VALIDITY OF THE GENERALIZED LUMPED PARAMETER HYDROSALINITY MODEL IN PREDICTING IRRIGATION RETURN FLOW

by

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ABSTRACT

The generalized lumped parameter model, with a simulated linear or nonlinear subsurface reservoir, is a simplified approach to representing convective transport of a conservative non-reacting solute in a stream connected aquifer system. Since this approach implicity neglects any hydrodynamic dispersion effects, it is applicable when system-wide temporal responses in groundwater levels and water quality resulting from distributed input stresses are of interest. Although this technique has received relatively little attention in groundwater hydrology, its inherent advantages of reduced structural complexity and input data requirements suggest that it may be a suitable tool in many situations. Furthermore, in both the linear and nonlinear formulations, the requirement for observed or independently computed groundwater pumpage and evapotranspiration rates may be avoided, thereby eliminating those terms that tend to introduce large errors into the typical water balance approach.

Vertical flow effects on the system outflow concentration history resulting from fully or partially penetrating streams and aquifer heterogeneity are examined by utilizing the linearized Dupuit and Laplace distributed models. A hydraulic and mass equivalence between the linear lumped parameter and Dupuit models is established; these analyses produced identical outflow concentration histories for each model. This similitude is extended to include multiple aquifer systems when several lumped models are linked in a parallel configuration. These results indicate that the total mass leaving the Dupuit and lumped multiple systems are identical, while their respective concentration outflow

histories are approximately equivalent. Vertical flow effects on system outflow concentration resulting from varying aquifer geometry are characterized in the Laplace model by using an aspect ratio. This ratio is defined as $\eta = (L/D)(K_z/K_x)^{1/2}$, where L is the drain half-spacing, D is the aquifer depth, and K_z/K_x is the vertical to horizontal hydraulic conductivity ratio. For values of η greater than about five (and hence, most practical situations), the lumped parameter model approximates the Laplacian concentration break-through curves quite well; however, when η is less than five pronounced vertical flow effects cause significant differences in outflow histories. Vertical flow effects resulting from aquifer stratification are also shown to have an effect on the Laplacian outflow concentration histories. Both the effects of partial stream penetration and aquifer heterogeneity, however, are approximately incorporated into the combined lumped parameter parallel configuration with surprisingly good results by utilizing two empirical correction factors characterizing the aquifer system. These analyses demonstrate that in many situations, pronounced aquifer circulation patterns may not greatly influence system outflow concentrations; furthermore, in those instances where vertical flow effects are important, they may be successfully incorporated into the generalized lumped parameter format.

Finally, the generalized lumped approach is field tested in two separate irrigated valleys in order to demonstrate its general applicability and overall flexibility. The first of these is a linear subsubsurface reservoir for the Arkansas River Valley of southeastern Colorado over a one year period. Results favorably compare with observed data, and with a more complex convective-dispersive model (Konikow and

Bredehoeft, 1974a, 1974b) previously tested in the same area under similar conditions. A second application with a nonlinear reservoir is tested in the Mesilla Valley of southcentral New Mexico over a ten year period. Results show good to excellent agreement with observed data, and to a model (USBR, 1977) previously tested there (Gelhar and McLin, 1979). Both field applications also demonstrate that the lumped modeling technique can easily be utilized to evaluate the effects of various real and/or hypothetical system stress patterns, including the individual effects of improvements in irrigation efficiency and lining of conveyance canals. These simulations first require a determination of the system's hydraulic and solute response times from known data, and then an estimation of the quantity and quality of applied water from various known sources.

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TABLE OF CONTENTS

	Page
ABSTRACT	ii
ACKNOWLEDGEMENTS	v
LIST OF FIGURES	ix
LIST OF TABLES	xvi
LIST OF SYMBOLS	xvii
CHAPTER 1. INTRODUCTION	1
1.1 Background	1
1.2 Review of Previous Work	3
1.3 Purpose and Scope of Present Research	11
CHAPTER 2. THEORY OF OUTFLOW CONCENTRATION FROM LINEAR PHREATIC AQUIFERS	14
2.1 Introduction	14
2.2 Generalized Lumped Parameter Model	15
2.2.1 Water Balance Equation	15
2.2.2 Mass Balance Equatuion	21
2.2.3 Linear Reservoir Models In Combination	26
2.3 Linearized Dupuit Aquifer Model	34
2.3.1 Dupuit Approximation	34
2.3.2 Relationship Between Lumped Parameter and Linearized Dupuit Models	38
2.3.3 Multi-Layered Dupuit Aquifer System	44
2.3.4 Relationship Between Combined Lumped Parameter Model and Linearized Multi-Layered Dupuit Aquifer Model	47
2.4 Laplace Aquifer Model	71
2.4.1 Flow Field Description	71
2.4.2 Convective Outflow Concentration from the Laplace Aquifer Model	79

TABLE OF CONTENTS (Continued)

			Page
	2.4.3	Effects of Partial Stream Penetration. . . .	86
	2.4.4	Effects of Anisotropic Porous Medium	91
	2.4.5	Impermeable Basement at Infinite Depth . . .	95
	2.4.6	Multiple Aquifer Systems	98
	2.4.7	Relationship Between Laplace and Combined Lumped Models.	131
	2.5	General Conclusions.	149
CHAPTER	3.	FIELD APPLICATION OF THE LINEAR RESERVOIR MODEL. . .	153
	3.1	Introduction	153
	3.2	Arkansas River Linear Reservoir Model.	157
	3.3	Parameter Estimation Procedure	165
	3.4	Comparative Study Results.	171
	3.5	Water Management Options with The Linear Model . . .	179
	3.6	Conclusions.	195
CHAPTER	4.	FIELD APPLICATION OF THE NONLINEAR RESERVOIR MODEL .	198
	4.1	Introduction	198
	4.2	USBR-EPA Hydrosalinity Model	201
	4.3	Mesilla Valley Nonlinear Reservoir Model	210
	4.4	Comparative Study Results.	227
	4.5	Water Management Options with The Nonlinear Model. .	228
	4.6	Conclusions.	262
CHAPTER	5.	SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS.	266
REFERENCES CITED			272
APPENDICES			280
	A.	Dupuit Model Program	281
	B.	Modified U.S. Corps of Engineers Program	292

TABLE OF CONTENTS (Continued)

		Page
C.	Linear Reservoir Model Program, Arkansas River Valley	315
D.	Data Summary for Arkansas River Valley Study	325
E.	Nonlinear Reservoir Model Program, Mesilla Valley. .	370
F.	Estimate of Porosity and River Leakage	423
G.	Water Management Options, Mesilla Valley	452

LIST OF FIGURES

Figure		Page
2.1	Schematic representation of an idealized stream connected phreatic aquifer system.	17
2.2	Equation (2.2.15) versus time for several values of c_i . . .	25
2.3	Schematic representation of an idealized horizontally stratified aquifer system with a fully penetrating stream, and where $K_u > K_L$.	27
2.4	Schematic representation of linear reservoirs in combination.	28
2.5	Schematic vertical cross-section through a stream connected phreatic aquifer system with uniform accretion . .	35
2.6	Log (c/c_{aq}) versus t/t_{c1} for case (1)	62
2.7	Log (c/c_{aq}) versus t/t_{c1} for case (2)	63
2.8	Log (c/c_{aq}) versus t/t_{c1} for case (3)	64
2.9	Log (c/c_{aq}) versus t/t_{c1} for case (4)	65
2.10	Log (c/c_{aq}) versus t/t_{c1} for case (5)	66
2.11	Log (c/c_{aq}) versus t/t_{c1} for case (6)	67
2.12	Log (c/c_{aq}) versus t/t_{c1} for case (7)	68
2.13	Schematic diagram for an idealized Laplace aquifer showing one possible streamtube.	74
2.14	Idealized relationship indicating the total dimensionless area swept out by a given dimensionless streamline	83
2.15	Idealized breakthrough curve computed from the area versus streamline relationship.	84
2.16	Program grid network showing boundary conditions	87
2.17	$\bar{A}$ $(\bar{\Psi})$ as a function of $\bar{\Psi}$ for different values of η	88
2.18	c/c_0 as a function of t/t_c for different values of η . . .	89
2.19	Log (c/c_0) as a function of t/t_c for different values of η.	92
2.20	Schematic Laplace aquifer with impermeable basement at an infinite depth below the drain	96

LIST OF FIGURES (Continued)

Figure		Page
2.21	Schematic diagram showing the Laplace aquifer configuration for geologic layering.	100
2.22	$\bar{A}$ ($\bar{\Psi}$) vs. $\bar{\Psi}$ for different η; case (1) in Table 2.3 with α = 20.	103
2.23	c/c_0 vs. t/t_{c1} for different η; case (1) in Table 2.3 with α = 20.	104
2.24	Log c/c_0 vs. t/t_{c1} for different η; case (1) in Table 2.3 with α = 20.	105
2.25	$\bar{A}$ ($\bar{\Psi}$) vs. $\bar{\Psi}$ for different η; case (1) in Table 2.3 with α = 10.	106
2.26	c/c_0 vs. t/t_{c1} for different η; case (1) in Table 2.3 with α = 10.	107
2.27	Log c/c_0 vs. t/t_{c1} for different η; case (1) in Table 2.3 with α = 10.	108
2.28	$\bar{A}$ ($\bar{\Psi}$) vs. $\bar{\Psi}$ for different η; case (1) in Table 2.3 with α = 5	109
2.29	c/c_0 vs. t/t_{c1} for different η; case (1) in Table 2.3 with α = 5	110
2.30	Log c/c_0 vs. t/t_{c1} for different η; case (1) in Table 2.3 with α = 5	111
2.31	$\bar{A}$ ($\bar{\Psi}$) vs. $\bar{\Psi}$ for different η; case (1) in Table 2.3 with α = 2	112
2.32	c/c_0 vs. t/t_{c1} for different η; case (1) in Table 2.3 with α = 2	113
2.33	Log c/c_0 vs. t/t_{c1} for different η; case (1) in Table 2.3 with α = 2	114
2.34	$\bar{A}$ ($\bar{\Psi}$) vs. $\bar{\Psi}$ for different η; case (2) in Table 2.3 with α = 10.	115
2.35	c/c_0 vs. t/t_{c1} for different η; case (2) in Table 2.3 with α = 10.	116
2.36	Log c/c_0 vs. t/t_{c1} for different η; case (2) in Table 2.3 with α = 10.	117

Figure Page

2.37 $\bar{A}$ $(\bar{\Psi})$ vs. $\bar{\Psi}$ for different η; case (3) in Table 2.3 with α = 10. 118

2.38 c/c_0 vs. t/t_{c1} for different η; case (3) in Table 2.3 with α = 10. 119

2.39 Log c/c_0 vs. t/t_{c1} for different η; case (3) in Table 2.3 with α = 10. 120

2.40 $\bar{A}$ $(\bar{\Psi})$ vs. $\bar{\Psi}$ for different η; case (4) in Table 2.3 with α = 10. 121

2.41 c/c_0 vs. t/t_{c1} for different η; case (4) in Table 2.3 with α = 10. 122

2.42 Log c/c_0 vs. t/t_{c1} for different η; case (4) in Table 2.3 with α = 10. 123

2.43 $\bar{A}$ $(\bar{\Psi})$ vs. $\bar{\Psi}$ for different η; case (5) in Table 2.3 with α = 10. 124

2.44 c/c_0 vs. t/t_{c1} for different η; case (5) in Table 2.3 with α = 10. 125

2.45 $\bar{A}$ $(\bar{\Psi})$ vs. $\bar{\Psi}$ for different η; case (5) in Table 2.3 with α = 100 126

2.46 c/c_0 vs. t/t_{c1} for different η; case (5) in Table 2.3 with α = 100 127

2.47 $\bar{A}$ $(\bar{\Psi})$ vs. $\bar{\Psi}$ for different η; case (6) in Table 2.3 with α = 10. 128

2.48 c/c_0 vs. t/t_{c1} for different η; case (6) in Table 2.3 with α = 10. 129

2.49 Log c/c_0 vs. t/t_{c1} for different η; case (6) in Table 2.3 with α = 10. 130

2.50 Laplace and combined lumped model c/c_{aq} vs. t/t_{c1} curves (see Figures 2.6 and 2.24). 133

2.51 Laplace and combined lumped model c/c_{aq} vs. t/t_{c1} curves (see Figures 2.7 and 2.27). 134

2.52 Laplace and combined lumped model c/c_{aq} vs. t/t_{c1} curves (see Figures 2.8 and 2.30). 135

LIST OF FIGURES (Continued)

Figure		Page
2.53	Laplace and combined lumped model c/c_{aq} vs. t/t_{c1} curves (see Figures 2.9 and 2.33).	136
2.54	Laplace and combined lumped model c/c_{aq} vs. t/t_{c1} curves (see Figures 2.11 and 2.36)	137
2.55	Laplace and combined lumped model c/c_{aq} vs. t/t_{c1} curves (see Figures 2.12 and 2.39)	138
2.56	Lumped (μ/m) vs. Laplace (γ) model slopes for different values of η.	141
2.57	Lumped (μ) vs. Laplace (β) model intercepts for different values of η.	142
2.58	Corrected lumped vs. Laplace c/c_{aq} vs. t/t_{c1} curves for $\eta = 10$	143
2.59	Corrected lumped vs. Laplace c/c_{aq} vs. t/t_{c1} curves for $\eta = 5$.	144
2.60	Corrected lumped vs. Laplace c/c_{aq} vs. t/t_{c1} curves for $\eta = 4$.	145
2.61	Corrected lumped vs. Laplace c/c_{aq} vs. t/t_{c1} curves for $\eta = 3$.	146
2.62	Corrected lumped vs. Laplace c/c_{aq} vs. t/t_{c1} curves for $\eta = 2$.	147
2.63	Corrected lumped vs. Laplace c/c_{aq} vs. t/t_{c1} curves for $\eta = 1$.	148
3.1	Lumped parameter representation of the irrigated stream-aquifer system near La Junta, Colorado	159
3.2	Discretized subscript notation for water balance equation. .	161
3.3	Discretized subscript notation for mass balance equation . .	164
3.4	Changes in mean monthly river flow over the study reach. . .	172
3.5	Total changes in river TDS between the Ft. Lyon canal diversion and the Bent-Otero County line	173
3.6	Study reach changes in river TDS	174
3.7	Changes in average aquifer water levels in the Arkansas River Valley study area.	175

LIST OF FIGURES (Continued)

Figure		Page
3.8	Changes in average aquifer TDS concentration in the study reach.	176
3.9	Study reach changes in streamflow and surface water quality as a result of extending the lumped model simulation period an additional four years	177
3.10	Study reach changes in groundwater storage and water quality as a result of extending the lumped model simulation period an additional four years	178
3.11	Changes in streamflow and surface water quality relative to the base simulation for no surface water diversion for irrigation	182
3.12	Changes in groundwater storage and water quality relative to the base simulation for no surface water diversion for irrigation	183
3.13	Changes in streamflow and surface water quality relative to the base simulation for no groundwater pumpage for irrigation	185
3.14	Changes in groundwater storage and water quality relative to the base simulation for no groundwater pumpage for irrigation	186
3.15	Changes in streamflow and surface water quality relative to the base simulation for a 20 percent improvement in irrigation efficiency.	189
3.16	Changes in groundwater storage and water quality relative to the base simulation for a 20 percent improvement in irrigation efficiency.	190
3.17	Changes in streamflow and surface water quality relative to the base simulation as a result of canal lining to prevent leakage.	193
3.18	Changes in groundwater storage and water quality relative to the base simulation as a result of canal lining to prevent leakage.	194
4.1	Location of the Mesilla Valley and Upper Rio Grande drainage basin, New Mexico.	199
4.2	Schematic nodal representation showing some features simulated in the USBR-EPA model.	202

LIST OF FIGURES (Continued)

Figure		Page
4.3	RMS error in simulated USBR-EPA aquifer water levels and simulated river outflow chemistry as a function of the consumptive use multiplier	207
4.4	USBR-EPA model results using an irrigation efficiency of 50 percent; the RMS error between observed and predicted output is 344 mg/l	208
4.5	USBR-EPA model results using a hypothetical irrigation efficiency of 75 percent; the observed data are shown for reference only	209
4.6	Lumped parameter representation of the irrigated stream-aquifer system in the Mesilla Valley	211
4.7	Monthly observed and simulated average aquifer water levels using the nonlinear lumped model; the RMS error is 0.18 feet	218
4.8	Lumped parameter monthly simulated and observed average valley drain flow; the RMS error is 0.02 feet per month. . .	219
4.9	Lumped parameter monthly observed and simulated Rio Grande TDS at El Paso, Texas; the RMS error is 213 mg/l	221
4.10	Lumped parameter monthly observed and simulated Rio Grande flow at El Paso, Texas; the RMS error is 7324 acre feet per month.	222
4.11	Lumped parameter monthly predicted average aquifer TDS; only a few months of data were observed	223
4.12	Base period simulation of average aquifer water levels and drain flow in the Mesilla Valley	230
4.13	Base period simulation of average aquifer TDS and net average recharge in the Mesilla Valley	231
4.14	Base period simulation of average river TDS at El Paso, Texas, the Mesilla Valley outflow point.	232
4.15	Base period simulation of average river outflow at El Paso, Texas, the Mesilla Valley outflow point.	233
4.16	Case (1) changes from the base simulation in average aquifer water levels and valley drain flow	237
4.17	Case (1) changes from the base simulation in average aquifer TDS and net average aquifer recharge	238

LIST OF FIGURES (Continued)

Figure		Page
4.18	Case (1) changes from the base simulation in average river TDS at El Paso, Texas.	239
4.19	Case (1) changes from the base simulation in average river outflow at El Paso, Texas.	240
4.20	Case (2) changes from the base simulation in average aquifer water levels and average valley drain flow	244
4.21	Case (2) changes from the base simulation in average aquifer TDS and net average aquifer recharge	245
4.22	Case (2) changes from the base simulation in average river TDS at El Paso, Texas.	246
4.23	Case (2) changes from the base simulation in average river outflow at El Paso, Texas.	247
4.24	Case (3) changes from the base simulation in average aquifer water levels and valley drain flow	251
4.25	Case (3) changes from the base simulation in average aquifer TDS at El Paso, Texas.	252
4.26	Case (3) changes from the base simulation in average river TDS at El Paso, Texas.	253
4.27	Case (3) changes from the base simulation in average river outflow at El Paso, Texas.	254
4.28	Case (4) changes from the base simulation in average aquifer water levels and valley drain flow	258
4.29	Case (4) changes from the base simulation in average aquifer TDS and net average aquifer recharge	259
4.30	Case (4) changes from the base simulation in average river TDS at El Paso, Texas.	260
4.31	Case (4) changes from the base simulation in average river outflow at El Paso, Texas.	261
D.1	Arkansas River Valley study area showing well locations and Theissen weighting polygons.	329

LIST OF TABLES

Table		Page
2.1	Comparison between the combined lumped and linearized Dupuit models.	61
2.2	Comparison between the Laplace model and the generalized lumped parameter model	94
2.3	Cases examined for geological layering effects	101
2.4	Areas under c/c_0 vs t/t_c curves.	132
2.5	Values of γ and β from Figures 2.56 and 2.57 with K_L/K_u = 0.20, m=3, and μ =0.375.	140
3.1	Data summary for the parameter estimation.	170
3.2	Summary comparison between the five year lumped output and the Konikow-Bredehoeft model output.	180
4.1	Summary of major USBR-EPA model features	205
4.2	Comparison of linear and nonlinear aquifer parameters for the Mesilla Valley	217
4.3	Arithmetic means of observed TDS values.	225
4.4	List of wells used for arithmetic means.	226
4.5	Summary of water management options simulated, showing changes from base period simulation.	263

LIST OF SYMBOLS

The following list covers the symbols which are widely used herein. The dimensions of dimensional quantities are given in parenthesis.

Symbol	Description
a	lumped parameter outflow constant (1/T)
a, b, c, l, m	arbitrary constants
A	horizontal surface area of aquifer (L^2)
b_L	thickness of lower aquifer in a multiple aquifer system, (L)
B	equal to b_L/h_o
c, c_o, c_{aq}	average aquifer solute concentration, (M/L^3)
c_i	average aquifer solute input concentration, (M/L^3)
c_s	average solute concentration of surface waters, (M/L^3)
c_a, c_n	average solute concentration of artificial or natural recharge waters, respectively, (M/L^3)
D	Depth to an impermeable basement below the stream or tile drain, (L)
E	lumped time dependent aquifer water inputs minus outputs, ($L^3/T/L^2$)
$f(x)$	constant of integration with respect to z
h, $\overline{h}$	average saturated thickness of the lumped model aquifer, (L)
h_o	water elevation above some reference datum at the stream or drain (L)
h_r	average aquifer water level elevation above some reference datum at time t = o, (L)
h_1, h_2	average saturated thickness in the upper and lower aquifers, respectively, in a multiple aquifer system, (L)
i, j	vector subscript notation corresponding to the x, z unit vector directions, respectively

LIST OF SYMBOLS (Continued)

Symbol	Description
$\bar{J}$	the hydraulic gradient vector
k	a rate constant in the mass balance equation, (1/T)
K, K_u, K_L	the hydraulic conductivity; upper and lower K values in a multiple aquifer system, (L/T)
L	aquifer length, or drain half spacing, (L)
n	average effective aquifer porosity
q_a, q_n	artifical or natural aquifer volume recharge rate per unit horizontal surface area, $(L^3/T/L^2)$
q_b	net volumetric aquifer boundary inflow per unit horizontal surface area, $(L^3/T/L^2)$
q_l, q_r	net volumetric canal or river leakage rate per unit horizontal surface area lost to the aquifer, $(L^3/T/L^2)$
q_m, q_p	municipal or irrigation pumpage rate per unit horizontal surface area, $(L^3/T/L^2)$
Q	volumetric flow rate, (L^3/T)
r'	volumetric mass source-sink term in the mass balance equation, $(M/L^3/T)$
r	an aquifer shape factor in a multiple aquifer system, and equal to h_2K_L/h_1K_u
S	average aquifer specific yield, or drainable porosity
t	time, (T)
T	aquifer transmissivity, (L^2/T)
t_c	solute response time of the mass balance equation for the lumped parameter and Laplace models, and equal to nh/ε, (T)
t_{c_1}	solute response time for the combined lumped parameter or multiple layer Laplace model relative to the upper aquifer, and equal to nh_1/ε, (T)

LIST OF SYMBOLS (Continued)

Symbol	Description
t_c'	solute response time for the linearized Dupuit model and equal to nh_0/ε, (T)
$t_{c'_1}$	solute response time for the linearized multiple layer Dupuit aquifer model, and equal to $n(h_0 + \xi/2)/\varepsilon$, or $(1 + r)\ t_{c_1}$, (T)
t_h	the hydraulic response time of the water balance equation for the lumped parameter model, and equal to S/a, (T)
V	aquifer saturated pore volume, (L^3)
x, y, z	spatial Cartesian coordinates, (L)
$\bar{x}$, $\bar{z}$	average horizontal and vertical particle coordinates, (L)
X, Z	equal to x/L and z/L, respectively
α	the ratio K_u/K_L
β	a constant relating a, T, and L
γ	the ratio of the solute response times from the upper and lower aquifers in a multiple aquifer system
ε	average aquifer volumetric recharge rate per unit of horizontal surface area, $(L^3/T/L^2)$
η	an aspect ratio defined as, $(L/D)(K_z/K_x)^{1/2}$
μ	the ratio of the aquifer volumetric flow rate
ξ	an aquifer shape factor relating b_L, K_u, and K_L, (L)
$\hat{\xi}$	equal to $\xi/2h_0 = b_L(K_L - K_u)/h_0K_u$
τ	a dummy integration variable, (T)
ψ	the stream function, $(L^3/T/L)$
ψ_u, ψ_L	dimensionless stream function of the upper and lower aquifers, respectively, in a multiple aquifer system

CHAPTER 1

INTRODUCTION

1.1 Background

In the semiarid regions of the western United States, one of the more common sources of shallow groundwater contamination is irrigated agriculture. Typically these irrigated areas are located along alluvial floodplains where relatively inexpensive, high quality surface water supplies are readily available. Elaborate water storage, delivery, and drainage control systems are usually installed to maximize benefits, while attempting to simultaneously control seepage and soil salinity problems. More expensive shallow groundwater of lower quality may also be utilized when surface supplies become limited. The total applied waters tend to increase in solute concentration because of surface evaporation and plant transpiration; furthermore, a potential for upward fluid and solute movement from the underlying saline water table into the plant root zone may also periodically be created. In these irrigated areas it is evident that soluble salts will eventually accumulate in the plant root zone, resulting in lower crop yields, unless preventative measures are taken.

Since the problem solutes in question are primarily transported into or out of the unsaturated plant root zone in the water phase, their temporal and spatial distributions within this zone are controllable through appropriate water and agricultural management techniques. Historically these management approaches have centered around seepage and salinity drainage control techniques, improvements in water conveyance structures, reductions in phreatophyte and crop evapotranspiration rates, and on farm irrigation efficiency and scheduling improvements. These measures in turn may have associated environmental impacts on hydraulically connected ground and surface water supplies.

In order to evaluate these impacts, many analytical, electric analog, sand tank, and computer based modeling efforts simulating the simultaneous transport of water and solutes through the unsaturated zone have evolved over the past several decades. While these approaches have reached an advanced level of detailed refinement, the saturated flow regime may actually dominate in a systems approach sense. Saturated multidimensional convective-dispersive groundwater models also exist for this situation, but sufficient observed data are seldom adequate to determine the necessary model parameters for site specific applications. Simpler lumped parameter modeling efforts which are more consistent with data availability have been proposed and utilized with some success; these models are not widely accepted because their relibility has not been adquately demonstrated. Hence, there is a need to evaluate the implied limitations and field applicability of lumped models to irrigated stream-aquifer systems. If this realibility can be established, such an approach will offer an important practical tool for management of large scale irrigation systems.

In view of Public Law 92-500 (Federal Water Pollution Control Act Amendments of 1972), U.S. international treaty agreements, and socioeconomic considerations, the lumped modeling approach may prove to be a useful tool in areally extensive river basins where irrigated agriculture is fully developed or still evolving. Hence, the environmental impact of established or newly developed irrigation related water management schemes in one or more subbasins can be evaluated from a systems oriented approach. For example, if improvements in irrigation efficiency were proposed for an upstream subbasin in the Colorado River or Rio Grande Basins, the resulting shallow ground and surface water alterations at Yuma or El Paso could be simulated before extensive capital expenditures were made. Actually a variety of management options at a number of subbasins within the entire watershed could be easily computed. Furthermore, the technical implications of local, regional, and international legal obligations could be evaluated. Ideally optimal solutions could then be selected so as to maximize basin wide benefits while minimizing undesireable effects.

1.2 Review of Previous Work

We begin this review with a historical discussion on research developments which enable a conceptualization of water and mass transport phenomena in irrigated stream-aquifer systems. The physical basis underlying the various subsurface modeling efforts are briefly highlighted. These basic principles will suggest an appropriate solution technique and determine the required input data for a given approach; furthermore, the intended use of each model type should become apparent. Finally for purposes of specific comparison, we mention several hydrosalinity return flow field simulation efforts utilizing these different methods. The need for and applicability of the generalized lumped parameter model will hopefully become evident in this review.

A great deal of research emphasis in irrigation return flow modeling has focused on the flow and chemical characteristics in the near-surface unsaturated zone above the water table. It is here that the majority of salinity increases associated with return flow occurs. Evapotranspired waters cause any original contaminants present to further concentrate; these constituents are free to biologically or chemically interact with soil organisms, soil minerals, or interstitial waters, usually resulting in even further degradation. Early physical descriptions of the steady convective leaching, or flushing, phenomenon were developed by Gardner and Brooks (1957), even though dispersion and adsorption effects were already known to be simultaneously operative in laboratory column experiments (Lapidus and Amundson, 1952). Other models developing along this trend continued to emphasize the simultaneous convective flow of solutes and water in one-dimensional unsaturated flow (Bresler, 1967; Bresler and Hanks, 1969; and Freeze, 1969a), but for the unsteady case. Warrick, et al., (1971) improved upon these techniques by including dispersion effects, even though they used a constant dispersion coefficient in the mass transport equation; furthermore, they assumed steady-state conditions would be quickly established around the moving solute front. Later Warrick, et al., (1972) allowed the dispersion coefficient to vary as an empirical function of time in order to account for unsteady flows. Bresler (1973a; 1973b) and Kirda, et al., (1973) extended the analysis to transient unsaturated convective-dispersive transport without these earlier limitations. Bresler's (1973b) numerical approach nicely combined explicit-like efficiency, unconditional stability, and second order accuracy. Wilson and Gelhar (1974) have also overcome some of the previous conceptual and mathematical limitations inherent to earlier unsaturated models by analytically relating the dispersion coefficient to moisture content, seepage velocity, and molecular diffusion.

Solute adsorption and ion exchange reactions in the unsaturated zone were considered separately from convective-dispersive effects at first (Hiester and Vermeuler, 1952; and Dutt, 1962). However comparative studies of several cation adsorption and dispersion models later stressed the coupled importance of these and other possible effects (Biggar and Nielsen, 1963; and Hornsby, 1973). As a result, Dutt, et al., (1972) improved upon the earlier models by including individual soil layer plant water uptake, and chemical and biological effects in their one-dimensional considerations. Other one-dimensional modeling efforts also began to include chemical effects (Bresler, 1973b; and Nimah and Hanks, 1973), but in a convective-dispersive framework. Recent refinements (Bresler, 1977; and Hanks, et al., 1977) include a plant water uptake distribution function in the flow equation, and a source-sink rate term in the mass balance equation. The relative importance between these two terms on aquifer contaminant inputs appears to be site dependent (Hanks, et al., 1977). In addition, the specific form of the plant water uptake function is reported to be more important than variations in either soil hydraulic properties or surface contaminant inputs in causing variations in aquifer contaminant inputs (Jury, et al., 1977).

Without exception input data requirements for these and other unsaturated models grow in direct relation to model complexity; for example, a chemical simulation model might require spatial and temporal distributions of dissolved carbon dioxide, among other data, to realistically represent the unsaturated interval. Without such information, an observer might wonder exactly what a given model is simulating. Furthermore, all of the previously mentioned models stop short of actually predicting time history concentration fluctuations in hydraulically connected ground or surface waters. Instead these models are designed to simulate solute fluctuations leaving the unsaturated zone and entering a shallow water table.

Not surprisingly, a corresponding amount of research effort has also been directed towards saturated flow through porous media. Early analytical and numerical modeling techniques were developed to simulate steady saturated convective transport (Warrick and Kirkham, 1969; Freeze, 1969b; and Cooley, 1970), but were quickly extended to include the unsteady case as well (Prickett and Lonnquist, 1971; Cooley, 1974; and Trescott, et al., 1976). Most recent efforts have concentrated on improving numerical procedures, although Flores W., et al., (1978) have deviated from the more traditional deterministic approach (as summarized by Prickett, 1976; and Gelhar, 1976) in their development of a stochastic water management model for a stream-aquifer system.

Saturated convective-dispersive transport models developed alongside of the saturated hydraulic models (Shamir and Harleman, 1967; and Guymon, 1970), and also initially used the steady flow approximation. This limitation was overcome, however, when Reddell and Sunada (1970) used the method of characteristics in solving the coupled, unsteady convective-dispersive equation, while Guymon, et al., (1970), Huyakorn (1977), and Huyakorn and Nilkula (1979) have suggested applications utilizing the finite element technique. Reactive solute effects were included in early one-dimensional models (Lai and Juinak, 1972; Gupta and Greenkorn, 1973; and Rubin and James, 1973). Various simplifying assumptions made primarily for mathematical or numerical convenience, however, limited many of these efforts. These limitations centered around the form of the dispersion coefficient, model initial and boundary conditions, various empirical approximations to a cation adsorption function or other fluid-solid disturbances, and the numerical method selected for solution. Schwartz and Domenico (1973) in their refinements, attempted to solve the two-dimensional mass transport problem considering chemical and biological interactive effects for the Upper Kettle Creek, Ontario, Canada, using the steady flow model described by Freeze (1969b).

Some model interfacing between the unsaturated and saturated flow zones has occurred. Freeze (1971) developed a convective three-dimensional transient solution for an entire drainage basin that considers aquifer heterogenity, compressibility, and soil hysteresis. He has extended this approach to contaminant migration from subsurface waste disposal sites (Freeze, 1972), but does not consider dispersion or hydrochemical reactions. Perez, et al., (1972) presented an overview of a conjunctive use model for a surface-groundwater system. They represented the unsaturated zone by a one-dimensional analytical solution and the groundwater flow by a steady-state solution for each time step. Pikul, et al., (1974) chose to link the solution for one-dimensional vertical unsaturated flow to a one-dimensional horizontal saturated flow condition. Again, none of these models considered simultaneous mass transport by the dispersion process, or any chemical interaction effects. Some of these efforts may be conceptually objectional, but they do attempt to address the problem of surface solute introduction and subsequent convective transport through the groundwater flow regime. Furthermore, recent refinements of this approach (Neuman, et al., 1974) now consider transient, three-dimensional convective-dispersive transport with slight medium compressibility, plant water uptake in the unsaturated zone, and well withdrawal from the saturated zone. Finally it should be noted that these works suggest the relative importance of the unsaturated zone may sometimes be small in relation to other factors contributing to return flow degradation.

None of the models previously mentioned relates time history fluctuations in contaminant inputs to hydraulically connected surface water outputs. While these spatially distributed convective-dispersive models will directly yield unsaturated and/or saturated concentration profiles for the region of interest, the impact of various water and agricultural management practices has not been directly evaluated from any of these models. Instead these approaches have been used to provide insight on the relative importance of several transport mechanisms involved in irrigation-related water quality degradation.

In irrigated stream-aquifer situations, groundwater contaminant inputs may be regarded as being uniformly distributed throughout the system. In such cases it would appear that hydrodynamic dispersion in saturated media is only a second order effect since adjacent streamlines usually do not show large velocity variations in space or time. Gelhar and Collins (1971) attempted to quantify the relative importance of longitudinal dispersion effects; they used an approximate analytical technique for steady, nonuniform flows with variable dispersion coefficients. Although they did not consider natural nonhomogeneity and anisotropy effects on dispersion, they concluded that accelerating (or converging) flows showed greater dispersion than decelerating (or diverging) flows. One might also logically suspect that transverse dispersion would become dominant over that in the longitudinal direction when a contaminant front approached a shallow irrigation drain, since convective streamline patterns may begin to move nearly parallel to the front. This may indeed be the case of this idealized example, but Eldor and Dagan (1972) have shown rather convincingly that hydrodynamic dispersion tensor effects (i.e., including both the longitudinal and transverse components) have very little overall effect on contaminant output fluctuations. They examined a two-dimensional flow field with fully penetrating streams under steady uniform recharge. Hence, the relative importance of hydrodynamic dispersion in irrigated stream-aquifer systems appears to be small in comparison to convective effects; this conclusion is obviously of major importance. Field testing of a two-dimensional convective-dispersive model in an irrigated stream-aquifer system in the Arkansas River Valley of Colorado further demonstrated that hydrodynamic dispersion effects were not a major contributor to contaminant mixing in the aquifer (Konikow and Bredehoeft, 1974a, 1974b). These authors concluded that changes in dissolved solid concentrations in shallow groundwaters resulted primarily from convective transport, and by the mixing of recharged waters of different quality. The model developed by them provides flexibility in water planning and management options as demonstrated in the above references, in addition to its application in the San Luis Rey River Basin, California (Helweg and Labadie, 1976; and Labadie, et al., 1976). This model does require extensive input data and access to a digital computer, however.

Recently several workers have begun to re-examine solute travel times along convective stream patterns resulting from typical irrigated stream-aquifer situations. Two-dimensional fluid displacement processes were previously examined analytically for the case of an infinite plane source to a line sink by Muskat (1946), and for tile drain displacement patterns by Luthin, et al., (1969), and Ortiz and Luthin (1970). More recently, Miyamoto and Warrick (1974a, 1974b) have investigated steady piston displacement of salts into tile drains from surface ponding, using mathematical and sand tank modeling techniques. Jury (1975) numerically integrated the analytical solution of Kirkham (in Kirkham and Powers, 1972, p. 115) in order to calculate relationships between solute travel times and distances from tile drains. Field comparisons of chloride effluent for a ponded leaching experiment were predicted rather well by his model. Raats (1975) developed a conceptually similar technique for unsaturated-saturated solute flow. His method basically involved tracking space-time trajectories of parcels of water for a given flow system, assuming the solute follows this same saturated zone trajectory as the water parcel (i.e., neglecting hydrodynamic dispersion). He has also considered several complicating phenomena in the unsaturated zone; that is, evapotranspiration, hydrodynamic dispersion, adsorption, and dissolution-precipitation reactions for the one-dimensional transient case.

A lumped parameter hydrologic model developed by Riley, et al., (1966) was coupled to a chemical model (described by Tanki and Doneen, 1966; Tanji, et al., 1967; and Dutt, et al., 1970) by Thomas, et al., (1972). An electric analog simulation was used for the hydraulic model, while a digital simulation was utilized for chemical equilibrium reactions within the unsaturated zone. This model was applied to an irrigated area of the Little Bear River Basin of Utah, and showed excellent agreement between observed and predicted monthly TDS outflow history. The model also showed good to excellent histories for water outflow and the six dominant ions common to western waters (i.e., Ca, Mg, Na, SO_4, Cl, and HCO_3). This lumped model (i.e., Thomas, et al., 1972), perhaps more than any other, has come closer to satisfactorily relating surface contaminant inputs to resulting downstream surface outputs. The electric analog portion of the model does make routine applications to other sites more difficult, however.

1.3 Purpose and Scope of the Present Research

A general objective of this research is to develop a simple method to predict future changes in downstream water quality resulting from various alternative management practices in irrigated agriculture. Desirable features of this method should include a minimum of input data requirements and overall flexibility and simplicity of operation, while still physically representing the irrigated stream-aquifer system in a realistic manner. The main features of this work are the deterministic representation of the stream-aquifer system by a lumped parameter linear or nonlinear reservoir model, and a comparison of outflow concentration histories between this so called black-box approach and more complex spatially distributed models. The immediate goal of this work is to formulate a basis of analyzing the individual effects of several complicating phenomena on downstream water quality variations that are not explicity inherent to the generalized lumped parameter groundwater model. The following specific objectives are established:

(1) To develop solutions to the problem of outflow concentration history from a homogeneous, isotropic aquifer with fully or partially penetrating streams under steady, saturated, convective transport

flow conditions; and with a steady, uniformly distributed conservative contaminant input;

(2) To extend the approach of step (1) to non-homogeneous, anisotropic aquifers with and without an impermeable basement at some finite depth;

(3) To develop solutions to the problem of outflow concentration history for the lumped parameter linear reservoir model in single or parallel configurations, and to compare the results to those obtained in steps (1) and (2);

(4) To examine the predictive capability of the linear lumped parameter model under actual field conditions in the Arkansas River Valley of southeastern Colorado using various management alternatives, and to compare these results to an existing distributed convective-dispersive transport model (Konikow and Bredehoeft, 1974a; 1974b) previously tested in the same area under similar conditions; and

(5) To examine the predictive capability of the nonlinear lumped parameter model for a second field test in the Mesilla Valley of southcentral New Mexico, and to compare these results to an existing hydrosalinity model (U.S. Bureau of Reclamination, 1977) previously tested in the same area (Gelhar and McLin, 1979) under similar conditions.

The generalized lumped parameter groundwater model is a simplified approach to an overall water and mass balance for a given contaminant transported in a stream-aquifer system. The distinctive feature of this method is that spatial coordinates of variables are not required in the problem formulation and solution. The corresponding problem dimensionality is reduced; variables are considered functions of time only. When system parameters are expressed in this lumped form, the total system is regarded as a single point in space. These descriptive parameters relate the nature of system input to system output. Parameters are determined from known aquifer properties, or can be estimated from system averaged water levels and water quality changes over time by standard regression methods. Once these parameters are determined, application of the lumped model can provide a technique for future prediction of downstream water quantity and quality changes. Access to a digital computer is not required; calculations can be conveniently made on a programmable pocket calculator. These same parameters can also be used to estimate downstream water quantity and quality changes resulting from various management options in the system operation, if system inputs can be estimated.

CHAPTER 2

THEORY OF OUTFLOW CONCENTRATION FROM LINEAR PHREATIC AQUIFERS

2.1 Introduction

According to the U.S. Soil Conservation Service (1972, p. 18), "the purpose of subsurface drainage is to lower the water table to a point where it will not interfere with plant growth and development. The minimum depth at which the water level should be maintained varies according to both the crop requirement and the soil. One of the principal factors in the height of the water table in arid areas is the control of salinity and alkalinity in the soil and ground water." Over the past several decades considerable research effort has been directed towards developing quantitative drain spacing criteria based on steady and unsteady flow theories (Glover, 1974; and references therin) in order to control the water table elevation in time and space. In more recent years researchers have begun to focus their attention on the simultaneous transport of solutes in and below the plant root zone. Processes that have been used to describe this solute transport include time and/or spatially dependent flow models, often coupled in such a manner so as to include dispersive mixing and hydrochemical effects. Several such recent modeling efforts are classified and compared by Gelhar (1976). In irrigation return flow water quality studies, however, convective transport seems to dominate other solute transport mechanisms in the saturated zone (Eldor and Dagan, 1972; Konikow and Bredehoeft, 1974a), although hydrochemical and dispersive mixing effects may be equally important in many areas (Schwartz and Domenico, 1973; Shaffer, et al., 1976).

In this chapter the physical and mathematical basis for several saturated, convective transport models are described; these include the generalized lumped parameter model, the linearized Dupuit model, and the Laplace model. Methods of obtaining solute outflow concentration histories from each model are derived. These outflow concentration histories can serve as a basis of model comparison in the problem of water quality prediction of irrigation return flow. Hopefully, advantages and disadvantages of each of these modeling techniques will become apparent, and subsequent potential users will have an additional basis for model selection.

2.2 Generalized Lumped Parameter Model

2.2.1 The Water Balance Equation

The simplest type of model that can be used to describe convective transport in a dynamically connected stream-aquifer system is the lumped parameter model. Structurally it is simple because this type of model treats only system averaged input-output-storage changes over time. Since variables are averaged over space, they are considered independent of spatial coordinates. Thus only the mean temporal fluctuations of these variables are used to describe the physical nature of a given system. This type of modeling approach is applicable when system wide responses in groundwater levels or water quality resulting from distributed input stresses are of interest. This technique has received relatively little attention in subsurface hydrology (Kraijenhoff van deLeur, 1958; Dooge, 1960; van Schilfgaarde, 1965; Eriksson, 1970; and Eliasson, 1971), but renewed interest is evident (Gelhar and Wilson, 1974: Mercado, 1976; Flores W. and Gelhar, 1976; and Updegraff and Gelhar, 1978). Hydrochemical interaction effects between the flowing groundwater and the porous media may also be included (Thomas, et al., 1972), though additional complexity is introduced.

The structural simplicity of the generalized lumped parameter model is inherently related to the systems operation approach it takes; the system is described only to the degree that it relates averaged inputs to averaged outputs (Dooge, 1973). Thus for the stream connected phreatic aquifer system depicted in Figure 2.1, a simple water balance equation can be written as

$$S \frac{dh}{dt} = q_n + q_a - q_o - q_p \qquad (2.2.1)$$

where

S	=	average aquifer specific yield (drainable porosity),
$h(t)$	=	average thickness of the saturated zone,
$q_n(t)$	=	natural aquifer volume recharge rate per unit of horizontal aquifer area,
$q_a(t)$	=	artificial aquifer volume recharge rate per unit of horizontal aquifer area,
$q_o(h,t)$	=	natural volume outflow rate from the aquifer per unit of horizontal aquifer area,
$q_p(t)$	=	volume pumping rate per unit of horizontal aquifer area,
t	=	time.

Multiplying each term of (2.2.1) by the horizontal aquifer area, one can see that changes in aquifer storage (left hand side of (2.2.1)) are given by temporal changes in volume inputs minus outputs (right hand side of (2.2.1)). All of the terms in the water balance equation are functions of time only, except for the aquifer outflow term, q_o, which is a

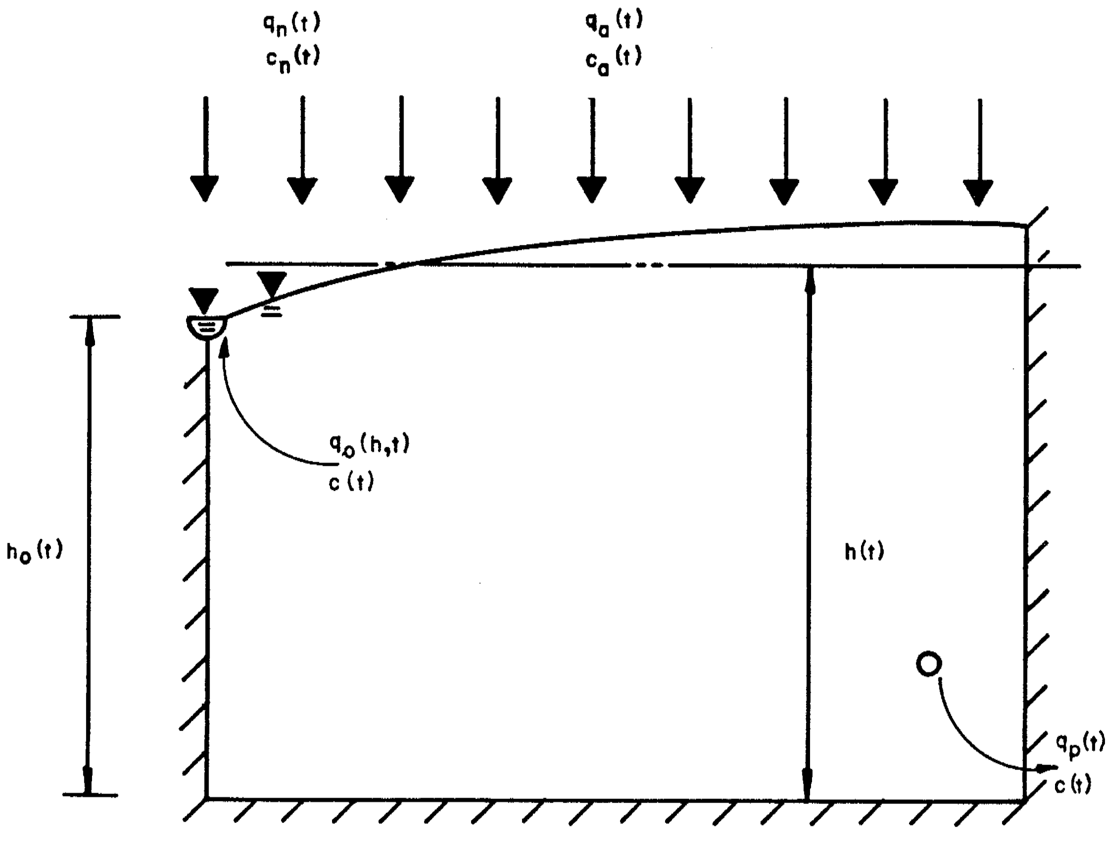

Figure 2.1 Schematic representation of an idealized stream connected phreatic aquifer system.

function of h and t. In general, any number of identifiable input/output terms can be added to the water balance equation without altering its basic form.

The natural outflow rate from the aquifer has been approximated by a linear relationship (Gelhar and Wilson, 1974) given by

$$q_0 = a(h-h_0) \qquad (2.2.2)$$

where the parameter a is a lumped outflow constant having units of inverse time and h_0 is the stream reference level. When the average aquifer water level, h, falls below h_0 the flow direction will change according to (2.2.2) and the stream will lose water to the aquifer. Physically, however, when this occurs the stream may no longer have any water to maintain this reversed flow situation. In such cases q_0 must be constrained to values greater than or equal to zero. In general h_0 can be a function of time, but is usually assumed to be constant since fluctuations in h_0 usually are much smaller than those for h. The model represented by (2.2.1) with the natural outflow given by (2.2.2) is a lumped parameter model in the form of a well-mixed linear reservoir. This "well-mixed" assumption will be developed more fully in a later section.

The linear outflow expression given by (2.2.2) is inherently related to a linear form of Daray's law. As such, the lumped parameter model approximated by a linear reservoir outflow term is intuitively related to some of the simple distributed flow models more frequently encountered in the literature. Quantitative expressions describing this relationship have been developed for several specific cases (Gelhar and Wilson, 1974;

and Flores W. and Gelhar, 1976) which solidify this intuitive connection between the parameter a and certain other aquifer parameters used to characterize distributed systems. One such expression may be written as

$$a = \beta T/L^2 \tag{2.2.3}$$

where T = aquifer transmissivity,
L = aquifer length,
β = some constant.

The manner in which β in (2.2.3) is affected by several particular Dupuit type aquifer systems has been explored in some detail (Flores W. and Gelhar, 1976; Flores W., et al., 1978). They considered the steady flow effects on β while varying the recharge distribution and aquifer boundary geometry. They also have considered the unsteady flow effects on β resulting from a declining sinusoidal water table and reported an overall range for β from 1.07 to 8.0; these results essentially verified and expanded upon those of Gelhar, et al., (1974), who used a spectral analysis approach rather than a deterministic one. The physical basis that completes the intuitive coupling of the lumped parameter model and the linearized Dupuit aquifer will be explored in more detail later.

Although the above discussion shows that in principle the parameter a may be estimated analytically, there are problems in its practical application. While both β and T in (2.2.3) may often be estimated without difficulty, the aquifer length L, usually being uncertain, has an important effect on the parameter a. Updegraff and Gelhar (1978) were able to avoid this problem in a field application for the Mesilla Valley of New Mexico. They used a standard least squares linear regression technique to find the parameters a and h_0 in (2.2.2), since values for

q_o and h were known. Once these lumped aquifer parameters are determined for a given system, (2.2.1) and (2.2.2) can be utilized in several fundamental ways. These are: (1) finding temporal fluctuations in h, knowing system inputs and outputs, (2) finding system inputs, knowing outputs and fluctuations in h, and (3) finding system outputs, knowing inputs and fluctuations in h.

Substituting (2.2.2) into (2.2.1) yields a linear first-order, ordinary differential equation of the form

$$S \frac{dh}{dt} + a(h - h_o) = E \qquad (2.2.4)$$

where E represents the lumped time dependent inputs minus outputs. The general solution for (2.2.4) with a constant h_o is

$$h - h_o = (h_R - h_o)\exp(-at/S) + \frac{1}{S} \int_o^t E(\tau)\exp\,[-a(t-\tau)/S]\; d\tau \qquad (2.2.5)$$

where h_R is the average aquifer water level at the starting time t = o, and τ is a dummy variable of integration. The parameter S/a can be referred to as the hydraulic response time (t_h) of the system since it characterizes the average response time of the water balance equation. We can therefore rewrite (2.2.5) in the form

$$h - h_o = (h_R - h_o)\exp\,(-t/t_h) + \frac{1}{S} \int_o^t E(\tau)\exp\,[-(t-\tau)/t_h]\; d\tau \qquad (2.2.6)$$

where $t_h = S/a$.

2.2.2 The Mass Balance Equation

Extending the approach of the previous paragraphs, we can write a mass balance equation for the phreatic aquifer system depicted in Figure 2.1 for some given contaminant of average solute concentration c(t). Thus

$$n \frac{d(hc)}{dt} = q_n c_n + q_a c_a - q_o c - q_p c + nhr' \qquad (2.2.7)$$

where n is the effective porosity, c_n and c_a are the average solute concentrations of the natural and artificial recharge waters, respectively, and r' is a volumetric source-sink term that accounts for contaminant additions or degradation within the flow zone; it has units of mass of contaminant per unit volume of water per unit of time. All remaining terms in (2.2.7) have been previously defined. The mass balance equation, like the water balance equation, represents a conservation of mass statement relating changes in mass storage to changes in net mass input. If (2.2.7) is multiplied by the horizontal aquifer area, as was done for the water balance equation, we can see that the mass balance relationship simply becomes a volumetric mass balance statement.

The major underlying assumption in (2.2.7) concerns the concentration of outflow waters; all outflows from the system are assumed to carry the same mass concentration. It is thus implied in (2.2.7) that the aquifer is a well-mixed reservoir and that any system outflow carries this average aquifer concentration. This assumption has been related to the nature of two-dimensional convective transport by Gelhar and Wilson (1974); it will be further discussed in the next section.

It is evident that the source-sink term, r', in the mass balance equation may be of considerable importance in specific modeling applications. Two widely used forms for r' are discussed by Bear (1972). The first case is that of a contaminant undergoing radioactive decay (or a first order decay). The change in the solute concentration resulting from such a decay can be given by

$$r' = -kc \tag{2.2.8}$$

where k is some rate constant for the contaminant; this form for r' has been used by Przewlocki and Yurtsever (1974) and Rabinowitz, et al. (1976). The second form commonly used for r' is a linear adsorption isotherm which relates the contaminant concentration in the liquid phase to that on the solid matrix. This relation can be written as

$$r' = -\frac{(1-n)}{n} \; b \; \frac{\partial c}{\partial t} \tag{2.2.9}$$

where n is the medium porosity and b is some proportionality constant; this form for r' has been used by Robertson (1974), Pickens and Lennox (1976), and Willis (1976). Other more complex forms for r' have occasionally been used; these complex forms generally approach the problem from a chemical equilibrium (Thomas, et al., 1972; Shaffer, et al., 1976) or chemical kenetics (Schwartz and Domenico, 1973; Polciauskas and Domenico, 1976) point of view.

Once all net inputs in the mass balance equation are identified, a solution may be sought. Expanding the left-hand side of (2.2.7) yields

$$nc\,\frac{dh}{dt} + nh\,\frac{dc}{dt} = q_n c_n + q_a c_a - q_o c - q_p c + nhr' \tag{2.2.10}$$

Multiplying (2.2.1) by c, substituting the resulting expression for the first term of (2.2.10), and assuming that S = n gives,

$$\frac{dc}{dt} + c\left(\frac{\varepsilon}{nh} + k\right) = \frac{\varepsilon}{nh} c_i \qquad (2.2.11)$$

where

$$\varepsilon = q_n + q_a \qquad (2.2.12)$$

$$c_i = \frac{q_n c_n + q_a c_a}{\varepsilon}$$

and where a first order decay process is used to account for the source-sink effects. The expressions in (2.2.12) are equivalent to a volumetric mixing of inputs and serve to simplify the mass balance equation. Note that the linear outflow relationship given by (2.2.2) need not be used in arriving at (2.2.11). For steady flow, the general solution for (2.2.11) is given by

$$c = c_{aq} \exp\left[-(\varepsilon/nh + k)t\right] + \int_o^t (\varepsilon/nh) c_i(\tau) \exp\left[-(\varepsilon/nh + k)(t-\tau)\right] d\tau \qquad (2.2.13)$$

where c_{aq} is the average aquifer concentration at time t = o. If we assume a constant recharge (ε = some constant) and a step change in input concentration (c_i = some constant) at time $t \geq o$ (and zero otherwise), the explicit solution for (2.2.13) is

$$c = c_{aq} \exp\left[-(\varepsilon/nh + k)t\right] + \left(\frac{\varepsilon}{\varepsilon + nhk}\right) c_i \left\{1 - \exp\left[-(\varepsilon/nh + k)t\right]\right\} \qquad (2.2.14)$$

For a conservative solute, k is equal to zero. Thus (2.2.14) reduces to

$$c = c_i + (c_{aq} - c_i) \exp(-t/t_c) \qquad (2.2.15)$$

where $t_c = \frac{nh}{\varepsilon}$ is the response time for the mass balance system; t_c may be referred to as the solute response time since it characterizes the average residence time of the contaminant c(t) in the aquifer. Figure 2.2 illustrates the general behavior of (2.2.15).

The water and mass balance statements given by (2.2.1) and (2.2.7), together with the linear outflow approximation given by (2.2.2), form a coupled systems description of subsurface water and mass transport in a lumped parameter format. These equations are easily manipulated to supply a variety of explicit analytical solutions for a relatively wide range of specified initial conditions. Furthermore, the system equations are amenable to very simple numerical solution which may be conveniently carried out on a programmable pocket calculator. Examples of both analytical and numerical solutions may be found in Gelhar and Wilson (1974), Flores W., et al., (1978), and Updegraff and Gelhar (1978).

Although the linear outflow assumption made in the water balance equation is the simplest and perhaps most universal approach, the generalized lumped parameter modeling technique certainly is not limited to linear systems. Pinzon (1978) has utilized a nonlinear outflow approximation in a numerical solution of the water balance equation. He obtained recharge estimates for a large irrigated area in New Mexico over the thirty year period 1946-1975. His nonlinear model more accurately simulated time dependent drain flows and average water level fluctuations than did a linear reservoir model tested for the period 1946-1951

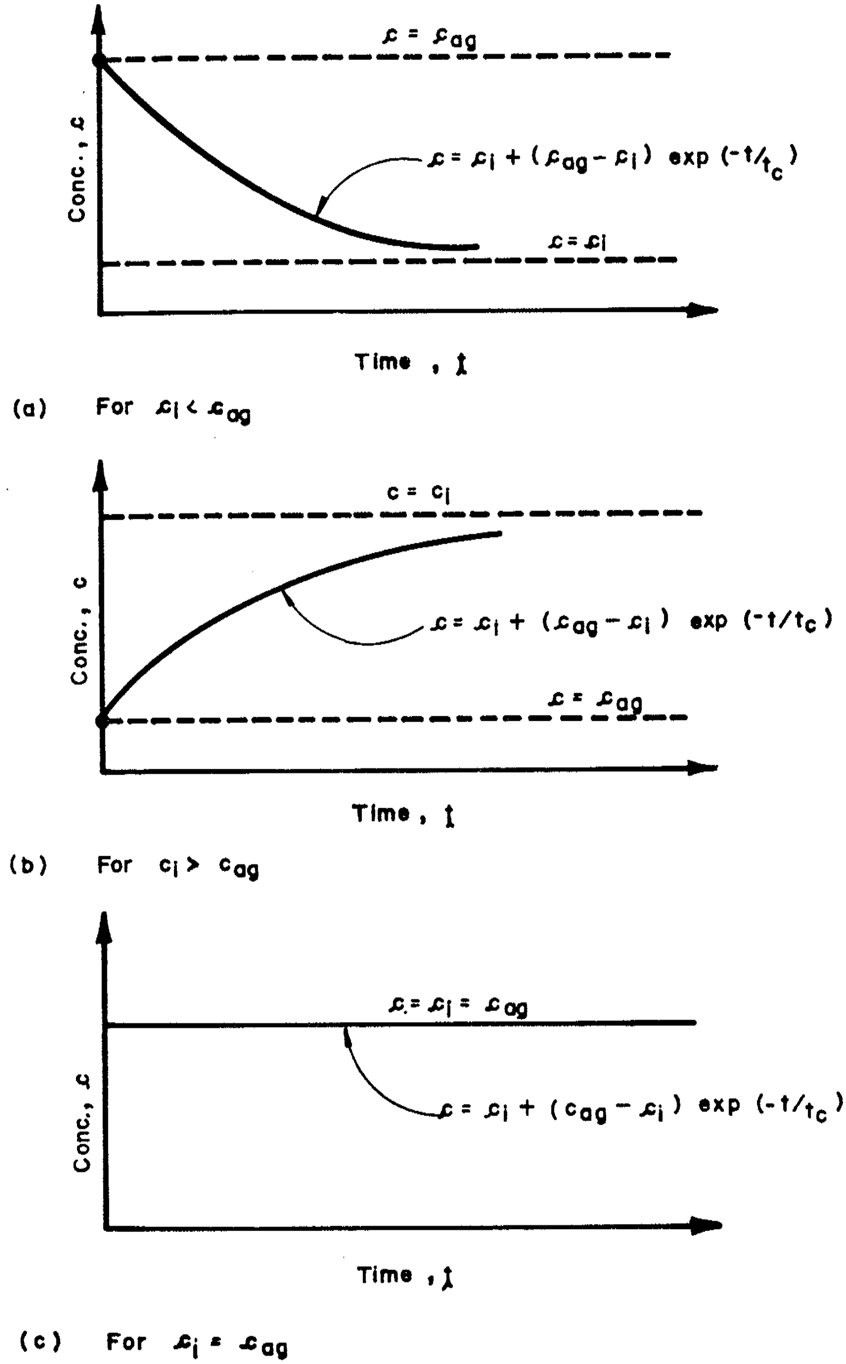

Figure 2.2 Equation (2.2.15) versus time for several values of c_i

(Updegraff and Gelhar, 1978). Nonlinearity will be more fully addressed in a later chapter.

Now that some physical basis has been established to describe the lumped parameter model in the form of a well-mixed linear reservoir, we may proceed to expand the lumped parameter modeling technique to multiple reservoir systems.

2.2.3 Linear Reservoir Models in Combination

In certain field situations, the idea of representing physical systems in the generalized lumped format may appear unrealistic, even though net input stresses may be distributed throughout the area of interest. One such example might include the case of horizontally stratified aquifers as depicted in Figure 2.3, where several idealized streamlines could be sketched in as shown. Here K_u is the idealized isotropic, homogenous hydraulic conductivity of the upper layer, while K_L represents some different idealized isotropic, homogenous hydraulic conductivity for the lower layer. The term ε (t) represents the time dependent net input into the aquifer; it is uniformly distributed throughout the system and has units of volume per unit time per unit of surface area.

The simple flow field depicted in Figure 2.3 may be represented by a combination of linear reservoirs as shown in Figure 2.4. The appropriate form of the water balance equation for each linear reservoir shown would be identical to that given by (2.2.4); however, each term in the equation should be subscripted to denote the individual reservoir variables. In the figure all terms except the respective porosites, n_1, and n_2, and

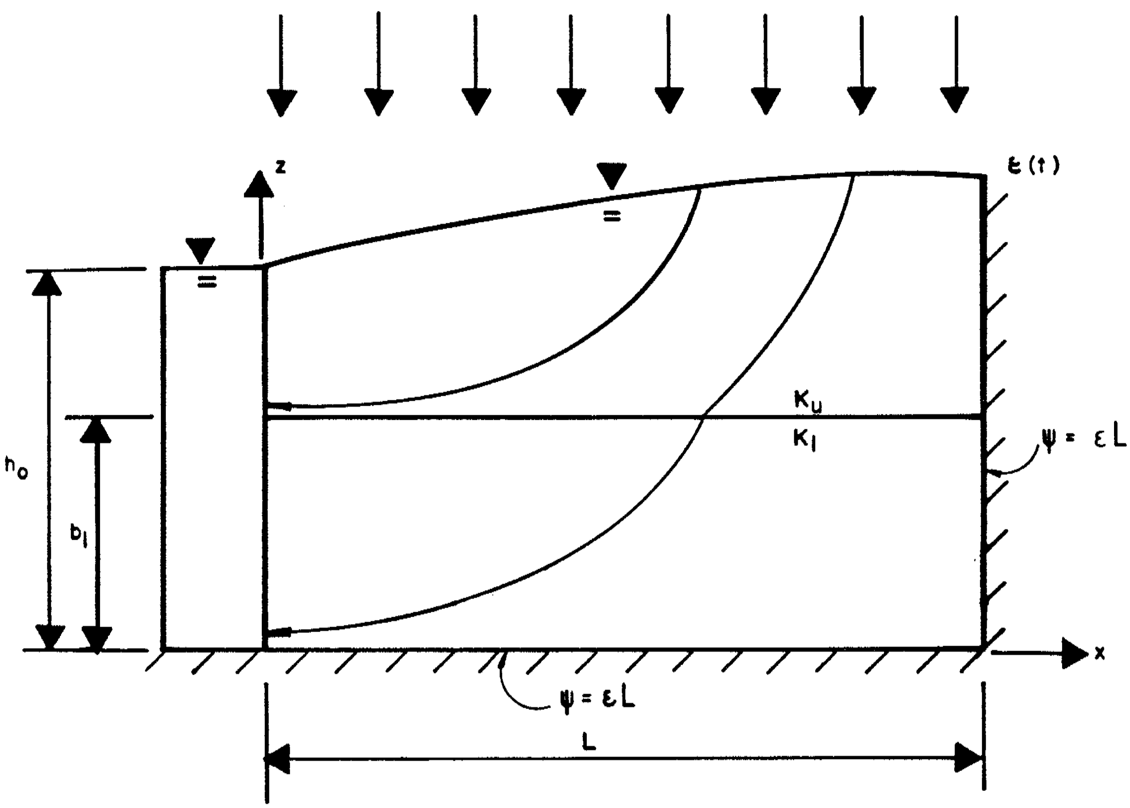

Figure 2.3 Schematic representation of an idealized horizontally stratified aquifer system with a fully penetrating stream, and where $K_u > K_L$.

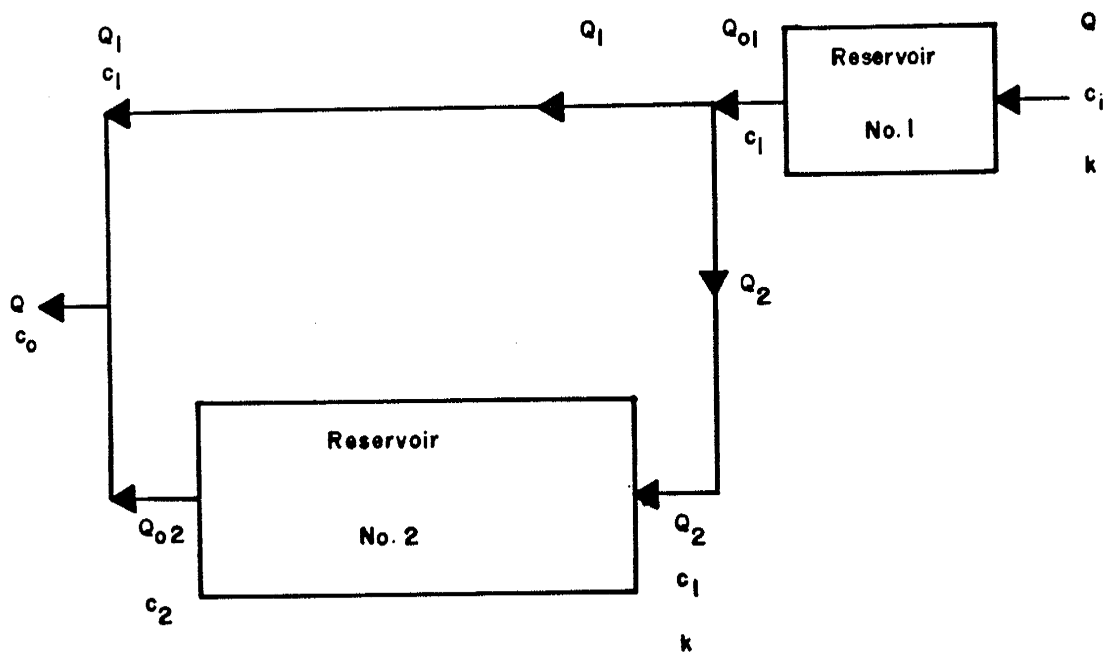

Figure 2.4 Schematic representation of linear reservoirs in combination.

the first order contaminant decay constant, k, are assumed to be functions of time only. As seen in the figure, Q represents the volumetric inflow rate and c_i the contaminant input into the upper aquifer (reservoir no. 1). The outflow from this upper reservoir is Q_{01}, while the corresponding contaminant output is given by c_1. Only a portion of the outflow from the upper reservoir penetrates into the lower aquifer (reservoir no. 2); the remainder discharges directly into the surface stream. The contaminant input into the lower aquifer is the concentration flowing out of the upper reservoir. The outflow volume and concentration from the lower reservoir are given by Q_{02} and c_2 respectively. Finally, the time history of concentration in the stream can be found by a volumetric mix of concentrations from both reservoirs, noting that the flow rate in the stream is simply the sum of flows from the respective reservoirs.

A mass balance expression can be written for each reservoir depicted in Figure 2.4; the final expression will have the same form as (2.2.11), written below for the upper reservoir only,

$$\frac{dc_1}{dt} + c_1 \left(\frac{\varepsilon}{n_1 h_1} + k\right) = \left(\frac{\varepsilon}{n_1 h_1}\right) c_i \qquad (2.2.16)$$

where $\varepsilon = \frac{Q}{A_1}$ and has units of $(L^3/T/L^2)$,

A_1 = horizontal area of the upper aquifer with units of (L^2).

All other terms have been previously defined. For steady flow, the general solution to (2.2.16) takes the same form as (2.2.13). Thus

$$c_1 = c_{aq_1} \exp\left[-(\varepsilon/n_1 h_1 + k)t\right] + \int_0^t (\varepsilon/n_1 h_1)\, c_i(\tau) \exp\left[-(\varepsilon/n_1 h_1 + k)(t-\tau)\right] d\tau \qquad (2.2.17)$$

where c_{aq1} is the average aquifer concentration in the upper reservoir at time t = o, and τ is a dummy variable of integration. Likewise for the lower reservoir, the general solution for steady flow would be

$$c_2 = c_{aq_2} \exp[-(\varepsilon_2/n_2h_2+k)t] +$$

$$\int_o^t (\varepsilon_2/n_2h_2)\ c_{i_2}(\tau)\ \exp\ [-(\varepsilon_2/n_2h_2+k)(t-\tau)d\tau \qquad (2.2.18)$$

where c_{aq_2} = average aquifer concentration in the lower reservoir at time t = 0,

$c_{i_2}(\tau)$ = input concentration into the lower reservoir,

ε_2 = $\frac{Q_2}{A_2}$ and has units of $(L^3/T/L^2)$,

A_2 = horizontal area of the lower reservoir with units of (L^2).

A simple flushing situation may be used to demonstrate the behavior of the combined linear reservoirs in Figure 2.4. Thus for these conditions we would have:

(1) $c_i(t) = 0$, for $t \geq 0$,

(2) $c_{aq_1} = C_{aq_2}$, at $t = 0$,

(3) $k = 0$,

(4) $\varepsilon\ _1(t) = \varepsilon_1$, a constant for $t \geq 0$,

(5) $\varepsilon\ _2(t) = \varepsilon_2$, a constant for $t \geq 0$.

The first two conditions above state that at t = 0 both reservoirs are uniformly mixed with an identical contaminant. All recharge waters introduced into the system at $t \geq 0$ contain no contamination. The resulting time history of concentration in the stream will reflect the time necessary to flush out all pre-existing aquifer contamination that has accumulated up to t = 0. The third condition tells us that there is no contaminant degradation over time. Finally, the last two conditions say there is a steady volume rate of flushing recharge water into both aquifers; these conditions imply that there are no average water table fluctuations over time.

The solution to (2.2.17) is easily found to be

$$c_1 = c_{aq_1} \exp(-t/t_{c_1}) \tag{2.2.19}$$

where $t_{c_1} = \frac{n_1 h_1}{\varepsilon}$. Subject to the conditions stated above, we note that in (2.2.18)

$$c_{i_2}(t) = c_{aq_1} \exp(-t/t_{c_1}), \text{ for } t \geq 0 .$$

Substituting this input concentration into (2.2.18) and performing the indicated integration, we obtain after simplification

$$C_2 = C_{aq_2} \exp(-t/t_{c_2}) + \frac{c_{aq_1} t_{c_1}}{t_{c_1} - t_{c_2}} [\exp(-t/t_{c_1}) - \exp(-t/t_{c_2})] \tag{2.2.20}$$

where $t_{c_2} = \frac{n_2 h_2}{\varepsilon_2}$. Now if we let $\mu = Q_2/Q$ and $h_2 = mh$, where m is some arbitrary constant, then we see that

$$\frac{t_{c_1}}{t_{c_2}} = \frac{n_1\ h_1}{\varepsilon} \frac{\varepsilon\mu}{n_2 m h_1} = \frac{n_1}{n_2} \frac{\mu}{m} = \gamma$$

Substituting this last relationship into (2.2.20) yields

$$\frac{C_2}{C_{aq_1}} = \exp(-\gamma t/t_{c_1}) + \frac{\gamma}{\gamma - 1} [\exp(-t/t_{c_1}) - \exp(-\gamma t/t_{c_1})] \tag{2.2.21}$$

The final outflow concentration in the stream can now be calculated since the volumetric flow rate and contaminant output from each reservoir is known. The volumetric mass balance equation takes the form

$$c_o = (\varepsilon_1/\varepsilon)\ c_1 + (\varepsilon_2/\varepsilon)\ c_2$$

where $\frac{\varepsilon 1}{\varepsilon} = \frac{Q_1/A_1}{Q/A_1} = \frac{Q_1}{Q} = \frac{Q-Q_2}{Q} = (1-\mu)$

and $\frac{\varepsilon 2}{\varepsilon} = \frac{Q_2/A_2}{Q/A_2} = \frac{Q_2}{Q} = \mu$

Thus for $A_1 = A_2$ we see that

$$c_o = (1-\mu)\ c_1 + \mu c_2 \qquad (2.2.22)$$

Substituting (2.2.19) and (2.2.21) into (2.2.22) and simplying yields

$$\frac{c_o}{c_{aq_1}} = a \exp\ (-t/t_{c_1}) - b \exp\ (-\gamma\ t/t_{c_1}) \qquad (2.2.23)$$

where $a = (1 + \mu/(\gamma - 1)$

$b = a - 1$

$\gamma = \frac{n_1}{n_2} \frac{\mu}{m}$

$m = h_2/h_1$

$\mu = \varepsilon_2/\varepsilon = \frac{m\ K_L/K_u}{1 + mK_L/K_u}$

This last relationship will be derived in the Section 2.3.4. For the time being, however, we will simply say that the parameter μ can be related to certain physical parameters that characterize the so called Dupuit aquifer. Hence by using this last relationship we can directly compare the behavior of (2.2.23) with the concentration outflow history obtained from a Dupuit aquifer analysis. We therefore establish a basis in which to explore the relationship between lumped models and spatially distributed models.

Before leaving this section, it would be beneficial to compute the total mass flowing out of the system pictured in Figure 2.4, and that predicted by (2.2.23). For simplicity we will consider only the situation where $n_1 = n_2$, $c_{aq_1} = c_{aq_2}$ at $t < o$, and for zero aquifer input concentration at $t \geq o$. Hence the total solute mass convected out of the system is given by

$$\int_o^{\infty} Qcdt = c_{aq}V_{aq} \tag{2.2.24}$$

where V_{aq} is the aquifer fluid volume, and where all other terms have been previously defined. For the steady flow situation Q is constant and (2.2.24) becomes in dimensionless form

$$\int_o^{\infty} (\frac{c}{c_{aq}})\ d\ (\frac{t}{t_{c_1}}) = \frac{c_{aq}\ n\ (h_1 + h_2)\ A}{Q} (\frac{t_{c_1}}{c_{aq}}) \tag{2.2.25}$$

This last equation may be evaluated by inserting (2.2.23) for (c/c_{aq}), and preforming the indicated integration. Thus upon substitution and simplification we obtain

$$\int_o^{\infty} (\frac{c}{c_{aq}})\ d\ (\frac{t}{t_{c_1}}) = \int_o^{\infty} [a\ \exp(-t/t_{c_1})\ -b\ \exp(-\gamma\ t/t_{c_1})]d(t/t_{c_1})$$

$$= 1 + \frac{\mu m}{\mu - m} - \frac{1}{\gamma}\ (\frac{\mu m}{\mu - m}) = 1 + m \tag{2.2.26}$$

Note that in this evaluation our dimensionless time was normalized with respect to $t_{c_1} = \frac{nh_1}{\varepsilon}$.

2.3 Linearized Dupuit Aquifer Model

2.3.1 Dupuit Approximation

The Dupuit approximation is perhaps one of the most powerful and widely applied tools available to the groundwater hydrologist in treating unconfined fluid flow through saturated porous materials. This approximation requires the assumptions that equipotential surfaces are very nearly vertical and the resulting fluid flow pratically horizontal (Bear, 1972). As a result the Dupuit approximation is paramount to neglecting the vertical component of fluid flow over some given imaginary section drawn through the aquifer. Thus for a phreatic aquifer system with a fully penetrating stream, as shown in Figure 2.5, the following governing partial differential equation can be derived using this classical approximating technique (Bear, 1972).

$$\frac{\partial}{\partial x}\left(K_x h \frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y h \frac{\partial h}{\partial y}\right) + \varepsilon = S \frac{\partial h}{\partial t} \qquad (2.3.1)$$

where $h\ (x,y,t)$ = thickness of the saturated flow zone,
x,y = horizontal coordinates,
K_x, K_y = directional hydraulic conductivity taken parallel to the $(x,\ y)$ axes, respectively,
ε = accretion, which is assumed to be uniform over x and y,
S = specific yield (drainable porosity),
t = time.

Equation (2.3.1) is referred to as Boussinesq's equation for unsteady flow in a phreatic aquifer with accretion. Considerable attention has been focused on this and related problems (van Schilfgaarde, 1970; Bear, 1972; Gelhar, et al., 1974; Collins, 1976; and

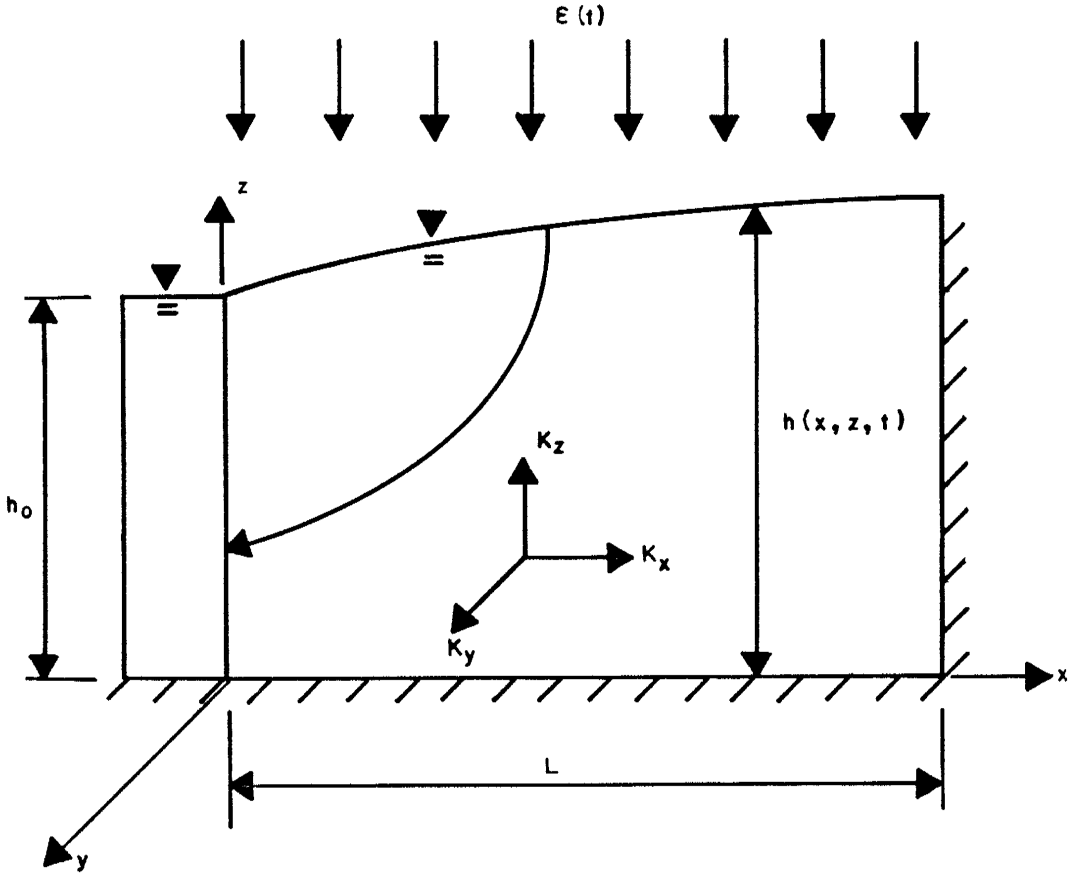

Figure 2.5 Schematic vertical cross-section through a stream connected phreatic aquifer system with uniform accretion.

references therin) in order to describe the temporal and spatial dependence of the free surface elevation. Thus once the necessary initial and boundary conditions are specified, a particular solution to (2.3.1) may be sought. Solution techniques that have been used include: (a) linearizing (2.3.1) in h, (b) linearizing (2.3.1) in h^2, (c) the method of successive steady states, (d) the method of small perturbations, and (e) numerical methods that are usually related in some fashion to the other four analytical techniques. However, an analysis describing the convective transport of some given contaminant through such systems has been explored only recently (Gelhar and Wilson, 1974).

Consider the case of steady, one dimensional flow in a stream-connected phreatic aquifer system with uniform accretion. The governing flow equation obtained from (2.3.1) is

$$\frac{d}{dx}\left(Kh\frac{dh}{dx}\right) + \varepsilon = 0 \tag{2.3.2}$$

where $K = K_x$. Integrating this equation with respect to x yields

$$\frac{K}{2}\frac{d}{dx}(h^2) = -\varepsilon x + C$$

The integration constant, C, is easily obtained from the no flux boundary condition $\left(\frac{dh^2}{dx} = 0\right)$ at $x = L$. Thus

$$\frac{K}{2}\frac{d}{dx}(h^2) = \varepsilon(L-x) \tag{2.3.3}$$

Noting that $h = h_o$ at $x = o$, the final solution becomes

$$h^2 - h_o^2 = \frac{\varepsilon x}{K}(2L-x) \tag{2.3.4}$$

which reduces to

$$(h - h_o) = \frac{\varepsilon x(2L-x)}{K(h+h_o)} \tag{2.3.5}$$

If $(h-h_o) << h_o$, which is equivalent with our original Dupuit approximation in arriving at (2.3.2), then $h \approx h_o$ and (2.3.5) can be approximately written as

$$(h-h_o) \simeq \frac{\varepsilon x(2L-x)}{2\ T} \tag{2.3.6}$$

where $T = K\bar{h}$, the aquifer transmissivity, and $\bar{h}$ represents the average saturated thickness of the aquifer. This last expression gives us the so called Dupuit-Forcheimer parabolically shaped water table (Kirkham and Powers, 1972). At $x = L$ (2.3.6) tells us that the maximum water table elevation is given by

$$h = h_o + \frac{\varepsilon L^2}{2T} \tag{2.3.7}$$

The average saturated thickness of the one-dimensional Dupuit aquifer can be defined by

$$\bar{h} = \frac{1}{L} \int_o^L h\ dx \tag{2.3.8}$$

Inserting (2.3.6) into (2.3.8) and integrating yields

$$\bar{h} = h_o + \frac{\varepsilon L^2}{3T} \tag{2.3.9}$$

Referring back to the lumped parameter model, we recall that the aquifer outflow term in the water balance equation (see (2.2.1)) was approximated by the linear expression given by (2.2.2). For a steady flow field, the inflow term, ε, is equal to the aquifer outflow, q_0. Thus from (2.2.2) and (2.3.9), we see that

$$a = \frac{\varepsilon}{(\bar{h}-h_0)} = \frac{3T}{L^2} \quad (2.3.10)$$

We may therefore conclude that if the linear outflow constant, a, from the lumped parameter model is calculated from (2.3.10), then the lumped model will be hydraulically equivalent to the average steady one-dimensional Dupuit model analysis derived above.

2.3.2 Relationship Between Lumped Parameter and Linearized Dupuit Models

In the previous section we established a hydraulic equivalence between the lumped parameter model described by a linear reservoir and the linearized Dupuit model under steady flow conditions. This equivalence was previously developed by Gelhar and Wilson (1974), and expanded upon by Flores W. and Gelhar (1976) for a variety of steady and unsteady flow conditions. We may now extend the analysis to include a mass transport similitude as well.

The relationship of steady, convective contaminant transport through a stream-connected aquifer system can be derived from an analysis of kinematic particle movement through the aquifer. Following Gelhar and Wilson (1974), we can conceptually visualize a small parcel of contaminated water following some given space-time trajectory through the steady flow field. We can determine the total change in quality of all such parcels at the stream-aquifer boundary where all parcels begin to mix together. We must assume of course that no chemical interaction effects between adjacent water parcels of different quality or between water parcels and the porous medium occur. Similar conceptual approaches have also been used by Jury (1975) and Raats (1977).

The flow field implied in Figure 2.5 can be quantified by first assuming steady flow and then by using Darcy's law and the stream function ψ (Bear, 1972). Thus the horizontal component of the specific discharge vector is given by

$$q_x = -K\frac{dh}{dx} = \frac{\partial\psi}{\partial z} \qquad (2.3.11)$$

where ψ is the stream function that describes the particle trajectories for steady flow through the aquifer. From (2.3.2) and Figure 2.5 we observe that

$$Kh\frac{dh}{dx} = -\varepsilon x + \varepsilon L$$

and with $h \simeq h_o$, (2.3.11) becomes

$$q_x = \frac{\partial\psi}{\partial_z} = -\frac{\varepsilon(L-x)}{h_o} \qquad (2.3.12)$$

from which we see that

$$\psi = \psi_o - \frac{\varepsilon(L-x)z}{h_o} \qquad (2.3.13)$$

where ψ_o = some constant, since $\psi = \psi_o$ at $x = L$. In a similar fashion we can write the vertical component of the specific discharge as

$$q_z = -\frac{\partial\psi}{\partial x} \qquad (2.3.14)$$

Thus

$$q_z = -\frac{\partial}{\partial x}\left[\psi_0 - \frac{\varepsilon(L-x)z}{h_0}\right] = -\frac{\varepsilon z}{h_0} \qquad (2.3.15)$$

The vertical position $\bar{z}$ of some small parcel of water originating at the surface $\bar{z} = h$ can be described by the Darcy flow velocity relation and (2.3.15), so

$$\frac{d\bar{z}}{dt} = \frac{q_z}{n} = -\frac{\varepsilon \bar{z}}{nh_0}$$

which can be rewritten as

$$\int_{z=h}^{z=\bar{z}} \frac{dz}{z} = -\int_{\tau=0}^{\tau=t} \frac{\varepsilon d\tau}{nh_0}$$

The solution becomes

$$\ln(\bar{z}) - \ln(h) = -\frac{\varepsilon t}{nh_0}$$

This last expression may be simplified to yield

$$\bar{z} = h(x) \exp(-t/t_{c'}) \qquad (2.3.16)$$

where $t_{c'} = \frac{nh_0}{\varepsilon}$. Likewise the horizontal position $\bar{x}$ of the same parcel of water starting at the water surface $\bar{x} = x$ can be described by the Darcy flow velocity and (2.3.12), or

$$\frac{d\bar{x}}{dt} = \frac{q_x}{n} = -\frac{\varepsilon(L-\bar{x})}{nh_0}$$

from which we find that

$$(L - \bar{x}) = (L-x) \exp(t/t_{c'}) \qquad (2.3.17)$$

where $t_{c'} = \frac{nh_0}{\varepsilon}$. When the parcel just arrives at the stream at some time t, $\bar{x} = 0$ and (2.3.17) becomes

$$(1 - x/L) = \exp(-t/t_{c'}) \qquad (2.3.18)$$

Substituting (2.3.6) and (2.3.18) into (2.3.16) yields

$$\bar{z} = \left[h_o + \frac{\varepsilon x(2L-x)}{2T}\right] \exp\left(-t/t_{c'}\right)$$

$$= \left\{h_o + \frac{\varepsilon L[1-\exp(-t/t_{c'})]\,[2L-L(1-\exp(-t/t_{c'}))]}{2T}\right\}\exp(-t/t_{c'})$$

$$= \left\{h_o + \frac{\varepsilon L^2[1-\exp(-t/t_{c'})][1+\exp(-t/t_{c'})]}{2T}\right\}\exp(-t/t_{c'})$$

$$\bar{z} = h_o\left\{1 + \frac{\varepsilon L^2[1-\exp(-2\ t/t_{c'})]}{2Th_o}\right\}\exp(-t/t_{c'}) \qquad (2.3.19)$$

We may observe that the maximum water table elevation given by (2.3.7) can be normalized to

$$\frac{h - h_o}{h_o} = \frac{\varepsilon L^2}{2Th_o}$$

But according to the linearization of the Dupuit approximation made earlier, $(h-h_o) << h_o$. Therefore in (2.3.19) we have

$$\frac{\varepsilon L^2}{2Th_o} << 1$$

Thus (2.3.19) may be approximately written as

$$\bar{z} = h_o \exp\left(-t/t_{c'}\right) \qquad (2.3.20)$$

Equations (2.3.17) and (2.3.20) define the $(\bar{x}, \bar{z})$ coordinate positions of some given parcel of water originating on the phreatic surface at (x, z) at time t = 0 and flowing through the steady Dupuit aquifer system shown in Figure 2.5. The time required for a water parcel starting at some x on the phreatic surface to arrive at the stream was given by (2.3.18). This time is the same as that in (2.3.20). Thus

$$\bar{z}/h_o = 1 - x/L \tag{2.3.21}$$

If the aquifer waters are originally contaminated at some uniform concentration level, c_{aq}, and at time t=o the recharge waters entering the aquifer contain no contaminants, then (2.3.17), (2.3.20), and (2.3.21) can be used to define the uncontaminated front being convected through the aquifer system. For example if some uncontaminated parcel of water enters the phreatic surface at $x/L = 0.40$, it will exit the Dupuit aquifer on the stream boundary $\bar{z}/h_o = 0.60$ at some dimensionless time $t/t_{c'} = -\ln(0.60) = 0.51$ later. The uncontaminated parcels of water entering the phreatic surface at $x/L < 0.40$ will already have arrived at the stream-aquifer boundary at $\bar{z}/h_o > 0.60$, while those entering at $x/L > 0.40$ are still in the aquifer at some distance away from this boundary. The concentration in the stream at dimensionless time $t/t_{c'} = 0.51$ will therefore be only 60 percent of that at time $t/t_{c'} = 0$. We can express the entire time history of concentration in the stream as

$$c/c_{aq} = \exp(-t/t_{c'}) = \bar{z}/h_o = 1 - x/L \tag{2.3.22}$$

Alternately we could have written a simple mass balance statement at the stream-aquifer boundary as

$$q_x h_o \bar{c} = q_{x_1}(h_o - \bar{z})\, c_i + q_{x_2}\, \bar{z}\, c_{aq}$$

where q_x = the specific discharge at the stream boundary,
h_o = the stream elevation,
q_{x_1}, q_{x_2} = uncontaminated and contaminated specific discharges into the stream, respectively,
$\bar{z}$ = the elevation of the uncontaminated front at the stream,
c = the concentration in the stream,
c_{aq} = the aquifer concentration at $t = o$,
c_i = the concentration of the recharge water.

As previously mentioned, the Dupuit approximation neglects any explicit consideration for vertical flow effects so that the horizontal component of specific discharge is implied to be constant over any vertical depth in the aquifer. Therefore $q_x = q_{x_1} = q_{x_2}$ and the average concentration in the stream is given by

$$\bar{c} = (1 - \frac{\bar{z}}{h_o})\ c_i + (\frac{\bar{z}}{h_o})\ c_{aq}$$

But from (2.3.20) we see that $\bar{z}/h_o = \exp(-t/t_{c'})$ so the stream concentration may also be written as

$$c = c_i + (c_{aq} - c_i) \exp(-t/t_{c'}) \qquad (2.3.23)$$

If $c_i = o$, then (2.3.23) reduces to the same result obtained in (2.3.22). If $t_{c'}$ in the above analysis is equal to t_c, then this relationship is also equivalent to that obtained in (2.2.15) for a conservative tracer (k=0) with a corresponding step change in input concentration at $t \geq o$. In (2.2.15) $t_c = nh/\varepsilon$, while in (2.3.23) $t_{c'} = nh_o/\varepsilon$. However if the original Dupuit approximation, $(h-h_o) \ll h_o$, is satisfied, then $h \approx h_o$ and $t_c \approx t_{c'}$.

The average concentration in the Dupuit aquifer can be expressed as

$$c_{aq} = \frac{1}{L} \int_o^L \langle c_{aq} \rangle \, dx$$

where $\langle c_{aq} \rangle = (1-\bar{z}/h_o)c_i + (\bar{z}/h_o)\ c_{aq}$ at some $\bar{x}$. From this relationship and (2.3.20), we conclude that

$$\bar{c}_{aq} = c_i + (c_{aq} - c_i) \exp(-t/t_{c'})$$

which is identical to the concentration in the stream. These analyses show that the average concentration in the Dupuit aquifer is not only the same as that in the stream, but is also equivalent to the concentration previously found for the well mixed linear aquifer system of the lumped parameter model. Hence we may conclude from the Dupuit analysis presented here, that the well mixed reservoir assumption made for the lumped system can be justified from a distributed systems approach.

2.3.3 Multi-Layered Dupuit Aquifer System

We have previously developed the water and mass balance relationships that can represent the time dependent hydraulic and solute response characteristics of a stream-connected phreatic aquifer system using the generalized lumped parameter format. Furthermore it was shown that a one-dimensional linearized Dupuit model behaves in a similar fashion to this lumped approach when a linear reservoir assumption is employed. At that time it was also suggested that representing certain physical systems by the generalized lumped approach might be unrealistic, even though net input stresses on the system were uniformly distributed throughout it. One such possibility was schematically drawn in Figure 2.3. This physical system was analyzed by utilizing the linear reservoir lumped parameter model in a parallel-type configuration as depicted in Figure 2.4. An obvious question immediately arise: Is this combined lumped approach capable of accurately representing the physical system shown in Figure 2.3? We might proceed to answer this question by first exploring the hydraulic and solute response characteristics that would result from treating the multi-layered aquifer system of Figure 2.3. as separate Dupuit type reservoirs. Results from this analysis can then be directly compared with those previously obtained from the combined lumped approach.

The governing partial differential equation applicable to the physical situation represented by Figure 2.3 is

$$\frac{\partial}{\partial x_i} [K_u(h-b_L) + K_L b_L] \frac{\partial h}{\partial x_i} + \varepsilon = S \frac{\partial h}{\partial t} \qquad (2.3.24)$$

where x_i with $i = 1,2$ are the horizontal coordinates; all other terms have been previously defined. If the flow is steady, then (2.3.24) in one dimension reduces to

$$\frac{d}{dx} [K_u(h-b_L) \frac{dh}{dx}] + \frac{d}{dx} [K_L b_L \frac{dh}{dx}] = -\varepsilon \qquad (2.3.25)$$

subject to the boundary conditions implied in Figure 2.3:

$$\begin{aligned} &(1) \quad h = h_0 \text{ at } x = 0 \\ &(2) \quad dh/dx = 0 \text{ at } x = L \end{aligned} \qquad (2.3.26)$$

Integrating (2.3.25) with respect to x, and applying the second condition from (2.3.26) yields

$$\frac{K_u}{2} \frac{d(h^2)}{dx} - K_u b_L \frac{dh}{dx} + K_L b_L \frac{dh}{dx} = -\varepsilon x + \varepsilon L$$

which may be simplified to give

$$\frac{d(h^2)}{dx} + \xi \frac{d(h)}{dx} = \frac{2\,\varepsilon\,(L-x)}{K_u} \qquad (2.3.27)$$

where $\zeta = 2b_L(K_L-K_u)/K_u$. Integrating this last equation with respect to x and applying the first boundary condition from (2.3.26) yields

$$(h^2 - h_o^2) + \zeta(h-h_o) = \varepsilon x(L-x)/K_u \qquad (2.3.28)$$

This solution, which describes the steady Dupuit water table shape, is similar in form to that in (2.3.4) for a single Dupuit aquifer. The second term in (2.3.28) alters the water table elevation because of the presence of the lower aquifer. Note that (2.3.4) is actually a special case of (2.3.28); if $K_u = K_L$ then $\zeta = o$ and (2.3.28) reduces to (2.3.4). For $(h-h_o) << h_o$ and $h \simeq h_o$, equation (2.3.28) may be simplified to

$$(h-h_o)(1 + \frac{\zeta}{h+h_o}) = \frac{\varepsilon x(2L-x)}{K_u(h+h_o)}$$

from which we see that $h+h_o \simeq 2h_o$. Hence this last expression may be approximated by

$$h - h_o = \frac{\varepsilon x(2L-x)}{K_u(2h_o+\zeta)} \qquad (2.3.29)$$

At x = L, the maximum water table elevation is given by

$$h = h_o + \frac{\varepsilon L^2}{K_u(2h_o+\zeta)} \qquad (2.3.30)$$

The average saturated thickness of the two layered Dupuit aquifer system can be defined in a similar fashion to (2.3.8), or

$$\bar{h} = \frac{1}{L}\int_o^L h\, dx \qquad (2.3.31)$$

Inserting (2.3.29) into (2.3.31), preforming the necessary integration, and simplifying yields

$$\bar{h} = h_o + \frac{2 \varepsilon L^2}{3K_u(2h_o + \zeta)} \qquad (2.3.32)$$

If we were to choose to represent the multi-aquifer system with a single linear reservoir lumped parameter model for a steady flow field, then the outflow constant given in (2.2.2) would be

$$a = \frac{\varepsilon}{(\bar{h} - h_o)} = \frac{3K_u(2h_o + \zeta)}{2L^2} \qquad (2.3.33)$$

where $(\bar{h}-h_o)$ in (2.3.33) is given by (2.3.29). Once again, note that if $K_u = K_L$, then $\zeta = o$ and (2.3.33) reduces to (2.3.10) where $T = K_u h_o$.

2.3.4. Relationship Between Combined Lumped Parameter Model and Linearized Multi-Layered Dupuit Aquifer Model

We may proceed in establishing the relationship of steady convective mass transport through the multi-layered Dupuit aquifer system shown in Figure 2.3 using the previously employed conceptual approach of kinematic particle movement. However one would expect the lower aquifer system to either impede or enhance contaminant migration through the system, depending on whether the lower layer hydraulic conductivity was less than or greater than that of the upper layer.

The horizontal component of the specific discharge in the upper layer, q_{xu}, is once again related to Darcy's law and the stream function:

$$q_{xu} = - K_u \frac{dh}{dx} = \left. \frac{\partial \Psi}{\partial z} \right|_u \qquad (2.3.34)$$

where Ψ is the stream function describing particle trajectories through the multi-layer system. Differentiating (2.3.29) with respect to x we obtain

$$\frac{dh}{dx} = \frac{2\varepsilon(L-x)}{K_u(2h_o + \zeta)}$$

from which we note

$$q_{xu} = - \frac{2\varepsilon(L-x)}{(2h_o + \zeta)} = \left. \frac{\partial \Psi}{\partial z} \right|_u \qquad (2.3.35)$$

Integrating this last equation with respect to z yields

$$\Psi_u = - \frac{2\ \varepsilon(L-x)z}{(2h_o + \zeta)} + f_1(x) \qquad (2.3.36)$$

where $f_1(x)$, the constant of integration with respect to z, is in general some function of x. Equation (2.3.36) describes the stream function, $\Psi_u(x, z)$, in the upper aquifer between ($b_L \leq z \leq h$). Similarily we note that

$$q_{xL} = - K_L \frac{dh}{dx} = \left. \frac{\partial \Psi}{\partial z} \right|_L$$

from which we immediately see that

$$q_{xL} = - \frac{K_L 2\varepsilon(L-x)}{K_u(2h_o + \zeta)} = \left. \frac{\partial \Psi}{\partial z} \right|_L$$

Thus

$$\Psi_L = - \frac{K_L}{K_u} \frac{2\varepsilon(L-x)z}{(2h_o + \zeta)} + f_2(x) \qquad (2.3.37)$$

where f_2 (x) is some different function of x. Equation (2.3.37) describes the stream function, $\psi_L(x, z)$, in the lower aquifer between $(o \leq z \leq b_L)$. The implied boundary conditions for the multi-layered Dupuit aquifer system of Figure 2.3. are:

$$\begin{aligned} &(1) \quad \psi_u = \varepsilon x \text{ at } z = h(x) \simeq h_o \\ &(2) \quad \psi = \varepsilon L \text{ at } x = L \\ &(3) \quad \psi_L = \varepsilon L \text{ at } z = 0 \\ &(4) \quad \psi_u = \psi_L \text{ at } z = b_L \end{aligned} \qquad (2.3.38)$$

Employing condition (4) from (2.3.38) in (2.3.36) and (2.3.37) yields

$$-\frac{2\,\varepsilon(L-x)b_L}{(2h_o + \zeta)} + f_1(x) = -\frac{K_L}{K_u}\,\frac{2\,\varepsilon\,(L-x)b_L}{(2h_o + \zeta)} + f_2(x)$$

Solving this last equation for f_2 (x) and inserting the result into (2.3.37) gives

$$\psi_L = f_1(x) - \frac{2\,\varepsilon(L-x)}{(2h_o + \zeta)}\left[\frac{K_L z}{K_u} + b_L\left(1 - \frac{K_L}{K_u}\right)\right] \qquad (2.3.39)$$

Using condition (1) from (2.3.38) in (2.3.36) yields

$$\psi_u = \varepsilon x = f_1(x) - \frac{2\,\varepsilon\,(L-x)h_o}{(2h_o + \zeta)}$$

Therefore

$$f_1(x) = \varepsilon x + \frac{2\,\varepsilon(L-x)h_o}{(2h_o + \zeta)} \qquad (2.3.40)$$

and from (2.3.36) we see that

$$\Psi_u = \varepsilon x + \frac{\varepsilon(L - x)}{(h_o + \xi/2)} \; (h_o - z) \tag{2.3.41}$$

which describes Ψ_u in the interval ($b_L \leq z \leq h$). From (2.3.39) and (2.3.40) we observe that

$$\Psi_L = \varepsilon x + \frac{\varepsilon(L - x)}{(h_o + \xi/2)} \left[h_o - \frac{K_L z}{K_u} - b_L \left(1 - \frac{K_L}{K_u}\right)\right]$$

which describes Ψ_L in the interval ($o \leq z \leq b_L$). This last equation may be simplified to

$$\Psi_L = \varepsilon L - \frac{K_L \; \varepsilon(L - x)z}{K_u(h_o + \xi/2)} \tag{2.3.42}$$

Using the transformations defined below, we may express (2.3.41) and (2.3.42) in a dimensionless form. Thus for

$$\begin{aligned}
X &= x/L; \; 0 \leq X \leq 1 \\
Z &= z/h_o; \; 0 \leq Z \leq 1 \\
\hat{\xi} &= \xi/2h_o = b_L \; (K_L - K_u)/h_o K_u \\
\overline{\Psi}_u &= \Psi_u \; /\varepsilon L \\
\overline{\Psi}_L &= \Psi_L/\varepsilon L \\
B &= b_L/h_o
\end{aligned} \tag{2.3.43}$$

we see that

$$\overline{\Psi}_u = X - \frac{(1 - X)(1 - Z)}{(1 + \hat{\xi})} \; ; \; (B \leq Z \leq 1) \tag{2.3.44}$$

$$\overline{\Psi}_L = 1 - \frac{K_L \; (1 - X)}{K_u \; (1 + \hat{\xi})} \quad ; \quad (0 \leq Z \leq B)$$

The vertical position $\bar{z}$ of some small parcel of water originating at the surface $\bar{z} = h_0$ may be described by the Darcy flow velocity, and (2.3.41) and (2.3.42). Thus for the upper aquifer we have

$$\frac{1}{n} q_{zu} = \frac{d\bar{z}}{dt} = -\frac{1}{n}\frac{\partial \Psi_u}{\partial x} = -\frac{1}{n}\frac{\partial}{\partial x}\left[\varepsilon x + \frac{\varepsilon(L-x)(h_o-\bar{z})}{(h_o + \zeta/2)}\right]$$

or,

$$\frac{1}{n} q_{zu} = -\frac{\varepsilon}{n}\left[1-\frac{(h_o-\bar{z})}{(h_o+\zeta/2)}\right] = \frac{d\bar{z}}{dt}$$

If we let $V = 1 - (h_o - \bar{z})/(h_o + \zeta/2)$, then $dV/d\bar{z} = 1/(h_o+\zeta/2)$

and $$\frac{d\bar{z}}{dt}\frac{dV}{d\bar{z}} = -\frac{\varepsilon V}{n(h_o+\zeta/2)}$$

Upon rearranging we note that

$$\int_{V=V_1}^{V=V_2}\frac{dV}{V} = -\int_{t=t_1}^{t=t_2}\frac{\varepsilon dt}{h(h_o+\zeta/2)}$$

from which our solution becomes

$$\left[1-\frac{h_o-\bar{z}_2}{h_o+\zeta/2}\right] = \left[1-\frac{h_o-\bar{z}_1}{h_o+\zeta/2}\right]\exp\left[-\frac{\varepsilon(t_2-t_1)}{n(h_o+\zeta/2)}\right]$$

where $\bar{z}_1 = h_o$ at $t_1 = o$, and $\bar{z}_2 = \bar{z}_u$ at some later time $t_2 = t$. Thus

$$(\bar{z}_u + \zeta/2) = (h_o+\zeta/2)\exp\left[-\frac{\varepsilon t}{n(h_o+\zeta/2)}\right] \qquad (2.3.45)$$

This last equation gives the vertical position, $\bar{z}_u$, of some given parcel of water in the upper aquifer at time t between ($b_L \leq z_u \leq h_o$) starting at $\bar{z}_u = h_o$ at time t = o.

For the lower aquifer we have from (2.3.42)

$$\frac{1}{n} q_{zL} = \frac{d\bar{z}_L}{dt} = -\frac{1}{n} \frac{d\Psi_L}{dx} = -\frac{1}{n} \frac{\partial}{\partial x} [\varepsilon L - \frac{K_L \ \varepsilon(L-x)\bar{z}_L)}{(h_o + \zeta/2)}]$$

or upon rearranging and integration with respect to t we have

$$\int_{\bar{z}_L = b_L}^{\bar{z}_L = \bar{z}_L} \frac{d\bar{z}_L}{\bar{z}_L} = -\int_{t = t_1}^{t = t_2} \frac{\varepsilon K_L dt}{nK_u \ (h_o + \zeta/2)}$$

where t = t_1, represents the travel time of the parcel to reach the lower aquifer. The solution of this last equations is

$$\bar{z}_L = b_L \exp [-\frac{\varepsilon K_L (t-t_1)}{nK_u (h_o + \zeta/2)}] \qquad (2.3.46)$$

where t_1 may be obtained from (2.3.45) with $\bar{z}_u = b_L$, or

$$\frac{\varepsilon t_1}{n(h_o + \zeta/2)} = -\ln [\frac{b_L + \zeta/2}{h_o + \zeta/2}] \qquad (2.2.47)$$

Equation (2.3.46) represents the vertical position of our parcel in the lower aquifer between ($o \leq \bar{z}_L \leq b_L$) starting at $\bar{z}_L = b_L$ at some time $t = t_1$. In both (2.3.45) and (2.3.46) we have neglected the travel time of the parcel from h to h_o, which is assumed small since $(h-h_o) << h_o$ in the Dupuit approximation.

In a similar fashion we may find the horizontal position, $\bar{x}$, of the same parcel. For the upper aquifer we would have

$$\frac{1}{n} q_{xu} = \frac{d\bar{x}}{dt} = \frac{1}{n} \frac{\partial \Psi u}{\partial z}$$

and from (2.3.41) we obtain

$$\frac{1}{n} q_{xu} = - \frac{\varepsilon}{n} \frac{L - \bar{x}_u}{h_o + \zeta/2} = \frac{d\bar{x}_u}{dt}$$

If we let $W = L - \bar{x}_u$, then $dW/d\bar{x}_u = -1$ and

$$\frac{d\bar{x}_u}{dt} \frac{dW}{d\bar{x}_u} = - \frac{\varepsilon W}{n(h_o + \zeta/2)} \frac{dW}{d\bar{x}_u}$$

so we see that

$$\int \frac{dW}{W} = \int \frac{\varepsilon dt}{n(h_o + \zeta/2)}$$

which yields

$$\ln(W) = \frac{\varepsilon t}{n(h_o + \zeta/2)} + C_1$$

where C_1 is some constant of integration. This last equation may be simplified to yield

$$(L-x_u) = C_2 \exp \left[\frac{\varepsilon t}{n(h_o + \zeta/2)}\right]$$

where C_2 is some different constant. At t=0 the parcel of water is located at the starting point $\bar{x}_u = x$ on h_o, so $C_2 = (L-x)$ and we obtain

$$(L-\bar{x}_u) = (L-x)\ \exp\left[\frac{\epsilon t}{n(h_o + \zeta/2)}\right] \qquad (2.3.48)$$

Equations (2.3.45) and (2.3.48) together define the $(\bar{x},\bar{z})$ particle position in the upper layer at some time t after it enters the system. We may therefore eliminate the term containing this common time t, and arrive at a single expression in (x,z) only. Thus

$$(L-x)/(L-\bar{x}_u) = (\bar{z}_u + \zeta/2)/(h_o + \zeta/2) \qquad (2.3.49)$$

Using the realtionships defined in equation (2.3.43) we may express (2.3.49) in dimensionless form, or

$$(1-X)/(1-\bar{X}_u) = (\bar{Z}_u + \hat{\zeta})/(1+\hat{\zeta}) \qquad (2.3.50)$$

where the particle position after some time t is given by $(\bar{X}_u, \bar{Z}_u)$. At the stream boundary $\bar{X}_u = 0$, so that (2.3.50) may be expressed in terms of the original particle starting point, X, and its exit point on the stream, $\bar{Z}_u$. So

$$(1 - X) = (\bar{Z}_u + \hat{\zeta})/(1 + \hat{\zeta}) \qquad (2.3.51)$$

which is valid in the interval $(B \leq Z_u \leq 1)$. The maximum value of X may be found when Z_u is a mimimum. Thus $X \leq (1-B)/(1 + \hat{\zeta})$ and the maximum dimensionless streamline that remains in the upper aquifer is found to be $\bar{\Psi}_u = (1-B)/(1+\hat{\zeta})$, since $\bar{\Psi}_u = X$ on $Z = 1$ from (2.3.44).

Likewise for the lower layer we observe that

$$\frac{1}{n} q_{xL} = \frac{d\bar{x}_L}{dt} = \frac{1}{n}\frac{d\psi_L}{dz} = \frac{K_L\ \epsilon\ (L - \bar{x}_L)}{nK_u(h_o + \zeta/2)}$$

from (2.3.42); and we note that

$$\frac{d\bar{x}_L}{dt}\;\frac{dW}{d\bar{x}_L} = - \frac{K_L \varepsilon W}{nK_u(h_o + \zeta/2)}\;\frac{dW}{d\bar{x}_L}$$

where $W = (L - \bar{x}_L)$ and $dW/d\bar{x}_L = -1$. Hence we obtain

$$\ln (W) = \frac{K_1 \varepsilon t}{nK_u(h_o + \zeta/2)} + C_3$$

We may write this last equation as

$$(L - \bar{x}_L) = C_4 \exp[\frac{K_L \varepsilon t}{nK_u(h_o + \zeta/2)}] \qquad (2.3.52)$$

where C_3 and C_4 are different arbitrary constants. Noticing that at $t = t_1$, $\bar{x}_L = \bar{x}_u$, and from (2.3.48) we see that

$$(L - \bar{x}_L) = C_4 \exp [\frac{K_L \varepsilon t_1}{nK_u(h_o + \zeta/2)}] = (L - x) \exp[\frac{\varepsilon t_1}{n(h_o + \zeta/2)}]$$

so that

$$C_4 = (L - x) \exp[\frac{\varepsilon t_1}{n(h_o + \zeta/2)} \quad (1 - K_L/K_u)]$$

and

$$(L - \bar{x}_L) = (L - x) \exp \frac{\varepsilon}{n(h_o + \zeta/2)} [\frac{K_L}{K_u} (t - t_1) + t_1] \qquad (2.3.53)$$

where $t > t_1$. Equation (2.3.53) describes the horizontal position, $\bar{x}_L$, of the parcel of water in the lower aquifer which originally starts at time t=o at the surface position x and intersects the lower boundary at some later time $t=t_1$. When $\bar{x}_L = o$ the particle will just arrive at the stream. Thus

$$\frac{L}{L - x} = \exp\left[\frac{K_L \varepsilon t}{nK_u(h_o + \zeta/2)} + a(1 - K_L/K_u)\right] \qquad (2.3.54)$$

where $a = \dfrac{\varepsilon t_1}{n(h_o + \zeta/2)} = -\ln (b_L + \zeta/2)/(h_o + \zeta/2)$, and is obtained from (2.3.47) with $z_u = b_L$ at $t=t_1$. Rearranging (2.3.54) we see that the total travel time of some parcel through both aquifers is given by

$$\frac{\varepsilon t}{n(h_o + \zeta/2)} = a(1-K_L/K_u) - \frac{K_u}{K_L} \ln (1 - x/L) \qquad (2.3.55)$$

According to (2.3.43) we may express the above relationship in the dimensionless form

$$t/t_{c'} = A(1 - K_L/K_u) - \frac{K_u}{K_L} \ln (1-X) \qquad (2.3.56)$$

where $A = -\ln (B + \hat{\zeta})/(1 + \hat{\zeta})$, $t_{c'} = n(h_o + \zeta/2)/\varepsilon$, and $X > (1-B)/(1 + \hat{\zeta})$ according to (2.3.51) with $\bar{Z}_u = B$.

We are now in a position to compare the concentration outflow histories between the linearized multi-layered Dupuit aquifer model derived above, and that previously derived for the combined lumped parameter model. Using the simple situation previously employed for a flushing system, we have the following initial conditions:

(1) $c_{aq} = c_{aq_2}$ at $t = o$

(2) $c_i(t) = o$ for $t \geq o$

(3) $\varepsilon(t) = \varepsilon$, a constant, for $t \geq o$

To reiterate, these conditions state that our two-layered Dupuit aquifer system of Figure 2.3 has some uniformly mixed contaminant in both reservoirs. The flow is at steady state, but at time $t \geq o$ the recharge waters no longer carry any contamination into the upper aquifer. Our problem, then, is to define the contaminant outflow concentration in the stream for $t \geq o$.

We can utlze the expressions given by (2.3.44), (2.3.45), and (2.3.56) to relate the concentration in the stream to time. For example, a particle of water entering the upper aquifer at $t = o$ at some X (where $Z = 1$) will follow a streamline through this reservoir defined by

$$\overline{\Psi}_u = X + \frac{(1 - X)(1 - Z)}{(1 + \hat{\xi})} \qquad (2.3.57)$$

where $(o \leq X \leq 1)$, the horizontal position of the particle,

$(o \leq Z \leq 1)$, the vertical position of the particle,

$(o \leq \overline{\Psi}_u \leq 1)$, the dimensionless streamline,

and where $\hat{\xi} = b_L \ (K_L - K_u)/h_o K_u = B(K_L - K_u)/K_u$. According to (2.3.51) if $X > (1-B)/(1+\hat{\xi})$ at Z=1, then the streamline will penetrate into the lower aquifer; it will be defined by (2.3.57) in the upper reservoir and by

$$\overline{\Psi}_L = 1 - \frac{K_L}{K_u} \frac{(1-X)Z}{(1 + \hat{\xi})}, \quad 0 \leq Z \leq B \qquad (2.3.58)$$

in the lower reservoir. If $X < (1-B)/(1+\hat{\xi})$ at Z=1, then the steamline will remain in the upper aquifer and be completely defined by (2.3.57).

Some particle that is following a given $\overline{\Psi}_u$ will arrive at the stream in time t, given by (2.3.45), or

$$t/t'_{c_1} = \ln \ (Z_u + \hat{\xi})/(1 + \hat{\xi}) \qquad (2.3.59)$$

in dimensionless form where $t'_{c_1} = n(h_o + \xi/2)/\varepsilon$; it is called the solute response time since it characterizes the average contaminant residence time in the aquifer system. Note, however, that t'_{c_1} is based on parameters that characterize the system geometry and hydraulic conductivity contrast so that it is actually the average contaminant residence time in the system. If $K_L = K_u$, then $\xi = o$ and $t'_{c_1} = t_{c'}$, the single Dupuit aquifer solute response time from (2.3.23). The dimensionless travel time (t/t'_c) is therefore based relative to this average solute residence time in the system.

The concentration in the stream at X = 0 and and at time t < o will be same as in the system, c_{aq} ; at some later time $t \geq o$, this concentration, c, will simply be

$$c/c_{aq} = 1 - \overline{\Psi}_u = (Z + \hat{\xi})/(1 + \hat{\xi}) \qquad (2.3.60)$$

according to (2.3.51). But from (2.3.45) this last relationship becomes

$$c/c_{aq} = \exp\ (t/t'_{c_1}) = (Z + \hat{\xi})/(1 + \hat{\xi});\ b \leq Z \leq 1 \qquad (2.3.61)$$

where $t/t'_{c_1} \leq -\ln\ (B + \hat{\xi})/(1 + \hat{\xi}) = A$, according to (2.3.47) and (2.3.56), and where $\hat{\xi} = b_L(K_L - K_u)/h_o K_u$. Equation (2.3.61) is similar to the outflow concentration obtained in (2.2.19) for a linear lumped parameter reservoir forming the upper layer of the combined lumped system previously examined, except in that analysis the solute residence time was defined as $t_{c_1} = n_1 h_1/\varepsilon$.

If the particle starting point on Z = 1 is $X > (1-B)/(1 + \hat{\xi})$, then the dimensionless streamline will penetrate into the lower aquifer. Hence from (2.3.46)

$$\bar{z}_L/h_o = Z_L = \frac{b_L}{h_o} = \exp\left[-\frac{K_L}{K_u}\frac{(t-t_1)}{t'_{c_1}}\right] \qquad (2.3.62)$$

But from (2.3.44) we note that at the stream X=0, and

$$c/c_{aq} = 1 - \bar{\Psi}_L = \frac{K_L Z_L}{K_u(1 + \hat{\xi})} , \qquad 0 \le Z \le B \qquad (2.3.63)$$

Combining this last expression with (2.3.62) yields

$$c/c_{aq} = \frac{K_L B}{K_u (1 + \hat{\xi})} \exp\left[-\frac{K_L}{K_u}\frac{(t-t_1)}{t'_{c_1}}\right] \qquad (2.3.64)$$

where $t \geq t_1$, and where t_1 is given by (2.3.59) with $Z_u = B$.

Equations (2.3.61) and (2.3.64) define the time history solute concentration in the stream. Furthermore, these relationships are identical at $t = t_1$; thus a check at Z = B yields the identity

$$c/c_{aq} = (B + \hat{\xi})/(1 + \hat{\xi}) = K_L B/K_u (1 + \hat{\xi})$$

Again, notice that the dimensionless travel time is based on the total system thickness, the net recharge rate, ε, the upper layer porosity, n, and the parameter $\hat{\xi}$, which characterizes the alteration of the water table shape resulting from the presence of the lower reservoir.

In order to relate the concentration outflow histories of the combined lumped parameter model and the linearized multi-layered Dupuit aquifer model, we must first relate the parameter μ in equation (2.2.23) to our Dupuit model. From Figure 2.5 we may write a water balance at the stream-aquifer boundary as

$$Q = Q_L + Q_u \tag{2.3.65}$$

where Q represents the total volume outflow rate leaving the aquifer; it is composed of the volume outflows leaving the lower and upper aquifers respectively. For a steady flow field, Q is equal to the net recharge rate ε, times the horizontal aquifer area, A. Thus from the definition for μ in (2.2.23) we had

$$\mu = \frac{\varepsilon L}{\varepsilon} = \frac{Q_{L/A}}{Q/A} = Q_2/Q$$

But from (2.3.65) we also note that

$$\mu = Q_L/Q = Q_L/(Q_u + Q_L) = Q_2/(Q_1 + Q_2)$$

and from Darcy's Law

$$Q_L = Q_2 = h_L K_L \bar{J}_L \text{ and } Q_u = Q_1 = h_u K_u \bar{J}_u$$

where h_L, h_u = lower and upper layer saturated thicknesses,

K_L, K_u = lower and upper layer hydraulic conductivies,

J_L, J_u = lower and upper layer hydraulic gradients.

From the Dupuit approximation we concluded that $J_L = J_u$ and

$$\mu = (mh_u K_L J_L)/(h_u K_u J_u + mh_u K_L J_L)$$

where $h_L = mh_u$ and m is some constant. Thus

$$\mu = (mK_L/K_u)/(1 + mK_L/K_u) \qquad (2.3.66)$$

By selecting μ in (2.2.3) according to (2.3.66) the combined lumped parameter model should approximate the linearized Dupuit results of (2.3.63) and (2.3.64).

Seven specific cases for a comparison between the combined lumped parameter model and the linearized Dupuit model were made. Table 2.1 summarizes the hydraulic features of each case examined.

Table 2.1 Comparison between the combined lumped and linearized Dupuit models

Number	K_u/K_L	m	$1+m^{(1)}$	Remarks
1	20	3	4	Fig. 2.6
2	10	3	4	Fig. 2.7
3	5	3	4	Fig. 2.8
4	2	3	4	Fig. 2.9
5	1	0	1	Fig. 2.10
6	10	9	10	Fig. 2.11
7	10	19	20	Fig. 2.12

(1) Theortical area under (c/c_{aq}) versus (t/t_{c_1}) curve

The concentration outflow histories from both models are shown in Figures 2.6 through 2.12; each case examined shows good to excellent agreement between the models. In these figures the dimensionless concentration, c/c_{aq}, is plotted against the dimensionless time t/t_{c_1} from the lumped model. Here c is the concentration in the stream, while c_{aq} is the initial average aquifer concentration in the system. Likewise t is the time required for the concentration c to appear in the stream, and t_{c_1}

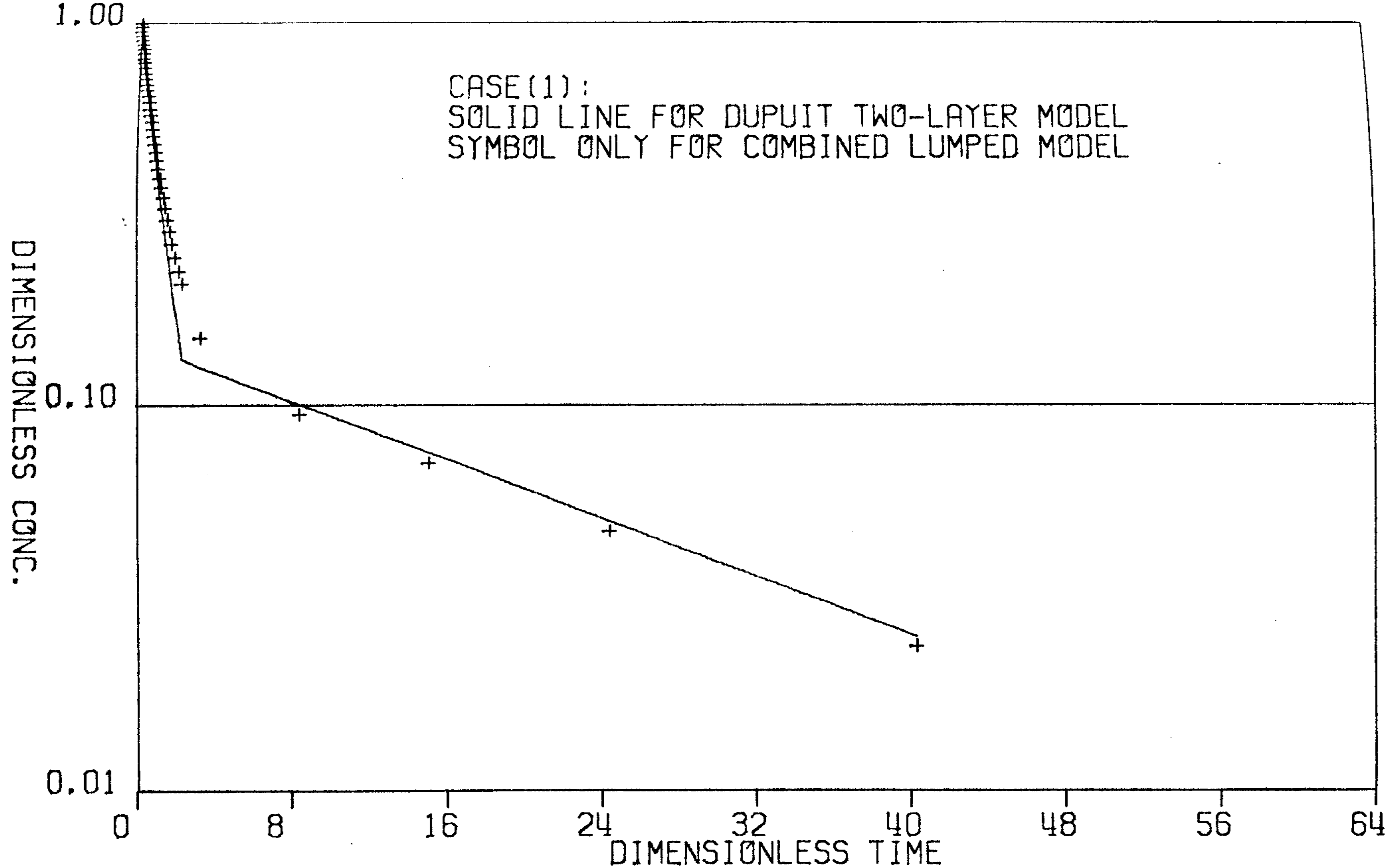

Figure 2.6: Log (c/c_{aq}) versus t/t_{c1} for case (1).

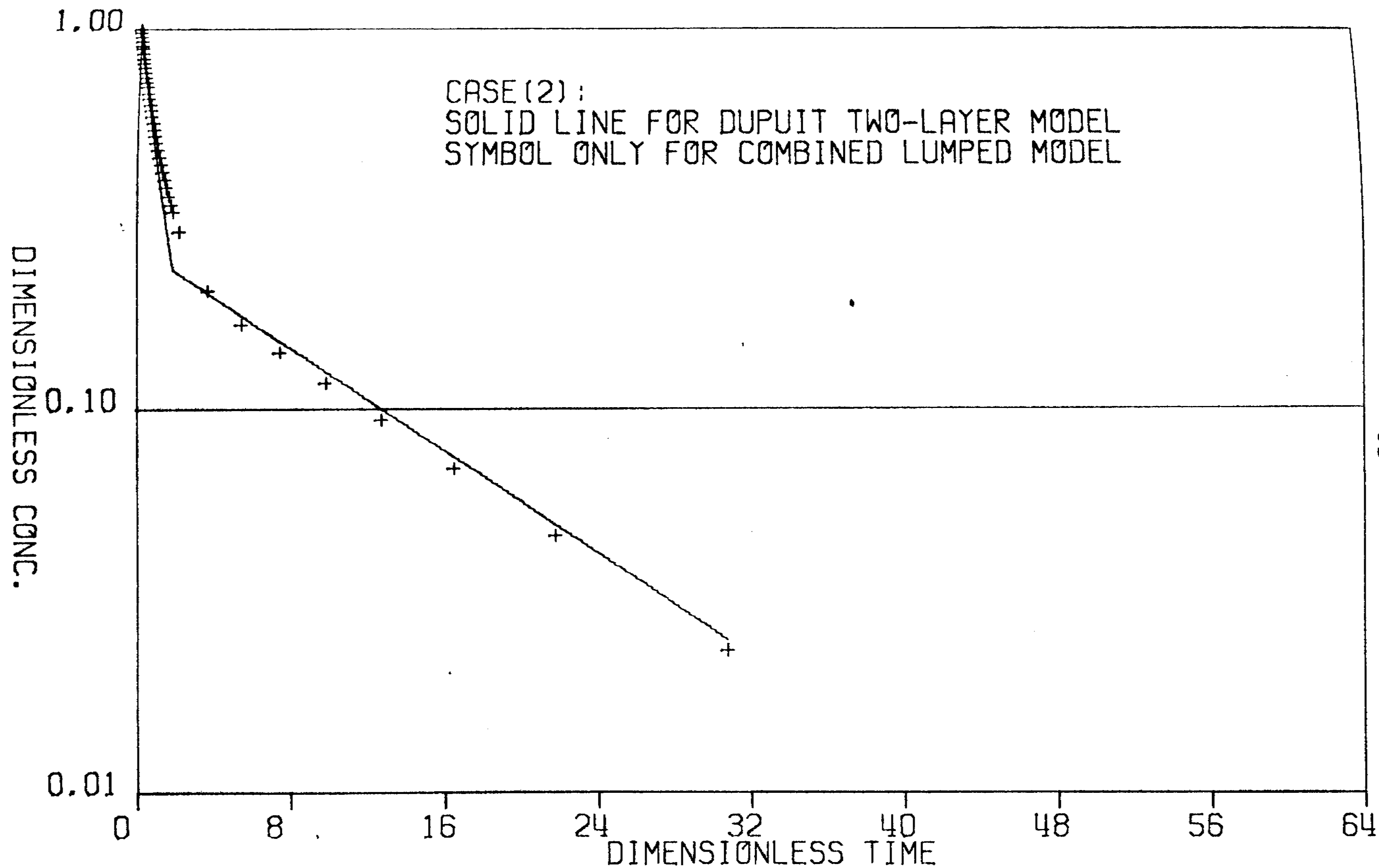

Figure 2.7: Log (c/c_{aq}) versus t/t_{c1} for case (2).

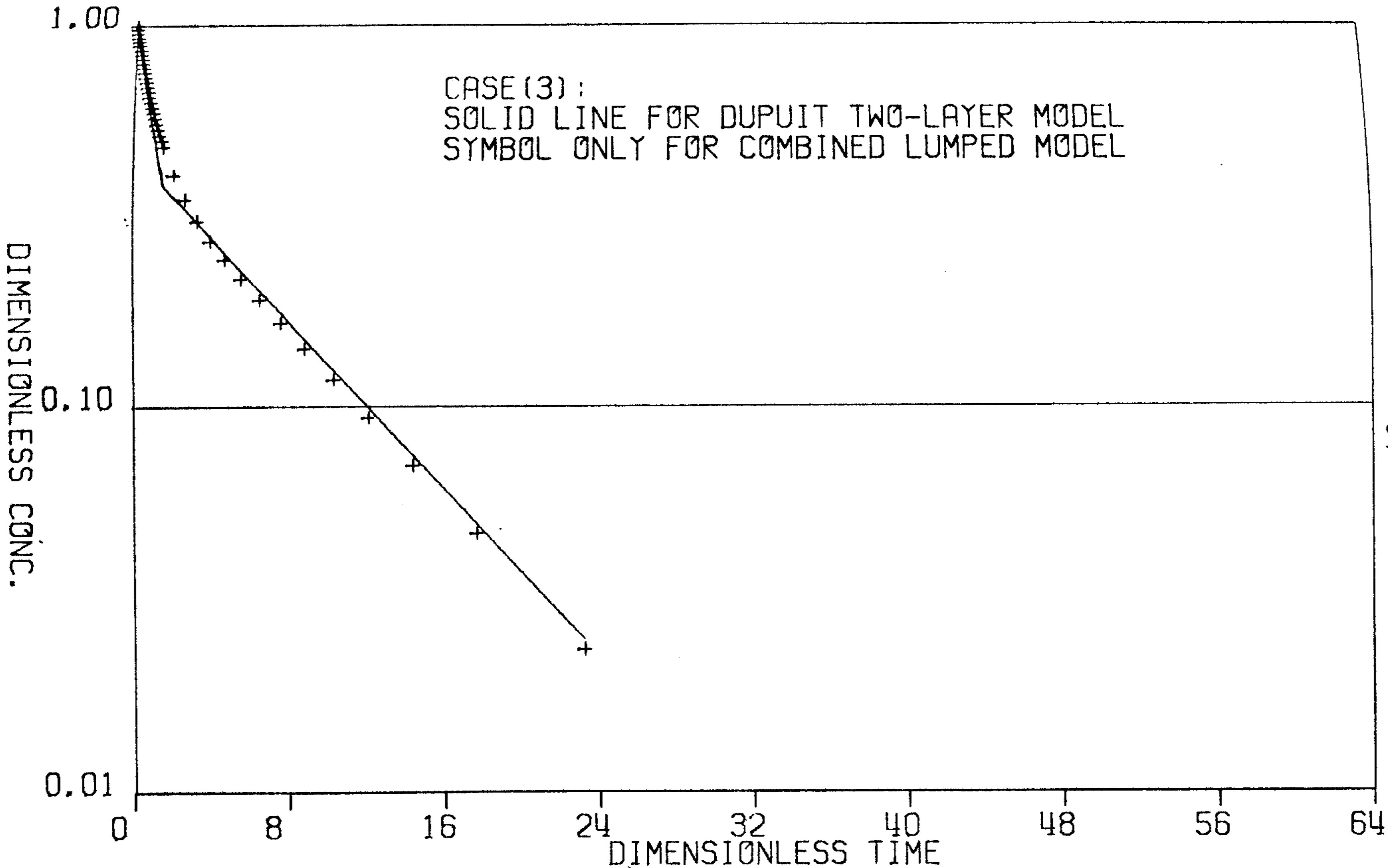

Figure 2.8: Log (c/c_{aq}) versus t/t_{c1} for case (3).

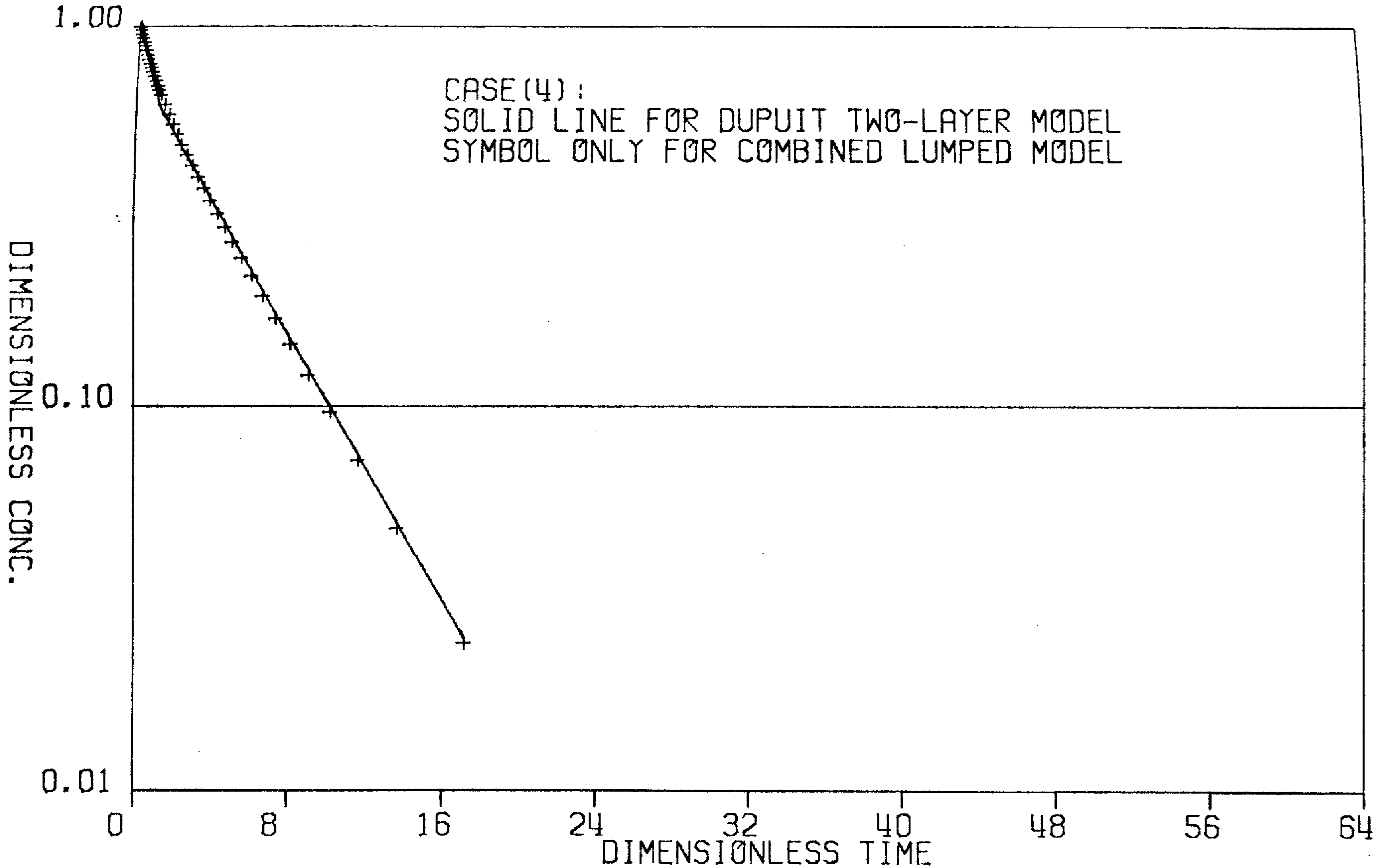

Figure 2.9: Log (c/c_{aq}) versus t/t_{c1} for case (4).

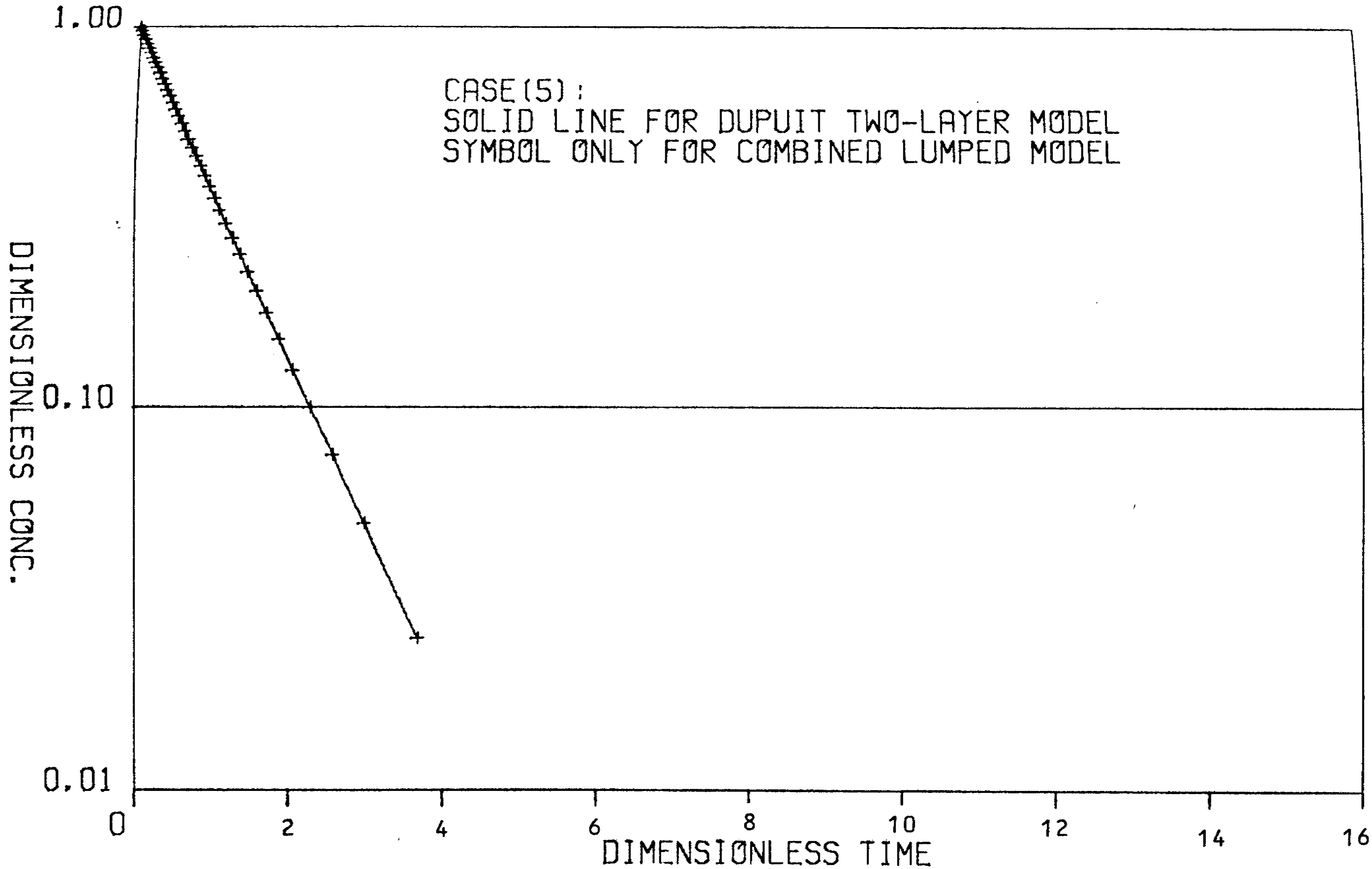

Figure 2.10: Log (c/c_{aq}) versus t/t_{c1} for case (5).

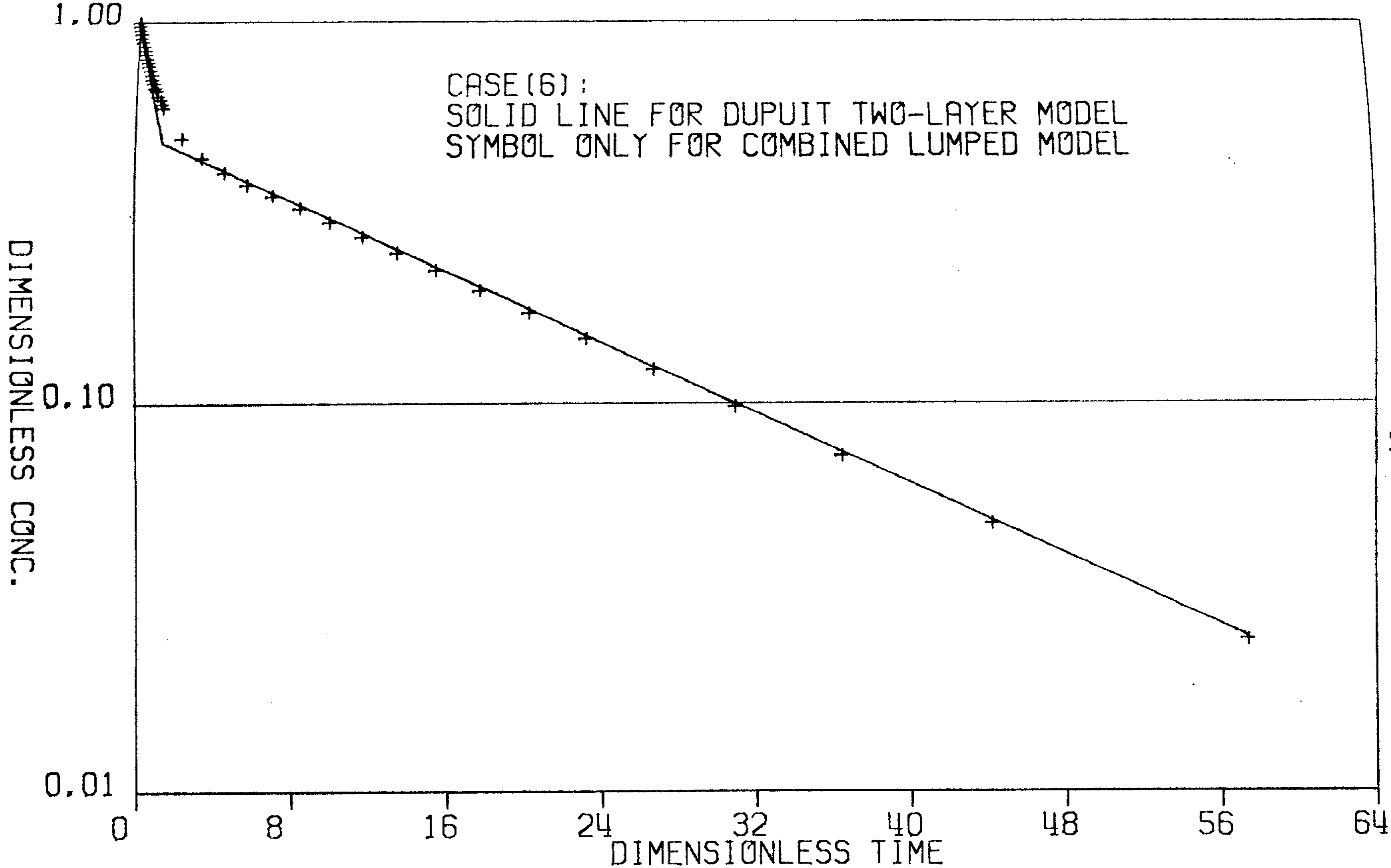

Figure 2.11: Log (c/c_{aq}) versus t/t_{c1} for case (6).

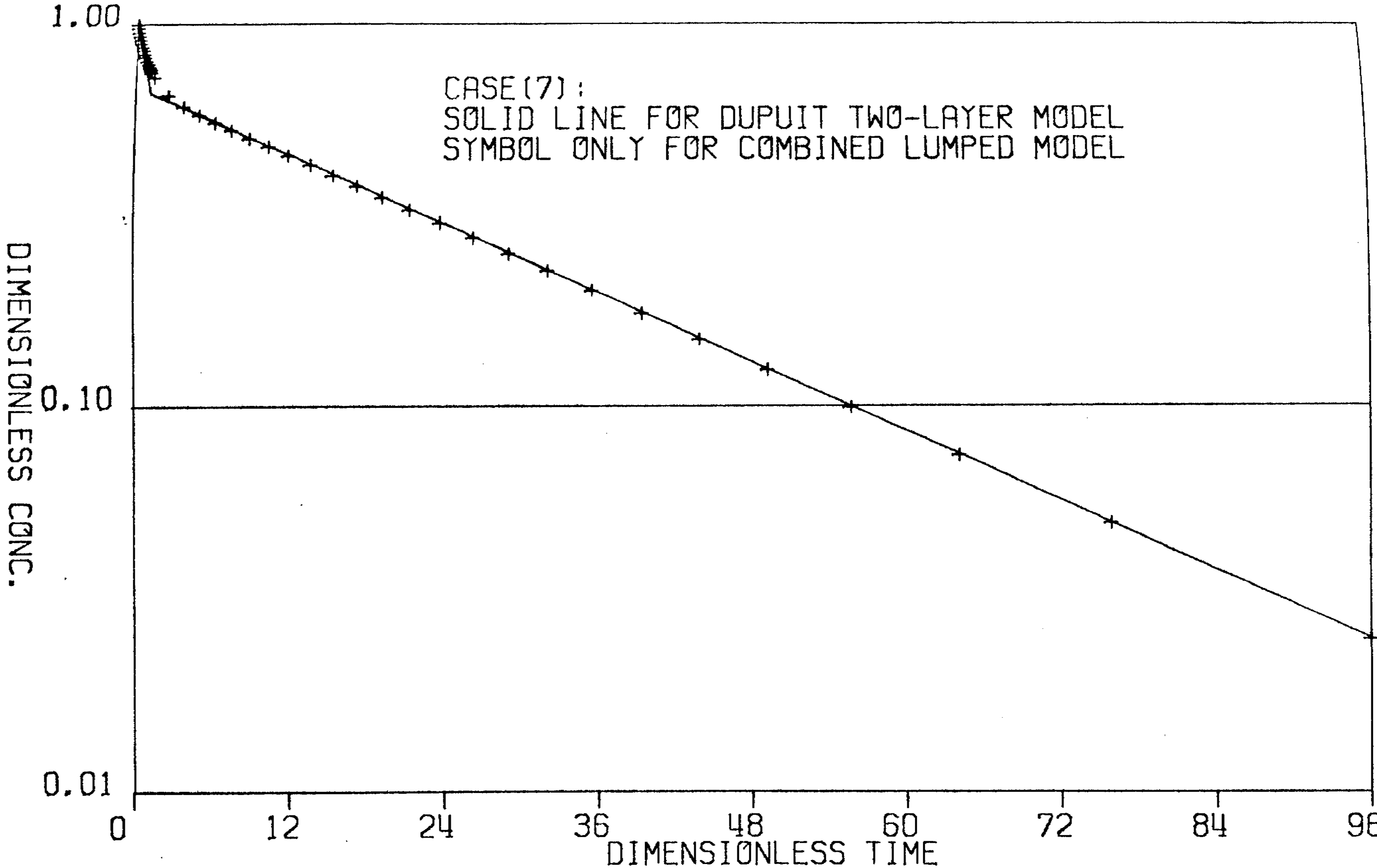

Figure 2.12: Log (c/c_{aq}) versus t/t_{c1} for case (7).

$= nh_1/\varepsilon$ is the solute response time, or average solute residence time in the upper aquifer.

As was done in (2.2.25), we may compute the total mass leaving the system of Figure 2.5 utilizing (2.3.61), (2.3.64), and the realtionship

$$\int_0^\infty (c/c_{aq})d(t/t'_{c_1}) = (c_{aq}V_{aq}/Q)(t'_{c_1}/c_{aq})$$

While evaluation of this integral presents no problem, we would like to compare the results to those previously obtained in (2.2.26). Hence we must relate (t/t'_{c_1}) to (t/t_{c_1}) since they are different. Thus from Figures 2.4 and 2.5 we observe that

$$\frac{t'_{c_1}}{t_{c_1}} = \frac{n(h_o + \xi/2)}{\varepsilon} \quad \frac{\varepsilon}{nh_1} = \frac{h_1 + h_2 + \xi/2}{h_1}$$

$$= 1 + \frac{h_2}{h_1} + \frac{b_L(K_L - K_u)}{h_1 K_u}$$

$$= 1 + \frac{h_2}{h_1} + \frac{h_2 K_L}{h_1 K_u} - \frac{h_2}{h_1} = 1 + r$$

where $r = h_2K_L/h_1K_u$. Thus

$$\int_0^\infty (\frac{c}{c_{aq}}) \; d \; (\frac{t}{t'_{c_1}})(\frac{t'_{c_1}}{t_{c_1}}) = (1 + r) \int_0^\infty (\frac{c}{c_{aq}}) \; d \; (\frac{t}{t'_{c_1}}) \qquad (2.3.67)$$

Substituting (2.3.61) and (2.3.64) into (2.3.67) yields

$$\int_0^\infty \frac{c}{c_{aq}} \, d\left(\frac{t}{t_{c_1}}\right) = (1 + r) \int_0^{t/t'_{c_1}} \exp(-t/t'_{c_1}) \, d\left(\frac{t}{t'_{c_1}}\right)$$

$$+ (1 + r) \int_{t/t'_{c_1}}^\infty \left[\frac{K_L B}{K_u (1 + \quad)}\right] \exp\left[-\frac{K_L (t - t_1)}{t'_{c_1}}\right] d\left(\frac{t}{t'_{c_1}}\right)$$

Performing the indicated integration and simplyfing, noting that $Z = B$ at $t = t_1$ in (2.3.61) yields

$$\int_0^\infty \left(\frac{c}{c_{aq}}\right) d\left(\frac{t}{t_{c_1}}\right) = (1 + r) \left(1 - \frac{B + \hat{\xi}}{1 + \hat{\xi}} + \frac{B}{1 + \hat{\xi}}\right)$$

$$= (1 + r)/(1 + \hat{\xi}) = 1 + m \qquad (2.3.68)$$

since $\hat{\xi} = b_L(K_L - K_u)/h_o K_u = h_2(K_L - K_u)/(h_1 + h_2) K_u$ and $r = h_2 K_L / h_1 K_u$. Equation (2.3.68) is exactly that obtained from (2.2.26); hence, we conclude that the combined lumped and linearized multi-layered Dupuit analyses yield exactly the same total mass convected from the system in the same time.

Figures 2.6 through 2.12 demonstrate that the output concentration history from the combined lumped parameter model is very nearly identical to that from a linearized multi-layered Dupuit aquifer analysis when the parameter μ in equation (2.2.23) is calculated according to equation (2.3.66). While we still have not demontrated that either model accurately represents the physical situation depicted in Figure 2.2, we have shown that the combined lumped model is approximately equivalent to a two-dimensional representation of convective water and mass transport through a multi-aquifer system; furthermore, the total mass outflow from both systems is exactly the same. Thus if we conclude that a Dupuit approximation is a valid assumption in a particular system analysis, we must also conclude that a combined lumped system analysis will approximately represent the Dupuit model, but in a hydraulically averaged sense.

In the comparison between the combined lumped model and multi-layer Dupuit aquifer model we used a simple flushing situation; that is, at time $t \geq o$ all input contamination in recharge waters was taken to be zero. The reverse situation would be for initially uncontaminated aquifers at $t < o$, and recharge waters carrying some constant contaminant input concentration c_o at $t \geq o$; all other conditions would remain unchanged. The resulting output concentration history in the stream would simply be identical to Figures 2.6 to 2.12, with the ordinate inverted, i.e. $c = c_o(1-y)$. A third hypothetical case may also be easily verified. If the input concentration at $t \geq o$ is given by $c_i(t)=c_o$, a constant where $c_o < c_{aq}$, then the output concentration history in the stream would also appear identical to Figures 2.6 to 2.12. However the ordinate would be translated upward by the constant c_o/c_{aq}, i.e. $c = (c_{aq}-c_o)y+c_o$.

2.4 Laplace Aquifer Model

2.4.1. Flow Field Description

In the preceeding sections we showed that the lumped parameter model in the form of a linear reservoir could be related to a linearized Dupuit aquifer system. In the case of a single reservoir we saw that both models could be made to produce identical convective water and mass transport results under simple flow conditions. When the system consisted of multiple aquifers, the lumped model with linear reservoirs approximated the linearized Dupuit analysis quite well. It should be clear, however, that neither model can be expected to accurately represent a given physical situation in which the original Dupuit assumptions are violated, or where net system stresses are highly localized. The first situation would lead us to at least consider the vertical flow effects on contaminant outflow concentration that were neglected in the horizontal Dupuit and lumped parameter models; the second situation would imply that hydrodynamic dispersion effects might be approaching the same order of magnitude as convective transport effects. Hydrodynamic dispersion has been investigated by many workers (for example, see Bear, 1972; Fried and Combarnous, 1971; Fried, 1975; and references therein), and will not be addressed here. Subsurface vertical flow effects have also been the topic of considerable research effort. From this work one is likely to ask exactly when do the prediction errors in stream concentration resulting from neglecting these vertical effects actually become critical? Based on the preceding analysis, we might suspect that such errors will grow in some direct relation to which the Dupuit assumptions are violated. For example, Murray and Monkmeyer (1973) reported that for steady flow conditions, a free surface water table slope of less than 0.10 will produce less than 1 percent difference in the predicted water table shapes of the Dupuit and Laplace aquifer models. Verma and Brutsaert (1971) showed that the predicted nonlinear Dupuit and Laplace aquifer free surfaces were in reasonable agreement as long as the aquifer length was four times its initial saturated thickness. Neglecting any hydrodynamic dispersion and hydrochemical interaction effects between the fluid and porous media, we might also expect the predicted outflow concentrations from such aquifer models to also be similar under such conditions.

Since these aquifer models are not exactly equivalent (the Dupuit aquifer model assumes a fully penetrating stream while the Laplace aquifer as used here has only a partially penetrating stream of some finite width), we would not expect to analytically relate differences in predicted free surface shapes to predicted outflow concentrations. We can gain some insight on the physical behavior of these models, however, by comparing their concentration outflow histories under simple flow conditions.

Figure 2.13 shows a schematic diagram of some idealized phreatic aquifer hydraulically connected to a partially penetrating stream or tile drain of some finite width. We will refer to this diagram as the idealized Laplace aquifer since some form of the so called Laplace equation, subject to appropriate initial and boundary conditions, will describe the spatial distribution of the piezometric head, h, or the streamline distribution. The Laplace equation describes these distributions since it is obtained by combining the continuity equation with Darcy's law (Bear, 1972). Using the vector summation convention, Darcy's law will be given by

$$q_i = - K_{ij} \frac{\partial h}{\partial x_j} \quad ; \quad (i,j = 1, 2, 3)$$

where the principal axes of the hydraulic conductivity tensor, K_{ij}, may be assumed to lie in the same direction as our orthogonal coordinate

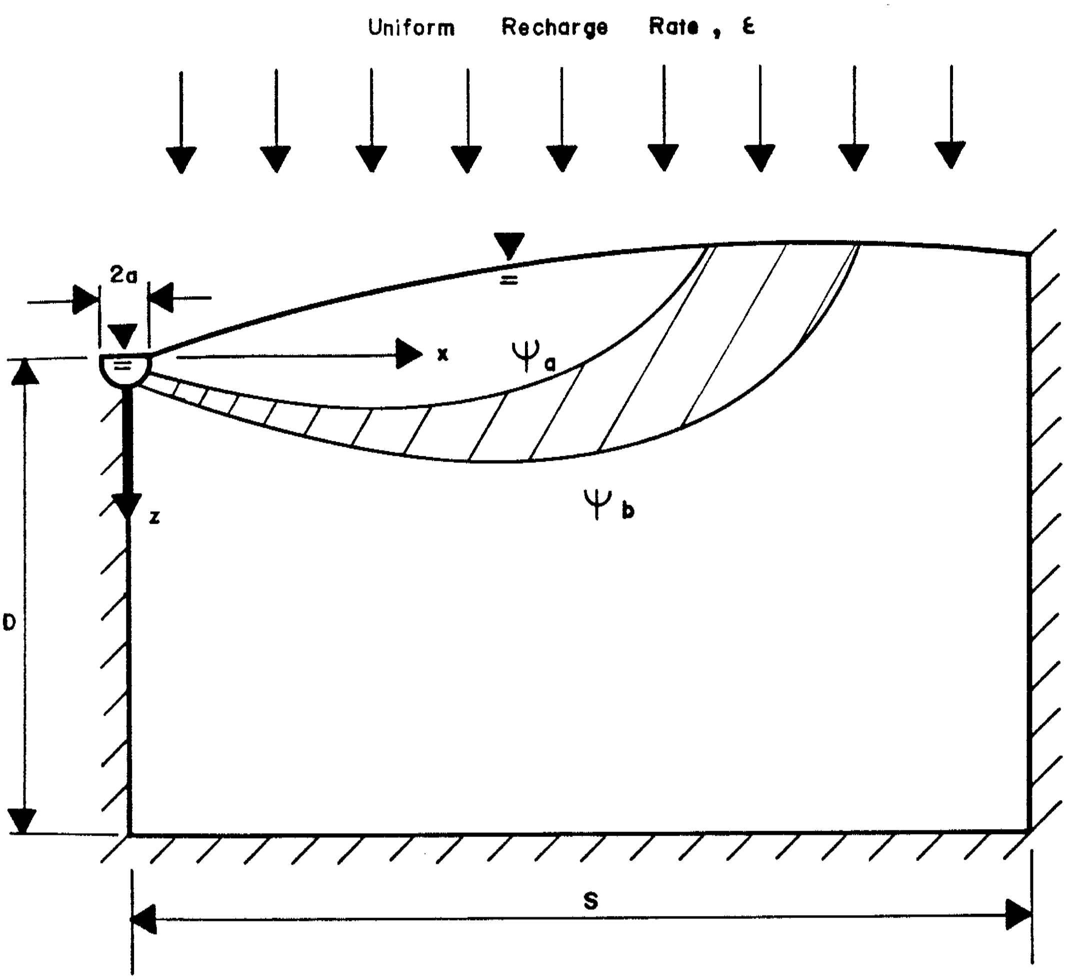

Figure 2.13 Schematic diagram for an idealized Laplace aquifer showing one possible streamtube.

system. The continuity equation for a non-deforming, saturated porous media with an incompressible fluid is given by (Bear, 1972)

$$\frac{\partial q_i}{\partial x_i} = 0; \; (i = 1, 2, 3)$$

where the system contains no sources or sinks. Combining these equations yields

$$\frac{\partial}{\partial x_i} (K_{ij} \frac{\partial h}{\partial x_j}) = 0; \; (i = 1,2,3) \tag{2.4.1}$$

This last equation is sometimes referred to as Richard's equation in the soil science literature; however, appropriate coordinate transformations will produce the familar Laplace form. Thus if we let

$$X_i = x_i \, (K_i/K_j)^{1/2} \text{ , where } i = 1, 2, 3 \text{ and } j = \text{either } 1, 2, \text{ or } 3$$

then (2.4.1) becomes

$$\frac{\partial^2 h}{\partial X_i^2} = 0; \quad (i = 1,2,3) \tag{2.4.2}$$

for a homogeneous medium and where the x_i are the principal axes of the conductivity tensor. Equation (2.4.1) is valid for steady or unsteady flow in heterogeneous, anisotropic porous media; (2.4.2) would apply to steady or unsteady flow in homogeneous, anisotropic media. Both equations are obviously subject to the implied limitation contained in the continuity equation. Note that any time dependency will be introduced through the boundary conditions.

If we wish to describe the instantaneous spatial distribution of the loci of points which are everywhere tangent to the specific discharge vector, q_i, then we must find all of the infinitesimally small position vectors that are everywhere tangent to q_i. These small position vectors will, in the limit, reduce to the required loci of points and describe the streamline. Mathematically a streamline will be defined by the vector cross product $\hat{q} \times d\hat{r} = o$, where $d\hat{r}$ is some small position vector tangent to $\hat{q}$. Thus $\hat{i}(q_z dy - q_y dz) = \hat{j}(q_x dz - q_z dx) = \hat{k}(q_y dx - q_x dy) = o$, where $\hat{i}$, $\hat{j}$, and $\hat{k}$ are the unit vectors in the x,y,z coordinate system, respectively. This last relation may be written as

$$\frac{dx}{q_x} = \frac{dy}{q_y} = \frac{dz}{q_z}$$

For two dimensional flow in the x-z plane we obtain

$$q_z dx - q_x dz = 0.$$

The solution to this equation is given by the stream function $\Psi = \Psi(x,z)$ = a constant, which describes the instantaneous streamline distribution; Ψ is an exact differential only if $\partial q_i/\partial x_i = 0$, (i=1,2). Since $\Psi(x,z)$ is to be exact then

$$d\Psi = 0 = \frac{\partial \Psi}{\partial x} dx + \frac{\partial \Psi}{\partial z} dz = q_z dx - q_x dz$$

Thus $q_x = -\frac{\partial \Psi}{\partial z}$ and $q_z = \frac{\partial \Psi}{\partial x}$. For macroscopic irrotational flow in porous media where the principal axes of the hydraulic conductivity tensor are parallel to the cartesian coordinate system, $\nabla \times (\nabla h) = 0$ (Bear, 1972). If (x,z) are principal axes of the hydraulic conductivity this relationship may be combined with Darcy's law to yield $\nabla \times (-q_x/K_x, q_z/K_z) = 0$. For two-dimensional flow in non-homogeneous, anisotropic media this last expression becomes

$$\frac{\partial}{\partial x}\left(\frac{1}{K_z}\frac{\partial \psi}{\partial x}\right) + \frac{\partial}{\partial z}\left(\frac{1}{K_x}\frac{\partial \psi}{\partial z}\right) = 0 \qquad (2.4.3)$$

For homogeneous, isotropic media, (2.4.3) is simply Laplace's equation, or

$$\frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial z^2} = 0 \qquad (2.4.3a)$$

subject to the implied boundary conditions depicted in Figure 2.13. Thus for steady flow we have

$$\begin{aligned}
&(1)\quad \psi = \psi_0 \text{ on } x = 0,\ 0 \le z \le D\\
&(2)\quad \psi = \psi_0 \text{ on } z = D,\ 0 \le x \le L\\
&(3)\quad \psi = \psi_0 \text{ on } x = L,\ 0 \le z \le D\\
&(4)\quad \psi = \left(\frac{x-a}{S-a}\right)\psi_0 \text{ on } z = 0,\ a \le x \le L\\
&(5)\quad \psi = \left(\frac{a-x}{a}\right)\psi_0 \text{ on } z = 0,\ 0 \le x \le a
\end{aligned} \qquad (2.4.3b)$$

where $\psi_0 = \varepsilon L$ and the medium is isotropic and homogeneous. Using separation of variables and superposition of solutions, Kirkham (in

Kirkham and Powers, 1972, eq. 3-71; or see Carslaw and Jaeger, 1959, p. 167, eq. 9) obtained the solution

$$\psi(x,z) = \psi_0 - \frac{2\psi_0}{\pi} \sum_{m=1}^{\infty} \frac{\sin\left(\frac{m\pi x}{L}\right) \sinh\left[\frac{m\pi}{L}(D-z)\right]}{m \sinh(m\pi D/L)}$$

which is valid when a << L. If we let

$$\begin{aligned} \bar{\psi} &= \psi/\psi_0 \\ X &= x/L \\ Z &= z/D \\ \eta &= L/D \end{aligned} \qquad (2.4.4)$$

Then we may express the solution to (2.4.3a) in dimensionless form, or

$$\bar{\psi}(X,Z) = 1 - \frac{2}{\pi} \sum_{m=1}^{\infty} \frac{\sin(m\pi X)\sinh\left[\frac{m\pi}{\eta}(1-Z)\right]}{m\sinh(m\pi/\eta)} \qquad (2.4.5)$$

The boundary conditions employed in arriving at the solution to (2.4.3a) imply that the water table height above x = o in Figure 2.13 is zero; that is, (2.4.5) neglects the height of the water table above the stream or tile drain elevation. If this height is small, then (2.4.5) will approximate the streamline distribution adequately. Thus our solution to the Laplace model will differ from the Dupuit or lumped parameter aquifer analyses previously given because vertical flow effects resulting from partial stream penetration have been included.

2.4.2. Convective Outflow Concentration from the Laplace Aquifer Model

We have previously established the convective water and mass transport equivalence between the lumped parameter model and the linearized Dupuit model under steady flow conditions. We will now expand our analysis to include a quantitative comparison of convective mass transport through the steady flow field of the Laplace aquifer model. Again we my conceptually visualize a small parcel of contaminated water following some given space-time trajectory through the steady flow field of the Laplace aquifer; these trajectories may be approximately described by (2.4.5). We can determine the total change in quality of all such parcels at the partially penetrating stream or tile drain where all parcels begin to mix together. As before we must of course assume that no chemical interaction effects between adjacent water parcels of different quality or between water parcels and the porous medium occur. Hydrodynamic dispersion effects are likewise neglected.

The streamlines described by (2.4.5) represent the actual flow path followed by the moving parcels of contaminated water through the aquifer model. If conservation of mass is to be maintained, then the total fluid discharge between any two adjacent streamlines must remain constant. Thus the discharge between any two streamlines is

$$Q_{AB} = \int_A^B (q_x dz - q_z dx) = \int_A^B (-d\psi) = \psi_A - \psi_B$$

where $d\psi = q_z dx - q_x dz$ was obtained in the previous section. The dimensions of ψ are volume per unit time per unit of width. According to the sign convention employed here, $\psi_B > \psi_A$, so Q_{AB} is negative.

In Figure 2.13 a hypothetical streamtube bounded by the streamlines ψ_A and ψ_B is illustrated as the shaded area. Recharging water entering this streamtube at the water table will eventually discharge in the partially penetrating stream or tile drain. The volume of water entering this tube per unit time, assuming a unit length in the third dimension, is given by $Q = \varepsilon \Delta x \hat{j}$. The fluid velocity at any point within this streamtube will be $ds/dt = Q/nA$, where ds is the differential arclength along the flow path, n is th effective porosity of the porous medium, and A is the unit cross-sectional area of the tube. The time required for a parcel of contaminated water to pass between two points s_1 and s_2 in the tube is therefore

$$\int_{t_1}^{t_2} dt = \int_{s_1}^{s_2} (nA/Q)ds = \frac{n}{\varepsilon \Delta X} \int_{s_1}^{s_2} Ads$$

where the integral $n \int Ads$ is the volume of water (the x-z plane area times a unit thickness in the third dimension) in the streamtube between s_1 and s_2. Therefore

$$t_2 - t_1 = t = n\Delta\ A/\Delta\psi$$

Written in differential form this last experession is

$$t = \frac{ndA(\psi)}{d\psi}$$

where $dA\ (\psi)$ is a single valued function of ψ. Now if we let

A_o = LD, the aquifer cross-sectional area,

Ψ_o = εL as before,

$\bar{A}(\bar{\Psi})$ = $A(\Psi)/A_o$, a dimensionless area, and

$\bar{\Psi}$ = Ψ/Ψ_o, a dimensionless streamline,

then we see that

$$t = \frac{nA_o d\bar{A}\ (\bar{\Psi})}{\Psi_o d\ \bar{\Psi}} = \frac{nLDd\bar{A}(\bar{\Psi})}{\varepsilon L d\bar{\Psi}}$$

Thus,

$$t/t_c = d\bar{A}(\bar{\Psi})/d\bar{\Psi} \tag{2.4.6}$$

where $t_c = nD/\varepsilon$ was previously defined as the solute response time for the lumped parameter model. Equation (2.4.6) says that the dimensionless travel time, t/t_c, of some parcel of water following some specified streamline will be given by the slope of the dimensionless $d\bar{A}$ verus $d\bar{\Psi}$ curve. If we know how the streamline cross-sectional area changes for different streamtubes, then we can find the travel time of some parcel following the intermediate streamline contained in that streamtube. Note that for the aquifer depicted in Figure 2.13, $\bar{A}(\bar{\Psi})$ is only a function of $\bar{\Psi}$. Using (2.4.5) we may numerically integrate between streamlines to obtain the area. Jury (1975) used a Gaussian quaduature technique in a similar procedure (Jury, 1976, personnal communication) to obtain solute travel time estimates for tile-drained fields where (2.4.5) approximately defines the streamline distribution. His approach, however, is limited to those idealized situations where an analytical solution to the Laplace equation is possible. These solutions are not generally practical, or even possible, when irregular boundaries are present or when the porous medium is anisotropic and non-homogeneous.

The dimensionless concentration appearing in the stream or tile drain of Figure 2.13 at the dimensionless time given by (2.4.6) can be found as before. Thus if some particle enters the aquifer system at $\bar{\Psi} = x/L$ at time $t/t_c = o$, it will follow the space trajectory described by (2.4.5) to the stream or tile drain. If the aquifer is initially contaminated at some uniform concentration level, c_{aq}, at time $t/t_c \leq o$, and for $t/t_c \geq o$ no new contamination is introduced with the recharge waters, then the dimensionless concentration in the stream or drain will be given by

$$c/c_{aq} = 1 - \bar{\Psi} \tag{2.4.7}$$

This concentration level will appear in the stream after the time given by (2.4.6).

Unless we have some analytical function that relates $\bar{A}(\bar{\Psi})$ to $\bar{\Psi}$ in (2.4.6), we must evaluate this derivative numerically. One possibility to obtaining the desired solution is to develop a finite difference or finite element program that will solve for the spatial distribution of $\bar{\Psi}(X,Z)$. Once this distribution is known, then we may proceed to contour in the streamlines and evaluate the area under each of several specified values of $\bar{\Psi}$. Finally we may plot a curve of $\bar{A}(\bar{\Psi})$ versus $\bar{\Psi}$ and graphically or numerically evaluate the slope along various points; this information will enable us to develop concentration break-through curves (i.e., c/c_o vs. t/t_c) for various aquifer geometry configurations. This procedure is illustrated in Figures 2.14 and 2.15 below. Note in

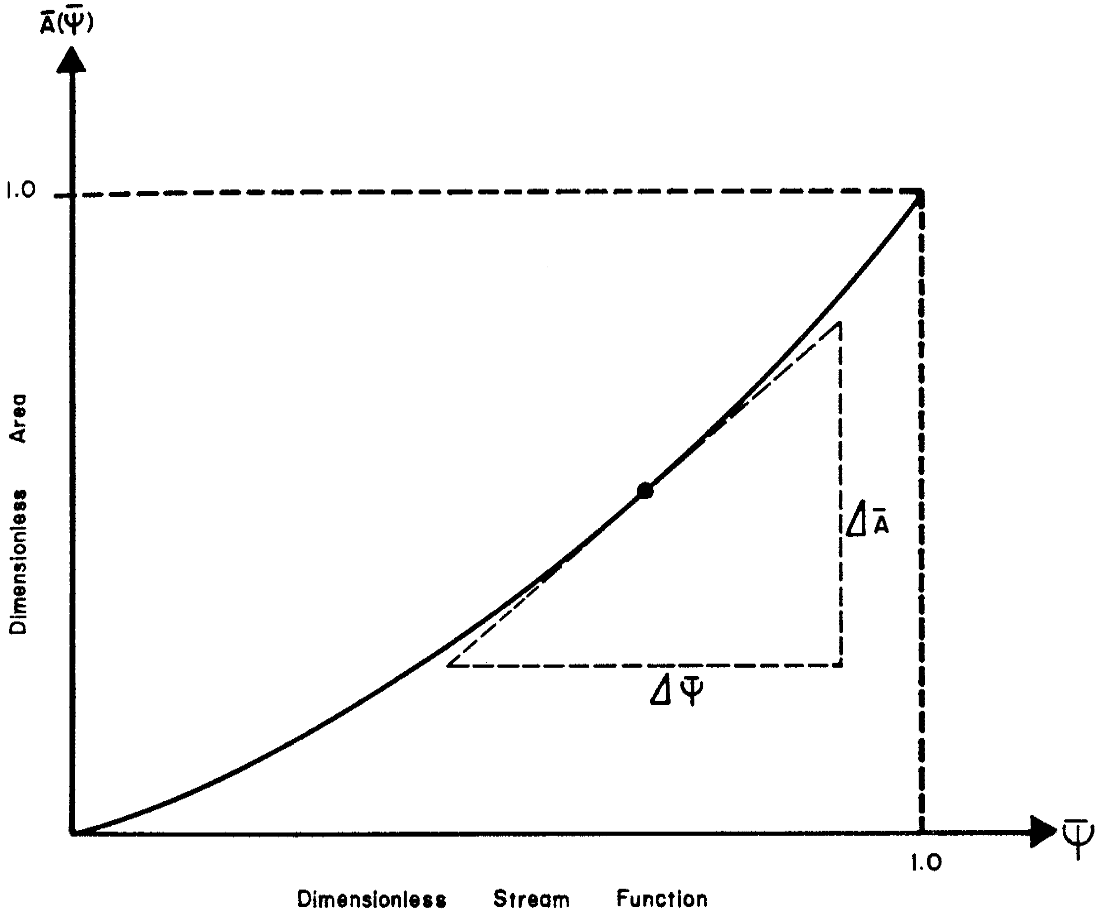

Figure 2.14 Idealized relationship indicating the total dimensionless area swept out by a given dimensionless streamline.

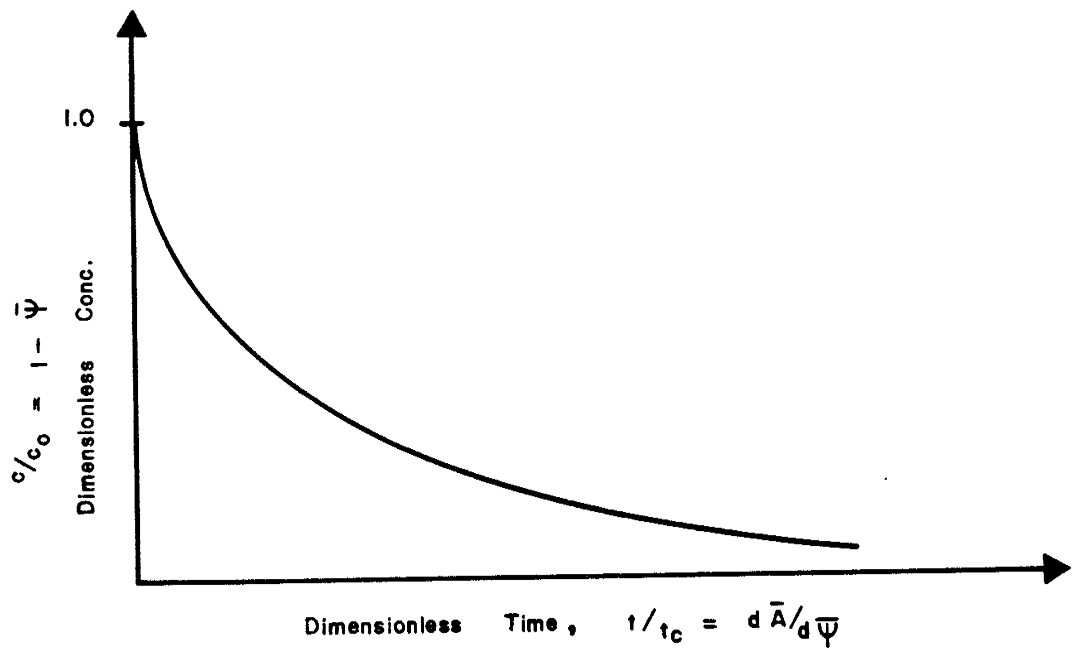

Figure 2.15 Idealized breakthrough curve computed from the area versus streamline relationship.

Figure 2.14 that the dimensionless area swept out by the dimensionless streamline $\bar{\Psi} = o$ is zero, and that at $\bar{\Psi} = 1$, $\bar{A} = 1$. These values correspond to a dimensionless concentration of 1 in the stream at $t/t_c = o$ (the onset of non-contaminated recharge water infiltration) in Figure 2.15; similarily for $\bar{\Psi} = 1$ we have $c/c_o = o$, which requires an infinite travel time. In other words a particle flowing along $\bar{\Psi} = 1$ (the aquifer boundary) will require an infinitely large travel time to reach the stream since $d\bar{A}/d\bar{\Psi} = \infty$ at $\bar{\Psi} = 1$.

In arriving at a solution to our problem, the critical step is obtaining an accurate $\bar{A}$ ($\bar{\Psi}$) versus $\bar{\Psi}$ relationship. Most existing computer models for subsurface hydrology, however, are designed to solve (2.4.1) for the spacial distribution of peizometric head, h. One existing finite element program (U.S. Corps of Engineers, 1972) may be easily modified to solve (2.4.3); however, care must be used to also modify the implied boundary conditions. This particular program also has the advantage that anisotropic, non-homogeneous problems containing sources and sinks are easily handled for any irregular flow zone geometry.

The governing partial differential equation for an area containing no sources or sinks is given by (2.4.3), subject to the boundary conditions implied in Figure 2.13, and given by (2.4.3b). Recall that we have assumed that $a << L$. We may use the above procedure and the modified U.S. Corps of Engineers program to solve several problems, varying L, D, K_x, and K_z in combination. Since the same coordinate grid network may be used in all of the analyses, an internal grid generator was incorporated into the model program. Finally, the program was further modified so as to track specified streamlines from x=o to the stream-aquifer boundary. A linear interpolation scheme was employed to track streamline coordinates between grid lines so that the area under a given $\overline{\Psi}$ could be simultaneously calculated using a simple trapazodial summation. The complete modified U.S. Corps of Engineers program is listed in Appendix B along with a partial sample output. Output results were modified so that $\overline{A}(\overline{\Psi})$ could be plotted against $\overline{\Psi}$; the corresponding c/c_o versus t/t_c curves could then be easily computed for various $(L/D)(K_z/K_x)^{1/2}$ ratios. In the program a 41 by 21 mesh was used in conjunction with quadrilateral (rectangular) elements; Figure 2.16 shows a diagram of this grid network.

2.4.3 Effects of Partial Stream Penetration

Using the procedure outlined in the previous section, we may quantify the concentration outflow history from the Laplace aquifer of Figure 2.13 for various ratios of L/D and a step change in input concentration at time $t/t_c = 0$ (the flushing system previously employed). The ratio, $\eta = L/D$, may be referred to as an aspect ratio that characterizes the aquifer geometry. The stream or tile drain is assumed to be a point sink located at the (x,z) coordinates (o,o). The Laplace model will yield a streamline distribution similar to that shown in Figure 3-8 of Kirkham and Powers (1972, p. 95), from which the $\overline{A}(\overline{\Psi})$ versus $\overline{\Psi}$ curves for various values of η may be constructed. Equations (2.4.6) and (2.4.7) of the previous section will yield the corresponding c/c_o versus t/t_c curves for a flushing aquifer system. These curves are shown in Figure 2.17 for values of $\eta = 1$ through 5, and $\eta = 10$. For the sake of clarity only, the curves for values of $\eta = 1$, 5, and 10 are shown in Figure 2.18. Also shown in Figure 2.18 as a reference is the

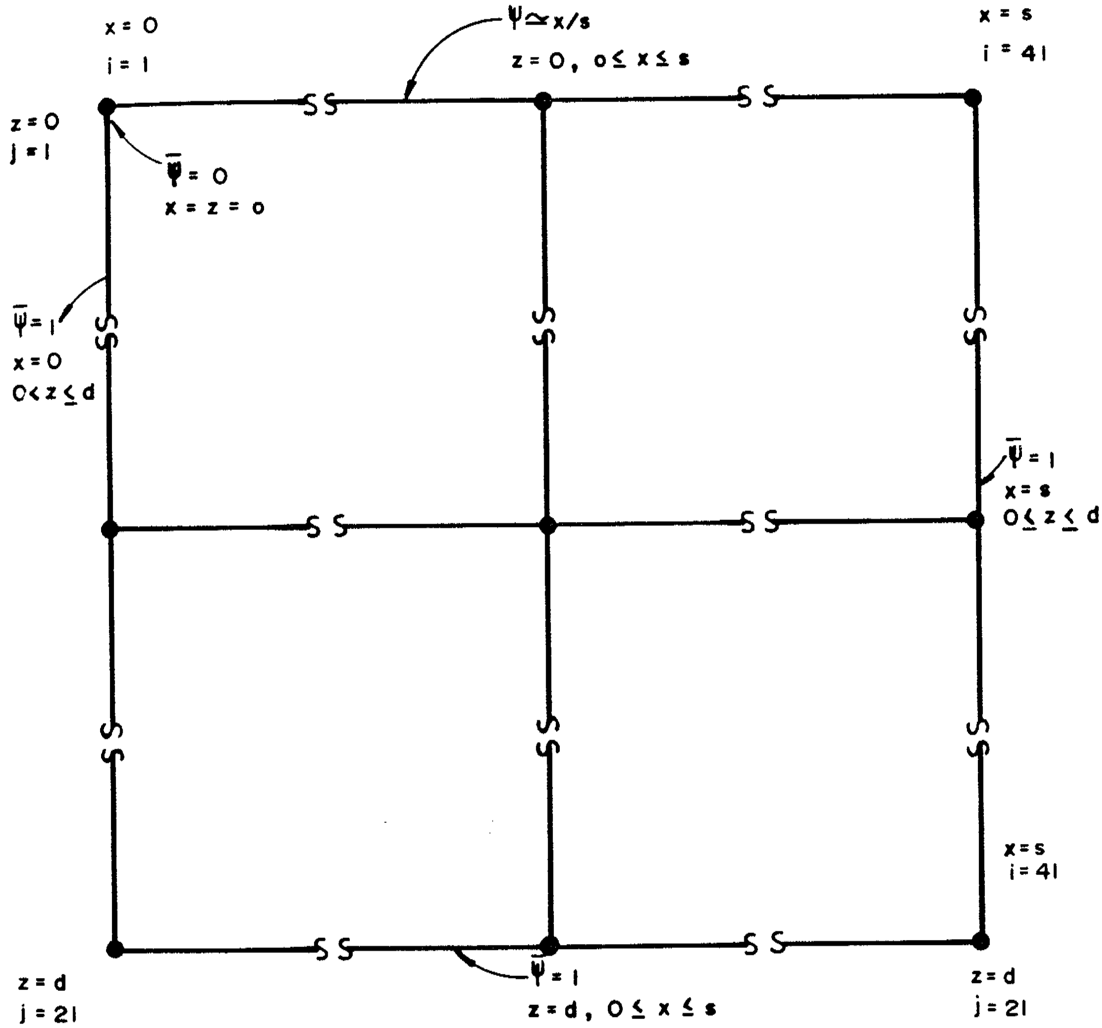

Figure 2.16 Program grid network showing boundary conditions.

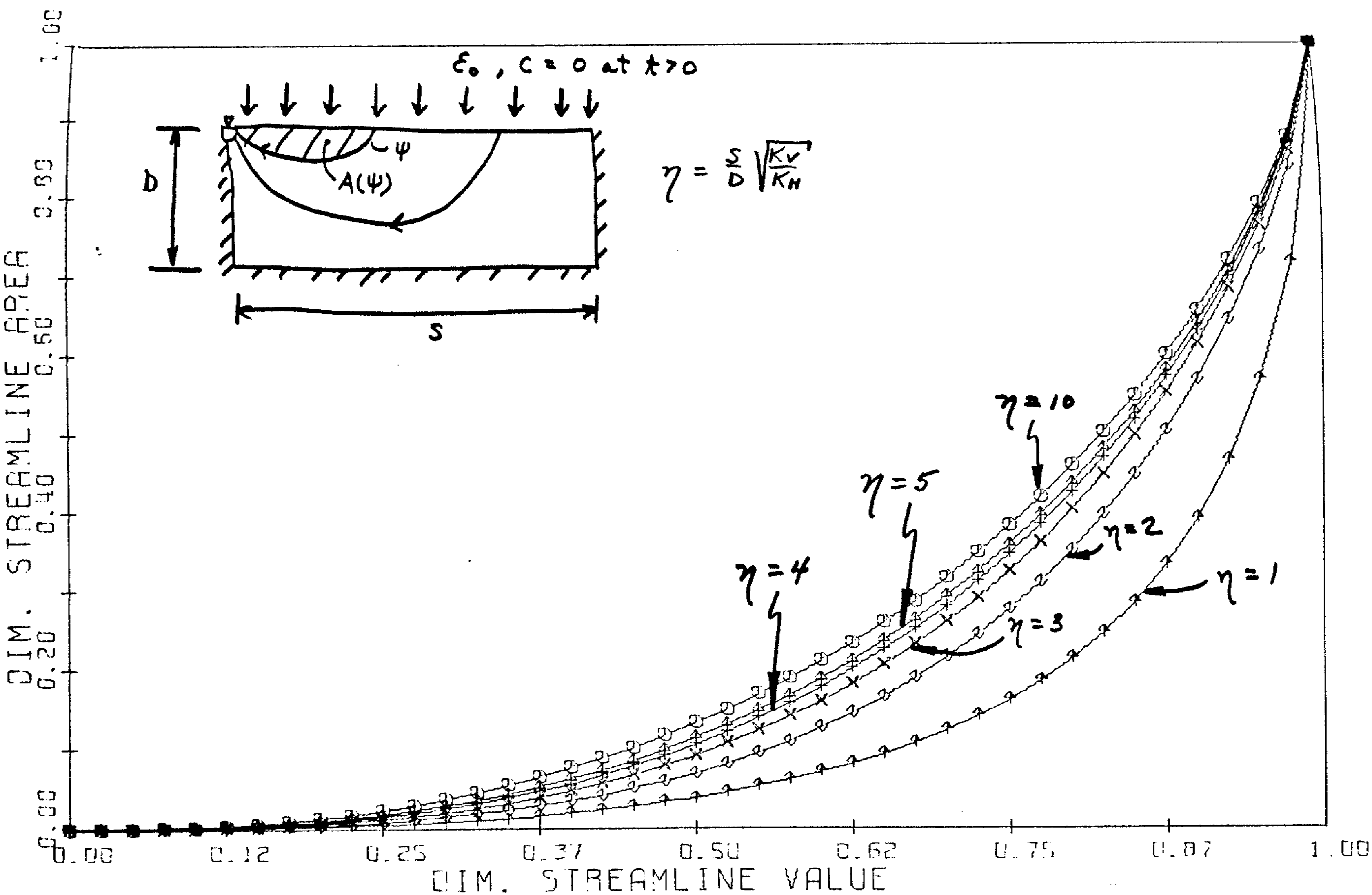

Figure 2.17: $\bar{A}(\bar{\Psi})$ as a function of $\bar{\Psi}$ for different values of η.

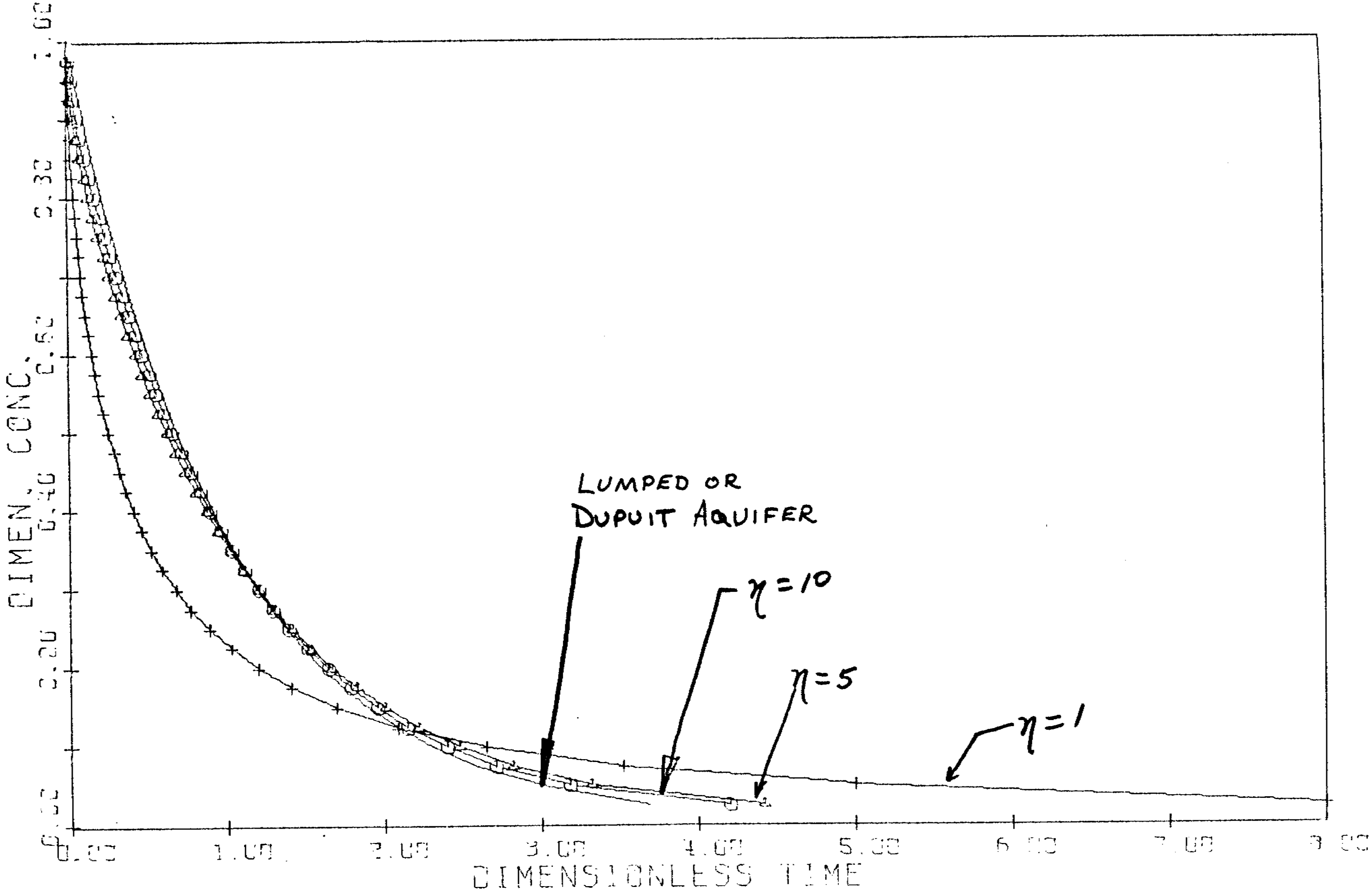

Figure 2.18: c/c_0 as a function of t/t_c for different values of η.

lumped parameter outflow concentration previously calculated; this lumped concentration was shown to be identical to that obtained in the Dupuit aquifer analysis. From Figure 2.18 we may conclude that the larger the aspect ratio, the smaller the difference in outflow concentrations from the Laplace and lumped parameter (or Dupuit) models. Another way of stating this conclusion is that the vertical flow effects on the outflow concentration resulting from partial stream penetration become small for a larger drain spacing to aquifer depth ratio. Actually we would expect these concentration differences to be small since we already know that the vertical flow effects (Kirkham and Powers, 1972; and others) become less pronounced with increasing values of η. As seen in Figure 2.18 for a value of $\eta \geq 5$, there is practically no difference in the predicted outflow concentrations for the models and flow conditions used in this analysis. A similar value of $\eta \geq 4$ has also been obtained for differences in the water table shape predicted from several distributed models applied to a fully penetrating well in a phreatic aquifer (Elbakhbekhi, 1976).

The above results are similar to those obtained by Jury (1975a) using a slightly different solution technique; however, he chose to plot the dimensionless distance from the tile drain, x/L, versus the dimensionless travel times. He did compare his model results to observed chloride effluent concentration as a function of time for a ponded leaching experiment and obtained remarkably good results. He did not relate his model behavior to that of the lumped parameter model. If one were to plot his results depicted in Figure 1 (Jury, 1975b) on a semi-logarithmic scale, the exponential behavior characteristic of the lumped parameter model with a linear reservoir could be approximated.

This type of exponential behavior is shown in Figure 2.19, plotting the results shown in Figure 2.18 on a semi-log scale. Note that the lumped parameter concentration break-through curve plots as a straight line, while Laplace model curves are distorted away from this line for different values of η.

2.4.4 Effects of an Anisotropic Porous Medium

Again using the same procedure previously employed, along with similar flow boundaries and input concentration initial conditions, we may quantify the concentration outflow history from an anisotropic porous medium with a partially penetrating stream. The only change required in the modified Corps of Engineers program (Appendix B) is in the specified input data for hydraulic conductivity. Mathematically we must now solve (2.4.3), which for a homogeneous porous medium becomes

$$K_x \frac{\partial^2 \Psi}{\partial (x')^2} + K_z \frac{\partial^2 \Psi}{\partial (z')^2} = 0 \qquad (2.4.8)$$

where the primed notation refers to the real Cartesian coordinate system. Equation (2.4.8) is subject to the same boundary conditions given by (2.4.3b). Note, however, that the primed notation for x and z should be used. We may transform (2.4.8) to an equivalent isotropic system (EIS) using the well-known transformations given by

$$x = x' \, (K_z/K_x)^{1/2} \text{ and } z = z' \qquad (2.4.9)$$

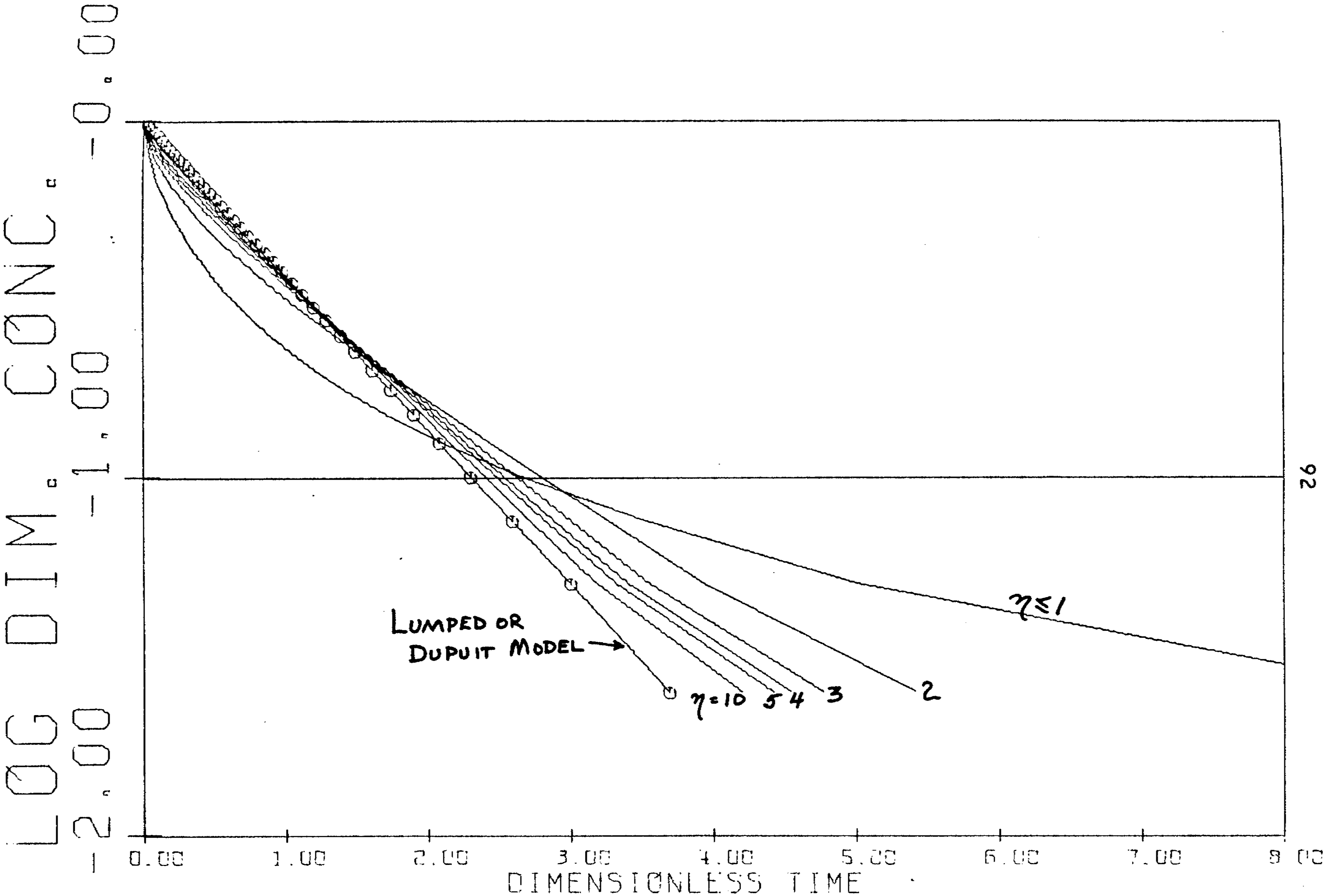

Figure 2.19: Log (c/c_0) as a function of t/t_c for different values of η.

where x and z represent the EIS Cartesian coordinate scale. These coordinate transformations are equivalent to a shrinkage or expansion of the real x' coordinate scale so that the resulting perzometric head contours may be graphically drawn perpendicular to streamlines in the transformed x-z coordinate system. Using (2.4.9), (2.4.8) is transformed to

$$\frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial z^2} = 0 \qquad (2.4.10)$$

subject to the transformed boundary conditions given in (2.4.3b) without the primed notation. The solution to (2.4.10) in the EIS scale, subject to the appropriate boundary conditions, is given by (2.4.5) using the dimensionless parameters defined in (2.4.4). We may again use (2.4.9) to transform our EIS solution back to the real x'-z' coordinate system. We, therefore, obtain the solution in dimensionless form as

$$\bar{\psi}(X',Z') = 1 - \frac{2}{\pi} \sum_{m=1}^{\infty} \frac{\sin(m\,\pi X')\,\sinh[m\,\pi\,(1-Z')/\eta']}{m\,\sinh(m\,\pi\,/\eta')} \qquad (2.4.11)$$

where the primed notation refers to the real Cartesian coordinate system and $\eta' = L'/D'\ (K_z/K_x)^{1/2}$. Dropping the primes we see that (2.4.11), the solution for an anisotropic and homogeneous media, is identical to (2.4.5) for the isotropic homogeneous case with the exception that $\eta = L/D$ in (2.4.5). Actually the solution given by (2.4.5) is a special case (2.4.11) with $K_x = K_z$.

We may still use (2.4.6) and (2.4.7) to calculate concentration break-through curves for anisotropic, homogeneous media. Thus for the flushing system used in the previous section, we obtain identical solutions to those depicted in Figures 2.17 through 2.19, with the exception that $\eta = L/D\ (K_z/K_x)^{1/2}$. Again we may conclude that as long as $\eta \geq 5$, there is practically no difference in the predicted outflow concentrations for the models and flow conditions used in the analysis.

A crude conservation of mass check may be used for each of the break-through curves developed from the Laplace model analysis. Thus, recalling that we are employing the flushing system boundary and initial conditions here, the area under each c/c_o versus t/t_c curves must approach 1.0 given sufficient time. This is simply another way of saying that all of the mass originally present in aquifer waters must be flushed out after some long time t. The dimensionless areas calculated for each of the aspect ratios are summarized in Table 2.2; however, in computing these areas, the integration procedure was terminated when c/c_{aq} = 0.025.

Table 2.2: Comparison between the Laplace model and the generalized lumped parameter model.

η (1)	LAPLACE(2) AREA	LUMPED AREA
1	0.964	0.977
2	0.985	0.977
3	0.986	0.977
4	0.986	0.977
5	0.986	0.977
10	0.976	0.977

(1) The aspect ratio is defined as $L/D(K_z/K_x)^{1/2}$

(2) Areas under the dimensionless concentration (c/c_o) versus dimensionless time (t/t_c) curves for (c/c_o) greater than 0.025 as obtained from the Laplace model.

2.4.5 Impermeable Basement at Infinite Depth

Up to now we have examined the effects of vertical flow on the aquifer outflow concentration resulting from varying the drain half-spacing aquifer depth ratio and the hydraulic conductivity. These vertical flow effects were lumped into a single parameter, defined as $\eta=(L/D)(K_z/K_x)^{1/2}$. In the analysis, we always assumed that an impermeable basement was located at some finite distance, D, below the stream or tile drain. An obvious question that arises is, What happens to the concentration outflow history when D approaches infinity? Figure 2.20 schematically depicts the flow field in question. The governing partial differential equation is identical to (2.4.8) for an anisotropic, homogeneous medium subject to the implied boundary conditions in Figure 2.20. Thus,

(1) $\Psi = \Psi_o = \varepsilon L$ on $x = o$; $o \leq z \leq \infty$

(2) $\lim_{z\to\infty} \Psi = \Psi_o$ on $z \to \infty$; $o \leq x \leq L$

(3) $\Psi = \Psi_o$ on $x = L$; $o \leq z \leq \infty$

(4) $\Psi = \left(\frac{x-a}{L-a}\right)\Psi_o$ on $z = o$; $a \leq x \leq L$

(5) $\Psi = \left(\frac{a-x}{a}\right)\Psi_o$ on $z = o$; $o \leq x \leq a$

Using the transformations in (2.4.9), the governing differential equation in the EIS coordinate scale looks like that given in (2.4.3a). The solution has been found to be (Carslaw and Jaeger, 1959, p. 163, eq. 6).

$$\bar{\Psi} = 1 - \frac{2}{\pi} \sum_{m=1}^{\infty} \left(\frac{1}{m}\right) \exp\left(-m\pi Z\right) \sin\left(m\pi X\right) \qquad (2.4.12)$$

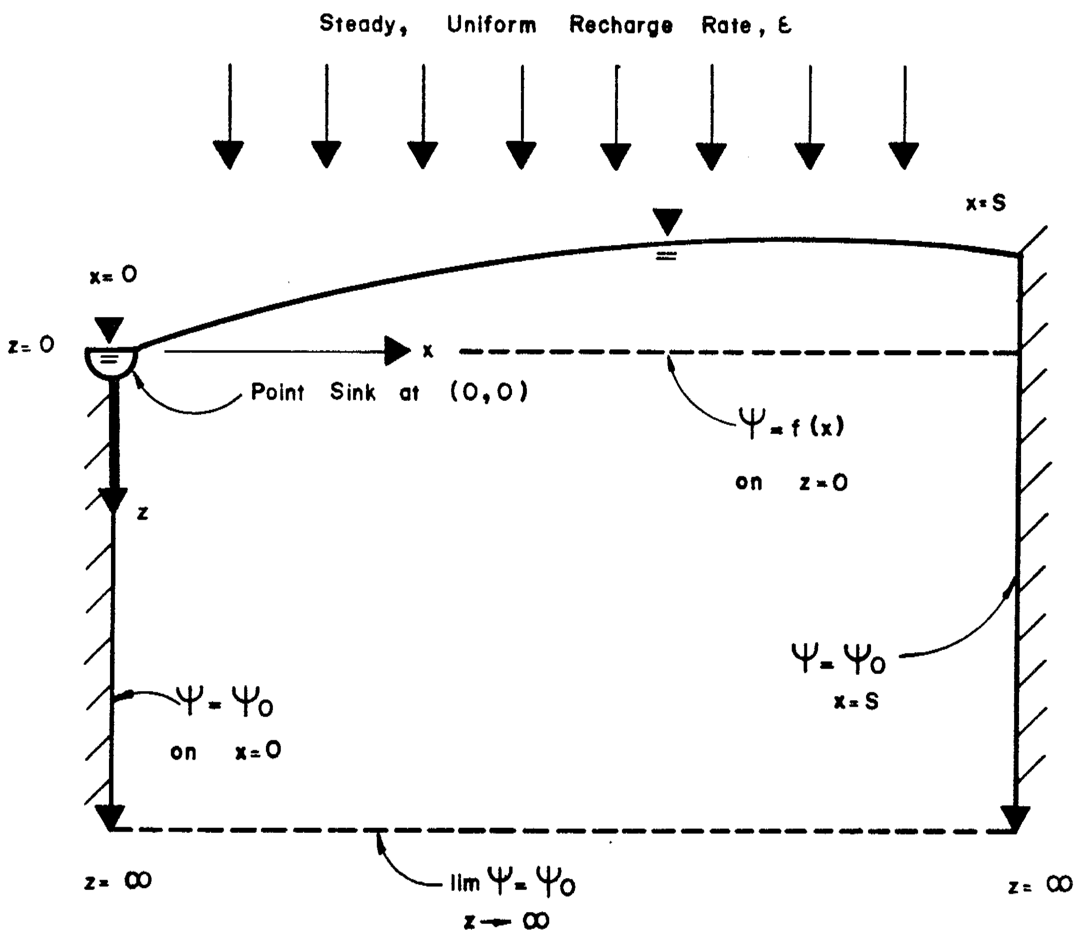

Figure 2.20 Schematic Laplace aquifer with impermeable basement at an infinite depth below the drain.

where the dimensionless parameters previously defined in (2.4.4) are used. In (2.4.12) we have assumed that a << L, as was done earlier.

The Fourier series solution found by Kirkham, and given here as (2.4.5), may be written for $\eta = 1$ as

$$\bar{\psi} = 1 - \frac{2}{\pi}\sum_{m=1}^{\infty} \frac{\sin(m\pi X)\sinh[m\pi(1-Z)]}{m\sinh(m\pi)} \tag{2.4.13}$$

Using the trigometric identity sinh (A–B) = sinh (A) cosh (B) – cosh (A) sinh (B) we see that

$$\frac{\sinh[m\pi(1-Z)]}{\sinh(m\pi)} = \frac{\sinh(m\pi)\cosh(m\pi Z)-\cosh(m\pi)\sinh(m\pi Z)}{\sinh(m\pi)}$$

which may be simplified to

$$\frac{\sinh[m\pi(1-Z)]}{\sinh(m\pi)} = \cosh(m\pi Z) - \frac{\sinh(m\pi Z)}{\tanh(m\pi)}$$

where the term $1/\tanh(m\pi) = 1.0037$ for $m = 1$, and rapidly converges to 1.0 for all $m > 1$. Therefore, (2.4.13) may be approximately written as

$$\bar{\psi} = 1 - \frac{2}{\pi}\sum_{m=1}^{\infty} \frac{\sin(m\pi X)}{m}[\cosh(m\pi Z) - \sinh(m\pi Z)]$$

where $\cosh(m\pi Z) - \sinh(m\pi Z) = \exp(-m\pi Z)$. Thus (2.4.13) approximates the expression

$$\bar{\Psi} \simeq 1 - \frac{2}{\pi} \sum_{m=1}^{\infty} \left(\frac{1}{m}\right) \exp(-m\pi Z) \sin(-m\pi X) \qquad (2.4.14)$$

This is exactly the solution found in (2.4.12) for the infinite depth aquifer. We may then conclude that the streamline distribution for $\eta = (L/D)\ K_z/K_x)^{1/2} = 1$ is nearly identical to that obtained for an infinitely deep impermeable basement. Muskat (1946) has also found nearly identical streamline distributions for the cases of $z \to \infty$ and $z = L$. The corresponding concentration outflow history for $\eta \to 0$ is approximately the same as for $\eta = 1$. Thus in Figures 2.17 through 2.19 these curves are indicated as $\eta \leq 1$.

2.4.6 Multiple Aquifer Systems

In sections 2.4.2 through 2.4.5, we have obtained the concentration outflow histories for a partially penetrating stream or tile drain for a variety of $(L/D)(K_z/K_x)^{1/2}$ ratios; we have compared these solution to that obtained from the lumped parameter model with a linear reservoir term (or Dupuit aquifer model with a fully penetrating stream). Explicit assumptions made in the foregoing analyses include: (1) steady flow; (2) the height of the water table above the top of the stream was quite small, and its slope nearly horizontal; (3) that the drain width was much smaller than the drain half-spacing ($a \ll L$); and (4) the porous media is anisotropic and homogeneous. The first three restrictions are often met in actual field situations. However stream-connected phreatic aquifer systems are seldom isotropic and homogeneous. The above analyses addressed the problem of anisotropy but did assume a homogeneous porous media (ie, where K_x and K_z are both independent of the spatial coordinates). The modified Corps of Engineers program (Appendix B) may be used to solve for the concentration break-through curves resulting from any spatial distribution of K_x and K_z. For brevity, however, only the relative importance of several simple combinations of aquifer geometry (i.e., the L/D ratio) and heterogenity (i.e., the spatial variation of the K_z/K_x ratio) were examined in a geologically layered system. Figure 2.21 depicts the general Laplace aquifer system examined, using the same modified Corps of Engineers program described earlier and subject to the implied limitations previously mentioned. Kirkham, et al., (1974) have analytically solved similar problems for the potential distribution in multi-layered systems. Thus the same 41 by 21 rectangular grid was retained. This portion of the research was designed to investigate the differences in concentration outflow history resulting from variations in: (1) the upper layer thickness; (2) the isotropic, homogeneous hydraulic conductivity contrast between the upper and lower aquifers; (3) anisotropy in each aquifer; and (4) an isotropic, homogeneous hydraulic conductivity reduction near the drain. For all specific cases examined values for the aspect ratio, defined here as η = L/D, were the same as previously used (i.e., η =1 through 5, and η = 10). Table 2.3 summarizes the cases examined; the "REMARKS" column refers to the figures where concentration break-through curves are presented. The notation used in the table corresponds to that used in Figure 2.21. For cases (1) through (5), the aquifers were considered to be isotropic and homogeneous; for case (6), anisotropic, homogeneous effects were included. Case (5) in the table examines the effect of stream clogging on concentration outflow histories. Thus K_{aq} represents the isotropic, homogeneous hydraulic conductivity of the entire model aquifer, while

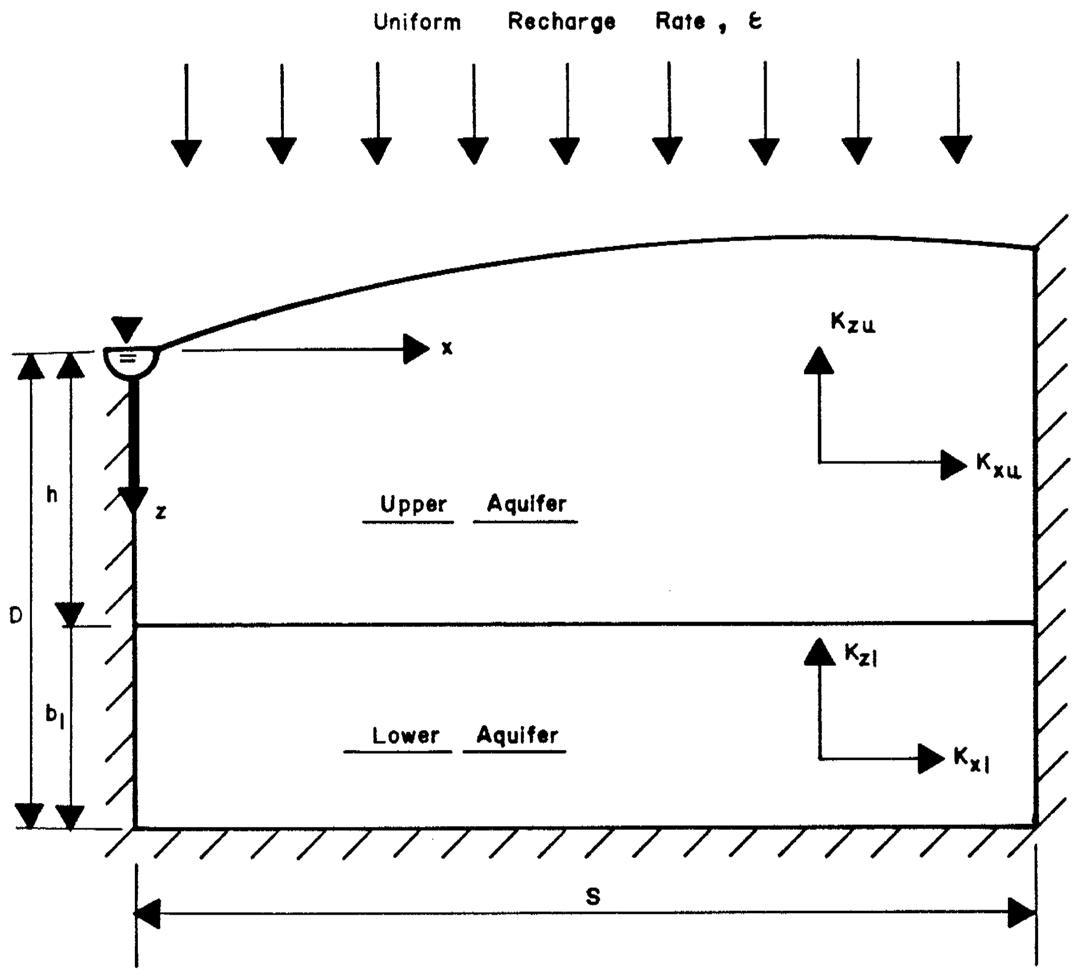

Figure 2.21 Schematic diagram showing the Laplace aquifer configuration for geologic layering.

K_c represents that value in the immediate vicinity of the stream or tile drain where clogging occurs (represented in the model program as the single finite element adjacent to the stream).

Table 2.3: Cases examined for geological layering effects; see Figure 2.21 for notation definitions.

CASE EXAMINED	$m=b_L/(h_o-b_L)$	N=D/h	RANGE OF α	REMARKS
1. $K_u = \alpha K_L$	3	4	20, 10, 5, 2	See Figs. 2.22-2.33
2. $K_u = \alpha K_L$	9	10	10	See Figs. 2.34-2.36
3. $K_u = \alpha K_L$	19	20	10	See Figs. 2.37-2.39
4. $K_L = \alpha K_u$	3	4	10	See Figs. 2.40-2.42
5. $K_{aq} = \alpha K_C$	0	1	10, 100	See Figs. 2.43-2.46
6. $K_{xu} = \alpha K_{uL}$	3	4	10	See Figs. 2.47-2.49
$K_{zu} = \alpha K_{zL}$	3	4	1	

In the calculation of the dimensionless concentration (c/c_o) versus dimensionless time (t/t_c) curves, (2.4.6) and (2.4.7) may still be used. These concentration break-through curves will reflect the vertical flow effects on the outflow concentration history resulting from the various hydraulic and aquifer geometry factors summarized in Table 2.3. We would like to compare these c/c_o versus t/t_c curves with that obtained prevously using a lumped parameter modeling approach that characterizes only the upper aquifer of Figure 2.21. The reason for this comparison is to qualify those situations where vertical flow through multiple reservoirs may have relatively little effect on outflow concentration. The application of the lumped modeling approach to only the upper aquifer constitutes the simplest tool available for analyzing such problems, and hence retains its primary advantage. In order to make such a comparison, however, we must modify our definition of the solute response time, $t_c = nD/\varepsilon$, such that the distance D is the same for all concentration break-through curves. Since we have chosen the lumped parameter model to characterize only the upper aquifer, its solute response time will be given by $t_c = nh/\varepsilon$. For the specific cases examined, the relationship between h and D is given in Table 2.3. We therefore see that D = Nh where N is some specified integer for a particular case of interest. The lumped parameter solute response time for the upper aquifer of Figure 2.21 may therefore be related to the dimensionless travel time found from (2.4.6) for any case shown in Table 2.3. Thus

$$\frac{t}{t_c} = \frac{t\varepsilon}{nD} = \left(\frac{t\varepsilon}{nh}\right)\left(\frac{h}{D}\right) = \frac{d\bar{A}(\bar{\Psi})}{d\,\bar{\Psi}}$$

or $$t/t_{c_1} = \frac{d\bar{A}(\bar{\Psi})}{d\,\bar{\Psi}} \tag{2.4.15}$$

where $t_{c_1} = \frac{nh}{\varepsilon}\frac{D}{h}\;t_c$. This new t_{c_1} characterizes the average solute travel time through the multiple reservoir system of Figure 2.21 times the ratio D/h; it is identical to the lumped parameter solute response time for a single reservoir of thickness h. Equations (2.4.7) and (2.4.15) therefore define the dimensionless concentration break-through curves characterizing a flushing aquifer system depicted in Figure 2.21; furthermore, these curves may be directly compared to the resulting dimensionless concentration break-through curves obtained from the lumped parameter model previously developed for a single reservoir. Results of these analyses are shown in Figures 2.22 through 2.49, and correspond to the specific cases outlined in Table 2.3.

Again, the same conservation of mass check procedure previously employed may be used for the above analyses. Thus the area under each

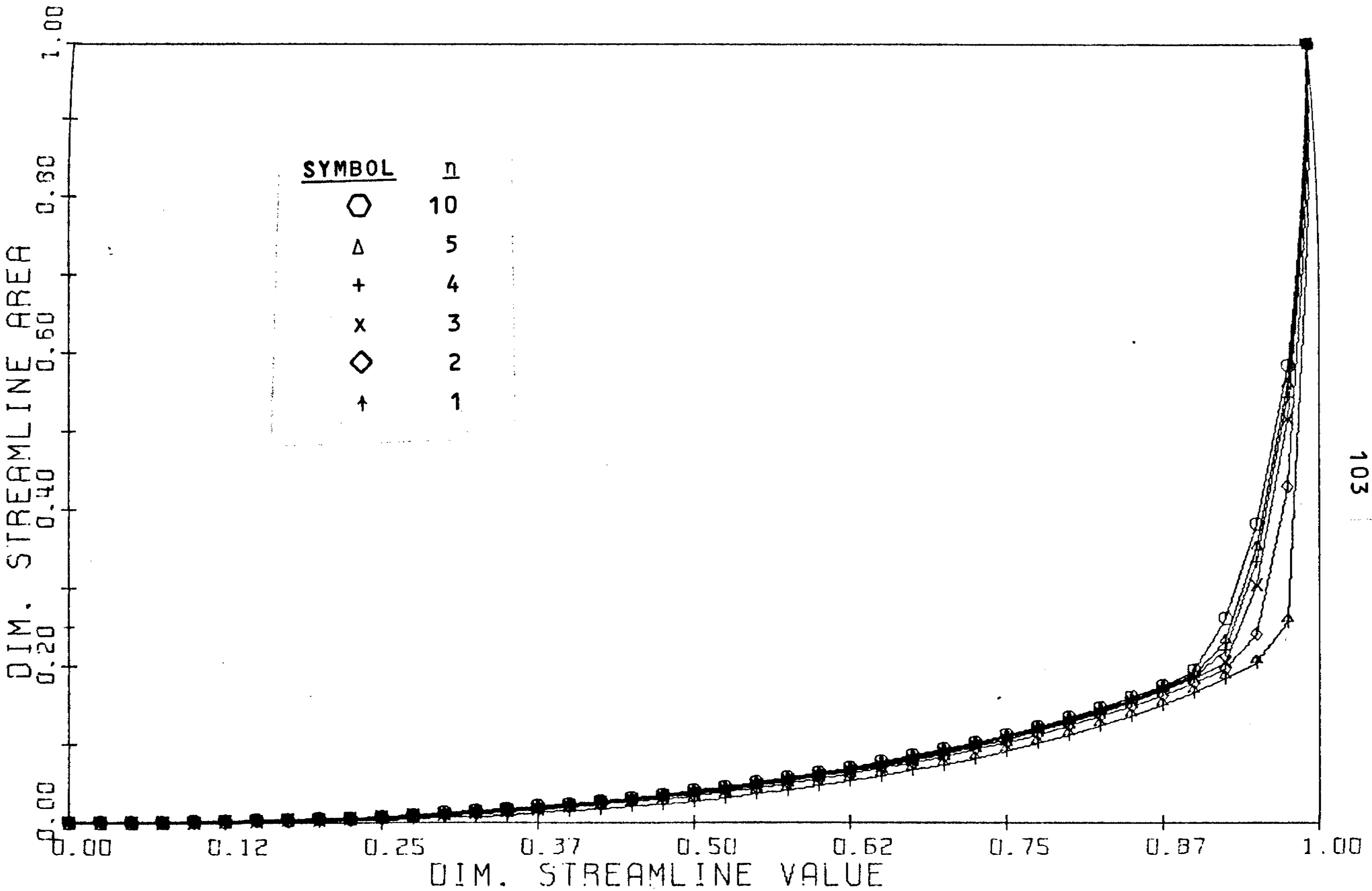

Figure 2.22: $\overline{A}(\overline{\Psi})$ vs. $\overline{\Psi}$ for different n; case (1) in Table 2.3 with $\alpha = 20$.

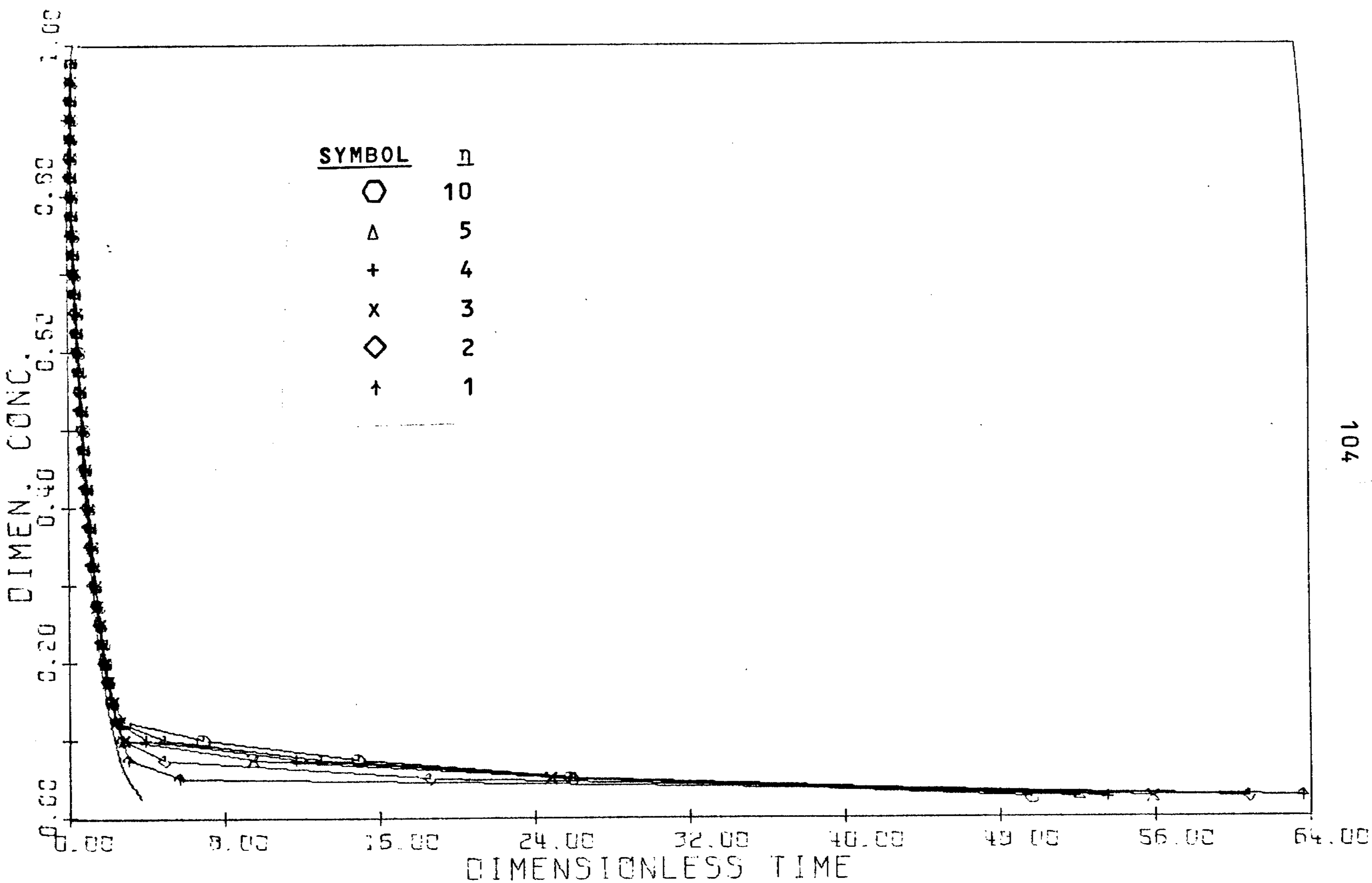

Figure 2.23: c/c_0 vs. t/t_{c1} for different η; case (1) in Table 2.3 with $\alpha = 20$.

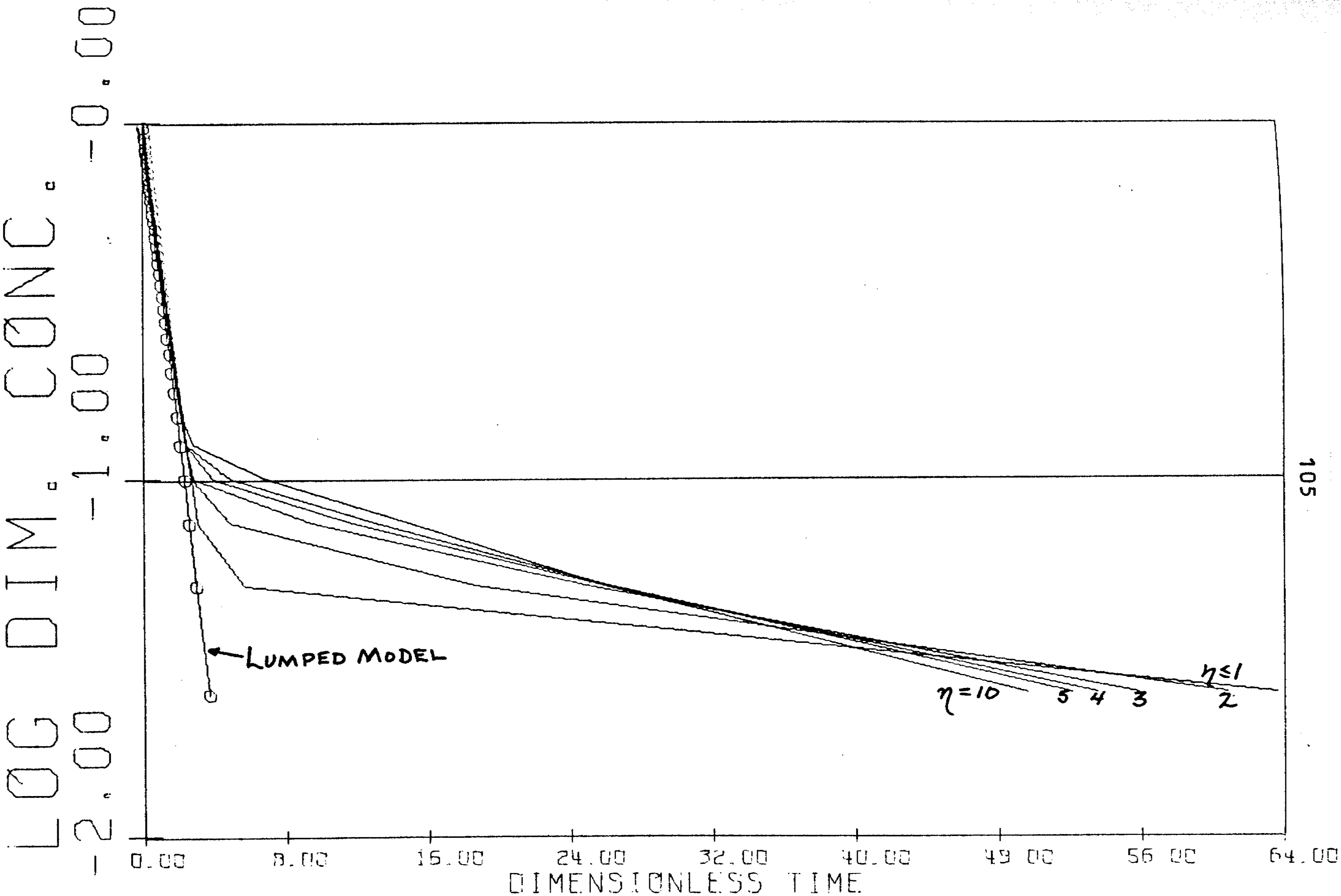

Figure 2.24: Log c/c_0 vs. t/t_{c_1} for different η; case (1) in Table 2.3 with α = 20.

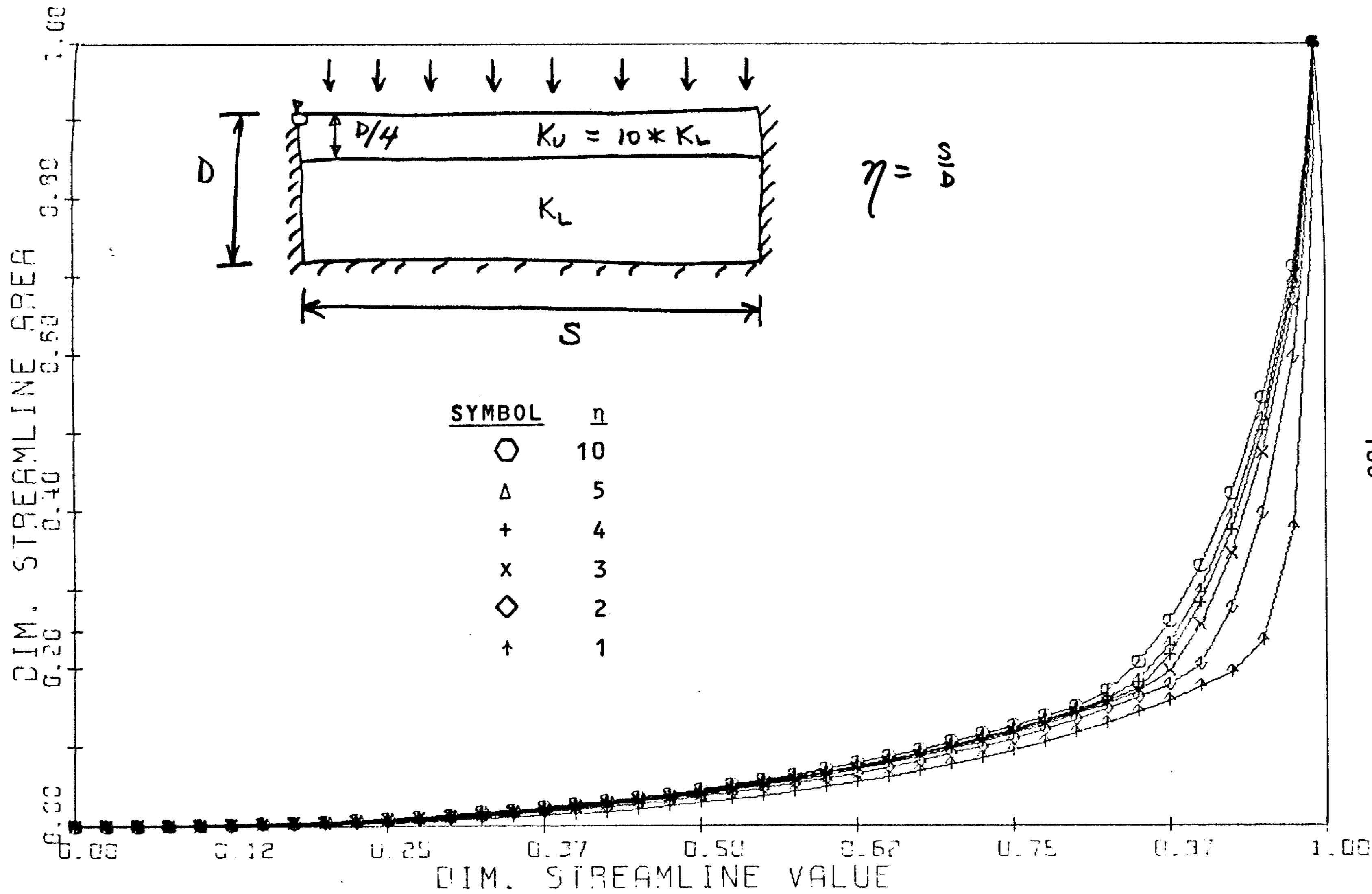

Figure 2.25: $\bar{A}(\bar{\Psi})$ vs. $\bar{\Psi}$ for different η; case (1) in Table 2.3 with $\alpha = 10$.

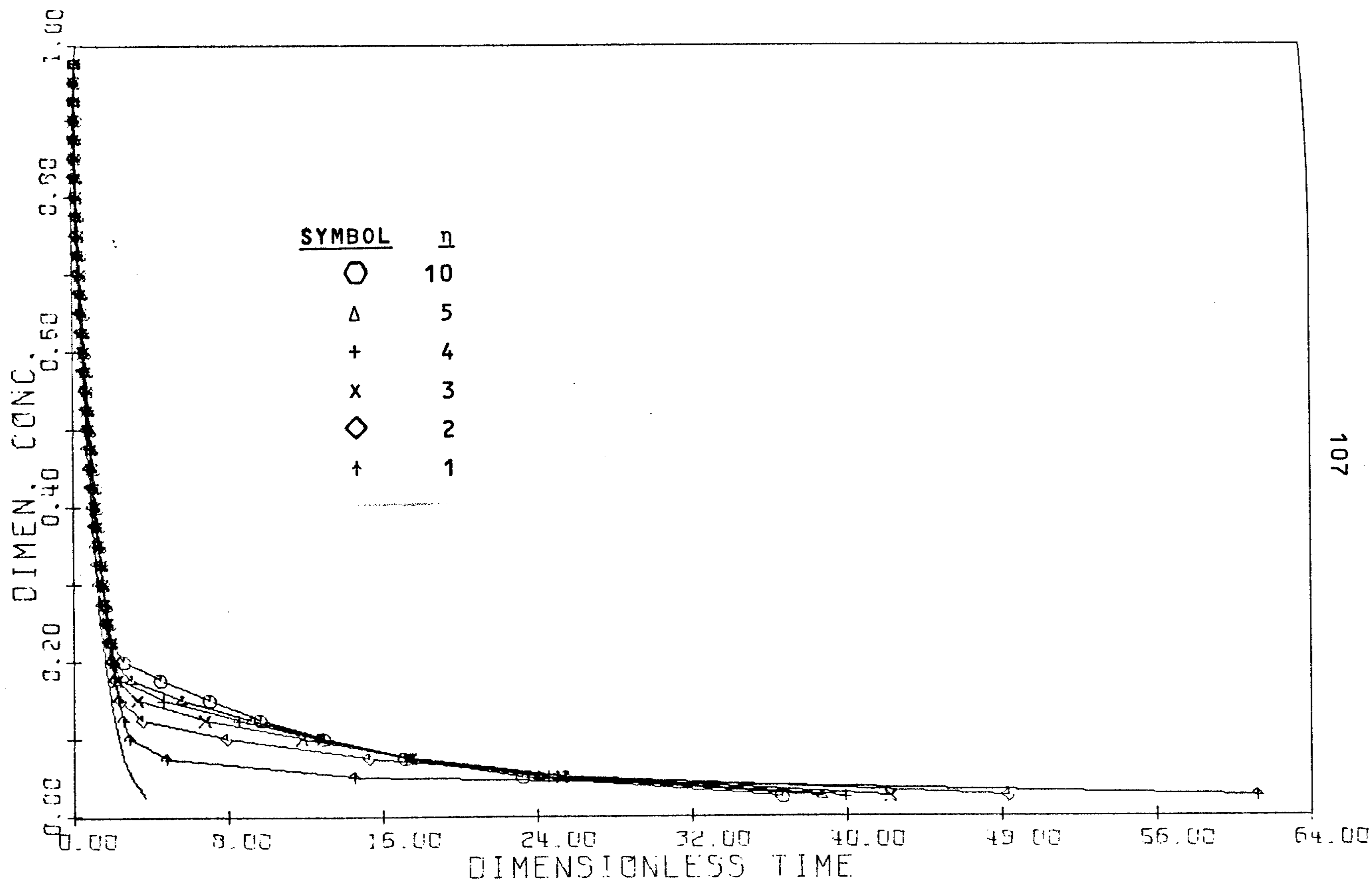

Figure 2.26: c/c_0 vs. t/t_{c1} for different η; case (1) in Table 2.3 with $\alpha = 10$.

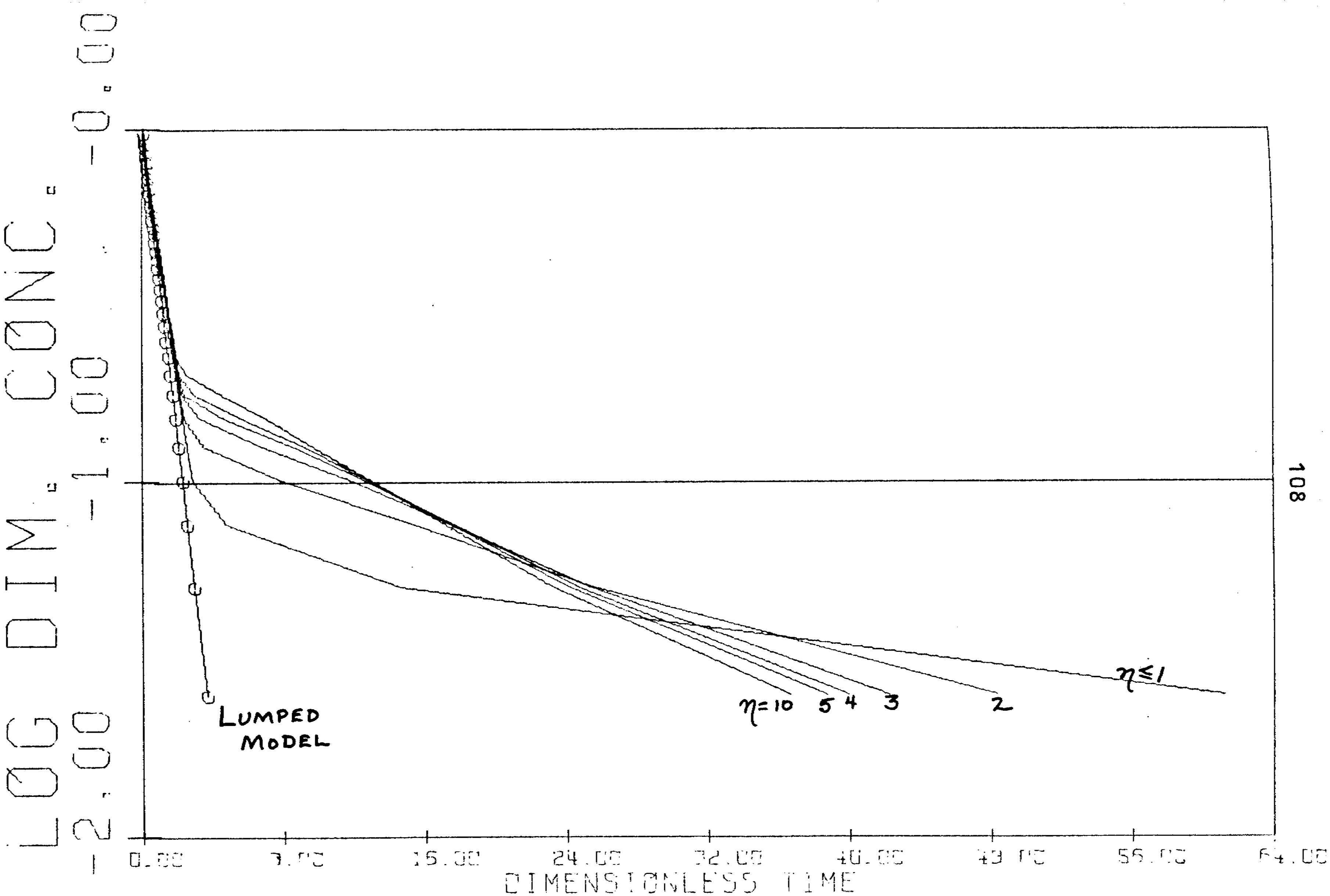

Figure 2.27: Log c/c_0 vs. t/t_{c1} for different η; case (1) in Table 2.3 with α = 10.

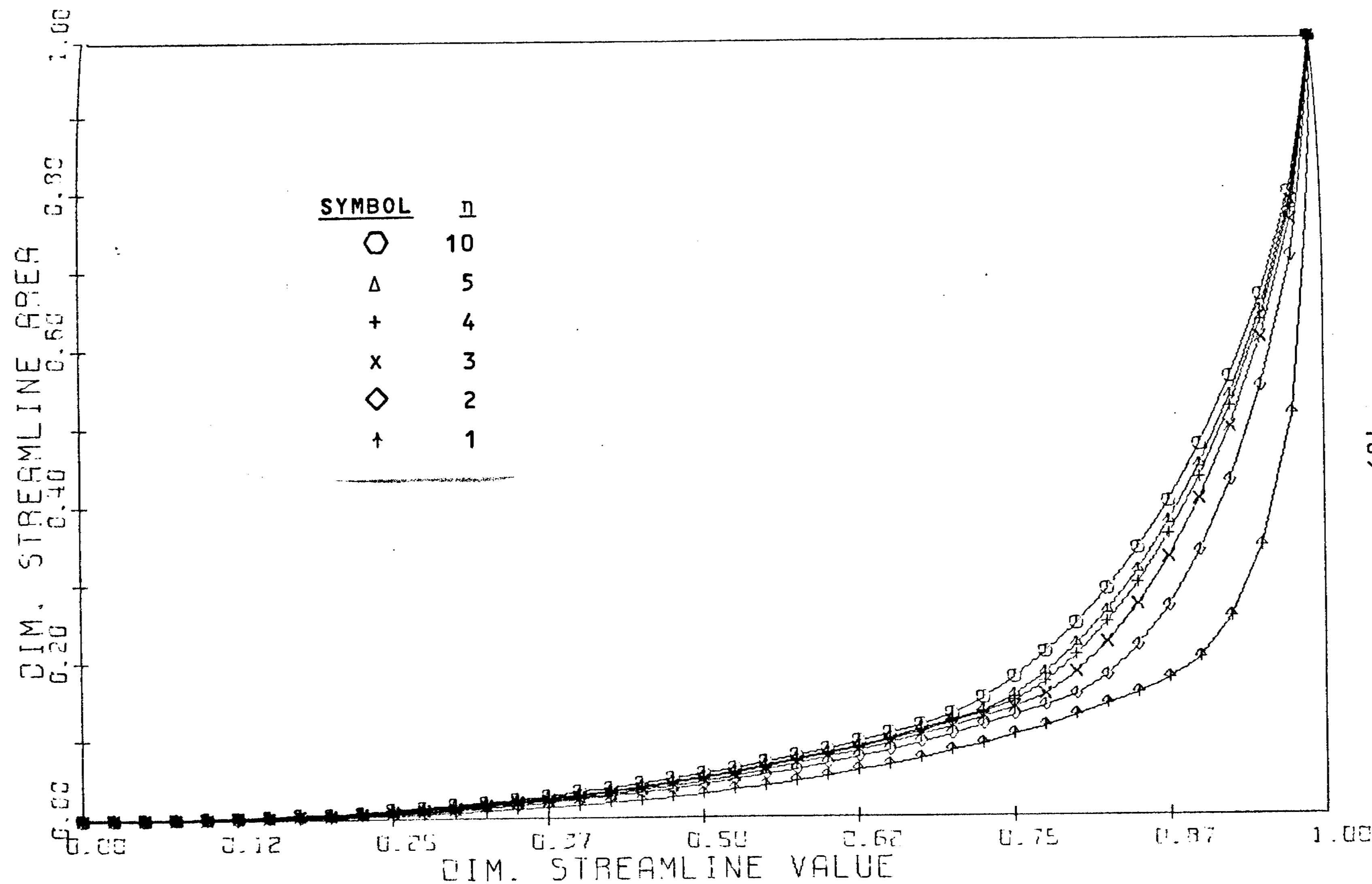

Figure 2.28: $\overline{A}(\overline{\Psi})$ vs. $\overline{\Psi}$ for different n; case (1) in Table 2.3 with α = 5.

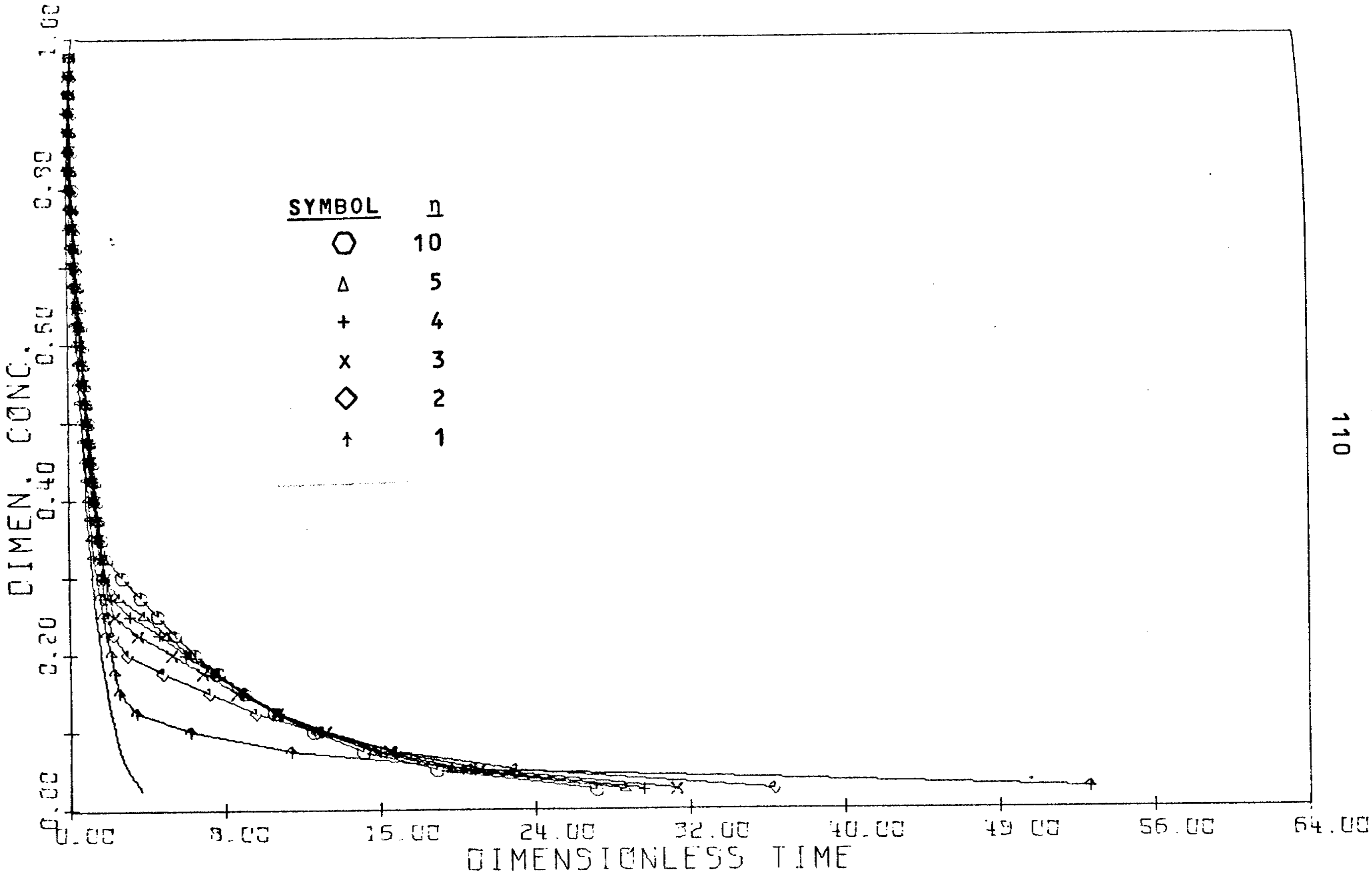

Figure 2.29: c/c_0 vs. t/t_{c1} for different n; case (1) in Table 2.3 with α = 5.

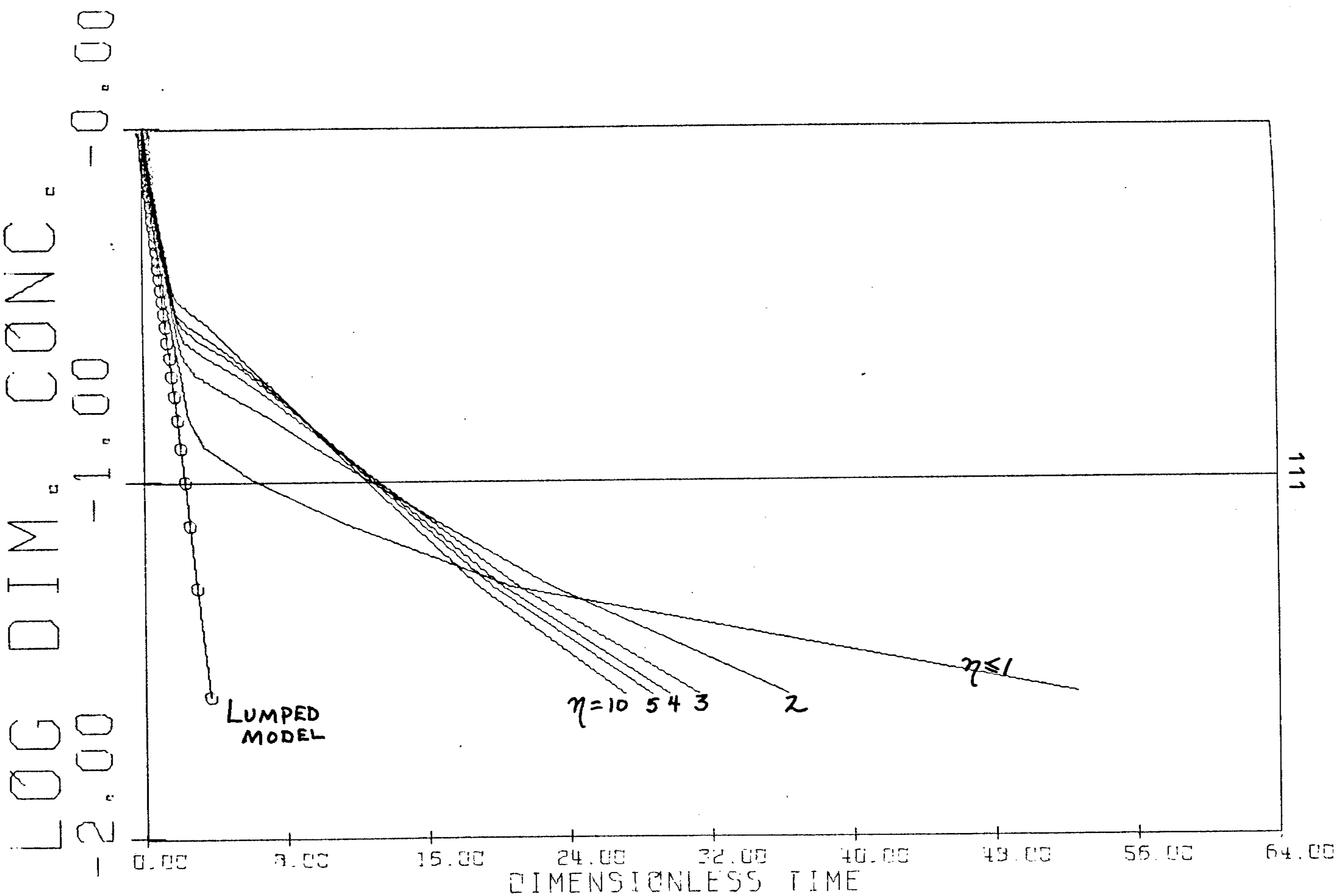

Figure 2.30: Log c/c_0 vs. t/t_{c1} for different η; case (1) in Table 2.3 with α = 5.

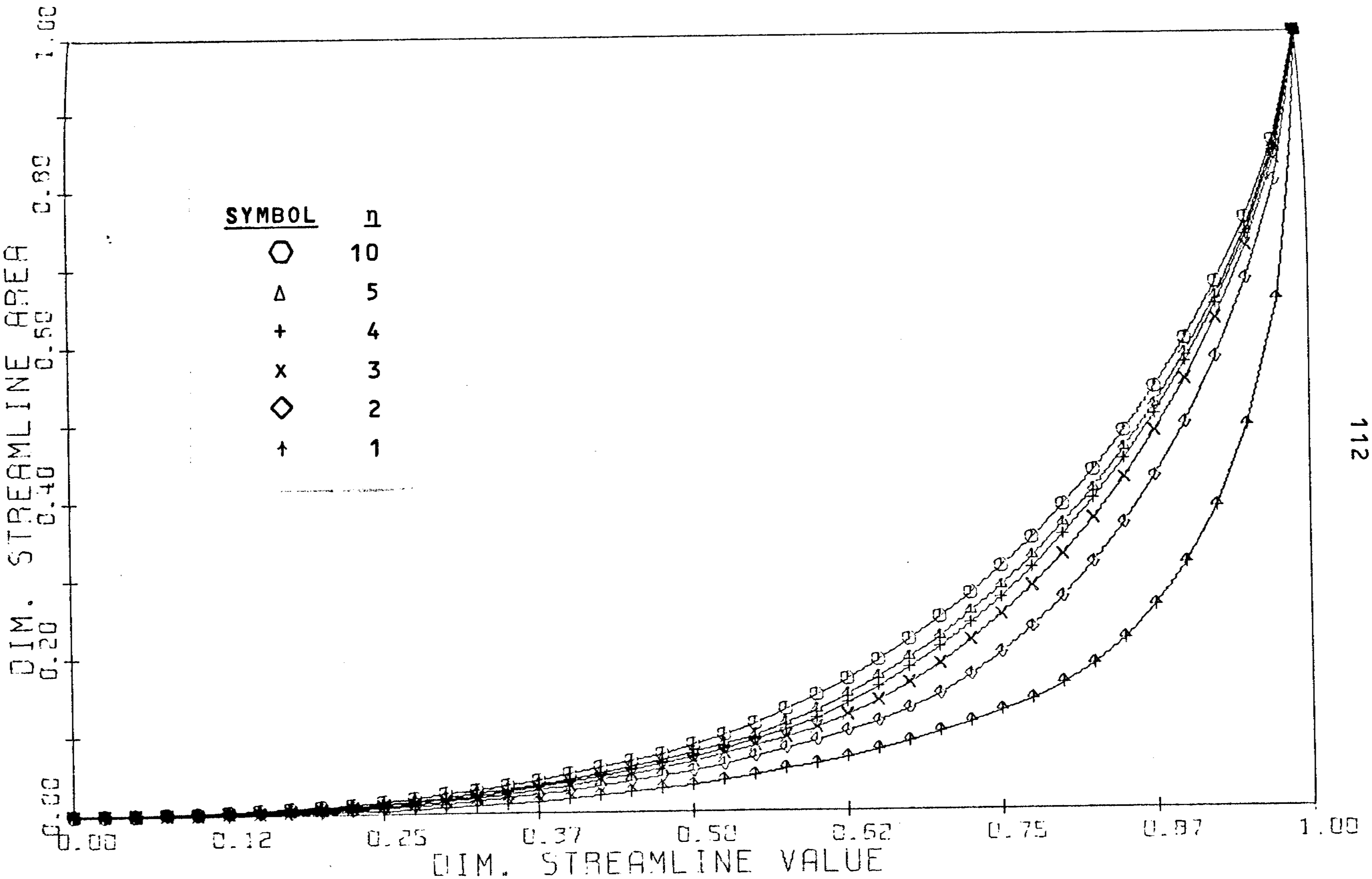

Figure 2.31: $\overline{A}(\overline{\Psi})$ vs. $\overline{\Psi}$ for different n; case (1) in Table 2.3 with α = 2.

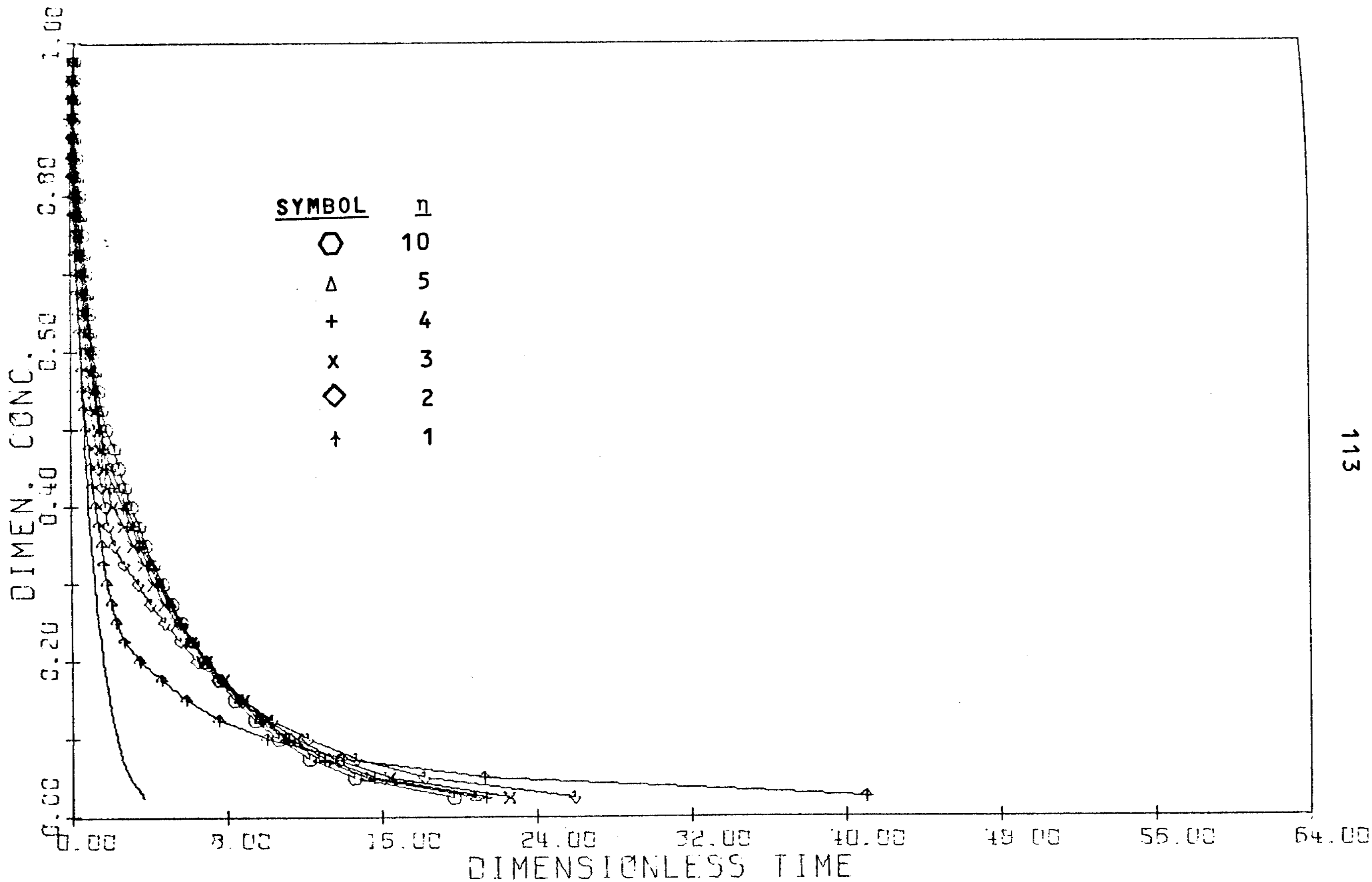

Figure 2.32: c/c_0 vs. t/t_{c_1} for different n; case (1) in Table 2.3 with $\alpha = 2$.

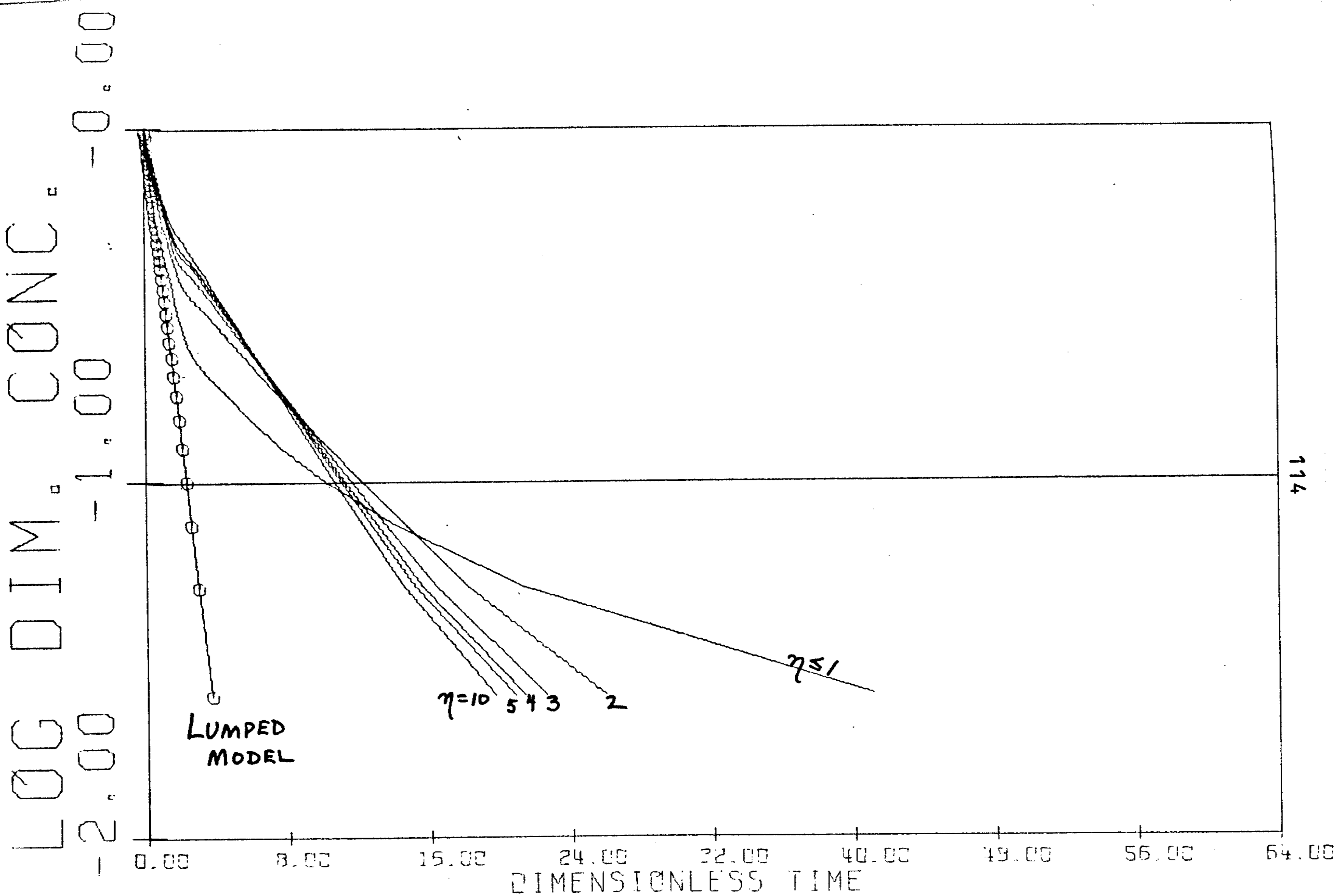

Figure 2.33: Log c/c_0 vs. t/t_{c1} for different η; case (1) in Table 2.3 with α = 2.

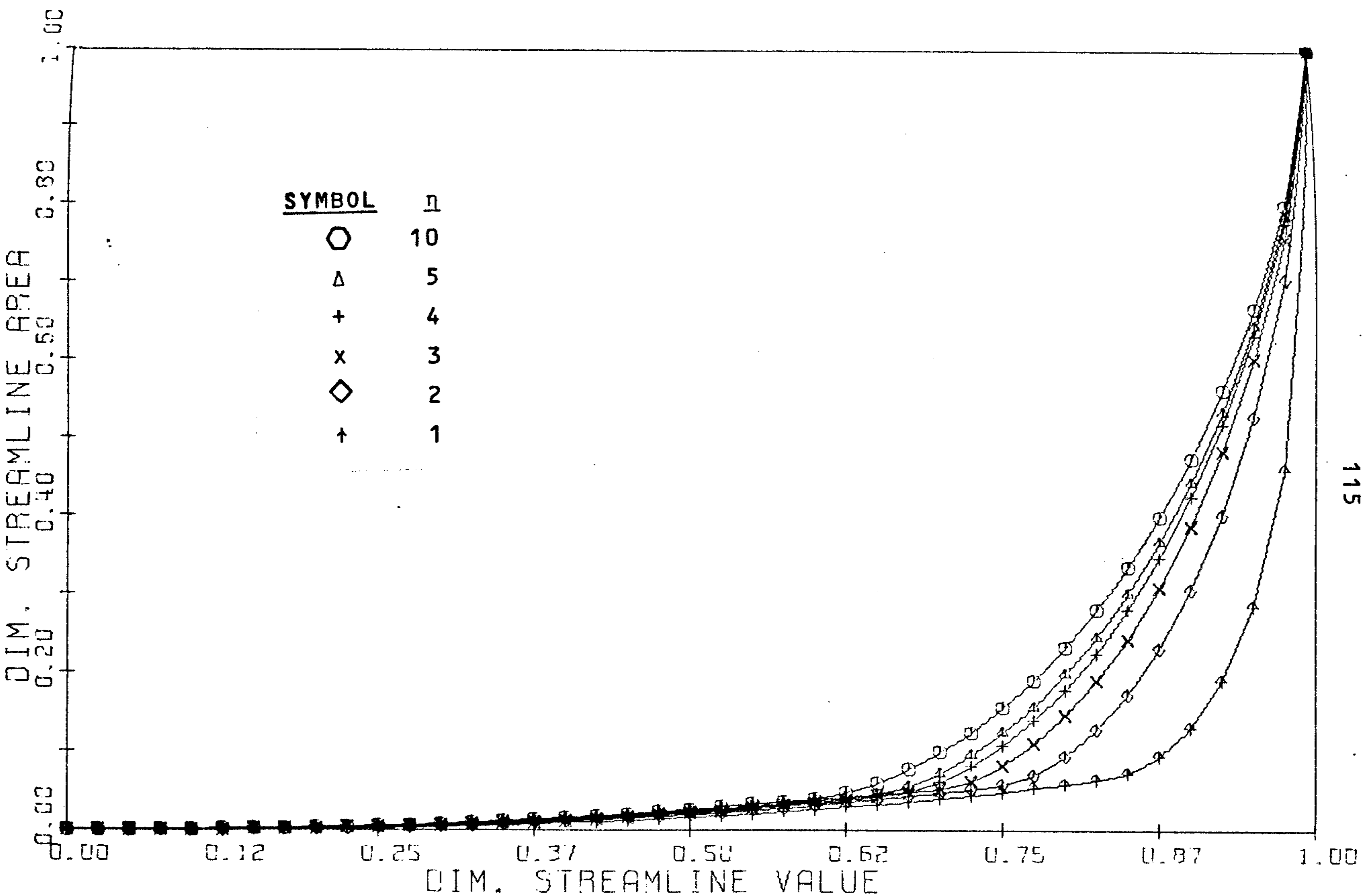

Figure 2.34: $\overline{A}$ ($\overline{\Psi}$) vs. $\overline{\Psi}$ for different n; case (2) in Table 2.3 with α = 10.

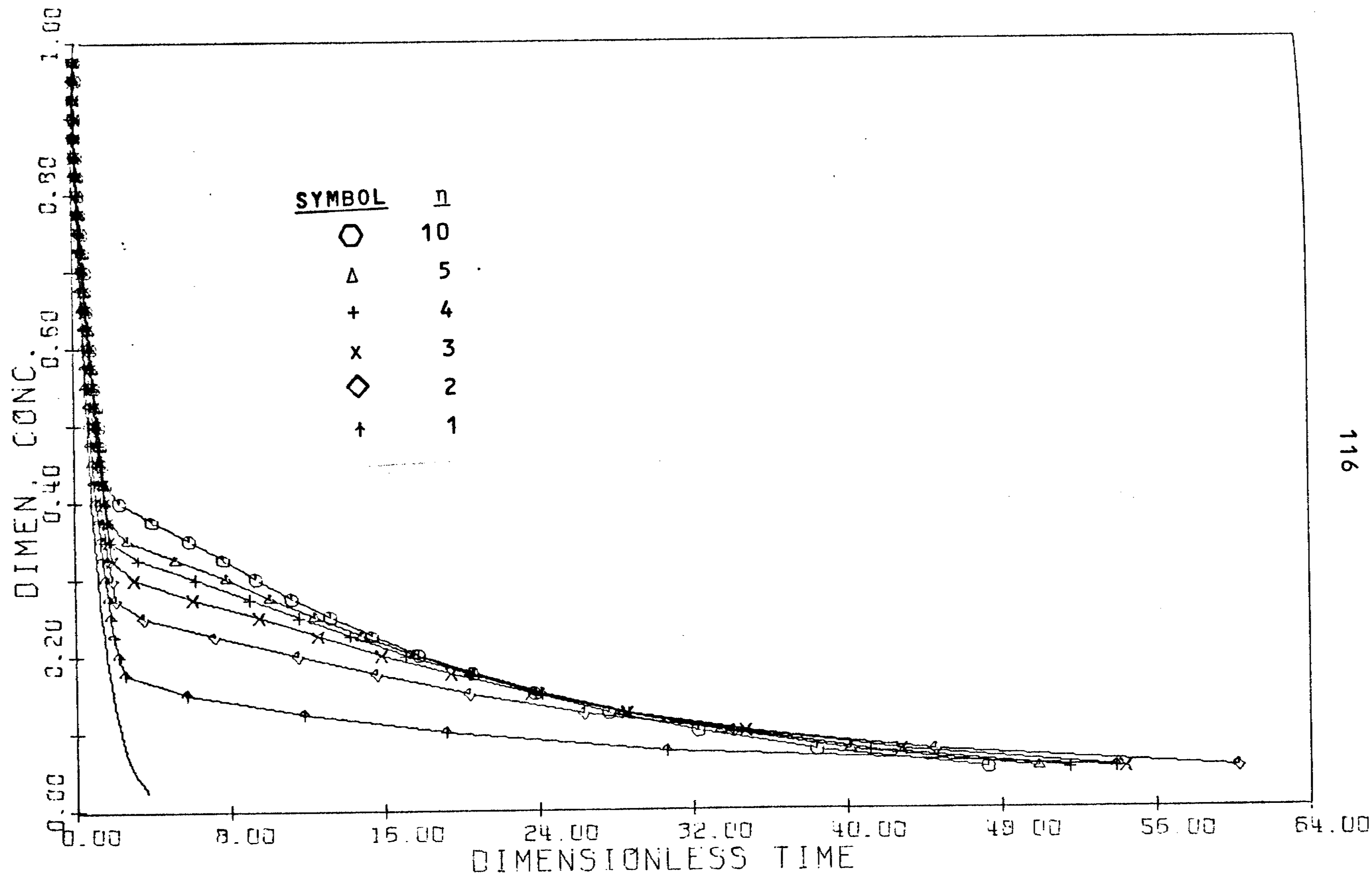

Figure 2.35: c/c_0 vs. t/t_{c1} for different n; case (2) in Table 2.3 with α = 10.

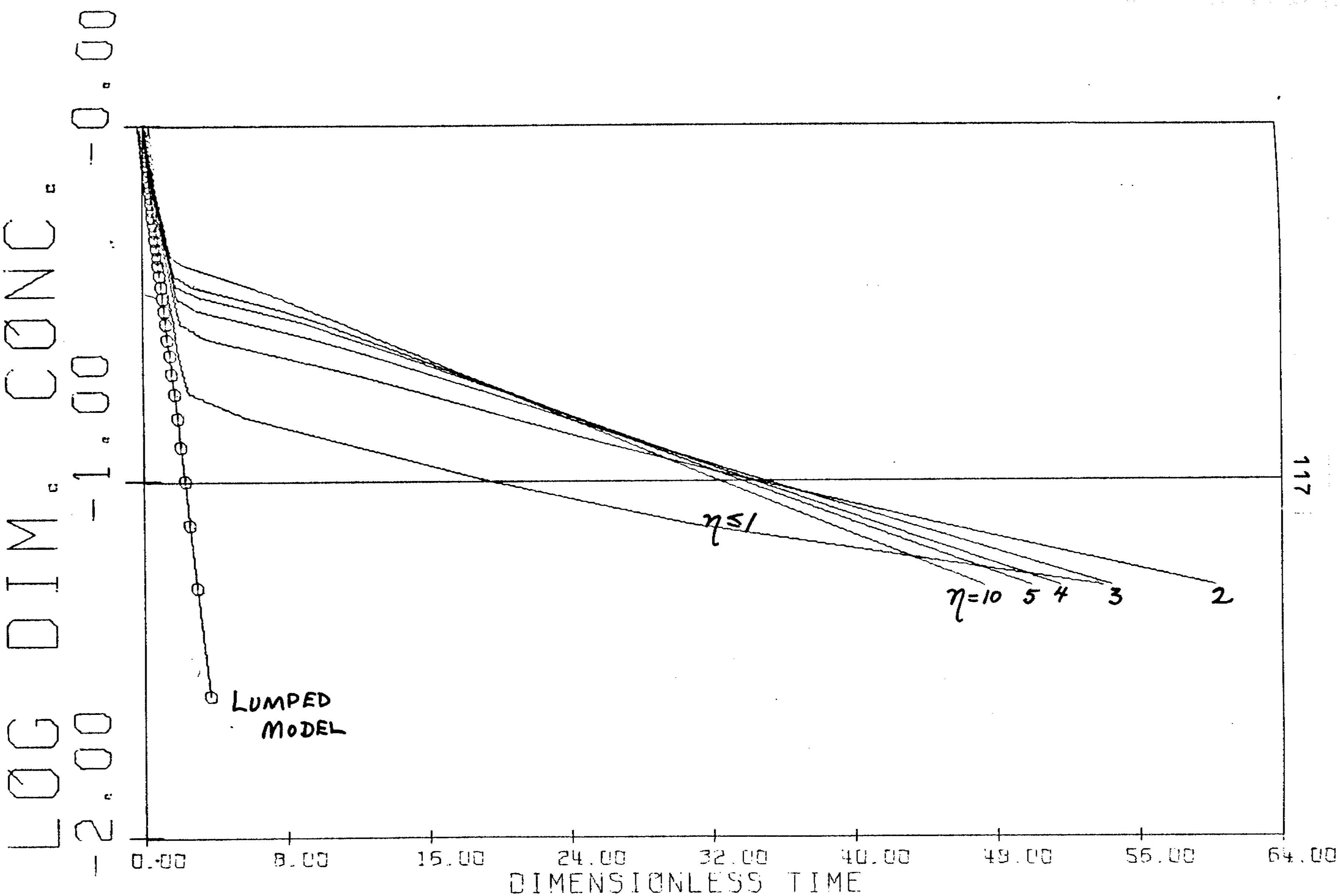

Figure 2.36: Log c/c_0 vs. t/t_{c1} for different η; case (2) in Table 2.3 with α = 10.

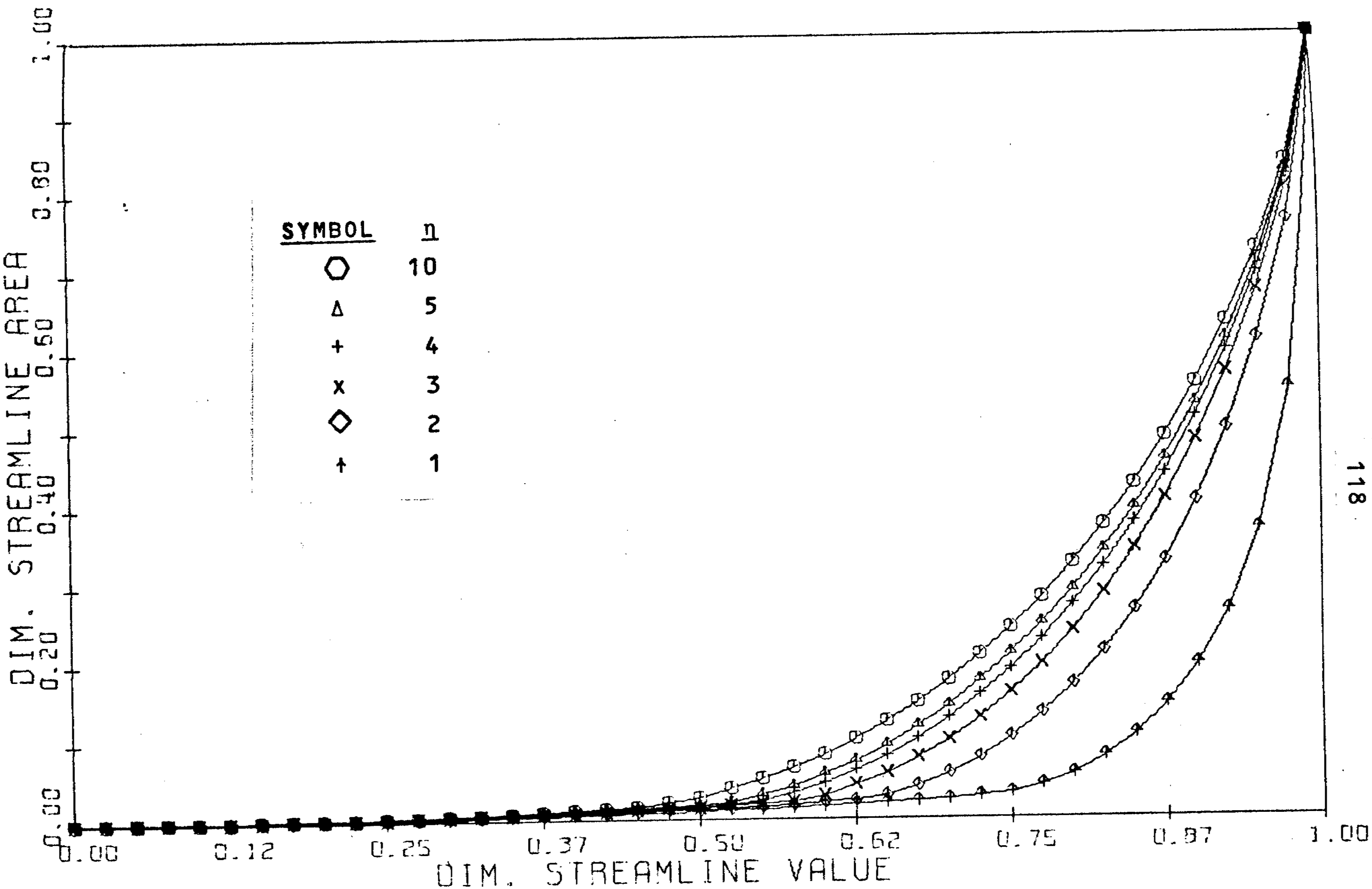

Figure 2.37: $\overline{A}(\overline{\Psi})$ vs. $\overline{\Psi}$ for different n; case (3) in Table 2.3 with α = 10.

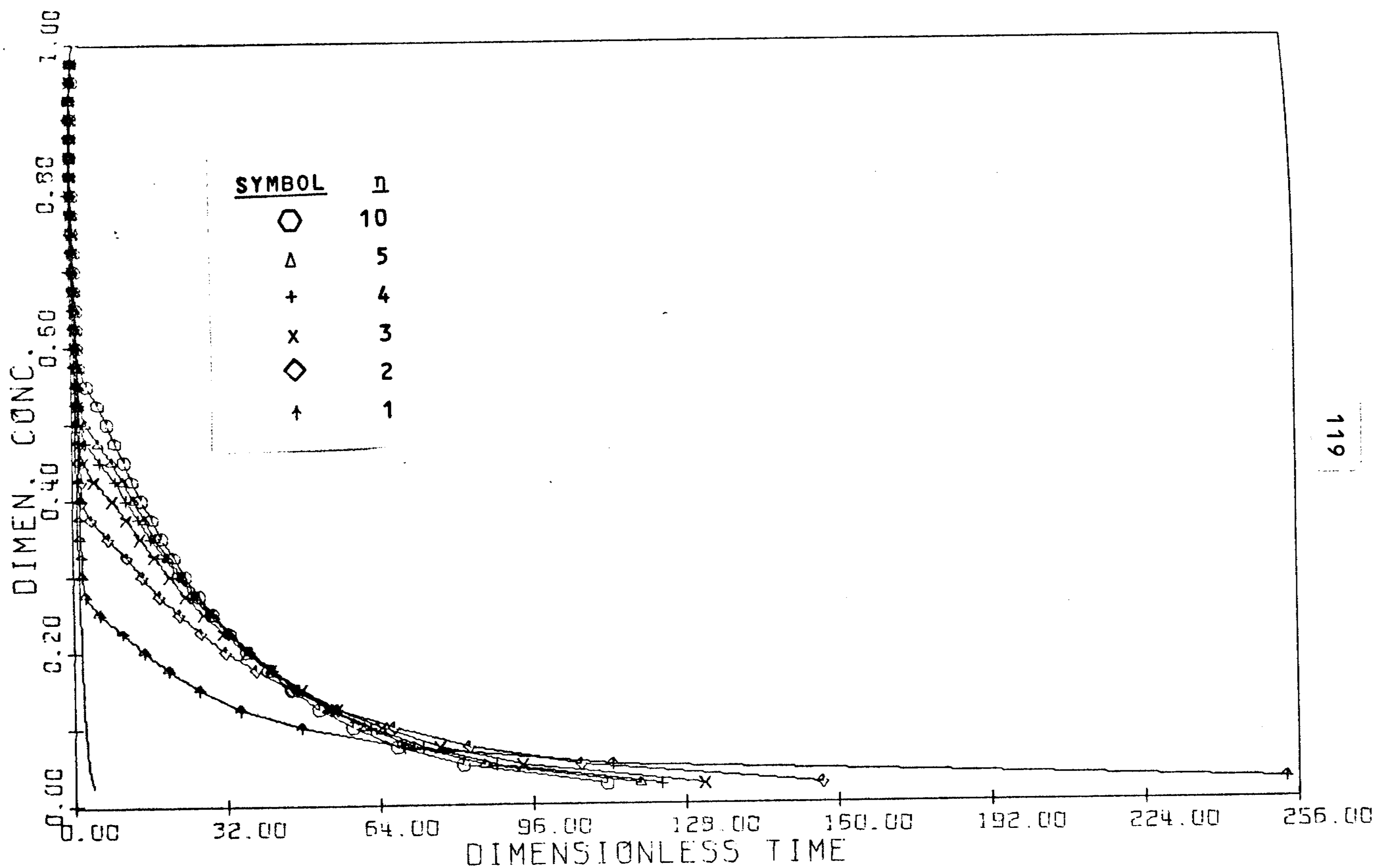

Figure 2.38: c/c_o vs. t/t_{c_1} for different n; case (3) in Table 2.3 with α = 10.

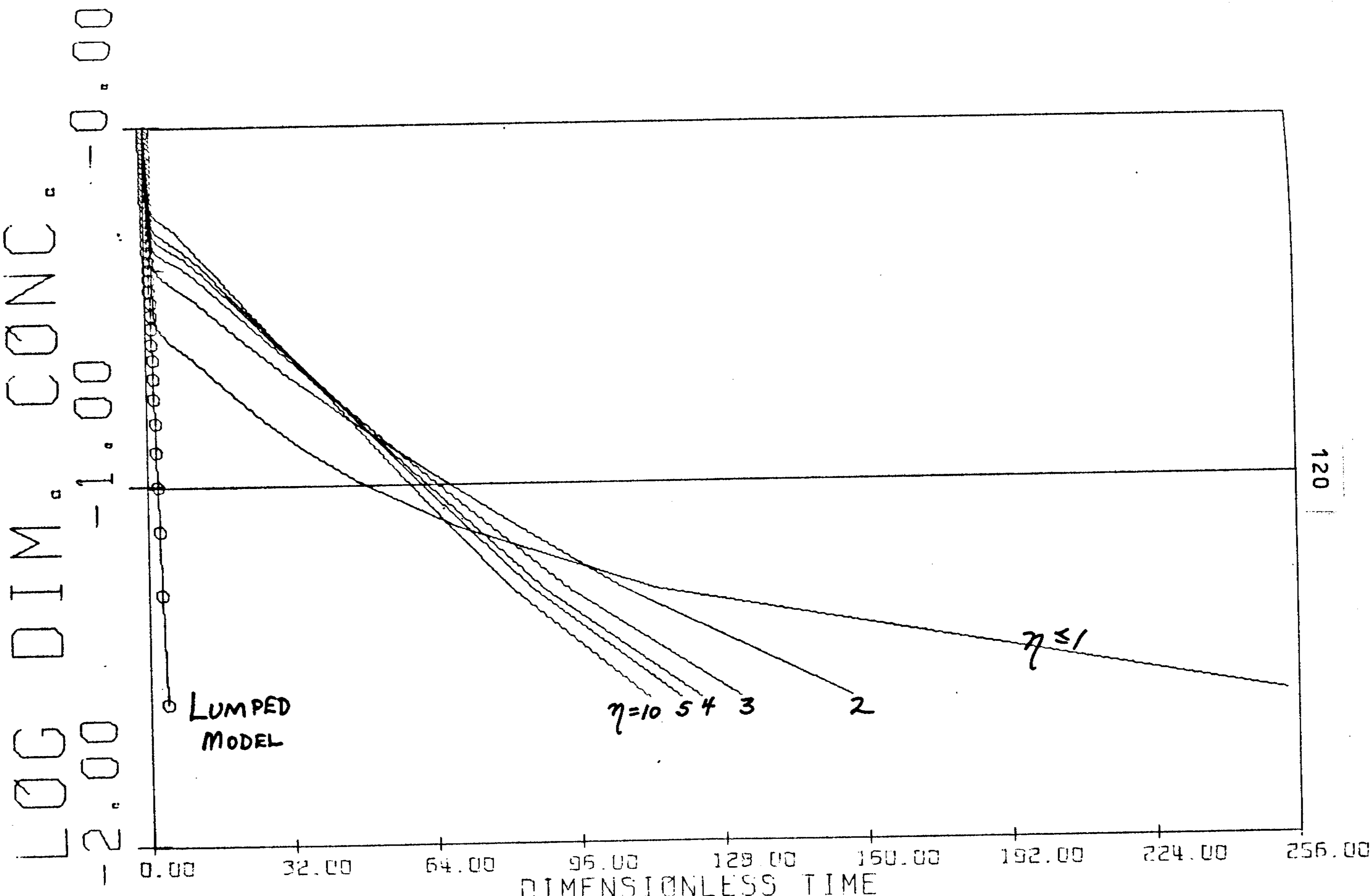

Figure 2.39: Log c/c_0 vs. t/t_{c1} for different η; case (3) in Table 2.3 with α = 10.

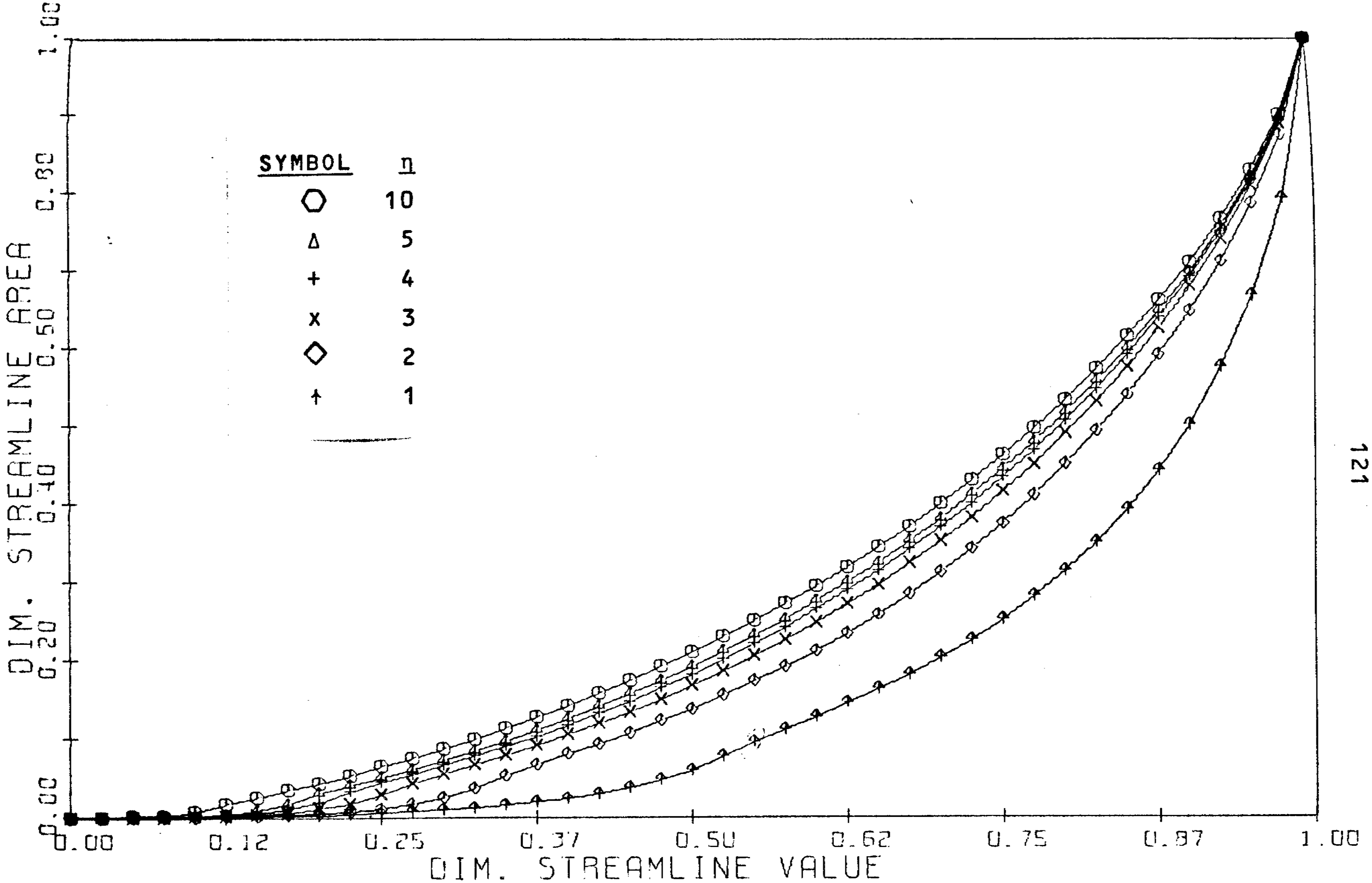

Figure 2.40: $\bar{A}(\bar{\Psi})$ vs. $\bar{\Psi}$ for different n; case (4) in Table 2.3 with $\alpha = 10$.

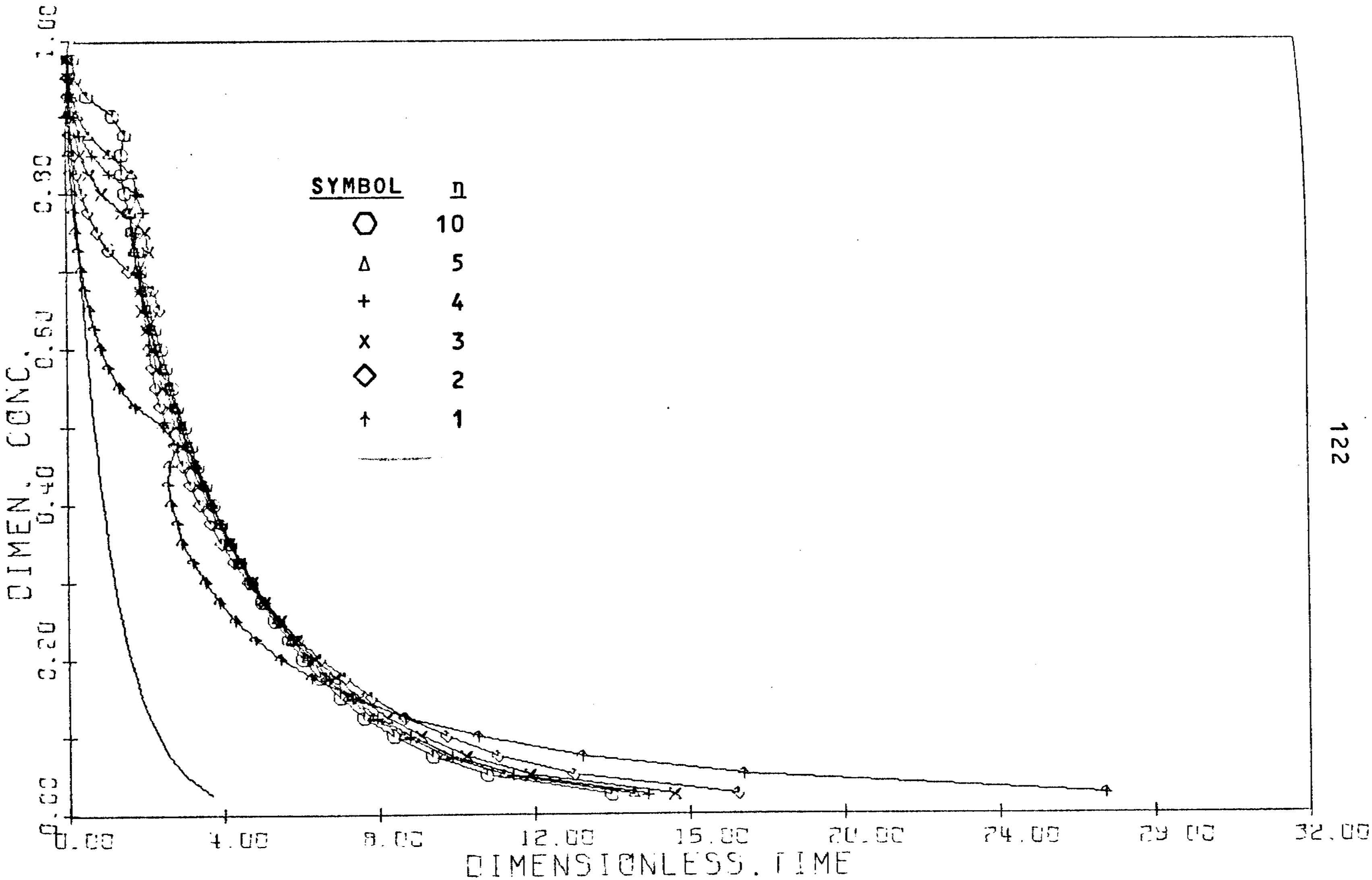

Figure 2.41: c/c_0 vs. t/t_{c_1} for different η; case (4) in Table 2.3 with α = 10.

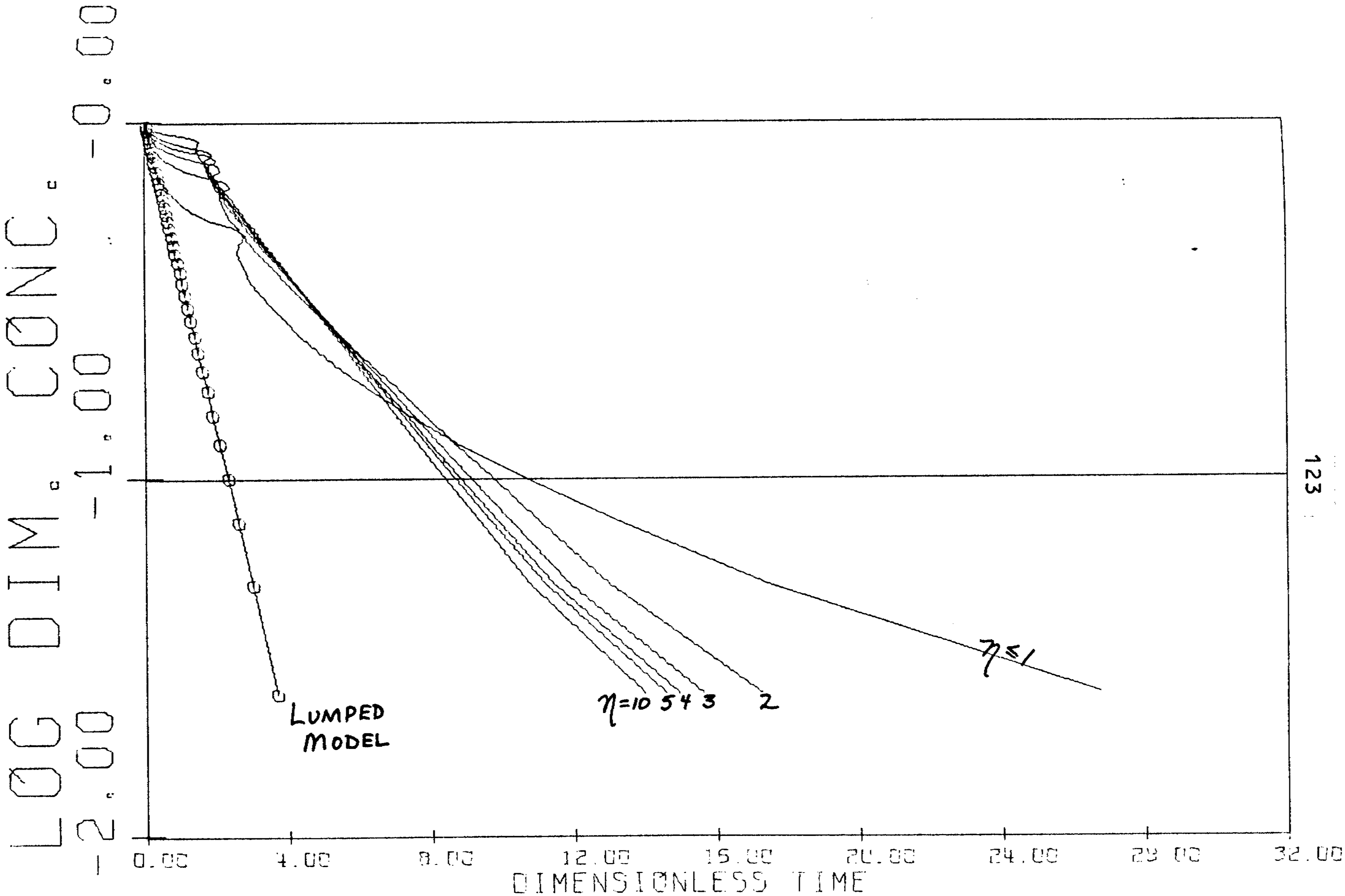

Figure 2.42: Log c/c_0 vs. t/t_{c_1} for different η; case (4) in Table 2.3 with $\alpha = 10$.

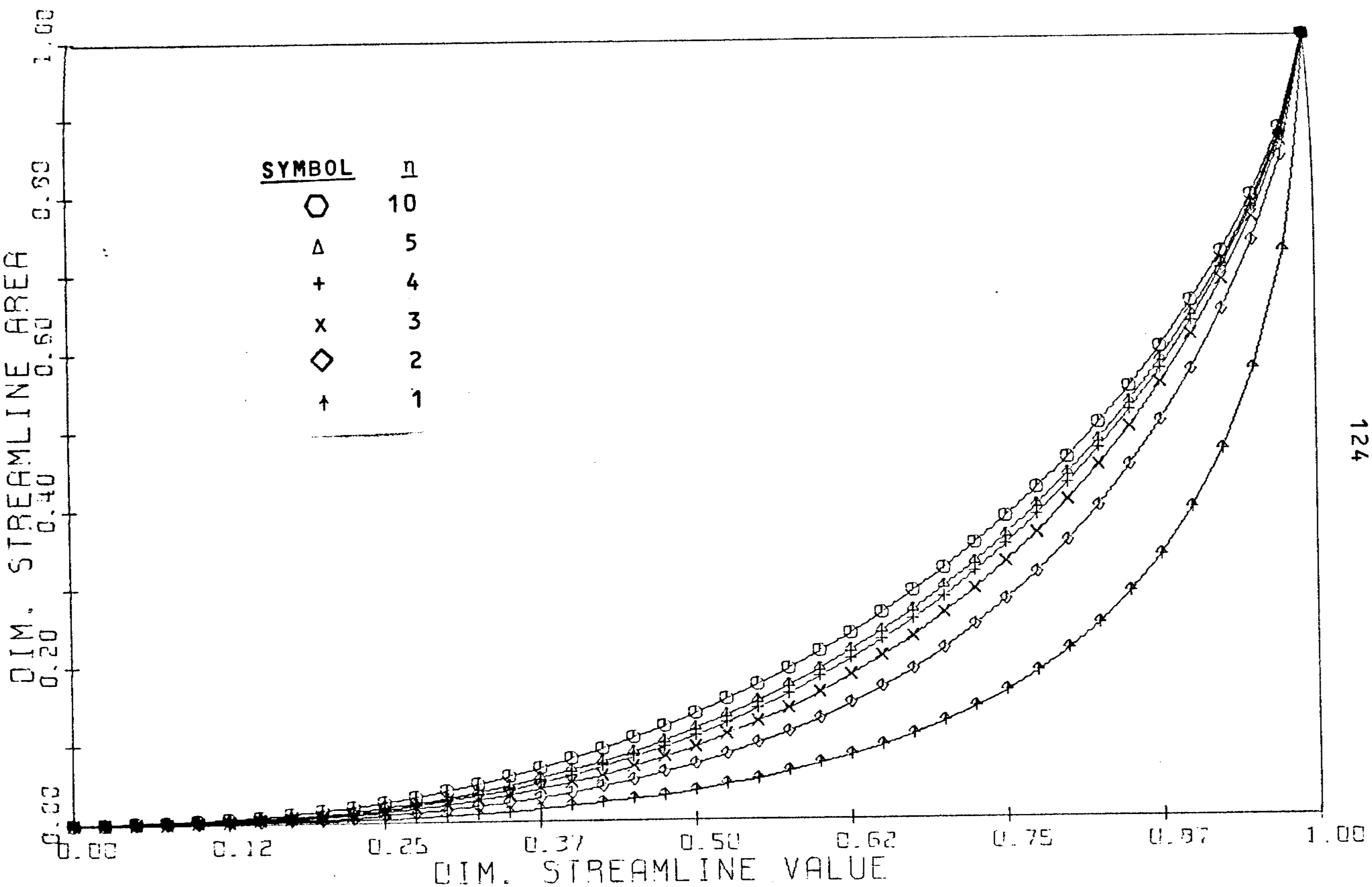

Figure 2.43: $\overline{A}(\overline{\Psi})$ vs. $\overline{\Psi}$ for different n; case (5) in Table 2.3 with $\alpha = 10$.

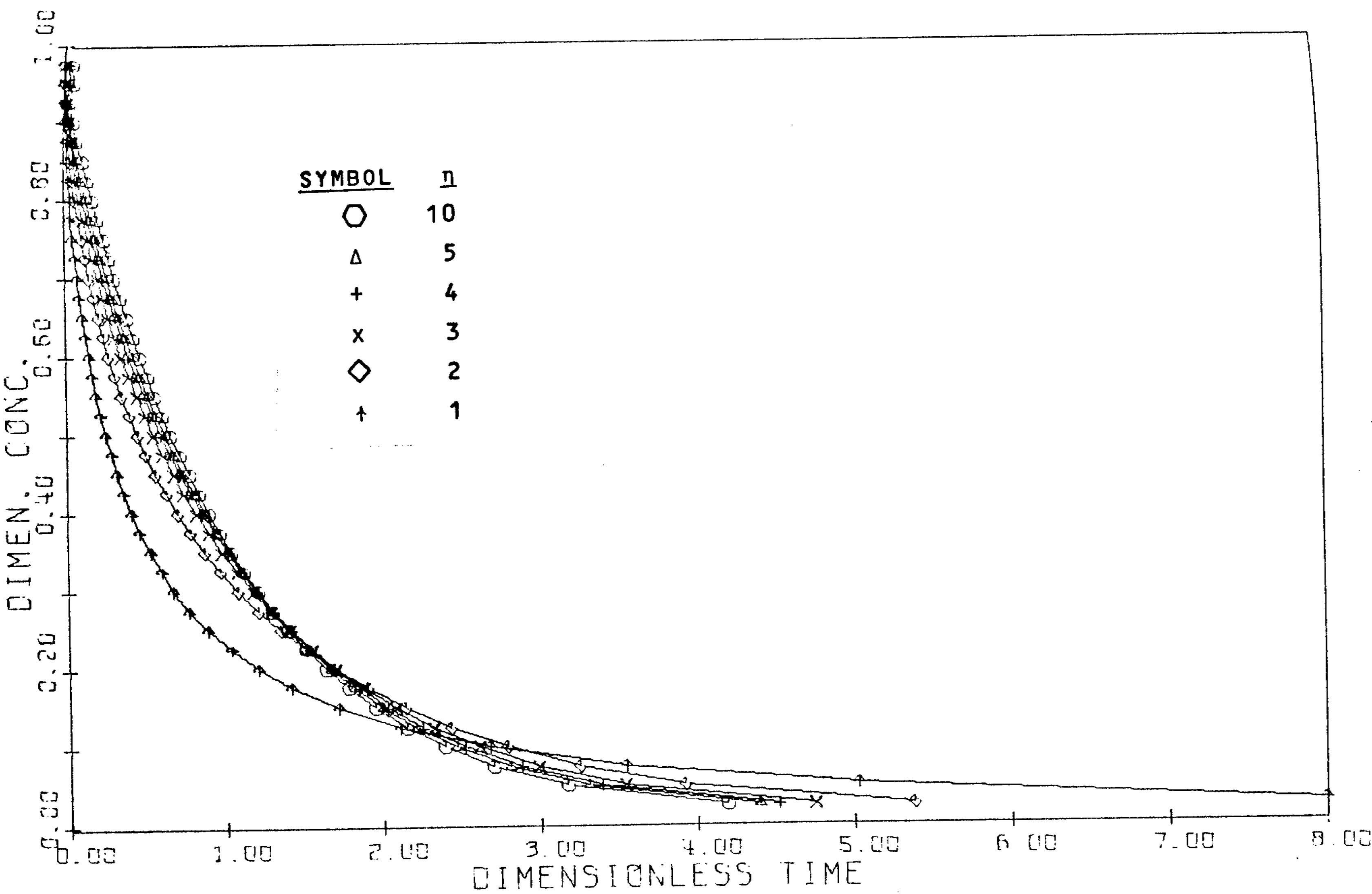

Figure 2.44: c/c_0 vs. t/t_{c1} for different n; case (5) in Table 2.3 with $\alpha = 10$.

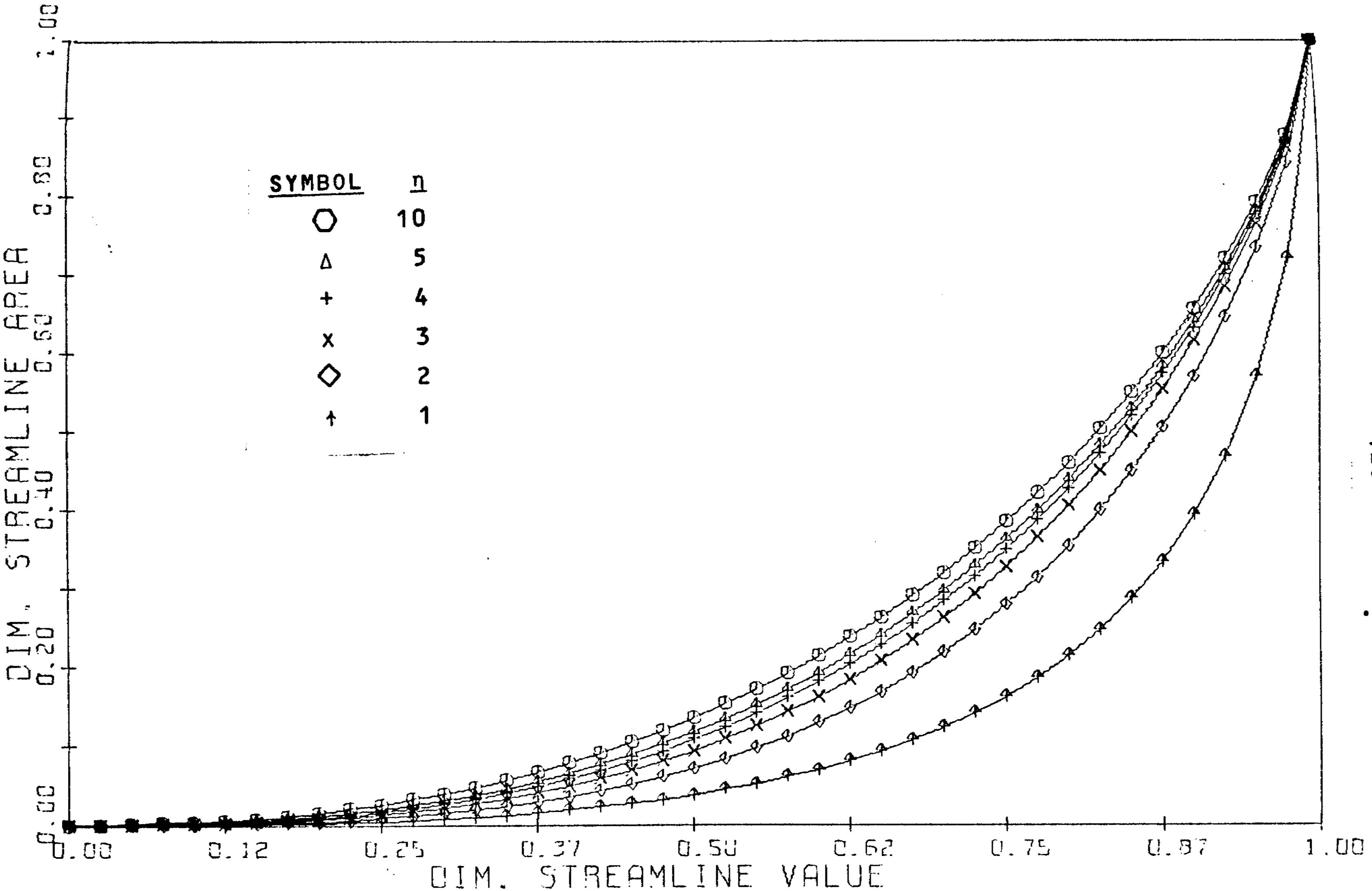

Figure 2.45: $\bar{A}(\bar{\Psi})$ vs. $\bar{\Psi}$ for different n; case (5) in Table 2.3 with α = 100.

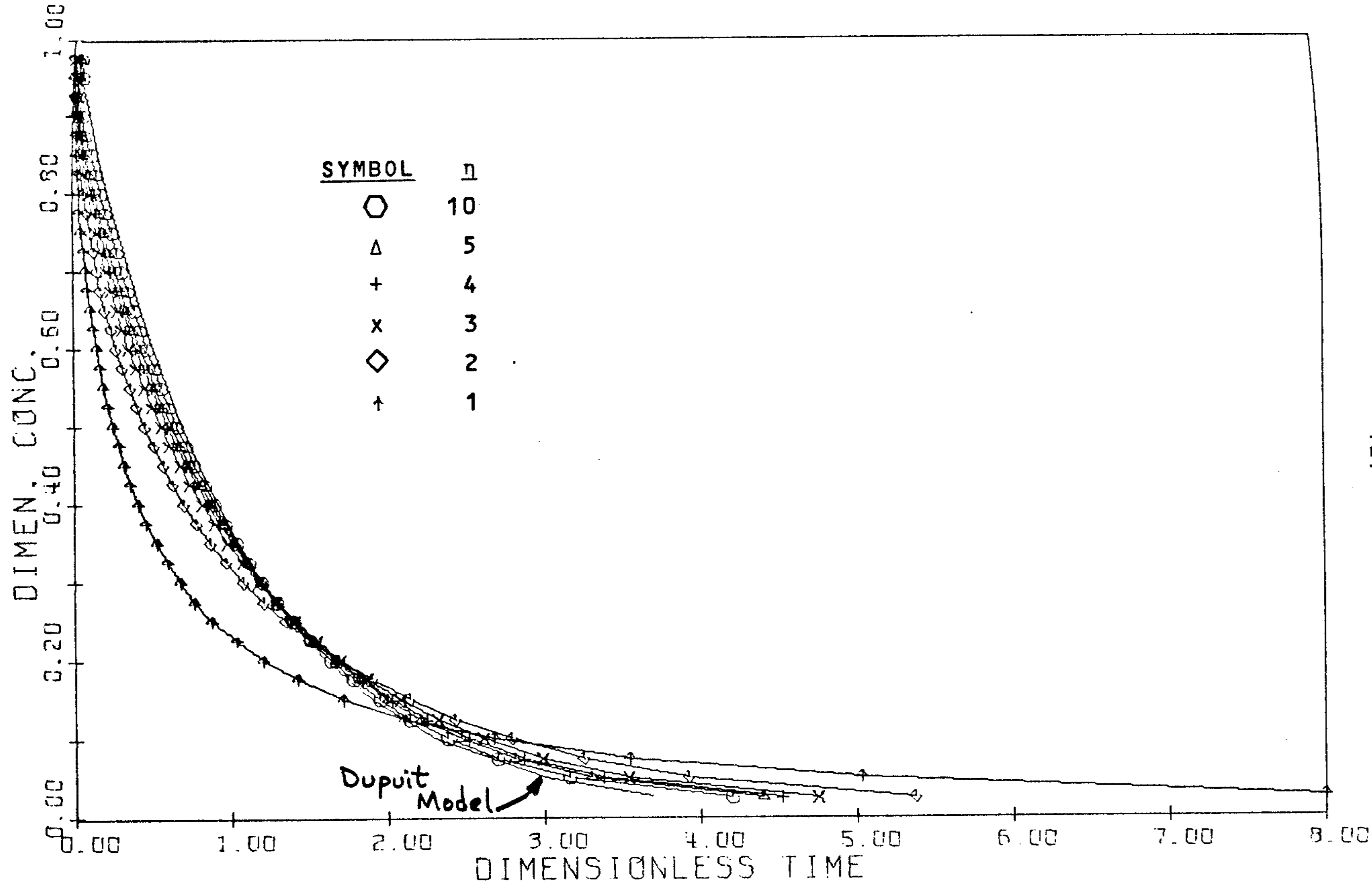

Figure 2.46: c/c_0 vs. t/t_{c1} for different η; case (5) in Table 2.3 with α = 100.

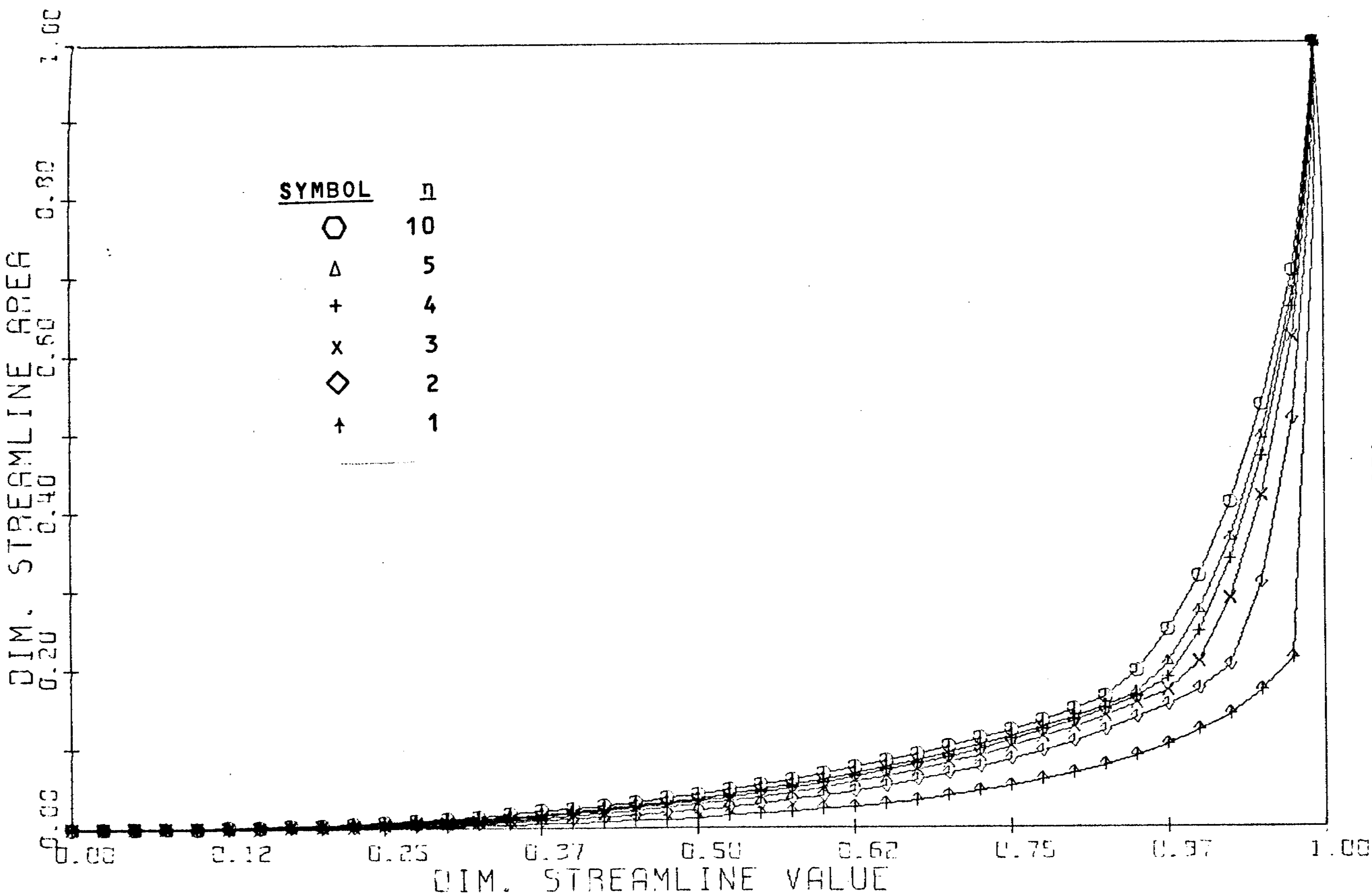

Figure 2.47: $\widehat{A}(\overline{\Psi})$ vs. $\overline{\Psi}$ for different n; case (6) in Table 2.3 with α = 10.

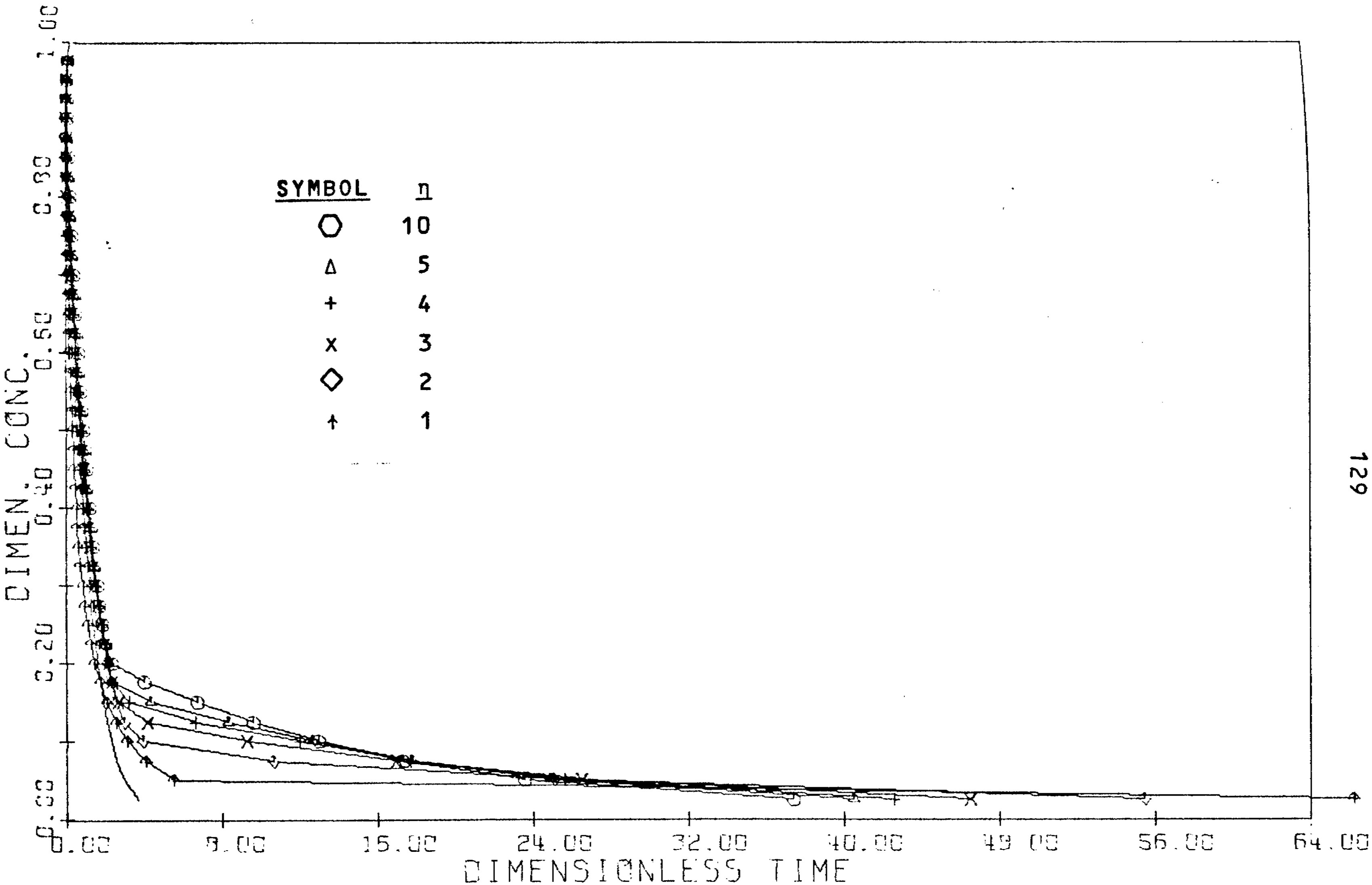

Figure 2.48: c/c_0 vs. t/t_{c1} for different η; case (6) in Table 2.3 with $\alpha = 10$.

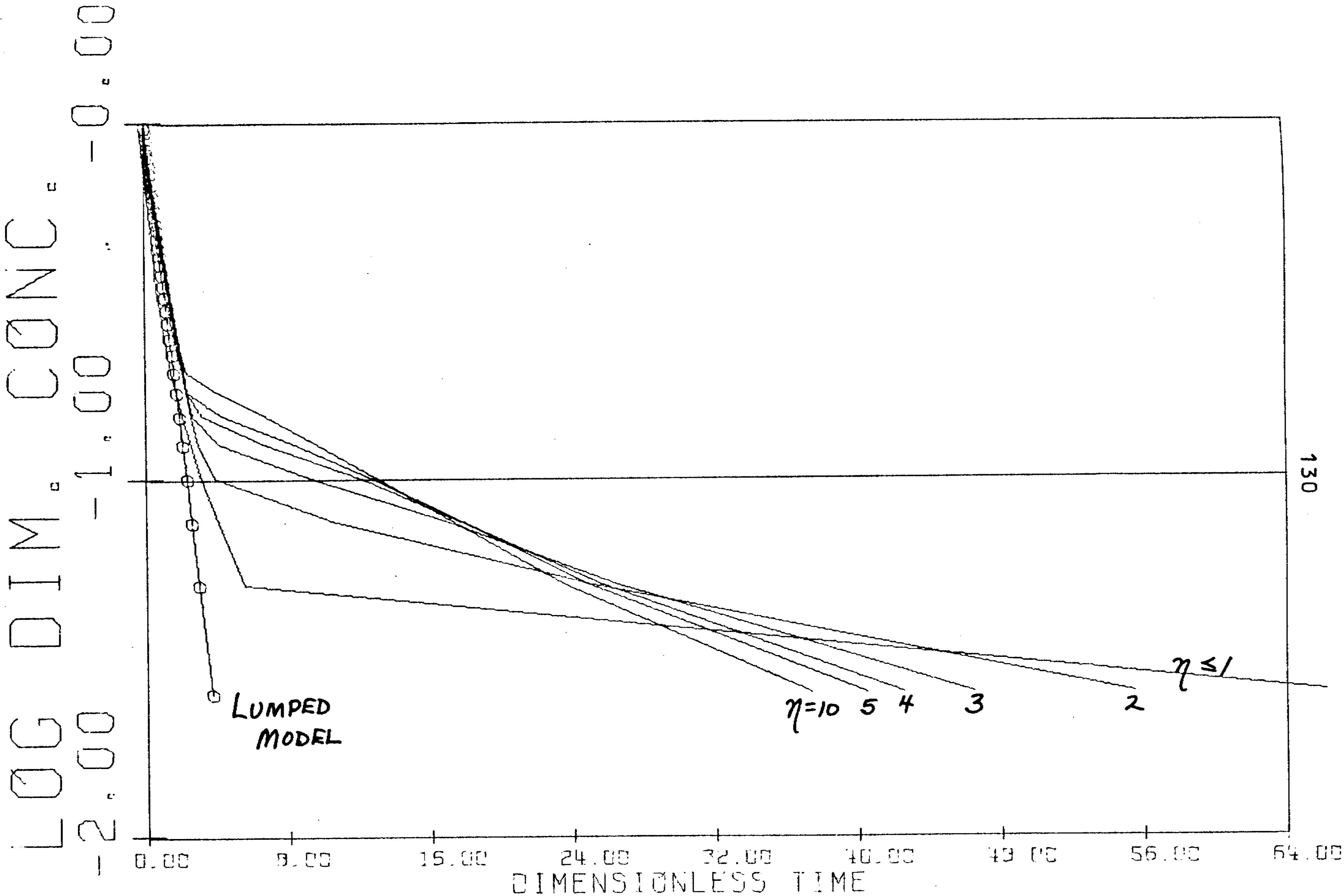

Figure 2.49: Log c/c_o vs. t/t_{c1} for different η; case (6) in Table 2.3 with $\alpha = 10$.

dimensionless c/c_o versus t/t_c curve should approach 1.0 after some sufficiently long time. These areas were calculated for each of the cases examined in Table 2.3, and are summarized in Tables 2.4a and 2.4b.

2.4.7 Relationship Between the Laplace and Combined Lumped Models

We are now in a position to compare concentration outflow histories between the multi-layered Laplace and combined lumped parameter models. Again, we are still using the same steady recharge condition with a flushing initial condition for input concentration. We have already seen the Laplace outflow curves for several multi-layered aquifer configurations in the previous section; similarly, the combined lumped results were also previously given. Plotting these results on the same scale then, will enable a direct visual comparison between models. These graphs are presented in Figures 2.50 through 2.55 for several conditions already given in Tables 2.2. and 2.3. Recall that the combined lumped results were found using (2.2.23) with uniform porosity in both aquifers. Thus

$$c/c_{aq} = (1-\beta)\ \exp\ (-t/t_{c_1}) + \beta\ \exp\ (-\ \gamma t/t_{c_1}) \qquad (2.4.16)$$

where
$$\beta = \mu/(1-\gamma)$$
$$\gamma = \mu/m$$
$$m = b_L/(h_o-b_L)$$
$$\mu = (mk_L/K_u)/(1+mk_L/K_u)$$

Table 2.4a. Areas Under c/c_o vs. t/t_c For Case (1) shown in Table 2.3.

η=L/D	α=20	α=10	α=5	α=2
1	0.825	0.878	0.918	0.952
2	.902	.946	.968	.980
3	.929	.960	.975	.983
4	.935	.962	.976	.984
5	.938	.964	.976	.984
10	.940	.963	.974	.978
See Fig. No.	2.23	2.26	2.29	2.32

Table 2.4b. Areas Under c/c_o vs. t/t_c For Case (1) shown in Table 2.3.

	Case (2)	Case (3)	Case (4)	Case (5)		Case (6)
η=L/D	α=10	α=10	α=10	α=10	α=100	α=10
1	0.908	0.930	0.977	0.965	.965	.812
2	.968	.976	.988	.984	.984	.930
3	.975	.981	.989	.984	.980	.954
4	.977	.982	.989	.964	.958	.961
5	.977	.982	.988	.957	.952	.963
10	.972	.980	.962	.944	.937	.966
See Fig. No.	2.35	2.38	2.41	2.44	2.46	2.48

NOTE: To compute the actual area under the c/c_o vs. t/t_{c1} curves depicted in Figures 2.22 to 2.49, multiply the appropriate area by the corresponding N value given in Table 2.3. The areas listed here are for the c/c_o vs. t/t_c curves and are intended for comparison to the lumped parameter curve area previously found to be 0.977. Furthermore, the integration procedure used in these area determinations are terminated when c/c_{aq} = 0.025.

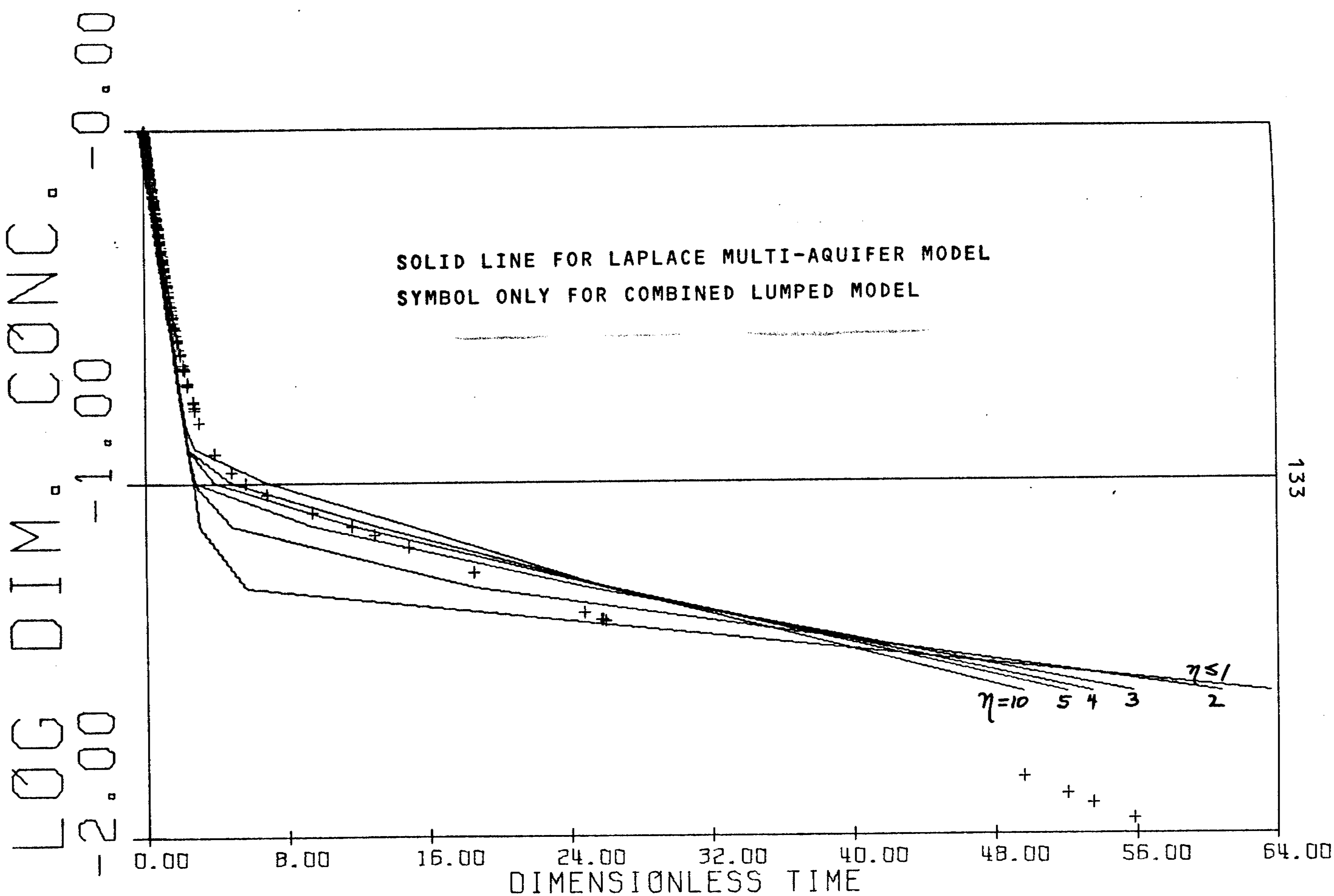

Figure 2.50: Laplace and combined lumped model c/c_{aq} vs. t/t_{c1} curves (see Figures 2.6 and 2.24).

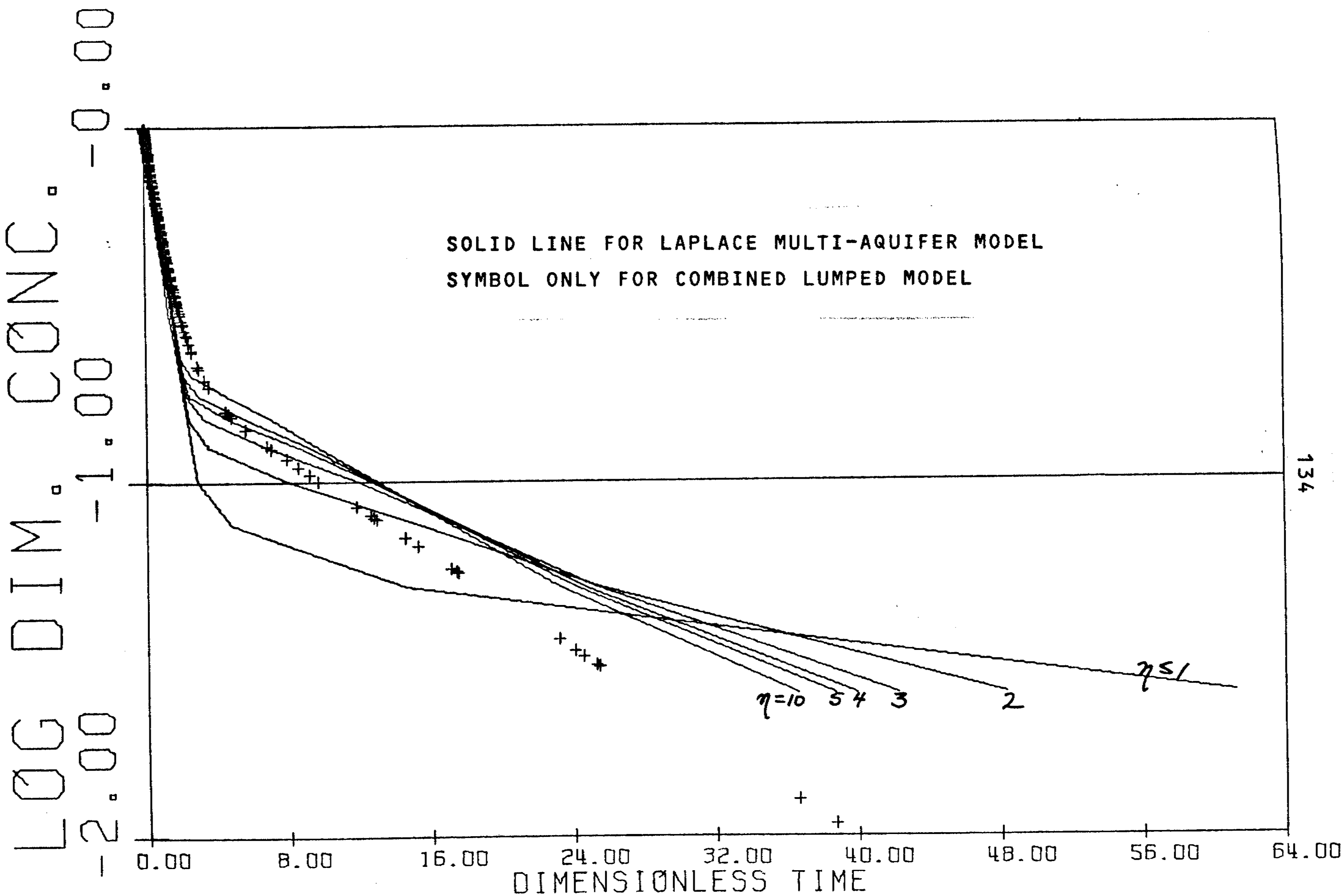

Figure 2.51: Laplace and combined lumped model c/c_{aq} vs. t/t_{c1} curves (see Figures 2.7 and 2.27).

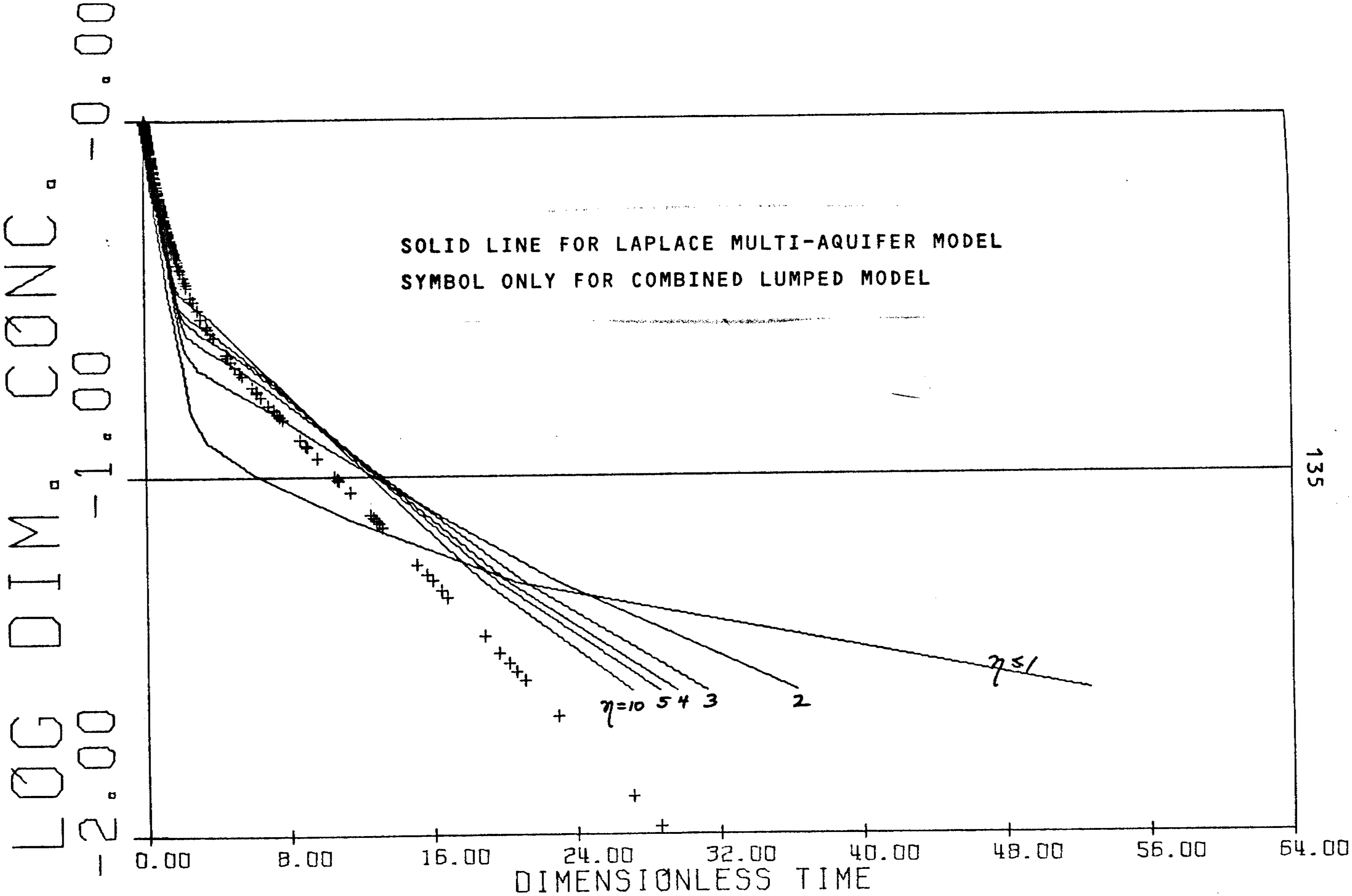

Figure 2.52: Laplace and combined lumped model c/c_{aq} vs. t/t_{c1} curves (see Figures 2.8 and 2.30).

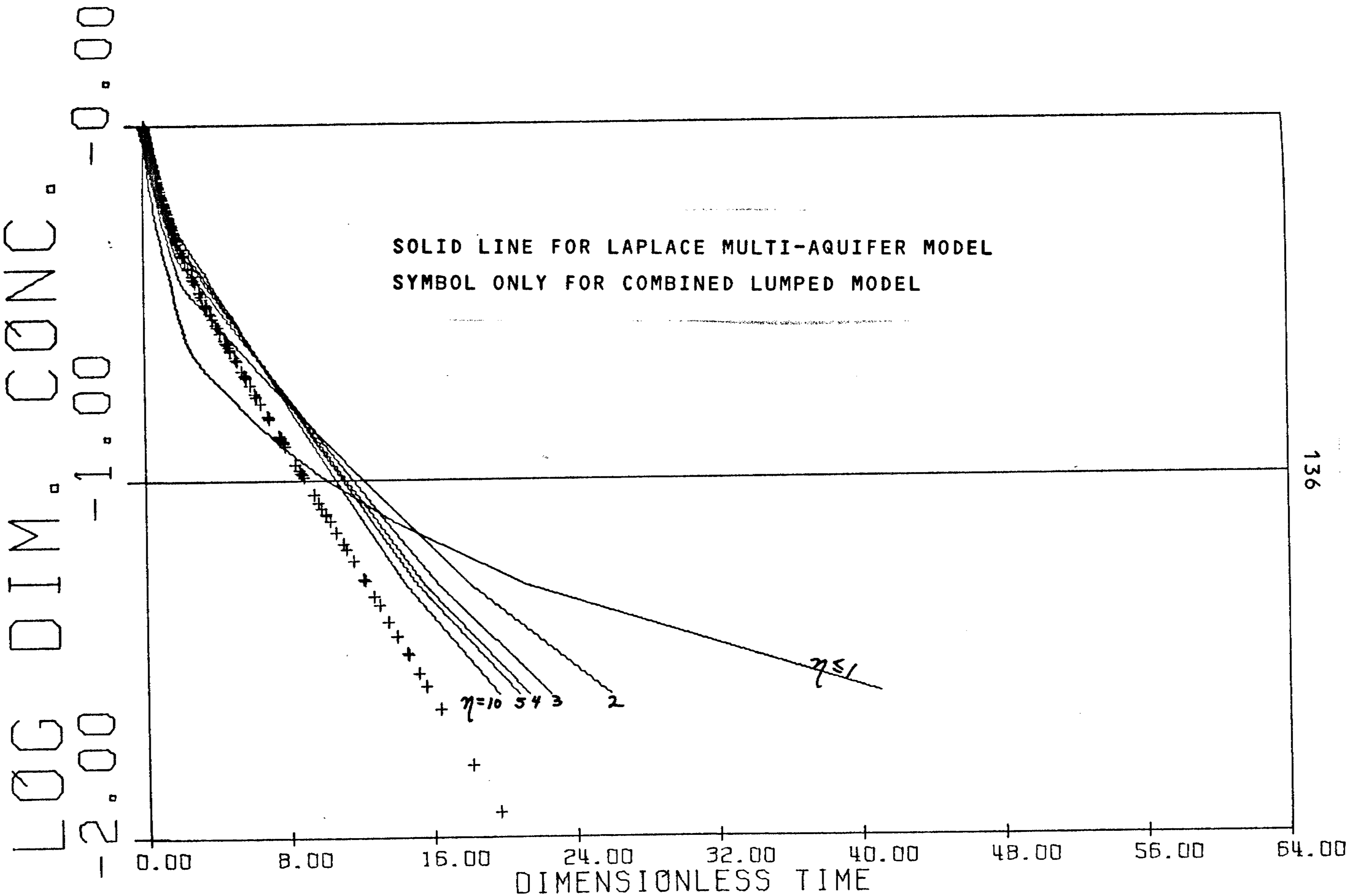

Figure 2.53: Laplace and combined lumped model c/c_{aq} vs. t/t_{c1} curves (see Figures 2.9 and 2.33).

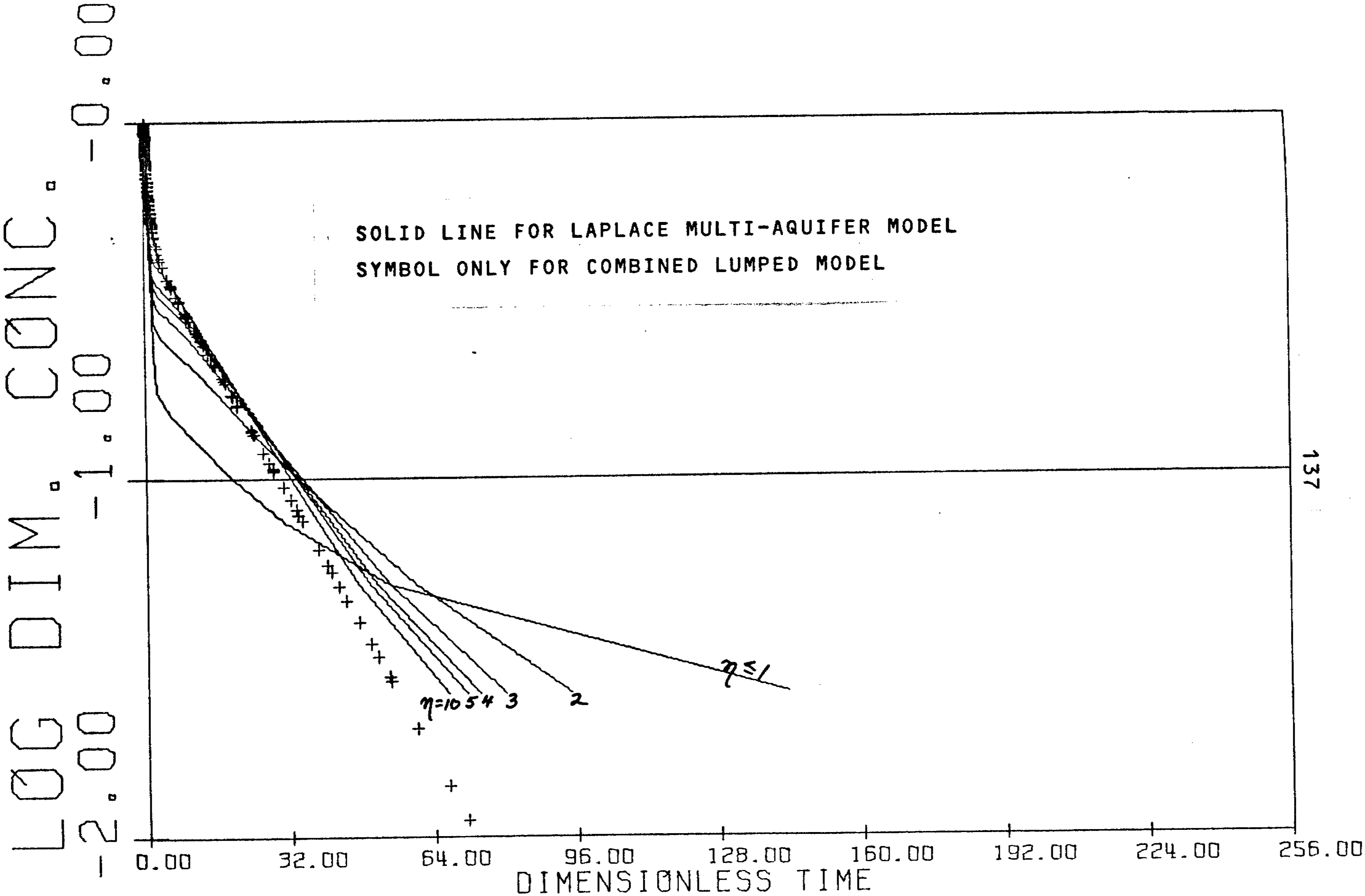

Figure 2.54: Laplace and combined lumped model c/c_{aq} vs. t/t_{c1} curves (see Figures 2.11 and 2.36).

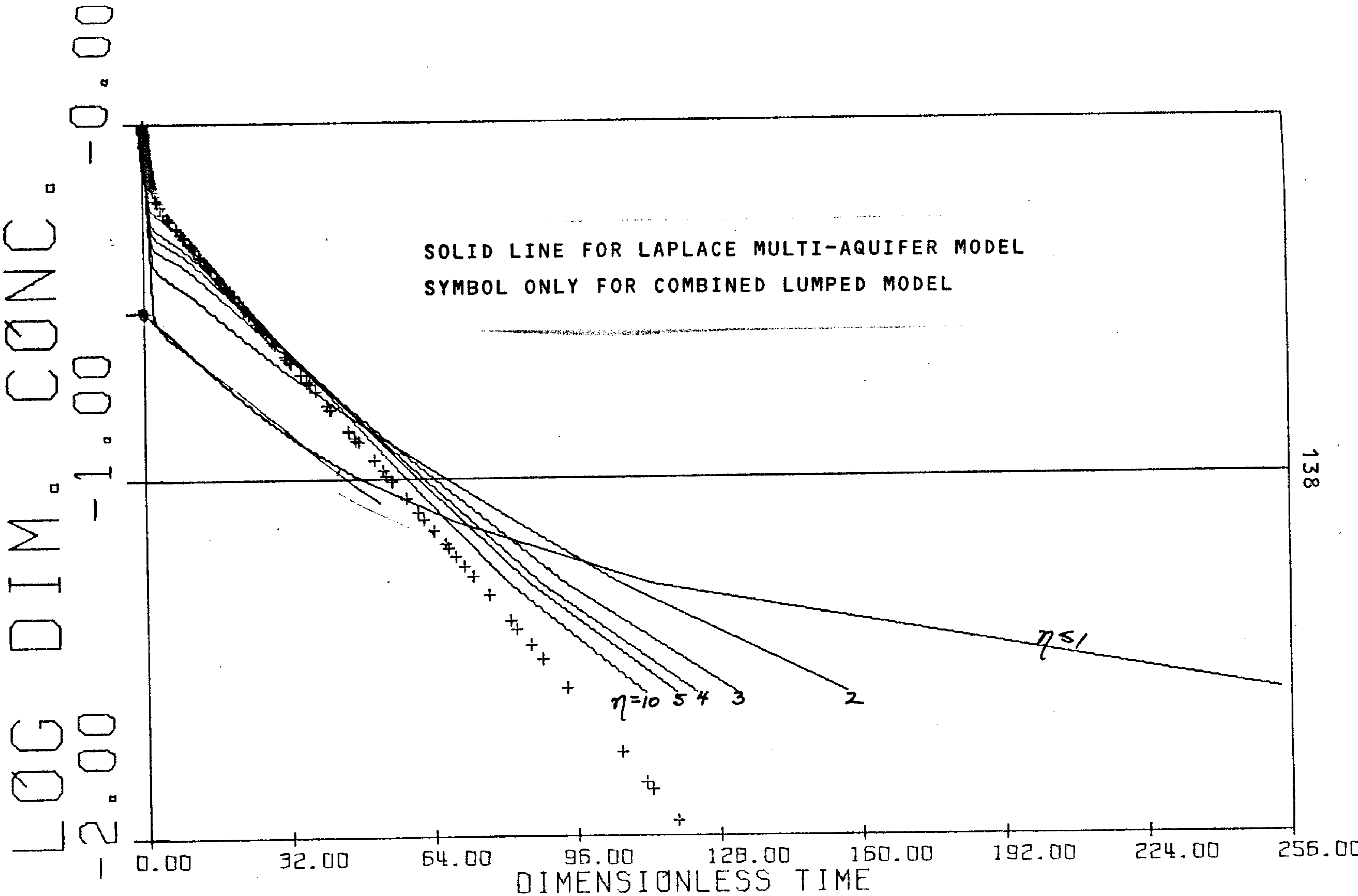

Figure 2.55: Laplace and combined lumped model c/c_{aq} vs. t/t_{c1} curves (see Figures 2.12 and 2.39).

The relation for μ was found using the Dupuit approximation. For convenience, we have also assumed that the upper and lower reservoirs have identical initial average concentrations. Figures 2.50 through 2.55 show that the multi-layered Laplace results are approximated fairly well by (2.4.16), although differences in concentration resulting from vertical flow are not considered. Even when these vertical flow components become quite pronounced (Figure 2.55, for example) the combined lumped model still predicts concentration outflow behavior surprisingly well.

Equation (2.4.16) may be thought of as simply two exponential curves summed together to give the concentration in the stream. The first exponential term represents convective travel time through the upper reservoir, while the second term represents travel time in the lower aquifer. At early time, the first exponential term predominates since γ is less than one in all cases examined here. Similarly, the second term dominates at late time. By "adjusting" the parameters β and γ we may alter the shape of the combined lumped parameter breakthrough curves. It may easily be shown that the second term in (2.4.16) has a slope of $-\gamma$ and a c/c_{aq} intercept of β when the dimensionless concentration versus dimensionless time values are plotted on semi-logarithmic scales respectively. For example, the first term in (2.4.16) has a slope of -1 and an intercept of +1. Since the Laplace concentration break-through curves also appear to exhibit this exponential behavior, we should be able to read these intercept and slope values of the lower portion of each of the Laplace curves. Substitution of these resulting new β and γ values into (2.4.16) will then "correct" the combined lumped parameter outflow concentration so that vertical flow effects are approximately taken into account. Figures 2.56 and 2.57 show the relationship between these respective slope and intercept values. To use the figures, we must first calculate μ, m, and γ for the lumped model using the previously derived Dupuit relationships given along with (2.4.16). The lumped model intercept value will ideally be μ, while its slope will be given by γ. Once we know these values, we can refer to Figures 2.56 and 2.57. Reading upward from the appropriate abscissa to the corresponding η=L/D ratio in the Laplace model and over to the ordinate, we obtain the "corrected" Laplace β and γ values to be used in (2.4.16). If the Laplace and lumped models agreed perfectly, then the η curves would fall on the "theoretical" line indicated in each figure. We can see that for large η, and hence decreased importance of vertical flow, these curves do approach this theoretical limit. Thus vertical flow effects may be incorporated into the seeming crude lumped parameter model with reasonable success. For example, with a K_L/K_u ratio of 0.20 and a value of m=3, Table 2.5 lists the corresponding values of γ from Figure 2.56 and values of β from Figure 2.57; these γ and β values may be used in (2.4.16) to correct the combined lumped model for vertical flow effects. Figures 2.58 through 2.63 show the resulting concentration breakthrough curves so obtained; the corresponding Laplace curves previously found are also shown for reference.

Table 2.5. Values of γ and β from Figures 2.56 and 2.57 with K_L/K_u = 0.20, m=3, and μ =0.375.

η	γ	β	REMARKS
10	0.096	0.322	See Fig. 2.58
5	.084	.280	See Fig. 2.59
4	.081	.266	See Fig. 2.60
3	.074	.242	See Fig. 2.61
2	.062	.202	See Fig. 2.62
1	.038	.121	See Fig. 2.63

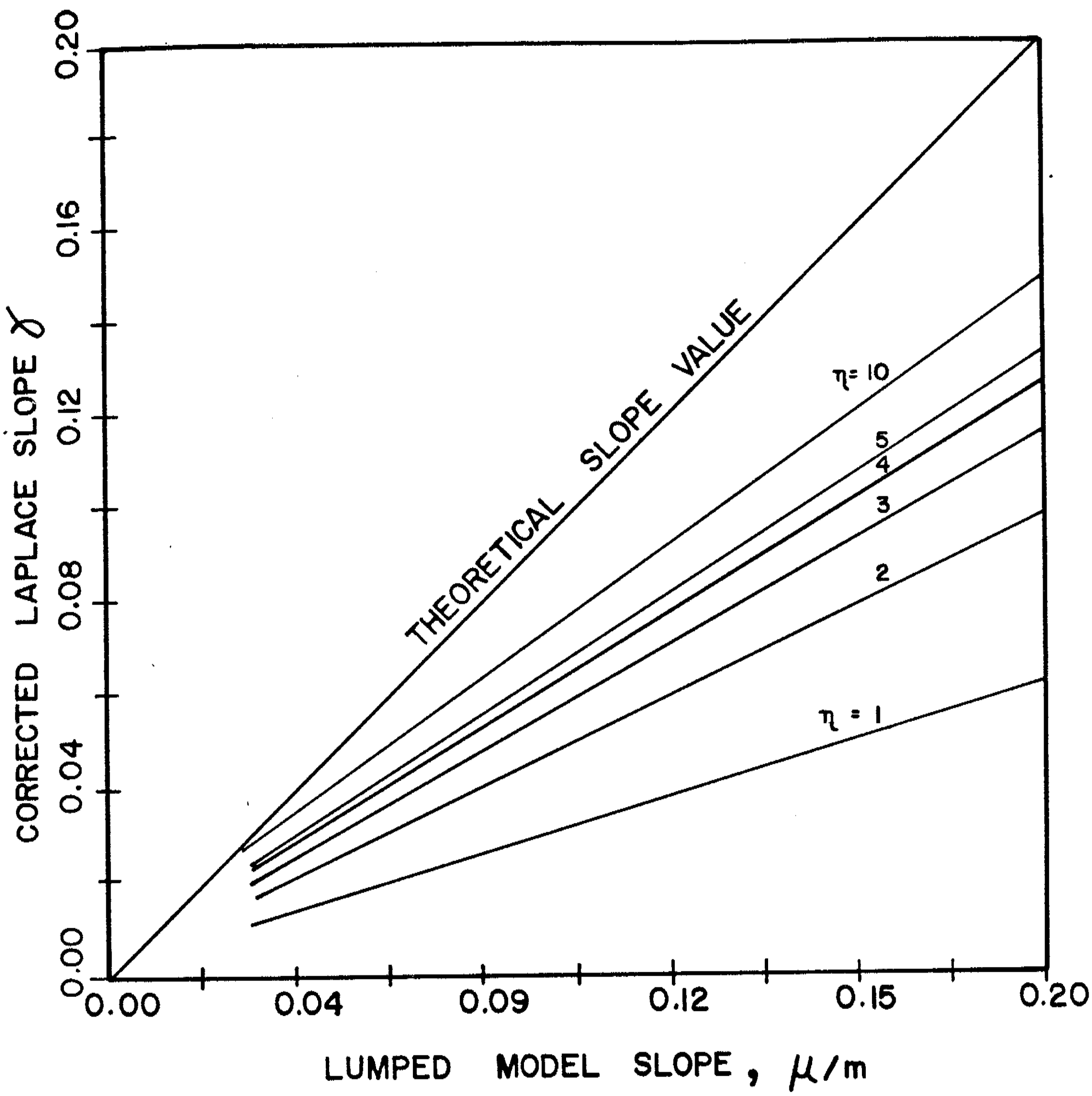

Figure 2.56 Lumped (μ/m) vs. Laplace (γ) model slopes for different values of η.

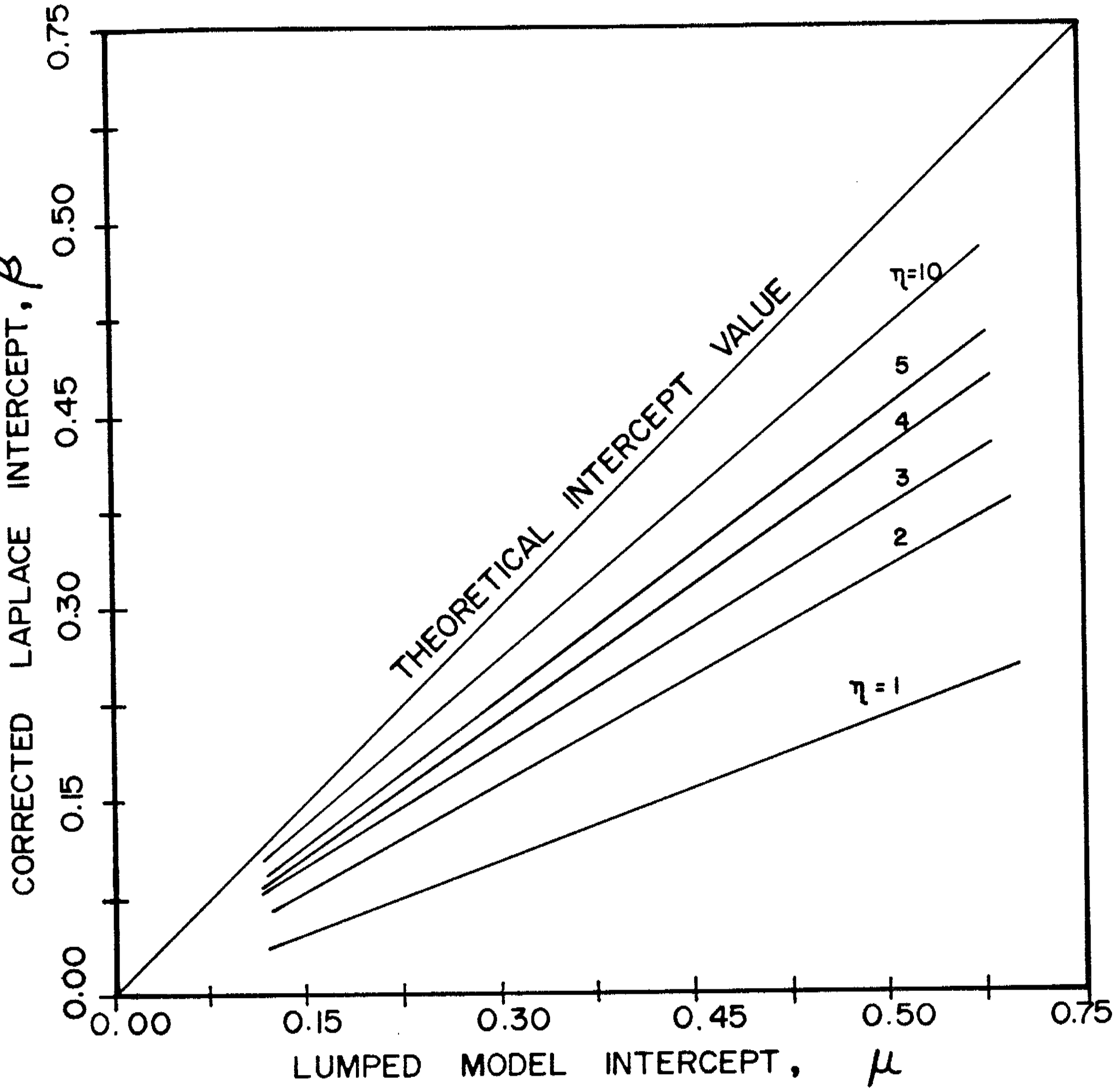

Figure 2.57 Lumped (μ) vs. Laplace (β) model intercepts for different values of η.

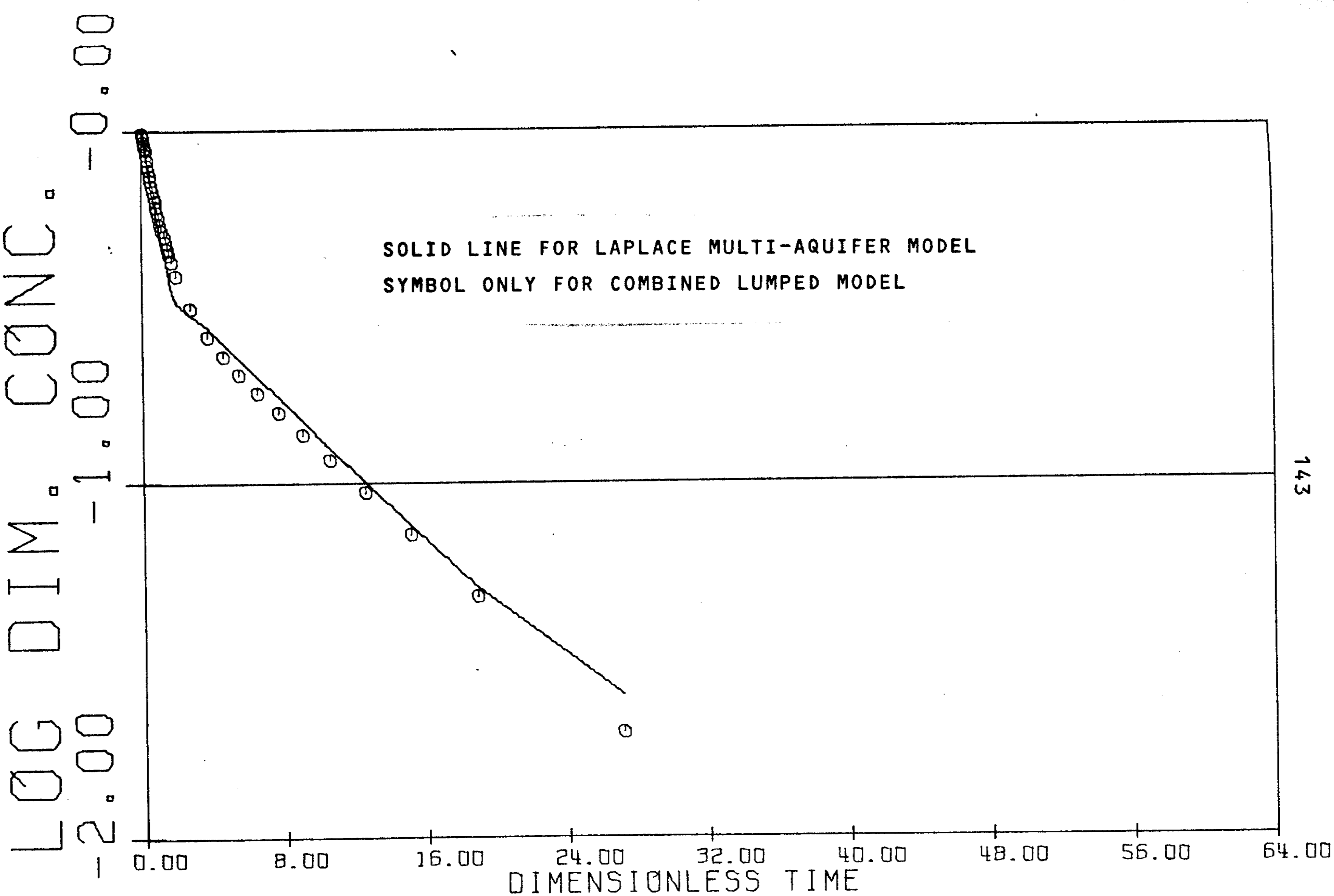

Figure 2.58: Corrected lumped vs. Laplace c/c_{aq} vs. t/t_{c1} curves for $n = 10$.

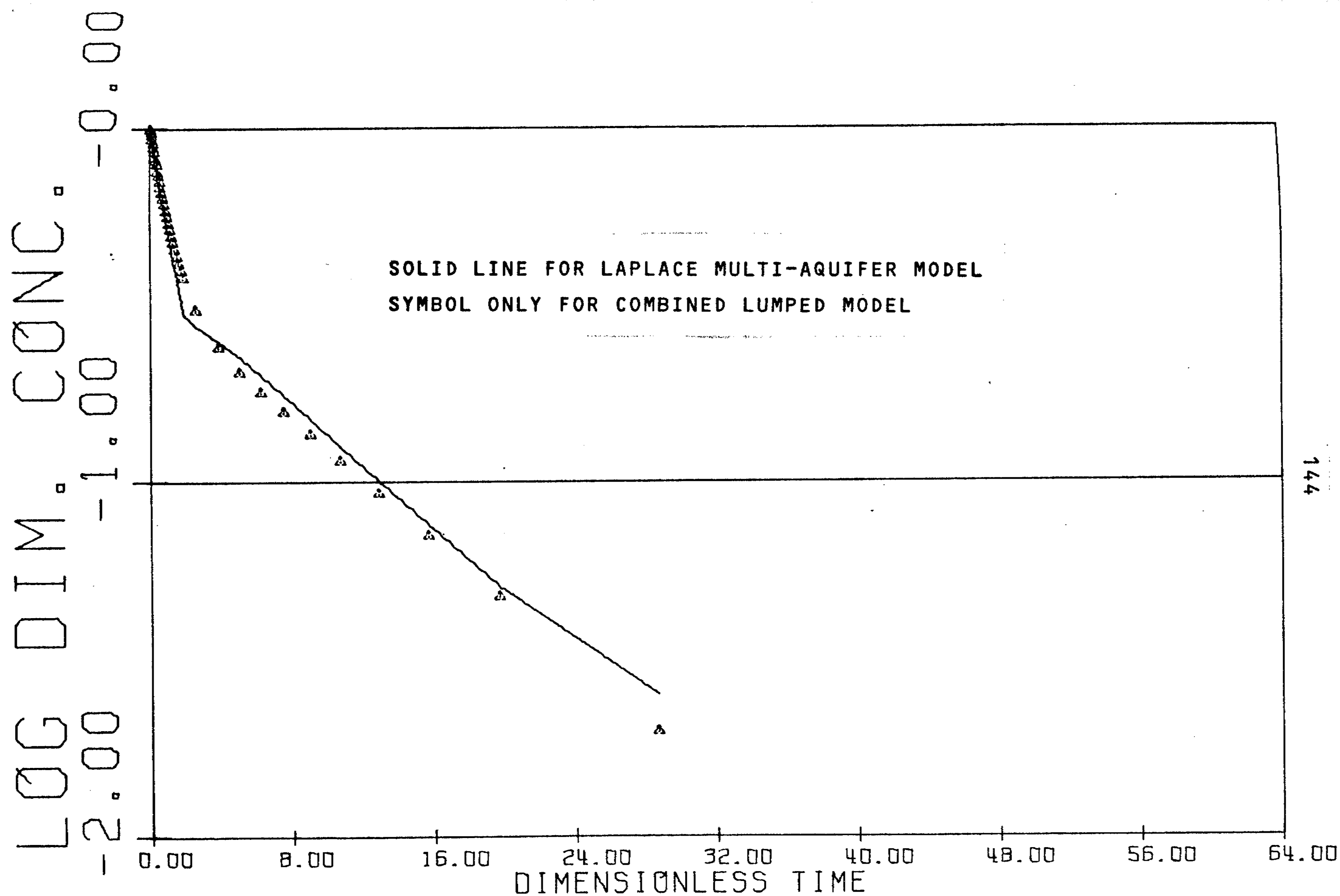

Figure 2.59: Corrected lumped vs. Laplace c/c_{aq} vs. t/t_{c1} curves for $n = 5$.

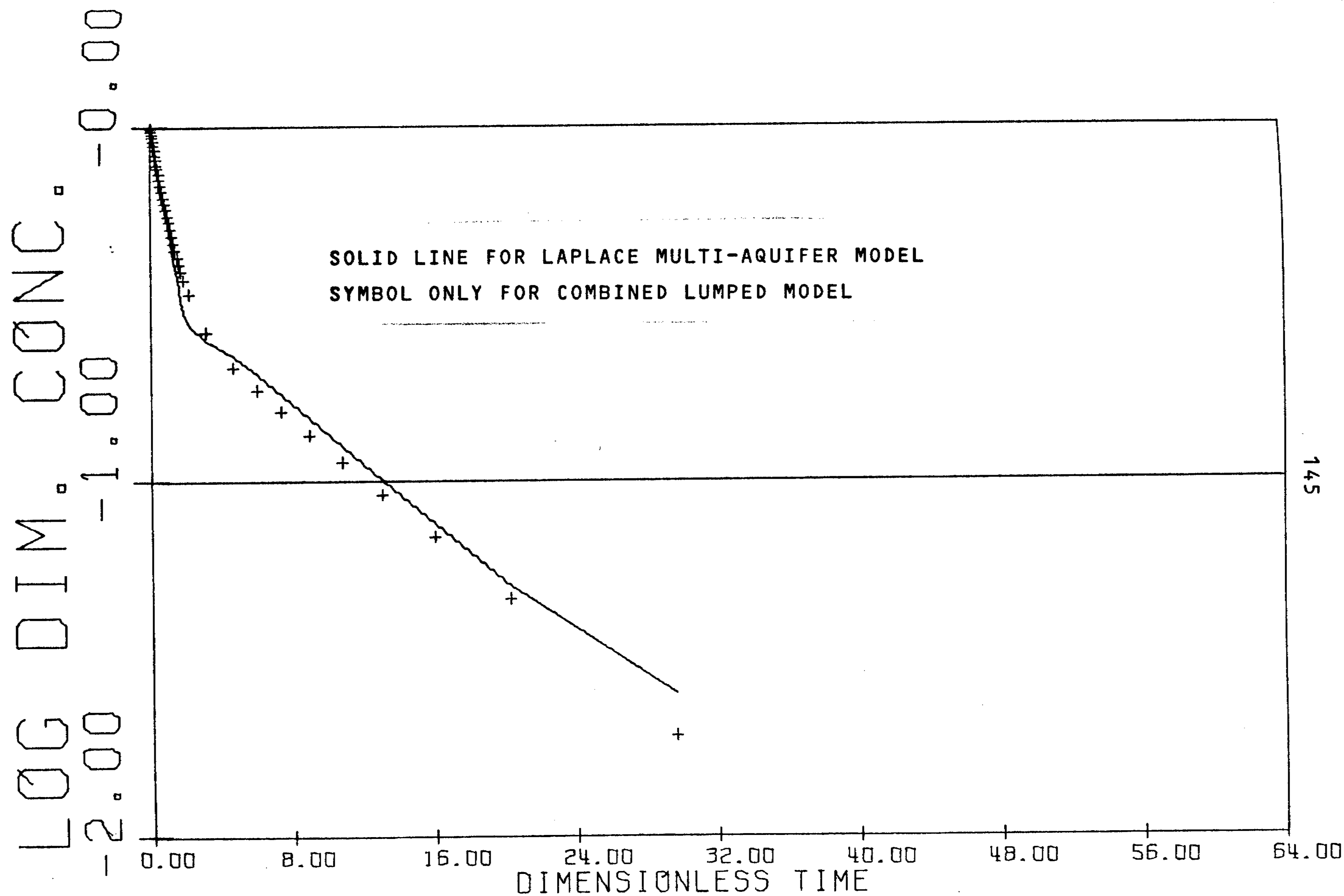

Figure 2.60: Corrected lumped vs. Laplace c/c_{aq} vs. t/t_{c1} curves for n = 4.

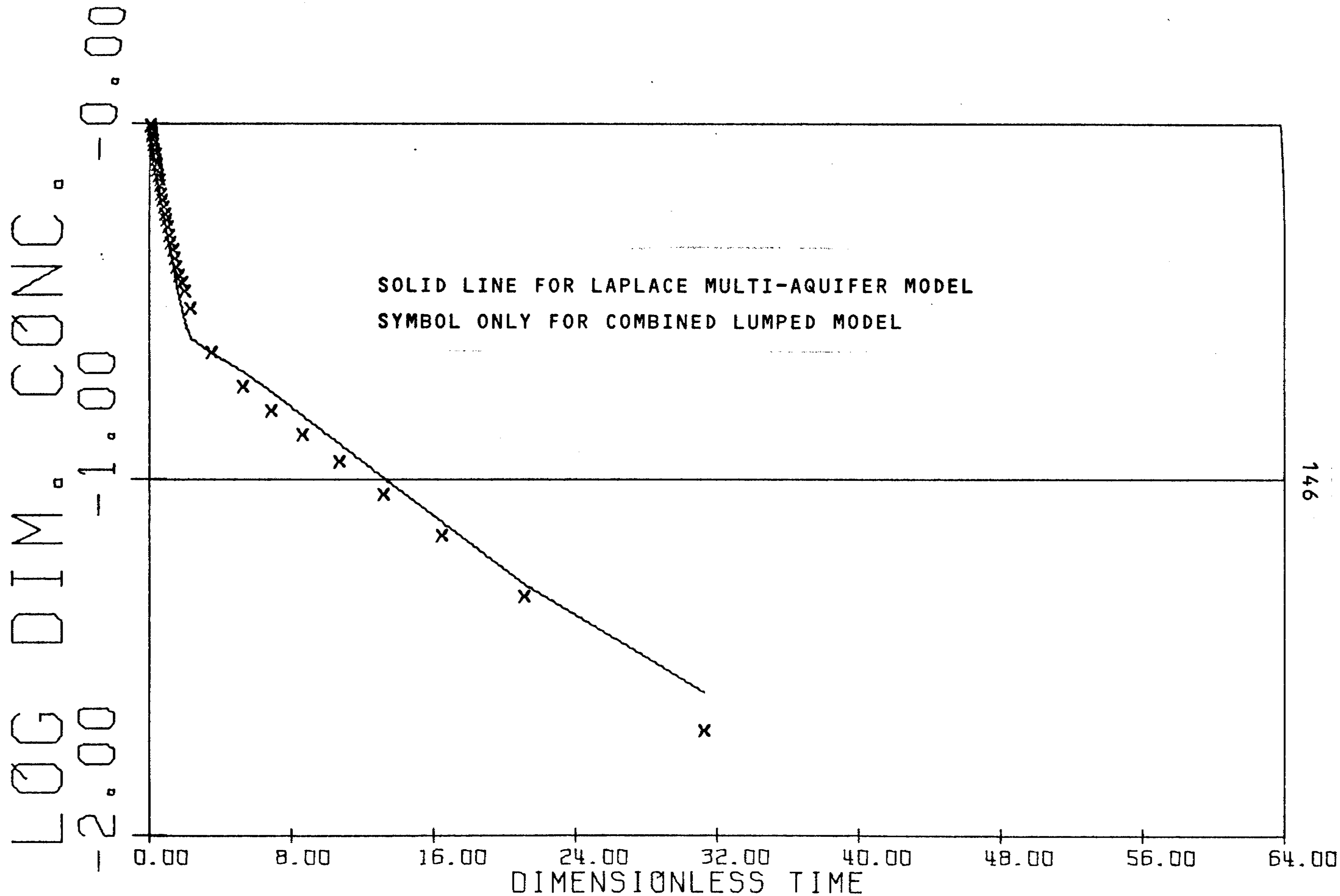

Figure 2.61: Corrected lumped vs. Laplace c/c_{aq} vs. t/t_{c_1} curves for $n = 3$.

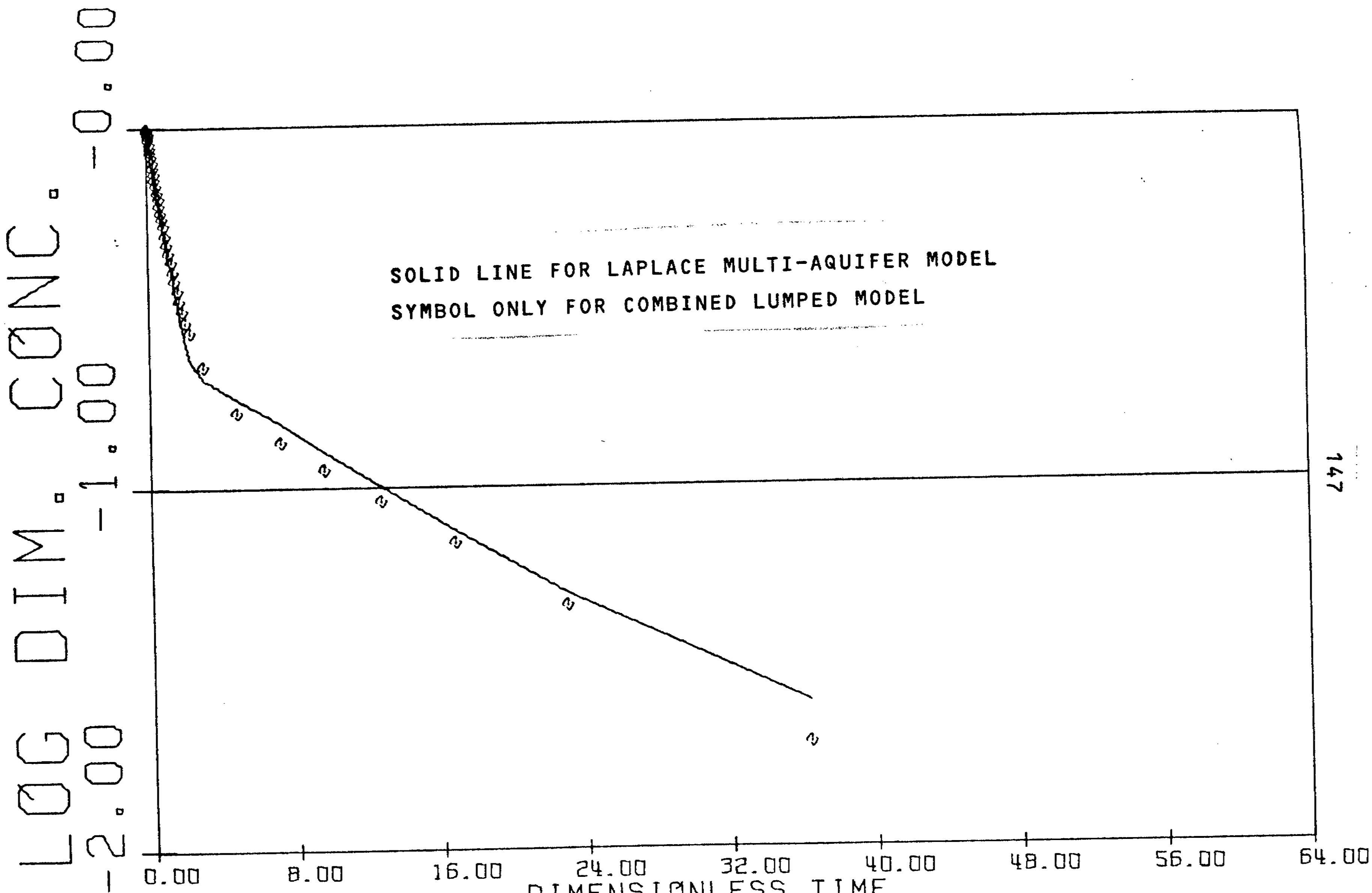

Figure 2.62: Corrected lumped vs. Laplace c/c_{aq} vs. t/t_{c1} curves for $n = 2$.

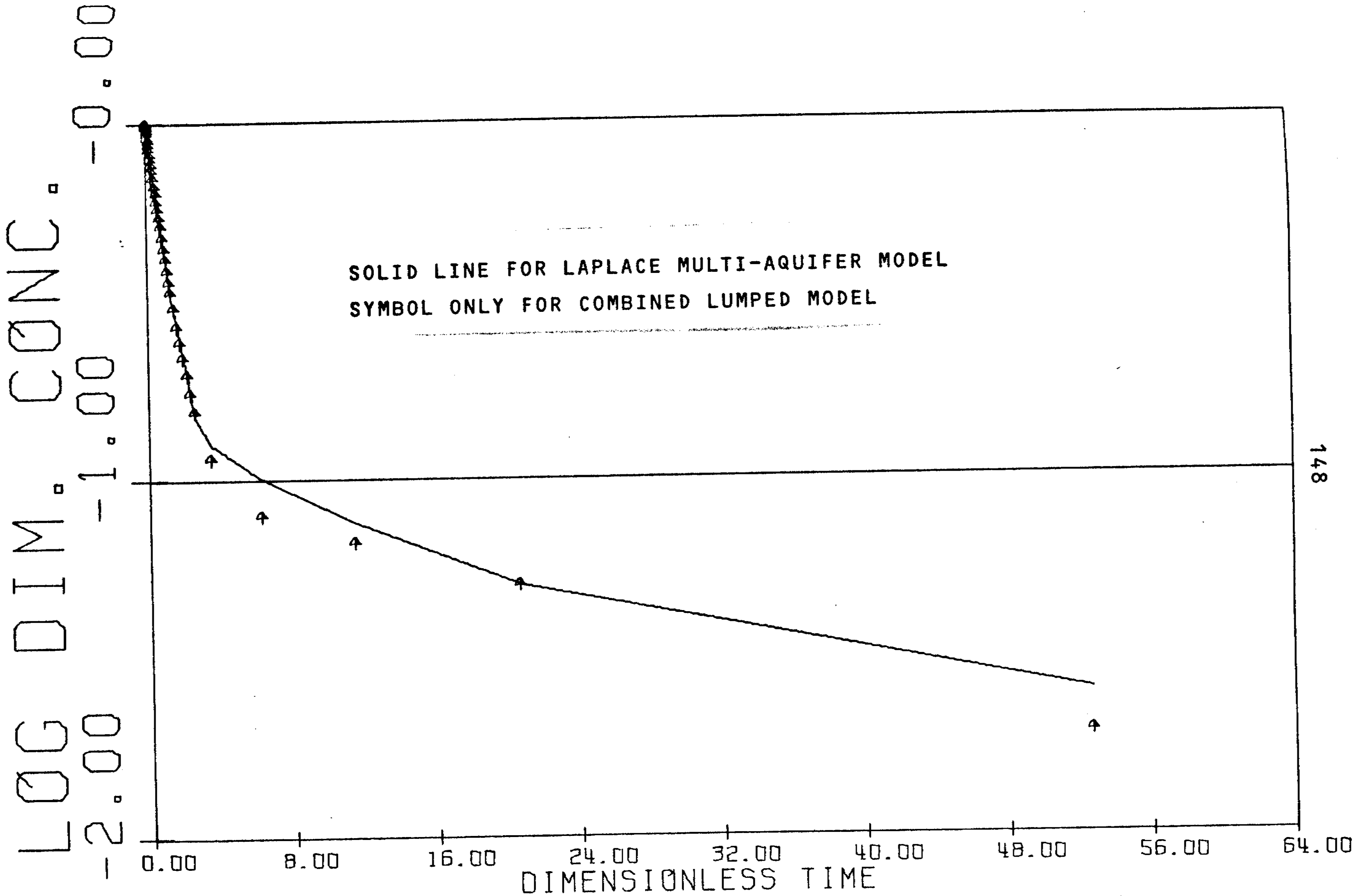

Figure 2.63: Corrected lumped vs. Laplace c/c_{aq} vs. t/t_{c1} curves for $n = 1$.

2.5 General Conclusions

The following general conclusions are made based on the foregoing analyses conducted in this chapter.

1. For a constant uniform recharge and a step change in input concentration, the preceding analyses have shown that the lumped parameter model in the form of a linear reservoir yields an identical connective outflow concentration in the stream compared to the one-dimensional Dupuit aquifer analysis ((2.2.15) and (2.3.23) are identical). Furthermore, the instantaneous average concentration of contaminants being transported through the Dupuit aquifer was shown to be identical to this stream concentration. Hence the well-mixed reservoir assumption inherent to the lumped parameter approach is justified, based on these two-dimensional modeling considerations. A similar conclusion was also reached by Gelhar and Wilson (1974).

2. For multi-layered aquifer systems with constant uniform recharge and a step change in input concentration, the multi-layered Dupuit analysis produced a nearly identical convective outflow concentration to two lumped parameter models linked in a parallel configuration. Thus (2.2.23) and (2.3.64) show nearly identical concentration break-through curves as seen in Figures 2.6 through 2.12. Furthermore, the total mass leaving each system was shown to be identical.

3. Vertical flow effects on convective outflow concentration were examined from a two-dimensional Laplacian point of view using the steady uniform recharge condition and a step change in contaminant input concentration. These vertical flow components of specific discharge are a consequence of the assumed partial stream penetration and an

anisotropic, homogeneous porous medium. Concentration break-through curves for different values of the aspect ratio, $\eta=(L/D)(K_z/K_x)^{1/2}$, are shown in Figure 2.19; the parameter η combines anisotropy and partial penetration into a single variable. For values of η greater than about five, the lumped parameter model (or equivalent Dupuit model) approximates these Laplace break-through curves quite well. However, for values of η less than about five, there are considerable differences between curves. At early time, the Laplace model concentration curves show faster arrival times at the stream or tile drain than does the lumped model curve. At late time, however, these Laplace curves are "retarded" in comparison to the lumped curve. These arrival times simply reflect the longer contaminant flow paths resulting from pronounced vertical flow effects. Furthermore, when the impermeable basement is taken at some infinite depth below the stream or tile drain, the resulting concentration break-through curve is nearly identical to that for $\eta = 1$. Thus the vertical flow effects seem to reach a maximum for near a value of η near one. In other words, the shallow aquifer circulation pattern does not significantly change for η values less than about one; the resulting break-through curves therefore do not significantly change either. In these analyses, the degree of partial stream penetration was assumed to be very small in relation to total saturated thickness. Thus, the Laplace results presented here, along with the fully penetrating Dupuit or equivalent lumped parameter analysis, should be viewed as extreme situations. When the degree of stream penetration is not small in comparison to the total saturated thickness, the Laplacian analysis should yield concentration break-through curves somewhere between the above mentioned limits.

4. The effects of stream clogging, resulting from reductions in hydraulic conductivity up to two orders of magnitude in the small zone surrounding the stream or tile drain, have negligible effects on concentration break-through curves (see Figure 2.18 compared to Figures 2.44 and 2.46).

5. The vertical flow effects associated with multi-layered aquifer systems were shown to have an influence on the convective outflow concentration in the stream or tile drain (see Figures 2.24, 2.27, 2.30, 2.33, 2.36, 2.39, 2.42, and 2.49). These results indicate large systematic departures from the well-mixed linear lumped parameter curve at late time, even though the early time concentrations are in fair agreement. These departures are most pronounced for relatively thin upper layers (i.e., the upper layer is less than 1/4 the total saturated thickness); and for the upper layer having nearly the same hydraulic conductivity as the lower layer. Vertical flow effects obviously are important under such circumstances. However, for an upper to lower hydraulic conductivity (K_u/K_L) equal to 20, and a total saturated thickness to upper layer thickness ratio (D/h) equal to four, the lumped model will accurately predict the stream concentration level down to about $c/c_o = 0.15$ for all values of η (Figure 2.24). In all cases examined, decreasing the drain half spacing to total saturated thickness ratio (L/D) results in large departures from the lumped break-through curves. The pronounced vertical flow effects associated with smaller L/D ratios are at least partially offset by increases in the K_x/K_z ratio.

6. Outflow concentration from the lumped parameter model used in a parallel type configuration as given by (2.4.16) closely approximates the multi-layered concentrations predicted from the two-dimensional analysis

quite well (see Figures 2.50 through 2.55), although vertical flow effects do result in some differences between the Laplace break-through curves for different physical situations (i.e., different ratios for K_x/K_z, L/D, and D/h). Certain parameters in the combined lumped curves predicted from (2.4.16) may be corrected, however, using Figures 2.56 and 2.57. The resulting concentration break-through curves will closely approximate those from the multi-layered Laplace analysis (see Figures 2.58 through 2.63). Thus vertical flow effects resulting from aquifer layering may be approximately incorporated into the seeming crude lumped parameter model with surprisingly good results.

7. The foregoing analyses have attempted to justify certain simplifying assumptions inherent to the lumped modeling approach, and to demonstrate the overall flexibility for incorporating consideration of complex physical phenomena into this format. Though appearing to be superficially crude, this approach implicitly incorporates many multi-dimensional effects found in more elaborate models presently available.

CHAPTER 3

FIELD APPLICATION OF THE LINEAR RESERVOIR MODEL

3.1 Introduction

The predictive capabilities of the lumped parameter linear reservoir model were examined under actual field conditions in the Arkansas River Valley near La Junta, Colorado, where a distributed convective-dispersive model was previously tested (Konikow and Bredehoeft, 1974a; 1974b). Application of the lumped model under these conditions served a dual purpose. First the linear model could be field tested so as to demonstrate the applicability of this approach in representing average temporal hydrological and water quality variations occurring in an irrigated stream-aquifer system under a semiarid climatic setting. Secondly, the lumped model's performance could be directly compared to a conceptually more complex digital model. Of course one would not expect this lumped temporal approach to produce the complete system-wide description inherent to a time dependent spatial model; however, if one's primary objective is to simulate downstream changes in quantity and quality of surface flows, the lumped approach may be sufficient.

The area selected for this detailed field investigation includes an 11 mile reach of the Arkansas River in southeastern Colorado between La Junta and the Bent-Otero County line. This study area has been previously described by Konikow and Bredehoeft (1974a; 1974b; and references therein); Appendix D shows a site location map of the study area. Briefly, in this 11 mile study reach of the Arkansas River, downstream changes in surface water total dissolved solids and shallow groundwater quality have been observed from some time. These changes have been attributed primarily to return flows from irrigated agriculture, but surface runoff from summer thundershowers also contributes to the surface water quality deterioration. The alluvial valley in the study reach is about 1.5 miles wide and covers a gross area of about 17 square miles. Southeastern Colorado has a predominantly semiarid climate characterized by low humidity and scant rainfall. The mean annual precipitation is about 13 inches, two-thirds of which occurs during the growing season (May through September). Irrigation waters are diverted from the Arkansas River into the Fort Lyon Canal just above the study area and west of La Junta. Several minor tributaries and the La Junta municipal sewage effuent enter the river within the study reach. When surface diversions are not sufficient to meet irrigation requirements, additional shallow groundwaters are pumped from the many irrigation wells located throughout the 11 mile reach. The La Junta municipal water supply also depends entirely upon groundwater withdrawn from the valley alluvium inside the study area. The saturated thickness of the recent alluvium in the study reach varies from only a few feet to over forty feet and averages about 18 feet. This shallow alluvium is underlain by a thick sequence of relatively impermeable bedrock.

The computer-based finite difference model used by Konikow and Bredehoeft (1974a) in their study is based on a discretized form of the partial differential equation governing groundwater flow, subject to appropriate initial and boundary conditions. For nonsteady, two-dimensional flow in a nonhomogeneous, anisotropic aquifer, this equation is given by

$$\frac{\partial}{\partial x_i}\left[T_{ij}\ \frac{\partial h}{\partial x_j}\right] = S\ \frac{\partial h}{\partial t} + W\ (x,y,t);\ i,j = 1,2 \qquad (3.1.1)$$

where T_{ij} is the transmissivity tensor (having dimensions of L^2/T); h is the hydraulic head (having dimensions of L); S is the storage coefficient (dimensionless); t is time (having dimensions of T); and W is the volume water flux per unit area (having dimensions of $L^3/T/L^2$). In (3.1.1) W is given by

$$W\ (x,\ y,\ t) = Q\ (x,\ y) + \frac{K_z}{m}\ (H_f - h) \qquad (3.1.2)$$

where Q represents groundwater pumpage or recharge (dimensions of $L^3/T/L^2$); K_z is the vertical hydraulic conductivity of the steambed (dimensions of L/T); m is the streambed thickness (dimensions of L); and H_f is the hydraulic head in the river (dimensions of L). Using an iterative alternating direction implicit procedure, the authors were able to solve a discretized form of (3.1.1) for the time dependent spatial distribution of hydraulic head throughout the study reach. These values of head were then used to calculate the seepage velocity throughout the finite difference grid network using Darcy's law in the form of

$$v_i = -\frac{K_{ij}}{n}\frac{\partial h}{\partial x_j}\ ;\quad i,\ j = 1,2 \qquad (3.1.3)$$

where n is the effective porosity of the aquifer (dimensionless); K_{ij} is the hydraulic conductivity tensor (dimensions of L/T); and v_i is the seepage velocity (dimensions of L/T). Once this seepage velocity was found, the mass transport equation describing the time dependent spatial distribution of dissolved chemical constituents in the saturated porous media could be solved. This mass transport equation is given by

$$\frac{\partial c}{\partial t} = \frac{\partial}{\partial x_i} \left(D_{ij} \frac{\partial c}{\partial x_j}\right) - \frac{\partial (v_i c)}{\partial x_i} - W_i; \; i,j = 1,2 \qquad (3.1.4)$$

where c is the mass concentration of dissolved solids (dimensions of M/L^3); D_{ij} is the hydrodynamic dispersion tensor (dimensions of L^2/T); and W_i is the mass flux of any sources or sinks of dissolved solids (dimensions of M/L^3T). In the study by Konikow and Bredehoeft, contributions of molecular and ionic diffusion to the hydrodynamic dispersion tensor were neglected since seepage velocities were sufficiently large so as to overwhelm these effects. The hydrodynamic dispersion tensor was further decomposed into longitudinal and transverse components taken parallel and perpendicular, respectively, to a given streampath. These components were described by the relationship

$$D_L = \alpha_1 v \text{ and } D_T = \alpha_2 v \qquad (3.1.5)$$

where D_L and D_T are these respective components; α_1 and α_2 are the longitudinal and transverse dispersivities; and v is the seepage velocity. The authors further assumed that $\alpha_2 = 0.3 \alpha_1$, but pointed out that sensitivity of the output results to variations in this relationship were not evaluated. Finally the authors used the method of characteristics to solve the discretized version of (3.1.4) since this method does not introduce any artificial dispersion associated with the numerical procedure. The interested reader is referred to the original references already given for a more complete description of these procedures used in the Arkansas River Valley study.

3.2 Arkansas River Linear Reservoir Model

Derivation of the lumped parameter linear reservoir model for application to the irrigated stream-aquifer configuration along the Arkansas River Valley is nearly identical to that previously derived in Chapter 2. However, slight modifications to the general form of the model are often required for specific case studies; the derivation here will thus serve to demonstrate the flexible nature of the lumped modeling approach.

Based on the data summary provided by Leonard F. Konikow (personal communication, 1977), the irrigated system along the Arkansas River near La Junta may be depicted as a series of observed and estimated inputs and outputs as shown in Figure 3.1 below. One major difference between the model representation here and that given previously in Chapter 2 is the water source of q_{et}; the reason for this depicted difference will become obvious later. In the figure, q_s represents the volumetric surface water application rate per unit surface area and has a concentration level c_o; q_l represents the volumetric surface water seepage per unit surface area lost to the aquifer; q_b represents the net volumetric boundary flux per unit surface area having a concentration level c which is assumed identical to the average aquifer concentration level; q_p and q_m represent the volumetric irrigation and municipal pumpage rates per unit surface area, respectively; q_{et} represents the volumetric phreatophyte evapotranspiration rate per unit surface area which is assumed to contain no dissolved contaminants; ε represents the net aquifer recharge rate (that is, the total applied water minus the crop evapotranspiration) per unit surface area and has a concentration level of c_i; and q_r represents the natural aquifer outflow rate to the river or aquifer drains per unit surface area having a concentration level of c'. If q_r is positive as depicted in the figure, then c' = c, the average aquifer concentration. Using the linear reservoir assumption previously introduced, q_r may be approximated by the relationship:

$$q_r = a_r\ (h - h_r) \tag{3.2.1}$$

which is analogous to (2.2.2). If the average aquifer water level, h, falls below the average stream reference level, h_r, then q_r will be negative and water will be transferred from the river to the aquifer with $c' = c_r$, the concentration level in the river. Note that for this situation, one would generally expect $c_r = c_o$, the concentration level of surface irrigation waters; however, in the Arkansas River Valley near La Junta, surface waters are diverted from the river above the actual irrigation site. The river water quality actually deteriorates somewhat before arriving at the study reach while concentration levels in the canal waters remain essentially unchanged. It should also be pointed out that during the study calibration period, there was sufficient water available in the river to maintain the occasional "reverse flow" situation predicted in (3.2.1); that is, for those months when $h < h_r$.

Again it is implied in Figure 3.1 that the aquifer is a well-mixed reservoir, and that any outflows (other than ET) leaving the aquifer will carry this average concentration level. It should also be noted that the valley drainage term q_o in (2.2.1) has been lumped together with the

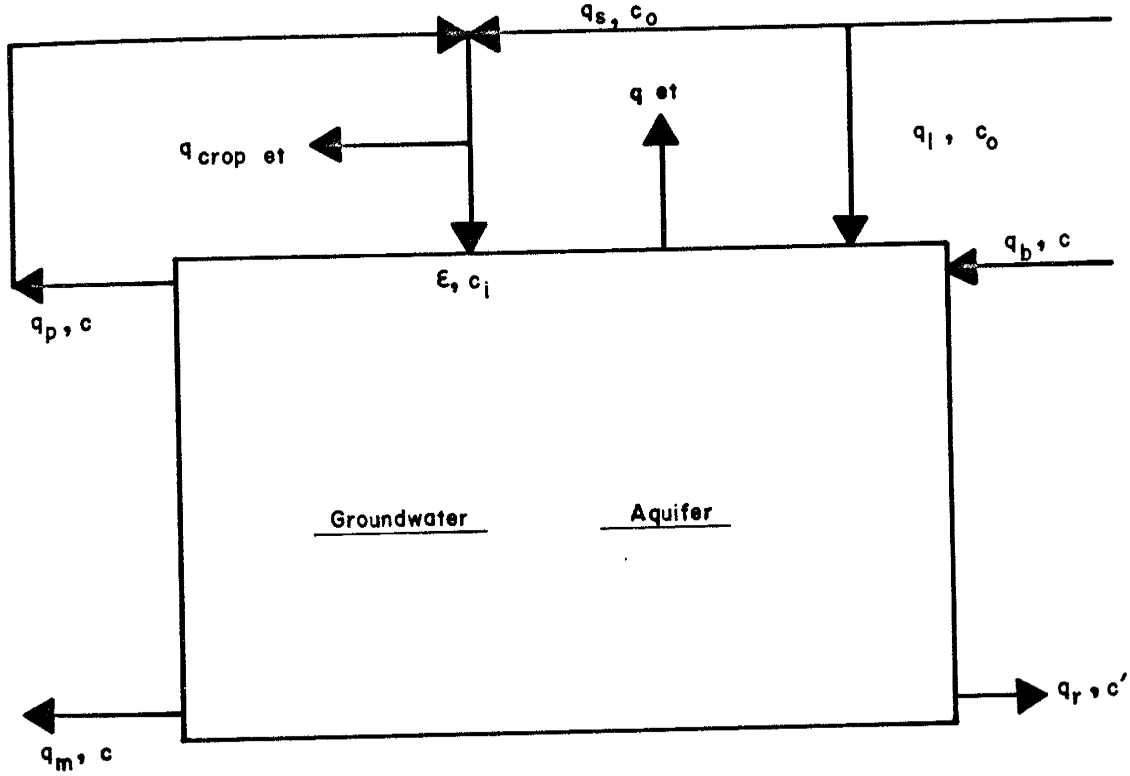

Figure 3.1 Lumped parameter representation of the irrigated stream-aquifer system near La Junta, Colorado.

river-aquifer leakage term, q_r, since observed drain flow data for the study period were not available.

If S is the average storage coefficient (specific yield) of the aquifer, the water balance equation for Figure 3.1 may be written as

$$S \frac{dh}{dt} = \varepsilon + q_1 + q_b - (q_p + q_m + q_{et}) - q_r$$

which may be simplified to

$$\frac{dh}{dt} + (a_r/S)h = \frac{\varepsilon_{net} + a_r h_r}{S} \qquad (3.2.2)$$

where q_r is given by (3.2.1) and where $\varepsilon_{net} = \varepsilon + q_1 + q_b - (q_p + q_m + q_{et})$. In the data provided by Konikow (personal communication, 1977), the terms in parentheses were not reported individually but rather were all combined. Hence in Figure 3.1, the q_{et} term is depicted as having an aquifer source. This representation will not affect the mass balance equation because the total dissolved solids content of the q_{et} waters was assumed to be zero. The general solution to (3.2.2) for a pulsed net recharge, ε_{net}, may be easily found by utilizing an integration factor of $\exp(- a_r t/S)$. Thus

$$h = (h_r + \frac{\varepsilon_{net}}{a_r}) + (h_o - h_r - \frac{\varepsilon_{net}}{a_r}) \exp(-a_r t/S)$$

where h_o is the average aquifer water level at time t = 0. This equation may be discretized over any time interval Δ t, as shown in Figure 3.2, by considering the pulsed net recharge ($\varepsilon_{net_{i+1/2}}$) to be

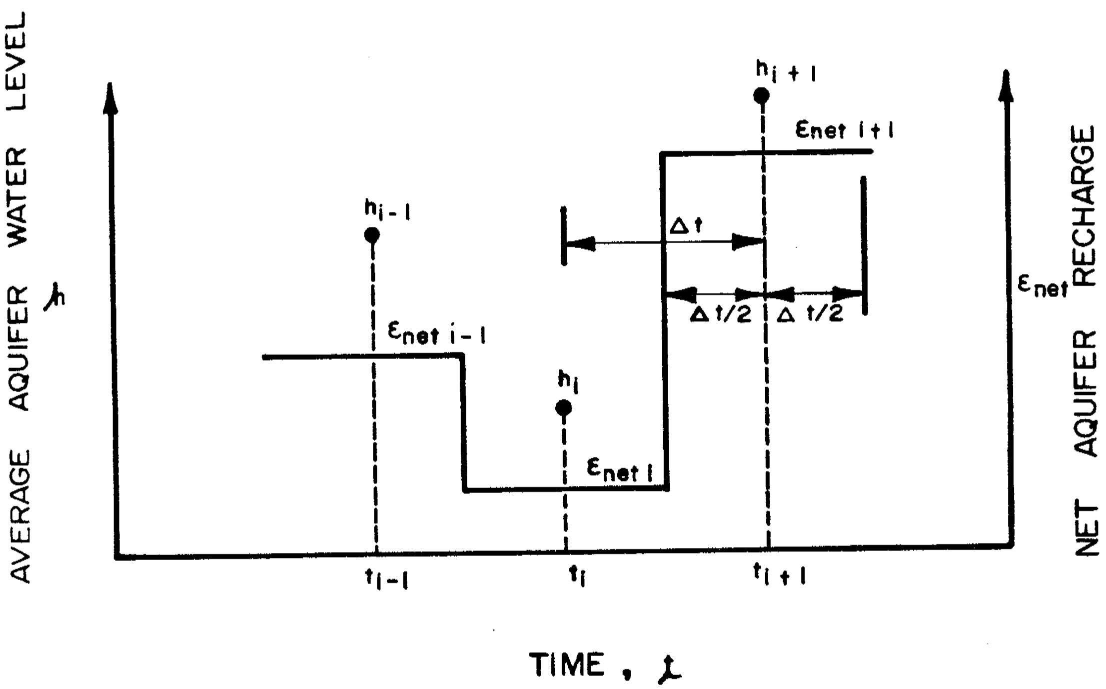

Figure 3.2 Discretized subscript notation for water balance equation.

measured in the middle of the i th and (i+1) time steps. Thus we may write the relationships

$$h_{i+1/2} = (h_r + \frac{\varepsilon_{net_i}}{a_r}) + (h_i - h_r - \frac{\varepsilon_{net_i}}{a_r}) \exp(-\Delta t/2t_h)$$

$$h_{i+1} = (h_r + \frac{\varepsilon_{net_{i+1}}}{a_r}) + (h_{i+1/2} - h_r - \frac{\varepsilon_{net_{i+1}}}{a_r}) \exp(-\Delta t/2t_h)$$

where $t_h = S/a_r$, the hydraulic response time of (3.2.2). Combining these last two equations yields

$$h_{i+1} = (h_r + \frac{\varepsilon_{net_{i+1}}}{a_r}) + (h_i - h_r - \frac{\varepsilon_{net_i}}{a_r}) \exp(-\Delta t/2t_h)$$

$$+ \frac{1}{a_r} (\varepsilon_{net_i} - \varepsilon_{net_{i+1}}) \exp(-\Delta t/2t_h) \qquad (3.2.3)$$

A mass balance relationship for Figure 3.1 may also be written. Thus

$$n \frac{d(hc)}{dt} = \varepsilon c_i - q_{et} c_{et} + q_l c_o + q_b c - q_p c - q_m c - q_r c' \qquad (3.2.4)$$

where $c_{et} \simeq 0$. Combining (3.2.2) and (3.2.4), and assuming that $S = n$, yields

$$Sh \frac{dc}{dt} + c(\varepsilon + q - q_p - q_{et} - q_r) = c_o (q_s + q_l) - q_r c' \qquad (3.2.5)$$

where $\varepsilon c_i = q_s c_o + q_p c$. If $q_r > 0$ (i.e., $h > h_r$), then $c' = c$, and (3.2.5) becomes

$$Sh \frac{dc}{dt} + (\varepsilon_{TOT})c = (q_{TOT})c_o \qquad (3.2.6)$$

where $\varepsilon_{TOT} = \varepsilon + q_l - q_p - q_{et}$ and $q_{TOT} = q_s + q_l$. If $q_r < 0$ (i.e., $h < h_r$), then $c' = c_r$, and (3.2.5) becomes

$$Sh \frac{dc}{dt} + (\varepsilon'_{TOT})\, c = (q'_{TOT})c'_o \qquad (3.2.7)$$

where

$$\varepsilon'_{TOT} = \varepsilon + q_l - q_p - q_{et} - q_r = \varepsilon_{TOT} - q_r$$

$$q'_{TOT} = q_s + q_l - q_r = q_{TOT} - q_r$$

$$c'_o = [c_o(q_s + q_l) - q_r c_r]/q'_{TOT}$$

A general analytical solution to (3.2.5) for a pulsed recharge of constant concentration is not readily available when h is not constant. However, a numerical approximation may be obtained via an explicit discretization. Hence, for (3.2.6) and from Figure 3.3, we obtain the backward difference relationship given by

$$[\frac{c_i - c_{i-1}}{\Delta t}] + c_i\, [\frac{\varepsilon TOT_i + \varepsilon TOT_{i-1}}{2}] \,/\, [\frac{S\; h_i + h_{i-1}}{2}]$$

$$= c_o\, [\frac{q_{TOT_i} + q_{TOT_{i-1}}}{2}]/[\frac{S\,(h_i + h_{i-1})}{2}]$$

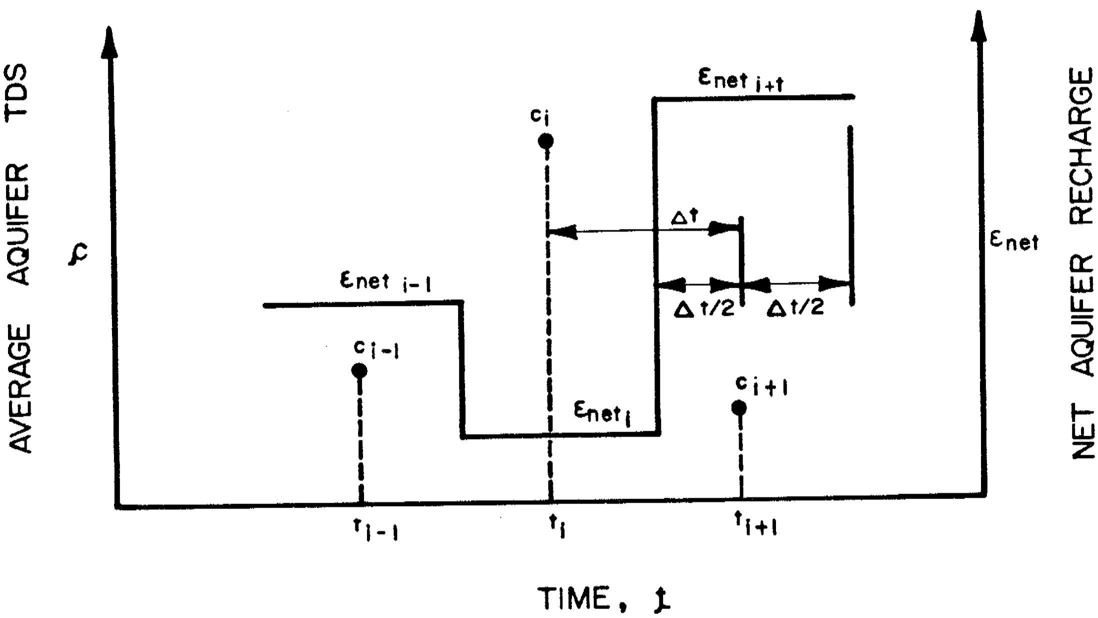

Figure 3.3 Discretized subscript notation for mass balance equation.

This expression may be rearranged to yield

$$c_i = [c_{i-1} + \frac{\Delta t(q_{TOT_i} + q_{TOT_{i-1}})\, c_{o_i}}{S(h_i + h_{i-1})}]/[1 + \frac{\Delta t\,(\varepsilon_{TOT_i} + \varepsilon_{TOT_{i-1}})}{S(h_i + h_{i-1})}$$

A similar expression for (3.2.7) may also be written.

Equations (3.2.1), (3.2.2), (3.2.6), and (3.2.7) form a coupled linear description of convective water and mass transport through the irrigated stream connected aquifer system along the Arkansas River Valley near La Junta, Colorado. Although the lumped modeling technique previously given in Chapter 2 would probably form an adequate system-wide temporal description if observed drain flow data were available, the model alterations given here serve to demonstrate the adaptability of this general approach. In addition, these alterations allow the direct comparison of the lumped approach to a physically more complex solution presented by Konikow and Bredehoeft, since their spatially averaged input data may be used directly. These data are summarized in Appendix D. The computer code for the lumped parameter simulations of the Arkansas River Valley is listed in Appendix C.

3.3 Parameter Estimation Procedure

In the proceeding analyses (3.2.2) will yield a general solution for the predicted average water table elevation above some reference datum for the lumped parameter linear reservoir model; (3.2.5) will similarly yield a corresponding aquifer outflow concentration. The lumped model is therefore dynamic when these equations are coupled together; hence it is a truly predictive management tool. Thus if future input stresses can be estimated, then the corresponding system outputs can be found. However, certain physical parameters which characterize the system response must first be estimated. Updegraff and Gelhar (1978) proceeded to estimate a_r and h_r in (3.2.1) for a linear reservoir model using a least squares regression technique for observed average water level and drain flow data in the Mesilla Valley of southcentral New Mexico. Once these parameters were found, they discretized an equation similar to (3.2.2), except that a net aquifer recharge term (ε_{net}) and a constant river leakage term (q_l) were separately identified. They obtained a least squares estimate of n and q_l for periods of no irrigation (i.e., no net recharge). Their equation could then be resolved for net recharge using the above parameters and observed values of average water level elevations for periods of active irrigation assuming the river leakage remained constant for a given recharge-recession period. Their procedure worked extremely well in the Mesilla Valley for the five year period 1946-1951. However, in the Arkansas River Valley study, no drain flow data is currently available; thus their technique does not apply here. Instead, an alternate but similar procedure was employed since the data of Konikow and Bredehoeft includes water level elevations from 40 observation wells (see Appendix D) and their calculated net aquifer recharge. Furthermore, they have estimated the effective porosity and storage coefficient as $n = S = 0.20$.

Rewriting (3.2.2) in integral form and using a Simpson integration approximation yields

$$n\,(h_{i+2} - h_i) + \frac{a_r\,\Delta t}{3}\,(h_i + 4h_{i+1} + h_{i+2}) - 2a_r h_r\,\Delta t \qquad (3.3.1)$$

$$= \frac{\Delta t}{3}\,(\varepsilon_{net_i} + 4\ net_{i+1} + \varepsilon_{net_{i+2}})$$

where i represents a given time step and Δt the time interval. In this equation, h and ε_{net} are known over twelve time intervals for $\Delta t = 1$ month. Thus we may represent the best estimate of (3.3.1) as

$$Y = \beta_o + \beta_1 X_1 + \beta_2 X_2 + E \qquad (3.3.2)$$

where

$$Y = \Delta t/3\ (\varepsilon_{net_i} + 4\varepsilon_{net_{i+1}} + \varepsilon_{net_{i+2}})$$

$$\beta_o = -\ 2a_r h_r\ \Delta t,$$

$$\beta_1 = n$$

$$\beta_2 = a_r$$

$$X_1 = (h_{i+2} - h_i)$$

$$X_2 = \Delta t/3\ (h_i + 4h_{i+1} + h_{i+2})$$

and where E represents the residual between the observed value of the dependent variable Y and its "true" value, and where $\varepsilon_{net} = \varepsilon + q_1 + q_b - (q_p + q_m + q_{et})$, from (3.2.2). Equation (3.3.2) may be viewed as a parametric equation describing the "true" value of some dependent variable Y, while (3.3.1) describes the corresponding observed value. Since ε_{net} and h are known in (3.3.1), the parameters β_o, β_1, and β_2 may be estimated via a least squares regression so as to minimize the difference between the two equations; that is, to minimize E. This procedure is well known (Draper and Smith, 1966, for example) and will not be fully described here. However, the procedure basically involves solving the simultaneous equations given below for b_o, b_1, and b_2.

$$\sum_{i=1}^{m} Y_i = b_o m + b_1 \sum_{i=1}^{m} X_{1_i} + b_2 \sum_{i=1}^{m} X_{2_i} \qquad (3.3.3)$$

$$\sum_{i=1}^{m} X_{1_i} Y_i = b_o \sum_{i=1}^{m} X_{1_i} + b_1 \sum_{i-1}^{m} X_{1_i}^2 + b_2 \sum_{i=1}^{m} X_{1_i} X_{2_i}$$

$$\sum_{i=1}^{m} X_{2_i} Y_i = b_o \sum_{i=1}^{m} X_{2_i} + b_2 \sum_{i=1}^{m} X_{1_i} X_{2_i} + b_2 \sum_{i=1}^{m} X_{2_i}^2$$

In these equations b_o, b_1, and b_2 represent the best estimates for β_o, β_1, β_2, respectively. Since the Konikow-Bredehoeft data has 12 monthly water level and recharge observations and the Simpson approximation implies a moving three point averaging process, m = 10 in the above relationships. For a complete data description see Appendix D. These "observations" used in (3.3.3) are actually the mean water level values as found using a Thiessen polygon weighting technique for the 40 observation wells and the average valley recharge (ε) estimated by Konikow and Bredehoeft. This information together with (3.3.2) and (3.3.3) yields

$$S = 0.098$$

$$a_r = 0.0791/\text{month}$$

$$h_r = 4011.13 \text{ feet}$$

$$t_h = 1.24 \text{ months}$$

Since the S found above is less than half that used by Konikow and Bredehoeft, it was decided to let S equal their value (i.e., S = 0.20), and resolve (3.3.3) to obtain

$$S = 0.20$$
$$a_r = 0.0720/\text{month}$$
$$h_r = 4011.16 \text{ feet}$$
$$t_h = 2.78 \text{ months}$$

The differences in the two techniques probably reflect some errors in calculating the net aquifer recharge; furthermore, some substantial differences were found between the Thiessen weighted average water levels and the spatially averaged values obtained from the Konikow-Bredehoeft model. While some variation is expected, the differences encountered (see Table 3.1 or Figure 3.7) were rather large and may have resulted from the location of the observation wells. That is, if too many of these wells are located near drains, pumping wells, or conveyance canals, they may not show a representative water level. It is interesting to note that if the Konikow-Bredehoeft average water levels were used in (3.3.3) above instead of the Thiessen values, one would find that

$$S = 0.233$$
$$a_r = 0.0204/\text{month}$$
$$h_r = 4013.67 \text{ feet}$$
$$t_h = 11.42 \text{ months}$$

Since S = 0.233 as compared to 0.20, one might expect this third parameter set to be the most representative of the data; however, the large aquifer response time leads one to suspect that the parameter a_r is too small. Whatever the shortcomings of the data or parameter estimation procedure may be, the second set of parameters was chosen for all subsequent simulations. The data used in the above parameter estimation procedures are briefly summarized in Table 3.1

Table 3.1: Data summary for the parameter estimation.

	Konikow-Bredehoeft ave aq. water level(1)	Thiessen aq. water level(2)	Net Aq. Recharge(3)
March 1971	4013.74 feet	4011.80 feet	0.011 ft/mo
April	4013.60	4011.24	-0.013
May	4013.64	4011.13	-0.016
June	4013.74	4010.57	-0.071
July	4013.76	4010.82	-0.058
August	4013.45	4010.50	-0.061
September	4013.35	4010.57	-0.036
October	4013.46	4010.64	0.016
November	4013.64	4011.21	0.067
December	4013.66	4011.61	0.046
January 1972	4013.68	4011.70	0.043
February	4013.68	4011.65	0.036

(1) The arithmetically averaged water levels as predicted from the uniformly spaced, block-centered, rectangular finite difference grid used by Konikow and Bredehoeft (1974a), and consisting of 20 rows and 44 columns.

(2) Thiessen averaged water levels based on forty observation wells located within the study reach, as depicted in Appendix D.

(3) The lumped net recharge, ε_{net}, as defined in (3.2.2); a negative sign indicates a net valley withdrawal (from Konikow and Bredehoeft, 1974a, and listed in Appendix D).

3.4. Comparative Study Results

Figures 3.4 through 3.8 show a comparison between the spatially averaged data for the 40 observation wells obtained from data provided by Leonard F. Konikow (personal communication, 1977), the Konikow-Bredehoeft spatially averaged model output, and that obtained here for the study period March 1971 through February 1972 using the second parameter set. This calibration period had sufficient input data available to enable a model simulation of the river valley. It can be seen in these figures that both the Konikow-Bredehoeft spatial model and the lumped temporal model reproduce the average observed data in a similar fashion, with the exception of the changes in average aquifer water levels and the aquifer total dissolved solids concentration, in which case the Konikow and Bredehoeft results seem to predict somewhat smaller seasonal changes than that observed or simulated by the lumped parameter model. These later differences may be a result of the difference in spatial averaging (Thiessen polygons for the lumped parameter model versus grid averaging in the Konikow and Bredehoeft model; see Table 3.1).

As was done by Konikow and Bredehoeft with their simulations, the lumped model was used to predict any long-term changes that might occur within the stream-aquifer system. This was accomplished by simulating a five year period, assuming that all system averaged stresses that occurred during the calibration period (March 1971 to February 1972) would also occur in each of the succeeding four years. These simulation results are depicted in Figures 3.9 and 3.10. Extending the simulation period on the basis of the one year observed irrigation practices served three purposes: (1) to further demonstrate the lumped model's

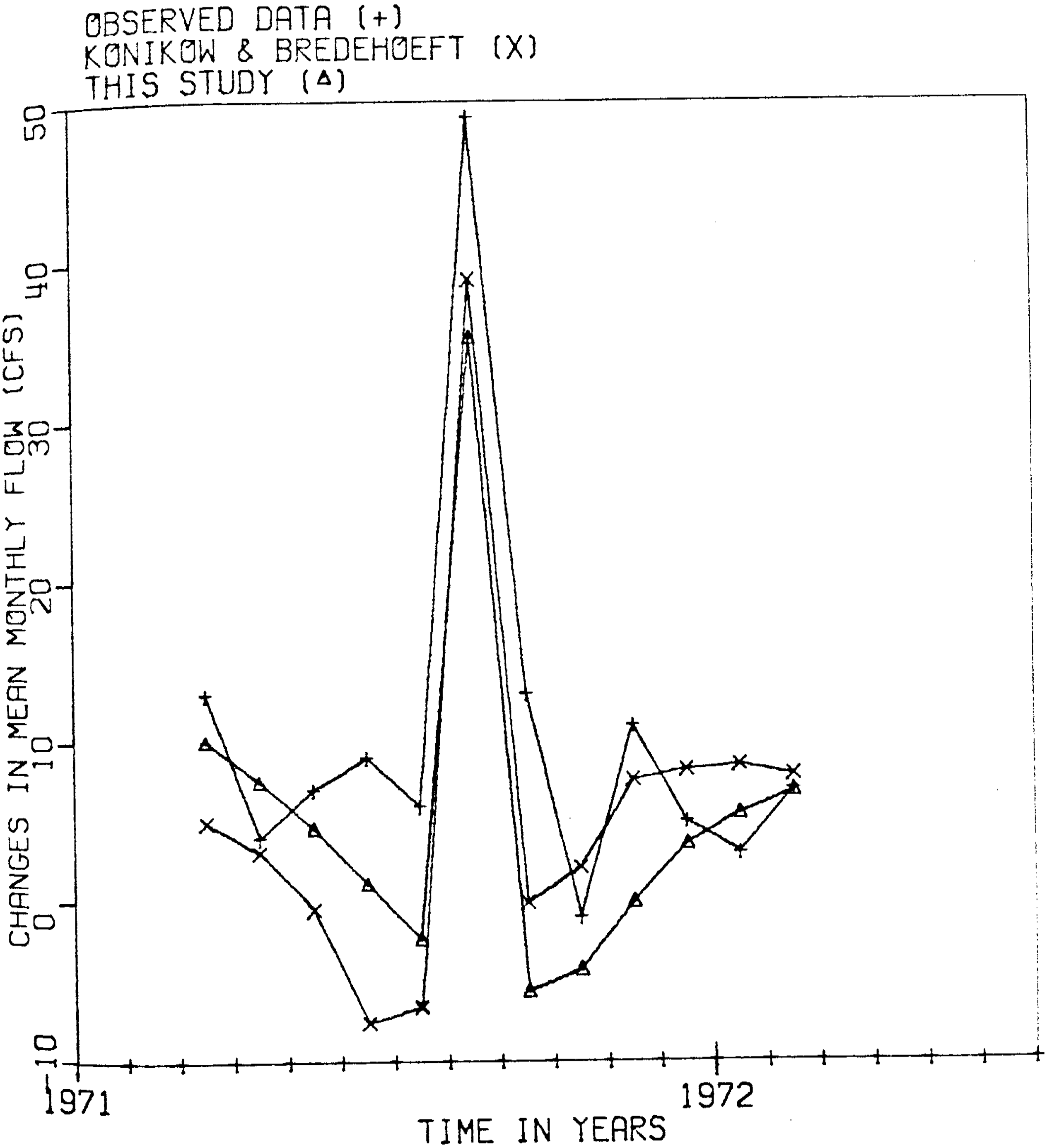

Figure 3.4 Changes in mean monthly river flow over the study reach.

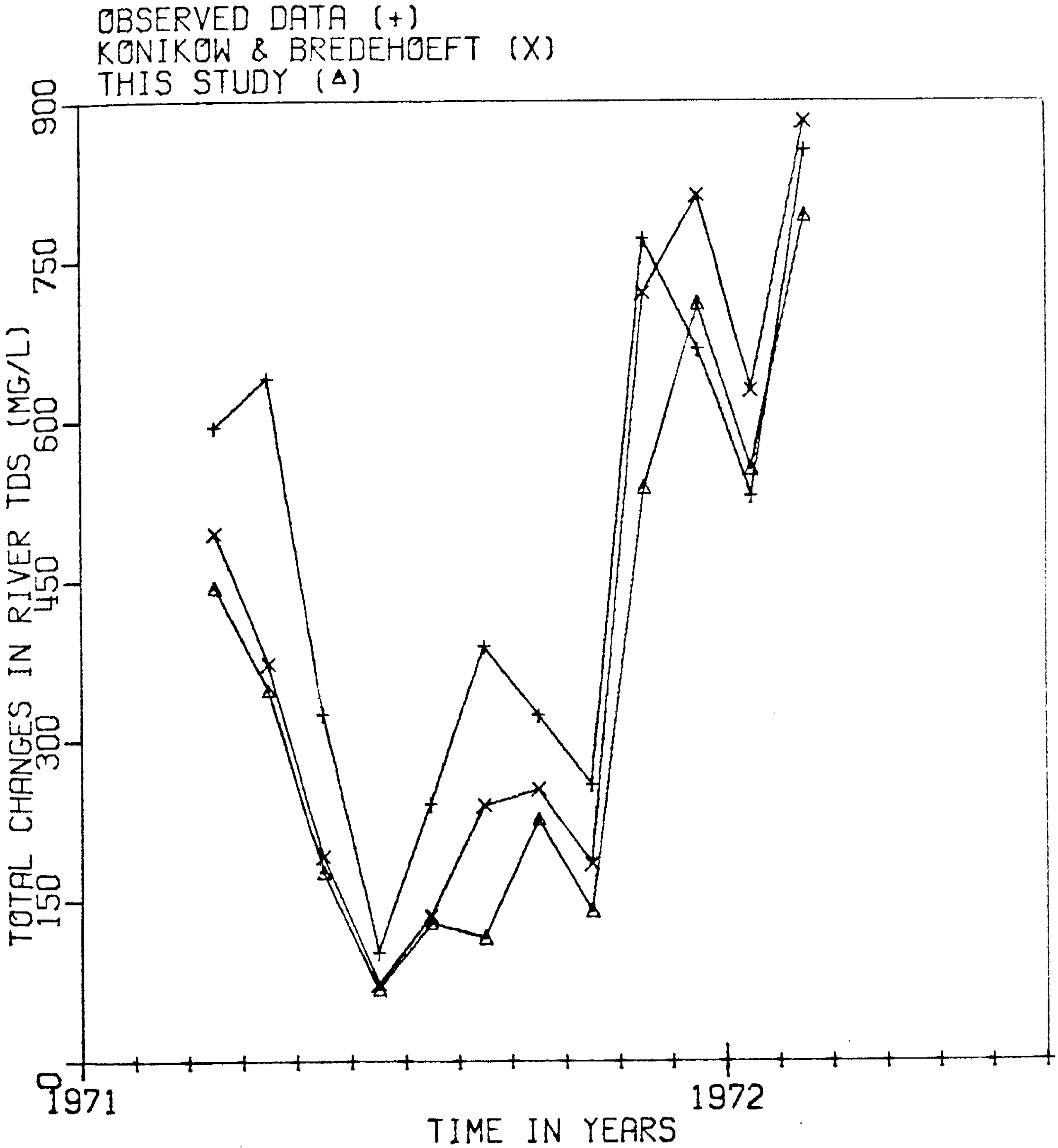

Figure 3.5 Total changes in river TDS between the Ft. Lyon canal diversion and the Bent-Otero County line.

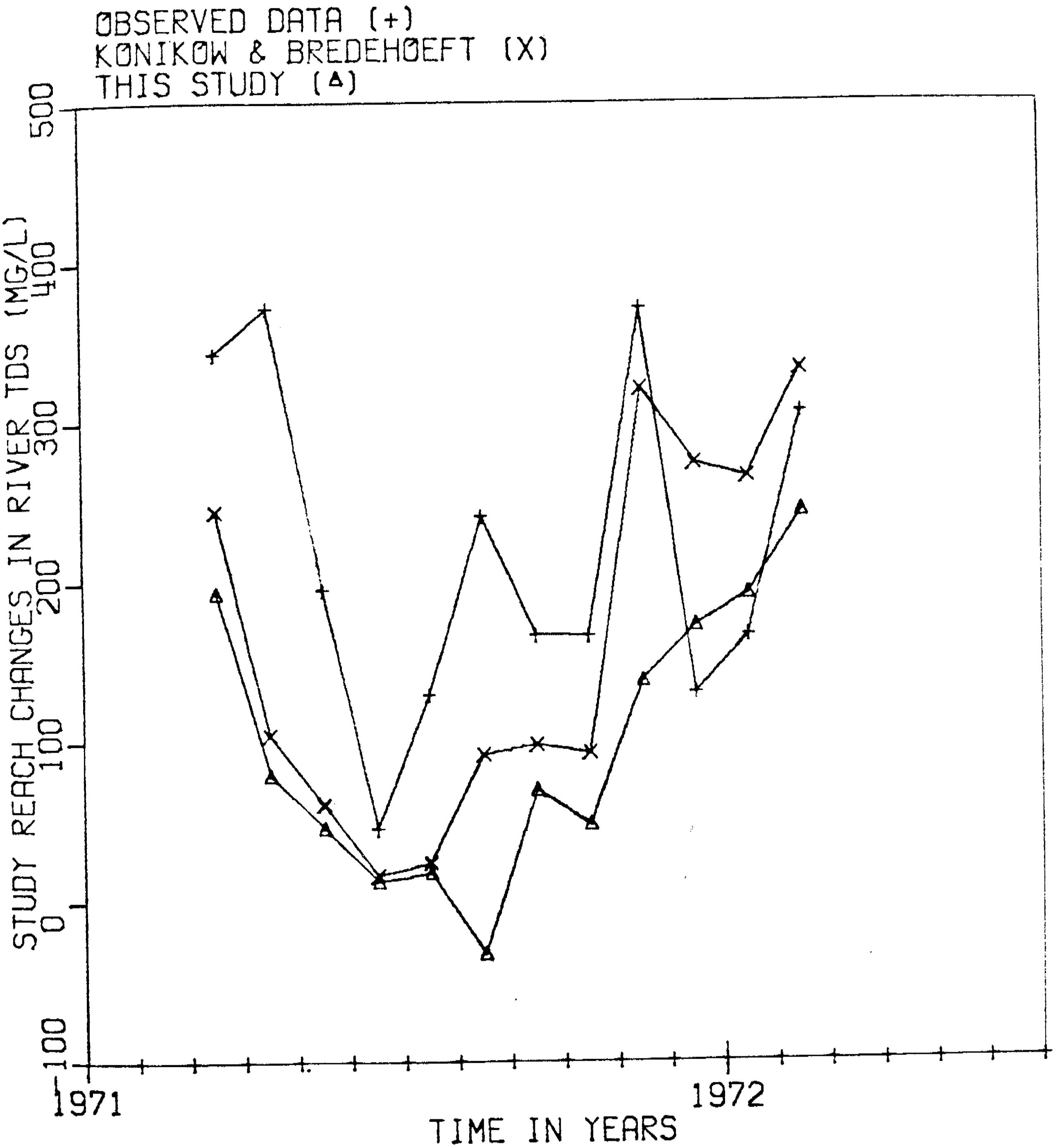

Figure 3.6 Study reach changes in river TDS.

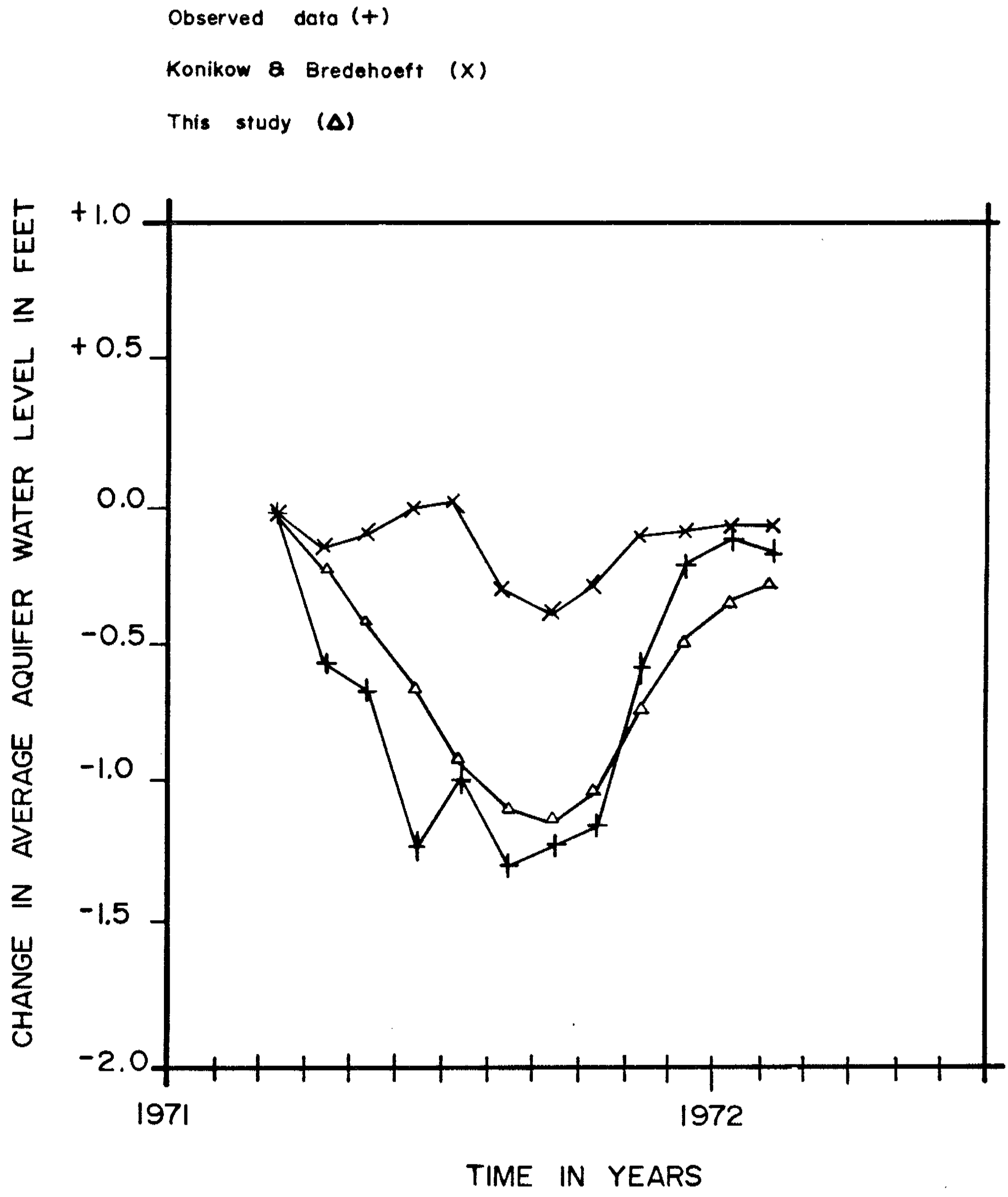

Figure 3.7 Changes in average aquifer water levels in the Arkansas River Valley study area.

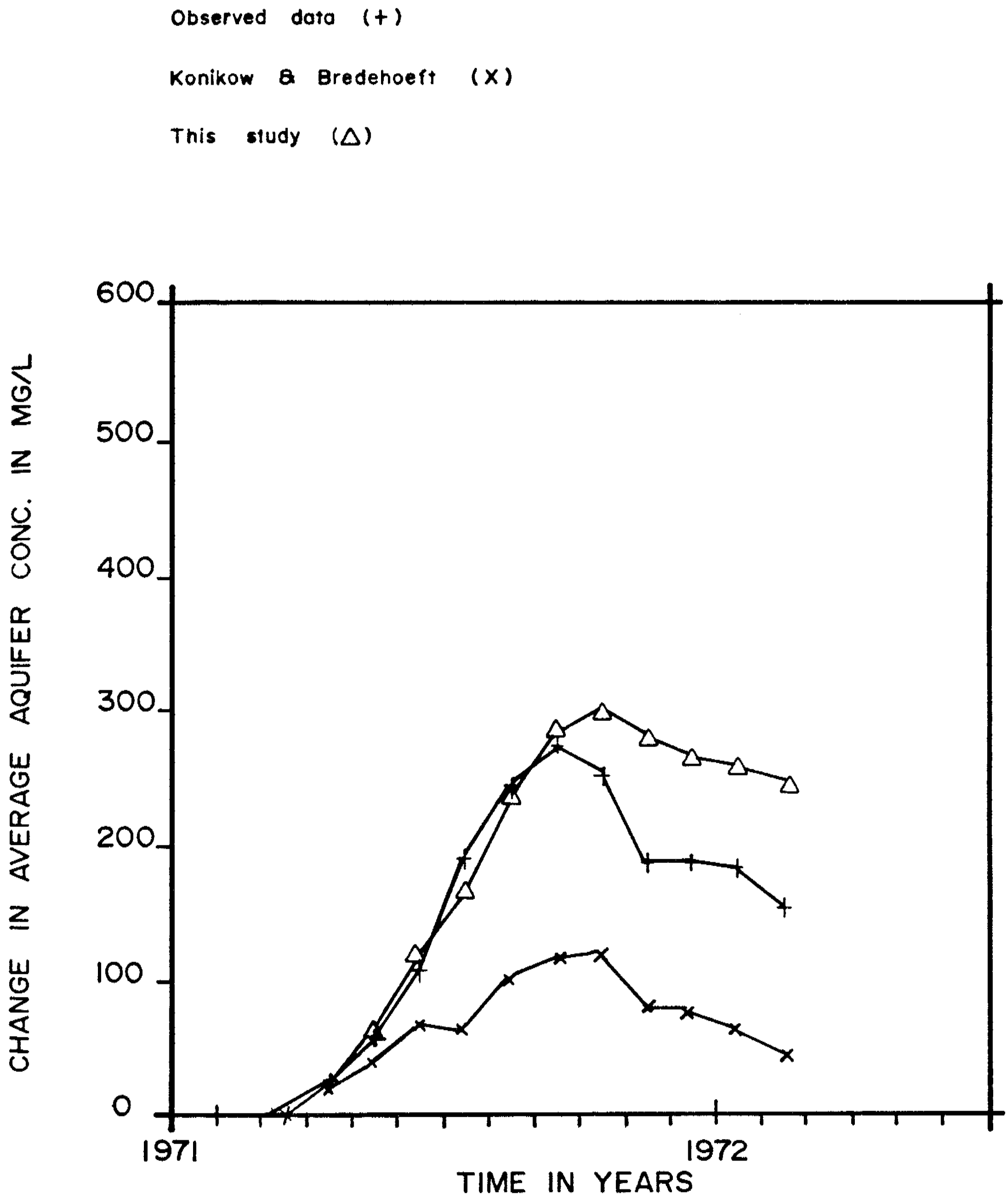

Figure 3.8 Changes in average aquifer TDS concentration in the study reach.

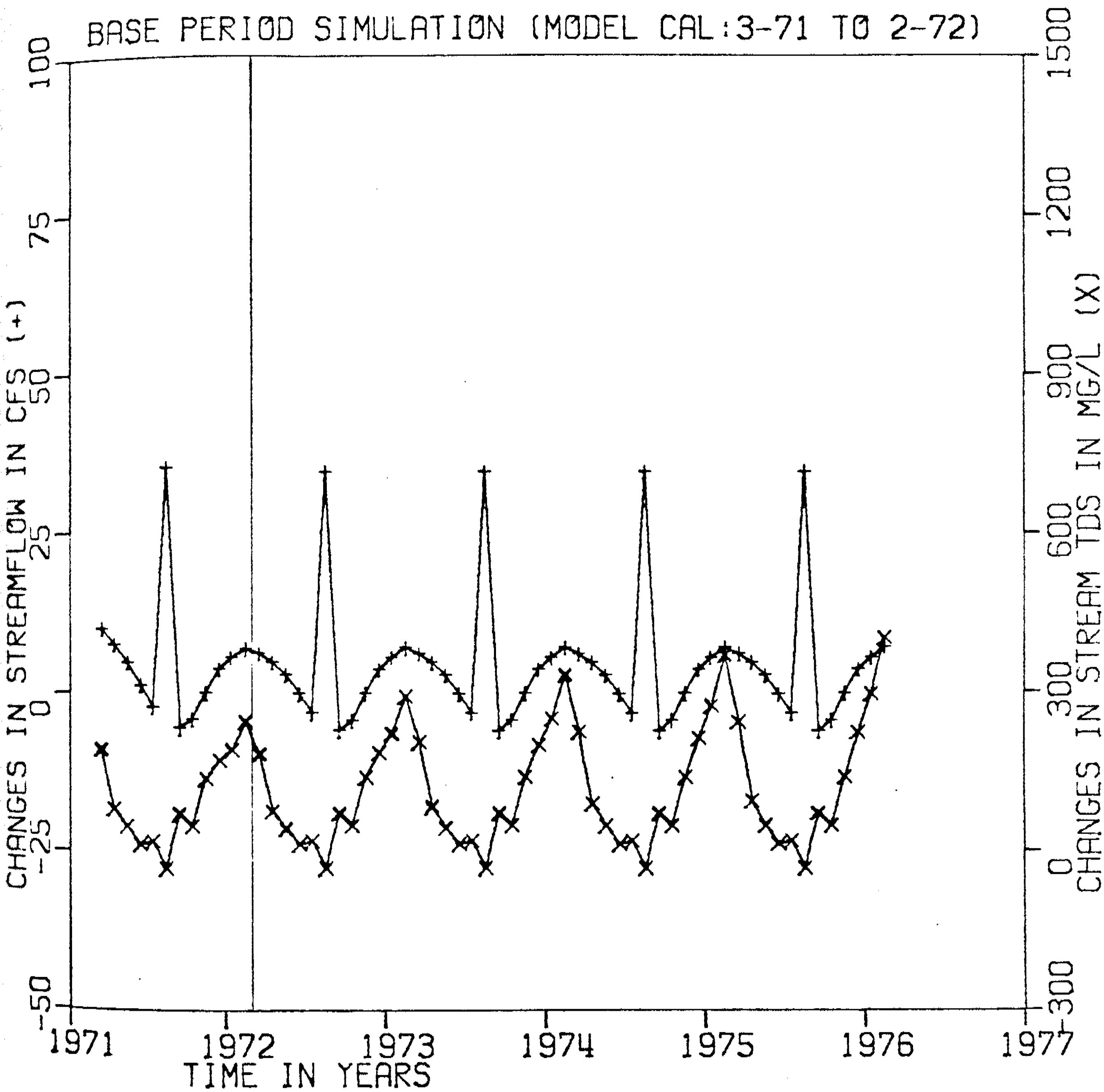

Figure 3.9 Study reach changes in streamflow and surface water quality as a result of extending the lumped model simulation period an additional four years

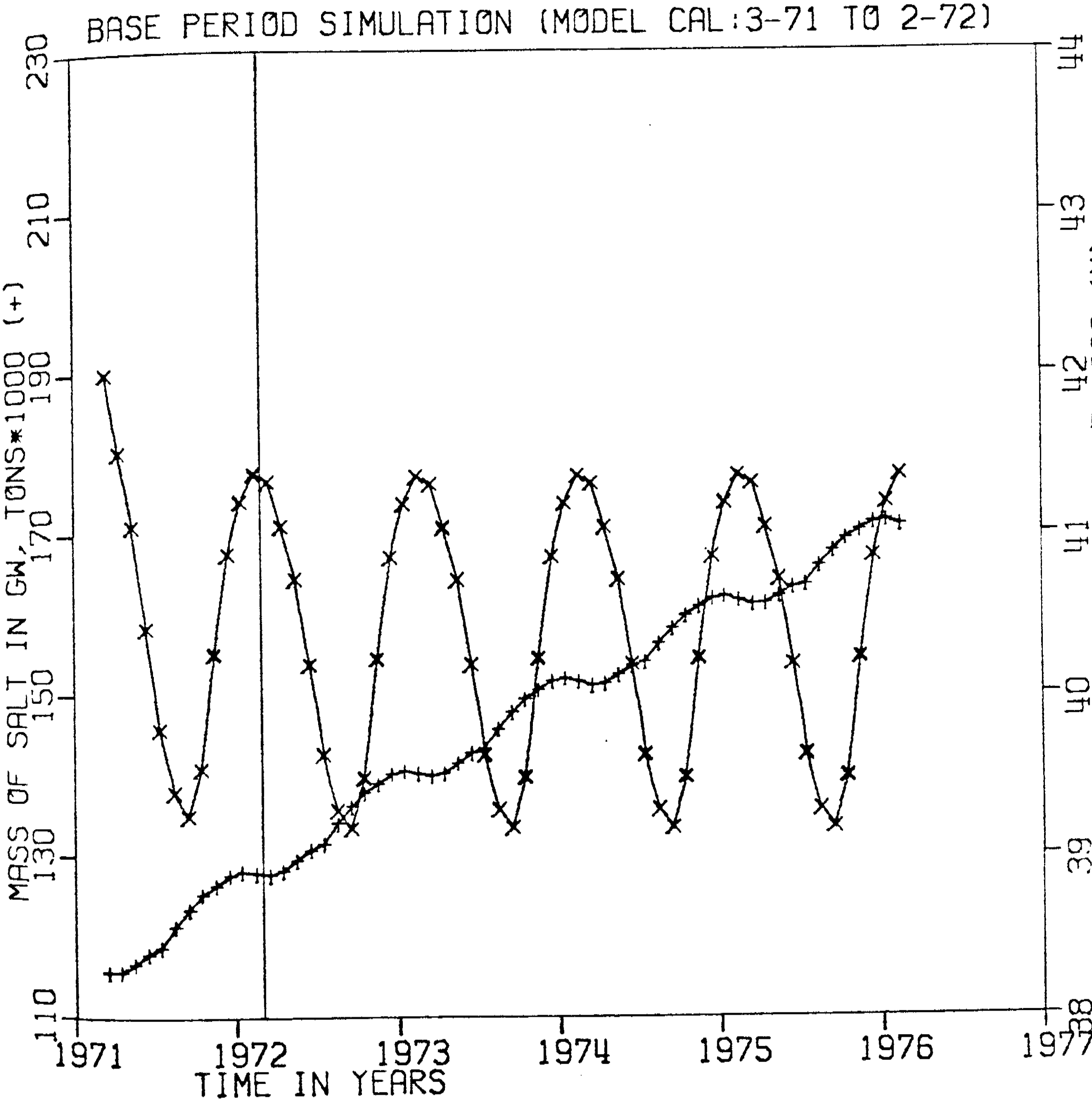

Figure 3.10 Study reach changes in groundwater storage and water quality as a result of extending the lumped model simulation period an additional four years.

capabilities, (2) to provide a basis for comparing the results of other water management options, and (3) to provide an additional basis of comparison with the Konikow-Bredehoeft model simulations.

The results of this five-year simulation are depicted in Figures 3.9 and 3.10; these data are summarized in Table 3.2 along with that from the Konikow-Bredehoeft model. Two hydrological parameters, the volume of groundwater in storage (Figure 3.10) and net stream gains or losses (Figure 3.9), show marked seasonal variations comparable to the Konikow-Bredehoeft model (see Figure 3.9, Konikow and Bredehoeft, 1974b, p. 50). Even though the aquifer parameter estimation procedure used here may only be a crude approximation of actual conditions, the model output still favorably compares to that of Konikow and Bredehoeft.

3.5 Water Management Options with the Linear Model

Following Konikow and Bredehoeft (1974b) the lumped model was evaluated for its ability to predict the long term response of the stream-aquifer system within the study reach associated with changes in irrigation practices or water management options. Because of the uncertainty associated with long term historical precipitation, groundwater withdrawals, surface water irrigation, and the ratio of groundwater to surface water applications, it was decided to present the simulation results on a relative rather than an absolute response; a similar presentation was used by Konikow and Bredehoeft (1974b). However, Appendix D lists both absolute and relative responses to the base period simulation. The four specific water management options are

Table 3.2: Summary comparison between the five year lumped output and the Konikow-Bredehoeft model output

	Lumped Model (1)	Konikow-Bredehoeft Model	Observed (2)
1. Change in groundwater storage in 1000's acre-feet per month:			
minimum	39.2	40.5	
maximum	42.0	42.0	
2. Study reach changes in streamflow in cubic feet per second:			
minimum	-6.3	-7.3	-1.0
maximum	+35.2	+38.9	+49.0
3. Changes in mass of salt stored in groundwater in 1000's tons:			
minimum	116.2	116.2	
maximum	171.2	128.8	
4. Total changes in stream concentration level in milligrams per liter:			
minimum	68.6	72.7	102.2
maximum	793.0	882.0	854.7
5. Study reach changes in stream concentration level in mg/l:			
minimum	-32.4	+17.0	+46.4
maximum	+244.9	+333.9	+371.6

(1) Using $S = n = 0.20$, $a_r = 0.0720$/month, $h_r = 4011.16$ feet. For this case study, $t_h = 2.8$ months, and $t_c = 10.4$ years.

(2) Based on observed data over the period March 1971 to February 1972.

identical to those of Konikow and Bredehoeft (1974b); these are: (1) increased groundwater use, (2) increased surface water use, (3) improved irrigation efficiency, and (4) lining the Fort Lyon Canal to prevent seepage losses.

The first case addressed the following questions: What would the hydrological and chemical effects on the stream-aquifer system be if surface water diversions were not available for irrigation use within the study reach? As was pointed out by Konikow and Bredehoeft, this represents an extreme situation that might occur during a very low flow period in the Arkansas River. As was done by them, it was assumed that both irrigated acreage and total applied water would not change, and that a sufficient number of wells existed to supply the irrigation demand entirely from groundwater pumpage. The results of this test as shown in Figures 3.11 and 3.12, and indicated the following:

1. The water table elevation throughout the study reach near the end of the growing season (September) would decrease by an average 0.8 foot. Konikow and Bredehoeft also reported an average decline of 0.8 foot.

2. A serious deterioration in groundwater quality would occur during the first year; the TDS in the aquifer throughout the study period would increase by an average of 343 mg/l (420 mg/l according to Konikow and Bredehoeft).

3. Streamflow gains resulting from increased groundwater flow directly to the river within the study reach would decrease by an average of 7.2 CFS (cubic feet per second) during the first year. Konikow and Bredehoeft also reported a decrease in flow of 7.2 CFS.

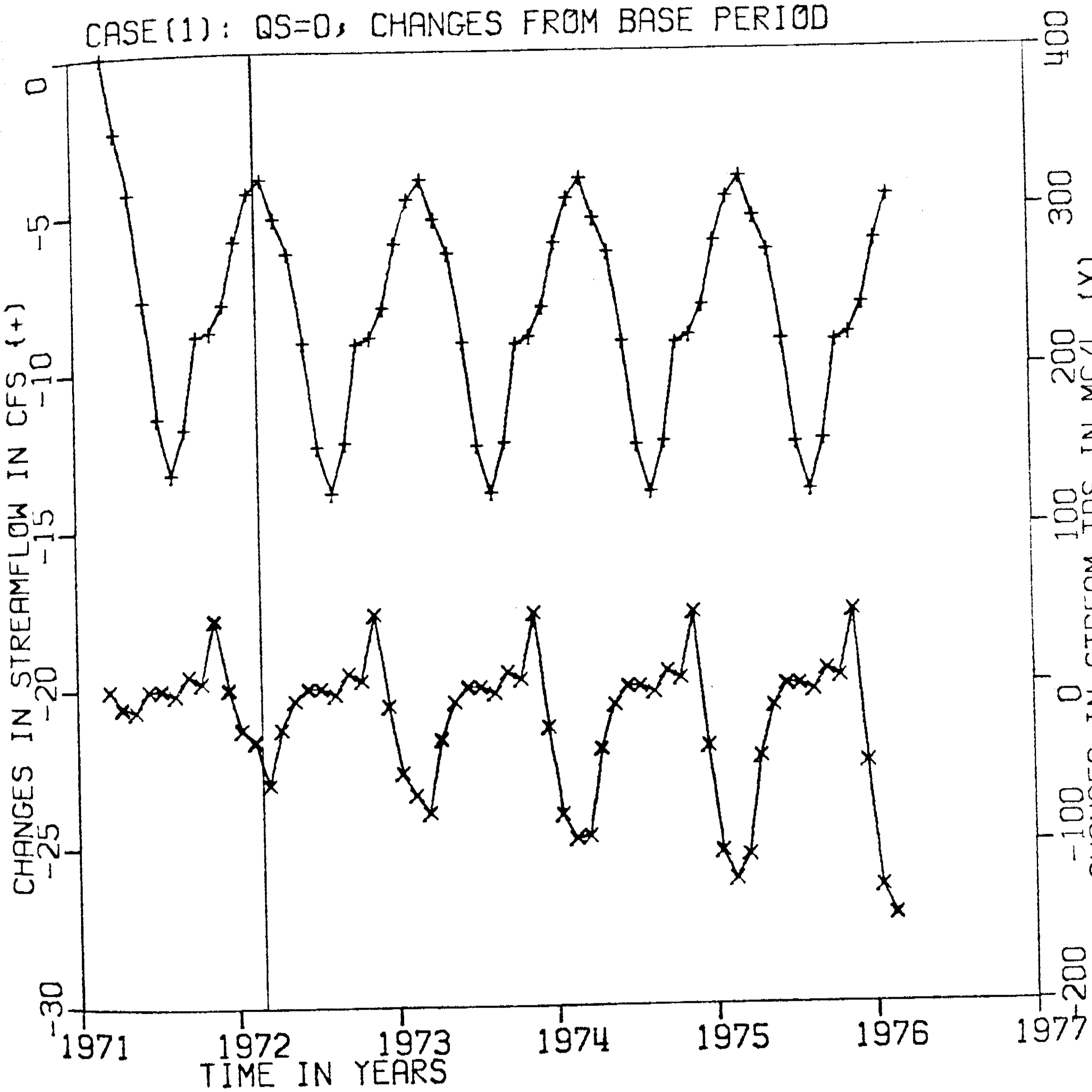

Figure 3.11 Changes in streamflow and surface water quality relative to the base simulation for no surface water diversion for irrigation.

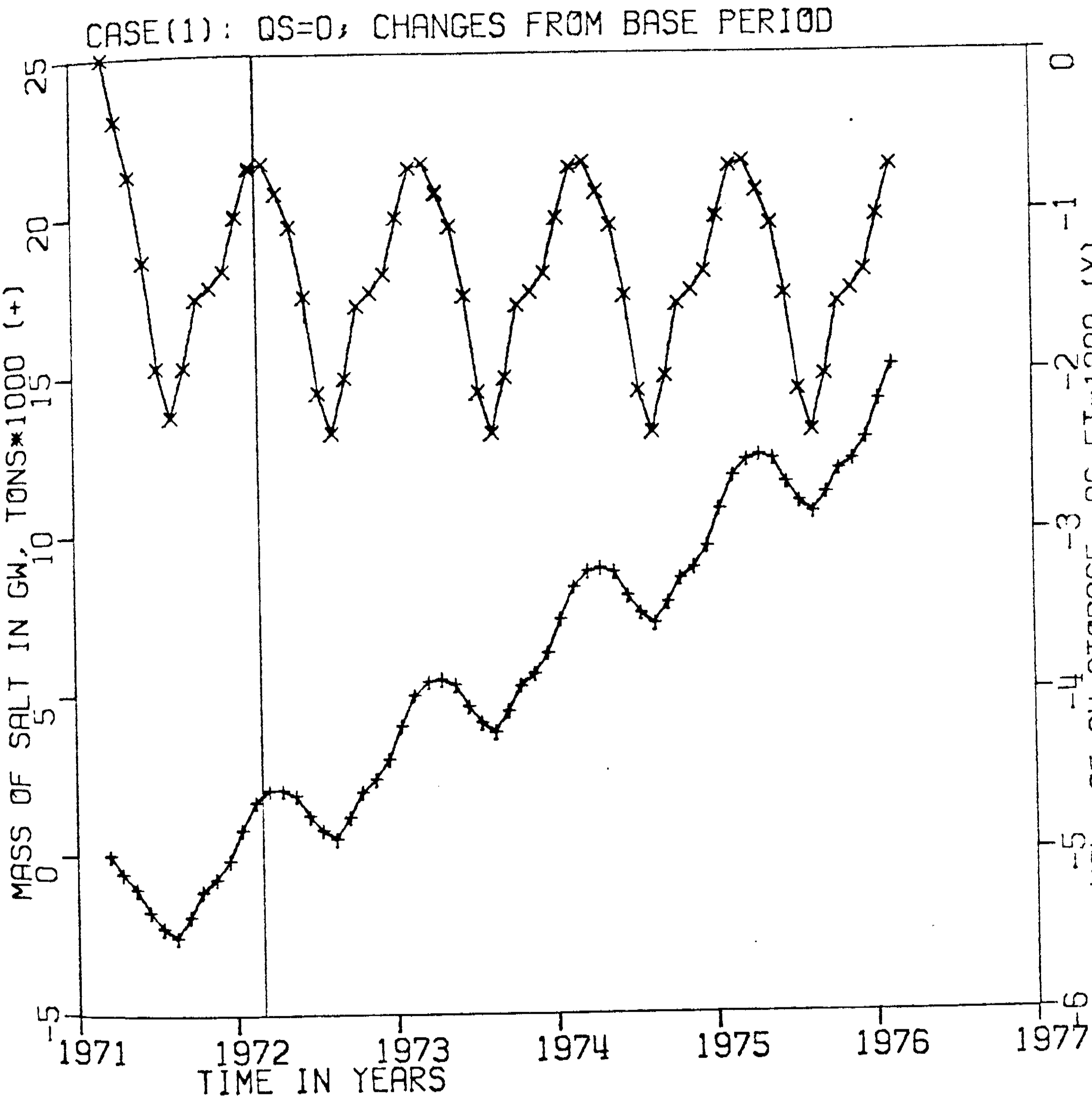

Figure 3.12 Changes in groundwater storage and water quality relative to the base simulation for no surface water diversion for irrigation.

4. The dissolved solids concentration in the Arkansas River at the Bent-Otero County line would decrease by an average of 2.1 mg/l during the first year, and show an average decrease of 35.4 mg/l after five years. Konikow and Bredehoeft reported an average decrease of 20 mg/ in their study.

As was reported in Konikow and Bredehoeft, when all of the irrigation demand is supplied by groundwater, the aquifer TDS concentration level rises dramatically. These increases are due primarily to a higher concentration level in recharge waters, but are also partially related to the decrease in groundwater storage throughout the year. Because average aquifer water levels would fall below the average stream level, the river looses water to the aquifer and a smaller salt load enters the river. This extreme situation demonstrates that an increased ratio of groundwater pumpage to surface water diversions in order to supply irrigation demand will probably result in deteriorating groundwater supplies, although the surface water quality may actually be improved somewhat if sustained pumpage results in a significant lowering of the water table near the river.

The second case also addressed a somewhat extreme situation by asking the question: What would be the effect on the stream aquifer system if all irrigation demands were supplied from surface diversions and no irrigation wells were pumped? It was again assumed that the total irrigated acreage and total applied water remained the same as the base period simulation; Figures 3.13 and 3.14 summarize these results. The results of this test indicated the following:

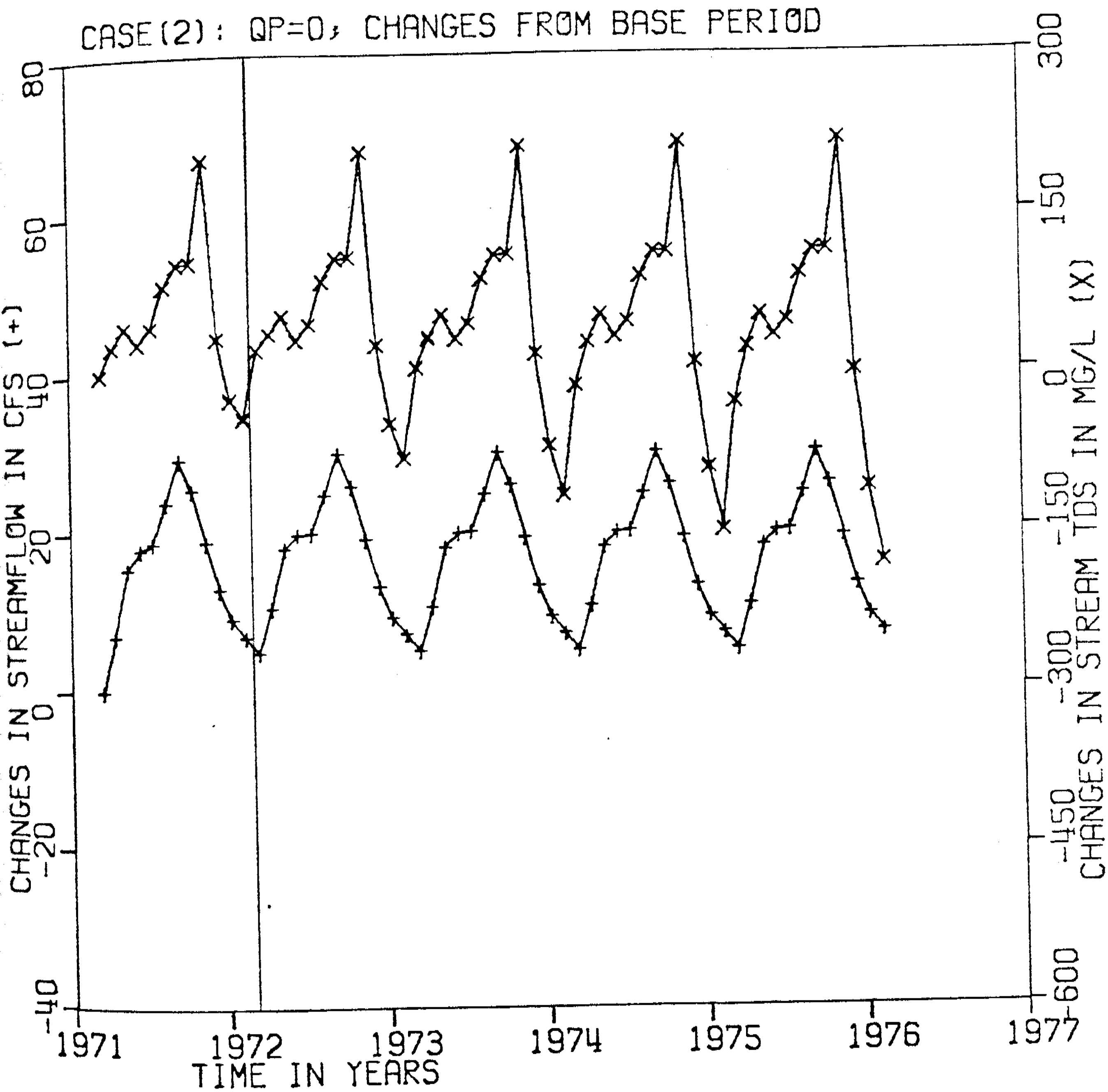

Figure 3.13 Changes in streamflow and surface water quality relative to the base simulation for no groundwater pumpage for irrigation.

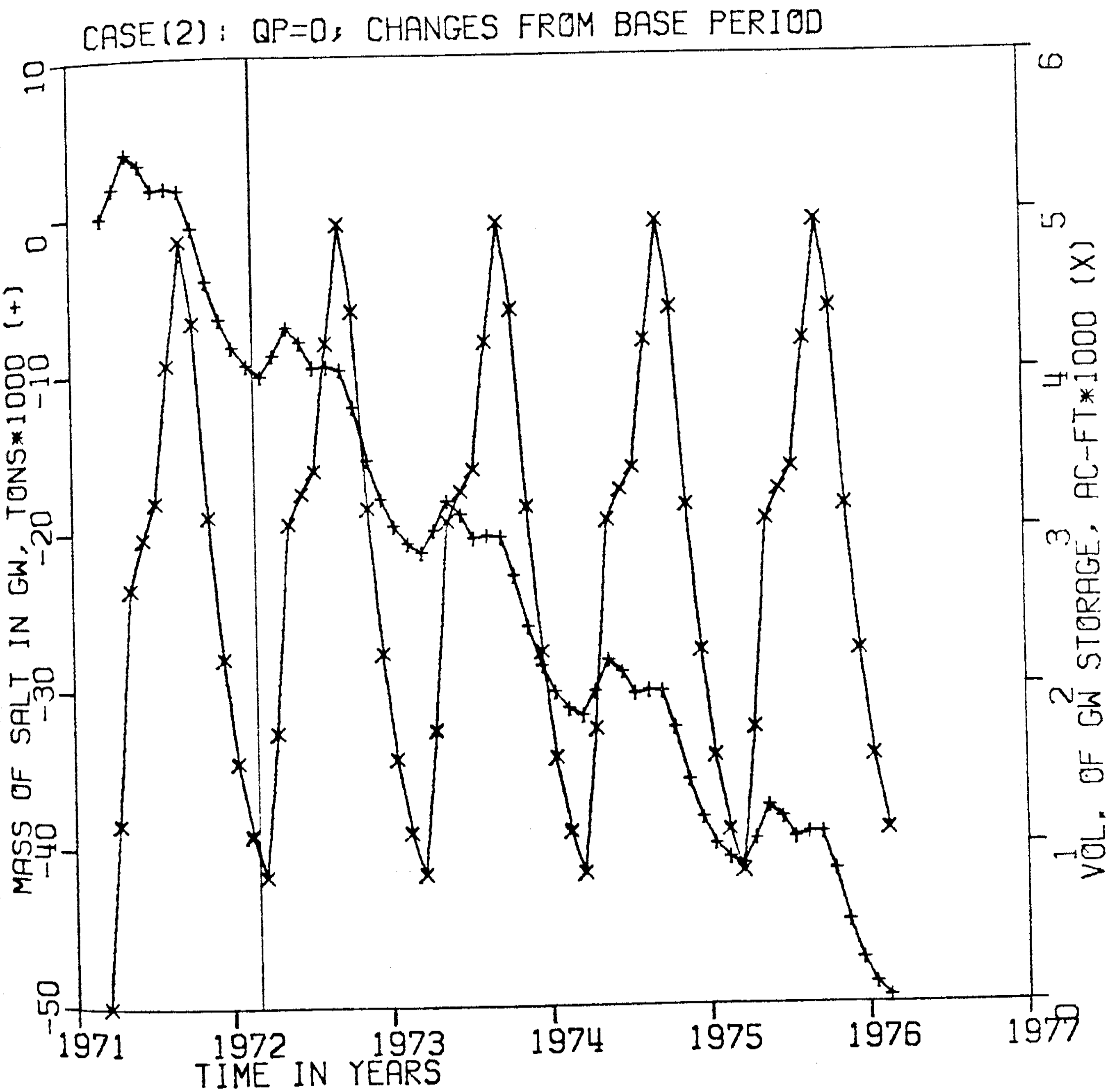

Figure 3.14 Changes in groundwater storage and water quality relative to the base simulation for no groundwater pumpage for irrigation.

1. The water table elevation throughout the study area would be increased by an average of 2.0 feet at the end of the growing season (September) as compared to an average increase of 1.6 feet reported by Konikow and Bredehoeft. However, all but about 0.4 feet of this increase had completely dissipated by the end of each simulation year (March); Konikow and Bredehoeft reported a complete dissipation in their simulation. The increase in volume of groundwater in storage would vary between zero and about 5000 acre-feet as compared to a reported increase of zero to about 4000 acre-feet in Konikow and Bredehoeft.

2. The most significant change was seen in the average decrease in the total dissolved solids concentration of groundwater, where an average decline of 156 mg/l was predicted during the first year; this decrease averaged 918 mg/l during the fifth year, and 553 mg/l over all five years. Konikow and Bredehoeft reported an average decrease of about 300 mg/l after one year throughout the study area.

3. The flow in the Arkansas River at the Bent-Otero County line would be increased by over 15.4 CFS as compared to an increase of 15.0 CFS according to the model of Konikow and Bredehoeft.

4. The dissolved solids concentration in the river at the Bent-Otero County line would increase by about 51 mg/l during the first year, but would only increase by about 30 mg/l during the fith year. Konikow and Bredehoeft reported an average increase of over 40 mg/l during the first year, but an average decrease of more than 60 mg/l after five years.

When all of the irrigation demand is supplied from better quality surface diversions, a lower salinity level of recharge waters results; furthermore, additional dilution is provided by the greater volume of groundwater in storage. However, as Konikow and Bredehoeft pointed out, this imporvement in groundwater would be of little benefit since no water was pumped for irrigation use. The benefit of this management option would probably be only minor and apply primarily to downstream water users only. After a new dynamic equilibrium is established, the temporary flushing effect of aquifer waters would decrease as seen in Figure 3.13, and a corresponding decrease in river water quality would result. However, this effect would take considerable time according to both the lumped model, and that of Konikow and Bredehoeft.

The third test addressed the following question: What would be the hydrological effects on the stream-aquifer system as a result of improving irrigation efficiency by 20 percent (that is, 20 percent less irrigation water is required to produce the same crop yields from the same irrigated acreage)? It was assumed that both groundwater pumpage and surface diversions for irrigation were reduced by 20 percent from the base period; furthermore, it was assumed that recharge was reduced by 39.3 percent (Konikow and Bredehoeft, 1974b, p. 55). The actual or predicted effects on crop yield from this improvement in water use were not explored. The results of this test are graphically depicted in Figures 3.15 and 3.16, and indicated the following:

1. Konikow and Bredehoeft reported that the total annual water requirement for irrigation was reduced by about 3600 acre-feet, while the annual recharge to the aquifer was reduced by some 2900 acre-feet. The average fraction of net applied water that was recharged was reduced from 0.30 to 0.27. The dissolved solids concentration of the recharged waters increased by an average of about 15 percent over that of the base period. Similar changes were used in the lumped parameter model for this

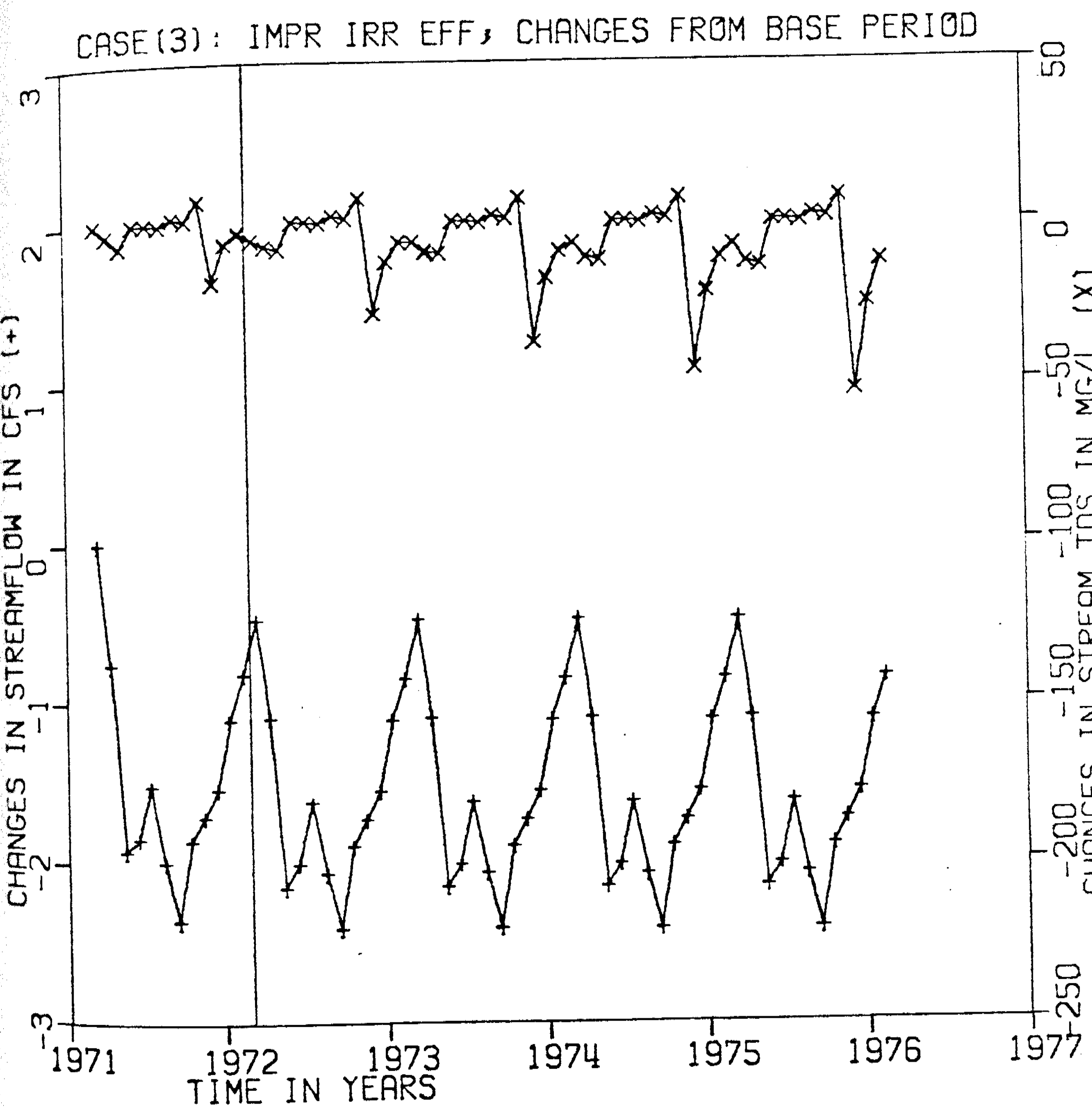

Figure 3.15 Changes in streamflow and surface water quality relative to the base simulation for a 20 percent improvement in irrigation efficiency.

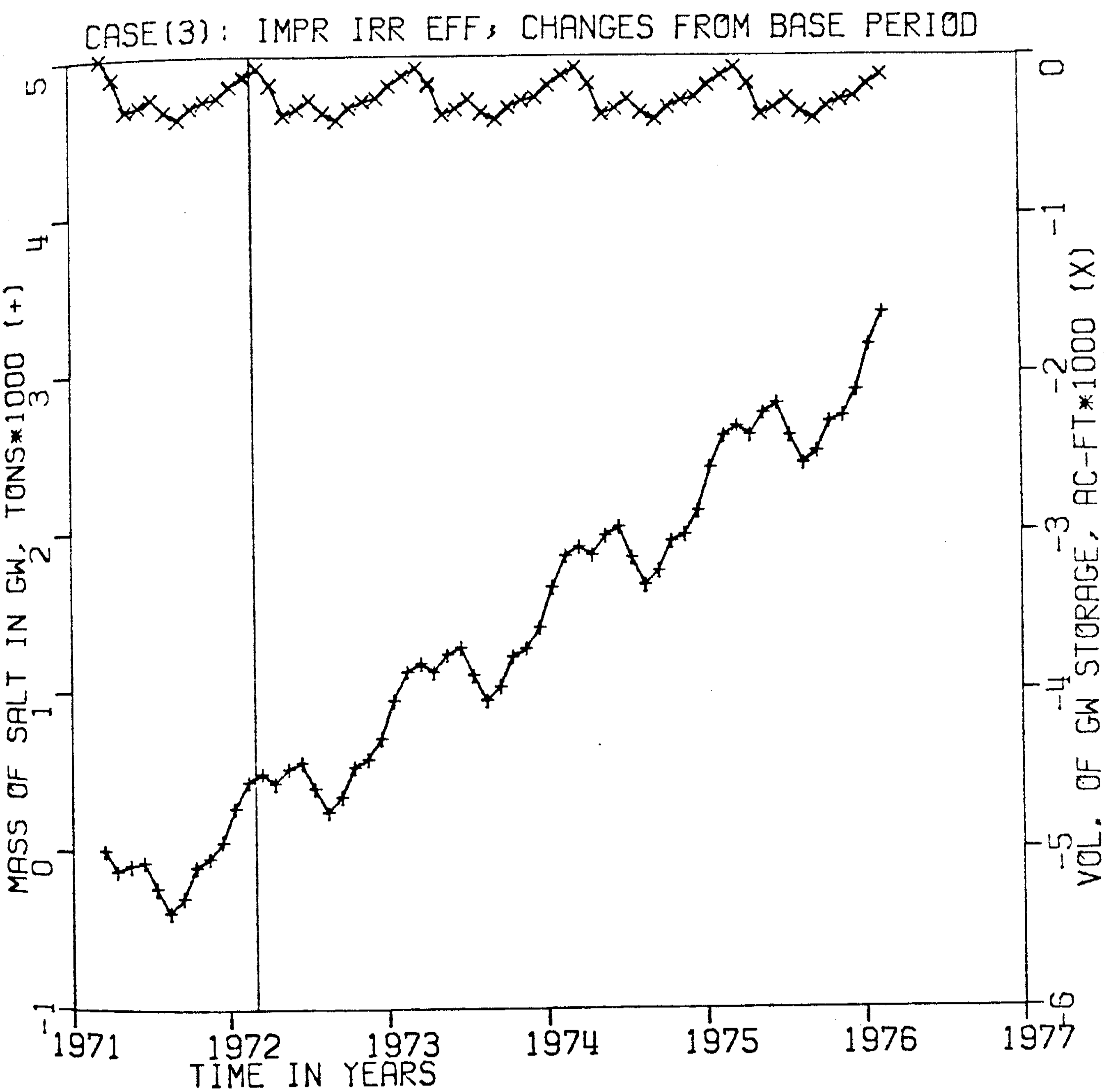

Figure 3.16 Changes in groundwater storage and water quality relative to the base simulation for a 20 percent improvement in irrigation efficiency.

case. Konikow and Bredehoeft assumed that tailwater would decrease from 15 to 7.5 percent of the applied water; however, tailwater quantities are not accounted for in the lumped model as formulated in this particular application.

2. The water table elevation throughout the study area near the end of the irrigation season averaged 0.2 foot lower than the base period, while Konikow and Bredehoeft reported an average increase of 0.1 foot.

3. The dissolved solids concentration of groundwater increased by 13 mg/l after one year, and 71 mg/l after five years. Konikow and Bredehoeft reported an average increase of about 50 mg/l after five years. The total mass of salt stored in the aquifer showed an initial decrease relative to the base period of about 0.04 kilotons after the first year, but increased during the second through fifth years, resulting in an average increase of 2.8 kilotons. Konikow and Bredehoeft's model showed a similar trend, but they reported the mass increase after the third year. Their model showed an average mass increase of about 2.5 kilotons after five years. The initial mass decrease predicted by the lumped model during the first year was apparently due to the decrease in the volume of water in storage; however, this decreased aquifer storage was eventually offset by the higher increase of salinity in recharged waters.

4. The flow of the Arkansas River at the Bent-Otero County line was decreased by an average of 1.5 CFS, while Konikow and Bredehoeft reported an average increase of less than 0.2 CFS.

5. The increase in the dissolved solids concentration in the river was less than 3 mg/l after one year, and less than 9 mg/l after five years. Konikow and Bredehoeft also reported small magnitude changes in

river concentration, but their changes more closely paralleled groundwater salinity fluctuations.

As was stated by Konikow and Bredehoeft, and verified here with the lumped model, improvements in irrigation efficiency would in general have a negative effect on groundwater quality. These effects, however, are partially offset by the benefits that might be derived from the salvaged water. Furthermore, reductions in pumping costs resulting from lower water applications would be a direct and immediate benefit to local irrigators, even though somewhat higher lifts are predicted by the lumped model.

The fourth case addressed the following question: What would be the hydrological effects on the stream-aquifer system as a result of lining the Fort Lyon Canal to prevent leakage losses? While lining canals has frequently been regarded as a management technique to improve irrigation efficiency, it is so often cited that it was decided to explore its individual effects separately. The results of this simulation are shown in Figures 3.17 and 3.18, and indicated the following:

1. The discharge of the Fort Lyon Canal at the Bent-Otero County line would be increased by an average of 12.4 CFS, which was also reported by Konikow and Bredehoeft.

2. The water table elevation throughout the study reach would decline by an average of about 0.7 foot during the first year, and by about 0.9 foot after five years. Konikow and Bredehoeft reported an average decline of about two feet after one year, and no significant additional declines after five years.

3. The total dissolved solids concentration in the aquifer increased by 67 mg/l during the first year, and 443 mg/l after five

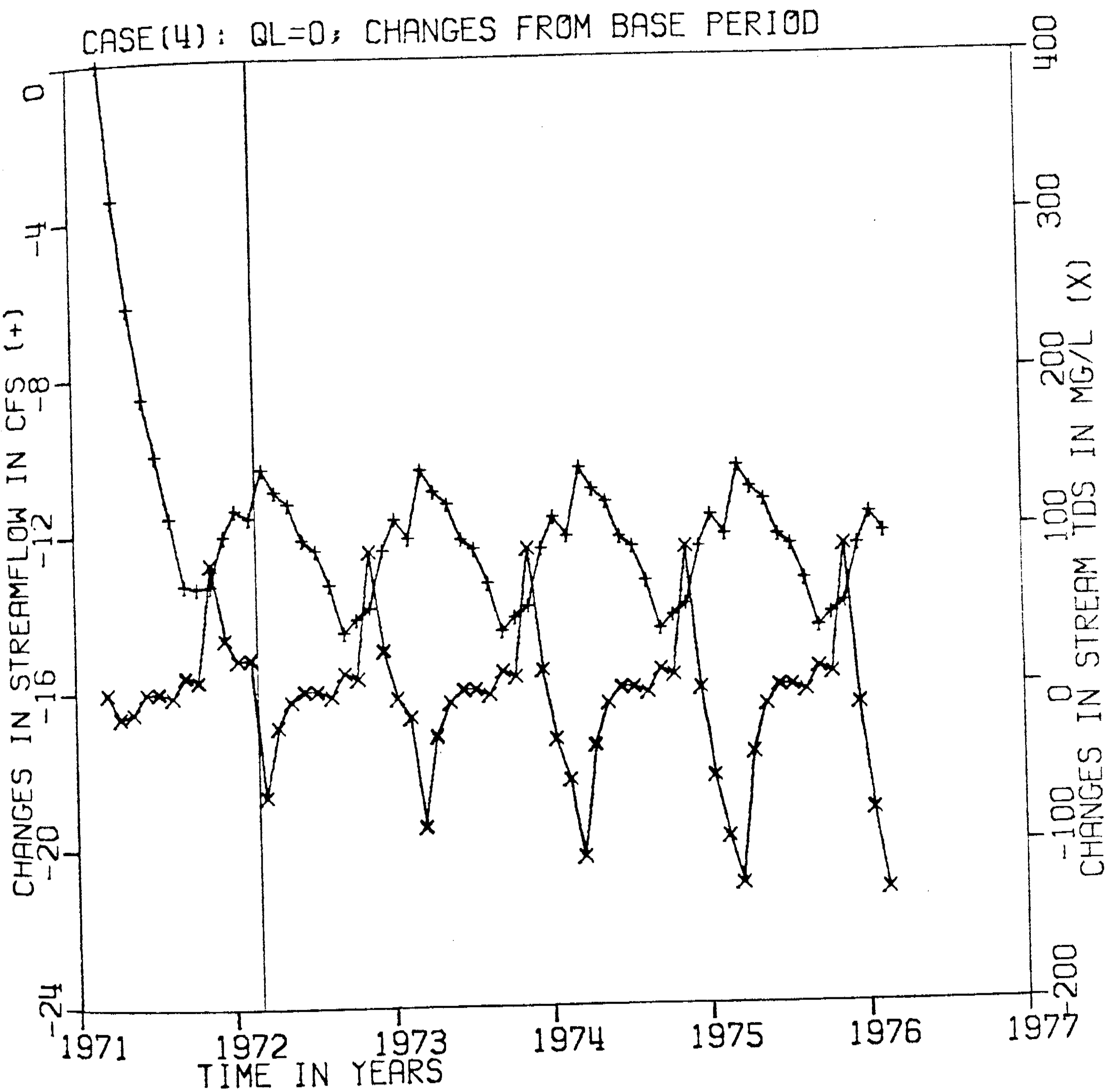

Figure 3.17 Changes in streamflow and surface water quality relative to the base simulation as a result of canal lining to prevent leakage.

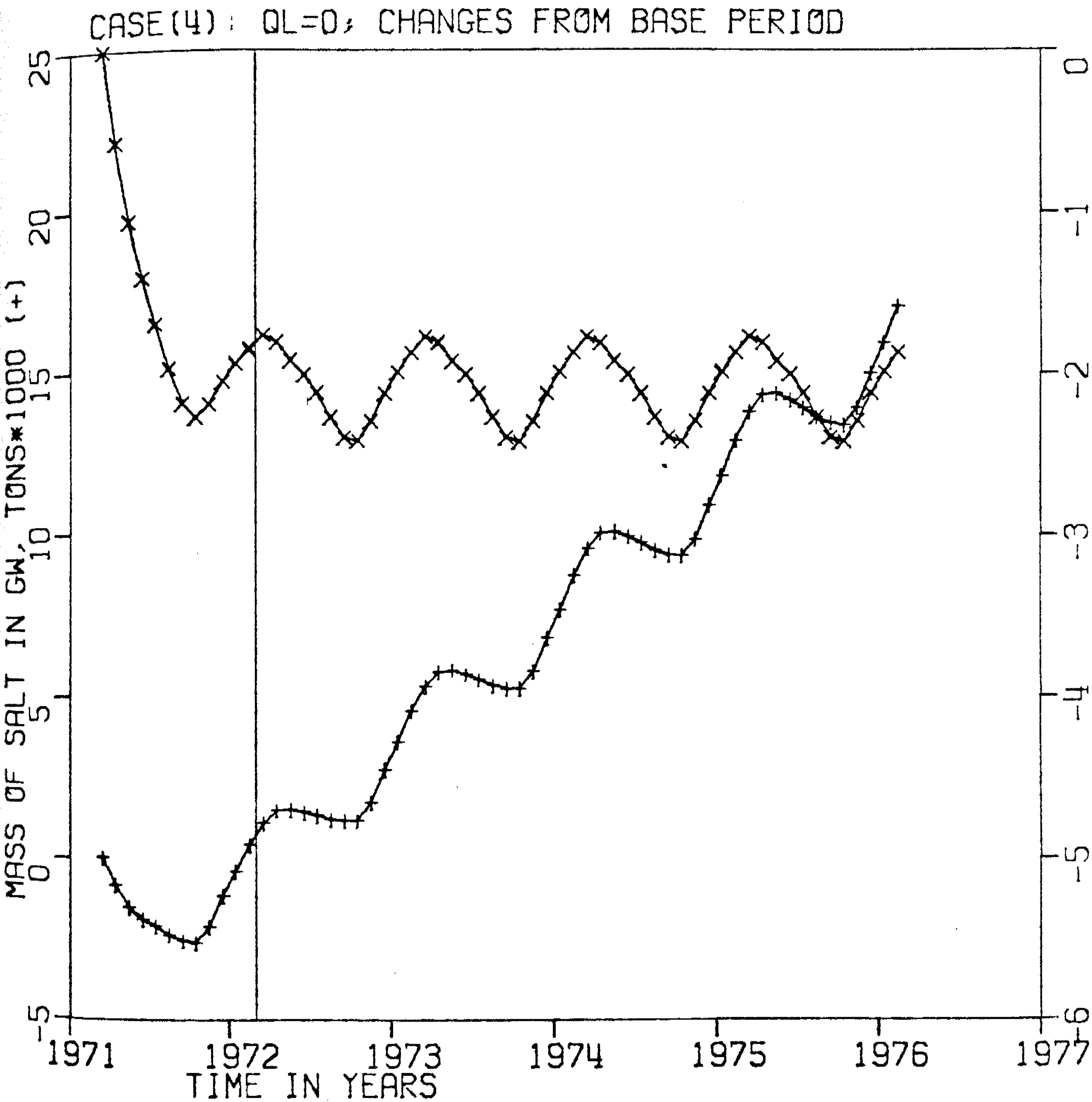

Figure 3.18 Changes in groundwater storage and water quality relative to the base simulation as a result of canal lining to prevent leakage.

years. Konikow and Bredehoeft reported a five average increase of more than 600 mg/l.

4. The flow in the Arkansas River at the Bent-Otero County line would decrease by 9.6 CFS after one year, and 12.4 CFS after five years. Konikow and Bredehoeft reported an average decrease of almost 5 CFS during the first year, and about 11 CFS during the fifth year.

5. The total dissolved solids concentration in the Arkansas River at the Bent-Otero County line would increase by an average of 12 mg/l after one year, but would decrease by an average of 24 mg/l after five years. Konikow and Bredehoeft did not report these changes for this case.

As was pointed out by Konikow and Bredehoeft, these results show that while seepage losses from the Fort Lyon Canal do represent water losses to downstream users, no losses are produced from a systems standpoint. Instead these seepage losses actually serve to maintain water levels in the study reach; furthermore, these higher quality waters tend to dilute the lower quality groundwaters. Canal lining would produce lower water table elevations that would result in higher pumping costs and lower well yields.

3.6 Conclusions

The complex water quantity and quality variations that exist in the irrigated stream-aquifer system along the Arkansas River Valley near La Junta, Colorado, have been successfully simulated by Konikow and Bredehoeft (1974a, 1974b). Their spatially distributed finite difference model solves the appropriate two-dimensional flow equation in order that the convective-dispersive mass transport equation may be solved. As a result, they obtained monthly distributions of aquifer water levels and total dissolved solids concentration levels throughout the 11 mile reach. They were also able to demonstrate the model's usefulness in evaluating alternative water management options. But as they pointed out (Konikow and Bredehoeft, 1974a), changes in the dissolved solids concentration of groundwater were predominately controlled by convective transport and by mixing with recharged waters of different quality. In their two-dimensional depth averaged model representation, the influence of hydrodynamic dispersion was relatively minor. This may indeed be close to physical reality, or perhaps only a characteristic of input data limitations describing the hydrodynamic dispersion tensor. As future research may show, it may also be that hydrodynamic dispersion effects cannot be adequately represented in a two-dimensional model where input stresses are uniformly distributed. In any case, their results still reasonably reproduce observations, even if some doubt remains about the controlling physics that governs the spatial and temporal distribution of dissolved solids.

Konikow and Bredehoeft also pointed out the relatively large amount of input data required for this and other spatially distributed models. In other words there is a price to pay for obtaining a highly detailed hydrologic description of a given area. If one's primary interest is in simulating the average temporal fluxuations in hydrological and chemical parameters in a system-wide stressed study reach where hydrodynamic dispersion effects are secondary to convective transport, the generalized lumped parameter model may prove useful. The field application of the linear reservoir model to the Arkansas River Valley near La Junta, Colorado, has demonstrated its ability to adequately represent these average temporal system responses. The predictive capabilities of this lumped approach produce results which are comparable with that obtained from the more complex, distributed, convective-dispersive model of Konikow and Bredehoeft (1974a, 1974b). Furthermore input data requirements and computional effort are greatly reduced, but one sacrifices a more detailed system wide description of water levels and contaminant distributions. While this lumped modeling approach has received relatively little attention in groundwater hydrology, its preformance here in the Arkansas River Valley does suggest some potential. For example, in those situations were input data are severely limited, a spatially distributed model may provide no better answers to problems than the lumped model. In other cases the detail provided by more complex techniques may not be warrented. This is not to say the lumped approach is without its own limitations. Environmental contamination and possible solute migration problems are indeed of utmost concern; a spatial and temporal contaminant distribution may be highly desirable. The generalized lumped modeling technique simply provides one with an additional choice in the problem solution.

CHAPTER 4

FIELD APPLICATION OF THE NONLINEAR RESERVOIR MODEL

4.1 Introduction

The predictive capabilities of the lumped parameter reservoir model were examined under a second field evaluation in the Mesilla Valley of southcentral New Mexico. However, this second application simulated a nonlinear stream-connected phreatic aquifer system. This second field test should serve to further demonstrate the general applicability of the lumped modeling approach. Because the required data base covers the thirty-one year period from 1946 to 1976, a better estimate of aquifer parameters can be obtained. Actual simulations were made for the ten year period from May 1967 to December 1976, since an initial estimate of average aquifer water quality was available for this period only. The performance of the lumped model may thus be compared to observed temporal hydrological and chemical concentration variations occurring in the Rio Grande at the valley outflow point as seen in Figure 4.1. Furthermore, these simulation results can also be directly compared to results from the U.S. Bureau of Reclamation Conjunctive Use and Water Quality Model (USBR, 1977) previously tested in the same area under identical conditions (Gelhar and McLin, 1979; McLin and Gelhar, 1979).

The Mesilla Valley is an alluvial valley adjacent to the Rio Grande in southcentral New Mexico; it extends approximately 60 miles from Seldon Canyon (near Radium Springs, New Mexico) to El Paso Canyon (near El Paso, Texas). The valley encompasses a gross area of about 108,600 acres; between 70 and 80 percent of this area is in agricultural production

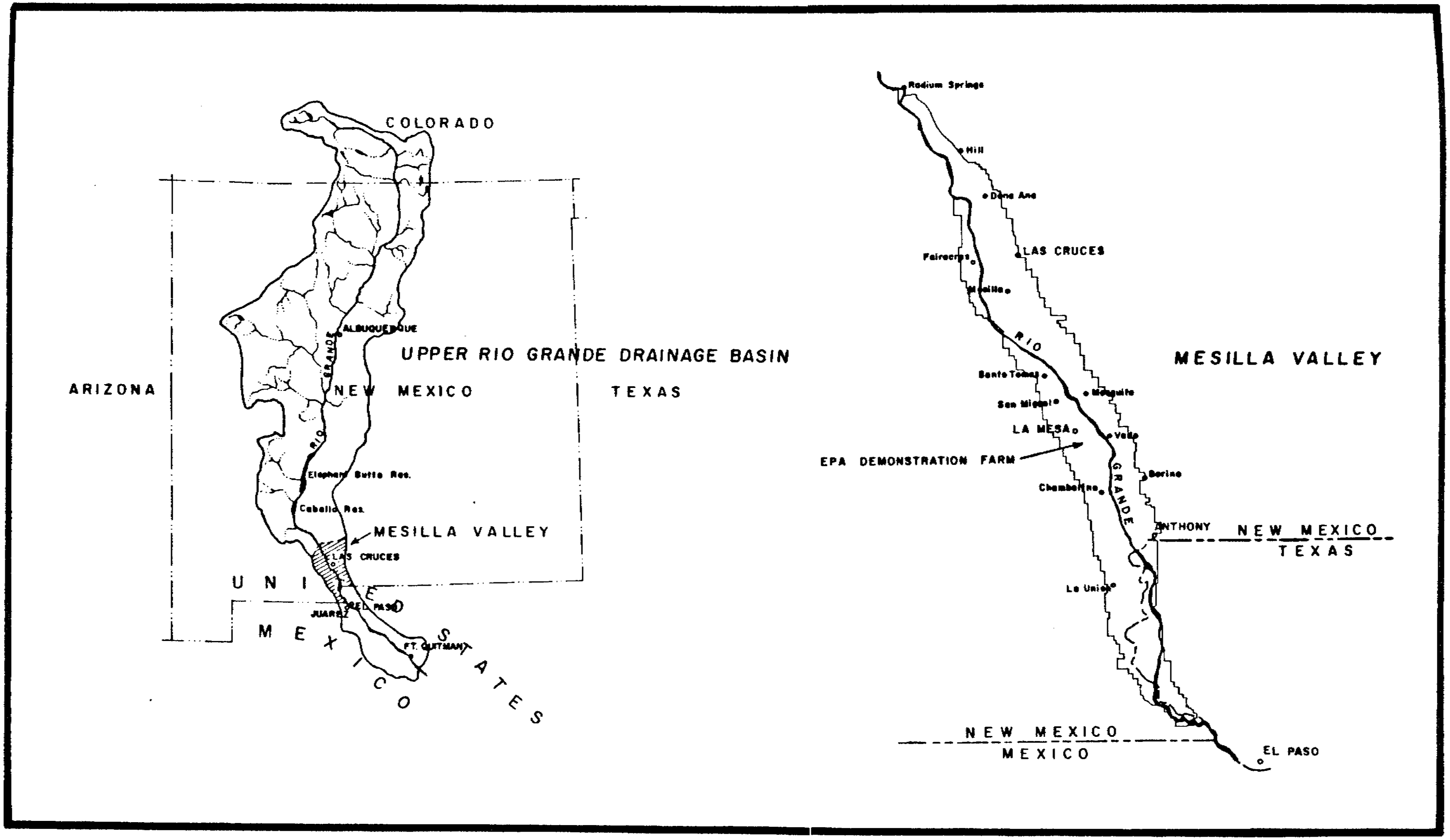

Figure 4.1: Location of the Mesilla Valley and Upper Rio Grande drainage basin, New Mexico.

during the average growing season. The area has had a relatively reliable supply of surface water for irrigation since the completion of Elephant Butte Reservoir in 1916. Groundwater was extensively developed to supplement surface water during the severe drought in the 1950's and continues to be an important source. Major population centers include Las Cruces, New Mexico, and El Paso, Texas. The valley has fairly level topography with a relatively flat alluvial floodplain ranging in width from about 100 yards to about 5 miles. It is bordered by steep bluffs 50 to 100 feet high and composed of loosely cemented sand, silt, clay, and gravel. Recent alluvium on the order of 100 feet thick forms the primary aquifer; this aquifer is underlain by basin fill deposits of the Santa Fe Group which may be several thousands of feet thick. This lower aquifer also yields substantial amounts of higher quality water. The climate of the valley is predominantly semiarid; it is characterized by clear and sunny days, large diurnal temperature ranges, low humidity, and scant rainfall. The mean annual precipitation averages less than 10 inches, with a recorded maximum of about 20 inches and a minimum of about 3 inches. The summer months are generally wettest when tropical air masses move in from the Gulf of Mexico or the Baja Peninsula and cause thundershowers.

Two separate hydrosalinity models of irrigation related water quality were applied to the Mesilla Valley. The USBR-EPA (U.S. Bureau of Reclamation and U.S. Environmental Protection Agency) hydrosalinity model would be classified as a multicell lumped parameter model. Its structure is based on a simple water balance for a given time interval which is computed for each cell. Nondynamic transfers of water between the river and aquifer are used to maintain this balance. A corresponding mass balance is simultaneously computed according to the volumes of water mixed; simulated chemical exchange reactions in the unsaturated zone may also be included. The generalized lumped parameter model in the form of a nonlinear subsurface reservoir formed the second model; this model dynamically couples the water and mass balance relations in its convective transport description. This second model does not consider any soil-water exchange effects; however, it has advantages of reduced complexity and input data requirements. The nonlinear lumped model may, in addition, be more easily utilized in evaluating the effects of various system management options.

4.2 USBR-EPA Hydrosalinity Model

An extensive description of the USBR Conjunctive Use and Water Quality Model (herein referred to as the USBR-EPA model) is given in the user's manual (U.S. Bureau of Reclamation, 1977); here we emphasize only major irrigation related features. This model is a computer-based mathematical description of an irrigated area represented by a series of small subunits, or nodes, as seen in Figure 4.2. The model structure is based on a water balance for a given time interval which is computed and maintained for each node; nondynamic transfers of water between the river and aquifer are essential to maintain this balance. A model soil column is included to simulate the chemical exchange between the soil and water as water percolates down through the vadose zone. This chemical exchange in the soil is represented by a series of chemical equilibrium reactions for major ions which contribute to agricultural salinity; this segment of the model is based on the development by Dutt, et al., (1972). The model

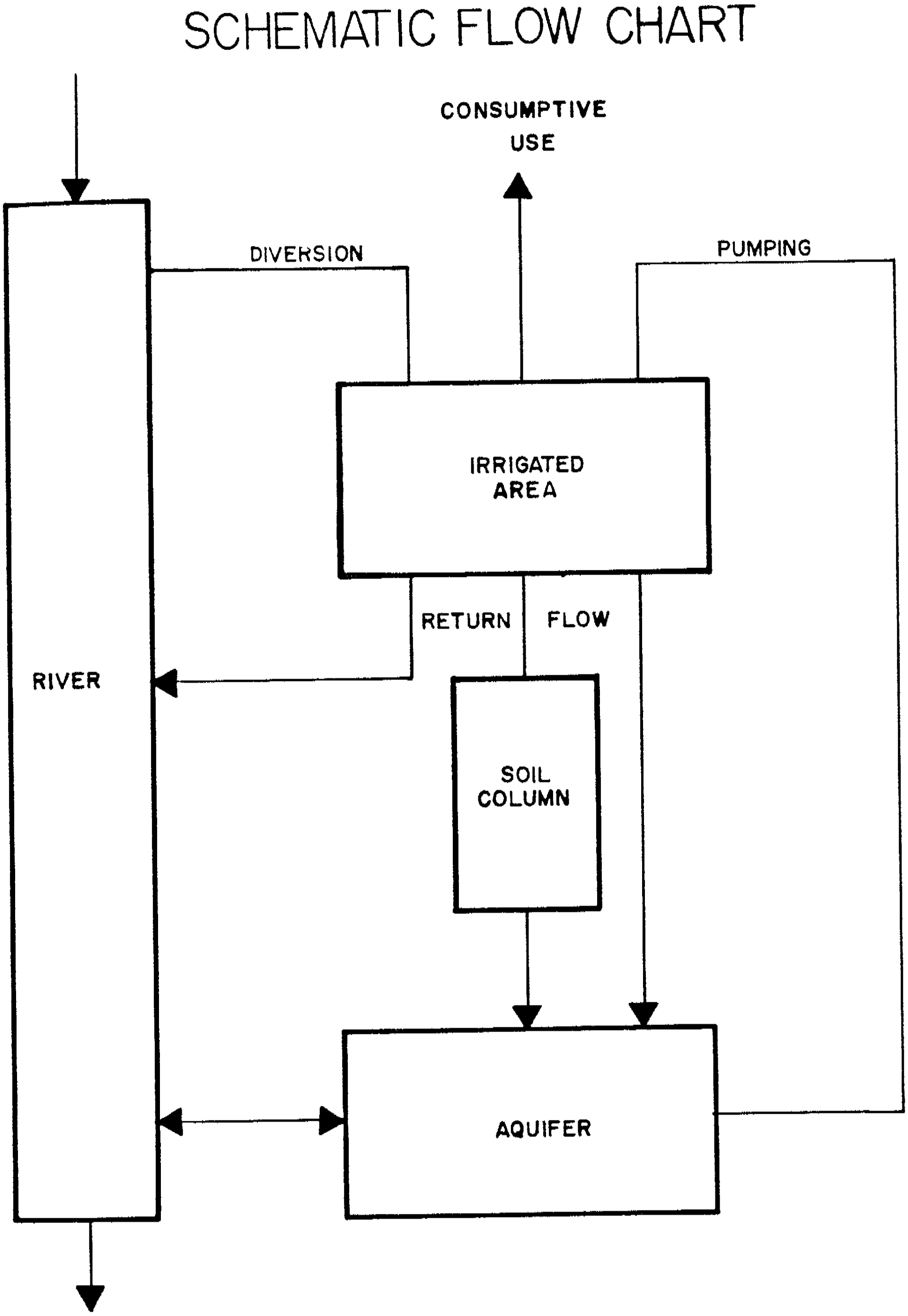

Figure 4.2: Schematic nodal representation showing some features simulated in the USBR-EPA model.

allows the mixing of one water with another, and computes the chemical quality of mixed waters in proportion to the volumes mixed. Hydrodynamic dispersion effects are not considered. All computations are performed for one node at a time and progress from the upstream to the downstream nodes.

A nodal operation includes the simulation of magnitude and quality of river flow, diversions to meet the irrigation demand, water transfers between the river and aquifer, and irrigation return flows. The river flow at the start of a nodal operation is a known quantity, a portion of which is diverted to meet the irrigation demand. The areal irrigation crop demand is computed independently, using the crop consumptive use (ET) and the overall average irrigation efficiency. If the amount of surface water diversion minus canal leakage is not sufficient to meet this demand, additional water is pumped from the model aquifer. The irrigation return flow is then computed by subtracting the ET from the irrigation demand. Simulation of irrigation return flow directly to the river, through the soil to the aquifer, and directly to the aquifer are user specified as a percent of total return flow and may vary for any given time interval. Once a portion of the return flow mixes with the river flow, the chemical quality is updated according to the volumes mixed; this river flow is identified as the predicted river flow. By transferring water to or from the model aquifer, the predicted river flow at the nodal outflow boundary is adjusted to agree with that observed, thereby maintaining an overall water balance. Finally, at the end of a nodal operation, the model yields the river flow and its chemical quality. In the model operation, no consideration is given to soil and aquifer hydraulic properties within a node. Input data needed to operate the model include irrigation demand, crop consumptive use, diversions, river water quality, initial aquifer water storage and chemical quality, soil moisture content and its chemical quality, and precipitation. Table 4.1 summarizes the major features of the USBR-EPA model as applied to the Mesilla Valley.

In the Mesilla Valley irrigated acreage is served by two diversion dams; these diversion points serve as natural nodes for the USBR-EPA model, since quantity and chemical quality of flows are observed here. Preliminary simulations were made with this internal structure for the period July 1967 through June 1968 in order to examine the model's sensitivity to observed and calculated input data (Gelhar and McLin, 1979). The analyses showed that the monthly predicted TDS outflow concentration history in the Rio Grande was most sensitive to the combined effects of average ET and irrigation efficiency, and to the average initial concentration of aquifer waters. The model output was much less sensitive to aquifer saturated thickness and soil chemistry. These results influenced the emphasis in data collection and final simulations.

Because of the general uncertainty in evaluating ET, we chose the simple Blaney-Criddle method (Blaney and Hanson, 1965) to obtain these initial estimates. In the USBR-EPA model simulations, these initial ET estimates were further adjusted so that the simulated and observed average aquifer water levels followed similar trends. This modification was made using an average ET multiplier that tended to minimize the root mean square (RMS) error between predicted and observed average valley water levels as found from a Thiessen polygon weighting technique.

Table 4.1: Summary of major USBR-EPA model features.

MODEL FUNCTION	IMPLIED LIMITATION	DATA REQUIRED	COMMENTS
Multi-cell lumped parameter model will accept up to 20 cells (or nodes)	All variables are functions of time only	See following	Number of nodes depends on available data and physical features of area
Irrigation water balance to compute return flow	Deals with monthly average over nodal area	Diversion, irrigation demand, GW pumpage, irr. eff., consumptive use, % of return to aquifer and to river	Much of required data is hypothetical
Irrigation water chemistry represented by eight chemical constituents and TDS (Ca^{++}, Mg^{++}, Na^{+}, Cl^{-}, $SO_4^{=}$, HCO_3^{-}, $CO_3^{=}$, NO_3^{-})	Deals with monthly average over nodal area	Surface diversion chemistry and GW chemistry	Chemistry based on volume proportion of waters mixed
Soil moisture movement thru as many as 10 soil column segments	Steady forced displacement each month	Soil moisture content	Optional feature of model
Soil chemistry includes reactions involving Ca^{++}, Mg^{++}, Na^{+}, $SO_4^{=}$, HCO_3^{-}, $CO_3^{=}$, and undissolved $CaSO_4$ and $MgSO_4$	Chemical equilibra approach where extended Debye-Huckel theory applies	Soil chemical analysis, cation exchange capacity, gypsum concentration	Neglects reactions involving Cl^{-} and NO_3^{-}
Aquifer balance transfers water to or from surface and to downstream nodal aquifer(s)	Transfer of flow between river and aquifer is forced to maintain water balance	Initial aquifer volume	River-aquifer transfer should depend on aquifer water level
Aquifer chemistry included in simulation	Uniform aquifer chemistry throughout an entire node	Average initial aquifer chemistry	Equivalent to a "well-mixed" reservoir assumption

Results of several simulation runs are summarized in Figure 4.3; these results indicated that this Blaney-Criddle ET multiplier has a value of about 1.7 for the Mesilla Valley.

The estimation of initial average aquifer water quality was made using the previously obtained Thiessen weight factors (Gelhar and McLin, 1979); however, this approach is complicated by the fact that there are major changes of concentration not only horizontally, but also vertically for any point in the valley. Very little detailed information is currently available, but preliminary studies (C. A. Wilson, personal communication, 1977) indicate a water quality transition zone occurs 50 to 150 feet below land surface. We have simply assumed that concentration is constant with depth down to the average base of the alluvial aquifer at 80 feet in calculating an average aquifer concentration. A complete listing of all data used in the USBR-EPA model is given in Gelhar and McLin (1979), along with the USBR-EPA computer program listing with identified modifications made by us.

The nearly ten-year long period from May 1967 to December 1976 was used in the final simulation to evaluate the USBR-EPA model in the Mesilla Valley. Observed and predicted concentration outflow histories in the Rio Grande are depicted in Figures 4.4 and 4.5 for two of several cases examined. The first case (Figure 4.4) shows the effects of soil chemistry exchange reactions on outflow concentration, using an actual irrigation efficiency estimated to be 0.50. It can be seen that the model simulates the observed seasonal variation in water quality quite well. This seasonal pattern seems to be related to the fact that the relatively saline groundwater, which drains from the aquifer after the irrigation season, is the predominant source of river flow during the

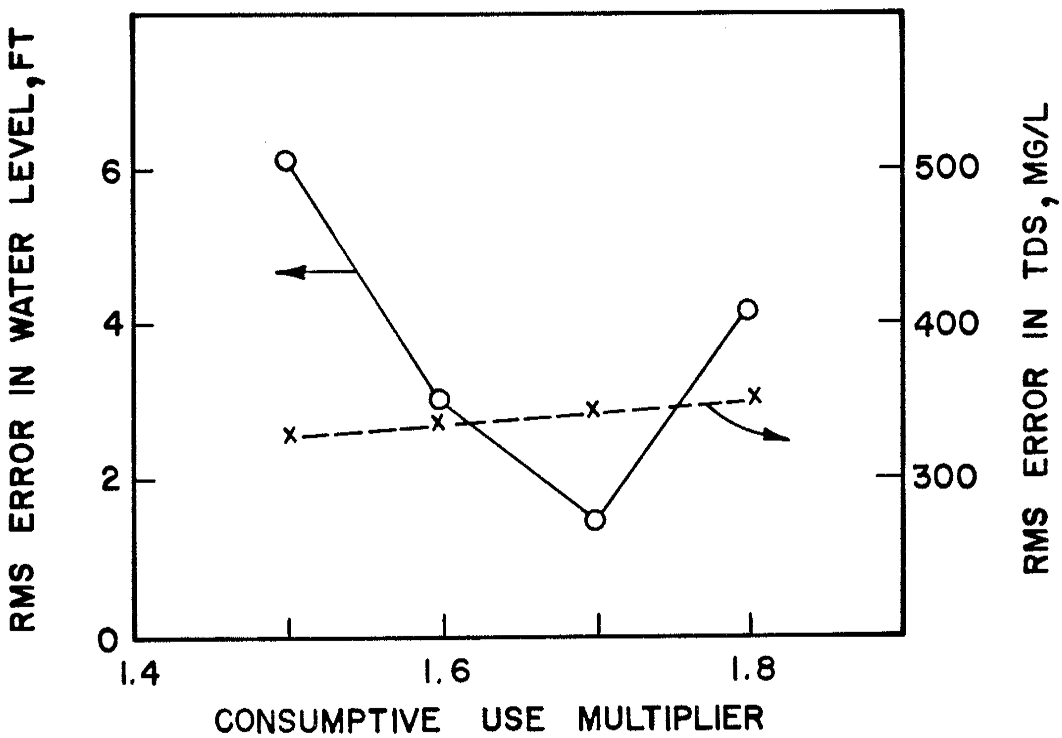

Figure 4.3: RMS error in simulated USBR-EPA aquifer water levels and simulated river outflow chemistry as a function of the consumptive use multiplier.

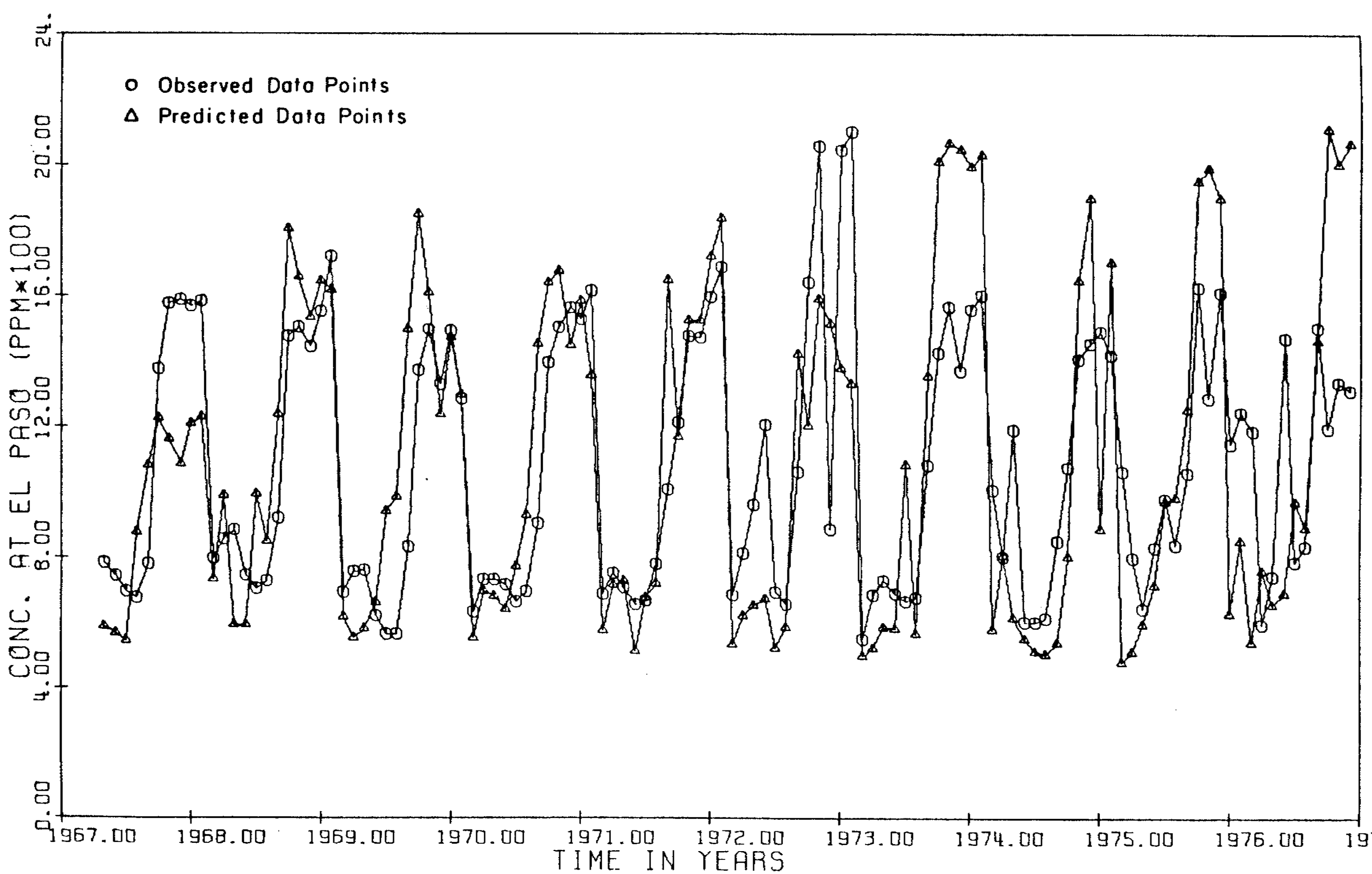

Figure 4.4: USBR-EPA model results using an irrigation efficiency of 50 percent; the RMS error between observed and predicted output is 344 mg/l.

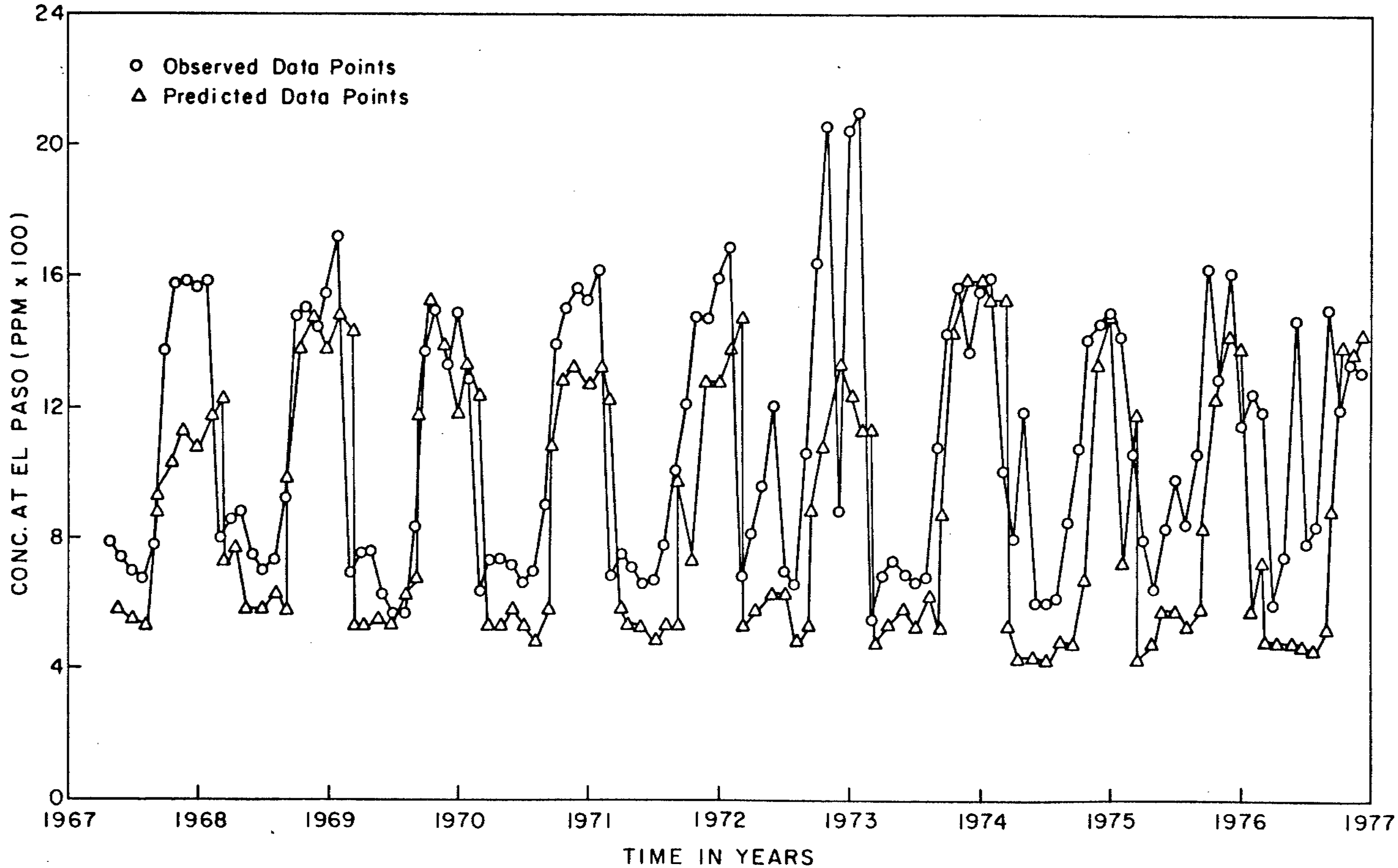

Figure 4.5: USBR-EPA model results using a hypothetical irrigation efficiency of 75 percent; the observed data are shown for reference only.

winter months. However, in the early part of a growing season, large quantities of relatively low salinity surface diversions are applied; these waters tend to dilute the drainage waters.

The second case (Figure 4.5) was run under identical conditions, but with a hypothetical irrigation efficiency of 0.75. These results indicate that a 25 percent improvement in irrigation efficiency over the ten years would have decreased the TDS concentration in the river, especially towards the end of the simulation period (the observed data is plotted in Figure 4.5 for reference only). Because of the relatively large solute response time of this system, several years are required before any noticeable improvements are seen in downstream water quality. In the Mesilla Valley this time period would apparently have been about six years and would have typically resulted in about a 550 mg/l lowering of TDS in the Rio Grande at El Paso, Texas.

4.3 Mesilla Valley Nonlinear Reservoir Model

Derivation of the lumped parameter nonlinear reservoir model for application to the irrigated stream-aquifer configuration along the Mesilla Valley requires only slight modification to the linear case already presented. Based on the data summary previously assembled (Gelhar and McLin, 1979; and references therein), this irrigated system may be represented as a series of observed and estimated inputs and outputs as depicted in Figure 4.6. Thus, the aquifer water balance equation would be

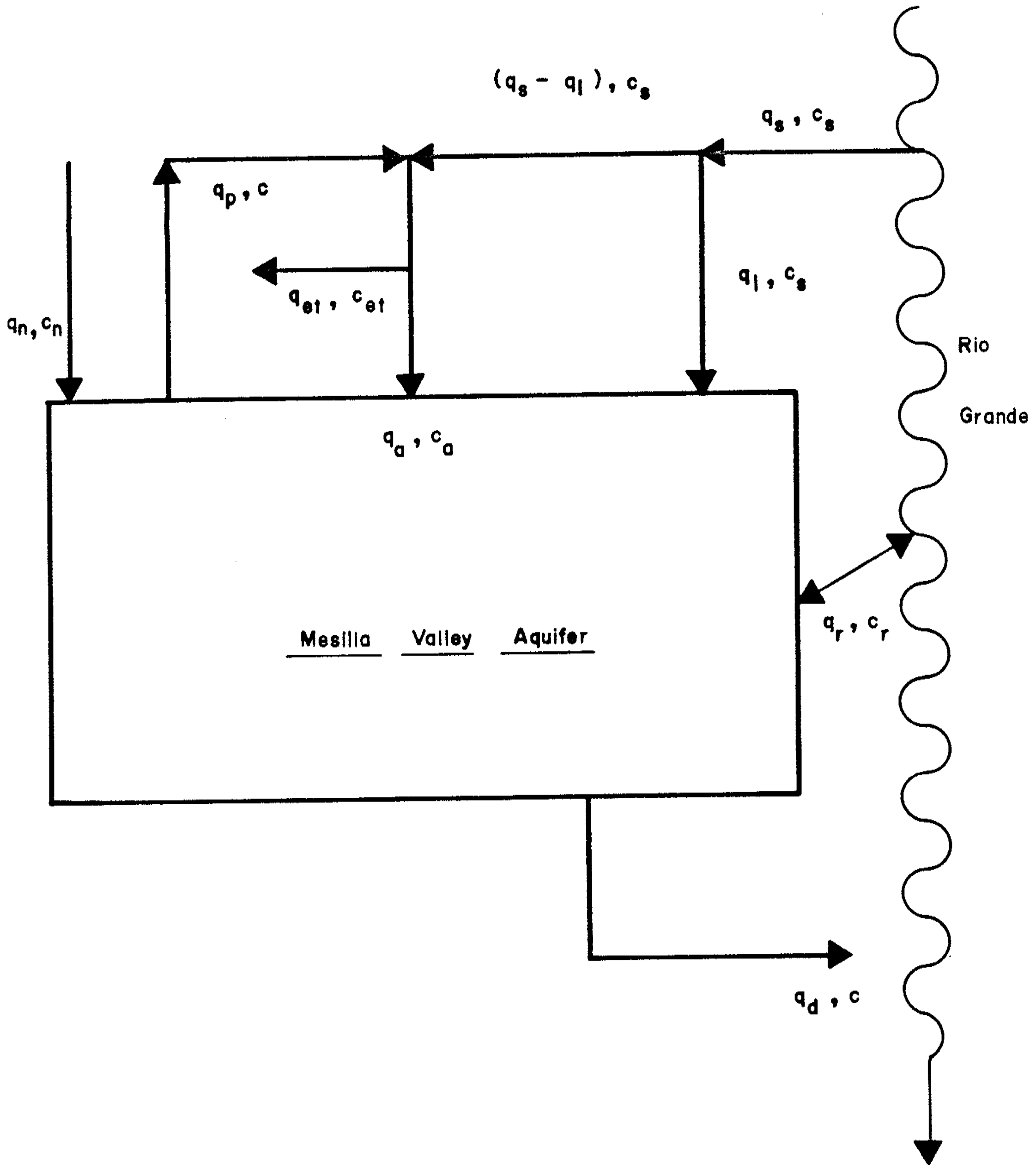

Figure 4.6: Lumped parameter representation of the irrigated stream-aquifer system in the Mesilla Valley.

$$S \frac{dh}{dt} = q_a + q_n + q_l \pm q_r - q_d - q_p \qquad (4.3.1)$$

where S = average specific yield of the aquifer,

$h(t)$ = average thickness of the aquifer,

$q_a(t)$ = average artificial recharge rate per unit surface area,

$q_n(t)$ = average natural recharge rate per unit surface area,

$q_l(t)$ = average canal leakage rate per unit surface area,

$q_r(t)$ = average river leakage rate per unit surface area,

$q_d(h,t)$ = natural aquifer outflow rate per unit surface area,

$q_p(t)$ = aquifer pumping rate per unit surface area.

The river leakage term in (4.3.1) is positive for river to aquifer transfers and negative otherwise. Also shown in Figure 4.6 are the respective contaminant concentration levels corresponding to the various average temporal inputs and outputs. In the figure the evapotranspiration term, q_{et}, is depicted as a net deficit on the applied irrigation waters and never enters the model aquifer. The advantage of this representation will become clear later; briefly stated, however, we may actually avoid having to evaluate the crop consumptive use and groundwater pumpage terms in the final water and mass balance equations. Data for q_p is often unavailable since this quantity is usually unmetered; furthermore, q_{et} will carry large inherent errors no matter what technique is utilized in its determination. Thus, we actually may avoid many of the shortcomings of the typical water balance approach to this type of problem solving by using this formulation.

The manner in which the natural aquifer outflow term (or aquifer drain flow), q_d, is approximated will determine whether the lumped model represented by (4.3.1) is linear or nonlinear. Updegraff and

Gelhar (1978) previously examined a linear representation of the Mesilla Valley water balance system using an expression like that in (3.2.1). Their approach worked extremely well for a normal precipitation period; however, it did not adequately represent average conditions in the valley for a subsequent low flow period. Pinzon (1978) was able to overcome this shortcoming by replacing (3.2.1) with the nonlinear expression

$$q_d = \frac{1}{N} \ln \left\{ \exp \left[aN(h-h_d)\right] + 1 \right\} \tag{4.3.2}$$

where N is some system constant and h_d is the average drain reference water level; all remaining terms have been previously defined. This equation is linear for sufficiently large values of $(h-h_d)$, but is nonlinear when $(h-h_d)$ becomes small or slightly negative; actually (4.3.2) is nearly identical to (3.2.1) over most of the range of values for h. Recall that the parameter a in (4.3.2) is a lumped outflow constant having units of inverse time; it is inherently related to Darcy's law (Flores W., et al., 1978). In general, h_d can be a function of time, but is usually assumed constant since fluctuations in h_d are usually much smaller than those for h. Substituting (4.3.2) into (4.3.1) yields a differential equation of the form

$$S \frac{dh}{dt} + q_d = E \pm q_r \tag{4.3.3}$$

where E represents the lumped time dependent inputs minus outputs (that is, $E = q_a + q_n + q_1 - q_p$); in (4.3.3) the term q_d is given by (4.3.2). When using a nonlinear aquifer outflow expression like (4.3.2), a numerical solution technique for (4.3.3) will usually be necessary.

This particular nonlinear expression worked well in the elongated Mesilla Valley, where average valley water levels sometimes fall below h_d; drainage then ceases in the upper portion of the valley while the lower end may still experience some active drainage.

The corresponding mass balance equation for the stream connected aquifer system would be

$$n \frac{d(hc)}{dt} = q_a c_a + q_n c_n + q_1 c_o \pm q_r c_r - q_d c - q_p c + nhr' \qquad (4.3.4)$$

where r' is a volumetric source-sink term that accounts for contaminant additions or degradation within the flow zone, c is the average aquifer concentration, and c_n and c_a are the respective concentrations for natural and artificial recharge waters. If the river leakage (q_r) is positive, then waters are transferred from the river to the aquifer; c_r is identical to the river concentration. If q_r is negative, then waters are transferred from the aquifer to the river and c_r is identical to the average aquifer concentration, c. It is implied in (4.3.4) that the aquifer is a well-mixed linear or nonlinear reservoir (depending on q_d) and that any system outflows will carry this average aquifer concentration; this assumption has been related to the nature of two-dimensional convective transport for the linear model in a previous chapter and earlier by Gelhar and Wilson (1974). Using (4.3.1) with S = n in (4.3.4) yields

$$\frac{dc}{dt} + c\left(\frac{\varepsilon}{nh} + k\right) = [q_n c_n + c_s(q_s + q)]/nh \qquad (4.3.5)$$

where $\varepsilon = E + q$

$q = q_r$, if $q_r > 0$

$q = 0$, if $q_r < 0$

$r' = -kc$, a first order declay process

and where q_s represents the volume rate of applied river water per unit area, and c_s is its concentration level. For irrigated systems the transported contaiminant will usually have a decay constant (k) equal to zero. The combined parameter nh/ε may be referred to as the solute response time (t_c) since it characterizes the average response time of (4.3.5); physically it represents the average solute residence time in the aquifer. For the Mesilla Valley study period, yearly averages for t_c varied between 11.4 and 40.3 years.

The water and mass balance statements given by (4.3.3) and (4.3.4), together with (4.3.2), form a coupled systems description of subsurface water and mass transport in a nonlinear lumped parameter format. Net stresses are assumed to be uniformly distributed throughout the system as was done for the linear reservoir model; hydrodynamic dispersion effects are not considered. These equations are easily manipulated in discretized form; examples of numerical solutions may be found in Gelhar and Wilson (1974), Flores W., et al., (1978), and Updegraff and Gelhar (1978).

In the proceeding analyses (4.3.3) will yield a general solution for the predicted average water table elevation above some reference datum for the lumped parameter nonlinear reservoir model; (4.3.5) will similarly yield a corresponding aquifer outflow concentration. The lumped model is therefore dynamic when these equations are coupled together; hence, it is a truly predictive management tool. Thus if future input stresses can be estimated, then the corresponding system outputs can be found. However, certain physical parameters must first be estimated which characterize the system response. Updegraff and Gelhar (1978), using a linear reservoir lumped parameter model, proceeded to estimate a and h_d in (3.2.1) using a least squares regression technique for observed average water level and drain flow data in the Mesilla Valley. Once these parameters were found, they discretized an equation similar to (4.3.3). They obtained a least squares estimate of n and q_r for periods of no irrigation (i.e., no net recharge). Their equation could then be resolved for net recharge using the above parameters and observed values of average water level elevations for periods of active irrigation assuming the river leakage remained constant for a given recharge-recession period. This linear approach worked extremely well in the Mesilla Valley for a five-year period (1946-1951) showing normal precipitation. The onset of several successive dry years (1952-1956) resulted in excessive groundwater pumpage and relatively large water level declines; their linear technique did not adequately represent average conditions in the valley for this low drain flow period. Pinzon (1978), using (4.3.2) instead of (3.2.1), was able to overcome this shortcoming of the linear model. The procedure used by him was nearly identical to that of Updegraff and Gelhar (1978). A least squares nonlinear solution of (4.3.2) using Mesilla Valley observed average water level and drain flow data for the period 1946-1976 therefore yielded estimates for N, a, and h_d. The discretized form of (4.3.3) was solved for n and q_r during periods of no irrigation using observed values of h (see Appendix F); this same equation was then resolved for net recharge

(E) during active irrigation periods (see Appendix E). Finally a predictor-corrector iteration procedure was used in conjunction with (4.3.3) to obtain the predicted average aquifer water levels for the above parameters. Constant river leakage was again assumed for a given recharge-recession period. Equation (4.3.2) and this simulated h then yielded a simulated drain flow. Figures 4.7 and 4.8 show these simulated results for the period 1967 to 1976, along with the corresponding observed data; Table 4.2 lists both the linear and nonlinear parameters for the Mesilla Valley. The nonlinear outflow term given by (4.3.2) obviously simulates the average hydrological conditions in the Mesilla Valley quite well, although changes in this expression might improve these results even further.

Table 4.2: Comparison of linear and nonlinear aquifer parameters for the Mesilla Valley.

Model	Parameter Value	Source
linear	a = 0.0812/month	Updegraff and Gelhar, 1978
	n = 0.210	
	h_d = 3824.85 feet	
	t_h = n/a = 2.59 months	
nonlinear	a = 0.0755/month	Pinzon, 1979, and here.
	n = 0.218	
	h_d = 3825.00 feet	
	N = 9.05	
	t_h = n/a = 2.89 months	

The generalized lumped parameter model in the form of a nonlinear subsurface reservoir was evaluated here for its ability to predict fluctuations in monthly river outflow total dissolved solids, using a portion of the same data base previously assembled for the USBR-EPA model, and the water balance parameters found by Pinzon (1978). This

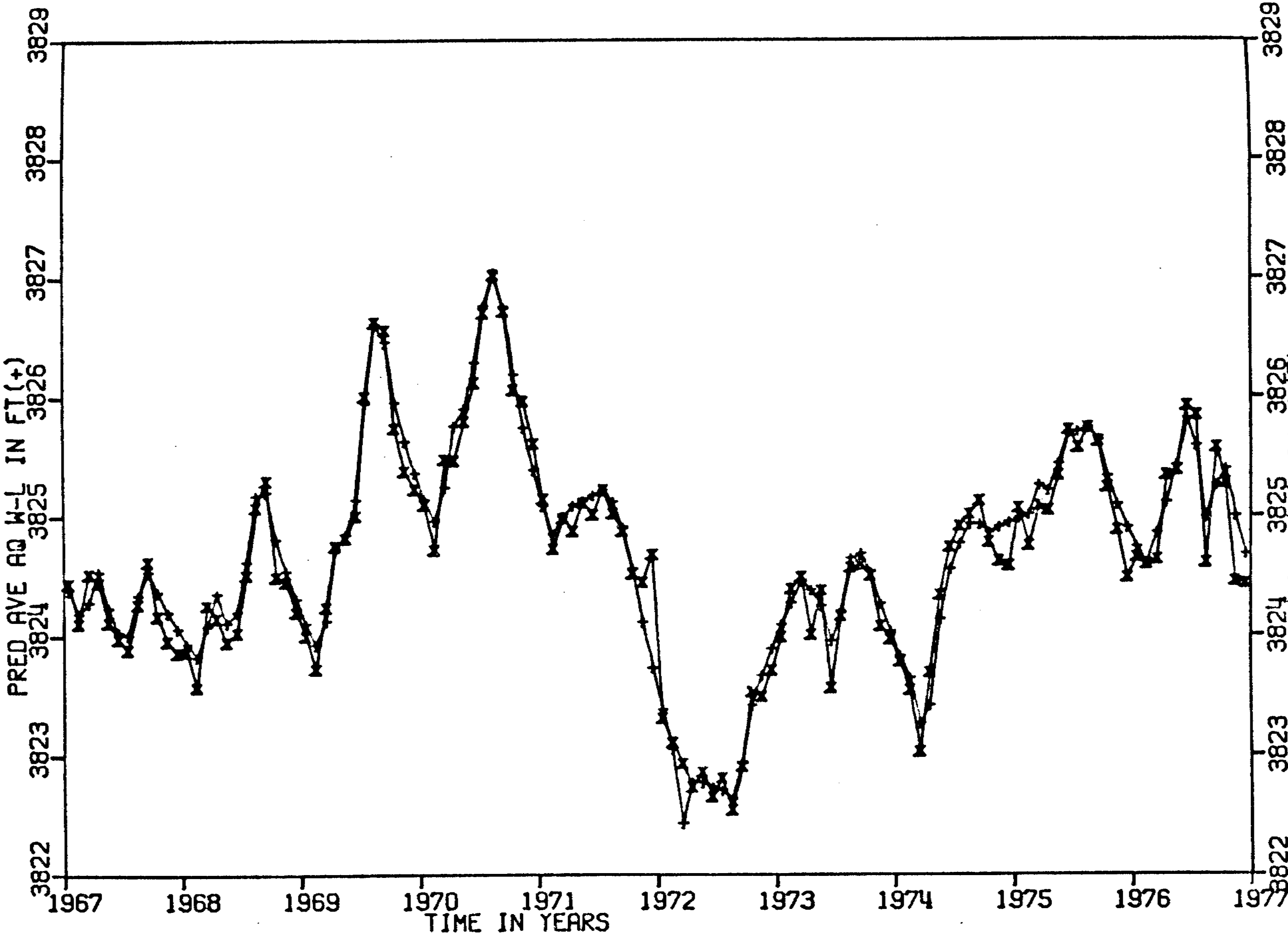

Figure 4.7: Monthly observed and simulated average aquifer water levels using the nonlinear lumped model; the RMS error is 0.18 feet (5.49 cm).

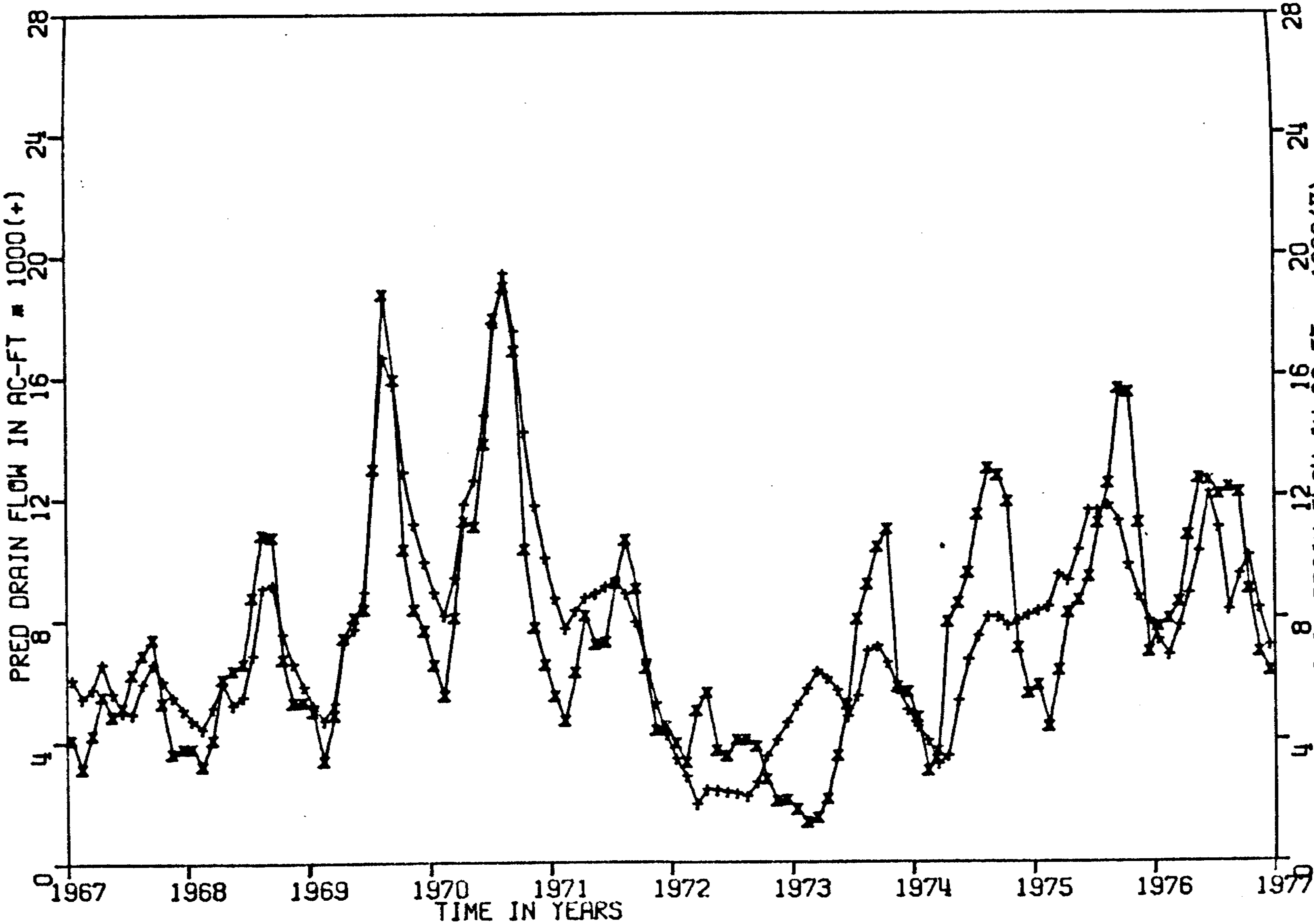

Figure 4.8: Lumped parameter monthly simulated and observed average valley drain flow; the RMS error is 0.02 feet per month (0.61 cm/month).

simulation was based on a discretized version of the mass balance relationship given by (4.3.5); thus, a backward difference approximation over the Δt time interval may be written as

$$\left(\frac{c_i - c_{i-1}}{\Delta t}\right) + \left(\frac{c_i + c_{i-1}}{2}\right) \left(\frac{E + q}{nh}\right)_{i-1} = c_{s_{i-1}} \left(\frac{q_s + q}{nh}\right)_{i-1}$$

where the decay constant k is zero and c_n is assumed to be negligible since $c_n << c_s$. In this expression we have considered the net recharge (E), the river leakage (q), and the surface diversion (q_s) to each be measured between the middle of the ith and (i+1)th time steps, as was done in the previous field application (see Figures 3.2 and 3.3). The above relationship may be solved to yield

$$c_i = \frac{c_{s_{i-1}} \left(\frac{q_s+q}{nh}\right)_{i-1} \Delta t - c_{i-1} \left(\frac{E+q}{nh}\right)_{i-1} \frac{\Delta t}{2}}{1 + \frac{\Delta t}{2} \left(\frac{E+q}{nh}\right)_{i-1}} \tag{4.3.6}$$

Equation (4.3.6) will yield the average aquifer concentration at each time step, assuming that the total net recharge, ε_i, is treated as a pulsed input of constant concentration during the ith month. In this discretized form (4.3.6) requires only q_s and c_s as input data, since all remaining terms may be found as a result of the parameter estimation procedure. Figure 4.9 shows predicted and observed changes in the Rio Grande TDS at El Paso, Texas (the Mesilla Valley outflow point), as found using the nonlinear lumped parameter model for the period 1967-1976. Other model output is shown in Figures 4.10 and 4.11; the complete computer program listings, input data and model output are listed in Appendices E, F, and G.

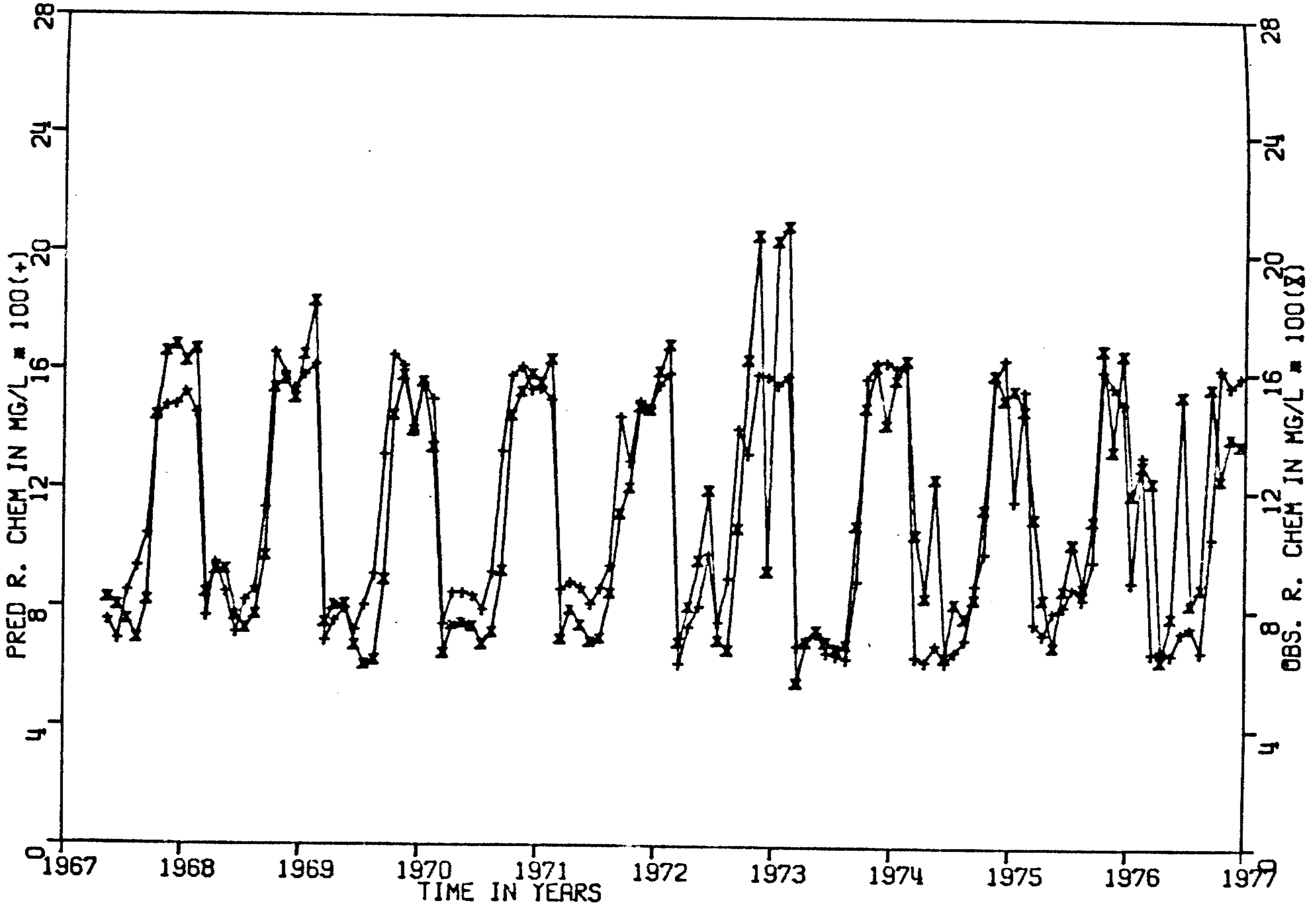

Figure 4.9: Lumped parameter monthly observed and simulated Rio Grande TDS at El Paso, Texas; the RMS error is 213 mg/l.

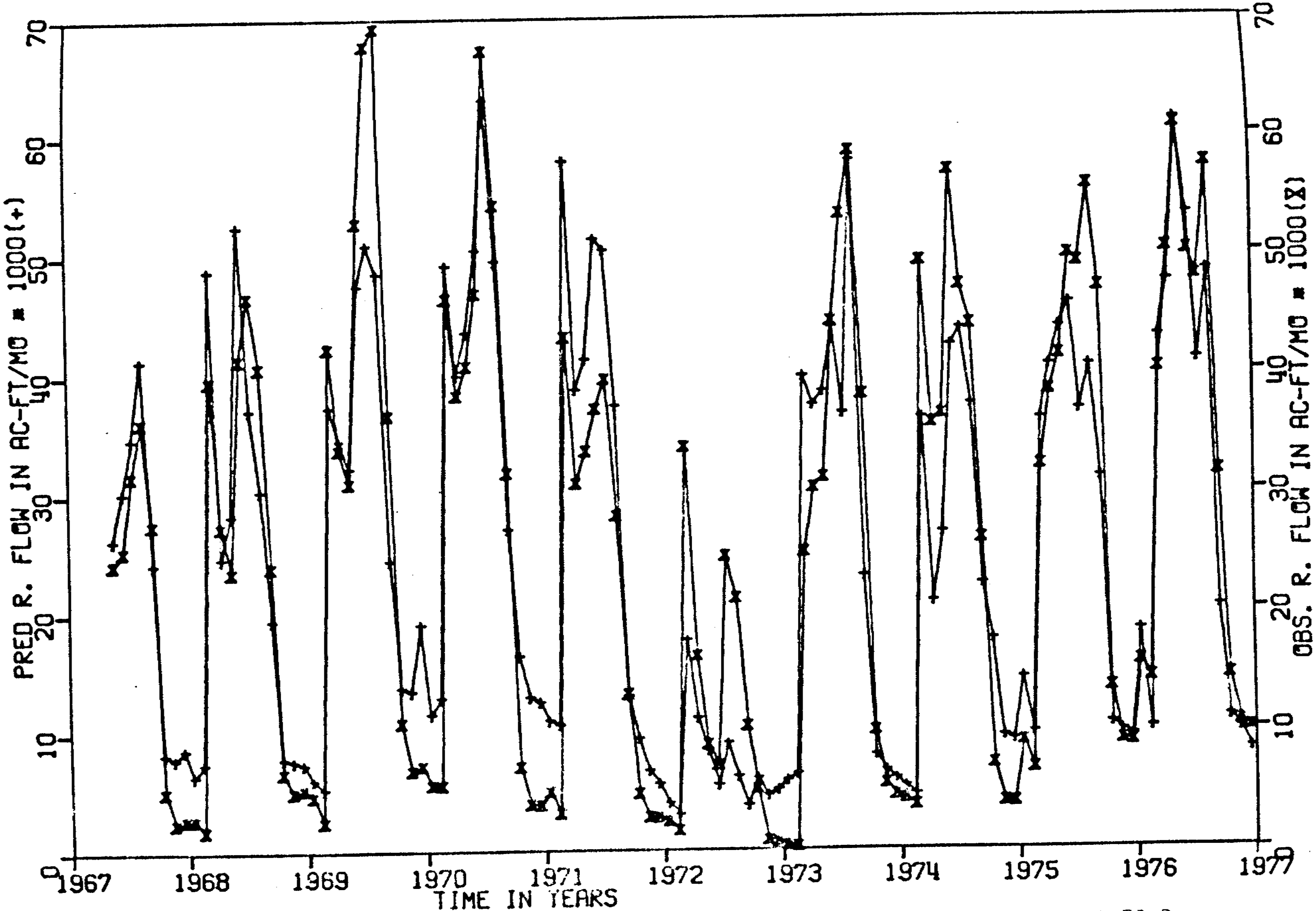

Figure 4.10: Lumped parameter monthly observed and simulated Rio Grande flow at El Paso, Texas; the RMS error is 7324 acre-feet per month (903 hectare-meters per month).

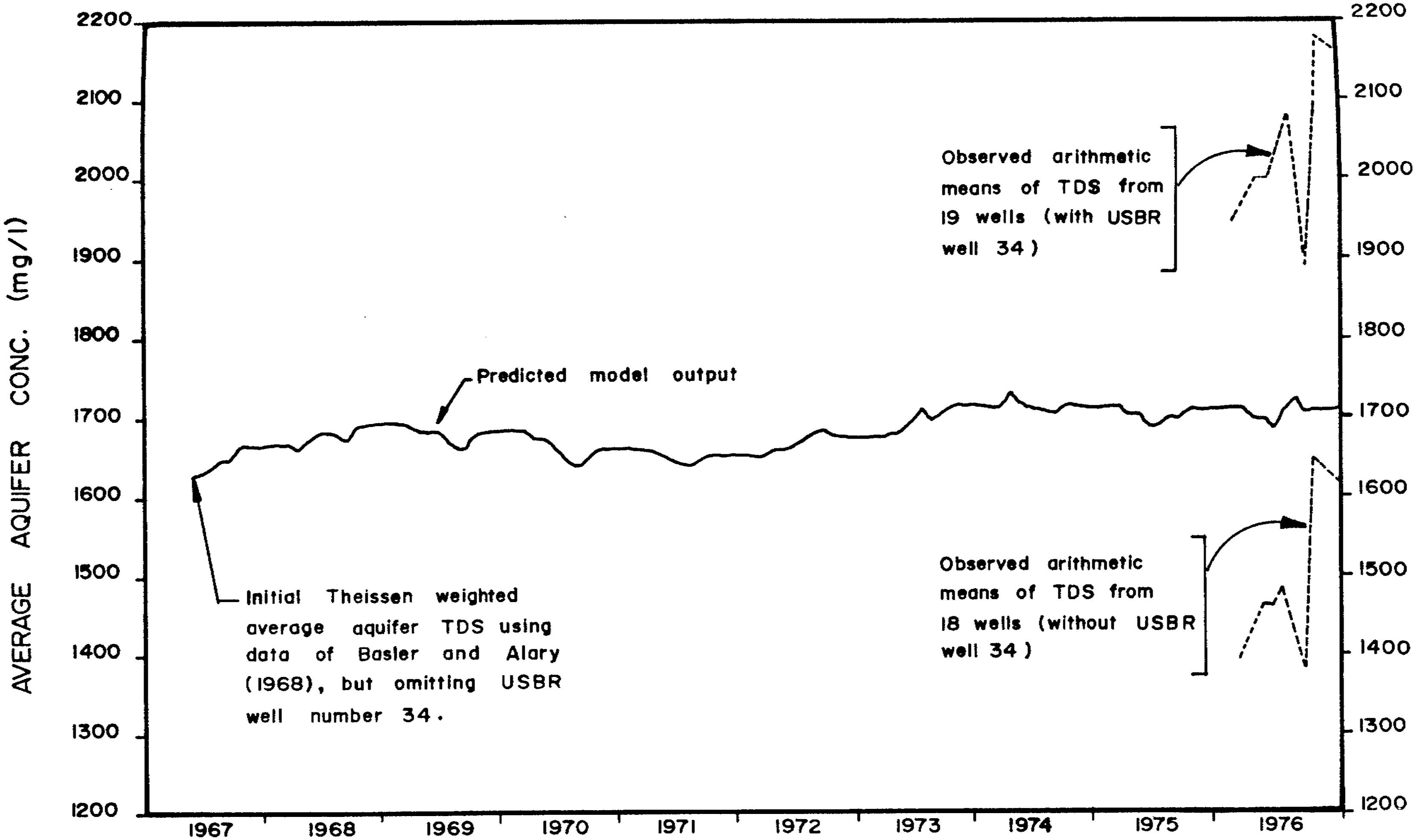

Figure 4.11: Lumped parameter monthly predicted average aquifer TDS; a few months of data were observed.

Figure 4.11 shows the lumped parameter model's prediction of average aquifer TDS over the ten year simulation period. These simulated results were obtained by using an initial average aquifer TDS value of 1626 mg/l. This initial value was computed from the observed water quality data reported by Basler and Alary (1968), and by utilizing the Theissen polygon weighing technique for 39 wells distributed throughout the 108,600 acre valley (Updegraff and Gelhar, 1978; and Gelhar and McLin, 1979). In this computation the data from USBR well number 34 was omitted (Gelhar and McLin, 1979, p. 153) because it was felt that the TDS value of about 11,000 mg/l was not representative. However, in Table 3 of Gelhar and McLin (1979, p. 30), this data was included in arriving at the Theissen weighed mean value of 1846 mg/l for TDS because of specific requirements there. Since water quality data from all of these same wells was not available after May 1967, no other Theissen averages appear on Figure 4.11; Table 4.3 summarizes these results. This figure does show, however, the results obtained from arithmetically averaging the observed TDS values from 19 wells having water quality data available over a portion of the simulation period (Gelhar and McLin, 1979, p. 128 to 153). No other water quality data is know to exist over this time interval. Furthermore, it is important to note that some of these 19 wells were installed after 1967, and therefore are not included in the original 39 wells used to establish initial conditions. Finally, if one well is omitted from this list of 19 wells (i.e., USBR well 34), the average aquifer TDS value is lowered by about 500 mg/l. Thus a band of these average TDS values is obtained, as shown in Figure 4.11.

As reported in Gelhar and McLin (1979, and references therein), the horizontal and vertical spatial variation in groundwater quality is very

Table 4.3: Arithmetic means of observed TDS values

DATE	UPPER(2) MEAN (mg/l)	LOWER(3) MEAN (mg/l)	PREDICTED(4) MODEL TDS (mg/l)
3-76	1961.7	1376.8	1715.6
4-76			1706.4
5-76	1998.4	1443.4	1698.3
6-76	2002.3	1465.8	1696.1
7-76	2039.6	1464.9	1683.2
8-76	2075.3	1485.9	1710.0
9-76			1722.2
10-76	1888.8	1388.7	1706.4
11-76	2183.7	1648.4	1707.6
12-76	2171.0	1630.0	1707.6
1-77	2134.9	1594.7	
2-77	1946.6	1450.0	
3-77			
4-77			
5-77	1996.0	1479.8	
6-77	2110.6	1587.6	
7-77			
8-77	1973.3	1500.5	
9-77			
10-77	2045.8	1577.7	
11-77	1993.3	1536.9	

(1) See Figure 4.11 for time history plot of means; see Table 4.4 for list of wells used to compute arithmetic means.

(2) Computed with data from USBR well no. 34.

(3) Computed without data from USBR well no. 34.

(4) No simulation results beyond December 1976.

Table 4.4: List of Wells used for Arithmetic means (1)

SITE	WELL NUMBER
3	USBR no. 19
5	USGS Well Nets, North Well
6	USBR no. 16
8	USBR no. 12
9	USGS Well Nest, North Well
10	USGS Well Nest, South Well
12	USBR no. 14
13	USBR no. 8
14	USBR no. 7
15	USBR no. 6
16	USBR no. 24
15	USBR no. 5
18	USGS Well Nest-2nd Well from East
19	USBR no. 22
20	USGS Well Nest-Middle Well
22	USBR no. 39
23	USBR no. 29
25	USBR no. 2
29	USBR no. 34

(1) The actual well locations and TDS data for each of the above wells is given in Gelhar and McLin (1979, p. 129-153).

complex in the Mesilla Valley. Any technique that is designed to yield a system wide average groundwater quality will yield results that are primarily dependent on the following: (a) well location and perforated interval, (b) total number of wells and their spatial distribution throughout the system, (c) time of year that samples are recovered, and (d) the precise technique employed in the averaging process. Furthermore, once a given technique is selected for this averaging process, the same wells should be utilized in comparing temporial fluctuations in this spatial average. Even if such a procedure is followed, one may still wonder if a representative temporal trend in average water quality is obtained. While such a fundamental question is beyond the intended scope of this work, the potential effect must at least be qualitatively realized. The example in Gelhar and McLin (1979, p. 29 to 30) illustrates this point rather well.

4.4 Comparative Study Results

Figures 4.4 and 4.5 depict the USBR-EPA simulation results. The results of the ten-year simulation in the Mesilla Valley demonstrate that both the USBR-EPA hydrosalinity and generalized lumped parameter models can simulate pre-existing conditions quite well if adequate data are available to describe the overall water and mass balance conditions of the aquifer. Our experience with the Mesilla Valley system indicates that the data base is reliable and consistent. However, groundwater quality does show a high degree of horizontal and vertical spatial variability; furthermore, the vertical extent of this higher saline groundwater is not well defined. The actual predictive capabilities of the USBR-EPA model are less clear than for the generalized lumped parameter model. In order to predict the hydrochemical effects of changes in water application, one must be able to synthesize the resulting changes of flow into and out of the system because this model completely ignores aquifer flow dynamics. In other words the aquifer hydraulic coefficients and changes in flow resulting from changes in water level are not used.

The generalized lumped parameter model, on the other hand, does incorporate the mixing cell structure plus the flow dynamics of the aquifer. This model can also be operated with a conceptually much simpler computer program; calculations can even be carried out on a programmable pocket calculator, though somewhat inconveniently for long simulation periods. The predictive capabilities of this same model for the Mesilla Valley are discussed in the next section.

4.5 Water Management Options with the Nonlinear Model

The same cases previously considered for the linear lumped parameter model (see Section 3.5) were used in this nonlinear application to demonstrate its ability to predict the long term response of the stream-aquifer system of the Mesilla Valley to changes in irrigation practices and water management options. It was again decided to present the simulation results on a relative rather than an absolute response; however, the original ten year simulation results of Section 4.4 are presented here in their absolute form for ease of comparison (see Figures 4.12 to 4.15). The same four specific water management options previously used in Section 3.5, and by Konikow and Bredehoeft, were employed here; these cases were: (1) increased groundwater use, (2) increased surface water use, (3) improved irrigation efficiency, and (4) lining all conveyance canals.

In Section 4.3 the water balance equation was simplified to the form given by equation (4.3.3) in order to avoid calculation of the crop consumptive use and groundwater pumpage terms. The net lumped inputs minus outputs were identified as E; these values were in turn determined as a result of the parameter estimation procedure. In order to utilize the nonlinar model to evaluate system responses to different water management options, we must be able to synthesize changes in E that result from changes in water application. These changes will in turn affect the water and mass balance equations, thereby yielding model predictions for any water management scheme envisioned.

We can see that in order to evaluate the effects of cases (1) through (4) above, appropriate source terms must appear explicitly in equations (4.3.3) and (4.3.5). Thus in case (1) for example, we need to know what fraction of the surface diversion (q_s) enters the aquifer as artifical recharge (q_a) in order to change this volume source in the mass balance relationship to reflect increased groundwater pumpage. Additional valley data or appropriate assumptions are therefore required in order to proceed. In the Mesilla Valley most of this type of information is costly and is therefore not generally available. Some estimations have been made, however, with regard to canal leakage and irrigation efficiency (Gelhar and McLin, 1979). Here we use the term irrigation efficiency to mean the percentage of the total amount of ground and surface waters diverted for use by agricultural crops. The irrigation demand is the total consumptive use (q_{et}) divided by the

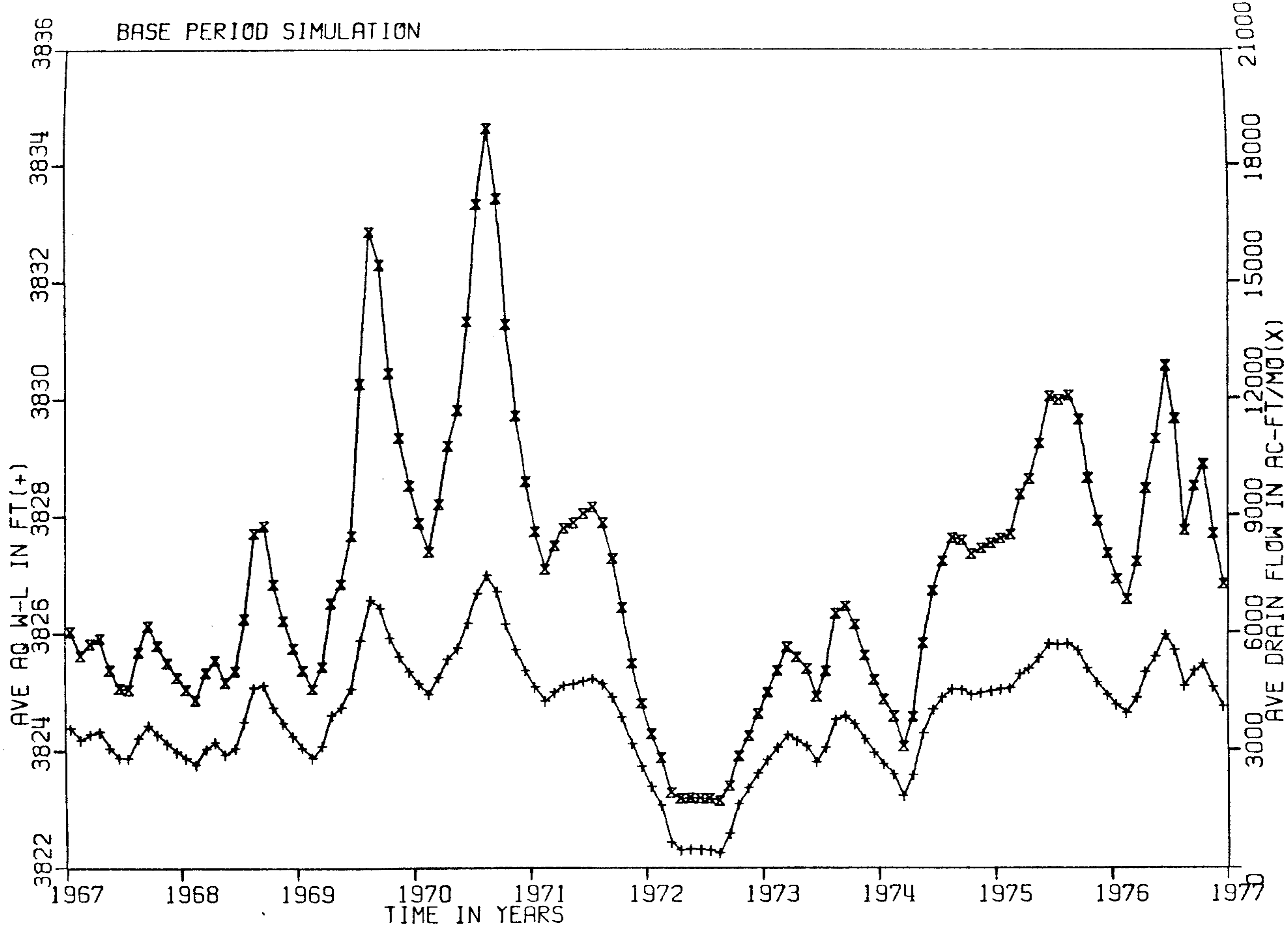

Figure 4.12: Base period simulation of average aquifer water levels and drain flow in the Mesilla Valley.

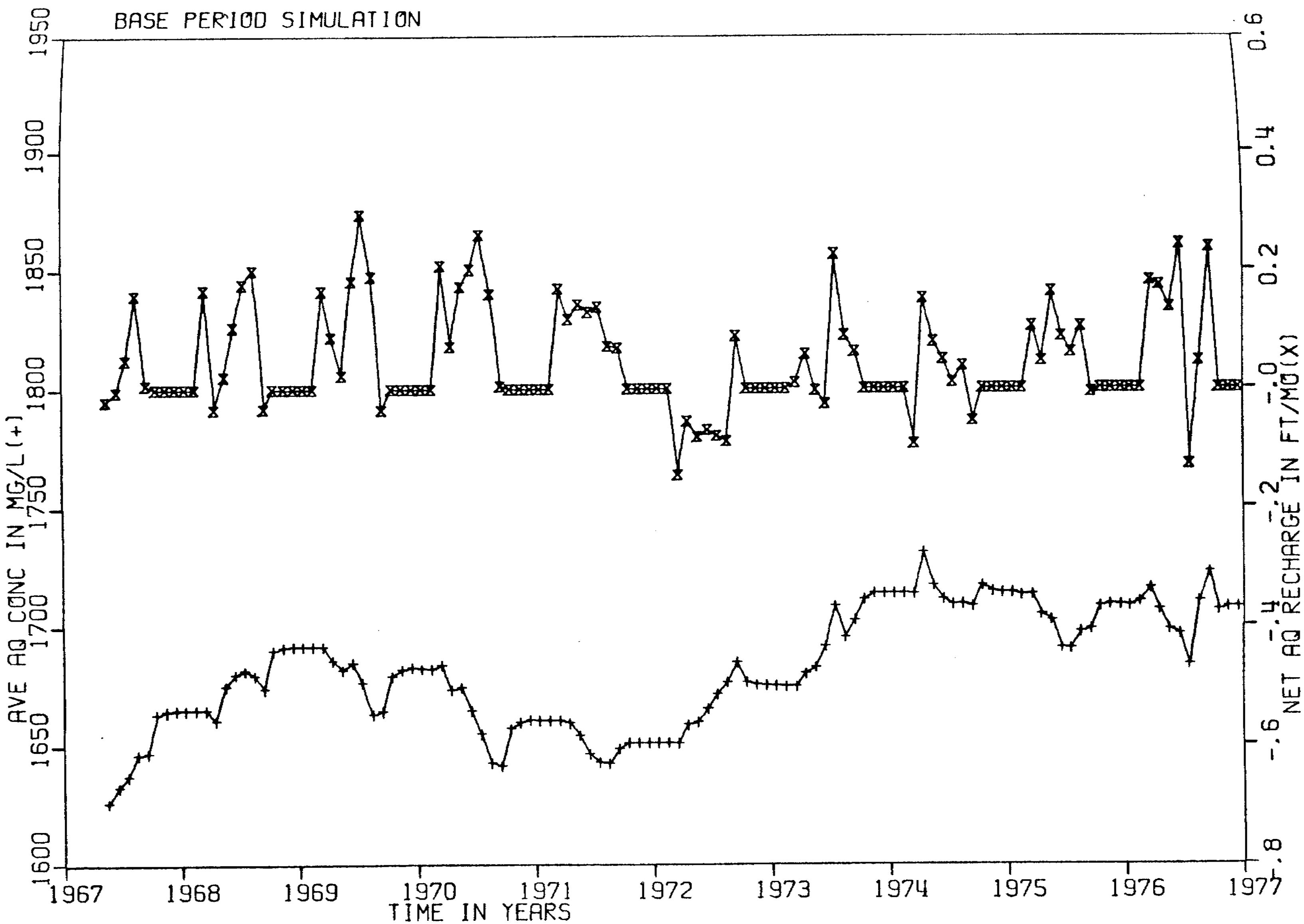

Figure 4.13: Base period simulation of average aquifer TDS and net aquifer recharge for the Mesilla Valley.

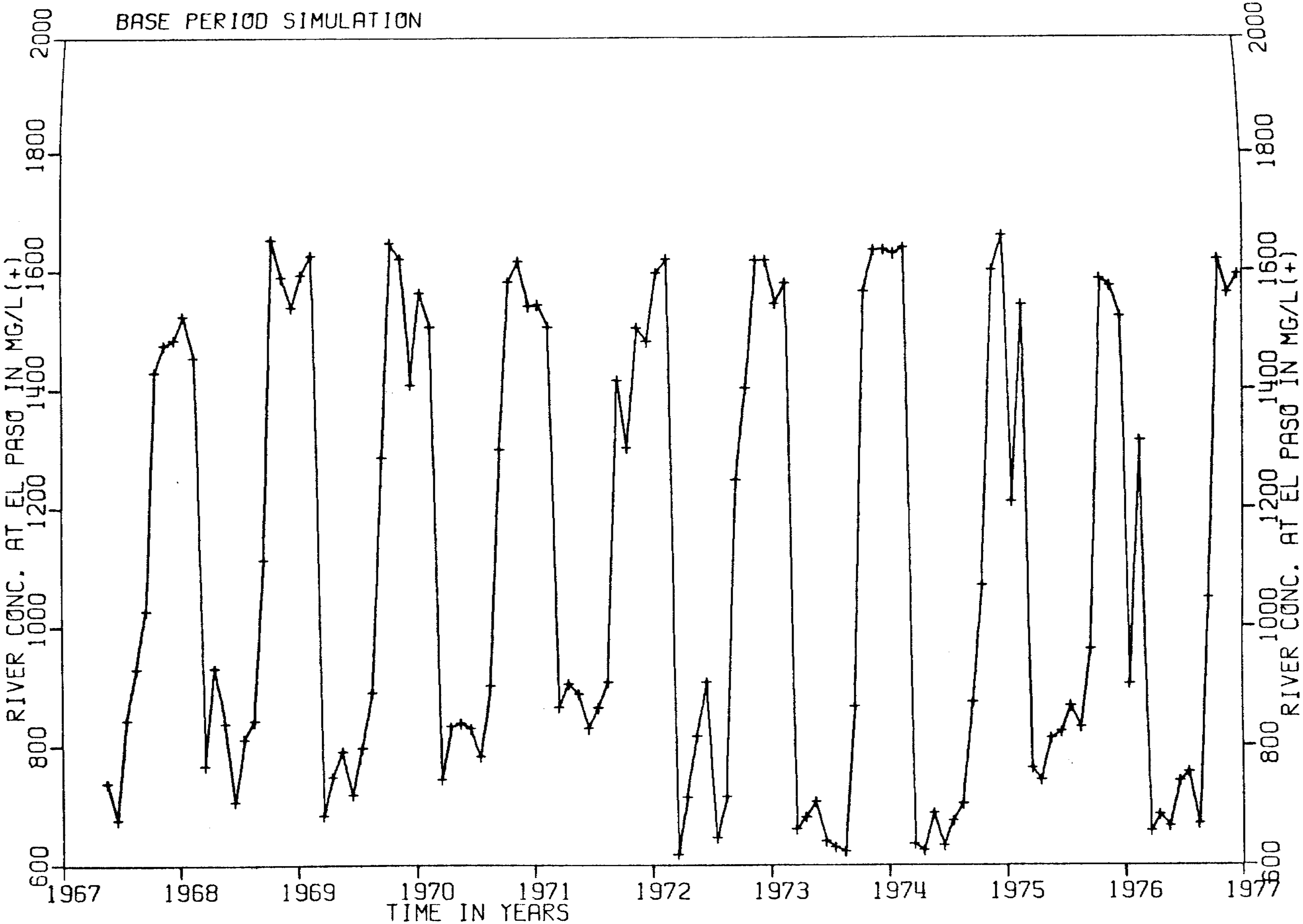

Figure 4.14: Base period simulation of average river TDS at El Paso, Texas, the Mesilla Valley outflow point.

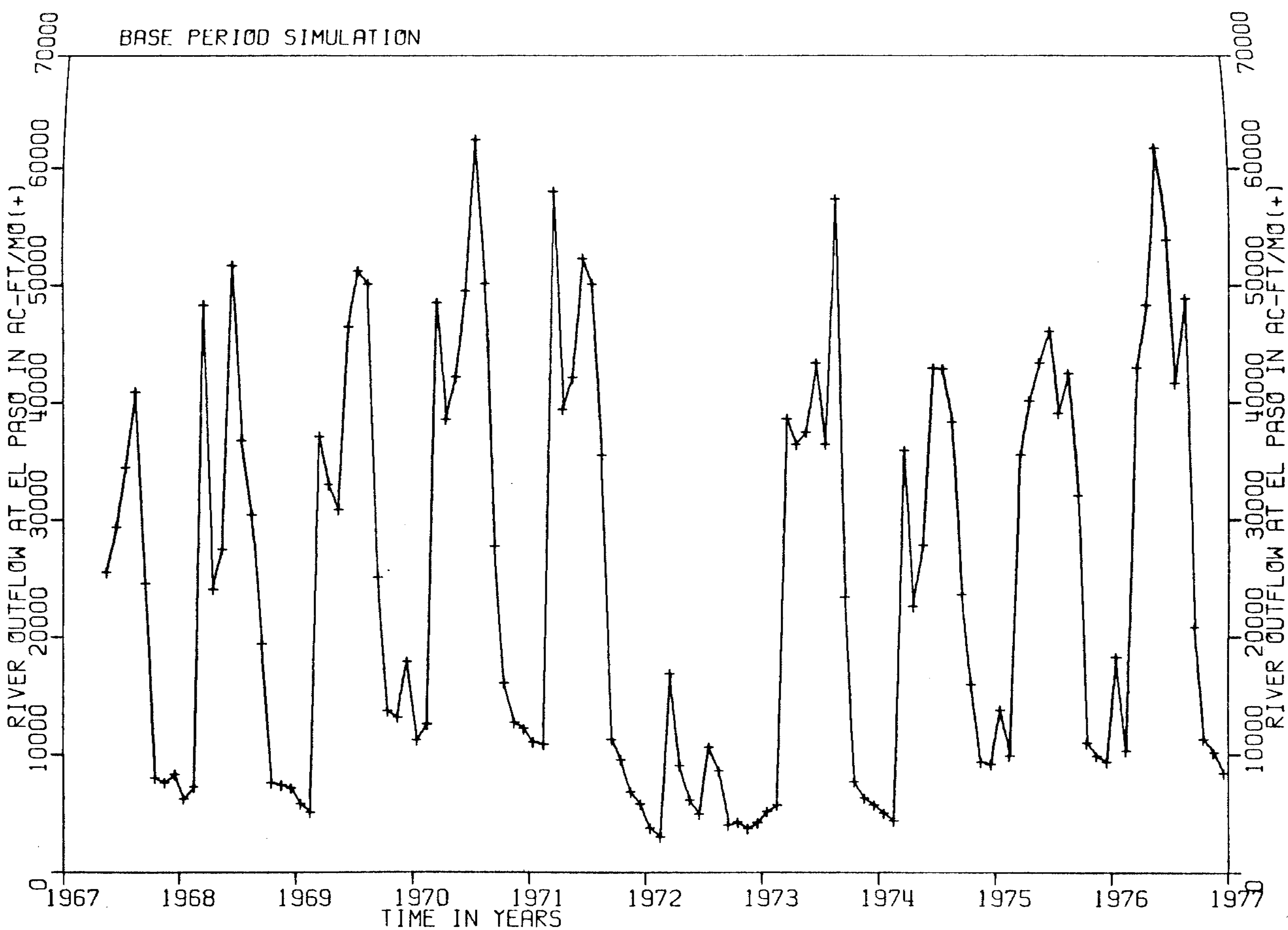

Figure 4.15: Base period simulation of average river outflow at El Paso, Texas, the Mesilla Valley outflow point.

irrigation efficiency (β). The groundwater pumped (q_p) from the valley for irrigation use is not metered; however, it may be estimated if we assume that groundwater will be pumped only after all of the surface diversions are utilized. Hence

$$q_p = q_{et}/\beta - (q_s - q_1) \tag{4.5.1a}$$

$$q_a = q_s - q_1 + q_p - q_{et} \tag{4.5.1b}$$

This last equation is written directly from Figure 4.6. The estimates of $q_1 = 0.45\ q_s$ and $\beta = 0.50$ were used in this study (see Gelhar and McLin, 1979, for the complete data basis for these estimates). In view of these assumptions, (4.3.3) can be rewritten for each of the four cases mentioned above; in all cases q_r was assumed to remain constant for a given recharge-recession period and was unchanged from the original simulation. A constant q_r for a given recharge-recession period, which covers several Δt time increments, produced somewhat inconsistent results over a portion of the simulation period for several of the management options examined. To correct these inconsistent results, a given q_r was subsequently assumed to be distributed over individual Δt increments within the same recharge-recession period in proportion to the observed river inflow below the Leasburg dam for that same Δt increment. All results that follow have utlized this later approach; Appendix G summarizes the computer code and output results of these management simulations.

The effect of this q_r distribution over individual Δt increments slightly altered the resulting model predictions for average aquifer water levels, drain flow, aquifer concentration, river outflow, and river water quality. That is, Figures 4.7 through 4.11 are slightly different than Figures 4.12 through 4.15, except for net aquifer recharge. These small differences can be computed from the listed output contained in Appendix E (the nonlinear simulation output utilizing the constant q_r terms for a given recharge-recession period), and Appendix F (the water managment base period simulation output using the appropriate q_r term which is distributed over the corresponding recharge-recession period and identified as q_R for a given Δt increment; however, the sum of all q_R values over a given recharge-recession period still totals the q_r value computed earlier.

The first case again addressed the question of evaluating the hydrologic effects on the system assuming all water demands were met by groundwater pumpage. Such an extreme situation would probably never actually occur (that is, a ten year long period with no surface diversions) but it will serve to illustrate the effects of one rather extreme management option. Again it was assumed that both irrigated acreage and total applied water would not change, and that a sufficient number of wells existed to supply the irrigation demand entirely from groundwater pumpage. In other words, the system averaged stresses remained identical to the original simulation; however, the source and chemical quality of applied water was changed to reflect this increase in pumpage and decrease in applied surface waters. In equation form this is represented by substituting (4.5.1b) into (4.3.1), assuming that S = n, and simplifying to obtain

$$n \frac{dh}{dt} + q_d = E \pm q_R \qquad (4.5.2)$$

where $E = q_s + q_n - q_{et}$ and where q_n was assumed to be zero since $q_n \ll q_s$ and $q_n \ll q_{et}$. The evapotranspiration term (q_{et}) was previously determined (Gelhar and McLin, 1979) for the USBR-EPA simulation study using the Blaney-Criddle method. Therefore in order to simulate the effects of no surface water diversions for case (1), all we need to do is set q_s equal to zero in (4.5.2) and solve for h, using the initial h at time zero and (4.3.2) for q_d along with the parameters previously determined.

The mass balance equation corresponding to (4.5.2) does not change form since only the water source terms and the associated water quality alters. Thus (4.3.5) was used for this and all subsequent water management options that were simulated. Actually this mass balance equation is two separate equations corresponding to the sign on q_R. If q_R is positive we have river to aquifer water transfers and (4.3.5) simply becomes,

$$nh \frac{dc}{dt} + c(E+q_R) = c_S\,(q_s+q_R) + q_n c_n;\ q_R > 0 \qquad (4.5.3a)$$

where $E = q_s+q_n-q_{et}$, and where $q_n \simeq o \simeq c_n$. If q_R is negative, we have aquifer to river water transfers and (4.3.5) becomes

$$nh \frac{dc}{dt} + cE = q_s c_s + q_n c_n;\ q_R < 0 \qquad (4.5.3b)$$

where E is defined above. For case (1), q_s is set to zero in both (4.5.3a) and (4.5.3b). The results of this first case are presented in Figure 4.16 through 4.19; they indicated the following:

1. The water table elevation throughout the valley decreased by an average of 2.9 (ft.) during the first year, and 43.9 ft. during the tenth year. Corresponding to these declines was an average reduction in groundwater recharge of 0.183 feet per month (ft/mo) during the first

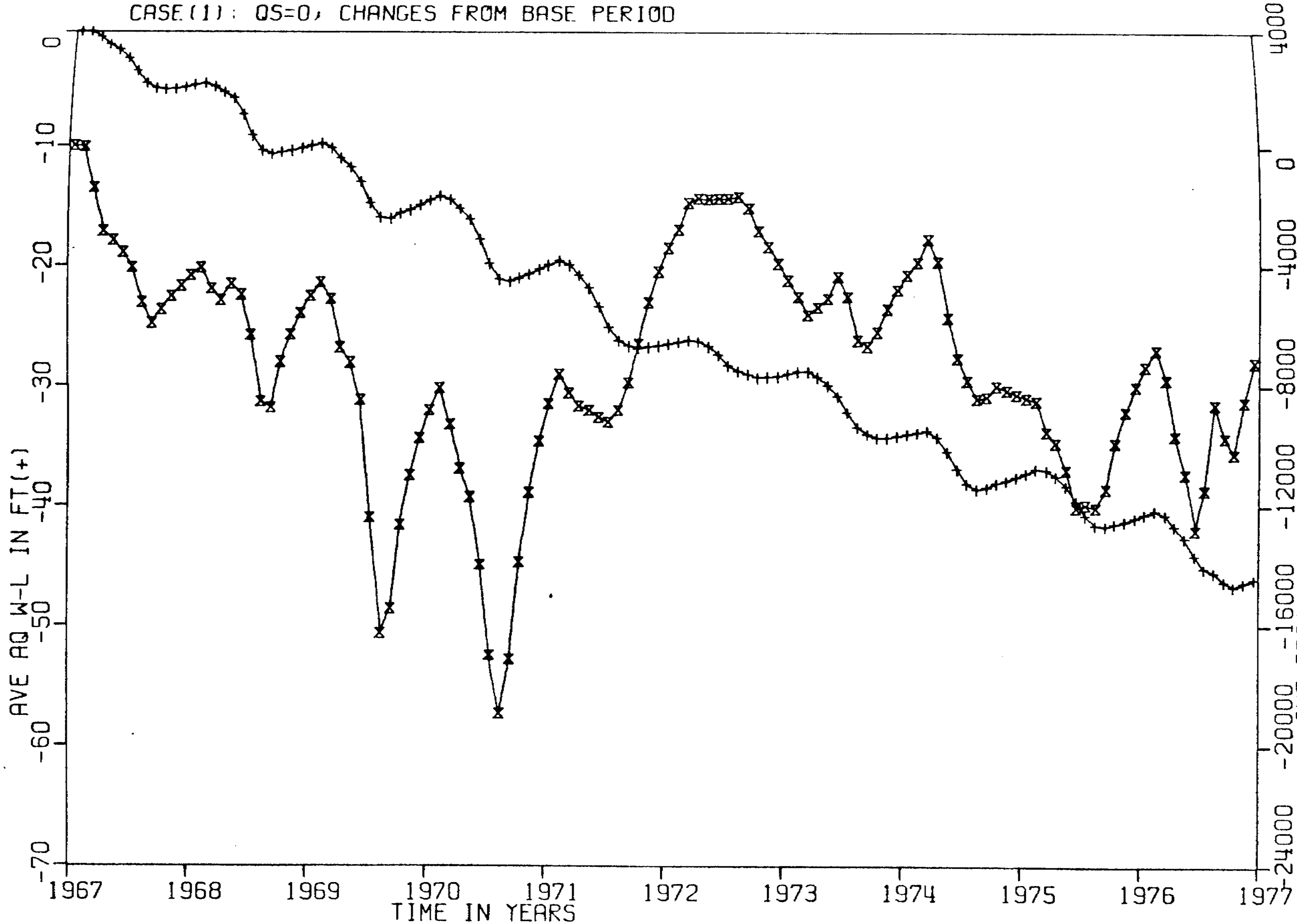

Figure 4.16 Case (1) changes from the base simulation in average aquifer water levels and valley drain flow.

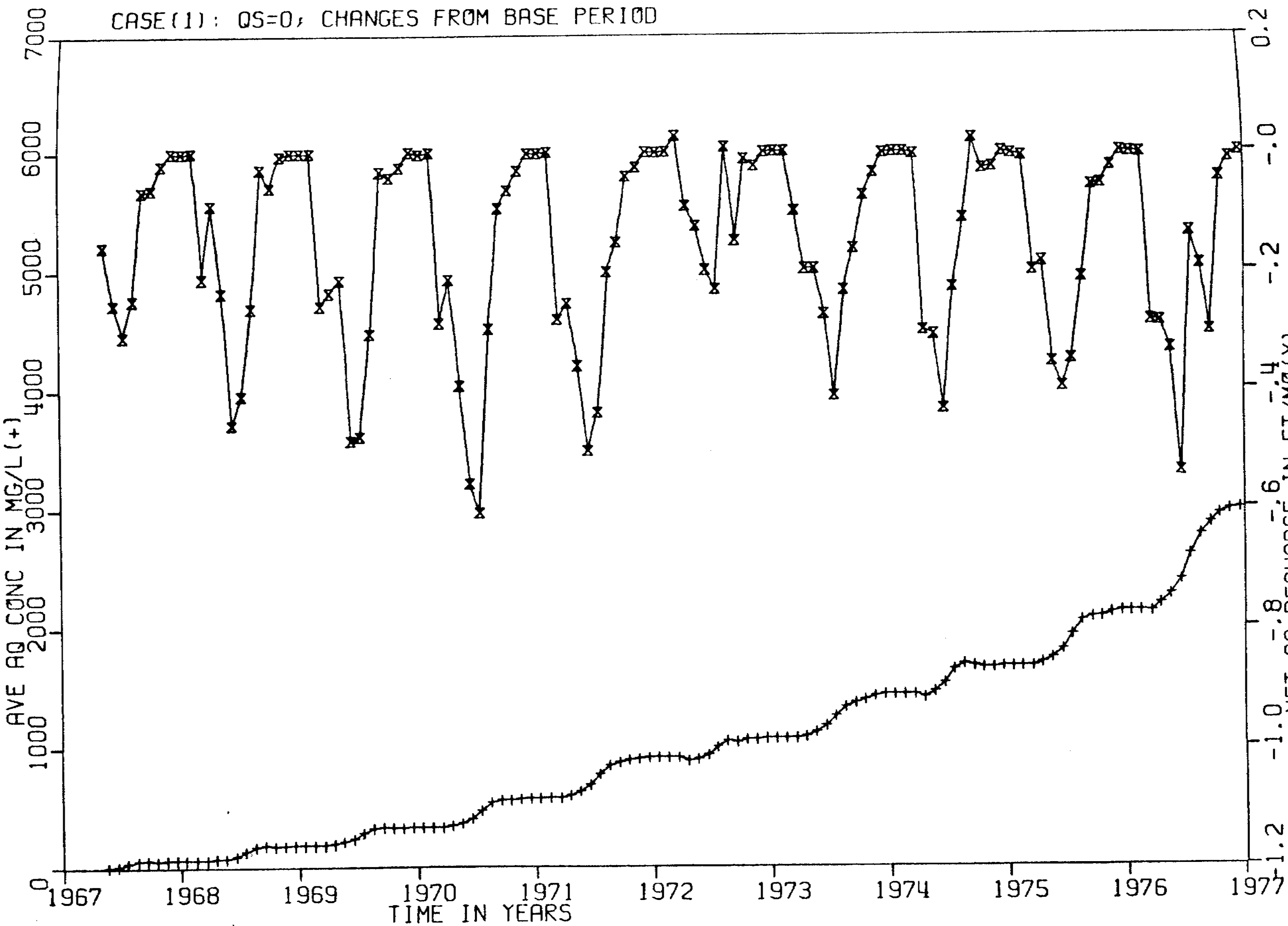

Figure 4.17 Case (1) changes from the base simulation in average aquifer TDS and net average aquifer recharge.

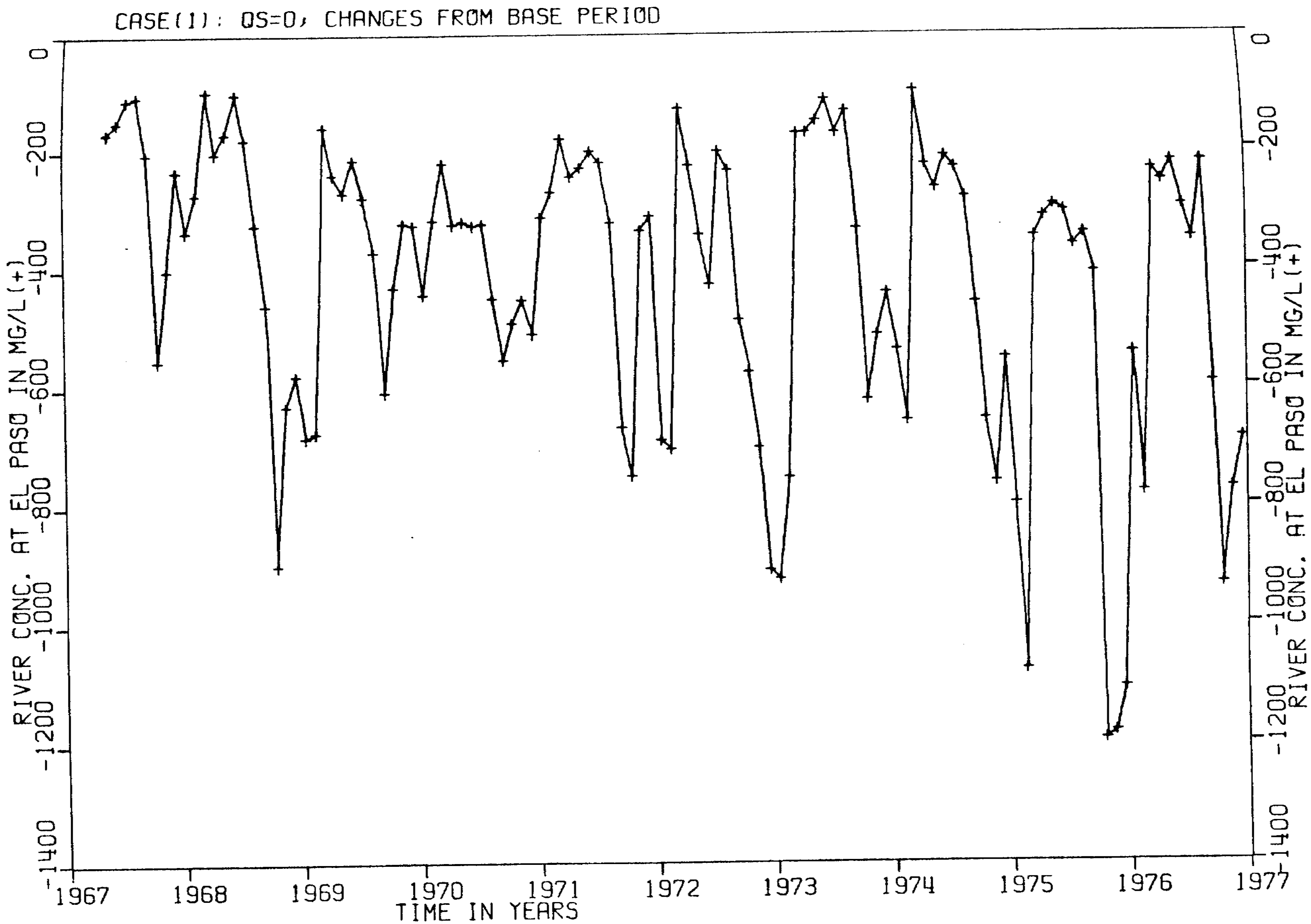

Figure 4.18 Case (1) changes from the base simulation in average river TDS at El Paso, Texas.

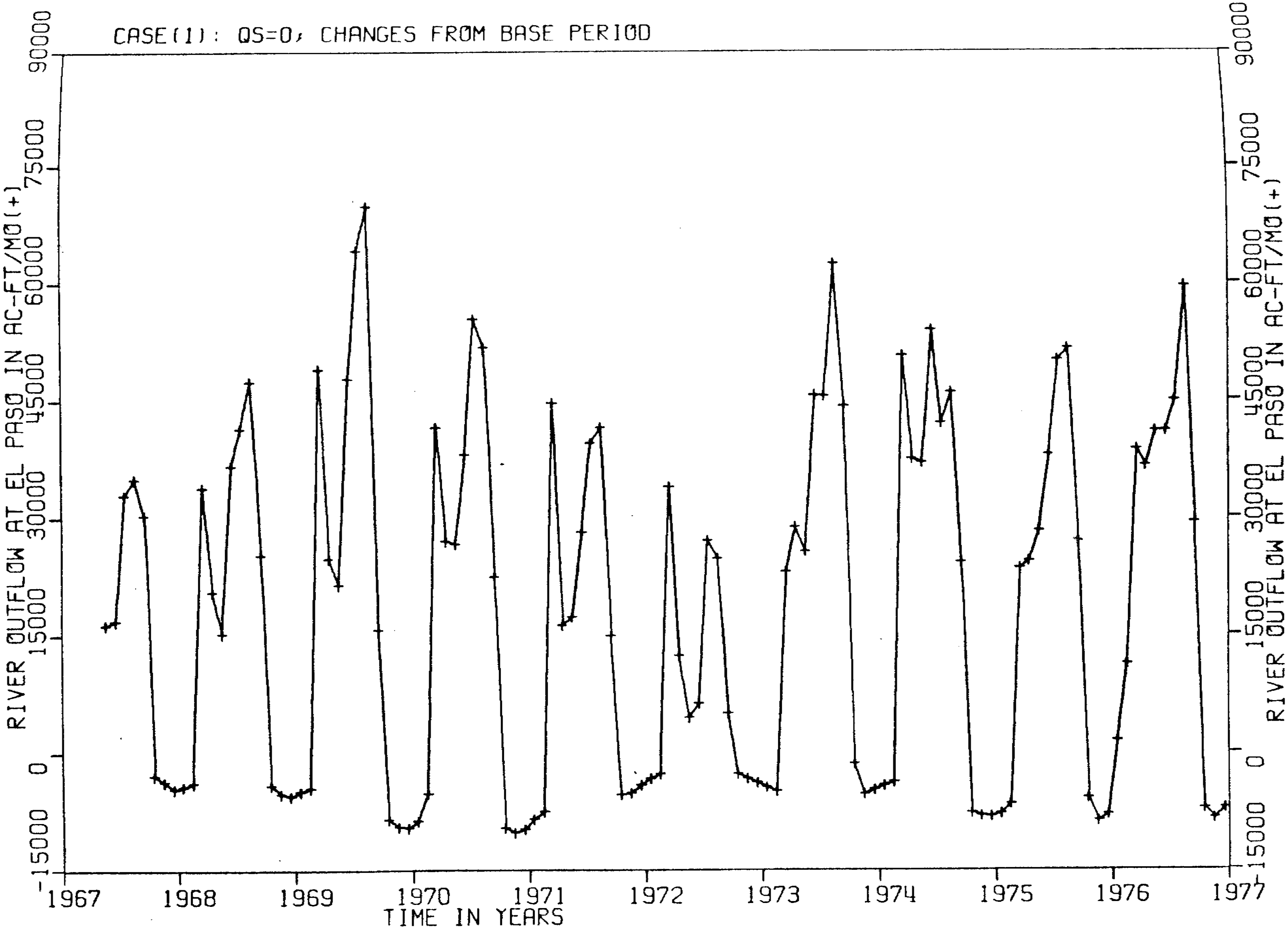

Figure 4.19 Case (1) changes from the base simulation in average river outflow at El Paso, Texas.

year, and 0.179 ft/mo during the tenth year; the average decrease over the ten year period was 0.160 ft/mo.

2. The groundwater quality showed an average TDS increase of 41 mg/l during the first year, and 2527 mg/l during the tenth year.

3. Streamflow gains in the Rio Grande at El Paso, Texas, resulting from decreased surface diversions, increased from an average of 14,967 acre-feet per month (ac-ft/mo) during the first year, to 23,351 ac-ft/mo during the tenth year; the ten year average increase was 17,609 ac-ft/mo. Likewise, there was a decrease in average drain flow of 3463 ac-ft/mo during the first year, and 9273 ac-ft/mo during the tenth year; the study period average drain flow decrease was 7284 ac-ft/mo. These drain flow decreases are obviously tied to the decrease in average aquifer water levels and recharge. In this case (1) all drain flow actually ceased after only a few months into the simulation.

4. The dissolved solids concentration in the Rio Grande at El Paso, Texas, decreased by an average of 243 mg/l during the first year, and 493 mg/l during the tenth year.

These results are graphically presented in Figures 4.16 to 4.19. While this extreme water management option does tend to improve downstream water flows and quality, these benefits are offset by drastic aquifer changes. These changes are a result of no surface water diversions into the valley, but rather simply conveying these supplies through the system. Furthermore, the dramatic water level declines essentially eliminate any drain flow, thereby reducing this source of low quality return flow back to the river. Instead these low quality waters remain in the valley aquifer to control the rapid decline in water quality there. Thus irrigators not only would have higher pumping costs associated with lower water levels, but the water they would obtain would be of questionable long term value due to its poor quality. This management option does demonstrate, however, the "closed cell" effect on the aquifer mass balance. In other words all contaminant mass from groundwater and drain flow is confined to the valley aquifer, while these same groundwaters are continually recirculated through the system

The second test also addressed an extreme question: What would be the effect on the stream-aquifer system if all irrigation demand were supplied from surface diversions, and no irrigation wells were pumped? Again it was assumed that the overall system stresses remained identical to the base simulation period. Only the source of irrigation waters, and the associated qualtiy, were allowed to change to reflect the new inflow surface diversions. In other words, the original surface diversions were increased by an amount equal to the computed irrigation pumpage, as defined in (4.5.1a). The irrigation pumpage was then set equal to zero. In this simulation an additional constraint was imposed; the procedure used in the constraint was first to check for sufficient river flow that would be available to meet the new surface diversion requirements. If not, the model allowed only a diversion equal to the amount of surface water that was physically observed to be present in the river; a crop water deficit would then occur for that time interval. This situation only rarely occurred in the ten year simulation however. Again all original system stresses remained identical to the original simulation, except for the increased surface diversions. While the mass balance equation did not change form; its predicted output changed to reflect increased use of the better quality surface waters. Figures 4.20 to 4.23 summarize these results; they indicated the following:

1. The water table elevation throughtout the valley increased by an average of 0.7 ft. during the first year, and 3.2 ft. during the tenth year. Groundwater recharge also increased from 0.090 ft/mo during the first year, to 0.183 ft/mo during the tenth year; the ten year average increase was 0.146 ft/mo.

2. The shallow groundwater quality showed a TDS decrease of 48 mg/l during the year, and 777 mg/l during the tenth year.

3. Initially streamflow in the Rio Grande decreased by some 4238 ac-ft/mo during the first year, but somewhat surprising increased by an average of 13,279 ac-ft/mo during the tenth year. A ten year average increase of 7485 ac-ft/mo was predicted for this second test; these results may have been affected by the relatively large RMS error obtained in the original simulation of river outflow (see Figure 4.10). This initial streamflow reduction may also have resulted in part from the diversion and utilization of all available surface water necessary to meet crop requirements; however, the river flow decline may have been later offset in part by increases in drain flow since there was no aquifer pumpage. The first year average increase in this drain flow was 3467 ac-ft/mo. By the tenth year, the average drain flow increased by 19,963 ac-ft/mo thereby apparently adding greatly to the net increase in river flow. The ten year average increase was 15,179 ac-ft/mo.

4. The dissolved solids in the Rio Grande predictably increased by 394 mg/l during the first year, but somewhat surprisingly decreased by 226 mg/l during the tenth year.

While many water managers would never advocate such an extreme water policy, this technique of diverting all available surface water does evidently show some promise in the Mesilla Valley. This technique does

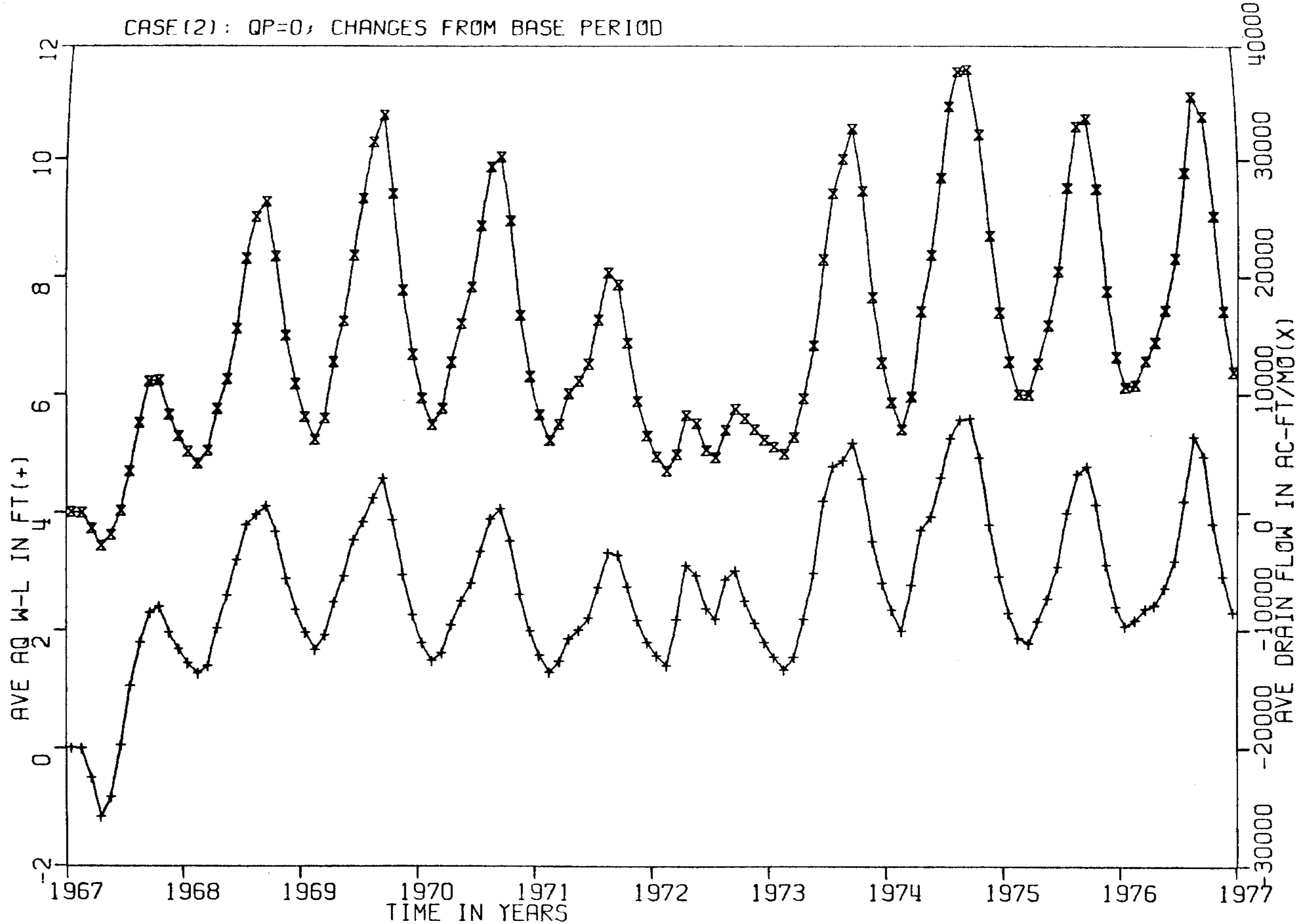

Figure 4.20 Case (2) changes from the base simulation in average aquifer water levels and average valley drain flow.

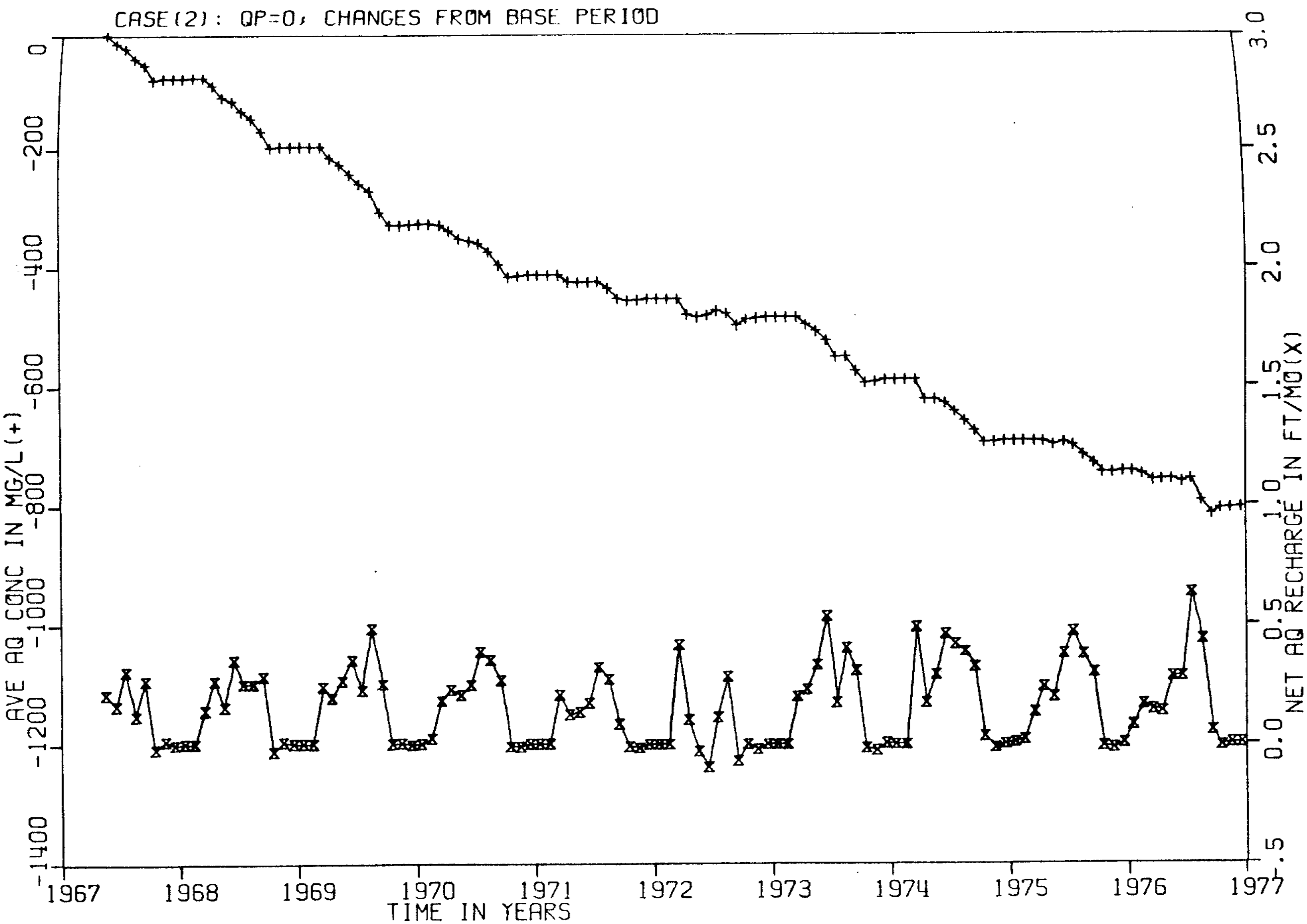

Figure 4.21 Case (2) changes from the base simulation in average aquifer TDS and net average aquifer recharge.

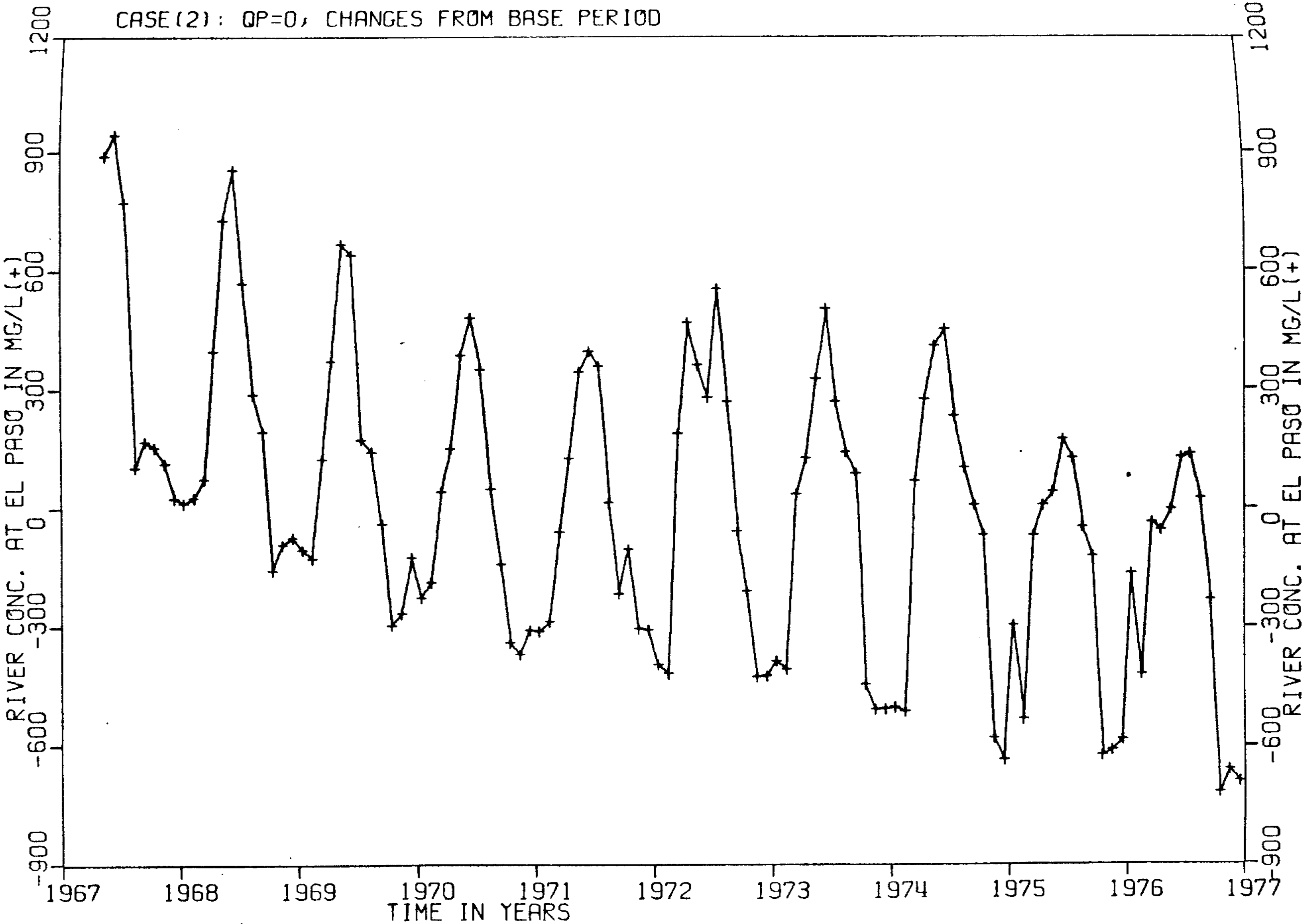

Figure 4.22 Case (2) changes from the base simulation in average river TDS at El Paso, Texas.

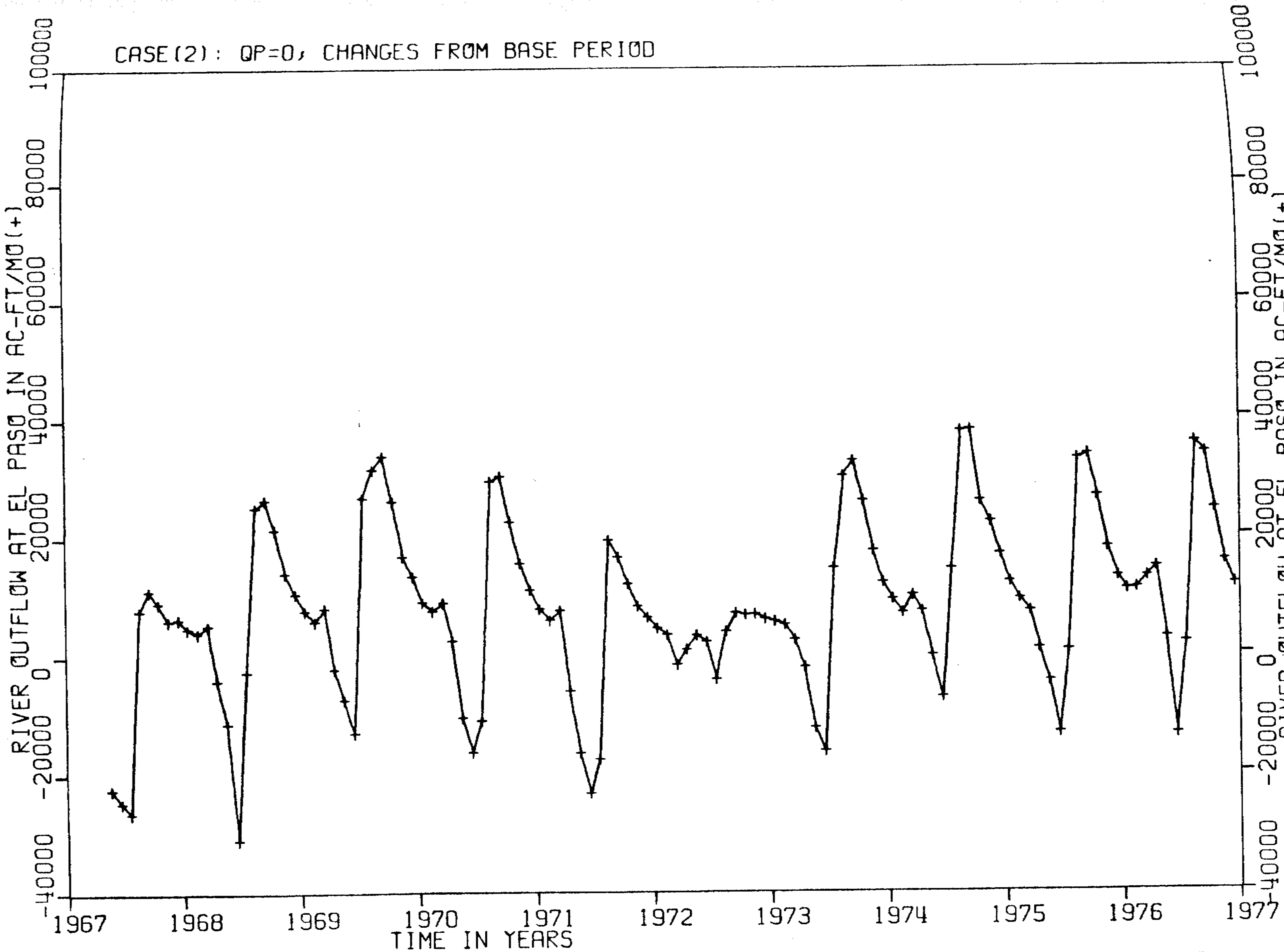

Figure 4.23 Case (2) changes from the base simulation in average river outflow at El Paso, Texas.

assume, however, that sufficient surface waters are available to meet all valley irrigation demands, as it was for most of this ten year period. While downstream users would initially receive lower quality water, the long term results apparently indicate an attractive decline in river contamination and shallow groundwaters. The major drawback to this water management option is rather predictable however. Downstream users would receiver lower volumes of river water precisely during the growing season when their requirements are highest, and higher volumes during the off season. A second disadvantage is that the long term improvement in groundwater quality and aquifer water levels would only serve to improve drain flow quality, since no pumpage occurs. Thus for all practical purposes, these improvements are essentially wasted as far as valley irrigators are concerned. This case does imply something we already should know: that a shallow groundwater circulation system exists in the uppermost alluvial aquifer. Thus the water levels and quality flucuate here according to the quantity and quality of applied waters, with some influence of attenuating contaminant migration through the aquifer.

The third test addressed the question: What would be the hydrologic effects on the stream-aquifer system as a result of improving irrigation efficiency by 25 percent (that is, 25 percent less irigation water is required to produce the same crop yields from the same irrigated acreage)? Again as with the other management options examined, only the water balance equation needs to be modified. Thus in (4.3.3), we need estimate only changes in E resulting from changes in irrigation efficiency. The form of the mass balance equation does not change, but since the water balance changes, the mass output naturally alters.

We may proceed to estimate these irrigation efficiency related water balance changes by referring back to (4.5.1a), and the basic definitions contained there. Thus these changes may be computed by recalling that the irrigation demand is simply the total crop consumptive use (q_{et}) divided by the average system irrigation efficiency (β). If we assume that we can improve β over some given time interval, then the resulting water savings may be expressed as

$$W = q_{et} \; (\beta_2 - \beta_1)/\beta_1\beta_2 \qquad (4.5.4)$$

where W is the water savings, β_1, is the original system irrigation efficiency, and β_2 is the improved efficiency. This net water savings to the system may be taken as either a reduction in groundwater pumpage (q_p) or surface diversion (q_s), or a combination of both. At first thought, it would seem logical to take advantage of these savings as reductions in q_p. If we do so we see that the individual components of net recharge ($E = q_s + q_n - q_{et}$) do not alter in view of (4.5.2); however, changes in soil-water moisture have not been taken into account. With this formulation, we may immediately conclude that any water savings resulting from improvements in irregation efficiency which are taken in the form of reduced pumpage amount to no net system changes. This conclusion applies to both the water and mass balance relationships, given by (4.3.3) and (4.3.5), respectively, as will become more obvious below.

It is also obvious that when these same savings are taken as reductions in q_s, then system water and mass alterations do occur; naturally the maximum changes occur when all of the savings are in the form of reduced q_s. We may express the range of these changes in q_s simply as,

$$q_{s2} = q_{s1} - \gamma W \tag{4.5.5}$$

where q_{s2} and q_{s1} are the new and old values for surface diversion corresponding to β_2 and β_1, respectively, and γ is the fraction of the water savings taken as a reduction in q_s. At the improved β_2 value, the net aquifer recharge is simply $E_2 = q_{s1} + q_n - q_{et}$, where the natural recharge (q_n) and crop consumptive use (q_{et}) do not change. Therefore in light of equation (4.5.5), we see that

$$E_2 = E_1 - \gamma W \tag{4.5.6}$$

If no water savings are taken in the form of reduced q_s but rather all in q_p, then $\gamma = o$ and $E_2 = E_1$. Likewise if no savings are taken as reductions in q_p but rather in q_s, then $\gamma = 1$ and maximum system changes occur.

In these simulations β_1 was taken as the original irrigation efficiency of 0.50, while β_2 was assumed to be 0.75; the resulting water savings is therefore given by (4.5.4). Since we already know that reductions in q_p result in no system changes, one limiting boundary is already known in the solution (see base period simulations presented earlier). The other boundary will occur at $\gamma = 1$, or when all water savings are taken as reductions in q_s. For $o \leq \gamma \leq 1$, the net system changes will fall between these two limits. Hence in this simulation, we

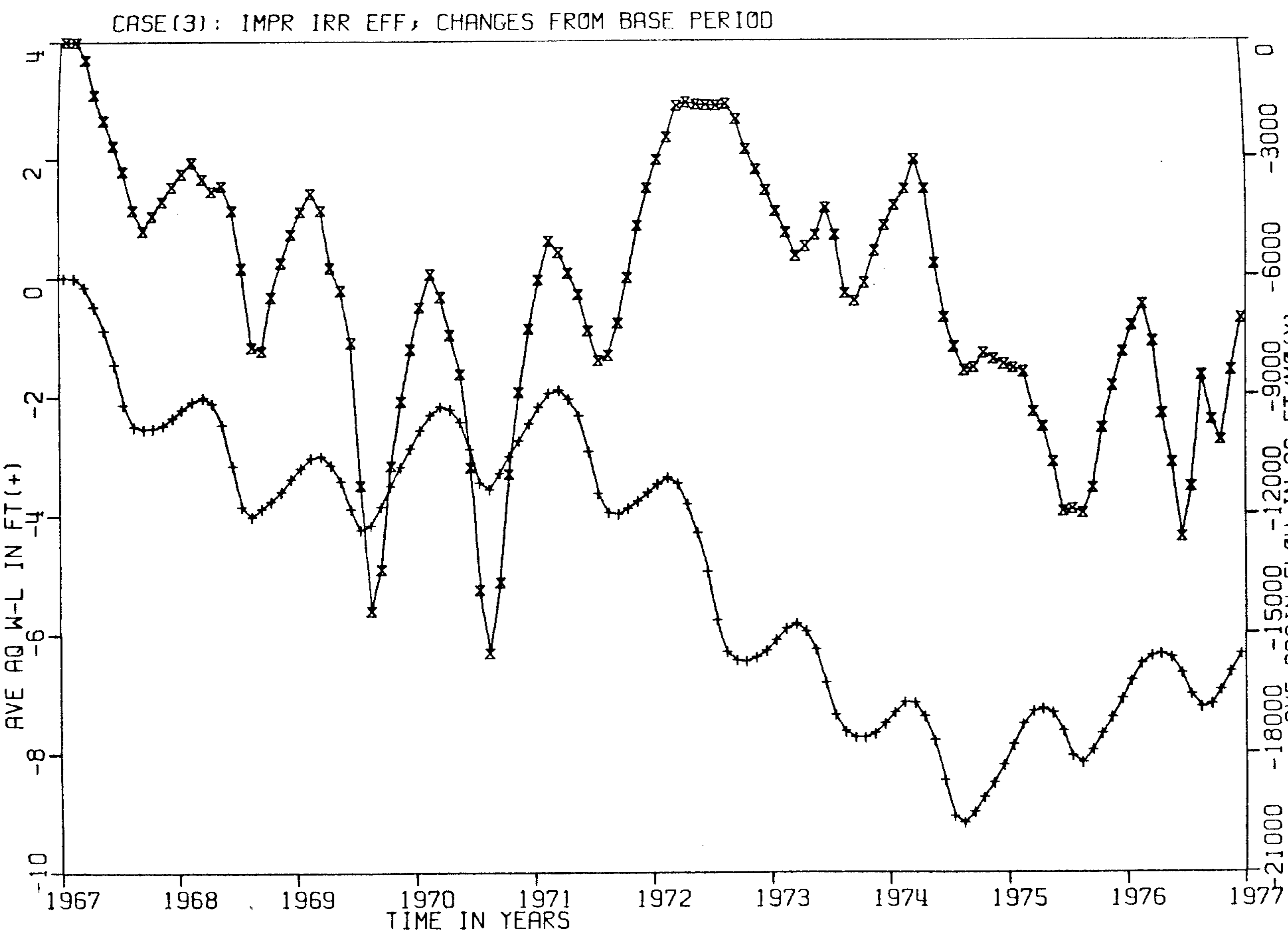

Figure 4.24 Case (3) changes from the base simulation in average aquifer water levels and valley drain flow.

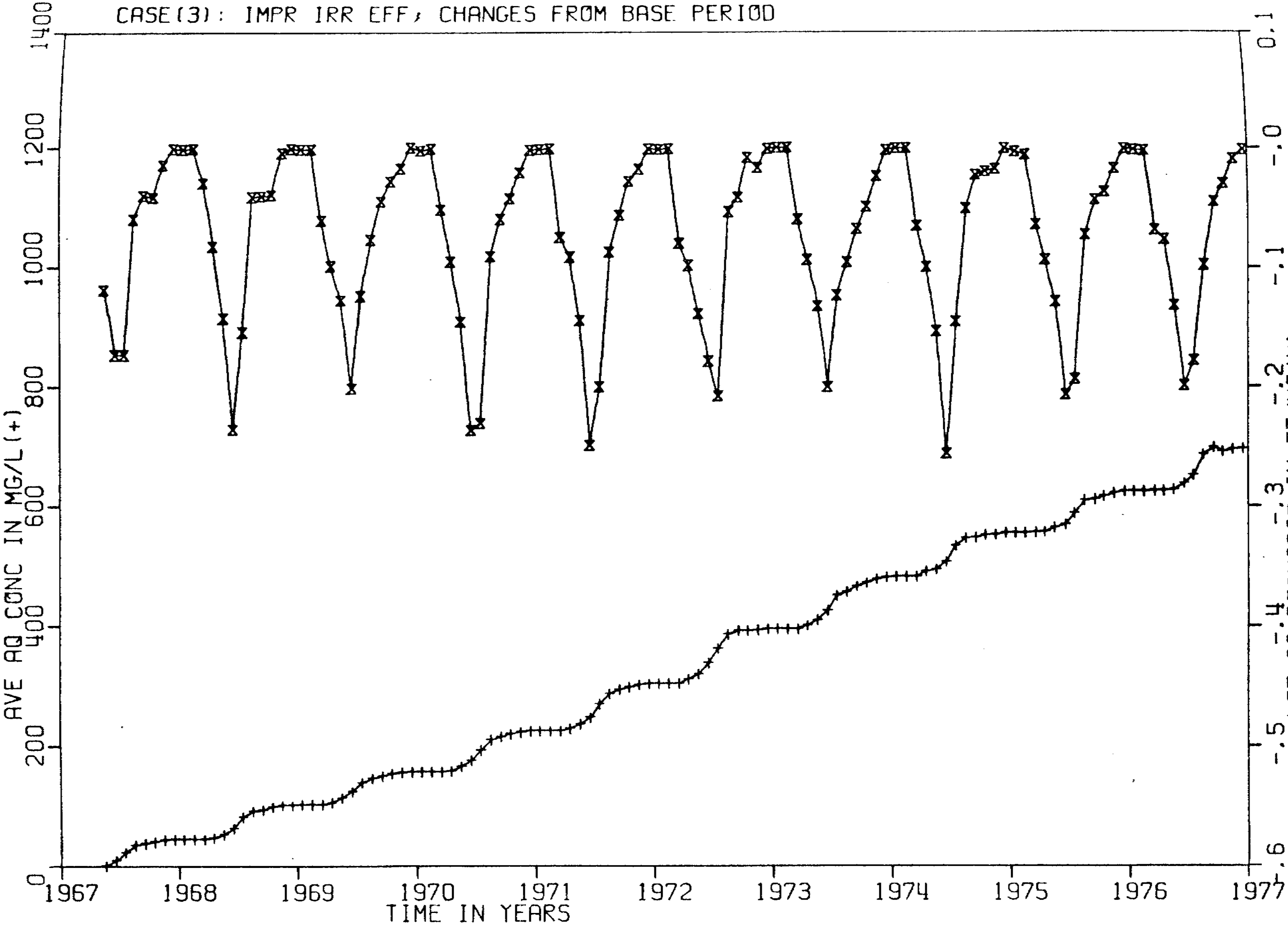

Figure 4.25 Case (3) changes from the base simulation in average aquifer TDS at El Paso, Texas.

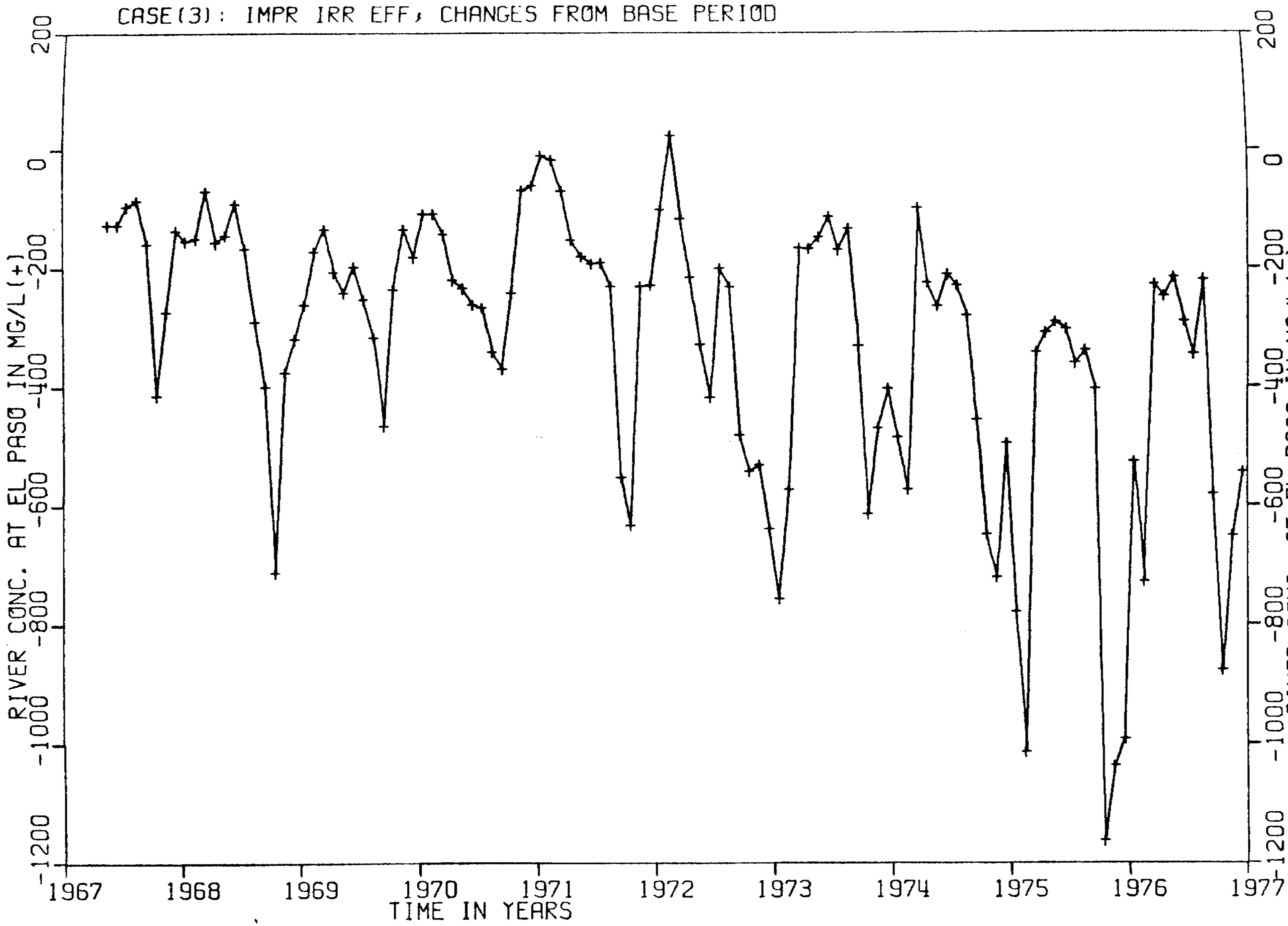

Figure 4.26 Case (3) changes from the base simulation in average river TDS at El Paso, Texas.

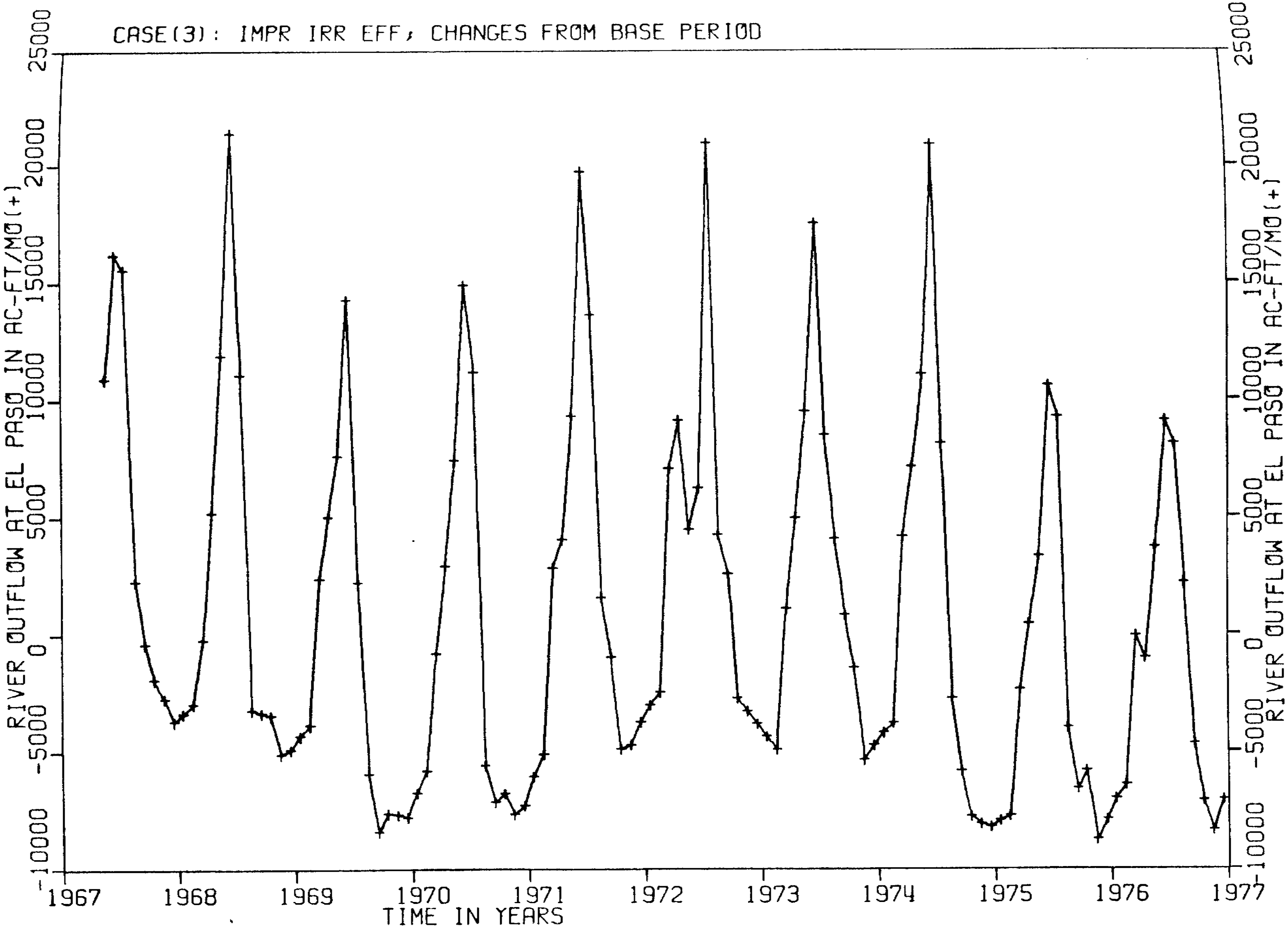

Figure 4.27 Case (3) changes from the base simulation in average river outflow at El Paso, Texas.

have assumed that $\gamma = 1$. These results are shown in Figures 4.24 through 4.27, and indicated the following:

1. The water table elevation throughout the valley decreased by an average of 1.5 ft. during the first year, and 6.7 ft. during the tenth season. These water level declines were also reflected in reduced aquifer recharge. During the first year, recharge declined by 0.099 ft/mo; whereas, during the tenth season these declines averaged 0.071 ft/mo. The ten year average decrease was 0.074 ft/mo.

2. The groundwater quality showed an average TDS increase of 28 mg/l during the first year, and 637 mg/l during the tenth year.

3. Streamflow fluctuations in the Rio Grande at El Paso, Texas, resulting from decreased surface diversions, increased by an average of 4788 ac-ft/mo during the first year, but decreased by an average of 1467 ac-ft/mo during the tenth year. A ten year average increase of 1252 ac-ft/mo was predicted by this option. As would be expected, there was a decrease in average drainflow of 2618 ac-ft/mo during the first year (or 49 percent of that originally avalable), and 9127 ac-ft/mo during the tenth year (or 98 percent of that available); the study period average drainflow decrease was 6492 ac-ft/mo (or 87 percent of that originally available). Obviously these reductions in drainflow are related to declines in aquifer water levels and recharge, and also influence the total river outflow volume.

4. The dissolved solids concentration in the Rio Grande at El Paso, Texas, decreased by an average of 186 mg/l during the first year, and 461 mg/l during the tenth year.

It is important to recall the conditions which led to the above conclusions. The water savings resulting from improvements in irrigation efficiency were taken only as reductions in surface diversions. If these same savings were taken as reductions in groundwater pumpage, then no changes from the original base simulation would occur. Some disadvantages of improved irrigation efficiency are obvious, especially when the resulting water savings are taken as reductions in surface diversions. Average aquifer water quality tends to suffer because of reductions in artificial aquifer recharge and drain flow; these reductions tend to restrict subsurface contaminant circulation by confining the dissolved solids in the shallow aquifer. Benefits are seen primarily by downstream users; these include improved downstream surface water quality and initial increases in river flow. Of course valley users see the benefit of reduced crop water requirements and pumpage if water savings are taken here. The downstream improvements are the direct result of slowly eliminating drain flow back to the river. However, the river volume also declines as drain flow is reduced, but this is partially offset by reduced surface diversion if water savings are applied here.

Some advocates of improving irrigation efficiency maintain that declines in aquifer water quality can also be eliminated, thereby making this option even more attractive. This certainly appears to be true in this work, but only if water savings are taken in the form of reduced pumpage. The proponents of this option maintain that the unsaturated zone below the crop roots can be utilized to store infiltrating contamination. However, the model used here does not directly address this question. Whether this contaminant storage in the unsaturated zone would be temporary or permanent remains unclear. Certainly if uncontrolled water applications (i.e., via excess rainfall or system mismanagement) enter the unsaturated zone in sufficient quantity, then some of the stored contamination would enter the aquifer. Evidently the best option, according to the results obtained here for the Mesilla Valley, would include taking the water savings resulting from an improved irrigation efficiency as reductions in groundwater pumpage.

The fourth and final case addressed the following question: What would be the hydrological and chemical effects on the stream-aquifer system as a result of lining all conveyance canals in the Mesilla Valley to prevent leakage losses. As pointed out earlier, this technique really is a method of improving irrigation efficiency, but it was decided to explore these effects separately. As was the situation in the three previous cases examined, only the water balance equation needs to be modified; however, the mass balance equation naturally alters since water input is changed. The results of this simulation are shown in Figures 4.28 through 4.31, and indicated the following:

1. The water table elevation throughout the valley decreased by an average of 0.5 ft. during the first year, and 0.2 ft. during the tenth season. These water level declines were also reflected in reduced aquifer recharge. During the first year, recharge declined by 0.037 ft/mo; whereas during the tenth season, they averaged 0.014 ft/mo. The ten year average decrease was 0.026 ft/mo.

2. The groundwater quality showed an average TDS increase of 9 mg/l during the first year, and a decrease of 72 mg/l during the tenth year.

3. Streamflow fluctuations in the Rio Grande at El Paso, Texas, resulting from increase surface flows, increased 7,001 ac-ft/mo during the first year, and 13,603 ac-ft/mo during the tenth season. The ten year average increase was 8,626 ac-ft/mo. As would be expected, there

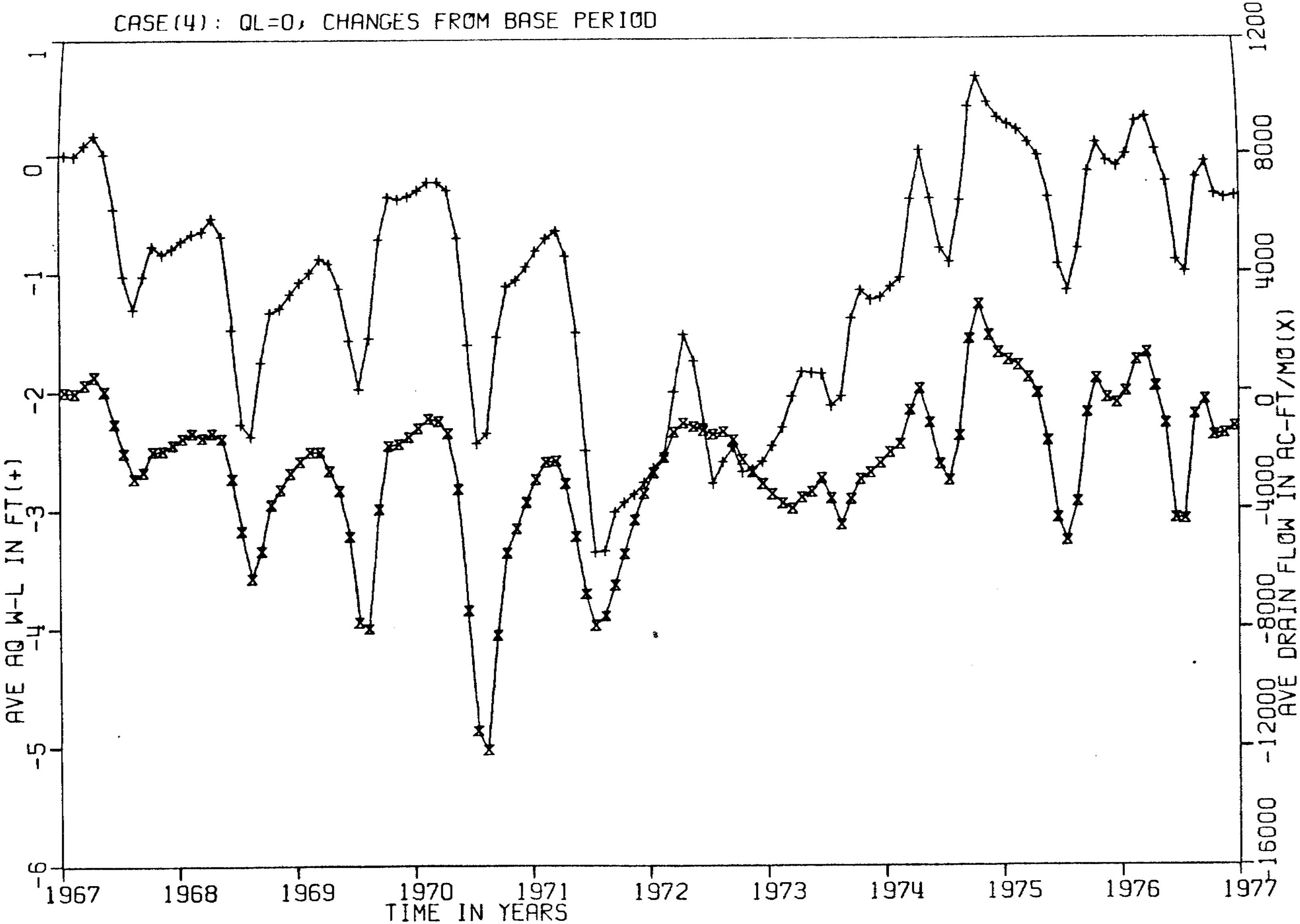

Figure 4.28 Case (4) changes from the base simulation in average aquifer water levels and valley drain flow.

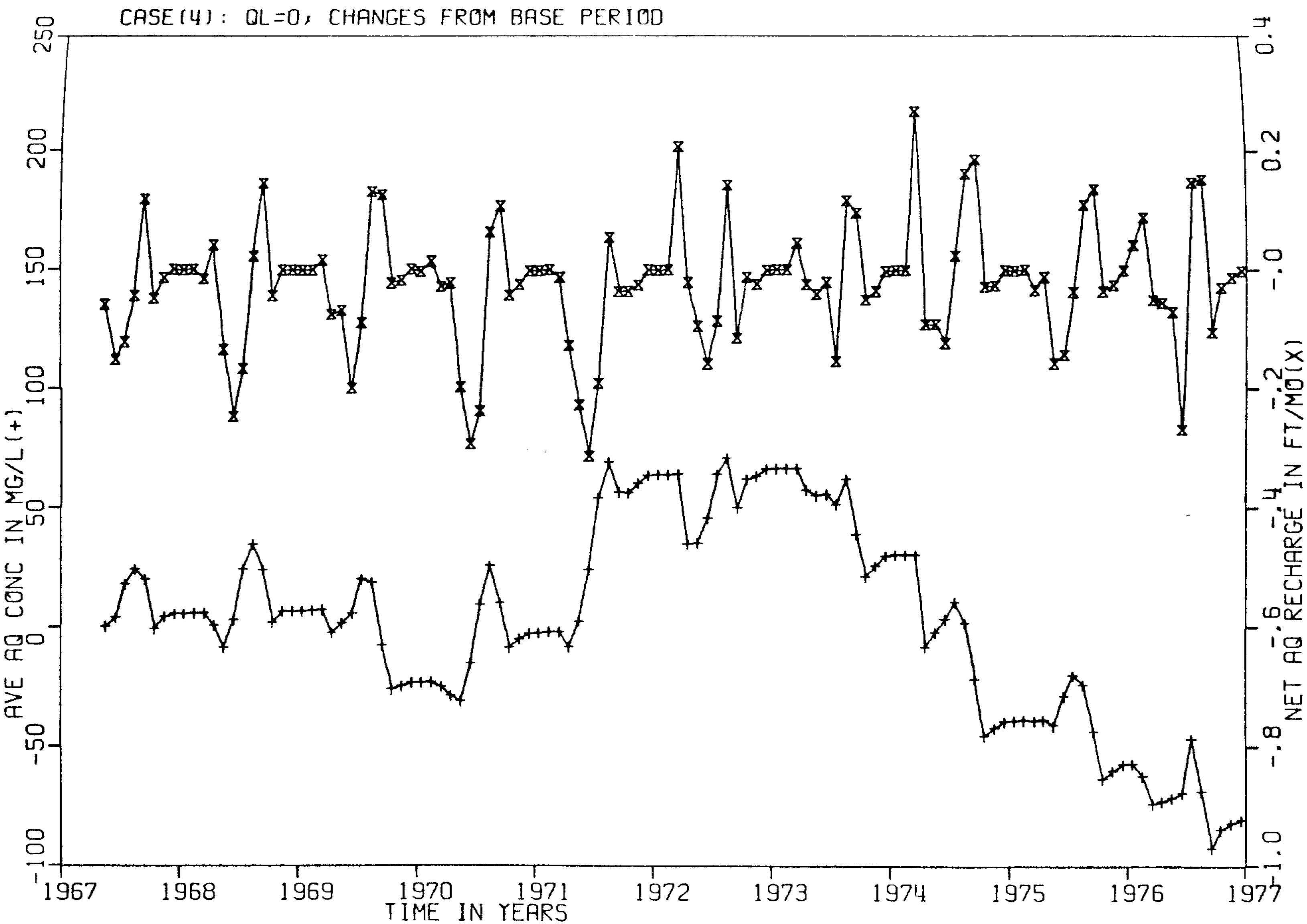

Figure 4.29 Case (4) changes from the base simulation in average aquifer TDS and net average aquifer recharge.

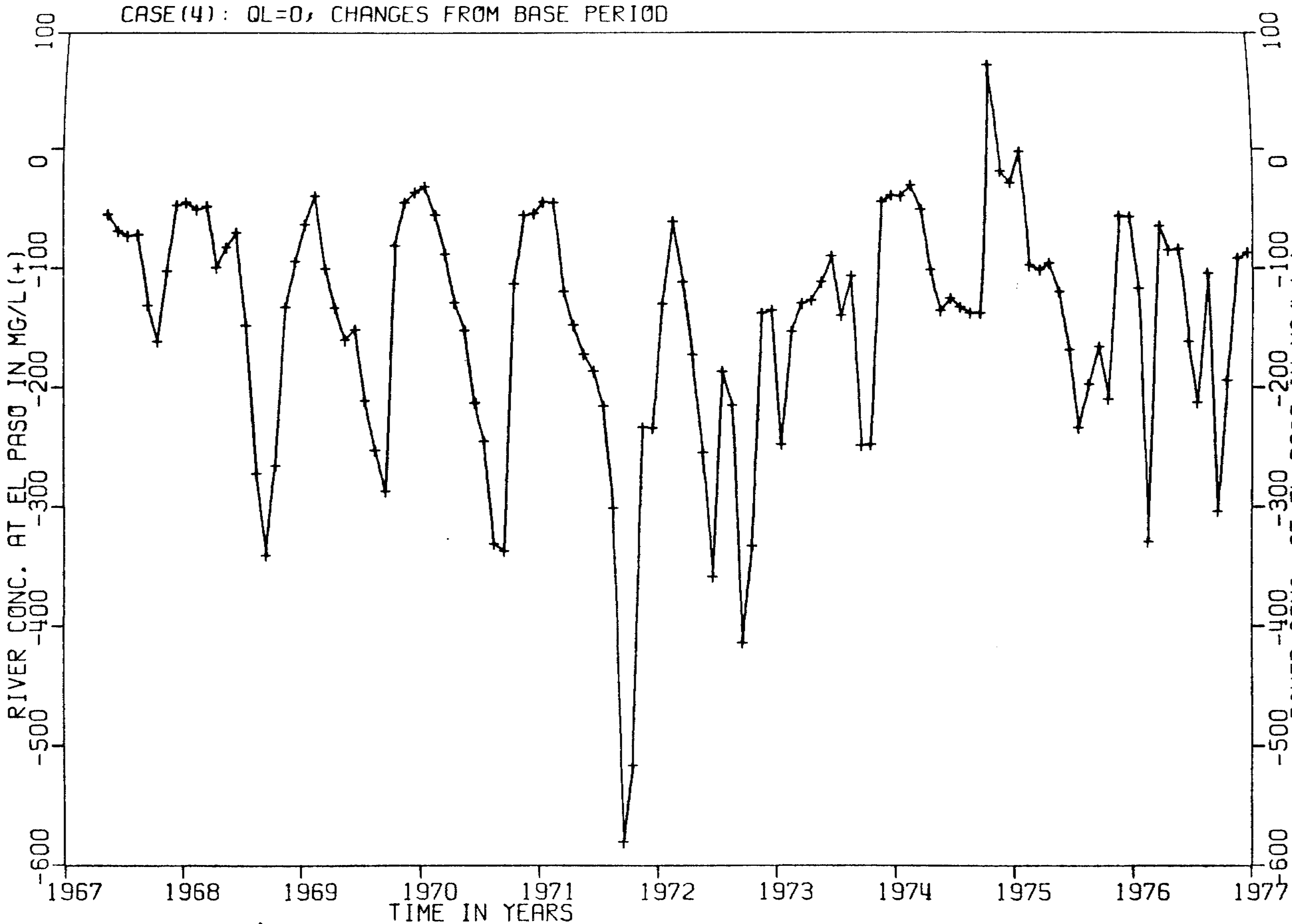

Figure 4.30 Case (4) changes from the base simulation in average river TDS at El Paso, Texas.

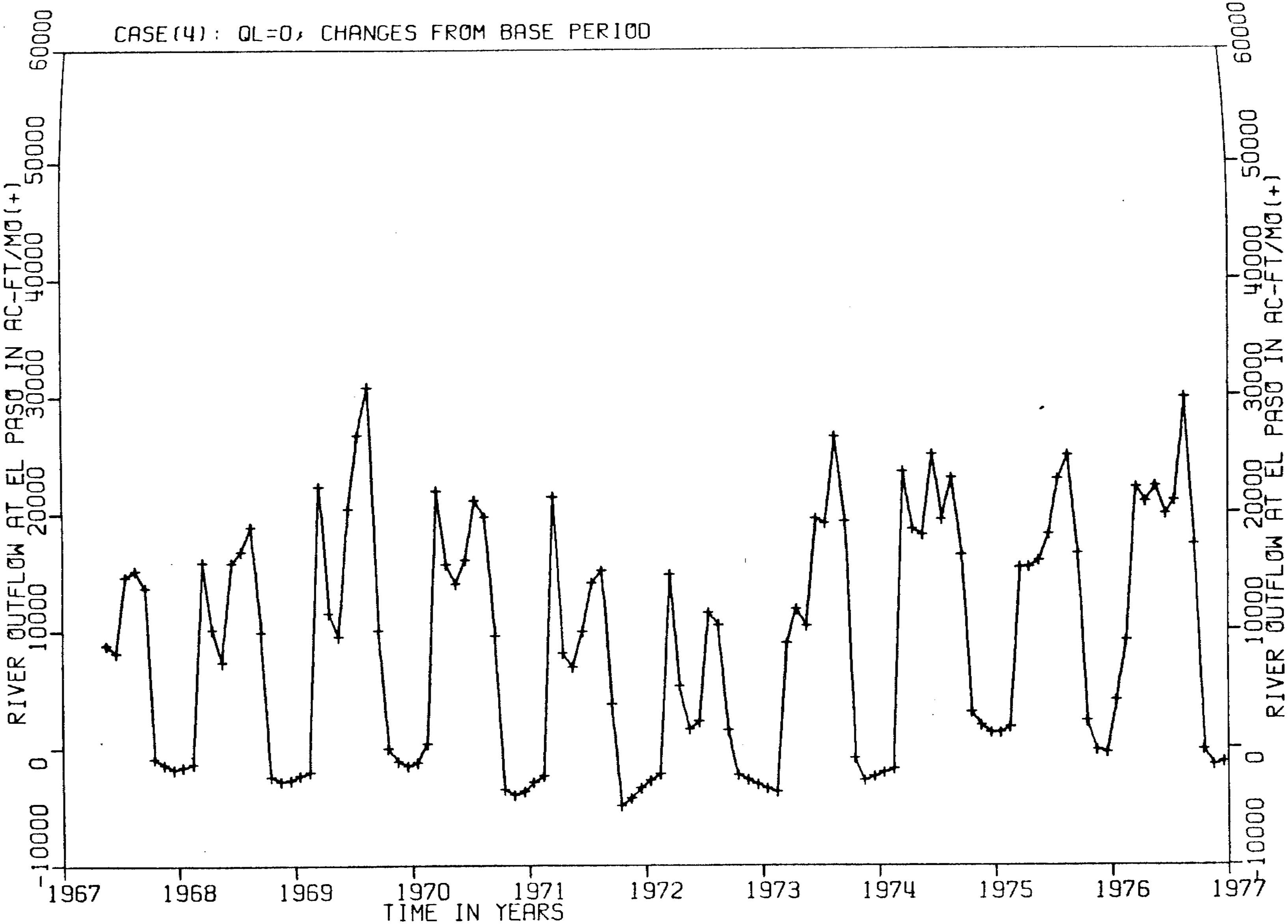

Figure 4.31 Case (4) changes from the base simulation in average river outflow at El Paso, Texas.

was a decrease in average drain flow of 1,156 ac-ft/mo during the first year (or 21 percent of that originally available) and 1,078 ac-ft/mo during the tenth year (or 12 percent of that available); the study period average drain flow decrease was 2,562 ac-ft/mo (or 34 percent of that originally available). Obviously these reductions in drain flow are related to declines in aquifer water levels and recharge, and have some impact on total river outflow volume.

4. The dissolved solids concentration in the Rio Grande at El Paso, Texas, decreased by an average of 90 mg/l during the first year and 153 mg/l during the tenth year.

The reduction in average aquifer TDS after 1973 (see Figure 4.29) came as somewhat of a surprise. However, an explanation may be found in the fact that there was a reduction in groundwater pumpage with a corresponding increase in surface water diversion after 1973 for the original base period simulation (see Figure 4.28 for the corresponding aquifer water level rise after 1973). This simulation indicates that many overall beneficial system changes could reasonably be expected to occur by lining conveyance canals in the Mesilla Valley. However, no cost-benefit analyses were performed for this or any other hypothetical water management scheme invisioned here. Such analyses would obviously need to be performed before any specific recommendations could be made. Results from all four cases are summarized in Table 4.5.

4.6 Conclusions

The results of the ten year simulation in the Mesilla Valley demonstrate that both the USBR-EPA hydrosalinity and nonlinear lumped

Table 4.5: Summary of water management options simulated, showing changes from base period simulation.

		Average aquifer water level (ft)	Average Drain flow (ac-ft/month)	Average aquifer TDS (mg/l)	Average aquifer recharge (ft/month)	Average River TDS at El Paso (mg/l)	Average River flow at El Paso (ac-ft/month)
Original Base Simulation	1st yr.	3824.16	5393	1648	0.0351	1074	22,289
	10th yr.	3825.20	9273	1706	0.0735	1017	31,357
	10 yr. ave.	3824.62	7486	1681	0.0453	1105	24,608
Case (1) No Surface Diversion	1st yr.	-2.90	-3463	+41	-0.1830	-243	+14,967
	10th yr.	-43.93	-9273	+2527	-0.1793	-493	+23,351
	10 yr. ave.	-24.52	-7284	+977	-0.1600	-412	+17,609
Case (2) No GW Pumpage	1st yr.	+0.72	+3467	-48	+0.0895	+394	-4,238
	10th yr.	+3.18	+19,963	-777	+0.1826	-226	+13,279
	10 yr. ave.	+2.70	+15,179	-439	+0.1464	+12	+7,485
Case (3) Improved Irr. Eff.	1st yr.	-1.47	-2618	+28	-0.0986	-186	+4,788
	10th yr.	-6.71	-9127	+637	-0.0705	-461	-1,467
	10 yr. ave.	-4.83	-6492	+313	-0.0743	-334	+1,252
Case (4) Lining Canals	1st yr.	-0.50	-1156	+9	-0.0369	-90	+7,001
	10th yr.	-0.24	-1078	-72	-0.0141	-153	+13,603
	10 yr. ave.	-1.09	-2562	+3	-0.0255	-145	+8,626

parameter models can simulate pre-existing conditions quite well if adequate data are available to descirbe the overall water and mass balance conditions of the aquifer. The experience with the Mesilla Valley system indicates that the data base is reliable and consistent. However, groundwater quality does show a high degree of horizontal and vertical spatial variability; furthermore, the vertical extent of this higher saline groundwater is not well defined. The actual predictive capabilities of the USBR-EPA model are less clear than for the nonlinear lumped parameter model. In order to predict the hydrochemical effects of changes in water application, one must be able to synthesize the resulting changes of flow into and out of the system, because the USBR-EPA model completely ignores aquifer flow dynamics. In other words, the aquifer hydraulic coefficients and changes in flow resulting from changes in water level are not used.

The nonlinear lumped parameter model, on the other hand, does incorporate the mixing cell structure plus the flow dynamics of the aquifer. This model can also be operated with a conceptually much simpler computer program; calculations can even be carried out on a programmable pocket calculator, though somewhat inconveniently for long simulation periods. The nonlinear formulation utilized here has the advantage of avoiding the calculation or measurement of evapotranspiration and groundwater pumpage; these terms probably introduce the greatest sources of error into the typical water balance approach of systems modeling. Furthermore, the nonlinear representation appears to more accurately simulate low drain flow periods than does the linear approach. Finally, the lumped parameter model, in both the linear and nonlinear forms, may be easily utilized in evaluating various system water management options once certain physical parameters are found which characterize the system response. However in such simulations, the individual components comprising the water balance equation must be estimated; hence, errors which were previously avoided may be inadvertently introduced into these management simulations.

The major disadvantage inherent to the lumped parameter format is that it does not provide a system wide spatial distribution for simulated aquifer water levels and contamination, nor does this model consider hydrodynamic dispersion effects.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This work has considered the problem of developing a simple method of predicting future changes in downstream water quality resulting from various alternative management practices in irrigated agriculture. The technique employed here is based on the generalized lumped parameter model which utilizes either a linear or nonlinear subsurface reservoir. Since this method represents the system only in a spatially averaged sense, a minimum of input data is required; however, several complicating hydraulic and mass transport phenomena are not explicitly incorporated into this lumped approach. Hence, a major facet of this work has attempted to clarify some of these differences between the lumped and spatially distributed models. These considerations included:

1. Vertical flow effects on the system outflow concentration history resulting from fully or partially penetrating streams under steady, saturated, convective transport flow conditions, assuming steady, uniformly distributed, conservative contaminant inputs;

2. Extending the approach of Step (1) to include nonhomogeneous anisotropic aquifers with and without an impermeable basement at some finite depth;

3. Incorporation of pronounced vertical flow effects into the lumped parameter format utilizing simple parallel and/or series configurations; and

4. Field demonstrations of the predictive capabilities of the linear and nonlinear lumped parameter model where direct comparisons to previous modeling efforts and observed data are possible.

The following conclusions can be drawn from this research:

1. A hydraulic and mass equivalence between the linear lumped parameter and linearized Dupuit models was established for a homogeneous, isotropic aquifer system. This analysis produced identical convective outflow concentration histories for each model; furthermore, the instantaneous average concentration in the two-dimensional Dupuit aquifer model analysis with a fully penetrating stream was shown to be identical to this system outflow concentration. Hence, the well-mixed reservoir assumption inherent to the lumped approach is justified from a distributed systems approach. The hydraulic and mass simulitude was extended to include multiple aquifer systems utilizing several lumped models in a parallel configuration, and a multi-layered Dupuit model analysis. These results indicated that the total mass outflow from each multiple system was identical, while the respective concentration outflow histories were approximately equivalent.

2. Vertical flow effects on convective outflow concentration resulting from partial stream penetration were examined from a two-dimensional Laplacian point of view. These aquifer geometry effects were combined into an aspect ratio defined as $\eta = L/D\ (K_z/K_x)^{1/2}$; thus incorporates the drain half-spacing (L), the aquifer depth (D) and the vertical to horizontal hydraulic conductivity contrast (K_z and K_x, respectively). Furthermore, when the impermeable Laplacian basement was taken at some infinite depth below the steam or tile drain, the resulting concentration break-through curve was nearly identical to that for $\eta = 1$. For values of η greater than about five (and hence, most practical applications), the lumped parameter model approximates the

Laplacian concentration break-through curves quite well. When η is less than five, however, pronounced vertical flow effects cause significant differences in outflow histories. Vertical flow effects resulting from horizontal aquifer stratification were also shown to have pronounced effects on the Laplacian outflow history. Both of these effects were approximately incorporated into the combined lumped parameter parallel configuration by utilizing two empirical correction factors. Thus, even the combined vertical flow effects resulting from aquifer layering and partial stream penetration were successfully incorporated into the seemingly crude lumped parameter format with surprisingly good results.

3. The lumped parameter model in the form of a linear reservoir was field tested in an irrigated area along the Arkansas River in southeastern Colorado over a one-year period. Results favorably compared with observed data and with a more complex convective-dispersive model (Konikow and Bredehoeft, 1974a, 1974b) previously tested in the same area under similar conditions. A second application of the model with a nonlinear phreatic aquifer was tested in the Mesilla Valley of southcentral New Mexico over a ten year period. Results showed good to excellent agreement with observed data and with a model (USBR, 1977) previously tested (Gelhar and McLin, 1979) in the same area under similar conditions. Both of these field applications have also demonstrated that the lumped modeling technique can easily be utilized to evaluate the effects of various real and/or hypothetical system stress patterns, including the individual effects of improvements in irrigation efficiency and lining of conveyance canals. These simulations require only that we first determine the system's hydraulic and solute response times from known data, and then estimate the quantity and quality of applied waters

from the various real or hypothetical sources. Hence, the generalized lumped parameter model is a truely predictive management tool.

4. In both the linear and nonlinear lumped parameter formulations, the requirement for showing or independently computing groundwater pumpage and evapotranspiration rates may be avoided in the water and mass balance relationships. This advantage is of major importance since one may avoid precisely those terms that tend to introduce large errors into the typical water balance approach to modeling. Thus, the lumped model format not only realistically incorporates many simplifying physical phenomena, the corresponding data base required for practical application is likewise reduced. These advantages are acquired, however, at the cost of a complete spatial description of hydraulic and mass transport mechanisms.

It is recommended that future research be conducted in the following:

1. An obvious extension of this work is to include the chemical exchange effects between the soil in the vadose zone and associated percolating recharge waters; several such models currently exist which could easily be incorporated (i.e., Dutt, et al., 1972; Bresler, 1977).

2. A question concerning aquifer parameter values from different hydrogeological settings might also be of interest. It is apparent that values for the parameter a from the Arkansas Valley and the Mesilla Valley are nearly identical, but both of these settings are actually hydrogeologically similar. However, irrigated coastal aquifer systems (as found along the northern coast of Lybia or the western shore of Isreal) might yield different values for a.

3. The Theissen polygon weighing technique was utilized to evaluate average aquifer water levels and initial contamination levels. This technique easily assigns appropriate weighing factors to account for horizontal variations in these variables. Such a procedure may not adequately account for vertical changes in aquifer water quality. Hence, other techniques may be more appropriate in obtaining these averages while still retaining the overall advantage of low input data requirements.

4. Many linear and/or nonlinear lumped models could be linked in a series and/or parallel combination in order to simulate regional water sheds where irrigation activity is widespread. The Colorado River Basin and the Rio Grande Basin are examples where water management options might be optimized so as to achieve minimal concentration outflow histories while maintaining economic agricultural practices. Although such an undertaking would be a massive effort, a sufficient data base probably already exists.

5. The nonlinear outflow expression given in (4.3.2) might be altered to produce even better results than those obtained for the Mesilla Valley. Furthermore, the precise form of such an expression may or may not be a site specific characteristic of the system in question.

6. The procedure of incorporating a retardation factor into the mass balance equation, which conceivably could be similar in some respects to the contamination degradation factor, might adequately account for reactive effects in a systems averaged sense.

7. Using a constant river leakage term for a given recharge-recession period may create problems in certain situations. This value is taken as a constant and may cover several time intervals in

the basic simulation. In some applications it might be more appropriate to obtain specific river leakage values over each of the given time intervals used in the water balance equation.

8. In the derivation of the generalized lumped parameter model, it was assumed that the aquifer specific yield was identical to the effective porosity (i.e., that S = n). In certain applications, this assumption may introduce errors into the mass balance equation. Hence, the affect of setting S = n should be evaluated.

9. Throughout this work a steady flow situation was employed in constructing idealized concentration break-through curves for the lumped parameter, Dupuit, and Laplace models. A logical extension of this work would be to extend the analysis to the unsteady case as well.

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APPENDICES

Appendix A

Dupuit Model Program: General Description

The computer program developed for this portion of the study is written in standard Fortran IV. It computes the dimensionless concentrations and times according to the analytical solutions for the combined lumped parameter and multi-layer Dupuit models derived in Sections 2.2.3, 2.3.3, and 2.3.4. The table below relates the appropriate symbol used in the program to the respective equation in the text.

Program Variable	Symbol	Equation	Remarks
AFAC	a	2.2.23	
BFAC	b	2.2.23	
CL	c/c_{aq_1}	2.2.23	
TL	t/t_{c_1}	below 2.2.20	TL=HU*T
AMU	μ	2.2.23	
GAMMA	γ	2.2.23	
AM	m	2.2.23	
HU	$1+m$	2.2.26 & 2.3.68	see Table 2.1
KU	K_u		upper layer K
KL	K_L		lower layer K
B	b_L/h_o	2.3.43	
ETA	$\hat{\xi}+1$	2.3.43	computational convenience
XMAX	$(1-B)/(1+\hat{\xi})$	below 2.3.51	
C	c/c_{aq}	2.3.51 & 2.3.61	
T	t/t'_{c_1}	2.3.61	relative to upper layer
		2.3.64	relative to lower layer
A	$(1+\hat{\xi})\ln\{(B+\hat{\xi})/(1+\hat{\xi})\}$	below 2.3.56	computational convenience

```
C
C       DUPUIT TWO-LAYER AQUIFER MODEL VS. COMBINED LUMPED MODEL
C
        REAL KU,KL
        DIMENSION X(41),B(7),KU(7),S(7),ERROR(41)
        COMMON C(41),T(41),CL(41),TP(41),ANAME(2)
        DATA B/5*0.75,0.90,0.95/
        DATA KU/20.0,10.0,5.0,2.0,1.0,2*10.0/
        DATA S/7*10.0/
        DATA IR,IW/22,23/
        OPEN(UNIT=22,DEVICE='DSK',ACCESS='SEQIN',FILE='DUP1.DAT')
        OPEN(UNIT=23,DEVICE='DSK',ACCESS='SEQOUT',FILE='DUP.DAT')
        CALL INITAL(1)
        POR1=1.0
        POR2=1.0
        KL=1.0
        D=1.0
        DO 1 J=1,7
        READ(IR,201)(ANAME(II),II=1,2)
    201 FORMAT(2A5)
        JK=J
        HU=D/(1.0-B(J))
        S(J)=S(J)/D
        ETA=1.0+B(J)*(KL-KU(J))/KU(J)
        XMAX=(1.0-B(J))/ETA
        AM=B(J)/(1.0-B(J))
        A=-ETA*ALOG(1.0-(1.0-B(J))/ETA)
        X(1)=0.0
        C(1)=1.0-X(1)
        T(1)=0.0
        AMU=(AM*KL/KU(J))/(1.0+AM*KL/KU(J))
        GAMMA=(POR1*AMU)/(POR2*AM)
        DO 2 I=2,40
        KOUNT=I
        X(I)=X(I-1)+0.025
        IF(X(I).GT.XMAX)GO TO 3
        C(I)=1.0-X(I)
        T(I)=-ETA*ALOG(1.0-X(I))
        GO TO 2
      3 XMAX1=X(I)
        X(I)=XMAX
        C(I)=1.0-X(I)
        T(I)=A
        KK=KOUNT+1
        X(I+1)=XMAX1
        C(I+1)=1.0-X(I+1)
        T(I+1)=A-ETA*(KU(J)/KL)*ALOG(KU(J)*ETA*C(I+1)/(KL*B(J)))
        GO TO 4
      2 CONTINUE
        C(41)=C(40)
        T(41)=T(40)
      4 IF(KOUNT.GE.40 .OR. KK.GE.41) GO TO 5
        KK=KK+1
        DO 6 I=KK,41
        X(I)=X(I-1)+0.025
        C(I)=1.0-X(I)
      6 T(I)=A-ETA*(KU(J)/KL)*ALOG(KU(J)*ETA*C(I)/(KL*B(J)))
        AREAD=0.0
        AREAL=0.0
        BFAC=AMU/(GAMMA-1.0)
```

```
      AFAC=1.0+BFAC
      CL(1)=AFAC-BFAC
    5 DO 7 I=2,41
      CL(I)=AFAC*EXP(-HU*T(I))-BFAC*EXP(-HU*GAMMA*T(I))
      AREAL=AREAL+0.5*(T(I)-T(I-1))*(CL(I)+CL(I-1))
      AREAD=AREAD+0.5*(T(I)-T(I-1))*(C(I)+C(I-1))
    7 ERROR(I)=(CL(I)-C(I))*100.0/C(I)
      WRITE(IW,101)(ANAME(II),II=1,2),KU(J),S(J),B(J),AMU,GAMMA
  101 FORMAT(1H1,//,10X,'DUPUIT TWO-LAYER AQUIFER AS COMPARED TO
     < THE COMBINED LUMPED MODEL',/,10X,2A5,//,11X,'KU/KL = ',F4.1,/,
     <11X,'S/D = ',F4.1,/,11X,'BL/D = ',F4.2,/,11X,'MU = ',F6.4,
     </,11X,'GAMMA = ',F6.4,//,10X,'STREAMLINE',2X,'DIM. TIME',2X,
     <'DUPUIT CONC.',2X,'LUMPED CONC.',2X,'% REL. ERROR',/,22X,
     < '(T PRIME)',/)
      DO 8 I=1,41
      TP(I)=HU*T(I)
    8 WRITE(IW,102)X(I),TP(I),C(I),CL(I),ERROR(I)
  102 FORMAT(10X,F7.3,4X,F10.5,4X,F6.3,7X,F7.3,8X,F8.2)
      WRITE(IW,103)AREAD,AREAL
  103 FORMAT(/,20X,'AREA UNDER DUPUIT CURVE: C VS. T = ',F10.7,/,20X,
     < 'AREA UNDER LUMPED CURVE: C VS. T = ',F10.7)
      DO 10 I=1,41
      C(I)=-ALOG10(C(I))
   10 CL(I)=-ALOG10(CL(I))
    1 CALL GRAFF(JK)
      CALL RSTR(0)
      CALL RSTR(2)
      CLOSE(UNIT=22,DEVICE='DSK',ACCESS='SEQIN',FILE='DUP1.DAT')
      CLOSE(UNIT=23,DEVICE='DSK',ACCESS='SEQOUT',FILE='DUP.DAT')
      STOP
      END
C
      SUBROUTINE GRAFF(JR)
      COMMON C(41),T(41),CL(41),TP(41),ANAME(2)
      DIMENSION LBX(4),LBY(4),TITLE1(8),TITLE2(8)
      DATA LBX/5H DIME,5HNSION,5HLESS ,5HCONC./
      DATA LBY/5H  DIM,5HENSIO,5HNLESS,5H TIME/
      DATA TITLE1/5HSOLID,5H LINE,5H FOR ,5HDUPUI,5HT TWO,5H-LAYE,
     <5HR MOD,5HEL   /
      DATA TITLE2/5HSYMBO,5HL ONL,5HY FOR,5H COMB,5HINED ,
     <5HLUMPE,5HD MOD,5HEL   /
      CALL RSTR(0)
      CALL RSTR(1)
      J0=0
      J1=1
      N=41
      ND=2
      FLT1=1.0
      FLT2=0.1
      FLT3=0.01
      XMIN=0.0
      DX=0.4
      YMIN=0.0
      DY=8.0
      IF(JR.EQ.7)DY=12.0
      DO 1 I=1,N
      IF(CL(I).GT.2.0)CL(I)=2.0
      C(I)=(C(I)-XMIN)/DX
      CL(I)=(CL(I)-XMIN)/DX
    1 TP(I)=(TP(I)-YMIN)/DY
```

```
      CALL PLOT(3.0,1.25,-3)
      CALL PLOT(5.0,0.0,2)
      CALL PLOT(5.0,8.0,2)
      CALL PLOT(0.0,8.0,2)
      CALL PLOT(0.0,0.0,2)
      CALL SYMBOL(0.5,2.0,0.14,ANAME,90.0,10)
      CALL SYMBOL(0.7,2.0,0.14,TITLE1,90.0,40)
      CALL SYMBOL(0.9,2.0,0.14,TITLE2,90.0,40)
      CALL AXIS(5.0,0.0,LBY,-20,8.0,90.0,YMIN,DY,-1)
      CALL SYMBOL(1.3,-0.8,0.14,LBX,0.0,20)
      CALL PLOT(2.5,0.0,3)
      CALL PLOT(2.5,8.0,2)
      CALL NUMBER(0.0,-0.6,0.14,FLT1,90.0,ND)
      CALL NUMBER(2.5,-0.6,0.14,FLT2,90.0,ND)
      CALL NUMBER(5.0,-0.6,0.14,FLT3,90.0,ND)
      CALL PLOT(0.0,0.0,3)
      CALL LINE(C,TP,N,JO,1)
      CALL PLOT(0.0,0.0,3)
      DO 2 I=1,N
      XCORD=CL(I)
      YCORD=TP(I)
      CALL PLOT(XCORD,YCORD,3)
      CALL MARKER(J1)
    2 CONTINUE
      CALL PLOT(0.0,0.0,3)
      RETURN
      END
```

DUPUIT TWO-LAYER AQUIFER AS COMPARED TO THE COMBINED LUMPED MODEL
CASE(1):

KU/KL = 20.0
S/D = 10.0
BL/D = .75
MU = .1304
GAMMA = .0435

STREAMLINE	DIM. TIME (T PRIME)	DUPUIT CONC.	LUMPED CONC.	% REL. ERROR
0.000	0.00000	1.000	1.000	0.00
0.025	0.02912	0.975	0.975	0.00
0.050	0.05899	0.950	0.950	0.02
0.075	0.08966	0.925	0.925	0.04
0.100	0.12116	0.900	0.901	0.08
0.125	0.15356	0.875	0.876	0.13
0.150	0.18690	0.850	0.852	0.20
0.175	0.22123	0.825	0.827	0.28
0.200	0.25662	0.800	0.803	0.38
0.225	0.29313	0.775	0.779	0.50
0.250	0.33083	0.750	0.755	0.64
0.275	0.36982	0.725	0.731	0.81
0.300	0.41018	0.700	0.707	1.00
0.325	0.45200	0.675	0.683	1.23
0.350	0.49540	0.650	0.660	1.49
0.375	0.54050	0.625	0.636	1.80
0.400	0.58745	0.600	0.613	2.15
0.425	0.63639	0.575	0.590	2.55
0.450	0.68751	0.550	0.567	3.02
0.475	0.74101	0.525	0.544	3.56
0.500	0.79712	0.500	0.521	4.18
0.525	0.85611	0.475	0.498	4.90
0.550	0.91828	0.450	0.476	5.73
0.575	0.98402	0.425	0.453	6.70
0.600	1.05373	0.400	0.431	7.84
0.625	1.12795	0.375	0.409	9.17
0.650	1.20730	0.350	0.388	10.75
0.675	1.29252	0.325	0.366	12.63
0.700	1.38457	0.300	0.345	14.89
0.725	1.48463	0.275	0.324	17.65
0.750	1.59424	0.250	0.303	21.04
0.775	1.71540	0.225	0.282	25.30
0.800	1.85085	0.200	0.262	30.75
0.825	2.00441	0.175	0.241	37.91
0.850	2.18169	0.150	0.221	47.66
0.870	2.34241	0.130	0.206	58.05
0.875	3.32128	0.125	0.149	19.37
0.900	8.45358	0.100	0.095	-5.39
0.925	15.07026	0.075	0.071	-5.58
0.950	24.39595	0.050	0.047	-5.58
0.975	40.33832	0.025	0.024	-5.58

AREA UNDER DUPUIT CURVE: C VS. T = 0.8656083
AREA UNDER LUMPED CURVE: C VS. T = 0.8866023

DUPUIT TWO-LAYER AQUIFER AS COMPARED TO THE COMBINED LUMPED MODEL
CASE(2):

KU/KL = 10.0
S/D = 10.0
BL/D = .75
MU = .2308
GAMMA = .0769

STREAMLINE	DIM. TIME (T PRIME)	DUPUIT CONC.	LUMPED CONC.	% REL. ERROR
0.000	0.00000	1.000	1.000	0.00
0.025	0.03291	0.975	0.975	0.01
0.050	0.06668	0.950	0.950	0.04
0.075	0.10135	0.925	0.926	0.08
0.100	0.13697	0.900	0.901	0.15
0.125	0.17359	0.875	0.877	0.25
0.150	0.21127	0.850	0.853	0.37
0.175	0.25008	0.825	0.829	0.52
0.200	0.29009	0.800	0.806	0.70
0.225	0.33136	0.775	0.782	0.92
0.250	0.37399	0.750	0.759	1.19
0.275	0.41806	0.725	0.736	1.49
0.300	0.46368	0.700	0.713	1.85
0.325	0.51096	0.675	0.690	2.27
0.350	0.56002	0.650	0.668	2.75
0.375	0.61100	0.625	0.646	3.30
0.400	0.66407	0.600	0.624	3.94
0.425	0.71940	0.575	0.602	4.67
0.450	0.77719	0.550	0.580	5.50
0.475	0.83766	0.525	0.559	6.46
0.500	0.90109	0.500	0.538	7.57
0.525	0.96777	0.475	0.517	8.84
0.550	1.03806	0.450	0.496	10.32
0.575	1.11237	0.425	0.476	12.02
0.600	1.19118	0.400	0.456	14.00
0.625	1.27508	0.375	0.436	16.32
0.650	1.36477	0.350	0.417	19.05
0.675	1.46111	0.325	0.397	22.28
0.700	1.56516	0.300	0.378	26.14
0.725	1.67828	0.275	0.360	30.82
0.750	1.80218	0.250	0.341	36.54
0.769	1.90624	0.231	0.327	41.87
0.775	2.23537	0.225	0.291	29.21
0.800	3.76655	0.200	0.204	2.23
0.825	5.50245	0.175	0.167	-4.70
0.850	7.50641	0.150	0.141	-6.17
0.875	9.87659	0.125	0.117	-6.41
0.900	12.77746	0.100	0.094	-6.44
0.925	16.51732	0.075	0.070	-6.44
0.950	21.78837	0.050	0.047	-6.44
0.975	30.79927	0.025	0.023	-6.44

AREA UNDER DUPUIT CURVE: C VS. T = 0.9246392
AREA UNDER LUMPED CURVE: C VS. T = 0.9336334

DUPUIT TWO-LAYER AQUIFER AS COMPARED TO THE COMBINED LUMPED MODEL
CASE(3):

KU/KL = 5.0
B/D = 10.0
BL/D = .75
MU = .3750
GAMMA = .1250

STREAMLINE	DIM. TIME (T PRIME)	DUPUIT CONC.	LUMPED CONC.	% REL. ERROR
0.000	0.00000	1.000	1.000	0.00
0.025	0.04051	0.975	0.975	0.02
0.050	0.08207	0.950	0.951	0.06
0.075	0.12474	0.925	0.926	0.15
0.100	0.16858	0.900	0.902	0.27
0.125	0.21365	0.875	0.879	0.43
0.150	0.26003	0.850	0.855	0.64
0.175	0.30780	0.825	0.832	0.90
0.200	0.35703	0.800	0.810	1.22
0.225	0.40783	0.775	0.787	1.59
0.250	0.46029	0.750	0.765	2.03
0.275	0.51453	0.725	0.743	2.55
0.300	0.57068	0.700	0.722	3.14
0.325	0.62887	0.675	0.701	3.83
0.350	0.68925	0.650	0.680	4.62
0.375	0.75201	0.625	0.660	5.52
0.400	0.81732	0.600	0.639	6.55
0.425	0.88542	0.575	0.619	7.72
0.450	0.95654	0.550	0.600	9.06
0.475	1.03097	0.525	0.581	10.58
0.500	1.10904	0.500	0.562	12.32
0.525	1.19110	0.475	0.543	14.30
0.550	1.27761	0.450	0.525	16.57
0.575	1.36907	0.425	0.507	19.18
0.600	1.46607	0.400	0.489	22.18
0.625	1.56933	0.375	0.471	25.65
0.625	1.56933	0.375	0.471	25.65
0.650	2.12127	0.350	0.397	13.50
0.675	2.71413	0.325	0.343	5.58
0.700	3.35447	0.300	0.302	0.58
0.725	4.05057	0.275	0.268	-2.45
0.750	4.81305	0.250	0.239	-4.21
0.775	5.65593	0.225	0.213	-5.18
0.800	6.59819	0.200	0.189	-5.68
0.825	7.66645	0.175	0.165	-5.92
0.850	8.89965	0.150	0.141	-6.02
0.875	10.35822	0.125	0.117	-6.06
0.900	12.14337	0.100	0.094	-6.07
0.925	14.44483	0.075	0.070	-6.07
0.950	17.68854	0.050	0.047	-6.07
0.975	23.23371	0.025	0.023	-6.07

AREA UNDER DUPUIT CURVE: C VS. T = 0.9538100
AREA UNDER LUMPED CURVE: C VS. T = 0.9575593

DUPUIT TWO-LAYER AQUIFER AS COMPARED TO THE COMBINED LUMPED MODEL
CASE(4):

KU/KL = 2.0
S/D = 10.0
BL/D = .75
MU = .6000
GAMMA = .2000

STREAMLINE	DIM. TIME (T PRIME)	DUPUIT CONC.	LUMPED CONC.	% REL. ERROR
0.000	0.00000	1.000	1.000	0.00
0.025	0.06329	0.975	0.975	0.02
0.050	0.12823	0.950	0.951	0.10
0.075	0.19490	0.925	0.927	0.22
0.100	0.26340	0.900	0.904	0.40
0.125	0.33383	0.875	0.881	0.64
0.150	0.40630	0.850	0.858	0.94
0.175	0.48093	0.825	0.836	1.31
0.200	0.55786	0.800	0.814	1.74
0.225	0.63723	0.775	0.792	2.25
0.250	0.71921	0.750	0.771	2.84
0.275	0.80396	0.725	0.750	3.52
0.300	0.89169	0.700	0.730	4.28
0.325	0.98261	0.675	0.710	5.15
0.350	1.07696	0.650	0.690	6.13
0.375	1.17501	0.625	0.670	7.22
0.400	1.27706	0.600	0.651	8.44
0.400	1.27706	0.600	0.651	8.44
0.425	1.48986	0.575	0.613	6.62
0.450	1.71212	0.550	0.578	5.03
0.475	1.94472	0.525	0.544	3.64
0.500	2.18867	0.500	0.512	2.43
0.525	2.44514	0.475	0.482	1.39
0.550	2.71547	0.450	0.452	0.50
0.575	3.00127	0.425	0.424	-0.25
0.600	3.30439	0.400	0.396	-0.88
0.625	3.62708	0.375	0.370	-1.40
0.650	3.97205	0.350	0.344	-1.83
0.675	4.34259	0.325	0.318	-2.18
0.700	4.74280	0.300	0.293	-2.45
0.725	5.17786	0.275	0.268	-2.66
0.750	5.65441	0.250	0.243	-2.83
0.775	6.18121	0.225	0.218	-2.95
0.800	6.77012	0.200	0.194	-3.03
0.825	7.43778	0.175	0.170	-3.09
0.850	8.20853	0.150	0.145	-3.13
0.875	9.12014	0.125	0.121	-3.15
0.900	10.23586	0.100	0.097	-3.17
0.925	11.67427	0.075	0.073	-3.17
0.950	13.70159	0.050	0.048	-3.17
0.975	17.16732	0.025	0.024	-3.18

AREA UNDER DUPUIT CURVE: C VS. T = 0.9711963
AREA UNDER LUMPED CURVE: C VS. T = 0.9722227

DUPUIT TWO-LAYER AQUIFER AS COMPARED TO THE COMBINED LUMPED MODEL
CASE(5):

KU/KL = 1.0
S/D = 10.0
BL/D = .75
MU = .7500
GAMMA = .2500

STREAMLINE	DIM. TIME (T PRIME)	DUPUIT CONC.	LUMPED CONC.	% REL. ERROR
0.000	0.00000	1.000	1.000	0.00
0.025	0.10127	0.975	0.975	-0.00
0.050	0.20517	0.950	0.950	0.00
0.075	0.31185	0.925	0.925	0.00
0.100	0.42144	0.900	0.900	-0.00
0.125	0.53413	0.875	0.875	-0.00
0.150	0.65008	0.850	0.850	-0.00
0.175	0.76949	0.825	0.825	0.00
0.200	0.89257	0.800	0.800	0.00
0.225	1.01957	0.775	0.775	-0.00
0.250	1.15073	0.750	0.750	0.00
0.250	1.15073	0.750	0.750	0.00
0.275	1.28633	0.725	0.725	-0.00
0.300	1.42670	0.700	0.700	0.00
0.325	1.57217	0.675	0.675	-0.00
0.350	1.72313	0.650	0.650	0.00
0.375	1.88001	0.625	0.625	-0.00
0.400	2.04330	0.600	0.600	-0.00
0.425	2.21354	0.575	0.575	0.00
0.450	2.39135	0.550	0.550	-0.00
0.475	2.57743	0.525	0.525	0.00
0.500	2.77259	0.500	0.500	-0.00
0.525	2.97776	0.475	0.475	-0.00
0.550	3.19403	0.450	0.450	-0.00
0.575	3.42266	0.425	0.425	-0.00
0.600	3.66516	0.400	0.400	-0.00
0.625	3.92332	0.375	0.375	-0.00
0.650	4.19929	0.350	0.350	-0.00
0.675	4.49572	0.325	0.325	-0.00
0.700	4.81589	0.300	0.300	-0.00
0.725	5.16394	0.275	0.275	0.00
0.750	5.54518	0.250	0.250	0.00
0.775	5.96662	0.225	0.225	0.00
0.800	6.43775	0.200	0.200	-0.00
0.825	6.97188	0.175	0.175	-0.00
0.850	7.58848	0.150	0.150	-0.00
0.875	8.31776	0.125	0.125	0.00
0.900	9.21034	0.100	0.100	-0.00
0.925	10.36107	0.075	0.075	-0.00
0.950	11.98293	0.050	0.050	-0.00
0.975	14.75551	0.025	0.025	-0.00

AREA UNDER DUPUIT CURVE: C VS. T = 0.9769744
AREA UNDER LUMPED CURVE: C VS. T = 0.9769744

DUPUIT TWO-LAYER AQUIFER AS COMPARED TO THE COMBINED LUMPED MODEL
CASE(6):

KU/KL = 10.0
S/D = 10.0
BL/D = .90
MU = .4737
GAMMA = .0526

STREAMLINE	DIM. TIME (T PRIME)	DUPUIT CONC.	LUMPED CONC.	% REL. ERROR
0.000	0.00000	1.000	1.000	0.00
0.025	0.04810	0.975	0.975	0.03
0.050	0.09746	0.950	0.951	0.11
0.075	0.14813	0.925	0.927	0.25
0.100	0.20018	0.900	0.904	0.45
0.125	0.25371	0.875	0.881	0.72
0.150	0.30879	0.850	0.859	1.07
0.175	0.36551	0.825	0.837	1.50
0.200	0.42397	0.800	0.816	2.02
0.225	0.48430	0.775	0.795	2.64
0.250	0.54660	0.750	0.775	3.37
0.275	0.61101	0.725	0.756	4.22
0.300	0.67768	0.700	0.736	5.20
0.325	0.74678	0.675	0.718	6.32
0.350	0.81849	0.650	0.699	7.61
0.375	0.89301	0.625	0.682	9.08
0.400	0.97057	0.600	0.665	10.76
0.425	1.05143	0.575	0.648	12.66
0.450	1.13589	0.550	0.632	14.83
0.475	1.22428	0.525	0.616	17.29
0.500	1.31698	0.500	0.600	20.10
0.525	1.41444	0.475	0.586	23.30
0.526	1.41971	0.474	0.585	23.48
0.550	2.39428	0.450	0.486	8.09
0.575	3.48029	0.425	0.432	1.58
0.600	4.63216	0.400	0.397	-0.83
0.625	5.85839	0.375	0.369	-1.66
0.650	7.16925	0.350	0.343	-1.93
0.675	8.57730	0.325	0.318	-2.02
0.700	10.09812	0.300	0.294	-2.04
0.725	11.75133	0.275	0.269	-2.04
0.750	13.56222	0.250	0.245	-2.04
0.775	15.56407	0.225	0.220	-2.04
0.800	17.80195	0.200	0.196	-2.04
0.825	20.33905	0.175	0.171	-2.04
0.850	23.26791	0.150	0.147	-2.04
0.875	26.73202	0.125	0.122	-2.04
0.900	30.97174	0.100	0.098	-2.04
0.925	36.43770	0.075	0.073	-2.04
0.950	44.14153	0.050	0.049	-2.04
0.975	57.31131	0.025	0.024	-2.04

AREA UNDER DUPUIT CURVE: C VS. T = 0.9561513
AREA UNDER LUMPED CURVE: C VS. T = 0.9581057

DUPUIT TWO-LAYER AQUIFER AS COMPARED TO THE COMBINED LUMPED MODEL
CASE(7):

KU/KL = 10.0
S/D = 10.0
BL/D = .95
MU = .6552
GAMMA = .0345

STREAMLINE	DIM. TIME (T PRIME)	DUPUIT CONC.	LUMPED CONC.	% REL. ERROR
0.000	0.00000	1.000	1.000	0.00
0.025	0.07342	0.975	0.976	0.05
0.050	0.14875	0.950	0.952	0.22
0.075	0.22609	0.925	0.930	0.51
0.100	0.30555	0.900	0.908	0.92
0.125	0.38724	0.875	0.888	1.46
0.150	0.47130	0.850	0.868	2.15
0.175	0.55788	0.825	0.850	2.99
0.200	0.64712	0.800	0.832	3.99
0.225	0.73919	0.775	0.815	5.16
0.250	0.83428	0.750	0.799	6.52
0.275	0.93259	0.725	0.784	8.08
0.300	1.03436	0.700	0.769	9.86
0.325	1.13982	0.675	0.755	11.89
0.345	1.22628	0.655	0.745	13.68
0.350	1.45614	0.650	0.720	10.81
0.375	2.59354	0.625	0.645	3.13
0.400	3.77738	0.600	0.603	0.51
0.425	5.01161	0.575	0.573	-0.34
0.450	6.30071	0.550	0.547	-0.61
0.475	7.64979	0.525	0.521	-0.69
0.500	9.06470	0.500	0.496	-0.71
0.525	10.55221	0.475	0.472	-0.72
0.550	12.12016	0.450	0.447	-0.72
0.575	13.77775	0.425	0.422	-0.72
0.600	15.53587	0.400	0.397	-0.72
0.625	17.40748	0.375	0.372	-0.72
0.650	19.40828	0.350	0.347	-0.72
0.675	21.55741	0.325	0.323	-0.72
0.700	23.87865	0.300	0.298	-0.72
0.725	26.40198	0.275	0.273	-0.72
0.750	29.16597	0.250	0.248	-0.72
0.775	32.22143	0.225	0.223	-0.72
0.800	35.63713	0.200	0.199	-0.72
0.825	39.50954	0.175	0.174	-0.72
0.850	43.97991	0.150	0.149	-0.72
0.875	49.26723	0.125	0.124	-0.72
0.900	55.73840	0.100	0.099	-0.72
0.925	64.08117	0.075	0.074	-0.72
0.950	75.83965	0.050	0.050	-0.72
0.975	95.94090	0.025	0.025	-0.72

AREA UNDER DUPUIT CURVE: C VS. T = 0.9665761
AREA UNDER LUMPED CURVE: C VS. T = 0.9672343

Appendix B

Modified U.S. Corps of Engineers Program

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// Q PEEPEE                                                                00:00:00
//FLOW EXEC  FORTRAN                                                       00:00:01

             C       FINITE ELEMENT SOLUTION OF STEADY STATE POTENTIAL FLOW PROBLEMS
             C       QUADRILATERAL AND/OR TRIANGULAR ELEMENTS
             C       PROGRAM 723-G2-L2440
             C       NOVEMBER 1970
             C       MODIFIED OCTOBER 1971 BY R. COOLEY
             C       MODIFIED IN FEBRUARY 1977, BY S.G.MCLIN
             C       SUBROUTINE GEES IS CALLED FROM STATEMENT 205.03
             C       SUBROUTINE BSOLVE IS CALLED FROM STATEMENT 265
             C       SUBROUTINE PRTOTA IS CALLED FROM STATEMENTS 47.01 AND 300.01
             C       SUBROUTINE PRTOTB IS CALLED FROM STATEMENTS 250.02 AND 265.03
 0001                DIMENSION TITLE(21),XCORD(861),YCORD(861),NODE(861,4),IZONE(861),
                    1 XPERM(5),YPERM(5),ALPHA(5),NDHD(120),HEAD(120),G(861,50),B(861),
                    2 QWELL(1),IWLEL(1),QBND(1),NDA(1),NDB(1),THICK(861)
                    3 ,PRES(1),CORDX(41),CORDY(21),PSI(41,21)
 0002                COMMON B,G,NRED,NELS,NNDS,NHDS,XCORD,YCORD,NODE,IZONE,XPERM,YPERM,
                    1ALPHA,HEAD,NDHD,MAXBW,QWELL,IWLEL,QBND,NDA,NDB,THICK,NWELS,NQBND,
                    2IRADL,LR,NBEG,NTELS,NQELS,NELT,NP1,N
 0003              1 FORMAT (1H ,I4,5X,E10.3)
 0004              2 FORMAT (1X,I7,9I8)
 0005              3 FORMAT (1X,1A1,2A3,18A4)
 0006              4 FORMAT (1X,I7,9F8.0)
 0007              5 FORMAT (2X,I6,F8.0,4(I8,F8.0))
 0008              6 FORMAT (1H0,10HINPUT DATA)
 0009              7 FORMAT(1H ,I4,9(3X,F10.2))
 0010              8 FORMAT (1H1)
 0011              9 FORMAT (1H0,6HOUTPUT)
 0012             10 FORMAT (1H0,15X,18HCOEFFICIENT MATRIX/1H ,5X,3HROW,8X,6HCOLUMN,16X
                    1,1HG)
 0013             11 FORMAT (1H ,5X,I3,9X,I3,13X,E10.3)
 0014             12 FORMAT (1H0,29X,12HKNOWN VECTOR/1H ,5H  ROW,10X,1HB,10X,3HROW,10X
                    1,1HB,10X,3HROW,10X,1HB)
 0015             13 FORMAT (1H ,5X,I3,2(11X,E11.4))
 0016             14 FORMAT (1H0,18X,33HCOMPUTED VALUES OF HYDRAULIC HEAD/1H ,6H  NODE
                    1,8X,4HHEAD,8X,4HNODE,8X,4HHEAD,8X,4HNODE,8X,4HHEAD)
 0017             15 FORMAT (45HOKNOWN VALUES OF HYDRAULIC HEAD AT BOUNDARIES/1H ,5X,
                    14HNODE,14X,4HHEAD)
 0018             16 FORMAT (10HOMAXBW OF I5,24H, CORRESPONDING TO NODE ,I5,68H, IS GRE
                    1ATER THAN ORDER OF MATRIX (NRED) OR EXCEEDS DIMENSION LIMITS)
 0019             17 FORMAT (41HONO. OF QUADRILATERAL ELEMENTS (NQELS) = ,I6/38H NO. OF
                    1 TRIANGULAR ELEMENTS (NTELS) = ,I6/23H NO. OF NODES (NNDS) = ,I6/
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              241H NO. OF MATERIAL PROPERTY ZONES (NZNS) = ,I6/42H NO. OF SPECIFI
              3ED BOUNDARY HEADS (NHDS) = ,I6/35H NO. OF SOURCES OR SINKS (NWELS)
              4 = ,I6/74H NO. OF BOUNDARY ELEMENT SIDES (NQBND) FOR WHICH DISCHAR
              5GE IS SPECIFIED = ,I6)
0020       18 FORMAT (1H0,8X,57HCOMPUTED VALUES OF HYDRAULIC HEAD AND FLUID PRES
              1SURE HEAD/1H ,6H  NODE,5X,8HHYD. HD.,6X,10HPRESS. HD.,4X,4HNODE
              2,5X,8HHYD. HD.,6X,10HPRESS. HD.)
0021       19 FORMAT (1H0,2X,4HNODE,6X,5HXCORD,10X,5HYCORD,7X,4HNODE,6X,5HXCORD
              1,10X,5HYCORD)
0022       20 FORMAT (1H0,20X,22HQUADRILATERAL ELEMENTS/9H0 ELEMENT,2X,6HNODE 1,
              12X,6HNODE 2,2X,6HNODE 3,2X,6HNODE 4,4X,4HZONE,4X,9HTHICKNESS)
0023       21 FORMAT (5H0ZONE,8X,5HXPERM,8X,5HYPERM,8X,5HALPHA)
0024       22 FORMAT (1H0,9X,9HSPECIFIED/1H ,4HNODE,6X,8HBOUNDARY/1H ,12X,4HHEAD
              1)
0025       23 FORMAT (1X,I7,5I8,4F8.0)
0026       24 FORMAT (2X,I6,5I8,4X,F10.2)
0027       25 FORMAT (63H0SOURCES OR SINKS (+ INDICATES RECHARGE, - INDICATES DI
              1SCHARGE)/1H ,19HELEMENT    DISCHARGE)
0028       26 FORMAT (1H0,29HSPECIFIED BOUNDARY DISCHARGES/1H ,6X,28HUNIT       B
              1OUNDARY  BOUNDARY/1H ,33H    DISCHARGE     NODE A     NODE B)
0029       27 FORMAT (1X,I7,I8,8F8.0)
0030       28 FORMAT (1H ,3X,F10.3,4X,I4,6X,I4)
0031       29 FORMAT (63H0KNOWN VALUES OF HYDRAULIC HEAD AND PRESSURE HEAD AT BO
              1UNDARIES/1H ,5X,4HNODE,12X,8HHYD. HD.,13X,10HPRESS. HD.)
0032       31 FORMAT (1H0,40H*** AXI-SYMMETRIC RADIAL COORDINATES ***)
0033       33 FORMAT (1H ,I4,5X,2(E10.4,3X),F8.2)
0034       35 FORMAT (1H0,37HMAXIMUM MATRIX BAND WIDTH (MAXBW) OF ,I4,21H CORRES
              1PONDS TO NODE ,I4)
0035       36 FORMAT (1H0,35HSCALE CHANGE FOR NODAL COORDINATES:)
0036       37 FORMAT (1H0,18X,19HTRIANGULAR ELEMENTS/9H0 ELEMENT,2X,6HNODE 1,2X,
              16HNODE 2,2X,6HNODE 3,4X,4HZONE,4X,9HTHICKNESS)
0037       38 FORMAT (1X,I7,4I8,4F8.0)
0038       39 FORMAT (1X,I7,4I8,4X,F10.2)
0039       40 FORMAT (1X,F7.0,9F8.0)
0040      444 FORMAT(2I10,5F10.0,I5)
0041      445 FORMAT(/,1X,'NUMBER OF ROWS = ',I3,/,1X,'NUMBER OF COLUMNS = ',I3
              <,/,1X,'AQUIFER WIDTH = ',F7.0,/,1X,'AQUIFER DEPTH = ',F6.0,/,1X,'D
              <ISTANCE BETWEEN COLUMN  NODES = ',F5.1,/,1X,'DISTANCE BETWEEN ROW
              <NODES = ',F6.2,/,1X,'AFTER',I3,' ROWS, DISTANCE BETWEEN ROW NODES
              <= ',F7.4)
0042       45 PRINT 8
        C     CARD ADDED
0043          READ(5,444)MM1,NN1,S,D,CONSTX,CONSTY,CONSTA,NROWS
        C     CARD ADDED
        C
        C          READ 3 TITLE CARDS
        C
0044          DO 46 I=1,3
0045          READ 3, (TITLE(N),N=1,21)                                     00CARD0A
0046          PRINT 3, (TITLE(N),N=1,21)
0047       46 CONTINUE
0048          PRINT 445,MM1,NN1,S,D,CONSTX,CONSTY,NROWS,CONSTA
        C
        C          READ JOB SPECIFICATION
        C
0049          READ 2,NQELS,NTELS,NNDS,NZNS,NHDS,NWELS,NQBND                 00CARD0B
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0050          IF (NNDS.LE.0) STOP
0051          READ 2,IRADL,IPRGS,IUNIT,IPRES                                    00CARDOC
0052          PRINT 6
0053          PRINT 17,NQELS,NTELS,NNDS,NZNS,NHDS,NWELS,NQBND
0054          IF(IRADL.GT.0) PRINT 31
        C
        C        READ NODAL COORDINATES
        C
        C     CARD ADDED
        C     PRINT 19
        C     DO 47  J=1,NNDS
        C     READ 4, I,XCORD(I),YCORD(I)                                       00CARDOD
        C  47 CONTINUE
0055          CALL CORDXY(NN1,MM1,CONSTX,CONSTY,CONSTA,S,D,NROWS)
        C     CALL PRTOTA(XCORD,YCORD,NNDS)
        C     CARD ADDED
        C
        C       CONVERT SCALE
        C
0056          IF (IUNIT.LE.0) GO TO 51
0057          PRINT 36
0058          READ 3, (TITLE(N),N=1,21)                                         00CARDOE
0059          PRINT 3, (TITLE(N),N=1,21)
0060          READ 40,CONST
0061          DO 50 I=1,NNDS
0062          XCORD(I)=XCORD(I)*CONST
0063          YCORD(I)=YCORD(I)*CONST
0064       50 CONTINUE
        C
        C        READ QUADRILATERAL ELEMENT DATA
        C
0065       51 NELT=0
0066          IF (NQELS.LE.0) GO TO 53
        C     CARD ADDED
        C     PRINT 20
        C     DO 52  K=1,NQELS
        C     READ 23, I,(NODE(I,J),J=1,4),IZONE(I),THICK(I)                   00CARDOG
        C     PRINT 24, I,(NODE(I,J),J=1,4),IZONE(I),THICK(I)
        C     IF(IZONE(I).LE.0)IZONE(I)=1
0067          CALL COORD(NN1,MM1,NROWS)
0068          DO 52 I=1,NQELS
0069          THICK(I)=0.0
        C  52 PRINT 24,I,(NODE(I,J),J=1,4),IZONE(I),THICK(I)
0070       52 CONTINUE
        C  52 CONTINUE
        C     CARD ADDED
0071          NELT=1
0072          NP1=5
0073          N=4
0074          NELS=NQELS
0075          NBEG=1
        C
        C        READ TRIANGULAR ELEMENT DATA
        C
0076          IF (NTELS.LE.0) GO TO 55
0077       53 PRINT 37
```

```
      DO 54 K=1,NTELS
      READ 38,I,(NODE(I,J),J=1,3),IZONE(I),THICK(I)                   00CARDOH
      PRINT 39,I,(NODE(I,J),J=1,3),IZONE(I),THICK(I)
      IF (IZONE(I).LE.0) IZONE(I)=1
   54 CONTINUE
      NELT=NELT+1
      NP1=4
      N=3
      NELS=NQELS+NTELS
      NBEG=NQELS+1
C
C          READ MEDIA PROPERTIES
C
   55 PRINT 21
      DO 56  J=1,NZNS
      READ 4, I,XPERM(I),YPERM(I),ALPHA(I)                            00CARDOI
      PRINT 33, I,XPERM(I),YPERM(I),ALPHA(I)
   56 CONTINUE
C
C          READ BOUNDARY CONDITIONS
C
      IF (NHDS.LE.0) GO TO 65
C     PRINT 22
C     CARD ADDED
C     DO 60  I=1,NHDS
C     READ 4,NDHD(I),HEAD(I)                                          00CARDOJ
C     PRINT 7,NDHD(I),HEAD(I)
C  60 CONTINUE
      ICON=(NN1-2)*(MM1-2)
      INUM=NHDS-MM1
      JNUM=INUM+1
      KNUM=INUM-1
      LNUM=MM1+2
      MNUM=LNUM-1
      DO 60 I=1,MM1
      NDHD(I)=I+ICON
   60 HEAD(I)=1.0
      HEAD(1)=0.0
      DO 61 I=LNUM,INUM,2
      NDHD(I)=I+ICON
   61 HEAD(I)=1.0
      DO 62 I=JNUM,NHDS
      NDHD(I)=I+ICON
   62 HEAD(I)=1.0
      DO 63 I=MNUM,KNUM,2
      NDHD(I)=I+ICON
      IX=I+ICON
   63 HEAD(I)=XCORD(IX)/S
C     DO 64 I=1,NHDS
C  64 PRINT 7,NDHD(I),HEAD(I)
C     CARD ADDED
   65 IF(NWELS.LE.0) GO TO 75
      PRINT 25
      DO 70 I=1,NWELS
      READ 4, IWLEL(I),QWELL(I)                                       00CARDOK
      PRINT 1, IWLEL(I),QWELL(I)
```

```
   70 CONTINUE
   75 IF(NQBND.LE.0) GO TO 81
      PRINT 26
      DO 80 I=1,NQBND
      READ 27, NDA(I),NDB(I),QBND(I)
      PRINT 28, QBND(I),NDA(I),NDB(I)
   80 CONTINUE
C
C        QBND FOR AXI-SYMMETRIC RADIAL COORDINATES
C
   81 IF(IRADL.LE.0.OR.NQBND.LE.0) GO TO 85
      DO 83 I=1,NQBND
      QBND(I)=QBND(I)/6.283
   83 CONTINUE
C
C          DETERMINE MAXIMUM BAND WIDTH (MAXBW)
C
   85 NRED=NNDS-NHDS
      MAXBW=0
      DO 200 I=1,NRED
      MINND=NRED
      MAXND=0
      NT=N
      NTMP=NELS
      NBGT=NBEG
      DO 190 NO=1,NELT
      DO 180 J=NBGT,NTMP
      DO 110 K=1,NT
      IF (NODE(J,K).EQ.I) GO TO 120
  110 CONTINUE
      GO TO 180
  120 DO 150 K=1,NT
      NUDE=NODE(J,K)
      IF(NUDE.GT.NRED) GO TO 150
      IF (NUDE.GT.MAXND) MAXND=NUDE
      IF (NUDE.LT.MINND) MINND=NUDE
  150 CONTINUE
  180 CONTINUE
      NBGT=1
      NTMP=NQELS
      NT=4
  190 CONTINUE
      NTEMP=I-MINND
      IF ((MAXND-I).GT.NTEMP) NTEMP=MAXND-I
      IF(NTEMP.LE.MAXBW) GO TO 200
      MAXBW=NTEMP
      KEYND=I
  200 CONTINUE
      MAXBW=MAXBW*2+1
      IF(MAXBW .LE. 50 .AND. MAXBW .LE. NRED) GO TO 205
      PRINT 16,MAXBW,KEYND
      GO TO 45
  205 CONTINUE
C 205 PRINT 8
C     PRINT 9
C     PRINT 35,MAXBW,KEYND
```

```
C
C          CALL SUBROUTINE GEES TO SET UP MATRIX EQUATION
C
      CALL GEES
      IF(IPRGS.LE.0) GO TO 265
      PRINT 10
      DO 250 I=1,NRED
      DO 210 J=1,MAXBW
      NROW=I
      NCOL=J-LR+I
      IF (G(I,J).EQ.0.) GO TO 210
      PRINT 11,(NROW,NCOL,G(I,J))
  210 CONTINUE
  250 CONTINUE
      PRINT 12
      CALL PRTOTB(B,NRED)
C
C          SOLVE MATRIX EQUATION
C
  265 CALL BSOLVE(G,B,NRED,MAXBW)
C
C         PRINT HYDRAULIC HEADS OR HYDRAULIC HEADS AND PRESSURE HEADS
C
      IF(IPRES.GT.0) GO TO 290
C     PRINT 14
C     CALL PRTOTB(B,NRED)
C     CARDS ADDED
C     PRINT 15
C     DO 280 I=1,NHDS
C     PRINT 13,NDHD(I),HEAD(I)
C 280 CONTINUE
      ETA=S/D*SQRT(YPERM(1)/XPERM(1))
      PRINT 1119,ETA
 1119 FORMAT(1H1,10X,'ETA = ',F5.1,//10X,'STREAMLINE VALUES')
      DELX=0.0
      DELY=0.0
      CORDX(1)=0.0
      CORDY(1)=0.0
      DO 312 I=2,NN1
      DELX=DELX+CONSTX
  312 CORDX(I)=DELX
      DO 314 J=2,MM1
      IF(J.LE.NROWS)DELY=DELY+CONSTY
      IF(J.GT.NROWS)DELY=DELY+CONSTA
  314 CORDY(J)=DELY
      PSI(1,1)=0.0
      DO 316 I=2,NN1
      PSI(I,MM1)=1.0
  316 PSI(I,1)=CORDX(I)/S
      DO 317 J=2,MM1
      PSI(1,J)=1.0
  317 PSI(NN1,J)=1.0
      MSUB1=MM1-1
      NSUB1=NN1-1
      KOUNT=0
      DO 318 I=2,NSUB1
```

```
      DO 318 J=2,MSUB1
      KOUNT=KOUNT+1
  318 PSI(I,J)=B(KOUNT)
      DO 319 I=1,NN1
  319 PRINT 1109,(PSI(I,J),J=1,MM1)
 1109 FORMAT(1H0,22(1X,F5.3))
      AREA1=S*D
      DO 320 II=1,NSUB1
      AREA=0.0
      J=1
      I=NN1-II
      IF(I .EQ. 1)GO TO 320
      WRITE(6,1113)
 1113 FORMAT(1H1,10X,'STREAMLINE',5X,'X-COORD',5X,'Y-COORD',//)
      STRMLN=PSI(I,J)
      XI=CORDX(I)
      YI=CORDY(J)
      WRITE(6,1114)STRMLN,XI,YI
      S1=STRMLN
      X1=XI
      Y1=YI
  331 J=J+1
      S2=PSI(I,J)
      X2=CORDX(I)
      Y2=CORDY(J)
      I=I-1
      S3=PSI(I,J)
      X3=CORDX(I)
      Y3=CORDY(J)
      J=J-1
      S4=PSI(I,J)
      X4=CORDX(I)
      Y4=CORDY(J)
  330 IF(S3-STRMLN)322,321,323
  321 Y12=Y3
      X12=X3
      S1=S3
      X1=X3
      Y1=Y3
      J=J+1
      GO TO 325
  322 S12=S2
      X12=X2
      Y12=Y2
      S21=S3
      X21=X3
      Y21=Y3
      IF(Y2 .NE. Y3)GO TO 324
      A=S12-S21
      BB=X12-X21
      C=S12-STRMLN
      X12=X12-BB*C/A
      I=I+1
      J=J+1
      S1=S2
      X1=X2
```

```
      Y1=Y2
      GO TO 325
  323 IF(S4-STRMLN)326,332,327
  326 S12=S4
      X12=X4
      Y12=Y4
      S21=S3
      X21=X3
      Y21=Y3
      IF(X3 .NE. X4)GO TO 328
      A=S21-S12
      BB=Y21-Y12
      C=STRMLN-S12
      Y12=Y12+BB*C/A
      S1=S4
      X1=X4
      Y1=Y4
  325 WRITE(6,1114)STRMLN,X12,Y12
 1114 FORMAT(1H0,15X,F5.3,5X,F10.5,3X,F10.5)
      AREA=AREA+0.5*(XI-X12)*(YI+Y12)
      XI=X12
      YI=Y12
      IF(I .EQ. 1 .AND. J .EQ. 1)GO TO 329
      GO TO 331
  324 WRITE(6,1115)X12,Y12
 1115 FORMAT(1H0,'Y-COORD WRONG AT X = ',F10.5,2X,'Y = ',F10.5)
      GO TO 320
  328 WRITE(6,1116)X12,Y12
 1116 FORMAT(1H0,'X-COORD WRONG AT X= ',F10.5,2X,'Y-COORD = ',F10.5)
      GO TO 320
  327 S12=S1
      X12=X1
      Y12=Y1
      S21=S4
      X21=X4
      Y21=Y4
      IF(Y1 .NE. Y4)GO TO 324
      A=S12-S21
      BB=X12-X21
      C=S12-STRMLN
      X12=X12-BB*C/A
      S2=S1
      X2=X1
      Y2=Y1
      S3=S4
      X3=X4
      Y3=Y4
      I=I+1
      J=J-1
      S1=PSI(I,J)
      X1=CORDX(I)
      Y1=CORDY(J)
      I=I-1
      S4=PSI(I,J)
      X4=CORDX(I)
      Y4=CORDY(J)
```

```
      WRITE(6,1114)STRMLN,X12,Y12
      AREA=AREA+0.5*(XI-X12)*(YI+Y12)
      XI=X12
      YI=Y12
      IF(I .EQ. 1 .AND. J .EQ. 1)GO TO 329
      GO TO 330
  329 X12=0.0
      Y12=0.0
      WRITE(6,1114)STRMLN,X12,Y12
      AREA=AREA+0.5*(XI-X12)*(YI+Y12)
      AREA=AREA/AREA1
      WRITE(6,1117)STRMLN,AREA,ETA
 1117 FORMAT(//,1HO,'THE AREA UNDER PSI = ',F6.4,2X,'IS  ',F10.7,3X,'(ET
     <A = ',F5.1,')')
      WRITE(7,2117)ETA,STRMLN,AREA
 2117 FORMAT(F5.1,5X,F6.4,5X,F10.7)
      GO TO 320
  332 X12=X4
      Y12=Y4
      WRITE(6,1114)STRMLN,X12,Y12
      AREA=AREA+0.5*(XI-X12)*(YI+Y12)
      XI=X12
      YI=Y12
      IF(I .EQ. 1 .AND. J .EQ. 1)GO TO 329
      S1=S4
      X1=X4
      Y1=Y4
      I=I-1
      IF(S4-STRMLN)333,332,327
  333 I=I+1
      J=J+1
      S2=PSI(I,J)
      X2=CORDX(I)
      Y2=CORDY(J)
      I=I-1
      S3=PSI(I,J)
      X3=CORDX(I)
      Y3=CORDY(J)
      J=J-1
      GO TO 325
  320 CONTINUE
C     CARDS ADDES
      GO TO 45
  290 PRINT 18
      DO 300 I=1,NRED
      PRES(I)=B(I)-YCORD(I)
  300 CONTINUE
      CALL PRTOTA(B,PRES,NRED)
       PRINT 29
      DO 310 I=1,NHDS
      J=NDHD(I)
      PRESS=HEAD(I)-YCORD(J)
      PRINT 13,NDHD(I),HEAD(I),PRESS
  310 CONTINUE
      GO TO 45
      END
```

```
   TOTAL MEMORY REQUIREMENTS 00392C BYTES

COMPILER HIGHEST SEVERITY CODE WAS   0

  0001              SUBROUTINE GEES
             C           SUBROUTINE TO CALCULATE MATRIX ELEMENTS
  0002              DIMENSION TITLE(21),XCORD(861),YCORD(861),NODE(861,4),IZONE(861),
                  1 XPERM(5),YPERM(5),ALPHA(5),NDHD(120),HEAD(120),G(861,50),B(861),
                  2 QWELL(1),IWLEL(1),QBND(1),NDA(1),NDB(1),THICK(861)
  0003              DIMENSION XX(5),YY(5),HD(5),GT(5),ND(5),ATRI(4)
  0004              COMMON B,G,NRED,NELS,NNDS,NHDS,XCORD,YCORD,NODE,IZONE,XPERM,YPERM,
                  1ALPHA,HEAD,NDHD,MAXBW,QWELL,IWLEL,QBND,NDA,NDB,THICK,NWELS,NQBND,
                  2IRADL,LR,NBEG,NTELS,NQELS,NELT,NP1,N
  0005              LR=(MAXBW+1)/2
  0006              DO  2 I=1,NNDS
  0007              B(I)=0.
  0008              DO  2 J=1,MAXBW
  0009              G(I,J)=0.
  0010            2 CONTINUE
             C
             C           ADD BOUNDARY DISCHARGES TO B VECTOR
             C
  0011              IF(NQBND.LE.0) GO TO 4
  0012              DO   3 I=1,NQBND
  0013              K=NDA(I)
  0014              L=NDB(I)
  0015              DIST=((XCORD(K)-XCORD(L))**2+(YCORD(K)-YCORD(L))**2)**.5
  0016              TEMP=QBND(I)*DIST/2.
  0017              B(K)=B(K)+TEMP
  0018              B(L)=B(L)+TEMP
  0019            3 CONTINUE
  0020              KOUNT=0
             C
             C    *** BEGIN OUTER TRIANGULAR AND/OR QUAD ELEMENT LOOP
             C
  0021            4 DO 300 NO=1,NELT
  0022              DO 200 I=NBEG,NELS
  0023              XX(4)=0.0
  0024              YY(4)=0.0
  0025              ATRI(4)=0.
  0026              GC=0.
  0027              BCN=0.
  0028              DO  5 K=1,NP1
  0029            5 GT(K)=0.
  0030              J=IZONE(I)
  0031              ANGLE=ALPHA(J)
  0032              XK=1.0/YPERM(J)
  0033              YK=1.0/XPERM(J)
             C
             C         SET HD ARRAY
             C
  0034              DO 9 JJ=1,N
  0035              ITMP=NODE(I,JJ)
```

```
      IF(ITMP.LE.NRED) GO TO 9
      DO 8 KK=1,NHDS
      JTMP=VDHD(KK)
      IF(ITMP.NE.JTMP) GO TO 8
      HD(JJ)=HEAD(KK)
      GO TO 9
    8 CONTINUE
    9 CONTINUE
      HD(NP1)=HD(1)
C
C          DETERMINE LOCAL COORDINATES
C
      DO 10 II=1,N
      KA=NODE(I,II)
      ND(II)=KA
      XX(II)=XCORD(KA)
   10 YY(II)=YCORD(KA)
      ANG=ABS(ANGLE)
      IF(ANG.LE.0.) GO TO 12
      SNALP=SIN(ANGLE)
      CSALP=COS(ANGLE)
      DO 11 II=1,N
      TEMP = XX(II)
      TMP=YY(II)
      XX(II)=TEMP*CSALP+TMP*SNALP
   11 YY(II)=-TEMP*SNALP+TMP*CSALP
   12 X4=XX(4)
      Y4=YY(4)
      XX(NP1)=XX(1)
      YY(NP1)=YY(1)
      ND(NP1)=ND(1)
      TMP=N
      XCN=(XX(1)+XX(2)+XX(3)+X4)/TMP
      YCN=(YY(1)+YY(2)+YY(3)+Y4)/TMP
C
C *** BEGIN INNER TRIANGULAR ELEMENT LOOP
C
      DO 100 II=1,N
      NA=ND(II)
      NB=ND(II+1)
      XNA=XX(II)
      YNA=YY(II)
      XNB=XX(II+1)
      YNB=YY(II+1)
      XKT=XK
      YKT=YK
C
C          DETERMINE TRANSMISSIVITY TERMS
C
      IF(IRADL.LE.0) GO TO 19
      TMP=(XNA+XNB+XCN)/3.
      GO TO 20
   19 IF(THICK(I).LE.0.) GO TO 23
      TMP=THICK(I)
   20 XKT=XKT*TMP
      YKT=YKT*TMP
```

```
C
C        THE MAZE
C
   23 BJ=YNB-YCN
      BK=YCN-YNA
      BL=YNA-YNB
      CJ=XCN-XNB
      CK=XNA-XCN
      CL=XNB-XNA
      TEMP=2.*(XNA*BJ+XNB*BK+XCN*BL)
      ATRI(II)=TEMP
      XKT=XKT/TEMP
      YKT=YKT/TEMP
      TPXL=XKT*BL
      TPYL=YKT*CL
      TPXJ=XKT*BJ
      TPYJ=YKT*CJ
      GC=GC+TPXL*BL+TPYL*CL
      IF(NA.LE.NRED) GO TO 35
      BCN=BCN-(TPXL*BJ+TPYL*CJ)*HD(II)
      IF(NB.LE.NRED) GO TO 32
   31 BCN=BCN-(TPXL*BK+TPYL*CK)*HD(II+1)
      GO TO 100
   32 B(NB)=B(NB)-(TPXJ*BK+TPYJ*CK)*HD(II)
   33 GT(II+1)=GT(II+1)+TPXL*BK+TPYL*CK
      G(NB,LR)=G(NB,LR)+XKT*BK*BK+YKT*CK*CK
      GO TO 100
   35 GT(II)=GT(II)+TPXJ*BL+TPYJ*CL
      G(NA,LR)=G(NA,LR)+TPXJ*BJ+TPYJ*CJ
      IF(NB.LE.NRED) GO TO 36
      B(NA)=B(NA)-(TPXJ*BK+TPYJ*CK)*HD(II+1)
      GO TO 31
   36 NAT=NA-NB+LR
      NBT=NB-NA+LR
      G(NA,NBT)=G(NA,NBT)+TPXJ*BK+TPYJ*CK
      G(NB,NAT)=G(NA,NBT)
      GO TO 33
  100 CONTINUE
      GT(1)=GT(1)+GT(NP1)
C
C          ADD SOURCES OR SINKS TO B VECTOR
C
      IF (NWELS.LE.0.OR.KOUNT.GE.NWELS) GO TO 50
      DO 45 JJ=1,NWELS
      IF (IWLEL(JJ).NE.I) GO TO 45
      KOUNT=KOUNT+1
      TEMP=QWELL(JJ)/((ATRI(1)+ATRI(2)+ATRI(3)+ATRI(4))*3.)
      DO 40 KK=1,N
      KA=ND(KK)
      KB=ND(KK+1)
      TMP= ATRI(KK)*TEMP
      B(KA)=B(KA)+TMP
      B(KB)=B(KB)+TMP
   40 BCN=BCN+TMP
      GO TO 50
   45 CONTINUE
```

```
C
C            ELIMINATE CENTRAL NODE POINT OF EACH OUTER TRIANGULAR OR
C            QUADRILATERAL ELEMENT FROM MATRIX EQUATION
C
      50 DO 61 JJ=1,N
         KA=ND(JJ)
         IF(KA.GT.NRED) GO TO 61
         TEMP=GT(JJ)/GC
         B(KA)=B(KA)-BCN*TEMP
         DO 60 KK=1,N
         KB=ND(KK)
         IF(KB.GT.NRED) GO TO 60
         KC=KB-KA+LR
         G(KA,KC)=G(KA,KC)-GT(KK)*TEMP
      60 CONTINUE
      61 CONTINUE
     200 CONTINUE
         NBEG=1
         NELS=NOELS
         NP1=5
         N=4
     300 CONTINUE
         RETURN
         END

TOTAL MEMORY REQUIREMENTS 000EFC BYTES

COMPILER HIGHEST SEVERITY CODE WAS  0

         SUBROUTINE BSOLVE(C,V,N,M)
C            SOLVE MATRIX EQUATION BY GAUSS ELIMINATION
         DIMENSION C(861,50),V(861)
         LR=(M-1)/2
         DO 20 L=1,LR
         IM=LR-L+1
         DO 20 I=1,IM
         DO 10 J=2,M
      10 C(L,J-1)=C(L,J)
         KN=N-L
         KM=M-I
         C(L,M)=0.
      20 C(KN+1,KM+1)=0.
         LR=LR+1
         IM=N-1
         DO 90 I=1,IM
         NPIV=I
         LS=I+1
         DO 30 L=LS,LR
         IF(ABS(C(L,1)).GT.ABS(C(NPIV,1))) NPIV=L
      30 CONTINUE
         IF(NPIV.LE.I) GO TO 50
         DO 40 J=1,M
         TEMP=C(I,J)
```

```
          C(I,J)=C(NPIV,J)
       40 C(NPIV,J)=TEMP
          TEMP=V(I)
          V(I)=V(NPIV)
          V(NPIV)=TEMP
       50 V(I)=V(I)/C(I,1)
          DO 60 J=2,M
       60 C(I,J)=C(I,J)/C(I,1)
          DO 80 L=LS,LR
          TEMP=C(L,1)
          V(L)=V(L)-TEMP*V(I)
          DO 70 J=2,M
       70 C(L,J-1)=C(L,J)-TEMP*C(I,J)
       80 C(L,M)=0.
          IF(LR.LT.N) LR=LR+1
       90 CONTINUE
          V(N)=V(N)/C(N,1)
          JM=2
          DO 110 I=1,IM
          L=N-I
          DO 100 J=2,JM
          KM=L+J
      100 V(L)=V(L)-C(L,J)*V(KM-1)
          IF(JM.LT.M) JM=JM+1
      110 CONTINUE
          RETURN
          END
```

TOTAL MEMORY REQUIREMENTS 0006D8 BYTES

COMPILER HIGHEST SEVERITY CODE WAS 0

```
          SUBROUTINE PRTOTA(VALA,VALB,NO)
C            PRINT OUT VALUES IN TWO GROUPS OF THREE COLUMNS
          DIMENSION VALA(861),VALB(861)
          IEND=NO/2
          ITMP=(NO+1)/2
          DO 1 I=1,IEND
          K=ITMP+I
          PRINT 20,I,VALA(I),VALB(I),K,VALA(K),VALB(K)
        1 CONTINUE
          IF(ITMP.EQ.IEND) GO TO 10
          PRINT 20,ITMP,VALA(ITMP),VALB(ITMP)
       20 FORMAT(1H ,2X,2(I4,4X,F6.1,8X,F6.1,9X))
       10 RETURN
          END
```

TOTAL MEMORY REQUIREMENTS 0002DC BYTES

COMPILER HIGHEST SEVERITY CODE WAS 0

```
0001                SUBROUTINE PRTOTB(VAL,NO)
          C            PRINT OUT VALUES IN THREE GROUPS OF TWO COLUMNS
0002                DIMENSION VAL(861)
0003                IEND=NO/3
0004                ITEMP=NO-IEND-IEND-IEND
0005                ITMP=IEND
0006                IF(ITEMP.EQ.0) GO TO 5
0007                ITMP=IEND+1
0008                IF(ITEMP.EQ.1) IEND=IEND-1
0009              5 DO 10 I=1,IEND
0010                K=ITMP+I
0011                L=ITMP+K
0012                PRINT 30,I,VAL(I),K,VAL(K),L,VAL(L)
0013             10 CONTINUE
0014                IF(ITEMP.EQ.0) GO TO 25
0015                I=IEND+1
0016                K=K+1
0017                PRINT 30,I,VAL(I),K,VAL(K)
0018                IF(ITEMP.EQ.2) GO TO 25
0019                I=I+1
0020                K=K+1
0021                PRINT 30,I,VAL(I),K,VAL(K)
0022             30 FORMAT(1H ,2X,3(I4,4X,F6.4,10X))
0023             25 RETURN
0024                END
TOTAL MEMORY REQUIREMENTS 0003E0 BYTES

COMPILER HIGHEST SEVERITY CODE WAS  0

0001                SUBROUTINE COORD(NN1,M,NROWS)
          C
          C         GENERATES ELEMENT NUMBERS AND SURROUNDING NODE NUMBERS FOR THE N*M
          C         MATRIX - D DATA CARDS
          C
0002                DIMENSION TITLE(21),XCORD(861),YCORD(861),NODE(861,4),IZONE(861),
               1 XPERM(5),YPERM(5),ALPHA(5),NDHD(120),HEAD(120),G(861,50),B(861),
               2 QWELL(1),IWLEL(1),QBND(1),NDA(1),NDB(1),THICK(861)
0003                COMMON B,G,NRED,NELS,NNDS,NHDS,XCORD,YCORD,NODE,IZONE,XPERM,YPERM,
               1ALPHA,HEAD,NDHD,MAXBW,QWELL,IWLEL,QBND,NDA,NDB,THICK,NWELS,NQBND,
               2IRADL,LR,NBEG,NTELS,NQELS,NELT,NP1,N
0004                KM=0
0005                K=0
0006                L=(NN1-2)*(M-2)
0007                K1=NN1-(NN1-2)
0008                K2=NN1-2
0009                K3=M-(M-2)
0010                K4=M-2
0011                NODE(1,1)=K+1
0012                NODE(1,2)=L+2
0013                NODE(1,3)=L+1
0014                NODE(1,4)=L+M+1
0015                IZONE(1)=1
```

```
      K=K+1
      L=L+1
      KELE=1
      DO 10 J=K3,K4
      KELE=KELE+1
      NODE(J,1)=K+1
      NODE(J,2)=L+2
      NODE(J,3)=L+1
      NODE(J,4)=K
      IF(KELE.LT.NROWS)IZONE(J)=1
      IF(KELE.GE.NROWS)IZONE(J)=2
      K=K+1
   10 L=L+1
      NODE(M-1,1)=L+4
      NODE(M-1,2)=L+2
      NODE(M-1,3)=L+1
      NODE(M-1,4)=K
      IZONE(M-1)=2
      NM=(M-1)*(NN1-1)-2*(M-1)+1
      MMM=M-1
      K=K+1
      L=L+3
      DO 20 I=M,NM,MMM
      KELE=1
      NODE(I,1)=K
      NODE(I,2)=K-K4
      NODE(I,3)=L
      NODE(I,4)=L+2
      IZONE(I)=1
      L=L+1
      K=K+1
      DO 30 J=K3,K4
      KELE=KELE+1
      NODE(J+I-1,1)=K
      NODE(J+I-1,2)=K-K4
      NODE(J+I-1,3)=K-K4-1
      NODE(J+I-1,4)=K-1
      IF(KELE.LT.NROWS)IZONE(J+I-1)=1
      IF(KELE.GE.NROWS)IZONE(J+I-1)=2
   30 K=K+1
      NODE(I+K4,1)=L+2
      NODE(I+K4,2)=L
      NODE(I+K4,3)=K-K4-1
      NODE(I+K4,4)=K-1
      IZONE(I+K4)=2
   20 L=L+1
      NM=(M-1)*(NN1-1)-(M-2)
      NODE(NM,1)=L+3
      NODE(NM,2)=K-K4
      NODE(NM,3)=L
      NODE(NM,4)=L+2
      IZONE(NM)=1
      KELE=1
      K=K+1
      L=L+3
      DO 40 J=K3,K4
```

```
      KFLE=KFLE+1
      MM=NM+J-1
      NODE(MM,1)=L+1
      NODE(MM,2)=K-K4
      NODE(MM,3)=K-K4-1
      NODE(MM,4)=L
      IF(KELE.LT.NROWS)IZONE(MM)=1
      IF(KELE.GE.NROWS)IZONE(MM)=2
      K=K+1
   40 L=L+1
      NN=(NN1-1)*(M-1)
      NODE(NN,1)=L+1
      NODE(NN,2)=L-K4-1
      NODE(NN,3)=K-K4-1
      NODE(NN,4)=L
      IZONE(NN)=2
      RETURN
      END

TOTAL MEMORY REQUIREMENTS 00095C BYTES

COMPILER HIGHEST SEVERITY CODE WAS  0

      SUBROUTINE CORDXY(NN1,M,CONSTX,CONSTY,CONSTA,S,D,NROWS)
C
C     GENERATES X AND Y COORDINATES FOR AN N*M NODAL FIELD-C DATA CARDS
C
      DIMENSION TITLE(21),XCORD(861),YCORD(861),NODE(861,4),IZONE(861),
     1 XPERM(5),YPERM(5),ALPHA(5),NDHD(120),HEAD(120),G(861,50),B(861),
     2 QWELL(1),IWLEL(1),QBND(1),NDA(1),NDB(1),THICK(861)
      COMMON B,G,NRED,NELS,NNDS,NHDS,XCORD,YCORD,NODE,IZONE,XPERM,YPERM,
     1ALPHA,HEAD,NDHD,MAXBW,QWELL,IWLEL,QBND,NDA,NDB,THICK,NWELS,NQBND,
     2IRADL,LR,NBEG,NTELS,NQELS,NELT,NP1,N
      NMAX=NN1*M
      K=0
      L=(NN1-2)*(M-2)
      K1=NN1-(NN1-2)
      K2=NN1-1
      K3=M-(M-2)
      K4=M-1
      SUMY=0.0
      DO 10 J=1,M
      L=L+1
      XCORD(L)=0.0
      YCORD(L)=SUMY
      IF(J.LT.NROWS)SUMY=SUMY+CONSTY
   10 IF(J.GE.NROWS)SUMY=SUMY+CONSTA
      SUMX=0.0
      SUMY=0.0
      DO 20 I=K1,K2
      L=L+1
      SUMX=SUMX+CONSTX
   12 XCORD(L)=SUMX
```

```
                YCORD(L)=SUMY
                DO 30 J=K3,K4
                K=K+1
                IF(J.LE.NROWS)SUMY=SUMY+CONSTY
                IF(J.GT.NROWS)SUMY=SUMY+CONSTA
             32 XCORD(K)=SUMX
                YCORD(K)=SUMY
         30     CONTINUE
                L=L+1
                XCORD(L)=SUMX
                YCORD(L)=SUMY+CONSTA
                SUMY=0.0
         20     CONTINUE
                SUMY=0.0
                SUMX=SUMX+CONSTX
                DO 40 J=1,M
                L=L+1
                XCORD(L)=SUMX
                YCORD(L)=SUMY
                IF(J.LT.NROWS)SUMY=SUMY+CONSTY
             40 IF(J.GE.NROWS)SUMY=SUMY+CONSTA
                XMAX=XCORD(NMAX)
                YMAX=YCORD(NMAX)
                IF(XMAX.NE.S.AND.YMAX.NE.D)GO TO 50
                RETURN
             50 WRITE(6,45)XMAX,YMAX
             45 FORMAT(////,10X,'X AND Y COORDINATES ARE WRONG: XMAX = 'F7.2,3X,'Y
               < = ',F7.2)
                CALL EXIT
                END

  TOTAL MEMORY REQUIREMENTS 000674 BYTES

COMPILER HIGHEST SEVERITY CODE WAS  0

   BATCH HIGHEST SEVERITY CODE WAS  0

// EXEC LNKEDT                                                            00:00:59
LIST          PHASE    FLOW,*                                           CREATED
LIST          INCLUDE  FLOW,L                                           CREATED
LIST          INCLUDE  FLOW0001,L                                       CREATED
LIST          INCLUDE  FLOW0002,L                                       CREATED
LIST          INCLUDE  FLOW0003,L                                       CREATED
LIST          INCLUDE  FLOW0004,L                                       CREATED
LIST          INCLUDE  FLOW0005,L                                       CREATED
LIST          INCLUDE  FLOW0006,L                                       CREATED
LIST      AUTOLINK     IBCOM#                                                   FROM  SYSREL
LIST      AUTOLINK     SQRT                                                     FROM  SYSREL
LIST      AUTOLINK     FRXPR#                                                   FROM  SYSREL
LIST      AUTOLINK     SIN                                                      FROM  SYSREL
LIST      AUTOLINK     EXIT                                                     FROM  SYSREL
LIST      AUTOLINK     USEROPT                                                  FROM  SYSREL
LIST      AUTOLINK     FIOCS#                                                   FROM  SYSREL
LIST      AUTOLINK     UNITAB#                                                  FROM  SYSREL
LIST      AUTOLINK     ALOG                                                     FROM  SYSREL
LIST      AUTOLINK     FXP                                                      FROM  SYSREL
LIST          ENTRY                                                     CREATED

 78/019     PHASE      TRANSFER ADDR.  LOCORE    HICORE    BLOCK NO.   ESD TYPE   LABEL     LOADED    REL-FACTOR
COMMON                                                                 COMMON               008200     000000
```

```
FLOW      03A008      03A008  043C3F     9    CSECT       MAIN44&     03A008   03A008
                                               * ENTRY     MAIN44      03A008

                                               CSECT       GEESS&      03D938   03D938
                                                 ENTRY     GEES        03D938

                                               CSECT       BSOLVE&     03E838   03E838
                                                 ENTRY     BSOLVE      03E838

                                               CSECT       PRTOTA&     03EF10   03EF10
                                                 ENTRY     PRTOTA      03EF10

                                               CSECT       PRTOTB&     03F1F0   03F1F0
                                                 ENTRY     PRTOTB      03F1F0

                                               CSECT       COORD&      03F5D0   03F5D0
                                                 ENTRY     COORD       03F5D0

                                               CSECT       CORDXY&     03FF30   03FF30
                                                 ENTRY     CORDXY      03FF30

                                               CSECT       BOAIBCOM    0405A8   0405A8
                                                 ENTRY     IBCOM#      0405A8
                                               * ENTRY     PISRCC#     041881
                                               * ENTRY     FIRSTIM     041B20
                                               * ENTRY     FIXPOINT    041AE8
                                               * ENTRY     MSGCC#      041A27
                                               * ENTRY     ADCON#      040664

                                               CSECT       BOASSQRT    0430E0   0430E0
                                                 ENTRY     SQRT        0430E6

                                               CSECT       BOAFRXPR    043190   043190
                                                 ENTRY     FRXPR#      043198

                                               CSECT       BOASSCN     043288   043288
                                                 ENTRY     SIN         0432A8
                                                 ENTRY     COS         04328C

                                               CSECT       BOAFEXIT    0433A0   0433A0
                                                 ENTRY     EXIT        0433A6

                                               CSECT       BOAUOPT     0433C0   0433C0
                                                 ENTRY     USEROPT     0433C0

                                               CSECT       BOAFIOCS    0433C8   0433C8
                                                 ENTRY     RCBORG#     043AC0
                                                 ENTRY     BUFORG#     043ABC
                                                 ENTRY     FIOCS#      0433C8
                                               * ENTRY     FIOCD#      043402
                                               * ENTRY     FIXB        043B30
                                               * ENTRY     VARB        043B3E
                                               * ENTRY     VDIOCS#     043AC4

                                               CSECT                   043B58   043B58
```

```
78/019    PHASE      TRANSFER ADDR.  LOCORE    HICORE    BLOCK NO.   ESD TYPE    LABEL      LOADED    REL-FACTOR
                                                                        ENTRY    UNITAB#    043B58
                                                                     CSECT       BOASLOG    043BE0    043BE0
                                                                        ENTRY    ALOG       043C02
                                                                      * ENTRY    ALOG10     043BE8
                                                                     CSECT       BOASEXP    043CF0    043CF0
                                                                        ENTRY    EXP        043CF4
                                          1 PHASE  USED   57 BLOCKS

LINKAGE EDITOR HIGHEST SEVERITY WAS  0
// EXEC FLOW                                                          00:01:14
```

```
     DISSERTATION - IRRIGATION RETURN FLOW WATER QUALITY
     FINITE ELEMENT PROGRAM TO CALCULATE STREAMLINES IN VERTICAL SECTION
     CASE(1 - FIRST 1/20 IS HIGH K ZONE) : ETA = 10

NUMBER OF ROWS =  21
NUMBER OF COLUMNS =  41
AQUIFER WIDTH =    1000.
AQUIFER DEPTH =    100.
DISTANCE BETWEEN COLUMN  NODES =  25.0
DISTANCE BETWEEN ROW NODES =   1.25
AFTER  5 ROWS, DISTANCE BETWEEN ROW NODES =  5.9375

INPUT DATA

NO. OF QUADRILATERAL ELEMENTS (NQELS) =     800
NO. OF TRIANGULAR ELEMENTS (NTELS) =       0
NO. OF NODES (NNDS) =     861
NO. OF MATERIAL PROPERTY ZONES (NZNS) =      2
NO. OF SPECIFIED BOUNDARY HEADS (NHDS) =    120
NO. OF SOURCES OR SINKS (NWELS) =      0
NO. OF BOUNDARY ELEMENT SIDES (NQBND) FOR WHICH DISCHARGE IS SPECIFIED =      0

ZONE        XPERM          YPERM          ALPHA
   1      0.1000E 02    0.1000E 02        0.0
   2      0.1000E 01    0.1000E 01        0.0
```

STREAMLINE	X-COORD	Y-COORD
0.450	450.00000	0.0
0.450	425.00000	0.63067
0.450	400.00000	1.20869
0.450	398.12939	1.25000
0.450	375.00000	1.74033
0.450	350.00000	2.23081
0.450	335.39575	2.50000
0.450	325.00000	2.68447
0.450	300.00000	3.10480
0.450	275.00000	3.49440
0.450	257.45142	3.75000
0.450	250.00000	3.85476
0.450	225.00000	4.18581
0.450	200.00000	4.48493
0.450	175.00000	4.74548
0.450	150.00000	4.95393
0.450	141.56207	5.00000
0.450	125.00000	5.86116
0.450	100.00000	6.00837
0.450	85.33429	5.00000
0.450	75.00000	4.93706
0.450	50.00000	4.47176
0.450	25.00000	4.06024
0.450	23.13147	3.75000
0.450	17.73195	2.50000
0.450	14.33233	1.25000
0.450	0.0	0.0

THE AREA UNDER PSI = 0.4500 IS 0.0154729 (ETA = 10.0)

Appendix C

Linear Reservoir Model Program: Arkansas River Valley

```
C
C     LUMPED PARAMETER MODEL FOR ARKANSAS RIVER VALLEY, LA JUNTA, COLORADO
C
      DIMENSION E(12),QL(12),QB(12),QP(12),QM(12),QPET(12),FACTOR(12),
     1 DAYS(12),QS(12),QIN(12),QMIN(12),QLIN(12),CIN(12),CMIN(12),
     2 CLIN(12),CO(12),GWPUMP(12),SURWAT(12),ZMON(12),RIVLEA(12),
     3 RIVWAT(12),CP(60),E1(12)
      COMMON /A1/ENET(60),QR(60),ETOT(60),QTOT(60),COUT(60),
     1 ALMASS(60),CAQ(60),H(60),HBAR(60),QOUT(60),TIME(62),TITLE(50)
      COMMON /A2/LB1(40),LB2(40),LB3(40),LB4(40),LB5(40),LB6(40),LB7(40)
     1 ,LB8(40),LB9(40),LB0(40),ANM1(40),ANM2(40),ANM3(40)
      COMMON /AVERS/AVECAU,AVEH,AVCOUT,AVETON,AVEQR,AVERIV,HMEAN,ESUM,
     1 S,AREA
      DATA DAYS/31.,30.,31.,30.,2*31.,30.,31.,30.,2*31.,28./
      DATA QB/12*1.20/
      DATA QLIN/5*0.2,40.2,6*0.2/
      DATA E1/0.297,33.10,28.40,3.38,21.70,29.50,26.40,0.00314,7.17,
     < 0.819,0.0182,0.000122/
      DATA QL/9.20,13.03,13.00,13.36,14.74,15.70,16.32,13.33,10.84,9.89,
     <9.84,9.92/
      DATA QS/6.651, 8.637, 9.749, 19.505, 21.907, 13.434,
     < 2.159, 3.773, 11.001, 3.040, 0.00, 0.00/
      DATA QM/ 3.621, 5.346, 5.303, 9.149, 7.400, 7.403,
     < 6.029, 5.560, 3.320, 2.432, 2.528, 3.081/
      DATA QPET/ 2.501, 4.104, 7.696, 10.254, 11.872, 10.564,
     < 5.765, 3.858, 1.291, 0.112, 0.000, 0.490/
      DATA QP/ 2.378, 40.550, 32.701, 12.697, 29.728, 40.233,
     < 39.306, 1.982, 1.229, 0.396, 0.092, 0.089/
      DATA QIN/42.0,95.0,139.0,464.0,413.0,114.0,109.0,106.0,36.0,30.0,
     <26.0,21.0/
      DATA QMIN/0.9,2*1.0,1.2,2*1.4,1.6,5*1.0/
      DATA CIN/1398.,1509.,1509.,1231.,748.,1296.,1361.,1352.,1296.,
     <1732.,1872.,1835./
      DATA CLIN/5*6450.,1037.,6*6450./
      DATA CMIN/12*5244./
      DATA CO/1147.,1240.,1379.,1175.,636.,1147.,1203.,1259.,896.,1194.,
     <1509.,1287./
      DATA ZMON/5H MAR ,5H APR ,5H MAY ,5H JUN ,5H JUL ,5H AUG ,5H SEP ,
     < 5H OCT ,5H NOV ,5H DEC ,5H JAN ,5H FEB /
      DATA IR,IW/23,3/
      DATA NCASES,NYR,IYR/5,3,1971/
      OPEN(UNIT=23,DEVICE='DSK',ACCESS='SEQIN',FILE='USGS.DAT')
      CALL INITAL(1)
      N=12*NYR
      CONST=3600.*24./43560.
      AR=0.0720
      S=0.20
      HR=4011.16
      AREA=11950.0
      HBAR(1)=42000./(S*AREA)
      TH=S/AR
      CK1P=EXP(-1.0/TH)
      CK2P=EXP(-0.5/TH)
      CAQ(1)=2024.3
      H(1)=4011.80
      BASE=H(1)-HBAR(1)
      CK=CONST/735.0
      AYR=IYR
      DO 61 I=1,N
      AI=I
```

```
   61 TIME(I)=(AI+1.5)/12.0 + AYR
      READ(IR,69)(LB1(I),I=1,8)
      READ(IR,69)(LB2(I),I=1,8)
      READ(IR,69)(LB3(I),I=1,8)
      READ(IR,69)(LB4(I),I=1,8)
      READ(IR,69)(LB5(I),I=1,8)
      READ(IR,69)(LB6(I),I=1,8)
      READ(IR,69)(LB7(I),I=1,8)
      READ(IR,69)(LB8(I),I=1,8)
      READ(IR,69)(LB9(I),I=1,8)
      READ(IR,69)(LB0(I),I=1,8)
      READ(IR,69)(ANM1(I),I=1,8)
      READ(IR,69)(ANM2(I),I=1,8)
      READ(IR,69)(ANM3(I),I=1,8)
   69 FORMAT(10A5)
      DO 77 I=1,12
      GWPUMP(I)=QP(I)
      RIVLEA(I)=QL(I)
      RIVWAT(I)=QIN(I)
   77 SURWAT(I)=QS(I)
      DO 98 JR=1,NCASES
      JGR=JR
      DO 76 I=1,12
      E(I)=E1(I)
      QP(I)=GWPUMP(I)
      QL(I)=RIVLEA(I)
      QIN(I)=RIVWAT(I)
   76 QS(I)=SURWAT(I)
      READ(IR,69)(TITLE(I),I=1,10)
      IYRBEG=IYR
      GO TO (80,81,85,86,83),JR
   81 DO 82 II=1,12
      QS(II)=QS(II)+QP(II)
   82 QP(II)=0.0
      GO TO 80
   83 DO 88 II=1,12
   88 QL(II)=0.0
      GO TO 80
   85 DO 84 II=1,12
      QP(II)=QP(II)+QS(II)
   84 QS(II)=0.0
      GO TO 80
   86 DO 87 II=1,12
      E(II)=E(II)-0.393*E(II)
      QS(II)=QS(II)-0.2*QS(II)
   87 QP(II)=QP(II)-0.2*QP(II)
   80 AYR=IYR-1
      DO 1 J=1,NYR
      JYR=J
      AVECAQ=0.0
      AVEH=0.0
      AVCOUT=0.0
      AVETON=0.0
      AVEQH=0.0
      AVERIV=0.0
      HMEAN=0.0
```

```
      ESUM=0.0
      AYR=AYR+1.0
      WRITE(IW,250)(TITLE(I),I=1,10)
  250 FORMAT(1H1,////////,4X,10A5)
      WRITE(IW,200)IYRBEG
  200 FORMAT(/,5X,'ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR ',
     <I4,//,7X,'ENET ',2X,'ETOT ',2X,'QTOT ',1X,'AQ. CHEM.',3X,'AQ. W-L'
     <,3X,'RIVER CHEM.',2X,'RIVER FLOW',2X,'SALT',2X,'RIVER TRANS',2X,
     <'HBAR',/,7X,'(FT)',3X,'(FT)',3X,'(FT)',4X,'(MG/L)',6X,'(FT)',7X,
     <'(MG/L)',7X,'(CFS)',4X,'(TONS)',4X,'(CFS)',5X,'(FT)',/)
      IF(AYR .EQ. 1971.)GO TO 2
      DAYS(12)=28.0
      GO TO 3
    2 DAYS(12)=29.0
    3 DO 112 I=1,12
      KI=12*(J-1)+I
      FACTOR(I)=CONST*DAYS(I)
      ENET(KI)=E(I)+QL(I)+QB(I)-(QP(I)+QM(I)+QPET(I))
  112 ENET(KI)=ENET(KI)*FACTOR(I)/AREA
      DO 111 I=1,12
      KI=12*(J-1)+I
      IF(KI .LE. 1)GO TO 7
      CK3P=H(KI-1)-HR-ENET(KI-1)/AR
      CK4=HR+ENET(KI)/AR
      CK5=(ENET(KI-1)-ENET(KI))/AR
      H(KI)=CK3P*CK1P+CK4+CK5*CK2P
      HBAR(KI)=H(KI)-BASE
    7 QR(KI)=AREA*AR*(H(KI)-HR)/FACTOR(I)
      AVEQR=AVEQR+QR(KI)
      AVEH=AVEH+H(KI)
      HMEAN=HMEAN+HBAR(KI)
      IF(QR(KI) .GT. 0.0)GO TO 8
      ETOT(KI)=E(I)+QL(I)-QP(I)-QPET(I)-QR(KI)
      QTOT(KI)=QS(I)+QL(I)-QR(KI)
      CP(KI)=((QS(I)+QL(I))*CO(I)-QR(KI)*CIN(I))/QTOT(KI)
      GO TO 9
    8 ETOT(KI)=E(I)+QL(I)-QP(I)-QPET(I)
      QTOT(KI)=QS(I)+QL(I)
      CP(KI)=CO(I)
    9 ETOT(KI)=ETOT(KI)*FACTOR(I)/AREA
      QTOT(KI)=QTOT(KI)*FACTOR(I)/AREA
      ESUM=ESUM+ETOT(KI)
      IF(J.EQ.1 .AND. I.EQ.1)GO TO 14
      CM1=S*(HBAR(KI)+HBAR(KI-1))
      CM2=ETOT(KI)+ETOT(KI-1)
      CM3=QTOT(KI)+QTOT(KI-1)
      CAQ(KI)=(CAQ(KI-1)*CM1+CP(KI)*CM3)/(CM1+CM2)
   14 QOUT(KI)=QIN(I)+QLIN(I)+QMIN(I)+QR(KI)
      AVERIV=AVERIV+QOUT(KI)
      IF(QR(KI) .GT. 0.0)GO TO 12
      COUT(KI)=(QIN(I)*CIN(I)+QLIN(I)*CLIN(I)+QMIN(I)*CMIN(I)+QR(KI)*CIN
     <(I))/QOUT(KI)
      GO TO 13
   12 COUT(KI)=(QIN(I)*CIN(I)+QLIN(I)*CLIN(I)+QMIN(I)*CMIN(I)+QR(KI)*CAQ
     <(KI))/QOUT(KI)
   13 CDAYS=CK*DAYS(I)
      ALMASS(KI)=CDAYS*COUT(KI)*QOUT(KI)
      AVECAQ=AVECAQ+CAQ(KI)
      AVETON=AVETON+ALMASS(KI)
      AVCOUT=AVCOUT+COUT(KI)
```

```
      WRITE(IW,201)ZMON(I),ENET(KI),ETOT(KI),QTOT(KI),CAQ(KI),H(KI),
     <COUT(KI),QOUT(KI),ALMASS(KI),QR(KI),HBAR(KI)
  201 FORMAT(1X,A5,2(F6.3,1X),F5.3,2X,F9.2,3X,F7.2,1X,F11.2,F10.2,
     < 3X,F10.2,2X,F7.2,1X,F7.2)
  111 CONTINUE
      AVECAQ=AVECAQ/12.0
      AVEH=AVEH/12.0
      AVCOUT=AVCOUT/12.0
      AVETON=AVETON/12.0
      AVEQR=AVEQR/12.0
      HMEAN=HMEAN/12.0
      AVERIV=AVERIV/12.0
      TC=S*HMEAN/ESUM
      WRITE(IW,301)AVECAQ,AVEH,AVCOUT,AVERIV,AVETON,AVEQR,HMEAN
  301 FORMAT(/,5X,'YEARLY AVERAGES:',6X,F9.2,3X,F7.2,1X,F11.2,F10.2,3X,
     < F10.2,2X,F7.2,1X,F7.2)
      WRITE(IW,202)TH,TC
  202 FORMAT(/,5X,'HYDRAULIC RESPONSE TIME = ',F4.1,1X,'MONTHS',3X,
     < 'SOLUTE RESPONSE TIME = ',F6.1,1X,'YEARS')
      CALL DELTA(IW,JGR,JYR,IYRBEG,ZMON,N,QIN,CIN,NYR)
    1 IYRBEG=IYRBEG+1
   98 CALL GRAFF(IW,JGR,N,IYR,CIN,QIN,CO)
      CLOSE(UNIT=23,DEVICE='DSK',ACCESS='SEQIN',FILE='USGS.DAT')
      CALL RSTR(0)
      CALL RSTR(2)
      STOP
      END
C
      SUBROUTINE GRAFF(IW,JR,N,IYR,CIN,QIN,CO)
C
      DIMENSION HKOW(12),DELY2(5),DELY3(5),YSC3B(5),DELY3B(5),
     1 CAQKOW(12),Y1(62),Y2(62),YSC1(5),YSC2(5),YSC3(5),DELY1(5),
     2 QOBS(12),COBS(12),QKOW(12),CKOW(12),LBY1(40),LBY2(40),
     3 HOB(12),CAQOB(12),X(62),CIN(12),QIN(12),CO(12),
     4 OD1(14),OD2(14),OD3(14),NUM1(1),NUM2(1),X1(14)
      COMMON /A1/ENET(60),QR(60),ETOT(60),QTOT(60),COUT(60),
     1 ALMASS(60),CAQ(60),H(60),HBAR(60),QOUT(60),TIME(62),TITLE(50)
      COMMON /A2/LB1(40),LB2(40),LB3(40),LB4(40),LB5(40),LB6(40),LB7(40)
     1 ,LB8(40),LB9(40),LB0(40),ANM1(40),ANM2(40),ANM3(40)
      COMMON /APLOT/H2(60),CAQ2(60),QOUT2(60),COUT2(60)
      DATA QOBS/55.,99.,146.,473.,419.,163.,122.,105.,47.,35.,29.,28./
      DATA COBS/1741.7, 1681.0, 1704.5, 1277.2, 877.7, 1537.3,
     1 1528.0, 1518.7, 1667.3, 1862.4, 2038.9, 2141.1/
      DATA QKOW/47.0, 98.1, 138.5, 456.4, 406.4, 152.9,
     1 108.9, 108.1, 43.6, 38.2, 34.5, 28.9/
      DATA CKOW/1643.0, 1613.6, 1570.7, 1247.7, 772.7, 1387.9,
     1 1459.1, 1444.8, 1617.0, 2006.6, 2138.1, 2168.5/
      DATA HOB/4011.80,4011.24,4011.13,4010.57,4010.82,
     1 4010.50,4010.57,4010.64,4011.21,4011.61,4011.70,4011.65/
      DATA CAQOB/2024.3,2051.1,2084.8,2143.1,2216.6,2270.4,
     1 2300.2,2278.7,2214.0,2212.6,2209.5,2180.9/
      DATA HKOW/4013.74,4013.60,4013.64,4013.74,4013.76,
     1 4013.45,4013.35,4013.46,4013.64,4013.66,4013.68,4013.68/
      DATA CAQKOW/1880.8,1899.8,1920.0,1948.7,1942.0,
     < 1984.7,1998.8,2001.5,1961.9,1958.5,1944.9,1926.7/
      DATA NUM1/4H1971/
```

```
      DATA NUM2/4H1972/
      DATA YSC1/30.0,0.0,-6.0,0.0,-6.0/
      DATA DELY1/5*1.0/
      DATA YSC2/110.0,-50.0,-5.0,-18.0,-5.0/
      DATA DELY2/20.0,10.0,5.0,3.0,5.0/
      DATA YSC3B/-300.0,-600.0,-200.0,-200.0,-200.0/
      DATA DELY3B/300.0,150.0,100.0,50.0,100.0/
      DATA YSC3/-50.0,-40.0,-30.0,0.0,-24.0/
      DATA DELY3/25.0,20.0,5.0,1.0,4.0/
      KOUNT=1
      J1=1
      J2=2
      J3=3
      AYR=IYR
      CALL PLOT(6.0,0.0,-3)
    5 CONTINUE
      CALL RSTR(0)
      CALL RSTR(1)
      GO TO (3,2),KOUNT
    2 DO 23 I=1,N
      X(I)=TIME(I)
      Y1(I)=CAQ2(I)/1000.0
   23 Y2(I)=H2(I)/1000.0
      DO 233 I=1,8
      LBY1(I)=LB3(I)
  233 LBY2(I)=LB2(I)
      Y1MIN=YSC2(JR)
      DY1=DELY2(JR)
      Y2MIN=YSC1(JR)
      DY2=DELY1(JR)
      GO TO 4
    3 DO 34 I=1,N
      X(I)=TIME(I)
      Y1(I)=QOUT2(I)
   34 Y2(I)=COUT2(I)
      DO 344 I=1,8
      LBY1(I)=LB6(I)
  344 LBY2(I)=LB7(I)
      Y1MIN=YSC3(JR)
      DY1=DELY3(JR)
      Y2MIN=YSC3B(JR)
      DY2=DELY3B(JR)
    4 XMIN=AYR
      DX=1.0
      DO 6 I=1,N
      X(I)=(X(I)-XMIN)/DX
      Y1(I)=(Y1(I)-Y1MIN)/DY1
    6 Y2(I)=(Y2(I)-Y2MIN)/DY2
      CALL PLOT(1.56,2.5,-3)
      CALL AXIS(0.,0.,LP1,-40,6.,0.,XMIN,DX,-1)
      CALL PLOT(0.,6.,3)
      CALL PLOT(6.,6.,2)
      CALL PLOT(1.1667,6.0,3)
      CALL PLOT(1.1667,0.0,2)
      CALL PLOT(0.,0.,3)
      CALL AXIS(0.,0.,LBY1,40,6.,90.,Y1MIN,DY1,-1)
      CALL PLOT(0.,0.,3)
      CALL LINE(X,Y1,N,J1,1)
      CALL PLOT(6.,0.,3)
      CALL AXIS(6.,0.,LBY2,-40,6.,90.,Y2MIN,DY2,-1)
```

```
  451 CALL PLOT(0.0,0.0,3)
      CALL LINE(X,Y2,N,J2,1)
      CALL PLOT(0.,6.10,3)
      CALL SYMBOL(0.,6.10,0.14,TITLE,0.0,50)
      CALL PLOT(0.,-2.5,-3)
      KOUNT=KOUNT+1
      IF(KOUNT.LT.3)GO TO 5
      IF(JR.GT.1)RETURN
      ICOUNT=1
   55 CONTINUE
      CALL RSTR(0)
      CALL RSTR(1)
      GO TO (11,22,65,33,44),ICOUNT
   11 DO 112 I=1,12
      AI=I
      X1(I)=AYR+(AI+1.5)/12.0
      CONST=QIN(I)
      OD1(I)=QOBS(I)-CONST
      OD2(I)=QKOW(I)-CONST
  112 OD3(I)=QOUT(I)-CONST
      DO 113 I=1,8
  113 LBY1(I)=LB4(I)
      OD1MIN=-10.0
      DOD1=10.0
      GO TO 444
   22 DO 220 I=1,12
      AI=I
      X1(I)=AYR+(AI+1.5)/12.0
      CONST=CO(I)
      OD1(I)=COBS(I)-CONST
      OD2(I)=CKOW(I)-CONST
  220 OD3(I)=COUT(I)-CONST
      DO 221 I=1,8
  221 LBY1(I)=LB5(I)
      OD1MIN=0.0
      DOD1=150.0
      GO TO 444
   65 DO 650 I=1,12
      AI=I
      X1(I)=AYR+(AI+1.5)/12.0
      CONST=CIN(I)
      OD1(I)=COBS(I)-CONST
      OD2(I)=CKOW(I)-CONST
  650 OD3(I)=COUT(I)-CONST
      DO 651 I=1,8
  651 LBY1(I)=LB8(I)
      OD1MIN=-100.0
      DOD1=100.0
      GO TO 444
   33 DO 330 I=1,12
      AI=I
      X1(I)=AYR+(AI+1.5)/12.0
      OD1(I)=HOB(I)
      OD2(I)=HKOW(I)
  330 OD3(I)=H(I)
      DO 331 I=1,8
  331 LBY1(I)=LB9(I)
```

```
      OD1MIN=4009.0
      DOD1=1.0
      GO TO 444
   44 DO 440 I=1,12
      AI=I
      X1(I)=AYR+(AI+1.5)/12.0
      OD1(I)=CAQOB(I)
      OD2(I)=CAQKOW(I)
  440 OD3(I)=CAQ(I)
      DO 441 I=1,8
  441 LBY1(I)=LBO(I)
      OD1MIN=1500.0
      DOD1=200.0
  444 OD2MIN=OD1MIN
      DOD2=DOD1
      OD3MIN=OD1MIN
      DOD3=DOD1
      XMIN=AYR
      DX=1.0/4.0
      DO 445 I=1,12
      X1(I)=(X1(I)-XMIN)/DX
      OD1(I)=(OD1(I)-OD1MIN)/DOD1
      OD2(I)=(OD2(I)-OD2MIN)/DOD2
  445 OD3(I)=(OD3(I)-OD3MIN)/DOD3
      CALL PLOT(1.56,2.5,-3)
      CALL PLOT(0.0,-0.1,3)
      CALL PLOT(0.0,0.0,2)
      CALL PLOT(6.0,0.0,2)
      CALL PLOT(0.0,0.0,3)
      DELX=0.0
      DO 446 IK=1,18
      DELX=DELX+1.0/3.0
      CALL PLOT(DELX,0.0,3)
  446 CALL MARKER(J1)
      CALL PLOT(4.0,-0.1,3)
      CALL PLOT(4.0,0.1,2)
      CALL SYMBOL(2.0,-0.5,0.14,LB1,0.0,40)
      CALL SYMBOL(-0.25,-0.3,0.14,NUM1,0.0,4)
      CALL SYMBOL(3.75,-0.3,0.14,NUM2,0.0,4)
      CALL PLOT(0.0,6.0,3)
      CALL PLOT(6.0,6.0,2)
      CALL PLOT(6.0,0.0,2)
  448 CALL PLOT(0.,0.,3)
      CALL AXIS(0.,0.,LBY1,40,6.,90.,OD1MIN,DOD1,-1)
      CALL PLOT(0.,0.,3)
      CALL LINE(X1,OD1,12,J1,1)
      CALL PLOT(0.,0.,3)
      CALL LINE(X1,OD2,12,J2,1)
      CALL PLOT(0.,0.,3)
      CALL LINE(X1,OD3,12,J3,1)
      CALL SYMBOL(0.,6.46,0.14,ANM1,0.,40)
      CALL SYMBOL(0.,6.26,0.14,ANM2,0.,40)
      CALL SYMBOL(0.,6.06,0.14,ANM3,0.,40)
      CALL PLOT(1.625,6.156,3)
      CALL MARKER(J3)
      CALL PLOT(0.,-2.5,-3)
      ICOUNT=ICOUNT+1
      IF(ICOUNT.LT.6)GO TO 55
      RETURN
      END
```

```
C
      SUBROUTINE DELTA(IW,JR,JYR,IYR,ZMON,N,QIN,CIN,NYR)
C
      DIMENSION CAQ1(60),H1(60),QOUT1(60),ALMAS1(60),QR1(60),HB1(60),
     1 ZMON(12),QIN(12),CIN(12),ACAQ(5),AH(5),ACOUT(5),ATON(5),AQR(5),
     2 ARIV(5),AHBAR(5),QIN1(12),COUT1(60),DELC(60)
      COMMON /A1/ENET(60),QR(60),ETOT(60),QTOT(60),COUT(60),ALMASS(60),
     1 CAQ(60),H(60),HBAR(60),QOUT(60),X(62),TITLE(50)
      COMMON /AVERS/AVECAQ,AVEH,AVCOUT,AVETON,AVEQR,AVERIV,HMEAN,ESUM,
     1 S, AREA
      COMMON /APLOT/H2(60),CAQ2(60),QOUT2(60),COUT2(60)
      IF(JR .GT. 1)GO TO 1
      FAC1=S*AREA
      ACAQ(JYR)=AVECAQ
      AH(JYR)=AVEH
      ACOUT(JYR)=AVCOUT
      ATON(JYR)=AVETON
      AQR(JYR)=AVEQR
      ARIV(JYR)=AVERIV
      AHBAR(JYR)=HMEAN
      DO 2 KI=1,12
      I=12*(JYR-1)+KI
      DELC(I)=CAQ(I)
      CAQ1(I)=CAQ(I)*HBAR(I)*FAC1/735.
      H1(I)=H(I)*FAC1
      QOUT1(I)=QOUT(I)-QIN(KI)
      ALMAS1(I)=ALMASS(I)
      COUT1(I)=COUT(I)-CIN(KI)
      HB1(I)=HBAR(I)
      QIN1(KI)=QIN(KI)
    2 QR1(I)=QR(I)
      IF(JYR-NYR)6,5,5
    5 DO 7 I=1,N
      H2(I)=HB1(I)*FAC1
      QOUT2(I)=QOUT1(I)
      COUT2(I)=COUT1(I)
    7 CAQ2(I)=CAQ1(I)
      GO TO 6
    1 AVEC=AVECAQ-ACAQ(JYR)
      AVECAQ=(AVECAQ*HMEAN-ACAQ(JYR)*AHBAR(JYR))*FAC1/735.0
      AVEH=(AVEH-AH(JYR))*FAC1
      AVCOUT=AVCOUT-ACOUT(JYR)
      AVETON=AVETON-ATON(JYR)
      AVEQR=AVEQR-AQR(JYR)
      AVERIV=AVERIV-ARIV(JYR)
      HMEAN=HMEAN-AHBAR(JYR)
      WRITE(IW,200)IYR
  200 FORMAT(//,5X,'ARKANSAS RIVER VALLEY STUDY: CHANGES FROM BASE PERIO
     <D FOR ',I4,//,16X,'AQ. CHEM.',2X,'AQ. CHEM.',3X,'AQ. VOL',3X,
     <'RIVER CHEM.',2X,'RIVER FLOW',2X,'SALT',2X,'RIVER TRANS',2X,
     <'HBAR',/,17X,'(MG/L)',5X,'(TONS)',5X,'(AC-FT)',4X,'(MG/L)',7X,
     <'(CFS)',5X,'(TONS)',7X,'(CFS)',2X,'(FT)',/)
      DO 3 KI=1,12
      I=12*(JYR-1) + KI
      DC=CAQ(I)-DELC(I)
      CAQ2(I)=CAQ(I)*HBAR(I)*FAC1/735.0-CAQ1(I)
      H2(I)=H(I)*FAC1 - H1(I)
```

```
      QOUT2(I)=QOUT(I)-QOUT1(I)-QIN1(KI)
      ALMAS2=ALMASS(I)-ALMAS1(I)
      COUT2(I)=COUT(I)-COUT1(I)-CIN(KI)
      QR2=QR(I)-QR1(I)
      HBAR2=HBAR(I)-HB1(I)
    3 WRITE(IW,201)ZMON(KI),DC,CAQ2(I),H2(I),COUT2(I),QOUT2(I),ALMAS2,
     < QR2,HBAR2
  201 FORMAT(4X,A5,7X,F9.2,2X,F9.2,F10.2,F12.2,F10.2,F13.2,F9.2,F8.2)
      WRITE(IW,301)AVEC,AVECAQ,AVEH,AVCOUT,AVERIV,AVETON,AVEQR,HMEAN
  301 FORMAT(/,5X,'AVE CHANGE:',1X,F8.2,1X,2F10.2,F12.2,F10.2,F13.2,
     1 F9.2,F8.2)
    6 RETURN
      END
```

Appendix D

Data Summary for Arkansas River Valley Study

Input Data Summary

Output Model Simulation Results

Definition of Terms

The following definitions are used in the Arkansas River valley linear reservoir model program (see Appendix C and Figure 3.1). All definitions apply to the study reach area (information source: L.F. Konikow, personal communication, 1977).

Program Term	Chap. 3 Term	Definition
QB	q_b	Net aquifer boundary inflow
QIN		Arkansas R. streamflow above La Junta
QL	q_L	Ft. Lyon and feeder canal leakage to aquifer
QLIN		Tributary inflows into Arkansas River
QM	q_m	La Junta municipal pumpage from groundwater
QMIN		La Junta municipal sewage effluent to river
QP	q_p	Study reach irrigation pumpage from aquifer
QPET		Phreatophyte evapotranspiration
QS	q_s	Surface water irrigation applications
E1	ε	Total aquifer recharge
HBAR	$\bar{h}$	Average aquifer saturated thichness(17.57 ft.)
CIN		Arkansas R. water quality above La Junta
CLIN		Tributary inflow water quality
CMIN		Municipal sewage water quality
CO	c_o	Ft. Lyon canal water quality above La Junta
QOBS, COBS		Arkansas R. streamflow and water quality at downstream gage
QKOW,CKOW		Konikow-Bredehoeft predicted river water flow and quality at downstream gage
HOB, CAQOB		Average aquifer water levels and water quality from Thiessen polygon weighting technique
HKOW,CAQKOW		Konikow-Bredehoeft predicted average aquifer water levels and water quality
CROP ET	$q_{crop\ et}$	Blaney-Criddle crop consumptive use
QDIV		Ft. Lyon canal diversions
A		Study reach area (11,950 acres)

Arkansas River Data Summary

(Information Source: L.F. Konikow, personal communication, 1977)

Note: All units are in cubic feet per second (CFS) unless noted.

Month	QLIN	E1	QL	QS	QDIV	QM
Mar 71	0.2	0.297	9.20	6.651	246.0	3.621
Apr	0.2	33.10	13.03	8.637	170.0	5.346
May	0.2	28.40	13.00	9.749	180.0	5.303
Jun	0.2	3.38	13.36	19.505	646.0	9.149
Jul	0.2	21.70	14.74	21.907	624.0	7.400
Aug	40.2	29.50	15.70	13.434	214.0	7.403
Sep	0.2	26.40	16.32	2.159	166.0	6.029
Oct	0.2	0.00314	13.33	3.773	173.0	5.560
Nov	0.2	7.17	10.84	11.001	529.0	3.320
Dec	0.2	0.819	9.89	3.040	273.0	2.432
Jan 72	0.2	0.0182	9.84	0.000	200.0	2.528
Feb	0.2	0.0001	9.92	0.000	240.0	3.081

Month	QPET	QP	QIN	QMIN	QB	CROP ET
Mar 71	2.501	2.378	42.0	0.9	1.2	0.21 ft.
Apr	4.104	40.550	95.0	1.0	1.2	0.33
May	7.696	32.701	139.0	1.0	1.2	0.47
Jun	10.254	12.697	464.0	1.2	1.2	0.66
Jul	11.872	29.728	413.0	1.4	1.2	0.71
Aug	10.564	40.233	144.0	1.4	1.2	0.63
Sep	5.765	39.306	109.0	1.6	1.2	0.43
Oct	3.858	1.982	106.0	1.0	1.2	0.29
Nov	1.291	1.229	36.0	1.0	1.2	0.14
Dec	0.112	0.396	30.0	1.0	1.2	0.08
Jan 72	0.000	0.092	26.0	1.0	1.2	0.05
Feb	0.490	0.089	21.0	1.1	1.2	0.10
						4.10 ft.

Arkansas River Data Summary

(Information Source: L.F. Konikow, personal communication, 1977)

Note: All water quality values are for TDS in mg/l.

Month	CIN (mg/l)	CO (mg/l)	CLIN (mg/l)	CMIN (mg/l)	QOBS (cfs)	COBS (mg/l)
Mar 71	1397.9	1147.1	6450	5244	55.0	1741.7
Apr	1509.4	1240.0	6450	5244	99.0	1881.0
May	1509.4	1379.4	6450	5244	146.0	1704.5
Jun	1230.7	1175.0	6450	5244	473.0	1277.2
Jul	747.6	636.2	6450	5244	419.0	877.7
Aug	1295.7	1147.1	1037	5244	163.0	1537.3
Sep	1360.8	1202.8	6450	5244	122.0	1528.0
Oct	1351.5	1258.6	6450	5244	105.0	1518.7
Nov	1295.7	896.3	6450	5244	47.0	1667.3
Dec	1732.4	1193.6	6450	5244	35.0	1862.4
Jan 72	1871.7	1509.4	6450	5244	29.0	2038.9
Feb	1834.6	1286.5	6450	5244	28.0	2142.2

Month	QKOW (cfs)	CKOW (mg/l)	HOB (ft)	CAQOB (mg/l)	HKOW (ft)	CAQKOW (mg/l)
Mar 71	47.0	1643.0	4011.80	2024.3	4013.74	1880.8
Apr	98.1	1613.6	4011.24	2051.1	4013.60	1899.8
May	138.5	1570.7	4011.13	2084.8	4013.64	1920.0
Jun	456.4	1247.7	4010.57	2143.1	4013.74	1948.7
Jul	406.4	772.7	4010.82	2216.6	4013.76	1942.9
Aug	152.9	1387.9	4010.50	2270.4	4013.45	1984.7
Sep	108.9	1459.1	4010.57	2300.2	4013.35	1998.8
Oct	108.1	1444.8	4010.64	2278.7	4013.46	2001.5
Nov	43.6	1617.0	4011.21	2214.0	4013.64	1961.9
Dec	38.2	2006.6	4011.61	2212.6	4013.66	1958.5
Jan 72	34.5	2138.1	4011.70	2209.5	4013.68	1944.9
Feb	28.9	2168.5	4011.65	2180.9	4013.68	1926.7

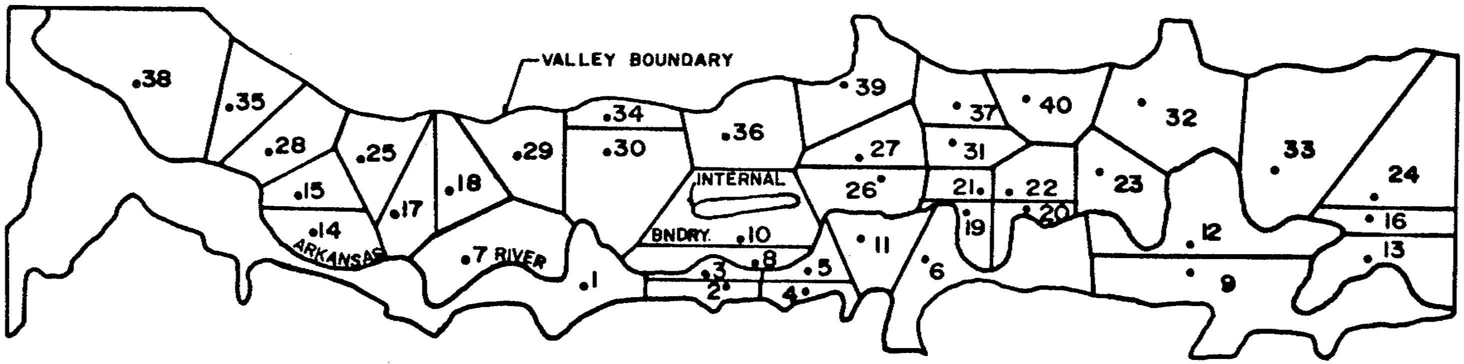

Figure D.1

Arkansas River Valley Study Area Showing Well Location and Thiessen Weighing Polygons

ARKANSAS RIVER VALLEY DATA, SOUTHEASTERN COLORADO
REFERENCE: KONIKOW, L.F., 1977

***** AVERAGE VALUES USING THEISSCN POLYGON WEIGHTING FACTORS *****

MONTH	AVE W-L (FT)	AVE CHEM (PPM)	AVE CHEM (SP. COND.)
0	4012.41	2047.3	2556.2
1	4011.80	2024.3	2531.5
2	4011.24	2051.1	2560.3
3	4011.13	2084.8	2596.6
4	4010.57	2143.1	2659.2
5	4010.82	2216.6	2738.3
6	4010.50	2270.4	2796.2
7	4010.57	2300.2	2828.2
8	4010.64	2278.7	2805.1
9	4011.21	2214.0	2735.5
10	4011.61	2212.6	2734.0
11	4011.70	2209.5	2730.7
12	4011.65	2180.9	2699.9

***** ARITHMETIC MEAN OF 40 OBSERVATION WELLS *****

MONTH	AVE W-L (FT)	AVE CHEM (PPM)	AVE CHEM (SP. COND.)
0	4010.74	2236.3	2759.5
1	4010.50	2240.8	2764.3
2	4010.27	2276.0	2802.2
3	4010.30	2302.3	2830.4
4	4010.17	2374.3	2907.9
5	4010.29	2417.9	2954.7
6	4009.96	2471.8	3012.7
7	4009.91	2493.0	3035.5
8	4010.09	2464.3	3004.6
9	4010.43	2408.7	2944.8
10	4010.51	2402.5	2938.2
11	4010.52	2395.8	2931.0
12	4010.50	2361.9	2894.5

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ARKANSAS RIVER VALLEY DATA, SOUTHEASTERN COLORADO
REFERENCE: KONIKOW, L.F., 1977

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.	WEIGHT FACTOR = 0.04035
		FT.	PPM	AT 25 C	
1	0	4022.5	1713.8	2197.6	
	1	4021.9	1730.5	2215.6	
	2	4021.4	1859.4	2354.2	
	3	4021.5	1919.7	2419.0	
	4	4022.1	2021.9	2528.9	
	5	4022.1	2144.1	2660.3	
	6	4021.6	2319.4	2848.8	
	7	4021.4	2497.9	3040.8	
	8	4021.9	2412.4	2948.8	
	9	4021.9	2295.7	2823.3	
	10	4021.9	1903.2	2401.3	
	11	4021.9	1904.2	2402.4	
	12	4021.8	1905.3	2403.5	

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.	WEIGHT FACTOR = 0.01272
		FT.	PPM	AT 25 C	
2	0	4014.0	3107.3	3696.0	
	1	4013.8	3106.4	3695.1	
	2	4013.7	3105.5	3694.1	
	3	4013.8	3104.9	3693.4	
	4	4014.3	3103.0	3691.4	
	5	4014.5	3029.5	3612.4	
	6	4014.1	3028.8	3611.6	
	7	4014.0	3027.9	3610.6	
	8	4013.9	2979.3	3558.4	
	9	4013.7	2954.9	3532.2	
	10	4013.7	2953.9	3531.1	
	11	4013.7	2952.3	3529.4	
	12	4013.6	2880.1	3451.7	

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.	WEIGHT FACTOR = 0.00603
		FT.	PPM	AT 25 C	
3	0	4014.0	3200.2	3795.9	
	1	4013.6	3200.4	3796.1	
	2	4013.6	3199.9	3795.6	
	3	4013.8	3197.6	3793.1	
	4	4014.5	3017.8	3599.8	
	5	4014.5	3011.6	3593.1	
	6	4013.9	3001.5	3582.3	
	7	4013.9	2828.7	3396.5	
	8	4013.9	2822.5	3389.8	
	9	4013.6	2816.3	3383.1	
	10	4013.6	2648.4	3202.6	
	11	4013.6	2645.7	3199.7	
	12	4013.6	2484.6	3026.5	

ARKANSAS RIVER VALLEY DATA, SOUTHEASTERN COLORADO
REFERENCE: KONIKOW, L.F., 1977

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.
		FT.	PPM	AT 25 C
4	0	4009.5	3386.0	3995.7
	1	4008.9	3382.6	3992.0
	2	4008.8	3379.0	3988.2
	3	4008.9	3375.4	3984.3
	4	4009.3	3370.8	3979.4
	5	4009.5	3372.4	3981.1
	6	4009.1	3368.8	3977.2
	7	4009.0	3365.3	3973.4
	8	4008.9	3362.0	3969.9
	9	4008.8	3357.4	3964.9
	10	4008.7	3356.0	3963.4
	11	4008.7	3351.6	3958.7
	12	4008.7	3346.9	3953.7

WEIGHT FACTOR = 0.00577

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.
		FT.	PPM	AT 25 C
5	0	4009.0	3571.8	4195.5
	1	4008.7	3566.0	4189.2
	2	4008.6	3558.8	4181.5
	3	4008.8	3549.4	4171.4
	4	4009.4	3461.7	4077.1
	5	4009.5	3319.7	3924.4
	6	4008.9	3253.5	3853.2
	7	4008.9	3239.2	3837.8
	8	4008.8	3286.7	3888.9
	9	4008.7	2994.9	3575.2
	10	4008.6	2985.6	3565.2
	11	4008.6	2975.9	3554.7
	12	4008.6	2883.0	3454.8

WEIGHT FACTOR = 0.00623

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.
		FT.	PPM	AT 25 C
6	0	4003.5	2364.1	2896.9
	1	4003.5	2360.4	2892.9
	2	4003.4	2356.8	2889.0
	3	4003.5	2353.3	2885.3
	4	4003.8	2350.3	2882.0
	5	4003.9	2346.9	2878.4
	6	4003.7	2342.9	2874.1
	7	4003.6	2168.5	2686.6
	8	4003.5	2185.1	2704.4
	9	4003.4	2183.8	2703.0
	10	4003.4	2182.2	2701.3
	11	4003.3	2180.5	2699.5
	12	4003.3	2166.6	2684.5

WEIGHT FACTOR = 0.02121

ARKANSAS RIVER VALLEY DATA, SOUTHEASTERN COLORADO
REFERENCE: KONIKOW, L.F., 1977

OBS. WELL # 7 — WEIGHT FACTOR = 0.03938

OBS. WELL #	MONTH	W-L ELEV FT.	GW CHEM PPM	SP. COND. AT 25 C
7	0	4029.5	1806.7	2297.5
	1	4029.1	1840.4	2333.8
	2	4029.4	1965.7	2468.5
	3	4029.5	2072.9	2583.8
	4	4029.6	2245.8	2769.7
	5	4029.9	2212.1	2733.4
	6	4029.4	2434.8	2972.9
	7	4029.3	2627.8	3180.4
	8	4029.2	2645.8	3199.8
	9	4029.3	2600.5	3151.1
	10	4029.3	2462.8	3003.0
	11	4029.3	2458.1	2998.0
	12	4029.4	2360.6	2893.1

OBS. WELL # 8 — WEIGHT FACTOR = 0.00590

OBS. WELL #	MONTH	W-L ELEV FT.	GW CHEM PPM	SP. COND. AT 25 C
8	C	4012.0	3478.9	4095.6
	1	4011.9	3478.1	4094.7
	2	4012.0	3477.9	4094.5
	3	4012.2	3431.6	4044.7
	4	4012.7	3422.4	4034.8
	5	4012.8	3419.7	4031.9
	6	4012.2	3287.8	3890.1
	7	4012.1	3243.1	3842.0
	8	4012.1	3159.6	3752.3
	9	4012.0	3106.2	3694.8
	10	4011.9	3037.0	3620.4
	11	4011.9	3039.8	3623.4
	12	4011.9	3043.0	3626.9

OBS. WELL # 9 — WEIGHT FACTOR = 0.03503

OBS. WELL #	MONTH	W-L ELEV FT.	GW CHEM PPM	SP. COND. AT 25 C
9	0	3978.5	1806.7	2297.5
	1	3979.1	1807.2	2298.1
	2	3978.8	1879.4	2375.7
	3	3978.7	2000.5	2505.9
	4	3978.9	2077.3	2588.5
	5	3978.8	2162.4	2680.0
	6	3978.4	2271.2	2797.0
	7	3978.3	2453.1	2992.6
	8	3978.8	2520.8	3065.4
	9	3979.0	2516.8	3061.1
	10	3979.2	2538.2	3084.1
	11	3979.3	2633.3	3186.3
	12	3979.4	2624.8	3177.2

ARKANSAS RIVER VALLEY DATA, SOUTHEASTERN COLORADO
REFERENCE: KONIKOW, L.F., 1977

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.	WEIGHT FACTOR = 0.02757
		FT.	PPM	AT 25 C	
10	0	4011.5	3571.8	4195.5	
	1	4011.8	3643.9	4273.0	
	2	4012.0	3731.8	4367.5	
	3	4012.2	3746.0	4382.8	
	4	4012.4	3993.9	4649.4	
	5	4012.8	4091.2	4754.0	
	6	4012.3	4322.6	5002.8	
	7	4012.1	4291.8	4969.7	
	8	4012.0	4148.0	4815.1	
	9	4012.0	4268.5	4944.6	
	10	4011.9	4271.2	4947.5	
	11	4011.9	4158.0	4825.8	
	12	4011.9	4053.3	4713.2	

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.	WEIGHT FACTOR = 0.01771
		FT.	PPM	AT 25 C	
11	0	4005.5	1528.0	1997.8	
	1	4005.9	1545.4	2016.6	
	2	4005.7	1612.9	2089.1	
	3	4005.8	1678.2	2159.4	
	4	4006.4	2191.6	2711.4	
	5	4006.3	2288.6	2815.7	
	6	4005.8	2499.6	3042.6	
	7	4005.7	2588.0	3137.6	
	8	4006.0	2732.1	3292.6	
	9	4005.9	2732.4	3292.9	
	10	4005.9	2722.0	3281.7	
	11	4005.9	2767.5	3330.6	
	12	4005.9	2873.2	3444.3	

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.	WEIGHT FACTOR = 0.03010
		FT.	PPM	AT 25 C	
12	0	3979.0	1992.5	2497.3	
	1	3979.5	1995.3	2500.3	
	2	3979.5	2046.3	2555.2	
	3	3979.5	2128.5	2643.5	
	4	3979.6	2173.6	2692.0	
	5	3979.7	2217.9	2739.7	
	6	3979.4	2366.4	2899.4	
	7	3979.2	2487.9	3030.0	
	8	3979.4	2456.2	2995.9	
	9	3979.6	2470.2	3011.0	
	10	3979.7	2431.3	2969.1	
	11	3979.8	2571.7	3120.1	
	12	3979.8	2611.5	3162.9	

ARKANSAS RIVER VALLEY DATA, SOUTHEASTERN COLORADO
REFERENCE: KONIKOW, L.F., 1977

OBS. WELL # 13 — WEIGHT FACTOR = 0.04230

MONTH	W-L ELEV FT.	GW CHEM PPM	SP. COND. AT 25 C
0	3967.0	1435.1	1898.0
1	3967.2	1630.8	2108.4
2	3967.3	1725.5	2210.2
3	3967.4	1891.8	2389.0
4	3968.0	1884.8	2381.5
5	3968.1	1962.0	2464.5
6	3967.6	2014.5	2521.0
7	3967.5	2033.7	2541.6
8	3967.4	1905.8	2404.1
9	3967.3	1665.0	2145.2
10	3967.2	2119.9	2634.3
11	3967.2	1743.7	2229.8
12	3967.2	2164.0	2681.7

OBS. WELL # 14 — WEIGHT FACTOR = 0.02757

MONTH	W-L ELEV FT.	GW CHEM PPM	SP. COND. AT 25 C
0	4039.5	1528.0	1997.8
1	4039.7	1534.5	2004.8
2	4039.7	1551.2	2022.8
3	4039.7	1562.6	2035.1
4	4038.6	1594.3	2069.1
5	4039.0	1620.3	2097.1
6	4038.5	1583.5	2057.5
7	4039.6	1621.1	2098.0
8	4039.9	1606.7	2082.5
9	4040.1	1592.7	2067.4
10	4040.2	1521.8	1991.2
11	4040.2	1539.0	2009.7
12	4040.3	1536.7	2007.2

OBS. WELL # 15 — WEIGHT FACTOR = 0.02141

MONTH	W-L ELEV FT.	GW CHEM PPM	SP. COND. AT 25 C
0	4040.0	1620.9	2097.7
1	4040.1	1633.1	2110.9
2	4040.1	1660.0	2139.8
3	4040.2	1632.2	2109.9
4	4039.7	1694.9	2177.3
5	4039.8	1612.4	2088.6
6	4039.5	1581.0	2054.8
7	4040.0	1586.3	2060.5
8	4040.2	1620.7	2097.5
9	4040.3	1607.1	2082.9
10	4040.4	1566.6	2039.4
11	4040.5	1471.3	1936.9
12	4040.5	1471.4	1937.0

ARKANSAS RIVER VALLEY DATA, SOUTHEASTERN COLORADO
REFERENCE: KONIKOW, L.F., 1977

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.	WEIGHT FACTOR = 0.00947
		FT.	PPM	AT 25 C	
16	C	3971.0	2549.9	3096.7	
	1	3971.0	2504.7	3048.1	
	2	3971.1	2467.1	3007.6	
	3	3971.2	2434.5	2972.6	
	4	3971.4	2495.0	3037.6	
	5	3971.5	2483.4	3025.2	
	6	3971.2	2417.9	2954.7	
	7	3971.1	2447.4	2986.5	
	8	3971.0	2384.0	2918.3	
	9	3970.9	2375.2	2908.8	
	10	3971.0	2383.8	2918.1	
	11	3971.0	2646.1	3200.1	
	12	3971.0	2642.5	3196.2	

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.	WEIGHT FACTOR = 0.01356
		FT.	PPM	AT 25 C	
17	0	4034.5	2457.0	2996.8	
	1	4034.6	2471.5	3012.4	
	2	4034.8	2534.1	3079.7	
	3	4035.0	2492.3	3034.7	
	4	4034.8	2527.3	3072.4	
	5	4034.8	2525.8	3070.8	
	6	4034.7	2565.2	3113.1	
	7	4034.6	2577.1	3125.9	
	8	4034.7	2543.0	3089.2	
	9	4034.9	2515.5	3059.7	
	10	4034.9	2527.6	3072.7	
	11	4035.0	2385.6	2920.0	
	12	4035.0	2386.5	2921.0	

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.	WEIGHT FACTOR = 0.01933
		FT.	PPM	AT 25 C	
18	0	4024.0	3386.0	3995.7	
	1	4024.5	3312.3	3916.5	
	2	4024.5	3209.7	3806.1	
	3	4024.7	3186.8	3781.5	
	4	4024.8	3172.5	3766.1	
	5	4024.8	3322.7	3927.6	
	6	4024.4	3343.7	3950.2	
	7	4024.3	3463.4	4078.9	
	8	4024.6	3382.5	3991.9	
	9	4024.8	3049.3	3633.7	
	10	4024.8	3104.2	3692.7	
	11	4024.8	2917.8	3492.3	
	12	4024.9	3026.4	3609.0	

ARKANSAS RIVER VALLEY DATA, SOUTHEASTERN COLORADO
REFERENCE: KONIKOW, L.F., 1977

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.
19		FT.	PPM	AT 25 C
	0	4002.0	2271.2	2797.0
	1	4002.2	2383.8	2918.1
	2	4002.2	2549.9	3096.7
	3	4002.3	2400.6	2936.1
	4	4002.9	2431.2	2969.0
	5	4002.9	2408.0	2944.1
	6	4002.4	2504.4	3047.7
	7	4002.2	2514.6	3058.7
	8	4002.2	1956.2	2458.3
	9	4002.3	2352.8	2884.7
	10	4002.2	2739.4	3300.4
	11	4002.2	2477.8	3019.1
	12	4002.2	2704.3	3262.7

WEIGHT FACTOR = 0.00649

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.
20		FT.	PPM	AT 25 C
	0	3999.5	2364.1	2896.9
	1	4000.0	2488.3	3030.4
	2	4000.0	2611.9	3163.3
	3	4000.1	2739.5	3300.5
	4	4000.6	2794.6	3359.8
	5	4000.6	2799.7	3365.3
	6	4000.2	2902.2	3475.5
	7	4000.0	3131.2	3721.7
	8	4000.0	3149.9	3741.8
	9	4000.1	3571.9	4195.6
	10	4000.1	3634.6	4263.0
	11	4000.1	3533.5	4154.3
	12	4000.0	3673.5	4304.8

WEIGHT FACTOR = 0.02057

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.
21		FT.	PPM	AT 25 C
	0	4002.5	2828.6	3396.3
	1	4002.7	3148.0	3739.8
	2	4002.6	3322.8	3927.7
	3	4002.7	3392.3	4002.5
	4	4003.0	3606.5	4232.8
	5	4003.1	3834.0	4477.4
	6	4002.6	3882.7	4529.8
	7	4002.4	3833.1	4476.4
	8	4002.5	3857.5	4502.7
	9	4002.8	3584.4	4209.0
	10	4002.7	3710.1	4344.2
	11	4002.6	3522.6	4142.6
	12	4002.6	3458.6	4073.8

WEIGHT FACTOR = 0.00779

ARKANSAS RIVER VALLEY DATA, SOUTHEASTERN COLORADO
REFERENCE: KONIKOW, L.F., 1977

OBS. WELL #	MONTH	W-L ELEV FT.	GW CHEM PPM	SP. COND. AT 25 C
22	0	4000.0	2828.6	3396.3
	1	4000.6	3030.6	3667.3
	2	4000.5	3408.4	4019.8
	3	4000.6	3636.1	4264.6
	4	4000.8	3817.3	4459.5
	5	4000.9	3924.4	4574.6
	6	4000.6	4019.8	4677.2
	7	4000.3	3899.1	4547.4
	8	4000.4	3905.6	4554.4
	9	4000.8	3640.0	4268.8
	10	4000.7	3657.9	4288.1
	11	4000.6	3692.7	4325.5
	12	4000.6	3695.9	4328.9

WEIGHT FACTOR = 0.01155

OBS. WELL #	MONTH	W-L ELEV FT.	GW CHEM PPM	SP. COND. AT 25 C
23	C	3990.0	3571.8	4195.5
	1	3990.7	3529.1	4149.6
	2	3990.8	3478.8	4095.5
	3	3990.9	3519.4	4139.1
	4	3991.3	357C.8	4194.4
	5	3991.4	3620.0	4247.3
	6	3991.0	3624.0	4251.6
	7	3990.8	3622.0	4249.5
	8	3990.8	3804.6	4445.8
	9	3990.9	3782.5	4422.0
	10	3990.9	3993.3	4648.7
	11	3990.9	4008.5	4665.1
	12	3990.9	3906.5	4555.4

WEIGHT FACTOR = 0.04055

OBS. WELL #	MONTH	W-L ELEV FT.	GW CHEM PPM	SP. COND. AT 25 C
24	0	3972.5	2457.0	2996.8
	1	3972.7	2391.7	2926.6
	2	3972.8	2340.6	2871.6
	3	3972.8	2266.1	2791.5
	4	3972.8	2321.4	2851.0
	5	3972.9	2384.9	2919.2
	6	3972.7	2348.0	2879.6
	7	3972.5	2267.8	2793.3
	8	3972.4	2418.3	2955.2
	9	3972.5	2261.9	2787.0
	10	3972.6	2414.4	2951.0
	11	3972.6	2437.8	2976.1
	12	3972.6	2870.1	3441.0

WEIGHT FACTOR = 0.03776

ARKANSAS RIVER VALLEY DATA, SOUTHEASTERN COLORADO
REFERENCE: KONIKOW, L.F., 1977

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.	WEIGHT FACTOR = 0.01901
		FT.	PPM	AT 25 C	
25	0	4036.5	2178.3	2697.1	
	1	4036.9	2180.9	2699.9	
	2	4037.1	2195.8	2715.9	
	3	4037.2	2147.0	2663.4	
	4	4037.2	2151.5	2668.3	
	5	4037.2	2108.1	2621.6	
	6	4037.1	2089.8	2601.9	
	7	4037.1	2023.9	2531.1	
	8	4037.1	2006.7	2512.6	
	9	4037.1	2004.9	2510.6	
	10	4037.2	1946.8	2448.2	
	11	4037.3	1927.3	2427.2	
	12	4037.3	1913.1	2411.9	

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.	WEIGHT FACTOR = 0.01804
		FT.	PPM	AT 25 C	
26	0	4008.5	3664.7	4295.4	
	1	4008.3	3503.6	4122.1	
	2	4008.1	3443.6	4057.6	
	3	4008.0	3170.0	3763.4	
	4	4008.2	3262.8	3863.2	
	5	4008.3	3219.8	3817.0	
	6	4007.9	3259.1	3859.2	
	7	4007.7	2957.0	3534.4	
	8	4007.7	2944.0	3520.4	
	9	4008.2	2587.7	3137.3	
	10	4008.1	2572.8	3121.3	
	11	4008.0	3630.5	4312.4	
	12	4008.0	2704.8	3263.2	

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.	WEIGHT FACTOR = 0.01499
		FT.	PPM	AT 25 C	
27	0	4009.5	3200.2	3795.9	
	1	4009.4	3224.8	3822.4	
	2	4009.1	2860.5	3430.6	
	3	4008.9	2706.5	3265.1	
	4	4008.9	2523.9	3068.7	
	5	4008.9	2524.9	3069.8	
	6	4008.7	2608.1	3159.2	
	7	4008.4	2673.6	3229.7	
	8	4008.5	2638.3	3191.7	
	9	4009.2	2543.6	3089.9	
	10	4009.1	2551.6	3098.5	
	11	4009.0	2524.0	3068.8	
	12	4009.0	2539.2	3085.2	

ARKANSAS RIVER VALLEY DATA, SOUTHEASTERN COLORADO
REFERENCE: KONIKOW, L.F., 1977

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.	WEIGHT FACTOR = 0.02374
		FT.	PPM	AT 25 C	
28	0	4043.0	1620.9	2097.7	
	1	4043.1	1624.4	2101.5	
	2	4042.9	1643.5	2122.0	
	3	4042.8	1683.9	2165.5	
	4	4042.2	1724.1	2208.7	
	5	4042.0	1685.2	2166.9	
	6	4041.8	1633.6	2165.2	
	7	4041.9	1664.3	2144.4	
	8	4042.1	1673.0	2153.8	
	9	4042.6	1659.8	2139.6	
	10	4042.9	1654.6	2134.0	
	11	4043.0	1556.0	2028.0	
	12	4043.0	1554.2	2026.0	

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.	WEIGHT FACTOR = 0.02277
		FT.	PPM	AT 25 C	
29	0	4031.0	1806.7	2297.5	
	1	4030.1	1736.4	2221.9	
	2	4029.4	1864.2	2359.4	
	3	4029.7	1931.4	2431.6	
	4	4029.8	1963.2	2465.8	
	5	4029.6	2235.1	2758.2	
	6	4029.3	2367.1	2900.1	
	7	4029.3	2521.9	3066.6	
	8	4030.1	2474.9	3016.0	
	9	4030.3	2346.2	2877.6	
	10	4030.3	2237.5	2760.8	
	11	4030.4	2006.7	2512.6	
	12	4030.4	1584.2	2058.3	

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.	WEIGHT FACTOR = 0.02615
		FT.	PPM	AT 25 C	
30	0	4026.0	1063.5	1498.4	
	1	4025.2	1040.3	1473.4	
	2	4024.7	1126.1	1565.7	
	3	4024.9	1228.4	1675.7	
	4	4025.0	1334.1	1843.1	
	5	4024.8	1479.2	1945.4	
	6	4024.5	1583.6	2057.6	
	7	4024.5	1679.1	2160.3	
	8	4025.2	1658.5	2138.2	
	9	4025.5	1649.4	2128.4	
	10	4025.5	1610.6	2086.7	
	11	4025.5	1523.3	1992.8	
	12	4025.6	1450.1	1914.1	

ARKANSAS RIVER VALLEY DATA, SOUTHEASTERN COLORADO
REFERENCE: KONIKOW, L.F., 1977

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.
		FT.	PPM	AT 25 C
31	0	4005.0	3014.4	3596.1
	1	4004.6	2927.0	3502.2
	2	4004.1	2985.0	3564.5
	3	4004.1	3039.8	3623.4
	4	4003.9	3294.4	3897.2
	5	4004.0	3365.4	3973.5
	6	4003.7	3250.5	3850.0
	7	4003.3	3558.2	4180.9
	8	4003.9	3507.1	4125.9
	9	4004.7	3552.2	4174.4
	10	4004.6	3188.5	3783.3
	11	4004.5	3090.0	3677.4
	12	4004.5	2646.5	3200.5

WEIGHT FACTOR = 0.01259

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.
		FT.	PPM	AT 25 C
32	C	3988.0	1899.6	2397.4
	1	3989.1	1682.2	2163.7
	2	3989.0	1598.8	2074.0
	3	3989.1	1635.4	2113.3
	4	3989.3	1679.5	2160.8
	5	3989.4	1870.9	2366.6
	6	3988.9	1992.5	2497.3
	7	3988.8	2010.9	2517.1
	8	3989.0	2075.4	2586.5
	9	3989.3	2019.6	2526.5
	10	3989.3	1943.1	2444.2
	11	3989.2	1857.7	2352.4
	12	3989.2	1939.0	2439.8

WEIGHT FACTOR = 0.04528

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.
		FT.	PPM	AT 25 C
33	0	3982.0	2178.3	2697.1
	1	3981.7	1945.3	2446.6
	2	3981.4	1753.5	2240.3
	3	3981.1	1842.6	2336.1
	4	3980.5	1784.0	2273.1
	5	3980.6	2079.9	2591.3
	6	3980.4	2272.1	2798.C
	7	3979.9	2303.6	2831.8
	8	3980.2	2266.9	2792.4
	9	3981.2	1858.5	2353.2
	10	3981.3	159C.8	2065.4
	11	3981.2	1629.8	2107.3
	12	3981.2	1466.4	1931.6

WEIGHT FACTOR = 0.05995

ARKANSAS RIVER VALLEY DATA, SOUTHEASTERN COLORADO
REFERENCE: KONIKOW, L.F., 1977

OBS. WELL # 34 — WEIGHT FACTOR = 0.00947

MONTH	W-L ELEV FT.	GW CHEM PPM	SP. COND. AT 25 C
0	4027.0	734.8	1198.7
1	4026.2	838.7	1256.7
2	4026.2	984.3	1413.2
3	4026.3	1161.8	1604.1
4	4026.0	1357.2	1814.2
5	4026.1	1284.9	1736.5
6	4026.1	1468.2	1933.5
7	4026.0	1386.2	1845.4
8	4026.1	1216.8	1663.2
9	4026.3	1214.7	1661.0
10	4026.3	1172.1	1615.2
11	4026.3	1148.7	1590.0
12	4026.3	1242.6	1691.0

OBS. WELL # 35 — WEIGHT FACTOR = 0.02361

MONTH	W-L ELEV FT.	GW CHEM PPM	SP. COND. AT 25 C
0	4045.5	1156.4	1558.3
1	4042.9	1120.9	1560.1
2	4040.5	1269.4	1719.8
3	4040.3	1218.2	1664.7
4	4035.3	1366.6	1824.3
5	4035.9	1338.9	1794.5
6	4036.1	1430.9	1893.4
7	4036.8	1414.3	1875.6
8	4039.2	1356.2	1813.1
9	4042.8	1361.7	1819.0
10	4043.1	1358.6	1815.7
11	4043.2	1353.4	1810.1
12	4042.6	1351.6	1808.2

OBS. WELL # 36 — WEIGHT FACTOR = 0.02615

MONTH	W-L ELEV FT.	GW CHEM PPM	SP. COND. AT 25 C
0	4019.0	784.8	1198.7
1	4018.1	821.7	1238.4
2	4018.1	921.2	1345.4
3	4018.2	1010.6	1441.5
4	4017.8	1183.7	1627.6
5	4017.9	1261.4	1711.2
6	4017.8	1375.5	1833.9
7	4017.7	1525.3	1994.9
8	4017.9	1475.9	1941.8
9	4018.2	1422.3	1884.2
10	4018.2	1468.9	1934.3
11	4018.3	1432.4	1895.1
12	4018.3	1421.1	1882.9

ARKANSAS RIVER VALLEY DATA, SOUTHEASTERN COLORADO
REFERENCE: KONIKOW, L.F., 1977

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.	WEIGHT FACTOR = 0.01401
		FT.	PPM	AT 25 C	
37	0	4007.0	1435.1	1898.0	
	1	4006.0	1354.7	1811.5	
	2	4005.8	1335.7	1791.1	
	3	4005.7	1448.4	1912.3	
	4	4005.3	1549.1	2020.5	
	5	4005.5	1619.0	2095.7	
	6	4005.4	1665.4	2145.6	
	7	4005.0	1722.6	2207.1	
	8	4005.3	1790.1	2279.7	
	9	4006.1	1728.6	2213.5	
	10	4006.0	1693.3	2175.6	
	11	4005.9	1737.7	2223.3	
	12	4005.8	1708.5	2191.9	

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.	WEIGHT FACTOR = 0.13546
		FT.	PPM	AT 25 C	
38	0	4050.0	1713.8	2197.6	
	1	4046.0	1631.8	2109.5	
	2	4043.0	1680.6	2161.9	
	3	4042.0	1667.6	2148.0	
	4	4038.5	1615.1	2091.5	
	5	4039.7	1726.2	2211.0	
	6	4039.4	1607.9	2083.8	
	7	4040.5	1587.0	2061.3	
	8	4039.5	1499.2	1966.9	
	9	4041.5	1518.0	1987.1	
	10	4044.3	1609.2	2085.2	
	11	4045.0	1678.6	2159.8	
	12	4044.7	1557.9	2030.0	

OBS. WELL #	MONTH	W-L ELEV	GW CHEM	SP. COND.	WEIGHT FACTOR = 0.02478
		FT.	PPM	AT 25 C	
39	0	4015.0	1156.4	1598.3	
	1	4014.0	1215.7	1662.0	
	2	4013.8	1243.6	1692.0	
	3	4013.6	1293.5	1745.7	
	4	4013.0	1450.9	1914.9	
	5	4013.3	1516.5	1985.5	
	6	4013.2	1572.9	2046.1	
	7	4012.9	1374.4	1832.7	
	8	4013.0	1279.8	1731.0	
	9	4013.8	1207.5	1653.2	
	10	4013.7	1243.6	1692.0	
	11	4013.6	1235.4	1683.2	
	12	4013.6	1255.8	1705.2	

ARKANSAS RIVER VALLEY DATA, SOUTHEASTERN COLORADO
REFERENCE: KONIKOW, L.F., 1977

WEIGHT FACTOR = 0.01765

OBS. WELL #	MONTH	W-L ELEV FT.	GW CHEM PPM	SP. COND. AT 25 C
40	0	4005.5	970.6	1398.5
	1	4004.9	1018.2	1449.7
	2	4004.3	1103.1	1541.0
	3	4004.3	1194.5	1639.2
	4	4004.2	1342.9	1798.8
	5	4004.2	1286.7	1738.4
	6	4004.0	1360.8	1818.1
	7	4003.7	1501.5	1969.4
	8	4004.4	1464.0	1929.0
	9	4005.0	1376.7	1835.2
	10	4004.9	1394.7	1854.5
	11	4004.9	1437.3	1900.3
	12	4004.8	1371.0	1829.0

BASE PERIOD SIMULATION (MODEL CAL:3-71 TO 2-72)

ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR 1971

	ENET (FT)	ETOT (FT)	QTOT (FT)	AQ. CHEM. (MG/L)	AQ. W-L (FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	0.011	0.024	.082	2024.30	4011.80	1591.65	52.06	6931.28	8.96	17.57
APR	-0.013	0.007	.108	2048.79	4011.60	1588.39	102.53	13184.43	6.33	17.37
MAY	-0.016	0.005	.117	2089.90	4011.40	1555.67	143.61	18689.38	3.41	17.18
JUN	-0.071	-0.029	.165	2146.19	4011.14	1243.60	465.08	46824.23	-0.32	16.91
JUL	-0.058	-0.006	.209	2193.85	4010.88	766.11	410.63	26317.16	-3.97	16.65
AUG	-0.061	0.003	.182	2264.02	4010.71	1263.29	149.32	15780.86	-6.28	16.48
SEP	-0.036	0.025	.129	2312.96	4010.65	1430.92	103.41	11979.98	-7.39	16.42
OCT	0.016	0.066	.116	2328.19	4010.77	1400.26	101.77	11921.87	-5.43	16.55
NOV	0.067	0.083	.115	2308.13	4011.07	1434.55	35.94	4173.56	-1.26	16.85
DEC	0.046	0.052	.067	2294.14	4011.33	1904.81	33.60	5354.91	2.40	17.11
JAN	0.043	0.050	.051	2285.69	4011.47	2064.60	31.50	5440.85	4.30	17.24
FEB	0.036	0.045	.048	2272.70	4011.54	2079.54	27.88	4537.08	5.68	17.31
YEARLY AVERAGES:				2214.07	4011.20	1526.95	138.11	14261.30	0.54	16.97

HYDRAULIC RESPONSE TIME = 2.8 MONTHS   SOLUTE RESPONSE TIME = 10.4 YEARS

BASE PERIOD SIMULATION (MODEL CAL:3-71 TO 2-72)

ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR 1972

	ENET (FT)	ETOT (FT)	QTOT (FT)	AQ. CHEM. (MG/L)	AQ. W-L (FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	0.011	0.024	.082	2271.57	4011.52	1582.18	48.13	6370.27	5.03	17.29
APR	-0.013	0.007	.108	2295.29	4011.40	1583.96	99.70	12784.63	3.50	17.18
MAY	-0.016	0.005	.117	2336.35	4011.27	1551.07	141.70	18385.96	1.50	17.04
JUN	-0.071	-0.022	.172	2392.76	4011.04	1243.64	463.71	46686.89	-1.69	16.82
JUL	-0.058	-0.001	.214	2438.96	4010.81	766.15	409.70	26258.94	-4.90	16.58
AUG	-0.061	0.007	.186	2507.95	4010.67	1263.15	148.67	15710.44	-6.93	16.44
SEP	-0.036	0.027	.131	2554.92	4010.62	1431.24	102.95	11928.39	-7.85	16.39
OCT	0.016	0.068	.118	2566.14	4010.75	1400.41	101.46	11886.13	-5.74	16.52
NOV	0.067	0.085	.116	2540.29	4011.06	1435.43	35.71	4149.67	-1.49	16.83
DEC	0.046	0.052	.067	2521.52	4011.32	1918.32	33.45	5368.22	2.25	17.09
JAN	0.043	0.050	.051	2509.71	4011.46	2093.77	31.39	5498.96	4.19	17.23
FEB	0.035	0.043	.046	2493.92	4011.53	2125.60	27.95	4489.72	5.75	17.30
YEARLY AVERAGES:				2452.45	4011.12	1532.91	137.04	14126.52	-0.53	16.89

HYDRAULIC RESPONSE TIME = 2.8 MONTHS SOLUTE RESPONSE TIME = 9.8 YEARS

BASE PERIOD SIMULATION (MODEL CAL:3-71 TO 2-72)

ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR 1973

	ENET (FT)	ETOT (FT)	QTOT (FT)	AQ. CHEM. (MG/L)	AQ. W-L (FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	0.011	0.024	.082	2490.90	4011.51	1603.00	48.01	6438.86	4.91	17.28
APR	-0.013	0.007	.108	2513.64	4011.40	1590.86	99.62	12829.75	3.42	17.17
MAY	-0.016	0.005	.117	2554.31	4011.26	1552.97	141.64	18401.37	1.44	17.04
JUN	-0.071	-0.022	.172	2611.26	4011.04	1243.64	463.66	46682.89	-1.74	16.81
JUL	-0.058	-0.001	.214	2658.15	4010.81	766.15	409.67	26257.25	-4.93	16.58
AUG	-0.061	0.007	.186	2726.91	4010.66	1263.14	148.66	15708.41	-6.94	16.44
SEP	-0.036	0.027	.131	2772.71	4010.62	1431.25	102.93	11926.89	-7.87	16.39
OCT	0.016	0.068	.118	2780.79	4010.75	1400.41	101.45	11885.07	-5.75	16.52
NOV	0.067	0.085	.116	2750.12	4011.06	1435.46	35.70	4148.93	-1.50	16.83
DEC	0.046	0.052	.067	2727.18	4011.32	1932.05	33.45	5405.87	2.25	17.09
JAN	0.043	0.050	.051	2712.34	4011.46	2120.78	31.39	5569.29	4.19	17.23
FEB	0.035	0.043	.046	2693.84	4011.53	2166.70	27.95	4576.15	5.75	17.30
YEARLY AVERAGES:				2666.01	4011.12	1542.20	137.01	14152.56	-0.56	16.89

HYDRAULIC RESPONSE TIME = 2.8 MONTHS SOLUTE RESPONSE TIME = 9.8 YEARS

BASE PERIOD SIMULATION (MODEL CAL:3-71 TO 2-72)

ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR 1974

	ENET (FT)	ETOT (FT)	QTOT (FT)	AQ. CHEM. (MG/L)	AQ. W-L (FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	0.011	0.024	.082	2688.90	4011.51	1623.24	48.01	6519.98	4.91	17.28
APR	-0.013	0.007	.108	2710.75	4011.40	1597.61	99.61	12884.06	3.41	17.17
MAY	-0.016	0.005	.117	2751.06	4011.26	1554.97	141.64	18424.97	1.44	17.04
JUN	-0.071	-0.022	.172	2808.50	4011.04	1243.64	463.66	46682.89	-1.74	16.81
JUL	-0.058	-0.001	.214	2856.09	4010.81	766.15	409.67	26257.25	-4.93	16.58
AUG	-0.061	0.007	.186	2924.68	4010.66	1263.14	148.66	15708.41	-6.94	16.44
SEP	-0.036	0.027	.131	2969.46	4010.62	1431.25	102.93	11926.89	-7.87	16.39
OCT	0.016	0.068	.118	2974.71	4010.75	1400.41	101.45	11885.07	-5.75	16.52
NOV	0.067	0.085	.116	2939.70	4011.06	1435.46	35.70	4148.93	-1.50	16.83
DEC	0.046	0.052	.067	2913.01	4011.32	1944.53	33.45	5440.79	2.25	17.09
JAN	0.043	0.050	.051	2895.43	4011.46	2145.22	31.39	5633.48	4.19	17.23
FEB	0.035	0.043	.046	2874.48	4011.53	2203.87	27.95	4654.66	5.75	17.30
YEARLY AVERAGES:				2858.90	4011.12	1550.79	137.01	14180.61	-0.56	16.89

HYDRAULIC RESPONSE TIME = 2.8 MONTHS SOLUTE RESPONSE TIME = 9.8 YEARS

BASE PERIOD SIMULATION (MODEL CAL:3-71 TO 2-72)

ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR 1975

	ENET (FT)	ETOT (FT)	QTOT (FT)	AQ. CHEM. (MG/L)	AQ. W-L (FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	0.011	0.024	.082	2867.80	4011.51	1641.55	48.01	6593.51	4.91	17.28
APR	-0.013	0.007	.108	2888.85	4011.40	1603.71	99.61	12933.29	3.41	17.17
MAY	-0.016	0.005	.117	2928.83	4011.26	1556.78	141.64	18446.38	1.44	17.04
JUN	-0.071	-0.022	.172	2986.73	4011.04	1243.64	463.66	46682.89	-1.74	16.81
JUL	-0.058	-0.001	.214	3034.94	4010.81	766.15	409.67	26257.25	-4.93	16.58
AUG	-0.061	0.007	.186	3103.38	4010.66	1263.14	148.66	15708.41	-6.94	16.44
SEP	-0.036	0.027	.131	3147.22	4010.62	1431.25	102.93	11926.89	-7.87	16.39
OCT	0.016	0.068	.118	3149.93	4010.75	1400.41	101.45	11885.07	-5.75	16.52
NOV	0.067	0.085	.116	3111.00	4011.06	1435.46	35.70	4148.93	-1.50	16.83
DEC	0.046	0.052	.067	3080.91	4011.32	1955.81	33.45	5472.34	2.25	17.09
JAN	0.043	0.050	.051	3060.86	4011.46	2167.31	31.39	5691.48	4.19	17.23
FEB	0.035	0.043	.046	3037.69	4011.53	2237.46	27.95	4725.59	5.75	17.30
YEARLY AVERAGES:				3033.18	4011.12	1558.55	137.01	14206.00	-0.56	16.89

HYDRAULIC RESPONSE TIME = 2.8 MONTHS   SOLUTE RESPONSE TIME = 9.8 YEARS

CASE(1): QS=0; CHANGES FROM BASE PERIOD

ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR 1971

	ENET (FT)	ETOT (FT)	QTOT (FT)	AQ. CHEM. (MG/L)	AQ. W-L (FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	-0.023	-0.010	.047	2024.30	4011.80	1591.65	52.06	6931.28	8.96	17.57
APR	-0.056	-0.036	.065	2057.95	4011.43	1577.86	100.16	12794.54	3.96	17.21
MAY	-0.066	-0.040	.072	2109.23	4011.09	1542.92	139.25	17973.99	-0.95	16.87
JUN	-0.168	-0.088	.107	2183.39	4010.60	1243.81	457.34	46052.97	-8.06	16.38
JUL	-0.171	-0.060	.155	2263.55	4010.06	766.62	399.20	25601.88	-15.40	15.83
AUG	-0.130	0.002	.181	2351.03	4009.77	1260.12	136.12	14349.45	-19.48	15.54
SEP	-0.047	0.073	.177	2396.05	4009.83	1439.91	91.63	10681.56	-19.17	15.61
OCT	-0.003	0.093	.142	2399.11	4010.14	1404.86	92.91	10919.18	-14.29	15.91
NOV	0.012	0.072	.104	2379.71	4010.47	1479.07	27.20	3256.52	-10.00	16.24
DEC	0.031	0.065	.079	2368.79	4010.77	1905.12	25.74	4101.91	-5.46	16.54
JAN	0.043	0.059	.059	2357.41	4011.05	2039.52	25.59	4366.96	-1.61	16.82
FEB	0.036	0.045	.048	2341.88	4011.25	2047.04	23.47	3760.41	1.27	17.02
YEARLY AVERAGES:				2269.37	4010.69	1524.88	130.89	13399.22	-6.69	16.46

HYDRAULIC RESPONSE TIME = 2.8 MONTHS SOLUTE RESPONSE TIME = 18.9 YEARS

ARKANSAS RIVER VALLEY STUDY: CHANGES FROM BASE PERIOD FOR 1971

	AQ. CHEM. (MG/L)	AQ. CHEM. (TONS)	AQ. VOL (AC-FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
APR	9.16	-578.89	-391.50	-10.52	-2.37	-389.88	-2.37	-0.16
MAY	19.33	-1054.99	-743.88	-12.75	-4.36	-715.39	-4.36	-0.31
JUN	37.20	-1754.37	-1279.13	0.21	-7.74	-771.26	-7.74	-0.54
JUL	69.69	-2239.51	-1952.38	0.52	-11.43	-715.29	-11.43	-0.82
AUG	87.01	-2548.91	-2255.00	-3.17	-13.20	-1431.41	-13.20	-0.94
SEP	83.09	-1912.50	-1947.75	8.99	-11.78	-1298.42	-11.78	-0.81
OCT	70.92	-1126.92	-1514.25	4.60	-8.87	-1002.69	-8.87	-0.63
NOV	71.59	-756.13	-1444.63	44.53	-8.74	-917.04	-8.74	-0.60
DEC	74.66	-177.99	-1343.75	0.30	-7.87	-1252.99	-7.87	-0.56
JAN	71.72	785.09	-1008.88	-25.08	-5.91	-1073.89	-5.91	-0.42
FEB	69.19	1652.12	-703.88	-32.50	-4.41	-776.67	-4.41	-0.29
AVE CHANGE:	55.30	-701.39	-1215.35	-2.07	-7.22	-862.08	-7.22	-0.51

CASE(1): QS=0; CHANGES FROM BASE PERIOD

ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR 1972

	ENET (FT)	ETOT (FT)	QTOT (FT)	AQ. CHEM. (MG/L)	AQ. W-L (FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	-0.023	-0.010	.047	2346.01	4011.24	1521.97	44.16	5622.24	1.06	17.01
APR	-0.056	-0.027	.074	2381.93	4011.04	1559.00	94.47	11922.91	-1.73	16.81
MAY	-0.066	-0.020	.092	2434.13	4010.82	1543.88	135.41	17488.66	-4.79	16.59
JUN	-0.168	-0.074	.120	2509.10	4010.41	1243.89	454.57	45776.75	-10.83	16.18
JUL	-0.171	-0.050	.165	2590.84	4009.93	766.71	397.33	25484.78	-17.27	15.70
AUG	-0.130	0.009	.188	2678.33	4009.67	1259.77	134.82	14207.91	-20.78	15.45
SEP	-0.047	0.078	.181	2717.16	4009.77	1440.73	90.69	10577.86	-20.11	15.54
OCT	-0.003	0.096	.145	2710.30	4010.09	1405.23	92.27	10847.31	-14.93	15.87
NOV	0.012	0.074	.106	2681.89	4010.44	1482.21	26.74	3208.46	-10.46	16.21
DEC	0.031	0.067	.081	2664.20	4010.75	1907.22	25.43	4057.11	-5.77	16.52
JAN	0.043	0.060	.060	2647.12	4011.03	2040.94	25.30	4333.19	-1.82	16.80
FEB	0.035	0.043	.046	2627.28	4011.23	2058.52	23.31	3625.36	1.11	17.00
YEARLY AVERAGES:				2582.36	4010.53	1519.17	128.71	13096.05	-8.86	16.31

HYDRAULIC RESPONSE TIME = 2.8 MONTHS SOLUTE RESPONSE TIME = 13.3 YEARS

ARKANSAS RIVER VALLEY STUDY; CHANGES FROM BASE PERIOD FOR 1972

	AQ. CHEM. (MG/L)	AQ. CHEM. (TONS)	AQ. VOL (AC-FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	74.45	2021.23	-678.25	-60.21	-3.97	-748.03	-3.97	-0.28
APR	86.64	2036.77	-864.63	-24.96	-5.23	-861.72	-5.23	-0.36
MAY	97.78	1861.10	-1074.00	-7.18	-6.29	-897.30	-6.29	-0.45
JUN	116.34	1208.46	-1509.50	0.25	-9.13	-910.14	-9.13	-0.63
JUL	151.88	741.41	-2113.00	0.57	-12.37	-774.16	-12.37	-0.88
AUG	170.37	481.50	-2367.13	-3.38	-13.86	-1502.53	-13.86	-0.99
SEP	162.23	1156.69	-2026.00	9.49	-12.26	-1350.54	-12.26	-0.85
OCT	144.16	1960.63	-1568.75	4.82	-9.18	-1038.82	-9.18	-0.66
NOV	141.59	2338.61	-1482.75	46.78	-8.97	-941.20	-8.97	-0.62
DEC	142.69	2964.38	-1370.25	-11.10	-8.02	-1311.10	-8.02	-0.57
JAN	137.41	3999.78	-1027.38	-52.83	-6.02	-1165.77	-6.02	-0.43
FEB	133.36	4942.28	-716.75	-67.08	-4.65	-864.36	-4.65	-0.30
AVE CHANGE:	129.91	2217.88	-1399.88	-13.74	-8.33	-1030.47	-8.33	-0.59

CASE(1); QS=0; CHANGES FROM BASE PERIOD

ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR 1973

	ENET (FT)	ETOT (FT)	QTOT (FT)	AQ. CHEM. (MG/L)	AQ. W-L (FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	-0.023	-0.010	.047	2630.30	4011.22	1524.63	43.99	5610.92	0.89	17.00
APR	-0.056	-0.026	.074	2667.73	4011.03	1559.06	94.35	11908.35	-1.85	16.81
MAY	-0.066	-0.020	.092	2721.80	4010.81	1543.90	135.33	17478.53	-4.87	16.58
JUN	-0.168	-0.074	.121	2800.84	4010.41	1243.89	454.51	45770.99	-10.89	16.18
JUL	-0.171	-0.050	.165	2888.24	4009.92	766.71	397.29	25482.32	-17.31	15.70
AUG	-0.130	0.009	.188	2977.63	4009.67	1259.76	134.79	14204.95	-20.81	15.45
SEP	-0.047	0.078	.182	3012.27	4009.77	1440.75	90.67	10575.72	-20.13	15.54
OCT	-0.003	0.096	.145	2997.43	4010.09	1405.24	92.26	10845.81	-14.94	15.87
NOV	0.012	0.074	.106	2961.56	4010.44	1482.27	26.73	3207.44	-10.47	16.21
DEC	0.031	0.067	.081	2937.96	4010.75	1907.27	25.42	4056.19	-5.78	16.52
JAN	0.043	0.060	.060	2915.79	4011.03	2040.97	25.37	4332.45	-1.83	16.80
FEB	0.035	0.043	.046	2891.91	4011.23	2070.96	23.30	3646.68	1.10	17.00
YEARLY AVERAGES:				2866.95	4010.53	1520.45	128.67	13093.36	-8.91	16.30

HYDRAULIC RESPONSE TIME = 2.8 MONTHS SOLUTE RESPONSE TIME = 13.2 YEARS

ARKANSAS RIVER VALLEY STUDY; CHANGES FROM BASE PERIOD FOR 1973

	AQ. CHEM. (MG/L)	AQ. CHEM. (TONS)	AQ. VOL (AC-FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	139.40	5375.77	-687.13	-78.37	-4.02	-827.93	-4.02	-0.29
APR	154.09	5442.34	-870.88	-31.80	-5.27	-921.39	-5.27	-0.36
MAY	167.49	5285.57	-1078.25	-9.07	-6.31	-922.84	-6.31	-0.45
JUN	189.58	4601.28	-1512.38	0.25	-9.15	-911.90	-9.15	-0.63
JUL	230.09	4094.03	-2115.25	0.57	-12.38	-774.93	-12.38	-0.89
AUG	250.72	3805.29	-2368.50	-3.38	-13.87	-1503.46	-13.87	-0.99
SEP	239.56	4459.73	-2026.88	9.50	-12.26	-1351.17	-12.26	-0.85
OCT	216.64	5239.03	-1569.38	4.82	-9.19	-1039.25	-9.19	-0.66
NOV	211.44	5594.72	-1483.25	46.82	-8.97	-941.48	-8.97	-0.62
DEC	210.78	6237.73	-1370.50	-24.78	-8.02	-1349.69	-8.02	-0.57
JAN	203.44	7323.48	-1027.63	-79.81	-6.02	-1236.84	-6.02	-0.43
FEB	198.07	8324.23	-717.00	-95.74	-4.65	-929.47	-4.65	-0.30
AVE CHANGE:	200.94	5567.13	-1402.14	-21.75	-8.34	-1059.20	-8.34	-0.59

CASE(1): QS=0; CHANGES FROM BASE PERIOD

ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR 1974

	ENET (FT)	ETOT (FT)	QTOT (FT)	AQ. CHEM. (MG/L)	AQ. W-L (FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	-0.023	-0.010	.047	2893.65	4011.22	1529.89	43.99	5629.95	0.89	17.00
APR	-0.056	-0.026	.074	2932.53	4011.03	1559.06	94.34	11908.09	-1.86	16.80
MAY	-0.066	-0.020	.092	2988.44	4010.81	1543.90	135.33	17478.31	-4.87	16.58
JUN	-0.168	-0.074	.121	3071.34	4010.41	1243.89	454.51	45770.86	-10.89	16.18
JUL	-0.171	-0.050	.165	3164.11	4009.92	766.71	397.29	25482.27	-17.31	15.70
AUG	-0.130	0.009	.188	3255.33	4009.67	1259.76	134.79	14204.86	-20.81	15.45
SEP	-0.047	0.078	.162	3286.13	4009.77	1440.75	90.67	10575.62	-20.13	15.54
OCT	-0.003	0.096	.145	3263.91	4010.09	1405.24	92.26	10845.76	-14.94	15.87
NOV	0.012	0.074	.106	3221.14	4010.44	1482.27	26.73	3207.44	-10.47	16.21
DEC	0.031	0.067	.081	3192.07	4010.75	1907.27	25.42	4056.19	-5.78	16.52
JAN	0.043	0.060	.060	3165.17	4011.03	2040.97	25.37	4332.45	-1.83	16.80
FEB	0.035	0.043	.046	3137.54	4011.23	2082.60	23.30	3667.17	1.10	17.00
YEARLY AVERAGES:				3130.95	4010.53	1521.86	128.67	13096.58	-8.91	16.30

HYDRAULIC RESPONSE TIME = 2.8 MONTHS SOLUTE RESPONSE TIME = 13.2 YEARS

ARKANSAS RIVER VALLEY STUDY: CHANGES FROM BASE PERIOD FOR 1974

	AQ. CHEM. (MG/L)	AQ. CHEM. (TONS)	AQ. VOL (AC-FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	204.75	8801.71	-687.38	-93.35	-4.02	-890.03	-4.02	-0.29
APR	221.78	8906.58	-871.00	-38.54	-5.27	-975.97	-5.27	-0.36
MAY	237.38	8765.29	-1078.38	-11.07	-6.31	-946.66	-6.31	-0.45
JUN	262.84	8049.02	-1512.63	0.25	-9.15	-912.03	-9.15	-0.63
JUL	308.02	7501.14	-2115.38	0.57	-12.38	-774.98	-12.38	-0.89
AUG	330.65	7181.73	-2368.63	-3.38	-13.87	-1503.55	-13.87	-0.99
SEP	316.67	7813.46	-2027.00	9.50	-12.26	-1351.27	-12.26	-0.85
OCT	289.20	8567.78	-1569.50	4.82	-9.19	-1039.30	-9.19	-0.66
NOV	281.43	8901.45	-1483.25	46.82	-8.97	-941.48	-8.97	-0.62
DEC	279.06	9558.86	-1370.50	-37.26	-8.02	-1384.60	-8.02	-0.57
JAN	269.73	10689.51	-1027.63	-104.25	-6.02	-1301.03	-6.02	-0.43
FEB	263.07	11741.93	-717.00	-121.28	-4.65	-987.48	-4.65	-0.30
AVE CHANGE:	272.05	8968.48	-1402.21	-28.93	-8.34	-1084.03	-8.34	-0.59

CASE(1): QS=0; CHANGES FROM BASE PERIOD

ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR 1975

	ENET (FT)	ETOT (FT)	QTOT (FT)	AQ. CHEM. (MG/L)	AQ. W-L (FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	-0.023	-0.010	.047	3138.10	4011.22	1534.83	43.99	5648.13	0.89	17.00
APR	-0.056	-0.026	.074	3178.32	4011.03	1559.06	94.34	11908.09	-1.86	16.80
MAY	-0.066	-0.020	.092	3235.45	4010.81	1543.90	135.33	17478.31	-4.87	16.58
JUN	-0.168	-0.074	.121	3322.45	4010.41	1243.89	454.51	45770.86	-10.89	16.18
JUL	-0.171	-0.050	.165	3420.20	4009.92	766.71	397.29	25482.27	-17.31	15.70
AUG	-0.130	0.009	.188	3513.11	4009.67	1259.76	134.79	14204.86	-20.81	15.45
SEP	-0.047	0.070	.182	3540.34	4009.77	1440.75	90.67	10575.62	-20.13	15.54
OCT	-0.003	0.096	.145	3511.28	4010.09	1405.24	92.26	10845.76	-14.94	15.87
NOV	0.012	0.074	.106	3462.11	4010.44	1482.27	26.73	3207.44	-10.47	16.21
DEC	0.031	0.067	.081	3427.95	4010.75	1907.27	25.42	4056.19	-5.78	16.52
JAN	0.043	0.060	.060	3396.66	4011.03	2040.97	25.37	4332.45	-1.83	16.80
FEB	0.035	0.043	.046	3365.57	4011.23	2093.40	23.30	3686.19	1.10	17.00
YEARLY AVERAGES:				3376.00	4010.53	1523.17	128.67	13099.68	-8.91	16.30

HYDRAULIC RESPONSE TIME = 2.8 MONTHS SOLUTE RESPONSE TIME = 13.2 YEARS

ARKANSAS RIVER VALLEY STUDY: CHANGES FROM BASE PERIOD FOR 1975

	AQ. CHEM. (MG/L)	AQ. CHEM. (TONS)	AQ. VOL (AC-FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	270.30	12257.23	-687.38	-106.72	-4.02	-945.38	-4.02	-0.29
APR	289.47	12394.68	-871.00	-44.65	-5.27	-1025.20	-5.27	-0.36
MAY	307.12	12265.32	-1078.38	-12.87	-6.31	-968.07	-6.31	-0.45
JUN	335.72	11516.67	-1512.63	0.25	-9.15	-912.03	-9.15	-0.63
JUL	385.25	10928.26	-2115.38	0.57	-12.38	-774.98	-12.38	-0.89
AUG	409.73	10577.98	-2368.63	-3.38	-13.87	-1503.55	-13.87	-0.99
SEP	393.12	11186.60	-2027.00	9.50	-12.26	-1351.27	-12.26	-0.85
OCT	361.35	11915.91	-1569.50	4.82	-9.19	-1039.30	-9.19	-0.66
NOV	351.10	12227.81	-1483.25	46.82	-8.97	-941.48	-8.97	-0.62
DEC	347.04	12897.46	-1370.50	-48.54	-8.02	-1416.16	-8.02	-0.57
JAN	335.80	14068.07	-1027.63	-126.34	-6.02	-1359.03	-6.02	-0.43
FEB	327.87	15166.11	-717.00	-144.06	-4.65	-1039.40	-4.65	-0.30
AVE CHANGE:	342.82	12388.24	-1402.21	-35.38	-8.34	-1106.32	-8.34	-0.59

CASE(2); QP=0; CHANGES FROM BASE PERIOD

ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR 1971

	ENET (FT)	ETOT (FT)	QTOT (FT)	AQ. CHEM. (MG/L)	AQ. W-L (FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	0.024	0.036	.094	2024.30	4011.80	1591.65	52.06	6931.28	8.96	17.57
APR	0.189	0.209	.310	2024.84	4012.08	1614.96	109.55	14322.52	13.35	17.86
MAY	0.152	0.173	.285	2030.86	4012.51	1600.76	159.13	21309.92	18.93	18.29
JUN	-0.007	0.032	.227	2055.42	4012.38	1273.20	483.02	49787.06	17.62	18.15
JUL	0.095	0.126	.342	2060.20	4012.21	810.32	429.32	29103.32	14.72	17.99
AUG	0.146	0.178	.357	2083.22	4012.41	1347.30	173.08	19508.32	17.48	18.18
SEP	0.160	0.184	.288	2085.94	4012.68	1535.29	132.74	16498.73	21.94	18.45
OCT	0.026	0.049	.098	2085.98	4012.58	1505.71	127.13	16014.06	19.93	18.36
NOV	0.073	0.083	.115	2074.62	4012.37	1636.14	54.70	7245.63	17.50	18.14
DEC	0.048	0.055	.069	2065.56	4012.25	1937.58	46.50	7537.64	15.30	18.03
JAN	0.044	0.051	.051	2060.51	4012.12	2039.81	40.57	6923.08	13.37	17.69
FEB	0.036	0.045	.048	2050.78	4011.99	2037.56	34.67	5528.39	12.47	17.77
YEARLY AVERAGES:				2058.52	4012.28	1577.52	153.54	16725.86	15.96	18.06

HYDRAULIC RESPONSE TIME = 2.6 MONTHS SOLUTE RESPONSE TIME = 3.0 YEARS

ARKANSAS RIVER VALLEY STUDY: CHANGES FROM BASE PERIOD FOR 1971

	AQ. CHEM. (MG/L)	AQ. CHEM. (TONS)	AQ. VOL (AC-FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
APR	-23.95	1842.62	1159.88	26.58	7.02	1138.09	7.02	0.49
MAY	-59.04	4028.21	2651.38	45.09	15.52	2620.54	15.52	1.11
JUN	-90.77	3297.79	2964.00	29.60	17.93	2962.83	17.93	1.24
JUL	-133.66	1714.06	3193.00	44.21	18.69	2786.15	18.69	1.34
AUG	-180.80	1810.69	4058.25	84.01	23.76	3727.46	23.76	1.70
SEP	-227.02	1633.09	4847.13	104.37	29.32	4518.75	29.32	2.03
OCT	-242.21	-738.14	4331.38	105.45	25.36	4092.19	25.36	1.81
NOV	-233.50	-4035.45	3101.88	201.60	18.77	3072.27	18.77	1.30
DEC	-228.58	-6522.10	2203.13	32.77	12.90	2182.94	12.90	0.92
JAN	-225.18	-8281.46	1549.00	-24.79	9.07	1482.23	9.07	0.65
FEB	-221.91	-9465.18	1085.13	-41.98	6.79	991.31	6.79	0.45
AVE CHANGE:	-155.55	-1314.69	2595.39	50.58	15.43	2464.56	15.43	1.09

CASE(2): QP=0; CHANGES FROM BASE PERIOD

ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR 1972

	ENET (FT)	ETOT (FT)	QTOT (FT)	AQ. CHEM. (MG/L)	AQ. W-L (FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	0.024	0.036	.094	2050.22	4011.86	1603.90	52.96	7106.55	9.86	17.64
APR	0.189	0.209	.310	2049.89	4012.13	1620.58	110.20	14458.33	14.00	17.90
MAY	0.152	0.173	.285	2054.64	4012.54	1604.84	159.57	21423.63	19.37	18.32
JUN	-0.007	0.032	.227	2078.51	4012.40	1274.57	483.33	49873.68	17.93	18.17
JUL	0.095	0.126	.342	2082.79	4012.23	811.73	429.54	29168.72	14.94	18.00
AUG	0.146	0.178	.357	2104.88	4012.42	1350.14	173.23	19566.48	17.63	18.19
SEP	0.160	0.184	.288	2106.58	4012.68	1539.17	132.85	16553.91	22.05	18.46
OCT	0.026	0.049	.098	2105.99	4012.59	1509.20	127.21	16060.37	20.01	18.36
NOV	0.073	0.083	.115	2094.28	4012.37	1642.87	54.76	7282.66	17.56	18.15
DEC	0.048	0.055	.069	2084.85	4012.26	1944.04	46.54	7568.72	15.34	18.03
JAN	0.044	0.051	.051	2079.52	4012.12	2046.09	40.60	6948.66	13.40	17.89
FEB	0.035	0.044	.047	2069.70	4011.99	2044.67	35.09	5421.23	12.89	17.77
YEARLY AVERAGES:				2080.16	4012.30	1582.65	153.82	16786.08	16.25	18.07

HYDRAULIC RESPONSE TIME = 2.8 MONTHS SOLUTE RESPONSE TIME = 3.0 YEARS

ARKANSAS RIVER VALLEY STUDY: CHANGES FROM BASE PERIOD FOR 1972

	AQ. CHEM. (MG/L)	AQ. CHEM. (TONS)	AQ. VOL (AC-FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	-221.35	-10142.84	825.88	21.72	4.84	736.28	4.84	0.35
APR	-245.39	-8862.70	1736.25	36.62	10.50	1673.71	10.50	0.73
MAY	-281.71	-7073.32	3053.50	53.78	17.88	3037.67	17.88	1.28
JUN	-314.25	-8008.05	3244.50	30.93	19.63	3186.79	19.63	1.36
JUL	-356.17	-9602.83	3388.88	45.59	19.84	2909.78	19.84	1.42
AUG	-403.07	-9532.10	4194.75	87.00	24.56	3856.03	24.56	1.76
SEP	-448.34	-9729.32	4942.50	107.93	29.90	4625.52	29.90	2.07
OCT	-460.14	-12121.11	4397.88	108.79	25.75	4174.24	25.75	1.84
NOV	-446.01	-15438.20	3148.25	207.44	19.05	3132.99	19.05	1.32
DEC	-436.66	-17930.95	2235.38	25.71	13.09	2200.51	13.09	0.94
JAN	-430.19	-19659.94	1571.50	-47.68	9.20	1449.69	9.20	0.66
FEB	-424.22	-20770.61	1100.88	-80.93	7.14	931.52	7.14	0.46
AVE CHANGE:	-372.29	-12469.76	2820.04	49.74	16.78	2659.56	16.78	1.18

CASE(2): QP=0; CHANGES FROM BASE PERIOD

ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR 1973

	ENET (FT)	ETOT (FT)	QTOT (FT)	AQ. CHEM. (MG/L)	AQ. W-L (FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	0.024	0.036	.094	2069.10	4011.86	1606.98	52.91	7113.49	9.81	17.63
APR	0.189	0.209	.310	2068.15	4012.13	1622.76	110.17	14472.97	13.97	17.90
MAY	0.152	0.173	.285	2071.98	4012.54	1606.88	159.55	21447.51	19.35	18.32
JUN	-0.007	0.032	.227	2095.38	4012.40	1275.17	483.32	49895.18	17.92	18.17
JUL	0.095	0.126	.342	2099.30	4012.23	812.27	429.53	29187.25	14.93	18.00
AUG	0.146	0.178	.357	2120.72	4012.42	1351.72	173.23	19588.40	17.63	18.19
SEP	0.160	0.184	.288	2121.67	4012.68	1541.65	132.84	16579.87	22.04	18.46
OCT	0.026	0.049	.098	2120.63	4012.59	1511.48	127.20	16084.18	20.00	18.36
NOV	0.073	0.083	.115	2108.65	4012.37	1647.45	54.75	7302.63	17.55	18.15
DEC	0.048	0.055	.069	2098.95	4012.26	1948.68	46.54	7586.52	15.34	18.03
JAN	0.044	0.051	.051	2093.42	4012.12	2050.68	40.59	6964.01	13.39	17.89
FEB	0.035	0.044	.047	2083.42	4011.99	2049.71	35.09	5434.44	12.89	17.77
YEARLY AVERAGES:				2095.95	4012.30	1585.45	153.81	16804.70	16.23	18.07

HYDRAULIC RESPONSE TIME = 2.8 MONTHS SOLUTE RESPONSE TIME = 3.0 YEARS

ARKANSAS RIVER VALLEY STUDY: CHANGES FROM BASE PERIOD FOR 1973

	AQ. CHEM. (MG/L)	AQ. CHEM. (TONS)	AQ. VOL (AC-FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	-421.79	-21350.74	836.75	3.98	4.90	674.63	4.90	0.35
APR	-445.49	-19964.97	1743.75	31.90	10.55	1643.22	10.55	0.73
MAY	-482.33	-18096.45	3058.75	53.90	17.91	3046.15	17.91	1.28
JUN	-515.88	-18943.45	3248.25	31.53	19.65	3212.29	19.65	1.36
JUL	-558.85	-20445.02	3391.38	46.12	19.86	2930.00	19.86	1.42
AUG	-606.19	-20290.92	4196.63	88.58	24.57	3880.00	24.57	1.76
SEP	-651.04	-20424.83	4943.75	110.40	29.91	4652.98	29.91	2.07
OCT	-660.16	-22775.88	4398.88	111.06	25.75	4199.11	25.75	1.84
NOV	-641.47	-26070.18	3149.00	212.00	19.05	3153.71	19.05	1.32
DEC	-628.23	-28533.91	2236.00	16.63	13.09	2180.65	13.09	0.94
JAN	-618.92	-30204.68	1571.88	-70.10	9.20	1394.72	9.20	0.66
FEB	-610.42	-31226.79	1101.00	-117.00	7.14	858.29	7.14	0.46
AVE CHANGE:	-570.06	-23260.49	2823.03	43.25	16.80	2652.14	16.80	1.18

CASE(2): QP=0; CHANGES FROM BASE PERIOD

ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR 1974

	ENET (FT)	ETOT (FT)	QTOT (FT)	AQ. CHEM. (MG/L)	AQ. W-L (FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	0.024	0.036	.094	2082.67	4011.86	1609.49	52.91	7124.47	9.81	17.63
APR	0.189	0.209	.310	2081.26	4012.13	1624.42	110.16	14487.72	13.96	17.90
MAY	0.152	0.173	.285	2084.43	4012.54	1608.39	159.55	21467.60	19.35	18.32
JUN	-0.007	0.032	.227	2107.49	4012.40	1275.62	483.32	49912.75	17.92	18.17
JUL	0.095	0.126	.342	2111.15	4012.23	812.68	429.53	29202.05	14.93	18.00
AUG	0.146	0.178	.357	2132.09	4012.42	1352.88	173.23	19605.17	17.63	18.19
SEP	0.160	0.184	.288	2132.51	4012.68	1543.45	132.84	16599.21	22.04	18.46
OCT	0.026	0.049	.098	2131.13	4012.59	1513.13	127.20	16101.76	20.00	18.36
NOV	0.073	0.083	.115	2118.97	4012.37	1650.76	54.75	7317.30	17.55	18.15
DEC	0.048	0.055	.069	2109.08	4012.26	1952.02	46.54	7599.51	15.34	18.03
JAN	0.044	0.051	.051	2103.40	4012.12	2053.97	40.59	6975.19	13.39	17.89
FEB	0.035	0.044	.047	2093.27	4011.99	2053.32	35.09	5444.04	12.89	17.77
YEARLY AVERAGES:				2107.29	4012.30	1587.51	153.81	16819.73	16.23	18.07

HYDRAULIC RESPONSE TIME = 2.8 MONTHS   SOLUTE RESPONSE TIME = 3.0 YEARS

ARKANSAS RIVER VALLEY STUDY: CHANGES FROM BASE PERIOD FOR 1974

	AQ. CHEM. (MG/L)	AQ. CHEM. (TONS)	AQ. VOL (AC-FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	-606.23	-31700.87	836.88	-13.75	4.90	604.50	4.90	0.35
APR	-629.49	-30206.10	1743.88	26.81	10.55	1603.66	10.55	0.73
MAY	-666.63	-28253.89	3058.88	53.42	17.91	3042.63	17.91	1.28
JUN	-701.01	-29011.63	3248.25	31.98	19.65	3229.86	19.65	1.36
JUL	-744.94	-30423.80	3391.38	46.54	19.86	2944.80	19.86	1.42
AUG	-792.59	-30188.64	4196.63	89.73	24.57	3896.77	24.57	1.76
SEP	-836.94	-30259.22	4943.75	112.20	29.91	4672.32	29.91	2.07
OCT	-843.58	-32567.22	4398.88	112.72	25.75	4216.69	25.75	1.84
NOV	-820.73	-35836.16	3149.00	215.31	19.05	3168.37	19.05	1.32
DEC	-803.93	-38269.29	2236.00	7.49	13.09	2158.72	13.09	0.94
JAN	-792.03	-39883.59	1571.88	-91.25	9.20	1341.71	9.20	0.66
FEB	-781.21	-40822.20	1101.00	-150.55	7.14	789.38	7.14	0.46
AVE CHANGE:	-751.61	-33188.20	2823.17	36.72	16.80	2639.12	16.80	1.18

CASE(2): QP=0; CHANGES FROM BASE PERIOD

ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR 1975

	ENET (FT)	ETOT (FT)	QTOT (FT)	AQ. CHEM. (MG/L)	AQ. W-L (FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	0.024	0.036	.094	2092.41	4011.86	1611.30	52.91	7132.47	9.81	17.63
APR	0.189	0.209	.310	2090.68	4012.13	1625.61	110.16	14498.36	13.96	17.90
MAY	0.152	0.173	.285	2093.38	4012.54	1609.47	159.55	21402.07	19.35	18.32
JUN	-0.007	0.032	.227	2116.19	4012.40	1275.94	483.32	49925.36	17.92	18.17
JUL	0.095	0.126	.342	2119.66	4012.23	812.98	429.53	29212.68	14.93	18.00
AUG	0.146	0.178	.357	2140.26	4012.42	1353.71	173.23	19617.21	17.63	18.19
SEP	0.160	0.184	.288	2140.29	4012.68	1544.74	132.84	16613.09	22.04	18.46
OCT	0.026	0.049	.098	2138.67	4012.59	1514.32	127.20	16114.38	20.00	18.36
NOV	0.073	0.083	.115	2126.38	4012.37	1653.14	54.75	7327.83	17.55	18.15
DEC	0.048	0.055	.069	2116.35	4012.26	1954.41	46.54	7608.84	15.34	18.03
JAN	0.044	0.051	.051	2110.57	4012.12	2056.34	40.59	6983.22	13.39	17.89
FEB	0.035	0.044	.047	2100.34	4011.99	2055.92	35.09	5450.92	12.89	17.77
YEARLY AVERAGES:				2115.43	4012.30	1588.99	153.81	16830.54	16.23	18.07

HYDRAULIC RESPONSE TIME = 2.8 MONTHS SOLUTE RESPONSE TIME = 3.0 YEARS

ARKANSAS RIVER VALLEY STUDY: CHANGES FROM BASE PERIOD FOR 1975

	AQ. CHEM. (MG/L)	AQ. CHEM. (TONS)	AQ. VOL (AC-FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	-775.39	-41197.31	836.88	-30.25	4.90	538.96	4.90	0.35
APR	-798.17	-39601.28	1743.88	21.90	10.55	1565.07	10.55	0.73
MAY	-835.46	-37569.26	3058.88	52.69	17.91	3035.69	17.91	1.28
JUN	-870.54	-38241.48	3248.25	32.30	19.65	3242.47	19.65	1.36
JUL	-915.29	-39568.80	3391.38	46.83	19.86	2955.42	19.86	1.42
AUG	-963.12	-39256.51	4196.63	90.56	24.57	3908.81	24.57	1.76
SEP	-1006.93	-39265.72	4943.75	113.49	29.91	4686.21	29.91	2.07
OCT	-1011.26	-41530.52	4398.88	113.90	25.75	4229.31	25.75	1.84
NOV	-984.62	-44773.14	3149.00	217.68	19.05	3178.90	19.05	1.32
DEC	-964.56	-47175.81	2236.00	-1.39	13.09	2136.50	13.09	0.94
JAN	-950.29	-48736.65	1571.88	-110.97	9.20	1291.74	9.20	0.66
FEB	-937.36	-49597.65	1101.00	-181.53	7.14	725.34	7.14	0.46
AVE CHANGE:	-917.75	-42282.04	2823.17	30.43	16.80	2624.54	16.80	1.18

CASE(3): IMPR IRR EFF; CHANGES FROM BASE PERIOD

ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR 1971

	ENET (FT)	ETOT (FT)	QTOT (FT)	AQ. CHEM. (MG/L)	AQ. W-L (FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	0.013	0.026	.075	2024.30	4011.80	1591.65	52.06	6931.28	8.96	17.57
APR	-0.038	-0.017	.099	2052.70	4011.55	1585.18	101.77	13060.81	5.57	17.32
MAY	-0.040	-0.019	.107	2105.02	4011.27	1548.57	141.68	18354.76	1.48	17.04
JUN	-0.064	-0.014	.155	2161.15	4011.01	1243.65	463.24	46640.36	-2.16	16.78
JUL	-0.072	-0.012	.194	2203.84	4010.77	766.17	409.12	26222.65	-5.48	16.54
AUG	-0.079	-0.004	.179	2276.47	4010.57	1262.85	147.33	15564.70	-8.27	16.34
SEP	-0.048	0.024	.138	2330.57	4010.49	1432.55	101.06	11720.39	-9.74	16.26
OCT	0.018	0.078	.122	2345.07	4010.64	1401.16	99.91	11711.43	-7.29	16.41
NOV	0.054	0.079	.113	2323.48	4010.95	1441.47	34.23	3994.20	-2.97	16.73
DEC	0.045	0.051	.063	2309.99	4011.22	1886.59	32.07	5061.18	0.87	17.00
JAN	0.043	0.050	.051	2300.97	4011.39	2058.18	30.40	5234.03	3.20	17.16
FEB	0.036	0.045	.048	2287.68	4011.48	2076.39	27.06	4397.12	4.86	17.26
YEARLY AVERAGES:				2226.77	4011.09	1524.53	136.66	14074.41	-0.91	16.87

HYDRAULIC RESPONSE TIME = 2.8 MONTHS SOLUTE RESPONSE TIME = 11.7 YEARS

ARKANSAS RIVER VALLEY STUDY: CHANGES FROM BASE PERIOD FOR 1971

	AQ. CHEM. (MG/L)	AQ. CHEM. (TONS)	AQ. VOL (AC-FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
APR	3.91	-128.30	-125.00	-3.21	-0.76	-123.62	-0.76	-0.05
MAY	15.12	-96.86	-328.75	-7.10	-1.92	-334.62	-1.92	-0.14
JUN	14.96	-74.08	-304.88	0.05	-1.84	-103.87	-1.84	-0.13
JUL	9.99	-232.58	-258.00	0.07	-1.51	-94.51	-1.51	-0.11
AUG	12.45	-387.40	-340.50	-0.44	-1.99	-216.17	-1.99	-0.14
SEP	17.62	-293.87	-389.38	1.63	-2.36	-259.59	-2.36	-0.16
OCT	16.88	-105.64	-317.88	0.90	-1.86	-210.44	-1.86	-0.13
NOV	15.35	-52.12	-282.50	6.92	-1.71	-179.36	-1.71	-0.12
DEC	15.85	56.98	-262.38	-18.22	-1.54	-293.73	-1.54	-0.11
JAN	15.29	267.19	-188.38	-6.41	-1.10	-206.82	-1.10	-0.08
FEB	14.98	436.12	-130.88	-3.16	-0.82	-139.96	-0.82	-0.05
AVE CHANGE:	12.70	-38.55	-243.97	-2.41	-1.45	-186.89	-1.45	-0.10

CASE(3): IMPR IRR EFF; CHANGES FROM BASE PERIOD

ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR 1972

	ENET (FT)	ETOT (FT)	QTOT (FT)	AQ. CHEM. (MG/L)	AQ. W-L (FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	0.013	0.026	.075	2284.64	4011.49	1576.59	47.66	6285.42	4.56	17.26
APR	-0.038	-0.017	.099	2313.16	4011.33	1576.48	98.60	12584.34	2.40	17.10
MAY	-0.040	-0.015	.110	2367.06	4011.11	1542.85	139.54	18010.49	-0.66	16.89
JUN	-0.064	-0.006	.163	2422.94	4010.90	1243.69	461.69	46486.49	-3.71	16.68
JUL	-0.072	-0.006	.200	2463.46	4010.69	766.22	408.08	26157.42	-6.52	16.47
AUG	-0.079	-0.001	.182	2535.25	4010.52	1262.68	146.60	15485.85	-9.00	16.29
SEP	-0.048	0.027	.141	2587.52	4010.45	1432.92	100.53	11662.63	-10.27	16.22
OCT	0.018	0.080	.123	2597.24	4010.61	1401.33	99.56	11671.39	-7.64	16.39
NOV	0.054	0.080	.114	2569.16	4010.94	1442.56	33.97	3967.44	-3.23	16.71
DEC	0.045	0.051	.063	2550.75	4011.21	1889.55	31.90	5041.85	0.70	16.98
JAN	0.043	0.050	.051	2538.20	4011.38	2081.33	30.28	5271.93	3.08	17.15
FEB	0.035	0.043	.046	2521.91	4011.48	2119.00	27.10	4338.55	4.90	17.25
YEARLY AVERAGES:				2479.27	4011.01	1527.93	135.46	13913.65	-2.12	16.78

HYDRAULIC RESPONSE TIME = 2.8 MONTHS SOLUTE RESPONSE TIME = 10.8 YEARS

ARKANSAS RIVER VALLEY STUDY; CHANGES FROM BASE PERIOD FOR 1972

	AQ. CHEM. (MG/L)	AQ. CHEM. (TONS)	AQ. VOL (AC-FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	13.07	484.05	-80.75	-5.59	-0.47	-84.85	-0.47	-0.03
APR	17.87	427.48	-181.25	-7.48	-1.10	-200.29	-1.10	-0.08
MAY	30.71	516.76	-368.00	-8.22	-2.15	-375.47	-2.15	-0.15
JUN	30.18	554.65	-332.38	-0.06	-2.01	-200.40	-2.01	-0.14
JUL	24.49	392.08	-277.00	0.07	-1.62	-101.52	-1.62	-0.12
AUG	27.30	238.68	-353.88	-0.46	-2.07	-224.59	-2.07	-0.15
SEP	32.60	333.71	-398.63	1.69	-2.41	-265.76	-2.41	-0.17
OCT	31.10	524.84	-324.25	0.92	-1.90	-214.74	-1.90	-0.14
NOV	28.87	576.47	-287.13	7.13	-1.74	-182.23	-1.74	-0.12
DEC	29.23	702.90	-265.63	-28.77	-1.56	-326.37	-1.56	-0.11
JAN	28.49	937.90	-190.63	-12.44	-1.12	-227.03	-1.12	-0.08
FEB	27.99	1121.39	-132.13	-6.59	-0.86	-151.17	-0.86	-0.06
AVE CHANGE:	26.82	576.33	-266.07	-4.97	-1.58	-212.87	-1.58	-0.11

CASE(3): IMPR IRR EFF; CHANGES FROM BASE PERIOD

ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR 1973

	ENET (FT)	ETOT (FT)	QTOT (FT)	AQ. CHEM. (MG/L)	AQ. W-L (FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	0.013	0.026	.075	2516.79	4011.48	1596.48	47.54	6348.71	4.44	17.25
APR	-0.038	-0.017	.099	2545.03	4011.32	1581.29	98.51	12611.68	2.31	17.09
MAY	-0.040	-0.015	.111	2600.01	4011.11	1542.86	139.48	18003.16	-0.72	16.88
JUN	-0.064	-0.006	.163	2656.55	4010.90	1243.69	461.65	46482.31	-3.75	16.67
JUL	-0.072	-0.006	.200	2697.41	4010.69	766.22	408.05	26155.66	-6.55	16.47
AUG	-0.079	-0.001	.182	2769.41	4010.52	1262.68	146.58	15483.72	-9.02	16.29
SEP	-0.048	0.027	.141	2820.71	4010.45	1432.93	100.52	11661.08	-10.28	16.22
OCT	0.018	0.080	.123	2826.64	4010.61	1401.34	99.55	11670.33	-7.65	16.39
NOV	0.054	0.080	.114	2793.12	4010.94	1442.59	33.97	3966.74	-3.23	16.71
DEC	0.045	0.051	.063	2770.41	4011.21	1894.22	31.89	5053.64	0.69	16.98
JAN	0.043	0.050	.051	2754.64	4011.38	2103.27	30.28	5326.98	3.08	17.15
FEB	0.035	0.043	.046	2735.44	4011.48	2157.55	27.09	4417.16	4.89	17.25
YEARLY AVERAGES:				2707.18	4011.01	1535.43	135.43	13931.76	-2.15	16.78

HYDRAULIC RESPONSE TIME = 2.8 MONTHS SOLUTE RESPONSE TIME = 10.7 YEARS

ARKANSAS RIVER VALLEY STUDY: CHANGES FROM BASE PERIOD FOR 1973

	AQ. CHEM. (MG/L)	AQ. CHEM. (TONS)	AQ. VOL (AC-FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	25.89	1175.20	-81.75	-6.53	-0.48	-90.14	-0.48	-0.03
APR	31.39	1122.44	-182.00	-9.57	-1.10	-218.07	-1.10	-0.08
MAY	45.70	1228.29	-368.38	-10.11	-2.16	-398.21	-2.16	-0.15
JUN	45.29	1273.84	-332.63	0.06	-2.01	-200.58	-2.01	-0.14
JUL	39.26	1099.30	-277.38	0.07	-1.62	-101.60	-1.62	-0.12
AUG	42.50	937.73	-354.00	-0.46	-2.07	-224.69	-2.07	-0.15
SEP	47.99	1027.36	-398.75	1.69	-2.41	-265.81	-2.41	-0.17
OCT	45.85	1216.14	-324.25	0.92	-1.90	-214.74	-1.90	-0.14
NOV	43.00	1262.53	-287.00	7.13	-1.74	-182.19	-1.74	-0.12
DEC	43.22	1401.59	-265.50	-37.83	-1.55	-352.23	-1.55	-0.11
JAN	42.29	1655.69	-190.63	-17.51	-1.12	-242.31	-1.12	-0.08
FEB	41.60	1848.88	-132.25	-9.15	-0.86	-150.99	-0.86	-0.06
AVE CHANGE:	41.17	1280.56	-266.22	-6.77	-1.58	-220.80	-1.58	-0.11

CASE(3): IMPR IRR EFF; CHANGES FROM BASE PERIOD

ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR 1974

	ENET (FT)	ETOT (FT)	QTOT (FT)	AQ. CHEM. (MG/L)	AQ. W-L (FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	0.013	0.026	.075	2728.20	4011.48	1616.18	47.53	6426.88	4.43	17.25
APR	-0.038	-0.017	.099	2756.17	4011.32	1586.24	98.51	12651.05	2.31	17.09
MAY	-0.040	-0.015	.111	2812.15	4011.11	1542.86	139.40	18003.10	-0.72	16.88
JUN	-0.064	-0.006	.163	2869.36	4010.90	1243.69	461.65	46482.27	-3.75	16.67
JUL	-0.072	-0.006	.200	2910.62	4010.69	766.22	408.05	26155.63	-6.55	16.46
AUG	-0.079	-0.001	.182	2982.84	4010.52	1262.68	146.58	15483.67	-9.02	16.29
SEP	-0.048	0.027	.141	3033.28	4010.45	1432.93	100.52	11661.03	-10.28	16.22
OCT	0.018	0.080	.123	3035.78	4010.61	1401.34	99.55	11670.28	-7.65	16.39
NOV	0.054	0.080	.114	2997.31	4010.94	1442.59	33.96	3966.69	-3.24	16.71
DEC	0.045	0.051	.063	2970.68	4011.21	1898.55	31.89	5065.12	0.69	16.98
JAN	0.043	0.050	.051	2951.98	4011.38	2123.30	30.27	5377.64	3.07	17.15
FEB	0.035	0.043	.046	2930.13	4011.48	2192.71	27.09	4489.06	4.89	17.25
YEARLY AVERAGES:				2914.68	4011.01	1542.44	135.43	13952.70	-2.15	16.78

HYDRAULIC RESPONSE TIME = 2.8 MONTHS SOLUTE RESPONSE TIME = 10.7 YEARS

ARKANSAS RIVER VALLEY STUDY; CHANGES FROM BASE PERIOD FOR 1974

	AQ. CHEM. (MG/L)	AQ. CHEM. (TONS)	AQ. VOL (AC-FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	39.30	1905.49	-81.75	-7.07	-0.48	-93.10	-0.48	-0.03
APR	45.43	1853.96	-181.88	-11.37	-1.10	-233.01	-1.10	-0.08
MAY	61.09	1974.85	-368.38	-12.11	-2.16	-421.87	-2.16	-0.15
JUN	60.86	2028.32	-332.75	0.06	-2.01	-200.62	-2.01	-0.14
JUL	54.53	1841.75	-277.38	0.07	-1.62	-101.62	-1.62	-0.12
AUG	58.16	1671.62	-354.00	-0.46	-2.07	-224.73	-2.07	-0.15
SEP	63.82	1755.32	-398.75	1.69	-2.41	-265.86	-2.41	-0.17
OCT	61.07	1941.08	-324.38	0.92	-1.90	-214.79	-1.90	-0.14
NOV	57.61	1981.97	-287.13	7.13	-1.74	-182.23	-1.74	-0.12
DEC	57.67	2132.09	-265.63	-45.98	-1.56	-375.67	-1.56	-0.11
JAN	56.55	2402.96	-190.75	-21.92	-1.12	-255.84	-1.12	-0.08
FEB	55.65	2604.11	-132.25	-11.16	-0.86	-165.59	-0.86	-0.06
AVE CHANGE:	55.98	2018.69	-266.15	-8.35	-1.59	-227.91	-1.59	-0.11

CASE(3): IMPR IRR EFF; CHANGES FROM BASE PERIOD

ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR 1975

	ENET (FT)	ETOT (FT)	QTOT (FT)	AQ. CHEM. (MG/L)	AQ. W-L (FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	0.013	0.026	.075	2920.96	4011.48	1634.16	47.53	6498.39	4.43	17.25
APR	-0.038	-0.017	.099	2948.69	4011.32	1590.76	98.51	12687.12	2.31	17.09
MAY	-0.040	-0.015	.111	3005.58	4011.11	1542.86	139.48	18003.10	-0.72	16.88
JUN	-0.064	-0.006	.163	3063.40	4010.90	1243.69	461.65	46482.27	-3.75	16.67
JUL	-0.072	-0.006	.200	3105.02	4010.69	766.22	408.05	26155.63	-6.55	16.46
AUG	-0.079	-0.001	.182	3177.44	4010.52	1262.68	146.58	15483.67	-9.02	16.29
SEP	-0.048	0.027	.141	3227.10	4010.45	1432.93	100.52	11661.03	-10.28	16.22
OCT	0.018	0.080	.123	3226.47	4010.61	1401.34	99.55	11670.28	-7.65	16.39
NOV	0.054	0.080	.114	3183.50	4010.94	1442.59	33.96	3966.69	-3.24	16.71
DEC	0.045	0.051	.063	3153.30	4011.21	1902.51	31.89	5075.68	0.69	16.98
JAN	0.043	0.050	.051	3131.92	4011.38	2141.58	30.27	5423.92	3.07	17.15
FEB	0.035	0.043	.046	3107.64	4011.48	2224.78	27.09	4554.71	4.89	17.25
YEARLY AVERAGES:				3104.25	4011.01	1548.84	135.43	13971.87	-2.15	16.78

HYDRAULIC RESPONSE TIME = 2.8 MONTHS   SOLUTE RESPONSE TIME = 10.7 YEARS

ARKANSAS RIVER VALLEY STUDY: CHANGES FROM BASE PERIOD FOR 1975

	AQ. CHEM. (MG/L)	AQ. CHEM. (TONS)	AQ. VOL (AC-FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	53.16	2662.80	-81.75	-7.39	-0.48	-95.12	-0.48	-0.03
APR	59.85	2611.37	-181.88	-12.95	-1.10	-246.17	-1.10	-0.08
MAY	76.75	2745.13	-368.38	-13.91	-2.16	-443.27	-2.16	-0.15
JUN	76.68	2805.15	-332.75	0.06	-2.01	-200.62	-2.01	-0.14
JUL	70.08	2606.77	-277.38	0.07	-1.62	-101.62	-1.62	-0.12
AUG	74.06	2428.03	-354.00	-0.46	-2.07	-224.73	-2.07	-0.15
SEP	79.87	2505.67	-398.75	1.69	-2.41	-265.86	-2.41	-0.17
OCT	76.54	2688.19	-324.38	0.92	-1.90	-214.79	-1.90	-0.14
NOV	72.49	2723.75	-287.13	7.13	-1.74	-182.23	-1.74	-0.12
DEC	72.38	2883.60	-265.63	-53.30	-1.56	-396.67	-1.56	-0.11
JAN	71.05	3169.19	-190.75	-25.73	-1.12	-267.56	-1.12	-0.08
FEB	69.95	3376.02	-132.25	-12.68	-0.86	-170.88	-0.86	-0.06
AVE CHANGE:	71.07	2779.11	-266.15	-9.71	-1.59	-234.13	-1.59	-0.11

CASE(4): QL=0; CHANGES FROM BASE PERIOD

ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR 1971

	ENET (FT)	ETOT (FT)	QTOT (FT)	AQ. CHEM. (MG/L)	AQ. W-L (FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	-0.036	-0.024	.034	2024.30	4011.80	1591.65	52.06	6931.28	8.96	17.57
APR	-0.078	-0.058	.043	2062.19	4011.36	1572.72	99.07	12614.60	2.87	17.13
MAY	-0.083	-0.047	.065	2117.34	4010.96	1543.38	137.40	17739.92	-2.80	16.73
JUN	-0.137	-0.053	.141	2187.78	4010.55	1243.83	456.56	45974.56	-8.84	16.32
JUL	-0.134	-0.031	.184	2251.43	4010.16	766.56	400.67	25693.69	-13.93	15.94
AUG	-0.141	-0.018	.161	2336.68	4009.88	1260.54	137.76	14526.82	-17.84	15.66
SEP	-0.117	0.010	.114	2399.02	4009.73	1441.20	90.15	10518.98	-20.65	15.51
OCT	-0.052	0.066	.116	2418.66	4009.82	1407.53	88.45	10415.18	-18.75	15.59
NOV	0.013	0.096	.127	2400.30	4010.15	1515.81	22.65	2779.64	-14.55	15.93
DEC	-0.005	0.051	.065	2393.64	4010.47	1938.64	21.56	3496.90	-9.64	16.24
JAN	-0.007	0.036	.036	2390.84	4010.65	2085.13	20.12	3509.21	-7.08	16.43
FEB	-0.012	0.026	.028	2386.57	4010.77	2100.66	16.31	2680.71	-5.89	16.54
YEARLY AVERAGES:				2280.73	4010.53	1538.97	128.56	13073.46	-9.01	16.30

HYDRAULIC RESPONSE TIME = 2.8 MONTHS   SOLUTE RESPONSE TIME = 59.9 YEARS

ARKANSAS RIVER VALLEY STUDY: CHANGES FROM BASE PERIOD FOR 1971

	AQ. CHEM. (MG/L)	AQ. CHEM. (TONS)	AQ. VOL (AC-FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
APR	13.40	-844.95	-571.00	-15.66	-3.45	-569.83	-3.45	-0.24
MAY	27.43	-1522.98	-1060.63	-12.30	-6.21	-949.46	-6.21	-0.44
JUN	41.59	-1907.45	-1409.13	0.24	-8.53	-849.67	-8.53	-0.59
JUL	57.58	-2095.73	-1701.75	0.45	-9.96	-623.47	-9.96	-0.71
AUG	72.66	-2385.65	-1975.63	-2.75	-11.57	-1254.04	-11.57	-0.83
SEP	86.06	-2557.85	-2191.63	10.28	-13.26	-1461.00	-13.26	-0.92
OCT	90.47	-2619.91	-2275.25	7.27	-13.32	-1506.69	-13.32	-0.95
NOV	92.17	-2122.18	-2195.88	81.26	-13.29	-1393.91	-13.29	-0.92
DEC	99.50	-1164.18	-2056.88	33.83	-12.04	-1858.00	-12.04	-0.86
JAN	105.15	-429.56	-1944.38	20.53	-11.38	-1931.64	-11.38	-0.81
FEB	113.07	406.63	-1849.00	21.12	-11.57	-1856.38	-11.57	-0.77
AVE CHANGE:	66.66	-1294.66	-1602.57	12.02	-9.55	-1187.84	-9.55	-0.67

CASE(4): QL=0; CHANGES FROM BASE PERIOD

ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR 1972

	ENET (FT)	ETOT (FT)	QTOT (FT)	AQ. CHEM. (MG/L)	AQ. W-L (FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	-0.036	0.004	.062	2393.05	4010.78	1516.35	37.78	4792.94	-5.32	16.55
APR	-0.078	-0.021	.080	2428.52	4010.65	1562.20	88.79	11228.90	-7.41	16.42
MAY	-0.083	-0.012	.100	2480.60	4010.46	1545.21	130.45	16863.01	-9.75	16.24
JUN	-0.137	-0.028	.166	2545.98	4010.20	1243.98	451.55	45475.42	-13.85	15.98
JUL	-0.134	-0.013	.202	2602.96	4009.92	766.71	397.28	25482.11	-17.32	15.70
AUG	-0.141	-0.006	.173	2685.43	4009.72	1259.92	135.40	14271.07	-20.20	15.49
SEP	-0.117	0.018	.122	2744.17	4009.61	1442.74	88.45	10331.59	-22.35	15.39
OCT	-0.052	0.072	.122	2756.50	4009.74	1408.26	87.30	10285.30	-19.90	15.51
NOV	0.013	0.100	.131	2727.27	4010.10	1524.14	21.82	2692.79	-15.38	15.87
DEC	-0.005	0.054	.068	2712.26	4010.43	1944.14	21.00	3415.91	-10.20	16.20
JAN	-0.007	0.038	.038	2704.64	4010.63	2089.34	19.73	3448.15	-7.47	16.40
FEB	-0.011	0.027	.030	2696.97	4010.75	2109.02	15.81	2519.36	-6.39	16.52
YEARLY AVERAGES:				2623.20	4010.25	1534.33	124.61	12567.21	-12.96	16.02

HYDRAULIC RESPONSE TIME = 2.8 MONTHS SOLUTE RESPONSE TIME = 13.7 YEARS

ARKANSAS RIVER VALLEY STUDY: CHANGES FROM BASE PERIOD FOR 1972

	AQ. CHEM. (MG/L)	AQ. CHEM. (TONS)	AQ. VOL (AC-FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	121.48	1078.28	-1766.88	-65.83	-10.34	-1577.33	-10.34	-0.74
APR	133.24	1481.52	-1803.63	-21.76	-10.91	-1555.73	-10.91	-0.75
MAY	144.25	1511.18	-1920.50	-5.86	-11.24	-1522.96	-11.24	-0.80
JUN	153.22	1418.02	-2009.25	0.34	-12.16	-1211.47	-12.16	-0.84
JUL	164.00	1334.14	-2120.25	0.57	-12.41	-776.83	-12.41	-0.89
AUG	177.48	1201.80	-2267.63	-3.22	-13.28	-1439.38	-13.28	-0.95
SEP	189.25	1142.75	-2395.38	11.51	-14.49	-1596.80	-14.49	-1.00
OCT	190.36	1161.38	-2417.38	7.85	-14.15	-1600.83	-14.16	-1.01
NOV	186.98	1716.52	-2295.13	88.71	-13.89	-1456.88	-13.89	-0.96
DEC	190.74	2756.81	-2126.13	25.82	-12.45	-1952.31	-12.45	-0.89
JAN	194.93	3590.44	-1992.63	-4.43	-11.67	-2050.81	-11.67	-0.83
FEB	203.05	4551.10	-1873.50	-16.58	-12.14	-1970.36	-12.14	-0.78
AVE CHANGE:	170.75	1947.59	-2082.42	1.43	-12.43	-1559.31	-12.43	-0.87

CASE(4): QL=0; CHANGES FROM BASE PERIOD

ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR 1973

	ENET (FT)	ETOT (FT)	QTOT (FT)	AQ. CHEM. (MG/L)	AQ. W-L (FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	-0.036	0.005	.062	2701.60	4010.77	1516.89	37.61	4773.06	-5.49	16.54
APR	-0.078	-0.020	.081	2737.60	4010.64	1562.27	88.66	11213.97	-7.54	16.41
MAY	-0.083	-0.011	.101	2791.02	4010.46	1545.23	130.37	16852.55	-9.83	16.23
JUN	-0.137	-0.028	.166	2858.18	4010.20	1243.98	451.49	45469.49	-13.91	15.97
JUL	-0.134	-0.013	.202	2917.07	4009.92	766.72	397.24	25479.57	-17.36	15.69
AUG	-0.141	-0.005	.173	3000.41	4009.71	1259.92	135.37	14268.01	-20.23	15.49
SEP	-0.117	0.018	.122	3058.45	4009.61	1442.76	88.43	10329.36	-22.37	15.39
OCT	-0.052	0.072	.122	3066.19	4009.74	1408.27	87.29	10283.75	-19.91	15.51
NOV	0.013	0.100	.131	3028.66	4010.10	1524.25	21.81	2691.77	-15.39	15.87
DEC	-0.005	0.054	.068	3006.58	4010.43	1944.21	21.00	3414.98	-10.20	16.20
JAN	-0.007	0.038	.038	2994.84	4010.63	2089.39	19.72	3447.42	-7.48	16.40
FEB	-0.011	0.027	.030	2984.33	4010.75	2109.07	15.81	2518.90	-6.39	16.52
YEARLY AVERAGES:				2928.74	4010.25	1534.41	124.57	12561.90	-13.01	16.02

HYDRAULIC RESPONSE TIME = 2.8 MONTHS SOLUTE RESPONSE TIME = 13.5 YEARS

ARKANSAS RIVER VALLEY STUDY: CHANGES FROM BASE PERIOD FOR 1973

	AQ. CHEM. (MG/L)	AQ. CHEM. (TONS)	AQ. VOL (AC-FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	210.70	5312.48	-1776.50	-86.11	-10.40	-1665.79	-10.40	-0.74
APR	223.96	5760.93	-1810.38	-28.59	-10.95	-1615.78	-10.95	-0.76
MAY	236.71	5802.27	-1925.25	-7.74	-11.27	-1548.82	-11.27	-0.81
JUN	246.92	5673.66	-2012.50	0.34	-12.18	-1213.40	-12.18	-0.84
JUL	258.92	5535.73	-2122.75	0.57	-12.43	-777.68	-12.43	-0.89
AUG	273.50	5355.03	-2269.13	-3.22	-13.29	-1440.40	-13.29	-0.95
SEP	285.74	5255.38	-2396.50	11.52	-14.50	-1597.53	-14.50	-1.00
OCT	285.40	5245.22	-2418.13	7.85	-14.16	-1601.31	-14.16	-1.01
NOV	278.54	5783.94	-2295.63	88.79	-13.89	-1457.16	-13.89	-0.96
DEC	279.40	6831.59	-2126.38	12.16	-12.45	-1990.89	-12.45	-0.89
JAN	282.50	7709.83	-1992.88	-31.39	-11.67	-2121.87	-11.67	-0.83
FEB	290.49	8737.88	-1873.75	-57.63	-12.15	-2057.26	-12.15	-0.78
AVE CHANGE:	262.73	6122.55	-2085.05	-7.79	-12.44	-1590.66	-12.44	-0.87

CASE(4): QL=0; CHANGES FROM BASE PERIOD

ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR 1974

	ENET (FT)	ETOT (FT)	QTOT (FT)	AQ. CHEM. (MG/L)	AQ. W-L (FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	-0.036	0.005	.062	2987.58	4010.77	1516.89	37.61	4772.86	-5.49	16.54
APR	-0.078	-0.020	.081	3024.24	4010.64	1562.27	88.66	11213.81	-7.54	16.41
MAY	-0.083	-0.011	.101	3079.04	4010.46	1545.23	130.37	16852.44	-9.83	16.23
JUN	-0.137	-0.028	.166	3147.96	4010.20	1243.98	451.49	45469.44	-13.91	15.97
JUL	-0.134	-0.013	.202	3208.76	4009.92	766.72	397.24	25479.57	-17.36	15.69
AUG	-0.141	-0.005	.173	3292.97	4009.71	1259.92	135.37	14268.01	-20.23	15.49
SEP	-0.117	0.018	.122	3350.40	4009.61	1442.76	88.43	10329.36	-22.37	15.39
OCT	-0.052	0.072	.122	3353.90	4009.74	1408.27	87.29	10283.75	-19.91	15.51
NOV	0.013	0.100	.131	3308.70	4010.10	1524.25	21.81	2691.77	-15.39	15.87
DEC	-0.005	0.054	.068	3280.05	4010.43	1944.21	21.00	3414.98	-10.20	16.20
JAN	-0.007	0.038	.038	3264.50	4010.63	2089.39	19.72	3447.42	-7.48	16.40
FEB	-0.011	0.027	.030	3251.35	4010.75	2109.07	15.81	2518.90	-6.39	16.52
YEARLY AVERAGES:				3212.45	4010.25	1534.41	124.57	12561.86	-13.01	16.02

HYDRAULIC RESPONSE TIME = 2.8 MONTHS SOLUTE RESPONSE TIME = 13.5 YEARS

ARKANSAS RIVER VALLEY STUDY; CHANGES FROM BASE PERIOD FOR 1974

	AQ. CHEM. (MG/L)	AQ. CHEM. (TONS)	AQ. VOL (AC-FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	298.69	9565.88	-1776.63	-106.35	-10.40	-1747.11	-10.40	-0.74
APR	313.50	10053.43	-1810.38	-35.34	-10.95	-1670.25	-10.95	-0.76
MAY	327.98	10103.50	-1925.25	-9.74	-11.27	-1572.53	-11.27	-0.81
JUN	339.46	9939.07	-2012.50	0.34	-12.18	-1213.45	-12.18	-0.84
JUL	352.66	9747.58	-2122.75	0.57	-12.43	-777.68	-12.43	-0.89
AUG	368.29	9517.91	-2269.13	-3.22	-13.29	-1440.40	-13.29	-0.95
SEP	380.94	9377.25	-2396.50	11.52	-14.50	-1597.53	-14.50	-1.00
OCT	379.19	9337.76	-2418.13	7.85	-14.16	-1601.31	-14.16	-1.01
NOV	368.99	9859.36	-2295.63	88.79	-13.89	-1457.16	-13.89	-0.96
DEC	367.04	10912.20	-2126.38	-0.32	-12.45	-2025.81	-12.45	-0.89
JAN	369.07	11829.95	-1992.88	-55.83	-11.67	-2186.06	-11.67	-0.83
FEB	376.87	12917.68	-1873.75	-94.80	-12.15	-2135.76	-12.15	-0.78
AVE CHANGE:	353.56	10306.24	-2084.90	-16.38	-12.44	-1618.75	-12.44	-0.87

CASE(4): QL=0; CHANGES FROM BASE PERIOD

ARKANSAS RIVER VALLEY STUDY, DATA SUMMARY FOR 1975

	ENET (FT)	ETOT (FT)	QTOT (FT)	AQ. CHEM. (MG/L)	AQ. W-L (FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	-0.036	0.005	.062	3253.33	4010.77	1516.89	37.61	4772.86	-5.49	16.54
APR	-0.078	-0.020	.081	3290.61	4010.64	1562.27	88.66	11213.81	-7.54	16.41
MAY	-0.083	-0.011	.101	3346.68	4010.46	1545.23	130.37	16852.44	-9.83	16.23
JUN	-0.137	-0.028	.166	3417.25	4010.20	1243.98	451.49	45469.44	-13.91	15.97
JUL	-0.134	-0.013	.202	3479.81	4009.92	766.72	397.24	25479.57	-17.36	15.69
AUG	-0.141	-0.005	.173	3564.84	4009.71	1259.92	135.37	14268.01	-20.23	15.49
SEP	-0.117	0.018	.122	3621.70	4009.61	1442.76	88.43	10329.36	-22.37	15.39
OCT	-0.052	0.072	.122	3621.27	4009.74	1408.27	87.29	10283.75	-19.91	15.51
NOV	0.013	0.100	.131	3568.93	4010.10	1524.25	21.81	2691.77	-15.39	15.87
DEC	-0.005	0.054	.068	3534.19	4010.43	1944.21	21.00	3414.98	-10.20	16.20
JAN	-0.007	0.038	.038	3515.09	4010.63	2089.39	19.72	3447.42	-7.48	16.48
FEB	-0.011	0.027	.030	3499.49	4010.75	2109.07	15.81	2518.90	-6.39	16.52
YEARLY AVERAGES:				3476.10	4010.25	1534.41	124.57	12561.86	-13.01	16.02

HYDRAULIC RESPONSE TIME = 2.8 MONTHS SOLUTE RESPONSE TIME = 13.5 YEARS

ARKANSAS RIVER VALLEY STUDY: CHANGES FROM BASE PERIOD FOR 1975

	AQ. CHEM. (MG/L)	AQ. CHEM. (TONS)	AQ. VOL (AC-FT)	RIVER CHEM. (MG/L)	RIVER FLOW (CFS)	SALT (TONS)	RIVER TRANS (CFS)	HBAR (FT)
MAR	385.53	13804.64	-1776.63	-124.65	-10.40	-1820.65	-10.40	-0.74
APR	401.77	14325.47	-1810.38	-41.44	-10.95	-1719.48	-10.95	-0.76
MAY	417.85	14381.03	-1925.25	-11.55	-11.27	-1593.94	-11.27	-0.81
JUN	430.52	14180.41	-2012.50	0.34	-12.18	-1213.45	-12.18	-0.84
JUL	444.87	13936.06	-2122.75	0.57	-12.43	-777.68	-12.43	-0.89
AUG	461.46	13658.26	-2269.13	-3.22	-13.29	-1440.40	-13.29	-0.95
SEP	474.47	13477.28	-2396.50	11.52	-14.50	-1597.53	-14.50	-1.00
OCT	471.34	13408.85	-2418.13	7.85	-14.16	-1601.31	-14.16	-1.01
NOV	457.93	13913.41	-2295.63	88.79	-13.89	-1457.16	-13.89	-0.96
DEC	453.27	14969.87	-2126.38	-11.60	-12.45	-2057.36	-12.45	-0.89
JAN	454.23	15922.57	-1992.88	-77.92	-11.67	-2244.06	-11.67	-0.83
FEB	461.79	17063.70	-1873.75	-128.38	-12.15	-2206.69	-12.15	-0.78
AVE CHANGE:	442.92	14466.58	-2084.90	-24.14	-12.44	-1644.14	-12.44	-0.87

Appendix E

Non-linear Reservoir Model Program for the Mesilla Valley with Output Results

```
C
C
C     ************************************************************
C             PROGRAM TO ESTIMATE MONTHLY VALUES OF
C             RECHARGE,PREDICTED WATER LEVELS AND
C             DRAIN FLOWS USING A NON-LINEAR
C             LUMPED-PARAMETER MODEL.
C     ************************************************************
C
C
      INTEGER DATE
      DIMENSION ABSE(32,14),SMSE(32,14),ABSEX(32),SMSEX(32),RMEX(32)
     < ,ICOUNT(32,14)
      DIMENSION C(14),D(32,14),E(32,14),F(32,14),G(32,14)
      COMMON DATE(32,14),H(32,14),DRAIN(32,14),QR(32),RECH(32,14),
     <HPRED(32,14),DRED(32,14)
      DATA IR,IW/25,26/
      OPEN(UNIT=25,DEVICE='DSK',ACCESS='SEQIN',FILE='OBSV.DAT')
      OPEN(UNIT=26,DEVICE='DSK',ACCESS='SEQOUT',FILE='APNZ.DAT')
      OPEN(UNIT=27,DEVICE='DSK',ACCESS='SEQOUT',FILE='AMES.DAT')
C
C
C     ************************************************************
C             MODEL     PARAMETERS
C     ************************************************************
C
C     DEFINITION OF VARIABLES:
C     ALPHA:CONSTANT FOR THE NON-LINEAR TERM
C     HO:CONSTANT FOR THE NON-LINEAR TERM
C     NREC: # OF RECHARGE-RECESSION PERIODS
C     POR: POROSITY OF THE AQUIFER
C     Z:CONSTANT FOR THE NON-LINEAR TERM
C
      ALPHA=0.0755
      HO=3825.0
      NREC=31
      POR=0.218
      Z=9.05
      WRITE(IW,6)
      WRITE(IW,16)
C
C
C     ************************************************************
C             READ  THE  DATA
C     ************************************************************
C
C     DEFINITION OF VARIABLES:
C     J: PERIOD NUMBER
C     I: MONTHLY VALUES (12 IN EACH J)
C     DATE(J,I):DATE OF WATER LEVEL AND DRAIN FLOW OBSERVATION
C     H(J,I): WATER LEVEL OBSERVATION
C     DRAIN(J,I):DRAIN FLOW OBSERVATION
C     QR(J): DRAIN-RIVER LEAKAGE RECHARGE TERM
C
      DO 2 J=1,NREC
      READ(IR,15) QR(J)
      WRITE(IW,26) J,QR(J)
      DO 1 I=1,12
      READ(IR,5) DATE(J,I),H(J,I),DRAIN(J,I)
      G(J,I)=(1./Z)*ALOG(EXP(ALPHA*Z*(H(J,I)-HO))+1.0)
```

```
      WRITE(IW,36)DATE(J,I),H(J,I),DRAIN(J,I),G(J,I)
    1 CONTINUE
    2 CONTINUE
C
C
C     ****************************************************************
C             SOLUTION OF THE TRIDIAGONAL MATRIX TO ESTIMATE RECHARGE
C     ****************************************************************
C
C     DEFINITION OF VARIABLES:
C     A: CONSTANT COEFFICIENT
C     B: CONSTANT COEFFICIENT
C     C(I): COEFFICIENT
C     D(J,I): SOLUTION OF THE MODEL BY SIMPSON'S RULE
C     E(J,I): COEFFICIENT
C     F(J,I): COEFFICIENT
C     N: # OF MONTHS OF POSSIBLE RECHARGE
C     DRIN:INITIAL DRAIN FLOW VALUE(FEB. 1946)
C     HIN:INITIAL WATER LEVEL VALUE(FEB. 1946)
C     GIN: INITIAL VALUE OF THE NON-LINEAR TERM(FEB. 1946)
C     RECH(J,I):RECHARGE MONTHLY ESTIMATES
C
      A=1.0
      B=4.0
      DRIN=0.0898
      HIN=3826.12
      GIN=(1./Z)*ALOG(EXP(ALPHA*Z*(HIN-HO))+1.0)
      DO 8 J=1,NREC
      WRITE(IW,46) J
      C(1)=1.0
      D(J,1)=3.0*POR*(H(J,2)-HIN)-6.0*QR(J)+G(J,2)+4.0*G(J,1)+GIN
      E(J,1)=C(1)/B
      F(J,1)=D(J,1)/B
      WRITE(IW,56)
      WRITE(IW,66) D(J,1),E(J,1),F(J,1)
      DRIN=DRAIN(J,12)
      HIN=H(J,12)
      GIN=(1./Z)*ALOG(EXP(ALPHA*Z*(HIN-HO))+1.0)
      N=7
      DO 3 I=2,N
      C(I)=1.0
      C(N)=0.0
      D(J,I)=3.0*POR*(H(J,I+1)-H(J,I-1))-6.0*QR(J)+G(J,I+1)+
     *4.0*G(J,I)+G(J,I-1)
      E(J,I)=C(I)/(B-E(J,I-1)*A)
      F(J,I)=(D(J,I)-A*F(J,I-1))/(B-A*E(J,I-1))
      WRITE(IW,76) D(J,I),E(J,I),F(J,I)
    3 CONTINUE
      RECH(J,N)=F(J,N)
    4 RECH(J,N-1)=F(J,N-1)-E(J,N-1)*RECH(J,N)
      N=N-1
      IF(N.EQ.1)GO TO 8
      GO TO 4
    8 CONTINUE
      DO 12 J=1,NREC
      WRITE(IW,86) J
      WRITE(IW,96)
      DO 11 I=1,12
      WRITE(IW,106) DATE(J,I),RECH(J,I)
```

```
   11 CONTINUE
   12 CONTINUE
C
C
C     ****************************************************************
C                        SIMULATION
C
C     AN ITERATIVE PROCESS TO PREDICT WATER LEVELS AND DRAIN FLOWS
C     ****************************************************************
C
C     DEFINITION OF VARIABLES:
C     AVREC:AVERAGE OF TWO ADJACENT RECHARGE VALUES
C     HBEG:BEGINNING ESTIMATION OF WATER LEVEL
C     HNEW:NEW ESTIMATION OF WATER LEVEL
C     HOLD:OLD ESTIMATION OF WATER LEVEL
C     GBEG:NON-LINEAR FCN. EVALUATED AT HBEG
C     GOLD:NON-LINEAR FCN. EVALUATED AT HOLD
C     AVG:AVERAGE OF TWO ADJACENT NON-LINEAR FCN. VALUES
C     DIFF:ABSOLUTE ERROR BETWEEN A NEW AND OLD ESTIMATE
C     TOL:TOLERANCE IN ITERATION
C     HPRED(J,I):PREDICTED WATER LEVEL
C     DRED(J,I):PREDICTED DRAIN FLOW
C
      TOL=0.01
      HPRED(1,1)=3826.38
      DO 23 J=1,NREC
      DO 22 I=1,12
      ICOUNT(J,I)=0
      DRED(J,I)=(1.0/Z)*ALOG(EXP(ALPHA*Z*(HPRED(J,I)-H0))+1.0)
      IF(J.GT.1.AND.I.GT.1) GO TO 13
      HOLD=H(J,I)
      HBEG=HOLD
      GO TO 18
   13 HBEG=HNEW
      GO TO 18
   14 HOLD=HNEW
   18 GBEG=(1.0/Z)*ALOG(EXP(ALPHA*Z*(HBEG-H0))+1.0)
      GOLD=(1.0/Z)*ALOG(EXP(ALPHA*Z*(HOLD-H0))+1.0)
      AVG=(GOLD+GBEG)/2.0
      ICOUNT(J,I)=ICOUNT(J,I)+1
      IF(I.EQ.12) GO TO 19
      AVREC=(RECH(J,I+1)+RECH(J,I))/2.0
      GO TO 20
   19 AVREC=(RECH(J+1,1)+RECH(J,I))/2.0
   20 HNEW=HBEG+(AVREC+QR(J)-AVG)/POR
      DIFF=ABS(HNEW-HOLD)
      IF(DIFF.GT.TOL) GO TO 14
      IF(I.LT.12) GO TO 21
      HPRED(J+1,1)=HNEW
      GO TO 22
   21 HPRED(J,I+1)=HNEW
   22 CONTINUE
   23 CONTINUE
C
C
C     ****************************************************************
C              COMPUTATION OF ERRORS IN SIMULATION
C     ****************************************************************
C
C     DEFINITION OF VARIABLES:
```

```
C     ABSE(J,I):ABSOLUTE ERROR BETWEEN EACH PRED. & OBS. VALUE
C     SMSE(J,I):MEAN SQUARE ERROR BETWEEN EACH PRED. & OBS. VALUE
C     ABSEX(J):ABSOLUTE ERROR FOR J PERIOD
C     SMSEX(J):MEAN SQUARE ERROR FOR J PERIOD
C     RMEX(J):ROOT MEAN SQUARE ERROR FOR J PERIOD
C     SABS:ABSOLUTE ERROR FOR SIMULATION
C     SSQ:MEAN SQUARE ERROR FOR THE SIMULATION
C     RMS: ROOT MEAN SQUARE ERROR FOR THE SIMULATION
C
      KOUNT=0
      NPTS=NREC*12
   24 SABS=0.0
      SSQ=0.0
      WRITE(IW,116)
      IF(KOUNT.EQ.1) GO TO 25
      WRITE(IW,126)
      GO TO 255
   25 WRITE(IW,136)
  255 DO 32 J=1,NREC
      ABSEX(J)=0.0
      SMSEX(J)=0.0
      DO 31 I=1,12
      IF(KOUNT.EQ.1) GO TO 27
      ABSE(J,I)=HPRED(J,I)-H(J,I)
      GO TO 28
   27 ABSE(J,I)=DRED(J,I)-DRAIN(J,I)
   28 SMSE(J,I)=ABSE(J,I)*ABSE(J,I)
      IF(KOUNT.EQ.1) GO TO 29
      WRITE(IW,146)DATE(J,I),HPRED(J,I),H(J,I),ABSE(J,I),SMSE(J,I)
     < ,ICOUNT(J,I)
      GO TO 30
   29 WRITE(IW,156)DATE(J,I),DRED(J,I),DRAIN(J,I),ABSE(J,I),SMSE(J,I)
   30 ABSEX(J)=ABSEX(J)+ABSE(J,I)
      SMSEX(J)=SMSEX(J)+SMSE(J,I)
   31 CONTINUE
      SABS=SABS+ABSEX(J)
      SSQ=SSQ+SMSEX(J)
      RMEX(J)=SQRT(SMSEX(J)/12.0)
      WRITE(IW,166) J,ABSEX(J),SMSEX(J),RMEX(J)
   32 CONTINUE
      ANPTS=NPTS
      RMS=SQRT(SSQ/ANPTS)
      WRITE(IW,176)SABS,SSQ,RMS
      KOUNT=KOUNT+1
      IF(KOUNT.EQ.1) GO TO 24
      CALL MASBAL(IR,IW,NREC,ALPHA,POR)
      CLOSE(UNIT=25,DEVICE='DSK',ACCESS='SEQIN',FILE='OBSV.DAT')
      CLOSE(UNIT=26,DEVICE='DSK',ACCESS='SEQOUT',FILE='APNZ.DAT')
      CLOSE(UNIT=27,DEVICE='DSK',ACCESS='SEQOUT',FILE='AMES.DAT')
      STOP
    5 FORMAT(I4,F10.2,F10.4)
    6 FORMAT(45X,'        DATA        '///)
    7 FORMAT(I4,F10.2,F10.2,F10.4,F10.4)
   15 FORMAT(2X,F10.4)
   16 FORMAT(20X,'DATE',4X,'WATER LEVEL',3X,'DRAIN FLOW',3X,
     #'NON-LINEAR FCN.'//)
   26 FORMAT(///,20X,I2,2X,'PERIOD',2X,'QR=',F10.4)
   36 FORMAT(20X,I4,3X,F10.2,3X,F10.4,3X,F10.4)
   46 FORMAT(///,5X,'TRIDIAGONAL MATRIX COEFFS  FOR THE',1X,I2,1X,
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      #'PERIOD'/)
   56 FORMAT(5X,'D',13X,'E',13X,'F'/)
   66 FORMAT(3(3X,F10.2))
   76 FORMAT(3(3X,F10.2))
   86 FORMAT(//,20X,'RECHARGE ESTIMATES FOR THE',2X,I2,1X,'TH PERIOD'/)
   96 FORMAT(20X,'DATE',3X,'RECHARGE (FT/MO)'/)
  106 FORMAT(20X,I4,3X,F10.4)
  116 FORMAT(1H1,5X,'MODEL PREDICTIONS AND COMPUTATION OF ERRORS'//)
  126 FORMAT(/,2X,'DATE',5X,'PRED W.L.',6X,'OBS. W.L.',4X,'ABS. ERROR',
      #4X,'SQ. OF ABS. ERR.'/)
  136 FORMAT(/,2X,'DATE',5X,'PRED. DRAIN',4X,'OBS. DRAIN',4X,
      #'ABS. ERROR',4X,'SQ. OF ABS. ERR.'/)
  146 FORMAT(2X,I4,3(4X,F10.2),4X,F10.4,10X,I3)
  156 FORMAT(2X,I4,4(4X,F10.4))
  166 FORMAT(/,5X,'ERRORS FOR ',2X,I2,1X,'TH PERIOD',4X,'ABS=',F10.2,
      #4X,'SQ(ABS)=',F10.4,4X,'RMS=',F10.2/)
  176 FORMAT(//,5X,'SIMULATION ERRORS(TOTAL):',7X,'ABSOLUTE ERROR=',
      #F10.2,4X,'SQUARE OF ABSOL.=',F10.2,4X,'ROOT MEAN SQ. ERROR=',
      #F10.2)
      END
      SUBROUTINE MASBAL(IR,IW,NREC,AD,POR)
      INTEGER DATE
      COMMON DATE(32,14),H(32,14),DRAIN(32,14),QR(32),RECH(32,14),
     < HPRED(32,14),DRED(32,14)
      COMMON/GRAPH/CAQ(11,12),HOB(10,12),HPD(10,12),QDOB(10,12),COUT(10
     1,12),QROUT(10,12),COBS(10,12),QD(10,12),QOBS(10,12)
      DIMENSION WL(10,12),QS(10,12),ENET(10,12),CSUR(10,12),QRIN(10,12)
     1 , MON(12),IYR(10),QP(10,12),CUNUSE(10,12)
      DIMENSION TC(10),D1(12),D2(12),QL(10,12),QLR(10,12)
      DIMENSION TONPR(12),TONOB(12),D3(12)
      DATA MON/5H JAN ,5H FEB ,5H MAR ,5H APR ,5H MAY ,5H JUN ,5H JUL ,
     <5H AUG ,5H SEP ,5H OCT ,5H NOV ,5H DEC /
      AREA=108626.0
      HO=3754.0
      CAQ(1,1)=0.0
      CAQ(1,2)=0.0
      CAQ(1,3)=0.0
      CAQ(1,4)=0.0
      CAQ(1,5)=1626.0
      TH=POR/AD
      DO 1 JI=22,NREC
      J=JI-21
      DO 1 I=1,12
      IF(I.GT.10)GO TO 11
      WL(J,I+2)=HPRED(JI,I)-HO
      HOB(J,I+2)=H(JI,I)
      ENET(J,I+2)=RECH(JI,I)
      QD(J,I+2)=DRED(JI,I)*AREA
      QDOB(J,I+2)=DRAIN(JI,I)*AREA
      QL(J,I+2)=QR(JI)
      GO TO 1
   11 WL(J,I-10)=HPRED(JI-1,I)-HO
      HOB(J,I-10)=H(JI-1,I)
      ENET(J,I-10)=RECH(JI-1,I)
      QD(J,I-10)=DRED(JI-1,I)*AREA
      QDOB(J,I-10)=DRAIN(JI-1,I)*AREA
      QL(J,I-10)=QR(JI-1)
    1 CONTINUE
      DO 2 J=1,10
      READ(IR,100)IYR(J)
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```
  100 FORMAT(I4)
      READ(IR,101)(QS(J,I),I=1,12)
      READ(IR,101)(QRIN(J,I),I=1,12)
      READ(IR,101)(CSUR(J,I),I=1,12)
      READ(IR,101)(QOBS(J,I),I=1,12)
      READ(IR,101)(COBS(J,I),I=1,12)
      READ(IR,101)(CONUSE(J,I),I=1,12)
    2 CONTINUE
  101 FORMAT(8F10.0,/,4F10.0)
      CALL RIVLEA(QL,QS,QP,CONUSE,QRIN,QLR,MON,IYR,AREA,IW)
      STOT1=0.0
      STOT2=0.0
      STOT3=0.0
      DO 3 J=1,10
      A1=0.0
      A2=0.0
      A3=0.0
      A4=0.0
      A5=0.0
      A6=0.0
      A7=0.0
      TC(J)=0.0
      ETOT=0.0
      DO 4 I=1,12
      TC(J)=TC(J)+WL(J,I)
      IF(QLR(J,I).LT.0.0)GO TO 44
      QLEAK=QLR(J,I)
      GO TO 43
   44 QLEAK=0.0
   43 TOTREC=ENET(J,I)+QLEAK/AREA
      ETOT=ETOT+TOTREC
      IF(J.EQ.1 .AND. I.LT.5)GO TO 4
      AK1=TOTREC/(POR*WL(J,I))
      AK2=(QS(J,I)+QLEAK)/(AREA*POR*WL(J,I))
      IF(I.EQ.12)GO TO 5
      CAQ(J,I+1)=CSUR(J,I)*2.*AK2/(AK1+2.)-CAQ(J,I)*(AK1-2.)/(AK1+2.)
      GO TO 6
    5 CAQ(J+1,1)=CSUR(J,I)*2.*AK2/(AK1+2.)-CAQ(J,I)*(AK1-2.)/(AK1+2.)
    6 QOUT=QS(J,I)+QLR(J,I)
      QROUT(J,I)=QD(J,I)+QRIN(J,I)-QOUT
      IF(QLR(J,I).LT.0.0)GO TO 45
      COUT(J,I)=((QRIN(J,I)-QOUT)*CSUR(J,I)+QD(J,I)*CAQ(J,I))/QROUT(J,I)
      GO TO 4
   45 COUT(J,I)=((QRIN(J,I)-QS(J,I))*CSUR(J,I)+CAQ(J,I)*(QD(J,I)-QLR(J,I
     <)))/QROUT(J,I)
    4 CONTINUE
      WRITE(27,277)(ENET(J,I),I=1,12)
  277 FORMAT(8F10.7,/,4F10.7)
      WRITE(27,278)(QLR(J,I),I=1,12)
  278 FORMAT(8F10.2,/,4F10.2)
      TC(J)=POR*TC(J)/(12.0*ETOT)
      WRITE(IW,200)IYR(J)
  200 FORMAT(1H1,////,5X,'MESILLA VALLEY, N.MEX.; HYDROSALINITY MODEL RE
     <SULTS FOR THE WATER YEAR',I5,//,5X,'MONTH',2X,' AQ. HEAD ',2X,'DRA
     <IN FLOW',2X,' LEAS. QR ',2X,'LEAS. CHEM',2X,' AQ. CHEM ',2X,'EL PA
     <SO QR',2X,'EL PASO QR',2X,'EL PA CHEM',2X,'EL PA CHEM',/,12X,'(PRE
     <D: FT)',2X,'(PRD:AC-FT)',1X,'(OB:AC-FT)',2X,'(OB:MG/L)',3X,'(PRD:M
     <G/L)',2X,'(PD:AC-FT)',2X,'(OB:AC-FT)',2X,'(PRD:MG/L)',2X,'(OBS:MG/
     <L)',//)
      SD1SQ=0.0
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      SD2SQ=0.0
      SD3SQ=0.0
      DO 7 I=1,12
      D1(I)=QROUT(J,I)-QOBS(J,I)
      D2(I)=COUT(J,I)-COBS(J,I)
      TONOB(I)=QOBS(J,I)*COBS(J,I)/735.0
      TONPR(I)=QROUT(J,I)*COUT(J,I)/735.0
      D3(I)=TONPR(I)-TONOB(I)
      SD1SQ=SD1SQ+D1(I)*D1(I)
      SD2SQ=SD2SQ+D2(I)*D2(I)
      SD3SQ=SD3SQ+D3(I)*D3(I)
      WLEVEL=WL(J,I)+HO
      HPD(J,I)=WLEVEL
      A1=A1+WLEVEL
      A2=A2+QD(J,I)
      A3=A3+CAQ(J,I)
      A4=A4+QROUT(J,I)
      A5=A5+QOBS(J,I)
      A6=A6+COUT(J,I)
      A7=A7+COBS(J,I)
      WRITE(IW,201)MON(I),WLEVEL,QD(J,I),QRIN(J,I),CSUR(J,I),CAQ(J,I),
     < QROUT(J,I),QOBS(J,I),COUT(J,I),COBS(J,I)
  201 FORMAT(5X,A5,9(2X,F10.2))
    7 CONTINUE
      STOT1=STOT1+SD1SQ
      STOT2=STOT2+SD2SQ
      STOT3=STOT3+SD3SQ
      IF(J.EQ.1)GO TO 33
      RMS1=SQRT(SD1SQ/12.0)
      RMS2=SQRT(SD2SQ/12.0)
      RMS3=SQPT(SD3SQ/12.0)
      A1=A1/12.0
      A2=A2/12.0
      A3=A3/12.0
      A4=A4/12.0
      A5=A5/12.0
      A6=A6/12.0
      A7=A7/12.0
      GO TO 34
   33 RMS1=SQRT(SD1SQ/8.0)
      RMS2=SQRT(SD2SQ/8.0)
      RMS3=SQRT(SD3SQ/8.0)
      A1=A1/12.0
      A2=A2/12.0
      A3=A3/8.0
      A4=A4/8.0
      A5=A5/8.0
      A6=A6/8.0
      A7=A7/8.0
   34 CONTINUE
      WRITE(IW,501)A1,A2,A3,A4,A5,A6,A7
  501 FORMAT(/,5X,'YEARLY AVERAGES:',/,10X,2(2X,F10.2),24X,5(2X,F10.2))
      WRITE(IW,300)TH,TC(J)
  300 FORMAT(//,5X,'HYDRAULIC RESPONSE TIME = ',F4.1,' MO.',/,5X,'SOLUTE
     < RESPONSE TIME = ',F7.1,' YRS.',////,5X,'ERRORS: DIFF BETWEEN PRED
     <ICTED AND OBSERVED',/,13X,'RIVER FLOW & TDS AT EL PASO',21X,'TONS
     <OF SALT AT EL PASO',//,5X,'MONTH',5X,'QPRED-QOBS',5X,'CMPRED-CMOBS
     <',19X,'TONS(PRED)',5X,'TONS (OBS)',5X,'DIFF',/,16X,'(AC-FT)',10X,
     < '(MG/L)',/)
      DO 77 I=1,12
```

```
   77 WRITE(IW,301)MON(I),D1(I),D2(I),TONPR(I),TUNOB(I),D3(I)
  301 FORMAT(5X,A5,5X,F10.1,6X,F10.1,19X,F11.1,4X,F11.1,F10.2)
      WRITE(IW,302)RMS1,RMS2,RMS3
  302 FORMAT(//,4X,'RMS ERRORS:',F10.1,6X,F10.1,44X,F10.1)
    3 CONTINUE
      TRMS1=SQRT(STOT1/116.0)
      TRMS2=SQRT(STOT2/116.0)
      TRMS3=SQRT(STOT3/116.0)
      WRITE(IW,303)TRMS1,TRMS2,TRMS3
  303 FORMAT(///,5X,'TOTAL RMS ERRORS:',/,5X,'RMS ERROR IN RIVER FLOW ='
     <,F10.1,/,5X,'RMS ERROP IN TDS = ',F10.1,/,5X,'RMS ERROR IN TONS =
     <',F10.1)
      CALL GRAFF(IR,IW)
      RETURN
      END
      SUBROUTINE RIVLEA(QL,QS,QP,CONUSE,QRIN,QLR,MON,IYR,AREA,IW)
      DIMENSION QL(10,12),QFIN(10,12),QLR(10,12),MON(12),IYR(10),
     < PERC(10),QS(10,12),PERS(10),QP(10,12),CONUSE(10,12)
      BETA=0.50
      FLEAK=1.0-0.45
      DO 1 J=1,10
      SRFLO=0.0
      SRFLW=0.0
      SQL=0.0
      SQS=0.0
      DO 2 I=1,12
      QP(J,I)=CONUSE(J,I)/BETA-FLEAK*QS(J,I)
      IF(QP(J,I).LT.0.0)QP(J,I)=0.0
      IF(J.EQ.1 .AND. I.LT.5)GO TO 2
      SRFLO=SRFLO+QRIN(J,I)
      SRFLW=SRFLW+QRIN(J,I)-QS(J,I)
      SQL=SQL+AREA*QL(J,I)
      SQS=SQS+QS(J,I)
    2 CONTINUE
      PERC(J)=SQL/SRFLW
      PERS(J)=100.0*SQS/SRFLO
      DO 3 I=1,12
      QLR(J,I)=PERC(J)*(QFIN(J,I)-QS(J,I))
    3 IF(J.EQ.1 .AND. I.LT.5)QLR(J,I)=0.0
    1 PERC(J)=100.0*PERC(J)
      WRITE(IW,101)(IYR(J),J=1,10)
  101 FORMAT(1H1,////,5X,'MESILLA VALLEY, N. MEX.',//,5X,'CALC. RIVER LE
     <AKAGE (AC-FT/MO)',//,12X,10(3X,I4,3X))
      DO 4 I=1,12
    4 WRITE(IW,102)MON(I),(QLR(J,I),J=1,10)
  102 FORMAT(5X,A5,10F10.1)
      WRITE(IW,103)(PERC(J),J=1,10)
  103 FORMAT(//,5X,'PERCENTAGE OF YEARLY RIVER LEAKAGE INTO ALLUVIAL AQU
     <IFER:',//,13X,10(2X,F5.1,3X))
      WRITE(IW,201)(IYR(J),J=1,10)
  201 FORMAT(////,5X,'OBS. SURFACE DIVERSION (AC-FT/MO)',//,12X,
     < 10(3X,I4,3X))
      DO 5 I=1,12
    5 WRITE(IW,102)MON(I),(QS(J,I),J=1,10)
      WRITE(IW,203)(PERS(J),J=1,10)
  203 FORMAT(//,5X,'PERCENTAGE OF YEARLY RIVER FLOW THAT IS DIVERTED:',
     < //,13X,10(3X,F4.1,3X))
      WRITE(IW,301)(IYR(J),J=1,10)
  301 FORMAT(1H1,////,5X,'MESILLA VALLEY, N.MEX.',/,5X,'BLANEY-CRIDDLE C
     <ONSUMPTIVE USE (AC-FT/MO)',//,12X,10(3X,I4,3X))
```

```
      DO 6 I=1,12
    6 WRITE(IW,102)MON(I),(CONUSE(J,I),J=1,10)
      WRITE(IW,401)(IYR(J),J=1,10)
  401 FORMAT(/////,5X,'CALC. GROUNDWATER PUMPAGE (AC-FT/MO)',//,12X,
     < 10(3X,I4,3X))
      DO 7 I=1,12
    7 WRITE(IW,102)MON(I),(QP(J,I),J=1,10)
      RETURN
      END
      SUBROUTINE GRAFF(IR,IW)
      COMMON/GRAPH/CAQ(11,12),HOB(10,12),HPD(10,12),QDOB(10,12),COUT(10
     1,12),QROUT(10,12),COBS(10,12),QD(10,12),QOBS(10,12)
      DIMENSION X(122),Y1(122),Y2(122),LBX(35),LB1(35),LB2(35),LB3(35),
     1LB4(35),LB5(35),LB6(35),LB7(35),LB8(35),LBY1(35),LBY2(35),LB9(35)
      CALL INITAL(1)
      KOUNT=1
      J1=1
      J2=5
      N=120
      READ(IR,101)(LBX(I),I=1,7)
      READ(IR,101)(LB1(I),I=1,7)
      READ(IR,101)(LB2(I),I=1,7)
      READ(IR,101)(LB3(I),I=1,7)
      READ(IR,101)(LB4(I),I=1,7)
      READ(IR,101)(LB5(I),I=1,7)
      READ(IR,101)(LB6(I),I=1,7)
      READ(IR,101)(LB7(I),I=1,7)
      READ(IR,101)(LB8(I),I=1,7)
      READ(IR,101)(LB9(I),I=1,7)
  101 FORMAT(7A5)
      XMIN=1967.0
      DX=1.0
    5 CONTINUE
      IN=5
      CALL RSTR(0)
      CALL RSTR(1)
      GO TO (1,44,3,2,55),KOUNT
    1 DO 12 J=1,10
      DO 12 I=1,12
      K=12*(J-1)+I
      AK=K
      X(K)=1967.0+(AK-0.5)/12.0
      Y1(K)=HPD(J,I)
   12 Y2(K)=HOB(J,I)
      DO 11 I=1,7
      LBY1(I)=LB1(I)
   11 LBY2(I)=LB7(I)
      Y1MIN=3822.0
      DY1=1.0
      GO TO 4
    2 DO 23 J=1,10
      IF(J.GT.1)IN=1
      DO 23 I=IN,12
      K=12*(J-1)+I
      AK=K
      X(K-4)=1967.0+(AK-0.5)/12.0
      Y1(K-4)=QROUT(J,I)/1000.0
   23 Y2(K-4)=QOBS(J,I)/1000.0
      DO 22 I=1,7
      LBY1(I)=LB3(I)
```

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   22 LBY2(I)=LB4(I)
      Y1MIN=0.0
      DY1=10.0
      GO TO 4
    3 DO 34 J=1,10
      IF(J.GT.1)IN=1
      DO 34 I=IN,12
      K=12*(J-1)+1
      AK=K
      X(K-4)=1967.0+(AK-0.5)/12.0
      Y1(K-4)=COUT(J,I)/100.0
   34 Y2(K-4)=CURS(J,I)/100.0
      DO 33 I=1,7
      LBY1(I)=LB5(I)
   33 LBY2(I)=LB6(I)
      N=116
      Y1MIN=0.0
      DY1=4.0
      GO TO 4
   44 DO 45 J=1,10
      DO 45 I=1,12
      K=12*(J-1)+I
      AK=K
      X(K)=1967.0+(AK-0.5)/12.0
      Y1(K)=QD(J,I)/1000.0
   45 Y2(K)=QDOB(J,I)/1000.0
      DO 46 I=1,7
      LBY1(I)=LB2(I)
   46 LBY2(I)=LB8(I)
      Y1MIN=0.0
      DY1=4.0
      GO TO 4
   55 DO 56 J=1,10
      IF(J.GT.1)IN=1
      DO 56 I=IN,12
      K=12*(J-1)+1
      AK=K
      X(K-4)=1967.0+(AK-0.5)/12.0
      Y1(K-4)=1500.0
   56 Y2(K-4)=CAQ(J,I)
      DO 57 I=1,7
      LBY1(I)=LB9(I)
   57 LBY2(I)=LB9(I)
      Y1MIN=1500.0
      DY1=50.0
    4 Y2MIN=Y1MIN
      DY2=DY1
      DO 444 I=1,N
      X(I)=(X(I)-XMIN)/DX
      Y1(I)=(Y1(I)-Y1MIN)/DY1
  444 Y2(I)=(Y2(I)-Y2MIN)/DY2
      WRITE(IW,500)KOUNT
  500 FORMAT(1H1,////,5X,'PLOTTED VALUES FOR KOUNT = ',I4,//,5X,
     < 'X',10X,'Y1',10X,'Y2',//)
      DO 502 I=1,N
  502 WRITE(IW,503)I,X(I),Y1(I),Y2(I)
  503 FORMAT(1X,I3,3(3X,F10.2))
      CALL PLOT(0.35,1.0,-3)
      CALL AXIS(0.,0.,LBX,-35,10.,0.,XMIN,DX,-1)
      CALL PLOT(0.0,7.0,3)
```

```
      CALL PLOT(10.0,7.0,2)
      CALL PLOT(10.0,0.0,2)
      CALL PLOT(0.0,0.0,3)
      CALL AXIS(0.,0.,LBY1,35,7.,90.,Y1MIN,DY1,-1)
      CALL PLOT(0.,0.,3)
      CALL LINE(X,Y1,N,J1,1)
      CALL PLOT(10.,0.,3)
      CALL AXIS(10.,0.,LBY2,-35,7.,90.,Y2MIN,DY2,-1)
      CALL PLOT(0.,0.,3)
      CALL LINE(X,Y2,N,J2,1)
      CALL PLOT(15.,-1.,-3)
      KOUNT=KOUNT+1
      IF(KOUNT.LT.6)GO TO 5
      CALL RSTR(0)
      CALL RSTR(2)
      RETURN
      END
```

DATA

DATE	WATER LEVEL	DRAIN FLOW	NON-LINEAR FCN.
1 PERIOD QR=	0.0776		
346	3826.38	0.1268	0.1405
446	3827.34	0.2031	0.1970
546	3827.53	0.2308	0.2091
646	3828.00	0.2485	0.2399
746	3828.36	0.2853	0.2643
846	3828.42	0.3010	0.2684
946	3827.68	0.2441	0.2188
1046	3826.84	0.1613	0.1666
1146	3826.52	0.1254	0.1482
1246	3826.17	0.1122	0.1294
147	3825.95	0.0973	0.1182
247	3825.89	0.0773	0.1152
2 PERIOD QR=	0.0723		
347	3826.18	0.1103	0.1299
447	3827.18	0.1827	0.1871
547	3827.50	0.1991	0.2072
647	3827.80	0.2097	0.2266
747	3828.32	0.2498	0.2615
847	3828.32	0.2636	0.2615
947	3827.77	0.2178	0.2246
1047	3826.84	0.1372	0.1666
1147	3826.38	0.1059	0.1405
1247	3826.18	0.0913	0.1299
148	3825.86	0.0829	0.1138
248	3825.79	0.0718	0.1104
3 PERIOD QR=	0.0699		
348	3825.74	0.0743	0.1080
448	3826.78	0.1482	0.1631
548	3827.21	0.1872	0.1889
648	3827.38	0.1940	0.1995
748	3828.05	0.2534	0.2432
848	3828.24	0.2770	0.2561
948	3827.69	0.2424	0.2194
1048	3826.95	0.1617	0.1731
1148	3826.58	0.1201	0.1516
1248	3826.25	0.1132	0.1336
149	3825.89	0.1043	0.1152
249	3825.86	0.0821	0.1138
4 PERIOD QR=	0.0833		
349	3826.17	0.1180	0.1294
449	3827.01	0.1957	0.1767
549	3827.27	0.2188	0.1926
649	3827.43	0.2280	0.2027
749	3828.06	0.2755	0.2439
849	3828.11	0.2839	0.2473
949	3827.62	0.2226	0.2149
1049	3826.87	0.1478	0.1683
1149	3826.52	0.1283	0.1482
1249	3826.24	0.1104	0.1330
150	3826.02	0.0945	0.1217
250	3825.94	0.0775	0.1177
5 PERIOD QR=	0.0805		
350	3826.20	0.1381	0.1309
450	3826.98	0.1884	0.1749
550	3827.40	0.2036	0.2008
650	3827.59	0.2085	0.2129
750	3827.80	0.2629	0.2266
850	3827.99	0.2636	0.2392
950	3827.38	0.2296	0.1995
1050	3826.68	0.1606	0.1573
1150	3826.33	0.1176	0.1378
1250	3826.11	0.1017	0.1263
151	3825.89	0.0922	0.1152
251	3825.83	0.0658	0.1123
6 PERIOD QR=	-0.0023		
351	3825.93	0.0760	0.1172
451	3826.31	0.1246	0.1368
551	3825.99	0.1127	0.1202
651	3826.18	0.1116	0.1299
751	3826.23	0.1381	0.1325
851	3826.28	0.1488	0.1352
951	3826.00	0.1171	0.1207
1051	3825.82	0.0711	0.1118
1151	3825.74	0.0557	0.1080
1251	3824.76	0.0531	0.0679
152	3824.69	0.0461	0.0655
252	3824.59	0.0360	0.0622
7 PERIOD QR=	0.0460		
352	3823.86	0.0309	0.0417
452	3824.33	0.0607	0.0542
552	3824.33	0.0770	0.0542
652	3824.56	0.0837	0.0612
752	3824.69	0.0893	0.0655
852	3825.17	0.1082	0.0832
952	3825.45	0.0984	0.0949
1052	3824.96	0.0689	0.0751
1152	3824.84	0.0529	0.0707
1252	3824.70	0.0527	0.0658
153	3824.71	0.0471	0.0662
253	3824.50	0.0306	0.0593

8 PERIOD QR= 0.0327

353	3824.65	0.0284	0.0642
453	3825.01	0.0798	0.0770
553	3824.59	0.0774	0.0622
653	3824.79	0.0766	0.0689
753	3824.48	0.1000	0.0587
853	3824.72	0.1165	0.0665
953	3824.91	0.0933	0.0732
1053	3824.46	0.0553	0.0581
1153	3824.40	0.0440	0.0562
1253	3824.27	0.0381	0.0524
154	3824.33	0.0339	0.0542
254	3823.95	0.0239	0.0439

9 PERIOD QR= 0.0232

354	3823.33	0.0164	0.0306
454	3823.30	0.0365	0.0301
554	3823.13	0.0394	0.0272
654	3822.79	0.0323	0.0221
754	3822.20	0.0307	0.0152
854	3822.20	0.0279	0.0152
954	3822.13	0.0184	0.0145
1054	3822.43	0.0171	0.0176
1154	3822.38	0.0131	0.0171
1254	3822.40	0.0117	0.0173
155	3822.55	0.0110	0.0190
255	3822.41	0.0073	0.0174

10 PERIOD QR= 0.0249

355	3821.36	0.0039	0.0088
455	3821.19	0.0106	0.0079
555	3820.71	0.0093	0.0057
655	3820.19	0.0029	0.0041
755	3820.16	0.0089	0.0040
855	3819.91	0.0093	0.0034
955	3819.99	0.0111	0.0035
1055	3820.34	0.0072	0.0045
1155	3820.56	0.0036	0.0052
1255	3820.73	0.0037	0.0058
156	3820.77	0.0032	0.0060
256	3820.66	0.0029	0.0056

11 PERIOD QR= 0.0390

356	3819.66	0.0014	0.0028
456	3819.98	0.0077	0.0035
556	3819.50	0.0058	0.0025
656	3819.14	0.0037	0.0020
756	3818.40	0.0050	0.0012
856	3818.14	0.0035	0.0010
956	3818.25	0.0029	0.0011
1056	3818.37	0.0020	0.0012
1156	3818.59	0.0016	0.0014
1256	3818.73	0.0021	0.0015
157	3818.99	0.0023	0.0018
257	3819.00	0.0019	0.0018

12 PERIOD QR= 0.0483

357	3818.13	0.0010	0.0010
457	3817.72	0.0015	0.0008
557	3817.53	0.0013	0.0007
657	3817.35	0.0013	0.0006
757	3817.31	0.0037	0.0006
857	3818.22	0.0088	0.0011
957	3819.05	0.0190	0.0019
1057	3819.33	0.0144	0.0023
1157	3819.67	0.0111	0.0029
1257	3819.81	0.0082	0.0031
158	3820.17	0.0065	0.0040
258	3820.07	0.0043	0.0037

13 PERIOD QR= 0.0090

358	3820.43	0.0105	0.0048
458	3821.34	0.0295	0.0087
558	3822.05	0.0394	0.0138
658	3823.07	0.0580	0.0262
758	3823.82	0.0790	0.0408
858	3824.79	0.0953	0.0689
958	3825.15	0.0946	0.0824
1058	3824.93	0.0747	0.0740
1158	3824.66	0.0563	0.0645
1258	3824.46	0.0459	0.0581
159	3824.27	0.0388	0.0524
259	3823.96	0.0352	0.0442

14 PERIOD QR= 0.0273

359	3824.53	0.0560	0.0603
459	3824.94	0.0887	0.0743
559	3825.02	0.1083	0.0773
659	3825.38	0.1197	0.0919
759	3825.89	0.1658	0.1152
859	3826.10	0.1757	0.1257
959	3825.86	0.1362	0.1138
1059	3825.18	0.0898	0.0836
1159	3824.88	0.0730	0.0722
1259	3824.68	0.0671	0.0652
160	3824.56	0.0581	0.0612
260	3824.42	0.0428	0.0569

15 PERIOD QR= 0.0286

360	3824.82	0.0654	0.0700
460	3825.56	0.1073	0.0997
560	3825.71	0.1179	0.1066
660	3826.07	0.1309	0.1242

760	3826.36	0.1700	0.1395
860	3826.83	0.2072	0.1660
960	3826.47	0.1730	0.1455
1060	3825.93	0.1089	0.1172
1160	3825.52	0.0793	0.0980
1260	3825.28	0.0647	0.0877
161	3825.01	0.0589	0.0770
261	3824.80	0.0504	0.0693
16 PERIOD	QR=	0.0370	
361	3824.49	0.0565	0.0590
461	3825.28	0.0888	0.0877
561	3825.19	0.0962	0.0840
661	3825.57	0.1077	0.1002
761	3825.77	0.1314	0.1094
861	3825.95	0.1404	0.1182
961	3825.95	0.1250	0.1182
1061	3825.26	0.0875	0.0868
1161	3825.00	0.0669	0.0766
1261	3824.87	0.0623	0.0718
162	3824.71	0.0589	0.0662
262	3824.59	0.0423	0.0622
17 PERIOD	QR=	0.0427	
362	3824.65	0.0669	0.0642
462	3825.56	0.1065	0.0997
562	3825.83	0.1155	0.1123
662	3826.35	0.1378	0.1389
762	3826.98	0.1722	0.1749
862	3827.00	0.1820	0.1761
962	3826.79	0.1685	0.1637
1062	3826.29	0.1094	0.1357
1162	3825.87	0.0835	0.1142
1262	3825.62	0.0760	0.1025
163	3825.41	0.0691	0.0931
263	3825.07	0.0519	0.0793
18 PERIOD	QR=	0.0397	
363	3825.64	0.0739	0.1034
463	3826.01	0.1029	0.1212
563	3825.91	0.0957	0.1162
663	3825.76	0.0949	0.1090
763	3825.77	0.1070	0.1094
863	3825.68	0.1205	0.1052
963	3825.52	0.1048	0.0980
1063	3825.13	0.0654	0.0816
1163	3824.99	0.0481	0.0762
1263	3824.88	0.0471	0.0722
164	3824.74	0.0417	0.0672
264	3824.50	0.0303	0.0593
19 PERIOD	QR=	0.0274	
364	3823.56	0.0283	0.0351
464	3823.47	0.0314	0.0333
564	3822.96	0.0192	0.0245
664	3822.54	0.0133	0.0189
764	3821.76	0.0150	0.0115
864	3821.08	0.0120	0.0073
964	3821.11	0.0137	0.0075
1064	3821.10	0.0076	0.0074
1164	3821.34	0.0053	0.0087
1264	3821.48	0.0049	0.0095
165	3821.49	0.0047	0.0096
265	3821.45	0.0034	0.0094
20 PERIOD	QR=	0.0194	
365	3821.18	0.0035	0.0078
465	3820.20	0.0097	0.0041
565	3819.96	0.0059	0.0035
665	3820.10	0.0151	0.0038
765	3820.59	0.0316	0.0053
865	3821.82	0.0425	0.0119
965	3822.44	0.0460	0.0177
1065	3822.22	0.0266	0.0154
1165	3822.35	0.0202	0.0167
1265	3822.41	0.0159	0.0174
166	3822.35	0.0174	0.0167
266	3822.29	0.0144	0.0161
21 PERIOD	QR=	0.0103	
366	3822.51	0.0193	0.0185
466	3823.33	0.0369	0.0306
566	3823.71	0.0554	0.0383
666	3824.37	0.0728	0.0553
766	3824.85	0.0918	0.0711
866	3825.65	0.1308	0.1038
966	3825.59	0.1098	0.1011
1066	3825.17	0.0662	0.0832
1166	3824.83	0.0480	0.0704
1266	3824.54	0.0451	0.0606
167	3824.44	0.0377	0.0575
267	3824.11	0.0288	0.0480
22 PERIOD	QR=	0.0175	
367	3824.52	0.0392	0.0599
467	3824.45	0.0508	0.0578
567	3824.12	0.0447	0.0483
667	3823.98	0.0472	0.0447
767	3823.89	0.0573	0.0425
867	3824.27	0.0631	0.0524
967	3824.62	0.0679	0.0632
1067	3824.17	0.0486	0.0496
1167	3823.96	0.0333	0.0442
1267	3823.86	0.0350	0.0417
168	3823.87	0.0350	0.0420
268	3823.57	0.0295	0.0353

23 PERIOD	QR=	0.0065	
368	3824.26	0.0375	0.0522
468	3824.15	0.0558	0.0491
568	3823.95	0.0584	0.0439
668	3824.03	0.0603	0.0459
768	3824.51	0.0807	0.0596
868	3825.08	0.0994	0.0797
968	3825.30	0.0986	0.0885
1068	3824.49	0.0617	0.0590
1168	3824.45	0.0486	0.0578
1268	3824.20	0.0487	0.0505
169	3824.00	0.0462	0.0452
269	3823.72	0.0309	0.0385
24 PERIOD	QR=	0.0389	
369	3824.24	0.0451	0.0516
469	3824.75	0.0682	0.0676
569	3824.82	0.0745	0.0700
669	3825.01	0.0770	0.0770
769	3826.01	0.1193	0.1212
869	3826.63	0.1723	0.1544
969	3826.56	0.1465	0.1505
1069	3825.74	0.0948	0.1080
1169	3825.38	0.0767	0.0919
1269	3825.23	0.0704	0.0856
170	3825.10	0.0598	0.0804
270	3824.72	0.0507	0.0665
25 PERIOD	QR=	0.0221	
370	3825.48	0.0744	0.0962
470	3825.47	0.1035	0.0958
570	3825.80	0.1019	0.1109
670	3826.13	0.1269	0.1273
770	3826.71	0.1650	0.1590
870	3827.03	0.1746	0.1779
970	3826.72	0.1553	0.1596
1070	3826.07	0.0949	0.1242
1170	3825.97	0.0712	0.1192
1270	3825.61	0.0598	0.1020
171	3825.15	0.0505	0.0824
271	3824.73	0.0430	0.0669
26 PERIOD	QR=	-0.0416	
371	3824.99	0.0577	0.0762
471	3824.88	0.0749	0.0722
571	3825.12	0.0661	0.0812
671	3825.02	0.0668	0.0773
771	3825.23	0.0847	0.0856
871	3825.03	0.0975	0.0777
971	3824.88	0.0830	0.0722
1071	3824.52	0.0588	0.0599
1171	3824.45	0.0403	0.0578
1271	3824.68	0.0413	0.0652
172	3823.31	0.0360	0.0303
272	3823.11	0.0302	0.0268
27 PERIOD	QR=	0.0890	
372	3822.93	0.0461	0.0240
472	3822.73	0.0513	0.0212
572	3822.86	0.0338	0.0230
672	3822.65	0.0323	0.0202
772	3822.81	0.0372	0.0223
872	3822.54	0.0371	0.0189
972	3822.91	0.0351	0.0237
1072	3823.53	0.0251	0.0345
1172	3823.49	0.0185	0.0337
1272	3823.71	0.0188	0.0383
173	3823.99	0.0159	0.0449
273	3824.39	0.0119	0.0559
28 PERIOD	QR=	-0.0016	
373	3824.49	0.0135	0.0590
473	3824.01	0.0191	0.0454
573	3824.38	0.0323	0.0556
673	3823.56	0.0477	0.0351
773	3824.17	0.0735	0.0496
873	3824.57	0.0839	0.0615
973	3824.59	0.0952	0.0622
1073	3824.50	0.1005	0.0593
1173	3824.08	0.0527	0.0472
1273	3823.97	0.0512	0.0444
174	3823.78	0.0436	0.0399
274	3823.54	0.0274	0.0347
29 PERIOD	QR=	0.0830	
374	3823.03	0.0336	0.0256
474	3823.69	0.0725	0.0379
574	3824.34	0.0783	0.0545
674	3824.74	0.0873	0.0672
774	3824.92	0.1050	0.0736
874	3825.02	0.1189	0.0773
974	3825.13	0.1168	0.0816
1074	3824.78	0.1089	0.0686
1174	3824.62	0.0645	0.0632
1274	3824.58	0.0509	0.0619
175	3825.07	0.0532	0.0793
275	3824.75	0.0408	0.0676
30 PERIOD	QR=	0.0337	
375	3825.09	0.0577	0.0800
475	3825.05	0.0751	0.0785
575	3825.34	0.0790	0.0902
675	3825.72	0.0860	0.1071

775	3825.57	0.1022	0.1002
875	3825.74	0.1143	0.1080
975	3825.62	0.1431	0.1025
1075	3825.24	0.1418	0.0860
1175	3824.88	0.1022	0.0722
1275	3824.48	0.0631	0.0587
176	3824.65	0.0709	0.0642
276	3824.59	0.0732	0.0622

31 PERIOD QR= -0.0001

376	3824.63	0.0784	0.0635
476	3825.34	0.0983	0.0902
576	3825.38	0.1158	0.0919
676	3825.92	0.1150	0.1167
776	3825.84	0.1109	0.1128
876	3824.60	0.1131	0.0625
976	3825.57	0.1114	0.1002
1076	3825.27	0.0822	0.0873
1176	3824.45	0.0630	0.0578
1276	3824.43	0.0572	0.0572
177	3824.22	0.0509	0.0510
277	3823.94	0.0436	0.0437

TRIDIAGONAL MATRIX COEFFS FOR THE 1 PERIOD

D	E	F
1.22	0.25	0.30
1.42	0.27	0.30
1.24	0.27	0.25
1.51	0.27	0.34
1.37	0.27	0.28
0.65	0.27	0.10
-0.19	0.00	-0.08

TRIDIAGONAL MATRIX COEFFS FOR THE 2 PERIOD

D	E	F
1.23	0.25	0.31
1.51	0.27	0.32
1.21	0.27	0.24
1.48	0.27	0.33
1.44	0.27	0.30
0.74	0.27	0.12
-0.08	0.00	-0.05

TRIDIAGONAL MATRIX COEFFS FOR THE 3 PERIOD

D	E	F
0.93	0.25	0.23
1.49	0.27	0.34
1.09	0.27	0.20
1.36	0.27	0.31
1.57	0.27	0.34
0.83	0.27	0.13
0.04	0.00	-0.02

TRIDIAGONAL MATRIX COEFFS FOR THE 4 PERIOD

D	E	F
1.06	0.25	0.27
1.25	0.27	0.26
0.92	0.27	0.18
1.26	0.27	0.29
1.37	0.27	0.29
0.66	0.27	0.10
-0.04	0.00	-0.04

TRIDIAGONAL MATRIX COEFFS FOR THE 5 PERIOD

D	E	F
1.01	0.25	0.25
1.33	0.27	0.29
1.11	0.27	0.22
1.06	0.27	0.22
1.14	0.27	0.24
0.63	0.27	0.10
-0.15	0.00	-0.07

TRIDIAGONAL MATRIX COEFFS FOR THE 6 PERIOD

D	E	F
1.05	0.25	0.26
0.84	0.27	0.15
0.68	0.27	0.14
0.94	0.27	0.22
0.87	0.27	0.18
0.66	0.27	0.13
0.44	0.00	0.08

TRIDIAGONAL MATRIX COEFFS FOR THE 7 PERIOD

D	E	F
-0.16	0.25	-0.04
0.34	0.27	0.10
0.21	0.27	0.03
0.32	0.27	0.08

0.53	0.27	0.12
0.71	0.27	0.16
0.12	0.00	-0.01

TRIDIAGONAL MATRIX COEFFS FOR THE 8 PERIOD

D	E	F
0.53	0.25	0.13
0.20	0.27	0.02
0.05	0.27	0.01
0.13	0.27	0.03
0.13	0.27	0.03
0.48	0.27	0.12
0.05	0.00	-0.02

TRIDIAGONAL MATRIX COEFFS FOR THE 9 PERIOD

D	E	F
-0.37	0.25	-0.09
-0.09	0.27	0.00
-0.31	0.27	-0.08
-0.62	0.27	-0.14
-0.43	0.27	-0.08
-0.09	0.27	-0.00
0.10	0.00	0.03

TRIDIAGONAL MATRIX COEFFS FOR THE 10 PERIOD

D	E	F
-0.89	0.25	-0.22
-0.53	0.27	-0.08
-0.77	0.27	-0.18
-0.48	0.27	-0.08
-0.31	0.27	-0.06
-0.24	0.27	-0.05
0.15	0.00	0.05

TRIDIAGONAL MATRIX COEFFS FOR THE 11 PERIOD

D	E	F
-0.66	0.25	-0.16
-0.32	0.27	-0.04
-0.77	0.27	-0.19
-0.94	0.27	-0.20
-0.88	0.27	-0.18
-0.33	0.27	-0.04
-0.08	0.00	-0.01

TRIDIAGONAL MATRIX COEFFS FOR THE 12 PERIOD

D	E	F
-1.12	0.25	-0.28
-0.68	0.27	-0.11
-0.53	0.27	-0.11
-0.43	0.27	-0.08
0.28	0.27	0.10
0.85	0.27	0.20
0.45	0.00	0.07

TRIDIAGONAL MATRIX COEFFS FOR THE 13 PERIOD

D	E	F
0.81	0.25	0.20
1.06	0.27	0.23
1.17	0.27	0.25
1.26	0.27	0.27
1.33	0.27	0.28
1.21	0.27	0.25
0.51	0.00	0.07

TRIDIAGONAL MATRIX COEFFS FOR THE 14 PERIOD

D	E	F
0.84	0.25	0.21
0.59	0.27	0.10
0.60	0.27	0.13
0.97	0.27	0.22
0.99	0.27	0.20
0.55	0.27	0.09
-0.10	0.00	-0.05

TRIDIAGONAL MATRIX COEFFS FOR THE 15 PERIOD

D	E	F
1.01	0.25	0.25
0.99	0.27	0.20
0.81	0.27	0.17
1.00	0.27	0.22
1.17	0.27	0.25
0.85	0.27	0.16
0.10	0.00	-0.01

TRIDIAGONAL MATRIX COEFFS FOR THE 16 PERIOD

D	E	F
0.48	0.25	0.12
0.73	0.27	0.16
0.49	0.27	0.09
0.75	0.27	0.18
0.68	0.27	0.14
0.60	0.27	0.12
0.00	0.00	-0.03

TRIDIAGONAL MATRIX COEFFS FOR THE 17 PERIOD

D	E	F
0.80	0.25	0.20
1.09	0.27	0.24
0.95	0.27	0.19
1.34	0.27	0.31
1.18	0.27	0.23
0.66	0.27	0.11
0.25	0.00	0.04

TRIDIAGONAL MATRIX COEFFS FOR THE 18 PERIOD

D	E	F
0.99	0.25	0.25
0.64	0.27	0.11
0.29	0.27	0.05
0.33	0.27	0.08
0.36	0.27	0.08
0.23	0.27	0.04
-0.02	0.00	-0.02

TRIDIAGONAL MATRIX COEFFS FOR THE 19 PERIOD

D	E	F
-0.61	0.25	-0.15
-0.36	0.27	-0.06
-0.62	0.27	-0.15
-0.84	0.27	-0.18
-1.05	0.27	-0.23
-0.54	0.27	-0.08
-0.11	0.00	-0.01

TRIDIAGONAL MATRIX COEFFS FOR THE 20 PERIOD

D	E	F
-0.89	0.25	-0.22
-0.89	0.27	-0.18
-0.16	0.27	0.00
0.32	0.27	0.08
1.05	0.27	0.26
1.16	0.27	0.24
0.24	0.00	0.00

TRIDIAGONAL MATRIX COEFFS FOR THE 21 PERIOD

D	E	F
0.74	0.25	0.18
0.90	0.27	0.19
0.86	0.27	0.18
1.01	0.27	0.22
1.22	0.27	0.27
1.01	0.27	0.20
0.22	0.00	0.00

TRIDIAGONAL MATRIX COEFFS FOR THE 22 PERIOD

D	E	F
0.46	0.25	0.12
-0.03	0.27	-0.04
-0.12	0.27	-0.02
0.01	0.27	0.01
0.35	0.27	0.09
0.69	0.27	0.16
0.18	0.00	0.01

TRIDIAGONAL MATRIX COEFFS FOR THE 23 PERIOD

D	E	F
0.63	0.25	0.16
0.05	0.27	-0.03
0.15	0.27	0.05
0.61	0.27	0.15
1.01	0.27	0.23
0.94	0.27	0.19
0.07	0.00	-0.03

TRIDIAGONAL MATRIX COEFFS FOR THE 24 PERIOD

D	E	F
0.75	0.25	0.19
0.54	0.27	0.09
0.36	0.27	0.07
1.04	0.27	0.26
1.54	0.27	0.34
1.02	0.27	0.18

0.05	0.00	-0.04

TRIDIAGONAL MATRIX COEFFS FOR THE 25 PERIOD

D	E	F
0.90	0.25	0.23
0.67	0.27	0.12
0.97	0.27	0.23
1.24	0.27	0.27
1.40	0.27	0.30
0.90	0.27	0.16
0.18	0.00	0.00

TRIDIAGONAL MATRIX COEFFS FOR THE 26 PERIOD

D	E	F
0.79	0.25	0.20
0.78	0.27	0.16
0.82	0.27	0.18
0.80	0.27	0.17
0.75	0.27	0.16
0.49	0.27	0.09
0.34	0.00	0.07

TRIDIAGONAL MATRIX COEFFS FOR THE 27 PERIOD

D	E	F
-0.64	0.25	-0.16
-0.45	0.27	-0.08
-0.45	0.27	-0.10
-0.44	0.27	-0.09
-0.48	0.27	-0.10
-0.35	0.27	-0.07
0.26	0.00	0.09

TRIDIAGONAL MATRIX COEFFS FOR THE 28 PERIOD

D	E	F
0.10	0.25	0.02
0.23	0.27	0.06
0.02	0.27	-0.01
0.12	0.27	0.03
0.97	0.27	0.25
0.64	0.27	0.11
0.33	0.00	0.06

TRIDIAGONAL MATRIX COEFFS FOR THE 29 PERIOD

D	E	F
-0.23	0.25	-0.06
0.59	0.27	0.17
0.51	0.27	0.09
0.28	0.27	0.05
0.12	0.27	0.02
0.10	0.27	0.02
-0.18	0.00	-0.05

TRIDIAGONAL MATRIX COEFFS FOR THE 30 PERIOD

D	E	F
0.46	0.25	0.12
0.45	0.27	0.09
0.78	0.27	0.19
0.57	0.27	0.10
0.43	0.27	0.09
0.47	0.27	0.10
0.07	0.00	-0.01

TRIDIAGONAL MATRIX COEFFS FOR THE 31 PERIOD

D	E	F
0.90	0.25	0.22
1.01	0.27	0.21
0.95	0.27	0.20
0.97	0.27	0.21
-0.23	0.27	-0.12
0.29	0.27	0.11
0.99	0.00	0.24

RECHARGE ESTIMATES FOR THE 1 TH PERIOD

DATE	RECHARGE (FT/MO)
346	0.2419
446	0.2507
546	0.1793
646	0.2712
746	0.2460
846	0.1194
946	-0.0771
1046	0.0000
1146	0.0000
1246	0.0000
147	0.0000
247	0.0000

RECHARGE ESTIMATES FOR THE 2 TH PERIOD

DATE	RECHARGE (FT/MO)
347	0.2387
447	0.2768
547	0.1688
647	0.2618
747	0.2616
847	0.1323
947	-0.0518
1047	0.0000
1147	0.0000
1247	0.0000
148	0.0000
248	0.0000

RECHARGE ESTIMATES FOR THE 3 TH PERIOD

DATE	RECHARGE (FT/MO)
348	0.1589
448	0.2978
548	0.1409
648	0.2296
748	0.3008
848	0.1388
948	-0.0237
1048	0.0000
1148	0.0000
1248	0.0000
149	0.0000
249	0.0000

RECHARGE ESTIMATES FOR THE 4 TH PERIOD

DATE	RECHARGE (FT/MO)
349	0.2074
449	0.2307
549	0.1181
649	0.2215
749	0.2600
849	0.1091
949	-0.0362
1049	0.0000
1149	0.0000
1249	0.0000
150	0.0000
250	0.0000

RECHARGE ESTIMATES FOR THE 5 TH PERIOD

DATE	RECHARGE (FT/MO)
350	0.1930
450	0.2414
550	0.1745
650	0.1677
750	0.2124
850	0.1198
950	-0.0662
1050	0.0000
1150	0.0000
1250	0.0000
151	0.0000
251	0.0000

RECHARGE ESTIMATES FOR THE 6 TH PERIOD

DATE	RECHARGE (FT/MO)
351	0.2292
451	0.1288
551	0.0929
651	0.1755
751	0.1481
851	0.1062
951	0.0841
1051	0.0000
1151	0.0000
1251	0.0000
152	0.0000
252	0.0000

RECHARGE ESTIMATES FOR THE 7 TH PERIOD

DATE	RECHARGE (FT/MO)
352	-0.0655
452	0.0993
552	0.0121
652	0.0586
752	0.0773
852	0.1615
952	-0.0093
1052	0.0000
1152	0.0000
1252	0.0000
153	0.0000
253	0.0000

RECHARGE ESTIMATES FOR THE 8 TH PERIOD

DATE	RECHARGE (FT/MO)
353	0.1282
453	0.0175
553	0.0008
653	0.0340
753	-0.0083
853	0.1276
953	-0.0191
1053	0.0000
1153	0.0000

1253	0.0000
154	0.0000
254	0.0000

RECHARGE ESTIMATES FOR THE 9 TH PERIOD

DATE	RECHARGE (FT/MO)
354	-0.0953
454	0.0135
554	-0.0505
654	-0.1234
754	-0.0727
854	-0.0126
954	0.0287
1054	0.0000
1154	0.0000
1254	0.0000
155	0.0000
255	0.0000

RECHARGE ESTIMATES FOR THE 10 TH PERIOD

DATE	RECHARGE (FT/MO)
355	-0.2123
455	-0.0376
555	-0.1657
655	-0.0682
755	-0.0447
855	-0.0622
955	0.0540
1055	0.0000
1155	0.0000
1255	0.0000
156	0.0000
256	0.0000

RECHARGE ESTIMATES FOR THE 11 TH PERIOD

DATE	RECHARGE (FT/MO)
356	-0.1645
456	-0.0003
556	-0.1533
656	-0.1539
756	-0.1726
856	-0.0357
956	-0.0103
1056	0.0000
1156	0.0000
1256	0.0000
157	0.0000
257	0.0000

RECHARGE ESTIMATES FOR THE 12 TH PERIOD

DATE	RECHARGE (FT/MO)
357	-0.2594
457	-0.0829
557	-0.0867
657	-0.0981
757	0.0490
857	0.1851
957	0.0655
1057	0.0000
1157	0.0000
1257	0.0000
158	0.0000
258	0.0000

RECHARGE ESTIMATES FOR THE 13 TH PERIOD

DATE	RECHARGE (FT/MO)
358	0.1579
458	0.1765
558	0.1949
658	0.2116
758	0.2217
858	0.2308
958	0.0698
1058	0.0000
1158	0.0000
1258	0.0000
159	0.0000
259	0.0000

RECHARGE ESTIMATES FOR THE 14 TH PERIOD

DATE	RECHARGE (FT/MO)
359	0.1894
459	0.0790
559	0.0862
659	0.1758
759	0.1759
859	0.1061
959	-0.0518
1059	0.0000
1159	0.0000
1259	0.0000
160	0.0000
260	0.0000

RECHARGE ESTIMATES FOR THE 15 TH PERIOD

DATE	RECHARGE (FT/MO)
360	0.2118
460	0.1634
560	0.1207

660	0.1662
760	0.2110
860	0.1632
960	-0.0146
1060	0.0000
1160	0.0000
1260	0.0000
161	0.0000
261	0.0000

RECHARGE ESTIMATES FOR THE 16 TH PERIOD

DATE	RECHARGE (FT/MO)
361	0.0839
461	0.1495
561	0.0478
661	0.1510
761	0.0999
861	0.1320
961	-0.0319
1061	0.0000
1161	0.0000
1261	0.0000
162	0.0000
262	0.0000

RECHARGE ESTIMATES FOR THE 17 TH PERIOD

DATE	RECHARGE (FT/MO)
362	0.1479
462	0.2051
562	0.1227
662	0.2524
762	0.2065
862	0.1052
962	0.0352
1062	0.0000
1162	0.0000
1262	0.0000
163	0.0000
263	0.0000

RECHARGE ESTIMATES FOR THE 18 TH PERIOD

DATE	RECHARGE (FT/MO)
363	0.2236
463	0.0961
563	0.0348
663	0.0581
763	0.0647
863	0.0444
963	-0.0159
1063	0.0000
1163	0.0000
1263	0.0000
164	0.0000
264	0.0000

RECHARGE ESTIMATES FOR THE 19 TH PERIOD

DATE	RECHARGE (FT/MO)
364	-0.1449
464	-0.0255
564	-0.1173
664	-0.1277
764	-0.2095
864	-0.0813
964	-0.0063
1064	0.0000
1164	0.0000
1264	0.0000
165	0.0000
265	0.0000

RECHARGE ESTIMATES FOR THE 20 TH PERIOD

DATE	RECHARGE (FT/MO)
365	-0.1783
465	-0.1760
565	-0.0042
665	0.0329
765	0.1924
865	0.2429
965	0.0001
1065	0.0000
1165	0.0000
1265	0.0000
166	0.0000
266	0.0000

RECHARGE ESTIMATES FOR THE 21 TH PERIOD

DATE	RECHARGE (FT/MO)
366	0.1459
466	0.1557
566	0.1338
666	0.1668
766	0.2135
866	0.1979
966	0.0044
1066	0.0000
1166	0.0000
1266	0.0000
167	0.0000
267	0.0000

RECHARGE ESTIMATES FOR THE 22 TH PERIOD

DATE	RECHARGE (FT/MO)
367	0.1239
467	-0.0328
567	-0.0200
667	-0.0038
767	0.0494
867	0.1580
967	0.0066
1067	0.0000
1167	0.0000
1267	0.0000
168	0.0000
268	0.0000

RECHARGE ESTIMATES FOR THE 23 TH PERIOD

DATE	RECHARGE (FT/MO)
368	0.1669
468	-0.0342
568	0.0208
668	0.1042
768	0.1769
868	0.2002
968	-0.0331
1068	0.0000
1168	0.0000
1268	0.0000
169	0.0000
269	0.0000

RECHARGE ESTIMATES FOR THE 24 TH PERIOD

DATE	RECHARGE (FT/MO)
369	0.1664
469	0.0871
569	0.0230
669	0.1821
769	0.2926
869	0.1896
969	-0.0352
1069	0.0000
1169	0.0000
1269	0.0000
170	0.0000
270	0.0000

RECHARGE ESTIMATES FOR THE 25 TH PERIOD

DATE	RECHARGE (FT/MO)
370	0.2084
470	0.0714
570	0.1729
670	0.2025
770	0.2587
870	0.1601
970	0.0050
1070	0.0000
1170	0.0000
1270	0.0000
171	0.0000
271	0.0000

RECHARGE ESTIMATES FOR THE 26 TH PERIOD

DATE	RECHARGE (FT/MO)
371	0.1685
471	0.1175
571	0.1422
671	0.1293
771	0.1384
871	0.0708
971	0.0679
1071	0.0000
1171	0.0000
1271	0.0000
172	0.0000
272	0.0000

RECHARGE ESTIMATES FOR THE 27 TH PERIOD

DATE	RECHARGE (FT/MO)
372	-0.1458
472	-0.0550
572	-0.0820
672	-0.0697
772	-0.0798
872	-0.0887
972	0.0876
1072	0.0000
1172	0.0000
1272	0.0000
173	0.0000
273	0.0000

RECHARGE ESTIMATES FOR THE 28 TH PERIOD

DATE	RECHARGE (FT/MO)
373	0.0105
473	0.0566
573	-0.0030
673	-0.0262
773	0.2257
873	0.0889
973	0.0611
1073	0.0000
1173	0.0000

1273	0.0000
174	0.0000
274	0.0000

RECHARGE ESTIMATES FOR THE 29 TH PERIOD

DATE	RECHARGE (FT/MO)
374	-0.0942
474	0.1516
574	0.0781
674	0.0476
774	0.0098
874	0.0373
974	-0.0550
1074	0.0000
1174	0.0000
1274	0.0000
175	0.0000
275	0.0000

RECHARGE ESTIMATES FOR THE 30 TH PERIOD

DATE	RECHARGE (FT/MO)
375	0.1039
475	0.0447
575	0.1628
675	0.0862
775	0.0593
875	0.1033
975	-0.0071
1075	0.0000
1175	0.0000
1275	0.0000
176	0.0000
276	0.0000

RECHARGE ESTIMATES FOR THE 31 TH PERIOD

DATE	RECHARGE (FT/MO)
376	0.1812
476	0.1728
576	0.1349
676	0.2420
776	-0.1299
876	0.0452
976	0.2360
1076	0.0000
1176	0.0000
1276	0.0000
177	0.0000
277	0.0000

MODEL PREDICTIONS AND COMPUTATION OF ERRORS

DATE	PRED W.L.	OBS. W.L.	ABS. ERROR	SQ. OF ABS. ERR.			
346	3826.38	3826.38	0.00	0.0000		4	
446	3827.12	3827.34	-0.22	0.0474		3	
546	3827.72	3827.53	0.19	0.0375		3	
646	3827.91	3828.00	-0.09	0.0089		4	
746	3828.38	3828.36	0.02	0.0005		2	
846	3828.34	3828.42	-0.08	0.0057		4	
946	3827.75	3827.68	0.07	0.0044		4	
1046	3826.96	3826.84	0.12	0.0143		3	
1146	3826.48	3826.52	-0.04	0.0017		3	
1246	3826.23	3826.17	0.06	0.0038		3	
147	3825.96	3825.95	0.01	0.0000		3	
247	3825.78	3825.89	-0.11	0.0116		3	
ERRORS FOR 1 TH PERIOD		ABS=	-0.07	SQ(ABS)=	0.1358	RMS=	0.11
347	3826.23	3826.18	0.05	0.0022		4	
447	3826.99	3827.18	-0.19	0.0350		4	
547	3827.47	3827.50	-0.03	0.0008		3	
647	3827.80	3827.80	0.00	0.0000		4	
747	3828.23	3828.32	-0.09	0.0084		2	
847	3828.28	3828.32	-0.04	0.0014		4	
947	3827.70	3827.77	-0.07	0.0049		4	
1047	3827.00	3826.84	0.16	0.0269		3	
1147	3826.58	3826.38	0.20	0.0409		3	
1247	3826.26	3826.18	0.08	0.0061		3	
148	3826.00	3825.86	0.14	0.0209		3	
248	3825.80	3825.79	0.01	0.0002		3	
ERRORS FOR 2 TH PERIOD		ABS=	0.24	SQ(ABS)=	0.1475	RMS=	0.11
348	3825.97	3825.74	0.23	0.0538		4	
448	3826.52	3826.78	-0.26	0.0675		4	
548	3827.09	3827.21	-0.12	0.0143		3	
648	3827.39	3827.38	0.01	0.0000		4	
748	3827.93	3828.05	-0.12	0.0153		3	
848	3828.14	3828.24	-0.10	0.0091		4	
948	3827.66	3827.69	-0.03	0.0010		4	
1048	3827.02	3826.95	0.07	0.0049		3	
1148	3826.58	3826.58	0.00	0.0000		3	
1248	3826.25	3826.25	-0.00	0.0000		3	
149	3825.99	3825.89	0.10	0.0096		3	
249	3825.78	3825.86	-0.08	0.0063		3	
ERRORS FOR 3 TH PERIOD		ABS=	-0.30	SQ(ABS)=	0.1818	RMS=	0.12
349	3826.04	3826.17	-0.13	0.0160		4	
449	3826.87	3827.01	-0.14	0.0187		3	
549	3827.23	3827.27	-0.04	0.0013		3	
649	3827.49	3827.43	0.06	0.0031		4	
749	3827.96	3828.06	-0.10	0.0109		3	
849	3828.08	3828.11	-0.03	0.0010		4	
949	3827.58	3827.62	-0.04	0.0016		4	
1049	3826.99	3826.87	0.12	0.0143		3	
1149	3826.62	3826.52	0.10	0.0092		3	

1249	3826.33	3826.24	0.09	0.0079		3	
150	3826.11	3826.02	0.09	0.0073		3	
250	3825.93	3825.94	-0.01	0.0001		3	
ERRORS FOR	4 TH PERIOD	ABS=	-0.04	SQ(ABS)=	0.0915	RMS=	0.09
350	3826.19	3826.20	-0.01	0.0002		4	
450	3826.88	3826.98	-0.10	0.0104		4	
550	3827.36	3827.40	-0.04	0.0017		3	
650	3827.57	3827.59	-0.02	0.0003		3	
750	3827.81	3827.80	0.01	0.0001		3	
850	3827.89	3827.99	-0.10	0.0108		4	
950	3827.39	3827.38	0.01	0.0000		4	
1050	3826.77	3826.68	0.09	0.0086		3	
1150	3826.44	3826.33	0.11	0.0118		3	
1250	3826.18	3826.11	0.07	0.0049		3	
151	3825.98	3825.89	0.09	0.0075		3	
251	3825.82	3825.83	-0.01	0.0002		3	
ERRORS FOR	5 TH PERIOD	ABS=	0.08	SQ(ABS)=	0.0565	RMS=	0.07
351	3826.16	3825.93	0.23	0.0528		3	
451	3826.17	3826.31	-0.14	0.0182		3	
551	3826.09	3825.99	0.10	0.0097		2	
651	3826.12	3826.18	-0.06	0.0041		3	
751	3826.25	3826.23	0.02	0.0004		2	
851	3826.22	3826.28	-0.06	0.0041		3	
951	3826.06	3826.00	0.06	0.0031		3	
1051	3825.71	3825.82	-0.11	0.0121		3	
1151	3825.26	3825.74	-0.48	0.2344		3	
1251	3824.88	3824.76	0.12	0.0146		3	
152	3824.56	3824.69	-0.13	0.0159		3	
252	3824.29	3824.59	-0.30	0.0895		3	
ERRORS FOR	6 TH PERIOD	ABS=	-0.76	SQ(ABS)=	0.4591	RMS=	0.20
352	3823.91	3823.86	0.05	0.0025		2	
452	3823.95	3824.33	-0.38	0.1431		3	
552	3824.20	3824.33	-0.13	0.0165		2	
652	3824.33	3824.56	-0.23	0.0511		3	
752	3824.59	3824.69	-0.10	0.0100		3	
852	3825.03	3825.17	-0.14	0.0201		3	
952	3825.22	3825.45	-0.23	0.0550		3	
1052	3825.03	3824.96	0.07	0.0051		3	
1152	3824.90	3824.84	0.06	0.0033		3	
1252	3824.78	3824.70	0.08	0.0070		2	
153	3824.69	3824.71	-0.02	0.0005		2	
253	3824.61	3824.50	0.11	0.0111		3	
ERRORS FOR	7 TH PERIOD	ABS=	-0.86	SQ(ABS)=	0.3252	RMS=	0.16
353	3824.81	3824.65	0.16	0.0247		3	
453	3824.83	3825.01	-0.18	0.0339		3	
553	3824.71	3824.59	0.12	0.0133		2	
653	3824.64	3824.79	-0.15	0.0232		2	
753	3824.56	3824.48	0.08	0.0065		3	
853	3824.69	3824.72	-0.03	0.0007		2	
953	3824.78	3824.91	-0.13	0.0160		3	
1053	3824.59	3824.46	0.13	0.0167		2	
1153	3824.46	3824.40	0.06	0.0041		2	

1253	3824.36	3824.27		0.09		0.0072		2
154	3824.26	3824.33		-0.07		0.0049		2
254	3824.18	3823.95		0.23		0.0513		3
ERRORS FOR	8 TH PERIOD		ABS=	0.30	SQ(ABS)=	0.2025	RMS=	0.13
354	3823.90	3823.33		0.57		0.3202		2
454	3823.12	3823.30		-0.18		0.0335		2
554	3823.02	3823.13		-0.11		0.0124		3
654	3822.62	3822.79		-0.17		0.0281		3
754	3822.20	3822.20		-0.00		0.0000		2
854	3822.04	3822.20		-0.16		0.0247		2
954	3822.12	3822.13		-0.01		0.0001		2
1054	3822.23	3822.43		-0.20		0.0420		2
1154	3822.26	3822.38		-0.12		0.0145		2
1254	3822.29	3822.40		-0.11		0.0115		2
155	3822.32	3822.55		-0.23		0.0508		2
255	3822.35	3822.41		-0.06		0.0031		2
ERRORS FOR	9 TH PERIOD		ABS=	-0.78	SQ(ABS)=	0.5407	RMS=	0.21
355	3821.91	3821.36		0.55		0.2992		2
455	3820.87	3821.19		-0.32		0.1048		2
555	3820.49	3820.71		-0.22		0.0491		2
655	3820.05	3820.19		-0.14		0.0206		2
755	3819.89	3820.16		-0.27		0.0753		2
855	3819.74	3819.91		-0.17		0.0288		2
955	3819.82	3819.99		-0.17		0.0284		2
1055	3820.04	3820.34		-0.30		0.0877		2
1155	3820.14	3820.56		-0.42		0.1759		2
1255	3820.24	3820.73		-0.49		0.2438		2
156	3820.33	3820.77		-0.44		0.1930		2
256	3820.42	3820.66		-0.24		0.0558		2
ERRORS FOR	10 TH PERIOD		ABS=	-2.64	SQ(ABS)=	1.3625	RMS=	0.34
356	3820.14	3819.66		0.48		0.2312		2
456	3819.45	3819.98		-0.53		0.2823		2
556	3819.26	3819.50		-0.24		0.0554		2
656	3818.73	3819.14		-0.41		0.1679		2
756	3818.15	3818.40		-0.25		0.0604		2
856	3817.85	3818.14		-0.29		0.0834		2
956	3817.92	3818.25		-0.33		0.1085		2
1056	3818.07	3818.37		-0.30		0.0891		2
1156	3818.25	3818.59		-0.34		0.1185		2
1256	3818.42	3818.73		-0.31		0.0965		2
157	3818.59	3818.99		-0.40		0.1582		2
257	3818.76	3819.00		-0.24		0.0555		2
ERRORS FOR	11 TH PERIOD		ABS=	-3.15	SQ(ABS)=	1.5069	RMS=	0.35
357	3818.34	3818.13		0.21		0.0451		2
457	3817.56	3817.72		-0.16		0.0247		2
557	3817.39	3817.53		-0.14		0.0189		2
657	3817.19	3817.35		-0.16		0.0264		2
757	3817.29	3817.31		-0.02		0.0003		2
857	3818.05	3818.22		-0.17		0.0292		2
957	3818.84	3819.05		-0.21		0.0443		2
1057	3819.20	3819.33		-0.13		0.0162		2
1157	3819.41	3819.67		-0.26		0.0655		2

1257	3819.62	3819.81	-0.19	0.0347	2
158	3819.83	3820.17	-0.34	0.1145	2
258	3820.04	3820.07	-0.03	0.0011	2

ERRORS FOR 12 TH PERIOD ABS= -1.58 SQ(ABS)= 0.4209 RMS= 0.19

358	3820.60	3820.43	0.17	0.0291	2
458	3821.21	3821.34	-0.13	0.0172	3
558	3822.05	3822.05	0.00	0.0000	3
658	3822.94	3823.07	-0.13	0.0173	3
758	3823.82	3823.82	0.00	0.0000	3
858	3824.66	3824.79	-0.13	0.0164	3
958	3825.06	3825.15	-0.09	0.0074	3
1058	3824.92	3824.93	-0.01	0.0002	3
1158	3824.64	3824.66	-0.02	0.0003	3
1258	3824.41	3824.46	-0.05	0.0028	3
159	3824.20	3824.27	-0.07	0.0045	3
259	3824.02	3823.96	0.06	0.0040	3

ERRORS FOR 13 TH PERIOD ABS= -0.39 SQ(ABS)= 0.0993 RMS= 0.09

359	3824.27	3824.53	-0.26	0.0658	3
459	3824.96	3824.94	0.02	0.0004	3
559	3825.11	3825.02	0.09	0.0077	3
659	3825.43	3825.38	0.05	0.0028	3
759	3825.89	3825.89	-0.00	0.0000	3
859	3826.11	3826.10	0.01	0.0000	3
959	3825.81	3825.86	-0.05	0.0025	3
1059	3825.35	3825.18	0.17	0.0298	3
1159	3825.09	3824.88	0.21	0.0426	3
1259	3824.86	3824.68	0.18	0.0339	3
160	3824.68	3824.56	0.12	0.0134	3
260	3824.51	3824.42	0.09	0.0090	3

ERRORS FOR 14 TH PERIOD ABS= 0.63 SQ(ABS)= 0.2080 RMS= 0.13

360	3824.83	3824.82	0.01	0.0001	3
460	3825.44	3825.56	-0.12	0.0155	3
560	3825.75	3825.71	0.04	0.0019	3
660	3826.02	3826.07	-0.05	0.0030	3
760	3826.41	3826.36	0.05	0.0023	3
860	3826.71	3826.83	-0.12	0.0149	3
960	3826.48	3826.47	0.01	0.0001	3
1060	3825.97	3825.93	0.04	0.0015	3
1160	3825.59	3825.52	0.07	0.0055	3
1260	3825.29	3825.28	0.01	0.0001	3
161	3825.04	3825.01	0.03	0.0009	3
261	3824.83	3824.80	0.03	0.0010	1

ERRORS FOR 15 TH PERIOD ABS= -0.01 SQ(ABS)= 0.0467 RMS= 0.06

361	3824.83	3824.49	0.34	0.1165	3
461	3824.89	3825.28	-0.39	0.1496	3
561	3825.16	3825.19	-0.03	0.0010	3
661	3825.38	3825.57	-0.19	0.0346	3
761	3825.68	3825.77	-0.09	0.0086	3
861	3825.88	3825.95	-0.07	0.0055	3
961	3825.76	3825.95	-0.19	0.0354	3
1061	3825.40	3825.26	0.14	0.0184	3
1161	3825.16	3825.00	0.16	0.0265	3

1261	3824.97	3824.87	0.10	0.0099	3
162	3824.81	3824.71	0.10	0.0093	3
262	3824.67	3824.59	0.08	0.0061	3

ERRORS FOR 16 TH PERIOD ABS= -0.05 SQ(ABS)= 0.4215 RMS= 0.19

362	3824.86	3824.65	0.21	0.0460	3
462	3825.31	3825.56	-0.25	0.0648	3
562	3825.80	3825.83	-0.03	0.0011	3
662	3826.29	3826.35	-0.06	0.0038	4
762	3826.84	3826.98	-0.14	0.0187	3
862	3826.97	3827.00	-0.03	0.0008	3
962	3826.72	3826.79	-0.07	0.0045	3
1062	3826.32	3826.29	0.03	0.0007	3
1162	3825.93	3825.87	0.06	0.0035	3
1262	3825.62	3825.62	0.00	0.0000	3
163	3825.37	3825.41	-0.04	0.0015	3
263	3825.17	3825.07	0.10	0.0094	3

ERRORS FOR 17 TH PERIOD ABS= -0.22 SQ(ABS)= 0.1548 RMS= 0.11

363	3825.47	3825.64	-0.17	0.0302	3
463	3826.04	3826.01	0.03	0.0008	2
563	3825.97	3825.91	0.06	0.0032	3
663	3825.83	3825.76	0.07	0.0050	2
763	3825.79	3825.77	0.02	0.0002	2
863	3825.72	3825.68	0.04	0.0016	3
963	3825.50	3825.52	-0.02	0.0004	3
1063	3825.23	3825.13	0.10	0.0092	3
1163	3825.03	3824.99	0.04	0.0019	3
1263	3824.87	3824.88	-0.01	0.0001	3
164	3824.74	3824.74	-0.00	0.0000	2
264	3824.62	3824.50	0.12	0.0143	3

ERRORS FOR 18 TH PERIOD ABS= 0.26 SQ(ABS)= 0.0670 RMS= 0.07

364	3824.21	3823.56	0.65	0.4201	3
464	3823.15	3823.47	-0.32	0.1015	3
564	3822.83	3822.96	-0.13	0.0158	3
664	3822.31	3822.54	-0.23	0.0535	3
764	3821.60	3821.76	-0.16	0.0257	2
864	3821.02	3821.08	-0.06	0.0038	2
964	3820.91	3821.11	-0.20	0.0392	2
1064	3820.99	3821.10	-0.11	0.0116	2
1164	3821.09	3821.34	-0.25	0.0650	2
1264	3821.18	3821.48	-0.30	0.0924	2
165	3821.26	3821.49	-0.23	0.0508	2
265	3821.35	3821.45	-0.10	0.0098	2

ERRORS FOR 19 TH PERIOD ABS= -1.44 SQ(ABS)= 0.8892 RMS= 0.27

365	3821.03	3821.18	-0.15	0.0220	2
465	3820.43	3820.20	0.23	0.0518	2
565	3820.08	3819.96	0.12	0.0153	2
665	3820.22	3820.10	0.12	0.0144	2
765	3820.80	3820.59	0.21	0.0451	3
865	3821.85	3821.82	0.03	0.0008	3
965	3822.43	3822.44	-0.01	0.0002	1
1065	3822.43	3822.22	0.21	0.0462	2
1165	3822.44	3822.35	0.09	0.0086	1

1265	3822.45	3822.41	0.04	0.0016		2	
166	3822.46	3822.35	0.11	0.0115		1	
266	3822.46	3822.29	0.17	0.0303		2	
ERRORS FOR 20 TH PERIOD		ABS=	1.18	SQ(ABS)=	0.2477	RMS=	0.14
366	3822.80	3822.51	0.29	0.0814		3	
466	3823.14	3823.33	-0.19	0.0347		3	
566	3823.70	3823.71	-0.01	0.0000		3	
666	3824.24	3824.37	-0.13	0.0181		3	
766	3824.87	3824.85	0.02	0.0005		3	
866	3825.48	3825.65	-0.17	0.0293		2	
966	3825.54	3825.59	-0.05	0.0023		3	
1066	3825.18	3825.17	0.01	0.0001		3	
1166	3824.87	3824.83	0.04	0.0017		3	
1266	3824.61	3824.54	0.07	0.0048		3	
167	3824.38	3824.44	-0.06	0.0031		3	
267	3824.19	3824.11	0.08	0.0062		2	
ERRORS FOR 21 TH PERIOD		ABS=	-0.09	SQ(ABS)=	0.1822	RMS=	0.12
367	3824.28	3824.52	-0.24	0.0559		2	
467	3824.53	3824.45	0.08	0.0069		3	
567	3824.24	3824.12	0.12	0.0134		3	
667	3824.04	3823.98	0.06	0.0033		2	
767	3824.01	3823.89	0.12	0.0149		3	
867	3824.34	3824.27	0.07	0.0047		3	
967	3824.53	3824.62	-0.09	0.0075		3	
1067	3824.36	3824.17	0.19	0.0375		3	
1167	3824.20	3823.96	0.24	0.0584		2	
1267	3824.06	3823.86	0.20	0.0398		2	
168	3823.93	3823.87	0.06	0.0040		2	
268	3823.82	3823.57	0.25	0.0627		3	
ERRORS FOR 22 TH PERIOD		ABS=	1.07	SQ(ABS)=	0.3091	RMS=	0.16
368	3824.08	3824.26	-0.18	0.0318		2	
468	3824.35	3824.15	0.20	0.0394		3	
568	3824.11	3823.95	0.16	0.0262		2	
668	3824.20	3824.03	0.17	0.0295		3	
768	3824.62	3824.51	0.11	0.0112		3	
868	3825.18	3825.08	0.10	0.0090		2	
968	3825.20	3825.30	-0.10	0.0095		3	
1068	3824.80	3824.49	0.31	0.0982		3	
1168	3824.54	3824.45	0.09	0.0073		3	
1268	3824.30	3824.20	0.10	0.0108		3	
169	3824.10	3824.00	0.10	0.0103		3	
269	3823.92	3823.72	0.20	0.0410		3	
ERRORS FOR 23 TH PERIOD		ABS=	1.26	SQ(ABS)=	0.3242	RMS=	0.16
369	3824.12	3824.24	-0.12	0.0135		3	
469	3824.73	3824.75	-0.02	0.0005		3	
569	3824.84	3824.82	0.02	0.0006		3	
669	3825.14	3825.01	0.13	0.0174		4	
769	3825.95	3826.01	-0.06	0.0036		4	
869	3826.61	3826.63	-0.02	0.0004		3	
969	3826.46	3826.56	-0.10	0.0101		3	
1069	3825.95	3825.74	0.21	0.0452		3	
1169	3825.62	3825.38	0.24	0.0595		3	

1269	3825.36	3825.23	0.13	0.0164	3
170	3825.14	3825.10	0.04	0.0016	3
270	3824.96	3824.72	0.24	0.0566	3

ERRORS FOR 24 TH PERIOD ABS= 0.70 SQ(ABS)= 0.2254 RMS= 0.14

370	3825.24	3825.48	-0.24	0.0553	3
470	3825.75	3825.47	0.28	0.0804	3
570	3825.90	3825.80	0.10	0.0101	3
670	3826.29	3826.13	0.16	0.0248	3
770	3826.76	3826.71	0.05	0.0030	3
870	3827.05	3827.03	0.02	0.0002	3
970	3826.75	3826.72	0.03	0.0006	3
1070	3826.19	3826.07	0.12	0.0141	3
1170	3825.74	3825.97	-0.23	0.0518	3
1270	3825.38	3825.61	-0.23	0.0510	3
171	3825.09	3825.15	-0.06	0.0035	3
271	3824.85	3824.73	0.12	0.0133	3

ERRORS FOR 25 TH PERIOD ABS= 0.12 SQ(ABS)= 0.3083 RMS= 0.16

371	3825.00	3824.99	0.01	0.0000	3
471	3825.10	3824.88	0.22	0.0468	2
571	3825.13	3825.12	0.01	0.0001	2
671	3825.18	3825.02	0.16	0.0262	2
771	3825.22	3825.23	-0.01	0.0002	2
871	3825.13	3825.03	0.10	0.0091	3
971	3824.90	3824.88	0.02	0.0003	3
1071	3824.56	3824.52	0.04	0.0013	3
1171	3824.11	3824.45	-0.34	0.1124	3
1271	3823.72	3824.68	-0.96	0.9124	3
172	3823.37	3823.31	0.06	0.0040	3
272	3823.05	3823.11	-0.06	0.0035	3

ERRORS FOR 26 TH PERIOD ABS= -0.76 SQ(ABS)= 1.1163 RMS= 0.31

372	3822.43	3822.93	-0.50	0.2540	2
472	3822.77	3822.73	0.04	0.0018	1
572	3822.77	3822.86	-0.09	0.0087	2
672	3822.73	3822.65	0.08	0.0062	2
772	3822.70	3822.81	-0.11	0.0126	2
872	3822.63	3822.54	0.09	0.0074	2
972	3822.93	3822.91	0.02	0.0004	3
1072	3823.41	3823.53	-0.12	0.0142	3
1172	3823.66	3823.49	0.17	0.0290	3
1272	3823.89	3823.71	0.18	0.0310	3
173	3824.09	3823.99	0.10	0.0097	3
273	3824.27	3824.39	-0.12	0.0150	3

ERRORS FOR 27 TH PERIOD ABS= -0.28 SQ(ABS)= 0.3899 RMS= 0.18

373	3824.45	3824.49	-0.04	0.0018	2
473	3824.37	3824.01	0.36	0.1329	2
573	3824.24	3824.38	-0.14	0.0183	3
673	3823.95	3823.56	0.39	0.1530	3
773	3824.19	3824.17	0.02	0.0002	3
873	3824.64	3824.57	0.07	0.0047	2
973	3824.68	3824.59	0.09	0.0080	3
1073	3824.53	3824.50	0.03	0.0006	3
1173	3824.26	3824.08	0.18	0.0325	3

1273	3824.03	3823.97		0.06	0.0034		3
174	3823.82	3823.78		0.04	0.0017		2
274	3823.64	3823.54		0.10	0.0094		3
ERRORS FOR 28 TH PERIOD			ABS=	1.15	SQ(ABS)=	0.3665	RMS= 0.17
374	3823.26	3823.03		0.23	0.0538		3
474	3823.41	3823.69		-0.28	0.0784		3
574	3824.13	3824.34		-0.21	0.0431		3
674	3824.55	3824.74		-0.19	0.0359		3
774	3824.77	3824.92		-0.15	0.0234		3
874	3824.93	3825.02		-0.09	0.0081		1
974	3824.93	3825.13		-0.20	0.0397		2
1074	3824.85	3824.78		0.07	0.0053		2
1174	3824.90	3824.62		0.28	0.0799		2
1274	3824.94	3824.58		0.36	0.1331		2
175	3824.98	3825.07		-0.09	0.0080		2
275	3825.01	3824.75		0.26	0.0678		3
ERRORS FOR 29 TH PERIOD			ABS=	0.00	SQ(ABS)=	0.5766	RMS= 0.22
375	3825.25	3825.09		0.16	0.0270		3
475	3825.21	3825.05		0.16	0.0248		3
575	3825.43	3825.34		0.09	0.0079		3
675	3825.70	3825.72		-0.02	0.0006		1
775	3825.70	3825.57		0.13	0.0166		2
875	3825.74	3825.74		-0.00	0.0000		3
975	3825.63	3825.62		0.01	0.0001		3
1075	3825.32	3825.24		0.08	0.0070		3
1175	3825.09	3824.88		0.21	0.0439		3
1275	3824.89	3824.48		0.41	0.1712		3
176	3824.73	3824.65		0.08	0.0062		3
276	3824.59	3824.59		-0.00	0.0000		3
ERRORS FOR 30 TH PERIOD			ABS=	1.30	SQ(ABS)=	0.3053	RMS= 0.16
376	3824.85	3824.63		0.22	0.0493		3
476	3825.11	3825.34		-0.23	0.0526		3
576	3825.42	3825.38		0.04	0.0013		3
676	3825.81	3825.92		-0.11	0.0119		3
776	3825.58	3825.84		-0.26	0.0671		3
876	3824.98	3824.60		0.38	0.1451		3
976	3825.25	3825.57		-0.32	0.1003		3
1076	3825.38	3825.27		0.11	0.0131		3
1176	3825.00	3824.45		0.55	0.2994		3
1276	3824.67	3824.43		0.24	0.0587		3
177	3824.39	3824.22		0.17	0.0304		3
277	3824.15	3823.94		0.21	0.0451		3
ERRORS FOR 31 TH PERIOD			ABS=	1.02	SQ(ABS)=	0.8744	RMS= 0.27

SIMULATION ERRORS(TOTAL): ABSOLUTE ERROR= -4.08 SQUARE OF ABSOL.= 12.54 ROOT MEAN SQ. ERROR= 0.1

MODEL PREDICTIONS AND COMPUTATION OF ERRORS

DATE	PRED. DRAIN	OBS. DRAIN	ABS. ERROR	SQ. OF ABS. ERR.
346	0.1405	0.1268	0.0137	0.0002
446	0.1835	0.2031	-0.0196	0.0004
546	0.2216	0.2308	-0.0092	0.0001
646	0.2336	0.2485	-0.0149	0.0002
746	0.2658	0.2853	-0.0195	0.0004
846	0.2632	0.3010	-0.0378	0.0014
946	0.2231	0.2441	-0.0210	0.0004
1046	0.1737	0.1613	0.0124	0.0002
1146	0.1459	0.1254	0.0205	0.0004
1246	0.1326	0.1122	0.0204	0.0004
147	0.1185	0.0973	0.0212	0.0005
247	0.1100	0.0773	0.0327	0.0011

ERRORS FOR 1 TH PERIOD ABS= -0.00 SQ(ABS)= 0.0056 RMS= 0.02

347	0.1323	0.1103	0.0220	0.0005
447	0.1757	0.1827	-0.0070	0.0000
547	0.2054	0.1991	0.0063	0.0000
647	0.2267	0.2097	0.0170	0.0003
747	0.2553	0.2498	0.0055	0.0000
847	0.2590	0.2636	-0.0046	0.0000
947	0.2201	0.2178	0.0023	0.0000
1047	0.1763	0.1372	0.0391	0.0015
1147	0.1517	0.1059	0.0458	0.0021
1247	0.1340	0.0913	0.0427	0.0018
148	0.1209	0.0829	0.0380	0.0014
248	0.1111	0.0718	0.0393	0.0015

ERRORS FOR 2 TH PERIOD ABS= 0.25 SQ(ABS)= 0.0094 RMS= 0.03

348	0.1193	0.0743	0.0450	0.0020
448	0.1483	0.1482	0.0001	0.0000
548	0.1816	0.1872	-0.0056	0.0000
648	0.2000	0.1940	0.0060	0.0000
748	0.2350	0.2534	-0.0184	0.0003
848	0.2496	0.2770	-0.0274	0.0008
948	0.2174	0.2424	-0.0250	0.0006
1048	0.1773	0.1617	0.0156	0.0002
1148	0.1519	0.1201	0.0318	0.0010
1248	0.1335	0.1132	0.0203	0.0004
149	0.1201	0.1043	0.0158	0.0002
249	0.1100	0.0821	0.0279	0.0008

ERRORS FOR 3 TH PERIOD ABS= 0.09 SQ(ABS)= 0.0065 RMS= 0.02

349	0.1229	0.1180	0.0049	0.0000
449	0.1685	0.1957	-0.0272	0.0007
549	0.1904	0.2188	-0.0284	0.0008
649	0.2063	0.2280	-0.0217	0.0005
749	0.2369	0.2755	-0.0386	0.0015
849	0.2452	0.2839	-0.0387	0.0015
949	0.2123	0.2226	-0.0103	0.0001
1049	0.1755	0.1478	0.0277	0.0008
1149	0.1536	0.1283	0.0253	0.0006

1249	0.1378	0.1104	0.0274	0.0007
150	0.1260	0.0945	0.0315	0.0010
250	0.1172	0.0775	0.0397	0.0016

ERRORS FOR 4 TH PERIOD ABS= -0.01 SQ(ABS)= 0.0099 RMS= 0.03

350	0.1303	0.1381	-0.0078	0.0001
450	0.1688	0.1884	-0.0196	0.0004
550	0.1982	0.2036	-0.0054	0.0000
650	0.2119	0.2085	0.0034	0.0000
750	0.2272	0.2629	-0.0357	0.0013
850	0.2323	0.2636	-0.0313	0.0010
950	0.2000	0.2296	-0.0296	0.0009
1050	0.1627	0.1606	0.0021	0.0000
1150	0.1437	0.1176	0.0261	0.0007
1250	0.1299	0.1017	0.0282	0.0008
151	0.1195	0.0922	0.0273	0.0007
251	0.1116	0.0658	0.0458	0.0021

ERRORS FOR 5 TH PERIOD ABS= 0.00 SQ(ABS)= 0.0079 RMS= 0.03

351	0.1288	0.0760	0.0528	0.0028
451	0.1296	0.1246	0.0050	0.0000
551	0.1252	0.1127	0.0125	0.0002
651	0.1266	0.1116	0.0150	0.0002
751	0.1336	0.1381	-0.0045	0.0000
851	0.1318	0.1488	-0.0170	0.0003
951	0.1235	0.1171	0.0064	0.0000
1051	0.1066	0.0711	0.0355	0.0013
1151	0.0867	0.0557	0.0310	0.0010
1251	0.0722	0.0531	0.0191	0.0004
152	0.0613	0.0461	0.0152	0.0002
252	0.0530	0.0360	0.0170	0.0003

ERRORS FOR 6 TH PERIOD ABS= 0.19 SQ(ABS)= 0.0067 RMS= 0.02

352	0.0429	0.0309	0.0120	0.0001
452	0.0440	0.0607	-0.0167	0.0003
552	0.0505	0.0770	-0.0265	0.0007
652	0.0543	0.0837	-0.0294	0.0009
752	0.0622	0.0893	-0.0271	0.0007
852	0.0777	0.1082	-0.0305	0.0009
952	0.0850	0.0984	-0.0134	0.0002
1052	0.0778	0.0689	0.0089	0.0001
1152	0.0728	0.0529	0.0199	0.0004
1252	0.0687	0.0527	0.0160	0.0003
153	0.0654	0.0471	0.0183	0.0003
253	0.0627	0.0306	0.0321	0.0010

ERRORS FOR 7 TH PERIOD ABS= -0.04 SQ(ABS)= 0.0059 RMS= 0.02

353	0.0695	0.0284	0.0411	0.0017
453	0.0702	0.0798	-0.0096	0.0001
553	0.0660	0.0774	-0.0114	0.0001
653	0.0638	0.0766	-0.0128	0.0002
753	0.0612	0.1000	-0.0388	0.0015
853	0.0656	0.1165	-0.0509	0.0026
953	0.0687	0.0933	-0.0246	0.0006
1053	0.0622	0.0553	0.0069	0.0000
1153	0.0582	0.0440	0.0142	0.0002

1253	0.0549	0.0381	0.0168	0.0003
154	0.0521	0.0339	0.0182	0.0003
254	0.0498	0.0239	0.0259	0.0007

ERRORS FOR 8 TH PERIOD ABS= -0.02 SQ(ABS)= 0.0083 RMS= 0.03

354	0.0426	0.0164	0.0262	0.0007
454	0.0269	0.0365	-0.0096	0.0001
554	0.0254	0.0394	-0.0140	0.0002
654	0.0199	0.0323	-0.0124	0.0002
754	0.0152	0.0307	-0.0155	0.0002
854	0.0138	0.0279	-0.0141	0.0002
954	0.0145	0.0184	-0.0039	0.0000
1054	0.0155	0.0171	-0.0016	0.0000
1154	0.0158	0.0131	0.0027	0.0000
1254	0.0161	0.0117	0.0044	0.0000
155	0.0165	0.0110	0.0055	0.0000
255	0.0168	0.0073	0.0095	0.0001

ERRORS FOR 9 TH PERIOD ABS= -0.02 SQ(ABS)= 0.0017 RMS= 0.01

355	0.0126	0.0039	0.0087	0.0001
455	0.0064	0.0106	-0.0042	0.0000
555	0.0050	0.0093	-0.0043	0.0000
655	0.0037	0.0029	0.0008	0.0000
755	0.0033	0.0089	-0.0056	0.0000
855	0.0030	0.0093	-0.0063	0.0000
955	0.0032	0.0111	-0.0079	0.0001
1055	0.0037	0.0072	-0.0035	0.0000
1155	0.0039	0.0036	0.0003	0.0000
1255	0.0042	0.0037	0.0005	0.0000
156	0.0045	0.0032	0.0013	0.0000
256	0.0047	0.0029	0.0018	0.0000

ERRORS FOR 10 TH PERIOD ABS= -0.02 SQ(ABS)= 0.0003 RMS= 0.00

356	0.0039	0.0014	0.0025	0.0000
456	0.0025	0.0077	-0.0052	0.0000
556	0.0022	0.0058	-0.0036	0.0000
656	0.0015	0.0037	-0.0022	0.0000
756	0.0010	0.0050	-0.0040	0.0000
856	0.0008	0.0035	-0.0027	0.0000
956	0.0009	0.0029	-0.0020	0.0000
1056	0.0010	0.0020	-0.0010	0.0000
1156	0.0011	0.0016	-0.0005	0.0000
1256	0.0012	0.0021	-0.0009	0.0000
157	0.0014	0.0023	-0.0009	0.0000
257	0.0015	0.0019	-0.0004	0.0000

ERRORS FOR 11 TH PERIOD ABS= -0.02 SQ(ABS)= 0.0001 RMS= 0.00

357	0.0012	0.0010	0.0002	0.0000
457	0.0007	0.0015	-0.0008	0.0000
557	0.0006	0.0013	-0.0007	0.0000
657	0.0005	0.0013	-0.0008	0.0000
757	0.0006	0.0037	-0.0031	0.0000
857	0.0010	0.0088	-0.0078	0.0001
957	0.0016	0.0190	-0.0174	0.0003
1057	0.0021	0.0144	-0.0123	0.0002
1157	0.0024	0.0111	-0.0087	0.0001

1257	0.0028	0.0082	-0.0054	0.0000
158	0.0032	0.0065	-0.0033	0.0000
258	0.0037	0.0043	-0.0006	0.0000

ERRORS FOR 12 TH PERIOD ABS= -0.06 SQ(ABS)= 0.0006 RMS= 0.01

358	0.0053	0.0105	-0.0052	0.0000
458	0.0080	0.0295	-0.0215	0.0005
558	0.0138	0.0394	-0.0256	0.0007
658	0.0242	0.0580	-0.0338	0.0011
758	0.0409	0.0790	-0.0381	0.0015
858	0.0646	0.0953	-0.0307	0.0009
958	0.0790	0.0946	-0.0156	0.0002
1058	0.0734	0.0747	-0.0013	0.0000
1158	0.0639	0.0563	0.0076	0.0001
1258	0.0565	0.0459	0.0106	0.0001
159	0.0505	0.0388	0.0117	0.0001
259	0.0458	0.0352	0.0106	0.0001

ERRORS FOR 13 TH PERIOD ABS= -0.13 SQ(ABS)= 0.0053 RMS= 0.02

359	0.0525	0.0560	-0.0035	0.0000
459	0.0751	0.0887	-0.0136	0.0002
559	0.0807	0.1083	-0.0276	0.0008
659	0.0941	0.1197	-0.0256	0.0007
759	0.1150	0.1658	-0.0508	0.0026
859	0.1260	0.1757	-0.0497	0.0025
959	0.1114	0.1362	-0.0248	0.0006
1059	0.0907	0.0898	0.0009	0.0000
1159	0.0799	0.0730	0.0069	0.0000
1259	0.0716	0.0671	0.0045	0.0000
160	0.0650	0.0581	0.0069	0.0000
260	0.0598	0.0428	0.0170	0.0003

ERRORS FOR 14 TH PERIOD ABS= -0.16 SQ(ABS)= 0.0077 RMS= 0.03

360	0.0703	0.0654	0.0049	0.0000
460	0.0943	0.1073	-0.0130	0.0002
560	0.1087	0.1179	-0.0092	0.0001
660	0.1214	0.1309	-0.0095	0.0001
760	0.1421	0.1700	-0.0279	0.0008
860	0.1589	0.2072	-0.0483	0.0023
960	0.1460	0.1730	-0.0270	0.0007
1060	0.1191	0.1089	0.0102	0.0001
1160	0.1013	0.0793	0.0220	0.0005
1260	0.0881	0.0647	0.0234	0.0005
161	0.0781	0.0589	0.0192	0.0004
261	0.0704	0.0504	0.0200	0.0004

ERRORS FOR 15 TH PERIOD ABS= -0.04 SQ(ABS)= 0.0061 RMS= 0.02

361	0.0704	0.0565	0.0139	0.0002
461	0.0726	0.0888	-0.0162	0.0003
561	0.0828	0.0962	-0.0134	0.0002
661	0.0920	0.1077	-0.0157	0.0002
761	0.1051	0.1314	-0.0263	0.0007
861	0.1145	0.1404	-0.0259	0.0007
961	0.1091	0.1250	-0.0159	0.0003
1061	0.0925	0.0875	0.0050	0.0000
1161	0.0829	0.0669	0.0160	0.0003

1261	0.0754	0.0623	0.0131	0.0002
162	0.0695	0.0589	0.0106	0.0001
262	0.0648	0.0423	0.0225	0.0005

ERRORS FOR 16 TH PERIOD ABS= -0.03 SQ(ABS)= 0.0036 RMS= 0.02

362	0.0716	0.0669	0.0047	0.0000
462	0.0887	0.1065	-0.0178	0.0003
562	0.1107	0.1155	-0.0048	0.0000
662	0.1356	0.1378	-0.0022	0.0000
762	0.1668	0.1722	-0.0054	0.0000
862	0.1744	0.1820	-0.0076	0.0001
962	0.1597	0.1685	-0.0088	0.0001
1062	0.1371	0.1094	0.0277	0.0008
1162	0.1171	0.0835	0.0336	0.0011
1262	0.1025	0.0760	0.0265	0.0007
163	0.0915	0.0691	0.0224	0.0005
263	0.0831	0.0519	0.0312	0.0010

ERRORS FOR 17 TH PERIOD ABS= 0.10 SQ(ABS)= 0.0046 RMS= 0.02

363	0.0956	0.0739	0.0217	0.0005
463	0.1226	0.1029	0.0197	0.0004
563	0.1190	0.0957	0.0233	0.0005
663	0.1124	0.0949	0.0175	0.0003
763	0.1102	0.1070	0.0032	0.0000
863	0.1071	0.1205	-0.0134	0.0002
963	0.0970	0.1048	-0.0078	0.0001
1063	0.0854	0.0654	0.0200	0.0004
1163	0.0779	0.0481	0.0298	0.0009
1263	0.0719	0.0471	0.0248	0.0006
164	0.0671	0.0417	0.0254	0.0006
264	0.0632	0.0303	0.0329	0.0011

ERRORS FOR 18 TH PERIOD ABS= 0.20 SQ(ABS)= 0.0056 RMS= 0.02

364	0.0507	0.0283	0.0224	0.0005
464	0.0275	0.0314	-0.0039	0.0000
564	0.0227	0.0192	0.0035	0.0000
664	0.0163	0.0133	0.0030	0.0000
764	0.0103	0.0150	-0.0047	0.0000
864	0.0070	0.0120	-0.0050	0.0000
964	0.0066	0.0137	-0.0071	0.0001
1064	0.0069	0.0076	-0.0007	0.0000
1164	0.0074	0.0053	0.0021	0.0000
1264	0.0078	0.0049	0.0029	0.0000
165	0.0083	0.0047	0.0036	0.0000
265	0.0088	0.0034	0.0054	0.0000

ERRORS FOR 19 TH PERIOD ABS= 0.02 SQ(ABS)= 0.0007 RMS= 0.01

365	0.0071	0.0035	0.0036	0.0000
465	0.0048	0.0097	-0.0049	0.0000
565	0.0038	0.0059	-0.0021	0.0000
665	0.0041	0.0151	-0.0110	0.0001
765	0.0061	0.0316	-0.0255	0.0007
865	0.0121	0.0425	-0.0304	0.0009
965	0.0176	0.0460	-0.0284	0.0008
1065	0.0177	0.0266	-0.0089	0.0001
1165	0.0177	0.0202	-0.0025	0.0000

1265	0.0178	0.0159	0.0019	0.0000
166	0.0179	0.0174	0.0005	0.0000
266	0.0180	0.0144	0.0036	0.0000

ERRORS FOR 20 TH PERIOD ABS= -0.10 SQ(ABS)= 0.0026 RMS= 0.01

366	0.0221	0.0193	0.0028	0.0000
466	0.0274	0.0369	-0.0095	0.0001
566	0.0382	0.0554	-0.0172	0.0003
666	0.0515	0.0728	-0.0213	0.0005
766	0.0719	0.0918	-0.0199	0.0004
866	0.0961	0.1308	-0.0347	0.0012
966	0.0989	0.1098	-0.0109	0.0001
1066	0.0836	0.0662	0.0174	0.0003
1166	0.0718	0.0480	0.0238	0.0006
1266	0.0628	0.0451	0.0177	0.0003
167	0.0558	0.0377	0.0181	0.0003
267	0.0502	0.0288	0.0214	0.0005

ERRORS FOR 21 TH PERIOD ABS= -0.01 SQ(ABS)= 0.0045 RMS= 0.02

367	0.0528	0.0392	0.0136	0.0002
467	0.0604	0.0508	0.0096	0.0001
567	0.0515	0.0447	0.0068	0.0000
667	0.0461	0.0472	-0.0011	0.0000
767	0.0455	0.0573	-0.0118	0.0001
867	0.0544	0.0631	-0.0087	0.0001
967	0.0604	0.0679	-0.0075	0.0001
1067	0.0552	0.0486	0.0066	0.0000
1167	0.0505	0.0333	0.0172	0.0003
1267	0.0467	0.0350	0.0117	0.0001
168	0.0435	0.0350	0.0085	0.0001
268	0.0408	0.0295	0.0113	0.0001

ERRORS FOR 22 TH PERIOD ABS= 0.06 SQ(ABS)= 0.0013 RMS= 0.01

368	0.0473	0.0375	0.0098	0.0001
468	0.0547	0.0558	-0.0011	0.0000
568	0.0481	0.0584	-0.0103	0.0001
668	0.0505	0.0603	-0.0098	0.0001
768	0.0630	0.0807	-0.0177	0.0003
868	0.0834	0.0994	-0.0160	0.0003
968	0.0845	0.0986	-0.0141	0.0002
1068	0.0694	0.0617	0.0077	0.0001
1168	0.0604	0.0486	0.0118	0.0001
1268	0.0534	0.0487	0.0047	0.0000
169	0.0478	0.0462	0.0016	0.0000
269	0.0432	0.0309	0.0123	0.0002

ERRORS FOR 23 TH PERIOD ABS= -0.02 SQ(ABS)= 0.0014 RMS= 0.01

369	0.0484	0.0451	0.0033	0.0000
469	0.0668	0.0682	-0.0014	0.0000
569	0.0708	0.0745	-0.0037	0.0000
669	0.0821	0.0770	0.0051	0.0000
769	0.1182	0.1193	-0.0011	0.0000
869	0.1534	0.1723	-0.0189	0.0004
969	0.1449	0.1465	-0.0016	0.0000
1069	0.1183	0.0948	0.0235	0.0006
1169	0.1026	0.0767	0.0259	0.0007

1269	0.0909	0.0704	0.0205	0.0004
170	0.0820	0.0598	0.0222	0.0005
270	0.0750	0.0507	0.0243	0.0006

ERRORS FOR 24 TH PERIOD ABS= 0.10 SQ(ABS)= 0.0031 RMS= 0.02

370	0.0862	0.0744	0.0118	0.0001
470	0.1087	0.1035	0.0052	0.0000
570	0.1157	0.1019	0.0138	0.0002
670	0.1356	0.1269	0.0087	0.0001
770	0.1622	0.1650	-0.0028	0.0000
870	0.1788	0.1746	0.0042	0.0000
970	0.1610	0.1553	0.0057	0.0000
1070	0.1303	0.0949	0.0354	0.0013
1170	0.1081	0.0712	0.0369	0.0014
1270	0.0920	0.0598	0.0322	0.0010
171	0.0801	0.0505	0.0296	0.0009
271	0.0709	0.0430	0.0279	0.0008

ERRORS FOR 25 TH PERIOD ABS= 0.21 SQ(ABS)= 0.0058 RMS= 0.02

371	0.0764	0.0577	0.0187	0.0004
471	0.0803	0.0749	0.0054	0.0000
571	0.0816	0.0661	0.0155	0.0002
671	0.0837	0.0668	0.0169	0.0003
771	0.0851	0.0847	0.0004	0.0000
871	0.0814	0.0975	-0.0161	0.0003
971	0.0728	0.0830	-0.0102	0.0001
1071	0.0611	0.0588	0.0023	0.0000
1171	0.0481	0.0403	0.0078	0.0001
1271	0.0386	0.0413	-0.0027	0.0000
172	0.0314	0.0360	-0.0046	0.0000
272	0.0259	0.0302	-0.0043	0.0000

ERRORS FOR 26 TH PERIOD ABS= 0.03 SQ(ABS)= 0.0014 RMS= 0.01

372	0.0176	0.0461	-0.0285	0.0008
472	0.0218	0.0513	-0.0295	0.0009
572	0.0217	0.0338	-0.0121	0.0001
672	0.0212	0.0323	-0.0111	0.0001
772	0.0208	0.0372	-0.0164	0.0003
872	0.0199	0.0371	-0.0172	0.0003
972	0.0241	0.0351	-0.0110	0.0001
1072	0.0321	0.0251	0.0070	0.0000
1172	0.0372	0.0185	0.0187	0.0003
1272	0.0424	0.0188	0.0236	0.0006
173	0.0475	0.0159	0.0316	0.0010
273	0.0524	0.0119	0.0405	0.0016

ERRORS FOR 27 TH PERIOD ABS= -0.00 SQ(ABS)= 0.0062 RMS= 0.02

373	0.0577	0.0135	0.0442	0.0020
473	0.0555	0.0191	0.0364	0.0013
573	0.0517	0.0323	0.0194	0.0004
673	0.0439	0.0477	-0.0038	0.0000
773	0.0501	0.0735	-0.0234	0.0005
873	0.0638	0.0839	-0.0201	0.0004
973	0.0652	0.0952	-0.0300	0.0009
1073	0.0601	0.1005	-0.0404	0.0016
1173	0.0522	0.0527	-0.0005	0.0000

1273	0.0459	0.0512	-0.0053	0.0000
174	0.0408	0.0436	-0.0028	0.0000
274	0.0367	0.0274	0.0093	0.0001

ERRORS FOR 28 TH PERIOD ABS= -0.02 SQ(ABS)= 0.0073 RMS= 0.02

374	0.0294	0.0336	-0.0042	0.0000
474	0.0321	0.0725	-0.0404	0.0016
574	0.0486	0.0783	-0.0297	0.0009
674	0.0609	0.0873	-0.0264	0.0007
774	0.0681	0.1050	-0.0369	0.0014
874	0.0740	0.1189	-0.0449	0.0020
974	0.0740	0.1168	-0.0428	0.0018
1074	0.0712	0.1089	-0.0377	0.0014
1174	0.0730	0.0645	0.0085	0.0001
1274	0.0745	0.0509	0.0236	0.0006
175	0.0759	0.0532	0.0227	0.0005
275	0.0770	0.0408	0.0362	0.0013

ERRORS FOR 29 TH PERIOD ABS= -0.17 SQ(ABS)= 0.0123 RMS= 0.03

375	0.0866	0.0577	0.0289	0.0008
475	0.0847	0.0751	0.0096	0.0001
575	0.0940	0.0790	0.0150	0.0002
675	0.1060	0.0860	0.0200	0.0004
775	0.1061	0.1022	0.0039	0.0000
875	0.1078	0.1143	-0.0065	0.0000
975	0.1028	0.1431	-0.0403	0.0016
1075	0.0895	0.1418	-0.0523	0.0027
1175	0.0800	0.1022	-0.0222	0.0005
1275	0.0727	0.0631	0.0096	0.0001
176	0.0668	0.0709	-0.0041	0.0000
276	0.0621	0.0732	-0.0111	0.0001

ERRORS FOR 30 TH PERIOD ABS= -0.05 SQ(ABS)= 0.0067 RMS= 0.02

376	0.0711	0.0784	-0.0073	0.0001
476	0.0808	0.0983	-0.0175	0.0003
576	0.0934	0.1158	-0.0224	0.0005
676	0.1114	0.1150	-0.0036	0.0000
776	0.1007	0.1109	-0.0102	0.0001
876	0.0759	0.1131	-0.0372	0.0014
976	0.0866	0.1114	-0.0248	0.0006
1076	0.0921	0.0822	0.0099	0.0001
1176	0.0765	0.0630	0.0135	0.0002
1276	0.0649	0.0572	0.0077	0.0001
177	0.0561	0.0509	0.0052	0.0000
277	0.0492	0.0436	0.0056	0.0000

ERRORS FOR 31 TH PERIOD ABS= -0.08 SQ(ABS)= 0.0034 RMS= 0.02

SIMULATION ERRORS(TOTAL): ABSOLUTE ERROR= 0.22 SQUARE OF ABSOL.= 0.15 ROOT MEAN SQ. ERROR= 0.02

MESILLA VALLEY, N. MEX.

CALC. RIVER LEAKAGE (AC-FT/MO)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	0.0	86.5	148.1	331.9	-418.0	495.5	46.7	303.2	1375.5	296.2
FEB	0.0	157.6	91.4	626.4	-543.9	235.6	47.5	200.2	352.5	94.9
MAR	0.0	2331.9	6508.3	5471.1	-8383.8	26402.0	2431.6	14678.5	6724.3	955.1
APR	0.0	1006.7	5343.1	3876.3	-5184.4	12856.5	2287.1	8380.3	7838.4	1051.3
MAY	2271.6	1225.6	4812.1	4245.0	-5617.2	7666.0	2387.6	9883.1	8424.6	1380.7
JUN	2759.3	2510.5	7724.0	4956.8	-7278.4	5524.4	2871.1	16038.1	8810.3	1115.2
JUL	3319.7	1636.6	7898.0	6334.8	-6884.1	15598.3	2312.8	15676.0	7027.2	820.4
AUG	3933.5	1179.1	6884.0	4349.3	-4488.1	12214.8	3749.1	13381.7	7871.8	1095.7
SEP	2039.5	574.8	1963.2	1481.3	-568.4	3305.6	1230.1	6805.3	5332.5	300.5
OCT	251.3	17.4	204.8	302.1	-493.1	2394.4	107.8	3540.4	265.8	26.5
NOV	255.3	55.7	430.0	157.9	-267.9	495.5	62.6	544.6	263.7	43.7
DEC	377.5	80.3	1660.7	324.5	-259.8	450.8	63.3	380.6	352.3	32.6

PERCENTAGE OF YEARLY RIVER LEAKAGE INTO ALLUVIAL AQUIFER:

10.0	5.1	16.9	12.2	-20.3	63.9	6.9	30.9	20.6	2.6

OBS. SURFACE DIVERSION (AC-FT/MO)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	42.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	524.0	8803.0
FEB	0.0	140.0	0.0	2765.0	0.0	0.0	0.0	0.0	1869.0	17997.0
MAR	53564.0	38533.0	54014.0	50867.0	52837.0	35761.0	28573.0	53611.0	32914.0	46384.0
APR	20365.0	25543.0	31427.0	37779.0	24843.0	14045.0	34098.0	41216.0	34217.0	46125.0
MAY	19464.0	19745.0	28564.0	38319.0	26080.0	6134.0	30615.0	42629.0	39052.0	51901.0
JUN	20373.0	41492.0	56173.0	52017.0	37214.0	7898.0	49954.0	60947.0	49920.0	53752.0
JUL	36916.0	47652.0	76475.0	72315.0	48677.0	28721.0	50503.0	49837.0	61914.0	56339.0
AUG	40136.0	55884.0	86025.0	70567.0	50274.0	26340.0	68790.0	54342.0	63515.0	68086.0
SEP	36241.0	33856.0	31047.0	39475.0	22729.0	6963.0	50858.0	32526.0	38279.0	39089.0
OCT	2520.0	2980.0	3950.0	4173.0	1120.0	40.0	4680.0	158.0	4020.0	3019.0
NOV	1310.0	972.0	1400.0	1211.0	0.0	0.0	0.0	0.0	0.0	0.0
DEC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

PERCENTAGE OF YEARLY RIVER FLOW THAT IS DIVERTED:

50.8	55.7	58.9	58.2	57.0	47.8	55.4	53.6	55.2	59.0

MESILLA VALLEY, N.MEX.
BLANEY-CRIDDLE CONSUMPTIVE USE (AC-FT/MO)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	363.5	213.9	248.8	383.1	279.3	238.7	0.0	102.8	541.8	353.3
FEB	205.3	153.6	226.8	149.1	144.7	160.6	7.0	114.3	974.3	440.3
MAR	11285.3	4906.2	9994.8	8517.5	12304.9	13094.4	9829.4	10771.0	10550.9	11333.6
APR	14924.1	13503.6	16135.3	15547.6	14912.3	16084.2	15283.7	16318.0	15304.0	12662.6
MAY	19415.2	23323.8	20838.4	23784.2	23616.3	22728.4	21695.4	25085.7	20990.3	21602.6
JUN	28247.6	38478.0	32869.7	38545.7	40634.3	29138.9	32638.3	41816.1	33752.1	32471.0
JUL	28296.1	25199.0	20167.6	37583.8	32590.5	33914.3	20137.6	23813.2	31648.1	29086.8
AUG	9814.4	6751.0	12661.5	14842.9	14268.1	8838.4	15672.3	8364.9	11937.8	15977.2
SEP	6612.5	6707.2	7382.2	9800.7	9293.9	6874.4	11123.4	3733.3	7133.3	7402.7
OCT	6861.4	6518.4	4628.7	7046.1	4610.4	1387.7	8132.1	3248.7	6125.9	4913.9
NOV	2364.0	771.1	2842.5	3457.6	2926.5	2765.5	3917.7	2948.4	2866.5	1439.2
DEC	125.0	200.2	0.0	289.7	133.5	123.9	324.3	79.2	148.7	204.6

CALC. GROUNDWATER PUMPAGE (AC-FT/MO)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	703.9	427.8	497.6	766.2	558.6	477.4	0.0	205.6	795.4	0.0
FEB	410.6	230.2	453.6	0.0	289.4	321.2	14.0	228.6	920.7	0.0
MAR	0.0	0.0	0.0	0.0	0.0	6520.3	3943.7	0.0	2999.1	0.0
APR	18647.4	12958.6	14985.8	10316.8	16161.0	24443.6	11813.5	9967.2	11788.7	0.0
MAY	28125.2	35787.9	25966.6	26492.9	32888.6	42083.1	26552.5	26725.4	20502.0	14659.7
JUN	45290.1	54135.4	34844.3	48482.1	60800.9	53933.9	37801.9	50111.4	40048.2	35378.4
JUL	36288.4	24189.4	0.0	35394.3	38408.7	52032.0	12498.6	20216.1	29243.5	27187.2
AUG	0.0	0.0	0.0	0.0	885.5	3189.8	0.0	0.0	0.0	0.0
SEP	0.0	0.0	0.0	0.0	6086.9	9919.2	0.0	0.0	0.0	0.0
OCT	12336.8	11397.8	7084.9	11797.0	8604.8	2753.4	13690.2	6410.5	10040.8	8167.4
NOV	4007.5	1007.6	4915.0	6249.2	5853.0	5531.0	7835.4	5896.8	5733.0	2878.4
DEC	250.0	400.4	0.0	579.4	267.0	247.8	648.6	158.4	297.4	409.2

MESILLA VALLEY, N.MEX.; HYDROSALINITY MODEL RESULTS FOR THE WATER YEAR 1967

MONTH	AQ. HEAD (PRED: FT)	DRAIN FLOW (PRD:AC-FT)	LEAS. QR (OB:AC-FT)	LEAS. CHEM (OB:MG/L)	AQ. CHEM (PRD:MG/L)	EL PASO QR (PD:AC-FT)	EL PASO QR (OB:AC-FT)	EL PA CHEM (PRD:MG/L)	EL PA CHEM (OBS:MG/L)
JAN	3824.38	6058.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FEB	3824.19	5447.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MAR	3824.28	5737.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00
APR	3824.53	6557.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MAY	3824.24	5590.50	42150.00	517.00	1626.00	26004.92	24209.00	755.41	831.00
JUN	3824.04	5010.21	47930.00	499.00	1632.66	29807.89	25298.00	689.55	805.00
JUL	3824.01	4939.81	70069.00	721.00	1637.31	34773.15	31663.00	851.17	756.00
AUG	3824.34	5912.20	79419.00	816.00	1646.21	41261.74	36122.00	934.96	692.00
SEP	3824.53	6558.01	56609.00	816.00	1646.95	24886.53	27475.00	1034.97	822.00
OCT	3824.36	5991.95	5030.00	838.00	1662.92	8250.62	5094.00	1437.10	1443.00
NOV	3824.20	5486.80	3860.00	1037.00	1664.07	7781.46	2522.00	1479.15	1662.00
DEC	3824.06	5072.18	3770.00	1221.00	1664.79	8464.69	2809.00	1486.93	1685.00
YEARLY AVERAGES:	3824.26	5696.99			1647.62	22653.88	19399.00	1083.65	1087.00

HYDRAULIC RESPONSE TIME = 2.9 MO.
SOLUTE RESPONSE TIME = 36.4 YRS.

ERRORS: DIFF BETWEEN PREDICTED AND OBSERVED RIVER FLOW & TDS AT EL PASO

TONSOF SALT AT EL PASO

MONTH	QPRED-QOBS (AC-FT)	CMPRED-CMOBS (MG/L)	TONS(PRED)	TONS (OBS)	DIFF
JAN	0.0	0.0	0.0	0.0	0.00
FEB	0.0	0.0	0.0	0.0	0.00
MAR	0.0	0.0	0.0	0.0	0.00
APR	0.0	0.0	0.0	0.0	0.00
MAY	1795.9	-75.6	26727.1	27371.0	-643.91
JUN	4509.9	-115.5	27964.7	27707.3	257.33
JUL	3110.2	95.2	40269.2	32567.7	7701.53
AUG	5139.7	243.0	52487.0	34008.7	18478.31
SEP	-2588.5	213.0	35043.3	30727.1	4316.14
OCT	3156.6	-5.9	16131.9	10000.9	6131.00
NOV	5259.5	-182.8	15659.8	5702.8	9957.01
DEC	5655.7	-198.1	17124.3	6439.7	10684.61
RMS ERRORS:	4122.6	160.2			9156.7

MESILLA VALLEY, N.MEX.; HYDROSALINITY MODEL RESULTS FOR THE WATER YEAR 1968

MONTH	AQ. HEAD (PRED: FT)	DRAIN FLOW (PRD:AC-FT)	LEAS. QR (OB:AC-FT)	LEAS. CHEM (OB:MG/L)	AQ. CHEM (PRD:MG/L)	EL PASO QR (PD:AC-FT)	EL PASO QR (OB:AC-FT)	EL PA CHEM (PRD:MG/L)	EL PA CHEM (OBS:MG/L)
JAN	3823.93	4725.48	1690.00	1118.00	1664.69	6329.02	2778.00	1526.18	1629.00
FEB	3823.82	4432.27	3220.00	1140.00	1664.66	7354.69	1878.00	1456.18	1669.00
MAR	3824.08	5135.12	84110.00	662.00	1664.71	48380.25	39553.00	768.43	847.00
APR	3824.35	5943.22	45220.00	721.00	1660.51	24613.48	27271.00	947.86	924.00
MAY	3824.11	5221.77	43700.00	662.00	1674.72	27951.15	23465.00	851.19	926.00
JUN	3824.20	5487.53	90560.00	600.00	1679.55	52045.06	41408.00	713.83	770.00
JUL	3824.62	6848.10	79640.00	628.00	1681.46	37199.49	46582.00	821.93	728.00
AUG	3825.18	9059.15	78930.00	514.00	1679.02	30926.05	40721.00	855.27	776.00
SEP	3825.20	9179.57	45090.00	649.00	1673.62	19838.80	23895.00	1123.10	972.00
OCT	3824.80	7540.30	3320.00	747.00	1689.89	7862.90	6630.00	1651.20	1540.00
NOV	3824.54	6564.43	2060.00	954.00	1691.21	7596.77	5000.00	1591.03	1567.00
DEC	3824.30	5801.36	1570.00	953.00	1691.74	7291.03	5227.00	1540.80	1503.00
YEARLY AVERAGES:	3824.43	6328.19			1676.31	23115.72	22034.00	1153.92	1154.25

HYDRAULIC RESPONSE TIME = 2.9 MO.
SOLUTE RESPONSE TIME = 21.9 YRS.

ERRORS: DIFF BETWEEN PREDICTED AND OBSERVED
RIVER FLOW & TDS AT EL PASO

MONTH	QPRED-QOBS (AC-FT)	CMPRED-CMOBS (MG/L)
JAN	3551.0	-102.8
FEB	5476.7	-212.8
MAR	8827.3	-78.6
APR	-2657.5	23.9
MAY	4486.2	-74.8
JUN	10637.1	-56.2
JUL	-9382.5	93.9
AUG	-9795.0	79.3
SEP	-4056.2	151.1
UCT	1232.9	111.2
NOV	2596.8	24.0
DEC	2064.0	37.8
RMS ERRORS:	6283.6	101.5

TONSOF SALT AT EL PASO

TONS(PRED)	TONS (OBS)	DIFF
13141.8	6157.0	6984.82
14571.1	4264.5	10306.65
50580.6	45580.1	5000.47
31741.5	34283.5	-2542.01
32369.8	29562.7	2807.12
50545.7	43379.8	7165.94
41599.2	46138.4	-4539.12
35986.5	42992.5	-7006.04
30314.3	31599.9	-1285.67
17664.3	13891.4	3772.85
16444.4	10659.9	5784.56
15284.4	10688.7	4595.71
		5670.6

MESILLA VALLEY, N.MEX.; HYDROSALINITY MODEL RESULTS FOR THE WATER YEAR 1969

MONTH	AQ. HEAD (PRED: FT)	DRAIN FLOW (PRD:AC-FT)	LEAS. QR (OB:AC-FT)	LEAS. CHEM (OB:MG/L)	AQ. CHEM (PRD:MG/L)	EL PASO QR (PD:AC-FT)	EL PASO QR (OB:AC-FT)	EL PA CHEM (PRD:MG/L)	EL PA CHEM (OBS:MG/L)
JAN	3824.10	5192.08	875.00	897.00	1691.70	5918.96	4687.00	1594.11	1653.00
FEB	3823.92	4696.72	540.00	933.00	1691.63	5145.31	2571.00	1625.49	1831.00
MAR	3824.12	5256.64	92460.00	520.00	1691.59	37194.33	42307.00	685.58	750.00
APR	3824.73	7257.83	62990.00	505.00	1685.54	33477.69	33723.00	760.94	807.00
MAY	3824.84	7696.13	56990.00	517.00	1681.75	31310.04	30947.00	803.30	811.00
JUN	3825.14	8916.29	101800.00	500.00	1684.70	46819.34	52791.00	725.61	671.00
JUL	3825.95	12835.81	123130.00	515.00	1676.23	51592.83	67715.00	803.90	608.00
AUG	3826.61	16660.09	126690.00	515.00	1662.85	50441.13	69244.00	894.12	621.00
SEP	3826.46	15737.81	42644.00	676.00	1664.09	25371.61	36607.00	1288.91	894.00
OCT	3825.95	12850.94	5160.00	1213.00	1678.91	13856.10	10842.00	1645.11	1448.00
NOV	3825.62	11148.77	3940.00	1294.00	1681.66	13258.78	6793.00	1619.97	1584.00
DEC	3825.36	9877.76	9810.00	1080.00	1682.63	18027.08	7180.00	1410.21	1396.00
YEARLY AVERAGES:	3825.23	9843.91			1681.11	27701.10	30450.58	1154.77	1089.50

HYDRAULIC RESPONSE TIME = 2.9 MO.
SOLUTE RESPONSE TIME = 11.9 YRS.

ERRORS: DIFF BETWEEN PREDICTED AND OBSERVED RIVER FLOW & TDS AT EL PASO

TONSOF SALT AT EL PASO

MONTH	QPRED-QOBS (AC-FT)	CMPRED-CMOBS (MG/L)	TONS(PRED)	TONS (OBS)	DIFF
JAN	1232.0	-58.9	12837.3	10541.0	2296.38
FEB	2574.3	-205.5	11379.1	6404.8	4974.34
MAR	-5112.7	-64.4	34693.4	43170.4	-8476.98
APR	-245.3	-46.1	34659.1	37026.5	-2367.41
MAY	363.0	-7.7	34219.5	34147.0	72.56
JUN	-5971.7	54.6	46221.5	48194.2	-1972.75
JUL	-16122.2	195.9	56429.5	56014.6	414.87
AUG	-18802.9	273.1	61361.1	58504.1	2856.97
SEP	-11235.4	394.9	44492.0	44526.1	-34.04
OCT	3014.1	197.1	31013.3	21359.5	9653.84
NOV	6465.8	36.0	29222.9	14639.6	14583.28
DEC	10847.1	14.2	34587.6	13637.1	20950.51
RMS ERRORS:	9029.6	174.2			8487.8

MESILLA VALLEY, N.MEX.; HYDROSALINITY MODEL RESULTS FOR THE WATER YEAR 1970

MONTH	AQ. HEAD (PRED: FT)	DRAIN FLOW (PRD:AC-FT)	LEAS. QR (OB:AC-FT)	LEAS. CHEM (OB:MG/L)	AQ. CHEM (PRD:MG/L)	EL PASO QR (PD:AC-FT)	EL PASO QR (OB:AC-FT)	EL PA CHEM (PRD:MG/L)	EL PA CHEM (OBS:MG/L)
JAN	3825.14	8906.45	2710.00	1118.00	1682.04	11284.56	5599.00	1563.17	1561.00
FEB	3824.96	8148.55	7880.00	1184.00	1681.93	12637.11	5572.00	1505.07	1339.00
MAR	3825.24	9365.57	95540.00	520.00	1683.69	48567.44	46386.00	744.40	645.00
APR	3825.75	11803.17	69430.00	505.00	1673.09	39577.85	38232.00	853.36	743.00
MAY	3825.90	12572.85	72980.00	515.00	1674.02	42988.89	40803.00	853.98	750.00
JUN	3826.29	14725.05	92490.00	500.00	1664.32	50241.29	46775.00	841.25	737.00
JUL	3826.76	17618.31	124040.00	456.00	1654.83	63008.51	67260.00	791.21	676.00
AUG	3827.05	19426.95	106080.00	449.00	1642.70	50590.64	54217.00	907.38	718.00
SEP	3826.75	17494.08	51570.00	743.00	1641.50	28107.79	31756.00	1302.22	925.00
OCT	3826.19	14157.13	6640.00	1088.00	1657.23	16321.99	7087.00	1581.73	1448.00
NOV	3825.74	11745.76	2500.00	1162.00	1659.79	12876.89	3932.00	1616.06	1530.00
DEC	3825.38	9998.40	2650.00	1029.00	1660.57	12323.85	3891.00	1541.39	1590.00
YEARLY AVERAGES:	3825.93	12996.86			1664.64	32377.23	29292.50	1175.10	1055.17

HYDRAULIC RESPONSE TIME = 2.9 MO.
SOLUTE RESPONSE TIME = 11.4 YRS.

ERRORS: DIFF BETWEEN PREDICTED AND OBSERVED RIVER FLOW & TDS AT EL PASO

MONTH	QPRED-QOBS (AC-FT)	CMPRED-CMOBS (MG/L)
JAN	5685.6	2.2
FEB	7065.1	166.1
MAR	2181.4	99.4
APR	1345.8	110.4
MAY	2185.9	104.0
JUN	3466.3	104.2
JUL	-4251.5	115.2
AUG	-3626.4	189.4
SEP	-3648.2	377.2
OCT	9235.0	133.7
NOV	8944.9	86.1
DEC	8432.8	-48.6
RMS ERRORS:	5675.6	155.6

TONSOF SALT AT EL PASO

TONS(PRED)	TONS (OBS)	DIFF
23999.6	11891.2	12108.43
25877.2	10150.9	15726.31
49188.7	40706.1	8482.63
45951.0	38648.1	7302.91
49947.6	41635.7	8311.87
57503.8	46902.3	10601.53
67827.5	61860.9	5966.64
62455.9	52963.0	9492.92
49799.4	39965.0	9834.36
35125.2	13961.9	21163.30
28312.7	8185.0	20127.71
25844.8	8417.3	17427.51
		13165.2

MESILLA VALLEY, N.MEX.; HYDROSALINITY MODEL RESULTS FOR THE WATER YEAR 1971

MONTH	AQ. HEAD (PRED: FT)	DRAIN FLOW (PRD:AC-FT)	LEAS. QR (OB:AC-FT)	LEAS. CHEM (OB:MG/L)	AQ. CHEM (PRD:MG/L)	EL PASO QR (PD:AC-FT)	EL PASO QR (OB:AC-FT)	EL PA CHEM (PRD:MG/L)	EL PA CHEM (OBS:MG/L)
JAN	3825.09	8697.05	2060.00	1022.00	1660.45	11175.10	5008.00	1542.76	1560.00
FEB	3824.85	7703.12	2680.00	1029.00	1660.45	10926.98	3187.00	1505.58	1640.00
MAR	3825.00	8301.75	94150.00	544.00	1660.45	57998.57	43173.00	865.19	695.00
APR	3825.10	8721.07	50390.00	493.00	1659.47	39452.43	30835.00	904.13	797.00
MAY	3825.13	8862.34	53760.00	485.00	1654.18	42159.56	33571.00	886.55	743.00
JUN	3825.18	9088.36	73080.00	456.00	1646.56	52232.80	37097.00	829.05	687.00
JUL	3825.22	9245.01	82600.00	493.00	1642.92	50052.15	39612.00	863.56	699.00
AUG	3825.13	8844.97	72390.00	463.00	1642.51	35449.07	28088.00	906.64	854.00
SEP	3824.90	7911.48	25530.00	706.00	1648.82	11280.90	13143.00	1414.72	1120.00
OCT	3824.56	6637.38	3550.00	272.00	1651.13	9560.51	4817.00	1300.59	1210.00
NOV	3824.11	5230.25	1320.00	882.00	1651.31	6818.12	2849.00	1502.37	1480.00
DEC	3823.72	4195.36	1280.00	882.00	1651.31	5735.11	2776.00	1479.61	1470.00
YEARLY AVERAGES:	3824.83	7786.51			1652.46	27736.77	20346.33	1166.73	1079.58

HYDRAULIC RESPONSE TIME = 2.9 MO.
SOLUTE RESPONSE TIME = 18.5 YRS.

ERRORS: DIFF BETWEEN PREDICTED AND OBSERVED RIVER FLOW & TDS AT EL PASO

MONTH	QPRED-QOBS (AC-FT)	CMPRED-CMOBS (MG/L)
JAN	6167.1	-17.2
FEB	7740.0	-134.4
MAR	14825.6	170.2
APR	8617.4	107.1
MAY	8588.6	143.6
JUN	15135.8	142.1
JUL	10440.1	164.6
AUG	7361.1	52.6
SEP	-1862.1	294.7
OCT	4743.5	90.6
NOV	3969.1	22.4
DEC	2959.1	9.6
RMS ERRORS:	8701.1	137.0

TONSOF SALT AT EL PASO

TONS(PRED)	TONS (OBS)	DIFF
23456.4	10629.2	12827.17
22382.9	7111.1	15271.72
68271.8	40823.4	27448.35
48531.0	33436.0	15094.98
50852.6	33936.4	16916.20
58916.8	34674.3	24242.44
58806.8	37671.8	21134.99
43727.1	32635.6	11091.49
21713.4	20027.4	1685.92
16917.5	7930.0	8987.45
13936.5	5736.8	8199.76
11545.2	5552.0	5993.22
		15836.1

MESILLA VALLEY, N.MEX.; HYDROSALINITY MODEL RESULTS FOR THE WATER YEAR 1972

MONTH	AQ. HEAD (PRED; FT)	DRAIN FLOW (PRD;AC-FT)	LEAS. QR (OB;AC-FT)	LEAS. CHEM (OB;MG/L)	AQ. CHEM (PRD;MG/L)	EL PASO QR (PD;AC-FT)	EL PASO QR (OB;AC-FT)	EL PA CHEM (PRD;MG/L)	EL PA CHEM (OBS;MG/L)
JAN	3823.37	3414.49	776.00	904.00	1651.31	3695.01	2495.00	1594.58	1600.00
FEB	3823.05	2812.19	369.00	912.00	1651.09	2945.58	1740.00	1617.62	1690.00
MAR	3822.43	1907.65	77110.00	485.00	1650.98	16854.67	33845.00	616.97	685.00
APR	3822.77	2370.11	34180.00	485.00	1658.80	9648.60	16312.00	773.34	807.00
MAY	3822.77	2361.47	18140.00	471.00	1659.79	6701.45	8898.00	869.91	961.00
JUN	3822.73	2306.14	16550.00	478.00	1665.06	5433.71	7165.00	981.80	1200.00
JUL	3822.70	2262.17	53150.00	441.00	1671.09	11092.87	24670.00	691.85	692.00
AUG	3822.63	2163.33	45470.00	478.00	1675.98	9078.53	21144.00	763.47	659.00
SEP	3822.93	2612.76	12140.00	757.00	1684.65	4484.17	10440.00	1297.51	1070.00
OCT	3823.41	3491.96	3790.00	824.00	1676.21	4847.52	5133.00	1437.90	1640.00
NOV	3823.66	4041.62	776.00	912.00	1674.99	4322.14	917.00	1625.47	2060.00
DEC	3823.89	4600.84	706.00	706.00	1674.76	4856.05	809.00	1623.85	926.00
YEARLY AVERAGES:	3823.03	2862.06			1666.23	6996.69	11130.67	1159.52	1165.83

HYDRAULIC RESPONSE TIME = 2.9 MO.
SOLUTE RESPONSE TIME = 40.3 YRS.

ERRORS: DIFF BETWEEN PREDICTED AND OBSERVED RIVER FLOW & TDS AT EL PASO

TONSOF SALT AT EL PASO

MONTH	QPRED-QOBS (AC-FT)	CMPRED-CMOBS (MG/L)	TONS(PRED)	TONS (OBS)	DIFF
JAN	1200.0	-5.4	8016.3	5431.3	2585.00
FEB	1205.6	-72.4	6482.8	4000.8	2481.93
MAR	-16990.3	-68.0	14148.0	31542.6	-17394.59
APR	-6663.4	-33.7	10151.8	17909.9	-7758.07
MAY	-2196.6	-71.1	8113.9	11634.0	-3520.13
JUN	-1731.3	-218.2	7258.3	11698.0	-4439.68
JUL	-13577.1	-0.1	10441.7	23226.7	-12785.05
AUG	-12065.5	104.5	9430.1	18957.7	-9527.55
SEP	-5955.8	227.5	7916.0	15198.4	-7282.39
OCT	-285.5	-202.1	9483.3	11453.2	-1969.90
NOV	3405.1	-434.5	9558.5	2570.1	6988.41
DEC	4047.1	697.8	10728.6	1019.2	9709.33
RMS ERRORS:	7838.1	265.1			8475.2

MESILLA VALLEY, N.MEX.; HYDROSALINITY MODEL RESULTS FOR THE WATER YEAR 1973

MONTH	AQ. HEAD (PRED: FT)	DRAIN FLOW (PRD:AC-FT)	LEAS. QR (OB:AC-FT)	LEAS. CHEM (OB:MG/L)	AQ. CHEM (PRD:MG/L)	EL PASO QR (PD:AC-FT)	EL PASO QR (OB:AC-FT)	EL PA CHEM (PRD:MG/L)	EL PA CHEM (OBS:MG/L)
JAN	3824.09	5154.48	680.00	618.00	1674.50	5787.78	465.00	1558.89	2040.00
FEB	3824.27	5688.74	692.00	824.00	1674.47	6333.21	344.00	1587.92	2090.00
MAR	3824.45	6267.06	63980.00	485.00	1674.44	39242.42	24938.00	674.96	552.00
APR	3824.37	6026.95	67400.00	507.00	1679.87	37041.87	30401.00	697.83	688.00
MAY	3824.24	5618.32	65380.00	552.00	1682.43	37995.77	31252.00	719.15	727.00
JUN	3823.95	4773.33	91760.00	522.00	1691.29	43708.23	44299.00	649.70	688.00
JUL	3824.19	5439.30	84180.00	456.00	1707.91	36803.47	53276.00	641.02	665.00
AUG	3824.64	6929.85	123380.00	485.00	1694.94	57770.78	58592.00	630.14	680.00
SEP	3824.68	7077.44	68770.00	529.00	1702.36	23759.30	38158.00	878.52	1080.00
OCT	3824.53	6529.50	6250.00	941.00	1710.79	7991.68	10008.00	1569.95	1478.00
NOV	3824.26	5665.25	912.00	1118.00	1713.38	6514.62	5512.00	1635.76	1617.00
DEC	3824.03	4983.62	922.00	1191.00	1713.36	5842.30	4544.00	1636.58	1419.00
YEARLY AVERAGES:	3824.31	5846.15			1693.31	25732.62	25149.08	1073.37	1143.67

HYDRAULIC RESPONSE TIME = 2.9 MO.
SOLUTE RESPONSE TIME = 26.6 YRS.

ERRORS: DIFF BETWEEN PREDICTED AND OBSERVED RIVER FLOW & TDS AT EL PASO

TONSOF SALT AT EL PASO

MONTH	QPRED-QOBS (AC-FT)	CMPRED-CMOBS (MG/L)	TONS(PRED)	TONS (OBS)	DIFF
JAN	5322.8	-481.1	12275.6	1290.6	10984.96
FEB	5989.2	-502.1	13682.5	978.2	12704.35
MAR	14304.4	123.0	36036.6	18728.9	17307.63
APR	6640.9	9.8	35168.8	28457.0	6711.79
MAY	6743.8	-7.8	37176.5	30911.8	6264.70
JUN	-590.8	-38.3	38635.5	41466.3	-2830.77
JUL	-16472.5	-24.0	32097.8	48202.1	-16104.30
AUG	-821.2	-49.9	49528.6	54207.6	-4678.99
SEP	-14398.7	-201.5	28398.7	56068.9	-27670.21
OCT	-2016.3	92.0	17070.1	20124.9	-3054.81
NOV	1002.6	18.8	14498.4	12126.4	2372.01
DEC	1298.3	217.6	13008.7	8772.7	4236.02
RMS ERRORS:	8390.7	223.6			12089.0

MESILLA VALLEY, N.MEX.; HYDROSALINITY MODEL RESULTS FOR THE WATER YEAR 1974

MONTH	AQ. HEAD (PRED: FT)	DRAIN FLOW (PRD:AC-FT)	LEAS. QR (OB:AC-FT)	LEAS. CHEM (OB:MG/L)	AQ. CHEM (PRD:MG/L)	EL PASO QR (PD:AC-FT)	EL PASO QR (OB:AC-FT)	EL PA CHEM (PRD:MG/L)	EL PA CHEM (OBS:MG/L)
JAN	3823.82	4435.21	980.00	1088.00	1713.34	5111.98	4270.00	1630.55	1574.00
FEB	3823.64	3987.34	647.00	978.00	1713.22	4434.14	3712.00	1639.14	1640.00
MAR	3823.26	3194.88	101050.00	532.00	1713.13	35955.40	49334.00	636.95	1050.00
APR	3823.41	3489.94	68300.00	397.00	1730.61	22193.66	35722.00	606.71	840.00
MAY	3824.13	5282.08	74570.00	419.00	1716.54	27339.96	36454.00	669.69	1239.00
JUN	3824.55	6617.31	112780.00	419.00	1710.84	42412.25	56888.00	620.56	637.00
JUL	3824.77	7402.06	100500.00	441.00	1708.44	42389.02	47254.00	662.32	819.00
AUG	3824.93	8035.51	97590.00	419.00	1708.61	37901.80	44018.00	692.41	770.00
SEP	3824.93	8039.29	54520.00	412.00	1707.78	23227.95	25925.00	860.48	836.00
OCT	3824.85	7732.20	11600.00	412.00	1716.58	15633.84	7087.00	1057.22	1138.00
NOV	3824.90	7927.31	1760.00	838.00	1713.87	9142.74	3932.00	1597.43	1592.00
DEC	3824.94	8095.63	1230.00	1103.00	1713.58	8945.05	3891.00	1655.60	1505.00
YEARLY AVERAGES:	3824.35	6186.56			1713.88	22890.65	26540.58	1027.42	1136.67

HYDRAULIC RESPONSE TIME = 2.9 MO.
SOLUTE RESPONSE TIME = 15.3 YRS.

ERRORS: DIFF BETWEEN PREDICTED AND OBSERVED RIVER FLOW & TDS AT EL PASO

TONSOF SALT AT EL PASO

MONTH	QPRED-QOBS (AC-FT)	CMPRED-CMOBS (MG/L)	TONS(PRED)	TONS (OBS)	DIFF
JAN	842.0	56.6	11340.6	9144.2	2196.40
FEB	722.1	-0.9	9888.7	8282.6	1606.12
MAR	-13378.6	-413.0	31159.0	70477.1	-39318.15
APR	-13528.3	-233.3	18319.9	40825.1	-22505.26
MAY	-9114.0	-569.3	24910.4	61451.0	-36540.60
JUN	-14475.8	-16.4	35808.5	49302.9	-13494.48
JUL	-4865.0	-156.7	38197.6	52654.5	-14456.84
AUG	-6116.2	-77.6	35705.5	46114.1	-10408.58
SEP	-2697.0	24.5	27193.3	29487.5	-2294.18
OCT	8546.8	-80.8	22487.6	10972.8	11514.82
NOV	5210.7	5.4	19870.6	8516.7	11353.93
DEC	5054.1	150.6	20148.9	7967.3	12181.62
RMS ERRORS:	8416.0	226.0			18950.9

MESILLA VALLEY, N.MEX.; HYDROSALINITY MODEL RESULTS FOR THE WATER YEAR 1975

MONTH	AQ. HEAD (PRED: FT)	DRAIN FLOW (PRD:AC-FT)	LEAS. QR (OB:AC-FT)	LEAS. CHEM (OB:MG/L)	AQ. CHEM (PRD:MG/L)	EL PASO QR (PD:AC-FT)	EL PASO QR (OB:AC-FT)	EL PA CHEM (PRD:MG/L)	EL PA CHEM (OBS:MG/L)
JAN	3824.98	8239.56	7200.00	412.00	1713.44	13540.04	9070.00	1203.97	1540.00
FEB	3825.01	8362.26	3580.00	463.00	1712.51	9720.72	6703.00	1537.89	1470.00
MAR	3825.25	9407.94	65550.00	412.00	1712.76	35319.62	32145.00	758.48	1106.00
APR	3825.21	9201.13	72260.00	426.00	1704.21	39405.75	38402.00	724.46	836.00
MAY	3825.43	10205.60	79940.00	515.00	1702.01	42669.04	41462.00	798.91	676.00
JUN	3825.70	11510.96	92680.00	515.00	1690.28	45460.70	49837.00	812.59	868.00
JUL	3825.70	11524.09	96020.00	500.00	1690.00	38602.89	49144.00	855.25	1022.00
AUG	3825.74	11709.08	101720.00	485.00	1696.87	42042.33	55585.00	822.51	878.00
SEP	3825.63	11164.52	64160.00	551.00	1698.18	31713.00	47040.00	954.86	1102.00
OCT	3825.32	9721.49	5310.00	390.00	1707.77	10745.70	13446.00	1582.17	1680.00
NOV	3825.09	8692.54	1280.00	390.00	1708.49	9708.81	9047.00	1570.48	1337.00
DEC	3824.89	7892.28	1710.00	412.00	1708.28	9249.96	8880.00	1518.02	1662.00
YEARLY AVERAGES:	3825.33	9802.62			1703.73	27348.21	30063.42	1094.97	1181.42

HYDRAULIC RESPONSE TIME = 2.9 MO.
SOLUTE RESPONSE TIME = 14.7 YRS.

ERRORS: DIFF BETWEEN PREDICTED AND OBSERVED RIVER FLOW & TDS AT EL PASO

TONSOF SALT AT EL PASO

MONTH	QPRED-QOBS (AC-FT)	CMPRED-CMOBS (MG/L)	TONS(PRED)	TONS (OBS)	DIFF
JAN	4470.0	-336.0	22179.4	19003.8	3175.54
FEB	3017.7	67.9	20339.3	13406.0	6933.32
MAR	3174.6	-347.5	36447.8	48370.6	-11922.73
APR	1003.8	-111.5	38840.5	43679.0	-4838.49
MAY	1207.0	122.9	46379.2	38133.8	8245.42
JUN	-4376.3	-55.4	50259.7	58855.1	-8595.45
JUL	-10541.1	-166.7	44918.6	68333.6	-23414.98
AUG	-13542.7	-55.5	47048.2	66399.5	-19351.31
SEP	-15327.0	-147.1	41199.4	70528.0	-29328.63
OCT	-2700.3	-97.8	23131.3	30733.7	-7602.41
NOV	661.8	233.5	20744.8	16456.9	4287.92
DEC	370.0	-144.0	19104.3	20079.7	-975.42
RMS ERRORS:	7059.8	184.0			13618.7

MESILLA VALLEY, N.MEX.; HYDROSALINITY MODEL RESULTS FOR THE WATER YEAR 1976

MONTH	AQ. HEAD (PRED: FT)	DRAIN FLOW (PRD:AC-FT)	LEAS. QR (OB:AC-FT)	LEAS. CHEM (OB:MG/L)	AQ. CHEM (PRD:MG/L)	EL PASO QR (PD:AC-FT)	EL PASO QR (OB:AC-FT)	EL PA CHEM (PRD:MG/L)	EL PA CHEM (OBS:MG/L)
JAN	3824.73	7257.83	19980.00	357.00	1708.01	18138.67	15600.00	897.58	1190.00
FEB	3824.59	6746.27	21580.00	532.00	1709.65	10234.33	14198.00	1308.28	1288.00
MAR	3824.85	7728.04	82430.00	420.00	1715.31	42818.95	40200.00	653.78	1232.00
APR	3825.11	8781.97	85800.00	427.00	1706.12	47405.71	50279.00	663.96	630.00
MAY	3825.42	10148.36	104010.00	441.00	1698.05	60876.65	60697.00	650.55	777.00
JUN	3825.81	12100.65	95840.00	441.00	1695.86	53073.46	50099.00	727.11	1523.00
JUL	3825.58	10936.96	87300.00	402.00	1682.87	41077.60	47905.00	743.03	822.00
AUG	3824.98	8241.92	109440.00	445.00	1709.72	48500.18	57382.00	659.92	875.00
SEP	3825.25	9403.04	50430.00	452.00	1721.90	20443.55	31511.00	1036.09	1551.00
OCT	3825.38	9999.95	4020.00	682.00	1706.10	10974.43	14340.00	1615.17	1242.00
NOV	3825.00	8308.38	1650.00	788.00	1707.31	9914.66	10475.00	1558.37	1382.00
DEC	3824.67	7051.05	1230.00	903.00	1707.28	8248.46	9999.00	1590.53	1358.00
YEARLY AVERAGES:	3825.11	8892.03			1705.68	30975.55	33557.08	1008.70	1155.83

HYDRAULIC RESPONSE TIME = 2.9 MO.
SOLUTE RESPONSE TIME = 16.3 YRS.

ERRORS: DIFF BETWEEN PREDICTED AND OBSERVED RIVER FLOW & TDS AT EL PASO

MONTH	QPRED-QOBS (AC-FT)	CMPRED-CMOBS (MG/L)
JAN	2538.7	-292.4
FEB	-3963.7	20.3
MAR	2618.9	-578.2
APR	-2873.3	34.0
MAY	179.7	-126.4
JUN	2974.5	-795.9
JUL	-6827.4	-79.0
AUG	-8881.8	-215.1
SEP	-11067.5	-514.9
OCT	-3365.6	373.2
NOV	-560.3	176.4
DEC	-1750.5	232.5
RMS ERRORS:	5073.2	366.6

TONSOF SALT AT EL PASO

TONS(PRED)	TONS (OBS)	DIFF
22150.9	25257.1	-3106.24
18216.9	24880.3	-6663.43
38087.3	67382.9	-29295.55
42823.7	43096.3	-272.58
53882.5	64165.4	-10282.94
52503.4	103810.6	-51307.21
41526.5	53575.4	-12048.88
43546.0	68311.9	-24765.90
28818.3	66494.6	-37676.38
24116.4	24231.7	-115.27
21021.4	19695.9	1325.50
17849.5	18474.3	-624.82
		22043.0

TOTAL RMS ERRORS:
RMS ERROR IN RIVER FLOW = 7323.9
RMS ERROR IN TDS = 213.4
RMS ERROR IN TONS = 13769.0

Appendix F

Program to Estimate Porosity and River Leakage for Periods of No Recharge

(Source: Pinzon, 1979)

```
MAIN.    LN2K1S.FOR      FORTRAN V.5A(621) /KI    2-MAY-78        8:18    PAGE 1

        REAL H,NP,NT,HO
        DIMENSION F(31,6),H(31,6),DH(31,6),G(31,6),X(31),XX(31),Y(31),
     1  XY(31),NM(31),QR(31),NP(31),PRED(31,6),DIFF(31,6),SQD(31,6),
     2  ENS(31),RMS(31),BB(31),QDOBS(31,6)
        IR=2
        IW=3
        A=0.0755*9.05
        B=1./9.05
        H0=3825.0
        AREA=108626.0
        NREC=31
        NT=0.0
        SX=0.0
        SY=0.0
        SXX=0.0
        SXY=0.0
        DO 1 J=1,NREC
        READ(IR,5) NM(J)
        LIMIT=NM(J)
        WRITE(IW,6) J
        WRITE(IW,16) NM(J)
        NP(J)=NM(J)-2
        NT=NT+NP(J)
        DO 2 I=1,LIMIT
        READ(IR,15)MON,IYR,H(J,I),QDOBS(J,I)
        F(J,I)=B*ALOG(EXP(A*(H(J,I)-H0))+1.)
        F(J,I)=AREA*F(J,I)
        WRITE(IW,26)MON,IYR,H(J,I),QDOBS(J,I),F(J,I)
        F(J,I)=F(J,I)/AREA
      2 CONTINUE
        WRITE(IW,36)
        X(J)=0.0
        XX(J)=0.0
        Y(J)=0.0
        XY(J)=0.0
        LIMIT=NM(J)-1
        DO 3 I=2,LIMIT
        DH(J,I)=H(J,I+1)-H(J,I-1)
        G(J,I)=(F(J,I-1)+4.*F(J,I)+F(J,I+1))/3.
        WRITE(IW,46) DH(J,I),G(J,I)
        X(J)=X(J)+DH(J,I)
        XX(J)=XX(J)+DH(J,I)**2
        Y(J)=Y(J)+G(J,I)
        XY(J)=XY(J)+DH(J,I)*G(J,I)
  3     CONTINUE
        WRITE(IW,56) X(J),XX(J),XY(J),Y(J)
        SX=SX+X(J)
        SY=SY+Y(J)
        SXX=SXX+XX(J)
        SXY=SXY+XY(J)
      1 WRITE(IW,66)SX,SY,SXX,SXY
        POR=0.218
        WRITE(IW,76)POR
        DO 4 J=1,NREC
        BB(J)=(Y(J)+POR*X(J))/NP(J)
        QR(J)=BB(J)/2.
```

```
          QRIV=AREA*QR(J)
          WRITE(IW,86)J,QR(J),QRIV
          EMS(J)=0.0
          DO 11 I=2,LIMIT
          PRED(J,I)=POR*DH(J,I)+BB(J)
          DIFF(J,I)=G(J,I)-PRED(J,I)
          SQD(J,I)=DIFF(J,I)**2
          EMS(J)=EMS(J)+SQD(J,I)
     11   WRITE(IW,96)G(J,I),PRED(J,I),DIFF(J,I),SQD(J,I)
          RMS(J)=SQRT(EMS(J)/NP(J))
      4   WRITE(IW,106)EMS(J),RMS(J)
          STOP
 5        FORMAT(I2)
 6        FORMAT(1H1,10X,I3,'TH',3X,'RECESSION PERIOD'//)
 7        FORMAT(2F10.4)
 17       FORMAT(I2,F10.4)
     15   FORMAT(2I2,2F10.2)
     16   FORMAT(RX,I2,3X,'MONTH OF RECESSION',//,3X,'MONTH',2X,'YEAR',3X,
        <'AVE. AQ. W-L',3X,'OBS. DRAIN FLOW',3X,'CALC. DRAIN FLOW',/,22X,
        <'(FT)',9X,'(AC-FT/MO)',9X,'(AC-FT/MO)',//)
     26   FORMAT(4X,I2,4X,'19',I2,4X,F10.2,6X,F10.1,9X,F10.1)
     36   FORMAT(///,5X,'X=H(I+1)-H(I-1)',5X,'Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I
        <+1))',/)
 46       FORMAT(5X,F10.2,6X,F10.4)
 56       FORMAT(//,40X,'X(J)=',F10.2,/,40X,'XX(J)=',F10.2,/,40X,'XY(J)=',
        #F10.2,/,40X,'Y(J)=',F10.4,///)
 66       FORMAT(40X,' SX=',F10.2,/,40X,'SY=',F10.2,/,40X,'SXX=',F10.2,/,
        #40X,'SXY=',F10.2///)
 76       FORMAT(5X,'FINAL POROSITY IS =',3X,F10.5)
     86   FORMAT(///,3X,I2,' TH RECESSION',6X,'QR(J)=',F10.6,' FT/MO =',
        < F10.1,' AC-FT/MO',//)
 96       FORMAT(/,'OBSERVED Y=',F10.4,3X,'PREDICTED Y=',F10.4,3X,
        #'DIFFERENCE=',F6.4,3X,'SQUARE OF DIFF.=',F6.4/)
 106      FORMAT(/,'SUM OF SQ. OF DIFFS.=',F10.4,4X,'RMS=',F10.4//)
          END
```

SUBPROGRAMS CALLED

SQRT.
ALOG.   EXP.

SCALARS AND ARRAYS ["*" NO EXPLICIT DEFINITION - "%" NOT REFERENCED]

RMS	1	*AREA	40	*POR	41	*SXX	42	*IW	43
DIFF	44	HM	336	H	375	BB	667	*B	726
QR	727	*NREC	766	*SY	767	*HO	770	*SXY	771
Y	772	PRED	1031	EMS	1323	*QRIV	1362	DH	1363
*J	1655	*SX	1656	G	1657	.S0004	2151	.S0003	2152
*A	2153	.S0002	2154	.S0001	2155	.S0000	2156	XY	2157
NP	2216	*IYR	2255	X	2256	SQD	2315	XX	2607
*I	2646	%HO		F	2647	NT	3141	*MON	3142
QDOBS	3143	*LIMIT	3435	*IR	3436				

1TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1946	3826.86	17520.0	18222.7
11	1946	3826.52	13620.0	16103.1
12	1946	3826.17	12190.0	14051.9
1	1947	3825.95	10570.0	12836.8
2	1947	3825.89	8400.0	12515.9

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
-0.69	0.2967
-0.57	0.2613
-0.28	0.2391

X(J)= -1.54
XX(J)= 0.88
XY(J)= -0.42
Y(J)= 0.7971

SX= -1.54
SY= 0.80
SXX= 0.88
SXY= -0.42

2TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1947	3826.84	14900.0	18094.9
11	1947	3826.38	11500.0	15265.9
12	1947	3826.18	9920.0	14108.5
1	1948	3825.86	9000.0	12357.0
2	1948	3825.79	7800.0	11991.3

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
-0.66	0.2862
-0.52	0.2579
-0.39	0.2318

X(J)= -1.57
XX(J)= 0.86
XY(J)= -0.41
Y(J)= 0.7759

SX= -3.11
SY= 1.57
SXX= 1.74
SXY= -0.83

3TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1948	3826.95	17570.0	18803.1
11	1948	3826.58	13050.0	16468.5
12	1948	3826.25	12300.0	14508.3
1	1949	3825.89	11330.0	12515.9
2	1949	3825.86	8920.0	12357.0

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
-0.70	0.3044
-0.69	0.2670
-0.39	0.2361

X(J)= -1.78
XX(J)= 1.12
XY(J)= -0.49
Y(J)= 0.8075

SX= -4.89
SY= 2.38
SXX= 2.86
SXY= -1.32

4TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1949	3826.87	16060.0	18286.9
11	1949	3826.52	13940.0	16103.1
12	1949	3826.24	11990.0	14450.8
1	1950	3826.02	10270.0	13216.8
2	1950	3825.94	8419.0	12782.9

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
-0.63	0.2981
-0.50	0.2673
-0.30	0.2458

X(J)= -1.43
XX(J)= 0.74
XY(J)= -0.40
Y(J)= 0.8113

SX= -6.32
SY= 3.19
SXX= 3.59
SXY= -1.72

5TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1950	3826.68	17447.0	17085.9
11	1950	3826.33	12769.0	14972.1
12	1950	3826.11	11046.0	13714.5
1	1951	3825.89	10020.0	12515.9
2	1951	3825.83	7150.0	12199.4

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
-0.57	0.2783
-0.44	0.2527
-0.28	0.2331

X(J)= -1.29
XX(J)= 0.60
XY(J)= -0.34
Y(J)= 0.7641

SX= -7.61
SY= 3.96
SXX= 4.19
SXY= -2.05

6TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1951	3825.82	7720.0	12147.3
11	1951	3825.74	6050.0	11733.7
12	1951	3824.76	5770.0	7375.9
1	1952	3824.69	5010.0	7115.8
2	1952	3824.59	3910.0	6755.9

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
-1.06	0.2039
-1.05	0.1484
-0.17	0.1307

X(J)= -2.28
XX(J)= 2.25
XY(J)= -0.39
Y(J)= 0.4830

SX= -9.89
SY= 4.44
SXX= 6.44
SXY= -2.45

7TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1952	3824.96	7480.0	8156.8
11	1952	3824.84	5750.0	7681.6
12	1952	3824.70	5720.0	7152.5
1	1953	3824.71	5120.0	7189.4
2	1953	3824.50	3320.0	6443.7

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
-0.26	0.1413
-0.13	0.1334
-0.20	0.1300

X(J)= -0.59
XX(J)= 0.12
XY(J)= -0.08
Y(J)= 0.4047

SX= -10.48
SY= 4.84
SXX= 6.57
SXY= -2.53

8TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1953	3824.46	6010.0	6308.5
11	1953	3824.40	4780.0	6109.8
12	1953	3824.27	4140.0	5695.7
1	1954	3824.33	3680.0	5884.0
2	1954	3823.95	2600.0	4770.4

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
-0.19	0.1118
-0.07	0.1067
-0.32	0.1043

X(J)= -0.58
XX(J)= 0.14
XY(J)= -0.06
Y(J)= 0.3229

SX= -11.06
SY= 5.17
SXX= 6.71
SXY= -2.59

9TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1954	3822.43	1860.0	1912.5
11	1954	3822.38	1420.0	1853.0
12	1954	3822.40	1270.0	1876.6
1	1955	3822.55	1200.0	2062.6
2	1955	3822.41	794.0	1888.5

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
-0.03	0.0344
0.17	0.0350
0.01	0.0369

X(J)= 0.15
XX(J)= 0.03
XY(J)= 0.01
Y(J)= 0.1063

SX= -10.91
SY= 5.27
SXX= 6.74
SXY= -2.58

10TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1955	3820.34	780.0	487.1
11	1955	3820.56	387.0	564.3
12	1955	3820.73	406.0	632.0
1	1956	3820.77	346.0	649.0
2	1956	3820.66	310.0	603.2

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
0.39	0.0104
0.21	0.0115
-0.07	0.0118

X(J)= 0.53
XX(J)= 0.20
XY(J)= 0.01
Y(J)= 0.0336

SX= -10.38
SY= 5.31
SXX= 6.94
SXY= -2.58

11TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1956	3818.37	215.0	128.7
11	1956	3818.59	173.0	149.4
12	1956	3818.73	228.0	164.3
1	1957	3818.99	246.0	196.0
2	1957	3819.00	205.0	197.4

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
0.36	0.0027
0.40	0.0031
0.27	0.0035

X(J)= 1.03
XX(J)= 0.36
XY(J)= 0.00
Y(J)= 0.0093

SX= -9.35
SY= 5.32
SXX= 7.31
SXY= -2.58

12TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1957	3819.33	1564.0	246.8
11	1957	3819.67	1201.0	310.5
12	1957	3819.81	886.0	341.2
1	1958	3820.17	710.0	434.6
2	1958	3820.07	470.0	406.4

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
0.48	0.0056
0.50	0.0065
0.26	0.0076

X(J)= 1.24
XX(J)= 0.55
XY(J)= 0.01
Y(J)= 0.0197

SX= -8.11
SY= 5.34
SXX= 7.85
SXY= -2.57

13TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1958	3824.93	8110.0	8036.1
11	1958	3824.66	6113.0	7006.3
12	1958	3824.46	4990.0	6308.5
1	1959	3824.27	4210.0	5695.7
2	1959	3823.96	3820.0	4797.3

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
-0.47	0.1300
-0.39	0.1164
-0.50	0.1040

X(J)= -1.36
XX(J)= 0.62
XY(J)= -0.16
Y(J)= 0.3504

SX= -9.47
SY= 5.69
SXX= 8.48
SXY= -2.73

14TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1959	3825.18	9760.0	9080.5
11	1959	3824.89	7930.0	7837.8
12	1959	3824.68	7290.0	7079.1
1	1960	3824.56	6310.0	6650.6
2	1960	3824.42	4650.0	6175.5

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
-0.50	0.1458
-0.32	0.1314
-0.26	0.1223

X(J)= -1.08
XX(J)= 0.42
XY(J)= -0.15
Y(J)= 0.3995

SX= -10.55
SY= 6.09
SXX= 8.90
SXY= -2.87

15TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1960	3825.93	11830.0	12729.2
11	1960	3825.52	8610.0	10640.5
12	1960	3825.28	7030.0	9522.8
1	1961	3825.01	6400.0	8360.9
2	1961	3824.80	5480.0	7527.6

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
-0.65	0.1989
-0.51	0.1752
-0.48	0.1549

X(J)= -1.64
XX(J)= 0.91
XY(J)= -0.29
Y(J)= 0.5290

SX= -12.19
SY= 6.61
SXX= 9.81
SXY= -3.17

16TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1961	3825.26	9500.0	9433.3
11	1961	3825.00	7270.0	8319.8
12	1961	3824.67	6770.0	7798.5
1	1962	3824.71	6400.0	7189.4
2	1962	3824.59	4590.0	6755.9

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
-0.39	0.1550
-0.29	0.1433
-0.28	0.1329

X(J)= -0.96
XX(J)= 0.31
XY(J)= -0.14
Y(J)= 0.4312

SX= -13.15
SY= 7.05
SXX= 10.12
SXY= -3.31

17TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1962	3826.29	11880.0	14739.4
11	1962	3825.87	9070.0	12409.8
12	1962	3825.62	8260.0	11129.4
1	1963	3825.41	7505.0	10118.4
2	1963	3825.07	5638.0	8610.3

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
-0.67	0.2317
-0.46	0.2057
-0.55	0.1848

X(J)= -1.68
XX(J)= 0.96
XY(J)= -0.35
Y(J)= 0.6222

SX= -14.83
SY= 7.67
SXX= 11.09
SXY= -3.66

18TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1963	3825.13	7104.0	8864.7
11	1963	3824.99	5226.0	8278.8
12	1963	3824.88	5120.0	7837.8
1	1964	3824.74	4531.0	7300.8
2	1964	3824.50	3295.0	6443.7

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
-0.25	0.1529
-0.25	0.1440
-0.38	0.1334

X(J)= -0.88
XX(J)= 0.27
XY(J)= -0.12
Y(J)= 0.4303

SX= -15.71
SY= 8.10
SXX= 11.36
SXY= -3.78

19TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1964	3821.10	824.0	807.8
11	1964	3821.34	577.0	946.2
12	1964	3821.48	530.0	1037.2
1	1965	3821.49	511.0	1044.0
2	1965	3821.45	367.0	1017.0

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
0.38	0.0173
0.15	0.0188
-0.03	0.0191

X(J)= 0.50
XX(J)= 0.17
XY(J)= 0.01
Y(J)= 0.0552

SX= -15.21
SY= 8.15
SXX= 11.52
SXY= -3.77

20TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1965	3822.22	2890.0	1673.8
11	1965	3822.35	2191.0	1818.1
12	1965	3822.41	1729.0	1888.5
1	1966	3822.35	1893.0	1818.1
2	1966	3822.29	1566.0	1750.1

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
0.19	0.0332
0.00	0.0343
-0.12	0.0335

X(J)= 0.07
XX(J)= 0.05
XY(J)= 0.00
Y(J)= 0.1011

SX= -15.14
SY= 8.25
SXX= 11.58
SXY= -3.77

21TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1966	3825.17	7188.0	9037.2
11	1966	3824.83	5213.0	7642.8
12	1966	3824.54	4804.0	6581.1
1	1967	3824.44	4096.0	6241.8
2	1967	3824.11	3132.0	5216.6

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
-0.63	0.1417
-0.39	0.1234
-0.43	0.1128

X(J)= -1.45
XX(J)= 0.73
XY(J)= -0.19
Y(J)= 0.3779

SX= -16.59
SY= 8.63
SXX= 12.31
SXY= -3.96

22TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1967	3824.17	5282.0	5392.5
11	1967	3823.96	3618.0	4797.3
12	1967	3823.86	3806.0	4533.2
1	1968	3823.87	3800.0	4559.1
2	1968	3823.57	3203.0	3834.7

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
-0.31	0.0893
-0.09	0.0844
-0.29	0.0816

X(J)= -0.69
XX(J)= 0.19
XY(J)= -0.06
Y(J)= 0.2553

SX= -17.28
SY= 8.89
SXX= 12.50
SXY= -4.02

23TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1968	3824.49	6704.0	6409.7
11	1968	3824.45	5284.0	6275.1
12	1968	3824.20	5294.0	5482.1
1	1969	3824.00	5015.0	4906.4
2	1969	3823.72	3356.0	4183.8

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
-0.29	0.1135
-0.45	0.1016
-0.48	0.0899

X(J)= -1.22
XX(J)= 0.52
XY(J)= -0.12
Y(J)= 0.3050

SX= -18.50
SY= 9.19
SXX= 13.01
SXY= -4.14

24TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1969	3825.74	10298.0	11733.7
11	1969	3825.38	8336.0	9978.9
12	1969	3825.23	7642.0	9300.0
1	1970	3825.10	6499.0	8736.8
2	1970	3824.72	5504.0	7226.4

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
-0.51	0.1870
-0.28	0.1716
-0.51	0.1580

X(J)= -1.30
XX(J)= 0.60
XY(J)= -0.22
Y(J)= 0.5166

SX= -19.80
SY= 9.71
SXX= 13.61
SXY= -4.36

25TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1970	3826.07	10311.0	13492.2
11	1970	3825.97	7736.0	12944.7
12	1970	3825.61	6498.0	11079.8
1	1971	3825.15	5484.0	8950.6
2	1971	3824.73	4671.0	7263.6

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
-0.46	0.2343
-0.82	0.2032
-0.88	0.1662

X(J)= -2.16
XX(J)= 1.66
XY(J)= -0.42
Y(J)= 0.6036

SX= -21.96
SY= 10.31
SXX= 15.27
SXY= -4.78

26TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1971	3824.52	6383.0	6512.1
11	1971	3824.45	4379.0	6275.1
12	1971	3824.68	4489.0	7079.1
1	1972	3823.31	3911.0	3288.1
2	1972	3823.11	3279.0	2915.0

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
0.16	0.1187
-1.14	0.1162
-1.57	0.0710

X(J)= -2.55
XX(J)= 3.79
XY(J)= -0.23
Y(J)= 0.3060

SX= -24.51
SY= 10.62
SXX= 19.06
SXY= -5.01

27TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1972	3823.53	2730.0	3745.8
11	1972	3823.49	2012.0	3658.7
12	1972	3823.71	2042.0	4159.7
1	1973	3823.99	1727.0	4878.9
2	1973	3824.39	1288.0	6077.2

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
0.18	0.0692
0.50	0.0773
0.68	0.0913

X(J)= 1.36
XX(J)= 0.74
XY(J)= 0.11
Y(J)= 0.2377

SX= -23.15
SY= 10.86
SXX= 19.81
SXY= -4.89

28TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1973	3824.50	10913.0	6443.7
11	1973	3824.08	5725.0	5130.5
12	1973	3823.97	5565.0	4824.4
1	1974	3823.78	4734.0	4330.7
2	1974	3823.54	2971.0	3767.9

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
-0.53	0.0976
-0.30	0.0883
-0.43	0.0795

X(J)= -1.26
XX(J)= 0.56
XY(J)= -0.11
Y(J)= 0.2653

SX= -24.41
SY= 11.12
SXX= 20.36
SXY= -5.01

29TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1974	3824.78	11824.0	7451.5
11	1974	3824.62	7003.0	6862.4
12	1974	3824.58	5534.0	6720.6
1	1975	3825.07	5780.0	8610.3
2	1975	3824.75	4436.0	7338.3

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
-0.20	0.1277
0.45	0.1300
0.17	0.1488

X(J)= 0.42
XX(J)= 0.27
XY(J)= 0.06
Y(J)= 0.4065

SX= -23.99
SY= 11.53
SXX= 20.63
SXY= -4.95

30TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1975	3825.24	15402.0	9344.2
11	1975	3824.88	11103.0	7837.8
12	1975	3824.49	6851.0	6375.9
1	1976	3824.65	7704.0	6970.1
2	1976	3824.59	7950.0	6755.9

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
-0.76	0.1444
-0.23	0.1237
0.11	0.1259

X(J)= -0.88
XX(J)= 0.64
XY(J)= -0.12
Y(J)= 0.3940

SX= -24.87
SY= 11.92
SXX= 21.28
SXY= -5.07

31TH RECESSION PERIOD

5 MONTH OF RECESSION

MONTH	YEAR	AVE. AQ. W-L (FT)	OBS. DRAIN FLOW (AC-FT/MO)	CALC. DRAIN FLOW (AC-FT/MO)
10	1976	3825.27	8934.0	9477.9
11	1976	3824.45	6843.0	6275.1
12	1976	3824.43	6217.0	6208.5
1	1977	3824.22	5534.0	5542.5
2	1977	3823.94	4737.0	4743.5

X=H(I+1)-H(I-1)	Y=(DT/3)*(QD(I-1)+4*QD(I)+QD(I+1))
-0.84	0.1252
-0.23	0.1125
-0.49	0.1016

X(J)= -1.56
XX(J)= 1.00
XY(J)= -0.18
Y(J)= 0.3393

SX= -26.43
SY= 12.26
SXX= 22.27
SXY= -5.25

FINAL POROSITY IS = 0.21800

1 TH RECESSION QR(J)= 0.076895 FT/MO = 8352.8 AC-FT/MO

BSERVED Y= 0.2967 PREDICTED Y= 0.0034 DIFFERENCE= .2933 SQUARE OF DIFF.= .0860

BSERVED Y= 0.2613 PREDICTED Y= 0.0295 DIFFERENCE= .2318 SQUARE OF DIFF.= .0537

BSERVED Y= 0.2391 PREDICTED Y= 0.0927 DIFFERENCE= .1463 SQUARE OF DIFF.= .0214

UM OF SQ. OF DIFFS.= 0.1612 RMS= . 0.2318

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   2 TH RECESSION       QR(J)=  0.072275 FT/MO =    7850.9 AC-FT/MO

BSERVED Y=     0.2862   PREDICTED Y=     0.0007   DIFFERENCE= .2855   SQUARE OF DIFF.= .0815
BSERVED Y=     0.2579   PREDICTED Y=     0.0312   DIFFERENCE= .2268   SQUARE OF DIFF.= .0514
BSERVED Y=     0.2318   PREDICTED Y=     0.0595   DIFFERENCE= .1722   SQUARE OF DIFF.= .0297
UM OF SQ. OF DIFFS.=     0.1626     RMS=    0.2328

   3 TH RECESSION       QR(J)=  0.069902 FT/MO =    7593.2 AC-FT/MO

BSERVED Y=     0.3044   PREDICTED Y=    -0.0128   DIFFERENCE= .3172   SQUARE OF DIFF.= .1006
BSERVED Y=     0.2670   PREDICTED Y=    -0.0106   DIFFERENCE= .2776   SQUARE OF DIFF.= .0771
BSERVED Y=     0.2361   PREDICTED Y=     0.0548   DIFFERENCE= .1813   SQUARE OF DIFF.= .0329
UM OF SQ. OF DIFFS.=     0.2105     RMS=    0.2649

   4 TH RECESSION       QR(J)=  0.083255 FT/MO =    9043.6 AC-FT/MO

BSERVED Y=     0.2981   PREDICTED Y=     0.0292   DIFFERENCE= .2689   SQUARE OF DIFF.= .0723
BSERVED Y=     0.2673   PREDICTED Y=     0.0575   DIFFERENCE= .2098   SQUARE OF DIFF.= .0440
BSERVED Y=     0.2458   PREDICTED Y=     0.1011   DIFFERENCE= .1447   SQUARE OF DIFF.= .0209
UM OF SQ. OF DIFFS.=     0.1373     RMS=    0.2139

   5 TH RECESSION       QR(J)=  0.080485 FT/MO =    8742.8 AC-FT/MO
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BSERVED Y=     0.2783   PREDICTED Y=    0.0367   DIFFERENCE= .2416   SQUARE OF DIFF.= .0584
BSERVED Y=     0.2527   PREDICTED Y=    0.0651   DIFFERENCE= .1876   SQUARE OF DIFF.= .0352
BSERVED Y=     0.2331   PREDICTED Y=    0.0999   DIFFERENCE= .1332   SQUARE OF DIFF.= .0177
UM OF SQ. OF DIFFS.=    0.1113    RMS=    0.1926

   6 TH RECESSION       QR(J)= -0.002336 FT/MO =    -253.8 AC-FT/MO

BSERVED Y=     0.2039   PREDICTED Y=   -0.2358   DIFFERENCE= .4397   SQUARE OF DIFF.= .1933
BSERVED Y=     0.1484   PREDICTED Y=   -0.2336   DIFFERENCE= .3819   SQUARE OF DIFF.= .1459
BSERVED Y=     0.1307   PREDICTED Y=   -0.0417   DIFFERENCE= .1724   SQUARE OF DIFF.= .0297
UM OF SQ. OF DIFFS.=    0.3689    RMS=    0.3507

   7 TH RECESSION       QR(J)=  0.046007 FT/MO =    4997.6 AC-FT/MO

BSERVED Y=     0.1413   PREDICTED Y=    0.0353   DIFFERENCE= .1059   SQUARE OF DIFF.= .0112
BSERVED Y=     0.1334   PREDICTED Y=    0.0637   DIFFERENCE= .0698   SQUARE OF DIFF.= .0049
BSERVED Y=     0.1300   PREDICTED Y=    0.0484   DIFFERENCE= .0816   SQUARE OF DIFF.= .0067
UM OF SQ. OF DIFFS.=    0.0227    RMS=    0.0871

   8 TH RECESSION       QR(J)=  0.032742 FT/MO =    3556.6 AC-FT/MO

BSERVED Y=     0.1118   PREDICTED Y=    0.0241   DIFFERENCE= .0878   SQUARE OF DIFF.= .0077
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BSERVED Y=     0.1067   PREDICTED Y=     0.0502   DIFFERENCE= .0565   SQUARE OF DIFF.= .0032
BSERVED Y=     0.1043   PREDICTED Y=    -0.0043   DIFFERENCE= .1086   SQUARE OF DIFF.= .0118
UM OF SQ. OF DIFFS.=     0.0227    RMS=     0.0870

   9 TH RECESSION       QR(J)=  0.023165 FT/MO =    2516.3 AC-FT/MO

BSERVED Y=     0.0344   PREDICTED Y=     0.0398   DIFFERENCE=-.0054   SQUARE OF DIFF.=0.0000
BSERVED Y=     0.0350   PREDICTED Y=     0.0834   DIFFERENCE=-.0483   SQUARE OF DIFF.= .0023
BSERVED Y=     0.0369   PREDICTED Y=     0.0485   DIFFERENCE=-.0116   SQUARE OF DIFF.= .0001
UM OF SQ. OF DIFFS.=     0.0025    RMS=     0.0289

  10 TH RECESSION       QR(J)=  0.024856 FT/MO =    2700.0 AC-FT/MO

BSERVED Y=     0.0104   PREDICTED Y=     0.1347   DIFFERENCE=-.1244   SQUARE OF DIFF.= .0155
BSERVED Y=     0.0115   PREDICTED Y=     0.0955   DIFFERENCE=-.0840   SQUARE OF DIFF.= .0071
BSERVED Y=     0.0118   PREDICTED Y=     0.0345   DIFFERENCE=-.0227   SQUARE OF DIFF.= .0005
UM OF SQ. OF DIFFS.=     0.0230    RMS=     0.0876

  11 TH RECESSION       QR(J)=  0.038978 FT/MO =    4234.0 AC-FT/MO

BSERVED Y=     0.0027   PREDICTED Y=     0.1564   DIFFERENCE=-.1537   SQUARE OF DIFF.= .0236
BSERVED Y=     0.0031   PREDICTED Y=     0.1652   DIFFERENCE=-.1621   SQUARE OF DIFF.= .0263
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BSERVED Y=    0.0035   PREDICTED Y=    0.1368   DIFFERENCE=-.1333   SQUARE OF DIFF.= .0178
UM OF SQ. OF DIFFS.=    0.0677    RMS=    0.1502

  12 TH RECESSION      QR(J)=  0.048341 FT/MO =    5251.0 AC-FT/MO

BSERVED Y=    0.0056   PREDICTED Y=    0.2013   DIFFERENCE=-.1957   SQUARE OF DIFF.= .0383
BSERVED Y=    0.0065   PREDICTED Y=    0.2057   DIFFERENCE=-.1992   SQUARE OF DIFF.= .0397
BSERVED Y=    0.0076   PREDICTED Y=    0.1534   DIFFERENCE=-.1457   SQUARE OF DIFF.= .0212
UM OF SQ. OF DIFFS.=    0.0992    RMS=    0.1819

  13 TH RECESSION      QR(J)=  0.008990 FT/MO =     976.5 AC-FT/MO

BSERVED Y=    0.1300   PREDICTED Y=   -0.0845   DIFFERENCE= .2145   SQUARE OF DIFF.= .0460
BSERVED Y=    0.1164   PREDICTED Y=   -0.0670   DIFFERENCE= .1835   SQUARE OF DIFF.= .0337
BSERVED Y=    0.1040   PREDICTED Y=   -0.0910   DIFFERENCE= .1950   SQUARE OF DIFF.= .0380
UM OF SQ. OF DIFFS.=    0.1177    RMS=    0.1981

  14 TH RECESSION      QR(J)=  0.027336 FT/MO =    2969.4 AC-FT/MO

BSERVED Y=    0.1458   PREDICTED Y=   -0.0543   DIFFERENCE= .2001   SQUARE OF DIFF.= .0400
BSERVED Y=    0.1314   PREDICTED Y=   -0.0151   DIFFERENCE= .1464   SQUARE OF DIFF.= .0214
BSERVED Y=    0.1223   PREDICTED Y=   -0.0020   DIFFERENCE= .1243   SQUARE OF DIFF.= .0155
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UM OF SQ. OF DIFFS.=     0.0769     RMS=     0.1602

  15 TH RECESSION       QR(J)=  0.028586 FT/MO =     3105.2 AC-FT/MO

BSERVED Y=    0.1989    PREDICTED Y=    -0.0845    DIFFERENCE= .2834    SQUARE OF DIFF.= .0803
BSERVED Y=    0.1752    PREDICTED Y=    -0.0540    DIFFERENCE= .2292    SQUARE OF DIFF.= .0525
BSERVED Y=    0.1549    PREDICTED Y=    -0.0475    DIFFERENCE= .2024    SQUARE OF DIFF.= .0410
UM OF SQ. OF DIFFS.=     0.1738     RMS=     0.2407

  16 TH RECESSION       QR(J)=  0.036989 FT/MO =     4018.0 AC-FT/MO

BSERVED Y=    0.1550    PREDICTED Y=    -0.0110    DIFFERENCE= .1660    SQUARE OF DIFF.= .0276
BSERVED Y=    0.1433    PREDICTED Y=     0.0108    DIFFERENCE= .1326    SQUARE OF DIFF.= .0176
BSERVED Y=    0.1329    PREDICTED Y=     0.0129    DIFFERENCE= .1200    SQUARE OF DIFF.= .0144
UM OF SQ. OF DIFFS.=     0.0595     RMS=     0.1409

  17 TH RECESSION       QR(J)=  0.042663 FT/MO =     4634.3 AC-FT/MO

BSERVED Y=    0.2317    PREDICTED Y=    -0.0607    DIFFERENCE= .2924    SQUARE OF DIFF.= .0855
BSERVED Y=    0.2057    PREDICTED Y=    -0.0150    DIFFERENCE= .2207    SQUARE OF DIFF.= .0487
BSERVED Y=    0.1848    PREDICTED Y=    -0.0346    DIFFERENCE= .2193    SQUARE OF DIFF.= .0481
UM OF SQ. OF DIFFS.=     0.1823     RMS=     0.2465
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  18 TH RECESSION      QR(J)=  0.039747 FT/MO =    4317.6 AC-FT/MO

BSERVED Y=    0.1529   PREDICTED Y=    0.0250   DIFFERENCE= .1279   SQUARE OF DIFF.= .0164

BSERVED Y=    0.1440   PREDICTED Y=    0.0250   DIFFERENCE= .1190   SQUARE OF DIFF.= .0142

BSERVED Y=    0.1334   PREDICTED Y=   -0.0033   DIFFERENCE= .1368   SQUARE OF DIFF.= .0187

UM OF SQ. OF DIFFS.=   0.0492    RMS=    0.1281


  19 TH RECESSION      QR(J)=  0.027372 FT/MO =    2973.3 AC-FT/MO

BSERVED Y=    0.0173   PREDICTED Y=    0.1376   DIFFERENCE=-.1203   SQUARE OF DIFF.= .0145

BSERVED Y=    0.0188   PREDICTED Y=    0.0874   DIFFERENCE=-.0686   SQUARE OF DIFF.= .0047

BSERVED Y=    0.0191   PREDICTED Y=    0.0482   DIFFERENCE=-.0291   SQUARE OF DIFF.= .0008

UM OF SQ. OF DIFFS.=   0.0200    RMS=    0.0817


  20 TH RECESSION      QR(J)=  0.019388 FT/MO =    2106.1 AC-FT/MO

BSERVED Y=    0.0332   PREDICTED Y=    0.0802   DIFFERENCE=-.0469   SQUARE OF DIFF.= .0022

BSERVED Y=    0.0343   PREDICTED Y=    0.0388   DIFFERENCE=-.0044   SQUARE OF DIFF.=0.0000

BSERVED Y=    0.0335   PREDICTED Y=    0.0126   DIFFERENCE= .0209   SQUARE OF DIFF.= .0004

UM OF SQ. OF DIFFS.=   0.0027    RMS=    0.0298
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 21 TH RECESSION      QR(J)=  0,010307 FT/MO =    1119,6 AC-FT/MO

BSERVED Y=    0,1417   PREDICTED Y=   -0,1167   DIFFERENCE= ,2585   SQUARE OF DIFF,= ,0668

BSERVED Y=    0,1234   PREDICTED Y=   -0,0644   DIFFERENCE= ,1878   SQUARE OF DIFF,= ,0353

BSERVED Y=    0,1128   PREDICTED Y=   -0,0731   DIFFERENCE= ,1859   SQUARE OF DIFF,= ,0346

UM OF SQ, OF DIFFS,=    0,1366    RMS=    0,2134


 22 TH RECESSION      QR(J)=  0,017486 FT/MO =    1899,4 AC-FT/MO

BSERVED Y=    0,0893   PREDICTED Y=   -0,0326   DIFFERENCE= ,1220   SQUARE OF DIFF,= ,0149

BSERVED Y=    0,0844   PREDICTED Y=    0,0154   DIFFERENCE= ,0690   SQUARE OF DIFF,= ,0048

BSERVED Y=    0,0816   PREDICTED Y=   -0,0282   DIFFERENCE= ,1099   SQUARE OF DIFF,= ,0121

UM OF SQ, OF DIFFS,=    0,0317    RMS=    0,1028


 23 TH RECESSION      QR(J)=  0,006507 FT/MO =     706,8 AC-FT/MO

BSERVED Y=    0,1135   PREDICTED Y=   -0,0502   DIFFERENCE= ,1637   SQUARE OF DIFF,= ,0268

BSERVED Y=    0,1016   PREDICTED Y=   -0,0851   DIFFERENCE= ,1867   SQUARE OF DIFF,= ,0349

BSERVED Y=    0,0899   PREDICTED Y=   -0,0916   DIFFERENCE= ,1815   SQUARE OF DIFF,= ,0329

UM OF SQ, OF DIFFS,=    0,0946    RMS=    0,1776


 24 TH RECESSION      QR(J)=  0,038862 FT/MO =    4221,4 AC-FT/MO
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```
BSERVED Y=    0.1870   PREDICTED Y=   -0.0335   DIFFERENCE= .2205   SQUARE OF DIFF.= .0486
BSERVED Y=    0.1716   PREDICTED Y=    0.0167   DIFFERENCE= .1549   SQUARE OF DIFF.= .0240
BSERVED Y=    0.1580   PREDICTED Y=   -0.0335   DIFFERENCE= .1914   SQUARE OF DIFF.= .0366
UM OF SQ. OF DIFFS.=    0.1092    RMS=    0.1908

  25 TH RECESSION      QR(J)=  0.022126 FT/MO =    2403.4 AC-FT/MO

BSERVED Y=    0.2343   PREDICTED Y=   -0.0560   DIFFERENCE= .2903   SQUARE OF DIFF.= .0843
BSERVED Y=    0.2032   PREDICTED Y=   -0.1345   DIFFERENCE= .3377   SQUARE OF DIFF.= .1140
BSERVED Y=    0.1662   PREDICTED Y=   -0.1476   DIFFERENCE= .3137   SQUARE OF DIFF.= .0984
UM OF SQ. OF DIFFS.=    0.2968    RMS=    0.3145

  26 TH RECESSION      QR(J)= -0.041651 FT/MO =   -4524.4 AC-FT/MO

BSERVED Y=    0.1187   PREDICTED Y=   -0.0484   DIFFERENCE= .1672   SQUARE OF DIFF.= .0279
BSERVED Y=    0.1162   PREDICTED Y=   -0.3318   DIFFERENCE= .4481   SQUARE OF DIFF.= .2008
BSERVED Y=    0.0710   PREDICTED Y=   -0.4256   DIFFERENCE= .4966   SQUARE OF DIFF.= .2466
UM OF SQ. OF DIFFS.=    0.4753    RMS=    0.3980

  27 TH RECESSION      QR(J)=  0.089035 FT/MO =    9671.5 AC-FT/MO
```

```
BSERVED Y=    0,0692   PREDICTED Y=    0,2173   DIFFERENCE=-,1481   SQUARE OF DIFF,= ,0219
BSERVED Y=    0,0773   PREDICTED Y=    0,2871   DIFFERENCE=-,2098   SQUARE OF DIFF,= ,0440
BSERVED Y=    0,0913   PREDICTED Y=    0,3263   DIFFERENCE=-,2350   SQUARE OF DIFF,= ,0552
UM OF SQ, OF DIFFS,=    0,1212    RMS=    0,2010

  28 TH RECESSION      QR(J)= -0,001558 FT/MO =    -169,3 AC-FT/MO

BSERVED Y=    0,0976   PREDICTED Y=   -0,1187   DIFFERENCE= ,2162   SQUARE OF DIFF,= ,0467
BSERVED Y=    0,0883   PREDICTED Y=   -0,0685   DIFFERENCE= ,1568   SQUARE OF DIFF,= ,0246
BSERVED Y=    0,0795   PREDICTED Y=   -0,0969   DIFFERENCE= ,1764   SQUARE OF DIFF,= ,0311
UM OF SQ, OF DIFFS,=    0,1024    RMS=    0,1848

  29 TH RECESSION      QR(J)=  0,083014 FT/MO =    9017,5 AC-FT/MO

BSERVED Y=    0,1277   PREDICTED Y=    0,1224   DIFFERENCE= ,0053   SQUARE OF DIFF,=0,0000
BSERVED Y=    0,1300   PREDICTED Y=    0,2641   DIFFERENCE=-,1342   SQUARE OF DIFF,= ,0180
BSERVED Y=    0,1488   PREDICTED Y=    0,2031   DIFFERENCE=-,0543   SQUARE OF DIFF,= ,0029
UM OF SQ, OF DIFFS,=    0,0210    RMS=    0,0836

  30 TH RECESSION      QR(J)=  0,033693 FT/MO =    3659,9 AC-FT/MO

BSERVED Y=    0,1444   PREDICTED Y=   -0,0983   DIFFERENCE= ,2427   SQUARE OF DIFF,= ,0589
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```
BSERVED Y=    0.1237   PREDICTED Y=    0.0172   DIFFERENCE= .1065   SQUARE OF DIFF.= .0113
BSERVED Y=    0.1259   PREDICTED Y=    0.0914   DIFFERENCE= .0345   SQUARE OF DIFF.= .0012
UM OF SQ. OF DIFFS.=    0.0714    RMS=    0.1543

  31 TH RECESSION       QR(J)= -0.000135 FT/MO =     -14.7 AC-FT/MO

BSERVED Y=    0.1252   PREDICTED Y=   -0.1834   DIFFERENCE= .3085   SQUARE OF DIFF.= .0952
BSERVED Y=    0.1125   PREDICTED Y=   -0.0504   DIFFERENCE= .1629   SQUARE OF DIFF.= .0265
BSERVED Y=    0.1016   PREDICTED Y=   -0.1071   DIFFERENCE= .2087   SQUARE OF DIFF.= .0436
UM OF SQ. OF DIFFS.=    0.1653    RMS=    0.2347
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Appendix G

Water Management Options in the Mesilla Valley Study

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C
C     LUMPED PARAMETER MODEL FOR THE MESILLA VALLEY, NEW MEXICO
C
      DIMENSION COBS(10,12),IYR(10),MON(12),
     1 QST(10,12),QPT(10,12),ETEM(11,12),QRINT(10,12),QLRT(10,12)
      COMMON /FIT/QS(10,12),QLR(10,12),QP(10,12),CONUSE(10,12),
     1 QRIN(10,12),CSUR(10,12),TC(10)
      COMMON /GRAPH/CAQ(11,12),QROUT(10,12),COUT(10,12),H(11,12),
     1 QD(10,12),QOBS(10,12),TITLE(50),ENET(11,12)
      COMMON /LABLE/LBX(40),LB1(40),LB2(40),LB3(40),LB4(40),LB5(40),
     1 LB6(40)
      COMMON /AVE/A1(10),A2(10),A3(10),A4(10),A5(10),A6(10)
      DATA MON/5H JAN ,5H FEB ,5H MAR ,5H APR ,5H MAY ,5H JUN ,
     1 5H JUL ,5H AUG ,5H SEP ,5H OCT ,5H NOV ,5H DEC /
      DATA IR1,IR2,IW/25,26,3/
      DATA QSAVED,BETA1,BETA2,CLEAK/1.0,0.50,0.75,0.45/
      DATA ALPHA,HO,POR,Z,AREA,HR/0.0755,3825.0,0.218,9.05,
     1 108626.0,3754.0/
      OPEN(UNIT=26,DEVICE='DSK',ACCESS='SEQIN',FILE='AMES.DAT')
      OPEN(UNIT=25,DEVICE='DSK',ACCESS='SEQIN',FILE='OBSV.DAT')
      FACTOR=(BETA2-BETA1)/(BETA1*BETA2)
      DO 6 J=1,10
      READ(IR1,100)IYR(J)
  100 FORMAT(I4)
      READ(IR1,101)(QST(J,I),I=1,12)
      READ(IR1,101)(QRINT(J,I),I=1,12)
      READ(IR1,101)(CSUR(J,I),I=1,12)
      READ(IR1,101)(QOBS(J,I),I=1,12)
      READ(IR1,101)(COBS(J,I),I=1,12)
      READ(IR1,101)(CONUSE(J,I),I=1,12)
      READ(IR2,101)(ETEM(J,I),I=1,12)
      READ(IR2,101)(QLRT(J,I),I=1,12)
      DO 6 I=1,12
      QPT(J,I)=CONUSE(J,I)/BETA1-(1.0-CLEAK)*QST(J,I)
      IF(QPT(J,I).LT.0.0)QPT(J,I)=0.0
    6 CONTINUE
  101 FORMAT(8F10.0,/,4F10.0)
      READ(IR1,104)(LBX(K),K=1,8)
      READ(IR1,104)(LB1(K),K=1,8)
      READ(IR1,104)(LB2(K),K=1,8)
      READ(IR1,104)(LB3(K),K=1,8)
      READ(IR1,104)(LB4(K),K=1,8)
      READ(IR1,104)(LB5(K),K=1,8)
      READ(IR1,104)(LB6(K),K=1,8)
      CALL INITAL(1)
      DO 8 JR=1,5
      CAQ(1,1)=0.0
      CAQ(1,2)=0.0
      CAQ(1,3)=0.0
      CAQ(1,4)=0.0
      CAQ(1,5)=1626.0
      JGR=JR
      READ(IR1,104)(TITLE(K),K=1,10)
  104 FORMAT(10A5)
      DO 7 J=1,10
      DO 7 I=1,12
      QRIN(J,I)=QRINT(J,I)
      QS(J,I)=QST(J,I)
      ENET(J,I)=ETEM(J,I)
      QLR(J,I)=QLRT(J,I)
```

```
    7 QP(J,I)=QPT(J,I)
      GO TO (9,1,2,3,4),JGR
    1 DO 111 J=1,10
      DO 111 I=1,12
      ENET(J,I)=-CONUSE(J,I)/AREA
  111 QS(J,I)=0.0
      GO TO 9
    2 DO 222 J=1,10
      DO 222 I=1,12
      IF(QLR(J,I).LT.0.0)GO TO 223
      DIFF=QRIN(J,I)-QS(J,I)-QP(J,I)-QLR(J,I)
      GO TO 224
  223 DIFF=QRIN(J,I)-QS(J,I)-QP(J,I)
  224 IF(DIFF.LT.0.0)QP(J,I)=QP(J,I)+DIFF
      QS(J,I)=QS(J,I)+QP(J,I)
      ENET(J,I)=(QS(J,I)-CONUSE(J,I))/AREA
  222 QP(J,I)=0.0
      GO TO 9
    4 DO 333 J=1,10
      DO 333 I=1,12
      QS(J,I)=(1.0-CLEAK)*QS(J,I)
      ENET(J,I)=(QS(J,I)-CONUSE(J,I))/AREA
  333 CONTINUE
      GO TO 9
    3 DO 444 J=1,10
      DO 444 I=1,12
      WATSAV=FACTOR*CONUSE(J,I)
      QS(J,I)=QS(J,I)-QSAVED*WATSAV
      IF(QS(J,I).LT.0.0)QS(J,I)=0.0
  444 ENET(J,I)=ENET(J,I)-QSAVED*WATSAV/AREA
    9 CONTINUE
      CALL WATBAL(JGR,ALPHA,POR,Z,HO,AREA,HR)
      CALL MASBAL(HR,AREA,POR)
      CALL DELTA(JGR)
      CALL GRAFF(JGR)
      WRITE(IW,201)(TITLE(K),K=1,10),(IYR(K),K=1,10)
  201 FORMAT(1H1,////,5X,'MESILLA VALLEY, N.MEX.-SIMULATION RESULTS',/,
     1 5X,'AVE AQ W-L (FT)',//,5X,10A5,//,12X,10(3X,I4,3X))
      DO 10 I=1,12
   10 WRITE(IW,202)MON(I),(H(J,I),J=1,10)
  202 FORMAT(5X,A5,10F10.2)
      WRITE(IW,301)(A1(J),J=1,10)
  301 FORMAT(/,1X,'AVERAGES:',10F10.2)
      WRITE(IW,203)(TITLE(K),K=1,10),(IYR(K),K=1,10)
  203 FORMAT(/////,5X,'MESILLA VALLEY, N.MEX.-SIMULATION RESULTS:',/,
     1 5X,'AVE AQ CHEM. (MG/L)',//,5X,10A5,//,12X,10(3X,I4,3X))
      DO 11 I=1,12
   11 WRITE(IW,202)MON(I),(CAQ(J,I),J=1,10)
      WRITE(IW,301)(A3(J),J=1,10)
      WRITE(IW,204)(TITLE(K),K=1,10),(IYR(K),K=1,10)
  204 FORMAT(1H1,////,5X,'MESILLA VALLEY, N.MEX.-SIMULATION RESULTS',/,
     15X,'AVE RIVER OUTFLOW (AC-FT/MO)',//,5X,10A5,//,12X,10(3X,I4,3X))
      DO 12 I=1,12
   12 WRITE(IW,202)MON(I),(QROUT(J,I),J=1,10)
      WRITE(IW,301)(A4(J),J=1,10)
      WRITE(IW,205)(TITLE(K),K=1,10),(IYR(K),K=1,10)
  205 FORMAT(/////,5X,'MESILLA VALLEY, N.MEX.-SIMULATION RESULTS',/,
     1 5X,'AVE RIVER CHEM (MG/L)',//,5X,10A5,//,12X,10(3X,I4,3X))
      DO 13 I=1,12
   13 WRITE(IW,202)MON(I),(COUT(J,I),J=1,10)
```

```
      WRITE(IW,301)(A5(J),J=1,10)
      WRITE(IW,206)(TITLE(K),K=1,10),(IYR(K),K=1,10)
      DO 14 I=1,12
   14 WRITE(IW,202)MON(I),(QD(J,I),J=1,10)
      WRITE(IW,301)(A2(J),J=1,10)
  206 FORMAT(1H1,////,5X,'MESILLA VALLEY, N.MEX.-SIMULATION RESULTS:',/,
     1 5X,'DRAIN FLOW (AC-FT/MO)',//,5X,10A5,//,12X,10(3X,I4,3X))
      WRITE(IW,207)(TITLE(K),K=1,10),(IYR(K),K=1,10)
  207 FORMAT(/////,5X,'MESILLA VALLEY, N.MEX.-SIMULATION RESULTS:',/,
     1 5X,'NET RECHARGE (FT)',//,5X,10A5,//,12X,10(3X,I4,3X))
      DO 15 I=1,12
   15 WRITE(IW,208)MON(I),(ENET(J,I),J=1,10)
  208 FORMAT(5X,A5,10F10.4)
      WRITE(IW,302)(A6(J),J=1,10)
  302 FORMAT(/,1X,'AVERAGES:',10F10.4)
    8 CONTINUE
      CALL RSTR(0)
      CALL RSTR(2)
      CLOSE(UNIT=26,DEVICE='DSK',ACCESS='SEQIN',FILE='AMES.DAT')
      CLOSE(UNIT=25,DEVICE='DSK',ACCESS='SEQIN',FILE='OBSV.DAT')
      STOP
      END
C
      SUBROUTINE WATBAL(JGR,ALPHA,POR,Z,HO,AREA,HR)
C
      COMMON /FIT/QS(10,12),QLR(10,12),QP(10,12),CONUSE(10,12),
     1 QRIN(10,12),CSUR(10,12),TC(10)
      COMMON /GRAPH/CAQ(11,12),QROUT(10,12),COUT(10,12),H(11,12),
     1 QD(10,12),QUBS(10,12),TITLE(50),ENET(11,12)
      DIMENSION QRT(11),QR(10,12)
      DATA QRT/0.0103,0.0175,0.0065,0.0389,0.0221,-0.0416,0.0890
     1 ,-0.0016,0.0830,0.0337,-0.0001/
      DO 1 JK=1,10
      DO 1 IK=1,12
      IF(IK.GT.10)GO TO 2
      QR(JK,IK+2)=QRT(JK+1)
      GO TO 1
    2 QR(JK,IK-10)=QRT(JK)
    1 CONTINUE
      ENET(11,1)=ENET(10,12)
      TOL=0.01
      H(1,1)=3824.38
      DO 23 J=1,10
      DO 22 I=1,12
      QD(J,I)=1.0/Z*ALOG(EXP(ALPHA*Z*(H(J,I)-HO))+1.0)
      IF(J.GT.1 .AND. I.GT.1)GO TO 13
      HOLD=H(J,I)
      HBEG=HOLD
      GO TO 18
   13 HBEG=HNEW
      GO TO 18
   14 HOLD=HNEW
   18 GBEG=1.0/Z*ALOG(EXP(ALPHA*Z*(HBEG-HO))+1.0)
      GOLD=1.0/Z*ALOG(EXP(ALPHA*Z*(HOLD-HO))+1.0)
      AVG=(GOLD+GBEG)/2.0
      IF(I.EQ.12)GO TO 19
      AVREC=(ENET(J,I+1)+ENET(J,I))/2.0
      GO TO 20
   19 AVREC=(ENET(J+1,1)+ENET(J,I))/2.0
   20 HNEW=HBEG+(AVREC+QR(J,I)-AVG)/POR
```

```
      DIFF=ABS(HNEW-HOLD)
      IF(DIFF.GT.TOL)GO TO 14
      IF(I.LT.12)GO TO 21
      H(J+1,1)=HNEW
      GO TO 22
   21 H(J,I+1)=HNEW
   22 CONTINUE
   23 CONTINUE
      DO 24 J=1,10
      DO 24 I=1,12
   24 QD(J,I)=AREA*QD(J,I)
      RETURN
      END
C
      SUBROUTINE MASBAL(HR,AREA,POR)
C
      COMMON /FIT/QS(10,12),QLR(10,12),QP(10,12),CONUSE(10,12),
     1 QRIN(10,12),CSUR(10,12),TC(10)
      COMMON /GRAPH/CAQ(11,12),QROUT(10,12),COUT(10,12),H(11,12),
     1 QD(10,12),QOBS(10,12),TITLE(50),ENET(11,12)
      COMMON /AVE/A1(10),A2(10),A3(10),A4(10),A5(10),A6(10)
      DIMENSION WL(10,12)
      DO 3 J=1,10
      A1(J)=0.0
      A2(J)=0.0
      A3(J)=0.0
      A4(J)=0.0
      A5(J)=0.0
      A6(J)=0.0
      TC(J)=0.0
      ETOT=0.0
      DO 4 I=1,12
      WL(J,I)=H(J,I)-HR
      TC(J)=TC(J)+WL(J,I)
      IF(QLR(J,I).LT.0.0)GO TO 44
      QLEAK=QLR(J,I)
      GO TO 43
   44 QLEAK=0.0
   43 TOTREC=ENET(J,I)+QLEAK/AREA
      ETOT=ETOT+TOTREC
      IF(J.EQ.1 .AND. I.LT.5)GO TO 4
      AK1=TOTREC/(POR*WL(J,I))
      AK2=(QS(J,I)+QLEAK)/(AREA*POR*WL(J,I))
      IF(I.EQ.12)GO TO 5
      CAQ(J,I+1)=CSUR(J,I)*2.*AK2/(AK1+2.)-CAQ(J,I)*(AK1-2.)/(AK1+2.)
      GO TO 6
    5 CAQ(J+1,1)=CSUR(J,I)*2.*AK2/(AK1+2.)-CAQ(J,I)*(AK1-2.)/(AK1+2.)
    6 QOUT=QS(J,I)+QLR(J,I)
      QROUT(J,I)=QD(J,I)+QRIN(J,I)-QOUT
      IF(QLR(J,I).LT.0.0)GO TO 45
      COUT(J,I)=((QRIN(J,I)-QOUT)*CSUR(J,I)+QD(J,I)*CAQ(J,I))/QROUT(J,I)
      GO TO 4
   45 COUT(J,I)=((QRIN(J,I)-QS(J,I))*CSUR(J,I)+CAQ(J,I)*(QD(J,I)-
     1 QLR(J,I)))/QROUT(J,I)
    4 CONTINUE
      IF(ETOT.EQ.0.0)GO TO 75
      TC(J)=POR*TC(J)/(12.0*ETOT)
   75 CONTINUE
      DO 46 I=1,12
      A1(J)=A1(J)+H(J,I)
```

```
      A2(J)=A2(J)+QD(J,I)
      A3(J)=A3(J)+CAQ(J,I)
      A4(J)=A4(J)+QROUT(J,I)
      A5(J)=A5(J)+COUT(J,I)
      A6(J)=A6(J)+ENET(J,I)
   46 CONTINUE
      A1(J)=A1(J)/12.0
      A2(J)=A2(J)/12.0
      IF(J.GT.1)GO TO 48
      A3(J)=A3(J)/8.0
      A4(J)=A4(J)/8.0
      A5(J)=A5(J)/8.0
      A6(J)=A6(J)/8.0
      GO TO 3
   48 A3(J)=A3(J)/12.0
      A4(J)=A4(J)/12.0
      A5(J)=A5(J)/12.0
      A6(J)=A6(J)/12.0
    3 CONTINUE
      RETURN
      END
C
      SUBROUTINE GRAFF(JR)
C
      COMMON /GRAPH/CAQ(11,12),QROUT(10,12),COUT(10,12),H(11,12),
     1 QD(10,12),QOBS(10,12),TITLE(50),ENET(11,12)
      COMMON /LABLE/LBX(40),LB1(40),LB2(40),LB3(40),LB4(40),LB5(40),
     1 LB6(40)
      DIMENSION X(122),Y1(122),Y2(122),T(122),LBY1(40),LBY2(40)
     1 ,YS1(5),YS2(5),YS3(5),YS4(5),YS5(5),YS6(5),DELY1(5),DELY2(5),
     2 DELY3(5),DELY4(5),DELY5(5),DELY6(5)
      DATA YS1/3822.,-70.,-2.,-10.,-6./
      DATA DELY1/2.,10.,2.,2.,1./
      DATA YS2/0.,-24000.,-30000.,-21000.,-16000./
      DATA DELY2/3000.,4000.,10000.,3000.,4000./
      DATA YS3/1600.,0.,-1400.,0.,-100./
      DATA DELY3/50.,1000.,200.,200.,50./
      DATA YS4/-.8,-1.2,-0.5,-.6,-1.0/
      DATA DELY4/.2,.2,.5,.1,.2/
      DATA YS5/0.,-15000.,-40000.,-10000.,-10000./
      DATA DELY5/10000.,15000.,20000.,5000.,10000./
      DATA YS6/600.,-1400.,-900.,-1200.,-600./
      DATA DELY6/200.,200.,300.,200.,100./
      KOUNT=1
      J1=1
      J2=5
      N=120
      M=-1
    5 CONTINUE
      IN=5
      CALL RSTR(0)
      CALL RSTR(1)
      GO TO (1,3,2,4),KOUNT
    1 DO 11 J=1,10
      DO 11 I=1,12
      K=12*(J-1)+I
      AK=K
      X(K)=(AK-0.5)/12.0+1967.0
      T(K)=X(K)
      Y1(K)=H(J,1)
```

```
      Y2(K)=QD(J,I)
   11 CONTINUE
      Y1MIN=YS1(JR)
      DY1=DELY1(JR)
      Y2MIN=YS2(JR)
      DY2=DELY2(JR)
      DO 111 KI=1,8
      LBY1(KI)=LB1(KI)
  111 LBY2(KI)=LB2(KI)
      GO TO 50
    2 DO 12 J=1,10
      IF(J.GT.1)IN=1
      DO 12 I=IN,12
      K=12*(J-1)+I
      AK=K
      X(K-4)=1967.0+(AK-0.5)/12.0
      Y1(K-4)=QROUT(J,I)
      Y2(K-4)=QROUT(J,I)
   12 CONTINUE
      Y1MIN=YS5(JR)
      DY1=DELY5(JR)
      Y2MIN=Y1MIN
      DY2=DY1
      DO 112 KI=1,8
      LBY1(KI)=LB3(KI)
  112 LBY2(KI)=LB3(KI)
      M=-1
      J2=J1
      GO TO 50
    4 DO 14 J=1,10
      IF(J.GT.1)IN=1
      DO 14 I=IN,12
      K=12*(J-1)+I
      AK=K
      X(K-4)=1967.0+(AK-0.5)/12.0
      Y1(K-4)=COUT(J,I)
      Y2(K-4)=COUT(J,I)
   14 CONTINUE
      Y1MIN=YS6(JR)
      DY1=DELY6(JR)
      Y2MIN=Y1MIN
      DY2=DY1
      DO 114 KI=1,8
      LBY1(KI)=LB4(KI)
  114 LBY2(KI)=LB4(KI)
      GO TO 50
    3 DO 13 J=1,10
      IF(J.GT.1)IN=1
      DO 13 I=IN,12
      K=12*(J-1)+I
      AK=K
      X(K-4)=1967.0+(AK-0.5)/12.0
      Y1(K-4)=CAQ(J,I)
      Y2(K-4)=ENET(J,I)
   13 CONTINUE
      Y1MIN=YS3(JR)
      DY1=DELY3(JR)
      Y2MIN=YS4(JR)
      DY2=DELY4(JR)
      M=1
```

```
      N=116
      DO 113 KI=1,8
      LBY1(KI)=LB5(KI)
  113 LBY2(KI)=LB6(KI)
   50 XMIN=1967.0
      DX=1.0
      DO 444 I=1,N
      X(I)=(X(I)-XMIN)/DX
      Y1(I)=(Y1(I)-Y1MIN)/DY1
  444 Y2(I)=(Y2(I)-Y2MIN)/DY2
      CALL PLOT(0.35,1.0,-3)
      CALL AXIS(0.,0.,LBX,-40,10.,0.,XMIN,DX,-1)
      CALL PLOT(0.,7.,3)
      CALL PLOT(10.,7.,2)
      CALL PLOT(0.,0.,3)
      CALL AXIS(0.,0.,LBY1,40,7.,90.,Y1MIN,DY1,-1)
      CALL SYMBOL(0.3,7.10,0.14,TITLE,0.,50)
      CALL PLOT(10.,0.,3)
      CALL AXIS(10.,0.,LBY2,-40,7.,90.,Y2MIN,DY2,M)
      CALL PLOT(0.,0.,3)
      CALL LINE(X,Y1,N,J1,1)
      CALL PLOT(0.,0.,3)
      CALL LINE(X,Y2,N,J2,1)
      CALL PLOT(0.,-1.,-3)
      KOUNT=KOUNT+1
      IF(KOUNT.LT.5)GO TO 5
      RETURN
      END
C
      SUBROUTINE DELTA(JR)
C
      COMMON /GRAPH/CAQ(11,12),QROUT(10,12),COUT(10,12),H(11,12),
     1 QD(10,12),QOBS(10,12),TITLE(50),ENET(11,12)
      COMMON /AVE/A1(10),A2(10),A3(10),A4(10),A5(10),A6(10)
      DIMENSION H1(11,12),QD1(10,12),CAQ1(11,12),ENET1(11,12),
     1 QROUT1(10,12),COUT1(10,12),AA1(10),AA2(10),AA3(10),AA4(10),
     2 AA5(10),AA6(10)
      IF(JR.GT.1)GO TO 1
      DO 2 J=1,10
      AA1(J)=A1(J)
      AA2(J)=A2(J)
      AA3(J)=A3(J)
      AA4(J)=A4(J)
      AA5(J)=A5(J)
      AA6(J)=A6(J)
      DO 2 I=1,12
      H1(J,I)=H(J,I)
      QD1(J,I)=QD(J,I)
      CAQ1(J,I)=CAQ(J,I)
      ENET1(J,I)=ENET(J,I)
      QROUT1(J,I)=QROUT(J,I)
    2 COUT1(J,I)=COUT(J,I)
      GO TO 3
    1 DO 4 J=1,10
      A1(J)=A1(J)-AA1(J)
      A2(J)=A2(J)-AA2(J)
      A3(J)=A3(J)-AA3(J)
      A4(J)=A4(J)-AA4(J)
      A5(J)=A5(J)-AA5(J)
      A6(J)=A6(J)-AA6(J)
```

```
      DO 4 I=1,12
      H(J,I)=H(J,I)-H1(J,I)
      QD(J,I)=QD(J,I)-QD1(J,I)
      CAQ(J,I)=CAQ(J,I)-CAQ1(J,I)
      ENET(J,I)=ENET(J,I)-ENET1(J,I)
      QROUT(J,I)=QROUT(J,I)-QROUT1(J,I)
    4 COUT(J,I)=COUT(J,I)-COUT1(J,I)
    3 RETURN
      END
```

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS
AVE AQ W-L (FT)

BASE PERIOD SIMULATION

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	3824.38	3823.87	3824.05	3825.12	3825.07	3823.37	3823.83	3823.76	3825.02	3824.75
FEB	3824.18	3823.76	3823.87	3824.94	3824.83	3823.05	3824.04	3823.58	3825.04	3824.61
MAR	3824.28	3824.03	3824.08	3825.23	3824.98	3822.42	3824.25	3823.21	3825.28	3824.87
APR	3824.32	3824.14	3824.59	3825.55	3825.09	3822.29	3824.16	3823.57	3825.37	3825.31
MAY	3824.05	3823.93	3824.72	3825.74	3825.12	3822.31	3824.06	3824.28	3825.56	3825.58
JUN	3823.88	3824.04	3825.04	3826.16	3825.17	3822.30	3823.79	3824.68	3825.80	3825.95
JUL	3823.87	3824.48	3825.87	3826.66	3825.21	3822.29	3824.04	3824.88	3825.78	3825.69
AUG	3824.21	3825.06	3826.55	3826.97	3825.12	3822.24	3824.51	3825.02	3825.80	3825.07
SEP	3824.42	3825.10	3826.41	3826.69	3824.89	3822.57	3824.57	3825.01	3825.68	3825.33
OCT	3824.27	3824.72	3825.91	3826.14	3824.55	3823.07	3824.43	3824.92	3825.37	3825.45
NOV	3824.12	3824.46	3825.59	3825.71	3824.11	3823.35	3824.18	3824.96	3825.13	3825.05
DEC	3823.98	3824.24	3825.33	3825.35	3823.72	3823.60	3823.95	3824.99	3824.92	3824.72
AVERAGES:	3824.16	3824.32	3825.17	3825.85	3824.82	3822.74	3824.15	3824.40	3825.40	3825.20

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS:
AVE AQ CHEM. (MG/L)

BASE PERIOD SIMULATION

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	0.00	1664.76	1691.84	1682.15	1660.50	1651.36	1674.65	1713.57	1713.72	1708.28
FEB	0.00	1664.73	1691.77	1682.04	1660.50	1651.14	1674.62	1713.46	1712.78	1709.92
MAR	0.00	1664.78	1691.72	1683.80	1660.50	1651.03	1674.60	1713.37	1713.03	1715.58
APR	0.00	1660.58	1685.67	1673.20	1659.53	1658.85	1680.04	1730.86	1704.48	1706.39
MAY	1626.00	1674.83	1681.87	1674.13	1654.24	1659.85	1682.60	1716.82	1702.29	1698.34
JUN	1632.68	1679.68	1684.83	1664.40	1646.62	1665.15	1691.49	1711.12	1690.57	1696.14
JUL	1637.34	1681.58	1676.34	1654.89	1642.98	1671.22	1708.15	1708.73	1690.30	1683.17
AUG	1646.26	1679.14	1662.94	1642.74	1642.56	1676.14	1695.14	1708.90	1697.15	1709.99
SEP	1647.00	1673.73	1664.19	1641.54	1648.87	1684.86	1702.58	1708.06	1698.45	1722.15
OCT	1663.00	1690.02	1679.01	1657.29	1651.18	1676.37	1711.03	1716.85	1708.04	1706.37
NOV	1664.14	1691.34	1681.77	1659.84	1651.36	1675.15	1713.62	1714.14	1708.76	1707.57
DEC	1664.86	1691.87	1682.74	1660.63	1651.36	1674.92	1713.59	1713.86	1708.55	1707.55
AVERAGES:	1647.66	1676.42	1681.22	1664.72	1652.52	1666.34	1693.51	1714.15	1704.01	1705.95

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS
AVE RIVER OUTFLOW (AC-FT/MO)

BASE PERIOD SIMULATION

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	0.00	6150.60	5761.31	11193.35	11072.55	3690.11	5099.99	4947.40	13702.11	18237.51
FEB	0.00	7202.57	5015.75	12565.18	10847.61	2941.77	5667.51	4297.85	9858.26	10314.53
MAR	0.00	48226.55	37067.74	46501.15	57927.81	16852.14	38607.36	35852.25	35443.63	42894.53
APR	0.00	23983.96	32972.06	38556.67	39410.88	9033.54	36389.14	22545.91	40118.37	48300.02
MAY	25468.17	27447.39	30856.98	42130.11	42124.46	6116.85	37449.29	27781.85	43291.78	61679.77
JUN	29370.15	51577.82	46393.32	49494.04	52203.09	4888.31	43280.86	42867.14	46001.80	53790.55
JUL	34384.06	36711.61	51152.99	62373.45	50027.17	10581.54	36378.14	42809.39	39035.46	41619.06
AUG	40862.10	30416.31	50044.61	50084.82	35428.85	8610.15	57319.96	38277.37	42394.04	48870.45
SEP	24507.40	19407.86	25072.98	27739.53	11265.08	3954.12	23363.36	23543.13	31988.11	20779.78
OCT	7941.93	7546.19	13645.39	16064.61	9548.72	4201.72	7669.30	15892.65	10951.18	11261.84
NOV	7527.84	7350.96	13103.04	12692.64	6809.55	3643.66	6262.09	9365.20	9866.73	10125.01
DEC	8253.21	7096.03	17909.21	12188.20	5728.70	4163.49	5640.31	9135.31	9373.77	8406.75
AVERAGES:	22289.35	22759.82	27416.28	31965.31	27699.54	6556.45	25260.61	23109.62	27668.77	31356.65

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS
AVE RIVER CHEM (MG/L)

BASE PERIOD SIMULATION

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	0.00	1522.22	1591.56	1562.29	1541.71	1594.55	1543.44	1628.00	1210.17	902.08
FEB	0.00	1451.82	1623.90	1504.13	1504.49	1617.62	1577.89	1637.00	1540.56	1311.58
MAR	0.00	765.58	682.16	743.14	864.23	616.82	658.54	633.88	761.89	655.70
APR	0.00	929.17	746.78	831.67	903.36	713.06	680.24	624.31	741.93	683.31
MAY	737.06	836.10	790.43	837.29	885.93	816.35	705.12	686.39	811.97	664.24
JUN	675.50	705.09	716.83	828.84	828.61	905.61	639.43	632.17	822.99	740.09
JUL	842.28	810.53	796.43	782.44	863.19	644.55	628.58	672.65	864.59	755.34
AUG	928.01	841.50	888.06	899.97	906.24	713.86	621.79	702.44	829.85	667.92
SEP	1025.51	1110.93	1284.50	1297.74	1414.43	1245.72	864.62	871.92	961.35	1047.31
OCT	1428.37	1649.71	1644.68	1580.57	1300.20	1401.38	1564.22	1068.09	1584.77	1617.73
NOV	1472.97	1587.79	1619.32	1615.48	1502.23	1616.40	1632.83	1600.43	1572.93	1561.69
DEC	1482.41	1536.76	1408.47	1540.11	1479.46	1615.52	1634.03	1657.06	1520.76	1592.95
AVERAGES:	1074.01	1145.60	1149.43	1168.64	1166.17	1125.12	1062.56	1034.53	1101.98	1016.66

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS;
DRAIN FLOW (AC-FT/MO)

BASE PERIOD SIMULATION

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	6044.65	4547.07	5034.43	8815.25	8594.51	3409.60	4466.69	4270.63	8401.63	7356.66
FEB	5436.47	4280.15	4567.16	8076.62	7623.75	2808.38	5023.03	3851.04	8499.79	6826.47
MAR	5727.29	4981.41	5130.06	9299.29	8230.99	1905.12	5632.00	3091.73	9531.95	7803.63
APR	5866.49	5313.70	6752.19	10781.99	8679.52	1755.05	5374.22	3842.19	9913.74	9676.27
MAY	5053.75	4718.00	7243.07	11714.07	8827.24	1776.87	5071.84	5723.97	10828.34	10951.48
JUN	4572.47	5020.29	8490.27	13977.80	9058.62	1760.75	4345.96	7072.20	12052.06	12817.74
JUL	4550.71	6360.22	12395.97	16983.25	9220.03	1750.84	5013.97	7822.43	11956.66	11478.42
AUG	5512.56	8549.42	16263.57	18921.12	8824.76	1694.95	6479.03	8411.08	12060.79	8612.19
SEP	6178.87	8748.63	15439.17	17125.81	7895.66	2082.72	6681.50	8354.47	11439.63	9739.28
OCT	5683.26	7223.59	12640.22	13899.75	6625.59	2846.15	6207.12	7991.01	9926.97	10287.36
NOV	5233.17	6318.63	10993.02	11561.50	5221.68	3363.15	5412.72	8149.78	8850.46	8518.73
DEC	4860.70	5606.36	9759.89	9862.75	4188.94	3908.28	4781.63	8285.89	8016.10	7209.34
AVERAGES:	5393.36	5972.29	9559.08	12584.93	7749.27	2421.82	5374.14	6405.54	10123.18	9273.13

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS;
NET RECHARGE (FT)

BASE PERIOD SIMULATION

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
FEB	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MAR	0.1239	0.1669	0.1664	0.2084	0.1685	-0.1458	0.0105	-0.0942	0.1039	0.1812
APR	-0.0328	-0.0342	0.0871	0.0714	0.1175	-0.0550	0.0566	0.1516	0.0447	0.1728
MAY	-0.0200	0.0208	0.0230	0.1729	0.1422	-0.0820	-0.0030	0.0781	0.1628	0.1349
JUN	-0.0038	0.1042	0.1821	0.2025	0.1293	-0.0697	-0.0262	0.0476	0.0862	0.2420
JUL	0.0494	0.1769	0.2926	0.2587	0.1384	-0.0798	0.2257	0.0098	0.0593	-0.1299
AUG	0.1580	0.2002	0.1896	0.1601	0.0708	-0.0887	0.0889	0.0373	0.1033	0.0452
SEP	0.0066	-0.0331	-0.0352	0.0050	0.0679	0.0876	0.0611	-0.0550	-0.0071	0.2360
OCT	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NOV	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DEC	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AVERAGES:	0.0351	0.0501	0.0755	0.0899	0.0695	-0.0361	0.0345	0.0146	0.0461	0.0735

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS
AVE AQ W-L (FT)

CASE(1): QS=0; CHANGES FROM BASE PERIOD

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	0.00	-4.87	-9.98	-14.61	-19.94	-26.53	-29.00	-34.04	-37.28	-40.70
FEB	-0.01	-4.70	-9.78	-14.27	-19.61	-26.41	-28.80	-33.88	-36.96	-40.42
MAR	-0.51	-5.00	-10.18	-14.56	-19.93	-26.25	-28.81	-33.74	-37.06	-40.77
APR	-1.18	-5.48	-11.06	-15.29	-20.80	-26.33	-29.26	-34.30	-37.53	-41.72
MAY	-1.65	-6.02	-11.80	-16.21	-21.84	-26.76	-29.94	-35.50	-38.34	-42.72
JUN	-2.46	-7.41	-13.07	-17.84	-23.44	-27.43	-30.83	-36.93	-39.58	-44.22
JUL	-3.60	-9.16	-14.84	-19.85	-25.21	-28.35	-32.20	-38.13	-40.79	-45.27
AUG	-4.68	-10.39	-16.03	-21.16	-26.30	-28.79	-33.44	-38.58	-41.58	-45.60
SEP	-5.17	-10.69	-16.14	-21.30	-26.76	-29.04	-34.07	-38.44	-41.70	-46.35
OCT	-5.23	-10.56	-15.72	-21.01	-26.91	-29.31	-34.34	-38.12	-41.52	-46.73
NOV	-5.20	-10.42	-15.38	-20.70	-26.82	-29.27	-34.35	-37.91	-41.31	-46.47
DEC	-5.05	-10.19	-15.00	-20.32	-26.68	-29.18	-34.22	-37.62	-41.02	-46.17
AVERAGES:	-2.90	-7.91	-13.25	-18.09	-23.69	-27.80	-31.61	-36.43	-39.56	-43.93

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS:
AVE AQ CHEM. (MG/L)

CASE(1): QS=0; CHANGES FROM BASE PERIOD

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	0.00	59.68	178.01	324.37	572.16	914.10	1068.78	1429.45	1666.77	2124.60
FEB	0.00	59.92	178.31	324.84	572.68	914.12	1068.71	1429.21	1664.89	2123.42
MAR	0.00	59.98	178.59	322.91	572.94	914.25	1068.66	1429.21	1667.44	2119.68
APR	0.00	68.07	191.63	340.20	596.77	885.21	1085.18	1406.40	1695.42	2185.70
MAY	0.00	68.47	211.78	358.46	630.49	898.77	1121.18	1454.41	1733.63	2259.43
JUN	11.35	89.80	232.49	400.29	684.82	936.64	1171.27	1524.26	1806.23	2381.37
JUL	34.02	132.36	279.26	466.38	773.80	997.60	1250.14	1641.27	1928.77	2594.63
AUG	53.45	165.20	313.54	534.55	847.62	1052.22	1323.77	1685.41	2050.27	2766.07
SEP	61.24	178.19	323.50	556.05	875.02	1039.89	1359.70	1671.43	2075.66	2866.53
OCT	51.38	170.12	317.77	556.29	895.25	1061.46	1387.26	1652.83	2079.81	2937.98
NOV	57.75	177.32	321.85	566.37	906.46	1061.86	1414.02	1656.16	2110.77	2975.76
DEC	59.57	177.76	324.93	571.83	913.77	1069.12	1428.37	1667.39	2125.22	2987.08
AVERAGES:	41.10	117.24	254.31	443.54	736.81	978.77	1228.92	1553.95	1883.74	2526.85

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS
AVE RIVER OUTFLOW (AC-FT/MO)

CASE(1): QS=0; CHANGES FROM BASE PERIOD

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	0.00	-4349.91	-5027.58	-8814.66	-8594.50	-3409.60	-4466.69	-4270.63	-7877.63	1446.34
FEB	0.00	-3934.25	-4560.22	-5310.95	-7623.73	-2808.38	-5023.03	-3851.04	-6630.79	11170.53
MAR	0.00	33752.65	48890.04	41568.38	44606.03	33855.88	22941.00	50519.27	23382.05	38580.37
APR	0.00	20386.12	24679.54	26997.52	16163.49	12289.95	28723.78	37373.81	24303.26	36448.73
MAY	16285.03	15120.99	21324.06	26605.24	17252.77	4357.13	25543.17	36905.03	28223.66	40949.52
JUN	16792.43	36511.04	47684.36	38039.33	28155.38	6137.25	45608.04	53874.80	37867.94	40934.26
JUL	32829.31	41307.80	64079.89	55331.80	39456.97	26970.16	45489.03	42014.57	49957.34	44860.58
AUG	34905.42	47344.89	69762.04	51645.91	41449.24	24645.05	62310.97	45930.92	51454.21	59473.81
SEP	30295.88	25116.03	15608.34	22349.20	14833.34	4880.28	44176.50	24171.53	26839.37	29349.72
OCT	-2960.96	-4236.28	-8689.73	-9726.73	-5505.59	-2806.15	-1527.12	-7833.01	-5906.97	-7268.36
NOV	-3737.01	-5339.92	-9592.52	-10350.49	-5221.68	-3363.15	-5412.72	-8149.78	-8850.46	-8518.73
DEC	-4672.02	-5599.61	-9759.35	-9862.74	-4188.94	-3908.28	-4781.63	-8285.89	-8016.10	-7209.34
AVERAGES:	14967.26	16339.96	21199.91	18205.98	14231.90	8070.01	21131.78	21533.30	17062.16	23351.45

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS
AVE RIVER CHEM (MG/L)

CASE(1): QS=0; CHANGES FROM BASE PERIOD

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	0.00	-337.81	-685.48	-444.07	-315.47	-690.55	-925.44	-540.00	-798.17	-545.08
FEB	0.00	-274.99	-676.63	-320.05	-272.34	-705.62	-753.89	-659.00	-1077.56	-779.58
MAR	0.00	-100.97	-162.07	-223.13	-182.09	-131.82	-173.54	-101.88	-349.89	-235.70
APR	0.00	-204.60	-241.67	-326.66	-245.87	-228.06	-173.24	-227.31	-315.93	-256.31
MAY	-170.27	-171.71	-273.35	-322.28	-230.67	-345.35	-153.12	-267.39	-296.97	-223.24
JUN	-151.89	-104.57	-216.81	-328.84	-202.74	-427.61	-117.43	-213.17	-307.99	-299.09
JUL	-114.72	-182.29	-281.42	-326.44	-222.19	-203.55	-172.58	-231.65	-364.59	-353.34
AUG	-108.72	-327.32	-373.05	-450.97	-324.89	-235.86	-136.79	-283.44	-344.85	-222.92
SEP	-205.71	-461.69	-608.48	-554.74	-668.84	-488.72	-335.62	-459.92	-410.35	-595.31
OCT	-554.78	-900.25	-431.61	-492.57	-750.79	-577.38	-623.22	-656.09	-1194.77	-935.73
NOV	-402.34	-630.74	-325.23	-453.47	-337.52	-704.40	-514.83	-762.43	-1182.93	-773.69
DEC	-234.89	-579.62	-328.41	-511.11	-313.51	-909.52	-443.03	-554.06	-1108.76	-689.95
AVERAGES:	-242.91	-356.38	-383.68	-396.19	-338.91	-470.70	-376.89	-413.03	-646.06	-492.50

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS:
DRAIN FLOW (AC-FT/MO)

CASE(1): QS=0; CHANGES FROM BASE PERIOD

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	0.00	-4349.91	-5027.58	-8814.66	-8594.50	-3409.60	-4466.69	-4270.63	-8401.63	-7356.66
FEB	-33.65	-4074.25	-4560.22	-8075.95	-7623.73	-2808.38	-5023.03	-3851.04	-8499.79	-6826.47
MAR	-1414.15	-4780.35	-5123.96	-9298.62	-8230.97	-1905.12	-5632.00	-3091.73	-9531.95	-7803.63
APR	-2887.60	-5156.88	-6747.46	-10781.48	-8679.51	-1755.05	-5374.22	-3842.19	-9913.74	-9676.27
MAY	-3178.97	-4624.01	-7239.94	-11713.76	-8827.23	-1776.87	-5071.84	-5723.97	-10828.34	-10951.48
JUN	-3580.57	-4980.96	-8488.64	-13977.67	-9058.62	-1760.75	-4345.96	-7072.20	-12052.06	-12817.74
JUL	-4086.69	-6344.20	-12395.11	-16983.20	-9220.03	-1750.84	-5013.97	-7822.43	-11956.66	-11478.42
AUG	-5230.58	-8539.11	-16262.96	-18921.09	-8824.76	-1694.95	-6479.03	-8411.08	-12060.79	-8612.19
SEP	-5945.12	-8739.97	-15438.66	-17125.80	-7895.66	-2082.72	-6681.50	-8354.47	-11439.63	-9739.28
OCT	-5480.96	-7216.28	-12639.73	-13899.73	-6625.59	-2846.15	-6207.12	-7991.01	-9926.97	-10287.36
NOV	-5047.01	-6311.92	-10992.52	-11561.49	-5221.68	-3363.15	-5412.72	-8149.78	-8850.46	-8518.73
DEC	-4672.02	-5599.61	-9759.35	-9862.74	-4188.94	-3908.28	-4781.63	-8285.89	-8016.10	-7209.34
AVERAGES:	-3463.11	-5893.12	-9556.34	-12584.68	-7749.27	-2421.82	-5374.14	-6405.54	-10123.18	-9273.13

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS:
NET RECHARGE (FT)

CASE(1): QS=0; CHANGES FROM BASE PERIOD

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	-0.0033	-0.0020	-0.0023	-0.0035	-0.0026	-0.0022	0.0000	-0.0009	-0.0050	-0.0033
FEB	-0.0019	-0.0014	-0.0021	-0.0014	-0.0013	-0.0015	-0.0001	-0.0011	-0.0090	-0.0041
MAR	-0.2278	-0.2121	-0.2584	-0.2868	-0.2818	0.0253	-0.1009	-0.0050	-0.2010	-0.2855
APR	-0.1046	-0.0901	-0.2356	-0.2145	-0.2548	-0.0931	-0.1973	-0.3018	-0.1856	-0.2893
MAY	-0.1587	-0.2355	-0.2148	-0.3919	-0.3596	-0.1272	-0.1967	-0.3091	-0.3561	-0.3337
JUN	-0.2562	-0.4584	-0.4847	-0.5573	-0.5034	-0.1986	-0.2743	-0.4325	-0.3969	-0.5409
JUL	-0.3098	-0.4088	-0.4783	-0.6046	-0.4384	-0.2324	-0.4111	-0.2290	-0.3507	-0.1379
AUG	-0.2483	-0.2623	-0.3061	-0.2968	-0.2021	0.0074	-0.2331	-0.1143	-0.2132	-0.1923
SEP	-0.0675	-0.0287	-0.0328	-0.0952	-0.1535	-0.1509	-0.1635	0.0206	-0.0585	-0.3042
OCT	-0.0632	-0.0600	-0.0426	-0.0649	-0.0424	-0.0128	-0.0749	-0.0299	-0.0564	-0.0452
NOV	-0.0218	-0.0071	-0.0262	-0.0318	-0.0269	-0.0255	-0.0361	-0.0271	-0.0264	-0.0132
DEC	-0.0012	-0.0018	0.0000	-0.0027	-0.0012	-0.0011	-0.0030	-0.0007	-0.0014	-0.0019
AVERAGES:	-0.1830	-0.1474	-0.1737	-0.2126	-0.1890	-0.0677	-0.1409	-0.1192	-0.1550	-0.1793

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS
AVE AQ W-L (FT)

CASE(2): QP=0; CHANGES FROM BASE PERIOD

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	0.00	1.43	1.95	1.78	1.57	1.56	1.54	2.33	2.28	2.06
FEB	-0.01	1.25	1.66	1.48	1.28	1.39	1.32	1.98	1.86	2.16
MAR	-0.51	1.38	1.91	1.61	1.47	2.17	1.54	2.75	1.77	2.35
APR	-1.18	2.03	2.46	2.09	1.85	3.08	2.18	3.69	2.14	2.41
MAY	-0.84	2.57	2.90	2.48	2.00	2.91	2.95	3.92	2.52	2.70
JUN	0.04	3.17	3.52	2.78	2.20	2.35	4.18	4.57	3.06	3.16
JUL	1.04	3.77	3.83	3.32	2.71	2.18	4.76	5.24	3.98	4.18
AUG	1.78	3.95	4.23	3.88	3.30	2.84	4.86	5.56	4.63	5.27
SEP	2.28	4.09	4.56	4.05	3.26	2.99	5.16	5.58	4.76	4.93
OCT	2.38	3.66	3.86	3.50	2.72	2.48	4.55	4.91	4.12	3.80
NOV	1.95	2.85	2.92	2.59	2.16	2.11	3.49	3.78	3.09	2.89
DEC	1.67	2.33	2.25	1.98	1.79	1.79	2.78	2.89	2.38	2.29
AVERAGES:	0.72	2.71	3.00	2.63	2.19	2.32	3.28	3.93	3.05	3.18

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS:
AVE AQ CHEM. (MG/L)

CASE(2): QP=0; CHANGES FROM BASE PERIOD

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	0.00	-79.54	-197.02	-328.41	-413.20	-453.92	-485.12	-589.97	-694.08	-745.11
FEB	0.00	-79.45	-196.96	-328.15	-413.07	-453.66	-485.11	-589.80	-693.77	-749.74
MAR	0.00	-79.49	-196.89	-330.13	-413.00	-453.50	-485.09	-589.67	-694.46	-759.63
APR	0.00	-92.82	-216.31	-339.79	-424.59	-480.89	-498.08	-623.50	-694.56	-758.74
MAY	0.00	-114.20	-227.50	-353.39	-426.21	-484.68	-509.01	-623.26	-701.45	-757.81
JUN	-15.88	-120.71	-243.58	-357.27	-424.85	-481.70	-524.51	-630.39	-696.50	-763.26
JUL	-25.28	-137.88	-260.43	-361.24	-424.81	-474.09	-552.60	-644.20	-702.24	-758.09
AUG	-44.10	-151.36	-273.04	-374.61	-435.77	-478.76	-552.10	-659.70	-717.63	-794.34
SEP	-55.83	-172.35	-308.55	-396.41	-453.78	-498.93	-575.98	-677.26	-731.77	-816.28
OCT	-82.85	-199.38	-330.15	-416.72	-456.87	-488.70	-594.68	-697.23	-747.50	-806.63
NOV	-79.86	-196.58	-329.82	-414.96	-455.77	-487.32	-592.77	-696.09	-746.62	-805.84
DEC	-79.62	-197.08	-328.74	-413.41	-453.96	-485.27	-590.23	-694.29	-745.26	-805.18
AVERAGES:	-47.93	-135.07	-259.08	-367.87	-432.99	-476.79	-537.11	-642.95	-713.82	-776.72

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS
AVE RIVER OUTFLOW (AC-FT/MO)

CASE(2): QP=0; CHANGES FROM BASE PERIOD

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	0.00	4622.51	7527.76	8871.15	7681.69	4364.10	5495.96	9076.01	11957.12	10575.47
FEB	0.00	3837.34	5668.46	7423.66	5770.51	3305.97	4874.32	6765.96	9066.56	10811.69
MAR	0.00	5146.12	7935.53	8790.94	7426.47	-1662.40	2420.04	9805.48	6954.13	12819.96
APR	0.00	-4225.83	-2267.83	2405.97	-6128.53	921.62	-2158.44	7103.32	835.37	14419.80
MAY	-22363.23	-11477.29	-7472.12	-10554.71	-16603.19	3176.24	-12457.81	-273.18	-4667.53	2499.46
JUN	-24680.88	-31068.92	-13114.57	-16418.25	-23301.92	2087.99	-16368.61	-7413.55	-13511.66	-13825.57
JUL	-26454.44	-2678.12	26582.67	-11119.95	-17615.89	-4229.96	14527.90	14294.79	481.05	1708.30
AUG	7552.55	25023.22	31377.88	29287.32	19418.69	3761.31	29983.40	37613.62	32802.78	35466.76
SEP	11025.20	26310.57	33691.55	30174.89	16506.92	6855.05	32562.83	37776.75	33472.56	33703.72
OCT	8913.07	21310.40	25989.23	22483.52	11873.23	6577.75	25768.73	25666.13	26445.19	24171.35
NOV	5931.76	13876.66	16737.32	15525.45	8097.53	6702.87	17395.84	22173.32	17759.00	15480.43
DEC	6169.51	10436.68	13345.03	10904.30	6167.30	5858.74	11986.54	16772.80	12837.54	11515.11
AVERAGES:	-4238.31	5092.78	12166.74	8147.86	1607.74	3143.27	9502.56	14946.79	11202.68	13278.87

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS
AVE RIVER CHEM (MG/L)

CASE(2): QP=0; CHANGES FROM BASE PERIOD

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	0.00	12.02	-107.05	-227.49	-312.44	-397.11	-388.07	-505.59	-297.21	-167.82
FEB	0.00	24.87	-129.10	-188.39	-288.47	-420.14	-410.24	-516.21	-534.41	-422.10
MAR	0.00	71.62	120.85	40.10	-61.44	185.42	32.45	65.26	-71.12	-37.31
APR	0.00	393.81	369.74	148.67	122.34	464.90	123.10	273.73	5.42	-56.28
MAY	888.94	724.53	663.94	383.34	342.10	358.83	323.60	407.17	38.41	-4.45
JUN	941.31	853.88	637.90	478.28	393.16	277.84	500.39	448.56	171.09	123.94
JUL	769.78	567.38	170.31	347.85	354.98	552.58	267.71	230.60	123.46	134.08
AUG	100.15	286.42	138.86	46.54	12.65	266.89	138.05	98.75	-49.81	23.06
SEP	165.81	191.73	-40.28	-144.64	-219.34	-59.79	83.72	5.61	-125.16	-233.41
OCT	151.78	-159.06	-295.82	-340.00	-105.89	-213.71	-447.87	-70.28	-624.23	-717.99
NOV	111.31	-93.66	-267.37	-370.59	-306.63	-428.57	-511.98	-582.39	-610.79	-659.96
DEC	23.47	-75.63	-125.92	-309.40	-308.92	-426.24	-509.87	-635.27	-583.79	-690.56
AVERAGES:	394.07	233.16	94.67	-11.31	-31.49	13.41	-66.58	-65.00	-213.18	-225.74

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS:
DRAIN FLOW (AC-FT/MO)

CASE(2): QP=0; CHANGES FROM BASE PERIOD

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	0.00	5050.31	8025.36	9637.35	8240.29	4644.61	5495.95	9281.61	12752.52	10575.47
FEB	-33.65	4067.54	6117.05	7423.66	6059.91	3439.36	4888.32	6994.56	9987.21	10811.69
MAR	-1414.15	5146.12	7935.53	8790.94	7426.47	4857.85	6363.69	9805.48	9953.23	12819.96
APR	-2887.60	8732.72	12717.92	12722.72	10032.42	8200.11	9655.06	17070.52	12624.02	14419.80
MAY	-1948.81	11252.10	16141.79	15938.24	11076.81	7516.22	14094.74	21784.70	15834.47	17159.11
JUN	116.80	15488.61	21729.68	19097.98	12564.08	5215.55	21433.29	28381.39	20438.08	21552.83
JUL	3378.91	21511.28	26587.67	24274.40	16307.11	4600.74	27026.45	34510.84	27559.86	28895.45
AUG	7552.55	25023.22	31377.88	29287.32	20304.19	6951.11	29983.40	37613.62	32802.78	35466.76
SEP	11025.20	26310.57	33691.55	30174.89	19307.92	8726.45	32562.83	37776.75	33472.56	33703.72
OCT	11171.74	21633.00	26994.40	24648.38	14303.23	7933.32	27230.91	32076.63	27469.40	25145.83
NOV	8226.43	14884.26	18847.34	16656.59	9417.53	6983.38	18245.21	23388.74	18775.27	17086.71
DEC	6419.51	10837.08	13345.03	11483.70	6434.30	6106.54	12635.14	16931.20	13134.94	11924.31
AVERAGES:	3467.24	14161.40	18625.52	17511.35	11789.52	6264.60	17467.92	22968.00	19567.03	19963.47

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS:
NET RECHARGE (FT)

CASE(2): QP=0; CHANGES FROM BASE PERIOD

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	-0.0033	0.0020	0.0023	0.0035	0.0026	0.0004	0.0000	0.0009	0.0072	0.0778
FEB	-0.0019	0.0020	0.0020	0.0241	0.0013	-0.0003	0.0001	0.0011	0.0167	0.1616
MAR	-0.2278	0.1427	0.2389	0.1815	0.2046	0.4145	0.1984	0.4886	0.1296	0.1415
APR	-0.1046	0.2644	0.1916	0.2283	0.1227	0.1032	0.2253	0.1694	0.2379	0.1353
MAY	0.2084	0.1555	0.2655	0.2048	0.1353	-0.0308	0.3296	0.2864	0.1922	0.2790
JUN	0.1596	0.3521	0.3532	0.2485	0.1694	-0.0971	0.5336	0.4581	0.3752	0.2796
JUL	0.3046	0.2525	0.2257	0.3869	0.3220	0.1133	0.1689	0.4159	0.4686	0.6310
AUG	0.1212	0.2522	0.4858	0.3529	0.2688	0.2792	0.4001	0.3860	0.3716	0.4345
SEP	0.2661	0.2830	0.2530	0.2682	0.0816	-0.0696	0.3046	0.3200	0.2939	0.0557
OCT	-0.0192	-0.0296	0.0030	-0.0065	-0.0098	0.0001	-0.0183	0.0306	-0.0100	-0.0085
NOV	0.0114	0.0111	0.0061	-0.0103	-0.0148	-0.0229	-0.0282	-0.0160	-0.0170	0.0015
DEC	0.0012	0.0018	0.0000	0.0027	0.0012	0.0011	0.0030	0.0007	0.0014	0.0019
AVERAGES:	0.0895	0.1408	0.1689	0.1570	0.1071	0.0576	0.1764	0.2118	0.1723	0.1826

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS
AVE AQ W-L (FT)

CASE(3): IMPR IRR EFF; CHANGES FROM BASE PERIOD

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	0.00	-2.22	-3.22	-2.58	-2.19	-3.50	-6.11	-7.34	-7.87	-6.80
FEB	-0.01	-2.09	-3.05	-2.32	-1.96	-3.39	-5.92	-7.17	-7.53	-6.51
MAR	-0.16	-2.02	-3.02	-2.18	-1.91	-3.49	-5.84	-7.18	-7.32	-6.38
APR	-0.49	-2.12	-3.17	-2.23	-2.06	-3.83	-5.96	-7.41	-7.28	-6.35
MAY	-0.90	-2.48	-3.44	-2.44	-2.34	-4.31	-6.27	-7.80	-7.35	-6.41
JUN	-1.47	-3.18	-3.90	-2.91	-2.95	-4.97	-6.84	-8.47	-7.65	-6.68
JUL	-2.14	-3.86	-4.25	-3.47	-3.65	-5.78	-7.38	-9.08	-8.06	-7.04
AUG	-2.51	-4.03	-4.17	-3.58	-3.97	-6.31	-7.65	-9.19	-8.17	-7.25
SEP	-2.55	-3.89	-3.86	-3.31	-3.99	-6.45	-7.75	-9.01	-7.95	-7.20
OCT	-2.54	-3.77	-3.52	-3.03	-3.90	-6.47	-7.75	-8.76	-7.69	-6.96
NOV	-2.49	-3.61	-3.20	-2.76	-3.78	-6.40	-7.68	-8.51	-7.42	-6.65
DEC	-2.36	-3.40	-2.89	-2.47	-3.64	-6.29	-7.52	-8.21	-7.11	-6.35
AVERAGES:	-1.47	-3.06	-3.47	-2.77	-3.03	-5.10	-6.89	-8.18	-7.62	-6.71

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS:
AVE AQ CHEM. (MG/L)

CASE(3): IMPR IRR EFF; CHANGES FROM BASE PERIOD

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	0.00	44.22	101.60	156.51	225.01	303.22	394.92	480.79	555.06	623.63
FEB	0.00	44.37	101.77	156.76	225.22	303.31	394.91	480.78	554.88	623.99
MAR	0.00	44.40	101.94	156.80	225.33	303.40	394.90	480.82	555.56	624.88
APR	0.00	45.83	105.40	158.33	229.50	310.09	401.29	489.56	556.57	625.00
MAY	0.00	51.92	112.88	165.61	236.02	319.19	409.87	493.03	563.99	626.58
JUN	8.91	62.41	123.69	175.68	247.07	337.82	425.04	506.40	569.01	637.42
JUL	22.38	80.54	139.01	193.31	268.93	362.40	450.42	532.86	588.03	651.19
AUG	33.67	91.39	145.53	209.78	285.68	385.64	456.06	546.32	608.62	684.76
SEP	36.77	93.29	149.86	215.38	293.46	392.24	464.57	546.68	610.69	697.23
OCT	39.71	97.58	154.35	220.33	297.07	392.04	471.34	550.78	615.59	689.96
NOV	43.29	101.16	155.66	223.02	300.69	392.55	476.65	552.37	620.83	693.88
DEC	44.14	101.45	156.69	224.83	303.11	394.95	480.49	555.14	623.65	695.37
AVERAGES:	28.61	71.55	129.03	188.03	261.42	349.74	435.04	517.96	585.21	656.16

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS
AVE RIVER OUTFLOW (AC-FT/MO)

CASE(3): IMPR IRR EFF; CHANGES FROM BASE PERIOD

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	0.00	-3389.79	-4358.53	-6770.77	-6068.08	-3055.24	-4384.03	-4236.58	-7984.24	-7023.94
FEB	0.00	-3000.85	-3893.70	-5824.52	-5114.28	-2500.87	-4914.21	-3817.27	-7778.62	-6426.10
MAR	0.00	-247.86	2320.99	-813.88	2808.03	7013.14	1053.36	4115.03	-2400.48	-107.76
APR	0.00	5163.73	4999.59	2896.76	4035.66	9104.89	4929.55	7064.99	395.27	-1042.19
MAY	10885.26	11848.68	7562.82	7395.67	9300.88	4457.63	9478.54	11035.39	3280.20	3672.61
JUN	16143.63	21321.37	14253.77	14876.45	19708.71	6200.79	17461.80	20834.69	10560.53	9066.40
JUL	15534.03	11023.56	2186.87	11147.11	13598.18	20894.92	8451.09	8075.29	9224.70	8068.53
AUG	2226.14	-3278.15	-5968.63	-5589.11	1520.25	4221.67	4015.27	-2811.69	-4024.51	2127.62
SEP	-432.85	-3404.22	-8457.09	-7178.51	-987.72	2527.83	778.88	-5840.03	-6600.70	-4694.97
OCT	-1948.03	-3511.45	-7684.59	-6803.56	-4906.03	-2767.53	-1486.41	-7804.58	-5826.47	-7128.69
NOV	-2783.97	-5120.65	-7729.78	-7705.30	-4737.46	-3314.20	-5376.68	-8115.08	-8768.60	-8387.85
DEC	-3723.63	-4928.14	-7826.81	-7314.81	-3780.23	-3845.49	-4747.24	-8242.23	-7927.96	-7081.02
AVERAGES:	4487.57	1873.02	-1216.26	-973.71	2114.83	3244.79	2104.99	854.83	-2320.91	-1579.78

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS
AVE RIVER CHEM (MG/L)

CASE(3): IMPR IRR EFF; CHANGES FROM BASE PERIOD

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	0.00	-156.49	-262.63	-111.14	-11.65	-104.15	-757.86	-487.01	-779.92	-527.96
FEB	0.00	-152.42	-174.41	-111.01	-19.23	21.44	-573.97	-573.53	-1015.39	-730.07
MAR	0.00	-71.65	-136.69	-145.40	-72.36	-120.20	-168.25	-100.79	-344.41	-229.41
APR	0.00	-158.30	-208.09	-220.64	-154.65	-216.84	-168.88	-225.56	-311.11	-248.56
MAY	-128.68	-146.53	-243.05	-235.26	-182.29	-331.02	-150.27	-265.75	-292.65	-216.83
JUN	-129.19	-94.29	-198.90	-263.12	-193.55	-418.87	-116.15	-212.34	-304.56	-291.96
JUL	-98.32	-168.65	-253.69	-268.22	-192.33	-201.72	-171.06	-230.86	-361.55	-347.29
AUG	-88.03	-291.82	-318.65	-342.57	-232.23	-232.85	-135.53	-282.26	-341.16	-219.55
SEP	-161.30	-400.94	-467.36	-369.81	-554.40	-483.10	-332.58	-457.26	-404.58	-581.95
OCT	-415.05	-713.88	-237.08	-243.33	-633.68	-543.88	-615.04	-649.57	-1164.39	-877.80
NOV	-274.97	-376.67	-136.89	-71.14	-231.84	-532.68	-471.18	-722.78	-1038.34	-652.12
DEC	-138.91	-320.87	-182.87	-63.34	-229.52	-640.22	-404.41	-497.06	-991.70	-544.77
AVERAGES:	-179.31	-254.37	-235.03	-203.75	-225.64	-317.01	-338.77	-392.06	-612.48	-455.69

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS;
DRAIN FLOW (AC-FT/MO)

CASE(3): IMPR IRR EFF; CHANGES FROM BASE PERIOD

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	0.00	-3389.79	-4358.53	-6770.77	-6068.08	-3055.24	-4384.03	-4236.58	-8345.44	-7259.47
FEB	-22.48	-3103.25	-3893.70	-5923.92	-5114.28	-2500.87	-4914.21	-3817.27	-8428.15	-6719.63
MAR	-475.70	-3518.66	-4342.21	-6492.22	-5395.23	-1716.46	-5499.58	-3065.63	-9434.41	-7663.49
APR	-1392.17	-3838.67	-5757.27	-7468.31	-5905.88	-1617.91	-5259.58	-3813.67	-9807.39	-9483.93
MAY	-2058.21	-3700.52	-6329.44	-8460.47	-6443.32	-1676.37	-4985.05	-5688.41	-10713.34	-10729.12
JUN	-2688.11	-4330.63	-7659.36	-10820.68	-7380.83	-1697.21	-4297.06	-7042.71	-11940.87	-12580.93
JUL	-3330.04	-5775.78	-11258.20	-13908.75	-8128.82	-1714.62	-4973.97	-7800.18	-11874.03	-11322.67
AUG	-4316.79	-7778.82	-14409.63	-15484.38	-7991.81	-1670.59	-6432.93	-8388.29	-11983.05	-8523.85
SEP	-4841.19	-7875.69	-13378.56	-13712.31	-7183.66	-2055.11	-6636.72	-8328.90	-11356.23	-9630.10
OCT	-4468.03	-6491.45	-10770.39	-10976.56	-6026.03	-2807.53	-6166.41	-7962.58	-9846.47	-10147.69
NOV	-4093.97	-5634.71	-9129.78	-8916.30	-4737.46	-3314.20	-5376.68	-8115.08	-8768.60	-8387.84
DEC	-3723.63	-4928.14	-7826.81	-7314.81	-3780.23	-3845.49	-4747.24	-8242.23	-7927.96	-7081.02
AVERAGES:	-2617.53	-5030.51	-8259.49	-9687.46	-6179.64	-2305.97	-5306.12	-6375.13	-10035.50	-9127.48

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS;
NET RECHARGE (FT)

CASE(3): IMPR IRR EFF; CHANGES FROM BASE PERIOD

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	-0.0022	-0.0013	-0.0015	-0.0024	-0.0017	-0.0015	0.0000	-0.0006	-0.0033	-0.0022
FEB	-0.0013	-0.0009	-0.0014	-0.0009	-0.0009	-0.0010	-0.0000	-0.0007	-0.0060	-0.0027
MAR	-0.0693	-0.0301	-0.0613	-0.0523	-0.0755	-0.0804	-0.0603	-0.0661	-0.0648	-0.0696
APR	-0.0916	-0.0829	-0.0990	-0.0954	-0.0915	-0.0987	-0.0938	-0.1001	-0.0939	-0.0777
MAY	-0.1192	-0.1431	-0.1279	-0.1460	-0.1449	-0.1395	-0.1332	-0.1540	-0.1288	-0.1326
JUN	-0.1734	-0.2361	-0.2017	-0.2366	-0.2494	-0.1788	-0.2003	-0.2566	-0.2071	-0.1993
JUL	-0.1737	-0.1547	-0.1238	-0.2307	-0.2000	-0.2081	-0.1236	-0.1461	-0.1942	-0.1785
AUG	-0.0602	-0.0414	-0.0777	-0.0911	-0.0876	-0.0542	-0.0962	-0.0513	-0.0733	-0.0981
SEP	-0.0406	-0.0412	-0.0453	-0.0601	-0.0570	-0.0422	-0.0683	-0.0229	-0.0438	-0.0454
OCT	-0.0421	-0.0400	-0.0284	-0.0432	-0.0283	-0.0085	-0.0499	-0.0199	-0.0376	-0.0302
NOV	-0.0145	-0.0047	-0.0174	-0.0212	-0.0180	-0.0170	-0.0240	-0.0181	-0.0176	-0.0088
DEC	-0.0008	-0.0012	0.0000	-0.0018	-0.0008	-0.0008	-0.0020	-0.0005	-0.0009	-0.0013
AVERAGES:	-0.0986	-0.0648	-0.0655	-0.0818	-0.0796	-0.0692	-0.0710	-0.0698	-0.0726	-0.0705

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS
AVE AQ W-L (FT)

CASE(4): QL=0; CHANGES FROM BASE PERIOD

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	0.00	-0.73	-1.08	-0.30	-0.82	-2.65	-2.47	-1.13	0.24	-0.01
FEB	-0.01	-0.67	-0.99	-0.24	-0.71	-2.56	-2.31	-1.05	0.20	0.26
MAR	0.08	-0.65	-0.88	-0.23	-0.65	-2.01	-2.05	-0.39	0.09	0.30
APR	0.16	-0.54	-0.92	-0.30	-0.86	-1.53	-1.85	0.02	-0.02	0.03
MAY	0.01	-0.70	-1.13	-0.71	-1.51	-1.75	-1.85	-0.38	-0.37	-0.24
JUN	-0.46	-1.48	-1.57	-1.62	-2.51	-2.28	-1.86	-0.80	-0.94	-0.91
JUL	-1.03	-2.27	-1.98	-2.44	-3.36	-2.79	-2.13	-0.92	-1.16	-1.00
AUG	-1.31	-2.38	-1.55	-2.35	-3.35	-2.60	-2.05	-0.40	-0.81	-0.20
SEP	-1.02	-1.76	-0.72	-1.54	-3.02	-2.48	-1.39	0.39	-0.15	-0.07
OCT	-0.77	-1.34	-0.36	-1.12	-2.94	-2.69	-1.16	0.65	0.08	-0.35
NOV	-0.84	-1.29	-0.38	-1.06	-2.88	-2.67	-1.23	0.42	-0.06	-0.38
DEC	-0.80	-1.18	-0.35	-0.95	-2.78	-2.61	-1.21	0.29	-0.11	-0.36
AVERAGES:	-0.50	-1.25	-0.99	-1.07	-2.12	-2.39	-1.80	-0.27	-0.25	-0.24

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS:
AVE AQ CHEM. (MG/L)

CASE(4): QL=0; CHANGES FROM BASE PERIOD

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	0.00	5.34	6.49	-23.52	-2.38	63.39	66.19	29.89	-39.56	-57.26
FEB	0.00	5.56	6.75	-23.13	-2.10	63.62	66.19	29.99	-39.33	-62.51
MAR	0.00	5.59	6.98	-25.36	-1.95	63.78	66.19	30.11	-39.61	-74.36
APR	0.00	0.40	-2.53	-28.90	-8.13	34.44	57.24	-8.48	-39.11	-73.27
MAY	0.00	-8.83	1.57	-31.32	2.45	34.93	55.09	-2.32	-41.37	-71.82
JUN	3.69	2.67	5.38	-15.34	23.65	45.56	55.44	3.28	-29.30	-69.83
JUL	17.57	23.84	19.68	9.15	53.91	63.74	51.13	10.19	-20.39	-47.08
AUG	23.86	34.32	18.23	25.40	68.71	70.58	61.78	1.54	-24.39	-68.92
SEP	19.57	23.42	-7.64	10.08	56.13	50.06	38.83	-22.23	-43.89	-92.85
OCT	-1.07	1.83	-26.25	-8.55	55.91	61.71	20.65	-45.80	-63.64	-85.09
NOV	3.91	6.28	-25.10	-5.06	60.09	63.07	25.36	-42.59	-60.24	-82.50
DEC	5.22	6.28	-23.54	-2.66	63.24	66.08	29.54	-39.65	-57.42	-81.10
AVERAGES:	9.10	8.89	-1.66	-9.93	30.79	56.75	49.47	-4.67	-41.52	-72.22

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS
AVE RIVER OUTFLOW (AC-FT/MO)

CASE(4): QL=0; CHANGES FROM BASE PERIOD

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	0.00	-1589.02	-2358.92	-1233.43	-2972.35	-2782.84	-3504.42	-2102.51	1261.30	3925.17
FEB	0.00	-1345.55	-2035.64	330.74	-2406.40	-2268.55	-3804.06	-1815.44	1681.37	9089.34
MAR	0.00	15776.60	22258.09	21889.61	21423.77	14699.86	8877.59	23473.22	15227.18	22117.31
APR	0.00	10095.54	11454.82	15584.13	8053.80	5210.82	11750.12	18598.29	15299.47	20883.25
MAY	8777.41	7310.05	9505.60	13947.24	6835.30	1547.58	10365.59	18086.85	15843.79	22210.03
JUN	8095.50	15727.25	20397.01	16015.08	9908.79	2185.16	19518.09	24921.34	18171.27	19858.52
JUL	14533.22	16738.30	26635.14	21109.04	14007.65	11451.10	19085.18	19393.17	22778.90	20987.54
AUG	15119.56	18832.76	30738.07	19677.89	15050.31	10461.54	26428.96	22912.82	24816.72	29816.28
SEP	13593.40	9849.17	10016.41	9551.73	3672.00	1461.02	19234.69	16350.67	16465.56	17263.46
OCT	-884.88	-2449.65	-68.85	-3588.23	-4989.76	-2327.70	-885.06	2963.25	2195.34	-189.89
NOV	-1418.89	-2861.61	-1144.19	-4065.38	-4339.08	-2752.70	-2781.59	1833.34	-267.20	-1484.45
DEC	-1804.93	-2769.45	-1531.13	-3737.08	-3460.01	-3154.05	-2458.06	1260.60	-438.26	-1236.45
AVERAGES:	7001.30	6942.87	10322.20	8790.11	5065.34	2810.94	8485.59	12156.30	11086.29	13603.34

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS
AVE RIVER CHEM (MG/L)

CASE(4): QL=0; CHANGES FROM BASE PERIOD

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	0.00	-46.19	-64.42	-32.74	-45.36	-130.47	-248.27	-40.47	-2.99	-117.66
FEB	0.00	-51.83	-40.62	-56.34	-45.91	-61.92	-154.17	-31.32	-97.83	-330.22
MAR	0.00	-49.73	-100.93	-88.92	-119.92	-111.84	-129.86	-52.05	-102.24	-65.73
APR	0.00	-100.19	-133.99	-129.59	-148.29	-173.29	-127.75	-101.90	-96.41	-85.40
MAY	-55.80	-83.32	-160.87	-152.99	-172.53	-255.27	-111.94	-136.69	-120.66	-84.67
JUN	-70.24	-71.70	-152.51	-213.34	-186.89	-359.33	-90.42	-125.89	-169.39	-162.48
JUL	-74.09	-149.17	-211.33	-246.12	-215.89	-187.26	-140.32	-133.26	-234.49	-213.13
AUG	-72.78	-273.08	-253.38	-331.37	-301.30	-215.67	-107.13	-138.45	-198.24	-104.51
SEP	-132.19	-341.46	-287.57	-337.55	-580.82	-414.61	-249.38	-138.43	-167.12	-304.02
OCT	-162.54	-266.27	-82.05	-113.53	-516.69	-333.28	-248.40	70.60	-210.70	-194.38
NOV	-102.86	-133.62	-45.75	-56.43	-233.96	-138.31	-45.39	-19.35	-57.64	-92.23
DEC	-48.60	-95.17	-37.47	-55.22	-234.61	-136.20	-39.88	-29.52	-57.90	-87.32
AVERAGES:	-89.89	-138.48	-130.91	-151.18	-233.51	-209.79	-141.08	-73.06	-126.30	-153.48

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS;
DRAIN FLOW (AC-FT/MO)

CASE(4); QL=0; CHANGES FROM BASE PERIOD

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	0.00	-1589.02	-2358.92	-1233.43	-2972.35	-2782.84	-3504.42	-2102.51	1025.50	-36.18
FEB	-32.29	-1408.55	-2035.64	-913.51	-2406.40	-2268.55	-3804.06	-1815.44	840.32	990.69
MAR	253.65	-1563.25	-2048.21	-1000.54	-2352.88	-1392.59	-3980.26	-651.73	415.88	1244.52
APR	522.40	-1398.81	-2687.33	-1416.42	-3125.55	-1109.43	-3593.98	51.09	-98.18	127.00
MAY	18.60	-1575.20	-3348.20	-3296.31	-4900.70	-1212.72	-3411.16	-1096.20	-1729.61	-1145.42
JUN	-1072.35	-2944.15	-4880.84	-7392.57	-6837.51	-1368.94	-2961.21	-2504.81	-4292.73	-4329.88
JUL	-2078.98	-4705.10	-7778.61	-11432.71	-7897.00	-1473.35	-3641.17	-3033.48	-5082.40	-4365.01
AUG	-2941.64	-6315.04	-7973.18	-12077.26	-7572.99	-1391.46	-4526.55	-1541.08	-3765.03	-822.42
SEP	-2715.05	-5386.03	-3954.74	-8212.02	-6556.05	-1672.33	-3651.41	1713.97	-759.99	-326.59
OCT	-2018.88	-3790.65	-1846.35	-5466.08	-5493.76	-2345.70	-2991.06	2892.15	386.34	-1548.44
NOV	-2008.39	-3299.01	-1774.19	-4610.33	-4339.08	-2752.70	-2781.59	1833.34	-267.20	-1484.45
DEC	-1804.93	-2769.45	-1531.13	-3737.08	-3460.01	-3154.05	-2458.06	1260.60	-438.26	-1236.45
AVERAGES:	-1156.49	-3062.02	-3518.11	-5065.69	-4826.19	-1910.39	-3442.08	-416.17	-1147.11	-1077.72

MESILLA VALLEY, N.MEX.-SIMULATION RESULTS;
NET RECHARGE (FT)

CASE(4); QL=0; CHANGES FROM BASE PERIOD

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
JAN	-0.0031	-0.0020	-0.0023	-0.0035	-0.0026	-0.0022	0.0000	-0.0009	-0.0023	0.0413
FEB	-0.0019	-0.0007	-0.0021	0.0126	-0.0013	-0.0015	-0.0001	-0.0011	0.0005	0.0871
MAR	0.0434	-0.0170	0.0151	-0.0293	-0.0143	0.2063	0.0437	0.2665	-0.0344	-0.0507
APR	-0.0015	0.0393	-0.0765	-0.0232	-0.1290	-0.0220	-0.0247	-0.0931	-0.0123	-0.0558
MAY	-0.0601	-0.1356	-0.0702	-0.1979	-0.2275	-0.0961	-0.0417	-0.0932	-0.1583	-0.0710
JUN	-0.1531	-0.2484	-0.2002	-0.2940	-0.3149	-0.1586	-0.0214	-0.1239	-0.1441	-0.2687
JUL	-0.1229	-0.1676	-0.0911	-0.2385	-0.1920	-0.0870	-0.1553	0.0233	-0.0372	0.1474
AUG	-0.0451	0.0207	0.1295	0.0605	0.0524	0.1407	0.1152	0.1609	0.1084	0.1524
SEP	0.1160	0.1428	0.1244	0.1047	-0.0384	-0.1157	0.0940	0.1853	0.1353	-0.1062
OCT	-0.0504	-0.0449	-0.0226	-0.0437	-0.0368	-0.0126	-0.0512	-0.0291	-0.0360	-0.0300
NOV	-0.0151	-0.0022	-0.0191	-0.0257	-0.0269	-0.0255	-0.0361	-0.0271	-0.0264	-0.0132
DEC	-0.0012	-0.0018	0.0000	-0.0027	-0.0012	-0.0011	-0.0030	-0.0007	-0.0014	-0.0019
AVERAGES:	-0.0369	-0.0348	-0.0179	-0.0567	-0.0777	-0.0146	-0.0067	0.0222	-0.0174	-0.0141

This dissertation is accepted on behalf of the faculty of the Institute by the following committee:

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Adviser

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Raz Khaleel
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10/16/81
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