Water table management in the Eastern Coastal Plain

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AGRICULTURAL enterprises in the Eastern Coastal Plain region of the United States historically have been influenced by high rainfall, occasional flooding, and seasonal drought. These factors contribute to the degradation of environmentally sensitive areas, such as wetlands and lowlands, and productive estuarine areas and marshes. Accommodation of all water needs will require more sophisticated agricultural water management techniques than traditional irrigation or drainage. Both population pressure and industrial development have affected agricultural and environmentally sensitive areas (*10*). With the municipal and industrial use of deep groundwater expanding rapidly in many areas, surface and shallow groundwater storage will become critically important for agricultural production (*2*).

Water table management offers more possibilities for flood control, improved water conservation, and improved water quality than conventional drainage systems (*22*). Water table management systems can incorporate drainage, drainage restrictions (controlled drainage), and subirrigation in one sophisticated operation to optimize soil water conditions for crop growth and to improve water quality. Such management systems can be applied at both the field and watershed scale using various water control structures and operational procedures (*4, 17*). Water table management is especially suited to relatively large, flat land areas where high water tables persist for long periods during the year. Potential water quality improvements occur when nutrients remain in the fields, allowing nutrient uptake and reduction (*5, 8, 22*). Although water table management has considerable

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application in the Eastern Coastal Plain, its implementation varies greatly across the region.

Implementation approaches

Federal programs and policy. Government involvement in the planning, installation, and financing of agricultural water table management systems has changed over time to reflect evolving regulations and policies. Current policies seek a balance between development, reclamation, and drainage on the one hand and environmental preservation on the other. This balance was illustrated by the National Environmental Policy Act of 1969, the Clean Water Act as amended in 1977, and Executive Order 11990 issued by President Carter in 1977. The order instructs federal agencies to avoid, where possible, the modification or destruction of wetlands.

As early as 1956, financing for the Agricultural Conservation Program (ACP) and Soil Conservation Service (SCS) technical assistance for wetland conversion to agricultural use began to diminish (*12*). By the 1960s, U.S. Department of Agriculture (USDA) agencies would not give assistance to landowners who drained wetlands because those areas were considered vital for waterfowl and wildlife habitat. In addition, only four percent of the cost of installing new or maintaining existing drainage improvements was financed through ACP cost-sharing or by Farmers Home Administration (FmHA) loans (*12*). About 82 percent of all drainage expenditures were self-financed by landowners. As of 1985, less than 10 percent of all existing surface or subsurface drainage improvements were financed via ACP (*16*).

The Food Security Act of 1985 denies price support and other farm program benefits to producers who grow crops on newly converted wetlands. It is within such laws and policies that USDA will provide technical and financial assistance for agricultural drainage as part of a conservation system related to irrigation water control or as an essential element of an environmental system of practices. Current programs are intended to help landowners improve drainage on existing agricultural fields where excessive wetness or waterlogging hamper efficient production without adversely impacting the environment. Corrective measures also are required where agricultural practices, including drainage, threaten off-site environmental values.

State and local programs, policy. State and local governments play an equally important role in the technical, financial, and regulatory aspects of water table management. States are developing or have promulgated regulations that affect wetland use and conversion. The regulations have permitted the creation of tax ditch (drainage district) associations as subdivisions of state government, initiated groundwater withdrawal permitting, and established cost-sharing of financial and technical assistance to protect water quality and quantity.

In the Southeast, Maryland, Virginia, Delaware, and Florida have state nontidal and tidal wetland regulations. North Carolina, South Carolina, and Georgia have wetland protection legislation for tidal wetlands. South Carolina's nontidal wetlands within its eight coastal counties are protected under the Coastal Zone Management Act. Delaware and South Carolina have committees studying the wetlands issue for the purpose of recommending state policy on wetland protection and use. State wetland regulations that effect cropland use and agricultural water table management systems parallel those of federal programs. In the Southeast, neither existing drainage systems nor cropland areas are subject to state wetland regulations.

State water quality management agencies are examining the effects of herbicides, pesticides, animal wastes, sediment, and fertilizers on water quality. State nonpoint-source management plans that address these agricultural issues, as well as the type of production, management practice(s) used, and control practice(s) implemented, have been drafted and submitted to the U.S. Environmental Protection Agency for review. Efforts to reduce nonpoint-source pollution have emphasized increased public awareness and educational efforts rather than regulatory controls.

State-enabling legislation allows groups of landowners to form a subdivision of state government for the purpose of draining low-lying lands. These organizations are generally referred to as tax ditch associations. In recent years, a number of states have enacted legislation permitting multiple-purpose associations. Their objectives include, but are not limited to, drainage; they can address numerous other water and resource management objectives (*16*). All of the six previously mentioned southeastern states have organized tax ditch associations (see table). The percentage of drained farmland using tax ditch associations ranges from a high of 60 percent in Florida to a low of 20 percent in Georgia and South Carolina (*16*).

Tax ditch associations construct channels to provide drainage outlets for flood protection. Funds for construction and maintenance are generated by taxing the landowners within the association who benefit from the improvements.

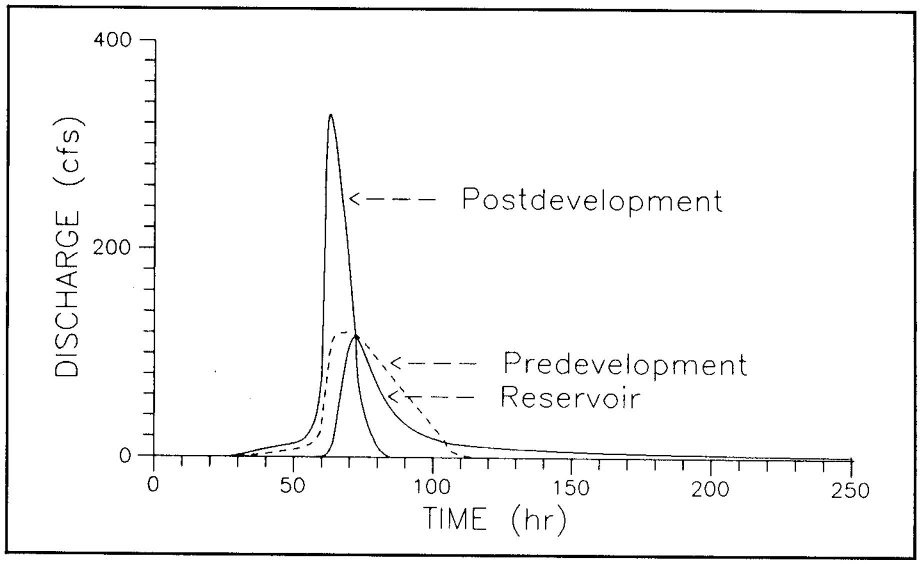
Proposed water table management systems that would affect channels of a tax ditch association would need the consent of the association. In multiple land use watersheds, for example, where cropland, forest land, and homesites exist together, there are potential problems in implementing stream-level control structures. All landowners would benefit from improvements to provide flood protection; however, not all would receive the same benefit from stream-level control. Those who would not benefit from stream-level control would be reluctant to accept assessments against their property. Land classification procedures would need to be revised to equitably distribute the cost of stream-level control projects. Evans discusses this conflict as well as other problem areas that must be resolved before watershed-scale water table management and stream-level control systems gain wider acceptance (*4*).

States with active and successful water table management programs have at least three things in common. First, individual producers and tax ditch associations at the local level have an interest in water table management. Second, funding is available for technical assistance. Third, cooperation

Rural land drained in the Eastern Coastal Plain of the United States in 1985 and percent of cropland drained, share of cropland drained, and drainage in drainage districts (*16*)

State	Total Land Drained (acres)	Cropland Drainage: Share of All Drainage	Cropland Drainage: Share of All Cropland	Organized Drainage Service
		%	%	%
Florida	6,291	45	45	60
North Carolina	5,401,000	45	25	25
South Carolina	1,754,000	60	25	20
Georgia	1,544,000	35	8	20
Maryland	1,208,000	75	30	35
Delaware	460,000	70	25	55

exists between federal, state, and local governments.



Simulated discharge hydrographs before and after site development (20).

Environmental concerns

Agricultural drainage systems previously were designed to remove excess water for timely agricultural operations and production at the least cost to the operator. Recognition that these systems may impact off-site areas through nonpoint-source pollution has lead to new design and management criteria. These new criteria are especially important when environmentally sensitive areas are located downstream from the drainage area.

Runoff from agriculturally developed sites can produce peak runoff rates three to four times higher than on similar undeveloped lands (see figure). These effects may be critically important near estuarine nursery areas where high runoff rates may cause unnatural salinity fluctuations and reduce fish and shellfish productivity. Systems that depend primarily on surface drainage tend to have higher runoff rates with more sediment, phosphorus, and pesticides than do systems with effective subsurface drainage. However, effective subsurface drainage increases the outflow of nitrates with the drainage water (*18*). Water table management using controlled drainage or subsurface irrigation also will affect drainage outflow and water quality (*22*). Recognizing the potential for off-site effects of development, the South Florida Management District has promulgated permitting guidelines for new agricultural developments in southern Florida (*19*). Peak rates of off-site discharge for the developed land should not exceed the peak-rate discharges prior to development. This usually results in some form of on-site storage of excess runoff water.

The use of water table management could minimize off-site impacts by reducing total nutrient and water released into the environment. Controlled drainage proved effective in reducing drainage outflow and potential transport of nutrients to receiving waters in a North Carolina study (*5*). Controlled drainage had little influence on the nutrient concentrations in the drainage outflow; the dominant factor influencing total nutrient transport was the reduction in total drainage outflow. The reduction in nutrient transport was nearly proportional to the reduction in drainage outflow. No evidence of increased nitrate transport to groundwater resulting from the reduction in drainage outflow was observed. These results suggest that nitrates were reduced by denitrification upon reaching the saturated zone. Controlled drainage reduced the annual transport of total nitrogen by 6 pounds per acre (46.5 percent) and total phosphorus by 0.17 pound per acre (44 percent). Considering the large, artifically drained land area, this could result in a tremendous reduction in nutrient outflows if this practice were implemented widely.

In a previous study, researchers found that on poorly drained soils about 13 pounds of nitrogen per acre were lost annually to surface water via subsurface drainage (*18*). In the specific, moderately well-drained soil studied, about 41 pounds of nitrogen per acre were lost annually to surface water. Gambrell and associates attributed this reduction of nitrogen to denitrificaiton in the shallow groundwater. Thomas summarizes water table management effects on water quality in streams and shallow groundwater (*22*).

Conversion of forests to intensive agriculture has contributed to the degradation of water quality in North Carolina's estuaries (*11*). Researchers found that in the upper portion of the estuary surface water salinity decreased, turbidity increased, and the concentration of phosphate, nitrate, and ammonia increased. They concluded that, where practical, drainage from developed land should be removed from the estuarine system. Ideally, the drainage should pass through a buffer of unmodified wetlands before being allowed to enter the headwaters of the estuarine system. The discharge should be managed on a watershed basis to minimize the impact on salinity profiles, reduce suspended solids, and reduce nutrient loading.

Tourism and fishing are major income-producing activities in much of the Eastern Coastal Plain. Deterioration of water quality could have drastic economic impacts on this industry. In 1981, the governor of North Carolina appointed a task force to address the conflict between agricultural and forestry interests who wanted to clear and drain more land and fisheries and wildlife interests who wanted to maintain productive saline nursery areas and wildlife habitat in the Albemarle-Pamlico Peninsula and surrounding area (*14*). The task force was directed to formulate a balanced approach that would allow agriculture, forestry, fishing, and wildlife to develop in a manner acceptable to all parties. The task force made 10 recommendations that included implementing best management practices (BMPs) for forestry and agricultural lands and the development of resource management systems. Resource management systems would include, but not be limited to, the BMPs developed for water quality; they would consist of a combination of practices and management to maintain and improve resources. Other recommendations included the development of a comprehensive water management plan for the study area by the state, promotion of wildlife management practices using tax incentives to encourage establishment of wildlife habitat, and the design and implementation of a demonstration project for comprehensive water management. These events, along with others, lead North Carolia to cost-share controlled drainage as a BMP in 1984 (*5*).

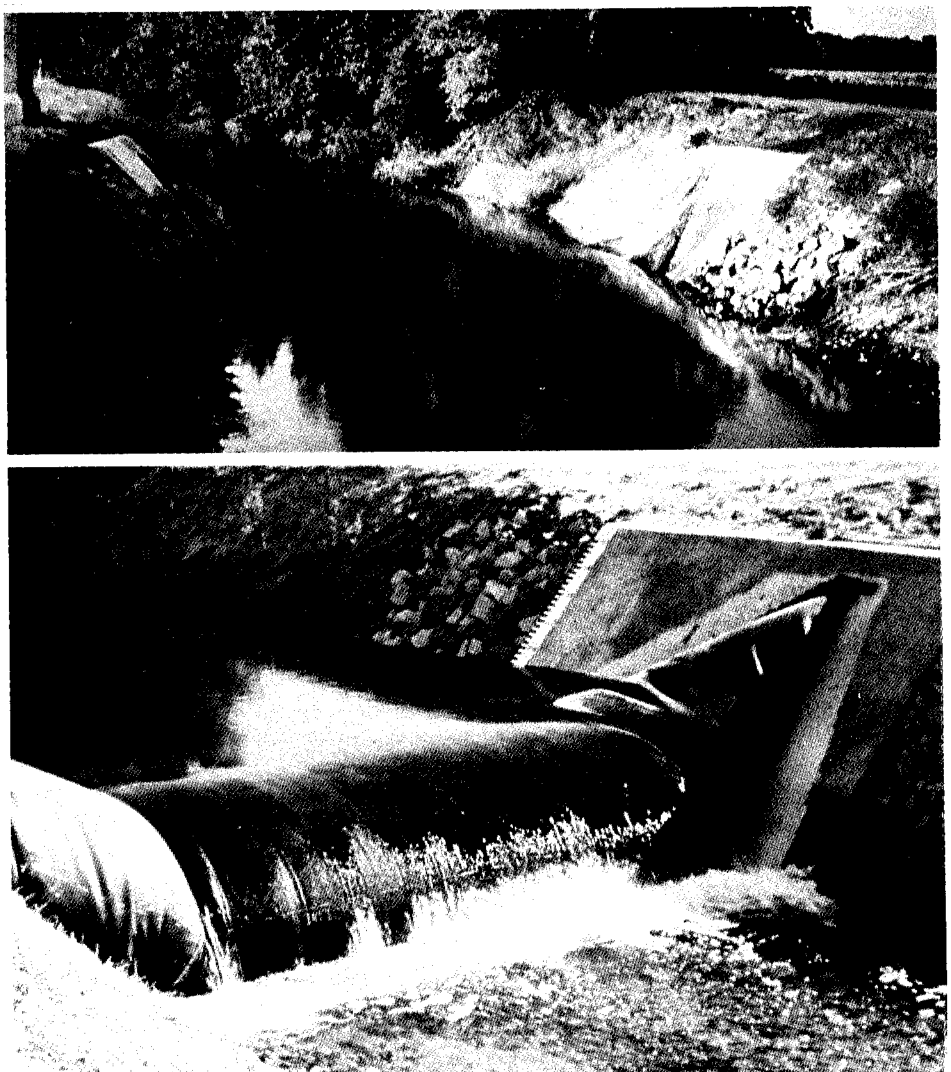
In the Inland Bays area of Delaware, similar concerns have arisen (*23*). Comprehensive recommendations were made for improved land use and wastewater planning on highly developed areas as well as the implementation of BMPs on agricultural land to prevent groundwater and surface water contamination.

Development of almost any site will produce off-site ramifications, whether it be agricultural, urban, or industrial development. Water table management may reduce the detrimental effects of agricultural development by retaining water in the field, allowing timely discharge of water into the environment, and allowing natural processes to reduce nutrients in the field.

Water use and economics

In many areas of the Eastern Coastal Plain, groundwater supplies are declining while agricultural, industrial, and urban water demands are increasing. In some areas of the country, groundwater levels are declining 6 to 10 feet per year (*25*). Some aquifers in the Eastern Coastal Plain have dropped from 10 to 100 feet since 1965 (*24*). Groundwater levels have dropped because withdrawals from aquifers have exceeded recharge. Public and industry demands for water also are increasing and competing with agriculture for both groundwater and surface water supplies. Continued population influx and industrial development in these areas will further strain available resources (*10*).

The fabridam on Mitchell Creek in a deflated (top) and inflated condition.



Stream-level control could provide additional water for irrigation and reduce dependance upon groundwater supplies in some areas where such control is feasible. For example, stream-level control was implemented on Mitchell Creek in North Carolina (*23*) with a rubber-coated nylon, water-inflatable fabric dam commonly referred to as a fabridam. The fabridam automatically deflates to allow flood waters to pass and also stores water in the stream and surrounding soil profiles. During dry periods, the fabridam provides additional water for irrigation. Before installation of the control structure, two center pivots and volume guns irrigated 195 acres. After the control structure was installed, farmers used eight center pivots, four volume guns, and one controlled-drainage/subirrigation system to irrigate 808 acres. Controlling the stream water level provided surface and subsurface water storage for irrigation supply and at the same time increased yields of nonirrigated crops through water-table control. Other less sophisticated and less expensive manually operated structures could also provide water storage (*7*).

Stream-level control also improved water quality in the stream. Nitrate-nitrogen concentrations in the stream before and after installation of the fabridam indicated a one- to five-parts-per-million decrease in concentration after installation (*2*). The reduced nitrate levels were attributed to an increase in denitrification, influenced by reduced depth to the water table, increased nitrogen uptake by the crops as indicated by increased yields, and denitrification in subsurface flow and in the stream channel.

Comparing the cost of stream-level control with stream impoundments and excavated ponds as sources for irrigation water, Doty and associates (*1*) found the cost of the stream-level control system was 28 percent less than for surface impoundments and 70 percent less than for excavated ponds. Stream-level control systems that are designed and managed properly would provide water storage in the soil profile and in surface stream channels economically compared to impoundments and ponds. At the same time, stream-level control provides water for crop needs either directly to plant roots by capillary rise from the water table or through irrigation water pumped from the stream.

Field-scale water-table management systems are economically competitive with conventional irrigation systems. Energy requirements for subirrigation generally are much lower than for center-pivot irrigation systems (*13, 26*) and may reduce yield variabilities in the long run (*13*).

Both economically and environmentally, it is in the best interest of urban, industrial, and agricultural communities to protect and manage the environment. Water table management could provide the agricultural community with a means for better managing and conserving water resources and for providing additional water storage.

Acceptance and implementation

Water table managment offers the possibility for improved water conservation through the use of annual rainfall and shallow groundwater for agricultural crop production. This is critically important in many areas of the Eastern Coastal Plain where municipal and industrial use of deep groundwaters is expanding rapidly. Water table management also offers the potential for improved water quality via the retrofitting of existing drainage channels and the subsequent improvements in nutrient

Surface water and groundwater use in Eastern Coastal Plain from 1980, excluding withdrawals for thermoelectric power (24)

State	Public Supply Surface	Public Supply Groundwater	Rural Supply Surface	Rural Supply Groundwater	Industrial Surface	Industrial Groundwater	Irrigation Surface	Irrigation Groundwater	Total
	million gallons per day								
Delaware	49	30	0	27	8	21	2.4	4.1	142
Maryland	657	65	6	63	155	34	9	13	1,002
Virginia	488	100	27	153	384	110	19	8	1,289
North Carolina	513	70	6	173	2,293	490	91	39	3,675
South Carolina	291	82	5	63	874	46	41	15	1,417
Georgia	563	230	11	157	302	400	196	380	2,239
Florida	195	1,200	20	289	156	710	1,419	1,600	5,589
Total	2,756	1,777	75	925	4,172	1,811	1,777	2,059	15,353

management. Research has shown that water table management can reduce nitrogen by denitrification, but more research is needed to determine its effect on phosphorus and pesticides.

In many areas, particularly where the lateral hydraulic conductivity is high, stream-level control structures can prevent overdrainage and provide an adequate source of irrigation water at costs comparable to deep irrigation wells. Water can be pumped from these channels and shallow groundwater with substantially less energy than is required for pumping from deep wells. Operational costs are thus lower compared to sprinkler-type irrigation systems.

Water table management has been implemented in many areas of the Eastern Coastal Plain, particularly in Florida and North Carolina. However, such systems are suitable for many other areas. Acceptance and implementation has been slowed by regulatory or environmental concerns in some areas. In areas where water table management systems have been installed and are functioning satisfactorily, landowners, local drainage districts, regulatory agencies, action agencies, and support agencies have worked together to design, finance, construct, and operate the systems.

To facilitate the adoption of water table management in appropriate areas, improved information is needed on the functionality of such systems in agricultural systems that are environmentally and economically sustainable. Information on the movement of pesticides in water table management systems is particularly scarce but critically needed. Better management and design models, as well as improved information systems for technology transfer, are important to the adoption and successful implementation of water table management across the region. Additionally, management protocols are needed to allow consideration of each landowner's needs without paralyzing an entire drainage district system. Thus, implementation and system improvements need to proceed simultaneously to capitalize on the benefits of water table management, while improving the performance data base and operational techniques.

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