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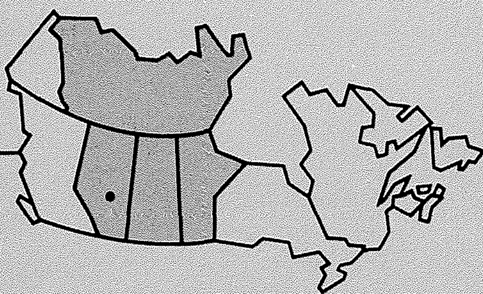
T. Singh



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A PROPOSED METHOD FOR PRELIMINARY ASSESSMENT OF EROSION HAZARDS IN WEST-CENTRAL ALBERTA

T. SINGH

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ABSTRACT

An infiltration-rated approach was used to indicate land units of high erosion susceptibility in west-central Alberta. Three main forest cover types, lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.), spruce-fir (*Picea glauca* (Moench) Voss, *Picea mariana* (Mill.) B.S.P.- *Abies lasiocarpa* (Hook) Nutt.), and aspen (*Populus tremuloides* Michx.), were stratified according to soil delimitations based on surficial deposits. Infiltration determinations were made with constant-head double-ring infiltrometers. Five groups were identified as having very low, low, moderate, high, and very high erosion potentials. The average infiltration capacity in each forest cover type suggested low erosion susceptibility for lodgepole pine sites, very high susceptibility for spruce-fir forests, and moderate susceptibility for aspen forests. Such ranking of land units can serve as first approximations for planning purposes.

RESUME

L'infiltromêtrie a servi â dêterminer les unités três êrodables de sol dans le centre-ouest de l'Alberta. Trois principaux types de forêts, â pin tordu var. latifolié (*Pinus contorta* Dougl. var. *latifolia* Engelm.), â êpinette et â sapin (*Picea glauca* (Moench) Voss, *P. mariana* (Mill.) B.S.P. et *Abies lasiocarpa* (Hook) Nutt.) et â peuplier faux-tremble (*Populus tremuloides* Michx.), ont été stratifiés selon une dêlimitation pédologique en fonction des dêpôts superficiels. On a utilisé des infiltromêtres â double cylindre et â pression constante. Cinq classes d'érodabilité ont été déterminées: três faible, faible, moyenne, forte, três forte. La capacité moyenne d'infiltration sous chaque type de couvert porte â attribuer une érodabilité faible aux stations â pin tordu, três forte aux stations â sapin et â épinette et moyenne aux stations â peuplier faux-tremble. Un tel classement des unités de sol peut servir, en première approximation, â la planification.

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INTRODUCTION

Soil disturbance occurs wherever forests are harvested. There is a need for a simple procedure based on easily obtainable information to identify areas of high erosion susceptibility to assist forest managers in planning road construction and timber harvesting operations.

Buckman and Brady (1960) list infiltration capacity and structural stability, two closely related properties, as the most significant soil characteristics influencing erosion. Dunford and Weitzman (1955) recognize surface water movement as the primary cause of surface erosion.

Factors affecting overland flow are directly related to those involved in water-caused erosion. Blackburn and Skau (1974) and Singh (1963, 1969b) have shown that soils with high infiltration ratings have low sediment production and those with low infiltration levels have high sediment production. Because more overland flow is generated on soils having low water-intake rates, the measurement of infiltration capacity provides a method for estimating surface erosion susceptibility of forest lands.

The capacity of soil to absorb large quantities of water is an important site characteristic related to erosion hazards. Soils having low infiltration capacities are able to transmit only a small amount of water through the profile. Consequently, the excess amount becomes available for flow along or near the surface. Such flow can detach soil particles and cause severe erosion damage during heavy rain. The areas of low infiltration potential are therefore essentially the areas of high erosion susceptibility.

Previous work (Singh 1969a) has shown that on-site estimates of infiltration capacity are best obtained by direct measurement rather than by assessment of the many contributing factors and that vegetation is a useful indicator for the infiltration potential of wildlands.

Dumanski *et al.* (1972) have reported that lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) is generally the predominant tree species on well-drained sites in west-central Alberta, whereas white spruce (*Picea glauca* (Moench) Voss) and black spruce (*Picea mariana* (Mill.) B.S.P.) usually occupy imperfectly drained areas and muskegs. The significance of vegetation as a hydrologic parameter has been similarly substantiated by Satterlund (1967).

In this study the infiltration rates were measured directly, and the dominant vegetation and soil types were used as the criteria for stratification of infiltration capacities. Lodgepole pine, spruce-fir (*Picea glauca* (Moench) Voss, *Picea mariana* (Mill.) B.S.P.-*Abies lasiocarpa* (Hook.) Nutt.), and aspen (*Populus tremuloides* Michx.) forest types were considered to be typical of west-central Alberta. Eighteen soil types were identified in the study area (Dumanski *et al.* 1972): Alluvium, Blackmud, Edson, Erith, Errington, Fickle, Hinton, Jarvis, Lendrum, Lodge, Marlboro, Maskuta, Mayberne, Obed, River Bank, Robb, Summit, and Tri-Creek.

DESCRIPTION OF THE STUDY AREA

The study area was in a leasehold of St. Regis (Alberta) Ltd. that extends from 52°56′N to 53°59′N and from 116°23′W to 118°27′W (Fig. 1). Lodgepole pine vegetation comprises 53% of the growing stock (MacArthur 1968), spruce-fir and aspen vegetation average 27% and 9%, respectively, subalpine fir occupies 5%, and the remainder consists of standing dead trees. An average of 4450 ha are cut annually; the cut material is composed of 60% lodgepole pine, 30% white spruce, and 10% black spruce and subalpine fir (MacArthur 1968). The amount of material actually cut, however, varies from year to year. A recent 10-yr average (1970-79) for the actual annual cut is 3980 ha[1].

The climate is subhumid continental with long, cold winters and short, cool summers. Rainfall, which accounts for about 70% of the total precipitation, occurs mostly in June, July, and August, with July being the wettest month. Powell

[1]Communication with R. Ranger, St. Regis Ltd., Hinton, Alberta.

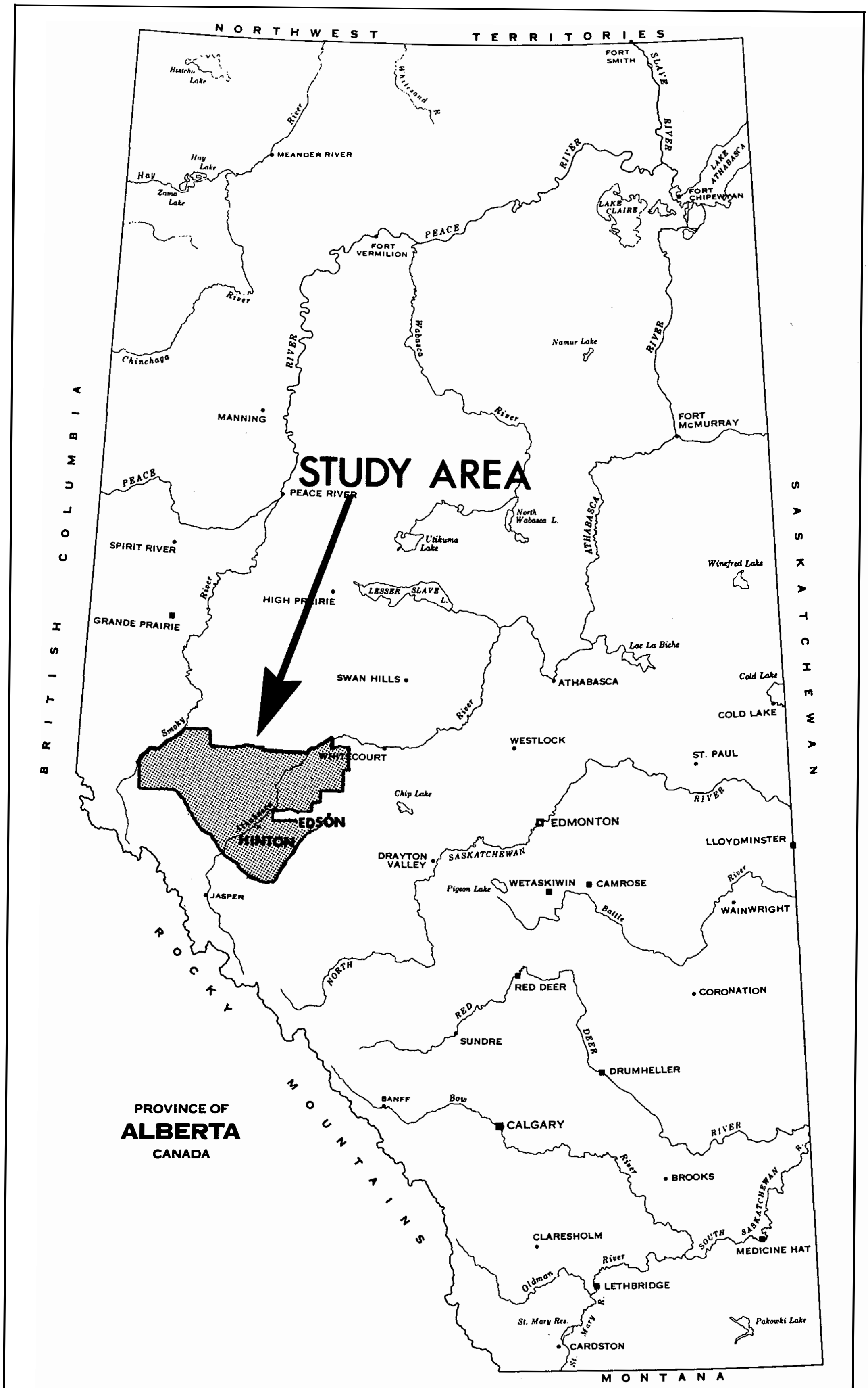

Figure 1. Location of the study area in west-central Alberta.

and MacIver (1976) have described the summer climate (May to September) using daily temperature and precipitation data for 1961-70. The listings of maximum 24-h rainfall are available for 1941-70 (Environment Canada 1975) for most of the climatic stations located in and near the study area (Fig. 2). The greatest 24-h rainfalls for the study area and vicinity for each month are June, 89 mm (Whitecourt); July, 94 mm (Lovett Lo); August, 107 mm (Huckleburry Lo); and September, 82 mm (Muskeg Lo).

The area experienced multiple glaciation during the Pleistocene period, and the surficial materials are derived from the Continental and Cordilleran ice sheets (Roed 1975). Marlboro, Robb, Mayberne, Obed, and Edson glacial tills are extensive throughout the lease area. Lacustrine deposits occur in the lowlands, and postglacial aeloian materials, glaciofluvial deposits, and preglacial gravels occur in some parts. The surficial geology of the lease area has been mapped and described by Roed (1968, 1970). MacArthur (1968) and Crossley (1975) have described vegetation and forest operations, respectively. The soils have been described by Dumanski *et al.* (1972) and Lindsay *et al.* (1963). The degree of erosion on cut blocks within the leasehold is described in a report by the Eastern Rockies Forest Conservation Board (1969).

METHODS

The leasehold was stratified according to the soil associations mapped by Dumanski *et al.* (1972). Each association is closely related to the parent material on which it has developed under essentially similar climatic conditions. The soil association maps provided a convenient means of identifying the surficial materials for the entire lease area.

Infiltration determinations were made using double-ring infiltrometers with a constant head, designed according to Adams *et al.* (1957) (Fig. 3). The design and description of the infiltrometers used are given in Appendix 1.

Six runs were made for each surficial material in a forest cover type. Each run was on a randomly selected site and lasted for 2 h, during which infiltration readings were taken at 15-min intervals. Steady infiltration rates were usually attained within the first hour. The second-hour rates were therefore considered to be the steady infiltration rates for the purposes of this study. A total of 72 infiltration runs were obtained for lodgepole pine stands, 83 for spruce-fir stands, and 84 for aspen stands. The fieldwork for lodgepole pine, spruce-fir, and aspen sites was completed in that order during the summers of 1973-76.

Soil samples were taken for particle-size analysis at each infiltration site. These samples were obtained from the upper soil layer (0-15 cm), through which water had infiltrated to lower depths while running across the field. The samples were air-dried, ground, and passed through a 2-mm sieve. Particle-size analysis was performed using the modified Bouyoucos hydrometer sedimentation technique (Day 1965) after removal of the alkaline-earth carbonates by dilute HCl. (Soil texture can be determined directly in the field by the method described in Appendix 2).

Analysis of variance on the basis of steady infiltration rates was performed to test significance of differences among soil associations in each of the three forest cover types. Individual comparisons were also made. The mean steady infiltration rate for each soil association was arbitrarily ranked as very low, low, moderate, high, or very high.

When plotted, infiltration rates show an exponential decreasing trend with time. An inverse, increasing relationship to this trend is shown by erosion rates (Singh 1963, 1969b). Satterlund (1972) noted that for every site there exists a critical point of deterioration due to surface runoff and erosion, beyond which further deterioration occurs even more rapidly. The five infiltration rating groups arbitrarily chosen for this report are therefore in accordance with the following exponential scale:

1. Very low (steady infiltration rate of <3 cm/h);
2. Low (steady infiltration rate of 3-4 cm/h);
3. Moderate (steady infiltration rate of 4-7 cm/h);
4. High (steady infiltration rate of 7-20 cm/h); and
5. Very high (steady infiltration rate of >20 cm/h).

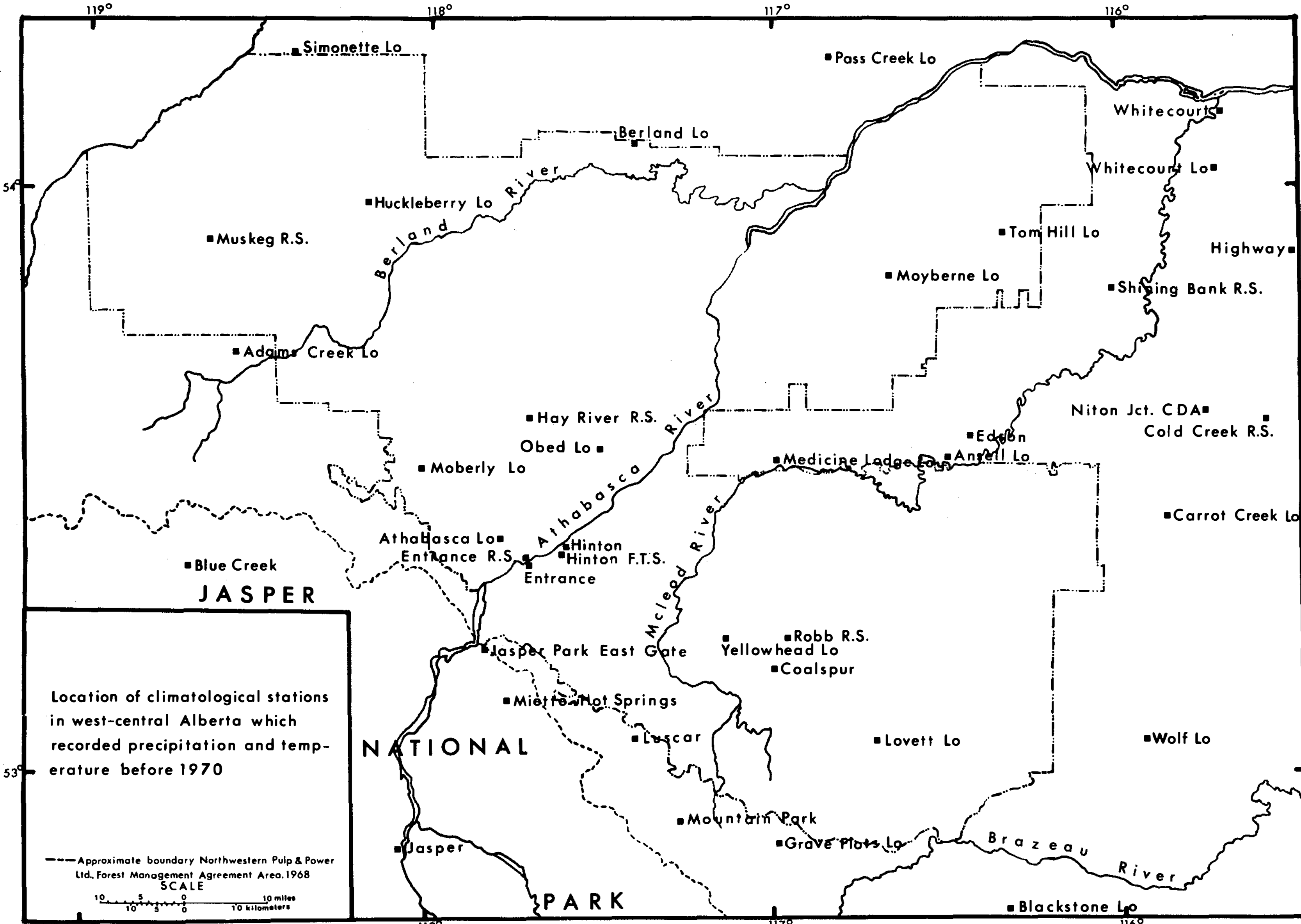

Figure 2. Location of climatological stations in west-central Alberta. Source: Powell and MacIver (1967).

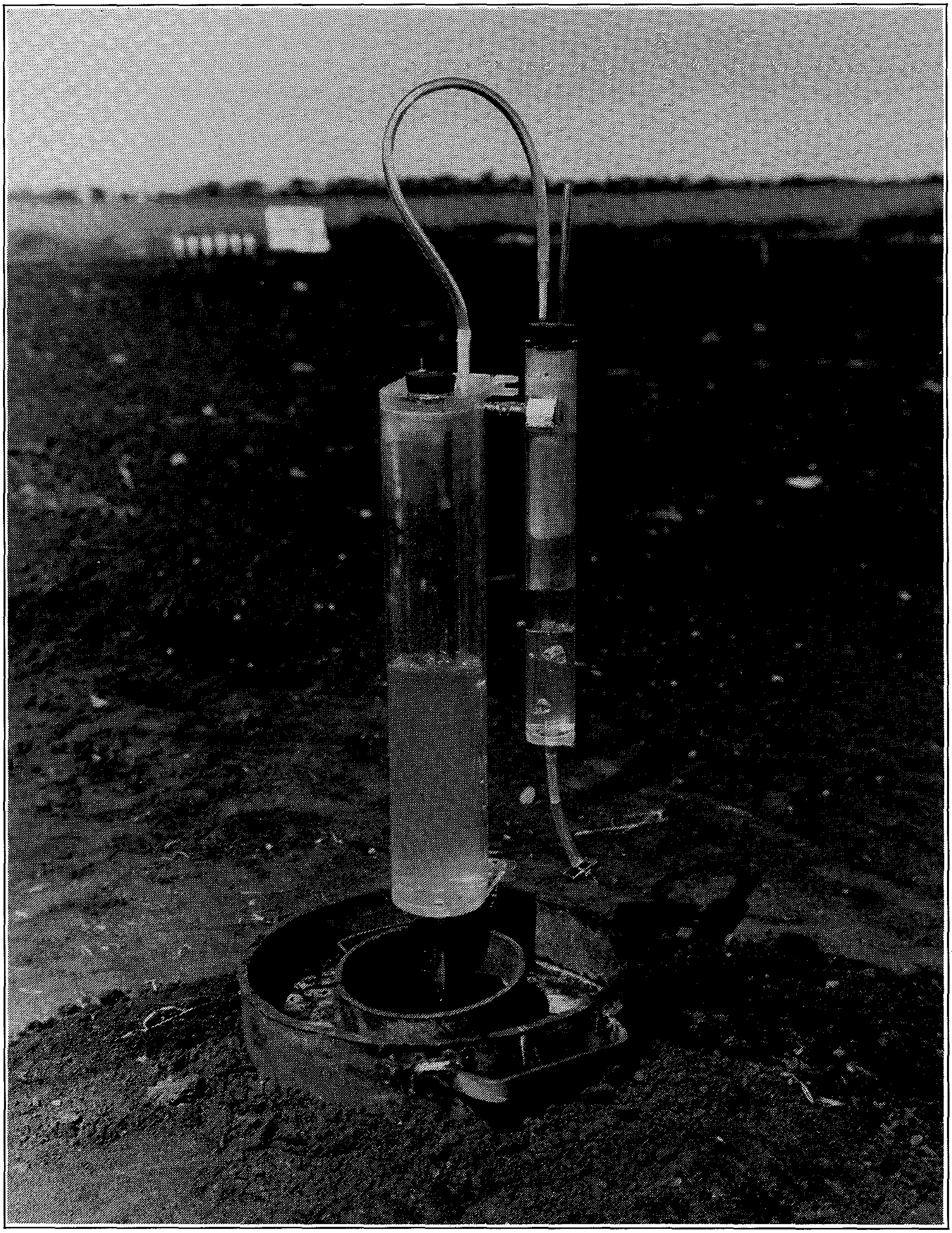

Figure 3. A constant-head double-ring infiltrometer for field use.

RESULTS

INFILTRATION RATES

The soil associations are listed in Tables 1-3 for the three forest cover types along with the mean standard deviation and standard error of the mean for the steady infiltration rates. The mean steady rate for all lodgepole pine stands was 14.20 cm/h (standard error of mean 1.98) compared to 2.08 cm/h (standard error of mean 0.31) for spruce-fir and 7.19 cm/h (standard error of mean 0.78) for aspen forests.

A matrix listing the results of individual comparisons among the soil associations supporting lodgepole pine on the basis of their steady infiltration rates is given in Table 4. The majority (37 of 66) of the comparisons had significant differences (37 significant at 95% and 22 of those at the 99% level), suggesting that most of the soils represented by the associations differed in properties governing infiltration. Of the 91 spruce-fir stand comparisons, 37 were significantly different at the 95% level (Table 5). Only 25 of 91 individual comparisons for the aspen stands were significantly different (95% level) from each other (Table 6). It is obvious that the differences in infiltration due to vegetation and soil are greatest under lodgepole pine forests, less substantial under spruce-fir, and least significant under aspen.

Although the three forest covers contain some soil types that are similar in infiltration rates, a soil type often has a different infiltration rate under a different forest cover due to the modifying in-

Table 1. Steady infiltration rates (cm/h) of lodgepole pine stands growing on various soil types

Soil type	Textural* group	Mean	Standard deviation	Standard error of mean
Association				
Blackmud	Sand	34.88	8.26	3.37
Edson	Loam	2.28	1.32	0.54
Hinton	Loam	10.38	7.94	3.24
Jarvis	Loam	15.63	14.39	5.87
Lodge	Loam	1.46	1.96	0.30
Marlboro	Loam	4.67	5.90	2.41
Maskuta	Loam	30.99	21.45	8.76
Mayberne	Loam	3.83	3.52	1.44
Obed	Loam	10.00	6.62	2.70
Robb	Loam	11.15	7.92	3.23
Summit	Clay loam	0.75	0.54	0.22
Tri-Creek	Clay loam	44.40	15.42	6.29
Mean		14.20	16.81	1.98

* Textural group was derived from sampling of the upper soil layer (0-15 cm) only and is based on the Canada Soil Survey Committee (1978) nomenclature.

Table 2. Steady infiltration rates (cm/h) of spruce-fir stands growing on various soil types

Soil type	Textural* group	Mean	Standard deviation	Standard error of mean
Association				
Blackmud	Loam	4.38	2.91	1.19
Hinton	Loam	2.87	1.21	0.49
Jarvis	Silty loam	5.38	4.63	1.89
Lendrum	Loam	0.13	0.13	0.05
Lodge	Loam	0.44	0.35	0.14
Marlboro	Loam	2.11	1.57	0.64
Mayberne	Silty loam	0.87	0.99	0.40
Obed	Loam	4.35	4.74	1.94
Summit	Loam	3.35	2.27	0.93
Tri-Creek	Loam	0.22	0.07	0.03
Complex				
Alluvium	Clay loam	1.29	0.83	0.34
Erith	Loam	0.53	0.81	0.33
Fickle	Silty loam	0.43	0.22	0.09
Land unit				
River Bank	Silty clay loam	3.00	5.08	2.27
Mean		2.08	2.86	0.31

* Textural group was derived from sampling of the upper soil layer (0-15 cm) only and is based on the Canada Soil Survey Committee (1978) nomenclature.

Table 3. Steady infiltration rates (cm/h) of aspen stands growing on various soil types

Soil type	Textural* group	Mean	Standard deviation	Standard error of mean
Association				
Blackmud	Sand	1.95	1.35	0.55
Edson	Silty loam	5.40	3.41	1.39
Errington	Loam	5.71	6.00	2.45
Hinton	Loam	6.06	1.91	0.78
Jarvis	Loam	6.25	3.67	1.50
Lendrum	Clay loam	5.25	3.87	1.58
Lodge	Silty loam	0.98	0.46	0.19
Marlboro	Loam	3.49	3.27	1.33
Mayberne	Clay loam	2.83	2.48	1.01
Obed	Loam	12.72	7.63	3.12
Robb	Loam	4.33	1.04	0.42
Tri-Creek	Loam	1.25	0.55	0.23
Complex				
Alluvium	Silty loam	13.64	11.38	4.65
Land unit				
River Bank	Loam	13.60	16.59	6.77
Mean		5.96	7.19	0.78

* Textural group was derived from sampling of the upper soil layer (0-15 cm) only and is based on the Canada Soil Survey Committee (1978) nomenclature.

Table 4. Matrix of F-values computed from individual comparisons of the steady infiltration rates of soil types supporting lodgepole pine forests

Soil type	Blackmud	Edson	Hinton	Jarvis	Lodge	Marlboro	Maskuta	Mayberne	Obed	Robb	Summit	Tri-Creek
Blackmud		**	**	*	**	**		**	**	**	**	
Edson	91.22		*	*			**		*	*	*	**
Hinton	27.49	6.07			*						*	**
Jarvis	8.09	5.12	0.61		*						*	**
Lodge	93.11	0.73	7.14	5.71			**		*	*		**
Marlboro	53.21	0.93	2.00	2.98	1.59		*					**
Maskuta	0.17	10.71	4.88	2.12	11.28	8.40		*	*		**	
Mayberne	71.85	1.02	3.41	3.80	2.08	0.09	9.37					**
Obed	33.18	7.85	0.01	0.76	9.19	2.17	5.25	4.07			**	**
Robb	25.83	7.31	0.03	0.45	8.46	2.58	4.52	4.28	0.07		**	**
Summit	102.12	6.88	8.78	6.40	0.73	2.62	11.92	4.49	11.64	10.29		**
Tri-Creek	1.78	44.44	23.10	11.17	45.80	34.76	1.55	39.48	25.22	22.08	48.02	

* Indicates significance at $P < 0.05$.
** Indicates significance at $P < 0.01$.

Table 5. Matrix of F-values computed for individual comparisons of the steady infiltration rates of soil types supporting spruce-fir forests

Soil type	Alluvium	Blackmud	Erith	Fickle	Hinton	Jarvis	Lendrum	Lodge	Marlboro	Mayberne	Obed	River Bank	Summit	Tri-Creek
Alluvium		*		*	*		**	*						**
Blackmud	6.28		**	**			**	**		*				**
Erith	2.60	9.79			**	*			*				*	
Fickle	6.03	11.03	0.08		**	*	*		*				**	*
Hinton	6.99	1.38	15.57	23.62			**	**		**				**
Jarvis	4.53	0.20	6.38	6.83	1.64		*	*		*				*
Lendrum	11.41	12.80	1.40	8.21	30.36	7.69			**				**	
Lodge	5.26	10.84	0.05	0.01	22.21	6.76	4.24		*				**	
Marlboro	1.28	2.83	4.82	6.73	0.89	2.68	9.44	6.41						*
Mayberne	0.62	7.83	0.44	1.15	9.79	5.42	3.30	1.00	2.66				*	
Obed	2.42	0.0002	3.78	4.09	0.54	0.15	4.74	4.04	1.20	3.08				
River Bank	0.68	0.32	1.42	1.58	0.004	0.66	1.96	1.55	0.17	1.03	0.20			
Summit	4.38	0.46	8.26	9.87	0.21	0.92	12.04	9.62	1.22	6.01	0.21	0.02		**
Tri-Creek	9.88	12.29	0.86	4.81	28.63	7.43	2.19	2.36	8.65	2.59	4.54	1.84	11.41	

* Indicates significance at $P < 0.05$.
** Indicates significance at $P < 0.01$.

Table 6. Matrix of F-values for individual comparisons of the steady infiltration rates of soil types supporting aspen stands

Soil type	Alluvium	Blackmud	Edson	Errington	Hinton	Jarvis	Lendrum	Lodge	Marlboro	Mayberne	Obed	Robb	River Bank	Tri-Creek
Alluvium		*						*		*				*
Blackmud	6.25		*		**	*					**	**		
Edson	2.89	5.32						**						*
Errington	2.28	2.24	0.01											
Hinton	2.59	18.52	0.17	0.02				**		*				**
Jarvis	2.29	7.26	0.17	0.04	0.01			**						**
Lendrum	2.93	3.89	0.01	0.02	0.21	0.21		*						*
Lodge	7.41	2.74	9.90	3.70	40.05	12.15	7.19				**	**		
Marlboro	4.41	1.14	0.98	0.63	2.78	1.90	0.73	3.46			*			
Mayberne	5.17	0.59	2.23	1.18	6.40	3.58	1.66	3.24	0.15		*			
Obed	0.03	11.59	4.60	3.13	4.30	3.50	4.57	14.14	7.42	9.11		*		**
Robb	3.98	11.75	0.54	0.31	3.79	1.52	0.31	52.42	0.37	1.88	7.11			**
River Bank	0.00	2.94	1.41	1.20	1.22	1.12	1.44	3.47	2.15	2.47	0.01	1.87		
Tri-Creek	7.10	1.37	8.68	3.29	35.08	10.89	6.29	0.82	2.74	2.34	13.48	41.26	3.32	

* Indicates significance at $P < 0.05$.
** Indicates significance at $P < 0.01$.

fluence of vegetation. Soil types within a forest cover may thus appear in a different main infiltration rating group (Table 7). The information provided in Tables 4-6 is helpful in identifying the soil types that are significantly different from or similar to each other within the same forest cover.

EROSION SUSCEPTIBILITY

As mentioned above, infiltration capacity of the mineral soil surface layer is of great importance in regulating overland flow and consequent erosion; there is no surface erosion without overland flow (Baver *et al.* 1972). Thus, the elimination of overland flow is generally sufficient to control most surface erosion (Satterlund 1972). Under normal conditions, there is an inverse relationship between infiltration capacities and surface erosion rates (Singh 1969b).

The infiltration capacities determined by the constant-head double-ring infiltrometer are therefore an index of the erosion vulnerability of forest soils in the Hinton-Edson area. Although subject to the modifying influence of other site characteristics such as slope, rainfall intensity, texture, hydrologic depth of soil, and antecedent soil moisture (Rothwell 1971; Taylor and Ashcroft 1972), reasonable estimates of erosion susceptibility can be obtained from the infiltration capacities of the soil types under a dominant vegetation cover (Table 7).

DISCUSSION

Dumanski *et al.* (1972) have given a comparative rating of the potential soil erosion hazards judged from many soil characteristics and suggest that essentially all soils in the Hinton-Edson area are highly erosive. The approach used in this study is somewhat different. It is based primarily on the infiltration capacities of forest and soil sites and is intended to assist the land manager in identifying critical areas that should receive special attention when planning timber harvesting and related operations.

It is quite justifiable to use on-site measurements of infiltration as a direct index of erosion. Erosion itself is more often a consequence of reduced infiltration capacity than it is an original cause (Satterlund 1972). A distinction must therefore be made between the susceptibility of soil material to the eroding action of water and the susceptibility to erosion of a soil mantle in place in nature (Colman 1953). Whereas permeability was estimated from soil properties by Dumanski *et al.* (1972), infiltration rates were measured directly in this study.

As stated by Oosting (1956), "the soil and its processes do not constitute an independent system, but rather are a part of the larger ecosystem which includes vegetation and all of its environment". The importance of vegetation as a hydrological parameter (Satterlund 1967; Singh 1969a, b) was mentioned earlier. Lindsay *et al.* (1963) state that vegetation cover is a factor in soil formation. Vegetation also has an indicator role in assessing soil drainage and texture. Although a spectrum of infiltration capacities wider than that indicated by the mean rates exists in a single forest type, a first approximation of erosion susceptibility thus seems possible on the basis of soil types and the dominant vegetation.

As shown by the field data collected for different forest cover types, lodgepole pine forest sites can be treated as areas of high infiltration capacity, aspen sites as moderate, and spruce-fir as very low. Assessments based on the average rating suggest low erosion susceptibility for lodgepole pine sites, very high susceptibility for spruce-fir sites, and moderate susceptibility for aspen sites.

Vegetational and surfical material stratification used in this report should suffice for most planning purposes. When combined, they provide an improvement over the single criterion of vegetation as an indicator of erosion vulnerability. Nonetheless, actual runs with a constant-head double-ring infiltrometer can be made when more accurate information is needed. Because forest soils often show considerable variation in edaphic characteristics over local areas, data collected on site will be more pertinent than a general estimate provided by vegetation and soil type combinations. Such data would be particularly useful for evaluating critical sites that need special attention for timber harvesting and road construction purposes.

Table 7. Soil types ranked according to their steady infiltration rates and erosion susceptibilities within three forest cover types

Soil type	Lodgepole pine		Spruce-fir		Aspen	
	Infiltration rating*	Erosion susceptibility rating**	Infiltration rating	Erosion susceptibility rating	Infiltration rating	Erosion susceptibility rating
Association						
Blackmud	5	I	3	III	1	V
Edson	1	V			3	III
Errington					3	III
Hinton	4	II	1	V	3	III
Jarvis	4	II	3	III	3	III
Lendrum			1	V	3	III
Lodge	1	V	1	V	1	V
Marlboro	3	III	1	V	2	IV
Maskuta	5	I				
Mayberne	2	IV	1	V	1	V
Obed	4	II	3	III	4	II
Robb	4	II			3	III
Summit	1	V	2	IV		
Tri-Creek	5	I	1	V	1	V
Complex						
Alluvium			1	V	4	II
Erith			1	V		
Fickle			1	V		
Land unit						
River Bank			2	IV	4	II
Average rating	4	II	1	V	3	III

* Infiltration ratings: 1, very low; 2, low; 3, moderate; 4, high; 5, very high.
** Erosion susceptibility ratings: I, very low; II, low; III, moderate; IV, high; V, very high.

CONCLUSIONS

The modifying effect of vegetation exercised over hundreds of years makes it essential for soil and vegetation influences on erosion to be considered together. This study shows that similar soil types often behave differently under different forest cover types.

In view of their regulatory control of overland flow and consequent erosion, the steady infiltration capacities of soil types in the lodgepole pine, spruce-fir, and aspen forests of west-central Alberta should provide a reasonably accurate indication of erosion susceptibilities. The steady infiltration rates listed in Tables 1-3 serve as first approximations to help minimize soil losses during road construction and timber-harvesting operations. Further refinements are possible when the steady infiltration capacities are considered in conjunction with the local slope, rainfall, and other site factors such as ground cover, soil structure, texture, antecedent soil moisture, hydrologic depth of soil, and the nature of underlying material.

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APPENDIX 1

AN INEXPENSIVE FIELD APPARATUS FOR MEASUREMENT OF INFILTRATION RATES

Many variations and designs of ring infiltrometers have been developed to study water-absorption properties of soil. Such equipment can be costly if constructed in a machine shop with new materials. To keep costs low without impairing accuracy, the system described below was devised and used in the field.

THE RINGS

In this particular experiment, a 20-cm diameter inner infiltration ring with a 50-cm diameter buffer ring was required. Hot-water tanks, readily available in local scrap metal yards, were used for infiltrometer rings. These tanks vary in size from 20 to 122 cm in diameter and may be either lap- or butt-welded on the side seam. The butt-welded tanks are closer to a perfect circle, which makes them more suitable for the buffer ring. A power hacksaw was used to saw the tanks into 30-cm sections to form the rings. Metal handles, 3 x 0.7 cm, were welded on opposite sides of the rings for portability. The tanks vary somewhat in thickness of metal, and the rings may be beveled on the bottom to form a cutting edge for easier insertion into the soil.

INSTALLATION APPARATUS

The driving hammer for pounding the rings into the soil was made of a 7-kg solid steel block with a 3-cm steel shaft welded on to form a handle. A steel plate of 1.25-cm thickness was laid on top of the ring and the hammer was dropped on the plate to drive the inner ring into the soil. The plate protects the rim of the ring while it is being driven into the ground. No plate was used on the outer ring because of the unwieldy size required to fit on top of the 50-cm diameter ring.

A slight change in the shape or capacity of the buffer ring does not affect the accuracy of the inner ring. It is meant primarily to control lateral movement of water.

A hook gauge or a simple point gauge can be used for visual assistance in maintaining a given head (water level) in the inner ring. Details of these and other devices for field measurement of infiltration are described by Johnson (1963)[1]. An equivalent head can be maintained visually in the outer ring.

The second-hour run is used for determining the steady infiltration rate. All water required for maintaining the selected water level in the inner ring during the second hour should be carefully noted and calculated as depth (in cm) over the surface area covered by the inner ring. This gives the required steady infiltration capacity in cm/h. A head of 1-3 cm is usually sufficient for most locations.

A 45-gal. (205-L) drum usually provides sufficient water for completing one 2-h run per infiltrometer.

[1]Johnson, A.I. 1963. A field method for measurement of infiltration. U.S. Geol. Surv. Water-Supply Pap. 1544-F.

APPENDIX 2

DETERMINING SOIL TEXTURE BY THE FEEL METHOD

Soil texture, or the relative proportion of sand, silt, and clay in the soil, can be accurately determined in a laboratory, but the following method described by Foth *et al.* (1972)[1] can be used to good advantage in the field. Proficiency required considerable practice, but the novice can do fairly well by carefully following the steps described here.

1. Place ½ to 1 tbsp. of soil in the palm of the hand. Add water from a water bottle or tap very slowly, drop by drop while kneading the soil, bringing it to the consistency of moist, workable putty. When the soil is at the proper consistency, try to press it into a ribbon between the thumb and forefinger. The type of ribbon formed determines the texture.

2. The textural triangle modified for determining texture by the feel method represents four groups: clays, clay loams, loams, and sands. When moist soil is manipulated in the hand, clays form good ribbons, clay loams form a medium ribbon, loams form poor or weak ribbons, and sands do not form ribbons.

The type of ribbon depends a great deal on the clay content of the soil. A soil containing a lot of clay can be molded and becomes plastic and pliable when water is added. Ribboning a soil is therefore a means of estimating its clay content.

Soils that are loose and single-grained when dry are sands. Upon drying, the other groups form very hard clods (clays), hard clods (clay loams), and soft clods (loams).

[1]Foth, H.D.; Jacobs, H.S.; Withee, L.V. 1972. Laboratory manual for introductory soil science. Wm. C. Brown Co., Dubuque, Iowa.