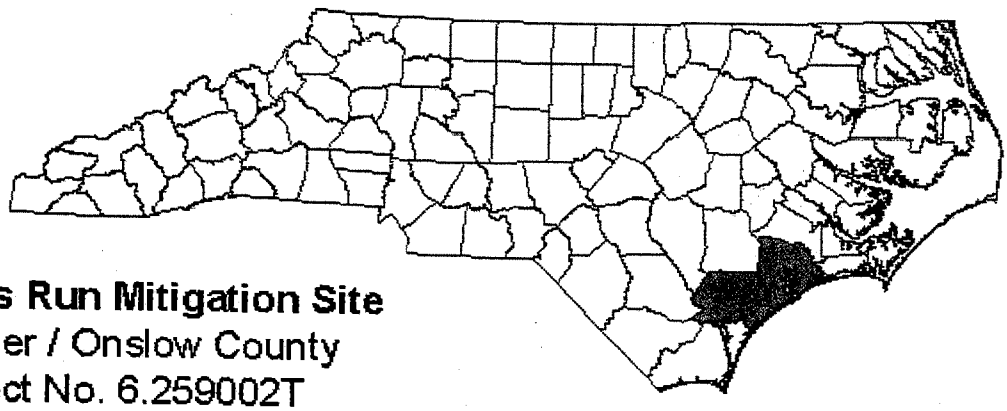
ANNUAL REPORT FOR 1999



Haws Run Mitigation Site
Pender / Onslow County
Project No. 6.259002T
TIP # R-2405WM

Prepared By:
Natural Systems Unit &
Roadside Environmental Unit
North Carolina Department of Transportation
December 1999

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SUMMARY

The following report summarizes the monitoring activities that have occurred in the past year at Haws Run Mitigation Site. This site was constructed in 1998 and planted in early 1999. Restoration activities at Haws Run included swamp forest and pine savanna restoration, enhancement, and preservation components. The site is equipped with 23 groundwater monitoring wells, 2 surface gauges, and one rain gauge. Local rainfall data was substituted for on-site data due to unreliability of the on-site rain gauge. Hydrologic monitoring results are presented by three methods: jurisdictional wetland criteria, average depth to groundwater, and duration of soil saturation.

The monitoring results in the swamp restoration area were very similar to results in the swamp reference area. All but one well met the 12.5% criteria for jurisdictional wetlands. The average depth to groundwater for the restoration area was at, above, or no deeper than 25% of the average depth to groundwater for the reference area for 70% of the recording period. The average duration of the hydroperiod in the swamp restoration area was 77% of the average duration of the hydroperiod in the reference area.

Only half the total number of wells in the pine savanna restoration area and the jurisdictional savanna wetlands exhibited hydroperiods greater than 8% of the growing season. However, the average depth to groundwater in the restoration area was at, above, or no deeper than 25% of the average depth to groundwater in the jurisdictional savanna wetlands for 72% of the recording period. The duration of saturation was very similar also, with the hydroperiod in the restoration area averaging 92% of the hydroperiod in the jurisdictional savanna wetlands.

The wells in the southern swamp area previously isolated by the haul road exhibited hydroperiods greater than 8% of the growing season, exceeding the hydroperiods of the reference wells on the swamp side of the road. The average depths to groundwater between the restoration and reference areas were comparable for 91% of the recording period. The duration of saturation in the restoration area was 153% of the duration of saturation in the reference wells.

Vegetation monitoring consists of ten tree plots and ten grass plots. Vegetation success criteria were met for 1999, with 30 trees per acre in the savanna area and 459 trees per acre in the swamp forest area. Planting of pond cypress in the savanna area is planned for Spring 2000.

Issues to be addressed in the 2000 monitoring season include the placement and elevation survey of wells, the stabilization of eroded areas on slope adjacent to the swamp area, and the potential cooperation with The Nature Conservancy on land adjacent to the eastern perimeter canal.

1.0 INTRODUCTION

1.1 Project Description

The Haws Run Mitigation Site was purchased in 1995 by the North Carolina Department of Transportation (NCDOT) to provide compensatory mitigation for unavoidable impacts to wetlands resulting from highway construction in the region. The site is located approximately 28 miles northeast of Wilmington, North Carolina, straddling the Pender-Onslow County line (Figure 1). The site consists of riverine swamp forests at the northern and southern ends and a cutover interior of former wet flats and savannas with an extensive ditch and canal system. The central canal and lateral ditches north of the electrical transmission line were plugged in December 1997 for a short-term study to determine effects of ditch plugging and filling.

Full site construction began in Summer 1998 with excavation of the northern end of the site to the reference swamp elevation and plugging/ filling of the central canal and lateral field ditches to the north of the powerline crossing. Construction was completed in February 1999 and the site was planted in the early spring 1999.

1.2 Purpose

In order to demonstrate successful mitigation, hydrologic and vegetative monitoring must be conducted for a minimum of three consecutive years. Development of the success criteria is discussed in the Haws Run Mitigation Plan. The following report documents the results of the hydrologic and vegetative monitoring activities in 1999 at the Haws Run mitigation site.

1.3 Project History

Winter 1997	Pilot Study
Summer 1998 - Winter 1999	Site Construction
Spring 1999	Site Planted
October 1999	Vegetation Monitoring (1 yr.)
March - November 1999	Hydrologic Monitoring

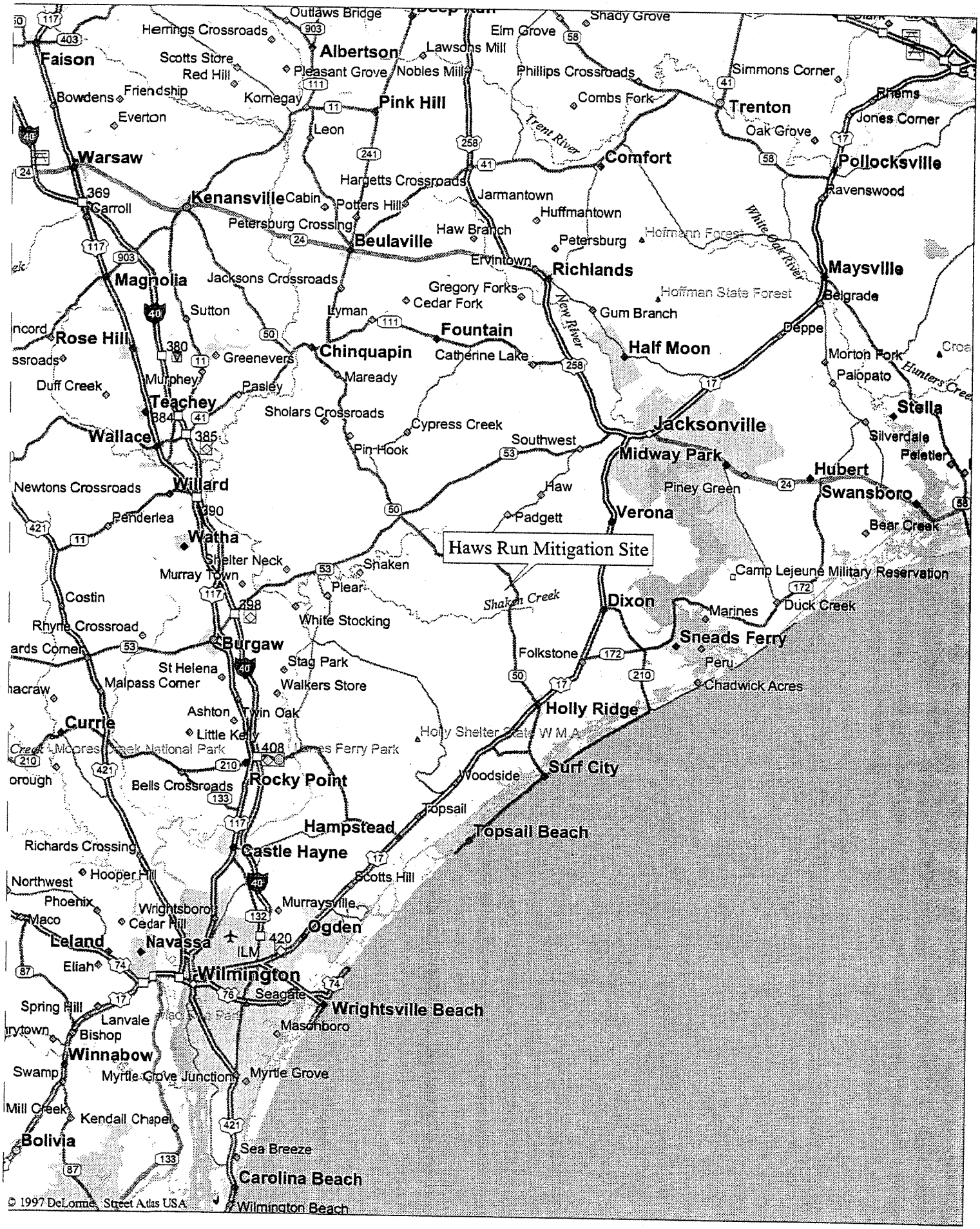


FIGURE 1 - Site Location Map

2.0 HYDROLOGY

2.1 Success Criteria

The Haws Run Mitigation Plan and the Final Responses to Agency Comments describe the success criteria for site hydrology. The success criteria for the swamp restoration area are based on the hydrologic regime of Sandy Run Swamp reference area. Specifically, the mean depth to groundwater for wells in the swamp restoration area should be at, above, or no more than 25% deeper than the mean depth to groundwater for wells in the reference area.

The success criteria for the pine savanna restoration area were initially tied to the Lanier Quarry Savanna reference site. Subsequent to review by NCDOT and USACE, Lanier Quarry savanna was deemed unsuitable as a reference site. Therefore, the success criteria for Haws Run savanna restoration area reverted to federal guidelines for wetlands as described in the 1987 USACE Wetlands Delineation Manual. These guidelines state that the area must be inundated or saturated (within 12" of the surface) by surface or ground water for a consecutive 12.5% of the growing season. Areas inundated less than 5% of the growing season are always classified as non-wetlands. Areas inundated between 5% - 12.5% of the growing season can be classified as wetlands depending upon factors such as the presence of hydrophytic vegetation and hydric soils.

The growing season for Haws Run site was calculated as an average of data from Pender County, Onslow County, and the U.S. Weather Bureau publication, *Low Temperature Probabilities in North Carolina*. Using all three data sets, the average growing season for the Haws Run site was estimated to be 237 days in length, lasting from March 23 to November 15. Therefore, for Haws Run to meet the optimum jurisdictional wetland hydrology, the water table must not fall below the 12-inch line for at least 30 consecutive days during the growing season under normal precipitation.

Success criteria for the area isolated by the forestry haul road was based on reestablishing the hydrologic connection of the area to the southern swamp. The flooding regime and groundwater depths should be similar in each area after removal of the haul road.

This document uses three methods to report the hydrologic monitoring results for Haws Run mitigation site: jurisdictional wetland criteria, average depth to groundwater, and duration of soil saturation.

2.2 Hydrologic Description

After site construction, nineteen groundwater monitoring wells (RDS WL-40) were installed on the site (Figure 2):

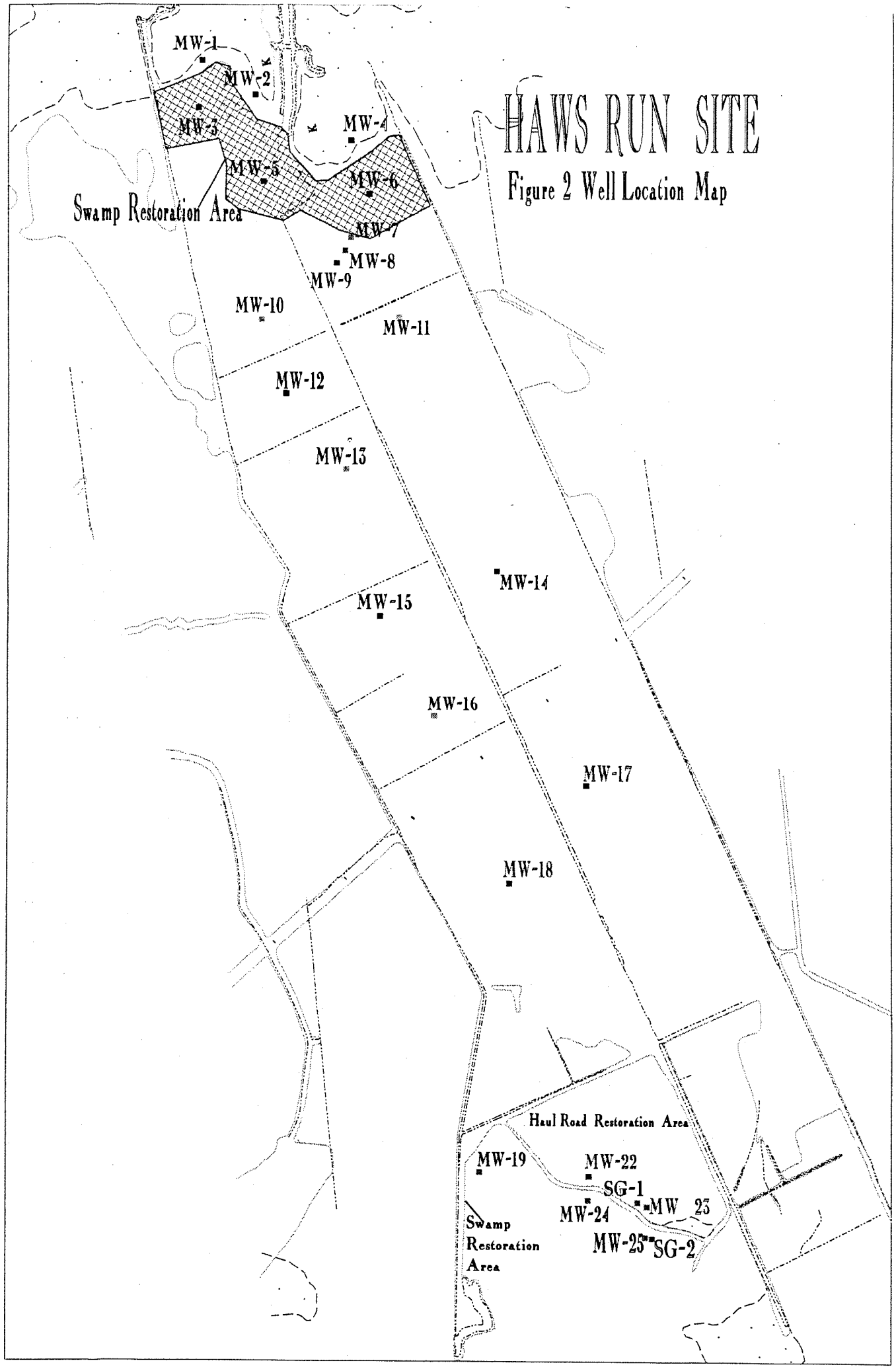
- three in the swamp reference area (MW-1, MW-2, MW-4)
- four in the swamp restoration area (MW-3, MW-5, MW-6) (MW-19 in the southern swamp restoration area)
- two on the slope transition area (MW-7, MW-8)
- four in the pine savanna restoration area (MW-9 through 12)
- six in the pine savanna jurisdictional wetlands (MW-13 through 18)

After field inspection in April 1999, monitoring wells MW-1 through MW-6 were relocated (as shown on Figure 2) to better represent site conditions. Ground surface elevation was surveyed at each well and used to correlate well data for restoration area and reference area comparisons. Based on similar elevations, the following wells were paired for hydrologic monitoring:

- MW-1 and MW-3 at approximately 6.2 ft above msl
- MW-2 and MW-5 at approximately 5.8 ft above msl
- MW-4 and MW-6 at approximately 4.9 ft above msl

There are also four groundwater wells, MW-22 through 25, and two surface gauges, SG-1and SG-2, located along the forestry haul road which were installed during the pre-construction monitoring phase.

All of the monitoring wells automatically record daily depth to groundwater or surface water on the site. Appendix A contains the graphs for each well along with daily rainfall data. Rainfall events, shown on each graph as bars, were recorded at the Trenton weather station maintained by the NC State Climate Office. A more reliable on-site rain gauge will be installed prior to the start of the 2000 growing season.


HAWS RUN SITE
Figure 2 Well Location Map
MW-1
MW-2
MW-3
MW-4
MW-5
MW-6
MW-7
MW-8
MW-9
MW-10
MW-11
MW-12
MW-13
MW-14
MW-15
MW-16
MW-17
MW-18
MW-19
MW-22
MW-23
MW-24
MW-25
SG-1
SG-2
Swamp Restoration Area
Haul Road Restoration Area
Swamp Restoration Area

2.3 Results of Hydrologic Monitoring

2.3.1 Site Data

The hydrologic monitoring results from the restoration areas are presented in this report by three methods:

1) Comparison to jurisdictional wetland criteria,
2) Comparison to reference area mean depth to groundwater,
3) Comparison to reference area duration of saturation.

Comparison to Jurisdictional Wetland Criteria:

The maximum number of consecutive days that the groundwater was within twelve inches of the surface was determined for each well. This number was converted into a percentage of the 237-day growing season. Because it is uncertain if all wetlands impacted by NCDOT highway projects meet the 12.5% criteria, the monitoring well results are segmented into percentage ranges. Table 1 presents the monitoring results for the 1999 growing season as a range of percentages, actual percentages, and success dates of the longest hydroperiod for each well on the site. Shaded rows indicate wells in restoration areas. Figure 3 is a graphical representation of the 1999 hydrologic monitoring results.

Data recorded after September 1, 1999, subjected to extreme weather conditions during the hurricane season, was not used to determine hydrologic success of the site.

All but one of the wells in swamp forest area achieved the optimum hydrology for jurisdictional wetland criteria. Well MW-5 was slightly below this level with soil saturation occurring for a consecutive 11.8% of the growing season.

In the pine savanna area, two wells met the 12.5% level, three met the 8 – 12.5% level, and two met the 5-8% level of hydrology for jurisdictional wetland criteria. The other three wells failed to meet any level of jurisdictional wetland status with soil saturation occurring for less than 5 % of the growing season.

The wells along the haul road fell within the lower two categories of jurisdictional wetland criteria, with two at the 5 –8% level and two at the 8-12.5% level.

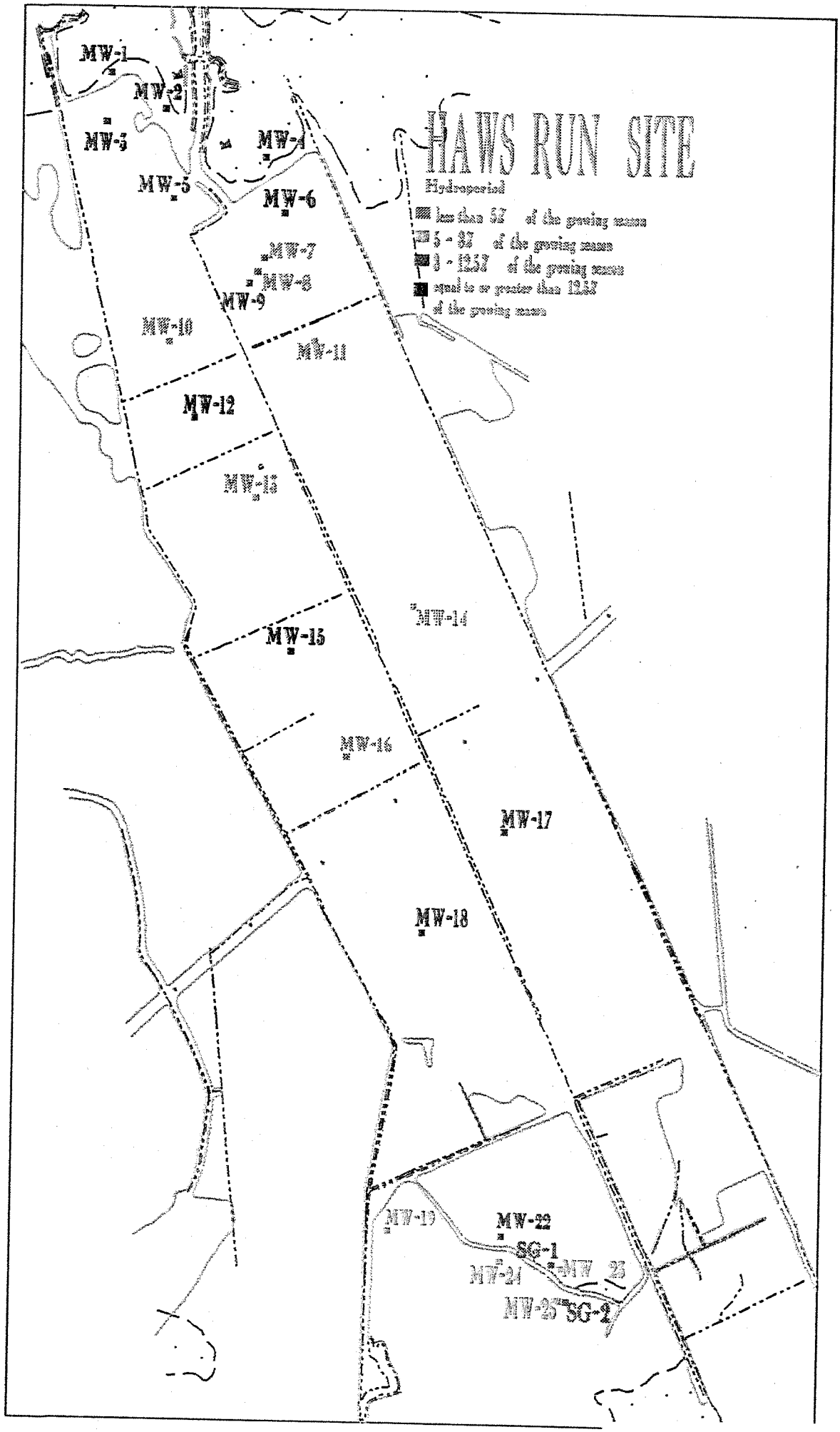

HAWS RUN SITE
Hydroperiod
less than 5% of the growing season
5 - 8% of the growing season
8 - 12.5% of the growing season
equal to or greater than 12.5% of the growing season
MW-1
MW-2
MW-3
MW-4
MW-5
MW-6
MW-7
MW-8
MW-9
MW-10
MW-11
MW-12
MW-13
MW-14
MW-15
MW-16
MW-17
MW-18
MW-19
MW-22
SG-1
MW-21
MW-25
SG-2

FIGURE 3

Table 1 HYDROLOGIC MONITORING RESULTS
(Pre-hurricane Influence)

Monitoring Well		< 5%	5% - 8%	8% - 12.5%	> 12.5%	Actual %	Success Dates
SWAMP FOREST	MW-1				✓	19.8	April 21 – June 26
	MW-2				✓	35.8	Mar 23 – June 15
	MW-3				✓	15.6	April 27 – May 28
	MW-4				✓	16.1	June 15 – July 30
	MW-5			✓		11.8	April 30 – May 27
	MW-6				✓	16.0	June 2 – July 14
	MW-19				✓	13.5	Mar 23 – Apr 23
Trans Zone	MW-7	✓				3.4	May 1 – May 8
	MW-8	✓				4.6	June 17 – June 27
PINE SAVANNA	MW-9			✓		10.1	May 6 – May 21
	MW-10	✓				4.6	June 17 – June 27
	MW-11	✓				4.6	June 17 – June 27
	MW-12				✓	13.5	April 29 – May 30
	MW-13		✓			5.1	June 17 – June 28
	MW-14		✓			7.1	June 17 – July 4
	MW-15				✓	15.2	April29 – June 5
	MW-16	✓				3.4	April 30 – May 8
	MW-17			✓		11.4	April 30 – May 27
	MW-18			✓		11.4	April 30 – May 26
HAUL ROAD	MW-22			✓		10.9	Mar 23 – April 14
	MW-23			✓		8.1	Mar 23 – April 9
	MW-24		✓			5.5	Mar 23 – April 4
	MW-25		✓			6.8	Mar 23 – April 7

Comparison of Average Depth to Groundwater:

The average depth to groundwater for both the reference and restoration area wells was calculated and plotted for the recording period before the hurricane season (Appendix B). Appendix B also contains the comparisons of depth to groundwater for paired wells. The recording period for the swamp area began after the wells were relocated on April 26, 1999. No data was available for MW-4 before May 25 due to equipment malfunctions. The results are presented as a percentage of the days during the recording period when the depth to groundwater in the restoration area was at, above, or no deeper than 25% of the depth to groundwater in the reference area. The results are as follows.

- Average Swamp restoration area was comparable for 70% of days in the Average Swamp reference area.
- MW-3: 66% of days at MW-1.
- MW-5: 62% of days at MW-2.
- MW-6: 74% of days at MW-4.

- Average Pine Savanna restoration area was comparable for 72% of days in the Average Pine Savanna reference area.

- Average Haul road restoration area was comparable for 91% of days in the Average Haul road reference area.

Comparison of Duration of Saturation:

For each well, the longest hydroperiod i.e., the number of consecutive days of soil saturation (free water table) within 12 inches of the surface, was calculated and averaged for the restoration areas and the reference areas. The average hydroperiod for the restoration area is reported as a percentage of the average hydroperiod for the reference area. The comparison is also made for the paired wells. The results are as follows:

- Average Swamp restoration area hydroperiod was 77% of Average Swamp reference area hydroperiod.
- MW-3: 79% of MW-1.
- MW-5: 60% of MW-2.
- MW-6: 95% of MW-4.

- Average Pine Savanna restoration area hydroperiod was 92% of Average Pine Savanna reference area hydroperiod.

- Average Haul road restoration area hydroperiod was 153% of Average Haul road reference area hydroperiod.

2.3.2 Climatic Data

Figure 4 represents an examination of the local climate in comparison with historical data to determine if 1999 rainfall is within the normal rainfall range of the area. The historical data was provided by the National Climatic Data Center; the recent rainfall data was provided by the State Climate Office at NC State University. Both sets of data were recorded at Trenton, NC. The Trenton station was used in place of the Marine Corp Air Station at New River station because of incomplete data records.

Rainfall during May, June, and August were below the normal range for the area. March, April, and July rainfall fell within the normal range. Data after August was not available.

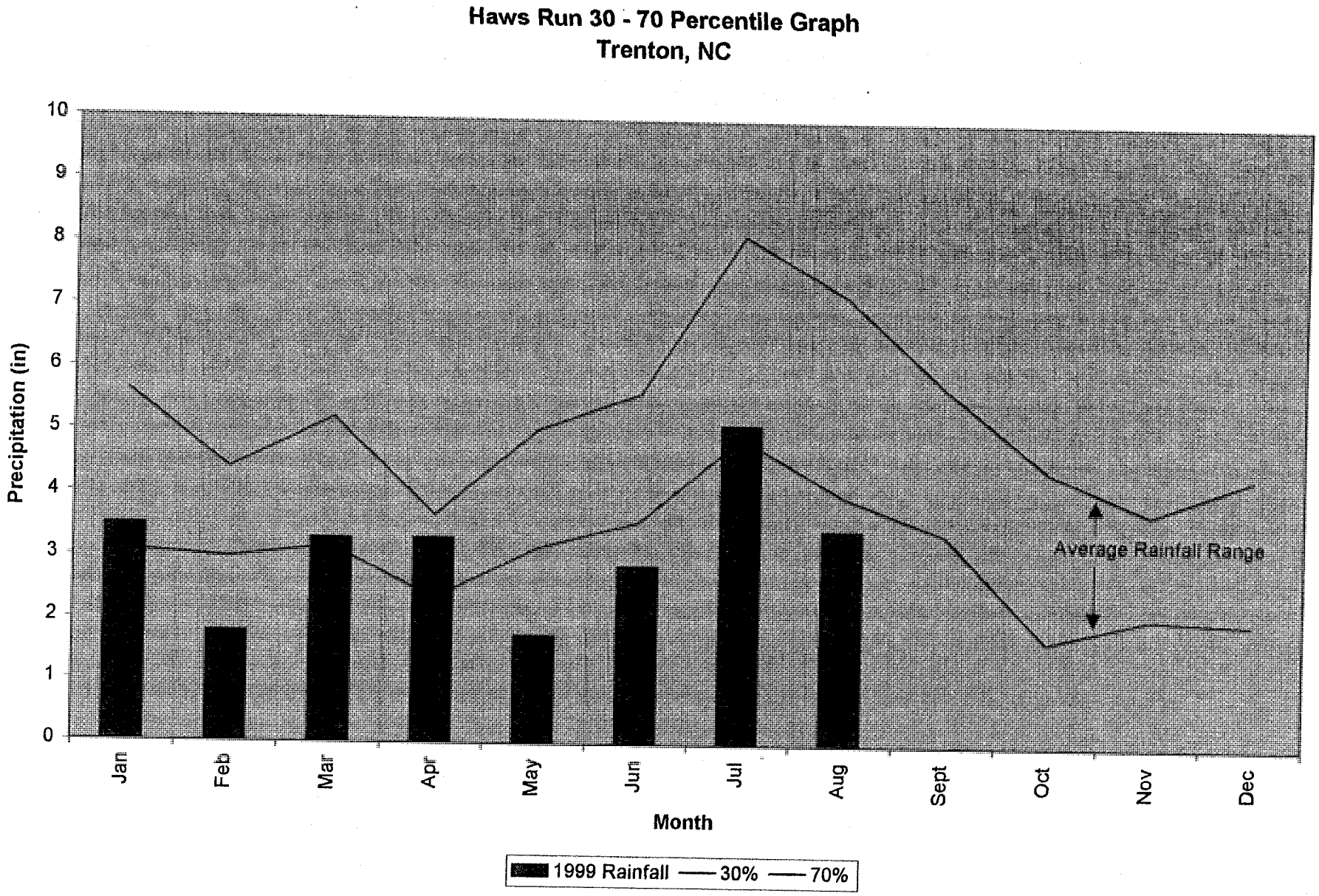

Haws Run 30 - 70 Percentile Graph
Trenton, NC
Precipitation (in)
10
9
8
7
6
5
4
3
2
1
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Month
Average Rainfall Range
1999 Rainfall
30%
70%

FIGURE 4

2.4 Conclusions

Based on jurisdictional wetland criteria, the Haws Run mitigation site monitoring had mixed results. In the swamp forest area, all wells except one met or exceeded the 12.5% jurisdictional wetland criteria. In the pine savanna area, only one restoration area well and one jurisdictional wetland area well met the 12.5% criteria. None of the wells in the haul road area met the 12.5% criteria.

However, trends in the restoration areas across the site did follow trends in the reference areas. Flooding frequency and depth in the swamp restoration area coincided with flooding in the swamp reference area. The water table did decline quicker in the swamp restoration area than in the swamp reference area, resulting in less storage time. This can be partially attributed to differences in soil organic matter content between the two areas.

Water table fluctuations in the pine savanna area were more variable between wells. However, average restoration and reference area values were very similar. The daily average depth to groundwater and the average hydroperiod in the pine savanna restoration area matched the reference area more than 70 % of the time.

Results at the haul road area were very similar also, meeting or exceeding the depth to groundwater and the length of the hydroperiod in the reference area. The data illustrated the effects of removal of the haul road, reestablishing the hydrologic connection of the isolated area to the southern swamp area.

3.0 VEGETATION

3.1 Success Criteria

A. Savanna Areas

Success Criteria states that there must be a minimum of 20 trees per acre living for at least five consecutive years.

B. Swamp Forest Area

Success Criteria states that there must be a minimum of 320 trees per acre living for at least five consecutive years.

C. Grass Area

No success criteria were established for the planted grass areas.

3.2 Description of Species

A. Savanna Areas

The following tree species were planted in the Savanna Restoration and Enhancement Areas (Figure 5):

Zone 1: Wet Savanna Restoration and Enhancement Area (202 acres)
Pinus palustris, Long-leaf Pine
Pinus serotina, Pond Pine
Taxodium ascendens, Pond Cypress

Zone 2: Dry Savanna Enhancement Area (113 acres)
Pinus palustris, Long-leaf Pine

B. Swamp Forest Area

The following tree species were planted in the Swamp Forest Area (Figure 5):

Zone 3: Swamp Forest Restoration Area (33 acres)
Nyssa sylvatica var. *biflora*, Swamp Tupelo
Taxodium distichum, Bald Cypress
Quercus laurifolia, Laurel Oak
Quercus lyrata, Overcup Oak
Quercus michauxii, Swamp Chestnut Oak
Liriodendron tulipfera, Tulip Poplar
Quercus falcata var. *pagodaefolia*, Cherrybark Oak

Fraxinus pennsylvanica, Green Ash
Platanus occidentalis, American Sycamore

C. Grass Area

The following grass species were planted in ten 100' x 100' grass plots (Figure 5):

Wiregrass
Carolina Dropseed
Toothache grass
Savanna muhly

HAW'S RUN MITIGATION SITE

PROJ. REFERENCE NO.	SHEET NO.	TOTAL SHEETS
STATE PROJECT NO.	F.A. PROJ. NO.	DESCRIPTION

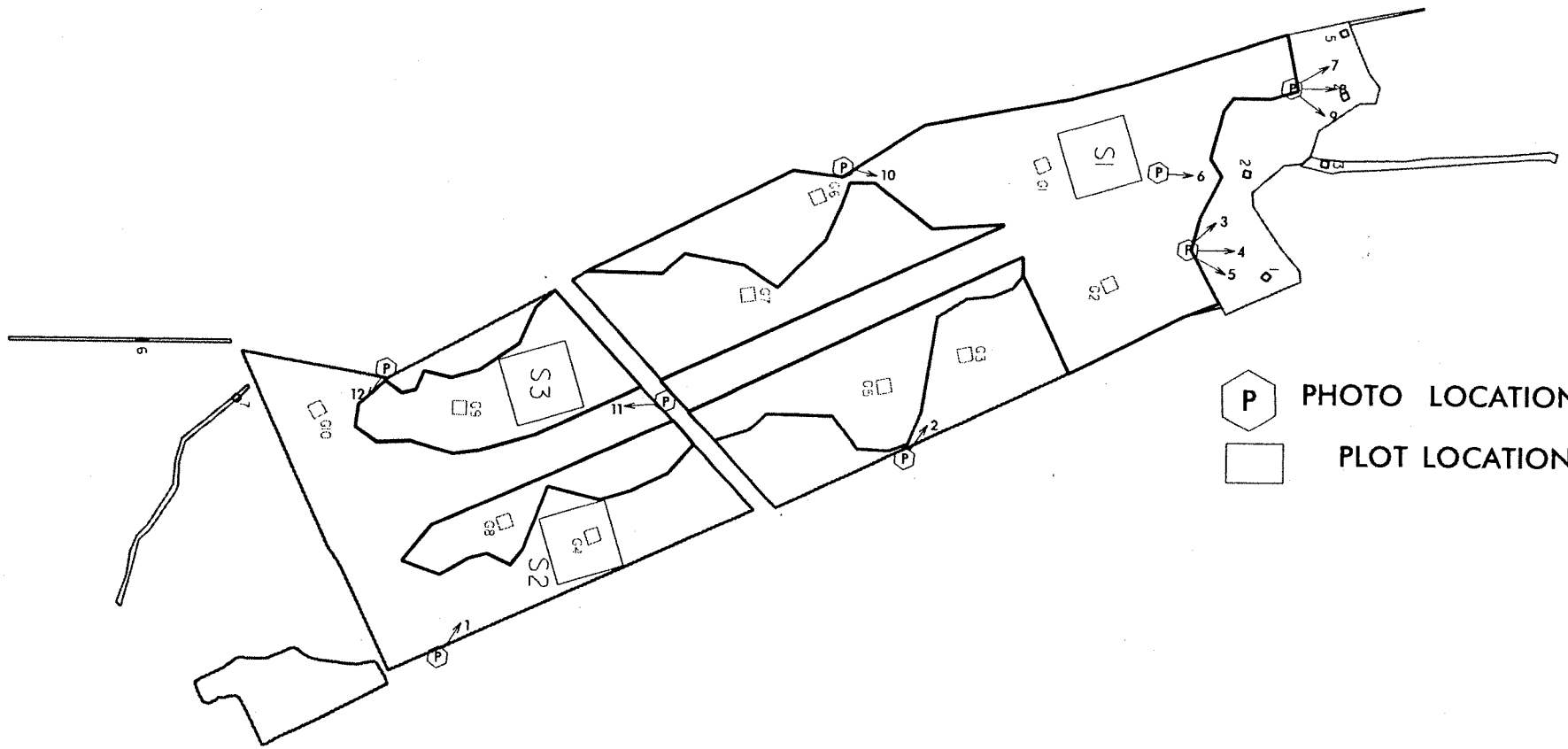


FIGURE 5. Vegetation Monitoring Map

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3.3 Results of Vegetation Monitoring (1 year)

A. Savanna Areas

ZONE	Plot #	Long-leaf Pine	Pond Pine	Pond Cypress	Total (1 year)	Density (Tree/Acre)
1	S1	41	50		91	16
	S3	189	137		326	57
	ZONE 1 AVG.					37
2	S2	200			200	35
	ZONE 2 AVG.					35
	TOTAL AVG.					36

To determine tree density, 500' x 500' plots (5.7 acre) were installed immediately following planting. The actual numbers of planted trees, which occur within the plot, are counted. Since the actual plot size is 5.7 acres, actual trees per acre can be estimated.

Notes from Report: Pines in savanna areas growing well. Broomsedge present throughout plots. The wet savanna restoration area will be planted with pond cypress in Spring 2000.

B. Swamp Forest Area

Plot #	Swamp Tupelo	Baldcypress	Pond Cypress	Laurel Oak	Overcup Oak	Swamp Chestnut Oak	Tulip Poplar	Cherrybark Oak	Green Ash	American Sycamore	Total (1 year)	Total (at planting)	Density (Tree/Acre)
1		1		5	7	3		5			21	32	446
2	6	11		4	4	6		12	5		48	53	616
3	2	4		1	3	5			6		21	34	420
4	3	3		3	7	8		2	2		28	35	544
5					22	6		6			34	39	593
6	1				6			1			8	36	151
7		2			3			8	3	12	28	43	443
TOTAL AVG.													**459**

To determine tree density, 50' x 50' plots are installed immediately following planting. The actual numbers of planted trees, which occur within the plot, are counted. This number is equated to the number within each plot, which represents 680 trees per acre (average). The survival monitoring number is compared to the planted number to obtain survival percentage. This percentage is applied to the 680 trees per acre to obtain an estimated tree per acre for the site.

$$\text{Density} = \frac{\text{monitoring count}}{\text{planted trees}} \times 680 \text{ (trees per acre)}$$

Notes from Report: Many trees had lost their leaves due to flooding, making identification difficult. Plot #1 had 12" standing water at time of monitoring. Plot #6 had damage from vehicle traffic. Plot #7 had heavy beaver damage. Transect areas on the southern end of the site will be supplementary planted in Spring 2000.

C. Grass Area

Only visual inspection was done within the grass plots. Grasses appear to be establishing well.

3.4 Conclusions

A. Savanna Areas

Of the 595 acres of this site, approximately 315 acres involved savanna tree planting. There were 3 test plots established throughout the planting. The first year vegetation monitoring of the planted areas revealed an average density to be 30 trees per acre, which is well above the minimum requirement of 20 trees per acre.

Pond cypress will be planted in the wet savanna restoration area in Spring 2000.

B. Swamp Forest Area

Of the 595 acres of this site, approximately 33 acres involved tree planting. There were 7 test plots established throughout the planting. The first year vegetation monitoring of the planted areas revealed an average density to be 459 trees per acre, which is well above the minimum requirement of 320 trees per acre.

The transect areas at the southern end of the site will be supplementary planted Spring 2000.

Several washouts have occurred along the northern side of the site adjacent to the swamp forest area. NCDOT will repair and stabilize these areas during the 2000 construction season.

NCDOT recommends that the success criteria for the swamp forest area be revised to current standards. NCDOT will monitor the site for five years. A 320 stems per acre survival criterion for planted seedlings will be used to determine success for the first three years. The required survival criterion will decrease by 10% per year after the third year of vegetation monitoring (i.e., for an expected 290 stems per acre for year 4, and 260 stems per acre for year 5).

C. Grass Area

Of the 595 acres of this site, approximately 2.3 acres involved grass planting. The grasses were planted in ten 100' x 100' test plots. The first year vegetation monitoring of the planted areas revealed that the planted grasses were establishing well.

4.0 OVERALL CONCLUSIONS / RECOMMENDATIONS

Hydrologic monitoring in 1999 showed trends in the restoration areas similar to those in the references areas. While the majority of wells on site did not meet the 12.5% jurisdictional wetland criteria, the hydroperiods and other hydrologic indicators were comparable between the restoration and reference areas.

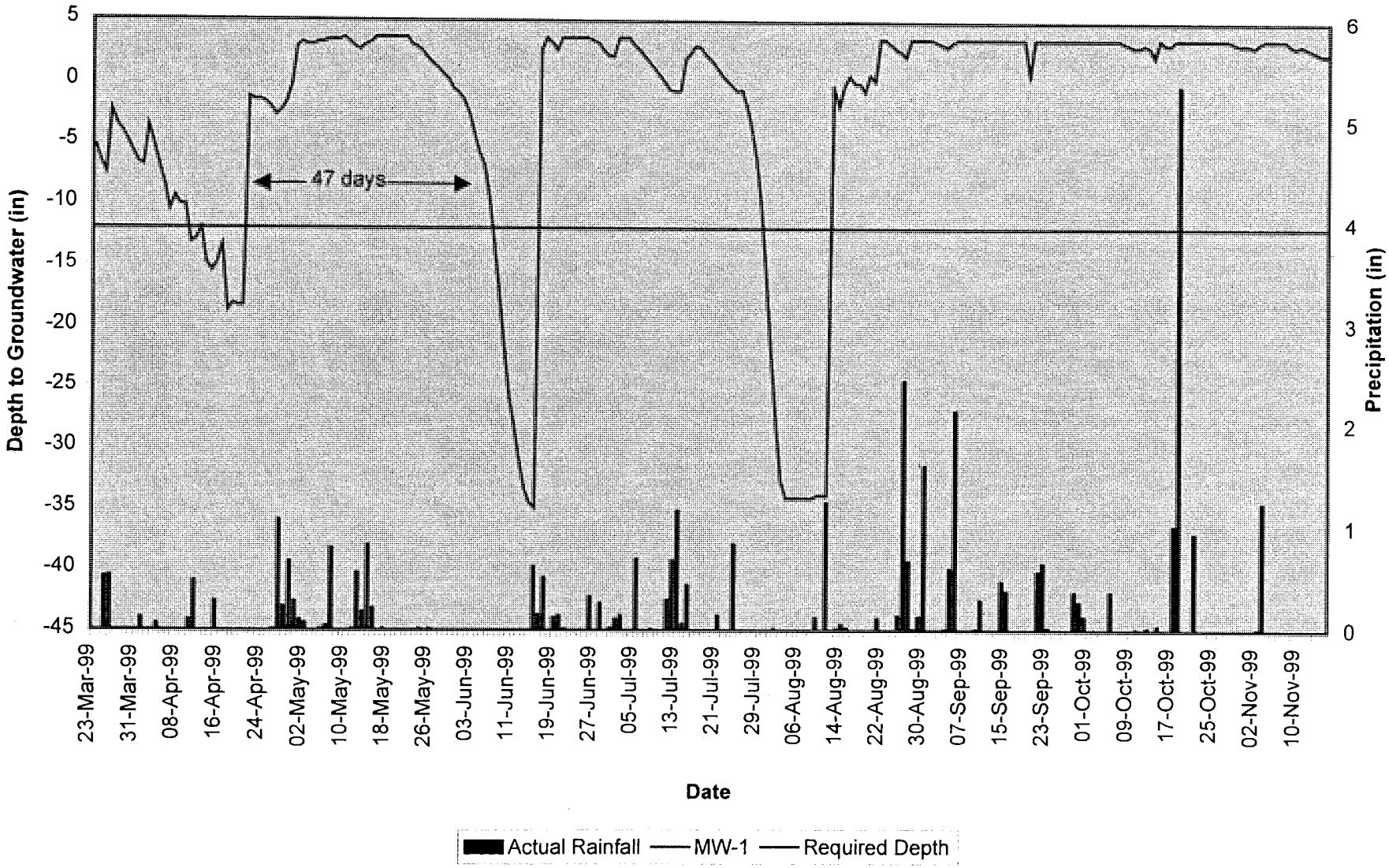
Vegetation on Haws Run is doing well in both the swamp and savanna areas, with exceptions as noted in the report. Final planting is planned for Spring 2000. Erosion and monitoring well issues will be addressed during the 2000 monitoring period. As-built reports will be submitted after final plantings and well modifications are completed.

NCDOT will continue to monitor the site for both vegetation and hydrologic success.

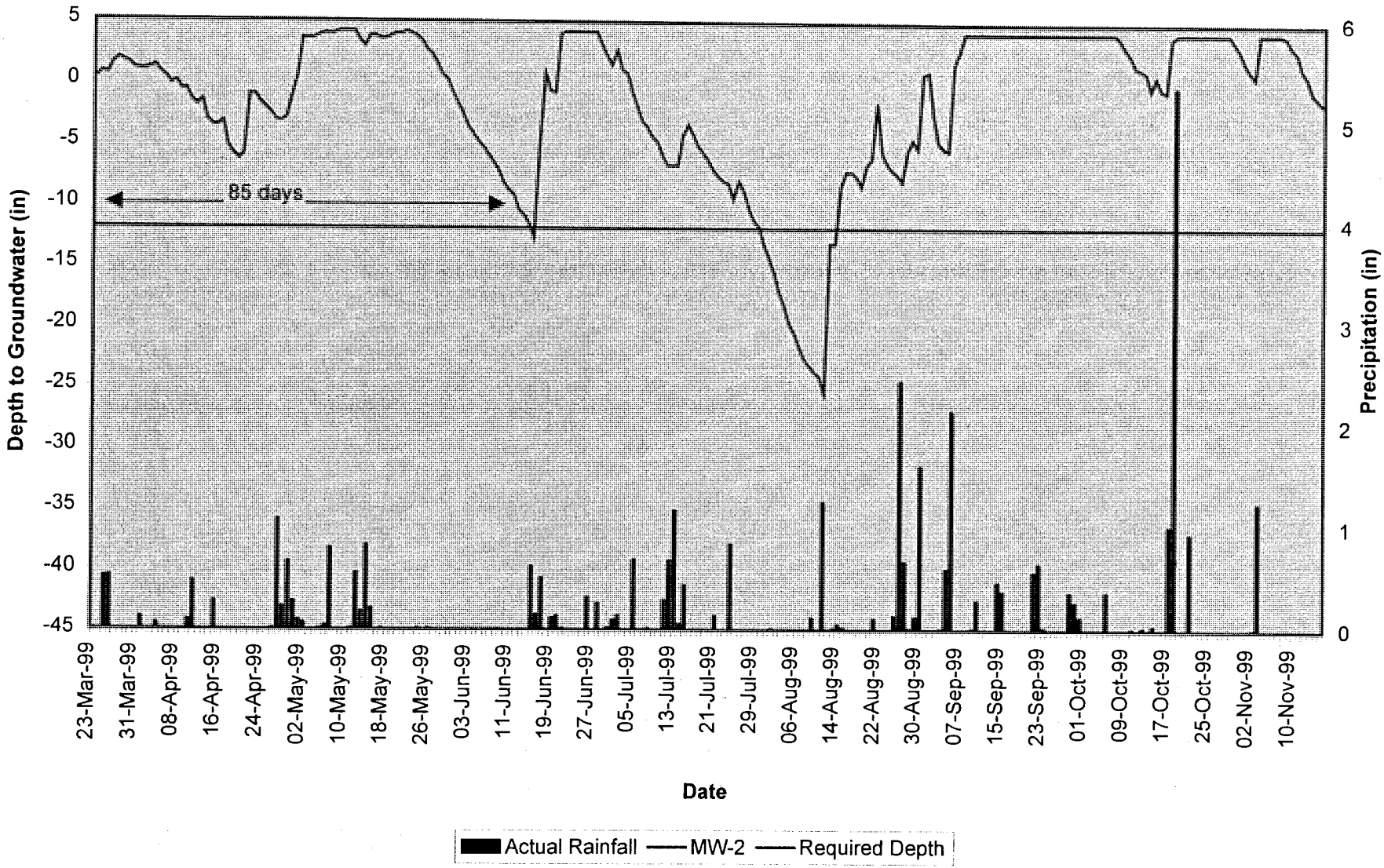
APPENDIX A

DEPTH TO GROUNDWATER PLOTS

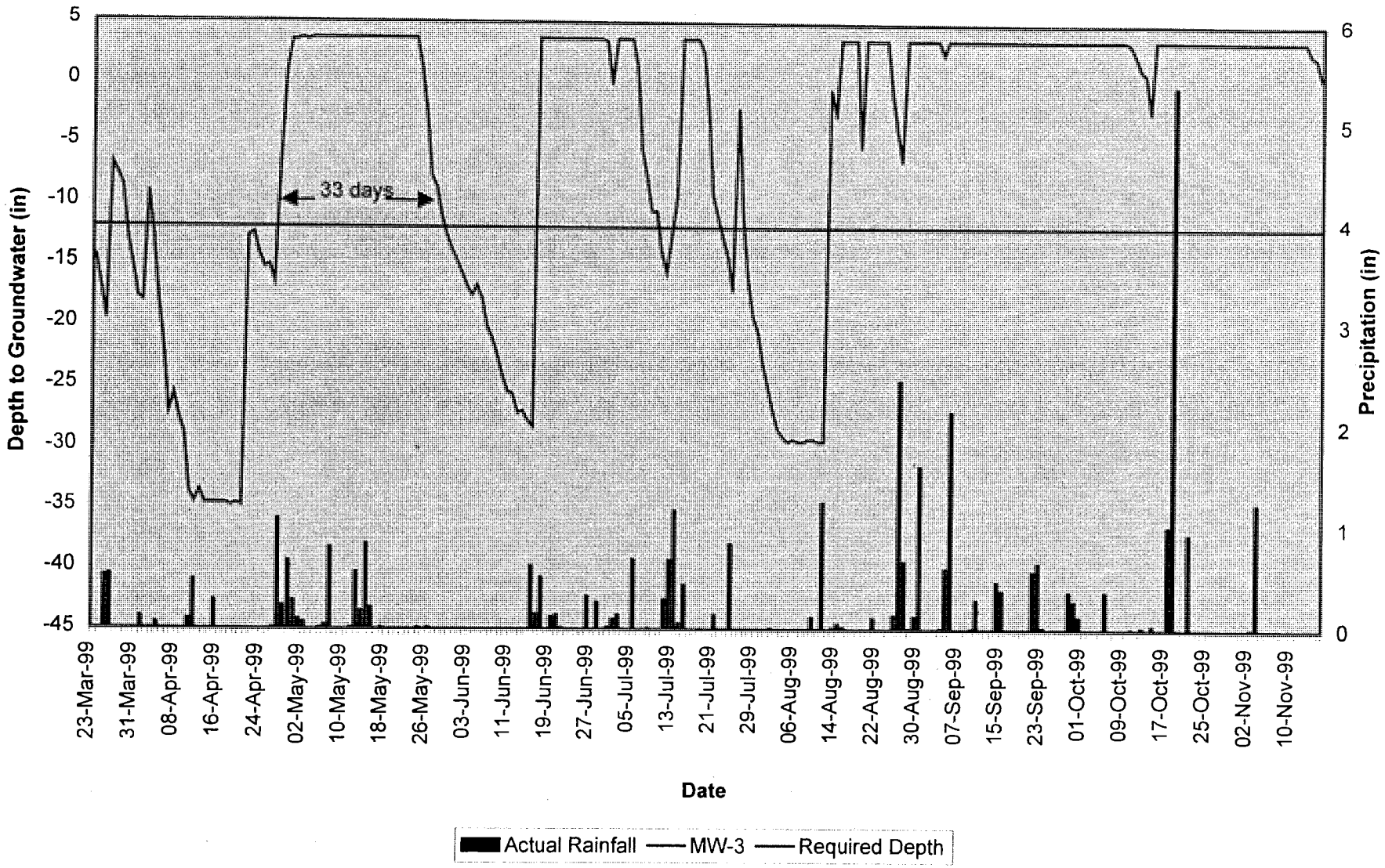
Haws Run MW-1

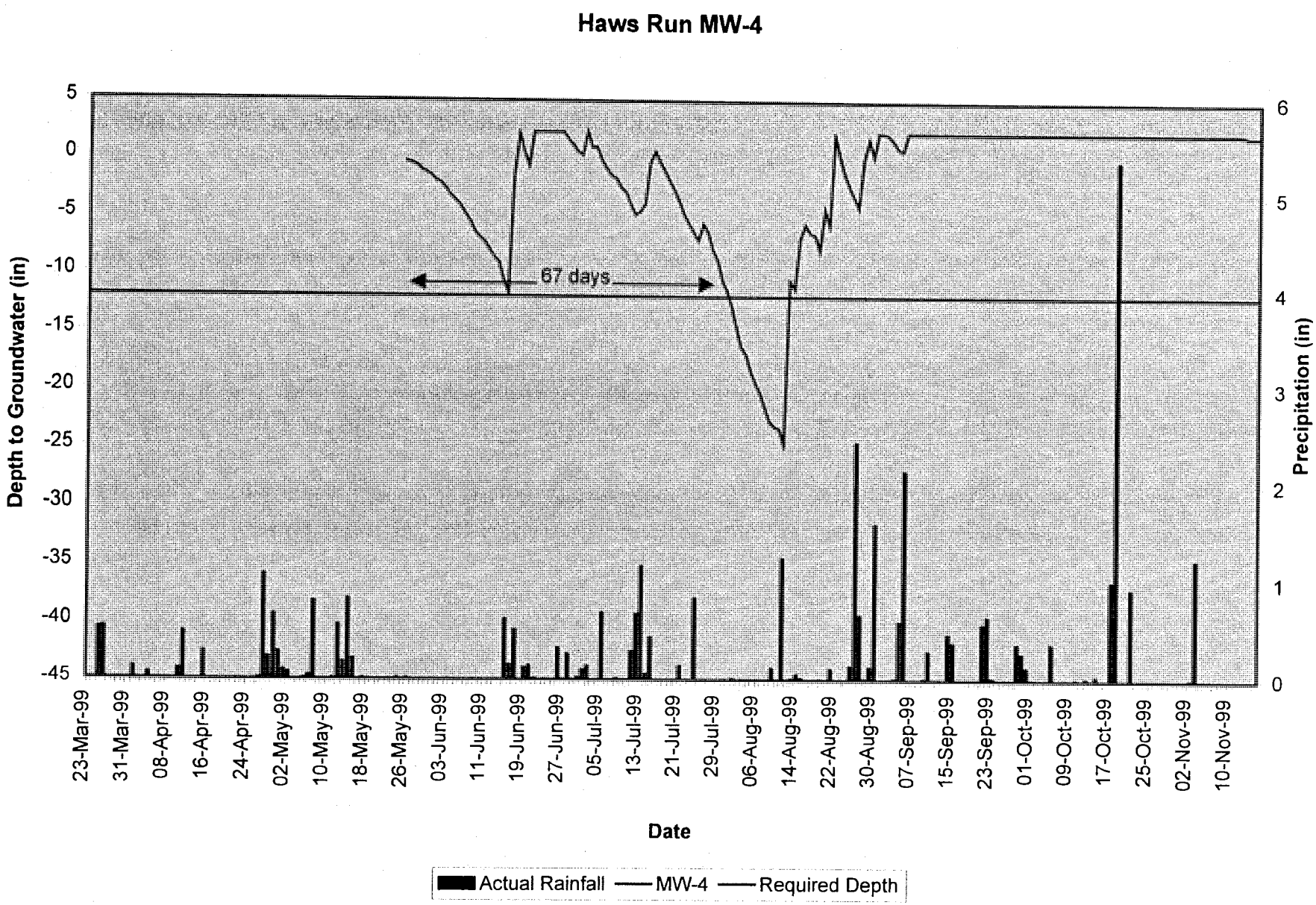

Depth to Groundwater (in)
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
47 days
Precipitation (in)
6
5
4
3
2
1
0
23-Mar-99
31-Mar-99
08-Apr-99
16-Apr-99
24-Apr-99
02-May-99
10-May-99
18-May-99
26-May-99
03-Jun-99
11-Jun-99
19-Jun-99
27-Jun-99
05-Jul-99
13-Jul-99
21-Jul-99
29-Jul-99
06-Aug-99
14-Aug-99
22-Aug-99
30-Aug-99
07-Sep-99
15-Sep-99
23-Sep-99
01-Oct-99
09-Oct-99
17-Oct-99
25-Oct-99
02-Nov-99
10-Nov-99
Date
Actual Rainfall
MW-1
Required Depth

Haws Run MW-2

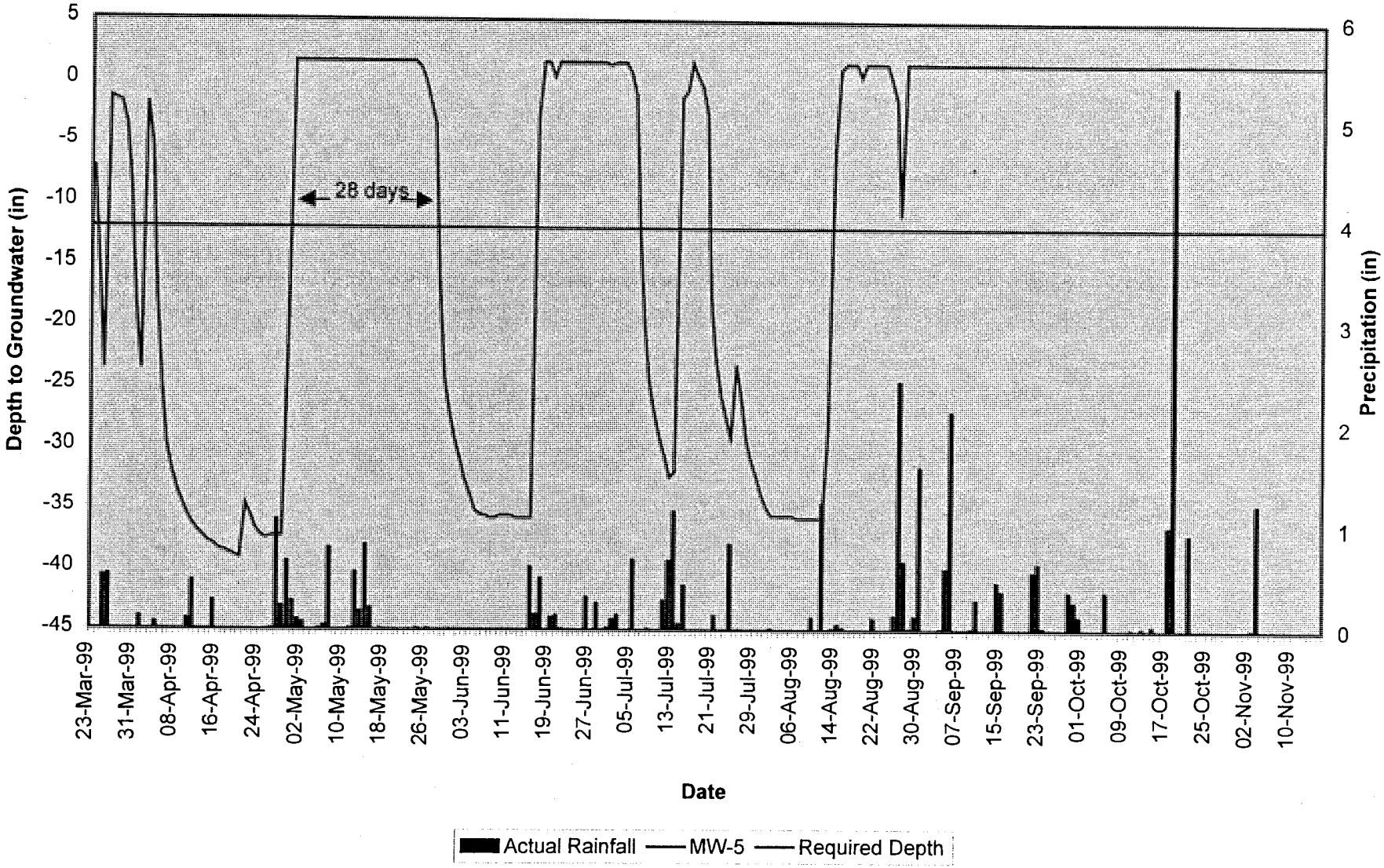

Depth to Groundwater (in)
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
85 days
Precipitation (in)
6
5
4
3
2
1
0
23-Mar-99
31-Mar-99
08-Apr-99
16-Apr-99
24-Apr-99
02-May-99
10-May-99
18-May-99
26-May-99
03-Jun-99
11-Jun-99
19-Jun-99
27-Jun-99
05-Jul-99
13-Jul-99
21-Jul-99
29-Jul-99
06-Aug-99
14-Aug-99
22-Aug-99
30-Aug-99
07-Sep-99
15-Sep-99
23-Sep-99
01-Oct-99
09-Oct-99
17-Oct-99
25-Oct-99
02-Nov-99
10-Nov-99
Date
Actual Rainfall
MW-2
Required Depth

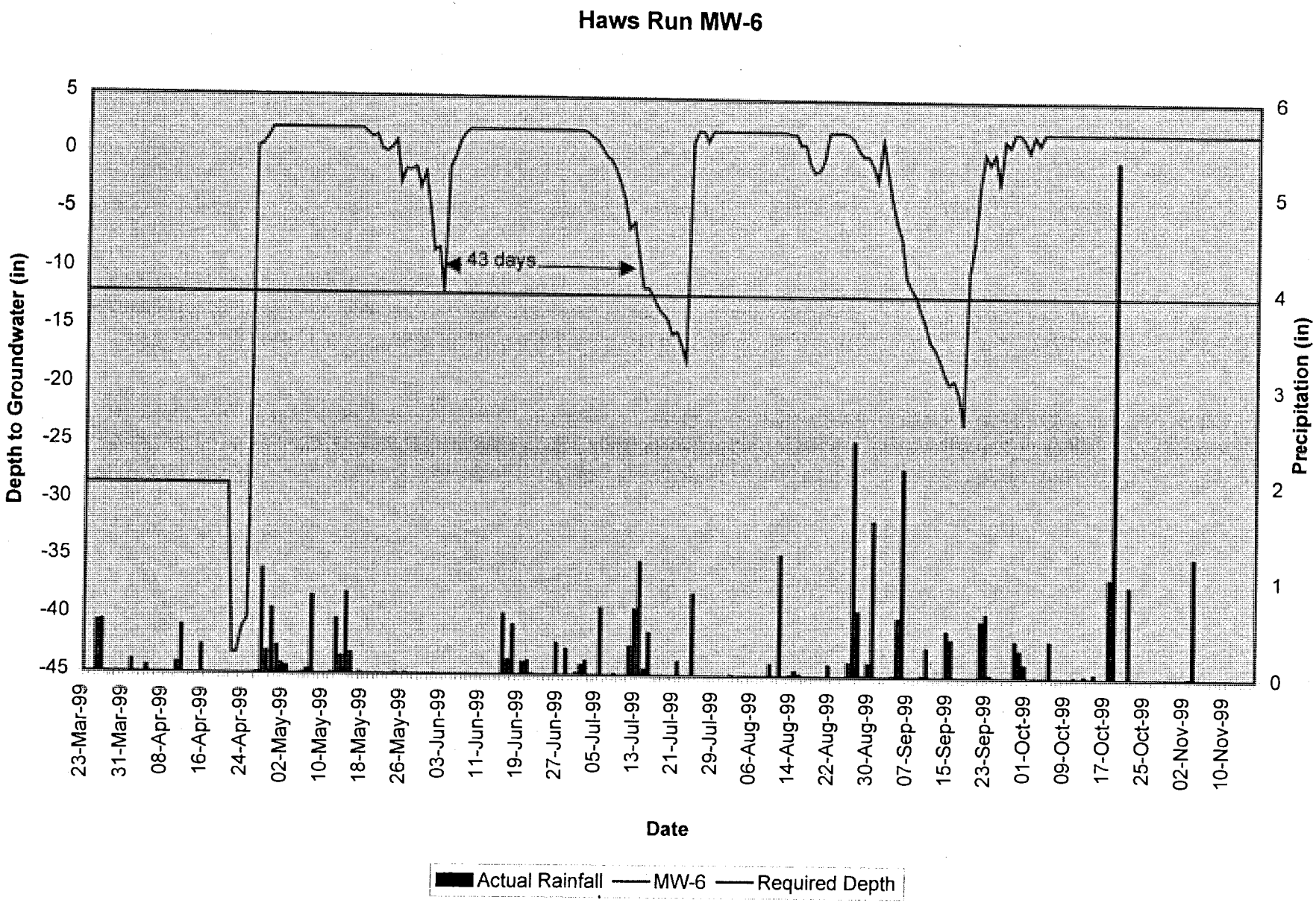
Haws Run MW-3

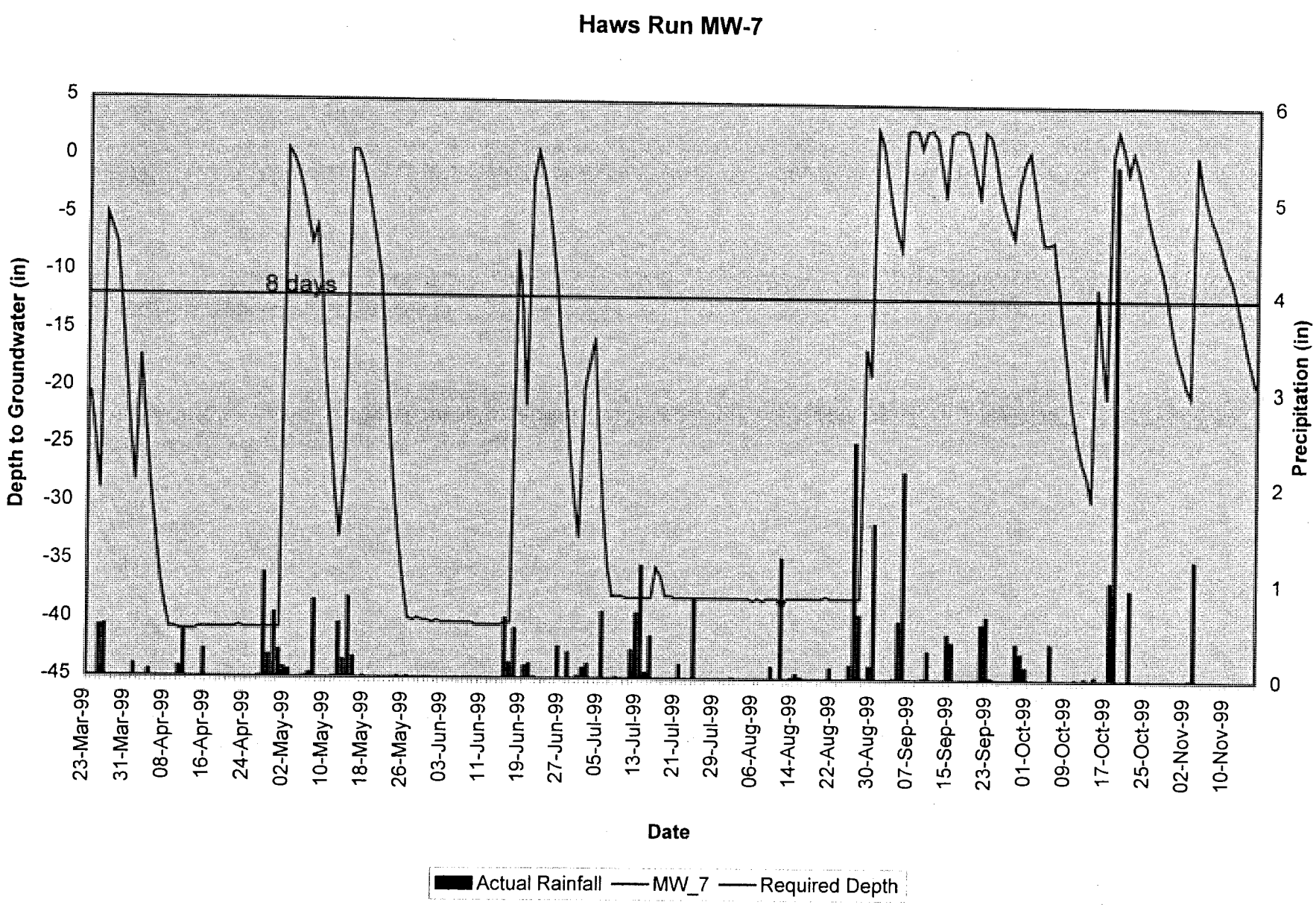

Depth to Groundwater (in)
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
33 days
Precipitation (in)
6
5
4
3
2
1
0
23-Mar-99
31-Mar-99
08-Apr-99
16-Apr-99
24-Apr-99
02-May-99
10-May-99
18-May-99
26-May-99
03-Jun-99
11-Jun-99
19-Jun-99
27-Jun-99
05-Jul-99
13-Jul-99
21-Jul-99
29-Jul-99
06-Aug-99
14-Aug-99
22-Aug-99
30-Aug-99
07-Sep-99
15-Sep-99
23-Sep-99
01-Oct-99
09-Oct-99
17-Oct-99
25-Oct-99
02-Nov-99
10-Nov-99
Date
Actual Rainfall
MW-3
Required Depth


Haws Run MW-4
Depth to Groundwater (in)
Precipitation (in)
67 days
Date
Actual Rainfall
MW-4
Required Depth

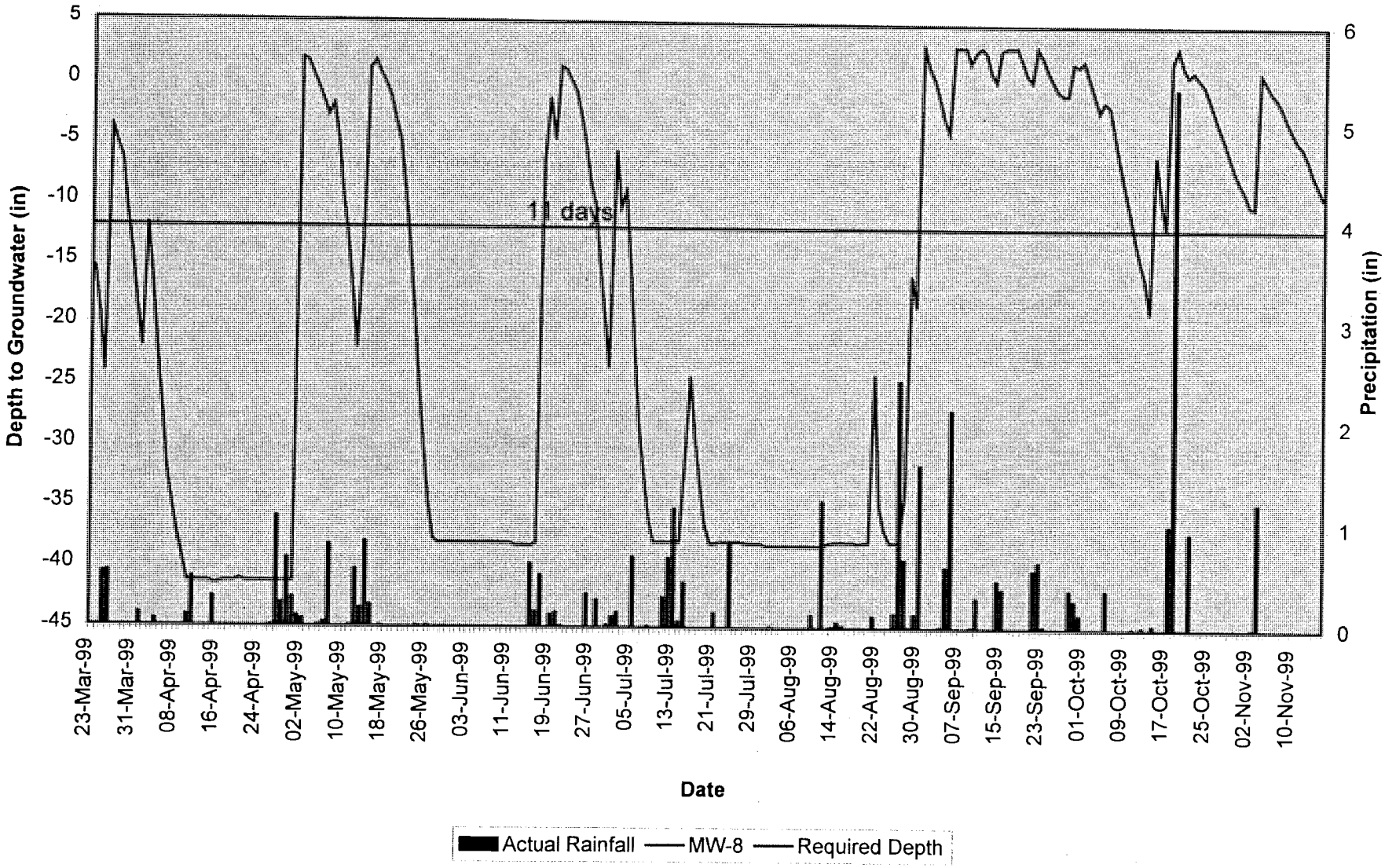
Haws Run MW-5


Depth to Groundwater (in)
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
28 days
Precipitation (in)
6
5
4
3
2
1
0
23-Mar-99
31-Mar-99
08-Apr-99
16-Apr-99
24-Apr-99
02-May-99
10-May-99
18-May-99
26-May-99
03-Jun-99
11-Jun-99
19-Jun-99
27-Jun-99
05-Jul-99
13-Jul-99
21-Jul-99
29-Jul-99
06-Aug-99
14-Aug-99
22-Aug-99
30-Aug-99
07-Sep-99
15-Sep-99
23-Sep-99
01-Oct-99
09-Oct-99
17-Oct-99
25-Oct-99
02-Nov-99
10-Nov-99
Date
Actual Rainfall
MW-5
Required Depth

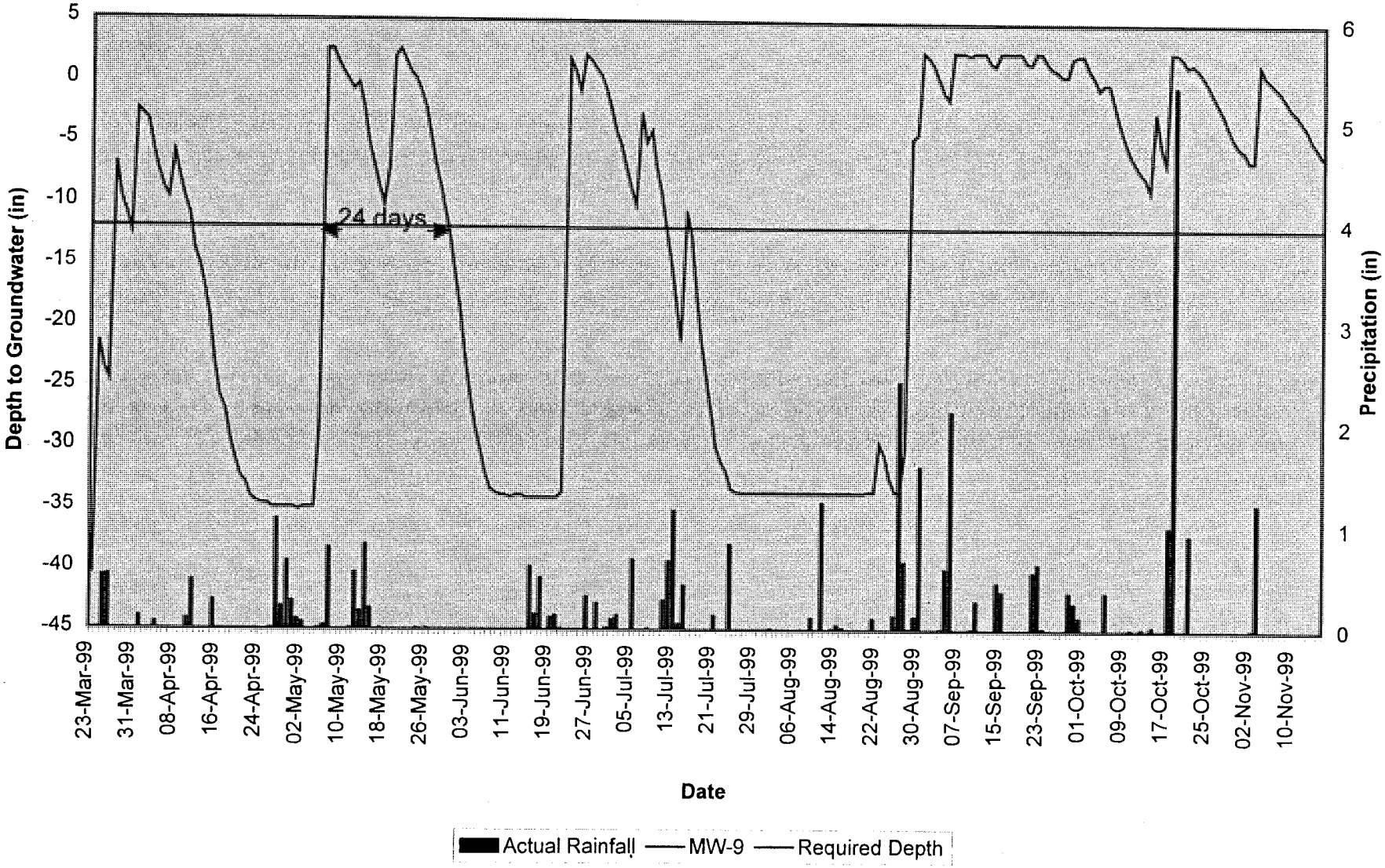

Haws Run MW-6
Depth to Groundwater (in)
Precipitation (in)
43 days
Date
Actual Rainfall
MW-6
Required Depth

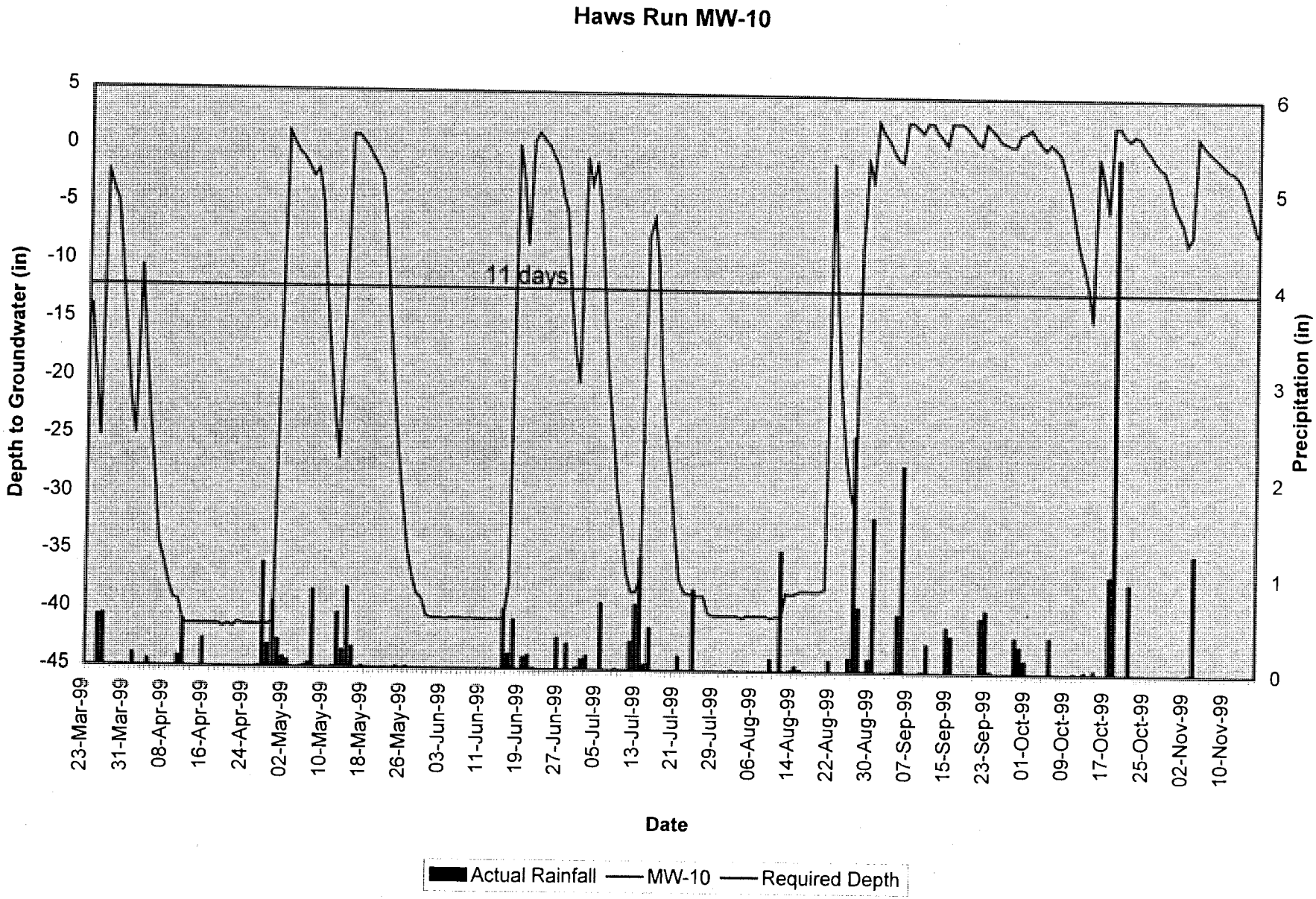

Haws Run MW-7
Depth to Groundwater (in)
Precipitation (in)
8 days
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
6
5
4
3
2
1
0
23-Mar-99
31-Mar-99
08-Apr-99
16-Apr-99
24-Apr-99
02-May-99
10-May-99
18-May-99
26-May-99
03-Jun-99
11-Jun-99
19-Jun-99
27-Jun-99
05-Jul-99
13-Jul-99
21-Jul-99
29-Jul-99
06-Aug-99
14-Aug-99
22-Aug-99
30-Aug-99
07-Sep-99
15-Sep-99
23-Sep-99
01-Oct-99
09-Oct-99
17-Oct-99
25-Oct-99
02-Nov-99
10-Nov-99
Date
Actual Rainfall
MW_7
Required Depth

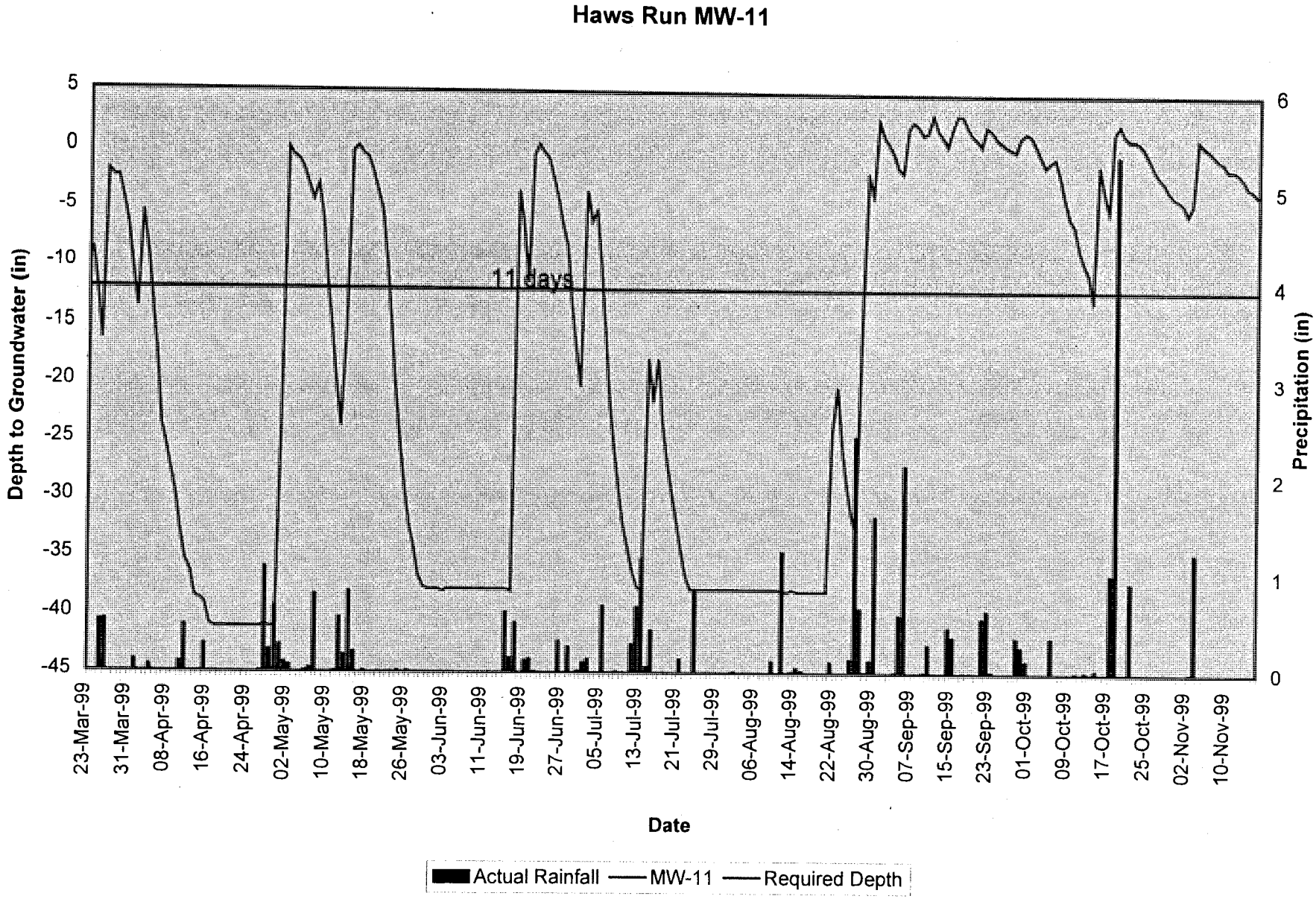
Haws Run MW-8


Depth to Groundwater (in)
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
11 days
Precipitation (in)
6
5
4
3
2
1
0
23-Mar-99
31-Mar-99
08-Apr-99
16-Apr-99
24-Apr-99
02-May-99
10-May-99
18-May-99
26-May-99
03-Jun-99
11-Jun-99
19-Jun-99
27-Jun-99
05-Jul-99
13-Jul-99
21-Jul-99
29-Jul-99
06-Aug-99
14-Aug-99
22-Aug-99
30-Aug-99
07-Sep-99
15-Sep-99
23-Sep-99
01-Oct-99
09-Oct-99
17-Oct-99
25-Oct-99
02-Nov-99
10-Nov-99
Date
Actual Rainfall
MW-8
Required Depth

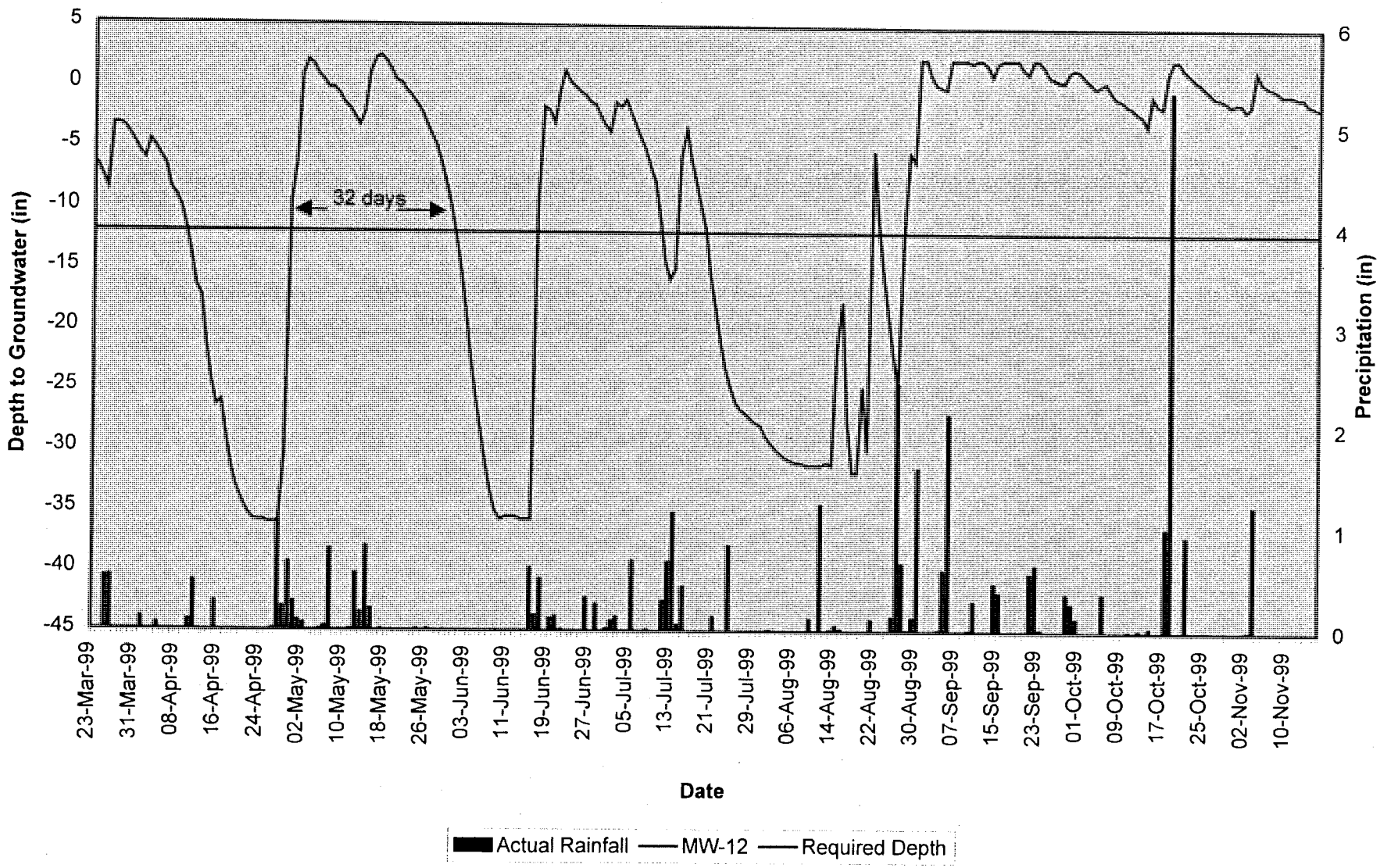
Haws Run MW-9

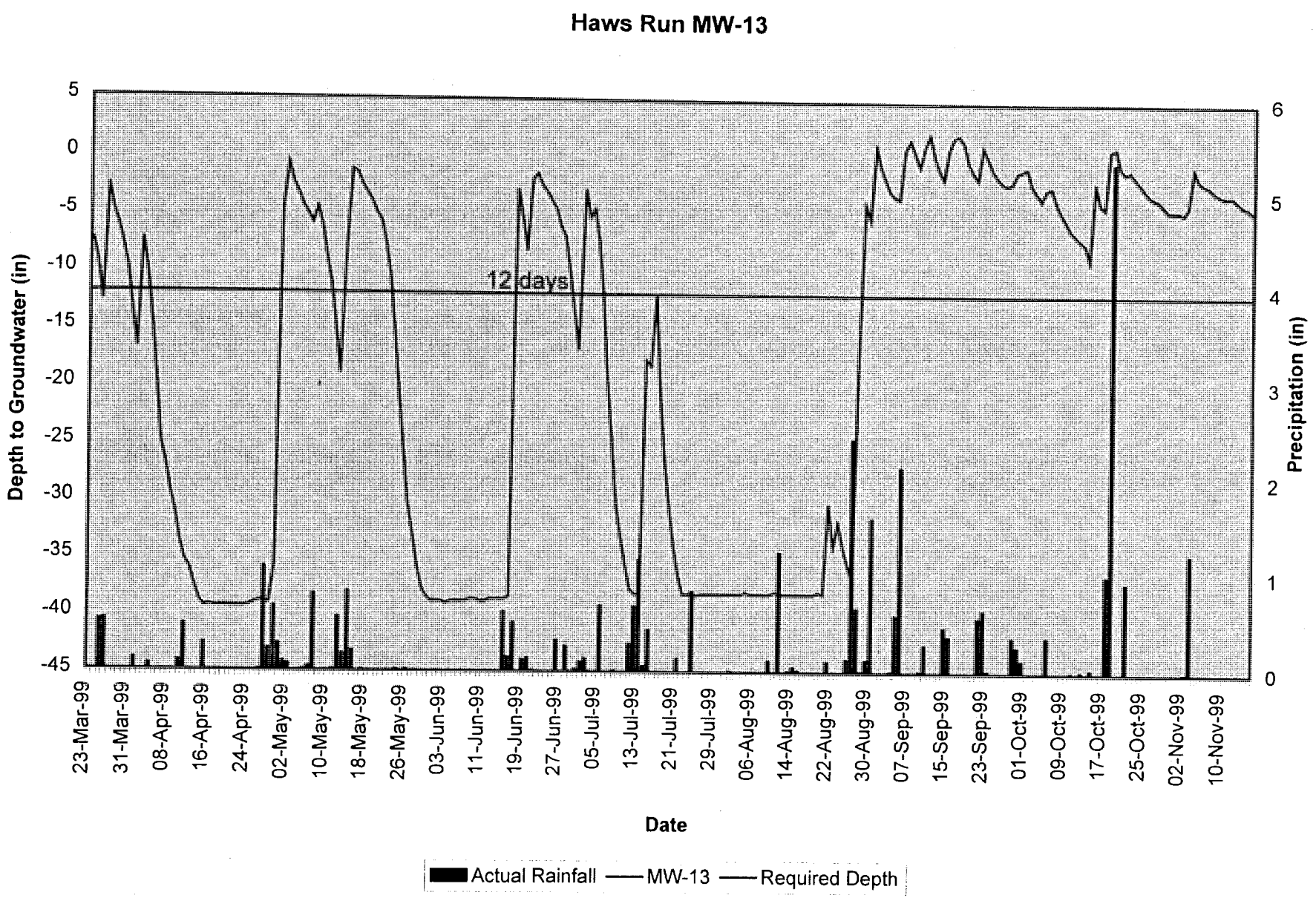

Depth to Groundwater (in)
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
24 days
Precipitation (in)
6
5
4
3
2
1
0
23-Mar-99
31-Mar-99
08-Apr-99
16-Apr-99
24-Apr-99
02-May-99
10-May-99
18-May-99
26-May-99
03-Jun-99
11-Jun-99
19-Jun-99
27-Jun-99
05-Jul-99
13-Jul-99
21-Jul-99
29-Jul-99
06-Aug-99
14-Aug-99
22-Aug-99
30-Aug-99
07-Sep-99
15-Sep-99
23-Sep-99
01-Oct-99
09-Oct-99
17-Oct-99
25-Oct-99
02-Nov-99
10-Nov-99
Date
Actual Rainfall
MW-9
Required Depth


Haws Run MW-10
11 days
Depth to Groundwater (in)
Precipitation (in)
Date
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
6
5
4
3
2
1
0
23-Mar-99
31-Mar-99
08-Apr-99
16-Apr-99
24-Apr-99
02-May-99
10-May-99
18-May-99
26-May-99
03-Jun-99
11-Jun-99
19-Jun-99
27-Jun-99
05-Jul-99
13-Jul-99
21-Jul-99
29-Jul-99
06-Aug-99
14-Aug-99
22-Aug-99
30-Aug-99
07-Sep-99
15-Sep-99
23-Sep-99
01-Oct-99
09-Oct-99
17-Oct-99
25-Oct-99
02-Nov-99
10-Nov-99
Actual Rainfall
MW-10
Required Depth

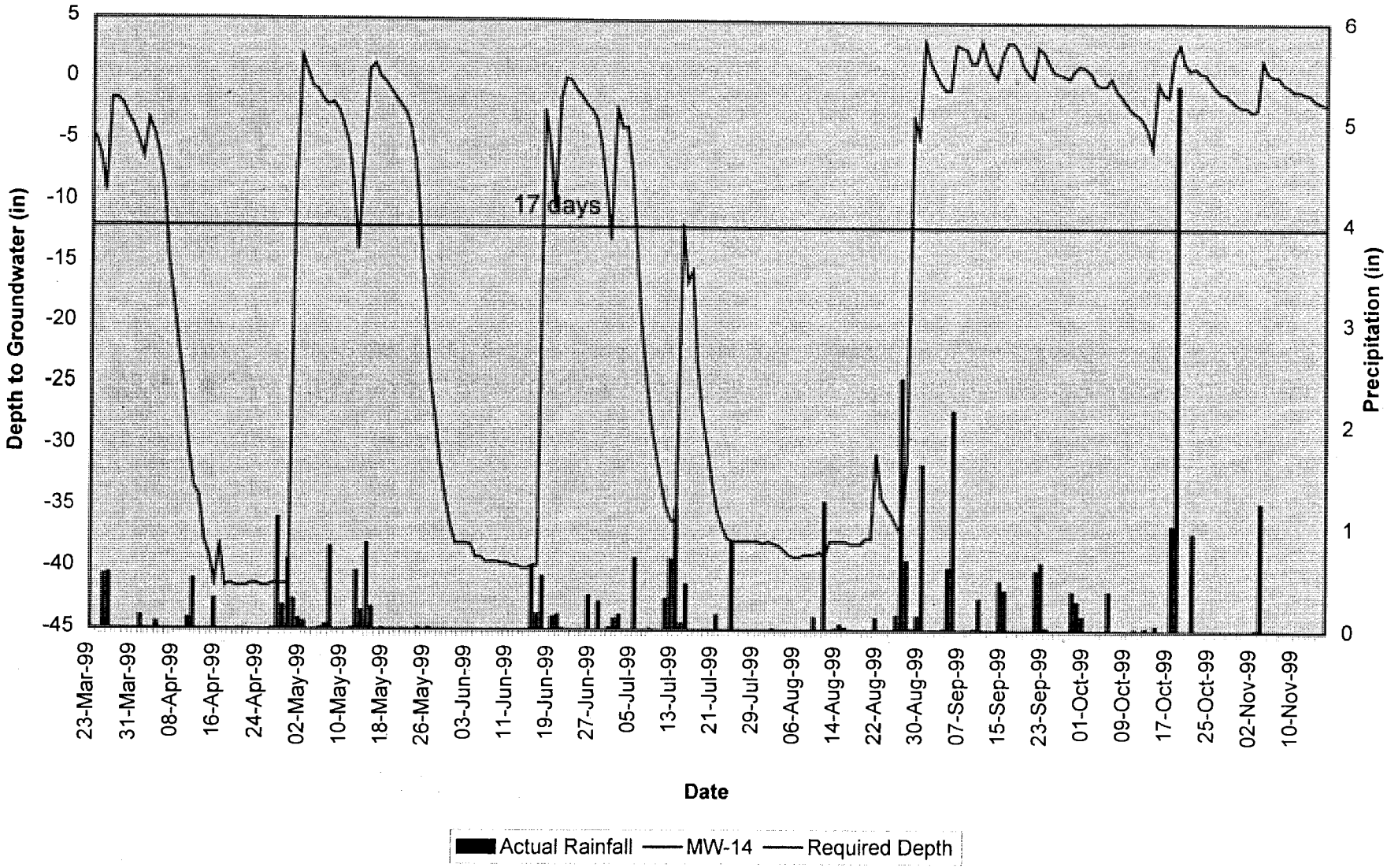

Haws Run MW-11
Depth to Groundwater (in)
Precipitation (in)
11 days
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
6
5
4
3
2
1
0
23-Mar-99
31-Mar-99
08-Apr-99
16-Apr-99
24-Apr-99
02-May-99
10-May-99
18-May-99
26-May-99
03-Jun-99
11-Jun-99
19-Jun-99
27-Jun-99
05-Jul-99
13-Jul-99
21-Jul-99
29-Jul-99
06-Aug-99
14-Aug-99
22-Aug-99
30-Aug-99
07-Sep-99
15-Sep-99
23-Sep-99
01-Oct-99
09-Oct-99
17-Oct-99
25-Oct-99
02-Nov-99
10-Nov-99
Date
Actual Rainfall
MW-11
Required Depth

Haws Run MW-12

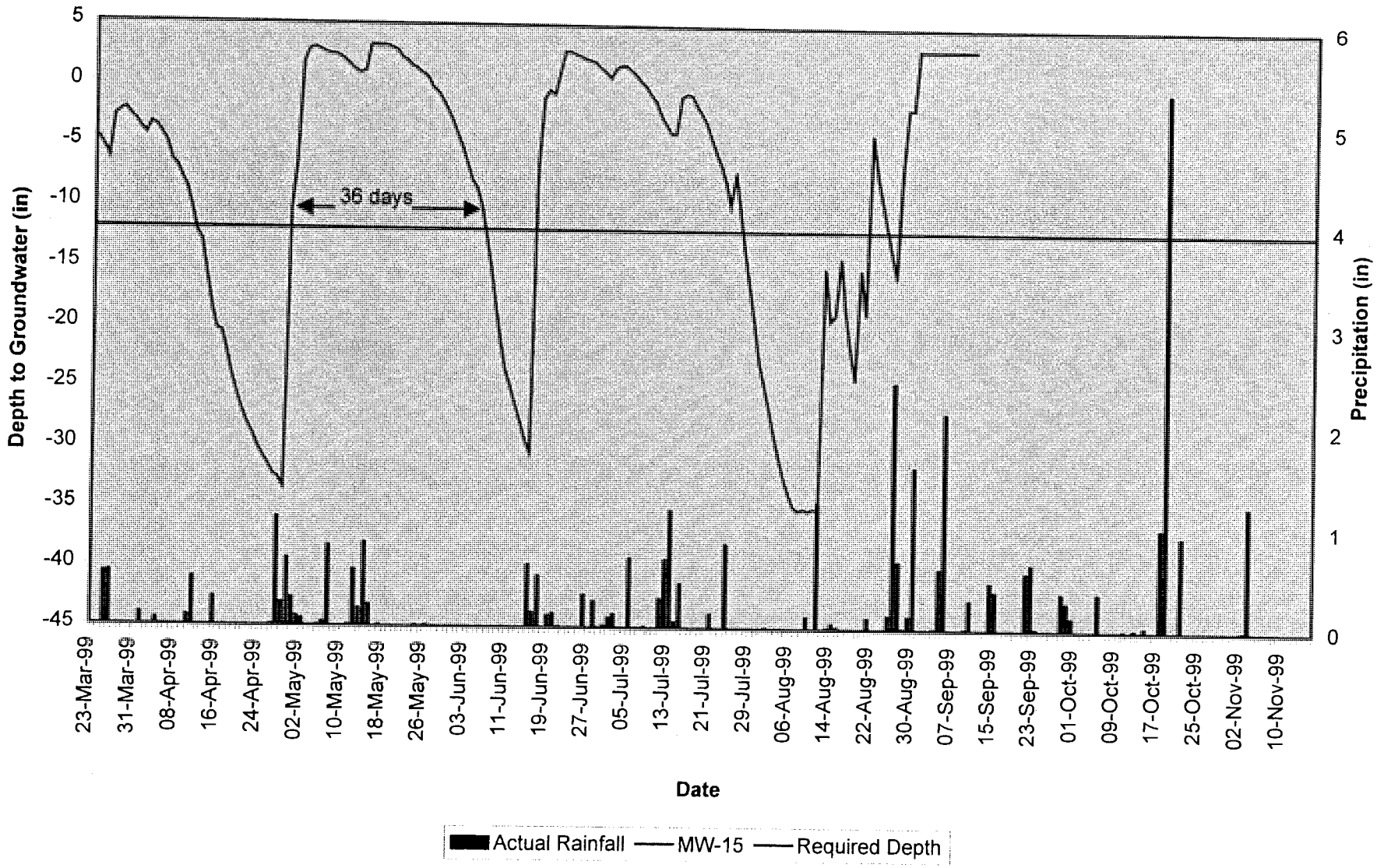


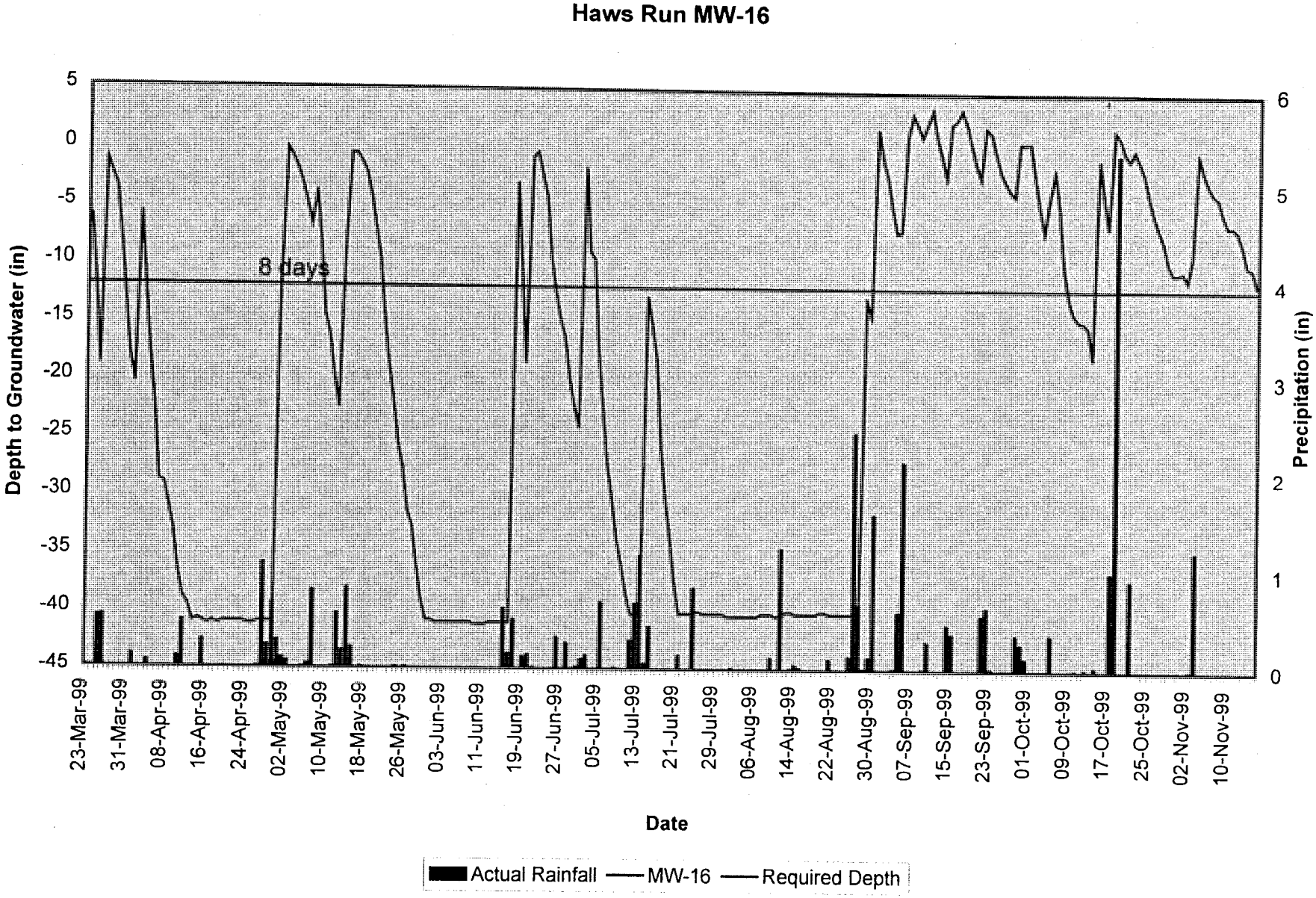

Haws Run MW-13
Depth to Groundwater (in)
Precipitation (in)
12 days
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
6
5
4
3
2
1
0
23-Mar-99
31-Mar-99
08-Apr-99
16-Apr-99
24-Apr-99
02-May-99
10-May-99
18-May-99
26-May-99
03-Jun-99
11-Jun-99
19-Jun-99
27-Jun-99
05-Jul-99
13-Jul-99
21-Jul-99
29-Jul-99
06-Aug-99
14-Aug-99
22-Aug-99
30-Aug-99
07-Sep-99
15-Sep-99
23-Sep-99
01-Oct-99
09-Oct-99
17-Oct-99
25-Oct-99
02-Nov-99
10-Nov-99
Date
Actual Rainfall
MW-13
Required Depth

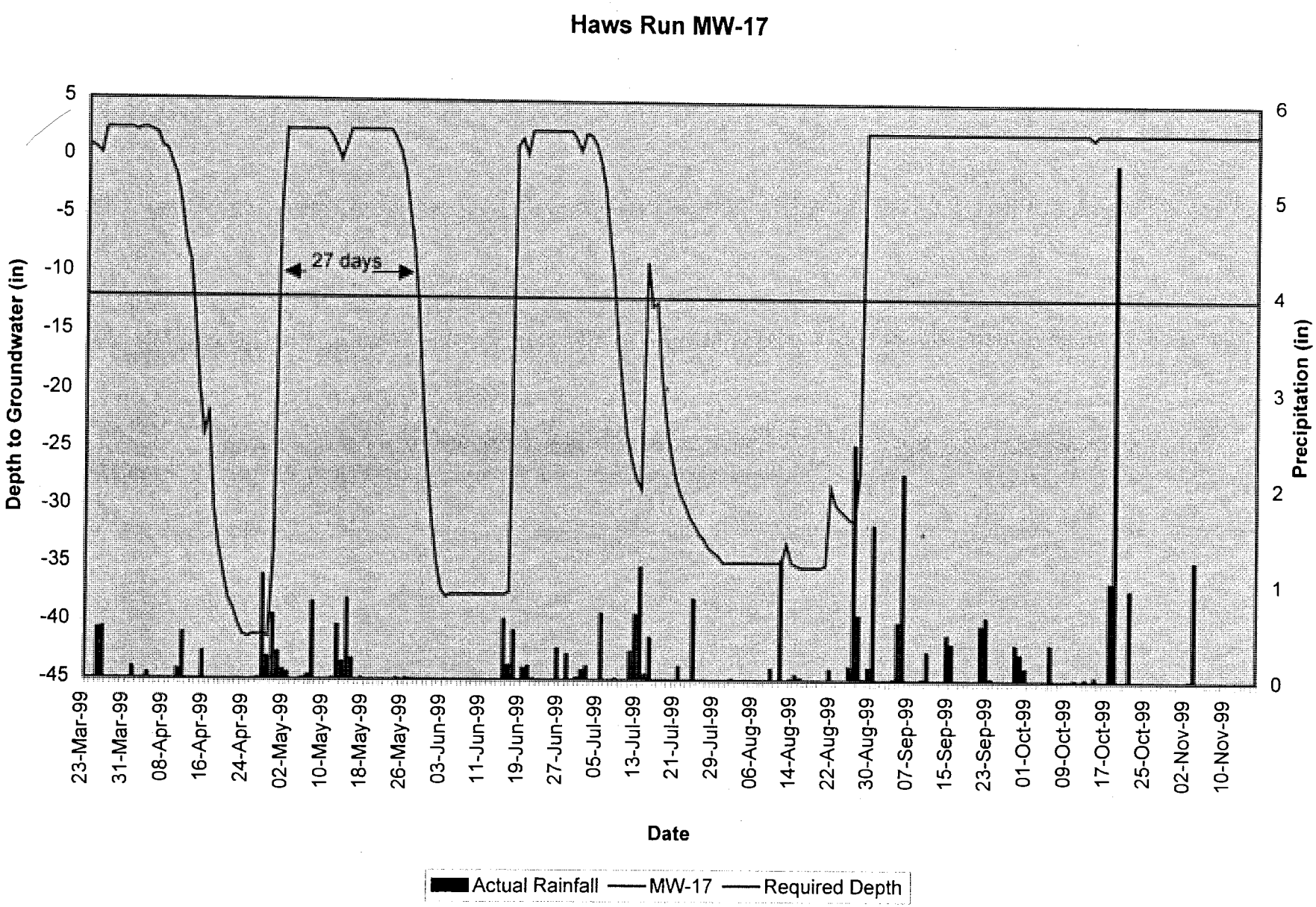
Haws Run MW-14



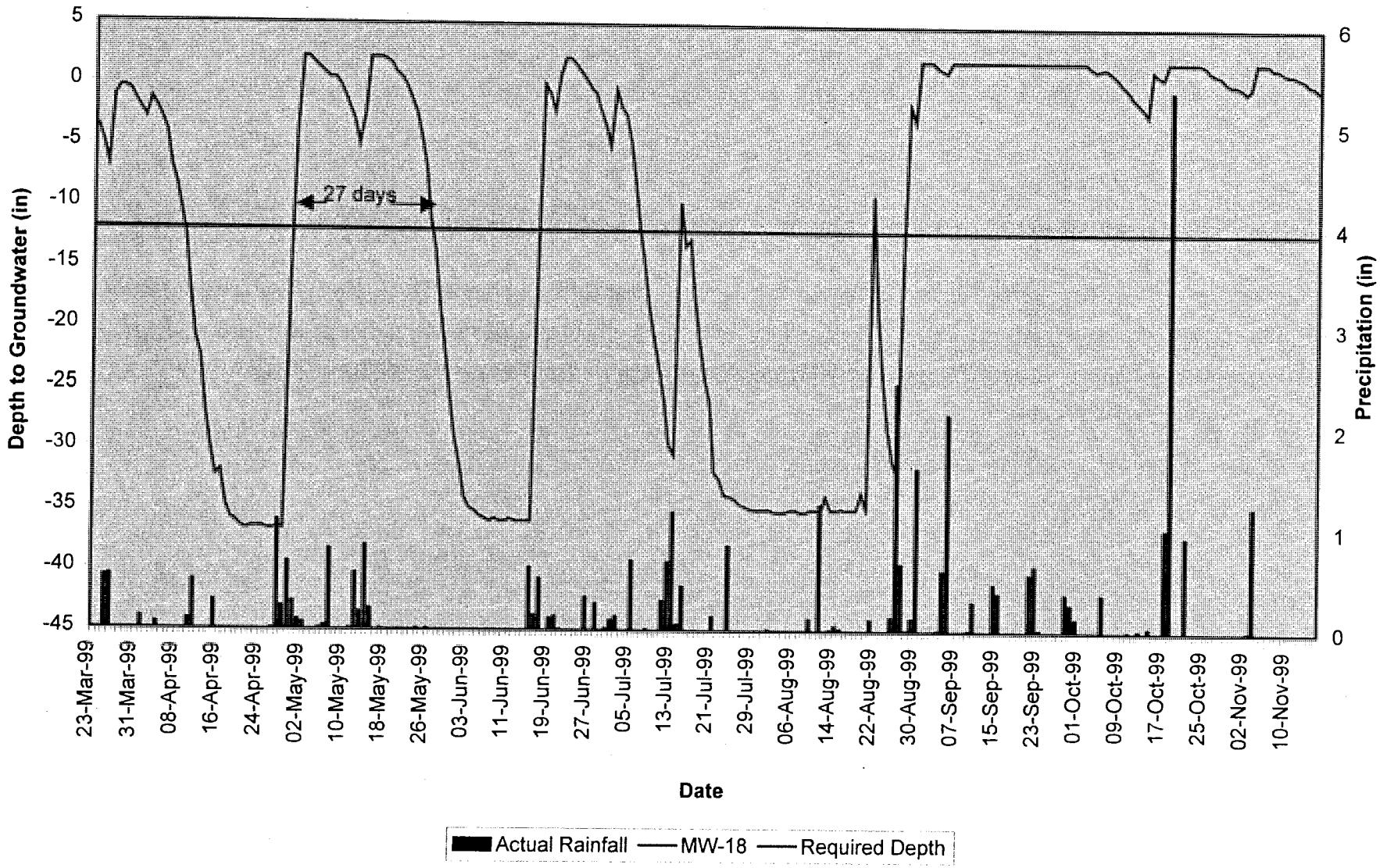
Haws Run MW-15



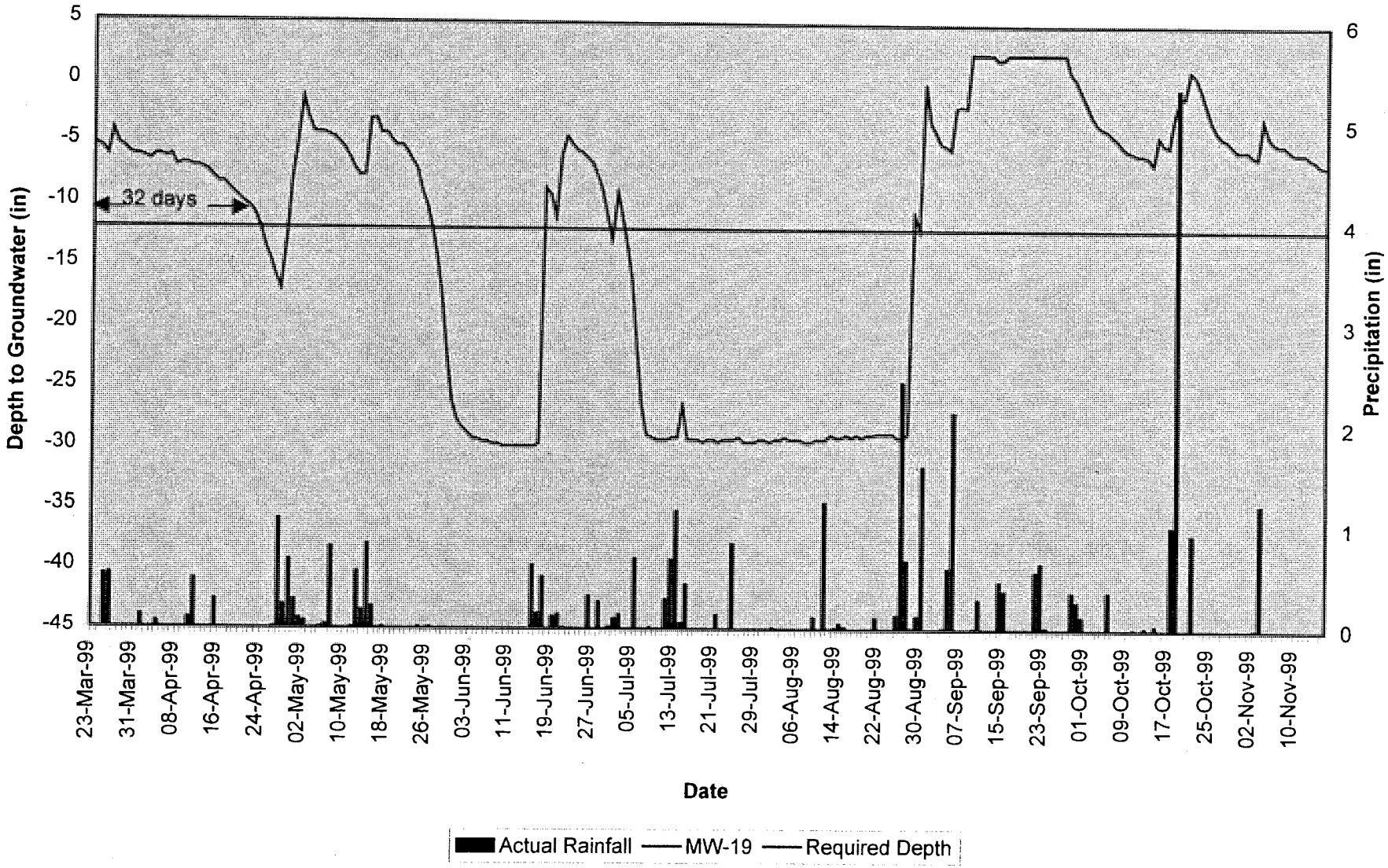

Haws Run MW-16
Depth to Groundwater (in)
Precipitation (in)
8 days
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
6
5
4
3
2
1
0
23-Mar-99
31-Mar-99
08-Apr-99
16-Apr-99
24-Apr-99
02-May-99
10-May-99
18-May-99
26-May-99
03-Jun-99
11-Jun-99
19-Jun-99
27-Jun-99
05-Jul-99
13-Jul-99
21-Jul-99
29-Jul-99
06-Aug-99
14-Aug-99
22-Aug-99
30-Aug-99
07-Sep-99
15-Sep-99
23-Sep-99
01-Oct-99
09-Oct-99
17-Oct-99
25-Oct-99
02-Nov-99
10-Nov-99
Date
Actual Rainfall
MW-16
Required Depth

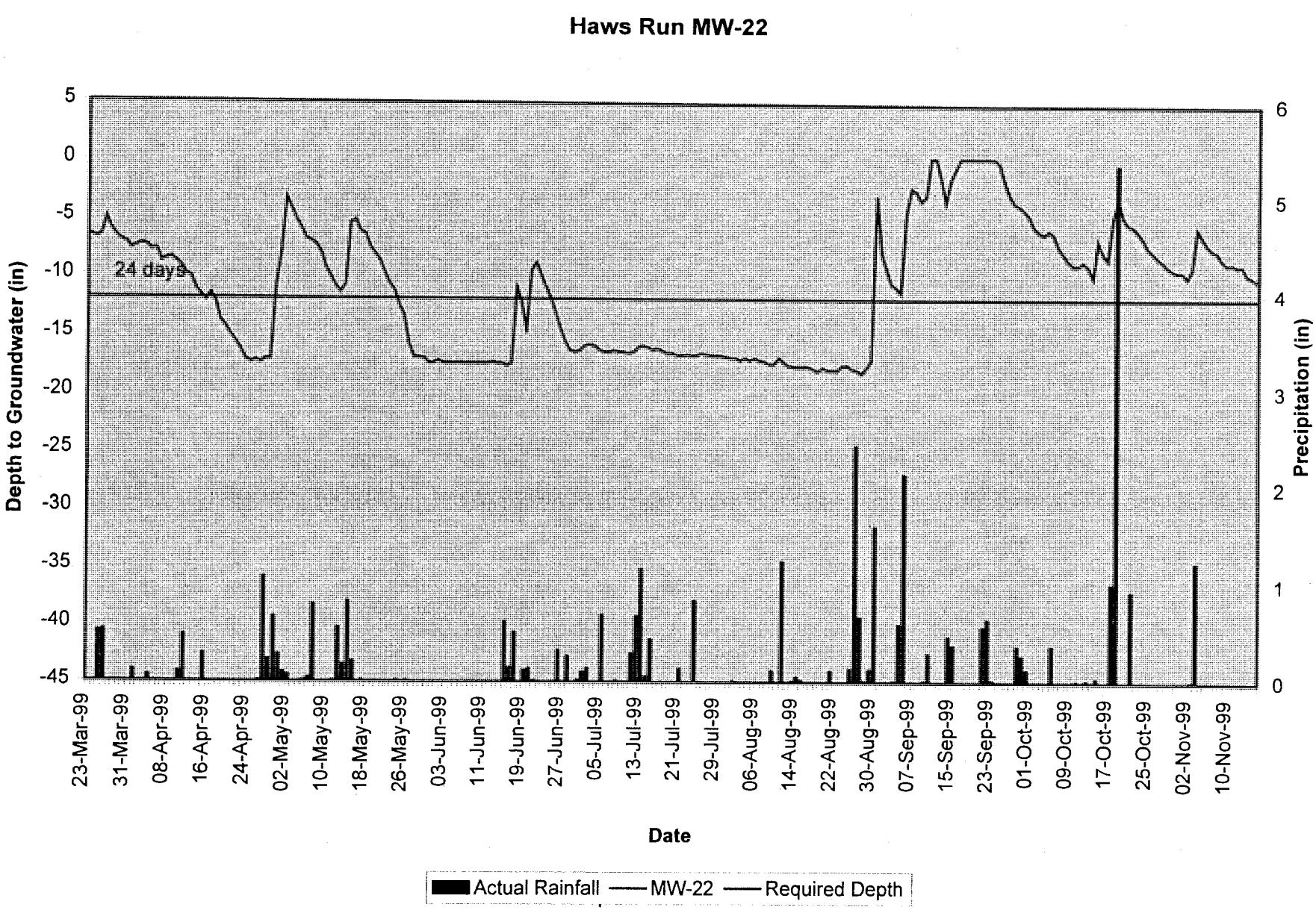

Haws Run MW-17
Depth to Groundwater (in)
Precipitation (in)
27 days
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
6
5
4
3
2
1
0
23-Mar-99
31-Mar-99
08-Apr-99
16-Apr-99
24-Apr-99
02-May-99
10-May-99
18-May-99
26-May-99
03-Jun-99
11-Jun-99
19-Jun-99
27-Jun-99
05-Jul-99
13-Jul-99
21-Jul-99
29-Jul-99
06-Aug-99
14-Aug-99
22-Aug-99
30-Aug-99
07-Sep-99
15-Sep-99
23-Sep-99
01-Oct-99
09-Oct-99
17-Oct-99
25-Oct-99
02-Nov-99
10-Nov-99
Date
Actual Rainfall
MW-17
Required Depth

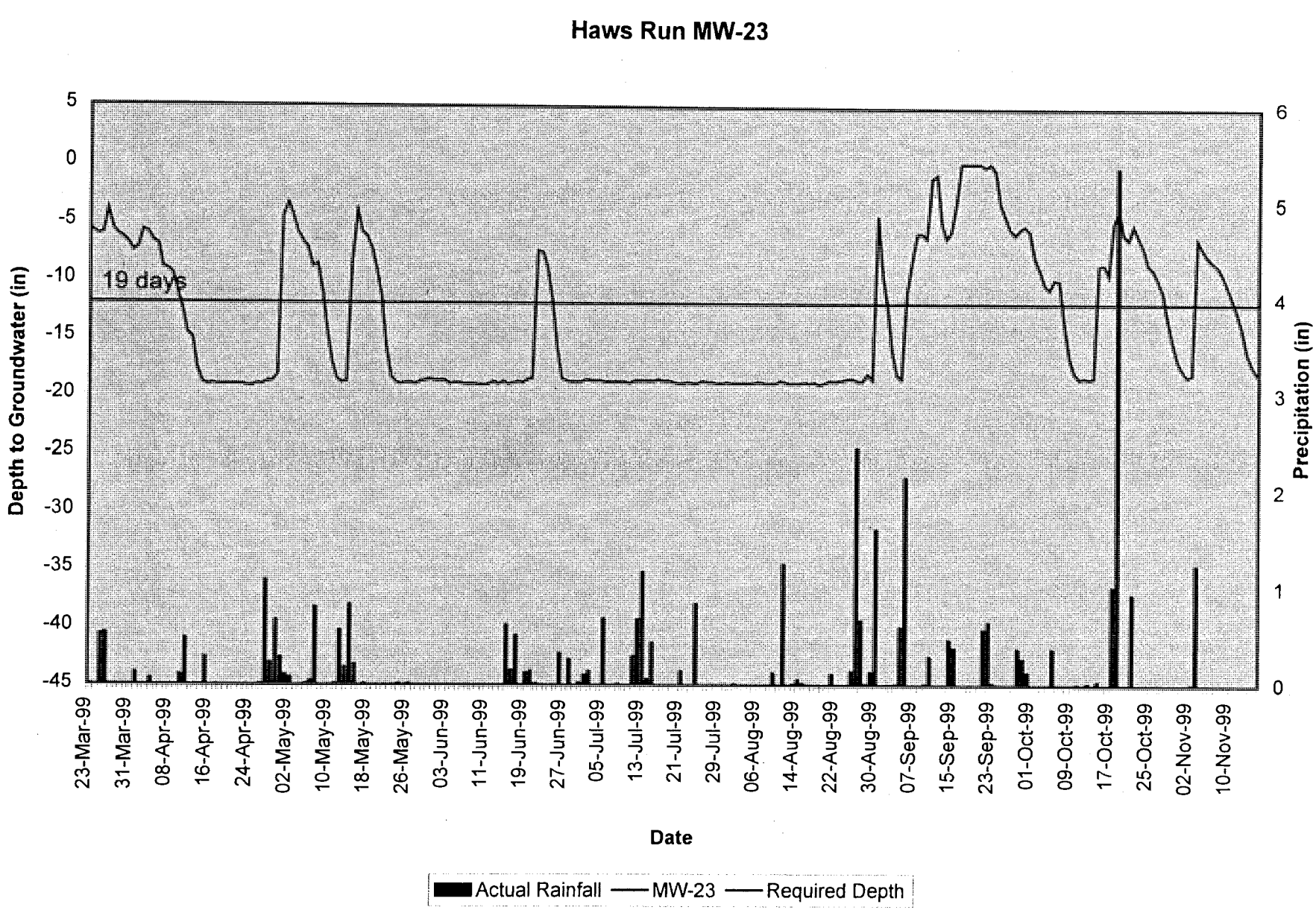
Haws Run MW-18

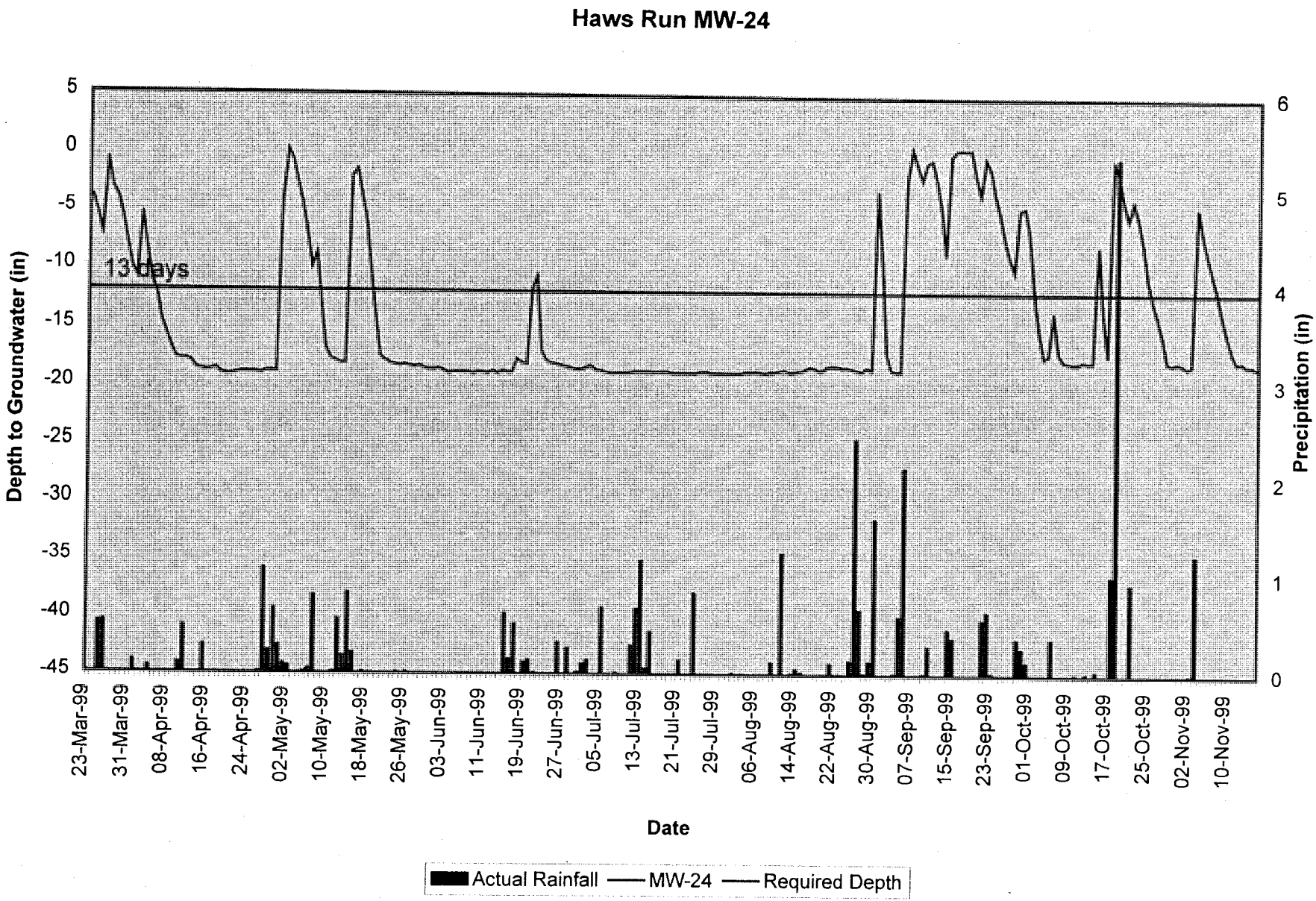


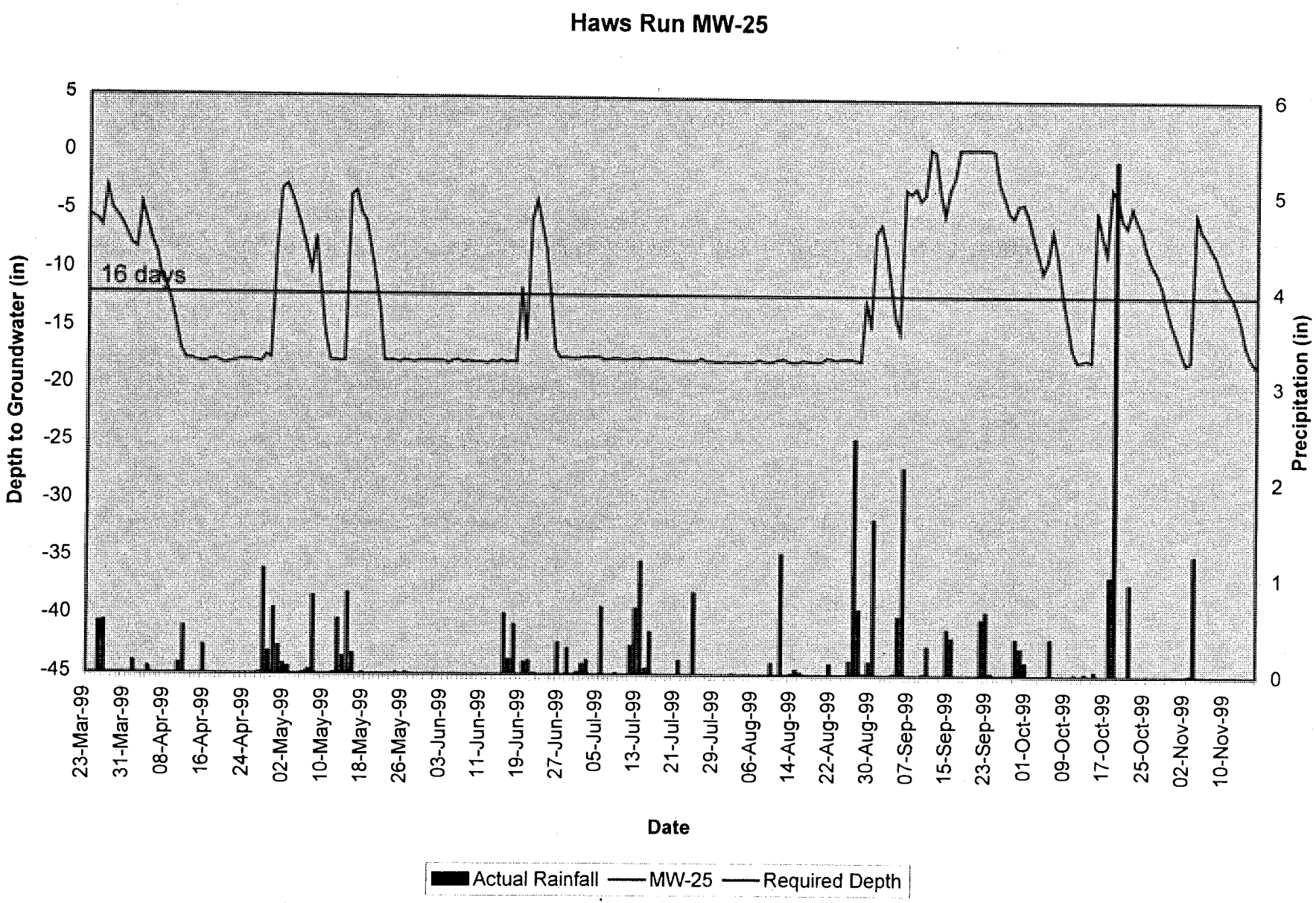
Haws Run MW-19



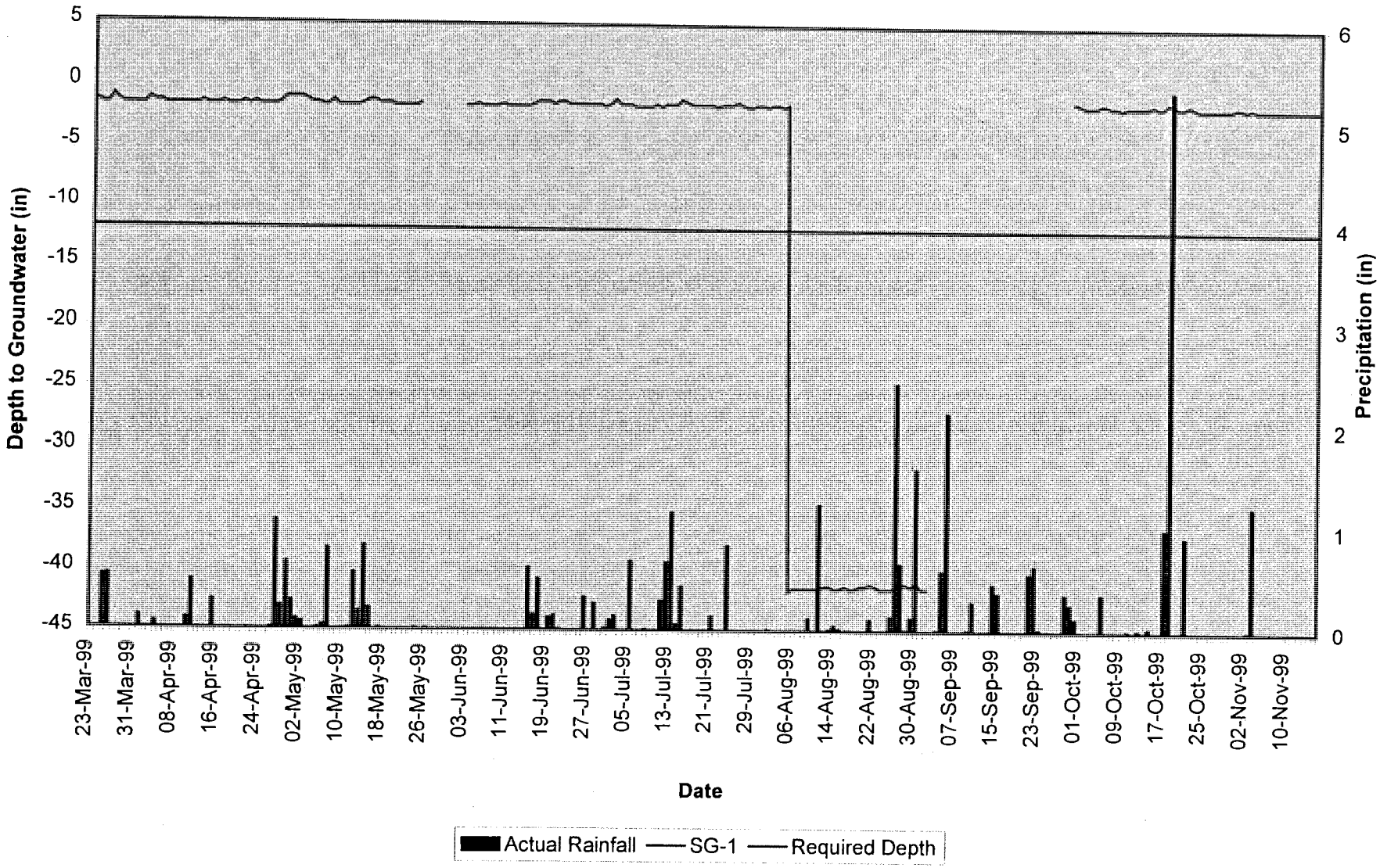

Haws Run MW-22
24 days
Depth to Groundwater (in)
Precipitation (in)
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
6
5
4
3
2
1
0
23-Mar-99
31-Mar-99
08-Apr-99
16-Apr-99
24-Apr-99
02-May-99
10-May-99
18-May-99
26-May-99
03-Jun-99
11-Jun-99
19-Jun-99
27-Jun-99
05-Jul-99
13-Jul-99
21-Jul-99
29-Jul-99
06-Aug-99
14-Aug-99
22-Aug-99
30-Aug-99
07-Sep-99
15-Sep-99
23-Sep-99
01-Oct-99
09-Oct-99
17-Oct-99
25-Oct-99
02-Nov-99
10-Nov-99
Date
Actual Rainfall
MW-22
Required Depth


Haws Run MW-23
19 days
Depth to Groundwater (in)
Precipitation (in)
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
6
5
4
3
2
1
0
23-Mar-99
31-Mar-99
08-Apr-99
16-Apr-99
24-Apr-99
02-May-99
10-May-99
18-May-99
26-May-99
03-Jun-99
11-Jun-99
19-Jun-99
27-Jun-99
05-Jul-99
13-Jul-99
21-Jul-99
29-Jul-99
06-Aug-99
14-Aug-99
22-Aug-99
30-Aug-99
07-Sep-99
15-Sep-99
23-Sep-99
01-Oct-99
09-Oct-99
17-Oct-99
25-Oct-99
02-Nov-99
10-Nov-99
Date
Actual Rainfall
MW-23
Required Depth

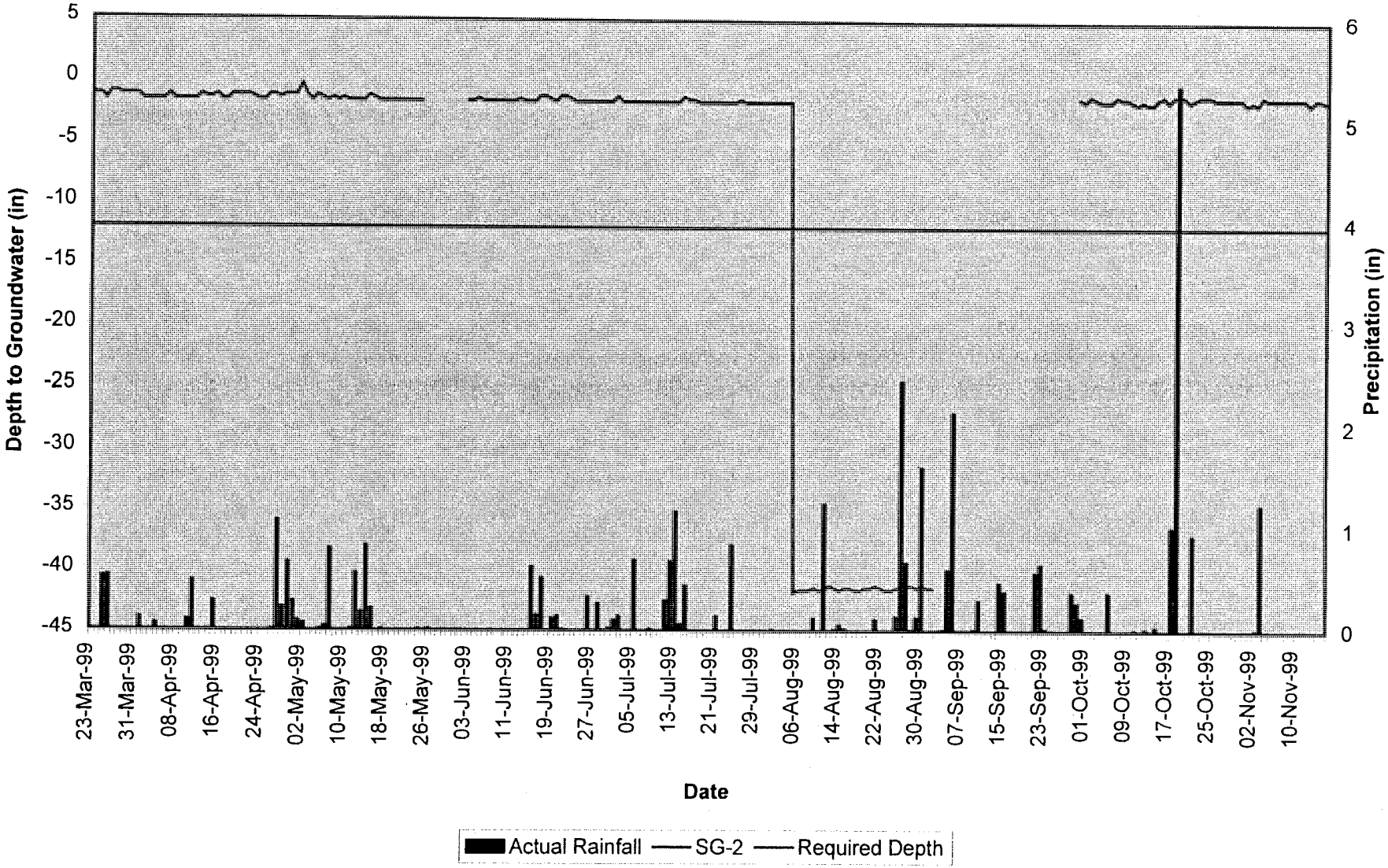

Haws Run MW-24
13 days
Depth to Groundwater (in)
Precipitation (in)
Date
Actual Rainfall
MW-24
Required Depth
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
6
5
4
3
2
1
0
23-Mar-99
31-Mar-99
08-Apr-99
16-Apr-99
24-Apr-99
02-May-99
10-May-99
18-May-99
26-May-99
03-Jun-99
11-Jun-99
19-Jun-99
27-Jun-99
05-Jul-99
13-Jul-99
21-Jul-99
29-Jul-99
06-Aug-99
14-Aug-99
22-Aug-99
30-Aug-99
07-Sep-99
15-Sep-99
23-Sep-99
01-Oct-99
09-Oct-99
17-Oct-99
25-Oct-99
02-Nov-99
10-Nov-99


Haws Run MW-25
16 days
Depth to Groundwater (in)
Precipitation (in)
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
6
5
4
3
2
1
0
23-Mar-99
31-Mar-99
08-Apr-99
16-Apr-99
24-Apr-99
02-May-99
10-May-99
18-May-99
26-May-99
03-Jun-99
11-Jun-99
19-Jun-99
27-Jun-99
05-Jul-99
13-Jul-99
21-Jul-99
29-Jul-99
06-Aug-99
14-Aug-99
22-Aug-99
30-Aug-99
07-Sep-99
15-Sep-99
23-Sep-99
01-Oct-99
09-Oct-99
17-Oct-99
25-Oct-99
02-Nov-99
10-Nov-99
Date
Actual Rainfall
MW-25
Required Depth

Haws Run SG-1


Depth to Groundwater (in)
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
Precipitation (in)
6
5
4
3
2
1
0
23-Mar-99
31-Mar-99
08-Apr-99
16-Apr-99
24-Apr-99
02-May-99
10-May-99
18-May-99
26-May-99
03-Jun-99
11-Jun-99
19-Jun-99
27-Jun-99
05-Jul-99
13-Jul-99
21-Jul-99
29-Jul-99
06-Aug-99
14-Aug-99
22-Aug-99
30-Aug-99
07-Sep-99
15-Sep-99
23-Sep-99
01-Oct-99
09-Oct-99
17-Oct-99
25-Oct-99
02-Nov-99
10-Nov-99
Date
Actual Rainfall
SG-1
Required Depth

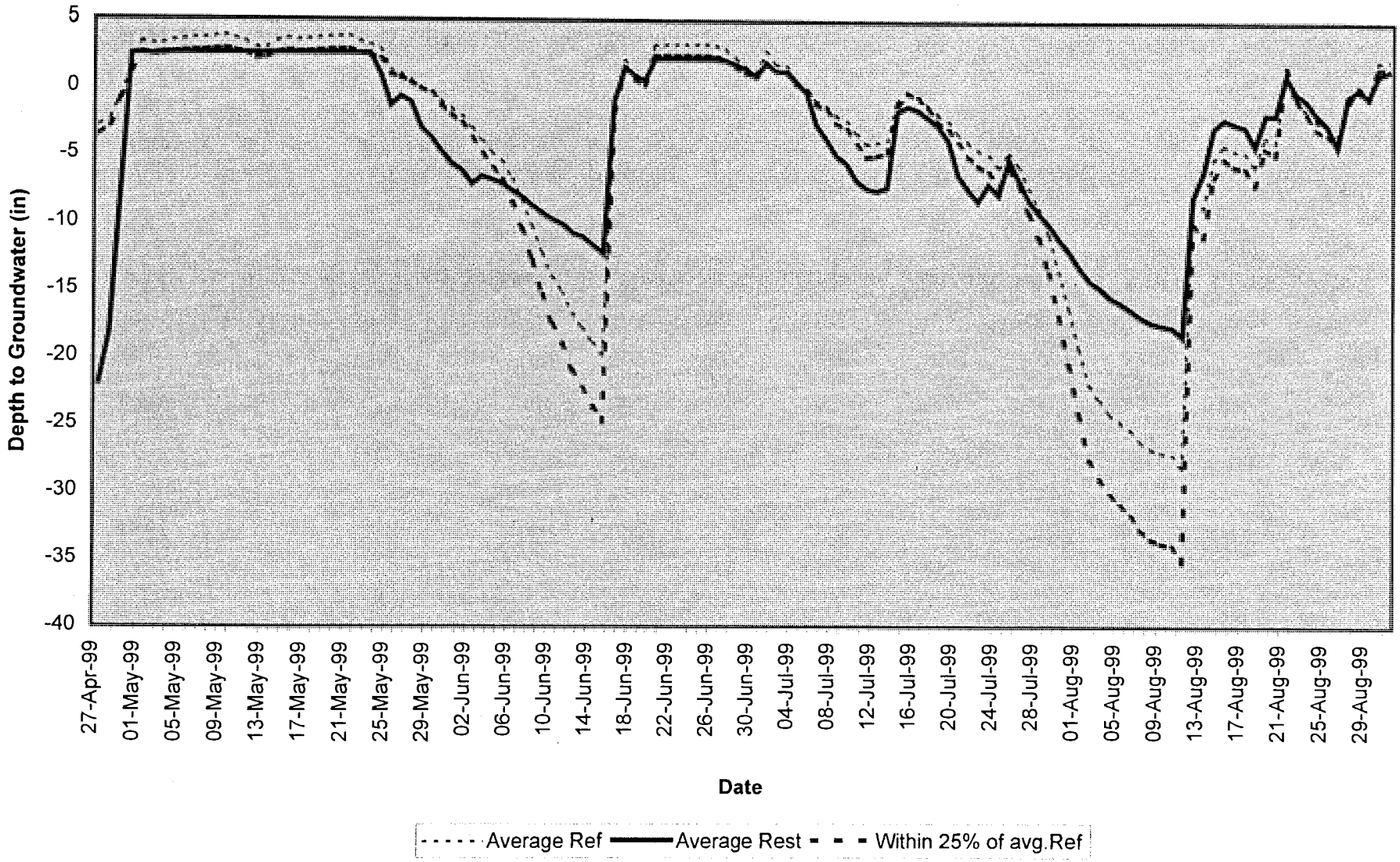
Haws Run SG-2


Depth to Groundwater (in)
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
Precipitation (in)
6
5
4
3
2
1
0
23-Mar-99
31-Mar-99
08-Apr-99
16-Apr-99
24-Apr-99
02-May-99
10-May-99
18-May-99
26-May-99
03-Jun-99
11-Jun-99
19-Jun-99
27-Jun-99
05-Jul-99
13-Jul-99
21-Jul-99
29-Jul-99
06-Aug-99
14-Aug-99
22-Aug-99
30-Aug-99
07-Sep-99
15-Sep-99
23-Sep-99
01-Oct-99
09-Oct-99
17-Oct-99
25-Oct-99
02-Nov-99
10-Nov-99
Date
Actual Rainfall
SG-2
Required Depth

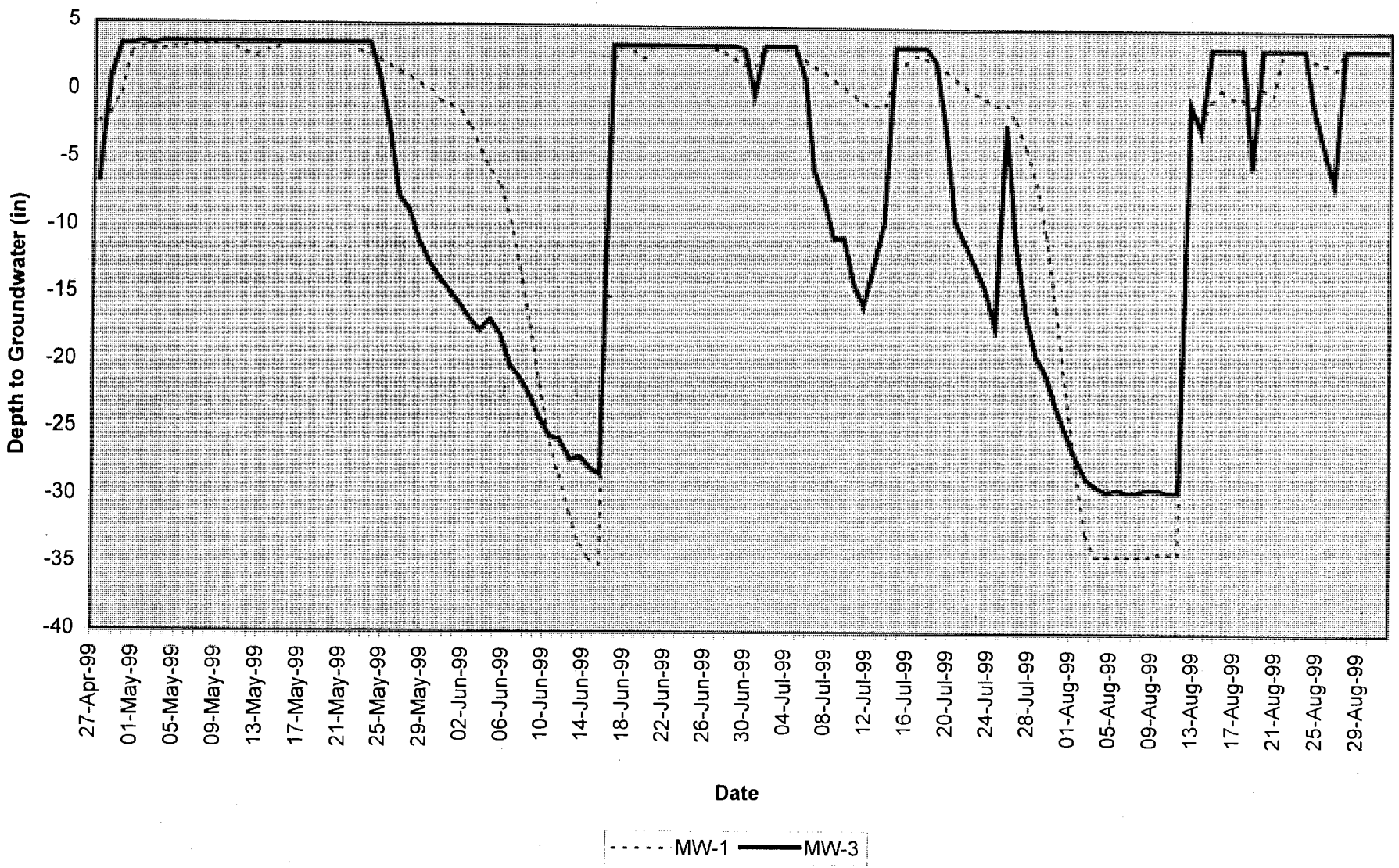
APPENDIX B

COMPARISON OF REFERENCE AND RESTORATION WELLS

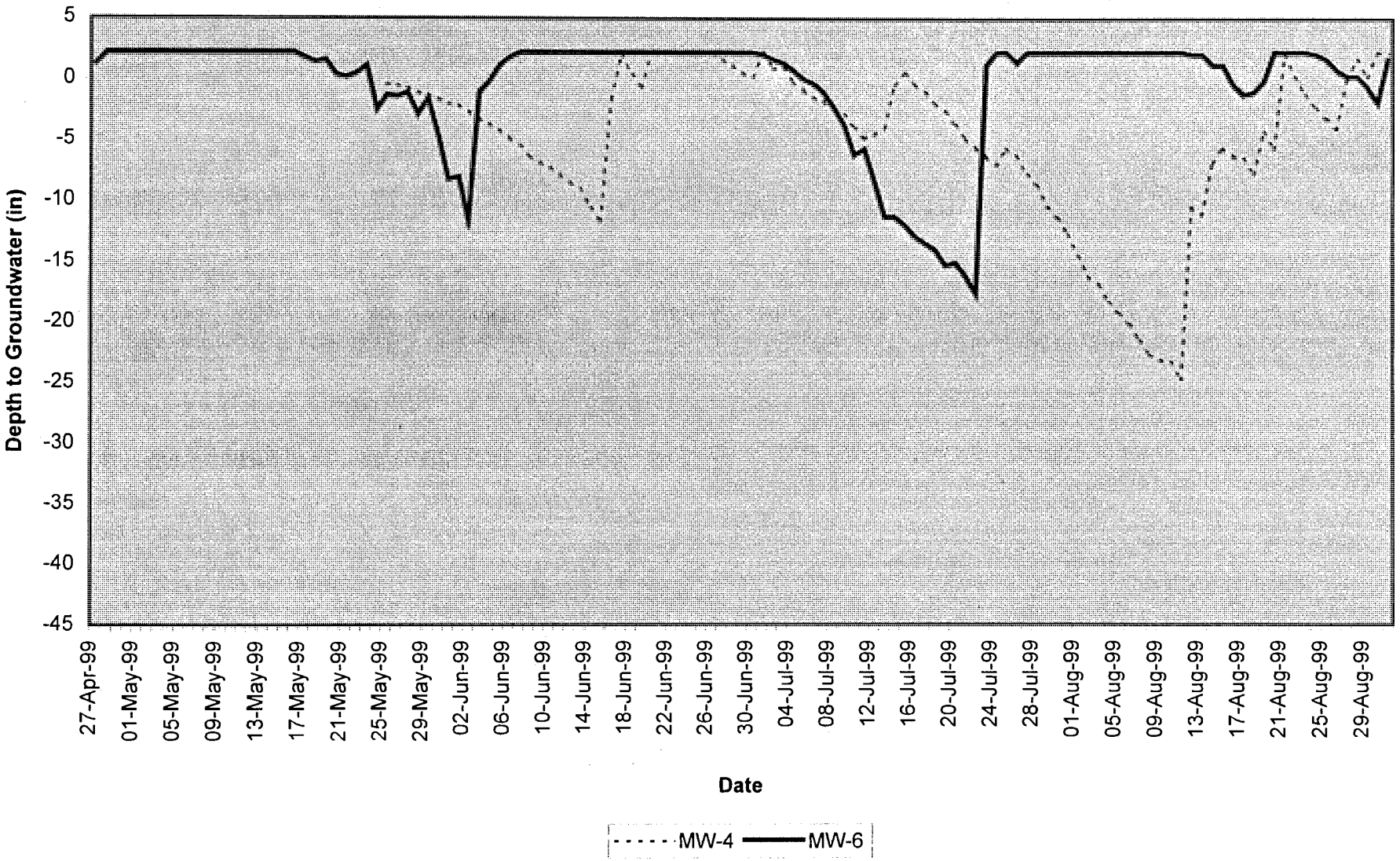
Swamp Forest
Average Reference and Average Restoration Wells



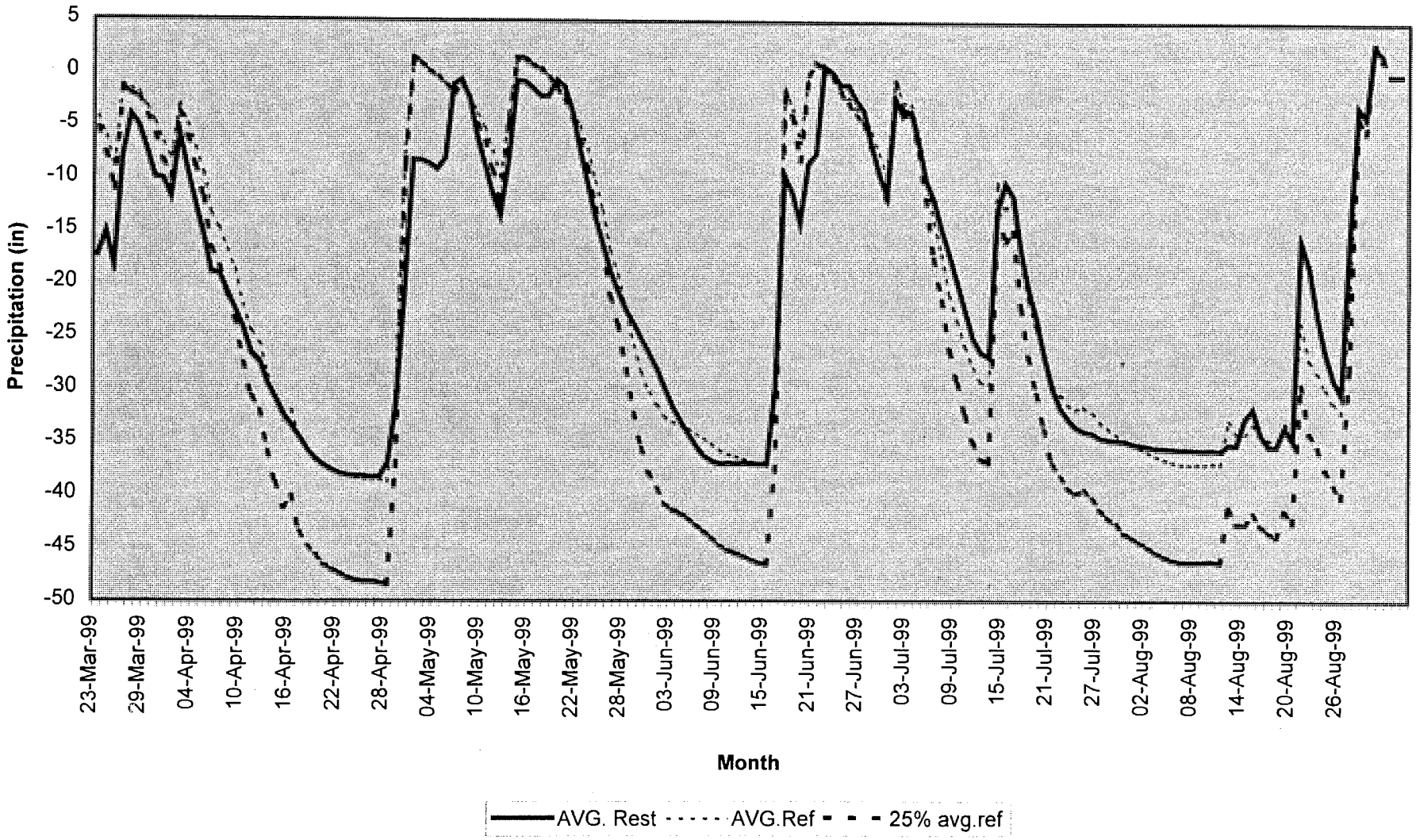
Comparison of MW1 and MW-3



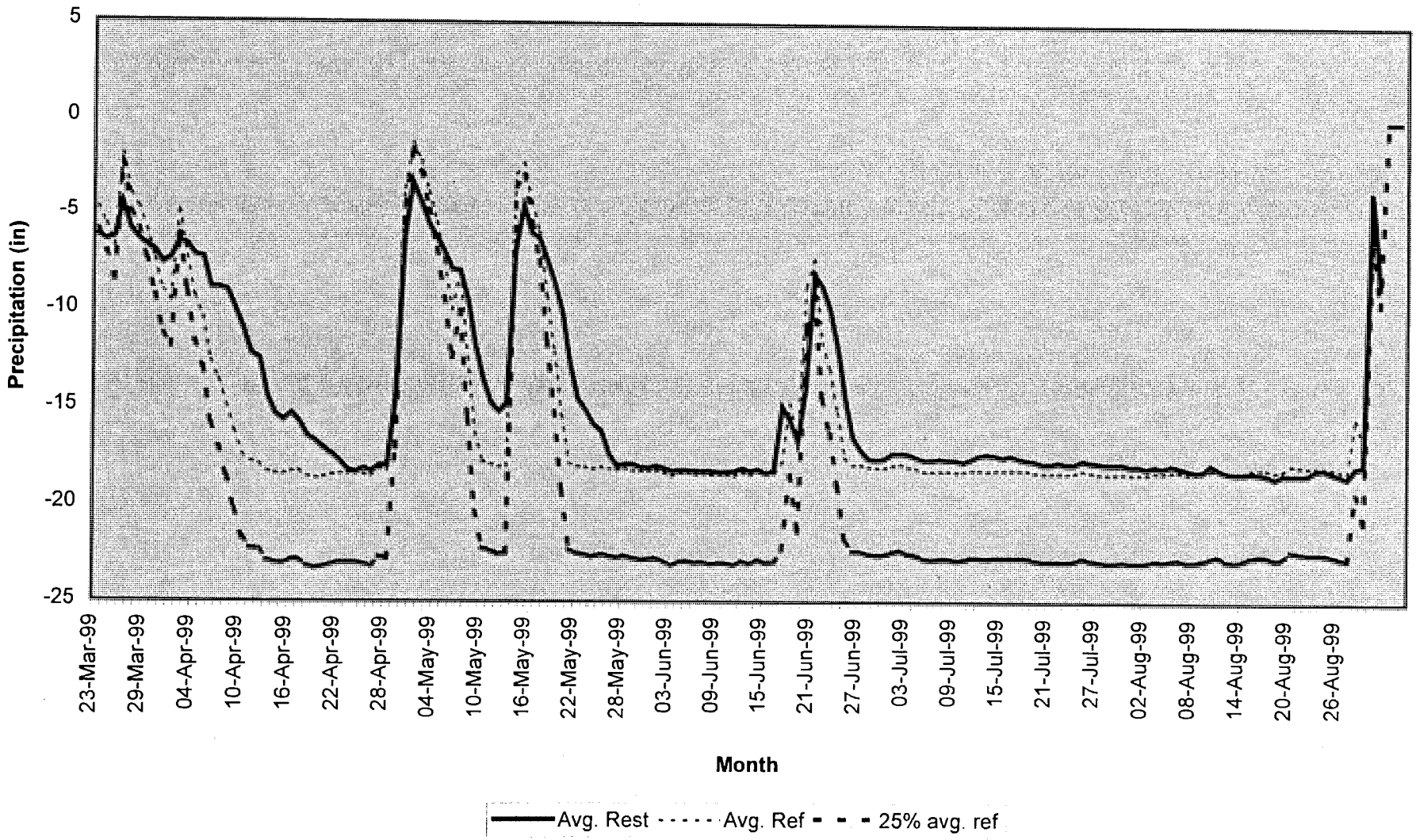
Comparison of MW-4 and MW-6



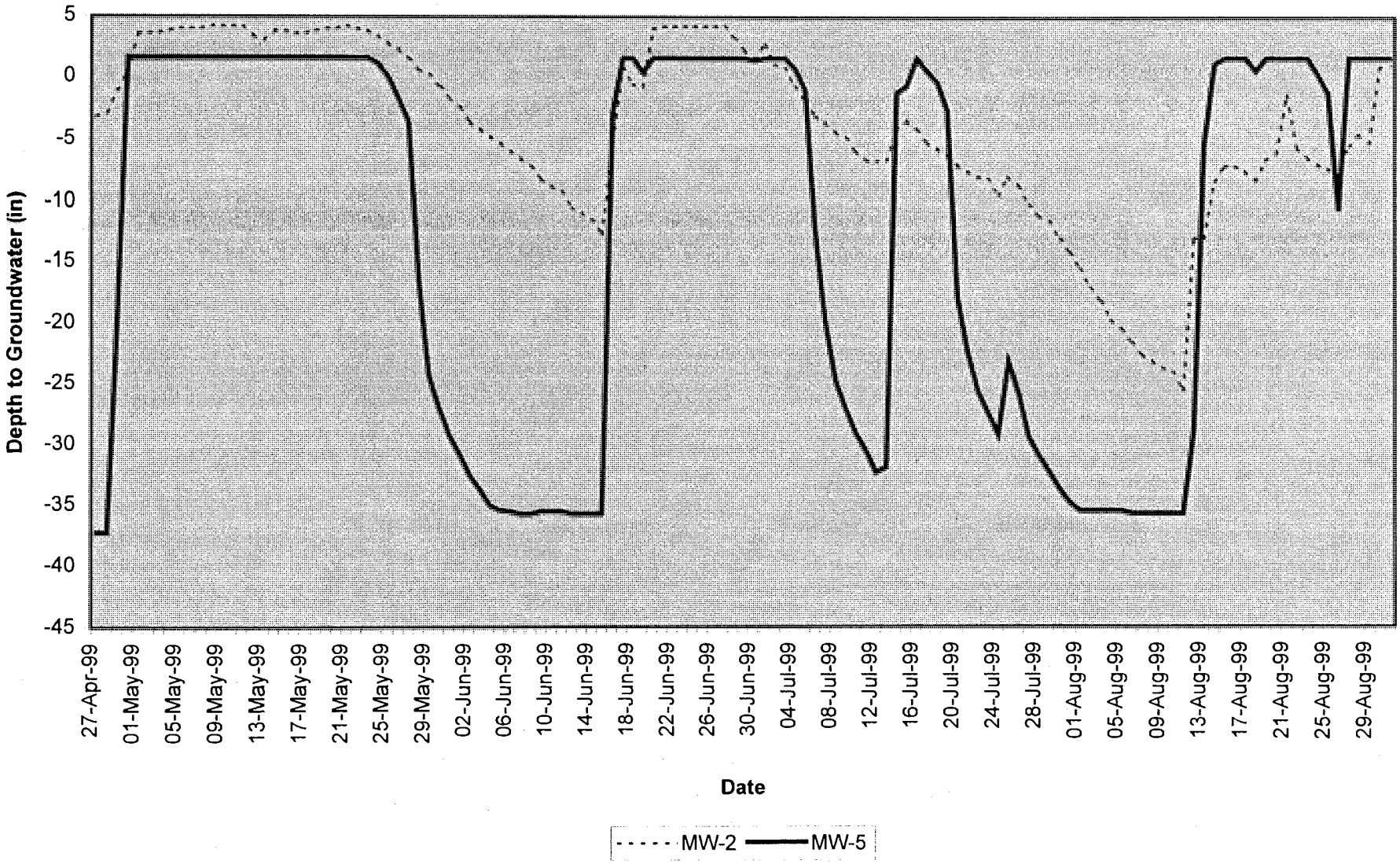
Pine Savanna
Average Reference and Average Restoration Wells



Haws Run Haul Road
Average Reference and Average Restoration Wells



Comparison of MW-2 and MW-5



APPENDIX C

SITE PHOTOS

HAW'S RUN

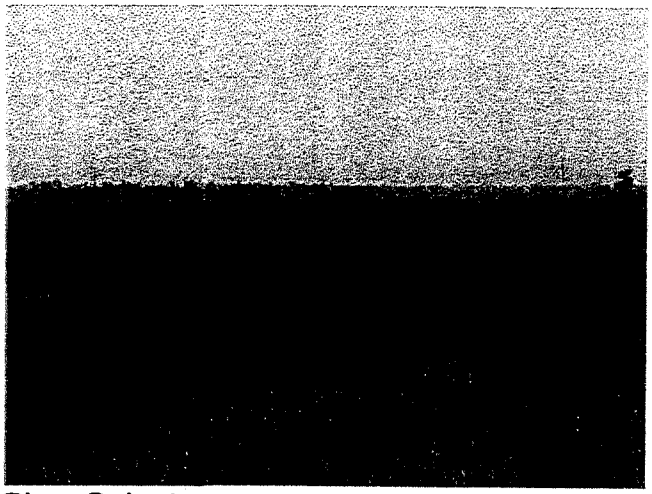


Photo Point 1

Photo Point 2

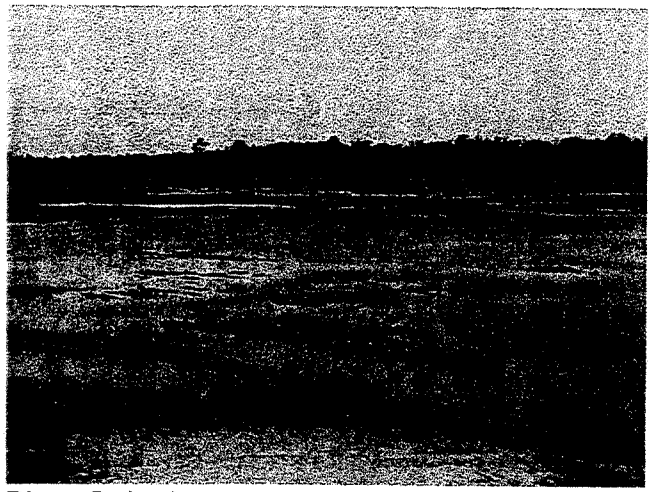


Photo Point 3

Photo Point 4

Photo Point 5

Photo Point 6 (Washout along Northern edge)

HAW'S RUN

Photo Point 7

Photo Point 8

Photo Point 9

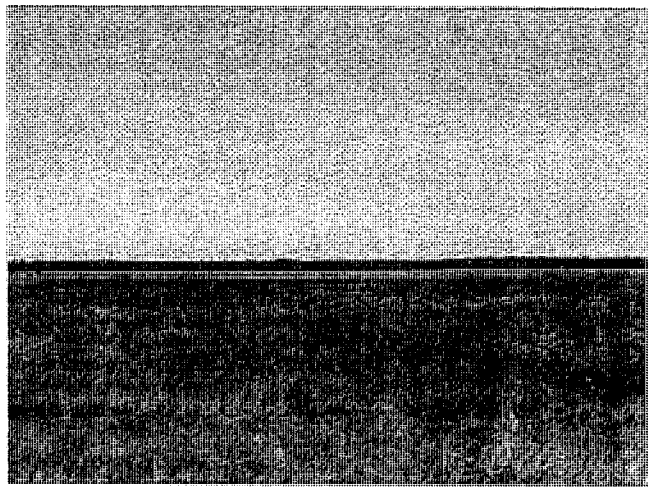


Photo Point 10

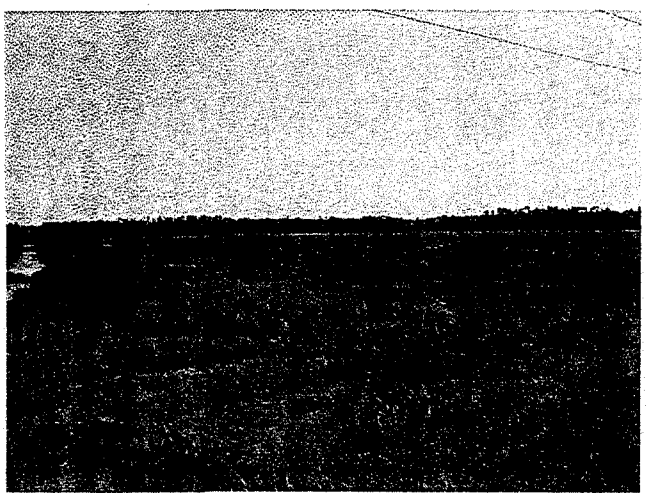


Photo Point 11

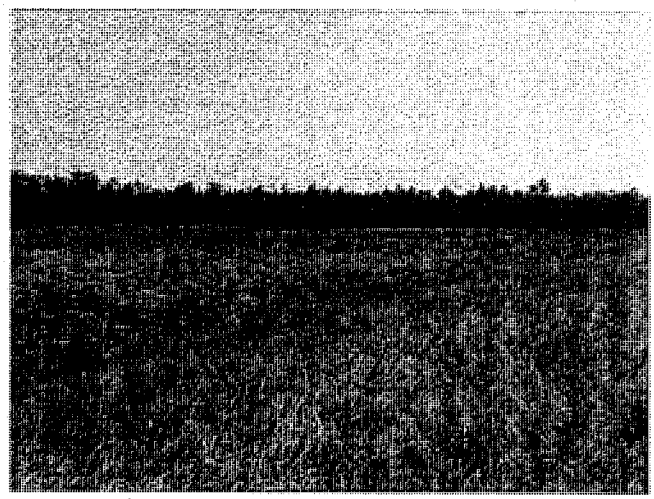


Photo Point 12