A--Length of growing season

Table 1.--Length of growing season (frost to frost) recorded at each station in the Powder River Basin, 1965-74

[The mean growing-season length is the interval between the mean date of last spring frost and the mean date of first autumn frost computed from the entire 10-year period; the maximum is the longest frost-free interval recorded during the 10-year period and the minimum is the shortest frost-free interval. *, synthesized record]

Station	Mean: Last spring	Mean: First fall	Mean: Interval (days)	Maximum: Year	Maximum: Last spring	Maximum: First fall	Maximum: Interval (days)	Minimum: Year	Minimum: Last spring	Minimum: First fall	Minimum: Interval (days)
MONTANA											
Albion 1N*	5-19	9-12	116	1967	5-13	9-24	134	1966	5-19	8-23	96
Biddle 8SW	5-21	9-15	117	1967	5-12	9-27	138	1966	5-19	8-22	95
Birney 2SW*	5-24	9-12	111	1972	5-2	9-20	141	1964	6-2	8-25	84
Brandenburg	5-21	9-19	121	1966	5-19	10-10	144	1969	6-14	9-15	93
Broadus	5-22	9-13	114	1972	5-4	9-17	136	1966	5-19	8-23	96
Busby*	5-30	8-30	92	1968	5-20	9-17	120	1972	5-26	7-3	38
Colstrip*	5-25	9-17	115	1966	5-12	10-4	145	1965	6-8	9-7	91
Crow Agency*	5-20	9-24	127	1966	5-19	10-10	144	1965	6-8	9-16	100
Custer	5-18	9-21	126	1972	5-2	9-21	142	1965	5-27	9-17	113
Ekalaka	5-27	9-15	111	1967	5-13	9-27	137	1972	6-20	9-1	73
Forsyth 2E*	5-14	9-24	133	1966	5-12	10-10	151	1974	5-23	9-2	102
Hardin*	5-21	9-24	126	1967	5-15	10-17	155	1965	6-8	9-16	100
Hysham	5-19	9-20	124	1966	5-19	10-2	136	1974	5-23	9-2	102
Hysham 19SSE*	5-24	9-5	104	1967	5-15	9-23	131	1973	5-29	7-2	34
Kirby 1S	6-11	8-23	73	1968	6-1	9-17	108	1971	6-30	7-8	8
Miles City FAA AP	5-9	9-26	140	1973	4-29	10-12	166	1965	5-27	9-16	112
Mizpah 4NNW	5-19	9-7	111	1972	5-3	9-21	141	1969	6-14	9-7	85
Moorhead 9NE*	5-19	9-9	113	1972	5-4	9-21	140	1969	6-13	9-7	86
Otter 9SSW	5-20	9-21	124	1967	5-14	10-4	143	1965	5-27	9-16	112
Powderville 8NNE*	5-18	9-18	123	1966	5-12	10-1	142	1965	6-8	9-1	85
Ridgeway 1S*	5-22	9-9	110	1972	5-6	9-21	138	1974	6-7	8-3	57
Sonnette 2WNW*	5-26	9-11	108	1972	5-6	9-21	138	1966	6-12	8-22	71
Wyola	5-30	9-15	108	1966	5-23	10-1	131	1969	6-14	9-6	84
Yellowtail Dam	5-12	9-19	130	1967	5-13	10-18	158	1969	6-13	10-11	120
WYOMING											
Alcova 17NW*	6-12	9-17	97	1965	5-27	9-28	124	1968	6-30	8-17	48
Arvada 3N*	5-17	9-10	116	1967	5-11	9-27	139	1972	5-2	7-14	73
Bates Creek	6-4	8-30	87	1967	5-20	9-13	116	1972	5-13	7-4	52
Billy Creek	5-29	9-19	113	1967	5-20	9-27	130	1973	6-18	9-15	89
Buffalo	5-28	9-12	107	1972	5-9	9-22	136	1970	6-1	9-10	101
Casper AP	5-27	9-11	107	1967	5-14	10-7	146	1965	5-27	9-1	97
Clearmont 5SW	5-27	9-4	100	1966	5-23	10-1	131	1972	5-26	7-4	39
Dead Horse Creek*	5-25	9-19	117	1967	5-14	10-7	146	1973	6-18	9-15	89
Devils Tower No. 2	6-5	8-26	82	1970	5-9	9-13	127	1972	6-20	7-4	14
Dillinger	5-25	9-7	105	1966	5-24	9-30	129	1972	5-7	7-4	58
Douglas Aviation*	5-21	9-15	117	1967	5-15	9-27	135	1969	6-13	9-23	102
Dull Center 1SE	5-22	9-16	117	1972	5-7	9-21	137	1971	5-19	7-22	64
Echeta 2NW*	5-24	9-14	113	1972	5-2	9-25	146	1966	6-16	8-22	67
Gillette 2E	5-22	9-19	120	1972	5-3	9-21	141	1965	5-27	9-5	101
Gillette 18SW*	5-28	9-17	112	1967	5-14	9-27	136	1973	6-18	9-15	89
Glenrock 5ESE	5-18	9-19	124	1967	5-14	10-13	152	1973	5-28	9-3	98
Glenrock 14SSE	6-5	9-2	89	1967	5-20	9-27	130	1968	5-21	7-1	41
Kaycee*	5-28	9-5	100	1967	5-17	9-27	133	1972	5-11	7-4	54
Keeline*	5-27	9-8	104	1967	5-15	9-13	121	1972	5-14	7-4	51
Lance Creek 3WNW*	5-24	9-17	116	1967	5-14	9-27	136	1974	5-31	9-3	95
Lawver 10SW*	5-28	9-17	112	1968	5-20	10-2	135	1974	6-8	9-3	87
Leiter 9N	5-18	9-21	126	1972	5-2	9-21	142	1969	6-14	10-3	111
Lost Cabin	6-1	9-4	95	1967	5-22	9-13	114	1972	5-12	7-4	53
Midwest 1SW	5-21	9-22	124	1967	5-14	10-7	146	1974	5-31	9-12	104
Moorcroft*	5-25	9-20	118	1972	5-3	9-21	141	1967	6-1	9-12	103
Morrisey*	5-18	9-19	124	1972	5-1	9-21	143	1966	5-20	8-22	94
Newcastle*	5-21	9-22	124	1968	5-11	10-3	145	1974	5-31	9-13	105
Powder River 2SW	5-29	9-8	102	1967	5-20	10-7	140	1972	5-12	7-3	52
Recluse 14NNW*	5-24	9-12	111	1967	5-13	9-27	137	1971	5-19	7-29	71
Redbird 1NW*	5-23	9-18	118	1967	5-14	9-27	136	1965	5-27	9-1	97
Reno*	5-27	9-17	113	1967	5-14	9-27	136	1973	6-18	9-15	89
Rochelle 3E	5-22	9-7	108	1966	5-14	9-27	136	1972	5-4	7-3	60
Sheridan Field Station	5-27	9-7	103	1967	5-16	9-27	134	1969	6-15	7-28	43
Spencer 10NE*	5-21	9-14	116	1971	4-28	9-15	140	1966	5-24	8-22	90
Sundance	5-26	9-15	112	1968	5-20	10-3	136	1973	6-18	9-15	89
Ten Sleep 4NE	5-22	9-26	127	1967	5-12	10-16	157	1970	6-13	9-13	92
Ten Sleep 16SSE*	5-29	9-5	99	1967	5-13	10-7	147	1972	5-26	7-4	39
Upton	5-27	8-30	95	1967	5-15	9-27	135	1972	5-14	7-4	51
Weston 1E	5-21	9-12	114	1972	5-2	9-21	142	1966	5-24	8-22	90

Table 2.--Mean monthly precipitation from stations in the Powder River Basin, in inches

[These statistics were computed using the average precipitation for each of the 12 months. Pattern indicates months included in growing season]

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Based on year: Mean ($\bar{x}$)	Based on year: Standard deviation (σ)	Based on growing season: Mean ($\bar{x}$)	Based on growing season: Standard deviation (σ)
MONTANA																
Albion 1N	0.29	0.29	0.46	2.02	2.36	3.06	1.49	1.28	1.19	1.12	0.40	0.45	1.201	0.904	1.876	0.808
Biddle 8SW	.59	.33	.74	1.68	2.30	2.63	1.36	1.03	1.82	1.28	.39	.48	1.219	.765	1.828	.656
Birney 2SW	.68	.47	.58	1.47	1.77	3.18	1.05	1.02	1.50	1.25	.53	.53	1.169	.771	1.704	.883
Brandenburg	.76	.56	.64	1.84	2.34	2.80	.83	1.49	1.40	1.46	.64	.69	1.288	.738	1.772	.788
Broadus	.55	.39	.63	1.71	2.51	2.45	1.35	.88	1.54	1.36	.46	.55	1.198	.749	1.746	.712
Busby	1.11	.74	.86	1.58	2.24	3.03	1.25	1.21	1.99	1.63	.62	.95	1.434	.705	1.933	.873
Colstrip	.84	.62	.72	2.43	2.27	3.06	1.01	1.36	1.50	1.76	.52	.78	1.406	.821	1.84	.823
Crow Agency	.92	.74	1.00	2.23	2.31	2.82	.76	1.22	1.79	1.65	.74	.77	1.413	.729	1.78	.824
Custer	.76	.44	.67	1.90	1.84	2.75	.76	1.11	1.08	1.18	.50	.62	1.134	.697	1.508	.799
Ekalaka	.55	.38	.57	2.02	2.83	4.68	1.51	1.07	2.00	1.35	.64	.59	1.516	1.25	2.418	1.423
Forsyth 2E	.46	.33	.41	1.67	2.01	2.76	1.26	1.02	1.32	1.04	.36	.54	1.098	.759	1.674	.710
Hardin	.88	.50	.68	1.84	1.70	2.33	.78	1.25	1.37	1.35	.58	.63	1.158	.581	1.486	.576
Hysham	.74	.41	.67	1.94	1.78	2.36	1.07	.90	1.17	1.20	.38	.69	1.109	.624	1.456	.605
Hysham 19SSE	.59	.37	.64	2.44	2.26	3.43	.86	.78	1.55	1.03	.57	.55	1.256	.965	1.776	1.101
Kirby 1S	1.45	1.12	1.38	2.28	2.57	2.90	1.06	1.78	2.00	1.65	.81	1.18	1.682	.647	1.913	.927
Miles City FAA AP	.78	.60	.72	1.81	2.15	3.21	1.51	1.30	1.26	1.33	.42	.92	1.134	.779	1.886	.821
Mizpah 4NNW	.38	.25	.47	1.74	2.17	2.79	1.24	1.02	1.41	1.18	.35	.49	1.124	.804	1.726	.735
Moorhead 9NE	.62	.33	.64	1.72	2.29	2.42	1.44	1.02	1.36	1.37	.43	.50	1.178	.712	1.706	.615
Otter 9SSW	1.12	.77	1.22	2.77	2.32	2.89	1.35	1.29	1.85	1.59	.74	1.02	1.578	.733	1.94	.676
Powderville 8NNE	.52	.24	.32	1.78	2.20	3.19	1.65	.93	1.55	1.25	.50	.67	1.233	.885	1.904	.849
Ridgeway 1S	.35	.43	.48	1.63	2.25	2.65	1.64	1.18	1.16	1.00	.47	.45	1.141	.769	1.776	.66
Sonnette 2WNW	.77	.47	.74	1.96	2.64	2.41	1.38	1.08	1.69	1.36	.54	.54	1.298	.745	1.84	.666
Wyola	1.18	.74	1.30	2.53	2.29	2.67	.67	.83	1.96	1.67	.87	.80	1.459	.74	1.684	.891
Yellowtail Dam	1.16	.68	1.46	2.55	2.57	2.94	1.02	1.36	2.40	2.03	1.10	.74	1.668	.789	2.058	.825
WYOMING																
Alcova 17NW	0.47	0.36	0.56	1.26	1.76	2.03	0.91	0.39	1.03	1.25	0.84	0.51	0.948	0.545	1.09	0.685
Arvada 3N	.71	.53	.67	1.52	1.94	2.59	1.10	.88	1.12	1.18	.47	.54	1.104	.642	1.526	.719
Bates Creek	.67	.58	1.24	2.46	1.75	1.49	.86	.63	.92	.96	.68	.76	1.083	.566	.993	.445
Billy Creek	.35	.26	.62	1.38	1.89	2.39	1.18	1.22	1.05	1.06	.34	.24	.998	.68	1.546	.574
Buffalo	.71	.49	.90	1.72	1.94	2.59	.90	.90	1.45	1.14	.55	.35	1.137	.699	1.56	.723
Casper WSO AP	.52	.49	.87	2.04	1.88	1.59	.97	.62	1.00	1.12	.67	.55	1.027	.537	1.212	.511
Clearmont 5SW	.99	.56	.78	1.96	2.02	2.52	1.11	1.09	1.36	1.18	.64	.59	1.233	.628	1.62	.628
Dead Horse Creek	.29	.11	.21	.82	1.19	2.12	1.04	1.09	1.18	.80	.19	.19	.769	.603	1.324	.449
Devils Tower No. 2	.70	.48	.97	2.21	2.47	3.25	1.57	1.46	1.97	1.42	.56	.79	1.488	.858	2.093	1.003
Dillinger	.45	.47	.71	1.98	1.90	2.25	1.67	.96	1.41	1.11	.41	.47	1.149	.674	1.638	.489
Douglas Aviation	.49	.35	.72	2.07	2.02	2.14	1.46	.80	1.28	.76	.59	.33	1.084	.685	1.54	.55
Dull Center 1SE	.27	.23	.58	1.49	2.01	2.34	2.11	1.12	1.29	.76	.39	.31	1.075	.77	1.774	.536
Echeta 2NW	.66	.46	.76	2.49	1.98	2.13	1.21	.87	1.39	1.53	.61	.64	1.228	.679	1.516	.529
Gillette 2E	.63	.51	.87	2.38	2.30	3.05	1.78	.93	1.65	1.46	.54	.59	1.391	.852	1.942	.789
Gillette 18SW	.60	.60	1.16	2.50	2.09	2.77	1.24	1.04	1.41	1.47	.54	.71	1.344	.753	1.71	.712
Glenrock 5ESE	.62	.55	.81	2.30	2.28	2.74	1.31	.84	1.41	1.11	.45	.48	1.242	.793	1.716	.773
Glenrock 14SSE	.84	.69	1.13	2.58	2.91	2.84	1.63	.75	1.44	1.11	.90	.73	1.463	.845	1.665	.87
Kaycee	.56	.31	.73	2.09	1.97	2.28	.99	.88	1.03	1.03	.46	.40	1.061	.683	1.43	.646
Keeline	.68	.61	1.16	2.45	2.43	2.71	1.66	.94	1.46	1.01	.71	.61	1.369	.775	1.84	.723
Lance Creek 3WNW	.39	.30	.72	2.12	2.68	2.58	2.02	1.04	1.49	.87	.57	.34	1.26	.885	1.962	.702
Lawver 10SW	.44	.27	.67	1.77	1.99	2.19	1.65	.76	1.29	.92	.60	.43	1.082	.669	1.576	.570
Leiter 9N	.84	.46	.81	2.02	1.99	2.49	1.10	1.38	1.49	1.42	.62	.52	1.262	.655	1.69	.551
Lost Cabin	.20	.12	.53	1.05	1.06	1.62	.45	.55	.81	1.14	.36	.28	.681	.456	.858	.53
Midwest 1SW	1.06	.59	.83	2.20	2.16	2.05	1.37	.83	1.20	.91	.57	.97	1.228	.593	1.522	.568
Moorcroft	.38	.30	.29	1.11	1.35	2.35	1.35	.96	1.38	.88	.34	.41	.925	.628	1.478	.517
Morrisey	.24	.29	.50	1.72	1.86	1.96	1.79	1.02	1.11	.87	.42	.28	1.005	.675	1.548	.446
Newcastle	.48	.38	.47	1.88	1.74	2.66	2.26	1.58	1.41	.85	.41	.56	1.223	.802	1.93	.517
Powder River 2SW	.41	.38	.73	1.78	1.36	2.10	1.28	.61	.80	.96	.78	.61	.983	.541	1.23	.58
Recluse 14NNW	.66	.34	.80	1.89	2.39	2.43	1.35	1.17	1.43	1.49	.63	.58	1.263	.702	1.754	.606
Redbird 1NW	.26	.36	.49	1.83	2.07	2.61	2.23	1.21	1.40	.94	.33	.23	1.163	.857	1.904	.585
Reno	.39	.27	.48	1.51	2.15	2.21	1.24	.96	1.20	.64	.32	.40	.981	.692	1.552	.584
Rochelle 3E	.29	.28	.66	1.69	2.34	2.09	1.63	1.24	1.12	.86	.41	.39	1.083	.721	1.684	.528
Sheridan Field Station	.73	.41	.97	1.82	2.30	2.72	.82	1.15	1.72	1.33	.74	.50	1.268	.731	1.742	.786
Spencer 10NE	.20	.33	.43	1.81	2.11	2.42	2.19	.92	1.48	.77	.47	.13	1.105	.849	1.824	.614
Sundance	.69	.55	.89	2.06	2.65	3.45	1.52	1.64	1.80	1.02	.57	.61	1.454	.922	2.212	.822
Ten Sleep 4NE	.73	.40	.65	1.71	1.76	2.37	.77	.81	1.17	1.37	.67	.52	1.078	.606	1.376	.683
Ten Sleep 16SSE	.57	.47	.85	1.76	1.65	2.18	.71	.90	.86	1.30	.66	.61	1.403	.55	1.26	.631
Upton	.44	.50	.48	1.77	2.37	2.52	1.90	1.55	1.42	1.02	.50	.68	1.263	.764	2.085	.444
Weston 1E	.38	.29	.53	1.36	2.27	2.57	1.43	1.03	1.32	.97	.41	.40	1.08	.753	1.724	.661

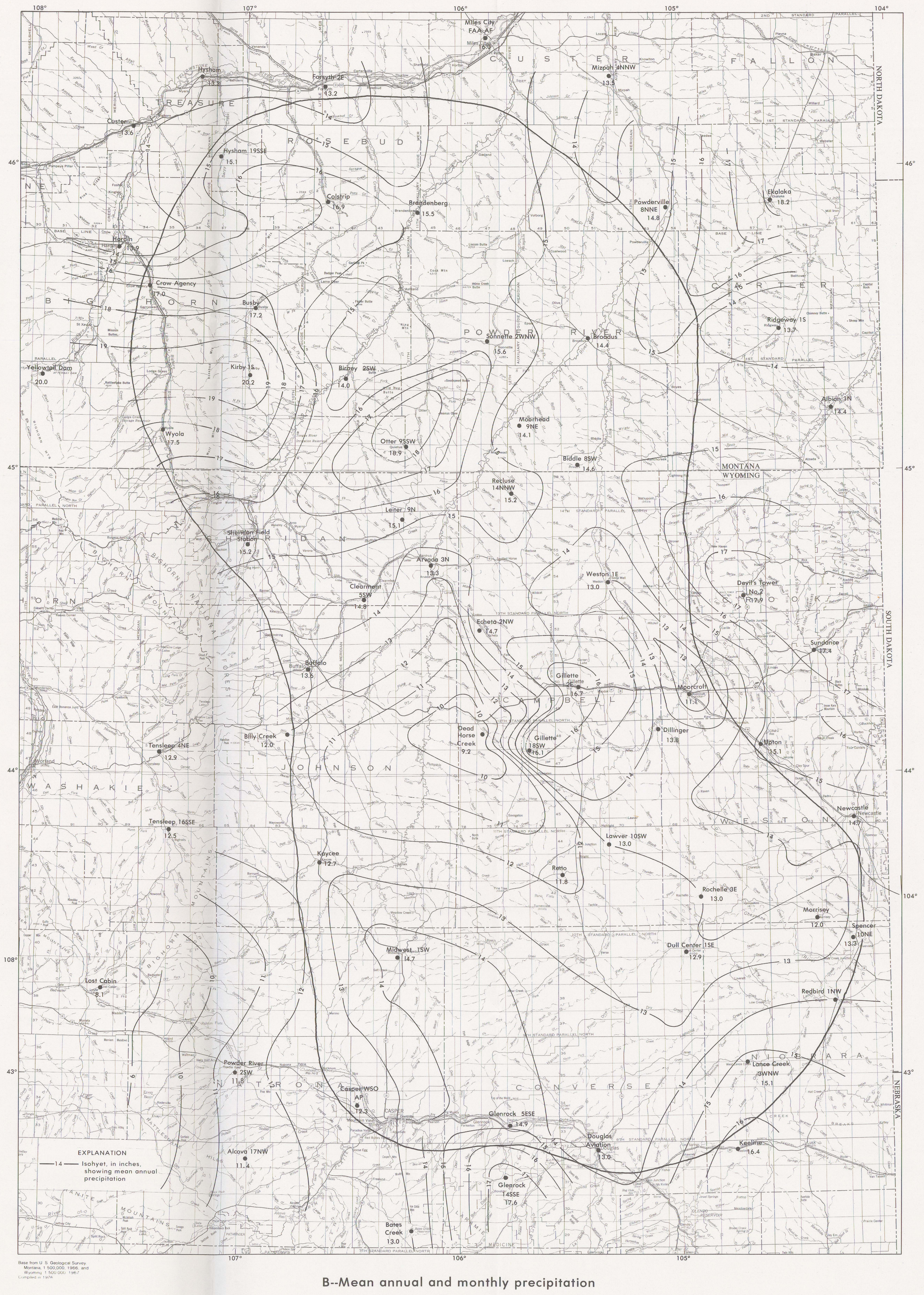
C--Total growing-season precipitation

Table 3.--Annual precipitation characteristics from stations in the Powder River Basin, in inches

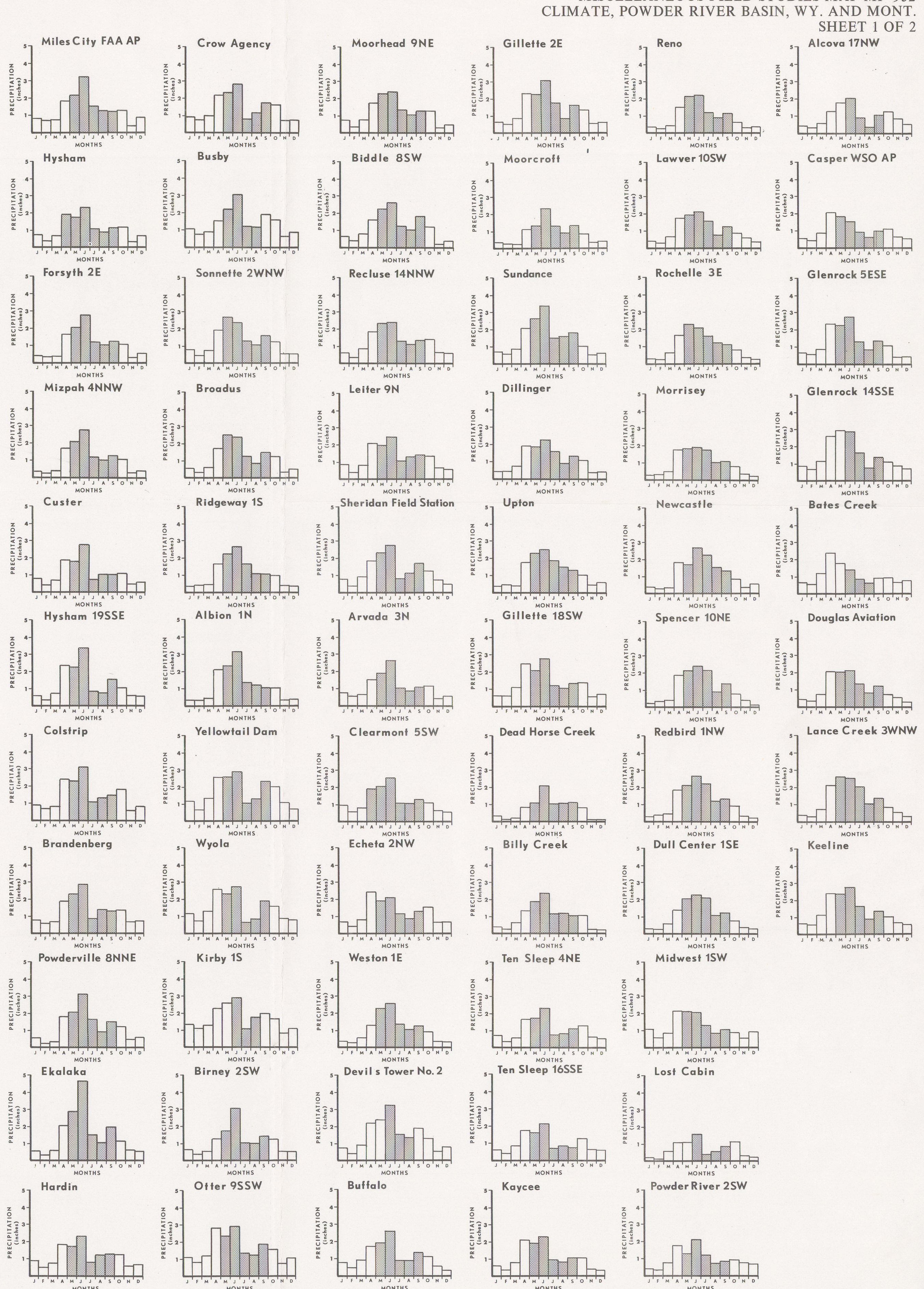
Station	Mean ($\bar{x}$)	Standard deviation (σ)	Standard error of mean (S.E.)	Max	Min	Range (Max - Min)
MONTANA						
Albion 1N	14.4	1.9	0.6	18.8	12.2	6.6
Biddle 8SW	14.6	3.2	1.0	22.0	11.1	10.9
Birney 2SW	14.0	1.7	.5	16.7	11.3	5.4
Brandenburg	15.5	2.5	.8	18.9	11.7	7.3
Broadus	14.4	2.7	.9	18.2	10.2	8.0
Busby	17.2	2.7	.8	21.0	12.7	8.4
Colstrip	16.9	2.1	.7	19.8	13.0	6.9
Crow Agency	17.0	2.8	.9	21.0	11.2	9.8
Custer	13.6	3.0	.9	19.9	8.6	11.3
Ekalaka	18.2	4.7	1.5	27.0	14.0	13.0
Forsyth 2E	13.2	2.5	.8	17.2	9.9	7.3
Hardin	13.9	1.9	.6	17.2	10.2	7.0
Hysham	13.3	1.9	.6	15.9	10.7	5.2
Hysham 19SSE	15.1	2.4	.8	18.4	10.9	7.5
Kirby 1S	20.2	2.4	.8	23.2	15.6	7.6
Miles City FAA AP	16.0	2.2	.7	18.7	11.6	7.1
Mizpah 4NNW	13.5	3.2	1.0	17.7	8.7	9.0
Moorhead 9NE	14.1	2.5	.8	18.8	10.7	8.1
Otter 9SSW	18.9	2.2	.7	21.7	15.0	6.7
Powderville 8NNE	14.8	4.0	1.3	20.7	8.5	12.2
Ridgeway 1S	13.7	2.3	.7	17.8	10.5	7.3
Sonnette 2WNW	15.6	2.2	.7	17.6	12.1	5.5
Wyola	17.5	3.0	1.0	20.4	11.3	9.1
Yellowtail Dam	20.0	2.8	.9	22.7	13.8	8.9
WYOMING						
Alcova 17NW	11.4	3.9	1.2	19.0	6.4	12.6
Arvada 3N	13.3	2.9	.9	16.7	7.0	9.7
Bates Creek	13.0	2.0	.6	16.2	10.8	5.4
Billy Creek	12.0	3.9	1.2	19.5	7.3	12.2
Buffalo	13.6	3.6	1.1	20.7	9.1	11.6
Casper WSO AP	12.3	2.3	.7	15.3	8.1	7.2
Clearmont 5SW	14.8	2.6	.8	18.7	10.7	8.0
Dead Horse Creek	9.2	1.6	.5	12.9	7.2	5.7
Devils Tower No. 2	17.9	2.3	.7	23.2	15.8	7.4
Dillinger	13.8	2.1	.7	16.7	10.1	6.6
Douglas Aviation	13.0	3.8	1.2	17.2	6.6	10.6
Dull Center 1SE	12.9	3.0	1.0	17.0	8.0	9.0
Echeta 2NW	14.7	2.6	.8	17.4	8.8	8.6
Gillette 2E	16.7	1.7	.5	19.1	14.6	4.5
Gillette 18SW	16.1	2.4	.7	20.1	13.2	6.9
Glenrock 5ESE	14.9	5.1	1.6	21.9	7.0	14.9
Glenrock 14SSE	17.6	2.8	.9	21.9	13.1	8.8
Kaycee	12.7	2.6	.8	16.8	9.0	7.8
Keeline	16.4	5.0	1.6	23.4	8.3	15.1
Lance Creek 3WNW	15.1	3.6	1.1	20.8	8.6	12.2
Lawver 10SW	13.0	2.0	.6	15.0	9.4	5.6
Leiter 9N	15.1	2.6	.8	20.7	11.2	9.5
Lost Cabin	8.1	2.5	.8	12.4	4.8	7.6
Midwest 1SW	14.7	3.4	1.1	19.8	8.5	11.3
Moorcroft	11.1	1.7	.6	13.6	9.0	4.6
Morrisey	12.0	2.4	.7	15.5	9.1	6.4
Newcastle	14.7	2.5	.8	18.2	10.8	7.4
Powder River 2SW	11.8	3.0	1.0	16.3	6.8	9.5
Recluse 14NNW	15.2	2.7	.9	18.9	10.4	8.5
Redbird 1NW	14.0	4.1	1.3	20.4	8.8	11.6
Reno	11.8	3.0	.9	15.0	6.3	8.7
Rochelle 3E	13.0	3.2	1.0	17.1	6.8	10.3
Sheridan Field Station	15.2	3.0	.9	20.9	11.5	9.4
Spencer 10NE	13.3	3.2	1.0	20.2	8.3	11.9
Sundance	17.4	3.1	1.0	21.3	11.7	9.6
Ten Sleep 4NE	12.9	3.2	1.0	18.8	8.6	10.2
Ten Sleep 16SSE	12.5	2.7	.9	18.6	8.7	9.9
Upton	15.1	2.4	.8	17.6	9.3	8.3
Weston 1E	13.0	2.9	.9	19.6	9.6	10.0

Table 4.--Growing-season precipitation characteristics at selected stations in the Powder River Basin, in inches

Station	Mean ($\bar{x}$)	Standard deviation (σ)	Standard error of mean (S.E.)	Max	Min	Range (Max - Min)
MONTANA						
Albion 1N	9.4	1.1	0.4	10.6	7.4	3.2
Biddle 8SW	9.2	1.7	.5	11.7	6.5	5.2
Birney 2SW	8.5	1.3	.4	10.8	6.2	4.6
Brandenberg	8.9	2.2	.7	13.3	6.2	7.1
Broadus	8.7	2.0	.6	11.6	5.9	5.7
Busby	7.7	2.5	.8	12.9	4.3	8.6
Colstrip	9.2	2.3	.7	13.9	6.4	7.5
Crow Agency	8.9	2.3	.7	13.9	5.6	8.3
Custer	7.5	2.9	.9	14.6	3.6	11.0
Ekalaka	12.1	3.3	1.0	17.8	8.6	9.2
Forsyth 2E	8.4	1.4	.4	11.7	7.0	4.7
Hardin	7.4	2.2	.7	11.5	3.7	7.8
Hysham	7.3	2.6	.8	12.2	4.6	7.6
Hysham 19SSE	8.9	2.3	.7	13.8	6.2	7.6
Kirby 1S	5.7	2.4	.8	10.3	1.8	8.5
Miles City FAA AP	9.4	2.1	.7	12.4	6.4	6.0
Mizpah 4NNW	8.6	2.3	.7	12.4	5.6	6.8
Moorhead 9NE	8.5	2.2	.7	13.9	5.6	8.3
Otter 9SSW	9.7	1.6	.5	12.5	6.8	5.7
Powderville 8NNE	9.5	2.6	.8	13.2	5.4	7.8
Ridgeway 1S	8.9	1.7	.5	11.6	6.9	4.7
Sonnette 2WNW	9.2	1.9	.6	12.6	5.4	7.2
Wyola	8.4	2.1	.7	11.6	5.3	6.3
Yellowtail Dam	10.3	2.3	.7	12.8	7.1	5.7
WYOMING						
Alcova 17NW	4.4	1.7	0.5	6.7	1.0	5.7
Arvada 3N	7.6	2.9	.9	13.1	3.4	9.7
Bates Creek	3.0	1.1	.4	4.6	.9	3.7
Billy Creek	7.7	3.6	1.1	15.2	4.2	11.0
Buffalo	7.8	3.4	1.1	15.0	3.8	11.2
Casper WSO AP	6.1	2.0	.6	8.9	3.3	5.6
Clearmont 5SW	8.1	2.9	.9	12.6	4.2	8.4
Dead Horse Creek	6.6	2.0	.6	10.8	4.1	6.7
Devils Tower No. 2	6.3	1.6	.5	8.4	3.4	5.0
Dillinger	8.2	1.9	.6	11.1	5.5	5.6
Douglas Aviation	7.7	3.0	1.0	11.2	3.0	8.2
Dull Center 1SE	8.9	2.3	.7	13.0	5.7	7.3
Echeta 2NW	7.6	2.8	.9	12.9	3.4	9.5
Gillette 2E	9.7	2.6	.8	13.9	6.6	7.3
Gillette 18SW	8.6	2.7	.8	12.6	5.3	7.3
Glenrock 5ESE	8.6	3.6	1.1	14.1	2.6	11.5
Glenrock 14SSE	6.7	1.8	.6	8.9	3.1	5.8
Kaycee	7.2	2.4	.8	11.0	3.9	7.1
Keeline	9.2	4.2	1.3	16.9	3.5	13.4
Lance Creek 3WNW	9.8	2.7	.9	13.6	5.0	8.6
Lawver 10SW	7.9	1.7	.5	9.8	4.8	5.0
Leiter 9N	8.4	3.2	1.0	16.1	5.5	10.6
Lost Cabin	3.4	2.2	.7	7.6	.8	6.8
Midwest 1SW	7.6	2.4	.8	10.5	4.0	6.5
Moorcroft	7.4	1.8	.6	10.0	5.2	4.8
Morrisey	7.7	2.3	.7	11.9	4.5	7.4
Newcastle	9.7	3.1	1.0	15.1	3.8	11.3
Powder River 2SW	6.1	2.0	.6	9.1	2.5	6.6
Recluse 14NNW	8.8	2.3	.7	13.5	5.4	8.1
Redbird 1NW	9.5	3.2	1.0	15.1	4.6	10.5
Reno	7.8	2.6	.8	10.8	3.8	7.0
Rochelle 3E	8.4	2.6	.8	12.3	3.6	8.7
Sheridan Field Station	8.7	3.2	1.0	15.1	5.2	9.9
Spencer 10NE	9.1	3.6	1.1	18.2	5.2	13.0
Sundance	11.1	3.2	1.0	16.9	6.7	10.2
Ten Sleep 4NE	6.9	2.4	.8	10.9	4.1	6.8
Ten Sleep 16SSE	6.3	2.0	.6	9.5	3.0	6.5
Upton	8.3	2.1	.7	12.9	5.8	7.1
Weston 1E	8.6	3.2	1.0	16.6	5.2	11.4



B--Mean annual and monthly precipitation



INTRODUCTION

The Powder River Basin of Wyoming and Montana lies within a semiarid climate region, which according to Critchfield (1966) indicates the lack of sufficient rainfall to sustain dense vegetation growth. The annual rate of evapotranspiration (loss of water into the atmosphere through the combined processes of surface evaporation and plant transpiration) exceeds the annual rate of precipitation in this area. Consequently, the potential growing season, as defined on the basis of temperature, is truncated by drought-induced dormancy of vegetation.

This report shows the variability of climatic elements in the Powder River Basin and provides estimates of the irrigation-water requirement for natural vegetation. The rehabilitation of areas that have been surface mined necessitates timely revegetation, which can be achieved most effectively if the entire potential growing season is utilized. We feel that irrigation could be practiced only for the first few years to produce better than normal conditions and to enhance the probability of successful revegetation. Following this initial period, supplemental moisture can be reduced and eventually eliminated as the vegetation adjusts to natural conditions.

We used detailed climatic information, such as growing-season length, precipitation characteristics, and consumptive water use by natural vegetation, to estimate the magnitude of water deficiency and irrigation requirement. Consumptive water use is a term commonly used synonymously with potential evapotranspiration. It was necessary to gather as much detailed climatic information as possible in order to make the estimates. On-site data would be best, but were rarely available. Maps based on available records provide a reasonably accurate portrayal of climatic conditions.

Sixty-three climate stations were selected on the basis of length and completeness of record for the data base of this report. Two time intervals were considered, 1965-74 and 1955-74. The shorter period was selected because more stations had a 10-year record than had a 20-year record, thus yielding a better spatial coverage of the basin (fig. 1) and a more complete set of data was developed for each selected station.

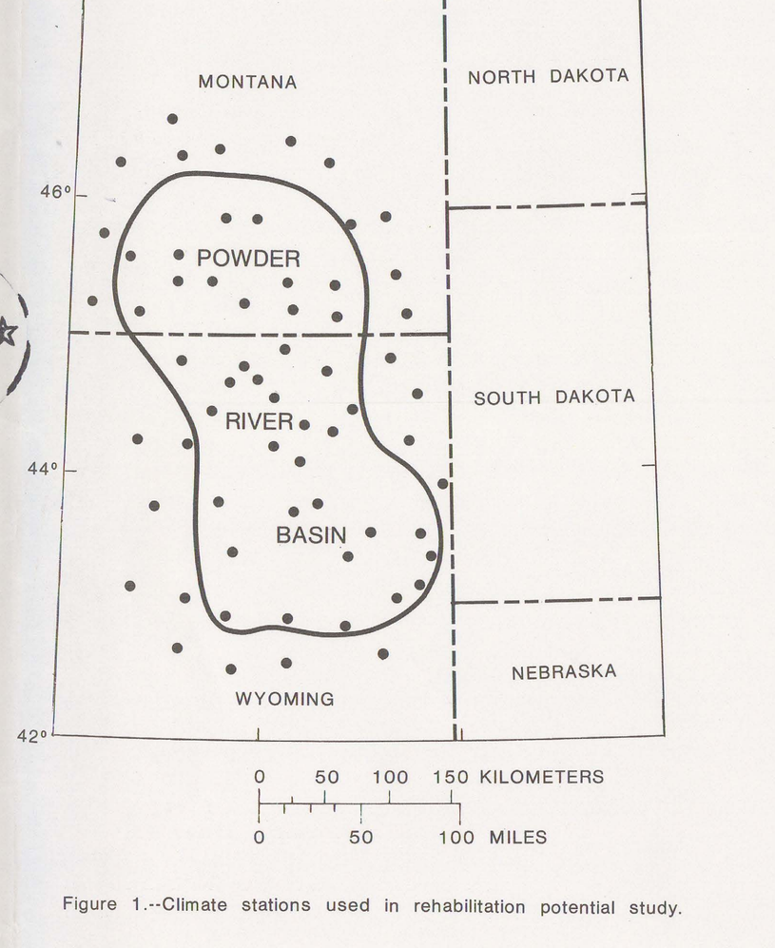


Figure 1.--Climate stations used in rehabilitation potential study.

Monthly precipitation totals were obtained for each station from the U.S. Dept. of Commerce, National Climatic Center, Asheville, N.C. Totals for each of the ten years (1965-74) were used in the calculation of annual means (map B). (The term "mean" can be used synonymously with average.) The mean precipitation was computed for each month during the 10-year period (1965-74) of record (map B, graphs). Infrequently a monthly entry was missing from the record. In such cases the available data for a particular month were averaged. For example, if April precipitation was missing for 1965, the mean April precipitation for 1966-74 was inserted into the record. Subsequent analyses are based on the reconstructed record.

Mean monthly temperature data were also obtained from the National Climatic Center. Where a monthly entry was missing, it was reconstructed using the method described for precipitation.

The dates of last spring frost and first autumn frost were obtained for each station during the 1965-74 period from the U.S. National Oceanic and Atmospheric Administration (1965-74). Mean dates and average growing seasons were determined for each station. Infrequently a critical date was missing from the record and in these cases, the record was synthesized by transposing the date from a nearby station. Appropriate transfers were made in consultation with U.S. Geological Survey personnel having long-term experience in the area.

EXPLANATION AND USE OF STANDARD DEVIATION AND STANDARD ERROR OF THE MEAN

Statistical data of annual precipitation from each station used in this report are shown on table 3; growing-season precipitation data are shown on table 4. Although the mean ($\bar{x}$), maximum, minimum, and range are easily understood, the standard deviation (σ) and standard error of the mean (S.E.) may require explanation. The standard deviation is a measure of variability of the items in the data set about the mean. In this case, the larger the standard deviation, the more variable is the precipitation from year to year (table 3), or, from growing season to growing season (table 4). For example, Ekalaka experiences greater variability in annual precipitation ($\sigma = 4.7$) and growing-season precipitation ($\sigma = 3.3$) than does any other of the Montana stations used in this report.

The mean and standard deviation of monthly precipitation for each station are shown on table 2. In this case, the greatest variability in monthly precipitation occurs at Ekalaka ($\sigma = 1.25$), which averages 4.68 inches of precipitation in June and 0.38 inches in February. The most even distribution (least variation from month to month) occurs at Lost Cabin, Wyo. ($\sigma = 0.456$), averaging 1.62 inches in June and 0.12 inches in February which is an evenly-distributed yearly drought!

Statistical inferences can be made using the standard deviation. A complete discussion is beyond the scope of this report and can be found in any elementary statistics text. However, one use can be demonstrated. The precipitation received in any year at a particular station is very unlikely (2.25 percent of the time, or, one year in 43) to be less than the number of inches determined by the value of the mean minus two standard deviations ($\bar{x} - 2\sigma$). For example, Albion 1N, Mont., is likely to receive less than 10.6 inches of precipitation [10.6 = 14.4 -(2x1.9)] only once in 43 years. By the same token, it is equally unlikely that a station will receive more precipitation than that determined by the mean plus two standard deviations ($\bar{x} + 2\sigma$). For example, it is unlikely that Albion 1N will receive more than 18.2 inches of precipitation in any one year. Of course, the rare year has to occur sometime as illustrated by the maximum for Albion 1N in table 3. This procedure is based on probabilities determined over long periods of time.

If a small number of years is selected to represent a longer period, there is likely to be a difference between the mean determined by the sample and that which would have been determined by the entire population of years, sometimes called the true mean. The standard error of the mean shows how much discrepancy is likely between the sample mean and the true mean. It is unlikely that the true mean will differ from the sample mean by more than two standard errors. The true mean may be greater or lesser than the sample mean. For example, using the information provided in table 3, the true mean of annual precipitation for Albion 1N is likely to be between 13.2 and 15.6 inches [$\bar{x} \pm$ (2S.E.)]. The range in which the true mean lies can be determined for any station using this procedure.

LENGTH OF GROWING SEASON

The growing season is generally considered to be the period of time during which atmospheric temperatures favor plant growth. More specific definitions are elusive because plant species in a given locale possess varying degrees of frost hardiness and also because the critical temperatures for a particular species remain a subject of debate. The growing season utilized in this report is actually the frost-free period extending from the mean date of last spring frost to the mean date of first autumn frost. According to Critchfield (1966), the frost-free period is commonly taken to be the growing season at a particular place. The U.S. Soil Conservation Service (1970) uses the frost-free period in making seasonal consumptive water use estimates to compute irrigation water requirements. The so-defined growing season was extended to the beginning of the first month and the end of the last month in the calculation of growing-season precipitation and the accompanying histograms reflect this change (map B).

The mean, maximum, and minimum growing-season lengths for each station used in this report are shown in Table 1. Miles City, Mont., has the longest growing season, averaging 140 days. Kirby, Mont., has the shortest growing season, averaging only 73 days. The variation from year to year in growing-season length at a particular station can be evaluated by comparing the maximum, minimum, and mean growing-season lengths for that station.

Map A shows the spatial variation in mean growing-season length for the Powder River Basin. The isochronal lines on this map, connecting points of inferred equal growing-season length, were determined by the average values shown in table 1. A general pattern is discernable wherein the average growing season is longer in the northern part than in the southwestern part of the basin.

Explanation of variation in length of growing season requires detailed investigation of several possible controls. Statistical analysis attempting to predict the length of growing season on the basis of elevation and latitude taken together or separately is not sufficiently accurate to be of use. Local terrain characteristics probably are the principal governing factor. There are no available data to support either latitude or elevation as influential factor. Kirby 1S, and Otter 9SSW, Mont., differ by only 13 minutes of latitude; the elevation at Kirby is 3,950 feet, at Otter 4,100 feet. The mean growing-season length at Kirby is only 73 days, at Otter 124 days. Glenrock 5ESE, Wyo., is more than 2 degrees of latitude to the south and 848 feet higher than Otter, but has the same length of growing season.

PRECIPITATION

The amount of precipitation received in a particular region can be expressed in a variety of ways. Mean annual totals are frequently computed and used as representative statistics of regional climate. For example, Packer (1974) uses precipitation zones based on mean annual precipitation in an evaluation of rehabilitation potential of surface-mined lands in the northern Great Plains. Mean annual totals provide only the crudest estimate of available moisture for plant growth; the distribution of precipitation during the growing season, however is of paramount importance in planning the revegetation of surface-mined areas. Even so, mean growing-season precipitation totals may disguise periods of low precipitation within the growing season.

Precipitation is a complex element of climate and must be examined in detail to gain a useful understanding of its characteristics. Annual, seasonal, or monthly precipitation totals are indices of effective precipitation, that is, precipitation remaining after some runoff and deep percolation. (See section on irrigation-water requirement for a more detailed discussion.)

The mean monthly precipitation for stations in the Powder River Basin is shown in Table 2. These data were used in computing the annual and growing-season precipitation characteristics (tables 3 and 4).

The variation of mean annual precipitation in the Powder River Basin is shown by the data in table 3. Kirby 1S, Mont., receives an average of 20.2 inches of precipitation annually; Lost Cabin, Wyo., receives 8.2 inches and Dead Horse Creek, Wyo. (actually within the basin), 9.2 inches. There are two differences between stations within this region, standard deviation and standard error of the mean. These indicate the variability of annual precipitation from year to year for a particular station.

Map B shows a general pattern in the distribution of mean annual precipitation. Precipitation is least in the central part of the basin and increases toward the perimeter. There also seems to be a slight tendency for stations in the northern part of the basin to receive, on the average, somewhat more precipitation than stations in the southern part of the basin.

The data in table 4 show the variation in mean growing-season precipitation in the Powder River Basin. Ekalaka, Mont., receives an average of 12.1 inches, Bates Creek, Wyo., only 3.0 inches. There is nearly a four-fold difference between some stations in this region during the growing season; the standard deviations and standard errors of the mean indicate the variation of growing-season precipitation from year to year for a particular station.

Map C shows the distribution of mean growing-season precipitation throughout the Powder River Basin. The pattern of mean growing-season precipitation is only very general. The amount of growing-season precipitation tends to be relatively low in the southwestern part of the basin and relatively large in the northeastern and southeastern part.

The importance of growing-season precipitation and the problem associated with using annual statistics is illustrated in the case of Alcova 17NW, Wyo. The average precipitation is 11.4 inches annually; however, only 4.4 inches are received during the four-month growing season. On the basis of annual statistics, one might conclude that there is sufficient moisture for revegetation (Environmental Studies Board of NAS and NAE, 1974), although, in fact, there is a period of low precipitation during July and, particularly, August.

Table 2 and the graphs on map B, which show the distribution of mean monthly precipitation, reveal two high points. The greater peak, the period of maximum precipitation, occurs during April-June and the lesser peak, a period receiving above average precipitation, occurs in September-October. The winter months, December-February, receive the smallest proportion of the total annual precipitation. July and August receive a relatively small share of the annual precipitation. This midsummer period of low precipitation is expected to be of critical importance in regard to surface-mine rehabilitation. The mean monthly precipitation and the standard deviation of the mean are shown in table 2 for each station.

Generally, stations having relatively low mean monthly precipitation and relatively low annual totals have relatively low standard deviations (lesser variability) and stations having relatively high average monthly precipitation and relatively high annual totals have relatively high standard deviations (greater variability). This trend probably results from the large proportion of precipitation received during the April-June period at stations having relatively high average monthly precipitation, relatively high annual totals, and resultant relatively high standard deviations.

The larger the standard deviation, the more variable the precipitation from month to month. The greatest variability in monthly precipitation occurs at Ekalaka, Mont., and the most even distribution (least monthly variability) at Lost Cabin, Wyo.

The amounts of precipitation received during the relatively dry late autumn and winter months are comparable at most stations; however, there are considerable differences during the period of late spring to early summer. These differences are illustrated by comparison of the data for the Ekalaka, Mont., and Lost Cabin, Wyo., stations (table 2).

The greatest proportion of growing-season precipitation is received during May and June with decreasing amounts in July and August. September generally receives more precipitation than either of the midsummer months. At Hysham 19SSE, Mont., 64 percent of the growing-season precipitation is received in May and June, 18 percent in July and August, and 18 percent in September. The period of low precipitation in midsummer may be of critical importance to rehabilitation of surface-mined land in this area.

The mean monthly precipitation and standard deviation for the growing-season months at each station are shown in table 2. It can be noted that the larger the standard deviation, the more variable the precipitation from month to month during the growing season. The greatest variability in monthly precipitation during the growing season occurs at Ekalaka, which averages 4.68 inches in June and 1.07 inches in August. The most even distribution of growing-season precipitation (least monthly variability and lowest standard deviation) is at Upton, Wyo., which averages 2.52 inches in June and 1.55 inches in August. Stations receiving relatively high mean growing-season precipitation, and having relatively high standard deviations, generally have greater difference between the amount of precipitation received during the highest and lowest months than stations receiving relatively lower mean growing-season precipitation. In other words, stations receiving the greatest amount of growing-season precipitation exhibit the greatest amount of variability of precipitation from month to month during the growing season.

Explanations for the distribution of precipitation usually are speculative and require detailed investigation of several possible factors including elevation and topography. Stations at higher elevations receive greater amounts of precipitation annually. The western part of the basin receives relatively less precipitation than the eastern part; this may be the result if the position of the basin in the lee of the Bighorn Mountains on the west and windward of the Black Hills on the east. The effect of topography on precipitation is described by Trewartha (1968). Elevation and growing-season precipitation also appear to be related. The higher elevations receive relatively low mean growing-season precipitation and the lower elevations receive relatively larger amounts. This hypothesis is rather tenuous because the higher stations are clustered in the southwestern part of the basin. Some other factor may contribute to or actually produce this pattern.

NOTE: References listed on sheet 2

SCALE 1:1 000 000

25 0 25 50 75 100 MILES

25 0 25 50 75 100 KILOMETERS

CLIMATE APPRAISAL MAPS OF THE REHABILITATION POTENTIAL OF STRIPPABLE COAL LANDS IN THE POWDER RIVER BASIN, WYOMING AND MONTANA

By
Terrence J. Toy and Brian E. Munson
1978

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