

Supplemental Report Submitted to the St. Johns River Water Management District, Contract
#25325

**STATISTICAL EVALUATION OF LONG TERM GROUNDWATER
LEVEL IN NORTHEASTERN FLORIDA AND SOUTHERN GEORGIA**

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1. Long-Term Groundwater Levels and Trends

In this supplement report to the final report submitted under Contract #25325, the entire period of record for historic groundwater levels (upper Floridan) data in the Suwannee River basin and northeast Florida were analyzed for long-term trends and cluster analysis. In the final report under the original contract, groundwater level data available prior to 1980 was neglected since other time series of interest (principally groundwater withdrawal estimates) were not consistently available before then.

There are 52 SRWMD wells that have more than 20 years of data. All available groundwater level data, for the entire period of record, were combined into annual time series, labeled as SRWMD Florida Groundwater, for trend analysis (**Section 1.1**). Units are feet above NGVD29.

Groundwater level data from seven wells with more than 20 years of data were obtained from the USGS for the Georgia region of the study area. All available groundwater level data, for the entire period of record, were combined into time series, labeled as were labeled as USGS Georgia Groundwater for trend analysis (**Section 1.2**). Units were in feet below land surface.

We received an additional set of groundwater level data from the SJRWMD for counties in northeastern Florida (Clay, Duval, Nassau, Putnam, and St Johns) and southeastern Georgia (Camden) that are east of the original study area. There were 73 wells with more than a 20 year data record. All available groundwater level data, for the entire period of record were combined into time series, labeled as SJRWMD Groundwater, for trend analysis (**Section 1.3**). Units are feet above mean sea level.

1.1 SRWMD Florida Groundwater Trend

The 52 SRWMD groundwater wells with more than 20 years of data are located in 11 counties within the study area and each of the counties had at least three groundwater wells except Gilchrist County which had two (**Figure 1.1**). The raw data were processed into annual averages.

Time series analysis was performed to statistically characterize each well time series as described in the methods section in the final report of contract #25325. LOWESS was used to determine whether the dataset contained monotonic or piecewise trends. Trend detections were conducted with the nonparametric statistical test (Mann-Kendall) on the residuals transformed using autocorrelation filtration (**Appendix S1**). Analysis was performed based on annual data to determine if long-term systematic trends existed. Therefore seasonality analysis was not performed. Finally, trends in historic groundwater levels were determined based on p-values and slopes (**Table 1.1**). A total of 13 wells were identified with either very certain (6), probably trending (1), or warning (6) monotonic trends, and all trends were downward (**Figure 1.1** and **Table 1.2**). This is different from the results in the final report submitted under Contract #25325, which presented the trend analysis of SRWMD groundwater level data between 1980 and 2007. The trend analysis for this shorter data record only showed 8 trending wells with one very certain, two probable, and six warning trends.

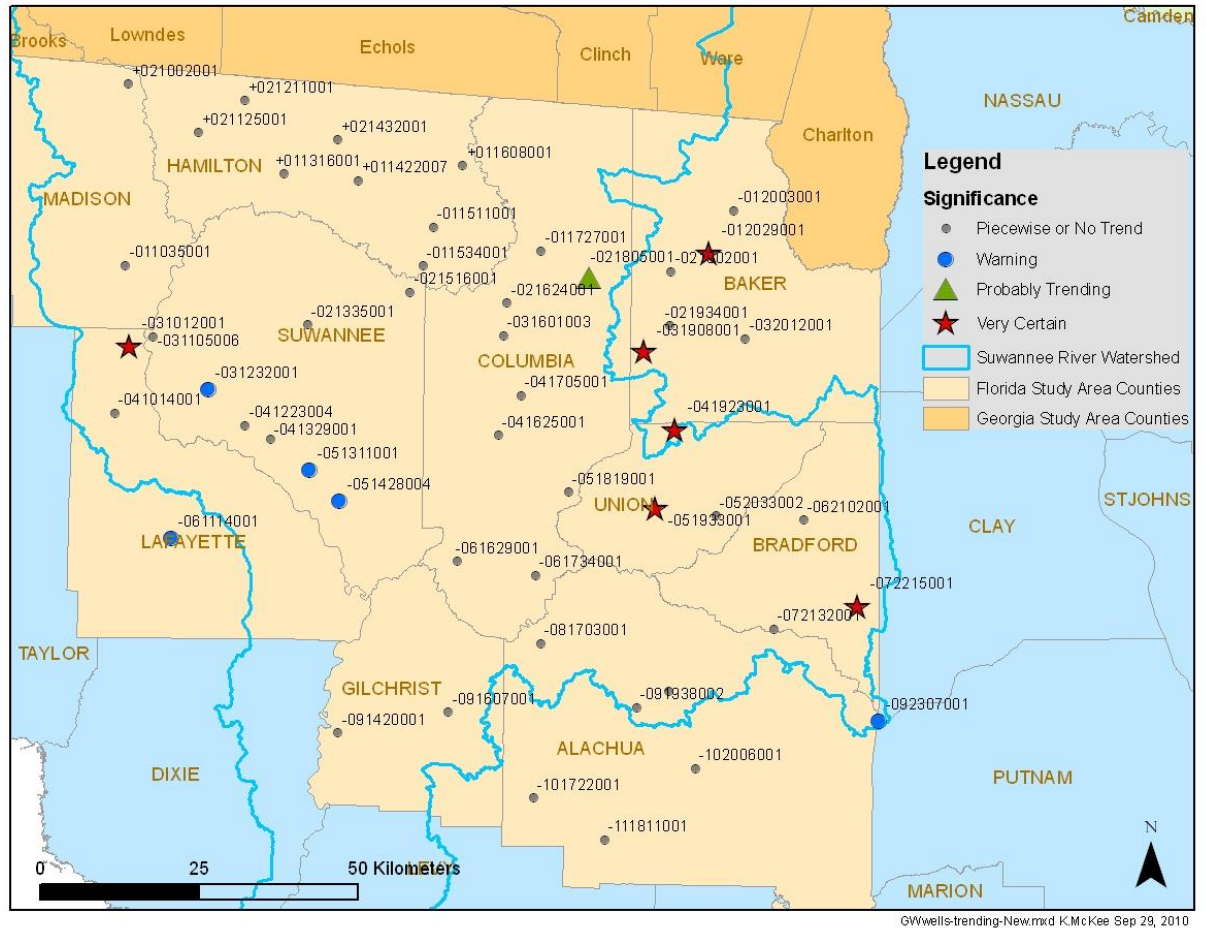


Figure 1.1 Map of 52 SRWMD groundwater wells utilized for trend analysis and classification of trends. All trends are downwards.

1.2 USGS Georgia Groundwater Trend

Seven wells in the Georgia study area had data records longer than 20 years. These groundwater wells were located in six counties within the state of Georgia (**Figure 1.1**). The raw data were processed by calculating annual averages. The same statistical analysis described above was conducted on this dataset (**Appendix S2**). Trends in the data were determined based on the p-value and the slope (**Table 1.3**). A total of 5 wells were identified with very certain (3) probably trending (1), or warning (1) monotonic trends, and all the trends were downward (**Figure 1.2** and **Table 1.4**). *This is similar to the results in the final report submitted under Contract #25325, which presented the trend analysis for USGS Georgia groundwater level data for the period between 1980 and 2007. The trend analysis for the shorter data record showed 4 trending wells at the same locations.*



Figure 1.2 Map of 7 USGS groundwater wells used for trend analysis and classification of trends in Georgia. All trends are downwards.

1.3 SJRWMD Groundwater Trend

After initial data analysis for the study area was completed, the St. Johns Water Management District (SJRWMD) requested trend analyses for additional groundwater levels in northeastern Florida (Clay, Duval, Nassau, Putnam, and St Johns Counties) and southeastern Georgia (Camden County) outside the previously defined study area. **(Figure 1.3)**. The same statistical analysis was conducted on this dataset (**Appendix S3**). There were 73 additional wells with more than a 20 year time period, after omitting those that were already represented by the SRWMD groundwater level dataset. Trends in the data were determined based on the p-value and the slope (**Table 1.5**). A total of 28 wells were identified with very certain (21), probably trending (3), or warning (4) monotonic trends (**Figure 1.3, Table 1.4**). Of these trends, all were downward except one well with an upward trending slope in St. Johns County (ID 295357081294301). Figure 1.3 shows the distribution of the trending wells in the study area. This is different from the results in the final report submitted under Contract #25325, which presented the trend analysis for SJRWMD groundwater level data between 1980 and 2007. The trend analysis for the shorter time record showed 17 trending wells: seven were identified as very certain trending, four as probably trending, and six as having a warning trend.

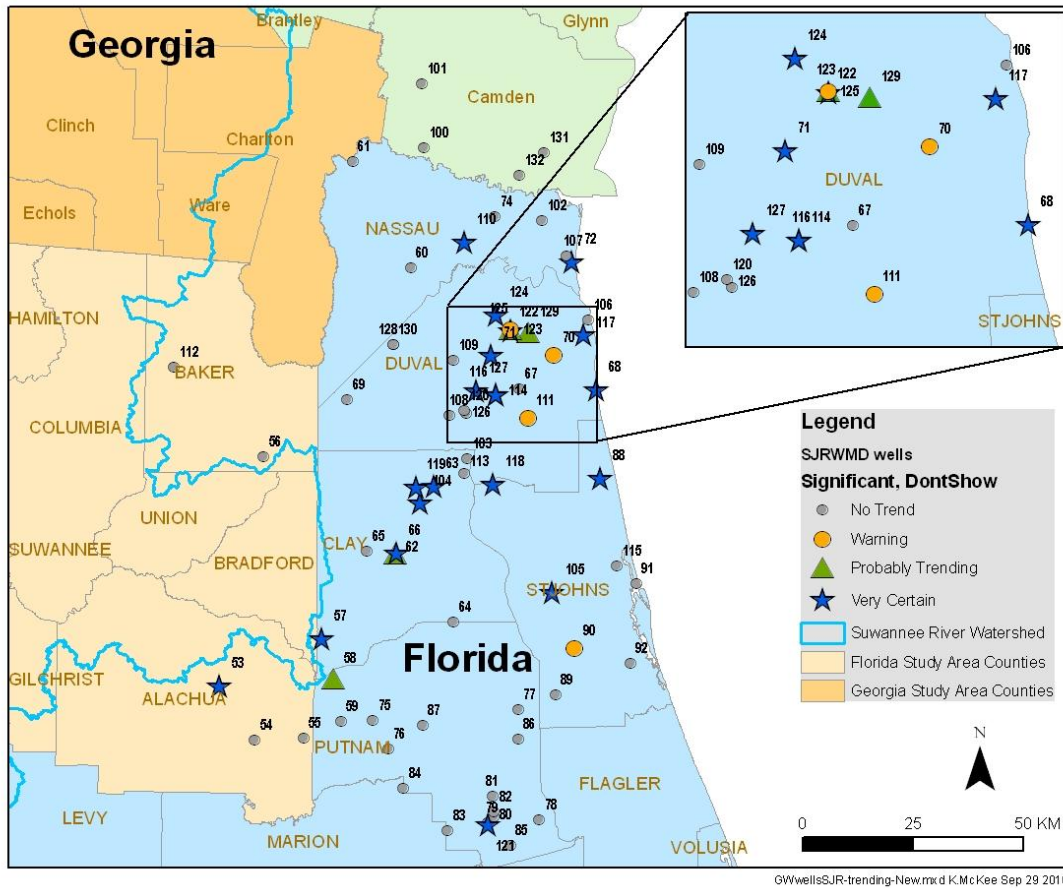


Figure 1.3 Map of 73 SJRWMD groundwater wells used for trend analyses and classification of trends. All trends are downward except #105 which trends upward. Map IDs listed in Table 1.5.

Table 1.1 Mann-Kendall trend analysis, with trend direction, of Florida annual groundwater levels from SRWMD.

Site ID	County	SJRWMD Site ID	Trend Type	Slope (ft/y)	p-value	Trend & Direction
-111811001	Alachua	A-0004	M	-0.118	0.527	NT ↓
-092307001	Clay	C-0009	M	-0.164	0.075	W ↓
-081926001	Alachua	A-0056	M	-0.104	0.253	NT ↓
-081703001	Alachua	A-0002	M	-0.062	0.123	NT ↓
-072215001	Bradford	B-0011	M	-0.188	0.004	VC ↓
-072132001	Bradford	B-0012	M	-0.099	0.175	NT ↓
-061734001	Colombia	CO0008	M	-0.053	0.156	NT ↓
-061629001	Columbia	NA	M	-0.062	0.187	NT ↓
-061114001	Lafayette	NA	M	-0.160	0.090	W ↓
-052033002	Union	NA	data not suitable for the analysis			
-051933001	Union	U-0004	M	-0.135	0.020	VC ↓
-051819001	Columbia	CO0005	M	-0.104	0.130	NT ↓
-051428004	Suwannee	NA	M	-0.223	0.088	W ↓
-051311001	Suwannee	NA	M	-0.175	0.054	W ↓

Site ID	County	SJRWMD Site ID	Trend Type	Slope (ft/y)	p-value	Trend & Direction
-041923001	Union	U-0001	M	-0.176	0.014	VC ↓
-041705001	Columbia	CO0010	M	-0.119	0.164	NT ↓
-041625001	Columbia	CO0011	M	-0.211	0.253	NT ↓
-041329001	Suwannee	NA	M	-0.118	0.245	NT ↓
-041223004	Suwannee	NA	M	-0.098	0.287	NT ↓
-041014001	Lafayette	NA	M	-0.165	0.200	NT ↓
-032012001	Baker	BA0011	M	-0.125	0.270	NT ↓
-031908001	Baker	BA0015	M	-0.108	0.006	VC ↓
-031601003	Columbia	NA	M	-0.191	0.342	NT ↓
-031232001	Suwannee	NA	M	-0.150	0.093	W ↓
-031105006	Suwannee	NA	M	-0.072	0.433	NT ↓
-031012001	Lafayette	NA	M	-0.198	0.016	VC ↓
-021934001	Baker	BA0024	M	-0.282	0.187	NT ↓
-021902001	Baker	BA0005	M	-0.258	0.199	NT ↓
-021805001	Columbia	CO0007	M	-0.214	0.042	PT ↓
-021624001	Columbia	NA	M	-0.156	0.215	NT ↓
-021516001	Suwannee	NA	M	-0.159	0.111	NT ↓
-021335001	Suwannee	SW0078	M	-0.173	0.161	NT ↓
-012029001	Baker	BA0018	M	-0.181	0.014	VC ↓
-012003001	Baker	BA0009	M	-0.117	0.294	NT ↓
-011727001	Columbia	CO0117	M	-0.147	0.103	NT ↓
-011534001	Hamilton	H-0071	M	-0.113	0.403	NT ↓
-011511001	Hamilton	NA	M	-0.183	0.152	NT ↓
-011035001	Madison	NA	M	-0.196	0.125	NT ↓
+010719001	Madison	NA	M	-0.125	0.094	W ↓
+011316001	Hamilton	NA	M	-0.074	0.282	NT ↓
+011422007	Hamilton	H-0072	M	-0.135	0.264	NT ↓
+011608001	Hamilton	NA	M	-0.133	0.191	NT ↓
+021002001	Madison	NA	M	-0.041	0.570	NT ↓
+021125001	Hamilton	NA	M	-0.086	0.316	NT ↓
+021432001	Hamilton	H-0073	M	-0.088	0.316	NT ↓
-102006001	Alachua	A-0019	P	0.707	0.175	NT ↑
				-0.017	0.958	NT ↓
-101722001	Alachua	A-0068	P	0.640	0.052	W ↑
				-0.238	0.197	NT ↓
-091938002	Alachua	A-0075	P	1.021	0.265	NT ↑
				-0.170	0.112	NT ↓
-091607001	Gilchrist	GI0065	P	1.379	0.014	VC ↑
				-0.478	0.161	NT ↓
-091420001	Gilchrist	NA	P	0.186	0.291	NT ↑
				-0.098	0.284	NT ↓
-062102001	Bradford	B-0010	P	0.277	0.119	NT ↑
				-0.050	0.535	NT ↓
+021211001	Hamilton	NA	P	0.227	0.392	NT ↑
				-0.345	0.115	NT ↓

M=Monotonic; P=Piecewise; NA=not available, VC=Very Certain, PT=Probably Trend, W=Warning, NT=No Trend;

Table 1.2 Summary of monotonic trends (all downward) of SRWMD Florida annual groundwater level time series.

Label	Count	Site ID
Very Certain	6	-072215001 -041923001 -051933001 -031908001 -031012001 -012029001
Probably Trend	1	-021805001
Warning	6	-092307001 -061114001 -051428004 -051311001 -031232001 +010719001

Table 1.3 Mann-Kendall trend analysis, with trend direction, of Georgia annual groundwater levels from USGS.

Site ID	County	Trend Type	Slope (ft/y)	p Value	Trend & Direction
312712082593301	Tift	M	-0.888	0.000	VC ↓
310706082155101	Ware	M	-0.186	0.050	PT ↓
304942082213801	Charlton	M	-0.339	0.099	W ↓
313146083491601	Worth	M	-0.651	0.000	VC ↓
310813083260301	Cook	M	-0.342	0.000	VC ↓
314330084005402	Worth	P	-0.324	0.243	NT ↓
			0.244	0.201	NT ↑
304949083165301	Lowndes	P	0.440	0.010	W ↑
			-0.063	0.721	NT ↓

M=Monotonic; P=Piecewise; NA=not available, VC=Very Certain, PT=Probably Trend, W=Warning, NT=No Trend;

Table 1.4 Summary of monotonic trends (all downward) of USGS Georgia annual groundwater level time series.

Label	Count	Site ID
Very Certain	3	310813083260301 312712082593301 313146083491601
Probably Trend	1	310706082155101
Warning	1	304942082213801

Table 1.5 Mann-Kendall trend analysis, with trend direction, of Florida annual groundwater levels from SJRWMD. Map IDs are used in Figure 1.3.

Map ID	Well ID #	County	Trend Type	Slope (ft/y)	p-value	Trend and Direction
53	A-0001	Alachua	M	-0.49	0.00	VC ↓
54	A-0005	Alachua	M	-0.07	0.50	NT ↓
55	A-0071	Alachua	M	-0.14	0.35	NT ↓
56	BA0019	Baker	M	-0.19	0.14	NT ↓
57	C-0120	Clay	M	-0.25	0.00	VC ↓
58	P-0001	Putnam	M	-0.16	0.03	PT ↓
59	P-0008	Putnam	M	-0.15	0.29	NT ↓

Map ID	Well ID #	County	Trend Type	Slope (ft/y)	p-value	Trend and Direction	
60	N-0051	Nassau	data not suitable for the analysis				
61	WN0018	Nassau	M	-0.02	0.84	NT↓	
62	C-0018	Clay	M	-0.13	0.04	PT ↓	
63	C-0094	Clay	M	-0.26	0.00	VC ↓	
64	C-0123	Clay	M	-0.04	0.79	NT↓	
65	C-0128	Clay	M	-0.15	0.33	NT↓	
66	C-0607	Clay	M	-0.14	0.02	VC ↓	
67	D-0094	Duval	M	-0.03	0.49	NT↓	
68	D-0160	Duval	M	-0.35	0.00	VC ↓	
69	D-0254	Duval	M	0.00	0.97	NT	
70	D-0424	Duval	M	-0.22	0.09	W ↓	
71	D-0667	Duval	M	-0.29	0.00	VC ↓	
72	N-0046	Nassau	M	-0.23	0.01	VC ↓	
73	N-0051	Nassau	M	-0.08	0.37	NT↓	
74	N-0121	Nassau	M	0.17	0.21	NT↑	
75	P-0016	Putnam	M	-0.17	0.25	NT↓	
76	P-0017	Putnam	M	0.03	0.84	NT ↑	
77	P-0172	Putnam	M	0.42	0.34	NT ↑	
78	P-0242	Putnam	M	-0.03	0.78	NT↓	
79	P-0270	Putnam	M	0.01	0.74	NT ↑	
80	P-0373	Putnam	M	-0.08	0.27	NT↓	
81	P-0408	Putnam	M	-0.04	0.54	NT↓	
82	P-0416	Putnam	M	-0.08	0.39	NT↓	
83	P-0427	Putnam	M	0.01	0.80	NT↑	
84	P-0450	Putnam	M	0.02	0.60	NT ↑	
85	P-0469	Putnam	M	0.08	0.52	NT ↑	
86	P-0474	Putnam	M	-0.05	0.56	NT↓	
87	P-0510	Putnam	M	-0.01	0.81	NT↓	
88	SJ0005	St. Johns	M	-0.22	0.01	VC ↓	
89	SJ0263	St. Johns	M	-0.06	0.15	NT↓	
90	SJ0317	St. Johns	M	-0.11	0.07	W ↓	
91	SJ0413	St. Johns	M	-0.08	0.29	NT↓	
92	SJ0516	St. Johns	M	-0.01	0.76	NT↓	
100	304830081481201	Camden, Ga	M	-0.51	0.43	NT↓	
101	305627081473101	Camden, Ga	M	-0.05	0.88	NT↓	
102	303939081312601	Nassau	M	0.07	0.31	NT ↑	
103	301018081415101	Clay	M	-0.11	0.14	NT↓	
104	300450081482801	Clay	M	-0.32	0.00	VC ↓	
105	295357081294301	St. Johns	M	0.11	0.01	VC ↑	
106	302724081244801	Duval	M	-0.04	0.40	NT↓	
107	303518081275001	Nassau	M	0.01	0.90	NT ↑	
108	301537081441901	Duval	M	0.17	0.39	NT ↑	
109	302227081435001	Duval	M	-0.09	0.41	NT↓	
110	303658081422601	Nassau	M	-0.36	0.00	VC ↓	
111	301522081331301	Duval	M	-0.62	0.08	W ↓	
112	302115082232201	Baker	M	0.03	0.94	NT ↑	
113	300834081421301	Clay	M	-0.17	0.38	NT↓	

Map ID	Well ID #	County	Trend Type	Slope (ft/y)	p-value	Trend and Direction
114	301817081374902	Duval	M	-0.19	0.02	VC ↓
115	295713081203401	St. Johns	M	-0.07	0.18	NT↓
116	301817081374901	Duval	M	-0.17	0.02	VC ↓
117	302538081253101	Duval	M	-0.33	0.00	VC ↓
118	300717081381001	St. Johns	M	-0.32	0.00	VC ↓
119	300649081485901	Clay	M	-0.38	0.00	VC ↓
120	301617081421601	Duval	M	-0.32	0.15	NT↓
121	292528081383501	Putnam	M	-0.03	0.00	VC ↓
122	302608081354903	Duval	M	-0.26	0.06	W ↓
123	302608081354902	Duval	M	-0.24	0.01	VC ↓
124	302801081375101	Duval	M	-0.36	0.00	VC ↓
125	302608081354901	Duval	M	-0.27	0.03	PT ↓
126	301551081415701	Duval	M	-0.36	0.11	NT↓
127	301844081403801	Duval	M	-0.21	0.01	VC ↓
128	302416081522601	Duval	M	-0.02	0.78	NT↓
129	302550081331501	Duval	M	-0.56	0.00	VC ↓
130	302416081522602	Duval	M	-0.07	0.15	NT↓
131	304756081311101	Camden, Ga	M	0.05	0.73	NT ↑
132	304512081343601	Camden, Ga	M	0.57	0.55	NT ↑

M=Monotonic; P=Piecewise; NA=not available, VC=Very Certain, PT=Probably Trend, W=Warning, NT=No Trend;

Table 1.6 Summary of monotonic trends (all downward except underlined Site ID is upward) of SJRWMD annual groundwater level time series. Map IDs are in parentheses.

Label	Count	Site ID
Very Certain	21	A-0001 (53) C-0094 (63) C-0120 (57) C-0607 (66)
		D-0160 (68) D-0667 (71) N-0046 (72) SJ0005 (88)
		302550081331501 300450081482801 <u>295357081294301</u> 303658081422601
		(129) (104) (105) (110)
		301817081374902 302538081253101 300717081381001 300649081485901
		(114) (117) (118) (119)
292528081383501 302608081354902 302801081375101 301844081403801		
(121) (123) (124) (127)		
		301817081374901
		(116)
Probably Trend	3	C-0018 (62) P-0001 (58) 302608081354901 (125)
Warning	4	D-0424 (70) SJ0317 (90) 301522081331301 (111) 302608081354903 (122)

2. Cluster Analysis of Long-Term Groundwater Level

A statistical cluster analysis was conducted using all three datasets of groundwater level time series: SRWMD wells in Florida, USGS wells in Georgia, and SJRWMD data containing SJRWMD wells and USGS wells in Northeast Florida and Southeast Georgia. The groundwater level data for each well were first normalized by subtracting the mean groundwater level and dividing by the groundwater level standard deviation for the entire period of record (note that the period of record varied from well to well). A total of 102 wells with coincident and continuous, normalized data from 1986-2005 were analyzed. Following is the summary of the results.

2.1 Dendrogram

An agglomerative hierarchical cluster analysis (AHCA) was performed on the normalized groundwater level time series. The dendrogram (i.e., cluster tree) of the cluster structure is shown in **Figure 2.1**. The roots of the tree are different clusters and the leaves represent individual observations of groundwater levels. The cluster height is the value of the criterion associated with the agglomerative algorithm. The data can be separated into different clusters depending on chosen height. In this study, we clustered the data into 2, 3, and 4 clusters (**Appendix S4**).

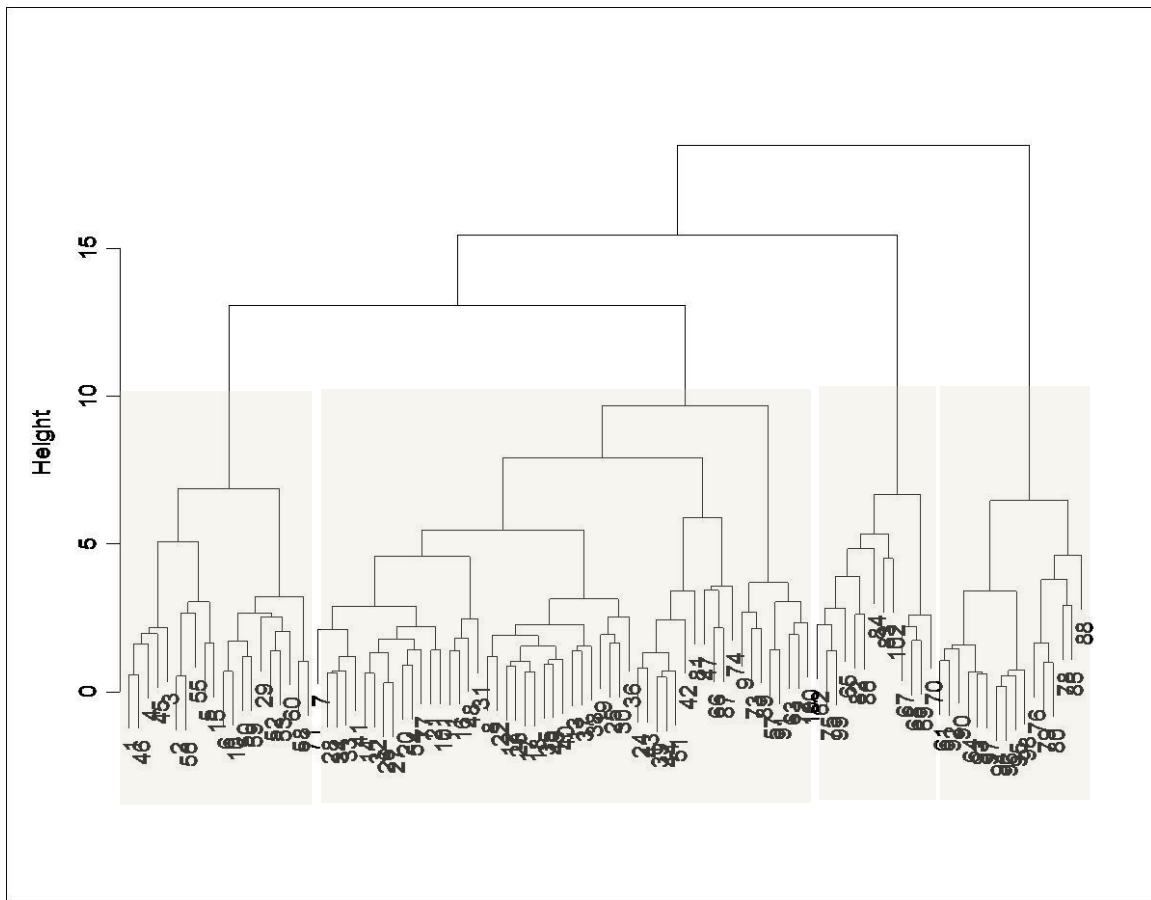
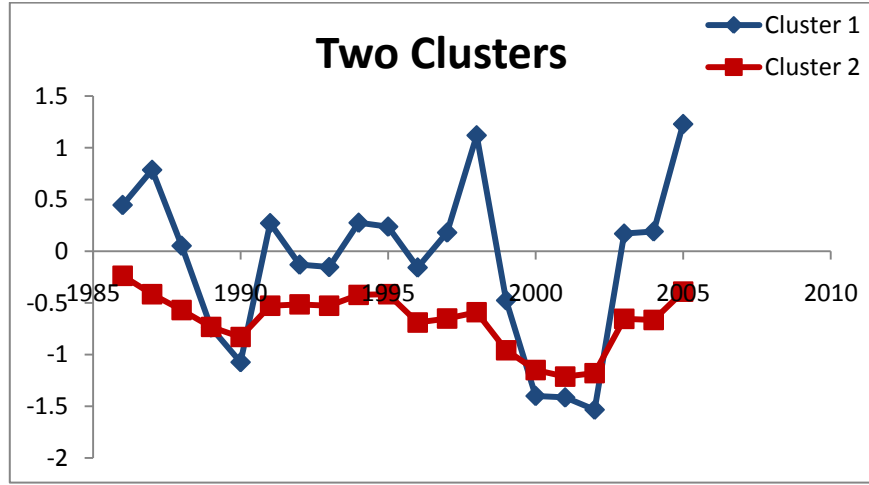


Figure 2.1 Dendrogram formed by agglomerative hierarchical cluster analysis (AHCA).

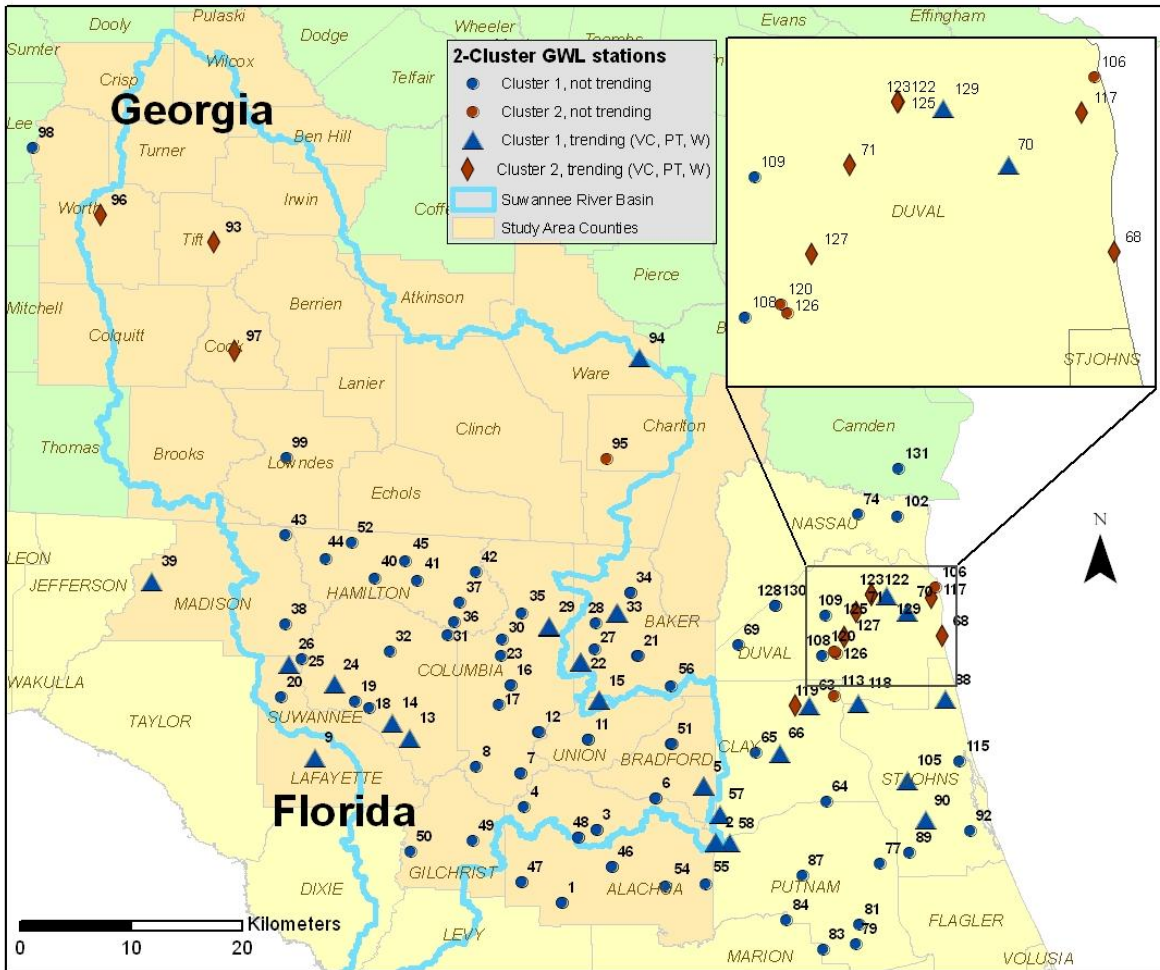
2.2 Two Clusters

The data separate into 2 clusters when a large height was used (>15) (**Figure 2.2**). The normalized groundwater level data were averaged for each cluster and plotted together in **Figure 2.2A**. The time series of cluster 1 and 2 show significant differences in their patterns. The averaged and normalized groundwater level in cluster 2 are all negative suggesting that most of the groundwater levels in this cluster were lower in the selected time period (i.e., 1986-2005) than in the earlier period of record available. **Figure 2.2B** shows the spatial location of the wells in each cluster. In the two-cluster analysis results, most of the wells fall into cluster 1 and are predominantly located in the southern part of the study area. Fewer wells (14) fall into cluster 2 and are located in Georgia (4), and Duval (8) and Clay (2) County Florida. Almost all the wells (13) in cluster 2 have a relatively large slope with a groundwater level decline rate larger than 0.15 ft/year (slope between -0.17 and -0.89) except one well in Duval County (Map ID 106, Well ID 302724081244801, slope -0.04 ft/year, no trend).

The 2-cluster analysis in the final report submitted under Contract #25325 included 100 identical wells the groundwater level data were normalized using statistics from a shorter time period (i.e., 1986-2005). The cluster results are quite different between the two analyses. When the shorter period of record was used the wells generally separated in clusters that were either had predominantly moderate to large negative slopes (74) and those with predominantly positive or very small negative slopes (26).



(A)



(B)

Figure 2.2 2-Cluster Plot and Map. (A) Averages of normalized groundwater levels for clusters 1 (blue) and 2 (red). (B) Spatial distribution of the groundwater wells for clusters 1 (blue) and 2 (red).

1.3 Three Clusters

The data separate into 3 clusters when a smaller height was used (between 14 to 15) (**Figure 2.3**). The normalized groundwater level data were averaged for each cluster and plotted together in **Figure 2.3A**. **Figure 2.3B** shows spatial location of the wells in each cluster. Most of the wells fall into cluster 1, are predominantly located in the southern part of the study area, and generally coincide with those in cluster 1 in the two cluster analysis. Few wells fall into cluster 2, most of these have upward slopes, and one of them has a very certain upward trend (295357081294301). Cluster 3 also has fewer wells than cluster 1 and these wells are located in Georgia (4), and Duval (8) and Clay (2) County Florida, coinciding with those in Cluster 2 of the two cluster analysis. Almost all the wells in cluster 3 have a relatively steep slope with a groundwater level decline rate bigger than 0.15 ft/year (slope between -0.17 and -0.89) except one well in Duval County (Map ID 106, Well ID 302724081244801, slope -0.04 ft/year, no trend).

The 3-cluster analysis in the final report submitted under Contract #25325 included 100 identical wells but the groundwater level data were normalized using statistics from a shorter time period (i.e., 1986-2005). The 3- cluster results from both analyses are very similar with respect to distributions of wells in each of the three clusters.

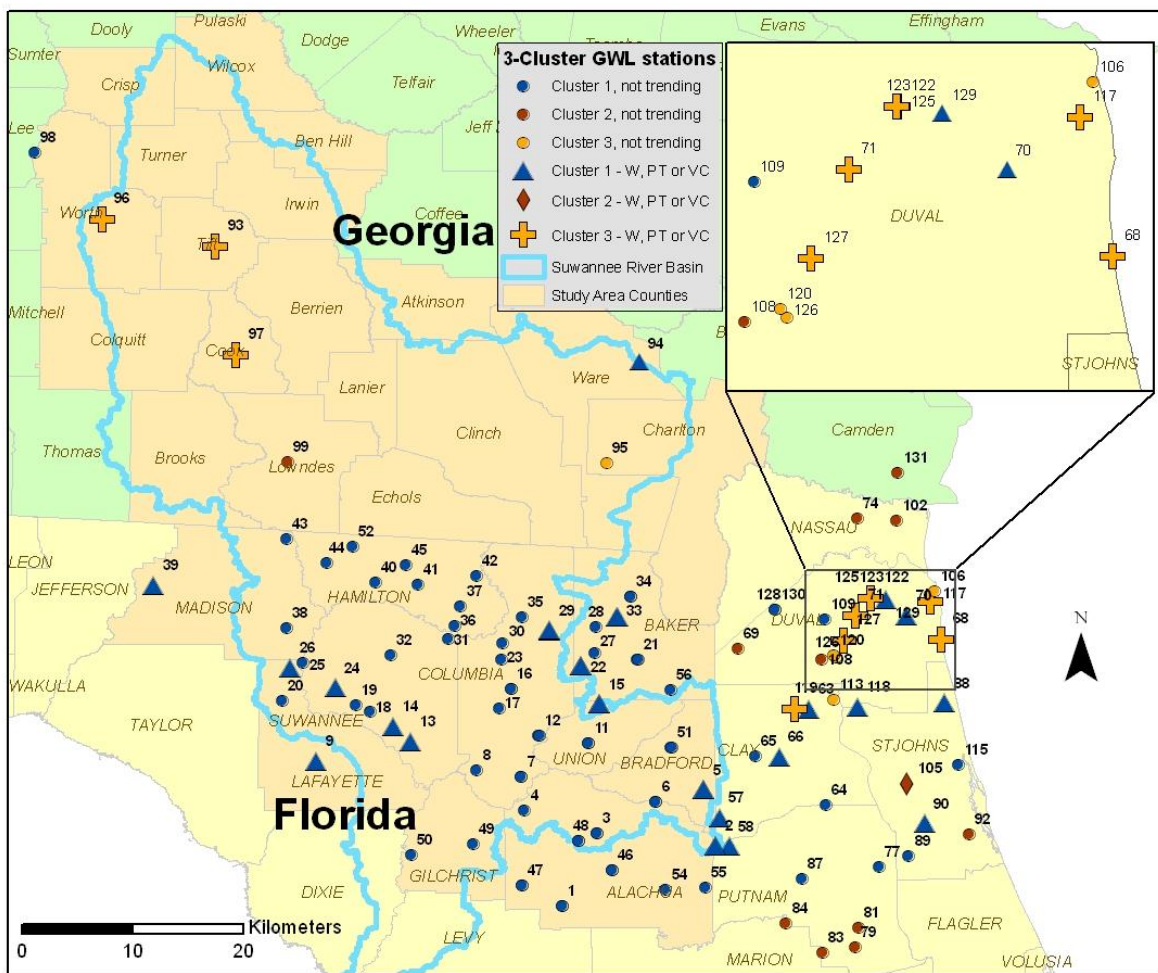
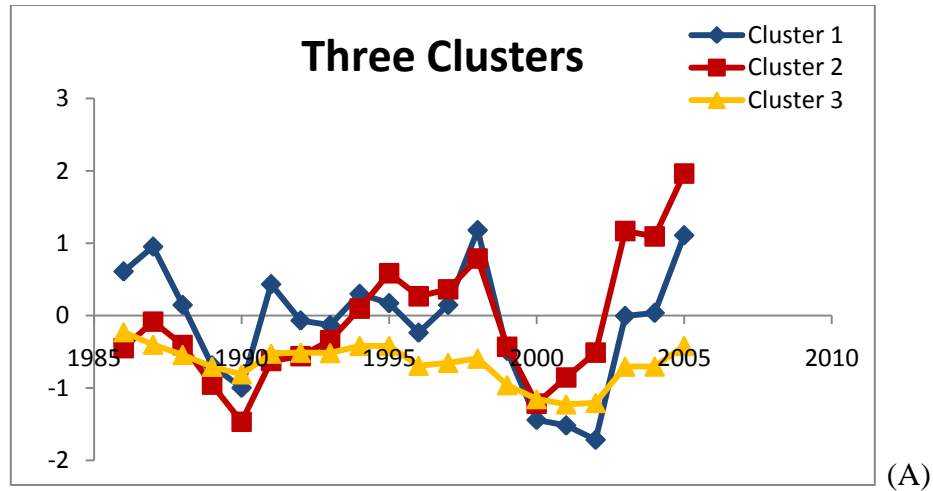


Figure 2.3 3-Cluster Plot and Map. (A) Averages of normalized groundwater levels for clusters 1 (blue), 2 (red), and 3 (yellow). (B) Spatial distribution of the groundwater wells for clusters 1 (blue), 2 (red), and 3 (yellow).

2.4 Four Clusters

The data separate into 4 clusters when a smaller height was used (between 10 to 14) (**Figure 2.4**). The normalized groundwater level data were averaged for each cluster and plotted together in **Figure 2.4A**. **Figure 2.4B** shows spatial location of the wells in each cluster. Most of the wells fall into clusters 1 and 2, are predominantly located in the southern part of the study area, and generally coincide with those in cluster 1 in the two and three cluster analyses. Most of the wells in cluster 3 have upward slopes and one of them has a very certain upward trend (295357081294301). All cluster 4 wells in this section are located in Georgia (4), Clay (2) and Duval (8) County Florida, coinciding with those in cluster 2 of the two cluster analysis and cluster 3 of the 3 cluster analysis. Almost all the wells in cluster 4 have a relatively steep slope with a groundwater level decline rate bigger than 0.15 ft/year (slope between -0.17 and -0.89) except one well in Duval County (Map ID 106, Well ID 302724081244801, slope -0.04 ft/year, no trend).

The 4-cluster analysis in the final report submitted under Contract #25325 included 100 identical wells but the groundwater level data were normalized using statistics from a shorter time period (i.e., 1986-2005). The 4-cluster results from both analyses are very similar with respect to distributions of wells in each of the four clusters.

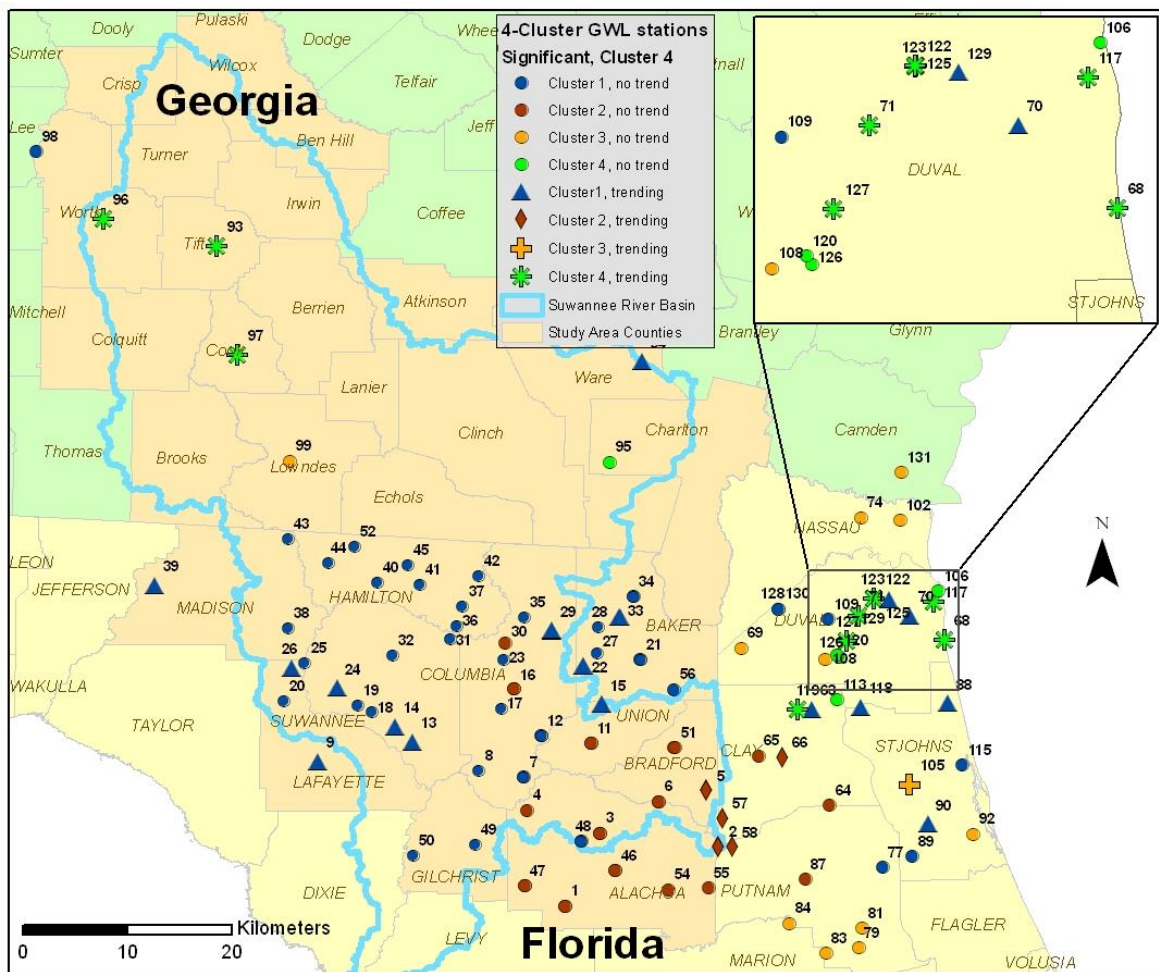
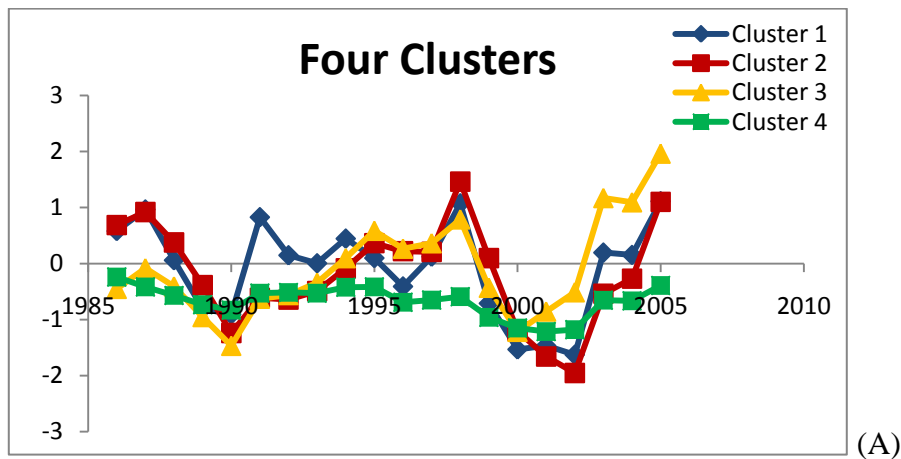
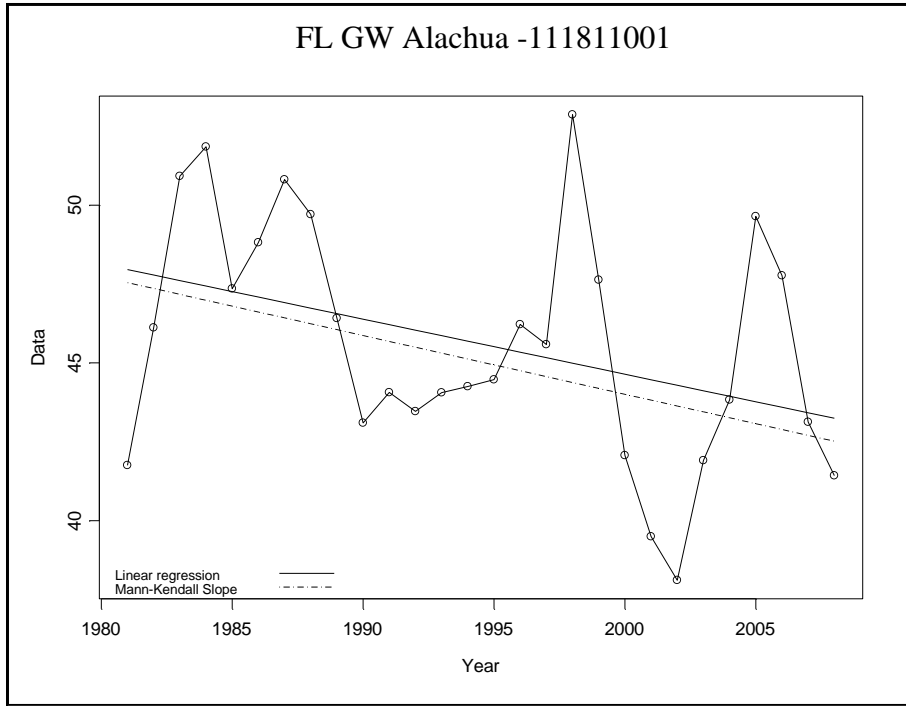


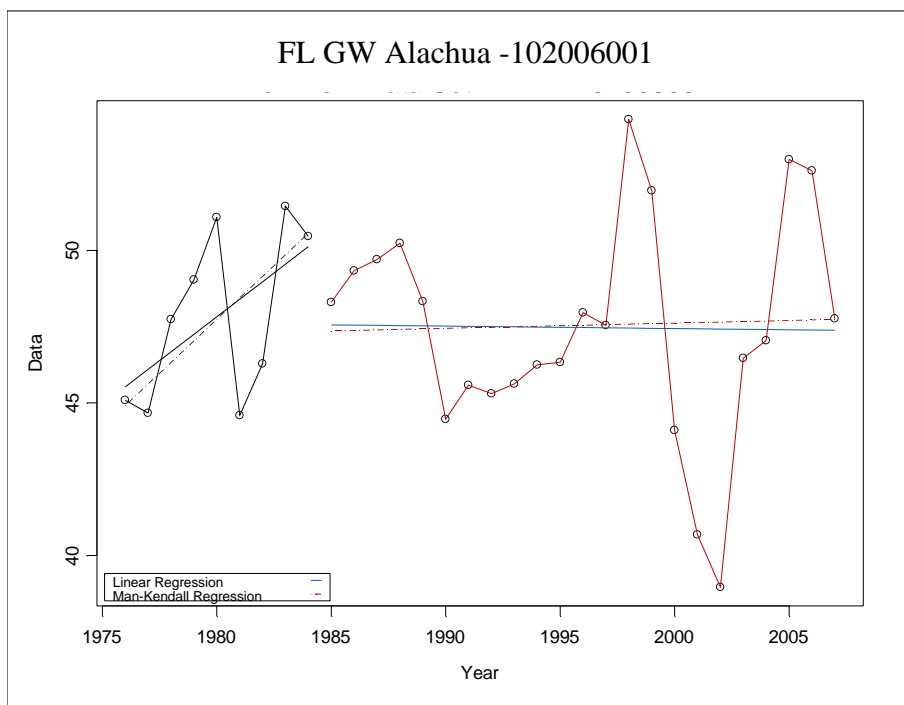
Figure 2.4 4-Cluster Results. (A) Averages of normalized groundwater levels for clusters 1 (blue), 2 (red), 3 (yellow) and 4 (green). (B) Spatial distribution of the groundwater wells for clusters 1 (blue), 2 (red), 3 (yellow), and 4 (green).

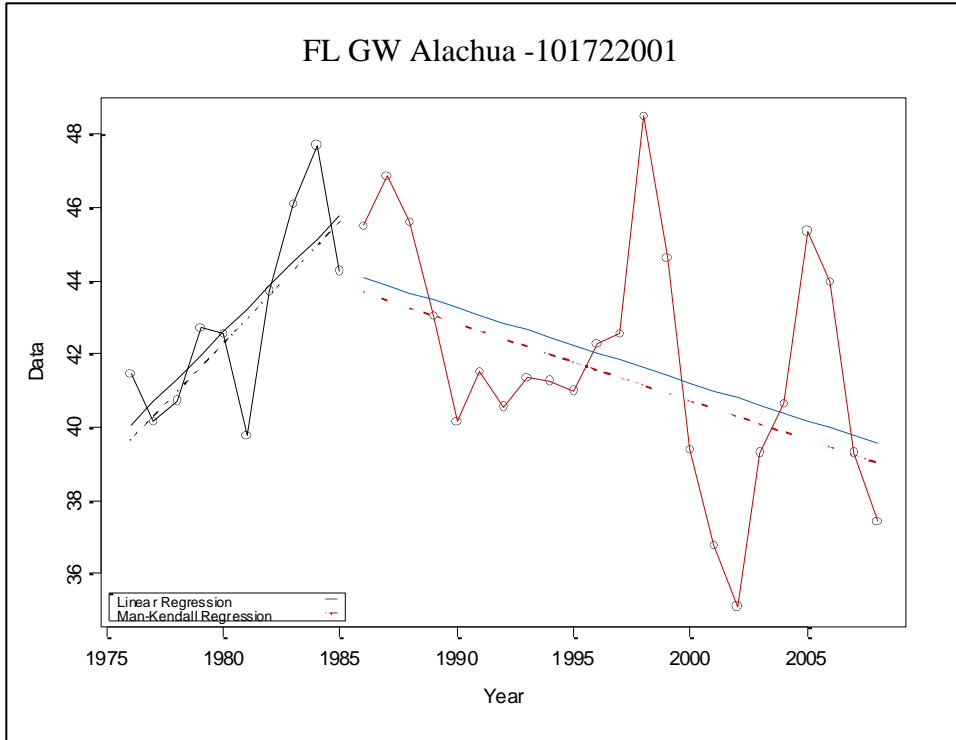
Appendix S1: SRWMD Florida Groundwater Level Trend

Following is a summary of the trend detection plots of SJRWMD groundwater level data. Annual average groundwater level data in feet above NGVD 1929 were labeled as “data” (y-axes) and plotted against record year (x-axes).

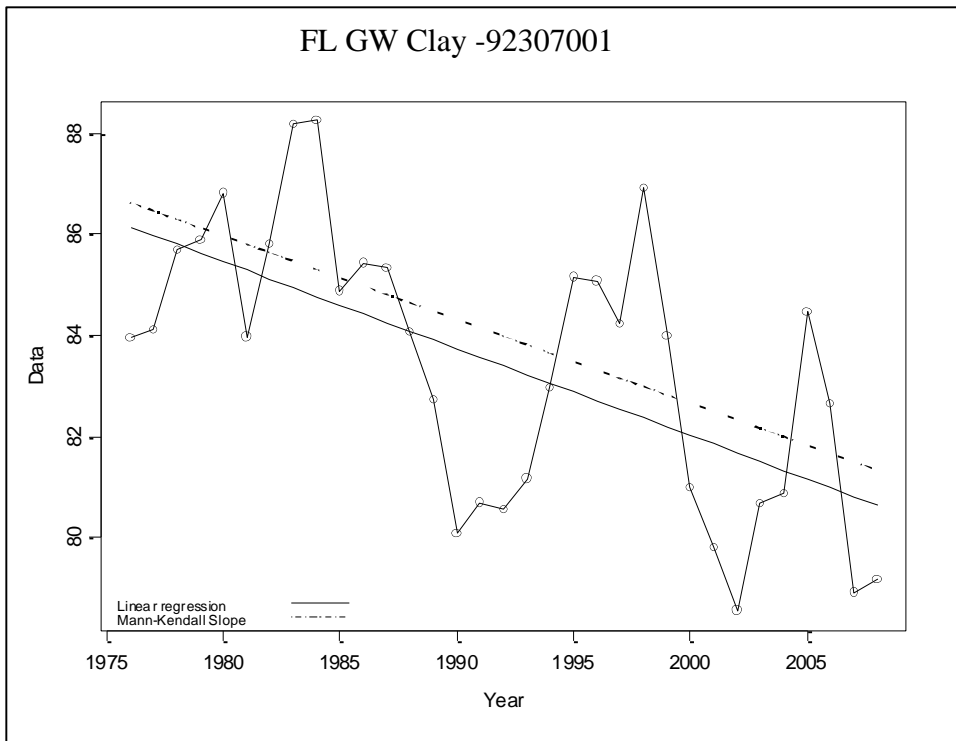


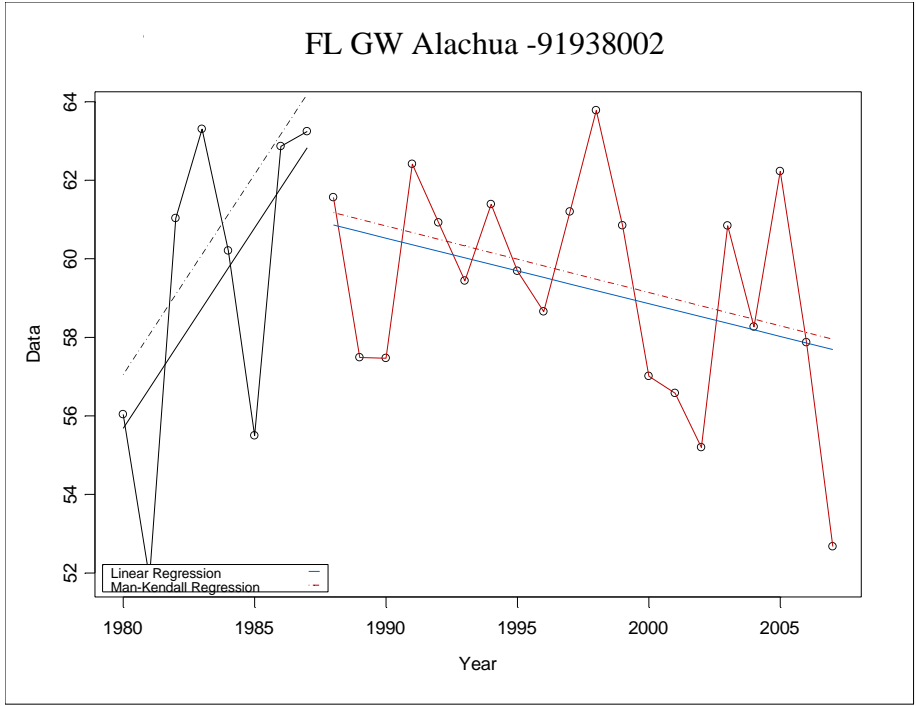
Data = annual average groundwater level in feet above NGVD 1929



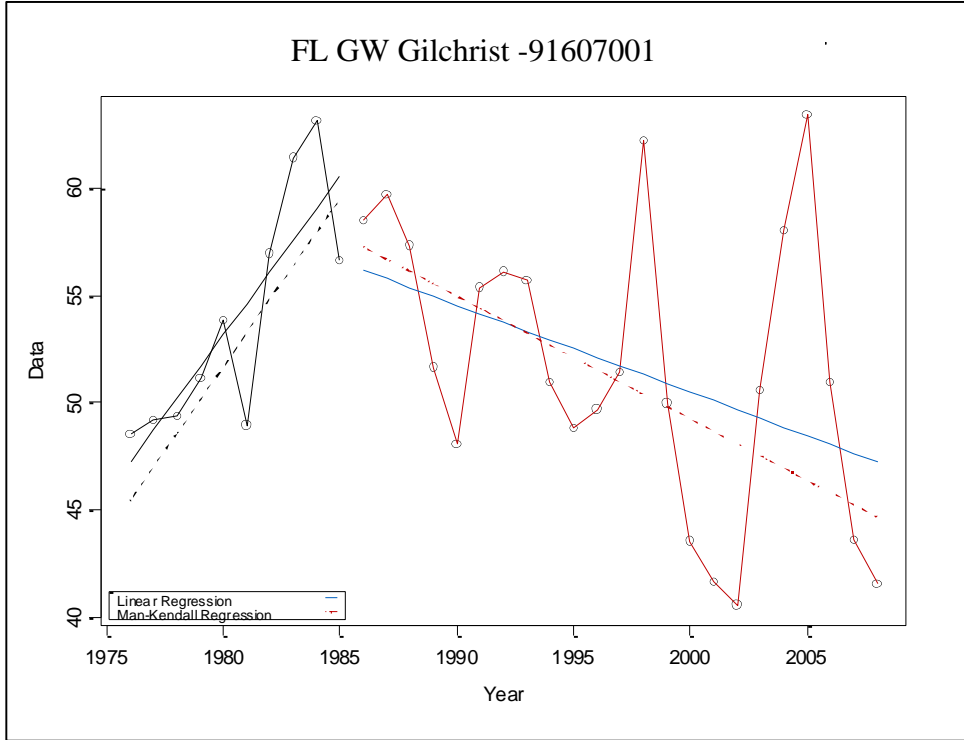


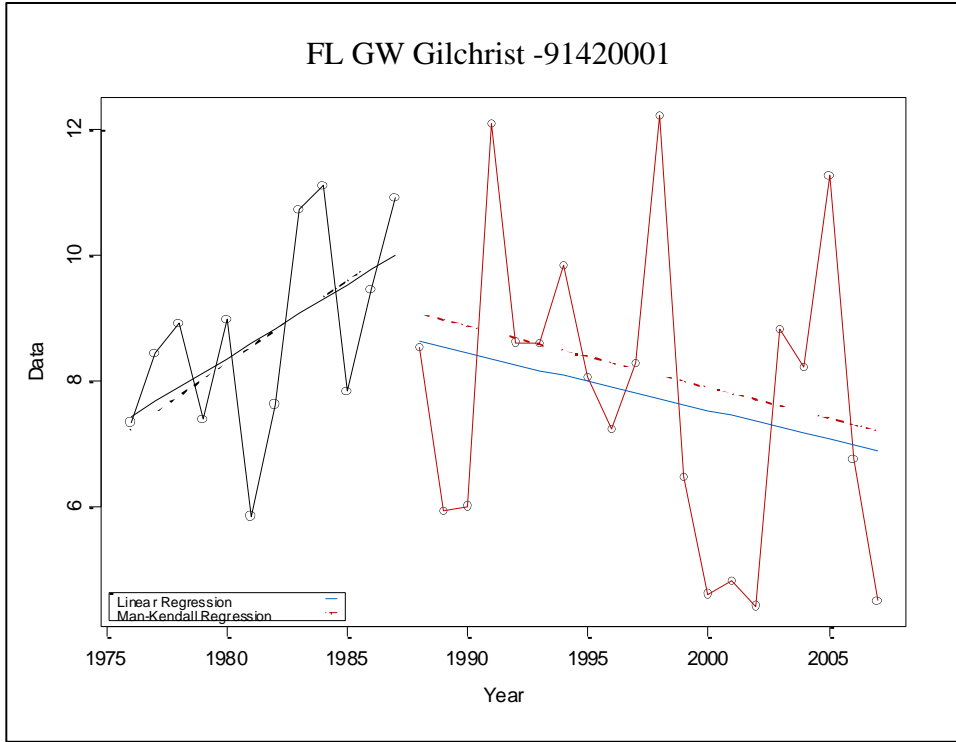
Data = annual average groundwater level in feet above NGVD 1929



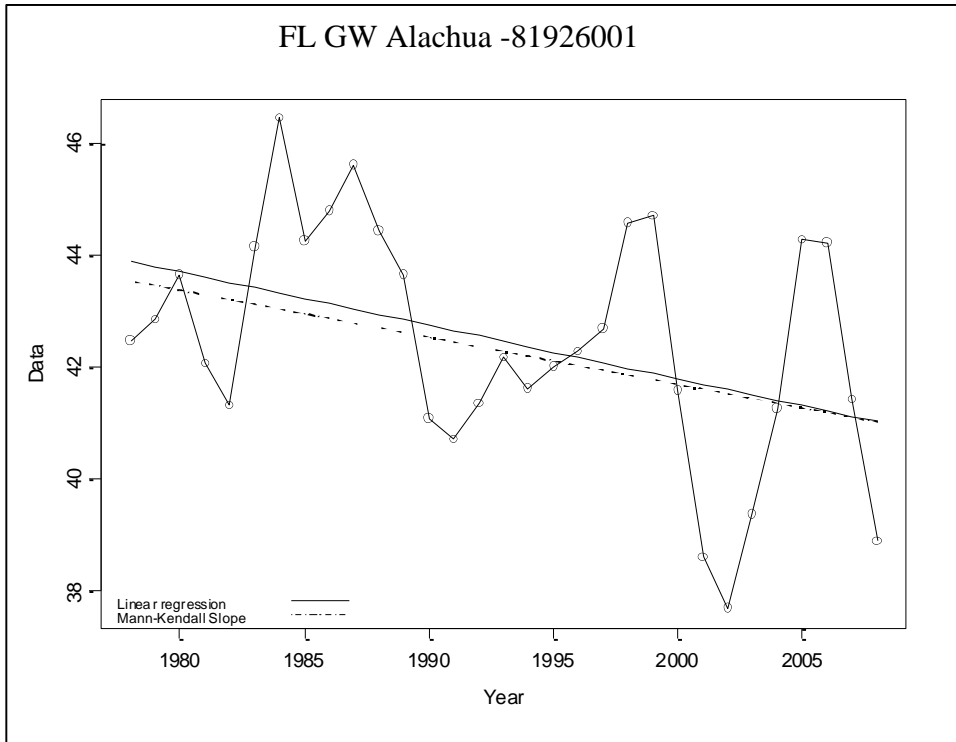


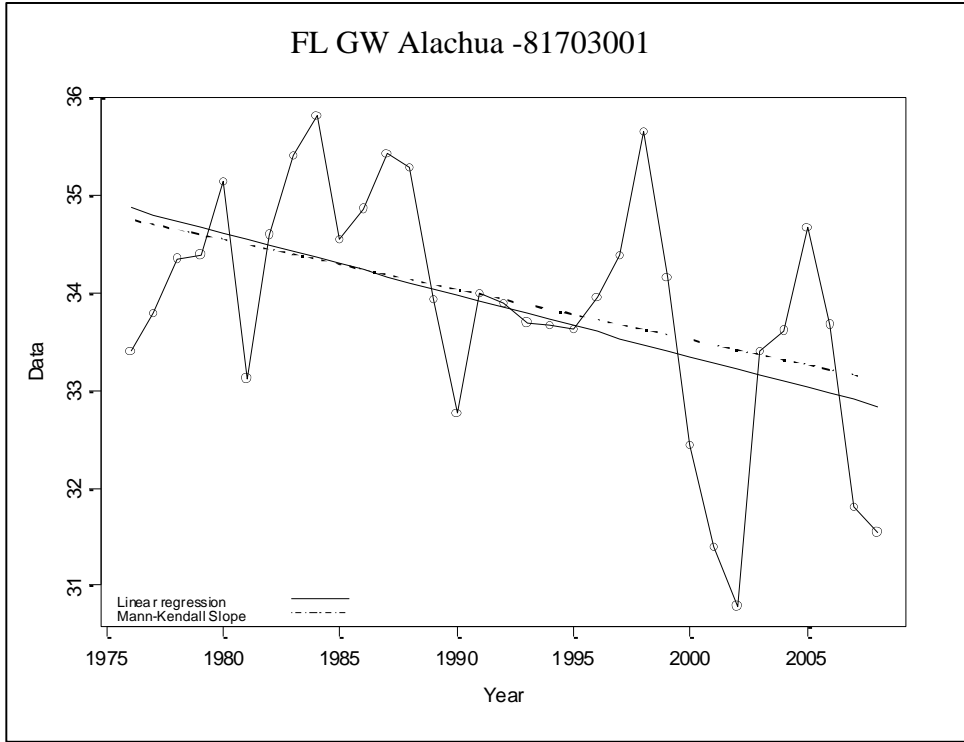
Data = annual average groundwater level in feet above NGVD 1929



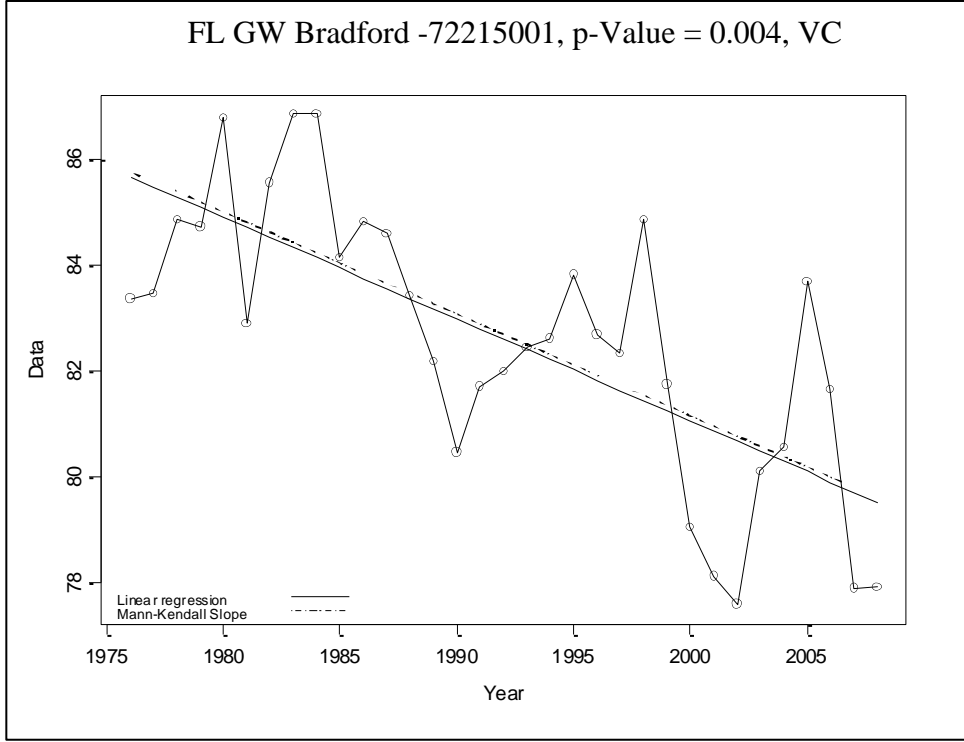


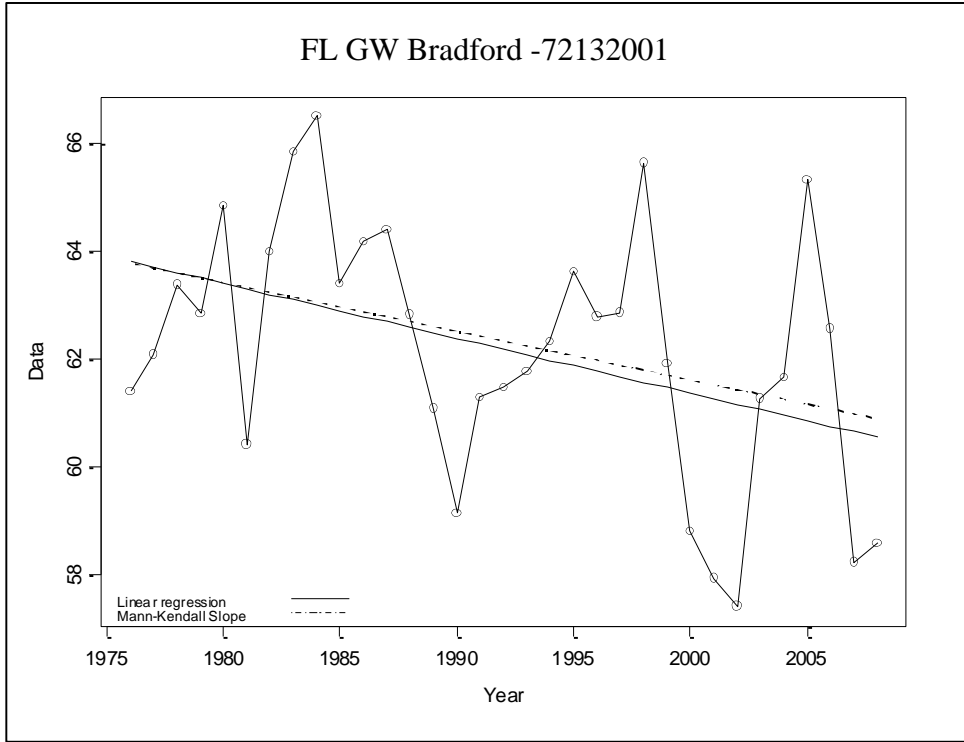
Data = annual average groundwater level in feet above NGVD 1929



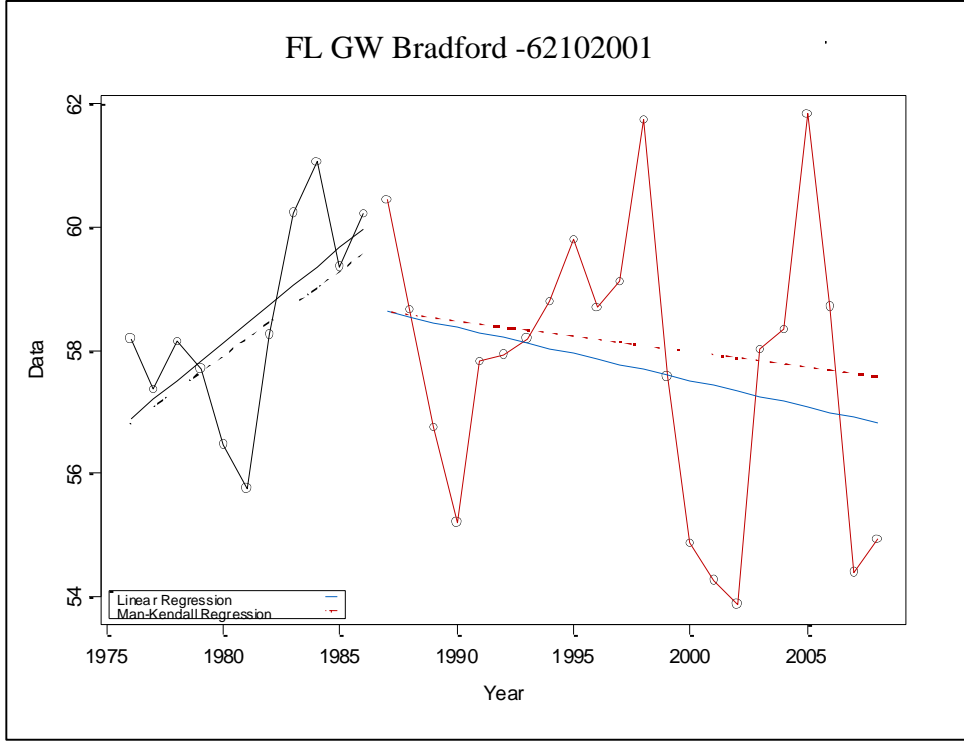


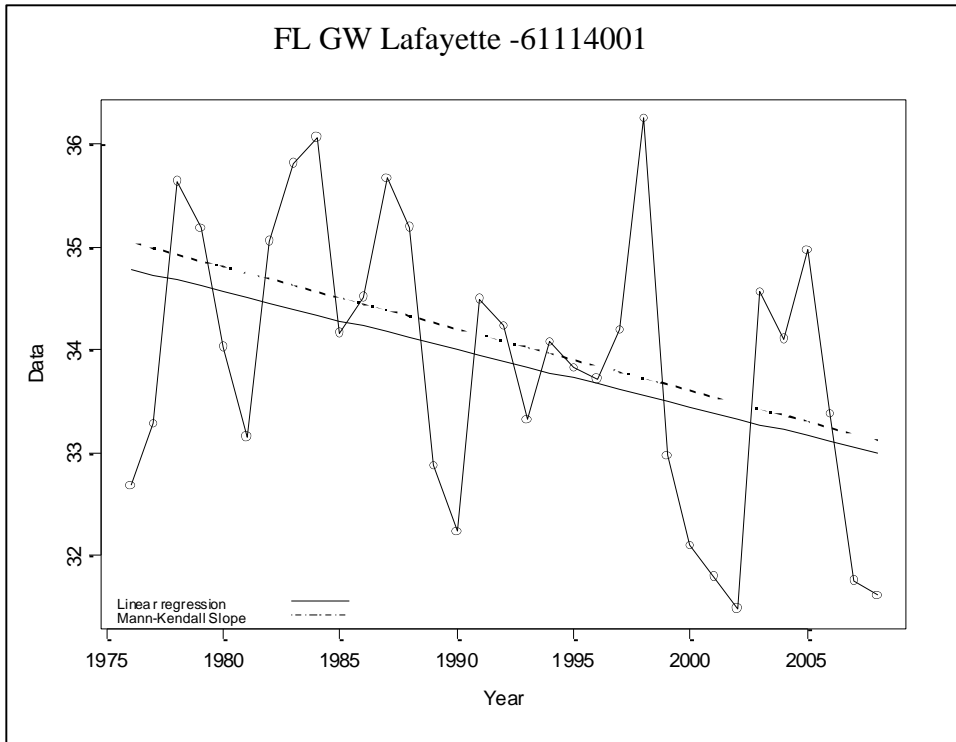
Data = annual average groundwater level in feet above NGVD 1929



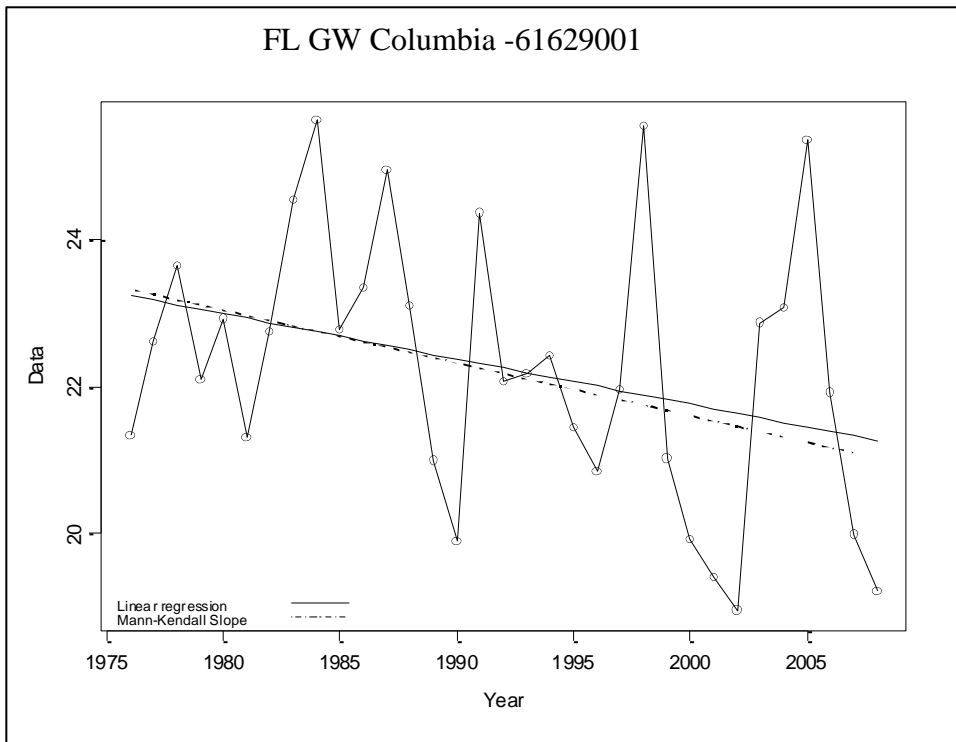


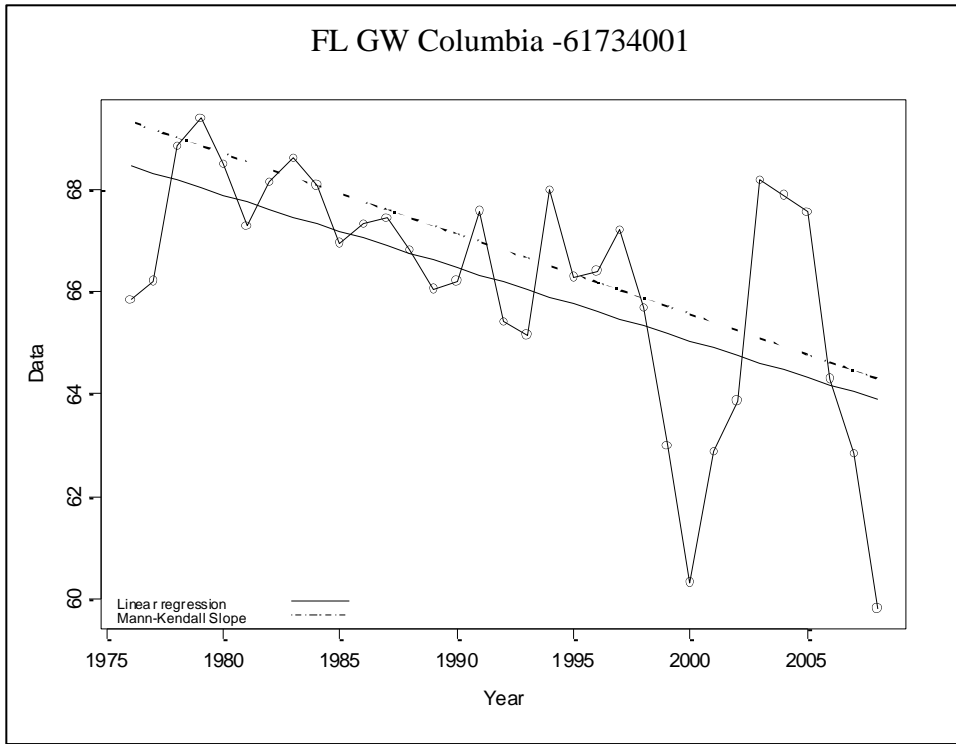
Data = annual average groundwater level in feet above NGVD 1929



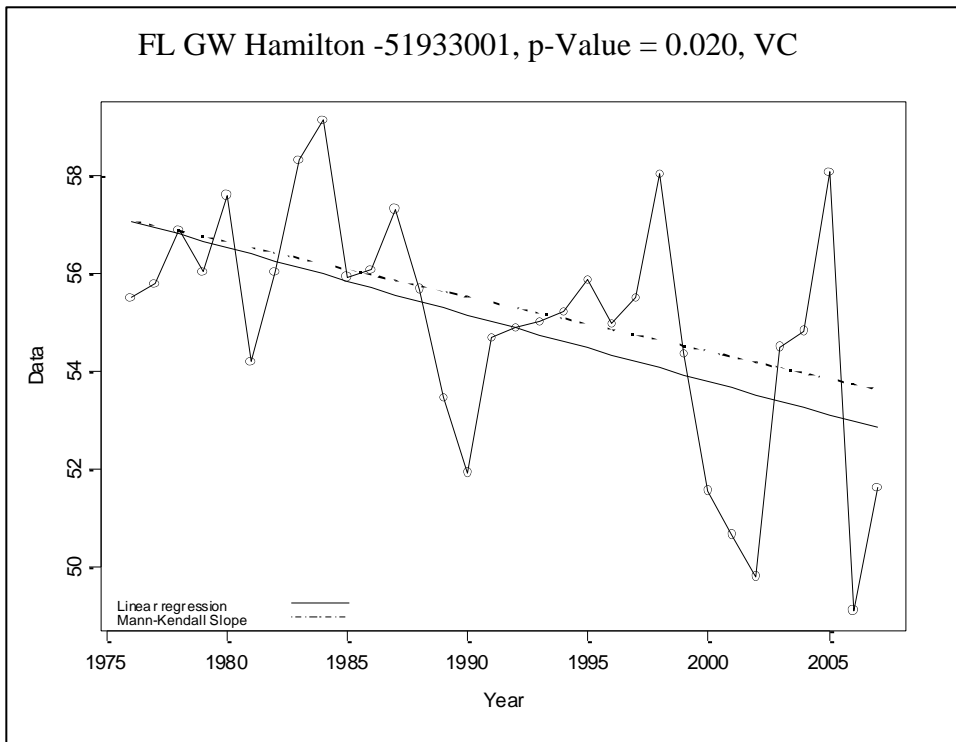


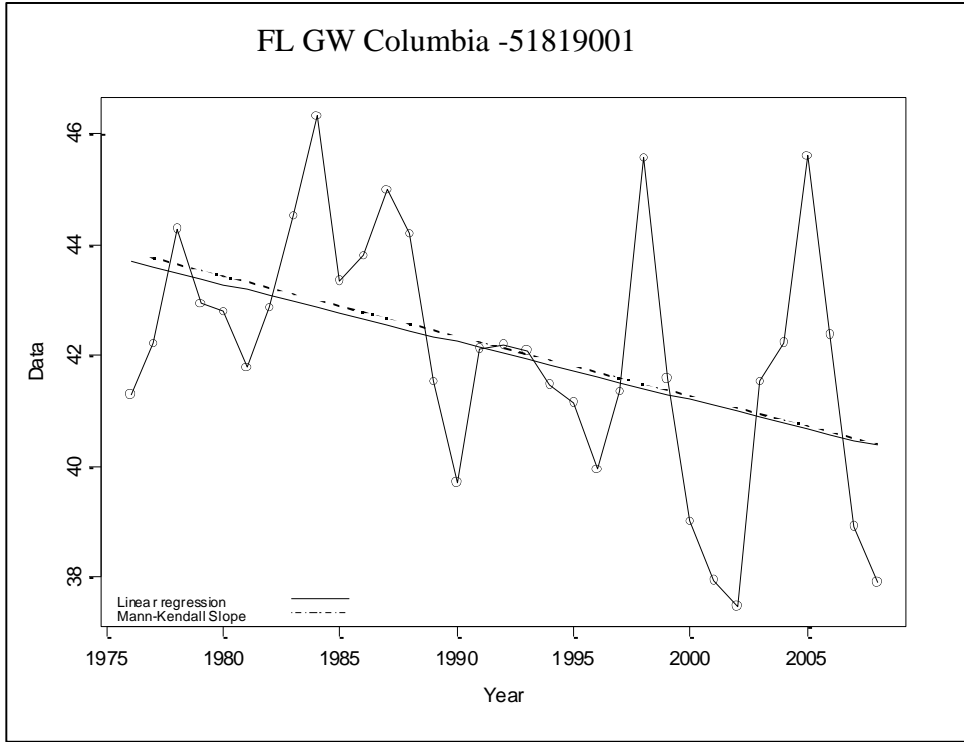
Data = annual average groundwater level in feet above NGVD 1929



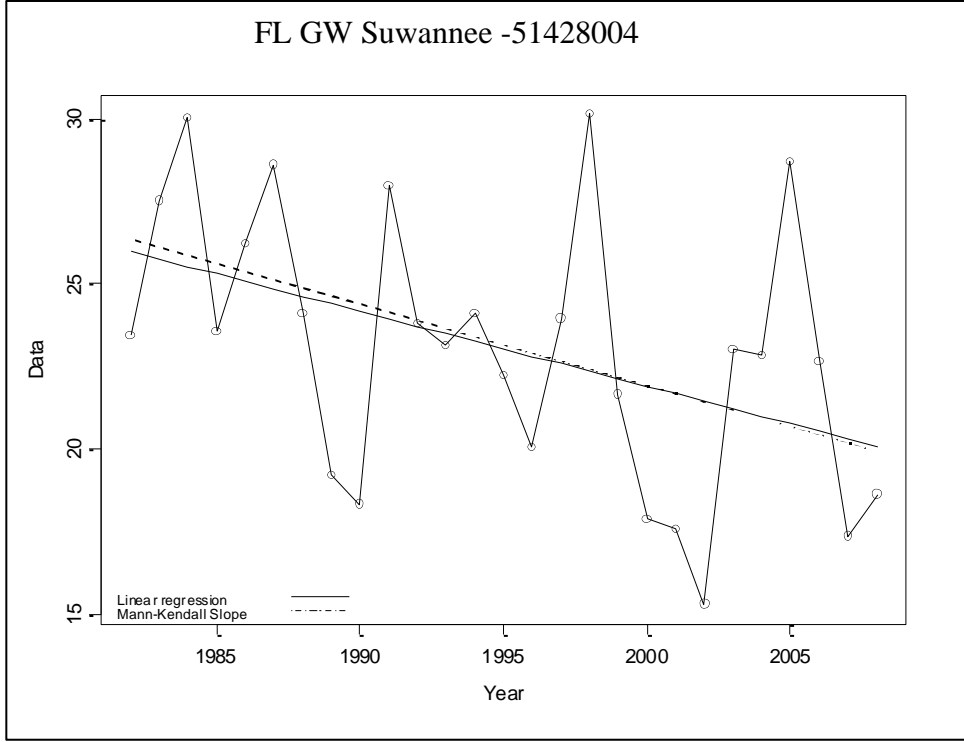


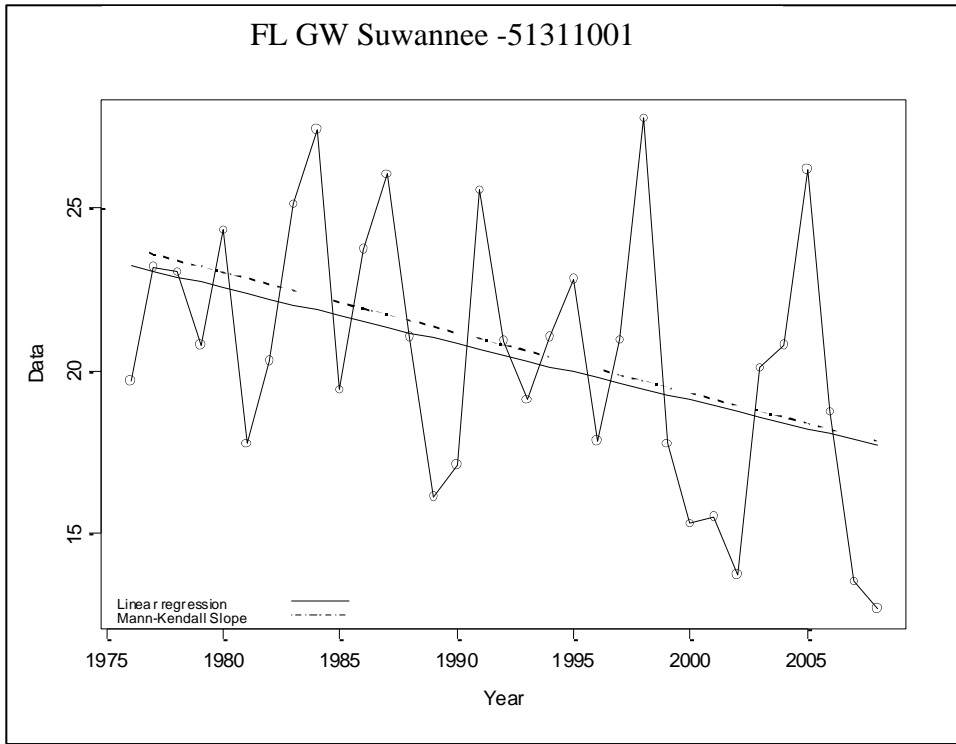
Data = annual average groundwater level in feet above NGVD 1929



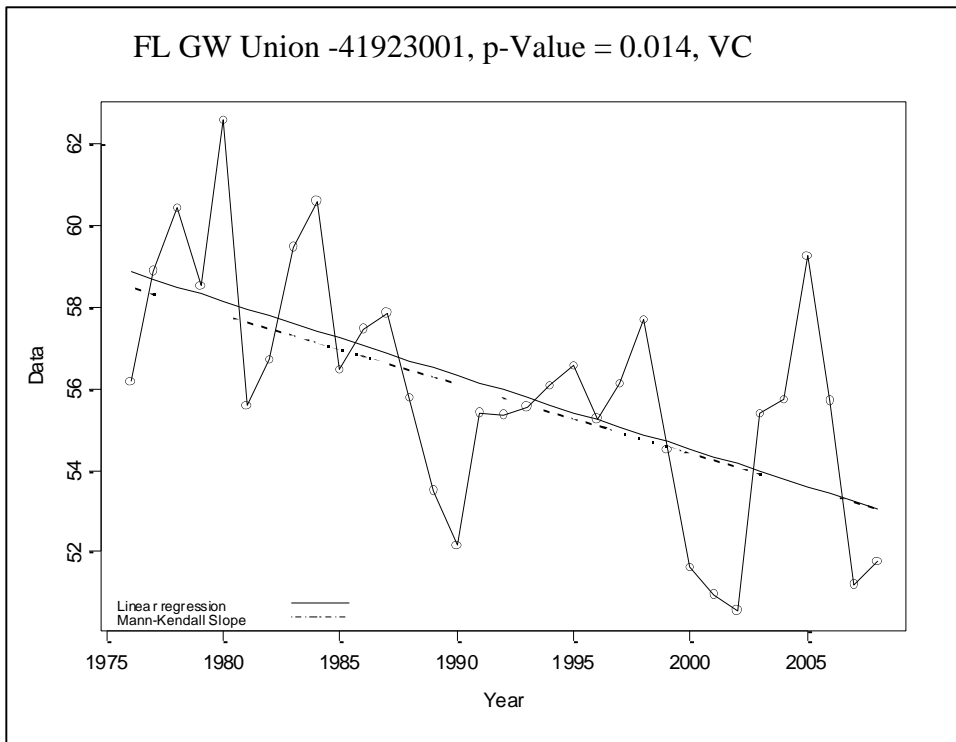


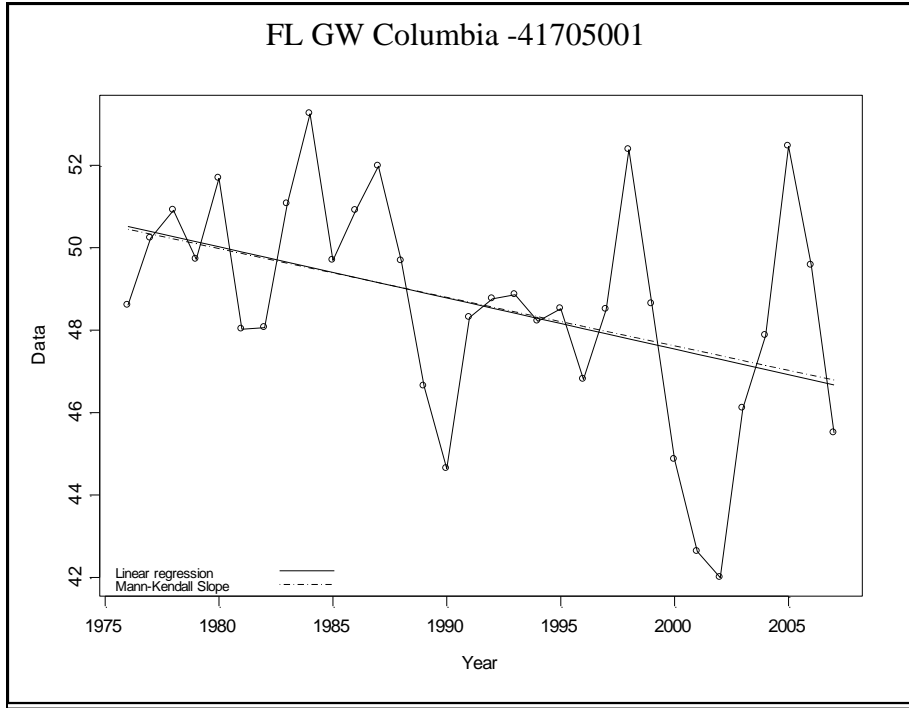
Data = annual average groundwater level in feet above NGVD 1929



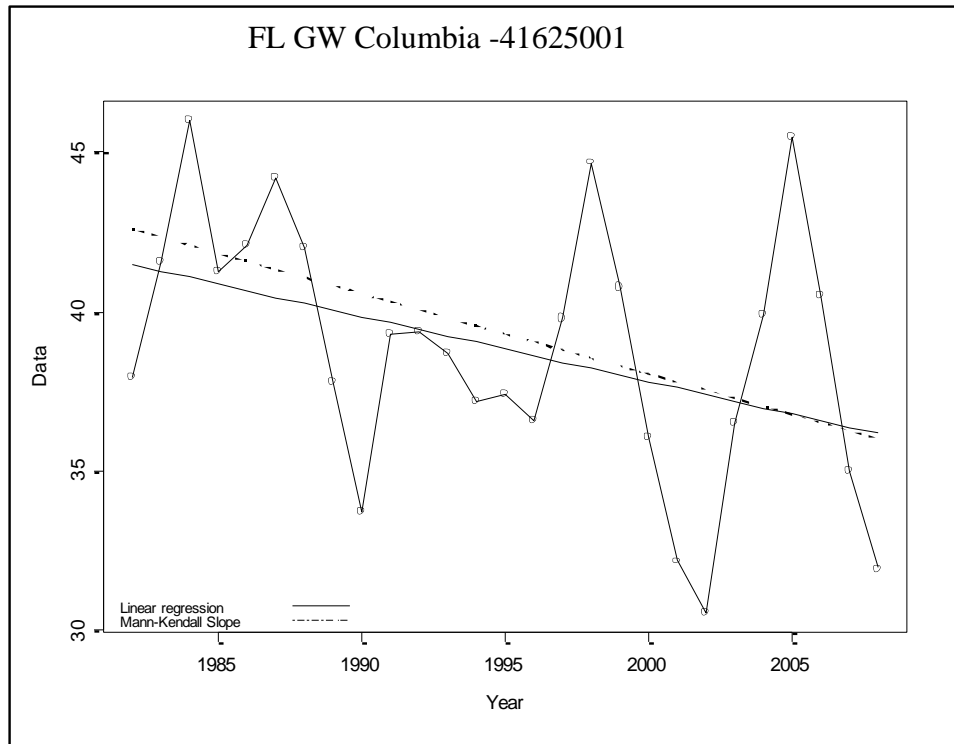


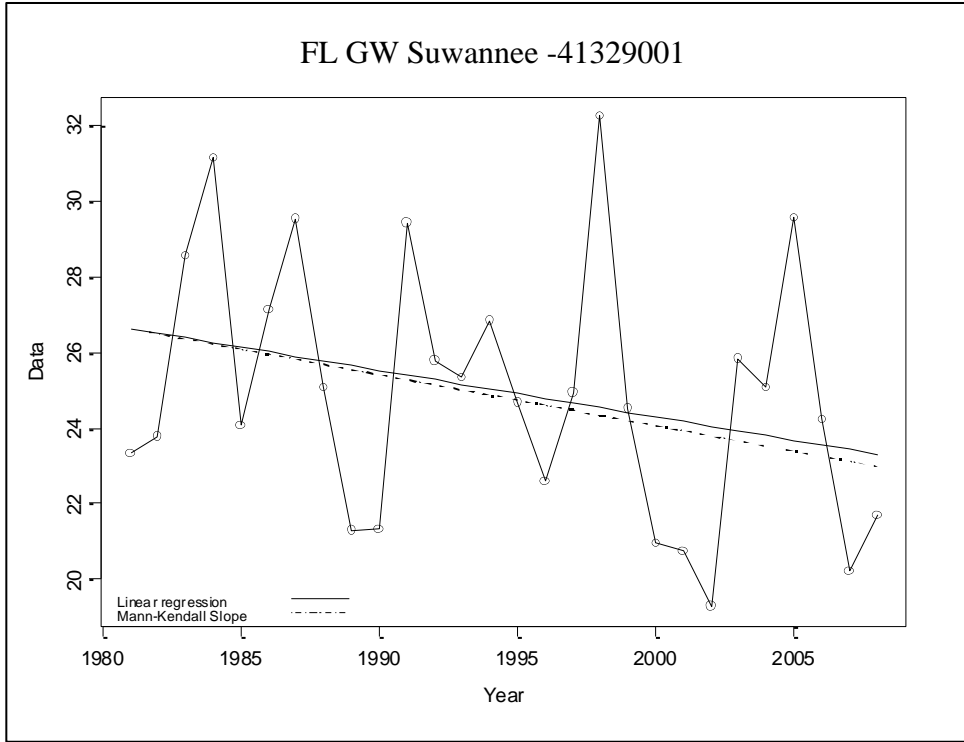
Data = annual average groundwater level in feet above NGVD 1929



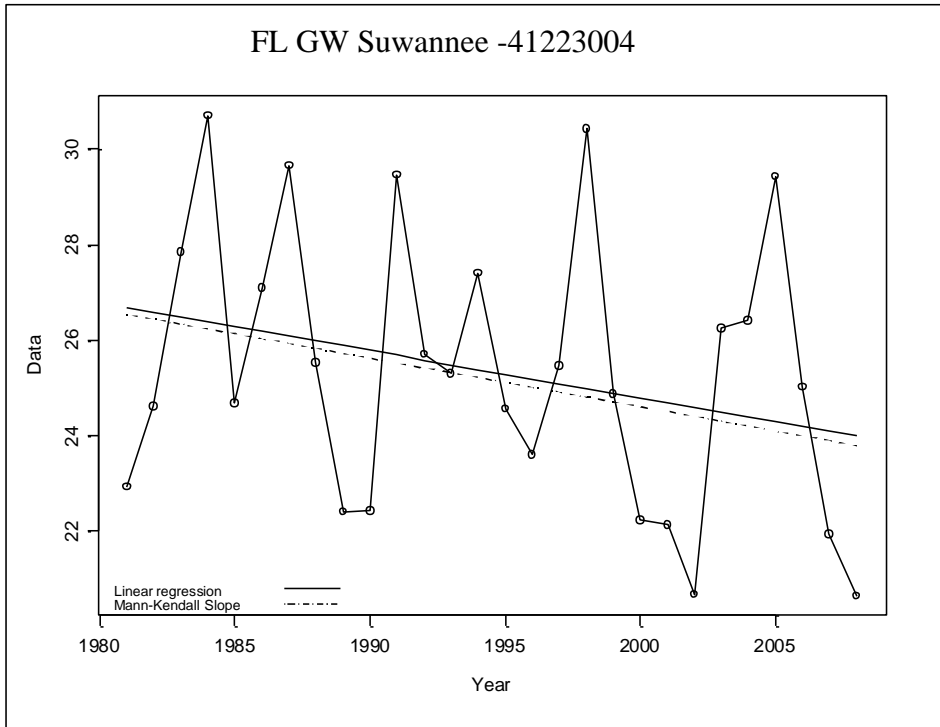


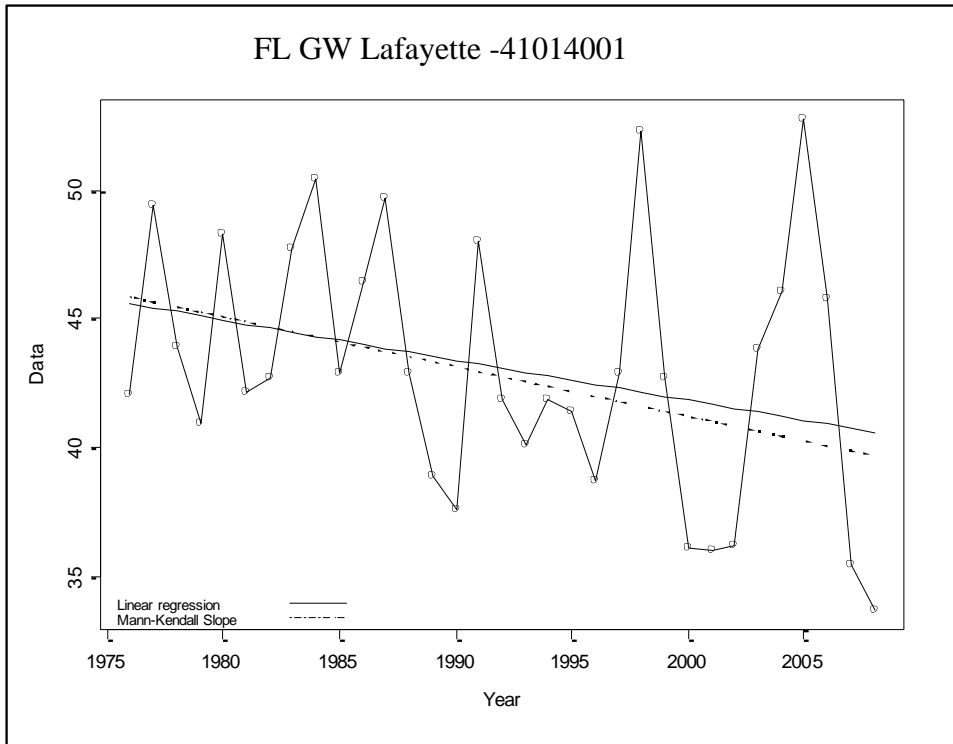
Data = annual average groundwater level in feet above NGVD 1929



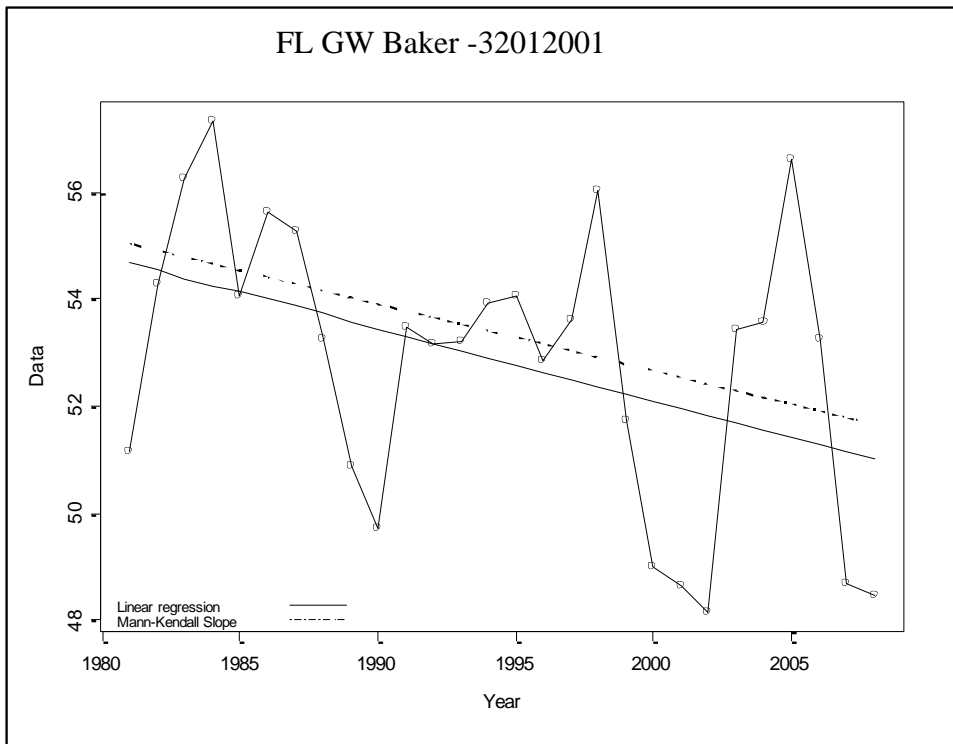


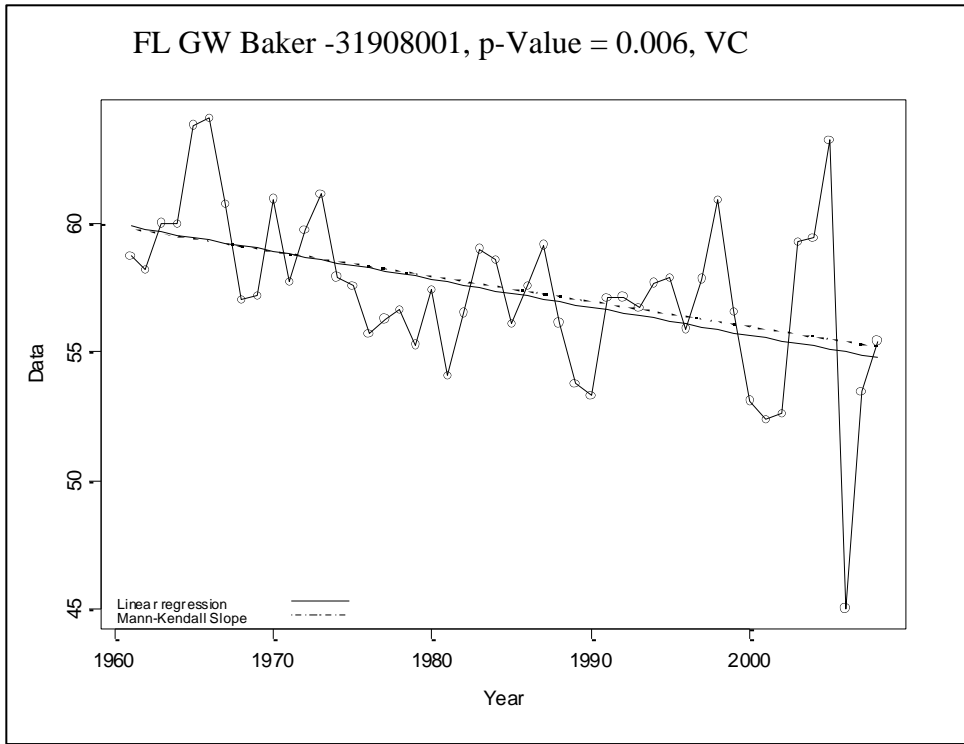
Data = annual average groundwater level in feet above NGVD 1929



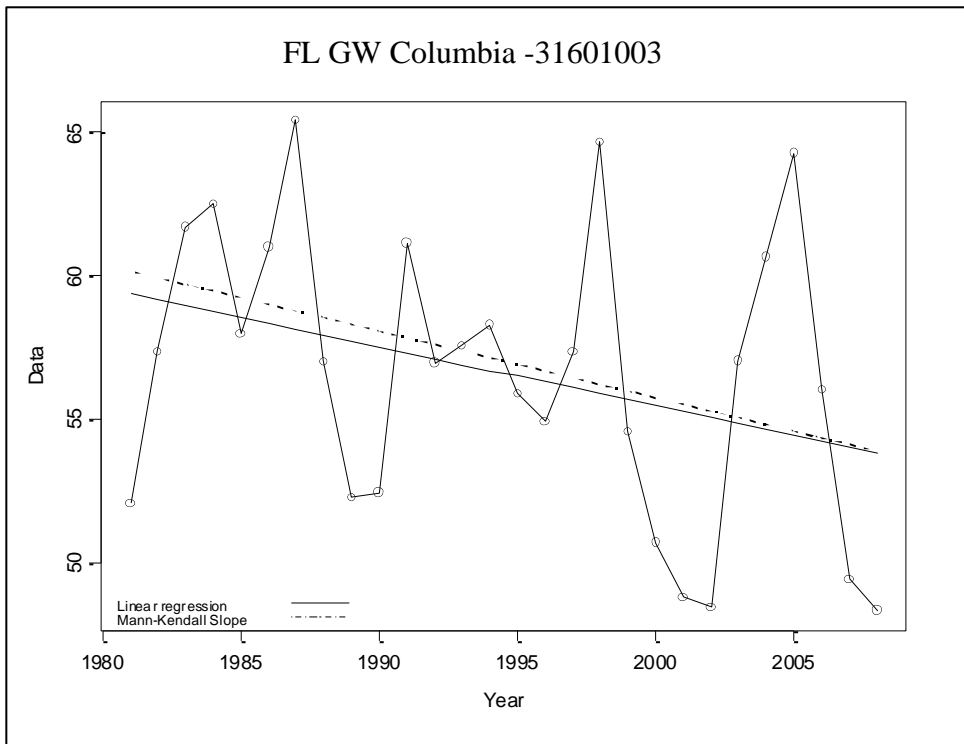


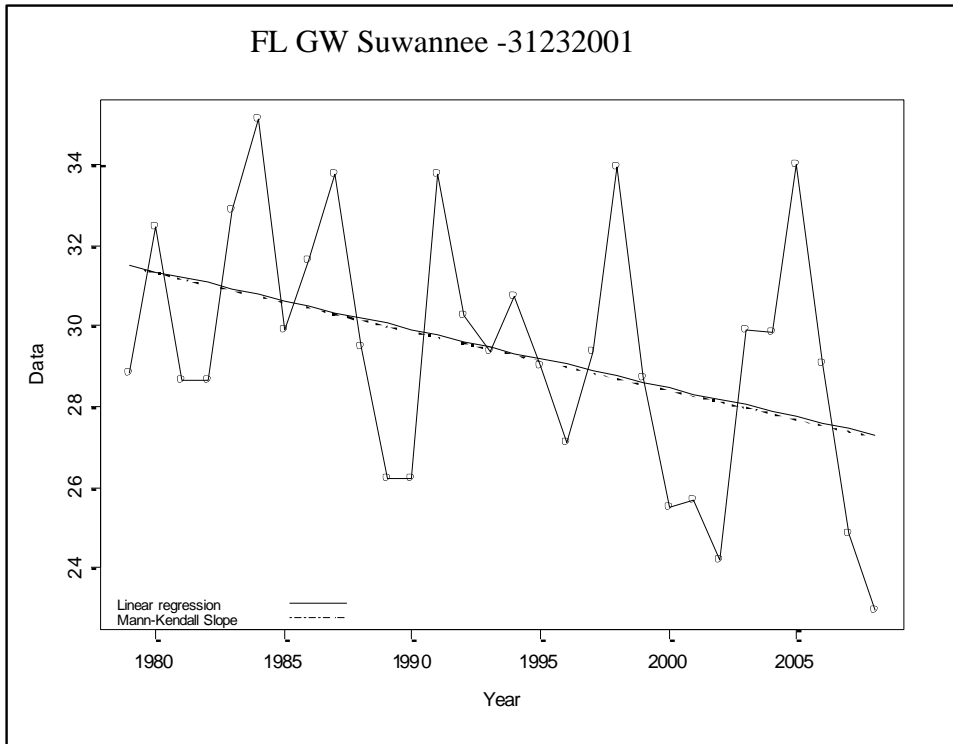
Data = annual average groundwater level in feet above NGVD 1929



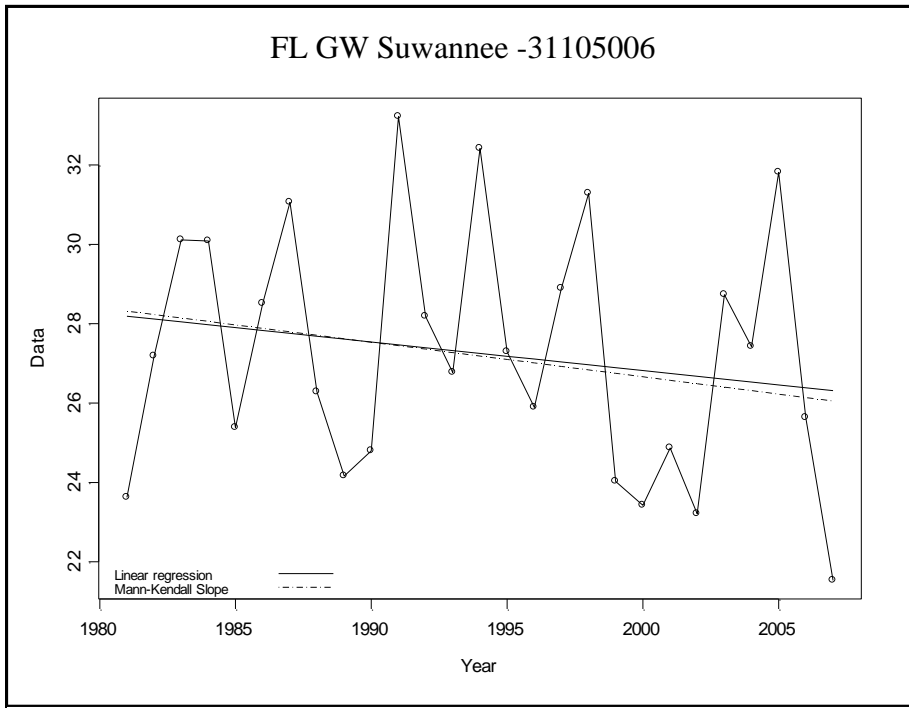


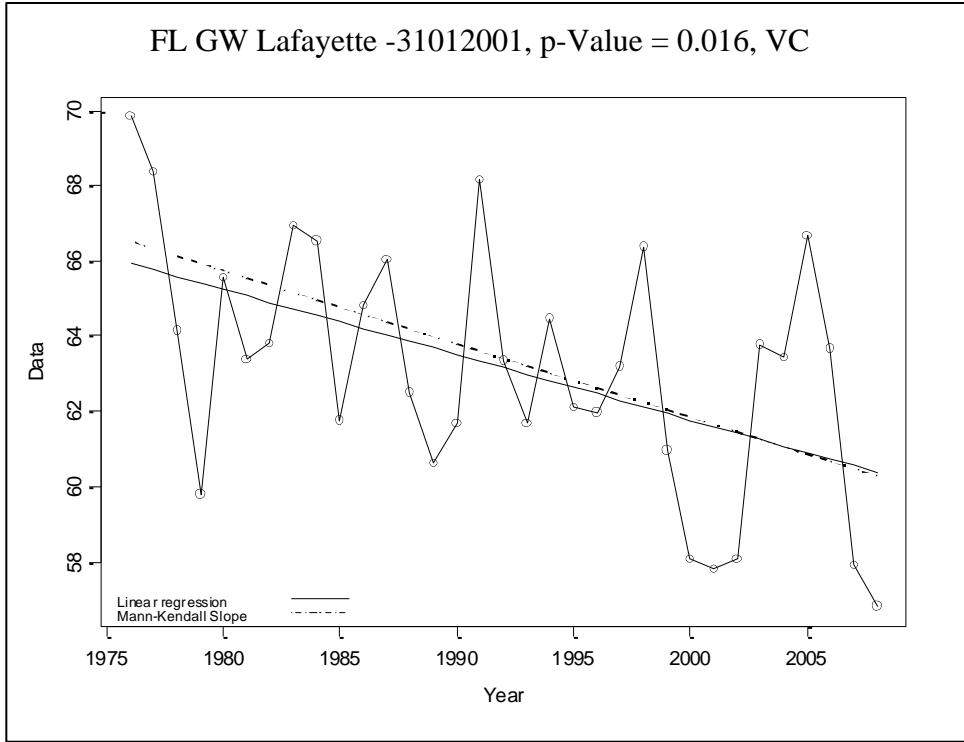
Data = annual average groundwater level in feet above NGVD 1929



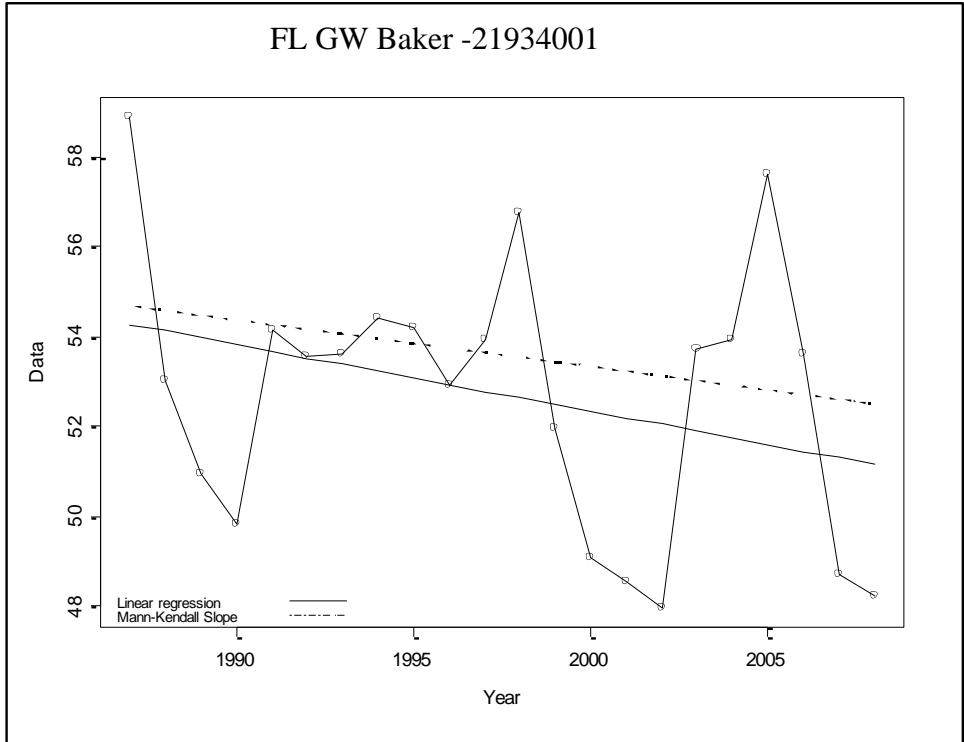


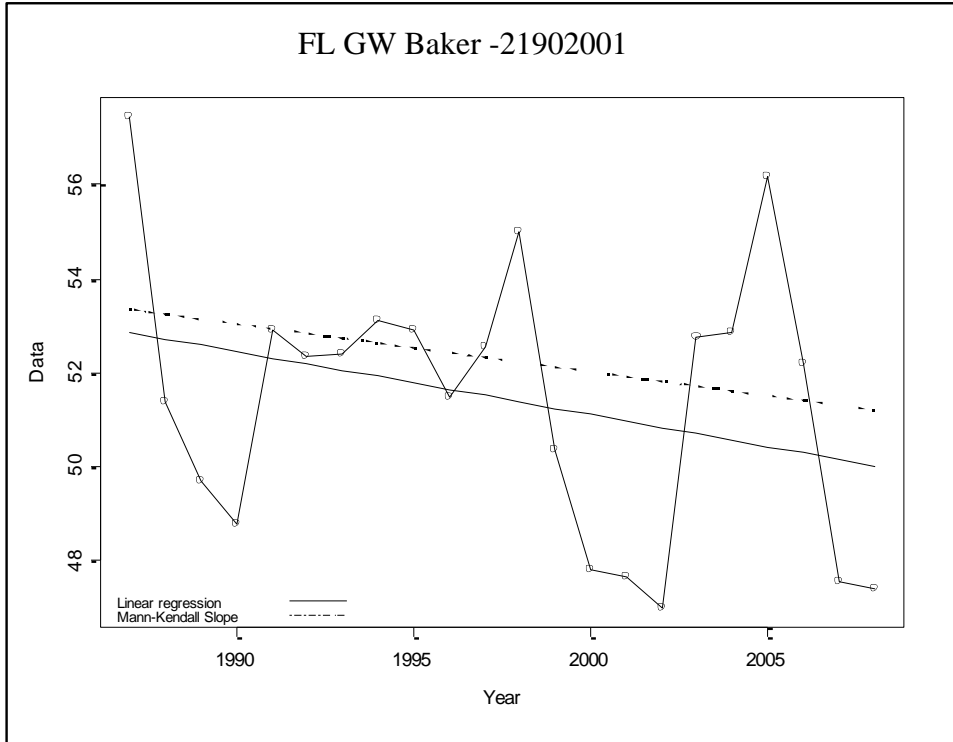
Data = annual average groundwater level in feet above NGVD 1929



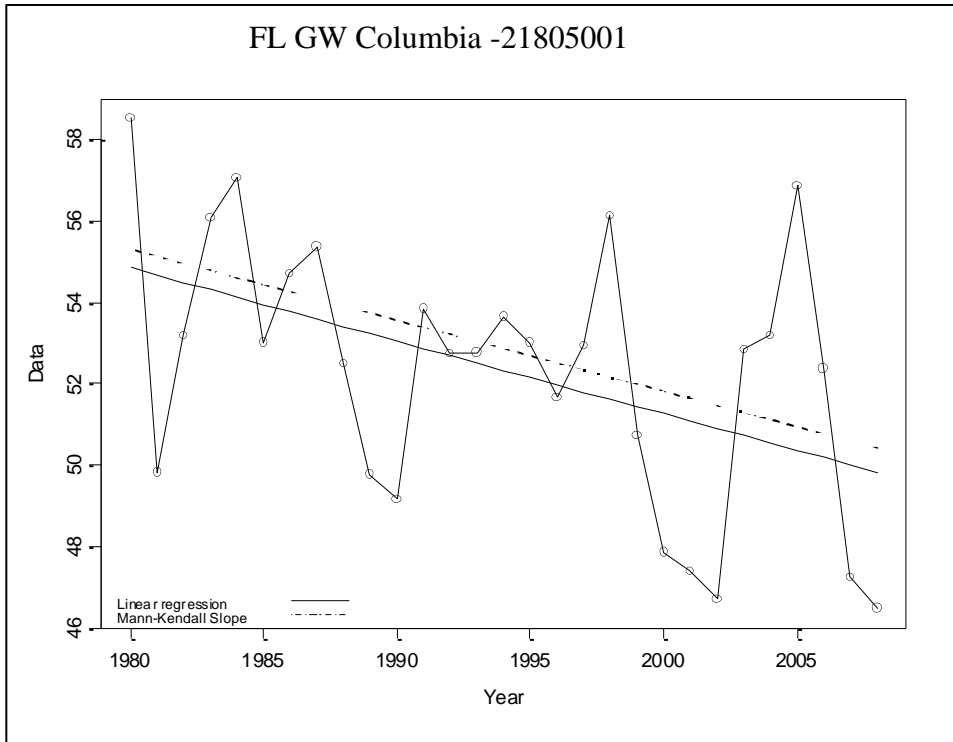


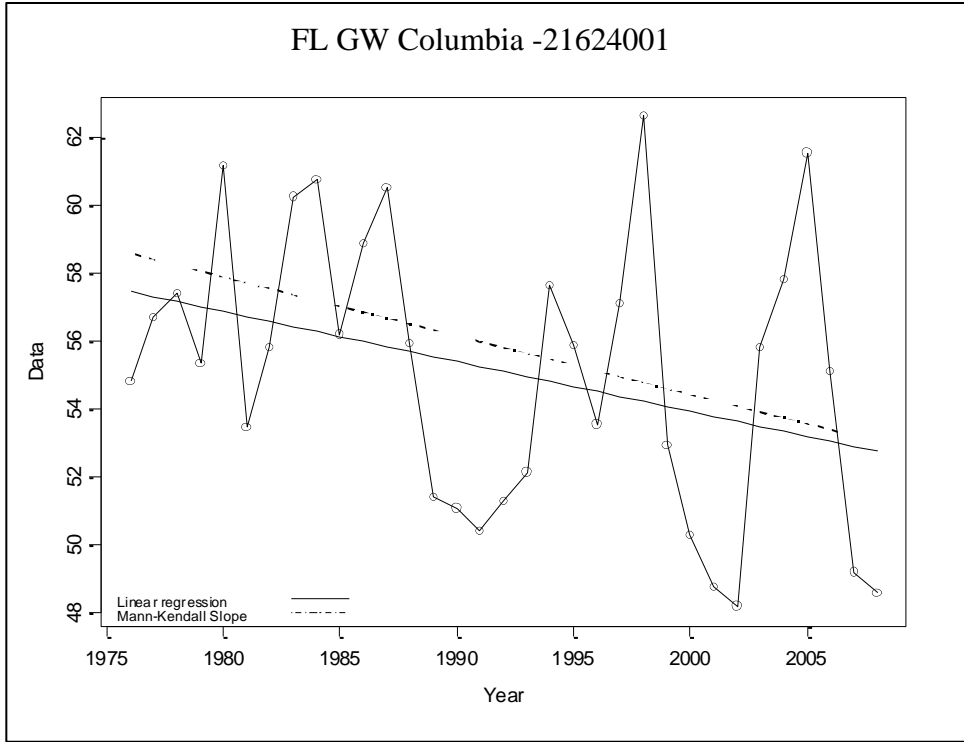
Data = annual average groundwater level in feet above NGVD 1929



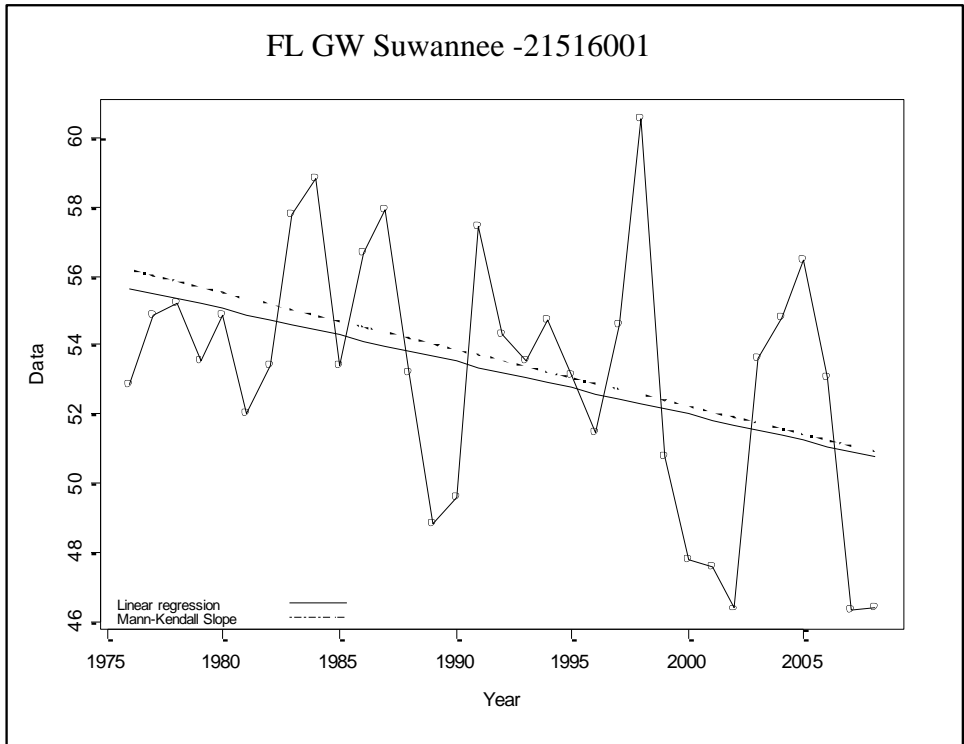


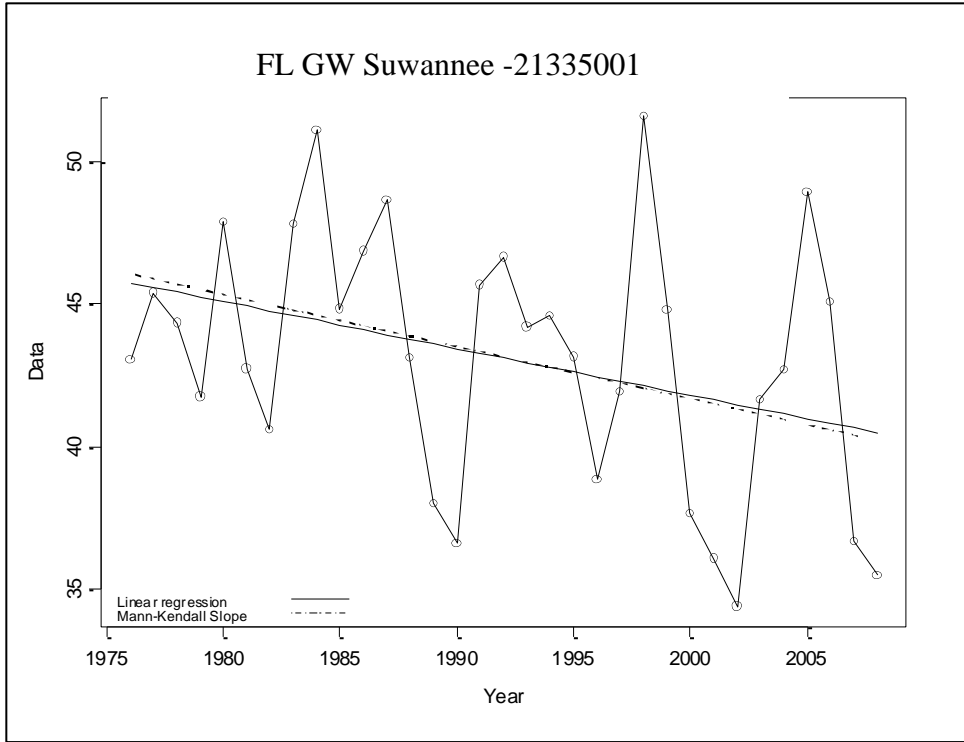
Data = annual average groundwater level in feet above NGVD 1929



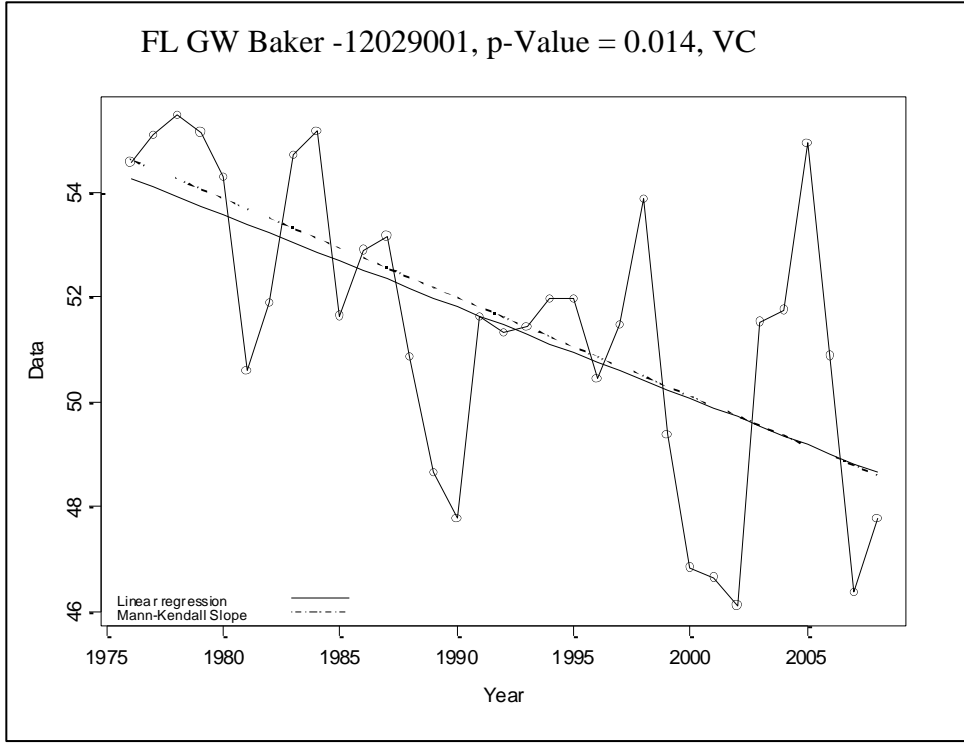


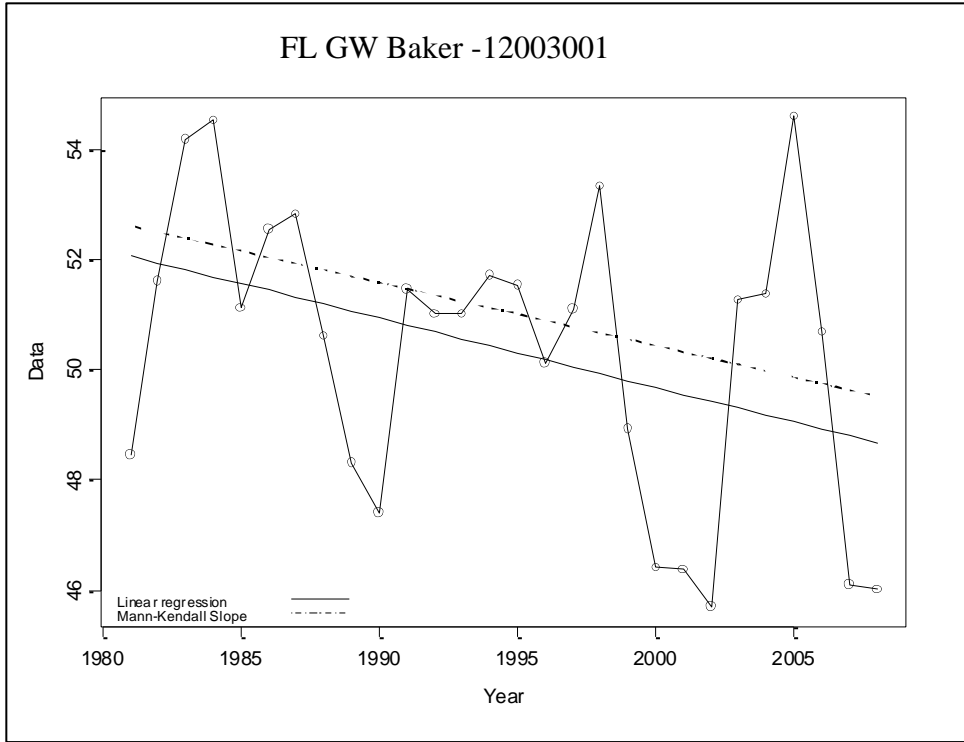
Data = annual average groundwater level in feet above NGVD 1929



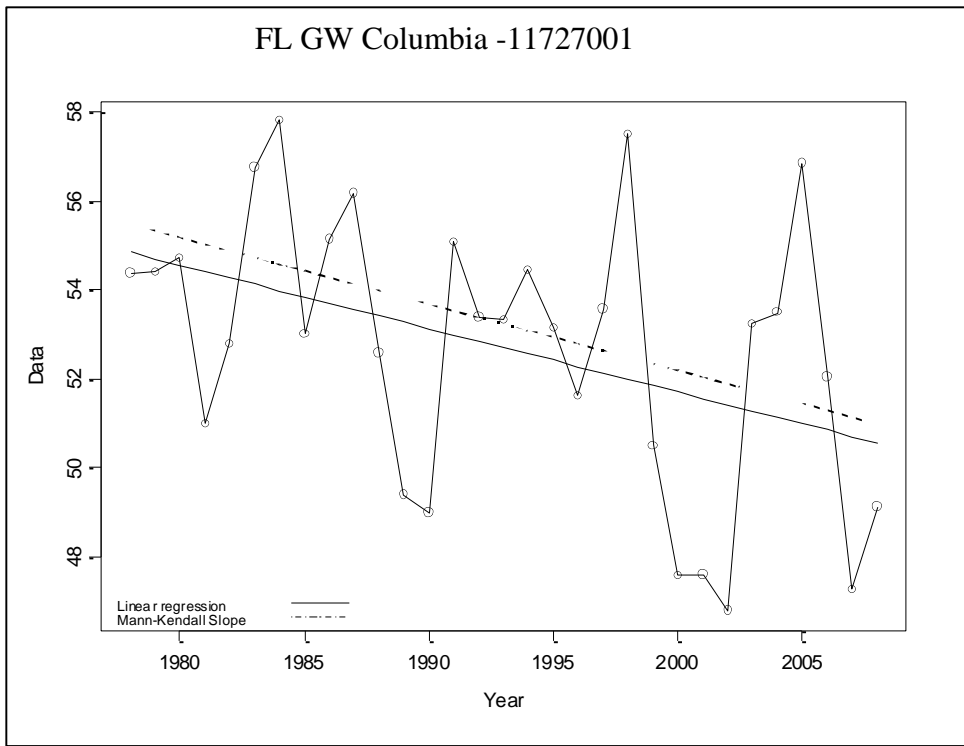


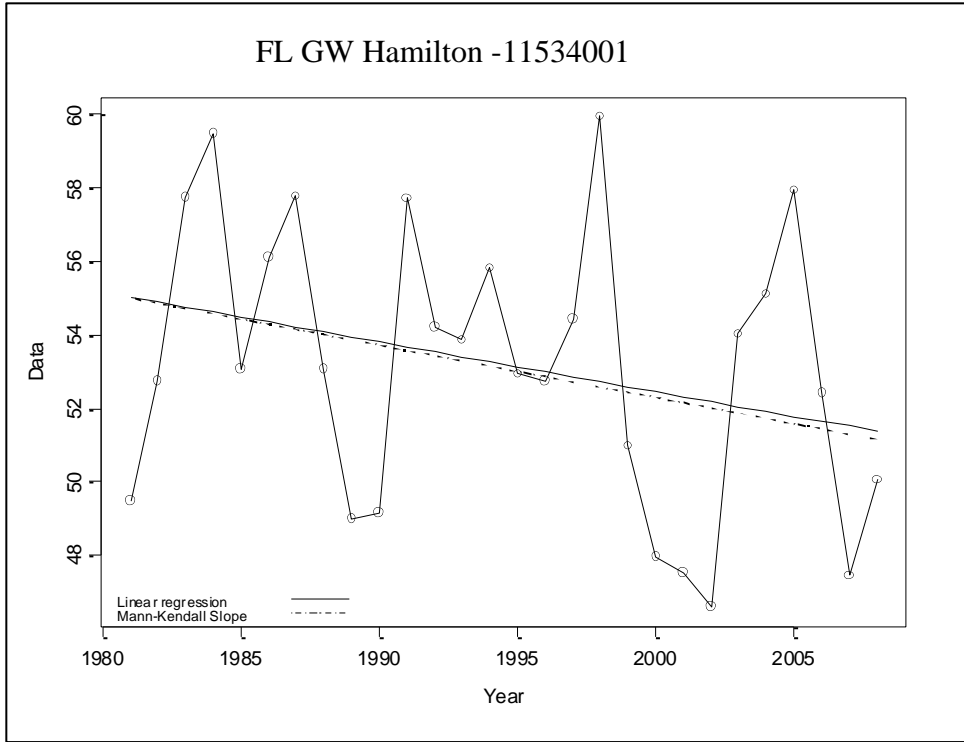
Data = annual average groundwater level in feet above NGVD 1929



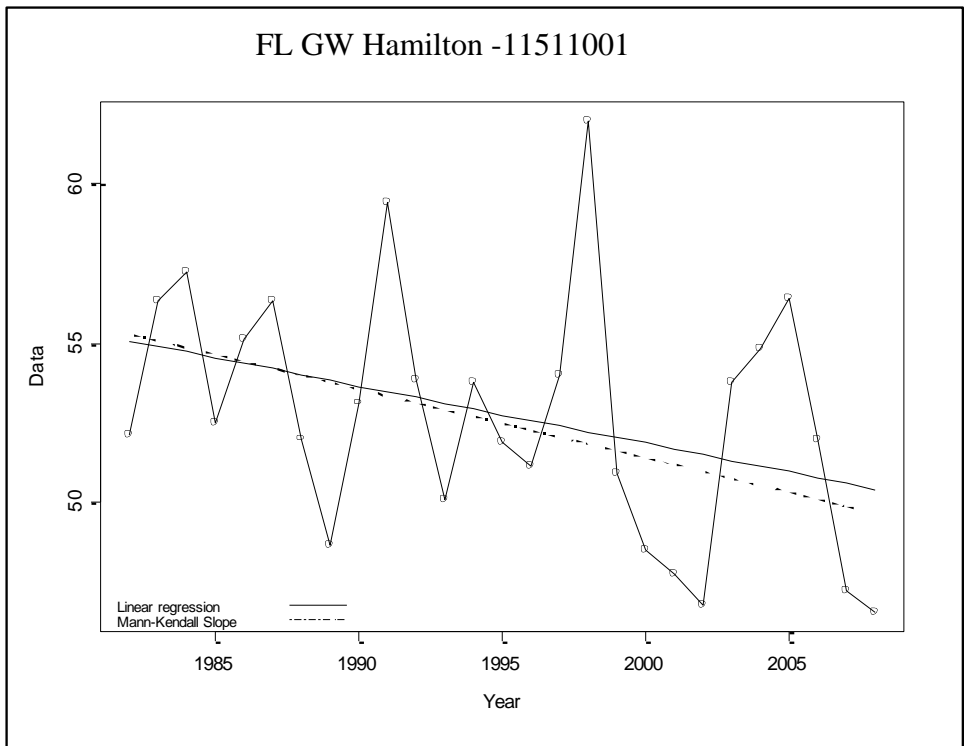


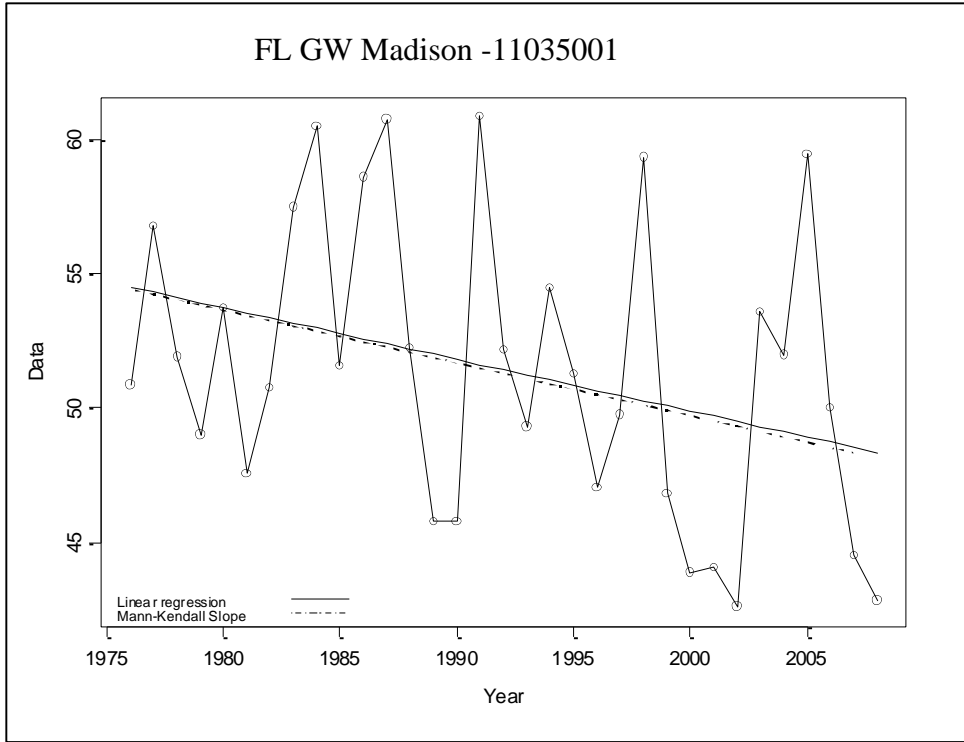
Data = annual average groundwater level in feet above NGVD 1929



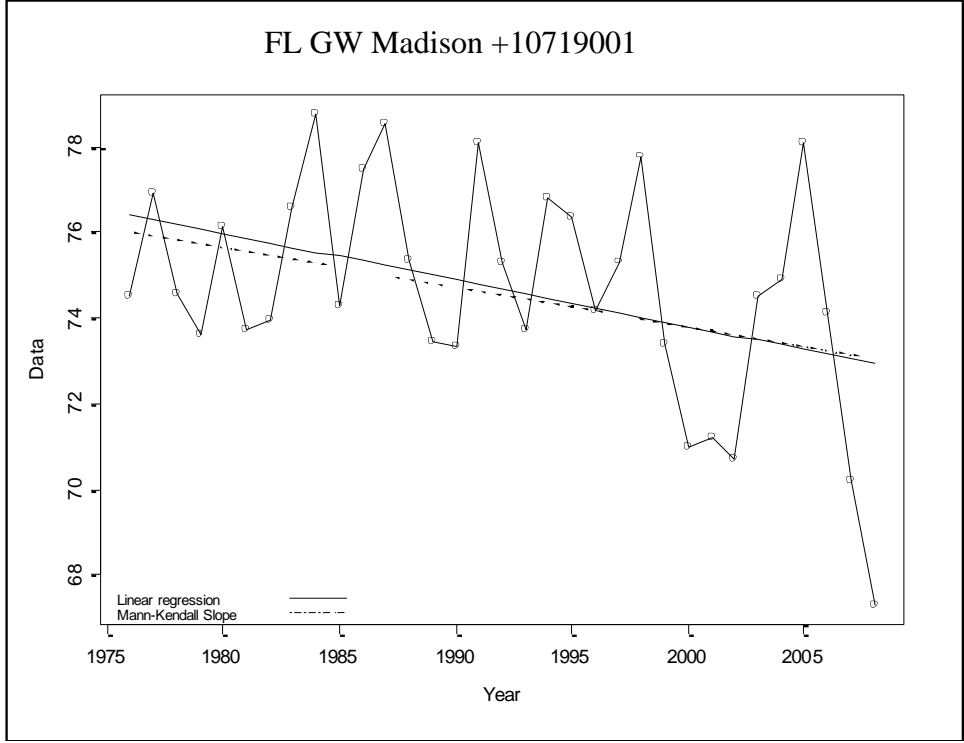


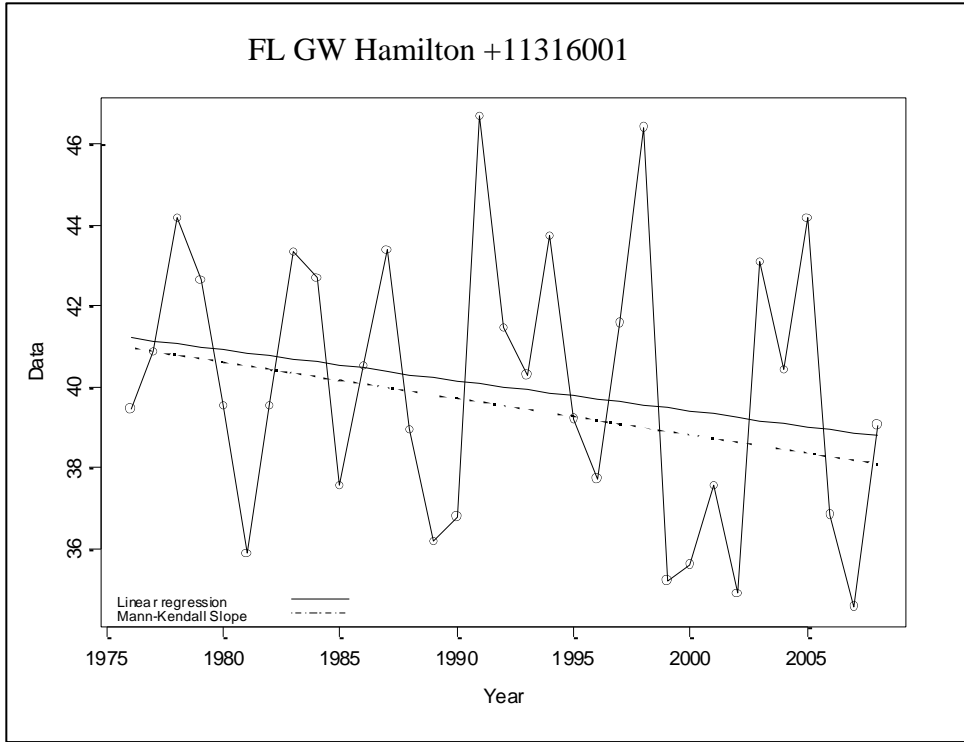
Data = annual average groundwater level in feet above NGVD 1929



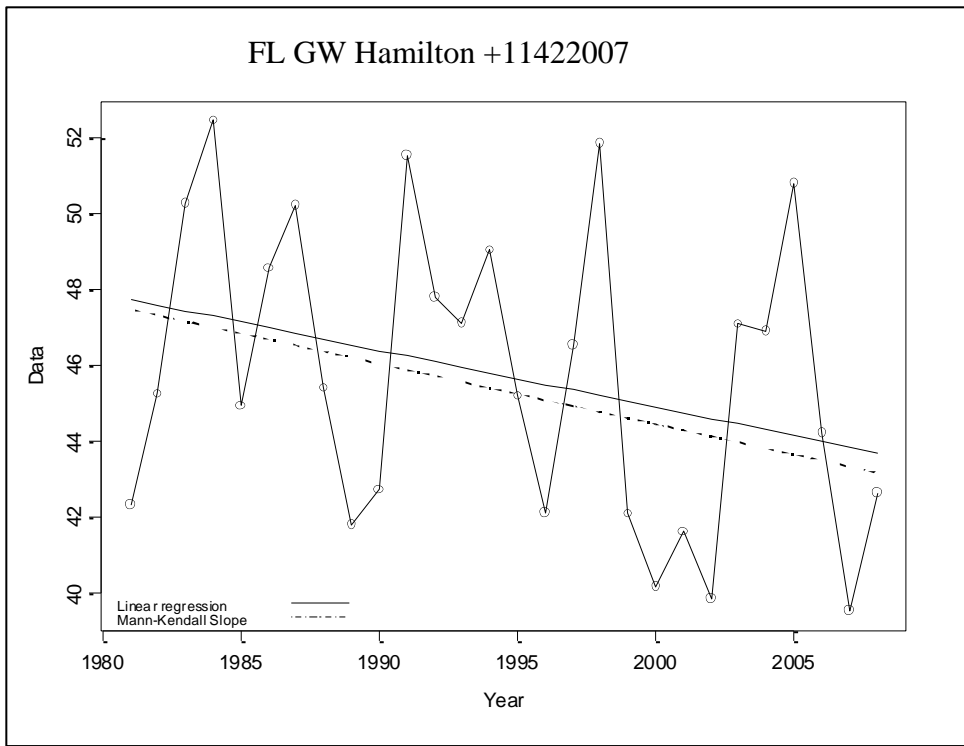


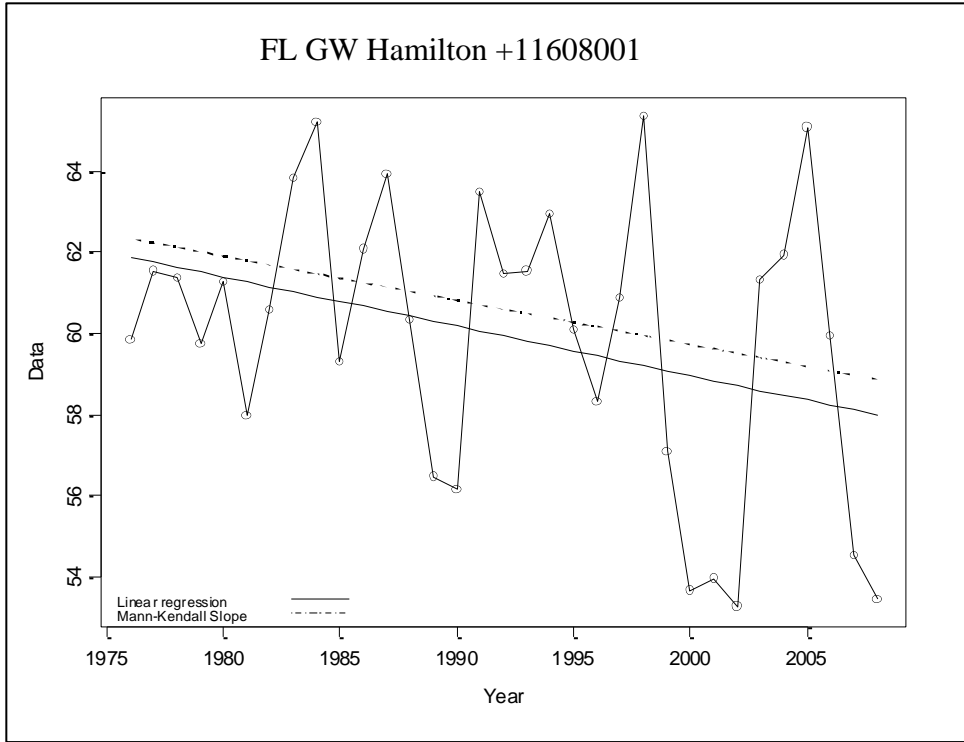
Data = annual average groundwater level in feet above NGVD 1929



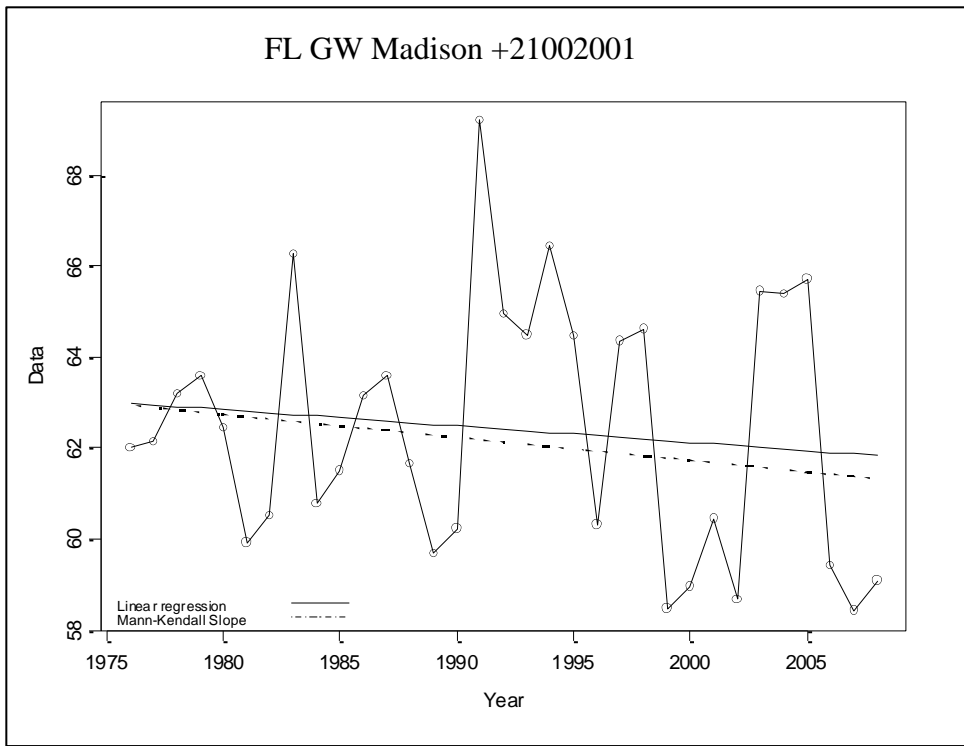


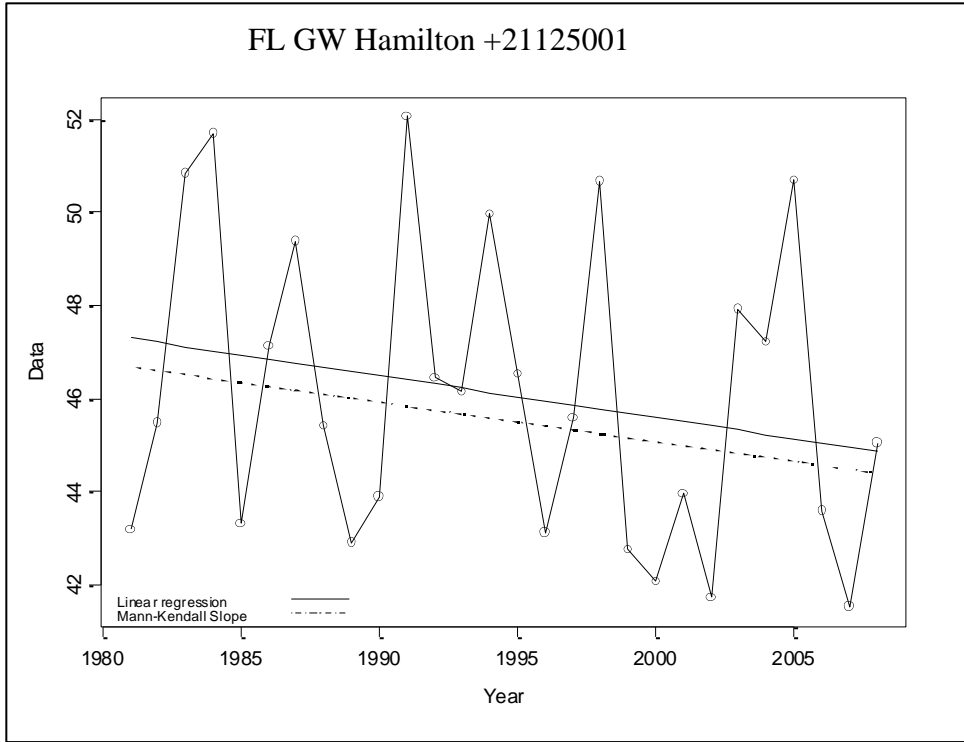
Data = annual average groundwater level in feet above NGVD 1929



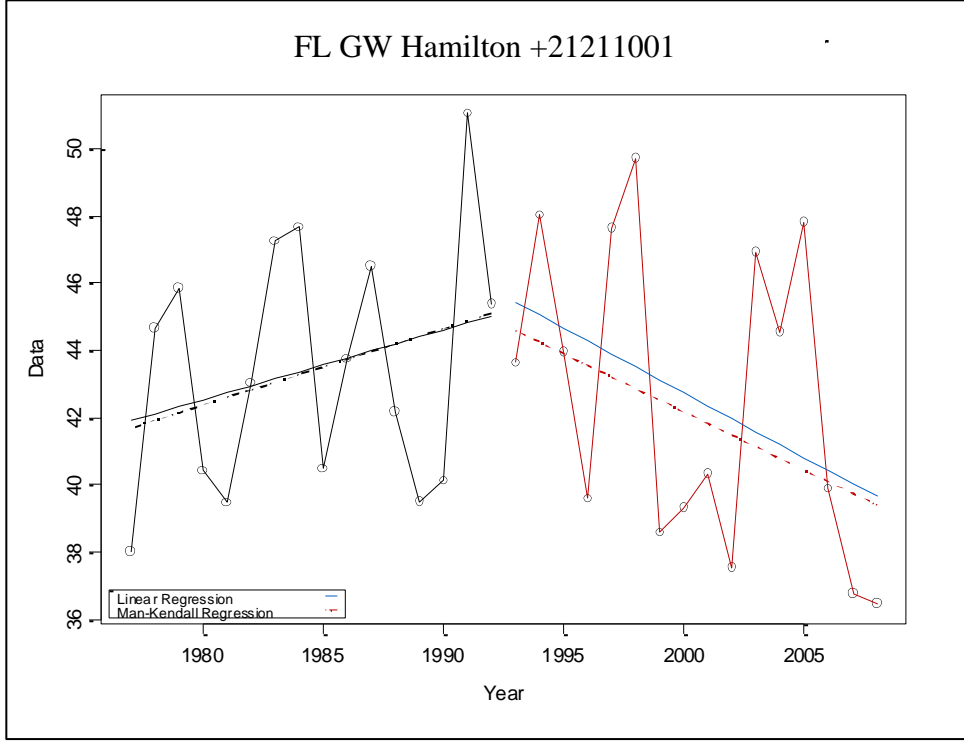


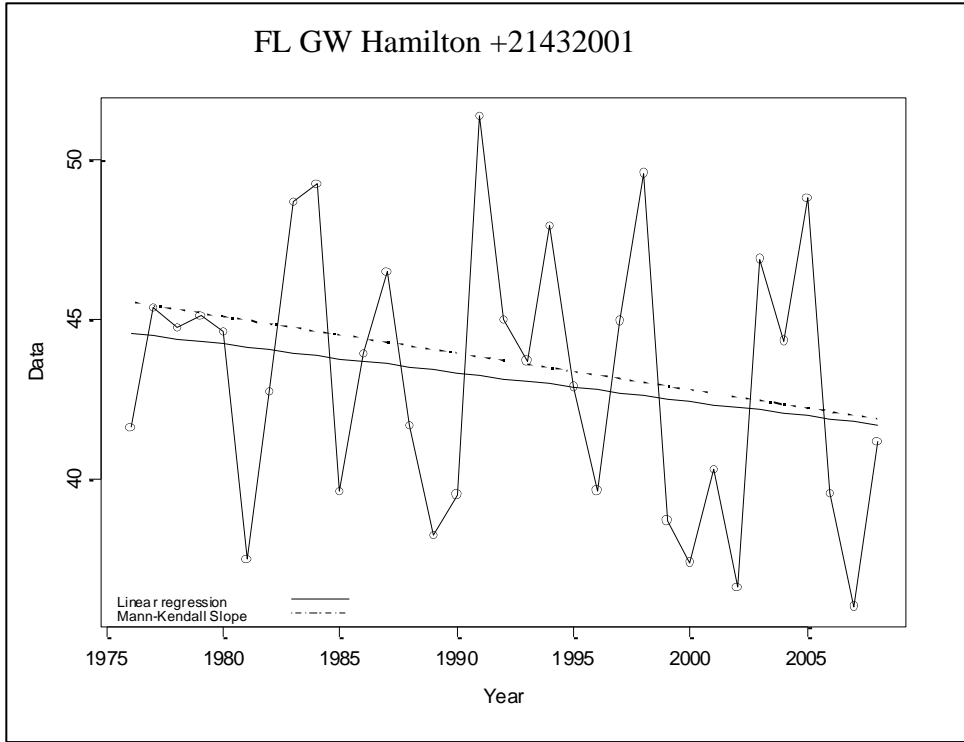
Data = annual average groundwater level in feet above NGVD 1929





Data = annual average groundwater level in feet above NGVD 1929

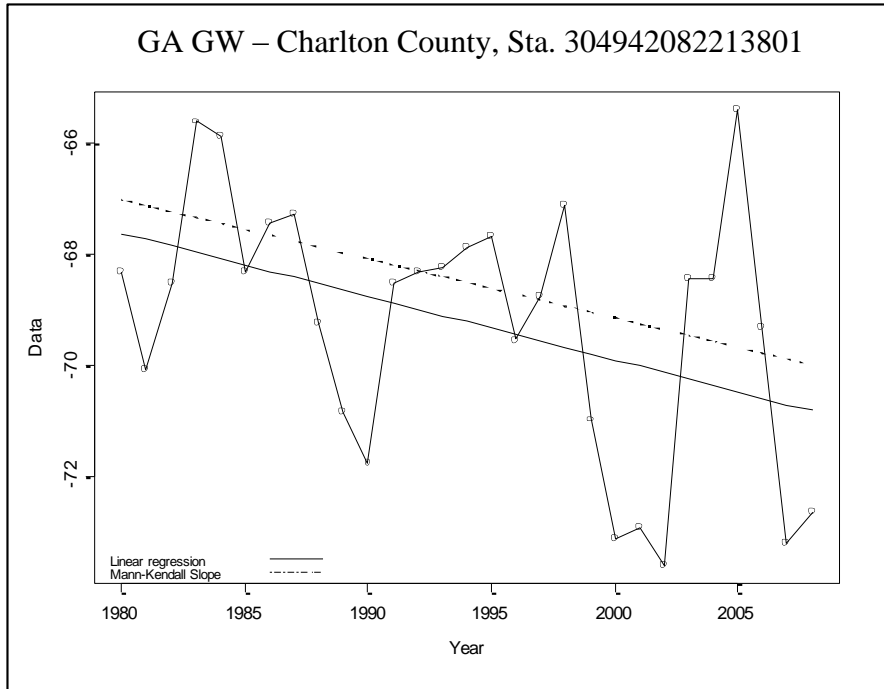




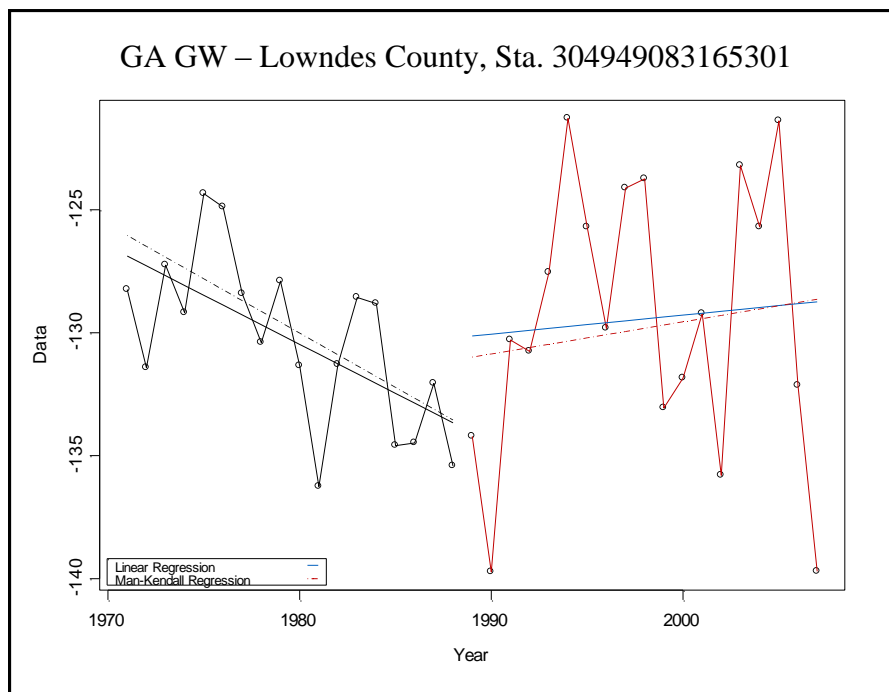
Data = annual average groundwater level in feet above NGVD 1929

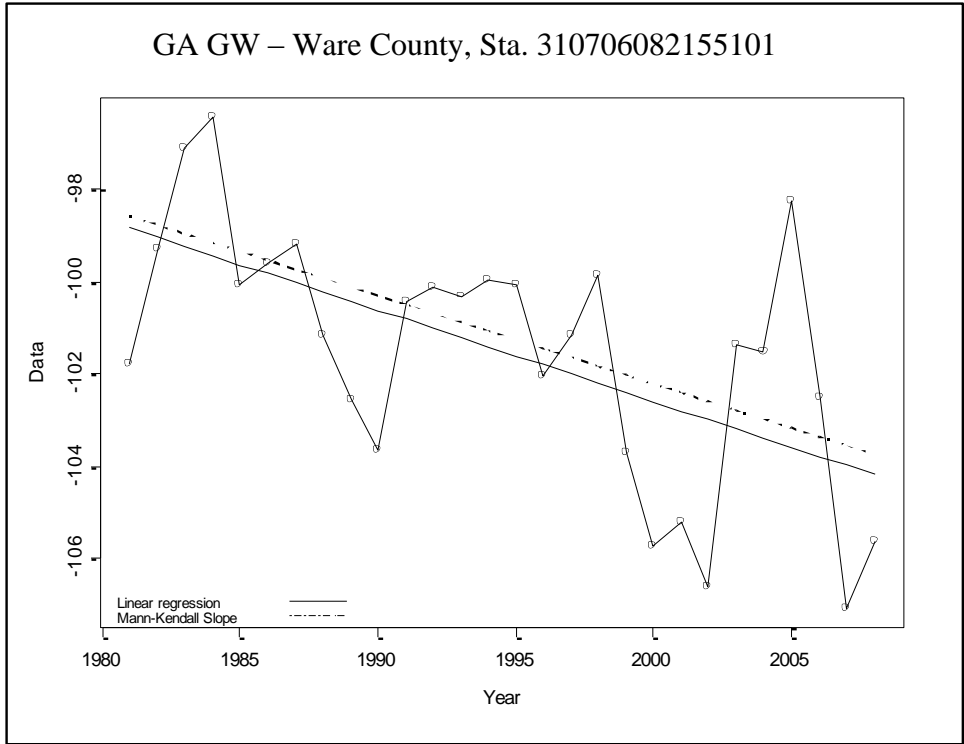
Appendix S2: USGS Georgia Groundwater Level Trend

Following is a summary of the trend detection plots of Georgia groundwater level data. Annual average groundwater level data in feet below land surface were labeled as “data” (y-axes) and plotted against record year (x-axes).

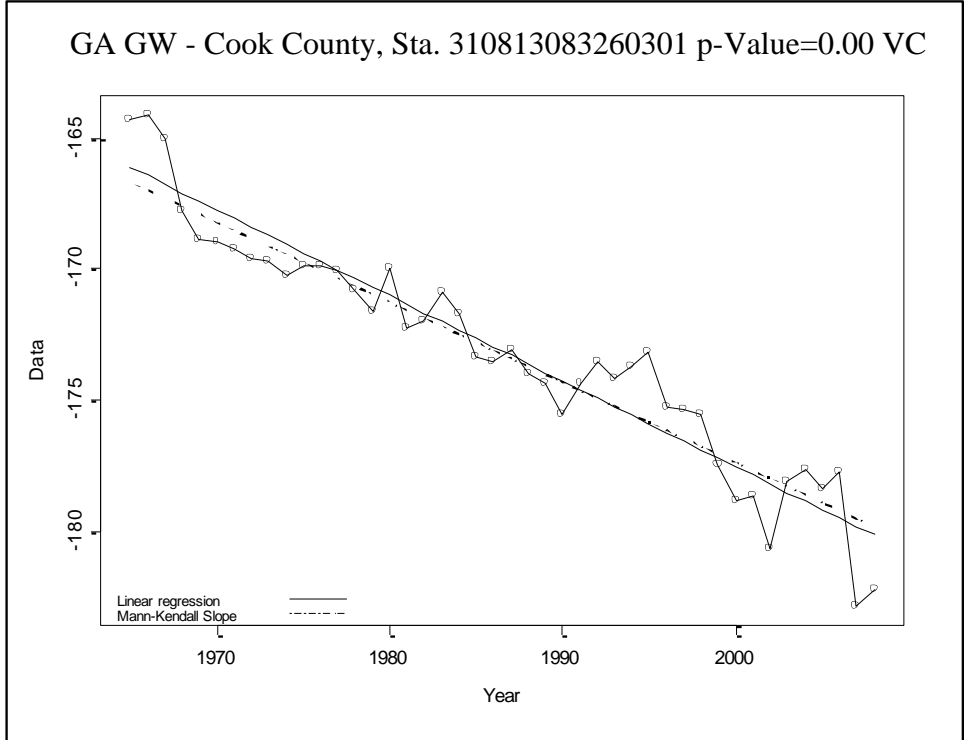


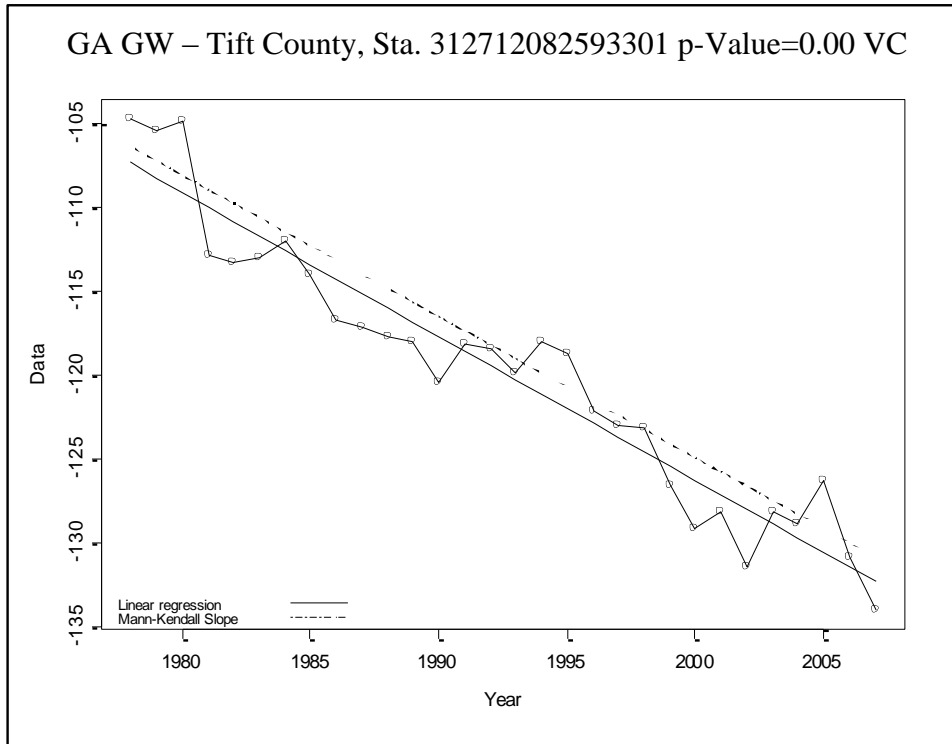
Data = annual average groundwater level in feet referenced to land surface. Negative values indicate groundwater level is below land surface.



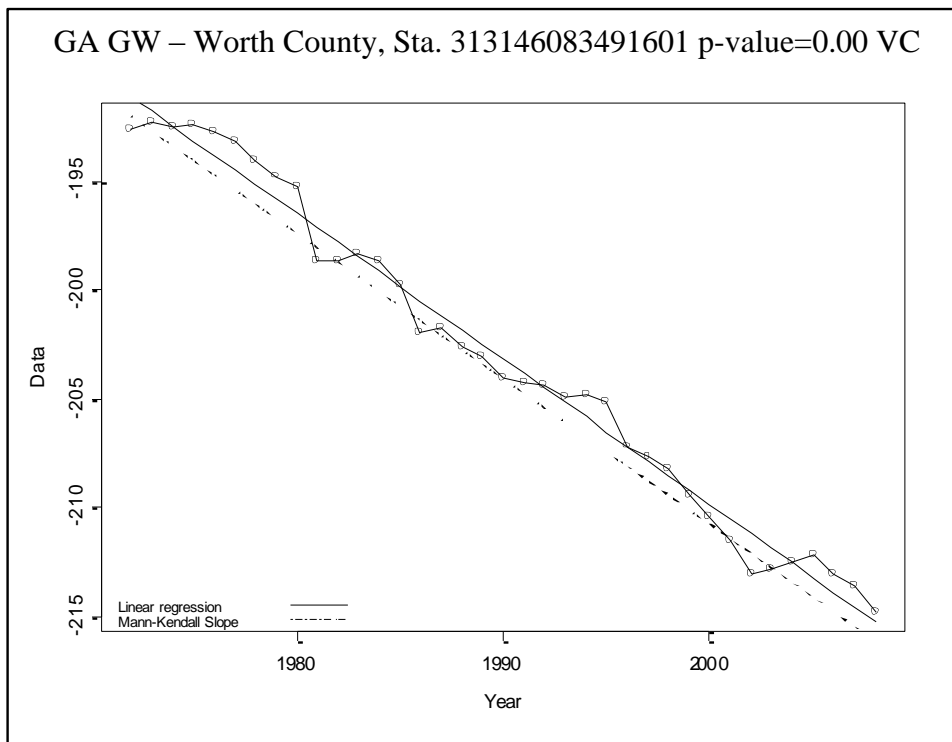


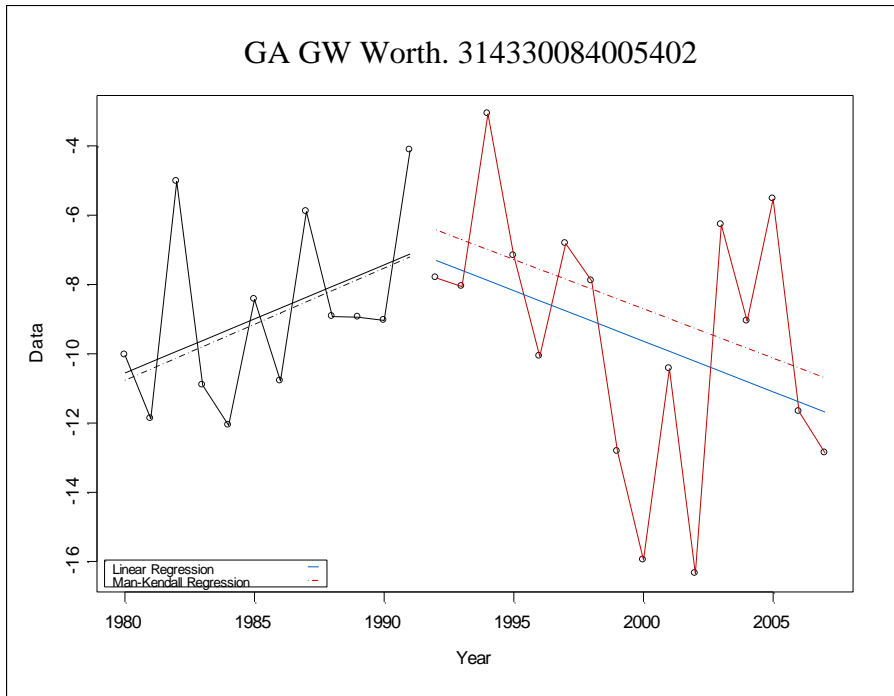
Data = annual average groundwater level in feet referenced to land surface. Negative values indicate groundwater level is below land surface.





Data = annual average groundwater level in feet referenced to land surface. Negative values indicate groundwater level is below land surface.

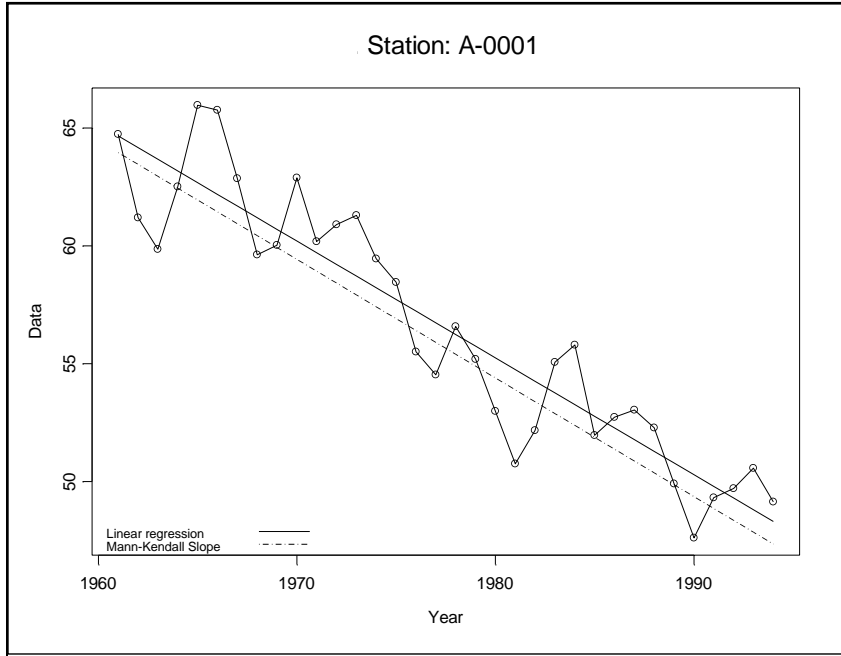




Data = annual average groundwater level in feet referenced to land surface. Negative values indicate groundwater level is below land surface.

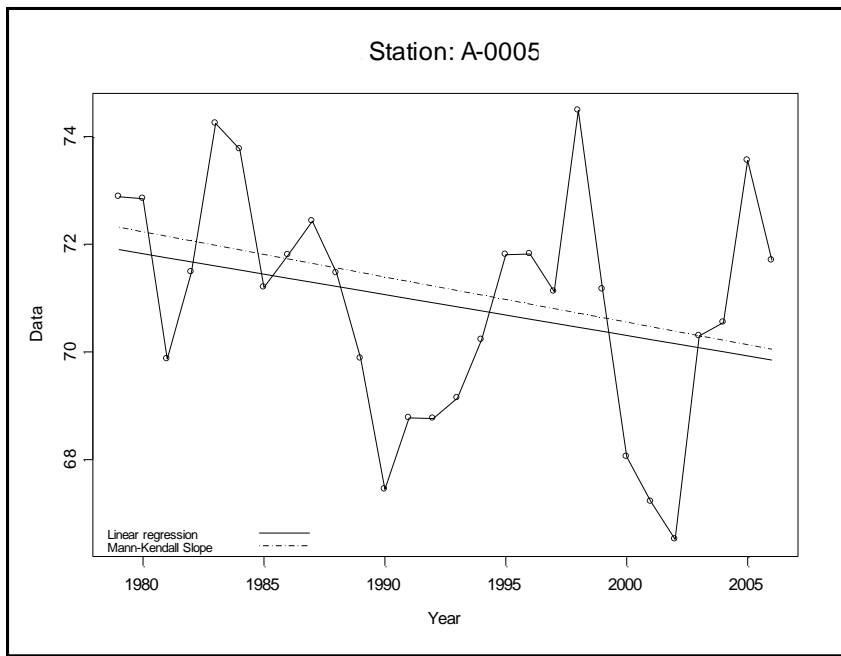
Appendix S3: SJRWMD Groundwater Level Trend

Following is a summary of the trend detection plots of SJRWMD groundwater level data. Annual average groundwater level data in feet below mean sea level were labeled as “data” (y-axes) and plotted against record year (x-axes). Map ID #s refer to Figure 1.3 in the supplemental report.

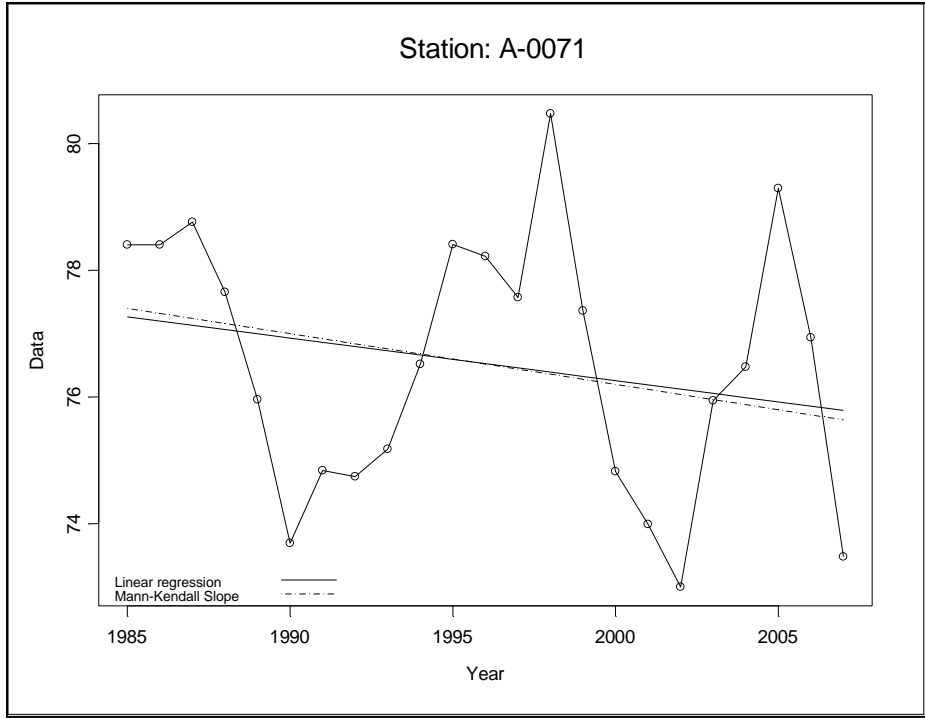


Map ID 53

Data = Annual average groundwater level in feet above mean sea level

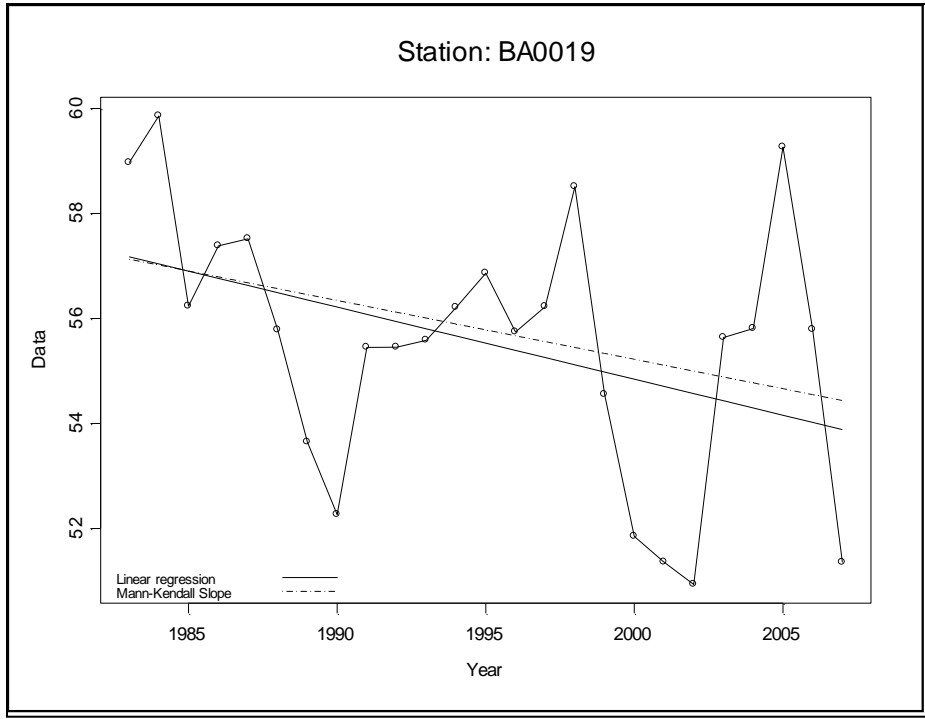


Map ID 54

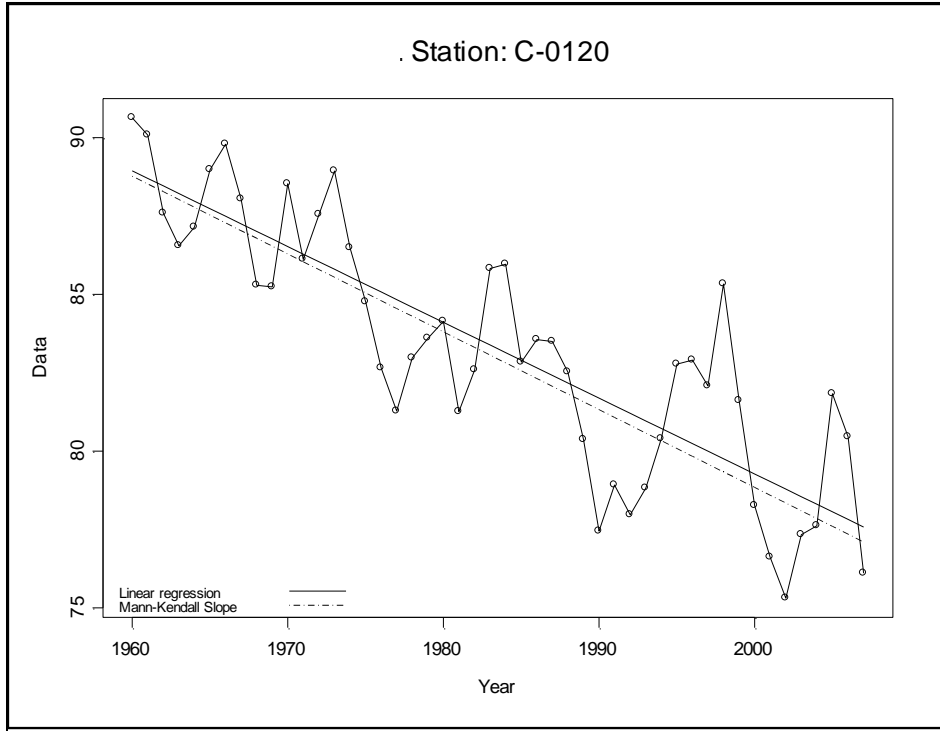


Map ID 55

Data = Annual average groundwater level in feet above mean sea level

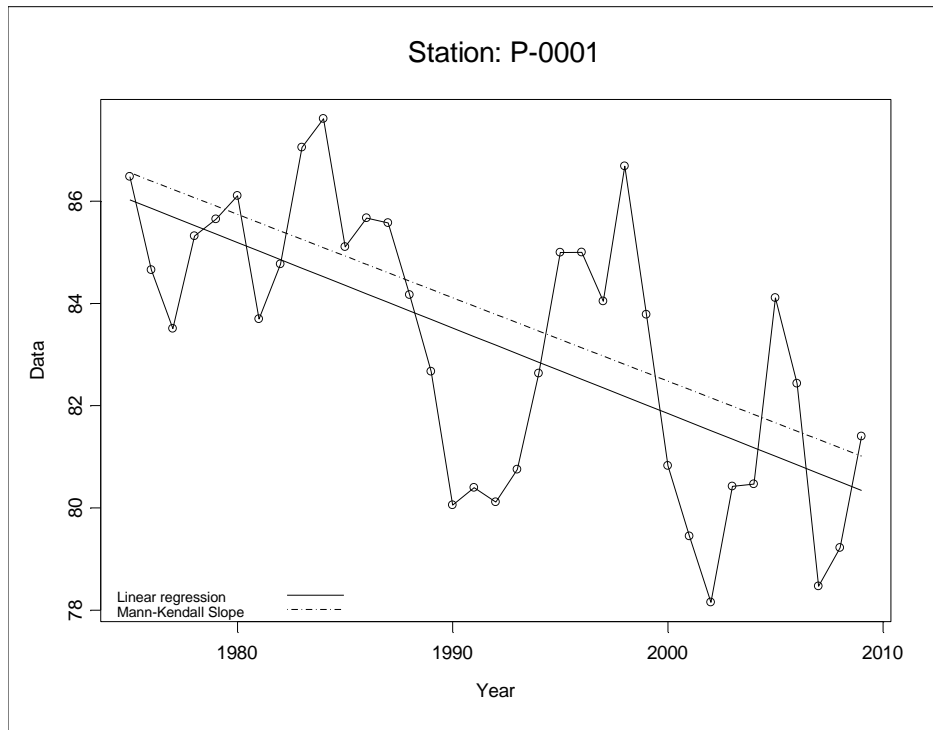


Map ID 56

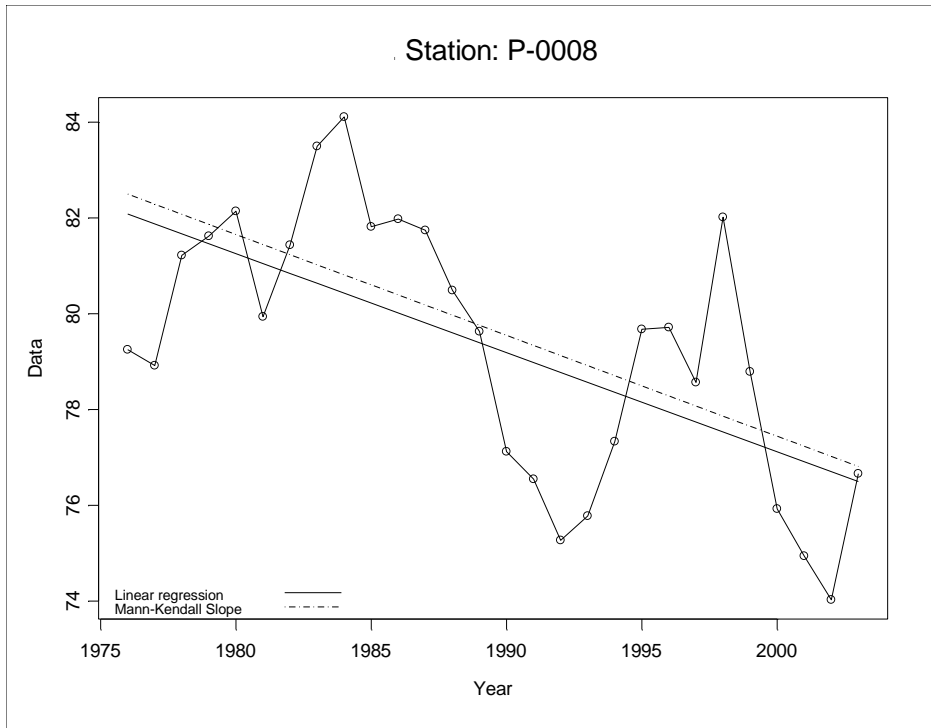


Map ID 57

Data = Annual average groundwater level in feet above mean sea level

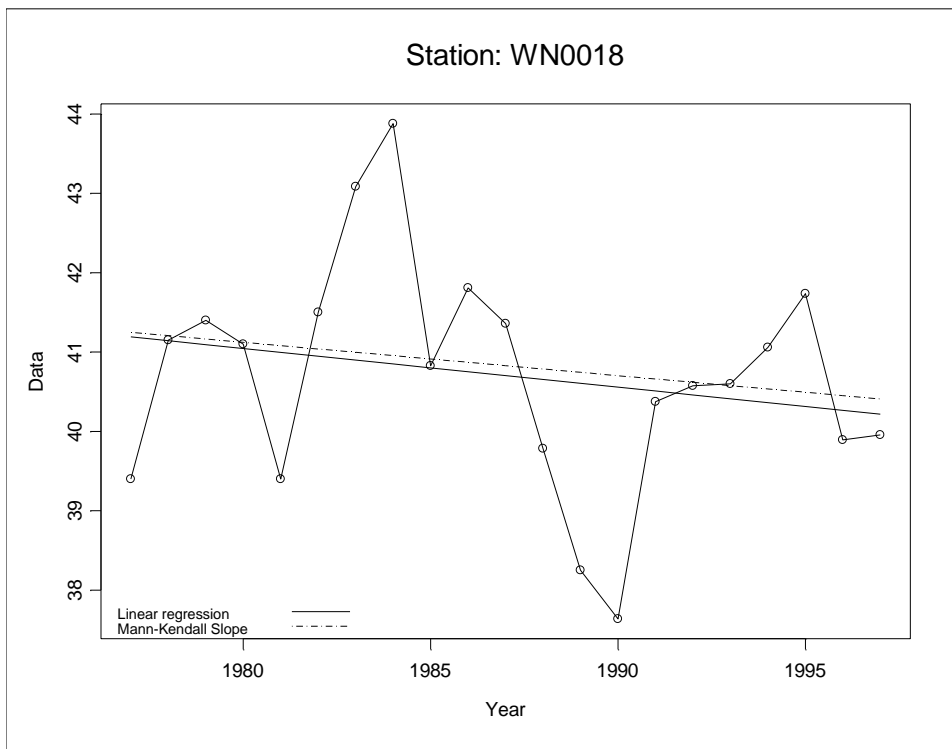


Map ID 58

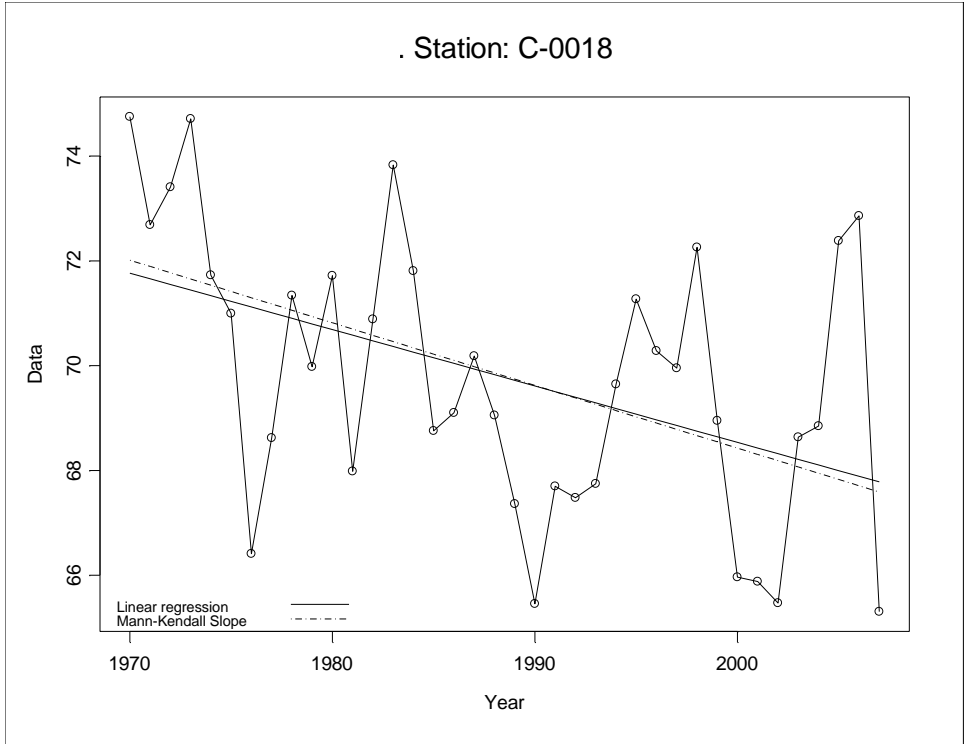


Map ID 59

Data = Annual average groundwater level in feet above mean sea level

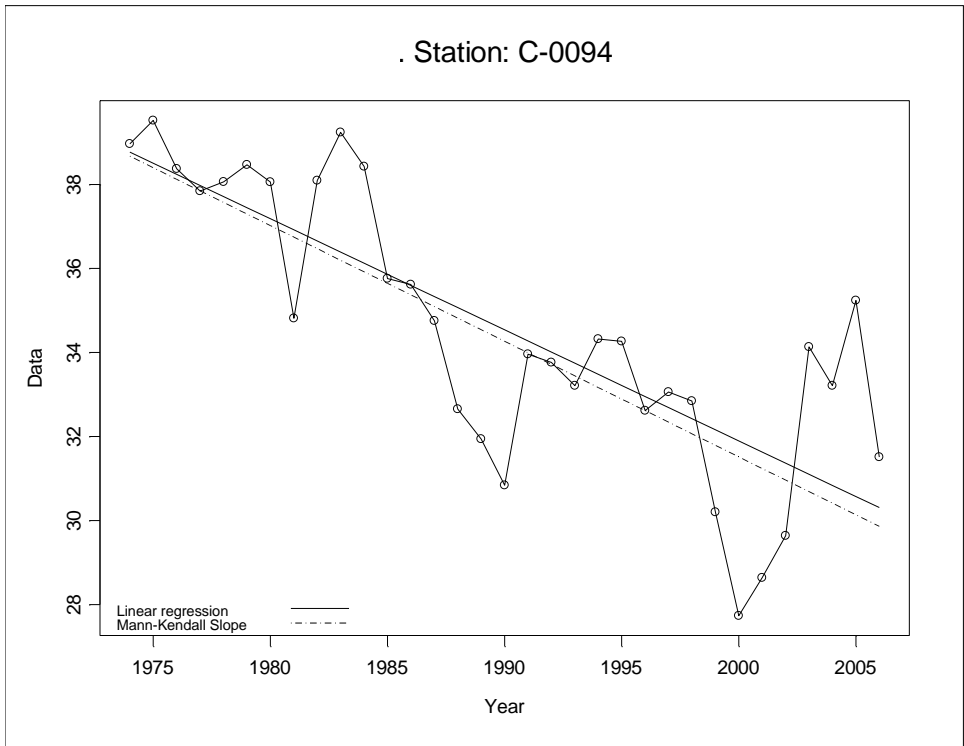


Map ID 61

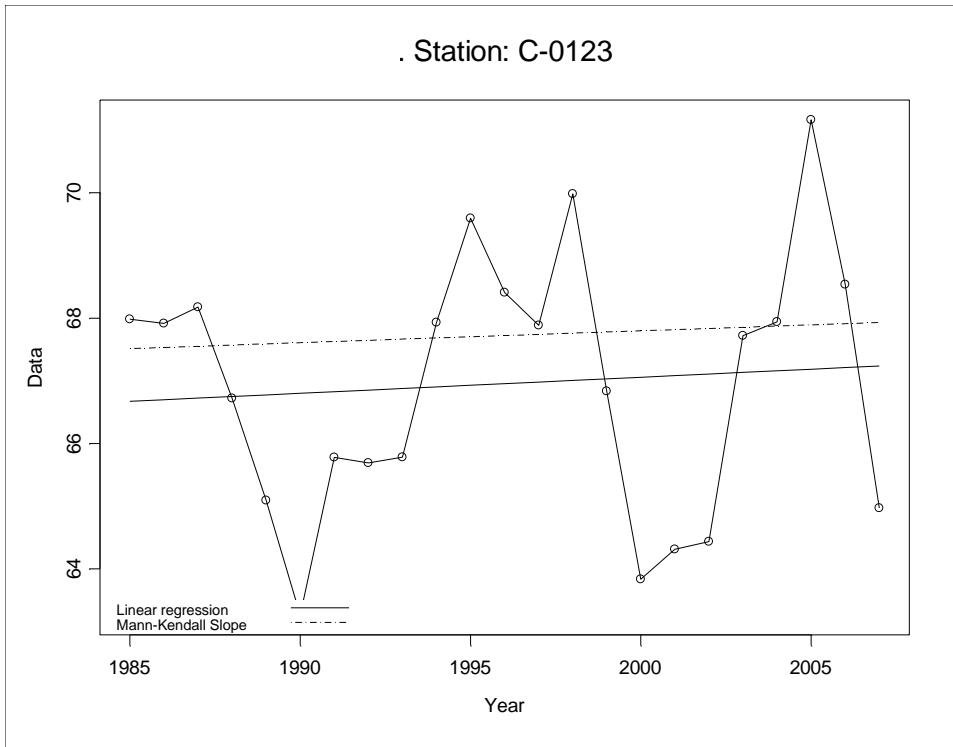


Map ID 62

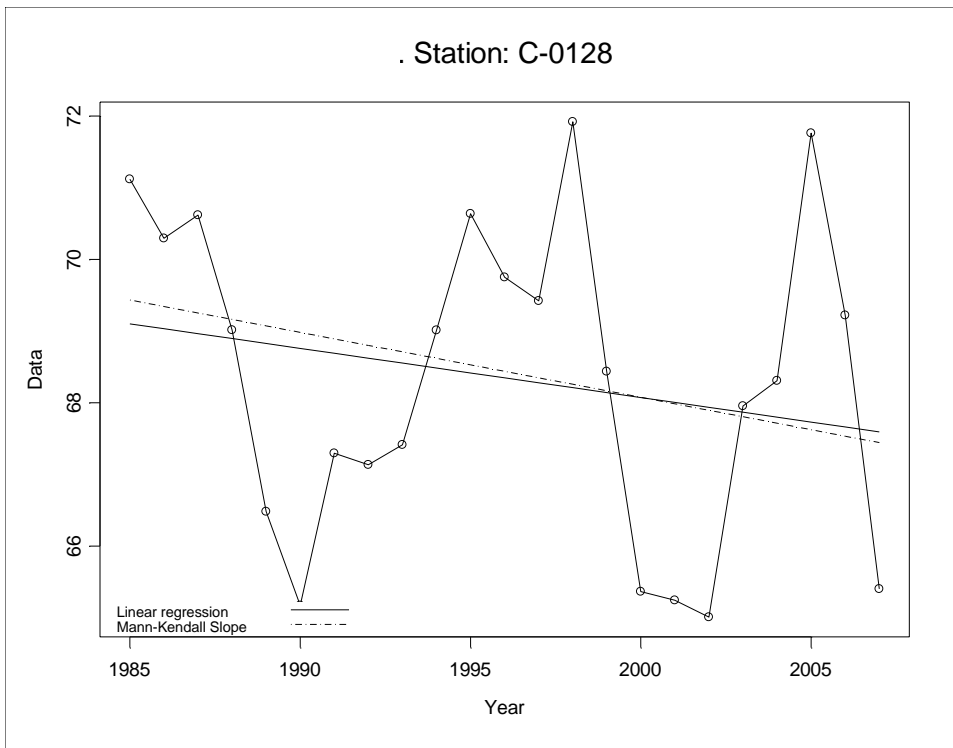
Data = Annual average groundwater level in feet above mean sea level

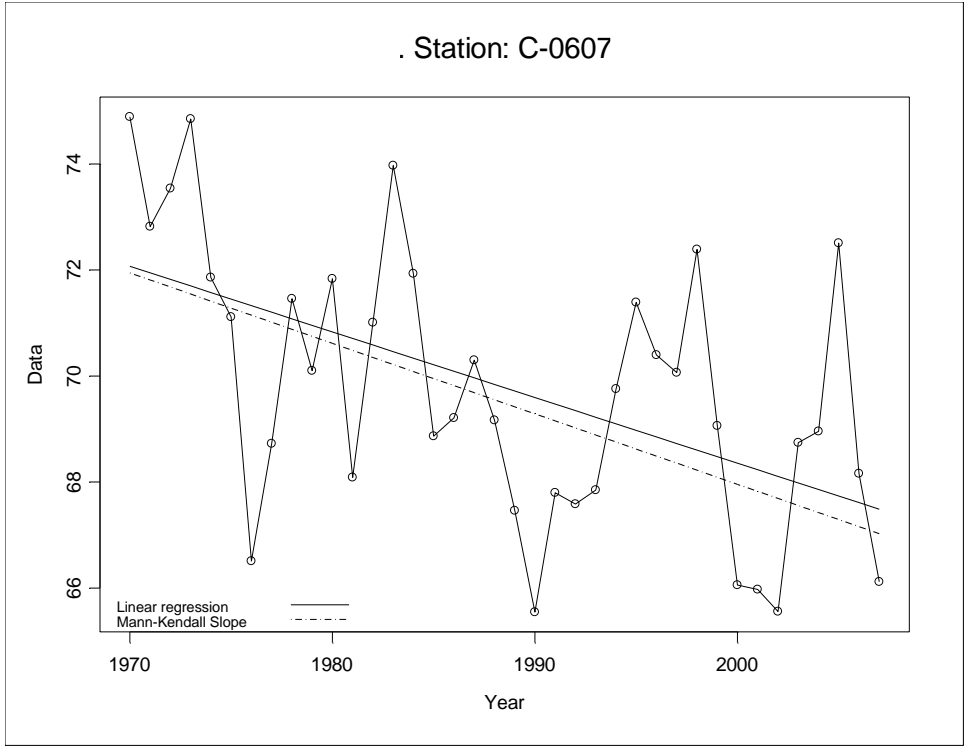


Map ID 63



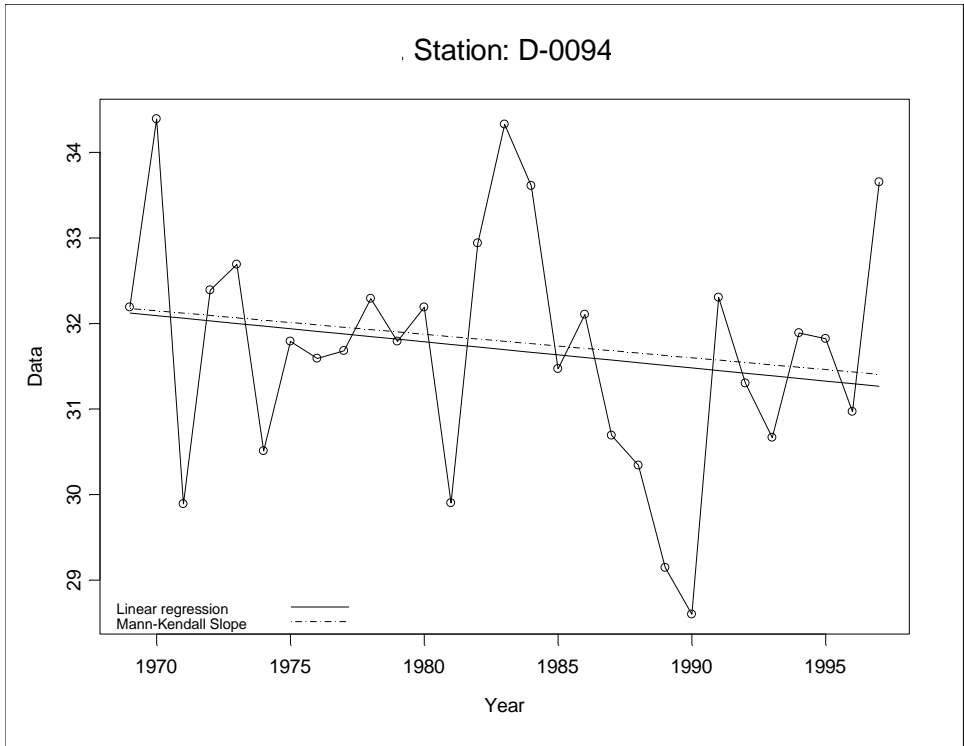
Data = Annual average groundwater level in feet above mean sea level



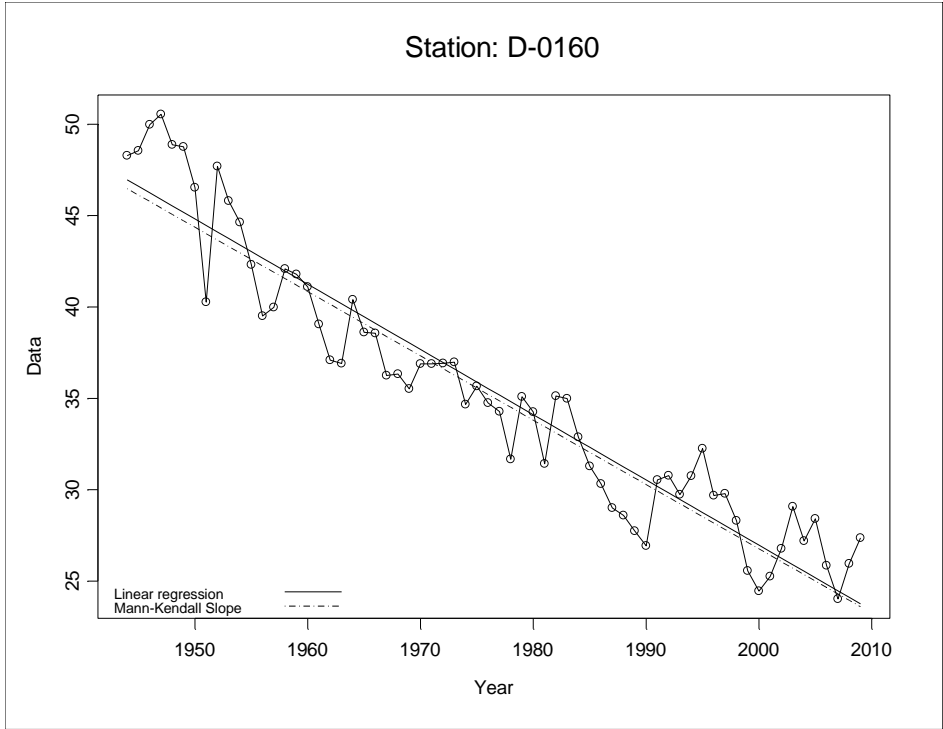


Map ID 66

Data = Annual average groundwater level in feet above mean sea level

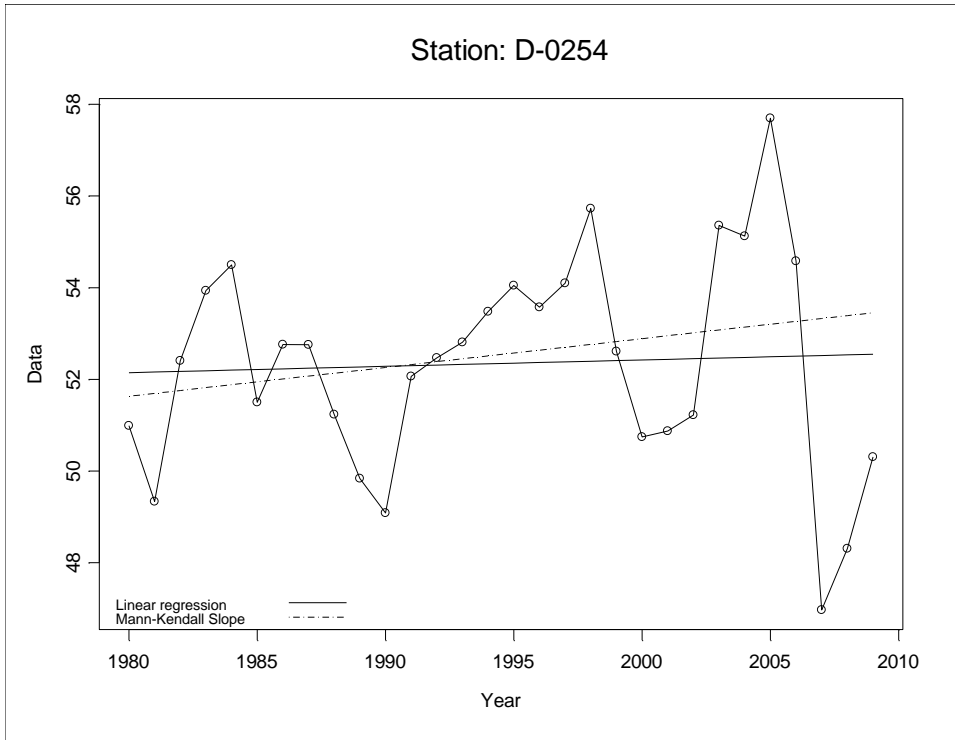


Map ID 67

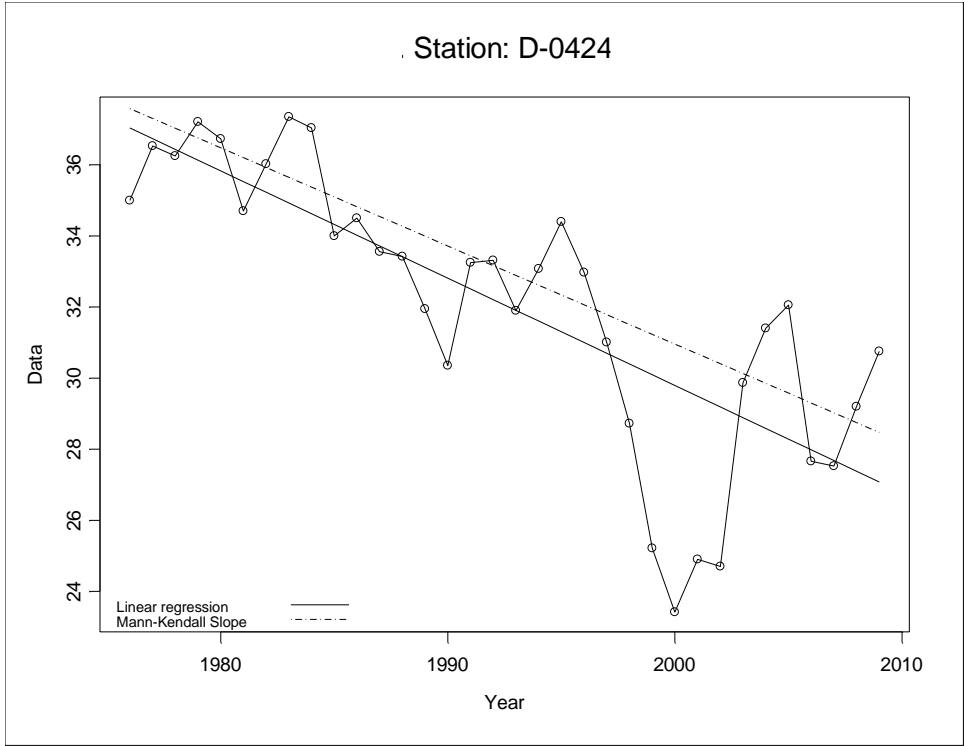


Map ID 68

Data = Annual average groundwater level in feet above mean sea level

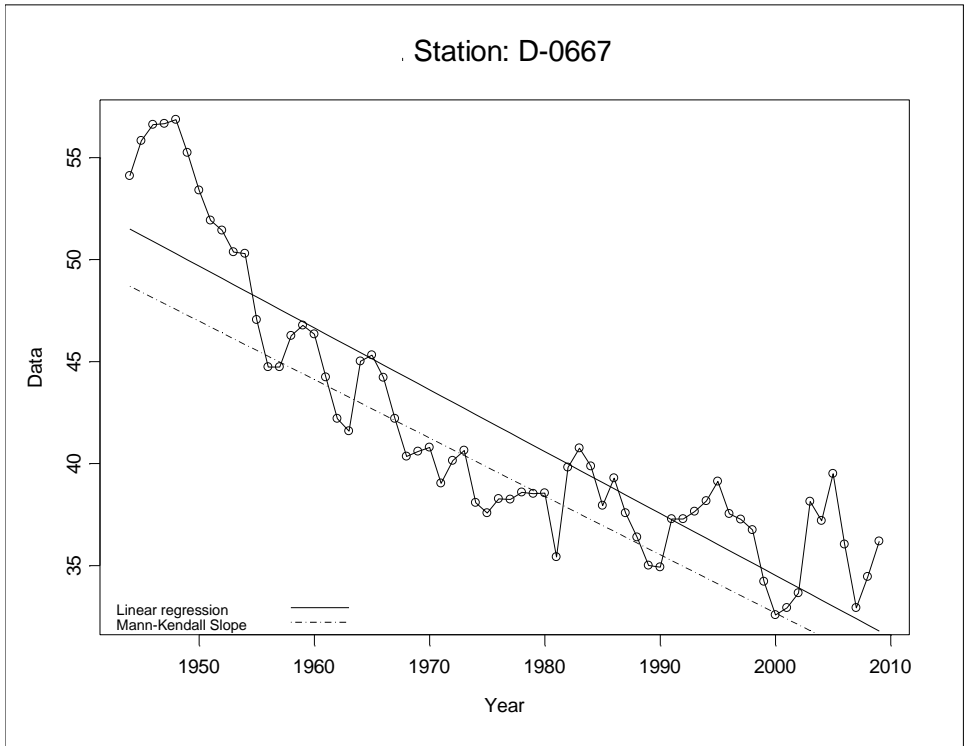


Map ID 69

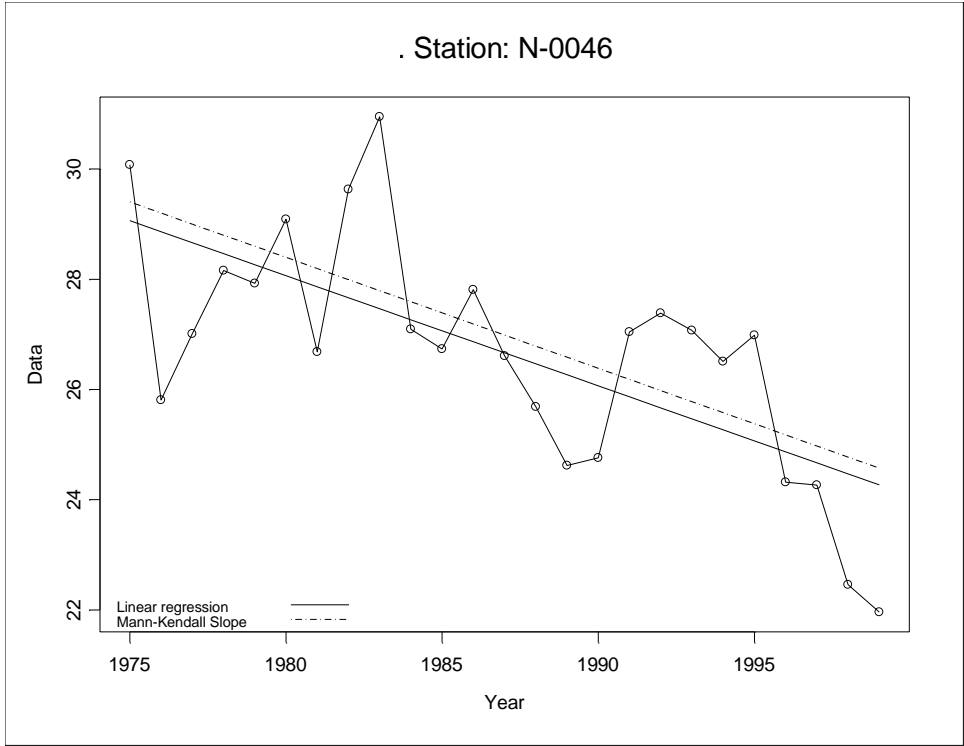


Map ID 70

Data = Annual average groundwater level in feet above mean sea level

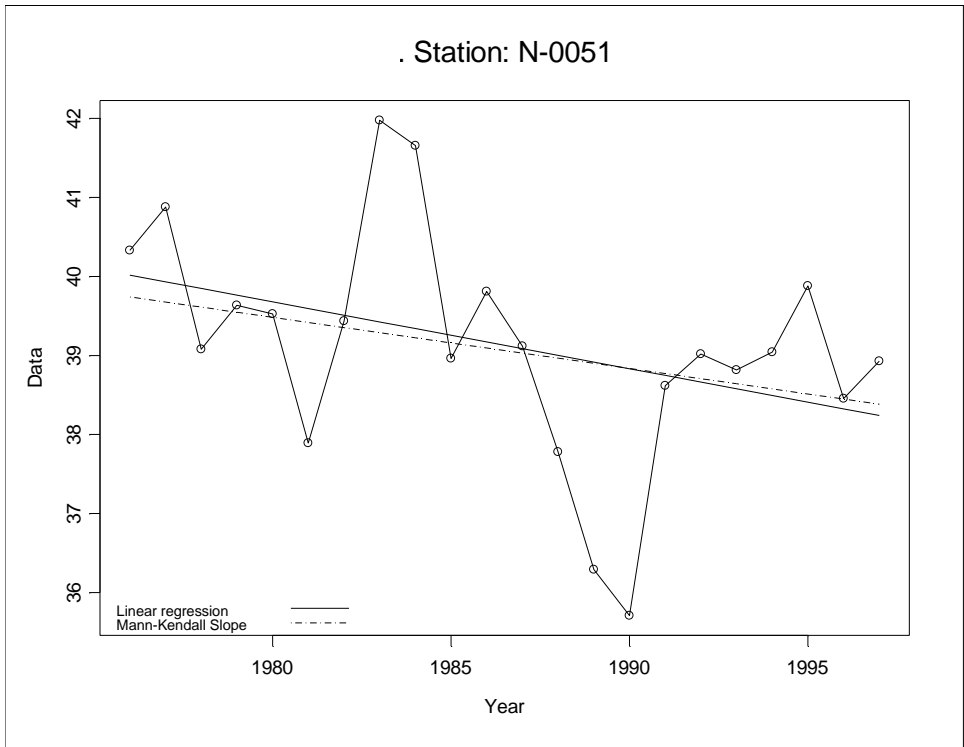


Map ID 71

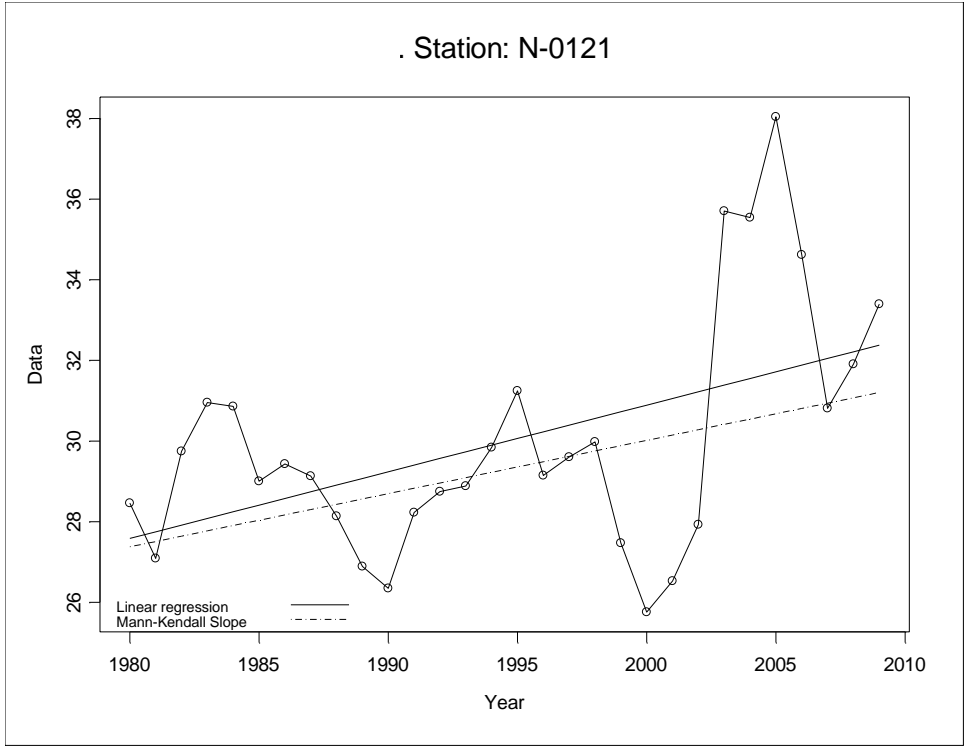


Map ID 72

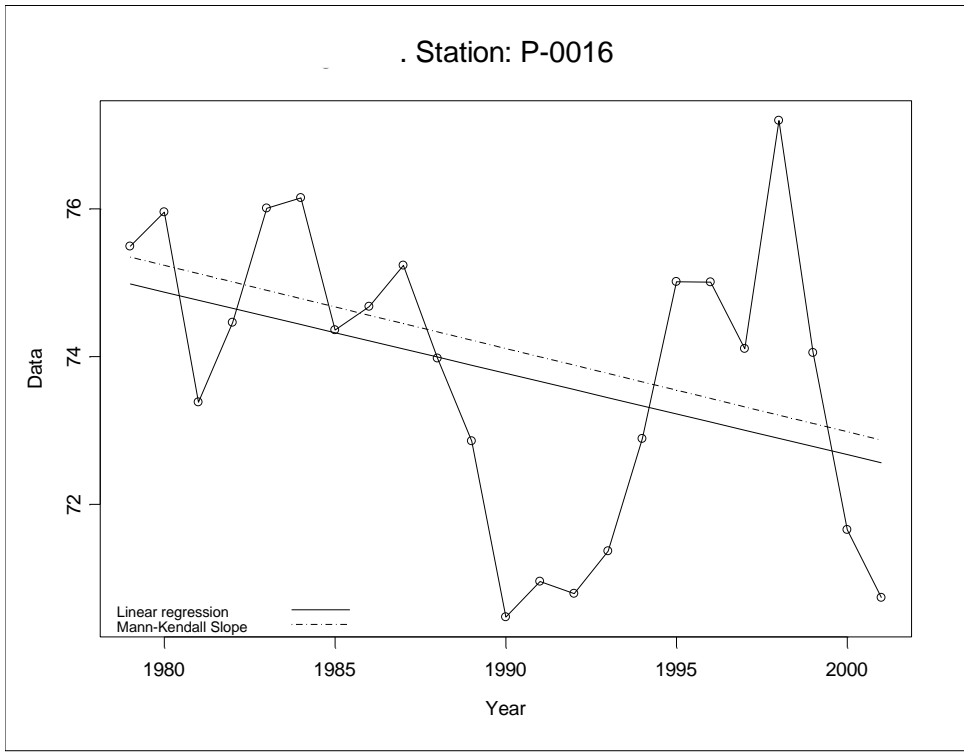
Data = Annual average groundwater level in feet above mean sea level

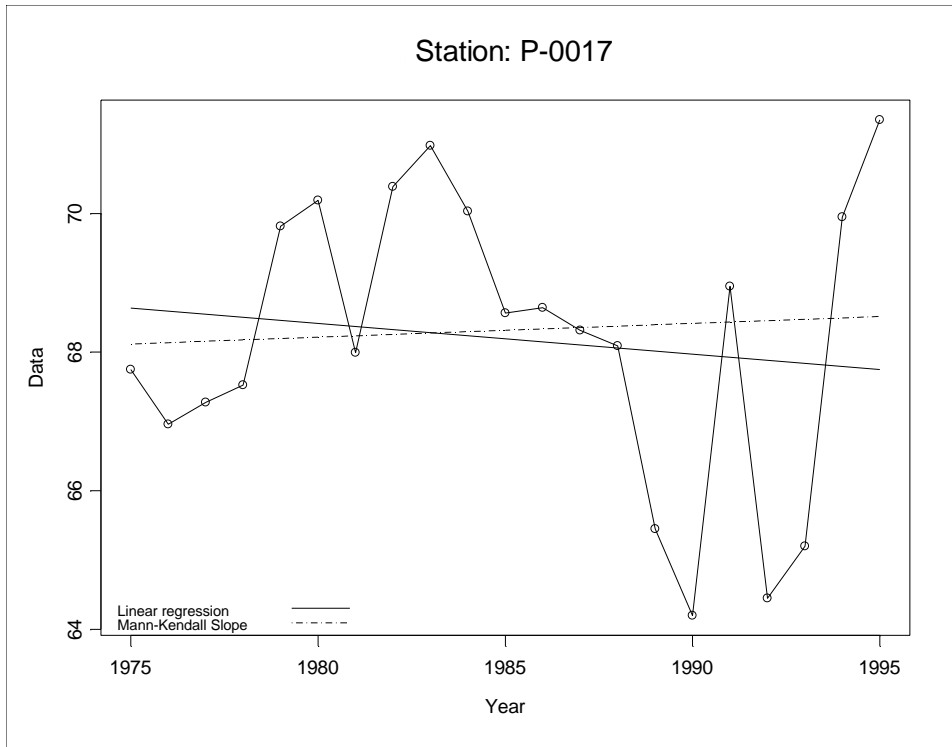


Map ID 73



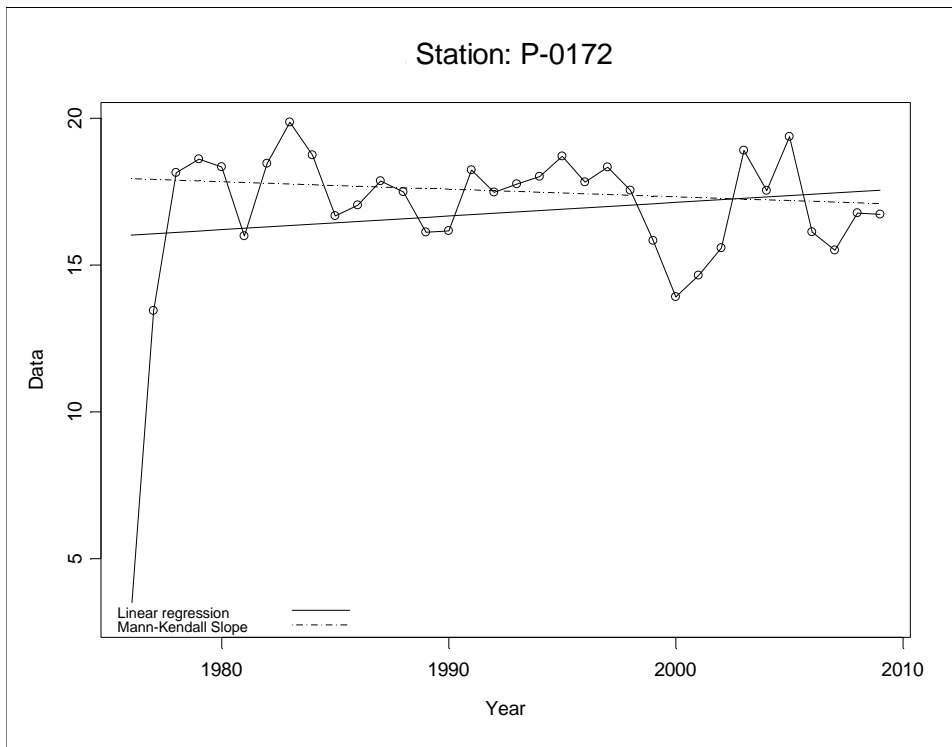
Data = Annual average groundwater level in feet above mean sea level



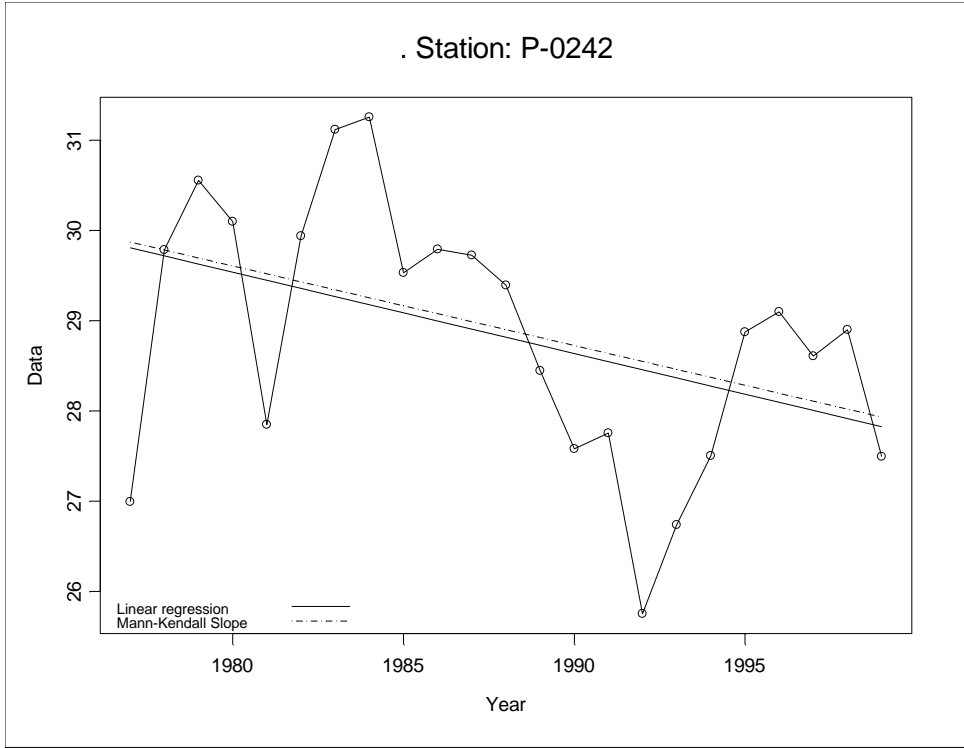


Map ID 76

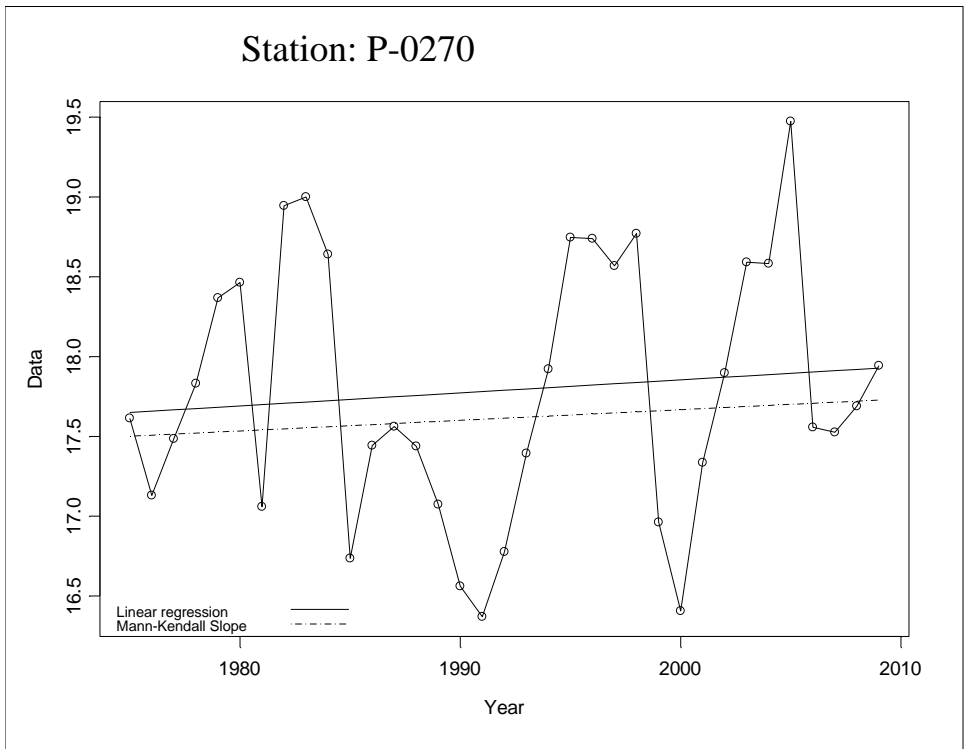
Data = Annual average groundwater level in feet above mean sea level

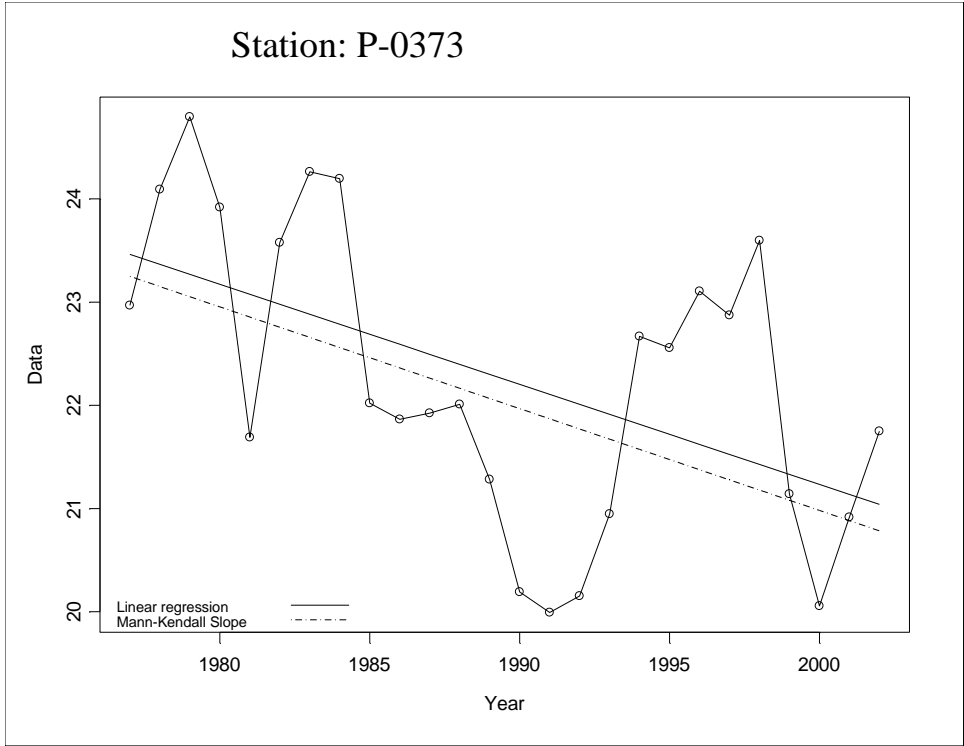


Map ID 77



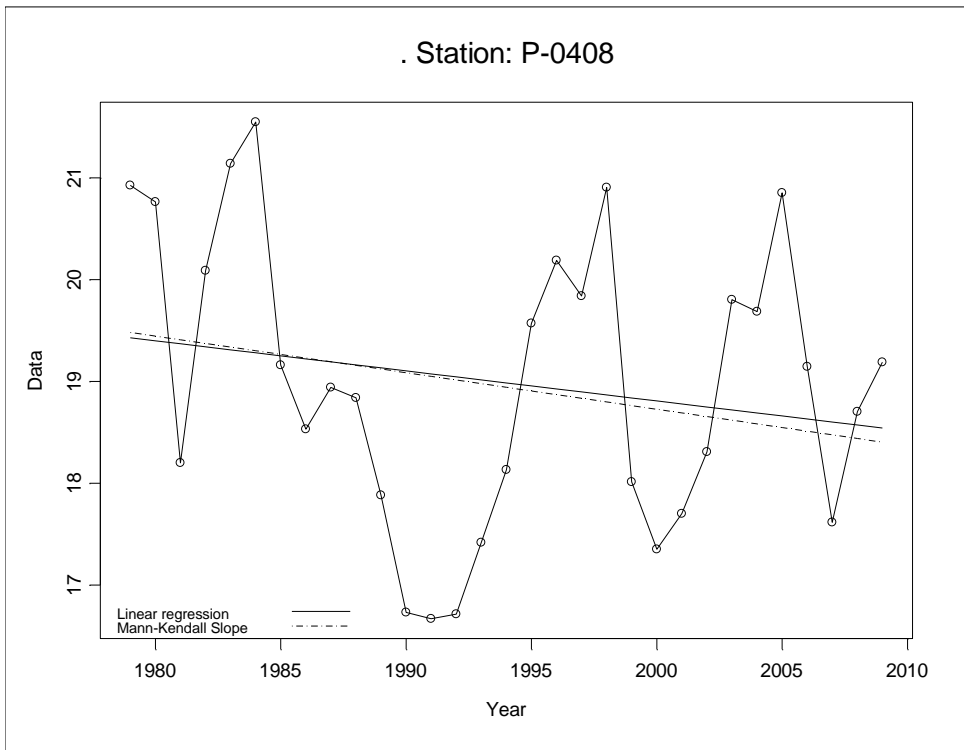
Data = Annual average groundwater level in feet above mean sea level



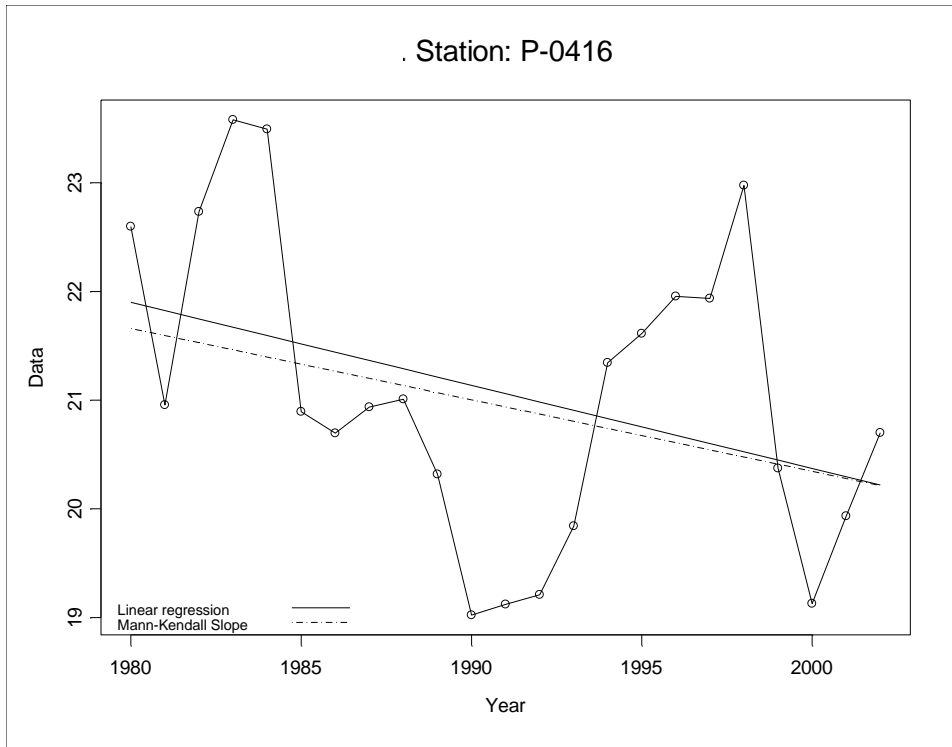


Map ID: 80

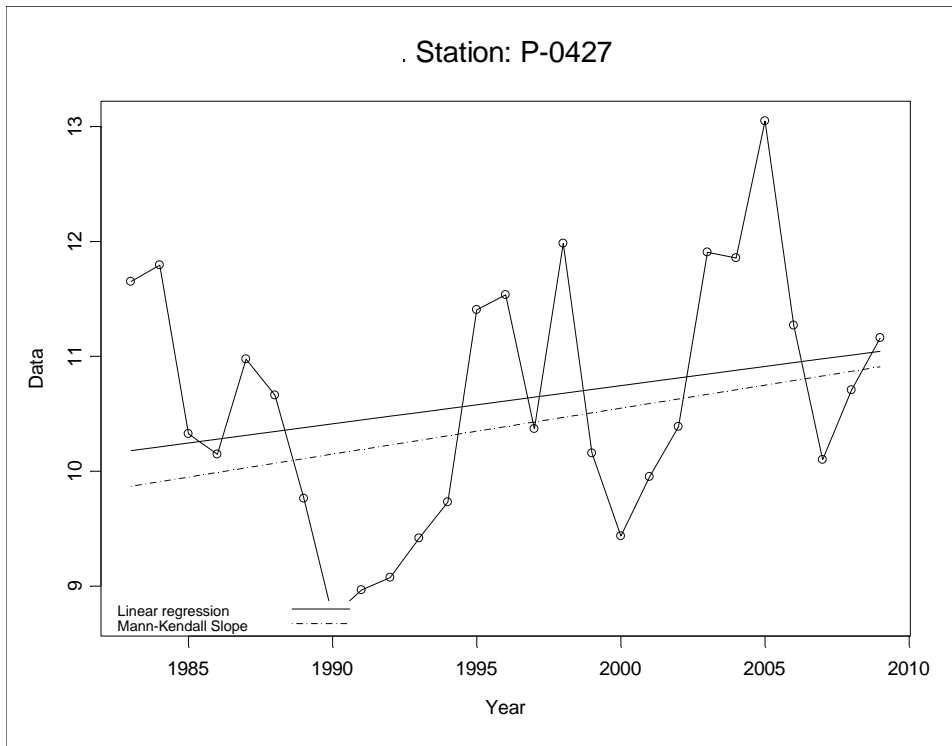
Data = Annual average groundwater level in feet above mean sea level

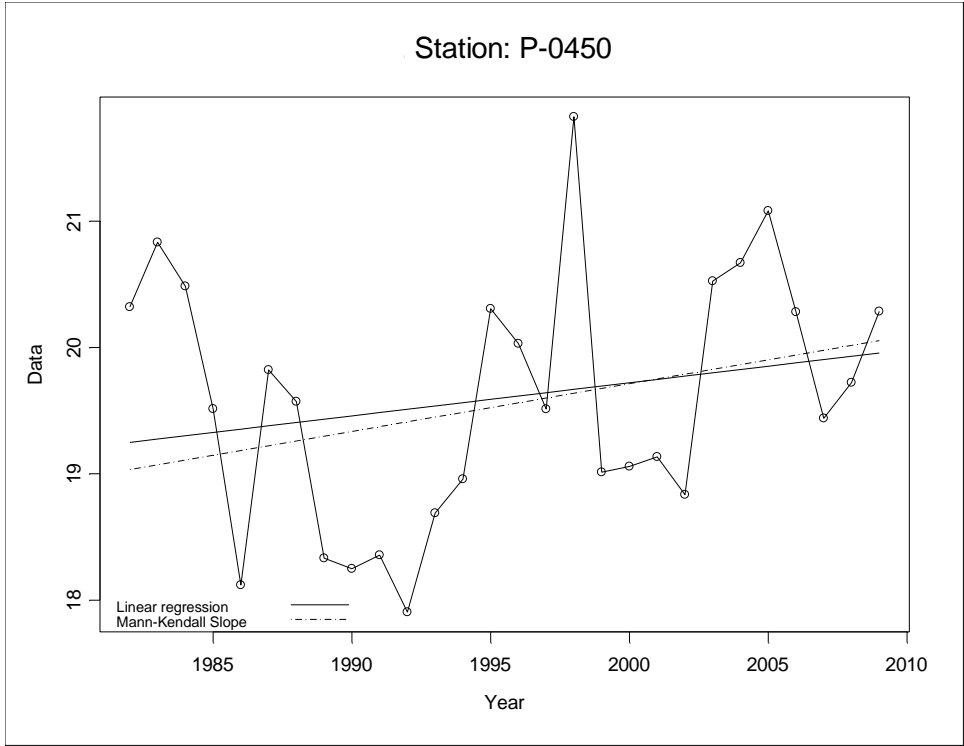


Map ID 81



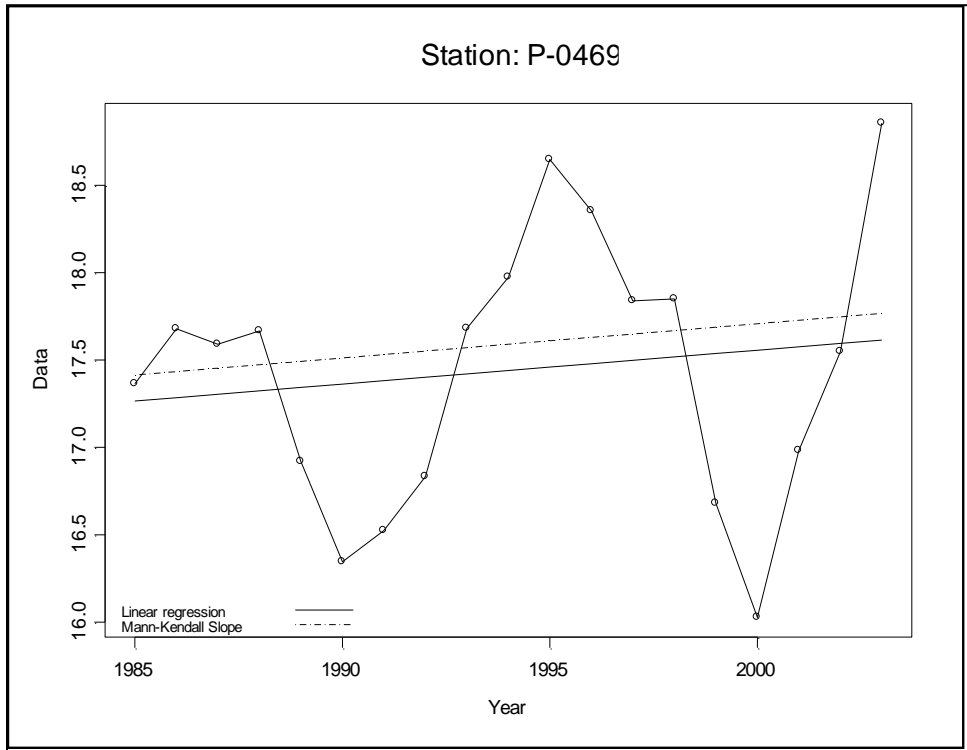
Data = Annual average groundwater level in feet above mean sea level



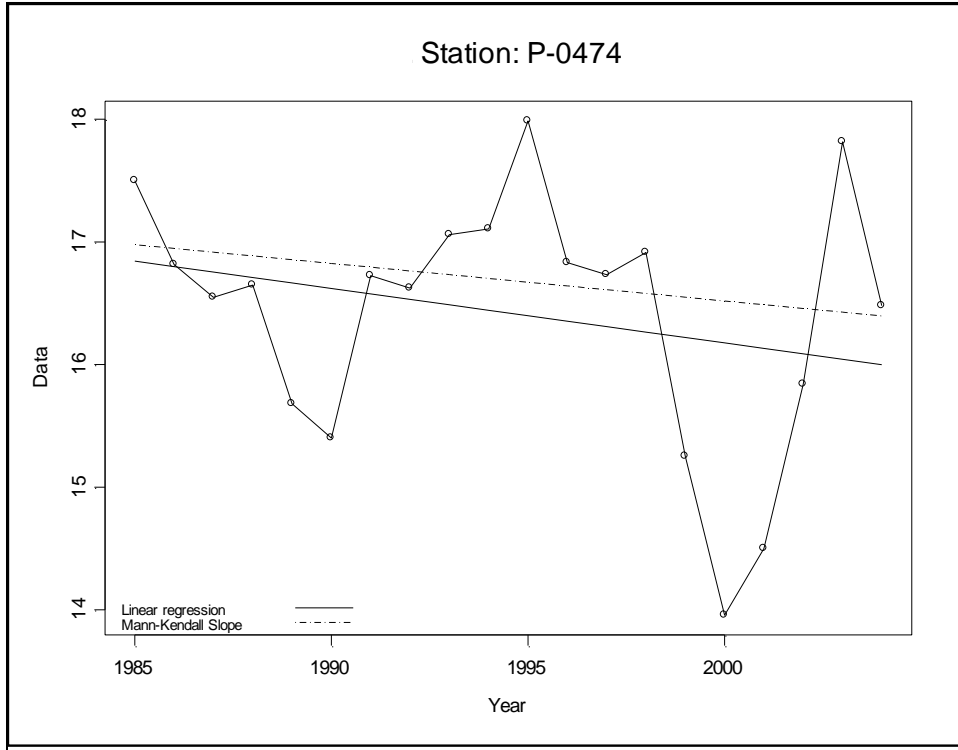


Map ID 84

Data = Annual average groundwater level in feet above mean sea level

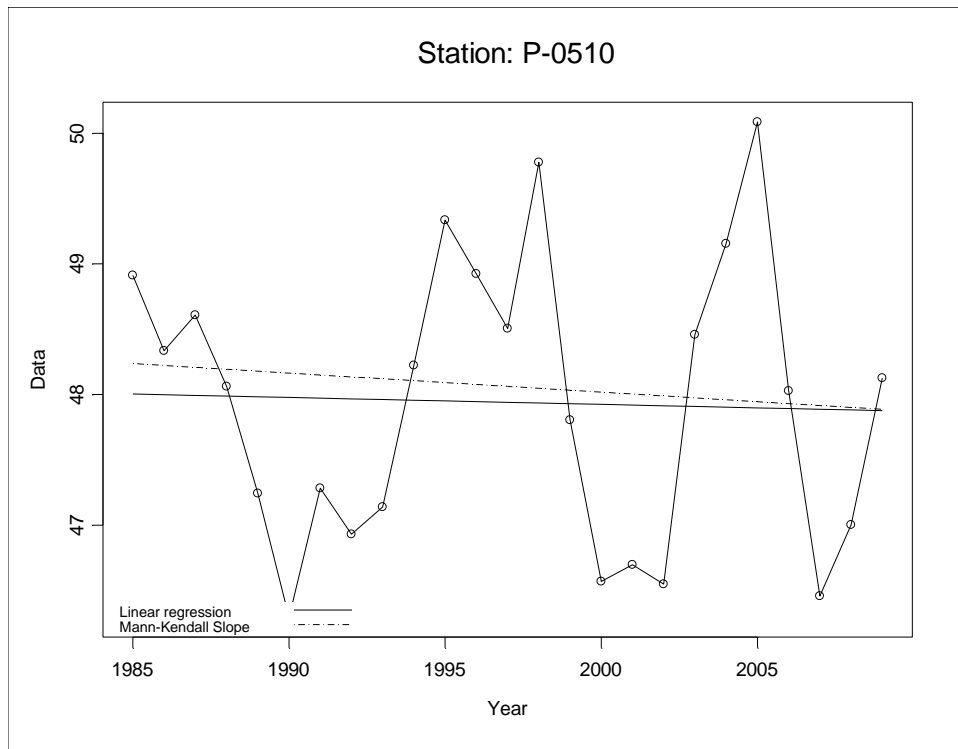


Map ID 85

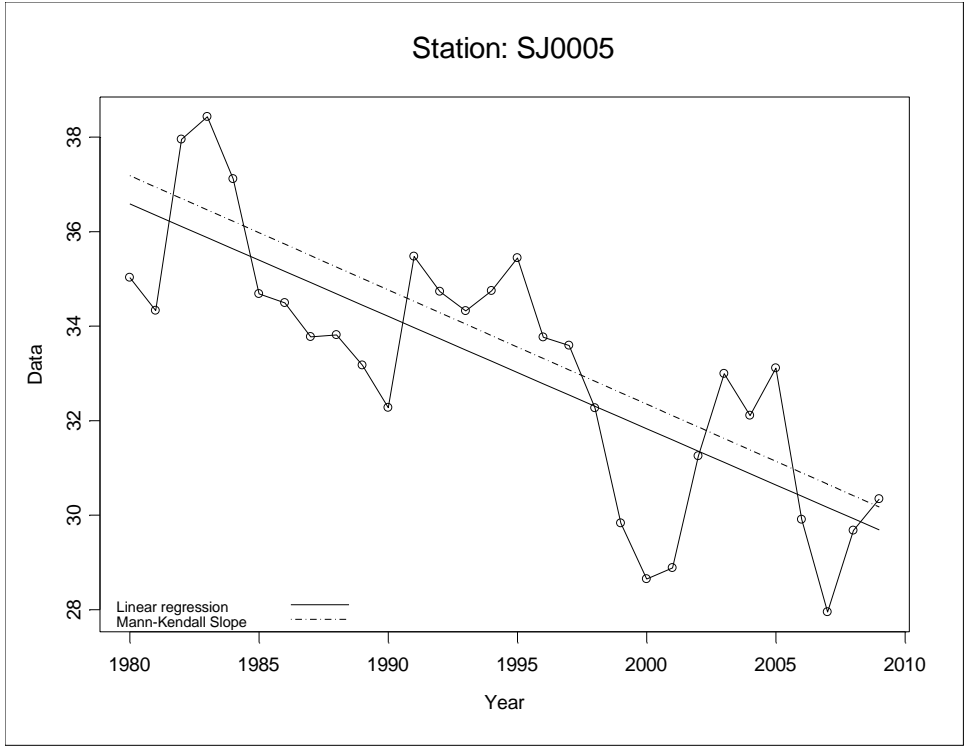


Map ID 86

Data = Annual average groundwater level in feet above mean sea level

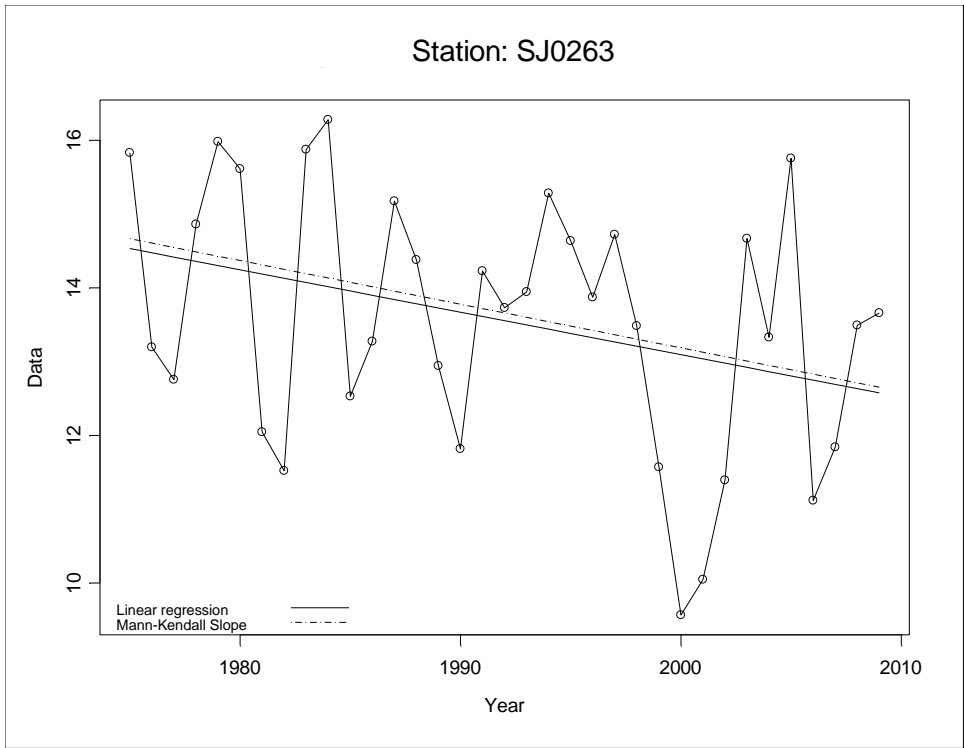


Map ID 87

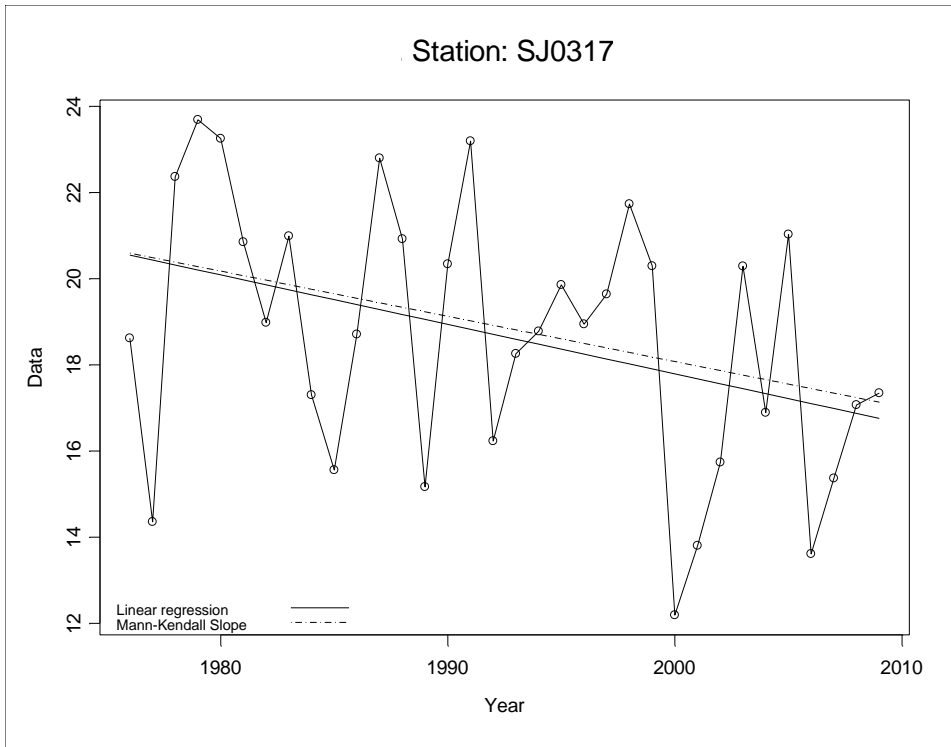


Map ID 88

Data = Annual average groundwater level in feet above mean sea level

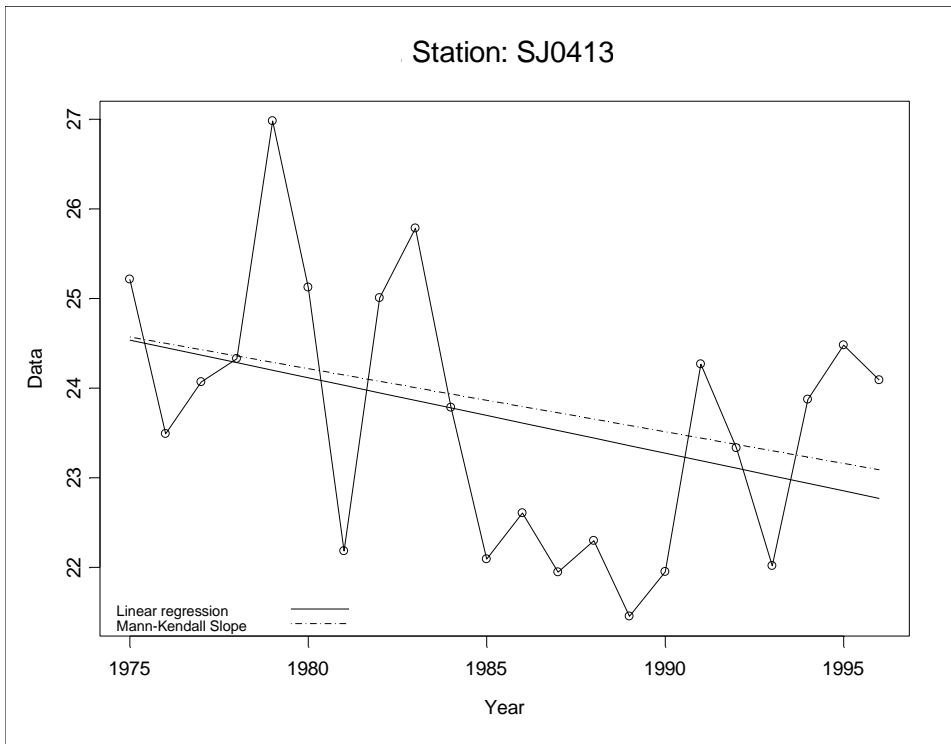


Map ID 89

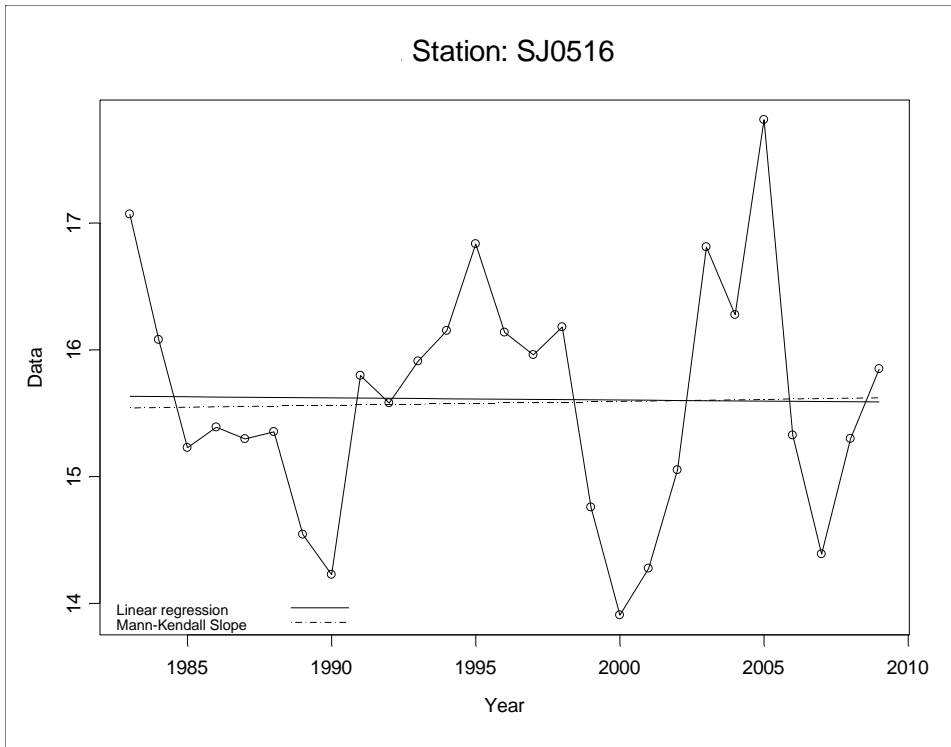


Map ID 90

Data = Annual average groundwater level in feet above mean sea level

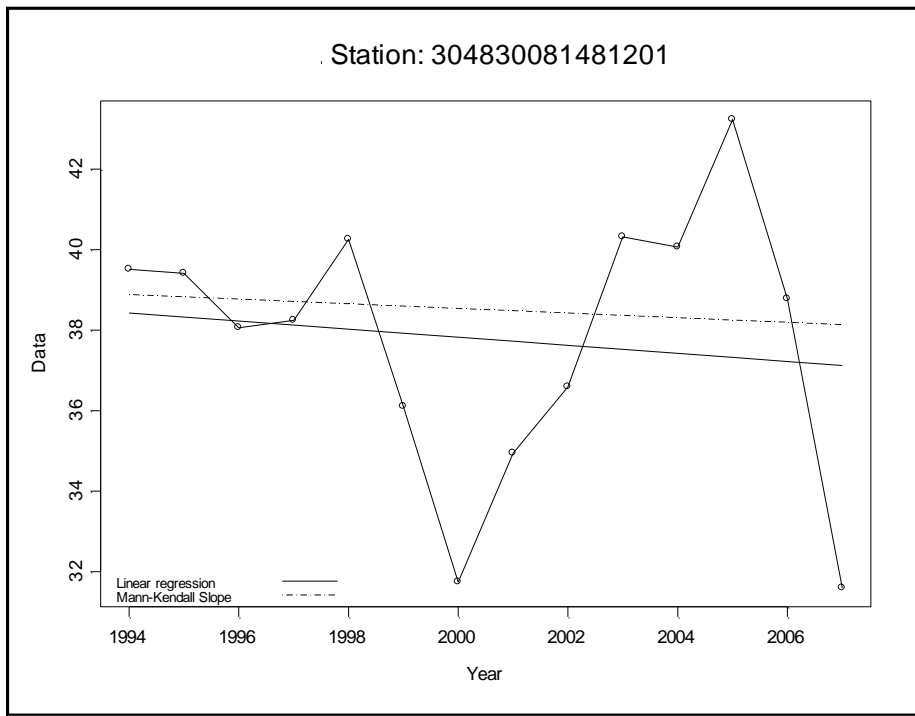


Map ID 91

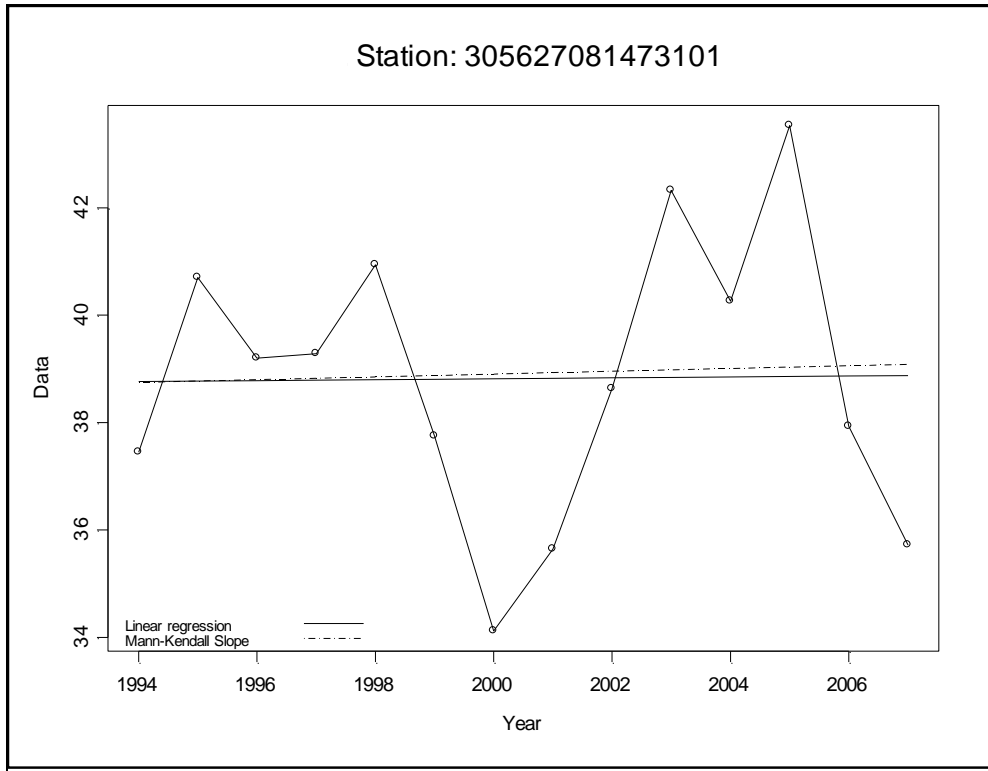


Map ID 92

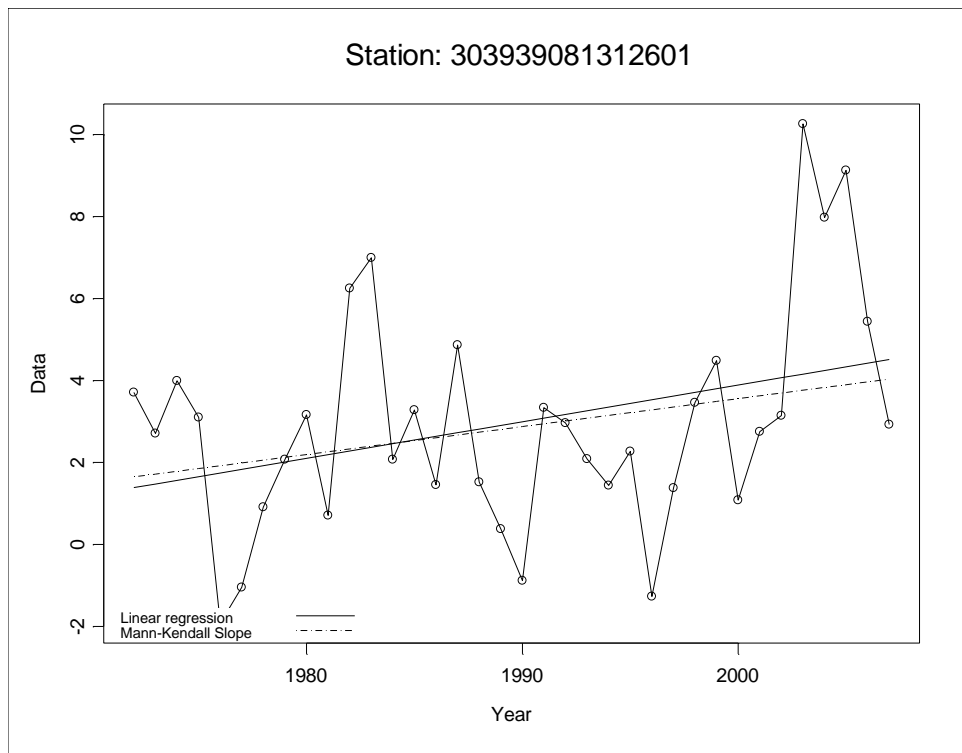
Data = Annual average groundwater level in feet above mean sea level

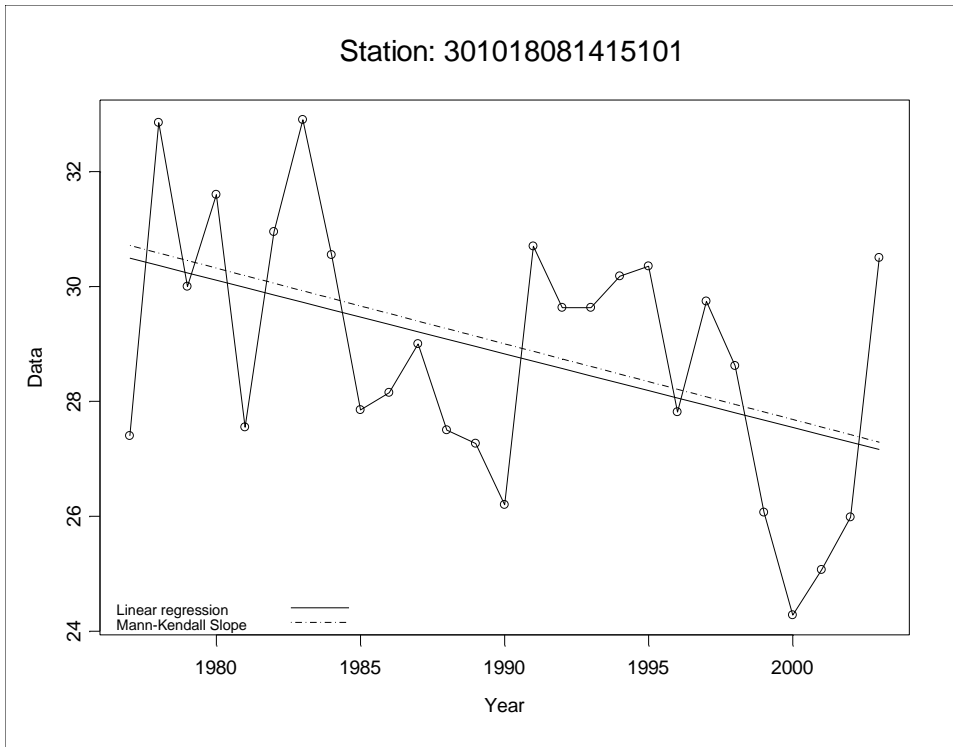


Map ID: 100



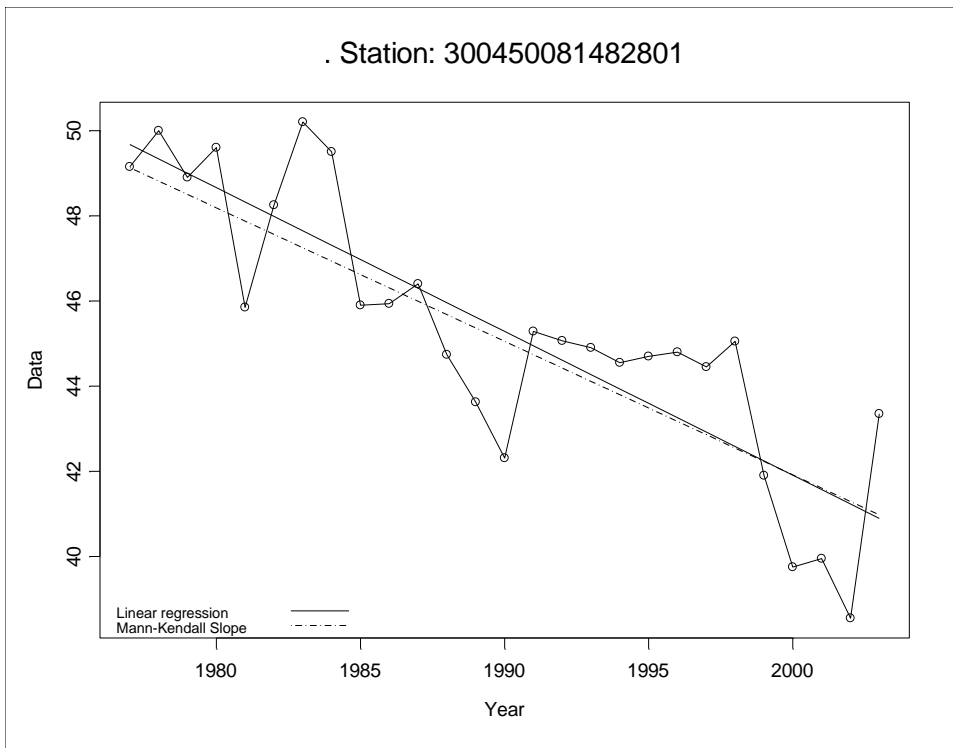
Data = Annual average groundwater level in feet above mean sea level



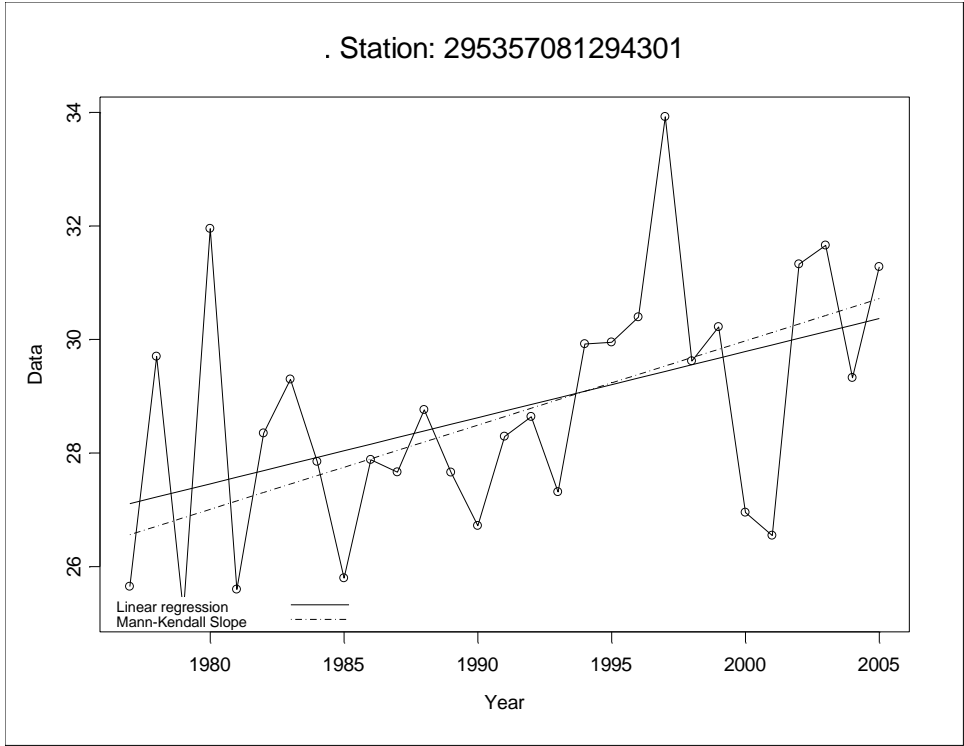


Map ID 103

Data = Annual average groundwater level in feet above mean sea level

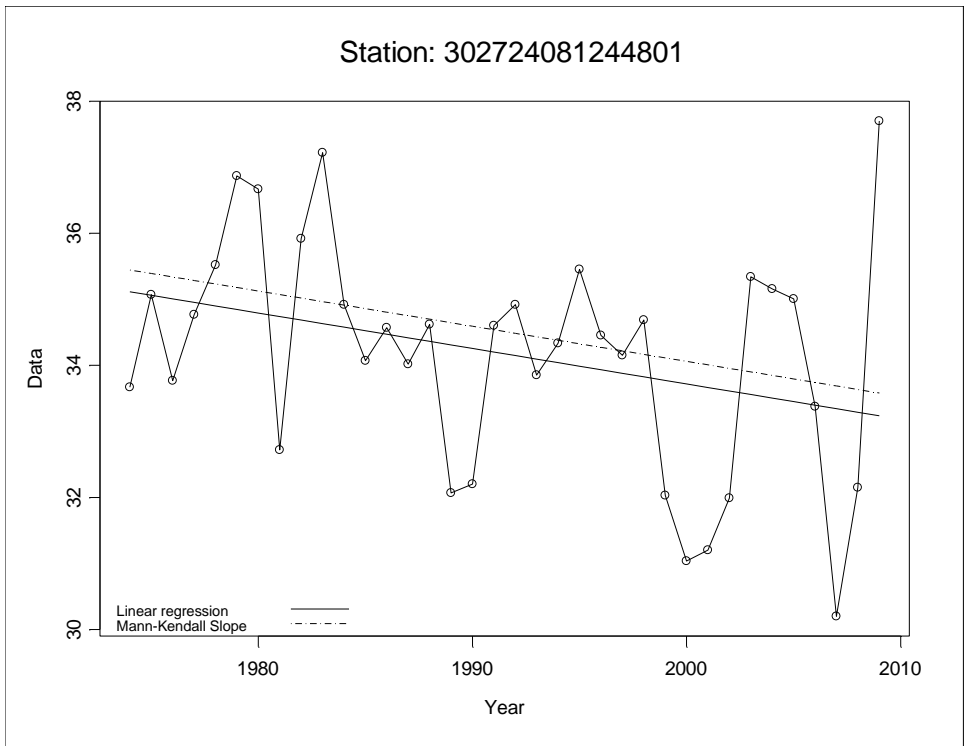


Map ID 104

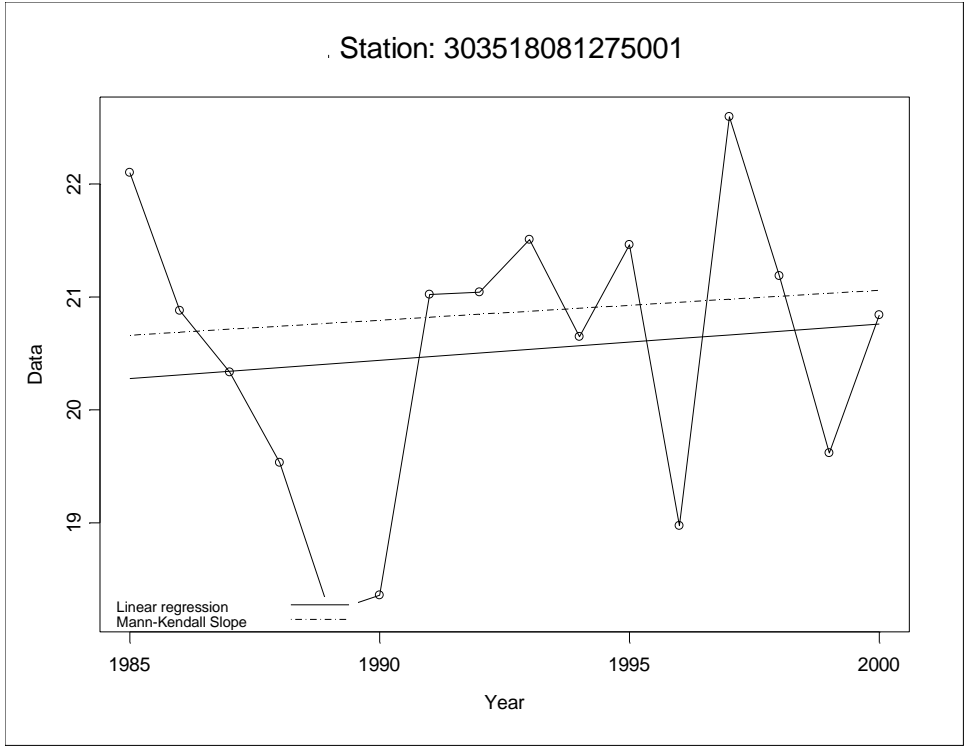


Map ID 105

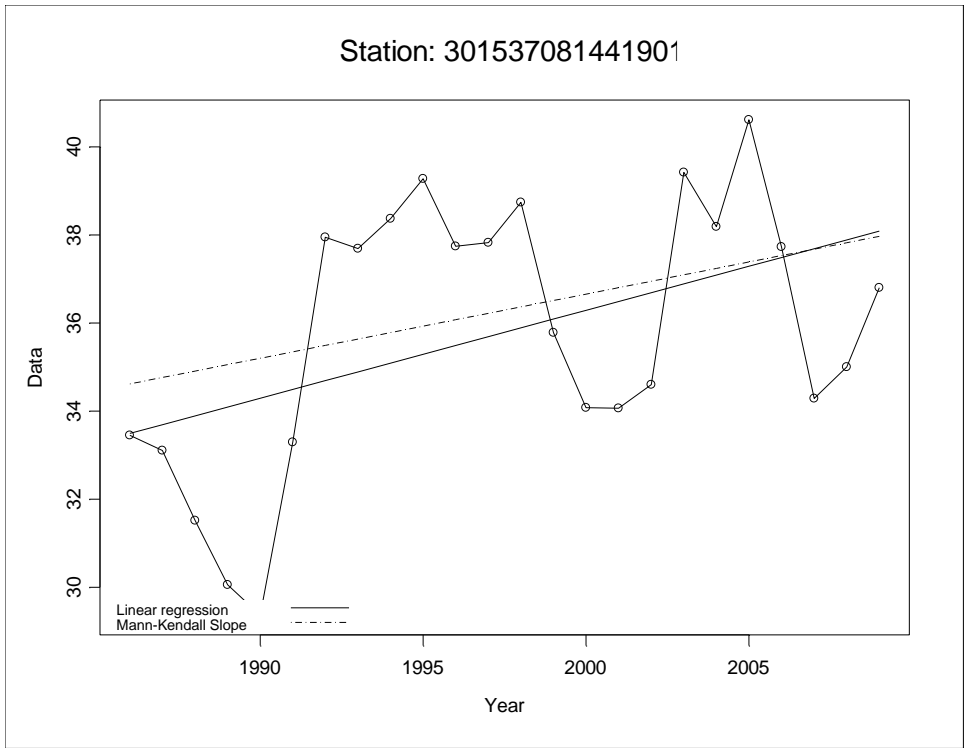
Data = Annual average groundwater level in feet above mean sea level

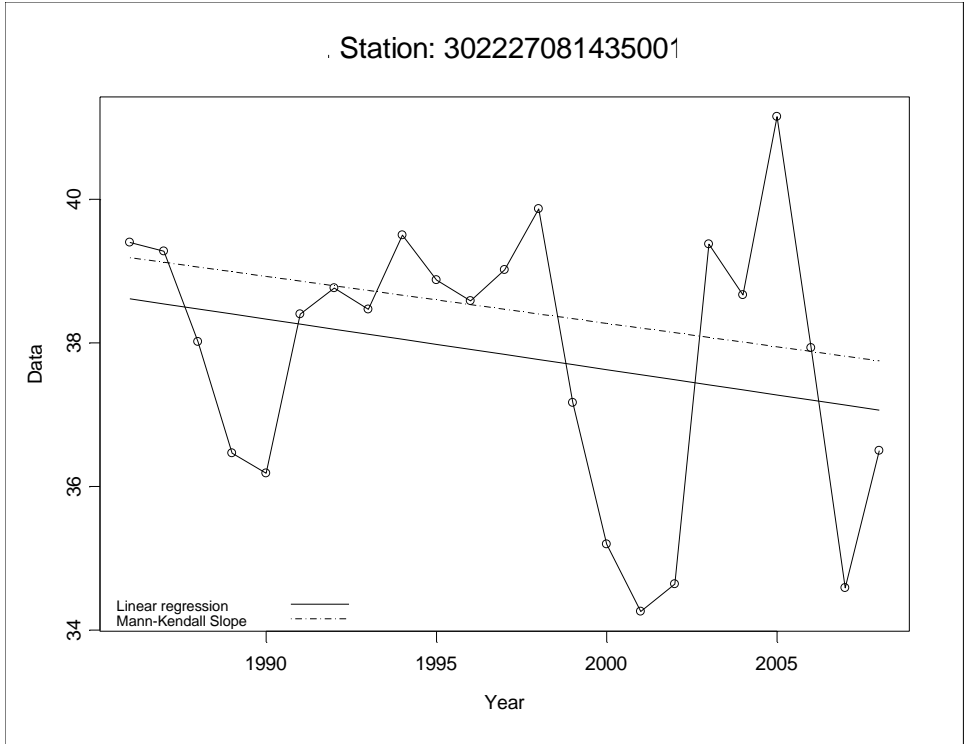


Map ID 106



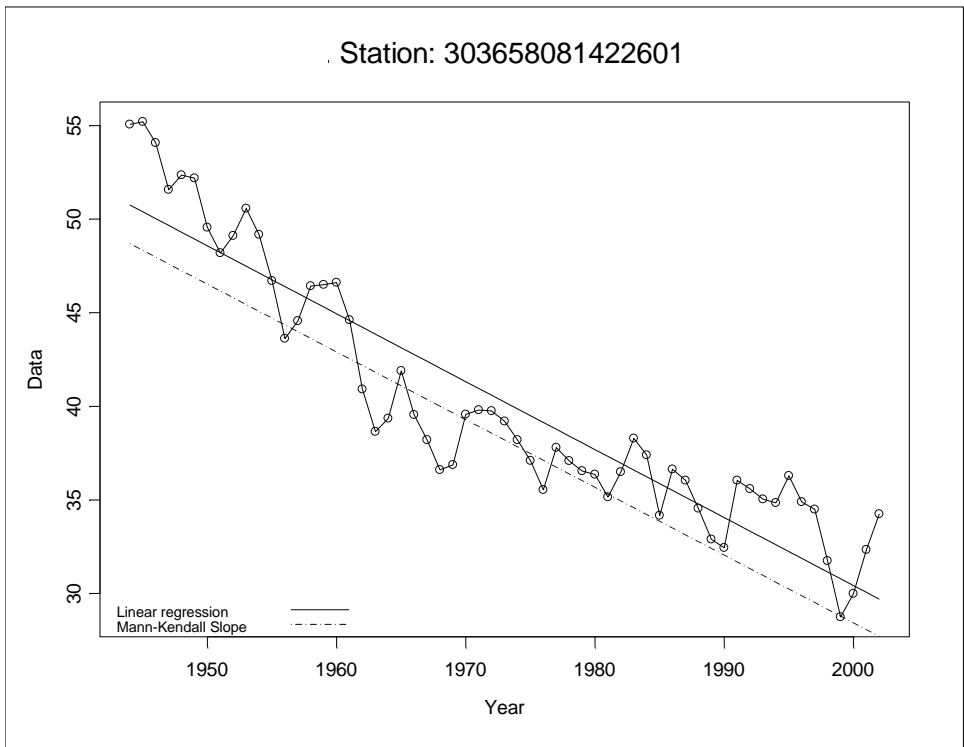
Data = Annual average groundwater level in feet above mean sea level



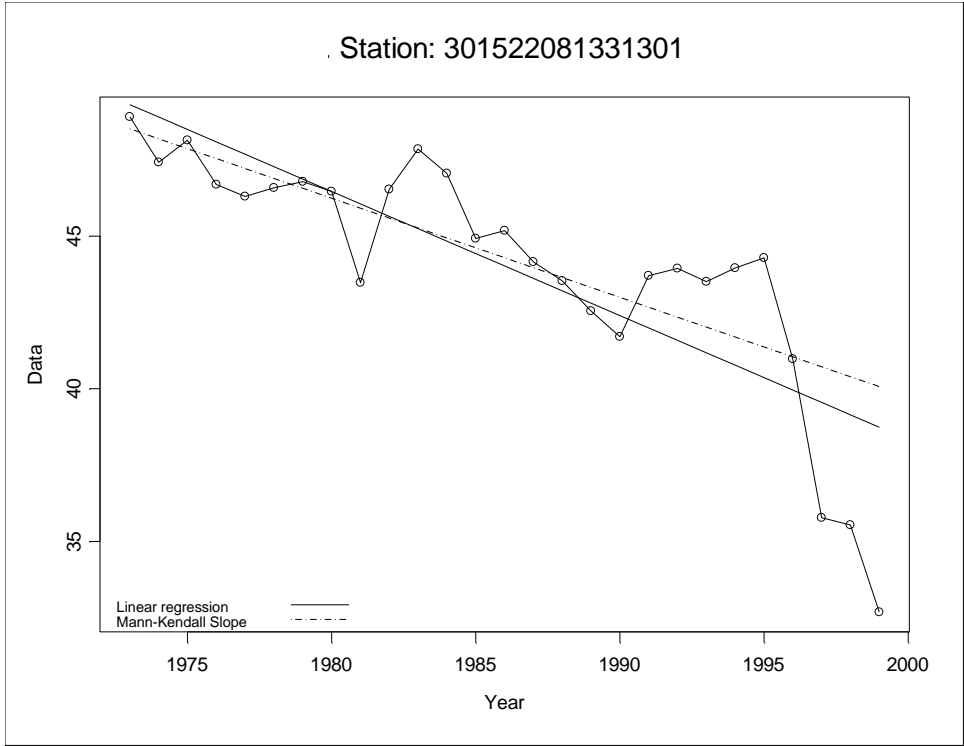


Map ID 109

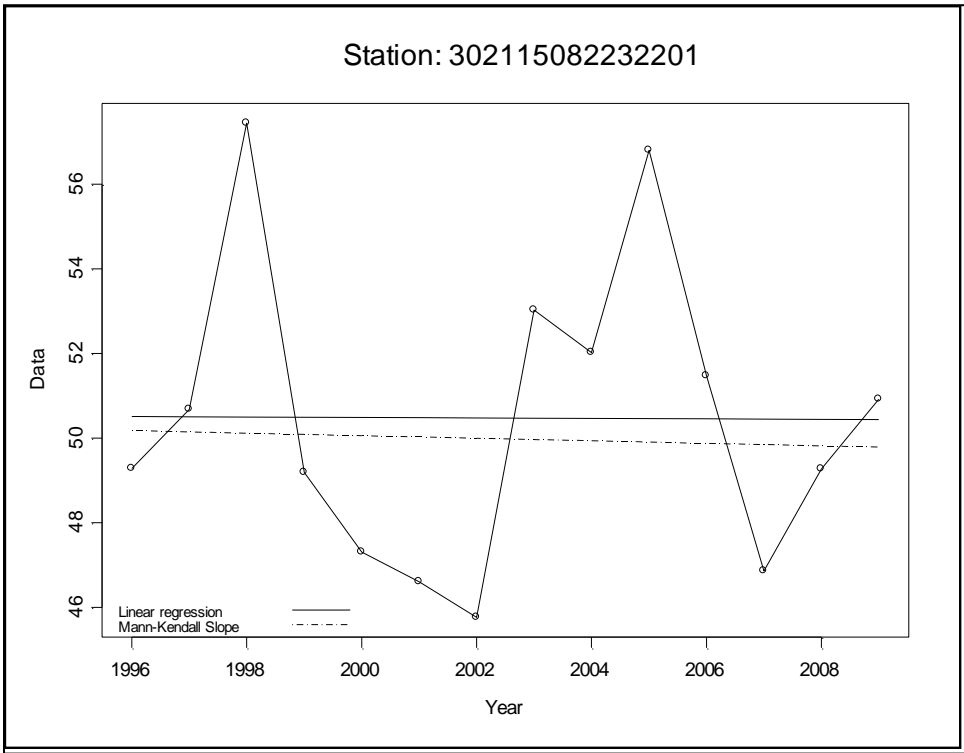
Data = Annual average groundwater level in feet above mean sea level

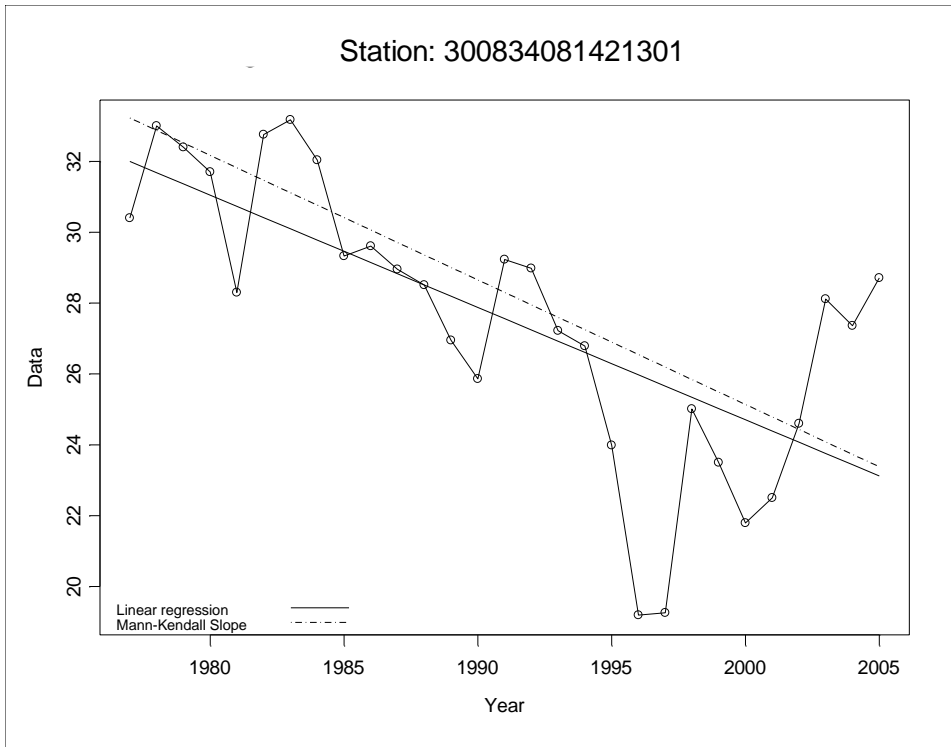


Map ID 110

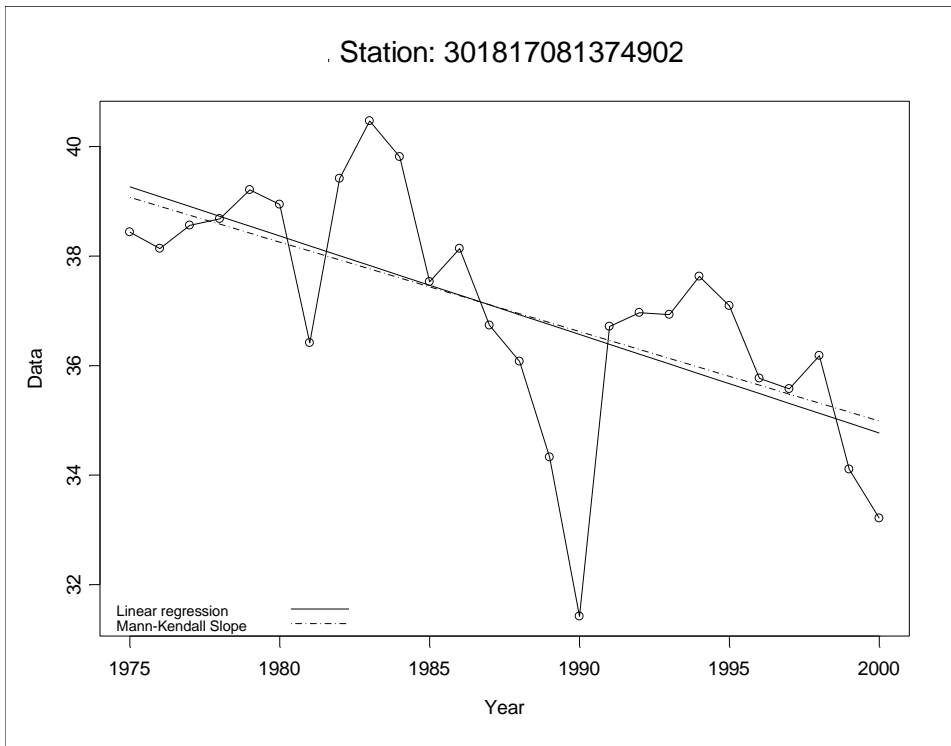


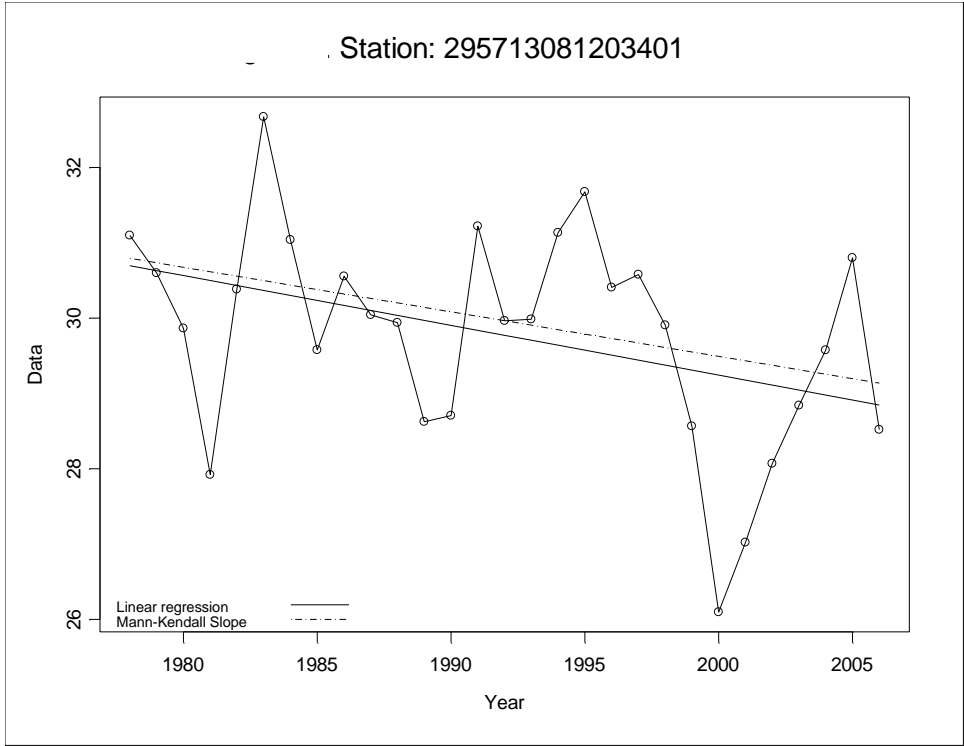
Data = Annual average groundwater level in feet above mean sea level





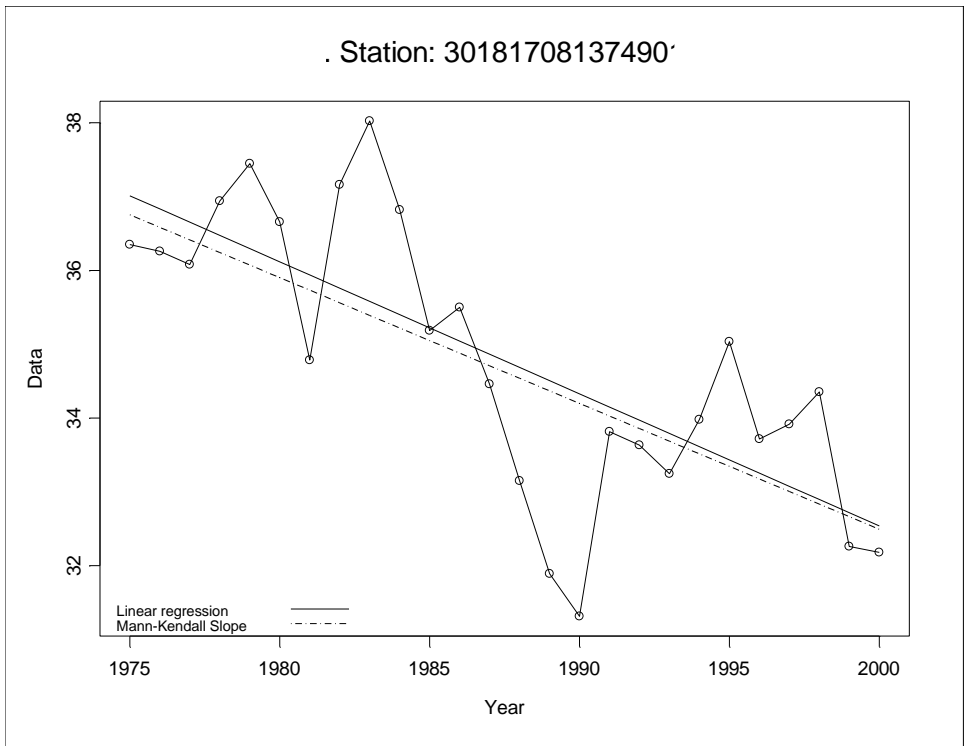
Data = Annual average groundwater level in feet above mean sea level



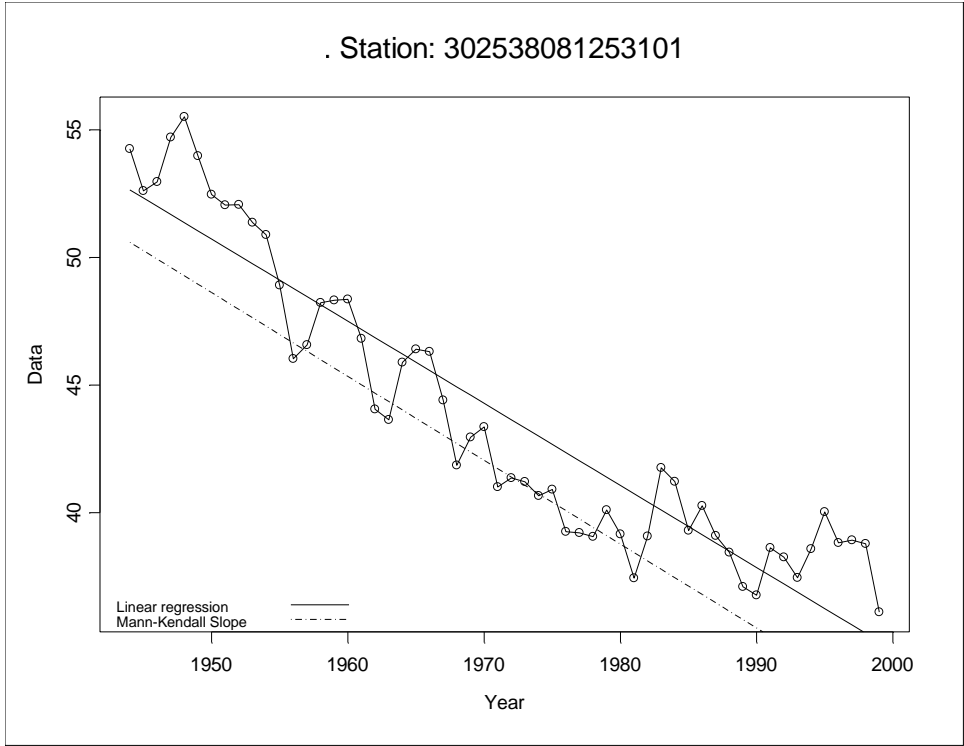


Map ID 115

Data = Annual average groundwater level in feet above mean sea level

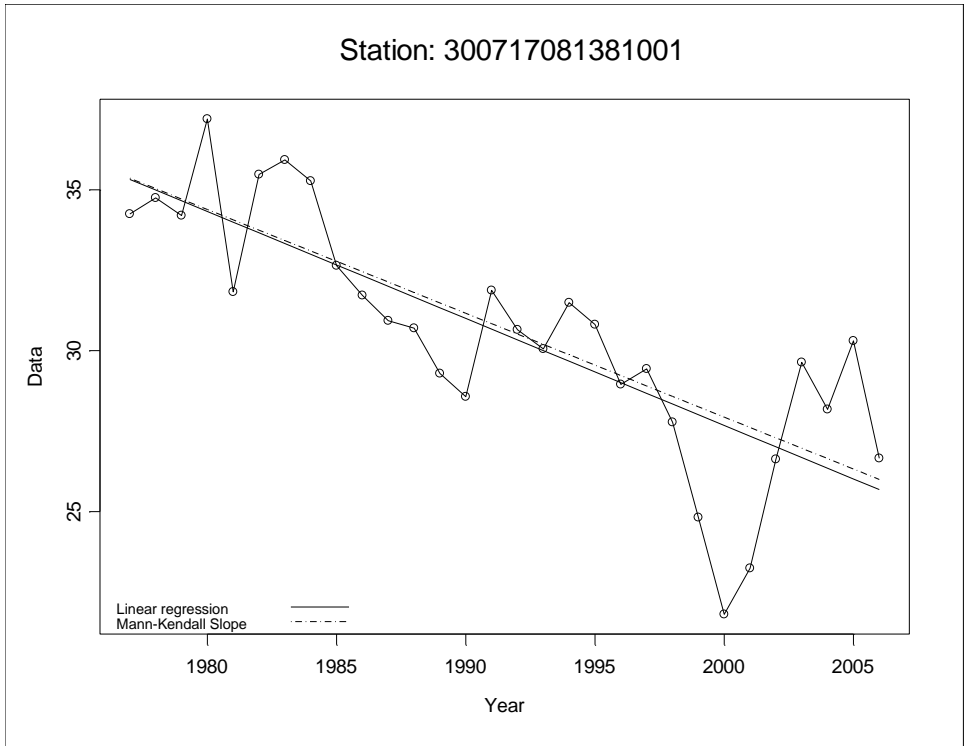


Map ID 116

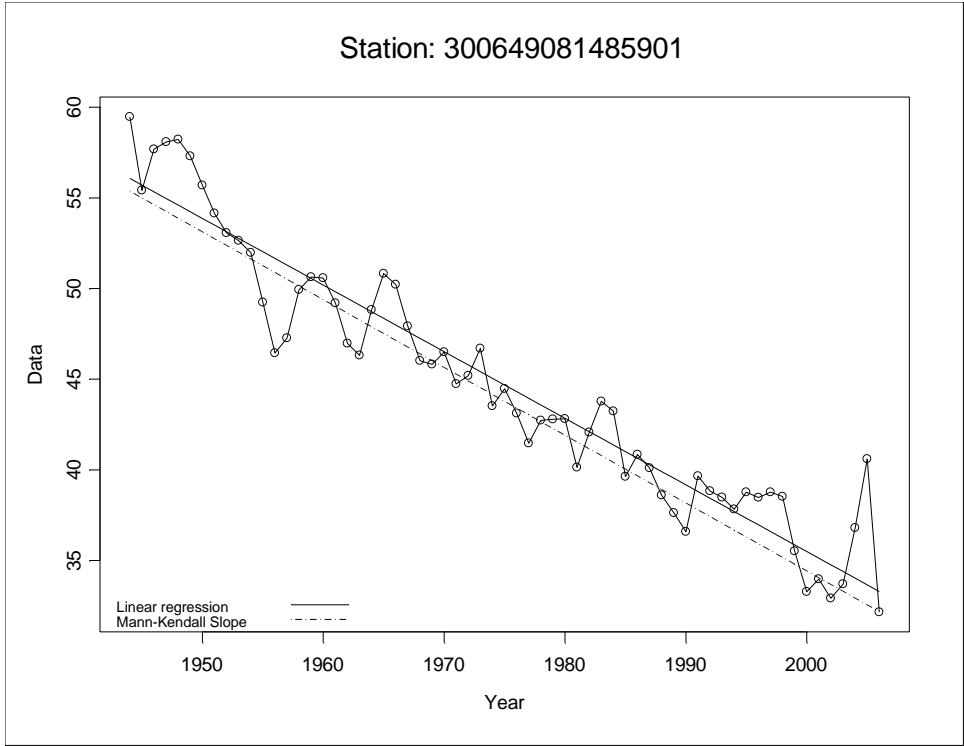


Map ID 117

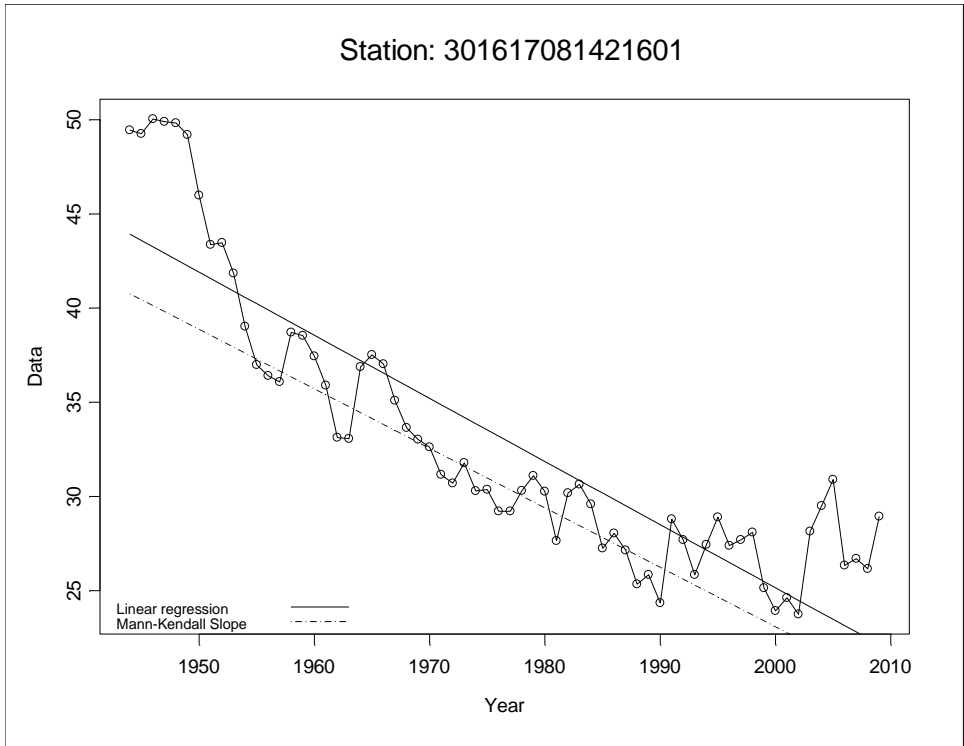
Data = Annual average groundwater level in feet above mean sea level

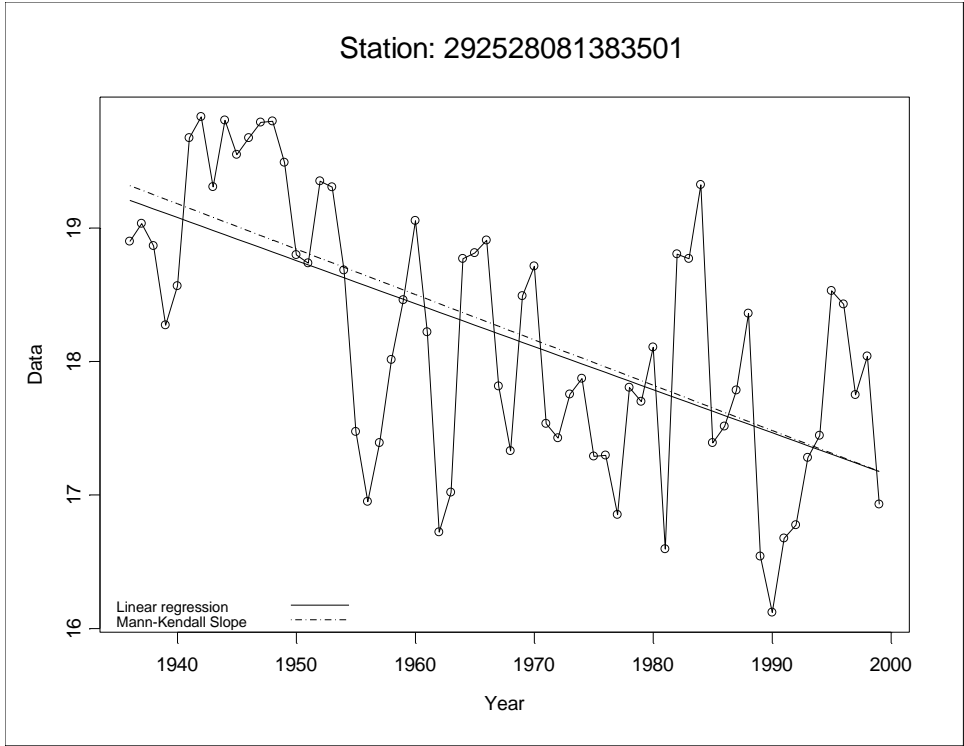


Map ID 118



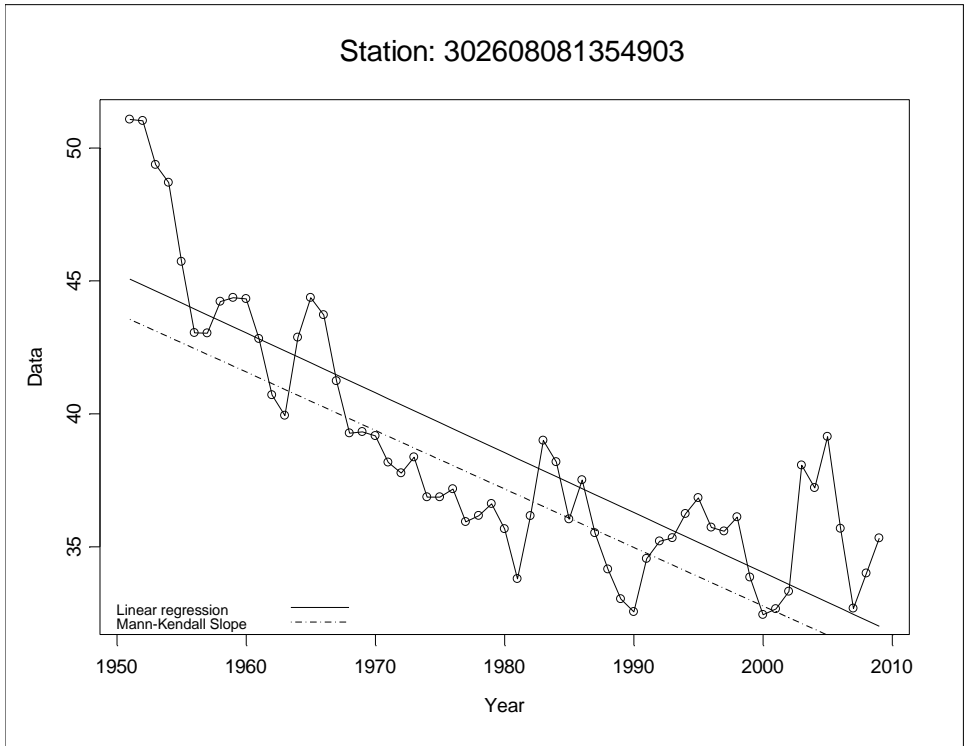
Data = Annual average groundwater level in feet above mean sea level



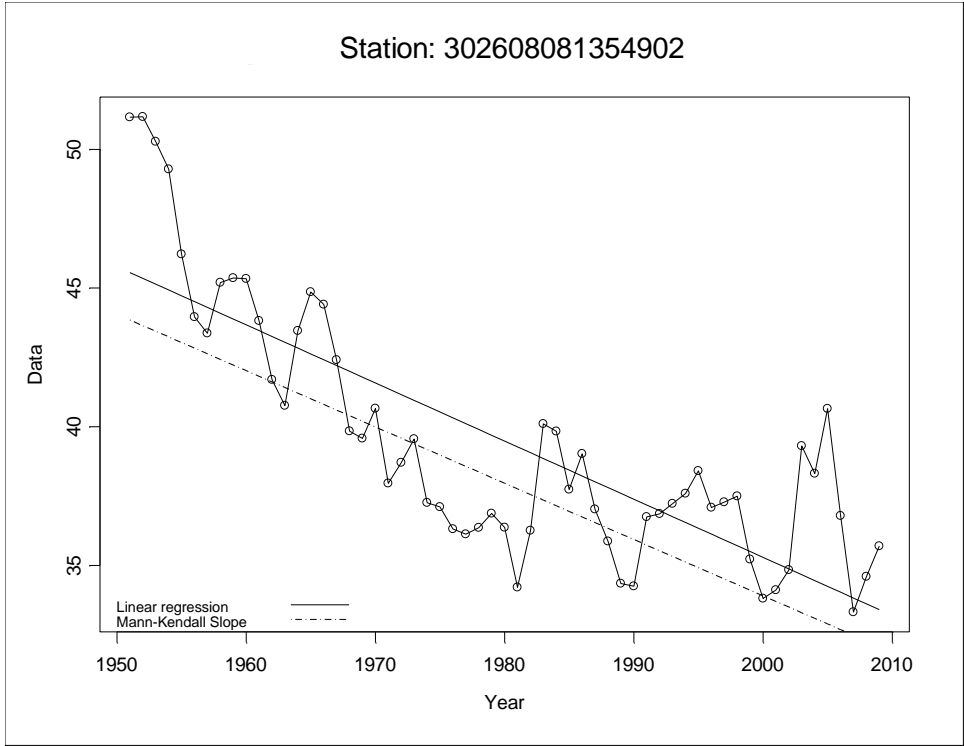


Map ID 121

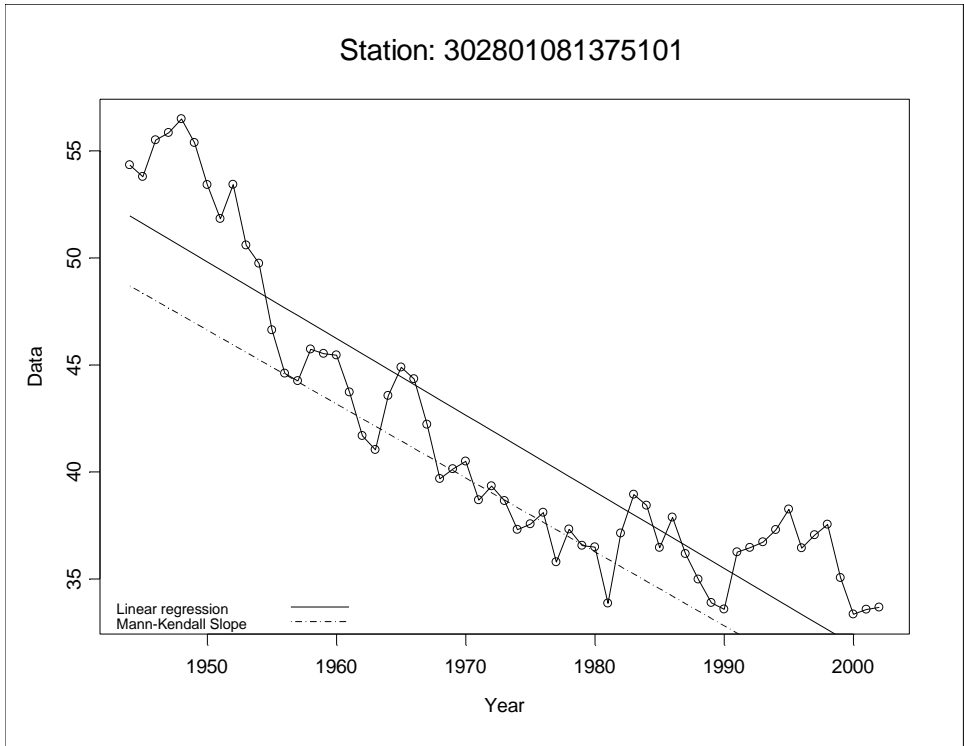
Data = Annual average groundwater level in feet above mean sea level

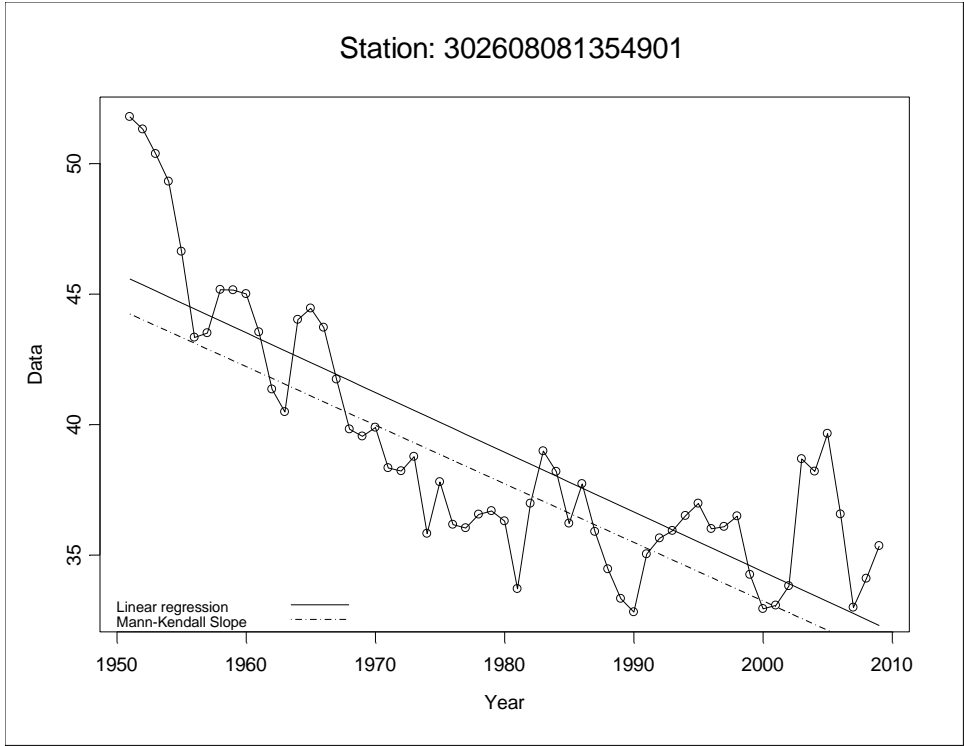


Map ID 122



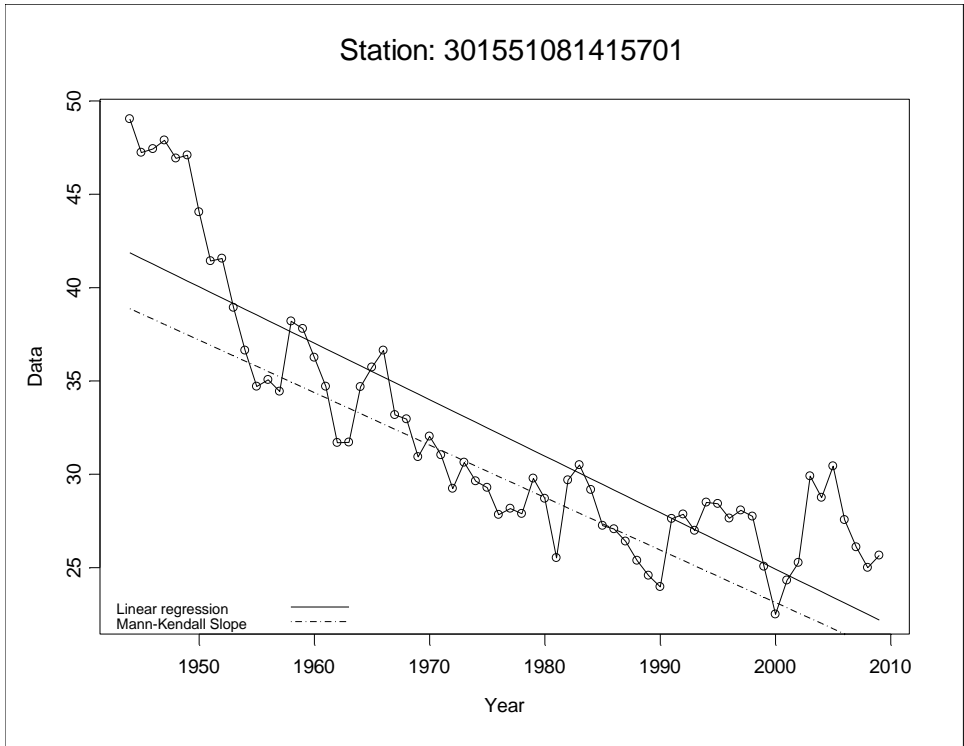
Data = Annual average groundwater level in feet above mean sea level



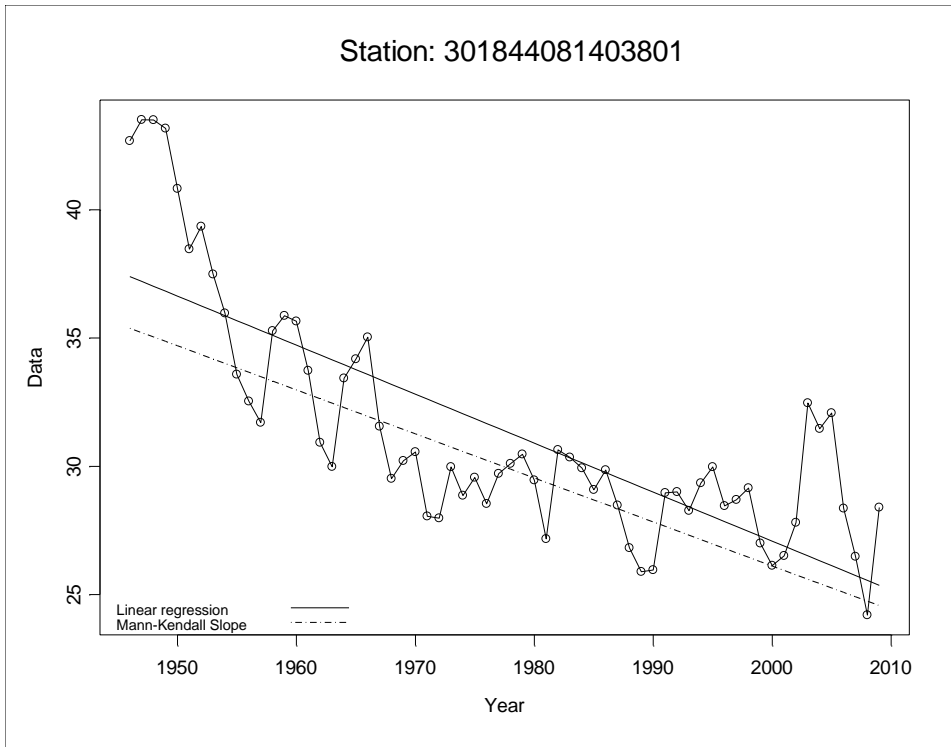


Map ID 125

Data = Annual average groundwater level in feet above mean sea level

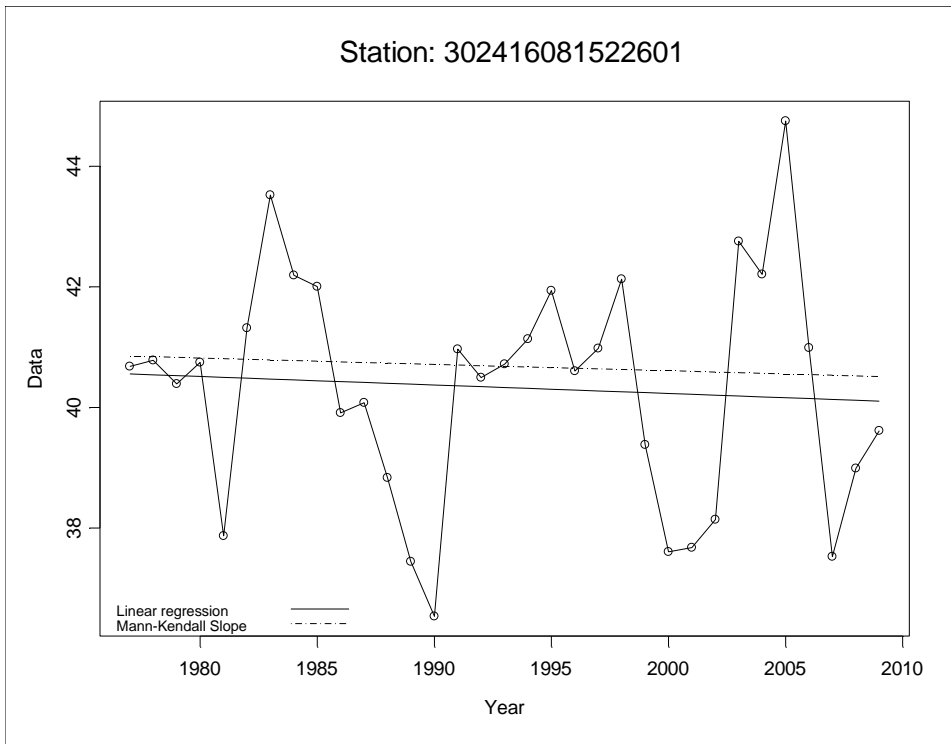


Map ID 126

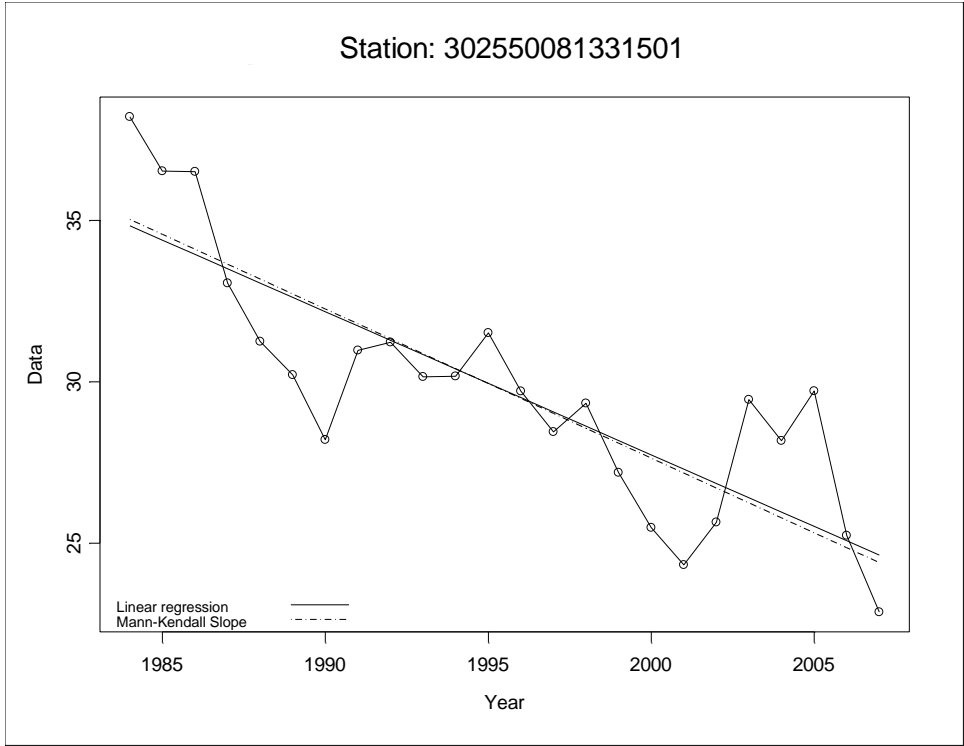


Map ID 127

Data = Annual average groundwater level in feet above mean sea level

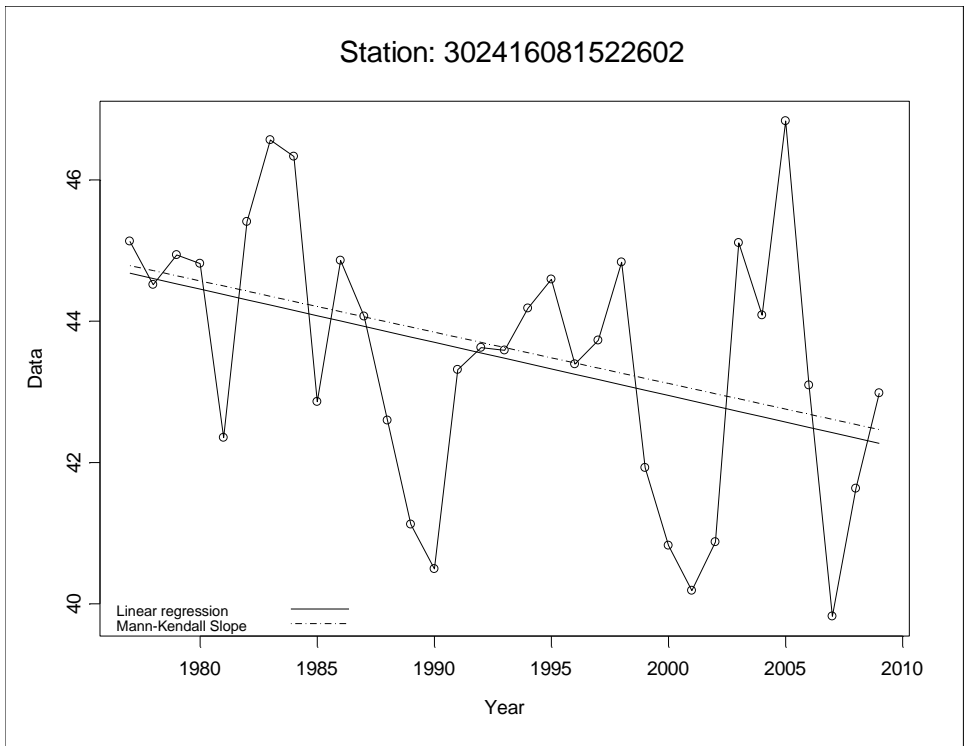


Map ID 128

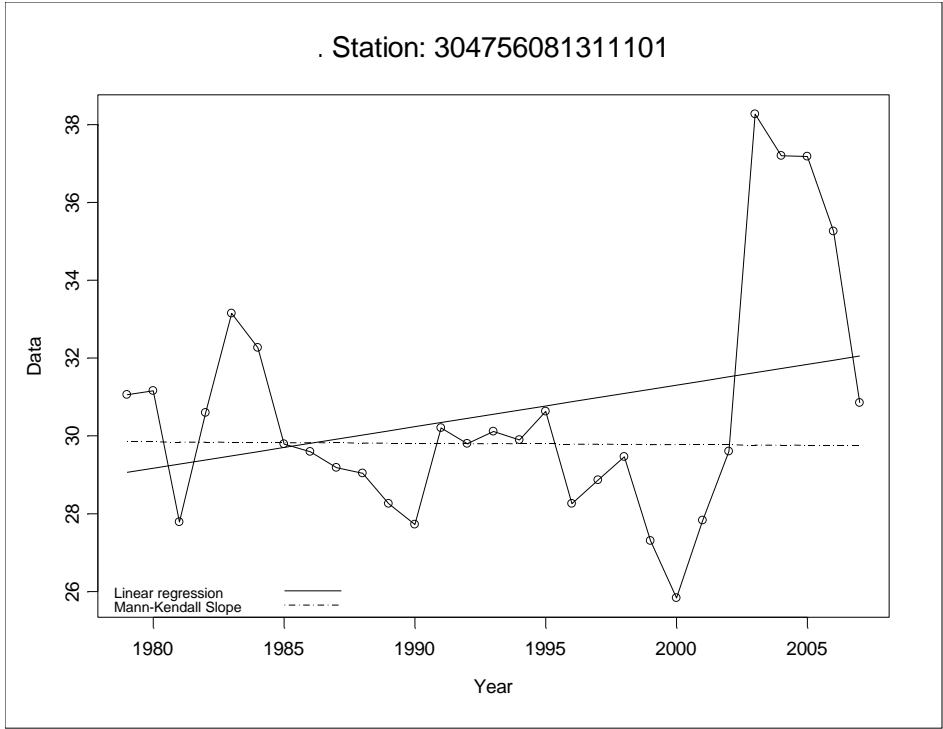


Map ID 129

Data = Annual average groundwater level in feet above mean sea level

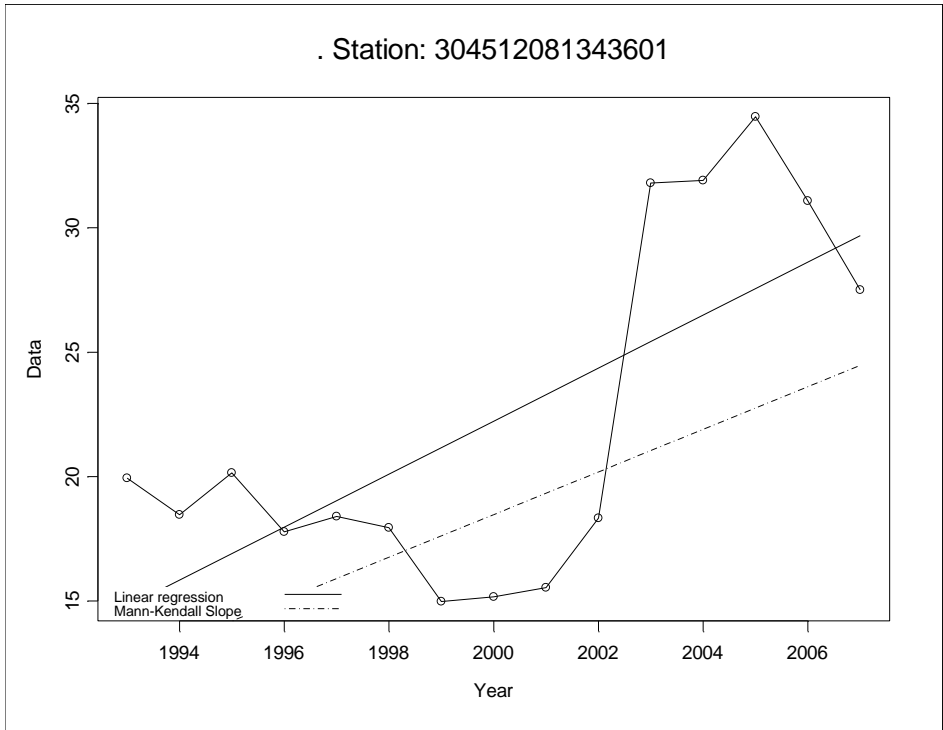


Map ID 130



Map ID: 131

Data = Annual average groundwater level in feet above mean sea level



Map ID: 132

Appendix S4: Groundwater Stations Cluster Assignments

Following is a summary of 102 Groundwater level stations in Florida and Georgia and which clusters they were assigned to in the agglomerative hierarchical cluster analysis (AHCA). Map Number refers to mapped station locations in report Figures 9.2, 9.3 and 9.4.

Groundwater level stations and cluster assignments.

Map Number	Source	Station ID	Significant	2-Cluster	3-Cluster	4-Cluster
1	SRWMD	-111811001	NT	1	1	2
2	SRWMD	-092307001	W	1	1	2
3	SRWMD	-081926001	NT	1	1	2
4	SRWMD	-081703001	NT	1	1	2
5	SRWMD	-072215001	VC	1	1	2
6	SRWMD	-072132001	NT	1	1	2
7	SRWMD	-061734001	NT	1	1	1
8	SRWMD	-061629001	NT	1	1	1
9	SRWMD	-061114001	W	1	1	1
11	SRWMD	-051933001	NT	1	1	2
12	SRWMD	-051819001	NT	1	1	1
13	SRWMD	-051428004	W	1	1	1
14	SRWMD	-051311001	W	1	1	1
15	SRWMD	-041923001	VC	1	1	1
16	SRWMD	-041705001	NT	1	1	2
17	SRWMD	-041625001	NT	1	1	1
18	SRWMD	-041329001	NT	1	1	1
19	SRWMD	-041223004	NT	1	1	1
20	SRWMD	-041014001	NT	1	1	1
21	SRWMD	-032012001	NT	1	1	1
22	SRWMD	-031908001	VC	1	1	1
23	SRWMD	-031601003	NT	1	1	1
24	SRWMD	-031232001	W	1	1	1
25	SRWMD	-031105006	NT	1	1	1
26	SRWMD	-031012001	VC	1	1	1
27	SRWMD	-021934001	NT	1	1	1
28	SRWMD	-021902001	NT	1	1	1
29	SRWMD	-021805001	PT	1	1	1
30	SRWMD	-021624001	NT	1	1	2
31	SRWMD	-021516001	NT	1	1	1
32	SRWMD	-021335001	NT	1	1	1
33	SRWMD	-012029001	VC	1	1	1
34	SRWMD	-012003001	NT	1	1	1
35	SRWMD	-011727001	NT	1	1	1
36	SRWMD	-011534001	NT	1	1	1
37	SRWMD	-011511001	NT	1	1	1
38	SRWMD	-011035001	NT	1	1	1
39	SRWMD	+010719001	W	1	1	1
40	SRWMD	+011316001	NT	1	1	1

Map Number	Source	Station ID	Significant	2-Cluster	3-Cluster	4-Cluster
41	SRWMD	+011422007	NT	1	1	1
42	SRWMD	+011608001	NT	1	1	1
43	SRWMD	+021002001	NT	1	1	1
44	SRWMD	+021125001	NT	1	1	1
45	SRWMD	+021432001	NT	1	1	1
46	SRWMD	-102006001	PW	1	1	2
47	SRWMD	-101722001	PW	1	1	2
48	SRWMD	-091938002	PW	1	1	1
49	SRWMD	-091607001	PW	1	1	1
50	SRWMD	-091420001	PW	1	1	1
51	SRWMD	-062102001	PW	1	1	2
52	SRWMD	+021211001	PW	1	1	1
54	SJRWMD	A-0005	NT	1	1	2
55	SJRWMD	A-0071	NT	1	1	2
56	SJRWMD	BA0019	NT	1	1	1
57	SJRWMD	C-0120	VC	1	1	2
58	SJRWMD	P-0001	PT	1	1	2
63	SJRWMD	C-0094	VC	1	1	1
64	SJRWMD	C-0123	NT	1	1	2
65	SJRWMD	C-0128	NT	1	1	2
66	SJRWMD	C-0607	VC	1	1	2
68	SJRWMD	D-0160	VC	2	3	4
69	SJRWMD	D-0254	NT	1	2	3
70	SJRWMD	D-0424	W	1	1	1
71	SJRWMD	D-0667	VC	2	3	4
74	SJRWMD	N-0121	NT	1	2	3
77	SJRWMD	P-0172	NT	1	1	1
79	SJRWMD	P-0270	NT	1	2	3
81	SJRWMD	P-0408	NT	1	2	3
83	SJRWMD	P-0427	NT	1	2	3
84	SJRWMD	P-0450	NT	1	2	3
87	SJRWMD	P-0510	NT	1	1	2
88	SJRWMD	SJ0005	VC	1	1	1
89	SJRWMD	SJ0263	NT	1	1	1
90	SJRWMD	SJ0317	W	1	1	1
92	SJRWMD	SJ0516	NT	1	2	3
93	USGS	312712082593301	VC	2	3	4
94	USGS	310706082155101	PT	1	1	1
95	USGS	304942082213801	NT	2	3	4
96	USGS	313146083491601	VC	2	3	4
97	USGS	310813083260301	VC	2	3	4
98	USGS	314330084005402	PW	1	1	1
99	USGS	304949083165301	PW	1	2	3
102	USGS	303939081312601	NT	1	2	3
105	USGS	295357081294301	VC	1	2	3
106	USGS	302724081244801	NT	2	3	4
108	USGS	301537081441901	NT	1	2	3

Map Number	Source	Station ID	Significant	2-Cluster	3-Cluster	4-Cluster
109	USGS	302227081435001	NT	1	1	1
113	USGS	300834081421301	NT	2	3	4
115	USGS	295713081203401	NT	1	1	1
117	USGS	302538081253101	VC	2	3	4
118	USGS	300717081381001	VC	1	1	1
119	USGS	300649081485901	VC	2	3	4
120	USGS	301617081421601	NT	2	3	4
122	USGS	302608081354903	W	2	3	4
123	USGS	302608081354902	VC	2	3	4
125	USGS	302608081354901	PT	2	3	4
126	USGS	301551081415701	NT	2	3	4
127	USGS	301844081403801	VC	2	3	4
128	USGS	302416081522601	NT	1	2	3
129	USGS	302550081331501	PT	1	1	1
130	USGS	302416081522602	NT	1	1	1
131	USGS	304756081311101	NT	1	2	3

*: VC = Very Certain, PT = Probably Trend, W = Warning, NT = No Trend, PW = Piecewise