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# WATER MANAGEMENT IN WETLAND FORESTS OF THE SOUTHEASTERN UNITED STATES

by

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## ABSTRACT

Water management is being practiced on more than two million acres of wetland forest in Southeastern United States. Most of this work has been accomplished to benefit the timber productivity of the land: accessibility, tree growth, site preparation, planting, fire protection, etc. The primary objective of a water management system on a wetland forest site is to hold sufficient water to fulfill the productivity objectives; surplus water must be removed in an orderly manner without damage to other downstream values.

Wetland forests are characterized by abundant supplies of water, but vary widely in other attributes. Some are highly productive in their natural state, while others support only degenerate forests. They can be grouped into four categories: Wet Flats, Bays, Swamps and Upland Ponds, and Bottomlands.

Water management is a tool which can be used to improve the productivity of millions of acres of wetland forests in the Southeastern United States for wildlife, timber, forage, and water. Its effects should be well enough understood and sufficiently controlled to enable changes in design and shifts in productivity from one resource to another as changing needs demand.

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The physiography, climate, and soils of the Southeastern Coastal Plain and Southern Mississippi Valley alluvium have enabled forests there to develop into a humid, subtropical-to-tropical setting where water is a key resource and knowledge of hydrology is essential for water management. Water management has been imposed on more than two million acres (809,380 ha.) of wetland forest in the southeastern part of the United States (fig. 1). The purpose of this report is to describe where this water management is being done, why it has been undertaken, and how it is effected on the wide range of forest sites that make up the biological complex called "wetland forests."

## LOCATION OF WETLAND FORESTS

Wetland forests cover nearly 37 million acres (14,973,530 ha.) in a 2,000-mile (3,218 km.) band along the lower Atlantic and Gulf Coast and in the large area of Southern Mississippi Valley alluvium (fig. 2). The geographic range is from latitude 25 to 38 degrees north and longitude 75 to 94 degrees west. Rainfall averages 50 inches (127 cm.) per year over the area. Near the coast, summers tend to be more moist than winters, while farther inland winter and summer rainfall are about equal. Both inland and coastal areas experience a drying period in the late summer and early fall. Temperature averages 70 degrees F. through the southern part of the region. The mean frost-free period is about 240 days, ranging from 200 days in the north to more than 320 days in the south.

The upper edge of the coastal plain falls along the transition from sedimentary formations to the crystalline geologic formations of the Piedmont Plateau. In general, the coastal plain is relatively flat with rolling hills near the margins of former Pleistocene marine terraces. The Flatwoods section of the coastal plain is characterized by larger, flatter, more poorly drained interstream areas (Braun 1950). Stream bottoms are broader than farther inland, and slopes are limited to the immediate vicinity of stream bottoms.

The largest single area of bottomland is the alluvium along the southern Mississippi River. Flat surfaces characterize this area, but numerous minor features of relief are associated with large changes in drainage conditions, vegetation, and soils. The entire region--coastal plain and alluvium--is built of water-laid deposits of sand, silt, clay, and calcareous sediments.

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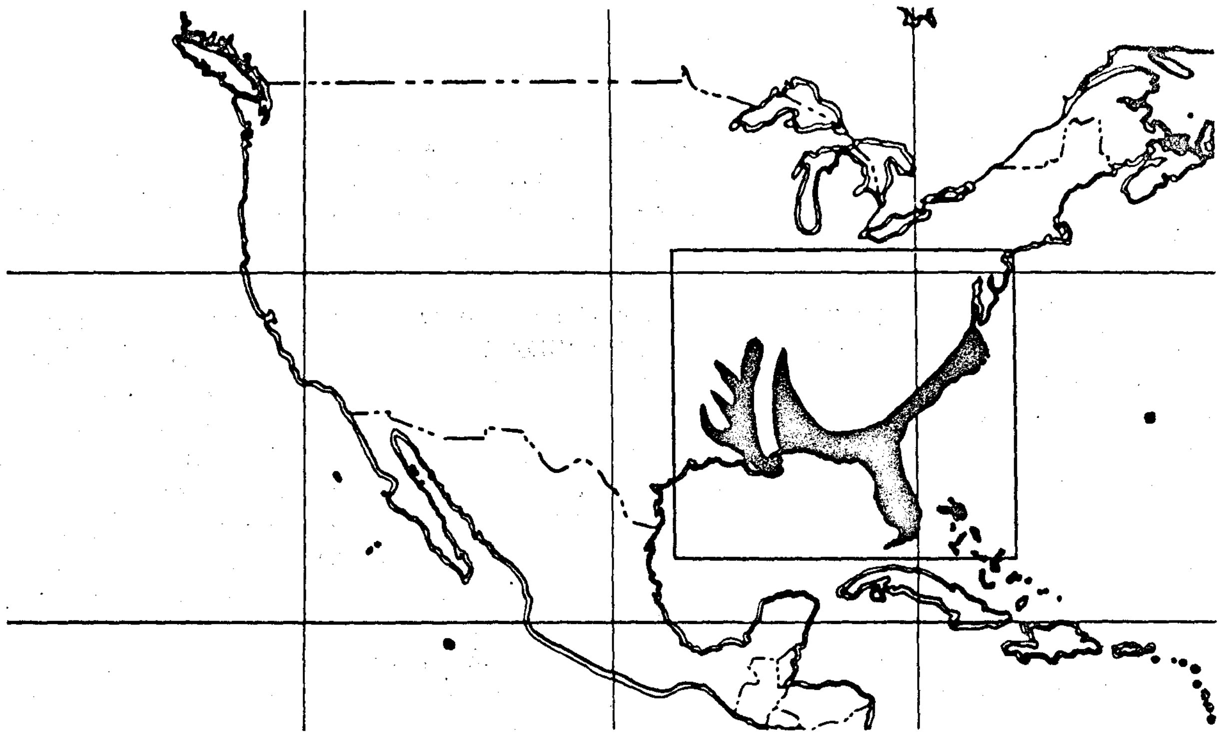

Figure 1. --Portion of North America showing location of the Southeastern United States and wetland forests.

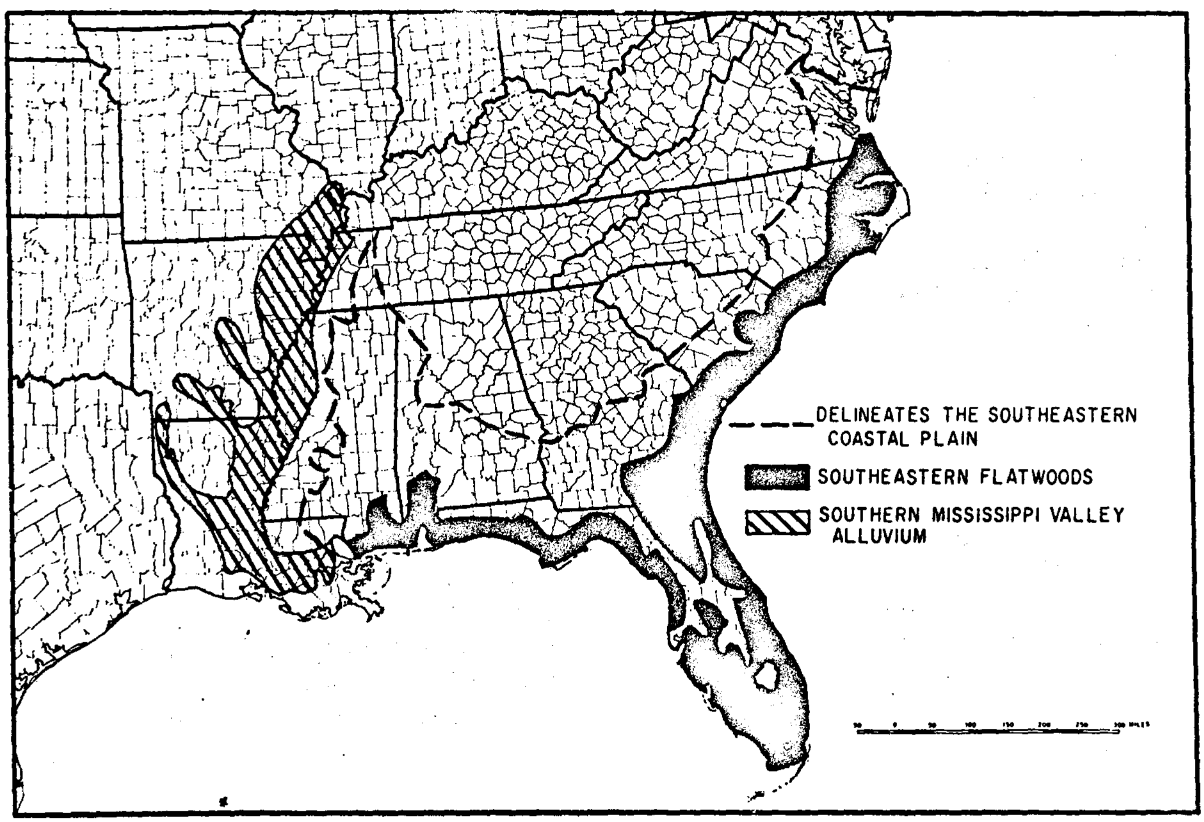


Figure 2. --Location of the three physiographic provinces containing wetland forests of the Southeastern United States.

## REASONS FOR WETLAND FOREST MANAGEMENT

The unique values of wetland forests to the Nation's resources were overlooked until recent years. They were once viewed as a curse to the logger and roadbuilder trying to extract timber. Now they are recognized as major assets to the economy for wildlife, timber, water, forage and recreation.

By the year 2000, every woodland acre will have to produce its fair share of timber if cut is not to exceed growth in the South (USDA Forest Service 1958). One key objective of wetland forest management, therefore, is to increase the production of timber. Research into improvement of pine production on the Apalachicola National Forest in northwest Florida was begun as early as 1935 by the Forest Service. But it was not until after a water regulation test in south Georgia in 1947 that landowner interest was really awakened (Olson et al. 1954). Surface water was removed from a series of shallow depressions through a shallow, 2-foot (61 cm.) deep ditch. Natural pine which seeded onto the pond margins demonstrated that excess water was a primary factor in preventing afforestation of unproductive land with pine. Demonstrations of this kind encouraged lumber and pulp and paper companies to begin development of their wetland holdings on an increasingly large scale that continues to the present time.

Manifold benefits were obtained by timber producers for their water management investments. For many fine stands of mature timber, previously inaccessible to loggers with conventional, rubber-tired or tracked logging equipment, removal of surface and ground water increased trafficability immediately. Spoil from the drainage ditches was spread and shaped into roads for logging trucks. These roads also served as access routes for crews involved in a host of management activities, i. e., site preparation, planting, fire, insect and disease control. Consequently, more acres could be put to work growing timber as unproductive acres were converted to productive land. Better survival, better stocking, and better growth all resulted from the investments. Little wonder that the practice began to be applied in such a widespread fashion throughout the Southeastern Coastal Plain.

Wildlife managers soon discovered that water management measures applied to wetland forests could improve the habitat for certain species of wildlife. Plants preferred by some wild animals were soon planted on additional unproductive forest land after removal of surplus surface and ground water. Prescribed burning was also easier to initiate and control to increase the production of quail foods and deer browse and to improve turkey range. Roads along the ditches provided a means to harvest surplus game and preserve the balance between natural food supplies and wildlife populations (Klawitter 1965). These roads also opened up streams and ponds, as well as water in the ditches, to family use for fishing and relaxation. Moreover, dams and dikes in selected locations increased waterfowl habitat (Broadfoot 1958) and provided escape water for deer (Litchfield and Woodhouse 1965). Finally, water in these reservoirs became available for irrigation of crops.

Elsewhere, range managers hold water levels high on rangeland to increase forage production when rainfall is low, and a small community withdraws ground water from otherwise unproductive swampland. Of increasing importance too are the flood control measures applied to wetland forests. Total yearly losses caused by floods in headwater areas exceed losses caused by major rivers overflowing their banks farther downstream (Ford 1964). Flood protection for upstream urban areas, industrial sites, and cropland is provided by opening and clearing bottomland channels of aquatic vegetation and debris and by building canals (Klawitter 1966).

## WETLAND FOREST SITES AND WATER MANAGEMENT OBJECTIVES

Wetland forests reflect the dominating influence of an abundant supply of water seasonally or otherwise (Bay and Klawitter 1963). But beyond this common feature they may vary widely from one locality to the next, each one with its own peculiar combination of landform, soil, vegetation, hydrology, and wildlife. Some are highly productive in their natural state, supplying large quantities of timber and other resources. Others may support only low-growing heaths and degenerate forests or open stretches of grass overtopped by an occasional slow-growing pine. Frequently, the various site attributes do not complement one another in the natural state to best serve man's needs. One or more may then have to be altered by a scientific water or land management measure to enhance the usefulness of the site as a resource area. To discuss these measures and their application, some grouping of sites is necessary. One scheme that has proved useful lists four general categories of sites: Wet Flats, Bays, Swamps and Upland Ponds, and Bottomlands.

### Wet Flats

Wet Flats are upland sites located on the broad, level to nearly level, interstream areas of the lower coastal plain and flatwoods section. Primary source of water for these wetlands is precipitation which lingers on and in the soil for long periods. Occasional rises in the surface of a few inches retard surface flow over large areas, except in the immediate vicinity of shallow streams where most land slope occurs. Water moves slowly through the soil because of slowly permeable subsoil layers, lack of soil profile development, insufficient hydraulic head between the soil surface and stream flowline, or some combination of these factors. Although Wet Flats are somewhat poorly to poorly drained, their wetness is seasonal and they frequently alternate in being excessively wet and dry.

Dominant vegetation on Wet Flats can range from pure stands of pine to pure stands of hardwoods, with a considerable variation in the proportion of each. Usually pine dominates those sites where soils are coarse-textured and low in colloidal clay and humus; hardwoods or pine-hardwood types predominate on soils higher in water-holding capacity and in cation exchange capacity. Understories in many cases are extremely dense, frequently averaging more than 10,000 stems per acre (25,000 stems per hectare) except where wildfires or prescribed burning have kept them under control (Lotti et al. 1960).

Productive hardwood or pine-hardwood flats seldom receive any specific water management treatment beyond that incidental to treatments applied to adjacent pinelands or that resulting from roadside ditches along transportation systems transecting them. The reason is that these sites are as a rule highly productive in their natural state for valuable hardwood species and wildlife. At one time, some forest landowners began an intensive effort to convert all pine-hardwood and hardwood flats to pine because they were primarily interested in the raw material from conifers. As a result of an increased need for hardwood timber and fiber, however, conversion of hardwoods to pine is largely a thing of the past.

Most efforts in water management are now concentrated on the four million acres (1,618,748 ha.) of Wet Flats supporting pine. A procedure commonly practiced is to remove surface water and lower the ground water enough by means of surface ditches to increase trafficability of heavy equipment and thereby facilitate road construction and timber harvest. Thereafter the site is cleared, bedded, and replanted with one of the southern pine species. After planting, additional collection ditches are installed as needed in an effort to reduce the water table during the growing season to an average of about 2 feet (61 cm.) below the surface in sandy soils. This average water level has produced survival rates in excess of 85 percent and height growth rates of 2 feet (61 cm.) per year with slash pine (Pinus elliottii Engelm.) in northwest Florida.

Internal water movement in clay soils is often much slower than in sandy soils, particularly where profile development is lacking and structure is poor. Most lowering of the water table will result from removal of surface water and decrease in the amount of recharge. In either case, the physical properties of the soils improve and soil fauna is encouraged (Barrett 1962).

The response of pine to water management in many Wet Flats has been good. Graham and Rebuck (1958) reported that both basal area and height growth of pond pine (Pinus serotina Michx.) was nearly doubled by drainage. Pruitt (1947) attributed improvement of pond pine to lowered water levels and subsequent improved soil properties. Klawitter and Young (1965) determined that yield from slash pine on excessively wet sites can be doubled with water management; they estimated the same was true with loblolly pine (Pinus taeda L.) on wet, pond pine sites in North Carolina. Totally nonproductive wet sites could often be converted into high-yielding pine sites with proper water management.

The amount of response to a specific water management measure can vary depending upon soil conditions. Young (1966) suggested that finer-textured soils responded well to drainage and that loblolly pine on these soils tolerated higher water levels and grew faster than they would on coarse-textured soils. The work by Coile (1952) indicated that productivity of poorly drained soils for all the southern pines increased with increasing fineness in texture and depth of the subsoil. Generally, more fine-textured soils are found in the northern end of the coastal plain than in the southern part. In any case, it seems likely that water management will continue to be applied throughout the coastal plain to increase productivity of wet pinelands as long as projected timber and pulpwood demands exceed supplies.

Bays

Bays, or upland bogs, cover approximately 3 million acres (1,214,061 ha.) of wet forest land in the coastal plain. Although they can be found throughout the Southeast, they occur most frequently in eastern North Carolina in the northern part of the flatwoods section. Their physiography is quite variable, ranging from the elliptical-shaped "Carolina Bays" (enclosed by a full or partial sandy rim) to irregularly-shaped Bays with alternating ridges and depressions that lie parallel (Ralston 1965). Natural drainage is very slow because of the long elevated ridges through them or along their margins, and the lack of fall toward outlets slows the natural process of stream dissection. In addition, depressed, slowly permeable subsoils impede downward drainage, and outlets are blocked by accumulations of plant debris and the growth of mosses, grasses, and shrubs. These sites are wetted primarily by rainfall and, consequently, vary in wetness with seasonal and long-term precipitation cycles.

Because natural drainage is poor to very poor, mineral soils usually contain a well-defined, humus-infiltrated layer which may be overtopped by peat accumulations many feet deep. These peat layers generally are well decomposed with poor structure and low rates of permeability, although exceptions occur where the type of peat differs (Klawitter 1968).

Primary source of peat in the upper layers is Sphagnum mosses. Inclusions of woody peat and sedge peats occur also as basal layers within large Bays, indicating that significant changes in vegetation have taken place. Particularly striking are the numerous stumps uncovered during road and ditch construction. Possibly the early vegetation was composed of sedges and reeds in marshy communities and scattered swamp forest which spread out over time. Sphagnum mosses later may have increased with the result being expansion of the Bays, obstructed drainage, rising water tables, and site deterioration in the typical process of paludification (Heinselman 1963).

Bays are vegetated by dense tangles of evergreen shrubs, vines, and small deciduous trees overtopped by pond pine alone or in the company of one of the other southern pines (Ralston 1965). Composition of the vegetation is variable, depending upon the effects of wildfires which remove most of the accumulated peat and retard plant development. In extreme cases of burning, the entire site can revert to open, wet, grassy and sedgy savannahs with only an occasional scattered pine over the site (Wells 1942).

Coastal plain Bays typically are at best relatively poor producers of timber, water, forage, and wildlife. Where mineral soils or subsoils lie within 2 feet (61 cm.) of the surface, adequate drainage in combination with chopping, prescribed burning, bedding, and planting produces considerable improvement in timber productivity. Part of the response probably results because the peaty material subsides after drainage, is further reduced by burning, and finally is combined with mineral soil during the bedding process. Best site indices are usually found where subsoils contain a significant amount of clay (Coile 1952). Similar site improvement measures are used by wildlife managers to install food patches in Bays to improve the habitat for deer. In the process, however, bear populations may be adversely affected as roads open up these sanctuaries to increased hunting pressure.

Deep, relatively infertile peat soils yielded by Sphagnum mosses are more of a problem. Bays with this type of soil seldom display the responsiveness to management of water and land shown by the shallow peat soils or mineral soils. Early survival of planted trees may be good, which indicates initially at least that high water levels may have been a limiting factor. With increasing time, survival sometimes declines and growth is slow, indicating that drainage and site preparation measures by themselves are not enough to cure the problem. Fertilization has been suggested as an additional measure required to bring such sites into production (Huikari 1959). However, not enough is known at this time about the hydrochemical processes of infertile Bay soils to recommend suitable amelioration measures (Ralston 1965).

Selection of the site for improvement, therefore, still remains as the key to success in rehabilitation of Bays. Where the peat layers are shallow or the peat is rich in nutrients, response to water management is likely to be most favorable.

Swamps and Upland Ponds

Swamps occupy the lowest locations along sluggish streams and rivers in the Coastal Plain and in the broad depressions at the heads of streams. Occasionally, marine terraces or sand ridges formed by the sea block areas of low-lying land and form large swamps (Barrett 1962). Two examples are the Dismal Swamp in the northern part of the flatwoods and Okefenokee Swamp in the southern part. Many times the mouths of slow-moving streams are also blocked by bars, and this further tends to increase the size of some swamps (Braun 1950).

Swamps are wetted by precipitation, filled by overflow from the streams they border, and replenished by seepage from adjacent uplands. Water levels frequently stand above the soil surface for long periods and may be subject to considerable fluctuation in depth. Often water movement is so slow as to be almost imperceptible, but in wet cycles large volumes of water may pass through these sites. Soil texture can vary from coarse to fine, depending upon the parent material and source of alluvium. Surface soils frequently are infiltrated with sufficient humus to be mucky; in other situations, thick accumulations of sedge and woody peat may have developed.

By contrast, Upland Ponds occupy small depressions in Bays, Wet Flats, or piney woods and are managed in conjunction with them. They frequently are as wet as swamps, but depend on overland flow and seepage from surrounding uplands for their supply of water. Soils are similar to those of swamps, except they are not subject to overflow or alluvial deposition because of their location in headwater areas. Vegetation of Upland Ponds and Swamps is similar because they share species in the Nyssa-Taxodium community (Braun 1950).

Swamp vegetation is well adapted to a wet environment. Applequist (1959) reported the best growth of swamp tupelo (Nyssa sylvatica var. biflora (Walt.) Sarg.) under flooded or near flooded conditions. Klawitter (1961, 1964) observed the best growth of baldcypress (Taxodium distichum (L.) Rich.) on the wettest sites and excellent development of water tupelo (Nyssa aquatica L.) where soil and other site characteristics encouraged poor drainage, long periods of wetness, and frequent flooding. Consequently, drainage of ponds and swamps will be detrimental to these species (Klawitter 1966) and will kill older trees if it permanently lowers the water table (Putnam et al. 1960).

Removal of surface and ground water in swamps also destroys waterfowl habitat, sanctuaries and escape for deer, and conditions suitable for reptiles, bear, and many other kinds of wildlife (Critcher 1964, Litchfield and Woodhouse 1965). On the other hand, water management rather than uncontrolled drainage can increase the productivity of swamps for timber and wildlife, preserve their general character, and enable them to be used as waterways in flood control for headwater farmlands and urban developments. Methods to achieve these ends include the installation of dikes and control structures at well-chosen locations and the control of water stage.

## Bottomlands

Bottomlands provide the extra channel capacity required to carry stormflow to the sea. Small streams seldom support a width of more than a few hundred feet, while major rivers are frequently separated from adjacent uplands by several miles of Bottomlands. Land surfaces are characteristically flat with slight differences in elevation that produce large differences in drainage conditions, soils, and vegetation.

Bottomlands are wetted by seepage, overflow, and precipitation. Although they are flooded for considerable periods during the year, water levels decline as the river level drops and soil surfaces remain dry for considerable lengths of time. They are the repository of water-borne sand, silt, and clay which results in the typical indistinct soil profile associated with flooding (Barrett 1962).

The varied and complex forests of the Bottomlands contain about 40 species of commercial importance. Most common are sweetgum (Liquidambar styraciflua L.), Quercus spp., Carya spp., Ulmus spp., Acer spp., Fraxinus spp., and Populus spp. (Braun 1950). These forests are usually dense, with many trees more than

3 feet (91 cm.) in diameter and large numbers of small trees and shrubs. Dense thickets of cane and a profuse growth of lianes and vines often prevent reforestation.

Productivity for timber and wildlife is unexcelled because of the inherent fertility and abundant moisture of Bottomland forests. Site changes resulting from uncontrolled drainage effect profound changes on stand composition, tree growth, and regenerative potential. At this point our knowledge of cause and effect is strained. Consequently, recommended water management measures are limited to those likely to increase the amount of soil water available for plant growth (Broadfoot 1960).

Seasonal flooding of Bottomlands can benefit timber. Broadfoot (1964, 1967) learned that temporary, shallow-water impoundments can increase the amount of water stored by the soil, and the extra moisture benefits tree growth, mast production, and reproduction. The impoundments are created by constructing low dikes and dams in flats and shallow drainageways. Water is supplied by precipitation, headwater streamflow, pumping, or some combination depending upon local circumstances. It should be drained promptly each spring because the growth of many trees is reduced and others are killed if water stands all year. If the irrigation system is properly handled, timber growth can be increased by about 50 percent.

Shallow-water impoundments in Bottomlands are used also by wildlife managers to attract waterfowl (Linduska 1964). The main requirements in this operation are mast-producing forest trees, suitable terrain and soils, and water. Flooding is begun when leaves start to change color in the fall and ends in the spring when dormancy ends. The usual depth of flooding is from 1 to 18 inches (3 to 46 cm.) to facilitate feeding.

## THE WATER MANAGEMENT SYSTEM

The primary objective in the design of a wetland forest water management system is to hold sufficient water on wetland sites to fulfill the productivity objectives of timber, wildlife, forage, and water. A critical secondary objective is removal of surplus water in an orderly manner, without damage to soil, channels, downstream improvements, or estuarine environments. Mature pine forests use considerable amounts of water; approximately 38 inches (97 cm.) according to one estimate (Young and Klawitter 1968). As a result, clearcutting has an appreciable effect upon water levels, causing them to rise enough to endanger regeneration or seriously hamper logging operations (Trousdell and Hoover 1955). Thus, the design should consider the effect that later manipulation of vegetation will have on the amount of water that will have to be removed.

Water management systems should also be planned to handle the water from individual watersheds or anticipate the effects of rerouting water from the headwaters of several watersheds into one large, improved channel. Streams may dry up in watersheds which lose water from the upper parts of their basins. The net effect on adjacent bottomlands, swamps, and estuaries is likely to be the same as with uncontrolled drainage: a reduction in resource value and productivity. Streams which gain additional water may soon show the effects through channel erosion and estuary despoilment by silt-ladened waters.

Finally, surplus water accumulated from Bays and Wet Flats in headwaters is not waste water in downstream channels. It can be used to recharge Swamp and Bottomland soils; it maintains waterfowl, aquatic, and estuary habitats; and it provides a buffer against salt water intrusion. To accomplish these objectives effectively, the water management system must be well planned and efficiently controlled.

## Planning Factors

The design of the cross-section of disposal channels for Wet Flats and Bays depends upon the size of the watershed, slope of the land, and hydraulic characteristics of the section selected (Schlaudt 1960a, 1960b). Reliable estimates of maximum 24-hour-average-runoff rates for flatwoods watersheds are given by the Cypress Creek formula: $Q = CM^{5/6}$, where $Q$ is the average runoff rate in cubic feet per second for the 24-hour period of greatest runoff for a storm event; $M$ is drainage area in square miles; and $C$ is a coefficient mainly dependent upon degree of protection desired (Stephens and Mills 1965). Water storage capacity of the soil prior to rainfall influences runoff from wetland forests so some error in estimation can be expected with the use of this formula for very dry or very wet conditions (Young and Klawitter 1968). Application of the formula with a $C$ coefficient of 27 produces a removal rate of 1 inch (2.54 cm.) in 24 hours from one square mile (2.59 square km.), which appears adequate if based upon removing runoff from a 1-day rainfall of 3.5 inches (8.89 cm.) from the Atlantic Coastal Plain and 4.5 inches (11.43 cm.) from the Gulf Coastal Plain (Table 1.).

To reduce construction costs, disposal channels usually are located in the lowest and wettest areas. Where pronounced low areas are not available, they are dug across the slope. A minimum depth of 4 feet (122 cm.) accelerates outflow through permeable soils, extends the length of time between periodic cleanings, and provides a suitable outlet for collection ditches.

Surface water usually does not move freely over the vegetated surfaces of wetland forests. In addition, some wetland sites fall at the drier end of the wetland spectrum where surface water may be less a problem than ground water levels, which are slightly too high for best root development and produce a consequent reduction in growth below the soil potential. For such conditions, bedding alone or bedding in conjunction with shallow collection ditches may be all that is necessary to increase early survival and growth. Where shallow collection ditches are used to lead water (from intense or above-average rainfall) away from the furrows between the beds, they are 1 to 2 feet (30 to 61 cm.) deep and are oriented across the slope, except where they lead into the main disposal channels. Pipe inlets or other mechanical structures should be used where surface water is dropped from

Table 1.--Removal rates of 1-day rainfalls of 3.5 and 4.5 inches on each of two parts of the Southeastern Coastal Plain

| Drainage area | Removal rate per sq. mile | Removal rate per 24 hours | Total removal rate | Approximate time to remove an annual 1-day rain | | | |
|---|---|---|---|---|---|---|---|
| | | | | Gulf Coast soils with permeability | | Atlantic Coast soils with permeability | |
| (Sq. miles) | | | | Rapid | Slow | Rapid | Slow |
| | C.f.s. | Inches | C.f.s. | - - - - - - - - | - - Days - - | - - - - - - - - | |
| 1 | 27.0 | 1.00 | 27 | 1.5 | 2.5 | 1.0 | 1.5 |
| 5 | 20.8 | 0.76 | 104 | 2.0 | 3.0 | 1.0 | 2.0 |
| 10 | 18.7 | 0.68 | 187 | 2.0 | 3.0 | 1.5 | 2.0 |
| 15 | 17.5 | 0.64 | 262 | 2.5 | 3.5 | 1.5 | 2.5 |
| 20 | 16.8 | 0.60 | 336 | 2.5 | 3.5 | 1.5 | 2.5 |
| 25 | 16.2 | 0.58 | 405 | 2.5 | 4.0 | 1.5 | 2.5 |
| 30 | 15.7 | 0.56 | 471 | 3.0 | 4.0 | 2.0 | 3.0 |

collection ditches into disposal channels (Schlaudt 1955, Stewart and Saveson 1955). They prevent serious erosion and blockage of the channel by sediment.

Several tests have shown that bedding alone can produce significant increases in survival, as well as growth rates two or three times that experienced on unbedded sites (Langdon 1956, 1962). The question also arose as to whether beds were beneficial on sites drained with deep ditches and shallow collection ditches to an average water table depth of 2 feet during the growing season. A study in northwest Florida indicated that growth could be improved significantly though survival was not (Klawitter 1970). Even in the level flatwoods, small wet depressions which are impractical to drain individually hold enough water to adversely affect tree growth. Moreover, slight changes in soil conductivity can create wet spots that do not become apparent until after planting. Most of these problems can be alleviated by the use of beds to elevate seedlings above the wet spots, increase their effective rooting zone, and provide other benefits (Bethune 1963).

Beds are usually constructed with especially designed disk harrows that pull the soil up into a high ridge to achieve a settled height of at least 5 inches (13 cm.) above ground level. Originally, fire plows with discs 28 inches (71 cm.) or larger were used, but a more efficient and satisfactory bed results when properly designed equipment is used.

Cooper (1961) tested two variations of the bedding method, for use where funds or bedding equipment are not available. One variation uses mounds pushed up by a bulldozer or other equipment; the other utilizes slightly elevated tussocks, windfalls, or other natural physiographic rises. He suggests pressing six to eight treated seed into these locations at about 15- to 20-foot (4.6 to 6.1-m.) intervals. As an alternative, seedlings can be planted instead of seed at these locations.

Additional information that should be considered before installation of the water management system includes soil conditions where ditches must be dug, land grades along the ditches, suitability of the outlet, and, water requirements of the timber and other vegetation to be produced.

A water management system for slash pine on Wet Flats should be similar in many respects to the systems used on farm lands (fig. 3) (Stewart and Saveson 1955). Disposal ditches should be installed across the slope or in natural, low, wet locations at intervals of about 1,320 feet (402 m.) to remove subsurface water. Collection ditches should be installed at 660-foot (201-m.) intervals across the slope or at random where slopes are broken. Beds should be constructed up and down the prevailing slope to raise seedlings above any surface water and to use the furrows to conduct water to collection ditches. This design is based upon the experience gained on a wet, sandy pine flat on the gulf flatwoods where a less-intensive system has not functioned as effectively as first expected (Klawitter and Young 1965).

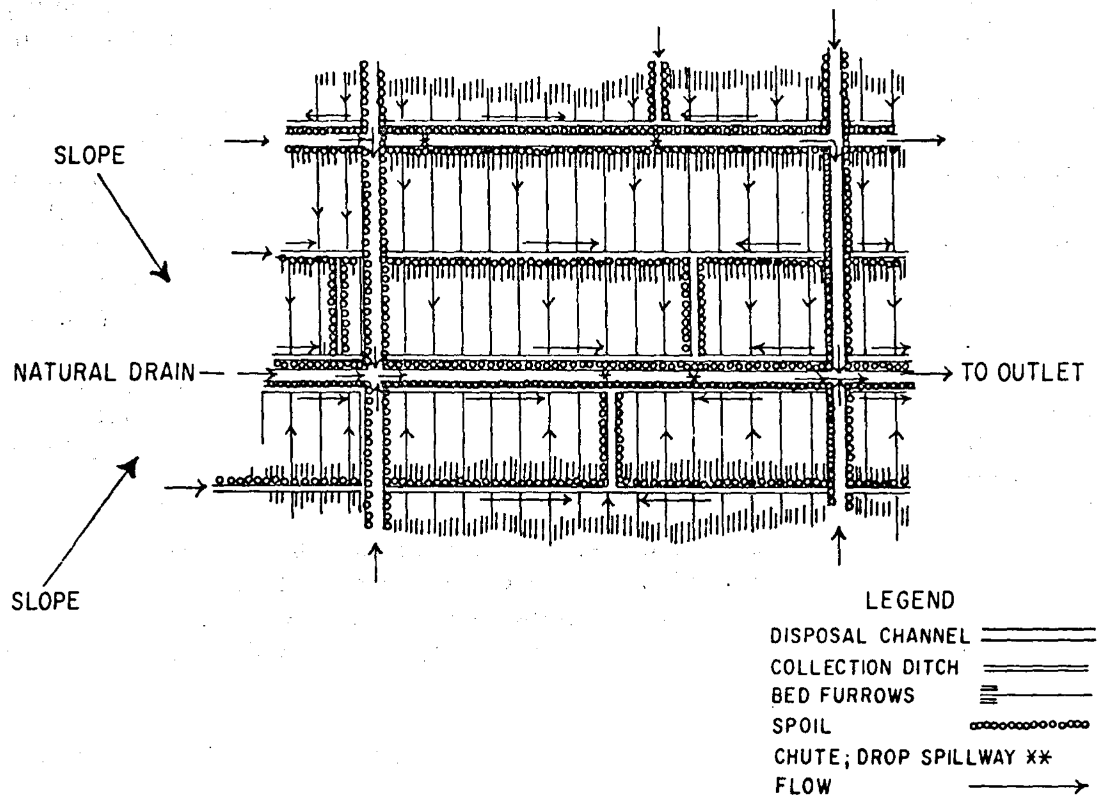


Figure 3. --Design of a proposed water management system for a Wet Flat supporting pine.

Water Control Structures

The facilities required to carry flood and drainage water through Swamps and Bottomlands with beneficial effects on wildlife populations and hardwood timber stands are still under consideration. One solution is locating the floodwater channel through slightly elevated flood-plain channels and isolating the Swamps and Bottomlands where water is to be managed for hardwood timber and wildlife. Isolation is achieved by shaping the channel spoil into a dike and by tying the dikes into adjoining uplands at narrow points in the flood plain. Another solution is to use simple, cleared floodways instead of excavated channels. Low dikes would still be needed to hold water in selected areas for multiple-use objectives. Dike installation should avoid creating stagnant water conditions which can be deleterious to trees and other plants.

The control structures used can vary considerably. Increased interest is being shown in a neoprene-coated nylon dam which automatically inflates or deflates. During rainy seasons, it collapses at a predetermined water pressure to prevent flooding. After storms, it reinflates and continues to conserve water. Another type of structure automatically maintains a constant water level on the upstream side of the gate section without any outside source of power, regardless of the volume of increasing flow. On the upstream face a sector-shaped container plays the part of a float and balances the gate against a counterweight. The gate adjusts itself automatically to pass the discharge required to maintain a constant upstream water level.

Owners of large commercial forests frequently use a structure of either corrugated, treated metal pipe or concrete pipe. The control section is a half-round pipe fastened in an upright position, with the opening facing upstream, to the upper end of a culvert (Schlaudt 1960a). The upright section has an iron frame into which stop logs are inserted to hold water at a prescribed elevation. The stop logs are inserted and removed manually which can create difficulty during storms when roads may be impassable. To provide some protection against a washout, the road fill over the culvert is elevated 1 foot (30 cm.) or more above the ground level. One disadvantage of the culvert-type control is that it offers resistance to water flow, and the turbulence that results can cause bank and ditch-bottom scouring (Schlaudt 1955).

Obviously, any water management system must have planned, periodic maintenance if it is to achieve its objectives and if costly washouts and erosion are to be prevented. Fallen trees, debris, and sand or silt bars and vegetation growing in them should be removed to maintain efficient hydraulic conditions.

## CONCLUSIONS

Water management is a tool which can be used to improve the productivity of millions of acres of wetland forests for wildlife, timber, forage, and water in the Southeastern United States. But like any tool, it works best when properly applied to the task for which it is designed. Consequently, it must be tailored to fit particular kinds of wetland sites to achieve maximum productivity and fulfill the landowner's needs at minimum cost. In some cases, the landowner's immediate objective may be aimed toward maximum production of timber or of wildlife; in another, his primary concern may be forage or water; or his objective may be some combination of all these resources. However, the needs of man are ever changing and it is difficult to predict which resources wetland forests will have to produce in greatest abundance in the future. Thus, the water management measures we apply today should be well enough understood and sufficiently controlled to enable changes in design and shifts in productivity from one resource to another as the future demands.

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