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**DATE:** July 10, 1991

**SUBJECT:** Results of Pilot Project Operations and Infiltration Tests--  
Brawley Wash

**PROJECT:** PHX21325.10

The purpose of this memorandum is to document the evaluation of basin infiltration rates at the Brawley Wash Pilot Project. To accomplish this purpose, this memorandum will discuss the following topics:

- Background of the project
- Data collection
- Basin operation
- Infiltration rates
- Evaporation rates
- Conclusions and recommendations

## BACKGROUND

### INTRODUCTION

The Brawley Wash Pilot Project, depicted in Figure 1, was operated from February 19, 1990, through January 31, 1991. The objective of the pilot project was to determine site suitability for a potential full-scale basin recharge facility located at Brawley Wash. To accomplish this objective, data were collected to determine infiltration rates for different soil conditions, potential for perching water in the vadose zone, water level response of the aquifer, and changes in water quality.

### BASIN CONSTRUCTION

The Brawley Wash Pilot Project was designed with four testing basins and two waste basins as illustrated in Figure 1. Initial construction included Basins 2 and 4, and the waste basin adjacent to Basin 4. Results from the first 6 months of operation indicated that minimal value would be obtained from the additional construction of Basins 1 and 3. Therefore, these basins have not been constructed.

Basins 2 and 4 were constructed at different depths to assess the infiltration rates through different soil profiles. A soils investigation was conducted by a soil scientist using a backhoe. Fourteen test pits were excavated to a depth of approximately 130 inches. The investigation revealed a soil profile generally consisting of silty loams to a depth of 85 to 108 inches, underlain by gravel and coarse sands.

Ring infiltrometer tests were conducted at various depths to determine variability of infiltration rates with depth. The tests revealed that infiltration rates in the silty loam soil ranged between 0.38 and 2.98 ft/day and the gravel and coarse sandy soil averaged 21.6 ft/day. From these results, it was decided to construct Basin 2 in the silty loam soil at a depth of 48 inches, and Basin 4 in the gravel and coarse sandy soil at a depth of 120 inches. The expected infiltration rates for Basins 2 and 4 were 1 and 20 ft/day, respectively.

### WATER SUPPLY

An existing production well (AF-64) with an estimated capacity of 700 gpm was used to supply the testing recharge water source. Two pumping conditions were considered as potential design concepts. The first was intermittent pumping. This concept required on and off controls to maintain supply to the basin in operation. The second condition was continuous pumping. This concept required valves to direct flow to and from the basin in operation. Continuous pumping was selected as the desirable operating condition based on the following:

- Facilitation in assessment of the hydrogeology impacts.



- Reduction in the amount of required Instrumentation and Control; no start/stop cycling controls needed on the pumping system.
- Minimize sand production from the well which is heaviest during each pump startup.

To convey water from the well to the recharge basins, two delivery systems were considered: gravity flow using an existing ditch, or pressurized flow using a new pipeline. A pressurized system was chosen for the following reasons:

- Greater flexibility in providing water control systems.
- Improved monitoring of flow rates.
- Maintenance of the canal is not required.

## **WATERFLOW CONTROL**

Only one test basin operated at a time. The active test basin was filled to a designated high water level and allowed to infiltrate to a designated low water level before refilling. The production well pump ran continuously while an automated control system directed the flow either into the test basin for filling or into the waste basin. The control system consisted of control relays and switches at solenoid-activated valves.

## **WET/DRY CYCLES**

The wet/dry cycle consisted of two phases, the wetting phase and the drying phase. During the wetting phase of the cycle, the test basin was monitored to measure infiltration rates. The drying phase then acted as a passive maintenance procedure to maintain high, long-term infiltration rates.

The wetting phase consists of two components. The first is the filling component. As an example, during the filling component water was pumped into Basin 2 until it reached the high water level. The monitoring system and control then redirected the flow into the waste basin. This began the falling component of the wetting cycle. When the water level in Basin 2 dropped to the low water level, the monitoring and control system would redirect water back into the test basin, filling it to the high water level.

This procedure of directing the flow between Basin 2 and the waste basin continued for the length of the wetting phase of the wet/dry cycle. At the beginning of the drying phase of the cycle, flow would switch from Basin 2 to Basin 4, allowing Basin 2 to undergo a drying period. During the drying period of Basin 2, Basin 4 was in the wetting phase of the wet/dry cycle. The wet/dry cycles are depicted in Figures 2 and 3.

# BASIN 2

DATE	FEB		MARCH		APRIL		MAY		JUNE		JULY						
	2/19	2/28	3/11	3/21	3/31	4/10	4/20	4/30	5/10	5/20	5/31	6/10	6/20	6/30	7/10	7/20	7/31
WET	7 DAYS	7 DAYS	7 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS
DRY	7 DAYS	7 DAYS	7 DAYS	7 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	13 DAYS	13 DAYS	20 DAYS	20 DAYS	20 DAYS	20 DAYS	5 DAYS
INFILTRATION RATE (ft./day)	1.5	1.0	0.5	0													
	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

RECORDED DATA

PUMP ON

# BASIN 4

DATE	FEB		MARCH		APRIL		MAY		JUNE		JULY						
	2/19	2/28	3/11	3/21	3/31	4/10	4/20	4/30	5/10	5/20	5/31	6/10	6/20	6/30	7/10	7/20	7/31
WET	7 DAYS	7 DAYS	7 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS
DRY	7 DAYS	7 DAYS	7 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS	14 DAYS
INFILTRATION RATE (ft/day)	25	20	15	10	5												
	>19	>19	>19	>19	>19	>19	>19	>19	>19	>19	>19	>19	>19	>19	>19	>19	>19
	<19	<19	<19	<19	<19	<19	<19	<19	<19	<19	<19	<19	<19	<19	<19	<19	<19
	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

WETTING PHASE

# BRAWLEY WASH OPERATION AND INFILTRATION DATA (February 19 Through July 31)

BASIN 2																				
DATE	AUGUST				SEPTEMBER				OCTOBER				NOVEMBER				DECEMBER			
	8/1	8/10	8/20	8/31	9/10	9/20	9/30	10/10	10/20	10/31	11/10	11/20	11/30	12/10	12/20	12/31	1/10	1/20	1/31	
WET		14 DAYS			10 DAYS			19 DAYS							28 DAYS				6 DAYS	
DRY	7 DAYS		20 DAYS				13 DAYS		7 DAYS								14 DAYS			
1.5																				
1.0																				
0.5	*****				*	*		***	***	***	***	***								
0																				
NOTE: BASIN 2 MODIFIED. INFILTRATION RATES ARE NOT REFLECTIVE OF ORIGINAL SOIL CONDITIONS.																				
RECORDED DATA																				
PUMP ON																				
BASIN 4																				
DATE	AUGUST				SEPTEMBER				OCTOBER				NOVEMBER				DECEMBER			
	8/1	8/10	8/20	8/31	9/10	9/20	9/30	10/10	10/20	10/31	11/10	11/20	11/30	12/10	12/20	12/31	1/10	1/20	1/31	
WET	7 DAYS			20 DAYS			13 DAYS			7 DAYS								14 DAYS		
DRY		14 DAYS			10 DAYS			19 DAYS							28 DAYS			6 DAYS		
25																				
20																				
15																				
10		*****		***													*	*	*	
5					*****	*	*	*	*	*	*	*	*	*	*	*	*	*	*	

WETTING PHASE

BRAWLEY WASH  
OPERATION AND INFILTRATION DATA  
(August 1 Through January 31)

## BASIN DESIGN

The basins were designed based on the following criteria:

- Basin inverts would be level to facilitate an "even" filling and infiltration rate. This would produce better definition of the initial portion of the infiltration curve. The disadvantage is that sloping basins would provide better drainage to facilitate drying.
- Basins were sized using the average infiltration rate for the first 24-hour period of infiltrometer ring data. The basin size was computed by dividing the supply rate by the initial 24-hour measured infiltration rate.

To illustrate the basin sizing methodology, calculations for Basin 2 at a depth of 48 inches will be discussed. Calculations of the total amount of infiltration during the desired wetting period of 24 hours may be seen in Table 1.

<p align="center"><b>Table 1</b> <b>Infiltration Data and Calculations for Sizing of Basin 2</b></p>			
<b>Time Period After Start-Up (hours)</b>	<b>Total Hours</b>	<b>Average Infiltration Rate from Ring Infiltrimeters (inch/hour)</b>	<b>Total Infiltration<sup>1</sup> (inch)</b>
0-3	3	2.5	7.5
3-6	3	1.7	5.1
6-12	6	1.4	8.4
12-18	6	1.1	6.6
18-24	6	1.0	6.0
Total Infiltration in 24 hours			33.6 inches = 2.8 feet
Size of basin = $\frac{\text{Supply Rate}}{\text{Infiltration Rate}} = \frac{3.1 \text{ ac-ft/day}^2}{2.8 \text{ ft/day}} = 1.1 \text{ ac}$			
<sup>1</sup> Total infiltration = Total hours x Average Infiltration Rate <sup>2</sup> 700 gpm = 3.1 ac-ft/day			

Table 2 presents the size and depth information for each basin.

Table 2 Size and Depth of Basins				
Basin	Basin Invert Depth (inches)	Pump Flow Rate <sup>1</sup> (ac-ft/day)	Projected Infiltration Rate <sup>2</sup> (ft/day)	Basin Area <sup>3</sup> (ac)
1	96	3.10	6	0.5
2	48	3.10	2.8	1.1
3	24	3.10	2.5	1.3
4	120	3.10	32	0.14
<sup>1</sup> 3.10 ac-ft day = 700 gpm <sup>2</sup> Total projected amount of infiltration on Day 1 <sup>3</sup> Surface area = Pump Flow Rate/Projected Infiltration Rate				

The waste basin was designed to provide drainage from the test basins at the conclusion of the wetting phase of each cycle. In addition, flow was diverted to the waste basin when the water level in the test basin reached the designated high water level.

The waste basin was located immediately adjacent to Basin 4. To provide drainage, the depth of the waste basin was set below Basin 4 by 12 inches. The size of the waste basin was related to its estimated infiltration rate (assumed to be equivalent to that measured in the ring infiltrometer tests at 113 inches) and the duration of flow. The worst-case design assumed full flow rate into the waste basin for 7 consecutive days. The size of the waste basin was set at 0.75 acres.

For further information on the Brawley Wash Pilot Project, the reader is referred to the following technical memoranda:

- *Design of Brawley Wash Pilot Recharge Project*, November 1989.
- *Brawley Wash Surface Recharge Pilot Project Data Management Plan*, August 1990.
- *Interim Results of Pilot Project Operations and Infiltration Tests--Brawley Wash*, October 1990.
- *Analysis of Groundwater Level Response During Pilot Surface Recharge Operations at Brawley Wash Pilot Recharge Site* (Draft), March 1991, Errol L. Montgomery & Associates, Inc.
- *Brawley Wash Water Quality* (Draft), April 1991.



# DATA COLLECTION

## INTRODUCTION

An objective of this memorandum is to evaluate the data collected for documenting basin infiltration rates. This section discusses the critical data collected, the means of collecting it, and the problems encountered in the data collection process.

## CRITICAL DATA COLLECTION METHODOLOGIES

An assessment of infiltration rates and impacts from various wet/dry cycles on infiltration requires the following data:

- Water level measurements in the test basin.
- Times of water level measurements.
- Flow rate of water into the basins.

The system used to record the data was a Geokon Micro-10 Data Logger. This system consisted of a data logger and a modem for telephone communications which was housed in a vandal-proof cabinet near the basins. Data inputs were received from the following devices: flowmeter transmitters, control valve status relays, and pressure transducers in monitoring wells and piezometers. A cellular telephone provided dial-up communications with off-site computers.

For infiltration data, the date, time, and cumulative volume of flow was logged every time the basin water level activated the high or low level probes in the test basin. Water level measurements obtained from pressure transducers installed in the monitor wells and piezometers were logged several times each day. Logged data was transferred to a floppy disk by an operator at the site using a linkup with a lap-top computer or from the office by using the dial-up modem.

## OPERATIONAL AND DATA COLLECTION PROBLEMS

The Brawley Wash Pilot Project was designed for continuous operation. During the length of the project, operations and/or data collection were interrupted by a series of problems as discussed in the following paragraphs.

During the 12-month period of operations, there were 20 incidents when either data collection or pumping was interrupted. The majority of the interruptions lasted less than 2 days. The maximum operational down time was a five-week period during July and August.

The project was not operational during this five-week period due to a lightning strike. The Brawley Wash site is in a severe lightning strike area, and the strike destroyed portions of the electrical monitoring system, and data collection devices. On two other occasions the data logger was not operational due to electrical problems which resulted in a discharged battery.

For the majority of the interruptions, the supply systems (Well AF-64) inadvertently stopped operating. Well AF-64 is located at the end of a power line, and several interruptions occurred during peak energy demands leading to the hypothesis that power supply fluctuations caused the system to shut down. This situation indicates a possible cause for the interruptions. However, there is not enough data to confirm this hypothesis. Methods and equipment needed to establish the cause of data or operational interruptions were not considered during the design and implementation of the pilot project. Further details are shown in Table 3.

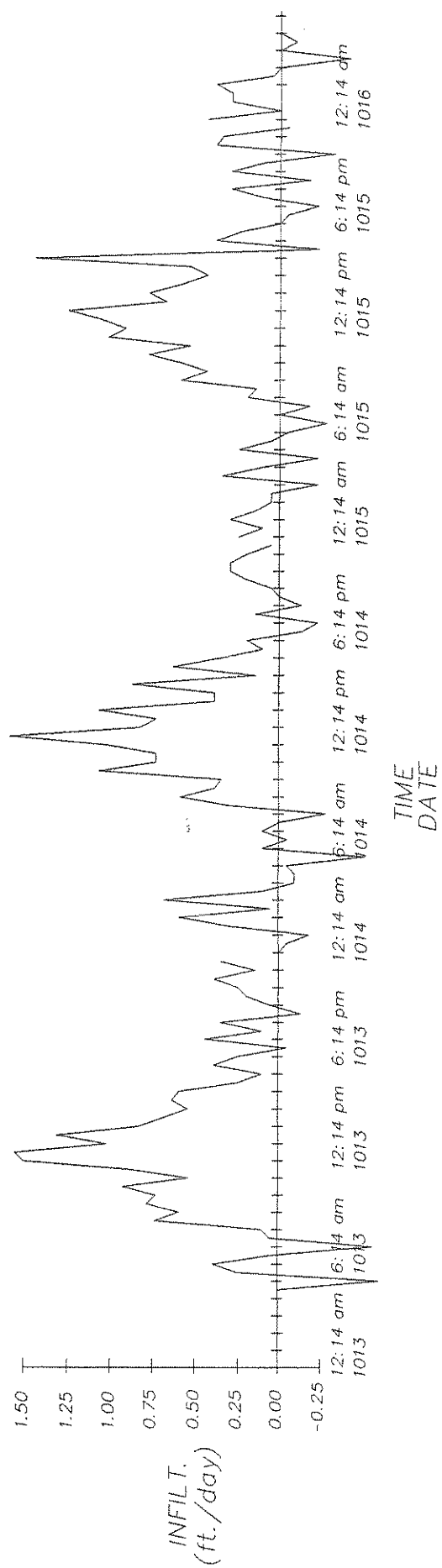
Table 3 Data Collection and Operational Interruptions		
Dates of Interruptions	Equipment	Probable Cause
3/22	Pump Off	Unknown*
3/25	Pump Off	Unknown*
4/12 to 4/13	Pump Off	Unknown*
5/4	Pump Off	Unknown*
6/30	Pump Off	Unknown*
7/2 to 8/7	Data Logger/Transducers	Lightning Strike
8/27 to 9/1	Pump Off	Unknown*
8/28 to 9/4	Data Logger	Discharged Battery
9/6 to 9/11	Pump Off	Unknown*
9/7 to 9/13	Data Logger	Discharged Battery
9/16 to 9/17	Data Logger	Unknown*
9/20	Pump Off	Unknown*
9/21 to 9/22	Data Logger	Unknown*
9/27 to 9/29	Data Logger	Unknown*
9/30 to 10/1	Pump Off	Unknown
12/23 to 12/25	Pump Off	Unknown*
12/25	Data Logger	Unknown*
12/28 to 1/1	Data Logger	Unknown*
1/5	Data Logger	Unknown*
* Possible Cause: Power supply fluctuations		

In addition to problems with the source supply and the data logger, data collection was hindered by other factors:

- Solenoid control valves were slow-acting (typical closing times were 1 to 5 minutes) and often would not close. The principal problem was that the valves did not function properly at back pressures less than 18 psi.
- Absence of transducers in each of the basins until midway through the project. Water elevations in the basins were recorded once transducers were installed.
- Flow into the basins was initially established at 700 gallons per minute (gpm) based on measurements by a flow sensor located at the pump. Subsequently, it was determined that the actual flow rate was significantly less. Based on totalizer measurements obtained from the McCrometer flowmeters located at the basins, pumping rates actually varied from 570 to 680 gpm.
- During the first 4 months of operation, Basin 4 did not operate as designed due to a combination of high infiltration rates and less flow into the basin than expected. This condition resulted in a situation where the water surface did not reach the high water level until infiltration rates dropped below 15 ft/day.
- Initial calculations for infiltration rates in Basins 2 and 4 were biased and incorrect because of the inaccurate flow measurements from the flow sensor. These inaccuracies were especially apparent during the filling component of the wet/dry cycle.

Since Basin 4 did not experience a falling component during the first 4 months of operations, accurate infiltration rates were not available until corrections were made to the flow measurements.

- The anticipated soil conditions did not exist in Basin 4 at the design depth. Additional excavation of approximately 12 inches in depth exposed the anticipated soil types. The additional excavation also increased the area of the basin from 6,000 to 6,400 sq. ft.
- The electronic measuring equipment appears to have been sensitive to the rate of change in the ambient air and/or water temperature. This sensitivity may have caused the diurnal peak in infiltration rates indicated in the data. The data showed a daily peak in the infiltration rate between 11:00 a.m. and 1:00 p.m., as depicted in Figure 4. This cycle may not be indicative of the infiltration variance during the day, but of the sensitivity of the electronic equipment.



INFILTRATION RATES - BASIN 2  
 COMPUTED USING 30 MINUTE INTERVALS  
 OCTOBER 13 - OCTOBER 17, 1990

FIGURE 4

Figure 4 also depicts negative infiltration rates. A negative infiltration rate indicates a rise in the water surface elevation. Turbulence in the stilling well or, again, the sensitivity of the measuring equipment, could cause the measuring equipment to record a rise in the water level. An exact cause is not known. The final analysis consisted of average infiltration rates taken over several off days, therefore, the highs and lows indicated were not critical to the final data analysis.

## BASIN OPERATION

### INTRODUCTION

As discussed previously, continuous operation of the pilot project was accomplished by alternating flow between a test basin and the waste basin depending on the water level in the test basin. This section discusses the wetting and drying cycles that were investigated during the course of the project.

### CYCLE LENGTHS

During the first 4 weeks of the project, both basins were operating on a 7-day wet/7-day dry cycle. The cycle length was then increased to a 14-day wet/14-day dry cycle for the next 10 weeks (April through May). From June through October, the cycle lengths were varied (e.g., 20 days wet/17 days dry, 14 days wet/20 days dry, etc.). At the end of October, it was decided to cease infiltration operations in Basin 2 and Basin 4 for the month of November to allow the basins to dry.

During the month of November, modifications were made to Basin 2 for the purpose of measuring vadose zone parameters. The modifications consisted of excavating two crossing trenches, 8-feet deep, to expose more permeable subsurface material. Basin 2 was then operated for a 29-day wetting period. The results of these modifications are discussed in the report titled, *Analysis of Groundwater Level Response During Pilot Surface Recharge Operations at Brawley Wash Pilot Recharge Site* (Draft), March 1991, by Errol L. Montgomery & Associates, Inc.

Flow was then diverted for 14 days to Basin 4, which had been essentially dry for over 2 months. Operation of the test basins for measurement of infiltration data was terminated on January 22, 1991. The cycle lengths are illustrated in Figures 2 and 3.

# INFILTRATION RATES

## INTRODUCTION

One of the objectives of this pilot project was to investigate and determine the infiltration rates through distinctively different soil profiles. This section describes how the infiltration rates were calculated, identifies the infiltration rates for the test basins, and describes what factors impacted the infiltration rates.

## INFILTRATION RATE CALCULATIONS

Infiltration rates were calculated for two situations, the filling component and the falling component of the wetting phase.

To calculate the infiltration rate during the filling phase required an accurate flowrate measurement and the area of the infiltration surface. The infiltration rate for the first four months of Basin 4 operations was calculated using this method. The average flowrate into Basin 4 during this period was 620 gpm and the area was 6,400 ft.<sup>2</sup>. The infiltration rate was then calculated as shown:

$$\frac{\text{Flowrate in}}{\text{Area of Infiltration Surface}} = \frac{\left( \frac{620 \text{ Gal.}}{\text{Min.}} \right) \left( \frac{1,440 \text{ Min.}}{\text{Day}} \right) \left( \frac{\text{Ft.}^3}{7.48 \text{ Gal.}} \right)}{6,400 \text{ Ft.}^2} = 18.7 \text{ or } \pm 19 \text{ Ft./Day}$$

To calculate the infiltration rates during the falling phase of the wetting cycle required a measured drop in water surface elevation and the time period over which the drop occurred. The infiltration rate was calculated using the following equation:

$$\frac{\text{Water Surface Elevation 1} - \text{Water Surface Elevation 2}}{\text{Elapsed Time}} = \text{Infiltration Rate}$$

The infiltration rates calculated for each time interval varied widely depending upon the basin and the interval duration. The average infiltration rate over a larger time interval (1 day) gave a more accurate representation.

## INFILTRATION RATES

From ring infiltrometer tests, the estimated infiltration rate for Basin 2 was 1.0 ft/day. As Figures 3 and 5 show, the initial infiltration rate for Basin 2 exceeded 1 ft/day but fell to 0.6 ft/day after the first wet/dry cycle. This 45 percent decrease is significant. The next four months of operation showed a reasonably constant infiltration rate that varied between 0.5 and 0.7 ft/day. During the final two months of operation, the

**BASIN 2**  
**MONTHLY INFILTRATION RATES**

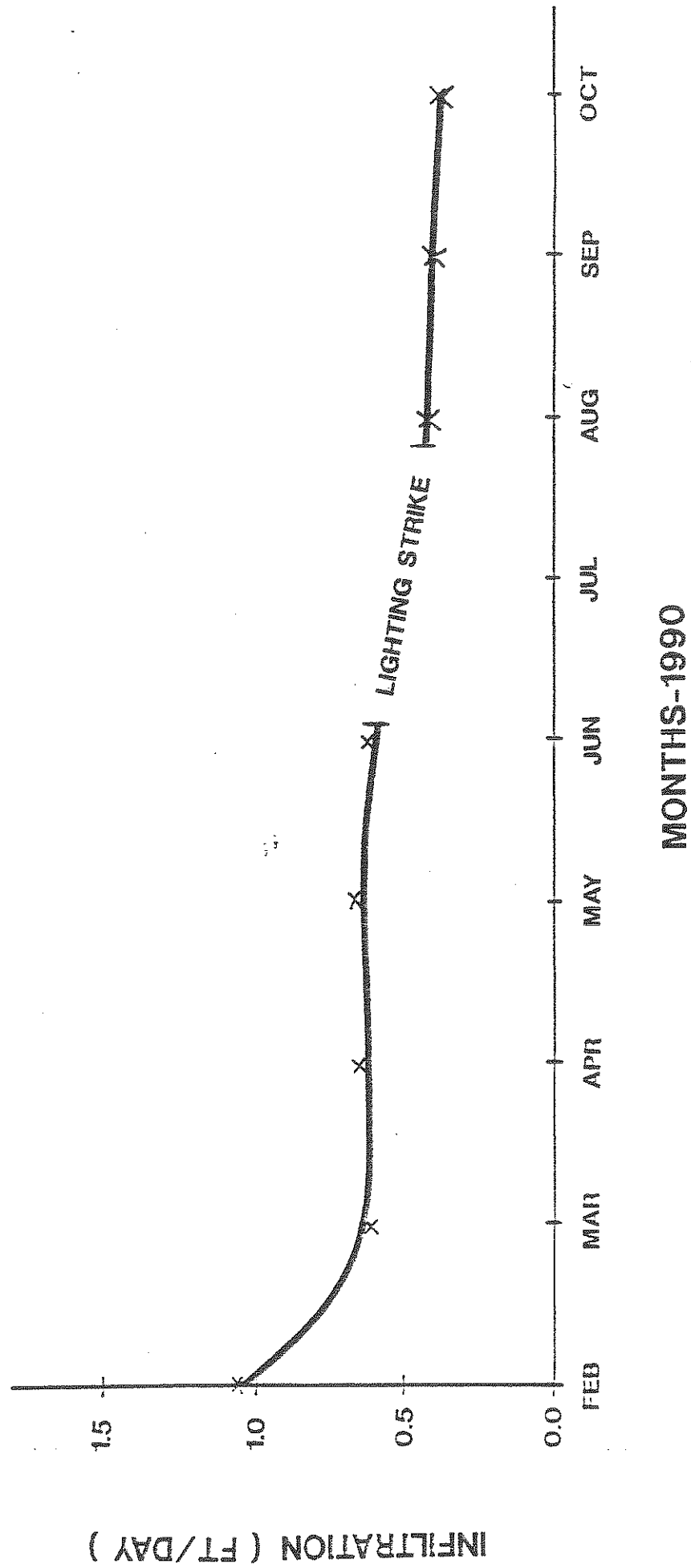


FIGURE 5

infiltration rate dropped to 0.4 ft/day. There was a 60 to 65 percent total decrease in the infiltration rate over the length of the project.

The estimated Basin 4 infiltration rate of 21.6 ft/day was based on ring infiltrometer tests. Computed infiltration rates for the first four months of Basin 4 operations (Figures 4 and 6) indicated infiltration rates of 19 ft/day. In June, the infiltration rate dropped from 19 to 13 ft/day, a decrease of 32 percent. In April, a rust-colored algae growing in the sand was first observed in the basin. Two months later, a second type of algae, green, floating mass, was observed. This algae growth corresponds to the observed decrease in the infiltration rate and is considered the primary cause for the decrease. Infiltration rates steadily declined over the next five months as algae growth increased. After eight months of operation, infiltration had decreased to about 8 ft/day or a 58 percent decrease in infiltration. The final 14-day test, after 65 days of drying, had an average infiltration rate of 9 ft/day.

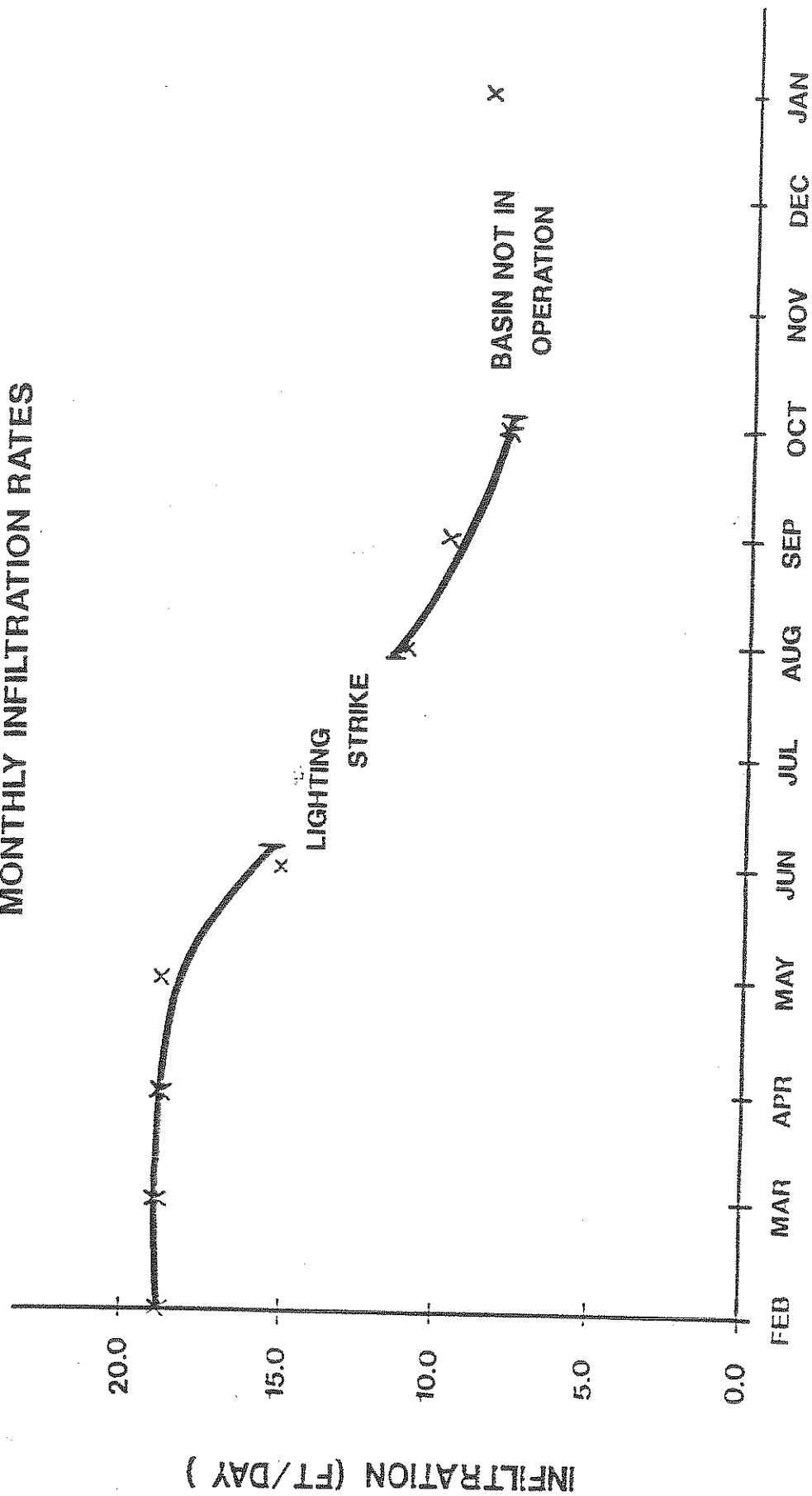
In summary, the decrease in infiltration rates for both Basins 2 and 4 was expected. Drying of the basins over a 7- or 24-day period was done so infiltration rates would recover. Generally, this recovery was not observed. The loss of infiltration in Basin 2 can be attributed to the general degradation (sediments, unseen algae, etc.) of the basin. Infiltration losses in Basin 4 are from the two distinct algae blooms.

#### **IMPACT OF WET AND DRY CYCLE LENGTHS ON INFILTRATION**

Wet and dry cycling for any length of time did not appreciably redevelop basin infiltration rates. The 65-day dry period before final testing in Basin 4 produced a 5 percent recovery (of the initial 19 ft/day rate); a small portion of the 58 percent decrease over 8 months of operation.



# **BASIN 4** **MONTHLY INFILTRATION RATES**



MONTHS-1990

FIGURE 6

# EVAPORATION RATES

## INTRODUCTION

The loss of water due to evaporation could impact calculation of the infiltration rates. This section analyzes the effect of evaporation on the infiltration rates.

## EVAPORATION RATES

Pan evaporation rates were obtained from *Arizona Climate* (Green and Sellers, 1964) and the Arizona Department of Environmental Quality, June 1989, *Minimum Requirements for the Design and Installation of Septic Tank Systems and Alternative On-site Disposal Systems, Engineering Bulletin No. 12*. The following table summarizes the evaporation rates by month. A pan factor of 0.75 is used, to convert pan evaporation to basin evaporation.

Table 4 Evaporation Data Inches of Water per Month		
Month	Pan Evaporation (inches)	Basin Evaporation (inches)
January	3.30	2.48
February	3.68	2.70
March	6.36	4.77
April	9.15	6.86
May	12.42	9.32
June	13.54	10.16
July	12.32	9.24
August	10.02	7.52
September	8.91	6.68
October	6.26	4.70
November	4.12	3.09
December	3.27	2.45
Annual	93.35	70.01

Assuming the basins operate 24 hours per day and 365 days per year, June would have the highest evaporation losses. During the month of June, slightly over 10 inches of water may have been lost due to evaporation as indicated in Table 4. Assuming an average of 0.6 ft/day of infiltration in Basin 2, 4.7 percent of the measured infiltration is due to evaporation.

Assuming an average infiltration rate of 15 ft/day in Basin 4, 0.19 percent of the measured infiltration is due to evaporation.

Because a wet/dry cycle was used in this pilot study, the test basins were actually full no more than 50 percent of the time, and a full-scale facility would probably not be used during the months of June, July, August, and September due to high water demands. Using these two assumptions, evaporation losses are shown in the table below:

<p style="text-align: center;"><b>Table 5</b>  <b>Evaporation Data</b>  <b>Inches of Water Per Month (Adjusted)</b></p>		
<b>Month</b>	<b>Pan Evaporation (inches)</b>	<b>Basin Evaporation (inches)</b>
January	1.65	1.24
February	1.84	1.38
March	3.18	2.38
April	3.00	2.25
May	7.21	5.41
June	NA	NA
July	NA	NA
August	NA	NA
September	NA	NA
October	3.13	2.35
November	2.06	1.54
December	1.64	1.23
Annual	23.71	17.78

From Table 5, evaporation is highest in May with losses of 5.41 inches per month. The calculated infiltration rates for Basins 2 and 4 during May are 0.6 and 19 ft/day, respectively. In Basin 2, 2.4 percent of the calculated infiltration is due to evaporation losses. Evaporation losses account for 0.08 percent of the calculated infiltration of Basin 4.

Annually, evaporation may account for approximately 1.5 ft/yr. of the calculated infiltration. The average annual infiltration rates for Basins 2 and 4 are 0.55 and 14.0 ft/day respectively. Evaporation is therefore responsible for 1.1 percent of Basin 2 infiltration and 0.04 percent of Basin 4 infiltration, annually.

From this evaluation, evaporation does not significantly affect the accuracy of the infiltration rate calculations.

## CONCLUSIONS AND RECOMMENDATIONS

### INTRODUCTION

This section of the report presents conclusions related to infiltration testing using groundwater at the Brawley Wash Pilot Project and recommendations for design criteria and improvements to future pilot project operations and design.

### INFILTRATION TESTING CONCLUSIONS

1. Infiltration rates varied considerably for the two basins tested at Brawley Wash. Basin 2 rates started at 1.0 ft/day and decreased to about 0.4 ft/day after 9 months of operation. Basin 4 rates decreased from 19 ft/day to about 9 ft/day over the same operating period.
2. Infiltration rates can be dramatically increased for surface recharge basins when the invert is placed in coarse sands and gravels as compared to finer silt materials. For Brawley Wash, infiltration rates were about 0.6 ft/day in soils comprised of silty material, at the 48-inch depth compared to infiltration rates of 8 to 19 ft/day for soils comprised of coarse sands and gravels, at 132-inch depth.
3. A rust-colored algae was observed about three months after the start of Basin 4 operations. A second variety of algae was observed 2 months later. A decrease in the infiltration rate was experienced with occurrence of this algae. Algae was not observed in Basin 2.
4. For wet/dry cycles of 7, 14, and 20 days, there was generally no restoration of basin infiltration rates. After 65 days of drying Basin 4, there was a slight increase in infiltration rates.
5. Ring infiltrometer tests provided accurate measurements of initial infiltration rates. During the first weeks of testing, basin infiltration rates were within 10 percent of ring infiltrometer test results.
6. Interruptions were experienced with recharge source supply and logging of data at Brawley Wash. Assessments indicate that these interruptions did not alter the conclusions of this investigation.
7. Evaporation rates from surface basins do not significantly impact computed infiltration rates. For the worst month (June), consideration of evaporation losses will reduce the infiltration rates in Basin 2 by 4.7 percent and by 0.19 percent in Basin 4. On an annual basis (with no summer operation), the respective losses to evaporation in Basins 2 and 4 are estimated to be about 1.1 and 0.04 percent.

## RECOMMENDATIONS

1. No work was done to identify algae types or origins at Brawley Wash as a full-scale project will probably not be built in the near future. In addition, the final recharge source water (CAP, reclaimed, or effluent) will have its own algae characteristics. Consideration for mitigation of algae in surface basins needs review.
2. Maintenance of basins at Brawley Wash, especially for algae control, was not done. Maintenance consideration, especially to reduce algae growth and maintain large recharge rates, needs consideration.
3. Instrumentation and control equipment at Brawley Wash was designed for the pilot project. The functioning of the I&C equipment did not meet expectations. Full-scale and pilot projects should consider carefully the minimum I&C equipment needed to meet their objectives.
4. Specific improvements for I&C on pilot projects includes:
  - Use of propeller flowmeters calibrated with an annubar type meter.
  - Motor-operated butterfly valves to direct flow, not solenoid-controlled valves.
  - Pressure transducers in each test basin to measure the change in water levels over time.
  - Power supply monitors to protect against power surges.
  - Lightning arresters to protect against possible lightning strikes.
5. The well water used to test infiltration rates at Brawley Wash is significantly different from CAP, reclaimed water, or effluent, which will likely have higher concentrations of contaminants (algae) and suspended solids. Therefore, a recommended design infiltration rate of 5 to 8 ft/day at the Brawley Wash site using CAP waters must be based on several assumptions:
  - Infiltrating in soils similar to Basin 4
  - Active algae management and maintenance
  - Design for minimum infiltration rates
  - A 50 percent wet/dry cycle operation of basins

Referring to Figure 6, the minimum infiltration rate in Basin 4 was approximately 8 ft/day, and the maximum infiltration rate was  $\pm 19$  ft/day. The minimum and maximum infiltration rates will be lower when using CAP, reclaimed, or effluent waters. As Figure 6 illustrates, the initial infiltration rates were high. As

infiltration continues, the rates decrease. By designing for the minimum rate, excess capacity is built into the project when infiltration begins. Only a portion of the basins will be needed initially due to higher than design infiltration rates. The infiltration rates will decrease as natural degradation of the basins and algae growth occur. As infiltration rates decrease, the unused basins will be brought on-line. At this time, the basins used initially can be taken off-line and maintenance, in the form of drying and removal of algae, can be performed.

By rotating basins on- and off-line in this manner the design infiltration rate of 5 to 8 ft/day should be obtained.