



*2005 INFILTRATION
MONITORING PROGRAM
FINAL REPORT*

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Executive Summary

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 an 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:

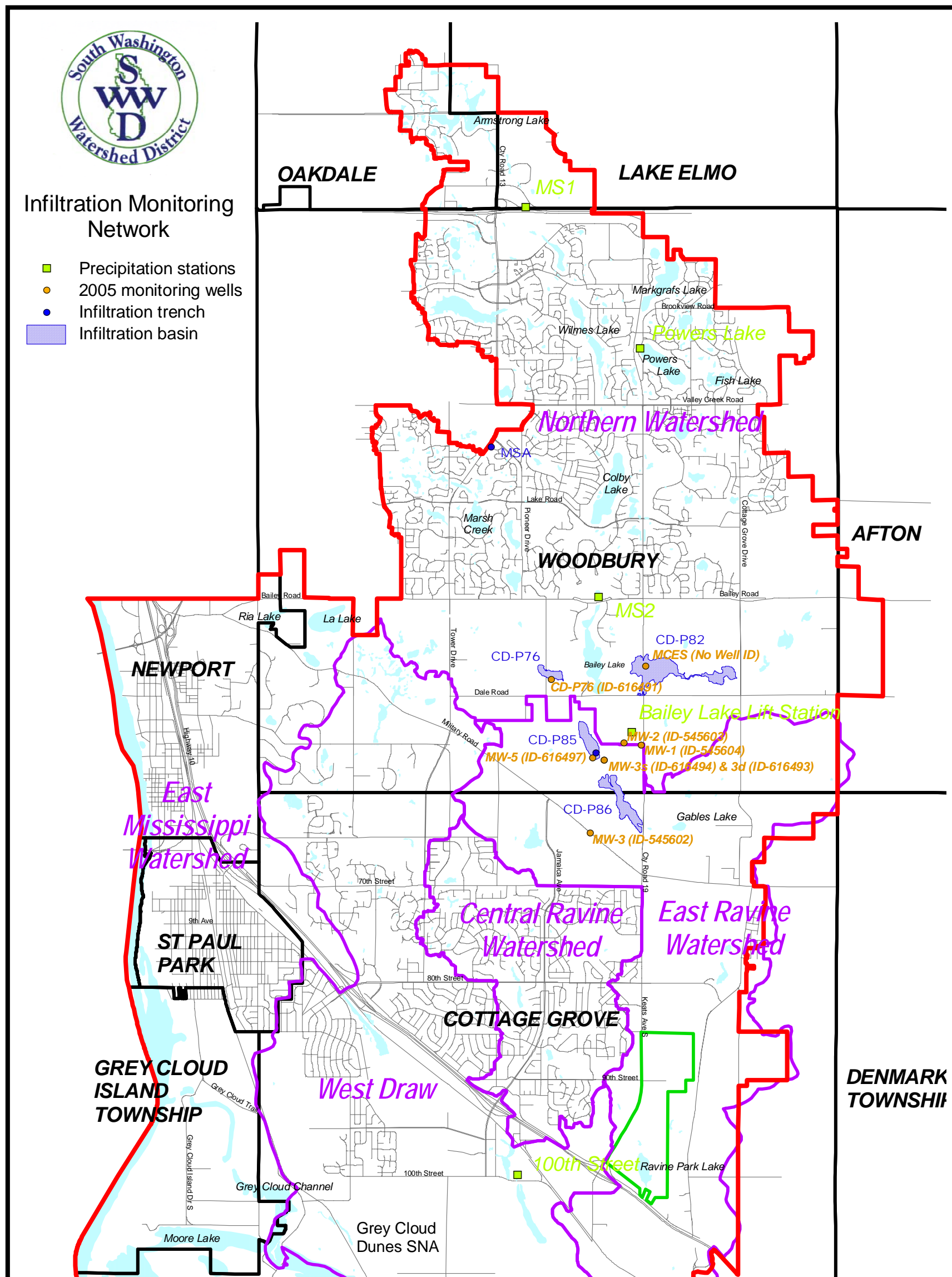
- SWWD IMS Progress Report, 1998;
- SWWD IMS Phase II Report, 2001;
- SWWD 2002 Infiltration Monitoring Report, 2003;
- SWWD 2003 Infiltration Monitoring Report, 2004; and
- SWWD 2004 Infiltration Monitoring Report, 2005.

Data were collected during 2005 at four natural infiltration basins including CD-P76, CD-P82, CD-P85 and CD-P86 and at two constructed infiltration trenches at CD-P85 and the Math and Science Academy (MSA). Figure 1 illustrates the location of monitoring sites in the SWWD.

The following analyses were conducted as part of the 2005 Infiltration Monitoring Program:

- Surface and groundwater chemistry;
- Groundwater mounding;
- 2005 infiltration rates and trend analysis;
- Subwatershed curve numbers; and
- Climatic conditions.

Figure 1. Infiltration Monitoring Network



Surface and Groundwater Chemistry

Surface water chemistry samples were collected at CD-P76, CD-P82, CD-P85, CD-P86, and the Math and Science Academy (MSA) during 2005. Groundwater samples were collected at CD-P82 and CD-P85 during 2005. These data are used to determine the interaction of infiltrating surface waters and groundwater quality, and to identify potential impacts or threats. During 2005, select surface water chemistry samples exceeded the Health Risk Limits (HRL) set by the Minnesota Department of Health (MDH) for manganese at CD-P82, CD-P86, and the MSA. This element is naturally occurring in the soils and is commonly found within surface and groundwater in southern Washington County. No other analyzed parameters in the surface waters exceeded drinking water standards. Copper was measured above the MPCA Class 2B Waters Chronic Standard in select surface water samples at CD-P76, CD-P85, and the MSA. Over the last few years, elevated levels of copper have been found in many surface water samples in all the basins, but it is unknown what is causing this trend.

Groundwater samples were collected in shallow monitoring wells adjacent to CD-P82 and CD-P85. Numerous groundwater samples collected at CD-P82 and CD-P85 (MW-2 and MW-3) contained nitrate concentrations greater than 5 mg/L and one sample from MW-3 exceeded the MDH HRL of 10 mg/L. A review of available surface and groundwater quality data indicates that surface water infiltrating within the basins and trenches is not negatively affecting the groundwater.

Groundwater Mounding

Data on shallow groundwater levels beneath infiltration areas were collected at CD-P82 and CD-P85. These data identify any groundwater mounding that is taking place beneath the infiltration area as a result of infiltration. In 2005, groundwater mounds were measured at CD-P82 and CD-P85, both of which correlated to high water levels in the infiltration areas. Groundwater mounding at CD-P85 was significant following several pumping events after an early October storm event. Groundwater levels in MW-5, the closest well to CD-P85, tracked very closely to surface water levels within the basin. The groundwater mound measured within MW-5 intersected the bottom of CD-P85 around October 10 and remained above the bottom of the basin until early November.

2005 Infiltration Rates

Surface water level data were collected at CD-P76, CD-P82, CD-P85, CD-P86, and the trenches at CD-P85 and the MSA. This was the first year of data collection at CD-P86 and due to the low number of data points collected, select analyses were not performed for this basin. Water level data at each of the sites were analyzed and infiltration rates or rates of water decline were calculated. Precipitation data used in conjunction with the analyses for CD-P76, CD-P82, CD-P85, and CD-P86 were obtained from the Bailey Lift station and analyses performed on MSA used precipitation data collected from the MSA station. These precipitation data sets are included within the figures throughout the report.

These rates were then compared to previously measured rates and the infiltration envelopes were updated with the new datasets. Infiltration envelopes represent the ranges of infiltration rates observed within a basin or trench at each elevation interval, and can be used to predict infiltration rates at a basin for which infiltration monitoring data do not exist. Average rates at each basin or trench were then calculated.

CD-P76

Monitored surface water elevations at CD-P76 during 2005 are illustrated in Figure 2. Figure 3 shows the revised infiltration envelope and Table 1 includes the average measured infiltration rates at CD-P76. Rates at several elevations in 2005 were greater than the previous infiltration envelope.

Figure 2. CD-P76 Water Elevation Versus Time. Numbers refer to drawdown events.

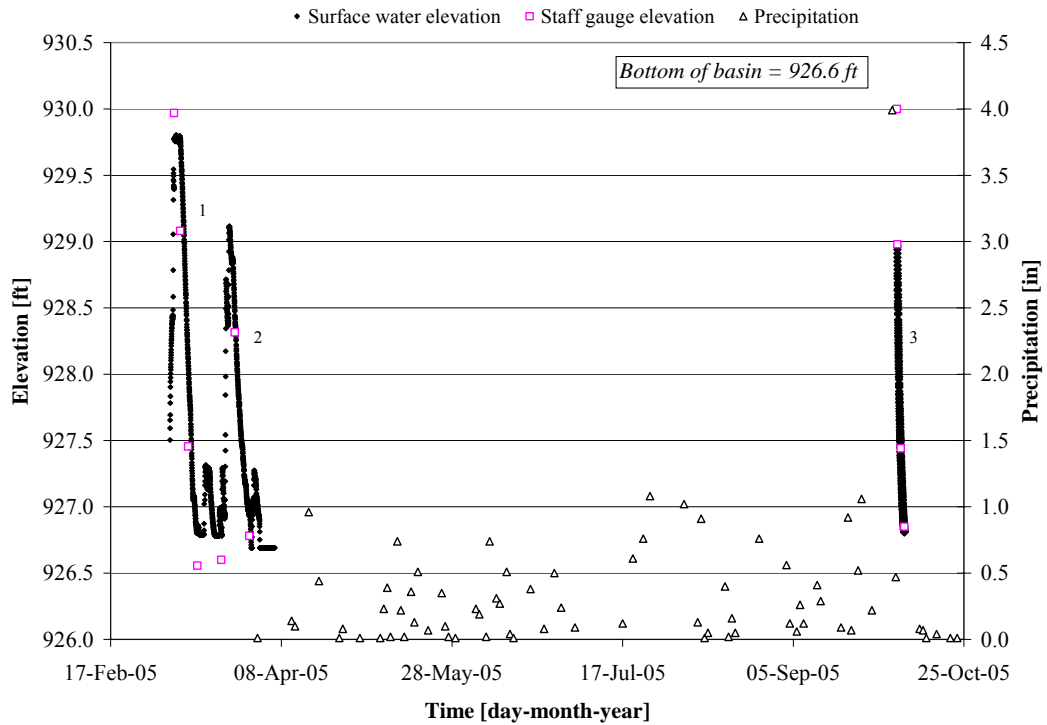


Figure 3. Infiltration Rate vs. Elevation and Infiltration Envelope for CD-P76, 1999-2005

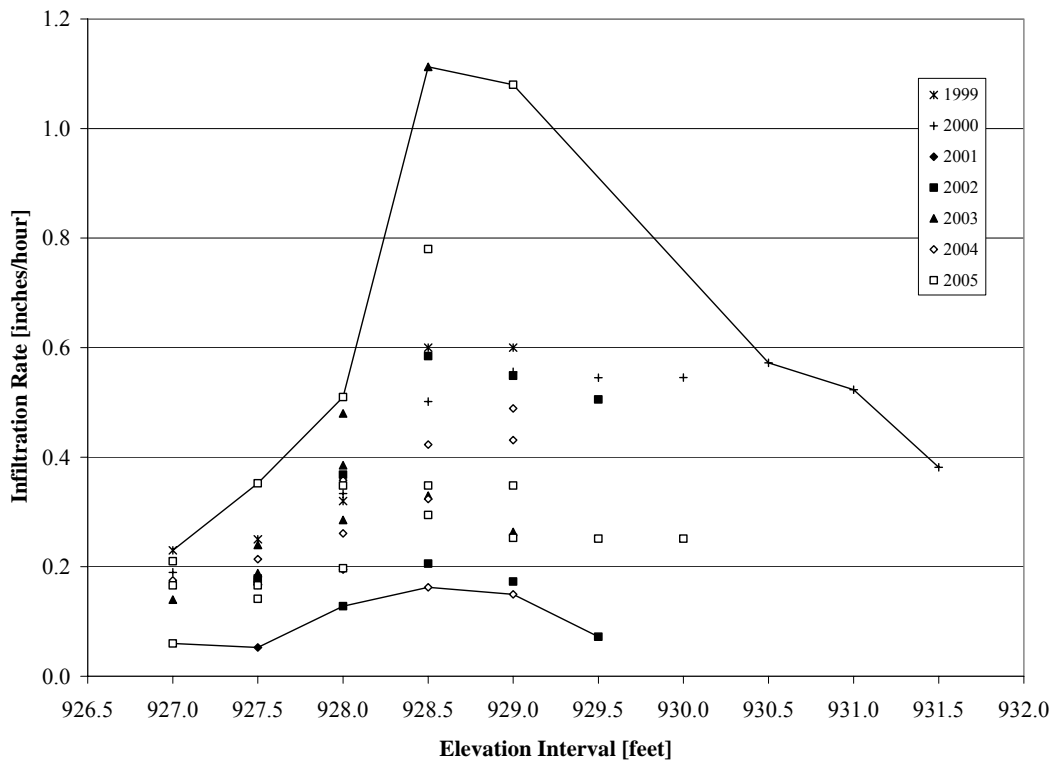


Table 1. CD-P76 Average Infiltration Rates and Ranges, 1999 – 2005

	Snowmelt		Rainfall	
	Average Rate	Rate Range	Average Rate	Rate Range
Infiltration Rate [inches/hour]	0.34	0.053 – 0.60	0.39	0.17 – 1.1
Volumetric Infiltration Rate [cfs]	1.7	0.015 – 3.9	1.1	0.044 – 3.8

CD-P82

Monitored surface water elevations at CD-P82 during 2005 are illustrated in Figure 4. Figure 5 shows the revised infiltration envelope and Table 2 includes the average measured infiltration rates at CD-P82. Most of the rates observed in 2005 fall inside of the previously defined infiltration envelope. However, one rate observed in 2005 was higher than last year's infiltration envelope, increasing the upper limit at that elevation. Dewatering activities from the construction of a lift station and associated sanitary sewer west of County Road 19 from CD-P82 occurred throughout monitoring season, except for the fall period. Runoff from the dewatering activities flowed through the culvert under County Road 19 and into the CD-P82 infiltration area, carrying with it a significant amount of sediment. The quantity of runoff and sediments delivered to the basin is unknown, but the additional inflow to the basin may have affected the infiltration rates calculated from February to mid August. Sediment in the runoff may also have influenced the infiltration rates by clogging the pore spaces in the soil. Dewatering activities ceased prior to the October storm event.

Figure 4. CD-P82 Water Elevation vs. Time. Numbers refer to drawdown events.

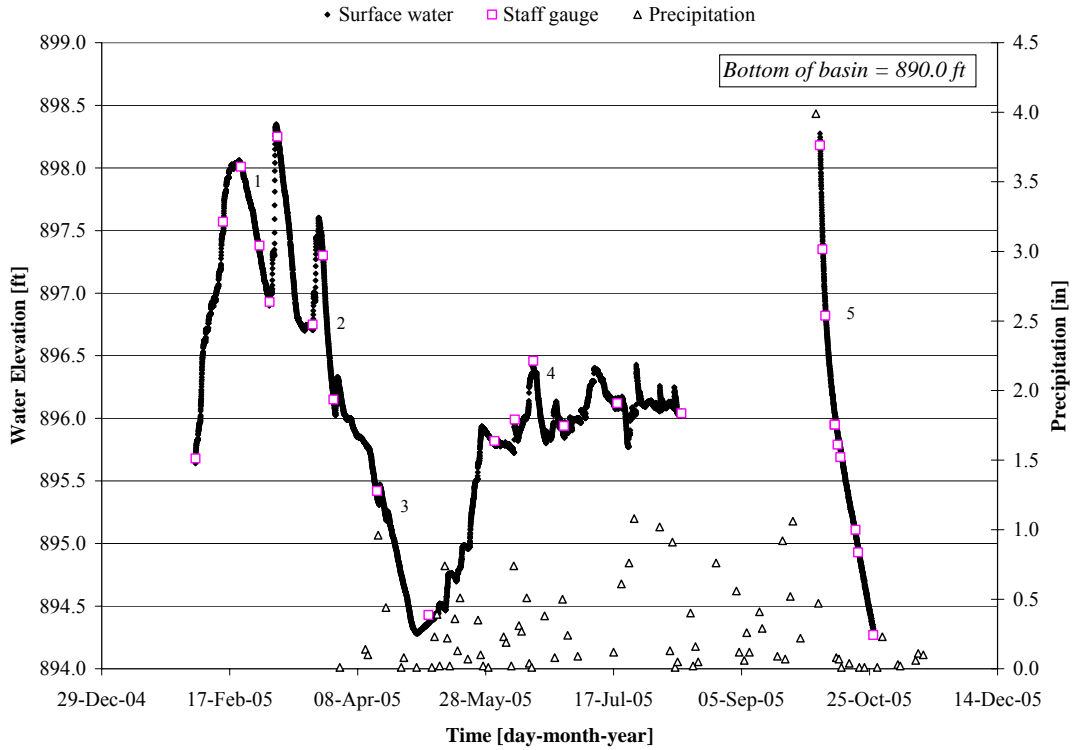


Figure 5. Infiltration Rate vs. Elevation and Infiltration Envelope for CD-P82, 1999-2005

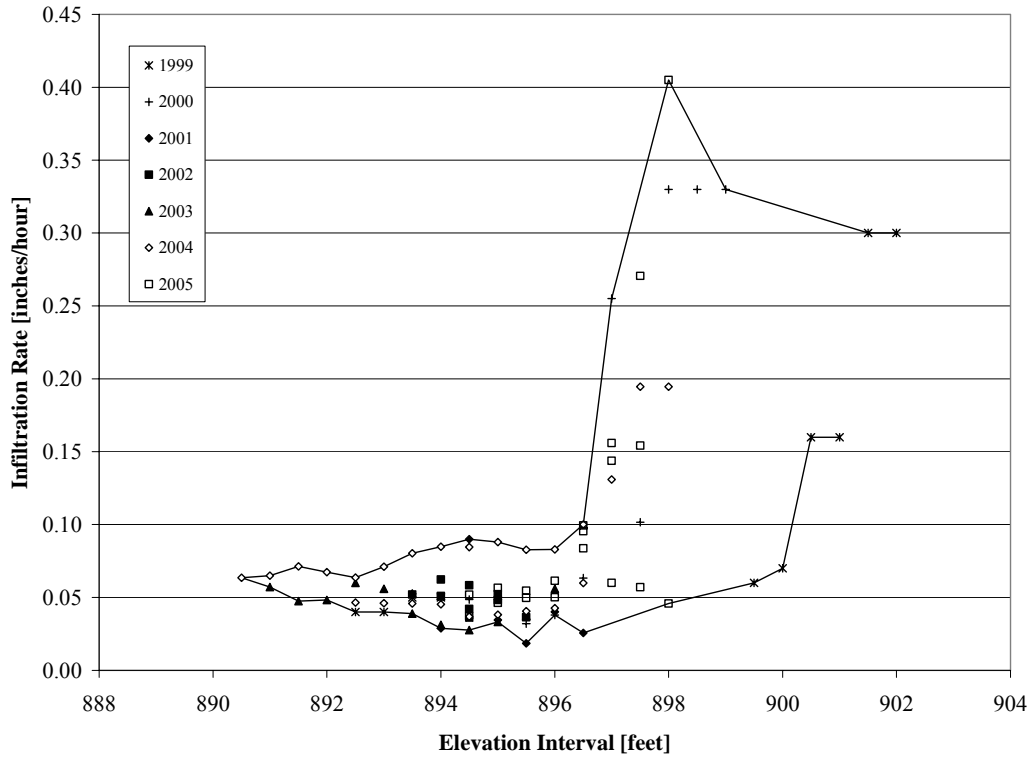


Table 2. CD-P82 Average Infiltration Rates and Ranges, 1999 - 2005

	Snowmelt		Rainfall	
	Average Rate	Rate Range	Average Rate	Rate Range
Infiltration Rate [inches/hour]	0.13	0.018 - 0.33	0.10	0.028 - 0.41
Volumetric Infiltration Rate [cfs]	0.84	0.028 - 2.7	0.38	0.0050 - 2.5

CD-P85

Monitored surface water elevations at CD-P85 during 2005 are illustrated in Figure 6. Figure 7 shows the revised infiltration envelope and Table 3 includes the average measured infiltration rates at CD-P85. The data collected in 2005 fit within the previously defined infiltration envelope. Pumping activities during mid October resulted in an overflow event that lasted for approximately 27 hours on October 18-19.

Figure 6. CD-P85 Water Elevation vs. Time, 2005. Numbers refer to drawdown events.

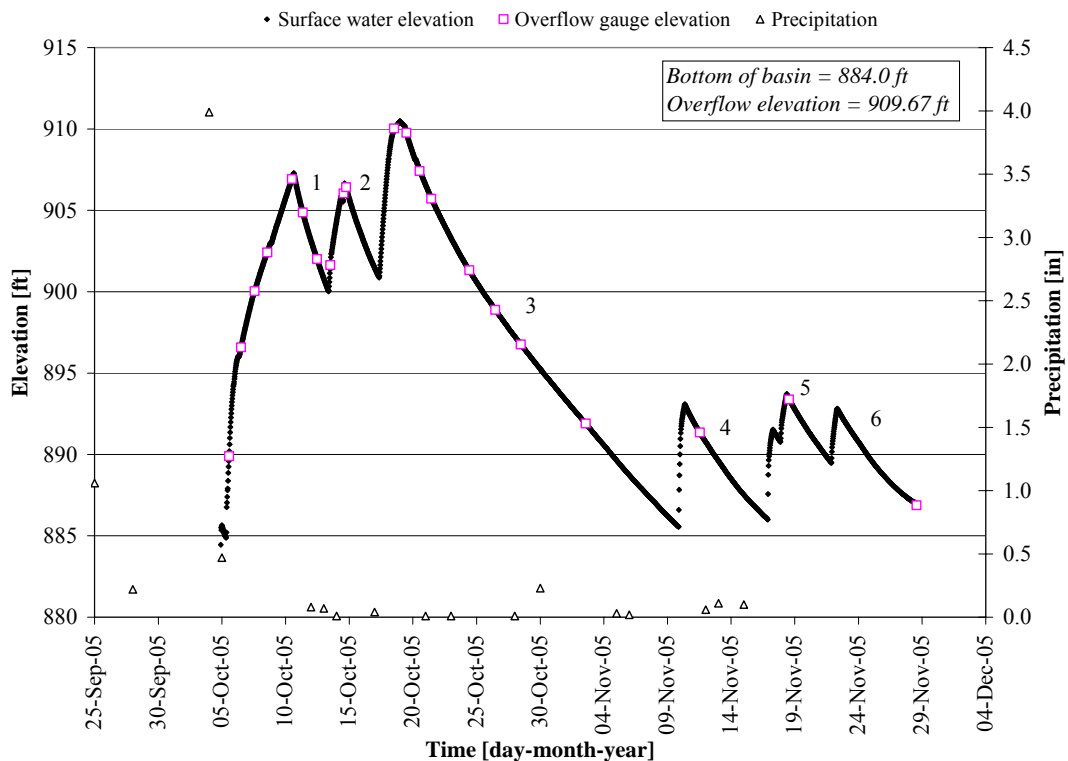


Figure 7. Infiltration Rate vs. Elevation and Infiltration Envelope for CD-P85, 1997-2005

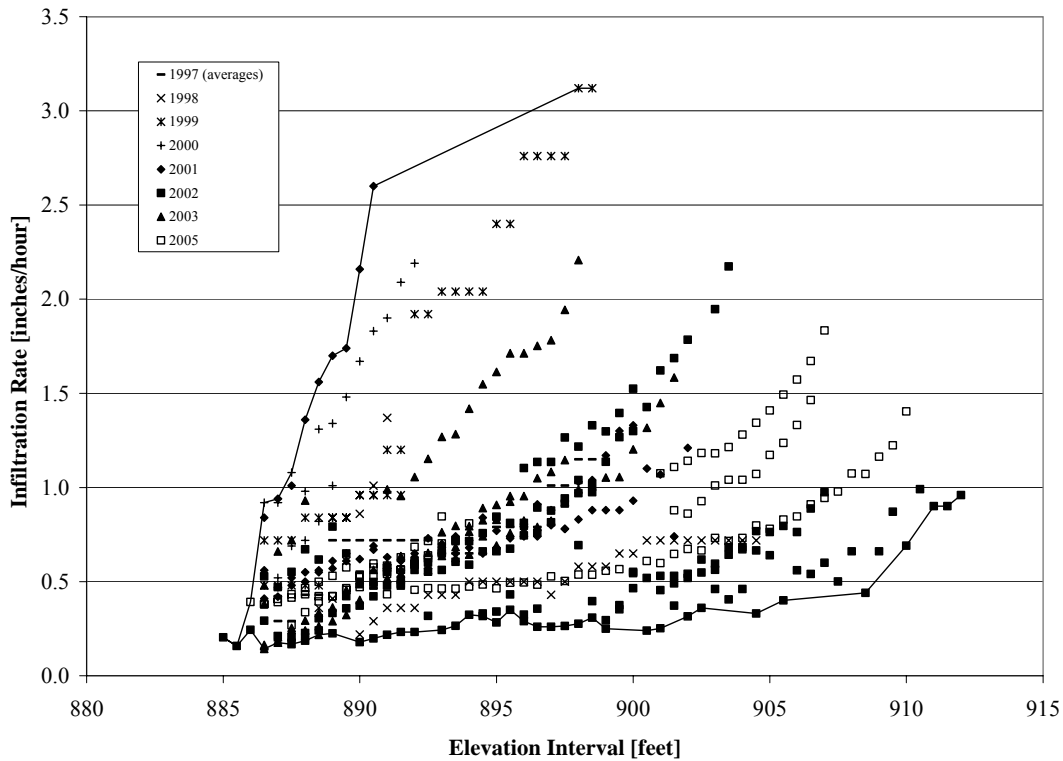


Table 3. CD-P85 Average Infiltration Rates and Range, 1997 - 2005

	Snowmelt		Rainfall	
	Average Rate	Rate Range	Average Rate	Rate Range
Infiltration Rate [inches/hour]	1.5	0.84 - 2.6	0.80	0.14 - 3.1
Volumetric Infiltration Rate [cfs]	6.5	1.5 - 16	13	0.21 - 52

CD-P86

Monitored surface water elevations at CD-P86 during 2005 are illustrated in Figure 8. This is the first year that CD-P86 has been monitored. Infiltration rate data are presented in Figure 9. Due to the low number of data points, infiltration envelopes were not added to these figures. Table 4 shows the average measured infiltration rates at CD-P86.

Figure 8. CD-P86 Water Elevation vs. Time, 2005. Numbers refer to drawdown events.

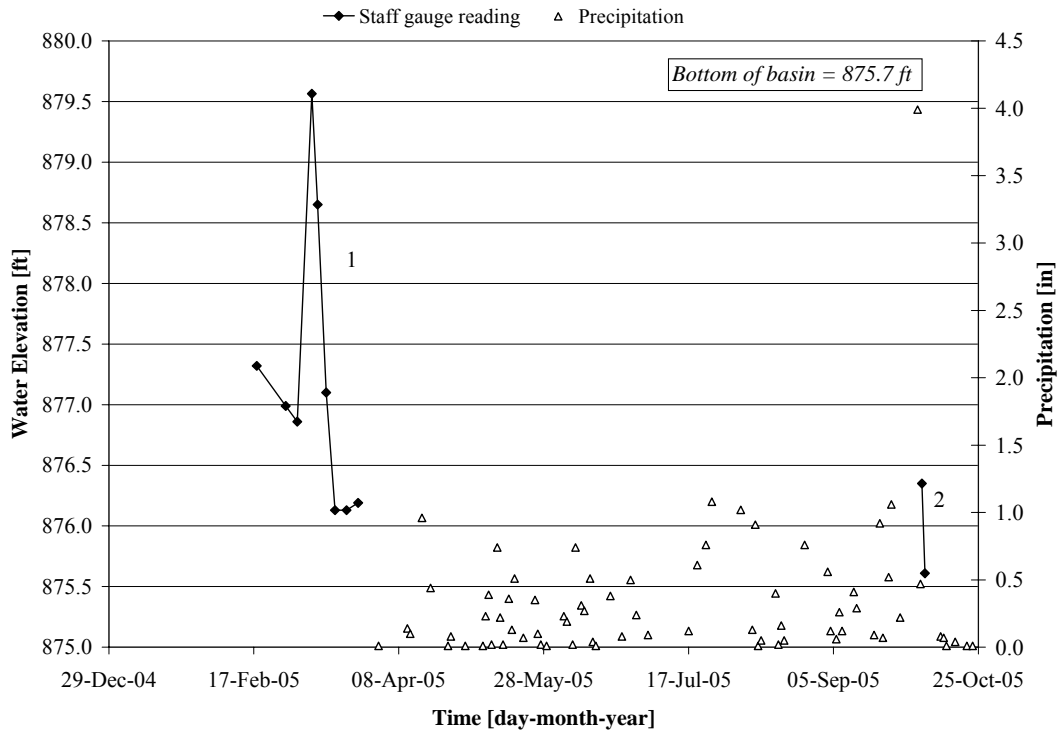


Figure 9. Infiltration Rate vs. Elevation for CD-P86, 2005

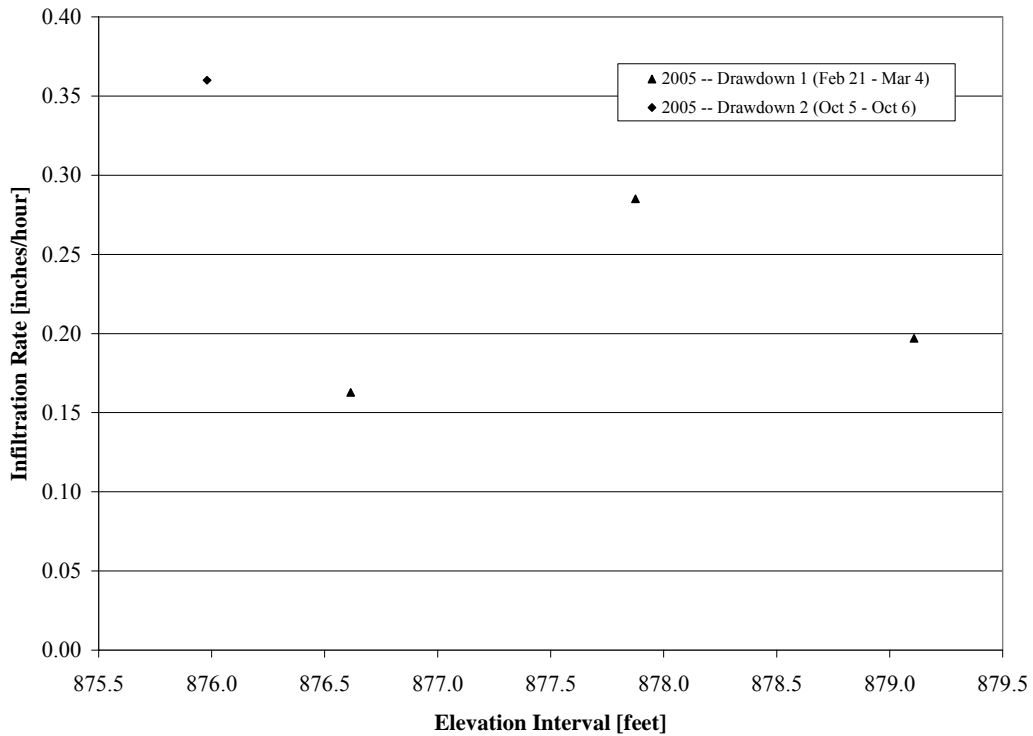


Table 4. CD-P86 Average Infiltration Rates and Range, 2005

	Snowmelt		Rainfall	
	Average Rate	Rate Range	Average Rate	Rate Range
Infiltration Rate [inches/hour]	0.21	0.16 – 0.29	0.36	0.36
Volumetric Infiltration Rate [cfs]	0.34	0.12 – 0.46	0.10	0.10

CD-P85 Trench

Monitored water elevations at the CD-P85 Trench during 2005 are illustrated in Figure 10. Figure 11 shows the infiltration envelope and Table 5 includes the average measured rate of water decline. Although the lower boundary of the infiltration envelope was further lowered with this year’s data, the downward trend of infiltration rates leveled off in 2005 (Figure 12). An operation and maintenance plan should be developed to assess and mitigate the causes for the decrease in rates of water level decline at the trench. Typically, maintenance is required for infiltration trenches every five years, depending on performance.

Figure 10. CD-P85 Trench Water Depth vs. Time, 2005. Numbers refer to drawdown events.

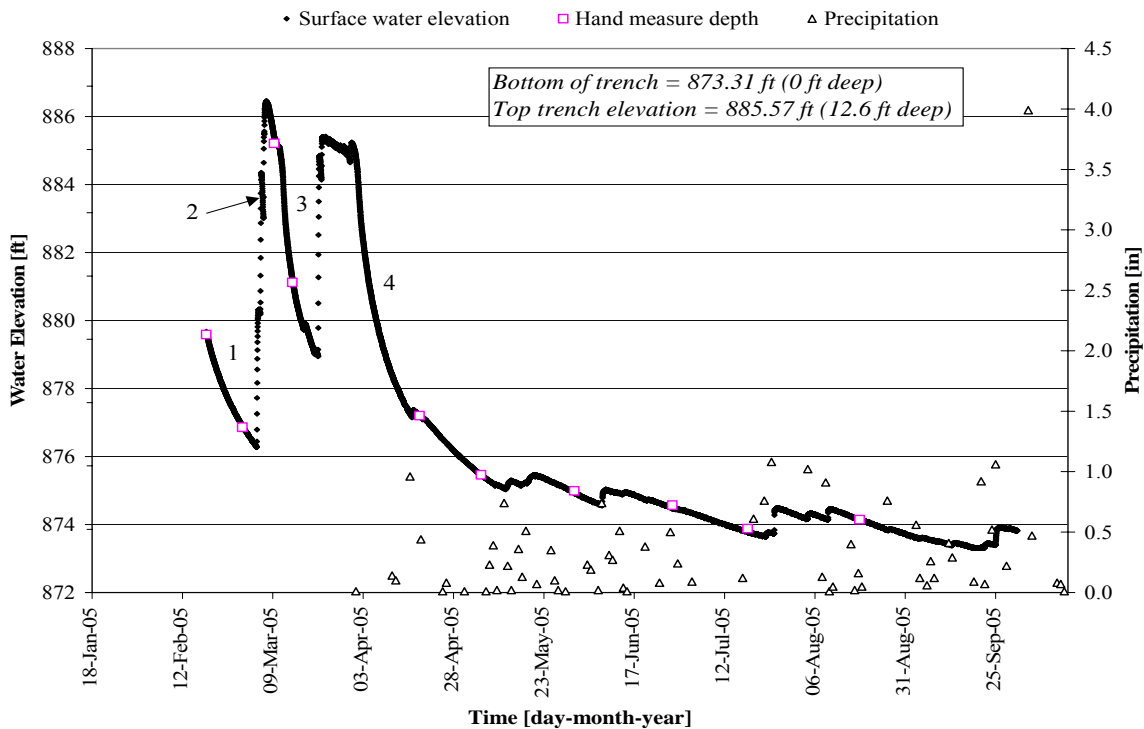


Figure 11. Rate of Decline vs. Depth for CD-P85 Trench, 1999-2005

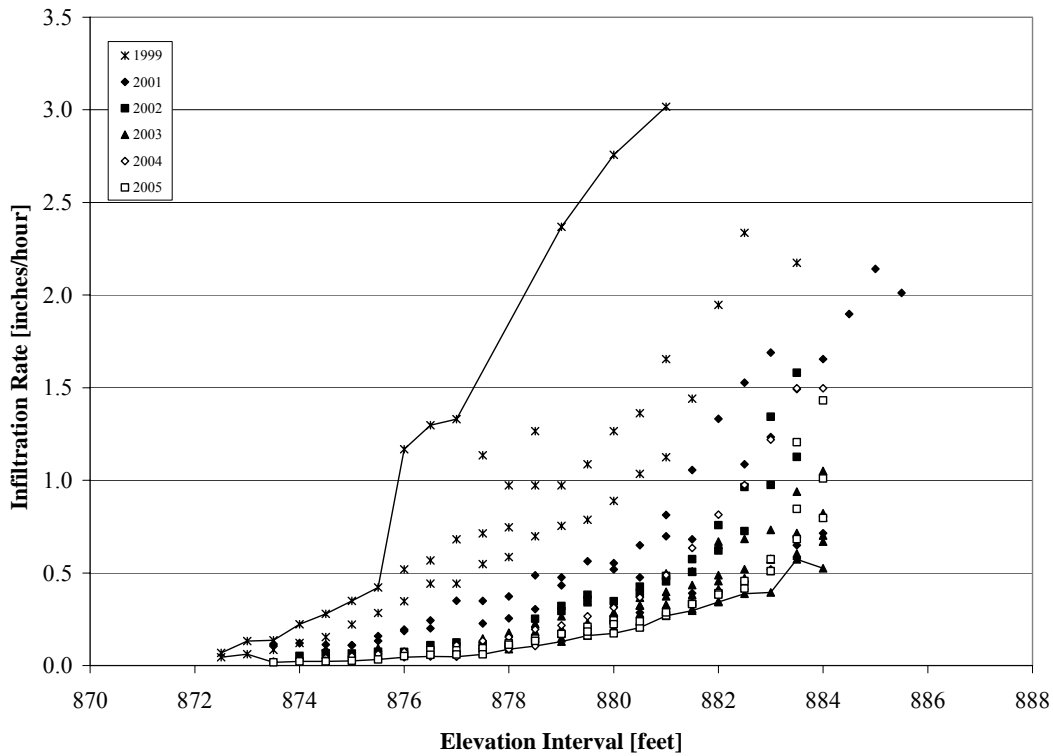


Figure 12. Annual infiltration rates (mean +/- standard deviation) for CD-P85 trench (includes both snowmelt and rainfall data), 1999-2005

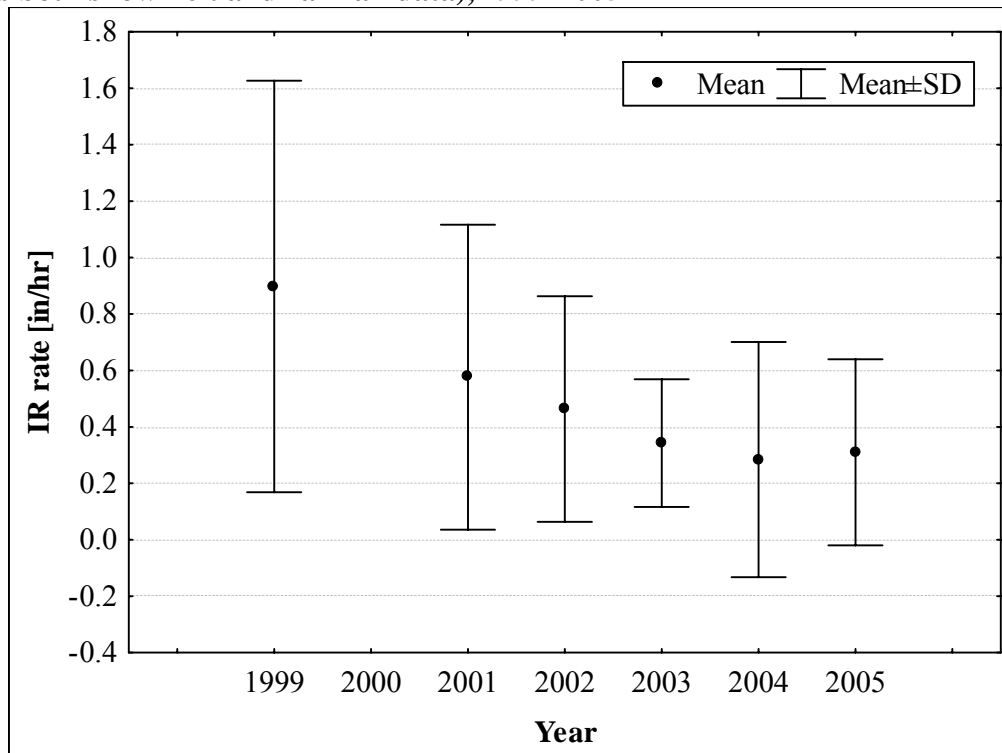


Table 5. CD-P85 Trench Average Infiltration Rate and Range, 1999 - 2005

	Average Rate	Rate Range
Rate of Decline [inches/hour]	0.60	0.017 – 3.0

Math and Science Academy (MSA) Trench

Monitored water elevations at the Math and Science Academy (MSA) Trench during 2005 are illustrated in Figure 13. Figure 14 shows the compiled data for 2001-2005 and Table 6 includes the average measured rate of water decline. The upper limit of the infiltration envelope was raised due to the high infiltration rates observed in 2005. The native seedlings planted within and around the basin have now reached maturity and may be the reason for the increase in infiltration at this site through soil penetration from root growth. An overflow event was recorded on October 4, which lasted for approximately two hours and fifteen minutes.

Figure 13. MSA Depth vs Time and Precipitation, 2005. Numbers refer to drawdown events.

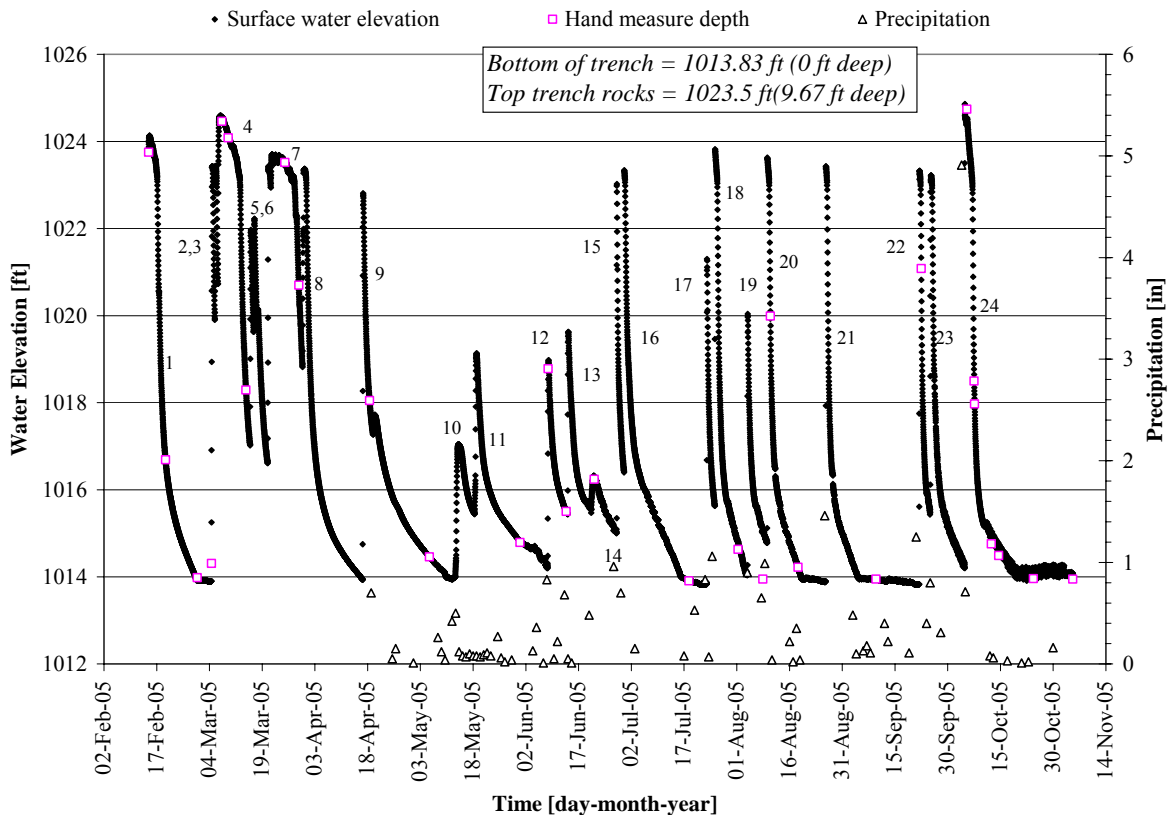


Figure 14. Rate of Decline vs. Depth for MSA Trench, 2001-2005

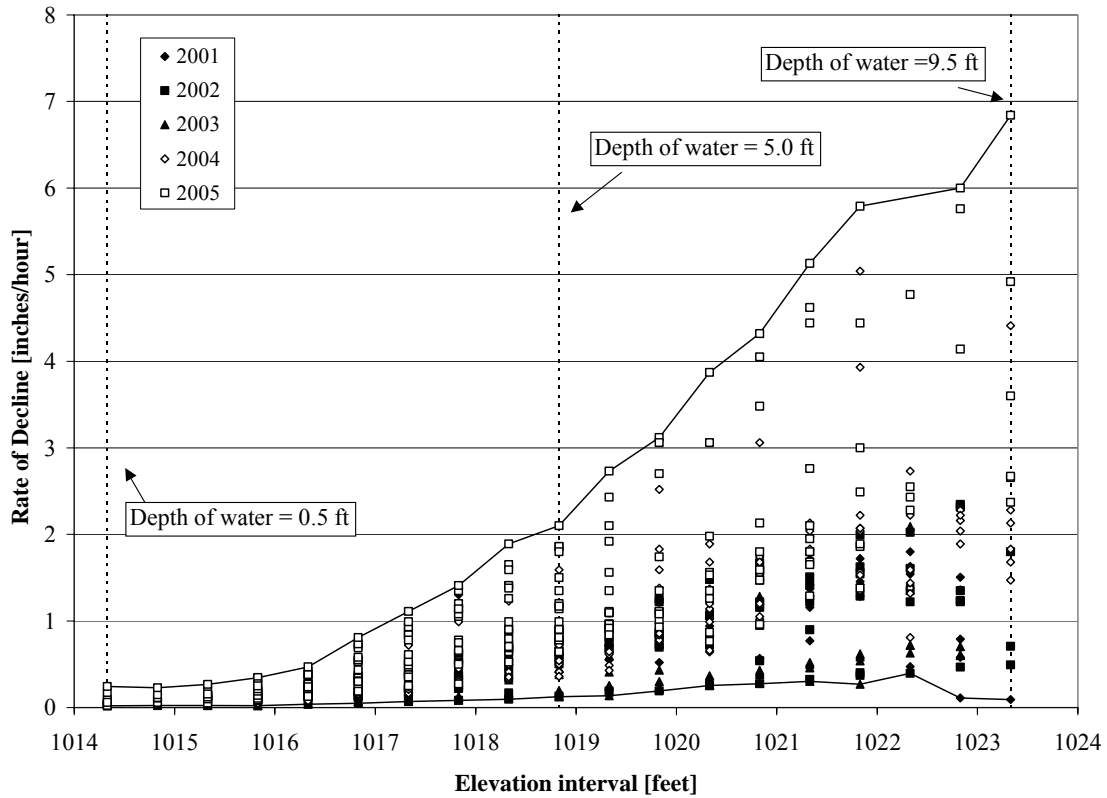


Table 6. MSA Trench Average Infiltration Rate and Range, 2001 - 2005

	Average Rate	Rate Range
Rate of Decline [inches/hour]	0.93	0.020 – 6.8

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 were calculated for the subwatersheds contributing to the monitored basins of CD-P76, CD-P82, and CD-P86 for snowmelt and rainfall events during 2005. CN values were not calculated for CD-P82 from February through August

of 2005 due to the unknown quantity of runoff delivered to the basin from dewatering activities west of County Road 19. Table 7 summarizes the results from 2003-2005.

Table 7. Average Subwatershed Curve Numbers, 2003-2005

Subwatershed Name	2005		2004		2003	
	Snowmelt	Rainfall	Snowmelt	Rainfall	Snowmelt	Rainfall
CD-P50	na	na	na	na	na	67
CD-P76	88	43	74	na	58	52.5
CD-P82	na	58	na	na	53	52
CD-P86	85	na	na	na	na	na

na – no data available

Climatic Conditions

Climatic conditions are characterized for the monitoring season beginning prior to the spring snow melt event and extending into the late fall. The 2004-2005 spring snow melt consisted of four separate snow melt events beginning in the first week of February and by March 23 all average daily temperatures were above the freezing point. The average temperature for the 2004-2005 December-March time period recorded at the Stillwater Station (218037) was 24.2 degrees Fahrenheit, 11.6 percent above the 40-year temperature average. Total snowfall for the same time frame was 35.5 inches, 9.2 percent below the 50-year snowfall average of 39.1 inches. Summer precipitation recorded at the Stillwater Station (218037) was above the fifty year average.

Precipitation data collected at the Stillwater Station (218037) illustrates total precipitation for the month of May through October of 2005 was equal to 30.8 inches, 24.6 percent above the 50-year average (23.2 inches) over the same time period. Precipitation data collected in the watershed by the WCD for the months of May through October of 2005 averaged 22.96 inches, 7.84 inches below the Stillwater Station average for that time period. A 100-year rainfall event over the days of October 4-5 delivered approximately twice the 2.67 inch 50 year average precipitation for the month of October.

Conclusions and Recommendations

Conclusions

1. The majority of measured infiltration rates at the CD-P82 and CD-P85 basins fell within the expected range of values. Several of the infiltration rates measured at CD-P76 were higher than those measured previously and increased the upper end of the infiltration envelope. Water level data were collected at CD-P86 for the first time in 2005.
2. Rates of water level decline at the infiltration trench at CD-P85 continue to be lower than rates measured in previous years, although the average infiltration rate for 2005 did not differ from the average in 2004. A plan should be developed to further assess and mitigate the decline in performance at the CD-P85 infiltration trench. Maintenance may be needed at the CD-P85 trenches to improve performance and ensure their long term viability.
3. Rates of water decline at the Math and Science Academy infiltration trench were higher than measured previously, forming the upper limit of the infiltration envelope. The native seedlings planted within and around the basin have now reached maturity and may be the reason for the increase in infiltration at this site.
4. Select surface water chemistry samples exceeded the Health Risk Limits set by the Minnesota Department of Health for manganese at CD-P82, CD-P86, and the MSA. This element is naturally occurring in the soils and is commonly found within surface and groundwater in southern Washington County. Copper was measured above the MPCA Class 2B Waters Chronic Standard in select surface water samples at CD-P76, CD-P85, and the MSA. Over the last few years, elevated levels of copper have been found in many surface water samples in all the basins, and it is unknown what is causing this trend. Surface and groundwater quality analysis indicates that infiltrating surface water is not negatively affecting the groundwater.
5. Several groundwater samples collected from CD-P82 and CD-P85 (MW-2 and MW-3) contained high (greater than 5 mg/L) concentrations of nitrates. One groundwater sample from MW-3 exceeded the MDH Health Risk Limit for combined nitrates with a concentration of 10.77 mg/L.

6. Calibrated CN values for subwatersheds draining to CD-P76, CD-P82, and CD-P86 were added to the database and can be used to refine existing watershed models in the future.

Recommendations

Surface Water Monitoring

1. Continue to monitor water levels and infiltration rates at CD-P76, CD-P82, CD-P85, CD-P86, and the MSA and CD-P85 trenches.
2. Continue to collect surface water and groundwater chemistry data at each monitoring site throughout the year.
3. Use extra monitoring equipment throughout the year as available to monitor surface and groundwater levels in wells and surface water flows in key subwatersheds.
4. Install a flow meter in the upper box culvert at CD-P85 to quantify any outlet flows that may occur during large pumping events.
5. 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.

Groundwater Monitoring

1. Continue to monitor groundwater levels in the watershed. Include shallow monitoring wells at CD-P69, CD-P50, and CD-P82 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 the lower well at CD-P82 and explore possibility of obtaining ownership of Metropolitan Council well (MCES well) at this basin.
4. Explore possibility of obtaining ownership of additional wells currently owned by the Metropolitan Council located in key areas.
5. Discontinue monitoring of the MW-3 well unless there is significant ponding within the CD-P86 infiltration basin.
6. Install a minimum of one additional well at CD-P76, CD-P82, CD-P86, MSA and three additional wells at CD-P85 to obtain additional information on groundwater flow, mounding and water quality.

7. Develop an enhanced groundwater monitoring network at CD-P85 and CD-P86 to include additional shallow monitoring wells, routine water quality sampling, and continuous groundwater level monitoring.

Management Options and Techniques

1. Develop subwatershed performance standards for volume control and water quality based on representative subwatersheds and incorporate into SWWD Plan and 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 and CD-P86 in order to ensure available infiltration capacity during spring melt conditions.
4. 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.
5. 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.

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;
- SWWD 2002 Infiltration Monitoring Report, 2003;
- SWWD 2003 Infiltration Monitoring Report, 2004; and
- SWWD 2004 Infiltration Monitoring Report, 2005.

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 snowmelt conditions provides the SWWD with detailed information on which to base emergency response plans and flood forecasting. The data collected at infiltration trenches provide additional information for planning and designing future infiltration practices that enhance infiltration performance and can mitigate frozen ground conditions.

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

Figure 1-1 illustrates the location of the monitoring sites in the SWWD. This report summarizes the results of the following monitoring events:

Snowmelt infiltration events at:

- CD-P76;
- CD-P82;
- CD-P86;
- CD-P85 Trench; and
- Math and Science Academy (MSA) Trench.

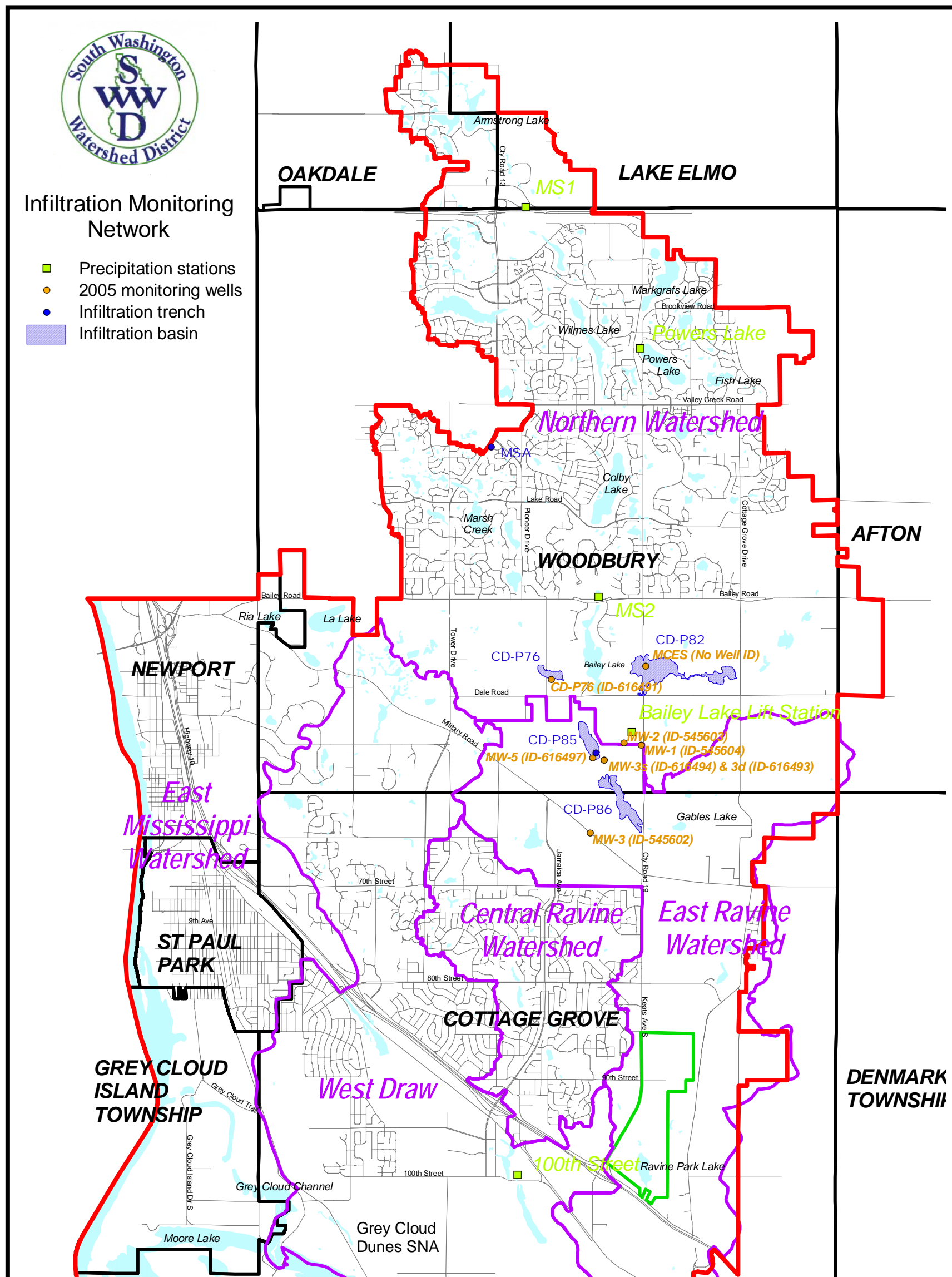
Rainfall infiltration events at:

- CD-P76;
- CD-P82;
- CD-P85;
- CD-P86;
- CD-P85 Trench; and
- Math and Science Academy (MSA) Trench.

In addition, CD-P76 and CD-P86 were monitored during the summer months in an effort 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. Dewatering activities within the CD-P82 subwatershed resulted in ponded water throughout the summer; however, the mix of both dewatering activities and precipitation resulted in unknown total runoff contributions to the basin. Dewatering to CD-P82 ceased prior to October; therefore, only fall subwatershed curve numbers were developed for CD-P82.

This report presents field data collected that includes surface water and groundwater quality, groundwater levels, and an analysis of infiltration rates in basins and trenches. Comparisons of measured infiltration rates from 1997 to 2005 are presented in Chapter III-D: Infiltration Envelopes. Conclusion and Recommendations are presented in Chapter VI.

Figure I-1. Infiltration Monitoring Network



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

Table I-1. Summary of Available Infiltration Data

Basin	1997	1998	1999		2000		2001		2002	
	Rain	Rain	Snow	Rain	Snow	Rain	Snow	Rain	Snow	Rain
CD-P50			X	X	X		X		X	X
CD-P69			X	X	X	X	X	X	X	X
CD-P76			X		X		X		X	
CD-P82			X	X	X		X		X	X
CD-P85	X	X		X		X		X	X	X
CD-P86										
CD-P85 Trench				X				X	X	X
MSA Trench								X	X	X

Basin	2003		2004		2005	
	Snow	Rain	Snow	Rain	Snow	Rain
CD-P50	X	X		X		
CD-P69						
CD-P76	X		X	X	X	X
CD-P82	X	X	X	X	X	X
CD-P85	X	X				X
CD-P86					X	X
CD-P85 Trench	X	X	X	X	X	X
MSA Trench	X	X	X	X	X	X

II. Water Quality and Groundwater Monitoring

Water quality sampling and analysis were completed to assess 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; 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 and groundwater interactions, the role that groundwater mounding has on the infiltration process, and allows for the early detection of potential down gradient effects.

II-A Methodology

Water Quality

An evaluation of both surface water (stormwater) quality and groundwater quality was completed to determine the potential impact of stormwater infiltration on the groundwater and soils. The monitoring of both surface water and groundwater quality establishes a data set 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.

The Metropolitan Council Environmental Services (MCES) lab analyzed all water quality samples collected during the 2005 monitoring season. Copies of all lab reports can be obtained by contacting the SWWD.

Surface Water Quality

Surface water quality has been monitored at infiltration basins by the SWWD since 1997. Results of past water quality sampling can be found in previous SWWD Infiltration Monitoring Reports.

Table II-1 describes the sampling schedule for 2005. The sampling schedule varied depending on activity at the site and project scope.

Table II-1. 2005 Surface/Trench Water Quality Sampling Schedule

	16-Feb	19-Feb	21-Feb	7-Mar	9-Mar	14-Mar	20-Jun	21-Jun
CD-P76	X	-	-	X	-	-	-	-
CD-P82	X	-	-	X	-	-	-	-
CD-P85	-	-	X	-	X	-	-	-
CD-P86	-	-	-	X	-	-	-	-
MSA surface	X	-	-	X	-	-	X	-
MSA trench	-	X	-	-	-	X	-	X

Table II-1 Continued. 2005 Surface/Trench Water Quality Sampling Schedule

	8-Aug	10-Aug	22-Sept	5-Oct	6-Oct	7-Oct	24-Oct
CD-P76	-	-	-	X	-	-	-
CD-P82	-	-	-	X	-	-	-
CD-P85	-	-	-	-	X	-	X
CD-P86	-	-	-	-	-	-	-
MSA Trench	X	X	X	X	-	-	-
MSA surface	-	X	X	-	-	X	-

Composite grab samples were collected using three-foot long polyethylene disposal bailers and the contents were poured into individual sample bottles. At MSA, composite flow-weighted samples were collected during an overflow event using an automatic sampler and flow meter. Sample bottles were stored on ice and delivered to the MCES labs. No holding times were exceeded.

Surface water samples collected at CD-P76, CD-P82, CD-P85, CD-P86, and MSA were analyzed for:

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

Groundwater Quality

Groundwater quality has been monitored by the SWWD since 1998. Results of past water quality sampling can be found in previous SWWD Infiltration Monitoring Reports.

Groundwater samples in 2005 were collected using a submersible pump, and a minimum of three well volumes were purged prior to sample collection. All samples were stored on ice and delivered to the lab. No holding times were exceeded. Table II-2 describes the 2005 sampling schedule, which varied depending on activity at the site and project scope.

Table II-2. 2005 Groundwater Quality Sampling Schedule

	2-Feb	21-Feb	29-Mar	16-May	31-May	5-Oct	11-Oct
CD-P82	X	X	X	X	-	X	X
MW-1	X	-	X	X	-	-	X
MW-2	X	-	X	X	-	-	X
MW-3	X	-	X	-	X	-	X
MW-3w	-	-	-	-	-	-	-
MW-5	-	-	-	-	-	-	X

Table II-2 Continued. 2005 Groundwater Quality Sampling Schedule

	18-Oct	7-Nov	20-Dec
CD-P82	-	-	X
MW-1	X	-	X
MW-2	X	-	X
MW-3	X	-	X
MW-3w	X	-	X
MW-5	X	X	X

Groundwater samples were analyzed for:

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

Water Quality Standards

The results from the water quality monitoring are compared to the water quality standards listed in Table II-3. 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 within the 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.

Table II-3. 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 phosphate as phosphorus	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ortho phosphate 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

* EPA Secondary Standards – not enforceable

N/A: No standard exists

Groundwater Level Monitoring

Groundwater mounding, a process in which infiltrating water causes a rise in the water table, can be a limiting factor for infiltration. Depths to groundwater, bedrock, or other impeding layers all contribute to mounding. If groundwater mounding rises high enough to intersect the bottom of the basin, it can contribute to ponding conditions in the basin, thus controlling the rate of

infiltration. The MPCA recommends a three-foot minimum depth to the seasonal high water table.

Groundwater level data were collected at eight wells throughout the watershed as part of this program. One well is located adjacent to each of the CD-P82 and CD-P76 basins, and six are located adjacent to or near CD-P85 / CD-P86. During construction of the new outlet at CD-P85, the MW-4 well was damaged and later abandoned in early spring 2005. Except for well MW-3w, the peak groundwater mound elevations could not be determined without the use of continuous data loggers in the wells. However, for the discussion on ground water mounding, the periodic hand measure well readings were used to identify the highest observed mounding in each well. Water level readings were taken at each well with the use of an electronic water level sounder, and an automatic data logger was installed in the MW-3w well to record continuous groundwater levels. The locations of these wells are identified on Figure I-1.

II-B. Results

CD-P76

Stormwater runoff to CD-P76 originates from predominantly agriculture land and large lot development. During 2005, the fenced in horse pasture built in 2004, west of Mile Drive, was reconverted into row crop agriculture (corn).

Water Quality

Table II-4 summarizes the water quality data collected at CD-P76. No groundwater sample was taken during the spring runoff event due to a lack of measurable water in the well. Copper exceeded the MPCA Class 2B Waters Chronic Standard for a hardness concentration of 50 mg/L.

Table II-4. CD-P76 Water Quality Results

Analyte [mg/L]	CD-P76 Surface Water			
	2/16/05	3/7/05	3/7/05*	10/5/05
Lead, dissolved	0.0003	0.0006	0.0002	0.0002
Cadmium, dissolved	<0.00004	<0.00004	<0.00004	<0.00004
Manganese, dissolved	0.038	0.043	0.043	0.006
Nickel, dissolved	0.0037	0.0029	0.0028	0.002
Copper, dissolved	0.008**	0.005	0.0053	0.0041
Zinc, dissolved	0.0065	0.004	0.0027	0.0041
Hardness as CaCO ₃	50	48	42	28
Volatile suspended solids	<10	~9	~10	~15
Total suspended solids	~18	44	45	149
Total phosphorus	0.719	0.657	0.668	1.09
Ortho phosphorus	0.394	0.448	0.451	0.475
Total Kjeldahl nitrogen	3.4	2.4	2	1.4
Nitrite	0.09	0.1	0.1	<0.03
Nitrate	1.24	0.97	0.95	0.23
Chloride	28	14	14	2

* Duplicate sample

**Copper MPCA Class 2B Waters Chronic Standard (Hardness of 50 mg/L) = 0.0064 mg/L

Groundwater Levels

There was no measurable water in the well at CD-P76 during the monitoring season.

CD-P82

Land use in the watershed of CD-P82 is primarily row crop agricultural (soybeans and corn) and commercial nursery. During 2005, the lift station construction was completed west of County Road 19 within the CD-P82 subwatershed. Dewatering activities during construction caused

erosion along the west ditch of County road 19 and runoff flowing through the culvert from the west carried sediments that were deposited along the swale and in the basin of CD-P82. It is unknown what quantity of sediment was deposited within the infiltration area and basin; however, the deposits measured approximately four inches deep within the drainage swale to the basin in mid July 2005. It is also unknown what affect the runoff had on the water quality samples collected during the monitoring season.

Water Quality

Table II-5 summarizes the water quality data collected at CD-P82.

Table II-5. CD-P82 Water Quality Results

Analyte [mg/L]	CD-P82 Surface Water		
	2/16/05	3/7/05	10/5/05
Lead, dissolved	0.0001	0.0001	0.0007
Cadmium, dissolved	0.00006	<0.00004	<0.00004
Manganese, dissolved	0.344**	0.409**	0.0125
Nickel, dissolved	0.0044	0.0037	0.0028
Copper, dissolved	0.0041	0.0033	0.004
Zinc, dissolved	0.0034	0.002	0.0117
Hardness as CaCO ₃	198	172	46
Volatile suspended solids	~10	~16	~31
Total suspended solids	33	88	208
Total phosphorus	0.73	0.899	1.23
Ortho phosphorus	0.34	0.475	0.202
Total Kjeldahl nitrogen	3.5	2.6	2.8
Nitrite	0.19	0.11	<0.03
Nitrate	2.31	1.82	0.16
Chloride	88	55	4

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

Table II-5 Continued. CD-P82 Water Quality Results

Analyte [mg/L]	CD-P82 Groundwater						
	2/2/05	2/21/05	3/29/05	5/16/05	10/5/05	10/11/05	12/20/05
Lead, dissolved	0.0001	0.0001	<0.00007	0.0001	0.0001	0.0002	<0.00007
Cadmium, dissolved	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
Manganese, dissolved	0.0069	0.0012	0.0007	0.0189	0.0124	0.0006	0.0008
Nickel, dissolved	0.0044	0.0028	0.0021	0.0029	0.0026	0.0021	0.0008
Copper, dissolved	0.0015	0.0024	0.002	0.0024	0.0013	0.0013	0.0008
Zinc, dissolved	0.0039	0.0038	0.001	0.0059	0.0025	0.004	0.0039
Nitrite	<0.03	<0.03	<0.03	<0.03	<0.03	0.03	<0.03
Nitrate	4.93	8.09	1.87	2.1	4.04	3.56	6.13
Chloride	9	15	70	77	63	64	33

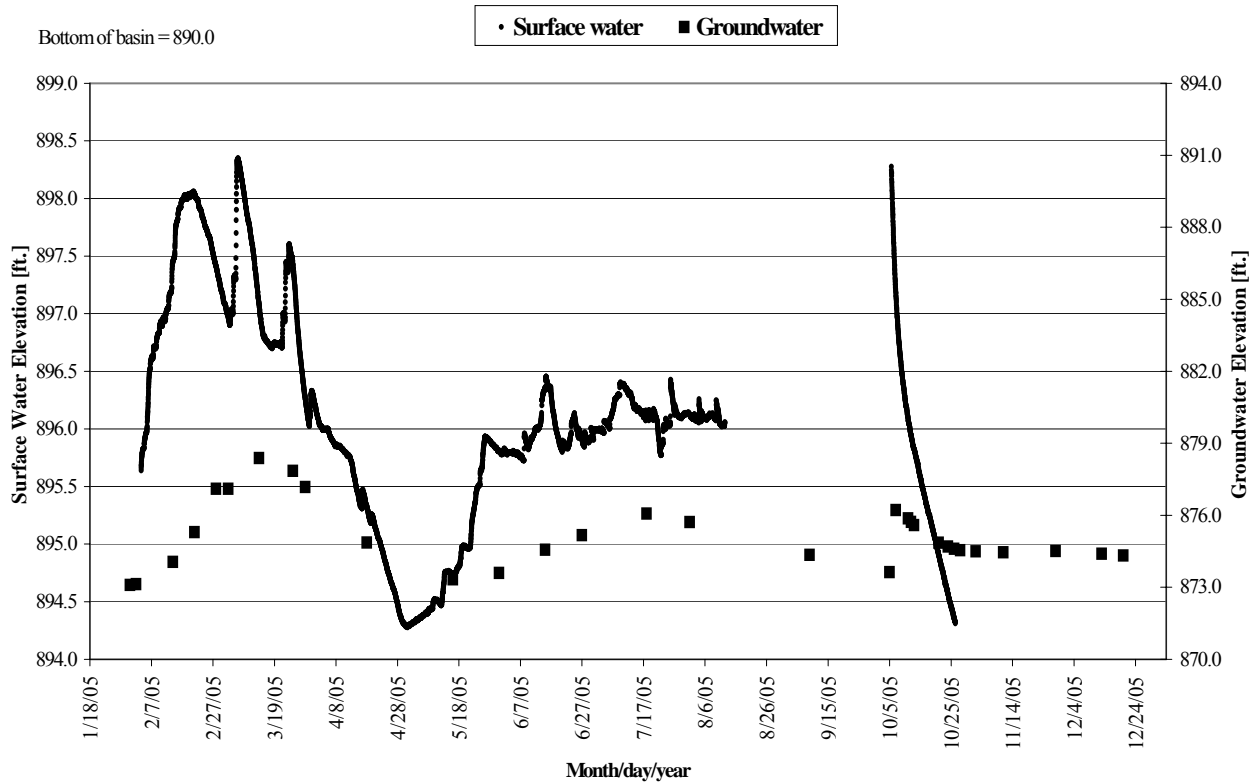
Manganese exceeded the MDH HRL in the February 16 and March 7 surface water samples. Manganese is a naturally occurring element in the soils of the watershed and historically has exceeded the MDH HRL in SWWD surface water chemistry. Nitrate plus nitrite levels in the February 21 groundwater sample approached the MDH HRL of 10 mg/L with a concentration of 8.09 mg/L.

Groundwater Levels

Measured groundwater levels at CD-P82 are summarized in Figure II-1. The rise and fall of the water table tracked well with the surface water fluctuations in the basin. Throughout the course of the monitoring season, three groundwater mounds were measured within the MCES well adjacent to the basin. Using a static water elevation of 873.10 on January 31 (the groundwater level prior to basin inundation), the first groundwater mound was measured on March 14 with a peak height of 5.28 feet, corresponding to an elevation of 878.38 feet. Starting with a static water elevation of 873.33 feet on May 16, a second groundwater mound with a peak height of 2.74 feet, corresponding to an elevation of 876.07 feet was measured on July 18. The third

groundwater mound began with a static water elevation on October 5 of 873.63 feet and shortly after a mound height of 2.59 feet, corresponding to an elevation of 876.22 feet was measured on October 7. The highest groundwater mound (March 14) peaked approximately 11.5 feet below the bottom of the basin.

Figure II-1. Water Fluctuations at CD-P82



CD-P85

Runoff reaching CD-P85 originates from two sources including direct subwatershed drainage and pumped overflow from the adjacent subwatersheds. 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.

Water Quality

Table II-6 summarizes the water quality data collected in 2005. Copper in the February 21 sample exceeded the MPCA Class 2B Waters Chronic Standard for a hardness concentration of 100 mg/L. Manganese concentrations exceeded both the MDH HRL and EPA secondary standard in all MW-1 groundwater samples. As mentioned previously, manganese is naturally occurring in the soils of this region and occasionally is present in groundwater chemistry. Nitrate plus nitrite concentrations measured in MW-2 on October 18 approached the MDH HRL of 10 mg/L with a concentration of 8.46 mg/L. Likewise, all MW-3 groundwater samples were near the MDH HRL for nitrate plus nitrite and exceeded the HRL of 10 mg/L with a combined concentration of 10.77 mg/L on October 18.

Table II-6. CD-P85 Water Quality Results

Analyte [mg/L]	CD-P85 Surface Water			
	2/21/05	3/9/05	10/6/05	10/24/05
Lead, dissolved	0.0002	0.0002	0.0003	0.00009
Cadmium, dissolved	<0.00004	0.00006	<0.00004	<0.00004
Manganese, dissolved	0.0069	0.021	0.0028	0.0061
Nickel, dissolved	0.0033	0.0018	0.0013	0.0011
Copper, dissolved	0.0126*	0.0049	0.0015	0.0018
Zinc, dissolved	0.0018	0.0109	0.0039	0.0028
Hardness as CaCO ₃	100	40	73	54
Volatile suspended solids	~3	7	~14	3
Total suspended solids	7	11	25	3
Total phosphorus	0.559	0.767	0.182	0.14
Ortho phosphorus	0.452	0.6	0.033	0.075
Total Kjeldahl nitrogen	1.5	2.9	1.9	0.96
Nitrite	0.1	<0.03	<0.03	<0.03
Nitrate	3.04	<0.05	0.09	0.14
Chloride	9	7	55	24

*Copper MPCA Class 2B Waters Chronic Standard (Hardness of 100 mg/L) = 0.0098 mg/L

Table II-6 Continued. CD-P85 Water Quality Results

Analyte [mg/L]	CD-P85 Groundwater														
	MW-1								MW-2						
	2/2/05	3/29/05	3/29/05*	5/16/05	5/16/05*	10/11/05	10/18/05	12/20/05	2/2/05	3/29/05	5/16/05	10/11/05	10/11/05*	10/18/05	12/20/05
Lead, dissolved	0.0001	<0.00007	<0.00007	0.00008	0.00008	<0.00007	<0.00007	0.00007	0.00009	<0.00007	0.0001	<0.00007	0.00008	0.00008	<0.00007
Cadmium, dissolved	0.00006	0.00007	0.00007	0.00006	0.00004	<0.00004	<0.00004	0.00007	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	
Manganese, dissolved	0.439**	0.522**	0.513**	0.464**	0.453**	0.234**	0.084**	0.092**	0.0011	0.0007	0.0019	0.0014	0.0013	0.0009	0.0065
Nickel, dissolved	0.0129	0.005	0.0054	0.0045	0.0047	0.0032	0.0026	0.0024	0.004	0.0035	0.0019	0.003	0.0032	0.0024	0.0026
Copper, dissolved	0.005	0.0042	0.0039	0.0034	0.0038	0.0032	0.0032	0.0104	0.0017	0.0007	0.0006	0.0008	0.0012	0.0011	0.001
Zinc, dissolved	0.0145	0.0019	0.002	0.0045	0.0272	0.0027	0.006	0.008	0.0092	0.0024	0.0094	0.0039	0.0057	0.0036	0.0036
Nitrite	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.07	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.08	<0.03
Nitrate	0.21	0.12	0.12	0.14	0.14	0.68	1.66	0.13	5.99	4.78	5.26	4.74	3.8	8.46	8.74
Chloride	53	76	77	106	105	45	43	25	38	37	32	41	41	30	26

*Duplicate sample

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

Table II-6 Continued. CD-P85 Water Quality Results

Analyte [mg/L]	CD-P85 Groundwater												
	MW-3						MW-3w			MW-5			Equipment Blank
	2/2/05	3/29/05	5/31/05	10/11/05	10/18/05	12/20/05	10/18/05	12/20/05	12/20/05*	10/11/05	10/18/05	11/7/05	12/20/05
Lead, dissolved	0.0002	<0.00007	<0.00007	0.00009	<0.00007	<0.00007	<0.00007	0.00009	0.00009	0.0001	<0.00007	<0.00007	<0.00007
Cadmium, dissolved	0.00007	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
Manganese, dissolved	0.0021	0.0017	0.006	0.0017	0.0031	0.0044	0.0025	0.0054	0.0027	0.0012	0.0008	0.0007	0.0003
Nickel, dissolved	0.0023	0.0023	0.0024	0.0021	0.0021	0.0016	0.002	0.0015	0.0027	0.0014	0.0008	0.0012	0.0002
Copper, dissolved	0.0015	0.0011	0.0013	0.0016	0.0008	0.0013	0.0015	0.0021	0.0022	0.0029	0.0036	0.0028	<0.0005
Zinc, dissolved	0.0086	0.0025	0.0041	0.0044	0.0039	0.0058	0.0065	0.029	0.0066	0.0044	0.003	0.0039	0.0035
Nitrite	<0.03	<0.03	<0.03	<0.03	0.07	<0.03	0.07	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Nitrate	6.37	8.08	6.91	7.24	10.7**	4.73	3.29	0.2	0.18	0.13	0.3	0.09	0.1
Chloride	81	72	75	42	33	45	26	30	29	36	28	24	<2

*Duplicate sample

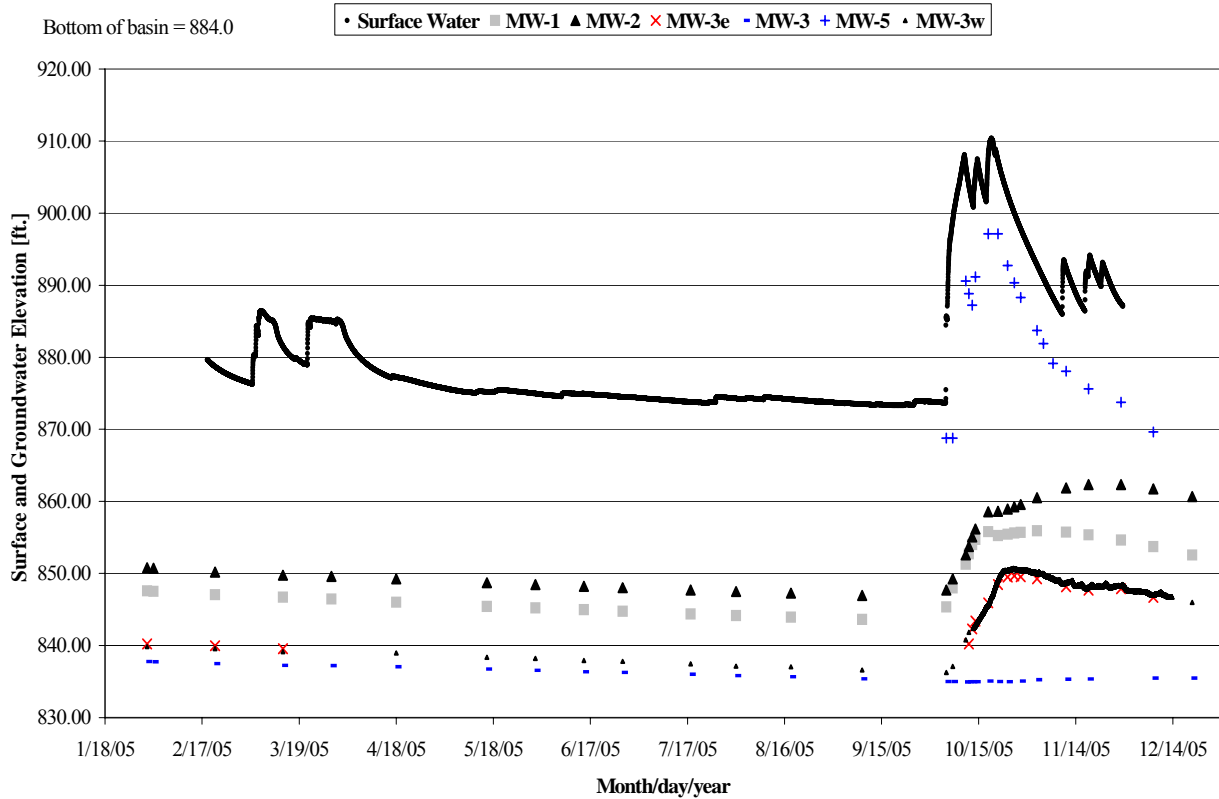
**Nitrate + Nitrite MDH Health Risk Limit = 10 mg/L

Groundwater Levels

Measured groundwater levels at CD-P85 are summarized in Figure II-2. Snowmelt and precipitation prior to early October did not cause any measurable rise in water levels within the wells near the basin; however, a large rainfall event on October 4-5 caused significant runoff throughout the watershed, which resulted in several pumping events at CD-P85 between October 5 and November 22. Subsequent groundwater mounding was measured within the adjacent monitoring wells around the basin.

The static groundwater elevation of MW-1 was 843.61 feet on September 9. South Bailey Lake became inundated during the October storm event, and a groundwater mound with a peak height of 12.17 feet, corresponding to an elevation of 855.78 feet, was measured in the well on October 14. Similarly, MW-2 had a static water level of 846.96 feet on September 9, and a peak mound of 15.38 feet was observed on November 28, which corresponded to a mound elevation of 862.34 feet. The two nested wells, MW-3w and MW-3e, responded quickly to the initial pumping event in CD-P85. For MW-3w, a static water elevation of 836.25 feet was measured on October 5 and the continuous data logger captured a peak groundwater mound of 14.51 feet, which corresponded to an elevation of 850.76 feet on October 25. Continuous water level data were collected in the MW-3w well from October 13 through December 13. The MW-3e well contained no measurable water on October 5th, but a static water level of 840.23 feet was recorded on October 12, and a peak groundwater mound of 9.44 feet, which corresponded to an elevation of 849.67 feet, was observed on October 26. There was no significant groundwater mound measured in MW-3 and historically this well has had no measurable response to pumping events at CD-P85. MW-5 is the closest well to CD-P85, and water levels within the well tracked very closely to surface water fluctuations in the basin. MW-5 is a shallow well (approximately 50 feet deep) with a bottom elevation of about 868.8 feet. Prior to pumping there was no observable water level in the well. Pumping to CD-P85 began the morning of October 5, and a peak groundwater mound with an elevation of 897.12 feet was recorded on October 18 at MW-5. This groundwater mound was approximately 13 feet above the bottom of the basin, which correlated to a surface water elevation of approximately 897.1 feet.

Figure II-2. Water Fluctuations at CD-P85



CD-P86

Runoff reaching CD-P86 originates from two sources including direct subwatershed drainage and from water outletting from CD-P85 during large pumping events. The direct watershed is mostly comprised of agricultural land uses. This runoff reaches CD-P86 during the spring melt and after large rainfall events. Stormwater that overflows into CD-P86 from pumped water within CD-P85 originates from typical suburban land uses including single and multi family residential, commercial, light industrial and agricultural drainage. Water present in the basin during 2005 was from snowmelt in the spring and from the large rain event in early October. Water outletting from CD-P85 during the pumping events in October never reached the lower basin of CD-P86 where the monitoring equipment was placed. The majority of this water infiltrated within the swales leading to CD-P86 before it could reach the bottom of the basin.

Water Quality

Table II-7 summarizes the water quality data collected in 2005. Due to a low volume of water delivered to the basin and infrequent events, only one surface water sample was collected during the season. Manganese exceeded the EPA Secondary Standard of 0.05 mg/L with a concentration of 0.052 mg/L.

Table II-7. CD-P86 Water Quality Results

Analyte [mg/L]	CD-P86 Surface Water
	3/7/05
Lead, dissolved	0.0002
Cadmium, dissolved	0.00005
Manganese, dissolved	0.052*
Nickel, dissolved	0.0022
Copper, dissolved	0.0054
Zinc, dissolved	0.0058
Hardness as CaCO ₃	38
Volatile suspended solids	~11
Total suspended solids	32
Total phosphorus	0.819
Ortho phosphorus	0.59
Total Kjeldahl nitrogen	3.5
Nitrite	0.08
Nitrate	0.96
Chloride	11

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

Math and Science Academy 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. Water quality samples were taken at three locations including the adjacent basin, within the trench, and within the outlet structure. Precipitation data were also collected on site.

Water Quality

Table II-8 summarizes the water quality data collected in 2005. An automatic Isco sampler and flow meter were installed inside the outlet drop structure on June 13. Samples collected from the trench and surface waters were sampled using disposable bailers, and the Isco sampler collected composite samples automatically. There is no available groundwater well in the vicinity of this site; therefore no groundwater samples were obtained.

In order to monitor pollutant removal effectiveness through the BMP system, sequential samples were collected from the surface water of the basin and trench. Water samples taken from the trench were collected after samples were collected from the surface water of the basin, and usually after the water level in the trench dropped from the peak trench water elevation. This approach was chosen to monitor the removal of pollutant loads from the surface water in the basin to water infiltrating through the trench.

Surface water samples collected on February 16 were equal to the EPA secondary standard for manganese at 0.05 mg/L, and trench samples collected on March 14 and June 21 exceeded the manganese MDH HRL of 0.10 mg/L. As stated previously, this is a naturally occurring element in the soils of this region. Copper concentrations in many surface and trench water samples were near the MPCA Class 2B Waters Chronic Standard for measured hardness concentrations, and copper in the February 16 surface water sample and the trench sample on March 14 exceeded MPCA Class 2B Waters Chronic Standard for hardness concentrations of 50 mg/L. Chloride

concentrations in the surface water sample on February 16 and the trench water sample on February 19 approached the MPCA Class 2B Waters Chronic Standard of 230 mg/L.

Table II-8. MSA Water Quality Results

Analyte [mg/L]	MSA Surface Water Samples						
	2/16/05	3/7/05	6/20/05	8/8/05	8/10/05	9/22/05	10/5/05*
Lead, dissolved	0.0005	0.0002	0.00007	<0.00007	0.0001	0.0002	0.0001
Cadmium, dissolved	0.00007	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
Manganese, dissolved	0.05**	0.045	0.0038	0.0024	0.003	0.0045	0.0012
Nickel, dissolved	0.0017	0.0011	0.0013	0.001	0.001	0.0013	0.0019
Copper, dissolved	0.0069***	0.0043	0.0059	0.0023	0.0023	0.004	0.001
Zinc, dissolved	0.015	0.0066	0.0108	0.0058	0.0076	0.014	0.0041
Hardness as CaCO ₃	50	28	20	24	26	28	19
Volatile suspended solids	~6	~6	~16	6	~3	~4	~3
Total suspended solids	~14	8	36	11	5	8	10
Total phosphorus	0.802	0.76	1.11	0.479	0.375	1.06	0.314
Ortho phosphorus	0.57	0.57	0.85	0.365	0.299	0.9	0.229
Total Kjeldahl nitrogen	2.6	2.7	2.4	1.3	0.82	1.4	0.53
Nitrite	0.06	0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Nitrate	0.39	0.51	0.42	0.35	0.14	0.29	0.27
Chloride	200	46	7	3	2	3	<2

*Outlet sample from Isco

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

*** Copper MPCA Class 2B Waters Chronic Standard (Hardness of 50 mg/L) = 0.0064 mg/L

Table II-8 Continued. MSA Water Quality Results

Analyte [mg/L]	MSA Trench Water Samples						
	2/19/05	3/14/05	6/21/05	8/10/05	9/22/05	9/22/05*	10/7/05
Lead, dissolved	0.0004	0.0002	0.0002	0.0002	0.0001	0.0012	0.0002
Cadmium, dissolved	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
Manganese, dissolved	0.04	0.135**	0.141**	0.0035	0.0034	0.0027	0.0038
Nickel, dissolved	0.0025	0.0028	0.0036	0.0014	0.0014	0.0014	0.0015
Copper, dissolved	0.0094	0.0077***	0.0037	0.004	0.0054	0.0049	0.0033
Zinc, dissolved	0.004	0.002	0.0024	0.005	0.0065	0.0076	0.0066
Hardness as CaCO ₃	96	70	94	54	66	58	50
Volatile suspended solids	~4	9	~6	~2	~4	~5	~2
Total suspended solids	13	32	31	7	13	14	10
Total phosphorus	0.531	0.477	0.336	0.313	0.776	0.867	0.287
Ortho phosphorus	0.348	0.321	0.19	0.266	0.65	0.69	0.227
Total Kjeldahl nitrogen	2	1.9	1.2	0.58	1.1	1.2	0.46
Nitrite	0.09	<0.03	<0.03	0.03	<0.03	<0.03	<0.03
Nitrate	0.4	0.05	0.1	0.11	0.3	0.32	<0.05
Chloride	205	57	5	2	3	3	<2

*Duplicate sample

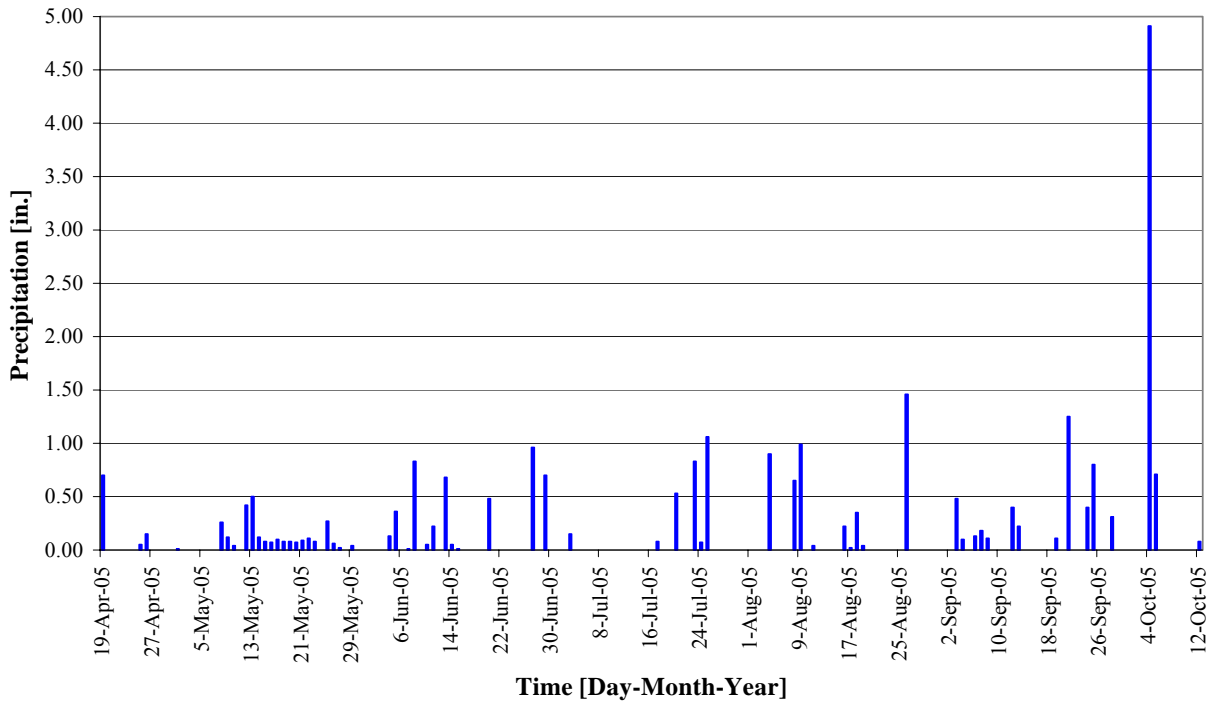
** Manganese MDH Health Risk Limit = 0.1 mg/L, EPA Secondary Standard = 0.05 mg/L

*** Copper MPCA Class 2B Waters Chronic Standard (Hardness of 50 mg/L) = 0.0064 mg/L, (Hardness of 100 mg/L) = 0.0098

Precipitation

Figure II-3 summarizes the precipitation totals at the MSA. A tipping bucket precipitation logger was installed near the swale at the south end of the basin on April 18 and was periodically checked for clogs and levelness to ensure accurate precipitation readings throughout the monitoring season.

Figure II-3. Precipitation at MSA, 2005



III. Basin Infiltration

III-A. Background

Snowmelt and summer infiltration data were collected at four basins and two trench locations in 2005. The basins include CD-P76, CD-P82, CD-P85, and CD-P86, 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 basins/trenches monitored in 2005. Spring infiltration of 2005 was the result of above average snowfall from December through February coupled with above average temperatures in early February and March. Fall infiltration was the result of one large rain event on October 4 and 5 and several pumping events at CD-P85.

Additional discussions of the spring melt and summer/fall climatic conditions are found in Section V. Climatic Conditions.

III-B. Methodology

In order to monitor basin infiltration rates and rates of water level decline in the infiltration trenches, water level equipment were installed at each of the five sites. In addition, flow monitoring equipment were installed at MSA and CD-P85 to monitor any overflow events. The following equipment was used for the 2005 monitoring season: an automatic tipping bucket rain logger, Isco 6712 portable samplers with an area/velocity flow meters to monitor flows at MSA and CD-P85, Telog dataloggers with Druck and Global Water pressure transducers or Global Water WL-15 level loggers to monitor water levels in the basins, wells, and trenches.

Staff gages were installed at each of the sites and their elevations were surveyed prior to basin inundation and after infiltration. Staff gauge readings were obtained at each of the sites throughout the monitoring season. Local precipitation data from the Bailey lift station were collected by the SWWD and data at the MSA station were collected by EOR. Precipitation data were recorded using automatic rain gages. These precipitation stations were the closest stations to the infiltration areas and are presented with the water levels in the basins and trenches.

A pressure transducer was used to measure water depth and was placed in the lowest portion of the basin or trench. Data were recorded from the pressure transducer using a data logger located in the field. Field inspection and maintenance of each of the data loggers were performed routinely. Staff gauge readings and hand measure depths were taken to check sensor accuracy and were incorporated in the data analysis.

Level monitoring equipment used during the spring snowmelt event were installed on February 2 at CD-P76 and CD-P82, and on February 18 at CD-P85 and CD-P86. A level sensor was installed at MSA on February 14 and an automatic rain logger was installed on April 18. An Isco automatic sampler and a flow meter were also installed in the overflow structure at MSA on June 13. Water was absent within the basins of CD-P76 and CD-P85 during spring equipment

installation, while frozen and standing water was present at CD-P82, CD-P86, and MSA during equipment installation. Monitoring of the sites occurred until most of the runoff generated by the events had infiltrated in the basins. Equipment was removed from CD-P76 and CD-P86 on April 15 and equipment from CD-P82 was removed on August 12. Monitoring continued at CD-P85 and the MSA throughout the summer and into the fall. Following the rain event on October 4th and 5th, equipment was re-installed at CD-P76 and CD-P82 until most of the stormwater infiltrated into the ground. An additional water level logger was also installed at CD-P85 on October 14 to capture the peak water elevation in the basin during the pumping events. Water levels at CD-P86 were taken by hand using wooden lathe and later surveyed in with a level. Monitoring equipment was removed from MSA on November 4 and from CD-P85 on November 28. A continuous level logger was installed within the MW-3w well on October 7 to track water table fluctuations in the well during the pumping events at CD-P85.

For infiltration trenches, the rate at which water levels drop in the trenches 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 ($\Delta\text{Depth}/\Delta\text{Time}$) 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 graphical form. A database with all infiltration rates is provided as an electronic appendix to this report. Tables with the average rates and ranges of the rates observed in each basin and trench are presented in Section III-D Infiltration Envelopes.

III-C. Infiltration Basin and Trench Results

CD-P76

Figure III-1 depicts CD-P76, its overflow elevation, and location of monitoring equipment. Table III- 1 contains the elevation versus area in this basin.

Table III-1. CD-P76 Elevation Versus Area

Elevation [ft]	Area [acres]
934	13.30
932	10.20
930	5.61
928	2.18
927	0.50
926.6	0.00

Figure III-2 illustrates the water elevation in CD-P76 over time. During Drawdown 1, March 7 through March 14, the sensor was dislodged from the staff gauge by ice activity. Therefore, the staff gauge data were used to calculate infiltration rates for this event instead of the level sensor data. Four staff gauge readings were taken during this period, and therefore three infiltration

rates were calculated. Each of these infiltration rates spanned more than one 0.5-foot interval; they are plotted in Figure III-2 at each 0.5-foot elevation that they span.

Figures III-3 and III-4 compare the infiltration rates from different events to one another, plotted with respect to elevation.

Figure III-1. CD-P76

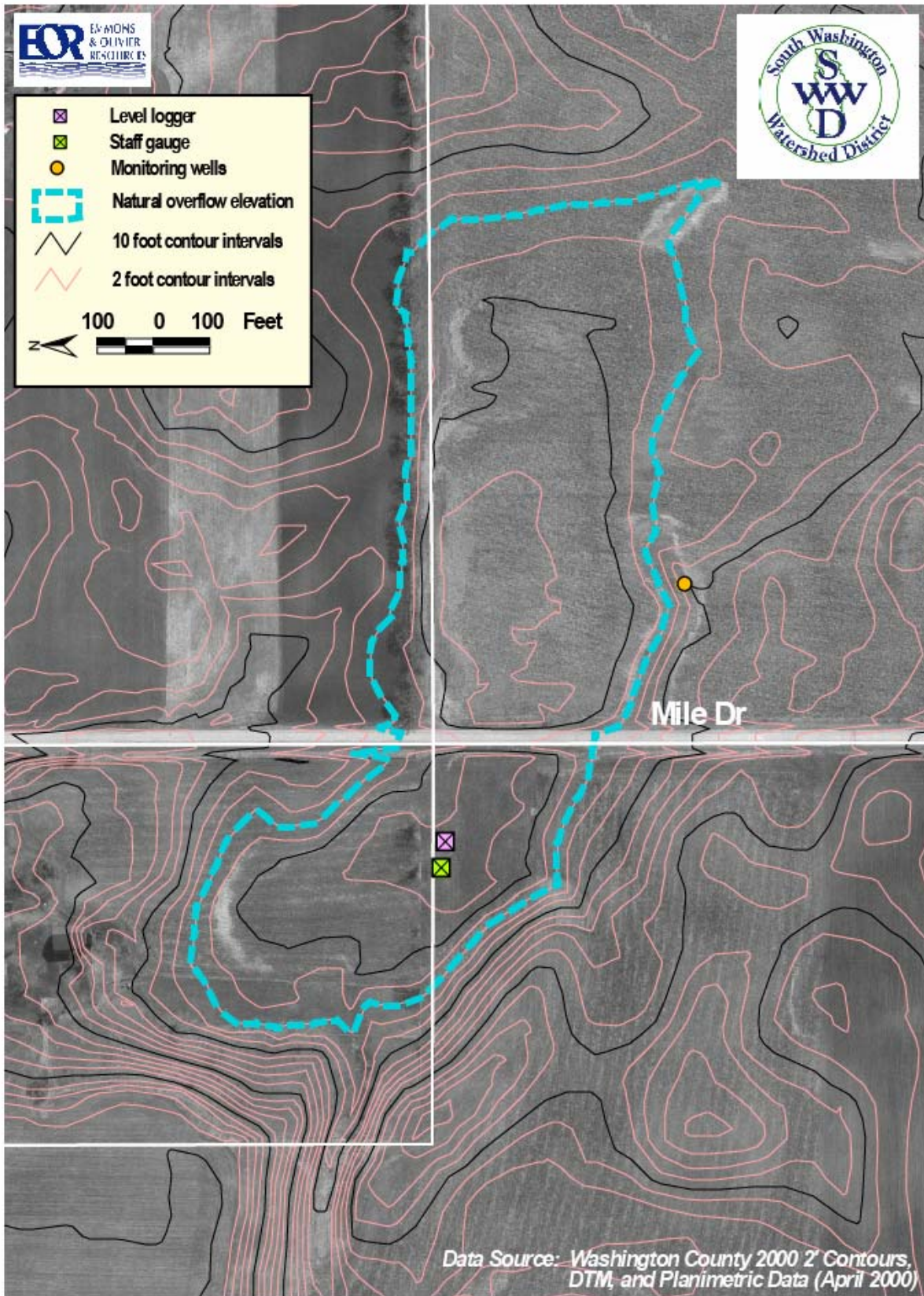


Figure III-2. CD-P76 Water Elevation Versus Time. Numbers refer to drawdown events.

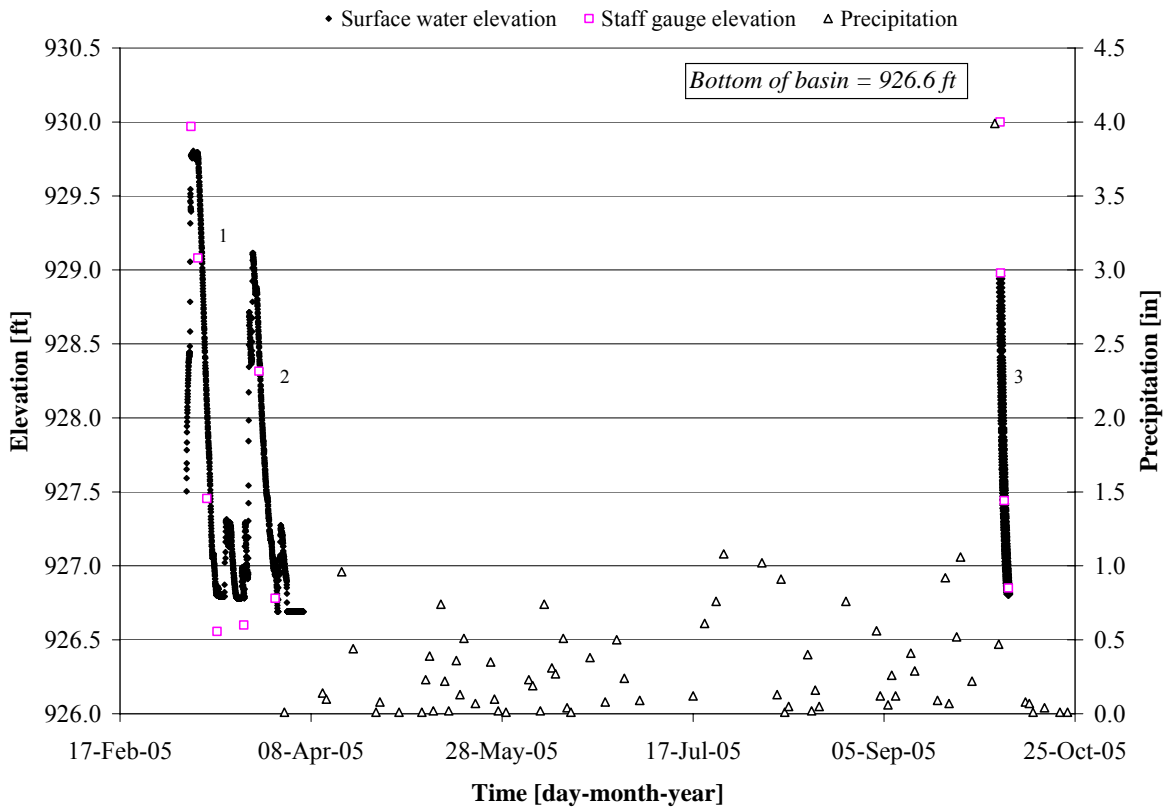


Figure III-3. CD-P76 Infiltration Rate Curves, 2005

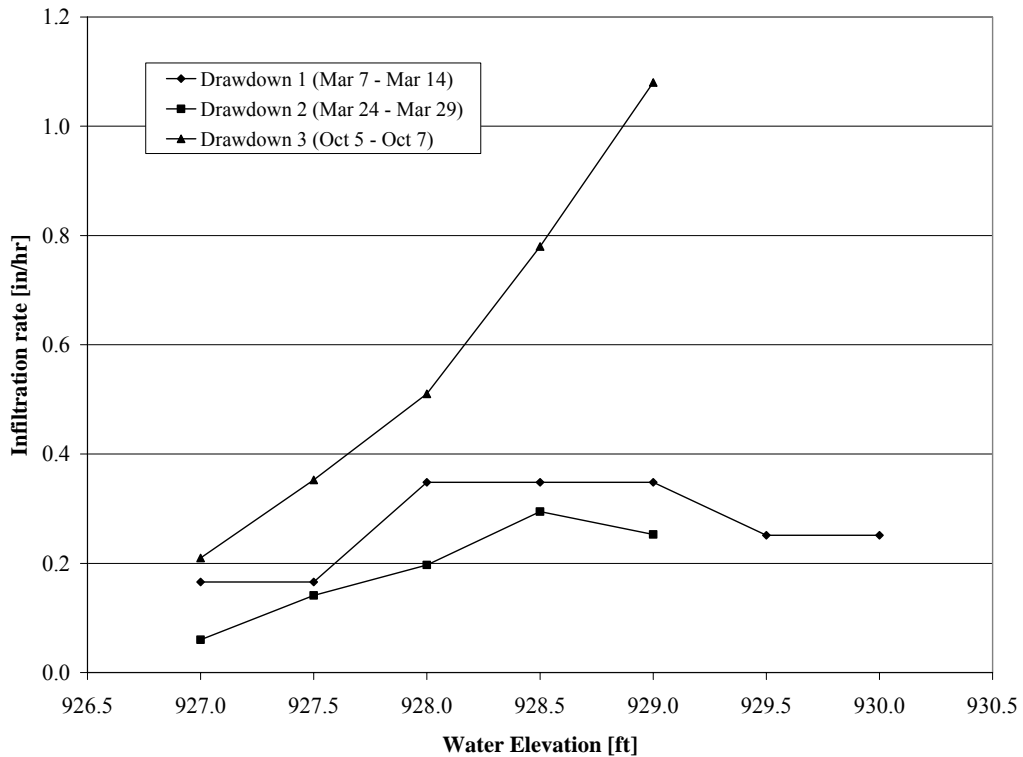
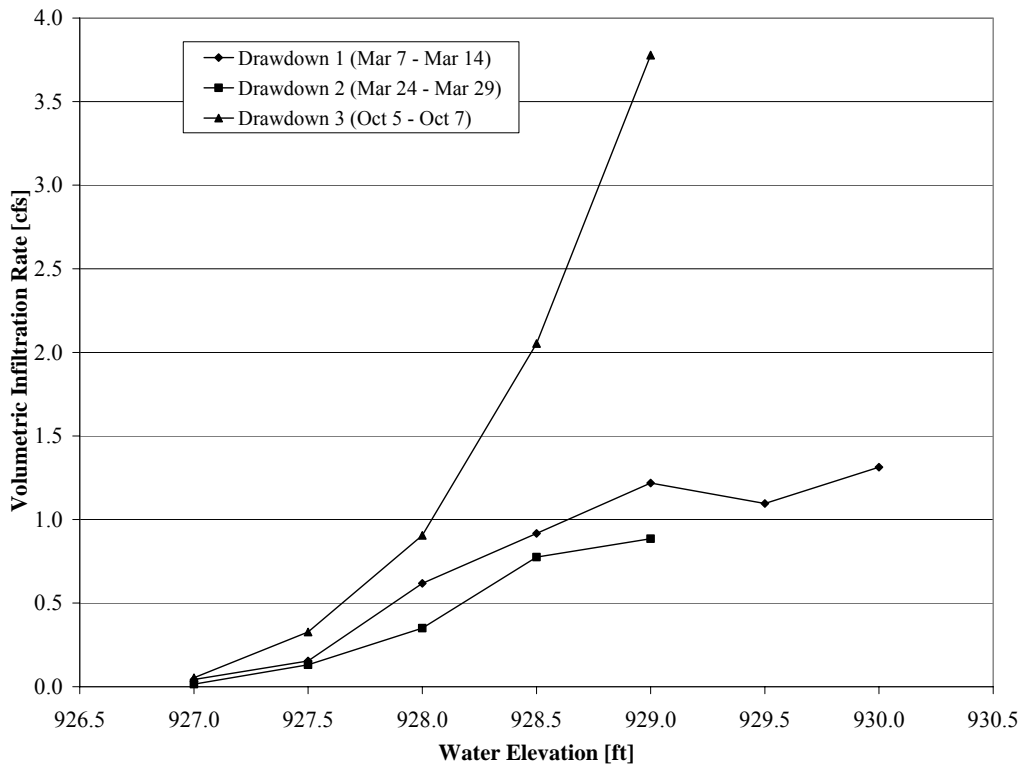


Figure III-4. CD-P76 Volumetric Infiltration Rate Curves, 2005



CD-P82

Figure III-5 depicts CD-P82, its overflow elevation, and the location of monitoring equipment. The following table contains the elevation versus area in this basin.

Figure III-6 illustrates the water elevation in CD-P82 over time. Data from approximately March 7 through March 17 (the unlabeled drawdown event in between events 1 and 2) were not used in the infiltration rate calculations due to the sensor not functioning properly during that period of time.

Figures III-7 and III-8 compare the infiltration rates from the two events, plotted with respect to elevation.

Table III-2. 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

Figure III-5. CD-P82

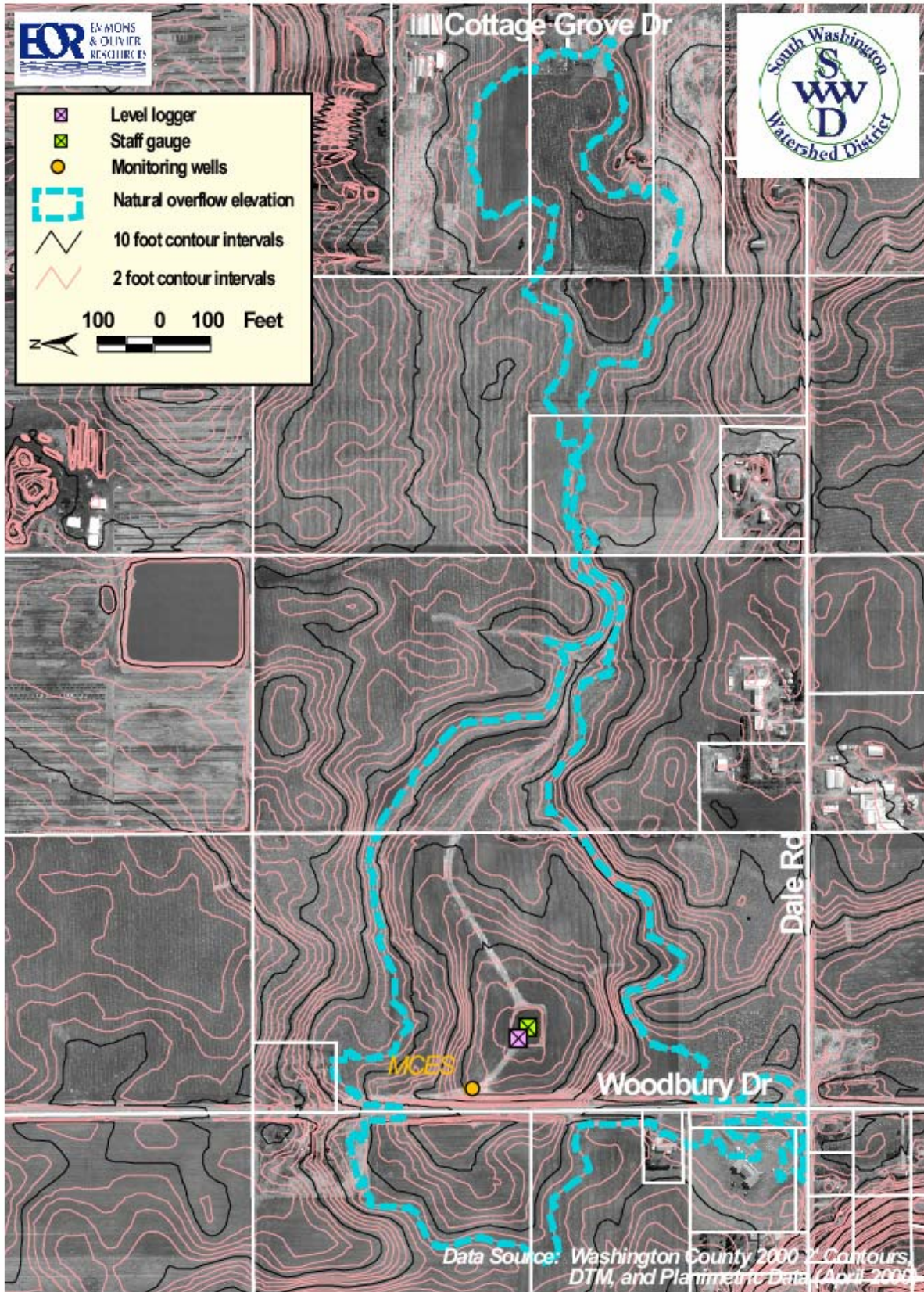


Figure III-6. CD-P82 Water Elevation vs. Time. Numbers refer to drawdown events.

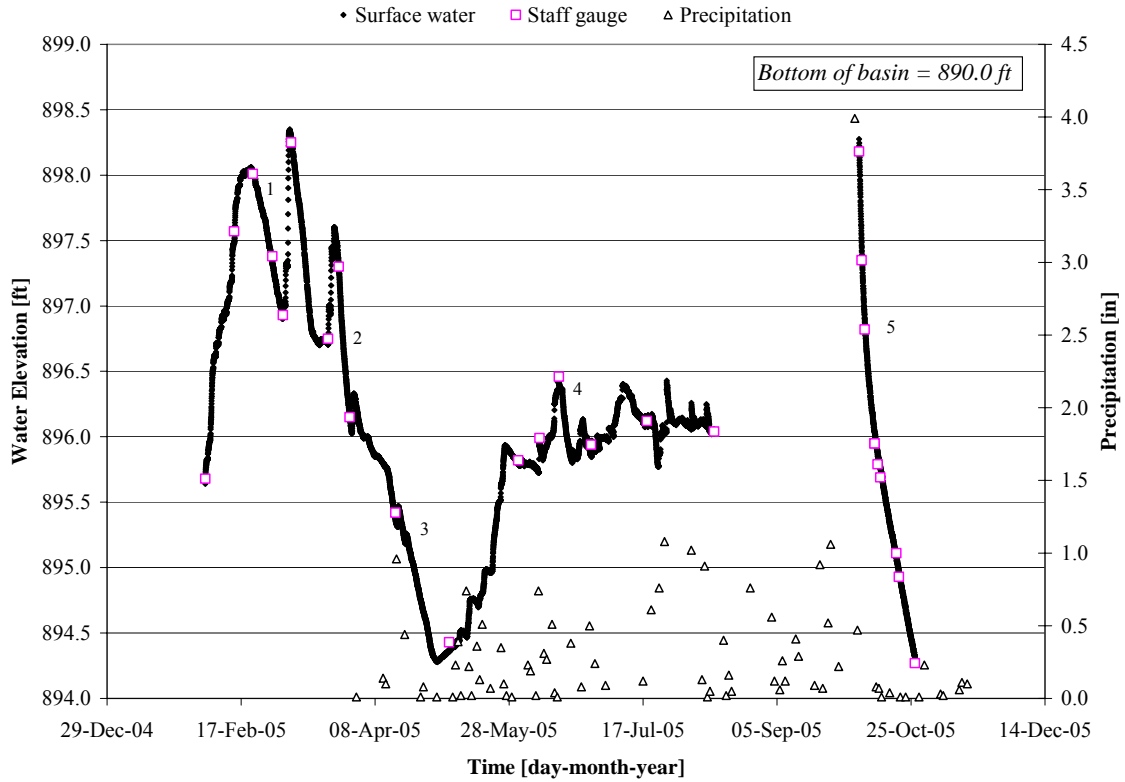


Figure III-7. CD-P82 Infiltration Rate Curves, 2005

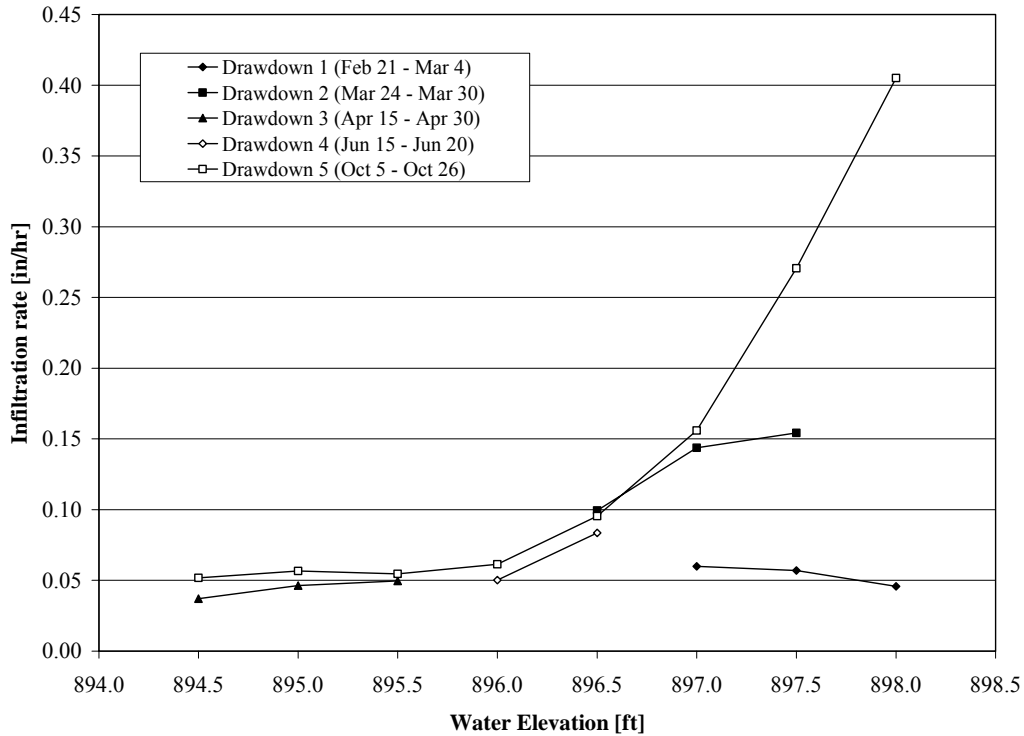
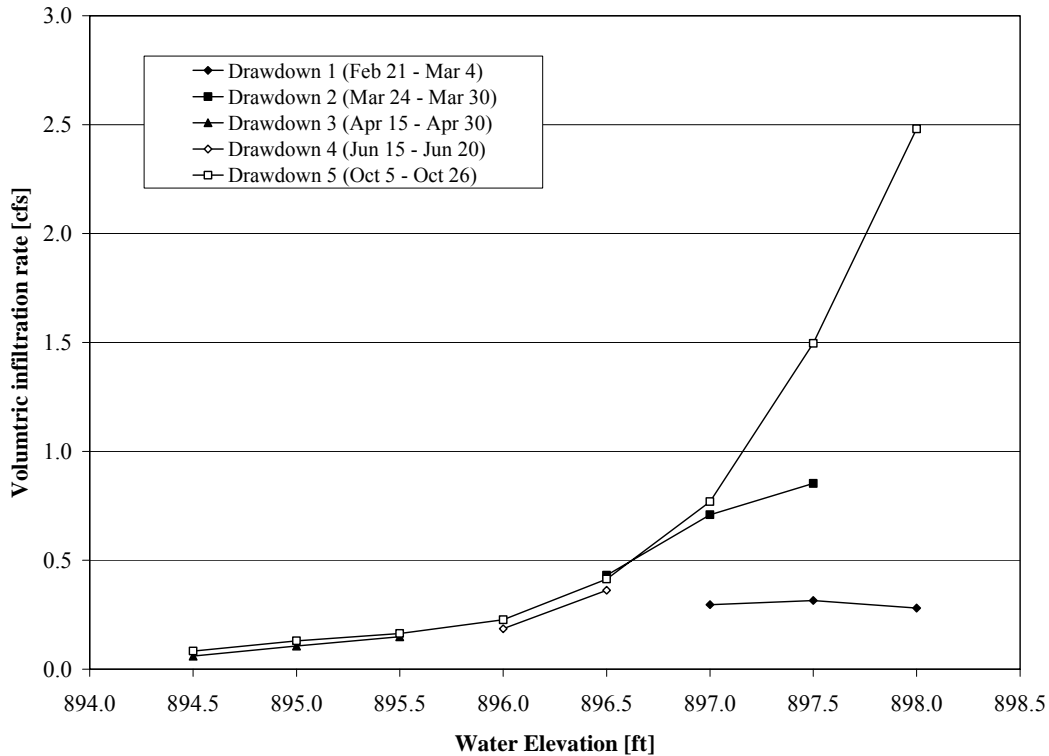


Figure III-8. CD-P82 Volumetric Infiltration Rate Curves, 2005



CD-P85

Figure III-9 depicts CD-P85, its overflow elevation, and the location of monitoring equipment. The following table contains the elevation versus area in this basin.

Figure III-10 illustrates the water elevation in CD-P85 over time. Surface water was minimal in the basin prior to October and is reported in the CD-P85 infiltration trench section. A groundwater mound, as observed in MW-5, intersected the bottom of the CD-P85 basin around October 10 and remained above the bottom of the basin until early November. Lower infiltration rates observed in 2005 may have been the result of groundwater mounding beneath the CD-P85 basin. Figures III-11 and III-12 compare the infiltration rates and volumetric rates plotted with respect to elevation.

Table III-3. 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

Figure III-9. CD-P85

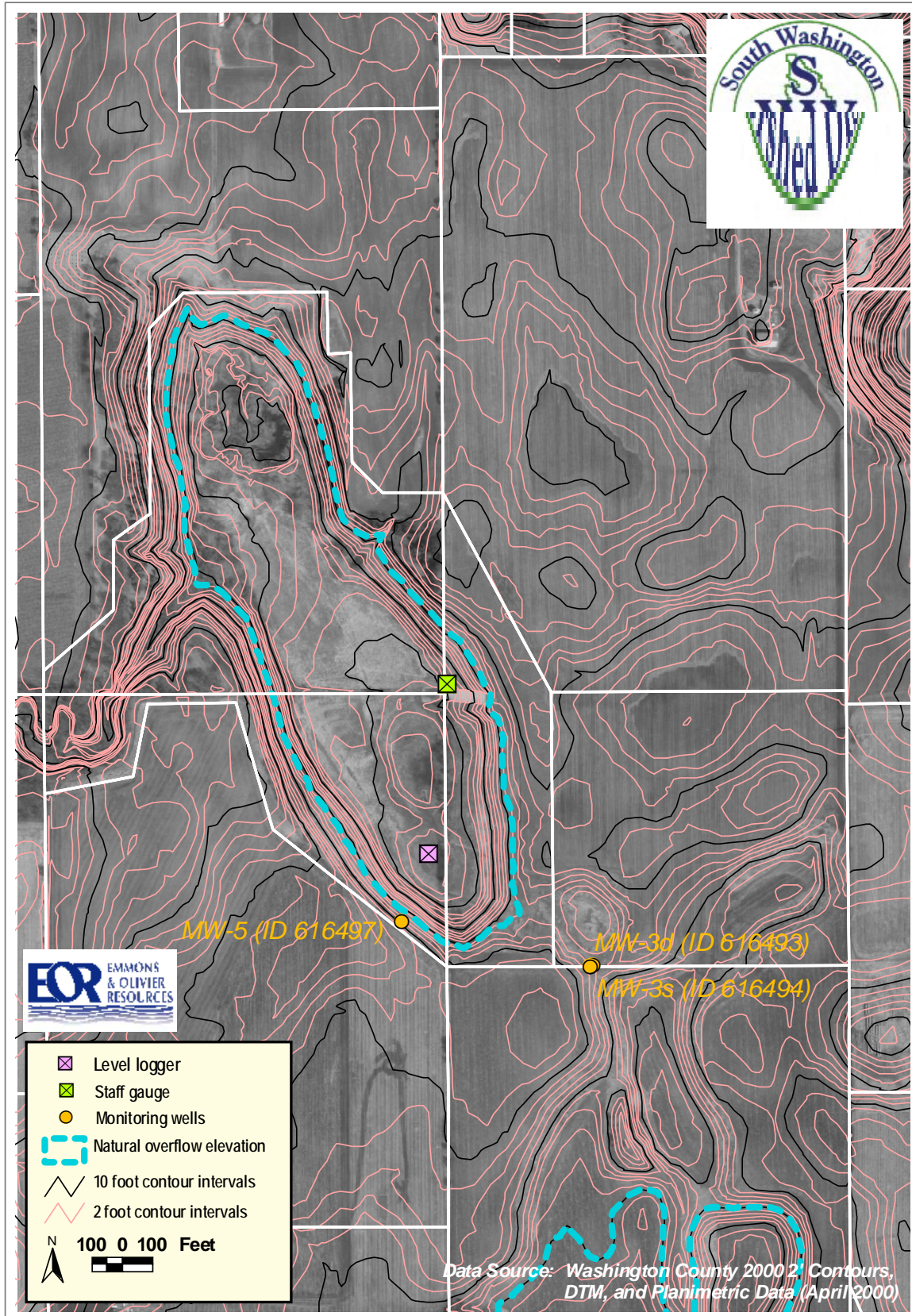


Figure III-10. CD-P85 Water Elevation vs. Time. Numbers refer to drawdown events.

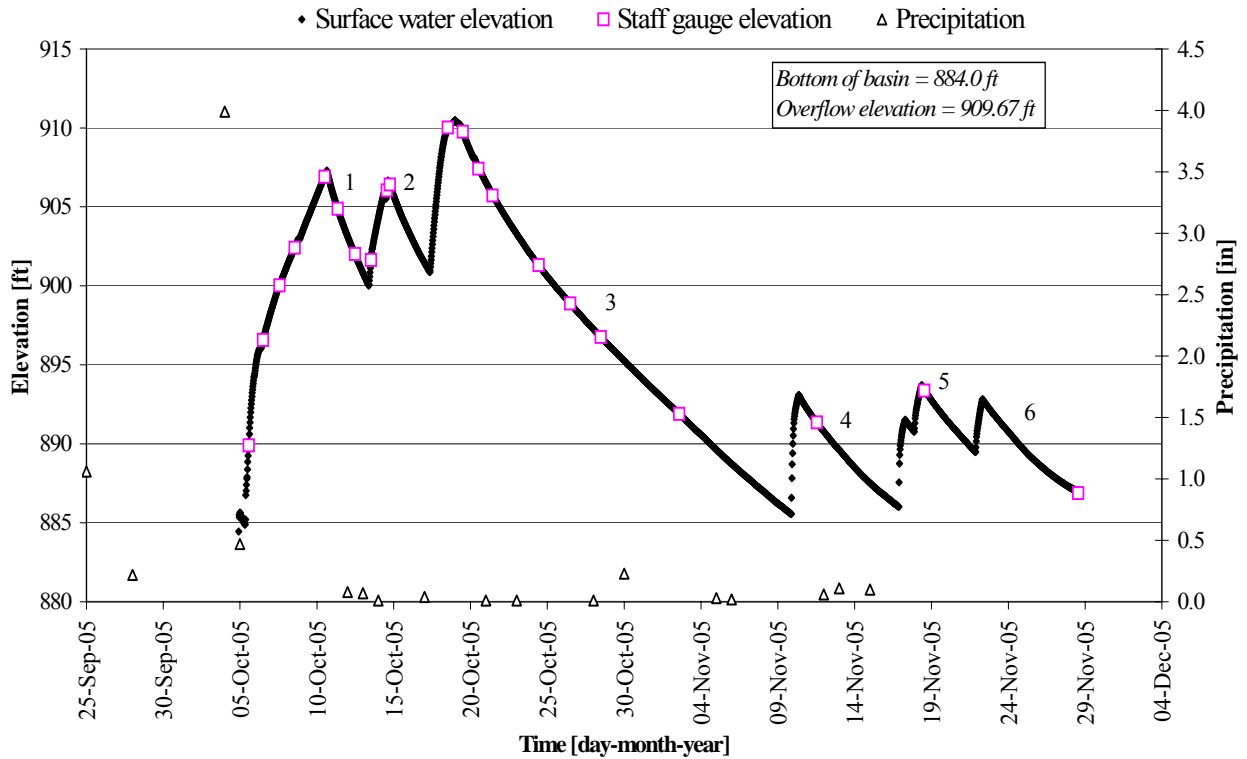


Figure III-11. CD-P85 Infiltration Rate Curves, 2005

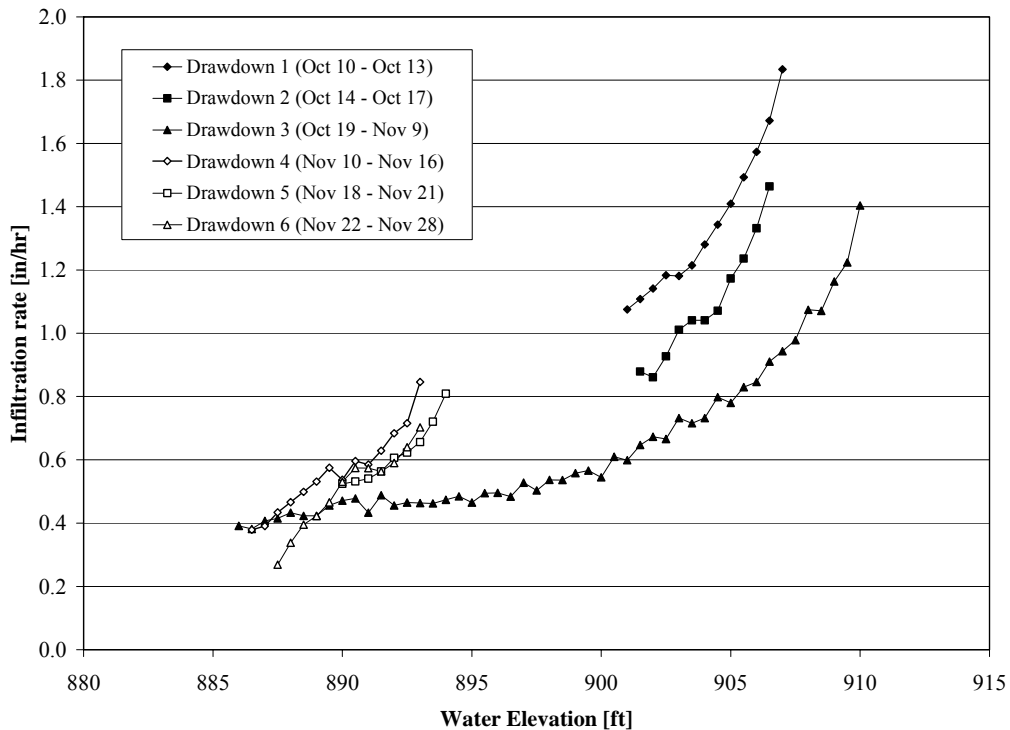
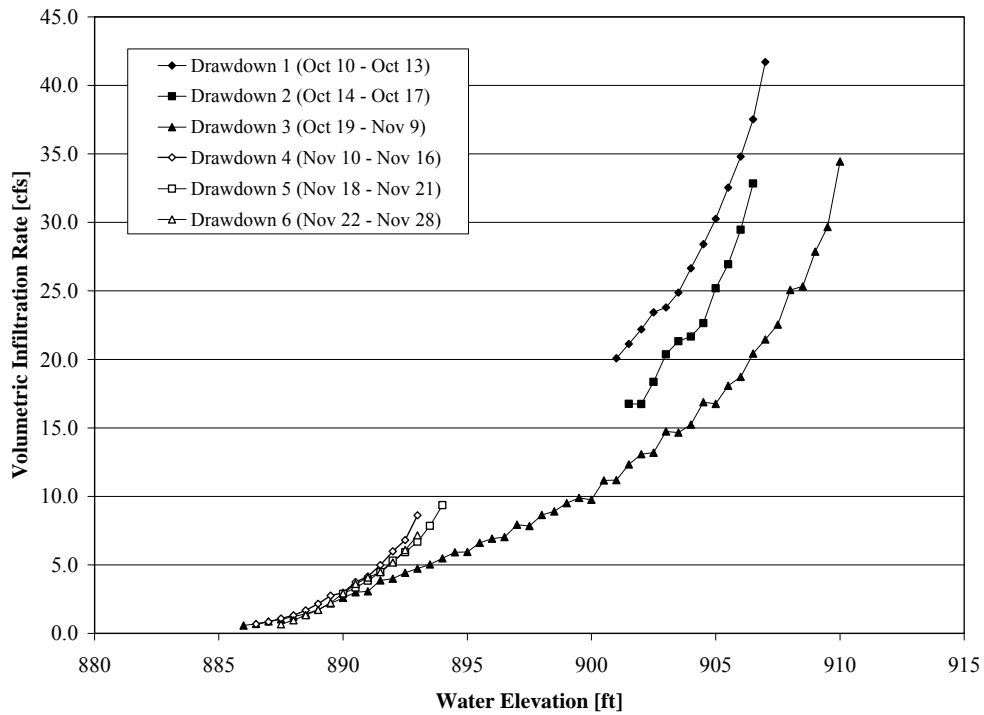


Figure III-12. CD-P85 Volumetric Infiltration Rate Curves, 2005



CD-P86

Figure III-13 depicts CD-P86, its overflow elevation, and the location of monitoring equipment. The following table contains the elevation versus area in this basin.

Table III-4. CD-P86 Elevation Versus Area

Elevation [ft]	Area [acres]
880.0	2.76
879.5	2.52
879.0	2.27
878.5	1.99
878.0	1.71
877.5	1.38
877.0	1.03
876.5	0.71
876.0	0.19

Figure III-13. CD-P86

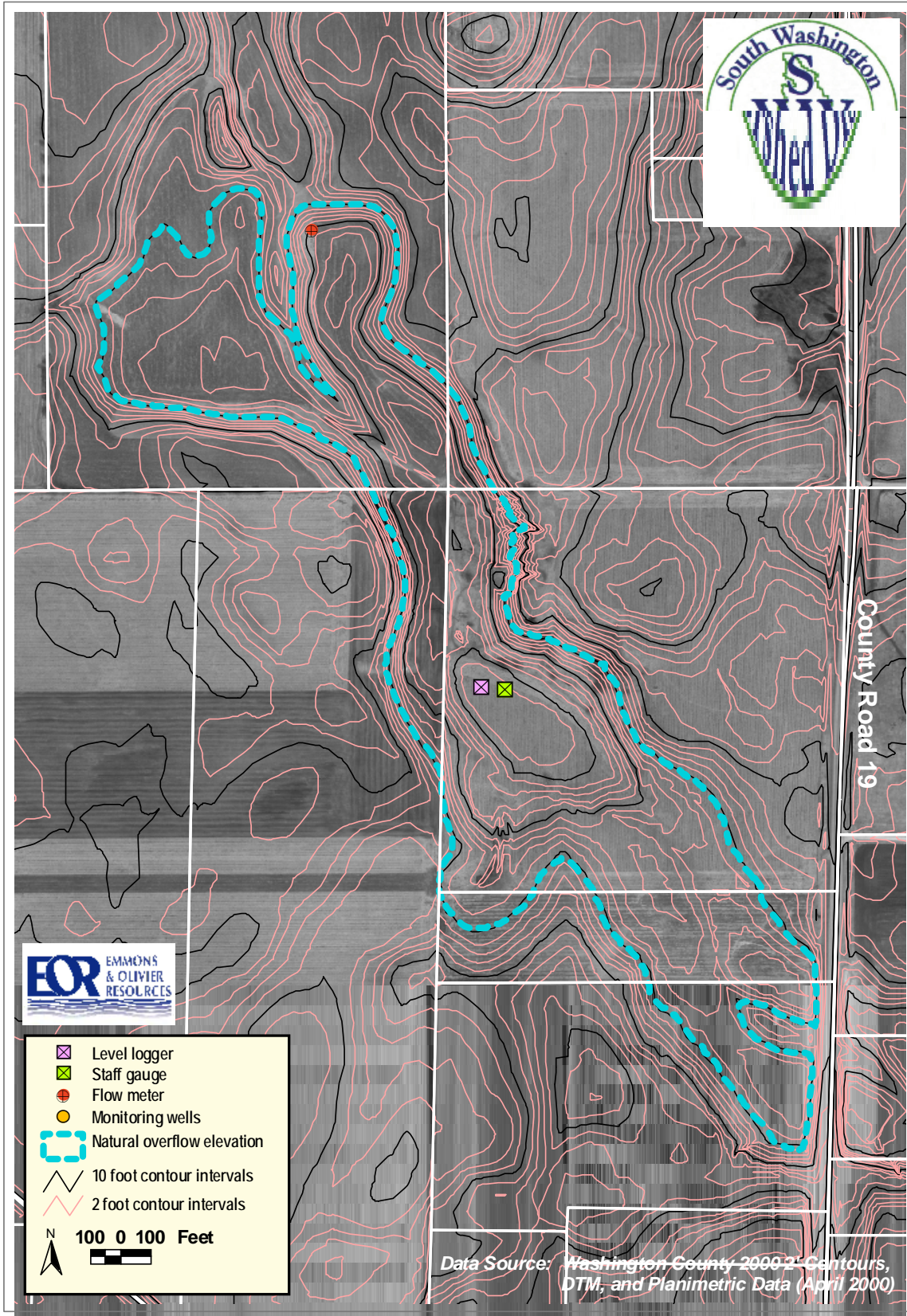


Figure III-14 illustrates the water elevations measured in CD-P86 during 2005. Figures III-15 and III-16 compare the infiltration rates from the two events, plotted with respect to elevation.

Figure III-14. CD-P86 Water Elevation vs. Time. Numbers refer to drawdown events.

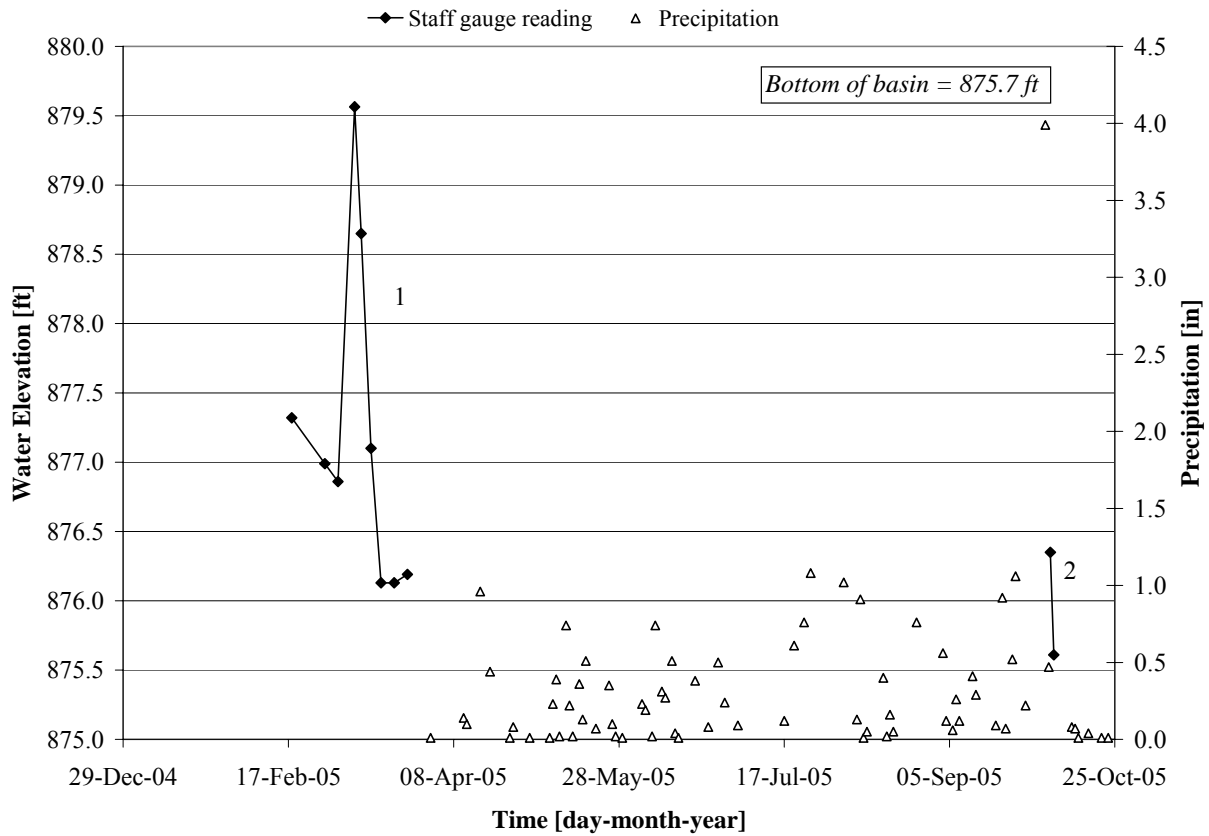


Figure III-15. CD-P86 Infiltration Rate Curves, 2005

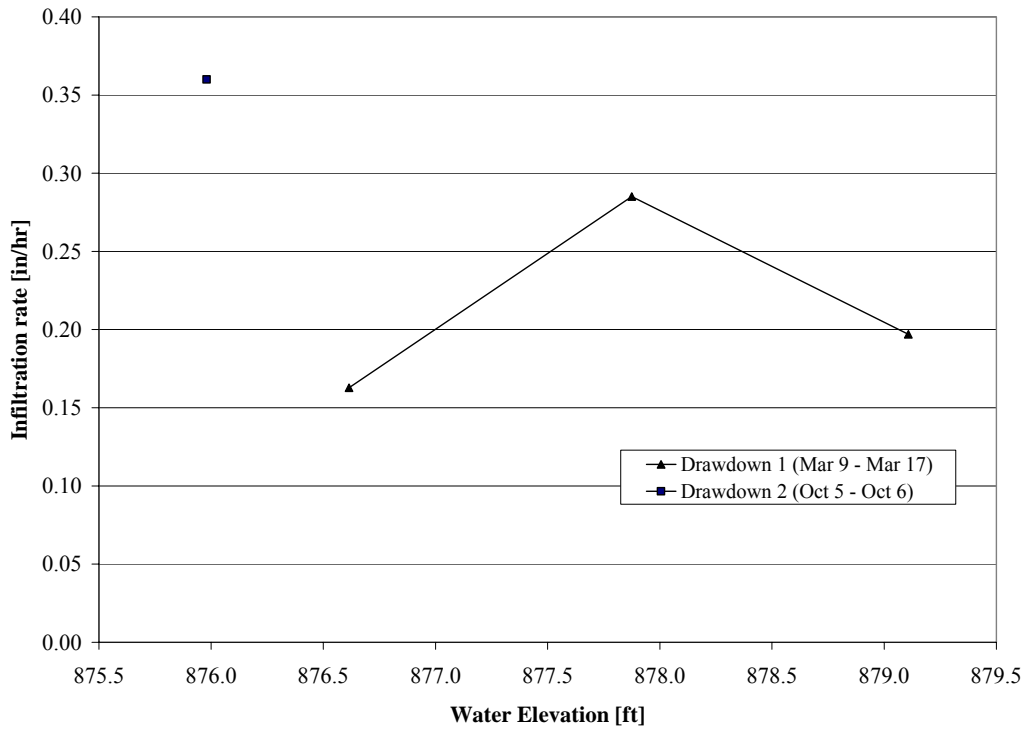
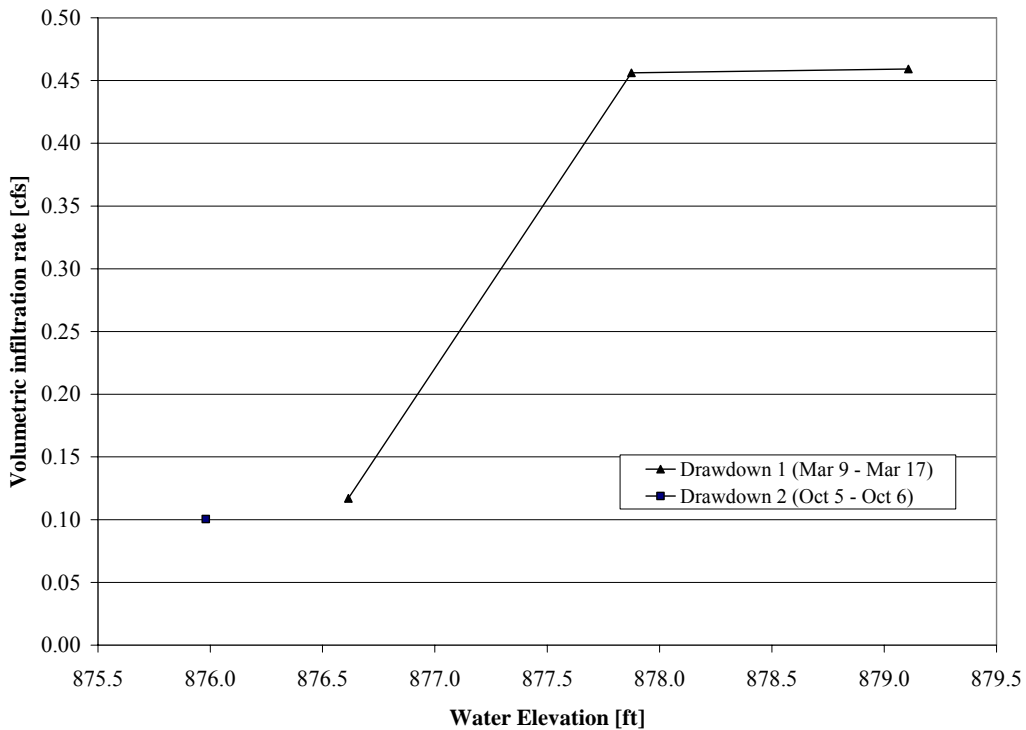


Figure III-16. CD-P86 Volumetric Infiltration Rate Curves, 2005



CD-P85 – Infiltration Trench

Monitoring equipment was installed within the south observation tube (trench) on February 18, and served the data collection needs of the trench and a portion of the basin throughout the monitoring season. Trench and staff gauge readings were taken throughout the year to verify the accuracy of the water level readings recorded by the loggers. Monitoring equipment remained in the field until late November after most of the water within the basin had infiltrated.

Construction activities for the new outlet of CD-P85 were completed in late 2004. Seeding and erosion fabric were installed within the construction areas of the basin and the vegetation has begun to be established. There appeared to be no direct sedimentation within the infiltration areas from these activities.

The rates of water decline for the trench were collected in the spring and summer of 2005. The data collected represent the infiltration trench 7 years after construction.

Figure III-17 illustrates the depth of water in the CD-P85 infiltration trench over time. Figure III-18 compares the infiltration rates from different events to one another, plotted with respect to water depth.

Figure III-17. CD-P85 Trench Water Depth vs. Time, 2005. Numbers refer to drawdown events.

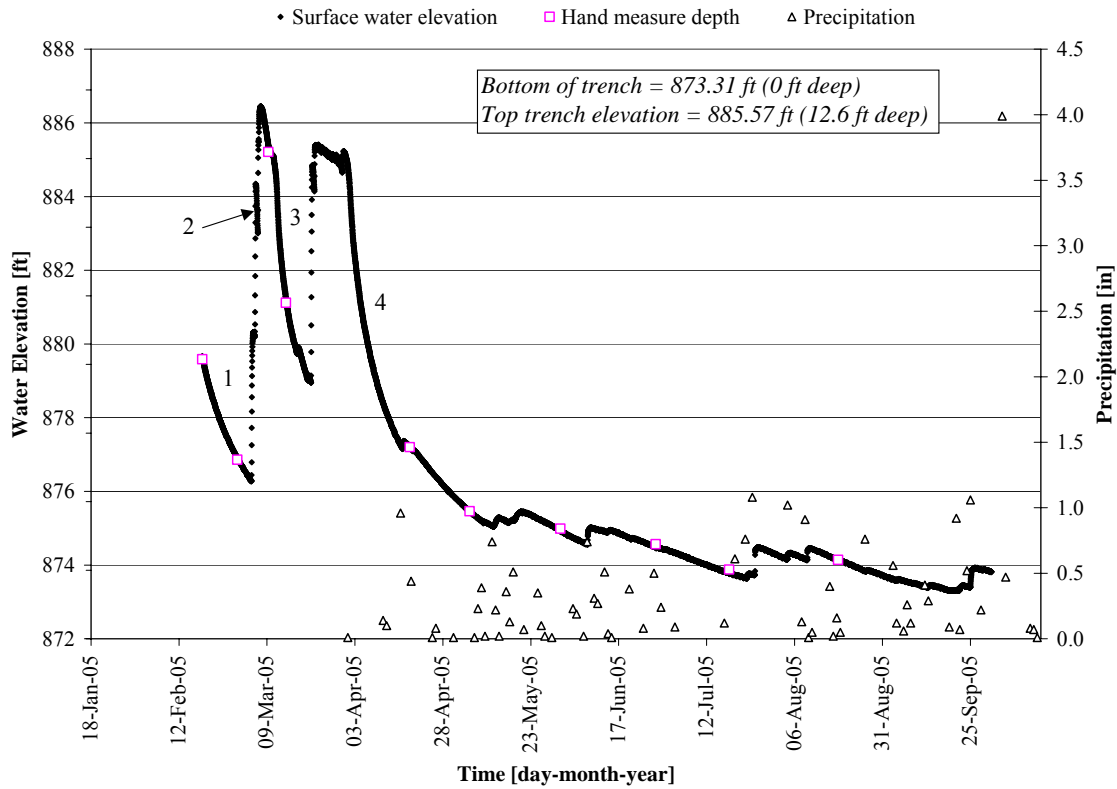
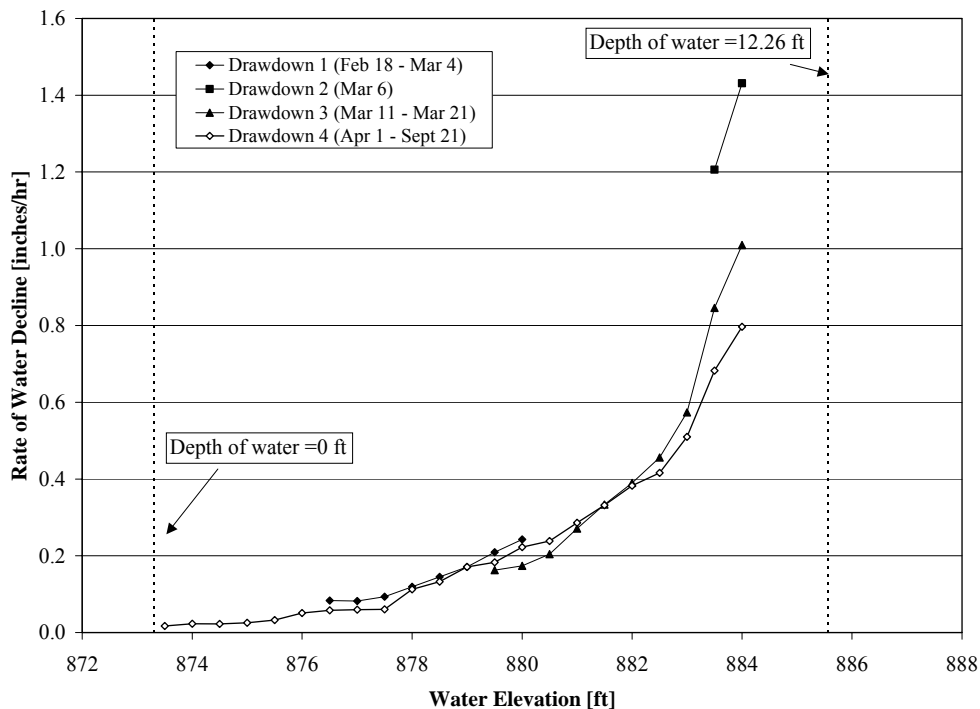


Figure III-18. CD-P85 Trench Rates of Water Decline, 2005



Math and Science Academy (MSA) Infiltration Trench

Figure III-19 depicts MSA, its overflow elevation, and the location of monitoring equipment. A pressure transducer was installed in the bottom of the observation trench on February 14, 2005. In order to monitor any overflow events, an Isco automatic sampler and flow meter were installed within the drop structure on June 13. A rain logger was installed at the edge of the basin on April 18. All monitoring equipment remained on site to record rainfall and runoff events throughout the monitoring season until late fall, when the equipment was removed on November 4. The storm in early October produced enough runoff to inundate the basin to the overflow elevation. Measurements from the level loggers and Isco sampler indicated the outlet was completely flooded and operated at full capacity for approximately one hour. The duration of the overflow event lasted for approximately 2 hours and 15 minutes. This is the first recorded overflow event since the infiltration trench was installed on site, and although the outlet was completely inundated, it effectively managed the large volume of runoff that entered the site

Figure III-19. Math and Science Academy

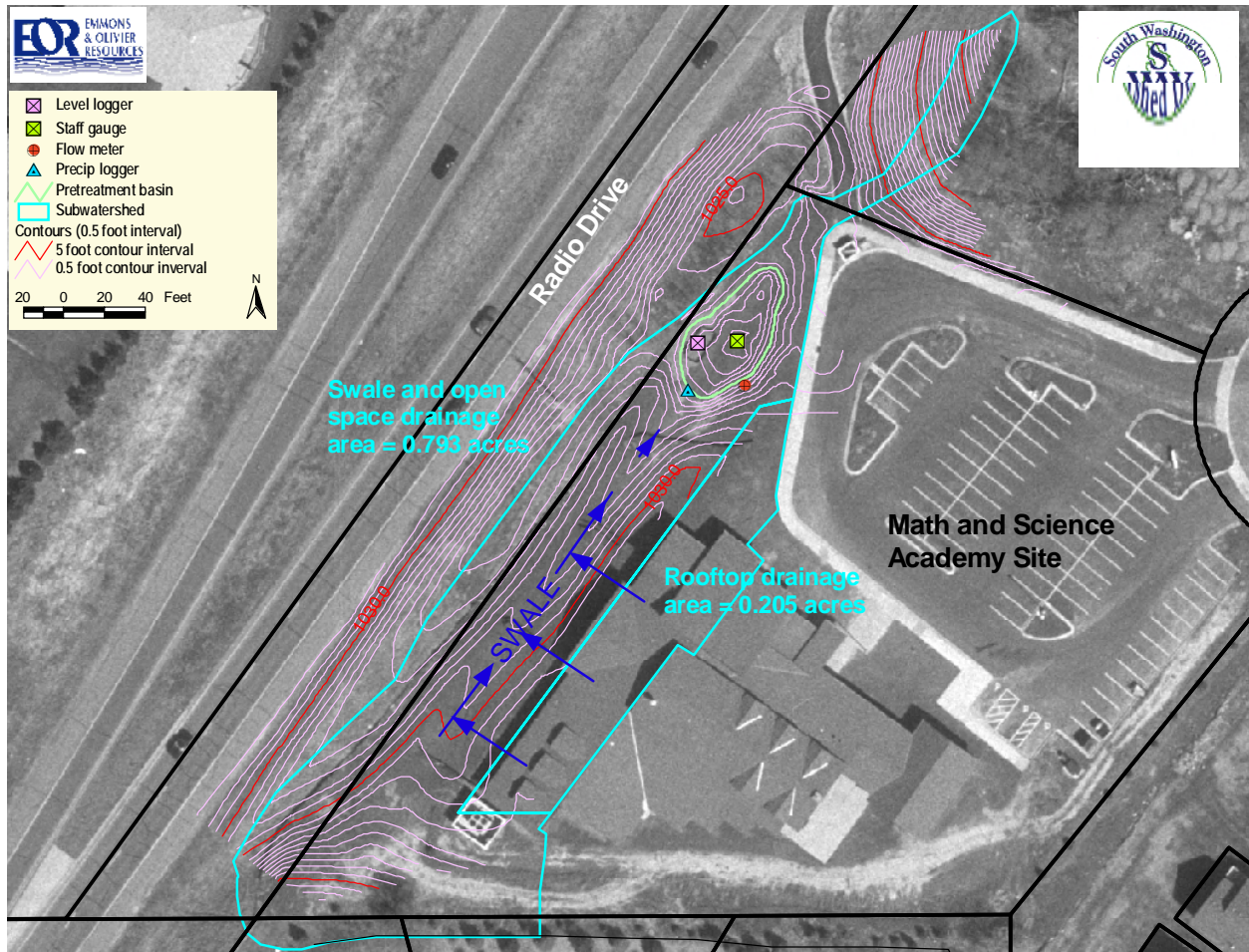


Figure III-20 illustrates the depth of water in the MSA trench over time. Water level data are presented as depth of water in the infiltration trench, as opposed to water elevation. Figure III-21 compares the infiltration rates from different events to one another, plotted with respect to elevation.

Figure III-20. MSA Depth vs. Time and Precipitation, 2005. Numbers refer to drawdown events.

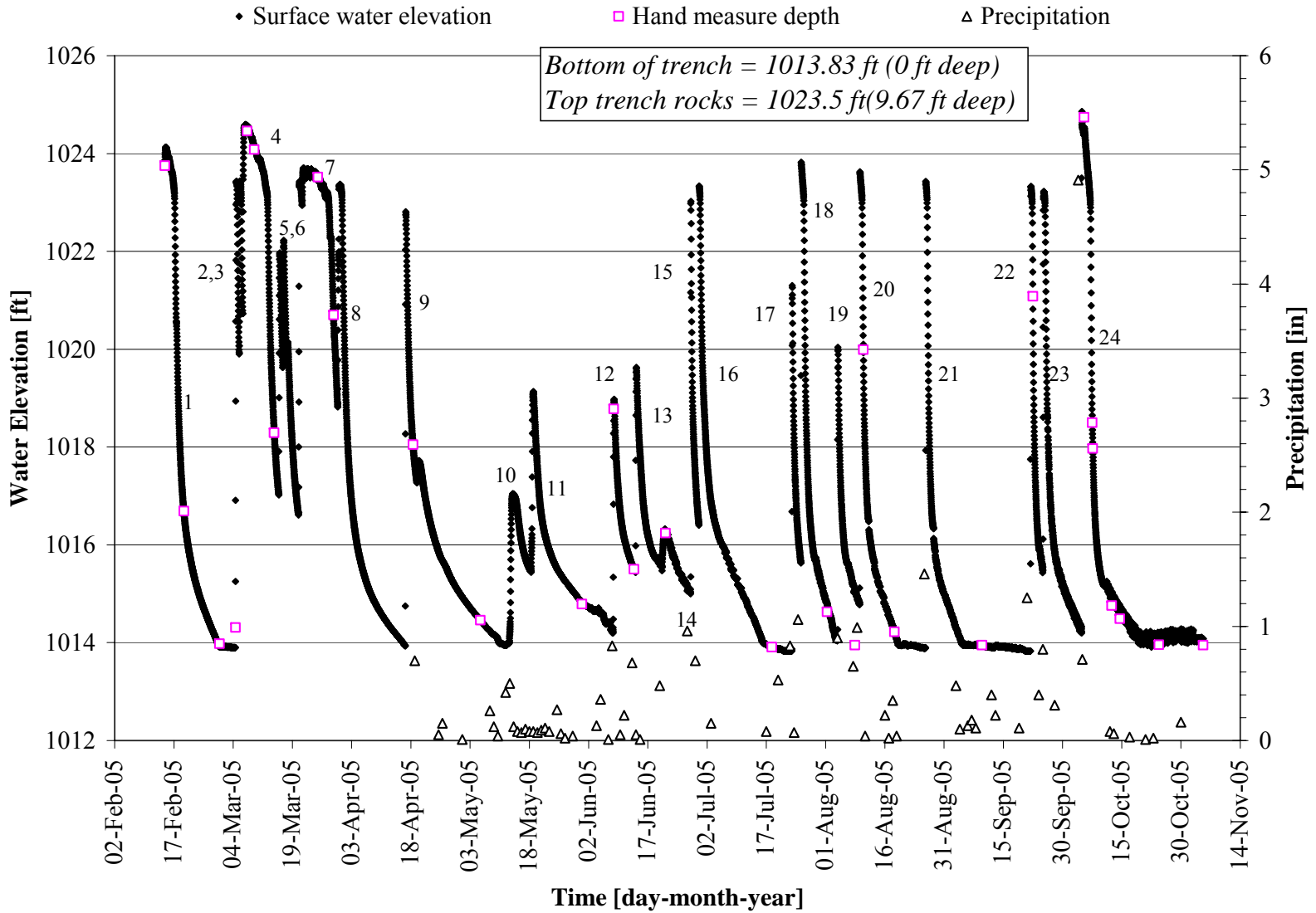
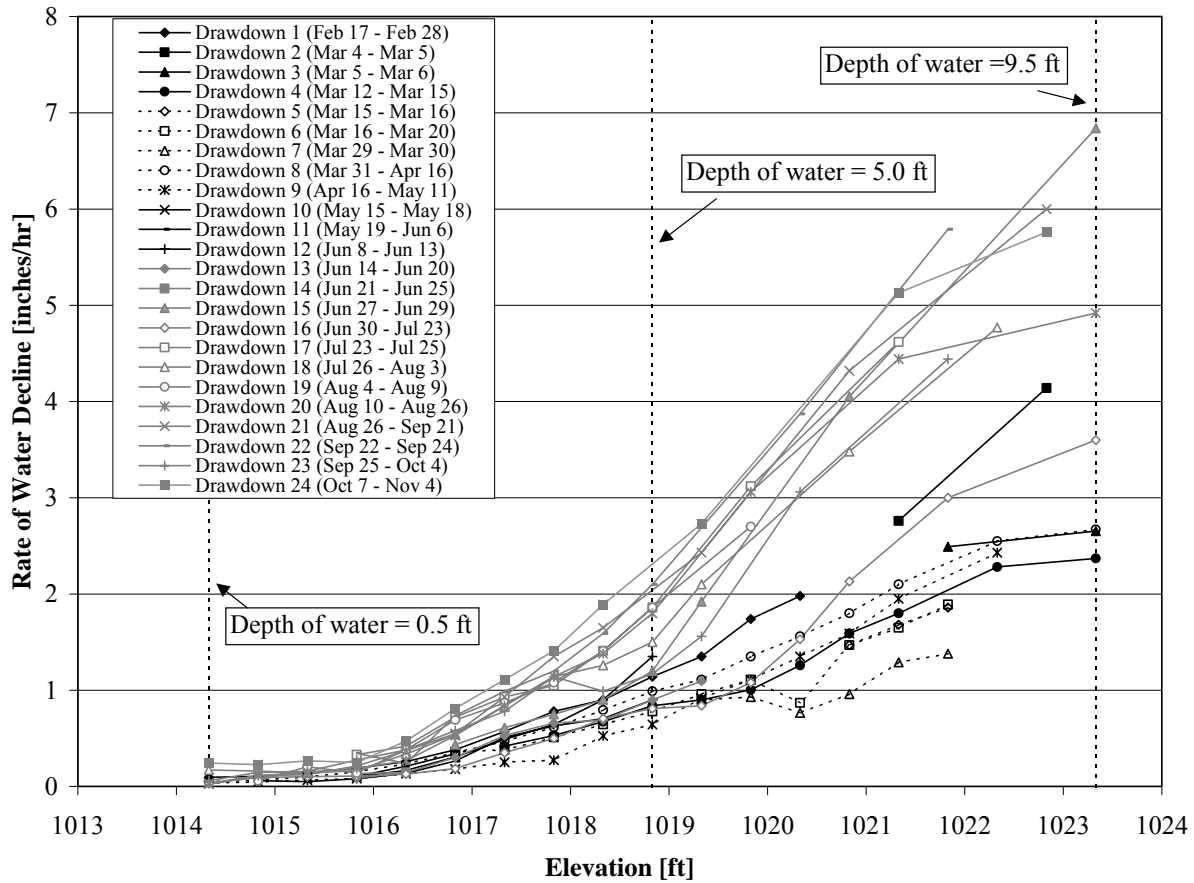


Figure III-21. MSA Trench Infiltration Rate Curves, 2005



III-D. Infiltration Envelopes

Infiltration envelopes represent the ranges of infiltration rates observed within a basin at each elevation interval, and can be used to predict infiltration rates at a basin for which infiltration monitoring data do not exist. Infiltration rates change over time due to factors such as soil moisture and temperature conditions, sediment type, and quality of runoff.

Analytical Approach

Infiltration envelopes and infiltration rate means and ranges were determined for each basin, based on multiple years of monitoring data. To determine the infiltration envelopes, all infiltration rates observed in a basin were plotted relative to elevation interval. The envelope

consists of the outer edges of the data set and is represented by a line in the figures. Outliers were included in the figures, but were not used when determining the actual infiltration envelopes.

Average infiltration rates and ranges were then determined for each basin and trench. Rates for the infiltration basins were summarized according to season (snowmelt vs. rainfall), whereas trench rates were not split up by season. Infiltration rates were shown to differ according to season in the basins but not in the trenches (SWWD 2004 Infiltration Monitoring Report, 2005). The average infiltration rate was calculated by first averaging the infiltration rates at each elevation interval, and then taking an average of these averages. The range of rates indicates the high and low value within the infiltration envelope and is useful for application in similar settings.

CD-P76

CD-P76 has been monitored since 1999. Figures III-22 and III-23 present the infiltration rates and volumetric infiltration rates at corresponding elevations of the basin for seven years of data, along with the infiltration envelopes. Rates at several elevations in 2005 were greater than the previous infiltration envelope.

Figure III-22. Infiltration Rate vs. Elevation and Infiltration Envelope for CD-P76, 1999-2005

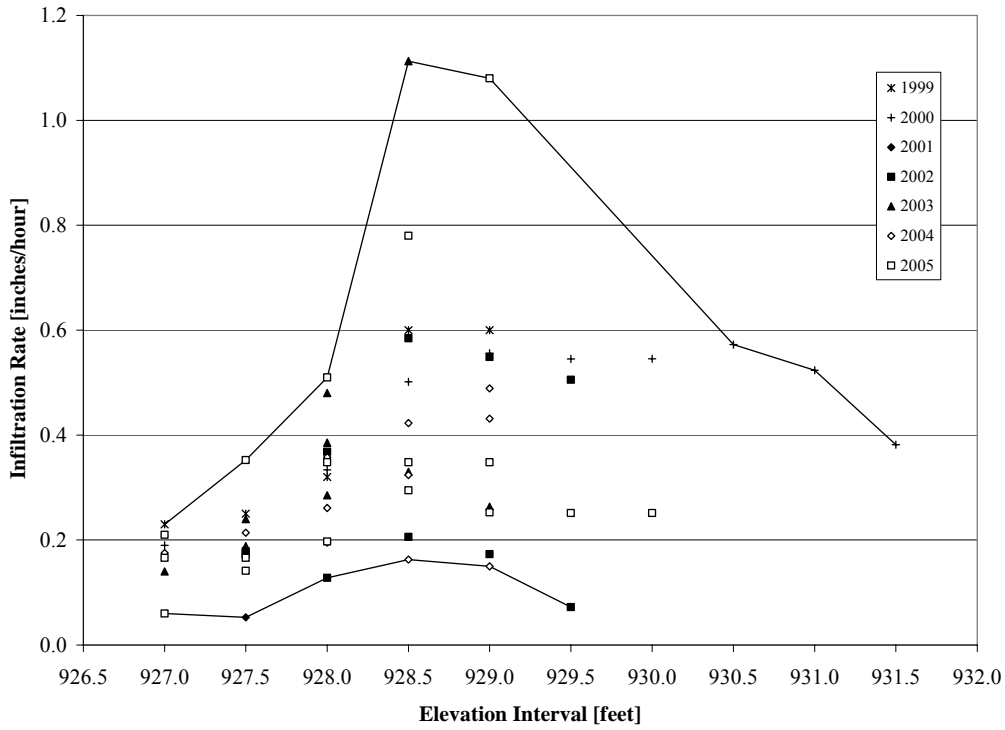


Figure III-23. Volumetric Infiltration Rate vs. Elevation and Infiltration Envelope for CD-P76, 1999-2005

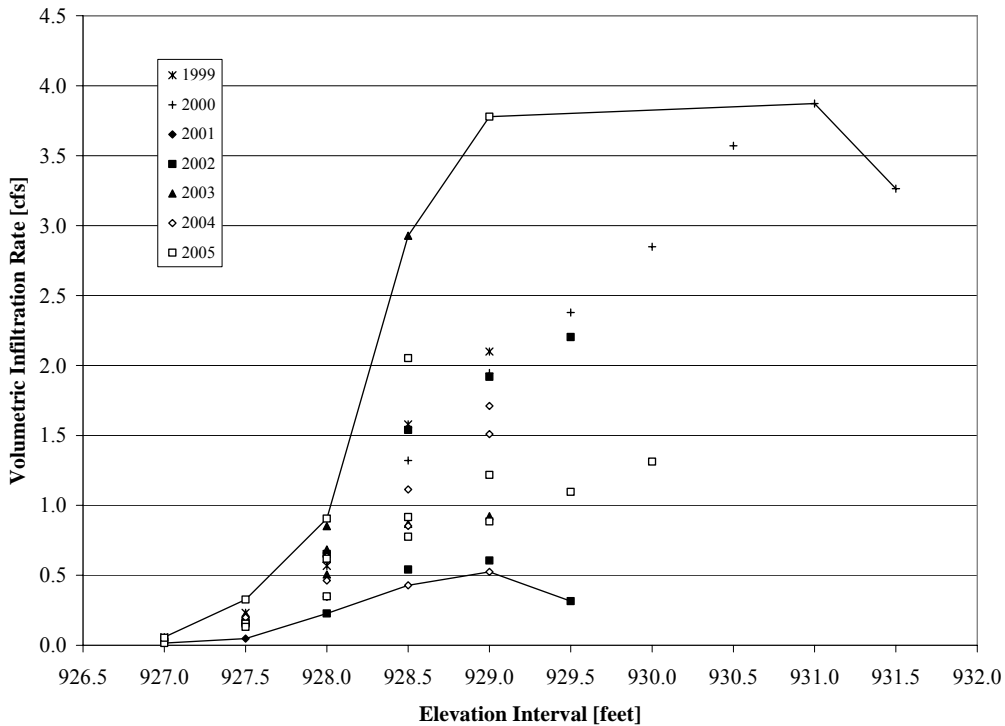


Table III-5 presents the average rates for snowmelt and rainfall infiltration events, along with the ranges of infiltration rates observed in those two categories, for the years 1999 through 2005. All data were included in determining the values for Table III-5. These rates can be used in calculations regarding expected infiltration rates in CD-P76 or in a basin with similar characteristics as CD-P76.

Table III-5. CD-P76 Average Infiltration Rates and Ranges, 1999 – 2005

	Snowmelt		Rainfall	
	Average Rate	Rate Range	Average Rate	Rate Range
Infiltration Rate [inches/hour]	0.34	0.053 – 0.60	0.39	0.17 – 1.1
Volumetric Infiltration Rate [cfs]	1.7	0.015 – 3.9	1.1	0.044 – 3.8

CD-P82

CD-P82 has been monitored since 1999. Figures III-24 and III-25 present the infiltration rates and volumetric infiltration rates at corresponding elevations of the basin for seven years of data, along with the infiltration envelopes. Most of the rates observed in 2005 fall inside of the previously defined infiltration envelope. However, one rate observed in 2005 was higher than last year's infiltration envelope, increasing the upper limit at that elevation. As mentioned previously, it is unknown what effect dewatering activities had on the infiltration rates from February through August of 2005.

Figure III-24. Infiltration Rate vs. Elevation and Infiltration Envelope for CD-P82, 1999-2005

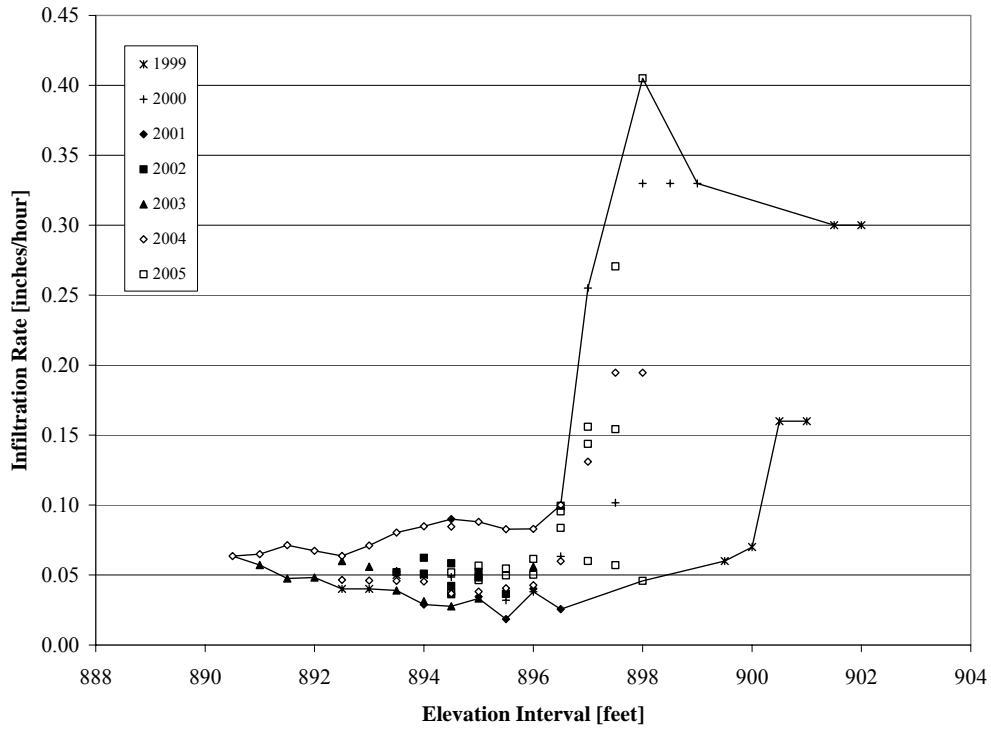


Figure III-25. Volumetric Infiltration Rate vs. Elevation and Infiltration Envelope for CD-P82, 1999-2005

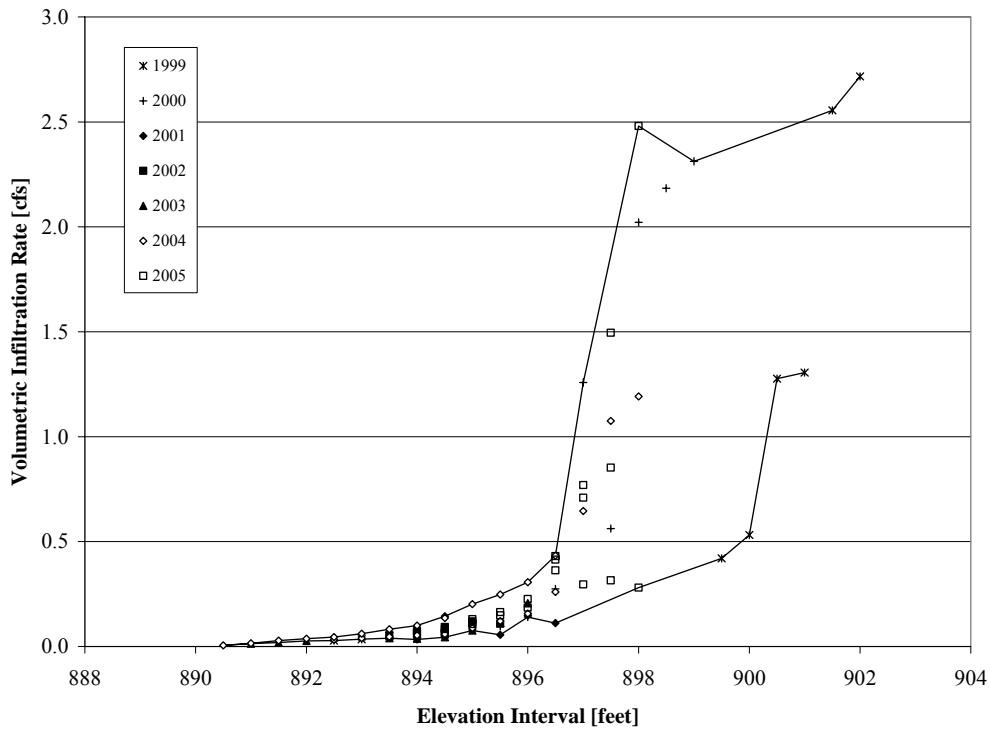


Table III-6 presents the average rates for snowmelt and rainfall infiltration events, along with the ranges of infiltration rates observed in those two categories, for the years 1999 through 2005. All data were included in determining the values for Table III-11. These rates can be used in calculations regarding expected infiltration rates in CD-P82 or in a basin with similar characteristics as CD-P82.

Table III-6. CD-P82 Average Infiltration Rates and Ranges, 1999 - 2005

	Snowmelt		Rainfall	
	Average Rate	Rate Range	Average Rate	Rate Range
Infiltration Rate [inches/hour]	0.13	0.018 - 0.33	0.10	0.028 - 0.41
Volumetric Infiltration Rate [cfs]	0.84	0.028 - 2.7	0.38	0.0050 - 2.5

CD-P85

CD-P85 has been monitored since 1997, except for 2004. Compiled infiltration rate data are presented in Figures III-26 and III-27. Typically, two drawdowns per year are presented for data collected prior to 2001 that represent the highest and lowest measured rates. Data from all drawdowns are presented for data collected from 2001 and after. The data collected in 2005 fit within the previously defined infiltration envelope. As mentioned previously, groundwater mounding in and around CD-P85 may have influenced the observed infiltration rates in 2005.

Figure III-26. Infiltration Rate vs. Elevation and Infiltration Envelope for CD-P85, 1997-2005

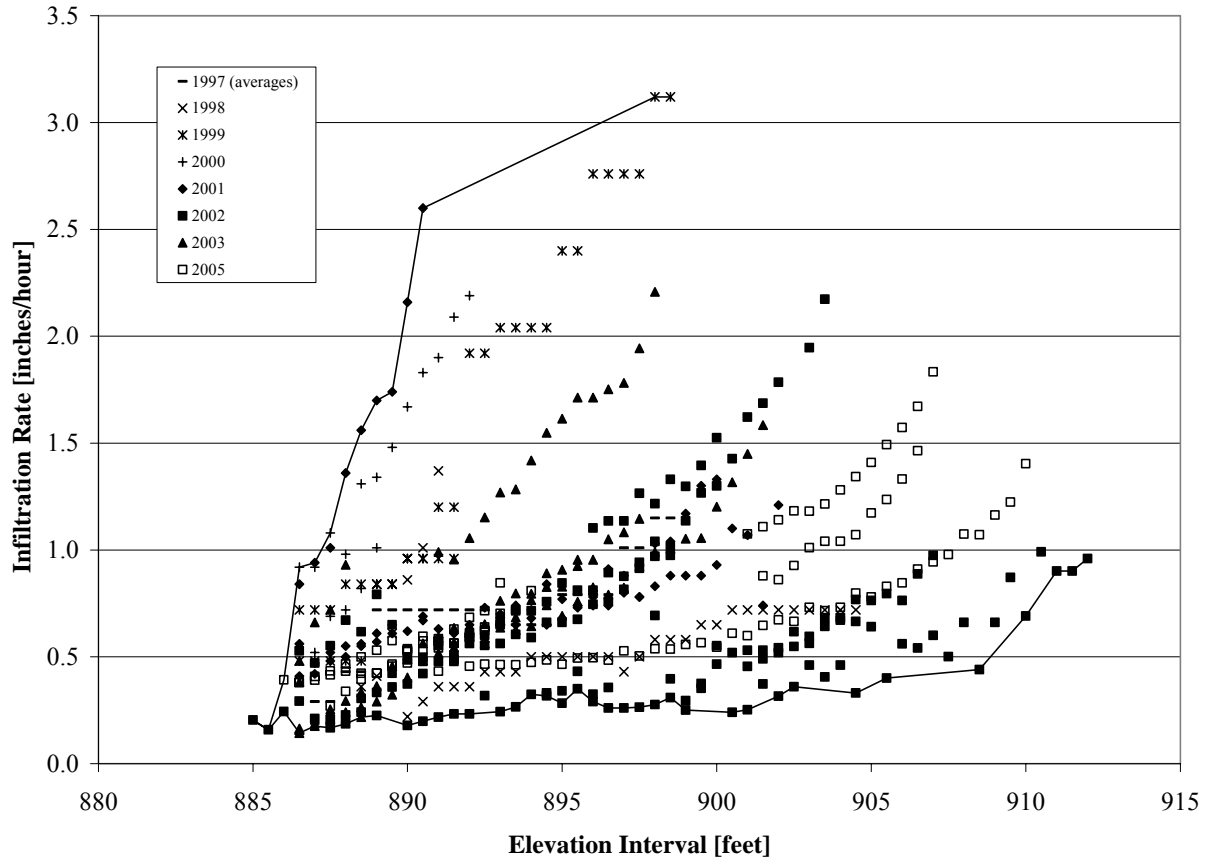


Figure III-27. Volumetric Infiltration Rate vs. Elevation and Infiltration Envelope for CD-P85, 1997-2005

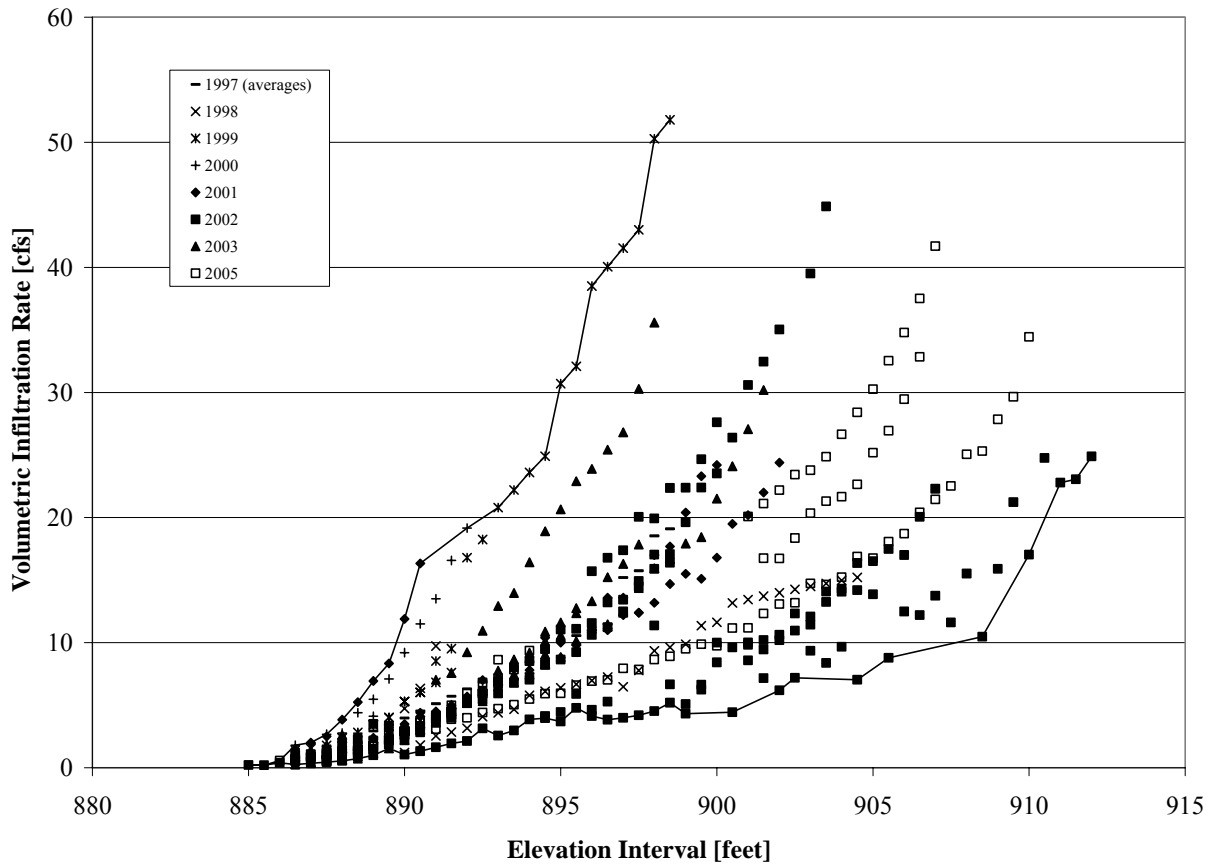


Table III-7. CD-P85 Average Infiltration Rate and Range, 1997 - 2005

	Snowmelt		Rainfall	
	Average Rate	Rate Range	Average Rate	Rate Range
Infiltration Rate [inches/hour]	1.5	0.84 - 2.6	0.80	0.14 - 3.1
Volumetric Infiltration Rate [cfs]	6.5	1.5 - 16	13	0.21 - 52

CD-P86

This is the first year that CD-P86 has been monitored. Infiltration rate data are presented in Figures III-28 and III-29. Due to the low number of data points, infiltration envelopes were not added on to these figures.

Figure III-28. Infiltration Rate vs. Elevation for CD-P86, 2005

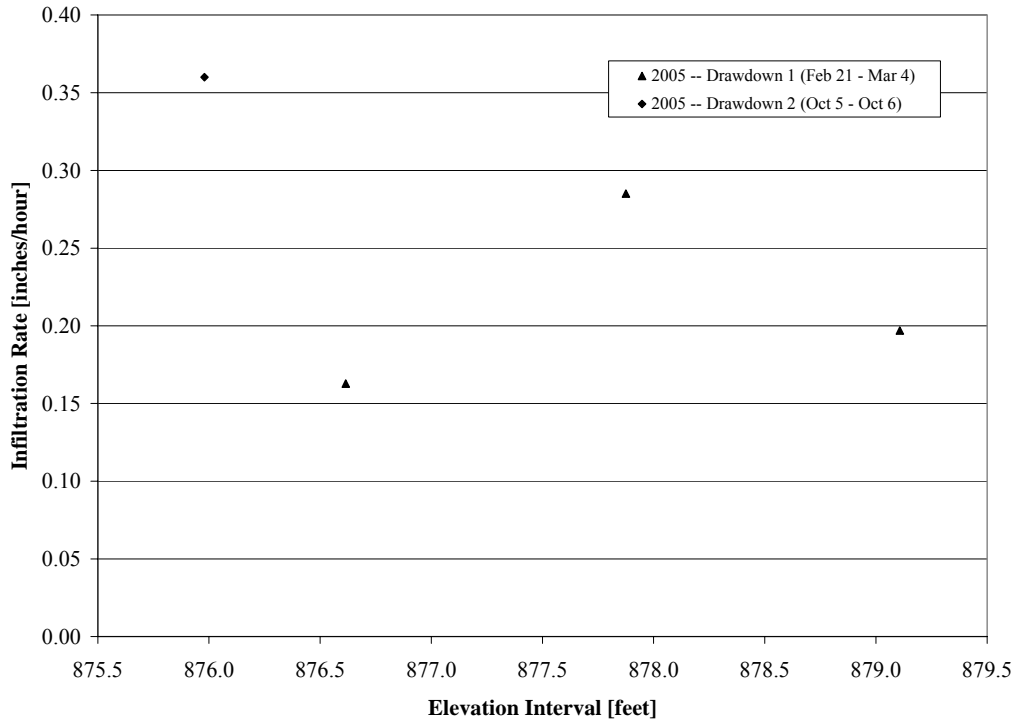


Figure III-29. Volumetric Infiltration Rate vs. Elevation for CD-P86, 2005

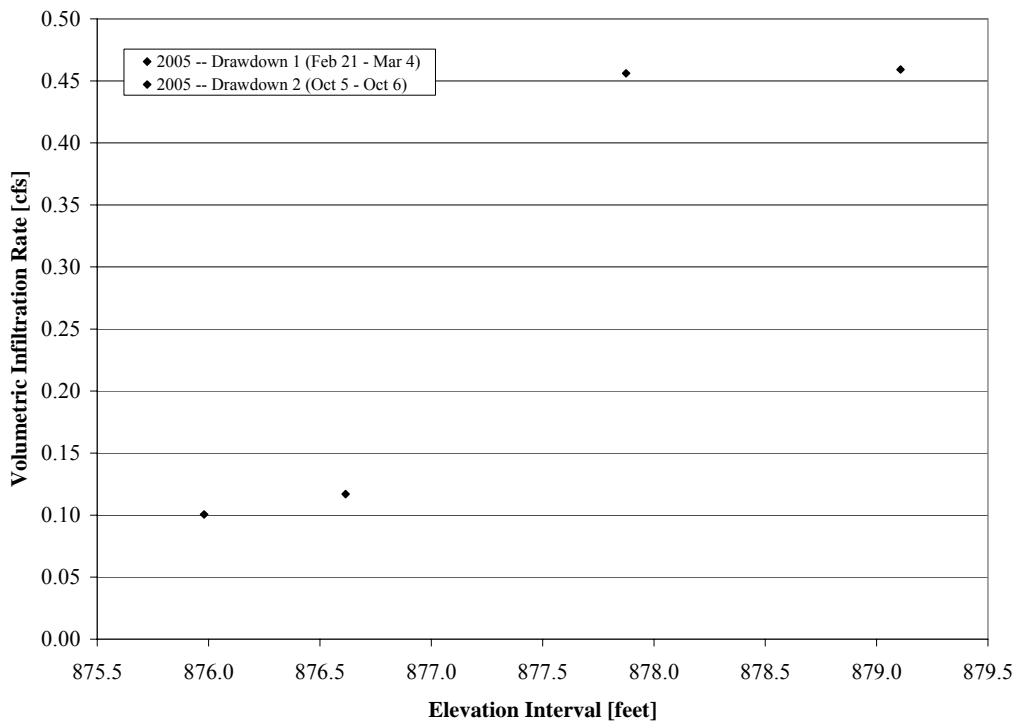


Table III-8. CD-P86 Average Infiltration Rate and Range, 2005

	Snowmelt		Rainfall	
	Average Rate	Rate Range	Average Rate	Rate Range
Infiltration Rate [inches/hour]	0.21	0.16 – 0.29	0.36	0.36
Volumetric Infiltration Rate [cfs]	0.34	0.12 – 0.46	0.10	0.10

CD-P85 - Infiltration Trench

The infiltration trench at CD-P85 has been monitored since 1999, although data were not collected during 2000. 2005 rates represent the lower boundary of the infiltration envelope at numerous elevations (Figure III-30). Although the lower boundary of the infiltration envelope was further lowered with this year's data, the downward trend of infiltration rates leveled off in 2005 (Figure III-31). An operation and maintenance plan should be developed to assess and mitigate the causes for the decrease in rates of water level decline at the trench. Typically, maintenance is required for infiltration trenches every five years, depending on performance.

Figure III-30. Rate of Decline vs. Depth for CD-P85 Trench, 1999-2005

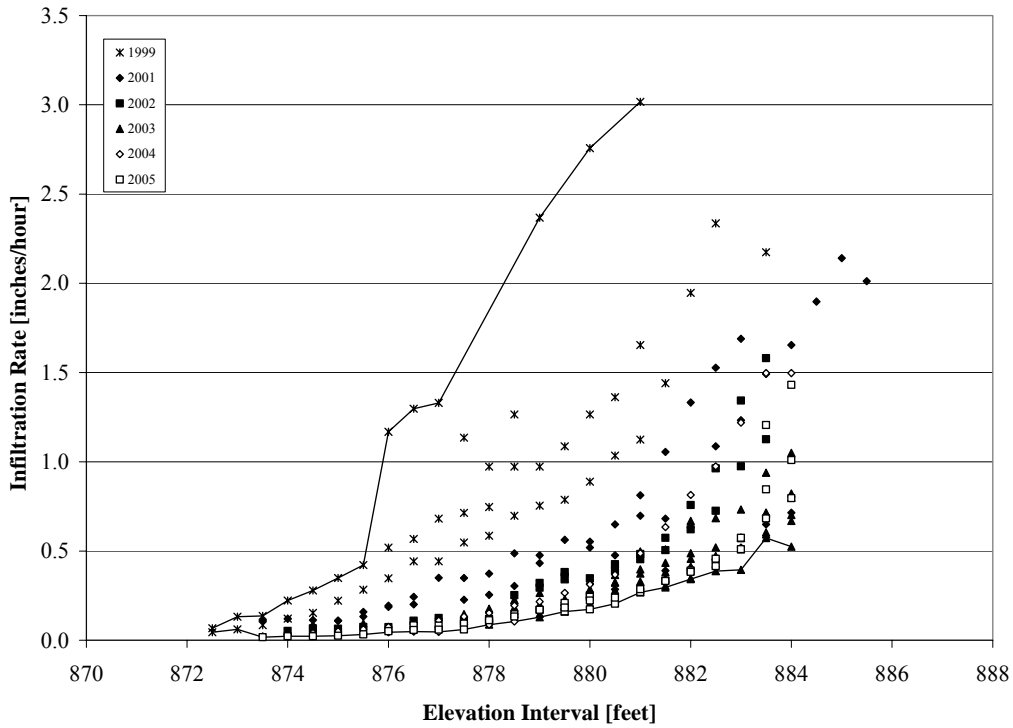


Figure III-31. Annual infiltration rates (mean +/- standard deviation) for CD-P85 trench (includes both snowmelt and rainfall data), 1999-2005

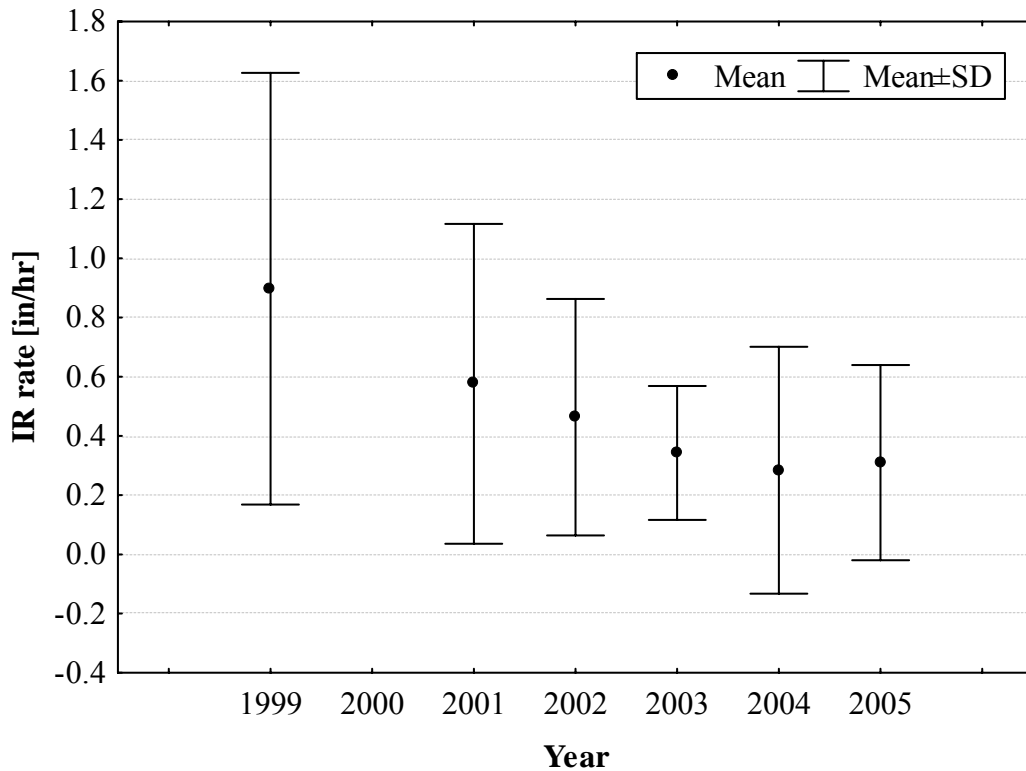


Table III-9 presents the average rates of decline, along with the ranges, for the years 1999 through 2005.

Table III-9. CD-P85 Trench Average Infiltration Rate and Range, 1999 - 2005

	Average Rate	Rate Range
Rate of Decline [inches/hour]	0.60	0.017 – 3.0

Math and Science Academy Trench

Data have been collected at the MSA trench since 2001. The upper limit of the infiltration envelope was raised due to the high infiltration rates observed in 2005 (Figure III-32).

Figure III-32. Rate of Decline vs. Depth for MSA Trench, 2001-2005

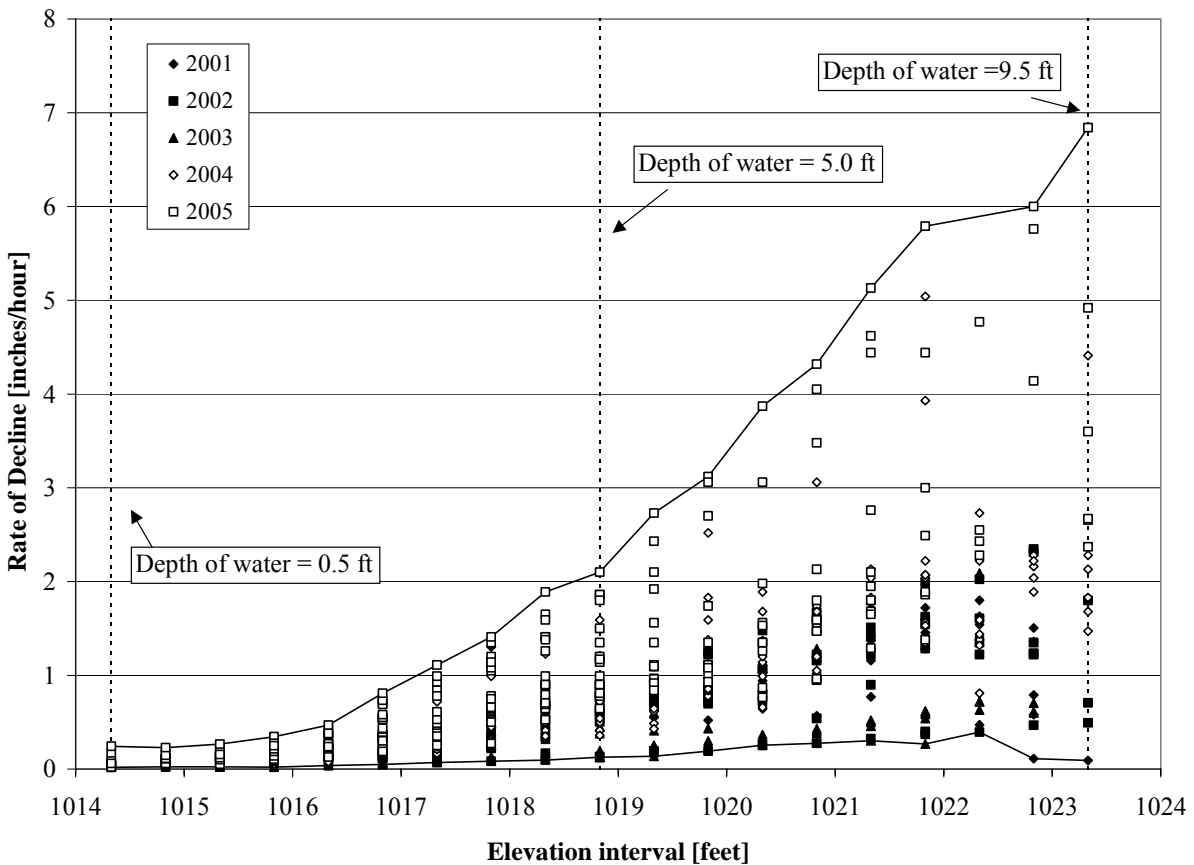


Table III-10 presents the average rates of decline, along with the ranges, for the years 2001 through 2005.

Table III-10. MSA Trench Average Infiltration Rate and Range, 2001 - 2005

	Average Rate	Rate Range
Rate of Decline [inches/hour]	0.93	0.020 – 6.8

IV. Subwatershed Curve Numbers

Only a portion of the rainfall or snowmelt within a subwatershed is eventually delivered to low areas to form ponded water. The remainder of the accumulated snowfall or rainfall evaporates, is taken up by vegetation, or filters into the soil. Thus, a three-inch rainfall, for example, will not necessarily produce three inches of runoff. In hydrologic modeling, an “initial abstraction” is typically applied on a subwatershed basis to account for the evaporation, transpiration, interception, and infiltration that occurs as runoff is generated. The volume of water delivered to a pond or basin after a rainfall or snowmelt event is a result of this abstraction. Monitoring the amount of runoff delivered to a basin allows quantification of the initial abstraction and allows for the development of calibrated curve number (CN) values for each subwatershed. A CN is a parameter created by the Soil Conservation Service (SCS) that indicates the runoff potential for an area. The curve number takes into account initial abstractions by assigning a CN value to different land uses. The CN ranges from zero to 100 where zero indicates that precipitation will not result in any runoff and 100 indicates that all precipitation results in runoff. Assigning a CN is a standard method to estimate the amount of runoff occurring in a watershed.

CNs were calculated for the subwatersheds contributing to the CD-P76 and CD-P86 monitoring basins for snowmelt and rainfall events during 2005. As mentioned previously, dewatering activities within the subwatershed of CD-P82 contributed unknown volumes of runoff to the site. Dewatering ceased in early fall prior to the October storm event; therefore, only a fall CN was calculated for CD-P82.

IV-A. Methodology

Precipitation Event

Two precipitation events were used to develop calibrated subwatershed CNs during 2005. These were one snowmelt event and one rainfall event as described in Table IV-1. The precipitation data was obtained through the SWWD Annual Monitoring Program conducted by the

Washington Conservation District. These data include daily rainfall depth, snow depth and snow water equivalent measurements.

Table IV-1. Precipitation Events

Precipitation Event	Total Precipitation [inches]
Snowmelt (March 3) *°	0.98
Rainfall (October 4-5) **°	4.46

*Snow water equivalent

**Bailey lift station

°Washington Conservation District (2006)

Basin Characteristics

Water levels at CD-P76, CD-P82, and CD-P86 and identified ponding events included in the CN analysis are presented in Figure IV-1, IV-2 and IV-3 respectively. Additional information on stage storage relationships, measured infiltration rates, and basin monitoring are summarized in Sections II and III. The measured maximum height of ponded water 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-1. CD-P76 Surface Water Elevations and Ponding Events

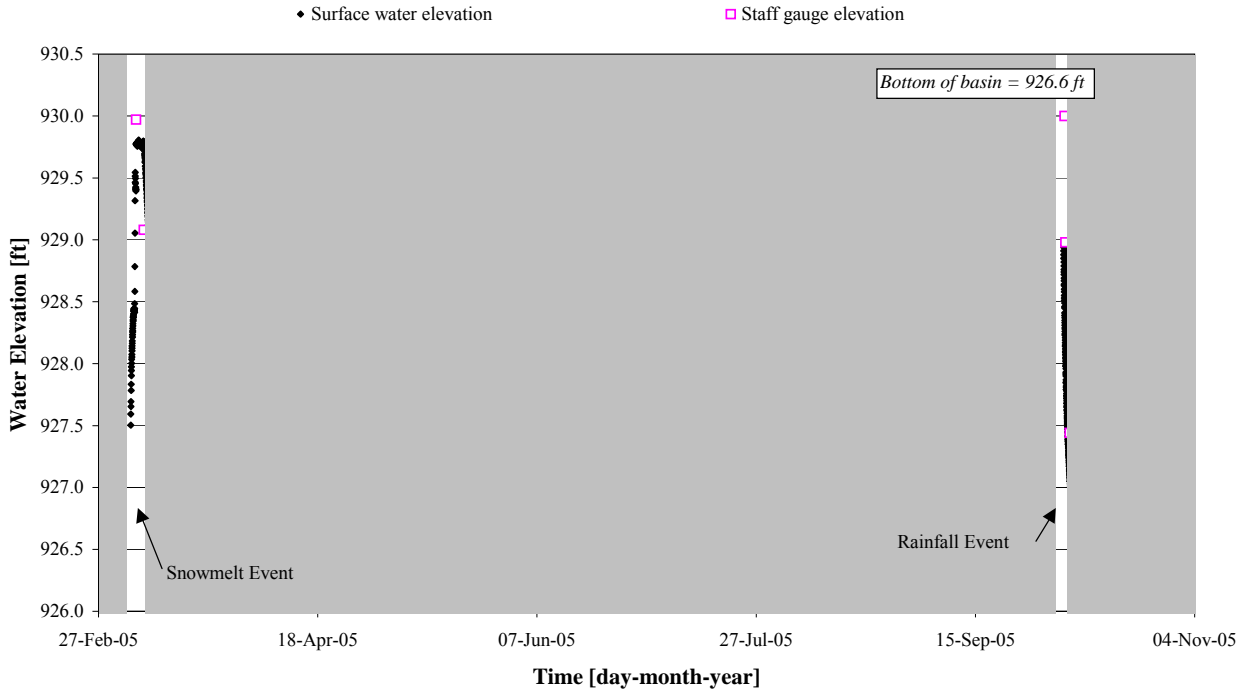


Figure IV-2. CD-P82 Surface Water Elevations and Ponding Events

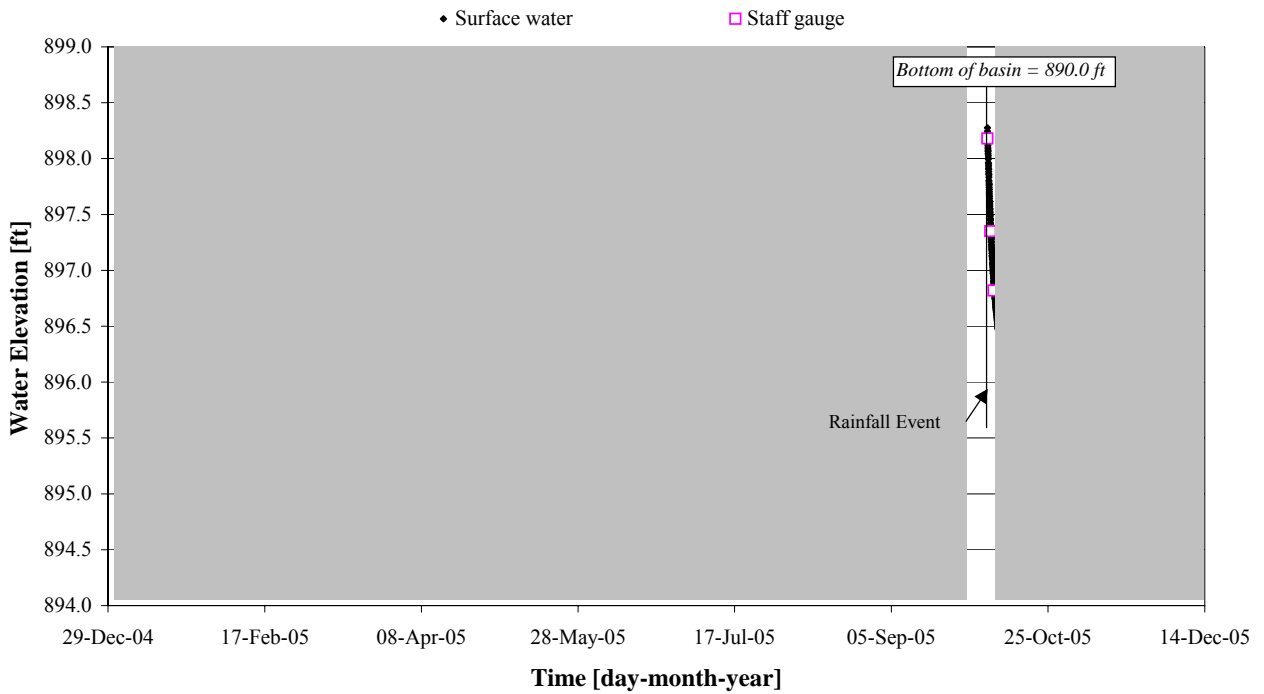
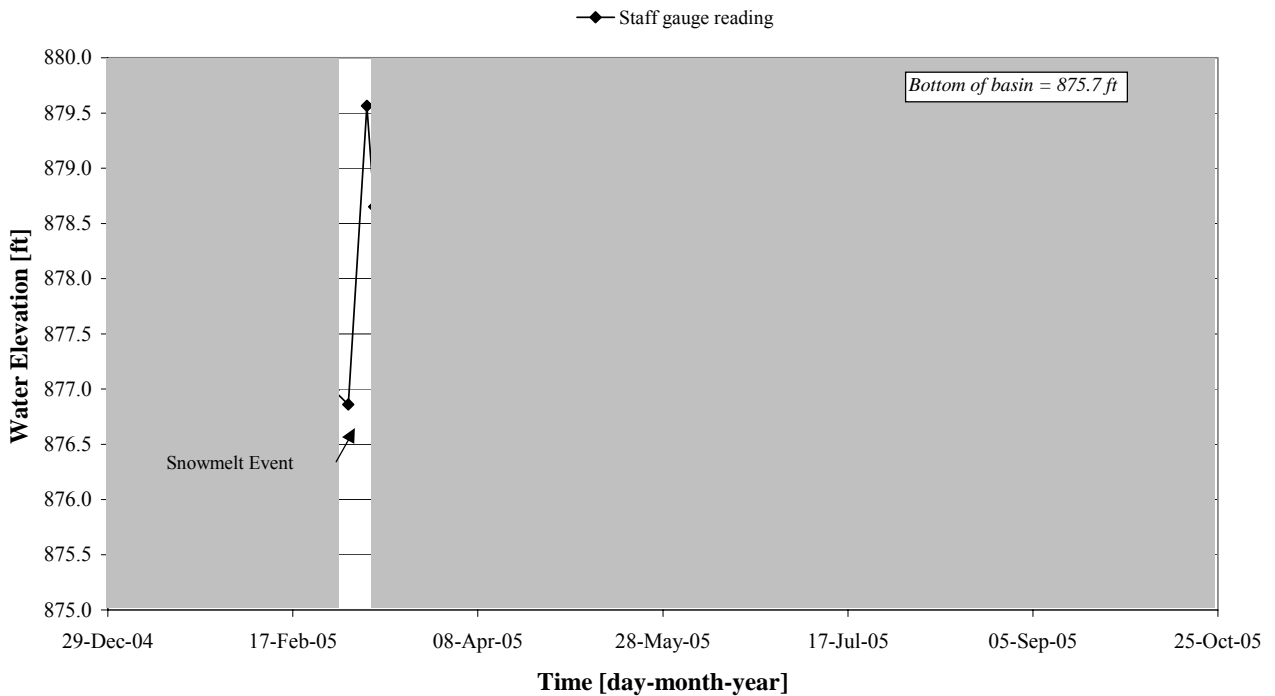


Figure IV-3. CD-P86 Surface Water Elevations and Ponding Events



Curve Number (CN) Calculations

Surface water level data collected at CD-P76, CD-P82, and CD-P86 were used to determine the volume of runoff delivered to the basin under different measured hydrologic scenarios. Spring snowmelt events and rainfall events were used in this analysis to calculate a CN value. CNs were 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

$$Z = (P - 0.2S)^2 / (P + 0.8S) \quad (IV-1)$$

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 Washington Conservation District. Solving for the maximum soil water retention parameter, S, and using the following relationship yields a CN value.

$$S = (1000 / CN) - 10 \quad (IV-2)$$

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. CN values were calculated using an AMC value of II.

Table IV-2. Subwatershed Characteristics

Subwatershed Name	Event	Runoff Volume Delivered to Pond [acre-ft]	Subwatershed Area [acres]	Depth of Runoff over Subwatershed [inches]
CD-P76	Snowmelt (March 6)	9.1	479.4	0.22
	Rainfall (October 4-5)	9.2		0.23
CD-P82	Rainfall (October 4-5)	20.1	271.8	0.89
CD-P86	Snowmelt (March 4)	4.9	346.2	0.17

IV-B. Results

Table IV-3 summarizes the results for CD-P76, CD-P82, and CD-P86 and includes the average calculated CN for snowmelt events in past years in the subwatershed. By calculating the CN value for this and other subwatersheds, a database was developed on which to base assumptions used in watershed hydrologic/hydraulic models. Using calculated CN values for these subwatersheds, and possibly applying them to similar subwatersheds, will lead to a more accurate representation of existing conditions in watershed hydrologic/hydraulic models.

A snowmelt CN value of 88 was calculated for CD-P76. This value is higher than the range of values previously determined for this basin. A CN value of 43 was calculated for the fall event at CD-P76. For the fall event at basin CD-P82 the curve number was 58, consistent with previous results. There were dewatering activities west of County Road 19 during the early snowmelt that may have influenced this basin, so curve numbers for earlier events were not included in this report. The one measured event for basin CD-P86 indicates a curve number of 85 under snowmelt conditions.

Table IV-3. Calculated Subwatershed Curve Numbers, 2003-2005

Subwatershed Name	Event Date(s)	Curve Number	Average Curve Number
2005 Events			
CD-P76	Snowmelt (March 6)	88	88
	Rainfall (October 4-5)	43	43
CD-P82	Rainfall (October 4-5)	58	58
CD-P86	Snowmelt (March 4)	85	85
2004 Events			
CD-P76	Snowmelt (March 2)	73	74
	Snowmelt (March 18)	75	
2003 Events			
CD-P50	Rainfall (April 15-16)	53	67
	Rainfall (June 6)	81	
CD-P76	Snowmelt (March 15)	58	52.5
	Rainfall (May 10-11)	50	
	Rainfall (June 24-25)	55	
CD-P82	Snowmelt (March 15)	53	53
	Rainfall (May 10-11)	52	52

V. Climatic Conditions

The climatic conditions in the watershed during the 2005 monitoring season are summarized below. Precipitation and climatic data were obtained from the National Weather Service station in Stillwater, MN (Station 218037). Dates when the Stillwater Station had no applicable data, the nearest station data were substituted. Local climatic data collected by the Washington Conservation District at MS1, MS2, 100th Street, Bailey Lift Station and Powers Lake and by EOR at MSA between April and October were also included in the analysis.

Winter and Spring Climatic Data

Figure V-1 compares the average monthly temperature for the 2004-2005 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 the 2004-2005 season were above the long-term average for the Stillwater weather station. The average temperature for the 2004-2005 December-March time period was 24.2 degrees Fahrenheit, 11.6 percent above the 40-year temperature average of 21.4 degrees Fahrenheit. The month of February had the highest deviation from the 40-year average temperature.

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

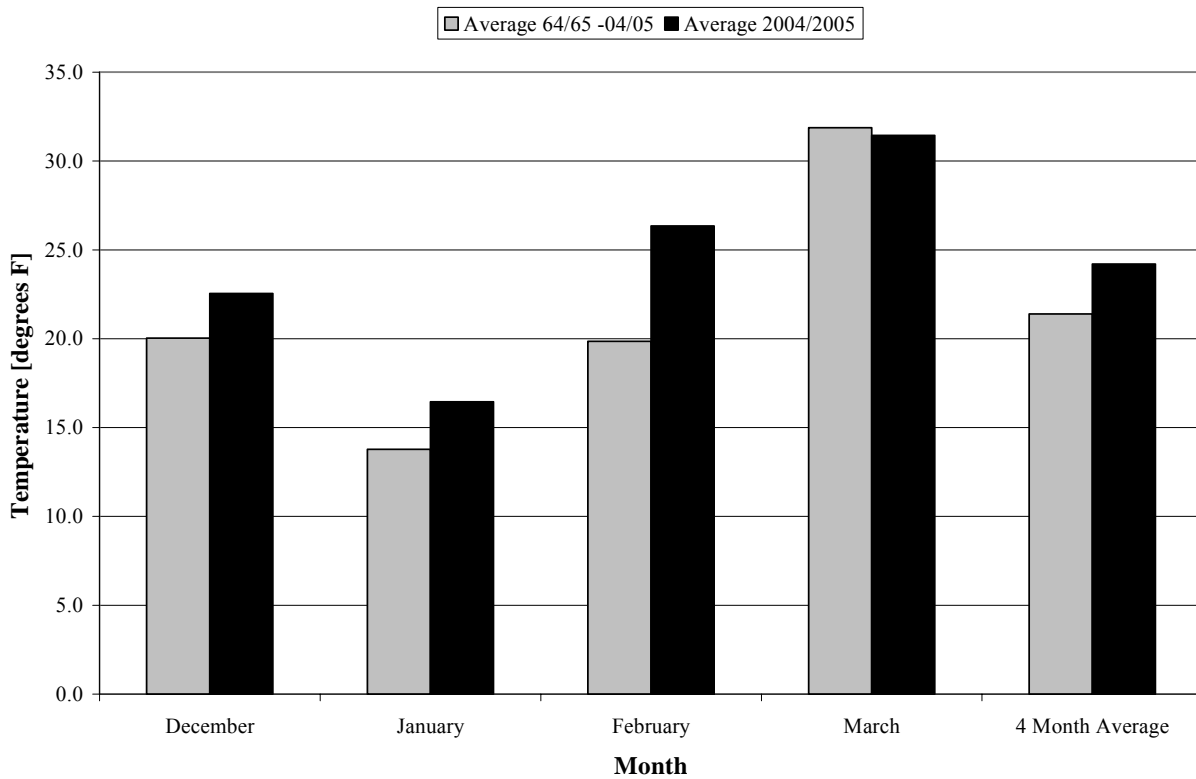
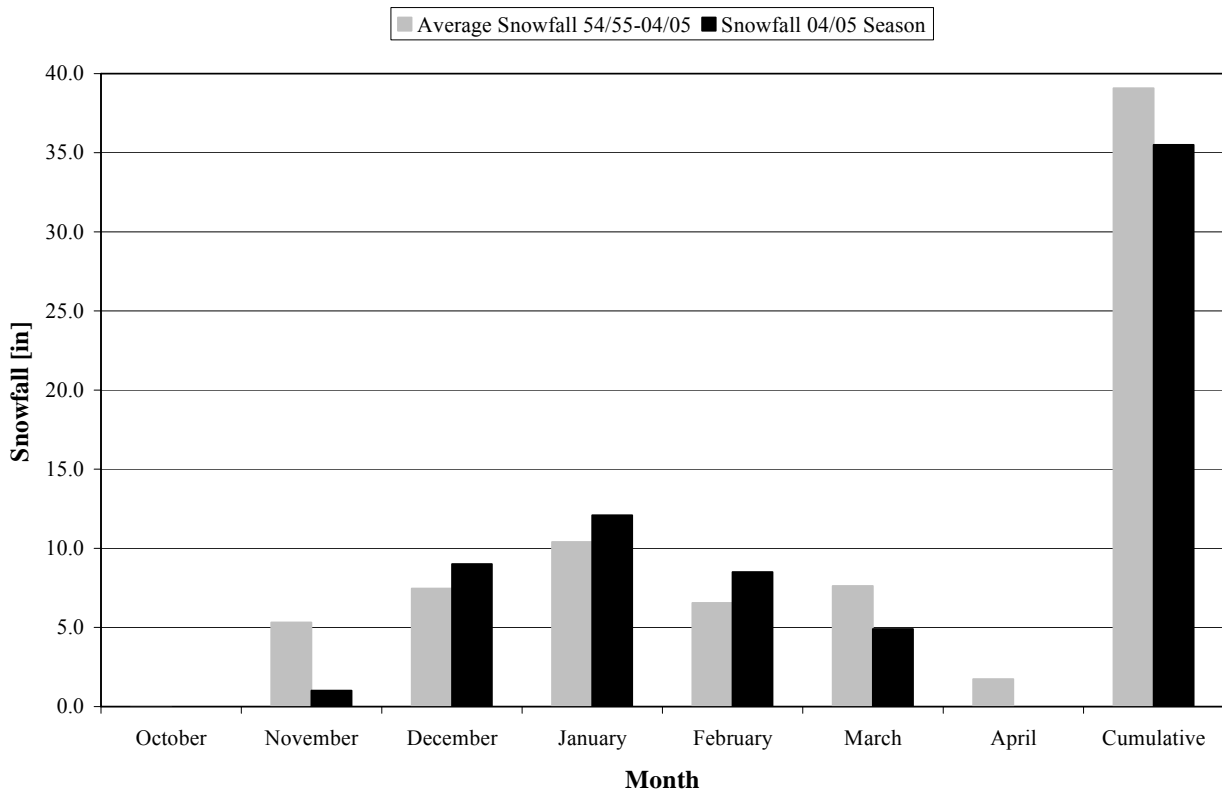


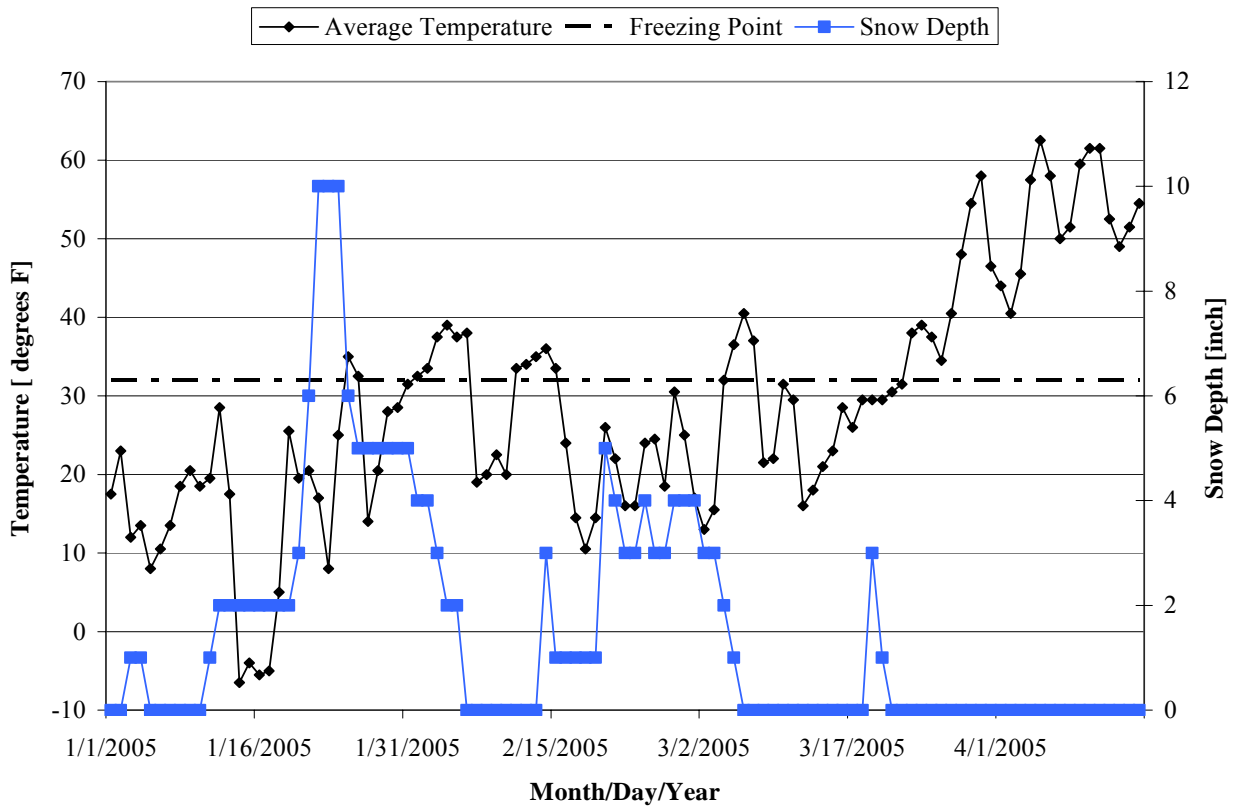
Figure V-2 shows the average total snowfall recorded at the State Climatology Office located in Stillwater, MN. The graph compares the monthly snowfall totals for the 2004–2005 season to the average monthly snowfall totals over the last 50 years for the same months. The total snowfall for the 2004-2005 season was 35.5 inches, 9.2 percent below the 50-year snowfall average of 39.1 inches for the same months. January received the largest amount of snow over the 2004-2005 season with 12.1 inches of snow, 14.1 percent above the 50-year snowfall average of 10.4 inches for the month of January.

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 depths are shown in Figure V-3 from January to April, 2005. A series of snowfalls beginning January 12, 2005 accumulated snow pack that remained until a warming trend beginning on February 1, 2005 resulted in melting of the snow pack. A second series of snowfalls beginning in mid February developed snow pack that remained until a warming trend starting March 5, 2005 melted the pack. A mid March snowfall accumulated within the watershed but melted quickly due to average temperatures above the freezing point. The start of the winter/spring snowmelt began in the first week of February. A final warming trend began March 23 with all average temperatures after this date above the freezing point.

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



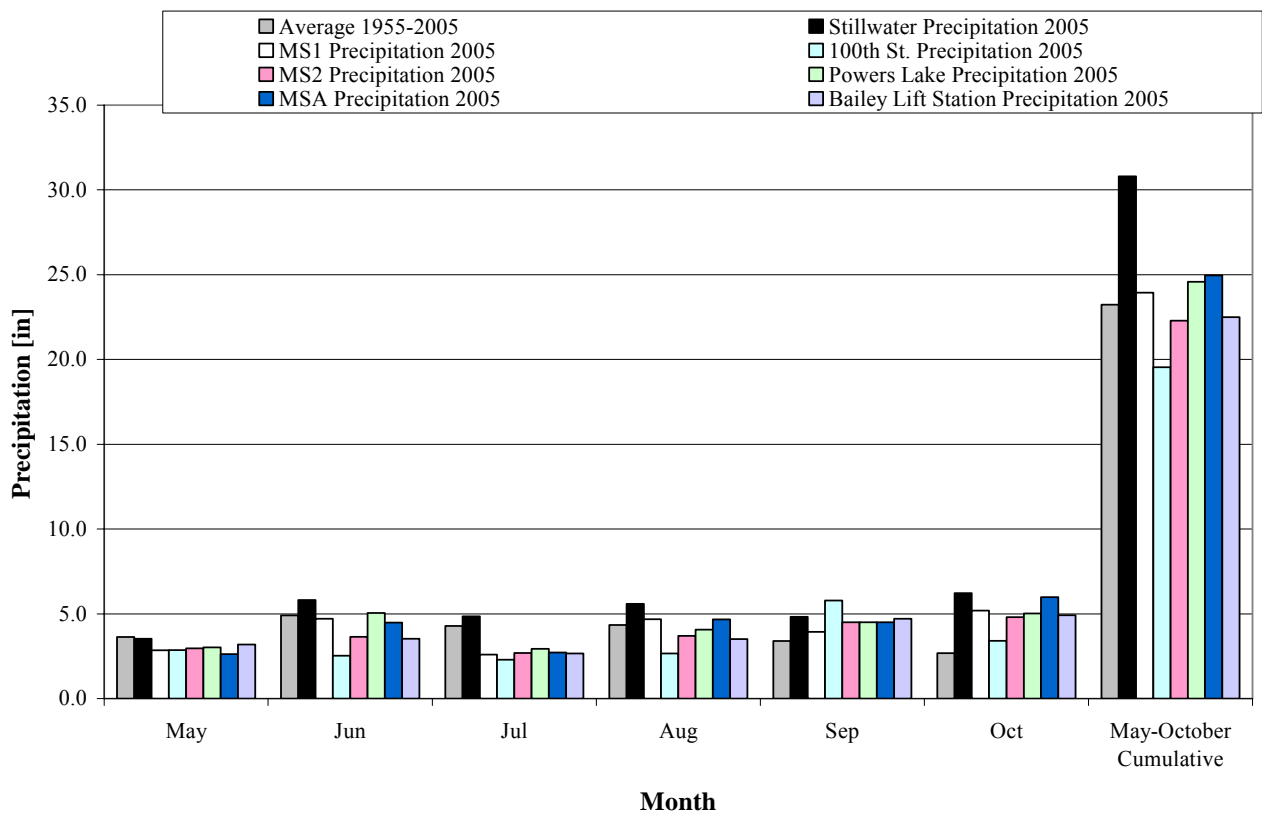
Summer Climatic Data

Figure V-4 compares the 2005 total monthly precipitation recorded at the State Climatology Office in Stillwater, MN, the average monthly precipitation recorded over the last 50 years from the Stillwater station, and data collected in 2005 at six SWWD Monitoring Stations (MS1, MS2, Powers Lake, 100th Street, Bailey Lift Station, and MSA) from May to October. Partial data for the month of October is presented for sites MS1, MS2, and Powers Lake. These data are included because a rainfall event on October 4-5, 2005 delivered the majority of precipitation for the month and represents the bulk of rain received in October. Based on the Stillwater precipitation data, total precipitation for the months of May through October of 2005 was equal to 30.8 inches, 24.6 percent above the 50-year average (23.22 inches) over the same time period.

Local precipitation data collected at the six SWWD Monitoring Stations illustrates the variability of rainfall over the watershed. The variability of cumulative precipitation is moderate, with the greatest difference of 5.42 inches between stations MSA (24.96”) and 100th Street (19.54”) from May through October. The lowest cumulative difference of 0.38 inches exists between sites MSA (24.96”) and the Powers Lake site (24.58”) during this same time period.

Local precipitation data collected at the six SWWD Monitoring Stations was on average 25.4 percent lower than the 2005 Stillwater station data (30.80 inches) and 1.1 percent below the 50-year average (23.22 inches) from May through October.

Figure V-4. Monthly Precipitation Totals from May to October



October 4-5, 2005 Rainfall Event

The SWWD was inundated on October 4-5, 2005 with a rainfall event that brought over six inches of rain to parts of Southern Washington County. The State Climatology Office reported

that North Central Woodbury received 6.46 inches of rain from this event and southwest Woodbury reported 7.40 inches of rain over the same time span. Data collected within the watershed by the WCD recorded cumulative precipitation values for the event between 2.86” and 5.62” (Table V-5). A rainfall event of this magnitude occurs approximately every 100 years. The volume of water delivered by this storm quickly overwhelmed stormwater systems in numerous municipalities. Flooding of basements and roads was reported in the Woodbury area due to this rainfall event.

Table V-5. Precipitation Totals from the October 4th-5th, 2005 Rainfall Event as Reported from the State Climatology Office in Stillwater, MN and the Washington Conservation District

Site	Precipitation [inches]	Source
MS1	4.99	WCD
MS2	4.8	WCD
MSA	5.62	EOR
Powers	5.02	WCD
100th Street	2.86	WCD
Bailey Lift Station	4.46	WCD
Stillwater	5.21	WCD
North Central Woodbury	6.46	MN Climatology Office
Southwest Woodbury	7.4	MN Climatology Office

VI. Conclusions and Recommendations

VI-A. Conclusions

1. The majority of measured infiltration rates at the CD-P82 and CD-P85 basins fell within the expected range of values. Several of the infiltration rates measured at CD-P76 were higher than those measured previously and increased the upper end of the infiltration envelope. Water level data were collected at CD-P86 for the first time in 2005.
2. Rates of water level decline at the infiltration trench at CD-P85 continue to be lower than rates measured in previous years, although the average infiltration rate for 2005 did not differ from the average in 2004. A plan should be developed to further assess and mitigate the decline in performance at the CD-P85 infiltration trench. Maintenance may be needed at the CD-P85 trenches to improve performance and ensure their long term viability.
3. Rates of water decline at the Math and Science Academy infiltration trench were higher than measured previously, forming the upper limit of the infiltration envelope. The native seedlings planted within and around the basin have now reached maturity and may be the reason for the increase in infiltration at this site.
4. Select surface water chemistry samples exceeded the Health Risk Limits set by the Minnesota Department of Health for manganese at CD-P82, CD-P86, and the MSA. This element is naturally occurring in the soils and is commonly found within surface and groundwater in southern Washington County. Copper was measured above the MPCA Class 2B Waters Chronic Standard in select surface water samples at CD-P76, CD-P85, and the MSA. Over the last few years, elevated levels of copper have been found in many surface water samples in all the basins, and it is unknown what is causing this trend. Surface and groundwater quality analysis indicates that infiltrating surface water is not negatively affecting the groundwater.
5. Several groundwater samples collected from CD-P82 and CD-P85 (MW-2 and MW-3) contained high (greater than 5 mg/L) concentrations of nitrates. One groundwater sample

from MW-3 exceeded the MDH Health Risk Limit for combined nitrates with a concentration of 10.77 mg/L.

6. Calibrated CN values for subwatersheds draining to CD-P76, CD-P82, and CD-P86 were added to the database and can be used to refine existing watershed models in the future.

VI-B. Recommendations

Surface Water Monitoring

1. Continue to monitor water levels and infiltration rates at CD-P76, CD-P82, CD-P85, CD-P86, and the MSA and CD-P85 trenches.
2. Continue to collect surface water and groundwater chemistry data at each monitoring site throughout the year.
3. Use extra monitoring equipment throughout the year as available to monitor surface and groundwater levels in wells and surface water flows in key subwatersheds.
4. Install a flow meter in the upper box culvert at CD-P85 to quantify any outlet flows that may occur during large pumping events.
5. 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.

Groundwater Monitoring

1. Continue to monitor groundwater levels in the watershed. Include shallow monitoring wells at CD-P69, CD-P50, and CD-P82 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 the lower well at CD-P82 and explore possibility of obtaining ownership of Metropolitan Council well (MCES well) at this basin.

4. Explore possibility of obtaining ownership of additional wells currently owned by the Metropolitan Council located in key areas.
5. Discontinue monitoring of the MW-3 well unless there is significant ponding within the CD-P86 infiltration basin.
6. Install a minimum of one additional well at CD-P76, CD-P82, CD-P86, MSA and three additional wells at CD-P85 to obtain additional information on groundwater flow, mounding and water quality.
7. Develop an enhanced groundwater monitoring network at CD-P85 and CD-P86 to include additional shallow monitoring wells, routine water quality sampling, and continuous groundwater level monitoring.

Management Options and Techniques

1. Develop subwatershed performance standards for volume control and water quality based on representative subwatersheds and incorporate into SWWD Plan and 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 and CD-P86 in order to ensure available infiltration capacity during spring melt conditions.
4. 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.
5. 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.

APPENDIX A

Photo Logs