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Operation of Rain Gauge and Groundwater Monitoring Networks for the Imperial Valley Water Authority

Year Ten: September 2001 - August 2002

by

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Abstract

The Illinois State Water Survey (ISWS), under contract to the Imperial Valley Water Authority (IVWA), has operated a network of rain gauges in Mason and Tazewell Counties since August 1992. The ISWS also established a network of groundwater observation wells in the Mason-Tazewell area in 1994 that is monitored by the IVWA. The purpose of the rain gauge network and the groundwater observation well network is to collect long-term data to determine the impact of groundwater withdrawals in dry periods and during the growing season, and the rate at which the aquifer recharges. This report presents data accumulated from both networks since their inception through August 2002. Precipitation is recorded continuously at 20 rain gauges. Groundwater levels are measured the first of each month at 13 observation wells. The database from these networks consists of ten years of precipitation data and eight years of groundwater observations.

During the preparation of the data for this report, it was found that the annual precipitation total at site 16 has been somewhat higher than at the surrounding gauges for the past six years, with the annual difference between site 16 and its neighbors increasing during the last three years (annual difference of 11.6 inches in 2001-2002). The gauge at this site was replaced on May 23, 2002, and the monthly totals were comparable with those at surrounding gauges. Accordingly, the annual spatial patterns for the past six years were redrawn omitting the precipitation from site 16 and replace maps from previous reports. Site 16 data also were omitted from the annual average network precipitation tabulations and from the average number of precipitation-days and events for the past six years (1996-1997 through 2001-2002). For the current year, the network received an average of 39.91 inches of precipitation, 4.02 inches greater than the network 10-year average precipitation.

In 2002, groundwater levels in wells close to the Illinois River peaked above levels observed at any time since the 1995 record highs, closely following Illinois River peak stages. Groundwater levels in the rest of the observation wells, more distant from the Illinois River, also showed their highest levels since 1995. Groundwater levels in many wells rose throughout the winter, starting from seasonal lows in October 2001. January 2002 water levels in most wells were above those observed in December 2001. Pronounced water level rises were seen in the river wells (Mason-Tazewell Observation Well or MTOW-5 and MTOW-9) in February-March, followed by wells MTOW-2 and MTOW-10 in April-May, then by the rest of the wells (except MTOW-11) between May and June.

Total irrigation for the June-September period was estimated to be 47 billion gallons, the second highest total since 1995 and tied with the 2001 irrigation season estimate. This can be attributed, in part, to the growth of irrigation systems in the Imperial Valley, which now has 1,839 systems. The timing of the rainfall during the irrigation season probably was more crucial, however. For June-August, 12.23 inches of the total network average of 13.59 inches (90 percent of the rain) fell in 15 days of the 92-day period (16 percent of the days).

Introduction

The Imperial Valley area, a portion of which also is called the Havana Lowlands, is located principally in Mason and southern Tazewell Counties in west-central Illinois, just east of the Illinois River (Figure 1). The area overlies the confluence of the ancient Mississippi and the Mahomet-Teays bedrock valleys. The sandy soils and rolling dunes of the confluence area in the western portion of the Imperial Valley stand in stark contrast to the typically flat silt loam soils throughout much of the rest of central Illinois. The sand-and-gravel deposits associated with these two valleys contain an abundant groundwater resource. The area is used primarily for row and specialty crops, all made possible by irrigation from the easily developed groundwater resource that underlies the Imperial Valley.

Regional precipitation variability affects irrigation water demand on the aquifer, recharge of the aquifer, and the extent to which the aquifer can be used for agricultural irrigation, and municipal, industrial, and domestic water supplies. All these factors affect any required water withdrawals from an aquifer. Therefore, knowledge of the precipitation variability and its relationship to groundwater recharge over an extensively irrigated region, such as the area within the Imperial Valley Water Authority (IVWA), should provide useful information for the management of groundwater resources in that region.

The Illinois State Water Survey (ISWS) has a long-term interest in precipitation measurement and related research, and has performed precipitation research in areas such as hydrology, weather modification, climate change, and urban influences on precipitation climate. Scientists and engineers from the ISWS have conducted extensive research on Illinois groundwater resources and have a continued interest in the hydrodynamics and recharge of aquifers in the state.

The objective of this project is to conduct long-term monitoring of precipitation and groundwater levels in the Imperial Valley region to learn how the groundwater resources respond to drought and seasonal irrigation, and to assess groundwater recharge.

Rain Gauge and Observation Well Networks

A number of studies (Walker et al., 1965; Panno et al., 1994; Clark, 1994) have shown that precipitation is the primary source of water for groundwater recharge in the Imperial Valley. Therefore, detailed precipitation measurements are important for understanding its contribution to groundwater levels in the Imperial Valley area.

During the last 40 years, the ISWS has operated rain gauge networks of varying areal gauge densities over various time periods in both rural and urban areas. Sampling requirements, as determined from these past studies (e.g., Huff, 1970), indicate that a 2- to 3-mile gridded rain gauge spacing should be adequate for properly capturing convective precipitation systems (spring and summer), while a 6-mile spacing is adequate for more widespread precipitation-producing systems (autumn and winter). The Belfort weighing bucket rain gauge provides precise and reliable precipitation measurements. Given the size of the IVWA area and the above spacing guidelines, a gridded, 25-site rain gauge network (Figure 1) with approximately 5 miles between gauges was established in late August 1992. The network was reduced to 20 sites in September 1996. Results of the previous years of the network operation are reported in Peppler and

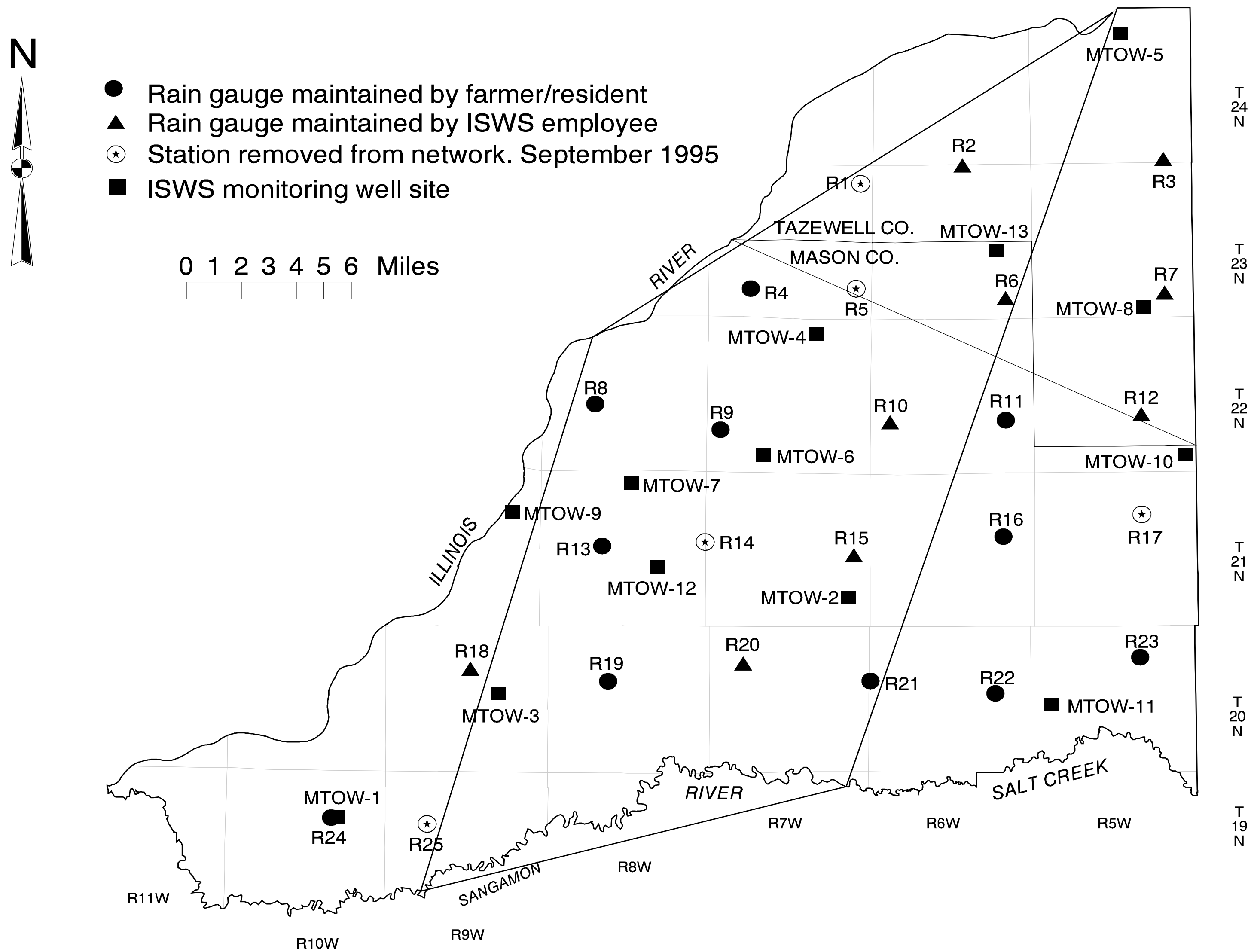

Figure 1. Configuration of the 13-site observation well and 25-site rain gauge networks in the Imperial Valley during the 2001 - 2002 observation year.

Hollinger (1994, 1995), Hollinger and Peppler (1996), Hollinger (1997), Hollinger and Scott (1998), Hollinger et al. (1999, 2000), and Scott et al. (2001, 2002).

The observation well network, originally consisting of 11 wells, Mason-Tazewell Observation Wells (MTOW)-1 through MTOW-11, was established for the IVWA in 1994 by Sanderson and Buck (1995). The IVWA added two wells (MTOW-12 and MTOW-13) in 1995 and 1996 to improve spatial coverage of the network. The 13 observation wells are located fairly uniformly across the Imperial Valley study area (Figure 1). Hollinger et al. (1999) includes the first summary of the groundwater level data and also statistical analyses of the correlation between precipitation, Illinois River stage, and groundwater levels for the four years that the observation well network had been in operation. Results of the fifth and sixth years of operation of the observation well network are reported in Hollinger et al. (2000) and Scott et al. (2001), respectively. Finally, Scott et al. (2002) includes groundwater level data and reanalysis of the correlation between precipitation, Illinois River stage, and groundwater levels for seven years of observation well network data.

Report Objective

This report documents the operation, maintenance, data reduction and analysis, and management of the networks during the tenth year of the rain gauge network operation and the eighth year of the observation well network operation. A discussion of observed relationships between precipitation, Illinois River stage, and groundwater levels is included.

Several appendices document groundwater hydrographs (Appendix A), observed groundwater level data for the observation wells (Appendix B), rain gauge network site descriptions (Appendix C), and rain gauge maintenance for the 2001-2002 period (Appendix D). Contour maps of the annual precipitation across the Imperial Valley are presented in Appendix E for Years One-Nine. Years Five-Nine were recontoured without erroneous data from rain gauge site 16. Finally, documentation is presented for precipitation events (Appendix F) and heavy storms (Appendix G).

Acknowledgments

This work was conducted for the Imperial Valley Water Authority (IVWA) with partial support from the Illinois State Water Survey (ISWS) General Revenue Fund. The IVWA Board under the direction of Mr. Morris Bell, chairman of the IVWA, administers the project. The views expressed in this report are those of the authors and do not necessarily reflect the views of the sponsor or of the ISWS. Paul Nelson and Robert Ranson ran the rain gauge network, and Morris Bell collected the monthly groundwater level data. Linda Hascall drafted the precipitation maps for this report, and Eva Kingston edited the report. Their efforts are greatly appreciated. The ISWS and IVWA take this opportunity to thank all of the local Mason/Tazewell county observers for their diligence in making this analysis possible.

Rain Gauge Network Description, Operation, and Maintenance

Peppler and Hollinger (1994) described construction of the IVWA rain gauge network and the type and setup of the weighing-bucket rain gauges used. Appendix C gives complete site description information for the 20 operational rain gauge locations as of August 31, 2002. Also included are the locations of five rain gauges removed from the network in 1996. In December 1997, the rain gauges were upgraded to include a data logger and linear potentiometer to automatically record the amount of water in the rain gauges every 10 minutes. This eliminates the necessity to digitize weekly or monthly paper charts, saving 2-3 days of co-principal investigator time each month. The collection of paper charts is maintained for backup if data loggers fail. At the end of the tenth year, local observers continued to perform weekly rain gauge maintenance at five sites. The remaining 15 sites were maintained by a local Mason County resident hired to change the charts once a month, download data from the data loggers, and serve as a local resource for the other volunteer observers. The five sites with weekly rain charts (sites 8, 11, 16, 19, and 24) were serviced every 6-11 days and also were visited at the end of each month to collect the rainfall data from the data loggers.

Rain gauge servicing included removing and replacing the current chart, checking the felt-tipped pen to make sure it was inking properly, emptying the bucket contents from approximately April-October, and noting any unusual problems, including chart-drive malfunction, gauge imbalance or instability, vandalism, unauthorized movement of the gauge, etc. During the warm season, evaporation shields were fitted into the collection orifice above the bucket to minimize evaporation. During the cold season, a one-quart charge of antifreeze was added to each rain gauge bucket so that any frozen precipitation collected would melt to allow a proper weight reading, and to prevent freeze damage to the collection bucket.

Approximately once a week, the five local observers mailed their charts to the ISWS. A memory card with the digital data and the 15 8-day charts were sent monthly to the ISWS. Complete descriptions of servicing instructions for rain gauge observers appear in previous reports. Minor maintenance and repairs were performed by the paid observer in Mason County. Champaign-based personnel visited the network to perform major maintenance and repairs as needed. This usually consisted of a site assessment of an observer-noted problem and determination of a solution. Because most problems pertained to the chart drives, the usual solution was to adjust or replace the chart drive. If replaced, the defective chart drive was cleaned and readied for reuse at the ISWS. Other typical problems, mentioned above, also were solved on these trips. Appendix D documents nonroutine maintenance or repairs, including any site relocations, for the 20 rain gauges during Year Ten.

Groundwater Level Observation Well Network Description, Operation, and Maintenance

A general description of each network well is provided in Table 1, including well location, depth, and the predominant soil associations in proximity to each well. This provides some determination of relative soil permeability around the wells. Generally, the greater permeabilities associated with the Plainfield-Bloomfield, Sparta-Plainfield-Ade, and Onarga-Dakota-Sparta soil associations (Calsyn, 1995) are found at MTOW-1, -3, -4, -6, -7, -9, and -12, all located on the western side of the study area (Figure 1). The fine-grained nature of the materials found in the upper portion of the geologic profiles at MTOW-10 and MTOW-11 (located in the southeastern portion of the study area) indicate that the water levels in these two wells are under artesian conditions. Because the water in these wells is under pressure, the water-level responses may be different from those of other wells.

The wells range in depth from 24 to 100 feet. Most network wells were constructed after 1985 as part of special studies within the Imperial Valley or for use in the observation well network. A few wells that existed prior to the development of the network were used for water supply. Well MTOW-1, located at Snicarte, is an inactive, large-diameter, hand-dug domestic well. All of the network wells have been surveyed for well head elevation above mean sea level.

From 1995 through 2001, groundwater levels in the IVWA observation wells were measured at the beginning of each month from March through November (December, January, and February readings typically were not collected). Beginning in 2002, monthly measurements were collected throughout the entire year. A mid-month measurement was collected during the irrigation seasons of 1995-1997 (May-October 1995, May-September 1996, and May-August 1997). Groundwater levels are measured manually with a steel tape or electric probe and are entered into a database as depth below land surface. The IVWA collects these measurements, maintains the database, and forwards the resulting data annually to the ISWS.

The Snicarte observation well, MTOW-1, has been monitored by the ISWS since 1958 and has been incorporated into the Shallow Groundwater Well Network of the ISWS Water and Atmospheric Resources Monitoring (WARM) Program. This well is equipped with a Stevens, Type F water-level recorder that produces a continuous record of the groundwater level on a 32-day paper chart. The ISWS staff visit the well monthly to measure the groundwater level, change the recorder chart, and perform recorder maintenance. Therefore, a longer and more complete groundwater level record is available for this well than for any other well in the IVWA network.

Table 1. Description of Imperial Valley Network Observation Wells

Name	*I.D.*	*Location*	*Depth (feet)*	*Generalized Soil Association*	*Remarks*
Snicarte	MTOW-1	Section 11.8b, T.19N., R.10W., Mason County	40.5	Sparta-Plainfield-Ade	Inactive well, continuous record since 1958
Easton	MTOW-2	Section 25.8a, T.21N., R.7W., Mason County	82	Elburn-Plano-Thorp	Abandoned city fire well
Mason County Wildlife Refuge & Recreation Area	MTOW-3	Section 14.8c, T.20N., R.9W., Mason County	24	Plainfield-Bloomfield	Installed in 1985 for ISGS study
Sand Ridge SR-11	MTOW-4	Section 2.8d, T.22N., R.7W., Mason County	27	Plainfield-Bloomfield	Installed in 1989 for ISWS study
Pekin - OW8	MTOW-5	Section 3.6a, T.24N., R.5W., Tazewell County	49	Selma-Harpster	Installed in 1991 for ISWS study
Mason State Tree Nursery	MTOW-6	Section 33.8f, T.22N., R.7W., Mason County	45.5	Onarga-Dakota-Sparta	Installed in 1993
IL Route 136 Rest Area	MTOW-7	Section 3.7e, T.21N., R.8W., Mason County	44	Onarga-Dakota-Sparta	Installed in 1993
Green Valley	MTOW-8	Section 34.1c, T.23N., R.5W., Mason County	53.5	Elburn-Plano-Thorp	Installed in 1993
IDOT - DWR	MTOW-9	Section 12.8e, T.21N., R.9W., Mason County	48	Sparta-Plainfield-Ade	Installed in 1994 for flood study
San Jose	MTOW-10	Section 36.2d, T.22N., R.5W., Mason County	56	Elburn-Plano-Thorp	Old municipal well
Mason City	MTOW-11	Section 18.2a, T.20N., R.5W., Mason County	63	Tama-Ipava	Old municipal well
Hahn Farm	MTOW-12	Section 23.8c, T.21N., R.8W., Mason County	100	Plainfield-Bloomfield	Old turkey farm well
Talbott Tree Farm	MTOW-13	Section 9.4a, T.23N, R.6W., Tazewell County	82	Selma-Harpster	Installed in 1996

Note: General Soil Map Units are from Calsyn, 1995. MTOW = Mason Tazewell Observation Well.

Precipitation and Groundwater Level Data Analysis

This report presents the rainfall and groundwater level data for the 2001-2002 year. Data collected from the rain gauge and observation well networks were maintained in separate databases, but the resulting data were evaluated together to examine the response of groundwater levels to local precipitation. Observed network groundwater levels may also be influenced by irrigation pumpage, so an estimate of monthly pumpage also is presented.

Irrigation Water Use Analysis

Since 1995, the IVWA has estimated irrigation pumpage from wells in the Imperial Valley based on electric power consumption, using the equation below:

$$Q = 1505 \times KWH \times IRR / MEC$$

where Q is the total estimated monthly irrigation pumpage (in gallons), KWH is the monthly electrical power consumption (in kilowatt hours) used by the irrigation accounts served by Menard Electric Cooperative, IRR is the total number of irrigation systems in the IVWA region, MEC is the number of Menard Electric Cooperative irrigation accounts, and 1505 is a power consumption conversion factor (in gallons/KWH). Electric power for the irrigation systems in the region is supplied by an electric cooperative (Menard Electric Cooperative) and two investor-owned utilities (AmerenCIPS and AmerenCILCO). Menard Electric Cooperative provides the IVWA with electric power consumption data for the irrigation services they serve during the growing season (June-September). However, only part of the irrigation systems use electric power to pump water and Menard serves only part of these. The pumpage estimate assumed that application rates for the irrigation wells with electric pumps on Menard Electric Cooperative are representative of those on the other utilities and those using other energy sources. Past estimates were based on the assumption that 33 percent of the irrigation wells were on Menard Electric Cooperative in 1995-1997, and that 40 percent of the wells were on Menard Electric Cooperative in 1998-2001.

In summer 2002, a U.S. Geological Survey (USGS) study indicated that a new power consumption conversion factor was needed. An updated conversion factor was determined by recording electrical consumption while closely measuring the pumping rate at 77 irrigation systems. The updated value, 1259 gallons/KWH, is appreciably lower than the previously used factor of 1505 gallons/KWH, suggesting that previous estimates of water withdrawals may have overestimated pumpage by approximately 20 percent (i.e., pumping system efficiency is 20 percent less than previously thought). Therefore, irrigation withdrawals for the years 1997 to the present were recalculated using the new formula, replacing earlier published estimates. The collection of additional data related to the irrigation systems (such as system age and size) and the conversion factors associated with those systems may enhance withdrawal estimates further.

Precipitation Analysis

Data reduction activities during Year Ten of network operation were similar to those performed during the past nine years (Peppler and Hollinger, 1994). Hourly rainfall amounts are totaled from 10-minute digital data and are placed into an array of monthly values for the 20 gauges. This data array is used to check for spatial and temporal consistency between gauges, and to divide the data into storm periods. If the digital data are missing, hourly rainfall amounts are read from the analog (paper) charts. If both the data logger failed and the chart data are missing, an unusual event, the hourly amounts are estimated based on an interpolation of values from the nearest surrounding gauges.

Groundwater Level Analysis

Groundwater levels for each well for the period of record (1995-2002) are presented graphically (Appendix A) and in tabular form (Appendix B). Graphs of groundwater levels are commonly called hydrographs. Each hydrograph contains the total monthly precipitation for the nearest rain gauge. For observation wells located between several rain gauges, an average of the surrounding rain gauge data is presented. For observation wells located relatively near the Illinois River (MTOW-1, -5, and -9), the stage of the river at the nearest U.S. Army Corps of Engineers (USACE) gauging station is included. Mean monthly stage data were downloaded from the USACE Internet site (http://water.mvr.usace.army.mil) for the Beardstown, Havana, and Kingston Mines stations. Because of an apparently strong correlation between groundwater levels and river stage at MTOW-2 (Hollinger et al., 1999), Illinois River stage at Havana also is presented with its hydrograph. This also was done for the hydrograph of MTOW-12 for visual inspection as part of the river stage and step-wise regression analyses. All hydrographs were plotted at the same vertical (depth-to-water) and horizontal (time) scales to simplify comparison of the observation well water levels.

Hollinger et al. (1999) first conducted a quantitative analysis of the correlation between total monthly precipitation and monthly groundwater level measurements. Scott et al. (2002) repeated the same analyses with three additional years of data. Observed groundwater levels in each well were correlated to total monthly precipitation at an adjacent rain gauge, or an average of the total monthly precipitation at selected surrounding rain gauges. Observed groundwater levels also were correlated to Illinois River stage for selected wells. No new correlation analyses were performed for this report. Instead, a qualitative description is provided to aid in understanding the data presented.

Results

Irrigation Water Use

Monthly and seasonal estimates of irrigation withdrawals were calculated for the Imperial Valley by previously described methods. Since 1995, irrigation withdrawals have averaged 40 billion gallons (bg) per year, but annual totals have varied from 30 to 52 bg (Table 2). Total annual irrigation withdrawals from highest to lowest occurred in 1996; 2001 and 2002 (tied); 1999; 1997 and 1995 (tied); and finally, 1998 and 2000 (tied); however, more irrigation systems are being added every year with more than 200 more systems reported operating in 2002 than just four years previously. The greatest average irrigation withdrawals typically occur in July and August, with September and June trailing far behind. Estimated irrigation withdrawals show July with the greatest monthly total in six of the eight years reported.

The estimated monthly irrigation pumpage also is displayed graphically in Figure 2 with average monthly network precipitation. These figures show a tendency toward lower irrigation amounts with increasing precipitation and vice versa, but also show that irrigation is dependent on the timing of precipitation. For example, in 2000 only 30 bg were pumped, even though Water Year 1999-2000 showed a deficit of 10 inches (Table 3). However, Figure 2 shows that significant precipitation fell during the summer of 2000, reducing the need for irrigation. Irrigation system growth also is important. Even though the Imperial Valley received above average precipitation in Water Year 2001-2002 (Table 3), 47 bg were pumped, tying it with Water Year 2000-2001 for second highest seasonal irrigation pumpage season since records have been kept.

Table 2. Estimated Monthly Irrigation Withdrawals (billion gallons), Number of Irrigation Systems, and Withdrawal Rank, Imperial Valley

Year	*June*	*July*	*August*	*September*	*Total*	*# Systems*	*Rank*
1995	2.6	14	10	11	38		4
1996	2.0	20	18	12	52		1
1997	2.6	19	14	2.0	38		4
1998	2.1	7.8	13	6.9	30	1622	5
1999	2.8	18	12	6.0	39	1771	3
2000	6.4	6.0	12	5.6	30	1799	5
2001	4.4	21	17	5.0	47	1818	2
2002	3.4	24	16	3.7	47	1839	2
Average	3.3	16	14	6.5	40		

Note:
Data were unavailable about the number of systems in 1995-1997.

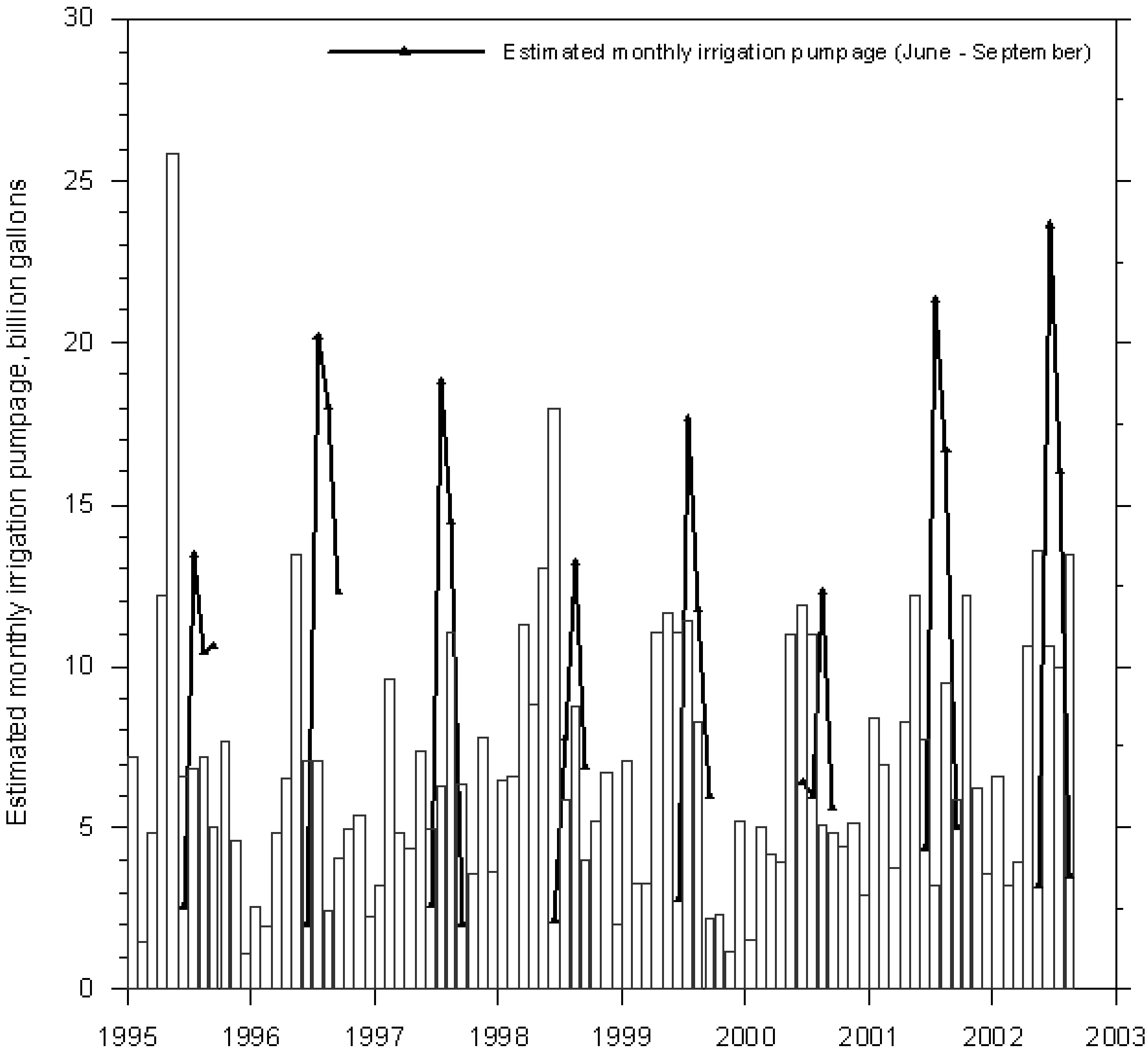

Figure 2. Estimated irrigation pumpage and average monthly precipitation in the IVWA.

Each of the last five months of the 2001-2002 study period (April-August) had a network total rainfall of 4 inches. Even so, total irrigation for the June-September period was estimated to be the second highest total since 1995 and tied with the 2001 irrigation season estimate of 47 bg. This can be attributed, in part, to the growth of irrigation systems within the IVWA. However, the timing of the rainfall during those months was probably more critical to the need for irrigation (refer to Appendix G-2). Although the June 2002 network average precipitation was 4.23 inches, most of the rain fell in storms on June 11-12 (3.41 inches); that is, more than 80 percent of June rain fell in two days. Then, no significant rainfall was recorded until July 11 (0.45 inches), followed by small rains until July 26-29 (3.19 inches). More than 90 percent of the July network average of 3.99 inches fell in four days, mostly at the end of the month. Therefore, significant irrigation was needed during July even though July's total was above average. August was much the same with significant rain falling only on August 13 (0.59 inches) and August 16-24 (4.59 inches). Therefore, 5.18 inches of the total August rainfall of 5.37 inches (96 percent)

Table 3. Imperial Valley Network Average Annual Precipitation, Annual Precipitation Surplus, Running Surplus, and Ranked Annual Precipitation and Irrigation, September-August

Year	*Network average precipitation (in.)*	*Annual surplus (in.)*	*Running surplus (in.)*	*Precip. rank*	*Irrigation rank*
1992 - 1993	55.55	+19.66	+19.66	1	-
1993 - 1994	40.21	+4.32	+23.98	2	-
1994 - 1995	39.42	+3.53	+27.51	5	4
1995 - 1996	25.70	-10.19	+17.32	10	1
1996 - 1997	27.31	-8.58	+8.74	8	4
1997 - 1998	40.06	+4.17	+12.91	3	5
1998 - 1999	34.02	-1.87	+11.04	6	3
1999 - 2000	25.81	-10.08	+0.96	9	5
2000 - 2001	30.97	-4.92	-3.96	7	2
2001 - 2002	39.91	+4.02	+0.06	4	2
1992 - 2002 average	35.89				
1971 - 2000 average	37.82 (Havana)				
	35.70 (Mason City)				

Note:
Site 16 was excluded from network average computations from 1996-1997 onward.

fell in nine days. Of the 13.59 inches of rain received during June-August, 12.23 inches (90 percent) fell in 15 days (16 percent of the days). Irrigation in July 2002 ranks as the highest July for the eight years over which estimates have been made, while June and August 2002 rank as third highest among their respective months during this same period.

Precipitation

Annual and Monthly Precipitation

Table 3 presents the average annual precipitation for the Water Year (September-August of the following year) for the entire rain gauge network. Average network precipitation for the 10-year period and the 30-year (1971-2000) precipitation average at Havana and Mason City also are included. The flood year of 1992-1993 had 55.55 inches of precipitation (19.66 inches above the 10-year network average). Water Years 1993-1994, and 1997-1998 also were above average (+4.32, and +4.17 inches, respectively), while Water Years 1995-1996, 1996-1997, and 1999-2000 were much below average (-10.19, -8.58, and -10.08 inches, respectively). Water Year 1994-1995 was above average (+3.53 inches), but 25-33 percent of this total fell in May 1995 alone, during which most network gauges recorded more than 10 inches of precipitation. However, the subsequent period, June-August 1995 and the following two years, were drier than normal. Water Year 1997-1998 was above normal, but the following three years were below normal.

Water Year 2001-2002 was an above average year, 4.02 inches greater than the network 10-year average precipitation. Interestingly, despite the tremendous surplus precipitation experienced during the first three years of observation, the running surplus over the 10-year period of record is essentially back to zero (Table 3).

The monthly and annual (September 2001-August 2002) precipitation amounts for each site in the IVWA network are presented in Table 4. The average precipitation pattern for the first ten years of network operation (Figure 3a) and the annual precipitation pattern for Year Ten (Figure 3b) also are presented. The annual precipitation patterns for Years One-Nine are presented in Appendix F.

Precipitation totals for the current year (Table 4) ranged from 49.86 inches at site 16 northwest of Mason City to 34.20 inches at site 21. The annual precipitation total at site 16 has been somewhat higher than the surrounding gages for the past six years, with the annual difference between site 16 and adjacent sites increasing during the last three years (annual difference of 11.6 inches in 2001-2002.) After the gauge at site 16 was replaced on May 23, 2002, the monthly totals have been comparable to those at surrounding gauges. The precipitation from site 16 has been omitted from the annual average network precipitation tabulations (Tables 3-4) and

Table 4. Monthly Precipitation Amounts (inches), September 2001-August 2002

	Month												
Site	*Sep*	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Total*
2	3.19	5.44	2.79	1.32	3.10	1.29	1.36	4.36	6.38	3.85	2.33	4.88	40.29
3	2.25	4.65	2.78	1.28	2.65	1.46	1.61	3.79	5.45	4.80	2.67	3.87	37.26
4	3.64	5.95	2.74	1.21	2.99	1.13	1.49	4.08	6.41	4.16	2.59	6.34	42.73
6	1.92	4.49	2.61	1.41	2.41	1.39	1.75	3.91	5.10	3.72	4.77	6.39	39.87
7	2.40	4.53	2.72	1.28	2.33	1.28	1.80	3.76	4.65	4.93	3.02	5.33	38.03
8	3.24	5.34	2.86	1.35	2.63	1.00	1.30	3.53	6.39	5.74	3.30	6.60	43.28
9	2.17	5.24	2.64	1.42	2.62	1.32	1.71	4.23	5.44	5.52	3.58	5.19	41.08
10	2.05	4.79	2.35	1.34	2.52	1.30	1.76	3.98	5.02	2.82	4.07	6.86	38.86
11	2.19	4.97	2.43	1.42	2.42	1.45	1.86	3.72	4.46	3.69	4.30	6.32	39.23
12	2.50	5.52	2.56	1.49	2.50	1.31	1.70	3.90	4.43	3.72	3.79	6.00	39.42
13	2.16	5.44	2.38	1.36	2.73	1.12	1.66	4.32	5.88	5.34	4.60	5.25	42.24
15	2.05	4.25	2.01	1.49	2.44	1.34	1.42	4.02	4.97	4.28	5.45	5.63	39.35
16	2.82	6.13	3.29	1.91	3.43	1.95	1.99	5.93	6.07	4.39	5.96	5.99	49.86
18	2.42	4.98	1.89	1.18	2.55	1.14	1.61	4.01	5.83	5.88	4.16	4.87	40.52
19	2.39	5.52	2.76	1.56	3.37	1.20	1.77	5.35	6.57	4.53	4.20	6.64	45.86
20	1.94	4.56	2.31	1.50	2.55	1.42	1.34	4.58	5.67	4.18	4.36	5.45	39.86
21	1.89	4.07	2.06	1.54	2.38	1.15	1.29	4.00	4.59	3.31	3.65	4.27	34.20
22	1.58	4.13	2.54	1.62	2.44	1.35	1.37	4.42	4.61	4.00	4.22	3.96	36.24
23	1.92	4.52	2.85	1.88	2.74	1.45	1.79	5.74	4.31	2.74	5.52	4.70	40.16
24	2.74	4.47	2.16	1.49	2.75	1.19	1.40	4.87	6.92	3.16	5.24	3.43	39.82
Average	2.35	4.89	2.50	1.43	2.64	1.28	1.58	4.24	5.43	4.23	3.99	5.37	39.91

Note:

Stations 1, 5, 14, 17, and 25 were removed from the network in September 1995. Site #16 was excluded from the network average precipitation computations.

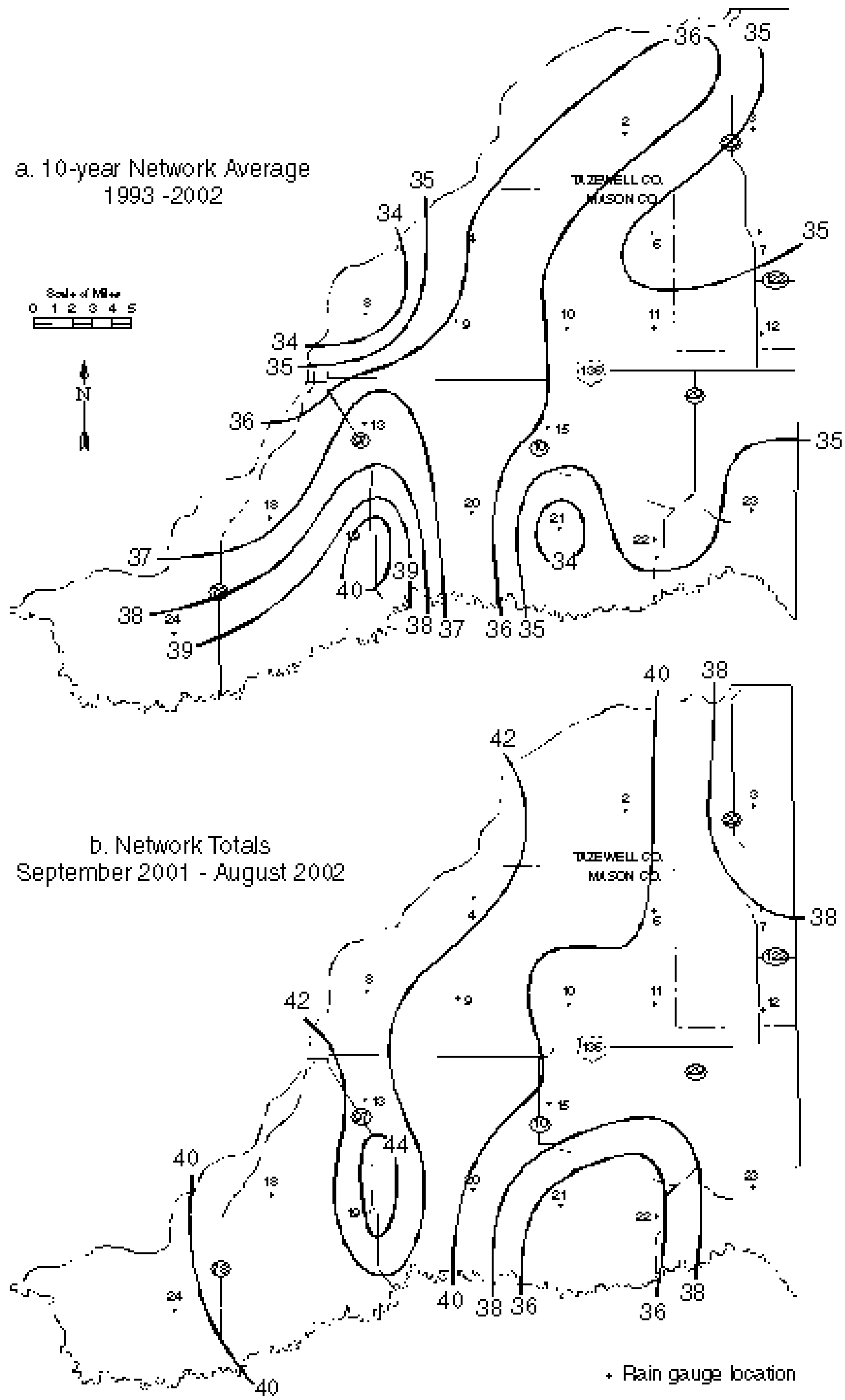

Figure 3. Average annual precipitation for September 1992-August 2002, and total precipitation for September 2001-August 2002 (inches).

from the average number of precipitation-days and events (Table 5) for years 1996-1997 through 2001-2002. Annual precipitation maps for the Imperial Valley for the past five years were recontoured without the site 16 data and are presented with maps from all previous years (Appendix E). Data for site 16 are included in Table 4, in Figures 4-9, and in Appendix G.

The pattern seen in the ten-year network average (Figure 3a) is reflected in the precipitation trends in Year Ten. On an annual basis, the gauge at site 21 has been low compared to neighboring gauges in five of the past six years (annual difference of -4.3 inches in 2001-2002), and the gauge at site 19 has been high in five of the past six years (annual difference of +5.0 inches in 2001-2002). The bias is not nearly as extreme as that at site 16, and often the monthly values are comparable to those at neighboring gauges. Thus, the precipitation data from sites 19 and 21 are included in all analyses, but the gauges at these sites are scheduled for cleaning and recalibration.

May 2002 (Figure 8a) was the wettest month of Year Ten, reporting a 5.43-inch network average, followed by August 2002 (Figure 9b, 5.37 inches), October 2001 (Figure 4b, 4.89 inches), April 2002 (Figure 7b, 4.24 inches), June 2002 (Figure 8b, 4.23 inches) and July 2002 (Figure 9a, 3.99 inches). Precipitation for those six months totaled 28.15 inches, or approximately 70 percent of the total annual precipitation. February 2002 was the driest month of the year (Figure 6b, 1.28 inches) followed by December 2001 (Figure 5b, 1.43 inches), and March 2002 (Figure 7a, 1.58 inches). Total average precipitation across the network in these three cold season months was light, 4.29 inches, or about 11 percent of the yearly total.

Individually, only October 2001 and August 2002 were wetter than average by 2 inches or more (Table 5). All other months were within ± 0.75 inches of the average. Summer 2002 (June-August) was the wettest season of the year (13.59 inches) followed by spring 2002 (March-May, 11.25 inches). Both seasons had totals above their corresponding nine-year network seasonal averages (departures of +0.64 and +2.24 inches, respectively). Autumn amounts (September-November 2001, 9.74 inches) were above normal (+1.74 inches departure from the nine-year network average autumn precipitation), due to heavy October 2001 precipitation. Winter precipitation totals (December 2001-February 2002, 5.35 inches) were average, and smaller than the other seasons as is usually the case.

Annual precipitation in 2001-2002 was the fourth wettest of the ten years of network operation (Table 3). The network received 15.64 inches less precipitation than in the wettest year (1992-1993) and 14.21 inches more than in the driest year (1995-1996). Year Ten had the third wettest autumn (1992-1993 and 1993-1994 were wetter) and the second wettest summer (only 1992-1993 was wetter). Spring 2002 was the fourth wettest (1992-1993, 1994-1995, and 1997-1998 were wetter). The last five months of the year (April-August 2002) each had rainfall totals of 4 inches or greater.

Storm Events

The number of precipitation periods were determined for the 10-year period. These periods were defined in three ways: by examining the periods of precipitation at individual gauges, by examining the number of days with precipitation, and by examining the encompassing network storm event periods.

Table 5. Comparison of Total Precipitation (inches), Average Number of Precipitation-Days and Precipitation per Day with Precipitation, and Average Number of Precipitation Events and Precipitation per Event for Each Month and Season, 1992-2001 and 2001-2002

	1992-2001 average					*2001-2002 average*				
Period	*Precipitation*	*Days*	*Inches/day*	*Events*	*Inches/event*	*Precipitation*	*Days*	*Inches/day*	*Events*	*Inches/event*
Sep	3.09	6.1	0.51	8.2	0.38	2.35	5.0	0.47	8.0	0.29
Oct	2.17	6.9	0.32	9.2	0.24	4.89	9.0	0.54	12.0	0.41
Nov	2.74	7.2	0.38	10.2	0.27	2.50	8.0	0.31	11.0	0.23
Dec	1.45	6.6	0.22	9.4	0.15	1.43	6.0	0.24	14.0	0.10
Jan	2.12	7.8	0.27	11.0	0.19	2.64	2.0	1.32	5.0	0.53
Feb	1.92	6.0	0.32	7.9	0.24	1.28	5.0	0.26	11.0	0.12
Mar	2.18	6.8	0.32	10.0	0.22	1.58	6.0	0.71	10.0	0.16
Apr	3.60	9.7	0.37	13.6	0.27	4.24	6.0	0.60	11.0	0.39
May	4.83	11.7	0.41	15.9	0.30	5.43	9.0	1.06	14.0	0.39
Jun	4.04	10.6	0.38	14.3	0.28	4.23	4.0	0.60	7.0	0.60
Jul	3.91	9.2	0.42	11.2	0.35	3.99	5.0	0.80	8.0	0.50
Aug	3.40	9.2	0.37	12.1	0.28	5.37	5.0	1.07	8.0	0.57
Autumn	8.00	20.2	0.40	27.7	0.29	9.74	22.0	0.44	31.0	0.31
Winter	5.49	20.3	0.27	28.3	0.19	5.35	13.0	0.41	30.0	0.18
Spring	10.61	28.1	0.38	39.4	0.27	11.25	21.0	0.54	35.0	0.32
Summer	11.35	29.0	0.39	37.7	0.30	13.59	14.0	0.97	23.0	0.59
Annual	35.45	97.7	0.36	133.1	0.27	39.93	70.0	0.57	119.0	0.34

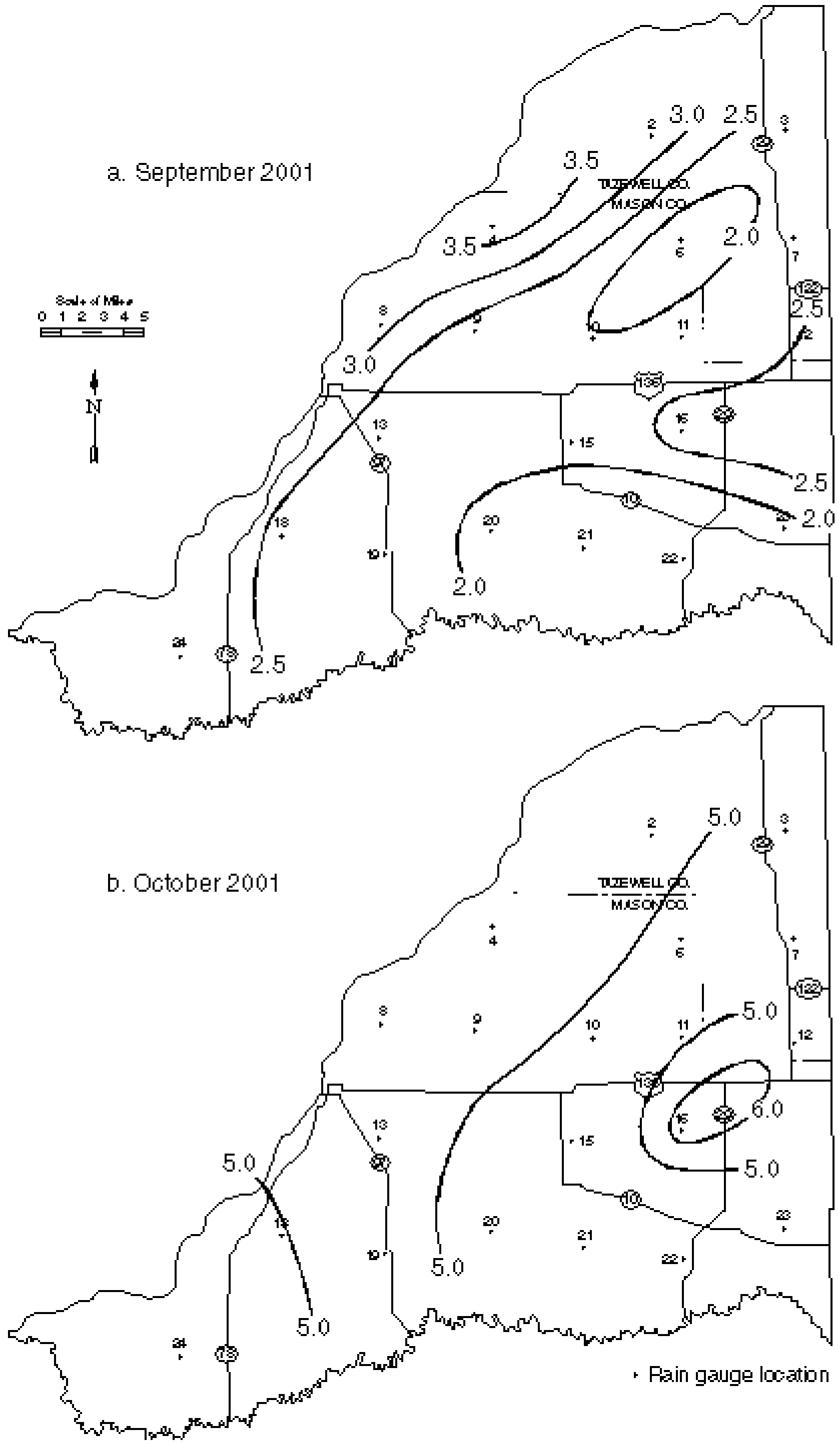

Figure 4. Precipitation (inches) for September 2001 and October 2001.

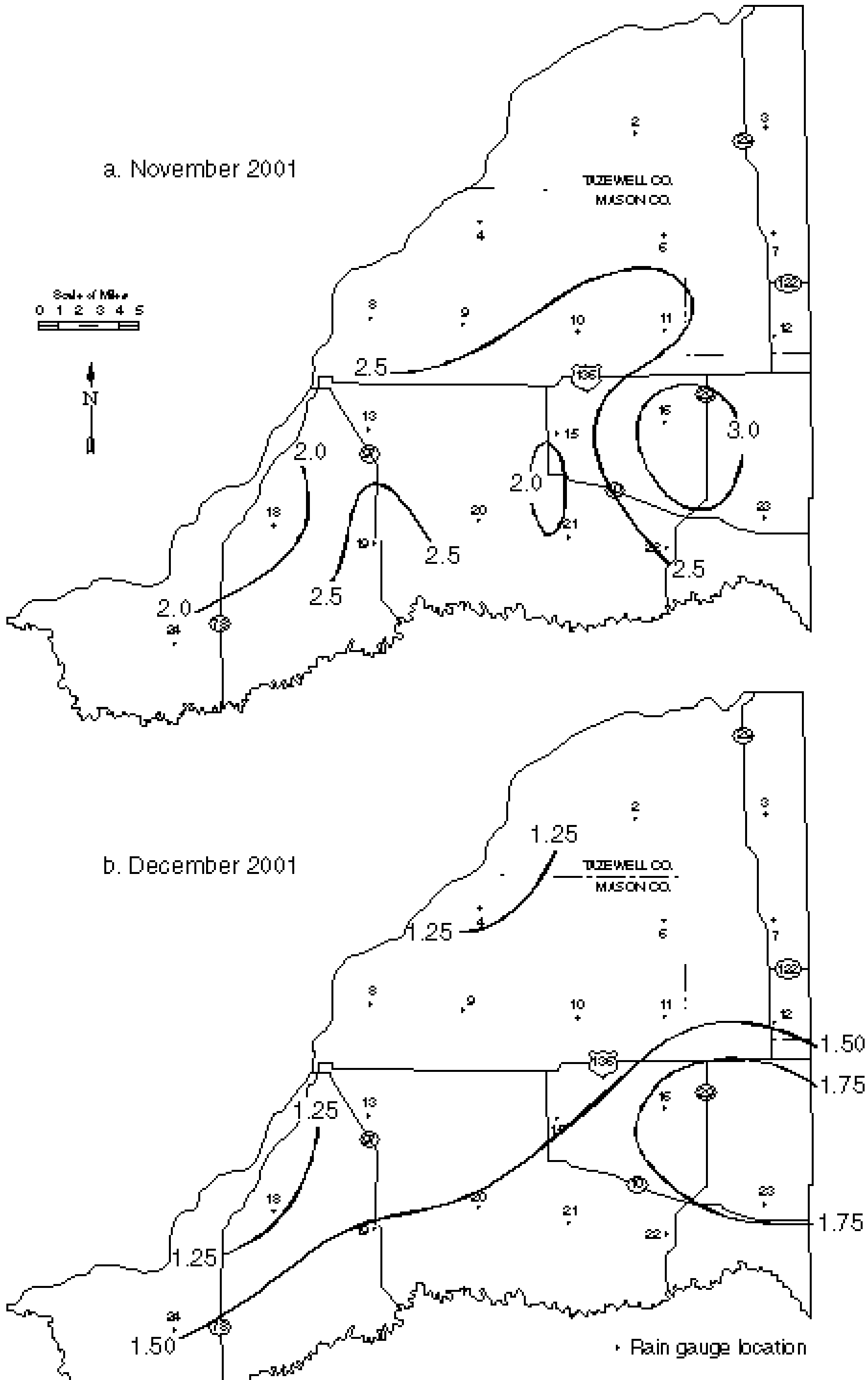

Figure 5. Precipitation (inches) for November 2001 and December 2001.

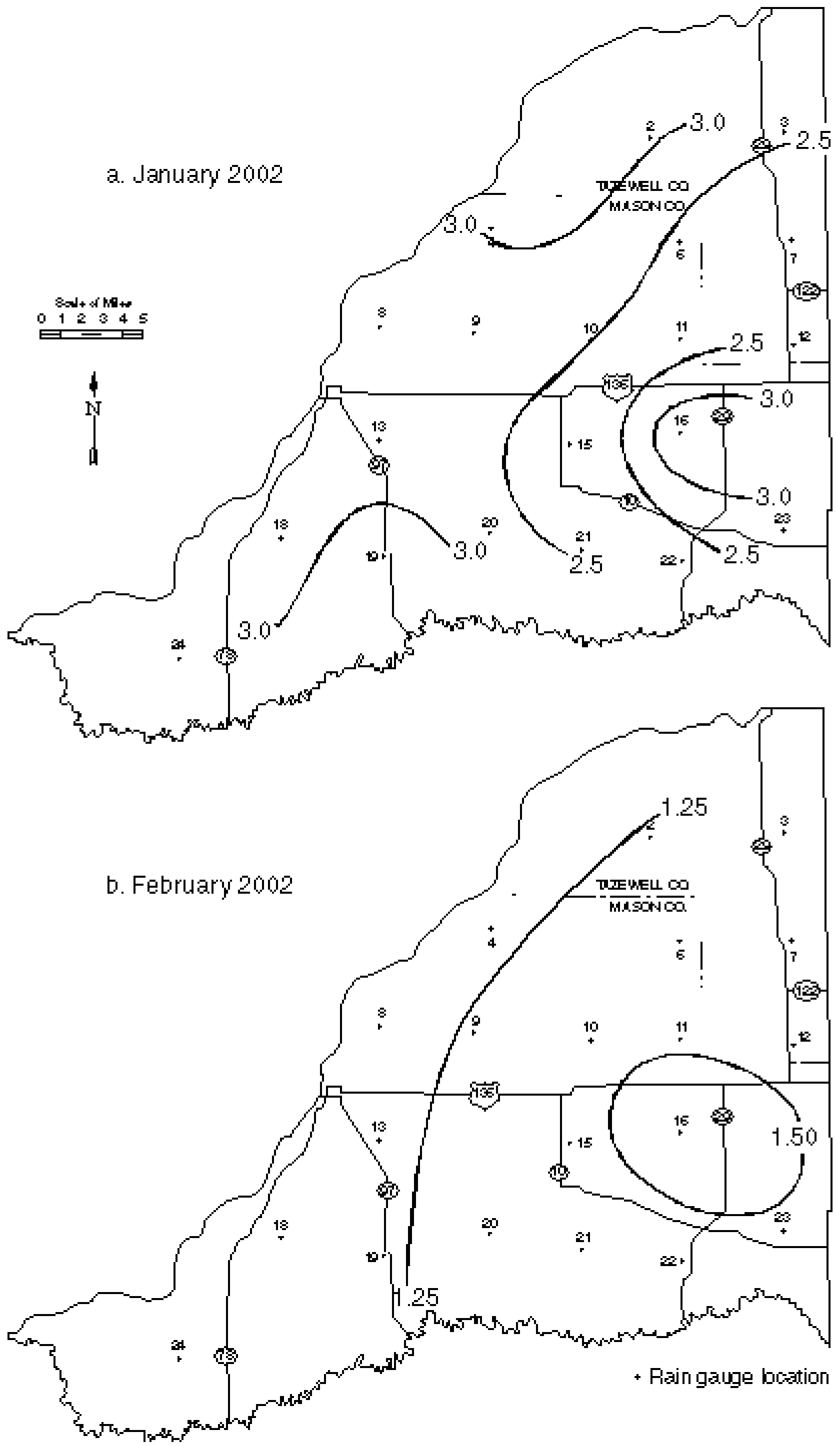

Figure 6. Precipitation (inches) for January 2002 and February 2002.

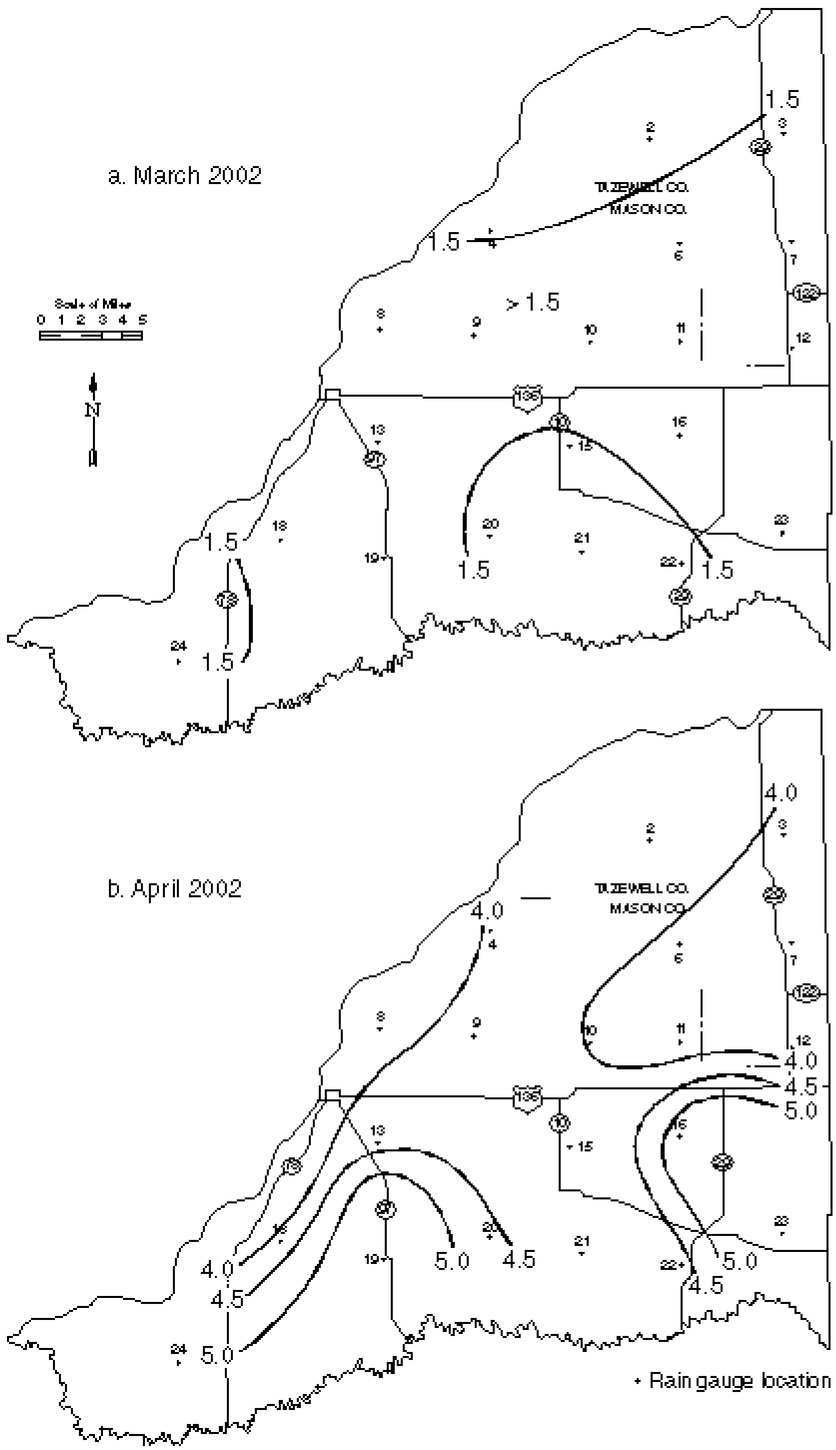

Figure 7. Precipitation (inches) for March 2002 and April 2002.

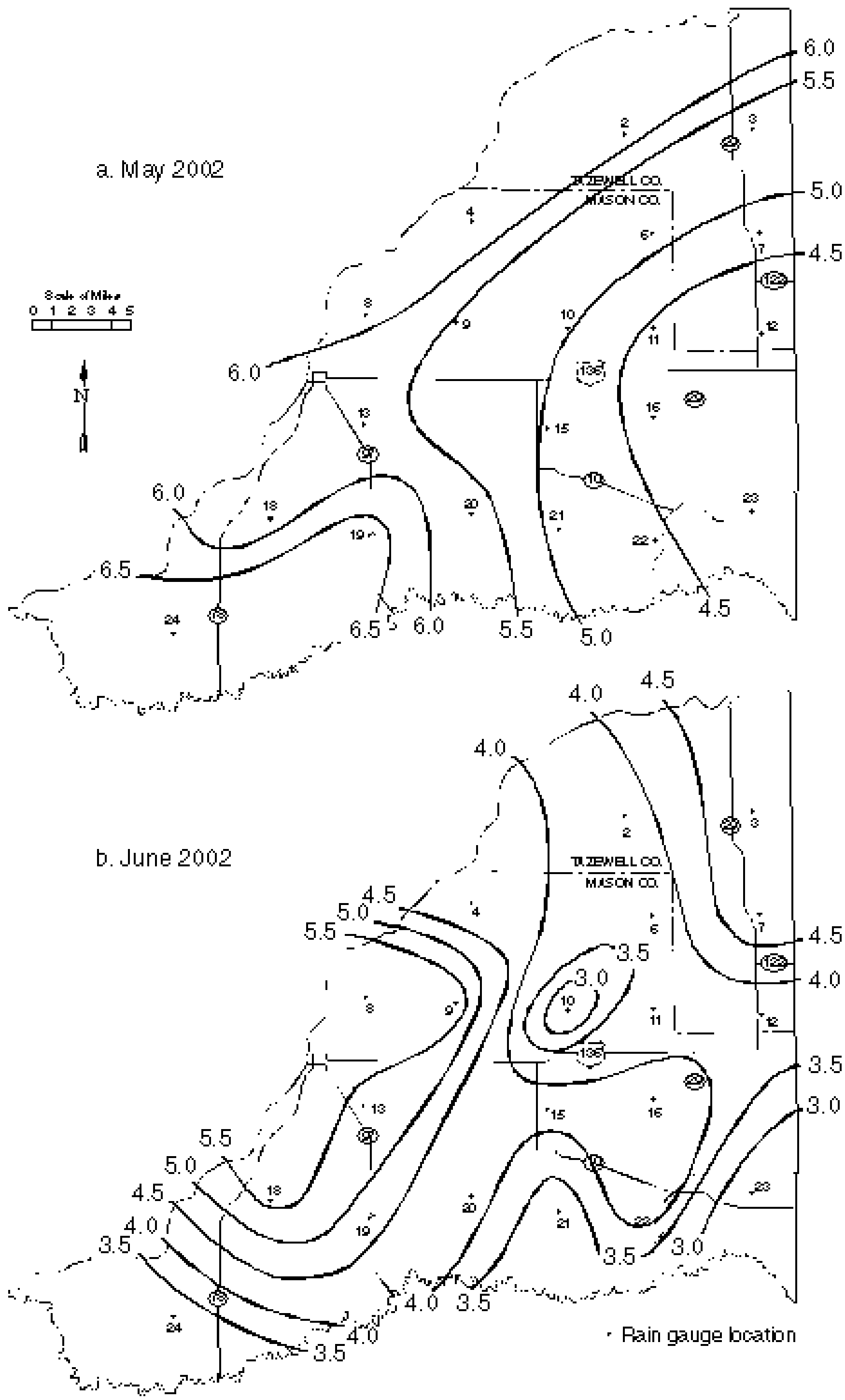

Figure 8. Precipitation (inches) for May 2002 and June 2002.

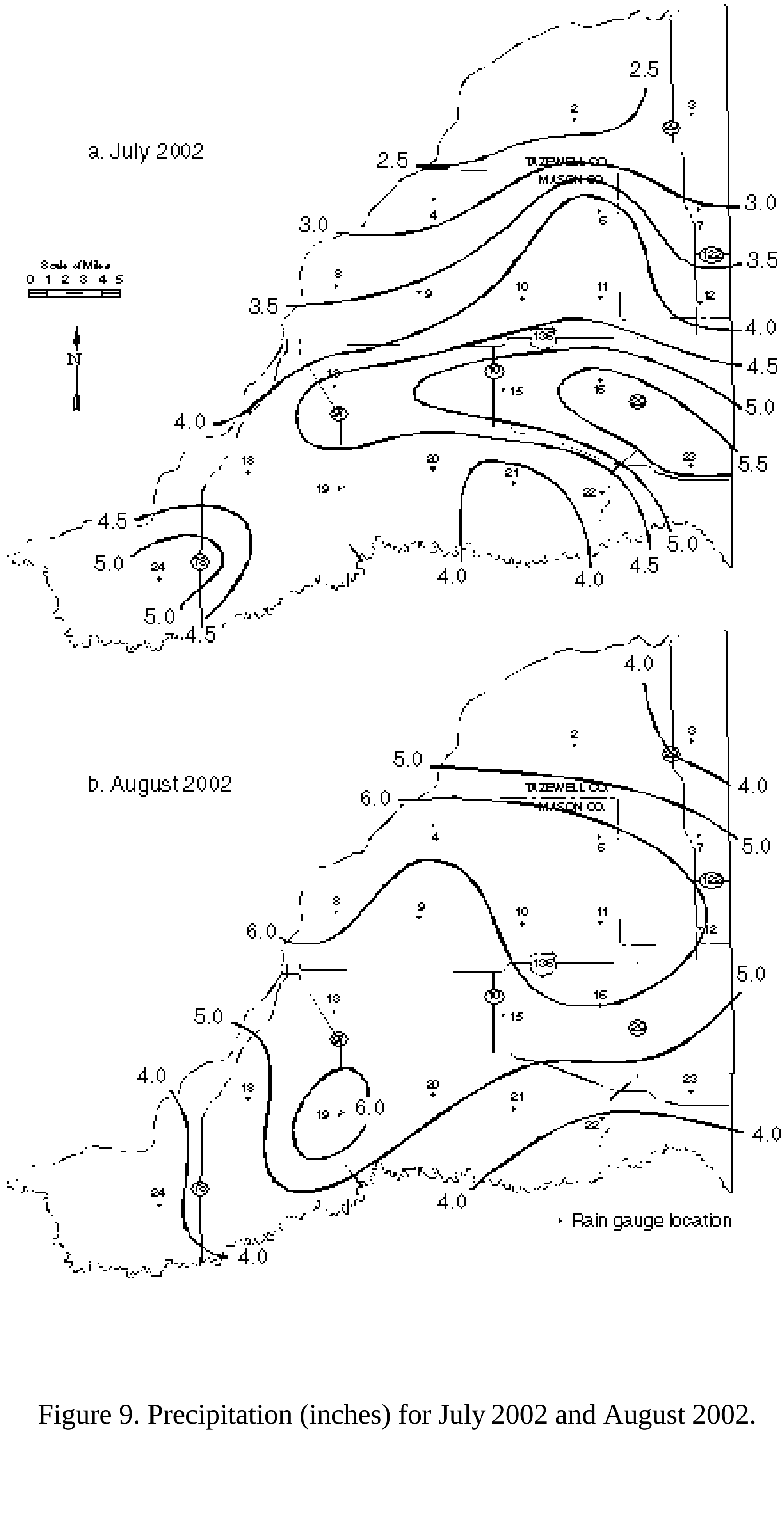

Figure 9. Precipitation (inches) for July 2002 and August 2002.

A storm day was defined at each gauge as any day when measurable precipitation was recorded at a given station. Storm events were defined at each gauge by the first hour that precipitation was recorded and continued through each consecutive hour with precipitation. The mean monthly, seasonal, and annual number of precipitation-days and events that are found on average at any given gauge are presented for each year (Appendix F) and for 2001-2002 (Table 5). The monthly, seasonal and annual mean number of days and events averaged over the 1992-2001 period also are presented (Table 5). A network storm period was defined as a precipitation event separated from preceding and succeeding events at all stations in the network by three hours. Data for the network storm periods are presented in Appendix G, and Tables G-2 and G-3. Typically, there are more precipitation events than network precipitation periods.

Year Ten reported 70 precipitation-days, the smallest number of any of the 10 years. Based on individual gauge precipitation periods, there were 119 precipitation events, the third lowest of the 10 years. Given the above average precipitation total for the year, the amount of precipitation per day in 2001-2002 was the highest of all years, 0.57 inches. The highest amount of precipitation per event occurred in the first two years of the analysis, with 2001-2002 having the third highest average precipitation per event, 0.34 inches.

Seasonally, the number of precipitation-days and precipitation events in autumn 2002 were close to average. As the total amount of precipitation during the autumn was above average (only the first two years were higher), the amounts of precipitation per day and per event were somewhat above average. The fewest days with precipitation in winter occurred in Year Ten, although the number of precipitation events was slightly above average. Thus, the amount of precipitation per day was highest during winter 2001-2002, and the amount of precipitation per event was about average.

Spring and summer 2002 were characterized by a very low frequency of precipitation-days and precipitation events. Precipitation during these two seasons was above average. Thus, the amount of precipitation per day and per event was above average. Spring and summer 2002 had the lowest frequency of precipitation-days of any of the 10 years of network operation (Table 5). On average, precipitation occurred about every 4.4 days in the spring and about every 6.6 days in the summer. The highest amount of precipitation per precipitation-day of the 10 years was found in spring and summer 2002, 0.54 inches per day and 0.97 inches per day, respectively. During summer 2002, the lowest number of precipitation events also was found, and precipitation events averaged 0.59 inches, the greatest precipitation per event of any of the first 10 years.

The plot of the network average monthly precipitation time series (Figure 10) shows the monthly variation of precipitation. Months with network average precipitation in excess of 10 inches, which occurred three times during the first three years of observations, have not occurred in any subsequent year. The last five months of 2002 (April-August) each had 4 or more inches of precipitation. Spring-summer 2002 was the fourth wettest of the 10 years of operation. Only 1992-1993, 1994-1995 and 1997-1998 had a wetter spring-summer period.

A total of 1302 network storm periods occurred during the 10-year observation period: 148 in 1992-1993, 102 in 1993-1994, 129 in 1994-1995, 98 in 1995-1996, 121 in 1996-1997, 134 in 1997-1998, 144 in 1998-1999, 156 in 1999-2000, 148 in 2000-2001, and 122 in 2001-2002, resulting in a 10-year average of 130 storms per year. Appendix G documents each network storm period for 2001-2002 with the date and hour of the start time, duration, number of

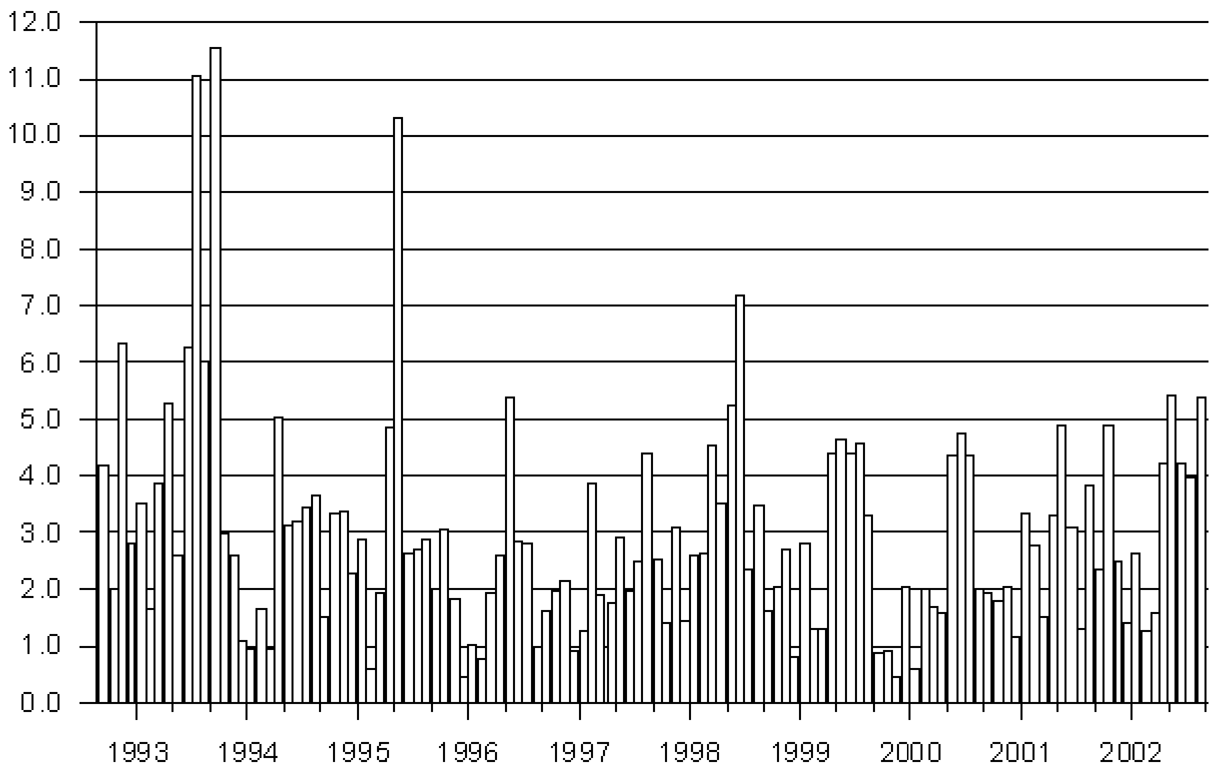

Figure 10. Network average monthly precipitation, September 1992-August 2002.

sites receiving precipitation, network average precipitation, storm average precipitation, maximum precipitation received, the station (gauge) where the maximum occurred, and storm recurrence frequency of the maximum observed precipitation (Table G-2). The network average precipitation is the arithmetic mean of the precipitation received at all 20 stations, while the storm average is the arithmetic mean of the precipitation received at stations reporting precipitation during the storm period. The storm recurrence frequency is the statistical probability of the recurrence of a storm with the reported precipitation (i.e., a 10-year storm would be expected to occur on average only once every 10 years at a given station, or have a 10 percent chance of occurring in any given year). The recurrence frequencies computed here are based upon the total storm duration for the area. See Appendix G for further explanation. Also included in Appendix G is a table indicating the precipitation received at each of the 20 stations for each network storm period (Table G-3) for 2001-2002. Sites that exceed the one-year or more recurrence frequency are indicated in bold type in Table G-3. Previous years of network storm periods can be found in Scott et al. (2002).

In the first nine years of operation, 41 of the 1180 storm periods produced maximum precipitation at one or more stations with a recurrence frequency greater than one year: 50-year (1 storm), 10-year (3 storms), 5-year (6 storms), 2-year (18 storms), and greater than 1-year but less than 2-year (13 storms). The 50-year storm (storm 153) occurred on 13 September 1993, and the 10-year storms on 16 May 1995 (storm 323), 8 May 1996 (storm 432), and 19 July 1997 (storm 580). Two 5-year storms occurred in June 1993 (storm 105) and September 1993 (storm 149), and four others occurred in in May 1995 (storm 327), July 1999 (storm 862), August 1999 (storm 872), and July 2000 (storm 1006). These 10 heaviest storms occurred during the warm season months (May-September). There were nine storms with a recurrence interval exceeding the one-year or greater recurrence frequency in 1992-1993, five in 1993-1994, six in 1994-1995, one in 1995-1996, three in 1996-1997, four in 1997-1998, four in 1998-1999, five in 1999-2000, and four in 2000-2001.

In 2001-2002, eight of the 122 network storm periods exceeded the one-year recurrence frequency. While Year Ten had a below average number of network storm periods, it had nearly the same number of heavy rainfall periods as the very wet year, 1992-1993. Of the events in 2001-2002, two were 5-year events, four were 2-year events and two were 1-year events. The two 5-year storms occurred on 26-27 August (storm 1289), and 22-23 September (storm 1301). The four 2-year storms occurred during May (storm 1264), June (storms 1278 and 1279), and July (storm 1290). The two one-year storms occurred in January (storm 1228) and April (storm 1259).

Groundwater Levels

Groundwater levels in observation wells MTOW-5 and MTOW-9, network wells closest to the Illinois River, fluctuate largely in response to river stage. Up to 80 percent of the variation in water level in these wells can be explained by river stage variation (Scott et al., 2002). Water levels in these wells have a wider, more easily discerned annual variation than other observation wells in the network (Appendix A). Water-level changes in these two wells range from 5 to 10 feet within a given year (up to 15 feet between the 1995 peak and the 1996 trough in MTOW-5). Annual peak water levels occur in the spring and early summer, often within a month of the peak river stage on the Illinois River. Groundwater-level response to river stage changes may be more rapid, but more frequent measurements than monthly are needed for a better determination of how rapid the response actually may be. In spring 2002, groundwater levels in these two wells peaked above levels observed at any time since the 1995 record highs, closely following levels on the Illinois River. Water levels fell rapidly during summer and fall 2002 but still were appreciably above seasonal levels observed in 2000 and 2001.

Groundwater levels in observation wells more distant from the Illinois River also showed their highest levels for the period of record in early to mid-1995. Less influenced by river stage, groundwater levels in these wells show a much more consistent downward trend from 1995 until 1998, a recovery in 1998 and 1999, followed by a period of decline through 2000, and then another recovery in 2001 or 2002 (Appendix A). As with wells MTOW-5 and MTOW-9, the annual maxima typically occur in the spring or early summer each year; however, these peaks are not as pronounced without the high-stage influence of spring stages on the Illinois River. For example, in some wells the 1996-1997 maxima appear only as small rises on a downward-trending hydrograph or as momentary reductions in downward slopes. A distinct rise in water levels is seen in 1998 with maxima generally occurring in July and August. This was followed in 1999 by a more natural seasonal cycle in water levels with maxima and minima similar to 1998 observations. Groundwater levels then fell throughout late 1999 and 2000. Recovery can be observed in 2001, but not consistently in all wells. Further recovery is consistently seen in 2002 to levels not seen since 1999.

As has been done in previous reports (Hollinger et al., 1999, 2000; Scott et al., 2001, 2002), the timing (i.e., month of occurrence) of the annual maximum water level in each observation well is presented (Table 6). These past reports suggested that the groundwater-level “peaks” presented in this table were coincident with maximum groundwater recharge. However, careful thought and discussion among ISWS scientists leads the authors to conclude that the groundwater peaks (and subsequent water-level declines) signify the end of the recharge period, the last observed time when infiltration exceeds evapotranspiration.

A determination of when recharge starts is made by examining water-level “troughs”: when declining water levels bottom out and begin to recover signifies the beginning of the period when infiltration exceeds evapotranspiration. Examination of the water-level data for the period when groundwater levels start to recover from preceding water-level declines (Table 7) shows that recharge is occurring much earlier in the year than when the peaks occur, in many cases, before most monthly observations started in March of each year. With the initiation of January and February observations in 2002, it can be seen that groundwater levels in January were rising from lows experienced in late 2001.

In 2002, after the initial January-February water-level rises, groundwater-level recoveries also tended to have a secondary, often more pronounced, jump later in the spring (Appendix A). For example, water levels in MTOW-1 increased 0.5 feet from 37.67 feet to 37.17 feet between January and May, then jumped 2.73 feet to 34.44 feet in June. Similar pronounced May-June jumps can be seen for wells MTOW-3, -4, -5, -6, -7, -8, -9, -12, and -13. Such water-level increases appear to correspond to higher than normal precipitation experienced across the network in April, May, and June (0.64 inches, 0.60 inches, and 0.19 inches above monthly network normals, respectively). In this instance, the water-level jumps do not appear to be attributable to the date of measurement (first of the month) relative to preceding precipitation events (see Table G-2 in Appendix G), although this could occur and bears further investigation. The locations of these wells also tend to conform to the pattern of high rainfall, especially for May, where a 6-inch contour parallels the Illinois River and a 6.5-inch contour surrounds the southwestern corner of the study area. River wells MTOW-5 and -9 also experienced earlier jumps in February-March, coincident with Illinois River stage jumps. Water-level jumps in April-May are seen for wells MTOW-2 and -10. No pronounced jump was seen for well MTOW-11.

Previous reports state that groundwater recharge and, hence water level peaks, typically occur in the spring and early summer. The authors now believe it is more correct to say that groundwater recharge in the Imperial Valley, as evidenced by a reversal from groundwater-level declines to groundwater-level rises, typically occurs in early spring and may occur during winter months in some years.

Some exceptions are notable. Wells MTOW-4, -10, -11, and -13 were observed to have their highest water level of the year in March 1996 (Table 6). Examination of the individual well hydrographs (Appendix A) shows a downward trend throughout the entire year with only slight spring groundwater level increases (i.e., recharge). Had observations been taken in January and February, higher water levels likely would have been observed than in March, based simply on a descending trend from higher water levels observed in December 1995. A similar downward

Table 6. Month in Which Observed Groundwater Levels Peaked, Imperial Valley Observation Well Network, 1995-2002

Month	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*
January								
February								
March		4, 10, 11, 13	4, 8, 10, 11		4	3, 4, 7, 8, 10, 11, 13		
April			2, 5, 9				4, 5, 9	
May	12		1, 6, 7, 13				11	
June	1, 2, 3, 5, 6, 7, 9, 10	2, 3, 5, 6, 7, 9, 12	3, 12	5, 9	1, 2, 5, 9		10	1, 2, 5, 9
July	8, 11	1, 8		1, 2, 6, 7, 10, 12	6, 7, 10, 12	2, 5, 6	1, 2, 3, 6, 7, 8,12, 13	3, 4, 6, 7, 12, 13
August	4			3, 8, 11, 13	3, 11	1, 9, 12		8, 10, 11
September					8, 13			
October								
November				4				
December								

____

Notes:

Number is observation well number (MTOW-x). Shading represents high water-level periods in wells along trends established when observations were not made (January-February 1995-2000; January-March 2001), that were not true "peaks". See text for more detail.

Table 7. Month in Which Observed Groundwater Levels Began Recharge, Imperial Valley Observation Well Network, 1995-2002

Month	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*
January				1	1			2, 3, 4, 6, 7, 10, 11, 12, 13
February	1?		1			1		1, 5, 8, 9
March	2, 3, 4, 5, 6, 7, 8, 9, 10, 12	2	2, 3, 5, 6, 7, 9, 12, 13	2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13	2, 3, 5?, 7, 9, 12	5, 9		
April	11	1, 5, 7, 9			6, 11		2, 3, 5, 6, 7, 8, 9, 10, 12, 13	
May		3, 6, 8, 11?, 12		4	4, 8, 10, 13	2?, 6, 10?		
June						1, 3, 7, 8?, 12		
July		10?				11?		
August			10?				11?	
September			4	13		13?		
October								
November								
December								
No Ascent		4, 13	8, 11					

____

Notes:

Number is observation well number (MTOW-x). A question mark indicates that the water-level period is not clearly defined for a particular well. The last row contains well numbers for which no increase in water level was seen that year.

trend from higher water levels the previous year (with only slight slope increases in some wells) is noted for wells MTOW-4, -8, -10, and -11 in 1997; for well MTOW-4 in 1999; and for wells MTOW-3, -4, -7, -8, -10, -11, and -13 in 2000. These periods are highlighted in gray in Table 6, to signify that no "recharge peak" was actually observed.

In 2002, the groundwater recharge period in many wells appears to have started from seasonal low water levels in October 2001. January 2002 water levels in most wells were above those observed in December 2001. More pronounced water-level "jumps" were seen in river wells MTOW-5 and -9 in February-March, wells MTOW-2 and -10 in April-May, and by the rest of the wells (except MTOW-11) between May and June. Also in 2002, the pattern for what is now recognized as the end of the groundwater recharge period followed a very distinct progression of wells from west to east within the IVWA. Groundwater levels first peaked in June in wells along the western edge of the IVWA, along or near the Illinois River (MTOW-1, -5, and -9) and in MTOW-2, which, although in the center of the IVWA, is influenced by stages in Crane Creek. This was followed by groundwater-level peaks in wells stretching from northeast to southwest down the center of the IVWA, including wells MTOW-3, -4, -6, -7, -12, and -13. Then groundwater levels peaked in August in wells MTOW-8, -10, and -11, on the eastern edge of the IVWA.

Transitions from declining to rising water levels, indicative of groundwater recharge, appear to be common in January and February. Monthly groundwater-level observation procedures were changed to include all 12 months starting in 2002.

The long-term hydrograph at MTOW-1 (Snicarte) in Figure 11 provides a reference for comparison with the shorter records of the other network wells. The ISWS has recorded water levels in this well since 1958. Annual fluctuations from less than a foot to more than 6 feet have been observed. These fluctuations often appear to be superimposed on longer term trends, up to 10 years in length. Interestingly, for the 44-year record, both the record low and high have been observed within the last 13 years. A detailed look at water levels since 1990 is shown in Figure 12 (the vertical scale is exaggerated from the scale of the hydrographs in Appendix A to more clearly portray the annual fluctuations). During and after the drought years of 1988 and 1989, the well was dry (meaning the water level fell below the bottom of the well at around 40.5 feet) for the only time in the period of record from September 1989 until April 1990. After the 1993 flood, groundwater levels rose almost 10 feet and peaked at approximately 30 feet in September 1993. In the years since then, groundwater levels in MTOW-1 show an almost linear decline until 1998. Water levels rose dramatically during 1998 and in 1999 recovered to peak levels similar to those observed in 1994 and 1995. Then, after the 1999 peak, groundwater levels fell dramatically until mid-summer 2000. Groundwater levels appear to return to somewhat more natural seasonal cycles from 2000 to 2002.

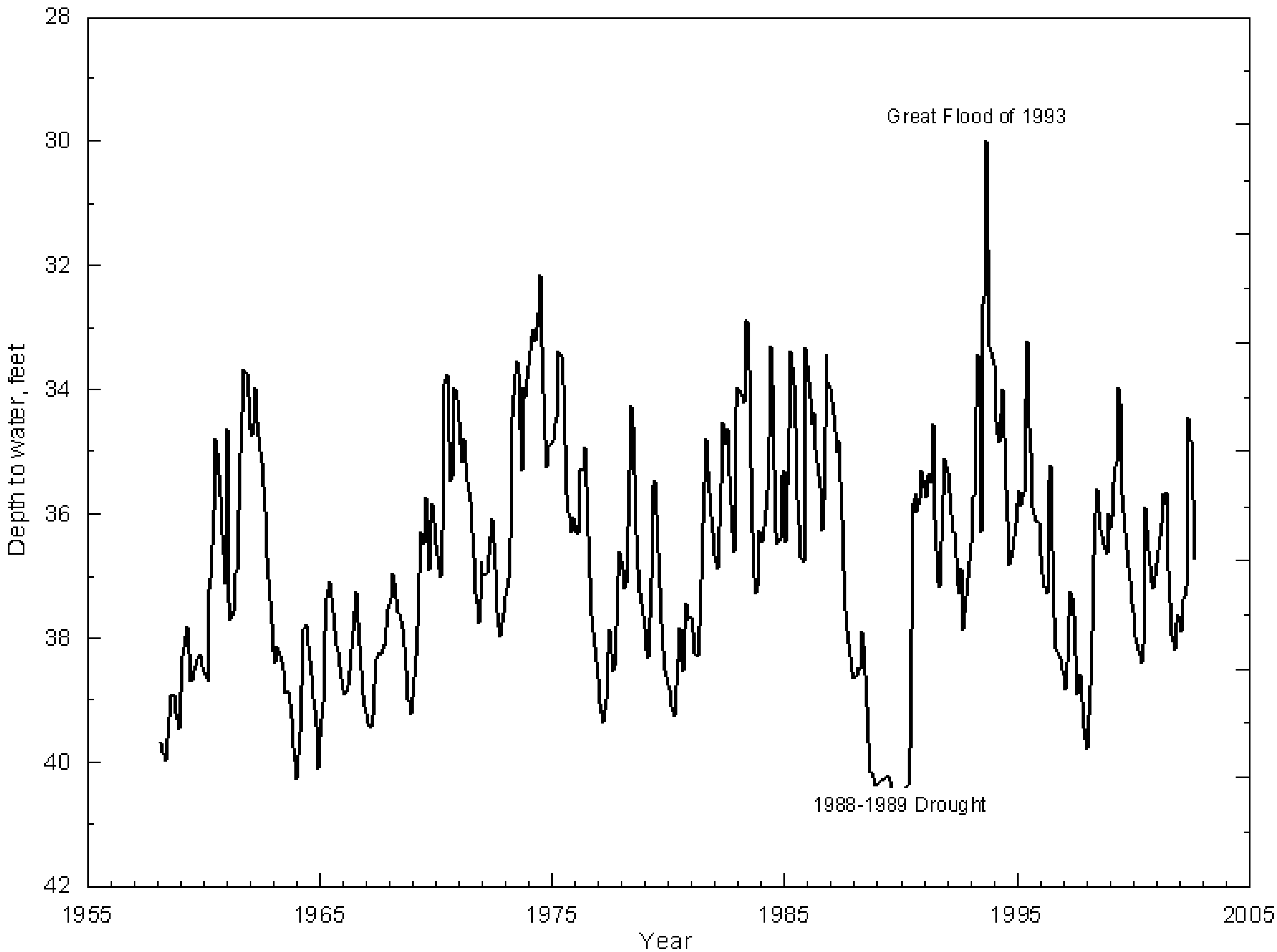

Figure 11. Groundwater levels at the Snicarte well, MTOW-1, 1958-2002.

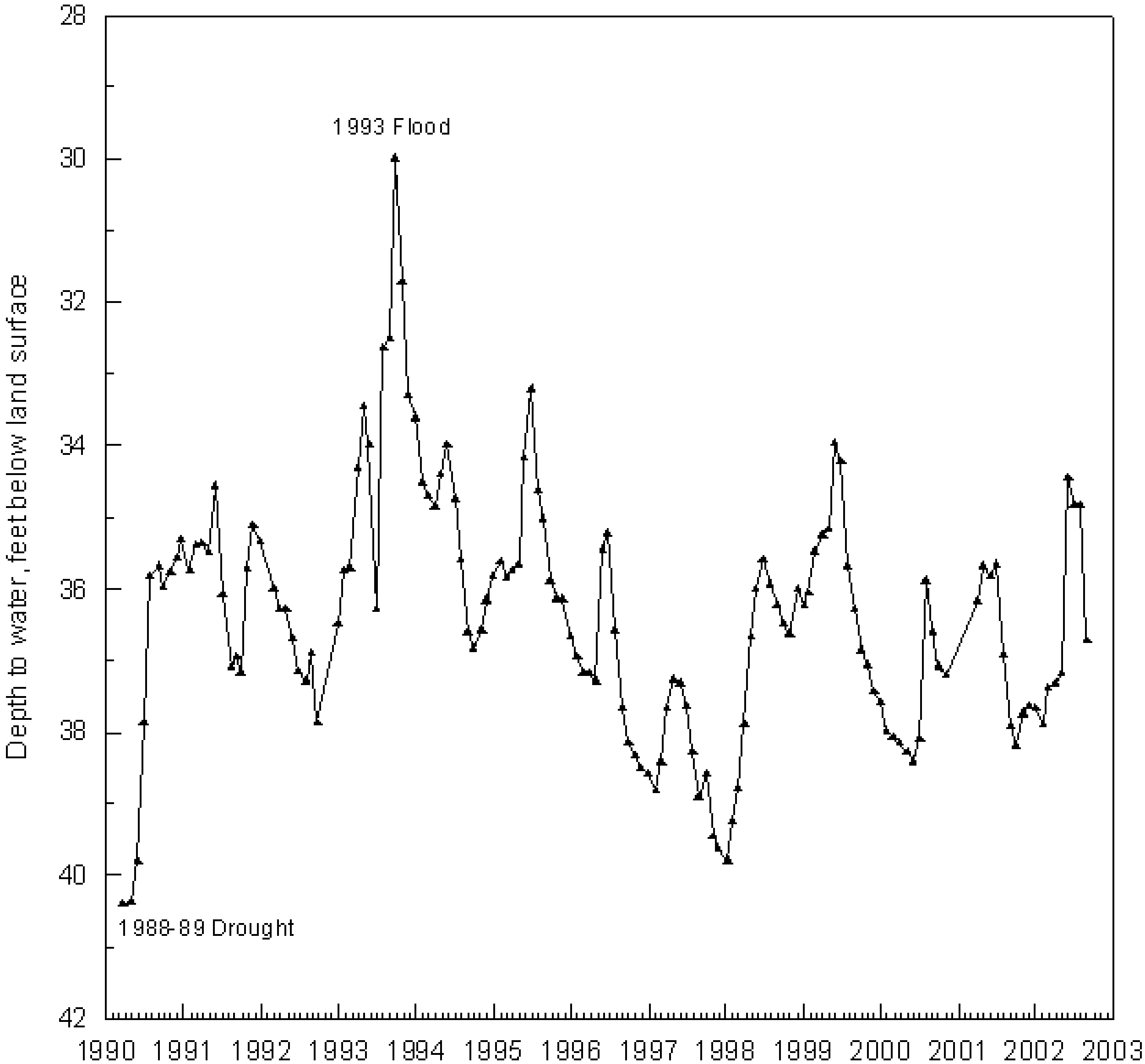

Figure 12. Groundwater levels at the Snicarte well, 1990-2002.

Summary

Groundwater levels tend to peak in most wells in the Imperial Valley during the spring and early summer, then decline in late summer and fall as precipitation is evaporated and transpired back into the atmosphere by growing crops and as a result of seasonal irrigation pumpage. In 2002, groundwater levels in many wells rose throughout the winter, starting from seasonal lows in October 2001. January 2002 water levels in most wells were above those observed in December 2001. Pronounced water-level rises were seen in river wells MTOW-5 and -9 in February-March, followed by wells MTOW-2 and -10 in April-May, then by the rest of the wells (except MTOW-11) between May and June. Transitions from declining to rising water levels, indicative of groundwater recharge, appear to be common in January and February. Collection of monthly groundwater levels throughout the winter was initiated in 2002 and already has shown how groundwater levels can recover during months not typically considered recharge months. Continued winter measurements will provide valuable data not previously collected.

During the preparation of the data for this report, it was found that the annual precipitation total at site 16 has been somewhat higher than the surrounding gauges for the past six years, with the annual difference between site 16 and its neighbors increasing during the last three years (annual difference of 11.6 inches in 2001-2002.) The gauge at this site was replaced on May 23, 2002, and the monthly totals became comparable with those at surrounding gauges. Accordingly, the annual spatial patterns for the 2001-2002 water year (Figure 3) and the previous five years (Appendix E) were redrawn omitting the precipitation data from site 16. Site 16 data also were omitted from the annual average network precipitation tabulations (Tables 3 and 4) and from the average number of precipitation-days and events (Table 5) for years 1996-1997 through 2001-2002.

For year 10 of the rain gauge network operation (September 2001-August 2002), the network received an average of 39.91 inches of precipitation, 4.02 inches greater than the network 10-year average precipitation. It had the third wettest autumn (September-November), fourth wettest spring, and second wettest summer (June-August) of the 10 years of measurement. Spring and summer 2002 had the lowest frequency of precipitation-days of any of the 10 years of network operation. On average, precipitation occurred about every 4.4 days in the spring and about every 6.6 days in the summer. However, the highest amount of precipitation per precipitation-day of the 10 years was found in spring and summer 2002, 0.54 and 0.97 inches, respectively. During this year, a below average number of network storm events occurred, but nearly as many of the heavy storm events exceeded the one-year or more recurrence interval frequency as in the very wet year 1992-1993. Each of the last five months of the 2001-2002 study period (April-August) had a network total rain of 4.0 inches.

Even so, total irrigation for the June-September period was an estimated 47 bg, the second highest total since 1995 and tied with the 2001 irrigation season estimate. This can be attributed, in part, to the growth of irrigation systems with the IVWA, which now has 1,839 systems. However, the timing of the rainfall during those months was probably more critical to irrigation need. For June-August, 12.23 inches of the total network average of 13.59 inches (90 percent of the rain) fell in 15 days of the 92-day period (16 percent of the days). Irrigation in July

2002 ranks as the highest July for the eight years over which estimates have been made, while June and August 2002 rank as third highest among their respective months.

Studies by the USGS in summer 2002 to improve the annual withdrawal estimates showed the previous energy to gallons pumped conversion factor was too high: 1,505 gallons per kilowatt-hour versus 1,259 gallons per kilowatt-hour. Such information is important to the IVWA and could be extended by examining the relationship of the conversion factor for the 77 systems measured to system age, size, and type (e.g., high pressure vs. low pressure). A database also could be built to assemble information on all the irrigation systems within the IVWA. Such a database could include owner name, system location, system size, age, pump rating, type of pressure system, well depth, pump depth, static and pumping water levels, measured pumping rate, date of measurement, and measurement method. The IVWA previously has created a map of the irrigation systems within the area; a database on these systems would be an excellent accompaniment to that map.

More continuous groundwater-level measurements collected from dataloggers at selected sites was initiated in summer 2003. These data will enhance examination of recharge in relation to storm events that may be occurring more rapidly than can be assessed by monthly measurement. Examination of the continuous record at MTOW-1 also is being conducted for selected time periods. In addition, a network of observation wells was installed near an irrigation system along Crane Creek in 2003. This network, in combination with measurement of Crane Creek discharges along several reaches during irrigation season, is designed to examine the influence of irrigation on groundwater discharges (baseflow) to Crane Creek. These measurements will aid in calibration of a groundwater flow model of the Imperial Valley area, updating previous modeling efforts by Clark (1994).

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Appendix A. Imperial Valley Observation Well Network Hydrographs

Appendix A. Imperial Valley Observation Well Network Hydrographs

This appendix shows the hydrographs of the groundwater levels in each of the Imperial Valley observation wells, precipitation from the nearest rain gauge or average of nearby gauges from the Imperial Valley rain gauge network and, where appropriate, Illinois River stage near the observation well.

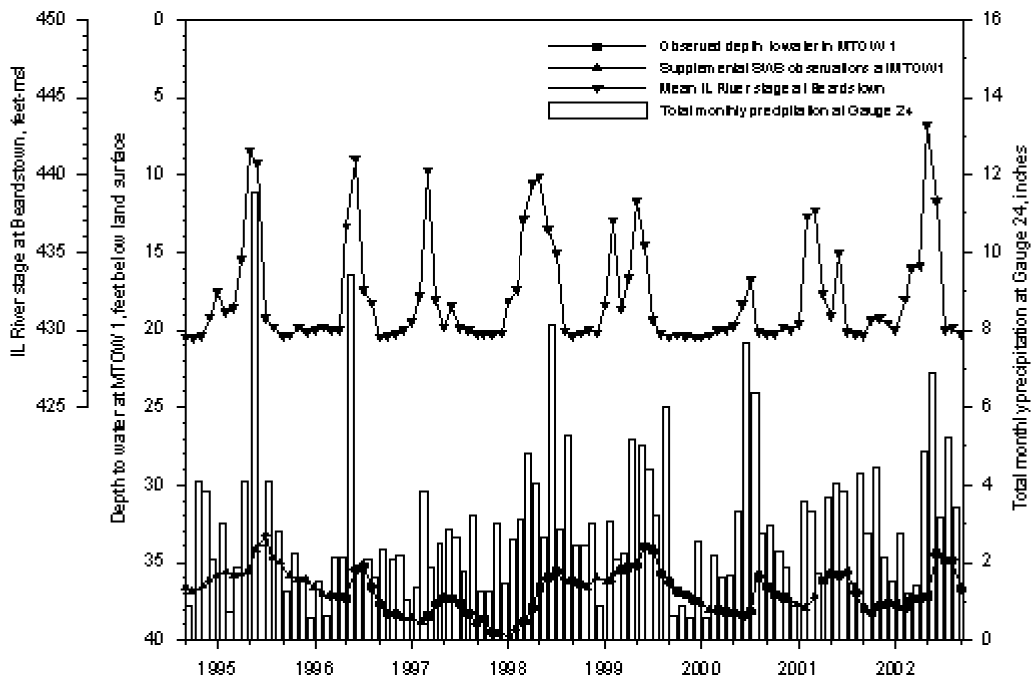


Figure A-1. Groundwater depth, monthly precipitation, and Illinois River stage for MTOW-1.

Appendix A. (continued)

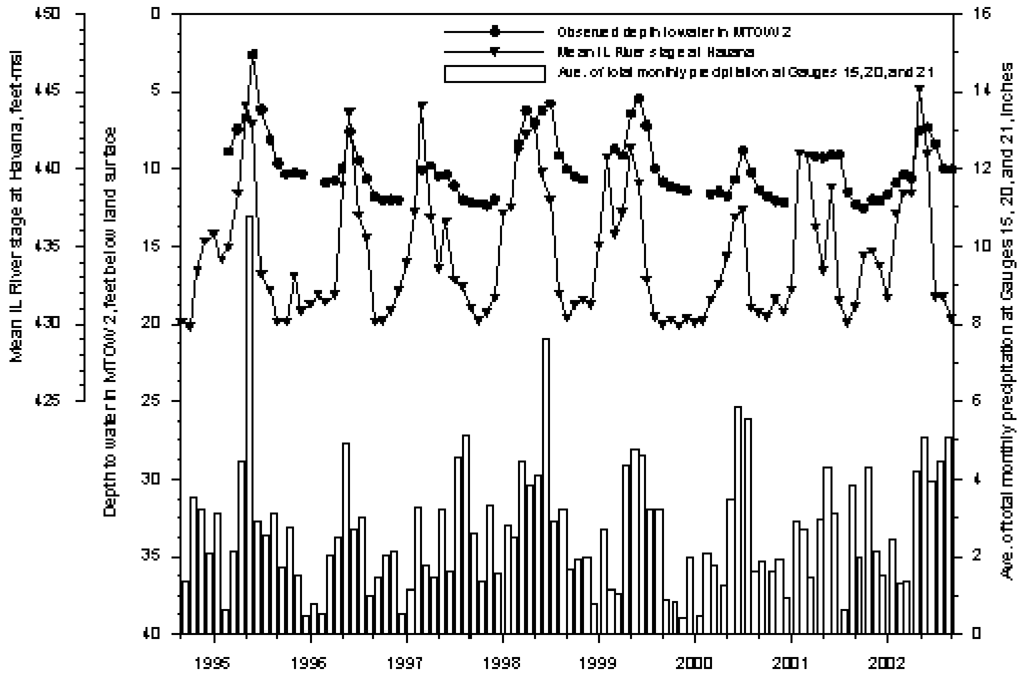


Figure A-2. Groundwater depth, monthly precipitation, and Illinois River stage for MTOW-2.

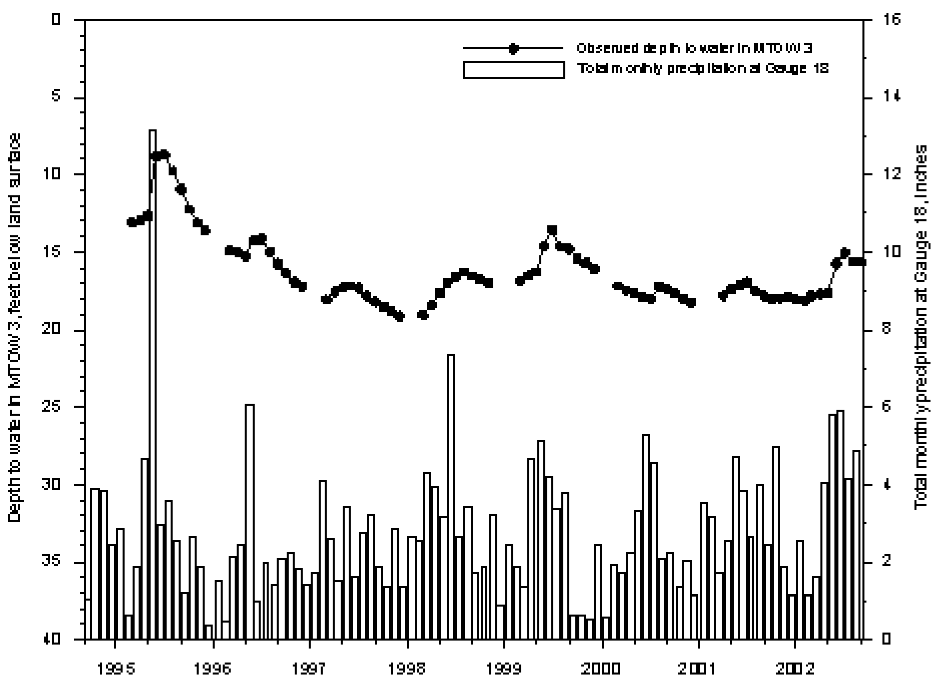


Figure A-3. Groundwater depth and monthly precipitation for MTOW-3.

Appendix A. (continued)

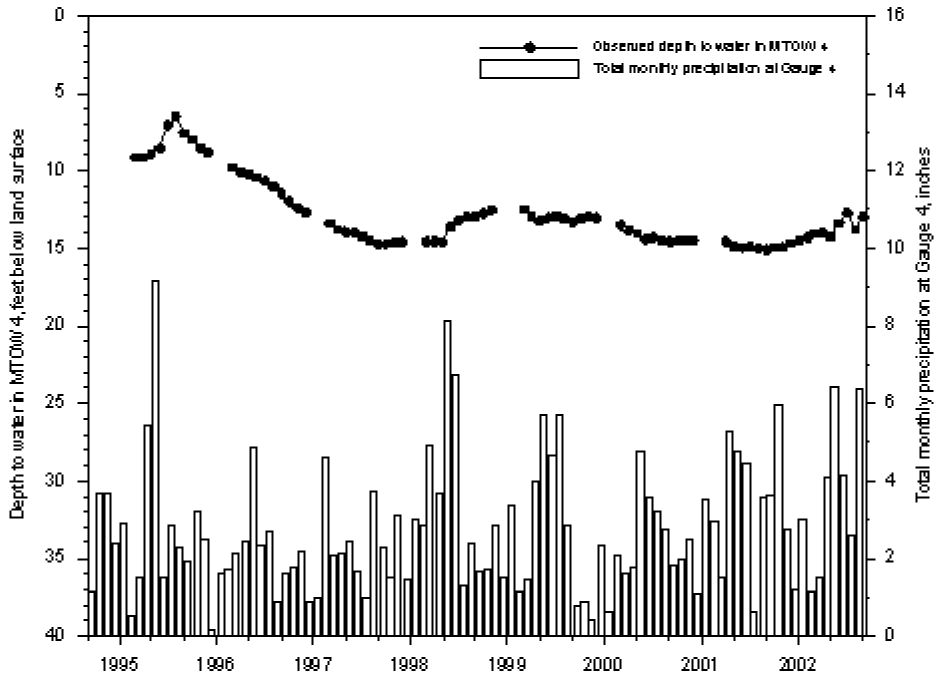


Figure A-4. Groundwater depth and monthly precipitation
for MTOW-4.

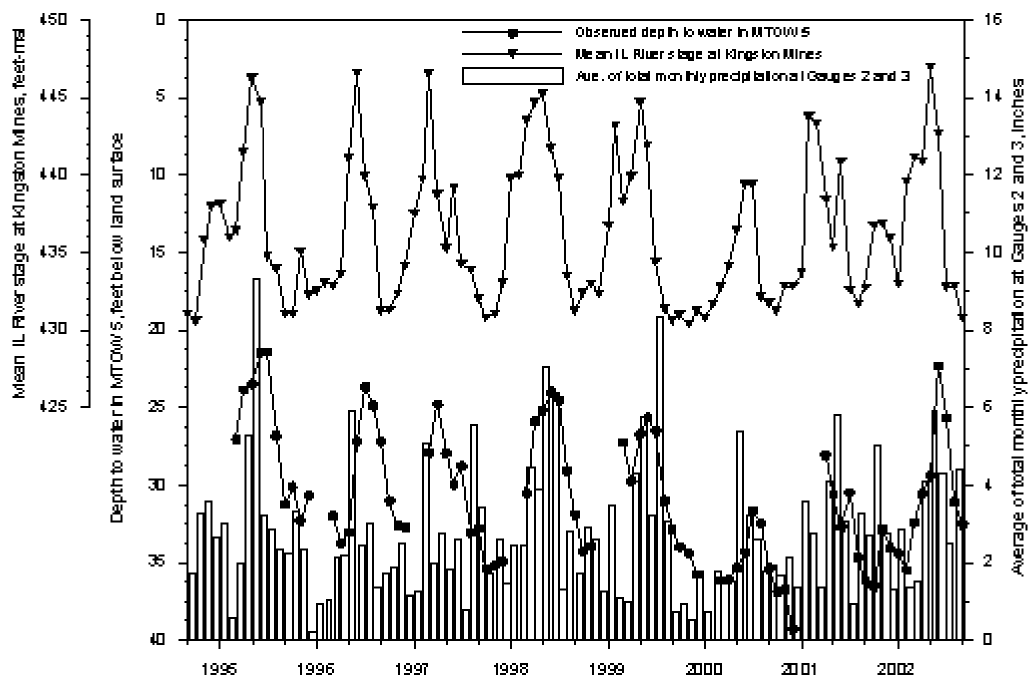


Figure A-5. Groundwater depth, monthly precipitation,
and Illinois River stage for MTOW-5.

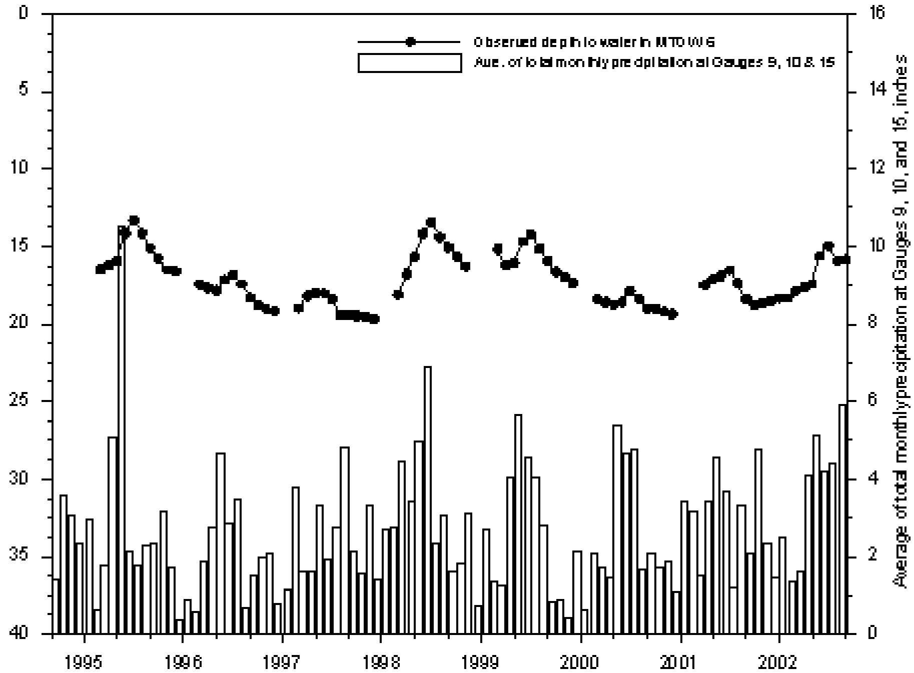


Figure A-6. Groundwater depth and monthly precipitation for MTOW-6.

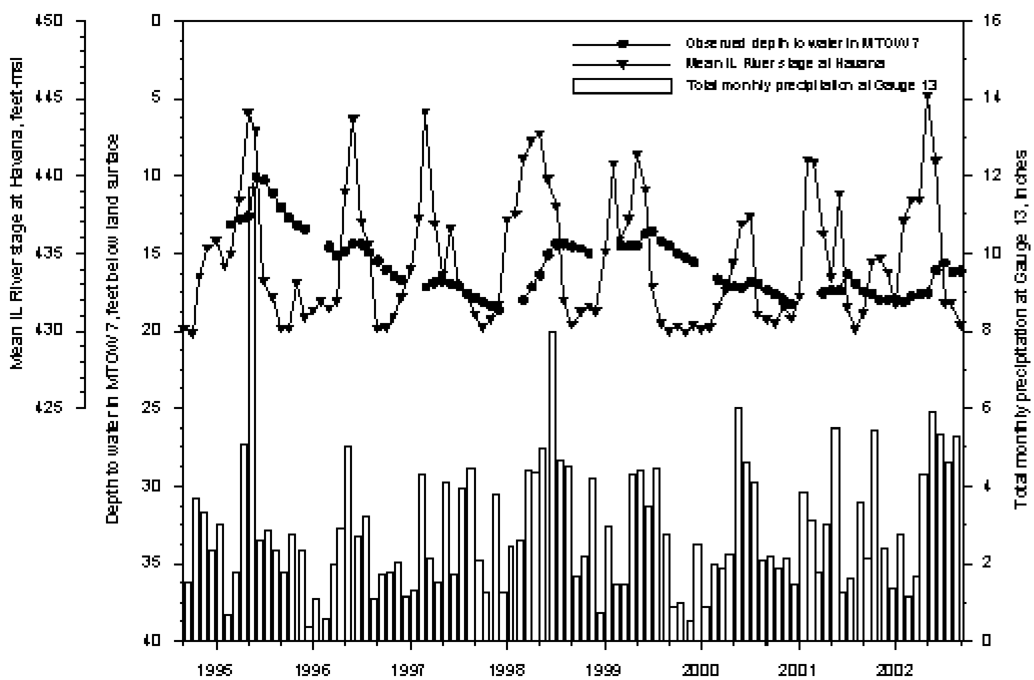


Figure A-7. Groundwater depth, monthly precipitation, and Illinois River stage for MTOW-7.

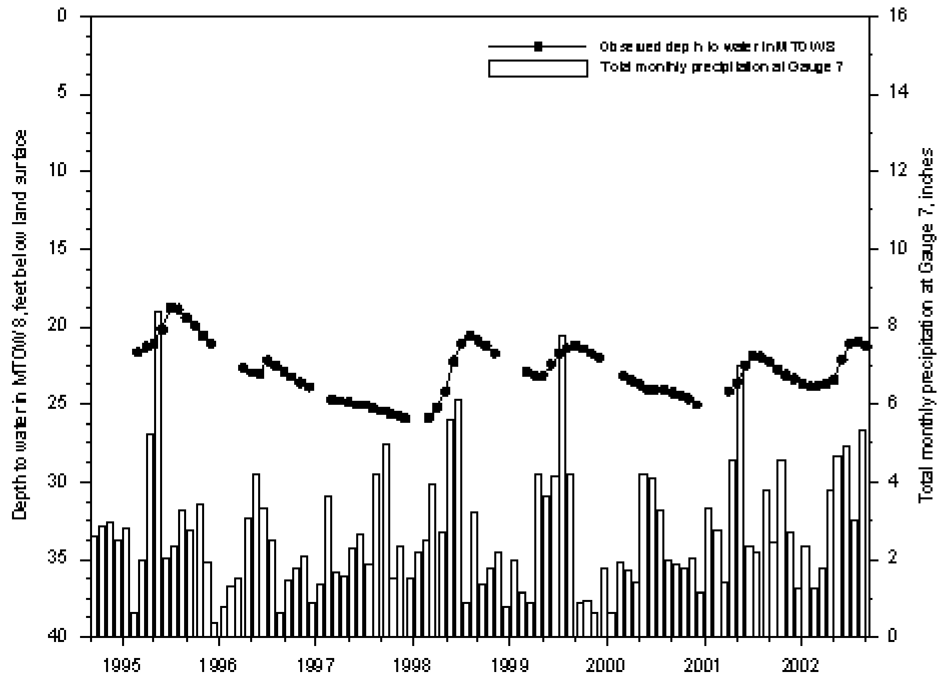


Figure A-8. Groundwater depth and monthly precipitation for MTOW-8.

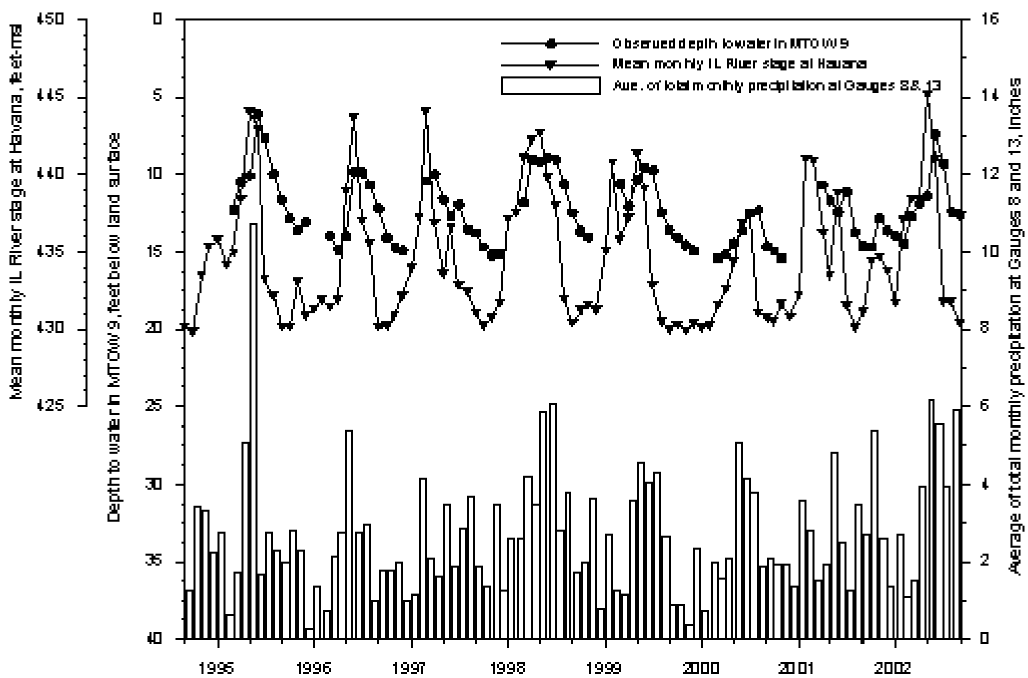


Figure A-9. Groundwater depth and monthly precipitation for MTOW-9.

Appendix A. (continued)

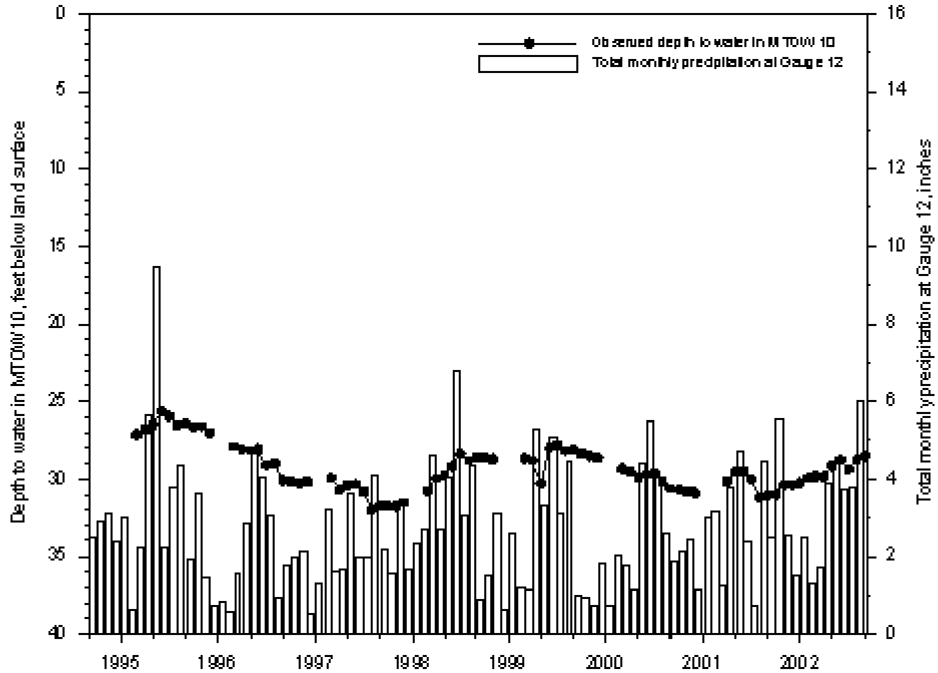


Figure A-10. Groundwater depth and monthly precipitation for MTOW-10.

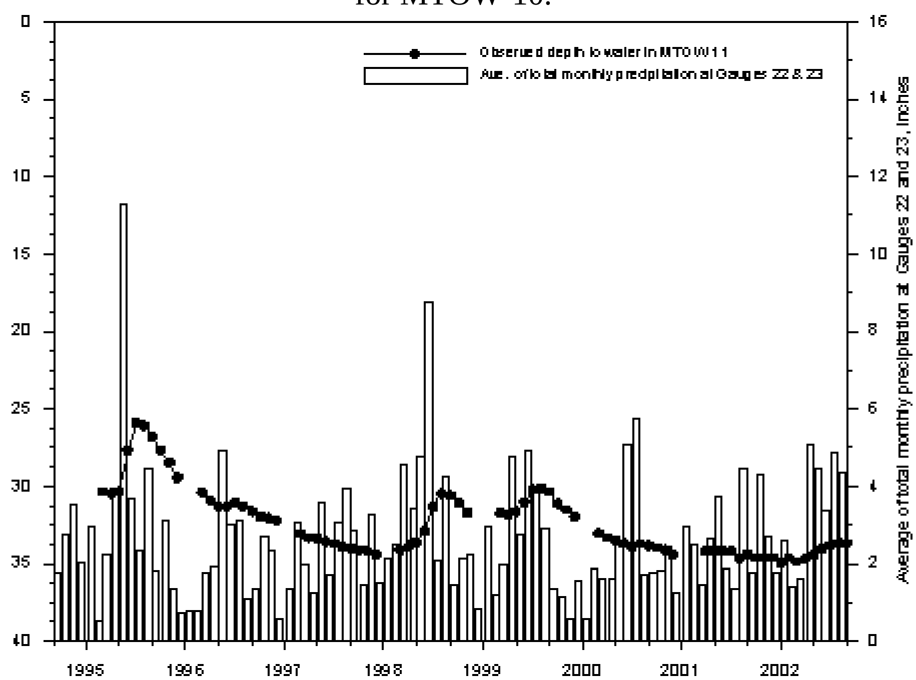


Figure A-11. Groundwater depth and monthly precipitation for MTOW-11.

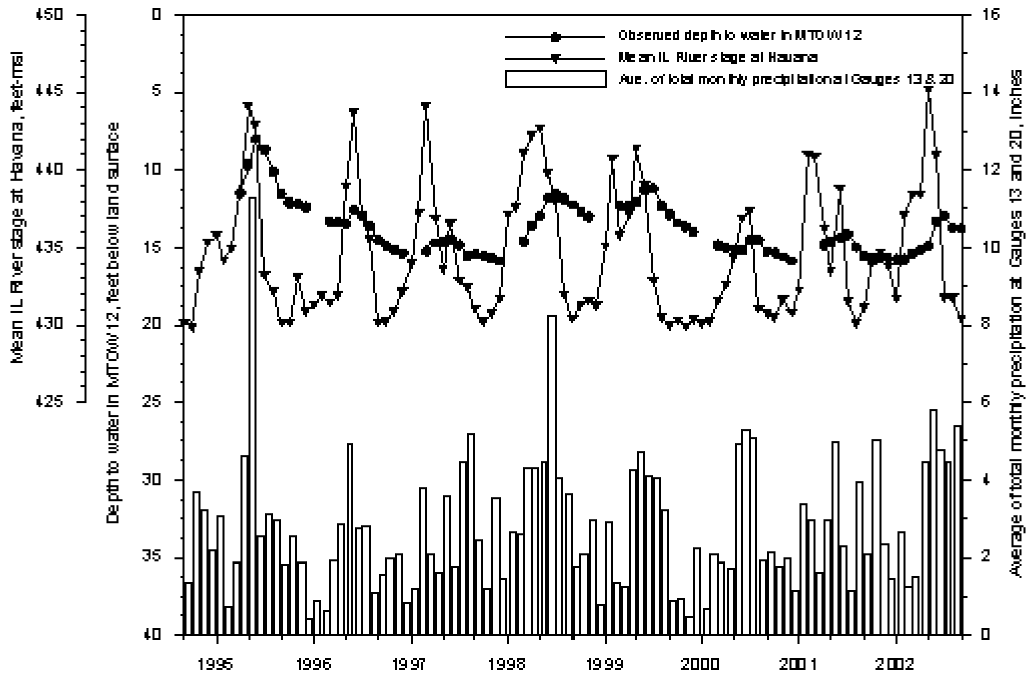


Figure A-12. Groundwater depth, monthly precipitation, and Illinois River stage for MTOW-12.

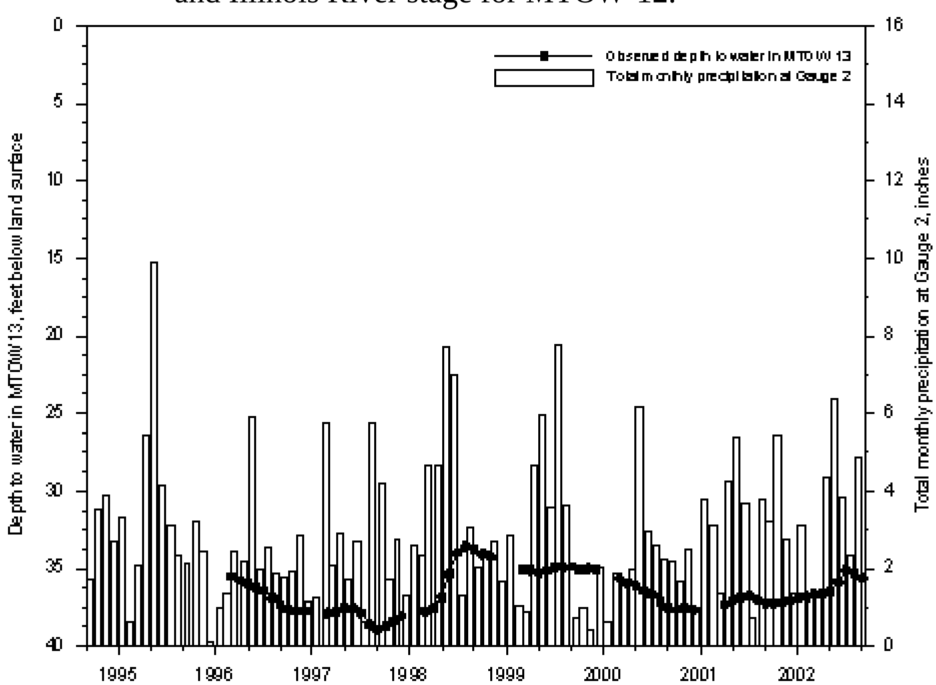


Figure A-13. Groundwater depth and monthly precipitation for MTOW-13.

Appendix B. Observed Groundwater Levels in the Imperial Valley Observation Well Network

Appendix B. Observed Groundwater Levels in the Imperial Valley Observation Well Network

	Depth to Water (feet below land surface) at Imperial Valley Network Observation Wells												
Date	*MTOW-1*	*MTOW-2*	*MTOW-3*	*MTOW-4*	*MTOW-5*	*MTOW-6*	*MTOW-7*	*MTOW-8*	*MTOW-9*	*MTOW-10*	*MTOW-11*	*MTOW-12*	*MTOW-13*
3-01-1995	-.--	8.88	13.11	*9.15*	27.06	16.45	13.15	*21.62*	12.54	*27.14*	30.38	-.--	-.--
4-01-1995	-.--	7.45	12.94	9.12	23.87	16.20	12.82	21.31	10.52	26.84	*30.48*	11.49	-.--
5-01-1995	-.--	6.69	12.65	8.92	23.50	15.95	12.63	21.09	10.12	26.48	30.32	9.67	-.--
5-15-1995	-.--	3.50	10.50	8.78	22.67	15.16	11.12	20.80	11.12	25.93	28.76	**7.97**	-.--
6-01-1995	-.--	**2.67**	8.80	8.57	21.50	14.17	10.07	20.16	6.12	**25.60**	27.67	8.00	-.--
6-15-1995	-.--	4.51	**8.07**	7.64	**18.24**	**13.15**	**9.74**	19.03	**5.26**	25.79	26.11	8.68	-.--
7-01-1995	-.--	6.15	8.74	7.03	21.43	13.31	10.30	18.73	7.66	25.97	25.88	8.64	-.--
7-15-1995	-.--	6.10	9.08	6.87	24.49	13.60	10.52	**18.69**	8.80	25.90	**25.68**	9.71	-.--
8-01-1995	-.--	8.10	9.77	**6.47**	26.82	14.17	11.11	18.87	9.98	26.55	26.05	10.13	-.--
8-15-1995	-.--	8.80	10.38	7.33	30.47	14.67	11.41	19.12	11.21	26.01	26.45	11.12	-.--
9-01-1995	-.--	9.65	10.96	7.58	31.28	15.11	12.00	19.40	11.65	26.42	26.79	11.52	-.--
9-15-1995	-.--	10.19	11.65	7.82	31.93	15.47	12.44	19.66	12.24	26.57	27.22	11.86	-.--
10-01-1995	-.--	10.35	12.27	7.99	30.09	15.76	12.69	19.94	12.84	26.64	27.69	12.12	-.--
10-15-1995	-.--	*10.40*	12.81	8.17	*32.79*	16.05	12.95	20.21	13.29	26.75	28.02	12.13	-.--
11-01-1995	-.--	10.30	13.12	8.55	32.30	16.50	13.19	20.60	*13.63*	26.61	28.47	12.17	-.--
12-01-1995	-.--	10.35	*13.62*	8.85	30.70	*16.60*	*13.45*	21.10	13.09	27.00	29.43	*12.39*	-.--
3-01-1996	37.18	10.90	14.89	**9.80**	32.00	17.47	14.58	-.--	13.98	**27.90**	**30.40**	13.30	**35.52**
4-01-1996	37.19	10.77	15.01	10.07	*33.77*	17.70	15.20	22.67	14.90	28.07	30.92	13.34	35.76
5-01-1996	37.28	9.93	15.27	10.24	33.05	17.80	14.88	22.97	14.02	28.14	31.33	13.47	36.00
5-15-1996	-.--	8.84	14.97	10.34	32.04	17.63	14.72	23.09	12.90	28.14	31.36	13.03	36.08
6-01-1996	35.45	**7.57**	14.31	10.43	27.17	17.14	14.38	23.08	9.85	28.04	31.33	12.58	36.25
6-15-1996	-.--	7.62	**14.07**	10.44	**23.36**	**16.78**	**14.25**	22.76	**8.64**	28.01	31.17	**12.54**	36.32
7-01-1996	**35.23**	9.45	14.17	10.64	23.69	16.85	14.40	**22.20**	9.90	29.10	31.09	12.88	36.47
7-15-1996	-.--	10.20	14.65	10.82	25.20	17.38	14.72	22.35	10.51	29.14	31.31	13.37	36.70
8-01-1996	36.58	10.63	15.01	11.00	24.90	17.42	14.95	22.52	10.69	28.97	31.33	13.65	36.92
8-15-1996	-.--	11.30	15.39	11.21	24.41	18.00	15.18	22.69	10.72	30.22	31.45	14.07	37.14
9-01-1996	37.68	11.78	15.75	11.48	27.17	18.29	15.48	22.90	12.20	30.07	31.61	14.55	37.30
9-15-1996	-.--	*12.02*	16.12	11.75	29.16	18.72	15.82	23.09	13.55	30.22	31.85	14.81	37.50
10-01-1996	*38.32*	12.00	16.35	11.95	31.00	18.80	16.00	23.24	14.12	30.12	31.93	14.89	37.63
11-01-1996	38.32	11.97	16.89	12.42	32.66	19.04	16.43	23.60	14.73	*30.30*	32.06	15.19	*37.73*
12-01-1996	-.--	11.99	*17.23*	*12.73*	32.74	*19.15*	*16.72*	*23.91*	*14.90*	30.20	*32.22*	*15.36*	37.71

Note: Bold numbers are the shallowest groundwater levels for the calendar year; *italic* numbers are the deepest groundwater levels. Shaded areas distinguish between years.

Appendix B. (continued)

Depth to Water (feet below land surface) at Imperial Valley Network Observation Wells

Date	*MTOW-1*	*MTOW-2*	*MTOW-3*	*MTOW-4*	*MTOW-5*	*MTOW-6*	*MTOW-7*	*MTOW-8*	*MTOW-9*	*MTOW-10*	*MTOW-11*	*MTOW-12*	*MTOW-13*
3-01-1997	38.41	10.07	18.05	**13.40**	27.94	19.00	17.18	**24.70**	10.43	**29.90**	**33.10**	15.24	37.87
4-01-1997	37.67	**9.87**	17.53	13.84	**24.80**	18.20	16.86	24.80	**10.00**	30.70	33.33	14.71	37.75
5-01-1997	**37.27**	10.50	17.27	13.95	27.95	**17.98**	**16.78**	24.88	11.62	30.42	33.40	14.65	**37.56**
6-01-1997	37.32	10.38	**17.17**	13.98	29.98	18.02	16.90	25.03	12.71	30.34	33.61	**14.45**	37.60
6-15-1997	-.--	-.--	-.--	-.--	-.--	-.--	-.--	-.--	-.--	31.45	-.--	-.--	-.--
7-01-1997	37.63	11.08	17.29	14.22	28.78	18.38	17.06	25.05	11.95	31.80	33.73	14.85	37.86
7-15-1997	-.--	11.54	17.45	14.35		19.00	17.24	25.12	12.67	31.45	33.78	15.17	38.15
8-01-1997	38.28	11.98	17.77	14.56	33.10	19.44	17.57	25.25	13.57	*31.99*	33.90	15.52	38.59
8-15-1997	-.--	12.19	17.94	14.68	33.70	19.55	17.74	25.35	14.07	31.79	33.97	15.37	38.84
9-01-1997	38.90	12.15	18.17	*14.80*	32.78	19.45	17.89	25.44	13.80	31.74	34.03	15.45	*38.92*
10-01-1997	38.59	12.25	18.51	14.75	*35.43*	19.51	18.14	25.58	14.72	31.77	34.14	15.52	38.75
11-01-1997	*39.46*	*12.36*	18.77	14.64	35.20	19.55	18.35	25.72	*15.24*	31.78	34.23	15.70	38.38
12-01-1997	-.--	11.97	*19.11*	14.60	34.95	*19.70*	*18.65*	*25.90*	15.10	31.51	*34.41*	*15.87*	38.08
3-01-1998	*38.78*	8.38	*19.04*	14.59	30.50	*18.10*	*17.98*	*25.88*	11.84	*30.77*	*34.13*	*14.61*	*37.75*
4-01-1998	37.91	6.25	18.41	14.58	25.95	16.78	17.14	25.21	9.04	29.95	33.85	13.61	37.52
5-01-1998	36.67	7.00	17.65	*14.64*	25.21	15.70	16.38	24.20	9.20	29.73	33.63	12.97	36.85
6-01-1998	36.00	6.23	16.92	13.66	**24.02**	14.18	15.08	22.22	**8.95**	29.15	32.93	11.82	35.38
7-01-1998	**35.61**	**5.77**	16.57	13.24	24.50	**13.47**	**14.40**	21.08	9.05	**28.40**	31.36	**11.55**	33.98
8-01-1998	-.--	9.13	**16.27**	13.00	29.10	14.42	14.40	**20.60**	10.65	28.79	**30.47**	11.87	**33.60**
9-01-1998	36.24	10.00	16.52	12.95	31.90	15.08	14.58	20.90	12.48	28.60	30.58	12.25	33.82
10-01-1998	36.48	10.55	16.72	12.78	*34.30*	15.68	14.72	21.25	13.70	28.60	31.10	12.65	34.07
11-01-1998	-.--	*10.70*	16.97	**12.55**	33.93	16.30	15.00	21.70	*14.10*	28.70	31.69	13.02	34.24
3-01-1999	35.48	8.74	*16.82*	**12.50**	27.25	15.22	14.54	22.92	10.61	28.67	31.75	12.31	35.03
4-01-1999	35.26	9.13	16.47	12.95	29.74	16.20	14.54	23.13	12.05	28.83	*31.85*	12.29	35.15
5-01-1999	35.16	6.42	16.27	13.25	26.73	16.06	14.48	*23.17*	10.38	*30.28*	31.63	12.01	*35.25*
6-01-1999	**33.95**	**5.45**	14.63	13.05	**25.64**	14.70	13.74	22.45	**9.54**	28.00	31.03	11.27	35.15
7-01-1999	34.23	7.19	**13.56**	12.90	26.50	**14.30**	**13.60**	21.74	9.74	**27.80**	30.23	**11.20**	34.94
8-01-1999	35.68	9.98	14.69	13.10	31.03	15.20	14.24	21.40	12.45	28.17	**30.11**	12.35	34.90
9-01-1999	36.30	10.82	14.83	*13.30*	32.84	15.92	14.55	**21.18**	13.56	28.10	30.37	12.85	**34.88**
10-01-1999	*36.87*	11.18	15.40	13.09	34.00	16.64	15.02	21.44	14.10	28.39	31.13	13.41	35.06
11-01-1999	-.--	11.30	15.71	13.00	34.42	17.00	15.28	21.72	14.60	28.50	31.51	13.69	35.00
12-01-1999	*37.43*	*11.45*	16.05	13.05	*35.79*	*17.35*	*15.55*	22.04	*14.91*	28.65	*31.97*	*14.01*	35.08

Note: Bold numbers are the shallowest groundwater levels for the calendar year; *italic* numbers are the deepest groundwater levels. Shaded areas distinguish between years.

Appendix B. (concluded)

Date	*Depth to Water (feet below land surface) at Imperial Valley Network Observation Wells*												
	MTOW-1	*MTOW-2*	*MTOW-3*	*MTOW-4*	*MTOW-5*	*MTOW-6*	*MTOW-7*	*MTOW-8*	*MTOW-9*	*MTOW-10*	*MTOW-11*	*MTOW-12*	*MTOW-13*
3-01-2000	38.07	11.65	**17.17**	**13.51**	36.21	18.38	**16.65**	**23.14**	15.40	**29.35**	**33.03**	14.85	**35.65**
4-01-2000	38.17	11.47	17.45	13.87	36.12	18.61	16.92	23.51	15.20	29.56	33.31	14.99	35.92
5-01-2000	38.26	11.74	17.63	14.05	35.38	18.71	17.13	23.77	14.44	29.85	33.51	15.11	36.15
6-01-2000	*38.40*	10.70	17.85	14.40	34.37	18.59	17.21	24.05	13.65	29.74	33.67	15.12	36.44
7-01-2000	38.11	**8.83**	*17.97*	14.34	**31.65**	**17.87**	16.84	24.05	12.50	29.63	33.86	14.56	36.70
8-01-2000	**35.89**	10.24	17.22	14.47	32.50	18.37	16.97	24.05	**12.35**	30.12	33.71	**14.53**	37.14
9-01-2000	36.59	11.39	17.37	*14.60*	35.40	19.02	17.33	24.24	14.68	30.60	33.83	15.27	37.54
10-01-2000	37.08	11.79	17.65	14.55	*36.88*	19.04	17.62	24.47	14.97	30.70	33.98	15.32	*37.65*
11-01-2000	37.22	*12.11*	*17.97*	14.47	36.75	*19.17*	*17.95*	*24.67*	*15.44*	*30.80*	*34.10*	*15.61*	37.60
4-01-2001	36.18	9.19	17.77	**14.59**	**28.07**	17.49	17.54	*24.17*	**10.69**	30.13	34.18	14.83	*37.30*
5-01-2001	35.69	9.25	17.38	14.90	30.57	17.10	17.35	23.62	11.70	29.53	**34.15**	14.61	37.00
6-01-2001	35.82	9.08	17.12	14.98	32.71	16.87	17.35	22.47	12.45	**29.51**	34.18	14.39	36.81
7-01-2001	**35.65**	**9.06**	**16.89**	14.90	30.51	**16.54**	**16.35**	**21.85**	11.15	30.03	34.22	**14.16**	**36.77**
8-01-2001	36.93	11.50	17.51	15.00	34.70	17.35	16.97	21.98	13.75	*31.21*	*34.68*	14.98	37.03
9-01-2001	37.94	12.32	17.77	*15.08*	36.25	18.39	17.45	22.28	14.67	31.00	34.42	15.58	37.23
10-01-2001	*38.18*	*12.58*	*17.97*	14.94	*36.55*	*18.76*	17.60	22.75	*14.70*	30.98	34.63	*15.90*	37.23
11-01-2001	37.74	11.97	*17.97*	14.93	32.85	18.63	*17.98*	23.12	12.84	30.42	34.63	15.65	37.21
12-01-2001	37.64	12.10	17.88	14.69	34.08	18.46	17.97	23.37	13.67	30.40	34.63	15.69	37.06
1-01-2002	37.67	*11.66*	18.02	*14.46*	34.41	*18.34*	17.97	23.68	13.97	*30.25*	*34.95*	*15.75*	*36.90*
2-01-2002	*37.89*	10.95	*18.11*	14.35	*35.49*	18.32	*18.15*	*23.83*	*14.51*	29.88	34.61	*15.75*	36.81
3-01-2002	37.38	10.35	17.77	14.06	32.44	17.85	17.75	23.82	12.73	29.84	34.85	15.35	36.69
4-01-2002	37.31	10.57	17.69	14.00	30.58	17.64	17.64	23.64	11.92	29.84	34.68	15.19	36.62
5-01-2002	37.17	7.50	17.57	14.25	29.40	17.40	17.54	23.49	11.40	29.15	34.44	14.91	36.53
6-01-2002	**34.44**	**7.30**	15.72	13.39	**22.34**	15.62	16.05	22.12	**7.42**	28.76	34.08	13.30	35.91
7-01-2002	34.82	8.39	**15.07**	**12.75**	25.70	**15.00**	**15.61**	21.08	9.30	29.36	33.83	**12.97**	**35.13**
8-01-2002	34.82	10.00	15.62	13.82	31.10	15.93	16.17	**21.01**	12.40	**28.73**	**33.66**	13.71	35.36

Note: **Bold** numbers are the shallowest groundwater levels for the calendar year; *italic* numbers are the deepest groundwater levels. Shaded areas distinguish between years.

Appendix C. Imperial Valley Rain Gauge Network Site Descriptions

Appendix C: Rain Gauge Site Descriptions

This appendix contains site descriptions of each rain gauge site in the IVWA network as of August 31, 2001. Sites that have been relocated since the network was established in August 1992 are so noted in the "Placement" portion of their site description. Sites with shaded descriptions have been removed from the network.

This appendix has been omitted to protect the privacy of the site owner

Appendix D. Documentation of 2001-2002
Imperial Valley Rain Gauge Network Maintenance

Appendix D. Documentation of 2001-2002 Imperial Valley Rain Gauge Network Maintenance

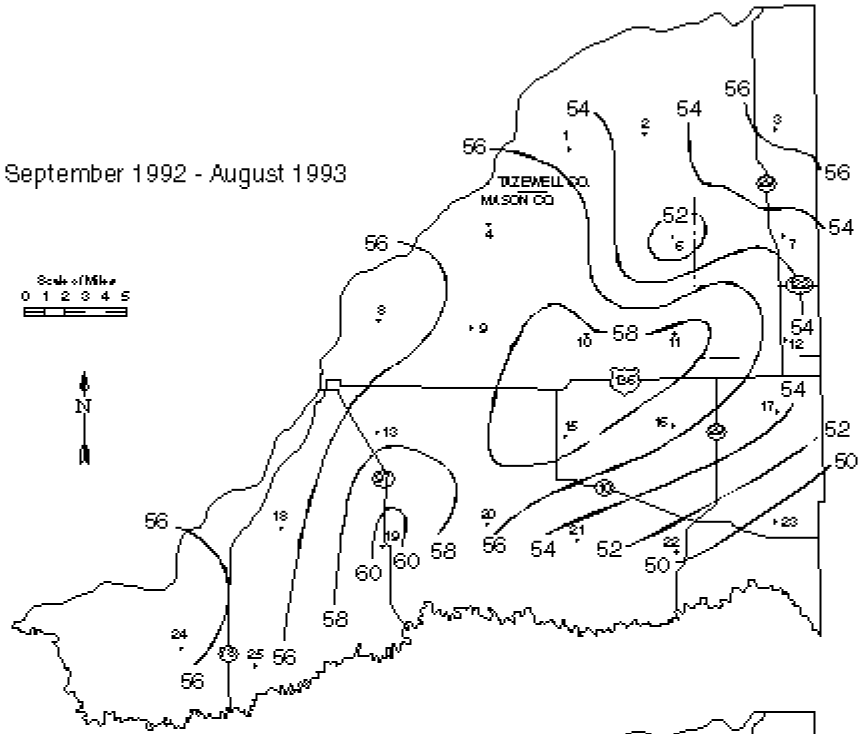
This appendix documents major maintenance work carried out at sites in the Imperial Valley rain gauge network from September 1, 2001 through August 31, 2002.

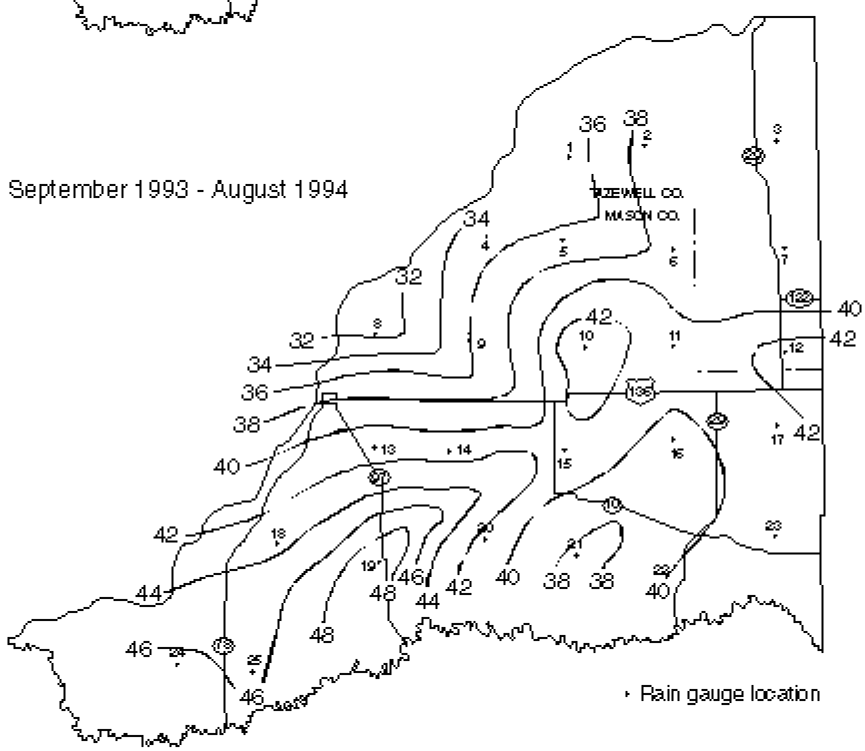
1. Replaced connector and wire assembly in data logger at site 2 on 09-01-2001.
2. Soldered data logger connector wires, replaced data logger battery, and replaced 9-volt connector and battery in chart drive at site 9 on 11-21-2001.
3. Recalibrated gauge and replaced data logger and chart drive batteries at site 16 on 11-21-2001.
4. Replaced all remaining data logger batteries on 12-11-2001.
5. Replaced gauge and data logger at site 9 on 01-10-2002.
6. Replaced clock drive in gauge at site 19 on 01-10-2002.
7. Repaired data logger at site 2 on 02-14-2002.
8. Replaced data logger battery at site 9 on 03-22-2002.
9. Replaced data logger battery at site 9 on 05-02-2002.
10. Replaced gauge and data logger at site 16 on 05-23-2002.
11. Moved site 8 to INHS station on Quiver Creek, 0.2 mile NE of old site 8 on 06-03-2002.
12. Replaced shelter damaged by mower at site 9 on 06-07-2002.
13. Resoldered data logger connector wires at site 12 on 06-07-2002.
14. Replaced chart drive and data logger batteries at site 9 on 06-27-2002.
15. Replaced damaged gauge and data logger at site 15 on 07-02-2002.
16. Resoldered wires on data logger connector at site 23 on 07-02-2002.
17. Replaced 24-hour chart drives with 8-day chart drives at sites 8, 11, 16, 19, and 24 on August 20, 2002.

Appendix E. Annual Precipitation, Years One-Nine

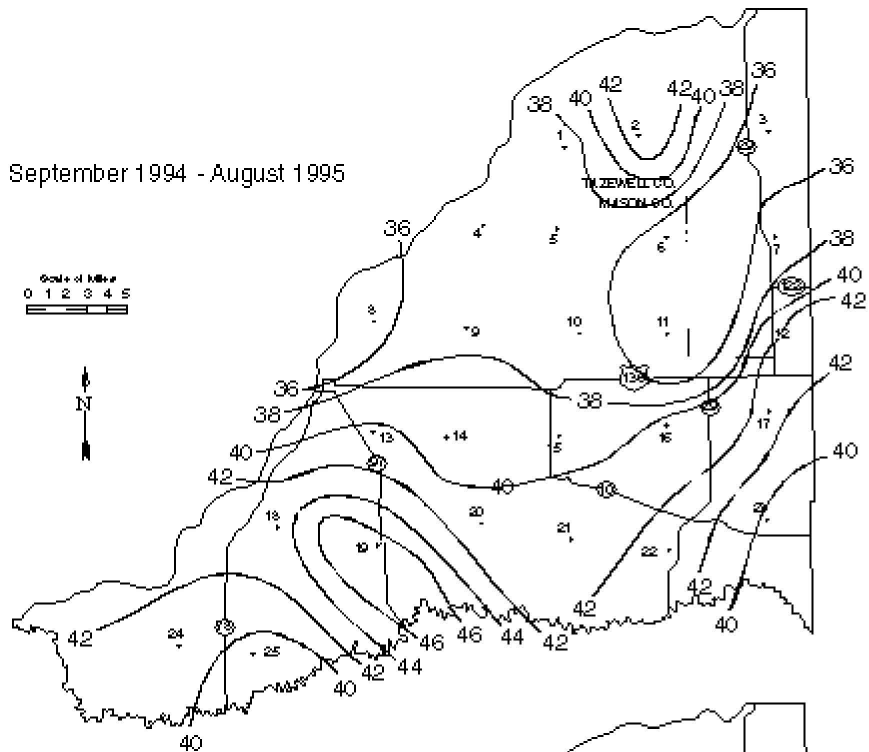
Appendix E. Annual Precipitation, Years One-Nine

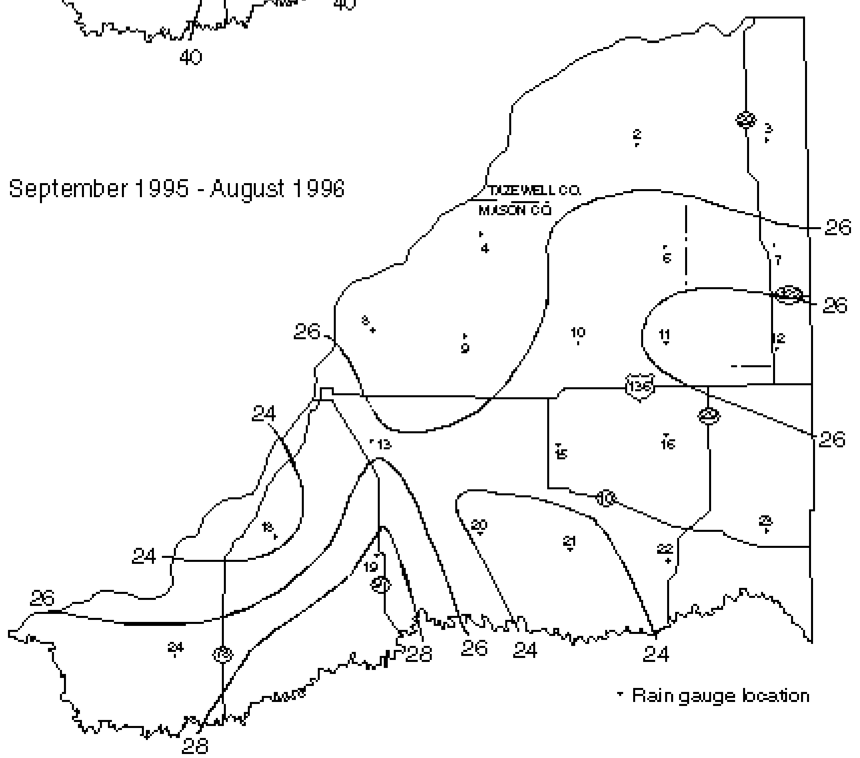
(Rain gauge #16 omitted from Years 5-9)



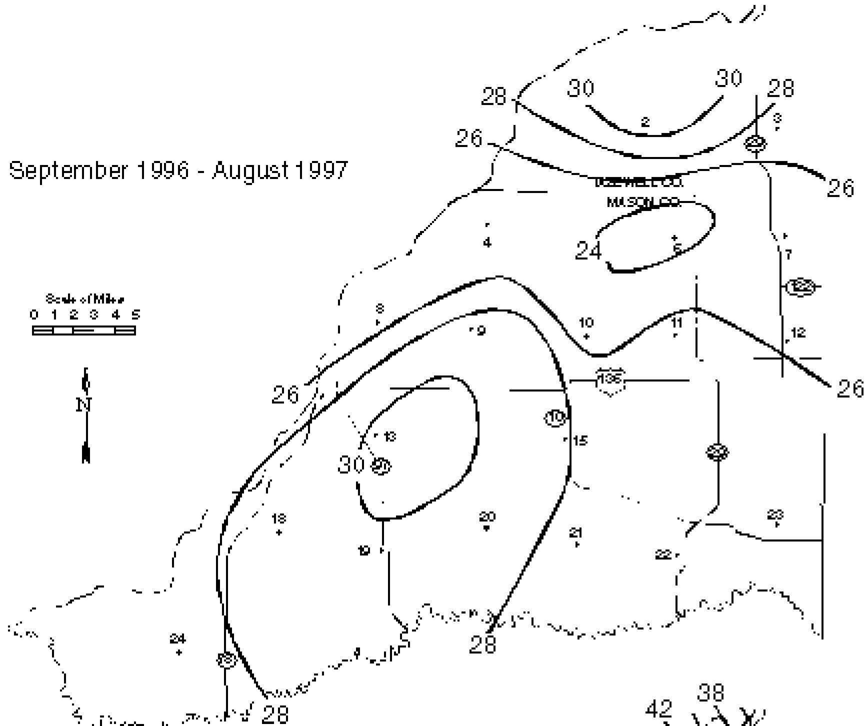


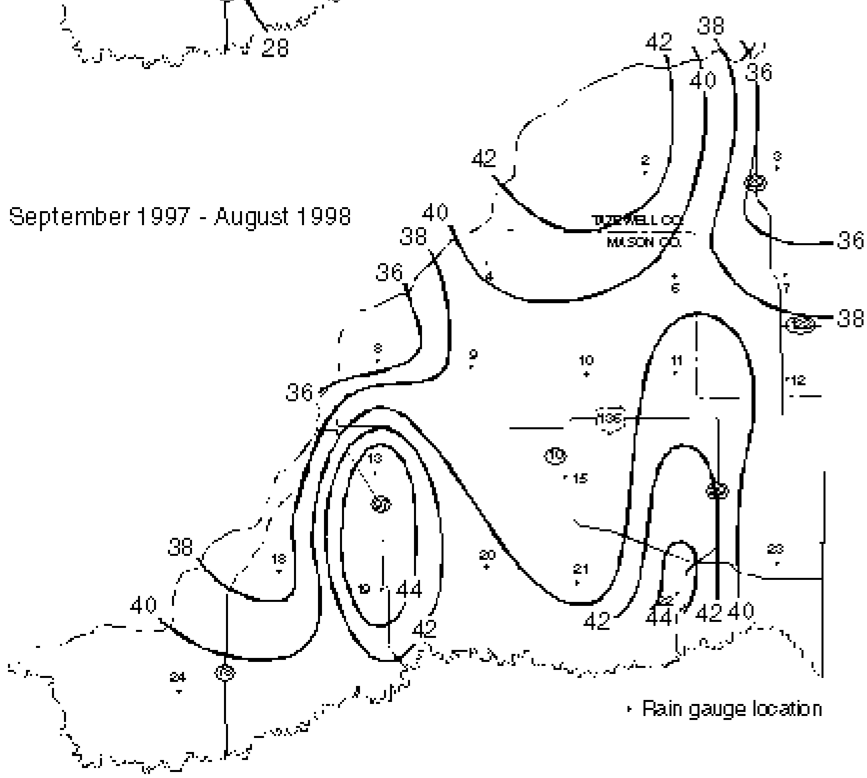
Appendix E. (continued)



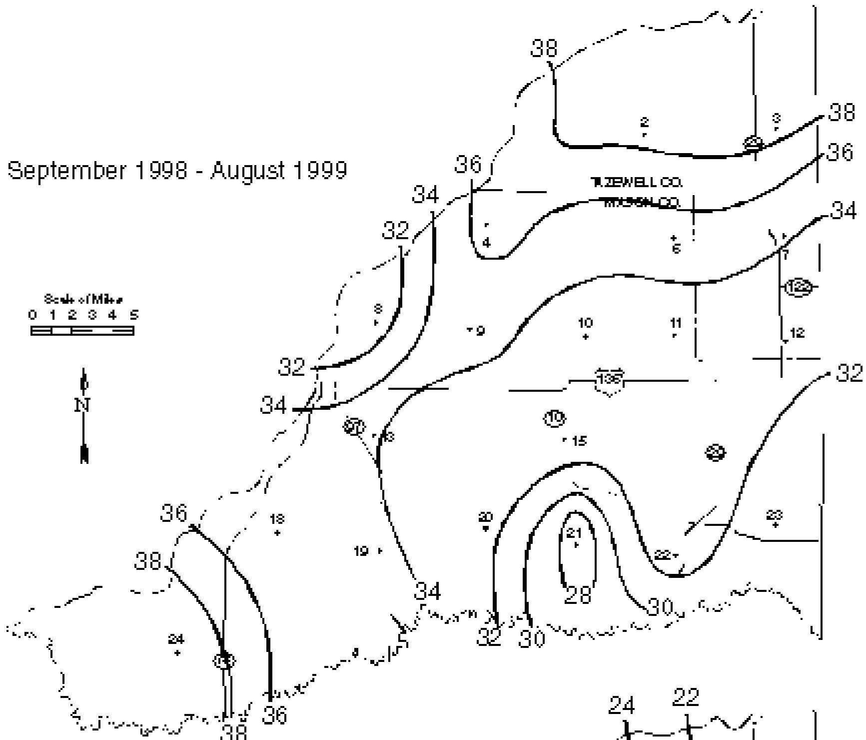


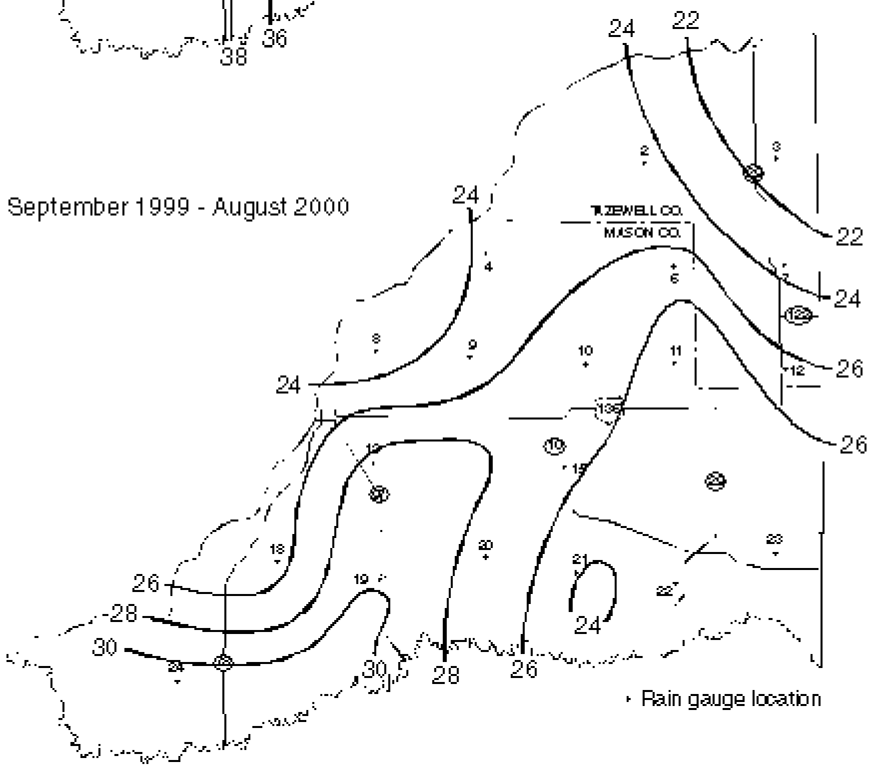
Appendix E. (continued)



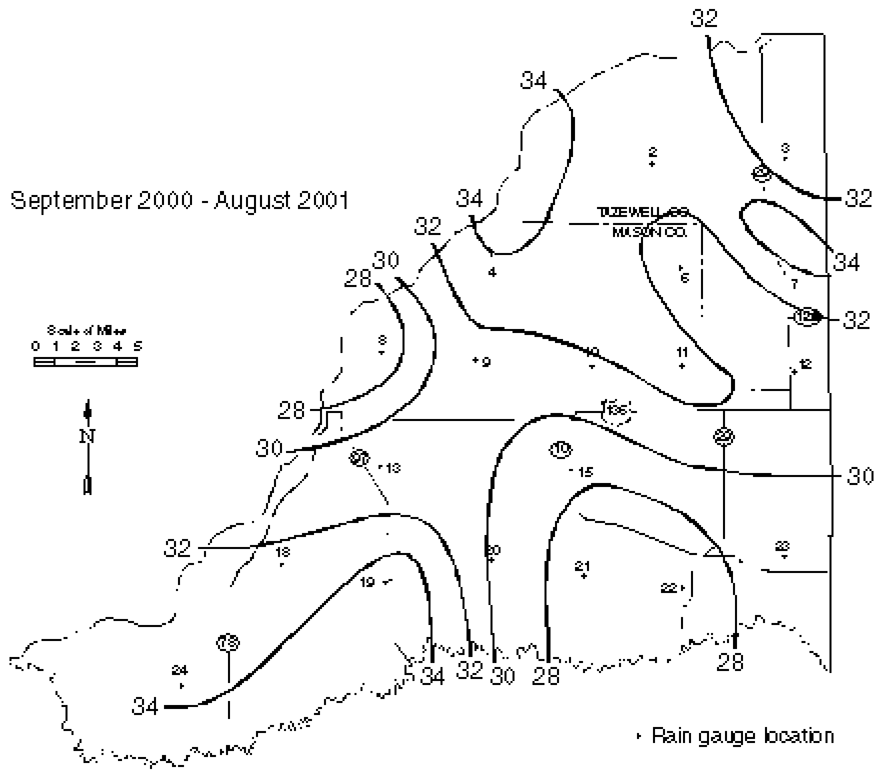


Appendix E. (continued)





Appendix E. (concluded)



Appendix F. Precipitation-Days, Precipitation Events, Total Precipitation, Precipitation per Precipitation-Day, and Precipitation per Precipitation Event by Month and Season, 1992-2002

Appendix F. Precipitation-Days, Precipitation Events, Total Precipitation, Precipitation per Precipitation-Day, and Precipitation per Precipitation Event by Month and Season, 1992-2002

Average number of precipitation-days

Month	*1992-93*	*1993-94*	*1994-95*	*1995-96*	*1996-97*	*1997-98*	*1998-99*	*1999-00*	*2000-01*	*2001-02*
September	8	8	5	6	4	6	7	4	7	5
October	9	5	7	9	6	7	9	4	6	9
November	13	5	7	3	9	6	8	7	7	8
December	6	7	7	5	5	8	4	7	10	6
January	8	7	5	8	10	6	10	7	9	2
February	5	6	3	3	7	7	7	10	6	5
March	10	6	5	7	7	10	5	6	5	6
April	10	11	14	5	10	8	11	9	9	6
May	14	7	14	20	11	11	8	10	10	9
June	11	11	13	10	13	13	8	10	6	4
July	18	8	13	10	6	6	7	10	5	5
August	16	10	14	4	13	6	4	7	9	5
Autumn	30	18	19	18	19	19	24	15	20	22
Winter	19	20	15	16	22	21	21	24	25	12
Spring	34	24	33	32	28	29	24	25	24	21
Summer	45	29	40	24	32	25	19	27	20	14
Annual	128	91	107	90	101	94	88	91	89	70

Average number of precipitation events

Month	*1992-93*	*1993-94*	*1994-95*	*1995-96*	*1996-97*	*1997-98*	*1998-99*	*1999-00*	*2000-01*	*2001-02*
September	10	8	6	6	6	8	12	8	10	8
October	10	5	7	9	11	11	15	5	10	12
November	13	7	10	3	9	7	18	10	15	11
December	9	9	8	5	5	9	6	15	19	14
January	9	8	5	8	13	8	19	11	18	5
February	5	6	3	4	8	10	10	12	13	11
March	10	6	6	7	8	23	8	10	12	10
April	11	12	19	6	11	12	20	14	17	11
May	16	7	16	25	15	18	12	16	18	14
June	13	13	15	11	14	21	13	18	11	7
July	21	9	16	10	6	9	10	14	6	8
August	21	12	18	4	15	11	8	9	11	8
Autumn	33	20	23	18	26	26	45	23	35	31
Winter	23	23	16	17	26	27	35	38	50	30
Spring	37	25	41	38	34	53	40	40	47	35
Summer	55	34	49	25	35	41	31	41	28	23
Annual	148	102	129	98	121	147	151	142	160	119

Appendix F. (continued)

Month	*Total precipitation, inches*									
	1992-93	*1993-94*	*1994-95*	*1995-96*	*1996-97*	*1997-98*	*1998-99*	*1999-00*	*2000-01*	*2001-02*
September	4.21	11.56	1.49	2.00	1.63	2.55	1.61	0.87	1.93	2.35
October	2.00	2.97	3.34	3.06	1.99	1.43	2.07	0.92	1.79	4.89
November	6.35	2.59	3.37	1.84	2.15	3.10	2.70	0.48	2.05	2.50
December	2.82	1.11	2.29	0.45	0.90	1.47	0.81	2.07	1.17	1.43
January	3.52	0.96	2.90	1.01	1.28	2.59	2.84	0.63	3.35	2.64
February	1.64	1.64	0.61	0.77	3.86	2.65	1.32	2.00	2.78	1.28
March	3.85	0.96	1.93	1.93	1.92	4.51	1.32	1.68	1.50	1.58
April	5.25	5.03	4.87	2.61	1.76	3.53	4.42	1.59	3.31	4.24
May	2.61	3.11	10.33	5.37	2.94	5.21	4.65	4.39	4.89	5.43
June	6.27	3.19	2.65	2.85	1.97	7.19	4.41	4.76	3.08	4.23
July	11.05	3.44	2.73	2.84	2.51	2.34	4.56	4.39	1.30	3.99
August	5.99	3.66	2.90	0.98	4.41	3.50	3.30	2.02	3.81	5.37
Autumn	12.56	17.12	8.20	6.89	5.77	7.08	6.38	2.27	5.77	9.74
Winter	7.97	3.70	5.80	2.23	6.04	6.71	4.97	4.70	7.30	5.35
Spring	11.71	9.10	17.14	9.91	6.62	13.25	10.39	7.66	9.70	11.25
Summer	23.31	10.29	8.28	6.68	8.89	13.03	12.27	11.17	8.19	13.59
Annual	55.55	40.21	39.42	25.70	27.31	40.06	34.02	25.81	30.97	39.91

Month	*Inches of precipitation per precipitation-day*									
	1992-93	*1993-94*	*1994-95*	*1995-96*	*1996-97*	*1997-98*	*1998-99*	*1999-00*	*2000-01*	*2001-02*
September	0.53	1.45	0.30	0.33	0.41	0.43	0.23	0.22	0.28	0.47
October	0.22	0.59	0.48	0.34	0.33	0.20	0.23	0.23	0.30	0.54
November	0.49	0.52	0.48	0.61	0.24	0.52	0.34	0.07	0.29	0.31
December	0.47	0.16	0.33	0.09	0.18	0.18	0.20	0.30	0.12	0.24
January	0.44	0.14	0.58	0.13	0.13	0.43	0.28	0.08	0.37	1.32
February	0.33	0.27	0.20	0.26	0.55	0.38	0.19	0.20	0.46	0.26
March	0.38	0.16	0.39	0.28	0.27	0.45	0.26	0.28	0.30	0.26
April	0.52	0.46	0.35	0.52	0.18	0.44	0.40	0.18	0.37	0.71
May	0.19	0.44	0.74	0.27	0.27	0.47	0.58	0.44	0.49	0.60
June	0.57	0.29	0.20	0.29	0.15	0.55	0.55	0.48	0.51	1.06
July	0.61	0.43	0.21	0.28	0.42	0.39	0.65	0.44	0.26	0.80
August	0.37	0.37	0.21	0.25	0.34	0.58	0.83	0.29	0.42	1.07
Autumn	0.42	0.95	0.43	0.38	0.30	0.37	0.27	0.15	0.29	0.44
Winter	0.42	0.19	0.39	0.14	0.27	0.32	0.24	0.20	0.29	0.41
Spring	0.34	0.38	0.52	0.31	0.24	0.46	0.43	0.31	0.40	0.54
Summer	0.52	0.35	0.21	0.28	0.28	0.52	0.65	0.41	0.41	0.97
Annual	0.43	0.44	0.37	0.29	0.27	0.43	0.39	0.28	0.35	0.57

Appendix F. (concluded)

Month	Inches of precipitation per precipitation event									
	1992-93	*1993-94*	*1994-95*	*1995-96*	*1996-97*	*1997-98*	*1998-99*	*1999-00*	*2000-01*	*2001-02*
September	0.42	1.45	0.25	0.33	0.27	0.32	0.13	0.11	0.19	0.29
October	0.20	0.59	0.48	0.34	0.18	0.13	0.14	0.18	0.18	0.41
November	0.49	0.37	0.34	0.61	0.24	0.44	0.15	0.05	0.14	0.23
December	0.31	0.12	0.29	0.09	0.18	0.16	0.14	0.14	0.06	0.10
January	0.39	0.12	0.58	0.13	0.10	0.32	0.15	0.06	0.19	0.53
February	0.33	0.27	0.20	0.19	0.48	0.27	0.13	0.17	0.21	0.12
March	0.38	0.16	0.32	0.28	0.24	0.20	0.17	0.17	0.13	0.16
April	0.48	0.42	0.26	0.43	0.16	0.29	0.22	0.11	0.19	0.39
May	0.16	0.44	0.65	0.21	0.20	0.29	0.39	0.27	0.27	0.39
June	0.48	0.25	0.18	0.26	0.14	0.34	0.34	0.26	0.28	0.60
July	0.53	0.38	0.17	0.28	0.42	0.26	0.46	0.31	0.22	0.50
August	0.29	0.31	0.16	0.25	0.29	0.32	0.41	0.22	0.35	0.67
Autumn	0.38	0.86	0.36	0.38	0.22	0.27	0.14	0.10	0.16	0.31
Winter	0.35	0.16	0.36	0.13	0.23	0.25	0.14	0.12	0.15	0.18
Spring	0.32	0.36	0.42	0.26	0.19	0.25	0.26	0.19	0.21	0.32
Summer	0.42	0.30	0.17	0.27	0.25	0.32	0.40	0.27	0.29	0.59
Annual	0.38	0.39	0.31	0.26	0.23	0.27	0.23	0.18	0.19	0.34

Note:
The tables are based upon the average of individual site data. For example, the average number of precipitation-days presented is the average number of days during a given month when precipitation was found at any individual site, not the total number of days in a month when precipitation was observed somewhere in the network.

Appendix G. Documentation of Heavy Storm Amounts in the Imperial Valley, 2001-2002

Appendix G. Documentation of Heavy Storm Amounts in the Imperial Valley, 2001-2002

This appendix documents all storm period amounts, start times, and durations, and notes those that exceed an expected event amount (for one-year to 100-year recurrence intervals) during the period September 1, 2001-August 31, 2002. The same information for previous years is found in Scott et al. (2002). Individual network storm durations of one hour to ten days were considered. The precipitation amounts and storm durations for one- to 100-year recurrence intervals for west-central Illinois are given below (Huff and Angel, 1989).

To determine the return frequency of any storm in Table G-2 or G-3, obtain the storm duration from the tables, then look in the left-hand column of Table G-1 to locate the storm duration that equals or just exceeds the storm duration in Table G-2 or G-3. If the precipitation for the event at any gauge in Table G-2 or G-3 exceeds the amount in Table G-1, obtain the return frequency by looking at the heading of the right-hand column that the precipitation amount exceeds. For example, Table G-3 indicates storm number 1301 has a duration of 17 hours. This storm duration falls between the 12- and 18-hour storm duration in Table G-1. Assume an 18-hour storm duration. Table G-3 indicates the gauge at site 4 recorded precipitation equal to 2.60 inches, and the gauge at site 8 recorded 3.88 inches. Therefore, site 4 exceeded the one-year return frequency amount (2.28 inches) for an 18-hour storm, and site 8 exceeded the 5-year return frequency amount (3.46 inches) for an 18-hour storm.

The following table documents for each network storm period, start times (CST), storm duration (hours), number of gauges recording precipitation, average precipitation (inches) over the 20-gauge network, average precipitation (inches) at gauges receiving precipitation during the event, maximum precipitation (inches) at any gauge during the storm period, and gauge location. The last column in the table indicates whether the maximum precipitation for the storm exceeds the expected amount for the observed storm duration (one-year to 100-year recurrence intervals) considered. A storm recurrence frequency of 50 years means that a storm of this intensity and duration would be expected once every 50 years.

Table G-1. Precipitation Amounts for Different Storm Durations and Recurrence Intervals

Storm duration	*Precipitation (inches) for given recurrence interval*						
	1-Yr	*2-Yr*	*5-Yr*	*10-Yr*	*25-Yr*	*50-Yr*	*100-Yr*
1 hour	1.18	1.42	1.77	2.09	2.50	2.86	3.25
2 hours	1.48	1.78	2.22	2.62	3.14	3.59	4.08
3 hours	1.61	1.93	2.41	2.85	3.41	3.89	4.43
6 hours	1.89	2.26	2.82	3.33	3.99	4.56	5.19
12 hours	2.17	2.62	3.27	3.87	4.63	5.29	6.02
18 hours	2.28	2.75	3.46	4.09	4.90	5.59	6.37
24 hours	2.52	3.02	3.76	4.45	5.32	6.08	6.92
48 hours	2.81	3.38	4.19	4.86	5.78	6.62	7.51
72 hours	3.05	3.70	4.55	5.26	6.15	7.25	8.16
5 days	3.48	4.17	5.11	5.84	6.96	7.98	9.21
10 days	4.29	5.12	6.27	7.10	8.19	9.10	10.18

Table G-2. Documentation of Heavy Storm Amounts in the Imperial Valley, 2001-2002

Storm number	*Storm day*	*Start time (CST)*	*Storm duration (hours)*	*Number of gauges with precipitation*	*Network average precipitation (inches)*	*Storm average precipitation (inches)*	*Network maxima precipitation (inches)*	*Gauge no. with maxima*	*Storm recurrence frequency*
					September 2001				
1181	6	1300	12	19	0.33	0.35	1.32	4	
1182	7	400	7	5	0.01	0.04	0.04	13	
1183	9	100	15	20	0.53	0.53	1.05	2	
1184	18	1300	22	20	0.93	0.93	1.35	4	
1185	20	1700	11	20	0.31	0.31	0.55	24	
1186	21	700	4	6	0.01	0.04	0.04	15	
1187	23	600	10	18	0.26	0.29	0.44	3	
					October 2001				
1188	1	800	3	3	0.01	0.04	0.04	9	
1189	4	900	1	1	0	0.09	0.09	9	
1190	4	1900	22	20	1.21	1.21	1.53	19	
1191	10	400	9	14	0.08	0.11	0.55	23	
1192	10	1900	1	3	0.01	0.04	0.04	13	
1193	11	200	10	9	0.02	0.04	0.05	3	
1194	11	1700	22	20	1.08	1.08	1.56	12	
1195	13	900	14	20	0.63	0.63	1.13	8	
1196	14	800	4	3	0.01	0.04	0.05	3	
1197	14	1600	1	3	0.01	0.08	0.13	16	
1198	15	900	17	20	0.87	0.87	1.15	16	
1199	16	700	5	5	0.01	0.05	0.08	18	
1200	17	800	2	2	0.01	0.09	0.13	2	
1201	21	2100	15	20	0.58	0.58	0.91	12	
1202	23	300	10	20	0.18	0.18	0.38	2	
1203	24	1200	5	20	0.24	0.24	0.39	12	
1204	24	2000	2	6	0.01	0.05	0.08	7	
					November 2001				
1205	1	2100	14	20	0.65	0.65	1.41	8	
1206	8	600	8	14	0.03	0.04	0.08	7	
1207	15	400	9	15	0.03	0.04	0.05	3	
1208	16	200	10	15	0.03	0.04	0.05	13	
1209	17	900	3	4	0.01	0.04	0.05	3	
1210	18	900	27	19	0.1	0.11	0.16	6	
1211	20	900	2	2	0.01	0.06	0.08	2	
1212	24	100	12	20	1.25	1.25	1.99	16	
1213	24	1800	12	15	0.04	0.06	0.17	16	
1214	26	1500	6	11	0.05	0.08	0.14	13	
1215	28	1900	6	17	0.04	0.05	0.1	13	
1216	29	600	31	20	0.3	0.3	0.46	19	
					December 2001				
1217	5	1900	3	19	0.09	0.1	0.17	24	
1218	12	500	19	20	0.56	0.56	0.89	16	
1219	13	500	4	3	0.01	0.04	0.04	10	
1220	14	400	9	20	0.13	0.13	0.2	3	
1221	15	900	6	7	0.01	0.04	0.04	6	

Table G-2. Documentation of Heavy Storm Amounts in the Imperial Valley, 2001-2002

Storm number	*Storm day*	*Start time (CST)*	*Storm duration (hours)*	*Number of gauges with precipitation*	*Network average precipitation (inches)*	*Storm average precipitation (inches)*	*Network maxima precipitation (inches)*	*Gauge no. with maxima*	*Storm recurrence frequency*
1222	15	2200	40	20	0.47	0.47	0.61	16	
1223	18	900	3	3	0.01	0.04	0.05	3	
1224	22	800	13	20	0.17	0.17	0.34	23	
1225	23	400	1	1	0	0.04	0.04	2	

Table G-2. (continued)

Storm number	*Storm day*	*Start time (CST)*	*Storm duration (hours)*	*Number of gauges with precipitation*	*Network average precipitation (inches)*	*Storm average precipitation (inches)*	*Network maxima precipitation (inches)*	*Gauge no. with maxima*	*Storm recurrence frequency*
					January 2002				
1226	5	2200	1	1	0	0.04	0.04	2	
1227	29	1200	4	8	0.02	0.06	0.12	23	
1228	29	2000	40	20	2.52	2.52	3.23	16	1-yr, 48-hr
1229	31	1500	15	20	0.15	0.15	0.18	2	
					February 2002				
1230	6	1100	4	4	0.01	0.04	0.04	2	
1231	7	900	7	5	0.01	0.04	0.05	3	
1232	8	600	5	10	0.02	0.04	0.04	4	
1233	8	1500	1	1	0	0.04	0.04	21	
1234	9	600	8	13	0.03	0.04	0.08	7	
1235	9	2200	18	20	0.3	0.3	0.46	2	
1236	19	200	36	20	0.84	0.84	1.38	16	
1237	25	1600	22	18	0.07	0.08	0.16	9	
1238	27	1000	6	5	0.01	0.05	0.09	22	
					March 2002				
1239	1	2000	23	20	0.61	0.61	0.8	16	
1240	3	1000	5	4	0.01	0.04	0.05	3	
1241	4	800	4	2	0	0.04	0.04	11	
1242	5	900	2	2	0	0.04	0.04	21	
1243	8	500	4	12	0.06	0.11	0.21	11	
1244	9	200	9	20	0.43	0.43	0.77	16	
1245	19	1900	19	19	0.08	0.08	0.12	10	
1246	25	100	3	6	0.01	0.04	0.04	12	
1247	25	800	5	11	0.03	0.05	0.12	7	
1248	26	700	4	4	0.01	0.04	0.05	13	
1249	29	700	10	20	0.34	0.34	0.54	19	
1250	31	1400	3	3	0.01	0.04	0.05	13	
					April 2002				
1251	1	900	8	2	0.01	0.1	0.16	9	
1252	2	800	7	9	0.03	0.07	0.17	4	
1253	7	500	47	20	1.2	1.2	1.63	16	
1254	9	700	7	7	0.01	0.04	0.04	8	
1255	19	1900	2	1	0.01	0.21	0.21	24	
1256	20	1000	1	1	0	0.04	0.04	24	
1257	20	2100	24	20	0.99	0.99	1.53	19	
1258	24	1400	4	20	0.5	0.5	0.76	13	
1259	27	700	20	20	1.57	1.57	2.54	23	1-yr, 24-hr

Table G-2. (continued)

Storm number	Storm day	Start time (CST)	Storm duration (hours)	Number of gauges with precipitation	Network average precipitation (inches)	Storm average precipitation (inches)	Network maxima precipitation (inches)	Gauge no. with maxima	Storm recurrence frequency
					May 2002				
1260	1	1400	10	18	0.15	0.17	0.54	24	
1261	6	300	10	19	0.31	0.33	0.55	24	
1262	7	300	10	13	0.06	0.09	0.17	8	
1263	8	2100	12	19	0.74	0.78	1.43	2	
1264	11	500	31	19	2.75	2.89	3.77	19	2-yr, 48-hr
1265	12	2100	2	6	0.02	0.06	0.13	24	
1266	13	1900	3	6	0.03	0.09	0.17	6	
1267	14	500	5	3	0.01	0.04	0.04	8	
1268	16	900	10	19	0.49	0.52	0.73	16	
1269	17	1200	9	19	0.35	0.37	0.47	7	
1270	18	600	7	11	0.02	0.04	0.05	3	
1271	23	2100	16	18	0.24	0.27	0.53	8	
1272	29	1500	4	2	0.01	0.08	0.13	23	
					June 2002				
1273	1	100	2	3	0.01	0.06	0.09	3	
1274	1	600	6	8	0.11	0.27	0.66	20	
1275	4	1700	7	12	0.13	0.21	0.43	7	
1276	5	900	4	4	0.01	0.04	0.04	16	
1277	9	1300	1	2	0.02	0.19	0.3	15	
1278	11	700	29	18	1.64	1.83	3.88	18	2-yr, 48-hr
1279	12	2400	14	19	1.77	1.86	2.84	16	2-yr, 18-hr
1280	15	1600	4	3	0.02	0.11	0.25	18	
1281	16	700	2	2	0	0.04	0.04	18	
1282	25	1700	4	6	0.16	0.53	1.12	3	
					July 2002				
1283	11	500	6	19	0.45	0.48	1.43	12	
1284	12	800	4	2	0.01	0.1	0.16	24	
1285	18	1200	5	4	0.05	0.25	0.46	18	
1286	18	2300	3	6	0.12	0.4	0.74	6	
1287	19	500	3	7	0.01	0.04	0.05	3	
1288	22	1800	14	14	0.25	0.36	1.09	20	
1289	26	400	10	20	0.8	0.8	2.85	24	2-yr, 12-hr
1290	26	2100	13	20	1.69	1.69	3.85	16	5-yr, 18-hr
1291	28	500	11	19	0.21	0.23	0.41	3	
1292	29	400	9	19	0.49	0.51	0.83	8	

Table G-2. (concluded)

Storm number	*Storm day*	*Start time (CST)*	*Storm duration (hours)*	*Number of gauges with precipitation*	*Network average precipitation (inches)*	*Storm average precipitation (inches)*	*Network maxima precipitation (inches)*	*Gauge no. with maxima*	*Storm recurrence frequency*
									August 2002
1293	1	700	3	4	0.01	0.04	0.05	13	
1294	2	500	4	9	0.15	0.33	1.21	11	
1295	5	2200	2	3	0.02	0.12	0.13	4	
1296	13	800	14	18	0.59	0.66	1.7	19	
1297	14	100	2	2	0	0.04	0.04	6	
1298	14	600	6	7	0.03	0.08	0.21	23	
1299	16	200	17	19	0.74	0.78	1.69	6	
1300	19	400	12	20	1.12	1.12	2.15	8	
1301	22	2200	17	20	2.73	2.73	3.88	8	5-yr, 18-hr
1302	24	800	4	3	0.01	0.04	0.04	16	

Appendix G-3. Precipitation (inches) Received at Each Station from Each Storm Period during the 2001-2002 Observation Period

Storm	Date	Hour	Duration*	Rain gauge site no. 2	3	4	6	7	8	9	10	11	12	13	15	16	18	19	20	21	22	23	24
1181	9062001	1300	12	0.46	0.54	1.32	0.17	0.39	0.84	0.08	0.12	0.17	0.56	0.15	0.13	0.39	0.25	0.12	0.08	0.00	0.17	0.21	0.46
1182	9072001	400	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.04	0.00	0.04	0.04	0.00	0.04
1183	9092001	100	15	1.05	0.46	0.46	0.42	0.47	0.43	0.52	0.62	0.56	0.52	0.51	0.38	0.67	0.45	0.58	0.37	0.74	0.47	0.51	0.45
1184	9182001	1300	22	1.14	0.59	1.35	0.72	0.85	1.35	0.87	0.65	0.81	0.78	0.87	0.86	1.18	0.96	1.11	1.20	0.82	0.60	0.68	1.12
1185	9202001	1700	11	0.21	0.22	0.17	0.26	0.30	0.22	0.26	0.29	0.35	0.30	0.23	0.25	0.42	0.43	0.38	0.21	0.25	0.30	0.52	0.55
1186	9212001	700	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.04	0.04	0.04	0.00	0.00	0.00	0.04
1187	9232001	600	10	0.33	0.44	0.34	0.35	0.39	0.40	0.44	0.37	0.30	0.34	0.36	0.39	0.12	0.29	0.12	0.04	0.04	0.00	0.00	0.08
1188	10012001	800	3	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
1189	10042001	900	1	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1190	10042001	1900	22	1.33	1.09	1.36	0.92	1.03	1.40	1.17	1.05	1.03	1.11	1.33	1.06	1.37	1.24	1.53	1.25	1.19	1.07	1.11	1.46
1191	10102001	400	9	0.00	0.04	0.00	0.08	0.04	0.00	0.06	0.04	0.17	0.00	0.00	0.04	0.08	0.04	0.08	0.13	0.00	0.08	0.55	0.17
1192	10102001	1900	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.04
1193	10112001	200	10	0.00	0.05	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.04	0.04	0.04	0.04	0.04
1194	10112001	1700	22	1.46	0.81	1.53	1.08	0.94	0.84	1.43	1.28	1.48	1.56	0.82	0.86	1.32	0.80	0.98	0.91	0.72	0.90	0.90	0.89
1195	10132001	900	14	0.59	0.64	1.10	0.45	0.46	1.13	0.68	0.49	0.33	0.51	1.08	0.33	0.64	0.92	0.89	0.46	0.37	0.50	0.42	0.71
1196	10142001	800	4	0.00	0.05	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1197	10142001	1600	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.13	0.08	0.00	0.00	0.00	0.00	0.00	0.00
1198	10152001	900	17	0.67	0.64	0.73	0.94	0.82	0.92	0.93	0.95	0.88	0.96	1.09	0.89	1.15	0.98	0.98	0.91	0.77	0.72	0.64	0.79
1199	10162001	700	5	0.00	0.05	0.00	0.00	0.04	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.04	0.00	0.00	0.00
1200	10172001	800	2	0.13	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1201	10212001	2100	15	0.80	0.60	0.81	0.64	0.51	0.79	0.52	0.54	0.65	0.91	0.70	0.52	0.85	0.46	0.55	0.43	0.43	0.35	0.47	0.04
1202	10232001	300	10	0.38	0.36	0.17	0.13	0.22	0.04	0.08	0.12	0.13	0.08	0.14	0.17	0.25	0.21	0.21	0.17	0.17	0.17	0.18	0.13
1203	10242001	1200	5	0.08	0.27	0.17	0.25	0.35	0.22	0.24	0.28	0.26	0.39	0.19	0.30	0.26	0.13	0.26	0.22	0.34	0.30	0.21	0.12
1204	10242001	2000	2	0.00	0.05	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.05	0.04	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.04
1205	11012001	2100	14	0.88	1.12	0.98	0.65	0.60	1.41	0.76	0.54	0.52	0.57	0.58	0.34	0.63	0.41	0.46	0.52	0.47	0.57	0.43	0.50
1206	11082001	600	8	0.04	0.04	0.00	0.04	0.08	0.04	0.05	0.04	0.04	0.00	0.04	0.00	0.00	0.04	0.04	0.00	0.04	0.04	0.04	0.00
1207	11152001	400	9	0.04	0.05	0.04	0.04	0.04	0.00	0.04	0.04	0.04	0.04	0.00	0.00	0.00	0.00	0.04	0.04	0.04	0.04	0.04	0.04
1208	11162001	200	10	0.04	0.00	0.04	0.04	0.04	0.04	0.00	0.00	0.04	0.04	0.05	0.04	0.00	0.04	0.04	0.04	0.04	0.00	0.04	0.04
1209	11172001	900	3	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.04	0.00	0.00
1210	11182001	900	27	0.08	0.09	0.08	0.16	0.16	0.08	0.09	0.08	0.12	0.08	0.10	0.12	0.00	0.12	0.12	0.12	0.08	0.12	0.12	0.12
1211	11202001	900	2	0.08	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes:

*Duration specified in hours. Values in boldface type exceed one-year storm recurrence frequency.

Appendix G-3. (continued)

Storm	Date	Hour	Duration*	*Rain gauge site no.* 2	3	4	6	7	8	9	10	11	12	13	15	16	18	19	20	21	22	23	24
1212	11242001	100	12	1.13	1.00	1.15	1.31	1.34	0.87	1.24	1.21	1.34	1.38	1.08	1.27	1.99	0.79	1.44	1.25	1.07	1.43	1.72	0.92
1213	11242001	1800	12	0.04	0.14	0.04	0.04	0.04	0.04	0.04	0.04	0.00	0.04	0.05	0.00	0.17	0.04	0.08	0.04	0.04	0.00	0.00	0.00
1214	11262001	1500	6	0.09	0.00	0.08	0.00	0.00	0.13	0.04	0.00	0.00	0.04	0.14	0.00	0.04	0.13	0.04	0.00	0.00	0.00	0.04	0.13
1215	11282001	1900	6	0.08	0.04	0.04	0.08	0.04	0.04	0.04	0.04	0.00	0.00	0.10	0.00	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
1216	11292001	600	31	0.29	0.20	0.29	0.25	0.38	0.21	0.34	0.32	0.33	0.37	0.24	0.24	0.42	0.24	0.46	0.26	0.24	0.26	0.38	0.37
1217	12052001	1900	3	0.16	0.00	0.08	0.13	0.04	0.13	0.09	0.04	0.04	0.04	0.14	0.04	0.04	0.12	0.09	0.13	0.13	0.17	0.04	0.17
1218	12122001	500	19	0.43	0.42	0.41	0.54	0.46	0.47	0.51	0.45	0.54	0.63	0.46	0.59	0.89	0.41	0.62	0.64	0.68	0.72	0.76	0.50
1219	12132001	500	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1220	12142001	400	9	0.12	0.20	0.08	0.08	0.20	0.08	0.12	0.08	0.13	0.16	0.10	0.16	0.08	0.12	0.12	0.12	0.20	0.17	0.17	0.17
1221	12152001	900	6	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.04	0.04	0.04	0.00	0.04	0.04	0.00
1222	12152001	2200	40	0.41	0.38	0.44	0.49	0.45	0.45	0.45	0.57	0.54	0.49	0.43	0.53	0.61	0.32	0.52	0.45	0.49	0.44	0.53	0.40
1223	12182001	900	3	0.00	0.05	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00
1224	12222001	800	13	0.16	0.23	0.20	0.13	0.13	0.22	0.21	0.16	0.17	0.13	0.19	0.13	0.29	0.13	0.17	0.12	0.04	0.08	0.34	0.25
1225	12232001	400	1	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1226	1052002	2200	1	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1227	1292002	1200	4	0.00	0.00	0.00	0.04	0.00	0.04	0.00	0.00	0.04	0.00	0.00	0.00	0.04	0.00	0.09	0.00	0.00	0.04	0.12	0.04
1228	1292002	2000	40	**2.88**	2.50	**2.87**	2.25	2.21	2.46	2.45	2.40	2.21	2.38	2.64	2.32	**3.23**	2.43	**3.11**	2.42	2.25	2.28	2.50	2.59
1229	1312002	1500	15	0.18	0.15	0.16	0.12	0.16	0.13	0.17	0.16	0.17	0.16	0.14	0.16	0.16	0.12	0.17	0.13	0.13	0.12	0.12	0.16
1230	2062002	1100	4	0.04	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00
1231	2072002	900	7	0.00	0.05	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.04	0.00	0.00
1232	2082002	600	5	0.00	0.00	0.04	0.00	0.00	0.04	0.04	0.04	0.04	0.04	0.00	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.04	0.04
1233	2082002	1500	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00
1234	2092002	600	8	0.04	0.05	0.00	0.04	0.08	0.00	0.04	0.00	0.00	0.04	0.05	0.00	0.04	0.00	0.04	0.04	0.00	0.04	0.04	0.04
1235	2092002	2200	18	0.46	0.29	0.37	0.32	0.20	0.29	0.33	0.37	0.33	0.16	0.32	0.41	0.37	0.29	0.33	0.37	0.33	0.20	0.12	0.24
1236	2192002	200	36	0.71	1.02	0.64	0.87	0.88	0.55	0.71	0.77	0.92	0.91	0.66	0.89	1.38	0.61	0.75	0.93	0.58	0.98	1.17	0.79
1237	2252002	1600	22	0.04	0.05	0.04	0.12	0.08	0.08	0.16	0.08	0.12	0.12	0.04	0.00	0.12	0.12	0.04	0.04	0.12	0.00	0.08	0.04
1238	2272002	1000	6	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.04	0.09	0.00	0.00
1239	3012002	2000	23	0.62	0.64	0.53	0.62	0.63	0.66	0.68	0.57	0.58	0.61	0.62	0.53	0.80	0.74	0.70	0.56	0.49	0.45	0.63	0.62
1240	3032002	1000	5	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.04	0.04	0.00
1241	3042002	800	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1242	3052002	900	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.00
1243	3082002	500	4	0.08	0.00	0.09	0.17	0.00	0.00	0.09	0.12	0.21	0.13	0.05	0.09	0.00	0.12	0.04	0.00	0.00	0.00	0.09	0.00

Notes:
*Duration specified in hours. Values in boldface type exceed one-year storm recurrence frequency.

Appendix G-3. (continued)

Storm	Date	Hour	Duration*	2	3	4	6	7	8	9	10	11	12	13	15	16	18	19	20	21	22	23	24
				Rain gauge site no.																			
1244	3092002	200	9	0.33	0.55	0.33	0.46	0.46	0.26	0.37	0.45	0.52	0.51	0.33	0.43	0.77	0.33	0.29	0.33	0.30	0.51	0.70	0.33
1245	3192002	1900	19	0.04	0.00	0.08	0.08	0.08	0.08	0.10	0.12	0.04	0.08	0.10	0.04	0.08	0.08	0.12	0.08	0.12	0.08	0.08	0.08
1246	3252002	100	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.04	0.00	0.04	0.04	0.00	0.00	0.04	0.04
1247	3252002	800	5	0.04	0.00	0.08	0.00	0.12	0.00	0.04	0.00	0.04	0.04	0.05	0.00	0.00	0.00	0.04	0.04	0.04	0.04	0.00	0.00
1248	3262002	700	4	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04
1249	3292002	700	10	0.21	0.37	0.34	0.42	0.51	0.30	0.39	0.50	0.43	0.29	0.41	0.29	0.30	0.30	0.54	0.29	0.30	0.21	0.17	0.29
1250	3312002	1400	3	0.04	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1251	4012002	900	8	0.00	0.05	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1252	4022002	800	7	0.16	0.09	0.17	0.04	0.00	0.04	0.03	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.00
1253	4072002	500	47	1.29	1.18	1.26	1.30	1.23	1.03	1.22	1.23	1.14	1.08	1.35	1.10	1.63	1.12	1.37	1.13	0.90	1.02	1.24	1.20
1254	4092002	700	7	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.04	0.00	0.00	0.04	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.04	0.04
1255	4192002	1900	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21
1256	4202002	1000	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
1257	4202002	2100	24	0.76	0.80	0.59	0.71	0.75	0.61	0.70	0.79	0.76	0.86	1.00	0.94	1.47	0.99	1.53	1.21	1.24	1.34	1.49	1.29
1258	4242002	1400	4	0.42	0.45	0.42	0.31	0.30	0.44	0.59	0.50	0.40	0.54	0.76	0.57	0.72	0.38	0.55	0.57	0.70	0.52	0.43	0.37
1259	4272002	700	20	1.73	1.22	1.64	1.55	1.48	1.37	1.49	1.42	1.38	1.42	1.17	1.41	2.11	1.48	1.86	1.63	1.16	1.54	**2.54**	1.72
1260	5012002	1400	10	0.30	0.09	0.16	0.17	0.12	0.12	0.00	0.16	0.17	0.00	0.19	0.08	0.20	0.12	0.21	0.12	0.04	0.17	0.08	0.54
1261	5062002	300	10	0.29	0.27	0.30	0.30	0.31	0.35	0.00	0.25	0.21	0.25	0.37	0.29	0.33	0.45	0.43	0.39	0.30	0.30	0.30	0.55
1262	5072002	300	10	0.00	0.05	0.00	0.00	0.00	0.17	0.00	0.00	0.08	0.00	0.09	0.08	0.04	0.04	0.04	0.17	0.08	0.12	0.08	0.13
1263	5082002	2100	12	1.43	0.87	1.36	0.74	0.65	1.22	0.00	0.92	0.52	0.47	1.30	0.55	0.41	0.84	0.89	0.55	0.43	0.42	0.34	0.92
1264	5112002	500	31	**3.15**	**2.85**	**3.29**	2.61	2.38	**2.99**	0.00	2.49	2.37	2.25	**2.79**	**2.78**	**3.68**	**3.35**	**3.77**	**3.26**	2.55	2.41	2.28	**3.66**
1265	5122002	2100	2	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.04	0.04	0.00	0.04	0.00	0.13
1266	5132002	1900	3	0.00	0.09	0.00	0.17	0.09	0.00	0.00	0.00	0.04	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00
1267	5142002	500	5	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.04	0.00	0.00	0.00
1268	5162002	900	10	0.42	0.41	0.48	0.52	0.42	0.49	0.00	0.54	0.46	0.61	0.50	0.55	0.73	0.54	0.59	0.51	0.47	0.56	0.55	0.45
1269	5172002	1200	9	0.33	0.31	0.39	0.34	0.47	0.39	0.00	0.33	0.35	0.34	0.41	0.39	0.39	0.37	0.43	0.38	0.34	0.34	0.30	0.46
1270	5182002	600	7	0.04	0.05	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.04	0.04	0.04	0.04	0.00	0.04	0.04	0.04	0.04
1271	5232002	2100	16	0.42	0.46	0.43	0.25	0.21	0.53	0.00	0.29	0.26	0.43	0.18	0.21	0.00	0.08	0.13	0.21	0.26	0.21	0.21	0.04
1272	5292002	1500	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.13	0.00
1273	6012002	100	2	0.04	0.09	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1274	6012002	600	6	0.00	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.54	0.21	0.66	0.13	0.00	0.00	0.04
1275	6042002	1700	7	0.29	0.18	0.21	0.26	0.43	0.27	0.00	0.29	0.13	0.39	0.05	0.00	0.00	0.00	0.04	0.00	0.00	0.04	0.00	0.00

Notes:
*Duration specified in hours. Values in boldface type exceed one-year storm recurrence frequency.

Appendix G-3. (concluded)

Storm	*Date*	*Hour*	*Duration**	*Rain gauge site no.* 2	*3*	*4*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*15*	*16*	*18*	*19*	*20*	*21*	*22*	*23*	*24*
1276	6052002	900	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.00	0.00	0.04	0.04	0.00
1277	6092002	1300	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1278	6112002	700	29	0.82	1.30	1.10	1.42	1.50	**2.79**	0.00	1.49	1.39	1.33	**2.72**	1.54	1.51	**3.88**	**2.81**	0.00	1.80	1.65	1.50	2.33
1279	6122002	2400	14	**2.70**	2.07	**2.81**	2.04	2.22	**2.68**	0.00	0.96	2.04	1.70	2.09	**2.44**	**2.84**	1.17	1.39	1.56	1.30	1.48	1.20	0.71
1280	6152002	1600	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.04	0.00	0.00	0.00	0.00	0.04
1281	6162002	700	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.04
1282	6252002	1700	4	0.00	1.12	0.00	0.00	0.74	0.00	0.00	0.00	0.13	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.79	0.00	0.00
1283	7112002	500	6	0.29	0.50	0.34	1.34	0.51	0.17	0.29	0.37	0.65	1.43	0.49	0.22	0.00	0.04	0.60	0.66	0.30	0.12	0.29	0.42
1284	7122002	800	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.16
1285	7182002	1200	5	0.00	0.00	0.00	0.00	0.04	0.36	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.46	0.00	0.00	0.00	0.00	0.00	0.00
1286	7182002	2300	3	0.16	0.13	0.00	0.74	0.26	0.00	0.00	0.00	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.69	0.00
1287	7192002	500	3	0.00	0.05	0.00	0.04	0.00	0.04	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.04	0.00	0.00	0.00
1288	7222002	1800	14	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.04	0.16	0.23	0.42	0.65	0.16	0.21	1.09	0.39	0.65	0.34	0.59
1289	7262002	400	10	0.50	0.55	0.08	0.52	0.74	0.58	0.80	0.37	0.29	0.47	0.72	0.88	0.95	1.35	1.02	0.87	0.83	0.70	0.90	**2.85**
1290	7262002	2100	13	0.59	0.36	1.49	1.39	0.60	1.24	1.49	**2.33**	1.91	1.09	2.07	**3.30**	**3.85**	1.14	1.70	1.45	1.92	**2.37**	**3.09**	0.42
1291	7282002	500	11	0.29	0.41	0.00	0.17	0.22	0.08	0.29	0.21	0.22	0.21	0.23	0.25	0.17	0.12	0.38	0.08	0.04	0.34	0.21	0.38
1292	7292002	400	9	0.50	0.67	0.68	0.57	0.65	0.83	0.67	0.71	0.75	0.43	0.72	0.38	0.34	0.81	0.25	0.21	0.13	0.04	0.00	0.42
1293	8012002	700	3	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.04	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1294	8022002	500	4	0.00	0.09	0.17	0.22	0.26	0.00	0.00	0.12	1.21	0.35	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.21	0.00
1295	8052002	2200	2	0.00	0.00	0.13	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1296	8132002	800	14	0.54	0.50	0.17	0.40	0.62	0.00	0.17	0.83	0.25	1.05	0.49	0.76	0.94	0.08	1.70	0.88	0.96	0.87	0.65	0.00
1297	8142002	100	2	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1298	8142002	600	6	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.04	0.00	0.00	0.04	0.08	0.12	0.21	0.00
1299	8162002	200	17	0.21	0.14	1.57	1.69	1.03	0.44	0.68	1.20	1.21	1.52	0.58	1.18	0.98	0.34	0.30	0.42	0.29	0.47	0.55	0.00
1300	8192002	400	12	1.01	0.67	1.70	0.83	0.60	2.15	1.56	1.34	0.79	0.70	1.69	0.80	0.76	1.55	1.36	1.09	0.91	1.00	0.73	1.16
1301	8222002	2200	17	**3.12**	2.47	**2.60**	**3.21**	**2.78**	**3.88**	**2.74**	**3.37**	**2.82**	2.26	2.35	**2.89**	**2.92**	**2.90**	**3.28**	**3.02**	1.99	1.50	2.31	2.27
1302	8242002	800	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.04	0.00	0.04	0.00

Notes:
*Duration specified in hours. Values in boldface type exceed one-year storm recurrence frequency.

Illinois State WATER Survey (1895)

ILLINOIS DEPARTMENT OF NATURAL RESOURCES

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