2003 INFILTRATION MONITORING PROGRAM

FINAL REPORT

February 2, 2004

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I. Background and Overview

Infiltration of stormwater has been shown to be a dominant component of the natural hydrologic system of the South Washington Watershed District (SWWD). The SWWD has been monitoring infiltration in the watershed as part of the Infiltration Management Study (IMS), which was initiated in 1997. A detailed description of past monitoring activities including infiltration monitoring, surface water quality monitoring, and groundwater quality monitoring can be found in the following reports:

- SWWD IMS Progress Report, 1998;
- SWWD IMS Phase II Report, 2001; and
- SWWD 2002 Infiltration Monitoring Report, 2003.

Monitoring of infiltration in the summer months provides a database to develop volume control standards based on predevelopment conditions. Monitoring of infiltration in the spring during snow melt conditions provides the SWWD with detailed information on which to base emergency response plans and flood forecasting. The data collected at infiltration trenches provides additional information for planning and designing future infiltration practices which enhance infiltration performance and can mitigate frozen ground conditions.

For the purposes of this report, spring melt and snowmelt infiltration data refer to data collected at the time of final snowmelt in the watershed. Spring melt often occurs during both frozen and non frozen ground conditions. Summer infiltration data refer to that data collected after the water ponded as a result of spring snowmelt recedes. Summer infiltration data collection ends in the late fall, usually prior to freezing temperatures.

This report summarizes the results of the following monitoring events - spring infiltration events at:

- CD-P50 (CL-P2.1),
- CD-P76 (BL-P5.2),
- CD-P82 (BL-P7.2),

- CD-P85 Trench, and
- Math and Science Academy (MSA) Trench;

and summer infiltration events at:

- CD-P50 (CL-P2.1),
- CD-P76 ((BL-P5.2),
- CD-P82 (BL-P7.2),
- CD-P85,
- CD-P85 Trench, and
- MSA Trench.

Figure I-1 illustrates the locations of monitored sites in the SWWD.

In addition, subwatersheds draining to CD-P50, CD-P76, and CD-P82 were analyzed to determine the amount of abstraction in the subwatershed during precipitation events. This abstraction is a result of infiltration, evaporation, transpiration, and interception taking place in the subwatershed. A resultant calibrated curve number is calculated which can be used to refine watershed hydrologic and hydraulic models with known hydrologic parameters.

This report presents data collected in the field including surface water and groundwater quality, groundwater levels, and an analysis of infiltration rates in basins. Analysis of subwatershed characteristics and runoff yield and a summary of the climatic conditions occurring in 2003 are also included. Comparison of measured infiltration rates from 1997 to 2003 and recommendations are found in Chapter VI. Conclusions and Recommendations.

The following table summarizes the available infiltration data in the SWWD.

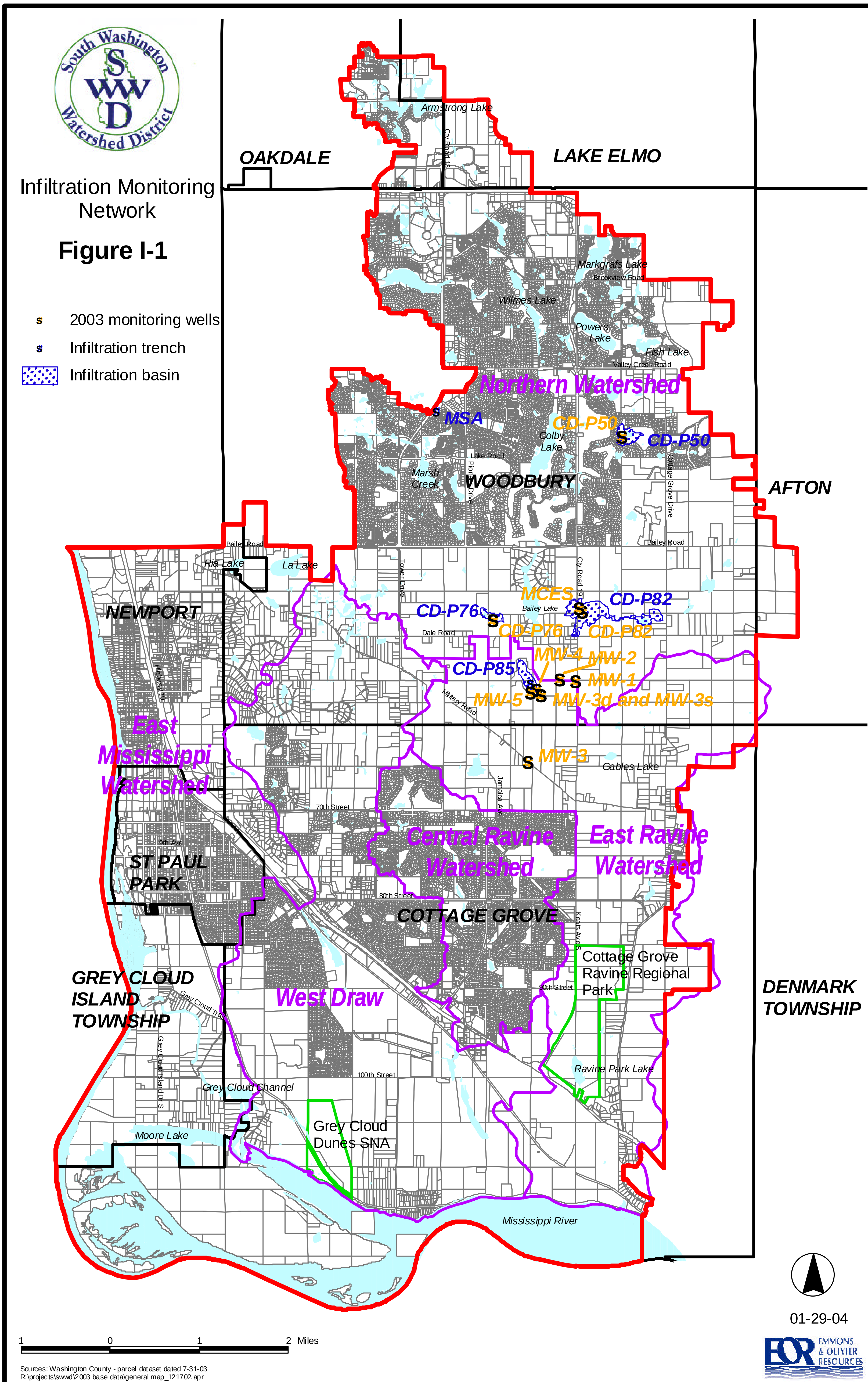

South Washington Watershed District
Infiltration Monitoring Network
Figure I-1
2003 monitoring wells
Infiltration trench
Infiltration basin
OAKDALE
LAKE ELMO
AFTON
WOODBURY
NEWPORT
ST PAUL PARK
COTTAGE GROVE
GREY CLOUD ISLAND TOWNSHIP
DENMARK TOWNSHIP
Northern Watershed
East Mississippi Watershed
Central Ravine Watershed
East Ravine Watershed
West Draw
Armstrong Lake
Markgrafs Lake
Wilmes Lake
Powers Lake
Fish Lake
Colby Lake
Marsh Creek
Bailey Lake
Ria Lake
La Lake
Gables Lake
Moore Lake
Ravine Park Lake
Grey Cloud Channel
Mississippi River
Cottage Grove Ravine Regional Park
Grey Cloud Dunes SNA
MSA
CD-P50
CD-P76
CD-P82
CD-P85
MCES
MW-1
MW-2
MW-3
MW-4
MW-5
MW-3d and MW-3s
Bailey Road
Dale Road
Lake Road
Valley Creek Road
Tower Drive
Jamaica Ave
Keats Ave S
70th Street
80th Street
90th Street
100th Street
Grey Cloud Trail
01-29-04
1 0 1 2 Miles
Sources: Washington County - parcel dataset dated 7-31-03
R:\projects\swwd\2003 base data\general map_121702.apr
Layout: 2003 Infiltration Monitoring Network
EMMONS & OLIVIER RESOURCES

Table I-1. Summary of Available Infiltration Data

Basin	1997 SUM	1998 SUM	1999 SPR	1999 SUM	2000 SPR	2000 SUM	2001 SPR	2001 SUM	2002 SPR	2002 SUM	2003 SPR	2003 SUM
CD-P50			X	X	X		X		X	X	X	X
CD-P69			X	X	X	X	X	X	X	X		
CD-P76			X		X		X		X		X	
CD-P82			X	X	X		X		X	X	X	X
CD-P85	X	X		X		X		X	X	X	X	X
CD-P85 Trench				X				X	X	X	X	X
MSA Trench								X	X	X	X	X

II. Water Quality and Groundwater Monitoring

Water quality sampling and analysis done as part of this study are aimed at addressing the issue of the potential risk stormwater infiltration has on groundwater quality. The benefits of infiltration on surface water quality have been well documented and are not specifically addressed here. It should be noted that infiltration is one of the most effective methods to protect surface water quality. Monitoring of groundwater levels provides data on groundwater flow conditions, surface water groundwater interactions, the role that groundwater mounding has on the infiltration process, and allows for the early detection of potential downstream effects.

II-A METHODOLOGY

Water Quality

An evaluation of both surface water (stormwater) quality and groundwater quality has been completed to determine the potential impact of stormwater infiltration on the groundwater and soils. The monitoring of both surface water and groundwater quality is important in establishing information that may be used to evaluate the short and long-term performance of a particular infiltration practice as well as an evaluation of its potential impacts to groundwater.

Braun Intertec analyzed samples collected on the February 20 and March 19 sampling events. The Metropolitan Council Environmental Service (MCES) lab was used to analyze all other samples. Labs were changed to provide additional consistency with other water quality data being collected in the SWWD. Each method of analysis was checked for consistency between labs prior to changing and all methods used were determined to be comparable. Table II-1 identifies any changes in analytic methods, all other analyses followed identical procedures. Copies of all lab reports can be obtained by contacting the SWWD.

Table II-1. Changes in Laboratory Methods

Analysis	Braun Method	MCES Method
Nitrate + plus nitrite as nitrogen	EPA 353.2	EPA 353.1
Total phosphorus as phosphorus	EPA 365.1	EPA 365.4
Ortho phosphorus as phosphorus	EPA 365.1	EPA 365.2
Volatile suspended solids	EPA 160.4	USGS

Surface Water Quality

Surface water quality has been monitored at the five infiltration basins by the SWWD since 1997. Results of past water quality sampling can be found in the SWWD IMS Progress Report, 1998, SWWD IMS Phase II Report, 2001, and SWWD 2002 Infiltration Monitoring Report, 2003.

Surface water was sampled at all monitored basins during the spring runoff event by taking grab samples. Grab samples were then taken throughout the season at the various monitored basins and trenches when water was present. Table II-2 details the sampling schedule. The sample schedule varies depending on activity at the site and project scope.

Table II-2. 2003 Surface Water Quality Sampling Schedule

	18-Mar	25-Mar	19-May	10-Jul	29-Jul	11-Aug	15-Sept
CD-P50	X	X	-	-	-	-	-
CD-P76	X	-	-	-	-	-	-
CD-P82	X	X	-	-	-	-	-
CD-P85	X	X	X	-	X	X	-
MSA Trench	X	X	-	X	-	-	X

Grab samples were obtained using a two-foot polyethylene disposal bailer, stored on ice and delivered to the lab. No holding times were exceeded.

Surface water samples were analyzed for:

- Dissolved metals (cadmium, lead, nickel, manganese, zinc, copper);
- Volatile suspended solids;
- Total suspended solids;
- Total phosphorus as phosphorus;
- Ortho phosphate as phosphorus;
- Total Kjeldahl nitrogen;
- Nitrate plus nitrite as nitrogen or nitrate and nitrite;
- Ammonia ionized as nitrogen;
- Chloride; and
- Hardness.

Selected surface water samples were also analyzed for organic carbon and chemical oxygen demand.

Groundwater Quality

Groundwater quality has been monitored by the SWWD since 1998. Results of past water quality sampling can be found in the SWWD IMS Progress Report, 1998; SWWD Groundwater

Monitoring and Protection Program Report, July 2000; SWWD IMS Phase II Report, 2001; and SWWD 2002 Infiltration Monitoring Program, 2003.

Groundwater was sampled according to the schedule outlined in Table II-3. The sample schedule varies depending on activity at the site and project scope.

Table II-3. 2003 Groundwater Quality Sampling Schedule.

	20-Feb	19-Mar	09-Apr	27-May	30-Jul	12-Aug	28-Oct
CD-P50	X	X	X	-	-	-	-
CD-P82	X	X	X	-	-	-	-
MW-1	X	X	X	X	X	-	X
MW-2	X	X	X	X	X	X	X
MW-3	X	X	X	X	X	-	X
MW-3s	X	X	X	X	-	-	X
MW-4	X	X	-	X	X	X	-
MW-5	-		-	-	X	X	-

Groundwater samples were analyzed for:

- Dissolved metals (cadmium, lead, nickel, manganese, zinc, copper);
- Nitrate plus nitrite as nitrogen;
- Chloride; and
- Hardness.

Due to a lab error, selected groundwater samples were also analyzed for several surface water parameters.

Groundwater sampled on February 20, March 19, April 9, May 27, and July 30 was collected by SampleTech, a subdivision of Peer Environmental and Engineering Resources, Inc. Wells were purged prior to sampling until measurements of temperature, pH, dissolved oxygen, and specific conductance redox were stable. Groundwater samples collected on August 12 and October 28 were collected by EOR staff. These samples were collected after the wells were purged a minimum of three well volumes. All samples were collected with polyethylene disposal bailers, stored on ice and delivered to the lab. No holding times were exceeded.

Water Quality Standards

The results from the water quality monitoring are compared to the water quality standards listed in Table II-4. This table summarizes the Minnesota Department of Health (MDH) Standards for drinking water, EPA Federal drinking water standards, and Minnesota Pollution Control Agency (MPCA) 7050 Class 2B water quality standards. The MDH identifies Health Risk Limits (HRLs) as the exposure value that can be safely consumed daily for a lifetime. The EPA has several different levels of standards. The "Action Level" is for lead and copper only, and determines treatment requirements for water systems. A Maximum Contaminant Level (MCL) is the highest level of a contaminant that is allowed in drinking water and is enforceable. Secondary standards are not enforceable at any level, but provide a baseline for aesthetic quality of drinking water. The MPCA 7050 Rules identify allowable analyte concentrations that will maintain a healthy community of cool or warm water sport or commercial fish and associated aquatic life and their habitats. All of the waters included in this program are categorized as within Class 2B or 2D waters by the MPCA. Class 2D waters have the same water quality standards as Class 2B. Class 2B and class 2D waters are not protected as a source of drinking water.

Samples that exceed at least one of the drinking water quality standards are highlighted. Samples that exceed the standards for Class 2B Waters are not highlighted but are mentioned in the results write up.

Table II-4. Water Quality Standards

Analyte [mg/L]	Drinking Water Standards				MPCA Class 2B Waters Chronic Standards		
	MDH Health Risk Limit	**EPA Action Level**	**EPA Maximum Contaminant Level**	**EPA Secondary Standard***	**Hardness = 200**	**Hardness = 100**	**Hardness = 50**
Lead, dissolved	N/A	**0.015**	N/A	N/A	**0.0077**	**0.0032**	**0.0013**
Cadmium, dissolved	**0.004**	N/A	**0.005**	N/A	**0.002**	**0.0011**	**0.00066**
Manganese, dissolved	**0.1**	N/A	N/A	**0.05**	N/A	N/A	N/A
Nickel, dissolved	**0.1**	N/A	N/A	N/A	**0.283**	**0.158**	**0.088**
Copper, dissolved	N/A	**1.3**	**1.3**	**1**	**0.015**	**0.0098**	**0.0064**
Zinc, dissolved	**2**	N/A	N/A	**5**	**0.191**	**0.106**	**0.059**
Volatile suspended solids	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total suspended solids	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total phosphorus as phosphorus	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ortho phosphorus as phosphorus	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Kjeldahl nitrogen	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrate + nitrite	**10**	N/A	N/A	N/A	N/A	N/A	N/A
Ammonia ionized as nitrogen	N/A	N/A	N/A	N/A	0.04	0.04	0.04
Chloride	N/A	N/A	N/A	**250**	**230**	**230**	**230**
Organic Carbon	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chemical Oxygen Demand	N/A	N/A	N/A	N/A	N/A	N/A	N/A

* EPA Secondary Standards – not enforceable
N/A: No standard exists

Groundwater Level Monitoring

Groundwater mounding, the process by which infiltrating water creates a mound on the water table, can be a limiting factor for infiltration. Depth to groundwater, bedrock, and other impermeable layers all contribute to mounding. If groundwater mounding becomes significant, it can intersect the bottom of the basin and contribute to ponding conditions in the basin, thus controlling the rate of infiltration. According to the literature, a minimum depth to the water table, bedrock, or impeding layers of 3 to 5 feet is recommended.

Groundwater level data were collected at eleven wells throughout the watershed as part of this program. Two are located adjacent to CD-P82; seven are located adjacent to or near CD-P85; and one well is located at each of the remaining basins including CD-P76, and CD-P50. Water table elevations at CD-P85 were also recorded monthly by the Washington Conservation District and are included in this analysis. Water level readings were taken with the use of an electronic water level tape at each well. The locations of these wells are identified on Figure I-1.

II-B. RESULTS

CD-P50 – Eagle Valley Golf Course Basin

The runoff entering CD-P50 originates from predominately single family residential areas, a golf course, and agricultural lands. During the winter of 2002-2003 much of the land within the tributary subwatershed was graded and many new homes were constructed. A notable amount of sediment was delivered to the basin from the stormwater system. In addition, a groundwater pump test was completed by the City of Woodbury during the spring of 2003. Pumped groundwater was discharged to CD-P50 and the city stormwater system.

Water Quality

All analyte concentrations in CD-P50 were below MPCA drinking water quality standards. Table II-5 summarizes the data.

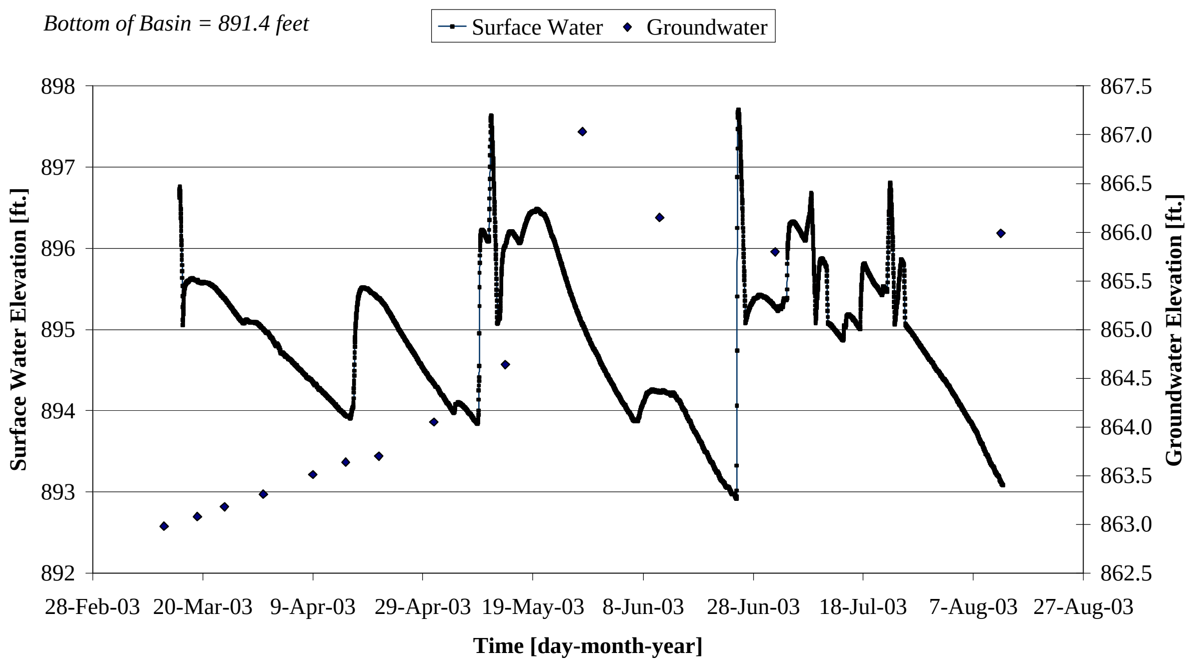
Table II-5. CD-P50 Water Quality Results

Analyte [mg/L]	CD-P50 Surface Water		CD-P50 Groundwater		
	18-Mar	25-Mar	20-Feb	19-Mar	9-Apr
Lead, dissolved	0.0003	0.0001	<0.0003	<0.0003	<.00007
Cadmium, dissolved	<.00004	0.00004	0.00013	0.0016	0.0001
Manganese, dissolved	0.092	--	0.0047	0.0038	--
Nickel, dissolved	0.0029	0.003	0.0011	0.001	0.00152
Copper, dissolved	0.0064	0.0061	0.0035	0.0016	0.0036
Zinc, dissolved	0.0031	0.0121	0.0061	<0.0006	0.0059
Hardness as $CaCO_3$	56	52	39	38	46
Volatile suspended solids	~10	<10	--	--	--
Total suspended solids	67	~23	--	--	--
Total phosphorus as phosphorus	0.657	0.218	--	--	--
Ortho phosphorus as phosphorus	0.29	0.062	--	--	--
Total Kjeldahl nitrogen	2.2	1.2	--	--	--
Nitrate plus nitrite as nitrogen	--	--	0.61	0.92	--
Nitrite	0.08	0.06	--	--	<0.03
Nitrate	0.97	0.43	--	--	0.88
Chloride	22	13	3.9	4	5
Ammonia ionized as nitrogen	--	0.28	--	--	<0.02

Groundwater Levels

Groundwater levels at CD-P50 fluctuated throughout the infiltration events at the basin. Figure II-2 summarizes the 2003 groundwater level data. A response was measured in the water table as a result of recharge following the peak water levels in the basin. Using a static water elevation equal to 860.0, the highest measured water table mound height of 7.0 feet, corresponding to an elevation of 867.0 was recorded on May 28, 2003. This elevation is approximately 25 feet below the bottom of the basin. The water table remained above the normal static groundwater elevation for the duration of the summer.

Figure II-1. Water Fluctuations at CD-P50



CD-P76 – Mile Drive Basin

Water Quality

Table II-6 summarizes the data collected at CD-P76. Stormwater runoff to CD-P76 originates from predominantly agriculture land with some large lot development. No groundwater sample was taken during the spring runoff event due to a lack of measurable water in the well. All analyte concentrations were below drinking water quality standards; however, copper exceeded the MN Class 2B Waters Chronic Standard for a hardness concentration of 50 mg/L.

Table II-6. CD-P76 Water Quality Results

Analyte [mg/L]	**CD-P76 Surface Water** 18-Mar
Lead, dissolved	0.0002
Cadmium, dissolved	0.00007
Manganese, dissolved	0.035
Nickel, dissolved	0.0049
Copper, dissolved	0.0146
Zinc, dissolved	0.0095
Hardness as $CaCO_3$	62
Volatile suspended solids	~12
Total suspended solids	41
Total phosphorus as phosphorus	0.721
Ortho phosphorus as phosphorus	0.88
Total Kjeldahl nitrogen	4.1
Nitrite	0.19
Nitrate	2.44
Chloride	39

Groundwater Levels

There was no measurable water in the well at CD-P76 during the field monitoring season. The well at CD-P76 is set 50 feet below the bottom of the basin, which is higher than the water table.

CD-P82 – County Road 19 Basin

Water Quality

Table II-7 summarizes the water quality data collected at CD-P82. Land use in the watershed of CD-P82 is primarily row crop agricultural and commercial nursery. Surface water total phosphorus concentrations continue to be high, most likely due to agriculture and nursery runoff. Nitrate concentrations in the groundwater are approaching the MPCA HRL. Groundwater at this basin has historically had high nitrate plus nitrite concentrations exceeding MPCA standards in the past. Manganese exceeded the MPCA HRL in both surface water samples. Manganese is naturally occurring in the soils of the watershed and is typically high in surface water chemistry. Copper concentrations in the surface water exceeded the MN Class 2B Waters Chronic Standard for a hardness concentration of 50 mg/L.

Groundwater Levels

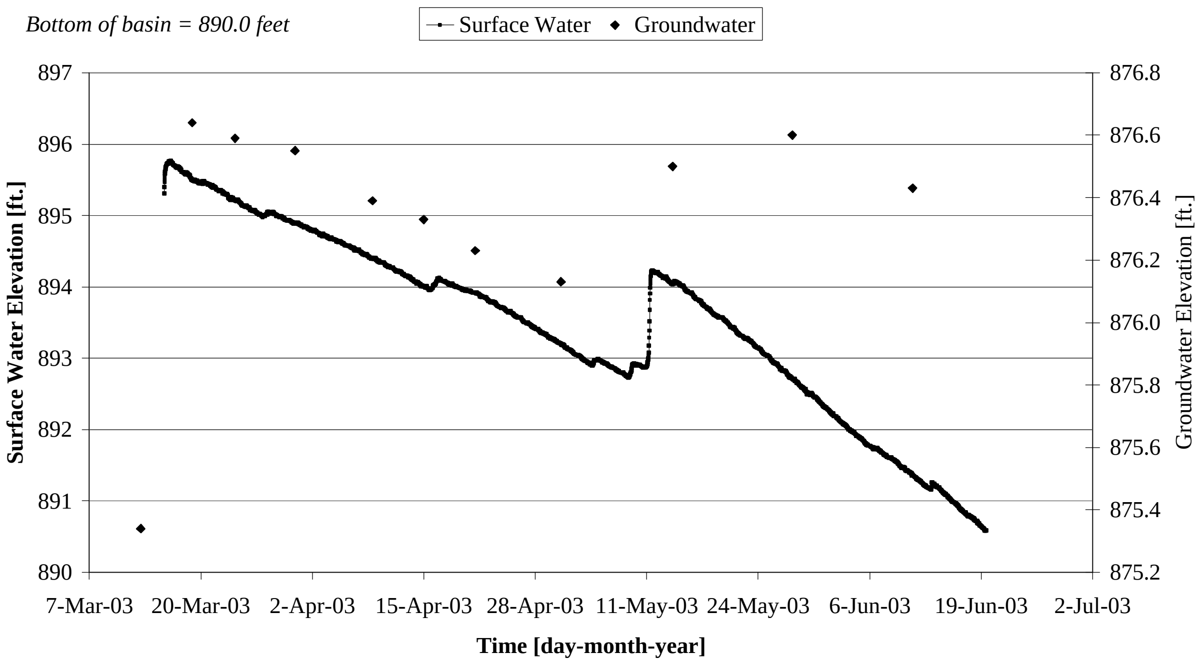
Measured groundwater levels at CD-P82 are summarized in Figure II-4. The rise and fall of the water table tracked with the surface water level fluctuations in the basin. Two groundwater mounds were measured reaching a peak height of 1.3 feet, corresponding to an elevation of 876.6 feet on March 19 and May 28. Measured groundwater levels remained approximately 13 feet below the bottom of the basin throughout the monitoring season.

Table II-7. CD-P82 Water Quality Results

Analyte [mg/L]	CD-P82 Surface Water			CD-P82 Groundwater		
	18-Mar	**18-Mar***	25-Mar	20-Feb	19-Mar	09-Apr
Lead, dissolved	0.0002	0.0002	0.0001	0.0018	<0.00030	0.0003
Cadmium, dissolved	0.0001	0.0002	0.00008	0.0019	0.0018	0.0004
Manganese, dissolved	**0.212****	**0.204****	--	0.016	0.03	--
Nickel, dissolved	0.0051	0.0049	0.0048	0.0014	0.0014	0.0032
Copper, dissolved	0.011	0.0093	0.0087	0.0038	0.003	0.0039
Zinc, dissolved	0.0131	0.0137	0.0109	0.019	0.011	0.0159
Hardness as $CaCO_3$	44	62	76	320	370	372
Volatile suspended solids	~22	~21	~11	--	--	--
Total suspended solids	66	64	~27	--	--	--
Total phosphorus as phosphorus	0.87	0.952	0.842	--	--	--
Ortho phosphorus as phosphorus	0.76	0.75	0.67	--	--	--
Total Kjeldahl nitrogen	5.6	5.7	5.2	--	--	--
Nitrate plus nitrite as nitrogen	--	--	--	9.4	8.1	--
Nitrite	0.13	0.13	0.17	--	--	<0.03
Nitrate	3.82	3.72	2.51	--	--	6.01
Chloride	72	71	73	14	17	16
Ammonia ionized as nitrogen	--	--	1.87	--	--	<0.02

*Duplicate sample
**Manganese MPCA Health Risk Limit = 0.1 mg/L, EPA Secondary Standard = 0.05 mg/L

Figure II-2. Water Fluctuations at CD-P82



CD-P85 – Regional Infiltration Basin

Water Quality

Runoff that reaches CD-P85 originated from two sources including direct subwatershed drainage and pumped overflow from an adjacent subwatershed. The direct watershed is mostly comprised of agricultural land uses. This runoff reaches CD-P85 during the spring melt and after large rainfall events. Stormwater runoff pumped to CD-P85 originates from typical suburban land uses including single and multi family residential, commercial, light industrial and agricultural drainage. The majority of stormwater reaching CD-P85 has passed through numerous water quality ponds, wetlands, and lakes prior to being discharged to the basin.

Table II-8 summarizes the water quality data collected in 2003. Measured manganese concentrations exceeded standards in surface water samples and MW-1, MW-2, and MW-4 groundwater samples. As mentioned previously, manganese is naturally occurring in this region. Nitrate plus nitrite concentrations in the groundwater did not exceed standards but were slightly elevated. Copper surface water concentrations exceeded the MN Class 2B Waters Chronic Standard for hardness concentrations of 50 mg/L and 100 mg/L respectively.

Groundwater Levels

Measured groundwater levels at CD-P85 are summarized in Figure II-5. The rise and fall of the water table tracked the surface water levels in the basin at monitored wells near CD-P85. The groundwater mound produced by infiltrating water at CD-P85 and South Bailey Lake extends to MW-1 and may extend as far as MW-3. The rise in groundwater levels at MW-3 could also be the result of climatic fluctuations alone.

The measured groundwater mound reached a peak height of 31.52 feet on August 4 corresponding to an elevation of 881.04 in MW-4 and 881.64 in MW-5. The static water level was determined to be equal to 850.12 and was derived from pre-pumping water table elevations measured in MW-3s. Measured groundwater levels in MW-4 and MW-5 did not intersect the bottom of this basin, although water table elevations did intersect the infiltration trench at times between May 22 and June 11, and August 4 and September 9. A minimum of 2 feet of unsaturated soils below the basin was maintained throughout the infiltration events, although the rate of water level decline in the infiltration trenches is being limited by the saturated hydraulic conductivity of the underlying sediments during these time intervals.

These data demonstrate that groundwater mounding processes and the greater understanding of the surface water groundwater interaction is critical to efficiently managing infiltration at CD-P85. Groundwater mounding and surface water data collected during 2002 at CD-P85 began to develop a relationship between infiltration rates and very high water table elevations, finding that infiltration rates were typically lower when the water table intersected the basin. 2003 data continue to refine that relationship with no intersection of the water table with the basin and measured infiltration rates higher than those measured in 2002.

Table II-8. CD-P85 Water Quality Results

Analyte [mg/L]	**CD-P85 Surface Water**								
	18-Mar	25-Mar	**25-Mar***	19-May	**19-May***	29-Jul	**29-Jul***	11-Aug	**11-Aug***
Lead, dissolved	0.0001	<.00007	<.00007	<.00007	<.00007	0.0002	0.0002	0.00007	<.00007
Cadmium, dissolved	<.00004	<.00004	<.00004	<.00004	<.00004	<.00004	<.00004	<.00004	<.00004
Manganese, dissolved	**0.103****	--	--	0.019	0.021	0.035	0.035	0.062	0.063
Nickel, dissolved	0.0018	0.0013	0.0013	0.0014	0.0031	0.0009	0.0009	0.0012	0.0012
Copper, dissolved	0.0069	0.0033	0.0056	0.0024	0.0033	0.0014	0.0013	0.0016	0.0021
Zinc, dissolved	0.0055	0.0078	0.0069	0.0027	0.0052	0.0014	0.0012	0.0013	0.0021
Hardness as $CaCO_3$	28	38	30	104	112	92	92	128	119
Volatile suspended solids	~7	~9	~9	7	10	17	15	14	12
Total suspended solids	~10	~10	~9	10	15	18	18	15	~12
Total phosphorus as phosphorus	0.384	0.379	0.428	0.206	0.176	0.205	0.184	0.221	0.196
Ortho phosphorus as phosphorus	0.26	0.176	0.172	0.059	0.062	<0.005	<0.005	<0.005	<0.005
Total Kjeldahl nitrogen	3.5	3.6	3.6	2.1	2	2.5	2.4	2.4	2.3
Nitrite	0.04	0.06	0.06	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Nitrate	1.3	0.91	0.89	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Chloride	7	6	6	44	45	47	47	48	48
Ammonia ionized as nitrogen	--	1.54	1.56	0.35	0.34	<0.02	<0.02	1.93	<0.02
Organic carbon	--	--	--	7.5	7.6	9.8	10.1	10.6	10.4
Chemical oxygen demand	--	--	--	45	44	54	50	51	50

*Duplicate sample

**Manganese MPCA Health Risk Limit = 0.1 mg/L, EPA Secondary Standard = 0.05 mg/L

Analyte [mg/L]	**CD-P85 Groundwater**													
	MW-1							***MW-2***						
	20-Feb	19-Mar	09-Apr	27-May	30-Jul	**30-Jul***	28-Oct	20-Feb	19-Mar	09-Apr	27-May	**27-May***	30-Jul	12-Aug	28-Oct
Lead, dissolved	<0.00030	<0.00030	<.00007	0.00007	<.00007	<.00007	0.0002	<0.00030	<0.00030	<.00007	<.00007	0.00008	<.00007	0.0001	<.00007
Cadmium, dissolved	0.00016	<0.00013	0.0001	0.0002	0.0002	0.0002	0.0001	0.00016	0.00027	0.0001	0.0002	0.0002	0.0001	<.00004	<.00004
Manganese, dissolved	**0.23****	**0.22****	--	**0.251****	**0.124****	**0.126****	**0.296****	0.085	**0.11****	--	0.075	0.075	0.032	0.0011	0.0012
Nickel, dissolved	0.0038	0.003	0.0034	0.0039	0.0037	0.0035	0.0039	0.065	0.059	0.037	0.069	0.075	0.042	0.0032	0.0012
Copper, dissolved	0.0037	0.0032	0.0054	0.0037	0.0067	0.0052	0.005	0.00084	<0.00080	0.0034	0.0012	0.0021	0.001	0.0018	0.0018
Zinc, dissolved	<0.006	<0.006	0.012	0.0026	0.0011	0.0011	0.003	<0.0060	<0.0060	0.0116	0.0042	0.0022	0.0009	0.0013	0.0038
Hardness as $CaCO_3$	130	130	146	190	182	180	188	300	280	288	250	212	278	206	282
Nitrate plus nitrite as nitrogen	--	--	--	--	--	--	--	3	2.5		--	--	--	--	--
Nitrite	--	--	<0.03	<0.03	<0.03	<0.03	<0.03	--	--	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Nitrate]	--	--	<0.05	0.22	<0.05	0.06	0.61	--	--	3.41	3.6	3.48	3.35	2.44	1.96
Chloride	29	31	28	33	44	44	45	53	53	45	39	39	37	45	45
Ammonia ionized as nitrogen	--	--	0.14	--	~0.04	~0.04	0.09	--	--	<0.02	--	--	<0.02	<0.02	<0.02
Organic carbon	--	--	--	--	2.9	3	--	--	--	--	--	--	<1	--	--
Chemical oxygen demand	--	--	--	--	21	18	--	--	--	--	--	--	~13	--	--

*Duplicate sample

**Manganese MPCA Health Risk Limit = 0.1 mg/L, EPA Secondary Standard = 0.05 mg/L

Table II-8. CD-P85 Water Quality Results Continued

Analyte [mg/L]	CD-P85 Groundwater													
	MW-3								*MW-3s*					
	20-Feb	19-Mar	**19-Mar***	09-Apr	**9-Apr***	27-May	30-Jul	28-Oct	20-Feb	**20-Feb***	19-Mar	09-Apr	27-May	28-Oct
Lead, dissolved	<0.00030	<0.00030	<0.00030	<.00007	<.00007	<.00007	<.00007	<.00007	<0.00030	<0.00030	<0.00030	<.00007	0.0015	<.00007
Cadmium, dissolved	<0.00013	0.0012	0.0061	0.00008	0.00008	0.00006	0.00009	0.00004	<0.00013	<0.00013	<0.00013	0.00004	<.00004	0.00008
Manganese, dissolved	0.0087	0.018	0.014	--	--	0.01	0.0062	0.0029	0.03	0.027	0.024	--	0.069	0.032
Nickel, dissolved	0.0025	0.003	0.0027	0.0029	0.0023	0.0032	0.0032	0.0029	0.0014	0.0012	0.001	0.0023	0.0023	0.0022
Copper, dissolved	<0.00080	<0.00080	<0.00080	0.0013	0.0008	0.0024	0.0012	0.0027	0.0019	0.0013	0.0011	0.004	0.0022	0.0032
Zinc, dissolved	<0.006	<0.006	<0.006	0.0123	0.0064	0.004	0.0032	0.0036	<0.0006	<0.0006	<0.006	0.025	0.001	0.003
Hardness as $CaCO_3$	89	94	92	102	102	112	96	108	120	120	120	126	136	198
Nitrate plus nitrite as nitrogen	3.6	3.4	3.5	--	--	--	--	--	<0.10	<0.10	<0.10	--	--	--
Nitrite	--	--	--	<0.03	<0.03	<0.03	<0.03	<0.03	--	--	--	<0.03	<0.03	0.03
Nitrate	--	--	--	3.49	3.43	3.56	3.06	4.72	--	--	--	<0.05	<0.05	2.27
Chloride	76	83	84	88	87	95	82	98	25	25	25	24	24	44
Ammonia ionized as nitrogen	--	--	--	<0.02	<0.02	--	<0.02	<0.02	--	--	--	<0.02	--	<0.02
Organic Carbon	--	--	--	--	--	--	<1	--	--	--	--	--	--	--
Chemical oxygen demand	--	--	--	--	--	--	~12	--	--	--	--	--	--	--

*Duplicate sample

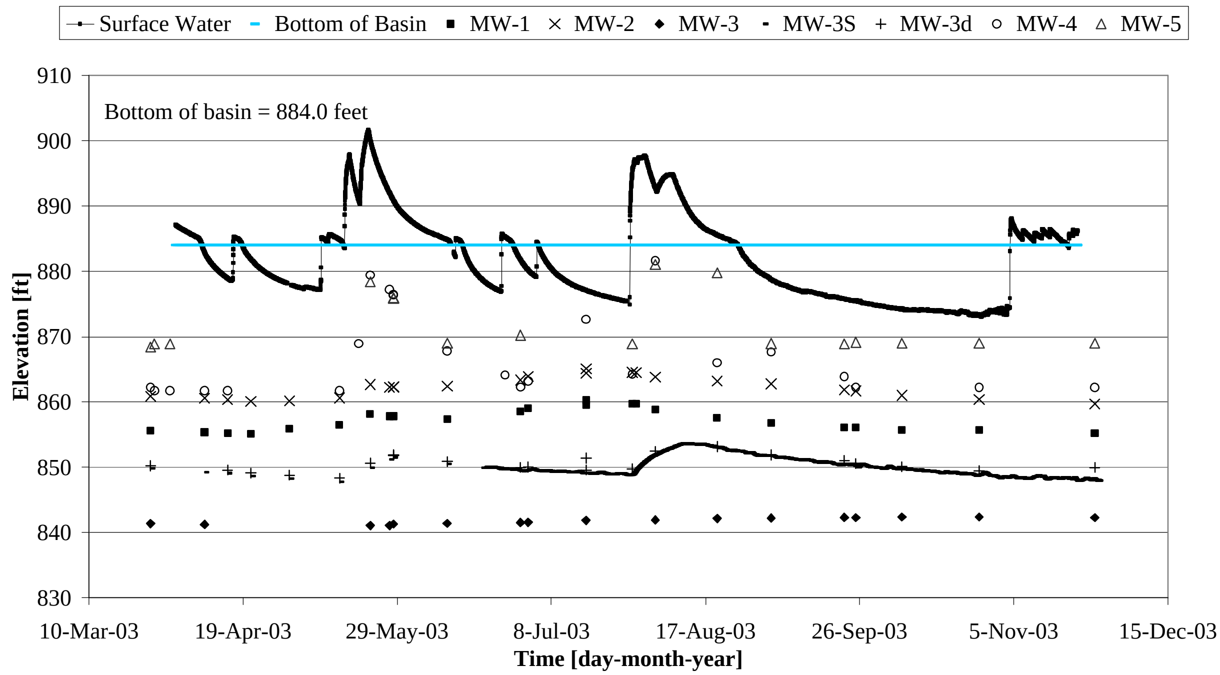
**Manganese MPCA Health Risk Limit = 0.1 mg/L, EPA Secondary Standard = 0.05 mg/L

Analyte [mg/L]	CD-P85 Groundwater							
	MW-4					*MW-5*		***Field Blank***
	20-Feb	19-Mar	27-May	30-Jul	12-Aug	30-Jul	12-Aug	12-Aug
Lead, dissolved	<0.00030	<0.00030	<.00007	<.00007	<.00007	<.00007	0.0001	0.0004
Cadmium, dissolved	0.00018	0.00015	<.00004	<.00004	<.00004	0.00005	<.00004	0.00004
Manganese, dissolved	0.031	**0.22****	0.004	0.001	0.0005	0.0004	0.0004	0.001
Nickel, dissolved	0.00094	0.0015	0.0022	0.0021	0.0016	0.0018	0.0018	0.0003
Copper, dissolved	0.0024	0.003	0.0035	0.0031	0.0043	0.003	0.0042	0.0022
Zinc, dissolved	<0.006	<0.006	0.0016	0.0008	0.0014	0.0008	0.0011	0.0068
Hardness as $CaCO_3$	150	150	188	194	162	202	188	0
Nitrate + nitrite	<0.02	<0.04	--	--	--	--	--	--
Nitrite	--	--	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Nitrate	--	--	0.7	0.52	0.09	0.66	<0.05	<0.05
Chloride	35	--	46	46	46	47	46	<2
Ammonia ionized as nitrogen	--	--	--	<0.02	~0.05	<0.02	<0.02	<0.02
Organic carbon	--	--	--	2.3	--	2.6	--	--
Chemical oxygen demand	--	--	--	~14	--	31	--	--

*Duplicate sample

**Manganese MPCA Health Risk Limit = 0.1 mg/L, EPA Secondary Standard = 0.05 mg/L

Figure II-3. Water Fluctuations at CD-P85



Math and Science Academy Trench Infiltration Trench

The infiltration trench at the Math and Science Academy (MSA) receives runoff from a portion of the school rooftop and surrounding open space. A swale and settling pond provide pretreatment to the majority of runoff generated on this site. All grab samples were obtained from the trench via an observation tube except on March 18 where samples were collected from the surface water of the basin. There is no available groundwater well in the vicinity of this site; therefore no groundwater samples were obtained. Table II-9 summarizes the water quality data collected in 2003.

All of the trench water samples exceeded drinking water standards for manganese. As stated previously, this is a naturally occurring element in the soils of this region. Copper concentrations in the trench water samples exceeded MN Class 2B Waters Chronic Standard for hardness concentrations of 50 mg/L and 100 mg/L.

Table II-9. Math and Science Academy Water Quality Results

Analyte [mg/L]	**Math and Science Academy Surface Water**					
	18-Mar**	25-Mar	10-Jul	**10-Jul***	15-Sep	**15-Sep***
Lead, dissolved	0.0003	0.0002	0.0004	0.0004	0.0001	0.0002
Cadmium, dissolved	0.00009	0.00006	0.00008	0.00006	0.00004	0.00004
Manganese, dissolved	**0.228*****	--	**0.238*****	**0.305*****	**0.785*****	**0.786*****
Nickel, dissolved	0.0089	0.0038	0.0038	0.0036	0.0057	0.0054
Copper, dissolved	0.0143	0.0125	0.0089	0.0053	0.015	0.0148
Zinc, dissolved	0.017	0.0062	0.002	0.0011	0.0031	0.003
Hardness as $CaCO_3$	64	122	102	104	128	124
Volatile suspended solids	~10	<4	~10	<4	~3	~3
Total suspended solids	~14	~5	174	59	6	~6
Total phosphorus as phosphorus	0.751	0.231	0.362	0.252	0.136	0.138
Ortho phosphorus as phosphorus	0.57	0.165	0.142	0.136	0.077	0.08
Total Kjeldahl nitrogen	3.6	1.5	0.75	0.6	0.88	0.83
Nitrate plus nitrite as nitrogen	--	--	--	--	--	--
Nitrite	<0.03	0.06	<0.03	<0.03	<0.03	<0.03
Nitrate	0.21	<0.05	0.24	<0.05	<0.05	<0.05
Chloride	147	119	2	2	4	3
Ammonia ionized as nitrogen	--	0.26	--	--	--	--

* Duplicate sample
**Basin surface water sample
***Manganese MPCA Health Risk Limit = 0.1 mg/L, EPA Secondary Standard = 0.05 mg/L

III. Basin Infiltration

III-A BACKGROUND

Snowmelt and summer infiltration data were collected at four basins and two trench locations in 2003. The basins include CD-P50, CD-P76, CD-P82, and CD-P85, and the monitored trenches were at CD-P85 and the Math and Science Academy (MSA). Figure I-1 illustrates the location of each of these sites. The attached electronic appendix contains a record of water level elevations for each basin.

Appendix A contains a photo log for each of the infiltration events monitored in 2003. Spring infiltration of 2003 was the result of a late season snowfall in March and above average precipitation throughout the spring and into early summer. Additional discussion of the spring melt and summer climatic conditions are found in Section V. Discussion of Infiltration Conditions.

III-B METHODOLOGY

In order to monitor basin infiltration rates and rates of water level decline in the infiltration trenches, water level and flow monitoring equipment was installed at each of the six sites. The following equipment was used for the 2003 monitoring season: American Sigma 910 area/velocity flow meters to monitor flows and Telog dataloggers with Druck and Global Water pressure transducers or Global Water WL-15 Level Loggers to monitor water levels in the basins and trenches.

Staff gages were installed at each of the sites and their elevations were surveyed. Staff gage readings were obtained at each of the sites throughout the monitoring season. Local precipitation data were collected by the SWWD at three sites with the use of automatic rain gages. Precipitation data collected at SWWD monitoring station MS-2, located at the north end of Bailey Lake, are presented with the water levels in the basins and trenches.

Depth measurements were recorded with a pressure transducer located in the lowest portion of the basin or trench. Data were recorded from the pressure transducer with a data logger located in the field. Calibration and field inspection of each of the units were performed routinely. Field measurements were taken and incorporated in the data analysis.

The equipment used to monitor the spring snowmelt event was installed on March 13 and 14 at CD-P50, CD-P76, and CD-P82. A water level recorder was installed on March 17 at MSA. Due to thick layers of ice at CD-P85, monitoring equipment could not be installed until March 27. Water was present at all sites during equipment installation with the exception of CD-P76 and CD-P82. Monitoring of the sites occurred until most of the runoff generated by the event had infiltrated in the basin. CD-P76 and CD-P82 were both monitored during large summer rainfall events. CD-P50, CD-P85, and the MSA continued to be monitored for the rest of the summer.

For infiltration trenches, the rate at which water levels drop in the trench has been monitored as an indicator to determine how the trenches are functioning over time. The rates being measured are not directly comparable to infiltration rates collected for other sites. In the trenches, a three-dimensional process for infiltration exists where loss of water occurs through the bottom and sides of the trench. Additionally, the trench is filled with aggregate and therefore the trench volume is limited by the void spaces.

The trench data are presented as a decline in the water levels in the trench. Since each infiltration trench is constructed with different dimensions and configurations, in different settings, and have potentially different aggregate materials that have different void ratios, the rates collected for a trench are somewhat unique to that trench.

Infiltration rates for both the basins and trenches were determined by calculating the slope (? Depth/? Time) of the water elevation/depth vs. time curve, every four hours, for each drawdown event, averaged over 0.5 foot intervals. If the sign of the infiltration rate indicated that the water elevation had increased during a four-hour time period, that rate was not used in the average for that depth interval. Drawdown events were determined from a visual inspection of the water elevation/depth vs. time curve; a drawdown was considered a separate event if there were no substantial changes in infiltration rate (slope) within the event. For the infiltration basins, volumetric infiltration rates were computed by multiplying the infiltration rates by the average area of the basin for the same elevation interval that was used in averaging the infiltration rates. Volumetric infiltration rates were not calculated for the trenches. This analysis was performed for all basin drawdowns to compare the change in infiltration rates.

Infiltration rate data are presented in tabular and graphical form. The tabular format consists of the 2003 infiltration envelope for each site. The infiltration envelope defines the upper and lower boundary of measured infiltration rates, typically he first and last drawdown event. Infiltration rate data for all drawdowns are available in the attached electronic appendix. Additional information on infiltration envelopes can be found in section VI-A.

III-C. INFILTRATION BASIN AND TRENCH RESULTS

CD-P50 – Eagle Valley Golf Course Basin

Figure III-1 depicts CD-P50, its overflow elevation, and the location of monitoring equipment. The following table contains the elevation versus area in this basin. This basin has been constructed with a pumped outlet which was utilized for the first time in 2003.

Infiltration Rates

A water level recorder and flow meter were installed in CD-P50 on March 14, 2003. Staff gage readings were taken throughout the infiltration events. The flow meter was installed at a large pipe inlet from the east to monitor inflows to the basin. Due to sedimentation within the inlet pipe, the flow meter did not produce reliable data. CD-P50 was monitored for a longer duration than in the past due to the presence of water in the basin until late summer. Monitoring equipment was removed from the basin on August 12, 2003.

Table III-1. CD-P50 Elevation Versus Area

Elevation [ft]	**Area** [acres]
920	24.69
918	22.69
916	20.07
914	17.45
912	15.25
910	12.70
908	11.02
906	9.82
904	8.74
902	7.71
900	6.52
898	5.07
896	2.62
891.4	0.00

Figure III-2 illustrates the water elevation in CD-P50 over time. During the spring infiltration event (Drawdown 1, March 21 through April 15), there was a short period of time during which the infiltration rate leveled off just above the normal water level for the pond. These data points were not used in the infiltration rate calculations for that event. This change in infiltration rate (slope) in the middle of the event was likely due to precipitation.

Table III-2 presents the infiltration rates observed for two of the drawdown events, representing the infiltration envelope for CD-P50. A discussion regarding the infiltration envelopes can be found in section VI-A. Figures III-3 and III-4 compare the infiltration rates from different events to one another, plotted with respect to elevation. Each drawdown event is fit with a linear trend line.

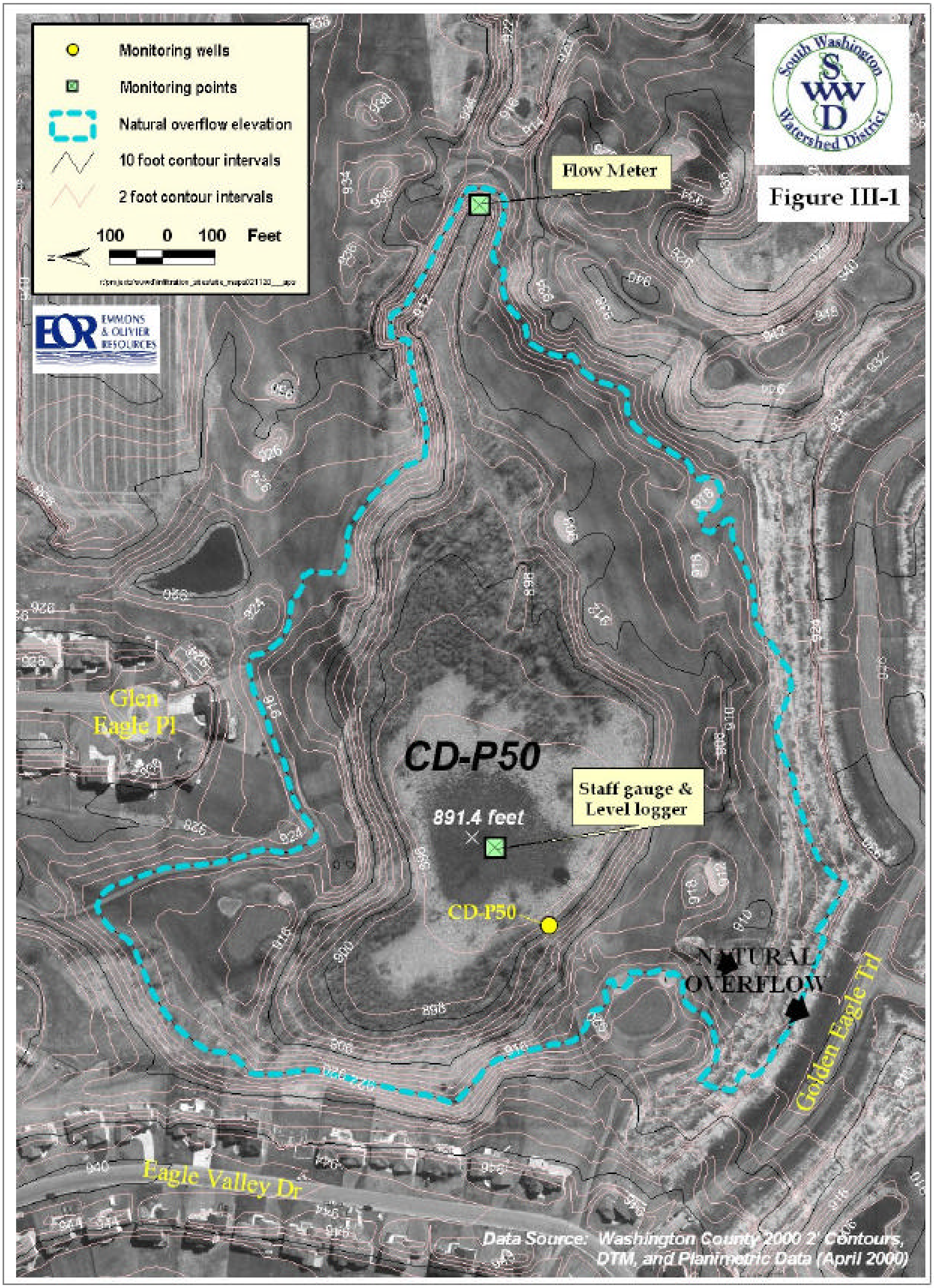

Monitoring wells
Monitoring points
Natural overflow elevation
10 foot contour intervals
2 foot contour intervals
100 0 100 Feet
EMMONS & OLIVIER RESOURCES
South Washington Watershed District
Figure III-1
Flow Meter
Glen Eagle Pl
CD-P50
891.4 feet
Staff gauge & Level logger
CD-P50
NATURAL OVERFLOW
Golden Eagle Trl
Eagle Valley Dr
Data Source: Washington County 2000 2' Contours, DTM, and Planimetric Data (April 2000)

Figure III-2. CD-P50 Water Elevation vs. Time. Numbers refer to drawdown events.

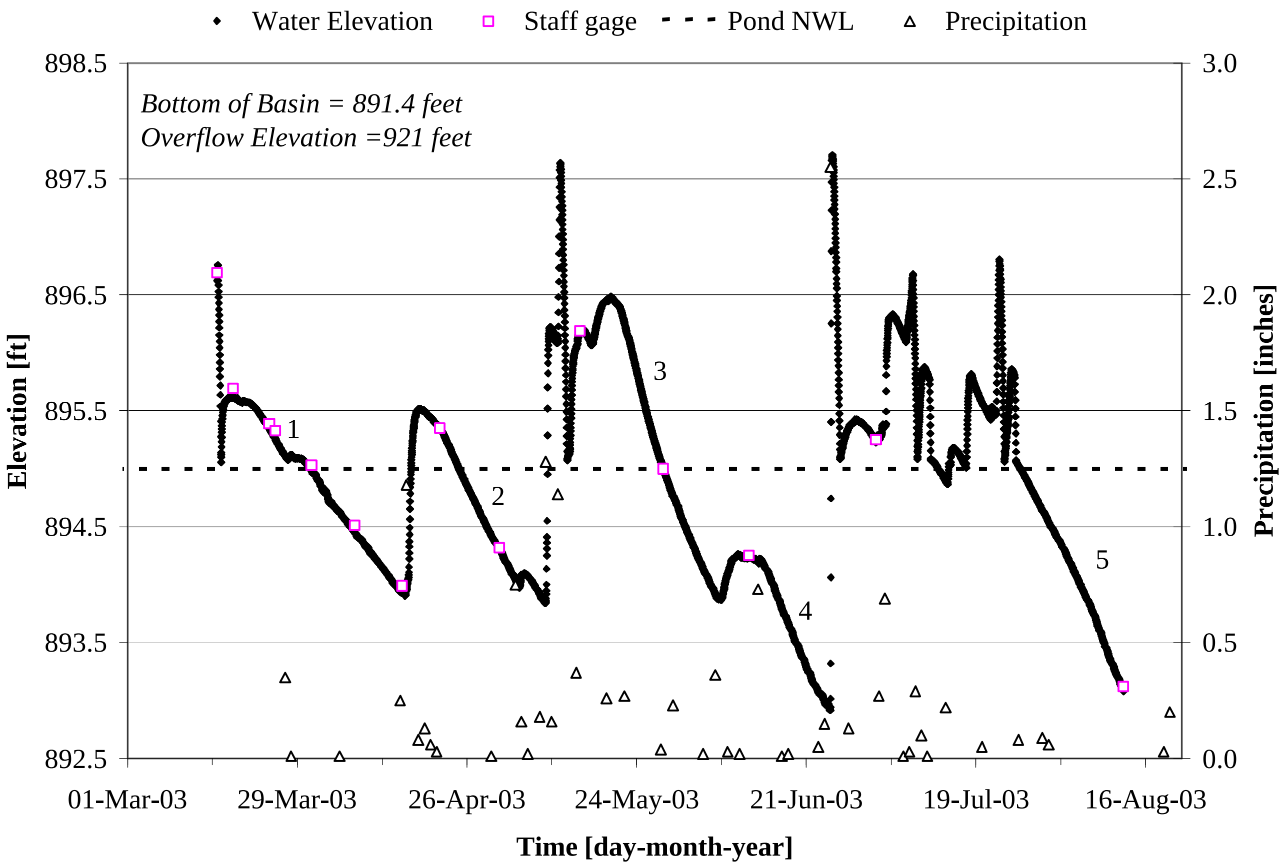


Table III-2. CD-P50 Infiltration Rates, 2003. The two drawdown events presented here represent the 2003 infiltration envelope for CD-P50. See section VI-A: Infiltration Envelopes.

Basin Elevation	Area	Drawdown 1 Infiltration Rate			Drawdown 1 Volumetric Infiltration Rate	Drawdown 3 Infiltration Rate			Drawdown 3 Volumetric Infiltration Rate
[feet]	[acres]	[ft/hr]	[ft/min]	[inch/hr]	[cfs]	[ft/hr]	[ft/min]	[inch/hr]	[cfs]
896.5	3.23	-	-	-	-	0.0083	0.00014	0.100	0.294
896.0	2.62	-	-	-	-	0.0092	0.00015	0.110	0.273
895.5	2.30	0.0035	0.00006	0.042	0.091	0.0073	0.00012	0.088	0.189
895.0	1.98	0.0036	0.00006	0.043	0.080	0.0057	0.00010	0.069	0.127
894.5	1.66	0.0030	0.00005	0.036	0.055	0.0050	0.00008	0.060	0.090
894.0	1.34	-	-	-	-	0.0039	0.00007	0.047	0.056

Figure III-3. CD-P50 Infiltration Rate Curves, 2003

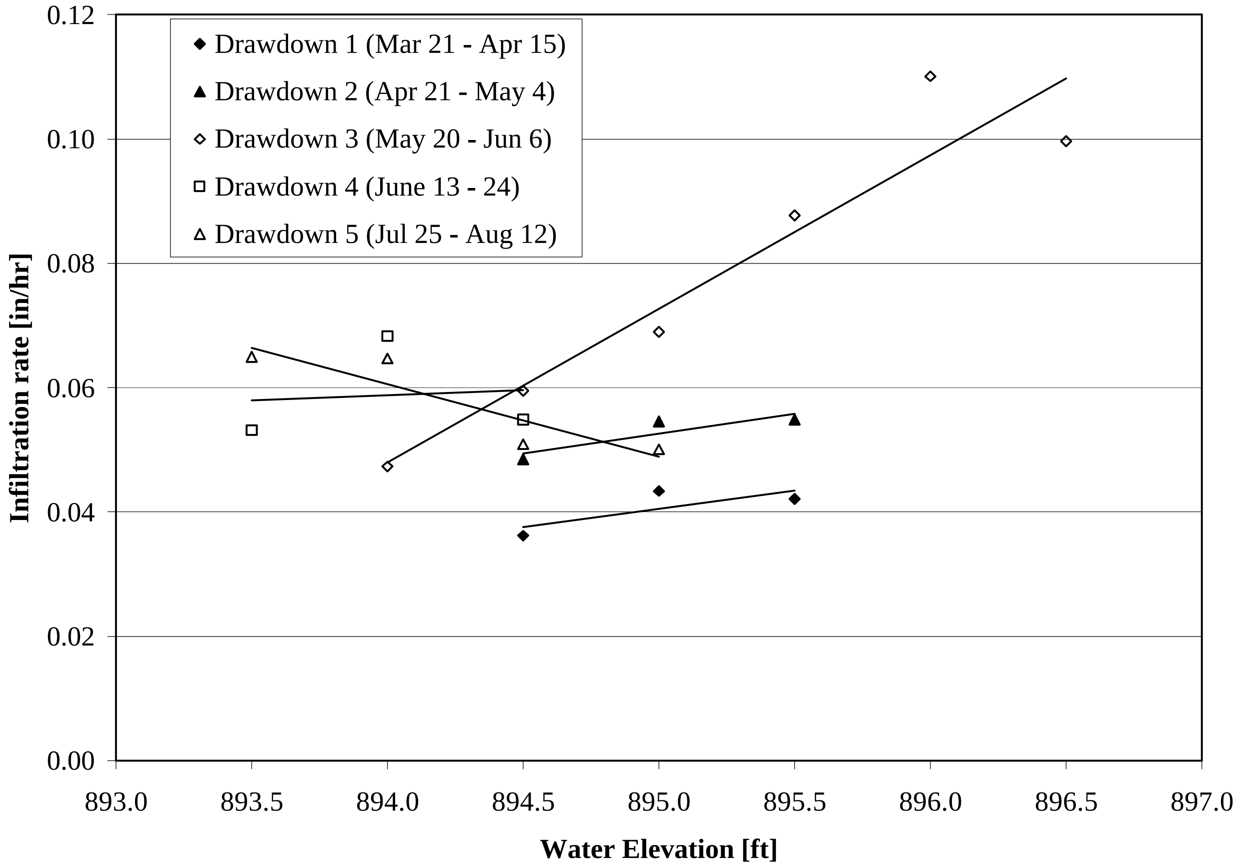
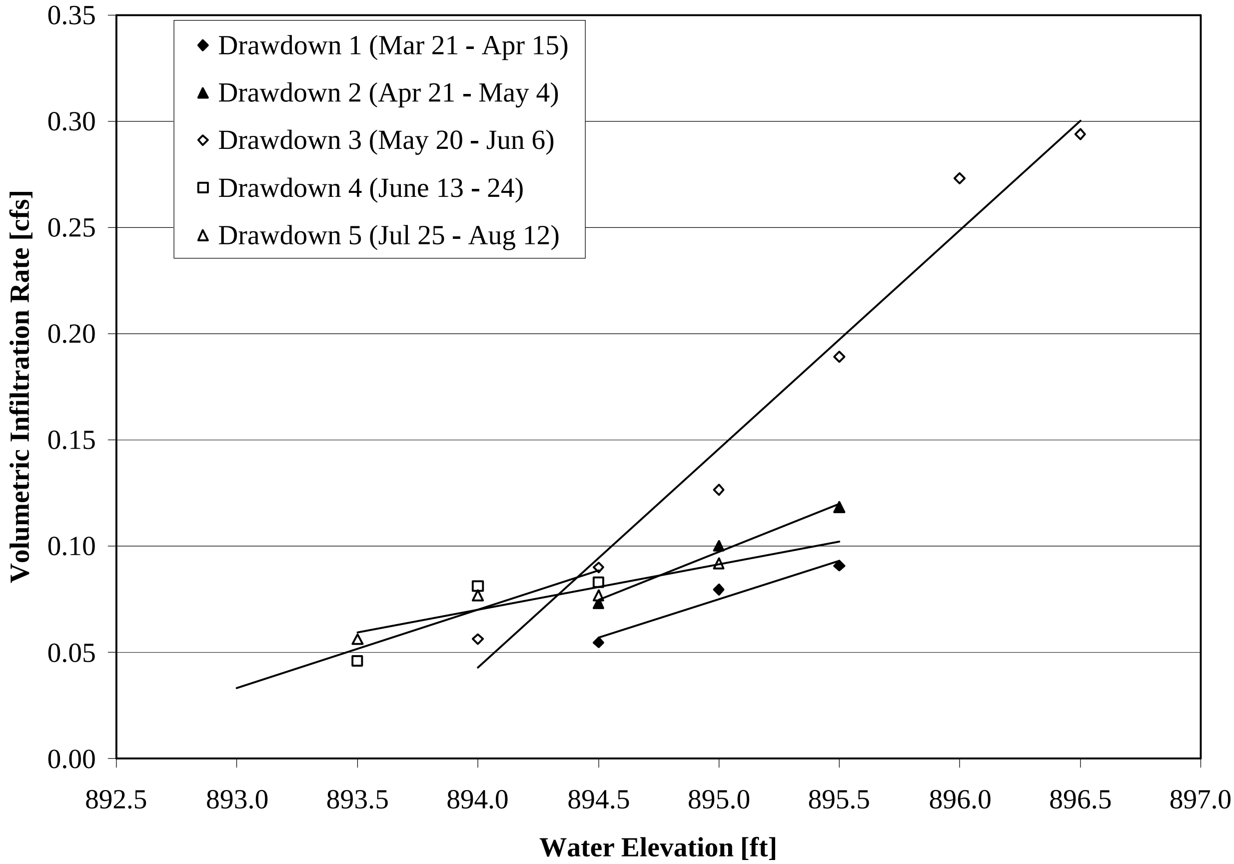


Figure III-4. CD-P50 Volumetric Infiltration Rate Curves, 2003

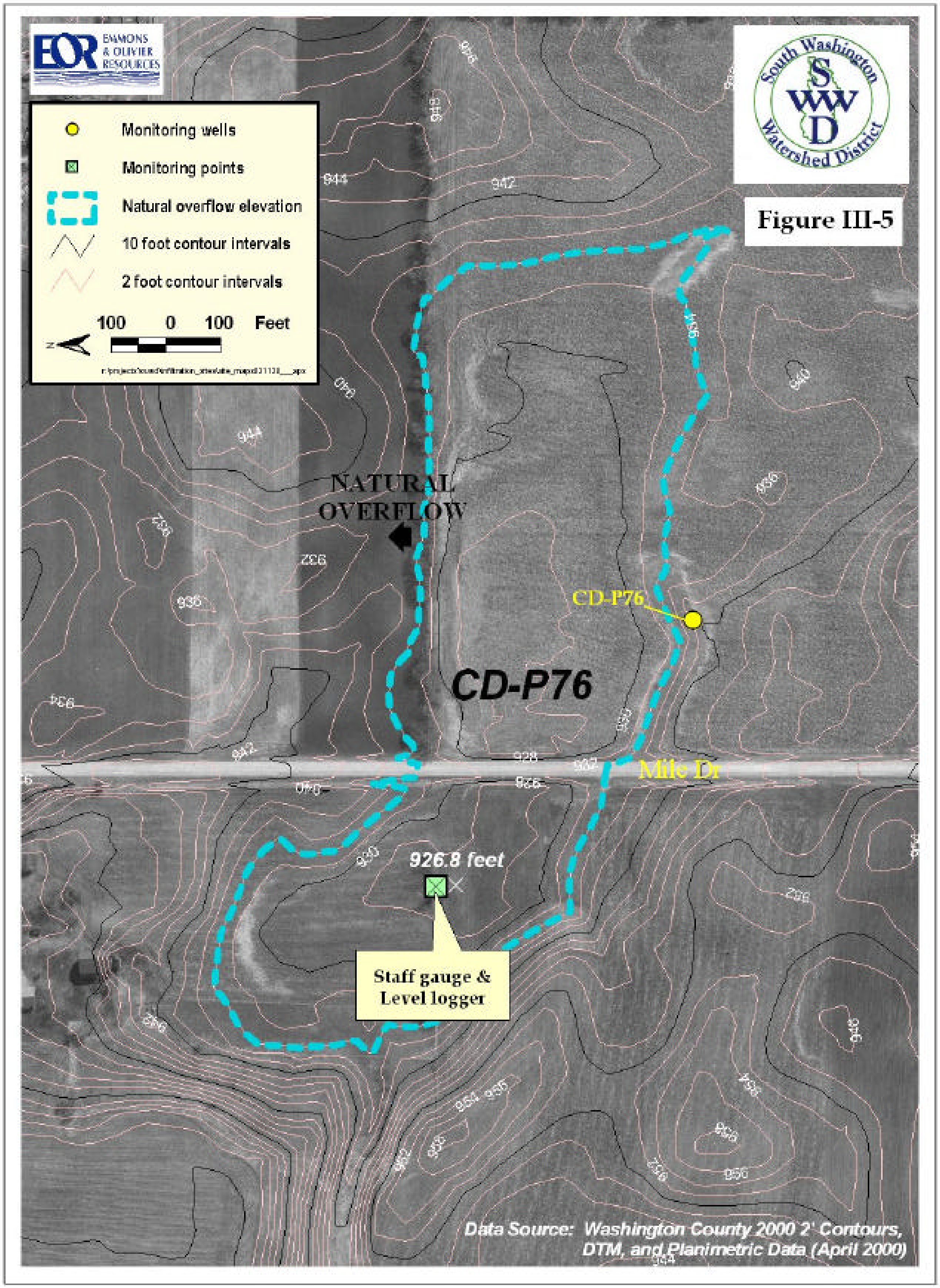


CD-P76 - Mile Drive Basin

Figure III-5 depicts CD-P76, its overflow elevation, and location of monitoring equipment. The following table contains the elevation versus area in this basin.

Table III-3. CD-P76 Elevation Versus Area

Elevation [ft]	**Area** [acres]
934	13.30
932	10.20
930	5.61
928	2.18
927	0.50
926.8	0.00


EMMONS & OLIVIER RESOURCES
South Washington Watershed District
SWWD
Figure III-5
Monitoring wells
Monitoring points
Natural overflow elevation
10 foot contour intervals
2 foot contour intervals
100 0 100 Feet
NATURAL OVERFLOW
CD-P76
CD-P76
Mile Dr
926.8 feet
Staff gauge & Level logger
Data Source: Washington County 2000 2' Contours, DTM, and Planimetric Data (April 2000)

Infiltration Rates

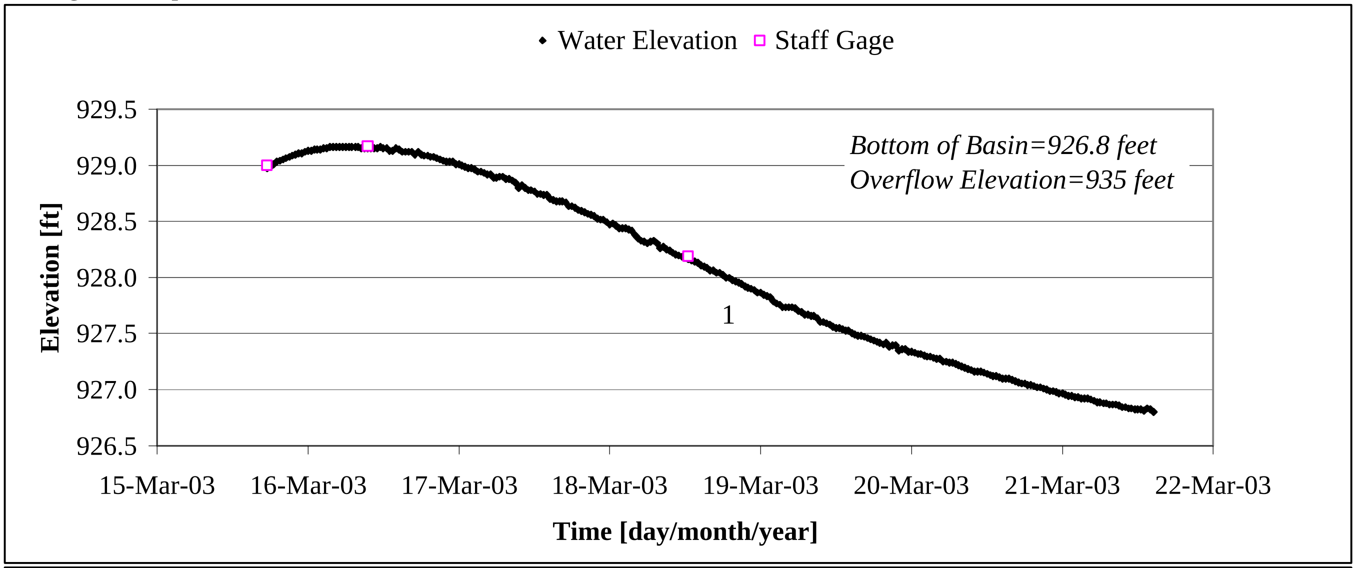
A single water level recorder was installed in CD-P76 on March 13, 2003 and removed on April 1, 2003. Staff gage readings were taken throughout the infiltration events. In addition, several staff gage readings were taken during a May and a June summer infiltration event. Drawdown 1 represents the ponding associated with the spring snowmelt event.

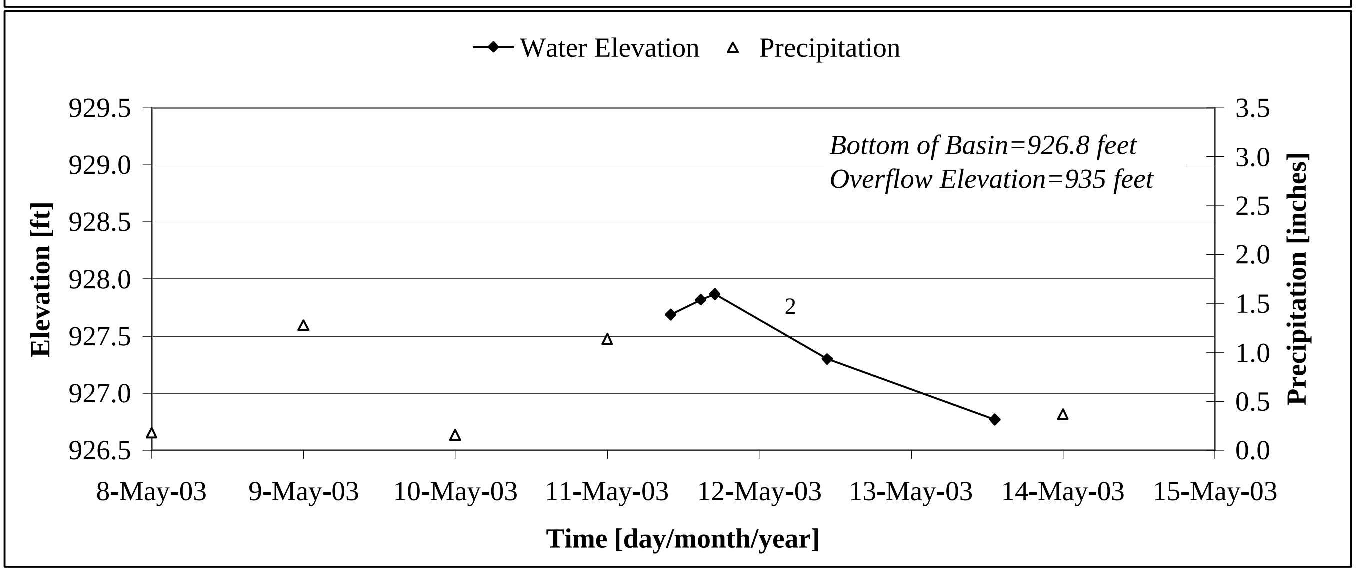
Figure III-6 illustrates the water elevation in CD-P76 over time. Table III-4 presents the infiltration rates observed for two of the drawdown events, representing the infiltration envelope for CD-P76. A discussion regarding the infiltration envelopes can be found in section VI-A. Figures III-7 and III-8 compare the infiltration rates from different events to one another, plotted with respect to elevation.

Table III-4. CD-P76 Infiltration Rates, 2003. The two drawdown events presented here represent the infiltration envelope for CD-P76. See section VI-A: Infiltration Envelopes.

Basin Elevation	**Area**	**Drawdown 1 Infiltration Rate**			**Drawdown 1 Volumetric Infiltration Rate**	**Drawdown 3 Infiltration Rate**			**Drawdown 3 Volumetric Infiltration Rate**
[feet]	[acres]	[ft/hr]	[ft/min]	[inch/hr]	[cfs]	[ft/hr]	[ft/min]	[inch/hr]	[cfs]
929.0	3.90	0.022	0.0004	0.264	0.922	-	-	-	-
928.5	3.04	0.027	0.0005	0.330	0.868	0.093	0.0015	1.113	2.928
928.0	2.18	0.024	0.0004	0.286	0.507	0.040	0.0007	0.480	0.852
927.5	1.34	0.016	0.0003	0.188	0.175	-	-	-	-
927.0	0.50	0.012	0.0002	0.140	0.035	-	-	-	-

Figure III-6. CD-P76 Water Elevation Versus Time. Numbers refer to drawdown events. The three figures are plotted on the same scale.





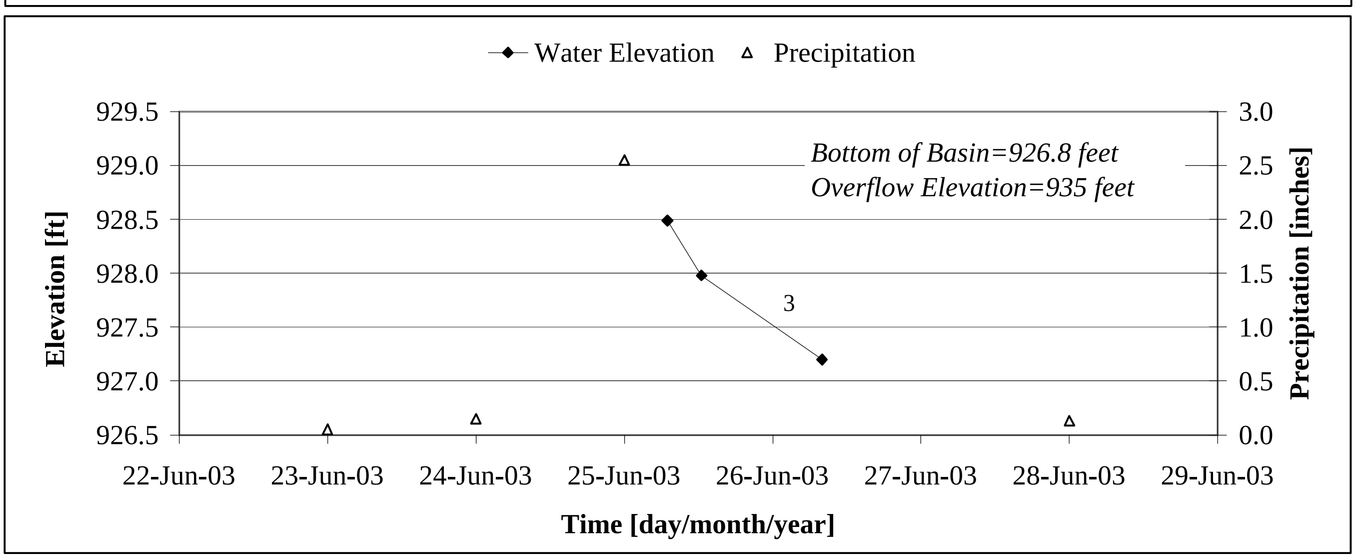


Figure III-7. CD-P76 Infiltration Rate Curves, 2003

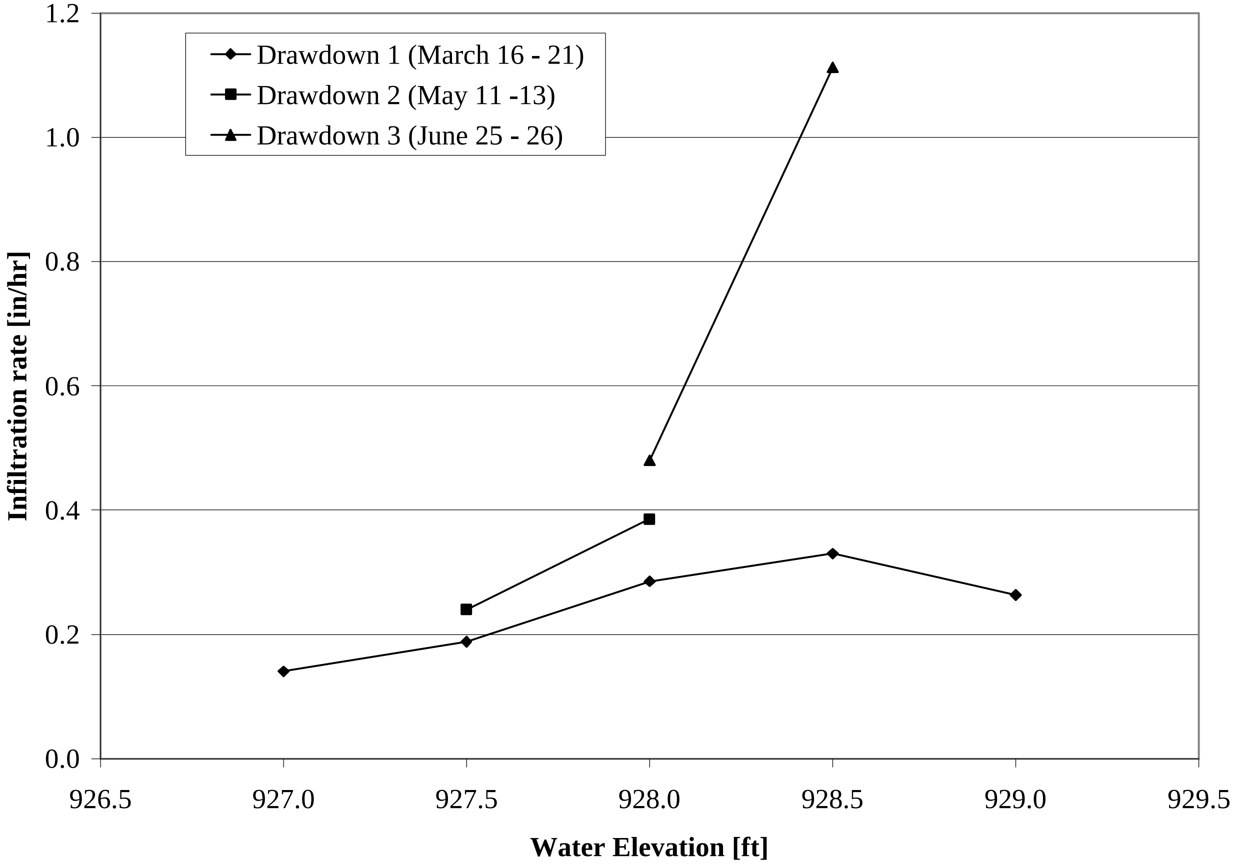
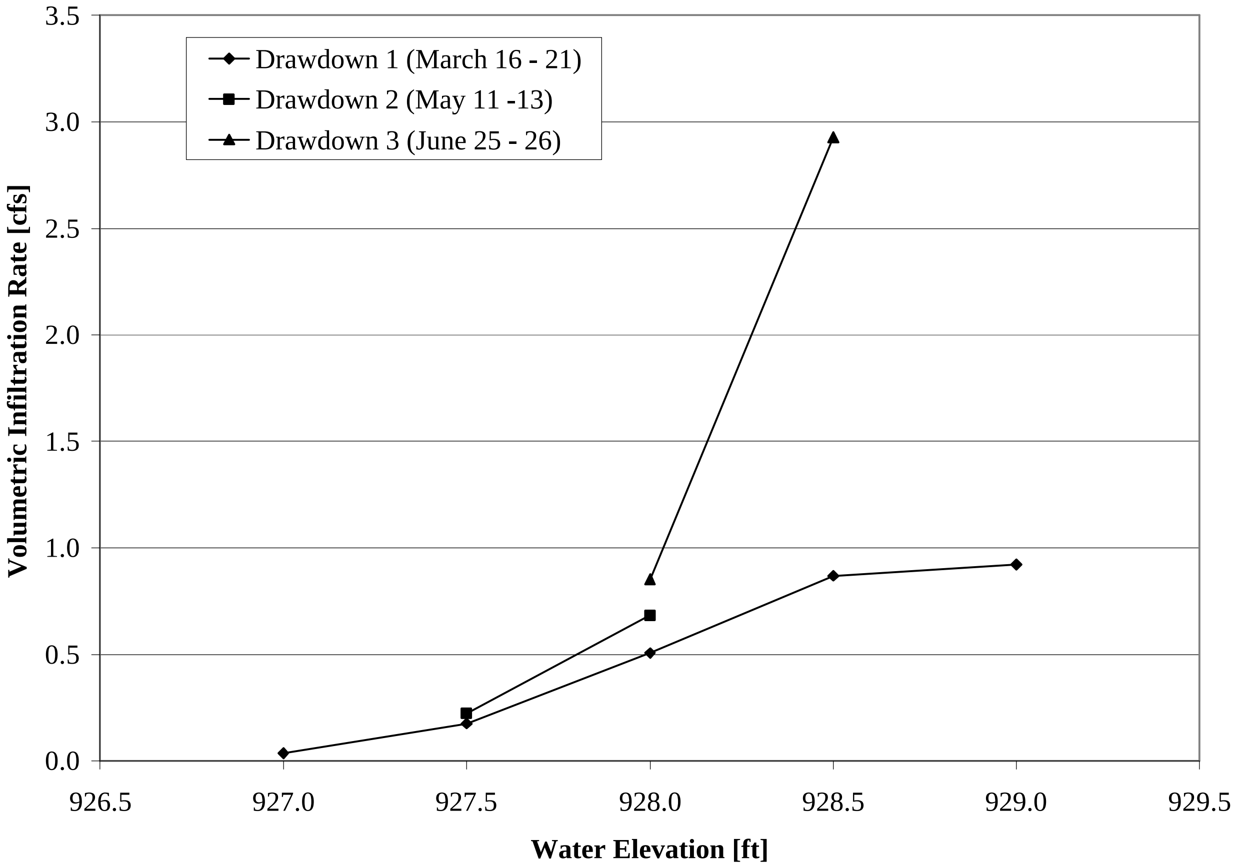


Figure III-8. CD-P76 Volumetric Infiltration Rate Curves, 2003



CD-P82 – County Road 19 Basin

Figure III-9 depicts CD-P82, its overflow elevation, and the location of monitoring equipment. The following table contains the elevation versus area in this basin.

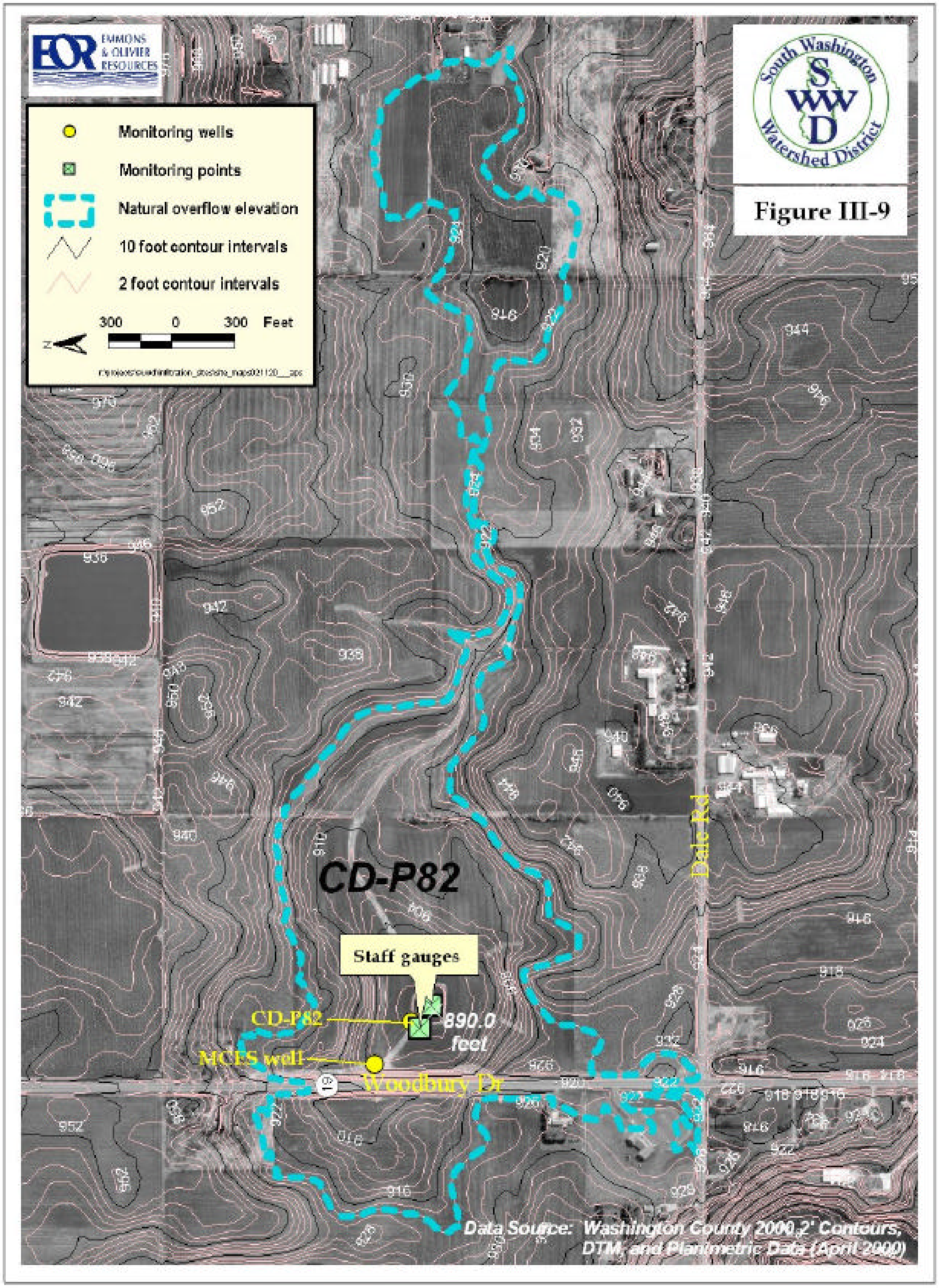

EMMONS & OLIVIER RESOURCES
Monitoring wells
Monitoring points
Natural overflow elevation
10 foot contour intervals
2 foot contour intervals
300 0 300 Feet
South Washington Watershed District
Figure III-9
CD-P82
Staff gauges
CD-P82
890.0 feet
MCES well
Woodbury Dr
Dale Rd
Data Source: Washington County 2000 2' Contours, DTM, and Planimetric Data (April 2000)

Table III-5. CD-P82 Elevation Versus Area

Elevation [ft]	**Area** [acres]
924	88.16
922	55.85
920	48.95
918	42.62
916	36.91
914	31.77
912	25.45
910	20.76
908	15.78
906	12.55
904	10.79
902	9.34
900	7.91
898	6.37
896	4.00
894	1.24
892	0.62
890	0.00

Infiltration Rates

A single water level recorder was installed in CD-P82 on March 13, 2003 and staff gage readings were also taken throughout the infiltration event. The water level recorder was removed from the basin on June 19, 2003.

Figure III-10 illustrates the water elevation in CD-P82 over time. During both the spring infiltration event (Drawdown 1, March 16 through April 14), and the second summer infiltration event (Drawdown 3, May 11 – Jun 19), there was a short period of time during which the water level in the basin increased (see Figure III-10). These data points were not used in the infiltration rate calculations for those events.

Table III-6 presents the infiltration rates observed for two of the drawdown events, representing the infiltration envelope for CD-P82. A discussion regarding the infiltration envelopes can be found in section VI-A. Figures III-11 and III-12 compare the infiltration rates from different events to one another, plotted with respect to elevation.

Figure III-10. CD-P82 Water Elevation vs. Time. Numbers refer to drawdown events.

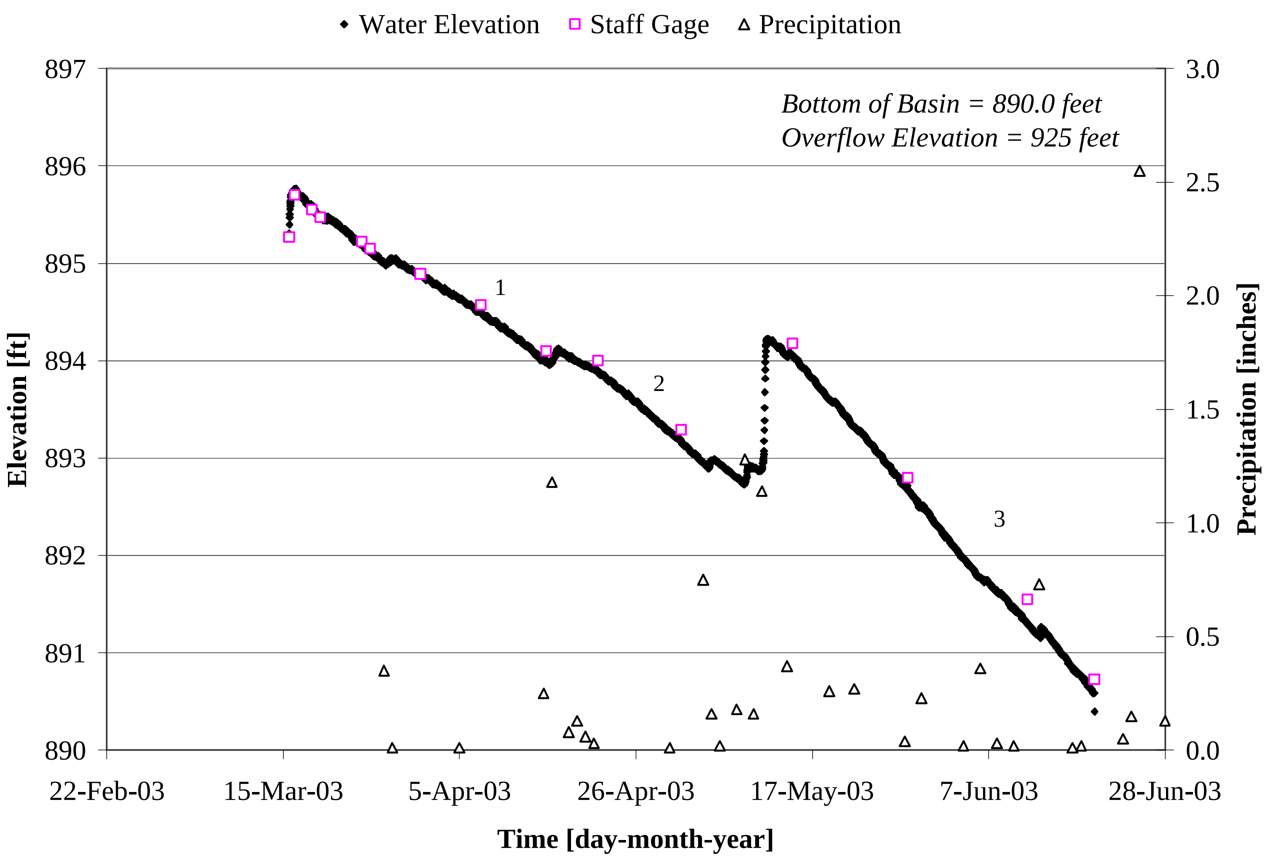


Table III-6. CD-P82 Infiltration Rates, 2003. The two drawdown events presented here represent the infiltration envelope for CD-P82. See section VI-A: Infiltration Envelopes.

Basin Elevation	**Area**	**Drawdown 1 Infiltration Rate**			**Drawdown 1 Volumetric Infiltration Rate**	**Drawdown 3 Infiltration Rate**			**Drawdown 3 Volumetric Infiltration Rate**
[feet]	[acres]	[ft/hr]	[ft/min]	[inch/hr]	[cfs]	[ft/hr]	[ft/min]	[inch/hr]	[cfs]
896.0	4.00	0.0047	0.000078	0.056	0.206	-	-	-	-
895.5	3.31	0.0031	0.000052	0.037	0.112	-	-	-	-
895.0	2.62	0.0028	0.000046	0.033	0.076	-	-	-	-
894.5	1.93	0.0030	0.000050	0.036	0.058	0.0032	0.000053	0.038	0.061
894.0	1.24	-	-	-	-	0.0042	0.000071	0.051	0.060
893.5	1.09	-	-	-	-	0.0044	0.000073	0.053	0.054
893.0	0.93	-	-	-	-	0.0047	0.000078	0.056	0.048
892.5	0.78	-	-	-	-	0.0050	0.000083	0.060	0.042
892.0	0.62	-	-	-	-	0.0040	0.000067	0.048	0.026
891.5	0.47	-	-	-	-	0.0040	0.000066	0.047	0.019
891.0	0.31	-	-	-	-	0.0048	0.000079	0.057	0.013

Figure III-11. CD-P82 Infiltration Rate Curves, 2003

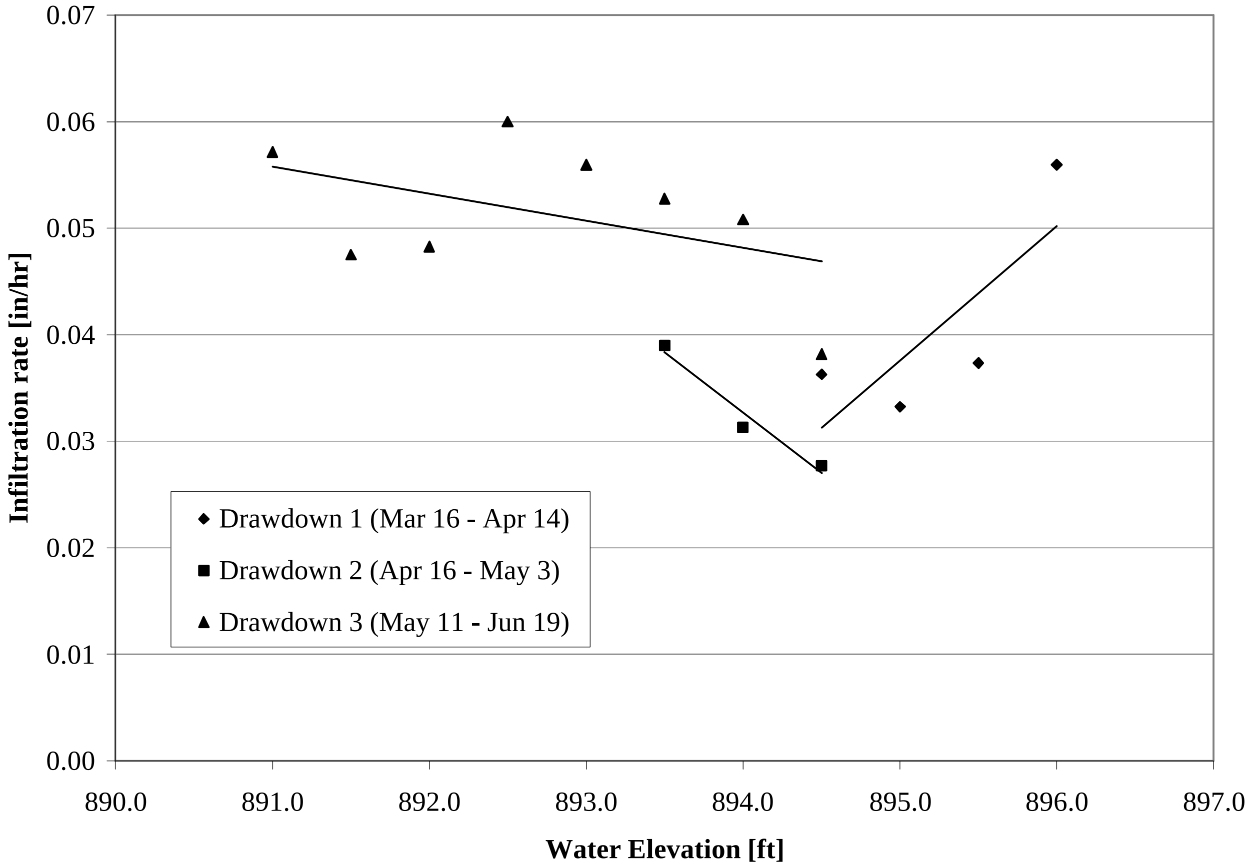
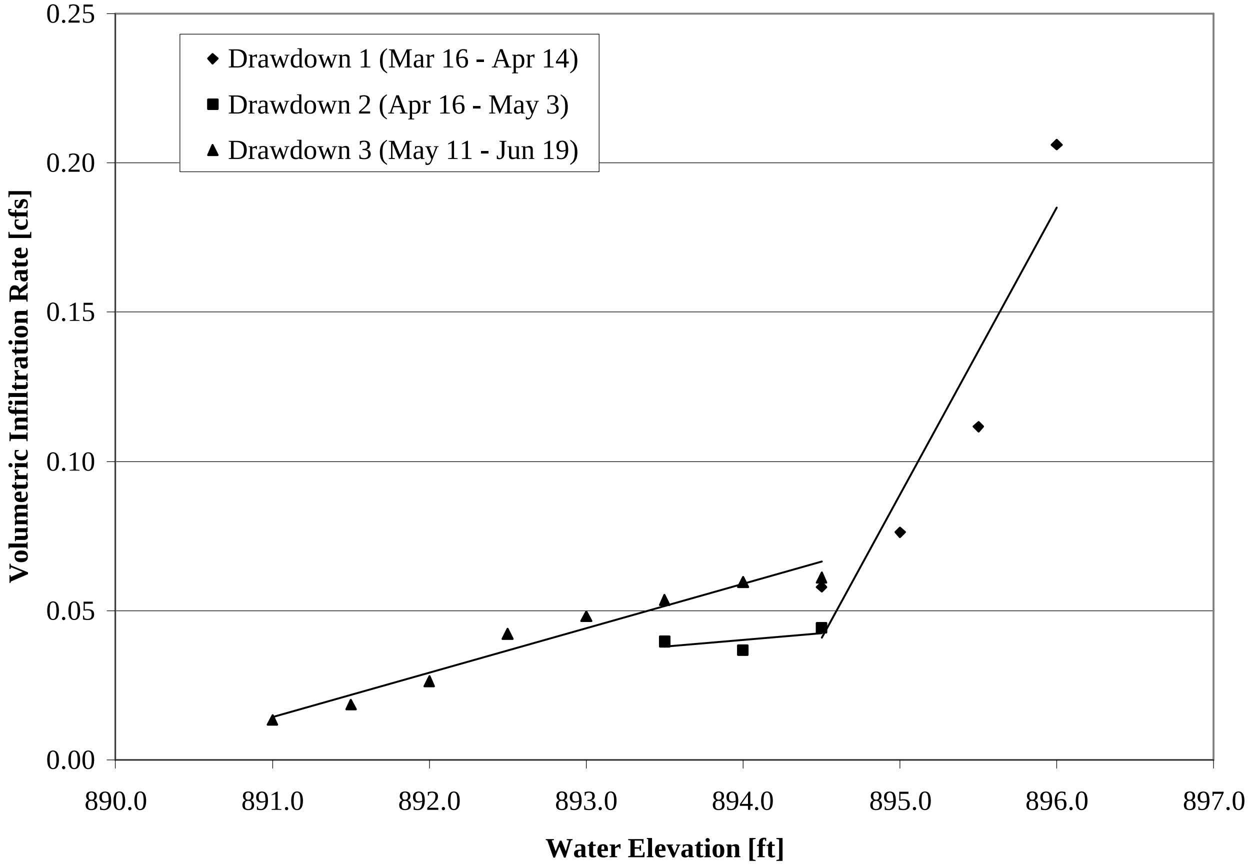
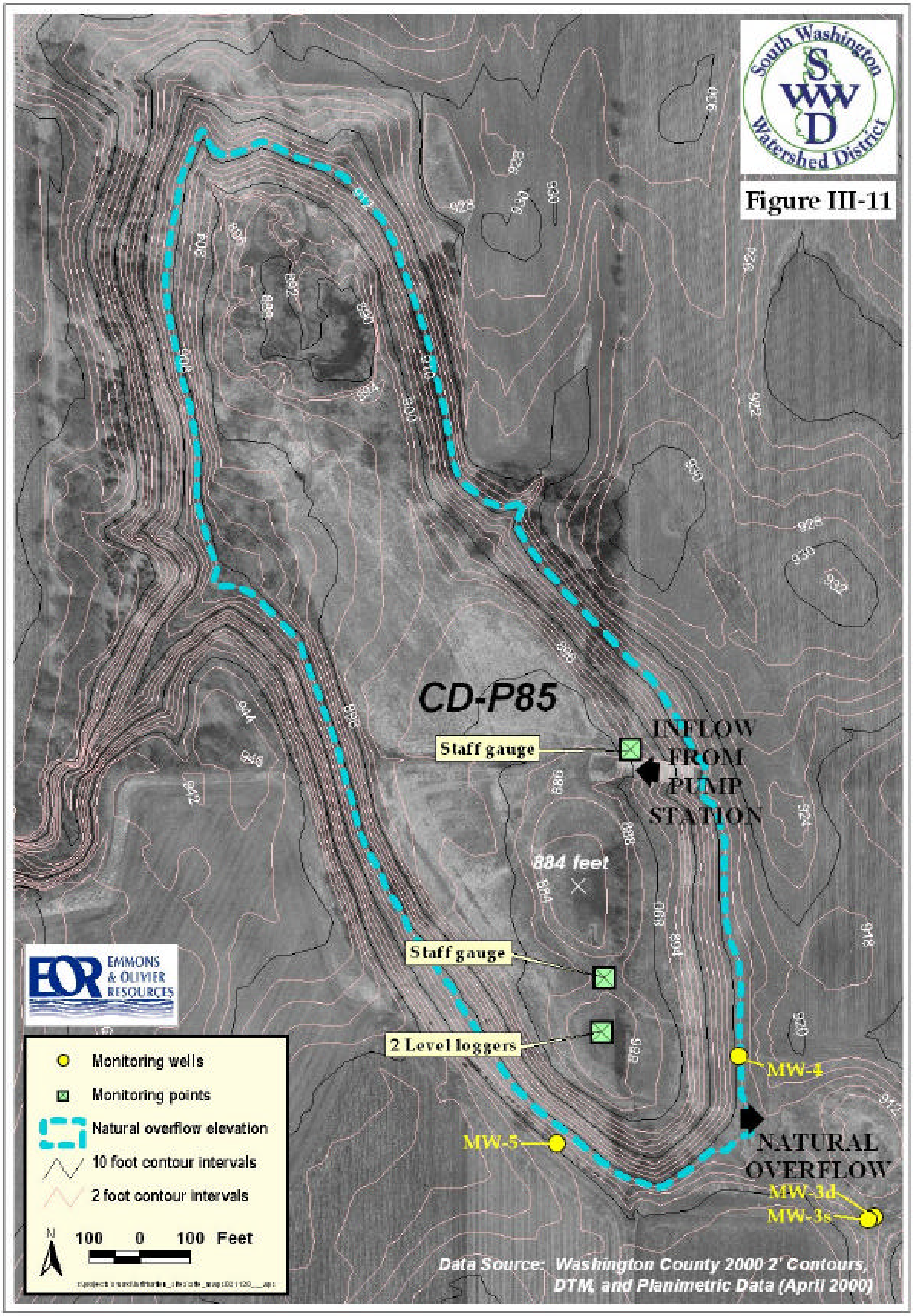


Figure III-12. CD-P82 Volumetric Infiltration Rate Curves, 2003



CD-P85 – Regional Infiltration Basin

Figure III-11 depicts CD-P85, its overflow elevation, and location of monitoring equipment. The following table contains the elevation versus area in this basin. The base of the trench pipe was surveyed in at an elevation of 883.7 feet and represents the approximate elevation of the bottom of the basin.



South Washington Watershed District
SWWD
Figure III-11
CD-P85
Staff gauge
INFLOW FROM PUMP STATION
884 feet
Staff gauge
2 Level loggers
MW-4
MW-5
NATURAL OVERFLOW
MW-3d
MW-3s
EMMONS & OLIVIER RESOURCES
Monitoring wells
Monitoring points
Natural overflow elevation
10 foot contour intervals
2 foot contour intervals
100 0 100 Feet
Data Source: Washington County 2000 2' Contours, DTM, and Planimetric Data (April 2000)

Table III-7. CD-P85 Elevation Versus Area

Elevation [ft]	**Area** [acres]
912	25.71
910	24.47
908	23.30
906	22.10
904	20.81
902	19.47
900	17.96
898	16.25
896	14.13
894	11.82
892	9.09
890	5.82
888	2.98
886	1.60
884	0.52

The monitoring data gathered in 2003 include data from the infiltration trench for the spring runoff event and for the basin during summer pumping and rainfall events. Data collected during these events represent the infiltration capacity of the basin after five years with improvements. These improvements include infiltration tubes and infiltration trenches and are presented in detail in the SWWD IMS Progress Report, 1998; and the SWWD IMS Phase II Report, 2001.

A pressure transducer was installed in the south trench through the existing observation tube on March 27, 2003. This equipment served the data collection needs of the trench and a portion of the basin. Additional equipment was installed, adjusted, and removed throughout the monitoring season as needed. Monitoring equipment was removed from CD-P85 on November 21, 2003. In order to further protect the equipment installed at CD-P85, the pressure transducer and cabling were routed through 2-inch PVC pipe and buried underground. At the observation tube within the trench, a Y connector and access hatch were installed to accommodate for ease in transducer installation and removal and obtaining manual level measurements.

CD-P85 – Infiltration Trench

The rates of water decline for the trench were collected in the spring and summer of 2003.

Figure III-12 illustrates the depth of water in the CD-P85 infiltration trench over time. Table III-8 presents the infiltration rates observed for two of the drawdown events, representing the infiltration envelope for this trench. A discussion regarding the infiltration envelopes can be found in section VI.A. Figure III-13 compares the infiltration rates from different events to one another, plotted with respect to water depth. Either a linear or a polynomial curve was fit to each drawdown event in Figure III-13, depending on which relationship explained more of the variation in the rate of water decline. Where the relationship is polynomial, this indicates that the rate of water decline was relatively higher at greater depths of water, compared to if the relationship had been linear.

Figure III-14. CD-P85 Trench Water Depth vs. Time, 2003. Numbers refer to drawdown events.

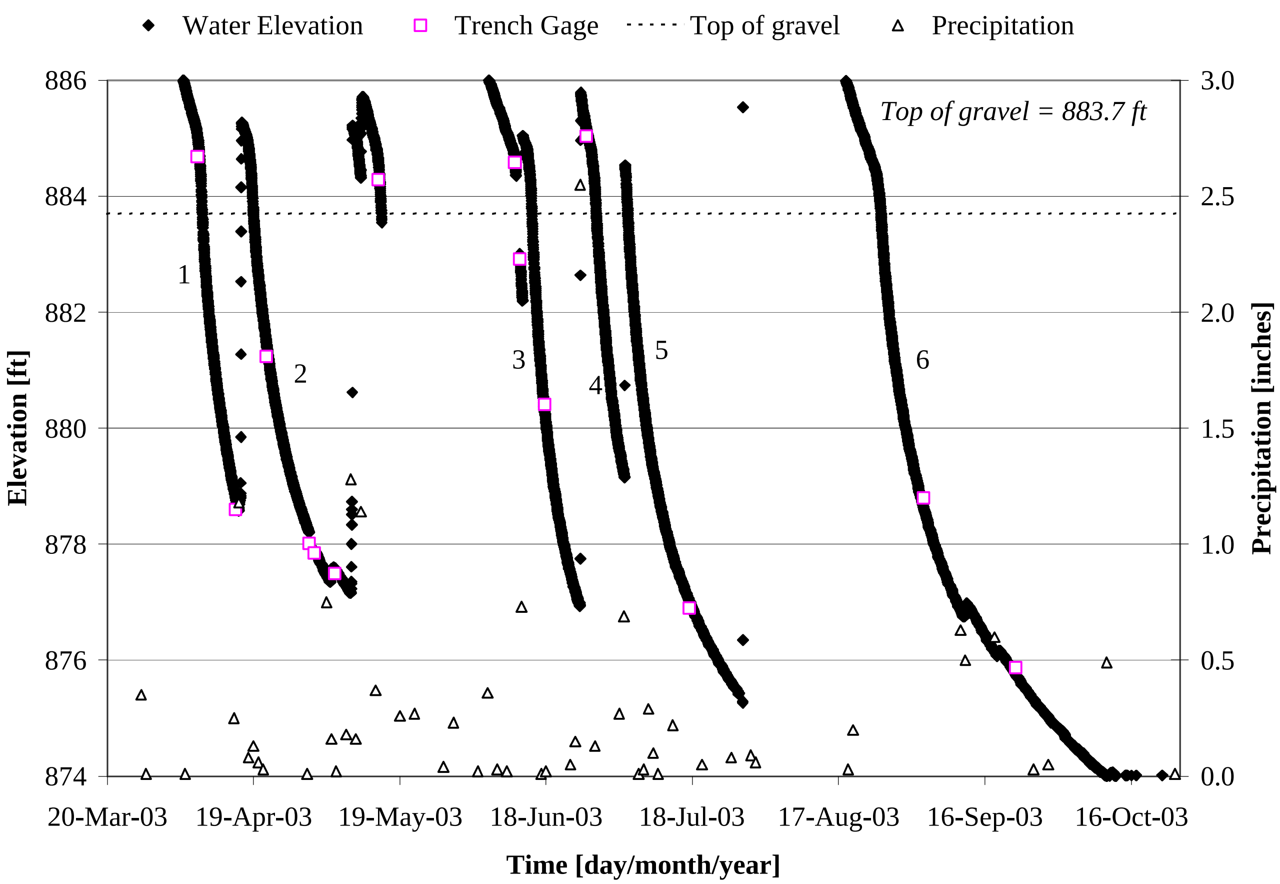
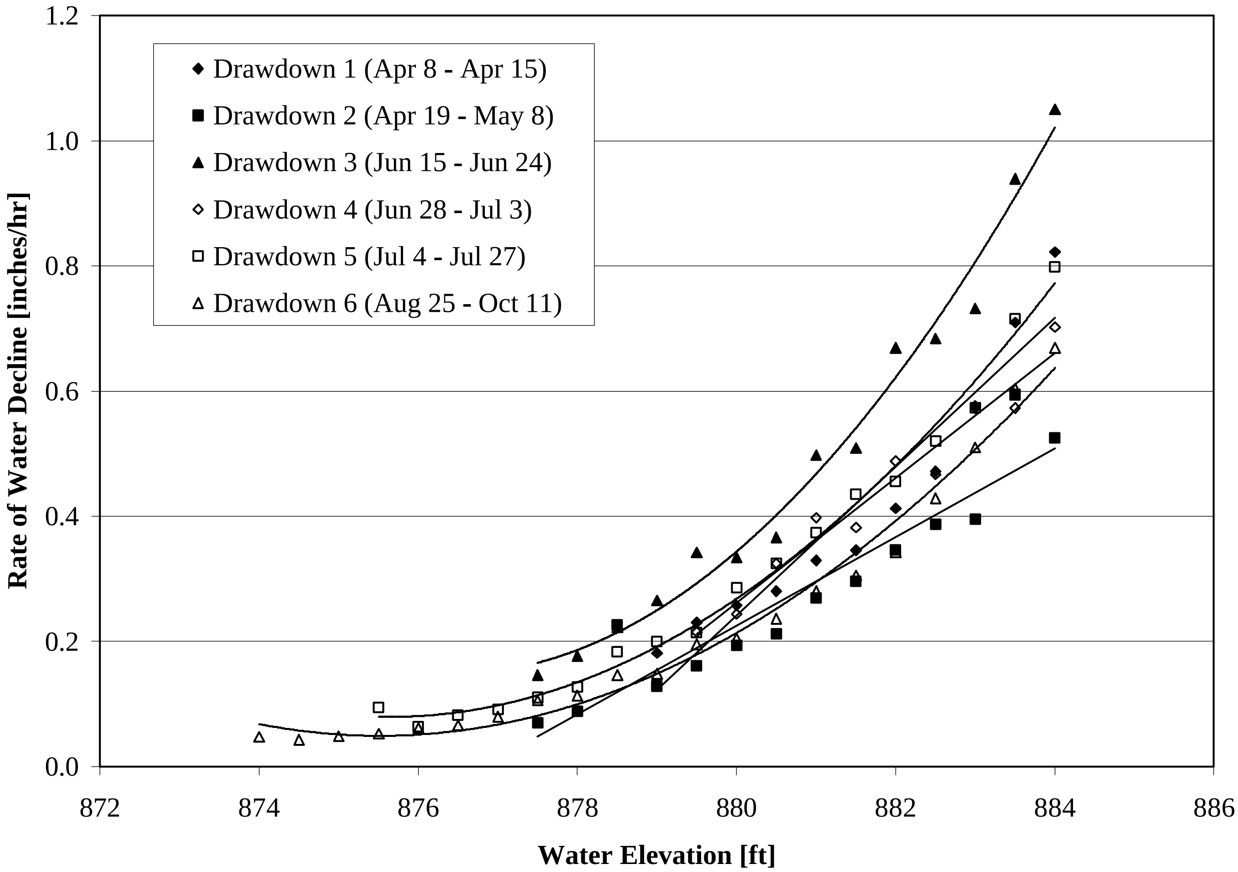


Table III-8: CD-P85 Trench Rates of Water Decline, 2003. The two drawdown events presented here represent the infiltration envelope for CD-P85. See section VI-A: Infiltration Envelopes.

Water Level Elevation	Drawdown 2 Rate of Water Decline			Drawdown 3 Rate of Water Decline		
[feet]	[ft/hr]	[ft/min]	[inch/hr]	[ft/hr]	[ft/min]	[inch/hr]
884.0	0.044	0.0007	0.52	0.087	0.0015	1.05
883.5	0.049	0.0008	0.59	0.078	0.0013	0.94
883.0	0.033	0.0005	0.40	0.061	0.0010	0.73
882.5	0.032	0.0005	0.39	0.057	0.0010	0.68
882.0	0.029	0.0005	0.35	0.056	0.0009	0.67
881.5	0.025	0.0004	0.30	0.042	0.0007	0.51
881.0	0.022	0.0004	0.27	0.041	0.0007	0.50
880.5	0.018	0.0003	0.21	0.031	0.0005	0.37
880.0	0.016	0.0003	0.19	0.028	0.0005	0.33
879.5	0.013	0.0002	0.16	0.028	0.0005	0.34
879.0	0.011	0.0002	0.13	0.022	0.0004	0.27
878.5	0.019	0.0003	0.23	0.019	0.0003	0.22
878.0	0.007	0.0001	0.09	0.015	0.0002	0.18
877.5	0.006	0.0001	0.07	0.012	0.0002	0.15

Figure III-15. CD-P85 Trench Rates of Water Decline, 2003



CD-P85 Infiltration Basin

During the fall and winter of 2002, a thick layer of ice formed at the bottom of the basin. Drawdown 1 (March 27 – April 4) is a result of this ice melting within the basin and direct drainage in the subwatershed. The City of Woodbury began a series of water pumping events beginning on May 9, 2003 from South Bailey Lake into regional infiltration basin CD-P85. Three separate pumping events occurred at CD-P85 in May, August and November.

Water levels in the basin were recorded with a pressure transducer located in the southern portion of the basin. The pressure transducer was installed before the pumping event began. Figure II-14 illustrates the water levels in CD-P85 over the course of the pumping events. A total of six recession curves were monitored.

Infiltration rates for each event are calculated down to an elevation of 886 ft, and not to 884 ft which is considered the bottom of the basin. A small berm is present between the north and south trench in CD-P85. The berm, which was surveyed at an elevation of 886 ft, isolates the southern trench from the remainder of the basin below that elevation. Because the monitoring equipment is located within the southern trench, infiltration rates calculated below the 886 elevation are not necessarily typical of the basin as a whole at and below that elevation and are therefore not included in the analysis.

Figure III-16. CD-P85 Water Elevation vs. Time, 2003. Numbers refer to drawdown events.

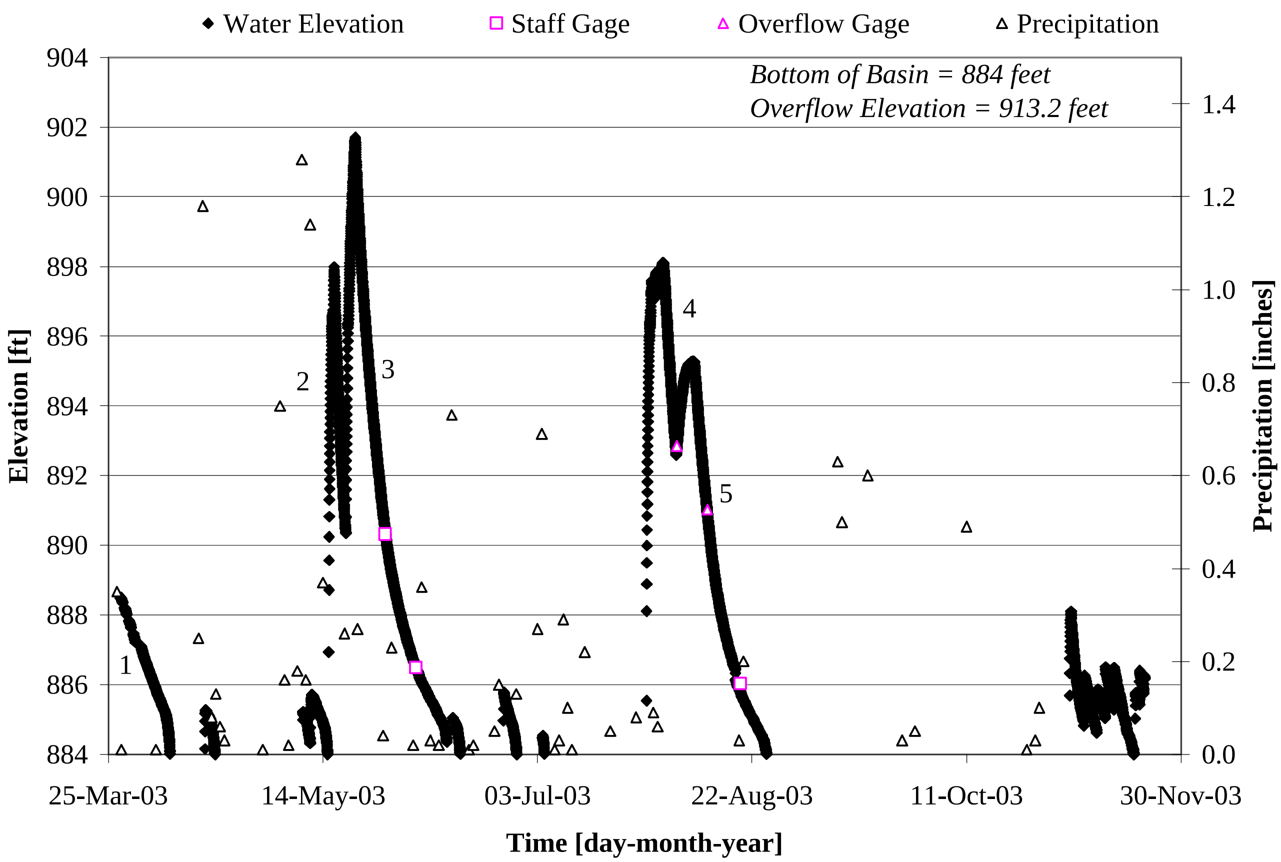


Table III-9 presents the infiltration rates observed for two of the drawdown events, representing the 2003 infiltration envelope for CD-P85. A discussion regarding the infiltration envelopes can be found in section V-A. Figures III-15 and III-16 compare the infiltration rates from different events to one another, plotted with respect to elevation.

Table III-9: CD-P85 Infiltration Rates, 2003. The two drawdown events presented here represent the infiltration envelope for CD-P85. See section VI-A: Infiltration Envelopes.

Basin Elevation	Area	Drawdown 3 Infiltration Rate			Drawdown 3 Volumetric Infiltration Rate	Drawdown 2 Infiltration Rate			Drawdown 2 Volumetric Infiltration Rate
[feet]	[acres]	[ft/hr]	[ft/min]	[inch/hr]	[cfs]	[ft/hr]	[ft/min]	[inch/hr]	[cfs]
901.5	19.09	0.132	0.0022	1.58	30.2				
901.0	18.72	0.121	0.0020	1.45	27.1				
900.5	18.34	0.110	0.0018	1.32	24.1				
900.0	17.96	0.100	0.0017	1.20	21.5				
899.5	17.53	0.088	0.0015	1.06	18.4				
899.0	17.11	0.088	0.0015	1.05	17.9				
898.5	16.68	0.084	0.0014	1.01	16.7				
898.0	16.25	0.082	0.0014	0.99	16.0	0.184	0.0031	2.21	35.6
897.5	15.72	0.077	0.0013	0.92	14.4	0.162	0.0027	1.94	30.3
897.0	15.19	0.069	0.0011	0.82	12.4	0.149	0.0025	1.78	26.8
896.5	14.66	0.066	0.0011	0.79	11.5	0.146	0.0024	1.75	25.4
896.0	14.13	0.069	0.0011	0.82	11.5	0.143	0.0024	1.71	23.9
895.5	13.55	0.063	0.0011	0.76	10.1	0.143	0.0024	1.71	22.9
895.0	12.98	0.058	0.0010	0.69	8.9	0.135	0.0022	1.61	20.7
894.5	12.4	0.062	0.0010	0.74	9.0	0.129	0.0022	1.55	18.9
894.0	11.82	0.054	0.0009	0.64	7.4	0.118	0.0020	1.42	16.4
893.5	11.14	0.052	0.0009	0.63	6.8	0.107	0.0018	1.28	14.0
893.0	10.45	0.053	0.0009	0.64	6.5	0.106	0.0018	1.27	12.9
892.5	9.77	0.047	0.0008	0.56	5.3	0.096	0.0016	1.15	11.0
892.0	9.09	0.049	0.0008	0.59	5.2	0.088	0.0015	1.06	9.2
891.5	8.27	0.045	0.0008	0.54	4.3	0.080	0.0013	0.96	7.6
891.0	7.46	0.043	0.0007	0.52	3.7	0.082	0.0014	0.99	7.0
890.5	6.64	0.040	0.0007	0.48	3.0				
890.0	5.82	0.034	0.0006	0.40	2.2				
889.5	5.11	0.027	0.0004	0.32	1.5				
889.0	4.4	0.024	0.0004	0.29	1.2				
888.5	3.69	0.022	0.0004	0.26	0.9				
888.0	2.98	0.020	0.0003	0.24	0.7				
887.5	2.63	0.018	0.0003	0.21	0.5				
887.0	2.29	0.016	0.0003	0.19	0.4				
886.5	1.94	0.012	0.0002	0.14	0.3				

Figure III-17. CD-P85 Infiltration Rate Curves, 2003

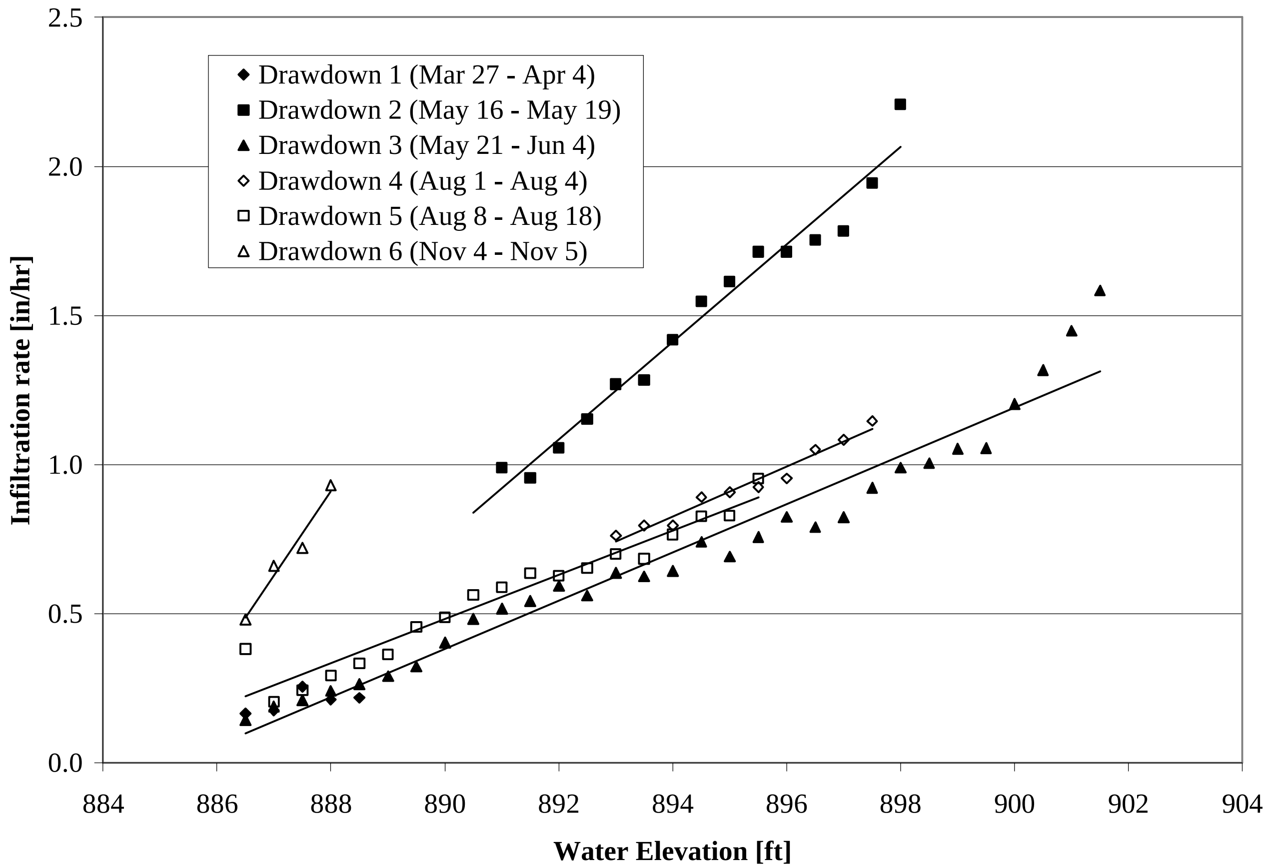
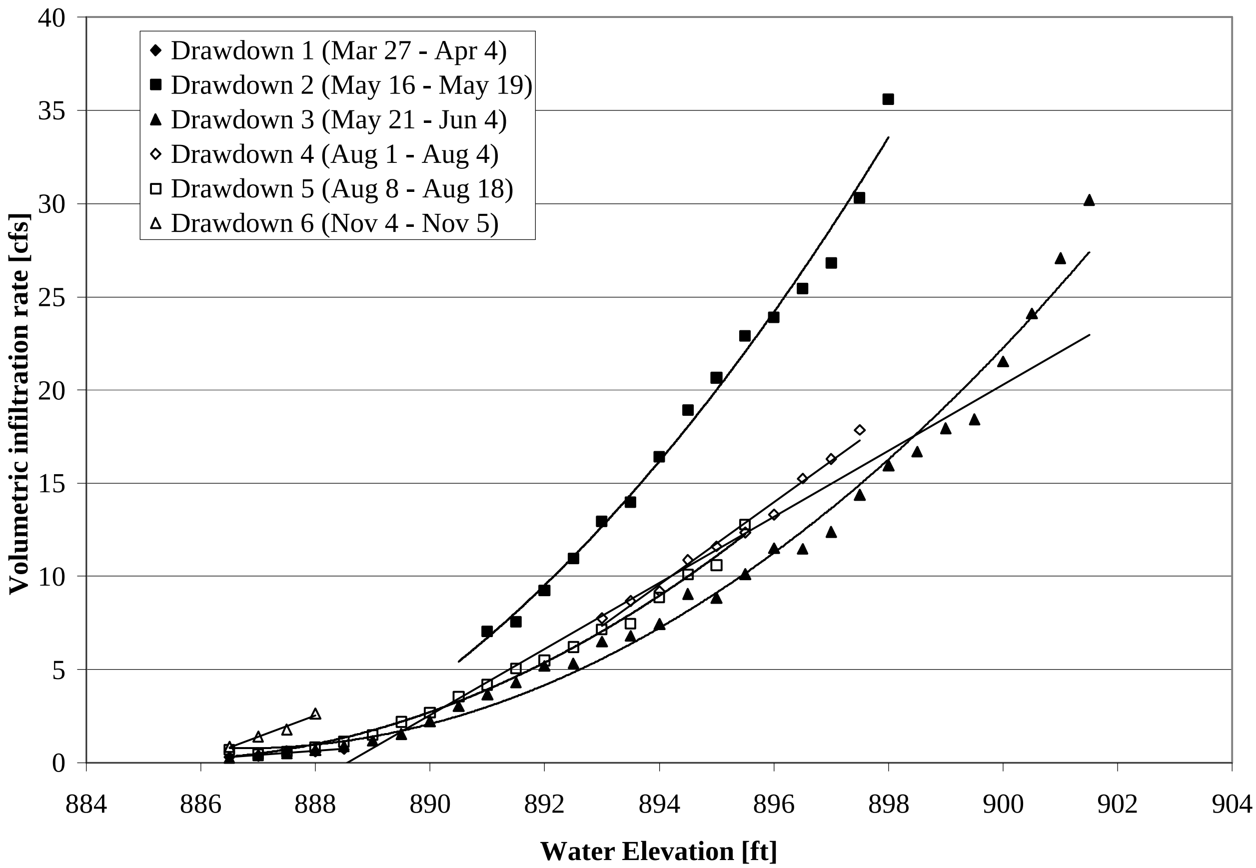


Figure III-18. CD-P85 Volumetric Infiltration Rate Curves, 2003



Water elevations in CD-P85 reached a maximum of 901.69 feet on May 21, 2003. This corresponds to a water depth of approximately 17.5 feet, during which the infiltration rate was 1.58 inches/hour. Groundwater mounding did not intersect the basin during 2003, although groundwater did rise to within 2 feet of the basin floor.

Math and Science Academy Infiltration Trench

Monitoring of the infiltration trench at the MSA began on March 17th, 2003. A pressure transducer was installed in the bottom of the trench via an observation well. Monitoring equipment remained at the site to record rainfall events over the entire monitoring season. The monitoring equipment was removed on November 3, 2003.

Figure III-19 illustrates the depth of water in the MSA trench over time. Water level data are presented as depth of water in the infiltration trench, as opposed to water elevation. In the MSA trench, the elevation of the surface water is not as relevant as in the other trench (in CD-P85), since the infiltration trench operates alone, and not in conjunction with an infiltration basin. Table III-10 presents the infiltration rates observed for two of the drawdown events, representing the infiltration envelope for the MSA trench. A discussion regarding the infiltration envelopes can be found in section VI-A. Figure III-20 compares the infiltration rates from different events to one another, plotted with respect to elevation.

Figure III-19. MSA Depth vs Time and Precipitation, 2003. Numbers refer to drawdown events.

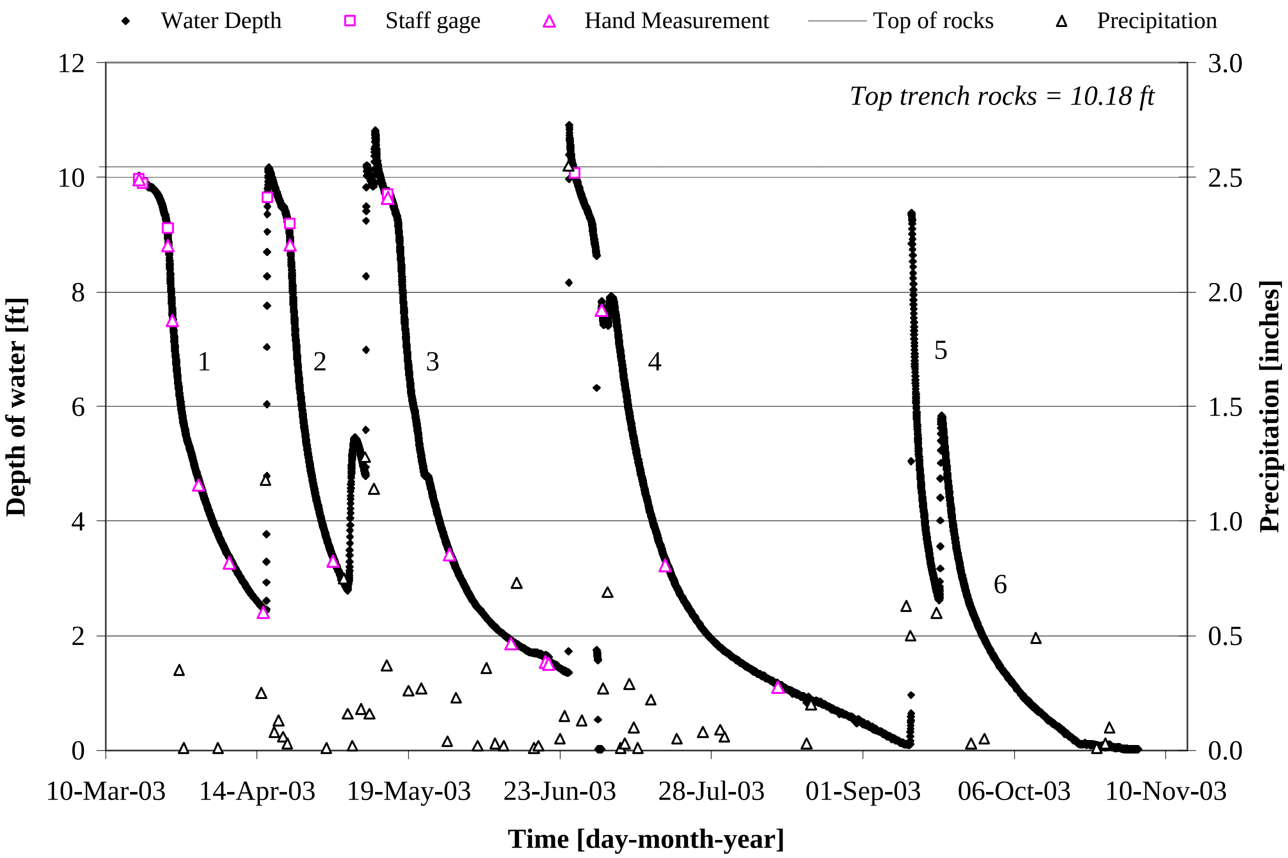
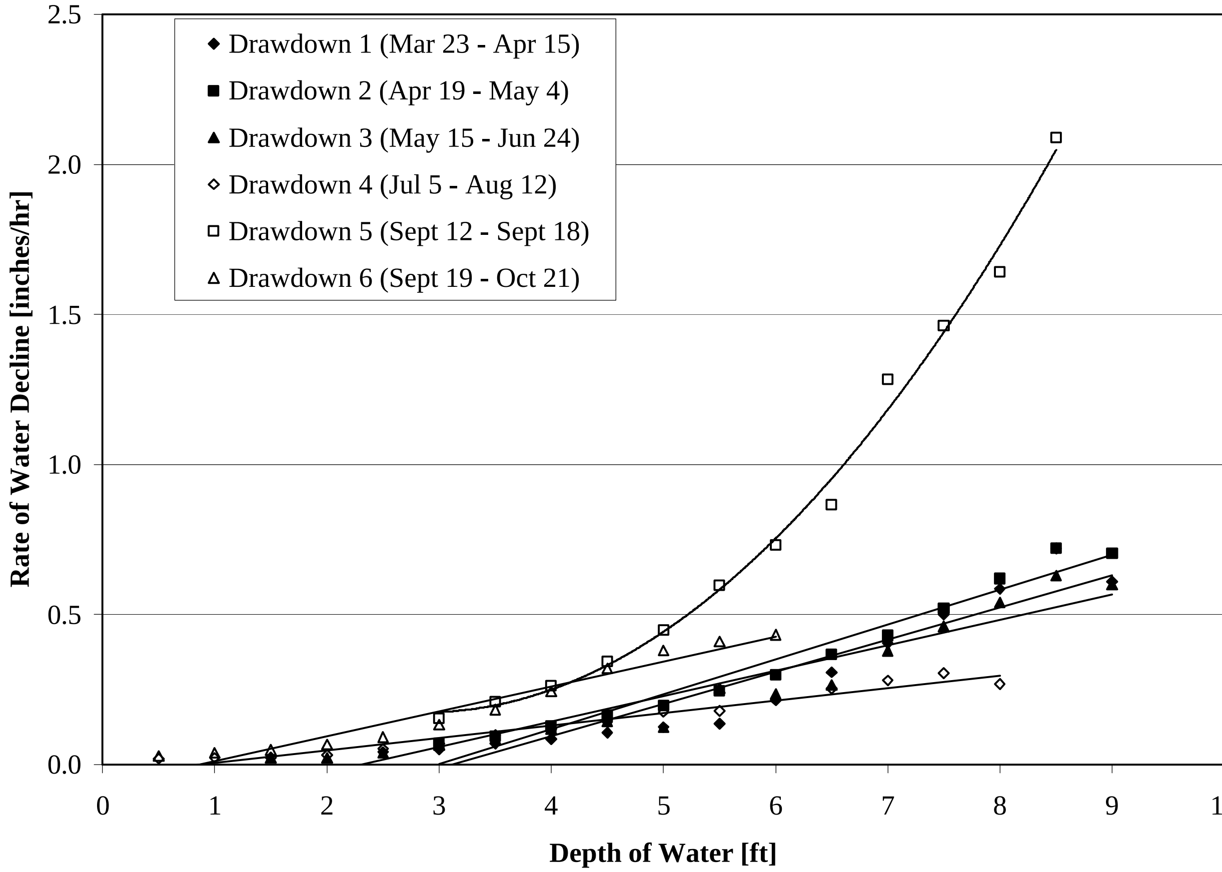


Table III-10. MSA Rates of Water Decline, 2003. The two drawdown events presented here represent the infiltration envelope for MSA. See section VI-A: Infiltration Envelopes.

Depth of Water	**Drawdown 4 Rate of Water Decline**			**Drawdown 5 Rate of Water Decline**		
[feet]	[ft/hr]	[ft/min]	[inch/hr]	[ft/hr]	[ft/min]	[inch/hr]
8.5				0.174	0.00290	2.090
8.0	0.022	0.00037	0.268	0.137	0.00228	1.642
7.5	0.025	0.00042	0.304	0.122	0.00203	1.463
7.0	0.023	0.00039	0.281	0.107	0.00178	1.284
6.5	0.021	0.00035	0.254	0.072	0.00120	0.866
6.0	0.018	0.00030	0.217	0.061	0.00102	0.731
5.5	0.015	0.00025	0.179	0.050	0.00083	0.597
5.0	0.015	0.00024	0.176	0.037	0.00062	0.448
4.5	0.012	0.00020	0.143	0.029	0.00048	0.343
4.0	0.010	0.00017	0.119	0.022	0.00036	0.263
3.5	0.008	0.00014	0.098	0.017	0.00029	0.209
3.0	0.006	0.00010	0.071	0.013	0.00021	0.154
2.5	0.004	0.00007	0.053			
2.0	0.003	0.00004	0.031			
1.5	0.002	0.00003	0.024			
1.0	0.002	0.00003	0.023			
0.5	0.002	0.00003	0.020			

Figure III-20. MSA Trench Infiltration Rate Curves, 2003



IV. Subwatershed Curve Numbers

Only a portion of the rainfall or snowmelt generated within a subwatershed is eventually delivered to low areas forming ponded water. An initial abstraction is typically applied on a subwatershed basis to account for evaporation, transpiration, interception, and infiltration that occurs as runoff is generated. The volume of water delivered to a pond or basin is a result of this abstraction. Quantifying the initial abstraction allows for the development of calibrated curve number (CN) values for each subwatershed. CNs are calculated for subwatersheds contributing to monitored basins CD-P50, CD-P76, and CD-P82 for various precipitation events during 2003. CD-P85 is not included in this analysis due to uncertainty of runoff volumes delivered to the basin.

IV-A. METHODOLOGY

Precipitation Events

Five precipitation events were used to develop calibrated subwatershed CNs. These events include snowmelt and rainfall events as described in Table IV-1. These data were obtained through the SWWD Annual Monitoring Program and include precipitation data on 15-minute intervals. Rainfall distribution is illustrated on Figures IV-1 through IV-4 for each event.

Table IV-1. Precipitation Events

Precipitation Event	**Duration of Event** [hours]	**Total Precipitation** [inches]
Snowmelt	--	0.63*
April 15-16 Rainfall	21.75	1.43
May 10-11 Rainfall	18	1.3
June 6 Rainfall (CD-P50)	11.25	0.36
June 24-25 Rainfall (CD-P76)	8.25	2.44

*Snow water equivalent (WCD, 2003)

Figure IV-1. April 15 through 16 Rainfall Distribution

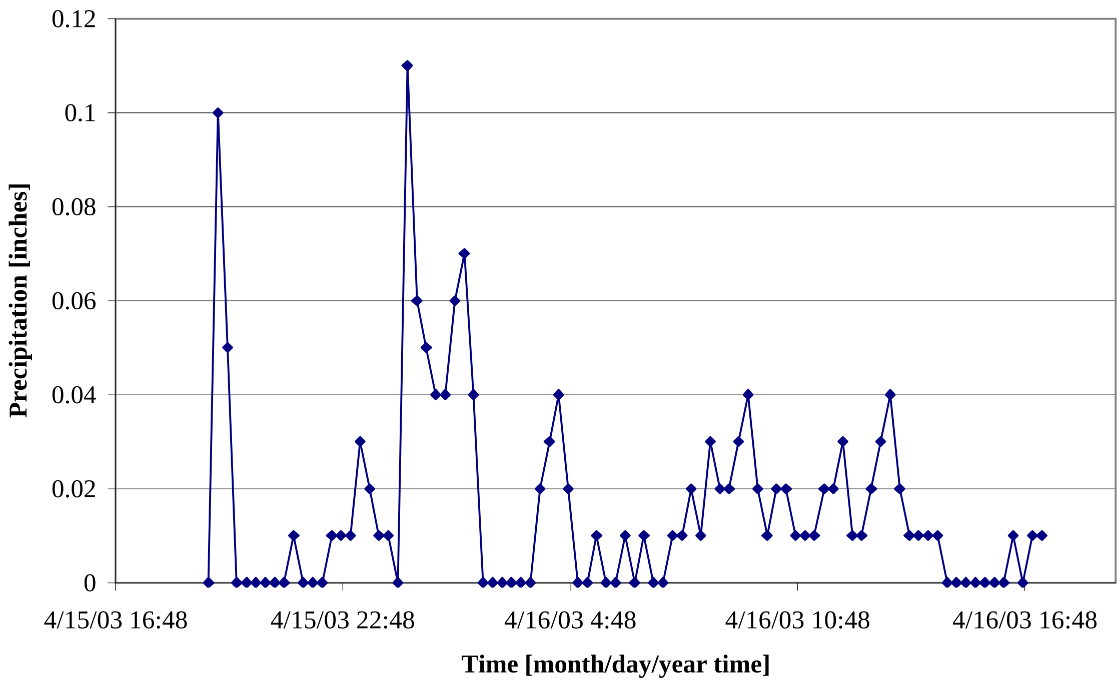


Figure IV-2. May 9-11 Rainfall Distribution

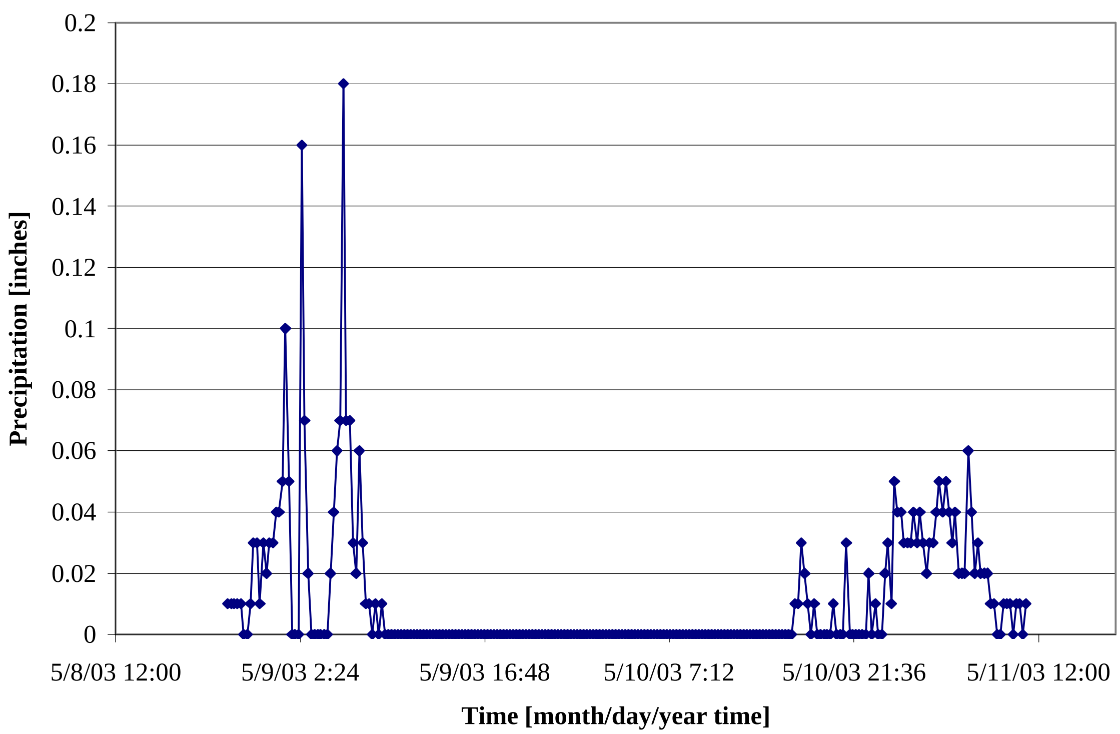


Figure IV-3. June 6 Rainfall Distribution

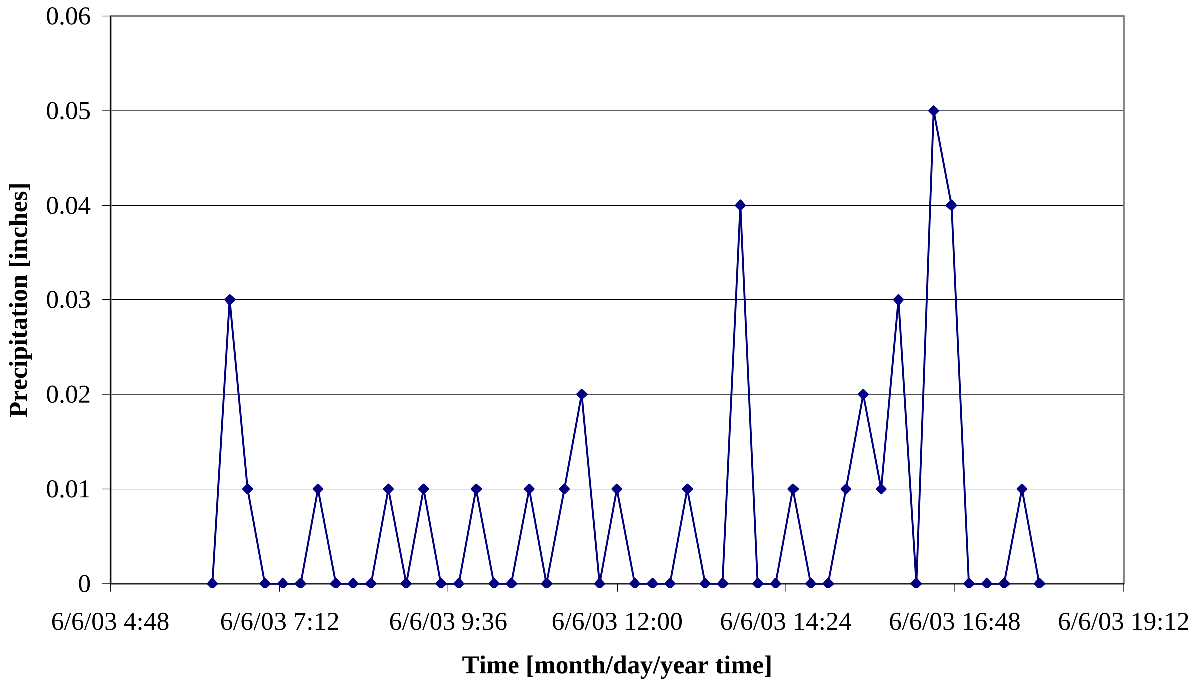
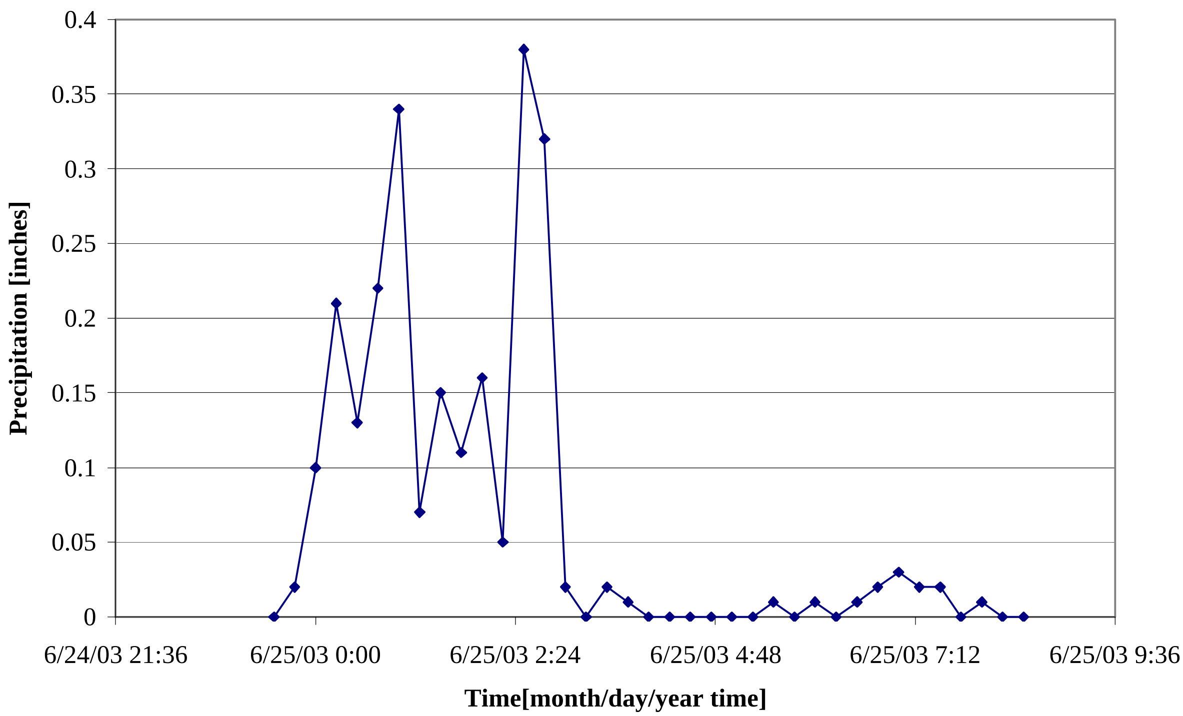


Figure IV-4. June 24-25 Rainfall Distribution



Basin Characteristics

Water levels at each basin and identified ponding events included in the CN analysis are presented in Figures IV-5 through Figure IV-7. Additional information on stage storage relationships, measured infiltration rates, and basin monitoring are summarized in Chapters II and III. The maximum height of ponded water within each basin during each precipitation event was used to calculate the volume of runoff delivered. The actual volume of runoff generated is likely higher than the volume used in this analysis due to infiltration occurring in the basins while the basin is filling. This will result in calculating lower than actual CN values.

Figure IV-5. CD-P50 Surface Water Elevations and Ponding Events

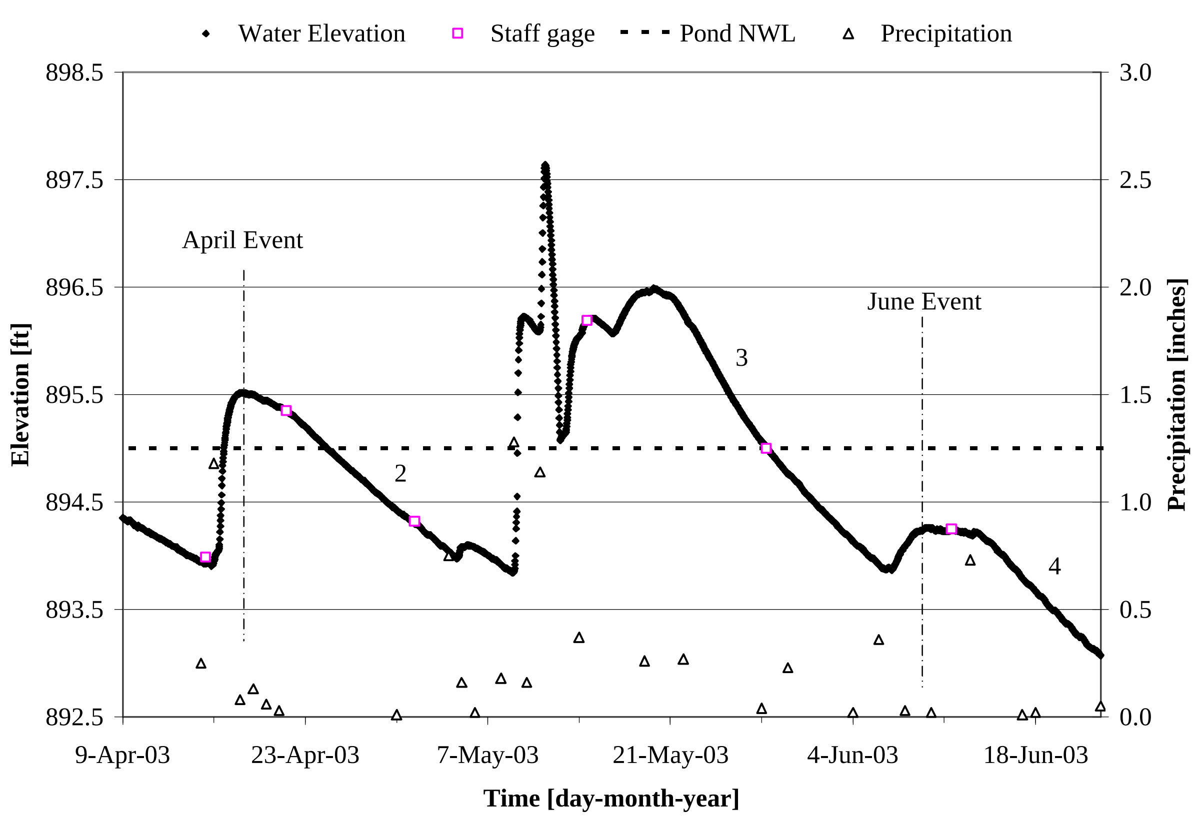


Figure IV-6. CD-P76 Surface Water Elevations and Ponding Events

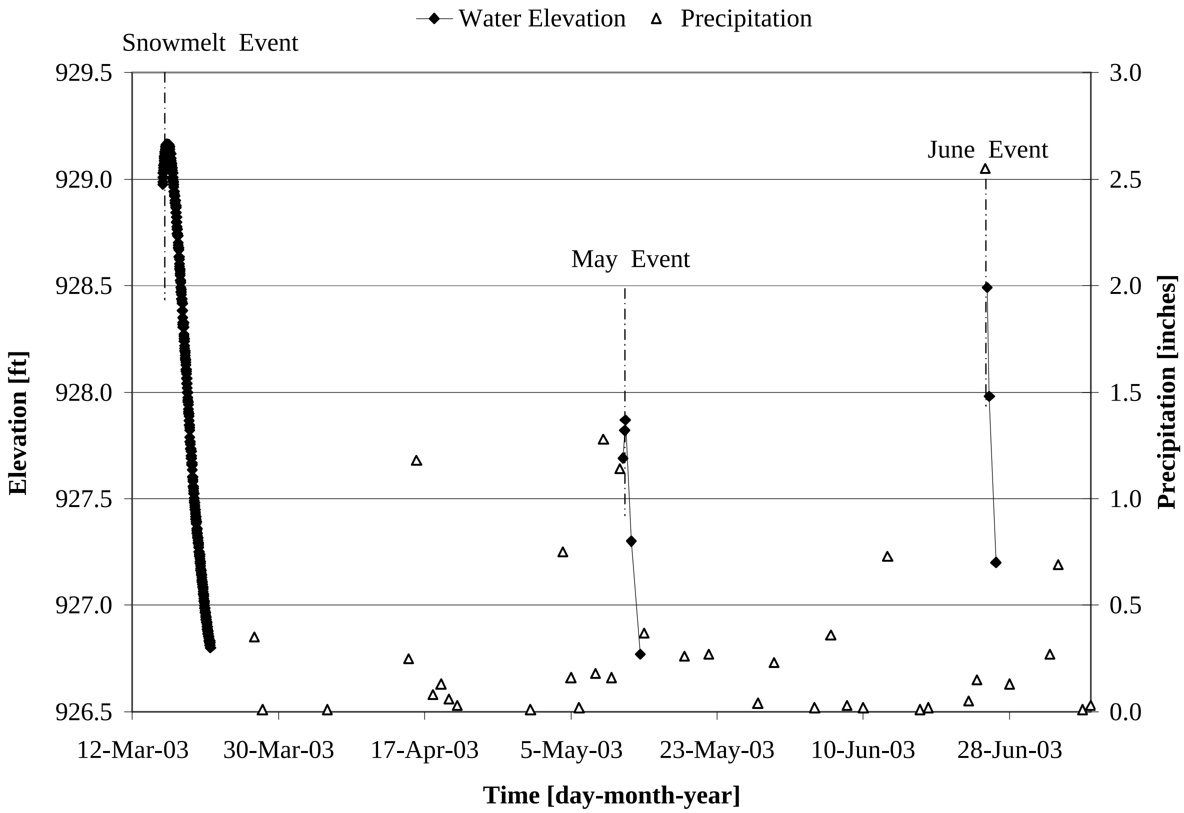
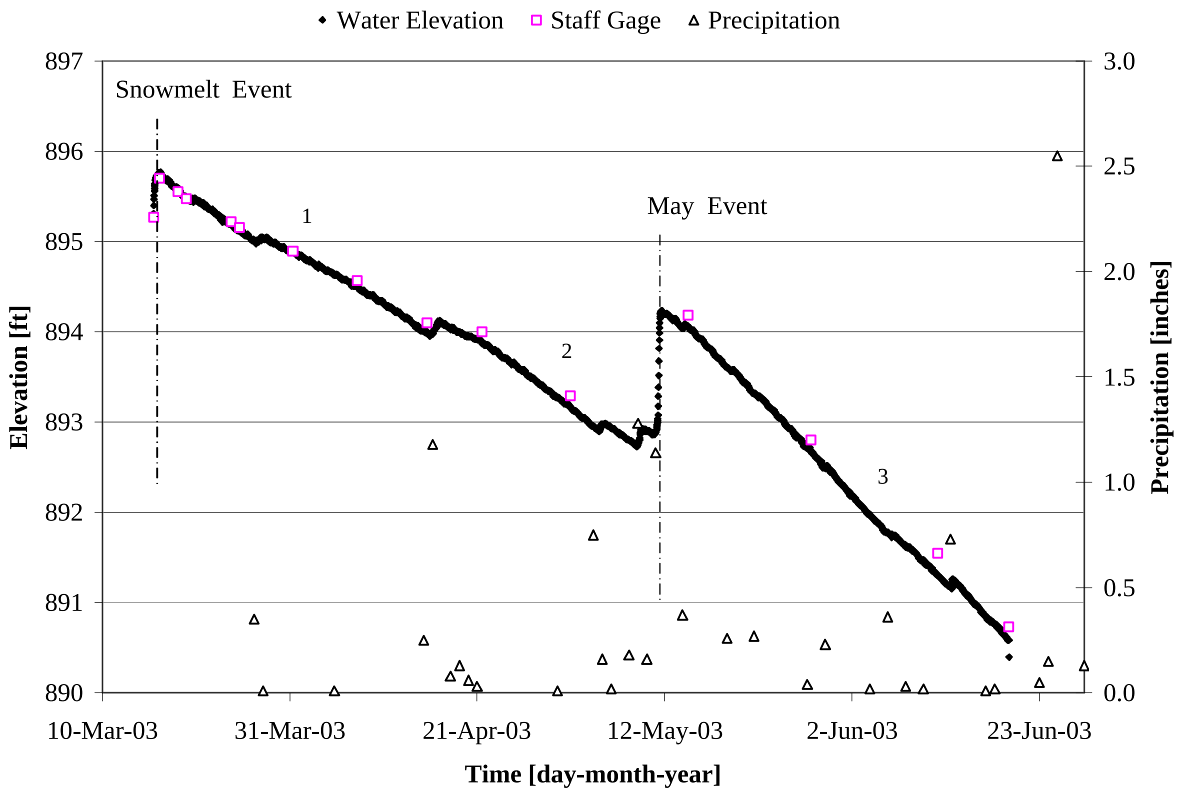


Figure IV-7. CD-P82 Surface Water Elevations and Ponding Events



Curve Number (CN) Calculations

Assigning a CN is a standard method to describe the amount of runoff occurring in a watershed. A CN is a parameter created by the Soil Conservation Service (SCS) that indicates the runoff potential for an area. CNs range from 0-100 where zero indicates that precipitation will not result in any runoff and 100 indicates that all precipitation results in runoff.

Surface water level data collected at CD-P50, CD-P76, and CD-P82 were used to determine the volume of runoff delivered to the basin under different measured hydrologic scenarios. Both spring snowmelt and summer rainfall events were used in this analysis to provide a CN value for a variety of precipitation events. The CN for each watershed was calculated using the equations for the SCS curve number approach as published by the U.S.D.A., 1972.

The SCS estimates the runoff depth by the equation

$$Z = (P-0.2S)^2 / (P + 0.8S) \qquad \text{(IV-1)}$$

where Z is the runoff depth in inches, P is the accumulated precipitation, and S is the maximum soil water retention parameter.

In our case the runoff depth, Z, can be calculated from the volume of runoff that reached the basins after each event. Dividing this volume of water by the subwatershed area yields the runoff depth in inches. Accumulated precipitation, P, was obtained from data collected by the SWWD. Solving for the maximum soil water retention parameter, S, and using the following relationship yields a CN value.

$$S = (1000 / CN) - 10 \qquad \text{(IV-2)}$$

Assumptions inherent in this method are that the depth of precipitation is greater than 0.2S. If the rainfall depth is less than 0.2S, then no runoff occurs and the equation is invalid. This assumption is reasonable in our case because we chose to only analyze events where runoff occurred, and therefore the rainfall depths were greater than 0.2S.

The condition of the soil prior to the rainfall or snowmelt event influences the CN value. A soil that starts out wet will produce more runoff than a soil that starts out dry. To account for the amount of soil moisture before the events, each watershed is assigned an antecedent moisture condition (AMC) of I, II, or III. An AMC of I indicates that the soil is especially dry, and an AMC of III indicates that the soil is near saturation. An AMC of II is typically applied to cases where a single hypothetical event is modeled or the antecedent moisture conditions are normal.

Subwatershed Characteristics

Subwatershed data are presented in Table IV-2. The condition of the soils varied prior to each event. All CN values were calculated using an AMC value of II. Soils were significantly wetter prior to the May 10-11 rainfall event when compared to the other events. However, the amount of precipitation during the 5 days prior to the May 10-11 rainfall event did not exceed the standard greater than 2.1 inches of rainfall to justify using a different AMC.

Table IV-2. Subwatershed Characteristics

Subwatershed Name	**Event**	**Runoff Volume Delivered to Pond** [acre-ft]	**Subwatershed Area** [acre]	**Depth of Runoff over Subwatershed** [inches]
CD-P50	April	2.096	725.1	0.035
	June 6	0.498	725.1	0.008
CD-P76	Snowmelt	5.978	479.4	0.150
	May	1.246	479.4	0.031
	June 24-25	3.369	479.4	0.084
CD-P82	Snowmelt	7.117	271.8	0.314
	May	1.644	271.8	0.073

IV-B. RESULTS

Table IV-3 summarizes the results for each basin and includes the average calculated CN for snowmelt and non-snowmelt events for each subwatershed. By calculating the CN value for these subwatersheds, a database is developed on which to base assumptions used in watershed hydrologic/hydraulic models. Using calculated CN values for these subwatersheds, and possible applying them to similar subwatersheds, will lead to a more accurate representation of existing conditions in watershed hydrologic/hydraulic models.

Snowmelt CN values were 45 and 54 for the CD-P82 and CD-P76 subwatersheds, respectively. The CN value did not change from the snowmelt to non-snowmelt events at CD-P76 and is lower during snowmelt at CD-P82. These results conflict with traditional assumptions that typically assume a curve number between 90 and 100 during snowmelt events.

Table IV-3. Calculated Subwatershed Curve Numbers

Subwatershed Name	2003 Event	Curve Number	Average Curve Number
CD-P50	April	50	59
	June 6	68	
CD-P76	Snowmelt	54	54
	May	52	54
	June 24-25	56	
CD-P82	Snowmelt	45	45
	May	48	48

V. Climatic Conditions

The climatic conditions in the watershed during data collection at the four regional infiltration basins and the Math and Science Academy are summarized below. Precipitation and climatic data were obtained from the National Weather Service station in Stillwater, MN. Local climatic data collected between March and October were also included in the analysis.

Winter and Spring Climatic Data

Figure V-1 compares the average monthly temperature for the 2002-2003 winter season to the average monthly temperatures for the last 40 years. An analysis of the average monthly temperature records for the Stillwater area shows that the average temperatures for 2003 were above the long-term average for that weather station. The average temperature for the 2002-2003 December-March time period was 24.9 degrees Fahrenheit, 16 percent above the 40-year temperature average of 20.9 degrees Fahrenheit over the same time period with the month of December having the highest deviation from the average.

Figure V-1. Average Monthly Temperatures from December to March as Reported by the State Climatology Office in Stillwater, MN.

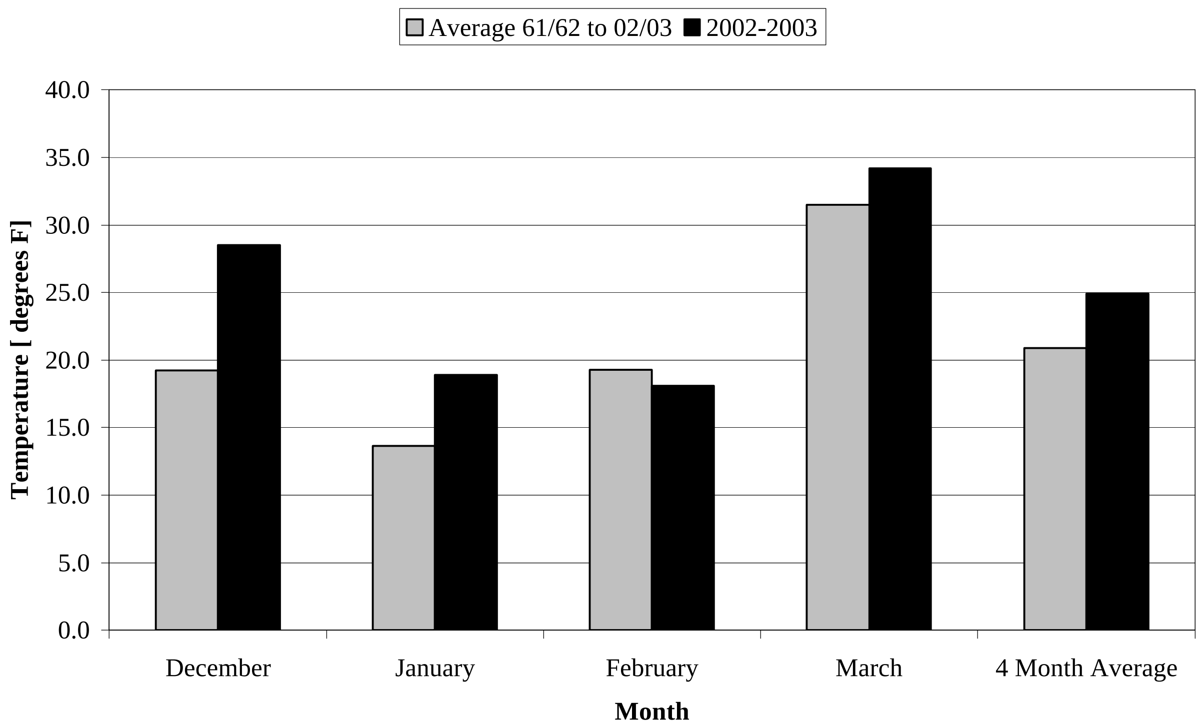
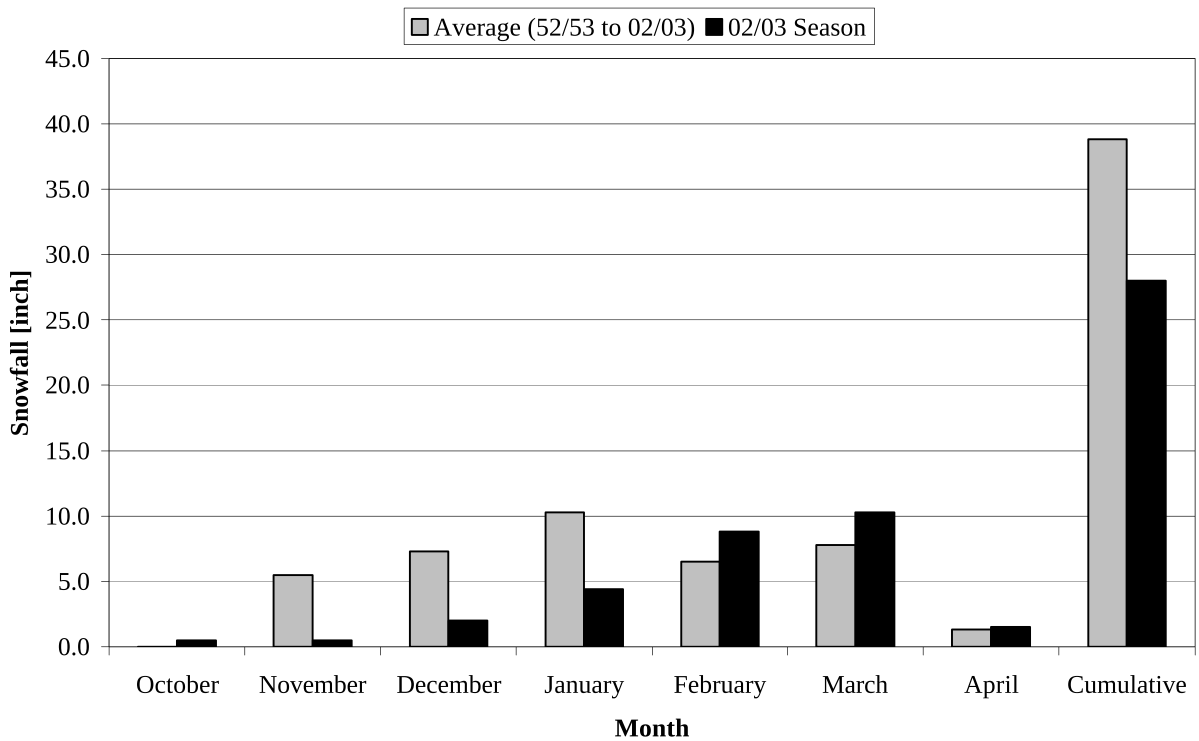


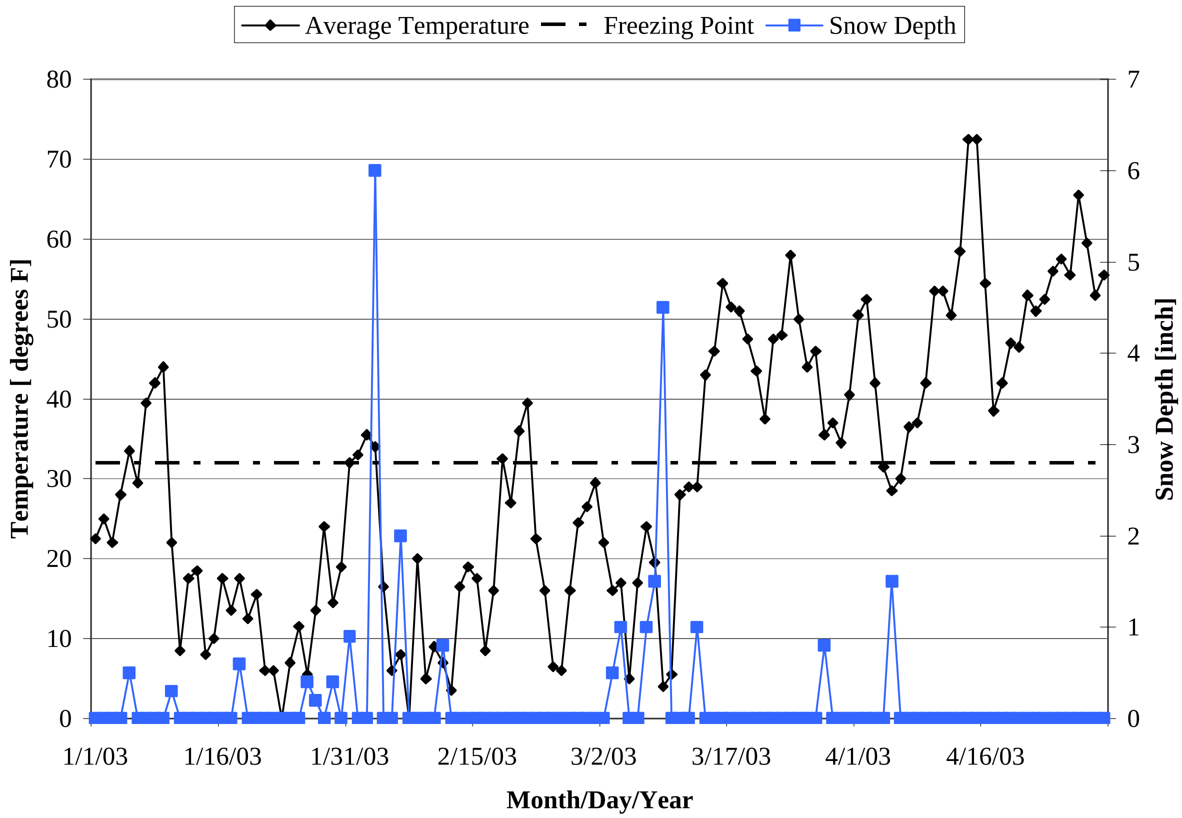
Figure V-2 shows the average total snowfall recorded at the State Climatology Office located in Stillwater, MN. The graph compares the monthly snowfall totals for the 2002–2003 season to the average monthly snowfall totals over the last 50 years for the same months. The total snowfall for the 2002-2003 season was 28 inches, 28 percent below the 50-year snowfall average of 38.8 inches for the same months. March received the largest amount of snow over the 2002-2003 seasons with 10.3 inches of snow.

Figure V-2. Snowfall Totals from October to April as Reported From the State Climatology Office in Stillwater, MN.



Average daily temperatures and average snow depth are shown in Figure V-3 from January to April, 2003. A series of warming trends during January and February melted all of the snow pack that had accumulated. Early March snowfalls accumulated within the watershed and remained until a final warming trend began in mid March that resulted in the start of the spring snow melt.

Figure V-3. Daily Temperature and Snow Depth from January to April, 2003 as Reported from the State Climatology Office in Stillwater, MN.



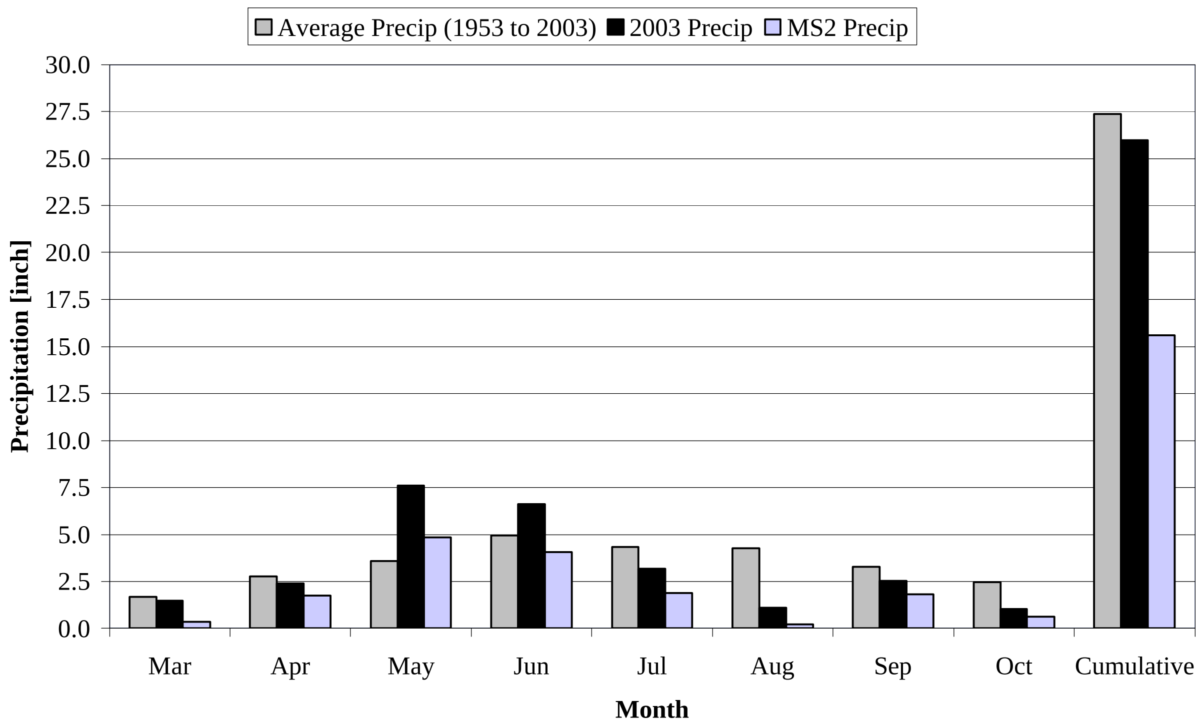
Summer Climatic Data

Figure V-4 compares the 2003 total monthly precipitation recorded at the State Climatology Office in Stillwater, MN and the SWWD Monitoring Station 2 (MS2) to the average monthly precipitation recorded over the last 50 years from the Stillwater station. Based on Stillwater precipitation data, total precipitation for the months of March through October of 2003 was equal to 25.97 inches, 5 percent below the 50-year average (27.4 inches) over the same time period.

Local precipitation data collected at MS-2 located on Bailey Road near Bailey Lake was significantly lower than the Stillwater station data. Based on MS-2 data, total precipitation for the months of March through October of 2003 was equal to 15.61 inches, 40 percent below the 2003 total precipitation recorded at the Stillwater station (25.97 inches) and 43 percent below the

50-year average (27.4 inches) over the same time period. Precipitation recorded from MS-2 was below the 50-year average for every month except May. The month of August provided the greatest deviation from the MS-2 station data with a difference of 4.07 inches of precipitation from the 50-year average.

Figure V-4. Monthly Precipitation Totals from March to October as Reported from the State Climatology Office in Stillwater, MN and the Washington Conservation District.



VI. Conclusions and Recommendations

VI-A. INFILTRATION ENVELOPES

Infiltration envelopes were developed for each of the four basins and two trenches monitored in 2003. These envelopes are a compilation of data collected between 1997 and 2003. The envelope consists of the outer edges of the data set and is represented by a line. Due to the number of data points collected at each basin, both the spring and summer infiltration data are presented together.

The methodology used to plot the envelopes has been modified to provide additional detail. For each basin, the infiltration rates and elevations for each drawdown event are presented on one figure. In previous SWWD infiltration monitoring reports, the average annual infiltration rates were presented, as opposed to the individual events. Since more data are now available, it was useful to utilize the entire dataset to determine the infiltration envelopes. The infiltration envelopes represent the range of infiltration rates that can be expected for each basin, at each 0.5 foot elevation interval. In most cases, the curves represent the highest and lowest infiltration rates measured. However, some clear outliers existed, and these were not included in the infiltration envelope.

A table is presented for each basin and trench with the average infiltration rate and range. The average infiltration rate was calculated by first averaging the infiltration rates at each elevation interval, then taking an average of these averages. The range of rates indicates the high and low value within the infiltration envelope. These values are useful for application in similar settings.

CD-P50

CD-P50 has been monitored since 1999. Figures VI-1 through VI-2 present the infiltration rates and volumetric infiltration rates at corresponding elevations of the basin for five years of data. The data collected in 2003 lie within the expected range of values based on previous year's data.

Figure VI-1. Infiltration Rate vs. Elevation for CD-P50 1999-2003 and Infiltration Envelope

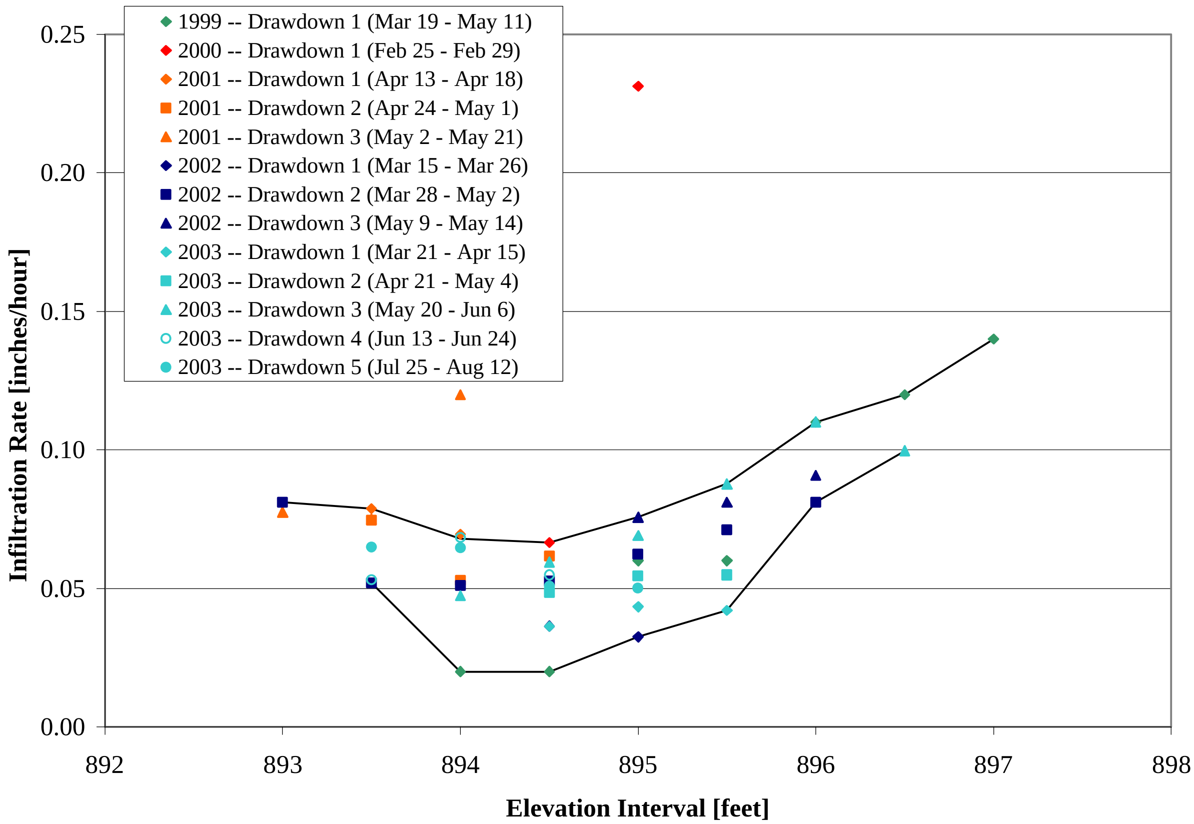


Figure VI-2. Volumetric Infiltration Rate vs. Elevation for CD-P50 1999-2003 and Infiltration Envelope

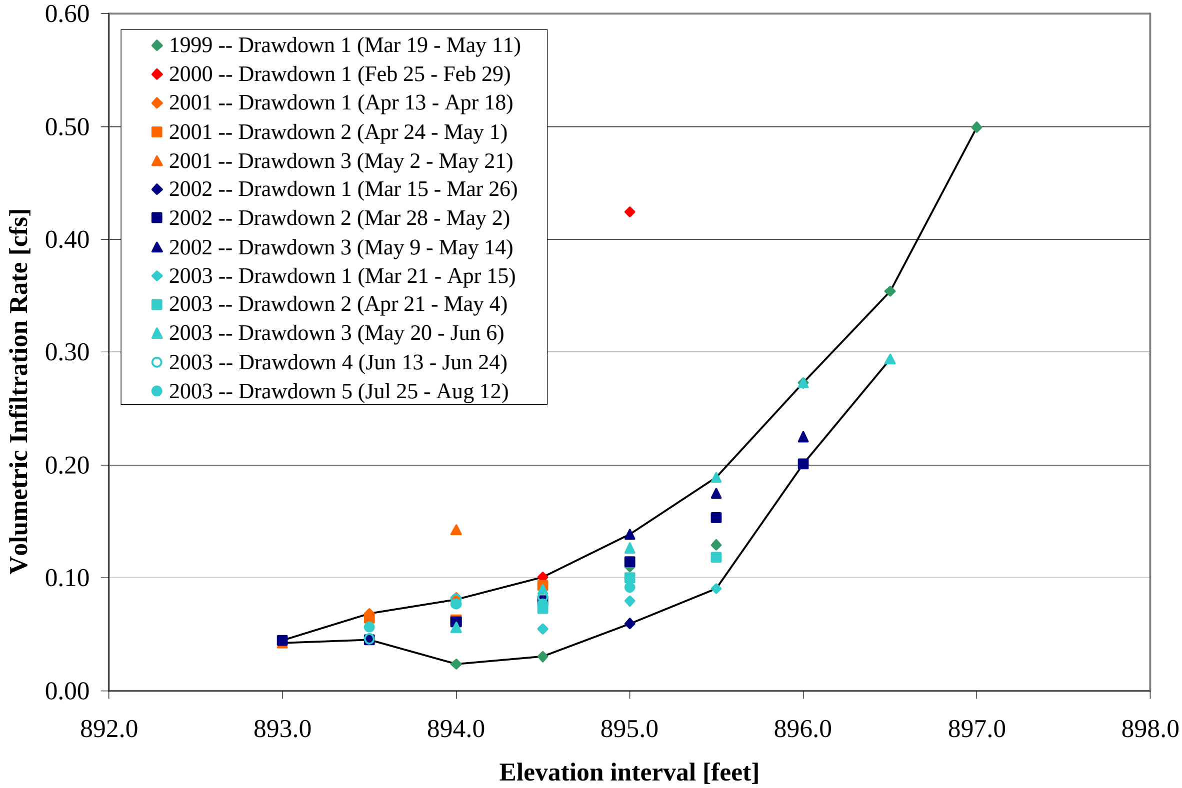


Table VI-1. CD-P50 Average Infiltration Rate and Range, 1999 - 2003

	Average Rate	Rate Range
Infiltration Rate [inches/hour]	0.08	0.020 – 0.14
Volumetric Infiltration Rate [cfs]	0.17	0.024 – 0.50

CD-P76

CD-P76 has been monitored since 1999. Figures VI-3 and V-4 present the infiltration rates and volumetric infiltration rates at corresponding elevations of the basin for five years of data. Most of the data collected in 2003 lie within the expected range of values with the exception of Drawdown 3 with resulted in the highest infiltration rates calculated to date at several elevation intervals.

Figure VI-3. Infiltration Rate vs. Elevation for CD-P76 1999-2003 and Infiltration Envelope

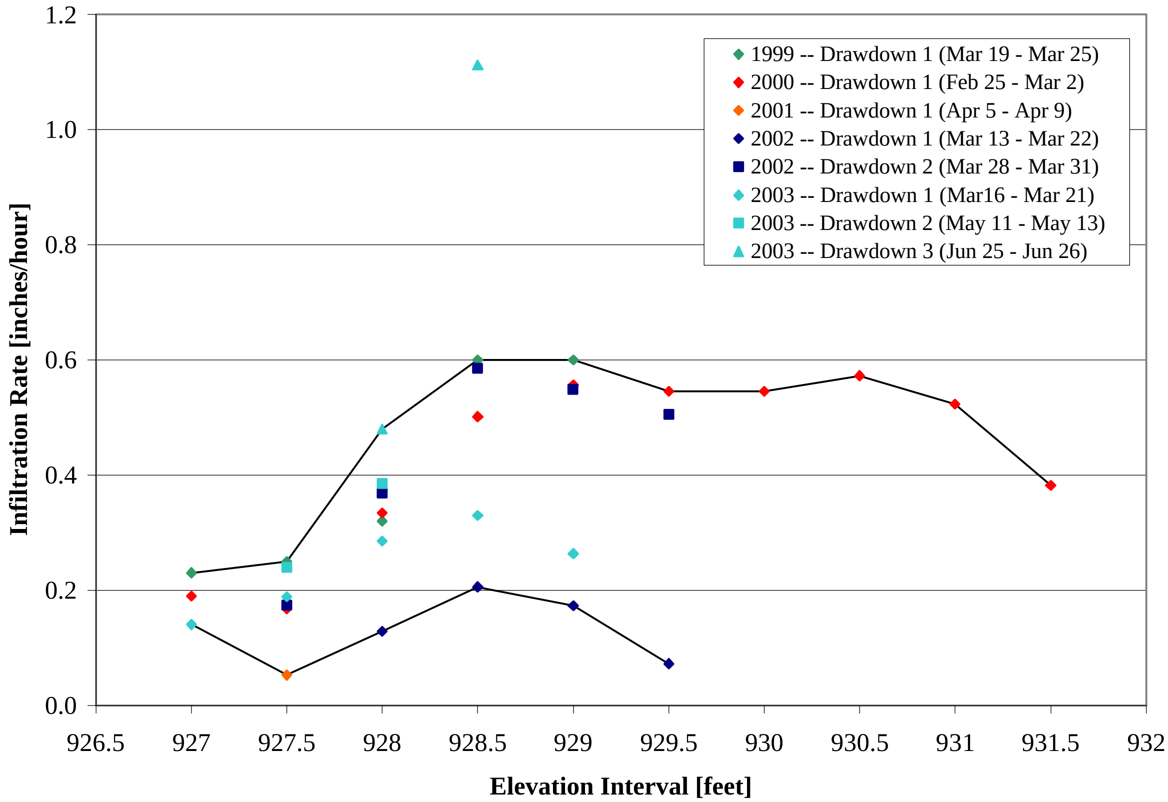


Figure VI-4. Volumetric Infiltration Rate vs. Elevation for CD-P76 1999-2003 and Infiltration Envelope

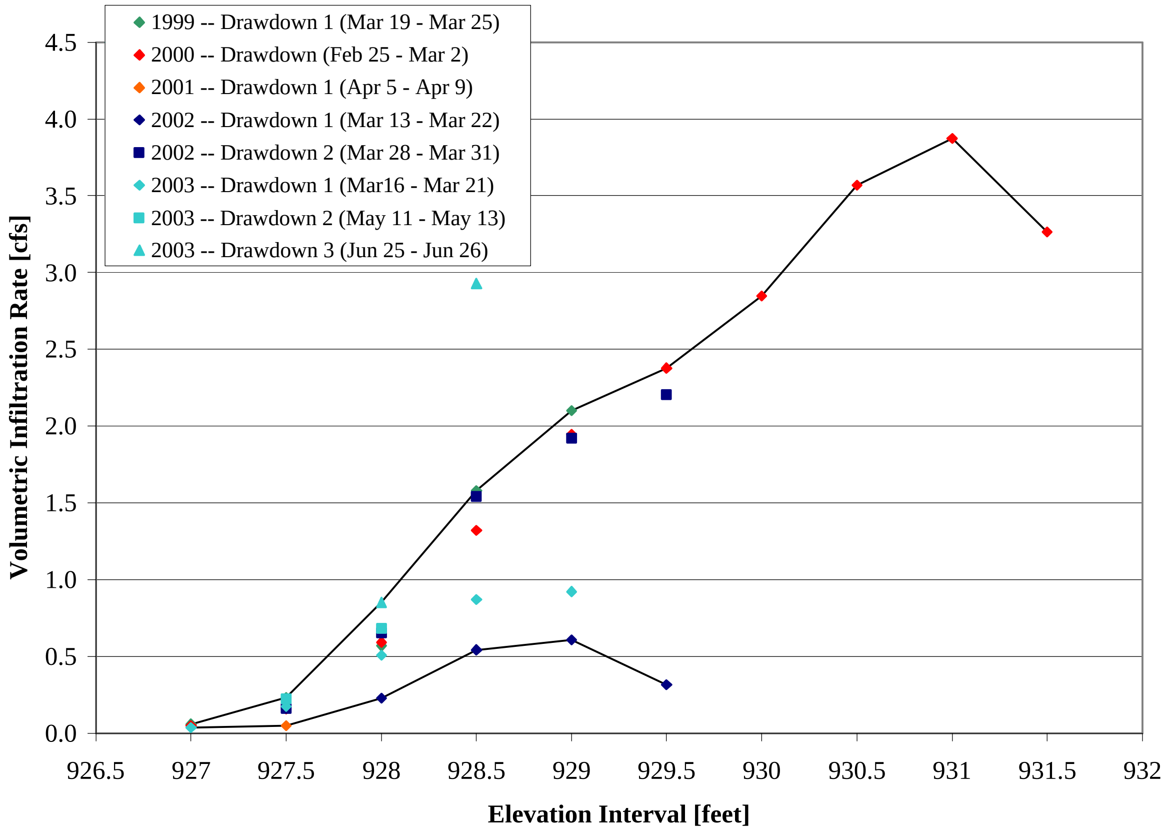


Table VI-2. CD-P76 Average Infiltration Rate and Range, 1999 - 2003

	Average Rate	**Rate Range**
Infiltration Rate [inches/hour]	0.41	0.053 – 0.60
Volumetric Infiltration Rate [cfs]	1.9	0.035 – 3.87

CD-P82

CD-P82 has been monitored since 1999. Figures VI-5 and VI-6 present the infiltration rates and volumetric infiltration rates at corresponding elevations of the basin for five years of data. The data collected in 2003 fit within the expected range of values.

Figure VI-5. Infiltration Rate vs. Elevation for CD-P82 1999-2003 and Infiltration Envelope

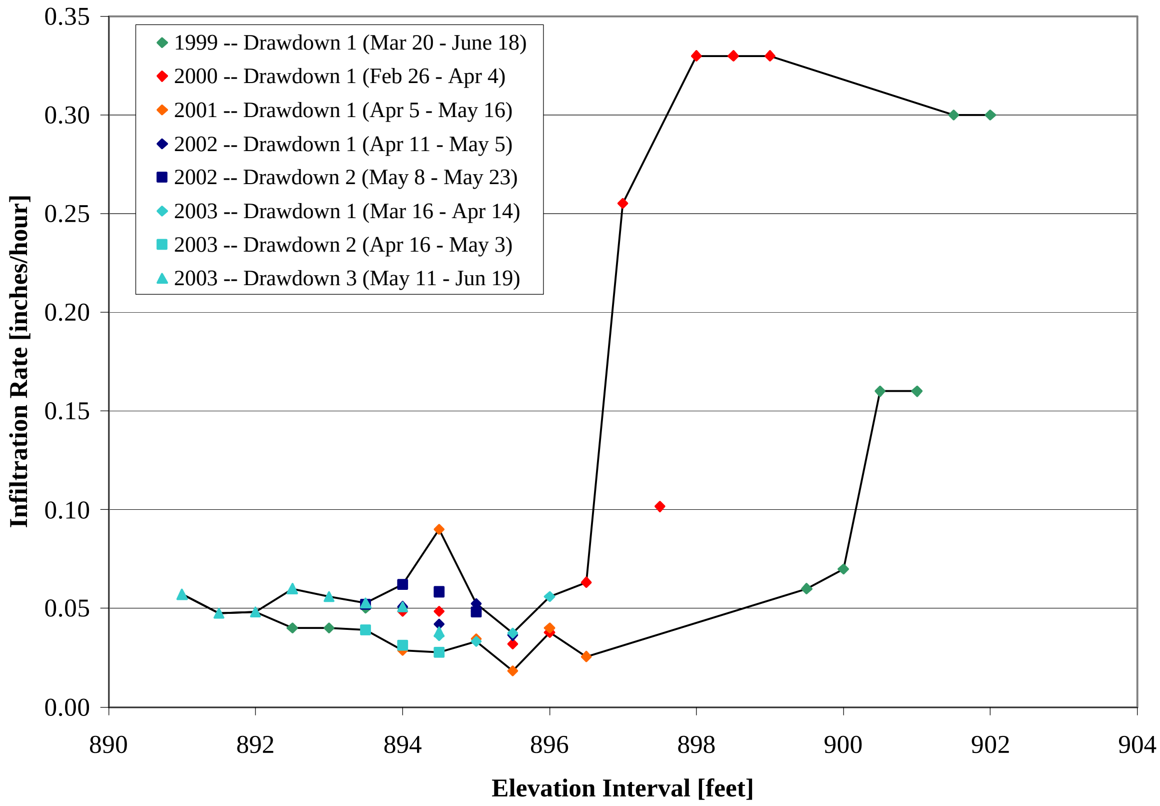


Figure VI-6. Volumetric Infiltration Rate vs. Elevation for CD-P82 1999-2003 and Infiltration Envelope

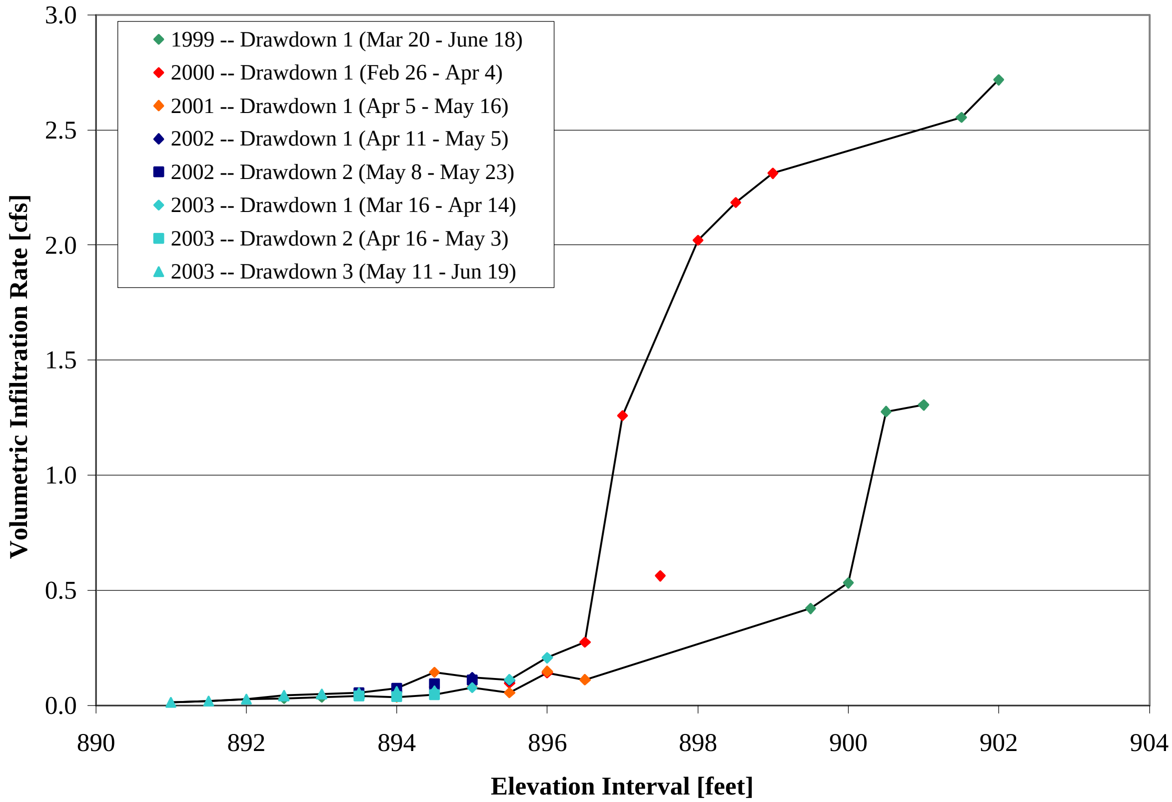


Table VI-3. CD-P82 Average Infiltration Rate and Range, 1999 - 2003

	Average Rate	Rate Range
Infiltration Rate [inches/hour]	0.13	0.018 - 0.33
Volumetric Infiltration Rate [cfs]	0.78	0.013 - 2.72

CD-P85

CD-P85 has been monitored since 1997. Compiled infiltration rate data are presented on Figures VI-11 and VI-12. Due to the shear number of data points, not all draw downs are presented. Typically, two draw downs per year are presented for data collected prior to 2001 that represent the highest and lowest measured rates. The data collected in 2003 fit within the expected range of values.

Figure VI-7. Infiltration Rate vs. Elevation for CD-P85 1997-2003 and Infiltration Envelope

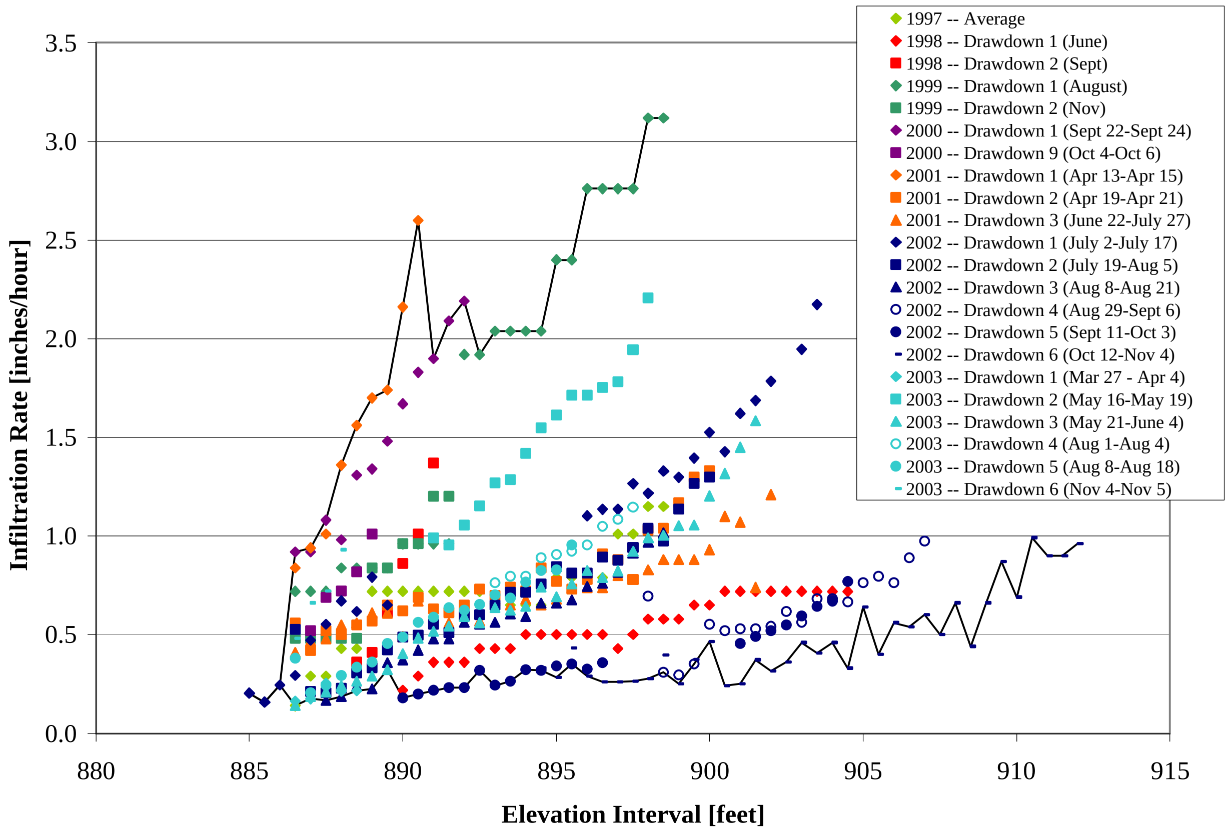


Figure VI-8. Volumetric Infiltration Rate vs. Elevation for CD-P85 1997-2003 and Infiltration Envelope

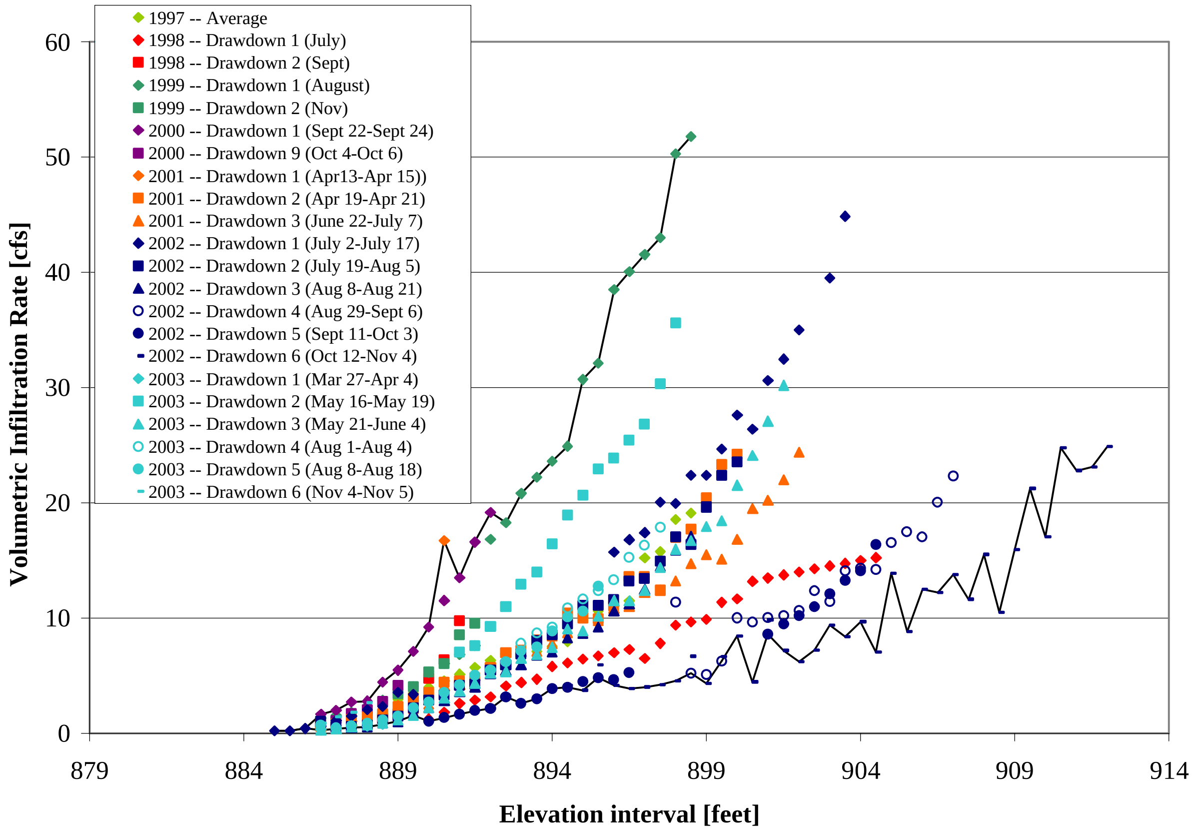


Table VI-4. CD-P85 Average Infiltration Rate and Range, 1997 - 2003

	Average Rate	Rate Range
Infiltration Rate [inches/hour]	0.76	0.14 - 3.12
Volumetric Infiltration Rate [cfs]	12	0.21 - 51.80

Infiltration Trenches

Data have been collected at the MSA trench since 2001. The infiltration trench at CD-P85 has been monitored since 1999, although data were not collected during 2001. Figure VI-9 presents the data collected at the CD-P85 trench since 1999. The rates of water level decline calculated for the MSA trench since 2001 are presented in Figure VI-10. For much of the datasets, rates of water level decline were lower than previously measured for both sites. At CD-P85, this data continues a trend identified in 2002 of lower rates. An operation and maintenance plan should be developed to assess and mitigate the causes for the decrease in rates of water level decline at each trench. Typically, maintenance is required for infiltration trenches every 5 years, dependent on performance. The trend of decreased performance during 2002 and 2003 identifies the need for maintenance at CD-P85.

Figure VI-9. Rate of Decline vs. Depth for CD-P85 Trench, 1999-2003

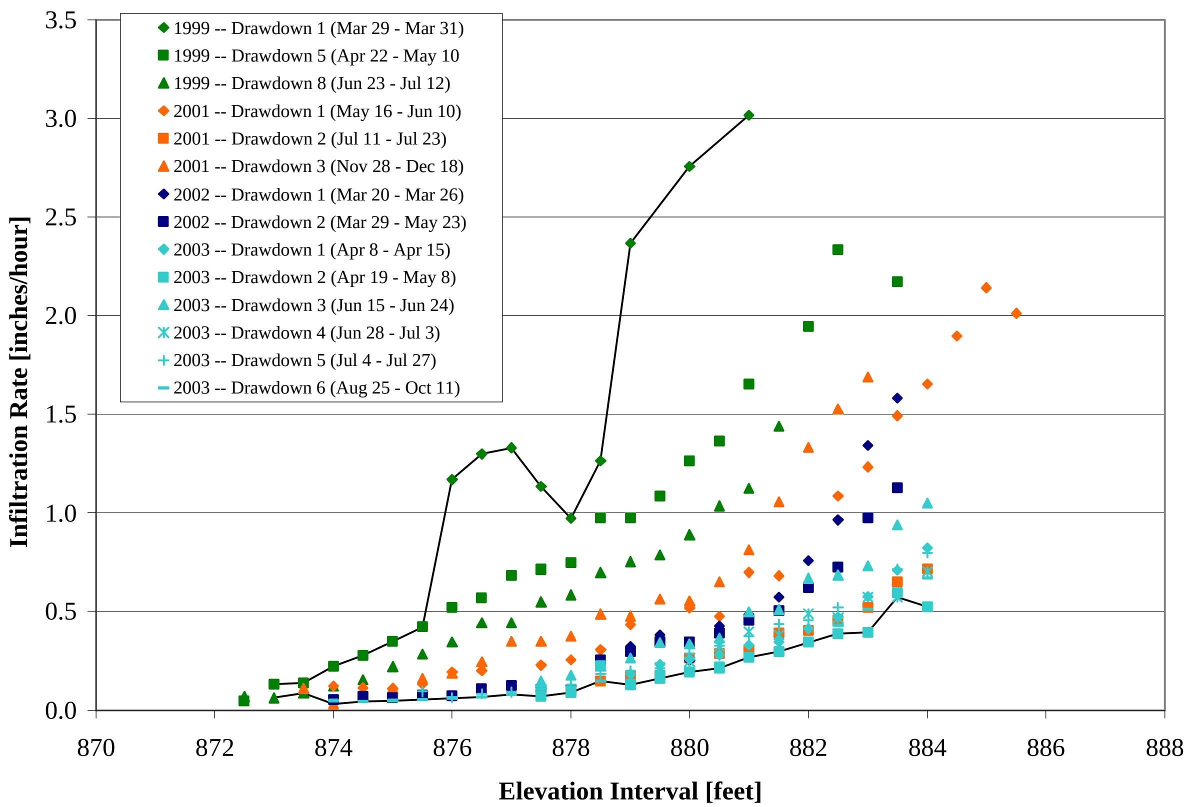


Table VI-5. CD-P85 Trench Average Infiltration Rate and Range, 1999 - 2003

	Average Rate	Rate Range
Infiltration Rate [inches/hour]	0.62	0.032 – 3.02

Figure VI-10. Rate of Decline vs. Depth for MSA Trench, 2001-2003

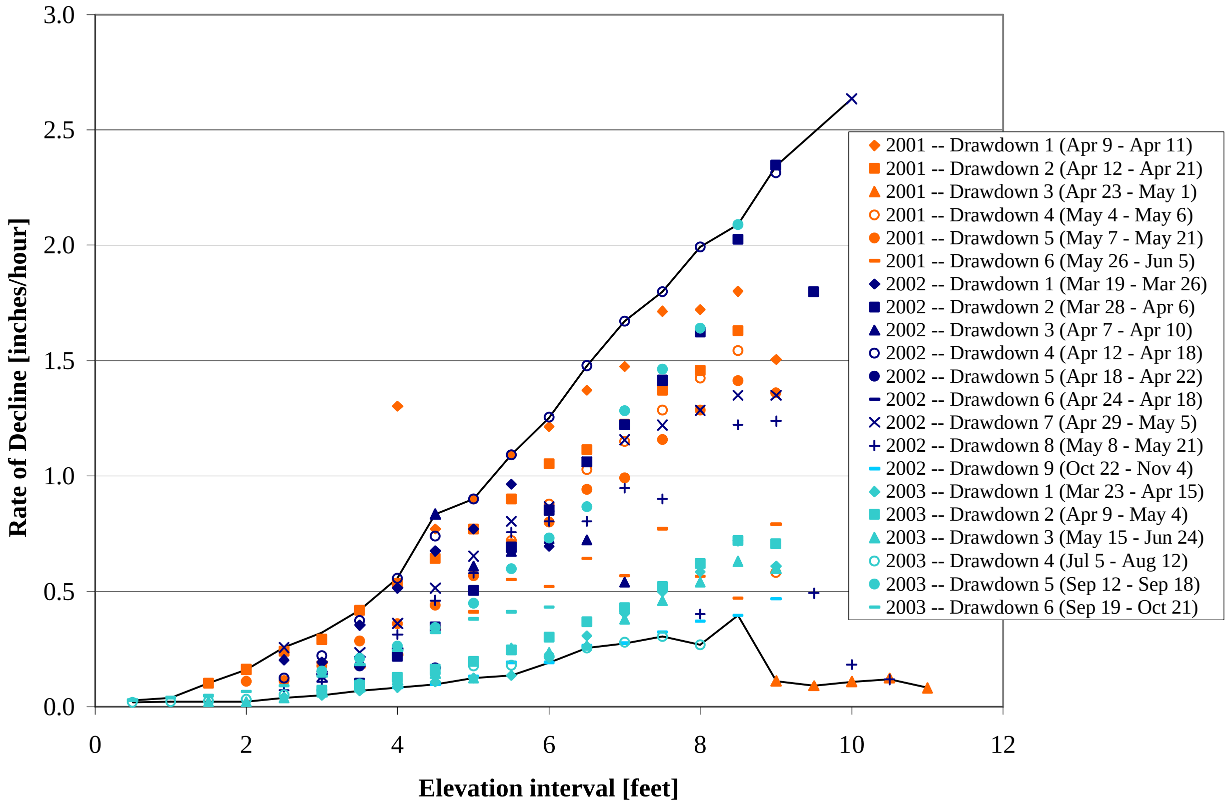


Table VI-6. MSA Trench Average Infiltration Rate and Range, 2001 - 2003

	Average Rate	**Rate Range**
Infiltration Rate [inches/hour]	0.52	0.020 – 2.64

VI-B. OVERALL CONCLUSIONS AND RECOMMENDATIONS

Overall Conclusions

1. Infiltration rates measured at CD-P50, CD-P76, CD-P82, and CD-P85 fell within the expected range of values.
2. Rates of water level decline at infiltration trenches at CD-P85 and the Math and Science Academy were generally lower than previously measured. A plan should be developed to further assess and mitigate the decline in performance at the CD-P85 infiltration trench.

3. Water quality analyses resulted in numerous surface and groundwater samples exceeding the drinking water Health Risk Limit for manganese. This element is naturally occurring and commonly found within surface and groundwater in southern Washington County. Surface and groundwater quality analysis indicates that infiltrating surface water is not negatively affecting the groundwater.
4. Maintenance may be needed at the CD-P85 trenches to improve performance and ensure their long term viability.
5. Calibrated CN values for subwatersheds draining to CD-P50, CD-P76, and CD-P82 can be used to refine existing watershed models.
6. CN values calculated for snowmelt runoff within subwatersheds draining to CD-P76 and CD-P82 did not vary significantly from non-snowmelt calculated CN values.

Overall Recommendations

Surface Water Monitoring

1. Continue to monitor water levels and infiltration rates at CD-P50, CD-P76, CD-P82, CD-P85, and MSA and CD-P85 trenches.
2. Continue to collect surface water and groundwater chemistry data at each monitored basin throughout the year.
3. Implement the MetroEnvironment Partnership Grant awarded to the SWWD in 2003 for additional water quality monitoring at the Math and Science Academy.
4. Include additional depressions in the overall monitoring program. Consider monitoring one to three basins within the East Cottage Grove Ravine or subwatersheds BL1W, BL4E or BL1E.
5. Develop a monitoring program for Park High School Infiltration Demonstration Project.

Groundwater Monitoring

1. Continue to monitor groundwater levels in the watershed. Include all SWWD owned wells in annual monitoring program conducted by the Washington Conservation District.

2. Continue to monitor the effects of stormwater on groundwater quality through a sampling program that includes surface water and groundwater chemistry.
3. Abandon well at CD-P82 and explore possibility of obtaining ownership of Metropolitan Council well at this basin.
4. Explore possibility of obtaining ownership of additional wells currently owned by the Metropolitan Council located in key areas.
5. Install a minimum of one well at CD-P76, CD-P50, and CD-P82 to obtain additional information on groundwater flow, mounding and water quality.
6. Develop an enhanced groundwater monitoring network at CD-P85 and CD-P86 to include additional shallow monitoring wells, routine water quality sampling, and continuous water level monitoring.

Management Options and Techniques

1. Develop infiltration standards based on representative subwatersheds and incorporate into SWWD Rules.
2. Incorporate new monitored data and calibrated subwatershed analysis into the District's models for use in design and flood forecasting.
3. Develop operation and maintenance plan for infiltration basins, specifically CD-P85, in order to ensure available infiltration capacity during spring melt conditions.
4. Utilize temperature profiles at infiltration trenches, along with monitored infiltration data, to refine the existing unsaturated flow model at CD-P85 to quantify the number of trenches needed to mitigate frozen ground conditions under and deliver a firm infiltration flow capacity during frozen ground conditions. Incorporate this information into the Emergency Response Plan.
5. Determine the feasibility of using South Bailey Lake as an infiltration basin through sediment removal and management of Bailey Lake outlet to alleviate some of the groundwater mounding occurring at CD-P85. Identify additional opportunities upstream.
6. Using data collected since 2000, update and calibrate existing groundwater models for CD-P85 and CD-P86 to determine expected infiltration rates and extent of groundwater mounding as a result of management scenarios.

7. Use data collected at MS-1 and MS-2 to better determine the losses in the developed portion of the watershed and identify potential infiltration enhancements upstream of CD-P85. Improvements in the existing system could lead to less groundwater mounding at CD-P85 and would improve the safety and buffer within the system at a potentially low cost.
8. Develop signage and education materials for Math and Science Academy Infiltration Trench Demonstration Site.

APPENDIX A
PHOTO LOGS