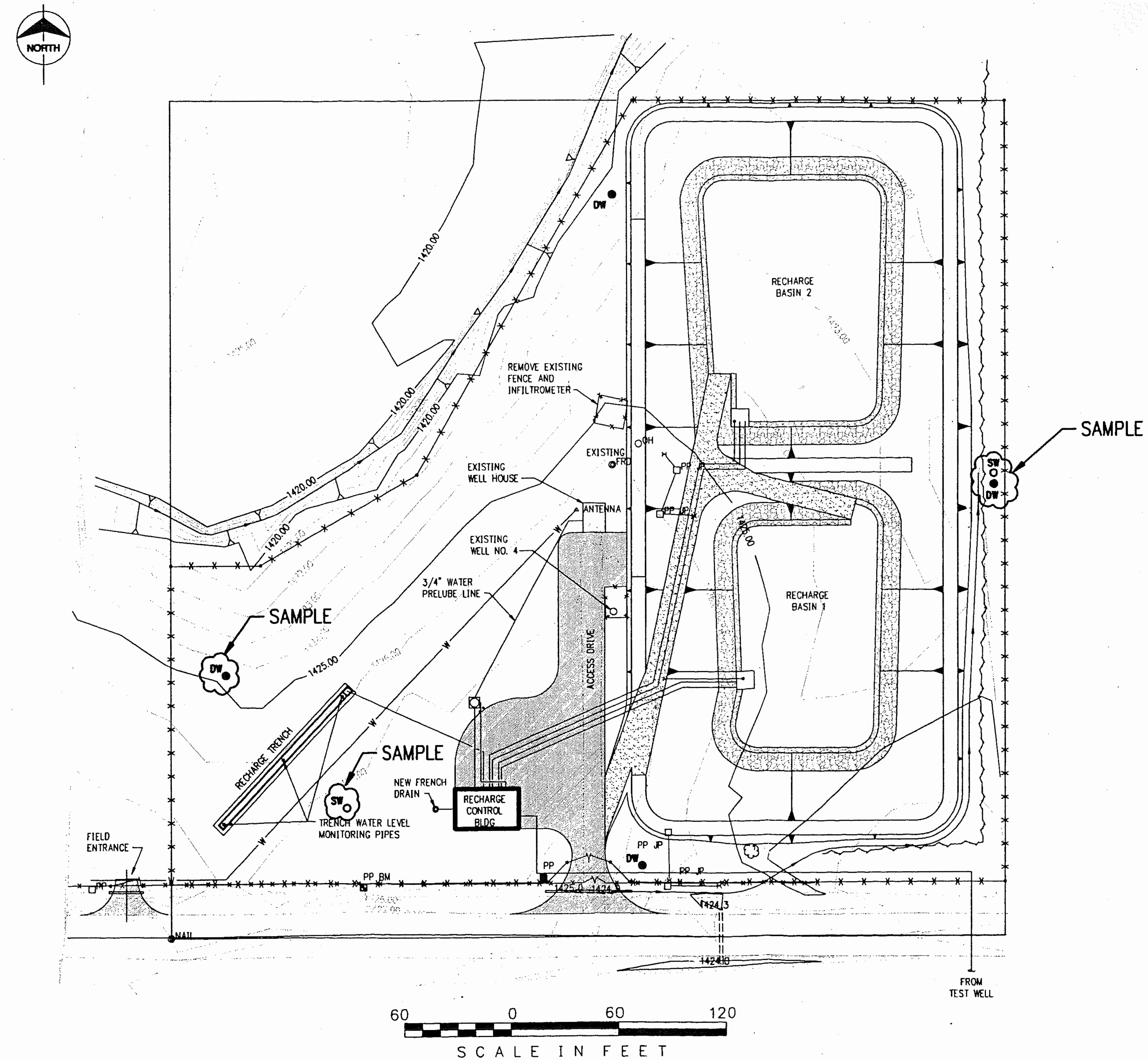
At the Sedgwick Site, the intake water flow and the recharge flow and water levels at the recharge basins are monitored with the SCADA System. Flow meters and level-indicating transmitters were used at those facilities for monitoring purposes. Monitoring wells S-9, S-10, S-11, S-12, S-13 and S-14 at the Sedgwick Recharge Site (see Figure I-33) were also equipped with level-indicating transmitters. Flow and level data are transmitted by the Sedgwick Recharge Site remote PLC through the SCADA radio communications network to the Master PLC located at the City Hall, where they are recorded.

(3) Water Quality

Sampling Network and Rationale

Sampling is conducted at the following locations as shown in Figures I-40 and I-41, respectively, for the Halstead Recharge Site and the Sedgwick Recharge Site:

- Halstead Recharge Site:
  - Sample tap in Control Building for recharge water.
  - Two shallow monitoring wells on recharge site.



NOTES:

1. MONITORING WELLS FOR WATER QUALITY SAMPLING.
2. DW ● DEEP MONITORING WELL (4)
   SW ○ SHALLOW MONITORING WELL (2)

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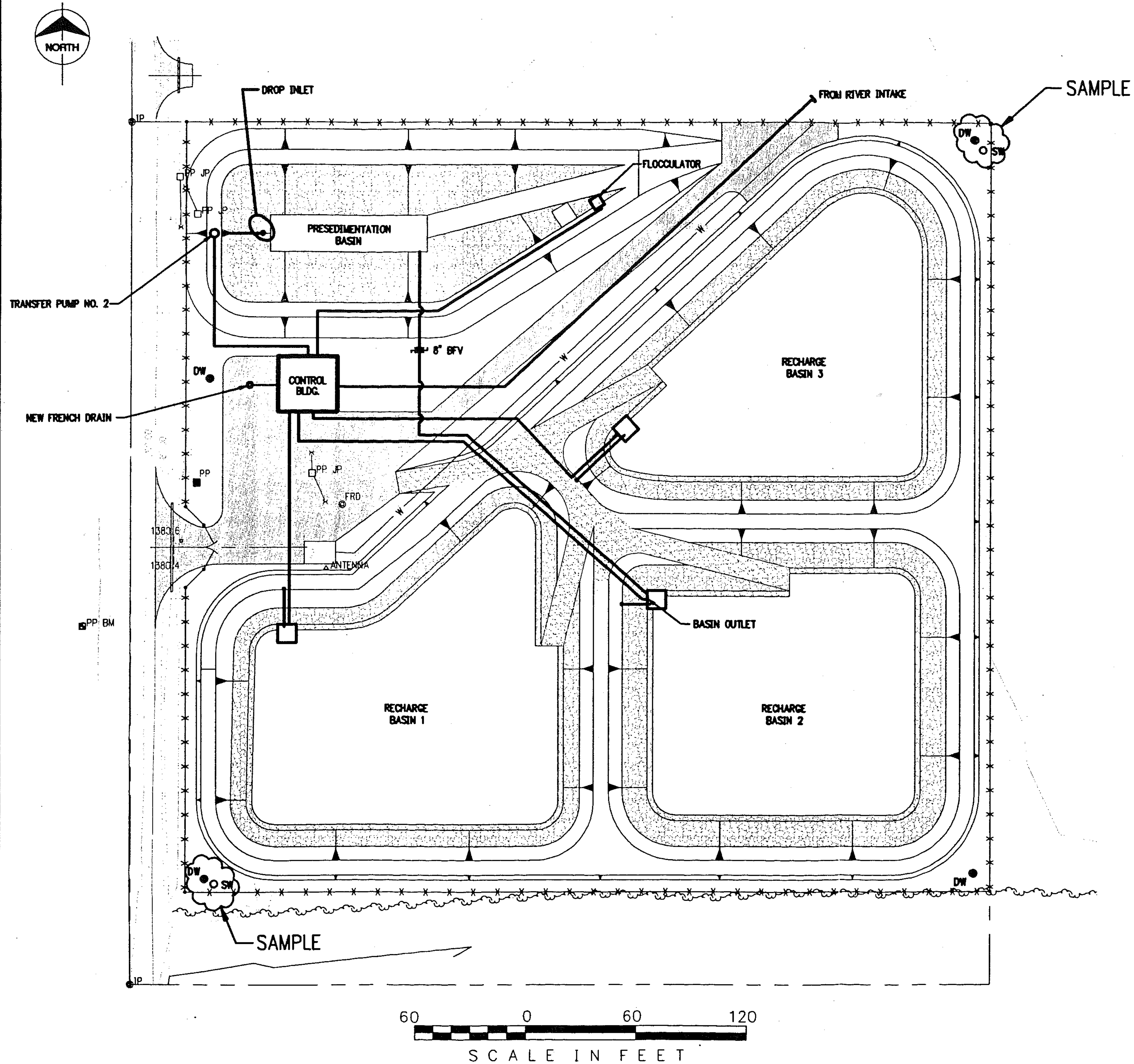
FigI-40

HALSTEAD RECHARGE SYSTEM
RECHARGE SITE

J:\WICHITA\921954.014\NEWFIG\FIGI-41.dwg 07-09-1999 11:20 AAO



NOTE:

1. MONITORING WELLS FOR WATER QUALITY SAMPLING.

DW ● DEEP MONITORING WELL (4)

SW ○ SHALLOW MONITORING WELL (2)

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Figure I-41

SEDGWICK RECHARGE SYSTEM
RECHARGE SITE

J:\WICHITA\921954.014\NEWFIG\FigI-40.dwg 07-09-1999 11:18 AAO

- Two deep monitoring wells on recharge site (one upgradient and one downgradient.

- Sedgwick Recharge Site:
  - Sample tap in Control Building for recharge water.
  - Two shallow monitoring wells on recharge site.
  - Two deep monitoring wells on recharge site (one upgradient and one downgradient).

The sample taps in the Control Buildings will provide a sample location to determine an indication of water quality immediately before the water is recharged. The shallow monitoring wells provide water quality data on the ambient groundwater (before recharge) and on the water quality changes in the aquifer (after recharge). The monitoring wells at each site will be used to assure that no significant water quality degradation (concentrations exceeding the MCL) occurs and when, if ever, the mitigation plan must be enacted. The mitigation plan is detailed above in Section 2.

Additional sampling and analysis were conducted for the Little Arkansas River and selected monitoring wells as listed in Table I-8.

Sample Schedule, Locations, Frequency and Duration

Schedules for sampling with the sample location, frequency and duration for fiscal years 1997 and 1998 are listed in Table I-8. Baseline and recharge sampling will occur during recharge activities, which occur when the stream flow exceeds "above-base" flow.

Sample Matrices, Target Analyte

Primary target analytes are atrazine and chlorides. These analytes of concern were confirmed during two years of baseline sampling during the feasibility studies. Baseline sampling and analysis for constituents identified in Table I-8 will continue to comply with state and federal regulations.

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Table I-8

Schedule for Baseline, Event, and Aquifer test sampling from October 1996 through September 1998[1]

					City Well No. 4 area			Sedgwick			City Well No. 36 area			Local Well Field			
Month	Analysis Group	HWY 50 SW	Test Well	THO4-A1 and PD5	City Well	Shallo 2 Wells	Deep 2 Wells	SW	Treated Water	THO8-A2 and EB142 Well	City Well	Shallo 2 Wells	Deep 2 Wells	Wells	Aquifer Test	QA	Total
October	Key	1		2				1						5		1	10
	Limited-EPA													3		1	4
	ELISA							2									2
November	Key	1		2				1								2	6
	ELISA							2									2
December	Key	1		2				1		2						2	8
	ELISA							2									2
January	Key	1		2				1								1	5
	ELISA							2									2
February	Key	1		2				1								1	5
	ELISA							2									2
March	Key	2		2				2						5		2	13
	Limited-EPA													3			3
	ELISA							30									30
April	Key	2	2	2		6	6	2	4	2		6	6		4	5	47
	Key-Plus		1			4	4					4	4			2	19
	Limited-EPA		1		1	2	2				1	2	2				11
	ELISA							60									60
May	Key	2	2	2	2	6	6	2	4		2	6	6	5	4	5	54
	Key-Plus	2			2	2	2	2			2	2	2			2	18
	Limited-EPA													3		1	4
	ELISA							60									60
June	Key	2	2	2		4	4	2	4	2		4	4			5	35
	Key-Plus	1	1					1								1	4
	ELISA							60									60
July	Key	1		2		4	4	1	2			4	4			2	24
	Key-Plus		1			2	2					2	2			2	11
	ELISA							30									30
August	Key	1	1	2		4	4	1	1			4	4	5		3	30
	Limited-EPA													3		1	4
	ELISA							30									30
September	Key	1	1	2		4	4	1	1	2		4	4			2	26
	ELISA							20									20
Summary of Sample Totals During FY97 and FY98																	
Totals	Key	16	8	24	2	28	28	16	16	8	2	28	28	20	8	32	264
	Key-Plus	3	3		2	8	8	3			2	8	8			7	52
	Limited-EPA		1		1	2	2				1	2	2	12		3	26
	ELISA							300									300
	GC/MS							40									40
Totals		19	12	24	5	38	38	359	16	8	5	38	38	32	8	42	682

[1] Refer to Appendix B for a complete list of constituents analyzed in the Key, Key-Plus, Limited-EPA, ELISA, and GS/MS analysis groups.

Recharge Water Quality Monitoring

At the Halstead Recharge Site, recharge water turbidity, conductivity, and temperature are monitored with the SCADA System. Similarly, at the Sedgwick Intake and Recharge Sites, respectively, intake water and recharge water turbidity, conductivity and temperature are monitored with the SCADA System. Data are transmitted by the remote PLCs through the SCADA radio communications network to the Master PLC located at the City Hall, where they are recorded.

b. Quality Control and Data Analysis

(1) Sampling and Analytical Methods Requirements

Refer to the Data Collection/QC Report for detailed information on requirements on sampling/decontamination procedures, sample preservation and holding times, sample shipment, laboratory coordination, sample custody, documentation of field activities, detection methods, and laboratory documentation.

(2) Quality Control Requirements

Refer to the Data Collection/QC Report for detailed information on requirements on field and laboratory quality control elements, frequency of quality control checks, control limits and corrective actions, as well as instrument/equipment testing, inspection, maintenance and calibration.

(3) Data Validation and Usability

Refer to the Data Collection/QC Report for detailed information on requirements on data review, validation, verification and reconciliation.

* * * * *

PART II
WATER QUALITY ANALYSIS
(completed by USEPA Region 7)

Part II (Water Quality Analysis) was not available at the time this report was completed. This section will be submitted when it becomes available from USEPA Region 7.

*See USGS Water Resources Investigations Report 99-4250

No separate report submitted by EPA

MDJ IDWR 1-5-03 per call to Jerry Blain City of Wichita

PART III
ANALYSIS AND CONCLUSIONS

PART III

ANALYSIS and CONCLUSIONS

A. COST ANALYSIS

1. CONSTRUCTION COSTS

Construction of the Equus Beds Groundwater Recharge Demonstration Project (Project) was completed in two contracts. Contract 1 included the construction of the demonstration facilities for the Halstead and Sedgwick Recharge Systems. Contract 2 included the installation of the SCADA system for system monitoring, data recording and control. The Project has a total construction cost of $3,133,000 with Contract 1 costing $2,703,000 and Contract 2 costing $430,000.

Construction cost items for the Project are described in Table III-1. Review of the table shows general items and SCADA cost $622,000; the Halstead Intake System cost $1,027,000, and the Sedgwick Recharge System cost $1,484,000. A detailed schedule of values for the Project is included in the Appendices.

2. SCHEDULE OF OPERATING COSTS

The Halstead Recharge System began operation in May 1997 and continued operation through December 1999. The Halstead System was operated for about 2,550 hours in 1997, 5,440 hours in 1998, and 4,520 hours in 1999. The operating hours for both November 1999 and December 1999 were unavailable due to difficulties with the SCADA system and were estimated in 250 hours per month. The Sedgwick Recharge System began operation in October 1997. The system was tested for two weeks and then shut-down for the winter. System operation was restarted on April 29, 1998 and continued through October 15, 1998. System operation was again restarted on March 9, 1999 and continued through October 1999. The Sedgwick System was operated for about 70 hours in 1997, 740 hours in 1998, and 3,020 hours in 1999. The operating hours for both September 1999 and October 1999 were unavailable due

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Table III - 1

CONSTRUCTION COST SUMMARY

Item/Components		Cost ($)	Total Cost ($)
Halstead and Sedgwick Recharge Systems:			
General:	Mobilization, Demobilization, Power Supply	192,000	
SCADA:	Monitoring and Control Equipment	430,000	622,000
Sedgwick Recharge System:			
Pipeline:	Pipeline from Intake to Recharge Site	264,000	
Intake Site:	Site Work, Electrical, Diversion Well and Pump, Valve/Meter Vault, and Chlorine Feed	256,000	
Recharge Site:	Site Work, Fence, Electrical, Control Building, Piping, Meters, Recharge Basins, Recharge Trench, and Rechrage Well	507,000	1,027,000
Sedgwick Recharge System:			
Pipeline:	Pipeline from Intake to Recharge Site	212,000	
Intake Site:	Site Work, Electrical, Diversion Intake and Pump, Meter, Chlorine Feed, PAC Feed, Polymer Feed, Control Building, Parallel Plate Seperator and Residuals Basins	840,000	
Recharge Site:	Site Work, Fence, Electrical, Control Building, Piping, Meters, Earthen Presedimantation Basin, Transfer Pump, and Three Recharge Basins	432,000	1,484,000

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to difficulties with the SCADA system and were estimated in 720 hours and 100 hours, respectively. Both recharge systems will be operated in year 2000. The City currently plans to continue recharge operations after completion of the Project.

Project operating costs for the Halstead Recharge System include electricity, operations staff, and periodic chemical treatment of the recharge well and system pipelines to control biological growth. Annual costs for the operation of the Halstead Recharge System are summarized in Table III-2. Electricity costs were calculated based on the number of operating hours per year and the power consumed by each component of the recharge system. Operations staffing was not continuous; however, City staff spent approximately 1318 hours in 1997, 568 hours 1998, and 400 hours in 1999 on system start-up, maintenance, physical system checks, manual measurements, equipment re-calibration, and operation and implementation of testing protocols. Chemical treatment costs were relatively small at the Halstead Site and are therefore neglected.

Project operating costs for the Sedgwick Recharge System include electricity, operations staff, and chemical treatment costs for removing turbidity and atrazine from the recharge water and periodic system chlorination to control biological growth. Annual costs for the operation of the Sedgwick Recharge System are summarized in Table III-2. Electricity costs were calculated based on the number of operating hours per year and the power consumed by each component of the recharge system. Operations staffing was not continuous; however, City staff spent approximately 233 hours in 1997, 852 hours in 1998, and 1,256 hours in 1999 on system start-up, maintenance, physical system checks, manual measurements, equipment re-calibration, and operation and implementation of testing protocols. Chemical treatment costs mainly included polymer for coagulation and settling of turbidity and powdered activated carbon (PAC). Chlorine costs were relatively small at the Sedgwick Site and are therefore neglected.

3. SCHEDULE OF MONITORING COSTS

Extensive water quality monitoring (sampling and analysis) was completed as part of this Project as shown in Table III-3. Monitoring performed in fiscal years 1995 and 1996 and the first half of 1997 developed the baseline for the Little Arkansas River, montoring wells along

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Table III - 2

SUMMARY OF ANNUAL COSTS FOR SYSTEM OPERATION

Item		Unif Cost ($)	Year 1997			Year 1998		
			Quantity	Cost ($)	Total Cost ($)	Quantity	Cost ($)	Total Cost ($)
Halstead Recharge System:								
Operations Staff	(Hours)	50	1,318	65,900		568	28,400	
Electricity	(KWh)	0.06	129,314	7,759	73,659	258,447	15,507	43,907
Sedgwick Recharge System:								
Operations Staff	(Hours)	50	233	11,650		852	42,600	
Electricity	(KWh)	0.06	22,973	1,378		60,392	3,624	
Polymer	(Pounds)	0.37	1,600	592		3,400	1,258	
Powdered Activated Carbon	(Pounds)	0.72	2,370	1,706	15,327	7,000	5,040	52,522

Table III - 2 (continued)

Item		Unif Cost ($)	Year 1999		
			Quantity	Cost ($)	Total Cost ($)
Halstead Recharge System:					
Operations Staff	(Hours)	50	400	20,000	
Electricity	(KWh)	0.06	217,447	13,047	33,047
Sedgwick Recharge System:					
Operations Staff	(Hours)	50	1,256	62,800	
Electricity	(KWh)	0.06	186,653	11,199	
Polymer	(Pounds)	0.52	6,000	3,120	
Powdered Activated Carbon	(Pounds)	0.76	7,000	5,320	82,439

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Table III - 3

MONITORING COST SUMMARY

Description	Site			Total
	Halstead	Sedgwick	Other	
Number of Samples for FY 1995 - 1999 (1)				
ELISA	1,177	1,782	183	3,142
Keys	474	252	93	819
Key Plus	158	78	40	276
Limited VOC	72	24	40	136
Full Organic	9	3	12	24
Subtotal	1,890	2,139	368	4,397
Costs ($) (2)				
FY 1995 - 1999				
Wichita Costs (including analyses)	1,018,844	1,085,051	-	2,103,895
USGS Costs	515,810	577,736	-	1,093,546
FY 2000 (Estimate)				
Wichita Costs (including analyses)	73,127	70,684	-	143,811
USGS Costs	53,065	59,435	-	112,500
Total Cost for FY 1995-2000	1,660,845	1,792,907	-	3,453,752

(1) Refer to Appendix B for a complete list of constituents analyzed in the Key, Key-Plus, Limited-EPA, Full-EPA, ELISA, and GS/MS analysis groups.

(2) Costs for other sites are equally distributed between the Halstead and Sedgwick Sites

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the river, monitoring wells at the recharge sites, and domestic wells adjacent to the recharge sites. The type and number of samples collected from February 1995 through September 1999 and associated total costs are shown in Table III-3. All water quality monitoring was conducted by the U.S. Geological Survey (USGS) in Lawrence, Kansas. USGS collected all samples and performed organic analyses. Additionally, USGS provided cost share funding for the Project as shown in Table III-3. The City of Wichita laboratory at the Central Water Plant performed all inorganic and bacteriological analyses.

B. RESULTS AND DISCUSSION

1. TECHNICAL RESULTS

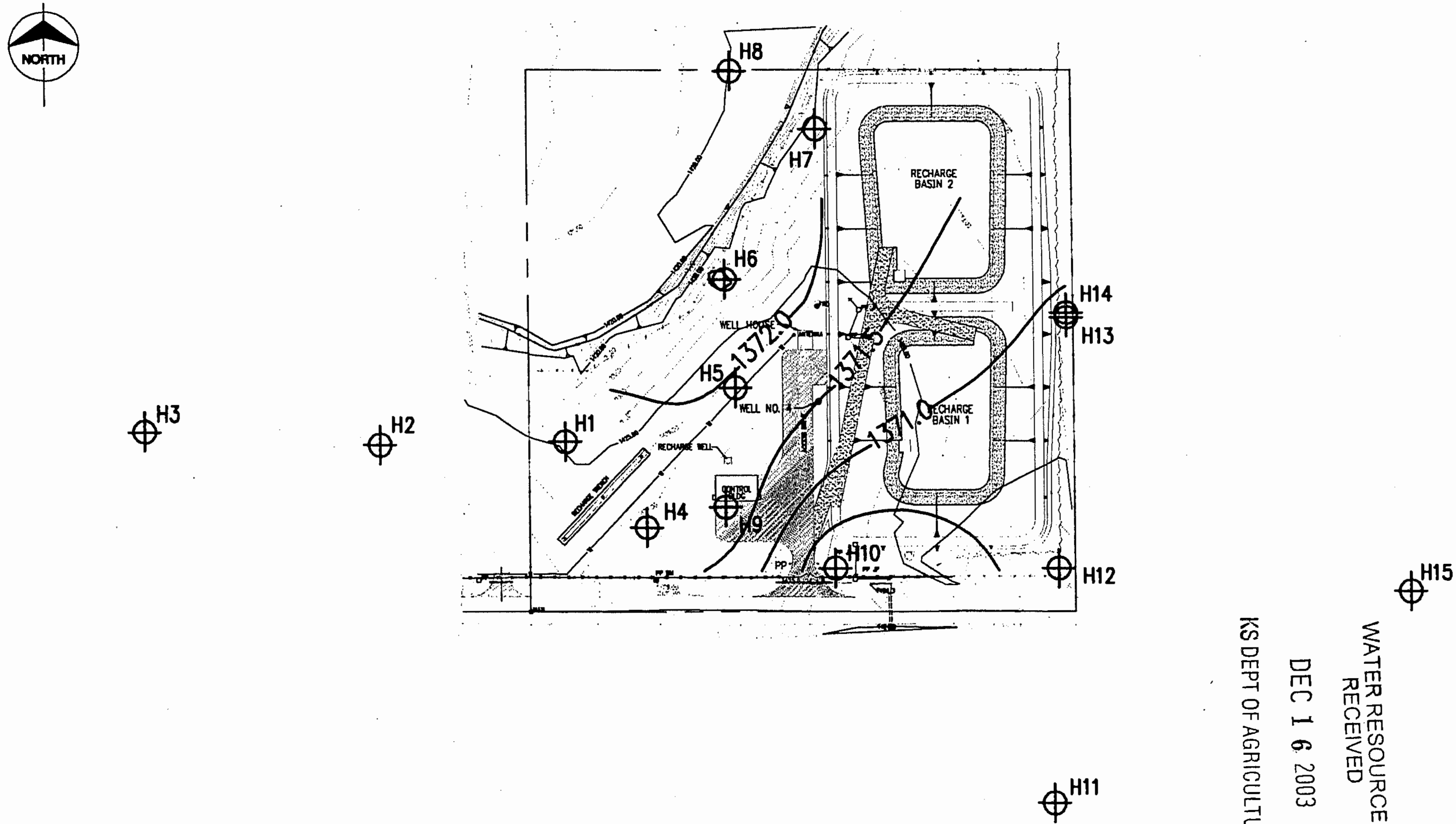
a. Halstead Recharge System

(1) Recharge Basins

The two Halstead recharge basins were the first components of the demonstration program to be brought into operation. The north basin has a bottom area of 0.35 acre and the south basin has a bottom area of 0.20 acre. Each basin is about 12 feet deep with the bottom of the basin below the surfacial clays. During construction, some spot removal of clay lenses was required after the excavation was completed to the design depth.

A significant clay layer exists from a depth of about 30 to 60 feet below ground surface, preventing direct movement of the recharge water to the main aquifer and causing water to "perch" above the clay layer. Drill logs from installed piezometers and a monitoring well indicate that the intermediate clay layer in this area is laterally extensive. The potentiometric water level in the lower aquifer was below the top of the clay layer when recharge operations began. A map of pre-operation groundwater levels in the main (lower) aquifer is shown in Figure III-1.

Testing conducted during 1997 and 1998 showed that, although the bottoms and underlying sand layers of the basins are very permeable, recharge rates decreased



LEGEND

MONITORING WELL

GROUNDWATER ELEVATION, MAY 23, 1997

125 0 125 250

SCALE IN FEET

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Figure III-1

HALSTEAD RECHARGE SYSTEM (PRE-RECHARGE) WATER LEVELS IN DEEP AQUIFER MAY 23, 1997

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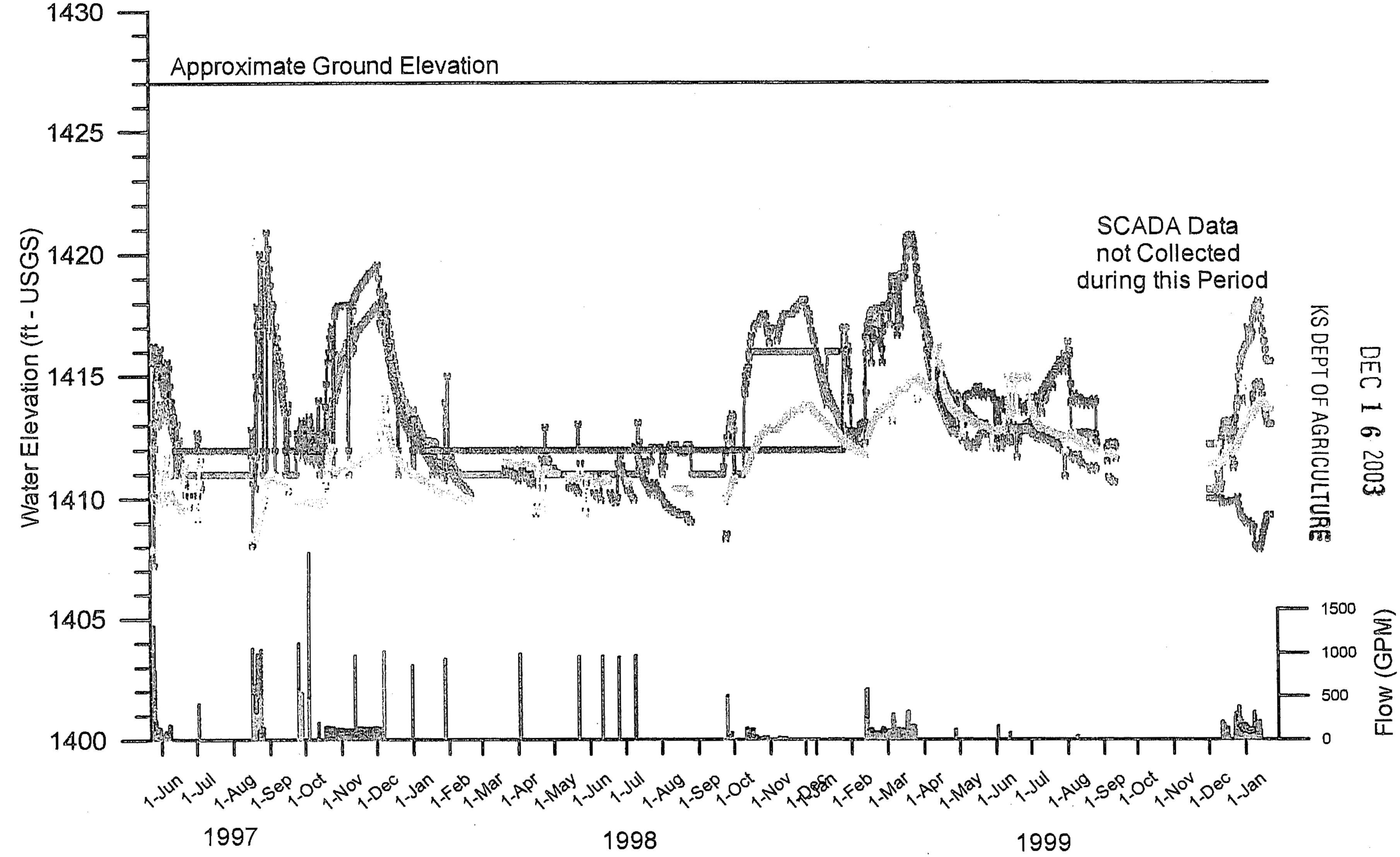
considerably after the sand above the relatively shallow, intermediate clay layer became saturated. While recharge rates of about 15 to 20 ft/day were observed during the system startup, those rates stabilized at about 1 to 2 ft/day once the subsurface sand layer was filled and "groundwater mounding" occurred. The change from vertical flow to predominantly horizontal flow in the sand above the clay layer was the cause for the lower recharge rates.

Similar results to those observed in 1997 and 1998 were obtained during the operation of the Halstead recharge basins in 1999. Figure III-2 shows the recharge rates with time and the associated water levels at both Halstead recharge basins. Figure III-2 also shows the response of shallow groundwater levels in selected monitoring wells. The rise in shallow groundwater levels is due to recharge through the basins or, to a lesser extent, through the recharge trench (discussed below). A profile of the recharge basins area showing the response of groundwater levels to recharge operations is presented in Figure III-3. These two figures show that shallow groundwater piezometric elevations near the basins are similar to the water level in the basin due to groundwater mounding during recharge operations. Maps showing contours of shallow water levels before and during continuous recharge events at the basins are provided respectively in Figures III-4 and III-5. Those maps illustrate how shallow groundwater rapidly saturates the sand bed above the intermediate clay layer in response to continuous recharge events.

Typically, a shallow water depth should be maintained in the basins when a perching layer is not present; however, when the piezometric levels rise above the bottom of the basin, flows can be increased by raising basin water levels to increase static head. In 1998 and 1999, testing was conducted to evaluate the response characteristics of the basins and the aquifer under different basin water elevations. Figure III-6 provides a graph of basin water depth (ft) vs. infiltration rate (ft/day) that illustrates the test results. These tests showed that infiltration rates of up to 3 ft/day could be obtained when the water elevation in the basins was raised to approximately 1,419 ft. (7 ft. and 8 ft. of water above the respective bottoms of the south and north basins). Above water elevation 1418 ft. (USGS), the dike between the north and south basins is



Monitoring Wells

- H-4 (s)
- H-14 (s)
- North Basin
- South Basin

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Figure III-2

HALSTEAD RECHARGE SITE
SHALLOW WELLS & BASIN
DEPTH WITH BASIN FLOW

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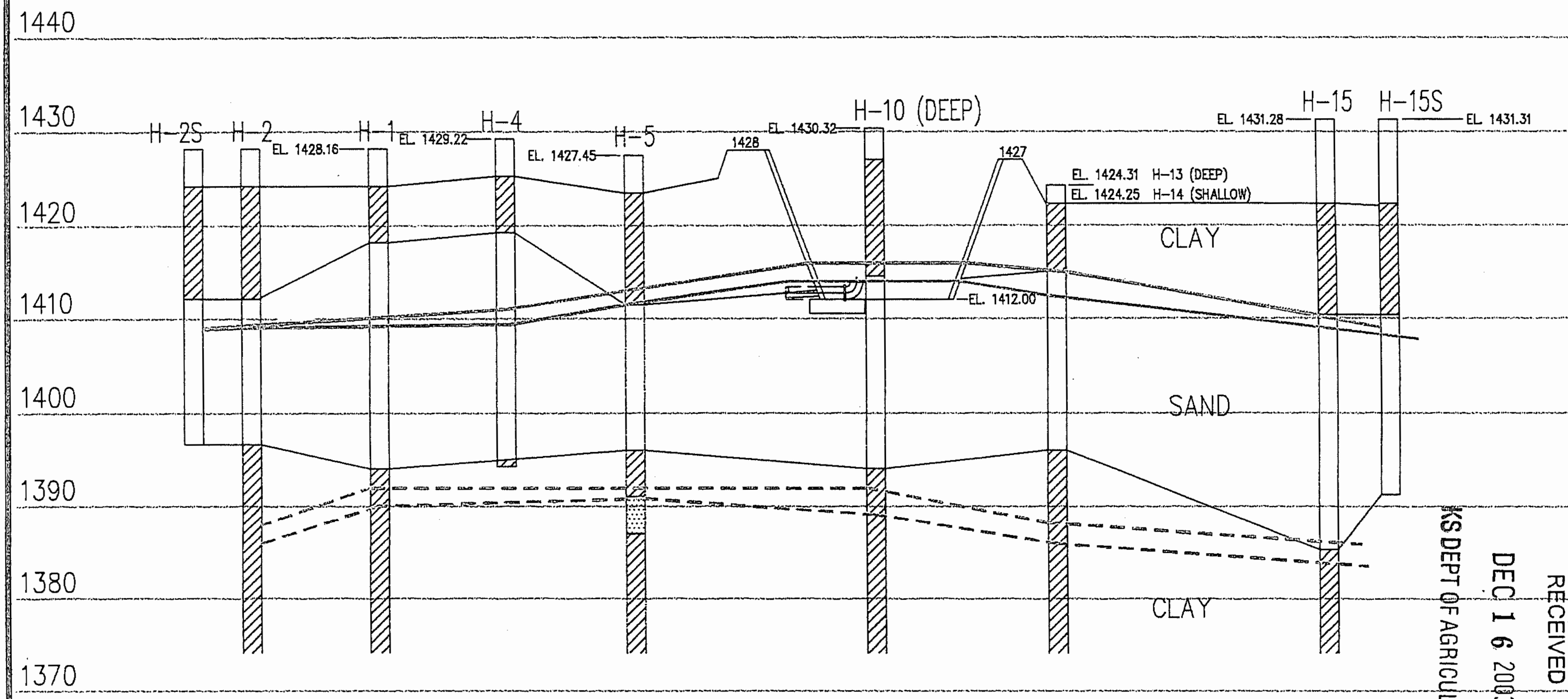

NOT TO SCALE

NOTE:

1. DEEP GROUND WATER LEVEL INFLUENCED BY RECHARGE WELL

—— SHALLOW WATER LEVELS WITH 2 FT. OF WATER IN RECHARGE BASIN SEPTEMBER 28, 1998

– – – DEEP WATER LEVELS WITH 2 FT. OF WATER IN RECHARGE BASIN SEPTEMBER 18, 1998

—— SHALLOW WATER LEVELS WITH 4 FT. OF WATER IN RECHARGE BASIN OCTOBER 13, 1998

– – – DEEP WATER LEVELS WITH 4 FT. OF WATER IN RECHARGE BASIN OCTOBER 3, 1990

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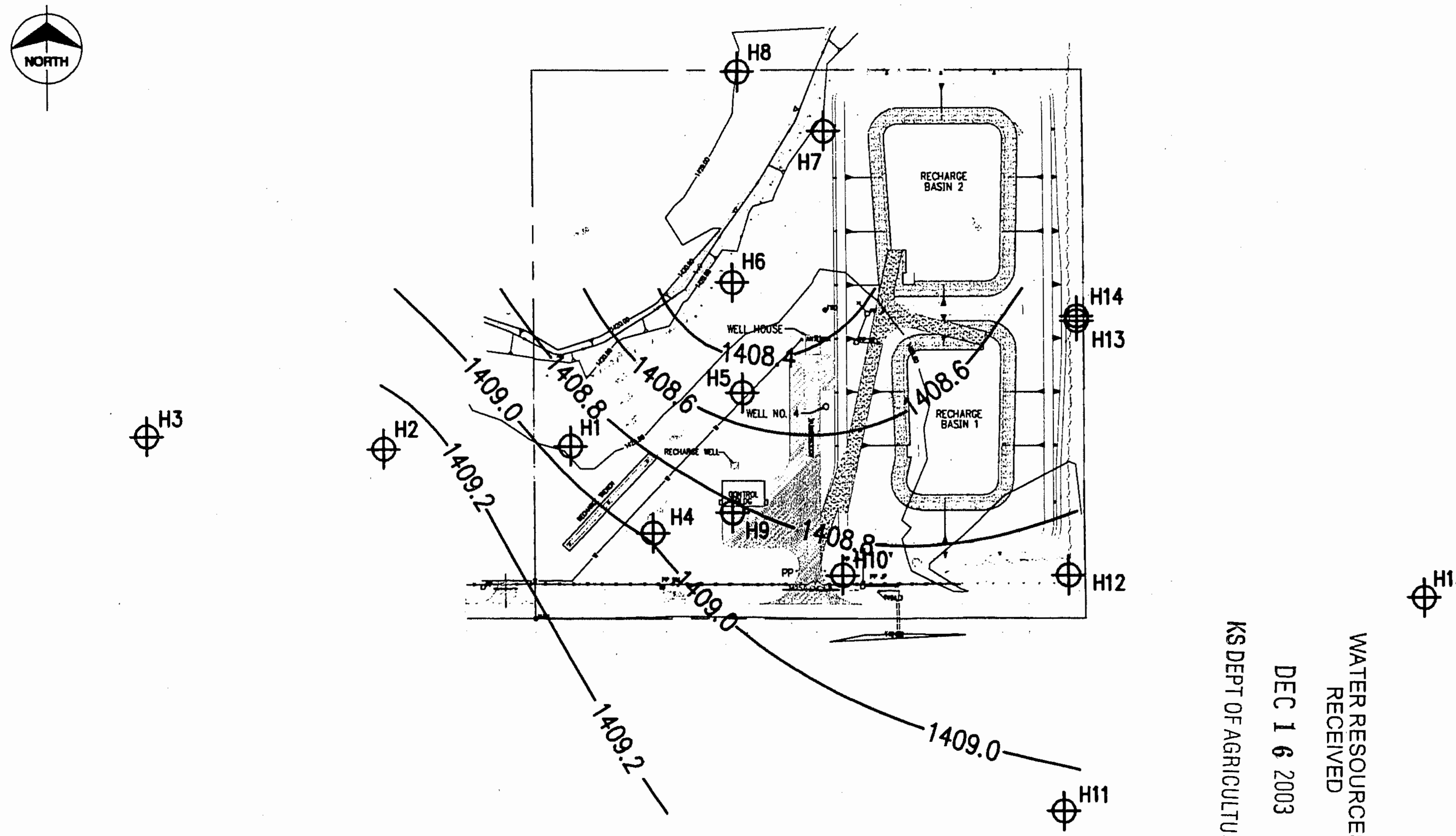
Figure III-3

HALSTEAD RECHARGE SYSTEM CROSS SECTION THROUGH RECHARGE BASINS

030



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LEGEND

MONITORING WELL

GROUNDWATER ELEVATION, JUNE 18, 1998

125 0 125 250

SCALE IN FEET

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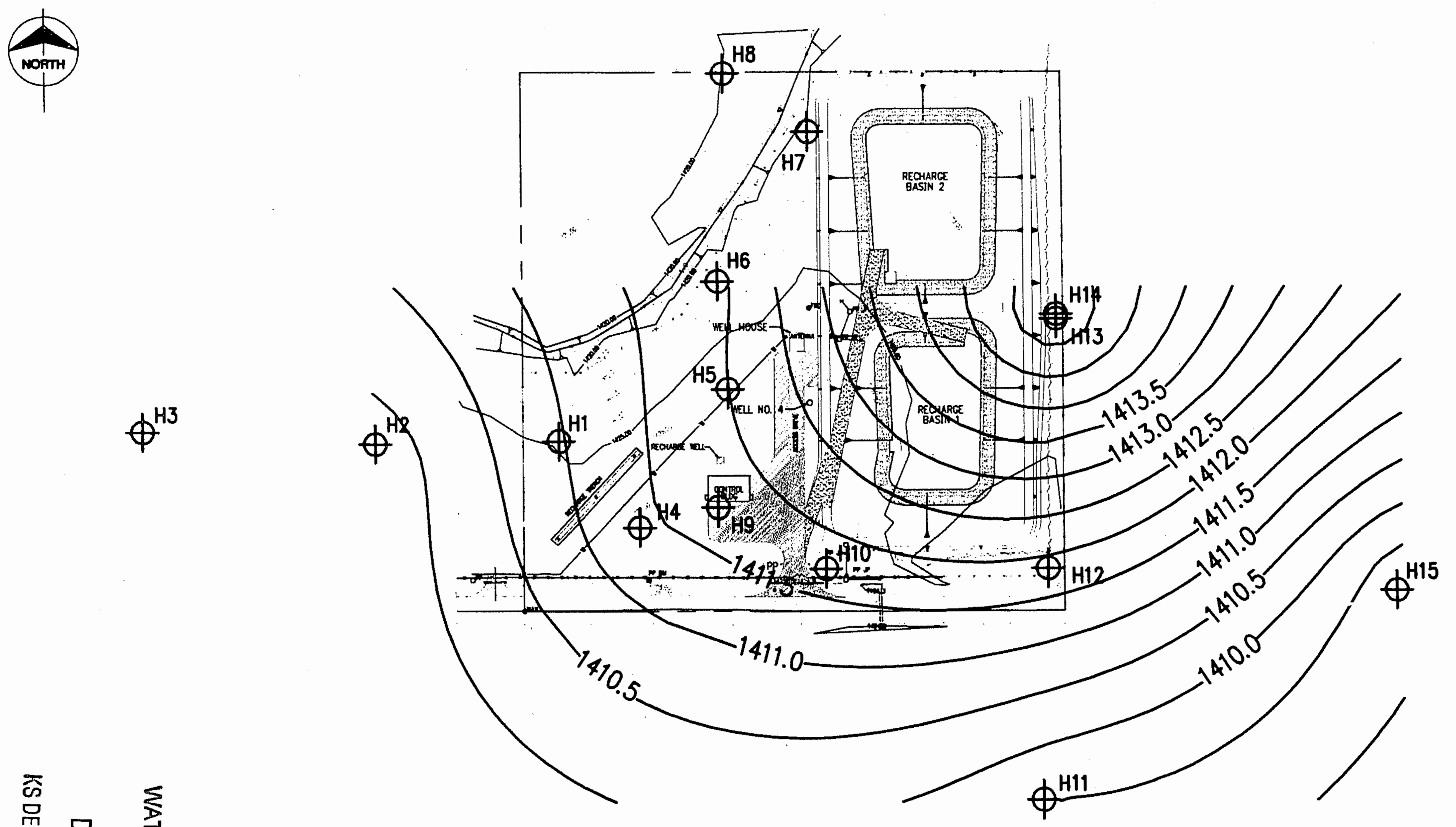
Figure III-4

HALSTEAD RECHARGE SYSTEM
WATER LEVELS
IN SHALLOW AQUIFER
JUNE 18, 1998

J:\WICHITA\921954.014\NEWFIG\FIGIII4.dwg 05-06-1999 09:49 MJC

631



LEGEND

MONITORING WELL

GROUNDWATER ELEVATION, OCTOBER 13, 1998

125 0 125 250

SCALE IN FEET

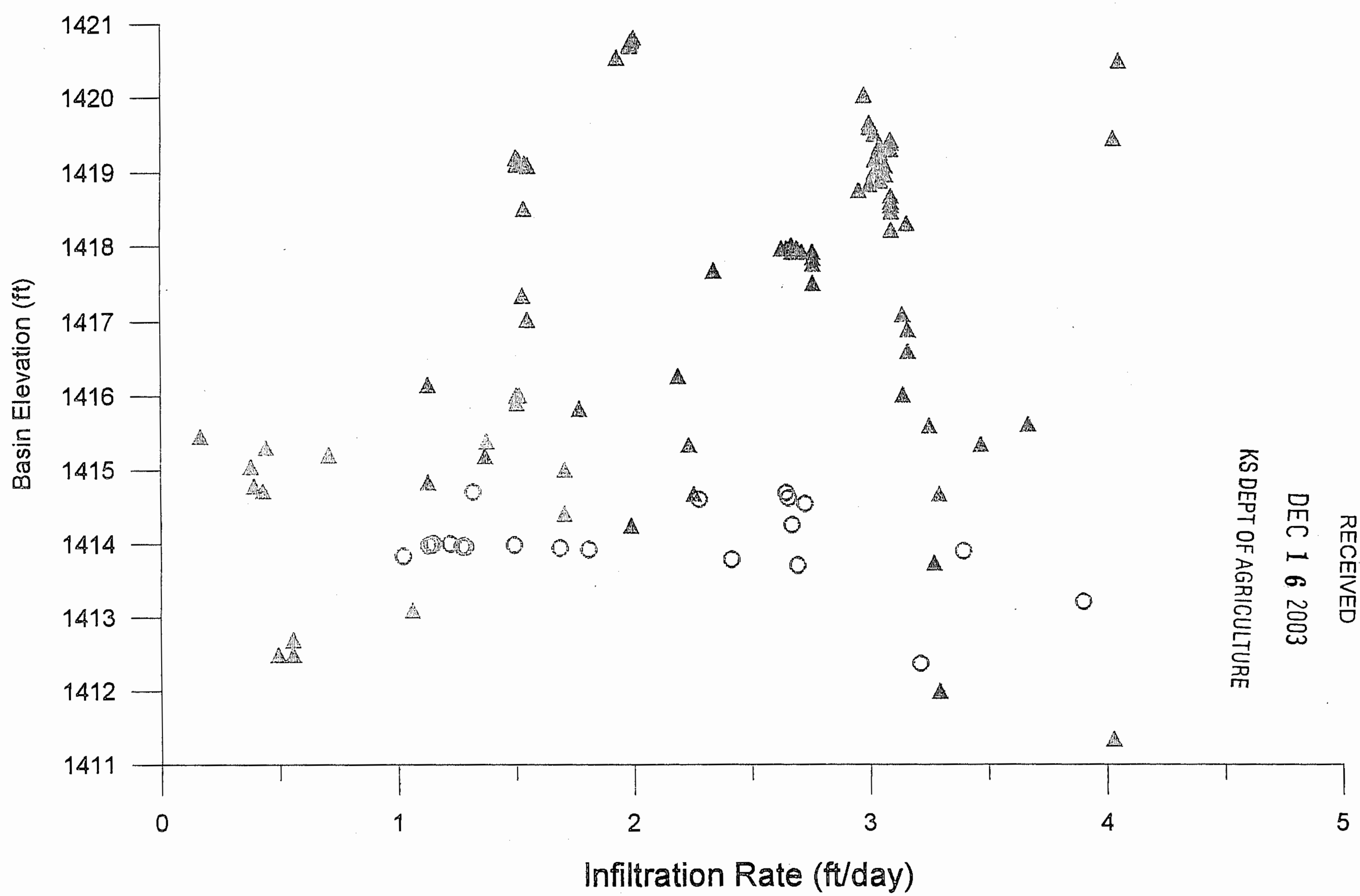
Burns & McDonnell

Figure III-5

HALSTEAD RECHARGE SYSTEM
WATER LEVELS IN
SHALLOW AQUIFER
OCTOBER 13, 1998

J:\WICHITA\921954.014\NEWFIG\FIGIII5.dwg 05-06-1999 09:47 MJC

632



LEGEND

- NORTH AND SOUTH BASINS (without gravity recharge wells)
- NORTH BASIN (without gravity recharge wells)
- SOUTH BASIN (without gravity recharge wells)
- NORTH BASIN (with gravity recharge wells)

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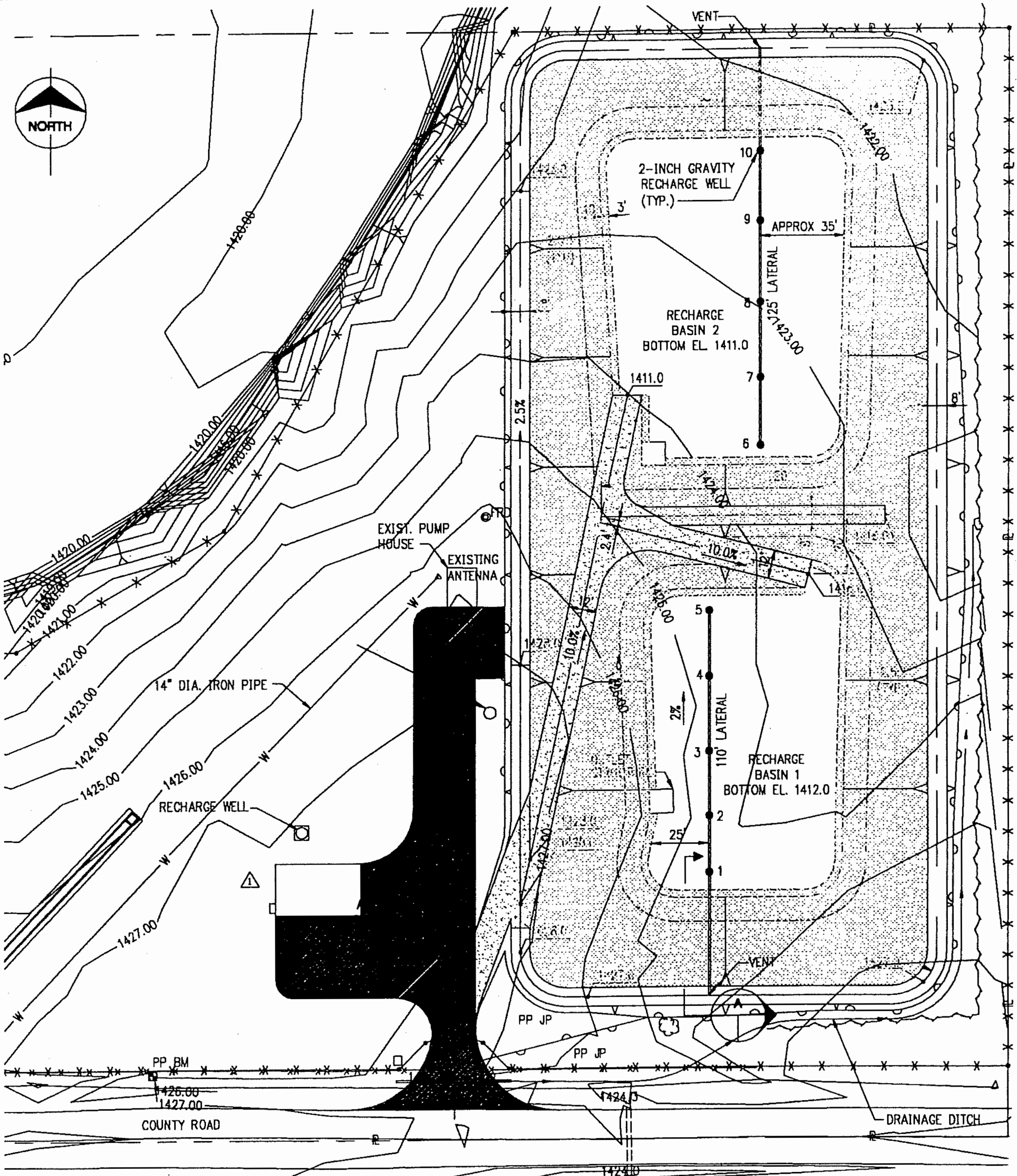
Figure III-6

HALSTEAD RECHARGE SITE
BASIN INFILTRATION RATE

overtopped and the basins function as a single unit. Data known to be collected immediately after relatively long system shutdown periods were not included on Figure III-6. Those data were not considered to reflect steady state conditions, since the subsurface sand layer would not be totally saturated after long periods of basin shutdown. Until the soil beneath the basins becomes totally saturated, infiltration rates are expected to be temporarily higher. In general, data reveal an increasing trend in infiltration rates as the basin water elevation is increased. Some data points appear to fall out of this general trend (infiltration rates of more than 3 ft/day at USGS water elevations of about 1413 ft) and may have been collected after unidentified basin shutdown intervals.

As discussed above, the existing intermediate clay lenses at the Halstead Site cause groundwater mounding beneath the recharge basins, which significantly limits the recharge rates. To overcome this limitation, construction of a series of gravity wells in the recharge basins was proposed in 1999. These wells would allow recharge water to flow freely down to the main aquifer through the clay layers increasing the attainable recharge rates. In November 1999, construction of the gravity recharge well system was completed. Five wells, constructed of two-inch PVC and screen, were installed in each basin to a depth of about 50 feet below the basin bottom (total depth of about 200 feet). The five wells in each basin are connected with a four-inch horizontal lateral screen buried about three feet below the basin bottom. The top of the wells is sealed to prevent direct introduction of water and each well is vented. Figure III-7 shows the layout of the gravity well system within the Halstead Recharge Basins. Figure III-8 shows a typical cross-section through a gravity recharge well.

Operation of the Halstead Recharge System was resumed in November after completion of construction of the gravity recharge well system. Initial testing was conducted until the system was shut down in late December. Initial testing of the basins, after addition of the gravity recharge system, showed a substantial improvement in recharge rates. Further improvement in recharge rates is expected as the system is operated and fine sediment that has washed into the laterals and formation is removed. A graph of basin water depth (ft) vs. infiltration rate (ft/day)



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SCALE IN FEET

HALSTEAD SITE

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Figure III-7

GRAVITY RECHARGE WELLS - LAYOUT

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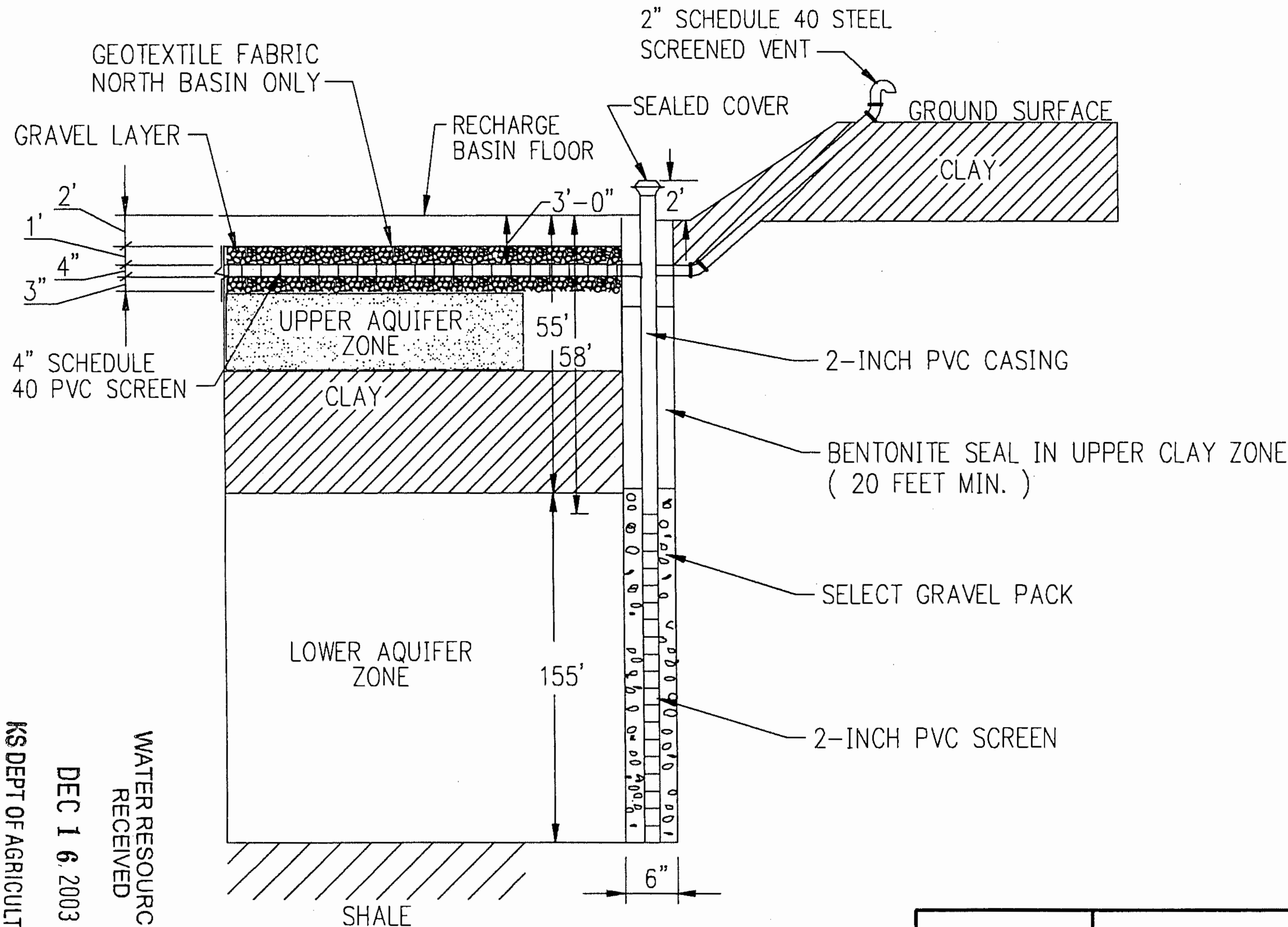

SECTION GRAVITY RECHARGE WELL (A)

NOT TO SCALE

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Figure III-8

TYPICAL GRAVITY RECHARGE WELL CROSS SECTION

for the initial tests performed with the gravity recharge wells is shown in Figure III-6. As seen in this figure, operation of the basins with the gravity recharge wells resulted in higher recharge rates for a given water depth as compared to the tests performed before installation of these wells. Testing of the basins will continue through the spring and summer of 2000 to collect additional data.

(2) Recharge Trench

The recharge trench was initially recommended as a test facility in a peer review of the recharge concepts because of the perched clay layer in the Halstead area. The recharge trench allows a thin vertical flow zone down to the clay layer, which is easily dispersed laterally. A "groundwater mound" is minimized using a linear recharge area (trench), whereas a non-linear area, such as a basin, will cause greater "groundwater mounding". As discussed above, when this groundwater mound rises above the bottom of the basins, vertical percolation ceases, resulting in reduced recharge rates.

The recharge trench has a history of minor operational problems caused by plugging of the upper filter fabric by iron precipitation. Wichita wellfield personnel periodically clean the filter fabric by wet shop vacuum as part of the normal operation and maintenance requirements for continuing recharge operations. Infiltration rates of up to 75 feet per day were obtained and the maximum recharge rate tested was about 120 gpm during the testing period.

In 1998, the recharge trench inlet structure was modified to minimize water aeration. During June 1999, additional modifications were made to the recharge trench to control water agitation and to reduce iron oxidation. Modifications include the installation of distribution piping and use of floating covers. Tests showed that run time was increased slightly; however, the filter fabric continues to experience problems with iron fouling.

(3) Recharge Well

The recharge well is screened below the extensive clay layer, from approximately 130 ft to 215 ft below the ground surface. This allows the demonstration project to recharge in the lower portion of the aquifer, which causes the groundwater system to respond as a confined aquifer. The recharge well was operated from August 1997 through the end of 1999 when the flow in the Little Arkansas River was above the minimum limit. To extend the period of operation and data collection during cold weather, Wichita wellfield personnel constructed an insulated building for the well.

During recharge operations, monitoring wells constructed in the lower aquifer showed large changes of 10 to 15 feet in water levels, depending on pumping or recharge conditions. Piezometric levels in the deep aquifer zone vary mainly in response to changes at the recharge well. However, pumping from City water supply wells and irrigation wells located over 1/2 mile away may also cause some fluctuations in piezometric levels. The responses of groundwater levels in the recharge well and associated piezometric levels in selected monitoring wells are presented in Figure III-9. The system recharge rates and groundwater levels in the shallow portion of the aquifer above the intermediate clay layer are also shown in Figure III-9. Recharge rates were maintained at an approximate average rate of 750 gpm during system operation. The observed rise in shallow groundwater levels is due to recharge through the basins or trench.

Maps showing groundwater contours (deep aquifer) during recharge operations at the end of 1997, at the end of the spring 1998, at the conclusion of the 1998 pumping season, and in January 1999 are presented respectively in Figures III-10, III-11, III-12 and III-13. Recharge operations in the deep aquifer area resulted in the formation of a 30-foot-high ground water "mound" around the recharge well.

The recharge well was periodically redeveloped to remove sediment that could potentially block the inside of the screen and reduce well performance. Redevelopment is accomplished by surging the redevelopment pump 10 to 20 times and then pumping to waste into one of the recharge basins for approximately one hour. Well performance can be evaluated by monitoring the difference between the water levels in the recharge well and a nearby monitoring well with time, as shown in Figure III-14. A stable difference between the recharge well and monitoring well water

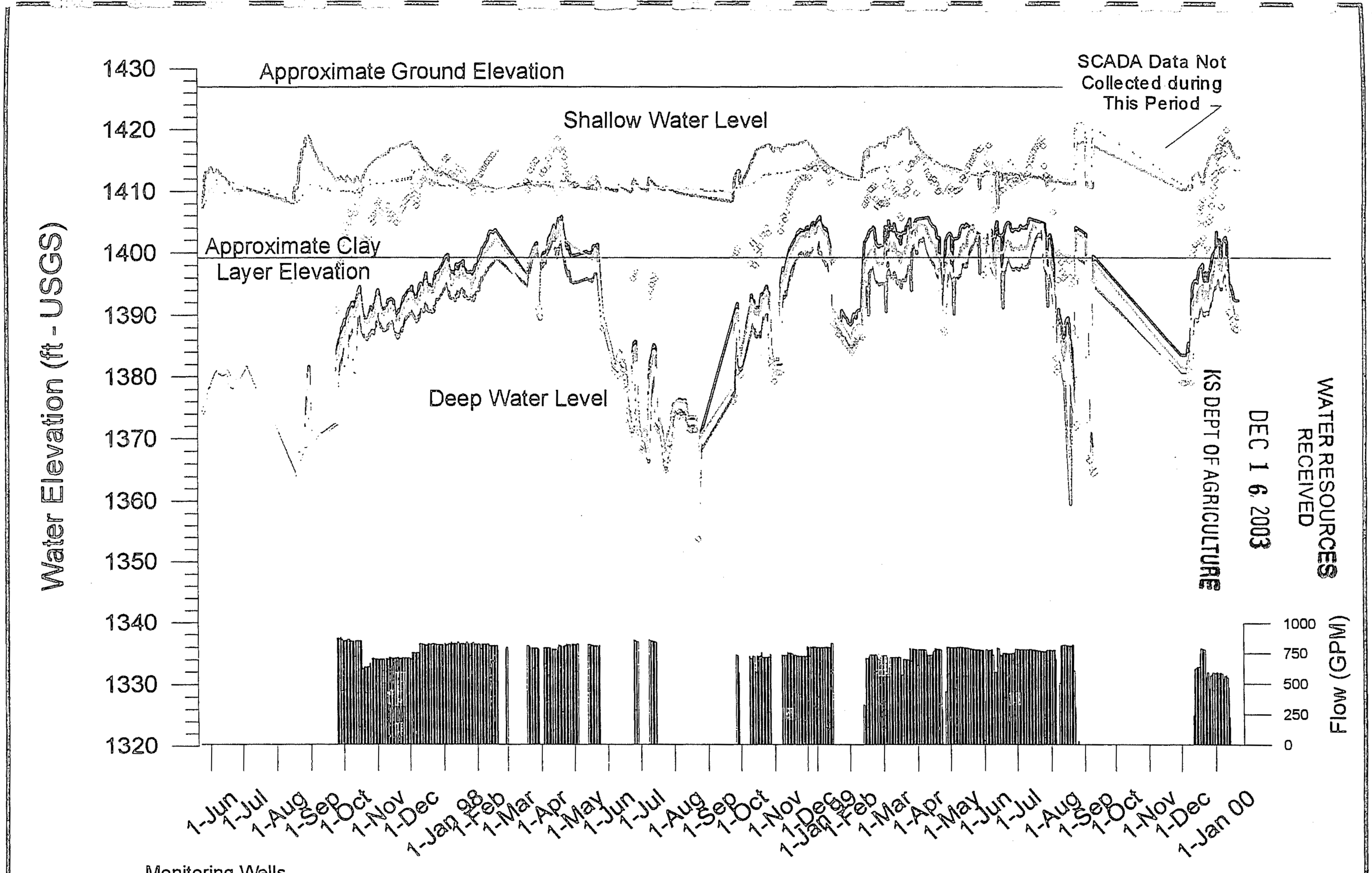

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Figure III-9
HALSTEAD RECHARGE SITE WATER ELEVATION AND WELL RECHARGE RATE

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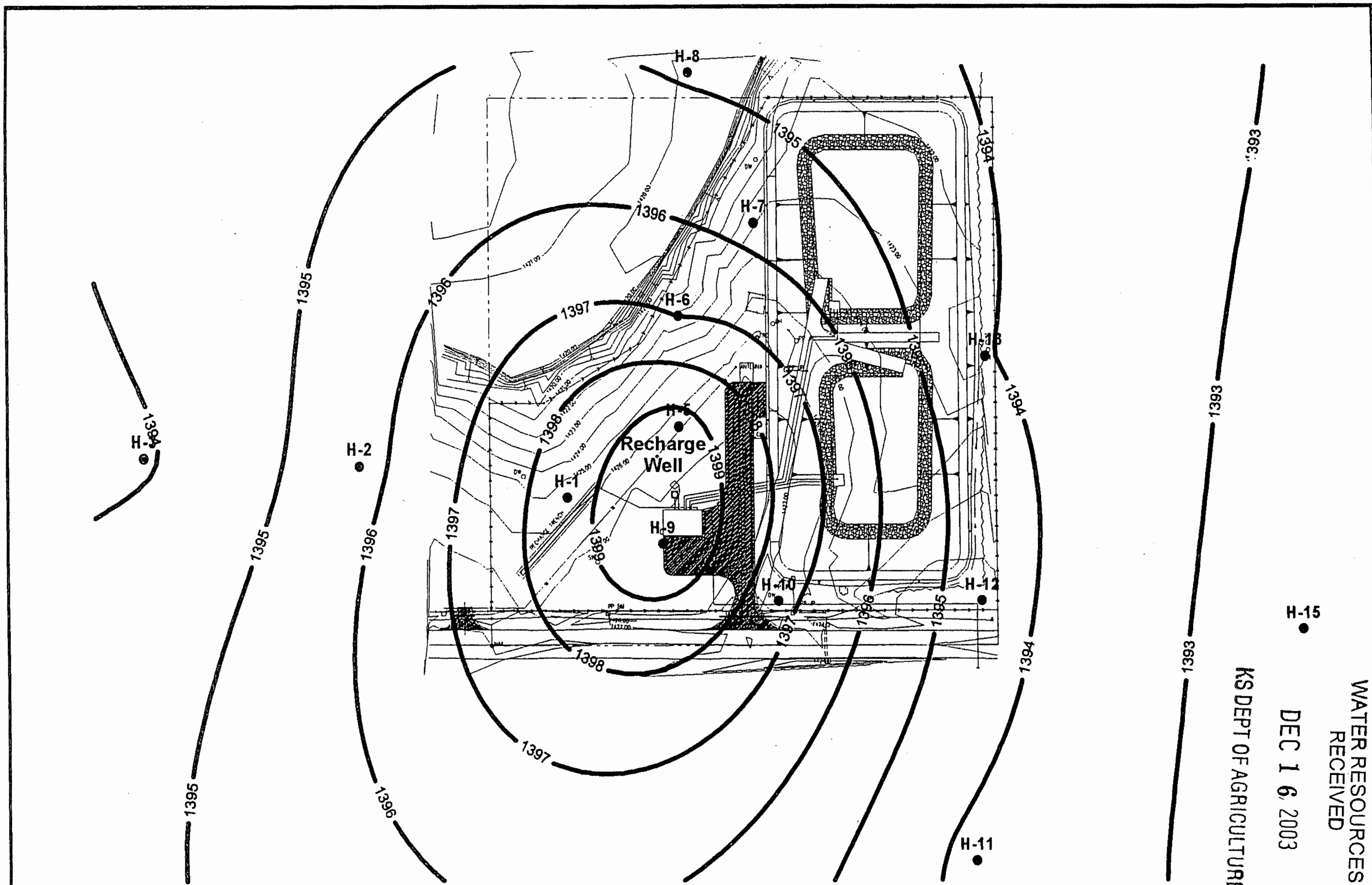

● Monitoring well

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Figure III-10

HALSTEAD RECHARGE SITE GROUNDWATER ELEVATION MAP DECEMBER 31, 1997

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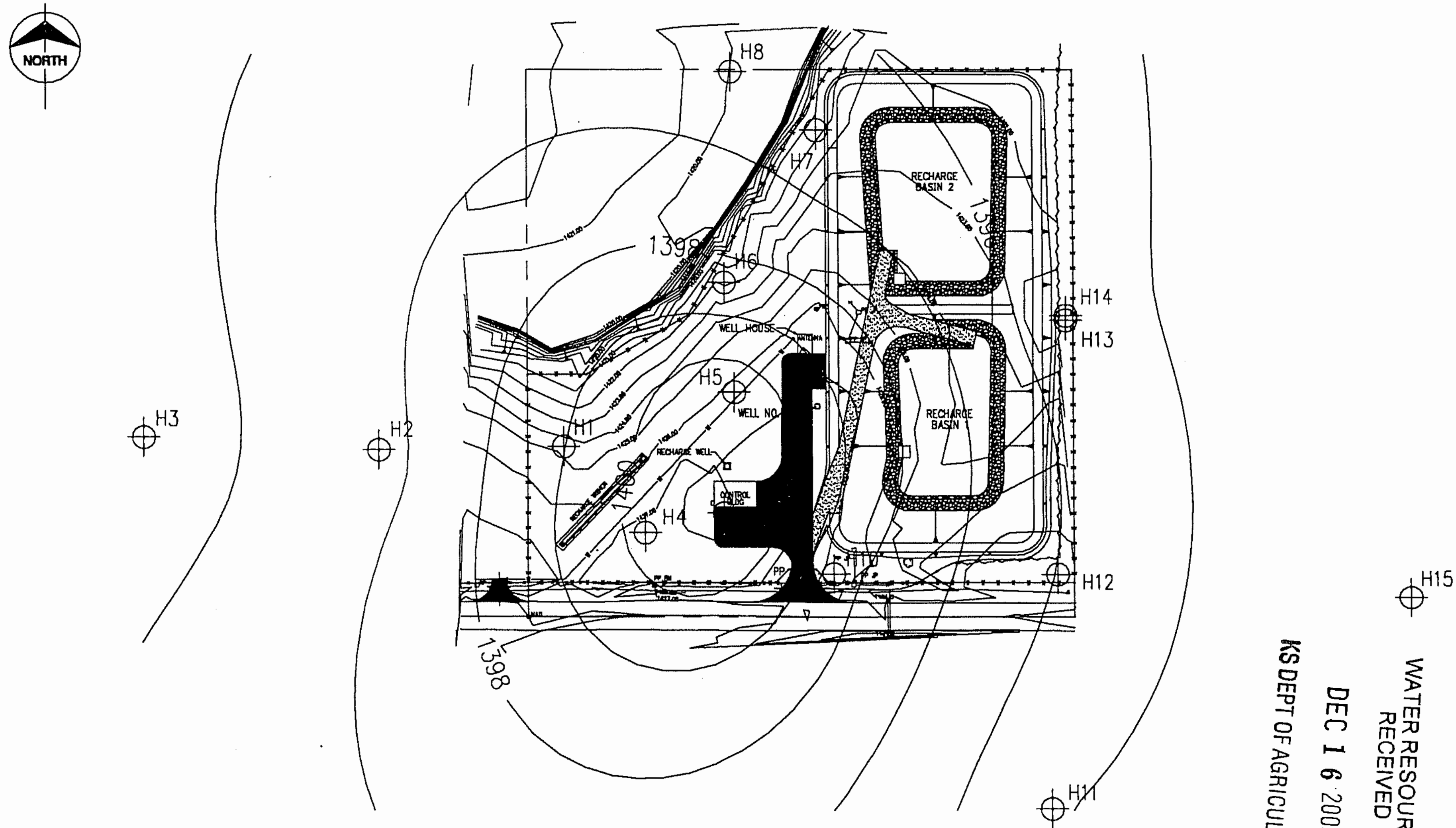
640



LEGEND

MONITORING WELL

GROUNDWATER ELEVATION, MAY 18, 1998

125 0 125 250

SCALE IN FEET

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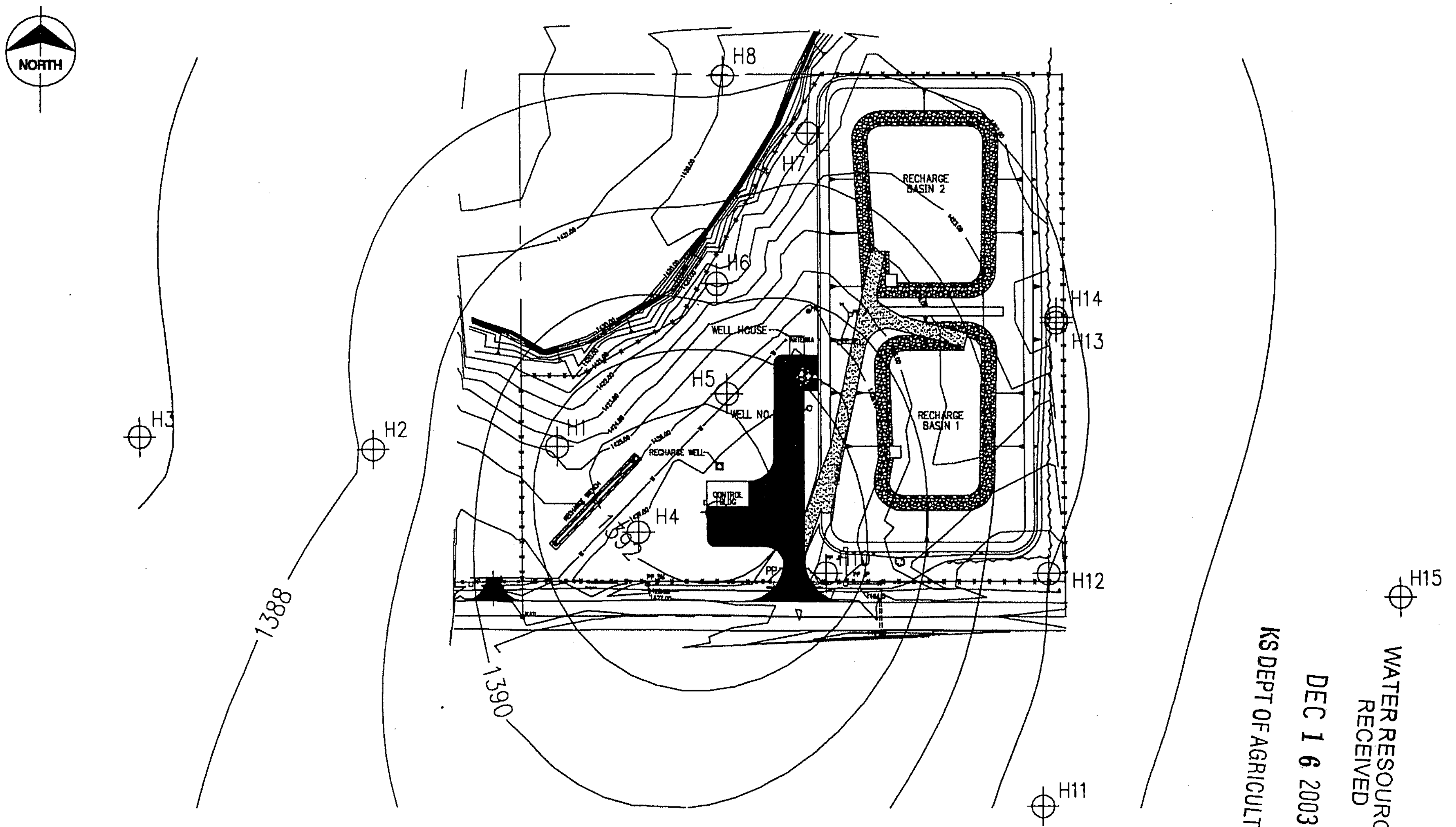
Figure III-11

HALSTEAD RECHARGE SYSTEM
WATER LEVELS IN DEEP AQUIFER
MAY 18, 1998

J:\WICHITA\921954.014\NEWFIG\FIGIII12.dwg 04-13-2000 11:20 dfv



LEGEND

MONITORING WELL

GROUNDWATER ELEVATION, OCTOBER 13, 1998

125 0 125 250

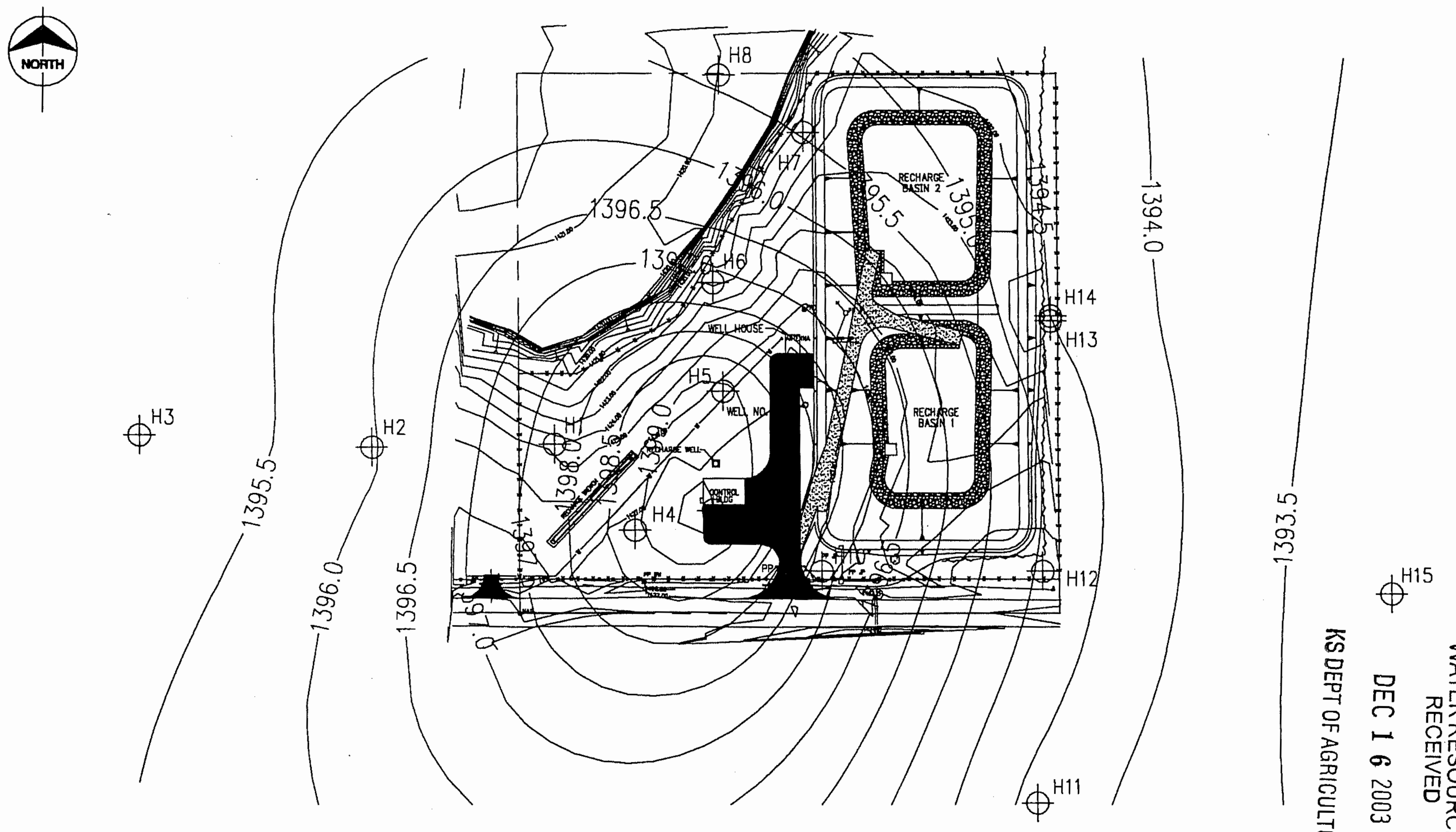
SCALE IN FEET

Burns & McDonnell

Figure III-12

HALSTEAD RECHARGE SYSTEM
WATER LEVELS IN DEEP AQUIFER
OCTOBER 13, 1998

J:\WICHITA\921954.014\NEWFIG\Figiii13.dwg 04-13-2000 11:23 dvf



LEGEND

⊕ MONITORING WELL

—— GROUNDWATER ELEVATION, JAN 22, 1999

125 0 125 250

SCALE IN FEET

Burns & McDonnell

Figure III-13

HALSTEAD RECHARGE SYSTEM
WATER LEVELS
IN DEEP AQUIFER
JANUARY 22, 1999

J:\WICHITA\921954.014\NEWFIG\FIGIII14.dwg 04-13-2000 13:37 dfv

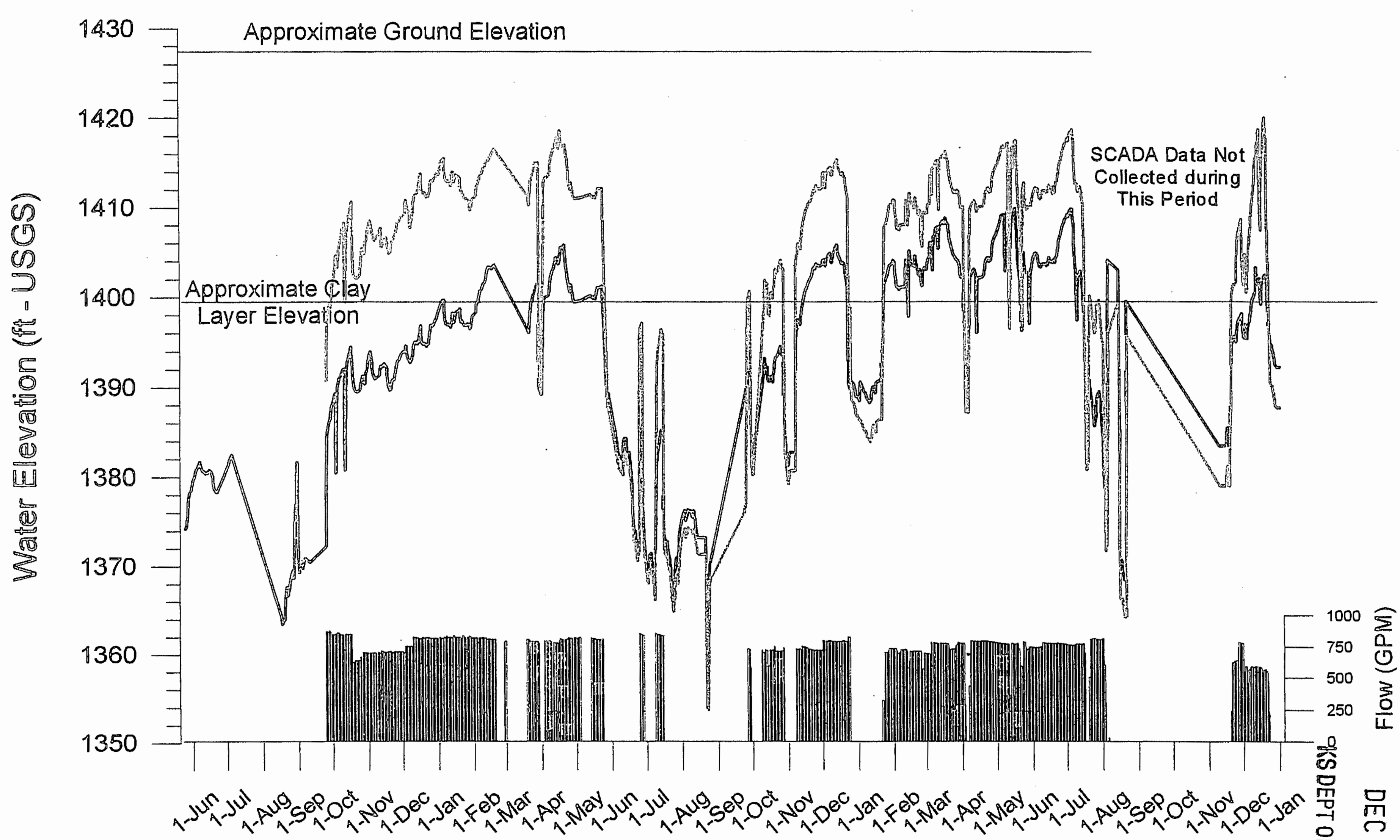


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Figure III-14
HALSTEAD RECHARGE SITE WELL H1 AND RECHARGE WELL WATER LEVEL COMPARISON

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levels is an indication of adequate well performance, while an increasing difference would be a sign of possible well deterioration due to well or formation plugging. The above figure shows that, during recharge events, the difference in water levels between the recharge well and Monitoring Well H-1 was in the range of 10 to 15 feet for over two years and did not show any noticeable increasing trend. However, during November and December 1999, the difference in water levels shows an increase to over 20 feet, which indicates additional headloss in the well screen and/or aquifer.

Well performance can also be evaluated by monitoring the well recharge specific capacity (ratio of recharge flow to groundwater rise at the well relative to the static level) with time as shown in Figure III-15. Recharge test results show that the well recharge specific capacity stabilized in the range of 25 gpm/ft-rise to 35 gpm/ft-rise during periods of continuous operation for over two years of well testing. However, a decrease in the well average recharge specific capacity was observed in 1999, which denotes a deteriorating well performance. This decrease in recharge specific capacity parallels the increase in the difference between the recharge well and monitoring well water levels described previously in Figure III-14. Since minimal redevelopment has been performed on the well during almost two years of operation, the observed decrease in well performance may indicate the need for more frequent redevelopment. Data collection difficulties experienced during the last quarter of 1999 are also suspected to be the cause of the above data trend. These difficulties were caused by the incorporation of the SCADA system for the Project intc the City's overall water monitoring system in September 1999. Well recharge specific capacity will continue to be monitored in year 2000 to verify well performance.

b. <u>Sedgwick Recharge System</u>

(1) Recharge Basin Testing

Testing of the Sedgwick Recharge System was initiated in October 1997 and continued through the end of 1999 when the river stage was above 40 cfs at the Sedgwick gage. System operation was interrupted during the winter months to avoid

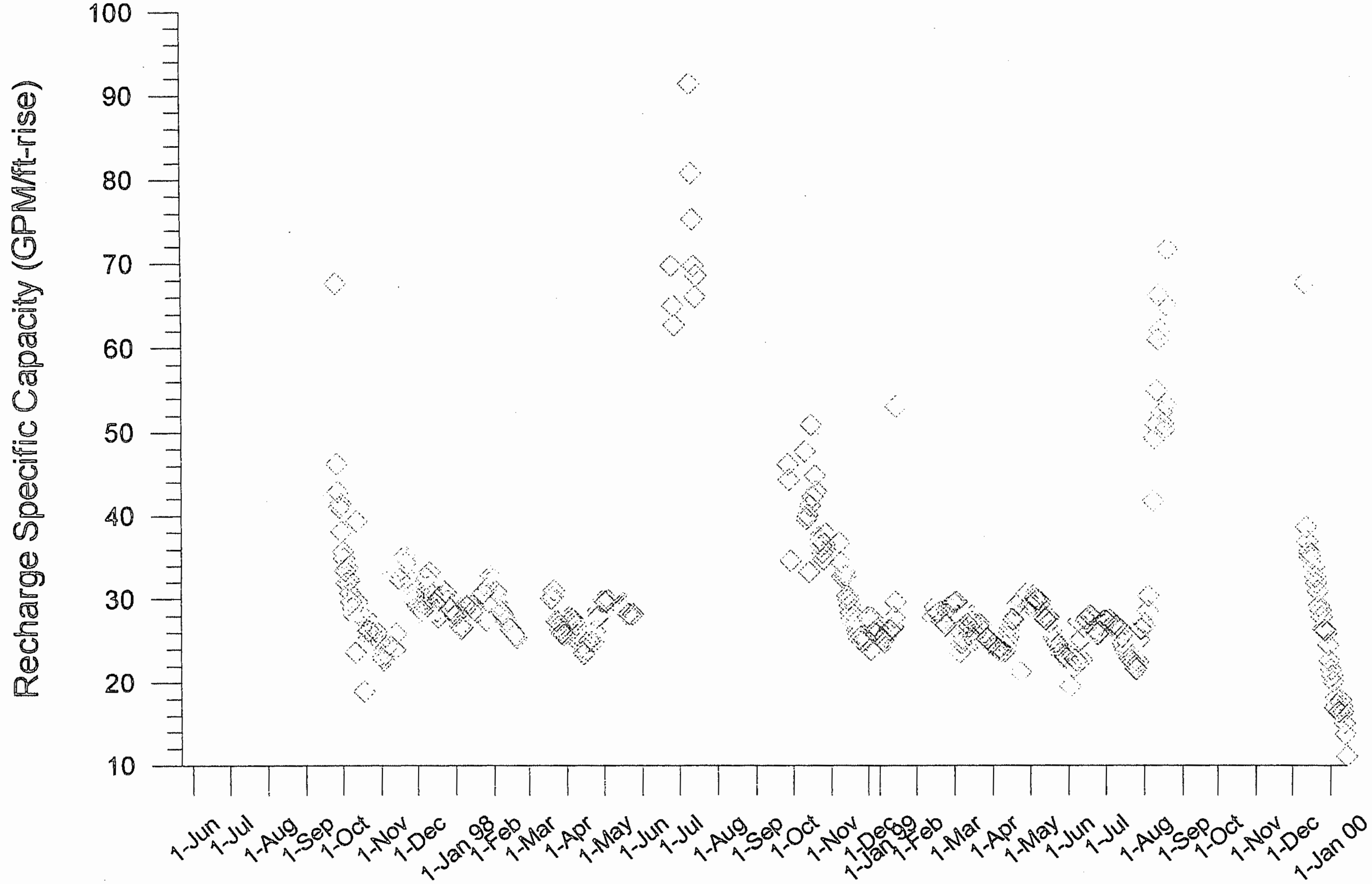

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Figure III-15

HALSTEAD RECHARGE SITE RECHARGE SPECIFIC CAPACITY

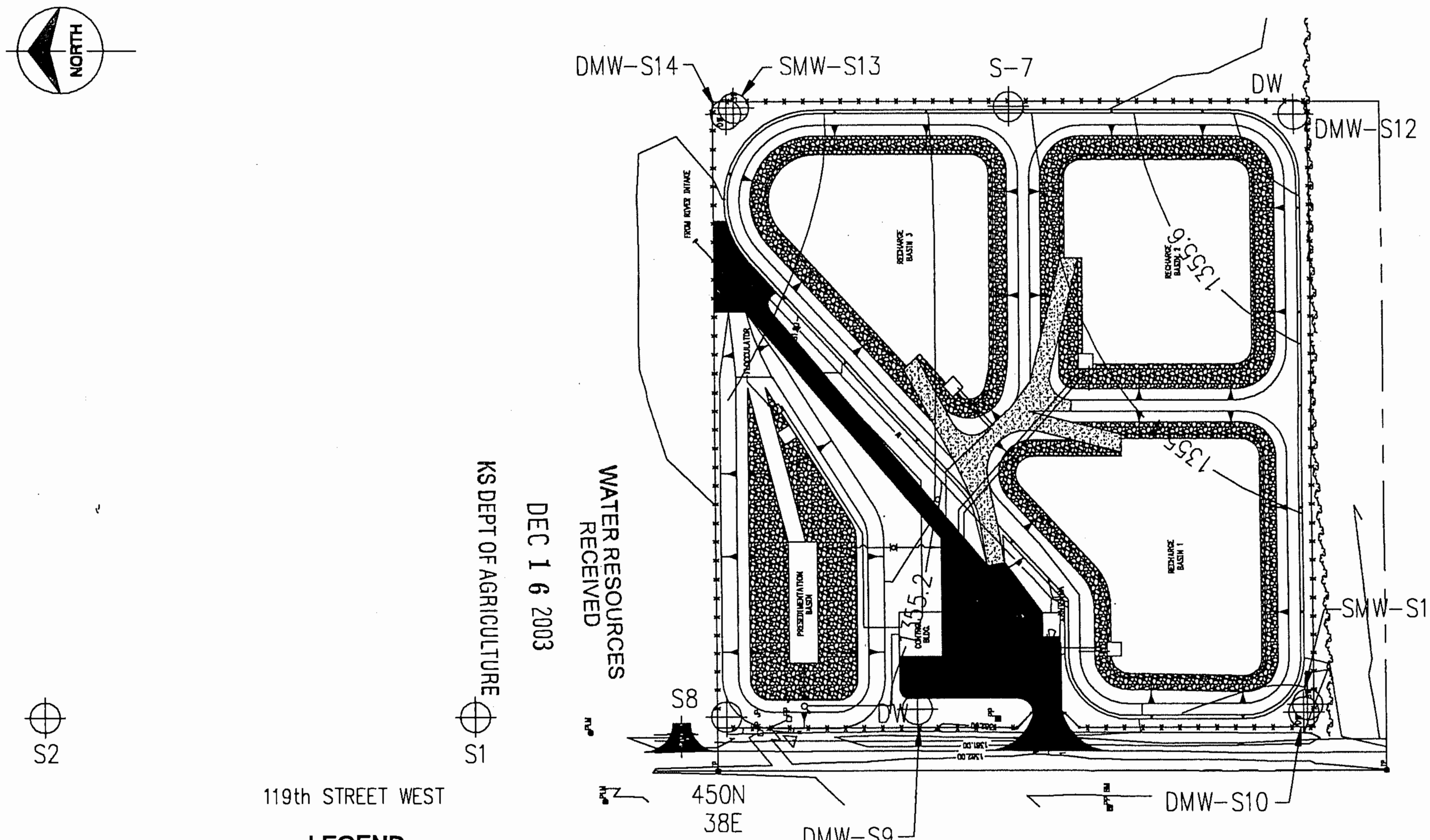
4/14/00 9:15 AM j:\wichita\921954.016\reports\figures\fig3_15.grf operating the pretreatment system at or below freezing temperatures. A map of pre-operation groundwater levels in the main aquifer is shown in Figure III-16.

Since, in contrast to the Halstead site, no extensive clay layers exist to impede vertical seepage of the recharge water at this location, the formation of a significant "groundwater mound" was not observed during the 1997, 1998 and 1999 tests. As a result of this, recharge rates observed at the Sedgwick Recharge Basins are higher than those obtained at the Halstead Basins. The recharge basins at Sedgwick infiltrate water at a rate of about 8 to 9 feet per day with low heads (shallow water levels). This rate could potentially be increased by raising the water level in the basins; however, the limiting factor at the Sedgwick Recharge Demonstration Site is the maximum supply of 1,000 gpm from the surface water intake. Based on this results, recharge basins appear to be an excellent method of recharging the Equus Beds Aquifer in regions with no intermediate clay layers.

During recharge operations, groundwater levels remained stable at an approximate average depth of 30 feet below the bottom of the recharge basins. Water elevations and recharge flow rates at the recharge basins with time, as well as the associated response of groundwater levels in selected monitoring wells are shown in Figure III-17. Groundwater recharge rates at the recharge basins and the pre-sedimentation basin are missing for several recharge events (May, August and November 1998 and April and August 1999) due to SCADA system malfunctions. Maps showing groundwater contours for pre-operation conditions and during recharge operations at the end of the spring of 1998, at the conclusion of the 1998 pumping season, and in January 1999 are presented respectively in Figures III-18, III-19, and III-20.

Extensive recharge occurred through the pre-sedimentation basin before sediment from the surface water and powdered activated carbon added to remove triazines began to plug the bottom to a significant extent. When this occurred, water levels rose high enough to be transferred to the recharge basins. As shown in Table I-6, more than 15 percent of the Sedgwick recharge volume in years 1997 through 1999 occurred through infiltration at the presedimentation basin.

J: \WICHITA\921954.014\NEWFIG\FIGIII16.dwg 04-18-2000 17:26 dfv



LEGEND

MONITORING WELL

GROUNDWATER ELEVATION, MARCH 23, 1999

100 0 100 200

SCALE IN FEET

Burns & McDonnell

Figure III-16

SEDGWICK RECHARGE SYSTEM PRE-RECHARGE WATER LEVELS

648

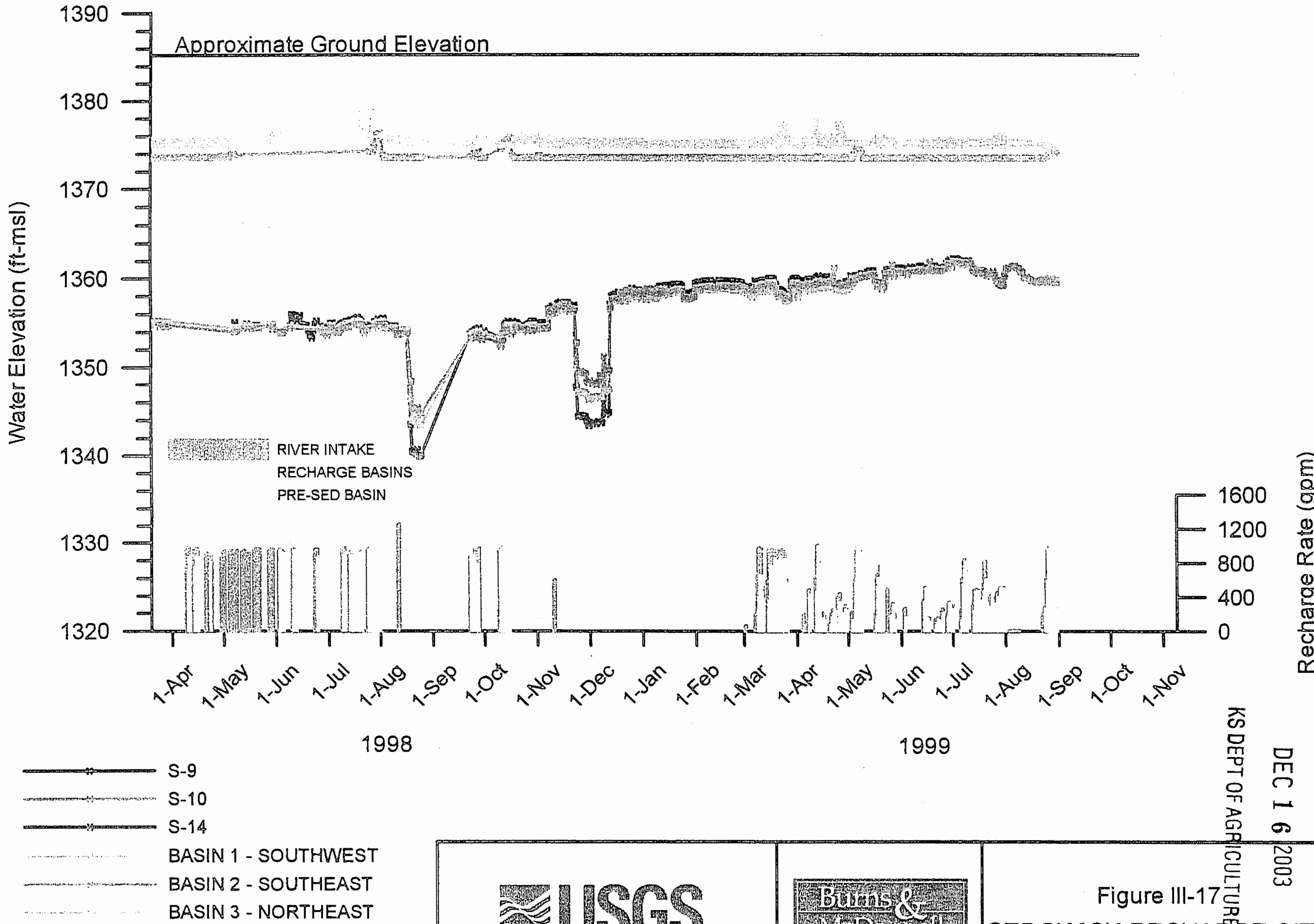


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Figure III-17
SEDGWICK RECHARGE SITE
WATER ELEVATION AND
BASIN RECHARGE RATE

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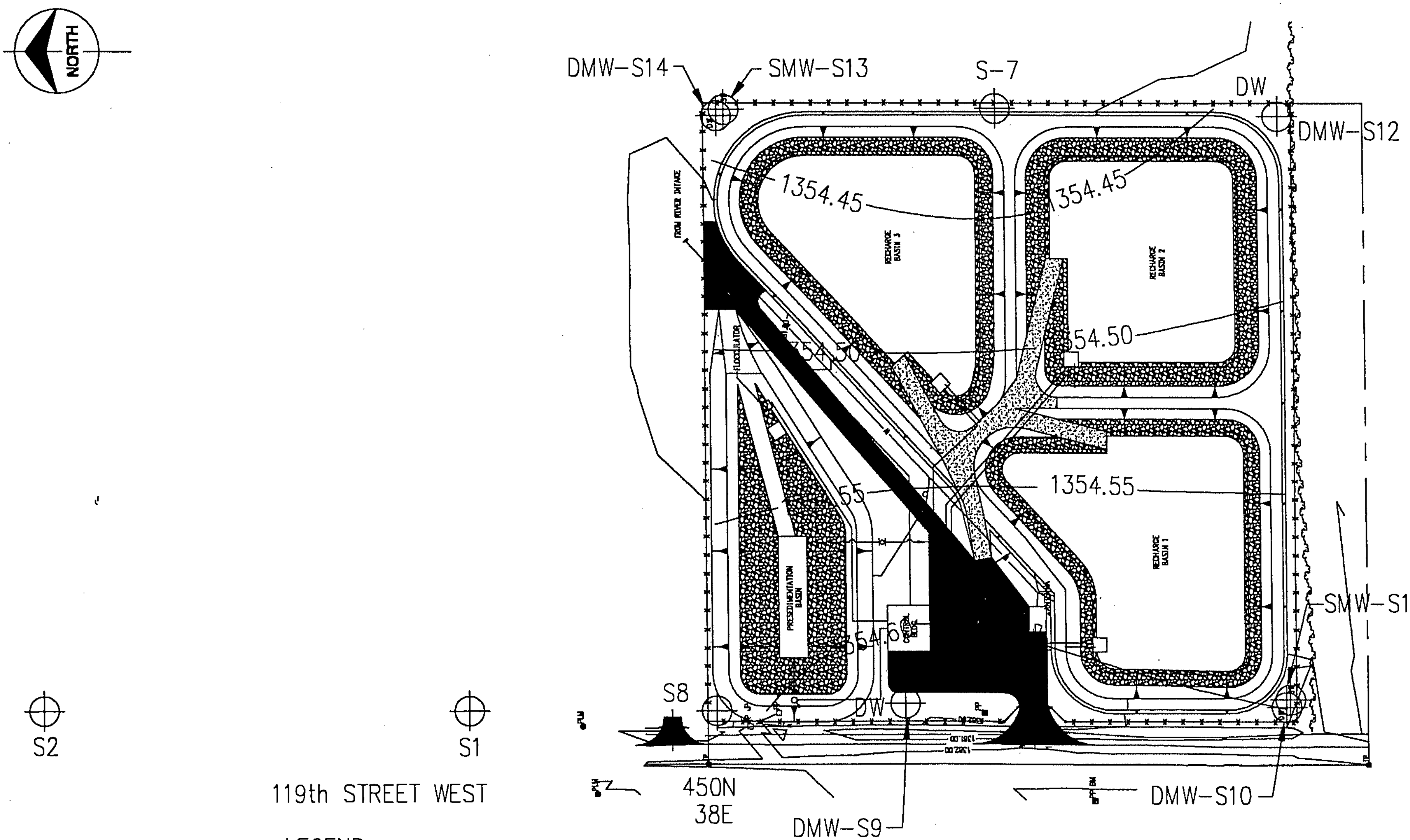
649

J:\WICHITA\921954.014\NEWFIG\FIGIII18.dwg 04-18-2000 17:31 dfv



LEGEND

MONITORING WELL

GROUNDWATER ELEVATION, MAY 21, 1998

100 0 100 200

SCALE IN FEET

Burns & McDonnell

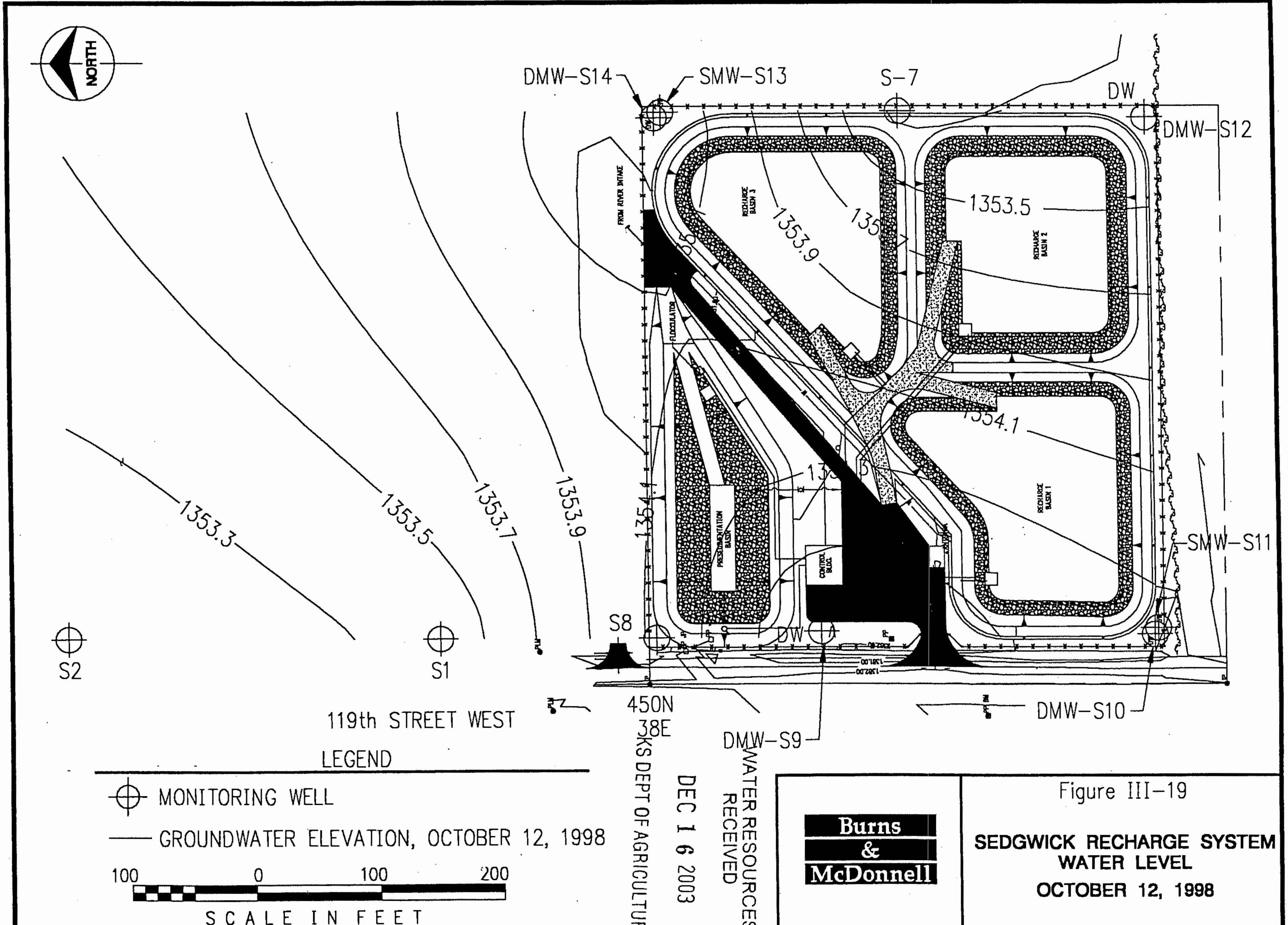
Figure III-18

SEDGWICK RECHARGE SYSTEM WATER LEVELS

MAY 21, 1998

650

J:\WICHITA\921954.014\NEWFIG\FIGIII19.dwg 04-18-2000 17:39 dfv



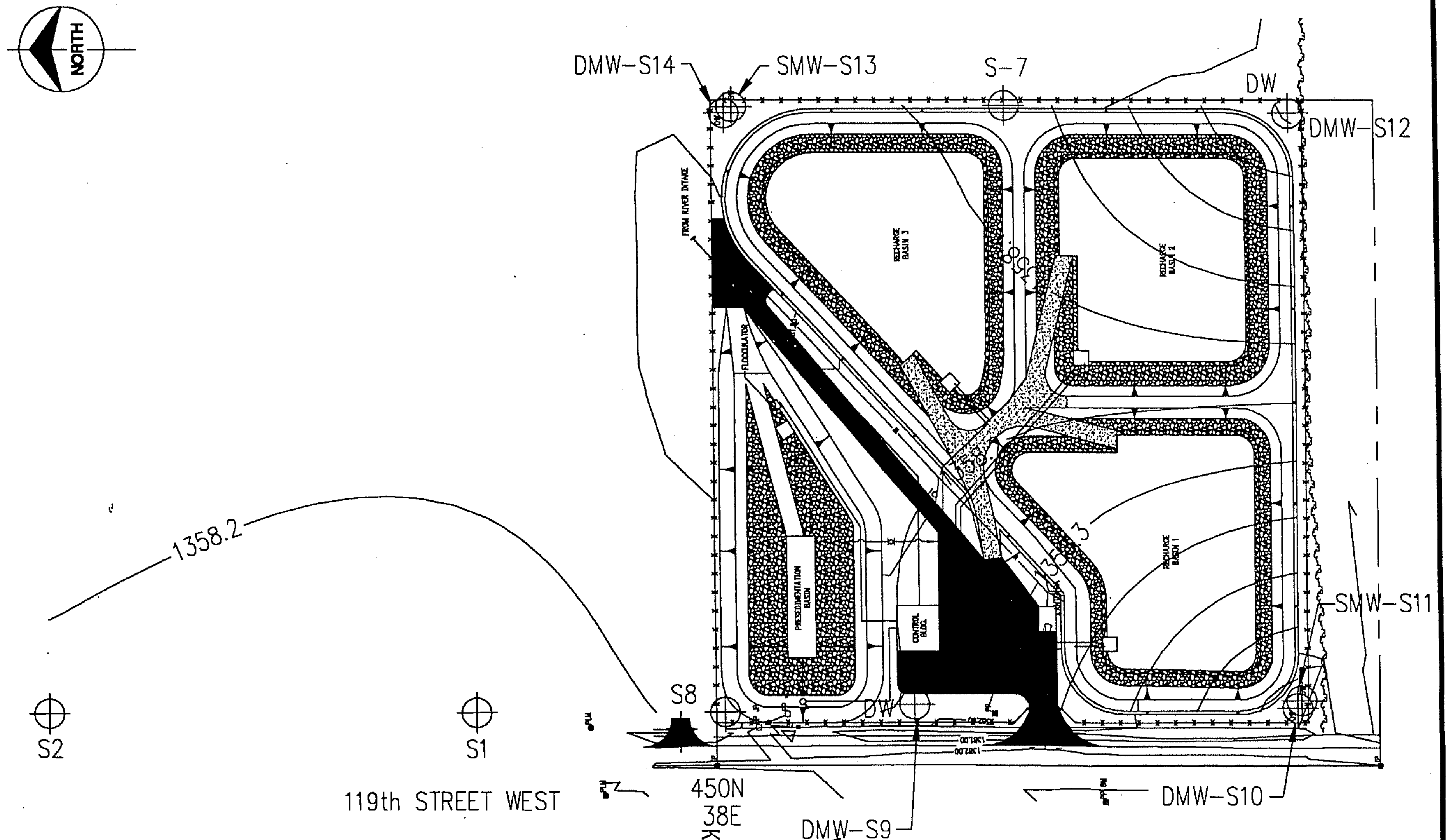
Burns & McDonnell

Figure III-19

SEDGWICK RECHARGE SYSTEM WATER LEVEL OCTOBER 12, 1998

651

J:\WICHITA\921954.014\NEWFIG\FIGIII20.dwg 04-18-2000 17:42 dvf



LEGEND

MONITORING WELL

GROUNDWATER ELEVATION, JANUARY 22, 1999

100 0 100 200

SCALE IN FEET

Burns & McDonnell

Figure III-20

SEDGWICK RECHARGE SYSTEM WATER LEVELS

JANUARY 22, 1999

(2) Recharge Water Pretreatment Investigations

The packaged pre-sedimentation unit installed as part of the demonstration facilities in the Sedgwick System is as parallel plate separator (Lamella) unit. The unit is located at the Sedgwick Intake Site to remove turbidity from the Little Arkansas River water prior to recharge. An earthen pre-sedimentation basin at the Sedgwick Recharge Site is used to settle out powdered activated carbon (PAC) which is fed into the flow of pre-settled water to reduce herbicides (mainly atrazine) as water is pumped to the recharge site.

When surface water is used for recharge, a direct relationship occurs between the amount of surface water pretreatment required to provide the necessary recharge and the level of maintenance required to keep the recharge facilities operational. Although high levels of turbidity removal from the recharge water would potentially allow extended operation of the basins with relatively low maintenance, construction and operation of facilities to provide a higher level of treatment is typically more expensive. Direct recharge without treatment, on the other hand, would eliminate the expenses associated with the treatment facilities, but would require high maintenance of the recharge basins or could potentially result in irreversible plugging of the recharge facilities (particle migration and accumulation deeper into the basin bottom).

In addition to the operation of the packaged water treatment unit at the Sedgwick Recharge System, several small-scale column infiltration tests were conducted to study how surface water pretreatment affects long-term recharge rates and the recharge basin maintenance requirements. Two testing columns were constructed and used at the Sedgwick Intake and Recharge Sites as a tool to conduct "compressed time testing." Data collected during these investigations were evaluated and used to develop recommendations on the level of surface water pretreatment required.

(a) <u>Filter Column Setup</u>

Two sand infiltration columns were built at the Sedgwick System, one at the Sedgwick Intake Site next to the Lamella unit and the other at the Sedgwick Recharge Site next to the pre-sedimentation facilities. These infiltration columns were used to test the Lamella effluent separately from the entire system and to compare data with tests of pre-sedimentation effluent turbidity.

Each column was constructed of 8-inch diameter PVC pipe and was mounted vertically (24 feet in height). The columns contained 3 feet of earth-fill material (sand) from the Sedgwick recharge basins. A diagram of the filter column is shown in Figure III-21. One column was connected to the effluent box of the Lamella unit at the intake site. The second column was attached to the pump discharge after the pre-sedimentation basin at the recharge site. Both columns were provided with backwash capabilities.

Immediately above the earth-fill material in each column is a piezometer which measured the potentiometric level above the fill. Six additional piezometers were situated throughout the length of the earth-fill material to measure the potentiometric head loss at different depths and allow for evaluation of turbidity/particle removal throughout the bed. Beneath the earthen material, a small layer of gravel and a media retaining cap were installed to prevent loss of finer material.

(b) Filter Column Field Testing

The two infiltration columns were used to test the plugging potential of water with varying turbidities and different treatment processes on recharge basin sands. Tests were performed at high flow rates and low flow rates. In the high flow rate tests, the water column was maintained approximately 13 feet above the top of the earth-fill material (high head). Lower flow rate tests had approximately 3 feet of water above the top of the earth-fill material.

Field testing at the Sedgwick Intake Site infiltration column was started on March 25 and 26, 1999. During these initial tests, the column was used to test the treated Lamella water and also the viability of recharge without any treatment at low raw-water turbidities. Additional field testing of the infiltration column at the Sedgwick Intake Site was conducted when raw water turbidity became elevated with high flow in the river. These tests began on May 24, 1999, were completed on May 28, 1999, and involved six additional infiltration test runs

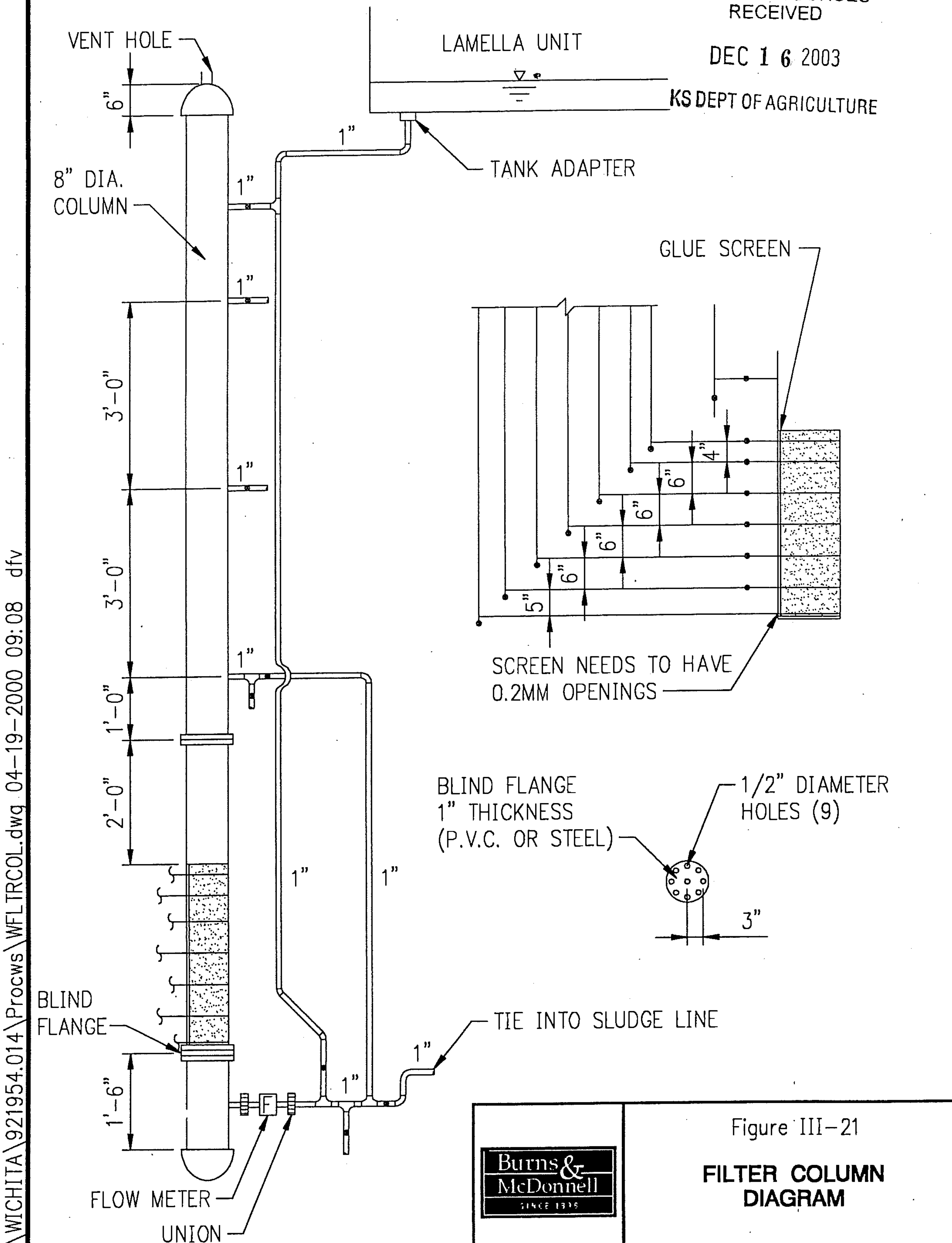


Figure III-21

FILTER COLUMN DIAGRAM

with treated water from the Lamella unit. The tests were conducted to investigate the following conditions:

- Effects of higher turbidity raw water compared to the initial runs conducted in March 1999,
- Impacts of reduced flow rate on system performance,
- Performance of a new polymer that appeared to provide better water clarity, and
- Effectiveness of a filter fabric on top the sand media.

Four infiltration runs with treated water from the pre-sedimentation basin were conducted at this site to study the effects of using a new polymer (PRC 3070 S) and a filter fabric on the top of the sand media.

Particle counting was conducted during some of the test runs to determine the nature of particulates in the raw water, treated water from the Lamella unit, treated water from the pre-sedimentation basin, and discharge from the column tests at the recharge site. Particle count analyses were used to determine the distribution of particle sizes in particular samples, influent, effluent and backwash. Particle counters have sensors available in different-size ranges which allow measurement of particle concentrations in these ranges.

The test conditions and observed results are summarized in Table III-4 for the intake site column and in Table III-5 for the recharge site column. Main observations and conclusions from the column infiltration tests include:

- <u>Viability of Recharge Without Treatment</u>
  When raw water from the Little Arkansas River was processed through the intake site column, the piezometer readings slowly decreased after

Table III-4
Sedgwick Intake Site Column Infiltration Results

System Variable	Test # 1	Test # 2[a]	Test # 3	Test # 4[a]	Test # 1	Test # 3	Test # 5[b]	Test # 6[c]	Test # 9	Test # 10
Test Date	03/25/99	03/25/99	03/26/99	03/26/99	05/24/99	05/25/99	05/26/99	05/27/99	05/28/99	05/28/99
Polymer	Superfloc C-587		Superfloc C-587		Superfloc C-587	Superfloc C-587	PRC 3070S	PRC 3070S	PRC 3070 S	Superfloc C-587
Approximate Flow Through Treatment System (gpm)	1,000	1,000	1,000	1,000	1,000	530	530	530	1,000	1,000
Raw Turbidity (NTU)	16	16	18	18	>1,000	>1,000	808	650	392	385
Lamella effluent turbidity (NTU)	13		15		69	28	26	33	32	34
Initial Infiltration Rate (ft/day)	1,925	3,526	2,742	2,938	3,288	3,524	2,100	2,060	3,293	3,795
Final Infiltration Rate (ft/day)	9	11	21	15	51	37	25	45	389	146
Recharge Time (min)	244	77	139	45	610	630	489	733	120	120
Total Volume Recharged (gallons)	40	60	60	42	298	436	278	346	260	193
Water Temperature (degrees F)	51	51	51	51	65	67	69	71	73	73
Days of recharge @ 10 ft/day	1.5	2.2	2.2	1.6	11.4	16.7	10.6	13.3	10.0	7.4

[a] Raw water from the Little Arkansas River was used

[b] A filter fabric was placed on top of the media

[c] Backwash of the media was not conducted prior to test

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Table III-5
Sedgwick Rec!harge Site Column Infiltration Results

System Variable	Test # 2	Test # 4	Test # 7[a]	Test # 8[a]
Test Date	05/24/99	05/25/99	05/26/99	05/27/99
Polymer	Superfloc C 587	Superfloc C 587	PRC 3070 S	PRC 3070 S
Approximate Flow Through Treatment System (gpm)	1,000	530	530	530
Raw Turbidity (NTU)	>1000	>1000	808	650
Presed Effluent Turbidity (NTU)	12	4	5	6
Initial Infiltration Rate (ft/day)	4,933	4,111	3,795	4,111
Final Infiltration Rate (ft/day)	27	36	143	129
Recharge Time (min)	211	450	285	441
Total Volume Recharged (gallons)	232	1,284	813	848
Water Temperature (degrees F)	65	67	69	71
Days of recharge @ 10 ft/day	8.9	49.3	31.2	32.5

[a] A filter fabric was placed on top of the media

initial start-up, exhibiting a higher head over a longer period of time as shown in Figure III-22 (raw water test on 3/26/99). The volume of water passed through the column was high and the amount of particles drawn deep into the bed appeared to be significant. This indicates that particle removal takes place throughout the entire depth of the sand media when raw water is applied to the column. This is not a desirable effect because particles that are below the first 2 to 3 inches cannot be easily removed, causing increased maintenance cost for media cleaning.

When raw water was applied to the column, infiltration rates of the raw water stream were initially higher than those observed when treated water from the packaged pretreatment (Lamella) unit was used. Since particles in raw water penetrate deeper into the media than floc particles which pack on top of the media, the initial headloss through the column is relatively small which results in higher initial infiltration rates. However, the loss of infiltration capacity over time was observed to be greater for the raw water compared to the water treated with polymer as shown in Figure III-23 (initial four-test summary). Based on this data, all surface water should be treated before recharge.

- Low vs. High Turbidity Recharge Water

  The turbidity of the water applied to the intake site column during the initial tests on March 25 and 26, 1999 was lower than the turbidity observed during the tests conducted in May 1999. Comparison of data for these tests revealed that high raw water turbidities produce treated waters which are easier to recharge (higher infiltration rates and larger total recharge volumes) than those produced by low raw water turbidities. Floc formation in low turbidity waters is slower and floc size is smaller, resulting in greater floc carry over. This results in recharge water with turbidity that causes earlier plugging of the test column.

- Effects of Reduced Flow Rate

  Reducing the flow rate through the treatment system by about 50 percent,

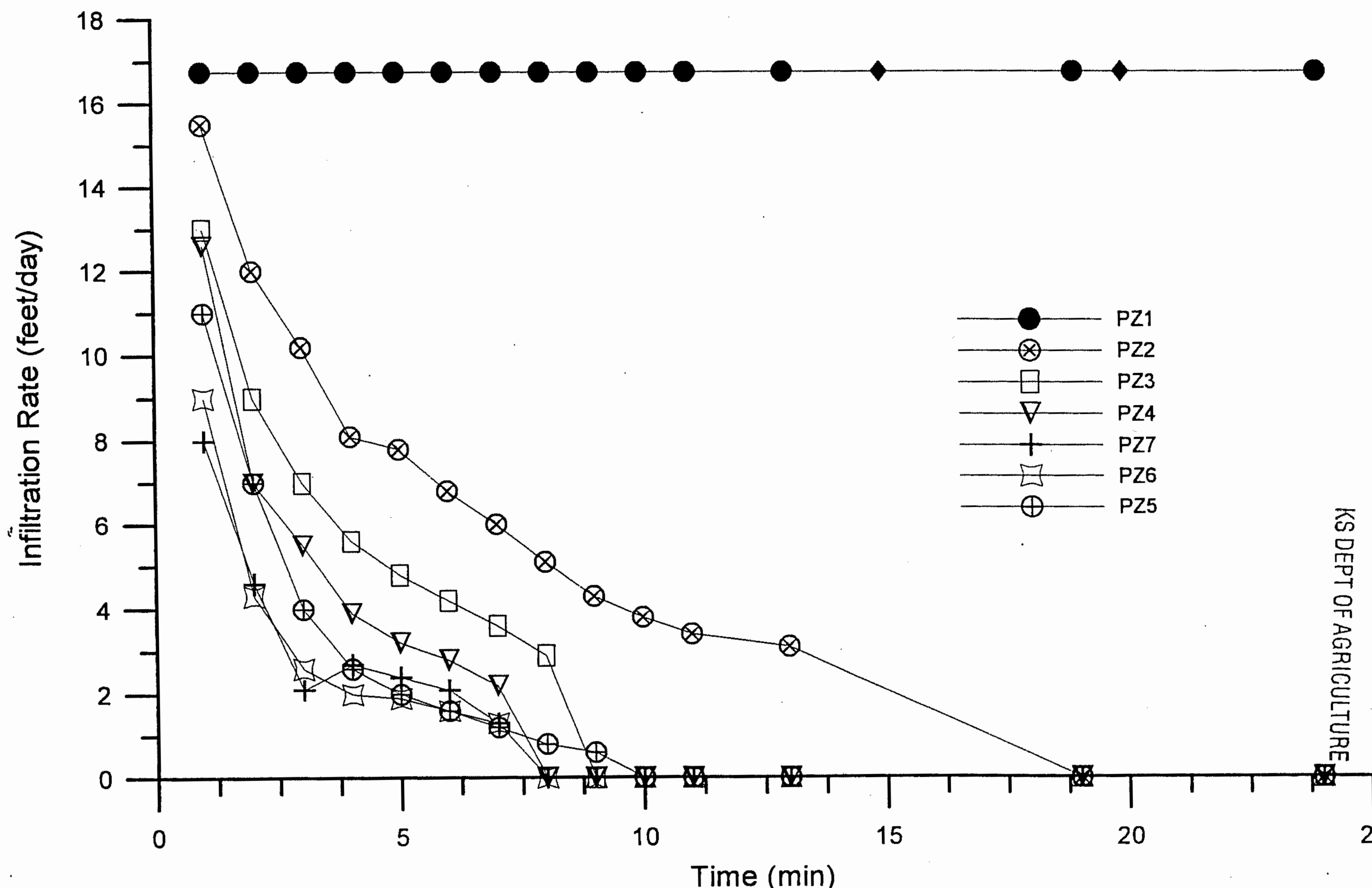

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Figure III-22

PIEZOMETER LEVELS
RAW WATER TEST - 3/26/99
SEDGWICK INTAKE SITE

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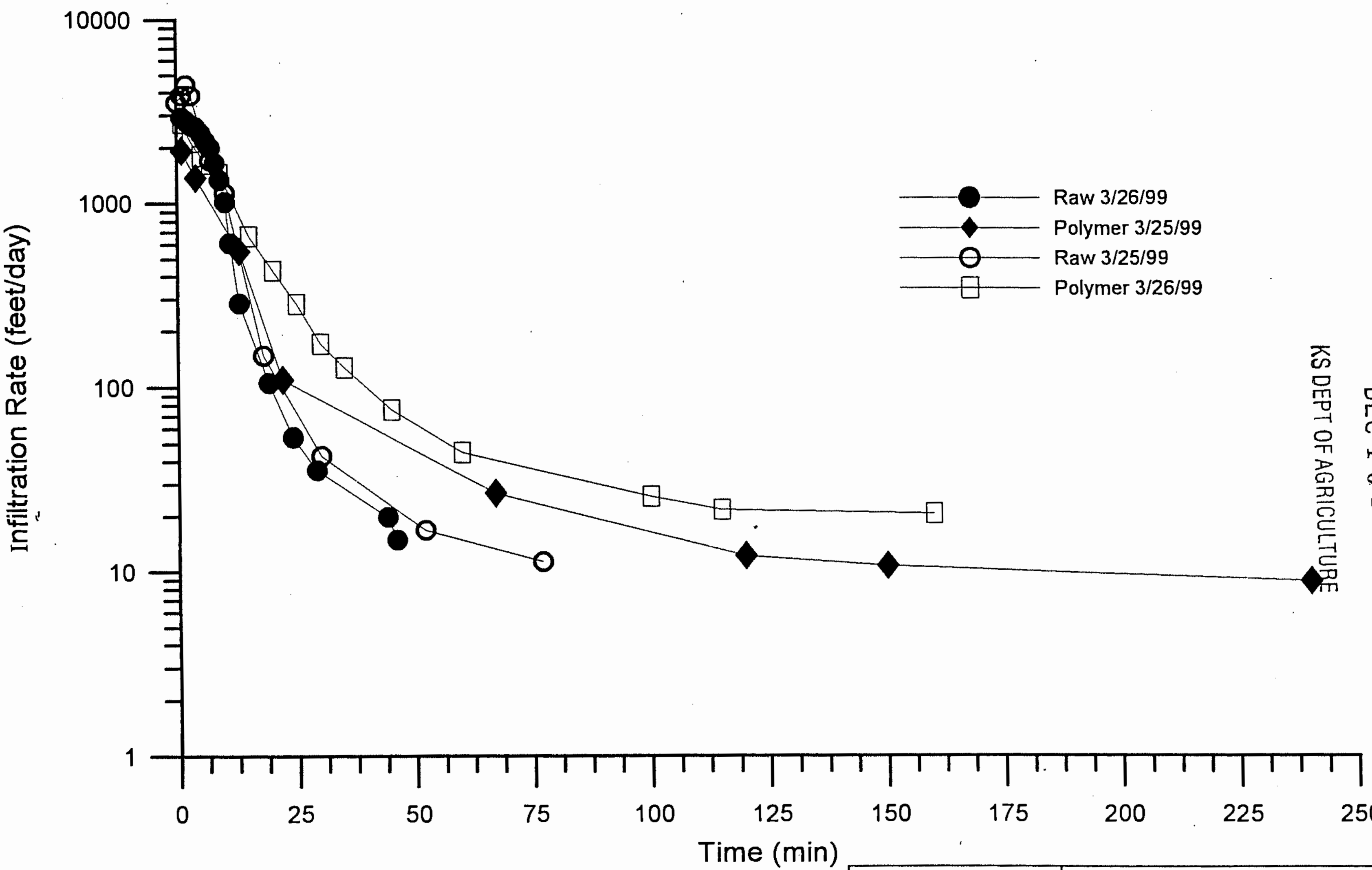

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Figure III-23

COLUMN TEST - LAMELLA
SEDGWICK INTAKE SITE

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from 1,000 gpm to 530 gpm, resulted in a significant drop in treated water turbidity. The lower turbidity of the treated water resulted in a recharge volume increase of 1.5 times at the intake site and 5.5 times at the recharge site columns. Reduced PAC carryover at lower flow rates is believed to be the principal reason for higher recharge volumes.

The change in flow rate through the Lamella unit from 1,000 gpm to 530 gpm increased the rapid mix time from 30 seconds to 1 minute and the flocculation time from 2 minutes to 4 minutes. The plate overflow rate was reduced from 0.5 gpm/ft^2 to 0.25 gpm/ft^2. To evaluate which of these changes had the biggest impact, half of the Lamella unit weirs were plugged to increase the plate overflow rate back to 0.5 gpm/ft^2. The increase of overflow rate had no effect on the low Lamella effluent turbidity, which leads to the conclusion that rapid mix and flocculation times are the limiting factors for turbidity reduction in the Lamella treatment unit.

- Polymer Type

  Two polymers were selected for testing in the pilot unit based on jar testing conducted in July, 1998. Superfloc C-587 was used at the water treatment plant and was also used for water treatment at the Sedgwick Recharge System. As an alternative, PRC 3070C, supplied by Polymer Research Corporation, was tested in the pilot treatment system.
  The PRC 3070 S performed better than Superfloc C-587, yielding better recharge rates and total volume of water passing through the test columns. Analysis showed that particles generated from the addition of PRC 3070 S were large in size and produced less headloss inside the column.

- Effects of Filter Fabric

  The use of a filter fabric at the intake site column reduced both the recharge rates and the total volume of water recharged through the column. The filter fabric was effective in reducing the solids which penetrated into the sand media and may be an option to be considered further for surface water recharge.

- Effects of Water Levels (Heads)

  Column testing with high water levels (high head) has a tendency to "pack" solids on top of the sand media. Lower water levels above the media allow longer recharge times before plugging occurs. The solids do not pack as tightly in the lower head application and lower head loss occurs. This effect is described in water treatment literature and emphasizes the need to remove as much turbidity as possible to prolong recharge time between basin media cleaning events.

(c) Basin Bottom Sampling

In addition to the column tests, sampling was conducted in the existing Sedgwick Recharge Basins to determine the depth at which particle removal occurred in the basins. The southwest basin was essentially plugged at the time of the sampling and the northeast basin had never been used. Both basins were sampled using a 1-inch diameter piece of schedule 80 PVC pipe. The pipe was driven into the basin bottom to collect a sample of the bottom material. The procedure was repeated in three-inch increments to a depth of 1 foot. Each 3-inch depth of sample was washed with 2 liters of low turbidity water to remove the fine particles. The rinseate was then analyzed by the particle counting instruments to determine the distribution of sediment from the recharge water with depth.

The turbidities detected in the water used to wash the samples from each basin are shown in Table III-6. In these tests, the southwest basin was operated while the northeast basin (control) had not yet been used for recharge. Analysis of the bottoms of Basins 1 and 2 showed particles of powdered activated carbon (PAC) carried over from the earthen pre-sedimentation basin. PAC particles are usually less than 50 microns in size and sand particles are 300 microns, or more, in size.

Table III-6

Basin Bottom Core Sampling Results

Depth of Sample (inches)	Southwest Basin Turbidity (NTU)	Northeast Basin Turbidity (NTU)
0 to 3	>1000	325
3 to 6	377	804
6 to 9	244	660
9 to 12	357	618

The smaller size allows PAC to penetrate several inches into the sand bottom which eventually reduces the recharge rate. Because of this potential plugging concern, effective removal of PAC is important in extending the operation of the recharge basins between maintenance events.

The test results indicate particles were removed from the recharge water in the top two to three inches of the bottom sand. The layers sampled beneath the top three inches were actually cleaner in the basin that received recharge than in the basin that had never been used. This is believed to be a result of "washing" by recharging large volumes of water through these layers. Based on the observations made during the column tests, most of the plugging in this basin is believed attributable to deposition of PAC. After the tests, the basin was dewatered, dried and recharge water was reapplied with no substantial recharge improvements. If most of the plugging were due to polymer accumulation, the results would be different. Polymer consists of organic molecules that break down by microbial action and by dewatering or drying. Infiltration characteristics typically increase in a basin that is dried for a period of time.

(3) Simulated Surface Water Recharge Trenches

Recharge trenches have shown to be an effective method of maintaining high recharge rates with diversion well water in areas where subsurface clay layers cause significant

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groundwater mounding. Use of recharge trenches, however, was not considered for treated surface water because of expected problems with plugging caused by water that contains some (carry-over) turbidity. For the same reason, treated surface water was not considered for application with recharge wells.

To evaluate the potential of using treated surface water in trenches, four test cells (or simulation surface water trenches) were installed in the southwest basin at the Sedgwick Recharge Site by the City's well field crew in August, 1999. The cells were set up using the 11.5 ft diameter steel tube assemblies that were used in the initial infiltration tests in 1995. The four cells were connected to the basin recharge inlet pipes by PVC piping. Each cell had a water meter and a valve to control flow. Different filter fabrics were installed in each of the three cells. No fabric was installed in the fourth cell which was used as a baseline or control cell.

Limited testing of the simulated surface water trenches occurred in September, 1999 before the Sedgwick Recharge System was shut down and winterized. Additional testing is planned in year 2000 to determine the viability of this recharge method.

c. **Water Quality Monitoring**

Over 4,300 water samples have been collected and analyzed through the end of fiscal year 1999 as part of the demonstration project. Baseline (or background) water quality data was collected in 1995, 1996 and part of 1997. Once demonstration facilities became operational in mid-to late-1997, additional water quality data were obtained in part of 1997, 1998 and 1999 to determine possible impacts caused by system operation.

Prior to recharge operations, the USGS obtained background samples from the monitoring wells and the City supply well at each site. During operation, water quality samples were collected by the USGS according to the approved Quality Assurance Protection Plan for Water Quality Sampling and Analysis.

Graphs of chlorides, triazine (herbicide class that includes, among other compounds, atrazine and cianazine), and specific conductance in the Little Arkansas River from samples at the Highway 50 gage are respectively shown in Figures III-24, III-25, and III-26. The figures show the test results for the last several years in addition to the 1999 data. River flow is also presented to illustrate the concentration variation of these parameters with the volume of stream flow. Similar graphs of chlorides, triazine, and specific conductance analyzed from samples obtained at the Sedgwick gage are respectively shown in Figures III-27, III-28 and III-29. As seen in Figures III-24, III-26, III-27 and III-29, increases in river flow are usually accompanied by decreases in both chlorides and specific conductance due to dilution. Similarly, dry weather periods are generally paralleled by higher concentrations of chlorides and specific conductance. In contrast to the above observations, Figures III-25 and III-28 show that increases in river flow are usually accompanied by increases in triazine concentrations. This can be explained by the fact that that pesticide loads are expected to increase with increasing surface runoff from agricultural areas, particularly at the beginning of each runoff event.

At the Halstead site, baseline water quality in the perched aquifer was relatively poor with an approximate specific conductance of 1,400 µs/cm. After recharge began, water quality immediately improved and eventually matched that of the recharge water (about 800 µs/cm). Water quality impacts also occurred in the lower aquifer due to the recharge well. Initial specific conductance of the lower aquifer water was about 350 µs/cm. As recharge operations continued and groundwater in the aquifer was replaced by recharged water, the specific conductance rose to that of the recharge water, indicating that the aquifer water had been replaced. Figure III-30 illustrates the impact of recharge water on groundwater quality (specific conductance) and the associated cumulative volume recharged at the Halstead site through the end of 1998.

At the Sedgwick site, initial specific conductance approximately ranged from 550 µs/cm to 700 µs/cm in the shallow portions of the aquifer and from 700 µs/cm to 800 µs/cm in the deep areas. Since the recharge water is collected directly from the river at the Sedgwick site, its specific conductivity is relatively variable as compared to the Halstead site, which uses river bank water for recharge. As a result of this, water quality in the aquifer is expected to vary depending on the recharge water quality.

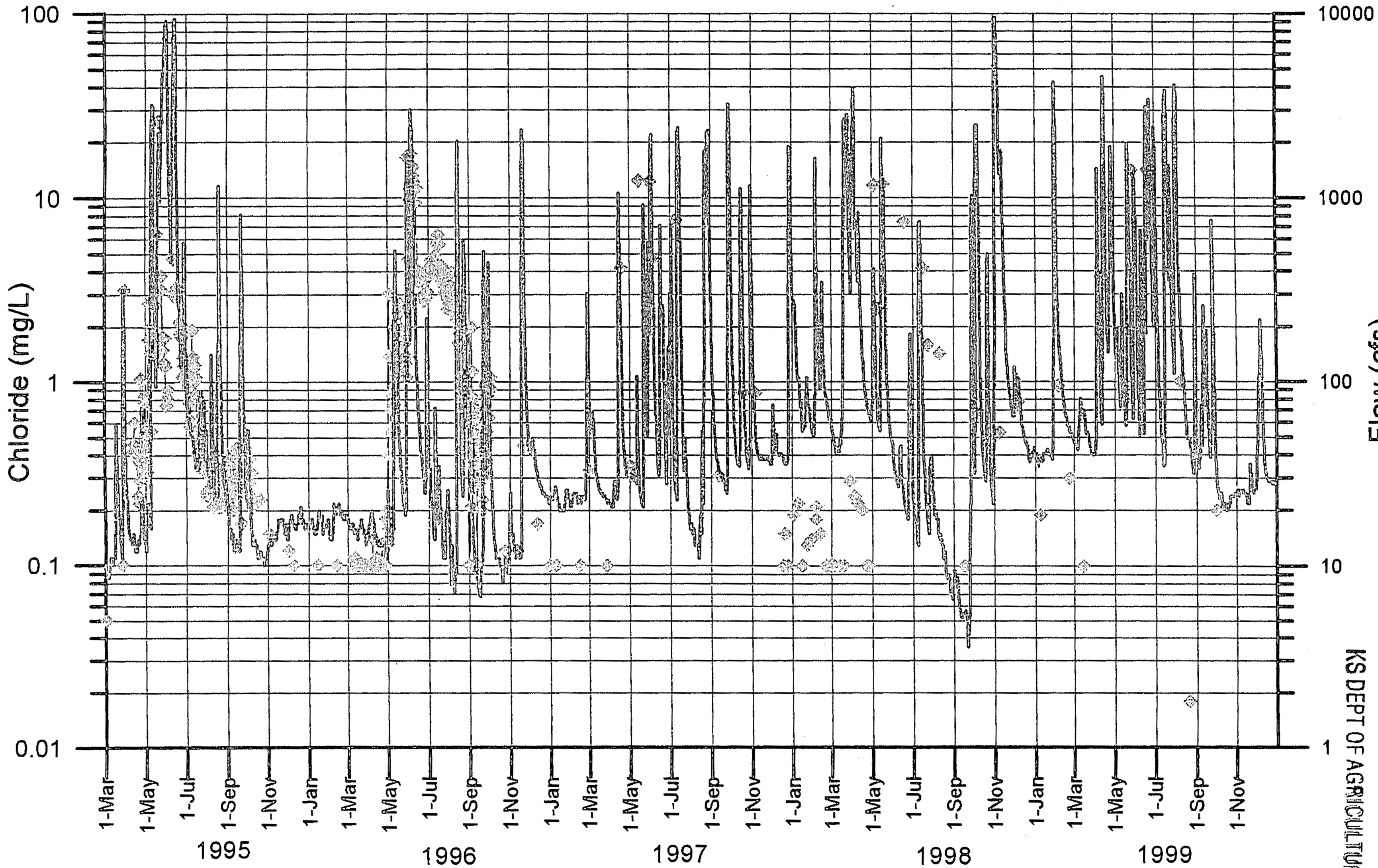

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Figure III-24

CHLORIDE CONCENTRATION LITTLE ARKANSAS RIVER AT HIGHWAY 50 NEAR HALSTEAD, KANSAS

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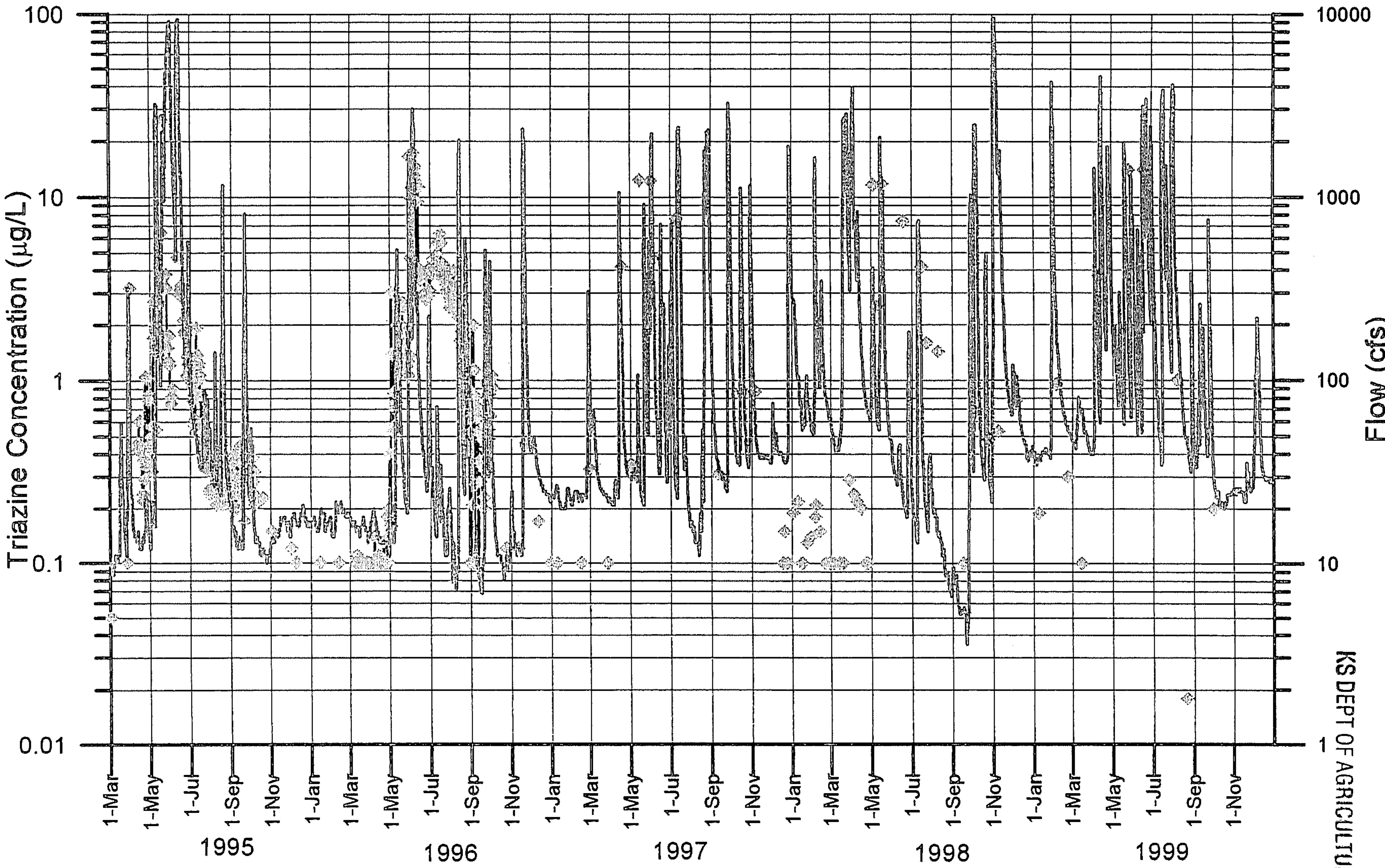

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Figure III-25

TRIAZINE CONCENTRATION LITTLE ARKANSAS RIVER AT HIGHWAY 50 NEAR HALSTEAD, KANSAS

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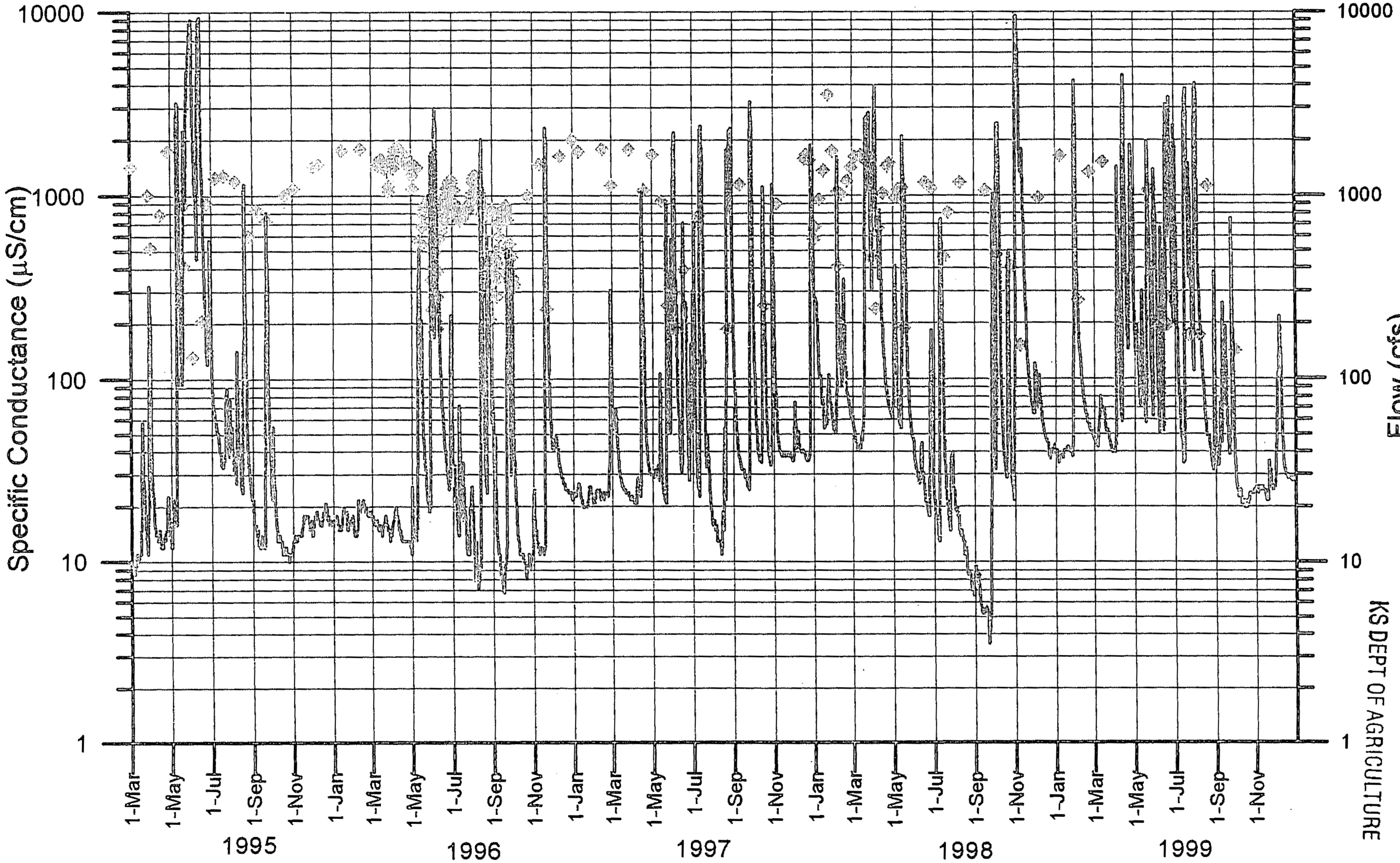

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Figure III-26

**SPECIFIC CONDUCTANCE
LITTLE ARKANSAS RIVER
AT HIGHWAY 50 NEAR
HALSTEAD, KANSAS**

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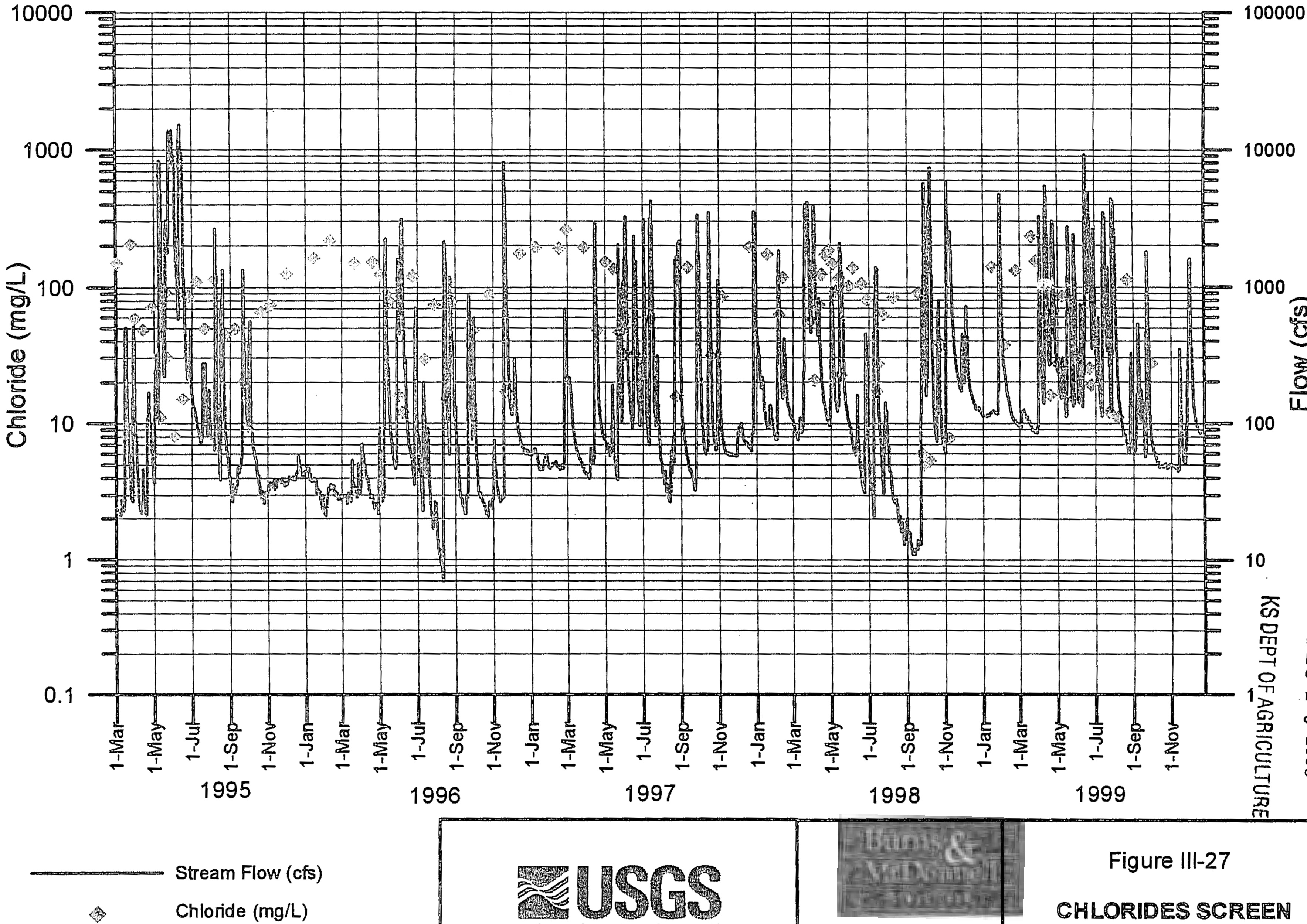

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Figure III-27

CHLORIDES SCREEN
LITTLE ARKANSAS RIVER
NEAR SEDGWICK, KANSAS

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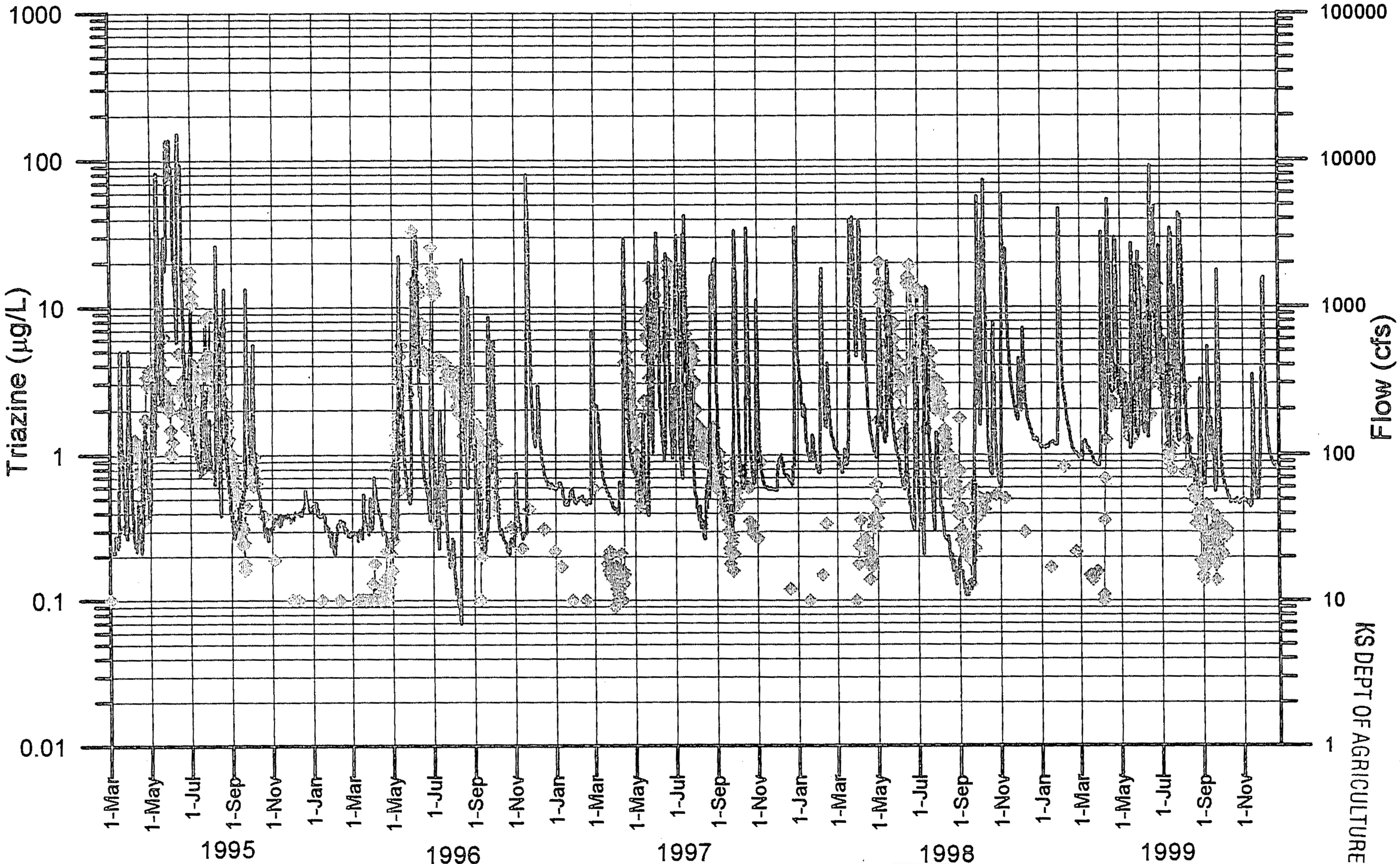

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Figure III-28

TRIAZINE SCREEN
LITTLE ARKANSAS RIVER
NEAR SEDGWICK, KANSAS

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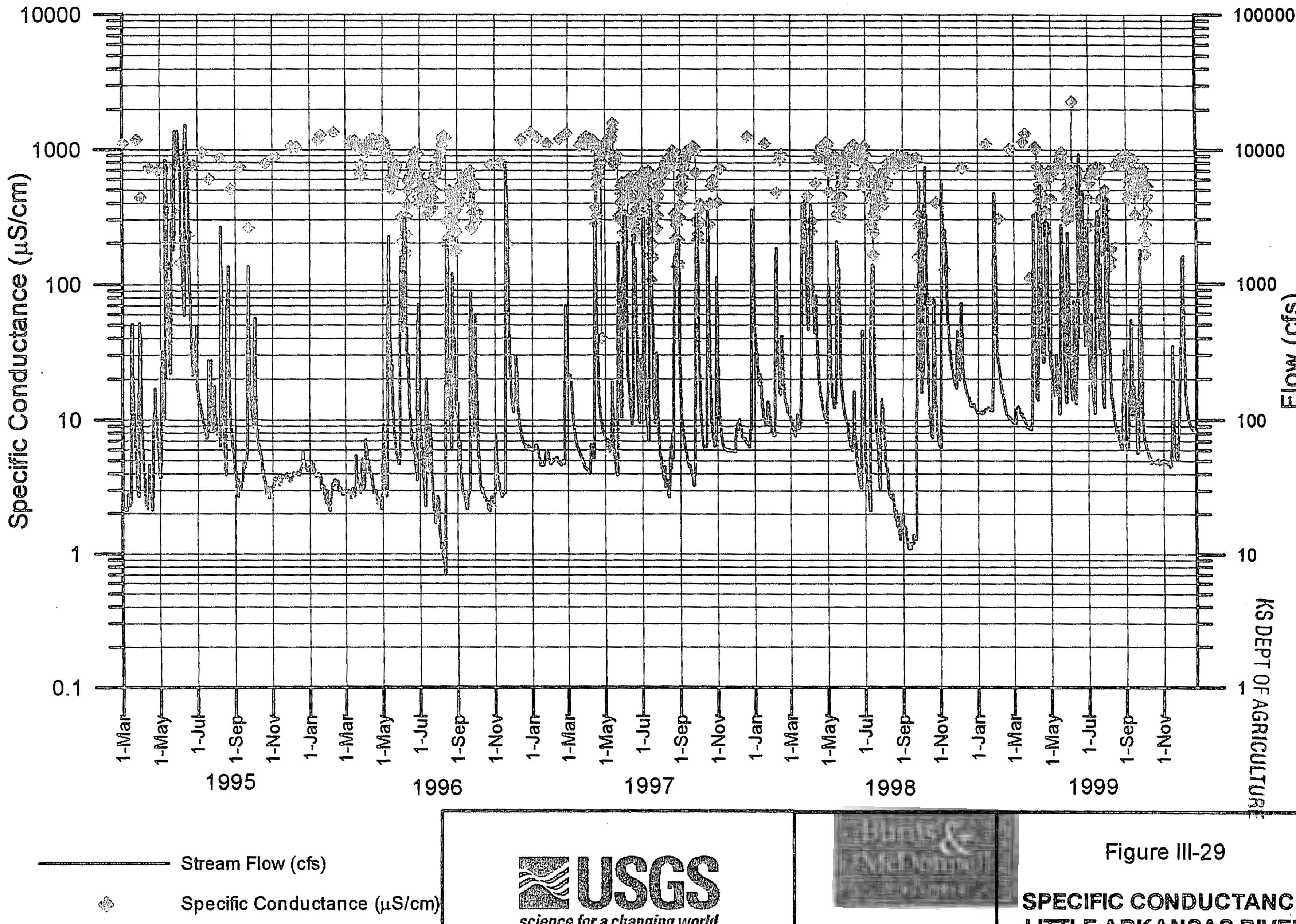

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Figure III-29

SPECIFIC CONDUCTANCE LITTLE ARKANSAS RIVER NEAR SEDGWICK, KANSAS

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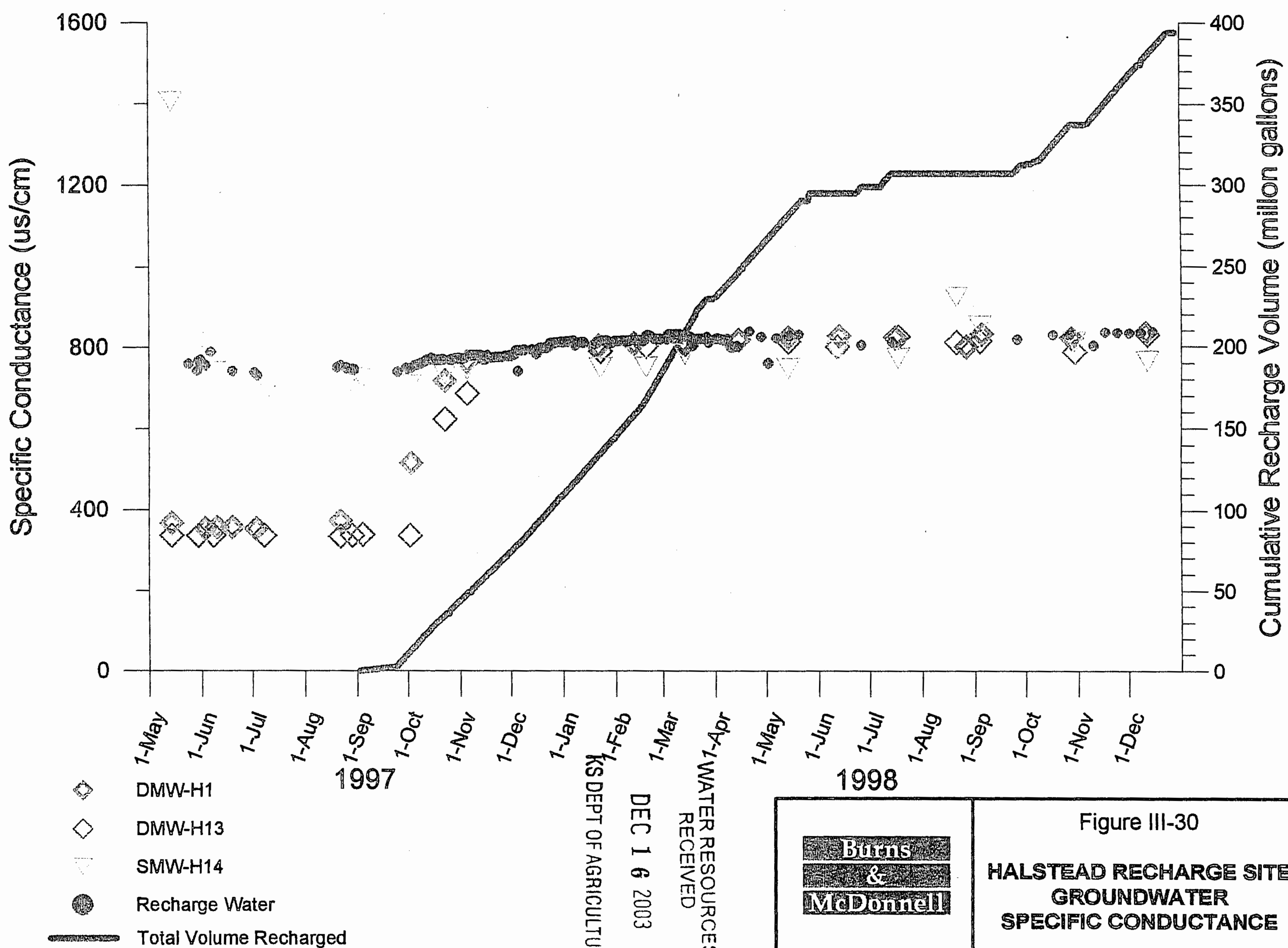

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Figure III-30

HALSTEAD RECHARGE SITE GROUNDWATER SPECIFIC CONDUCTANCE

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Atrazine and chloride, among other water quality parameters, were extensively monitored at the two sources of recharge water, the Halstead diversion well and the Sedgwick surface water treatment system. Atrazine concentrations for various types of water are shown in Figure III-31 for the Halstead Recharge System and in Figure III-32 for the Sedgwick Recharge System. Chloride concentrations for various types of water are shown in Figure III-33 for the Halstead Recharge System and in Figure III-34 for the Sedgwick Recharge System. These figures summarize the effect of demonstration recharge operations on water quality with respect to background water quality levels.

Baseline concentrations of atrazine in the surface water (at the Highway 50 gage near Halstead) during the study ranged from less than 0.10 to 46 μg/L[1] and chlorides ranged from 8 to 400 mg/L (Ziegler et al., 1999). Atrazine concentrations are typically higher at high river flows, depending on the timing of agricultural applications. Chlorides usually decreased with flow with higher chloride concentrations occurring at low stream flows.

Atrazine concentrations in the diversion well discharge ranged from less than 0.1 to 0.21 μg/L[1] (based on USGS data through July 1999) and were significantly less than the EPA's MCL of 3 μg/L. Chloride concentrations in the diversion well discharge ranged from 22 to 78 mg/L (based on USGS data through July 1999), which is similar to the average aquifer chloride concentration of about 55 mg/L (Burns & McDonnell, 1994).

Atrazine concentrations in the treated surface water at the Sedgwick Site ranged from less than 0.1 to 6.8 μg/L (based on USGS data through July 1999). Atrazine was detected above the MCL of 3 μg/L in only one occasion (6.8 μg/L) due to a temporary failure of the powered activated carbon feed system. All other detections were well below the MCL level. Chloride concentrations in the treated surface water at the Sedgwick Site ranged from 13 to 227 mg/L (based on USGS data through July 1999), which is below the EPA's Secondary Maximum Contaminant Level (SMCL) of 250 mg/L (Ziegler, et al 1999) for chloride.

[1]As determined by the ELISA detection method

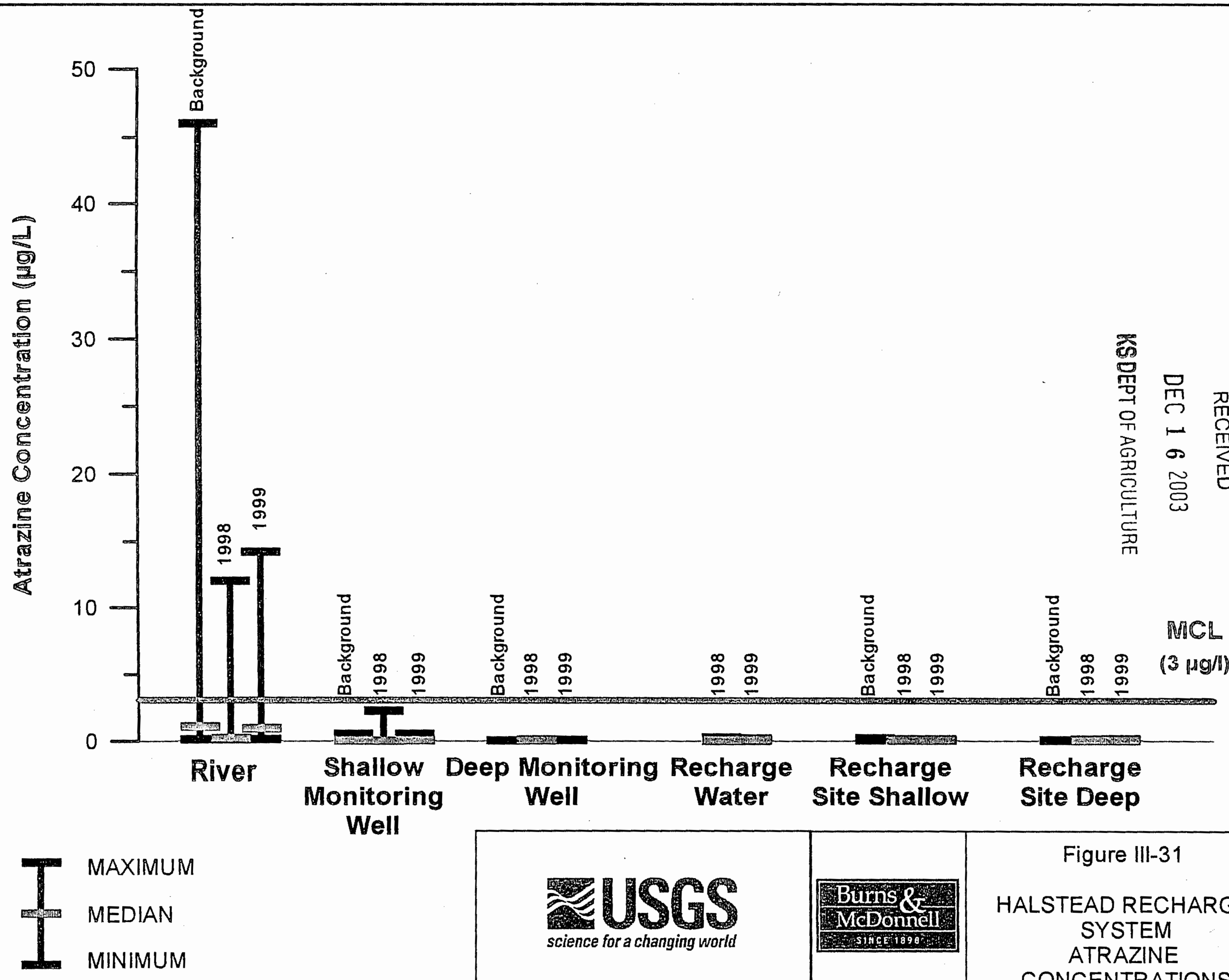

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Figure III-31

HALSTEAD RECHARGE SYSTEM ATRAZINE CONCENTRATIONS

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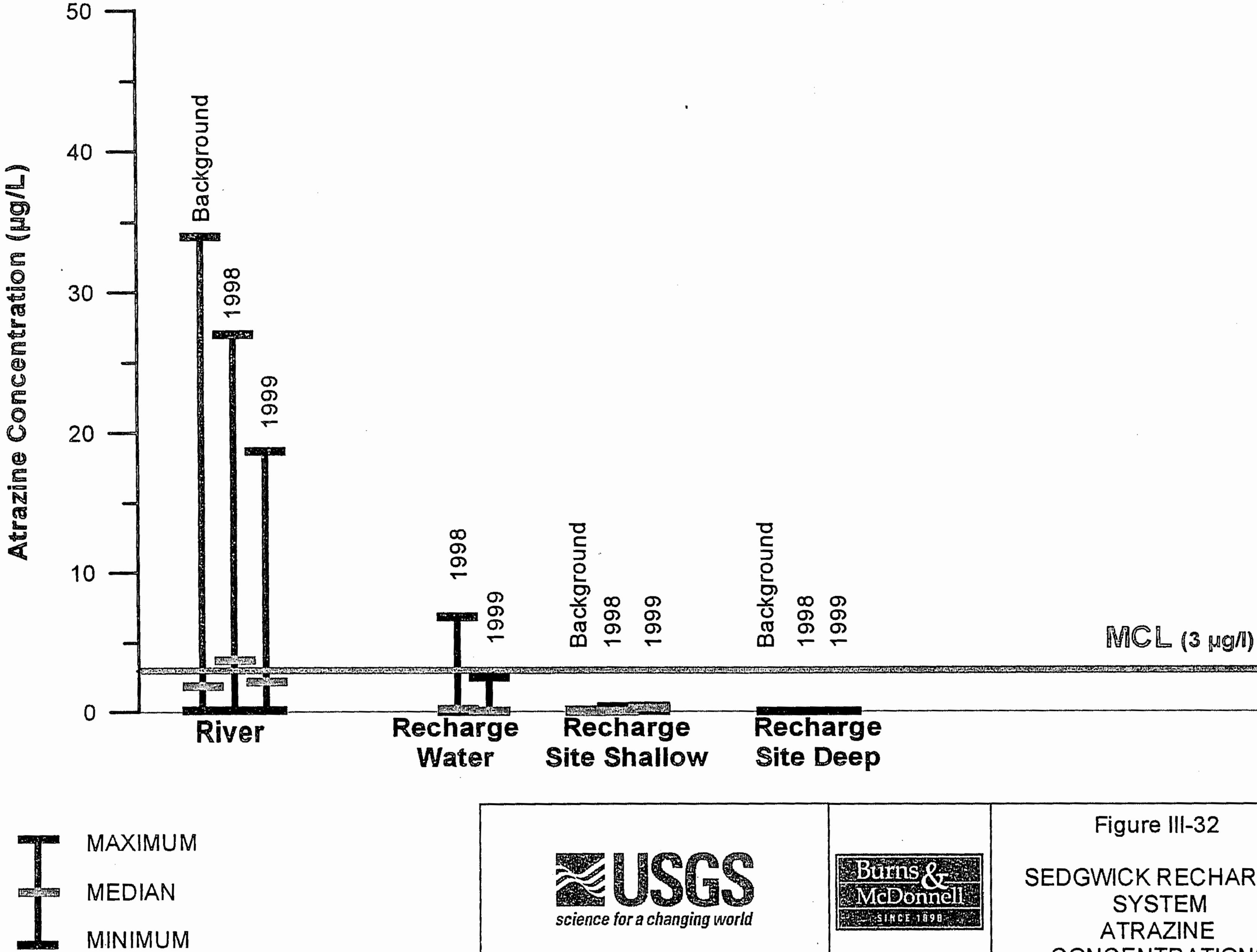

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Figure III-32

SEDGWICK RECHARGE SYSTEM ATRAZINE CONCENTRATIONS

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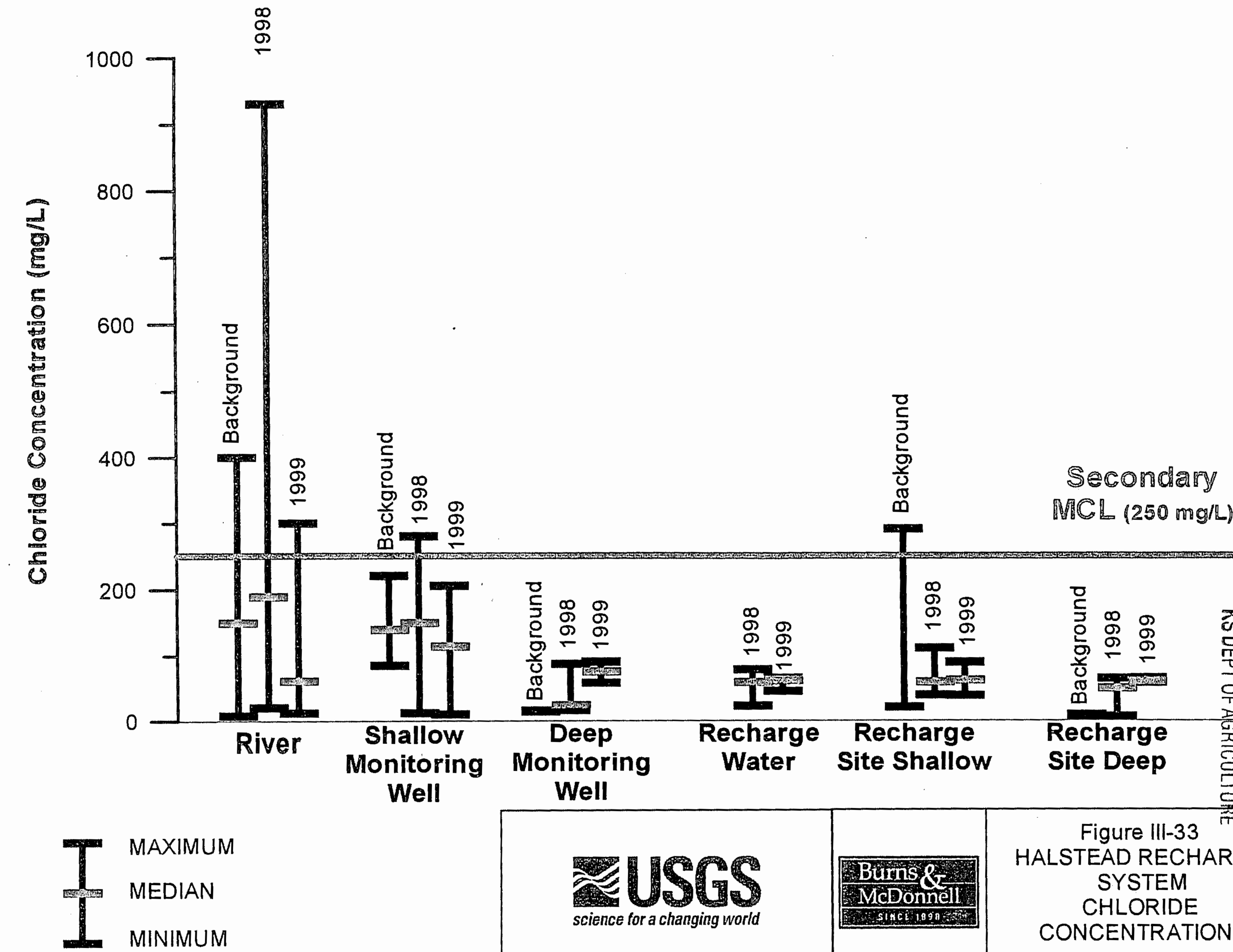

Figure III-33
HALSTEAD RECHARGE SYSTEM CHLORIDE CONCENTRATIONS

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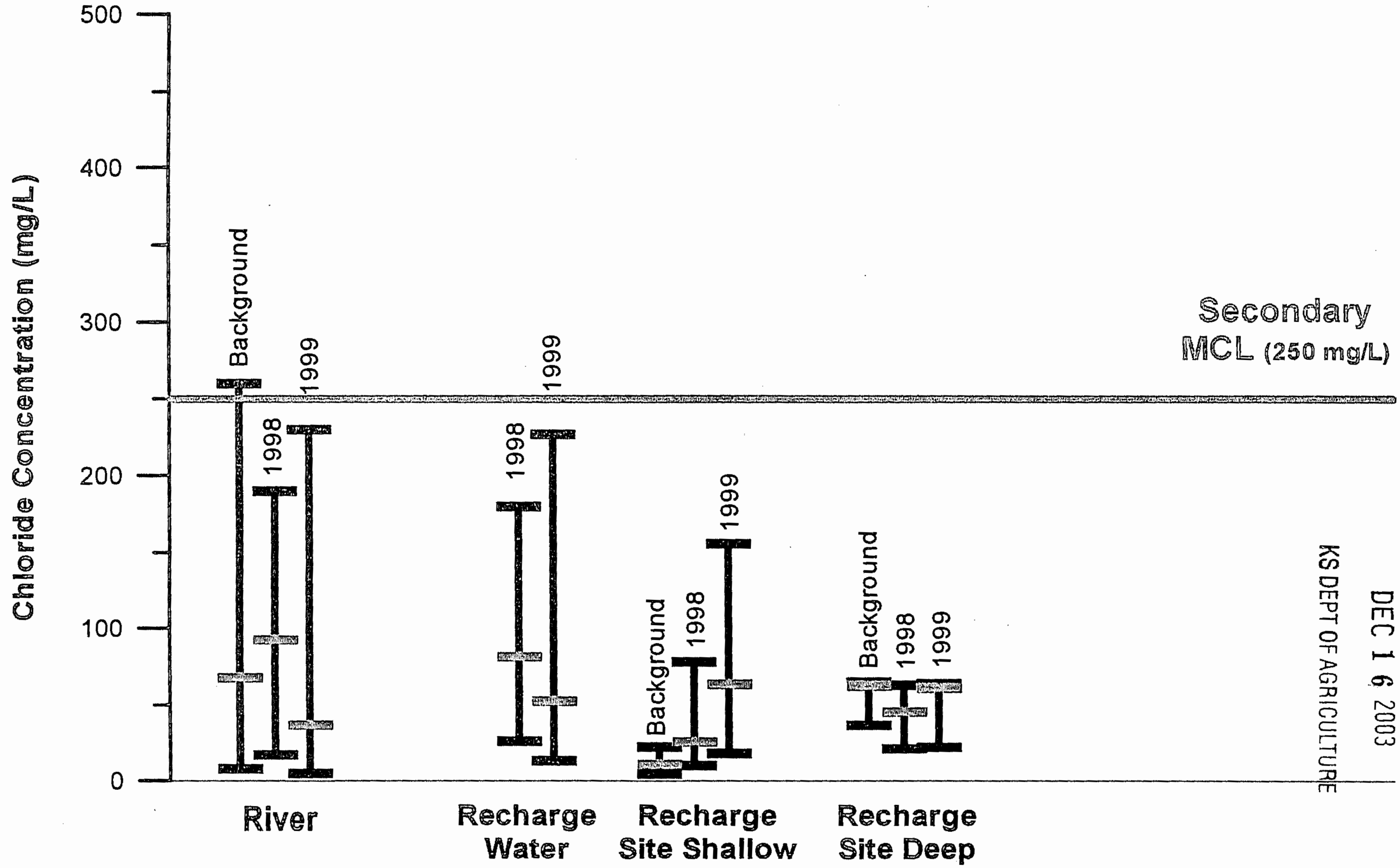

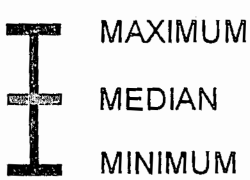

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Figure III-34

SEDGWICK RECHARGE SYSTEM CHLORIDE CONCENTRATIONS

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Water quality results at both the Halstead and Sedgwick Recharge Sites indicate that although concentrations of chloride and atrazine have increased in some monitoring wells, concentrations remain within the range of baseline values in the Equus Beds Aquifer and are significantly less than drinking water limits. Although river atrazine concentrations at both recharge sites were near to or sometimes above the MCL of 3 μg/L, adsorption and/or degradation at the river bank (Halstead Site) or recharge water treatment and dilution in the aquifer (Sedgwick Site) resulted in groundwater concentrations much lower than the MCL. Major ion and trace element chemistry of source water and receiving water was also analyzed as part of the water quality control program to determine the compatibility of waters for artificial recharge. Based on these evaluations, the source water and the receiving groundwater are believed to be generally compatible at both recharge sites.

2. ECONOMIC EVALUATION

Two types of cost analyses are conducted in this section for the Halstead Recharge System and the Sedgwick Recharge System based on construction costs and operational data through December 1999. The first analysis determines the annual costs incurred for the construction and operation of the demonstration project itself, while the second type of analysis evaluates the costs of the investigated recharge technologies on an annual cost per 1000-gallon of recharge basis.

a. <u>Demonstration Project Cost Evaluation</u>

A cost analysis for the Halstead and Sedgwick Recharge Demonstration Systems is conducted to determine annual expenses incurred by the demonstration project for the 1997, 1998 and 1999 operations as shown in Table III-7. Supporting cost data were presented in Tables III-1 through III-3. Construction costs are discounted to an annual basis by assuming a system life of twenty years and an interest rate of 6.5 percent. Monitoring costs from year 1995 through year 2000 (see Table III-3) were evenly distributed among these years. Review of Table III-7 shows that the Halstead Recharge Demonstration System had annual costs of $471,898 in 1997, $442,146 in 1998, and $431,286 in 1999. The Sedgwick Recharge Demonstration System had annual costs of $477,052 in 1997, $514,247 in 1998, and $544,165 in 1999.

Table III - 7

ANNUAL COST EVALUATION FOR DEMONSTRATION PROJECT

Item	Cost 1997 ($)	Cost 1998 ($)	Cost 1999 ($)
Halstead Recharge System:			
Construction Cost [a] (Total = $1,338,000)	121,432	121,432	121,432
Operation Cost [b]	73,659	43,907	33,047
Monitoring Cost [c] (Total = $1,660,845)	276,808	276,808	276,808
Cost Total	471,898	442,146	431,286
Sedgwick Recharge System:			
Construction Cost [a] (Total = $1,795,000)	162,908	162,908	162,908
Operation Cost [b]	15,327	52,522	82,439
Monitoring Cost [c] (Total = $1,792,907)	298,818	298,818	298,818
Cost Total	477,052	514,247	544,165

[a] Construction costs include Phase 1 and Phase 2 costs (facilities construction and SCADA). These costs are discounted to an annual basis by assuming a system life of 20 years and an interest rate of 6.5 percent.

[b] Operation costs include staff, electricity, and water treatment chemicals

[c] Monitoring costs from year 1995 through year 2000 were evenly distributed among these years.

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It is important to note that the above figures include many extra expenses associated with the investigations needed to confirm feasibility of recharge and to develop design parameters and data for a full-scale ASR system. Some of these extra costs include additional controls, instrumentation, water quality monitoring, operation support, and a new SCADA system. These costs are large compared to the total project cost and would represent a much smaller percentage of the total construction budget in a full-scale facility. Therefore, the actual full-scale project should reap the benefits of this work.

b. Evaluation of Annual Costs per 1000 Gallons of Recharge

One of the purposes of this report is to develop costs for the different recharge technologies used during the Project which can be directly compared to each other and used as a reference for other future ASR projects. Therefore, a cost analysis is conducted to determine the cost per 1,000 gallons of recharge water for each recharge technology tested during project operation as shown in Table III-8.

Recharge technologies used in the demonstration project had different recharge capacities, followed distinct operating schedules and required different levels of maintenance and monitoring. As a result of this, the costs for constructing the intake structures and items that are common to all the recharge units, as well as monitoring and operating the recharge systems cannot be easily allocated to each recharge technology. For example, while the Halstead Recharge Well was continuously operated during above-base flow events in the Little Arkansas River at an average rate of about 750 gpm with little maintenance, the Halstead Recharge Trench was operated intermittently at rates usually less than 100 gpm with higher maintenance requirements. If the costs observed during the demonstration project were directly translated into a common basis (i.e., cost per 1,000 gallons recharged), units that were operated at less than their full capacity or required more extensive research would appear to be more expensive than they actually are. Approaches used to overcome this difficulty and estimate accurate recharge costs are described below:

- Costs are developed for each type of recharge method (i.e., wells, trenches and basins) as if that method were exclusively used in conjunction with the existing intake

Table III-8

EQUUS BEDS GROUNDWATER RECHARGE DEMONSTRATION PROJECT
RECHARGE COST COMPARISON

Item	Base Cost (1)	Recharge Cost (2)	Capital Cost (3)	Annual Debt Service (4)	Annual Operation Total (5)	Annual Cost Total	Annual Recharge(6) (1000 gal)	Cost/Unit of Recharge ($/1000 gal)
Halstead:	1,042,000							
Recharge Well at 1,000 gpm		75,000	1,117,000	101,000	10,380	111,380	173,000	0.64
Recharge Trench at 1,000 gpm		640,000	1,682,000	153,000	10,380	163,380	173,000	0.94
Recharge Basins at 1,000 gpm in semiconfined		1,400,000	2,442,000	222,000	10,380	232,380	173,000	1.34
Recharge Basins at 1,000 gpm in unconfined		100,000	1,142,000	104,000	10,380	114,380	173,000	0.66
Sedgwick:	1,628,000							
Recharge Basin at 1,000 gpm (7)		100,000	1,728,000	157,000	38,060	195,060	173,000	1.13
Recharge Basins at 1,000 plus gpm (8)		167,000	1,795,000	163,000	38,060	201,060	173,000	1.16

Notes:
1. Base cost includes construction costs for the intake and items that are common to all the recharge units. Full-scale surface water treatment construction costs are anticipated to be more economical than in the demonstration project.
2. Recharge cost includes construction costs for each recharge method at a 1,000-gpm recharge capacity.
3. Capital cost is found by adding base cost to the respective recharge cost.
4. Debt service is calculated over a 20 year period at a rate of 6.5 percent.
5. Found by multiplying actual operation costs (see Table III-2) on a per-gallon basis by annual recharge. Excludes labor costs accrued during demonstration and monitoring costs..
6. Based on a recharge rate of 1000 gpm for 120 days a year.
7. Recharge cost ($100,000) includes the presedimentation basin plus two recharge basins which are estimated to have a steady-state capacity of 1,000 gpm.
8. Recharge cost ($167,000) includes the presedimentation basin plus the existing three recharge basins which have a combined capacity of more than 1,000 gpm.

TB-III-8.WK4

structure (i.e, either the induced infiltration well or the surface water intake) and other common facilities. By doing this, the approximation techniques needed to allocate the construction costs of these facilities to each recharge unit are avoided.

- To simulate full-capacity operating conditions, it was assumed that each type of recharge method would use as many units as needed to match the hydraulic capacity of the intake and the common facilities (i.e., 1,000 gpm at both the Halstead and Sedgwick sites). Thus, the cost estimate includes one 1,000-gpm recharge well, eight 125-gpm recharge trenches, ten 100-gpm recharge basins in semi-confined conditions, and one 1,000-gpm recharge basin in unconfined conditions at the Halstead Site. Similarly, one 1,000-gpm presedimentation basin is required in combination with one 1,000-plus-gpm recharge basin[2] in unconfined conditions at the Sedgwick Site.

- The time of operation for each recharge method depends on the precipitation patterns in the area. As a conservative figure, it was assumed that each type of recharge method runs 120 days a year at a fixed rate of 1,000 gpm (full capacity).

- Since monitoring and labor costs associated with the demonstration project are not representative of full-scale operations, these costs were excluded from the cost projection.

Costs shown in Table III-8 reveal that full-scale recharge costs (excluding labor and monitoring costs) are anticipated to range between approximately $0.60 and $1.30 per 1,000 gallons of water recharged depending on the intake type, required treatment of the recharge water, recharge method, and local geology.

C. PROJECT TERMINATION

The Project is currently scheduled to run through year 2000. After the demonstration phase is completed, the City will continue to operate the system to collect additional data and convert facilities to the full-scale ASR system. This system is currently under conceptual design, then goes

[2] The three Sedgwick Recharge Basins have a combined recharge capacity of more than 1,000 gpm.

through the final design and implementation phases. In the long term, the demonstration facilities will be incorporated to the full-scale ASR system and will remain in operation for the rest of the project life.

D. CONCLUSIONS AND RECOMMENDATIONS

1. GENERAL CONCLUSIONS ON PROJECT FEASIBILITY

Based on the findings of the Project through the end of 1999, the Equus Beds Well Field ASR Project is considered to be feasible and suitable for full-scale implementation. General conclusions reached from Project development, construction, and operation, and associated investigations and tests follow:

- In general, the unconsolidated materials forming the Equus Beds Aquifer are coarse-grained with intermediate fine-grained (silt and clay) units scattered throughout the area. Although the fine-grained layers, where present, are anticipated to inhibit vertical percolation of recharge water from the upper sand and gravel units, this is expected to be a localized problem only due to the scattered nature of the silt and clay layers. Consequently, the full-scale ASR Project is considered to be feasible based on location of facilities using detailed, site-specific hydrogeological information.

- Recharge basins are expected to work adequately in areas where no extensive clay layers exist to impede vertical seepage of the recharge water. At locations where fine-grained layers inhibit vertical percolation, the recharge basin concept will have to be modified to improve recharge rates. At these locations, the installation of passive wells in the recharge basins with may be an efficient alternative to improve infiltration rates. Recharge wells are expected to be effective in recharging the deep aquifer zones in all areas.

- Recharge operations are not anticipated to have any detrimental impacts on the long-term aquifer water quality. Both chloride and herbicide (atrazine) concentrations in the aquifer water, resulting from recharge operations, were substantially below regulatory maximum contaminant levels the entire period of demonstration system operation.

2. SITE SPECIFIC CONCLUSIONS

a. Induced Infiltration Recharge System at Halstead

(1) Diversion Well

- The diversion well adjacent to the Little Arkansas River consistently diverts water by induced infiltration with adequate quality for recharge at the Halstead Recharge Site. To date no atrazine has been detected in the diverted water.

(2) Recharge Well

- The recharge well conveys water into the deep portion of the aquifer with minimal redevelopment and chlorination treatments at a nominal rate of 1,000 gpm. Specific recharge capacity, an indicator of recharge well performance, stabilized in the range of 25 gpm/ft-rise to 35 gpm/ft-rise during periods of continuous operation for over two years of testing. A decrease in the well average recharge specific capacity was observed at the end of 1999, which may indicate the need for more frequent redevelopment. Based on the data collected during more than two years of operation, it appears that the recharge water and aquifer water are compatible with no apparent plugging or yield reduction of the aquifer.
- Redevelopment of the recharge well was originally thought to be required on a daily basis; however, the recharge well is redeveloped on a monthly basis to exercise the pump. Annual treatment will be established as standard maintenance.
- The recharge well can operate in cold weather.
- The recharge well is an excellent method to recharge aquifers with thick surfacial clay layers and interbedded clay lens.

(3) Recharge Trench

- The recharge trench allows rapid recharge through surfacial clays.
- The recharge trench infiltrates water at an initial rate of 75 feet per day through the surfacial clay. The trench appears to recharge water more efficiently than the basins in areas of perching clays.

- The geofabric in the recharge trench experienced clogging due to mineral oxidation, primarily iron, after approximately seven days of continuous operation.
- A wet-dry shop vacuum provides a simple means of removing mineral precipitation from the geofabric for the test trench, but may be impractical for larger systems.

(4) **Recharge Basins**

- The recharge basins initially infiltrate water at a high rate until groundwater mounding over a clay lens occurs depending on the water level in the basin. The recharge rate decreases rapidly to about 1-2 feet per day after groundwater mounding "floods" the bottom of the basin.
- Increasing the water level over the basin bottom 4, 6, and 8 feet respectively increases recharge rates from 1 foot per day to approximately 2, 3, and 4 feet per day.
- A clay lens located about 20 feet below the bottom of the basin caused groundwater mounding to occur. To mitigate the effects of mounding, passive recharge wells were added to the bottom of one basin in fall of 1999. These wells penetrate the intermediate clay lens and convey water into the deep portion of the aquifer (like the recharge well). Initial testing of the basins, after addition of the gravity recharge system, showed a 400 percent increase in recharge rates. Testing will continue in year 2000.

b. **Surface Water Recharge System at Sedgwick**

(1) **Surface Water Treatment**

- Surface water diverted from the Little Arkansas River is adequate for recharge after sedimentation and powdered activated carbon (PAC) are added. Sedimentation removes solids and the PAC adsorbs pesticides periodically found in the surface water of the Little Arkansas River.
- The level of surface water treatment appears to impact the long-term recharge rate and the need to clean the bottom of the recharge basin. Primary treatment factors for the recharge water are the turbidity, particle counts (particle size distribution),

and PAC carryover. The size and quantity of the particles in the recharge water directly impact recharge rates, time for a basin to clog, and basin restoration method.

(2) Recharge Basins

- The recharge basins at Sedgwick infiltrate water at a rate of about 8 to 9 feet per day with low heads (water levels). The limiting factor at the basins is the maximum supply quantity of 1,000 gallons per minute.
- Analysis of the bottoms of Basins 1 and 2 showed PAC carryover mixed with the sand. PAC is usually less than 50 microns in size, which is smaller than sand particles at more than 300 microns. PAC penetrates several inches into the sand bottom and reduces recharge rates. Water levels can rise to 2-3 feet in a basin that has experienced several "upset" conditions caused by high turbidity water and PAC carryover.

(3) Surface Water Trench

- Based on the success of the recharge trench in maintaining high recharge rates where perching clay layers are found, testing of this concept for surface water was initiated in 1999 at the Sedgwick site. The main objective of these tests was to determine the impacts of filtering the surface water sediments with a geofabric placed on the trench media. This application may be appropriate for recharging surface water in areas with deep surfacial clays that limit the feasibility of recharge basins.

3. RECOMMENDATIONS

The following are generalized recommendations based on the aquifer's geology:

a. <u>Areas with thick surfacial clay and intermediate clay layers</u>

- A recharge well provides the best method to recharge large quantities of water.
- A recharge trench provides the second best method of recharge.

- Recharge basins do not recharge the aquifer as effectively as other recharge methods in areas where groundwater mounding occurs. The installation of passive wells in the bottom of the basins may improve attainable recharge rates.

b. Areas with thin surfacial clays and intermediate clay layers

- A recharge well provides the best method to recharge large quantities of water.
- A recharge trench provides the second best method of recharge.
- Recharge basins do not recharge the aquifer as effectively as other recharge methods, but may require a lower capital investment. The installation of passive wells in the bottom of the basins may improve attainable recharge rates.

c. Areas with surfacial clay and no intermediate clay layers

All recharge methods work, but should be evaluated on an individual basis prior to implementation. Recharge basins and recharge wells appear to be the most effective means of recharge, especially if the surfacial clay layers are thin. Wells offer the advantage of cold weather operation; however, basins may require a lower capital investment.

4. FUTURE PLANS AND RESEARCH WORK

Further research work is planned at the demonstration facilities during fiscal year 2000 as discussed below.

a. Halstead Recharge Basins

Future research and testing objectives include:

- Continue testing of passive wells in recharge basins. These wells penetrate the intermediate clay layer and allow flow to the lower aquifer areas to increase the recharge rate at the Halstead Recharge Site. If proven feasible, this concept can potentially be applied at the full-scale ASR Project to overcome the vertical percolation inhibition problem caused by intermittent clay layers.

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- Continue development of operation and maintenance experience to determine required drying or bottom reconditioning frequency for the recharge basins.

- Continue studies on water level – recharge rate characteristics using the SCADA system alarms and controls.

b. Halstead Recharge Trench

Future research and testing objectives include:

- Oxidation and precipitation of iron caused some operational problems at the Halstead Recharge Trench by plugging the upper filter fabric. Testing to develop operation and maintenance experience associated with filter re-conditioning will be continued.

- Determine more precise water level – recharge rate characteristics using the SCADA system alarms and controls.

c. Halstead Recharge Well

Future research and testing objectives include:

- Continue on-going operation and maintenance data evaluation to determine required redevelopment and treatment frequency for the recharge well.

- Continue on-going monitoring of well recharge specific capacity using the SCADA system alarms and controls to verify well performance.

- Continue to evaluate water level and water quality impacts.

d. Sedgwick Recharge System

Future research and testing objectives include:

- Continue operation and maintenance data evaluation for the package water treatment unit. Continue on-going studies to determine the effects of recharge water quality on recharge rates, soil clogging characteristics, and maintenance requirements for basin permeability.

- Pilot-test alternative surface water treatment technologies to remove turbidity and atrazine from the recharge water.

- Continue on-going operation and maintenance data evaluation for the earthen pre-sedimentation basin and the recharge basin units using SCADA controls and monitoring.

- Continue on-going studies on water level – recharge rate characteristics using the SCADA system alarms and controls.

- Continue on-going testing of the recharge trench concept in a Sedgwick surface water basin to determine the impacts of surface water quality on the required maintenance.

- Continue collection of operating data on the quantity and handling characteristics of water treatment residuals.

* * * * *

REFERENCES

Burns & McDonnell, 1993, Water Supply Study.

Burns & McDonnell, 1994, Equus Beds Groundwater Recharge Demonstration Project Feasibility Study (Phase 1, Part I - Preliminary Data Review and Concept Development).

Burns & McDonnell, 1996, Equus Beds Groundwater Recharge Demonstration Project (Phase 1, Part II - Engineering Study Involving Water Quality Testing, Facility Siting, Test Well Construction and Aquifer Test).

Hathaway, L.R., Waugh, T.C., Galle, O.K., and Dickey, H.P., 1981, Chemical Quality of Irrigation Waters in the Equus Beds Area, South-Central Kansas, Kansas Geological Survey Chemical Quality Series 10.

Hoffman, B.R., and Dowd, L.W., 1974, Soil Survey of Harvey County, Kansas, United States Department of Agriculture, Soil Conservation Service.

Williams, C.C. and Lohman, S.W., 1949, Geology and Groundwater Resources of a Part of South-Central Kansas, Kansas Geological Survey, Bulletin 79.

Ziegler, A.C., Christensen, V.G., and Ross, H.C., 1999, Baseline Water Quality and Preliminary Effects of Artificial Recharge on Groundwater, South-Central Kansas, 1995-98, U.S. Geological Survey, Water Resources Investigations Report 99-4250.

Ziegler, A.C. and Combs, L.J., 1997, Baseline Data-Collection and Quality-Control Protocols and Procedures for the Equus Beds Ground-Water Recharge Demonstration Project Near Wichita, Kansas, 1995-96, U.S. Geological Survey, Open-File Report 97-235.

LIST OF ABBREVIATIONS

ASR	Aquifer Storage and Recovery
cfs	cubic feet per second
CPU	Central Processing Unit
DCP	Data Collection Platform
DWR	Division of Water Resources
EA	environmental assessment
ELISA	enzyme-linked immunosorbent assay (ELISA)
FONSI	Findings-Of-No-Significant Impact
GC	gas chromatography
GMD2	Groundwater Management District No. 2
HA	Health Advisory Limit
IFIM	Instream Flow Incremental Methodology
ILWS	Integrated Local Water Supply
KDHE	Kansas Department of Health and Environment
KDWP	Kansas Department of Wildlife and Parks
KWh	Kilowatt hour
MCL	Maximum Contaminant Limit
MGD	million gallons per day
MKEC	Mid-Kansas Engineering Consultants
MS	mass spectrometry
MSL	above mean sea level
ND	Non-detect
NEPA	National Environmental Policy Act
PAC	powdered activated carbon
PLC	Programmable Logic Controller
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
SCADA	Supervising Control and Data Acquisition
SDWA	Safe Drinking Water Act
SHPO	State Historic Preservation Office
SMCL	Suggested Maximum Contaminant Limit
U.S.EPA	United States Environmental Protection Agency
UPS	uninterruptible power system
USGS	United States Geological Survey
VOC	volatile organic compound

APPENDICES

Appendix A - Term Permits

TERM PERMITS

FACILITY	FILE NUMBER	RATE, GPM	MINIMUM RIVER FLOW, CFS	ANNUAL MAXIMUM, AC-FT	DATE OF PERMIT
Test Well (Halstead Diversion Site)	959087	1000	42 cfs April - Sept. 20 cfs Oct. - March	1,613	February 1, 1996 to February 1, 2000
Redevelopment Pump on Recharge Well (Halstead Recharge Site)	979005			23.2	
Carrier Water Well (Sedgwick Intake Site)	979006	30		21.2	
Surface Water Intake (Sedgwick Intake Site)	979004		40 cfs		

STATE OF KANSAS
-L GRAVES, GOVERNOR
...ce A. Devine, Secretary of Agriculture

DIVISION OF WATER RESOURCES
David L. Pope, Chief Engineer-Director
901 South Kansas Avenue, 2nd Floor
Topeka, Kansas 66612-1283
(913) 296-3717 FAX (913) 296-1176

KANSAS DEPARTMENT OF AGRICULTURE

DRAFT

October 10, 1995

CITY OF WICHITA
DEPT OF WATER AND SEWER
CITY HALL 8TH FLOOR
455 N MAIN ST
WICHITA KS 67202

RE: Term Permit
File No. 959087

Dear Sir or Madam:

Your application for term permit to appropriate water for beneficial use has been examined, approved, and is being returned herewith for your records.

The approval of your application constitutes a term permit to appropriate water for beneficial use as set forth in the application. It does not constitute authority under K.S.A. 82a-301 through 305 to construct any dam or other obstruction; it does not give authority to any right-of-way, or authorize injury to, or trespass upon public or private property, nor does it obviate the necessity of assent from Federal or Local Governmental authorities, when necessary. Please be advised that K.S.A. 82a-728 sets forth, in essence, that it is unlawful to divert or threaten to divert water for the type of use you propose without first acquiring approval of the Chief Engineer of the Division of Water Resources.

An acceptable meter shall be installed on the diversion works authorized by this term permit in accordance with specifications adopted by the Chief Engineer on February 27, 1985, and shall be installed prior to water being put to beneficial use. Notification of installation of the required meter must be received in the office of the Chief Engineer within thirty (30) days of installation of the meter. A form for this purpose and for your convenience is enclosed. Accurate and complete records from which the quantity of water diverted during each calendar year may be readily determined, shall be maintained by the applicant, and the applicant shall file an annual water use report with the Chief Engineer by March 1, following the end of each calendar year. Failure to file the annual water use report by the due date, shall cause the applicant to be subject to a civil penalty.

Upon the well under this term permit becoming abandoned for the use proposed by the applicant and/or this term permit is dismissed or expires, the applicant shall cause said well to be plugged in accordance with the requirements of Article 30 of the Rules and Regulations as adopted by the Kansas Department of Health and Environment, or if use and responsibility for maintenance of the well is to be transferred to the landowner, a copy of the legal transfer document must be transmitted to the Kansas Department of Health and Environment, Bureau of Water Protection, Forbes Field, Building 740, Topeka, Kansas 66620.

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MAY 5 1998

If you have any questions, please contact our office. If you wish to discuss a specific file, please have the file number ready so that we may help you more efficiently.

Sincerely,

Guy Ellis

Guy Ellis
Water Rights Section Head

GE:MDJ:aru
Enclosures
pc: Stafford Field Office
Groundwater Management District No. 2
Burns & McDonnell
Robert Lytle, D.W.R.

JUL 2 6 1995
11:09 A.M.
KS DEPT OF AGRICULTURE

GMD 2

The State of Kansas

MEETS K.A.R. 5-3-
7-27-
CWG

Submit To: CHIEF ENGINEER-DIRECTOR
Division of Water Resources
Kansas State Board of Agriculture
901 S. Kansas Avenue, 2nd Floor
Topeka, KS 66612-1283

Rec'd # 2nd. ck - 10356

95 9087

APPLICATION FOR TERM PERMIT

☒ GROUNDWATER
☐ SURFACE WATER
(check one)

A STATUTORY FILING FEE MUST ACCOMPANY THIS APPLICATION
(Make check payable to the Division of Water Resources)

1. Applicant: (Please print or type)

Name City of Wichita, Kansas

Street City Hall - Eighth floor R.R. ____

455 North Main Street

City and State Wichita, Kansas

Zip Code 67202 Telephone No. (316)268-4964

Social Security I.D. No. ____

and/or Taxpayer I.D. No. 48-6000653

2. Location of Point of Diversion:

Sec. 34, Twp. 23S, Rng. 2 (E) (W)

Harvey County, Kansas.

Distance from Southeast Corner of Section:

approximately ~~3050~~ + 3150 feet North from Southeast Corner

approximately ~~100~~ + 165 feet West from Southeast Corner

NOTE: If point of diversion is not site specific (i.e., groundwater pit) show the approximate geographic center.

3. Water Use Data:

Proposed Max. Pumping Rate (gpm) 1,000 gpm

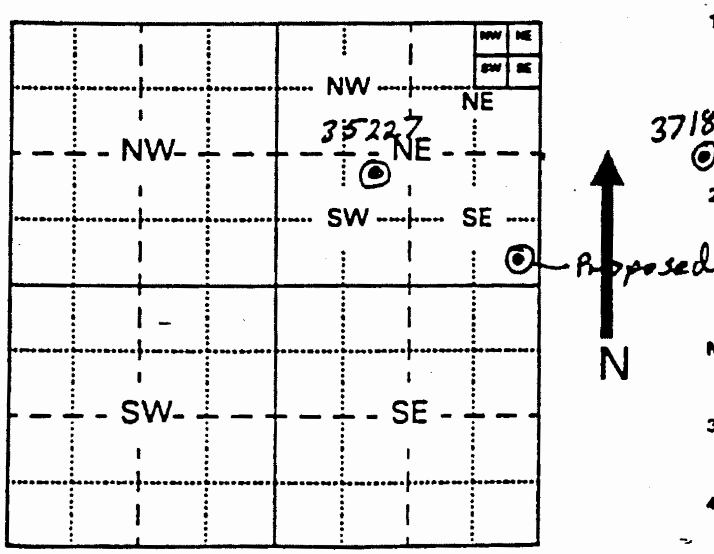
Amount Requested (acre-feet) 1,613 per calendar year

Depth of Well (feet) approximately 120 feet

Date (completed) (will be completed) Oct. 1995

Drainage Basin Little Arkansas River Basin

Name of Stream ____



Assisted by ____

DWR 1-100.7 (Rev. 11/04/93)

* Modified per instruction from Jeff Klein, Burns & McDonnell phone call 7-27-95 MDJ/DWR

4. Name and address of owner of land upon which point of diversion is located:

City of Wichita, Kansas by long term lease

If other than applicant, submit statement showing owner's permission to install diversion works has been obtained.

5. Water is to be used for (briefly describe proposed use and explain the rate and quantity requested):

Use is for groundwater recharge test and research

6. Location of place of use:

See Sec. III in Supplemental Information

7. Period of use:

Commencing date: Feb. 1, 1996

Ending date: Feb. 1, 2000

If off-stream pit, check here ☐.
Will pit floor intersect water table? Yes ☐ No ☐

8. Location of the proposed point of diversion and those of other water users within ½ mile shall be indicated on the diagram to the lower-left, scale 1 inch = 2,000 feet. If surface water, indicate on the diagram the course of the stream, and its name. List other D.W.R. permit numbers that cover the requested point(s) of diversion or place of use here:

MAY 5 1998
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FEE SCHEDULE

1. The filing fee for an application is based on the maximum amount of water use proposed within a year. Except for storage, the fee is:

Acre-feet	Fee
0 - 100	$100.00
101 - 320	$150.00
More than 320	$150.00

plus $10.00 for each additional 100 acre-feet or any part thereof.

2. The fee for an application in which storage is requested, is:

Acre-feet	Fee
0 - 250	$100.00
More than 250	$100.00

plus $10.00 for each additional 250 acre-feet of storage or any part thereof.

NOTE: If an application requests both direct use and storage, the fee charged shall be as determined under No. 1 or No. 2 above, whichever is greater, but not both fees.

3. The fee for an application for a permit to appropriate water for water power purposes shall be $100.00 plus $200.00 for each 100 cubic feet per second, or part thereof, of the diversion rate requested.

4. There is a separate application form for domestic use. Do not use this form for domestic use.

CONVERSION FACTORS

1 acre-foot equals 325,851 gallons
1 million gallons equal 3.07 acre-feet

* MDJ/DWR 8-2-95

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Done with Gillie

DRAFT

MAY 5 1998

EXHIBIT "A"

ADDITIONAL CONDITIONS OF TERM PERMIT

FILE NO. 959087

The approval of this term permit is subject to the following additional conditions:

1) The withdrawal well is equipped with a water meter pursuant to Equus Beds Groundwater Management District No. 2 (District) Metering Policy 8103.5;

2) The withdrawal well shall operate during bank storage events in the Little Arkansas River;

3) Bank storage, for the purpose of permit conditions, is limited to flows in the Little Arkansas River at the well site equal to or greater than 20 c.f.s. during the months of October through March, and equal to or greater than 42 c.f.s. during the months of April through September;

4) Well construction plans are submitted to the District for approval and shall include but not be limited to casing and screen schedules, grout intervals and pump settings;

5) At the well site a monitoring well is drilled and completed in the lower zone of the aquifer for measuring and testing purposes;

6) The applicant is granted a maximum of 5,760 operational hours of the authorized point of diversion for the purpose of conducting aquifer tests, water level measurements, water use measurements and other pertinent data, in order to determine if there is separation of the aquifer's upper and lower zones at the well site; and the applicant shall submit said data and test results to the Division of Water Resources and the District within the specified time period; 240 day

7) No water shall be pumped from the lower unit of the aquifer, if determined by the Division of Water Resources and the District that aquifer separation exists;

8) Based on the findings and conclusions of the Division of Water Resources and the District, the well is constructed to allow only withdrawal of bank storage water;

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MAY 5 1998

9) Final construction of the well shall maintain separation between the aquifer's upper and lower zones;

10) The use of Class V UIC recharge wells is authorized by the Kansas Department of Health and Environment and minimum water quality standards for effluent approved by the Department for organic and inorganic compounds, pesticides and bacteria are met;

11) The Class V UIC wells and basin discharge lines are equipped with flow meters;

12) The annual groundwater diversion and injection quantities, and water quality analyses are reported to the Division of Water Resources and the District by March 1, of each year;

13) The recharge system is constructed, operated and monitored to prevent groundwater contamination;

14) The operation of the withdrawal and recharge wells not impair existing water rights nor prejudicially affect the public interest; and

15) The diversion works shall be equipped with an hour meter so that total cumulative pumping time may be monitored.

BILL GRAVES, GOVERNOR
Alice A. Devine, Secretary of Agriculture

DIVISION OF WATER RESOURC
David L. Pope, Chief Engineer-Direc
901 South Kansas Avenue, 2nd Fl
Topeka, Kansas 66612-1
(913) 296-3717 FAX (913) 296-1

KANSAS DEPARTMENT OF AGRICULTURE

May 1, 1997

wichita
92-195-4-004

CITY OF WICHITA
C/O DAVID R WARREN
CITY HALL EIGHTH FLOOR
455 NORTH MAIN ST
WICHITA KS 67202

surface water

RE: Term Permit
File No. 979004

Dear Mr. Warren::

Your application for term permit to appropriate water for beneficial use has been examined, approved, and is being returned herewith for your records.

The approval of your application constitutes a term permit to appropriate water for beneficial use as set forth in the application. It does not constitute authority under K.S.A. 82a-301 through 305 to construct any dam or other obstruction; it does not give authority to any right-of-way, or authorize injury to, or trespass upon public or private property, nor does it obviate the necessity of assent from Federal or Local Governmental authorities, when necessary. Please be advised that K.S.A. 82a-728 sets forth, in essence, that it is unlawful to divert or threaten to divert water for the type of use you propose without first acquiring approval of the Chief Engineer of the Division of Water Resources.

An acceptable meter shall be installed on the diversion works authorized by this term permit in accordance with specifications adopted by the Chief Engineer on February 27, 1985, and shall be installed prior to water being put to beneficial use. Notification of installation of the required meter must be received in the office of the Chief Engineer within thirty (30) days of installation of the meter. A form for this purpose and for your convenience is enclosed. Accurate and complete records from which the quantity of water diverted during each calendar year may be readily determined, shall be maintained by the applicant, and the applicant shall file an annual water use report with the Chief Engineer by March 1 following the end of each calendar year. Failure to file the annual water use report by the due date, shall cause the applicant to be subject to a civil penalty.

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MAY 5 1998

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MAY 5 1998

If you have any questions, please contact our office. If you wish to discuss a specific file, please have the file number ready so that we may help you more efficiently.

Sincerely,

Guy Ellis

Guy Ellis
Water Rights Section Head

GE:MDJ:aru
Enclosures
pc: Stafford Field Office
David Stous

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Alice A. Devine, Secretary of Agriculture

DIVISION OF WATER RESOURC
David L. Pope, Chief Engineer-Direc
901 South Kansas Avenue, 2nd Fl
Topeka, Kansas 66612-1
(913) 296-3717 FAX (913) 296-1

KANSAS DEPARTMENT OF AGRICULTURE

May 1, 1997

Wichita
92-45-4-ccy

CITY OF WICHITA
C/O DAVID R WARREN
CITY HALL EIGHTH FLOOR
455 NORTH MAIN ST
WICHITA KS 67202

DRAFT
MAY 5 1998
Redevelopment pump

RE: Term Permit
File No. 979005

Dear Mr. Warren:

Your application for term permit to appropriate water for beneficial use has been examined, approved, and is being returned herewith for your records.

The approval of your application constitutes a term permit to appropriate water for beneficial use as set forth in the application. It does not constitute authority under K.S.A. 82a-301 through 305 to construct any dam or other obstruction; it does not give authority to any right-of-way, or authorize injury to, or trespass upon public or private property, nor does it obviate the necessity of assent from Federal or Local Governmental authorities, when necessary. Please be advised that K.S.A. 82a-728 sets forth, in essence, that it is unlawful to divert or threaten to divert water for the type of use you propose without first acquiring approval of the Chief Engineer of the Division of Water Resources.

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MAY 5 1998

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Sincerely,

Guy Ellis

Guy Ellis
Water Rights Section Head

GE:MDJ:aru
Enclosures
pc: Stafford Field Office
Groundwater Management District No. 2
David Stous

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KS DEPT OF AGRICULTURE

BILL GRAVES, GOVERNOR
Alice A. Devine, Secretary of Agriculture

15 '05 481

DIVISION OF WATER RESOURC
David L. Pope, Chief Engineer-Direc
901 South Kansas Avenue, 2nd Flc
Topeka, Kansas 66612-12
(913) 296-3717 FAX (913) 296-11

KANSAS DEPARTMENT OF AGRICULTURE

May 1, 1997

Wichita
97-195-4-00

COPY
FOR YOUR RETURN

CITY OF WICHITA
C/O DAVID R WARREN
CITY HALL EIGHTH FLOOR
455 NORTH MAIN ST
WICHITA KS 67202

RE: Term Permit
File No. 979006

DRAFT

MAY 5 1998

Dear Mr. Warren:

Your application for term permit to appropriate water for beneficial use has been examined, approved, and is being returned herewith for your records.

The approval of your application constitutes a term permit to appropriate water for beneficial use as set forth in the application. It does not constitute authority under K.S.A. 82a-301 through 305 to construct any dam or other obstruction; it does not give authority to any right-of-way, or authorize injury to, or trespass upon public or private property, nor does it obviate the necessity of assent from Federal or Local Governmental authorities, when necessary. Please be advised that K.S.A. 82a-728 sets forth, in essence, that it is unlawful to divert or threaten to divert water for the type of use you propose without first acquiring approval of the Chief Engineer of the Division of Water Resources.

An acceptable meter shall be installed on the diversion works authorized by this term permit in accordance with specifications adopted by the Chief Engineer on February 27, 1985, and shall be installed prior to water being put to beneficial use. Notification of installation of the required meter must be received in the office of the Chief Engineer within thirty (30) days of installation of the meter. A form for this purpose and for your convenience is enclosed. Accurate and complete records from which the quantity of water diverted during each calendar year may be readily determined, shall be maintained by the applicant, and the applicant shall file an annual water use report with the Chief Engineer by March 1, following the end of each calendar year. Failure to file the annual water use report by the due date, shall cause the applicant to be subject to a civil penalty.

Upon the well under this term permit becoming abandoned for the use proposed by the applicant and/or this term permit is dismissed or expires, the applicant shall cause said well to be plugged in accordance with the requirements of Article 30 of the Rules and Regulations as adopted by the Kansas Department of Health and Environment, or if use and responsibility for maintenance of the well is to be transferred to the landowner, a copy of the legal transfer document must be transmitted to the Kansas Department of Health and Environment, Bureau of Water Protection, Forbes Field, Building 740, Topeka, Kansas 66620.

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DRAFT

MAY 5 1998

If you have any questions, please contact our office. If you wish to discuss a specific file, please have the file number ready so that we may help you more efficiently.

Sincerely,

Guy Ellis
Water Rights Section Head

GE:MDJ:aru
Enclosures
pc: Stafford Field Office
Groundwater Management District No. 2
David Stous

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Appendix B - Sample Analytes

Table B-1. Key water-quality constituents analyzed for all samples (Ziegler and Combs, 1997)

[U.S. Geological Survey (USGS) collects the samples, and the city of Wichita provides analysis for all constituents except the triazine herbicide screen. USGS determines specific conductance, pH, and water temperature during sample collection. MCL, Maximum Contaminant Level for drinking water; HAL, recommended health advisory level; SMCL, Secondary Maximum Contaminant Level; MCL, HAL, and SMCLs are based on total recoverable concentrations in water samples. µS/cm, microsiemens per centimeter; EPA, U.S. Environmental Protection Agency; SM, standard methods; I, U.S. Department of Interior; mg/L, milligrams per liter; µg/L, micrograms per liter; mL, milliliters; --, not applicable]

Storet[1] code	Constituent (unit of measurement)	U.S. Environmental Protection Agency MCL, HAL, or SMCL[2]	Analytical method number[2] or reference	Minimum reporting level	Mean recovery goal (percent)	Completeness goal (percent)
00095	Specific conductance (µS/cm at 25 °C)	--	EPA 120.1	1	--	90
00400	pH[3,7] (standard units)	6.5–8.5	EPA 150.1	.1	--	90
00010	Water temperature[3] (degrees Celsius, °C)	--	EPA 170.1	--	--	90
00076	Turbidity[7] (nephalometric turbidity units)	0.5–1.0	SM 214A	.1	--	90
00300	Dissolved oxygen (mg/L)	--	I–1576–78	.1	--	90
00900	Hardness (mg/L)	--	EPA 200.7	1.0	80–120	90
00421	Alkalinity, dissolved (mg/L)	--	SM 2320B	2.0	80–120	90
70300	Dissolved solids[7] (mg/L)	500	EPA 160.1	10.0	80–120	90
00915	Calcium[4], dissolved (mg/L)	--	EPA 200.7	.03	80–120	90
00925	Magnesium[4], dissolved (mg/L)	--	do.	.05	80–120	90
00930	Sodium[6], dissolved (mg/L)	20	do.	.05	80–120	90
00935	Potassium, dissolved (mg/L)	--	do.	.07	80–120	90
29804	Bicarbonate, dissolved (mg/L)	--	SM 2320B	2.0	80–120	90
29807	Carbonate, dissolved (mg/L)	--	do.	1.0	80–120	90
00945	Sulfate[7], dissolved (mg/L)	250	EPA 300.0	5	80–120	90
00940	Chloride[7], dissolved (mg/L)	250	do.	5	80–120	90
00631	Nitrite plus nitrate[5], dissolved, (mg/L)	10	do.	.02	80–120	90
00608	Ammonia[6], dissolved (mg/L)	30	EPA 350.3	.007	80–120	90
00671	Orthophosphate, dissolved (mg/L)	--	EPA 300.0	.01	80–120	90
01046	Iron[7], dissolved (µg/L)	300	EPA 200.7	10.0	80–120	90
01056	Manganese, dissolved (µg/L)	--	do.	5.0	80–120	90
34756	Triazine herbicide screen, dissolved (µg/L)	--	Thurman and others (1990)	.05	80–120	90
31504	Total coliform bacteria[7] (colonies/100 mL)	0	SM 909A	1	80–120	90
31625	Fecal coliform bacteria (colonies/100 mL)	--	SM 909C	1	80–120	90
00530	Suspended solids (mg/L)	--	EPA 160.2	4.0	80–120	90

[1]U.S. Environmental Protection Agency data STOrage and RETrieval system (STORET).
[2]U.S. Environmental Protection Agency (1995).
[3]Must be analyzed immediately after sample collection.
[4]Required for calculation of hardness.
[5]On U.S. Environmental Protection Agency (1995) MCL list.
[6]HAL.
[7]SMCL.

Table B-2. Key water-quality constituents analyzed for comparison of total and dissolved concentrations (Ziegler and Combs, 1997)

[U.S. Geological Survey (USGS) collects the samples, and the city of Wichita provides analysis for all constituents except the triazine herbicide screen. USGS determines specific conductance, pH, and water temperature during sample collection. MCL, Maximum Contaminant Level for drinking water; HAL, recommended health advisory level; SMCL, Secondary Maximum Contaminant Level; MCL, HAL, and SMCLs are based on total recoverable concentrations in water samples. µS/cm, microsiemens per centimeter; EPA, U.S. Environmental Protection Agency; SM, standard methods; I, U.S. Department of Interior; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not applicable]

Storet[1] code	Constituent (unit of measurement)	U.S. Environmental Protection Agency MCL, HAL, or SMCL[2]	Analytical method number[2] or reference	Minimum reporting level	Mean recovery goal (percent)	Completeness goal (percent)
00416	Alkalinity, total (mg/L)	--	SM 2320B	2.0	80–120	90
00916	Calcium, total (mg/L)	--	EPA 200.7	.03	80–120	90
00927	Magnesium[4], total (mg/L)	--	do.	.05	80–120	90
00929	Sodium[7], total (mg/L)	20	do.	.05	80–120	90
00937	Potassium, total (mg/L)	--	do.	.07	80–120	90
00450	Bicarbonate, total (mg/L)	--	SM 2320B	2.0	80–120	90
00447	Carbonate, total (mg/L)	--	do.	1.0	80–120	90
00945	Sulfate[7], total (mg/L)	250	EPA 300.0	5	80–120	90
00940	Chloride[7], total (mg/L)	250	do.	5	80–120	90
00630	Nitrite plus nitrate[5], total (mg/L)	10	do.	.02	80–120	90
00610	Ammonia[6], total (mg/L)	30	EPA 350.3	.007	80–120	90
00665	Total phosphorus (mg/L)	--	EPA 365.2	.03	80–120	90
01045	Iron[7], total (µg/L)	300	EPA 200.7	10	80–120	90
01055	Manganese, total (µg/L)	--	do.	5.0	80–120	90
34757	Triazine herbicide screen, total (µg/L)	--	Thurman and others (1990)	.05	80–120	90

[1]U.S. Environmental Protection Agency data STOrage RETrieval system (STORET).
[2]U.S. Environmental Protection Agency (1995).
[3]Must be analyzed immediately after sample collection.
[4]Required for calculation of hardness.
[5]On U.S. Envionmental Protection Agency (1995) MCL list.
[6]HAL.
[7]SMCL.

Table B-3. Key-plus water-quality constituent analysis for dissolved inorganic constituent concentrations and Bacteria (Ziegler and Combs, 1997)

[U.S. Geological Survey (USGS) collects the samples, and the city of Wichita provides analysis for all constituents except the triazine herbicide screen. USGS determines specific conductance, pH, and water temperature during sample collection. MCL, Maximum Contaminant Level for drinking water; HAL, recommended health advisory level; SMCL, Secondary Maximum Contaminant Level; MCL, HAL, and SMCLs are based on total recoverable concentrations in water samples. µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; EPA, U.S. Environmental Protection Agency; SM, standard methods; I, U.S. Department of Interior, µg/L, micrograms per liter; mL, milliliters; --, not applicable]

Storet[1] code	Constituent (unit of measurement)	U.S. Environmental Protection Agency MCL, HAL, or SMCL[2]	Analytical method number[2] or reference	Minimum reporting level	Mean recovery goal (percent)	Completeness goal (percent)
00095	Specific conductance (µS/cm at 25 °C)	--	EPA 120.1	1	--	90
00400	pH[3,7] (standard units)	6.5–8.5	EPA 150.1	.1	--	90
00010	Water temperature[3] (degrees Celsius, °C)	--	EPA 170.1	--	--	90
00076	Turbidity[7] (nepholmetric turbidity unit)	.5–1.0	SM 214A	.1	--	90
00300	Dissolved oxygen (mg/L)	--	I–1576–78	.1	--	90
00900	Hardness (mg/L)	--	EPA 200.7	1.0	80–120	90
00421	Alkalinity, dissolved (mg/L)	--	SM 2320B	2.0	80–120	90
70300	Dissolved solids[7] (mg/L)	500	EPA 160.1	10	80–120	90
00915	Calcium[4], dissolved (mg/L)	--	EPA 200.7	.03	80–120	90
00925	Magnesium[4], dissolved (mg/L)	--	do.	.05	80–120	90
00930	Sodium[7], dissolved (mg/L)	20	do.	.05	80–120	90
00935	Potassium, dissolved (mg/L)	--	do.	.07	80–120	90
29804	Bicarbonate, dissolved (mg/L)	--	SM 2320B	2.0	80–120	90
29807	Carbonate, dissolved (mg/L)	--	do.	1.0	80–120	90
00945	Sulfate[7], dissolved (mg/L)	250	EPA 300.0	5	80–120	90
00940	Chloride[7], dissolved (mg/L)	250	do.	5	80–120	90
00950	Fluoride[7], dissolved (mg/L)	4.0	do.	.01	80–120	90
71870	Bromide, dissolved (mg/L)	--	do.	.1	80–120	90
00955	Silica, dissolved (mg/L)	--	EPA 200.7	.05	80–120	90
00613	Nitrite[5] (mg/L), dissolved	1.0	EPA 300.0	.01	80–120	90
00631	Nitrite plus nitrate[5], dissolved (mg/L)	10	do.	.02	80–120	90
00608	Ammonia[6], dissolved (mg/L)	30	EPA 350.3	.007	80–120	90
00671	Orthophosphate, dissolved (mg/L)	--	EPA 300.0	.01	80–120	90
01106	Aluminum[7], dissolved (µg/L)	50–200	EPA 200.7	10	80–120	90
01095	Antimony[5], dissolved (µg/L)	6	EPA 200.9	2.5	80–120	90
01000	Arsenic[5], dissolved (µg/L)	50	EPA 200.9	1.0	80–120	90

Table B-3. Key-plus water-quality constituent analysis for dissolved inorganic constituent concentrations and bacteria-Continued (Ziegler and Combs, 1997)

Storet[1] code	Constituent (unit of measurement)	U.S. Environmental Protection Agency MCL, HAL, or SMCL[2]	Analytical method number[2] or reference	Minimum reporting level	Mean recovery goal (percent)	Completeness goal (percent)
01005	Barium[5], dissolved (µg/L)	2,000	EPA 200.7	5.0	80–120	90
01010	Beryllium[5], dissolved (µg/L)	4	do.	1.0	80–120	90
01020	Boron[6], dissolved (µg/L)	600	do.	10	80–120	90
01025	Cadmium[5], dissolved (µg/L)	5	EPA 213.2	.1	80–120	90
01030	Chromium[5], dissolved (µg/L)	100	EPA 200.7	8	80–120	90
01040	Copper[5], dissolved (µg/L)	1,300[8]	do.	5	80–120	90
01046	Iron[7], dissolved (µg/L)	300	do.	10	80–120	90
01049	Lead[5], dissolved (µg/L)	15[8]	EPA 200.9	1	80–120	90
01056	Manganese, dissolved (µg/L)	--	EPA 200.7	5	80–120	90
71890	Mercury[5], dissolved (µg/L)	2	EPA 245.1	.02	80–120	90
01065	Nickel[5], dissolved (µg/L)	100	EPA 200.9	1.0	80–120	90
01147	Selenium[5], dissolved (µg/L)	50	EPA 270.2	2.0	80–120	90
01075	Silver[6], dissolved (µg/L)	100	EPA 200.7	10	80–120	90
01080	Strontium[6], dissolved (µg/L)	17,000	do.	1.0	80–120	90
01057	Thallium[5], dissolved (µg/L)	2.0	EPA 200.9	1.7	--	90
01085	Vanadium, dissolved (µg/L)	--	EPA 200.7	9.0	80–120	90
01090	Zinc[6], dissolved (µg/L)	2,000	do.	5.0	80–120	90
00680	Total organic carbon (mg/L)	--	EPA 415.2	.1	--	90
00723	Cyanide[5], dissolved (µg/L)	200	SM 4500–CN	1.0	80–120	90
34756	Triazine herbicide screen, dissolved (µg/L)	--	Thurman and others (1990)	.1	--	90
31504	Total coliform bacteria[7] (colonies/100 mL)	0	SM 909A	1.0	80–120	90
31625	Fecal coliform bacteria (colonies/100 mL)	--	SM 909C	1.0	80–120	90
00530	Suspended solids (mg/L)	--	EPA 160.2	4.0	--	90

[1]U.S. Environmental Protection Agency data STOrage and RETrieval system (STORET).
[2]U.S. Environmental Protection Agency (1995).
[3]Must be analyzed immediately after sample collection.
[4]Required for calculation of hardness.
[5]On U.S. Environmental Protection Agency (1995) MCL list.
[6]HAL.
[7]SMCL.
[8]TT, Treatment technique.

Table B-4. Key-plus water-quality constituents analysis for total inorganic constituent concentrations and bacteria analyzed for comparison of total and dissolved concentrations (Ziegler and Combs, 1997)

[U.S. Geological Survey (USGS) collects the samples, and the city of Wichita provides analysis for all constituents except the triazine herbicide screen. USGS determines specific conductance, pH, and water temperature during sample collection. MCL, Maximum Contantminant Level for drinking water; HAL, recommended health advisory level; SMCL, Secondary Maximum Contaminant Level; MCL, HAL, and SMCLs are based on total recoverable concentrations in water samples. µS/cm, microsiemens per centimeter; EPA, U.S. Environmental Protection Agency; SM, standard methods; I, U.S. Department of Interior; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not applicable]

Storet[1] code	Constituent (unit of measurement)	U.S. Environmental Protection Agency MCL, HAL, or SMCL[2]	Analytical method number[2] or reference	Minimum reporting level	Mean recovery goal (percent)	Completeness goal (percent)
00900	Hardness, total (mg/L)	--	EPA 200.7	1.0	80–120	90
00416	Alkalinity, total (mg/L)	--	SM 2320B	2.0	80–120	90
00916	Calcium[4], total (mg/L)	--	EPA 200.7	.03	80–120	90
00927	Magnesium[4], total (mg/L)	--	do.	.05	80–120	90
00929	Sodium[7], total (mg/L)	20	do.	.05	80–120	90
00937	Potassium, total (mg/L)	--	do.	.07	80–120	90
00450	Bicarbonate, total (mg/L)	--	SM 2320B	2	80–120	90
00447	Carbonate, total (mg/L)	--	do.	1	80–120	90
00945	Sulfate[7], total (mg/L)	250	EPA 300.0	5	80–120	90
00940	Chloride[7], total (mg/L)	250	do.	5	80–120	90
00951	Fluoride[5], total (mg/L)	4.0	do.	.1	80–120	90
71870	Bromide, total (mg/L)	--	do.	.1	80–120	90
00956	Silica, total (mg/L)	--	EPA 200.7	.05	80–120	90
00615	Nitrite[5], total (mg/L)	1.0	EPA 300.0	.02	80–120	90
00630	Nitrite plus nitrate[5], total (mg/L)	10	do.	.02	80–120	90
00610	Ammonia[6], total (mg/L)	30	EPA 350.3	.007	80–120	90
00665	Total phosphorus (mg/L)	--	EPA 365.2	.03	80–120	90
00678	Orthophosphate, total (mg/L)	--	EPA 300.0	.01	80–120	90
01104	Aluminum[7], total (µg/L)	50–200	EPA 200.7	10	80–120	90
01097	Antimony[5], total (µg/L)	6	EPA 200.9	2.5	80–120	90
01002	Arsenic[5], total (µg/L)	50	do.	1.0	80–120	90
01007	Barium[5], total (µg/L)	2,000	EPA 200.7	5.0	80–120	90
01012	Beryllium[5], total (µg/L)	4	do.	1.0	80–120	90
01022	Boron[6], total (µg/L)	10	do.	10	80–120	90
01027	Cadmium[5], total (µg/L)	5	EPA 213.2	.1	80–120	90

Table B-4. Key-plus water-quality constituents analysis for total inorganic constituent concentrations and bacteria analyzed for comparison of total and dissolved concentrations--Continued (Ziegler and Combs, 1997)

Storet[1] code	Constituent (unit of measurement)	U.S. Environmental Protection Agency MCL, HAL, or SMCL[2]	Analytical method number[2] or reference	Minimum reporting level	Mean recovery goal (percent)	Completeness goal (percent)
01034	Chromium[5], total (µg/L)	100	EPA 200.7	8	80–120	90
01042	Copper[5], total (µg/L)	1,300[8]	do.	5	80–120	90
01045	Iron[7], total (µg/L)	300	do.	10	80–120	90
01051	Lead[5], total (µg/L)	15[8]	EPA 200.9	1	80–120	90
01055	Manganese, total (µg/L)	--	EPA 200.7	5	80–120	90
71901	Mercury[5], total (µg/L)	2	EPA 245.1	.02	80–120	90
01067	Nickel[5], total (µg/L)	100	EPA 200.9	1.0	80–120	90
01147	Selenium[5], total (µg/L)	50	EPA 270.2	2.0	80–120	90
01077	Silver[6], total (µg/L)	100	EPA 200.7	10	80–120	90
01082	Strontium[6], total (µg/L)	17,000	do.	1.0	80–120	90
01059	Thallium[5], total (µg/L)	2	EPA 200.9	1.7	--	90
01087	Vanadium, total (µg/L)	--	EPA 200.7	9.0	80–120	90
01092	Zinc[6], total (µg/L)	2,000	do.	5.0	80–120	90
00680	Total organic carbon (mg/L)	--	EPA 415.2	.01	--	90
00720	Cyanide[5], total (µg/L)	200	SM 4500–CN	1.0	80–120	90
34757	Triazine herbicide screen, total (µg/L)	--	Thurman and others (1990)	.05	--	90

[1]U.S. Environmental Protection Agency data STOrage and RETrieval system (STORET).
[2]U.S. Environmental Protection Agency (1995).
[3]Must be analyzed immediately after sample collection.
[4]Required for calculation of hardness.
[5]On U.S. Environmental Protection Agency (1995) MCL list.
[6]HAL.
[7]SMCL.
[8]TT, Treatment technique.

Table B-5. Key-plus water-quailty constituents and limited U.S. Environmental Protection Maximum Contaminant Level analysis for dissolved concentrations of selected pesticides (Ziegler and Combs, 1997)

[U.S. Geological Survey (USGS) collects the samples. USGS provides sampling bottles, preservatives, and analysis (schedule 2001). MCL, Maximum Contaminant Level for drinking water; HAL, recommended health advisory level; MCL and HAL are based on total recoverable concentrations in water samples. µg/L, micrograms per liter; %, percent; --, not applicable]

Storet[1] code	Constituent (unit of measurement)	U.S. Environmental Protection Agency MCL or HAL[2]	U.S. Geological Survey analytical method number	Minimum reporting level	Mean recovery[5] (percent)	Relative standard deviation[5] (percent)	Completeness goal (percent)
		Schedule 2001					
49260	Acetochlor, dissolved (µg/L)	--	0–1126–95[5]	0.009	93	13	90
46342	Alachlor[3], dissolved (µg/L)	2	do.	.009	89	13	90
04038	Atrazine, deisopropyl, dissolved (µg/L)	--	do.	.05	--	--	90
04040	Atrazine, deethyl, dissolved (µg/L)	--	do.	.007	--	--	90
39632	Atrazine[3], dissolved (µg/L)	3	do.	.017	86	8	90
82686	Azinphos, methyl, dissolved (µg/L)		do.	.038	--	--	90
82673	Benfluralin, dissolved (µg/L)		do.	.013	72	21	90
04028	Butylate[4], dissolved (µg/L)	350	do.	.008	89	11	90
82680	Carbaryl[4], dissolved (µg/L)	700	do.	.046	90	34	90
82674	Carbofuran[3], dissolved (µg/L)	40	do.	.013	112	11	90
38933	Chlorpyrifos[4], dissolved (µg/L)	20	do.	.005	97	12	90
04041	Cyanazine[4], dissolved (µg/L)	1	do.	.013	94	14	90
82682	DCPA[4], dissolved (µg/L)	4	do.	.004	--	--	90
34653	DDE *p,p'*, dissolved (µg/L)	--	do.	.01	56	16	90
39572	Diazinon[4], dissolved (µg/L)	.6	do.	.008	88	3	90
39381	Dieldrin[4], dissolved (µg/L)	2.0	do.	.008	71	26	90
82660	Diethylaniline, dissolved (µg/L)	--	do.	.006	82	15	90
82677	Disulfoton[4], dissolved (µg/L)	.3	do.	.028	93	33	90
82668	EPTC, dissolved (µg/L)	--	do.	.005	89	13	90
82663	Ethalfluralin, dissolved (µg/L)	--	do.	.013	79	16	90
82672	Ethoprop, dissolved (µg/L)	--	do.	.012	83	5	90
04095	Fonofos[4], dissolved (µg/L)	10	do.	.008	93	4	90
34253	HCH *alpha*-, dissolved (µg/L)	--	do.	.007	71	16	90
91065	HCH *alpha* D_6-surrogate %, dissolved (µg/L)	--	do.	--	93	16	90
39341	HCH *gamma*-, Lindane[3], dissolved (µg/L)	.2	do.	.011	71	23	90
82666	Linuron, dissolved (µg/L)	--		.039	78	47	90
39532	Malathion[4], dissolved (µg/L)	200	do.	.01	90	18	90
82667	Methyl parathion[4], dissolved (µg/L)	2	do.	.035	82	23	90
39415	Metolachlor[4], dissolved (µg/L)	70	do.	.009	97	14	90
82630	Metribuzin[4], dissolved (µg/L)	100	do.	.012	75	17	90

Table B-5. Key-plus water-quality constituents and limited U.S. Environmental Protection Maximum Contaminant Level analysis for dissolved concentrations of selected pesticides--Continued (Ziegler and Combs, 1997)

Storet[1] code	Constituent (unit of measurement)	U.S. Environmental Protection Agency MCL or HAL[2]	U.S. Geological Survey analytical method number	Minimum reporting level	Mean recovery[5] (percent)	Relative standard deviation[5] (percent)	Completeness goal (percent)
		Schedule 2001—Continued					
82671	Molinate, dissolved (µg/L)	--	[5]0–1126–95	0.007	91	10	90
82684	Napropamide, dissolved (µg/L)	--	do.	.01	87	14	90
39542	Parathion, ethyl, dissolved (µg/L)	--	do.	.022	89	25	90
82669	Pebulate, dissolved (µg/L)	--	do.	.009	88	13	90
82683	Pendimethalin, dissolved (µg/L)	--	do.	.018	77	12	90
82687	Permethrin-*cis*, dissolved (µg/L)	--	do.	.019	43	6	90
82664	Phorate, dissolved (µg/L)	--	do.	.011	77	24	90
04037	Prometon[4], dissolved (µg/L)	100	do.	.018	32	86	90
82676	Pronamide[4], dissolved (µg/L)	50	do.	.003	79	4	90
04024	Propachlor[4], dissolved (µg/L)	90	do.	.015	97	17	90
82679	Propanil, dissolved (µg/L)	--	do.	.016	100	12	90
82685	Propargite I & II, dissolved (µg/L)	--	do.	.006	63	22	90
38535	Propazine[4], dissolved (µg/L)	10	do.	.01	--	--	90
04035	Simazine[3], dissolved (µg/L)	4.0	do.	.008	83	6	90
82670	Tebuthiuron[4], dissolved (µg/L)	500	do.	.015	107	13	90
82665	Terbacil[4], dissolved (µg/L)	90	do.	.03	81	13	90
82675	Terbufos[4], dissolved (µg/L)	.9	do.	.012	85	20	90
91064	Terbuthylazine, dissolved (µg/L)	--	do.		94	16	90
82681	Thiobencarb, dissolved (µg/L)	--	do.	.008	94	8	90
82678	Triallate, dissolved (µg/L)	--	do.	.008	80	5	90
82661	Trifluralin[4], dissolved (µg/L)	5	do.	.012	77	14	90
99856	Volume sample (schedule 2001 D)		--		--	--	90
99807	Set number (schedule 2001)		--		--	--	--

[1]U.S. Environmental Protection Agency data STOrage and RETrieval system (STORET).
[2]U.S. Environmental Protection Agency (1995).
[3]On U.S. Environmental Protection Agency (1995) MCL list.
[4]HAL.
[5]Sandstrom and others (1992).

Table B-6. Key-plus water-quality constituents and limited U.S. Environmental Protection Agency Maximum Contaminant Level analysis for total organonitrogen pesticides (Ziegler and Combs, 1997)

[U.S. Geological Survey (USGS) collects the samples. USGS provides sampling bottles, preservatives, and analysis (schedule 1389). MCL, Maximum Contaminant Level for drinking water; HAL, recommended health advisory level; MCL and HAL are based on total recoverable concentrations in water samples. µg/L, micrograms per liter; --, not applicable]

Storet[1] code	Constituent (unit of measurement)	U.S. Environmental Protection Agency MCL or HAL[2]	U.S. Geological Survey analytical method number	Minimum reporting level	Mean recovery[5] (percent)	Relative standard deviation[5] (percent)	Completeness goal (percent)
		Schedule 1389					
77825	Alachlor[3], whole water (µg/L)	2	0–3106–83[5]	0.10	--	--	90
82184	Ametryn[4], whole water (µg/L)	60	do.	.10	101	9	90
39630	Atrazine[3], whole water (µg/L)	3	do.	.10	96	8	90
30234	Bromacil[4], whole water (µg/L)	90	do.	.20	--	--	90
30235	Butachlor, whole water (µg/L)	--	do.	.100	--	--	90
30236	Butylate[4], whole water (µg/L)	350	do.	.10	--	--	90
30245	Carboxin[4], whole water (µg/L)	700	do.	.20	-	--	90
81757	Cyanazine[4], whole water (µg/L)	1	do.	.20	--	--	90
30254	Cycloate, whole water (µg/L)	--	do.	.10	--	--	90
75981	Deethylatrazine, whole water (µg/L)	--	do.	.20	--	--	90
75980	Deisopropylatrazine, whole water (µg/L)	--	do.	.20	--	--	90
30255	Diphenamide[4], whole water (µg/L)	200	do.	.10	--	--	90
30264	Hexazinone[4], whole water (µg/L)	200	do.	.20	--	--	90
82612	Metolachlor[4], whole water (µg/L)	70	do.	.20	-	--	90
82611	Metribuzin[4], whole water (µg/L)	100	do.	.10	--	--	90
39056	Prometon[4], whole water (µg/L)	100	do.	.20	95	6	90
39057	Prometryn, whole water (µg/L)	--	do.	.10	98	5	90
30295	Propachlor[4], whole water (µg/L)	90	do.	.10	--	--	90
39024	Propazine[4], whole water (µg/L)	10	do.	.10	96	6	90
39055	Simazine[3], whole water (µg/L)	4	do.	.10	97	5	90
39054	Simetryn, whole water (µg/L)	--	do.	.10	99	7	90
30311	Terbacil[4], whole water (µg/L)	90	do.	.20	--	--	90
39030	Trifluralin[4], whole water (µg/L)	5	do.	.10	--	--	90
30324	Vernolate, whole water (µg/L)	--	do.	.10	--	--	90
99861	Sample volume (milliliters, schedule 1389)	--	--	1.0	--	--	90

[1]U.S. Environmental Protection Agency data STOrage and RETrieval system (STORET).
[2]U.S. Environmental Protection Agency (1995).
[3]On U.S. Environmental Protection Agency (1995) MCL list.
[4]HAL.
[5]Markovchick and others (1994).

Table B-7. Limited U.S. Environmental Protection Agency Maximum Contaminant Level analysis for dissolved concentrations of pesticides (Ziegler and Combs, 1997)

[U.S. Geological Survey (USGS) collects the samples. USGS provides sampling bottles, preservatives, and analysis (schedule 2050). MCL, Maximum Contaminant Level for drinking water; HAL, recommended health advisory level; MCL and HAL are based on total recoverable concentrations in water samples. µg/L, micrograms per liter; %, percent; --, not applicable; DNOC, Dinitrocresol; MCPA, (4-chloro-2-methylphenoxy) acetic acid]

Storet[1] code	Constituent (unit of measurement)	U.S. Environmental Protection Agency MCL or HAL[2]	U.S. Geological Survey analytical method number	Minimum reporting level	Mean recovery[5] (percent)	Relative standard deviation[5] (percent)	Completeness goal (percent)
			Schedule 2050				
38746	2,4-DB, dissolved (µg/L)	--	0–1131–95[5]	0.05	44	8	90
39732	2,4-D[3], dissolved (µg/L)	70	do.	.05	71	13	90
39742	2,4,5-T[4], dissolved (µg/L)	70	do.	.05	77	17	90
49315	Acifluorfen[4], dissolved (µg/L)	400	do.	.05	83	18	90
49312	Aldicarb[3], dissolved (µg/L)	7	do.	.05	61	9	90
49313	Aldicarb sulfone[3], dissolved (µg/L)	7	do.	.05	53	20	90
49314	Aldicarb sulfoxide[3], dissolved (µg/L)	7	do.	.05	100	15	90
38711	Bentazon[4], dissolved (µg/L)	20	do.	.05	75	17	90
04029	Bromacil[4], dissolved (µg/L)	90	do.	.05	82	24	90
49311	Bromoxynil, dissolved (µg/L)	--	do.	.05	74	7	90
49310	Carbaryl[4], dissolved (µg/L)	700	do.	.05	61	7	90
49309	Carbofuran[3], dissolved (µg/L)	40	do.	.05	80	20	90
49308	Carbofuran, 3-hydroxy-, dissolved (µg/L)	--	do.	.05	--	12	90
49307	Chloramben[4], dissolved (ug/L)	100	do.	.05	60	24	90
49306	Chlorothalonil[4], dissolved (µg/L)	500	do.	.05	11	15	90
49305	Clopyralid, dissolved (µg/L)	--	do.	.05	60	10	90
49304	Dacthal, mono-acid-, dissolved (µg/L)	--	do.	.05	74	12	90
38442	Dicamba[4], dissolved (µg/L)	200	do.	.05	64	15	90
49303	Dichlobenil, dissolved (µg/L)	--	do.	.05	34	9	90
49302	Dichlorprop (2,4-DP), dissolved (µg/L)	--	do.	.05	73	26	90
49301	Dinoseb[3], dissolved (µg/L)	7	do.	.05	69	9	90
49300	Diuron[4], dissolved (µg/L)	10	do.	.05	61	11	90
49299	DNOC, dissolved (µg/L)	--	do.	.05	35	7	90
49298	Esfenvalerate, dissolved (µg/L)	--	do.	.05	17	47	90
49297	Fenuron, dissolved (µg/L)	--	do.	.05	66	36	90

Table B-7. Limited U.S. Environmental Protection Agency Max mum Contaminant Level analysis for dissolved concentrations of pesticides-Continued (Ziegler and Combs, 1997)

Storet[1] code	Constituent (unit of measurement)	U.S. Environmental Protection Agency MCL or HAL[2]	U.S. Geological Survey analytical method number	Minimum reporting level	Mean recovery[5] (percent)	Relative standard deviation[5] (percent)	Completeness goal (percent)
		Schedule 2050—Continued					
38811	Fluometron[4], dissolved (µg/L)	90	0–1131–95[5]	0.05	78	17	90
38478	Linuron, dissolved (µg/L)	--	do.	.05	74	12	90
38482	MCPA[4], dissolved (µg/L)	10	do.	.05	66	8	90
38487	MCPB, dissolved (µg/L)	--	do.	.050	39	25	90
38501	Methiocarb, dissolved (µg/L)	--	do.	.050	59	26	90
49296	Methomyl[4], dissolved (µg/L)	200	do.	.050	79	27	90
49295	1-Naphthol, dissolved (µg/L)	--	do.	.050	--	11	90
49294	Neburon, dissolved (µg/L)	--	do.	.050	69	19	90
49293	Norflurazon, dissolved (µg/L)	--	do.	.050	78	12	90
49292	Oryzalin, dissolved (µg/L)	--	do.	.050	68	21	90
38866	Oxamyl[3], dissolved (µg/L)	200	do.	.050	56	20	90
49291	Picloram[3], dissolved (µg/L)	500	do.	.050	55	17	90
49236	Propham[4], dissolved (µg/L)	100	do.	.050	64	9	90
38538	Propoxur, dissolved (µg/L)	--	do.	.050	76	11	90
39762	Silvex (2,4,5-TP)[3], dissolved (µg/L)	50	do.	.050	73	11	90
49235	Triclopyr, dissolved (µg/L)	--	do.	.050	63	18	90
99848	Sample volume (milliliters, schedule 2050)	--	--	1.0	--	--	90

[1]U.S. Environmental Protection Agency data STOrage and RETrieval system (STORET).
[2]U.S. Environmental Protection Agency (1995).
[3]On U.S. Environmental Protection Agency (1995) MCL list.
[4]HAL.
[5]Werner and others (1996).

Table B-8. Limited U.S. Environmental Protection Agency Maximum Contaminant Level analysis for total recoverable concentrations of organochlorine and carbamate pesticides (Ziegler and Combs, 1997)

[U.S. Geological Survey (USGS) collects the samples. USGS provides sampling bottles, preservatives, and analysis (schedules 79 and 1359). MCL, Maximum Contaminant Level for drinking water; HAL, recommended health advisory level; MCL and HAL are based on total recoverable concentrations in water samples. µg/L, micrograms per liter; --, not applicable]

Storet[1] code	Constituent (unit of measurement)	U.S. Environmental Protection Agency MCL or HAL[2]	U.S. Geological Survey analytical method number	Minimum reporting level	Mean recovery[5,6] (percent)	Relative standard deviation[5,6] (percent)	Completeness goal (percent)
	Schedule 79						
39730	2,4-D[3], total, water (µg/L)	70	0–3105–83[5]	0.01	67	8	90
82183	2,4-DP, total, water (µg/L)	--	--	.01	--	--	90
39740	2,4,5-T[4], total, water (µg/L)	70	--	.01	69	8	90
82052	Dicamba[4], total (µg/L)	200	--	.01	43	6	90
39720	Picloram[3], total (µg/L)	500	--	.01	51	15	90
39760	Silvex (2,4,5-TP)[3], total (water) (µg/L)	50	--	.01	77	5	90
99859	Sample volume (milliliters, schedule 79)	--	--	1.0	--	--	90
	Schedule 1359						
82619	Aldicarb[3], whole water (µg/L)	7	0–3123–93[6]	.50	67	11	90
39750	Carbaryl[4], whole water (µg/L)	700		.50	64	8	90
82615	Carbofuran[3], whole water (µg/L)	40	--	.50	76	9	90
30282	Methiocarb, whole water (µg/L)	--	--	.50	63	5	90
39051	Methomyl[4], whole water (µg/L)	200	--	.50	58	5	90
77441	1-Naphthol, whole water (µg/L)	--	--	.50	63	11	90
39052	Propham[4], whole water (µg/L)	100	--	.50	64	3	90
30296	Propoxur, whole water (µg/L)	--	--	.50	67	13	90
99869	Sample volume (milliliters, schedule 1359)	--	--	1.0	--	--	90

[1]U.S. Environmental Protection Agency data STOrage and RETrieval system (STORET).
[2]U.S. Environmental Protection Agency (1995).
[3]On U.S. Environmental Protection Agency (1995) MCL list.
[4]HAL.
[5]Wershaw and others (1987).
[6]Werner and Johnson (1994).

Table B-9. Limited U.S. Environmental Protection Agency Maximum Contaminant Level analysis for total recoverable volatile organic compounds (Ziegler and Combs, 1997)

[U.S. Geological Survey (USGS) collects the samples. USGS provides sampling bottles, preservatives, and analysis. After the first sampling, the schedule analyzed was changed from schedule 1390 to schedule 1380, which has a smaller minimum reporting level of 0.2 micrograms per liter. MCL, Maximum Contaminant Level for drinking water; HAL, recommended health advisory level; MCL and HAL are based on total recoverable concentrations in water samples. µg/L, micrograms per liter; --, not applicable]

Storet[1] code	Constituent (unit of measurement)	U.S. Environmental Protection Agency MCL or HAL[2]	U.S. Geological Survey analytical method number	Minimum reporting level (schedule 1390/ schedule 1380)	Mean recovery[5] (percent)	Relative standard deviation[5] (percent)	Completeness goal (percent)
34030	Benzene[3], total (µg/L)	5	0–3127–94[5]	3.0/0.2	104	3.0	90
81555	Bromobenzene, total (µg/L)	--	do.	3.0/.2	110	4.3	90
77297	Bromochloromethane[4], total (µg/L)	90	do.	3.0/.2	114	7.2	90
32101	Bromodichloromethane, total (µg/L)	--	do.	3.0/.2	98	6.9	90
32104	Bromoform[3], total (µg/L)	100	do.	3.0/.2	92	7.8	90
34413	Bromomethane[4], total (µg/L)	10	do.	3.0/.2	116	6.1	90
77342	*n*-Butylbenzene, total (µg/L)	--	do.	3.0/.2	104	4.6	90
77350	*sec*-Butylbenzene, total (µg/L)	--	do.	3.0/.2	104	6.3	90
77353	*tert*-Butylbenzene, total (µg/L)	--	do.	3.0/.2	106	4.7	90
32102	Carbon tetrachloride[3], total (µg/L)	5	do.	3.0/.2	110	5.4	90
34301	Chlorobenzene, total, (µg/L)	--	do.	3.0/.2	102	9.8	90
34311	Chloroethane, total (µg/L)	--	do.	3.0/.2	119	4.5	90
34576	2-Chloroethylvinylether, total (µg/L)	--	do.	3.0/.2	82	7.2	90
32106	Chloroform[3], total (µg/L)	100	do.	3.0/.2	116	5.0	90
34418	Chloromethane[4], total (µg/L)	3	do.	3.0/.2	98	5.7	90
77275	2-Chlorotoluene[4], total (µg/L)	100	do.	3.0/.2	110	4.7	90
77277	4-Chlorotoluene[4], total (µg/L)	100	do.	3.0/.2	100	13	90
82625	1,2-Dibromo-3-chloropropane[3], total (µg/L)	.2	do.	3.0/.2	70	12	90
77651	1,2-Dibromoethane, total (µg/L)	--	do.	3.0/.2	86	13	90
32105	Dibromochloromethane[3], total (µg/L)	100	do.	3.0/.2	86	4.9	90
30217	Dibromomethane, total (µg/L)	--	do.	3.0/.2	120	21	90
34536	1,2-Dichlorobenzene[3], total (µg/L)	600	do.	3.0/.2	114	5.0	90
34566	1,3-Dichlorobenzene[3], total (µg/L)	600	do.	3.0/.2	100	3.9	90
34571	1,4-Dichlorobenzene[3], total (µg/L)	75	do.	3.0/.2	96	7.0	90
34668	Dichlorodifluoromethane[4], total (µg/L)	1,000	do.	3.0/.2	98	10	90

Table B-9. Limited U.S. Environmental Protection Agency Maximum Contaminant Level analysis for total recoverable volatile organic compounds--Continued

Storet[1] code	Constituent (unit of measurement)	U.S. Environmental Protection Agency MCL or HAL[2]	U.S. Geological Survey analytical method number	Minimum reporting level (schedule 1390/ schedule 1380)	Mean recovery[5] (percent)	Relative standard deviation[5] (percent)	Completeness goal (percent)
34496	1,1-Dichloroethane, total (µg/L)	--	0–3127–94[5]	3.0/0.2	118	4.6	90
32103	1,2-Dichloroethane[3], total (µg/L)	5.0	do.	3.0/.2	126	7.7	90
34501	1,1-Dichloroethene[3], total (µg/L)	7	do.	3.0/.2	120	6.1	90
77093	*cis*-1,2-Dichloroethene[3], total (µg/L)	70	do.	3.0/.2	112	3.4	90
34546	*trans*-1,2-Dichloroethene[3], total (µg/L)	100	do.	3.0/.2	116	4.8	90
34541	1,2-Dichloropropane[3], total (µg/L)	5	do.	3.0/.2	108	5.7	90
77173	1,3-Dichloropropane, total (µg/L)	--	do.	3.0/.2	100	12	90
77170	2,2-Dichloropropane, total (µg/L)	--	do.	3.0/.2	72	4.8	90
77168	1,1-Dichloropropene, total (µg/L)	--	do.	3.0/.2	108	3.8	90
34704	*cis*-1,3-Dichloropropene[3], total (µg/L)	10	do.	3.0/.2	77	5.4	90
34699	*trans*-1,3-Dichloropropene[3], total (µg/L)	10	do.	3.0/.2	64	9.7	90
34371	Ethylbenzene[3], total (µg/L)	700	do.	3.0/.2	102	4.0	90
39702	Hexachlorobutadiene[4], total (µg/L)	1	do.	3.0/.2	114	5.3	90
77223	Isopropylbenzene, total (µg/L)	--	do.	3.0/.2	102	4.1	90
77356	*p*-Isopropyltoluene, total (µg/L)	--	do.	3.0/.2	104	4.4	90
78032	Methyl tert-butylether[4], total (µg/L)	1	do.	3.0/.2	--	--	90
34423	Methylene chloride[3], total (µg/L)	5	do.	3.0/.2	108	5.1	90
34696	Naphthalene[4], total (µg/L)	20	do.	3.0/.2	100	4.2	90
77224	*n*-Propylbenzene, total (µg/L)	--	do.	3.0/.2	102	6.7	90
77128	Styrene[3], total (µg/L)	100	do.	3.0/.2	92	7.8	90
34516	1,1,2,2-Tetrachloroethane[4], total (µg/L)	70	do.	3.0/.2	100	30	90
77562	1,1,1,2-Tetrachloroethane[4], total (µg/L)	70	do.	3.0/.2	110	4.6	90
34475	Tetrachloroethene[3], total (µg/L)	5	do.	3.0/.2	108	2.9	90
34010	Toluene[3], total (µg/L)	1,000	do.	3.0/.2	114	4.5	90
77652	1,1,2-Trichloro 1,2,2,-trifluoroethane, total (µg/L)	--	do.	3.0/.2	--	--	90
77613	1,2,3-Trichlorobenzene, total (µg/L)	--	do.	3.0/.2	110	2.9	90
34551	1,2,4-Trichlorobenzene[3], total (µg/L)	70	do.	3.0/.2	100	6.6	90

Table B-9. Limited U.S. Environmental Protection Agency Maximum Contaminant Level analysis for total recoverable volatile organic compounds-Continued

Storet[1] code	Constituent (unit of measurement)	U.S. Environmental Protection Agency MCL or HAL[2]	U.S. Geological Survey analytical method number	Minimum reporting level (schedule 1390/ schedule 1380)	Mean recovery[5] (percent)	Relative standard deviation[5] (percent)	Completeness goal (percent)
34506	1,1,1-Trichloroethane[3], total (µg/L)	200	0–3127–94[5]	3.0/0.2	108	3.1	90
34511	1,1,2-Trichloroethane[3], total (µg/L)	5	do.	3.0/.2	116	13	90
39180	Trichloroethylene[3], total (µg/L)	5	do.	3.0/.2	--	--	90
34488	Trichlorofluoromethane, total (µg/L)	--	do.	3.0/.2	92	6.2	90
77443	1,2,3-Trichloropropane[4], total (µg/L)	40	do.	3.0/.2	94	6.7	90
77222	1,2,4-Trimethylbenzene, total (µg/L)	--	do.	3.0/.2	108	4.0	90
77226	1,3,5-Trimethylbenzene, total (µg/L)	--	do.	3.0/.2	112	6.8	90
39175	Vinyl chloride[3], total (µg/L)	2	do.	1.0/.2	98	6.2	90
81551	Xylene[3], total (µg/L)	10,000	do.	3.0/.2	101	4.8	90

[1]U.S. Environmental Protection Agency data STOrage and RETrieval system (STORET).
[2]U.S. Environmental Protection Agency (1995).
[3]On U.S. Environmental Protection Agency (1995) MCL list.
[4]HAL.
[5]Rose and Schroeder (1995).

Table B-10. Full U.S. Environmental Protection Agency Maximum Contaminant Level analysis for dissolved radionuclides (Ziegler and Combs, 1997)

[U.S. Geological Survey (USGS) collects the samples. USGS provides sampling bottles, preservatives, and analysis (schedule 456). MCL, Maximum Contaminant Level for drinking water; MCL is based on total recoverable concentrations in water samples; mrem/yr, millirems per year; pCi/L, picocuries per liter; --, not applicable]

Storet[1] code	Constituent (unit of measurement)	U.S. Environmental Protection Agency MCL or HAL[2]	Analytical method number[2]	Minimum reporting level	Completeness (percent)
		Schedule 456			
80050	Gross beta[3], dissolved (pCi/L as strontium 90)	4 mrem/yr	EPA 900.0	0.6	90
03515	Gross beta[3], dissolved (pCi/L as cesium 137)	4 mrem/yr	do.	.6	90
80030	Gross alpha[3], dissolved (pCi/L as uranium)	15 pCi/L	do.	.6	90
04126	Gross alpha[3], dissolved (pCi/L as thorium-230)	15 pCi/L	do.	.6	90

[1]U.S. Environmental Protection Agency data STOrage and RETrieval system (STORET).
[2]U.S. Environmental Protection Agency (1995).
[3]On U.S. Envimomental Protection Agency (1995) MCL list.

Table B-12. Full U.S. Environmental Protection Agency Maximum Contaminant Level analysis for total recoverable concentrations of acid and base/neutral organic compounds (Ziegler and Combs, 1997)

[U.S. Geological Survey (USGS) collects the samples. USGS provides sampling bottles, preservatives, and analysis (schedule 1383). MCL, Maximum Contaminant Level for drinking water; HAL, recommended health advisory level; MCL and HAL are based on total recoverable concentrations in water samples. µg/L, micrograms per liter; --, not applicable]

Storet[1] code	Constituent (unit of measurement)	U.S. Environmental Protection Agency MCL or HAL[2]	U.S. Geological Survey analytical method number	Minimum reporting level	Mean recovery[5] (percent)	Relative standard deviation[5] (percent)	Completeness goal (percent)
		Schedule 1383					
34205	Acenaphthene, total (µg/L)	--	0–3116–87[5]	5.0	--	--	90
34200	Acenaphthylene, total (µg/L)	--	do.	5.0	--	--	90
34220	Anthracene, total (µg/L)	--	do.	5.0	--	--	90
39120	Benzidine, total (µg/L)	--	do.	40	--	--	90
34526	Benzo(*a*)anthracene[4], total (µg/L)	0.2	do.	10	--	--	90
34230	Benzo(*b*)fluoranthene[4], total (µg/L)	.2	do.	10	--	--	90
34242	Benzo(*k*)fluoranthene[4], total (µg/L)	.2	do.	10	--	--	90
34247	Benzo(*a*)pyrene[3], total (µg/L)	.2	do.	10	--	--	90
34521	Benzo(*ghi*)perylene, total (µg/L)	--	do.	10	--	--	90
34278	Bis-(2-Chlorethoxy)methane, total (µg/L)	--	do.	5.0	--	--	90
34273	Bis-(2-Chlorethyl)ether[4], total (µg/L)	--	do.	5.0	--	--	90
34283	Bis-(2-Chlorisopropyl)ether, total (µg/L)	300	do.	5.0	--	--	90
39100	Bis-(2-Ethlyhexyl)phthalate[3], total (µg/L)	6.0	do.	5.0	--	--	90
34636	4-Bromophenylphenylether, total (µg/L)	--	do.	5.0	--	--	90
34292	Butylbenzylphthalate[1], total (µg/L)	100	do.	5.0	--	--	90
34452	4-Chloro-3-methylphenol, total (µg/L)	--	do.	30	80	27	90
34581	2-Chloronaphthalene, total (µg/L)	--	do.	5.0	--	--	90
34586	2-Chlorophenol[4], total (µg/L)	40	do.	5.0	73	25	90
34641	4-Chlorophenylphenylether, total (µg/L)	--	do.	5.0	111	--	90
34320	Chrysene[3], total (µg/L)	.2	do.	10	42	46	90
34556	1,2,5,6-Dibenz(*a,h*)anthracene[3], total (µg/L)	.3	do.	10	--	--	90
34536	1,2-Dichlorobenzene[3], total (µg/L)	600	do.	5.0	56	43	90
34566	1,3-Dichlorobenzene[3], total (µg/L)	600	do.	5.0	97	30	90
34571	1,4-Dichlorobenzene[3], total (µg/L)	75	do.	5.0	51	--	90
34631	3,3-Dichlorobenzidine, total (µg/L)	--	do.	20	--	--	90
34601	2,4-Dichlorophenol[4], total (µg/L)	20	do.	5.0	84	21	90
34336	Diethylphthalate[4], total (µg/L)	5,000	do.	5.0	69	37	90
34606	2,4-Dimethylphenol, total (µg/L)	--	do.	5.0	74	23	90
34341	Dimethylphthalate, total (µg/L)	--	do.	5.0	19	--	90
39110	Di-*n*-butylphthalate[4], total (µg/L)	4,000	do.	5.0	--		90

Table B-12. Full U.S. Environmental Protection Agency Maximum Contaminant Level analysis for total recoverable concentrations of acid and base/neutral organic compounds--continued (Ziegler and Combs, 1997)

Storet[1] code	Constituent (unit of measurement)	U.S. Environmental Protection Agency MCL or HAL[2]	U.S. Geological Survey analytical method number	Minimum reporting level	Mean recovery[5] (percent)	Relative standard deviation[5] (percent)	Completeness goal (percent)
		Schedule 1383—Continued					
34657	4,6-Dinitro-2-methylphenol, total (µg/L)	--	0–3116–87[5]	30	--	--	90
34616	2,4-Dinitrophenol, total (µg/L)	--	do.	20	67	26	90
34611	2,4-Dinitrotoluene[4], total (µg/L)	100	do.	5.0	63	19	90
34626	2,6-Dinitrotoluene[4], total (µg/L)	40	do.	5.0	--	--	90
34596	Di-*n*-octylphthalate, total (µg/L)	--	do.	10	--	--	90
82626	1 2-Diphenylhydrazine (µg/L)	--	do.	5.0	--	--	90
34376	Fluoranthene, total (µg/L)	--	do.	5.0	98	--	90
34381	Fluorene, total (µg/L)	--	do.	5.0	99	11	90
39700	Hexachlorobenzene[3], total (µg/L)	1	do.	5.0	91	--	90
39702	Hexachlorobutadiene[4], total (µg/L)	1	do.	5.0	94	--	90
34386	Hexachlorocyclopentadiene[3], total (µg/L)	50	do.	5.0	--	--	90
34396	Hexachloroethane[3], total (µg/L)	1	do.	5.0	--	--	90
34403	Indeno(1,2,3-*cd*)pyrene[3], total (µg/L)	.4	do.	10	104	--	90
34408	Isophorone[4], total (µg/L)	100	do.	5.0	--	--	90
34696	Naphthalene[4], total (µg/L)	20	do.	5.0	81	17	90
34447	Nitrobenzene, total (µg/L)	--	do.	5.0	50	--	90
34433	N-Nitrosodiphenylamine, total (µg/L)	--	do.	5.0	48	--	90
34591	2-Nitrophenol, total (µg/L)	--	do.	5.0	78	32	90
34646	4-Nitrophenol, total (µg/L)	--	do.	30	61	44	90
34428	N-Nitrosodi-*n*-propylamine, total (µg/L)	--	do.	5.0	--	--	90
34438	N-Nitrosodimethlyamine, total (µg/L)	--	do.	5.0	68	--	90
39032	Pentachlorophenol[3], total (µg/L)	1	do.	30	77	31	90
34461	Phenanthrene, total (µg/L)	--	do.	5.0	94	--	90
34694	Phenol[4], total (µg/L)	4	do.	5.0	53	44	90
34469	Pyrene, total (µg/L)	--	do.	5.0	94	16	90
34551	1,2,4-Trichlorobenzene[3], total (µg/L)	70	do.	5.0	78	24	90
34621	2,4,6-Trichlorophenol, total (µg/L)	--	do.	20	17	31	90
99855	Sample volume (milliliters, schedule 1383)	--	--	1.0	--	--	90

[1] U.S. Environmental Protection Agency data STOrage and RETrieval system (STORET).
[2] U.S. Environmental Protection Agency (1995).
[3]On U.S. Environmental Protection Agency (1995) MCL list.
[4]HAL.
[5]Fishman (1993).

Table B-11. Full U.S. Environmental Protection Agency Maximum Contaminant Level analysis for total recoverable concentrations of organochlorine and organophosphate pesticides (Ziegler and Combs, 1997)

[U.S. Geological Survey (USGS) collects the samples. USGS provides sampling bottles, preservatives, and analysis (schedule 1334). MCL, Maximum Contaminant Level for drinking water; HAL, recommended health advisory level; MCL and HAL are based on total recoverable concentrations in water samples; μg/L, micrograms per liter; --, not applicable]

Storet[1] code	Constituent (unit of measurement)	U.S. Environmental Protection Agency MCL or HAL[2]	U.S. Geological Survey analytical method number	Minimum reporting level	Relative standard deviation (percent)	Completeness goal (percent)
		Schedule 1334				
39330	Aldrin[4], total, water (μg/L)	1	0–3104–83[5]	0.01	17	90
39350	Chlordane[3], total, water (μg/L)	2	do.	.10	13	90
38932	Chlorpyrifos[4], total (μg/L)	20	do.	.01	--	90
39360	DDD, *p,p'*-, total, water (μg/L)	--	do.	.01	13	90
39365	DDE, *p,p'*, total, water (μg/L)	--	do.	.01	19	90
39370	DDT, *p,p'*, total, water (μg/L)	--	do.	.01	19	90
39040	DEF, total (μg/L)	--	do.	.01	--	90
39570	Diazinon[4], total, water (μg/L)	.6	do.	.01	20	90
39380	Dieldrin[4], total, water(μg/L)	2	do.	.01	--	90
39011	Disulfoton, total (μg/L)	--	do.	.01	--	90
39388	Endosulfan I, total (μg/L)	--	do.	.01	8.9	90
39390	Endrin[3], total, water (μg/L)	2	do.	.01	--	90
39398	Ethion, total, water (μg/L)	--	do.	.01	7.4	90
82614	Fonofos[4], total (μg/L)	10	do.	.01	--	90
39410	Heptachlor[3], total, water (μg/L)	.4	do.	.01	15	90
39420	Heptachlor epoxide[3], total, water (μg/L)	.2	do.	.01	--	90
39340	Lindane[3], total, water (μg/L)	.2	do.	.01	12	90
39530	Malathion[4], total, water (μg/L)	200	do.	.01	32	90
39480	Methoxychlor[3], *p,p'*, total, water (μg/L)	40	do.	.01	8.5	90
39600	Methylparathion[4], total (μg/L)	2	do.	.01	9.2	90
39755	Mirex, total (μg/L)	--	do.	.01	34	90
39540	Parathion, total (μg/L)	--	do.	.01	6.3	90
39516	PCB's[3], gross, total, water (μg/L)	.5	do.	.10	--	90
39250	PCN's, gross, total, water (μg/L)	--	do.	.10	--	90
39034	Perthane, total (μg/L)	--	do.	.10	9.4	90
39023	Phorate, total (μg/L)	--	do.	.01	--	90
39400	Toxaphene[3], total , water (μg/L)	3	do.	1.0	--	90
39786	Trithion, total (μg/L)	--	do.	.01	7.6	90

[1]U.S. Environmental Protection Agency data STOrage and RETrieval system (STORET).
[2]U.S. Envirnomental Protection Agency (1995). [3]On U.S. Envirnomental Protection Agency (1995) MCL list.
[4]HAL. [5]Wershaw and others (1987).

Appendix C - Detailed Construction Cost

Appendix B
CONSTRUCTION COST
EQUUS BEDS GROUNDWATER RECHARGE DEMONSTRATION PROJECT
WICHITA, KANSAS

Item No.	Description of Work	Scheduled Value	Subtotal	Total
GENERAL ITEMS				
0	Mobilization	38,900	38,900	
21	Demobilization	38,900	38,900	
6.c.	Electrical Linework	90,000	90,000	
801	Elec Mark-up	24,600	24,600	192,400
2.a.	12" PVC Pipeline - Halstead	250,000		
2.b.	Air Vacs with Structure	14,000	264,000	264,000
15.a.	12" PVC Pipeline - Sedgwick	197,700		
15.b.	Air Vac with Structure	8,400		
CO3.	Sedgwick Pipeline Air Releases	5,600	211,700	211,700
SCADA				
1	Mobilization	10,820		
9	Operator Station & Radio Water	42,150		
10	Antenna/Radio City Hall	50,220		
8	Water Plant Antenna/Cable Base	2,840		
14	Systems Testing	3,000		
15	Personnel Training	2,000		
	SCADA (SWE)	318,100		
CO2.	Control Room SCADA	500	429,630	429,630
HALSTEAD INTAKE SITE:				
	General			
6.a.	Testwell Site Electrical	22,000		
6.b.	Recharge Site Electrical	28,000		
4.a.	Earthwork	2,000		
CO1.	Halstead Intake Site Piping Modification	15,600		
CO4.	Halstead Intake Site Fence	1,900	69,500	
	WELLS			
	Diversion Well	80,100		
	Monitoring Wells	31,700	111,800	
	Valve Vault			
4.c.	Buried Piping	8,500		
4.d.	Concrete Work	15,000		
4.f.	Process Piping(valve vault)	10,000	33,500	
	Chemical Feed			
4.e.	Chlorinating bldg. & Equip.	30,000		
CO6.	Halstead Intake Chlorine Bldg Imp.	1,000		
CO7.	Halstead Intake Site Cl Repair Kit	1,900	32,900	

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Appendix B
CONSTRUCTION COST
EQUUS BEDS GROUNDWATER RECHARGE DEMONSTRATION PROJECT
WICHITA, KANSAS

Item No.	Description of Work	Scheduled Value	Subtotal	Total
	SCADA			
CO1.	Halstead Intake SCADA	715		
3	Test Well Site Conduit/Wire	1,950		
6	Highway 50 Gage	1,880		
7	Antenna Bases	3,550	8,095	255,795
HALSTEAD RECHARGE SITE				
	General			
1.d.	Fencing	10,000		
1.e.	Seeding	3,000		
1.f.	Gravel Paving	12,000		
CO3.	Halstead Recharge Site Modifications	1,400		
CO7.	Halstead Recharge Site Transducers	1,800	28,200	
	Recharge Basins			
1.a.	Earthwork (basins)	60,000		
1.b.	Buried Piping	20,000		
1.c.	Rock Lining For Basins	27,500		
1.g.	Concrete-Outlet Pads	1,600		
CO5.	Halstead Recharge Site Basin Rock	31,200	140,300	
	Recharge Well			
4.b.	Well Drilling and Pumps	75,000	75,000	
	Recharge Trench			
3.a.	Earthwork	25,000		
3.b.	Concrete Structure	40,000		
3.c.	Roof Structure	15,000	80,000	
	Control Building			
5.a.	Earthwork	5,000		
5.b.	Concrete	15,000		
5.c	Building Structure & accss.	25,000		
5.d.	Mechanical(Domestic)	7,000		
5.e.	Process Piping	67,000		
CO6.	Halstead Recharge Site Piping & Drain	700		
CO7.	Halstead Recharge Site Sample Pump	1,000	120,700	
	SCADA			
4	Halstead Recharge Conduit/Wire	6,330		
11	Halstead Recharge Instrumentation	50,240		
CO1.	Halstead Recharge Site SCADA	1,605		
CO2.	Halstead Recharge Site SCADA	1,740		
CO5.	Halstead Recharge Basins Transducers	2,400	62,315	506,515

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Appendix B
CONSTRUCTION COST
EQUUS BEDS GROUNDWATER RECHARGE DEMONSTRATION PROJECT
WICHITA, KANSAS

Item No.	Description of Work	Scheduled Value	Subtotal	Total
SEDGWICK INTAKE SITE				
	General			
7.a.	Earthwork	60,000		
7.c.	Fencing	5,000		
7.d.	Seeding	3,000		
7.e.	Gravel Paving	35,000		
19.b.	Intake Electrical	30,000		
CO3.	Sedgwick Intake Site Modifications	3,400		
CO6.	Sedgwick Intake Fence	1,800		
CO6.	Sedgwick Intake Fence Carrier Well	2,200		
CO7.	Sedgwick Intake Site Fence Imp.	700	141,100	
	Intake			
7.b.	Well Drilling & pumps	75,000		
7.f.	Buried Piping	10,000		
12.a.	Earthwork	3,000		
12.b.	Wetwell River Pump Station	10,000		
12.c.	Submersible Pump System	12,000		
12.d.	Process Piping	3,000		
12.e	Buried Pipe & Screen	8,000		
19.c.	River intake Electrical	6,500		
CO2.	Sedgwick Intake Site Pump Modification	51,000		
CO2.	Sedgwick Intake Site Electrical Power	9,300	187,800	
	Chloine Feed			
11.a.	Foundation	1,500		
11.b.	CL2 Equip and Building	29,000		
CO7.	Sedgwick Intake Site Cl Repair Kit	2,000	32,500	
	PAC Feed			
10.a.	Earthwork	1,000		
10.b.	Concrete	14,000		
10.c.	PAC Equipment	50,000		
10.d.	Building Structure & accss.	22,000		
10.e.	Mechanical (Domestic)	7,500		
10.f.	Process Piping	15,000		
CO6.	Sedgwick Intake Chemical Feed	2,400	111,900	
	Treatment Units			
8.a.	Earthwork	1,000		
8.b.	Concrete	10,000		
8.c	Presedimentation Unit	130,000	141,000	
	Residuals Basins			
CO6.	Sedgwick Intake Sludge Basins	52,200		
CO5.	Sedgwick Intake Site Plug Valves	2,000	54,200	

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Appendix B
CONSTRUCTION COST
EQUUS BEDS GROUNDWATER RECHARGE DEMONSTRATION PROJECT
WICHITA, KANSAS

Item No.	Description of Work	Scheduled Value	Subtotal	Total
	Control Building			
9.a.	Earthwork	2,000		
9.b.	Concrete	15,000		
9.c.	Polymer Feed Equipment	10,000		
9.d.	Building Structure & accss	25,000		
9.e.	Mechanical(Domestic)	7,500		
9.f.	Process Piping	25,000		
CO7.	Sedgwick Intake Site Control Bldg Imp	4,200	88,700	
	Transfer Pump 1			
13.a.	Earthwork	1,500		
13.b.	Wetwell Transfer Pump #1	5,000		
13.c.	Submersible Pump System	12,000		
13.d.	Process Piping	2,000	20,500	
	SCADA			
5	Sedgwick Intake Conduit/Wire	6,310		
13	Sedgwick Intake Instrumentation	48,780		
CO1.	Sedgwick Intake SCADA	985		
CO4.	Sedgwick Intake Site SCADA Wiring	6,600	62,675	840,375
SEDGWICK RECHARGE SITE				
	General			
14.c.	Fencing	10,000		
14.d.	Seeding	3,000		
14.e.	Gravel Paving	15,000		
14.g.	Concrete work	2,000		
19.a.	Recharge Electrical	24,000		
CO3.	Sedgwick Recharge Site Modifications	7,000	61,000	
	Presedimentation & Recharge Basins			
14.a.	Earthwork	90,000		
14.b.	Rock Lining For Basins	60,000		
14.f.	Buried Piping	10,000		
CO5.	Sedgwick Recharge Site Add. Excav.	6,500	166,500	
	Control Building			
16.a.	Earthwork	4,000		
16.b.	Concrete	15,000		
16.d.	Building Structure & access	30,000		
16.e.	Mechanical(domestic)	7,500		
16.f.	Process Piping	50,000		
CO6.	Sedgwick Recharge Site Well & Drain	2,600	109,100	
	Chemical Feed			
16.c.	Polymer Feed Equipment	5,000		
18.a.	Earthwork	500		
18.b.	Concrete	7,000		
18.c.	Floculator Equipment	7,500	20,000	

Appendix B
CONSTRUCTION COST
EQUUS BEDS GROUNDWATER RECHARGE DEMONSTRATION PROJECT
WICHITA, KANSAS

Item No.	Description of Work	Scheduled Value	Subtotal	Total
	Transfer Pump 2			
17.a	Earthwork	1,000		
17.b.	Wetwell	6,000		
17.c.	Submersible Pump System	10,000		
17.d.	Process Piping	2,200	19,200	
	SCADA			
2	Sedgwick Recharge Conduit/Wire	5,550		
12	Sedgwick Recharge Instrumentation	48,760		
CO1.	Sedgwick Recharge Site	1,215		
CO2.	Sedgwick Recharge Site	565	56,090	431,890
		3,132,305	3,132,305	3,132,305