6

Managing Hydrology

Ann Berry Somers

Spring peeper (*Pseudacris crucifer*).

Managing Hydrology

A wetland is defined by its soil, vegetation, and hydrology. Of these hydrology is a primary factor in the development and long-term survival of all wetlands. Hydrology, as used here, includes both the hydrologic cycle and the hydrologic budget. The hydrologic cycle is the movement of water between the atmosphere and Earth. It consists of precipitation, evaporation, runoff, and infiltration of water into the ground. The hydrologic budget applied to many fresh water wetlands consists of six parameters arranged mathematically as:

Outflow = Precipitation $\pm$ Groundwater + Surface water - Evaporation - Transpiration

The outflow is dependent upon the precipitation that falls within the watershed of the wetland, surface run-off and flooding, and groundwater that is either discharged or percolates downward through the soil profile. Groundwater flows through the internal hydrogeologic framework of the wetland and may act as a source or sink for surface water. In some wetland systems, the hydrologic budget can be manipulated.

The Hydrology of Meadow Bogs and Related Wetlands

The Meadow Bog internally consists of fine-grained silts and clays in a mixture of cobbles and gravel. This mixture forms an internal permeability, allowing groundwater to migrate through the bog at various depths below the ground surface. This patchy and diverse hydrology promotes an equally diverse mixture of plant and animal life.

The hydrologic system in a Meadow Bog is analogous to a sieve with a sponge inside.

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Vegetation changes when hydrology is altered. Trees die as new beaver activity results in deeper water in this lowland.

The sponge serves as the wetland. The sieve would be tilted just enough to provide internal energy gradients for water to flow through the sponge. Water is input from a hose in the upper portion of the sieve, mimicking a series of springs. Water is

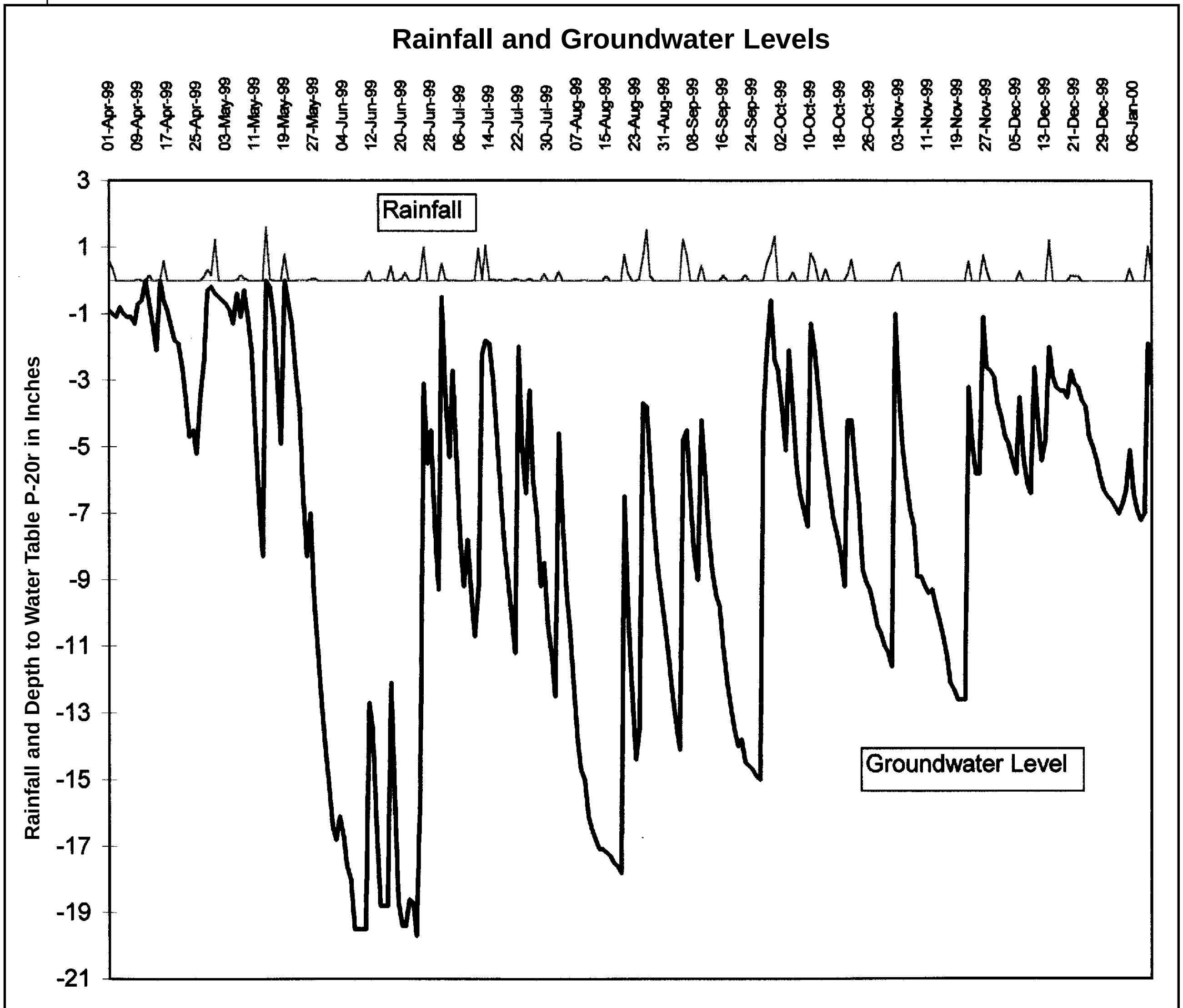


Figure 6.1 *Groundwater fluctuates with rainfall. Hydrologic management goals should include increasing the duration of ground-level saturation.*

occasionally sprinkled onto the sponge (precipitation). Water is then allowed to evaporate from the sponge, a process simulating evapotranspiration. A hole added to the sponge center acts as a drainage ditch. Through this analogy, we can develop ideas to balance the input and output of the altered system. In order to form a functional wetland, the water level must be maintained to saturate the top of the sponge.

In many freshwater wetlands the depth of water and the period of saturation are the major factors determining the structure of native plant communities. Typical bog communities, including bog turtle habitat, have a wet core area even in the driest summer. Areas that surround the core fluctuate in wetness seasonally or in relation to run-off patterns.

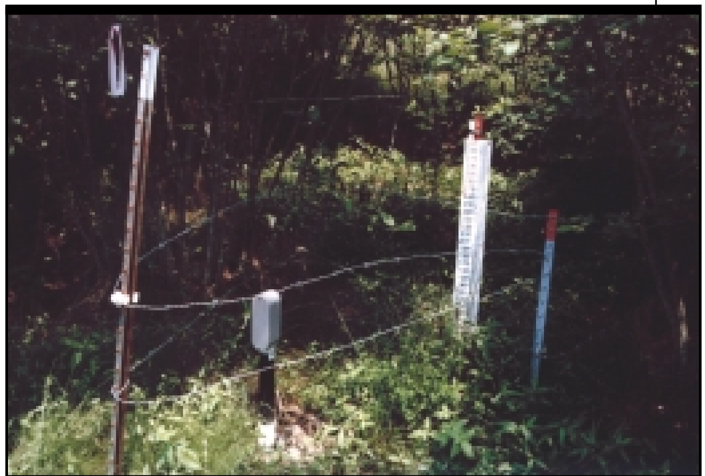
Figure 6.1 shows how the water table fluctuates seasonally and in response to precipitation events in a Piedmont Meadow Bog. Note that the level of the water table stays within 6 inches of the surface much of the year with occasional drops to below 13 inches during low rainfall periods. The post-restoration condition should reflect water at or above the surface for longer periods during years of average rainfall.

Natural changes and human activity can also cause significant changes in the hydrology, which promote changes in plant communities. As local conditions change, some wet spots dry up and other dry habitats become wetter. Such changes are easy to observe when beaver activity begins: A wetland forms behind the newly created dam and woody trees and shrubs that are not adapted for growth at the new level of saturation begin to die. A similar result can be expected in wetland restorations where the hydrology is changed to increase saturation depth or duration. In some cases the woody plants adapted to drier conditions will drown because their roots cannot get the needed oxygen. Many woody plants are adapted for saturated conditions during winter and spring, but require dry conditions during summer. If continually or temporarily flooded for an extended period during the summer, they may die.

Remediation Hydrology

One promising place to look for wetlands to revive is where past efforts at ditching and draining have been less than successful, a situation resulting in low wet areas, not quite suitable for crop production and usually left in persistently wet pasture. These places are usually viewed by the landowner as examples of failure to dry the site out and make it agriculturally useful and productive. Once the functions and values of wetlands (Table 1.1) become understood by these landowners, restoration and management will become equally, if not more, rewarding than altering the land use to a marginal activity. With added benefits from conservation technical assistance, easements, and cost-share programs, landowners can be compensated for their restoration and management of wetlands.

In many instances attempts to drain a wetland for agricultural use altered internal hydrologic systems. This was usually accomplished by digging a ditch near the lower end of the bog or installing tiles to drain the internal groundwater supply. It may be possible to alter this outflow and re-establish the internal hydrologic system to a degree that the bog can function as it did prior to intervention. Manipulating the hydrology of a



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This staff gauge and electronic water table monitor are protected from cattle by a small barbed-wire fence.

wetland should not be undertaken casually, and professionals should be consulted when this strategy is considered. Permits or certification may be required for some activities, including adding fill material or installing well-monitoring equipment.

When restoring the ecological function of wetlands, the goal may be to saturate the ground without producing deep-standing water. Deep water decreases the muddy terrestrial habitats available to species like the bog turtle, Gray's lily, and many other wetland plants.

Land managers should use the water budget on site to restore a wetland of optimum size, structure, and function. Historical maps, photos, physical evidence, and soil sampling can help determine the past extent of the wetland. Management of a fresh- water wetland generally requires that the hydrology of the site be maintained or enhanced by protecting the water source quantity and quality. Past alterations that drained off water or dropped the water level should be reversed if possible so that more water resides in the site, especially if this condition expands the wetland or increases the level or duration of saturation.

An accurate assessment of site hydrology is essential for restoration or enlargement of wetlands. In some instances hydrologic conditions are apparent or may only require accounts of recurring conditions by knowledgeable local residents or the

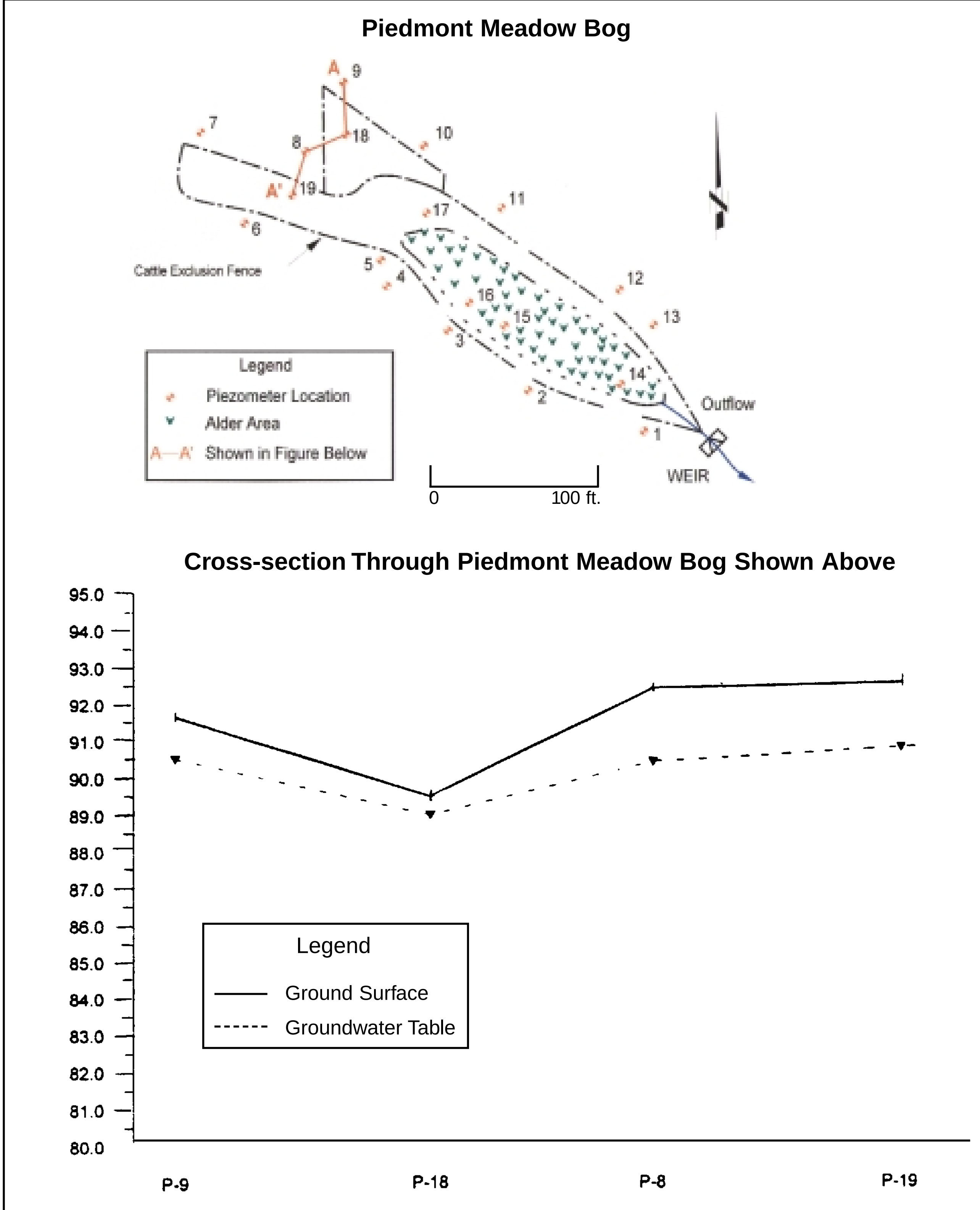

Figure 6.2 *Cross-section through a Meadow Bog showing the position of the water table with respect to the width of the wetland and the ground surface.* Note: Ground surface elevations are based on an arbitrary site survey benchmark of 100'.

examination of documents such as historical photographs. In other cases trained personnel are needed to confirm the suspected hydrologic regime. For a site where the hydrology is not known, measurement of groundwater levels with piezometers (small diameter wells) over the course of a year or two (assuming normal weather conditions) will provide valuable information about subsurface water levels. If rainfall or precipitation levels are excessively high or low during the period of monitoring, the monitoring should be extended to account for average conditions. Surface water levels can be measured using a staff gage in the site. Total surface water outflows can be measured with V-notch weirs or flumes at the inlet and outlet points of surface flow. V-notch weirs, flumes, and similar devices should be installed in such a say as to not alter the existing patterns of surface water flow.

These measurements can be compared in relation to seasonal weather and storm events to give a better understanding of the site's water dynamics. As with other ecological resources there is no extension beyond the water budget, so pairing the management objectives to the site capabilities requires hydrologic knowledge of the site.

The position of the water table throughout one Meadow Bog in the foothills of North Carolina was tracked over a two-year period. In this wetland system the water table generally mimicked seasonal precipitation highs and lows with lag times of one to two months. The relative position of the water table in this bog was higher adjacent to the spring, with a low towards the mid-line of the bog and a slightly higher water table along the lower side of the bog. Figure 6.2 is a cross-section showing the position of the water table through a section of the site.

Altering Flow

Using woody debris to create obstructions or low dams in water channels should alter the flow of surface water in the site (see Managing Woody Debris, Chapter 5). Another way in which the hydrology can be manipulated is by obstructing water flow at

Kenneth A. Bridle

A V-notch weir to measure water flow.

the outlet of any ditch that may exist. Installing a dirt plug or dike in the drainage ditch is the preferred method and requires the least resources and management over the long-term. Plugs should incorporate a small spillway or weir set at the desired water level. Standard surveying equipment can be used to determine the extent and depth of flooding for a given spillway elevation.

Increasing the depth of surface water to more than a few centimeters above the surface is disadvantageous for many rare species, but may be a temporary by-product of hydrologic manipulations. If erosion or digging has resulted in loss of substrate near the outlet, then surface water up-grade of the dam may initially become deeper than desired, forming a small pool. The pool will become shallower over time as the normal flow of sediment fills the area, deeper water infiltrates surrounding

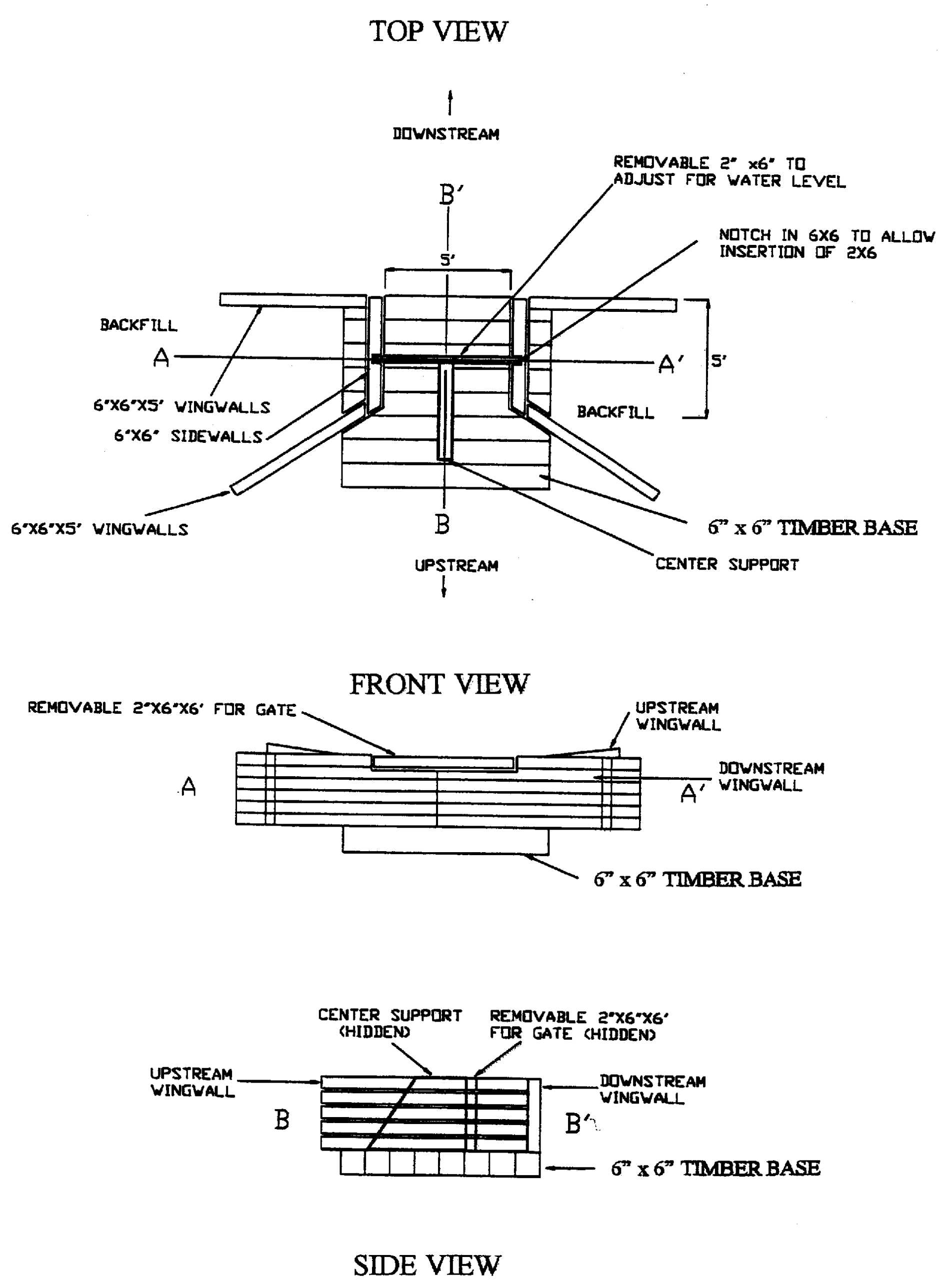

***Figure 6.3** Timber gate system used to manipulate surface and groundwater levels at the outlet point of the Meadow Bog.*

unsaturated zones (soil above the water table), and a balance is achieved in the wetland water budget.

Soil for the plug can often be found beside the ditch where it was placed as the ditch was being dug. Other sources for soil may be nearby, but they should roughly approximate the composition, grain size, and permeability (ability to have water flow through) of that removed to drain the site. The coarser the grain size, the longer the plug should be. Plant cover on soils disturbed by construction should be re-established. Advantages of this method are low maintenance and reduced risk of flooding.

In wetlands where tiles have been installed to collect and channel water from the area, tiles can be plugged with a low permeability, clay-type soil. Ideally the entire length of the tiles should be removed and the resulting ditch treated as outlined above.

Changes in Water Levels

Changes in the median water table level are often not observable for many months after changes in precipitation, i.e., the water table may not rise immediately with increased rainfall. An immediate “spike” followed by a drop to the median water level may be observed (see Figure 6.1). It is also likely that changes to the outlet will require similar lag times for long-term groundwater response. Surface water response will be much quicker and must be monitored closely to prevent flooding of critical areas.

Slowing down drainage from the site will increase the size and depth of the core wetland in most cases, so as to encompass the entire original wetland area. This development can be a benefit in returning the wetland to its former size and function, but might mean that the landowner would suffer a small reduction in agricultural lands. Each landowner must weigh costs and benefits individually. It may become important to find a way to promote the value of the wetland thus resulting in community support and possibly assistance for the landowner.

Dealing with Climate Change

There is no question that human overpopulation and overconsumption are causing profound changes in the landscape and the chemistry of the atmosphere, and a large body of evidence indicates that global climate change is one result. Human activity working in combination with natural fluctuations is most likely causing the observed shift in rainfall patterns and daytime and nighttime temperatures. It is reasonable to expect that most ecosystems will be affected, but it is too early to make predictions about how the wetlands of the Mountains and Piedmont of the Southeast will respond. Additional management options will be needed to preserve these ecosystems and the communities they support.

During restoration of most wetland types, benefits can be derived from manipulation of water levels at critical times to control the establishment and colonization of woody and herbaceous species. Hydrologic controls may seem expensive to construct, but may become one of the most reliable and efficient methods for long-term vegetation management. The ability to control wetland water level may also make the site more adaptive to changing conditions of climate or the watershed.

Sites are being evaluated in the western Piedmont to determine the potential for installing a control gate along with plugging an outlet ditch in restoring the original hydrologic regime in a Meadow Bog. Installing a freeboard dam with an outlet control gate or a V-notch weir may have benefits over the simple plugging of the outlet ditches. Although these systems are not recommended at this time because they require constant management and maintenance, they are included to inform the readers of experimental techniques under consideration and to stimulate interest in the development of new and creative ideas in hydrologic management of small wetlands.

The weir is used to measure the outflow from the wetland. The construction of an outlet control gate allows for manipulation of the discharge in the same manner as a dam and gate system. Figure 6.3 shows how a system of log-size timber can form a low dam with the capacity to change the height of water across and through the bog simply by installing or removing gate sections. Timbers should never be constructed of new creosote materials because of possible water contamination by toxic chemicals used to treat the lumber. To allow for water level manipulation, the section of the central “gate” extending above ground should have a removable section as shown on the figure.

A system such as the one described above may quickly alter surface water discharge to allow the internal groundwater system to build back to pre-drainage levels. Further manipulations maintain an “optimum” level of surface and groundwater in the bog. The time frame for achieving maximum benefits has not yet been determined. Currently the “optimum” groundwater level and the time frame for returning a degraded bog to its predrained status is being evaluated in different situations and locations.

The ability to control water level in wetland restoration may also have other practical advantages, such as allowing better access for management by people or equipment. The major drawback to this system is that it requires attentive and judicious management to prevent flooding. A decision to use this method must be made with caution—it is still experimental. Damming of surface flows may be beneficial in some cases, but not in all (see Wetland Management by Beavers, this Chapter).

Wetland Buffers to Control Polluted Runoff

Projects that are ditch and drain restorations will have similarities across many sites. In most cases the surrounding land is pasture, cropland, residential, or industrial, and may be regularly limed, fertilized, and impacted by manure and agricultural chemicals. These substances find their way into wetlands during rainstorms and may profoundly affect plants and aquatic life. Nutrient overloads from sources such as fertilizer and manure, may produce aquatic algal blooms and stimulate growth of weedy plant species. In addition to loss of biodiversity, uncontrolled nutrient runoff may result in an unstable, fluctuating ecosystem that will be more difficult to restore to a stable wetland requiring only minimal maintenance.

Runoff from nearby roads or parking lots can complicate the problem by adding oils and other petroleum products, asbestos from brake pads, and other substances such as antifreeze and salt. While trapping and removal of chemicals is one of the important functions of wetlands, we should try to reduce chemical loads entering a wetland, if only to make the restoration and management more predictable and successful.

Changes in surrounding land-use practices to reduce nutrient and chemical runoff must be part of the restoration and management plan in a ditch and drain restoration. Reducing runoff of agricultural chemicals is a priority of many agencies, and landowners can find plenty of help to accomplish these tasks. Buffer strips (filter strips) of native grass and herbs fringing a wetland can help absorb this nutrient load and may be used with ditches that divert the contaminated surface water away from the most sensitive parts of the wetland. Filter strips designed to utilize native vegetation can also have important benefits for native terrestrial species, including game species such as grouse and turkey.

Box 6.1 Hydrologic Management Suggestions for Meadow Bogs

- Formulate flow alteration strategy with the help of a professional.
- Determine whether permits are needed.
- As one option, consider installing a ditch plug to grade.
- Determine the best time of year to begin the manipulation.
- Avoid flooding hummocks and other areas where hatchlings or eggs could be disturbed.
- Use generous native vegetation buffers around the wetland to filter nutrient and chemical runoff and benefit wildlife.
- Use debris resulting from woody plant removal to construct small dams along water channels within the site to allow water to be diverted and retained.

Wetland Buffers as Life Zones for Wildlife

Terrestrial areas around wetlands have traditionally been considered vegetational buffers intended to provide some degree of protection for the water quality and wildlife supported by the wetland. This view is gradually giving way to an understanding of the greater biological importance of these structures. Studies indicate that they are more critical to the well being of many forms of wetland wildlife than first suggested. For salamanders and some other semiaquatic species, upland terrestrial zones are more than just areas where these species occasionally

Box 6.2 Culvert Use by Bog Turtles

By Dennis W. Herman

Bog turtle habitats are often fragmented, preventing normal movement between habitat patches. Most fragmentation of habitat comes from roads bisecting wetlands to create an often fatal dispersal route across the offending strip of pavement or gravel. The installation of 12” to 15” diameter culverts or pipes under the roads in normal seepage channels or small streams can provide bog turtles with a safe route from one habitat patch to another and connect wetlands with a natural water flow. State departments of transportation should provide culverts to connect wetlands and furnish bog turtles and other species dispersal routes safe from road crossings. The following case illustrates culvert use by bog turtles in a Tennessee study site.

Bog turtles were first reported from Tennessee in May 1986 from two small wetlands in the same valley. Shortly thereafter a mark-and-recapture study was initiated at the two sites by Bern Tryon of the Knoxville Zoo. The larger site was comprised of two habitat patches separated by a paved road. Bog turtles captured in the smaller habitat patch (the Annex) were found to be using a 15” culvert with several inches of mud on the bottom, as a means of moving between the two wetlands. Since 1987, fifteen individual turtles (33%) have been captured in the Annex; seemingly their movements are dependent on the hydrology of the site. The Annex is used by turtles when the wetland is unusually wet and water is flowing through the culvert. No bog turtles have been observed crossing the road or dead on the road during Tryon’s 14-year study.

Additional use of culverts by bog turtles has been observed recently in other states. Culvert installation for connecting fragmented wetlands should become policy when wetland restoration projects are being considered. It is an inexpensive method of providing natural water flow between wetlands and safe dispersal routes for small animals.

feed or wander. They are considered “life zones”; critical for feeding, growth, and maturation. Although bog turtles hibernate and nest within wetlands, they are known to use nearby dry areas, and experienced turtle biologists know when to look for them in surrounding fields. Some species of amphibians use wetlands for breeding, but their juvenile and adult populations depend entirely upon the surrounding drier terrestrial areas. Some species move great distances and may spend long intervals away from the wetland before returning at maturity. Spotted salamanders (Ambystoma maculatum) in Kentucky were recorded traveling up to 220 meters from the breeding wetland. The size of buffer needed to maintain biological integrity is indeed a question requiring more study and certainly will vary depending on wetland size and type. Ideally the buffer zones planned for a wetland project will include not only upland vegetation regions surrounding the wet area, but buffers which allow connections to nearby streams and forests. Maintaining connections between the wetland and surrounding areas will be critical to successful biodiversity protection and may sometimes conflict with economic interests.

Managing Roadways

The negative effects of roads on wildlife are often underestimated. In cases where roads bisect wetlands, they have a fragmenting effect on the ecosystem and can profoundly change the nature of species movements, interactions, and survivorship. Increased mortality within an isolated population can severely limit the potential of that population to persist into the future. Road mortality means fewer individuals successfully move between habitat patches and the risk of inbreeding increases. Additional problems result when hydrology is altered, a circumstance which is often the case when roads cross wetlands.

In wetland habitats already bisected by roads, installation of small diameter (12"- 15") pipes beneath the roadbed may provide a means to reconnect wetlands that have been fragmented (see Box 6.2). Traditional roadway fences should not block connections between fragmented sections, but a different type of fence can sometimes be used to direct small mammals, reptiles, and amphibians to protected openings. Fashioned after drift fences used by biologists to study small vertebrate fauna, these structures can be less than 20 cm in height and buried a few centimeters into the soil. They should be positioned in such as way as to gradually lead to the opening. Dense vegetation can also be planted to discourage road crossings. Ramps may be needed in some circumstances. More information is needed on the effectiveness of such measures, but the cost is minimal and these or similar techniques may prove highly effective.

Many wildlife species would benefit from the installation of open bridges over small streams and wetlands instead of culverts. Stream corridors often provide considerable cover and many species travel along them. Most small streams go under roads through culverts, leaving no place to cross under the road unless the animal can swim or is big enough to wade. Bridges over larger creeks and rivers usually have some dry land (floodplain) that animals can use to cross under the road. Reptiles (box turtles and snakes), medium sized mammals (mink, weasels, raccoons, skunks, rabbits, etc.), and some invertebrates would benefit the most. However, it is critical to manage the floodplain resource as part of the whole road building project so that planning to offset impacts such as those cited above can be mitigated.

Restoring Hydrologic Regimes to Floodplain Wetlands

Piedmont and Blue Ridge streams are typically entrenched in a larger floodplain. Ephemeral pools sometimes form in floodplain depressions. These wetlands are often discovered in a disturbed state and are in need of remediation efforts. Depending on the wetland location with respect to the river or stream, it is possible to re-establish periodic flooding of this wetland system by the main stream. The entrenchment factor in this system can be used to effect over bank flooding at a specific flood stage. This flooding is accomplished by cutting a ditch at the correct height and sloping it from the stream back to the floodplain containing the wetland. Use of this natural system to flood the wetland regularly and also possibly to fill ephemeral (temporary) pools within the floodplain can be used to enhance the wetland hydrologic cycle. Figure 6.4 illustrates the concept and a means for periodically flooding riparian wetlands and adjacent floodplains. Care must be exercised when digging the flooding ditch. The wrong angle can result in draining instead of flooding.

Bog turtles, it should be noted, and many other wetland species do not live in wetlands prone to frequent flooding. This technique may also harm preferred habitats. However, many floodplains contain wetlands requiring flooding, such as floodplain pools, and these would benefit from this manipulation. Many ecological functions of floodplains have been lost because of the disconnection of streams from their floodplains, a phenomenon which has occurred in many human land uses. Reconnecting the stream with its floodplain is an important part of wetland restoration techniques currently in use.

Wetland Management by Beavers

Beavers build dams to defend their dens and to change local conditions favoring this animal’s semiaquatic lifestyle. By simply cutting woody stems to build a dam across the flow of surface waters, beavers often form pools and fringing, spreading wetlands. Eventually, as local beaver populations increase, food supplies decline, the pool begins to fill with sediment, and the beavers will then range farther in search of new sites to build. When a better site is found, the beaver colony will abandon the old site, allowing it to recover and begin the succession toward the climax community for that spot.

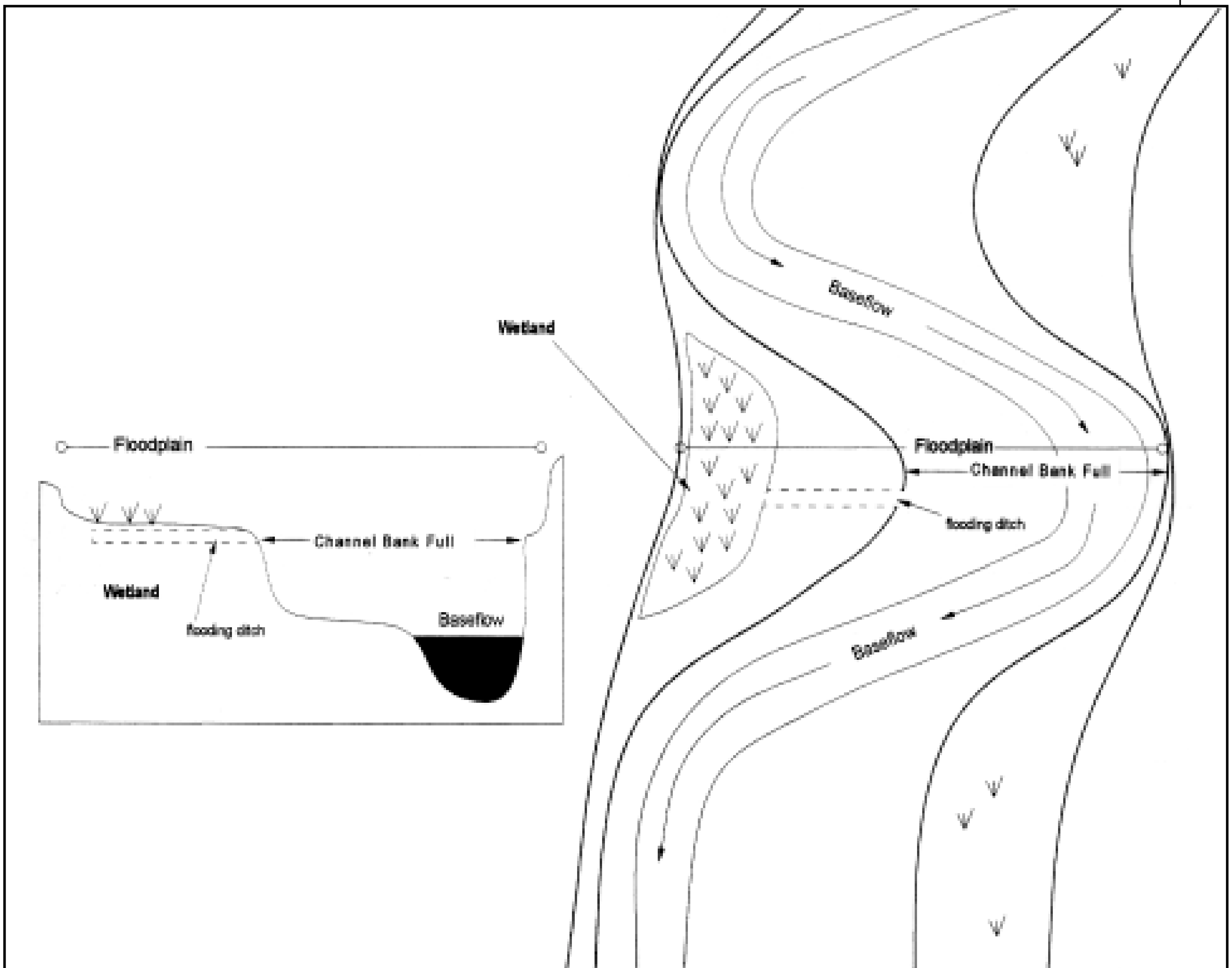

Figure 6.4 *Illustration of a means for restoring periodic flooding of floodplain wetlands. Flooding is accomplished when a channel bank fills as a result of rains. Care must be taken to carefully angle the ditch so the wetland fills rather than drains.*

The pre-Columbian North American landscape was full of lush watersheds, which were a mosaic of beaver maintained and abandoned wetland landscapes. The result was the biodiversity and natural wealth for which this continent was prized. With human development many wetlands were cleared and drained, and beavers were hunted to near extinction around the end of the 19th century. Beaver populations are now on the rebound and there is no reason to doubt that they will return to many of their former habitats and again begin constructing dams and wetlands. But they are returning to a different world.

Contemporary landscape and stream systems differ from those of pre-settlement times. Roads now transect streams and wetland habitats, cutting off important wildlife corridors. Most streams have been straightened and incised and have only a small fraction of the riparian vegetative cover of past times. By increasing the instability of streambanks, and the consequent erosion and down cutting, beaver dams can be detrimental to modern riparian wetland habitats. It is too early to determine whether beavers will help or hinder the restoration and management of wetlands for the benefit of human-perceived functions and values. Undeniably, however, they greatly impacted the environment in the past and are currently recovering from a century of absence throughout the Southeast. In this regard they, too, will have to be monitored and managed in the modern landscape.

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