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Inland Wetland Definitions

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Report No. 28

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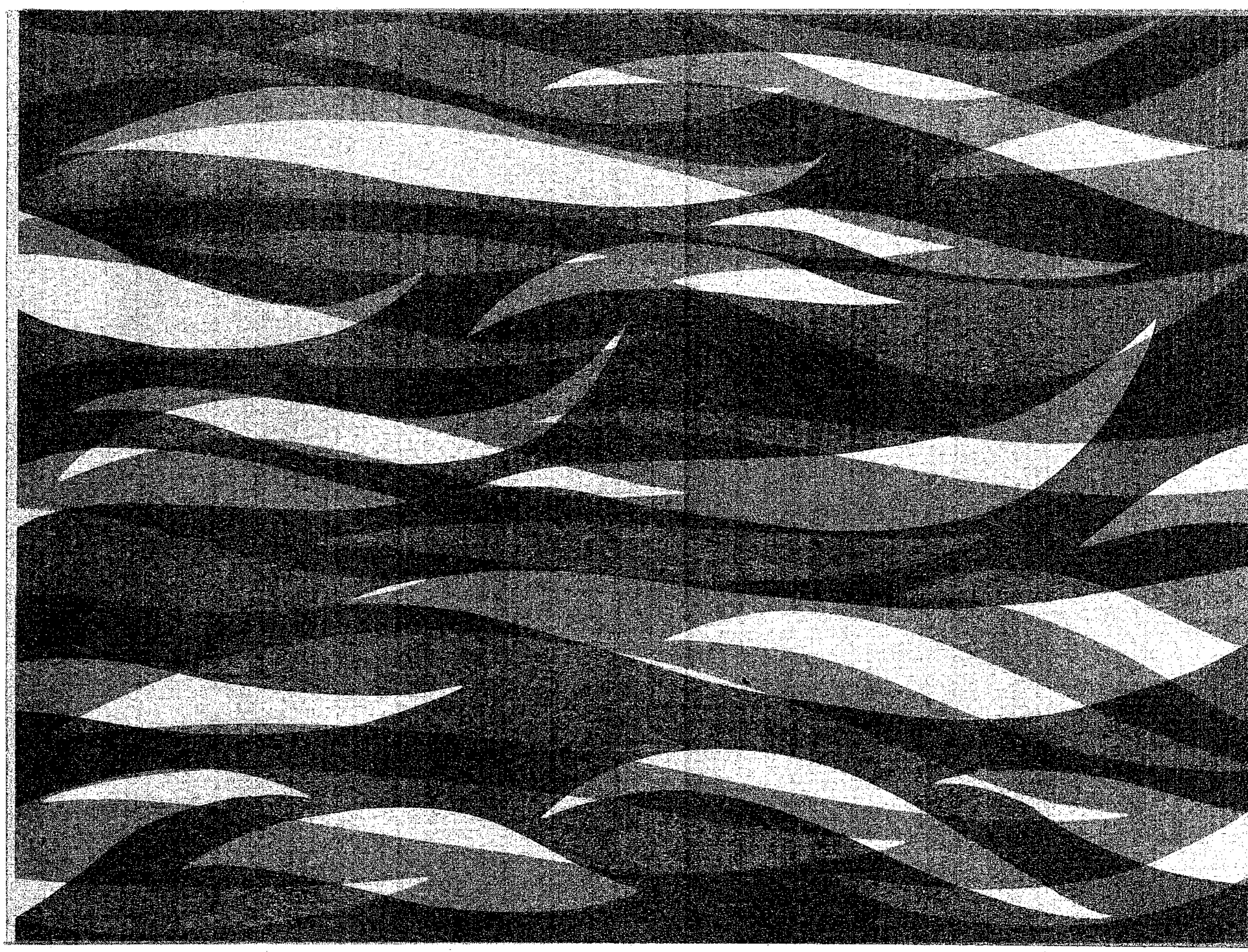

INSTITUTE OF WATER RESOURCES

The University of Connecticut

INLAND WETLAND DEFINITIONS

BY

M.W. LEFOR & W.C. KENNARD

WITH CONTRIBUTIONS BY T.B. HELFGOTT AND OTHER RESEARCHERS

• UNIVERSITY OF CONNECTICUT INSTITUTE OF WATER RESOURCES •

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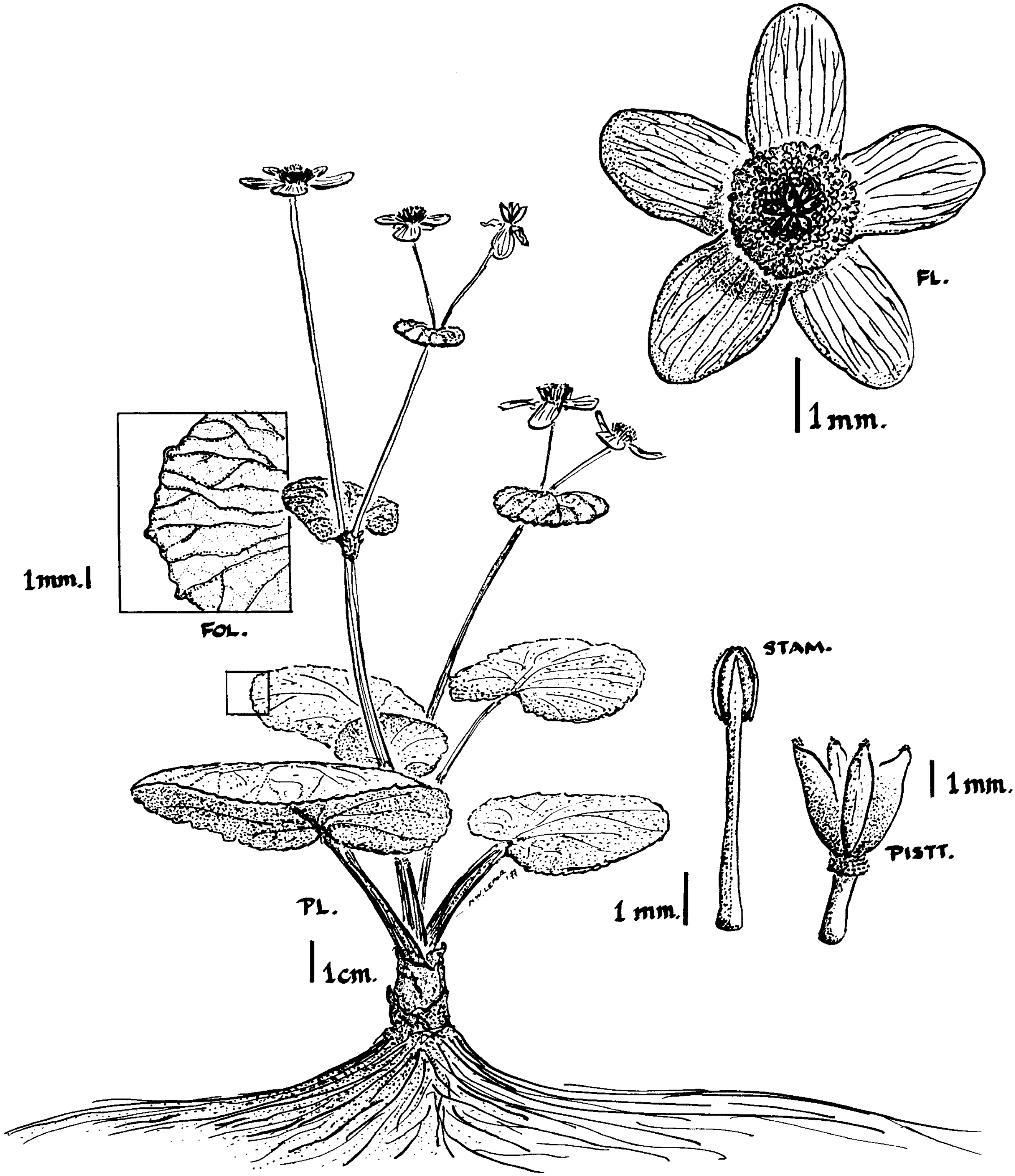

CALTHA PALUSTRIS L.

BROWN & PFEFFER 1537, HERB. LEFOR

M.W. LEFOR DEL. 1977.

FRONTISPIECE

Caltha palustris L., a common springtime plant of wetlands. Labels as indicated. From *Brown & Pfeffer 1537*, Herb. Lefor. [Artist: M. W. Lefor]

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DIRECTOR'S STATEMENT

The purpose of the research reported here is to provide a rational basis for the management of a vital natural resource--not as an isolated portion of the environment, but one which interacts closely with other ecosystems. The authors contend, first that there are three steps to the preservation and management of any natural area: 1) define the area; 2) delineate the area as accurately and precisely as possible; and 3) regulate the area. Second, any regulated ecosystem, related as they all are to neighboring ecosystems, should be defined in such a way that 1) it can be delineated at reasonable cost, and 2) the ensuing regulation of that ecosystem will be compatible with other existing and proposed land use legislation.

Drs. Lefor and Kennard propose that as a first step in statewide land use regulation, the Inland Wetlands and Watercourses Act should be amended to include both hydrological and botanical criteria in its definition of a "Wetland." This amendment could therefore permit a cohesive and economical land use mapping for Connecticut in the future, if all ecosystems and land use categories were defined on the basis of the same criteria.

The Institute of Water Resources is very pleased to be able to publish this report which naturally complements the three volumes of wetlands conference proceedings previously offered by the Institute. The three principal investigators, Drs. M. W. Lefor, W. C. Kennard and T. B. Helfgott, directing this research effort (B-010-CONN, "Inland Wetlands/Technical Definitions Directed Toward Emerging Policy Alternatives) should be commended for their outstanding contributions.

-Victor E. Scottron*

*Director of the Institute of Water Resources, U-37, The University of Connecticut, Storrs, Connecticut 06268.

INLAND WETLAND DEFINITIONS

by

M. W. Lefor and W. C. Kennard

with contributions by T. B. Helfgott and other researchers

A B S T R A C T

This work is the result of a year-long study of the definitions of inland wetlands in which definitions from geology, hydrogeology, hydrology, pedology, biology, systems ecology, sociology, economics, political sciences, public health and law were considered. Of these, geology, hydrogeology, hydrology, biology, systems ecology and economics are discussed in detail in this report and used in writing a final theoretical (ideal) definition of inland wetlands for the glaciated northeastern United States. A proposed legal definition for Connecticut is also offered with descriptions and explanations of terms.

INLAND WETLAND DEFINITIONS[1]

by

Michael Wm. Lefor[2] and William C. Kennard[3]

* * *

INTRODUCTION

Throughout history mankind has been concerned with wetlands. In areas where most of the world's civilization developed, wet areas were ubiquitous and had profound influences on the types and sizes of communities which developed nearby. Most of these settlements were located on the coasts, along rivers or in prime agricultural lands and rich forests, all of which possess areas which can be called "wetlands."

As a result of the close association of man with various wetlands, many terms have been developed to describe the types and locations of wet areas. Some of those of common usage in the English language are given later in this work.

In more recent years, especially about 1960, the term "wetlands" has come into widespread usage and means all types of land areas which are characteristically high in water content.

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1. This volume is an extension of a paper by T.B. Helfgott, Lefor and Kennard which appeared in the Proceedings of the Third Wetlands Conference held at the University of Connecticut on June 14, 1975 (*1*). The over 50 participants in research, consultation and seminar included faculty and students from the University of Connecticut and other institutions. See Appendix III. The work was made possible by a grant from the Office of Water Research and Technology, U.S. Department of the Interior, to T.B. Helfgott, M.W. Lefor and W.C. Kennard, Principal Investigators.
2. Research Associate in Biology, The Botany Section, Biological Sciences Group, The University of Connecticut, Storrs, Connecticut 06268.
3. Professor, Departments of Plant Science and Natural Resources Conservation, The University of Connecticut, Storrs.

This study was prompted by theoretical and practical concerns voiced by some at this University over the definition and management of the wetland ecosystems of our state; concerns which arose after the passage of Connecticut's precedent-setting Inland Wetlands and Watercourse Act (P.A. 155) of 1972. A comprehensive, multifaceted definition statement on inland wetlands was generated, as well as a practical legal definition, presented here as a proposed amendment to the existing Inland Wetlands Act.

From legal, administrative, technical and non-technical points of view, the term "wetland" can be so all-inclusive that it is subject to misinterpretation. It serves a useful purpose, nevertheless, since it immediately permits listeners and readers to conjure up a mental image of an area in which the land is *wet*. Furthermore, the term "wetland" can be used as a starting point for the development of terms useful for more specific purposes or situations. Thus, it seems desirable to strike a balance between a single, all-purpose term and a large number of terms (many with conflicting or overlapping shades of meaning). This multidisciplinary project was designed to study definitions in depth and to develop definitions suitable for widespread use.

Connecticut began its legislative efforts in the preservation of wetland ecosystems with the passage of the Tidal Wetlands Act in 1969. The Act was designed to closely regulate the use of the state's coastal marshes. A discussion of the Tidal Wetlands Act is in order here, because it forms an excellent basis of comparison with the Inland Wetlands and Watercourses Act (hereinafter, the "Inland Wetlands Act") enacted by the State legislature in 1972.

In the Tidal Wetlands Act (1969), "wetlands" were defined as follows:

> *"Wetland" means those areas which border on or lie beneath tidal waters, such as, but not limited to, banks, bogs, salt marshes, swamps, meadows, flats or other low lands subject to tidal action, including those areas now or formerly connected to tidal waters, and whose surface is at or below an elevation of one foot above local extreme high water; and upon which may grow, or be capable of growing, some, but not necessarily all of the following...* [*here follows a list of some fifteen species of flowering plants, mostly grasses and sedges, common to salt marshes*] *

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* Author's inserts in brackets [].

Upon a careful reading, it will be seen that an area of coastal land must meet three criteria to qualify for regulation under the Tidal Wetlands Act: (1) the land must be subject to tidal action; (2) it must lie at or above an elevation of one foot above local extreme high water (defined as the high water of record, which in most cases is the 1938 hurricane); *and* (3) it must possess an association of plants common to coastal salt marshes. The Tidal Wetlands Act was later amended (1972) to include those species of plants native to brackish and freshwater marshes, such as are found along the upper tidal reaches of the Connecticut River. The Commissioner of the State Department of Agriculture and Natural Resources (now the Commissioner of the Connecticut State Department of Environmental Protection), was mandated to effect an immediate survey of the tidal wetlands in such a manner as to make statewide regulation of the marshes possible. The method used, and carried out by the staff of the University of Connecticut and its Marine Research Laboratory at Noank, Connecticut, was a field survey of the salt marshes (*2*). This involved the placing of stakes or other boundary markers in the field along the upland boundaries of the marshes and the depiction of those markers and the marsh boundaries on unrectified aerial survey photograph enlargements at a scale of 1' = 200' (1:2,400). These maps were then redrawn to a class D standard * and the lines from the biological mapping were superimposed on lines showing approximate property ownership boundaries.

Wetland lines on the final legal maps are not the lines which matter so much for legal regulation; the *position of those drafted lines on the ground* is what matters for legal proceedings. These lines may be reestablished in the ground as necessary by referring to the original biologist's maps and field markers.

There are three steps to the management of a natural area:

1. Define it;
2. Delineate it;
3. Regulate it.

* A class D map is one combined from existing maps without ground control or field checking.

The important points about the Connecticut Tidal Wetlands Program in terms of wetland definition, wetland delineation and wetland regulation are these:

1. By and large, the tidal wetlands are characterized by only a few species of higher plants which represent a distinctive appearance on the aerial photography used for mapping.

2. The area dealt with is small, perhaps 17,000 acres.

3. The total cost for the biological field mapping portion of the tidal wetlands program was approximately $65,000 over a period of two and one-half years.

4. Wetland boundaries are fixed, and can be reestablished in the field as necessary in legal disputes (although a recent provision in the Act allows a resurvey in cases of error or natural change).

5. Regulation of the wetlands is under uniform state control and not non-uniform local control.

The Tidal Wetlands Act was passed as a result of a movement initiated by public and legislative concern for the environment, and the enthusiasm generated in part for this program was extended to the passage of the Inland Wetlands and Watercourses Act in 1972. The preamble to the latter states that "wetlands are an interrelated web of nature essential to an adequate supply of surface and underground water, important for hydrologic stability and the control of flooding and erosion, for recharging [*sic*] and purification of ground water, and for the existence of many forms of plant and animal life." The Inland Wetlands and Watercourses Act defines wetlands as:

> *"...land, including submerged land [not regulated according to the tidal wetlands statutes], which consists of any of the soil types designated as poorly drained, very poorly drained, alluvial and flood plain by the National Cooperative Soils Survey of the Soil Conservation Service of the United States Department of Agriculture."*

Things typically thought of as wetlands, such as swamps, bogs and marshes are treated as watercourses in this statute:

> *"Watercourses means rivers, streams, brooks, waterways, lakes, ponds, marshes, swamps, bogs, and all other bodies of water, natural or artificial, public or private, which are contained within, flow through, or*

border upon this state or any portion thereof, not regulated pursuant to... [the tidal wetlands statutes]."

It is our understanding that the use of the Soil Conservation Service (SCS) soil types and surveys as a basis for the regulation of inland wetlands was occasioned by the fact that at the time of the passage of the Inland Wetlands Act over 70% of the state had already been mapped for soil type and much of the remainder of the mapping was in progress (mapping is now over 80% complete). Thus an expensive new survey was avoided. The use of a soil criterion is a good starting point, for a soils definition of wetlands accurately represents the functional roles wetlands play in their interactions with water. The primary characteristic of wetlands is wetness, but water in a wetland is not always readily observable, however.

The present Connecticut definition of inland wetlands, although an excellent starting point, has basic scientific and practical inadequacies which may pose problems in continuing to implement the Inland Wetlands Act in the state. It was soon recognized, for example, that the SCS uses a two-acre minimum size unit for mapping; that is, if a two-acre area possesses more than 80% of a certain soil type, then the entire two acres is mapped as that soil type; no area of soil type smaller than two acres is mapped. Yet the act itself mentions no size limit as to what area shall be regulated. To be sure, a wetland or a watercourse may be smaller than even one-half acre and still have significant function in the local ecosystem.

Here are some other facts to compare the Inland Wetlands Act with the foregoing list of facts relating to the Tidal Wetlands Act:

1. The area of inland wetlands and water courses is great; perhaps 800,000 acres, or 25% of Connecticut's area.

2. Overall, the areas to be regulated are characterized by a large number of plant and animal species, some of which are characteristic of upland associes (see the biological section of this report).

3. Essentially, the SCS has paid for much of the mapping.

4. In the SCS mapping, present scale (1:15,840) and presentation on unrectified aerial photographs show only the approximate position of the

wetlands boundaries on the ground, and therefore a detailed field mapping by a properly qualified soils scientist is required at times of boundary dispute.

5. The Inland Wetlands Act allows local control of wetlands regulation by each of the 169 municipalities of Connecticut rather than placing that regulation in the hands of the state. However, some 22 or so towns have opted not to regulate their wetlands*, and the statute provides that the state shall regulate them until those towns choose to do so.

Perhaps the most important point to be made here is one of scientific support for environmental legislation. Prior to the Tidal Wetland Act an extensive and comprehensive literature had been developed dealing with the flora, fauna and ecosystem aspects of the tidal wetlands. We knew *what* we were protecting and *why*. But such is not the case with Connecticut's inland wetlands. Research on these complicated ecosystems has only just begun. In a way, Connecticut has put the cart before the horse in intuitively recognizing some of the values of inland wetlands.

The functions and limits of inland wetlands are not fully known. Since the legislation is based on the assumption that wetlands function in recharge and discharge of underground waters; in hydrologic stability and the control of floods and erosion; and as places for the existence of many unique forms of animal and plant life, it should be possible for scientists in those specialized areas to develop criteria that can be incorporated into a working definition which will be consistent with the preservation and regulation of other ecosystems -- e.g., a comprehensive land use policy. Providing strong, scientific reasons for the preservation of inland wetlands can have great value for the defense of those areas in court cases. The Inland Wetland Act is therefore one which will need refinement in the future.

The soils-only criterion for wetlands is not one which a geologist, an ecologist, a social scientist or even a layman may have selected. A geologist would have wanted to know what the causes for any local wet condition were; an ecologist might wish to know the population interactions of the flora and

* As of April 1977.

fauna and their energy flow relationships; the social scientist might want to know what the perceptions and uses of wetlands are by the human populations near them.

From the theoretical standpoint, the existing legal definition omits such considerations as the specific biota of the wetlands, the functional roles of the wetlands as possible receivers of waste waters, organic materials, inorganic nutrients and industrial wastes, their public health implications, and their geology, hydrology and economics.

The possibility that man's activities (such as construction of dams) interact with the wetlands boundaries is another questionable facet of Connecticut's wetland definition. For example, taking the definition of watercourse literally, is one's swimming pool to be regulated? It is, after all, "a body of water, natural or artificial." How can an administrator economically and practically distinguish between wetlands that exist over an impermeable layer from wetlands which participate in ground water recharge? Using only existing soils maps, town wetland administrators cannot distinguish between natural wetlands and those areas of "made wetlands" which might also qualify for regulation under the inland wetland statutes.

One of the purposes of inland wetland regulation in Connecticut is to protect certain plants and animals necessary to the long-term maintenance of these precious ecosystems. Yet the existing wetlands act makes no specific mention of the biota. Recall the biological criteria expressed in the tidal wetlands act -- there is an inconsistency between the laws governing these two water resources, one which overlooks the fact that they are interconnected as parts of the overall hydrologic and land system of the state.

There are some other aspects of the soils-only wetlands definition in Connecticut which deserve mention:

1. Soil surveys were developed primarily for agricultural purposes, not for the delineation and regulation of wetlands.

2. The soils mapping, which was begun some years ago, is dated in many cases and incomplete in others.

3. To truly represent the very nature of inland wetlands, biological criteria should be added to the definition;

4. Functional aspects of wetlands are important;

5. The need to preserve the public health should be recognized [note that in the Tidal Wetland Act, the activities of the State Department of Health's Mosquito Control Division are specifically exempt from regulation].

6. The detection of wetland boundaries by the remote sensing of vegetative cover and/or the presence of water may be more accurate, faster and cheaper than the soils surveys;

7. Periodic flooding may extend far beyond the boundaries of wetland soils types.

It is just as wrong to posit a technocracy -- that science should lead the legislature in the formulation of laws -- as it is to have regulatory statutes made without the proper scientific inputs. In this study, persons from many different areas -- biologists, engineers, agricultural administrators, public health experts, sociologists, etc., as well as experts in the law and in administration came together to provide inputs and share viewpoints.

* * *

ASPECTS OF INLAND WETLANDS DEFINITIONS DRAWN FROM SPECIALIZED FIELDS OF STUDY

Introduction. The complete analysis of any ecosystem can be divided into two parts: the study of its abiotic components and the study of its biotic components. The abiotic aspects (or physical aspects) are those of the nonliving portions of the system -- geology, water, soils and climate. Climate, since it affects other areas of the land surface not wetlands, is excluded in this treatment. The biotic components of an ecosystem consist of plants, animals and their interactions with one another, and their interactions with the abiotic components of the system.

In this study, the inland wetland definitions are examined according to the following outline:

I. Abiotic aspects
    A. Geology and hydrogeology
    B. Pedology (Soils)
II. Biotic aspects
    A. Botany
        1. Higher plants
        2. Lower plants
    B. Zoology
III. Societal aspects: Economics

This study received input on more than the above areas of inquiry (see Appendix III)*, and it soon became obvious that as we reviewed the year's work that not all areas were of equal value in arriving at a useful and accurate definition of inland wetlands. Some areas, such as the sociological and mental health aspects of wetlands were not useful in formulating a definition, but instead were valuable for understanding *why* we were formulating a definition and its possible effects not only on the wetlands themselves, but its effects on the interactions of regulatory agencies, the public and the law. For example, sociology could give us a wetlands definition from the standpoint of society, and tell us what society considers important about wetlands for a variety of reasons -- but could we draw a map of wetlands in a given land area using such a definition? The answer is, no.

Another aspect of wetlands regulation is the dollar values ascribed to wetlands by society. While an economic definition such as:

> *"A wetland is a wetland when its value as a wetland is greater than its value as anything else"*

again is not directly translatable into a map, it helps us to focus on the reasons why we are concerned with the regulation of the use of natural areas in the first place.

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*Individual contributions to this study are credited in Appendix III, and are keyed in text by parenthetical upper case letter, *e.g.*, (A).

In this report, we have provided extended treatments and explanatory material for those areas of inquiry which we felt led directly to an inland wetland definition which will:

1. Lend itself to the least expensive but quickest, most precise and accurate mapping of wetlands at a useable scale;

2. Reflect the functional roles wetlands play in the ecosystem;

3. Be consonant with the mapping already in use for other types of wetlands in Connecticut;

4. Be consonant with wetland definitions and mapping in use in adjacent states of our region;

5. Provide a basis for new legislation regulating the use of other natural systems.

Hydrogeologic and biologic aspects of wetlands relate directly to the very functions of those wetlands in the global ecosystem as removed from man. Although wetlands and society are related to one another, wetlands can operate very well indeed independent of society. But, society has imposed itself upon the wetlands. The economic and sociologic aspects of wetlands are those which relate most closely to man's regulation of the environment and the quality of his life, both for the present and for the future. Therefore, both absolute and man-related aspects of wetlands are extremely important for any usable wetland definition.

A useable definition should be compatible with other land use legislation (or set the mark for it), and we feel that land use legislation eventually will be necessary as the population of Connecticut increases and we continue to deplete our natural resources. Although statewide land use legislation is ill-regarded at the present, we feel that it could come into being within the next twenty years or so. For a cohesive land use policy, that land use legislation which is passed first must set a precedent for legislation which will follow.

For example, Massachusetts, New York and Rhode Island, all adjacent to Connecticut, began their wetland regulation with laws regulating the use of tidal wetlands, defining those wetlands on the basis of vegetation and related physical criteria. Inland wetland laws followed which similarly

employed vegetation as a tool in defining and delineating the areas to be regulated. In Connecticut, however, the Tidal Wetland Act and the Inland Wetland Act define our two major classes of wetlands differently, providing two different mapping criteria and two regulatory methods for two interlocked natural systems! (*3*)

As it happens, the 1972 amendment to the Tidal Wetlands Act (*4*) includes those species of higher plants common to inland wetlands (by and large) and could, with minor revision (the elimination of the criteria of elevation and tidality) serve as an effective definition for all wetlands (After some changes in implementation -- a field survey of 800,000 acres of wetlands is impracticable).

The effects of legal definition of certain types of privately owned lands to be regulated must be considered when formulating that definition. Therefore, economic and sociologic aspects of wetlands are considered here. It is our opinion that man must learn to coexist with his environment because it is not *his* alone. He, with other organisms, is a *part* of it, and was not "put here" on earth to be a wasteful usufruct. As the only thinking species which has had, and will continue to have, the greatest impact on the environment, we have become responsible for it. The way in which we, *qua* Society, treat the environment by Law may well determine our future (or lack of it) as a species.

Although the "highest and best use" of a particular wetland may be as a wetland, its fate as determined by its rulers, man, is placed in terms of the highest and best uses as determined by planning and zoning commissions. If a wetland is zoned as "open space," then for purposes of evaluation and assessment, its highest and best use is open space. When a wetland is zoned industrial, its highest and best use for purposes of assessment is for industrial development, even though its real and imperishable functions may be beyond price.

Before examining the general and specialized definitions of wetlands formulated in our work, we should look at dictionary definitions.

Definitions of Terms Related to "Wetlands"

Bog - Wet, spongy ground with soil composed mainly of decayed vegetable matter; an area or stretch of such ground. (*5*)

- Wet, spongy; especially: a poorly drained usually acid area rich in plant residues, frequently surrounding a body of open water, and having a characteristic flora (as of sedges, heaths, and sphagnum). (*6*)

Bottom - The ground under any body of water; usually Bottoms. Also called Bottom land. (*5*)

- Low-lying grassland along a watercourse - usually used in the plural. (*6*)

Everglade - Southern U.S., a tract of low, swampy land characterized by clumps of tall grass and numerous branching waterways. (*5*)

- A swampy grassland especially in southern Florida, usually containing sawgrass and at least seasonally covered by slowly moving water - usually used in the plural. (*6*)

Fen - (British) - Lowland covered wholly or partly with water; boggy land; a marsh. (*5*)

- Lowland covered wholly or partly with water unless artificially drained. (*6*)

Fenland - A low area of marshy ground. (*5*)

Heath - (British) - A tract of open and uncultivated land; waste land overgrown with shrubs. (*5*)

- A tract of wasteland; an extensive area of rather level open uncultivated land usually with poor coarse soil, inferior drainage, and a surface rich in peat or peaty humus. (*6*)

Marsh - A tract of low wet land, often treeless and periodically inundated: characterized by grasses, sedges, cattails and rushes. (*5*)

- A tract of soft wet land usually characterized by monocotyledons (as grasses or cattails). (*6*)

Marshland - A region, area, district, etc. characterized by marshes, swamps, bogs or the like. (*5*)

- A marshy district. (*6*)

Meadow - A tract of grassland used for pasture or serving as a hayfield; a tract of grassland in an upland area near the timber line. (*5*)

- Land in or predominantly in grass; especially a tract of moist low-lying usually level grassland. (*6*)

Mire - A section of wet, swampy ground; bog; marsh; ground of this kind, as wet, slimy soil of some depth; deep mud, etc. (*5*)

Moor - A tract of open, peaty, waste land, often overgrown with heath, common in high latitudes and altitudes where drainage is poor; a heath. (*5*)

- (British) - An expanse of open rolling infertile land; a boggy area of wasteland usually peaty and dominated by grasses and sedges. (*6*)

Moorland - (British) - An area of moors, especially country abounding in heather. (*5*)

- Land consisting of moors; a stretch of moor. (*6*)

Morass - A tract of low, soft wet land; a marsh or bog; marshy ground. (*5*)

- Marsh, swamp. (*6*)

Muskeg - A bog of northern North America, commonly having sphagnum mosses, sedge and sometimes stunted black spruce and tamarack trees. (*5*)

- A sphagnum bog of northern North America often with tussocks; a usually thick deposit of partially decayed vegetable matter of wet boreal regions. (*6*)

Quagmire - An area of miry or boggy ground whose surface yields under the tread; a bog. (*5*)

- Soft miry land that shakes or yields under the foot. (*6*)

Quicksand - A bed of soft or loose sand saturated with water and having considerable depth, yielding under weight and therefore apt to engulf persons, animals, etc., coming upon it. (*5*)

- Sand readily yielding to pressure: especially a deep mass of loose sand mixed with water into which heavy objects readily sink. (*6*)

Salt marsh - A marshy tract that is wet with salt water or flooded by the sea. (*5*)

- Flat land subject to overflow by salt water. (*6*)

Slough - An area of soft, muddy ground; muddy ground; swamp or swamplike region. (*5*)

- A place of deep mud or mire; swamp. (*6*)

Sump - (British) - A swamp, bog or muddy pool. (*5*)

- (British) - Marsh. (*6*)

Swale - A low place in a tract of land, usually moister and often having a ranker vegetation than the adjacent higher land. (*5*)

- A low-lying or depressed and often wet stretch of land. (*6*)

Swamp - A tract of wet, spongy land; marshy ground; a tract of soft, wet ground having a growth of certain types of trees and other vegetation, but unfit for cultivation. (*5*)

- Wet, spongy land saturated and sometimes partially or intermittently covered with water. (*6*)

Swampland - Land or an area covered with swamps. (*5*)

- Swamp. (*6*)

Wetland - Usually, wetlands - a tract of land having wet and spongy soil, as a marsh, swamp or bog. (*5*)

- Land or areas (as tidal flats or swamps) containing much soil moisture - usually used in plural. (*6*)

Geology and Hydrogeology

Wetlands are wet, and since they *are* wetlands because of the position of the water table relative to the ground surface, it follows that subsurface water flow, watershed budgets, balances of input and output and degrees of soil saturation should also be considered as factors in any comprehensive wetland definition.

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*This sample of dictionary definitions shows that popularly, at least, wetlands are thought to be 1) wet; 2) low; 3) covered with a characteristic assemblage of higher plants.

Two publications on the geological and hydrogeological aspects of wetlands, respectively, are papers by Black (*7*) and Holzer (*8*) in the *Proceedings: First Wetlands Conference* published in 1973 by the University of Connecticut's Institute of Water Resources. Holzer's definition, drawn from that study and presented in seminar for this work, is restricted to the freshwater wetlands of Connecticut. It excludes flood plains, which are better delineated by high water marks recorded by accurate surveys after peak floods:

> *"Wetland" means a topographic entity in which the shallowest ground water table is at or near the surface for part of the year; the surface ground water table need not be connected to the regional ground water system. The substrate underlying this depression consists of naturally deposited organic and or clastic sediments. The shallowest ground water body beneath the wetland need not be connected to the regional ground water system."*

While this may be an appropriate hydrogeologic definition for the Southern New England geographic region, it cannot be applied across the nation due to the many exceptions to it elsewhere. Raised bogs, peat plateaus and upland surfaces that hold water and ice are not covered by this definition.

Black gave a broader definition:

> *"A freshwater wetland exclusive of streams, flood plains, and lakes, is a topographic entity in which the ground water table does not drop below the surface for a part of each year."*

An analysis of wetlands and topographic position by Powers and Healy (*9*,V,L.) showed that lest one misconstrue Black's "topographic entity" to mean "topographically low," some 20 to 25% of all wetlands in Connecticut are topographically high.

In contrast to some of the more empirical offerings to a wetland definition made in this study, one of the most elegant contributions to this study was that offered by Bock (E). Wetlands are mathematically defined via a hydrologic model. As a function of the height of the water table he divided wetlands into:

1. Ponded wetlands;
2. Water-at-surface wetlands;
3. Sub-surface water wetlands.

Parameters for precipitation, evapotranspiration, surface runoff, ground water flow, flow in the zone of aeration, infiltration, storage changes, soil moisture content and change, level of surface water, surface area and other factors were included in a formula to come to a value W for the degree of certainty of wetland designation. This probability number is generated by a regression equation. The parameters in the wetland probability equation and the equations themselves are given in Appendix II.

While such an approach nears the ideal in that it adds quantitative factors to the definition and understanding of wetlands, its principal shortcoming relates the the difficulty of obtaining the data necessary to arrive at the term W and to refine the equations. Furthermore, the hydrologic condition of any area changes seasonally.

Wetlands might also be defined in terms of high water table levels over the wettest part of the year, when hydrologic conditions allow wet surfaces. A definition from this viewpoint has been suggested by Powers (*10*).

> *"Wetland" means land where the water table is near, at, or above the ground surface during a particular time of the year (mid-March through April in our region) and other conditions of specific antecedent precipitation [after* x *inches of rain have fallen*].

Pedology (Soils)

Soil conditions are in part a response to the average, normal variations of the hydrologic changes in a wetland: these more visual factors are indirect summaries of the hydrologic condition.

One contributor (L) to this research on wetlands definitions resisted offering a soils definition for the following reasons:

> *"The position of the water table relative to ground surface is a function of the topography, hydrology and sursurface properties of the area in question.*

The characterization of an area as a wetland or non-wetland is based entirely on the position of the water table relative to the ground surface. The flora, fauna, soil type and chemical activities that are commonly used to define wetlands are uniquely related to the position of the water table.

The position of the water table and its yearly and seasonal variations can be accurately measured in the field by stand pipes and test holes and with less accuracy and precision (but perhaps more cheaply by remote sensing techniques).

Any definition of wetlands should therefore be based primarily on the position of the water table relative to the ground surface."

The water table level conditions many other aspects of wetlands. The low oxygen-carrying capacity of water (8 to 10 mg/l) is easily depleted by aerobic microorganisms in metabolizing degradable organic debris. When allowed to become continually wet, soils become anaerobic and inhibitory to this process, and the rate of organic decomposition is retarded; bound, rather than free oxygen, becomes the electron (hydrogen) acceptor and the entire ecosystem changes: hydrogen sulfide appears, along with other odorous materials; nitrogen gas is released, pH is lowered, terrestrial plants die and aquatic plants succeed, rooted in the wet anaerobic zone and with their stems in the air above the surface. Different animals now thrive among these wetland plants.

It seems clear that in order to arrive at a reasonable wetland definition, both water as well as vegetation should be included in it. Even soils scientists draw their boundary lines by noting both standing water and vegetative changes relative to their widely spaced test hole.

Biology-Botany

In protecting wetlands, how can we even think of conserving or developing a wetland ecosystem when there is little idea of which organisms will be affected? How can we more effectively define these and other areas for preservation? This section provides additional information for clarifying the importance and biotic delineation of wetlands.

As mentioned earlier, under the Tidal Wetlands Act, the tidal wetlands of Connecticut were surveyed for the state according to criteria of tidality, elevation and vegetation by Lefor and his associates in 1969 through 1971 under the direction of J.S. Rankin (*2*). A later amendment to the Tidal Wetlands Act, Public Act 132 (1972)(B), extended the botanical portion of the definition of the tidal wetlands to include the brackish to fresh estuarine wetlands along Connecticut's major rivers, which were then also surveyed.

Although the nature of the field work in delineating Connecticut's tidal wetlands on the ground did not allow much time for extensive collecting, several new records (first observation) of higher plant species in the state were discovered. Data on the phytosociology of Connecticut's tidal marshes were gathered. Extensive lists of birds and other animals were kept, along with aerial photographs showing the exact location, nature and condition of the tidal and estuarine marshes (*12, 13*).

The salient fact which emerged from the delineation studies of Connecticut's tidal marshes was the vast lack of detailed information regarding their botany and zoology. This is especially true for the estuarine marshes, for example, those along the Connecticut River. These freshwater tidal marshes possess a high biotic diversity which renders them more difficult research subjects when compared to the more easily quantifiable salt water wetlands of lower diversity.

Although the larger and more obvious organisms of Connecticut's wetlands can be, and have been, used for the delineation of these areas, we have no idea of the totality of their biota.

In the survey of Connecticut's tidal marshes, and particularly in the freshwater estuarine wetlands, the first need was for a field manual of the botany of the higher plants for use by those non-botanists on the survey teams. Such a work ideally would be written in a simple fashion understandable by the interested layman.

In the delineation of inland wetlands by town regulatory agencies, there has arisen a great need for a simple floristic manual giving all of the species of Connecticut's wetlands. A floristic manual for all wetlands in Connecticut begun in this project has been presaged in the botanical

guide for the inland wetlands compiled by Niering and Goodwin (*14*). A wetlands flora will be of use not only in delineation but also in the preparation of legal cases involving the regulated uses of inland wetlands by individual owners. Information on the plants and their habitat relationships, occurrence and distribution needs to be presented in specific form for administrative purposes.

In the ongoing field surveys of the tidal wetlands, the higher plants were fairly easy things to teach those unskilled in taxonomic botany; as well, the zoologists taught the botanists the larger animal forms. As to the fungi, smaller algae, mosses, liverworts, insects and invertebrates, members of these more technical groups often had to be left unidentified because of the lack of identification manuals or up-to-date information on distribution and nomenclature.

Any systemic treatment of a group of organisms must be periodically updated. Taxonomic names, species distributions and species concepts are always in flux.

A review of the current specific information on the biota of Connecticut and its wetlands, both tidal and inland, shows the following: Fernald's Botanical Manual (*15*) is largely current to about 1946, although recently reprinted with corrections. Gleason and Cronquist's Manual (*16*) dates from 1963 and is essentially taken from Britton and Brown's work (*17*) of 1954. *The Flora of Connecticut* (*18*) is a floristic list, first published in 1910 and expanded in a supplement of 1930 (*19*). Both of these are long out of date. A review of the bulletins of the State Geological and Natural History Survey of Connecticut reveals that only three works in this series are current (and usable by a technical specialist). These are: *The Saltwater Fishes of Connecticut*, 1971 (*20*); *The Freshwater Fishes of Connecticut*, 1968 (*21*); and *Diatoms of the Streams of Eastern Connecticut*, 1973 (*22*). The algae, mosses, liverworts, fungi, insects and other invertebrates are either unwritten, incomplete or out of date.

One cannot write a manual for the identification of a group of organisms without knowing what one must identify, and a listing of such organisms can serve to help distinguish various types of wetlands while also

showing the need to protect these aquatic systems. The reader is referred to the paper by Golet in the Institute of Water Resources' *Proceedings: Third Wetlands Conference* (23).

In Connecticut, inland wetlands have been legally defined on the basis of whether or not the soil substrate in a given area can be classified as poorly drained, very poorly drained, alluvial or flood plain. Unilateral definitions such as this are difficult in the field. Again the primary characteristic of wetlands is wetness, either permanent or seasonal. Recognizing the difficulty of perceiving the boundaries of that wetness on the large scale necessity for the delineation of wetlands, some secondary manifestation of that wetness could be used to locate wetlands. If we are to delineate wetlands for regulation, and if we must use a definition of wetlands which makes that delineation possible, then a wetlands definition should be based on one of the secondary manifestations of wetness.

Higher Plants

A manifestation of wetlands is the vegetative cover of the plants common to the wetlands. Although other factors, such as the seasonal variations in water level, must be added to the botanical definition of wetlands to help cover all possible "grey areas" in delineation, it is possible to write a wetlands definition based on the occurrence of groups of plant species alone. Below is a brief listing of major plant groups:

Vascular Plants:	ANGIOSPERMS (seed plants)
	GYMNOSPERMS (pines, spruces, firs, larches and other "evergreens")
	PTERIDOPHYTES (ferns, club mosses, horsetails)
Non-Vascular Plants:	BRYOPHYTES (mosses and liverworts)
	ALGAE
	FUNGI
	BACTERIA

Of the groups of plants represented in wetlands, some are more useful and inclusive in characterizing grey areas than others. Although in most cases representatives of all these major groups can be found within and/or bordering on a wetland, the groups which are most obvious, both to the eye

and to remote sensors, are the vascular plants: Angiosperms, Gymnosperms and Pteridophytes. In Connecticut, there are over 1,000 species of vascular plants native to wetlands and their boundaries. But since there are different types of wetlands, it is not possible to define wetlands in a general way botanically with, say, the publication of a 1,000 item long list of plant names in a wetlands regulation law. But, when the term "wetland" is defined to include in its meaning "swamp, marsh, and bog", each of these major wetland types can then be defined according to the association of plants which they support (See p. *39*).

A botanical definition of the wetland types should be general, yet specific enough to cover all of the sub-types of the major wetlands categories. In plant taxonomy (plant classification), there are well-defined natural and artificial groupings of plant species:

Species:	a population of similar organisms which normally interbreed to produce fertile offspring resembling the parents.
Genus:	a grouping of species with similar characteristics and/or affinities.
Family:	a group of related genera
Order:	a group of related families
Class:	a group of related orders
Division:	a group of classes (e.g., Angiosperms, Gynosperms, etc.)

The groups family, genus and species are the most frequently used in everyday parlance by taxonomists, and there is rarely disagreement as to application. (See Appendix I) The circumscriptions of the higher, more theoretical divisions in the plant kingdom are often the subject of lengthy discussion, and therefore, these taxa are not really useful for the purpose of wetland definitions.

We can include and name wetland plants in whichever taxonomic category most completely describes them. For example, the pitcher plant, *Sarracenia purpurea*, is common in bogs in New England. For the purposes of a wetlands definition, we can say that among other species, bogs are "characterized by *Sarracenia purpurea*" (genus and species); or, wetlands are "characterized by members of the Sarraceniaceae" (family). Rather than list, say, the 11 or so

species of *Sparganium* (Bur-reed) native to Connecticut wetlands, we can say "*Sparganium* spp.," meaning "species of *Sparganium*" -- i.e., any or all species of this genus which may be encountered, or simply, "Sparganiaceae" (family). Where it is desired to use a term which includes a number of species of a genus when not all of the species are restricted to wetlands, a modifier may be added to indicate a sub-group within a family, for examply, "tussock-forming sedges (Cyperaceae)", or hydrophytic (water-loving) Gramineae (grasses)."

The purpose of the foregoing discussion is to allay the fears of some that a legal wetland definition based on plants would consist of a list of some 1,000 Latin plant names. Not only would a legislature, largely composed of non-technically oriented persons, reject such a list out-of-hand, but without careful review by experts before type is set, such a latinate law might be full of errors of orthography or omission.

Before suggesting botanical definitions of wetlands, some other factors of wetlands botany need to be mentioned. Wetlands, like all other areas, possess what ecologists call *associations* of plants -- i.e., groups of species growing together. The exact composition of a wetland plant association varies from wetland to wetland within the same major plant association type. Within each type some species are more prevalent than others. These last are the *dominant species* or "dominants." The dominant taxa can be named in a wetland definition broken down into subdefinitions of major wetlands types.

Given the above, one can formulate a definition of wetlands based on botanical criteria as proposed in this work. This definition is followed by a detailed layman's explanation of technical terms (Appendix I).

The major advantage of a botanical definition is that it lends itself readily to wetlands mapping via remote sensing techniques and/or photo-interpretation. The phrases relating to surface water or moisture add another element of the wetlands ecosystem which can be remotely sensed, and aids in the accuracy of any delineation.

Lower plants

Trainor and Bonanomi (H,I) undertook to formulate a definition of inland wetlands based upon algae. Applying such a definition in the field is difficult because of the problems in naming species of algae in the wild. The knowledge of the algae of Connecticut was first set together by Hylander (*24*) in his *Algae of Connecticut* (1928). This work is long out of date, since the impact of Man's activities has opened new habitats for algal growth. The use of phosphate fertilizers, the erection of dams, dredging, farming and other activities have all contributed to this habitat change. There are probably more habitats available to the algae now than at the turn of the century. These new habitats are not so much a result of change in habitat number alone as a change in nutrient availability due to fertilizer runoff and other aquatic pollutants.

The algae are almost all strictly aquatic, with the exception of the soil algae. Because algae are plants of a low level of structural organization and must therefore exchange gases and nutrients through their cell walls, they must have an environment with an appropriate concentration of water, dissolved gases and nutrients, or else pass into a resistant resting stage.

With respect to the use of algae as definitional criteria, we can quote Trainor and Bonanomi (*25*):

> *"To use algae in wetlands definitions, one would ideally look for a group of species that are distributed in all freshwater habitats, or a group of species which represents all habitats. With the present available information, such a system cannot be realized."*

There are many more types of algae than there are of wetlands, just as is true for the higher plants. However, even with our limited detailed knowledge of the algal flora we can cite some taxa of algae which characterize certain specialized inland wetland habitats. For example, found consistently submerged in freshwater are *Batrachospermum* spp., *Lemanea* spp., *Audouinella* spp. and *Draparnaldia* spp.

The major problem with the use of algae as a wetland definition criterion is their method of dispersal. Certain algae may occur in areas such as puddles, not true wetlands. Resting resistant stages can be carried

by wind or water. If a reservoir or other water body is emptied or dries up, many of the algae present will form resistant spores, which, after being windborne with dust or carried by birds, can germinate when proper conditions of light, water and nutrients are met. Therefore many algae can, and do, germinate in rain puddles and other artificial or temporary bodies of water, many of which would not qualify as wetlands in any judgment. Moreover, the algal flora of a body of water changes rapidly throughout the growing season, and the water should be examined every two weeks to gain a complete understanding of the species present.

There is, however, a group of algae which is conspicuous in wetlands by its *absence*: soil algae. This large group of organisms is largely restricted to areas of mesic (moist, but not wet) soils with available surface and capillary water and an appropriate nutrient supply. Such algae are unsuited for growth in a totally aquatic habitat. Trainor and Bonanomi state:

> *"The average soil flora consists of about 20 species of diatoms, 24 species of blue-green algae, and 20 species of green algae, among which:* Hantzschia amphroxys, Bumilleria exilis, Ulothrix subtilis, Chlorococcum humicolum *and* Chlorosarcina *spp. are some of the more frequently encountered."*

It should therefore be theoretically possible to define wetlands by the *absence* of these and similar algae.

Based on the material supplied by Trainor and Bonanomi (*25*), we can formulate the following algal wetlands definition:

> *"Wetlands are those areas which support a diverse algal flora when examined at least every two weeks for a period of one year; organisms such as members of the genera* Batrachospermum, Lemanea, *euglenoid organisms, and members of the Desmidiaceae and related families, zoospore-forming unicellular forms and sarcinoid forms are present in those areas only seasonally covered with water."*

This definition has theoretical appeal, but due to our lack of detailed knowledge of the algal flora of the Northeast, it is difficult to put into practice.

Zoology

Rankin (G) in a presentation to the Wetlands Definitions Seminar Series, discussed the use of animals in the formulation of a definition of inland wetlands. Plants are sessile and can be used in delineation; animals, at least the well-known and macroscopic ones, are motile. Can one use a raccoon, for example, as a boundary indicator of a wetland if the raccoon moves from place to place? Yes, only if one is ready to consider frequency of visitation to the wetland as a criterion. For those animals which are taxonomically well-known we can employ their names in a wetland definition by way of clarification as wetland *users*. For example, "wetlands are those areas covered by the following vegetation (list), and which are frequented by the following species of animals (list)."

The nomenclatural problems in the animal kingdom increase as one progresses down the evolutionary ladder. Therefore the difficulty of using animals increases also. Lefor and Tiner (*12*) listed wetland organisms from existing systematic treatments and their own observations. Even in an area with as rich a tradition of knowledge as New England, it was surprising to those authors to find such a large gap in the detailed knowledge of wetland fauna. As an example, Tiner collected several species of spiders new to science in a salt marsh in Groton, Connecticut (*26*).

Standard treatments of highly technical groups of animals (microscopic and/or of a lower level of differentiation, such as Protozoa, Nematodes, Platyhelminthes) are apt to be out of date and are not of utility in a definition because of the vast number of species involved. Attention should be directed toward the somewhat larger, taxonomically better known groups of animals. These include the molluscs, crustaceans, insects, fishes, amphibians, reptiles, birds and mammals.

The molluscs and many crustaceans of our watercourses and wetlands are comparatively well-known. Both groups are restricted to aquatic habitats. Of the two, the molluscs, although rarely of high populations in inland wetlands, are of greater value as wetlands definition criteria because they are sessile. Their infrequent occurrence there limits their utility, however. Some groups of the insects, at least for Connecticut, have been described and enumerated in the publications of the State Geological and Natural History

Survey of Connecticut, but much of this work is dated. With the vast numbers of insects in the world, one might expect to find a close relationship between insect species and habitat (e.g., wetland type or wetland plant species); this is the case. However, by and large the insects, a highly technical group, are insufficiently known to permit their use as wetlands definers/delineators on a regional basis.

The vertebrates of the wetlands and watercourses are much better known and are easier to observe. For the fish, many of which are restricted more to what might be called "watercourses" rather than "wetlands," we can say that their motility renders them useless for purpose of delineation. How can one draw a line around a swimming perch unless that lines adheres to the fish itself? The line should be drawn about that medium in which the fish swims -- the water. Fish, however, can be used in qualifying, refining or expanding a watercourse/wetland definition.

The case with birds and mammals is similar. Birds are another integral part of the wetlands ecosystem. Craig (*27*) has discussed those bird species which breed in and/or use the vegetation of estuarine marshes, many of which (in his study) were dominated by vegetation common to freshwater habitats.

Amphibians, reptiles and mammals, although similarly mobile and therefore useless for delineation purposes, can constitute another refinement in the multifaceted wetland definition. Raccoon, muskrat, otter, beaver, etc., are all wetland organisms, and their names could be added to habitat descriptions.

We could begin the formulation of a zoological wetland definition by saying: "Wetlands are those areas which provide a significant habitat or food source for (list of wetland animals)." This is not, legally, a definition which leads to delineation. Such a definition is vague, redundant and legally cumbersome. If the definition is to be used for delineation, how can one say, "...an area where...," if the word "area" is a place upon which the *motile* delineation criteria are to be imposed?

One other theoretically possible wetland definition is that based on diversity indices. Basically, a diversity index is a mathematical expression which includes parameters for area, number of species, and population density

per species (or per area). Since many wetlands are more diverse in this sense than uplands, it may be possible to arrive at a wetland definition using this criterion. The difficulties with this mathematical approach are, however, the same as those with Bock's mass water budget equation -- both require extended sampling of an area. Further, one presupposes that the area sampled is a wetland to begin with.

To summarize this section on the biological definitions of wetlands, it must be remembered that any unilateral definition is both theoretically and pragmatically untenable. We cannot always define a door by a doorknob, and neither can we tell absolutely *where* the door is by the same means.

Systems Ecology

One aspect of the wetland ecosystem which should not be ignored is systems ecology, a discipline which attempts to tell us in quantitative terms *what* an ecosystem is doing as well as *how* it is doing it. Wetlands exhibit some special features which deserve inclusion in a comprehensive definitions of those areas, even though those features might not lend themselves to rapid and/or practical delineation.

The wetland ecosystem is compressed vertically compared to lakes, for instance, so that the zone in which photosynthesis occurs (normally near the surface of the lake) and the zone in which decomposition occurs (the bottom) are literally interconnected by the same organism: the aquatic plant. While the shoots of the plant exist in an oxidizing zone of light and oxygen, the roots exist in a reducing zone of saturated, anaerobic sediments or soil.

Regardless of the presence or absence of wetland plants, the two zones participate in the functions of the dynamic detrital structure of aquatic ecosystems. The dynamic nature of the two metabolic zones may be observed from a detailed examination of the flow of electrons (or reducing power) through the aquatic ecosystem. Because grazing is generally minimal relative to primary production in temperate wetlands, the benthos, or zone of decomposition, becomes the primary consumer. As a consequence of electron flow in the bottom detritus, the benthos also becomes an important producer, production being in the form of reduced organic and inorganic compounds.

The profound importance of this production has been recognized in biogeochemical cycles and in lake eutrophication.

As part of an investigation undertaken by Rich and Kowalsczewski *(28)* the benthic detrital electron flux role of the benthos was studied intensively at Dunham Pond, a small, shallow bog/lake within a mile of the University of Connecticut Storrs campus.

Preliminary results indicate that wetlands are important collection and processing sites for all manner of organic and inorganic moieties. They are the only terrestrial sites which perform these functions to such a high and efficient degree. Wetlands which participate actively in their watersheds by intercepting surface run-off before passing it on downstream can and do filter out and bind silt and dissolved materials either physically or chemically.

Therefore, using the above process as a criterion, sampling sites might be set up around a suspected area to monitor wetland metabolic processes. By establishing a cutoff level for "wetland/non-wetland" and mapping the portion of the test sites, it is possible (but not practical) to locate a wetland boundary. However, systems ecology shows quite·clearly the *why* of wetlands regulation rather than a path to effective delineation via definition. *(28)*

Economics (C)

Land in its original state was a free gift of Nature. But in settled countries the value of land in one use must be weighed against its values in alternative uses. In the eastern half of the United States people generally have relied upon market prices to reflect relative values to society. Yet we have come to realize that some land uses have values beyond those accruing to a private owner. In order to reflect values ignored by the free market there has been for several decades an increase in both the scope and intensity of public regulation of the natural state. The long-term benefits, although exceedingly difficult to calculate, are very important factors to consider in ascribing values to land; they are inextricably bound to economic considerations, to legal issues and to political actions.

Johnson (*29*), speaking at the first Wetlands Conference held in 1973 by The University of Connecticut's Institute of Water Resources stated:

> *"The law relating to wetlands protection is a branch of what we refer to as 'police power': it deals with the extent to which government may regulate people's conduct. In the instance of wetlands, it relates to the extent to which the state may regulate one's use of his own wetlands without being confiscatory. That is, on the one hand, police power exercised within reasonable limits is deemed proper for protection of the general welfare; on the other, police power exercised to an extreme is deemed to be a confiscation of one's property, and, if engaged in, the state must pay for the taking of that property. The issue that is going to have to be resolved by the courts is where the line should be drawn between the valid exercise of police power and taking of property."*

Johnson then drew the analogy between wetlands protection and zoning laws. Unknown until 50 years ago, zoning laws developed from nuisance law under police power. These laws, long since upheld by the courts, established that the uses of property can be restricted for the benefit of other property owners. He stated, further, that we are now entering a phase where police power is being used to protect the ecosystem, once again for the general welfare. Suffern (*30*) speaking at the same conference as Johnson, concluded that "converting societal attitudes from traditional private property concepts to those of land stewardship is a slow process, and will require years of patient education." Perhaps so, but the use of economic principles and theory and the incorporation of social costs and benefits make it possible for rational decisions to be made now. Economics as a discipline has nothing to say as to whether society's goals are desirable, undesirable or merely indifferent. It does, however, provide the tools for comparing alternative means of achieving social goals; it also can provide a framework for determining the relationships among goals and whether or not they are consistent.

It is possible to define wetlands from an economic point of view; namely:

> *An area can be considered a wetland (and subject to protection under the law) when its dollar value to society as a wetland is higher than its value for any other use.*

We must now develop reliable procedures for determining such values. It is in computing the values of wetlands among alternative (competing) uses that the principles of economics are brought into play. Whether or not members of a legislative body plan for a connection between legislation controlling natural resources and economic factors, such a relationship always exists. This is certainly true with regard to Connecticut's Inland Wetlands and Water Courses Act. Not yet do we have effective techniques for determining the value to society of wetlands as a component in the hydrologic cycle -- the global process whereby water is drawn from the oceans and other water bodies in the form of vapor, carried over land where it falls as rain or snow, and moves over and through the soil back to the seas in a never-ending cycle. Yet any rational person should recognize that wetlands must be a vital component in this complex arrangement. While we cannot assign or calculate values for such a vast and complex process, we can do so for some of the ways in which wetlands are used.

In seeking ways to place values on wetlands and to use economic criteria in selecting among proposed conflicting uses, several studies have produced conclusions which are applicable to the problems which face Connecticut.

At the present state of knowledge, the value of coastal or estuarine wetlands can be more accurately defined and more precisely delineated than freshwater wetlands. A study by Gosselink, Odum and Pope (*31*) concerned the development of a "...step-wise means of assessing the true value of natural tidal marshes to society as a whole - a value based not only on commercial usage, but on social usage and the monetary value of natural (i.e., "undeveloped") estuarine environment." It is well-known that estuaries serve as a nursery ground for commercially important coastal fish and shellfish. The commercial value of such animals can be calculated and, by extension, the value of an estuarine marsh can be determined. They concluded that the minimum value of an acre of tidal marshland due to returns from fisheries and recreational uses is $2,000. In addition to providing a natural nursery and recreational area, the same marshland can contribute sustenance to nearby shellfish growing areas, such as in the raft

culture of oysters, which are man-organized and managed activities. Values for those purposes also can be calculated.

Turning to another aspect, that of cleansing effluents from sewage treatment plants, Gosselink *et al.* concluded that the economic value of estuarine marshes as tertiary treatment plants can be valued in tens of thousands of dollars per acre per year as compared to the hundreds that accrue from by-product uses. Salt marshes also play important roles in the global cycles of nitrogen and sulfur, in serving as buffers against storms, and in protecting sand beaches and dunes, and as habitats for migratory birds. These functions are difficult to quantify but no less real than the preceding examples. While not directly applicable to freshwater wetlands, the methodologies developed by Gosselink *et al.* are of great value in the design of investigation of such areas. The results of two excellent studies in inland freshwater wetlands have been published by Resources for the Future. In 1971, Goldstein (*32*) compared costs and benefits of wetlands in the upper Midwest and Canadian Prairie Provinces used by migratory water fowl, with the cost of their drainage as areas for agricultural crop production. As Goldstein stated, this allocation has the classical characteristic of a resource distribution problem: one scarce resource with two alternative uses. He concluded that drainage is socially inefficient and that reclamation of permanent and temporary wetlands would not continue if subsidies were not provided to the agricultural sector and if competitive prices for agricultural commodities existed in the market. While he was not successful in estimating the value of waterfowl, the mathematical approaches he developed in studying the problem have direct use to resource economists studying freshwater wetlands in southern New England.

Another study germane to southern New England wetlands is that of Hammock and Brown (*33*) who, in 1974, studied the interrelationship between waterfowl and the prairie pothole areas of south central Canada and parts of North Dakota, South Dakota and Minnesota. They developed a theoretical framework for the evaluation of waterfowl which might be used for determining the value of wildlife in the freshwater wetlands of southern New England. They also performed cost-benefit analyses of wetlands which joined economic and physical parameters to determine the optimal number of ponds, breeding birds

and seasonal kill. They concluded that the value of a bagged waterfowl, when more precise models have been developed, probably would be much greater than $3.00 per bird.

In neither of the two studies reported here were the authors concerned with defining or delineating the prairie potholes (inland wetlands). They stated simply that prairie potholes exist and are used by waterfowl for both resting and nesting sites during their biannual migrations. In southern New England, however, definitions of freshwater wetlands are not generally agreed upon and their development has been the purpose of our investigations. Procedures for accurately delineating inland wetlands also need further study and refinement.

An especially comprehensive study of the uses and values of a wooded wetland is that of Wharton (*34*) whose investigations in 1970 of the Alcovy River, a river/swamp system in Georgia, have direct implications for forested wetland areas of Connecticut, since such areas are the most commonly found type of wetland in the state. The benefits of such areas are both tangible and intangible -- the latter perhaps being the most important of all for the future. Wetlands are excellent outdoor laboratories where fundamental interrelationships of physical and biotic components of the ecosystem can be studied. Wharton estimated the value of the Alcovy River swamp (70 miles of streams and its adjacent 2,300 acre swamp) at $1,250,000 for educational purposes and over $4,000,000 annually for recreation. Marshes and swamps function both as water storage and discharge areas and also occasionally as groundwater recharge areas. He calculated the value of groundwater which could be pumped on a sustained basis from the Alcovy River swamp to be more than $200,000 per year. He directed attention also to the value of the natural system of water purification and sediment trapping which he estimated at $1,000,000 yearly. He recognized, but was not able to compute, values for primary production and for animals, but estimated the annual value of timber harvest to be $526,000. Altogether, Wharton estimated the annual value of the Alcovy River and its adjacent swamps to be over $7,000,000 per year! Even more impressive is the $430,000,000 value which he estimated for the system for the next 100 years. While these estimates appear high, the value of the system still is great if only a fraction, say 10%, of these calculated benefits are considered applicable.

Studies on the values of inland wetlands also have been carried out recently in southern New England, principally by Larson and his associates at the University of Massachusetts (*35, 36*). From an economic point of view, the results of these studies have been summarized in a publication by Gupta and Foster (*37*). They state:

> *"The opportunity costs associated with preserving a natural resource are the benefits society would receive from the resource in alternative uses and which must be foregone to achieve preservation."*

They calculated values for wetland uses such as wildlife, visual-cultural aspects, water supply and flood control on three bases -- high, medium and low productivity levels. Capitalized values per acre of benefits from preserved wetlands with various combinations of productivity levels ranged from $500 to $59,000 per acre. Based on this analysis and on general knowledge of wetland market prices, they estimated that permits for wetland development should be denied on more than 90% of Massachusetts wetlands. Each permit request would require an individual determination.

Only one study on Connecticut wetland forests, that of Grace (*38*), has come to our attention. While not giving specific acre values for such wetland timber stands, he clearly indicated that the trees, mostly red maples, were of value and that long-time proper management would result in improved growth of tree species with significant market value. Techniques for estimating the value of standing timber have long been in use with recognized accuracy. The wooded wetlands thus have direct value for their timber while still serving other functions such as flood abatement, recreation, water supply and water quality improvement.

Ehrenfeld (*39*), in a thoughtful and reasoned review of the situation, concludes that many natural resources are actually *non-resources*, and that attempts to assign economic values to them not only appear contrived, but also are weak from a practical, political point of view. He offers as an alternative that the non-economic values inherent in all natural communities and species be identified and weighed at least equally with resource values. The primary such value he call "natural are a value" -- preserve it because it is there and has an inherent right to continued existence. While

this approach will require a change in cultural values, it perhaps may serve better the conservation of our natural resources over the long term than the resource (value) approach presently being used. Perhaps so; but until that new ethic is developed, economic and political considerations still will decide the fate of the great part of our natural resources, including inland wetlands.

From the preceding review, it can be recognized that economic considerations are valuable not only in the process of deciding uses of wetland areas but also in formulating definitions of freshwater wetlands. Imperfect as these initial attempts are, they do form the basis for studying in detail the use values of wetlands in Connecticut and similar regions in the northeastern United States. Important as economic considerations are, however, the resolution of wetland use problems depends on political compromises and court decisions. Hopefully, though, results of studies designed to determine use-values of freshwater wetlands can be applied in the political process so that decisions result in long-term benefits to society at large while still permitting an orderly growth process.

SUMMARY OF DEFINITIONS

We now present a synopsis of wetland definitions and/or definitional statements drawn from the various fields of interest considered in this study, followed by a theoretical multidisciplinary definition and proposed amended legislation for Connecticut and other areas in our region.

I. Existing wetland definition in Connecticut statute:

> *..."Wetlands" means land, including submerged land,... [not otherwise regulated]...which consists of any of the soil types designated as poorly drained, very poorly drained, alluvial and flood plain by the National Cooperative Soil Survey of the U.S. Department of Agriculture.*
>
> *"Water Courses" means rivers, streams, brooks, waterways, lakes, ponds, marshes, swamps, bogs and all other bodies of water, natural or artificial, within the state or any portion thereof... not otherwise regulated ...*

II. Dictionary definition (6):

> *[Wetlands are]...land containing much soil moisture [as swamps or bogs]...*

III. Layman's conceptual definition (A):

> *An inland wetland is a damp, insect-ridden, often foul smelling and mysterious area of muddy soils and relatively still surface water where strange and different animals and plants reside.*

IV. Geohydrological definition (J):

> *Inland wetlands should be defined primarily on the position of the water table relative to the ground surface. The flora, fauna, soil type and chemical activities that can be used to delineate wetlands are uniquely related to the position of the water table.*

V. Systems definition - (1) (A,J,K):

> *Inland wetlands are those wet areas which, during a significant portion of the year, provide a unique habitat for certain species of higher plants specifically adapted to environments with low and varying available*

oxygen and with acidic conditions; shallow-rooted and/or aquatic plant species capable of aerobic and anaerobic metabolism are favored. Animals native to these areas are those which are dependent on the above types of plants for food and shelter or upon other animals which frequent these areas. In general, wetlands are distinguished from uplands by the type and diversity of the flora and fauna.

VI. Systems definition -(9)(J,K):

A wetland is an ecosystem that is compressed vertically, as compared to a true water course for instance, so that the photosynthetic zone and the zone of anerobic decomposition are interconnected by plants. While the shoots of the plants exist in an environment of light and free oxygen, the roots are in a reducing zone -- the anoxic sediments and water-saturated soils.

VII. Hydrologic definition -(1)(D)

The characterization of an area as a wetland or a non-wetland is based entirely on the position of the water table relative to ground surface. The flora, fauna, soil type and chemical activity commonly used to define wetlands are uniquely related to the position of the water table.

The position of the water table relative to ground surface is a function of the topography, hydrology and sub-surface properties of the area in question.

VIII. Hydrologic definition -(2)(E):

Wetlands are areas where the water table is at or above the ground surface during the growing season, and under conditions of specific antecedent precipitation. Balances between precipitation, percolation, evapotranspiration and runoff govern water accumulations in wetlands.

IX. Economic definition (C):

An area can be considered a wetland when its value to society as a wetland is higher than when it is used for any other purpose.

X. Delineational definition (E):

For a definition that leads to delineation, surface characterization of vegetation, water level and soil type are features that may be detected with aerial photographic techniques and then refined on the ground as necessary through field observation.

XI. Societal definition (Q,R,S):

Legally, wetlands have been defined as public goods. In practice, however, wetlands are those land areas which duly appointed or elected public officials choose (or are required) to regulate under the appropriate statutes. This decision, which may or may not involve the use of scientific knowledge is subject to appeal. A Wetland is Whatever the Law Says it is.

XII. Theoretical definition (A,B,C,S):

Freshwater inland wetlands means areas where, because of topographic, hydrologic and subsurface properties, the water table is at or near the ground surface for those parts of the year with the highest rainfall. Wetlands are not completely separable by definition or functional role from water courses and aquifers. The unique wetland flora, fauna, soil types and chemical activities are functions of the wetland water chemistry and depth of the water table. Because the soil substrates are not well drained, the free oxygen level in the soil-borne water is low and varying; therefore, anoxic and mildly acidic conditions characterize wetland soils. These characteristics provide a special habitat for shallow-rooted aquatic plants, capable of both aerobic and anaerobic metabolism. The photosynthetic zone and the zone of anaerobic decomposition are interconnected by certain aquatic higher plants. Fauna native to wetlands is dependent on wetland plants for food and shelter or upon other animals whech frequent wetlands. Thus, the diversity and composition of wetlands flora and fauna are different from those of dry-lands. Wet soil conditions can be determined by test holes, surface water and unique wetland vegetation. Wetland surface characteristics, such a vegetation, standing water and soils and visual features that can be discerned at ground level or by aerial photography. Subsurface characteristics can be discerned by field testing of the soils and by observation of geological conditions.

Economically, certain wetlands have value to society as common public land assets in which their exchangeable and intangible benefits are greater than for any other use or altered functional role.

In law, however, wetlands are whatever the law says; thus, wetlands can be whatever a duly constituted watershed region committee (or other governing body), deems it to be. To be politically and scientifically sound a wetland commission should be composed of at least a public representative, persons knowledgeable in hydrology and biology, a public health officer, an engineer and a surveyor so that wetland boundaries can be established as part of an overall land use strategy based on concern for public health, safety and the long-term preservation of the environment. Wetland preservation should be part of overall land use planning based in part on watershed regions as natural encompassing areas for water management. Land use maps showing wetlands, watercourses and other important boundaries should be published for public and private use to gain a constituency of support for such services. Wetlands are a part of a continuous environmental system and should not be segmented artificially from surrounding areas; overall land use planning would protect wetlands as part of the ecosystem that benefits the common good of all the people.

XII. Legal Definition (S,B):

"Inland wetlands" means those areas not regulated where the water table is at, above or below but near the ground surface for those parts of the year with the highest rainfall, and includes but is not limited to water courses and aquifers. Indicators of wetlands in addition to ground water table include but are not limited to unique wetland flora, fauna, soil types, chemical activity, low and varying free oxygen levels in soil borne water and anoxic and mildly acidic conditions. In order to regulate hereunder an agency must promulgate a map of inland wetlands in accordance with the requirements for the promulgation of regulation provided hereunder. Only areas approved on a properly promulgated map may be delineated for the purpose of regulation. Wetland soils conditions may be assessed by U.S. Soil Conservation District maps, test holes, surface water and their unique characteristics, such as vegetation, animals, standing water and wet soils, which are visual features that may be discerned by direct observation at ground level or by aerial photography, or may be discerned by field testing of the soils and by the observation of geological conditions.

XIV. PROPOSED AMENDMENT TO THE INLAND WETLANDS AND WATERCOURSES ACT,

General Statutes, Section 22a-38, paragraph 15 (B)

(Items in upper case letters are to be added.)

(15) "Wetlands" means land, including submerged land, not regulated pursuant to sections 22a-28 to 22a-35, inclusive, which consist(s) of any of the soil types designated as poorly drained, very poorly drained, alluvial or flood plain by the National Cooperative Soils Survey, as may be amended from time to time, of the Soil Conservation Service of the United States Department of Agriculture; AND SHALL INCLUDE, BUT NOT BE LIMITED TO, MARSHES, SWAMPS, BOGS, RIVERS, STREAMS, RIVER AND STREAM BANKS, AREAS SUBJECT TO FLOODING OR STORM FLOWAGE, AREAS WHERE GROUND WATER, FLOWING OR STANDING, SURFACE WATER OR ICE PROVIDE A SIGNIFICANT PORTION OF THE SUPPORTING SUBSTRATE FOR A PLANT COMMUNITY; EMERGENT AND SUBMERGENT PLANT COMMUNITIES IN WATER BODIES; AND THAT PORTION OF ANY BANK WHICH TOUCHES ANY INLAND WATERS.

"MARSH" MEANS THOSE AREAS WHERE A VEGETATIONAL COMMUNITY SHALL EXIST IN STANDING OR RUNNING WATER, AND WHERE THAT COMMUNITY SHALL INCLUDE, BUT NOT BE LIMITED TO, SOME, BUT NOT NECESSARILY ALL, OF THE FOLLOWING: HORSETAILS (Equisetaceae); BUR-REEDS (Sparganiaceae); CATTAILS (Typhaceae); PONDWEEDS (Zosteraceae); WATER-PLANTAINS (Alismaceae); FROG'S-BITS (Hydrocharitaceae); HYDROPHYTIC GRASSES (Gramineae); SEDGES (Cyperaceae); ARUMS (Araceae); DUCKWEEDS (Lemnaceae); RUSHES (Juncaceae); PICKERELWEED (Pontederiaceae); PIPEWORTS (Eriocaulonaceae); SWEET GALE (*Myrica gale*); TEARTHUMBS (Polygonaceae); WATER LILLIES (Nymphaeaceae); WATER-MILFOILS (Halorrhagidaceae); DOGWOODS (*Cornus* spp.); BUTTONBUSH (*Cephalanthus occidentalis*) AND ARROWWOOD (*Viburnum* spp.).

"SWAMP" MEANS THOSE AREAS WHERE GROUND WATER SHALL BE AT OR NEAR THE SURFACE FOR A SIGNIFICANT PORTION OF THE GROWING SEASON, OR WHERE RUNOFF WATER FROM SURFACE DRAINAGE SHALL COLLECT FREQUENTLY, AND WHERE THE VEGETATIONAL COMMUNITY SHALL INCLUDE, BUT NOT BE LIMITED TO, SOME BUT NOT NECESSARILY ALL, OF THE FOLLOWING: HEMLOCK (*Tsuga canadensis*); EASTERN WHITE CEDAR (*Chamaecyparis thyoides*); SKUNK CABBAGE (*Symplocarpus foetidus*);

WILD FALSE HELLEBORE (*Veratrum viride*); WILLOWS (*Salix* spp.); BIRCH (*Betula alleghaniensis*); ALDERS (*Alnus* spp.); MARSH MARIGOLDS (*Caltha palustris)*; SPICE BUSH (*Lindera benzoin*); RED MAPLE (*Acer rubrum*); SWEET PEPPER BUSH (*Clethra alnifolia*); BLUEBERRIES (*Vaccinium corymbosum* group); SWAMP AZALEAS (*Rhododendron* spp.); ASH (*Fraxinus* spp.).

"BOG" MEANS THOSE AREAS WHERE STANDING OR SLOWLY RUNNING WATER SHALL BE AT OR NEAR THE SURFACE DURING A NORMAL GROWING SEASON, AND WHERE THE VEGETATIONAL COMMUNITY SHALL HAVE A SIGNIFICANT PORTION OF THE GROUND OR WATER SURFACE COVERED WITH SPHAGNUM MOSS (*Sphagnum* sp.), AND WHERE THE VEGETATIONAL COMMUNITY SHALL INCLUDE, BUT NOT BE LIMITED TO, SOME BUT NOT NECESSARILY ALL, OF THE FOLLOWING: EASTERN WHITE CEDAR (*Chamaecyparis thyoides*); BLACK SPRUCE (*Picea mariana*); SEDGES (Cyperaceae); BOG-COTTON (*Eriophorum* spp.); ORCHIDS (Orchidaceae); PITCHER PLANT (Sarraceniaceae); SUNDEWS (Droseraceae); BLUEBERRIES (*Vaccinium corymbosum* group); CRANBERRIES (*Vaccinium oxycoccos, V. macrocarpon*); LEATHERLEAF (*Chamaedaphne calyculata*); BOG ROSEMARY (*Andromeda glaucophylla*); SWAMP AZALEAS (*Rhododendron* spp.).

"GROWING SEASON", FOR PURPOSES OF THIS ACT, SHALL MEAN THE PERIOD FROM APRIL 1 TO OCTOBER 1, INCLUSIVE, OF ANY CALENDAR YEAR.

APPENDIX I.

Descriptions and Explanations of Terms (B).

We felt it necessary to add some explanation and description to the proposed amendment here, so as to make the species list somewhat less formidable in impact upon the understanding. Common names of vascular plants are often inexact and misleading; there may be more than one common (English) name for one species, or one name for two or more unrelated taxa. The Latin names in the proposed amendment are internationally accepted, and there is (theoretically) only one correct accepted name for each taxon: thus the use of Latin scientific names here. In the short descriptions of the taxa which follow, technical descriptive terms of morphology* have been kept to a minimum. Taxa are listed in the order of appearance in the proposed amendment; that order is the same as that of Gray's *Manual of Botany*, 8th Ed., Revised (*15*).

1. Equisetaceae (Horsetails). This family of plants, numbered among the vascular cryptogams (plants with water-conducting tissue; reproduction by spores, not seeds) can be characterized by usually green, jointed, pipelike stems which often bear whorls of single or much-branched appendages at the joints. Spores for the production of a new generation of individuals are borne in a "cone" at the apex of the main stem. The plants also spread extensively by underground runners (rhizomes). Common in alluvial soils of flood plains and freshwater tidal marshes (*Equisetum hyemale*, *E. fluviatile*, *et al.*).

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*There is a series of very exacting English terms for structures and shapes in descriptive botany, most always based on Greek and Latin word roots. Two of this author's (B) favorites are: "Hippocrepiform" (Gr. *hippos*, horse, + Gr. *crep-*, shoe = horseshoe-shaped); and "praemorse" (L. *praemordeo*, to bite off = appearing as if bitten off). Note further that it is common (and correct) practice to place generic and species names in italics when setting type. Family names are always set in Roman. For further descriptions and illustrations the reader is referred to Gray (15) and Gleason and Cronquist (17), respectively.

2. Sparganiaceae (Bur-reeds). These flowering plants (Angiosperms) reproduce their number by seed as well as by rhizomes. Colonies of *Sparganium* (the only genus) are found emergent in standing or slowly flowing freshwater in open, sunny locations. The plants possess several strap-shaped, blunt-tipped, bright green leaves. The unisexual flowers are borne in a few to several globular heads along a flowering stem bearing one to several reduced leaves (bracts). The female heads are borne below the male heads.

3. Typhaceae (Cattails). One of the more common wetland plants, its yard-long, strap-shaped, dull green leaves and characteristic brown, cylindrical flowering heads are a familiar sight in open, sunny locations. The plants have unisexual flowers; the female flowers in the cattails are those which form the dark brown cylinder at the apex of the fertile stem. A close examination shows that the heads are composed of thousands of minute, densely packed pistils (structures which contain the female reproductive cells of the flower), each closely surrounded by fine hairs. The male flowers are borne above the female at the apex of the fertile stem and consist of stamens only and appear with the female, in late spring to early summer; the make flowers are later shed from the plant with most of the upper portions of the flowering stalk, leaving the "point" at the tip of the flowering axis above the cylinder of female flowers.

4. Zosteraceae (Pondweeds). The Zosteraceae are aquatic herbs found either below the surface of open water or with certain of the leaves floating at the surface. The flowers are either bisexual or unisexual and are often greatly reduced and inconspicuous within an enclosing bract (spathe). Our representatives of the family include the marine *Zostera*, or Eelgrass, which occurs along our coast from the waterward margins of the intertidal zone and into shallow, sunny waters; *Potamogeton*, or Pondweed, of stiller freshwaters and with floating and submersed leaves of different shapes; *Ruppia* (Ditchgrass) of the intertidal zone of salt waters; and *Zannichellia* (Horned pondweed) of brackish to fresh waters, similar in appearance to *Ruppia* with its submerged, slender branching habit.

5. Alismaceae (Water-plantains). This family includes a number of species common to Connecticut freshwater wetlands in sunny locations. The leaves of these emergent to submersed herbs are variously shaped throughout our representatives, but are mostly oval to heart- to arrow-shaped. The three-petaled flowers are most often borne several to a flowering stalk or in large terminal inflorescences of many flowers. (*Alisma*, Water-plantain); *Lophotocarpus; Sagittaria* (Arrowhead, Swamp-potato, Wapato, Duck-potato).

6. Hydrocharitaceae (Frog's-bits) are submerged aquatic herbs with inconspicuous unisexual or bisexual flowers. The leaves are strap-shaped as in *Zostera* of No. 4, and are usually whorled and closely set upon long trailing stems in *Elodea* (=*Anacharis*; Waterweed).

7. Gramineae (Hydrophytic grasses). By "hydrophytic" is meant "water-loving" -- that is, those grasses which grow in wet situations. ("Wet" meaning for all or part of the growing season). The word "grass" conjures up another example of the fallacies of common names. Most laymen consider any herbaceous plant with linear leaves and inconspicuous flowers a "grass." However, several unrelated families of flowering plants possess this same general habit. "Grass" and "Gramineae" refer to plants having greatly modified, laterally compressed, asymmetrical flowers; note again the common name for the unrelated *Ruppia* (not a true grass) in No. 4 above -- "ditchgrass" -- presumably because of its grasslike habit. Most members of the Gramineae are native to upland habitats. Only a few well-known species have become adapted to life in wet environments (See also Nos. 8, 11).

8. Cyperaceae (Sedges). Often confused with the grasses, the Cyperaceae present a similar appearance. Many more species of this technical group (especially the genus *Carex*) occur in inland wetlands than members of the Gramineae. The flowers in the Cyperaceae are radially symmetrical, not laterally compressed, and are ofter unisexual, with the male flowers borne on a separate spike above the female flowers. The "tussocks" or "hummocks" so often encountered in inland wetlands are often *Carex stricta*. Most wetland sedges are plants of open, sunny locations, although some

are found in shaded Red maple swamp forest. In addition to *Carex*, *Scirpus* spp. (Rushes and Bulrushes) are frequently met with in our range, as are several less common genera (See also Nos. 7, 11).

9. Araceae (Arums). This is the family of the Jack-in-the-Pulpit (*Arisaema*) so common in damp woods. The bisexual or unisexual flowers of these herbs are crowded onto a terminal spike (spadix) which in turn is surrounded or accompanied by a bract called a spathe. In addition to the Arisaemas, we find the common *Symplocarpus foetidus* (skunk cabbage) in areas where the water table is at least *near* the ground surface year round; Arrow-arum (*Peltandra virginica*), often confused at first with some of the Sagittarias (Alismaceae, No. 5, above), occurs along freshwater tidal streambanks and in some inland wetlands subject to fluctuations in depth of the shallow surface water.

10. Lemnaceae (Duckweeds). The smallest flowering plants, the Duckweeds, which float on the surface of still, fresh waters, range in size from 0.5 mm. to 3 mm. across. These tiny green shields or discs usually reproduce asexually by a sort of budding. Often confused with the structurally simple algae, the Duckweed plant has become reduced through evolution to its present form of a small, floating leaf with a few slender rootlets trailing in the water beneath.

11. Juncaceae (Rushes). Often also confused with the true grasses because of their appearance, the Juncaceae can be distinguished from them by the small, radially symmetrical six-parted bisexual flowers. The stems and leaves are circular in cross-section, as opposed to usually triangular in cross section in the Cyperaceae (circular in some *Scirpus*). The principal genus in our range, *Juncus*, often occurs with the tussock-forming Cyperaceae. (See also No. 7,8 above).

12. Pontederiaceae (Pickerel weeds). The only genus and species with us, *Pontederia cordata*, occurs emergent from fresh waters along stream banks and lakeshores. The dark green, glossy, heart-shaped leaves are borne aloft from the water on stout stalks. At midseason, dense terminal spikes of purple flowers, borne singly on the plants, create a striking visual effect in full sun.

13. Eriocaulonaceae (Pipeworts). The genus *Eriocaulon* (the Greek word roots here refers to a "stem with a beard") occurs emersed in shallow, acid waters in full sun. The narrow-triangular leaves at the base of the plant often take on a reddish hue in acid situations, and the flowers are borne in whitish heads at the apices of slender, still flowering stalks. The plants give the appearance of hatpins stuck into a leafy pincushion.

14. *Myrica gale* (Sweet gale, Myricaceae). These much-branched shrubs, commonly reaching a height of 3 to 4 feet occur on raised portions of freshwater marshes and/or along their upland boundaries. Male and female flowers are borne in catkins on separate plants; the leaves are alternately arranged on the stem, and narrow toward their bases from the broadened toothed apices.

15. Polygonaceae (Tear-thumbs or Knotweeds). The two most common species of this group in Connecticut's inland wetlands are *Polygonum sagittatum* and *P. arifolium*. These scrambling herbs sprawl over other vegetation in open, sunny locations. The two species above take their common name not from "tear" as in "weep", but from "tear" as in "rip", due to the stiff, retrorse (backward-pointing) barbs closely set upon the angles of the slender stems. These barbs can inflict painful scratches upon the unsuspecting flesh of the ill-clothed. The leaves are halberd-shaped and the light pink flowers are crowded into dense terminal heads.

16. Nymphaeaceae (Water-lillies). Many feel that these are the most attractive plants of the inland wetlands. Native to areas of open water, most species have a stout rhizome which runs along the lake or marsh bottom. The floating or emersed leaves are usually centrally attached to this underwater stem (peltate) by long leaf stalks (petioles). The white, pinkish or yellow flowers of 5 to many petals are borne floating on or emersed above the water surface. Common representatives of this family are *Nymphaea odorata* (White water lily), *Nuphar* spp. (Yellow spatter-dock) and *Brasenia* (Water-shield).

17. Haloragaceae (Halorrhagidaceae) (Water-milfoils) a family of wetland plants with inconspicuous unisexual or bisexual flowers. Our members of the family are the submerged *Myriophyllum* spp., the Water-milfoils, with their much-divided, feathery leaves and the emergent *Proserpinaca* with its submerged leaves finely divided as in the preceding, but the emergent leaves more coarsely divided. Members of this family and of No. 6 often choke lakes and ponds.

18. *Cornus* spp. (Cornaceae - Dogwoods). Wetland Dogwoods bear little superficial resemblance to the Flowering dogwood of our forests -- handsome small trees with large white to pinkish bracts surrounding the green flower heads. The species of *Cornus* referred to in the legislation proposed here are shrubs to 15 ft. The smooth margined leaves are almost always opposite (two at a stem joint, or *node*) oval in outline, possessing a characteristic pattern of veining in which several main veins parallel the midrib. The white, four-parted flowers are disposed in flat-topped inflorescences. Common in wetlands are *Cornus amomum* and *C. stolonifera*, either as upland boundary species or dominants.

19. *Cephalanthus occidentalis* (Button-bush; Rubiaceae). This distinctive, stiff, opposite-leaved shrub of wetland boundaries and shrub swamps has the white, 4-parted flowers in dense, spherical stalked heads which persist on the plant into the winter -- hence the common name.

20. *Viburnum* spp. (Arrow-wood; Caprifoliaceae). Another species of opposite-leaved shrubs of wetlands, often growing in association with No. 18, are the Viburnums. These, too, bear the flowers in flat-topped inflorescences. The plants can be distinguished from *Cornus* by the often toothed margins of the leaves and 5-parted flowers of the former.

21. *Tsuga canadensis* (Hemlock; Pinaceae). This tall, stately Gymnosperm (evergreen) has its flattened needles arranged laterally on the branches and its seeds in small cones. Commonly thought of as occurring primarily in forests or on cold air or north-facing drainage slopes, *Tsuga canadensis* is commonly in many wooded swamps in Connecticut as well.

22. *Chamaecyparis thyoides* (Eastern white cedar; Pinaceae). This tree species, common to the southeast coastal regions of Connecticut, also occurs as an apparent glacial relict in acid, freshwater wetlands more inland. The scale-like leaves are 2-ranked on the stems and the unisexual flowers are borne on separate branches of the same plant. In *Juniperus virginiana*, the "Red cedar," (which rarely occurs in wetlands), the leaves are opposite or in 3's, and the male and female flowers occur on different plants.

23. *Veratrum viride* (Wild false hellebore; Liliaceae). This virulently poisonous tall herb of shaded, wet locations contains numerous alkaloids, and must not be confused with Skunk cabbage (No. 9) which often grows with it and is sometimes used as a pot-herb. Young leaf-bearing shoots of *Symplocarpus* are round in cross-section, and the leaves are flat-surfaced as they expand to form a basal rosette. Young shoots of *Veratrum* tend to be triangular in cross-section, and the leaves are many time longitudinally folded accordion-fashion (plicate) in expansion. As plants of the latter species continue growth, the leaves are seen to be disposed in 3 ranks along a stout stem, which often reaches 2 to 3 ft. in height. The plants flower reluctantly to reveal the brown and green blooms disposed in terminal panicles (a branched inflorescence, conic in outline).

24. *Alnus* spp. (Alders; Betulaceae). These short-lived shrubs or small trees with their smooth, dark-grey bark are common along stream banks and wetlands boundaries, and often form the principal part of the vegetation in shrub swamps. The broad-oval leaves are alternate, rough-surfaced and toothed, and the unisexual flowers are borne in catkins -- the female having the appearance of a persistent woody cone.

25. Salicaceae (Willows; *Salix* spp.). In these shrubs or trees, the leaves are alternate, and the unisexual flowers are borne in catkins on separate plants. The "pussywillows," among the first plants to bloom in the spring, are shrubby members of this genus.

25. *Betula alleghaniensis* (Swamp birch; Betulaceae). These trees occur most commonly in Red maple and Hemlock swamps as sub-dominants. The leaves are alternate, oval and toothed. The flowers are unisexual and borne in

catkins on the same plant. The trees are readily identified via their yellowish-grey silvery bark, which exfoliates laterally in thin strips. The closely related *B. lutea* (Yellow birch) occurs in the uplands.

27. *Lindera benzoin* (Spice bush; Lauraceae). These shrubs or small trees most often form the major portion of the shrub understory in Red maple swamps. The unisexual plants bear their flowers in small yellow clusters, and are among the first wetland plants to bloom in the spring. The ovoid red berries form a distinctive contrast to the green leaves later in the season. The bark has a distinctive odor when crushed, due to the presence of essential oils.

28. *Rhus vernix* (Poison sumach; Anacardiaceae). These small trees or shrubs are a close relative of the common Poison ivy and possess the same allergenic principles. The leaves are pinnate with 7 to 13 leaflets, and the small, yellowish-white flowers are borne in panicles on the new growth.

29. *Ilex verticillata* (Black alder; Aquifoliaceae). Perhaps the most common native Holly in our region, this species is frequently encountered in drier areas of shrub swamps and along the margins of open marshes. The unisexual flowers are 4-parted, white and are borne in clusters along the stems. The bright red, spherical berries readily distinguish the plants; they persist in the fall after the oval, finely toothed leaves have been shed.

30. *Acer rubrum* (Red maple; Aceraceae). The most common wetland tree in our region, the opposite leaved *A. rubrum* dominates some 60% of all wetlands. These shallowly rooted, smooth gray-barked trees bear their clusters of mostly unisexual, red flowers in the spring before the emergence of 3-lobed leaves. The smooth bark of younger specimens gives way in age to the roughened covering of older plants, the trees then resembling the Sugar maple, *A. saccharum*. The latter, however, not wetland plants, bear their flowers *with* the 5-lobed leaves. (See the frontispiece to ref. *1*.)

31. *Clethra alnifolia* (Sweet-pepper bush; Clethraceae). These common wetland shrubs are most often found along the upland boundaries of wetlands but also occur in the wetlands themselves, often in association with native Azaleas (*Rhododendron* spp.). The plants can readily be distinguished by the spikes of fragrant white flowers which pass to persistent 3-cleft capsular fruits.

32., 33.

Vaccinium spp.; *Rhododendron* spp. (Blueberries and Swamp azaleas; Ericaceae). Both of these genera are common along wetland borders and in wetlands proper, either as dominants or associated species. Both are alternate-leaved shrubs to 10 ft. *Vaccinium* bears pendent, bell-shaped, white to pinkish radially symmetrical flowers; the fruit is a berry. In *Rhododendron* (Section *Azalea*) the white, symmetrical, sweet-scented blossoms occur in terminal few-flowered clusters which in fruit give way to 5-parted capsules.

34. *Fraxinus* spp. (Ash; Oleaceae). These opposite-leaved trees present a distinctive appearance as associated species in wooded wetlands with their evenly furrowed bark and pinnate leaves of 7 to 11 leaflets.

35. *Sphagnum* spp. (Sphagnum moss; Bryophyta-Sphagnaceae). A large and complex moss genus, *Sphagnum* occurs in almost all types of wetlands in Connecticut, at least to some extent, but is most common in bogs. The light-green to reddish plants, saturated throughout most of the year, have the lateral branches arranged in 5 or more ranks -- the only moss of our wetlands to present such an appearance. The plants occur in hummocks or in mats, most often associated with the bases of shrubs, sedges and other herbs in acid situations.

36. *Picea mariana* (Black spruce - Pinaceae). These Gymnosperms are a rare species in Connecticut, for they are at their southern limit here. While *P. mariana* forms the dominant portion of tree layer of many northern bogs and wooded wetlands, it does not do so with us, occurring as occasional individuals scattered through shrubby vegetation often composed of *Rhododendron, Vaccinium* and *Clethra*. The needle-like leaves of *P. mariana* are disposed helically on the branches, and the fruits are borne in a woody cone.

37. *Eriophorum* (Bog-cotton; Cyperaceae). Placed separately here from other members of the sedge family because of its distinctive appearance, *Eriophorum* spp. are restricted to bogs and bog-like habitats. The Latin name derives from the Greek, meaning "beard-bearer." The flower heads of fertile stems carry numerous white, silky hairs in fruit, and give the appearance of a tuft of cotton atop a stiff stalk.

38. Orchidaceae (Orchids). Many of Connecticut's species of orchids occur in specialized habitats, many under bog-like conditions with full sun and acid substrates. Although rarely numerous in any particular habitat, at least one individual may be met with after a careful search at the right time of the growing season. The flowers of these usually slender herbs are strongly bilaterally symmetrical and possess a highly modified floral structure. They bear little superficial resemblance to the showy tropical weeds offered in the florist's trade for corsages, etc. These rare native plants are only seldom successfully cultured out of the wild.

39. Sarraceniaceae (Pitcher Plants). Our only member of this family is the insectivorous pitcher plant, *Sarracenia purpurea*. The green to red, inflated, hollow leaves form a basal rosette in the wet, peaty substrate. A small amount of liquid lies in the bottom of each leaf, and is composed of water with dissolved proteolytic enzymes. Insects which enter the leaves are prevented from leaving by stiff, retrorse hairs, and the hapless wanderer is slowly dissolved for its nitrogen once it exhaustedly tumbles at last into the waiting waters. The dull red and green flowers are borne singly, terminal, and pendent. Plant enthusiasts are often tempted to dig up these plants for window culture indoors -- but without living *Sphagnum* (and no fertilizer!) their efforts often fail.

40. *Vaccinium oxycoccos, V. macrocarpon* (Cranberries; Ericaceae). These *Vaccinia* are mentioned separately here because of their distinctive growth form and habitat. Native to acid, sunny, wet localities, these slender, trailing plants are infrequently met with in Connecticut, but can be instantly recognized by their habit and the large, red berries.

In former times certain inland boggy habitats were managed for commercial cranberry culture in Connecticut.

41. *Chamaedaphne calyculata* (Leatherleaf; Ericaceae). Another Ericad which singled out here is the Leatherleaf, one of the more common dominant species in bog habitats in Connecticut. The brownish-green leaves of this small, often densely branched shrub stand erect on arching branches of the new growth, and the white pendent, bell-shaped flowers occur in a row beneath them. The plants often form extensive floating mats on wet organic substrates.

APPENDIX II.

A Hydrological Model for Inland Wetlands (E)

The hydrological parameters of Bock's model (plates 1-4) are as follows:

1. P= Precipitation as measured with a standard rain gauge or estimated from U.S. Weather Service data.
2. E= Evapotranspiration (evaporation from land and water surfaces and transpiration from vegetation), estimated using various energy formulas or from hydrologic budgeting techniques.
3. R= Surface runoff, directly measured if the runoff is channelized (streams, rivers), or estimated using comparative data from hydrologically similar areas.
4. G= Ground water flow, calculated from measurements of the slope of the ground water table, depth to impermeable strata and soil permeability.
5. B= Flow in the zone of aeration. There are no techniques presently available to measure this flow, but there are methods available for estimating it. Therefore, for this analysis we may have to exclude this parameter from the formula due to this limitation.
6. I_s= Infiltration in the saturated soil region, calculated through the hydrologic budget or through various empirical equations.
7. I_a= Infiltration in the unsaturated soil region, calculated as above.
8. SSW= Change in storage of surface water, determined by measuring the change in depth of surface waters and their areas plus changes in depth of snow cover.
9. SSM= Change in storage of soil moisture (soil moisture is that water stored in the unsaturated, i.e., aerated, zone of the soil), approximated by various measurement techniques.
10. SGW= Change in ground water storage (water stored in the saturated zone of the soil), calculated by measuring changes in the elevation of the ground water table and estimating the gravity yield of water through analysis of the hydrologic budget.
11. W= The degree of certainty of wetland designation. This is the probability number generated by the regression equation (note that while the regression analysis is being carried out, this value must be generated as a judgment term and entered with the data).

12. d_{sw}= Depth of surface water, approximated by determining the average depth of ponded waters at any particular site.

13. d_a= Depth of the aerated zone, measured in test holes (the difference between ground surface and the height of water in a test hole indicates the depth of the aerated zone).

14. d_{gw}= Depth of the ground water, directly measured in test holes bored to the underlying impermeable strata or through the use of seismic devices.

15. A_p= Area of ponded wetlands, measured from aerial photographs, with surveying techniques at the site, from topographic maps.

16. A_w= Area of "wet" wetlands, measured from photos by surveying, or estimated from USDA Soils Survey maps.

17. A_d= Areas of "dry" wetlands, estimated from Soils Survey maps or measured directly at the site.

18. Z= Elevation above mean sea level (of any significant feature such as the ground surface), determined from topographical maps.

19. S_{gs}= Slope of the ground surface, determined by a site survey or from examination of topographic maps.

20. ρ = Density of the fluid (water), from known average values or from detailed temperature and chemical analyses of water at the site (since the variation is slight, and the density of water at each site is likely to vary from point to point at the site, the use of average values may be justifiable).

21. μ= Viscosity of the fluid (water), determined as above.

22. σ= Surface tension of the fluid determined as above.

23. w= Weight of the fluid, determined as above.

24. N_a= Salinity of the water, measured by chemical analysis.

25. Y= Young's Modulus (modulus of elasticity) of the soil, estimated by laboratory testing of soil samples.

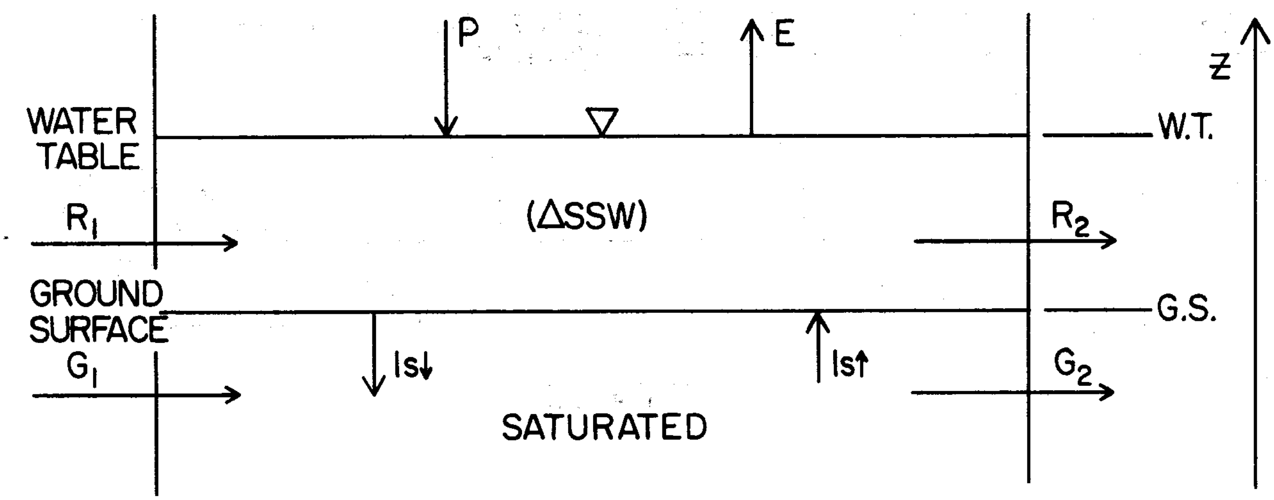
26. K= Soil permeability, estimated by a combination of field tests and laboratory tests of samples.

27. e= Soil porosity (relates to the amount of void space in the soil), estimated from laboratory analysis of the soil samples.

28. Y_g= Specific yield of water from the saturated soil, approximated by analysis of the hydrologic budget combined with testing of representative samples.

29. νv_{sw}= Velocity of the surface water, estimated from direct observation and runoff measurements with surface area data.
30. νv_B= Flow velocity in the unsaturated zone, approximated from estimates of B and measurements of the depth of the aerated zone plus estimates of the area of "dry" wetlands over which this occurs.
31. νv_{gw}= Velocity of the ground water flow, estimated from computations of G and measurements of K, d_{gw}, and the area through which this flow occurs.
32. Δpsw= Change in pressure in the surface water, computed by hydrostatic methods and measurement of the depth of surface water, or measured directly.
33. Δpa= Change in pressure in the aerated zone, measured directly.
34. Δpgw= Change in pressure in the ground water, computed via hydrostatics, depth of ground water and flow formulas, or measured directly.
35. S_{gw}= Slope of ground water table, measured in test holes at the site.
36. t_p= Time that the "ponded" condition exists at the particular site, measured by regular observations of the site or estimated from climatologic and hydrologic records.
37. t_w= Time that the "wet" condition exists at the site, obtained from regular observations of the site.
38. t_d= Time that the "dry" condition exists at the site, determined as above.

CASE A: "PONDED" WETLANDS —WATER TABLE ABOVE GROUND SURFACE



ZONE 1 — At or above Ground Surface ($Z \geq G.S.$):

① $(P-E)+(Is\uparrow - Is\downarrow)+(R_1-R_2)=\Delta SSW/\Delta t$

ZONE 2 — Below Ground Surface ($Z < G.S.$):

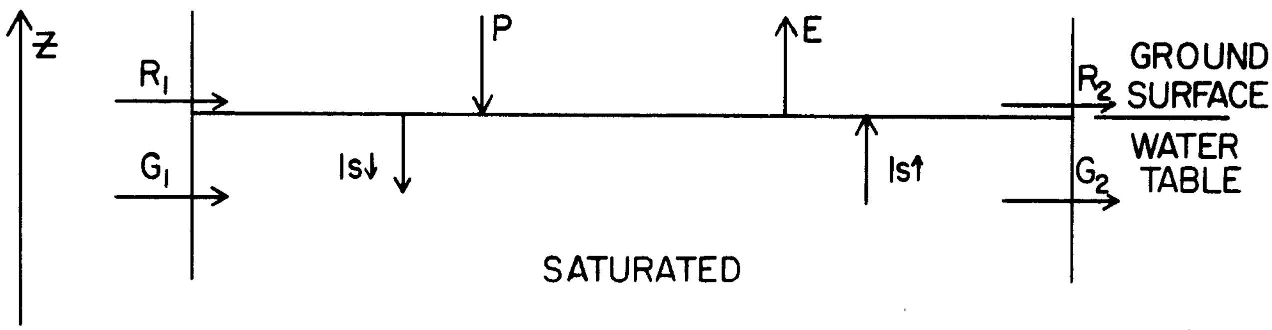
② $(G_1-G_2)+(Is\downarrow - Is\uparrow)=\Delta SGW/\Delta t=0$

ZONES 1 & 2 COMBINED ($Z \geq 0$)

①+②=③ $(P-E)+(R_1-R_2)+(G_1-G_2)=\Delta SSW/\Delta t$

Plate 1. Hydrological model for ponded wetlands.

CASE B: "WET" WETLANDS — WATER TABLE AT GROUND SURFACE



ZONE 1 — At or above Ground Surface ($Z \geq$ G.S.)

④ $(P-E)+(R_1-R_2)+(Is\uparrow - Is\downarrow) = \Delta SSW/\Delta t = 0$

ZONE 2 — Below Ground Surface ($Z <$ G.S.)

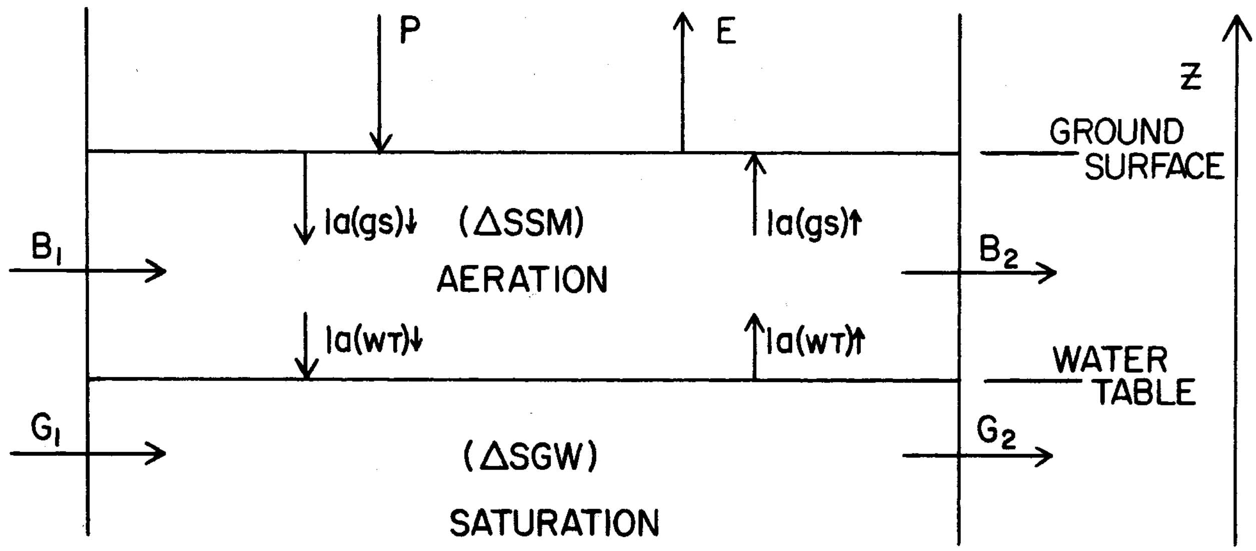
⑤ $(G_1-G_2)+(Is\downarrow - Is\uparrow) = \Delta SGW/\Delta t = 0$

ZONES 1 & 2 COMBINED ($Z \geq 0$)

④+⑤=⑥ $(P-E)+(R_1-R_2)+(G_1+G_2) = 0$

Plate 2. Hydrological model for water-at-surface wetlands.

CASE C: "DRY" WETLANDS — WATER TABLE BELOW GROUND SURFACE



ZONE 1 — At or above Ground Surface ($Z \geq$ G.S.)

⑦ $(P-E) + (Ia(gs)\uparrow - Ia(gs)\downarrow) = \Delta SSW/\Delta t = 0$

ZONE 2 — Between Ground Surface and Water Table (G.S. $> Z >$ W.T.)

⑧ $(Ia(gs)\downarrow - Ia(gs)\uparrow) + (B_1 - B_2) + (Ia(WT)\uparrow - Ia(WT)\downarrow) = \Delta SSM/\Delta t$

ZONES 1 & 2 COMBINED ($Z >$ W.T.) — ABOVE G.W.T.

⑦+⑧=⑨ $(P-E) + (B_1 - B_2) + (Ia(WT)\uparrow - (Ia(WT)\downarrow) = \Delta SSM/\Delta t$

ZONE 3 — At or below Ground Water Table ($Z \leq$ W.T.)

⑩ $(G_1 - G_2) + (Ia(WT)\downarrow - (Ia(WT)\uparrow) = \Delta SGW/\Delta t$

ZONES 2 & 3 COMBINED — Below Ground Surface ($Z <$ G.S.)

⑧+⑩=⑪ $(B_1 - B_2) + (G_1 - G_2) + (Ia(gs)\downarrow - Ia(gs)\uparrow) = \dfrac{\Delta SSM}{\Delta t} + \dfrac{\Delta SGW}{\Delta t}$

ZONES 1 & 2 & 3 COMBINED ($Z \geq 0$)

⑦+⑧+⑩=⑫ $(P-E) + (B_1 - B_2) + (G_1 - G_2) = \dfrac{\Delta SSM}{\Delta t} + \dfrac{\Delta SGW}{\Delta t}$

Plate 3. Hydrological model for water-below-surface wetlands.

DIMENSIONLESS Π'S

No.	Parameter	Dimensions	Π	No.	Parameter	Dimensions	Π
1	P	$[L^{3}/T]$	$P/(Ap)^{1/2}\nu$	20	ρ	$[M/L^3]$	—
2	E	↓	P/E	21	μ	$[M/LT]$	$\nu gw\, dgw/\nu$
3	R	↓	P/R	22	σ	$[M/T^2]$	$da\nu_B^2\rho/\sigma$
4	G	↓	P/G	23	w	$[M/L^2T^2]$	$\nu gw/(gdgw)^{1/2}$
5	B	↓	P/B	24	Na	[O]	Na
6	Is	↓	P/Is	25	Y	$[M/LT^2]$	$\nu_B^2\rho/Y$
7	Ia	↓	P/Ia	26	K	[L/T]	$K/\nu gw$
8	ΔSSW	$[L^3]$	ΔSSW/ΔSGW	27	e	[O]	e
9	ΔSSM	↓	ΔSSM/ΔSGW	28	yg	[O]	yg
10	ΔSGW	↓	$\Delta SGW/(dgw)^3$	29	νsw	[L/T]	$\nu sw/\nu gw$
11	W	[O]	W	30	ν_B	↓	$\nu_B/\nu sw$
12	dsw	[L]	dsw/dgw	31	νgw	↓	—
13	da	↓	da/dgw	32	Δpsw	$[M/LT^2]$	$\nu^2 sw\rho/\Delta psw$
14	dgw	↓	—	33	Δpa	↓	$\nu_B^2\rho/\Delta pa$
15	Ap	$[L^2]$	$Ap/(dgw)^2$	34	Δpgw	↓	$\nu^2 gw\rho/\Delta pgw$
16	Aw	↓	$Aw/(dgw)^2$	35	Sgw	[O]	Sgw
17	A_D	↓	$A_D/(dgw)$	36	tp	[T]	tp/tw
18	Z	[L]	Z/dgw	37	tw	↓	Apdgw/Istw
19	Sgs	[O]	Sgs	38	t_D	↓	t_D/tw

EQUATIONS:

(1) WETLANDS = ϕ(HYDROLOGY(10) + GEOMETRY(8) + FLUID(5) + POROUS MEDIA(4) + DYNAMIC/KINEMATIC(10))

m=38 n=3 ∴ 35Π's

(2) $Pr(W) = a_1\Pi_1^{n_1} + a_2\Pi_2^{n_2} + \ldots\ a_n\Pi_n^{n_n}$

WHERE: Pr(W) = PROBABILITY OF WETLANDS CLASSIFICATION

a_i, n_i = REGRESSION COEFFICIENTS

Π_i = DIMENSIONLESS GROUPINGS

Plate 4. Hydrological modeling parameters.

APPENDIX III

Participants (listed in order of presentation)

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Author's Note: Not included in this listing are the more than 30 senior undergraduates, graduate students and others who participated in a year-long course in wetlands offered as Civil Engineering 400.

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