RECLAMATION OF WASTEWATER FOR OPEN ACCESS IRRIGATION

By

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Introduction

The CH2M Hill/Rubel and Hager Joint Venture engineering team completed the Tucson Metropolitan Wastewater Reuse Assessment in March 1983. This study found that landscape irrigation was the largest potential use for reclaimed water in the Tucson area and that projected wastewater quantities were sufficient to meet these needs in the foreseeable future. In order to meet Arizona Department of Health (ADHS) proposed Regulations for Wastewater Reuse, Category G Open Access Irrigation, it was determined that filtration and disinfection of biologically treated sewage effluent would be required.

The study determined that the most cost effective source of wastewater for the initial reuse applications would be the Pima County, Arizona, Roger Road Wastewater Treatment Plant (RRWTP). Future upstream wastewater reclamation facilities may prove to be cost effective if controlled recharge and storage of reclaimed water is shown to be safe and effective.

Concurrent to the study, negotiations between the City of Tucson and Cottonwood Properties were in progress and resulted in an agreement to supply the proposed La Paloma Resort with 2 million gallons per day of reclaimed water for golf course irrigation. This agreement provided the opportunity to immediately demonstrate the commercial viability of a reclaimed water system. Consequently, the initial treatment facility was designed to provide 8 million gallons per day and the initial distribution line was routed to the La Paloma development. In order to meet the La Paloma water demand, detailed engineering proceeded concurrent to a pilot testing program.

The initial and ultimate system capacities are summarized as follows:

Stage	Area Served	Acreage Served	Peak Demand Rate (gpm)	Peak Daily Consumption (MGD)
Initial	La Paloma Project	200	1,530	2.2
	Landscape sites along the initial route.	270	4,860	2.9
		470	6,390	5.1
Ultimate	Metropolitan Tucson	1,939	23,527	20.9

Pilot Testing Program

Objectives

Granular media filtration testing of wastewater treatment plant effluent was conducted at the RRWTP over a five month period beginning June 9, 1983. The RRWTP is a conventional bio-filtration plant and is designed to treat a wastewater flow of 30 million gallons per day. Treatment processes include screening, grit removal, primary clarification, bio-filtration, secondary clarification and chlorination. Solids contained in the clarifier underflows are thickened in gravity thickeners and stabilized in anaerobic digesters of the complete mix type.

The testing program was conducted in two parts. The purpose of testing in the first part was to evaluate the use of dual and tri-media filters as a means of removing suspended solids and microorganisms.

The results of the initial filtration testing program indicated that either dual or tri-media filters employing combinations of coal, sand and garnet and operating at rates between 4 and 8 gpm/ft^2 could reduce turbidity below maximum levels set by ADHS proposed regulations. However, the data on microorganisms removal was incomplete.

The objectives of the second part of the testing program were:

- To evaluate the use of chemical addition ahead of the filters to enhance removal of turbidity and microorganisms
- To operate the pilot filters over an extended period on a 24-hour per day basis in order to define operating conditions to be expected in the start-up of the full scale facilities
- To identify the quality and quantity of backwash water to be returned to the RRWTP
- To assess the potential regrowth of microorganisms in the reclaimed water during distribution and storage

The testing results were evaluated on the basis of meeting effluent quality limits as set forth in the Arizona Department of Health Services, Proposed Regulations for Reuse of Wastewater, Category G, as follows:

QUALITY OBJECTIVES

pH	4.5 - 9
Fecal Coliform (CFU/100 ml)	25 (geometric mean) 75 (maximum in single sample)
Turbidity (NTU)	5
Enteric virus (PFU)	125/40 liters
Ascarius Lumbricoides (roundworm eggs)	none detectable
Trace Substances	R9-21-209

The concentration of enteric virus in the RRWTP chlorinated effluent was anticipated to be variable and possibly too low during the testing period to obtain a quantitative evaluation of filtration performance. Therefore, surrogate microorganisms were periodically added to the filter influent to provide removal performance data. Coliphage f2 and simian rotavirus were used as the enteric virus surrogates. Both are known to be difficult to filter with conventional granular medias.

Apparatus

The granular media filtration equipment consisted of two 10-inch diameter filter columns. The columns were six feet in overall height and were connected for parallel downflow operation. The underdrain consisted of a perforated plate supporting a polypropylene screen.

Filter A (dual media) contained 18 inches of 0.8-0.9 mm anthracite coal and 18 inches of 0.22-0.29 mm sand and Filter B (tri-media) contained 18 inches of 0.8-0.9 mm anthracite,15 inches of 0.22-0.29mm sand and three inches of 0.21 mm garnet.

Two chemical metering pumps were used to feed coagulant and polymer into the filter influent line. Mixing was provided by in-line static mixers.

Procedures

Turbidity and Headloss. Filtration rates of 5.5 gpm/ft^2 were maintained and chemicals (alum - 1.5 mg/l and polymer L691E - 0.25 mg/l) were added to the filter influent. Both filters were operated 24 hours per day during this study. Each filter was backwashed when the headloss exceeded 25 psi or effluent turbidity exceeded 5 NTU. Turbidity and headloss data were monitored hourly.

Sampling. Grab samples of filtered and unfiltered water were collected daily in sterile polypropylene bottles for fecal coliform and coliphage assay. In addition, periodic diurnal sampling was performed on an hourly basis for the same bacterial analyses. Samples of filtered and unfiltered water for enteric virus testing were collected at intervals ranging from once per week to three times per week.

Enteric Virus Concentration. Enteric viruses were concentrated from the water by adsorption-elution from microporous filters. In this study, the water to be sampled was first collected in a 100 gallon plastic tank and dechlorinated by addition of sodium thiosulfate. After the water was adjusted to pH 3.5 by addition of HCl, $AlCl_3$ added at a concentration of 0.0001 M, the water was then pumped through a 0.45 µg nominal pore size 10 inch pleated Filterite fiberglass filter. Viruses which were adsorbed to the filter were eluted by passage of one liter of beef extract adjusted to pH 9.5. Viruses in this eluate were reconcentrated to a final volume of 25-50 ml by bioflocculation with $FeCl_3$.

Determination of Coliphage f2 and Rotavirus Removal. To determine the removal of coliphage f2 and rotavirus removal, a 100 gallon tank was filled with wastewater from the Roger Road plant and dechlorinated by addition of sodium thiosulfate. A laboratory grown stock of either virus was then added, the wastewater mixed and then passed through one of the filter columns. The same procedure was repeated for each column. Samples of influent and effluent from the filter column were collected after various times until the entire 100 gallons had been passed through the filter column.

Bacterial Assays and Regrowth Tests. Influent and filtrate samples were collected in sterile polypropylene bottles containing thiosulfate and processed by the multiple tube method for fecal coliforms (Fc) and standard plate count (SPC) bacteria according to Standard Methods.

Regrowth of Fc and SPC bacteria in filter effluents were investigated in two series of tests. In the first experiment sodium hypochlorite was added to replicate filter samples to raise the free chlorine level to 0.8 ppm. The samples were inoculated with environmental (sewage effluent) isolate of Escherichia coli to an initial level of ≈ 50/100 ml and incubated at 27°C. At time intervals indicated subsamples were analyzed for free and total chlorine, fecal coliforms, and standard plate count bacteria.

In the second experiment, chlorine was added to replicate samples in situ and all filtered samples were inoculated with clarified effluent to a level of approximately 500 Fc/100 ml and analyzed as previously described.

Filter Backwashing. When backwashing was required to either filter, flow to that filter was stopped and the drain was opened to lower the water level to within six inches above the media. Air was then injected at the bottom of the filter at 3 cfm/ft^2 for two minutes to agitate the media and loosen the solids. Air was then stopped and the filter was backwashed at a rate of 15 gpm/ft^2. RRWTP process water, which was used for backwashing, was filtered through a sand media filter prior to entering the filter to be washed. All backwash water was collected in 55 gallon drums for sampling and analysis before being discarded. Grab samples of backwash water were collected at 0.5, 1, 2, 3, 4 and 6.25 minutes corresponding to 4, 8, 16, 24, 32 and 50 gallons for the first 27 runs. A composite sample of each of the first 50 gallons and second 50 gallons was also collected. This composite sampling was continued throughout the study.

Chlorine Residual Testing. Chlorine decay tests were performed on filtered water to determine the rate at which chlorine disappears. This was done by dosing the filter effluent to levels ranging between 5-15 mg/l total chlorine and monitoring chlorine residuals for 3-7 days. The chlorinated filtered effluent under test was stored in covered (not sealed) bottles at room temperature to simulate conditions which may exist in the storage reservoir. Both free and total chlorine residuals were monitored as well as pH and ammonia. Sodium hypochlorite was used for all tests except for two in which chlorine solution was obtained from a gaseous chlorinator.

Results

Turbidity and Headloss

The dual media filter had an average run time of 19.7 hours and produced an average volume of 2952 gallons. The tri-media filter averaged 16.3 hours per filter test and produced 2328 gallons of treated water. Effluent turbidity averaged 1.8 mg/l for the tri-media filter and 2.6 mg/l for the dual media filter. Filter influent and effluent water samples were tested for those contaminants listed in the Arizona Department of Health Services proposed regulations for reclaimed water use for open access irrigation. Both the dual and tri-media filter effluents (without post chlorination) met all of these standards except one (maximum single sample fecal coliform) as can be seen by the following comparison:

TABLE 1

Filtration Results

Quality Parameter	ADHS Proposed Standard	Dual Media Filter Effluent	Tri-Media Filter Effluent
pH	4.5-9	6.4-7.1	6.4-7.1
Fecal Coliform (CFU/100 ml)			
o Maximum 5 day geometric mean	25	11	8
o Maximum single sample	75	130	350
Enteric Virus (PFU/40 liters)	125	2.5	3.4
Ascarius Lumbricoides	None	None	None
Turbidity, maximum NTU	5	2.6	1.8

pH, Total Suspended Solids, COD and Aluminum

Data for pH and concentration of total suspended solids (TSS), COD and aluminum (Al) are presented in TABLE 2.

Nitrogen and Chlorine

Ammonia, nitrate and chlorine residual data for the period 9/29 to 10/4 are summarized in TABLE 3. The variability of ammonia concentrations and (0.15-9.6 mg/l) treatment plant flow variations as well as other operating variables resulted in total chlorine residuals ranging from 0.9 to 4.5 mg/l and free chlorine residuals ranging from 0.15 to 1.4. The RRWTP chlorinators are paced with plant flow to provide consistent chlorine dosing. Residual chlorine concentrations, therefore, vary with the chlorine demand of the RRWTP effluent.

TABLE 3 data also shows that the effluent contained nitrate concentrations ranging from 4.4 to 48.8 mg/l during this period.

Chlorine Decay With Time

Two chlorine decay tests were conducted on dual media filter effluent containing 2 NTU turbidity levels. In the first test conducted on August 30, chlorine solution was obtained from the chlorinator at the Randolph Park wastewater treatment plant. TABLE 4 shows the depletion of total chlorine over a seven day period and the effect of chlorination on pH. Total chlorine was depleted from initial values of 4.8, 9.6 and 13.0 mg/l to 0.2, 2.6 and 3.0 mg/l respectively after 7 days. The pH was suppressed from the initial 6.9 to a low value of 6.5 in the high dose sample and 6.7 in the medium dose sample. After 7 days, pH values in all of the samples were in the range of 6.9 - 7.1.

TABLE 2

SUMMARY DATA FOR pH, TSS, COD AND ALUMINUM

	Filter Influent (Range)	Filter Effluent (Range)
pH		
Dual Media	6.9-7.1	6.9-7.1
Tri-Media	6.9-7.1	6.9-7.9
TSS		
Dual Media	8.0-50.8	1.0-6.6
Tri-Media	4.8-41.0	0.2-5.0
COD		
Dual Media	33-95	9-60
Tri-Media	33-95	6-58
Al		
Dual Media	0.02-0.02**	0.04-0.13
Tri-Media	0.02-0.02**	0.03-0.10

** Prior to addition of 1.5 mg/l Al_2O_3.

TABLE 3

FILTER EFFLUENT
AMMONIA, NITRATE AND CHLORINE DATA
(mg/l)

Date	Ammonia	Nitrate	Chlorine Residual Total	Chlorine Residual Free
9-28	1.1	39.6	1.6	0.75
9-29	5.3	48.8	3.6	0.7
9-29	9.6	27.7	3.2	0.4
9-30	1.9	41.8	4.5	0.9
9-30	0.7	39.6	1.2	0.15
10-1	9.5	31.7	3.7	0.7
10-1	6.7	29.9	4.2	0.8
10-1	0.9	44.0	1.8	0.15
10-2	0.8	8.8	0.9	0.2
10-2	0.8	6.6	1.2	0.2
10-2	0.15	4.4	2.4	1.3
10-3	5.2	14.0	2.7	1.2
10-3	1.3	13.2	2.5	1.4
10-3	0.2	43.1	1.3	0.15
10-4	1.1	48.4	3.4	0.65
Range	0.15-9.6	4.4-48.4	0.9-4.5	0.15-1.4

TABLE 4

CHLORINE DECAY TEST DATA

DATE: 8/30/83
SAMPLE SOURCE: Dual Media Effluent
CHLORINE SOURCE: Randolph Park Chlorinator
TURBIDITY: 2.0 NTU
RRWTP: Chlorine residual 3.2 mg/l; pH 6.9

	Total Chlorine, mg/l		
SAMPLE	A	B	C
after Cl_2 addition	4.8	9.6	13.0
Day 1	1.6	4.9	7.2
Day 2	1.3	4.4	6.6
Day 3	0.9	3.75	5.6
Day 4	-	-	-
Day 5	-	-	-
Day 6	-	-	-
Day 7	0.2	2.6	3.0

	pH		
initial	6.9	-	-
after Cl_2 addition	6.9	6.9	6.8
Day 1	6.9	6.7	6.7
Day 2	6.9	6.7	6.5
Day 3	6.9	6.8	6.6
Day 4	-	-	-
Day 5	-	-	-
Day 6	-	-	-
Day 7	7.1	7.1	6.9

In the second chlorine/decay test, two samples of dual media effluent were tested (see TABLE 5). In the first sample (A), the initial chlorine concentration was 1.6 mg/l which remained from the RRWTP final effluent chlorination. In the second sample (B) sodium hypochlorite was added to adjust the chlorine concentration to 10 mg/l. The filter effluent had a turbidity level of 1.0 NTU. TABLE 5 summarizes chlorine, ammonia and pH levels for this test.

Total chlorine concentrations decreased from 10.0 to 0.75 mg/l in the adjusted sample (B) after five days and from 1.6 to 0.35 in the unadjusted sample.(A) Free chlorine disappeared in the unadjusted sample after the first day. In the adjusted sample the free chlorine decreased from 6.75 to a trace after five days.

Backwash Quantity and Suspended Solids

Typical data obtained from filter backwash operations are presented graphically in FIGURE 1. Analysis of grab samples collected at 4, 8, 16, 24, 32, 40 and 50 gallons showed that the concentration of suspended solids in the backwash water decreased rapidly from the sample collected after the first 4-8 gallons to the sample collected at 32 gallons. This was followed by a more gradual decrease through the remainder of the backwash.

Microorganism Removal

Enteric virus was detected in RRWTP chlorinated effluent on only four of eight samples taken over a 35 day period. For those four samples the dual media filter with chemical addition produced removal efficiencies of 0, 24, 68 and 100%. For those same samples the tri-media filter with chemical addition produced removal efficiencies of 0. 92, 0 and 100%. Since these erratic data on enteric virus detection were anticipated the removal efficiency data on surrogate organisms become more meaningful to projecting microorganism removal performance.

The data on naturally occurring coliphage detection in filter influents and effluents are presented in TABLE 6. When no chemical addition ahead of the filters was employed, removal efficiency for both filters was poor and ranged between 4 and 17%. Chemical addition ahead of the filters increased removal efficiencies to an average of 41% for the dual media filter and 35% for the tri-media filter. A wide range of coliphage concentration in the influent to the filters is also illustrated by the TABLE 8 data.

The removal of coliphage f2 by filtration was similar to the naturally occurring coliphage as can be seen in TABLE 7

TABLE 5

CHLORINE DECAY TEST DATA
DATE: 10/4/83
SAMPLE SOURCE: Dual Media Effluent
CHLORINE SOURCE: Sodium Hypochlorite
TURBIDITY: 1.0 NTU

SAMPLE	Total Chlorine, mg/l A	Total Chlorine, mg/l B	Free Chlorine, mg/l A	Free Chlorine, mg/l B
initial	1.6	1.6	0.15	0.15
after Cl_2 adddition	1.6	10.0	0.15	6.75
Day 1	0.9	3.5	0.05	1.4
Day 3	0.6	1.4	0.0	0.34
Day 5	0.35	0.75	0.0	trace

SAMPLE	pH A	pH B	Ammonia, mg/l A	Ammonia, mg/l B
initial	6.7	6.7	1.1	1.1
after Cl_2 addition	6.7	7.0	1.1	0.18
Day 1	7.2	7.2	0.8	0.04
Day 3	7.6	7.8	0.8	0.7
Day 5	8.1	8.2	0.6	0.6

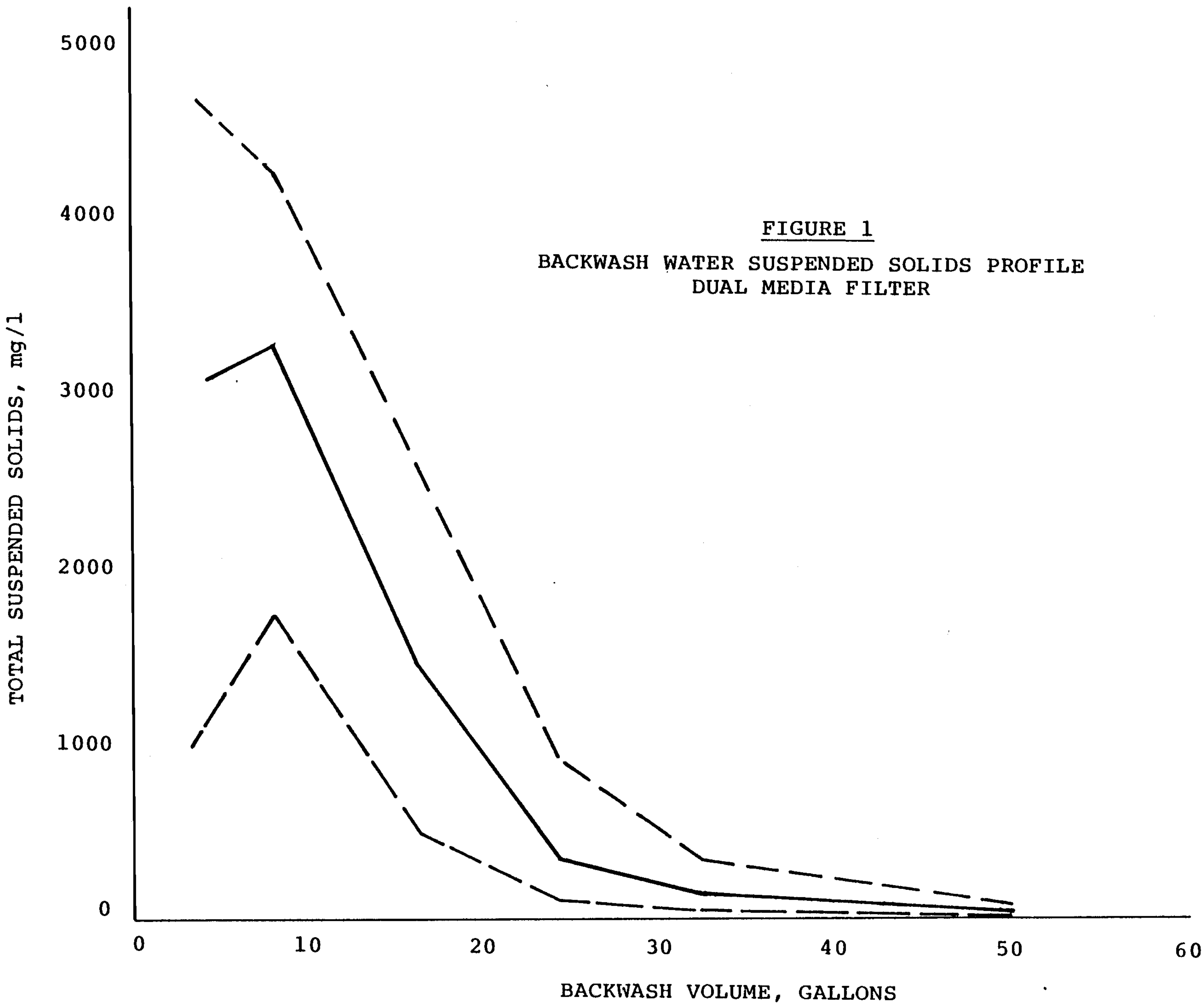
FIGURE 1
BACKWASH WATER SUSPENDED SOLIDS PROFILE
DUAL MEDIA FILTER
5000
4000
3000
2000
1000
0
TOTAL SUSPENDED SOLIDS, mg/l
0
10
20
30
40
50
60
BACKWASH VOLUME, GALLONS

TABLE 6

FILTRATION OF NATURALLY OCCURRING COLIPHAGE

Samle		Influent	Dual Media		Tri-Media	
Date	Time	PFU/ml	Effluent PFU/ml	% Removal	Effluent PFU/ml	% Removal
NO CHEMICAL ADDITION						
8/17	7:00 am	46	34	26	40	13
8/17	11:00 am	33	33	0	32	3
8/18	3:00 am	11	30	0	13	0
8/18	11:00 am	0.5	0.6	0	0.6	0
8/18	7:00 pm	28	14	50	28	0
8/18	11:00 pm	77	67	13	68	12
8/19	3:00 am	29	20	31	35	0
			mean	17		4
ADDITION OF ALUM 1.25 mg/l, L691E 0.25 mg/l						
8/23	8:00 am	5	3	40	1	80
8/23	12:00 pm	2	0.3	85	0	0
8/23	4:00 pm	8	8	0	8	0
8/23	8:00 pm	21	4	81	19	10
8/24	12:00 am	24	9	62	10	58
8/24	3:00 am	6	5	17	2	67
8/30	8:00 pm	74	54	27	47	36
8/31	1:00 am	44	38	14	22	50
8/31	8:00 pm	56	46	18	50	11
9/1	1:00 am	49	29	41	55	0
9/1	8:00 pm	131	62	53	77	41
9/2	1:00 am	103	43	58	51	50
9/29	5:00 pm	695	353	49	354	49
9/29	9:00 pm	422	290	31	308	27
9/30	1:00 am	295	180	39	170	42
9/30	5:00 am	92	52	43	55	40
			mean	41		35

TABLE 7

FILTRATION[a] OF COLIPHAGE f2

Date	Sample[b] Time (min.)	Dual Media Influent PFU/ml	Dual Media Effluent PFU/ml	% Removal	Tri-Media Influent PFU/ml	Tri-Media Effluent PFU/ml	% Removal
9/21	6	NS*	NS*	NS*	$3.4x10^7$	$1.8x10^7$	45
	14	$3.1x10^6$	$1.9x10^6$	38	$3.4x10^7$	$2.2x10^7$	36
	24	$3.1x10^6$	$1.9x10^6$	38	$3.4x10^7$	$2.2x10^7$	33
	26	$3.1x10^6$	$7.2x10^5$	77	$3.4x10^7$	$1.8x10^7$	45
9/22	10	$1.2x10^6$	$9.9x10^6$	21	$7.1x10^6$	$6.1x10^6$	14
	20	$1.2x10^6$	$8.9x10^6$	29	$7.1x10^6$	$4.8x10^6$	32
	30	$1.2x10^6$	$8.8x10^6$	30	$7.1x10^6$	$3.6x10^6$	49
	35	$1.2x10^6$	$8.6x10^6$	31	$7.1x10^6$	$5.2x10^6$	27
			Mean	38		Mean	35

a Alum (1.50 mg/l) + L691E (0.25 mg/l) addition to influent
b Time after beginning of passage of coliphage seeded sewage through the filters.
*NS No Sample.

TABLE 8

REMOVAL OF ROTAVIRUS BY FILTRATION[a]

Date	Sample[b] Time (min.)	Dual Media Influent PFU/ml	Dual Media Effluent PFU/ml	% Removal	Tri-Media Influent PFU/ml	Tri-Media Effluent PFU/ml	% Removal
10/4/83	10	630	565	10	910	725	20
	20	NS	495	21	NS	650	29
	30	NS	525	17	NS	780	14
	34	655	435	31	840	555	39
10/10/84	10	2450	1850	24	5840	4400	25
	20	NS	2200	10	NS	3300	44
	25	NS	1950	20	NS	4800	18
	34	2500	1650	33	6250	4250	27
			mean	21		mean	27

[a] Alum (1.50 mg/l) + L691E (0.25 mg/l) addition to influent.
[b] Time after beginning of passage of coliphage seeded sewage through the filters.
NS = No Sample.

data. The dual and tri-media filters with chemical addition removed 38 and 35% of coliphage f2 respectively.

As shown in TABLE 8 the removal of rotovirus by filtration with chemical addition averaged 21 and 27% for the dual and tri-media filters respectively.

Ascaris eggs were detected only twice in eight samples over a 45 day period in the chlorinated effluent of the RRWTP. Ascaris eggs were never detected in either filter effluent.

Fecal coliform analyses data are summarized in TABLE 9. Influent to the filters exceeded the single sample limit (75 CFU/100 ml) on 8 of 33 samples. The five day geometric mean limit (25 CFU/100 ml) was exceeded on 9 occasions.

Both dual and tri-media filter effluents exceeded the single day limit twice out of 33 samples. The 5 day geometric mean was not exceeded by either filter effluent. These effluents contained only the chlorine added by the RRWTP.

Fecal Coliform Regrowth

TABLES 10 and 11 present data on fecal coliform and total standard plate count analyses for both filter effluents after 3 and 5 days respectively. Chlorine concentrations are also shown. In the first experiment (TABLE 10) free chlorine residuals in the filter effluents were raised to 0.8 mg/l. Total chlorine concentrations were then 4.4 and 5.2 mg/l for the dual and tri-media filters respectively. As indicated in TABLE 10 total chlorine concentrations were zero after 24 hours. As would be expected both standard plate counts and fecal coliform populations increased dramatically over the 5 day test period.

In the second regrowth experiment two samples each of the dual and tri-media filter effluents were collected. Chlorine was added to one sample of each effluent which raised the starting concentrations of total chlorine from 3.3 to 7.0 mg/l for the dual media filter effluent and from 2.5 to 7.0 for the tri-media filter effluent. After three days the total chlorine residual ranged from 0.5 to 0.6 for all four samples. As shown in TABLE 11, there was no fecal coliform regrowth although there were increases in standard plate count. In this respect the dual media performance was better than the tri-media.

Conclusions

1. At the design filtration rate of 5.5 gpm/ft^2 which was selected for the full scale facilities, alum and anionic polymer additions of 1.5 and 0.25 mg/l respectively to the filter influent provided the best combination of turbidity removal and minimum of headloss buildup in the filters.

TABLE 9

FECAL COLIFORM (MPN) AND 5-DAY GEOMETRIC MEAN DATA

Date	Filter Influent MPN	Geometric Mean	Dual Media Effluent MPN	Geometric Mean	Tri-Media Effluent MPN	Geometric Mean
8/16	<2		<2		<2	
8/17	<2		<2		<2	
8/18	<2		2		2	
8/19	<2		2		<2	
8/20	<2	<2	49	3	2	1
8/21	170[a]	3	<2	3	<2	1
8/22	<2	3	<2	3	<2	1
8/23	<2	3	<2	3	<2	1
8/24	<2	3	<2	<2	<2	<2
8/25	<2	3	<2	<2	<2	<2
8/26	<2	<2	<2	<2	<2	<2
8/27	2	<2	<2	2	<2	2
8/28	49	2	7	2	27	2
8/29	240[a]	7	130[a]	4	2	2
8/30	14	8	<2	4	<2	2
8/31	34	26[b]	11	6	2	3
9/1	>2400[a]	106[b]	14	11	<2	3
9/2	>2400[a]	231[b]	<2	7	350[a]	4
9/6	>2400[a]	366[b]	11	4	49	8
9/7	2	248[b]	<2	4	<2	8
9/8	2	141[b]	<2	3	2	8
9/9	17	52[b]	<2	2	<2	8
9/22	46	24	79[a]	4	110[a]	6
9/23	<2	5	<2	2	<2	3
9/24	8	7	2	3	<2	3
9/25	<2	6	8	4	14	4
9/26	540[a]	11	49	0	13	7
9/27	<2	11	<2	4	<2	3
9/28	>2400[a]	25[b]	<2	4	<2	3
9/29	<2	17	<2	3	<2	3
9/30	<2	17	<2	<2	-	-
10/1	33	10	<2	<2	4	2
10/3	>2400[a]	45[b]	<2	2	2	1

[a] Samples exceeding the single sample maximum fecal coliform standard of 75/100 ml.

[b] Samples exceeding 5-day geometric mean fecal coliform standard of 25/100 ml.

TABLE 10

Regrowth of Cultrued Fecal Coliforms (Fc) and Standard Plate Count (SPC) Bacteria in Normal and Chlorine Supplemented (+) Filtrates With Time

	Dual Media Filter Effluent				Dual Media Filter Effluent+			
Analysis	Day 0	Day 1	Day 3	Day 5	Day 0	Day 1	Day 3	Day 5
Free Chlorine:								
A* Test	0.38	0	0	0	0.8	0	0	
Total Chlorine:								
A Test	2.58	0	0	0	4.4	0	0	0
SPC/ml	$5x10^3$	$8x10^4$	$1x10^7$	$1x10^7$	10^3	$8x10^5$	$8x10^6$	$1x10^7$
Fc/100 ml	1,600	>2,400	>2,400	>24,000	23	>2,400	>2,400	>24,000
	Tri-Media Filter Effluent				**Tri-Media Filter Effluent+**			
Free Chlorine:								
A*	0.42	0	0	0	0.8	0	0	0
Total Chlorine:								
A	2.4	0	0	0	5.2	0	0	0
SPC/ml	$1x10^4$	$4x10^5$	$9x10^6$	$9x10^6$	1,000	$2x10^6$	$8x10^6$	$1x10^7$
Fc/100 ml	130	>2,400	>2,400	>24,000	79	>2,400	>2,400	>24,000

A* = Amperometric (Fischer Chlorine Titrimeter)

TABLE 11

Regrowth of Natural Fecal Coliforms (Fc) and Standard Plate Count (SPC) Bacteria in Normal and Chlorine Supplemented (+) Filtrates With Time

(10/4/83)

	Dual Media Filter Eff.			Dual Media Filter Eff.+			Tri-Media Filter Eff.			Tri-Media Filter Eff.+		
Analysis	Day 0	Day 1	Day 3	Day 0	Day 1	Day 3	Day 0	Day 1	Day 3	Day 0	Day 1	Day 3
Free Chlorine												
H Test	0.45	0.2	0	1.0	0.16	0	0.4	0.3	0	1.9	0.1	0
A Test	0.5	NS	0	0.7	NS	0	0.4	NS	0	1.4	NS	0
Total Chlorine												
H Test	3.3	1.6	0.6	7.0	4.4	0.6	2.5	1.4	0.5	7.6	4.4	0.5
A Test	2.7	NS	0.8	6.3	NS	0.6	2.0	NS	0.7	5.2	NS	0.7
SPC/ml	2,600	8,000	150	10	1	300	2,100	10,000	2,400	1	100	3,100
Fc/100 ml	540	<2	<2	<2	<2	<2	350	<2	<2	<2	<2	<2

H = Hach chlorimeter
A = Amperometric (Fischer Chlorine Titrimeter)
NS = No Sample

2. While both the dual and tri-media filters effectively reduced turbidity in the wastewater to acceptable levels, the dual media filter was determined to be more cost effective because of longer filter runs between backwashing and lower projected capital costs.

3. Regrowth of bacteria in the filtered water can be controlled by maintaining a minimum total chlorine residual of 0.5 mg/l.

4. The filters removed only a fraction of virus type microorganisms and, therefore, a free chlorine minimum concentration of 0.5 mg/l in the post chlorination facilities will be needed for effective virus kill if they are present in the RRWTP effluent.

5. Backwash water from the dual media pilot filter averaged 1.7 percent of filtered water production.

Water Reuse Facilities Design

Description of Reuse Facilities

Location. The treatment facilities are to be located along the southeast boundary of the Roger Road Wastewater Treatment Plant, immediately north of the existing interceptor sewers. FIGURE 2 shows the location of the facilities at the Roger Road location.

Treatment System. The ultimate treatment system is sized for 25 MGD flow and will consist of a filtration plant, a chlorination storage and feed system, a chlorination contact chamber, a control building, feed pumps, pipe mains, and ancillary utilities.

The filtration plant will consist of nine filtration modules. Each module will include three 12'-0" x 8'-0" straight side vertical epoxy lined pressure filters piped in parallel.

Each filter module operates independently of all other modules. During filtration all three filters operate in parallel. When a backwash mode commences, the feed to one of the filters is terminated; and the feed is then distributed to the other two filters until the end of the backwash cycle of the first filter. The automatic cycle consists of drain, air scour, backwash, filter to waste, and filter to service. During the backwash, the automatic control valve in the effluent (module) branch closes resulting in the water filtering through two filters still in service, then flows upflow through the filter being backwashed. Thereby filtered feed water is used for backwash without need for storage or supplemental pumping. Backwash cycles will either be initiated by timer, excessive

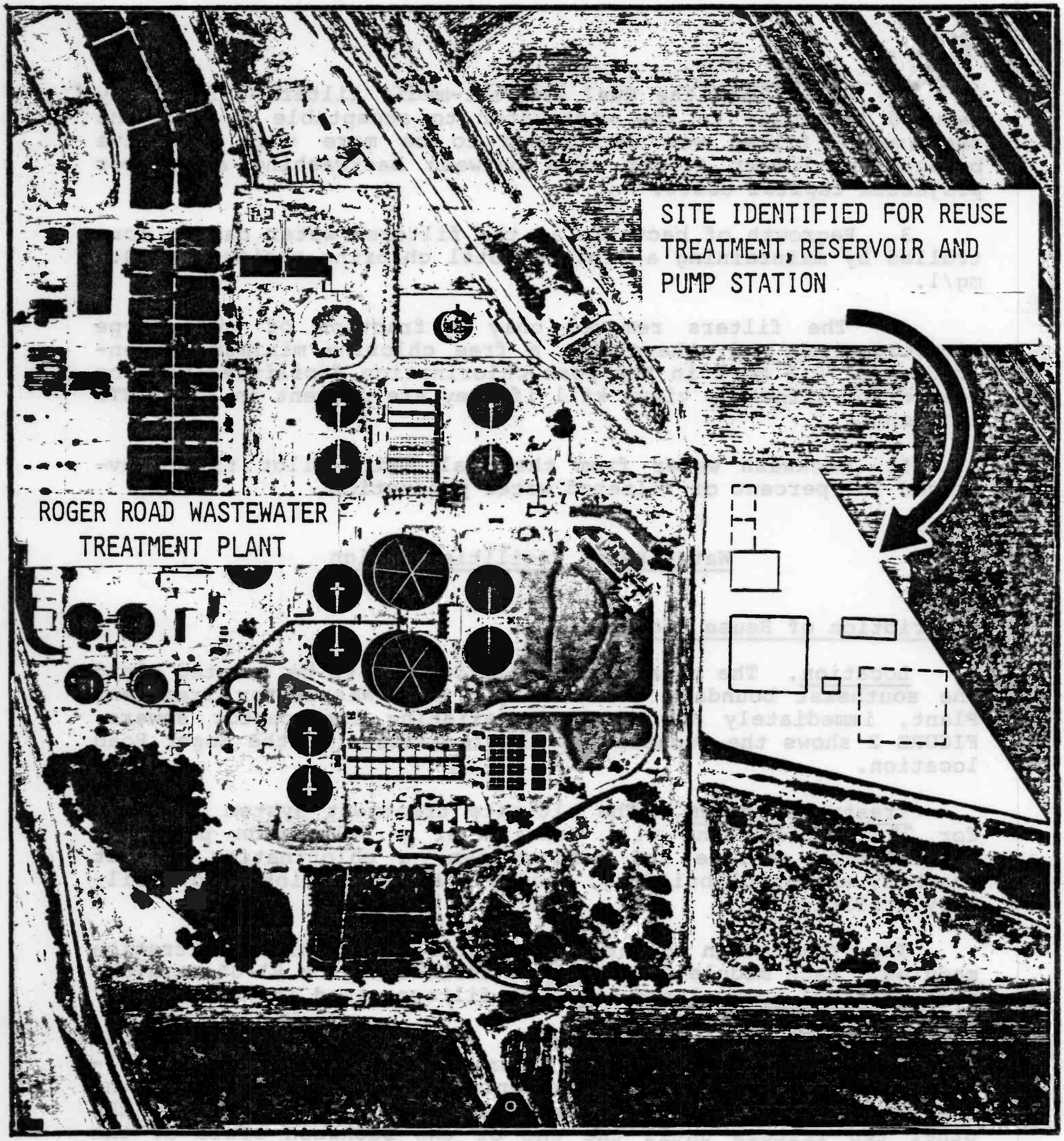

FIGURE 2

LOCATION OF REUSE TREATMENT, STORAGE
AND PUMPING FACILITIES ADJACENT TO
ROGER ROAD WASTEWATER TREATMENT PLANT

pressure loss across the filter or out of tolerance turbidity. A differential pressure switch across each filter will initiate backwash as will a turbidity meter which measures the treated water turbidity flowing from an automatic sampling system. Turbidity and pH for treated water from each filter in a module will be monitored by equipment dedicated to each module.

The initial filter system will consist of three modules for 8 MGD. The system can expand by adding an additional module for each 2.8 MGD (or function thereof) increase in system capacity. Each additional module will increase the length of the filter building twenty-four feet. The building will have a removable end wall which can be removed to enclose each 24'-0" bay expansion. For simplicity, the plans are for an initial 8 MGD capacity with two expansions of three modules each to the ultimate 25 MGD capacity.

The filters will be fed from the effluent wet well at the RRWTP by means of seven new 4 MGD feed pumps. Initially three new pumps will be furnished for the 8 MGD capacity. The pumps will be 150 HP, 1750 rpm with capacity of 2800 gpm at 67 psig TDH.

Ultimately, the feed water will be pumped through a new 36-inch diameter main to the treatment plant where it will be manifolded to feed each branch. The manifold size will be reduced in size every two branches until the 10-inch branch size is reached for the furthest module. The manifold will be 18" for the initial 8 MGD capacity.

The manifold for the treated water will be 36-inch diameter suitable for the ultimate 25 MGD; it in turn will reduce down to the 10-inch for the ninth module. The manifold will run to the chlorine contact chamber where it will elbow up to level one foot above the maximum liquid level. Besides the manifold portion, this main will have an automatic shut off valve that will be closed when the storage reservoir downstream of the chlorine contact chamber reaches an overflow level. Chlorine will be injected in this main just before it enters the contact chamber.

The backwash water main will be 10-inch which is the size required for backwash of a single filter. Initially the backwash water will flow directly to the headworks of the RRWTP during periods of low flow. During the first nine months of operation backwash quality data will be gathered to determine if pretreatment will be required to meet the Pima County Industrial Waste Discharge Ordinance. Alternate methods of disposing of the backwash water will also be evaluated.

Chlorine Contact Chamber. The chlorination contact chamber will be a covered concrete structure, located between the filter building and the storage reservoir. The structure will be initially sized for a two hour retention time for a 5 MGD flow.

As retention time requirements are gained through experience, the chlorine contact chamber will be expanded to provide the required retention time for the ultimate 25 MGD flow. The structure will also have a section that will house the chlorine bulk storage facility and the chlorine feed equipment. The bulk storage equipment will include a 4,000 gallon storage tank accompanied by a load cell, a dry nitrogen system and all additional ancillary equipment required for safe, simple operation. Housed in a separate room will be all necessary chlorine feed equipment required for automatic, simple, safe operation for all possible chlorine feed rates.

Control Building. The control building will contain space for a public display type control room, an analytical laboratory, an office, locker rooms, and chemical storage and feed equipment room, electrical closet and mechanical equipment room. The entire control system for the ultimate design flow, with the exception of the equipment that is mounted with the expansion modules, will be furnished and installed initially.

Reservoir. The initial reservoir will be a 3-million gallon cast-in-place covered concrete reservoir. The reservoir will be approximately 160-feet square and will have a maximum water depth of 25 feet with approximately 16 feet of the depth below grade. The bottom will be sloped to permit easy washdown for cleaning. The operating depth of the reservoir can be varied to minimize detention time in the reservoir during low flow periods. Space has been reserved for installation of a future reservoir. The reservoir will include interior baffles to minimize short circuiting of flow. Also, aeration will be provided to elevate the dissolved oxygen concentration of the effluent prior to distribution.

In addition to the reservoir described above, the La Paloma development will provide reservoir capacity of approximately two-million gallons.

Pump Station. The initial pumping station at Roger Road will pump to the reservoir at the La Paloma development in a single lift and will consist of 4-300 HP pumps capable of delivering approximately 9.2 MGD with one pump out of service. A location has been selected for a future booster pump station near the intersection of Alvernon and River Road. This booster station is not required to implement the initial project. The initial system working pressure will be approximately 185 psi, increasing to 240 psi ultimately if a booster pumping station is not installed near Alvernon.

Effluent Delivery Pipeline. The recommended route of the pipeline to deliver reclaimed water to the La Paloma development is shown on FIGURE 3. The pipeline will be installed under Interstate 10 and the Southern Pacific Railroad tracks by boring or tunneling techniques. The pipeline route will be primarily eastward along Gardner Lane, Roger Road and River Road to

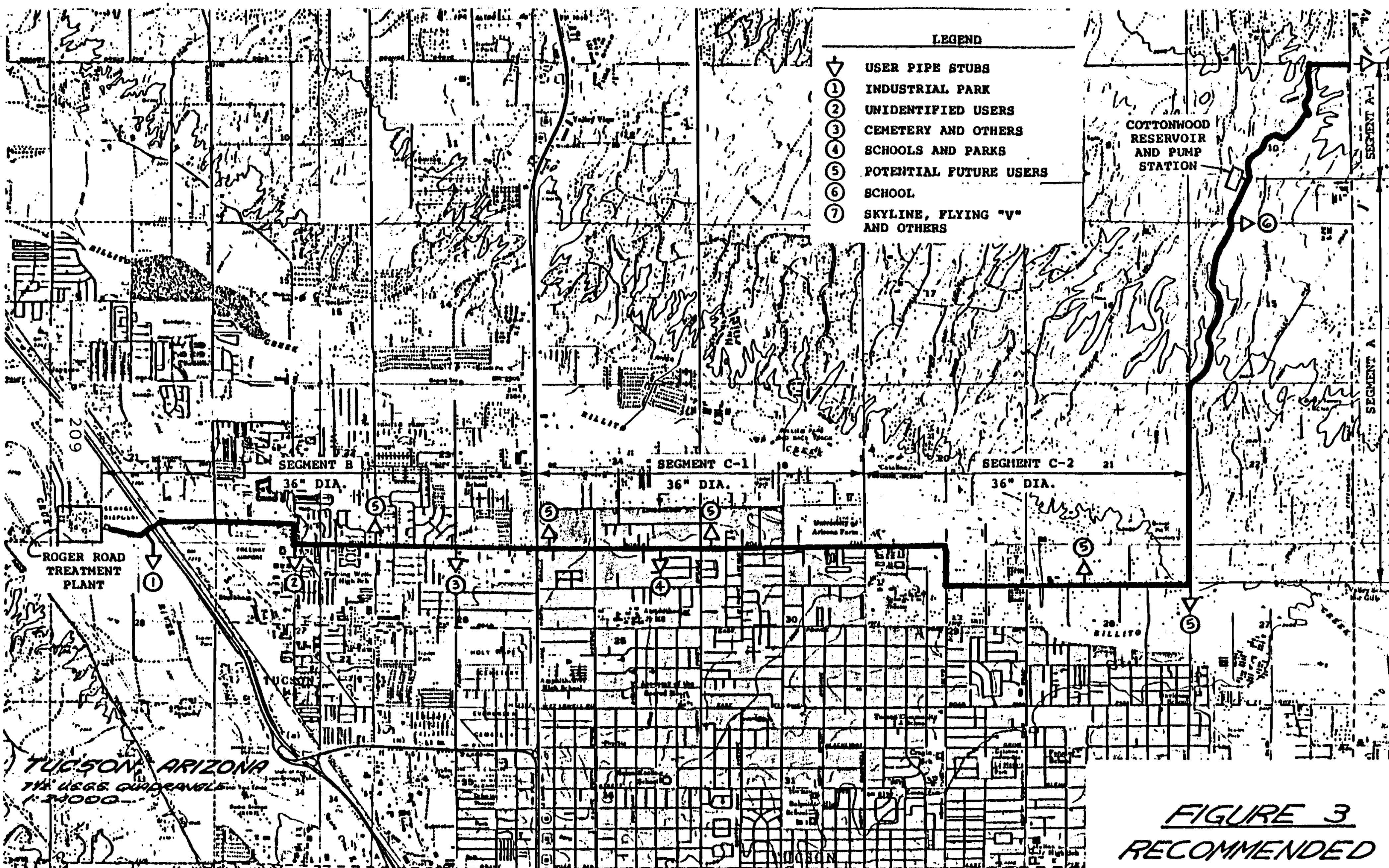

FIGURE 3
RECOMMENDED PIPELINE ROUTE

Alvernon Way. At that point, the pipeline route is northerly to the proposed site of the Cottonwood Reservoir. The pipeline to the Cottonwood Reservoir will require approximately 37,500 feet of 36-inch pipe and 13,000 feet of 24-inch pipe. In the future, the reuse pipeline will be extended by crossing Rillito Creek along Alvernon Way and then running eastward.

Construction Costs - Initial System

TABLE 12
CONSTRUCTION COST

Project Element	Total Estimated Costs	Total Bid Price
1. Treatment Facilities, 3 mg Reservoir and Main Pump Station	$2,980,000	$2,371,000
2. Pipeline	$3,217.775	$2,495,849
3. Prepurchased Materials	3,912,000	$3,197,766
Totals	$10,109,775	$8,064,615

The cost estimates were based on quantity takeoffs from layouts prepared during the final design stage. The lower actual bid prices reflect a two year trend in competitive bidding of public works construction projects.

The cost estimate listed in TABLE 12 does not include the cost of the initial portion of the pipeline to serve the Ventana Canyon development and Skyline Country Club which are also in progress.

Acknowledgements

The field and laboratory work necessary to collect and analyze water samples for microorganisms was provided by the University of Arizona Departments of Microbiology and Nutrition and Food Science under the direction of Charles P. Gerba, Ph.D. and Norval A. Sinclair, Ph.D.

Demonstration Recharge

A Demonstration Recharge project using reclaimed water is also underway at this time. This work is being conducted west of the RRWTP, just across the Santa Cruz River. The purpose of this work is to demonstrate that reclaimed water can be safely injected into the ground for storage and withdrawn as needed. If successful, this will allow smaller reclamation plants operating year round to be employed as opposed to larger plants operating only during the growing season. Significant capital cost savings are possible.