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ABSTRACT

A survey of wet meadow vegetation was conducted at 68 groundwater well monitoring sites in the summer of 1991. The well sites were grouped into 13 hydrologic regimes based on similarities in water level frequency in relation to depth below the ground surface. Groundwater levels were monitored weekly (some continuously) between July 1988 and January 1992. Cover of the dominant plant species was summarized by well group. Water sedge (*Carex aquatilis*), smartweed (*Polygonum spp.*), and cut-grass (*Leersia virginica*) were good indicators of the wettest hydrology, while a broad-spectrum of species were characteristic of mesic sites (e.g., canada goldenrod, smooth brome, big bluestem, ironweed, and white sweet clover). Grama grasses (*Bouteloua gracilis*) and purple poppy mallow (*Callirhoe involucrata*) were more characteristic of dry to xeric sites. Several species were ubiquitous (switchgrass, cordgrass, wheatgrass) or representative of disturbance (ragweed, bluegrass, foxtail barley), and were therefore not considered useful indicators. No apparent relationship was found between soil texture fractions and hydrology, although species such as water sedge were positively correlated with the percentage of coarse sand. Alternatively, redtop and a few other species were positively correlated with soils containing the highest percentage of silt and clay. The three study sites exhibited little variation in overall soil texture, but there were major differences in hydrology. Difficulties in interpreting the vegetation data are also discussed including the impacts of management, local disturbance at the well sites, and the bias involved in well site selection.

INTRODUCTION

Platte River wet meadows are lowland grasslands characterized by poorly drained soils, high water tables, and intermittent surface water in ponds and linear swales and sloughs. Their vegetation includes wetland species (e.g., sedges, bulrushes, smartweeds) on lowland sites, mid- to tallgrass prairie species (e.g., big bluestem, little bluestem, indiangrass, switchgrass, goldenrod, ironweed) over most of the area, and shortgrass prairie species (e.g., sideoats grama, blue grama, purple poppy mallow, coneflower) on more elevated ridges. Although wet meadows are generally dominated by herbaceous species, shrub, woodland, and savanna communities are also associated with these areas. Russian olive (*Eleagnus angustifolia*), mulberry (*Morus rubra*), Siberian elm (*Ulmus pumila*), buffalo berry (*Sheperdia argentea*), eastern red cedar (*Juniperus virginiana*), wild plum (*Prunus americana*), and false indigo (*Amorpha fruticosa*) are woody species commonly found at the periphery of wet meadows and on some wet meadow-woodland-shrub complexes.

Wet meadows play an important role in providing feeding and nesting habitat for large flocks of spring-migrating birds including sandhill cranes, waterfowl, and shore and other aquatic birds. They also provide migratory habitat for the endangered whooping crane, eskimo curlew, and peregrine falcon, feeding habitat for northern harriers, red-tail hawks, Swainson's hawks, and other raptors, and nesting habitat for both resident birds (pheasant, wild turkey) and summer breeding migrants (upland sandpiper, marsh wren, grasshopper sparrow, bob-o-link). Their storehouse of organisms including small mammals, amphibians, insects, insect larvae, earthworms, snails, other invertebrates, roots, seeds, tubers, and other plant parts, provide abundant food sources for many birds and other species of animals.

Since the late 1800s, an estimated 75-80% of the wet meadows along the Platte have disappeared from the landscape (Currier et al. 1985, Sidle et al. 1989). As settlement expanded onto the central plains, many meadows were ditched and drained to allow conversion to cropland. Intensive grazing and haying has also changed the character of many of the remaining sites by reducing the stature of the vegetation, eliminating sensitive species, and allowing invasion and expansion of weedy and introduced plants such as bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*). Water development in the Platte River Basin and reductions of about two-thirds of the peak and mean annual flows in the stream (Williams 1978, U.S. Geological Survey 1983, U.S. Fish and Wildlife Service 1994) have undoubtedly affected the hydrology of wet meadows as well. As a result of areal reductions and changes in hydrology, (including groundwater declines), wet meadows are now thought to be one of the most limiting habitat components in the Big Bend Reach of the Platte (Currier et al. 1985, Sidle et al. 1989).

In recent years, the Platte River Trust and other conservation groups have acquired and protected a number of wet meadows, and have begun restorations on other sites. Grazing and haying rotations, prescribed burning, reductions in stocking rates, and reseeding have been used to enhance and restore much of this habitat. The Trust has also experimented with windmills, low-head sills and dams, and the re-shaping of ground surface topography, as ways to enhance wet meadow hydrology.

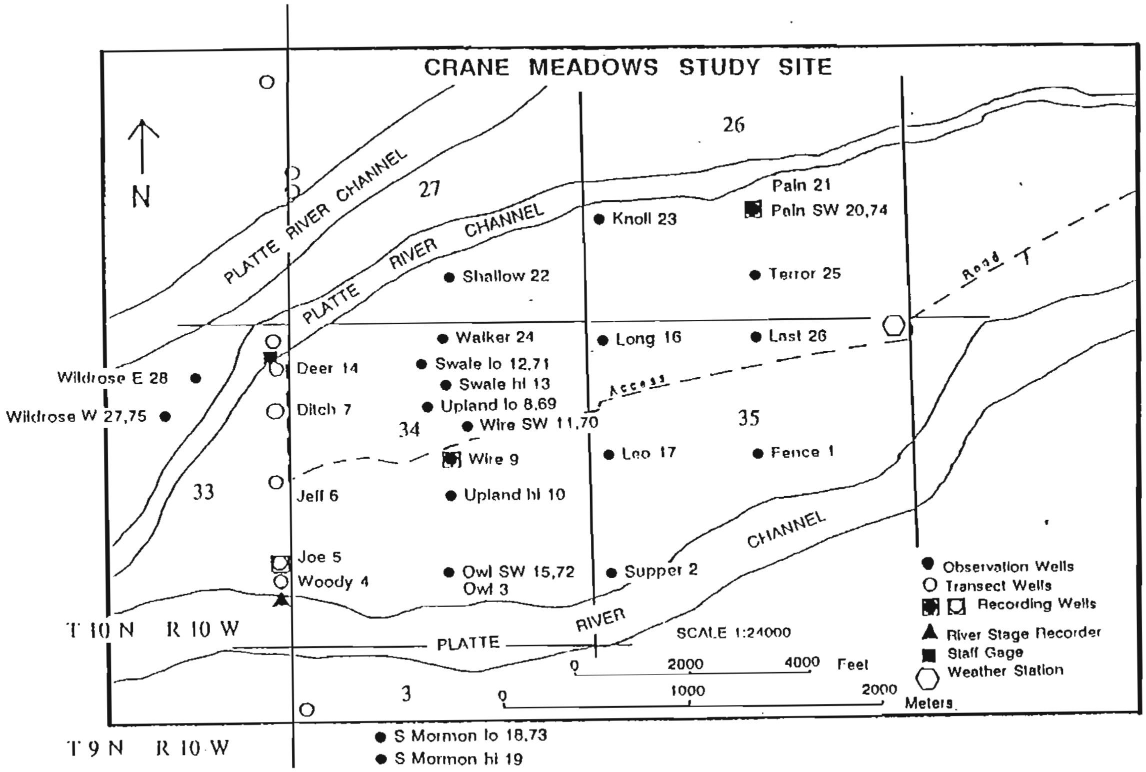
Although these land management techniques have made substantial improvements in the diversity and standing crop of wet meadows, important questions remain about the relationship between vegetation, soils, and hydrology, and the water regime that is necessary to manage and maintain wet meadows (See Currier 1995, this proceedings). Although several studies have been conducted characterizing the native vegetation of wet meadows (Nagel 1981, Kolstad 1981, Currier 1982, Currier 1987), and their hydrology (Schreurs and Rainwater 1956, Hurr 1983, Henszey and Wesche 1993, Wesche et al. 1994), the direct relationship between hydrology and plant distribution and abundance has not been investigated in detail.

A unique opportunity to study vegetation-hydrology relationships was afforded by the 4-year groundwater/surface water study being conducted by the Wyoming Water Research Center (Wesche et al. 1994). The Water Center Study was designed to monitor groundwater and surface water levels at 3 locations along the Central Platte through a series of staff gages, river stilling wells, observation wells, and continuous recording wells. In order to gather information concerning the direction and flow of groundwater, a grid of wells was established at the study sites (Figure 1). Because long-term hydrology data was already being collected at these locations, this study was planned to provide corresponding vegetation and soil data. Sampling was conducted in the immediate vicinity of each well site in mid-summer 1991.

It was hoped that the well locations would represent a broad spectrum of hydrologic conditions (i.e., in relation to the ground surface) that are found along the river. Potentially these sites could be used to help identify a variety of vegetative communities and soil types associated with particular water regimes. One purpose of the investigation was aimed at trying to identify individual plant species that could be used as indicators of certain community types and groundwater/surface water conditions. Such indicator species could be an important source of information for monitoring the long-term status and condition of wet meadows and ultimately an important tool for managing this habitat type.

<u>Study Sites</u>

The wells and well sites sampled during the study were located in 3 wet meadows adjacent to the channel in the Big Bend reach of the Platte (Figure 1, Table 1). The 3 sites were located in a 60-mile stretch of the river, approximately 30 miles apart. The Mormon Island Crane Meadows site near Grand Island (T10N R10W Sec. 26, 27, 33, 34 & 35 and T9N R10W Sec. 3, Hall Co.) and the Elm Creek site located between Elm Creek and Overton on the south edge of the river (T8N R19W Sec. 10, 15 and 16) are owned and managed by the Platte River Trust. The third study site at Rowe Sanctuary near Gibbon (T8N R14W Sec. 8 & 17 and T9N R14 Sec. 34), is owned and managed by The National Audubon Society. The study sites represent a gradient in wetland conditions from a very wet (Mormon Island) to intermediate moisture (Rowe Sanctuary) to relatively dry (Elm Creek). The Mormon and Rowe sites were located on large, several thousand acre, islands surrounded by river channels. The Elm Creek site was located adjacent to the river channel, but was also influenced by return flows from the Phelps County Canal and a large drainage canal running through the study area (see Wesche et al. 1994). Drainage patterns at the 3 sites also varied. The most dissected drainage was found at Mormon Island, with a network of inter-connected swales and sloughs. At Rowe Sanctuary, this pattern was repeated, but fewer sloughs and swales were present. Finally, at Elm Creek there were relatively few sloughs and some wetlands characteristic of prairie potholes. Nearly all the well sites at Mormon Island and Elm Creek are subject to grazing or haying. Portions of the Rowe Sanctuary site were also hayed. Prescribed burning has been used at all 3 study locations.



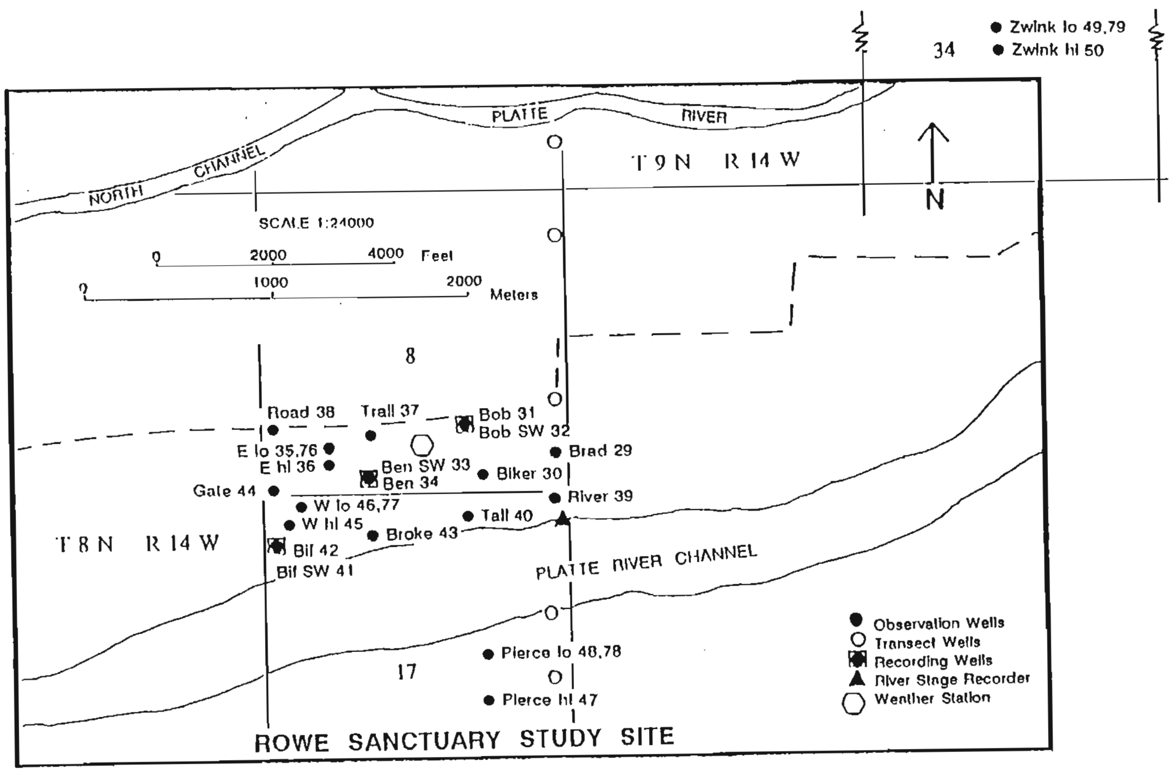


Figure 1. Location of observation wells, recorders, and staff gages at the Mormon Island Crane Meadows, Rowe Sanctuary, and Elm Creek Study Sites.

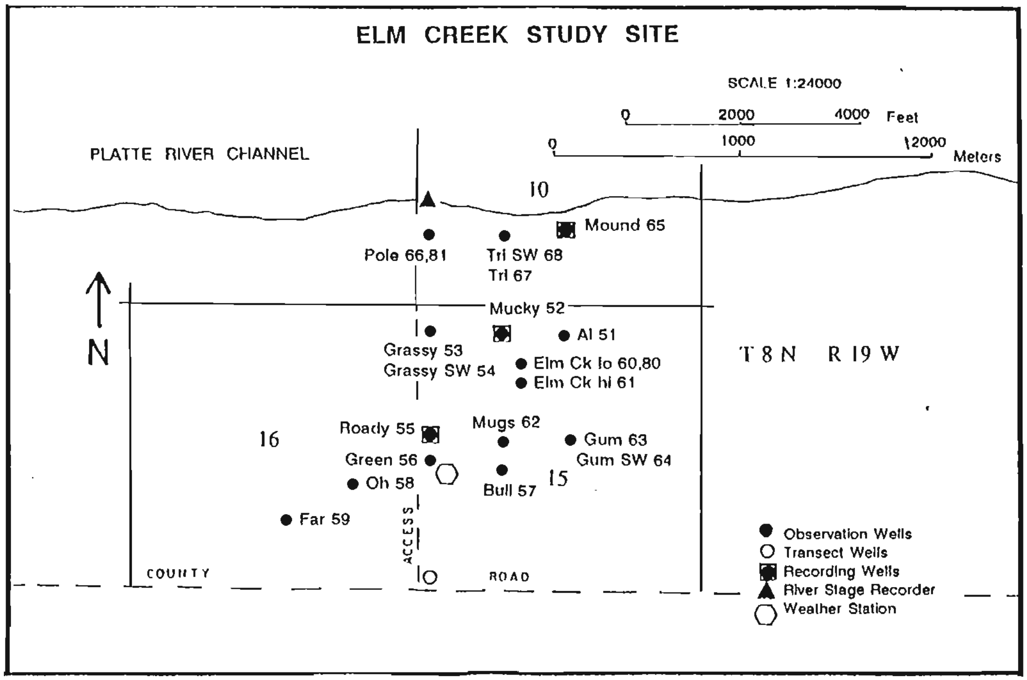


Figure 1. (continued).

METHODS

Groundwater well data from July 1988 to January 1992 were used in the study and were provided by the Wyoming Water Center and National Audubon Society (Wesche et al. 1994, per. comm. Bob Henszey & Bill Dunn). The wells used in the study were constructed of 10 to 20 foot long casings of 2-inch diameter PVC pipe with perforations on the bottom end. Most wells were drilled using a Giddings Rig. Wells were primarily measured on a weekly basis although a select number were monitored with continuous recorders. Measurements were made to the nearest 0.10 foot from the top of each well casing to the groundwater surface. Raw well measurements were adjusted to correct for the height of each well above the ground so that the data represented water table depths below the ground surface. In addition, elevation survey data was collected in a 25-foot radius around each well using a Topcon Level and stadia rod. Based on this elevational survey, an average land surface elevation was determined and the well data were then corrected to represent this average elevation (Table 1). On sites with variable topography (e.g., ridges and swales), the area was subdivided to represent "high" and "low" sites. The corresponding well data was also adjusted to the average elevation for each subdivision. Well numbers 69-81 represent these additional, subdivided sites (e.g., well 34CDA-sw was divided into #72, Owl-sw-lo and #15, Owl-sw-hi).

Table 1. Well numbers, names, and elevation corrections (in feet) for each well site. Elevations were adjusted to reflect the average ground surface around each well. At wells with deep swales and high ridges, low and high sites were analyzed separately. Section location names (e.g., 35ACC) are from Wesche et al. (1994).

Well Name		Well Number	Well Elevation	Average Elevation	Correction Factor
MORMON ISLAND CRANE MEADOWS					
35ACC	Fence	1	2.70	2.82	-0.12
35CCB	Supper	2	1.88	2.15	-0.27
34CDA	Owl	3	2.75	2.71	.0.04
34CDA-sw [1]	Owl-sw-lo	72	2.21	1.17	1.04
34CDA-sw	Owl-sw-hi	15	2.21	0.39	1.82
33DDA1	Woody	4	1.22	2.15	-0.93
33DDA2	Joe	5	2.20	2.19	0.01
33ADD	Jeff	6	1.86	1.67	0.19
33AAD	Ditch	7	1.57	1.73	-0.16
--	Upland-lo	8	3.92	3.69	0.23
--	Upland-hi	69	3.92	2.40	1.52
--	Upland-up	10	2.73	2.84	-0.11
34BDD	Wire	9	2.15	2.74	-0.59
34BDD-sw	Wire-sw-lo	11	1.24	0.77	0.47
34BDD-sw	Wire-sw-hi	70	1.24	-0.24	1.48
--	Swale-lo	12	3.95	3.75	0.20
--	Swale-hi	71	3.95	3.27	0.68
--	Swale-up	13	3.03	3.44	-0.41
33AAA	Deer	14	1.15	1.42	-0.27
35BBB	Long	16	2.26	2.27	-0.01
35BCC	Leo	17	2.12	2.23	-0.11
--	South-Mormon-lo	18	3.83	3.51	0.32
--	South-Mormon-hi	73	3.83	2.01	1.82
--	South-Mormon-up	19	2.90	2.88	0.02
26DBB	Pain	21	2.34	2.87	-0.53
26DBB-sw	Pain-sw-hi	74	1.84	0.45	1.39
26DBB-sw	Pain-sw-lo	20	1.84	1.64	0.20
--	Shallow	22	1.60	1.47	0.13
26CBB	Knoll	23	2.22	2.02	0.20
34ABB	Walker	24	3.65	4.08	-0.43
--	Terror	25	1.49	1.51	-0.02
35ABB	Last	26	2.15	2.22	-0.07
33ABC	Wildrose-west-lo	75	0.33	2.96	-2.63
33ABC	Wildrose-west-hi	27	0.33	0.05	0.28
33ABD	Wildrose-east	28	0.10	0.29	-0.19
ROWE SANCTUARY					
8DDD	Brad	29	2.14	2.15	-0.01
8DCD	Biker	30	1.74	1.94	-0.20
8DCA	Bob	31	2.42	2.14	0.28
8DCA-sw	Bob-sw	32	2.88	2.41	0.47

[1] sw = side wells located at higher or lower elevations than the main study well.

Table 1 (Continued).

Well Name		Well Number	Well Elevation	Average Elevation	Correction Factor
ROWE SANCTUARY					
8CDC	Ben	34	2.05	1.66	0.39
8CDC-sw	Ben-sw	33	2.00	2.53	-0.53
--	Rowe-east-lo	35	4.13	3.90	0.23
--	Rowe-east-hi	76	4.13	2.96	1.17
--	Rowe-east-up	36	3.70	3.78	-0.08
8CDB	Trail	37	2.79	3.01	-0.22
8CCB	Road	38	1.40	1.40	0.00
17AAA	River	39	1.98	2.03	-0.05
17ABA	Tall	40	1.91	2.06	-0.15
17BBC	Bif	42	1.99	2.32	-0.33
17BBC-sw	Bif-sw	41	2.15	2.52	-0.37
17BAC	Broke	43	2.04	1.95	0.09
8CCC	Gate	44	1.87	2.21	-0.34
--	Rowe-west-lo	46	3.90	3.50	0.40
--	Rowe-west-hi	77	3.90	2.37	1.53
--	Rowe-west-up	45	3.98	4.65	-0.67
--	Pierce-lo	78	3.79	3.59	0.20
--	Pierce-hi	48	3.79	2.65	1.14
--	Pierce-up	47	3.17	3.38	-0.21
--	Zwink-lo	49	3.83	3.55	0.28
--	Zwink-hi	79	3.83	2.46	1.37
--	Zwink-up	50	3.50	3.26	0.24
ELM CREEK					
15ABB	Al	51	0.50	0.45	0.05
15BBA	Mucky	52	2.06	2.31	-0.25
15BBB	Grassy	53	0.41	0.06	0.35
15BBB-sw	Grassy-sw	54	0.47	0.64	-0.17
15BCC	Roady	55	1.28	1.25	0.03
15CBB	Green	56	0.27	0.10	0.17
15CAB	Bull	57	0.52	0.59	-0.07
16DBA	Oh	58	2.93	3.27	-0.34
16DBC	Far	59	3.11	3.10	0.01
--	Elm-Creek-lo	80	3.72	2.96	0.76
--	Elm-Creek-hi	60	3.72	1.47	2.25
--	Elm-Creek-up	61	2.75	2.94	-0.19
15BDC	Mugs	62	1.77	1.86	-0.09
15ACC	Gum	63	1.80	1.92	-0.12
15ACC-sw	Gum-sw	64	1.25	1.18	0.07
10CAD	Mound	65	1.88	2.80	-0.92
10CBC	Pole-lo	81	3.17	4.68	-1.51
10CBC	Pole-hi	66	3.17	2.95	0.22
10CAC	Tri	67	2.84	3.70	-0.86
10CAC-sw	Tri-sw	68	2.07	1.48	0.59

The adjusted well data for the 81 sample sites were converted to a frequency distribution, representing the percent of time water levels were at various 0.5 foot intervals below the ground surface. Wells were divided into 13 groups according to similarities in hydrology. These divisions were made on the basis of the center of each frequency distribution and the value of a scaled hydrologic ranking index. The index weighted wells with high groundwater with lower values, and wells with lower groundwater levels with higher values. The frequency for each 0.5 ft interval between +1.5 ft to 10 ft below the surface was multiplied by an index value ranging from 0.1 to 2.3. These values were then summed for each sample location and the wells were then sorted according to their ranking.

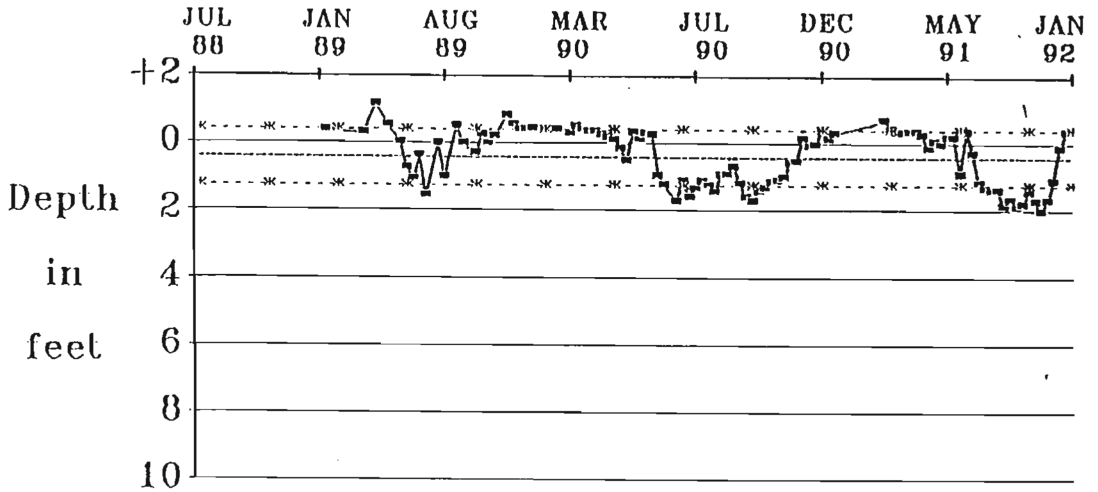
A vegetation survey was conducted in 1991 at each well or subdivided sample location (according to elevational variation). Percentage cover of all plant species within a 25-foot radius of each site was assessed by cover class using a Relevé technique (Mueller-Dombois and Ellenberg 1974). Cover was recorded by class mid-points as follows: 0-5% (3%), 5-15% (10%), 15-25% (20%), 25-50% (38%), 50-75% (63%), 75-100% (88%). Within each of the 13 well groups, the vegetation was averaged in order to examine the relationship between hydrology and vegetation distribution patterns. A list of 36 species was identified that occurred with at least moderate frequency and had a broad enough distribution to be potentially useful in identifying hydrology-vegetation relationships.

Soils were also collected at each sample location using a 1-inch diameter soil probe. Two soil samples were collected at each site and were subdivided into an upper division and a lower division, representing the top 6 inches of the profile and the portion of the profile from 6-12 inches in depth. The two samples were later combined for analysis as a composite sample for the upper and lower portions. A soil texture analysis was performed by drying and grinding each sample and passing them through a series of soil sieves. Percentage dry weight was determined for each of the following soil fractions: coarse sand (0.5 mm and greater), sand (0.125 to 0.5 mm), fine sand (0.063 to 0.125 mm) and silt and clay (finer than 0.063 mm). Although upper and lower profile samples were analyzed separately, the data were combined in the final analysis because the profiles showed little soil development and tended to be highly variable from site to site. Relationships between soil texture and the distributions of individual plant species were examined. In addition, a statistical comparison was made between soil fractions and hydrology, based on the calculated hydrologic index values.

RESULTS

Many of the wells showed similar groundwater fluctuations during the July 1988 to January 1992 monitoring period. Water levels were generally high in winter and spring, and dropped to their lowest levels in mid-summer (Figure 2). In a few isolated cases (i.e., at Wildrose Ranch), groundwater levels stayed high and rather uniform throughout the study (Figure 2). These sites are most likely maintained by springs or other groundwater sources, independent of river stage and precipitation.

SWALE LO – # 12



WILDROSE west LO – # 75

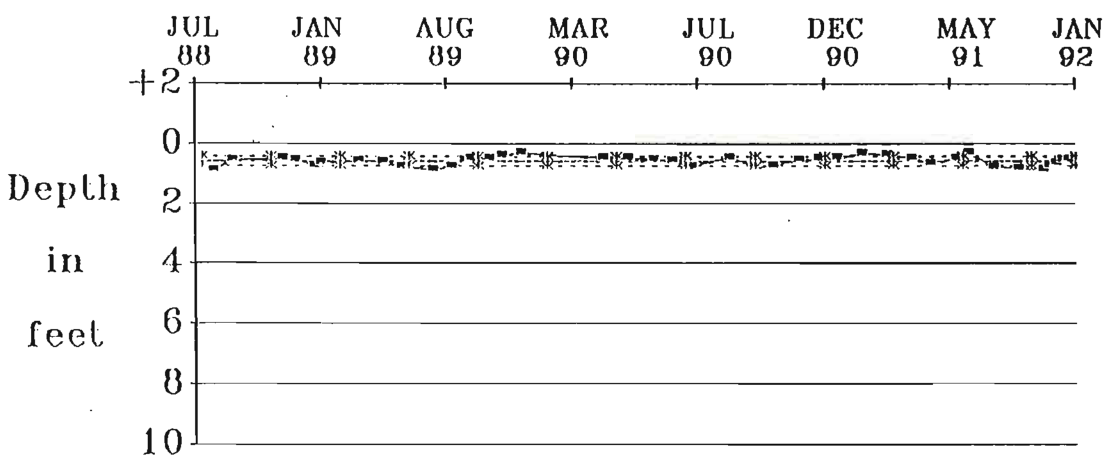


Figure 2. Examples of groundwater monitoring well data used in the study. Most wells exhibited seasonal variation in water levels, with the lowest groundwater level reached in mid-summer (top). A few isolated wells at the Wildrose Ranch showed little variation and the ground remained nearly saturated at these sites throughout the study (bottom). These wells were most likely maintained by underground springs and did not respond directly to changes in river stage or precipitation.

Water level frequency is shown in Table 2 for the 81 sample sites analyzed in the study. Positive values indicate that water was standing above the ground surface. Because above ground water is influenced by percolation rates and runoff, the accuracy of surface depths may be suspect, but the data do clearly indicate complete saturation at the ground surface. The majority of sites (77%) had maximum groundwater levels between 3 feet and 6 feet below the ground. A few sites (17%) had high groundwater levels that never dropped below 3 feet of the ground, and a relatively small number of sites (6%) had water levels at maximum depths of 6 to 9 feet of the surface. The hydrologic grouping for each sample site is shown below each well in Table 2. The wettest (Groups 1 and 2) and driest (Group 13) areas had only one sample site for analysis. In part, this was the result of the scarcity of such sites in the wet meadow landscape. But wells were also routinely placed in moderately elevated sites because they were easier to drill there, and problems with standing water seeping down an unsealed well casing could also generally be avoided.

The 3 study sites showed strong differences in hydrology (Figure 3). The Mormon Island and Rowe Sanctuary sites were dominated by wells where water levels were maintained between 1.0 to 3.5 feet below the ground surface for 60-70% of the time. Water levels were much lower at the Elm Creek site, where 65% of the time groundwater was between 3.5 to 6.0 feet below the surface. In addition, the Elm Creek site had no wells where water levels were maintained within 1 foot of the surface. At Mormon Island over 20% of the well locations were in this high water table group. The broadest range in hydrology was found at the Rowe site where some wells had water levels near the surface and others were up to 8.5 feet below the ground surface. These hydrologic differences support the interpretation of the Mormon Island site as a wet to mesic area, the Rowe Sanctuary as moderately wet, and the Elm Creek site as mesic to relatively dry.

Average cover values for plant species in each hydrologic group are shown in Table 3. Although more than 130 species were sampled during the vegetation survey, many occurred so infrequently that they exhibited no discernible relationship with hydrology. The 36 species listed in Table 3, however, were found frequently enough and with high enough cover values to allow for an examination of potential vegetation-hydrology relationships. In the table, the species have generally been sorted along a continuum from those with high affinity for wetland sites (e.g., spikerush, *Eleocharis macrostachya*) to those on high and quite dry sand ridges (e.g., gumweed, *Grindelia squarrosa*). Most of the species sampled fell between these two extremes and represent a variety of distribution patterns on moderately wet to mesic sites.

Water sedge (*Carex aquatilis*), 3-square (*Scirpus americanus*), and spikerush (*Eleocharis macrostachya*) were the predominant species at the wettest sites, but because they were widely distributed, they are probably not the most sensitive species for defining the boundaries of wetland microsites. Species with lower cover values such as bluejoint (*Calamagrostis inexpansa*), cutgrass (*Leersia virginica*) and smartweeds

Table 2. Water level frequency (percent) for wells at Mormon Island, Rowe Sanctuary, and Elm Creek at 0.5 foot intervals below the ground surface. Wells are ranked by their scaled index values. Centers of each frequency distribution are in **bold**. Positive (+) depths are above the land surface.

DEPTH	Swalelo 12	Wildwlo 75	Painswlo 20	Swalehi 71	Walker 24	Southlo 18	Swaleup 13	Terror 25	Uplandlo 8	Erowelo 35	Wireswlo 11
+1.5 to +1	1					1					
+1 to +0.5	5		2	1	1	2	1		1	2	1
+0.5 to 0	**38**		9	6	4	9	1	10	5	4	5
0 to 0.5	12	39	**29**	**41**	**36**	18	**31**	**32**	**22**	5	17
0.5 to 1	9	**61**	24	10	17	**20**	23	10	19	**26**	**19**
1 to 1.5	21		15	10	14	18	9	10	13	25	15
1.5 to 2	11		15	19	17	14	14	12	14	16	13
2 to 2.5	1		5	11	11	15	12	17	16	21	15
2.5 to 3				1		2	9	10	11		14
3 to 3.5											
Ranking Index	44	46	51	53	53	55	57	57	59	60	62
	Group 1	Group 2	----------	----------	----------	----------	Group 3	----------	----------	----------	----------

DEPTH	Piercelo 78	Long 16	Ditch 7	Leo 17	Bif 42	Owl 3	Owl swlo 72	Far 59	Broke 43	Bob 31	Pain swhi 74	Knoll 23	Wrowe lo 46	Jeff 6	Erowe hi 76
+1.5 to +1															
+1 to +0.5										1					
+0.5 to 0	5			1	1					2			1		
0 to 0.5	7	17	3	7	2	2	3	2	2	0			3	1	3
0.5 to 1	19	**33**	**30**	**26**	9	4	9	2	2	4	7	4	2	9	3
1 to 1.5	**29**	9	25	14	**33**	**30**	20	15	15	14	18	20	10	**24**	6
1.5 to 2	16	8	10	19	29	28	**27**	**35**	**40**	**35**	**33**	**30**	**36**	23	**32**
2 to 2.5	18	14	20	11	19	22	18	29	21	21	14	17	19	9	19
2.5 to 3	6	16	11	13	9	13	16	13	21	18	18	25	21	17	17
3 to 3.5		3	1	10		2	8	3		5	9	4	8	12	20
3.5 to 4											1			6	
4 to 4.5															
Ranking Index	62	63	65	68	68	71	73	74	74	74	75	75	76	76	79
	----------	Group 4	----------	----------	----------	----------	----------	----------	----------	----------	Group 5	----------	----------	----------	----------

Table 2. (continued - part 2).

DEPTH	Pierce hi 48	Wire swhi 70	Green 56	Elmck lo 80	River 39	South hi 73	Upland hi 69	Gumsw 64	Biker 30	Zwlo 49	Gate 44	Joe 5	Pierce up 47	Bifsw 41
+1.5 to +1														
+1 to +0.5														
+0.5 to 0				1						3				
0 to 0.5		1		0		1		1	2	1	1			
0.5 to 1	5	4		1		2	1	0	1	2	2	1	1	
1 to 1.5	10	17	2	3	2	9	11	0	2	9	2	1	5	2
1.5 to 2	20	**20**	11	5	19	18	**25**	1	7	10	9	17	9	3
2 to 2.5	**27**	15	**50**	33	**30**	**20**	17	35	**35**	11	**31**	**25**	**28**	29
2.5 to 3	18	12	30	**47**	24	18	10	**60**	24	**24**	24	24	20	**34**
3 to 3.5	18	16	8	10	24	14	17	2	21	24	17	15	17	19
3.5 to 4	2	13			1	14	13		7	8	15	17	18	13
4 to 4.5		1			3	7				6		1	2	
4.5 to 5										1				
5 to 5.5														
5.5 to 6														
Ranking Index	81	82	83	85	85	86	86	86	87	87	88	89	90	90
	Group 6													

DEPTH	Shallow 22	Last 26	Ben 34	Wroweup 45	Trail 37	Fence 1	Brad 29	Oh 58	Wire 9	Bensw 33	Wrowehi 77	Tall 40
+1.5 to +1												
+1 to +0.5												
+0.5 to 0												
0 to 0.5					1							
0.5 to 1			2	2	0	1	1		1	2		
1 to 1.5	4		2	2	2	2	2	2	2	1	4	
1.5 to 2	4	20	3	4	5	12	2	8	10	2	1	
2 to 2.5	21	**29**	21	19	17	**25**	19	6	**27**	9	7	8
2.5 to 3	27	12	**32**	**31**	**34**	16	**30**	25	15	**34**	**36**	31
3 to 3.5	**30**	11	19	18	18	19	23	**50**	13	22	21	**32**
3.5 to 4	11	11	22	19	23	9	19	9	11	21	15	23
4 to 4.5	1	12		5	2	13	4		15	8	15	6
4.5 to 5		4				3			7			
5 to 5.5												
5.5 to 6												
Ranking Index	91	92	92	93	93	93	94	94	95	97	98	99
	Group 7											

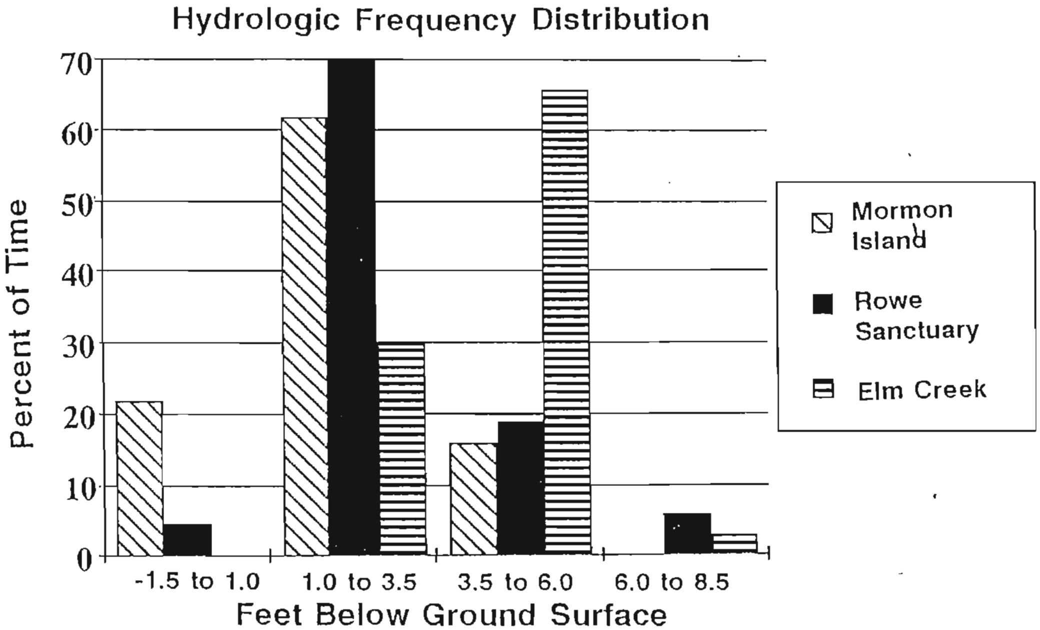
Table 2. (continued - part 3).

DEPTH	Eroweup 36	Pain 21	Wilde 28	Supper 2	Southup 19	Polelo 81	Wildwhi 27	Deer 14	Woody 4
+1.5 to +1									
+1 to +0.5									
+0.5 to 0									
0 to 0.5					1				
0.5 to 1	1				0				
1 to 1.5	1			1	1				
1.5 to 2	3	1		1	3	1			
2 to 2.5	7	15		10	13	1		7	2
2.5 to 3	**26**	**29**	14	**24**	12	5		12	15
3 to 3.5	24	20	**64**	24	**23**	**56**	**61**	24	**30**
3.5 to 4	16	15	23	23	20	36	39	**31**	29
4 to 4.5	21	14		18	20	3		19	21
4.5 to 5		7			6			6	3
5 to 5.5					1				
5.5 to 6									
Ranking Index	100	100	101	101	102	103	104	106	106
	Group 8								

DEPTH	Uplandup 10	Zwhi 79	Owlswhi 15	Trisw 68	Bull 57	Elmckhi 60	Grassy 53	Mucky 52	Mugs 62	Mound 65	Al 51	Elmckup 61
+1.5 to +1												
+1 to +0.5												
+0.5 to 0												
0 to 0.5												
0.5 to 1		3										
1 to 1.5	1	1				1						
1.5 to 2	1	2	1			0	1	1			1	1
2 to 2.5	5	8	2	1		1	1	0			0	0
2.5 to 3	**25**	5	15	0	2	3	2	2	1	1	1	0
3 to 3.5	21	15	**25**	10	9	6	5	6	1	1	4	3
3.5 to 4	12	21	22	**68**	**56**	32	10	7	7	12	8	4
4 to 4.5	12	**24**	17	18	32	**47**	**54**	**59**	**69**	**62**	**36**	13
4.5 to 5	14	13	15	4	2	10	24	21	22	19	32	**61**
5 to 5.5	10	7	3				2	4		6	17	19
5.5 to 6											1	
6 to 6.5												
6.5 to 7												
Ranking Index	107	109	109	111	112	115	119	120	121	121	125	128
	Group 9								Group 10			

Table 2. (continued - part 4).

DEPTH	Roady 55	Gum 63	Polehi 66	Tri 67	Bobsw 32	Road 38	Grassysw 54	Zwup 50
+1.5 to +1								
+1 to +0.5								
+0.5 to 0								
0 to 0.5								
0.5 to 1								
1 to 1.5								
1.5 to 2								
2 to 2.5								
2.5 to 3						1		
3 to 3.5	1	1			1	0		
3.5 to 4	0	0	1		2	1	1	
4 to 4.5	7	1	1	1	2	2	1	2
4.5 to 5	**56**	43	19	1	5	4	3	2
5 to 5.5	36	**54**	**66**	18	**31**	19	8	3
5.5 to 6			13	**68**	25	**35**	**41**	8
6 to 6.5				11	16	14	38	9
6.5 to 7				2	19	19	8	11
7 to 7.5						4		21
7.5 to 8								**22**
8 to 8.5								13
8.5 to 9								5
9 to 9.5								3
9.5 to 10								
Ranking Index	133	135	139	149	150	152	153	179
	---------- Group 11 ---------			---------------- Group 12 -----------------				Group 13



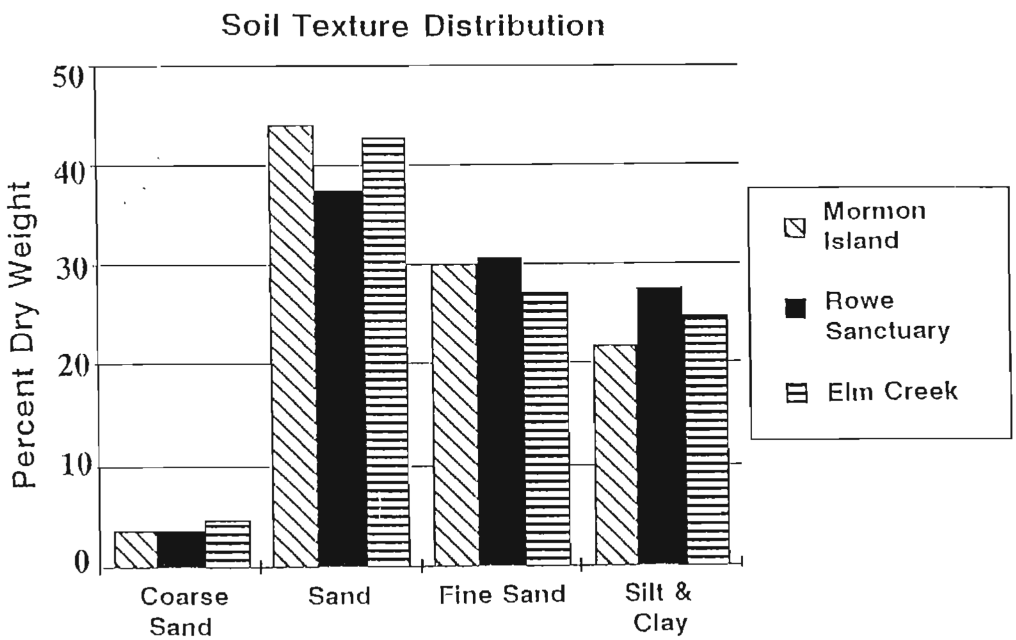


Figure 3. Hydrologic frequency and soil texture distribution at the 3 study areas. Major differences in hydrology establish Mormon Island as a wet site, Rowe Sanctuary as a moderately wet site, and Elm Creek as a relatively dry site. In contrast, soils showed little variation at the sites.

Table 3. Summary of dominant plant species by hydrologic well group. Average percentage cover for each species within each group is shown. Species are listed from wet to dry, according to their general wetland affinities.

	Hydrologic Well Group												
# SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13
55 Eleocharis macrostachya	38.0		24.9	4.6	10.6	4.3	3.2	10.3	0.4	14.5			
124 Polygonum nutans		10.0	7.6	2.0	2.0	0.7							
173 Xanthium strumarium	10.0		0.7	0.6		0.2		0.3					
123 Polygonum lapathifolium	10.0		8.4	0.6	1.3	1.1							
35 Carex aquatilis	63.0	20.0	64.6	8.0	28.0	20.5	0.8	3.3					
88 Leersia virginica	10.0		4.2	2.0	1.0								
116 Phyla lanceolata		20.0	6.2	9.6	5.0	7.1	0.3	1.1					
31 Calamagrostis inexpansa	20.0		8.7	2.0	2.3								
139 Scirpus americanus	3.0	63.0	6.2	12.6	10.0	6.2	1.7		1.3				
149 Spartina pectinata	10.0	20.0	13.4	2.0	14.1	11.3	9.4	5.9	6.6	12.5	13.3		3.0
166 Verbena hastata		10.0	0.7	0.6	1.3	0.2	0.3	2.2					
170 Vernonia fasciculata			11.8	6.6	3.3	3.5			1.6				
5 Agrostis stolonifera			10.7	23.2	9.8	10.8	12.3	9.8	12.0		1.0	3.3	
82 Hordeum jubatum			1.0	10.2	3.0	9.0	1.9	4.4	3.8				3.0
83 Iva annua			1.4	17.6	6.1	7.2							10.0
145 Solidago canadensis			8.7	10.2	8.1	4.4	5.5			0.8		1.0	
21 Aster ericoides		3.0	3.7	13.6	2.6	3.8	7.2	1.4	2.0	2.5	1.0		3.0
160 Trifolium hybridum				12.6		10.1		8.7					
99 Melilotus albus				12.6	1.6	4.2	5.9	6.4					
71 Glycyrrhiza lepidota			2.9	7.6	9.6	3.9			2.5				
15 Apocynum sibiricum			4.8	4.6	17.7	1.4	2.7		0.4				
2 Agropyron spp.			4.4	15.6	14.1	14.0	10.0	2.6	12.6	5.0	3.3	12.7	20.0
9 Ambrosia artemisiifolia		10.0	3.7	6.6	12.6	18.1	10.3	26.6	10.1	10.8	13.3	10.0	20.0
29 Bromus japonicus				0.6	0.6	5.3	0.8	8.2	5.0	5.8	6.7	6.7	10.0
52 Distichlis spicata				7.6	6.3	10.8	4.2	13.4	7.5		10.0		3.0
121 Poa pratensis		10.0	2.9	4.0	2.0	14.6	19.5	43.7	45.1	33.5	26.0	19.3	88.0
111 Panicum virgatum		20.0	22.4	35.4	24.2	25.0	37.1	18.2	28.0	33.5	22.7	12.7	3.0
13 Andropogon gerardi				2.0	15.9	13.6	46.3	15.7	26.1	56.8	33.7	27.7	
28 Bromus inermis					3.0	9.9	15.2	19.3	19.5	39.8	33.7	53.7	
128 Populus deltoides					2.3	0.2	0.3	4.2				21.0	
36 Carex heliophila								1.1	1.3	2.5			10.0
33 Cannabis sativa								1.0	0.4	9.5			
32 Callirhoe involucrata							1.1	3.7	2.0	3.3	10.0	1.0	
39 Cenchrus longispinus								1.1		5.0	1.0	3.3	
26 Bouteloua gracilis								2.2	18.9		13.3	25.3	
72 Grindelia squarrosa							1.7	1.1					10.0

(*Polygonum spp.*) are probably better candidates as wet site indicators because they had more narrowly defined distributions but were still closely associated with the wettest sites. A number of forbs with relatively low cover values were also characteristic of moderately wet sites. These included fog fruit (*Phyla lanceolata*), ironweed (*Vernonia fasciculata*), and blue vervain (*Verbena hastata*). In the middle of the moisture gradient, a number of grasses such as switchgrass (*Panicum virgatum*), cordgrass (*Spartina pectinata*), and wheatgrass (*Agropyron* spp.) were quite ubiquitous and did not appear to be very useful candidates as indicator species. However, wild licorice (*Glycyrrhiza lepidota*), dogbane (*Apocynum sibiricum*), Canada goldenrod (*Solidago canadensis*), and white sweet clover (*Melilotus albus*), had distributions that appeared to be quite sensitive to intermediate moisture sites. These species seem to appear quite abruptly at the boundary of the moderately wet/intermediately wet sites (between hydrologic groups 2 and 3), but extended various distances up the moisture gradient. Goldenrod for instance, was quite widely distributed (groups 3-12), but its greatest cover values were in the intermediate moisture sites (Figure 4). Because white sweet clover is often associated with past disturbances (e.g., overgrazed or tilled sites) it may not be a very useful long-term indicator species, even though its distribution was quite narrowly defined. In some situations, such as at Rowe Sanctuary, white sweet clover can persist long after a disturbance (more than a decade after cattle were removed and cropping was stopped).

Mesic to moderately dry sites were characterized by smooth brome (*Bromus inermis*), and big bluestem (*Andropogon gerardi*). These species were also quite widely distributed, but their cover values dropped-off sharply on both the wet and dry ends of the gradient (Figure 4). Blue grama (*Bouteloua gracilis*), field sandbur (*Cenchrus longispinus*), and purple poppy mallow (*Callirhoe involucrata*), were characteristic species for dry sites located primarily on high sand ridges in the meadows. A number of species had distributions that appeared to be more highly associated with disturbances than the general moisture regime. These included bluegrass (*Poa pratensis*), common ragweed (*Ambrosia artemisiifolia*), marsh elder (*Iva annua*), and foxtail barley (*Hordeum jubatum*) (Figure 4). These species are opportunistic colonizers that take advanatage of openings in the vegetative cover. Such openings can be the result of grazing, cattle hoof action, or standing water mudflats. Because these disturbances can occur on both low sites and high ridges, the distribution of the colonizing species may be quite heterogeneous and not very indicative of the moisture gradient present at a site. Although foxtail barley is often used as a general wetland indicator, its distribution in this study did not seem to be very sensitive to subtle differences in hydrology along the gradient.

Soil texture analyses did not reveal any major trends associated with the study sites or their general hydrology. Although major differences in hydrology were noted at the 3 study locations, there were only minor differences in soils (Figure 3). A few plants appeared to be associated with particular soil fractions. For instance, redtop (*Agrostis stolonifera*) was positively correlated with silt and clay, and water sedge was correlated with coarse sand, but these trends were not particularly strong (Figure 5).

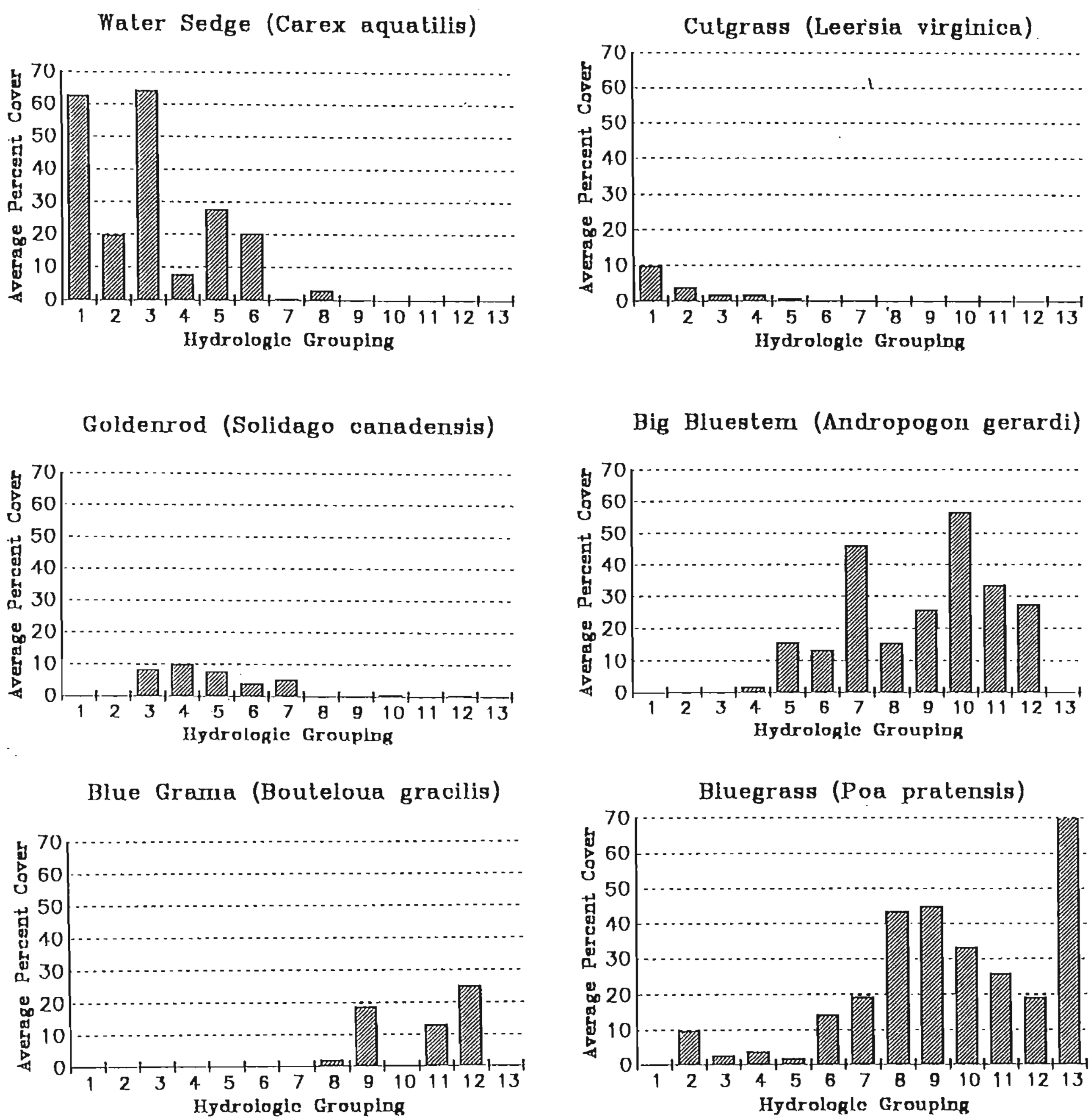


Figure 4. Examples of potential indicator species for wet (water sedge, cutgrass), moderately wet (goldenrod), mesic (big bluestem), and relatively dry (blue grama) sites in wet meadows. Bluegrass and other disturbance species were not very sensitive to the hydrologic gradient.

DISCUSSION

Of the more than 150 species of plants surveyed in this study, 36 were identified as having potential as indicator species for particular hydrologic conditions in wet meadows. Upon an examination of their distributions, approximately 13 or 14 of these species were thought to reflect particular aspects of the relationship between vegetation and hydrology along the Platte. The best of these species seemed to be moderately important in the flora rather than widespread dominants. This is a good start in understanding the dynamics of hydrology and vegetation in wet meadows, but the species identified in this study need to be examined more extensively in order to determine their actual distributions over the larger wet meadow landscape, and to investigate their true utility as indicator species. Hopefully the specific microsites associated with individual species or guilds of species would be identified in such an investigation.

One way that this could be done is to establish a grid of several hundred sampling points on a meadow. At each point, measurements would be made of the presence or absence of particular indicator species, a global position (GPS) for the site, relative elevation, and some measure of hydrology. One suggestion for rapid assessment of hydrology is to use the 'rusty rod' technique. In this technique, an iron reinforcing rod is driven into the ground. When the soil at the site becomes saturated for 2-3 weeks, oxidation occurs on the portion of the rod exposed to the saturation. By measuring the depth of the saturated zone below the ground, a relative measure of wet meadow hydrology can be obtained without having to drill and monitor an extensive network of groundwater wells. Using this technique, the hydrologic variability over a relatively large area and number of sites could be determined in relation to vegetation.

Such sampling and the refinement of specific indicator species could be very important in long-term monitoring of the status of wet meadows. In particular, if hydrologically-sensitive species can be identified, a rapid survey of their abundance and distribution could be used as a measure of sustainability or change in wet meadows. These indicators might also be used to define the minimum hydrologic regime needed to maintain or restore meadows and their diversity of habitats.

Further investigation is also needed to understand the relationship between wet meadow soils and hydrology. The lack of a direct relationship between soils and hydrology may simply indicate that wet meadow soils are relatively young, alluvial deposits, with little profile development. However, the limited number of well sites investigated during the study, and the variability in soils observed during the sampling, may have obscured whatever subtle relationship exists between the soils, hydrology, and vegetation. In future work, soils should also be sampled in relation to the distribution of specific indicator plants, rather than as a general sample representing an entire well site.

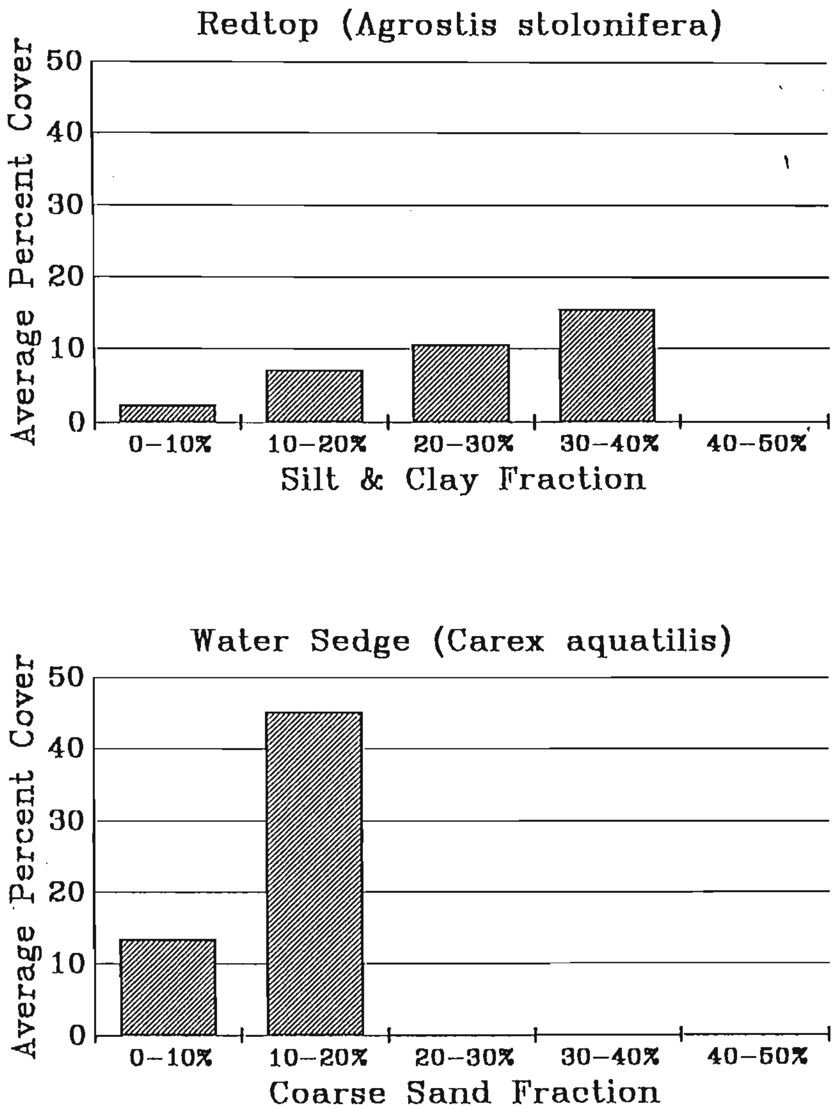


Figure 5. Relationships of redtop and water sedge to specific soil fractions. Few of the species sampled showed such associations.

The small number of sample sites examined in the study, and their predetermined locations may also have biased the analysis. Because most of the wells at a site fluctuated in tandem, the groundwater data collected was most likely unaffected by the selection of well sites. But well locations did influence how far below the surface the groundwater table was located, and thus had an impact on the vegetative communities included in the survey. Most wells were positioned on intermediately elevated sites in order to avoid the need for deep wells and to prevent standing water (in lowland sites) from accumulating around well casings. The result of this bias in selecting well locations is that few sample sites were located in the wettest or the driest communities that occur on the meadows.

Grazing and haying could also have influenced the study. Because plants undoubtedly respond differentially to grazing and haying pressures, their abundance and distribution may have been limited by management decisions, rather than soils or hydrologic conditions. This was thought to be the case with the disturbance species identified above (e.g., bluegrass, ragweed), and they were therefore excluded as indicators. But management could also have affected those species that were ultimately chosen as indicators. For instance, in one of the more extreme situations, the vegetation at well #48 Piercelo, (and sample site #78), was almost completely different on the 2 sides of a fenceline that ran through the middle of the sample area. In this case a decision was made to sample the vegetation on both sides of the fence and then average their cover values. Although this was probably an appropriate technique for assessing the vegetative cover at the site, it most likely confounded any attempt to sort out species distributions in relation to the water regime. In any case, this is a complicating factor that should be examined in greater detail.

Finally, one minor factor may also have affected the data sampled in the study. Because the wells were monitored on a weekly basis, there was a local, repeated disturbance at each site when the wells were measured. Additional disturbance may also have been created by cattle which would often rub against the wells or the fencing placed around them. These disturbances were primarily avoided by sampling at some distance from the base of each well. However, they could ultimately influence plant distributions and therefore the true relationship between vegetation and hydrology.

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