Water Storage Characteristics of Several Peats *in situ*[1]

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ABSTRACT

Water storage characteristics of the various horizons in a northern Minnesota bog were found to vary considerably with peat type. Surface horizons of sphagnum moss peat contain 0.020 g. per cc. of dry material and 95 to nearly 100% water by volume at saturation. Its total porosity consisted primarily of large pores which released 0.80 cc. of water per cc. between saturation and 0.1 bar suction.

Decomposed and herbaceous peats from horizons below 25 cm. had water-holding properties strikingly different from those of the moss peats. These materials had bulk densities of 0.24 and 0.14 g. per cc., respectively, and they contained between 80 and 90% water by volume at saturation. Their porosity, though high, consisted primarily of many small pores which are not easily drained at low suctions. They retained 65 to 75% water by volume at 0.1-bar suction.

These data show that a specific change in water table elevation in the horizons containing loose, porous, undecomposed moss peat would involve a great deal more water than the same change in horizons of more dense decomposed and herbaceous peats. Thus, the hydrologic role of any bog or bog area in a watershed will depend on the type of peat found in the organic soil profile.

Water storage characteristics of peats in their natural undisturbed condition as they would exist in the field profile are largely unknown. Water contents of various peats have been reported by others (Dyal 1960, Farnham 1957, and Feustel and Byers 1930), but only as the weight of water per ovendry weight of disturbed peat material. Boelter and Blake (1964) have shown that volumetric expression of the water content is necessary to show accurately the water storage of a peat profile *in situ*.

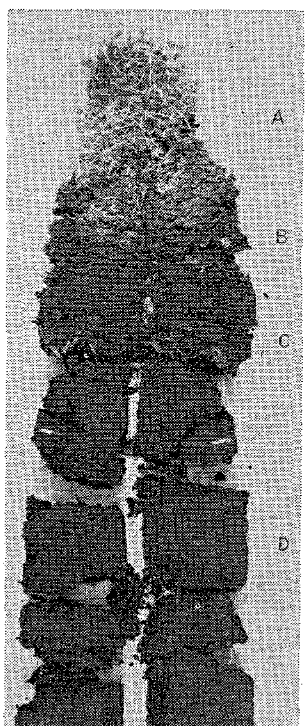
Since the structure and density of the different kinds of peat making up the profiles in Minnesota bogs vary considerably, their water storage characteristics are also expected to vary. The amount of water involved when a water table fluctuates will depend on the water retention characteristics of the peat in the horizon in which the change occurs. Therefore, the hydrologic role of bog areas in a watershed will depend on the types of peat found in the organic soil profile and their physical properties.

This paper shows how the water storage properties of the peat types in one bog vary for the major peat horizons and discusses the hydrologic implications.

MATERIALS

Peats used in this study were obtained from the upper horizons of the peat profile in a lake-filled bog in north-central Minnesota. The bog is on the Marcell Experimental Forest and within the boundaries of the Chippewa National Forest. It is approximately 25 acres in size and supports a stand of black spruce, *Picea mariana* (Mill.) B.S.P. The dominant feature of the ground vegetation is the carpet of mosses, primarily *Sphagnum* spp. The shrub layer contains primarily leatherleaf, *Chamaedaphne calyculata* (L.) Moench; Labrador tea, *Ledum groenlandicum* Oeder; false Solomon's-seal, *Smilacina trifolia* (L.) Desf.; and lesser amounts of blueberry and cranberry, *Vaccinium* spp., and bog laurel, *Kalmia polifolia* Wang.

The profile in the bog is made up of several horizons of strikingly different peat types. Figure 1 illustrates and describes the upper meter of the profile. Except for the surface horizon of live moss peat and the herbaceous peat, the depth and thickness of most horizons were relatively uniform throughout the bog. The live moss peat varied with the hummock and hollow microrelief of the surface. The horizon of herbaceous peat extended to within a few inches of the bottom of the bog and therefore varied in thickness from 0.5 to 2.0 meters, depending



A - Moss peat (live, undecomposed mosses) 0-15 cm. -yellowish brown (10 YR 5/3, moist) undecomposed moss peat; spongy hummocks of sphagnum moss; some leaves from heath plants (Labrador tea, leatherleaf, and others) mixed with moss; strongly acid reaction.

B - Moss peat (undecomposed mosses) 15-30 cm.- dark brown (10 YR 4/2, moist) relatively undecomposed sphagnum moss peat; fine fibrous structure; some roots from heath plants; strongly acid reaction.

C - Moss peat (partially decomposed mosses with wood inclusions) 30-45 cm.— dark reddish brown (5 YR 2/2, moist) moderately to well-decomposed peat derived largely from sphagnum mosses; somewhat granular or aggregated structure; many roots and wood fibers, largely from heath plants and black spruce; strongly acid reaction.

D - Decomposed peat 45-61 cm.- black (5 YR 2/1, moist) well-decomposed aggregated peat; unrecognizable plant remains; very friable fine granular structure; very good physical condition; acid reaction.

E - Herbaceous peat 61-200 cm.-dark reddish brown (5 YR 2/2, moist) relatively undecomposed pure herbaceous peat derived from reeds and sedges; coarse fibrous (laminated) matted structure; acid reaction.

Fig. 1—General profile description of peat in experimental bog, using average depths. Peats were described and classified using methods and terminology suggested by Farnham (1957).

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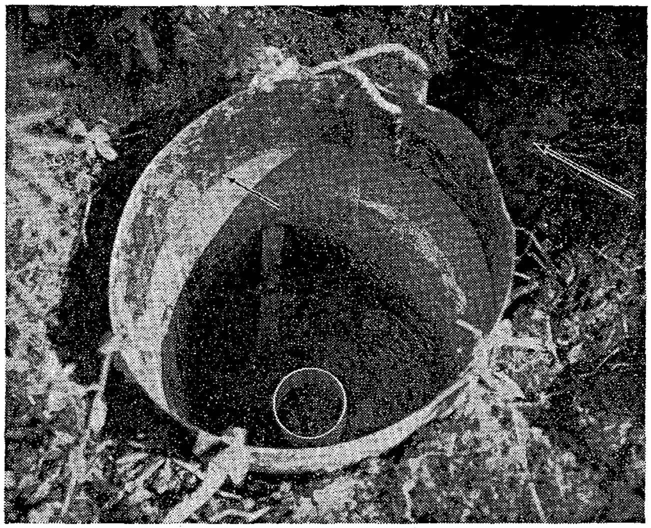

Fig. 2—To obtain samples from below the water table, a caisson (large cylinder) was pushed down into the peat profile to prevent free water entering the excavation. Arrows show water level outside the caisson. Core samples were obtained with the small cylinder inside the caisson.

on the depth of the bog. Aquatic peat was usually found at the bottom of the bog but was not sampled for laboratory measurements.

Although only one bog was sampled, the same sequence of horizons and peat types has been found in other watershed areas under study. Farnham (1957) found these peats to be common in Minnesota peatlands.

METHODS

Eight sampling points were selected at random in the bog. At each point six depths were sampled to represent the five horizons described in Fig. 1: 0 to 10 cm., 15 to 25 cm., 30 to 40 cm., 50 to 60 cm., 70 to 80 cm., and 90 to 100 cm. The first four represent the approximate midpoints of the upper four horizons. The last two represent the fifth horizon, herbaceous peat.

At each sampling point one core, 10.0 cm. high and 9.8 cm. in diameter, and one large undisturbed bulk sample were obtained from each depth. Each core sample was taken vertically at the bottom of an excavation, using a cylinder cut from seamless stainless steel tubing and sharpened at one end (Fig. 2). All samples were wrapped in aluminum foil or placed in plastic bags to prevent drying.

Samples from below the water table were obtained using a cylindrical caisson made from galvanized sheet metal. This caisson (Fig. 2), 65 cm. long and approximately 40 cm. in diameter, was pushed down into the peat profile as samples were taken. Once through the porous moss peat in the surface three layers, no free water entered the excavation through the more dense herbaceous peat below.

Water contents of the different peat types were determined at suctions ranging from 0.0 bars (saturation) to 15.0 bars by means of soil water extraction techniques in the laboratory. Water retention at suctions up to 0.1 bar were determined by using the undisturbed cores in a pressure cell apparatus similar to that described by Reginato and Van Bavel (1962). An asbestos board rather than a ceramic plate was used as the porous membrane to facilitate use of the pressure cells at these low suctions.

Pressure plate and pressure membrane extractors were used for suctions of 0.2 to 1.0 bar and 2.0 to 15.0 bars, respectively. Small undisturbed samples were cut from the bulk sample and placed on a slurry of asbestos to insure good contact with the porous plate or membrane. A piece of cheesecloth between the sample and the asbestos prevented contamination of the sample.

Water contents were measured on a volume basis by correcting for the bulk density based on the saturated volume, D_b (saturated volume basis), which was determined for each undisturbed core. D_b (saturated volume basis) is defined by Boelter and Blake (1964) as the mass of soil that has been dried to a constant weight at 105°C. per unit saturated bulk volume.

RESULTS AND DISCUSSION

Water Storage of Peats

Differences in water contents at a number of water suctions (Table 1) demonstrate that water storage characteristics vary for each of the peat types used in this study. Undecomposed moss peats in the surface horizons contained the most water at saturation (95 to nearly 100% by volume), indicating a high total porosity.[3] These peats give up a large part of their contained water at suctions from 0 to 15 millibars. Thus, the total porosity consists primarily of large pores easily drained at relatively low water suctions. The low D_b (saturated volume basis) is further evidence of the high porosity of these peat types (Table 2).

In contrast, the partially decomposed moss peat with wood inclusions, decomposed peat, and herbaceous peat are much more dense as evidenced by the higher D_b (saturated volume basis). Although the total porosity of these peats is lower than those of the undecomposed moss peats, it is still high since they contain between 80 and 90% water at saturation. However, the porosity of these lower horizons of peat consists chiefly of small pores which are not drained at low suctions.

Partially decomposed moss peat with wood inclusions (30- to 40-cm. samples) represents the most variable material because of the varying wood content. It is generally more dense than the undecomposed moss peats and retains considerably more water at higher tensions.

Decomposed peat (50 to 60 cm.) is well decomposed and therefore has the highest D_b (saturated volume basis). It has the lowest total porosity, releases the least water

[3]Total porosity as used in this report is considered to be equal to the total volume of water contained at saturation and includes not only the space between particles, but also any pores within these organic particles which contain water. No attempt has been made to separate the two or determine the relative water retention characteristics of each.

Table 1—Water contents of peat types at various suctions (cc./cc.).*

Peat type	Water suction (bars)												
	0.0	0.005	0.015	0.025	0.035	0.065	0.1	0.2	0.33	0.50	1.0	3.0	15.0
	Water contents, cc./cc.												
Moss peat													
Live undecomposed	1.012†	.423	.217	.182	.168	.143	.127	.092	.081	.072	.058	.044	.035
Undecomposed	0.966	.643	.491		.404	.344	.308	.257	.207	.189	.163	.130	.093
Partially decomposed‡	0.865	.843	.823		.748	.690	.636	.551	.473	.419	.353	.259	.205
Decomposed peat	0.833	.824			.782	.747	.715	.633	.589	.526	.440	.304	.223
Herbaceous peat													
70-80 cm.	0.869	.862			.820	.776	.738	.576	.501	.443	.352	.234	.177
90-100 cm.	0.891	.882			.830	.780	.740	.538	.459	.402	.315	.207	.142

* Analysis of variance indicated significant differences at P = 0.01 for each water suction.

† The water content greater than 1.00 for live, undecomposed moss peat at 0.0 bar suction is due to experimental error. ‡ With wood inclusions.

Table 2—Average D_b (saturated volume basis).

Peat type		Db (saturated volume basis)*
		g./cc.
Moss peat:	Live undecomposed	0.020
	Undecomposed	0.056
	Partially decomposed†	0.153
Decomposed peat		0.237
Herbaceous peat:	70-80 cm.	0.156
	90-100 cm.	0.125

* Differences were significant at P = 0.01. † With wood inclusions.

with increased increments of suction, and retains the most water at suctions of 0.2 bar and higher.

Herbaceous peat, represented by samples at 70 to 80 cm. and 90 to 100 cm., was nearly as dense as decomposed peat and demonstrated similar water retention characteristics.

Hydrologic Implications

Since the water retention characteristics of the different types of peat vary considerably, water table fluctuations in a peat profile do not in themselves indicate the volume of water involved. A given change in water table elevation within the horizon of undecomposed moss peat involves considerably more water than the same change in water table elevation occurring in the deeper horizons of decomposed and herbaceous peats. This is illustrated by the data in Fig. 3 showing the water storage capacity available at low water suctions.

Lowering the water table in the loose, porous, undecomposed moss peat empties many large pores and removes as much as 0.6 to 0.8 cm. of water in a 1-cm. horizon. An equal lowering of the water table in decomposed or herbaceous peat would remove about 0.1 cm. of water.

For the organic soils sampled, the potential storage capacity for snowmelt and runoff has definite limitations. Although a great deal of storage capacity is made available when the water table is lowered in the undecomposed moss peat horizons, additional lowering of the water table into the decomposed and herbaceous peat provides relatively little additional storage. The role of a particular bog as a storage reservoir, therefore, will depend not only on the depth to which the water table drops but also on the types of peat and the thickness of their horizons in the deposit.

These data also point out the importance of peat types to drainage. A great deal of water could easily be drained from undecomposed moss peats similar to those studied. On the other hand, lowering the water table would drain only a very small part of the water from a decomposed or herbaceous peat.

Since such a large portion of water can be drained from the undecomposed moss peat, these materials, when drained, may not retain a great deal of water available for

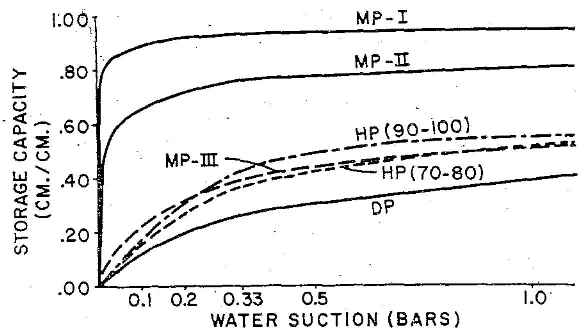

Fig. 3—Available water storage capacity of several undisturbed peat materials at low water suctions. The various types of peat are as follows:

MP-I	**Moss peat (live, undecomposed mosses)**
MP-II	**Moss peat (undecomposed mosses)**
MP-III	**Moss peat (partially decomposed mosses with wood inclusions)**
DP	**Decomposed peat**
HP (70-80)	**Herbaceous peat (70-80 cm. sample)**
HP (90-100)	**Herbaceous peat (90-100 cm. sample)**

plant growth. Furthermore, since the flex points of the available storage curves occur at very low suctions, apparently the capillary fringe does not extend to the surface in undecomposed moss peat with a water table 20 or more cm. from the surface. This being the case, there would be little upward movement of capillary water, and uncontrolled drainage may result in droughty conditions.

In undrained bogs, it is likely that the capillary fringe extends up to the rooting zone of well-established vegetation most of the time, and there is seldom a lack of water available for plant growth. However, water shortages may occur for new seedlings with shallow rooting depths if the water table drops below 20 to 30 cm. in raw undecomposed moss peats such as those described in this study.

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