Pima County Regional
FLOOD CONTROL
DISTRICT

PIMA COUNTY
REGIONAL FLOOD CONTROL DISTRICT
97 EAST CONGRESS STREET, THIRD FLOOR
TUCSON, ARIZONA 85701-1797

SUZANNE SHIELDS, P.E.
DIRECTOR

(520) 243-1800
FAX (520) 243-1821

May 29, 2008

Mr. John Bodenchuk
Recharge Program Manager
Arizona Department of Water Resources
Water Management Division
3550 N. Central Avenue
Phoenix, Arizona 85012

Re: Response to Incomplete and Incorrect Determination for Underground Storage Facility Application No. 71-563876.0006

Dear Mr. Bodenchuk:

We have reviewed your October 9, 2007 letter and have addressed the items you have listed:

Permits

We have included the updated ADEQ/ACOE 1401/404 permit dated October 25, 2004 extending the permit period to October 15, 2009 **(Attachment 1).**

Financial Capability

Please find attached a letter with a cost estimate for the proposed USF improvements to enhance infiltration rates and other **(Attachment 2)**. Also, please find a letter from the PCRFCD CFO Chuck Huckelberry certifying that PCRFCD has financial resources to meet the capital and operations and maintenance costs for the duration of the permit **(See also Attachment 2)**.

Facility Description and Design Plans

Bullet #1: Figure 2 has been modified to include the distribution pipelines, flow meters, and the manual and automated valves that make up the facility's conveyance system **(Attachment 3)**

Bullet #2: Well HP-2 was built to the specifications shown on Figure 13. There is no as-built well diagram for this piezometer. A revised copy of the well diagram (Figure 13) is provided for reference **(Attachment 4)**.

Bullet #3: A map view of cross-section B-B' is enclosed along with the well driller's logs for all the wells that were used to construct the cross-section **(Attachment 5)**.

Bullet #4: Table 4, Page 14- The infiltration galleries (**recharge enhancement trenches**) listed to be installed in basins 1, 3, and 4 are shown by the graphic in Figure 9 (preceding Page 14). The recharge components will include two trenches excavated up to 12-feet deep and 100-150 feet long, to more permeable sands and gravels. The trenches will be filled with river rock material to allow for rapid infiltration of the diverted treated effluent through the highly permeable river rock to the more permeable sands and gravels identified in the previous trenching evaluation described in Section 3.4, page 10. We will formally call them "recharge enhancement trenches" to avoid any further confusion.

Bullet #5: A description of the proposed modified recharge basins is provided in Table 4 and shown in Figure 8. A description of the design contingencies (1 through 4) is provided in Table 4a, and maps of the design contingencies are provided in Figures 12a, 12b, 13a and 13b **(Attachment 6).** Different design contingencies or a combination of design contingencies may be used in each of the basins based on field investigations.

Hydrologic Feasibility/Unreasonable Harm

Bullet #1: No unreasonable harm will occur as a result of the recharge mound from the Marana High Plains (MHP) Facility after 20 years. Based on Figures 18 and 19 of our report, the Tangerine Landfill is approximately 2.3 miles west of and hydrologically upgradient of the MHP Facility. In addition , the water surface elevation may rise approximately 0.8 feet above the current depth to water of 200 feet bls below the Tangerine Landfill after 20 years as a result of MHP recharge, based on our modeling results. Additional modeling information is available in **Attachment 12.**

Bullet #2: We are attaching the updated Birdstike Analysis and Mitigation Plan in addition to the original Entranco (1997) Plan **(Attachment 7)**. The new USF permit will also fit under the bird strike plan as we are not increasing the linear size of the facility. In addition, we are attaching a letter from the Marana Regional Airport Administrator indicating the project location will not pose a threat to airport operations **(also in Attachment 7)**

Bullet #3: Please find enclosed an inventory map of the closest sand and gravel operation, which is approximately 3 miles east of the project site. **(Attachment 8)** Also enclosed are a map and table that describe known areas of groundwater contamination (i.e., underground storage tanks) as identified by Arizona Department of Environmental Quality **(also in Attachment 8)**

Bullet #4: The MHP Facility will result in no net gain in recharged water that is occurring today. MHP diverts effluent or surface water from the Lower Santa Cruz Managed Facility (LSCMRF) at an Oxbow diversion on the Santa Cruz River 1.25 miles southwest of the Facility. The effluent that would normally recharge the LSCMRF is now being recharged in the MHP constructed USF. The amounts removed from the LSCMRF are accounted for in the LSCMRF water budget. Therefore, MHP will result in no additional regional water level increase. The regional models that Montgomery (1997, 2002a, 2002b) has performed for the LSCMRF, Lower Santa Cruz Replenishment Facility and the Avra State Demonstration Facility have already accounted for the recharge of effluent at the MHP site because of its diversion from the LSCMRF. However, during our modeling we did recharge 600 AF/yr for 20 years as a worst case scenario. For further details regarding rising water levels at the Marana High Plains Facility, please refer to the **Modeling section and Attachment 12.**

Bullet #5: The last sentence asks for a narrative demonstrating the basins can support the requested recharge rate without modifications. However, we contend that the earlier design was not realistic and could not support a design of 600 AF/yr. The reason for our proposed basins modifications is to attain a recharge capacity of 600 AF/yr (3.88 acres x 0.6 ft/dy x 258 recharge days). Currently the basins are operating at an effective loading rate of about 250 AF/yr based on four years of operation. We seek to improve upon that rate.

Bullet #6 : Our October 2006 investigation provided data based on trenching from the pond bottoms to 12 feet below the bottoms. Our particle size analyses give compelling evidence that infiltration rates will increase in material found approximately four feet below Cell# 2 and 7 feet below Cell # 4. In addition, we excavated in these areas because an earlier investigation by our consultant (Montgomery, 1996a) indicated that analyses of the soils and infiltration tests in test pits in these areas indicated potentially high (5-15 ft/day) in soils below 4.5 feet and 7.5 feet below Ponds #2 and #4 respectively. These rates will certainly slow as long-term recharge continues to rate more like 1-3 ft/day. Our 2006 trenching tests confirmed the earlier Montgomery (1996a) data. Laboratory particle size analyses showed the following:

Pima County Materials Laboratory Analyses
Marana High Plains Recharge Site
Log of Pond Samples for November 14, 2006

Pond	Depth Below Bottom	Percent Passing - #40 Sieve	Percent Passing - #200 Sieve	Soil Classification
2	1'	94	34.4	Silty Fine Sand
2	4'	95	53.4	Fine Sandy Silt
2	5 - 6'	94	4.7	Fine Sand (Poorly Graded)
2	6 - 7'	47	1.5	Fine to Medium Sand
2	8 - 9'	38	2.4	Medium to Fine Sand
2	9 - 10'	26	0.8	Medium – Fine – Coarse Sand
2	12 - 13'	26	1.5	Medium to Fine Sand
4	0.5 - 1'	97	46.9	Silty Fine Sand
4	2'	99	60.9	Fine Sandy Silt
4	2.5 - 3'	97	65.9	Fine Sandy Silt
4	6.5 - 7'	95	50.4	Fine Sandy Silt
4	7.5 - 8	24	5.9	Well Graded Medium and Fine Sand with Coarse Sand
4	9.5 - 10'	72	7.0	Fine Sand with Cobbles
4	10 - 11'	24	4.7	Well Graded Medium to Fine Sand with Cobbles
4	10.5 - 11'	46	16.8	Well Graded Fine to Medium Sand
4	12 - 12.5'	9	2.7	Medium to Coarse Sand

Bullet #7: There are two sources for the information in Table 5: SAHRA, 2006. Arizona Wells. http://www.sahra.arizona.edu/wells (Data obtained in June 2007) and ADWR, 2007. Wells-55 Registry (Data obtained in June 2007). A revised Table 5 is enclosed. **(Attachment 9)**

Monitoring Plan

Bullet #1: Well HP-2 will be included in the facility monitoring. Wells SC-09 and AVMW-1 will not be monitored by District staff, but quarterly data collected by Pima County Wastewater Department and Central Arizona Water Conservation District will be included in the facility's annual report.

Bullet #2: Alert levels for the on-site wells (HP-1 and HP-2) will be set at 30 feet below land surface and operational prohibition limits will be set at 20 feet below land surface. A table describing the facility's water level monitoring plan is enclosed **(Attachment 10)**

Bullet #3: A table listing all the water quantity measuring devices used in the facility is enclosed along with the manufacturers' specifications **(Attachment 11).**

Bullet #4: We will plan to notify you by e-mail or other means you so desire when the diversion berm is washed out and water for recharge is not available for recharge. Typically the monitoring is performed daily by BKW Farms personnel on contract with the Town of Marana. When water is not available at the wet well for pumping to the equalization basin, we are informed by either BKW or Town of Marana personnel. We can then e-mail a designated ADWR representative that the diversion berm is not operating.

Modeling

Since this response consists of a larger amount of text and graphics, we have included the entire response in **Attachment 12.**

If you have any questions, please call us at (520) 205-8356 or 520-253-1853

Sincerely,

David Scalero, Project Manager, Principal Hydrologist
Frank Postillion, CGWP, Chief Hydrologist
Water Resources Division – Regional Flood Control District

FP/tj

cc: Brad DeSpain, Town of Marana

Attachments

Attachment 1

Updated USCOE 404 Permit

DEPARTMENT OF THE ARMY
LOS ANGELES DISTRICT, CORPS OF ENGINEERS
ARIZONA-NEVADA AREA OFFICE
3636 NORTH CENTRAL AVENUE, SUITE 900
PHOENIX, ARIZONA 85012-1939

REPLY TO

October 25, 2004

Office of the Chief
Regulatory Branch

Mr. Frank Postillion, CGWP
Principal Hydrologist
Pima County Department of
Transportation and Flood Control
201 N. Stone Avenue, Fourth Floor
Tucson, Arizona 85701

File Number: 974-0474-RJD

Dear Mr. Postillion:

Reference is made to your request dated September 28, 2004 to amend Permit No. 974-0474-RJD which authorized you to construct the High Plains Effluent Discharge Project (Sections 3 and 4, T12S, R11E), Marana, Pima County, Arizona.

Under the provisions of 33 Code of Federal Regulation 325.6(d), the start date is to remain the same and the completion date is extended from October 15, 2004 to October 15, 2009.

The terms and conditions of Permit No. 974-0474-RJD, except as changed herein, remain in full force and effect. You should contact the Arizona Department of Environmental Quality to ensure your Section 401 water quality certification has not expired. If this certification has expired, please provide us with a copy of the extension of time.

Sincerely,

Cindy Lester P.E.
Chief, Arizona Section
Regulatory Branch

Copy Furnished:
Mr. Andy Travers, ADEQ

Attachment 2

Letters of Financial Responsibility and Cost

Pima County Regional
FLOOD CONTROL
DISTRICT

PIMA COUNTY
REGIONAL FLOOD CONTROL DISTRICT
97 EAST CONGRESS STREET, THIRD FLOOR
TUCSON, ARIZONA 85701-1797

SUZANNE SHIELDS, P.E.
DIRECTOR

(520) 243-1800
FAX (520) 243-1821

October 22, 2007

Ms. Diane Kusel
Arizona Department of Water Resources
Tucson Active Management Area
400 W. Congress Street, Suite 518
Tucson, AZ 85701

Subject: **Underground Storage Facility Permit No. 71-563876**
Marana High Plains Effluent Recharge Project

Dear Ms. Kusel,

The Pima County Regional Flood Control District (District) has installed a new flow meter at monitoring point FM_{eq}, at the subject facility's pump station (see enclosed Figure). The old flow meter at this location was providing inaccurate readings and could not be recalibrated during inspections in September 2007. The new flow meter will allow for easier calibration and repairs with little disruption to the facility's operations. Specifications for the new Magnetflow® Mag Meter are enclosed for your files.

With the installation of the new flow meter, District staff has restarted facility operations after approximately two months of downtime during the Monsoon season. If you have any questions regarding the new flow meter or any of the facility operations, please contact me at (520) 243-1858.

Sincerely,

David Scalero

David Scalero, Principal Hydrologist
Pima County Regional Flood Control District
Water Resources Division

c: Thomas J. Helfrich, Manager, Water Resources Division
Julia Fonseca, Environmental Planning Manager
Frank Postillion, Chief Hydrologist

Estimate of Costs for Marana High Plains Facility Improvements for Application to Extent Facility Operations (2007-2027)

***Proposed Improvements:**

Deepening Basin #2 (5-7feet)	$ 35,000
Six Recharge Enhancement Trenches Basins #1, 3 and 4 (2 ft.wide x 12 ft. deep x 40ft. max.)	$ 6,000
New Vegetative Plantings in Basin #1 and Equalization Basin	$ 7,000
Total Capital Costs	**$ 48,000**

****Annual Operations and Maintenance Costs**

Monitoring and Reporting	$12,000
Laboratory, equipment	$10,000
Basins cleaning and maintenance	$12,000
Annual O&M Costs	**$ 34,000**

***Proposed Contingencies (if implemented)**

(16) 36-in. diameter x 15 ft deep dry wells ($10,000/unit)	$160,000
(8) 36- in. recharge dry well systems with connected 100 ft 36" slotted culvert 8-10' deep. ($15,000/unit)	$120,000
Ridges and furrows for four basins	$25,000
Ridges and furrows in four basins Ridges over trenches 1.5'x 6'x 50' Six trenches total	$35,000

*These estimates were based upon unit costs established by the Price Book maintained with a Pima County Regional Flood Control District Job Order Contract (SFQ # 89646-2006) and KE&G Heavy Engineering Contractor.

**Operations and maintenance costs were based upon actual facility costs from 2002-2006.

COUNTY ADMINISTRATOR'S OFFICE
PIMA COUNTY GOVERNMENTAL CENTER
130 W. CONGRESS, TUCSON, AZ 85701-1317
(520) 740-8661 FAX (520) 740-8171

C.H. HUCKELBERRY
County Administrator

January 28, 2008

John Bodenchuk
Recharge Program Manager
Arizona Department of Water Resources
3550 North Central Avenue
Phoenix, Arizona 85012

Re: **Marana High Plains – 20-Year Permit Extension and Improvements ADWR Underground Storage Facility Application No. 71-563876.0006**

Dear Mr. Bodenchuk:

As the Pima County Regional Flood Control District (District) General Manager and Chief Financial Officer, I certify that the applicant, the District, has the existing financial resources and adequate taxing and bonding authority to pay the estimated construction and operation costs for the Marana High Plains Underground Storage Facility (Facility) as indicated on the enclosed Statement of Estimated Costs of Improvements.

The District has an annual property tax levy of over $17 million and also has bonding authority for capital projects. The Facility was built in 2002 with funds from the District, the United States Bureau of Reclamation, and the Arizona Water Protection Fund. The District will continue to maintain and operate the Facility as warranted, and invest capital improvements to enhance infiltration rates and facility efficiency.

If you have any questions, please call Frank Postillion at (520) 205-8356.

Sincerely,

C. Huckelberry

C.H. Huckelberry
County Administrator
Regional Flood Control District General Manager and CFO

CHH/jj
Attachment

c: John Bernal, Deputy County Administrator - Public Works
Suzanne Shields, Regional Flood Control District Director
Thomas Helfrich, Water Resources Division Manager, Regional Flood Control District
Frank Postillion, Chief Hydrologist - Water Resources Division, Regional Flood Control District
David Scalero, Principal Hydrologist - Water Resources Division, Regional Flood Control District

Estimate of Costs for Marana High Plains Facility Improvements for Application to Extent Facility Operations (2007-2027)

__*Proposed Improvements:__

Deepening Basin #2 (5-7feet)	$ 35,000
Six Recharge Enhancement Trenches Basins #1, 3 and 4 (2 ft.wide x 12 ft. deep x 40ft. max.)	$ 6,000
New Vegetative Plantings in Basin #1 and Equalization Basin	$ 7,000
Total Capital Costs	**$ 48,000**

****Annual Operations and Maintenance Costs**

Monitoring and Reporting	$12,000
Laboratory, equipment	$10,000
Basins cleaning and maintenance	$12,000
Annual O&M Costs	**$ 34,000**

__*Proposed Contingencies (if implemented)__

(16) 36-in. diameter x 15 ft deep dry wells ($10,000/unit)	$160,000
(8) 36- in. recharge dry well systems with connected 100 ft 36" slotted culvert 8-10' deep. ($15,000/unit)	$120,000
Ridges and furrows for four basins	$25,000
Ridges and furrows in four basins Ridges over trenches 1.5'x 6'x 50' Six trenches total	$35,000

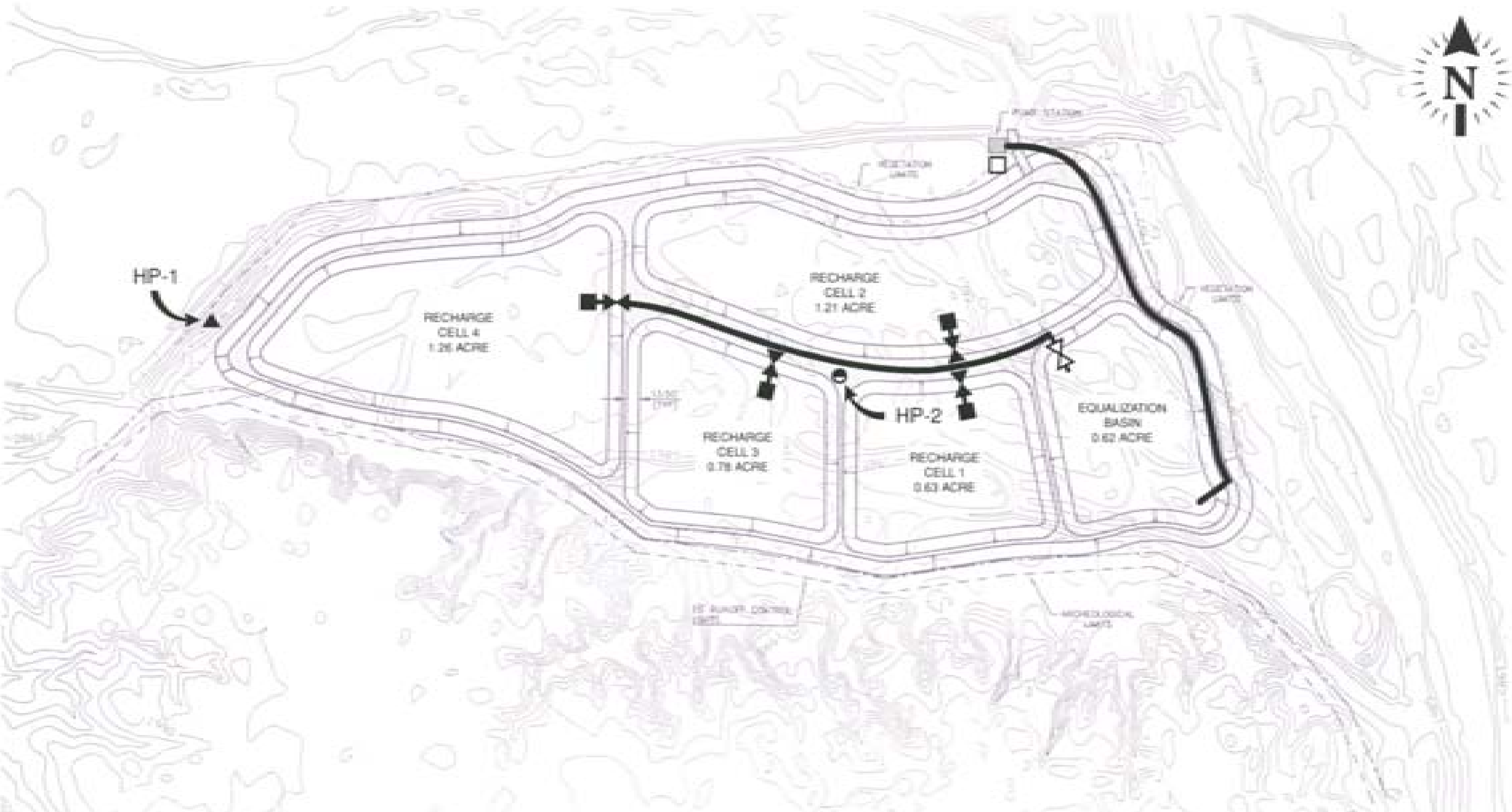
*These estimates were based upon unit costs established by the Price Book maintained with a Pima County Regional Flood Control District Job Order Contract (SFQ # 89646-2006) and KE&G Heavy Engineering Contractor.

**Operations and maintenance costs were based upon actual facility costs from 2002-2006.

Attachment 3

Modified Facility Figure

FIGURE 2 FACILITY MAP
MAP VIEW



MAP VIEW

CURRENT RECHARGE AREA = 3.88 ACRES

MODIFIED RECHARGE AREA = 4.50 ACRES

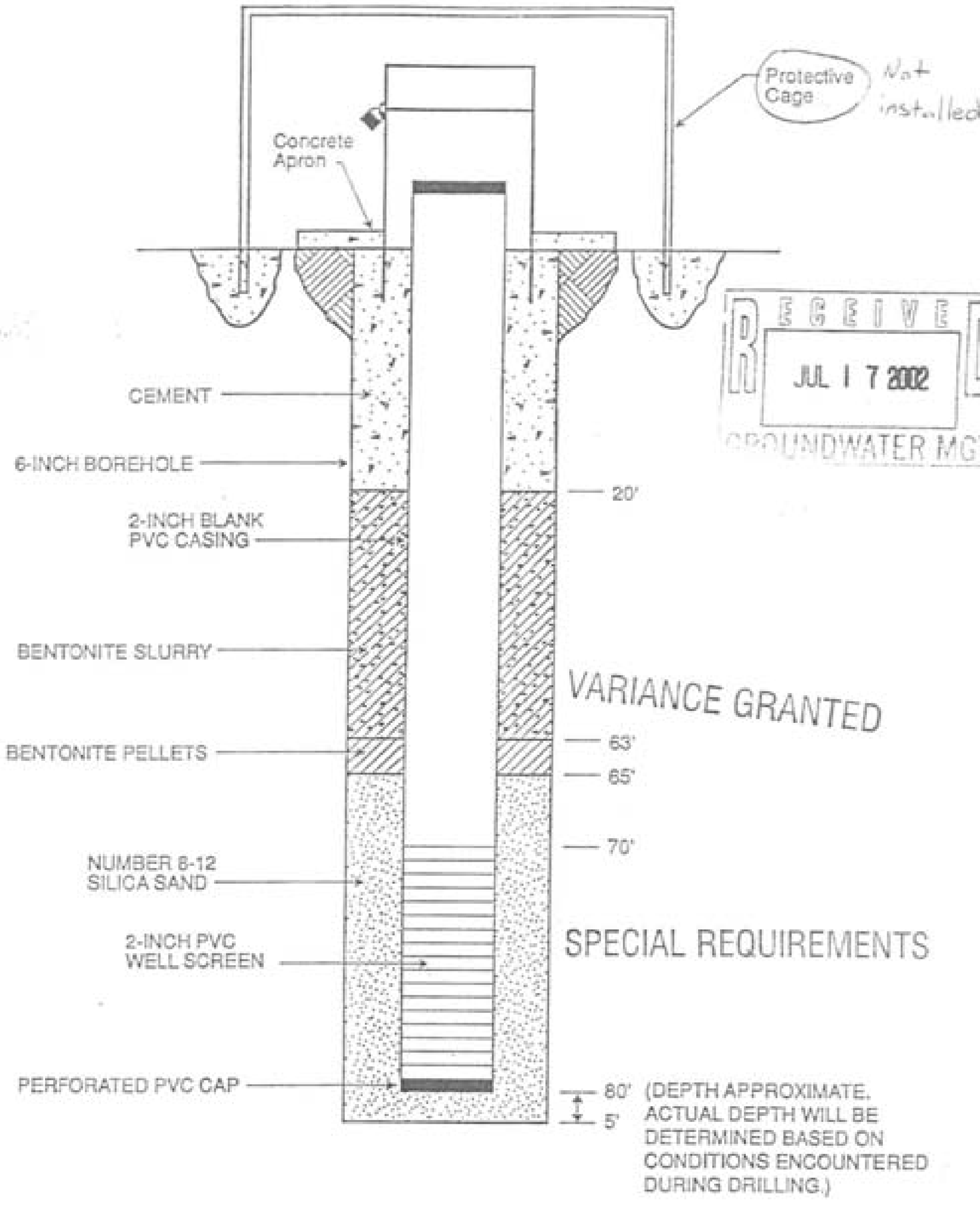
SCALE IN FEET:

LEGEND

- ▲ MONITOR WELL
- PIEZOMETER
- PIPE
- MANUAL GATE VALVE
- MOTORIZED BUTTERFLY VALVE
- ■ FLOW METER (AREA / VELOCITY)
- □ MAG METER (FLOW METER)

Attachment 4

Revised Monitor Well Diagram



VARIANCE GRANTED

SPECIAL REQUIREMENTS

FIGURE 13

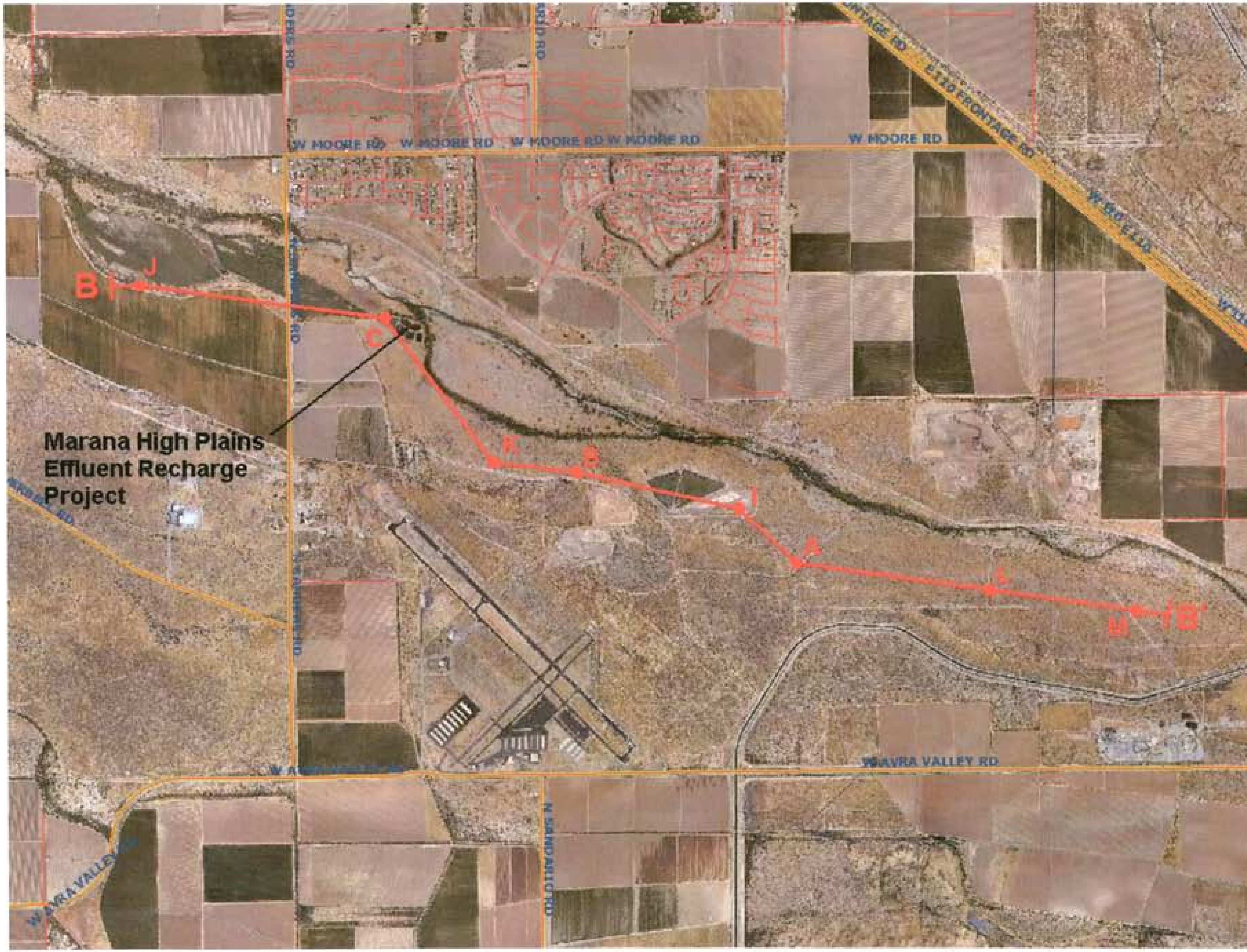
PIMA COUNTY DEPARTMENT OF TRANSPORTATION AND FLOOD CONTROL DISTRICT

CONSTRUCTION DIAGRAM
PIEZOMETER HP-2

Drawing is not to scale

Attachment 5

Cross Section B-B'



LEGEND

- Borehole Location & Identifier
- Location of Hydrologic Section

North

scale 1 : 30,100

LOCATIONS OF BOREHOLES
LOWER SANTA CRUZ RIVER

Source: Errol L. Montgomery & Associates, Inc. Results of Vadose Zone Investigations, Lower Santa Cruz River and Canada Del Oro Wash/Big Wash Sites, Recharge Feasibility Investigations, Northwest Replenishment Program, Pima County Arizona. May 16, 1996

LOG A-1. LITHOLOGIC DESCRIPTIONS FOR SPLIT-SPOON SAMPLES BOREHOLE A, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
	RECENT ALLUVIUM
15-16	**SANDY GRAVEL**; red-brown; gravel 60%, very fine to very coarse sand 40%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to subrounded granules and pebbles to 1 1/2-inch diameter; igneous and metamorphic rocks 60%; quartz and feldspar 25%; volcanic rocks 15%. Reaction to acid: weak.
20-21	**SANDY GRAVEL**; white-tan; gravel 70%, very fine to very coarse sand 30%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to well-rounded granules, pebbles, and cobbles to 3-inch diameter; igneous and metamorphic rocks 60%; quartz and feldspar 20%; sedimentary rocks 10%; volcanic rocks 10%. Reaction to acid: strong.
25-26	**GRAVELLY SAND**; medium red-brown; very fine to very coarse sand 70%, gravel 30%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 2-inch diameter; volcanic rocks 60%; quartz and feldspar 20%; igneous and metamorphic rocks 10%; sedimentary rocks 10%. Reaction to acid: moderate.
30-31	**SANDY GRAVEL**; medium red-brown; gravel 70%, very fine to very coarse sand 30%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1 1/2-inch diameter; igneous and metamorphic rocks 40%; volcanic rocks 40%; quartz and feldspar 20%; trace sedimentary rocks. Reaction to acid: weak.
35-36	**GRAVELLY SAND**; medium red-brown; gravel 60%, very fine to very coarse sand 40%, trace silt and clay; moist; non-lithified. Gravel fraction: subangular to subrounded granules, pebbles, and cobbles to 2 1/2-inch diameter; igneous and metamorphic rocks 50%; volcanic rocks 30%; quartz and feldspar 20%. Reaction to acid: none.
40-41	**SANDY GRAVEL**; dark red-brown; gravel 55%, very fine to very coarse sand 40%, silt and clay 5%; moist; non-lithified. Gravel fraction: subangular to subrounded granules, pebbles, and cobbles to 2 1/2-inch diameter; volcanic rocks 60%; igneous and metamorphic rocks 30%; quartz and feldspar 10%; trace sedimentary rocks. Reaction to acid: none.

LOG A-1. LITHOLOGIC DESCRIPTIONS FOR SPLIT-SPOON SAMPLES
BOREHOLE A, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
45-46	**SANDY GRAVEL**; orange-brown; gravel 50%, very fine to very coarse sand 45%, silt and clay 5%; moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1 1/2-inch diameter; igneous and metamorphic rocks 40%; volcanic rocks 40%; quartz and feldspar 20%. Reaction to acid: none.
	<u>FORT LOWELL FORMATION</u>
50-51	No recovery.
55-56	No sample obtained.
60-61	**SILTY AND CLAYEY GRAVELLY SAND**; orange-brown; very fine to very coarse sand 60%, gravel 30%, silt and clay 10%; slightly moist; non-lithified, but matrix is cohesive. Gravel fraction: subangular to rounded granules and pebbles to 2-inch diameter; igneous and metamorphic rocks 60%; quartz and feldspar 30%; volcanic rocks 10%. Reaction to acid: none.
65-66	**SILTY AND CLAYEY SANDY GRAVEL**; orange-brown; gravel 60%, very fine to very coarse sand 30%, silt and clay 10%; slightly moist; non-lithified, but matrix is cohesive. Gravel fraction: subangular to rounded granules and pebbles to 2-inch diameter; igneous and metamorphic rocks 50%; quartz and feldspar 30%; volcanic rocks 20%. Reaction to acid: none.
70-71	**SILTY AND CLAYEY GRAVELLY SAND**; orange-brown; very fine to very coarse sand 55%, gravel 35%, silt and clay 10%; slightly moist; non-lithified, but matrix is cohesive. Gravel fraction: subangular to rounded granules and pebbles to 1-inch diameter; igneous and metamorphic rocks 60%; quartz and feldspar 30%; volcanic rocks 10%. Reaction to acid: none.
75-76	**SANDY, SILTY AND CLAYEY GRAVEL**; orange; gravel 45%, silt and clay 35%, sand 20%; slightly moist; non-lithified; but matrix is cohesive. Gravel fraction: subangular to rounded granules, pebbles, and cobbles to 3-inch diameter; volcanic rocks 60%; quartz and feldspar 30%; igneous and metamorphic rocks 10%. Reaction to acid: none.

TOTAL DEPTH DRILLED: 76 FEET

LOG A-2. LITHOLOGIC DESCRIPTIONS FOR DRILL CUTTINGS SAMPLES BOREHOLE B, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
	RECENT ALLUVIUM
10-14	**SILTY AND CLAYEY SAND**; medium brown; very fine to medium sand 60%, silt and clay 40%, trace gravel; slightly moist; non-lithified. Silt and clay occurs chiefly as thin slightly moist layer. Reaction to acid: weak.
14-16	**SILTY AND CLAYEY GRAVELLY SAND**; medium red-brown; very fine to very coarse sand 55%, gravel 30%, silt and clay 15%; slightly moist; non-lithified, but matrix is somewhat cohesive. Gravel fraction: subangular to subrounded granules and pebbles to 1 1/2-inch diameter; volcanic rocks 70%; quartz and feldspar 30%. Reaction to acid: none.
16-30	**SANDY GRAVEL**; medium red-brown; gravel 65%, very fine to very coarse sand 30%, silt and clay 5%; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules, pebbles, and cobbles to 3-inch diameter; volcanic rocks 60%; quartz and feldspar 30%; igneous and metamorphic rocks 10%. Reaction to acid: none.
30-32	**SANDY GRAVEL**; medium red-brown; gravel 55%; very fine to very coarse sand 40%, silt and clay 5%; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1 1/2-inch diameter; volcanic rocks 60%; quartz and feldspar 30%; igneous and metamorphic rocks 10%. Reaction to acid: weak.
32-34	**GRAVELLY SILTY AND CLAYEY SAND**; medium red-brown; very fine to very coarse sand 50%, silt and clay 40%, gravel 10%; slightly moist; non-lithified. Silt and clay clumps. Gravel fraction: subangular to rounded granules and pebbles to 1/4-inch diameter. Reaction to acid: none.
34-36	**SILTY AND CLAYEY GRAVELLY SAND**; medium orange-brown; very fine to very coarse sand 60%, gravel 30%, silt and clay 10%; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1-inch diameter; volcanic rocks 60%; quartz and feldspar 30%; igneous and metamorphic rocks 10%. Reaction to acid: none.

LOG A-2. LITHOLOGIC DESCRIPTIONS FOR DRILL CUTTINGS SAMPLES
BOREHOLE B, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
36-46	**SANDY GRAVEL**; light orange-brown; gravel 60%, very fine to very coarse sand 40%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to subrounded granules and pebbles to 2-inch diameter; volcanic rocks 40%; igneous and metamorphic rocks 40%; quartz and feldspar 20%. Reaction to acid: none.
46-50	**SANDY GRAVEL**; medium orange-brown; gravel 50%, very fine to very coarse sand 45%, silt and clay 5%; slightly moist; non-lithified. Gravel fraction: subangular to subrounded granules and pebbles to 2-inch diameter; volcanic rocks 40%; igneous and metamorphic rocks 40%; quartz and feldspar 20%. Reaction to acid: none.
	FORT LOWELL FORMATION
50-60	**GRAVELLY SAND**; medium orange-brown; very fine to very coarse sand 50%, gravel 45%, silt and clay 5%; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules, pebbles, and cobbles to 4-inch diameter; volcanic rocks 40%; igneous and metamorphic rocks 40%; quartz and feldspar 20%. 54-56 feet: cobbles to 4-inch diameter, decreased clay content. Reaction to acid: none.
60-61 (split-spoon)[a]	**SILTY AND CLAYEY GRAVELLY SAND**; orange-brown; very fine to very coarse sand 50%, gravel 40%, silt and clay 10%; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1 1/2-inch diameter; volcanic rocks 40%; igneous and metamorphic rocks 40%; quartz and feldspar 20%. Reaction to acid: none.
60-62	**GRAVELLY SAND**; orange-brown; very fine to very coarse sand 55%, gravel 40%, silt and clay 5%; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1 1/2-inch diameter; volcanic rocks 40%; igneous and metamorphic rocks 40%; quartz and feldspar 20%. Reaction to acid: none.
62-64	**SILTY AND CLAYEY GRAVELLY SAND**; dark orange-brown; very fine to very coarse sand 55%, gravel 35%, silt and clay 10%; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1 1/2-inch diameter; volcanic rocks 50%; igneous and metamorphic rocks 30%; quartz and feldspar 20%. Reaction to acid: none.

LOG A-2. LITHOLOGIC DESCRIPTIONS FOR DRILL CUTTINGS SAMPLES
BOREHOLE B, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
64-70	**GRAVELLY SAND**; light orange-brown; very fine to very coarse sand 50%, gravel 45%, silt and clay 5%; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules, pebbles, and cobbles to 3-inch diameter; volcanic rocks 50%; igneous and metamorphic rocks 30%; quartz and feldspar 20%; increase clay at 66 feet. Reaction to acid: none.
70-84	**SILTY AND CLAYEY GRAVELLY SAND**; dark orange-brown; very fine to very coarse sand 50%, gravel 40%, silt and clay 10%; slightly moist; non-lithified. Sand is chiefly medium to coarse-grained. Gravel fraction: granules and pebbles to 1 1/2-inch diameter; volcanic rocks 40%; igneous and metamorphic rocks 40%; quartz and feldspar 20%. Reaction to acid: none.
84-86	**SANDY GRAVEL**; light orange-brown; gravel 60%, very fine to very coarse sand 40%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to well-rounded granules, pebbles, and cobbles to 3-inch diameter; volcanic rocks 40%; igneous and metamorphic rocks 40%; quartz and feldspar 20%. Reaction to acid: none.
86-90	**SILTY AND CLAYEY SANDY GRAVEL**; dark orange-brown; gravel 55%, very fine to very coarse sand 35%, silt and clay 10%; slightly moist; non-lithified. Sand is chiefly coarse to very coarse-grained. Gravel fraction: subangular to well-rounded granules, pebbles, and cobbles to 3-inch diameter; volcanic rocks 40%; igneous and metamorphic rocks 40%; quartz and feldspar 20%. Reaction to acid: none.
90-92	**SANDY GRAVELLY SILT AND CLAY**; dark orange-brown; silt and clay 45%, gravel 30%, very fine to very coarse sand 25%; slightly moist; non-lithified. Sand is chiefly very fine-grained and very coarse-grained. Reaction to acid: none.
92-94	**GRAVELLY SANDY SILT AND CLAY**; dark orange-brown; silt and clay 60%, very fine to very coarse sand 30%, gravel 10%; slightly moist; non-lithified. Sand is chiefly very fine to fine-grained. Reaction to acid: none.
94-98	**SANDY GRAVEL**; medium orange-brown; gravel 50%, very fine to very coarse sand 45%, silt and clay 5%; very slightly moist; non-lithified. Gravel fraction: subangular to well-rounded granules and pebbles to 1 1/2-inch diameter; volcanic rocks 40%; igneous and metamorphic rocks 40%; quartz and feldspar 20%. Reaction to acid: none.

LOG A-2. LITHOLOGIC DESCRIPTIONS FOR DRILL CUTTINGS SAMPLES
BOREHOLE B, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
98-108	**SANDY GRAVEL**; light orange-gray; gravel 55%, very fine to very coarse sand 45%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to well-rounded granules, pebbles, and cobbles 2 1/2-inch diameter; volcanic rocks 40%; igneous and metamorphic rocks 40%; quartz and feldspar 20%. Reaction to acid: none.
108-110	**SILTY AND CLAYEY SAND**; medium orange; very fine to medium sand 60%, silt and clay 40%, trace gravel; slightly moist; non-lithified. Reaction to acid: none.
110-111 (split-spoon)	**SILTY AND CLAYEY SAND**; medium orange; very fine to fine sand 60%, silt and clay 40%, trace gravel; slightly moist; non-lithified. Reaction to acid: none.
110-116	**SILTY AND CLAYEY SAND**; dark orange-brown; very fine to very coarse sand 70%, silt and clay 30%, trace gravel; slightly moist; non-lithified. Reaction to acid: none.
116-120	**SAND**; light orange-gray; very fine to medium sand 90%, silt and clay 5%, gravel 5%; slightly moist; non-lithified. Reaction to acid: none.
120-122	**SANDY GRAVEL**; medium orange-brown; gravel 50%, very fine to very coarse sand 45%, silt and clay 5%; slightly moist; non-lithified. Gravel fraction: granules and pebbles to 1/2-inch diameter; volcanic rocks 50%; quartz and feldspar 40%; igneous and metamorphic rocks 10%. Reaction to acid: none.
122-126	**SILTY AND CLAYEY SAND**; medium orange-brown; very fine to fine sand 75%, silt and clay 20%, gravel 5%; slightly moist; non-lithified. Reaction to acid: none.
126-130	**SILTY AND CLAYEY SAND**; dark orange-brown; very fine to fine sand 60%, silt and clay 40%, trace gravel; very slightly moist; non-lithified. Increasing clay content with depth. Reaction to acid: none.
130-132	**SANDY SILT AND CLAY**; dark orange-brown; silt and clay 60%, very fine to fine sand 40%, trace gravel; moist; non-lithified. Reaction to acid: none.
132-134	**SANDY SILT AND CLAY**; dark orange-brown; silt and clay 60%, very fine to fine sand 35%, gravel 5%; moist; non-lithified. Reaction to acid: none.

LOG A-2. LITHOLOGIC DESCRIPTIONS FOR DRILL CUTTINGS SAMPLES
BOREHOLE B, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
134-136	**SILTY AND CLAYEY GRAVELLY SAND**; dark orange-brown; very fine to very coarse sand 50%, silt and clay 25%, gravel 25%; slightly moist; non-lithified. Gravel fraction: subangular to subrounded granules and pebbles to 1/2-inch diameter; volcanic rocks 50%; igneous and metamorphic rocks 30%; quartz and feldspar 20%. Reaction to acid: none.
136-148	**SANDY GRAVEL**; light orange-brown; gravel 60%, very fine to very coarse sand 35%, silt and clay 5%; slightly moist; non-lithified. Gravel fraction: subangular to well-rounded granules and pebbles to 2-inch diameter; volcanic rocks 40%; quartz and feldspar 30%; igneous and metamorphic rocks 30%. Reaction to acid: none.
148-150	**SANDY GRAVEL**; light orange-brown; gravel 60%; very fine to very coarse sand 40%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to well-rounded granules and pebbles to 2-inch diameter; volcanic rocks 40%; quartz and feldspar 30%; igneous and metamorphic rocks 30%. Reaction to acid: none.

TOTAL DEPTH DRILLED: 150 FEET

[a] Sample obtained from brass-sleeve bearing split-spoon sampler driven using 140-pound hammer.

LOG A-3. LITHOLOGIC DESCRIPTIONS FOR DRILL CUTTINGS SAMPLES BOREHOLE C, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
	RECENT ALLUVIUM
15-20	**GRAVELLY SILTY AND CLAYEY SAND**; brown; very fine to very coarse sand 50%, silt and clay 30%, gravel 20%; slightly moist; non-lithified. Silt and clay occurs chiefly in thin layers. Reaction to acid: strong.
23-30	**SANDY GRAVEL**; brown; gravel 65%, very fine to very coarse sand 35%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to well-rounded granules, pebbles, and cobbles to 5-inch diameter; volcanic rocks 70%; quartz and feldspar 20%; igneous and metamorphic rocks 10%. Reaction to acid: strong.
35-40	**SANDY GRAVEL**; orange-brown; gravel 65%, very fine to very coarse sand 35%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to well-rounded granules, pebbles, and cobbles to 5-inch diameter; volcanic rocks 70%; quartz and feldspar 20%; igneous and metamorphic rocks 10%. Reaction to acid: none.
40-54	**SANDY GRAVEL**; dark red-brown; gravel 60%, very fine to very coarse sand 40%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules, pebbles, and cobbles to 5-inch diameter; volcanic rocks 50%; quartz and feldspar 30%; igneous and metamorphic rocks 20%. Reaction to acid: none.
	FORT LOWELL FORMATION
54-75	**SANDY GRAVEL**; dark orange-brown; gravel 60%, very fine to very coarse sand 40%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules, pebbles, and cobbles to 3-inch diameter; volcanic rocks 50%; igneous and metamorphic rocks 30%; quartz and feldspar 20%. Reaction to acid: none.
59-60 (split-spoon)[a]	**SANDY GRAVEL**; orange; gravel 55%, very fine to very coarse 40%, silt and clay 5%; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules, pebbles, and cobbles to 3-inch diameter; volcanic rocks 50%; igneous and metamorphic rocks 30%; quartz and feldspar. Reaction to acid: none.

LOG A-3. LITHOLOGIC DESCRIPTIONS FOR DRILL CUTTINGS SAMPLES
BOREHOLE C, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
75-79	**SILTY AND CLAYEY GRAVELLY SAND**; dark orange-brown; very fine to very coarse sand 50%, gravel 30%; silt and clay 20%; moist, non-lithified. Gravel fraction: subangular to subrounded granules and pebbles to 1-inch diameter. Reaction to acid: none.
79-80 (split-spoon)	**SILTY AND CLAYEY SANDY GRAVEL**; dark orange-brown; gravel 50%, very fine to very coarse sand 30%, silt and clay 20%; moist; non-lithified, but matrix is cohesive. Abundant weathering products. Reaction to acid: none.
79-97	**SILTY AND CLAYEY SANDY GRAVEL**; orange; gravel 50%, very fine to very coarse sand 40%, silt and clay 10%; slightly moist; non-lithified. Gravel fraction: cobbles and pebbles to 2-inch diameter; volcanic rocks 50%; quartz and feldspar 30%; igneous and metamorphic rocks 20%. Reaction to acid: none.
89-90 (split-spoon)	**SILTY AND CLAYEY SANDY GRAVEL**; orange; gravel 50%, very fine to very coarse sand 40%, silt and clay 10%; slightly moist; non-lithified. Gravel fraction: cobbles and pebbles to 2-inch diameter; volcanic rocks 50%; quartz and feldspar 30%; igneous and metamorphic rocks 20%. Reaction to acid: none.
97-99	**SANDY SILT AND CLAY**; dark orange-brown; silt and clay 60%, very fine to fine sand 40%; moist; non-lithified. Reaction to acid: none.
99-100 (split-spoon)	**GRAVELLY SILTY AND CLAYEY SAND**; dark orange-brown; very fine to very coarse sand 50%, silt and clay 30%, gravel 20%; slightly moist; non-lithified. Upper part of interval is andy silt and clay; lower part of interval is silty and clayey gravelly sand. Reaction to acid: none.
99-105	**SILTY AND CLAYEY SANDY GRAVEL**; orange; gravel 50%, very fine to very coarse sand 40%, silt and clay 10%; slightly moist; non-lithified. Gravel fraction: cobbles and pebbles to 2-inch diameter; volcanic rocks 50%; quartz and feldspar 30%; igneous and metamorphic rocks 20%. Reaction to acid: none.
105-115	**SANDY GRAVEL**; dark orange-brown; gravel 55%, very fine to very coarse sand 40%, silt and clay 5%; slightly moist; non-lithified. Gravel fraction: subangular to well-rounded granules, pebbles and cobbles to 3-inch diameter; volcanic rocks 60%; quartz and feldspar 30%; igneous and metamorphic rocks 10%. Reaction to acid: none.

LOG A-3. LITHOLOGIC DESCRIPTIONS FOR DRILL CUTTINGS SAMPLES
BOREHOLE C, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
115-120	**GRAVELLY SAND**; medium orange-brown; medium to very coarse sand 75%, gravel 20%, silt and clay 5%; slightly moist; non-lithified. Rare pebbles and cobbles. Reaction to acid; none.
120-134	**SANDY GRAVEL**; medium orange-brown; gravel 60%; very fine to very coarse sand 40%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1.5-inch diameter; volcanic rocks 60%; quartz and feldspar 30%; igneous and metamorphic rocks 10%. Reaction to acid: none.
134-149	**GRAVELLY SAND**; medium orange-brown; very fine to very coarse sand 90%, gravel 10%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: granules, pebbles, and cobbles to 3-inch diameter. Reaction to acid: none.
149-150 (split-spoon)	**SAND**; grey-brown; very fine to fine sand 100%, trace silt and clay; slightly moist; non-lithified. Reaction to acid: none.

TOTAL DEPTH DRILLED: 150 FEET

[a] Sample obtained from brass-sleeve bearing split-spoon sampler driven using 140-pound hammer.

LOG A-9. LITHOLOGIC DESCRIPTIONS FOR DRILL CUTTINGS SAMPLES BOREHOLE I, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
	RECENT ALLUVIUM
0-4	**SAND**; light brown; very fine to medium sand 95%, silt and clay 5%, trace gravel; slightly moist; non-lithified. Reaction to acid: moderate.
4-14	**SANDY SILT AND CLAY**; medium brown; silt and clay 60%, very fine to fine sand 40%; non-lithified. Reaction to acid: strong.
14-20	**SILTY AND CLAYEY GRAVELLY SAND**; dark red-brown; very fine to very coarse sand 60%, gravel 30%, silt and clay 10%; slightly moist; non-lithified. Gravel fraction: subangular to well-rounded granules and pebbles to 1 1/2-inch diameter. Reaction to acid: weak.
20-21 (split-spoon)[a]	**SANDY GRAVEL**; tan-brown; gravel 60%, very fine to very coarse sand 40%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: angular to rounded granules and pebbles to 1 1/2-inch diameter; volcanic rocks 60%; igneous and metamorphic rocks 20%; quartz and feldspar 10%. Reaction to acid: weak.
20-46	**SANDY GRAVEL**; medium red-brown; gravel 60%, very fine to very coarse sand 40%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: angular to rounded granules, pebbles, and cobbles to 3-inch diameter; volcanic rocks 60%; igneous and metamorphic rocks 15%; quartz and feldspar 15%. Reaction to acid: moderate.
	FORT LOWELL FORMATION
46-60	**SANDY GRAVEL**; medium orange-brown; gravel 55%, very fine to very coarse sand 40%, silt and clay 5%; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 2-inch diameter; volcanic rocks 50%; igneous and metamorphic rocks 30%; quartz and feldspar 20%; trace sedimentary rocks. Reaction to acid: none.
60-61 (split-spoon)	**SILTY AND CLAYEY SANDY GRAVEL**; orange-brown; gravel 55%, very fine to very coarse sand 35%, silt and clay 10%; slightly moist; non-lithified, but matrix is cohesive; abundant weathering products. Gravel fraction: subangular to rounded granules and pebbles to 1-inch diameter; volcanic rocks 50%; igneous and metamorphic rocks 30%; quartz and feldspar 20%; trace sedimentary rocks. Reaction to acid: none.

LOG A-9. LITHOLOGIC DESCRIPTIONS FOR DRILL CUTTINGS SAMPLES
BOREHOLE I, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
60-74	**SANDY GRAVEL**; dark red-brown; gravel 60%, very fine to very coarse sand 35%, silt and clay 5%; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules, pebbles, and cobbles to 3-inch diameter; volcanic rocks 50%; igneous and metamorphic rocks 30%; quartz and feldspar 20%. Reaction to acid: none.
74-88	**SILTY AND CLAYEY SANDY GRAVEL**; dark red-brown; gravel 55%, very fine to very coarse sand 35%, silt and clay 10%; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules, pebbles, and cobbles to 3-inch diameter; volcanic rocks 50%; igneous and metamorphic rocks 30%; quartz and feldspar 20%. Reaction to acid: none.
88-90	**SANDY SILT AND CLAY**; dark orange-brown; silt and clay 60%, very fine to fine sand 40%, trace gravel; slightly moist; non-lithified. Reaction to acid: none.
90-92	**SILTY AND CLAYEY SAND**; dark orange-brown; very fine to very coarse sand 55%, silt and clay 40%, gravel 5%; very slightly moist; non-lithified. Sand chiefly very fine- to medium-grained. Reaction to acid: none.
92-96	**SILTY AND CLAYEY GRAVELLY SAND**; dark orange-brown; very fine to very coarse sand 60%, gravel 30%, silt and clay 10%; very slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1/2-inch diameter; volcanic rocks 50%; igneous and metamorphic rocks 30%; quartz and feldspar 20%. Reaction to acid: none.
96-98	**SANDY GRAVEL**; orange-brown; gravel 60%, very fine to very coarse sand 40%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1 1/2-inch diameter; volcanic rocks 50%; igneous and metamorphic rocks 30%; quartz and feldspar 20%. Reaction to acid: none.
98-100	**GRAVELLY SAND**; orange-brown; very fine to very coarse sand 60%, gravel 40%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1 1/2-inch diameter; volcanic rocks 50%; igneous and metamorphic rocks 30%; quartz and feldspar 20%. Reaction to acid: none.

LOG A-9. LITHOLOGIC DESCRIPTIONS FOR DRILL CUTTINGS SAMPLES
BOREHOLE I, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
100-106	**SILTY AND CLAYEY SAND**; medium orange-brown; very fine to very coarse sand 75%; silt and clay 20%, gravel 5%; slightly moist; non-lithified. Sand is chiefly fine-grained. Reaction to acid: none.
106-108	**GRAVELLY SAND**; medium orange-brown; very fine to very coarse sand 55%, gravel 40%, silt and clay 5%; slightly moist; non-lithified. Gravel fraction: subangular to subrounded granules and pebbles to 1 1/2-inch diameter; igneous and metamorphic rocks 50%; volcanic rocks 30%; quartz and feldspar 20%. Reaction to acid: none.
108-112	**SILTY AND CLAYEY GRAVELLY SAND**; orange-brown; very fine to very coarse sand 60%, gravel 30%, silt and clay 10%; slightly moist; non-lithified. Gravel fraction: subangular to subrounded granules and pebbles to 1-inch diameter; volcanic rocks 50%; igneous and metamorphic rocks 30%; quartz and feldspar 20%. Reaction to acid: none.
112-116	**SANDY GRAVEL**; light orange-brown; gravel 70%, very fine to very coarse sand 30%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to subrounded granules and pebbles to 1-inch diameter; volcanic rocks 45%; igneous and metamorphic rocks 45%; quartz and feldspar 10%; Reaction to acid: none.
116-120	**SILTY AND CLAYEY SAND**; medium orange-brown; very fine to very coarse sand 55%; silt and clay 40%, gravel 5%; slightly moist; non-lithified. Reaction to acid: none.
120-121 (split-spoon)	**SILTY AND CLAYEY SAND**; medium orange-brown; very fine to very coarse sand 65%, silt and clay 35%, trace gravel; slightly moist; non-lithified. Reaction to acid: none.
120-124	**SILTY AND CLAYEY SAND**; medium orange-brown; very fine to very coarse sand 60%, silt and clay 40%, trace gravel; slightly moist; non-lithified. Sand is chiefly very fine- to fine-grained. Reaction to acid: none.
124-132	**SANDY SILT AND CLAY**; dark orange-brown; silt and clay 60%, very fine to very coarse sand 40%; moist; non-lithified. Sand is chiefly very fine- to fine-grained. Reaction to acid: none.

LOG A-9. LITHOLOGIC DESCRIPTIONS FOR DRILL CUTTINGS SAMPLES
BOREHOLE I, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
130-131 (split-spoon)	**SANDY SILT AND CLAY**; dark orange-brown; silt and clay 60%, very fine to very coarse sand 40%; moist; non-lithified. Sand is chiefly very fine- to fine-grained. Reaction to acid: none.
132-140	**SANDY SILT AND CLAY**; dark orange-brown; silt and clay 60%, very fine to very coarse sand 40%; slightly moist; non-lithified. Sand is chiefly very fine- to fine-grained. Reaction to acid: none.
140-146	**SILTY AND CLAYEY SAND**; light orange-brown; very fine to very coarse sand 85%, silt and clay 10%, gravel 5%; slightly moist; non-lithified. Silt and clay occurs in thin layer. Reaction to acid: none.
146-150	**SANDY SILT AND CLAY**; dark orange-brown; silt and clay 60%, very fine to very coarse sand 40%, trace gravel; slightly moist; non-lithified. Sand is chiefly very fine- to fine-grained. Reaction to acid: none.

TOTAL DEPTH DRILLED: 150 FEET

[a] Sample obtained from brass-sleeve bearing split-spoon sampler driven using 140-pound hammer.

LOG A-10. LITHOLOGIC DESCRIPTIONS FOR DRILL CUTTINGS SAMPLES BOREHOLE J, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
	RECENT ALLUVIUM
0-12	**SANDY SILT AND CLAY**; medium brown; silt and clay 55%, very fine to fine sand 45%, trace gravel; slightly moist; non-lithified. Reaction to acid: strong.
12-14	**SAND**; medium brown; very fine to medium sand 100%, trace silt and clay; slightly moist; non-lithified. Reaction to acid: weak.
14-16	**SAND**; medium brown; very fine to coarse sand 95%, silt and clay 5%; slightly moist; non-lithified. Sand is chiefly fine- to medium-grained; clayey sand layer at 16 feet. Reaction to acid: weak.
16-26	**SILTY AND CLAYEY SAND**; dark brown; very fine to fine sand 55%, silt and clay 45%, trace gravel; slightly moist; non-lithified. Thin sandy silt and clay layers occur: 65% silt and clay and 35% fine sand. Reaction to acid: strong.
26-30	**SILTY AND CLAYEY GRAVELLY SAND**; dark brown; very fine to very coarse sand 70%, gravel 20%, silt and clay 10%; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1/4-inch diameter; quartz and feldspar 70%; volcanic rocks 20%; igneous and metamorphic rocks 10%. Reaction to acid: moderate.
30-32	**SANDY GRAVEL**; medium tan-brown; gravel 55%, very fine to very coarse sand 45%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1-inch diameter; volcanic rocks 50%; quartz and feldspar 30%; igneous and metamorphic rocks 20%. Reaction to acid: weak.
32-34	**SILTY AND CLAYEY GRAVELLY SAND**; medium brown; very fine to very coarse sand 75%, gravel 15%, silt and clay 10%; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1-inch diameter. Reaction to acid: moderate.
34-38	**SANDY SILT AND CLAY**; dark red-brown; silt and clay 70%, very fine to very coarse sand 25%, gravel 5%; slightly moist; non-lithified. Alternating clayey sand and sandy clay layers. Reaction to acid: none.

LOG A-10. LITHOLOGIC DESCRIPTIONS FOR DRILL CUTTINGS SAMPLES
BOREHOLE J, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
38-42	**GRAVELLY SAND**; light tan-brown; very fine to very coarse sand 60%, gravel 40%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1 1/2-inch diameter; volcanic rocks 60%; quartz and feldspar 30%; igneous and metamorphic rocks 10%. Reaction to acid: none.
42-46	**GRAVELLY SAND**; medium red-brown; very fine to very coarse sand 50%, gravel 45%, silt and clay 5%; slightly moist; non-lithified. Gravel fraction: angular to subrounded granules and pebbles to 3/4-inch diameter; volcanic rocks 50%; igneous and metamorphic rocks 30%; quartz and feldspar 20%. Reaction to acid: none.
	FORT LOWELL FORMATION
46-60	**SILTY AND CLAYEY GRAVELLY SAND**; orange-brown; very fine to very coarse sand 50%, gravel 40%, silt and clay 10%; slightly moist; non-lithified, but matrix is somewhat cohesive. Gravel fraction: subangular to rounded granules and pebbles to 1-inch diameter; quartz and feldspar 50%; volcanic rocks 30%; igneous and metamorphic rocks 20%; trace sedimentary rocks. Reaction to acid: none.
60-62	**GRAVELLY SAND**; light orange-brown; very fine to very coarse sand 60%, gravel 40%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1 1/2-inch diameter; quartz and feldspar 50%; volcanic rocks 40%; igneous and metamorphic rocks 10%. Reaction to acid: none.
62-70	**SANDY GRAVEL**; orange-brown; gravel 50%, very fine to very coarse sand 45%, silt and clay 5%; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules, pebbles, and cobbles to 3-inch diameter; volcanic rocks 50%; quartz and feldspar 30%; igneous and metamorphic rocks 20%. Reaction to acid: none.
70-71 (split-spoon)[a]	**GRAVELLY SILTY AND CLAYEY SAND**; orange-brown; very fine to very coarse sand 50%, silt and clay 40%, gravel 10%; moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1/2-inch diameter. Reaction to acid: none.

LOG A-10. LITHOLOGIC DESCRIPTIONS FOR DRILL CUTTINGS SAMPLES
BOREHOLE J, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
70-74	**GRAVELLY SILTY AND CLAYEY SAND**; orange-brown; very fine to very coarse sand 50%; silt and clay 40%, gravel 10%; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1/2-inch diameter. Reaction to acid: none.
74-84	**SANDY GRAVEL**; orange-brown; gravel 65%, very fine to very coarse sand 35%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: granules and pebbles to 1-inch diameter; volcanic rocks 50%; igneous and metamorphic rocks 30%; quartz and feldspar 20%. Reaction to acid: none.
84-88	**SANDY GRAVEL**; light orange-brown; gravel 70%, very fine to very coarse sand 30%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: granules, pebbles, and cobbles to 3-inch diameter; volcanic rocks 50%; igneous and metamorphic rocks 30%; quartz and feldspar 20%. Reaction to acid: none.
88-90	**SANDY GRAVEL**; orange-brown; gravel 60%, very fine to very coarse sand 40%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1-inch diameter; volcanic rocks 50%; quartz and feldspar 30%; igneous and metamorphic rocks 20%. Reaction to acid: none.
90-104	**SILTY AND CLAYEY SANDY GRAVEL**; orange-brown; gravel 60%, very fine to very coarse sand 30%; silt and clay 10%; slightly moist; non-lithified. Gravel fraction: subangular to well-rounded granules, pebbles, and cobbles to 5-inch diameter; volcanic rocks 60%; igneous and metamorphic rocks 30%; quartz and feldspar 10%. Reaction to acid: none.
104-114	**SILTY AND CLAYEY SANDY GRAVEL**; orange-brown; gravel 50%, very fine to very coarse sand 35%, silt and clay 15%; slightly moist; non-lithified. Sand is chiefly coarse-grained. Gravel fraction: subangular to rounded granules and pebbles to 2-inch diameter; volcanic rocks 60%; igneous and metamorphic rocks 30%; quartz and feldspar 10%. Reaction to acid: none.
114-116	**SILTY AND CLAYEY SAND**; orange-brown; very fine to fine sand 80%, silt and clay 20%, trace gravel; very slightly moist; non-lithified. Reaction to acid: none.

LOG A-10. LITHOLOGIC DESCRIPTIONS FOR DRILL CUTTINGS SAMPLES
BOREHOLE J, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
116-122	**GRAVELLY SILTY AND CLAYEY SAND**; orange-brown; very fine to very coarse sand 60%, silt and clay 30%, gravel 10%; very slightly moist; non-lithified. Sand is chiefly very fine- to fine-grained. Reaction to acid: none.
122-124	**GRAVELLY SAND**; orange-brown; very fine to very coarse sand 75%, gravel 20%, silt and clay 5%; slightly moist; non-lithified. Gravel fraction: subangular to well-rounded granules and pebbles to 1/2-inch diameter; quartz and feldspar 70%; volcanic rocks 20%; igneous and metamorphic rocks 10%. Reaction to acid: none.
124-128	**GRAVELLY SILTY AND CLAYEY SAND**; orange-brown; very fine to very coarse sand 65%, silt and clay 20%, gravel 15%; slightly moist; non-lithified. Gravel fraction: subangular to well-rounded granules and pebbles to 1/4-inch diameter; quartz and feldspar 50%; igneous and metamorphic rocks 30%; quartz and feldspar 20%. Reaction to acid: none.
128-136	**SILTY AND CLAYEY SAND**; orange-brown; very fine to coarse sand 55%, silt and clay 45%, trace gravel; very slightly moist; non-lithified. Sand is chiefly very fine- to fine-grained. Reaction to acid: none.
136-142	**SILTY AND CLAYEY GRAVELLY SAND**; orange-brown; very fine to very coarse sand 50%, gravel 40%, silt and clay 10%; very slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1-inch diameter; igneous and metamorphic rocks 50%; quartz and feldspar 30%; volcanic rocks 20%. Reaction to acid: none.
142-150	**SANDY SILT AND CLAY**; dark orange-brown; silt and clay 60%. very fine to fine sand 40%; moist. Reaction to acid: none.
150-152	**SILTY AND CLAYEY SAND**; dark orange-brown; very fine to very coarse sand 60%, silt and clay 40%, trace gravel; very slightly moist. Reaction to acid: none.
152-159	**SANDY SILT AND CLAY**; dark orange-brown; silt and clay 70%, very fine to fine sand 30%; moist; non-lithified. Reaction to acid: none.

LOG A-10. LITHOLOGIC DESCRIPTIONS FOR DRILL CUTTINGS SAMPLES
BOREHOLE J, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
159-160	**GRAVELLY SILTY AND CLAYEY SAND**; dark orange-brown; very fine to very coarse sand 65%, silt and clay 25%, gravel 10%; very slightly moist; non-lithified. Reaction to acid: none.

TOTAL DEPTH DRILLED: 160 FEET

[a] Sample obtained from brass-sleeve bearing split-spoon sampler driven using 140-pound hammer.

LOG A-11. LITHOLOGIC DESCRIPTIONS FOR SPLIT-SPOON SAMPLES BOREHOLE K, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
	RECENT ALLUVIUM
3 (drill cuttings)[a]	**SAND**; medium brown; very fine to medium sand 90%, gravel 5%, silt and clay 5%; slightly moist; non-lithified. Reaction to acid: strong.
9.5 (drill cuttings)	**GRAVELLY SAND**; medium brown; very fine to very coarse sand 80%, gravel 15%, silt and clay 5%; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1/4-inch diameter; quartz and feldspar 50%; volcanic rocks 30%; igneous and metamorphic rocks 20%; trace sedimentary rocks. Reaction to acid: moderate.
14-15	**GRAVELLY, SILTY AND CLAYEY SAND**; medium red-brown; very fine to very coarse sand 45%, silt and clay 35%, gravel 20%; slightly moist; non-lithified, but matrix is cohesive. Gravel fraction: subangular to rounded granules and pebbles to 1-inch diameter; igneous and metamorphic rocks 50%; volcanic rocks 30%; quartz and feldspar 20%. Reaction to acid: strong.
20-21	**SANDY GRAVEL**; light red-brown; gravel 55%, very fine to very coarse sand 45%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 2-inch diameter; volcanic rocks 40%; igneous and metamorphic rocks 30%; quartz and feldspar 20%; sedimentary rocks 10%. Reaction to acid: strong.
25-26	**GRAVELLY SAND**; medium orange-brown; very fine to very coarse sand 50%, gravel 45%, silt and clay 5%; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1-inch diameter; quartz and feldspar 40%; volcanic rocks 30%; igneous and metamorphic rocks 25%; sedimentary rocks 5%. Reaction to acid: weak.
30-31	**GRAVELLY SAND**; medium orange-brown; very fine to very coarse sand 60%, gravel 40%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1-inch diameter; igneous and metamorphic rocks 40%; volcanic rocks 30%; quartz and feldspar 30%; trace sedimentary rocks. Reaction to acid: none.

LOG A-11. LITHOLOGIC DESCRIPTIONS SPLIT-SPOON SAMPLES
BOREHOLE K, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
35-36	**SANDY GRAVEL**; medium orange-brown; gravel 60%, very fine to very coarse sand 40%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles, and cobbles to 2 1/2-inch diameter; igneous and metamorphic rocks 40%; volcanic rocks 40%; quartz and feldspar 20%. Reaction to acid: none.
40-41	**SANDY GRAVEL**; medium orange-brown; gravel 55%, very fine to very coarse sand 45%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules, pebbles, and cobbles to 2 1/2-inch diameter; volcanic rocks 50%; quartz and feldspar 30%; igneous and metamorphic rocks 20%. Reaction to acid: none.
45-46	**SILTY AND CLAYEY GRAVELLY SAND**; medium orange-brown; very fine to very coarse sand 50%, gravel 40%, silt and clay 10%; slightly moist; non-lithified, but matrix is somewhat cohesive. Gravel fraction: subangular to rounded granules and pebbles to 1 1/2-inch diameter; volcanic rocks 40%; igneous and metamorphic rocks 40%; quartz and feldspar 20%; trace sedimentary rocks. Reaction to acid: none.
50-51	**SILTY AND CLAYEY SANDY GRAVEL**; medium orange-brown; gravel 50%, very fine to very coarse sand 40%, silt and clay 10%; slightly moist; non-lithified, but matrix is somewhat cohesive. Gravel fraction: subangular to rounded granules, pebbles, and cobbles to 2 1/2-inch diameter; volcanic rocks 40%; igneous and metamorphic rocks 40%; quartz and feldspar 20%; trace sedimentary rocks. Reaction to acid: none.
	<u>FORT LOWELL FORMATION</u>
55-56	**SANDY GRAVEL**; light orange-brown; very fine to very coarse sand 60%, gravel 35%, silt and clay 5%; slightly moist; non-lithified, but matrix is somewhat cohesive. Gravel fraction: subangular to rounded granules and pebbles to 1-inch diameter; quartz and feldspar 40%; volcanic rocks 30%; igneous and metamorphic rocks 30%. Reaction to acid: none.
60-61	**SANDY GRAVEL**; medium orange-brown; gravel 55%, very fine to very coarse sand 40%, silt and clay 5%; slightly moist; non-lithified, but matrix somewhat cohesive. Gravel fraction: subangular to rounded granules, pebbles, and cobbles to 3-inch diameter; quartz and feldspar 40%; volcanic rocks 30%; igneous and metamorphic rocks 30%. Very poor recovery. Reaction to acid: none.

LOG A-11. LITHOLOGIC DESCRIPTIONS SPLIT-SPOON SAMPLES
BOREHOLE K, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
65-66	No recovery.
70-71	No recovery.

TOTAL DEPTH DRILLED: 71 FEET

[a] Drill cuttings obtained from auger flights.

LOG A-12. LITHOLOGIC DESCRIPTIONS FOR SPLIT-SPOON SAMPLES BOREHOLE L, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
	RECENT ALLUVIUM
14.5-15.5	**SANDY GRAVEL**; red-brown; gravel 55%, very fine to very coarse sand 45%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 2-inch diameter; volcanic rocks 45%; igneous and metamorphic rocks 40%; quartz and feldspar 15%. Reaction to acid: none.
20-21	**SANDY GRAVEL**; light brown; gravel 55%, very fine to very coarse sand 45%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules, pebbles, and cobbles to 2 1/2-inch diameter; igneous and metamorphic rocks 45%; volcanic rocks 35%; quartz and feldspar 20%. Reaction to acid: none.
25-26	**GRAVELLY SAND**; red-brown; very fine to very coarse sand 55%, gravel 45%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1-inch diameter; volcanic rocks 60%; igneous and metamorphic rocks 20%; quartz and feldspar 20%. Reaction to acid: none.
30-31	**GRAVELLY SAND**; red-brown; very fine to very coarse sand 60%, gravel 40%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1/2-inch diameter; volcanic rocks 50%; igneous and metamorphic rocks 30%; quartz and feldspar 20%. Reaction to acid: none.
35-36	**GRAVELLY SAND**; red-brown; very fine to very coarse sand 60%, gravel 40%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1-inch diameter; volcanic rocks 60%; igneous and metamorphic rocks 20%; quartz and feldspar 20%. Reaction to acid: none.
40-41	**SILTY AND CLAYEY GRAVELLY SAND**; red-brown; very fine to very coarse sand 60%, gravel 30%, silt and clay 10%; very slightly moist; non-lithified, but matrix is somewhat cohesive. Gravel fraction: angular to subrounded granules, pebbles, and cobbles to 2 1/2-inch diameter; volcanic rocks 40%; quartzite 30%; quartz and feldspar 20%; igneous and metamorphic rocks 10%. Reaction to acid: none

LOG A-12. LITHOLOGIC DESCRIPTIONS FOR SPLIT-SPOON SAMPLES
BOREHOLE L, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
	FORT LOWELL FORMATION
45-46	**SILTY AND CLAYEY GRAVELLY SAND**; orange-brown; very fine to very coarse sand 60%, gravel 30%, silt and clay 10%; very slightly moist; non-lithified, but matrix is cohesive. Gravel fraction: angular to subrounded granules and pebbles to 1-inch diameter; volcanic rocks 50%; quartz and feldspar 20%; igneous and metamorphic rocks 20%; quartzite 10%. Reaction to acid: none.
50-51	**SILTY AND CLAYEY GRAVELLY SAND**; orange-brown; very fine to very coarse sand 60%, gravel 30%, silt and clay 10%; very slightly moist; non-lithified, but matrix is cohesive. Gravel fraction: angular to subrounded granules and pebbles to 1-inch diameter; volcanic rocks 50%; quartz and feldspar 20%; igneous and metamorphic rocks 20%; quartzite 10%. Reaction to acid: none.
55-56	**SILTY AND CLAYEY SANDY GRAVEL**; orange-brown; gravel 60%, very fine to very coarse sand 25%, silt and clay 15%; slightly moist; non-lithified, but matrix is cohesive. Gravel fraction: angular to subrounded granules, pebbles, and cobbles to 2 1/2-inch diameter; volcanic rocks 50%; igneous and metamorphic rocks 20%; quartz and feldspar 20%; quartzite 10%. Reaction to acid: none.
57-58	**SILTY AND CLAYEY SANDY GRAVEL**; orange-brown; gravel 65%, very fine to very coarse sand 25%, silt and clay 10%; slightly moist; non-lithified, but matrix is cohesive. Gravel fraction: angular to subrounded granules, pebbles, and cobbles to 2 1/2-inch diameter; volcanic rocks 50%; igneous and metamorphic rocks 20%; quartz and feldspar 20%; quartzite 10%. Reaction to acid: none.

TOTAL DEPTH DRILLED: 58 FEET

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LOG A-13. LITHOLOGIC DESCRIPTIONS FOR DRILL CUTTINGS SAMPLES BOREHOLE M, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
	RECENT ALLUVIUM
10-14	**SANDY GRAVEL**; light red-brown; gravel 65%, very fine to very coarse sand 35%, silt and clay 5%; slightly moist; non-lithified. Gravel fraction: subangular to subrounded granules and pebbles to 1-inch diameter; quartz and feldspar 70%; igneous and metamorphic rocks 20%; volcanic rocks 10%. Reaction to acid: none.
14-32	**SANDY GRAVEL**; light red-brown; gravel 75%, very fine to very coarse sand 25%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to subrounded granules, pebbles, and cobbles to 5-inch diameter; quartz and feldspar 60%; igneous and metamorphic rocks 25%; volcanic rocks 15%. Reaction to acid: none.
	FORT LOWELL FORMATION
32-34	**SILTY AND CLAYEY SANDY GRAVEL**; orange-brown; gravel 65%, medium to very coarse sand 25%, silt and clay 10%; slightly moist; non-lithified, but matrix is somewhat cohesive. Gravel fraction: granules and pebbles to 1 1/2-inch diameter; quartzite 50%; volcanic rocks 40%; quartz and feldspar 10%. Reaction to acid: none.
34-40	**SANDY GRAVEL**; orange-brown; gravel 65%, very fine to very coarse sand 35%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: granules and pebbles to 2-inch diameter; volcanic rocks 70%; quartzite 20%; quartz and feldspar 10%. Reaction to acid: none.
40-41 (split-spoon)[a]	**SILTY AND CLAYEY SANDY GRAVEL**; orange-brown; gravel 60%, very fine to very coarse sand 30%, silt and clay 10%; slightly moist; non-lithified, but matrix is cohesive. Gravel fraction: subangular to rounded granules and pebbles to 1-inch diameter; volcanic rocks 50%; igneous and metamorphic rocks 30%; quartz and feldspar 20%. Reaction to acid: none.
40-44	**SILTY AND CLAYEY SANDY GRAVEL**; orange-brown; gravel 60%, very fine to very coarse sand 30%, silt and clay 10%; slightly moist; non-lithified, but matrix is cohesive. Gravel fraction: subangular to rounded granules, pebbles, and cobbles to 3-inch diameter; volcanic rocks 50%; igneous and metamorphic rocks 30%; quartz and feldspar 20%. Reaction to acid: none.

LOG A-13. LITHOLOGIC DESCRIPTIONS FOR DRILL CUTTINGS SAMPLES
BOREHOLE M, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
44-48.5	**SANDY GRAVEL**; orange-brown; gravel 70%, very fine to very coarse sand 30%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules, pebbles, and cobbles to 3-inch diameter; volcanic rocks 50%; igneous and metamorphic rocks 30%; quartz and feldspar 10%; quartzite 10%. Reaction to acid: none.
48.5	**GRAVELLY SAND**; orange-brown; fine to coarse sand 85%, gravel 15%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to subrounded granules and pebbles to 1/2-inch diameter; volcanic rocks 60%; igneous and metamorphic rocks 25%; quartz and feldspar 15%. Reaction to acid: none.
48.5-52	**SANDY GRAVEL**; orange-brown; gravel 75%, very fine to very coarse sand 25%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules, pebbles, and cobbles to 3-inch diameter; volcanic rocks 70%; igneous and metamorphic rocks 20%; quartzite, quartz, and feldspar 10%. Reaction to acid: none.
50-51 (split-spoon)	**SILTY AND CLAYEY SANDY GRAVEL**; orange-brown; gravel 50%, fine to coarse sand 35%, silt and clay 15%; slightly moist; non-lithified,but matrix is cohesive. Gravel fraction: granules and pebbles to 2-inches diameter; volcanic rocks 75%; igneous and metamorphic rocks 15%; quartz and feldspar; trace sedimentary. Reaction to acid: none.
52-58	**SANDY GRAVEL**; orange brown; gravel 65%, fine to coarse sand 30%, silt and clay 5%; slightly moist; non-lithified, but matrix is cohesive. Gravel fraction: subangular to subrounded granules and pebbles to 1-inch; volcanic rocks 70%; quartzite 15%; igneous and metamorphic rocks 10%; quartz and feldspar 5%. Reaction to acid: none.
58-64	**GRAVELLY SANDY SILT AND CLAY**; orange-brown; silt and clay 50%, very fine to fine sand 40%, gravel 10%; slightly moist; non-lithified, but matrix is somewhat cohesive. Reaction to acid: none.
60-61 (split-spoon)	**GRAVELLY SANDY SILT AND CLAY**; orange-brown; silt and clay 50%, very fine to fine sand 40%, gravel 10%; slightly moist; non-lithified, but matrix is somewhat cohesive. Reaction to acid: none.

LOG A-13. LITHOLOGIC DESCRIPTIONS FOR DRILL CUTTINGS SAMPLES
BOREHOLE M, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
64-68	**SILTY AND CLAYEY SANDY GRAVEL**; orange brown; gravel 70%, fine to medium sand 25%, silt and clay 5%; slightly moist; non-lithified, but matrix is cohesive. Gravel fraction: subangular to rounded; granules and pebbles to 1 1/2-inch diameter; volcanic rocks 70%; igneous and metamorphic rocks 10%; quartz and feldspar 10%; sedimentary rocks 10%. Reaction to acid: none.
68-80	**SILTY AND CLAYEY SANDY GRAVEL**; orange-brown; gravel 65%, fine to medium sand 25%, silt and clay 10%; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules, pebbles, and cobbles to 3-inch diameter; volcanic rocks 80%; igneous and metamorphic rocks 10%; quartz and feldspar 10%. Reaction to acid: none.
80-90	**SILTY AND CLAYEY SANDY GRAVEL**; orange-brown; gravel 70%; fine to medium sand 25%, silt and clay 5%; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules, pebbles, and cobbles to 3-inch diameter; volcanic rocks 80%; igneous and metamorphic rocks 10%; quartzite, quartz, and feldspar 10%. Reaction to acid: none.
90-92	**SILTY AND CLAYEY SANDY GRAVEL**; orange brown; gravel 65%, fine to coarse sand 25%, silt and clay 10%; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1 1/2-inch diameter; volcanic rocks 80%; igneous and metamorphic rocks 10%; quartzite, quartz, and feldspar 10%. Reaction to acid: none.
92-94	**GRAVELLY, SANDY SILT AND CLAY**; orange-brown; silt and clay 50%, medium to coarse sand 30%, gravel 20%; moist; non-lithified. Gravel fraction: subangular to rounded granules, pebbles, and cobbles to 2 1/2-inch diameter. Reaction to acid: none.
94-98	**GRAVELLY SAND**; orange-brown; medium to coarse sand 90%,; gravel 10%, trace silt and clay; slightly moist; non-lithified, but contains some cohesion. Gravel fraction: subrounded to rounded granules to 1/8-inch diameter; quartz and feldspar 80%; volcanic rocks 20%. Reaction to acid: none.
98-100	**SILTY AND CLAYEY SAND**; orange-brown; fine to medium sand 60%, silt and clay 40%; trace gravel; slightly moist; non-lithified. Silty and clayey layers alternate with sandy layers. Reaction to acid: none.

LOG A-13. LITHOLOGIC DESCRIPTIONS FOR DRILL CUTTINGS SAMPLES
BOREHOLE M, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
100-104	**SILTY AND CLAYEY SAND**; orange-brown; very fine to fine sand 55%, silt and clay 45%; slightly moist; non-lithified. Reaction to acid: none.
104-110	**SANDY SILT AND CLAY**; orange-brown; silt and clay 60%, very fine to fine sand 40%; slightly moist; non-lithified. Reaction to acid: none.
110-111 (split-spoon)	**SANDY SILT AND CLAY**; orange-brown; silt and clay 70%, very fine to fine sand 30%; very slightly moist; moderately stiff; non-lithified.
110-114	**GRAVELLY SAND**; orange-brown; medium to coarse sand 70%, gravel 30%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1-inch diameter; quartz and feldspar 60%; volcanic rocks 20%; granitic and metamorphic rocks 20%. Reaction to acid: none.
114-116	**GRAVELLY SAND**; orange-brown; fine to medium sand 60%; gravel 40%; trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1-inch diameter; quartz and feldspar 60%; volcanic rocks 30%; granitic and metamorphic rocks 10%. Reaction to acid: none.
116-118	**SANDY GRAVEL**; orange-brown; gravel 65%, very fine to very coarse sand 35%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to subrounded granules and pebbles to 1-inch diameter; quartz and feldspar 60%; volcanic rocks 20%; granitic and metamorphic rocks 20%. Reaction to acid: none.
118-120	**SILTY AND CLAYEY SANDY GRAVEL**; orange-brown; gravel 65%, very fine to very coarse sand 30%, silt and clay 5%; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 2-inch diameter; granitic rocks and metamorphic rocks 60%; quartz and feldspar 40%. Reaction to acid: none.

LOG A-13. LITHOLOGIC DESCRIPTIONS FOR DRILL CUTTINGS SAMPLES
BOREHOLE M, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
120-121 (split-spoon)	**SILTY AND CLAYEY SANDY GRAVEL**; orange-brown; gravel 60%, very fine to very coarse sand 30%, silt and clay 10%; slightly moist; non-lithified, but matrix is cohesive. Gravel fraction: angular to subrounded granules, pebbles, and cobbles to 2 1/2-inch diameter; metamorphic rocks 60%; granitic rocks 30%; volcanic rocks 10%. Reaction to acid: none.
120-122	**SILTY AND CLAYEY SANDY GRAVEL**; orange-brown; gravel 65%, very fine to very coarse sand 25%, silt and clay 10%; slightly moist; non-lithified. Gravel fraction: subangular to subrounded granules, pebbles, and cobbles to 2 1/2-inch diameter; metamorphic rocks 50%; granitic rocks 20%; volcanic rocks 20%; quartz and feldspar 10%. Reaction to acid: none.
122-128	**GRAVELLY SAND**; orange-brown; fine to coarse sand 85%, gravel 15%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1/2-inch diameter; metamorphic rocks 40%; volcanic rocks 40%; quartz and feldspar 20%. Reaction to acid: none.
128-134	**SANDY SILT AND CLAY**; orange-brown; silt and clay 60%, very fine to fine sand 40%; slightly moist; non-lithified. Reaction to acid: none.
134-135	**GRAVELLY SAND**; orange-brown; medium to very coarse sand 60%, gravel 40%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 1/2-inch diameter; quartz and feldspar 40%; metamorphic rocks 30%; volcanic rocks 30%. Reaction to acid: none.
135-142	**SANDY GRAVEL**; orange-brown; gravel 60%, very fine to coarse sand 35%, silt and clay 5%; very slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 2-inch diameter; metamorphic rocks 60%; granitic rocks 30%; quartz and feldspar 10%. Reaction to acid: none.
140-141 (split-spoon)	**SANDY GRAVEL**; orange-brown; gravel 60%, very fine to coarse sand 35%, silt and clay 5%; very slightly moist; non-lithified. Gravel fraction: subangular to rounded granules and pebbles to 2-inch diameter; metamorphic rocks 60%; granitic rocks 30%; quartz and feldspar 10%. Reaction to acid: none.

LOG A-13. LITHOLOGIC DESCRIPTIONS FOR DRILL CUTTINGS SAMPLES
BOREHOLE M, LOWER SANTA CRUZ RIVER

DEPTH (feet)	DESCRIPTION
142-146	**SANDY GRAVEL**; orange-brown; gravel 60%, medium to very coarse sand 40%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to subrounded granules and pebbles to 1 1/2-inch diameter. Gravel fraction: metamorphic rocks 60%; volcanic rocks 30%; quartz and feldspar 10%. Reaction to acid: none.
146-150	**SANDY GRAVEL**; orange-brown; gravel 65%, fine to coarse sand 35%, trace silt and clay; slightly moist; non-lithified. Gravel fraction: subangular to rounded granules, pebbles, and cobbles to 3-inch diameter; metamorphic rocks 60%; volcanic rocks 30%; quartz and feldspar 10%. Reaction to acid: none.

TOTAL DEPTH DRILLED: 150 FEET

[a] Sample obtained from brass-sleeve bearing split-spoon sampler driven using 140-pound hammer.

Attachment 6

Tables and Figures of Design Contingencies

Table 4. Description of Modified Recharge Basins

Cell	Acreage	Basin Level (min/max)	Characteristics
Equalization Basin	0.62	2 ft./5 ft.	Settling and recharge basin; side slopes planted with riparian vegetation
1	0.63	3 in./12 in.	Perimeter and side slope vegetation; 2 recharge enhancement trenches in cell bottom with dimensions of 2 feet wide by 40 feet long by 12 feet deep.
2	1.21	3 in./5-7 ft.	Bare soil; 5-7 foot deep trench extending down the middle of the basin and sloping upward from the sides
3	0.78	3 in./12 in.	Perimeter and side slope vegetation; 2 recharge enhancement trenches in cell bottom with dimensions of 2 feet wide by 40 feet long by 12 feet deep.
4	1.26	3 in./12 in.	Perimeter vegetation; grass-lined bottom; 2 recharge enhancement trenches in cell bottom with dimensions of 2 feet wide by 40 feet long by 12 feet deep.

Table 4a. Description of Design Contingencies

Cell	Contingency #1	Contingency #2	Contingency #3	Contingency #4
Equalization Basin	Settling and recharge basin; side slopes planted with riparian vegetation	Settling and recharge basin; side slopes planted with riparian vegetation	Settling and recharge basin; side slopes planted with riparian vegetation	Settling and recharge basin; side slopes planted with riparian vegetation
1 thru 4*	Perimeter and side slope vegetation; 4, 36-inch diameter by 15-foot deep dry wells using perforated culvert pipe with pea gravel fill material	2 sets of recharge dry wells, each connected with a 100-150 foot of 36-inch slotted culvert pipe in the permeable strata and filled with pea gravel	Earthen ridges and furrows 1.5 feet wide and 6 feet deep aligned north to south to fit basin configuration	Earthen ridges and furrows over trenches that are 1.5 feet wide and 6 feet deep aligned to fit basin configuration and backfilled with permeable materials (sand , gravel and/or cobble)

*** Note: Different design contingencies may be used in each basin or a combination of contingencies may be used in each basin based on field investigations**

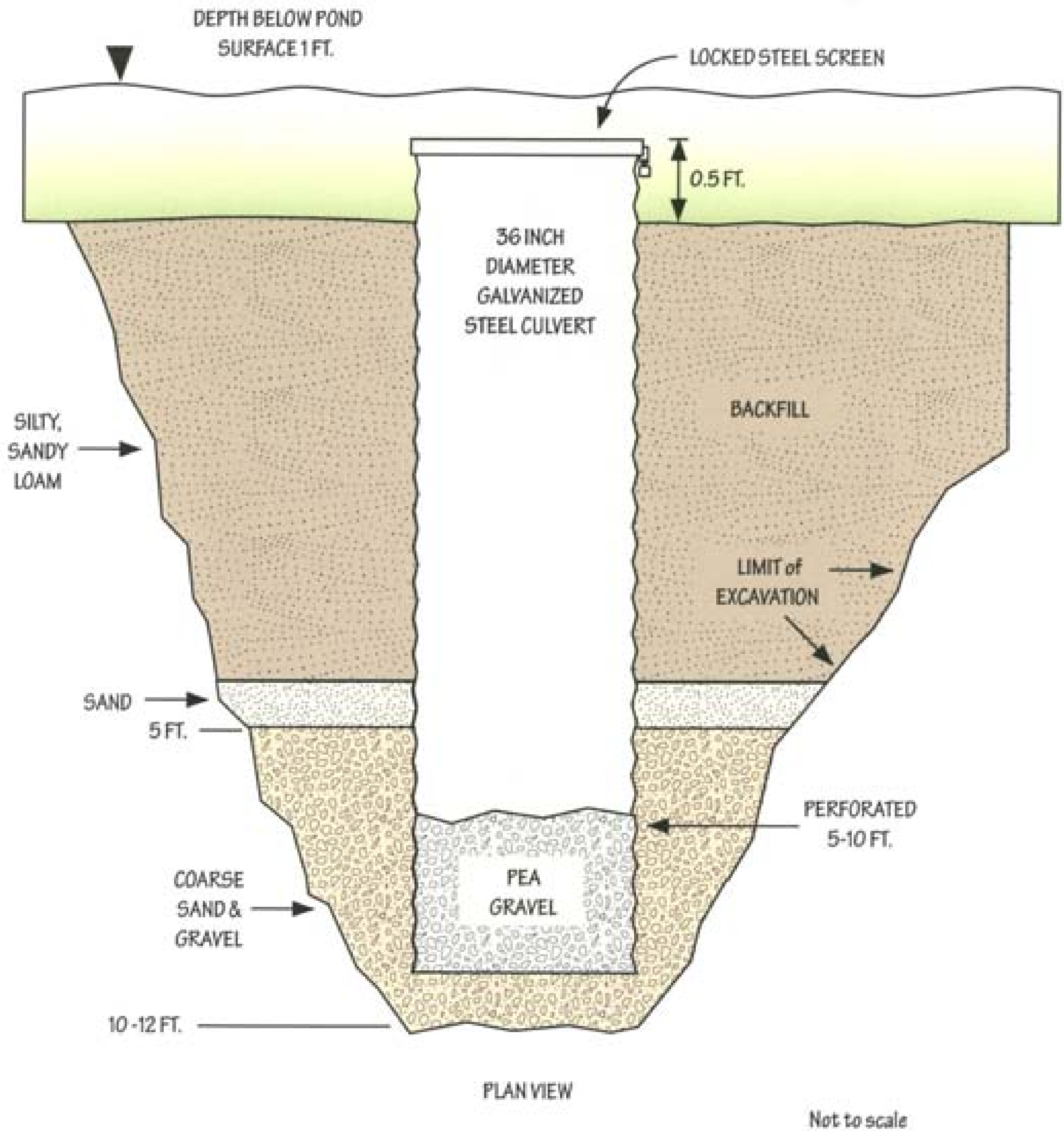
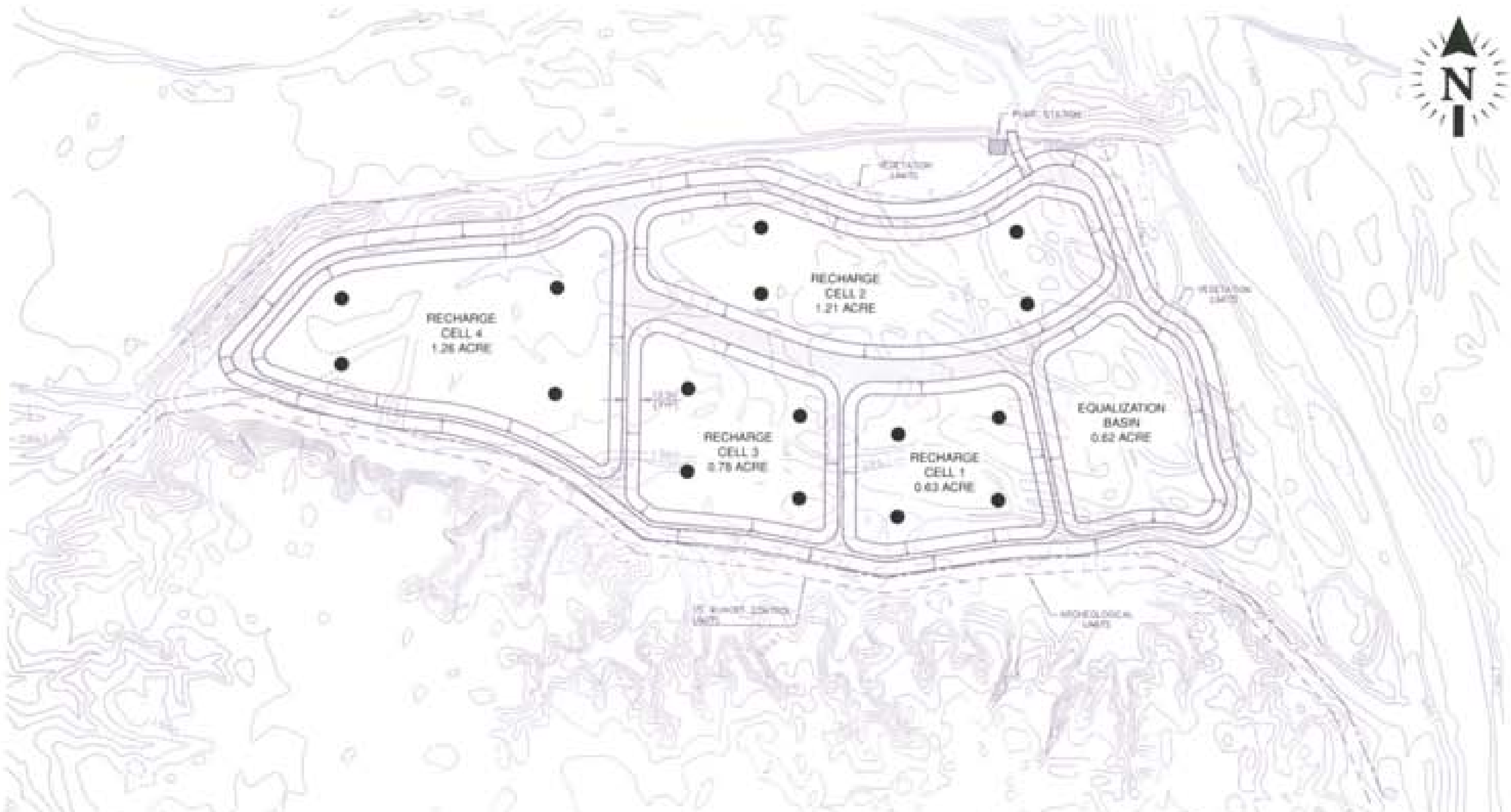


FIGURE 12. *Conceptual Drawing of Recharge Dry Well*

FIGURE 12a. CONTINGENCY # 1, RECHARGE DRY WELL



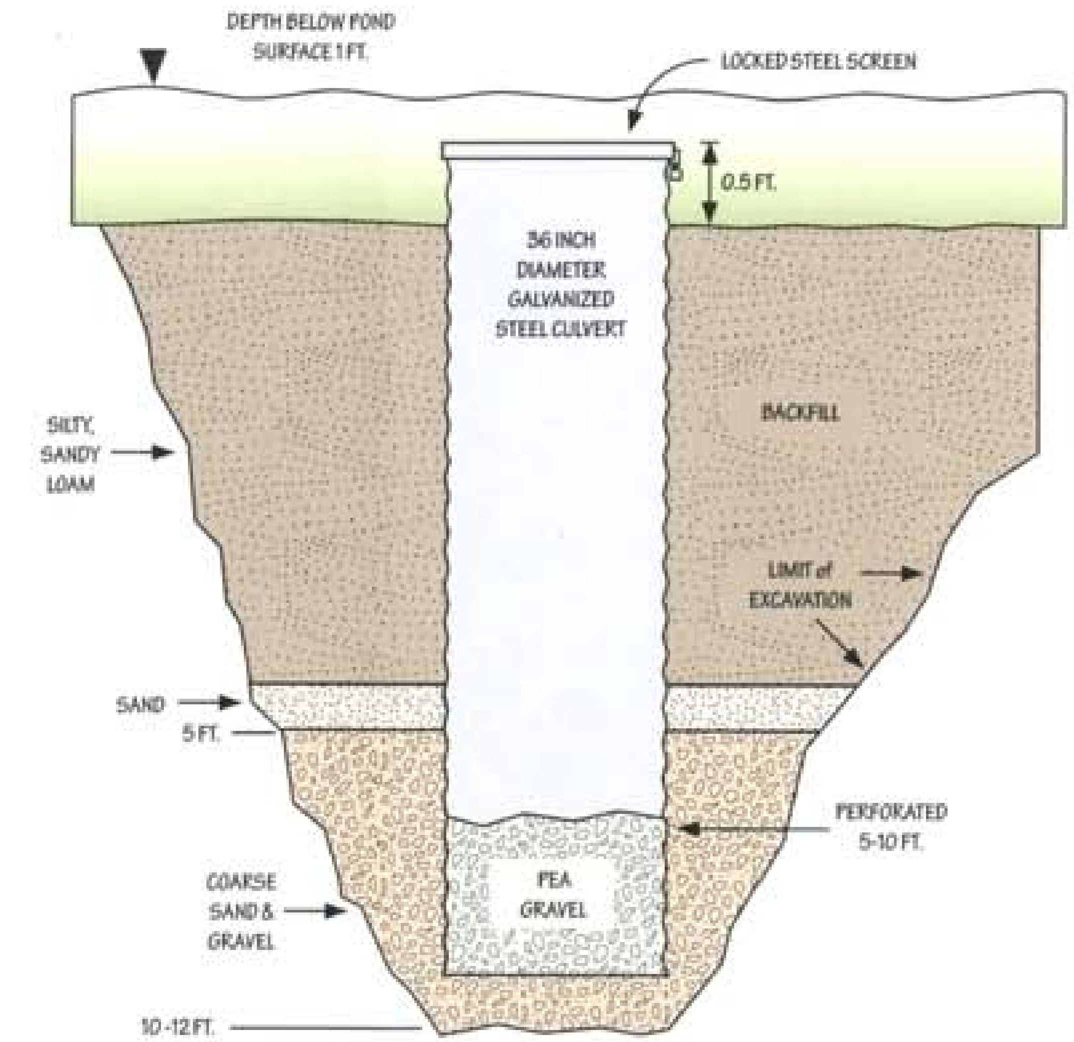
MAP VIEW

TOTAL RECHARGE AREA = 4.50 ACRES

SCALE IN FEET:

LEGEND

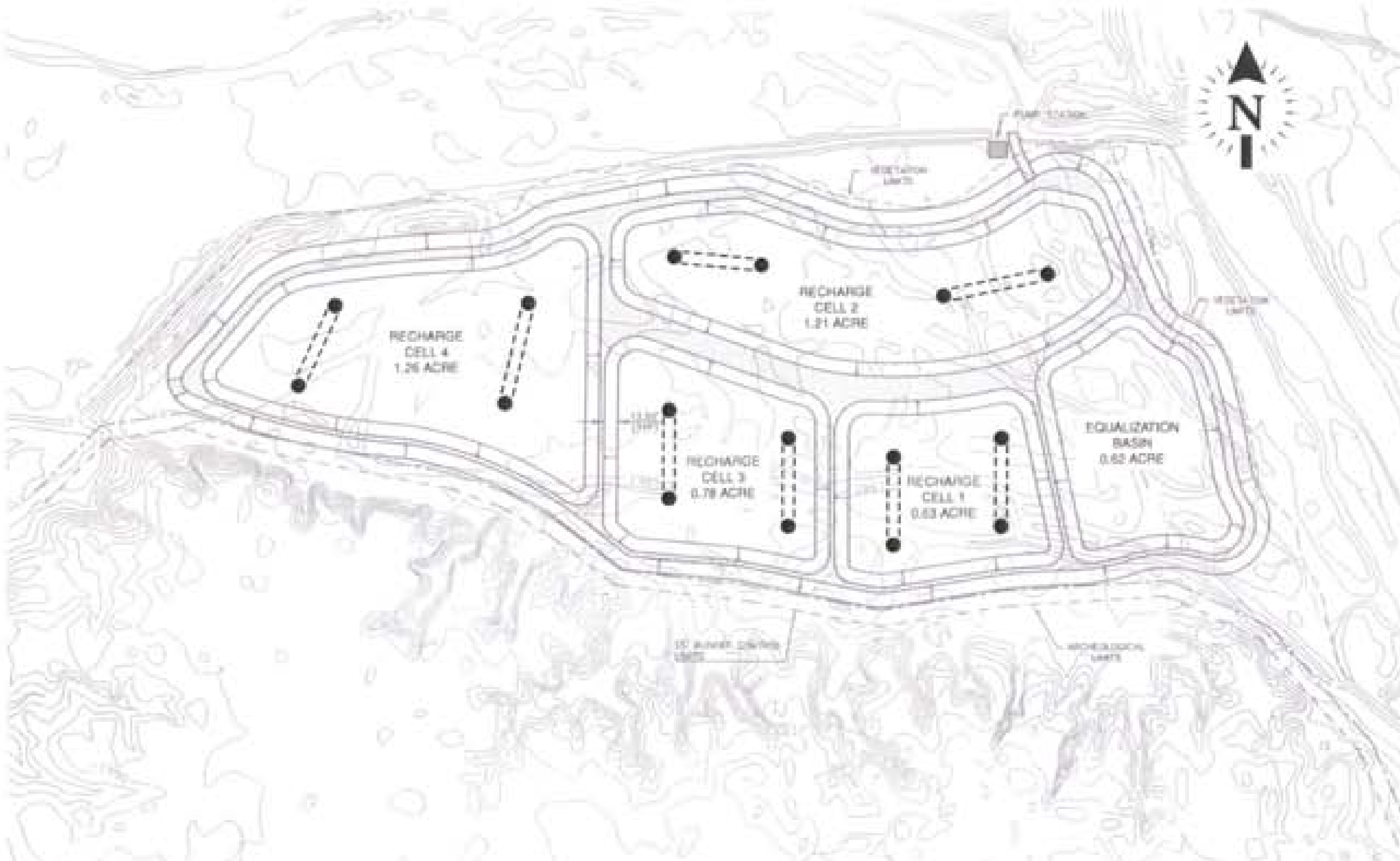
● 36 INCH PERFORATED CULVERT PIPE

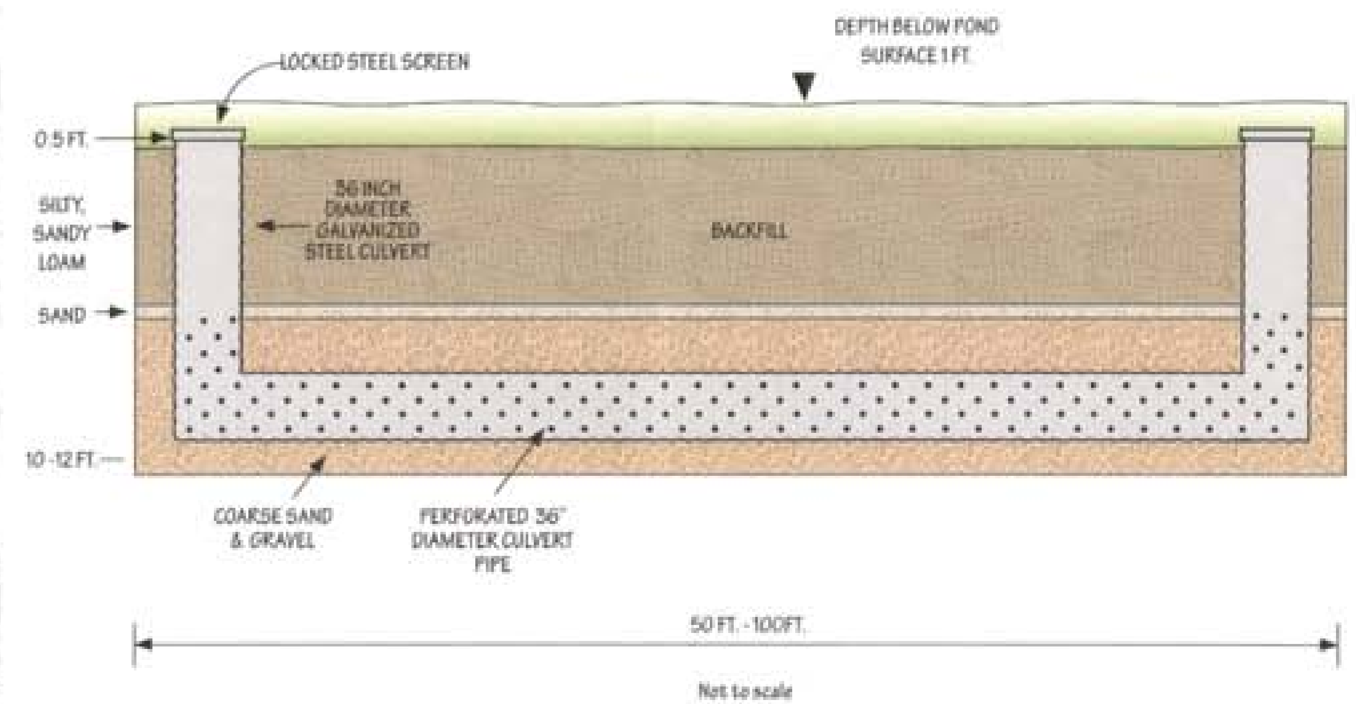


PLAN VIEW

Not to scale

FIGURE 12b. CONTINGENCY #2, HORIZONTAL RECHARGE DRY WELL





MAP VIEW

TOTAL RECHARGE AREA = 4.50 ACRES

SCALE IN FEET:

LEGEND

● 36 INCH PERFORATED CULVERT PIPE

PLAN VIEW

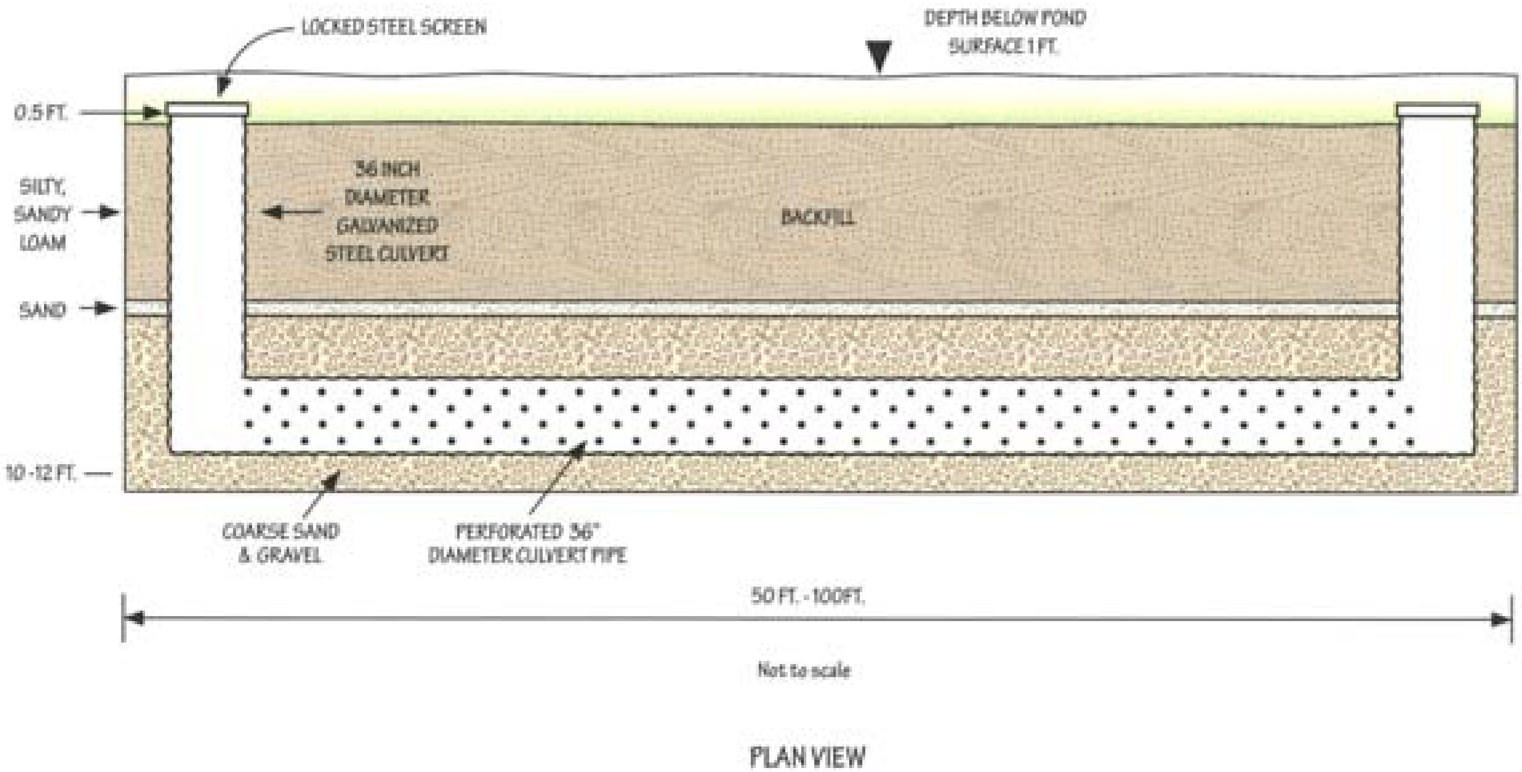
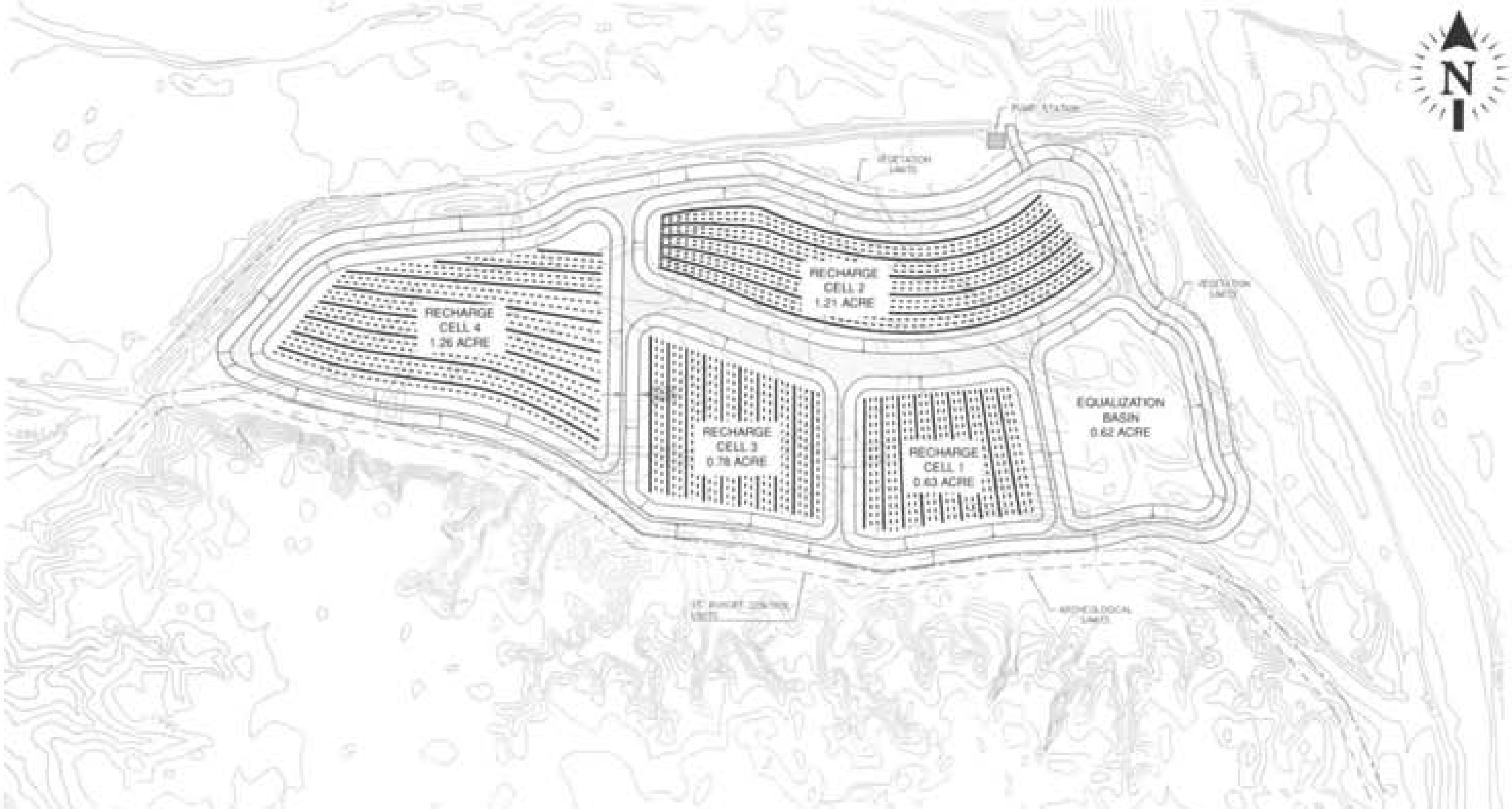


FIGURE 13. *Conceptual Drawing of Horizontal Recharge Dry Well*

fpwrp figure 13 HORIZ DRYWELL 1107.ai

FIGURE 13a. CONTINGENCY #3, RIDGES AND FURROWS



MAP VIEW

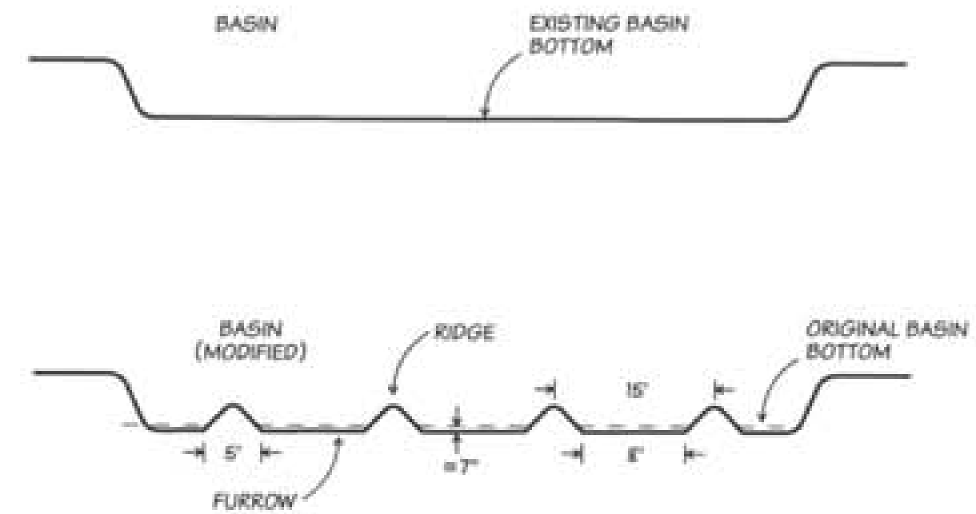
TOTAL RECHARGE AREA = 4.50 ACRES

SCALE IN FEET:

LEGEND

- TOP OF RIDGE
- TOP OF SLOPE

TYPICAL PLAN VIEW



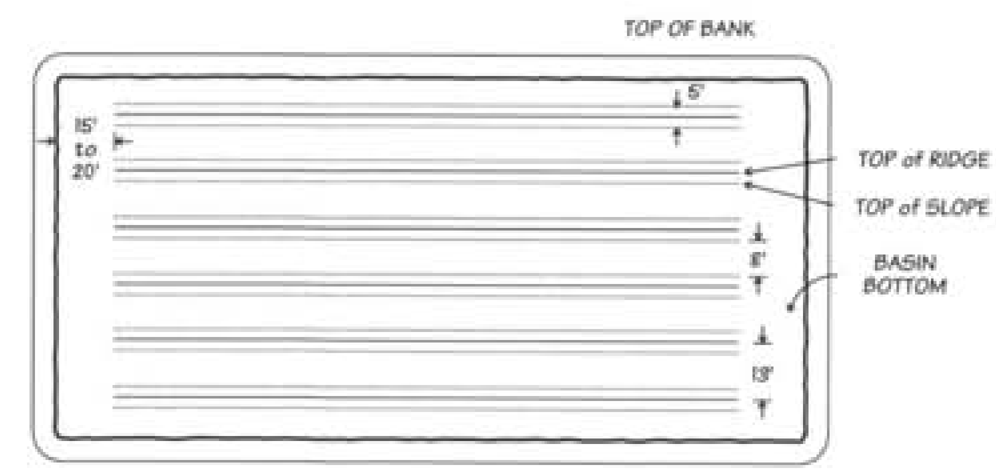
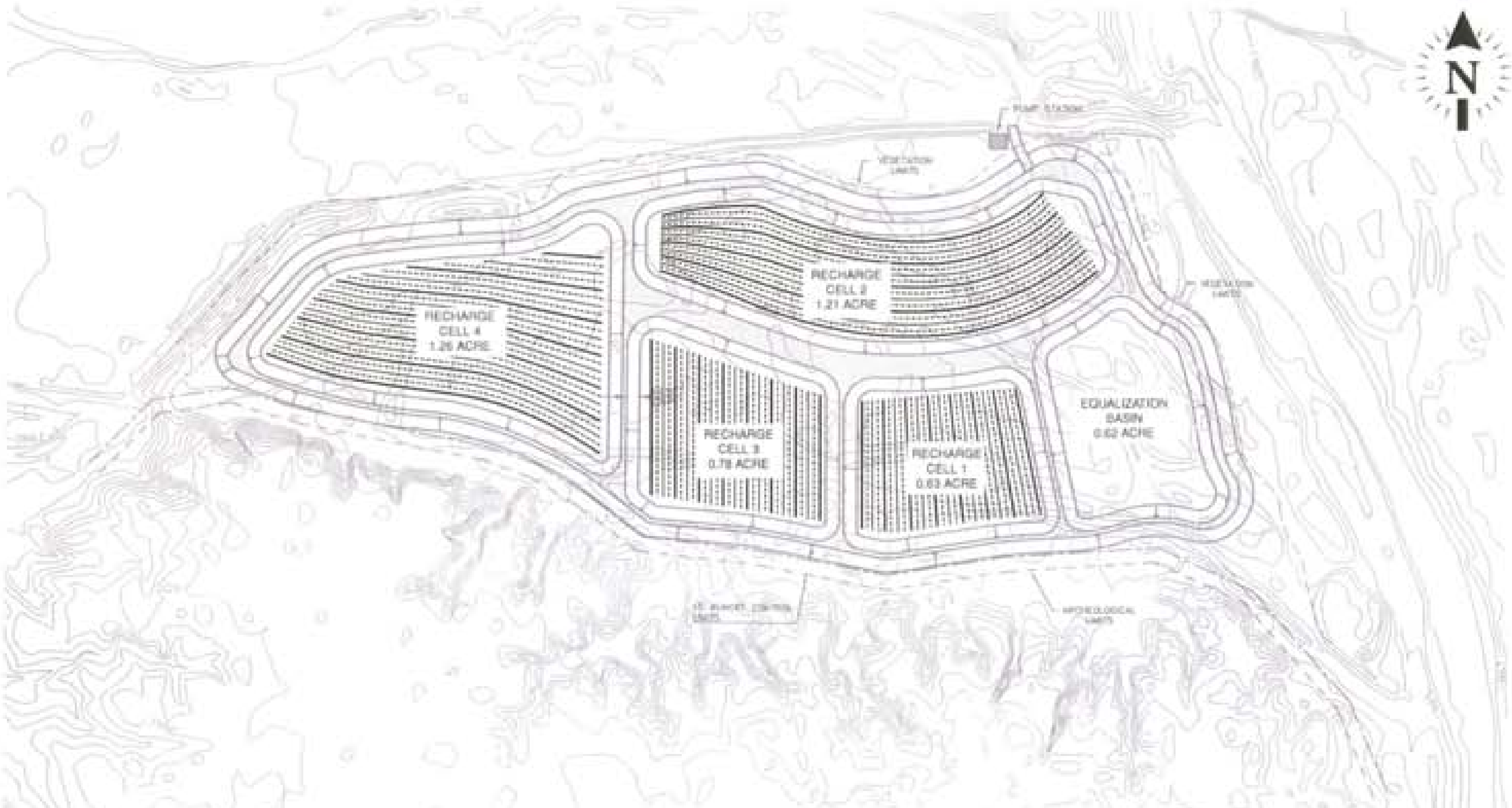


FIGURE 13b. CONTINGENCY #4, RIDGES AND FURROWS OVER TRENCHES FACILITY MAP



MAP VIEW

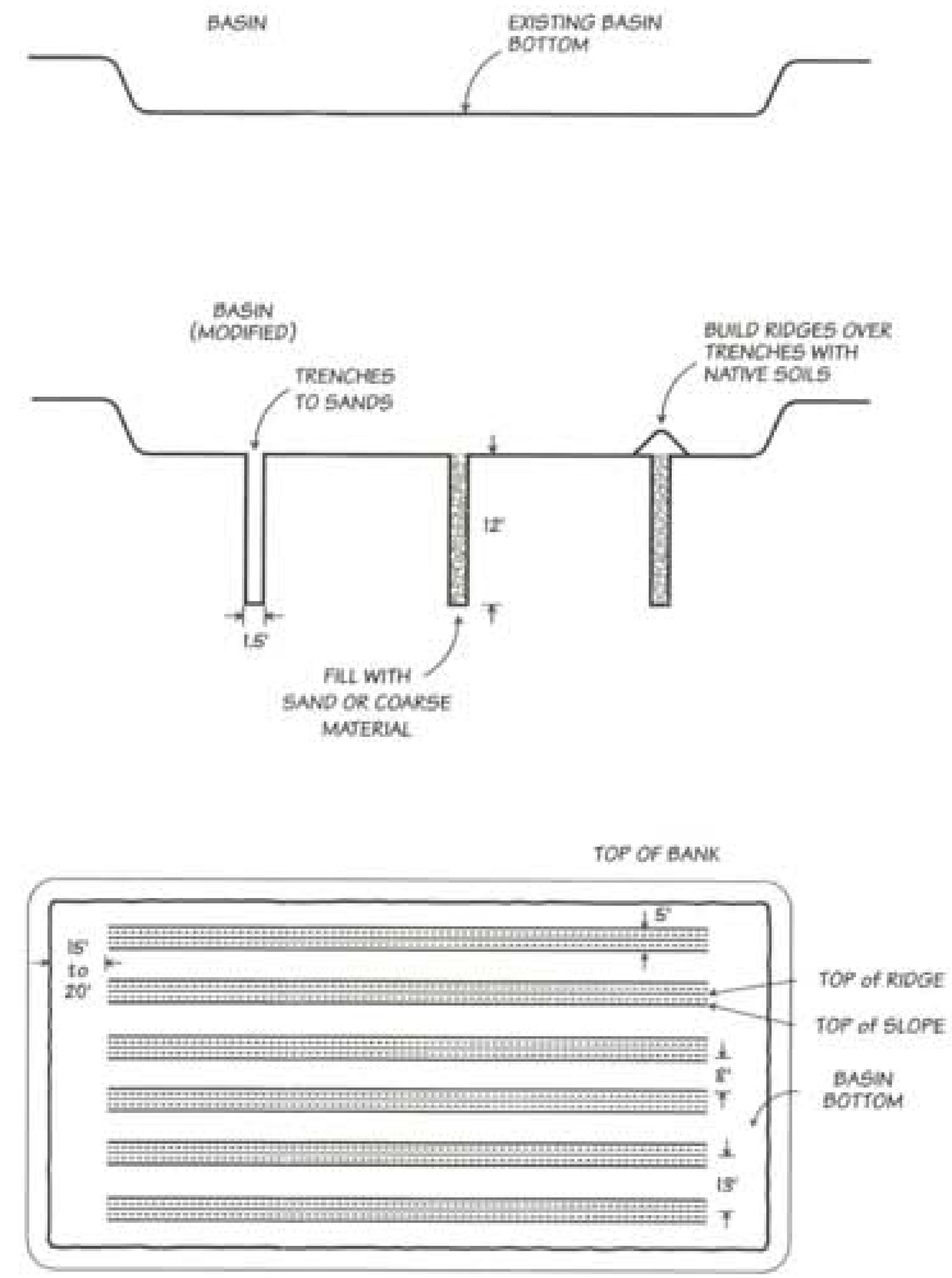
TOTAL RECHARGE AREA = 4.50 ACRES

SCALE IN FEET:

LEGEND

————————	TOP OF RIDGE
·················	TOP OF SLOPE
:::::::::::::::::	TRENCH WITH FILL MATERIAL

TYPICAL PLAN VIEW



Attachment 7

Updated Birdstike Analysis and Mitigation Plan and Letter from Marana Airport Administrator

Marana Regional Airport

May 28, 2008

Mr. John Bodenchuk
Recharge Program Manager
Arizona Department of Water Resources
3550 N. Central Avenue
Phoenix, Arizona 85012

Re: Concurrence Regarding Marana High Plains 20-year Permit Extension and Bird Strike Mitigation Plan. ADWR Underground Storage Facility Application No. 71-563876.0006

Dear Mr. Bodenchuk:

As Director of the Marana Regional Airport, I concur that the applicant, PCRFCD and Town of Marana, has provided an updated and adequate Bird Strike Mitigation Plan for the Marana High Plains Underground Storage Facility. The Town believes that the facility will not pose a threat to the Marana Regional Airport operations. If there are is any increased bird activity or other related airport issues that occur in the future the applicant has agreed that they will work with the Town of Marana and the airport to resolve these issues.

If you have any questions or comments please contact me at 520-682-9565 or at cmangum@marana.com.

Sincerely,

Charles E. Mangum, A.A.E.
Airport Director

CC: Frank Postillion, Chief Hydrologist, PCRFCD
David Scalero, Principal Hydrologist, PCRFCD
Brad DeSpain, Marana Utilities Director

MARANA HIGH PLAINS
EFFLUENT RECHARGE PROJECT

Updated
Bird-Strike Analysis
And
Mitigation Plan

Prepared by

Pima County Regional Flood Control District
Water Resources Division
97 E. Congress St., 3rd Floor
Tucson, AZ 85701

January 8, 2008

MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
BIRD-STRIKE MITIGATION PLAN UPDATE

INTRODUCTION

The Marana High Plains Effluent Recharge Project (MHEPRP) was developed in 2002 to demonstrate the feasibility of recharging effluent-dominated water from the Santa Cruz River, while simultaneously investigating wildlife habitat and recreation opportunities associated with recharge facilities. The project is located within Section 33 of Township 11 South, Range 33 East, approximately 3,500 feet north of the Marana Regional Airport (Figure 1). Because of its close proximity to the airport, the Federal Aviation Administration (FAA) expressed concern about the potential for aircraft to strike birds attracted to the site through comments on the Environmental Assessment prepared by the United States Department of the Interior. In response to these comments, the Pima County Regional Flood Control District (District) produced a report providing a bird-strike analysis and proposed mitigation plan for the project site (Entranco, 1997; see attached plan).

MHPERP has been operating as a pilot Underground Storage Facility (USF) project since February 2003 under a modified permit (ADWR-USF No. 71-563876.0005) to gather sufficient data for determining recharge feasibility at this site. The project is permitted to recharge up to 600 acre-feet per year within four recharge basins, totaling 3.88 acres of surface area (Figure 2).[1]

After experiencing low infiltration rates over the first four years of operation, District staff conducted a study to determine if more permeable soils could be encountered to make the project feasible over a long term. Soil trenches dug in December 2006 revealed more permeable materials (sands and gravels) at depths of 5 to 12 feet below the current basin bottoms. Using this information, staff concluded that a long term permit would be feasible if modifications were made to the basins to reach the permeable soils.

A new Underground Storage Facility Permit application was submitted in July 2007 for MHPERP. Through this application, the District is seeking to recharge an annual amount of 600 acre-feet of effluent water over the next twenty years. The basins will be modified in efforts to increase infiltration rates, reduce maintenance needs and continue the District's wildlife habitat enhancement efforts.

As part of the permit process, the District is seeking concurrence from the Federal Aviation Administration to continue project operations near the Marana Regional Airport. The following report provides an update on past efforts made by the District and a mitigation plan to limit future bird activity at the project site.

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[1] Total water surface area for the project is 4.5 acres when including the settling pond, which is currently not permitted for recharge credits. Total water surface area during a given period is usually less than 4.5 acres because the basins are operated on a wet/dry cycle.

CURRENT CONDITIONS AND MITIGATION EFFORTS

MHPERP currently consists of one settling basin (Equalization Basin) and four spreading basins (Recharge Cells). Effluent water from the Santa Cruz River is diverted into the oxbow channel, a remnant meander of the Santa Cruz River, where it travels approximately 1.5 miles before reaching the project site. A wet well collects the water and it is pumped into the Equalization Basin, which provides a more constant source for the recharge cells and helps settle fine sediment layers that could clog the basin bottoms. A gravity-fed pipeline is used to divert water to the recharge cells, which are opened and closed by motorized valves based on water levels within the basins. Level sensors are used to automatically control water levels in the recharge cells to maximize recharge. The valves can be manually closed for a drying cycle or to provide basin maintenance. Basin configurations and water level limits are provided in Table 1.

In accordance with the proposed bird-strike mitigation plan establish for the project in December 1997 (Entranco, 1997; see attached plan), District staff conducted weekly to bi-monthly bird surveys at the project site during routine inspections. Birds observed were classed into the FAA categories provided on the field forms provided by Entranco with the mitigation plan. A summary of the surveys is provided in Table 2.

Waterfowl was the most abundant bird type observed over the course of project operations so far. The largest numbers of waterfowl observed at the project consisted mostly of ducklings, which could not fly or were content to wander overland when disturbed. Large numbers of shorebirds were sited a few times when the basins water levels were low. However, the vast majority of this type tended to leave the site once the basins fully dried. Waders were rarely observed at the site, and the only large numbers seen would move off into the surrounding fields and nearby river when disturbed. Raptors and crows were also rare visitors to the site, mostly seen flying overhead and then leaving after a very short duration. No gulls have been observed at the project site.

Mitigation measures initiated to date consisted mostly of drying the ponds on the dates highlighted in Table2. Although some birds would move from pond to pond, the vast majority of birds would leave for surrounding areas. With its close proximity to the river and irrigated grazing fields to the west, it is believed that this project has not contributed any more birds associated with bird strikes to the area than would have existed without the project.

MODIFIED PROJECT CONDITIONS AND MITIGATION PLAN

In an effort to maximize efficiency of recharge operations, the District is proposing modifications to MHPERP. The modifications are designed to gain immediate access to coarser grained materials, which will increase infiltration rates and reduce the duration of ponded water within the basins. Proposed modifications and contingency plans for the project are provided in Table 3. Total annual recharge will remain at 600 acre-feet per year for all modifications and contingencies. The aerial extent of the ponds will not increase.

Less ponded water will most likely reduce the number of visits by birds associated with bird-strikes. However, the District will continue to monitor bird activity and initiate mitigation measures as appropriate. Mitigation measures to deter bird use within the basins will be triggered by defined thresholds of bird type and numbers as displayed in Table 4. Each weekly data compilation will determine the mitigation action. Thus, mitigation actions will be implemented on a weekly basis, depending on the data gathered and the threshold action criteria described below. Once implemented, a given mitigation action will be continued for a least two weeks to determine its effectiveness in reducing bird use. If proven ineffective after two weeks, the next mitigation action level will be implemented in addition to the currently used action. Should bird use reach higher action thresholds within the two week period, the next level of mitigation will be implemented as soon as it is triggered.

Action thresholds will vary seasonally in response to the more active runway at Marana Regional Airport and the seasonal nature of some bird occurrences. This plan takes into account the active runway at Marana Regional Airport, given local wind conditions. Birds that do no pose a threat are not harassed. If birds are routinely forced to move from MHPERP, despite the active runway, they may move to other locations that pose a greater hazard form the active runway (e.g. nearby agricultural fields). Where possible, operational features of the project may be adjusted to mitigate bird use (i.e. drying the ponds), depending on the experimental observations of recharge rates and basin conditions.

Mitigation Level 1

Mitigation level 1 includes passive actions to discourage bird use. Most of these methods mimic natural enemies of birds, evoke avoidance responses, or are frightening to birds. These include models of predators (hawks, owls, and mammals), wind-generated moving scare devices (foil, scarecrows, etc.), and mechanical movement devices. Birds habituate rapidly to these methods, therefore variation in their use and timing is important for maximum effect. These devices and methods do not require state or federal permits.

Mitigation Level 2

Mitigation level 2 includes passive and active means of interfering with bird use. Active measures include: physical barriers (e.g. wires strung across water or perches), removal of attractive features (e.g. perches, posts, etc.), and manipulating operation features of the project (basin wet/dry cycle) where feasible and consistent with project goals. Level 2 measures may cause bird injury or fatalities, therefore will require State and Federal permits for "take" of migratory birds. Migratory Bird Permits are issued on an annual basis from the United States Fish and Wildlife Service and Arizona Game and Fish Department by application. Federal and State Permits will be acquired by the District in advance for all potential actions under this plan.

Mitigation Level 3

Mitigation level 3 includes level 2 measures and active means of frightening birds from an area. These may include: pyrotechnic devices, noise making devices, high-pressure water sprays, and disrupting lights and sounds at night. Included in this level were operational aspects of the project outside of planned recharge mode, including adjusting wet/dry cycles and water depths, and drying out the basins. Level 3 measures may require State and Federal permits, as outline above. Some of these measures (e.g. pyrotechnic devices) may conflict with local ordinance.

ACTIVE RUNWAYS AT THE MARANA REGIONAL AIRPORT

The mitigation plan described above is based on the diurnal and seasonal use of runways at the airport, as provided in the 1997 Entranco report (see attached). A review of historic and current aerial photographs indicates no significant changes to the runways that would increase the bird-strike potential from MHPERP (Figure 3). District staff did review plans for an extension of Runway 3-21 (Figure 4), which appears to be affected by two other recharge projects in the area (Avra Valley Recharge Project and Lower Santa Cruz Recharge Project), but would not change flight patterns over MHPERP.

CONCLUSIONS

The District has operated MHPERP since February 2003. Based on bird observation records from the beginning of operations to the present, significant numbers of waterfowl have utilized the recharge basins on many occasions, while shorebirds and waders were infrequent users and only limited numbers of raptors and crows were seen. The wet/dry cycles for the basins were changed on many occasions to reduce the numbers of waterfowl at the site, which appeared to pose the greatest potential threat to air traffic. For the most part, changing the drying cycles of the basins was effective at reducing bird numbers.

Because of its close proximity to the Santa Cruz River (~ 350 feet) and other existing waters, it is unlikely that MHPERP significantly alters bird movements in the area. The oxbow channel and pasturelands surrounding MHPERP have been utilized for many decades prior to the existence of the recharge project. Since the project is, in effect, trading surface waters in the river channel for basin surface waters adjacent to the river channel, it is likely that the numbers and densities of waterfowl, waders and shorebirds at this site would have utilized the river and adjacent flooded pasturelands if the project were not present. Riparian vegetation contributed by the project is small in aerial extent and contiguous with the river channel, so no unique habitats have been created.

A mitigation plan was created by Entranco in 1997 (see attached) and has been used by District staff to monitor and reduce bird numbers at the site. Current mitigation thresholds and action levels are based on the information contained within the 1997 report and on observations made over the five-year operation of the recharge project.

A review of existing documents shows a planned extension for Runway 3-21 at the Marana Municipal Airport. Flights using this runway do not appear to be affected by MHPERP.

FIGURE 1
Location Map

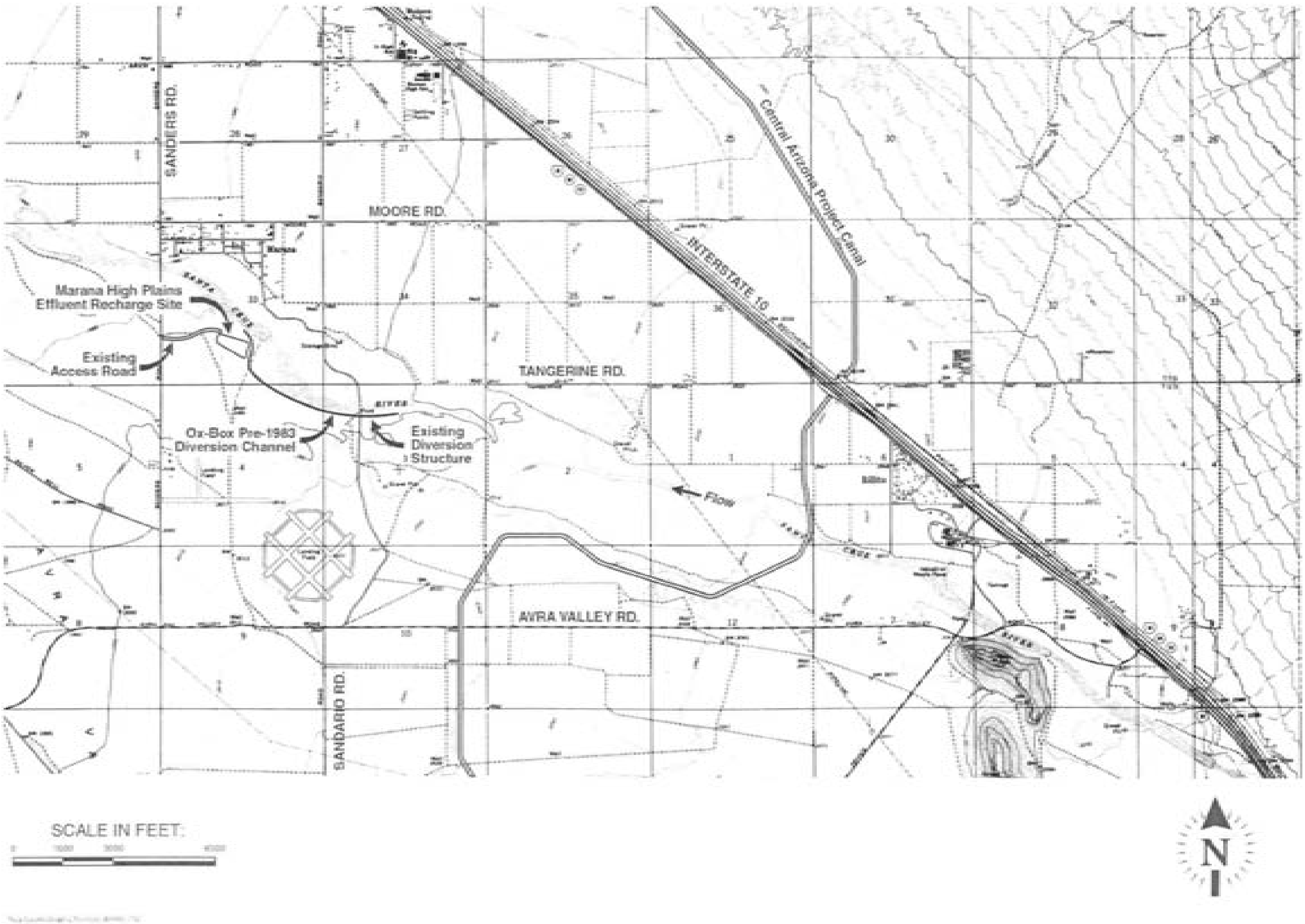

FIGURE 2
Facility Map

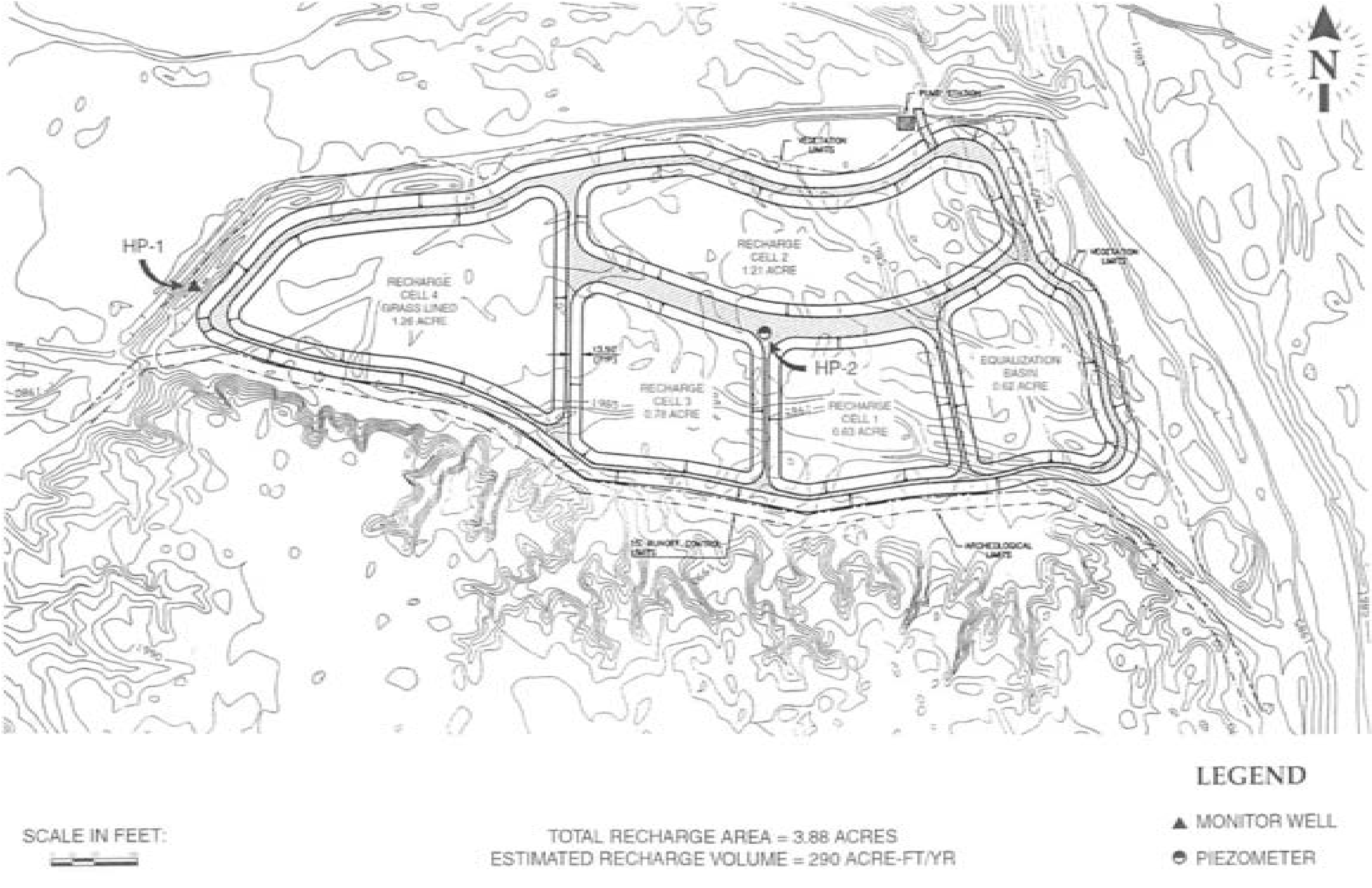

Figure 3. 2003 and 2007 Aerial Photos of Marana Regional Airport

2003 Aerial (Landiscore Aerial Imagery)

Source: http://www.dot.pima.gov/gis/maps/mapguide

2007 Aerial

Source: http://www.marana.com/index.asp?NID=329

Figure 4. Proposed Runway Extension at Marana Regional Airport (Runway 3-21)

Source: Draft Environmental Assessment, Runway 3-21 Shift, Kimley-Horn & Associates, Inc., March 2006

Table 1. Current recharge cell configuration for the Marana High Plains Effluent Recharge Project

Cell	Acreage	Basin Level (min/max)	Characteristics
Equalization Basin	0.62	2.0 ft/5.0 ft	Settling basin; no recharge
1	0.63	3.0 in/12.0 in	Bare soil
2	1.21	3.0 in/12.0 in	Bare soil
3	0.78	3.0 in/12.0 in	Perimeter & side slope vegetation
4	1.26	3.0 in/12.0 in	Fully vegetated

Table 2. Bird survey and mitigation action summary for the Marana High Plains Effluent Recharge Project

Date	Equalization Basin								Cell 1								Cell 2								Cell 3								Cell 4								Fly Over					
	WF	WA	SB	GU	RA	CR	PC	DIS	WF	WA	SB	GU	RA	CR	PC	DIS	WF	WA	SB	GU	RA	CR	PC	DIS	WF	WA	SB	GU	RA	CR	PC	DIS	WF	WA	SB	GU	RA	CR	PC	DIS	WF	W	SB	G	RA	CR
2/12/2003	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	3	0	0	0	D	N	0	0	0	0	0	0
2/20/2003	0	0	0	0	0	0	W	NA	2	0	0	0	0	0	W	Y	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	4	0	0	0	0	0
2/26/2003	0	0	0	0	0	0	W	NA	7	0	0	0	0	0	W	N	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	M	NA	0	0	0	0	0	0	W	NA	5	0	0	0	0	0
2/27/2003*	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	22	0	0	0	0	0	W	Y	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	M	NA	0	0	0	0	0	0
3/5/2003	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0
3/12/2003	0	0	0	0	0	0	W	NA	2	0	0	0	0	0	W	N	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	M	NA	0	0	0	0	0	0
3/19/2003	2	0	0	0	0	0	W	N	0	0	0	0	0	0	W	NA	4	0	0	0	0	0	W	Y	1	0	0	0	0	0	W	Y	0	0	0	0	0	0	D	NA	3	0	0	0	2	0
3/28/2003	0	0	1	0	0	0	W	N	2	0	1	0	0	0	W	Y	0	0	0	0	0	0	W/M	Y	0	0	4	0	0	0	W/M	Y	0	0	0	0	0	0	D	NA	1	0	0	0	3	0
4/2/2003*	0	0	0	0	0	0	W	NA	0	0	2	0	0	0	W	N	8	0	1	0	0	0	W	Y	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	D	NA	0	0	1	0	2	0
4/9/2003*	0	0	0	0	0	0	W	NA	11	0	7	0	0	0	W	Y	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	2	0	0	0	D	N	0	0	0	0	0	1
4/24/2003	0	0	0	0	0	0	W	NA	0	0	2	0	0	0	M	N	0	0	5	0	0	0	W	N	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0
5/2/2003	0	0	0	0	0	0	W	NA	2	15	7	0	0	0	W	Y	0	0	1	0	0	0	W	Y	0	0	3	0	0	0	W	Y	0	0	0	0	0	0	D	NA	2	0	0	0	0	0
5/14/2003*	2	0	0	0	0	0	W	N	1	0	0	0	0	0	W	N	1	0	4	0	0	0	W	N	0	0	2	0	0	0	W	N	3	22	2	0	0	0	M/W	N	0	0	2	0	0	1
5/20/2003*	0	0	1	0	0	0	W	Y	0	0	3	0	0	0	D/M	Y	18	0	2	0	0	0	W	Y	2	0	0	0	0	0	W	Y	0	0	0	0	0	0	D	NA	0	0	0	0	0	0
5/23/2003	0	0	0	0	0	0	W	NA	0	0	4	0	0	0	W	N	0	0	6	0	0	0	D	Y	18	0	2	0	0	0	W	Y	0	0	0	0	0	0	W	NA	3	0	0	0	0	0
5/27/2003	23	0	0	0	0	0	W	N	0	0	5	0	0	0	W/M	N	0	0	1	0	0	0	D	N	0	0	3	0	0	0	D	N	0	0	0	0	0	0	W	NA	0	0	0	0	0	0
6/2/2003*	0	0	0	0	0	0	W	N	0	0	0	0	0	0	D	NA	20	0	4	0	0	0	W	N	9	0	3	0	0	0	W	N	0	0	0	0	0	0	D	NA	2	0	0	0	0	0
6/10/2003	0	0	0	0	0	0	W	NA	23	0	2	0	0	0	W	Y	0	0	0	0	0	0	D	NA	0	0	8	0	0	0	D	N	0	0	0	0	0	0	W	NA	0	0	0	0	0	0
6/18/2003	0	0	0	0	0	0	W	NA	16	0	1	0	0	0	W	N	1	0	5	0	0	0	W	N	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0
6/24/2003	0	1	0	0	0	0	W	N	0	0	6	0	0	0	W/M	N	0	0	1	0	0	0	D	N	42	0	13	0	0	0	W/M	N	0	0	0	0	0	0	D	NA	0	0	0	0	1	0
7/2/2003	0	0	1	0	0	0	W	N	7	0	3	0	0	0	W/M	N	0	0	22	0	0	0	D	N	25	0	5	0	0	0	W	N	0	0	0	0	0	0	D	NA	0	0	0	0	0	0
7/14/2003	0	0	0	0	0	0	W	NA	0	0	10	0	0	0	W/M	N	0	0	0	0	0	0	D	NA	0	0	2	0	0	0	W	N	0	0	0	0	0	0	D	NA	0	0	0	0	0	0
7/25/2003	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0
8/21/2003	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0
8/28/2003	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	1	0
9/9/2003	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	1	0
9/25/2003	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	2	0	3	0
10/22/2003	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	2	0	0	0	W/M	N	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	19	0	0	0
10/28/2003	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W/D	NA	0	0	0	0	0	0
11/4/2003	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	M	NA	0	0	0	0	0	0	D	NA	0	0	2	0	1	0
12/5/2003	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	6	2
2/11/2004	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0
2/19/2004	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	1	0
2/24/2004	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	2	0	0	0
3/22/2004	2	0	1	0	0	0	W	Y	2	0	0	0	0	0	W	Y	0	0	1	0	0	0	W	N	0	0	1	0	0	0	D	Y	0	0	0	0	0	0	D	NA	0	0	0	0	0	0
3/30/2004	2	0	0	0	0	0	W	Y	2	0	0	0	0	0	W	Y	2	0	0	0	0	0	W	Y	0	0	1	0	0	0	D	N	0	0	0	0	0	0	D	NA	0	0	0	0	0	1
4/7/2004	8	0	4	0	0	0	W/M	Y	0	0	0	0	0	0	M	NA	0	0	0	0	0	0	M	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	M	NA	0	0	0	0	0	0
4/16/2004*	0	0	2	0	0	0	W	N	0	0	6	0	0	0	W	N	1	0	7	0	0	0	W	N	0	0	0	0	0	0	D	NA	2	0	0	0	0	0	W	N	3	0	1	0	0	0
4/30/2004	0	0	4	0	0	0	W	N	0	0	0	0	0	0	M	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	2	0	0	0	M	NA	5	0	0	0	0	0
5/12/2004	0	0	0	0	0	0	W	NA	3	0	1	0	0	0	W	Y	4	8	5	0	0	0	W	Y	0	0	0	0	0	0	D	NA	5	0	0	0	0	0	W	Y	0	0	0	0	0	0
5/19/2004*	0	0	0	0	0	0	W	NA	10	0	8	0	0	0	W	N	33	0	6	0	0	0	W	N	0	0	0	0	0	0	D	NA	3	0	0	0	0	0	W	N	0	0	0	0	0	0
6/3/2004	0	0	0	0	0	0	W	NA	0	0	4	0	0	0	D/M	N	7	0	0	0	0	0	W	N	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	2	0	0	0
6/11/2004	6	0	0	0	0	0	W	N	0	0	0	0	0	0	W	NA	0	0	17	0	0	0	D/W	N	0	0	0	0	0	0	D	NA	0	0	3	0	0	0	W	N	4	0	0	0	0	0
6/18/2004	26	0	0	0	0	0	W	N	0	7	4	0	0	0	W	N	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	1	0
6/28/2004	17	0	1	0	0	0	W	N	0	0	1	0	0	0	W	N	0	0	3	0	0	0	D/M	N	0	0	0	0	0	0	D	NA	8	0	0	0	0	0	W	N	0	0	0	0	0	0
7/29/2004	0	1	8	0	0	0	M	N	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	1	0
9/27/2004	0	0	1	0	0	0	M	N	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0
10/22/2004	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	6	0	0	0	1	0
11/19/2004	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	3	3
11/24/2004	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	M	NA	0	0	12	0	0	0	M	Y	0	0	0	0	0	0	M	NA	0	0	0	0	0	0	M	NA	0	0	0	0	1	0
4/27/2005	5	0	0	0	0	0	W	NA	1	0	2	0	0	0	W	N	0	0	5	0	0	0	W	N	3	0	1	0	0	0	W	N	0	0	0	0	0	0	D	NA	0	0	0	0	0	0
5/2/2005	12	0	0	0	0	0	W	N	8	0	3	0	0	0	W	N	11	0	8	0	0	0	W	N	5	0	2	0	0	0	W	N	0	0	0	0	0	0	D	NA	0	0	0	0	2	0
5/12/2005	0	0	0	0	0	0	W	NA	8	0	4	0	0	0	W	N	6	1	1	0	0	0	W	N	25	0	6	0	0	0	W	N	0	0	0	0	0	0	D	NA	6	0	0	0	1	0
5/17/2005	0	0	0	0	0	0	W	Y	6	0	2	0	0	0	W	Y	19	0	2	0	0	0	W	Y	0	0	6	0	0	0	W	Y	0	0	0	0	0	0	D	NA	0	0	0	0	3	0
5/26/2005*	1	0	0	0	0	0	W	N	1	0	2	0	0	0	W	N	47	0	7	0	0	0	W	N	0	0	1	0	0	0	W	N	0	0	0	0	0	0	D	NA	0	0	0	0	0	0
6/6/2005	15	0	0	0	0	0	W	N	4	0	2	0	0	0	W	N	0	0	1	0	0	0	D	N	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0
6/21/2005	10	0	0	0	0	0	W	N	0	0	2	0	0	0	D	N	11	0	2	0	0	0	W	N	8	0	3	0	0	0	W	N	0	0	0	0	0	0	D	NA	0	0	0	0	3	0
7/1/2005	9	0	0	0	0	0	W	N	0	0	6	0	0	0	D/M	N	0	0	0	0	0	0	W	NA	5	0	0	0	0	0	W	Y	0	0	0	0	0	0	M	NA	0	0	0	0	0	0
7/14/2005	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0
7/22/2005	22	0	25	0	0	0	W/M	Y	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0
7/27/2005	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0

WF – Waterfowl WA – Waders SB – Shorebirds GU – Gulls RA – Raptors CR – Crows PC – Pond Conditions (W – Wet; D – Dry; M – Muddy) DIS – Disturbance (Y – Yes; N – No; NA – Not Applicable) * Mitigation measure initiated

Table 2. Bird survey and mitigation action summary for the Marana High Plains Effluent Recharge Project

Date	Equalization Basin								Cell 1								Cell 2								Cell 3								Cell 4								Fly Over					
	WF	WA	SB	GU	RA	CR	PC	DIS	WF	WA	SB	GU	RA	CR	PC	DIS	WF	WA	SB	GU	RA	CR	PC	DIS	WF	WA	SB	GU	RA	CR	PC	DIS	WF	WA	SB	GU	RA	CR	PC	DIS	WF	W	SB	G	RA	CR
8/19/2005	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0
12/14/2005	1	0	0	0	0	0	W	N	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	W	NA	0	0	0	0	2	0
12/19/2005	2	0	0	0	0	0	W	N	3	0	6	0	0	0	W	N	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0
1/4/2006	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	W	NA	0	0	0	0	1	0	W	Y	0	0	0	0	0	0
1/13/2006	0	0	0	0	0	0	W	NA	6	0	2	0	0	0	W	Y	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0
1/30/2006	0	0	0	0	0	0	W	NA	17	0	0	0	0	0	W	Y	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0
2/3/2006	0	0	0	0	0	0	W	NA	1	0	0	0	0	0	W	Y	0	0	0	0	0	0	D	NA	15	0	0	0	0	0	W	N	0	0	0	0	0	0	W	NA	0	0	2	0	0	0
2/7/2006	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	D	NA	27	0	0	0	0	0	W	Y	0	0	0	0	0	0	W	NA	0	0	0	0	0	0
2/17/2007	0	0	0	0	0	0	W	NA	47	0	0	0	0	0	W	Y	0	0	0	0	0	0	W	NA	0	0	50	0	0	0	W/M	N	0	0	0	0	0	0	W	NA	0	0	0	0	1	0
2/25/2007	1	0	0	0	0	0	W	NA	20	0	0	0	0	0	W	Y	0	0	0	0	0	0	W	NA	7	0	0	0	0	0	W	N	0	0	0	0	0	0	W	NA	2	0	0	0	0	0
3/4/2006	8	0	0	0	0	0	W	N	20	0	0	0	0	0	W	N	20	0	6	0	0	0	W	N	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0
3/30/2006	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	5	0	0	0	W	Y	0	0	2	0	0	0	W	Y	0	0	0	0	0	0	W	NA	3	0	0	0	1	0
4/11/2006	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	3	0	0	0	W	N	0	5	0	0	0	0	W	N	0	0	0	0	0	0	W	NA	4	0	10	0	1	0
4/14/2006*	0	0	0	0	0	0	W	NA	0	50	20	0	0	0	W	N	16	0	0	0	0	0	W	N	2	0	0	0	0	0	W	N	0	0	0	0	0	0	W	NA	0	0	0	0	0	0
5/12/2006	0	0	0	0	0	0	W	NA	10	1	0	0	0	0	W	N	5	0	1	0	0	0	W	N	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0
5/19/2006	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	3	0	0	0	0	0	W	N	0	0	3	0	0	0	W	NA	2	0	0	0	0	0	W	NA	0	0	0	0	0	0
5/31/2006	9	0	0	0	0	0	W	N	11	0	0	0	0	0	W	N	7	0	0	0	0	0	W	N	0	0	3	0	0	0	D	N	8	0	7	0	0	0	W	N	0	0	0	0	0	0
6/9/2007*	30	0	2	0	0	0	W	Y	0	0	0	0	0	0	W	NA	12	0	4	0	0	0	W	N	0	0	2	0	0	0	D	N	0	0	0	0	0	0	W	NA	1	0	0	0	0	0
7/7/2006	0	0	0	0	0	0	W	NA	15	0	1	0	0	0	W	N	0	0	21	0	0	0	M	N	0	0	2	0	0	0	W	N	0	0	0	0	0	0	D	NA	0	0	0	0	0	0
7/19/2006	0	0	3	0	0	0	W	N	2	0	0	0	0	0	W/M	N	0	0	0	0	0	0	D	N	0	0	12	0	0	0	W	N	0	0	0	0	0	0	D	NA	0	0	6	0	0	0
10/20/2006	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0
11/24/2006	0	0	0	0	0	0	W	NA	0	0	28	0	0	0	W/M	N	0	0	1	0	0	0	W	N	2	0	0	0	0	0	W	N	0	0	0	0	0	0	W/M	NA	0	0	0	0	0	0
12/11/2006	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	D	NA	0	0	0	0	1	0	W	N	0	0	0	0	0	0
12/29/2006	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W/M	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	1	0	0	0	0	0	W	NA	0	0	0	0	1	0
1/19/2007	1	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	2	0	2	0	0	0	W	N	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	1	0
2/1/2007	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W/M	NA	0	0	0	0	0	0	W	NA	4	0	0	0	0	0	W	N	0	0	0	0	1	0	W/M	N	0	0	0	0	1	0
2/9/2007	15	0	0	0	0	0	W	Y	0	0	0	0	0	0	M	NA	2	0	2	0	0	0	W	N	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W/M	NA	0	0	0	0	2	0
2/22/2007	7	0	0	0	0	0	W	N	0	0	1	0	0	0	W	N	0	0	3	0	0	0	W	N	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0
3/6/2007	35	0	0	0	0	0	W	Y	0	0	0	0	0	0	W	NA	0	0	2	0	0	0	D	N	16	0	0	0	0	0	W	Y	0	0	0	0	0	0	W	NA	0	0	0	0	0	0
3/14/2007	0	0	0	0	0	0	W	NA	2	0	0	0	0	0	W	N	0	0	2	0	0	0	D	N	0	0	0	0	0	0	W	NA	9	0	2	0	0	0	W	Y	3	0	0	0	0	0
3/30/2007	0	0	0	0	0	0	W	NA	0	0	2	0	0	0	W	N	13	0	0	0	0	0	W	N	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	2	0	0	0	0
4/6/2007	3	0	0	0	0	0	W	Y	0	0	0	0	0	0	D	NA	9	0	0	0	0	0	W	Y	4	0	2	0	0	0	W/M	Y	0	0	0	0	0	0	D	NA	1	0	0	0	0	0
4/19/2007*	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	D	NA	4	0	44	0	0	0	W/M	N	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0
5/17/2007	1	0	4	0	0	0	W	N	2	0	0	0	0	0	W	N	0	0	0	0	0	0	D	NA	2	0	0	0	0	0	W	N	9	0	0	0	0	0	W	Y	2	0	0	0	0	0
5/25/2007	2	0	0	0	0	0	W	N	3	0	2	0	0	0	W	N	0	0	2	0	0	0	D	N	1	0	0	0	0	0	W	N	15	0	0	0	0	0	W	N	0	0	0	0	1	0
6/4/2007	0	0	0	0	0	0	W	NA	8	0	0	0	0	0	W	N	0	0	0	0	0	0	W	NA	3	0	0	0	0	0	W	N	0	0	0	0	0	0	W	NA	0	0	0	0	0	0
6/12/2007	0	0	0	0	0	0	W	NA	2	0	2	0	0	0	W	N	17	0	2	0	0	0	W	N	0	0	3	0	0	0	W	N	2	0	0	0	0	0	W	N	0	0	0	0	1	0
6/20/2007	1	0	0	0	0	0	W	N	24	0	4	0	0	0	W	N	5	0	8	0	0	0	W	NA	0	0	0	0	0	0	W	N	3	0	0	0	0	0	W	N	0	0	0	0	0	0
6/28/2007	0	0	0	0	0	0	W	NA	17	0	2	0	0	0	W	N	9	0	8	0	0	0	W	N	0	0	2	0	0	0	W	NA	4	0	4	0	0	0	W	N	0	0	0	0	0	0
7/5/2007	0	0	0	0	0	0	W	NA	13	0	4	0	0	0	W	N	14	0	9	0	0	0	W	N	4	1	3	0	0	0	W	N	5	0	0	0	0	0	W	N\	0	0	0	0	0	0
7/20/2007	3	0	0	0	0	0	W	N	5	0	0	0	0	0	W	N	2	0	3	0	0	0	W	NA	0	0	0	0	0	0	W	NA	3	0	20	0	0	0	M	N	6	0	0	0	0	0
7/25/2007	0	0	1	0	0	0	W	N	6	0	0	0	0	0	W	N	13	1	0	0	0	0	W	N	7	0	0	0	0	0	W	N	0	0	2	0	0	0	M	N	0	30	0	0	0	0
8/3/2007	3	0	6	0	0	0	W/M	N	33	0	4	0	0	0	W	N	0	9	65	0	0	0	W/M	N	0	0	33	0	0	0	W/M	N	0	0	0	0	0	0	M	NA	4	0	0	0	0	0
8/17/2007	0	0	0	0	0	0	M/D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	3	0	0	0	D	N	0	0	0	0	0	0	D	NA	0	0	0	0	0	0
8/30/2007	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0
9/4/2007	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0
9/11/07	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0
10/22/2007	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	D	NA	6	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	D	NA	0	0	0	0	1	0
10/30/2007	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	D	NA	0	0	1	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0
11/9/2007	0	0	3	0	0	0	W	N	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	M	NA	0	0	0	0	0	0
11/16/2007	3	0	0	0	0	0	W	Y	0	0	4	0	0	0	W	N	0	0	13	0	0	0	M	N	0	0	0	0	0	0	W	N	0	0	2	0	0	0	W	N	0	0	0	0	0	0
11/21/2007	14	0	0	0	0	0	W	N	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	D	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0
11/29/2007	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	W	NA	0	0	0	0	0	0	M/D	NA	1	0	0	0	0	0	W	N	0	0	0	0	0	0	W	NA	0	0	0	0	1	0
12/7/2007	0	1	1	0	0	0	W	N	0	0	48	0	0	0	W/M	N	0	0	0	0	0	0	M	NA	0	0	7	0	0	0	W/M	N	0	0	0	0	0	0	M	NA	0	0	0	0	0	1

WF – Waterfowl WA – Waders SB – Shorebirds GU – Gulls RA – Raptors CR – Crows PC – Pond Conditions (W – Wet; D – Dry; M – Muddy) DIS – Disturbance (Y – Yes; N – No; NA – Not Applicable) * Mitigation measure initiated

Table 3. Description of proposed modified recharge basins for the Marana High Plains Effluent Recharge Project

Cell	Acreage	Basin Level (min/max)	Modifications	Contingency 1	Contingency 2	Contingency 3	Contingency 4
Equal-ization Basin	0.62	2.0 ft/5.0 ft	Perimeter vegetation; settling and recharge basin	Perimeter vegetation; settling and recharge basin	Perimeter vegetation; settling and recharge basin	Perimeter vegetation; settling and recharge basin	Perimeter vegetation; settling and recharge basin
1	0.63	3 in/12 in	Perimeter & side slope vegetation; 2, 12-foot deep recharge enhancement trenches in cell bottom	Perimeter & side slope vegetation; 4, 36-inch diameter by 15-foot deep dry wells using perforated culvert pipe with pea gravel fill material	Perimeter & side slope vegetation; 2 sets of recharge dry wells, each connected with a 100-150 foot of 36-inch slotted culvert pipe in the permeable strata and filled with pea gravel	Perimeter & side slope vegetation; earthen furrows 1.5 feet wide and 6 feet deep aligned north to south to fit basin configuration	Perimeter & side slope vegetation; earthen furrows over trenches that are 1.5 feet wide and 6 feet deep aligned to fit basin configuration and backfilled with permeable materials (sand , gravel and/or cobble)
2	1.21	3 in/7 ft	Bare soil; 7 foot deep trench down middle and sloping upward to the sides	Bare soil; 4, 36-inch diameter by 15-foot deep dry wells using perforated culvert pipe with pea gravel fill material	Bare soil; 2 sets of recharge dry wells, each connected with a 100-150 foot of 36-inch slotted culvert pipe in the permeable strata and filled with pea gravel	Bare soil; earthen furrows 1.5 feet wide and 6 feet deep aligned north to south to fit basin configuration	Bare soil; earthen furrows over trenches that are 1.5 feet wide and 6 feet deep aligned to fit basin configuration and backfilled with permeable materials (sand , gravel and/or cobble)
3	0.78	3 in/12 in	Perimeter & side slope vegetation; 2, 12-foot deep recharge enhancement trenches in cell bottom	Perimeter & side slope vegetation; 4, 36-inch diameter by 15-foot deep dry wells using perforated culvert pipe with pea gravel fill material	Perimeter & side slope vegetation; 2 sets of recharge dry wells, each connected with a 100-150 foot of 36-inch slotted culvert pipe in the permeable strata and filled with pea gravel	Perimeter & side slope vegetation; earthen furrows 1.5 feet wide and 6 feet deep aligned north to south to fit basin configuration	Perimeter & side slope vegetation; earthen furrows over trenches that are 1.5 feet wide and 6 feet deep aligned to fit basin configuration and backfilled with permeable materials (sand , gravel and/or cobble)
4	1.26	3 in/12 in	Perimeter vegetation & grass line bottom; 2, 12-foot deep recharge enhancement trenches in cell bottom	Perimeter vegetation & grass line bottom; 4, 36-inch diameter by 15-foot deep dry wells using perforated culvert pipe with pea gravel fill material	Perimeter vegetation & grass line bottom; 2 sets of recharge dry wells, each connected with a 100-150 foot of 36-inch slotted culvert pipe in the permeable strata and filled with pea gravel	Perimeter vegetation & grass line bottom; earthen furrows 1.5 feet wide and 6 feet deep aligned north to south to fit basin configuration	Perimeter vegetation & grass line bottom; earthen furrows over trenches that are 1.5 feet wide and 6 feet deep aligned to fit basin configuration and backfilled with permeable materials (sand , gravel and/or cobble)

Table 4. Mitigation action thresholds and mitigation levels for the Marana High Plains Effluent Recharge Project

THRESHOLDS		MITIGATION ACTION LEVEL	
Bird Type	**Action Number**	**Summer** (Runway 12 less active)	**Winter** (Runway 12 more active)
Waterfowl	≤ 6	None	1
	> 6 < 12	None	2
	≤ 12	1	3
Wading Birds	≤ 10	None	1
	< 10 < 16	None	2
	≥ 16	1	3
Shorebirds	≤ 20	None	1
	> 20 ≤ 30	None	2
	> 30	1	3
Raptors	≤ 3	None	None
	> 3 > 6	None	2
	≥ 6	2	3
Crows (Ravens)	≤ 3	None	None
	> 3 > 6	None	2
	≥ 6	2	3

High Plains
Effluent Recharge Project

Bird-Strike Analysis
and
Proposed Mitigation Plan

Prepared for
Pima County Flood Control District
201 N. Stone Ave.
Tucson, AZ 85701

Prepared by
ENTRANCO
December 1997

HIGH PLAINS EFFLUENT RECHARGE PROJECT BIRD-STRIKE ANALYSIS AND PROPOSED MITIGATION PLAN

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INTRODUCTION

The purpose of this report is to examine the setting of the High Plains Recharge Project and the nearby Avra Valley Airport (AVA) as it relates to potential bird-aircraft collisions (bird-strikes). By examining the landscape features attractive to birds, we set the baseline against which the High Plains Project must be compared. The local bird habitat context is important in understanding and managing the potential contribution of bird-strike hazard posed by the construction and operation of the High Plains Recharge Project. The High Plains Project includes design elements that "may be compatible with safe airport operations" (e.g. retention basins) and elements similar to those considered "hazardous wildlife attractants near airports" (e.g. wetlands) (FAA 150/5200-33, sections 2-4 and 3-7). Groundwater recharge (detention) basins are not specifically addressed in Federal Aviation Administration (FAA) Advisory Circular 150/5200-33. This analysis is conducted for the High Plains Recharge Project by the project wildlife biologist, and is not to be confused with an airport wildlife hazard management plan recommended by the FAA (FAA 150/5200-33).

The proposed High Plains Recharge Project is a two year pilot project to demonstrate the feasibility of groundwater recharge by detention and percolation of waters from the effluent-dominated Santa Cruz River. Waters will be diverted from the Santa Cruz River into several small, vegetated basins. A secondary purpose of the project is to examine the potential for aquifer recharge projects to create or enhance native riparian habitats. The project is a joint project of the Pima County Flood Control District (PCFCD), Arizona Water Protection Fund, Town of Marana, and Bureau of Reclamation (BOR). To be consistent with the project purpose and need (BOR 1997), the project must be located near a source of water and on suitable substrates. The project design calls for gravity flow through the system.

The proposed site for the project is located near the Santa Cruz River, south of the town of Marana. The proposed site is located about 3500 feet (ft.) north of the threshold of runway 12 of the AVA. Because of the proximity of the project to the airport, the Federal Aviation Administration (FAA) has expressed concern about the potential for aircraft to strike birds attracted to the site by the project. Bird-aircraft collisions are serious safety concerns especially near airports where aircraft are flying low. Bird-strikes can cause catastrophic damage to aircraft, resulting in crashes and serious human injury or fatalities (see FAA 150/5200-32, FAA 150/5200-33, and Water Resources Research Center 1996).

The AVA is a general aviation airport with two paved runways: runway 12/30, 6,900 ft. long and runway 03/21, 4,200 ft. long. In 1996 there were an estimated 51,665 aircraft operations annually, composed of 71 percent local general aviation and 25 percent transient general aviation. Small amounts of air taxi and military flights comprise the remainder. The majority of aircraft operating from the AVA are piston-engine powered. About 10 percent of the aircraft are turbine (jet) powered. The Fixed Base Operator (FBO), Tucson Aeroservice Center, has seen increasing growth of turbine-powered use of the AVA in recent years. The AVA is not certified for air carrier operations (passenger aircraft) under FAA regulation (Part 139). According to the FBO, there have been six reported bird-strike incidents at the airport during the period 1990 to 1997, resulting in minor property damage only (Table 1). No human injuries or fatalities have occurred as a result of bird-strikes. None of these incidents was reported on FAA form No. 5200-7 for reporting bird-strikes.

Factors affecting the bird-strike threat near airports are complex. Different kinds of birds pose different degrees of threat. Body size, abundance, flight altitudes and flocking behavior are the best indicators of threat to aircraft (FAA 150/5200-32). The locations of habitats attractive to birds relative to the airport traffic pattern are also important considerations. Planes ascending during takeoff or descending on landing are most vulnerable to bird-strikes because they are at altitudes commonly used by birds. Generally, the FAA discourages the modification of habitats near airports that may result in increases in the probability of bird-strikes. Factors affecting local bird population density, movement, and roosting or perching are considered when evaluating potential increase in bird-strike hazard (FAA 150/5200-32). The FAA recommends that certain facilities known to increase bird hazards (e.g. waste disposal sites, wastewater treatment facilities, or wetlands) be restricted within (FAA 150/5200-32):

- a 5,000 ft. radius from a piston-use runway, or
- a 10,000 ft. radius from a turbine-use runway.

This purpose of this report is to review:

- the existing conditions near the AVA considering habitats that may be attractive to birds,
- aircraft traffic patterns at AVA, and any diurnal or seasonal variation,
- the expected habitat features at the proposed High Plains Effluent Recharge Project and potential effects on bird density, movements or community changes.

EXISTING CONDITIONS

Features likely to be attractive to birds within a 10,000 ft. radius of the AVA are summarized in Table 2. Feature locations relative to AVA are shown in Figure 1. Features were considered attractive to birds if they:

- contained surface water, either permanently or occasionally;
- contained stands of trees or shrubs that stand out from the surrounding landscape (edge) and/or provide roosting shelter for flocking birds, or

- provide concentrated feeding, watering or roosting opportunities (e.g. feedlots, landfills, etc.).

For each habitat feature in Table 2, the kinds of birds likely to use the feature were evaluated considering the habitats available and the bird group's habitat preference. For this evaluation birds are grouped into broad classes based on form, habit, and generally conforming with the classes recognized by the FAA (FAA 150/5200-32: 203(e.)) (i.e.: gulls, waterfowl, blackbirds, wading birds, raptors, doves, and others).

Given the relatively arid nature of the surrounding landscape, there are a number of habitats and features located near the AVA that are attractive to birds (Figure 1 and Table 2). As part of a baseline study of the High Plains Recharge Project, R. Wahl has observed birds at the site and in the vicinity periodically between March and October 1997. In all, 17 visits to the project area were made by R. Wahl, providing some data on local bird abundance and diversity. Because numbers of birds seen off the High Plains Project area were not recorded, and due to the limited nature of observations, numbers are not assigned to the birds seen. Where specific numbers are available in field notes or reports, they are used herein.

Near the AVA, the kinds of birds attracted vary with the habitat feature, season and surrounding landuse. There is little data on relative abundance of birds for most of the sites discussed below, however, abundance varies markedly by habitat, season and landuse. Seasonal abundance due to migration is probably most relevant to the bird-strike issue. For example, ducks and some wading birds are most abundant in the winter and spring.

The Santa Cruz River and the Santa Cruz River Diversion attract waterfowl, wading birds, raptors, and doves (R. Wahl, pers. obs.). Fields of palm and pine trees provide roosting habitats attractive to flocking birds, such as blackbirds and doves. Raptors (hawks, eagles, and vultures) are drawn to field edges and to concentrations of other birds, potential prey (R. Wahl, pers. obs.). In the arid southwest, raptors are drawn to bare fields by thermals (rising air currents) created from the heated soil surface (R. Wahl, pers. obs.). Flooded agricultural fields and pastures attract waterfowl, wading birds, and blackbirds (R. Wahl, pers. obs.). Mature and recently harvested grain fields attract blackbirds and doves. Recently plowed fields attract blackbirds and doves (R. Wahl, pers. obs.).

Avra Valley Recharge Project

In August 1996, the CAWCD began operation of a pilot aquifer recharge project, the Avra Valley Recharge Project (AVRP), located about 2000 ft. north of the AVA (Feature 4, Figure 1). The project recharges CAP water into the aquifer by means of infiltration from four shallow basins. The basin surface area totals eleven acres and the basins are usually filled with water to a depth of about one to two feet. Because of the proximity to the AVA, the AVRP conducts passive bird mitigation activities and monitors birds using the facility (AVRP Bird Attractant Mitigation Plan, FAA study no. 95-AWP-1209-OE). Periodic assessment reports by the AVRP provide some information on birds using the surface waters created by the facility.

Interpreting bird sightings reported for the AVRP is difficult due to both inter-observer variability in data recording, and varying expertise in identifying birds among the AVRP staff making observations. Relationships between birds reported and their location are not clear (e.g. some notes appear to count birds observed off the AVRP). The reports could benefit from detail concerning local environmental conditions during the observations (e.g. time of day, precedent human activity, functional condition of passive bird scare devices, etc.). Despite these drawbacks, the AVRP reports provide some bird-use data for recently created ponds in the local context.

Waterfowl are attracted to the AVRP in spring, winter and fall, as are shorebirds (i.e. Killdeer). Numbers of ducks (waterfowl) reported vary considerably among site visits at AVRP, as do numbers of other species observed, perhaps due to observer variability, effectiveness of passive bird mitigation devices or other activities preceding the bird observations. Ducks were observed at AVRP in at least 50% of each month's observations between October 1996 and March 1997, except for February 1997, when no ducks were observed (four observations). Numbers of ducks seen at AVRP during the period October 1996 to March 1997 ranged from two to fifty birds (CAP 1997). The AVRP basins were dry from March 18, 1997 to April 24, 1997 and no ducks were recorded in six observations. Flocks of shorebirds (i.e. Killdeer) were observed numbering about 25 individuals in October 1996 when two of the basins had large amounts of exposed moist soils. Wading birds (i.e. Black-necked Stilts) were observed in summer (June through August 1997) at the AVRP (CAP 1997). Birds that may be immature White-faced Ibis (described as: "34 white, 1-black crain (*sic*) looking birds...") were seen in September 1997 (CAP 1997). White-faced Ibis were seen nearby in April and May 1997 (R. Wahl, pers. obs.) Up to 50 dove (Mourning Dove) have been observed at the AVRP, apparently roosting on a fence at the site (CAP 1996 and 1997).

Central Arizona Project Canal

The CAP's Tucson Aqueduct (canal) was completed in 1989. A portion of the CAP canal approaches within 3000 ft. of AVA to the east. The canal provides a permanent water body about fifty feet wide and many miles long, perfectly suitable for waterfowl loafing. Pre-construction and post-construction observations of birds for the AVRP report relatively large numbers of waterfowl on the CAP canal in the vicinity of the AVA. Up to fifty ducks were reported on the CAP canal in each of the months of January, February, and March 1997.

BKW Farms Pond

A stock pond of about one acre surface area is located north of the AVA less than 2000 ft. from the threshold of runway 12. According to AVRP observations, waterfowl frequently use the ponds in the winter months. Numbers observed range from 15 coots to 15 to 20 mallards.

Santa Cruz River

The Santa Cruz River is located north of the AVA at distances ranging from over 3000 ft. at the closest point to beyond 8,000 ft. The river flows with treated effluent from nearby Tucson and has had at least an intermittent flow since about 1975. North of the AVA, a portion of the Santa Cruz River is diverted into a ditch system to irrigate pasture located in the Santa Cruz River Floodplain. The river and diversion provide relatively slow moving waters of 15 to 30 ft. width and substantial wet shoreline. Riparian habitats along the river and diversion include narrow stands of Tamarisk, Broom Baccharis and Willow with heights to about 30 ft. Waterfowl (i.e. ducks and coots) and wading birds (i.e. ibis, night-herons, ibis and herons) have been observed along the river (R. Wahl, pers. obs.) during baseline bird surveys for the proposed High Plains Effluent Recharge Project. Duck numbers observed range from several to groups of twelve or more. About 10 to 15 White-faced Ibis were seen on the river in April, 1997. Tree-roosting Black-crowned Night-Heron were seen in flocks of about ten individuals. Mourning and White-winged Dove are common along the river. Small numbers of shorebirds (i.e. Spotted Sandpiper and Killdeer) have been observed along the river during the spring months.

Fields and Pastures

There are many farm fields and pastures located within 10,000 ft of the AVA, mainly north and west of the airport. Farm fields vary in the types of bird habitat provided, depending on the season and crop planted. Blackbirds (i.e. Red-winged Blackbird, Brewer's Blackbird, Brown-headed Cowbird, grackles, and Crows), doves (i.e. Mourning dove, White-winged Dove, and Rock Dove), and raptors (i.e. hawks, vultures, and owls) are the most common groups attracted to fields. Notable near the AVA, are several large fields of trees which may provide roosts for blackbirds. Blackbird roosting flocks can be very large, especially near agricultural areas, such as Marana, with many grain crops. Fallow, bare fields may attract raptors, especially vultures, seeking thermals rising from warm soils. Turkey Vulture were frequently observed soaring over fields and other locations near AVA during 1997 (R. Wahl, pers. obs.).

Pastures provide habitat for wading birds (i.e. ibis, herons, and egrets), shorebirds (i.e. curlews, sandpipers, and killdeer), and waterfowl when flooded or moist. A grass pasture of at least 40 acres, located immediately west of the High Plains Site and within 5000 ft. of AVA, was frequently flooded by water diverted from the Santa Cruz River during the spring and summer of 1997. When flooded, the pasture had large numbers (>20 individuals) of wading birds (White-faced Ibis) and blackbirds (grackles). Waterfowl probably use the pasture when flooded, as well.

Summary of Existing Conditions

There are many sources of birds near the AVA. Agricultural fields and pastures probably pose the greatest bird-strike threat due to their attraction of flocking blackbirds, doves, and high-soaring vultures and other raptors (FAA 150/5200-32; Tables 3-1 and 3-2). Blackbirds pose the threat of multiple strikes or bird ingestions due to their habit of forming large, tightly knit flocks (R. Wahl pers. obs., FAA 150/5200-32 p. 19). Multiple ingestions or strikes are most hazardous, especially to turbine aircraft. A number of water bodies are located near the AVA which are attractive to waterfowl and wading birds. Waterfowl and larger wading birds (e.g. cranes, herons) are a serious bird-strike threat because of their relatively large mass which can cause substantial airframe damage. Waterfowl can also penetrate aircraft windscreens causing fatalities or serious bodily injury. Waterfowl are most abundant near the AVA in the cooler months (Fall, Winter, Spring).

PILOT EXPERIENCE WITH BIRD-STRIKES AT AVA

I interviewed several pilots at AVA on November 22, 1997 to determine the past record of bird-strikes at the airport and the pilot's perception of the threat posed by the recently created AVRP. The Director of Operations for the FBO, Mr. William Barbre added several more previously unreported bird-strike incidents to the list (Table 1). No FAA report forms have been completed for any of the AVA bird-strikes, and information is anecdotal.

Mr. Gary Abrams (Tucson Aeroservice Center and a self-described farmer) commented that there used to be more birds in the airport vicinity until the predominant local crop changed from grains (milo) to cotton. His perception was that bird numbers have decreased in response to the crop change.

The operator of a parachute jump school at AVA, Mr. Tony Frost (also a self-described farmer), reported experiencing frequent bird-strikes and near misses with his aircraft, an estimated one half to one strike per month (of 23,000 aircraft operations annually). He particularly noted the ingestion of a duck (identity presumed) in one engine of a twin-engine aircraft on departure (takeoff) from runway 30 in December 1996. The bird-strike did not result in immediate power loss, but ultimately required an expensive engine replacement. He points out that the incident could have been catastrophic if the engine had failed. He noted that his aircraft carry up to 24 persons at a time and flights are frequent. He also commented that trends in local crops are toward grains which will result in the presence of more birds. He expressed concern that areas providing surface water would be attractive to birds foraging on grains and create increased bird movements in the AVA vicinity.

All three interview subjects perceived birds attracted to the existing Avra Valley Recharge Project as a potential threat to air safety. The bird-strike history at AVA (Table 1) suggests the dominant influence of agricultural lands in contributing to bird-strikes. The species most frequently struck (dove, raven or crow, and vulture) are common in agricultural areas and areas with large amounts of bare soils. No clear pattern of bird-strikes emerges for any particular runway, which would indicate the direction of a concentrated threat. There have been remarkably few bird-strikes involving waterfowl or wading birds, considering the AVA's proximity to several water bodies (Figure 1 and Table 2). Completion of FAA form 5200-7 in these incidents would have proven valuable in this analysis.

Wind and Active Runways at Avra Valley Airport

There is diurnal and seasonal variation in wind direction at AVA, affecting the choice of runways used for departure and approach. Generally, early morning winds favor use of runway 12 (heading 120 degrees, true), mid-morning winds favor use of runway 30 (heading 300 degrees) (B. Barbre, pers. comm.). Prevailing afternoon winds are generally from the southwest, favoring use of runway 21 (heading 210 degrees). Winds are generally light (<12 miles per hour) about 82 per cent of the time (source: AVA wind rose), except when summer thunderstorms or winter cold fronts are in the area.

An analysis of daily wind summaries for 1996 from Tucson International Airport (National Climatic Data Center 1996) and a review of the AVA wind rose was made to determine the most active runways in each month. The resultant (average) daily wind direction was used, which does not necessarily account for the diurnal variation in runway use, outlined above. Generally, in the colder months (October through February) runway 12 is the more active runway. In the summer (March through September) winds are generally from the southwest, making runway 21 the most active. A monthly summary of the percentage use of AVA runways based on 1996 climate data (daily resultant wind direction) is shown in Appendix A in support of the above generalizations.

There are two runways at AVA (figure 2); runways 21 and 12 are left base (i.e. aircraft in the pattern turn left), runways 3 and 30 are right base. Runways 3 and 30 are right base to avoid creating excess noise for the few farm residents to the east (B. Barbre, pers. comm.), and perhaps to avoid the parachute landing area. Aircraft departing runway 30 turn toward, or over, a number of bird-attracting features including frequently flooded pasture, the Santa Cruz River and Santa Cruz River diversion (1,5,6,7 and 8 in Figure 1). Aircraft departing runway 3 turn right toward the Santa Cruz River and the CAP canal (3 and 7, Figure 1).

THE PROPOSED HIGH PLAINS EFFLUENT RECHARGE PROJECT

The proposed High Plains Recharge Project site is located in the departure path for AVA runway 30 (right base) and the base approach path for AVA runway 12 (left base) (Feature 10, Figure 1). The proposed project would create five shallow basins on what is now relatively bare ground adjacent to the Santa Cruz River. Each basin will be a different experimental treatment for demonstrating aquifer recharge and will vary as to vegetation planted and wet-dry cycle. Generally, the basins would be filled with water piped from the Santa Cruz River Diversion channel. All but the equalization basin would be operated on a wet-dry cycle, presently planned to be 7 days each. The 0.5 ac. equalization basin would be filled with water most of the time, except for periodic maintenance. Except for service roads, buildings, and other structures, the site would be re-vegetated with native vegetation similar to that present at the site today.

Bird habitats likely to be provided by the project include:

- 0.5 ac. of permanent surface water 3.0 ft. deep (pond)
- about 2.4 ac. of ponded water in three basins, intermittently drained
- about 1.0 ac. of tall grasses, periodically flooded for sustained periods
- about 2.0 ac. of riparian vegetation (trees and shrubs)

Absent mitigation measures, waterfowl and wading birds would be attracted to the ponded surface waters in four of the five basins. In the grass basin, flooded tall grasses are likely to be too tall to attract many waterfowl or wading birds, however, some may use this basin early in the project before grasses have completely covered the substrate. Because of the small surface area of each basin (1.0 ac., or less), limited numbers of waterfowl would be able to use them. During the dry cycle, when the basin bottom becomes exposed, they will attract shorebirds, especially during migration and winter. The riparian vegetation planted at the site will attract various passerine bird species, none considered a bird-strike hazard.

Because the High Plains Project basins are located within the Santa Cruz River floodplain and are immediately adjacent to existing waters, I do not expect that the project will significantly alter bird movements in the area. When compared with the 40+ acres of surface waters provided by the flooded grass pasture (Feature 8, Figure 1) adjacent to the High Plains Site and the Santa Cruz River (feature 7, Figure 1), it is unlikely that the High Plains Project will increase the local waterfowl population or density. The project is, in effect, trading surface waters in the river channel for basin surface waters adjacent the river channel, a condition unlikely to change waterfowl or wading bird densities (number per unit area). The project will not create abundant or unique food sources that would attract these birds to the area. If the project were located away from existing waters on uplands, as is the AVRP, it would attract waterfowl and other species not normally found in uplands.

Because the project will replace bare soils with water and vegetation, the site would cease to provide thermals for soaring birds (e.g. vultures). Because cattle would be excluded from the site and perennial plants would be planted, the site would be less attractive to doves and blackbirds, species typically attracted to weedy areas and livestock. Riparian vegetation contributed by the project would be contiguous with the existing riparian vegetation along the Santa Cruz River and, thus, would not create unique habitats locally.

The operation of the High Plains Project basins would have an effect on the project's attractiveness to different groups of birds. The duration and timing of the basin wet/dry cycle would have the greatest effect on bird use. Depth of water in the basins may also determine their suitability for certain groups, for example, wading birds prefer shallow water (<1 ft.). These operational variables, depth and wet/dry cycle, can not be determined until the project is in operation. The nature of the recharge investigation is to be able to experiment with these variables to achieve the desired goal; maximum recharge of groundwater. Thus, the extent to which these factors can be adjusted to mitigate for the project's attractiveness to birds can not be determined at the present.

Several design modifications were implemented to reduce the attractiveness of the site to waterfowl, wading birds and shorebirds. The area of the permanent water body (equalization basin) has been reduced in size from the one acre basin originally proposed to 0.5 acre. Basin margins will be planted with tall grasses and shrubs. Shoreline vegetation may conceal predators and may discourage some species from using the basins. Most of the basins are oblong in shape (length width ratio >1), and may will be less attractive to some species of waterfowl (FAA 150/5200-32). Other design considerations to mitigate for potential bird attractiveness, for example, recharge via a pipe field or french drains, are outside of the project's purpose and need (BOR 1997). A purpose of the project is to examine recharge feasibility from open basins. Because the project is a pilot project, there is limited budget flexibility available for design changes.

Monitoring and Adaptive Mitigation Measures

Changing AVA runway 30 to a left base turn would permit departing aircraft to avoid several potential bird hazards in the northwest-to-north quadrant, including the High Plains Recharge Project area. Likewise, changing runway 12 to right base would direct departing aircraft away from the CAP canal and Santa Cruz River. Aircraft approaching (landing on) runway 12 would not fly over the AVRP, High Plains Recharge Project Site, Santa Cruz River and fields in the northwest-to-north quadrant on downwind, base and final approach. At present, there are no noise abatement areas around AVA (Jesse Craft, pers. comm.) thus, modifying airport operations is the first option we recommend to mitigate bird-strike hazards during the initial 2-year period of recharge project operation.

The AVA could publish Notice to Airmen (NOTAM) advising of the change in airport operations and the potential for birds in the vicinity of the AVA as recommended in FAA 150/5200-33. In fact, even without modifying operations, AVA could publish a NOTAM to make pilots aware of the several existing bird attractants presently in the vicinity of AVA.

Pima County Real Property Management staff, who manage the AVA, do not recommend changing the present airport traffic patterns because: 1) aircraft would be in direct conflict with a parachute drop zone on the airport west side; 2) aircraft would fly over hangers, fuel storage, and buildings on downwind approach for runway 12 (they presently fly over buildings, hangers and fuel storage on downwind approach for runway 21, the most frequently used runway); 3) aircraft departing from runway 30 would fly over farm buildings to the west on climb-out.

Should the runway base turn pattern at AVA remain unchanged, or should noise abatement requirements under FAA part 139 become necessary during the life of the High Plains Recharge Project, the operators (PCFCD) will implement a bird mitigation program based on frequent bird monitoring observations of the project basins and grounds. The purpose of bird monitoring is not an attempt to prove or disprove an increase in bird numbers locally as a result of the High Plains Recharge Project. The purpose of bird monitoring will be to gather data upon which mitigation actions will be based.

Workers who visit the project site regularly will be trained twice yearly in a standardized data gathering method for making and recording bird-use observations. Birds observed will be classed into one of the FAA categories and identified to species if possible. Bird behavior (e.g. roosting, feeding, soaring, etc.) will also be recorded as a check-off on a standardized form. Data gathered will be compiled and summarized on a weekly basis by the PCFCD project manager, Julia Fonseca, to determine the number and types of birds using the site. During compilation, the data will be examined to assure that workers are using the standardized method and to insure that birds are assigned to the correct class.

Weekly data compilations (the action standard) will be filed with the Pima County Real Property Division, who manage the airport. Quarterly reports on bird data, action taken and results will be sent to FAA, Real Property, the AVA FBO and CAWCD. Bird observers will receive refresher training at least once each year, or if regular analysis of field data forms indicates poor performance. Near the end of the two year life of the pilot project, the project manager will discuss any plans for continuation of the project with the Pima County Real Property Division and the AVA FBOs.

Mitigation measures to deter bird use will be triggered at defined thresholds of bird type and numbers (Table 3). **Each weekly data compilation will determine the mitigation action. Thus, mitigation actions will be implemented on a weekly basis, depending on the data gathered and the threshold action criteria (see below).** Once implemented, a given mitigation action will be continued for at least a two week period to determine its effectiveness in reducing bird use. If, after two weeks of mitigation action, the numbers of a target bird group are not reduced to below the threshold the next action level will be implemented. A given mitigation level will not be discontinued until the target bird numbers are below the action threshold. Should bird use reach higher action thresholds during the two week period, the next level of mitigation will be implemented as soon as it is triggered.

Action thresholds will vary seasonally in response to the more active runway at AVA and the seasonal nature of some bird occurrences (e.g. waterfowl and wading birds). This plan takes into account the active runway at AVA, given local wind conditions. Birds that do not pose a threat are not harassed. If birds are routinely (always) forced to move from the High Plains Recharge project, despite the active runway at AVA, they may move to other locations that pose a greater hazard for the active runway, for example, the AVRP or nearby agricultural fields. Bird control efforts in the entire AVA area (e.g. High Plains Recharge Project and AVRP) need to be coordinated in such a way that birds are not frightened from one facility only to move to another, increasing the bird-strike threat there. Where possible, operational features of the project may be adjusted to mitigate bird use depending on the experimental observations of recharge rates and basin conditions.

Mitigation Level 1

Mitigation level 1 includes passive actions to discourage bird use. Most of these methods mimic natural enemies of birds, evoke avoidance responses, or are frightening to birds. These include models of predators (hawks, owls, mammals), wind-generated, moving scare devices (foil, scarecrows, etc.), and mechanical movement devices. Birds habituate rapidly to these methods, therefore variation in their use and timing is important for maximum effect. These devices and methods do not require state or federal permits.

Mitigation Level 2

Mitigation level 2 includes passive and active means of interfering with bird use of an area. Active measures include: physical barriers (e.g. wires strung across water or perches), removal of attractive features (e.g. perches, posts and etc.), and manipulating operational features of the project (e.g. basin wet/dry cycle) where feasible and consistent with the project goals. Level 2 measures may cause bird injury or fatalities, therefore will require state and federal permits for "take" of migratory birds. Migratory Bird Permits are issued on an annual basis from United States Fish and Wildlife Service and Arizona Game and Fish Department by application. Federal and State Permits will be acquired by PCFCD, in advance, for all potential actions under this plan.

Mitigation Level 3

Mitigation level 3 includes level 2 measures and active means of frightening birds from an area. These may include: pyrotechnic devices, noise making devices, high-pressure water sprays, and disrupting lights and sounds at night. Included in this level are adjusting operational aspects of the project outside of the planned recharge mode, including adjusting wet/dry cycles and water depths, and drying out the basins. Level 3 measures may require state and federal permits, as outlined above. Some of these measures (e.g. pyrotechnic devices) may conflict with local ordinance.

CITATIONS

Bureau of Reclamation, 1997. Draft Environmental Assessment Marana High Plains Effluent Recharge Project. U.S.D.I., Bureau of Reclamation, Phoenix, Az. 59 pp.

Central Arizona Project Memo. Sept. 1996. Bird Attractant Mitigation Plan - Report No. 1. Unpublished report to FAA, Central Arizona Project, Phoenix, AZ. 4 pp.

Central Arizona Project Memo. Nov. 1996. Bird Attractant Mitigation Plan - Report No. 2. Unpublished report to FAA, Central Arizona Project, Phoenix, AZ. 2 pp.

Central Arizona Project Memo. May 1997. Bird Attractant Mitigation Plan - Report No. 3. Assessment of Effectiveness. Unpublished report to FAA, Central Arizona Project, Phoenix, AZ. 18 pp.

Central Arizona Project Memo. Dec. 1997. Bird Attractant Mitigation Plan - Report No. 4. Assessment of Effectiveness. Unpublished report to FAA, Central Arizona Project, Phoenix, AZ. 38 pp.

Federal Aviation Administration (FAA), undated. Airport Wildlife Hazard Management (working copy approved for use). Advisory Circular (AC) 150/5200-32.

FAA, 1997. Hazardous wildlife attractants on or near airports. Advisory Circular (AC) 150/5200-33.

National Climatic Data Center (NOAA). 1996. Local Climatological Data: Tucson International Airport. Monthly summaries. Dept. of Commerce.

Water Resources Research Center. 1996. Recharge Activities Near the Avra Valley Airport. Unpublished report to the Bureau of Reclamation. 23 pp.

PREPARER

Rex Wahl, biologist
ENTRANCO

Rex Wahl holds a Bachelor of Science (BS) and a Master of Science (MS) in Biology from New Mexico State University. He has over sixteen years of experience in biology, mainly bird behavior, ecology and conservation. He earned a private pilot's license in 1974, through Air Force ROTC, with 40 hours of flight time.

Table 1. Bird-strike incidents at AVA compiled from anecdotal accounts. No FAA forms 5200-7 were completed for these bird-strikes.

Date	Aircraft Type	Runway Used	Flight Phase	Bird Type	Damage, Result
1990	Cessna 152	21	Final Approach	"buzzard" = Vulture	Wing structural damage, landed safely, no injury
1990	Cessna 172	21	Final Approach	Raven or Crow	cowling damage, landed safely, no injury
1992	Piper Aztec (twin engine)	30	Final Approach	Unknown	cowling damage, landed safely, no injury
1996	King Air (twin engine)	21	Final Approach	Dove	No damage or injury
1996	Pitts Special	21(?)	Final Approach	Unknown	Wing structural damage, landed safely, no injury
1996	Short Skyvan (twin engine, turbine)	30	Departure	Duck	Ingested into engine, engine later replaced, landed safely, no injury
1996	Beechcraft Baron (twin engine)	30	Final Approach	Dove	Unknown, landed safely, no injury

Table 2. Habitats attractive to birds located near Avra Valley Airport (AVA).

Bird Attractant (number keys feature to Figure 1)	**Distance from Avra Valley Airport** $_1$ **(feet)**	**True Heading, from AVA** $_2$ **10 degrees**	**Surface Area or Width** $_3$ **(ac. or ft.)**	**Feature Type**	**Bird Type Attracted (potential threat)**
1. BKW Farm Pond	<2000	328	1 ac.	pond with trees	Waterfowl, Blackbirds
2. Tree Field	<2000	300	11 ac.	rectangular field with trees, edge	Blackbirds, Raptors
3. CAP Canal	<2000 to 8000	87 to 220	60 ft.	linear irrigation canal, no vegetation	Waterfowl
4. Avra Valley Recharge Project	2200	020	11 ac.	rectangular ponds, little vegetation	Waterfowl, Wading Birds
5. Tree Field	>2400	300 to 320	30+ ac.	rectangular field with trees, edge	Blackbirds, Raptors
6. Santa Cruz River Diversion	>3000	340 to 360	20-30 ft.	linear stream, riparian vegetation	Waterfowl, Wading Birds, Blackbirds, Raptors
7. Santa Cruz River	<4000 to 6000+	330 to 70	10-30 ft.	linear stream, riparian vegetation	Waterfowl, Wading Birds, Blackbirds, Raptors
8. Irrigated Pasture	>4000	320 to 325	40+ ac.	frequently flooded grass field	Waterfowl, Wading birds
9. Land Fill	> 8000	55 to 65	120 ac.	landfill, weeds, bare soils	Blackbirds, Raptors

Subscripts:

1. Distance from airport measured from end of nearest runway.
2. Approximate heading from intersection of runways 12/30 and 03/21. If a range, the feature subtends the arc specified.
3. Surface area of ponds and fields, width if linear feature.

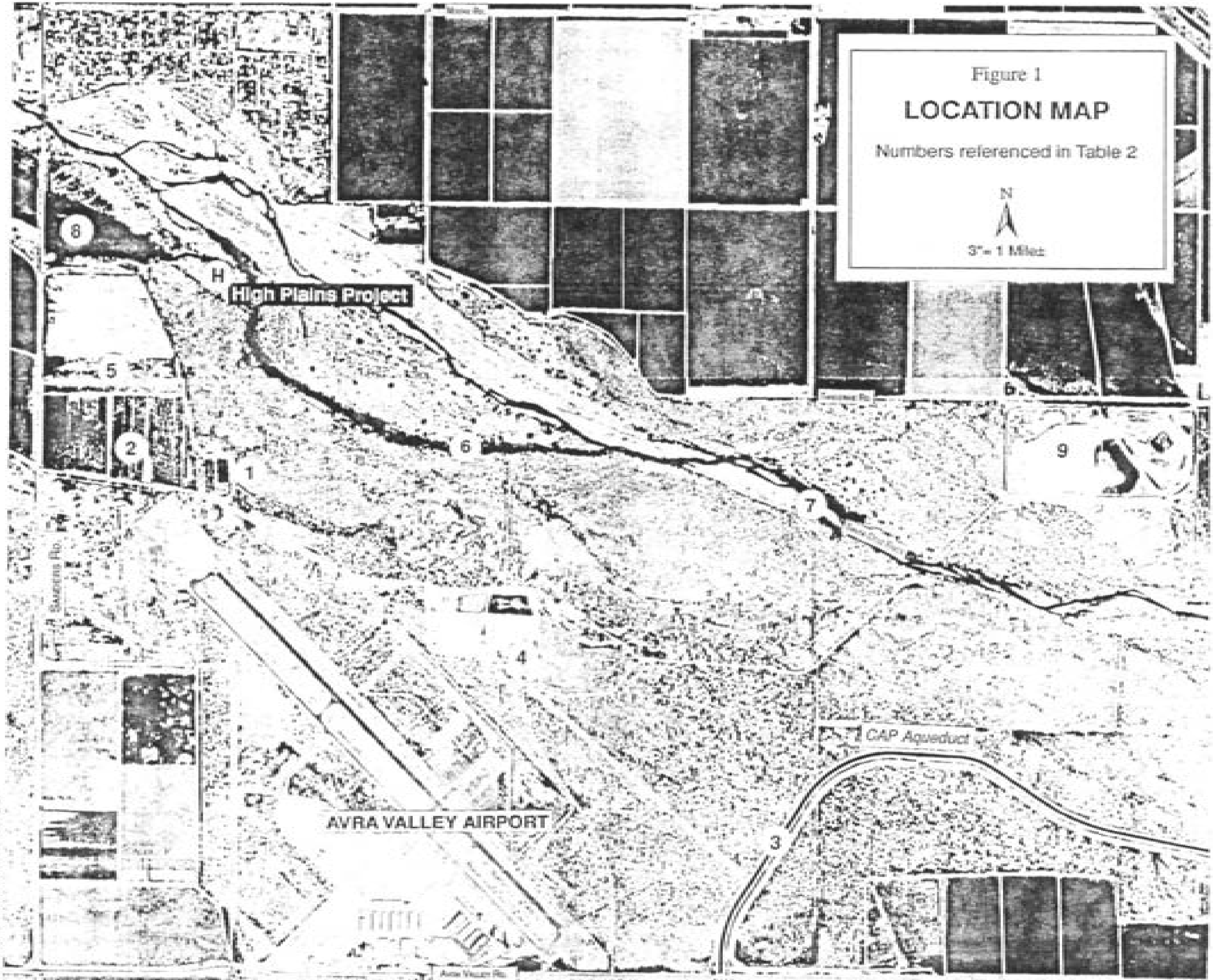
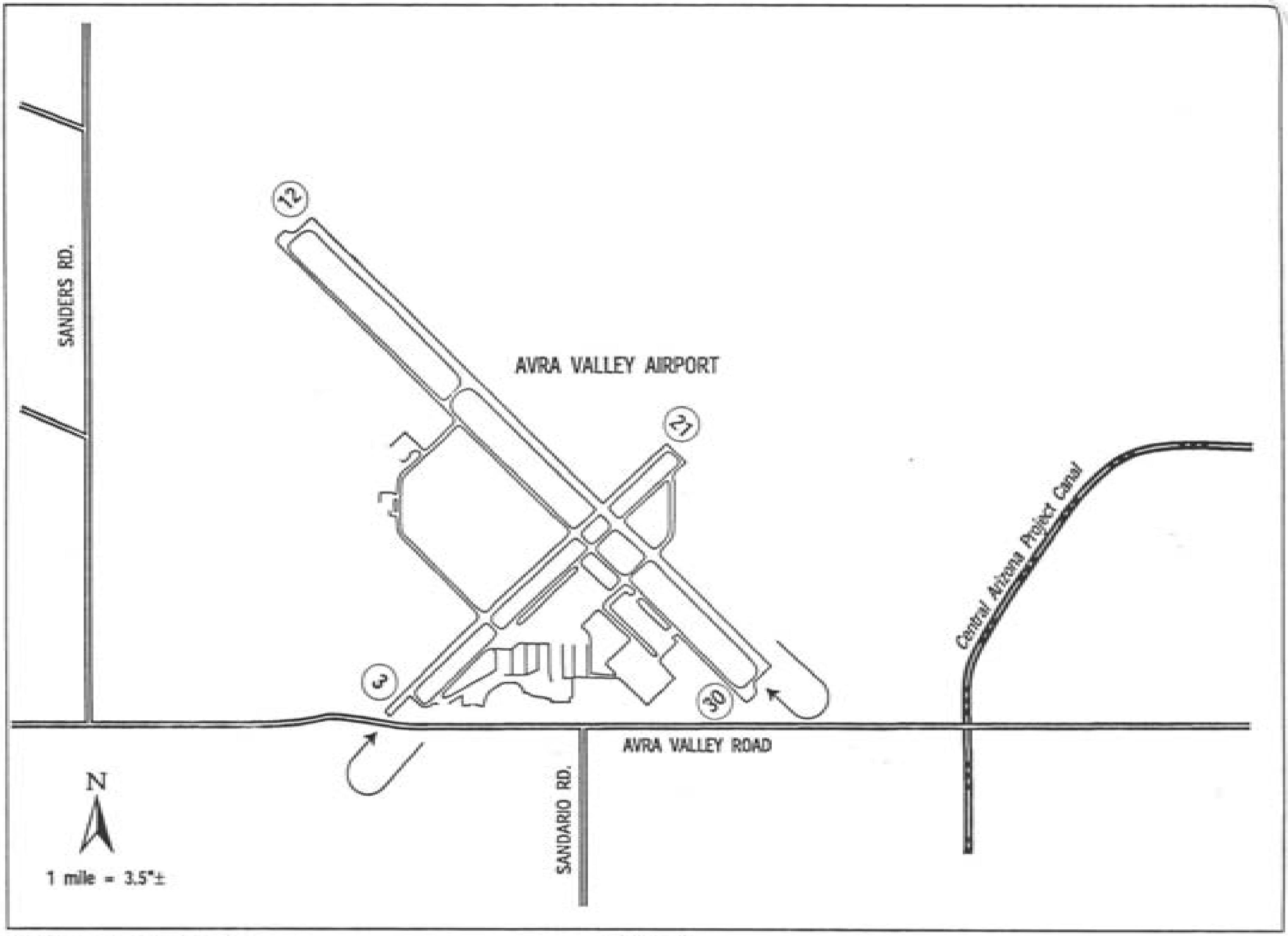
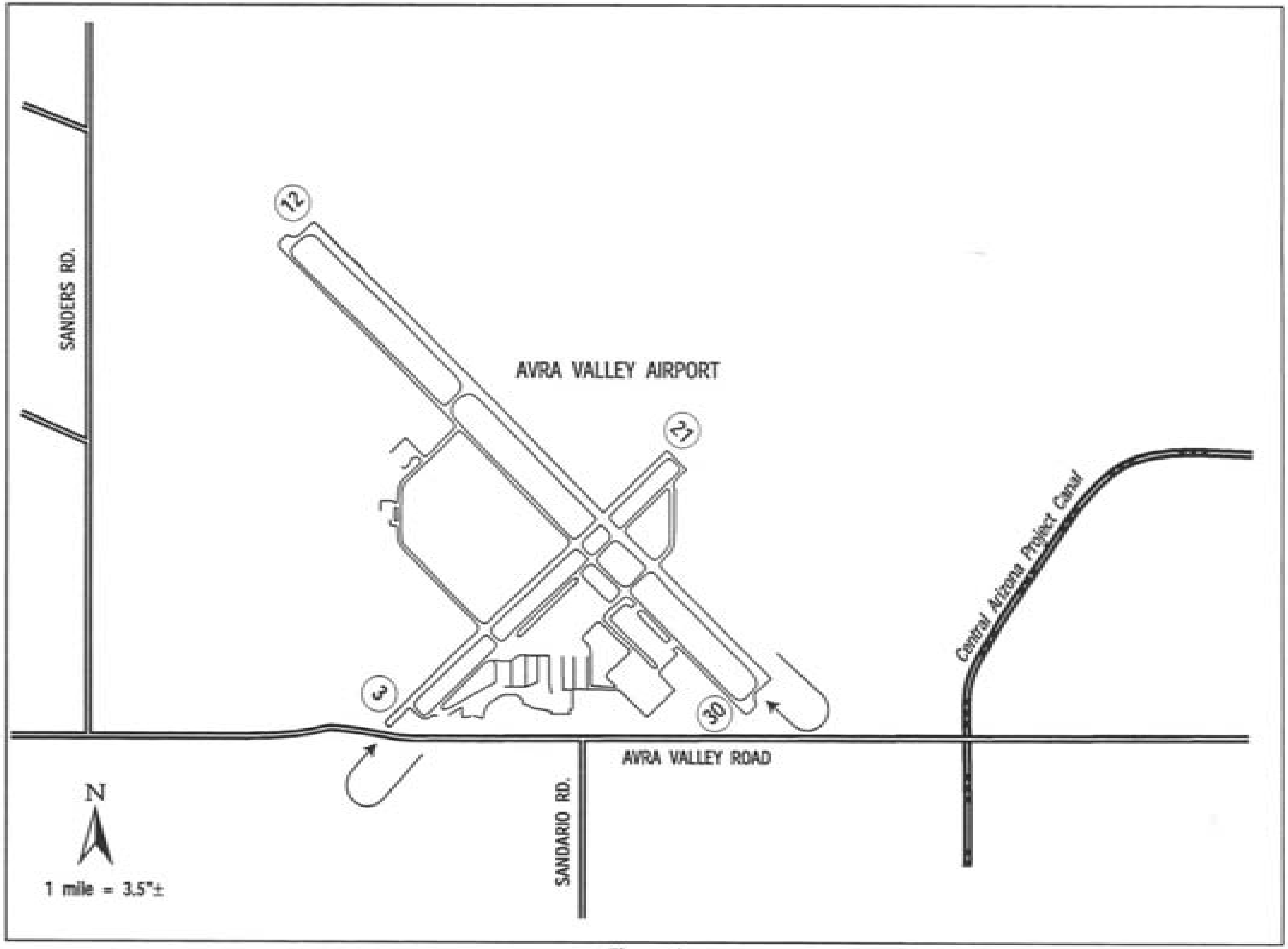


Figure 1
LOCATION MAP
Numbers referenced in Table 2



Pima County Illustration Section 12/97 sb

Figure 2
AVRA VALLEY AIRPORT
Existing Conditions



Pima County Illustration Section 12/97 sb

Figure 2
AVRA VALLEY AIRPORT
Existing Conditions

Table 3. Mitigation action thresholds and mitigation level for the High Plains Effluent Recharge Project.

THRESHOLDS		MITIGATION ACTION LEVEL	
Bird Type	**Action Number**	**Summer** (Runway 12 less active)	**Winter** (Runway 12 more active)
Waterfowl	≤ 6	none	1
	> 6 < 12	none	2
	≤ 12	1	3
Wading Birds	≤ 10	none	1
	> 10 < 16	none	2
	≥ 16	1	3
Blackbirds	≤ 20	none	1
	>20≤30	none	2
	>30	1	3
Dove	<20	none	none
	≥20<30	none	1
	≥30	1	2
Raptors	≤3	none	none
	>3<6	none	2
	≥6	2	3

Appendix A

Table 4. Seasonal pattern of active runway at AVA. Average daily active runway, as percent, at AVA based on average daily wind vector (direction), by month, for Tucson International Airport (National Climatic Data Center 1996). The number of days of each month (in parentheses) and as percent that the runway is active, based on wind direction alone, is shown.

Month	Runway 3 Percent (N)	Runway 12 Percent (N)	Runway 21 Percent (N)	Runway 30 Percent (N)
January	0	74 (23)	26 (8)	0
February	0	46 (13)	36 (10)	18 (5)
March	0	39 (12)	48 (15)	13 (4)
April	0	19 (6)	61 (19)	16 (5)
May	0	0	81 (25)	19 (6)
June	0	17 (5)	53 (16)	30 (9)
July	0	39 (12)	45 (14)	16 (5)
August	3 (1)	65 (20)	26 (8)	6 (2)
September	3 (1)	33 (10)	53 (16)	10 (3)
October	3 (1)	52 (16)	42 (13)	3 (1)
November	3 (1)	70 (21)	23 (7)	10 (3)
December	3 (1)	61 (19)	32 (10)	3 (1)

United States Department of the Interior
Bureau of Reclamation
Lower Colorado Region
Phoenix Area Office

FINDING OF NO SIGNIFICANT IMPACT

MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT

Approved: Thomas G. Burbey Date: 4/30/98
Thomas G. Burbey
Area Manager, Phoenix Area Office
Bureau of Reclamation

FONSI No. PXAO-98-2

United States Department of the Interior

BUREAU OF RECLAMATION
Phoenix Area Office
P.O. Box 9980
Phoenix, Arizona 85068-0980

IN REPLY REFER TO
PXAO-1500

APR 30 1998

To: All Interested Persons, Organizations, and Agencies

From: Thomas G. Burbey
Area Manager

Subject: Finding of No Significant Impact (FONSI) and Final Environmental Assessment (EA) for the Marana High Plains Effluent Recharge Project

We have determined that construction of the Marana High Plains Effluent Recharge Project will not significantly impact the environment. A copy of Reclamation's FONSI is attached. We are working jointly with Pima County Flood Control District, Arizona Water Protection Fund, and the town of Marana to recharge 600 acre-feet of treated effluent per year for 2 years into basins covering approximately 4 acres. The purpose of the project is to investigate the feasibility of recharging treated effluent into the ground-water aquifer while simultaneously enhancing wildlife habitat opportunities associated with recharge facilities.

On August 18, 1997, copies of the draft EA were distributed to over 45 Federal, State and local agencies, organizations, and interested individuals for a 30-day public review and comment. Public notices of the availability of the draft EA were also placed in local newspapers. The EA described the environmental consequences that were anticipated to occur from constructing the proposed recharge basins.

A total of two written comment letters were received during the public comment period, which ended on September 18, 1997. Those who commented were concerned about potential bird-strike hazards and preservation of cultural resources. We responded to the comment on bird-strike hazard by developing appropriate monitoring and mitigation measures. Cultural resource sites will be avoided.

A final EA has been prepared that incorporates changes made in response to all comments received, where appropriate. The final EA also includes copies of all written comments received and our responses to these comments.

On behalf of Reclamation, I thank everyone that participated in the public scoping and document review process. Your interest in this project is appreciated. Should you have any questions regarding this matter, please contact Ms. Sandy Eto, of my staff, at PO Box 81169, Phoenix, Arizona 85069-1169, Attention: PXAO-1500, or at 602-216-3857.

Thomas G. Burbey

Attachments 2

FINDING OF NO SIGNIFICANT IMPACT

Reclamation has determined that the Marana High Plains Effluent Recharge Project (Project) will not significantly impact the environment and that preparation of an environmental impact statement is not required. This decision is based upon the following considerations.

1. The treated effluent that will be used for this proposed project is already naturally recharging the ground-water aquifer in the same vicinity. The amount of natural recharge is about 40,000 acre-feet per year.

2. This proposed action recharges a relatively small (600 acre-feet per year) quantity of effluent for demonstration purposes.

3. This proposed action can be halted at any time; effluent does not have to continue to be recharged into the ground, and the basins could be filled in.

4. The State Historic Preservation Officer concurred with Reclamation's determination of "No Effect" on cultural resources.

5. Fish and Wildlife Service did not comment on Reclamation's determination of "No Effect" on threatened and endangered species.

6. Granting of the recharge permits is an action governed by the State of Arizona. The permit process involves preparation of an application packet that requires a hydrologic report, public notice, public hearing and review, and public comment. The State permitting process considers legal and environmental issues including ground-water mounding, ground-water quality, land use impacts, and impacts to other water users.

7. Potential bird-strike hazards (bird-airplane collisions) exist in and around the Project area. Potential bird-strike hazards will be monitored, and mitigation measures will be implemented if necessary. Both the Real Property Division of Pima County, that manages the airport, and the Federal Aviation Administration were involved in developing the monitoring and mitigation plan. If bird-strike hazards are found to be higher than anticipated, the project can be terminated.

U.S. Department of Transportation
Federal Aviation Administration

Western-Pacific Region
Airports Division

P.O. Box 92007
Worldway Postal Center
Los Angeles, California 90009

JAN 1998

JAN 21 1998

Mr. Brooks A. Keenan, Director
Pima County Department of Transportation and
Flood Control District
201 North Stone Avenue, Third Floor
Tucson, Arizona 85701-1207

Dear Mr. Keenan:

Marana High Plains Effluent Recharge Project
Bird-Strike Analysis and Proposed Mitigation Plan

In response to your letter of December 29, 1997, the Federal Aviation Administration (FAA) has reviewed your "Bird-Strike Analysis and Proposed Mitigation Plan" for subject project. The FAA disagrees with your suggestion that the airport should change their flight operations as a solution to the problem. This proposed mitigation is unacceptable.

The bird monitoring plan defined on pages 9 and 10 of subject report should be inclusive to the Environmental Assessment (EA). This should be the proposed mitigation measure to reduce the potential significant impact of bird-strikes, as a result of your project.

Please provide this office a copy of the pre-final EA for our review and comment. If you should have any questions regarding the above please contact Mr. Charles B. Lieber, Airport Planner, at (310) 725-3614.

Sincerely,

Mickeal R. Agaibi
Supervisor, Planning Section

cc: Mr. Thomas Burbey, Bureau of Reclamation
Mr. Jesse Craft, Avra Valley Airport

Attachment 8

Inventory Maps of Sand and Gravel Operations and Known Groundwater Contamination Areas

Center

Attachment 8

Inventory Maps of Sand and Gravel Operations and Known Groundwater Contamination Areas

SAND AND GRAVEL OPERATIONS IN PROXIMITY TO THE
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT

North

scale 1 : 26,475

Location of Known Groundwater Contamination Sites

Legend

- Underground Storage Tank
- Leaking Underground Storage Tank (Remediation Closure Date)

LUST

Facility ID:	0-003905
Leak ID:	2028.01
Priority Level:	5R1
Facility Name:	PIMA COUNTY - AVRA VALLEY AIRPORT
Facility Address: (If blank, no physical address on file)	11700 W AVRA VALLEY RD MARANA, AZ 85653
County:	PIMA
Reported Date:	10-31-91
Date Closed:	12-16-92

Facility ID:	0-006567
Facility Name:	PIMA COUNTY - AUTO SERVICE MARANA
Facility Address: (If blank, no physical address on file)	12600 N SANDERS RD MARANA, AZ 85653
County:	PIMA
Owner Name:	PIMA COUNTY AUTOMOTIVE SERVICES
Tank ID:	4
In Use:	Yes
Closure Type:	
Closure Date:	

USTs

Facility ID:	0-006567
Facility Name:	PIMA COUNTY - AUTO SERVICE MARANA
Facility Address: (If blank, no physical address on file)	12600 N SANDERS RD MARANA, AZ 85653
County:	PIMA
Owner Name:	PIMA COUNTY AUTOMOTIVE SERVICES
Tank ID:	3
In Use:	No
Closure Type:	Removal
Closure Date:	01-01-83

Facility ID:	0-006567
Facility Name:	PIMA COUNTY - AUTO SERVICE MARANA
Facility Address: (If blank, no physical address on file)	12600 N SANDERS RD MARANA, AZ 85653
County:	PIMA
Owner Name:	PIMA COUNTY AUTOMOTIVE SERVICES
Tank ID:	2
In Use:	Yes
Closure Type:	
Closure Date:	

Facility ID:	0-006567

Table 5. Inventory of wells within one-mile radius of Project

Location	ADWR Reg. #	Owner	Name	Type	Total Depth (ft)	Screened Interval (ft)	Case Dia. (in)	Pump Cap. (gpm)	Date Const.
D-11-11 28 DDD	55-604810	CMID	--	Production	768	326-584	20	2366	Jun-78
D-11-11 32 AAD	55-615767	ASLD	--	Production	430	--	8	--	1951
D-11-11 32 ADD	55-615768	ASLD	--	Production	440	192-395	12	--	Apr-49
D-11-11 33 ACA	55-632633	Honea Water Co.	East Well	Production	500	--	10	100	Apr-64
D-11-11 33 ACB	55-632634	Honea Water Co.	West Well	Production	503	--	10	100	Aug-70
D-11-11 33 ACD	55-552996	PCFCD	--	Exploration	150	--	--	--	Nov-95
D-11-11 33 BAC	55-530762	SW Gas Corp.	--	Cathodic Protection	228	--	--	--	Feb-91
D-11-11 33 BCB	55-520129	PCWWM	SC-10	Monitor	375	300-370	6	--	May-88
D-11-11 33 CAC	55-552995	PCFCD	--	Exploration	150	--	--	--	Nov-95
D-11-11 33 CAD	55-574110	PCFCD	HP-1	Monitor	340	220-330	6	35	Sep-99
D-11-11 33 CAD	55-593607	PCFCD	HP-2	Monitor	80	70-80	6	--	Sep-02
D-11-11 33 DAA	55-615769	ASLD	--	Production	440	220-400	12	--	1951
D-11-11 34 ABA	55-594508	CMID	--	Service Well	705	--	16	2000	Sep-03
D-11-11 34 CBC	55-520182	PCWWM	SC-09	Monitor	385	290-380	6	--	Jul-99
D-12-11 03 CBB	55-557544	CAWCD	AVM W-1	Monitor	405	239-390	6	22	Jun-96
D-12-11 04 ABA	55-552994	PCFCD	--	Exploration	150	--	--	--	Nov-95
D-12-11 04 BAD	55-621877	BKW Farms	BKW #8	Production	600	--	20	3000	1953
D-12-11 04 BCC	55-621866	BKW Farms	--	Production	450	--	8	22	1960
D-12-11 05 ACC	55-542843	Management & Training	--	Production	802	--	10	300	Mar-94
D-12-11 05 ACD	55-586194		--	Non-service	830	--	8	250	Jun-01
D-12-11 05 ADA	55-573800	Gee	--	Domestic	300	--	8	35	Mar-99
D-12-11 05 ADD	55-621899	BKW Farms	--	Production	400	--	--	35	--

Sources: SAHRA, 2006. Arizona Wells. http://www.sahra.arizona.edu/wells. Data obtained in June 2007.
ADWR, 2007. Wells-55 Registry. Data obtained in June 2007.

Water Quantity Monitoring

Monitor Point	Measuring Device	Parameter	Cadastral	Location	Monitoring Frequency	Reporting Frequency
FMeq	Flow meter with totalizer[1]	Total inflow to Facility	D-11-11-33dbc	See Figure 2	Daily	Annually
FM1	Flow meter with totalizer[2]	Water inflow to Recharge Cell 1	D-11-11-33cad		Daily	Annually
FM2	Flow meter with totalizer[2]	Water inflow to Recharge Cell 2	D-11-11-33cad		Daily	Annually
FM3	Flow meter with totalizer[2]	Water inflow to Recharge Cell 3	D-11-11-33cad		Daily	Annually
FM4	Flow meter with totalizer[2]	Water inflow to Recharge Cell 4	D-11-11-33cad		Daily	Annually

[1] Magnetoflow® Mag Meter, BadgerMeter, Inc.
[2] American Sigma 950 Flow Meter with Area/Velocity Probe

Attachment 9

Revised Table 5- Inventory of Wells

Table 5. Inventory of wells within one-mile radius of Project

Location	ADWR Reg. #	Owner	Name	Type	Total Depth (ft)	Screened Interval (ft)	Case Dia. (in)	Pump Cap. (gpm)	Date Const.
D-11-11 28 DDD	55-604810	CMID	--	Production	768	326-584	20	2366	Jun-78
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D-11-11 32 ADD	55-615768	ASLD	--	Production	440	192-395	12	--	Apr-49
D-11-11 33 ACA	55-632633	Honea Water Co.	East Well	Production	500	--	10	100	Apr-64
D-11-11 33 ACB	55-632634	Honea Water Co.	West Well	Production	503	--	10	100	Aug-70
D-11-11 33 ACD	55-552996	PCFCD	--	Exploration	150	--	--	--	Nov-95
D-11-11 33 BAC	55-530762	SW Gas Corp.	--	Cathodic Protection	228	--	--	--	Feb-91
D-11-11 33 BCB	55-520129	PCWWM	SC-10	Monitor	375	300-370	6	--	May-88
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D-11-11 33 CAD	55-574110	PCFCD	HP-1	Monitor	340	220-330	6	35	Sep-99
D-11-11 33 CAD	55-593607	PCFCD	HP-2	Monitor	80	70-80	6	--	Sep-02
D-11-11 33 DAA	55-615769	ASLD	--	Production	440	220-400	12	--	1951
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D-12-11 05 ACC	55-542843	Management & Training	--	Production	802	--	10	300	Mar-94
D-12-11 05 ACD	55-586194		--	Non-service	830	--	8	250	Jun-01
D-12-11 05 ADA	55-573800	Gee	--	Domestic	300	--	8	35	Mar-99
D-12-11 05 ADD	55-621899	BKW Farms	--	Production	400	--	--	35	--

Sources: SAHRA, 2006. Arizona Wells. http://www.sahra.arizona.edu/wells. Data obtained in June 2007.
ADWR, 2007. Wells-55 Registry. Data obtained in June 2007.

Attachment 10

Water Level Monitoring, Alert Levels and Operation Prohibition Limits

Water Level Monitoring, Alert Levels and Operation Prohibition Limits

Monitor Point	ADWR Registration Number	Cadastral Location	Well Elevation (feet amsl)	Well Depth (feet bls)	Screened Interval (feet bls)	Measuring Device	Monitoring Frequency	Reporting Frequency	Alert Water Level (feet bls)	Operation Prohibition Limit (feet bls)
HP-1	55-574110	D(11-11) 33cad	1985.17	330	220-330	Sounder	Monthly	Annually	30	20
HP-2	55-593607	D(11-11) 33cad	1986.75	80	70-80	Sounder	Monthly	Annually	30	20
SC-09	55-520182	D(11-11) 34cbc	1991.54	385	290-380	Sounder	Quarterly	Annually	30	20
SC-10	55-520129	D(11-11) 33bcb	1978.07	375	300-370	Sounder	Quarterly	Annually	30	20
AVMW-1	55-557544	D(12-11) 03cbb	2014.70	405	239-390	Pressure Transducer	Quarterly	Annually	30	20

amsl – above mean sea level
bls – below land surface

Attachment 11

Flow Measuring Devices and Manufacturers' Specifications

Magnetoflow® Mag Meter	Flanged Meter with Model Primo® 3.1	Installation & Operation Manual

IMPORTANT !!!! This manual contains important warnings and information. READ AND KEEP FOR REFERENCE.

BadgerMeter, Inc.

IOM-089-03
53400-089
5-06

SCOPE OF THIS MANUAL

This manual contains information concerning the installation, operation and maintenance of Badger's Magnetoflow® electromagnetic flow meter models with Primo® Amplifier.

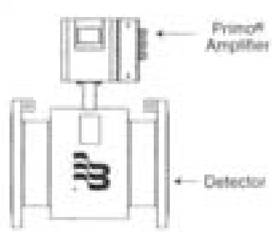
To ensure proper meter performance, the instructions given in this manual should be thoroughly understood. Keep a copy of this manual in a readily accessible location for future reference.

TABLE OF CONTENTS

SYSTEM DESCRIPTION

Magnetoflow® electromagnetic flow meters are intended for fluid metering in most industries including water, wastewater, food and beverage, pharmaceutical and chemical.

The basic components of an electromagnetic flow meter are two: 1) The Detector; which includes the flow tube, isolating liner and measuring electrodes, and 2) the Amplifier, which is the electronic device responsible for the signal processing, flow calculation, display and output signals.



The materials of construction of the wetted parts (liner and electrodes) should be appropriate for the specifications on the intended type of service. Review of the compatibilities consistent with the specifications is recommended.

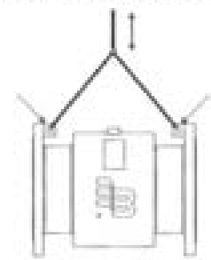
All Badger's Magnetoflow mag flow meters are factory tested and calibrated. A calibration certificate is included in the shipment of each meter.

UNPACKING AND INSPECTION

Magnetoflow mag flowmeters are shipped in special shipping containers. Upon receipt of the meter, perform the following unpacking and inspection procedures. If damage to the shipping container is evident, be present when the meter is unpacked.

A) Carefully open the shipping container following any instructions that may be marked on the exterior. Remove all cushioning material surrounding the meter.

B) Carefully lift the meter from the container. Always use the lifting lugs provided for safety on meter sizes 10" and larger.



C) Retain the shipping box or crate and all packing materials for possible use in reshipment or storage.

D) Visually inspect the meter for any physical damage such as scratches, loose or broken parts, or any other sign of damage that may have occurred during shipment.

NOTE: If damage is found, request an inspection report by the carrier's agent within 48 hours of delivery. Then file a claim with the carrier. A formal claim for equipment damaged in transit is the responsibility of the customer.

E) Verify that the meter received is consistent with the product ordered. The detail on the product labels on the detector and the amplifier should help this verification.

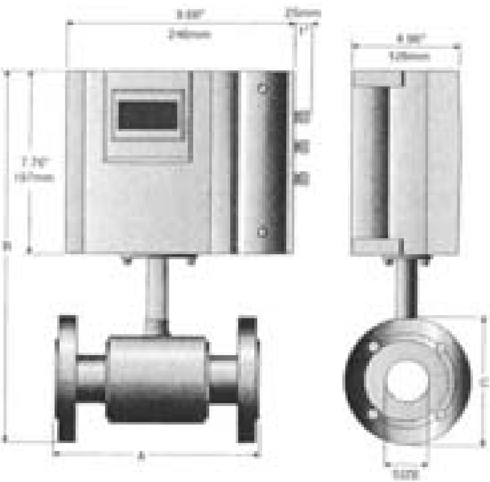
F) All detectors with PTFE liner are shipped from the factory with a liner protector. This protector maintains the proper form of the PTFE material and protects it during shipping and storage. Do not remove this protector until you are ready to install the unit.

G) Storage: If the meter is not to be immediately installed, store it in its original container in a dry, sheltered location. Storage temperature: -4 to 158 °F (-20 to 70 °C)

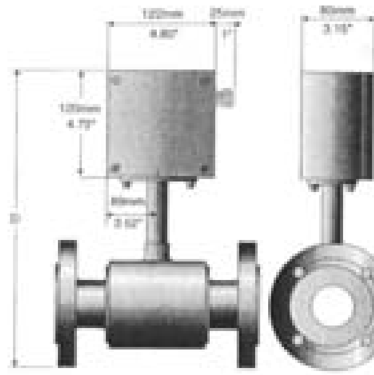
TRANSPORTATION AND HANDLING

Do not lift the detector from the amplifier housing, the junction box or the connecting cable. As noted earlier, use lifting lugs for larger sizes.

Very large meter sizes are packed and crated with the meter laying on its side for shipping safety and stability reasons. In order to lift the meter in vertical position, it's recommended to use a sling rigged method as shown below.



Meter with Primo®



Meter with junction box for remote Primo®

Size		A		B		C		D		Est. Weight with Primo		Flow Range			
												LPM		GPM	
inch	mm	inch	mm	inch	mm	inch	mm	inch	mm	Lbs	Kg	Min	Max	Min	Max
1/4	6	6.7	170	14.0	356	3.5	89	11.4	288	12	5.5	0.063	20	0.02	5
5/16	8	6.7	170	14.0	356	3.5	89	11.4	288	12	5.5	0.114	34	0.03	9
3/8	10	6.7	170	14.0	356	3.5	89	11.4	288	12	5.5	0.177	53	0.05	14
1/2	15	6.7	170	14.0	356	3.5	89	11.4	288	12	5.5	0.416	125	0.11	33
3/4	20	6.7	170	14.2	361	3.9	99	11.5	293	15	6.5	0.75	225	0.2	59
1	25	8.9	225	14.4	366	4.3	108	11.7	298	20	9.0	1.20	350	0.3	93
1 1/4	32	8.9	225	15.2	386	4.6	117	12.5	318	22	10.0	2.00	575	0.5	152
1 1/2	40	8.9	225	15.4	390	5.0	127	12.7	322	23	10.5	3.00	900	0.8	239
2	50	8.9	225	15.9	403	6.0	152	13.2	335	28	12.5	4.70	1400	1	373
2 1/2	65	11.0	280	17.1	434	7.0	178	14.4	366	54	24.5	8	2400	2	631
3	80	11.0	280	17.3	440	7.5	191	14.7	372	56	25.5	12	3600	3	956
4	100	11.0	280	18.4	466	9.0	229	15.7	398	58	26.5	19	5600	5	1493
5	125	15.8	400	19.6	498	10.0	254	16.9	430	60	27.0	30	8800	8	2334
6	150	15.8	400	20.6	524	11.0	279	17.9	456	62	28.0	40	12700	11	3361
8	200	15.8	400	22.5	572	13.5	343	20.4	518	88	40.0	75	22600	20	5975
10	250	19.7	500	26.8	681	16.0	406	24.1	613	180	82.0	120	35300	30	9336
12	300	19.7	500	28.9	734	19.0	483	26.2	666	209	95.0	170	50800	45	13444
14	350	19.7	500	30.8	782	21.0	533	28.2	716	260	118	230	69200	60	18299
16	400	23.6	590	33.7	856	23.5	597	31.0	788	308	140	300	90400	80	23901
18	450	23.6	590	35.0	890	25.0	635	32.4	822	287	130	380	114000	100	30250
20	500	23.6	590	38.2	969	27.5	699	35.5	901	495	225	470	140000	125	37346
22	550	23.6	590	39.6	1005	29.5	749	36.9	937	441	200	570	170000	150	45188
24	600	23.6	590	42.2	1071	32.0	813	39.5	1003	554	252	680	200000	180	53778
28	700	23.6	590	46.2	1173	36.5	927	44.0	1118	650	295	920	275000	240	73100
30	750	31.5	800	48.3	1228	39.0	984	45.7	1161	704	320	1060	315000	280	84000
32	800	31.5	800	52.2	1325	41.4	1015	49.5	1257	770	350	1200	361000	320	95600
36	900	31.5	800	55.3	1405	46.0	1168	54.1	1374	850	386	1500	457000	400	121000
40	1000	31.5	800	60.0	1525	50.2	1230	57.4	1457	924	420	1900	565000	500	149300
42	1050	36.0	800	66.0	1675	53.0	1346	63.4	1610	1100	500	2100	620000	550	164600
48	1200	39.4	1000	69.9	1775	59.4	1455	67.2	1707	1210	550	2700	814000	720	215100
54	1400	39.4	1000	78.5	1995	68.4	1675	75.9	1927	1364	620	3700	1100000	980	292700

SPECIFICATIONS - Detector

Flow Range: 0.1 - 39.4 fps (0.03-12 m/s)
Sizes: 1/4" to 54" (6 to 1400 mm)

Min. Conductivity: ≥ 5 micromhos/cm

Accuracy: ± 0.25% accuracy of rate from 1-33 fps.
± 0.5% accuracy of rate from 0.1-1.0 fps.

Electrode Materials: Standard: Alloy C
Optional: 316 Stainless Steel, Gold/Platinum Plated, Tantalum, Platinum/Rhodium

Liner Material: PTFE up to 24", Soft and Hard Rubber from 1" to 54", Halar® from 14" to 40"

Fluid Temperature:
With Remote Converter:
PTFE & Halar 311°F, (155°C)
Rubber 176°F, (80°C)
With Meter Mounted Converter:
PTFE & Halar 212°F, (100°C)
Rubber 176°F, (80°C)

Pressure Limits: 150 psi (10Bar) optional 300psi (20Bar)
Coil Power: Pulsed DC

Ambient Temperature: -4°F to 140°F, (-20°C to 60°C)
Pipe Spool Material : 316 Stainless Steel
Optional: Submersible NEMA 6P/1167 (Remote Amplifier Required) tested at 1.8m (6 feet) for 24 hours
Meter Housing Material: Carbon Steel welded
Flanges: Carbon Steel - Standard (ANSI B16.5 Class 150 RF)
316 Stainless Steel - Optional
Meter Enclosure Classification: Nema 4
Junction Box Enclosure Protection: (For Remote Converter Option) Powder coated die-cast aluminum, Nema 4
Cable Entries: 1/2" NPT Cord Grip
Optional Stainless Steel Grounding Rings:

Meter Size	Thickness (of one ring)
up thru 10"	.135"
12" to 20"	.187"

Chapter 1

Introduction

Overview of 950 Flow Meter

The SIGMA 950 is a portable flow meter which is complete and self-contained. With its rugged environmentally-sealed construction, the 950 is completely sealed — even with the door open. Conforming to NEMA 4X, 6 standards, the 950 also survives submersion and corrosive gases — again, with its door open. This means that access to the meter's controls is no problem in manholes, rain, and other harsh weather conditions.

The SIGMA 950 Flow Meter is suitable for the measurement and recording of flow in open channels, full pipes, submerged flow and surcharged lines.

- **Area Velocity/Bubbler**
- **Area Velocity/Submerged Sensor**

A maintenance free paperless chart recorder allows fast, on-site review of historical data.

In addition to its extensive data logging capabilities, the SIGMA 950 Flow Meter is capable of the following:

- **Enabling a sampler**
- **Pacing a sampler**
- **Controlling four external devices with N.O./N.C. relays**
- **Controlling two external devices with 4-20 mA current outputs**

Communications capabilities include a standard RS-232 port and an optional on-board modem for remote data transfer and internal embedded program updates using state of the art "Flash Memory" technology.

SIGMA's 950 flowmeter also provides Supervisory Control And Data Acquisition (SCADA) Communication Interface functionality using the Modbus® ASCII protocol. This software protocol communicates with the 950 via a standard RS-232 or modem connection.

Using American Sigma's InSight® data analysis software or VISION® integrated sewer system management software, 950 meters can be downloaded, remote programmed, and contribute to other data manipulation functions via and RS-232 cable connection or the optional modem.

To secure access to the meter's functionality and data, an operator may invoke password security access to the front-panel keypad via the keypad or password security access to the meter via InSight® and VISION® software or both front-panel and software security. Front panel and software password security operate independently of each other. Front panel operations are

Specifications

General

- Dimensions: 13.5" H x 10.0" W x 9.5" D (34.3 cm x 25.4 cm x 24.1 cm).
- Weight: 11 lbs. (5 kg) not including power source.
- Enclosure: NEMA 4X,6 with front cover open or closed. UV resistant, stable from -40° F to 176° F (-40° C 80° C).
- Temperature: Storage from -40° to 176° F (-40° C to 80° C). Operate from 14° F to 150° F (-10° C to 65.5° C).
- Power Requirements: 12 VDC supplied from 6 amp-hr. gel or 4 amp-hr. Ni-Cad battery - 115 VAC, 230 VAC or 100 VAC power supply/battery charger.
- Graphics Display: Back-lit liquid crystal display (LCD), auto-off when not in use (under battery operation). 8 line x 40 character in text mode, 60 x 240 pixels in graphics mode.
- Keypad: 21-position sealed-membrane switch with blinking green LED to indicate power on. Four "soft keys," functions defined by display.
- Totalizers: 8-digit resetable and 8-digit non-resetable software. 6-digit non-resetable mechanical †. Units - ft^3, gal, M^3, liter, acre-ft.
- Time Base Accuracy: ± 0.007%
- Measurement Modes:

  Flumes - Parshall, Palmer Bowlus, Leopold-Lagco, H, HL, HS, Trapezoidal
  Weirs - V-notch, Contracted/Non-contracted rectangular, Thel-mar, Cipolletti
  Manning Equation: Round, U and Rectangular Channels
  Flow Nozzle: California Pipe
  Head vs. Flow: Custom programmable curve of up to 100 points.
  Level only: Inches, Feet, Centimeters, Meters
  Power Equation: $Q=K_1H^{n1} \pm K_2H^{n2}$
  Area Velocity: Level-Area Table, Circular Pipe, U-Shaped Channel, Trapezoidal Channel, Rectangular Channel.

- Datalogging: "Smart" Dynamic memory allocation automatically partitions memory to provide the maximum logging time. No manual memory partitioning required.

  Memory Mode: Either slate or wrap-around may be selected.

- Material: PVC housing with PVC acoustic window.
- Cable: 4 conductor with integral stainless steel support cable
- Cable Length: Custom lengths to 850'(259 m) (contact factory for longer lengths).
- Crystal Specification: 50 KHz, 11.5° included beam angle.
- Dimensions (transducer only): 4.125" H x 2.75" D (10.5 cm x 7 cm).

Velocity Transducer

- Method: Doppler Principle
- Accuracy: ±2% of reading; Zero Stability: ± 0.05 fps (±1.52 cms)
- Range: -5 to +20 fps (-1.52 m to 6.1 m)
- Resolution: 0.01 fps (0.3 cms)
- Response time: 4.8 seconds
- Profile Time: 4.8 seconds
- Probe Dimensions:

Length: 3.65 inches (9.27 cm)

Width: 1.5 inches (3.81 cm)

Height: 0.72 inches (1.83 cm)

- Cable: Urethane Jacket

(2x) RG174U Coax Cables

(4x) #22 AWG Copper Stranded

- Cable Length: 25' (7.6 m).

Submerged Area Velocity Probe

- Method: Doppler Principle / Pressure Transducer

Velocity

- Velocity Accuracy:

2% of reading; Zero Stability: <0.05 fps (<0.015 m/s)

- Response time: 4.8 sec
- Profile Time: 4.8 sec
- Range: -5 to +20 fps (-1.52 m to 6.1 m/s)

Attachment 12

Modeling Response

Modeling (I and I Response-Marana High Plains)

Bullet #1 Page 31 of our application, paragraph 3, describes in detail the incorporation of the nearby recharge facilities. However, we will outline a similar approach after having discussions with ADWR Hydrology. In all these analytical approaches, we have superimposed the effects of 20 years of recharge at the MHP Facility at 600 AF/yr, using the Well & Pit Model, over the mounding effects from the other recharge facilities depicted in modeling studies for LSCRP and LSCMRP. In discussions with ADWR Hydrology a request was made for us to send the executable file and the output files of the Well and Pit Model (Molden, Sunada and Warner 1984). We have sent that to you for your use and review. It compares favorably to THWells and other analytical models, but is specifically designed for mounding, using a modification of Glover's Solution for mounding from rectangular basins. (See Attachment 12-1). The input parameters were derived from previous investigations in the areas described on p.26 of our original submittal. Several 24-hour aquifer tests in the vicinity yielded transmissivities of 200,000 and 184,000 gpd/ft (HLA, 1995). Montgomery, 2002a reported using a hydraulic conductivity of 100 ft/dy in their model for the LSCRP to calibrate the model more efficiently and from cuttings evaluations that confirmed higher values. We chose a conservative transmissivity value of 125,000 gpd/ft (16,700 ft^2/dy) and a specific yield of 0.18 for the Well & Pit Model.

Several models have been used to evaluate the mounding of CAP and effluent recharge in the vicinity of the MHP Facility. These models are similarly based on the numerical Modflow model for all three of the nearby facilities, including The Lower Santa Cruz Replenishment Facility (LSCRP; # 71-561366; Montgomery, 2002a); and the Lower Santa Cruz Managed Recharge Facility (# 71-591928; Montgomery, 2002b). Moreover, the estimated effects of other recharge facilities in the vicinity is a large over- estimation since the Lower Santa Cruz Replenishment Facility (LSCRF) is only allowed a total of 600,000 AF for the 20-year permit period, but 50,000 AF in any one year. Therefore, we will use the hydrograph presented in Montgomery (2002a, Figure 17) (Attachment 12-2a) that shows the rise of the mound after 12 years at 50,000 AF (see Attachment 2a). The mound after 12 years rises to approximately 90 % of the mound projected at 20 years (Attachment12-2a). Assuming a similar **maximum** rise at Marana High Plains Facility as a result of CAP recharge after 12 years at 50,000 AF/yr, the mound at MHP Facility would rise approximately 113 feet (90% of 126ft; Attachment 12-2b).

Montgomery's 2002b Modflow simulation of the LSCMRF showed an approximate water level recovery of 44 feet below the MHP site after 20 years (Attachment12-3-Figure 25). Based on review of four hydrographs in the vicinity of the LSCRP and MHP Facility (Attachments12-4-12-7) we were able to separate the regional water level recovery effects from the effects of the recharging effluent dominated Santa Cruz River before (1981-1995) permitting of the LSCMRF and from the prior regional recovery from the CAP recharge sites. That difference is shown in Table 1, and   indicates a regional recovery trend over and above the Santa Cruz River effluent recharge contribution of approximately 0.55 ft/yr, or 11 feet in 20 years (Table 1).

Superimposing the effects of a regional water level recovery of 11 feet in 20 years, 113 feet of recovery from the LSCRP (12 years at 50,000 AF/yr) and CAP Avra, and the 4-foot rise from 20-years at MHP, the overall water level beneath the MHP Facility is estimated at approximately 14 feet below the site after 20 years of operation with a total recovery of 172 feet. Table 2 summarizes these results. The current depth to water at the MHP point of compliance well is 186 ft bls.

Table 1. Regional Recovery Without Santa Cruz River Recharge

Well Location D(T,R)Sec.	Change. (ft)	ave.Cg. (ft./yr.)	20 yr Proj* (ft.)	20yr Proj (ft./yr.)	Diff(ft/yr)
D(12-11) 9DBB	+29.4 (84-95)	+2.7	42	2.1	0.6
D(12-11) 9ADD	+ 35.2 (84-95)	+3.2	44	2.2	1.0
D(12-11) 7BCC	+ 27.0 (84-95)	+2.4	32	1.6	0.8
(12-11) 7CDD	+ 20.4 (81-95)	+1.4	32	1.6	-0.2

Average Regional Recovery without Santa Cruz River Recharge +0..55 ft./yr**

*Recovery based on Montgomery 2002b Fig 25, 20-yr. recovery contours from LSCMRF at well location
** Regional recovery after 20-years of 11 feet

Table 2.

Results of Cumulative Mounding Beneath MHP Basins from Recharge Facilities and Regional Recovery in the MHP Vicinity	Mound Height. (Ft)
Marana High Plains Recharge (600 AF/yr for 20yr)[1]	4
Lower Santa Cruz Replenishment Project(50,000 AF/yr for 12yr; Avra Facility 11,000 AF/yr for 12 yr)[2]	113
Lower Santa Cruz Managed Recharge Project (5AF/mi/dy for 20 years)[3]	44
Regional Water Level Trend (0.55 ft/yr for 20 yr)[4]	11
Total Mound Height Beneath MHP Ponds (20 years)	172
Depth to Water beneath MHP ponds (2007)	186

1 Derived from Well & Pit modeling
2 Derived from Montgomery LSCRP Modeling Report 2002a
3 Montgomery 2002b model report for LSCMRP, Figure 25 (Attachment 12-3)
4 ADWR hydrographs 1981-95 minus LSCMRP effects from Fig 25 Montgomery 2002b

This assessment is a very conservatively worst case mounding analysis. This scenario assumes no regional well recovery of recharged CAP or effluent, and no baseline pumping in the area. **It also assumes no water level decline or leveling after recharge of 50,000 AF/yr of CAP stops at 12 years at LSCRP**. This scenario is highly unlikely because of significant projected population growth in the Marana area, continued irrigation pumping, CAP's projected plan to recover CAP during canal shortages and the LSCMRF Stakeholders recovering effluent in the vicinity.

We also reviewed the Tres Rios del Norte Project Groundwater Flow Modeling of Effluent Recharge Alternatives B, C and D prepared by Errol L Montgomery and Associates (2002c) This model (TRDN model) is a modification of the ADWR predictive flow model (Mason and Bota,2006) as of 2002, and included local calibration of the ADWR model from Roger Road to Trico Road along the Santa Cruz River area. MHP Facility and other facilities mentioned above were included as modeling inputs based on their ADWR permitted amounts. LSCRP was 30,000AF/yr from 2002-2025. The AVRP input was 11,000/yr 2002-2025. The MHP Facility only had inputs for 2001-2002. However, our Well & Pit Model shows a 4-foot rise at Marana High Plains from recharge of 600 AF/yr for 20 years. Alternative B is generally considered the most likely scenario by local water managers, including ones from Tucson Water, Bureau of Reclamation and Pima County (owners of over 90+% of the effluent in the River). Alternative B simulates effluent recharge resulting from discharge of all effluent from the Roger Road and the Ina Road Wastewater Treatment Facilities from 2000-2025 This amount was the same as the ADWR –TAMA predictive model 1994-1999 of 47,431 AF/yr. The TRDN model, Alternative B, shows a maximum water surface elevation of 1830 ft msl at the Marana High Plains Facility. **Adding the 4-feet of rise from Marana High Plains recharge over 20 years, the depth to water is estimated at approximately 146 feet bls by the year 2026 or 1834 ft msl.**

Finally, we reviewed the ADWR Predictive Flow Model (Mason and Bota, 2006). The model presents a Base Case using all the inputs of the associated recharge facilities in the vicinity of the MHP facility. The resulting ADWR Base Case analysis indicates the resulting depth to groundwater at the Marana High Plains Facility will be on the edge of the 100 feet bls contour (see figure 39 Modeling Report). **Assuming a 4-foot rise from MHP recharge over 20 years, depth to water at the MHP site is predicted at 96 feet bls**.

In summary, we evaluated the cumulative effects of the Marana High Plains 20-year recharge of 600 AF/yr using the scientific community accepted Well &Pit Model (Attachment 12-1; Molden, Sunada and Warner 1984) . We then superimposed the mounding effects from Marana High Plains over the predicted mounding effects of the other recharge Facilities in the area based on the computer models from previous CAP and managed recharge projects in the vicinity of MHP. This analysis demonstrated that water levels would not mound to the surface after 20-years of recharge. In addition to this worst-case analysis, we also superimposed the 4-foot water level rise from the 20-year, 600 AF/yr MHP recharge upon two additionally accepted regional models. These results also demonstrated that the recovery beneath the MHP facility would not mound to the surface.

References

Errol Montgomery and Associates. 2002a. *Groundwater Flow Modeling In Support of Application for Modification to Underground Storage Facility No. 71-561366, Lower Santa Cruz Replenishment Project, Pima County Arizona.* April 23.

Errol Montgomery and Associates. 2002b. *Groundwater Flow Modeling In Support of Application for Modification to Underground Storage Facility Permit No. 71-591928, Lower Santa Cruz Managed Recharge Project, Pima County Arizona.*

Errol Montgomery and Associates. 2002c. *Groundwater Flow Modeling of Effluent Recharge Alternatives B,C and D, Tres Rios del Norte Project, Pima County Arizona.* October.

Harding Lawson Associates.1995. *Arizona Department of Water Resources, Tucson Arizona, Northwest Area Hydrologic Study.* May 14.

Mason, D. and Bota, L. 2006. *Arizona Department of Water Resources Regional Groundwater Flow Model of the Tucson Active Management Area, Tucson, Arizona: Simulation and Application.* Modeling Report No. 13. Hydrology Division, Phoenix, Arizona.

Molden, D. Sunada, D.K., and Warner, J.W. 1984. *Microcomputer Model of Artificial Recharge Using Glover's Solution.* Vol. 22, No. 1. Ground Water. January.

Attachments 12-1 through 12-7

Attachment 12-1

Microcomputer Model of Artificial Recharge Using Glover's Solution

by D. Molden, D. K. Sunada, and J. W. Warner[a]

ABSTRACT

An interactive program written for an APPLE II+ 48K computer is presented which solves Glover's (1960) analytical solution for recharge from a rectangular basin. The program is capable of graphically displaying the rise and decline of the recharge mound for either an infinite homogeneous medium or for a stream aquifer system.

INTRODUCTION

Advances in technology are rapidly increasing the speed and storage capabilities of microcomputers, enabling them to perform more tasks that were previously reserved for main frame computers. But, unlike the many programs available for main frame computers, at present there are relatively few ground-water programs available for microcomputers. The program presented here is a model of artificial recharge, written in BASIC for use on the APPLE II+ 48K microcomputer (APPLE II+ is a trademark of APPLE computer). Glover's (1960) solution for a rectangular basin with a constant recharge rate and the principle of superposition are used to model the growth and decline of a recharge mound in the cases of an infinite, homogeneous aquifer and for a stream aquifer system. The model can also be used to calculate discharge from the recharge basin into a stream for various times. The results of the model are displayed both graphically and numerically. The program is interactive, allowing for easy data input and program execution.

Analytical solutions have been derived for the problem of artificial recharge from circular and rectangular recharge basins and for various assumed initial and boundary conditions (Baumann, 1952; Glover, 1960; Hantush, 1967; Hunt, 1971; Rao and Sarma, 1981). Most of these analytical solutions have not been used extensively by practicing hydrologists because the solutions often involve complex integrals which are poorly behaved and difficult to evaluate (Sunada *et al.*, 1982). Handheld programmable calculators are capable of solving many simple problems, such as those involving the well function. However, the analytical solutions for artificial recharge are typically too complex and impractical to solve on handheld calculators. Conventional solution of the artificial recharge problem on large main frame computers has been by numerical methods, such as finite-difference and finite-element methods. The microcomputer is ideally suited to solve many types of problems, such as that of artificial recharge, which do not require the enormous capabilities of the main frame computer. The advent of the microcomputer has added greater importance and usefulness of many analytical solutions, such as that for artificial recharge. The increasing capabilities of microcomputers coupled with their increasing personal availability, primarily due to their decreasing cost, are destined to make the microcomputer an indispensable tool of the hydrologist.

MATHEMATICAL BASIS OF RECHARGE FROM RECTANGULAR SOURCES

Glover's (1960) solution for constant recharge from a rectangular basin (Figure 1) has the form

$$H = \frac{Rt}{4S}\int_0^1 \left(\operatorname{erf}\frac{u_2}{\sqrt{\tau}} - \operatorname{erf}\frac{u_1}{\sqrt{\tau}}\right)\left(\operatorname{erf}\frac{u_4}{\sqrt{\tau}} - \operatorname{erf}\frac{u_3}{\sqrt{\tau}}\right)d\tau \quad (1)$$

where

$$u_1 = \left(\frac{x - W/2}{4T/St}\right) \qquad u_2 = \left(\frac{x + W/2}{4T/St}\right)$$

$$u_3 = \left(\frac{y - L/2}{4T/St}\right) \qquad u_4 = \left(\frac{y + L/2}{4T/St}\right)$$

and

H = mound height (L),

R = recharge rate (L/T),

S = storage coefficient (dimensionless),

T = transmissivity (L^2/T),

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Received February 1983, revised October 1983, accepted October 1983.

Discussion open until July 1, 1984.

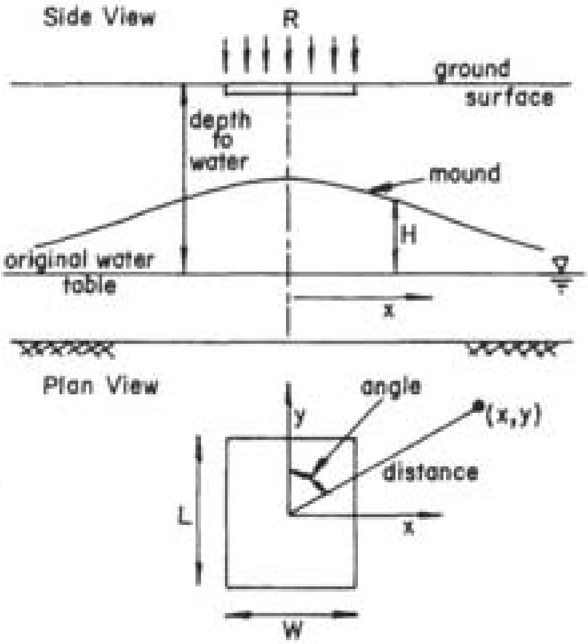

Fig. 1. Definition sketch of artificial recharge from a rectangular basin.

W = basin width (L),

L = basin length (L),

x,y = Cartesian coordinates (L),

t = time (T),

τ = dummy variable of integration,

erf(u) = error function.

Glover's solution is for a homogeneous, isotropic unconfined aquifer with constant recharge and an initially horizontal water table. For Glover's solution to be valid, the mound rise should be small compared to the initial saturated thickness of the aquifer.

To utilize Glover's solution it is necessary to evaluate the integral in equation (1). This integral is difficult to solve which is a major reason why Glover's solution is not used more extensively by practicing hydrologists. Both Simpson's rule in 10 steps and Gaussian Quadrature with up to 20 points (Abramowitz and Stegun, 1972) were tried to solve equation (1) directly, but neither method gave completely satisfactory results over a large range of data inputs. In evaluating Glover's solution, Simpson's rule applied directly to equation (1) gave the least satisfactory solution. Gaussian Quadrature applied directly to equation (1) gave satisfactory answers in most but not all cases that were simulated.

Hantush (1967) provides a better means of evaluating equation (1) by integration by parts. Performing the multiplication indicated in equation (1), Glover's solution is written as

$$H = \frac{Rt}{4S}\left[\int_0^1 \operatorname{erf}\frac{u_2}{\sqrt{\tau}}\operatorname{erf}\frac{u_4}{\sqrt{\tau}}\,d\tau - \int_0^1 \operatorname{erf}\frac{u_2}{\sqrt{\tau}}\operatorname{erf}\frac{u_3}{\sqrt{\tau}}\,d\tau - \int_0^1 \operatorname{erf}\frac{u_1}{\sqrt{\tau}}\operatorname{erf}\frac{u_4}{\sqrt{\tau}}\,d\tau + \int_0^1 \operatorname{erf}\frac{u_1}{\sqrt{\tau}}\operatorname{erf}\frac{u_3}{\sqrt{\tau}}\,d\tau\right]. \quad (2)$$

Hantush shows that the integrals in equation (2) can be evaluated as

$$\int_0^1 \operatorname{erf}\frac{u_i}{\sqrt{\tau}}\operatorname{erf}\frac{u_j}{\sqrt{\tau}}\,d\tau = \operatorname{erf}(u_i)\operatorname{erf}(u_j) + (4/\pi)\,u_i u_j W(u_i^2 + u_j^2) + (2/\sqrt{\pi})\,[u_i e^{-u_i^2}\operatorname{erf}(u_j) + u_j e^{-u_j^2}\operatorname{erf}(u_i)] - 2\,[u_i^2 M^*(u_i, u_j) + u_j^2 M^*(u_j, u_i)] \quad (3)$$

where

$$M^*(u_i, u_j) = \frac{u_j}{\pi u_i}\int_{-1}^{1}\frac{\exp[-u_i^2(1 + r^2)]}{1 + r^2}\,dv \quad (4)$$

$$r = (v + 1)\frac{u_j}{2u_i} \quad (5)$$

and W(u) = well function.

For implementation of equation (2) on the microcomputer, expressions for the error function and well function are used and the integral in the function M* is numerically evaluated by Gaussian Quadrature. In the program the error function is evaluated by a polynomial approximation (Abramowitz and Stegun, 1972).

For $u \geq 0$, the error function is given by

$$\operatorname{erf}(u) = 1 - (e_1 b + e_2 b^2 + e_3 b^3 + e_4 b^4 + e_5 b^5)e^{-u^2} \quad (6)$$

where

$b = 1/(1 + pu)$	$e_4 = -1.453152027$
$e_1 = .254829592$	$e_5 = 1.06140543$
$e_2 = -.284496736$	$p = .3275911$
$e_3 = 1.421413741$	

and $\operatorname{erf}(-u) = -\operatorname{erf}(u)$. The error in equation (6) is in the order of 10^{-7}.

The well function is found by approximations given by Huntoon (1980) and Abramowitz and Stegun (1972). For values of $u \leq 1$, the program uses

$$W(u) = a_0 - \ln(u) + a_1 u + a_2 u^2 + a_3 u^3 + a_4 u^4 + a_5 u^5 \quad (7)$$

where

$a_0 = -.57721566 \qquad a_3 = \ .05519968$

$a_1 = \ .99999193 \qquad a_4 = -.00976004$

$a_2 = -.24991055 \qquad a_5 = \ .00107857.$

For values of $1 \leq u \leq \infty$, the program uses

$$W(u) = \frac{1}{u\exp(u)} \, \frac{u^4 + b_1u^3 + b_2u^2 + b_3u + b_4}{u_4 + c_1u^3 + c_2u^2 + c_3u + c_4} \qquad (8)$$

where

$b_1 = \ 8.57332874 \qquad c_1 = \ 9.57332235$

$b_2 = 18.0590170 \qquad c_2 = 25.6329561$

$b_3 = \ 8.63476089 \qquad c_3 = 21.0996531$

$b_4 = \ .267773734 \qquad c_4 = \ 3.95849692$

In the program the integral in M* is evaluated using six-point Gaussian Quadrature given by

$$M^*(u_i, u_j) = \frac{u_j}{\pi u_i} \sum_{k=1}^{6} \frac{\exp[-u_i^2(1+r^2)]}{1+r^2} \cdot V_k \qquad (9)$$

where

$$r \quad = (A_k + 1)\frac{u_j}{2u_i}, \qquad (10)$$

A_k = abscissas of Guassian Quadrature,

V_k = weights of Guassian Quadrature.

The abscissas and weights are

$A_1 = -A_6 = 0.238619186 \qquad V_1 = V_6 = 0.467913935$

$A_2 = -A_5 = 0.661209386 \qquad V_2 = V_5 = 0.360761573$

$A_3 = -A_4 = 0.932469514 \qquad V_3 = V_4 = 0.171324492$

USE OF SUPERPOSITION

The principle of superposition (McWhorter and Sunada, 1977) is used to obtain additional solutions for the case of a finite aquifer or for the case of a variable recharge rate. Superposition in time is used to calculate the decline of the recharge mound after recharge is stopped. With a stream in the vicinity, superposition in space is used to calculate mound profile and discharge to the stream with time.

At the end of the recharge period an image basin at the same location as the real basin begins withdrawal (negative recharge) while the real basin continues to recharge. The mound height due to the real basin is added to the drawdown due to the discharging image basin to give the actual mound height:

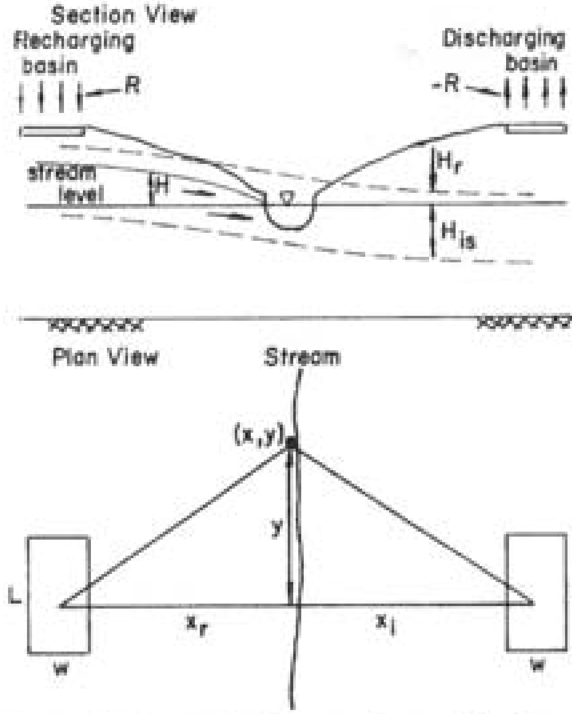

Fig. 2. Definition sketch of the use of superposition when a stream is in the vicinity (x_r = real x coordinate; x_i = image x coordinate).

$$H = H_r + H_{it} \qquad (11)$$

where

H_r = mound height contribution from the real basin,

H_{it} = mound height contribution from the image basin superimposed in time.

If a stream is in the vicinity, an image discharging basin is set up on the opposite side of the stream equidistant from the real basin (Figure 2). The drawdown from the image basin is superimposed onto the mound height contribution from the real basin to give the actual mound height

$$H = H_r + H_{is} \qquad (12)$$

where

H_{is} = drawdown contribution from the image basin superimposed in space.

If the end of the recharge period has been reached and a stream is in the vicinity, an image basin at the same location as the real basin begins discharging and another image basin at the same location as the image basin opposite the stream begins recharging. The mound height at a selected location is given by

$$H = H_r + H_{is} + H_{it} + H_{its} \tag{13}$$

where

H_{its} = mound height contribution from the image basin superimposed in time and space.

DISCHARGE TO THE STREAM

The integral equation for flow to a stream is (McWhorter and Sunada, 1977)

$$Q_T = \int_{-\infty}^{\infty} (T \frac{\partial H}{\partial x}) \, dy \tag{14}$$

where

Q_T = total discharge to the stream (L^3/T).

The integral is evaluated numerically by computing the integrand at selected intervals along the stream and integrating the distribution by the method of trapezoids. The numerical evaluation yields the expression for discharge

$$Q_T = 2 \sum_{i=1}^{n} \frac{[(T \, \partial H/\partial x)_{i-1} + (T \, \partial H/\partial x)_i] \, \Delta y_i}{2} \tag{15}$$

where

Δy_i = the interval between points i-1 and i along the length of the stream,

n = number of locations that stream discharge per unit length was calculated.

The value of n is selected by the program so that the discharge between locations n-1 and n is less than 0.1% of the total discharge calculated up to location n. The quantity $\partial H/\partial x$ is approximated by computing the mound height at 1 foot away from the stream denoted by H^1. Because the head at the stream is constant and known (selected to be zero in this case) the discharge is approximated by

$$Q_T = T \sum_{i=1}^{n} [H^1_{i-1} + H^1_i] \, \Delta y_i. \tag{16}$$

Figure 3 is a plot of discharge to the stream vs. time, with values obtained from the program using the data in Figure 5.

PROGRAM DESCRIPTION

Taking full advantage of the capabilities of the microcomputer, this interactive program is written to be self-explanatory and easy to use. The graphics are employed for quick visual study. An example run is described to demonstrate the flow of the program. The figures represent what would be shown on the screen.

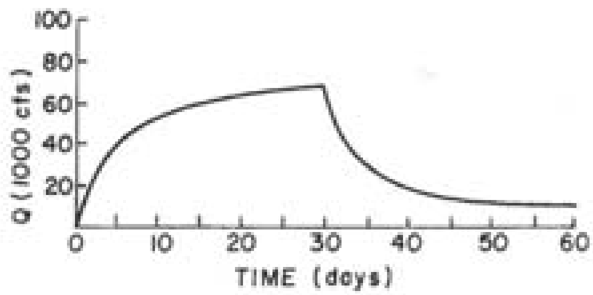

Fig. 3. Discharge to the stream vs. time.

The program can be easily operated by persons with very little knowledge of computers, yet many advantages of computer use are available. The program works by a "turn key" system; that is, the disk containing the program is inserted, the computer turned on and the program execution begins. The user is prompted at each step, often with a variety of options. Data are easily entered or changed; results are quickly obtained and readily compared.

When starting the program, a menu presents the user with selection of model options (Figure 4). For our example, option 1 is selected to model artificial recharge in an aquifer with a fully penetrating stream. The recharge parameters and their values are then displayed on the screen (Figure 5). To change a value, the number corresponding to the recharge parameter to be changed is input. The old value is displayed and the user asked to input a new value (Figure 6). The updated parameter list is again displayed and the process repeated until Ø is typed. The program then checks for any value which is out of range. A message will inform the user if there are any mistakes and appropriate values must be entered. With no mistakes, the program begins execution.

```
            ARTIFICIAL RECHARGE

OPTIONS

        1) STREAM IN VICINITY

        2) NO STREAM IN VICINITY

        3) READ FILES

        4) EXIT

TYPE THE NUMBER OF YOUR CHOICE 1
```

Fig. 4. Screen display. Model options: artificial recharge will be modeled with a stream in the vicinity.

In this example, both mound profile and discharge to the stream are calculated. As values for head are calculated at selected distance they are plotted on the graphics screen with the values of time, distance and mound height shown beneath the plot (Figure 7). Upon completion of the plot, the user is asked to type C to continue. The graphics screen is then cleared and discharge to the stream is calculated. The display gives the distance along the stream, the mound height at one foot away from the stream, and the discharge per unit length at that point as the points are calculated (Figure 8). When the discharge per unit length becomes negligible, the total discharge to the stream is given.

To reexamine and study the problem, the user is presented with a variety of output options (Figure 9). The "data display" option gives a list of the recharge parameters used. The "results display" tabulates the numerical values of the results. A hard copy of the data and results can be obtained with the "results printout" option. The graphics are quickly recreated by the "graphics display" option. Data and results can be stored on the disk

```
 1) RECHARGE RATE (FT/DAY)              2
 2) TRANSMISSIVITY (SQ.FT/DAY)          2500
 3) SPECIFIC YIELD                      .2
 4) BEGINNING TIME (DAYS)               30
    FINAL TIME (DAYS)                   30
    TIME INCREMENT (DAYS)               30
 5) END OF RECHARGE PERIOD (DAYS)       30
 6) BEGINNING DISTANCE (FT)             0
    FINAL DISTANCE (FT)                 500
    DISTANCE INCREMENT (FT)             50
 7) DEPTH TO WATER (FT)                 30
 8) BASIN WIDTH (FT)                    200
 9) BASIN LENGTH (FT)                   200
10) ANGLE FROM LENGTH AXIS (DEG)        0
11) DISTANCE TO STREAM                  250
12) CALCULATE MOUND PROFILE             YES
13) CALCULATE DISCHARGE TO STREAM       YES

TYPE THE NUMBER OF THE VARIABLE YOU
WISH TO CHANGE. TYPE 0 IF YOU WISH
TO CONTINUE WITHOUT CHANGING. 7
```

Fig. 5. Screen display. Parameter display: the depth to water will be changed.

```
DEPTH TO WATER = 30 FEET


INPUT NEW DEPTH TO WATER 20
```

Fig. 6. Screen display. The depth to water is changed from 30 to 20 feet.

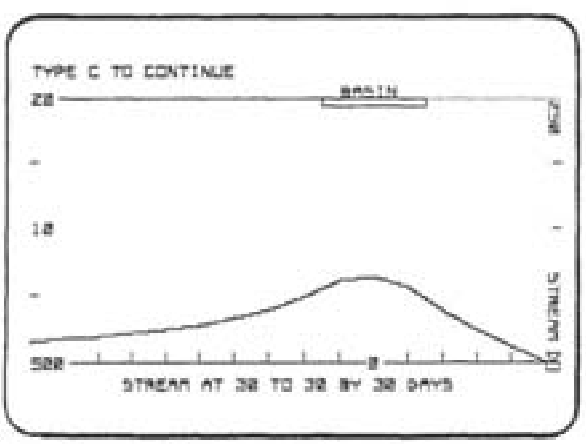

Fig. 7. Screen display. Mound profile at 30 days.

```
                DISCHARGE TO STREAM

        DISTANCE        HEAD        DISCHARGE/
         ALONG           AT            UNIT
         STREAM        1 FOOT         LENGTH
          (FT)          (FT)       (SQ.FT/DAY)

30 DAYS

         0            .03881         97.03
         50           .03739         93.48
         100          .03353         83.83
         200          .02329         58.23
         400          9.86E-03       24.65
         800          2.35E-03       5.88
         1600         3.2E-04        .8
         3200         0              0

TOTAL DISCHARGE = 68000 CUBIC FT./DAY
```

Fig. 8. Screen display. Discharge to the stream at 30 days.

```
OPTIONS

     1) DATA DISPLAY

     2) RESULTS DISPLAY

     3) GRAPHICS DISPLAY

     4) RESULTS PRINTOUT

     5) CREATE FILE

     6) ANOTHER RUN

     7) EXIT

TYPE THE NUMBER OF YOUR CHOICE 5
```

Fig. 9. Screen display. Output options: create file is chosen to store data on the disk.

Fig. 10. Screen display. Read files: the file "no stream" is read from the disk.

with the "create file" option. The "another run" option allows the user to go back to the original model option, retaining all the present values of the recharge parameters. The "create files" option is chosen and the name given to the file is "stream."

Next, the "another run" option is chosen and the original recharge option appears (Figure 4). "Read files" is then selected and the name of the file to be read is entered (Figure 10). The previously made file "no stream" is read from the disk. This file has exactly the same recharge parameters as "stream" but simulates recharge in an infinite aquifer. After the file has been read, the list of output options again appears on the screen with the exception that "create file" has been changed to "read another file." Up to 10 files can be read and simultaneously stored in memory. "Read another file" is chosen to read in the file "stream."

To compare the influence of a stream, the graphics will demonstrate any difference in mound profile. The "graphics display" option is chosen. The program has the capability of plotting several sets of points on the same graph enhancing comparison of solutions. "No stream" is chosen and plotted. The "graphics display" option is again chosen with "stream" to be plotted. The program asks if the same plot is to be used. In this manner, "stream" (dotted line) and "no stream" are plotted on the same graph (Figure 11). With a stream in the vicinity, the mound height is lower than an infinite aquifer and not symmetric around the center basin.

Glover (1960) also presents a solution for recharge from a circular basin using instantaneous slug injections. A comparison was made between the mound profile under a square basin using the data of "no stream" and a circular basin of the same area (Figure 12). Using 250 instantaneous injections took over 100 times the execution time required by the rectangular basin program, yet gave approximately the same solution, showing that this program could also be used to simulate recharge from a circular basin.

DISCUSSION

To calculate one point on the recharge mound takes about 13 seconds in interpreted basic and 6 seconds in compiled basic. To get a good graphical representation of the recharge mound height, it is usually adequate to calculate about 10 to 20 points, and total time of execution is usually only a few minutes. Memory requirements are not restrictive, as the program takes about 25K bytes of random access memory leaving about 15K bytes of memory for variables and 8K bytes for graphics

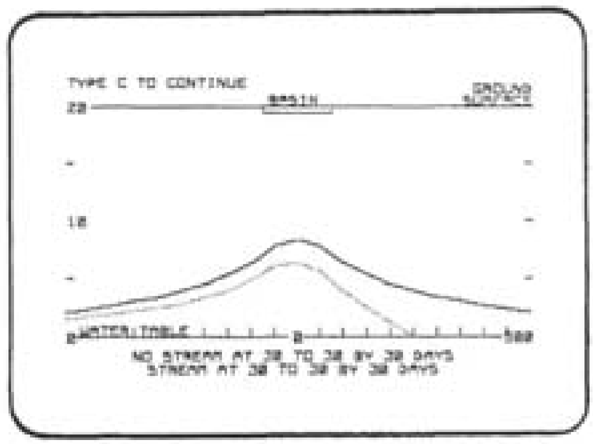

Fig. 11. Screen display. "Stream" (dotted line) and "no stream" are plotted on the same graph.

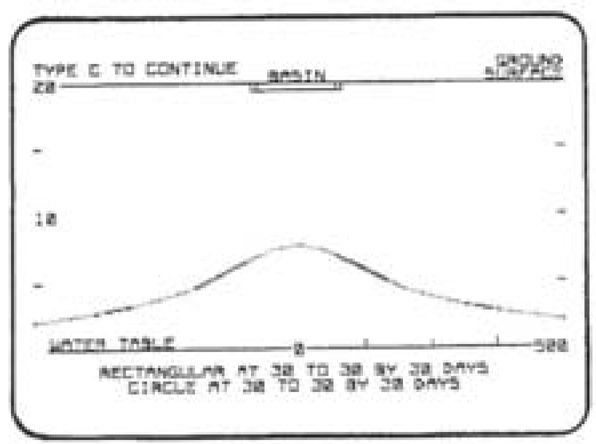

Fig. 12. Square basin (solid line) vs. circular basin (dotted line). The solution for the circular basin almost completely overlaps the solution for a rectangular basin.

in a 48K computer. The compiled version requires additional storage and will run on a 64K computer.

A major problem faced by hydrologists is to reduce the complex mathematical equations used in the study of ground water into results that can be readily understood by lay persons interested in water. By making programs which are very "user friendly" and which make extensive use of graphics, the ground-water hydrologist is much better able to communicate with nontechnical water users. This program was developed as part of a demonstration of artificial recharge in the San Luis Valley, Colorado, in cooperation with several local irrigation districts. The graphics features of the microcomputer were well suited to describe the effects of artificial recharge to nontechnical water users.

Using the program, the effects of various recharge strategies can be quickly investigated. For example, the user can study the effects of changing basin geometry, changing recharge rates and changing duration of recharge. The effects of different soil characteristics and boundary conditions can also be easily studied. The comparison of results for different case studies is enhanced by the capability of the program to plot several different case studies on the same graph.

CONCLUSIONS

The advent of microcomputers has given ground-water hydrologists another choice of tools for problem solving. The microcomputer is well suited to solve many types of problems, such as that of artificial recharge, which do not require the enormous capabilities of the large main frame computer. By making programs which are very "user friendly" and which make extensive use of graphics, the ground-water hydrologist is much better able to give a clear understanding of his results to the nontechnical water user. The program presented in this paper is one example of a large number of problems which could be solved on a microcomputer.

ACKNOWLEDGMENTS

The authors would like to thank the Office of Water Resources Technology and the Colorado State University Experiment Station Project 1-51101 for funding this project.

NOTE

A program listing is available, and can be obtained by request to *Ground Water*. A floppy disk for the APPLE II+ and documentation is available at duplication and mailing cost (approximately $20). Every effort has been made to provide an error-free program, but the authors do not take responsibility for any errors which may have been overlooked.

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* * * * *

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James W. Warner is an Assistant Professor of Civil Engineering in the ground-water program at Colorado State University. Formerly he worked as a ground-water hydrologist with the U.S.G.S. He has taught courses in ground water, ground-water modeling and basic engineering.

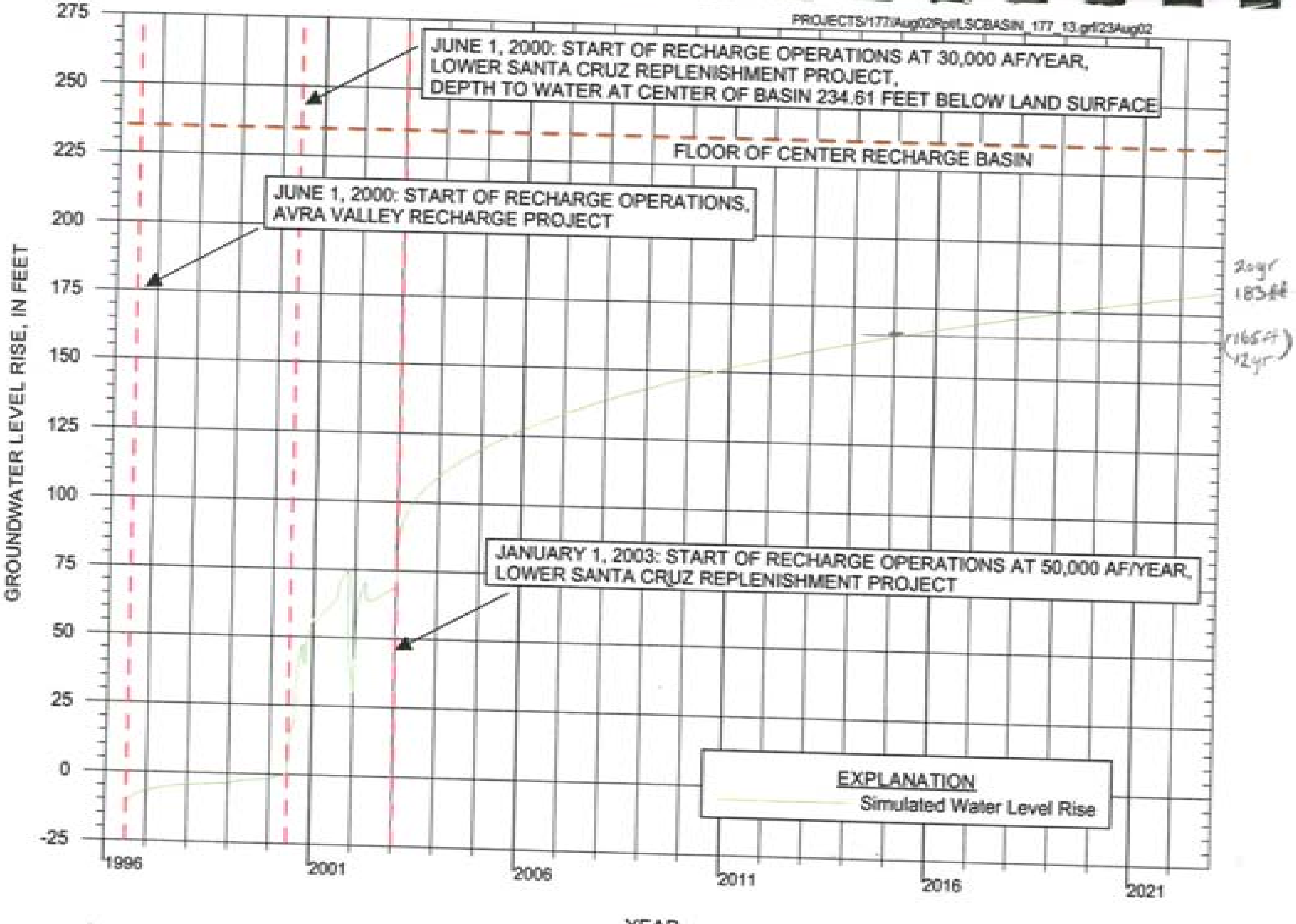

FIGURE 17. HYDROGRAPH OF SIMULATED GROUNDWATER LEVEL RISE AT CENTER OF RECHARGE BASINS, LOWER SANTA CRUZ REPLENISHMENT PROJECT, PIMA COUNTY, ARIZONA

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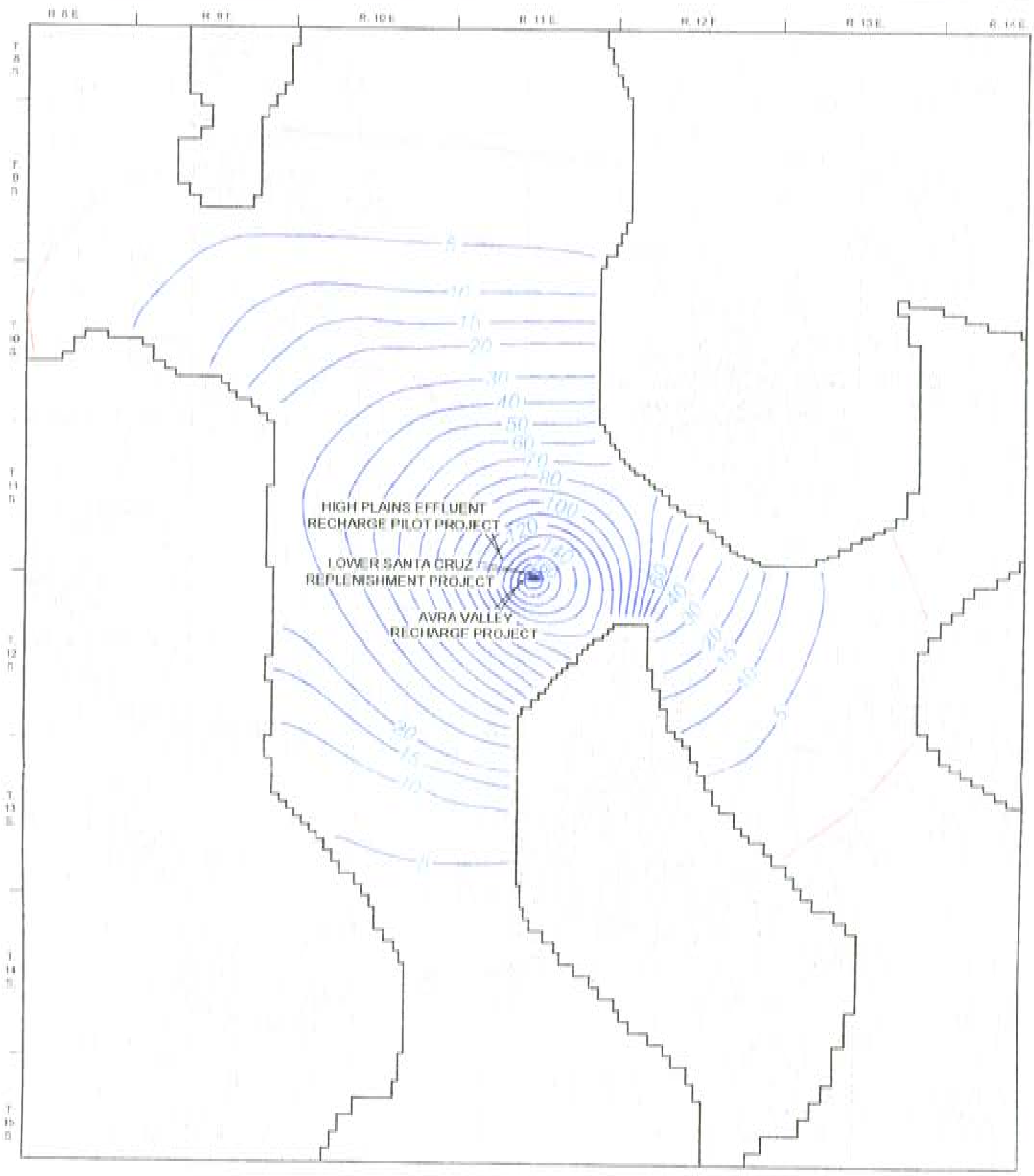
Attachment 12-2A



EXPLANATION

CONTOUR OF PROJECTED GROUNDWATER LEVEL RISE, in feet

EXTENT OF PROJECTED MAXIMUM AREA OF IMPACT

ACTIVE GRID CELLS IN GROUNDWATER FLOW MODEL

INACTIVE GRID CELLS IN GROUNDWATER FLOW MODEL

CENTRAL ARIZONA WATER CONSERVATION DISTRICT
LOWER SANTA CRUZ REPLENISHMENT PROJECT
PIMA COUNTY, ARIZONA

REGIONAL PROJECTED GROUNDWATER LEVEL RISE AND MAXIMUM AREA OF IMPACT AT END OF FULL-SCALE RECHARGE OPERATIONS

ERROL L. MONTGOMERY & ASSOCIATES, INC. 2002
CONSULTANTS IN HYDROGEOLOGY
TUCSON, ARIZONA

FIGURE 18

Attachment 12-3

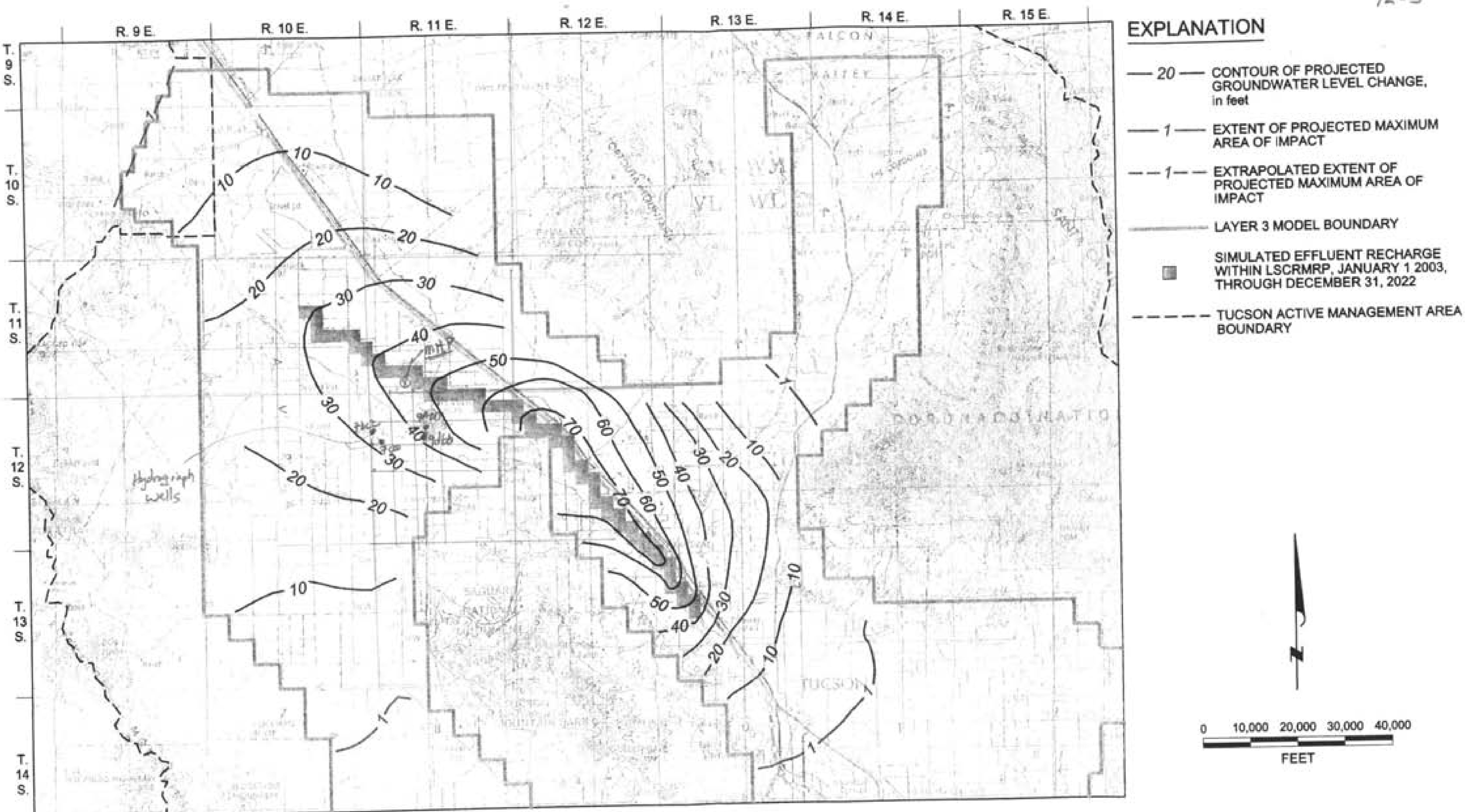


FIGURE 25. PROJECTED MAXIMUM AREA OF IMPACT AND GROUNDWATER LEVEL CHANGE RESULTING FROM EFFLUENT RECHARGE FROM JANUARY 1, 2003 THROUGH DECEMBER 31, 2022, WITHIN LOWER SANTA CRUZ RIVER MANAGED RECHARGE PROJECT (LSCRMRP), PIMA COUNTY, ARIZONA

ERROL L. MONTGOMERY & ASSOCIATES, INC.

153/Projected-GWLevel-Change-Maximum-Impact/23April2002 -- Topo CD: Tucson East

12-4

ARIZONAWELLS

General

GWSI Site

Site Type	W-WELL	Meridian	G-GILA AND SALT RIVER
Reliability	C-FIELD CHECKED		
Topo Setting	V-VALLEY FLAT	Source	USGS-UNITED STATES GEOLOGICAL SURVEY
Quad name	MARANA	Map Scale	024000

DMS- Lat/Lon

	Deg	Min	Sec
Lat	32	24	8.0
Lon	111	13	29.0
Lat/Lon Accuracy	2-TWO SECONDS	Lat/Lon Method	-

DEC- Lat/Lon

Lat	32.402222	Lon	-111.224722

Altitude

Altitude	2013.37	Method	M-MAP	Alt Accuracy	005

Basin/Location

USGS Basin	AVR-AVRA VALLEY
Sub Basin	TUC-TUCSON AMA
ADWR Basin	AVR-AVRA VALLEY
State	AZ-ARIZONA
County	19-PIMA
Cadastral	D(12-11)09 DBB

Well Information

Hole Depth	585.0	Depth Code	D-DRILLER		
Well Depth	585.0	Geo Unit		55 RegNo	615832

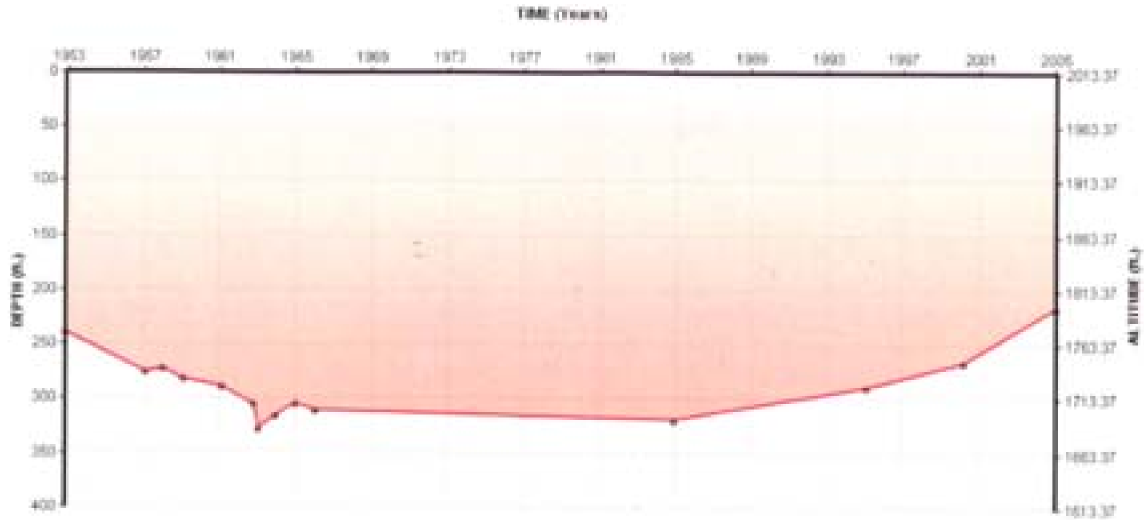
Site Uses		Water Uses		Last Update/User	
Use 1	W-WITHDRAWAL	Use 1	I-IRRIGATION	Last Update	07/02/2002
Use 2	-	Use 2	-	Last Operator	WRRLB
Use 3	-	Use 3	-	Create Date	02/24/1979

12-4

ARIZONAWELLS

General | Wtr. Level | Meas. Point | Remark | Const. |Owner | Lift/Pump | Logs | Other ID | Inventory | Pump Dis. | Flow Dis. | Water Quality | Spring

Water Level



Depth to water of well 322410111132501

Date	Depth to Water (ft.)	Method	Remark	Source	Altitude (ft.)
11/03/1952	240.3	Steel Tape (S)		USGS (U)	1773.07
01/31/1957	276.54	Steel Tape (S)		USGS (U)	1736.83
01/02/1958	273.25	Steel Tape (S)		USGS (U)	1740.12
01/30/1959	282.75	Steel Tape (S)		USGS (U)	1730.62
02/03/1961	289.72	Steel Tape (S)		USGS (U)	1723.65
10/12/1962	305.96	Steel Tape (S)		USGS (U)	1707.41
01/24/1963	328.48	Steel Tape (S)		USGS (U)	1684.89
01/29/1963	328.48	Steel Tape (S)		USGS (U)	1684.89
12/31/1963	316.34	Steel Tape (S)		USGS (U)	1697.03
01/13/1965	304.9	Steel Tape (S)		USGS (U)	1708.47
01/20/1966	311.51	Steel Tape (S)		USGS (U)	1701.86
11/28/1984	319.6	Electric Sounder (V)		ADWR (A)	1693.77
01/24/1995	290.2	Electric Sounder (V)		ADWR (A)	1723.17
02/25/2000	267.2	Electric Sounder (V)		ADWR (A)	1746.0
01/19/2005	216.6	Electric Sounder (V)		ADWR (A)	1796.77

General | Wtr. Level | Meas. Point | Remark | Const. |Owner | Lift/Pump | Logs | Other ID | Inventory | Pump Dis. | Flow Dis. | Water Quality | Spring

+ 2.7 ft/yr (84 − 95)

0.76 (66 − 95)

2.7 (84-95)
2.1 SLK MRF effects (Fig. 25 Report) (42ft/20yr) } attach. 12-3
0.6 ft/yr.

0.6 ft/yr. Regional effects

12-5

ARIZONAWELLS

General

GWSI Site

Site Type	W-WELL	Meridian	G-GILA AND SALT RIVER
Reliability	C-FIELD CHECKED		
Topo Setting	V-VALLEY FLAT	Source	USGS-UNITED STATES GEOLOGICAL SURVEY
Quad name	MARANA	Map Scale	024000

DMS- Lat/Lon

	Deg	Min	Sec
Lat	32	24	10.0
Lon	111	13	0.0
Lat/Lon Accuracy	2-TWO SECONDS	Lat/Lon Method	-

DEC- Lat/Lon

Lat	32.402778	Lon	-111.216667

Altitude

Altitude	2022.0	Method	M-MAP	Alt Accuracy	010

Basin/Location

USGS Basin	LSC-LOWER SANTA CRUZ BASIN
Sub Basin	TUC-TUCSON AMA
ADWR Basin	AVR-AVRA VALLEY
State	AZ-ARIZONA
County	19-PIMA
Cadastral	D(12-11)09 ADD

Well Information

Hole Depth	520.0	Depth Code	D-DRILLER		
Well Depth	520.0	Geo Unit		55 RegNo	604339

Site Uses		Water Uses		Last Update/User	
Use 1	W-WITHDRAWAL	Use 1	C-COMMERCIAL	Last Update	06/29/2004
Use 2	-	Use 2	-	Last Operator	WRRLB
Use 3	-	Use 3	-	Create Date	01/08/1979

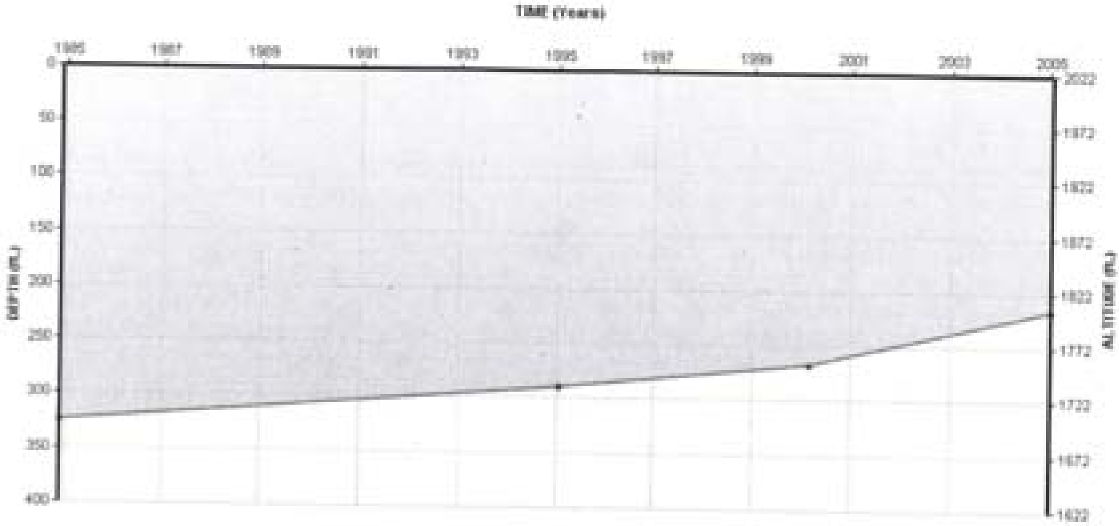
General | Wtr. Level | Meas. Point | Remark | Const. |Owner | Lift/Pump | Logs | Other ID | Inventory | Pump Dis. | Flow Dis. | Water Quality | Spring

12-5

ARIZONAWELLS

General | Wtr. Level | Meas. Point | Remark | Const. |Owner | Lift/Pump | Logs | Other ID | Inventory | Pump Dis. | Flow Dis. | Water Quality | Spring

Water Level



Depth to water of well 322418111130201

Date	Depth to Water (ft.)	Method	Remark	Source	Altitude (ft.)
11/27/1984	325.0	Electric Sounder (V)		ADWR (A)	1697.0
01/26/1995	290.2	Electric Sounder (V)		ADWR (A)	1731.8
02/28/2000	267.5	Electric Sounder (V)		ADWR (A)	1754.5
01/20/2005	216.9	Electric Sounder (V)		ADWR (A)	1805.1

General | Wtr. Level | Meas. Point | Remark | Const. |Owner | Lift/Pump | Logs | Other ID | Inventory | Pump Dis. | Flow Dis. | Water Quality | Spring

3.2 ft/yr. (84-95)
2.2 ft/yr LSCMRF → Figure. 25 LSCMRF Report (Attach 12-3)
1.0 ft/yr. Regional recovery trend.

12-6

ARIZONAWELLS

General | Wtr. Level | Meas. Point | Remark | Const. |Owner | Lift/Pump | Logs | Other ID | Inventory | Pump Dis. | Flow Dis. | Water Quality | Spring

General

GWSI Site

Site Type	W-WELL	Meridian	G-GILA AND SALT RIVER
Reliability	C-FIELD CHECKED		
Topo Setting	V-VALLEY FLAT	Source	USGS-UNITED STATES GEOLOGICAL SURVEY
Quad name	WEST OF MARANA	Map Scale	024000

DMS- Lat/Lon

	Deg	Min	Sec
Lat	32	24	9.0
Lon	111	15	34.0
Lat/Lon Accuracy	2-TWO SECONDS	Lat/Lon Method	-

DEC- Lat/Lon

Lat	32.4025	Lon	-111.259444

Altitude

Altitude	1983.0	Method	M-MAP	Alt Accuracy	020

Basin/Location

USGS Basin	AVR-AVRA VALLEY
Sub Basin	TUC-TUCSON AMA
ADWR Basin	AVR-AVRA VALLEY
State	AZ-ARIZONA
County	19-PIMA
Cadastral	D(12-11)07 BCC

Well Information

Hole Depth	550.0	Depth Code	D-DRILLER		
Well Depth	550.0	Geo Unit		55 RegNo	615830

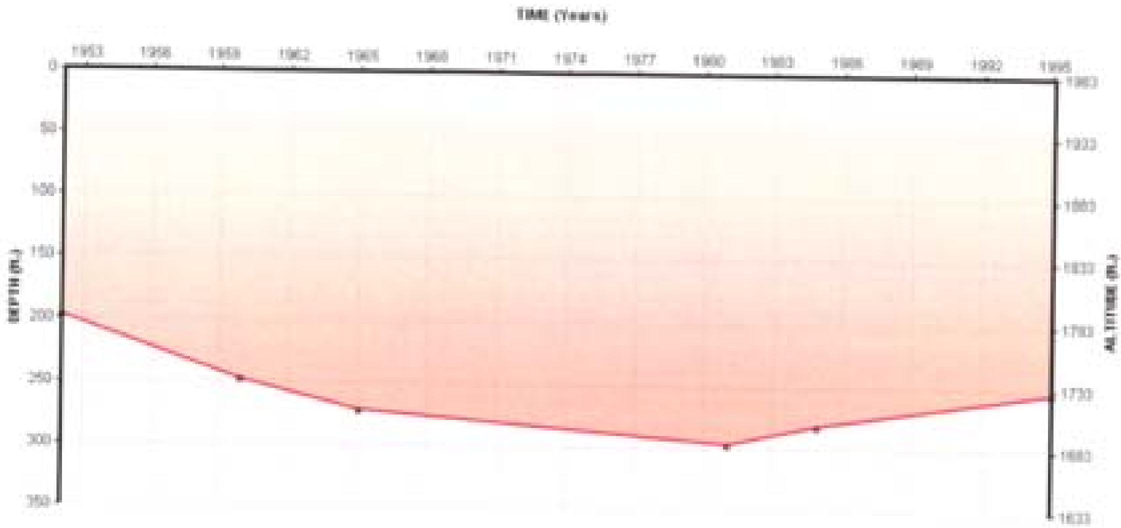
Site Uses		Water Uses		Last Update/User	
Use 1	W-WITHDRAWAL	Use 1	I-IRRIGATION	Last Update	03/12/2002
Use 2	-	Use 2	-	Last Operator	WRBAH
Use 3	-	Use 3	-	Create Date	02/24/1979

General | Wtr. Level | Meas. Point | Remark | Const. |Owner | Lift/Pump | Logs | Other ID | Inventory | Pump Dis. | Flow Dis. | Water Quality | Spring

12-6

ARIZONAWELLS

Water Level



Depth to water of well 322409111154001

Date	Depth to Water (ft.)	Method	Remark	Source	Altitude (ft.)
02/10/1952	198.5	Steel Tape (S)		USGS (U)	1784.5
12/01/1959	248.46	Steel Tape (S)		USGS (U)	1734.54
01/15/1965	272.34	Electric Tape (T)		USGS (U)	1710.66
01/07/1981	297.0	Electric Sounder (V)		ADWR (A)	1686.0
11/28/1984	281.9	Electric Sounder (V)		ADWR (A)	1701.1
01/23/1995	254.9	Electric Sounder (V)		ADWR (A)	1728.1

General | Wtr. Level | Meas. Point | Remark | Const. |Owner | Lift/Pump | Logs | Other ID | Inventory | Pump Dis. | Flow Dis. | Water Quality | Spring

2.4 ft/yr. 84-95
3 ft/yr. 81-95

2.4
1.6 LSCMRP effects (32ft/20yr)
0.8 ft/yr.
Regional effect

12-7

ARIZONAWELLS

General | Wtr. Level | Meas. Point | Remark | Const. |Owner | Lift/Pump | Logs | Other ID | Inventory | Pump Dis. | Flow Dis. | Water Quality | Spring

General

GWSI Site

Site Type	W-WELL	Meridian	G-GILA AND SALT RIVER
Reliability	C-FIELD CHECKED		
Topo Setting	V-VALLEY FLAT	Source	USGS-UNITED STATES GEOLOGICAL SURVEY
Quad name	WEST OF MARANA	Map Scale	024000

DMS- Lat/Lon

	Deg	Min	Sec
Lat	32	23	42.0
Lon	111	15	36.0
Lat/Lon Accuracy	2-TWO SECONDS	Lat/Lon Method	-

DEC- Lat/Lon

Lat	32.395	Lon	-111.26

Altitude

Altitude	1991.0	Method	M-MAP	Alt Accuracy	020

Basin/Location

USGS Basin	AVR-AVRA VALLEY
Sub Basin	TUC-TUCSON AMA
ADWR Basin	AVR-AVRA VALLEY
State	AZ-ARIZONA
County	19-PIMA
Cadastral	D(12-11)07 CDD

Well Information

Hole Depth	606.0	Depth Code	D-DRILLER		
Well Depth	606.0	Geo Unit		55 RegNo	618429

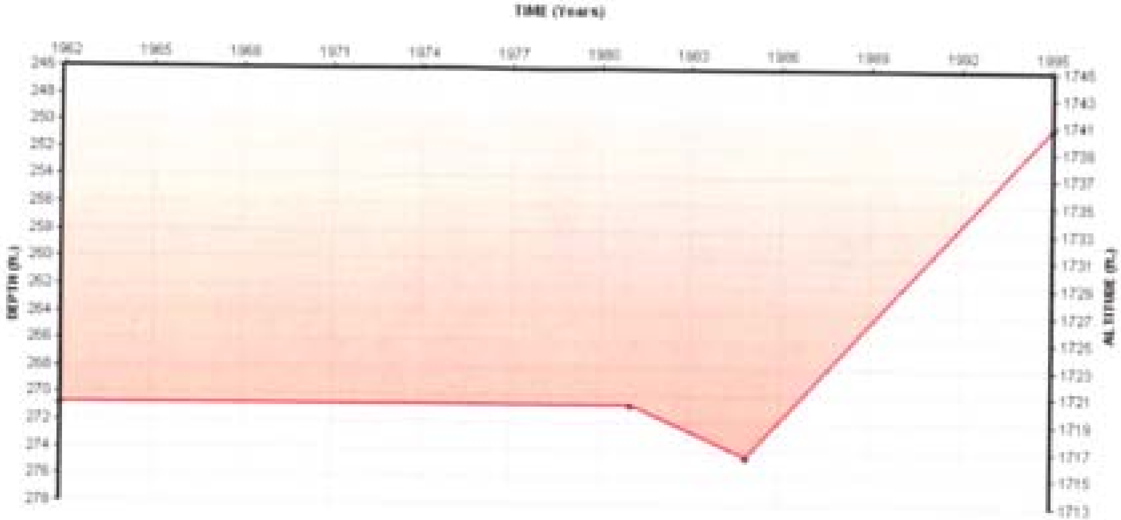
Site Uses		Water Uses		Last Update/User	
Use 1	W-WITHDRAWAL	Use 1	I-IRRIGATION	Last Update	03/12/2002
Use 2	-	Use 2	-	Last Operator	WRBAH
Use 3	-	Use 3	-	Create Date	01/08/1979

General | Wtr. Level | Meas. Point | Remark | Const. |Owner | Lift/Pump | Logs | Other ID | Inventory | Pump Dis. | Flow Dis. | Water Quality | Spring

12-7

ARIZONAWELLS

Water Level



Depth to water of well 322345111154101

Date	Depth to Water (ft.)	Method	Remark	Source	Altitude (ft.)
12/01/1961	270.8	Steel Tape (S)	UNDETERMINED (*)	USGS (U)	1720.2
01/07/1981	270.7	Electric Sounder (V)	UNDETERMINED (*)	ADWR (A)	1720.3
11/28/1984	274.5	Electric Sounder (V)	UNDETERMINED (*)	ADWR (A)	1717.0
01/23/1995	250.3	Electric Sounder (V)	UNDETERMINED (*)	ADWR (A)	1741.0

General | Wtr. Level | Meas. Point | Remark | Const. |Owner | Lift/Pump | Logs | Other ID | Inventory | Pump Dis. | Flow Dis. | Water Quality | Spring

1.4 ft/yr. 81 – 95
1.3 ft/yr. 84 – 95

1.4 ft/yr (81-95)
1.6 ft/yr LSCMLP (ft/32/20yr) (Attach 123)
– 0.2 ft/yr.
regional effects