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TECHNIQUES FOR WETLAND MANAGEMENT

By

Arlyn F. Linde

ACKNOWLEDGMENTS

My thanks go to the game managers of the Wisconsin Department of Natural Resources who so generously contributed their time and who willingly supplied data from their files. Without their complete cooperation this study would have been impossible. Essentially, this report is a compilation and evaluation of their experiences and their work in the management of wetland areas.

I wish to thank James B. Hale, under whose supervision this study was accomplished, and C. D. Besadny for critically reviewing the manuscript.

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Edited by Ruth L. Hine

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INTRODUCTION

This report results from a survey of wetland management areas throughout Wisconsin. It is a compilation and evaluation of wetland management techniques used in the various game management districts of the Department of Natural Resources.

It is intended to provide game managers with a ready source of reference material for their wetland development work. While it is not exhaustive, this report should serve to guide the new manager in wetland development and offer the experienced manager additional useful material. It also offers suggestions for correcting existing deficiencies. It is obvious from the amount of individual initiative shown by many of the managers in developing new techniques that wetland development in Wisconsin is not static. Progress is being made and we hope that this report will provide some guidelines for better management by putting in reference form the ideas and experiences of all managers.

The report is organized as a manual, according to management practices, using information from one or more management areas to provide examples. Work done at any particular site therefore may be referred to in several places throughout the text. While this hinders a ready picture of total development on an individual game management area, it does focus attention on individual practices and their application.

The report centers primarily around techniques for managing wetland game (ducks, muskrats, etc.) and has only limited reference to the effects of wetland habitat development on other species.

The survey began with a questionnaire sent to all game management districts to determine the extent of wetland management. Some districts had no development projects and were eliminated from the survey. Further contacts were then made with game managers who had undertaken wetland development projects and arrangements made to visit their districts to see their wetland areas. Through the use of a series of detailed questionnaires, field notes and photographs, an attempt was made to completely document each manager's experiences with the various wetland management techniques included in this report. Game management areas and locations of principle wildlife areas investigated are shown in Figure 1.

Field data were gathered mainly during the years 1960 through 1964. New techniques may have been used since 1964 which are not included, although an attempt was made to update this report as much as possible. In all instances the literature was surveyed and references are offered for further reading on any particular subject.

Cost figures are used wherever they are available, but in many instances costs were either not available or were in a form which could not be compared to other areas. There are many possibilities for errors in cost data compiled from diverse sources such as these, so it is well to consider the stated figures as indicative rather than absolute.

Since this is an evaluation of applied wetland management techniques, there is some disagreement with work done in the past. In such instances every attempt has been made to show the reason for disagreement and to point out that better methods should be investigated. Since wetland acquisition has been emphasized in Wisconsin, and wetland development is only beginning, it is probable that mistakes will be made in development work before sufficient experience is attained. If this report can help in some measure to reduce such errors by channeling development into more productive lines, it will have served its purpose.

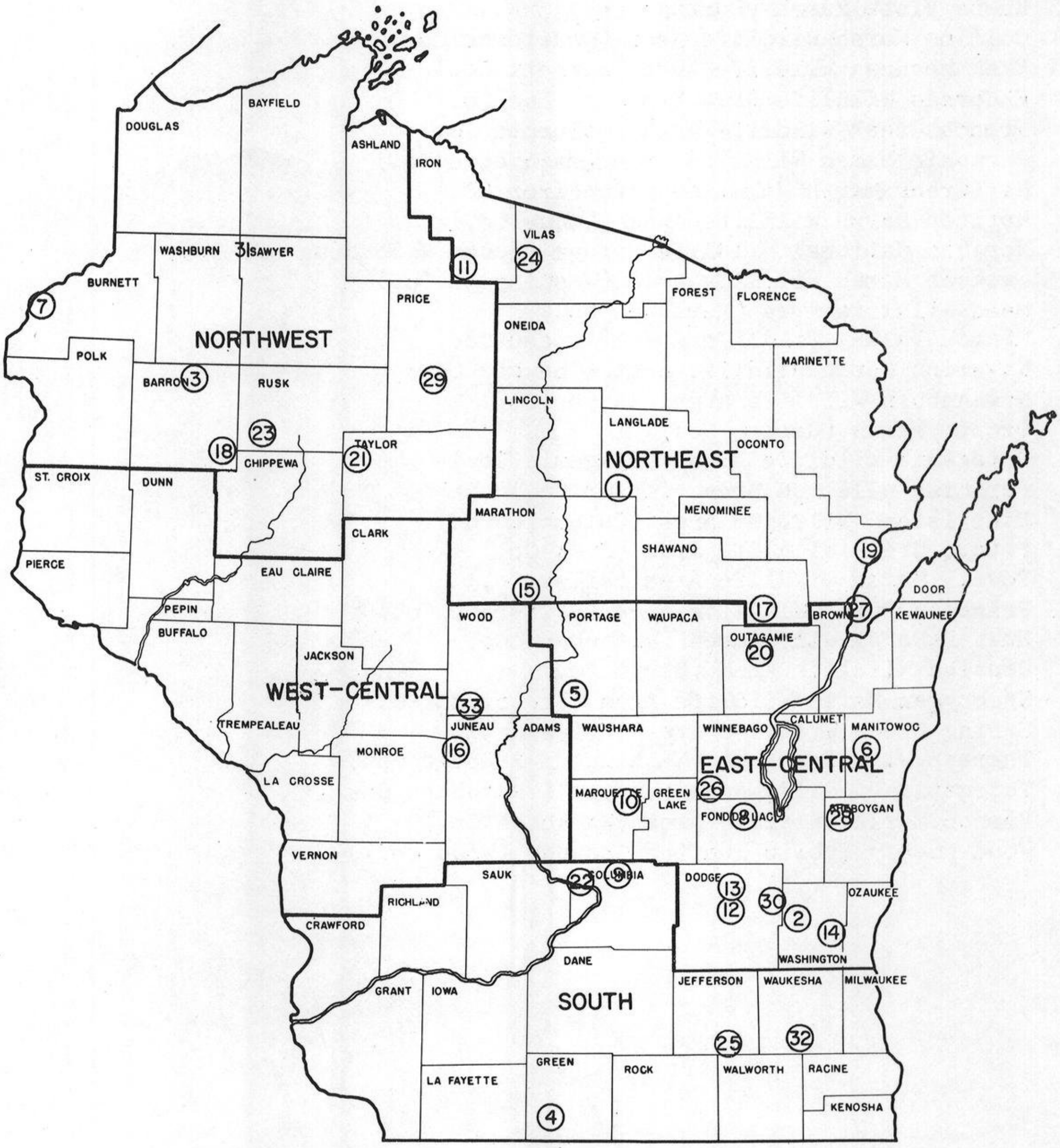


Figure 1. Game management areas and locations of principal wildlife areas investigated. (Key to areas on next page)

WISCONSIN WILDLIFE AREAS AND WETLANDS SHOWN IN FIGURE 1

1. Ackley Wildlife Area (Langlade Co.)
2. Allenton Wildlife Area (Washington Co.)
3. Barron County Forest (Barron Co.)
4. Browntown Wildlife Area (Green Co.)
5. Buena Vista Marsh (Portage Co.)
6. Collins Marsh Wildlife Area (Manitowoc Co.)
7. Crex Meadows Wildlife Area (Burnett Co.)
8. Eldorado Wildlife Area (Fond du Lac Co.)
9. French Creek Wildlife Area (Columbia Co.)
10. Germania Marsh Wildlife Area (Marquette Co.)
11. Hay Creek Marsh Wildlife Area (Iron Co.)
12. Horicon Marsh Wildlife Area (Dodge Co.)
13. Horicon National Wildlife Refuge (Dodge & Fond du Lac Cos.)
14. Jackson Marsh Wildlife Area (Washington Co.)
15. Mead Wildlife Area (Marathon Co.)
16. Meadow Valley Wildlife Area (Juneau Co.)
17. Navarino Marsh Wildlife Area (Shawano Co.)
18. New Auburn Wildlife Area (Barron Co.)
19. Oconto Marsh (Oconto Co.)
20. Outagamie Wildlife Area (Outagamie Co.)
21. Pershing Wildlife Area (Taylor Co.)
22. Pine Island Wildlife Area (Columbia Co.)
23. Potato Creek Wildlife Area (Rusk Co.)
24. Powell Marsh Wildlife Area (Vilas Co.)
25. Princess Point Wildlife Area (Jefferson Co.)
26. Rush Lake Wildlife Area (Winnebago Co.)
27. Sensiba Wildlife Area (Brown Co.)
28. Sheboygan Marsh Wildlife Area (Sheboygan Co.)
29. Spring Creek Wildlife Area (Price Co.)
30. Theresa Wildlife Area (Washington & Dodge Cos.)
31. Totogatic Wildlife Area (Sawyer & Washburn Cos.)
32. Vernon Marsh Wildlife Area (Waukesha Co.)
33. Wood County Public Hunting Grounds (Wood Co.)

IMPOUNDMENT CONSTRUCTION

Although the Bureau of Engineering is largely responsible for constructing impoundments, it is important for the game manager to be aware of the major steps involved and particularly their biological implications. Therefore, some information on impoundment construction obtained from the various game projects and the literature is presented here as background.

Site Selection

Before a decision is made to construct an impoundment, a complete survey of the proposed site should be made to determine if it is suitable topographically, biologically and economically.

The vegetative cover will change following flooding, but the pre-flooding cover is indicative of the impoundment's productivity potential. Plants are good indicators and as experience with impoundment management increases, a knowledge of which species of plants are indicative of better impoundment sites will be acquired. Indicator plants are of minor importance in selecting sites in the southern and east central parts of the state, since almost any impoundment site selected will be productive for the desired range of plants. However, in the north it is well to be more particular in site selection, since productivity may vary considerably from wetland to wetland and it is important to note plants that are indicative of more fertile areas.

Leatherleaf, black spruce, and sphagnum are indicators for sites of low productivity, while softstem bulrush and bur reed usually indicate high fertility. Submergent vegetation such as the Potomagetons also denotes some degree of fertility. The presence of Chara usually is associated with higher alkalinities and pH. However, if the submergent plants consist only of bladderwort they are of little significance, since this plant will grow in some of the poorest areas.

Because plant ranges are strongly dependent on the fertility of the soil and the quality of the water, soil tests and water analyses are highly recommended. Soils fertile for agriculture are generally productive for desirable wetland plants. Highly acid waters (pH 5.0 and below) having a total alkalinity of less than 10 ppm can usually be considered unproductive. In the north, water with a total alkalinity of 50 ppm or more and a pH between 6.0 and 7.0 has fair to good potential. Acid waters in the north often tend to be deeply stained if they are draining from a spruce or leatherleaf bog. These stains will limit the production of submergent plants in the deeper portions by seriously interfering with light transmission. In the event such a marsh is developed, the water will need to be held at much lower levels to be sure that there will be adequate light penetration.

Soils vary in productivity at different depths of flooding. Lower quality soils should be flooded at shallower depths, with the poorest soils being flooded only 1 foot or less, according to the Atlantic Flyway Council (1959). Shallow flooding such as this would be practical only in very flat basins.

A good source of water is very important. An ideal source is one sufficient to maintain desired water levels at all times and to reflood the area following a draw-down within a few weeks. Few of our impoundments have such a water source and if other impoundment site factors are good it will be necessary to accept a less abundant water source. However, it is obvious that the source of water must be sufficient to maintain water close to the desired pool level during the height of the summer when evapotranspiration losses are high.

It is highly desirable that flooding produce an area with a good dispersion of cover and open water if it is to be attractive and productive for waterfowl. The Atlantic Waterfowl Council (1959, Sec. 100.1) stated, "One must realize the value of emergent cover to the productive marsh and reject any site that does not show this potential." Solid stands of emergents without breaks to provide open water will have little or no bird use. At the opposite extreme, an open lake-like appearance without emergent cover to shelter adults and broods is equally poor. Patches of emergents, open enough to permit waterfowl to swim through them, alternated with patches of open water, is desirable habitat.

In New York state the highest waterfowl productivity was obtained on marshes which contain a combination of dense persistent woody cover, open water, and emergent aquatic vegetation (Atlantic Waterfowl Council, 1959). Similar observations were made in Wisconsin. Dense stands of alder and willow which persisted in flooded portions of the Totogatic Flowage were heavily used by waterfowl. Similar use of brush was noted on the Mead Wildlife Area and elsewhere. There is some indication that living woody cover may be more attractive than the dead stems.

If heavy bog mats are present, there is a possibility that this bog may rise and float after flooding. If the bog is extensive, the open water areas would be drastically reduced and the resulting impoundment would be unsatisfactory.

It is important to select an impoundment basin which is as flat as possible. The Atlantic Waterfowl Council (1959) recommended that basins with a gradient of 1 percent (a vertical rise of 1 foot in a horizontal distance of 100 feet) or more be rejected as impoundment sites. To obtain maximum puddle duck use, 75 percent of the basin should be flooded with depths of 2 feet or less. It requires a relatively flat basin to produce this degree of flooding.

Large watersheds require large control structures and result in higher costs. Short steep watersheds are subject to heavy runoffs over short periods of time and may also pose control problems. Watersheds which produce uncertain flows make an impoundment very difficult to manage because it may be impossible to raise marsh levels when needed.

All the criteria mentioned above can seldom be met for any particular site. Many times it is necessary to be satisfied with less, especially in the less fertile areas of the state. However, the decision to develop an impoundment should be based on a composite of factors and areas which are obviously poor in several of the more important aspects should be rejected. It is not enough to put water on an area, but the area must be capable of producing satisfactory results in line with the original objective, be it waterfowl, furbearers, or some other use.

Dikes

Construction and Costs

Core

Although core dikes are not always used in impoundment construction, they are a recommended form of construction, especially in the southern half of the state (Addy and MacNamara, 1948; Soil Conservation Service; 1958 and Atlantic Waterfowl Council, 1959). The proposed dike area should be cleared of large rocks, stumps, trees and debris. Failure to remove such material can result in seepage which may cause eventual dike failure. Some of the older dikes in the Black River State Forest impoundments were reported to have washed out where buried logs were located.

After the dike area has been cleared, a core trench is excavated either by dragline or by blasting. The core trench should be excavated down to solid inorganic subsoil. It should be 3 to 4 feet or more wide (Addy and MacNamara, 1948; Soil Conservation Service, 1958), and should extend the entire length of the dike. Since its purpose is to prevent seepage through the dike, the core trench should be filled with clay or other impervious mineral soils. The core should be added in layers and is thoroughly compacted by operating the equipment back and forth over it as the filling proceeds.

Fill

Equipment. Although soils may vary at the dike site, the materials used in construction depend not only on which soils are most readily available, but also on the construction methods and equipment employed. In drag-line constructions, the soil next to the dike will be used in the dike, but in constructions employing bulldozers with scrapers and turnpulls, better soil may be pushed in from the ends or hauled in from another location.

Soil types and construction methods in the northern areas make bulldozer operation more practical than dragline work. Use of experienced equipment operators is important in obtaining a good construction job.

Some of the game managers in the Northwest Area indicate that close supervision of the construction is important, especially if inexperienced operators are used. The Atlantic Waterfowl Council (1959, Sec. 420.4) stated, "Marsh construction involves a specialized type of earth moving and widespread patronage of several contractors can be costly to the project and exasperating to the supervisor."

Dike construction on Grand River Wildlife Area. Mineral fill is being hauled in from the upland. Peat and muck were previously stripped off the dike site to provide a solid base for the fill.

Soil. A large percentage of the dikes in the Southern and East Central Areas contain organic soils (Table 1). Peat was contained in 38 percent of the dikes checked in the Southern Area and in 75 percent of those checked in the East Central Area. Eighteen percent of the dikes contained peat in the Northeast Area and none were reported containing peat in the Northwest Area. Since information was not available on all dikes, these data must be used with some reservation. They do indicate a trend toward more mineral soils for dike construction in the north and the heavy use of organic soils in southern parts of the state. In the Northeast Area 55 percent of the dikes checked contained sand while in the Northwest 55 percent contained clay. Sand and peat appear to be used most often in the West Central Area.

Impervious mineral soils are superior to organic soils for diking and should be used whenever available. The Soil Conservation Service (1958) recommends clay, silt loams and other mineral soils with a high percentage of clay for dike construction. Soils of this type produce a firm dike which is much less susceptible to all forms of damage, even muskrat damage.

Soil for dikes is usually brought in from borrow areas in high ground at either end of the dike. Dike fill is usually applied in layers of not over 6 to 12 inches thick and thoroughly compacted by the equipment as construction proceeds. If mineral soil is in short supply, the best soil should be used for the core, extending through the center of the dike with poorer soils being used on either side of the central core. The poorest soils should be used in the downstream side of the dike and a topping of organic soils can be used to improve the surface for seeding a grass dike cover. At the Crex Meadows Wildlife Area sand dikes were top dressed with peat. Top dressing also prevents clay dikes from drying out and cracking.

Peat has been used extensively for subimpounding large peat marshes where the cost of hauling in mineral fill is prohibitive. Although the peat dike is less expensive to construct, it produces an inferior type of dike and maintenance costs are extremely high in areas of high muskrat population. Many times no core is used and the dike is built on top of the natural marsh floor. Since the marshes are often too wet for efficient bulldozer operation, construction is usually by dragline. Work is frequently accomplished in the winter months when it is easier to move equipment. This is also the off-season for construction work and prices are usually somewhat lower. A heavy steel ball is used to break the frost so that excavation for fill can be accomplished.

TABLE 1

Dike Materials

	Percent of Dikes			
Dike Material	NW Area	NE Area	EC Area	So. Area
Peat	-	18	75	38
Muck	-	9	6	13
Black Dirt	-	-	6	-
Silt	-	9	6	13
Silt Loam	-	9	-	13
Marl	-	-	-	13
Clay	55	23	38	25
Clay Loam	27	9	-	-
Sand	9	55	19	25
Sandy Loam	23	14	-	-
Gravel	9	23	-	13
Mineral Fill	-	-	6	38
Road Fill.	5	-	6	-
Unspecified Mineral Soil	9	-	-	-
Hard Pan	9	-	-	-
No. of Dikes	22	22	16	8

NOTE: More than one type of material may be included in any one dike.

During the summer, where the surface is wet, log mats are used to support the equipment. The use of mats is time-consuming and a helper is needed for moving the mats as the dragline moves forward.

In the southern and western parts of the state, where dragline work is widely utilized, material for the dike is usually taken from a borrow area along one edge of the dike. The borrow area becomes a ditch which extends all along the impoundment side of the dike. Since these are bottom soils, they consist mostly of peats and mucks. Final shaping and compaction is done by bulldozer after the material has had a chance to dry out during the spring months. Bog chunks and chunks of ice are sometimes included in the dike material. This makes for poor compaction and produces high seepage losses. The dike must be considerably overbuilt in height to allow for settling. Addy and MacNamara (1948) stated that this allowance should be 10 percent, but if muck is used for fill material, the figure should be increased to 50 percent. The Soil Conservation Service (1958) recommended allowing 5 percent for settling for dikes which are constructed from mineral soils by bulldozer and carefully compacted in layers during construction. A sheepfoot roller is sometimes used to improve dike compaction, but this cannot be used on saturated soils.

Slopes

To minimize erosion and maintenance costs, dikes should be sloped in an approved manner. Both Addy and MacNamara (1948) and the Atlantic Waterfowl Council (1959) recommended slopes of 3:1 on the impoundment side and 2:1 on the downstream side. A 3:1 slope means that there will be a drop of 1 foot for every 3 feet measured out laterally from the top edge of the dike. Slopes ranging from 1:1 to 4:1 have been used in Wisconsin. The gentler the slope, the better the construction, but the greater the cost since more fill is needed. Slopes of 1:1 have been used mostly on low dikes for small constructions. Such slopes would be extremely undesirable for high dikes. In the East Central Area where muskrat damage in peat dikes is a problem, slopes as gentle as 4:1 have been used, but even such shallow slopes are not sufficient to eliminate muskrat damage problems. Northeast and Northwest Area personnel most often used 2:1 and 3:1 slopes. To improve the quality of dike construction when inexperienced equipment operators are being employed, the Atlantic Waterfowl Council (1959, Sec. 420.3) recommended that batter-boards be used to set dike slopes (Fig. 2). Explanation for use of this board is as follows:

A short stake is driven at the outside edge of the slope and the "batter-board" attached with a single nail. A support stake is then driven a few feet inside the toe. The percent of slope (2:1 = 50% 3.1 = 33.3%) is set on the Abney level and the adjustment locked. The level is then placed on the "batter-board" and the inside end raised until the bubble on the instrument is level. The upper end of the support stake is nailed and the operator can now be guided by this simulated correct slope.

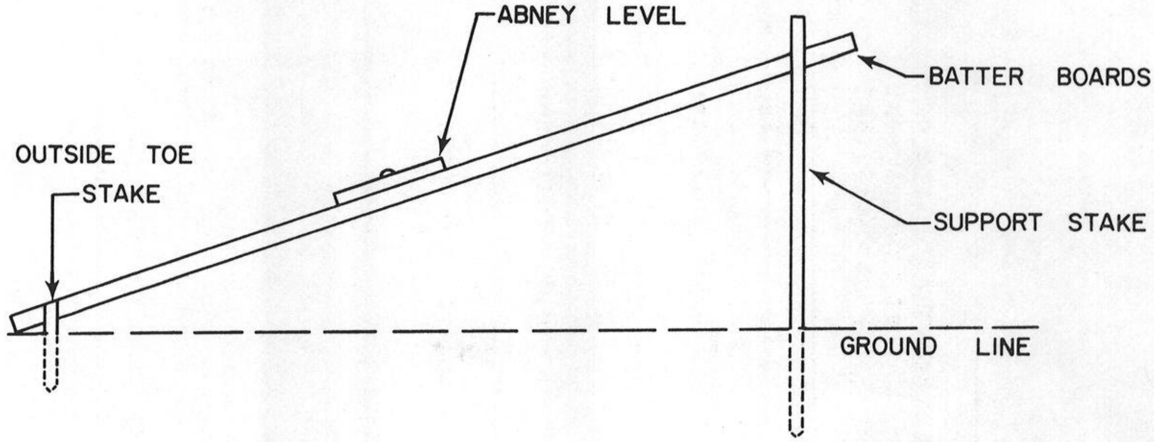


Figure 2. Use of "batter-boards" for setting dike slopes. (Atlantic Waterfowl Council, 1959)

Dike Dimensions

Height of the dike is primarily dependent on the contours of the area to be impounded. Narrow, deep basins will require much higher dikes to sufficiently flood the basin. Since marsh basins in the northern part of the state are usually deeper than those found in the south, the dikes average considerably higher (Table 2). Although there is only a minor difference in top width, the bases of the northern dikes are much wider. A greater base width and a wide berm between the borrow ditch and the dike can help reduce muskrat damage where this is a problem. Top width depends on whether or not the dike will serve as a roadway. If so, it should be gravelled. For two-lane travel, 20 feet is probably a minimum width. For single-lane travel, 10 feet is adequate. The National Resources Committee (1938) recommended a 2-foot shoulder on each side to prevent raveling. In any event, the dike should be at least wide enough for maintenance vehicles.

Emergency Spillways

Any basin which impounds runoff water or streamflow should be provided with an emergency spillway to pass flood waters above and beyond that which the control structure is capable of handling. The Atlantic Waterfowl Council (1959) recommended that the spillway for small marsh impoundments be large enough to handle the peak flow that could be expected to occur in the drainage area once in a 50-year period. This peak flow can be determined from stream flow records if they are available, or it can be calculated. The Soil Conservation Service (1958) gave a complete description for determining peak runoff for any particular

TABLE 2

Average Dimensions and Costs of Dikes

Area	Avg. Height	Avg. Top Width	Avg. Base Width	Avg. Cost Per Foot	Minimum Cost Per Foot	Maximum Cost Per Foot	Type of Equipment Utilized
East Central	4.5 ft.	11.8 ft.	27.4 ft.	$ 0.43	$ 0.20	$ 0.82	Drag-line*
Northeast	5.8 ft.	12.1 ft.	43.3 ft.	2.85	0.20	10.50	Bulldozer
Mead Wildlife Area**	4.5 ft.	12.1 ft.	30.0 ft.	0.16	0.11	0.24	Drag-line*
Northwest	7.8 ft.	12.9 ft.	57.7 ft.	5.23	1.47	8.79	Bulldozer

* Average cost for leveling drag-line constructed dikes by means of bulldozers is 6 cents per foot.

** The Mead Wildlife Area was an exception in the Northeast Area.

watershed in the midwest. Further help in this matter can be obtained from the district Soil Conservation Service office. After the peak flow has been determined, the length and depth of an emergency spillway which will safely pass this peak flow can be calculated. During peak flows the amount of water that can be temporarily retained in the impoundment above the normal storage capacity represents emergency storage capacity.

The Atlantic Waterfowl Council (1959) recommended the following formula for determining emergency spillway size for small marshes:

$$L = \frac{Q}{(CH)\ 3/2}$$

L = Width of spillway in feet
Q = Capacity of the watershed in cubic feet per second
H = Depth of spillway or head on crest of spillway in feet
C = A co-efficient: When H = 0.5 ft; C = 2.70
When H = 0.75 ft; C = 2.67
When H = 1.00 ft to 2.5 ft; C = 2.63

Width (L) is the size necessary to provide an emergency spillway in which the water depth will not exceed the depth of the spillway (H). The top of the dike after settlement should be a minimum of 1 foot above the maximum water depth expected to flow through the emergency spillway when peak flood conditions occur.

The Eldorado impoundment has its emergency spillway 2.6 feet above normal pool level. This provides 2.5 feet of additional storage before the emergency spillways begin to operate. Top of the dike is 2.4 feet above the emergency spillway level. The dike will accommodate a maximum flood stage of 4.6 feet of water above normal pool level at freeboard level and provides 8,020 acre-feet of emergency storage. The normal pool size is 1,500 acres, but this increases to 2,700 acres at 4.5 feet above normal pool level.

Freeboard, which is the height of the dike above the pool's surface at maximum flood stage, should be sufficient to prevent waves from over-topping the dike. This allowance for waves is based on the effect of a wind of maximum velocity blowing down the impoundment toward the dike. The Eldorado dike provides a 1-foot freeboard.

Emergency spillways are normally constructed on natural undisturbed soil if possible. Usually an area is chosen near the end of the dike, where the natural terrain approaches the expected dike level. It is sometimes possible to use an area which has the desired level and forms a natural spillway with no further improvement necessary. Such a situation is highly desirable, for a spillway area covered with natural sod is extremely resistant to washing. If no such area is available, an unfilled area higher than the desired spillway level will need to be cut down to the desired level. This should be accomplished before the dike filling is finished so that the fill removed from the spillway cut can be utilized in the dike construction and thus save on construction costs.

Beginning of wooden spillway installation, Antigo District

An emergency spillway has been developed in the Antigo District (Northeast Area) which is of rather unique design (Fig. 3). It consists of a heavy flat plank barrier securely bolted together with cross bracing. This plank structure is somewhat longer than the desired spillway length and about as wide as the dike is high. It is buried on its long edge in the dike with the top edge at spillway height. The ends extend back into the dike enough to prevent water from washing around them. The plank barrier is located in the downstream side of the dike and the dike level is reduced to the level of the plank spillway at this point. The downstream side of the plank spillway is heavily riprapped with stones and the earth portions on the upstream side are seeded. Water crossing the spillway is prevented from washing by the plank edge and as the water passes to the downstream side, erosion is eliminated by the rock riprapping. Several of these spillways have been installed and results have been very satisfactory.

Many spillways are seeded to a protective grass and legume cover, but in the West Central Area some spillways were constructed which were covered with a thick layer of rotten granite. In some of the Horicon Marsh subimpoundments, spillways were riprapped with flat quarry stone. Results seem satisfactory.

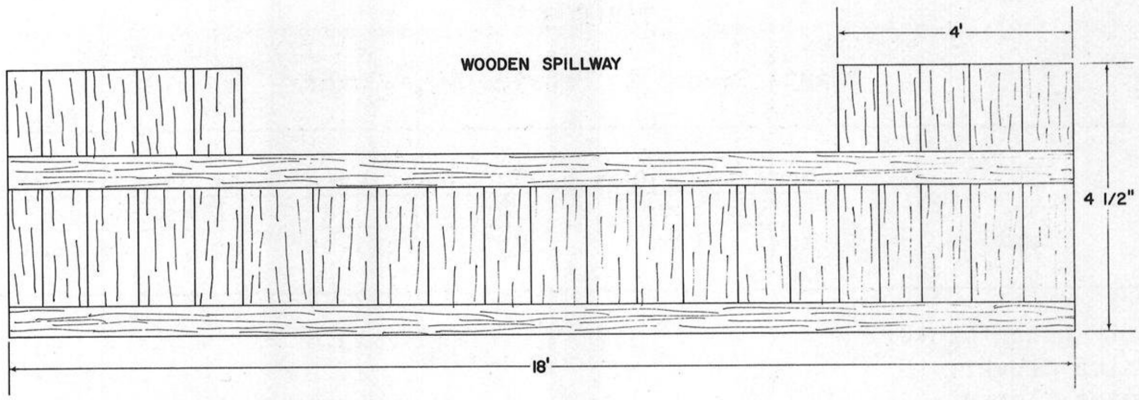


Figure 3. Wooden spillway used in the Antigo District. (Drawn by Glenn Kloes)

Dike Cover

In order to prevent erosion, impoundment dikes should be seeded as soon as practical following construction. A variety of plant species have been seeded on dikes (Table 3). Preferences for particular seeds varied from area to area. In the Northwest Area where the soils are predominantly clay or clay loams, mixed clovers and rye were generally used while in the Northeast Area where the dike soils are mostly sand and clay, clovers were again preferred with alsike being the first choice. Redtop grass was also a preferred seed in this area. In other areas of the state where the dikes are of peat, or are dressed with peat, canary grass was preferred. Rye was also used extensively in the East Central Area. Sweet clover was used along with canary grass in the Southern Area. In the West Central Area, where many of the dikes are sand dressed with peat, both canary grass and alsike clover were widely used. Quack grass and clover seeded in July and August proved to be good cover on sandy soils in the Woodruff District (Northeast Area). Self-seeded quack grass on sand dikes in the West Central Area was found to be a good soil binder. Another grass which proved useful on poor soils in the Woodruff District was panic grass. This grass provides good cover and does not burn easily.

To obtain a successful seeding on pure sand dikes, a mulch of 3-year-old hay was applied about 1 foot deep and was crisscrossed with binder twine tied to stakes to keep the mulch from blowing away. The "trail seed" mixture commonly used in the Northeast Area was seeded on dikes and excellent results were obtained. Prior to this, all seedings on these dikes were failures. This mixture is variable depending on soil types and location. The general composition used in the Northeast Area has been: Alsike clover at 5 to 8 lbs. per acre on lighter, better-drained soils (White Dutch clover is substituted for Alsike on heavy clay soils at 2 to 3 lbs. per acre); and Ladino clover at ½ lb. per acre. The tendency now is to use mostly White Dutch clover for trail seed. In the Crandon District (Northeast Area), dike seedings were mulched with wet hay 1 year old.

TABLE 3

Plants Seeded to Provide Dike Cover

Plant	Northwest Area Dikes Seeded No.	Northwest Area Dikes Seeded Percent	Northeast Area Dikes Seeded No.	Northeast Area Dikes Seeded Percent	East Central Area Dikes Seeded No.	East Central Area Dikes Seeded Percent
White Dutch Clover	1	1.7	4	13.8	-	-
Alsike Clover	1	1.7	7	24.2	-	-
Ladino Clover	-	-	1	3.4	2	11.8
Mixed Clovers	20	34.6	3	10.6	-	-
Bird's Foot Trefoil	2	3.4	-	-	-	-
Trail Seed Mixture	1	1.7	1	3.4	-	-
Rye	13	22.5	1	3.4	4	23.5
Winter Rye	7	12.2	1	3.4	-	-
Perennial Rye	2	3.4	-	-	-	-
Wheat	1	1.7	-	-	-	-
Winter Wheat	-	-	-	-	2	11.8
Timothy	2	3.4	-	-	-	-
Brome Grass	3	5.2	1	3.4	-	-
Alta Fescue	2	3.4	-	-	-	-
Redtop Grass	-	-	4	13.9	-	-
Canary Grass	-	-	-	-	5	29.3
Quack Grass	-	-	1	3.4	-	-
Jap Millet	1	1.7	-	-	-	-
Millet (spp.)	-	-	-	-	2	11.8
Oats	-	-	1	3.4	-	-
Buckwheat	1	1.7	1	3.4	2	11.8
Sod	1	1.7	2	6.9	-	-
Turnip	-	-	1	3.4	-	-
TOTALS	58	100	29	100	17	100

NOTE: West Central Area reported using canary grass and alsike clover but the number of seedings was not specified. Southern Area reported on two dike seedings, one using sweet clover and one using canary grass.

On the Mead Wildlife Area, dikes were seeded with a mixture of winter rye and canary grass immediately following construction. White clover was used in place of canary grass where the stabilizing effect of the canary grass was not needed. There seems to be little doubt that canary grass has the best stabilizing effects on peat dikes and is probably the best choice. The clovers, especially alsike, produce better results on sand and clay dikes.

Jute netting, called "erosion net", was used to protect a seeding on an emergency spillway in Taylor County. The species seeded were alta fescue and smooth brome grass. In this district, where seeded spillways are preferred to rock spillways, barnyard manure was used for mulch on emergency spillways with satisfactory results.

Information on various seeds and their normal seeding rates is shown in Table 4.

Sod was used on a number of developments, mostly for stabilizing emergency spillways. It produces excellent results, but is only practical on small spillways, since it involves time-consuming work and is costly, even though sod is cut nearby.

Dike Costs

Cost figures that can be used for comparisons have been rather difficult to find. Although total costs for dike construction could usually be obtained, the amount of material moved in the operation was often not available. However, average figures for the various dike dimensions were compiled along with costs per foot of dike constructed and these are compared on an Area basis in Table 2. Most diking was accomplished by dragline in the East Central Area, although final shaping was done by bulldozer. Average costs include only work done by dragline. Costs for dike shaping and leveling averaged about 6 cents per foot of dike.

Both the Northeast Area and the Northwest Area did most of their diking by bulldozer and cost figures for these areas include only bulldozer work. However, the Mead Wildlife Area was an exception in the Northeast Area and here dragline work was more popular. Cost figures for Mead are shown as a separate entry in Table 2 so that comparisons can be made with dragline construction done in the East Central Area. The average cost for dragline construction both at Mead and in the East Central Area was considerably less than for bulldozer work accomplished in the northern areas. Since the average dike in the northern areas was larger than the average dike in the East Central Area or at Mead, this is obviously one of the reasons for the cost difference. However, it could be expected that costs would be greater even if the dikes were of the same dimensions because of differences in the mechanics of construction. Many of the peat dikes constructed in the East Central Area were constructed without a core, thus reducing construction time and filling. Also, constructions by dragline utilized fill taken from beside the dike and this eliminated the necessity for moving fill from a distance.

For any particular method of construction, however, costs can vary considerably (Table 2). Equipment size, operator efficiency, soils, water table, and other operating conditions all enter into the cost figures. Cost figures presented here should be viewed in this light and no attempt should be made to use them for more than generalizations.

TABLE 4

Species Seeded for Dike Cover on Impoundments

Species	Size	Seeding Rate	Longevity	Soil Requirements	Characteristics
Legumes Alsike Clover Trifolium hybridum	1 to 3 feet tall	6 to 8 lbs per acre	Short-lived perennial	Successful on all soils except sand, including even wet, cold, acid soils.	Adapted to cool, moist climates with more than 38 inches of rain. Seldom winter-kills.
Birds foot trefoil Lotus corniculatus arvense	20 to 40 inches tall. Fine stem.	5 to 8 lbs per acre	Warm season perennial	Both dry and wet soils. Good firm seedbed essential. Spring seeding recommended.	Has a tap root with fibrous branching laterals. Good soil builder. Succeeds in northern areas.
Red Clover Trifolium pratense vars. Dollard Mammoth	2 to 16 inches tall	8 to 12 lbs per acre	Biennial	Most soils.	Dollard strain is the most winter hardy and resistant to disease. Mammoth strain is best on poor soils.
White Clover Trifolium repens vars. Ladino White Dutch	Ladino is 15 to 24 inches tall. White Dutch, low growing.	1 to 4 lbs per acre	Shallow-rooted perennial	Clay and silt soils. Excellent on low lands in mixtures. White Dutch succeeds on a variety of soils.	Creeping with surface runners which root at joints. White Dutch remains green in dry hot weather.
Sweet Clover Melilotus alba (white blossom)	White blossoms; 30 inches tall and coarse	10 to 15 lbs per acre	Biennials; sometimes annual forms	Neutral soil or limed	Drought tolerant--17 or more inches of rain required.
Melilotus Officinalis (yellow)	Yellow blossom; smaller and stools out closer to ground.	10 to 15 lbs per acre	Same	Neutral soil or limed	Yellow blossom more hardy and drought resistant than white blossom. It matures earlier and has a more reliable seed crop.

Species	Size	Seeding Rate	Longevity	Soil Requirements	Characteristics
Grasses					
Tall fescue <u>Festuca elatior</u> var. Alta	3 to 4 feet tall	10 to 25 lbs per acre	Perennial	Heavy organic soils in wet, poorly drained areas, but will withstand drought.	Deep-rooted with a long growing season. Excellent for erosion control in waterways. Forms dense turf.
Smooth brome <u>Bromus inermis</u>	3 to 4 feet tall	12 to 15 lbs per acre	Long-lived perennial	Well-drained clay loams. Good loose dry soil.	Requires moderate rainfall and low to moderate summer temperatures. Does not withstand extremes of low summer moisture and low winter temperatures. Excellent soil binder having strong creeping rhizomes.
Canary grass <u>Phalaris arundinacea</u>	Tall, growing in clumps 3 feet across. 2 to 6½ feet tall	5 to 10 lbs per acre	Long-lived perennial	Fertile, moist or wet soils. Best on muck and peat.	Winter hardy. Grows well even on upland soils which dry out for long periods in the summer.
Orchard grass <u>Dactylis glomerata</u>	1½ to 5 feet tall	6 to 15 lbs per acre	Long-lived perennial	Does best on rich soil but also does satisfactorily on light soils of medium to poor fertility	Cold resistant and one of earliest grasses to grow in the spring. Does well in shade and is excellent for erosion control in gullies. Tolerates more heat and drought then timothy, but winter-kills more easily. It is a bunch grass with no underground rhizomes.
Redtop grass <u>Agrostis alba</u>	3 to 5 feet tall	8 to 10 lbs per acre Fall seeding recommended	Perennial	Wide range of both dry and moist soils. Survives on highly acid soils. One of the best wetland grasses.	Strong creeping rhizomes produce a compact turf. Excellent erosion control.

Species	Size	Seeding Rate	Longevity	Soil Requirements	Characteristics
Ryegrass (common) <u>Lolium multiflorum</u>	2 to 3 feet tall	25 to 35 lbs per acre	Annual	Medium to high fertility	Provides quick temporary cover and acts as a nurse crop.
Ryegrass (perennial) <u>Lolium perenne</u>	1 to 2 feet tall	25 to 35 lbs per acre	Fast-growing perennial	Wide range of soils from medium to high fertility	Not winter hardy in severe climates. Slow to recover from drought and production declines in poorly drained soils.
Timothy <u>Phleum pratense</u>	20 to 40 inches tall	3 to 5 lbs in fall. 10 lbs per acre in spring	Short-lived perennial (3 to 5 years)	Rich moist bottom lands preferred, but adaptable to acid soils. Clay loams better than sandy soils.	Forms large clumps. Fall seeding is best.
Japanese millet <u>Echinochloa cursgalli</u>	Up to 6 feet tall	20 to 25 lbs per acre	Annual	Tolerant of wet acid conditions. Excellent on peats and mucks.	Susceptible to frost damage. Withstands flooding.
Proso millet <u>Panicum miliaceum</u>	Up to 39 inches tall	15 to 25 lbs per acre	Annual	Best on well-drained soils. Low moisture requirements.	Susceptible to frost damage.
Rye <u>Secale cereale</u>		90 to 160 lbs per acre	Annual	Best on fertile well-drained soils.	Provides good goose pasture and serves as a nurse crop for legumes.
Wheat <u>Triticum aestivum</u>		60 to 160 lbs per acre	Annual	Best on fertile well-drained soils	Provides good goose pasture and serves as a nurse crop for legumes.

Maintenance Problems

Sand dikes are susceptible to crayfish tunneling in the West Central Area. Although this type of damage does not appear to reach serious proportions, it does cause problems in maintenance.

Where large muskrat populations are present, muskrat damage can be a serious and expensive maintenance problem, especially in peat dikes. The problem may not be too serious if the dike is pure sand as was the case on the Meadow Valley Wildlife Area. The holes were filled with sand and damage was not too extensive. Holes in sand dikes were filled with peat on the Crex Meadows Wildlife Area and seemed to discourage muskrat use. Dikes constructed with mineral fill seemed to be the least susceptible to muskrat damage and maintenance problems were minimum. Cook (1957) noted that dikes composed of heavy clay soils were not damaged by muskrats even though high muskrat populations were present.

Various materials have been used to fill holes caused by muskrats. These included rotten granite, sand, rocks, peat and gravel.

Barriers have been utilized in several districts to discourage muskrats. Some of the old dikes constructed by the federal government in the West Central Area had barriers built in the center. These barriers consisted of Wakefield sheeting and in some cases chicken wire. Wakefield sheeting lasts for many years when it is buried in the dike. Chicken wire, if it is heavy gauge and galvanized, lasts about 12 years. Both materials appear to be effective, but in the West Central Area damage is never a serious problem and it is more economical to fill the holes than to put in barriers to prevent them. On the Sensiba Wildlife Area where damage has been extensive, Wakefield sheeting was jetted and driven in along about 150 feet of the dike having the most serious damage. This seemed to eliminate further damage in these sections.

On the Browntown Wildlife Area muskrat damage was repaired by digging a 4-foot-wide trench in the dike with a back hoe. The trench extended to the bottom of the dike and through the entire area that was damaged. This trench was filled with material taken from a borrow area beside the dike. This made a complete repair to the dike and reduced muskrat activity. As a preventive measure, rock riprapping was placed along the sides of the dike in a layer 2 feet thick. This material included fairly large boulders.

The National Resources Committee (1938) recommended that rock riprapping cover the area 3 feet below the normal low water mark to the maximum expected water level, which includes an allowance for wave action. To prevent muskrat damage, it should extend well above the high water mark. Riprapping can be quite expensive if a source of stones is not nearby.

On the Allenton Wildlife Area muskrat damage was controlled by making holes in the muskrat burrows with a bar, then dropping in a small handful of carbide and sealing up the holes with dirt. Soil moisture combined with the carbide to release acetylene gas which either drove out the muskrats because of the odor or possibly killed them. The results were quite satisfactory on this area. Perhaps the carbide could be loaded into empty shotgun shells and more conveniently inserted in the burrows by means of a pipe. After pushing the pipe into the desired location, the shell could be dropped into the pipe and forced out the other end and into the burrow by means of a rod or stick.

Cook (1957) reports that Hicks in Missouri used calcium carbide to control muskrats in dikes and found this method to be quite effective.

Carbide was tried on the Outagamie Wildlife Area but results were poor and adequate muskrat control was not obtained. Drain oil was poured into some of the holes. This drove muskrats from the damaged area, but it also killed the vegetation in the vicinity. In this district, fox-farm wire was used to control muskrats in lawn damage complaints. The wire was placed 4 feet into the ground, and although it effectively prevented them from digging tunnels at that point, the muskrats went over the barrier and dug new holes to their nests on the other side.

Cook (1957) found that heavily galvanized hardware cloth inserted in a dike before muskrat damage occurred or after the muskrats had been eliminated offered an effective barrier for about 4 years. Aluminum netting and poultry wire deteriorated rapidly in organic soils. The material that gave the best results was an asbestos cement sheet. These come in 4 x 8 foot sizes. When placed on edge in a trench dug along the upstream face of the dike, so that the bottom edge is located 2 feet below the water level and the top edge is 2 feet above, an effective and long-lasting barrier is provided. If muskrats were not eliminated from the problem area before the barrier was inserted, they tunneled beneath it in order to reach their nests on the other side. Cook found that the muskrat burrows were located an average of 7 inches below the water's surface, ranging from 0 to 20 inches. Asbestos barriers were installed by means of a mechanical ditcher. Costs should not exceed 50 cents per lineal foot including ditching, labor and material. Asbestos cement sheets were not affected by low soil pH, were more or less chemically inert, and their rigidity was increased by absorption of water.

A broad flat berm along the impoundment side of the dike with its top just above the normal water level of the impoundment will minimize muskrat damage even though it does not completely eliminate it. At Horicon Marsh where muskrat damage is of major proportions, berms of this type should be at least 20 feet wide. Attempts were made in some of the Horicon impoundments to eliminate muskrats by summer trapping in or near the dikes. Such measures proved very ineffective. For the effort expended (75 hours) only 15 muskrats were taken. Finding good trapping sets for a particular section of dike was not always easy. When impoundments contain good populations of muskrats, trapping is a never-ending job. As muskrats are removed from problem areas, more move in to take their place.

The U. S. Fish & Wildlife Service (1967) repaired muskrat burrow damage by blasting. They stated, "The blasting material (ammonium nitrate) is used to cave-in the burrow and seal off the leak. After locating the burrow, a hole is drilled about 3 feet deep directly above the burrow with a post-hole digger to accommodate a 15-pound charge of ammonium nitrate. Pack soil over the charge and detonate. The blast forces soil down and into the burrow sealing off the leak. After blasting, fill will be needed to level off the dike and pack to original elevation."

It would appear that not only does the blast seal the burrows, but also kills the muskrat or drives him from the burrow. This would eliminate the source of the trouble and should certainly be of value in cases where a muskrat barrier is planned.

Attempts have been made at Horicon to seal dike leaks by compacting the soil with a crawler tractor but results have been poor, since the deeper burrows are unaffected. Blasting, on the other hand, would compact burrows at all depths. If this technique proves effective on state impoundments, it would be more economical in manpower and material to make periodic dike inspections throughout the warm season to locate damage points and eliminate them before muskrats have a chance to become well established. The longer a muskrat occupies a burrow, the more extensive his tunnel system becomes and the more difficult the repair job. Cook (1957) found that in clay soils, burrows which had been in use for 3 or more years had 1 to 3 entrances and a complex system of tunnels, which may parallel the dike's direction, as well as cut through it at right angles. In peat dikes, tunneling would probably result in leaks long before 3 years. Tunnels cave in very easily and the 'rats are continually digging new ones to compensate.

Control Structures

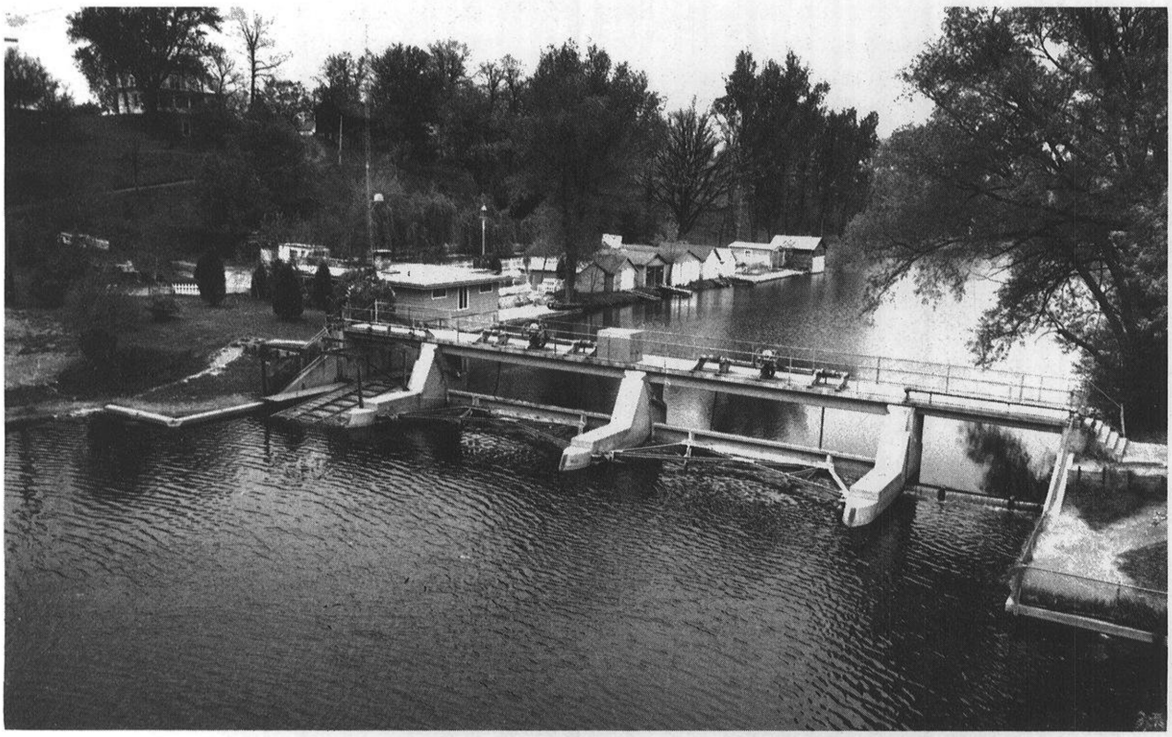
Control structures on Department impoundments vary from simple capped tubes to large radial gates mounted in concrete structures. The majority of the impoundments are equipped with a "tin whistle" or drop inlets. The tin whistle, or modifications of it, is probably the most popular type of structure for wildlife areas. This is probably because it is relatively simple to install and maintain, inexpensive when compared to concrete structures, and provides fairly good water level control. The simplest control is an overflow tube set at a fixed level without provisions for water level changes. If a drain tube is added, these structures will allow partial or full drawdowns.

Large Concrete Structures

These structures are used in larger impoundments and require construction by engineers. This discussion is confined to a brief description of the various types of structures.

Radial Gate Structures

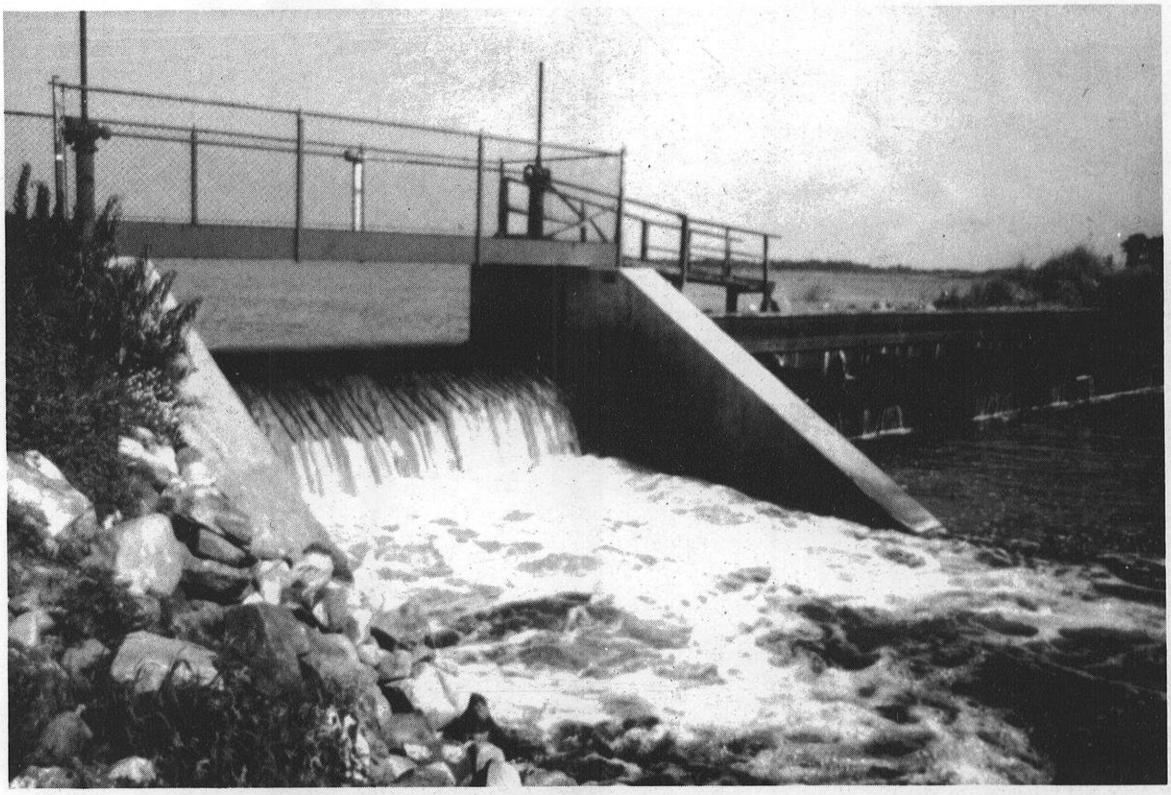
These are large steel gates which are mounted on control arms, the outer ends of which are pivoted to their mountings on the structure. Because the control arms are pivoted, the gate describes an arc through the radius of the arms as it moves up or down in opening or closing, thus the term "radial" gate. The edges of the gate and the bottom are sealed by means of heavy rubber flaps which are forced against the side of the gate channel in the structure by water pressure. Since these gates are extremely heavy, they are moved by pull chains fastened to a winch. Radial gates on large impoundments are highly desirable. It is false economy to handicap the potential of a large impoundment with and "economy" control structure which is not operable when conditions become critical.



Horicon Marsh dam. Note radial gates and stoplog bays.

Roller Gate Structures

Roller gate dams have sliding gates equipped with rollers which bear between the gate surface and its track to avoid the high lifting pressures required for operation of the ordinary sliding gate.



Germania Marsh dam, with sliding gates equipped with rollers.

Stoplog Structures

The Totogatic Wildlife Area has a large concrete dam which utilizes only stoplogs for control. It has 7 sections, each containing stoplogs which are 11 feet long. These are inserted in slots in the sides of the concrete abutments separating the various sections of the dam. Water level control is maintained by adding or taking out stoplogs. It is a laborious method which does not permit close water level control. During periods of peak flow it is difficult or at times impossible to remove stoplogs against the pressure of the water which forces the logs against the sides of their channels.

Eldorado Marsh Wildlife Area has another type of stoplog structure. Here two sections of stoplogs are used, each about 4-1/2 feet long, but the concrete abutments extend out into the impoundment so that the stoplogs are not easily accessible from the dike. The abutments are so located that when water is flowing at normal pool level or higher, the water flows over the two-side abutments as well as over the stoplog sections. There is no safe way to reach the stoplogs without some type of platform. Yet any platform placed directly on the abutments interferes with the water flow. Any turbulence created by obstructions will decrease the flow over the structure (National Resources Committee, 1938).

Eldorado Marsh control structure. Note that outer sections of the side abutments act as part of the spillway.

Stoplogs as the only means of control for large impoundments leave much to be desired. They do not give the precise control needed if impoundments are to be managed effectively. Many of the old control structures constructed by the Federal Government in the West Central Area are concrete and utilize stoplogs and drop inlets. Timber dams are also used with stoplog controls. Pilings were dip-treated and have lasted for 21 years.

Sliding Gates

Large impoundments may be controlled by sliding gates, but they must be of heavy construction and equipped with some sort of control mechanism for opening and closing. A commercially constructed Hydroflow steel gate is used in the Crex Meadows Wildlife Area for the 2,200-acre Phantom Lake impoundment. The gate is 3-1/2 feet in diameter and controls the water flowing through a large discharge tube. It is moved by a handwheel which raises the threaded control rod and gate.

Sliding steel gate used on Crex Meadows Wildlife Area for impoundment water level control. The handwheel on the top frame turns a threaded shaft attached to the gate and this moves the gate up or down.

Control Structures For Small Impoundments

High Tube Overflows

Small impoundments often do not warrant the expense of installing sophisticated control structures. This is often resolved by installing a simple overflow tube which is a horizontal tube of sufficient size to accommodate the expected spill (Fig. 4). Its lower edge is set at the height of the desired impoundment level and water rising above this point will flow out of the tube. Usually a grass or rock emergency spillway is also provided to accommodate excessive spill during flood conditions, should the tube become plugged or be inadequate to handle water from an exceptional storm. No water level manipulations are possible with this type of control, but if a low drain tube is also installed, pond levels may be lowered or the pond can be drained. This feature is highly desirable for impoundment management.

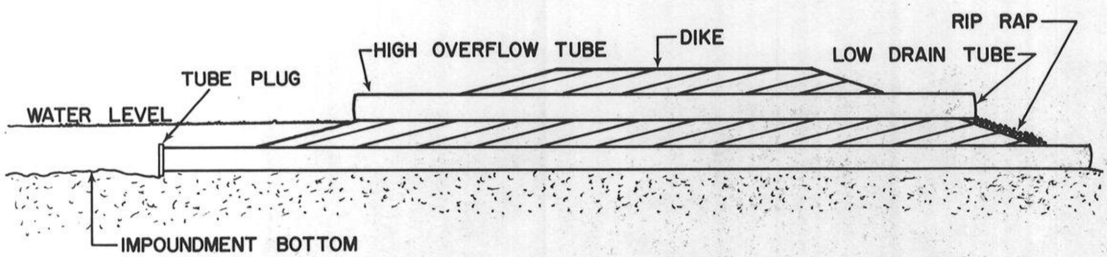


Figure 4. Control structures for small impoundments may consist simply of a horizontal overflow tube.

Capped or Gated Tubes

In small impoundments where heads are low, a single low tube can be installed (Fig. 4). It is capped from the impoundment side by a flanged wooden plug which just fits inside the tube and has a shoulder which fits against the end of the tube. It is held in place by water pressure from the impoundment side, but water levels must be quite shallow or it will be extremely difficult to remove the plug to drain the impoundment. Cost of a 12-inch capped tube is $60.

A much more satisfactory arrangement is to weld a header plate to the impoundment side of a low tube and install a sliding gate. The header plate is provided with slots formed by welding angle irons to the header and fitted with a steel or plywood gate. Usually the slots are made somewhat wider than the thickness of the gate, so that the gate will slide more easily when under water pressure. Any distortion of the gate will tend to cause its edges to bind in the slot unless there is sufficient clearance. Wooden wedges can be used to keep the gate in close proximity to the bearing surface in the slot.

On the Pershing Wildlife Area (Taylor County) a steel gate was used and instead of wooden wedges, 1/4-inch steel shims were placed in the slots. The gate was made of 1/4-inch steel plate. Steel seems to be superior to wood for gate material since it will withstand more abuse. At Horicon Marsh (Dodge County) plywood gates were used, but if it was necessary to open the gates in the early spring when ice was frozen in the slots, the gates were badly damaged before they could be opened. However, regardless of whether wood or steel is used, it must be of sufficient thickness or be reinforced in such a way that it will distort only very little under water pressure.

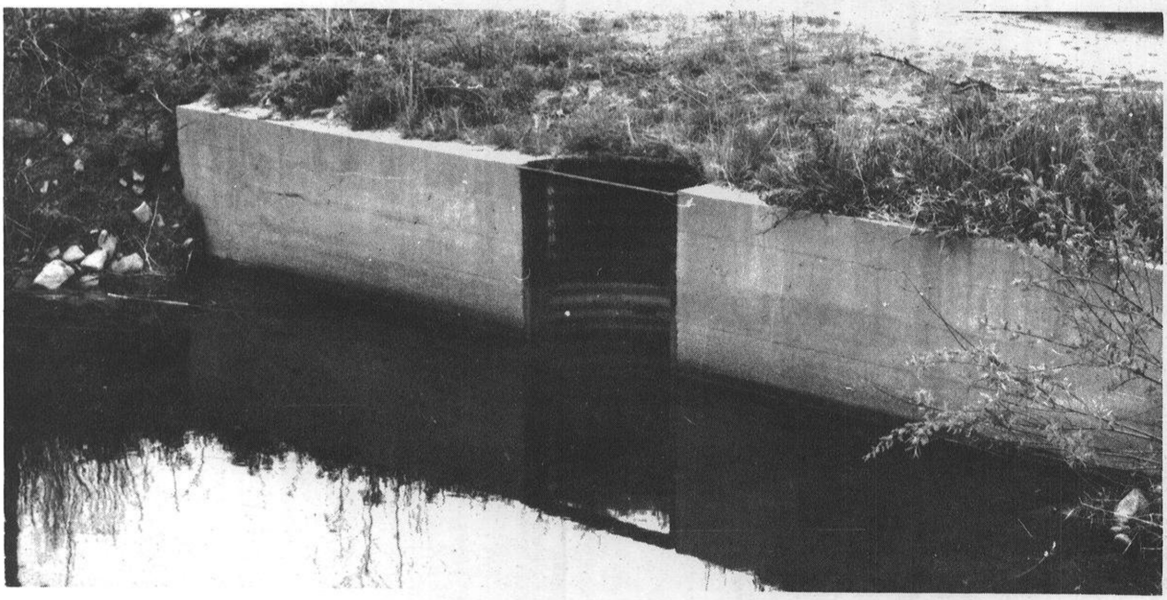
Header plates and plywood doors of 3 culverts 24 inches in diameter averaged about $40.14 per culvert at Horicon.

Outlet control structures used on small impoundments often incorporate a sliding gate. The sliding gate shown here is plywood, but metal is usually preferred because it is easier to remove and is less subject to ice damage. (Horicon Marsh)

In the Antigo District (Northeast Area) header plates were added to culvert drain tubes, but were equipped for stoplogs instead of sliding gates. These were 18-inch and 24-inch tubes. The costs for the entire structures were $65 and $70 respectively. Tubes equipped in this manner must be set so that the normal impoundment water-level range is below the top of the tube. Changes in stoplog height set the water level in the impoundment. If the water levels are to be above the top of the tube, all stoplogs would need to be in place and there would be no advantage in stoplogs over a regular gate.

Drop Inlets

These structures when constructed for fixed level flow are used mostly in ponds and are generally not utilized in Department impoundments. They consist of a vertical tube positioned at the desired water level. The lower end is connected to a horizontal tube which discharges through the dike. The vertical tube acts as an overflow tube which collects excess impoundment water. This type of structure provides no means for water level manipulation. Water levels can be maintained only at or near the level of the overflow tube. During periods of extremely high flow, the inlet cannot be opened wider to remove excess water. The only means for additional flow is over the emergency spillway when water levels increase. Unless a separate drain tube is provided, there is no means for draining the impoundment.



Drop-inlet structure used in West Central Area (Stoplog control)

A form of drop inlet which is occasionally used consists of a vertical tube or riser made from a half culvert opened along its length, with the open edges fitted with channels for stoplogs or flashboards. This vertical riser is attached to a horizontal discharge tube at its lower end. Height of the stoplogs in the vertical riser controls the impoundment overflow and water levels. This provides control for water level manipulations and if all flashboards are removed, the impoundment can be drained. Most of the impoundments equipped with this type of structure are located in the West Central Area. They vary in size, with stoplogs ranging from 48 to 60 inches long. Because of the drop inlet or overflow type design, only surface water is removed from the impoundment by the structure.

<u>"Tin Whistles"</u>

In this type of structure a vertical riser tube is usuually located in the impoundment dike. At its bottom end it is connected to a horizontal intake tube from inside the impoundment and also to a horizontal discharge tube leading out of the impoundment. The vertical riser is equipped with stoplog channels along its length. When stoplogs are inserted they separate the intake (impoundment side) and discharge openings at the bottom, thus forcing the impoundment water to rise up and spill over the stoplogs before it can discharge out of the impoundment. Height of the stoplogs, therefore, regulates the water levels in the impoundment.

Tin whistle control structure. A cover with a locking strap is usually used to close the top of the riser. This minimizes vandalism and prevents unauthorized manipulation of the stoplogs.

Since the horizontal tubes are located at the bottom of the impoundment, only bottom water is discharged from this type of structure in contrast to the drop inlet, where surface water is discharged. Bottom water discharge has some significance to the water chemistry of the impoundment and downstream discharge area. Since most of the dissolved substances and nutrients are located near the bottom, a bottom discharge system will remove a large portion of them from the impoundment (Cook and Powers, 1958:53). If the horizontal tubes are located deep enough, removal of the stoplogs will allow the impoundment to be drained. This is an important feature for proper management of the impoundment.

The tin whistle type of control structure is more widely used than any other type structure on Department impoundments, mainly because its simplicity allows it to be prefabricated, which keeps construction costs to a minimum. However, in the Grantsburg District (Northwest Area) where trouble has been experienced with frost heaving, drop inlets and gated tubes are preferred.

A modification of the conventional tin whistle is employed on the Mead Wildlife Area (Marathon County) where stoplogs were replaced by a sliding steel gate, which is operated by a handwheel. The handwheel turns a long screw shaft which raises or lowers the gate. The gate has two sections which slide across one another in such a way that the gate may be opened to allow flow from either above it or beneath it. This structure is much easier to operate than the stoplog control and it makes for better and more precise water level control. Operation is unaffected by heavy flows or flood conditions, and the operator merely has to turn the handwheel to adjust the gate opening. Cost of this type of structure runs much higher than a structure of similar size equipped with stoplogs instead of the gate. A stoplog-equipped tin whistle using 48-inch horizontal tubes and a 60-inch riser costs $750 while a steel-gated tin whistle with a 48-inch horizontal tube and 48-inch riser cost $1,300.

Tin whistle with sliding gate and handwheel control, Mead Wildlife Area.

Material Variations

There are a number of variations in construction materials and techniques used by various game managers throughout the state. Tin whistles have varied in size from 13-inch to 48-inch diameter horizontal tubes, while vertical risers have ranged upward to 6 feet in diameter (Table 5). Most of the tubes have been corrugated, asphalt-coated steel, but during the last few years there have been some installations which utilized corrugated aluminum. The first aluminum installation made in the Northeast Area was somewhat less expensive than a similar steel structure but the price is now higher than for equivalent steel tubing. The average cost for a 36-inch steel structure was $617 while the average cost of 36-inch aluminum structures was $747 (Table 5). Table 5 shows that there is a considerable range in price for structures having the same horizontal tube diameter. This is due to the fact that some structures required longer tubes than others for either the horizontal or vertical tubes or both and also the vertical riser diameter varied for any particular size of horizontal tube. Costs can therefore only be considered as average structural costs for comparing structures that have the same horizontal tube diameter.

Aluminum Tubing. The relative merits of aluminum tubing as compared to steel tubing are difficult to assess at this time, since none of the aluminum structures have been in long enough to determine their life span. Aluminum will not rust but it may corrode if chemicals in the water react with the metal. Aluminum trap tags submerged in the water for one trapping season at Horicon slowly dissolved away. Perhaps the composition of the aluminum used in the tubes will prove to be more durable. No complaints have been heard on corrosion so far, but at least one game manager found that aluminum structures were more difficult to install because they tended to bend much more easily than steel. He found that when back filling and compacting soil around the tube, he had to be very careful or the tube would flatten. The great advantage in the use of aluminum is that it is extremely lightweight and fairly large-diameter tubing can be handled by hand without the need for special equipment. This simplifies installation and reduces transportation costs.

TABLE 5

Construction and Cost Information on Tin Whistles

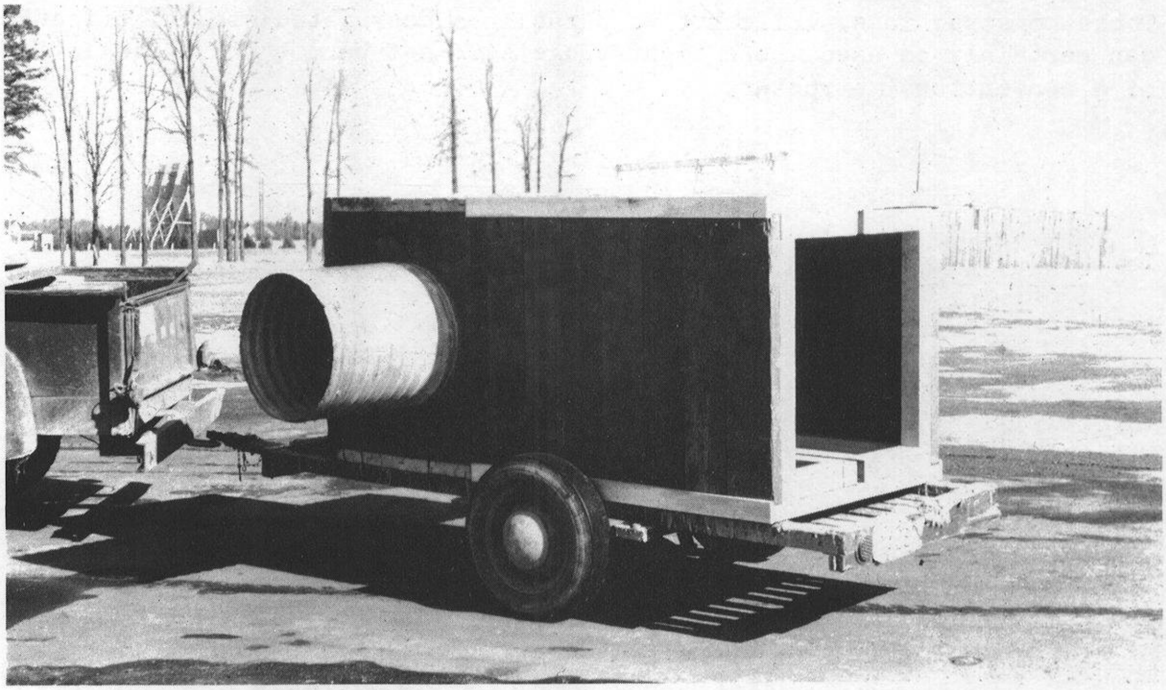
Size of Horizontal Tube	Size Range of Riser	Riser Size Most Used	Steel Structure Avg. Cost for Structure	Steel Structure Extremes in Cost	Aluminum Structure Avg. Cost for Structure	Aluminum Structure Extremes in Cost
13"	20" x 20"	-	-	-	-	-
20"	36"	-	900.00	-	-	-
24"	36" to 48"	36"	$402.08	$295-595	-	-
30"	40" to 54"	40"	634.31	400-1,000	-	-
36"	36" to 72"	48"	617.80	500-889	$747.25	$619-1,000
48"	48", 60", 72"	-	-	-	-	-

Steel Tubing. Usually steel tubes and nonbearing surfaces of the structures are coated with asphalt before installation to help preserve them from rusting. This is in addition to the conventional galvanized coating which is a factory standard. In some areas asphalt coatings are very short lived. In the Antigo District (Northeast Area) asphalt began to peel off in a matter of a few days, but rusting did not seem to occur. In the West Central Area, the asphalt coating also peeled off in a short time, but rusting accompanied or followed it. This appeared to be related to the soil and water chemistry of the area where the pipe was installed.

The Wisconsin State Highway Division has been having difficulty in certain areas with severe rusting of culverts and they are making a detailed study of this problem (Patenaude, 1967, pers. comm.). Preliminary studies indicate that soil and water tests which include pH and resistivity may be used to predict the location of corrosive sites. Areas within the state which are believed to contain corrosive agents have been mapped. The most extensive problem area lies in the west central counties and some counties of the northwest. In such areas it is well to take all precautions possible to protect structures. In extreme cases, concrete tubes and structures may be warranted.

Wooden Risers. Wooden risers have been used in various parts of the state. The West Central Area managers were probably the pioneers in this type of construction. The Antigo District (Northeast Area) has found widespread use for them, and the Campbellsport District (East Central Area) has been experimenting with a number of modifications. Essentially, they are square tubes constructed of 2-inch creosoted or pressure-treated planks. In the larger sizes the plank walls are 2 inches by 6 inches. The type of wooden control structure used in the Antigo District is shown in Figure 5. Horizontal metal tubes are bolted to the lower end of the riser by means of metal plates to which the tubes are welded. Stoplog slots are provided by two wooden rails bolted to the interior of the riser on each side and spaced for the width of the stoplogs. The main advantage of this type of construction is its low cost. A fabricated wooden control structure costs only about $140 in the Antigo District when salvaged lumber is used. Another advantage is that it is extremely rigid and not easily distorted when it is installed, or by subsequent frost action. Treated wood is relatively long lasting. Dip-treated pilings used in the West Central Area were reported still solid 21 years after being installed. Pressure-treated lumber could be expected to last even longer.

In the Campbellsport District (East Central Area) another form of wooden control structure was devised which substitutes the use of oil drums for corrugated culvert tubing in the horizontal tubes. Total cost of materials for a wooden riser constructed of new pressure-treated yellow pine or douglas fir and equipped with tubes constructed of six 55-gallon oil drums was $121 (Table 6). This did not include labor estimated at 4 man-days. Ends of the oil drums were cut out and the resulting tubes spot-welded together to form the desired length. Tubes were painted with Rustoleum primer to minimize rusting. Small control structures



Wooden control structure being transported to installation site (Antigo District)

Wooden control structure after installation (Antigo District) using 13-inch grease drums for tubes and 20-by-20 inch wooden risers have been in use for 10 years without trouble. Some of these utilized 2-by-8-inch salvaged lumber which was thoroughly creosoted before use. These constructions, while not as durable as corrugated steel fabrications, can certainly be used where tight budgets do not permit the installation of a conventional structure.

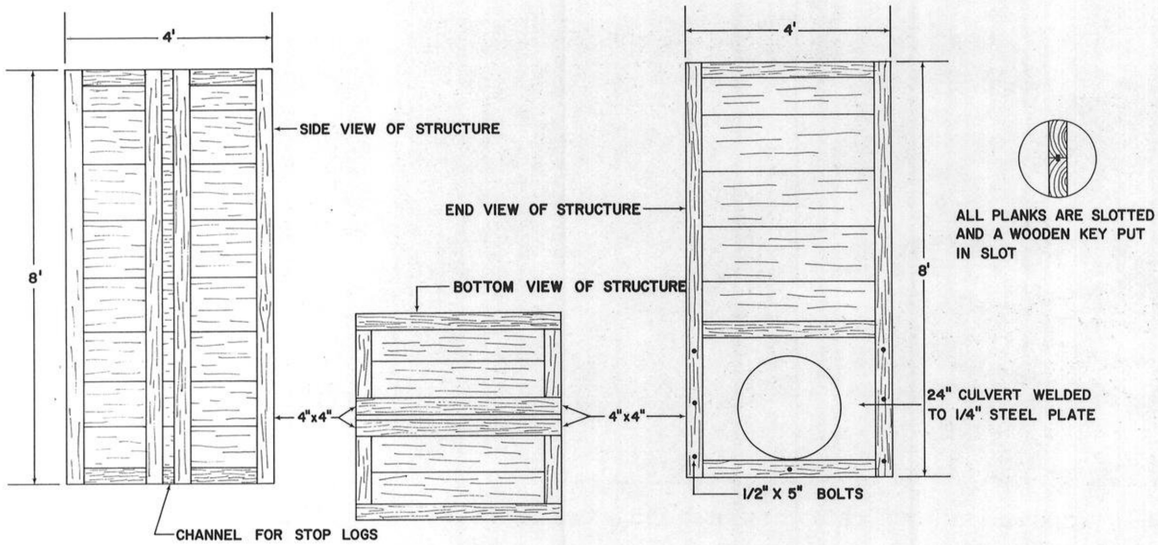


Figure 5. Wooden control structure used in the Antigo District. (Drawing by Glenn Kloes)

TABLE 6

Cost of Wooden Control Structures Equipped With Oil Drum Tubes (Campellsport District)

LUMBER:	
342 lineal feet of pressure treated Douglas fir or yellow pine 1-3/4" x 6"	$ 87
40 lineal feet of 4" x 4" braces	10
HARDWARE:	
. . . .	6
TUBES:	
Six 55 gallon oil drums	18
	$ 121

NOTE:

1. Bottoms are cut out of oil drums and they are spot-welded together end to end. Completed tube is painted with Rustoleum primer to reduce rusting.

2. About 4 man days of labor are needed for construction.

Concrete Culverts. Concrete culverts are seldom used on Department impoundments. They are more costly and much more difficult to install than the metal culverts. Pipes must be perfectly aligned on undisturbed ground and they should be supported on concrete cradles which are poured at intervals along its length. Cradles poured at joints may serve the dual purpose of sealing the joint and by increasing its size act as an antiseep collar. Careful work in installation is required to prevent misalignment or settling which could rupture the pipe and cause leaks (Atlantic Waterfowl Council, 1959 and Soil Conservation Service, 1958). In acid waters where severe rusting is a problem with metal pipe, the installation of concrete pipe and structures should be investigated.

General Considerations

Stoplogs

Stoplogs may be constructed from most any structural lumber, either treated or untreated (National Resources Committee, 1938). Pressure-treated lumber is the most economical because of the severe service to which they are subjected. However, these allowable stresses should be reduced by 20 to 40 percent for use in extreme conditions of alternate wetting and drying of untreated lumber. Size or thickness of the logs will vary with their length and the head of water to which they will be subjected. Maximum spans or lengths recommended for various thicknesses and heads of water are shown in Figure 6. These figures were abstracted from charts compiled by the National Resources Committee (1938). It is recommended that design stresses be kept conservative since undersized stoplogs under full stress may deflect or bend suffiently to cause the stoplog to bear heavily on the inside corner of the stoplog slot and make it extremely difficult to remove. Two-inch-thick stoplogs were used in a 6-foot span on Powell Marsh Wildlife Area and trouble was experienced with the stoplogs deflecting and popping out under a full head of water. Three-inch-thick logs should have been used. This same structure also had the stoplog channels coated with asphalt and this made it more difficult for the stoplogs to slide and increased the problems of removing them.

Stoplogs may be matched lumber with tongue and groove or half laps, or they may be plain edged. However, considerable leakage will be prevented if they are matched lumber. Uhler (1956) described control structures which have two sets of stoplogs with a space of 8 inches between them. This space was filled with carefully packed clay to prevent any leakage. Bottom stoplogs were set in key slots in the sill and all logs were pressure-treated white oak 2 x 8's. As is done in most Department impoundments, thin wooden wedges were used to hold the logs tight against their channels and prevent them from shifting. Double stoplogs appear to be unnecessary for the average Department impoundment, since leakage is usually rather minor. The National Resources Committee (1938) recommended that the bottom stoplog should be fitted with a rubber gasket which may be a length of rubber hose. This will prevent leaks at the sill.

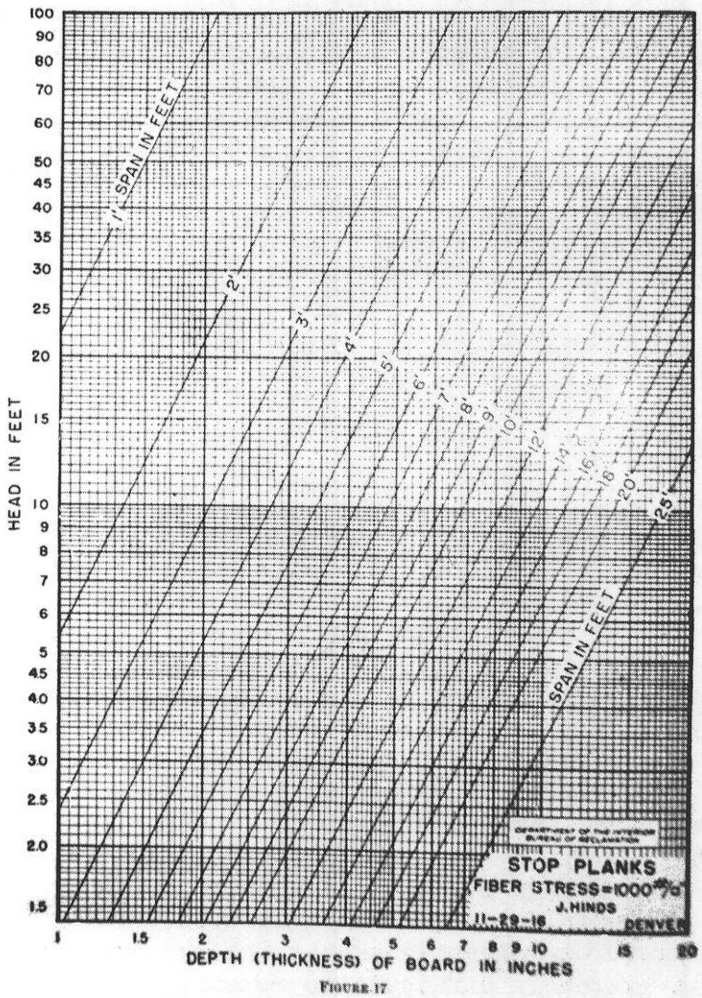


Figure 6. Recommended stoplog dimensions (from National Resources Committee, 1938).

Stoplog removal is difficult when the logs are under water pressure. It is a common practice to equip each stoplog with a screw eye bolt at each end, so that hooks can be used to remove the logs. On the Sensiba Wildlife Area a heavy loop of strong wire is attached to the screw eyes in the stoplogs; using a board as a lever the stoplog is pried out by putting leverage on the wire loop. Much less effort is needed using this method than if the logs are pulled with hooks. To decrease water pressure on the stoplogs while they are being removed, a sheet of 3/4-inch plywood is placed in front of the horizontal tube on the impoundment side of the structure.

On the Crex Meadows Wildlife Area trouble was experienced with large ice chunks splintering the stoplogs on drop inlets during the spring breakup. This was alleviated by dumping a load of sand in front of the stoplogs so that ice chunks struck the sand first and were cushioned. With tin whistles, ice is no problem since water is being drawn off from the bottom of the impoundment and large chunks of ice do not enter the structure if the tubes are deep enough.

Antiseep Collars

Proper installation of antiseep collars on horizontal tubes will prevent water from seeping along the tube and eventually causing severe leaks or a washout. Washouts at the control structure can be costly.

These collars are flat metal plates or fins which are clamped or welded to the tube to act as a vertical barrier to any flow of water. In the case of concrete pipe, the collars are concrete slabs poured around the pipe.

The Soil Conservation Service (1958) recommended that all lengths of metal corrugated pipe be joined together with the usual water-tight bands manufactured for this purpose and that metal antiseep collars be installed 4 feet above the dike center where these pipes pass through the dike as in overflow tubes, drain tubes, and drop inlets. If the total length of tube exceeds 60 feet, then antiseep collars should be installed at the 1/3 and 2/3 points on the upstream side of the dike. The Atlantic Waterfowl Council (1959) stated that a single collar at 4 feet above the dike center is inadequate for corrugated pipe and that another should be located near the center of the dike or at the second pipe joint. The National Resources Committee (1938:114) pointed out that the National Park Service requires that antiseep collars or fins have a minimum projection of 3 feet and completely encircle the tube on all sides; and that the spacing of these fins, "... shall be such that the increased length of the path around the fins shall not be less than 20 percent of the length of the conduit."

Riprapping

It is a common practice to use stone riprapping around the entrance and exit of the control structure tubes to prevent sloughing and erosion which could eventually result in a washout. Since slopes are often fairly steep, they are usually riprapped with stone. However, in some areas stone is difficult to obtain and a number of managers have turned to using cement bags. Ordinary cement bags or burlap bags especially manufactured to a small size can be used for this purpose. They are filled with a mixture of gravel, sand and cement. In most cases the proportions have been 4 parts gravel, 3 parts sand and 1 part cement. Too much sand and too little cement will prevent the mixture from setting hard. However, the National Resources Committee (1938) recommends a mixture of cement and gravel in the proportions of 8 gravel to 1 of cement. This would be a somewhat cheaper mixture, but the omission of sand probably makes it as strong. The material should be mixed dry and sacked. It is then laid in place, shingle-fashion. After a layer is in place, the sacks can be thoroughly soaked with water to cause the mixture to set. This makes a durable form of riprapping which holds in place better than stone, since the sacks take on the shape of the sacks beneath and the area they are laid on.

Rock riprapping (Rhinelander District)

Cement bag riprapping (Antigo District)

Where no other material is readily available, the National Resources Committee (1938) recommends the use of a "willow mattress". This consists of tying together 1- to 2-inch diameter willow saplings with wire in bundles of 12 to 18 inches in thickness. These bundles are used to cover the area to be protected. Bundle lengths vary as needed up to 20 feet.

On the Spring Creek Wildlife Area, blacktopping was tried on the emergency spillway as a riprapping, but it gave very poor results, since the water broke it up and washed it away in pieces.

Placement of the Control Structure

In the Ladysmith District (Northwest Area), control structures which will impound stream flow were never located directly in the streambed, but were placed in firm ground next to the stream. Mucks in the streambed would cause the structure to shift and raise, making it difficult to obtain a tight seal around the structure. By locating the structure in firm ground a bulldozer could be used to do the excavating instead of a dragline or other specialized equipment hired just for this purpose. With the control structure placed on an undisturbed base, back fill was packed solidly to form a tight seal around the structure. The tube was often located slightly above the stream level to make the construction easier and improve the quality of the installation. The Atlantic Waterfowl Council (1959) stressed that proper compaction of the backfill around the structure tubes is extremely important to assure that there will be no leakage along the pipe which could eventually result in a washout.

Problems

On the Powell Marsh Wildlife Area a steel tin whistle with a 6-foot riser was installed. Frost action put uneven stresses on this structure and distorted the riser into an egg shape at the top and caused the stoplogs to bind. It was necessary to cut the stoplogs to fit the distorted channels. Since the distortion was uneven, the logs had to be numbered and kept in their proper order to operate the structure in this condition. Where frost action is a problem on large risers it would be helpful to reinforce the riser at ground level to prevent distortion. This could be accomplished by pouring about a 6-inch thick concrete slab around the riser at ground level. The slab should contain reinforcing rods to strengthen the concrete and hold the riser in shape.

Powell Marsh is located in an area where the soils and water have an extremely high iron content. This presents a problem which is probably unique to this particular area. Iron bacteria of the genus *Lepotothrix* precipitate out ferric sulphate on their cell walls. These bacteria are present in such large numbers that they produce a brown scum on the water, which builds up to form flocculent masses. In addition to being offensive to look at, this scum cuts down light transmission in the water and eliminates any desirable submergents. Only 3 ppm of iron in the water will cause trouble of this sort; water at Powell Marsh contains 16 ppm. Control was attained by treating the water with copper sulphate to kill the bacteria.

In the northern and western parts of the state, beaver often plug culverts and outlets in impoundments and their water courses causing the water levels to rise to flood proportions. A constant vigil must be maintained so that obstructions can be removed before impoundment damage results. Beaver are presently being controlled by trapping and by blasting their dams and lodges.

Pumps

To flood or increase water depths in high-contour areas in the impoundment the most practical approach is to subimpound by diking and raise the water in these subimpoundments while still maintaining the desired water levels in the main pool. This can be accomplished either by diverting part or all of the source water into the subimpoundment first and then letting it spill over into the main pool, or by lifting water into these subimpoundments by means of pumping equipment.

Diversionary structures many times are initially more expensive on a large impoundment than are pumping installations, but over a period of years the maintenance and operating costs of pumping will gradually cause the pumping development to lose its economic advantage. However, since a gravity diversion system requires that water levels in the stream above the impoundment be raised to gain the necessary advantage in head, this may be impractical if other interests along the floodplain of the stream will be adversely affected. Pumping is the only alternative if such impoundments are to be flooded.

Eight different state-owned wildlife areas had pumping developments or were about to begin developments at the time of this survey. They are listed in Table 7. All developments are of relatively recent origin, none having been in use more than 8 years. As a result, much can be learned from additional experience with this equipment. There are mechanical and technical problems which must still be solved. The Horicon Marsh Wildlife Area had 4 subimpoundments, each with an individual pumping station. This was the first state area to have pumping equipment installed. The pumps were all designed by Department personnel. One was constructed by Mayville Metal Products and the others were made by the Hafemeister Company (Table 8). Three were powered by gasoline engines and one utilized an electric motor. Electric motors were used on only two state wildlife areas.

TABLE 7

Pumping Developments

1. Horicon Marsh Wildlife Area	
(a) Redhead Impoundment	13-inch pump
(b) Greenhead Impoundment	15-inch pump - electric
(c) Burnett Impoundment	15-inch pump
(d) Mieske's Ditch Impoundment	
2. Outagamie Wildlife Area	15-inch pump
3. Sensiba Wildlife Area	15-inch pump - electric
4. Mead Wildlife Area	24-inch pump - diesel
5. Crex Meadows Wildlife Area	24-inch pump
6. Sheboygan Marsh Wildlife Area	15-inch pump
7. Princess Point Wildlife Area	
8. Theresa Marsh Wildlife Area	6-inch Lang

There are four different types of pumps which are suitable for high capacity pumping: propeller, mixed flow, centrifugal and turbine. The propeller pump is the best for low-head, high-capacity pumping required in wetland work, where the heads seldon exceed 10 feet. The mixed-flow pump is a hybrid of the low-head propeller pump and the high-head centrifugal pump, having an impeller which is a combination of the two. It is used principally in irrigation work where moderately high pumping heads are needed. The turbine pump is used principally in pumping from wells where very high pumping heads are required. All pumps used on state-owned wildlife areas were propeller pumps. Propeller sizes varied from 6 inches to 24 inches and pump capacities from 600 to 23,000 gallons per minute (gpm). A listing of pumps and associated data are shown in Table 8.

TABLE 8

Pumps Used on Development Areas

Location	Propeller Size (Inches)	Pump (rpm)*	Capacity (gpm)	Head (Ft.)	Pump Cost	Installation Cost	Kind of Pump
Horicon Marsh Redhead Impoundment**	13	1,650	3,000	3.5	$ 520.66	$ 296.80	Mayville Metal Products (mfg. according to plans supplied by DNR)
			3,500				
			6,187	2.73			
			5,300				
Horicon Marsh Burnett Impoundment**	15	750	4,000	-	517.12	349.60	Hafemeister
		950	6,000				
		1,100	8,500				
			8,748				
		1,166	10,000				
		1,300	10,395				
Horicon Marsh Greenhead Impoundment	15	-	-	1.5	575.00	-	Hafemeister
Horicon Marsh Mieske Impoundment	15	-	1,520[1]	-	93.52	-	Home-made
Sensiba Wildlife Area	15	-	-	3	575.00	-	Hafemeister
Outagamie Wildlife Area	15	-	-	4	575.00	-	Hafemeister
Sheboygan Marsh Wildlife Area	15	-	-	5	575.00	-	Hafemeister

TABLE 8 (continued)

Location	Propeller Size (Inches)	Pump (rpm)*	Capacity (gpm)	Head (Ft.)	Pump Cost	Installation Cost	Kind of Pump
Mead Wildlife Area	24	500 to 750[2]	23,000	8 - 10	658.75	-	Nekoosa
Crex Wildlife Area	24	500 to 750[2]	23,000[2]	8 - 10[2]	658.75	-	Nekoosa
Theresa Marsh Wildlife Area	6	-	600[2]	6[2]	250.00	-	Lang

(All Hafemeister Pumps were manufactured to Department specifications)

* All pumps in East Central Area presently operating between 1,306 and 1,350 revolutions per minute (rpm) (except Theresa Marsh pump).

** Remodeling resulted in changes in output rpm.

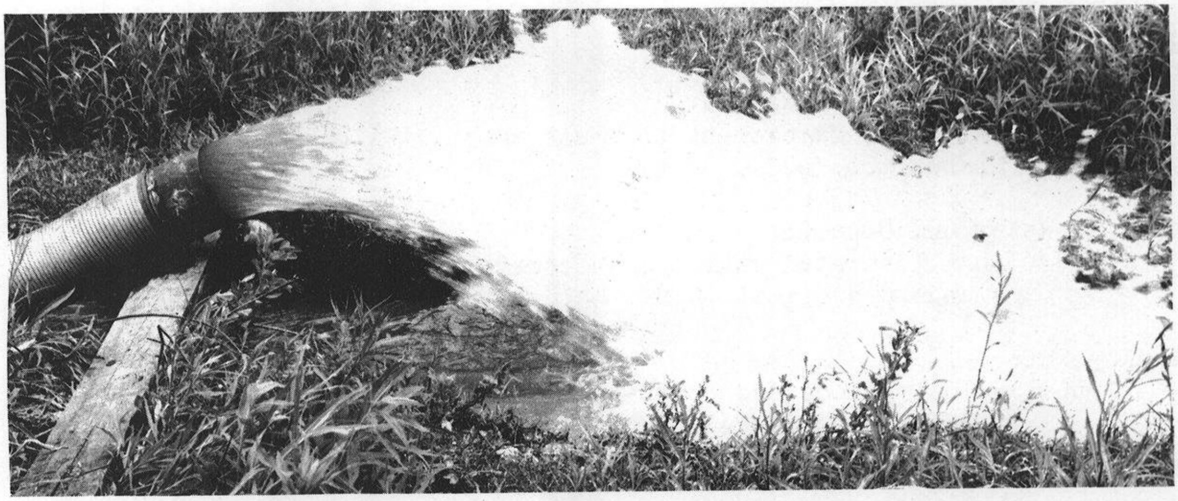
1 Calculated from available data.

2 Manufacturers rating.

In 1956 the Fur Research Project of the Wisconsin Conservation Department developed a portable pump which utilized a 10 horsepower outboard motor as a power unit (Linde, 1960). This pump was primarily designed to clean semifluid mucks from level ditches, but its relative high capacity made it a practical unit for flooding or draining small ponds and impoundments. Although it is only a 6-inch pump, it has a capacity of between 1,000 and 1,500 gpm when pumping water at low pumping lifts. A 5-acre pond was completely drained in 35 hours pumping time with one of these pumps. Outboard pumps have been used in both the Northeast and West Central Areas for draining ditches and small impoundments. Pumps of higher capacity could easily be constructed by utilizing higher horsepower outboard motors equipped with larger pump housings and impellers. It should be possible to increase pump capacity several times over that of the smaller 6-inch pumps.

The advantage of the outboard pump is its portability. The pump housing adds about 12 pounds to a standard 10-horsepower outboard motor. Thus a pump can be moved from one small impoundment to another and individual permanently mounted pump stations become unnecessary. The Michigan Conservation Department constructed several pumps utilizing modifications of the Wisconsin plans. Outboard motors of 50 horsepower were used for the power units. Their pumps were used for regulating water levels in small fish spawning marshes (U. S. Bureau of Sport Fisheries and Wildlife, 1961:4, 11). In New York state the owner of a private waterfowl marsh cleaned several miles of shallow level ditches with an outboard pump. Since the development of the Fur Research outboard pump, commercial pumps in the portable class have come on the market. Generally these have a considerably smaller capacity than our outboard-type pump.

Portable outboard pump operating from the stern of a small pram.



Water discharging from the 6-inch discharge tube of an outboard pump.

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WATER LEVEL MANIPULATION

The simplest and most widely used method for flooding wetland developments is gravity flow. A section of a stream or runoff drainage area is impounded and water fills the impoundment by gravity flow. However, it is obvious that this technique is necessarily restricted by the contours of the wetland basin and the size of the dikes impounding the area. In most large impoundments there will be areas of higher elevation that cannot be flooded without increasing the size of the structure and the freeboard on the dikes. This is usually uneconomical.

Adding more water over the entire impoundment to flood shallow peripheral areas would increase water depths in the center to the point where much of the emergent vegetation would be eliminated by deep flooding. This would decrease the value of the main portion of the impoundment for puddle ducks, furbearers and other wildlife by making it into an open-water lake.

It is highly desirable to keep open water areas 18 inches deep or less for puddle duck use. The goal should be an interspersion of open water and emergent cover. This can be maintained only by water level manipulations, since high water tends to open up and eliminate emergent vegetation and low water levels tend to increase vegetation density and close in open water areas.

By alternating draw-downs and flooding in varying degrees and in proper sequence, it is possible to change the habitat, control plant succession, and produce food crops for wildlife.

District game managers have expressed the following objectives for manipulating water levels in their impoundments:

1. Increase waterfowl breeding habitat by increasing water depths to create a better interspersion of cover.

2. Kill out sedge-grass monotypes and brush by flooding to bring about a succession of plants from moist soil and upland types to shallow and deep water aquatics.

3. Increase the production of natural food for waterfowl by the use of summer draw-downs.

4. Provide mudflat areas for artificial seeding of waterfowl food plants by summer draw-down.

5. Make it possible to till the bottom for food patch planting by removing the water.

6. Bring back desirable cover plants which were lost due to wave and ice action and continuous deep-water flooding through the use of draw-downs.

7. Control muskrat damage to dikes by reducing muskrat populations through winter draw-downs.

8. Control carp reproduction by lowering water levels immediately after the spawning season to strand eggs and fry in shallow temporary pools.

Mechanics of Water Level Control

Impoundment Potential

Before manipulating water levels in an impoundment or setting up a management plan, the following questions should be considered in determining its potential for producing the desired results:

1. Is adequate control of the water levels possible, or is control primarily related to the weather? In other words, in the event of a draw-down, is the flow sufficient to permit refilling of the impoundment within a reasonably short period of time when needed? Impoundments with uncertain reflooding capabilities are best managed with water levels at close to full pool. Annual reductions in summer water levels are risky since there is no assurance that the impoundment can be refilled in the fall.

2. What are the food production capabilities of the impoundment, assuming that unrestricted regulation of the water levels is possible? Will the area produce good growths of desirable food plants if mud flats are exposed? Some impoundments, especially in the Northeast Area, are only poor to fair in this respect and annual draw-downs certainly are not warranted. A full or partially full pool during the summer may produce some duck broods, but a dry or semidry impoundment will produce little or nothing that is desired.

3. What natural food plants are present? Are submergent food plants present in sufficient quantity for management to be attempted? Know the ecological potential of the area before deciding on a water level management plan. Manage within its capabilities. Response to management practices will vary with the capabilities of the area, and these practices should not be used indiscriminately or as "cook book" formulas.

Records

On impoundments of 1,000 acres or more a record of water-level controls should be kept since it can be an invaluable aid in planning future management on the area and in predicting control measures. A water-level gauge should be installed above the structure and readings should be taken periodically, preferably weekly. If a record is also kept on control-structure regulations, precipitation and vegetation changes, a better knowledge will be gained of the functioning of the impoundment in relation to the habitat.

Flow

The critical time for water control is in the spring at the time of break-up. If a heavy flow is not anticipated and corrective measures not taken early, flood conditions will ensue. When ice breaks up, the portions that are frozen into emergent vegetation will rise with flood waters and tear loose the vegetation and bog. Large areas can be denuded of vegetation in a single spring when these conditions occur. Vegetation destruction occurred at the Horicon Marsh Wildlife Area (Dodge County) where large sections in the center of the marsh lost vegetation (Linde, 1962). This problem can be alleviated if, when the spring thaws occur at the beginning of the break-up, the control structure is opened to draw off the impounded water. Usually the water levels will drop drastically within a short space of time as the free water is drawn off. However, this apparent draw-down is only temporary; the heavy flows from runoff will quickly replace it. The low gauge readings are not true readings, since much of the impounded water is bound as ice and will be released when the break-up and melt begins. This technique of operation will usually hold water levels below flood levels and the structure can again be closed as soon as the high flow conditions have subsided.

Evapotranspiration and Water Losses

Water losses from a wetland area may reach critical proportions during a dry period if the source of water for the impoundment is upland drainage or a stream having an intermittent or unreliable flow. During the months of July and August losses due to evaporation and plant transpiration are maximum. High air temperatures contribute to a high rate of evaporation and plants having reached their maximum growth are transpiring large quantities of water from leaves to the atmosphere. The magnitude of this loss is rather difficult to imagine. Holt (1965:9) reports that in Portage County, "The estimated annual evapotranspiration from about 44,000 acres covered by surface water bodies is about 110,000 acre-feet". Evapotranspiration is the sum of the combined water losses due to evaporation and plant transpiration. Computing from Holt's figures for Portage County, this loss would amount to about 2.5 acre-feet of water per acre per year where surface water is involved or about 814,572 gallons for every acre.

On land areas, evapotranspiration losses vary with soil moisture, but on flooded areas it is always at maximum potential since soils are completely saturated. The higher the aquatic plant density the greater the transpiration losses. It is obvious, therefore, that evapotranspiration losses are a major factor to be considered in impoundment management. If the source of water for an impoundment is of insufficient magnitude to overcome this high loss during the period of maximum evapotranspiration (Linde, 1962 and 1963), a declining impoundment level will result. With some impoundments this will be an annual occurrence and in others it will occur infrequently or not at all. If it does occur, then any planned summer draw-down must take into consideration that if the draw-down is partial there will be a further decline in water levels by midsummer and that an early fall recovery may be doubtful. Evapotranspiration losses can be a help in attempting a summer draw-down (Linde, 1962 and 1963) but they can be a distinct liability when trying to maintain water levels in an impoundment which has an unreliable water source.

Draw-Downs

The planned draw-down of normal water levels can be an efficient and productive technique in marsh management providing that an adequate control structure and a reliable source of water are available. Unless the source of water for the impoundment is dependable and of sufficient magnitude so that it can be relied upon to refill the impoundment within a reasonably short period of time, attempts to produce waterfowl food crops by the draw-down technique should not be attempted. It is of little value to produce a bumper crop of waterfowl food which cannot be made available to the waterfowl because there is no water available to flood the crop. Addy and MacNamara (1948:61) state, "Water supply should be of sufficient magnitude to allow the water levels in the impoundment to be controlled by spillway manipulation rather than by the vagaries of the weather."

Purpose of Draw-Downs

Food Patch Establishment

If the bottom soils are to be tilled and planted to food patches, the draw-down should begin early enough so the soils will have time to dry out sufficiently for mechanical tillage and planting. This, of course, will vary with the weather and the season. However, the average date used by East Central Area managers for this type of draw-down was April 26. This date should be adjusted for other areas of the state according to local differences.

In the Burnett subimpoundment of Horicon Marsh Wildlife Area it is seldom possible to reduce the groundwater table sufficiently by gravity drainage to allow food patch tillage at the desired time. Since this impoundment is flooded by pumping, the pump can be reversed and water pumped out of the peripheral ditches inside the impoundment until the groundwater table is sufficiently reduced. This may entail a series of pumpings since seepage refills the ditches after pumping stops for the day.

Mud-Flat Food Production

Where no tillage is involved and the impoundment is drawn down to obtain volunteer growths of smartweeds and other food plants, the draw-down can be started somewhat later in spring since volunteer growths will appear as soon as the water table has receded below the surface. The average date used by managers statewide for this type of draw-down has been May 28. If the mud flats are to be hand-seeded or seeded by plane, without use of equipment in the impoundment, the draw-down can begin about the same time as for volunteer growths. The average date has been about June 1.

These are average dates offered merely as a guide. Mud flats can also be exposed by a series of water level reductions over the span of several weeks. Since the range of bottom elevations exposed by any one water level reduction is relatively narrow, moist soil conditions for maximum seed germination are easily maintained and excessive drying at higher elevations is prevented. On Germania Marsh Wildlife Area (Marquette County), three 18-inch water level reductions were made at weekly intervals beginning June 7. Three days after each water level reduction the mud flats in the most recently exposed zone were aerially seeded to millet.

Muskrat Control

Where muskrats burrow into impoundment dikes and cause damage, draw-downs have been used as a form of control. On Horicon Marsh Wildlife Area the subimpoundments have been drawn down in November and on Vernon Marsh Wildlife Area the draw-down was from September through December. While this technique will serve to keep muskrats in the impoundment in check, it may not eliminate the animals which are doing the damage. Since most dikes in subimpoundments are constructed by digging a ditch and using the soil obtained to construct the dike, muskrats living in the dike will still have access to water in the ditch even after the impoundment is dry, unless this ditch can be drained completely. This is seldom possible due to the high groundwater tables in most marshes.

It is also a common practice in some of the smaller northern impoundments which use simple control structures to draw the impoundments down immediately after the hunting season. Since spring runoff is relatively large, draw-down of the impoundment makes room for the spring runoff and puts less strain on the dikes and structure. Where muskrats are a desired crop this practice should be avoided.

Effects on Wildlife

Waterfowl

If a complete summer draw-down occurs in a subimpoundment which is adjacent to other water areas or subimpoundments which remain flooded, the effects on breeding waterfowl will probably be negligible for that general area. However, if the impounded area which is drawn down is the only water available in that vicinity, it may have a negative effect on local waterfowl production. Birds will have to move to other water areas during the breeding season and any breeding tradition which has developed for that area will certainly be set back or lost. It is important, therefore, to keep at least one impoundment on an area at full pool during the breeding season. If there is only one impoundment, then the draw-down should be only a partial one. This would keep some water available for breeding birds and broods. When the lower impoundment on Germania Marsh Wildlife Area is drawn down it is kept 6 inches above full draw-down so that 50 acres of water can be maintained for waterfowl broods. It would seem unwise to completely sacrifice brood production for the sake of attracting migrant birds during the hunting season.

A factor to consider when making a draw-down on a wetland area which has sustained heavy waterfowl shooting for years is the danger of lead poisoning if normal water levels are not regained by fall. The lead shot buildup on some of these basins has been sufficiently large that geese pick it up with their food when it becomes exposed by drawn-down conditions. Lead poisoning of geese occurred during the Horicon draw-downs of 1962 and 1963 when it was not possible to regain normal water levels by fall, and again when Fox Lake was drawn down under similar circumstances in the winter of 1966-67.

Muskrats

Summer draw-downs do not afford optimum conditions for muskrats. However, if reflooding occurs in the fall before freeze-up, they do not seem to suffer appreciable mortality. No doubt they are more susceptible to predation during this period, but no figures are available concerning this type of loss. In 1962 a drastic summer draw-down was made on Horicon Marsh in an attempt to bring back vegetation on large areas which had lost it because of high water and ice action. This resulted in little or no surface water over large sections of the marsh. Muskrat houses in dry areas continued to be inhabited by muskrats through the summer. They dug tunnels and trenches out from the houses in their search for food and water. Some tunnels extended as much as 2 feet below the surface to reach the water table (Mathiak, 1966:54). Water levels did not recover by winter and the muskrats in the dry areas were eliminated.

Another draw-down of even greater proportions was made on Horicon Marsh in the summer of 1963 and complete recovery did not occur until the spring of 1965. Muskrats were almost completely eliminated and the season was not opened for trapping in 1964. Old unused muskrat houses crumbled and disappeared, thus eliminating many old houses which through continuous use had become focal points for disease. The draw-downs produced an extremely large amount of new vegetation in areas formerly devoid of vegetation. In general, muskrat food and cover was greatly improved over what it had been previous to the draw-downs. In 1965, with normal water levels again prevailing, the muskrats made a noticeable comeback and in 1966 the population literally exploded. Judging from the number of houses, the population was higher than it had been since the early 1950's when 35,000 'rats were harvested on the state-owned end of the marsh. This is an excellent example of what improved habitat can do for a species. Although many muskrats were sacrificed during the draw-downs the gains more than outweighed the losses.

If water levels must be drawn down in the winter, the draw-down should begin as late in winter as possible. If there is a good ice cover before draw-down begins, muskrats can often survive even if water levels are low. The ice layer and air beneath act as insulators and prevent deep freezing of the bottom muds, thus keeping the muskrat's all-important food supply available to him. Fall or early winter draw-downs can cause complete freezeouts and elimination of a muskrat population.

Effects on Carp

A summer draw-down will probably have little or no effect on the carp which normally inhabit the marsh, other than to concentrate their numbers or to move them into other more suitable habitat. If the draw-down is not complete the fish will be concentrated in the shallow pools which remain. Under these conditions their intensified feeding activities may result in greatly increased turbidity and the destruction of any submergent vegetation which may be present. If the draw-down continues into the winter the fish leave the shallow bog areas and move into the channels and deeper water courses. This occurred on Horicon Marsh during the first year of draw-down in 1962 (Linde, 1963). If the draw-down is severe and water levels in the channels are insufficient to maintain fish life through the winter, the fish will either move out of the marsh area completely or, if trapped in disconnected pools, they may die due to lack of oxygen or to freezing. In the second year of the Horicon draw-down little water was left in the channels because they contained large quantities of muck. The dam gates were closed in the fall but water levels did not begin to recover until the middle of March. An extremely cold winter with little snow cover caused deep freezing and any fish which remained in the marsh probably did not survive. Complete recovery to normal water levels occurred in April, but no carp activity was noted at that time. It was not until the dam gates were partially opened in May that carp were again noted on the marsh. However, these all appeared to be rather small in size so it may have been that there was a winter kill in other parts of the river system. With reduced carp numbers during the summer of 1964 and resulting clear water, submergent vegetation made a good come-back.

Threinen (1952) states, "Where shallow waters are concerned fish and game managers will of necessity have to consider the carp. It is very clear that the carp are destructive of submergent and emergent vegetation. Therefore, if the management of ducks and muskrats is a primary concern, the carp are intolerable, for they are incompatible with the marsh economy."

Effects on Vegetation

Submergents

A severe draw-down which dries out the bottom soils will tend to increase submergent vegetation in the succeeding year when the area is again flooded. Following the drastic draw-downs of 1962 and 1963 on Horicon Marsh, sago pondweed increased greatly (Linde, 1965). There was probably a two-fold effect involved. Since carp were almost eliminated during the draw-down years, their suppressing effect on submergents was removed. In addition, the nutrient release which probably resulted because of dry soil conditions during the draw-down (Kadlec, 1960 and Emerson, 1961) stimulated submergent growths.

Moist Soil Species

Draw-downs commonly result in excellent growths of many desirable food plants such as smartweeds, millets, umbrella-sedges (nutgrasses), dock, rice cutgrass and pigweeds. The vegetative response to a draw-down depends on where the wetland is located and what seeds are residual in the soil. In the southern half of the state a great profusion of moist soil plants can be expected to appear following a draw-down. During the 1962-63 draw-down on Horicon Marsh, the dominant moist soil species was dockleaved smartweed (nodding smartweed), with a heavy understory of red-rooted nut grass. Rice cutgrass and Walter's millet were also found in profusion. In certain areas pigweed was present in almost solid stands. These areas may have been old farm fields before the marsh was restored, since many seeds will survive for years when covered with water. Crocker (1916) states that some species "have the germination of a single crop distributed over the growing seasons of from one to many years." He also mentions that seeds of various water plants will withstand storage under water for years and still will germinate when conditions are right. This would seem to explain why smartweed appears to be omnipresent on most of our wetland areas. Neely (1958), experimenting with various species of seeds and their relative rates of deterioration when stored under water, found that smartweed deteriorated from 6 to 21 percent, depending upon the species, when subjected to underwater storage for 90 days in a simulated natural state.

Japanese millet, on the other hand, suffered a 57 percent loss due to deterioration after 90 days of flooding, according to Neely (1958), so there is not a large amount left in the soil after heavy bird use. This helps to explain why volunteer crops are so much smaller than the planted crops. On Germania Marsh Wildlife Area in 1964, volunteer crops of Japanese millet were only 25 percent the size of planted millet crops of the year before. Volunteer millet crops on Horicon Marsh were also considerably less dense than those planted in the preceding year. On Germania Marsh, only when a bumper crop of planted millet is obtained can a good volunteer crop be expected the following year.

Although on many wetland areas it is possible to obtain excellent volunteer growths of many native moist soil plants merely by drawing down the water levels and exposing mud flats, this type of operation cannot be continued indefinitely on an annual basis. With each succeeding draw-down more emergent aquatic species appear and close in the mud flat areas which were originally so productive. On the Mead Wildlife Area smartweed production was best for the first 2 years. Smartweeds then declined in favor of stick-tights and cattails, with cattail tending to invade even the deeper water areas. On the Wood County Public Hunting Grounds and Meadow Valley Wildlife Area, managers found that 2 or 3 successive years of draw-down permitted sedge to invade the mud flat areas and compete with smartweeds and millets. On these wildlife areas, pools are now alternated for flooding and draw-downs. On Wood County Public Hunting Grounds, a pool is drawn down one year and kept flooded for the next 2 or 3 years. Meadow Valley pools are drawn down no oftener than every 4 years. Since many pools are involved in both of these areas it is possible to always keep some in production while others are flooded. This seems like the only practical way to keep an area in constant production.

Early draw-downs tend to give emergent seedlings a longer period of growth and this undoubtedly enhances their numbers and survival rate. A draw-down in the latter part of June will favor the annual plants and emergent survival will be poorer. However, the time that a draw-down can be accomplished often depends on weather conditions and the type of control available.

Emergents

Following the 1962 and 1963 draw-downs on Horicon Marsh, cattail, giant burreed, sweetflag, softstem bulrush, and river bulrush were the dominant emergent aquatic species which seeded in on the mud flats. Burreed seeds were able to germinate and grow in as much as 6 inches of water, but all the other species seemed to require moist mud flats on which to germinate. Softstem bulrush seedlings matured and produced seed heads in the first summer. In the West Central Area the dominant emergent found invading the mud flats was sedge, and on the Mead Wildlife Area cattail was the principal invader. Sedge and cattail will probably be the principal emergent aquatic invaders in the northern parts of the state. Germania Marsh Wildlife Area showed an expansion of sedge during draw-down periods. It was set back somewhat by the long period of reflooding which lasted from the middle of August to the following June. Eighteen inches of water were required on this area to suppress sedge. Where cattail monotypes on Eldorado Marsh Wildlife Area and sedge-grass meadows on Germania Marsh were broken and planted to food patches, emergent aquatic species invaded these areas after they were abandoned and reflooded. On Eldorado more than 90 percent of the formerly tilled area came up to burreed in the first year. In the second year, cattail began reappearing in patches, but burreed was still by far

In shallow waters of 6-inches or less burreed seedlings may invade open water areas without mud flat conditions. Destructive activities of carp usually prevent these growths from occurring where carp populations are high.

Brush and debris in open water areas cause silts to deposit and form deltas on which emergent growths may appear when water levels are lowered.

the dominant plant. These examples indicate the type of succession which can be expected with bottom disturbance and changes in water levels. The slow natural succession which normally occurs with a change in water levels was disrupted abruptly and drastically by bottom disturbance.

Effects on Soils and Nutrients

After a period of prolonged flooding organic muck soils may become flocculent and semifloating suspensions. They make boat travel difficult in the shallower areas. When water is drawn off, the soils settle and compact (Linde, 1963) and a reduction of the muck level occurs.

Compacting and shrinking of the muck layer may reduce the bottom profile by as much as 6 inches (Kernen, 1966, pers. comm.). After all surface water has disappeared, a thin dry crust occurs on the surface and the muck mass begins to shrink and crack. Although the muck is still quite moist beneath the surface layer the entire mass splits and cracks, forming crevices which may be over 2 inches wide. Compacting and settling of the muck layer continues throughout the period of the draw-down as oxidation and decay of the organic layer occurs. Most seedling growths appear on the mud flat areas immediately after the surface water has disappeared and before the surface crusts. Little or no growth is evident when the surface is still wet from standing water.

New seedling growths of emergent aquatics and moist soil species appearing on a mud-flat area following a draw-down in water levels. Note that most of the growth appears only after the surface water has disappeared.

A draw-down which results in the drainage of the organic bottom soils seems to be accompanied by an increased growth of submergent vegetation when the area is reflooded. Before the drastic draw-down on Horicon Marsh in 1962 and 1963, established stands of softstem bulrush and cattail in many areas seemed to be declining in vigor and the stands were deteriorating. In some locations whole sections of the bog died and all that remained were clumps of stem stubble and roots. After the marsh was reflooded following the draw-down, the entire marsh took on a new appearance of increased vitality and growth even in old established stands. This would indicate that some form of nutrient release had occurred. Kadlec (1960:49) states, "... there is good evidence that a draw-down increases the amount of soluble or possibly in some cases, suspended mineral nutrients. The amount of increase, or decrease, is closely related to soil moisture and the amount of leaching during the draw-down." He also noted that the greatest amount of decomposition of the bottom soils occurred when the soils remained moist and did not completely dry. It has been pointed out by a number of workers including Kadlec that decomposition and destruction of organic material under water proceed at a very slow rate. When the water is removed and adequate oxygen is available, decomposition and oxidation greatly increase. Since soil bacteria and fungi are involved in this process, moisture and oxygen are essential.

Kadlec feels that the colloidal fraction of the soil may be an important regulator of marsh productivity, since there appears to be a large amount of nutrient ions adsorbed by the colloidal fraction of the soil. When the soil dries these ions are released. Since the colloidal soil fraction increases with continuous flooding and age this could partially explain declines in impoundment productivity with age. Periodic draw-downs are necessary if the productivity of the impoundment is to be maintained.

Partial vs. Complete Draw-Downs

Unless a marsh is in need of complete rejuvenation, or repairs are to be made to the dikes or structure, a partial draw-down is probably preferable to a complete draw-down for the following reasons:

1. A partial draw-down will maintain some water on the area through the summer waterfowl brood period.

2. Invertebrates would be reduced to very low levels by a complete draw-down (Kadlec, 1960), and this would affect waterfowl brood use in the year following reflooding.

3. If the impoundment basin has steep contours, a partial draw-down to bring in food plants is more desirable than a complete draw-down, since removal of all the water would so reduce the groundwater tables that very little volunteer millet and smartweed would appear at the higher elevations. Only in the deeper portions of the impoundment where the soil is slow to dry out can heavy growths be

expected. However, when the impoundment is reflooded, the water will be too deep to allow feeding by puddle ducks on this food crop. Shallow flooding is not always practical since the water area is greatly reduced. The maximum depth for puddle duck feeding is 15 to 18 inches.

4. Complete draw-downs practiced annually on a shallow marsh could result in the vegetative growth completely closing in all open-water areas in the impoundment.

5. Complete draw-downs are not compatible with good muskrat management. Muskrats are valuable to the ecology of the marsh since they help maintain a desirable interspersion of open water and vegetative cover. However, should their numbers become too plentiful some form of control is necessary.

A complete draw-down may become necessary if a marsh begins to deteriorate, showing loss of vegetative cover and productivity. A draw-down such as this was made on Horicon Marsh in 1962 and 1963 (Linde, 1963, 1964, 1965). The marsh had been flooded for more than 15 years with no reductions in water level ever exceeding 1 foot below normal. Continuous high muskrat populations, high flood waters in the spring and ice action on the vegetation removed large blocks of vegetation from the center of the marsh. To expose mud flats in these areas and to encourage new growths, it was necessary to make a drastic draw-down. Since the Hustisford impoundment located on the Rock River below Horicon prevented a complete draw-down, water levels could only be drawn down to the level of the Hustisford spillway. However, drought conditions during the summer of 1963 caused evapotranspiration losses to reduce the water levels at Horicon 0.88 feet below the level of the Hustisford spillway. Large amounts of both emergent and moist soil vegetation revegetated many acres of Horicon mud flats. An excellent recovery of the vegetative cover was made in many areas. Unfortunately, openings in the shallow peripheral areas where open water is desirable also tended to close in because of the draw-down. However, since muskrat populations are now at high levels, their house building and feeding activities will recreate openings in these areas.

General Considerations

There is more to flooding a marsh than merely filling the basin with water. A new impoundment should be watched closely to observe the effects of flooding, which plants are increasing and which are decreasing, and which plants should be encouraged and which should be discouraged. Every species has both an optimum depth of water in which it will grow and a lethal depth at which it will be eliminated. By careful observation of resulting vegetative cover changes it is possible to determine the water levels which will create the desired effect on the vegetation. Water levels can be raised to thin the vegetative cover and lowered to increase its density, but the marsh is a continually changing environment and water level controls will have to change as the vegetation changes dictate. Sweetflag may dominate an area immediately after flooding, but in another year river bulrush or burreed may replace it.

Marshes in various parts of the state vary considerably in their response to water level changes since the plant composition of wetlands changes from one geographic area to another. There are no rules for water level management that can be applied to all impoundments without modification. There are only broad principles. The summer draw-down technique has been applied as a sort of universal formula for impoundment management, yet it is obvious that it does not always work in the manner desired.

In northern impoundments especially, the amount of food produced by this technique is sometimes negligible. Sometimes the soil fertility is so low that even attempts to plant millet or smartweed produce mediocre results. In one state area partial draw-downs were made each summer, but the results were practically nil in terms of moist-soil food plants. Yet, continuously flooded portions of this impoundment were producing good crops of pondweeds which fruited heavily. Efforts in this case could have been much more profitably directed toward increasing the pondweeds.

Keith (1961) observed an instance where slowly dropping water levels during July and early August exposed extensive beds of pondweeds which responded by seeding out heavily. A rise in water level later in August brought in large numbers of dabbling ducks which fed heavily on the seeds. Lowering water levels at the time of seeding to stimulate seed production might be a technique which could be profitably employed in impoundments where there is a good crop of pondweeds.

It is well to remember that waterfowl brood production is important, and that wetland management for the harvest should not be accomplished to the complete detriment of brood production. Some areas may be better adapted to brood production than they are to harvest. It is obvious that every wetland area is not necessarily a good harvest area. In many of the northern wetlands, managing to increase brood use may actually increase the harvest more than would a summer draw-down. Local birds using the area may tend to decoy in more migrants than would a poor or nonexistent food crop.

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WETLAND FARMING

The objective of this technique is to attract and hold waterfowl during the fall migration so as to provide better hunting opportunities for the wetland area on which it is practiced. Essentially it consists of lowering the water levels in an impoundment in the spring or early summer and planting the bottom to desirable waterfowl food crops. This may be accomplished by either breaking ground and preparing the seedbed in a conventional manner or by merely seeding mud flats exposed by the draw-down. Both methods have been used in this state with good results. However, crops produced by mechanical tillage of the soil are much more expensive. The technique can be applied to any impoundment which has a controllable water level. "Controllable" should be stressed since it is of little value to put a food patch for waterfowl in a wetland basin when the source of water is unpredictable and it is uncertain as to whether sufficient water will be available to reflood the basin in the fall. Although small-scale hand seeding on mud flats might be warranted, more expensive wetland farming operation should be avoided where the water supply is uncertain.

This section concerns only practices which are applied to wetland basins which will be reflooded later in the summer and fall. Conventional upland farming will not be considered. Since most of the data collected for this section were from relatively new developments, experiences of Wisconsin game managers with this practice have been rather limited and much of it has been experimental. Seeding dates, seeding rates, types of tillage and planting techniques have been modified from year to year as experience dictated. This accounts for the great variations in techniques and results.

Seed for Wetland Plantings

Records show that 6 different species have been seeded on wetland game areas in this state: (1) Japanese millet, (2) buckwheat, (3) Proso millet, (4) smartweed, (5) German millet, and (6) browntop millet. Only Japanese millet and buckwheat have shown promise for use on wetlands in Wisconsin.

Japanese Millet

In Wisconsin, better results have been obtained with this species in wetland basins than with any other species. It is more tolerant of conditions commonly encountered in wetland areas than are most food plants of this type. Japanese millet is an annual grass which attains a height of 3 to 5 feet under optimum conditions, is extremely tolerant of flooding, will germinate in 4 days under warm, moist conditions, and will mature in 70 to 73 days. These germination and maturation periods have been established through large-scale plantings at Germania Marsh Wildlife Area and an experimental planting at Horicon Marsh Wildlife Area. Only when the soil is wet and warm can the shortest germination period and the greatest germination be expected. Data from Germania Marsh indicate the following points should be observed to produce maximum results:

1. Draw-downs for seeding should be quick and decisive so that mud flats may be quickly seeded before they have a chance to dry and undesirable perennials become established. (This does not pertain to areas which will be tilled mechanically, since here it is necessary to wait for conditions to become right for tillage).

2. Soil surfaces should remain moist until germination.

3. Covering the seed with soil or compacting it into the soil either mechanically or by other means improves germination.

On the Horicon experimental planting millet germinated in rain puddles and produced excellent growth if water was not so deep that the new growth could not rise above it. Slow rises in water levels do not seem to hurt established millet if the plant is able to grow fast enough to keep its leaves above the surface. McLain (1957) recommended that water levels be raised 6 inches as soon as the millet plants reach 10 inches in height and 6 inches more every two weeks until maximum water levels are attained. This was highly effective in keeping down weed competition in the millet stand and providing excellent cover for the new waterfowl broods. No adverse effects were noted on millet production from this progressive flooding.

However, in areas of high waterfowl concentration, early flooding might allow waterfowl to prematurely consume the millet crop before the hunting season, since ducks tend to use the mature millet as soon as it is flooded. They "walk" down the stems to get at the seed head in even the densest stands. If the stand is sufficiently extensive to provide food through the season, this might not be a problem. Early flooding (middle of August) is practiced on Germania Marsh, but water is raised in stages with each stage being between 6 and 18 inches. Since the draw-down and seeding is also done at intervals, millet is in three different stages of maturation and it allows the newest growth to be consumed by the ducks first and the other two at later dates. This spreads the use out over a much longer period. Most other management districts which use progressive flooding begin at later dates (Table 25). Germania Marsh usually has such a large food crop, both planted and natural, that the food supply does not become exhausted even with heavy waterfowl use over an extended period of time.

Early flooding has an advantage which is of some importance where early frosts are a problem. Because of the residual heat in bodies of water covering flooded areas, frosts must be very severe before they will damage millet crops growing on these areas. This has been noted repeatedly on Germania Marsh. It was pointedly demonstrated at Eldorado Marsh Wildlife Area when a heavy July frost killed back cattails and other vegetation outside the impoundment, but all vegetation in the flooded impoundment remained green and uninjured. Flooding to prevent frost damage is, of course, a well-known part of cranberry culture.

Seeding Dates

Wisconsin seeding dates have varied from May 15 to July 20 (Table 25). Although July 20 was too late and planting's failed, the early seeding on May 15 in the Southern Area produced good results. The average statewide date for Japanese millet seedings on game areas was June 13. On Germania Marsh, there was a bumper crop of 300 acres of millet in 1963; the ideal period for draw-down and seeding was June 10 to June 28. During this period soil temperatures reached the optimum 70° F.

McLain (1957) stated that in Connecticut June 10 to June 20 produced the best seeding results for Japanese millet. During this period rains frequently occurred which stimulated growth. Later in July drier weather usually occurred. This also holds true in Wisconsin.

During July evapotranspiration losses of soil moisture are building up to a peak and germinating conditions are generally unfavorable, unless soil moisture can be kept at optimum by raising the water table in the impoundment. Since this is often impractical, the surface usually becomes crusted and dry, making a poor seed bed.

Because the normal growing season for cultivated crops varies from a minimum of 30 days in parts of Vilas County in the northeast part of the state to a maximum of 140 days in the southeast along Lake Michigan (Wang and Suomi, 1957), it is obvious the recommended dates for seeding wetlands will not hold for the entire state. It will be necessary to adjust these dates according to local conditions, remembering that marshes are more prone to localized frosts than uplands in the same locality. In fact, summer frosts occur in low areas throughout the state (Wong and Suomi, 1957). In general, the planting will have to be made late enough so that the danger of spring frosts is past and early enough so that the millet will mature before it is killed by fall frosts. Since the time necessary for millet to achieve maturity is about 70 days, there are parts of northeastern Wisconsin where it will be difficult or impossible to get a mature crop of millet without the use of early flooding.

Soil Requirements

McLain (1957) noted that Japanese millet was highly tolerant of low pH in New Jersey and has been grown successfully on areas having a soil pH of 4.8, but that the growth and development were better when the pH was above 5.4. This fact would make Japanese millet suitable for use on many of our northern wetlands. Liming and fertilization were recommended practices for acid soils in New Jersey.

Seeding Rates

Seeding rates used in Wisconsin have ranged from 20 to 50 pounds per acre, with an average of 29.6 pounds per acre (Table 9). Successes and failures have been experienced within this range but more than 30 pounds per acre is probably unnecessary. Overcrowding of the seedlings could result if germination is high. Stanton (1957) recommended a seeding rate of 20 to 30 pounds per acre for millet planted on Oregon wetland areas. The higher rates are used on rich bottom lands where the highest yields are obtained.

Deer and Blackbird Damage

Deer damage to the millet crop has been reported on several wetland developments in the northeast part of the state. In two instances the millet crop was completely destroyed.

McLain (1957) reported that deer graze the millet in the early growth stages when the young plants are succulent, but after the plants reach 12 inches they leave it for other foods. No adverse effect was noted from this early grazing. However, heavy depredations were experienced later when the seed heads had formed. Deer then fed heavily on the seed heads. McLain found that a diversionary rye field planted during the middle of August prior to the ripening of the millet was highly successful in preventing heavy deer damage to the millet seed heads.

Blackbird damage to the ripe seed heads was experienced at the Horicon Marsh Wildlife Area. Little can be done to prevent such damage, However, the birds knock ripe seed into the water while they are feeding and a substantial amount of seed is probably still available to waterfowl. More extensive food patches might minimize the effects of these depredations. This would amount to planting sufficient millet so that waste grain left in the water by blackbirds plus that which remains is enough to supply waterfowl needs. In Oregon blackbirds took as much as 40 percent of the crop before the ducks got to it (Stanton, 1957). Wilson (1962) recommended that where large losses to blackbirds are expected the entire area should be flooded to cover the millet when it becomes ripe and then water levels should be reduced in stages to expose the millet and make it available to waterfowl. This, of course, is a reverse of the usual procedure of flooding in stages to make the seed available over a period of time. This method is actually a progressive draw-down. It would only work where the impoundments are of sufficient depth and the food patches are so situated that deep flooding can be effected within the normal capabilities of the flowage basin.

Buckwheat

Buckwheat is one of the more important wildlife foods seeded in impoundments and made available for duck use by flooding. A number of varieties are available. Short-maturing varieties are commonly utilized throughout Wisconsin.

Stanton (1957) reported that the type preferred for waterfowl food plantings in Oregon is the Tartary species known commonly as "duck wheat". It is higher yielding, less susceptible to frost damage, grows better on poorer soils, and sets seed under more adverse conditions than other buckwheat varieties. Tartary buckwheat has been used in the West Central Area and found to be quite satisfactory, but sharecroppers prefer the silver hull variety.

TABLE 9

Seeding and Flooding Recommendations for Japanese Millet Food Patches

Area	Seeding Date	Seeding Rate (Lbs/A)	Method of Seeding	Seed Bed Preparation	Results	Flooding Date	Number of Days to Complete Flooding
SA	May 15	50	Hand	Mud flats	Good crop	Aug. 1	32
ECA	May 29 - June 20	28	Drilled 1"	Break and disc	80% catch	Sept. 19	18
ECA	June 3 - 6	20-25	Cyclone seeder	Double disced	Good crop	Sept. 26	
ECA	June 10, 17, and 24	30	Aerial	Mud flats (3 zones)	Excellent crop	Aug. 17	18
ECA	June 12	22	Aerial	Mud flats	Good crop in area last exposed	Aug. 18	
ECA	June 23 - 27	28	Drilled and broadcast	Break and disc	Thin catch	Sept. 19	43
ECA	June 30	25	Hand	Break and disc	Good crop, but too late	Oct. 16	
ECA	July 6	30	Drilled 1"	Plowed and disced	Poor crop	Sept. 15	35
ECA	July 20	30	Drilled 1-1/2" - 2"	Burned, break & disc	Failure	Oct. 1	
ECA	June 8 - 10	30	Drilled and hand seeded	Plowed and disced, dragged	Excellent	Sept. 7	56
ECA	May 23	28	Drilled	Disced	Fair to poor	Sept. 19	43
NEA	May	9lbs/mi	Hand	Mud flats	Good crop	Sept. 1	
NEA	June 3	30	Aerial	Mud flats	Good crop but destroyed by deer		
NEA	June 12	20	Cyclone seeder	Mud flats	Fair crop but did not ripen		
WCA	June 10	35	Hand	Mud flats	Good crops	Sept. 15 - 21	
WCA	June 10	35	Hand	Mud flats	Good crops	Sept. 15 - 21	
Avg.	June 14						

Buckwheat grows best on well-drained loam, but good crops are obtained on drained bottomlands. However, it is quite susceptible to wet conditions and if there is danger of flooding before the crop is mature, Japanese millet is undoubtedly a better choice. The usual farming practices are utilized in producing this crop. The seeds are often drilled in about 1 inch deep. Buckwheat is also harrowed or dragged and may be seeded on moist mud flats by broadcast seeding.

Seeding Dates

Seeding dates in Wisconsin varied from the first week in June to July 12, with an average date of June 26 (Table 10). Reflooding took place between September 1 and October 4 with the average date being September 11. Good crops were obtained in the Northeast Area by seeding as early as the first week in June. Satisfactory crops were obtained in the Northwest Area by seeding on June 18.

In the East Central Area, a June 6 planting was made, but it was considered too early. A July 20 planting was frozen before it matured and an early frost on September 5 killed a crop planted on July 10. Only 10 percent of the latter crop had matured by this date. It would appear, therefore, that optimum planting time in the East Central Area should be in the latter part of June or the first part of July.

The more northern parts of the state need to have planting dates adjusted to suit local needs. Dates should be somewhat earlier to prevent damage from early fall or late summer frosts. In colder portions of the Northeast Area, in Vilas County, planting should probably be about 3 weeks earlier, which would make the optimum planting date during the first week in June. In other northern locations, planting will be progressively later (Wang and Suomi, 1957).

Seeding Rates

Buckwheat seeding rates as used in this state for wetland plantings have varied from 42 to 100 pounds per acre (Table 26). Satisfactory to excellent stands have been obtained with seeding rates of 50 pounds per acre when the seed was drilled in 1-inch deep, but satisfactory stands were also obtained at 47 pounds per acre when seeded with a cyclone seeder. The average seeding rate used in Wisconsin was 62 pounds per acre, but the actual rate will depend on the soils and the type of seeding equipment used. Stanton (1957) recommended using approximately 25 percent higher seeding rates when the seeds are broadcast.

Proso Millet

Proso millet has had limited use as a waterfowl food crop on wetland areas in Wisconsin. It is a relatively low-growing millet having a seed head which shatters early and which is readily consumed by waterfowl. However, the crop is very susceptible to damage by frost and flooding. There seems to be no advantage in using this species since Japanese millet thrives under wet soil conditions which would kill Proso.

TABLE 10

Seeding and Flooding Recommendations for Buckwheat Food Patches

Area	Seeding Date	Seeding Rate (Lbs/A)	Method of Seeding	Seed Bed Preparation	Results	Flooding Date	Number of Days to Complete Flooding
ECA	June 29	50	Drilled 1"	Plowed and disced	Satisfactory	Sept. 8	50
ECA	June 8	50	Drilled 1"	Plowed and disced	Fair	Sept. 2	57
ECA	June 29 - 30	50	Drilled 1" and broadcast	Break and disc	Fair	Sept. 19	19
ECA	July 10	50	Drilled 1"	Plowed and disced	Excellent stand but frostbitten Sept. 5	Oct. 4	21
ECA	July 6 - 12	50	Drilled 1"	Disced	Drowned out - Rain		
ECA	July 6	50	Drilled 1"	Plowed and disced	Good	Sept. 15	36
ECA	June 28	50	Drilled 1"	Break and disc		Sept. 19	44
ECA	July 3 - 7	42	Drilled 1"	Break and disc	Fair	Sept. 8	23
ECA	June 3 - 6		Cyclone seeder	Double disced	Planted to early	Sept. 26	
ECA	June 15		Drilled 1-1/2" - 2"	Burn and mow			
	July 15 - 20	100		Break and disc	Froze	Oct. 1	
NEA	June 1 - 14	100	Hand	Mud flats	Good		
NEA	June 1 - 7	100	Cyclone seeder	Break, disc, lime and drag	Fair		
NWA	June 18 - 30	47	Cyclone seeder	Wet mud flats	Satisfactory	Sept. 3	
NWA	June 18 - 30	47	Cyclone seeder	Wet mud flats	Satisfactory	Sept. 3	
Avg.	June 26					Sept. 11	

It is a poor risk crop on drained bottom lands where a wet summer might produce some flooding. It probably has its greatest value on the well-drained uplands since it has the lowest water requirement of any of the millets (Stanton, 1957)

The only reported use for Proso in flowage basins has been on Horicon Marsh Wildlife Area and in the Northwest Area. Seeding was accomplished on June 24 at Horicon and the planting was on bottom land mineral soils. It made a good growth and matured. In the Northwest Area the planting was made during the last two weeks in June. Results in this case were unsatisfactory; the planting should have been two weeks earlier. However, the planting at Horicon was on tilled soil and was drilled in 1-inch deep, while the planting in the Northwest Area was seeded with a cyclone seeder on wet mud flats. The method and conditions of planting may have contributed to the differences in the results obtained on the two areas. The seeding rates were 35 pounds per acre at Horicon and 37 pounds per acre in the Northwest Area. Stanton (1957) recommended a rate of 30 to 40 pounds per acre seeded with a grain drill at a depth of 1 inch.

Smartweed

Several attempts to cultivate smartweed were made on wetland areas in the East Central Area. Only one was successful. Seedings took place on May 15, June 12 and July 8. The May 15 seeding was made in a tilled field on an impoundment basin. Seed was drilled in 1-inch deep at 20 pounds per acre. However, soils in this impoundment were mineral and had a history of farming before they were developed for wildlife crops. As a result, many common upland weed seeds remained in the soil. Tillage released large amounts of pigweed and giant ragweed and the smartweeds were choked out. Mineral soils appear to be a poor medium for smartweed growth if the soils have a past history of cropping.

Another seeding made on tilled peat soils also produced poor results, but in this case seeding was not accomplished until July 8 and only 50 percent of the crop had ripened by October 30. Seed was drilled in 1-inch deep and at 15 pounds per acre.

Aerial seeding of smartweed on mud flats in a drawn down mill pond was accomplished successfully in the East Central Area. Seeding was on June 12 and a good stand was established.

Since annual smartweeds are generally fairly late in maturing, early draw-down and seeding is to be desired. If they are to ripen by the time of the waterfowl season they should be planted in late May or early June. Broadcast or aerial seeding on wet mud flats is undoubtedly the best technique if early planting is to be accomplished since it is sometimes difficult to till the soil in impoundment basins for May or June planting because of wet conditions. Of course, mud flat seeding is also considerably cheaper than seedings established through tillage. A point to remember is that many of the smartweeds require a period of after-ripening before they will germinate. If smartweed seeds are gathered in the fall for planting the following spring, they may not germinate until the second spring after gathering (Wilson, 1962).

About 14 species of smartweed are listed by Fassett (1957) as being present in Wisconsin. Representative species are found in every part of the state. They are the most common and probably the most important of our native waterfowl food plants found growing under moist soil conditions. Most impoundment basins will produce varying amounts of smartweeds by merely drawing off the water and exposing mud flats in the early spring. In most cases smartweed seeds are residual in the soil and they will quickly respond when conditions become favorable to their germination. Drastic draw-downs on Horicon Marsh Wildlife Area during the early 1960's produced tremendous smartweed crops on the exposed mud flats. Germania Marsh Wildlife Area is being managed to produce annual crops of smartweeds and other natural waterfowl food crops through use of draw-downs with an extremely high degree of success.

Since smartweeds are so widespread, it seems unnecessary and impractical to cultivate them through normal tillage practices. If they fail to respond to normal draw-down techniques, the area is probably of such low fertility that seeding and cultivation would also produce poor results unless fertilizers are used. Since mud flats produced by draw-down conditions afford ideal conditions and seed bed for all types of moist soil species including smartweed and millets, it is much more economical to utilize this method than to practice the high cost cultivation. The money saved could be better used to lime and fertilize if the soils are low quality. Fertilizing should be done only after soil tests have proved a deficiency. Advice of the county agricultural agent is helpful in determining the amount and type of fertilizer needed.

Browntop and German Millets

The true value of these species in Wisconsin is difficult to judge because only one planting of each was made in impoundment basins. However, since browntop millet requires a water table at least 4 inches below the surface, its usefulness in many areas is limited. The Soil Conservation Service state office indicates that browntop requires moderate to heavy fertilization, preferably with 6-12-6 at 500 pounds per acre. This was the recommendation given for the experimental planting on Germania Marsh Wildlife Area. Seed beds should be prepared well in advance and should be disced just before seeding. Seed may be drilled or broadcast at 20 to 30 pounds per acre. It matures in about 60 days producing a plant that is 2 to 3 feet tall with a yellowish-brown open-panicle seed head.

A test planting of browntop made on the Horicon Marsh Wildlife Area was a failure. The planting was made May 9 in a tilled impoundment basin field. Seeding rate was 20 pounds per acre; however, ragweed, mustard and sedge choked it out and it matured at 2 feet high in a thin stand of little or no value.

German millet was aerially seeded on the Hortonville Pond in Outagamie County. Seeding rate was 200 pounds of German millet and 40 pounds of smartweed on 62 acres. The crop made a good growth by the end of the summer. The pond was not flooded that fall so there was no waterfowl use of the crop. The next summer no volunteer seeding from the previous year's crop could be observed. If lack of reseeding is characteristic of this species, this again is a limiting factor because Japanese millet commonly reseeds itself after a good crop, thus eliminating the need for mechanical reseeding every year.

Seeding Mud Flats

The simplest and least expensive form of seed-bed preparation is to draw water levels down and seed the resulting mud flats. This presupposes that mud flats will be available in the area in which the planting is desired. Unless normal high water levels have been held for at least one full growing season before the draw-down, mud flats may not result. Fall and winter flooding under normal circumstances will not eliminate dense sedge and grass cover. It may set back its phenology, but before the end of the summer the cover will be almost as dense as before. To eliminate undesirable cover in the areas of a new impoundment where it is desired to plant food crops, deep flooding through two growing seasons is a desirable pretreatment.

Hand Seeding

Mud flats can be seeded by hand either broadcasting the seed or using a hand-operated cyclone seeder. In the West Central Area, seeding was accomplished from a platform on a specially equipped crawler tractor known as a "mud puppy". This light tractor has 30-inch, 2-x-4-inch cleats bolted at intervals on the tracks. The cleats allow it to operate on wet sandy mucks without becoming bogged down. Using a cyclone seeder from the tractor platform a man can seed mud flat areas much more easily than by walking. Conventional ground-operated equipment would be unable to operate in such wet areas. Cost of hand seeding when accomplished by walking the mud flat area has been $7.00 per acre in the West Central Area. Approximately $5.64 of this cost is labor.

Aerial Seeding

An alternative to hand seeding is aerial seeding. It is probably the least expensive and most efficient way to seed large mud flat acreages. In the Northeast Area, some small acreages were seeded with a conventional light plane. The seed was poured into a section of stove pipe with a funnel attached while it was partially extended through an opening in the plane. Flight altitude during seeding operations was 150 feet. A good catch resulted. Cost of this operation was $5.00 per acre including cost of the seed.

Up to 300 acres of millet were seeded on Germania Marsh Wildlife Area by plane. A commercial crop dusting plane with special seeding equipment was used. Flight altitude was 35 feet. It was thought that the prop wash at this altitude helped to bury the seed in the mud and thus improve the germination rate. Cost of plane rental with the pilot was about $3.75 per acre. Seed cost at a seeding rate of 30 pounds per acre was $2.03.

Mechanical Tillage

If sufficient mud flat areas cannot be produced by draw-down techniques, as would be the case in a new impoundment which has never been flooded, then the alternative is to break ground and work up food patches by mechanical tillage. Since ground-breaking costs usually run high (Table 9) this is one of the most expensive techniques utilized in wetland management. Costs from wetland to wetland are extremely unpredictable. They vary with soil types, water table and vegetative cover of the site to be broken. Water tables are affected by precipitation as well as the extent of the draw-down. In the Horicon Marsh Wildlife Area impoundments during wet springs, not only was gravity drain used to remove surface water, but it was also necessary to pump out the ditch system to lower the water table sufficiently so that early tillage could be accomplished. Where the gradient is relatively flat, drainage is slow and the impoundment might not become dry enough to work in a wet summer before the middle of the summer -- if at all. This, of course, adds to the overall costs of food patch establishment.

Various types of breaker plows have been used in breaking new ground for food patch establishment. On the Powell Marsh Wildlife Area a 24-inch breaker plow was used which had been especially designed for plowing bog or muskeg. Rental cost for this equipment was $18.00 per acre and it could plow 1 acre per hour. A double-bottom breaker plow used on the Germania Marsh Wildlife Area had a 30-inch colter and cut a furrow 14 inches deep and 2-1/2 feet wide. This plow was powered by a D-8 crawler tractor. On the Outagamie Wildlife Area a 36-inch breaker plow was used with a D-4 crawler tractor. A private contractor in the East Central Area uses a 18-inch breaker plow for marsh breaking and he pulls it with two D-2 crawler tractors; this equipment plows 3 feet deep.

On the Sensiba Wildlife Area a food patch was double disced using a Rome disc in place of a breaker plow. Results in terms of food production were good, but in some places it was necessary to disc the vegetative cover 4 times in order to properly break it up. A relatively recent technique is the use of a Rotovator. This equipment is being tested in various places throughout the East Central and West Central Areas. It consists of a 71-inch wide Rotovator mounted on a 707 International diesel tractor. Twelve acres of sedge grass marsh were worked up 8 to 12 inches deep in about 12 hours on Theresa Marsh Wildlife Area. The water table at the time the field was being worked was about 12 inches below the surface. Equipment worked well as long as the wheels remained on the sod, but it bogged down when attempts were made to go over the newly rotovated field. The field was well leveled and relatively free of humps, with the sod completely shredded. This type of equipment eliminates the discing operation and should reduce the cost of establishing food patches by a considerable amount.

Available figures show that the cost of breaking ground for food patches averaged $10.81 per acre, while discing and seeding averaged $7.64 per acre (Table 11). There was considerable variation in costs between areas of operation. Costs depend on a number of uncontrollable variables inherent within each area. Other available cost figures showing combined costs of all operations in food patch establishment are shown in Table 11. The average cost was $25.71 per acre not including the cost of seed. In areas where breaking had been accomplished in previous seasons and only conventional plowing and discing were needed as preparation, the complete operational cost was reduced to $13.01.

TABLE 11

Costs for Wetland Farming Operations

Land Breaking With Breaker Plows

Area	Acres	Cost Per Acre
ECA	40	$ 6.30
ECA	12	8.33
ECA	25.8	10.61
NEA	Commercial Rate	18.00
Avg.		$ 10.81

Use of Breaker Plow and Marsh Disc

Area	Acres	Cost Per Acre
ECA	3.5	$ 9.83

Break Land, Disc, and Plant (Seed Costs Not Included)

Area	Acres	Cost Per Acre
ECA	26.5	$ 19.12
ECA	22	31.69
Avg.		$ 25.71

Aerial Seeding of Mud Flats (Seed Costs Not Included)

Area	Acres	Cost Per Acre
NEA	6	$ 2.97
ECA	12-16	3.75
Horicon Marsh National Wildlife Refuge		1.65
Avg.		$ 2.79

TABLE 11 (continued)

Costs for Wetland Farming Operations

Area	Plow, Disc and Plant (Seed Costs Not Included) Acres	Cost Per Acre
ECA	10	$ 11.83
ECA	17.3	12.42
ECA	5	14.32
ECA	8.8	13.45
Avg.		$ 13.01

Area	Disc and Plant (Seed Costs Not Included) Acres	Cost Per Acre
ECA	16	$ 11.02
ECA	18.1	4.19
ECA	16.5	7.72
Avg.		$ 7.64

Reflooding

This subject has already been covered for Japanese millet. However, buckwheat and the other millets previously discussed are intolerant of wet conditions and flooding. Soil must be kept moist, but not saturated until the crop reaches maturity. Flooding before this time may result in loss of the crop. The time required to flood a food crop depends not only on the desired speed of flooding, but also on the flooding potential of the individual impoundment. Impoundments with an adequate source of water can be reflooded relatively quickly while impoundments with an unreliable water source may require weeks, or if the weather is dry may fail to completely flood.

Reflooding of Japanese millet has begun as early as August 1 and as late as October 16 on a statewide basis (Table 9). The October 16 flooding was too late to be of use during the waterfowl season. This late flooding was due to a pump breakdown which prevented flooding earlier.

Since Japanese millet will withstand progressive flooding, the crop matured and results were good when it was flooded on August 1. However, with such an early flooding there is a good possibility that if the duck use were heavy and the crop small, it would be entirely eaten well before the opening of the season. Germania Marsh Wildlife Area with 300 acres of millet and 500 acres of volunteer smartweed, on the other hand, had more than enough food to feed ducks through the entire hunting season in 1963. A mid-August progressive flooding was commonly practiced here since the crops are normally large. The average statewide date for beginning the reflooding of Japanese millet food patches was September 11. The proper date for any particular area will depend on the size of the food crop, and when it can be expected to mature. Where progressive flooding was practiced the span of time used to raise the water levels to maximum varied from 18 to 56 days. The average was 35 days. If seeding was accomplished on June 13, which is the average date statewide for planting Japanese millet on wetland areas, the crop would mature about the third week in August.

Germania Marsh Wildlife Area is the only wetland area which was flooded before the crop matured. Results were extremely good. With a very large food crop there is no fear of having it entirely eaten before the hunting season. It should serve to hold more early migrant and locally produced waterfowl for the opening of the waterfowl hunting season. As was previously mentioned, flooding before maturity serves to protect the crop from early frosts and therefore offers some insurance against that form of crop failure.

Buckwheat food patches had an average statewide planting date about 2 weeks later than Japanese millet and an average flooding date about a week later (Tables 9 and 10). Since buckwheat is sensitive to water damage it cannot be flooded before it reaches maturity. This is true of all the other wetland food crops previously mentioned, with the exception of smartweed. Annual smartweed will continue to grow after it is partially flooded and will produce a seed crop.

At Horicon Marsh Wildlife Area Japanese millet was completely utilized by the ducks before they began using smartweed. Once they began eating smartweed, however, it received heavy use. On Germania Marsh Wildlife Area the green smartweeds were used very little and it was not until after the frosts had caused the plant to dry that heavy use was experienced. This has also been my observation on experimental areas in Horicon Marsh. Since these areas had millet crops available for early use, this also may have influenced the use of the smartweeds. Without millet present ducks may have used the smartweed earlier.

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NESTING ISLAND CONSTRUCTION

Nesting islands for waterfowl constructed in Wisconsin date back to the early 1950's. They range from simple piles of hay heaped up in shallow flowage basins to more elaborate islands of earth ranging in size up to 1/4 acre.

Brush

Islands can be constructed by placing brush in piles about 10 to 15 feet across and high enough to be well above the water, usually about 4 feet. The top of the brush pile is then covered with a layer of hay or straw -- usually a couple of broken bales are sufficient. On both Horicon Marsh and Powell Marsh Wildlife Areas this has proven to be an effective means of enticing geese to nest in the vicinity of captive goose flocks. Islands of this type also received use from nesting mallards.

Brush islands will last for a number of seasons if ice action does not destroy them. They usually require replenishment of the hay nesting material annually, however. Much depends on where they are located. If they are subject to ice and wave action they may be destroyed in a relatively short time. If located in the middle of a quiet slough or pothole and built of fairly heavy branches, they can be expected to survive for 3 or 4 seasons.

At Horicon Marsh some brush islands constructed in a windswept open slough were destroyed during the first spring break-up. Only islands constructed from heavy limbs 6 to 10 inches in diameter survived. These heavy limbs formed the center of the structure and were piled in a criss-cross fashion with the small limbs on top.

Brush islands are usually constructed on the ice when it is easy to get equipment out on the flowage. Brush is hauled to the desired location and piled on the ice. In the spring the brush pile settles to the bottom as the ice melts. It must be piled sufficiently high so that a large portion of it remains above the surface after it settles. It is probably better to add the hay or straw after the spring break-up, if this is possible, since the island can be reformed somewhat at that time to compensate for settling. Hay added in the winter may be in the water after the brush island settles in the spring. It could also be washed away by spring floods.

On Horicon Marsh, brush islands were established in and around the pond occupied by a flock of captive Canada geese. Ten of the 18 brush piles located on the water received use in 1952 and 9 out of 20 piles on the shoreline were also used (Hunt and Jahn, 1966). In succeeding years there was a gradual shift to use of the islands in the water. Of 22 nests found in 1956, 18 were located on islands over the water. Hunt and Jahn (1966) concluded that brush piles for use by captive flocks increased nesting success by decreasing territorial strife.

Brush islands for nesting geese, located in the open water of the Horicon Marsh Wildlife Area goose pond.

Hay

On Powell Marsh Wildlife Area a variation of the brush island was created by building islands completely of hay. These were located in a reservoir and proved to be very attractive for duck nesting. Between 30 and 40 hay islands were constructed and received 100 percent use. It required about 3 man-days of work to construct them at a cost of $2.00 per island. However, the usable life of this type of construction was rather short. It was no longer of value during the second season.

Earth

Another simple type of nesting island is utilized at the Meadow Valley Wildlife Area. This consists of about 4-1/2 cubic yards of fill which was dumped onto the ice in the flowage. The top was leveled with a plank and a few shovels of top-soil were added before seeding. Four men, 4 dump trucks and one front-end loader were needed to build these islands. It required about 1/2 hour per island and the cost per island was $1.62. In the first year following their construction, duck egg shells were found on 3 islands. No use figures were available after this first year. The islands, however, should probably have been somewhat higher and larger; they projected about 2 feet above the surrounding water.

On Crex Meadows Wildlife Area a number of earth islands were constructed. These ranged from 10 feet x 10 feet in size to about 1/4 acre. They were constructed by digging a circular channel and piling the spoil in the center to form the island. A 5/8-yard drag-line was used in the construction. No costs were available. These islands were combination loafing and nesting sites and were heavily used by both geese and ducks during migration. Mallards and geese also used them for nesting. The islands were strategically located where it was thought that they would get the best use. To improve them for goose nesting, 2 bales of straw were added as nesting material. Results have been highly satisfactory.

Similar islands were constructed at Horicon Marsh Wildlife Area. They too were constructed by dragline, but they were built at the ends of a series of level ditches. Eleven ditches were ended by constructing a circular channel 100 feet in diameter and piling the spoil in the center of the circle, thus forming a moat around the entire island. No costs are available on the island construction since costs were included in the level ditching, which was done at a cost of 13 cents per yard using a 1/2-yard dragline.

In the spring of 1960, a check for waterfowl use was made on the islands. One island was found to have an abandoned goose nest containing 3 eggs. A destroyed mallard nest was located on another island while on a third a goose was setting on an active nest. This would seem to indicate that island constructions of this type hold some attraction as nesting sites. Use in this particular instance may have been influenced by high water which put good nesting sites on muskrat houses and other locations on the marsh at a premium. However, since waterfowl commonly used ditchbanks for nesting even during years of normal water level (Mathiak and Linde, 1956), it is quite likely that the islands were used for nesting regardless of water levels as long as there was water in the ditches adjacent to them.

On the Potato Creek Wildlife Area some islands were constructed during the course of small flowage construction. Several islands were built in each impoundment before the impoundments were flooded. A D-4 bulldozer was used to make some push-ups 15 to 20 feet in diameter and about 4 feet above the waterline. Bulldozer costs were $10 per hour, but actual costs of the islands are not available since they are included in the flowage construction costs. Construction costs must have been fairly cheap, however. These islands were originally seeded to buckwheat and rye, but they later grew up to grasses, stick-tights and sedges. Whether the islands were utilized by waterfowl is not known. Similar constructions have been made in the Wausau District (Northeast Area), but again use data are not available.

Natural

On Holcombe Flowage in the Northwest Area some natural islands were cleared of river-bottom hardwoods by the use of herbicides. A mixture of 2,4,5-T and fuel oil was used as a basal spray and applied by backpack pressure spray cans. The cost was $42 per acre. No data are available on waterfowl use following the clearing operations.

"Push-up" islands constructed by bulldozer (Black River Falls Districts).

Cooperative Constructions

Islands and ponds may sometimes be constructed at no cost if the manager is careful to watch for opportunities for cooperative work with other agencies. In the Plymouth District (East Central Area) gravel was sold from Department lands for highway construction and the borrow area was shaped into a pond 200 x 180 feet. A 14-foot-wide island located 20 - 30 feet from either end of the pond was left down the center. Shaping of the pond was done by the contractor at no extra cost. The island is about 2 feet above the water and is covered with annual weeds.

The use of nesting islands to increase goose production on an area seems to be a well-accepted practice. Islands give the birds a measure of protection from predators and probably give them a better chance to defend their nests. However, whether or not small nesting islands are desirable for duck nesting is a question still to be answered. Opponents of the technique claim that island nests are much easier for predators to find since high areas in an impoundment are also attractive for mammalian predator use.

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CONTROLLED BURNING

Purposes

Controlled burning is a practice frequently used by game managers in Wisconsin. It can be a highly effective wetland management tool when properly utilized. The principal reasons given by game managers for controlled burning are to:

1. Remove annual "rough" or dead herbaceous cover and thus prevent the build-up of debris on a marsh floor.

2. Reduce the level of a marsh floor by using hot fires which burn down into the organic soils.

3. Thin out or eliminate woody vegetation in impoundments.

4. Clean up dead trees and brush in impoundment basins before flooding.

5. Destroy sphagnum moss and bring about a succession to sedge and grasses.

6. Create nesting areas for waterfowl and prairie grouse by bringing about a succession to grasses and other herbaceous cover.

7. Produce open areas that will provide better spring grazing for waterfowl.

Control burning on the Horicon Marsh Wildlife Area. Fire is one of the cheapest marsh management tools.

Removal of Annual "Rough"

Grange (1948:201) stated, "Fire for the purpose of eliminating marshland or upland 'rough' is of great service and the only effective and cheap tool that can be used."

This type of burning has been developed to a high degree in some of the southern and western states where it is used in pine forests to remove highly flammable "pine straw" and other ground debris, thus providing protection against uncontrolled wild fires. Game managers in Wisconsin who practice controlled burning on wetland areas usually have the removal of duff as one of their objectives, but on Horicon Marsh Wildlife Area this objective has probably been stressed more than on many of the other areas. Burning has been practiced here since 1947 and it has become more or less an annual practice with burns ranging from 700 to 3,000 acres. Without periodic controlled burns the shallow peripheral areas of the marsh become dense tangles of mixed dead and living stems and foliage which makes travel difficult and greatly restricts wildlife use. A winter burn on these areas creates open areas in the spring which often receive a considerable amount of waterfowl use. Since large quantities of vegetation are removed by the fire this slows up the natural build-up of the marsh floor and holds back plant succession.

Reduction of Marsh Floor Levels by Fire

Although many managers express hope that they can actually reduce the marsh floor by a conventional burn this is seldom accomplished in the southern half of the state where most of the marshes are fired in the winter, usually over an ice cover. Reduction of the floor is many times accidental to other types of burning, since it occurs only when conditions are right. Ground conditions must be relatively dry and the fire extremely hot and slow moving. With sufficient heat the organic surface soils ignite and burn downward into the under-lying peat to produce subsurface or peat burns. These subsurface fires may continue to smoulder and burn for days, weeks, months and in some cases even years after the initial surface fire is out, and are very difficult to extinguish. Shallow burns of this type may do no more than burn out the rootstocks of the vegetative cover and create a vegetation-free opening, but deep long-burning peat burns may create potholes 6 to 8 feet deep. Wildfires during the drought years in the early 1930's produced many such potholes on the Horicon and Eldorado Wildlife Areas. Peat burns occurred again on Horicon in the early 1960's during an early fall uncontrolled wildfire.

Peat burns are usually associated with late summer or early fall burning when extremely hot fires result. On the Navarino Marsh Wildlife Area it is customary to control burn in August and September. About 25 peat burns resulted from a controlled burn accomplished in 1966. Some of these reached depths of 18 inches. Ten or 15 peat burns resulted from a previous burn on this area, but these were somewhat shallower. The older burns have received excellent goose and duck use during migration periods. Peat burns create a highly desirable pothole effect which breaks up dense monotypes and provides open water. In general, peat burns can be considered as being highly desirable on most of the shallow, densely vegetated wetland areas needing a better interspersion of cover and open water. However, burns of this type should only be encouraged if they can be properly controlled and there is no danger that fires in the peat burns will escape to the surrounding uplands. If populated areas are nearby, long-burning peat fires may cause objectionable smoke, but it is a cheap way to create some very natural-appearing potholes that are attractive to wildlife. It has been stated that peat burns result in loss of soil fertility, but even if this is true the value of the openings created will outweigh the loss in value due to decreased fertility on these spots. In marshes subject to periodic flooding this fertility is probably soon replaced.

Control burning on the Navarino Wildlife Area produced a number of peat burns which opened up the solid vegetative cover and produced small potholes that later filled with water. This photograph shows peat burn potholes after the vegetation began greening up the following spring. The potholes proved extremely attractive to both geese and ducks during the spring migration.

Control of Woody Vegetation

In wetland management as practiced in Wisconsin this is probably the most common objective for controlled burning. Encroachment of woody vegetation into semidry wetlands proceeds at a rather rapid pace when water level controls are inadequate to eliminate or set back such growths.

Open sedge-grass meadows gradually become shrub swamps with the steady encroachment of various species of lowland brush. Fire is the most economical means of slowing down and setting back this encroachment. A controlled burn used at the right time and in the proper manner can produce a high degree of kill. Burns during the period when the vegetation is still actively growing tend to produce the best results. Burns made during the dormant season generally produced poorer kills than those made during the late summer and early fall. However, a slow hot burn made on Germania Marsh Wildlife Area during late February or early March produced a 75 percent kill on willows and paper birch. This was accomplished before the impoundment was flooded. On Wood County Public Hunting Ground willow was only retarded unless April burns were repeated every year. Very successful April burns were obtained on Crex Meadows Wildlife Area where the objective was to eliminate jack pine, aspen and oak and restore the original prairie, thus creating areas for waterfowl and prairie grouse. On the Ackley and Navarino Marsh Wildlife Areas very successful burns were made which controlled aspen, willow and leatherleaf. These were made in August and September when woody species were still actively growing. Any vegetation is more susceptible to injury during its period of active growth. Cooper (1963:33) stated, "If high fire temperatures are sought, as in the case of controlling undesirables, summer or hot weather burning has been shown to be more effective than dormant season burning."

However, this type of burning will necessarily have to be confined to late summer and early fall to prevent losses to nesting wildlife. Burning followed by flooding on French Creek Wildlife Area eliminated a considerable amount of willow. The burn was accomplished on May 25. It was also noted on this area that an uncontrolled burn in March, which apparently was of insufficient intensity, produced no kill on willow, but did encourage resprouting and actually increased the density of the stand. It would seem, therefore, that unless conditions are right for producing a hot killing burn, it might be better not to burn woody growths at all. A burn on the Princess Point Wildlife Area retarded willow growths, but brought in nettle and ragweed instead of the expected grass.

Destruction of Sphagnum to Bring About Plant Succession

Northern bog areas are often heavily and frequently burned to kill out leatherleaf and sphagnum and to bring about a recession to sedge-grass meadows which are more attractive for waterfowl and sharptails. Powell Marsh Wildlife Area is an example of such management. Controlled burning is practiced from April through September. Extremely hot fires produce a complete kill of leatherleaf. These hot fires are hard to control but produce excellent results. In one instance, heat was so intense that buckwheat in a field 1/4 mile from the burn was killed. Burning is continued annually to lower marsh levels.

Cleaning Impoundment Basins Prior to Flooding

This practice removes ground litter and reduces woody growths in the impoundment. Injury to woody growths due to burning hastens their complete kill by flooding. Some discretion must be used in applying this practice since much depends on the characteristics of the area involved.

There is some controversy over whether all brush should be removed from new impoundments. One faction feels that woody growths and debris produce acid stains in the water which restrict the growth of desirable submergents, while other workers feel that brush in impoundments adds valuable cover for breeding waterfowl. Large acreages of flooded timber on the Horicon National Wildlife Refuge seemed to add very little stain to the water in the early years following its flooding, but did afford a heavy tangle of woody cover which was heavily utilized by molting ducks. These woody stands also contained extremely heavy growths of duckweed, seemingly more than was produced in other types of habitat on the marsh at that time.

Organic stains seem to be relatively unimportant in the southern part of the state which has for the most part highly alkaline soils. Stains which would be of sufficient intensity to limit submergent vegetation do not seem to form. Deep organic stains do form in acid bog areas of the northern part of the state, but whether or not these are due primarily to standing woody growths is a matter for conjecture. There is some evidence to indicate that if these stains are a direct result of standing woody vegetation their intensity is governed by the species of shrub or tree involved (Linde, 1965). Impoundments containing mostly willow and aspen should develop only minor stains as a result of being flooded. This would account for the very light stains occurring in impoundments in the southern part of the state when woody growths are flooded since most of these impoundments contain primarily these two species. More is probably involved than merely the woody growths; soils and water chemistry are undoubtedly of considerable importance.

Probably the most important effect produced by burning off an impoundment before flooding is elimination of herbaceous rough and woody debris which would otherwise build up a layer on the bottom.

Production of Open Areas for Waterfowl Feeding and Nesting

Areas which are control burned during the dormant period seem to green up earlier in the spring. Being free from tangles of old vegetation these areas provide openings which are often heavily used by waterfowl during the spring migration. Desirable seeds from smartweeds, burreed, sedges and other aquatics are exposed and readily available to waterfowl on the burn, thus making these areas valuable as feeding and loafing sites. Geese utilize the tender new shoots which appear early on the burn. Palatability of these "greens" is probably increased by burning. Grange (1948:201) stated, "that fire-grown vegetation ranks high in palatability has been noted by game managers, but whether this is due to increased succulence of the new growth or to different chemical composition resulting from ash-fertilizer is again difficult to decipher."

Komarek (1965:177), speaking of the mineral and protein content of grasses following burning, noted that "this has been widely studied and these studies nearly all point to the fact that grasses arising from the burn are more nutritious, have more minerals and protein, and are more tender."

It would seem therefore, that fire not only stimulates new growth by opening up the "rough", but may also increase palatability and nutrition of the new shoots arising from the burn.

Irregular, patchy burns made during the dormant season on semidry sedge-grass meadows could improve the accessibility on these areas for nesting waterfowl the following spring by providing more edge effect. Givens (1962) used alternating patch burning which he considers more attractive to upland wildlife.

Burns seemed to have a definite effect on coot nesting by improving the water-to-cover ratio. Controlled burning on Horicon Marsh during the winter of 1959 was followed by high water in the spring of 1960, and the combination of vegetative removal by fire and the rise in water levels made many areas much more accessible. An erratic burn was produced in areas where the vegetation was sparse and of coarser texture and thus failed to carry the fire properly. This area when covered by abnormally high water levels provided a semi-open cover type interspersed with many small patches of unburned cattail, river bulrush and burreed. These patches seemed ideal sites for coot nesting platforms.

During a field trip which covered both burned and unburned areas Harold Mathiak and I counted 36 coot nests with eggs and an additional 16 empty platforms. Most of these nests were located in the burned area, which would indicate that the burn provided more desirable nesting habitat than did the unburned areas in the same habitat range. Of course, burning of this type would only have value to coots if it is accomplished in deeper portions of the marsh that will normally be well flooded during the spring nesting season. Kiel (1955) mentioned the importance of "isolated" stands of cattail and bulrush for coot nesting cover in his studies.

Techniques

Types of Fire

Fires may be classed as being either low intensity or high intensity, depending on the burning temperature. Low intensity fires are used primarily where protection of woody growths located in the burn area is desired. They are seldom used in marsh management where hot fires are needed to produce relatively clean burns that will carry through a variety of vegetation, some of which because of its coarseness or sparseness has low flammability.

Conditions which keep fire intensity at a low level are:

1. High humidity and high fuel moisture content.

2. A backfire moving into a strong wind which beats the flames to the ground.

3. A headfire which is driven by a relatively strong wind that causes the fire to move so fast that an incomplete burn is obtained.

4. Sparse vegetation of low stem density and flammability.

5. Cold air temperatures.

High intensity fires are produced by:

1. Low to normal humidities and low fuel moisture content.

2. Warm to hot air temperatures.

3. Fuels with high flammability, and high stem density.

4. A very slow-moving backfire moving into a light wind.

5. A headfire moving with a light to moderate wind.

When to Burn

Controlled burning has been accomplished during every month of the year in this state.

Reported burns by areas are as follows:

Southern Area . . . . . . March through May
East Central Area . . . . November into May
West Central Area . . . . January through April
Northeast Area. . . . . . April through September
Northwest Area. . . . . . April, Spring and Fall

It is to be expected that the hottest burns will be accomplished during warm weather, all other criteria for a good burn being optimum. However, spring and early summer burning involves the risk of destroying duck and upland bird nests. The spring nesting period varies within the state from south to north with nesting in the north beginning somewhat later. In general this period extends from April into July, but early mallard nesting in the south may begin as early as the latter part of March. It is well to avoid burning during this period.

Late summer burns after all nesting is completed or early fall burns are desirable. However, in areas which are heavily hunted there may be some conflicts since it does remove the hunting cover. However, if patch and irregular burns were obtained in dense monotypes it is possible that it might open the area up just enough to actually improve hunting by improving accessibility and creating more opening for the birds. If the burn was made early enough the area would green up before the hunting season. Winter and very early spring burns, although they probably would not produce as hot or clean a burn, are undoubtedly the least conflicting with other interests on waterfowl areas. However, they cannot be satisfactorily accomplished with a heavy snow cover. If it is a winter of heavy snowfall very little burning may be accomplished unless it is done early.

In the final analysis, the game manager should judge when he should burn, since he is the one best acquainted with his area and should know just how serious the previously mentioned conflicts will be.

Criteria for a Good Burn

In the Antigo District (Northeast Area) the preferred period of burning is August and September. At this time the vegetation is mature, but still green. Desired humidity is 30 percent, but a successful leatherleaf burn was obtained with a humidity of 45 percent. The Bureau of Fire Control is more favorable to controlled burning at this time since most of the wetlands which are burned are surrounded by forested uplands. Fire control is a major consideration when planning a controlled burn and in the forested areas cooperation of the Bureau of Fire Control is usually requested.

Fire control lines around the perimeter of the burn usually utilize established roads in the Antigo District, but when necessary, 4-foot firebreaks are plowed which are two furrows wide. Type and number of fire lines needed will depend on the individual area. Many marshes in the southern part of the state have sufficient natural firebreaks, such as plowed uplands, ditches and rivers which make the plowing of firebreaks unnecessary.

Burning usually starts about 10:00 a.m. after the sun has dried the dew off the vegetation and continues until the job is completed -- sometimes after dark. Desired wind velocity is below 10 mph and headfires (burning with the wind) are usually used on large burns since they are much faster than backfires. Backfires (burning into the wind) are used only on small areas where very hot fires are needed. A backfire will burn against a 5 to 10 mph wind at the rate of 66 to 100 feet per hour when burning duff in a pine forest in Florida (Bonninghausen, 1962). While these rates probably do not apply to marsh burning it is obvious that back burning is extremely slow. For best results parallel interior firebreaks should be plowed at 600- to 800-foot intervals (90° to the wind) to confine each section to an 8-hour burn. However, to speed up the process 8 of these divided sections should be fired in succession after the base line in the preceding section has been established as safe so that all are burning simultaneously. Eight 600- to 800-foot sections are therefore burned in a single day. Five to six men are needed for the average 300- to 600-acre burn.

This method should be applied only to a dry marsh where it is possible to plow firebreaks or where the marsh has some natural breaks which would lend themselves to such control. One of the most important requirements is that the material being burned is present in sufficient density to carry the fire. In burning living brush and trees a good understory of herbaceous cover is necessary.

Costs

Costs are dependent on a great number of variables and it is impossible to set any standard for judging costs other than to say that usually the larger the burn the cheaper the per acre costs, since it costs relatively little more for controlling the fire on a much larger acreage. This does not always hold true, however. Areas surrounded by forested uplands may require much more elaborate control measures than a small area in farming country where little or no controls are needed. Per acre costs would necessarily favor the small area in this case. An extreme example of this is indicated by the cost figure of $4.48 per acre for an 80-acre burn and a cost of $1.25 per acre for a burn of only 18 acres. Very elaborate fire control was needed in the first instance cited.

Grange (1948) experimentally control-burned 200 acres using a crew of 5 men at a cost of 30 cents per acre. He felt that this cost was abnormally high and that it should be possible with a smaller crew and better conditions to reduce the costs to an estimated 10 cents per acre. However, since this work was accomplished in the early 1940's the costs are not directly comparable.

Controlled burning data supplied by game managers when averaged for the entire state show that the average sized burn is 726 acres and the average cost is 56 cents per acre. The cheapest burn recorded was 5 cents per acre and the most expensive was $4.58, cited previously. Data for the Mead Wildlife Area further illustrate the extremes in control burning costs (Table 12). Costs vary from 5 cents to $1.06 per acre. Since all these burns were accomplished by the same game manager and on the same area it illustrates the great variation in burning conditions which can be encountered from one burn to the next. A survey of the literature shows comparable extremes in burning costs for control burning in pine forests.

Effects of Fire

Increased Nutritive Value of Plants Following Burning

DeWitt and Derby (1955) found that burning of a wooded area produced nutritive effects on 4 common deer browse species which were more pronounced during the early part of the growing season and gradually decreased as the season advanced. They also found that deer feeding exclusively on the species in the burned areas ingested from 10 to 26 percent more protein per calory unit than animals feeding in unburned control plots.

TABLE 12

A Series of Controlled Burning
Costs on the Mead Wildlife Area
April 1961 and 1962

Acreage Burned	Cost Per Acre Burned
450	$ 0.36
920	0.05
815	0.14
235	0.41
100	0.30
155	0.35
110	0.16
650	0.28
35	0.48
250	0.51
275	0.49
700	0.21
50	1.06
75	0.62
500	0.59
360	0.32
Avg. 355	$ 0.40

Note: No expensive fire controls are necessary on this area, but costs include firebreaks and fire protection help when needed. Burns are accomplished in the spring when the ground is still frozen.

Biswell (1963) found that soil nitrogen increased in burned-over pine forest soils. Intensively burned soils showed more nitrogen than lightly burned soils and both showed an increase over unburned soil. pH increased only in soils where brush piles had been burned and there was no increase where broadcast burning was practiced.

Ahlgren (1963) noted that burning increased soil fertility temporarily. In the top inch of soil, nitrogen, phosphates, magnesium, potash and calcium increased immediately after the fire. Nitrogen, potash and calcium returned to preburn levels during the second growing season. pH was higher immediately after the fire, but returned to normal in the second year. These tests were made in an area of burned-over jack pine slash.

Studies have shown that grasses arising from a burned area are more nutritious, have more minerals and protein and are more tender than grasses in unburned areas (Komarek, 1965). Hilmon and Hughes (1965), reporting on studies conducted by the U.S. Forest Service, stated that protein, phosphorous and calcium were higher in spring forage from burned areas. Cattle preferred forage on burned areas, and gains were 37 percent higher there. These studies would tend to indicate that on waterfowl areas, especially where goose grazing is of major importance, burning off areas to produce spring and fall greens should be practiced instead of mowing the areas. Mowing is presently a common practice where marsh hay is in demand. Game managers often sell the hay to farmers who do the mowing and thus the crop is removed making way for a crop of fall greens and opening up the area for fall goose use. An early fall burn in such cases would accomplish the same thing, but at the same time might provide more nutritious and palatable greens for goose use.

Other studies by the U.S. Forest Service (Hilmon and Hughes, 1965) indicated that frequently burned over soils were slightly less acid, and contained more bacteria, organic matter, total nitrogen and replaceable calcium. Forage quality was also highest immediately after fire, but declined rapidly to borderline for proper cow nutrition 3 months after burning in pine-bluestem and pine-wiregrass. Winter burning increased protein and phosphorous content for the period from March through May, but forages from burned areas show no advantages over forages from unburned areas after that.

Lotti (1962) found that organic matter increased in the soil after burning in pine woods, because woody debris breaks up into fine charred bits which are more easily assimilated into the soil.

Fruit and Seed Production

Biswell and Lemon (in Hilmon and Hughes, 1965) found that late spring and early summer burning at Alapaha stimulated seeding of native grasses more than fires in the winter or early spring. Fire has a stimulating effect on seed and fruit production of many desirable wetland species. Grange (1948:198) stated, "Smartweed sometimes makes dense stands, almost as though seeded as a crop on burned organic soil, notably peat". He also noted that ragweed became abundant following fires on sods of old farm sites. A control burn on the Princess Point Wildlife Area for the purpose of eliminating willow from a sedge-grass monotype brought in ragweed and nettle while retarding the willow. No grass came into these ragweed-nettle areas. It is possible that this may have been an old farm field in the past and that fire released residual ragweed and nettle seeds.

Curtis (1959), Grange (1948), and others have mentioned the effect that fire has on the seed and fruit production of many species including such wetland or lowland species as blueberry, cranberry, sedge and cotton grass. Vogl (1964:326) said, "Fruit and seed production following burning is particularly conspicuous in species like sweet blueberry, small cranberry, few-seeded sedge, and cotton grass."

An excellent example of this response occurred on the Ackley Wildlife Area following a controlled burn on a former black spruce-leatherleaf bog which had been opened up through the use of fire and herbicides. During the summer following the fire, cotton grass covered most of the area with a white carpet of blooms as far as the eye could see. The succeeding summer this again occurred and in that fall an extremely heavy blueberry crop brought many blueberry pickers to the area. Cotton grass was reported utilized on Powell Marsh Wildlife Area by grazing geese and is a desired species on this area. However, Vogl (1964) found that, on Powell Marsh, although cotton grass and blueberries may be stimulated by fire to bloom and produce more fruit the actual number of plants may decrease after a fire. But he pointed out that investigators in other states have found increases in blueberries and cranberries following fire and much depends on the location of plants involved. If these species actually decrease in number following a fire, burning at too frequent intervals is undesirable if the goal is to propagate them. Increased fruit production was noted by Vogl for 1 to 3 years following a fire.

A sea of cotton grass blooms appeared on the Ackley Wildlife area following a control burn. In the Northeast Area cotton grass has proven to be a desirable goose food. Tender new shoots which appear following a fire are grazed by geese.

The use of fire as a game management technique is well expressed by Grange (1948:202), "How to use fire wisely is a matter of game management technique. The principle of such use should be accepted as necessary, with any debate on the matter limited to methods of application."

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VEGETATION CONTROL

Use of Herbicides

Herbicides are coming into wider use in the area of fish and game management as new techniques and new chemicals are developed which fit program needs. Herbicide research has been primarily directed toward agricultural uses since agriculture is by far the largest single user of these materials. In the development of aquatic herbicides the emphasis has been on control of many of the species which game managers have been seeking to propagate. Submergents, such as the pondweeds, are considered some of our best waterfowl foods and should be encouraged in aquatic environments managed for wildlife. However, it is obvious that here again we are at a disadvantage since the concern of cottage owners, boating interests and commercial interests is for more effective chemicals to eliminate these weedy growths interfering with fishing, boating, swimming and other uses of the waterways.

However, the picture is not completely gloomy, since many of the chemical manufacturers have been sympathetic to the problems of wildlife technicians and most cooperative in attempts to help them. Some have supplied chemicals for experimental use in wildlife habitat management and have attempted to make results available to other workers in the field. Wildlife technicians have developed better techniques for the use of standard chemicals through this cooperative effort and are in a better position to know of new developments in chemicals.

Herbicides have been used in the management of wetland and upland game habitat in various places in Wisconsin during the past decade. There is probably no management district in the state that has not used chemicals, but the results of these efforts are difficult to obtain in a usable form since accurate records of the work are most often combined with records of other work done at the same time.

Use of Herbicides on State Areas

Woody Growths

Brush control on dikes and the suppression or elimination of brush and trees during land clearing operations have been the most common uses of herbicides. For this purpose 2,4-D and 2,4,5-T have been the standard chemicals used, both singly and in combinations. Information in game management files indicates that costs of these operations have varied from $1.44 per acre for sprout control in land clearing to $19 per acre in brush control on impoundment dikes. The excessively high cost of dike brush control seemed to be due to excessive use of the chemical. Utilizing the data available on this operation, the application rate was calculated to be about 5.3 pounds of 2,4,5-T acid equivalent per acre. Since effective control was obtained on other areas at 1-1/2 to 3 pounds acid equivalent per acre, it is apparent that a much larger amount of chemical was used than was needed. Not only was this high application rate uneconomical, but it resulted in a lower rate of kill. Only a 60 percent top kill resulted. Excessive application rates often produce a quick burn of the leaves which prevents proper translocation of the chemicals. A slower leaf kill produced by the proper amount of chemical will allow translocation of the chemical to take place over a longer period of time and the chemical will spread more efficiently throughout the plant, resulting in a higher rate of kill. It is well to follow recommended application rates rather closely.

The two management areas which had the largest amount of data available on the use of chemicals for tree and brush control are the Buena Vista Marsh and the Ackley Wildlife Area. Both areas are being managed primarily for grouse, but the methods being used to control woody growths are applicable to any area.

Buena Vista Marsh. The commercial preparation known as Weedone was the principal chemical used on this area. This is a 1 to 1 mixture of 2,4-D and 2,4,5-T as a butoxy ethanol ester. The chemical application was made to the new sprout growth during the summer following land clearing operations.

The application rate of 1-1/2 pounds of acid equivalent per acre was made from late June into July, the period of maximum sprout growth. A 90 to 100 percent kill was obtained on willow and spiraea and about 75 percent kill on aspen. A second follow-up spraying was made the following summer on remaining live sprouts. While 2,4-D alone was found to be effective against willows (this agrees with Martin et al., 1957), the mixture of 2,4-D and 2,4,5-T was more efficient where other woody species were involved. The cost of chemical treatment was about $3.00 per acre. While a boom sprayer had been used initially to apply the chemical, a three-nozzel Hanson Brodjet which was used later proved to be more efficient. On rough ground the boom tended to dig in. Equipment was tractor-mounted and the six-roller spray pump was operated off the power take-off of the tractor.

Six years after treatment large areas which were cleared of brush and trees and chemically treated in this manner still remained open meadows and were almost completely free of brush.

Ackley Wildlife Area. Almost 700 acres of brush and timber were cleared and chemically treated on Ackley during the years 1959 through 1964. Three different methods of chemical application were used during this period.

(1) Aerial Application: Chemicals were applied at two different rates and with two different herbicides on a total treated area of about 356 acres. Three quarts of 2,4-D per 7 quarts of water or 3 pounds of acid equivalent per acre were used for part of the area and the remainder of the area was treated with 1-1/2 quarts of 2,4,5-T in 8.5 quarts of water or 1-1/2 pounds acid equivalent per acre.

Aspen, willow, elm and hardwoods from brush up to 8 inches in stem diameter (DBH) were the principal species treated. Most stems were over 3 inches in diameter. The objective of this operation was to obtain a top kill of the woody overstory and open up the area to an invasion of grasses and herbaceous cover. This in turn would make the area more flammable and permit an effective cleanup burn. In terms of the objectives, the results were very satisfactory even though the percentage of kill on red maple was rather low for both chemicals. Although both chemicals gave very satisfactory results, 2,4-D was the more effective of the two. Cost of this operation for both spray areas combined was $5.57 per acre. This included cost of the plane rental which was about $1.35 per acre of herbicide applied. Spraying was done in June.

Spray Operations on Buena Vista Prairie Chicken Area

Before land clearing (above); after land clearing, which involved cutting and herbicide treatment (below).

Tractor-mounted spray rig used in herbicide work.

(2) Ground Application Using a "T" Jet Spray Nozzle. In 1963, 152 acres of timber and brush which had previously been "walked-down" with a bulldozer were sprayed for sprout growth. Equipment consisted of a trailer- mounted Darley pumper with its own power source and a "T" jet spray nozzle. Trailer and equipment were pulled behind a crawler tractor. Aspen, willow and alder sprouts were treated with 2,4-D at a cost of $2.15 per acre. Very good results were obtained.

(3) Ground Application Using a Mist Blower. A mist-blower-type sprayer mounted on a trailer and pulled by a crawler tractor was used in 1964 to treat 176 acres of knocked-down timber and brush for sprout growth. Most of this growth was aspen, maple and willow. About an 85 percent kill was obtained and the operation was considered very satisfactory. Cost of the operation was about $1.98 per acre for labor and equipment. The mist blower seems quite efficient, but care must be exercised when using this equipment in the vicinity of vegetation which should not be killed since the spray mist is very light and drifts long distances. Experience on the Ackley area shows that this equipment is simple and easier to operate than other types of spray equipment used. Spraying was done in July using 2,4,5-T as a herbicide.

Cattails

Chemical control of cattail was attempted in various districts but usable records of these applications have been difficult to obtain. Radapon was used to treat cattail on Rush Lake Wildlife Area on two different occasions. An aerial application was made in the middle of July using 10 pounds of Radapon per acre. The area covered was a strip 100 feet wide and 500 feet long. A commercial crop dusting plane was used for this operation. Costs were high and the results unsatisfactory. In another attempt at cattail control on this area Radapon was applied with backpack fire cans using a mixture of 5 pounds of chemical in 5 gallons of water. The area covered was 30 feet wide and 200 feet long. A repeat application was made the following year and a satisfactory control was obtained. This type of treatment was considered satisfactory for small areas.

Seed heads had already formed by the time these treatments were made. No doubt both treatments would have been more effective if they had been made before the seed heads had formed. Perhaps only one application would have been needed. Martin et al. (1957), Lopinot (1953) and others have mentioned the importance of treating cattail at exactly the right stage in its growth if maximum control is to be obtained. This stage occurs before the seed head has formed and when the staminate spike is not yet dry.

Experimental herbicide test plots at Horicon Marsh Wildlife Area indicate that cattail treated just before the seed heads have formed with 2 gallons of Amitrol-T (ATA) (2 lbs. active ingredient per gallon) (Linde, 1963:65) or with 20 pounds of Radapon showed good control on cattail into the second year following the treatment. When the application rate was 4 gallons per acre the effects persisted into the beginning of the third summer. Only minor encroachment by cattail and burreed seedlings had occurred at this time. At the rate of 2 gallons of Amitrol-T per acre, the cost for chemicals was $19.90 per acre.

Any chemical treatment is more efficient if the area to be treated is mowed or burned to remove the old vegetation first (Martin et al., 1957). This is especially true for cattail control since the old stems and leaves are so dense. Burning removes the large amount of dead material which would prevent maximum penetration of the spray into the stand, and thus chemical is saved.

Steenis et al. (1959) experimented with both Dalapon (similar to Radapon) and Amitrol-T and found that combination treatments involving both chemicals in a mixture were more economical than if either herbicide was used separately. Two or three pounds of Amitrol-T mixed with 5 pounds of Dalapon per acre afforded effective cattail control, was just as effective as either chemical applied separately, and cost only $17 per acre. When Dalapon was used alone 20 pounds per acre were needed and the cost was $20 per acre. Amitrol-T used alone required 5 pounds per acre and also cost $20.

Water Lilies

An attempt was made (Hopkins and Bell, 1958) to control white water lilies on Horicon Marsh Wildlife Area with Kuron. Aerial treatment was made to one set of plots at 2.0 pounds per acre of acid equivalent. Another set of plots received a split treatment. The first application to this set was on June 9 and the second was made on June 23. Both applications were at the rate of 2 pounds per acre of acid equivalent, the same as the treatment in the first set of plots. The area receiving the single treatment showed some initital effects of the herbicide, but by July 30 had completely recovered. Plots receiving the double treatment showed control throughout the 1958 growing season. However, by the end of the 1959 growing season recovery seemed to be complete.

Northern Bog Plants

Leatherleaf and other bog species were treated with a variety of chemicals including 2,4-D and 2,4,5-T by Jahn and Popov (1956). Application rates of 2,4-D and 2,4,5-T ranged from 4 to 24 pounds acid equivalent per 100 gallons of water. None of the treatments resulted in a consistent 100 percent kill.

Experimental Herbicide Plots

During the 1962 and 1963 growing seasons on Horicon Marsh Wildlife Area (Dodge County), various herbicides were tested singly, in combinations which included split treatments and mixtures, and under a variety of conditions. A listing of the chemicals and their current costs are shown in Table 13. The objective of these experiments was to find an economical and efficient method for opening up dense monotypes of wetland vegetation and to produce openings that would be favorable sites for the growth of smartweeds, millets and other waterfowl food plants.

Pretreating areas by mowing and burning before spraying seemed to improve the effectiveness of the herbicide in most cases. Where some of the herbicide plots were flooded late in the second spring and early summer, excellent crops of water smartweed invaded these openings.

No heavy stands of smartweed resulted from any treatment in the first year. In most instances plants existing at the time of spraying were either stunted or killed and very few produced seed. Most smartweed growths which germinated after spraying came in too late to flower. In the case of soil-absorbed herbicides such as atrazine and simazine smartweeds were stunted by the chemical after germination and never flowered. Smartweeds seemed to be more tolerant of chemicals than many species, however. In the second summer fairly good growths of smartweed often appeared and flowered where chemical treatments were not too heavy.

Results indicated that when using more than one chemical in a treatment split applications are desirable unless the chemicals involved are known to be compatible with one another. If the wrong chemicals are combined in a mixture the effectiveness of the treatment may be reduced.

TABLE 13

Costs of Herbicides Mentioned in the Text

Herbicide	Cost (1968)	Active Ingredient
2,4-D	$ 4.00 per gallon	65%
2,4,5-T	Not Available	
Tordon	13.33 per 1/2 gallon	2 lbs/gal.
Radapon	1.15 per pound	85%
Dalapon	1.08 per pound	85%
Amitrol-T	10.75 per gallon	21.1%
TCA	0.445 per pound	94%
Simazine	2.90 per pound	80%
Atrazine	2.20 per pound	80%

Radapon (85 percent active ingredient, 74 percent acid equivalent). Effective control of cattail was obtained at 20 pounds of the product per acre. Cattail plots which received 10 and 30 pound treatments were accidentally burned by an uncontrolled fire a few days after being treated. These plots showed little chemical effect when the new vegetation came in following the burn. Since this is a leaf-absorbed herbicide the chemical was apparently destroyed by the fire before it could be translocated to the rest of the plant to effect a kill.

In sedge-grass areas applications of 20 to 30 pounds of product per acre showed a good kill early in the second summer. These areas were partly flooded at this time and fair amounts of water smartweed invaded the open flooded portions of the plots. This species is a common invader of disturbed land in this area. Chemicals in conjunction with water level control would seem to be an effective combination to use in such areas.

Only the plot treated with 30 pounds of product per acre showed visible effects of the chemical in the third summer.

Combination Treatments. Radapon mixed with atrazine as a single treatment was not effective when less than 3 pounds of Atrazine was used per acre. If each chemical was applied individually a fairly good kill was obtained with 5 pounds of Radapon and 3 pounds of atrazine per acre on sedge-grass areas. Radapon and Tordon showed similar results when applied as a mixture, but produced a fairly good kill on sedges and grasses and broadleaf species when applied as split treatments.

Simazine (80 percent active ingredient). An application of 40 pounds of product per acre in a sedge-grass area that had been burned the previous winter produced an opening that presisted with very little re-invasion through the third growing season. Only sweet flag showed resistance to this treatment. It actually spread during the second and third summer. Tufted loosestrife invaded the area in the third summer and flowered, although grass and sedge were still being severely affected by the residual chemical.

Sedge-grass and broadleaf mixtures were controlled by 30 pounds of product per acre in areas which had not been mowed first, but only 10 pounds per acre were needed where the plot had been mowed first. Only grass was satisfactorily controlled at 15 pounds per acre of product in unmowed areas and only 5 pounds per acre were required in mowed areas. Smartweeds were present in larger amounts at the end of the summer in the plot treated with 5 pounds per acre than in those treated with higher application rates. Considering the high cost of chemicals it seems advisable to mow or burn the area to be treated before application is made since in the case of simazine only about 1/3 as much chemical is needed in pretreated areas to obtain the same result.

An attempt in the second spring to seed Japanese millet on mudflat areas cleared of vegetation by applications of 10 and 20 pounds of simazine product per acre failed. Residual effects were apparently too great.

A heavy application of Simazine on an experimental herbicide plot on the Horicon Marsh Wildlife Area killed all species present except for sweetflag. This opening lasted through 3 summers.

Atrazine (80 percent active ingredient). Grass was satisfactorily controlled with atrazine on an area burned the preceding winter. Application rate was 5 pounds of product per acre. In an area which had been mowed prior to treatment, only 3 pounds were needed to give the same result. Sedge control which extended through the first year was obtained at 10 pounds of product per acre. When a 15 pound application was made on a previously mowed area there was a heavy residual effect into the second summer, but in the third summer smartweed growths were good. At this same application rate, but on an area that was mowed and burned prior to treatment, excellent common smartweed growths appeared during the second summer. Smartweed seems to be highly resistant to atrazine and invaded areas which were still strongly affected by residual chemical.

Tordon (2 pounds per gallon active ingredient). Tordon is very effective at small application rates in the control of woody vegetation as well as for herbaceous broadleaf plants (Wiltse, 1964). Since it is a relatively new development in the chemical field its full potential has not yet been realized. It has residual properties which produce relatively long-lasting effects. This is because it degrades slowly. Leaching occurs rapidly in most soils, however, and the length of its effectiveness will therefore depend on the amount of precipitation which follows the application. It is not only absorbed through the roots but is translocated by the leaves as well. Therefore, if a heavy top kill results in suckering, the portion of the chemical in the soil could continue to produce toxic conditions which might eventually destroy the suckers. The residual period during the Horicon experiments seemed to last throughout the first growing season and in some cases into the second. This chemical should be tested for brush and tree control where 2,4-D and 2,4,5-T are now being used. It is available in various forms including both pellets and liquid.

In the Horicon test plots willow was severely affected by a treatment of 10 pounds of Radapon (product) per acre and 1/2 pound of Tordon (active incredient) per acre in a split application. The willow continued to live through the summer but was dead by the following spring. Since Radapon is primarily a control chemical for grasses and not for broadleaf species, the effects on the willow must have been principally those of Tordon. Higher application rates will probably produce quicker and longer lasting kills. Control on grass in this plot continued into the second summer, when a heavy growth of panic grass invaded the plot. Original grass cover was mostly blue-joint.

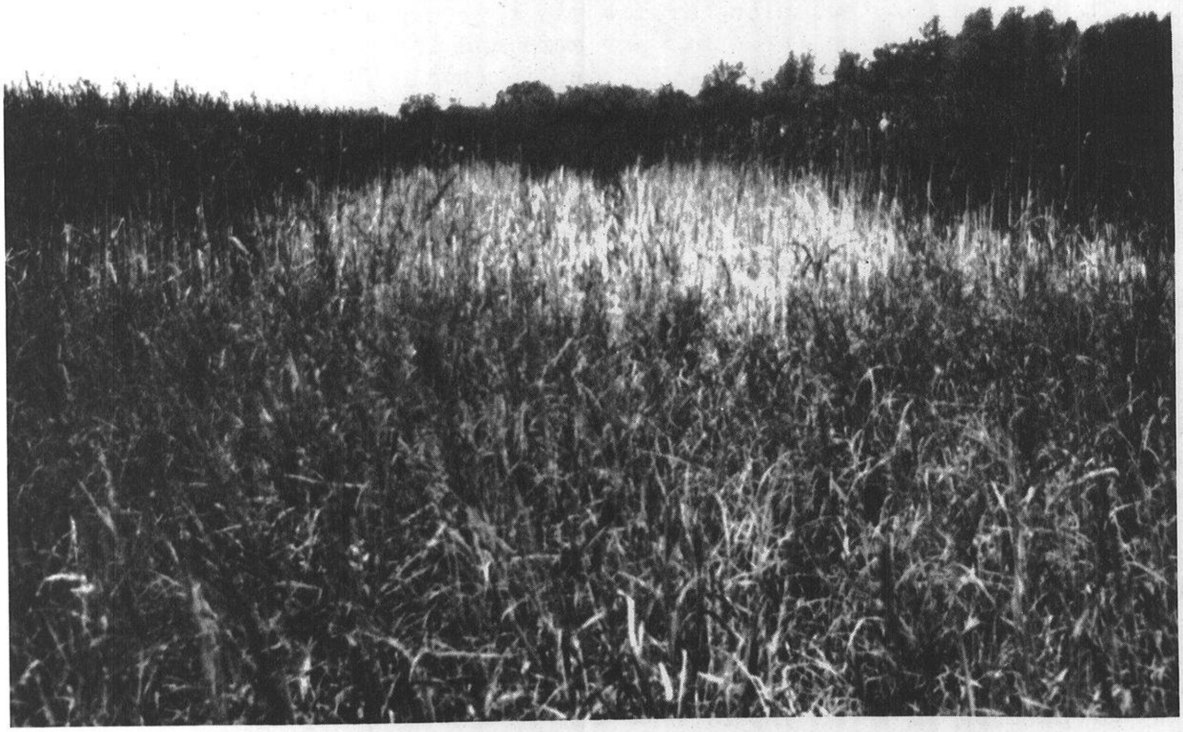
Three pounds of Tordon (active ingredient) applied to an area which was primarily sedge but which also contained a mixture of broadleaf species produced excellent control of the broadleaf plants but seemed to have little or no effect on the sedge. These effects were very pronounced through the second summer.

This chemical should have application in brush control on impoundment dikes. It may produce longer lasting effects than 2,4-D and give cleaner kills. Grass dike cover should be improved by its use since it suppresses broadleaf growth throughout the growing season of application and at higher application rates may continue on into the second season. All tordon used in these experiments was in the liquid form.

<u>TCA</u> (94 percent active ingredient or 82.8 percent acid equivalent). This chemical produced a heavy initial kill on existing smartweeds in the herbicide plots. Smartweeds were fairly resistant to most of the chemicals tested but TCA produced heavy kills on this species. However, since TCA is a leaf-absorbed herbicide there was no residual effect even at high application rates and by fall new growths of smartweed were well established.

A heavy top kill on grass was produced during the first summer, but sedge could not be satisfactorily controlled even at 50 pounds of product per acre. Although grass seemed to be severely affected this was apparently only a top kill and by fall regeneration from the roots was heavy. No effects of the herbicide could be found in the second summer. This was obviously the least effective of any of the herbicides tested.

Amitrol T (21.1 percent active ingredient). Applications made at 4 gallons of product per acre produced excellent control of cattail with only minor re-invasion in the third summer following treatment. No mowing or burning preceded these treatments. If the old vegetation had been removed and only new growth treated, effective control could have been obtained with lower application rates.



Amitrol T produced a heavy kill on experimentally treated cattail which lasted through the 3rd summer.

Spraying

Types of Sprays

There are two main types of chemicals which are commonly used in wildlife management. These are: (a) foliar or leaf-absorbed sprays such as Radapon, Amitrol-T, TCA, 2,4-D and 2,4,5-T, and (b) soil-absorbed chemicals such as atrazine, simazine and tordon (tordon is a combination foliar and soil-absorbed spray, working in both ways).

Soil Absorbed. When using the soil-absorbed chemicals it is desirable to reduce the ground cover by mowing or burning before application so that as much herbicide is sprayed directly on the ground surface as possible. This increases speed of kill and more effective uses the chemical. Penetration into the soil is speeded up if treatments are followed by light to moderate rains involving a minimum of surface runoff, and a maximum of soil penetration. These herbicides are often very slow acting, taking a month or more before results become noticeable on the vegetation. The results therefore are usually longer lasting and re-invasion of treated areas is usually slow to occur because of residual chemical effects.

Foliar. Foliar sprays are also more efficient if the area to be treated is prepared first by mowing or burning. In the case of woody growths the operation is much more efficient if tall heavy brush and trees are cut and only the new sprouts are sprayed. This reduces the amount of woody material to be covered to a minimum and improves spray penetration of the stand. As a result, the chemical costs are reduced and a maximum kill is produced. Brush up to 2 inches in diameter can be mowed quite efficiently with a tractor-mounted rotary cutter or "Bush-Hog" if the terrain is suitable. Where the herbaceous understory is dense enough, a sufficiently hot fire may be obtained which will kill back the brush stems and reduce the number of large stems to be sprayed. Spraying should be accomplished on the regrowth material or on old growths when the new leaves are fully opened and actively producing and translocating food. Earlier when the leaves are first opening, nutrients are passing from the stems to the leaves and late in the summer transfer of food from leaves to the stems is tapering off to a minimum. Both of these periods are to be avoided when spraying. Since these herbicides must be translocated by the plant to its various tissues, the most active stage of growth when the exchange of food from the leaves to the stems is greatest, is desired. Herbicides produce the best effects when conditions are optimum for plant growth during sunny, warm and humid weather (Martin et al., 1957). Water soluble foliar sprays should remain on the plants at least 6 hours before a rain. Breezes should be minimum to prevent spray drift.

Basal Sprays. To kill trees or prevent stump sprouting a basal spray may be used. (Buchholtz and Briggs, 1953). This consists of 2,4-D or a mixture of 2,4-D and 2,4,5-T in kerosene or fuel oil. One pound of active ingredient in an ester formulation mixed with 10 gallons of oil can be used. The stump should be thoroughly covered with the mixture to the level of the ground. In treating standing trees the lower 18 inches of the tree should be completely covered. Heavy dead bark should be notched or frilled before the mixture is applied. Basal spray applications can be made at any time of the year.

Phenoxy Compounds

These are the most commonly used herbicides at the disposal of game managers for foliar and basal spraying. They include 2,4-D and 2,4,5-T and are available in various formulations. In their pure form they are water insoluble crystaline solids. To make these materials usable for field use they must be formulated into soluble substances which can be applied in the field. This can be done either by esterfication or by changing them to an amine salt.

Esters. Esterfication is merely a chemical combination of the basic compound with an alcohol to form an "ester". This process makes it soluble in oil and since other substances have also been added the solution of herbicide and oil will also emulsify in water. The mixture can therefore be diluted to the proper degree with either oil or water for application. Esters, because they are made with alcohols, are volatile in varying degrees depending on the type of alcohol. Ester formulations are classified as being volatile or low volatile formulations. Since these formulations are all volatile in some degree they vaporize readily and if this vapor drifts into areas where they are not wanted damage to the vegetation may result. Therefore care must be exercised in their use. The chemical continues to vaporize even after it has been applied and it is not merely a matter of the wind causing the spray from the sprayer to drift. Ester preparations are probably best used for brush control if conditions permit.

Amines. Amine salt forms of 2,4-D and 2,4,5-T are also available. To make these formulations, the chemical is neutralized by an amine, several of which are available for this use. This forms a water soluble liquid that produces a clear solution when mixed with water. The amine formulations are not soluble in oil and are not volatile. Where fuel-oil mixtures are desired, such as for basal sprays, these formulations cannot be used. Near sensitive crops the amine or low volatile esters are the best formulations.

Mixing Chemicals

Active Ingredient. Chemicals are compared on the basis of the active materials or the acid equivalent of the product. Since most herbicide preparations contain inert material as well as the active chemical, and since these active ingredients vary with the formulation and the manufacturer, application rates are most often expressed in terms of "active ingredient" or "acid equivalent". Product packages are labeled to inform the user of the amount of active chemical contained in a pound or gallon of the preparation or formulation. If the product of one manufacturer of a certain herbicide contains 60 percent active ingredient the same chemical may be produced by a different manufacturer with the product containing 80 percent active ingredient. It is obvious that if the first preparation gives the desired results when using 1 pound of the product, this amount should be reduced by 20 percent if comparable results are desired when using the second product. In figuring chemical costs, making chemical purchases or comparing products, it is important that costs be figured in terms of pounds of active ingredient and not pounds of product.

Diluent. The application rate for the chemical is the same whether 1 pound of the active ingredient mixed with 100 gallons of water is applied to an acre or whether 1 pound of active ingredient mixed with only 50 gallons of water is applied to an acre. Only the amount of the carrier (water) has changed. The use of large amounts of water when making the application is often recommended since it is easier to obtain a more even coverage of the area to be sprayed. However, Buchholtz and Briggs (1953) noted that good results have been obtained using only 10 to 20 gallons of water mixture per acre. Less water can be used with more efficient spraying equipment if it effectively covers the vegetation, even when small amounts of solution are used. However, unless effective coverage is known to be good at low spray rates it is better to use a fairly high volume of water in the spray mix (100 gallons per acre for small areas). Since spraying of large quantities of solution is not always practical when large areas are being sprayed, it is necessary to take every precaution to obtain the best coverage possible with a smaller quantity of diluent. Martin et al. (1957) recommended the use of 50 to 500 gallons per acre of solution when spraying from land or boat. Much less diluent is used if aerial spraying is used. Good coverage without wasteful runoff should be the goal.

Sticker-Spreader. To make the sprays more effective a sticker or wetting agent is often used, especially on shiny, water-repellent foliage. Common household detergent makes an effective wetting agent when added in amounts just sufficient to give good adherence. The exact amount needed can be determined experimentally by adding in increasing amounts to a pure water spray and checking the vegetation as the spraying progresses.

Application Rate. In most instances application rates are figured in terms of active ingredient per acre, but when spraying dense brush an application rate on a per acre basis is not always practical. In such cases the application rate may be determined as active ingredient per 100 gallons of spray solution (AHG). In brush control work, the amount of solution used on an area depends upon the density of the brush coverage. Since hand guns are usually used, adequate wetting of the foliage determines the amount of spray used on any particular area. Spray solutions are therefore mixed on the basis of pounds of active ingredient mixed with 100 gallons of water. When small scattered fractional-acre areas are sprayed using a back-pack-can sprayer, application rates are best figured using this method, since per acre application rates would be next to impossible to determine and apply.

Where power-operated spray rigs are available which can be tractor propelled at a constant slow rate of speed, the per acre application rate is more accurate and should be used.

Unless the treatments are made by experienced personnel the application rates obtained by hand-gun spraying may be quite erratic since proper coverage depends on the judgment of the operator. It is quite easy to overapply herbicide by this method. Overapplication of the phenoxy compounds usually results in a quick and spectacular top kill followed by intense resprouting, making a re-application necessary.

Cutting heavy brush before herbicide treatment and then treating the sprout growth is much more efficient than trying to apply herbicide to dense, tall brush since it is often impossible to drive the spray through the leaves for any distance even with high pressure spray equipment. The result is a kill close to the sprayer and only a partial top kill to stems farther in the stand.

Spray Equipment

A number of types of spray equipment have been used by game managers in this state. Most of them have already been mentioned but it might be well to briefly describe the equipment and explain how each is used.

Back-Pack Sprayers. Back-pack sprayers may be of the garden sprayer variety where the supply tank is pressurized by means of a hand pump and the spray is regulated with an adjustable hand gun. However, Indian back-pack fire cans have been the most commonly used equipment for treating small areas, probably because they are readily available at most stations as standard fire-fighting equipment. These have a 5-gallon supply tank and are equipped with a pressure-operated hand gun having an adjustable nozzle.

Power Operated. Various types of power-operated spray equipment used in game management work all have several components in common: (a) power-operated pump which is either powered by the power take off of the tractor on which it is mounted or else by a separate small gas engine, (b) supply tank which may be a clean 55-gallon steel barrel or a special tank which is an integral part of the sprayer, and (c) pressure regulator, gauge and shut off which control the spraying pressure and flow.

The characteristic component of the boom sprayer is a long horizontally mounted boom or tube along which is mounted at intervals a series of spray nozzles. Spray width depends primarily on the length of the boom. Its principal use is for spraying row crops in farming operations. Since there is a series of nozzles, each can be spaced over an individual row and there is little spray waste and excellent coverage. However, since the boom is relatively long it has a tendency to dig in on uneven ground. Its use is therefore somewhat restricted in wildlife management since much of the work is often accomplished under conditions that are less than ideal for this type of equipment.

"T" or brodjet sprayers consist of a single cluster of nozzles which throw a fan-shaped spray to either side of the sprayer head. The area of coverage may be 36 feet or more depending on spray pressures. This is a versatile spray unit and can find wide application in wildlife management. It is the type of equipment used on the Buena Vista Marsh to spray hundreds of acres of woody sprout growth.

Gun sprayers have a hand-held sprayer head or "gun" which is turned on and off by the operator by means of a trigger control valve. Its principal use is in roadside brush control work where brush occurs in patches and where a constant spray pattern is not needed since it would waste spray solution. It also is of particular value where the brush is so dense that a constant spray pattern cannot penetrate efficiently. Since the "gun" is hand-held and connected only by a flexible hose to the sprayer it allows the operator to easily change the direction of spray for better coverage. The back-pack sprayer operates on the same principle and accomplishes the same thing, but it does not have a power-operated pump and is necessarily restricted by its small supply tank.

Gun sprayer in operation on the Buena Vista Prairie Chicken Area.

Mist blowers blow an extremely fine mist or vapor-like cloud over the area to be sprayed. The chief draw-back of the vapor spray is its tendency to drift over much greater distances than sprays from other types of ground-operated sprayers. However, is is quite efficient where large tracts of land are to be covered. It was operated at very low cost on the Ackley Wildlife Area and proved to be more efficient and effective than the other types of spray units used.

Aerial spraying equipment is extremely specialized and must be contracted from commercial operators since the Department has no planes equipped for this type of work. Aerial spraying has been accomplished in various management districts with varying results. Probably the most effective use of this equipment was made on the Ackley Wildlife Area where hundreds of acres of trees were sprayed in land-clearing operations for sharptail management.

It is used most efficiently where large areas are to be sprayed. The cost of aircraft rental on the Ackley Wildlife Area was $1.34 per acre of area sprayed. This did not include the cost of the herbicide, only the plane and pilot.

Spray Calibration. All power-operated sprayers which operate at a predetermined speed across the terrain should be calibrated to operate at the desired application rate. To determine sprayer output a test run can be made over a 220-yard distance using plain water in the tank (Martin et al., 1957). Preferably, the test should be run over the same type of terrain to be sprayed since tractor speed is affected by firmness of the soil and roughness of the terrain. Fill the sprayer tank with water, adjust the spraying pressure with the regulator (usually about 35 pounds pressure for low pressure spraying) and set the tractor speed for the desired rate of progression (about 2 to 5 mph). If the sprayer is powered by the tractor power take-off, low tractor operating speeds will diminish sprayer capacity considerably. At very low speeds the sprayer pressure may be too low to be efficient. This points up the advantage of having a separate power source for the sprayer which can maintain a constant speed despite adjustments in tractor speed.

The 220-yard test run is made and the amount of water used from the tank during this run is measured. To calculate the number of gallons per acre applied by the sprayer during the test run, use the following formula:

$$\frac{\text{(Gallons of water used)} \times 66}{\text{(Spray width in feet)}} = \text{Sprayer application rate}$$

If, for example, the sprayer applied 50 gallons per acre with the desired operating settings in the test run and 1 pound of atrazine per acre was the desired application rate, then it would be necessary to mix 1 pound of atrazine with 50 gallons of water to obtain an application rate of 1 pound per acre.

If the herbicide application rate is in terms of active ingredient instead of product as in the above example, adjustments will have to be made accordingly. As an example, if the above herbicide contained 80 percent active ingredient and the application rate was to be 1 pound of active ingredient per acre, then 20 percent more product or 1 pound and 3.2 ounces of product would be used in 50 gallons of water. Additional information on applications and calibration of herbicide sprayers can be obtained from the information circular by Gordinier (1963). If any changes are made in tractor speed, rate of travel, spraying pressure, or nozzle size, the application rate will also change. Spray width of the Brodjet and "T" jet-type spray nozzles will vary considerably with the operating pressure. Higher spray pressures will produce a wider spray width.

For hand sprayers, Martin et al. (1957) offers the following method of calibration:

"The number of pints per acre applied by a full 3-gallon hand sprayer can be calculated by testing on a 10 x 10 foot (100 square feet) area as follows: 1/2 pint applied to 100 square feet equals 27 gallons per acre, 1 pint equals 55 gallons per acre, and 1 quart equals 110 gallons per acre. Accordingly, if one wishes to apply 1 pint of commercial weed killer per acre, it should be mixed with 27 gallons of diluent if the sprayer applies 1/2 pint to 100 square feet, 55 gallons of diluent if sprayer applies 1 pint to 100 square feet, and 110 gallons of diluent if the sprayer applies 1 quart to 100 square feet."

Mechanical Control of Cattails

Summer

Mowing and crushing cattails during the summer is a form of vegetation control which may supplement or replace the use of herbicides. It has seen only minor use in this state and although the results have been negative further experimenting is warranted since apparently it has been successfully used in other states.

On Horicon Marsh Wildlife Area during the summer of 1962, 15 acres of cattail were crushed with a tractor-drawn mulcher and the area was later burned. Cost of this work was $6.13 per acre. The objective was to eliminate or at least obtain some measure of control over dense cattail stands in this area. However, the results at the end of the summer were completely unsatisfactory. Cattail showed heavy resprouting and 10 acres were plowed under later in the summer. The only positive results of this experiment were to make tender new cattail sprouts available to the geese during fall migration. Goose use on the experimental area was good. Wilson (1955) found that in North Carolina cattail showed an increase of 90 and 121 percent, due to new growths of seedlings released by removal of the mature tops and stems.

However, successful control of cattails by mowing has been accomplished by other workers. Uhler (1956) reported that cattail (Typha latifolia) was mowed at ground level or under water in mid-July after the fruiting spikes were about 2/3 grown. A second mowing was made a month later when the new growth had attained a height of 2 to 3 feet. This gave excellent control through the summer and permitted the establishment of a successful stand of wild rice in the area the following September. Martin et al. (1957) reported that cutting cattails close to the ground twice during the same season resulted in 90 to 100 percent kill in Maryland, Tennessee and Utah tests. The first cutting was made when the pistillate spikes are well formed and at least 2/3 full size, but not mature enough to scatter viable seeds. The second mowing was made a month later after the new growth had reached a height of 2 feet. He mentioned that control is likely to be greater if water is present and covers the cut stems, but this is not absolutely necessary. He also found that mechanical crushing of the stems gave results similar to mowing.

It would seem, therefore, that when treatments are made at exactly the right stage of growth effective control can be attained. However, this apparently necessitates two mowings during the same summer. The reasoning behind this type of treatment is that when cattails are actively growing and developing fruiting heads they are utilizing their starch reserves to supplement food supplies being produced by the leaves. Therefore, when development of the fruiting head is almost completed the food reserves are less than at any time during the year. Removal of the leaves at this time cuts off food production until the leaves can be replaced and puts a further drain on the nearly exhausted reserve food stores. When the leaves are cut a second time after recovery has been nearly attained the reserve foods are completely exhausted and the plant is unable to make another recovery. Apparently timing of these cuttings must be precise if the desired results are to be attained. Since only one cutting was made during the Horicon experiments this may be the reason why the results were negative.

Winter

Cattails were mowed on the ice during the late winter on a private development in northeastern Wisconsin in an effort to eliminate cattail. Water levels rose during the spring floods and covered the cut stubble. A good kill seemed to have been attained and the area remained void of living cattail through the next summer. During the succeeding winter another 6 acres of cattail were mowed. However, a dry fall dropped water levels below the surface so the cattail was mowed off close to the ground level. No flooding occurred until after the spring break-up. Cattail came up normally during that spring in the treated area and there was no indication of any kill.

Jahn (1958) mentioned that Minnesota had success with mowing cattail on the ice. They raised the water level in the spring to cover the cut stubble. The basis for the success of this technique centers around the fact that dormant cattail rhizomes need oxygen throughout the winter period in order to survive. Normally this oxygen reaches the rhizome through the air cells in the stem. Even though the old stem is dead it remains connected to the rhizome and air cells conduct air from the surface to the base. During periods of winter stagnation when anaerobic conditions occur beneath the ice cover this is the only means for oxygen to reach the rhizome. If the dead stems are cut and the cut ends become sealed or plugged by ice the air supply is shut off. An extended period of anaerobic conditions could then kill the plant. Perhaps this happened when mowing was attempted the first time on this private development. The area was flooded by 12 to 15 inches of water at the time of the mowing and flood waters covered the stubble before and after the break-up. Conditions were right for the resulting kill to occur. On the second attempt no water covered the cattail and anaerobic conditions in the rhizomes never developed, so mowing had no effect.

Further experimenting should be done with cattail mowing since it would certainly provide a cheap method of cattail control if dependable techniques could be worked out.

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LAND CLEARING

The term land clearing as used in this paper means clearing wetland sites of woody growths either before or after they are flooded. It does not include breaking or plowing to make the land tillable. This is covered under the section on Wetland Farming.

Land clearing is principally accomplished by 3 methods: (1) mechanically, through the use of hand tools and heavy equipment; (2) chemically, through the use of herbicides; and (3) through the use of fire. The use of fire and chemicals have been covered in the sections on Controlled Burning and Vegetation Control.

Land clearing may be practiced for a number of reasons, but the main reasons given by the managers are:

1. To remove woody growths from impoundment sites before they are flooded to prevent the formation of organic stains.

2. To remove woody growths from impoundment edges and provide grassy cover for waterfowl nesting.

3. To create a better dispersion of open water and cover so that the area is more accessible for waterfowl use and also to provide better hunter access.

4. To provide edge-type habitat for all game.

5. To enlarge goose management areas and open up waterfowl flight lanes to tall trees.

6. To clear refuge boundaries and to improve the view across the marsh.

Some of the more efficient operations have utilized combinations of these various types of removal. This survey indicated that clearing has been accomplished more often by means of power saws and other hand tools than it has through the use of heavy equipment. This has probably been a matter of expedience and not a matter of choice since heavy equipment is not always available. Some managers took advantage of public work programs to obtain less expensive labor to keep their costs down when a large amount of manual labor was involved in the operation.

So many variables enter into these operations that it is difficult to make good comparisons. Available cost figures do not always indicate the reason for unusually high or unusally low costs. If the operation is performed in the winter, snow depth, ice thickness and subzero temperatures can make a considerable difference in the efficiency of the operation since they affect the mobility of the crew and equipment. If the operation is carried on during the summer, water levels will be of importance for this same reason. Because there has been no standard method of categorizing the density and composition of the cover being removed there is no way of making accurate comparisons between individual operations. For these reasons available cost figures have been grouped under two major types of operations and will be given as average figures for these types. The cost figures supplied by the various game managers showed that there was a significant difference between the efficiency of the operations carried on entirely by the use of power saws and hand tools and the operations involving the use of heavy equipment. The average cost of clearing woody vegetation by hand was $96 per acre, while the average cost for using heavy equipment was only $31 per acre.

Use of Heavy Equipment

Buena Vista Marsh (Portage County Grouse Management Area)

On this area a combination of methods was used. Brush up to 2 inches in diameter was mowed with a McCormick 25 rotary cutter mounted on a farm tractor. Cost for this type of operation was $3.00 per acre for mowing willows. Aspen is somewhat more difficult and costs would be somewhat higher. This appears to be the most efficient means of clearing brush on areas where it is possible to operate a farm tractor. Larger trees were knocked down with a D-8 bulldozer at a cost of from $5 to $15 per acre, depending on the operating conditions and the size, density and species of trees. It is important to minimize turn-around time for the dozer and to try to keep it continually moving at a fast walking pace. It was more efficient to cut trees larger than 8 inches with a chain saw than to use dozer time on them.

Front view (left) and rear view (right) of tractor-mounted rotary cutter in operation on the Buena Vista Prairie Chicken Area.

When cutting brush with the rotary brush cutter it is important to keep the cutting blade about 6 inches above the ground to avoid the heavy bases of the brush clumps which would damage the equipment. This keeps breakdown time to a minimum. These attachments are relatively low priced and they eliminate a considerable amount of clean-up labor since they chop the brush in small pieces.

Slash was removed by burning and the following summer sprout growth was treated with herbicides. The use of herbicides for this operation has already been discussed under the section on herbicides.

A similar type operation was utilized on Meadow Valley Wildlife Area but on a much smaller scale.

Crex Meadows Wildlife Area

On this area a somewhat different technique was used. A D-7 bulldozer was used to shear off and knock down trees and a rootrake attachment uprooted stumps and brush. The rootrake was also used to gather the debris in piles for burning. Woody growths ranged upward from brush to 18-inch oaks and 9-inch aspen. This was a winter operation. Costs ranged from $21 per acre on areas which had been burned over first, to $51 per acre for areas which were unburned.

There is one difficulty with using the rootrake. When operating in brush the rake may become plugged with brush stems and as a result, large amounts of dirt are collected and deposited on the piles along with the brush and makes them hard to burn. However, despite this drawback, costs for the operation seem to compare very favorably. Removal of stumps eliminates sprout growth which otherwise requires herbicide treatment.

Hand Labor

Hand labor seems to run considerably higher than operations involving the use of equipment. One exception to this was on the Totogatic Lake Wildlife Area where the flowage basin was cleared of swamp conifers and lowland brush 2 to 12 inches in diameter using only a chain saw and hand tools. It took 4 men 31 man-days to clear 110 acres. However, the slash was left and no clean-up was attempted. In another operation on the same area 5 men in 38-1/2 man-days were able to clear cut 178 acres at a cost of only $3.70 per acre. Again no attempt was made at clean-up. If the clean-up of debris after cutting is of no importance, then this type of operation can cut costs considerably. All work was done on the ice in the winter. The flowage had been drawn down so that the stems could be cut as close to the soil as possible. Working conditions were such that it was possible to drive trucks into the area being cleared. However, no estimate was made of the density of the stands which were cut and this could be a very important factor in the efficiency of the operation.

The cost of hand-clearing operations ranged from a low of $3.70 to $178. In the latter operation a chain saw with a brushcutter attachment and 5 men with hand tools were used for 56 man-days. A flowage edge was cleared of 6- to 8-inch birch, aspen, alder and willow. Brush and slash were removed and piled above the water line.

Complete clean-up operations are apparently more efficiently carried out by the use of heavy equipment unless hand labor is extremely cheap or the area to be cleaned is small. At Kirby Lake (Barron County Forest) 20 boys belonging to the FFA (Future Farmers of America) volunteered free labor on a clearing project. Forty boy-days of labor were obtained to clean up a flowage basin of dead brush. While no cost figures are available we can probably assume that this was a very reasonable operation requiring mostly supervision.

All cutting operations which are not followed by flooding should receive herbicide treatment after resprouting occurs. Herbicides should be applied the summer following brush and tree removal. Herbicide recommendation will be found in the section covering the use of herbicides.

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POTHOLE AND POND CONSTRUCTION

Value

Some form of pothole construction has been tried on state-owned wildlife areas in almost every management district in the state. These constructions range from simple blasted potholes to more sophisticated runoff ponds. Although runoff ponds in the strictest sense are not true potholes, they serve many of the same objectives and are included in this section. The principle objective of these constructions was to provide territorial sites for breeding waterfowl. On the Pine Island Wildlife Area their value as water holes for upland birds and mammals was also considered important. Certainly the greatest return on potholes in terms of waterfowl use can be expected in areas of high waterfowl density where territorial sites are at a premium. In areas of very low density there may not be sufficient waterfowl to fill the additional habitat created by the addition of potholes. In such locations potholes may be only partially utilized. It may take a considerable period of time before breeding waterfowl populations build up so that all portions of this newly created habitat are fully utilized.

Evans and Black (1956:53) found that on the prairie of South Dakota all types of potholes are of practically equal value. They stated, "The small temporaries are of no value through most of the year, but acre for acre of water, they are the most valuable type during the critical breeding period. The large permanent areas serve a number of functions in duck production through a much longer period, but do not have as high a value during the breeding season. Furthermore, as water levels, weather and duck populations fluctuate, the birds vary their use of the habitat, further equalizing the long-term values of the different types."

They also point out that the main value of small potholes is to allow the breeding pairs to disperse and maintain a measure of isolation from other birds of the same species. It should not be construed that a pair of birds use one pothole to the exclusion of all others, but rather a series of potholes will be used and defended against intrusion. However, other birds may use the same pothole or potholes when they are unoccupied by the original pair. There is considerable overlap in use, therefore, and any one pothole may be used by several pairs at different times during the day. Evans and Black (1956) noted a single pair of birds using seven different potholes as part of their home range.

Mathiak (1965), working on the Allenton Wildlife Area found that nesting blue-winged teal used from 5 to 10 different potholes in one day and mallards used only 2 to 3. However, when several pairs of mallards were present as many as 8 potholes were used.

Construction and Costs

Most potholes dug on state wildlife areas in Wisconsin were either rectangular or square in shape. Bottom contours were trepezoidal or wedge-shaped (Fig. 8). Exceptions to the rectangular shape are found on the Ackley Wildlife Area where "V" shaped and circular ponds were constructed. Circular ponds contained small loafing islands. Some of the larger farm ponds constructed by the Soil Conservation Service were also circular and contained an island. Wedge-shaped bottoms provided shallow edge for puddle ducks despite fluctuations in water level and at the same time provide a maximum surface area of water during drought periods. In the more fertile southern part of the state this shallow edge construction should probably be modified. Increased edge depth would prevent rapid encroachment of the open water area by cattail.

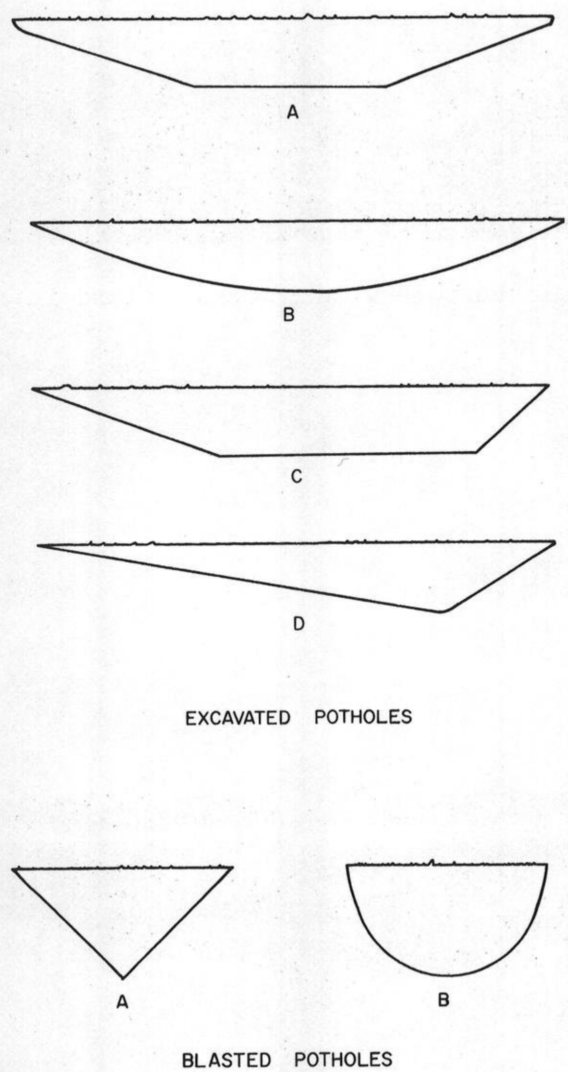

Figure 8. Variations in longitudinal profile of bottom contours for constructed potholes.

Circular bulldozed pothole with resting island in center (Antigo District).

"V" shaped bulldozed pothole (Antigo District).

Hammond and Lacy (1959) who pioneered in pothole construction believed that on their study area the optimum size of potholes was 20 to 25 feet wide and 40 to 75 feet long with a water surface area of 500 to 2,000 square feet. They recommended that the pothole have one or two gradually sloping edges so that there could be some use of bottom foods by dabblers. They did not feel that it was necessary to level spoilbanks. Increases in size within the above range gave a proportional increase in use. They recommended 150- to 200-foot spacings between potholes. Potholes should have a depth of about 4 feet and a berm should be left between the spoil pile and the water to reduce silting. Pattern of pothole arrangement should be in block form and well within the daily pair travelling range from a marsh and large breeding and brooding pond. On their area this was 1/4 mile or more.

Detailed cost and use figures for pothole constructions in Wisconsin were not always available. Use was seldom recorded in sufficient detail to be of value except in certain instances where some form of study was actually made. However, available costs ranged from $77 per acre-foot to $923. This included construction by blasting, dragline and bulldozer. Compared on a per acre-foot basis, bulldozing produced the cheapest construction, but on the per pothole basis, blasting was by far the cheapest form of construction. This indicates that if many very small potholes are to be constructed, blasting is the most economical form of construction, but if fewer and larger constructions are wanted, bulldozing would prove to be more economical providing conditions are right for using this type of equipment. The average cost for all forms of constructions was $435 per acre-foot of water produced. It is difficult to compare operations since there were no figures available to indicate how much earth was moved to create an acre-foot of water. If the pothole or pond is created in a natural depression, less earth must be moved than if the pond or pothole was located on level terrain.

Hammond and Lacy (1959) reported that pothole costs are about one-half the cost of level ditching. They found that the cost per breeding pair when prorated over a 30-year period ranged from 45 cents to $1.43. Level ditching ranged from 81 cents per breeding pair to $1.43. These costs varied with the size of the construction and the type of equipment used.

Types of Construction Used on State Management Areas

Blasted Potholes

Blasted potholes have been widely promoted in this state and no detailed descriptions of construction techniques are necessary since they were well covered in a recent Department publication (Mathiak, 1965). One of the first attempts at pothole blasting (42 ponds) was made by Dreis (1963) on Hay Creek Wildlife Area in Dunn County. Using 189 sticks of 60 percent ditching dynamite, a hole approximately 20 by 40 feet and 4 feet deep was constructed. Cost of explosives were estimated at $29 per pothole. Shortly thereafter Mathiak (1965) introduced the use of

ANFO (ammonium nitrate fuel oil mixture) for pothole blasting in Wisconsin. Since it is considerably cheaper, it has supplanted the use of dynamite.

A 50-pound charge of ANFO will cost about $3.00, complete with detonating charge, fuse and cap and will produce a circular hole 19 to 35 feet in diameter depending on the soil and water conditions (Mathiak, 1965). Bottom contours vary from cone to bowl shape and depths range from 30 to 72 inches in the ponds measured, but they may be greater. Since pond sizes show such extreme variation due to soil characteristics, it is difficult to predict pond sizes in advance from area to area or even within the same general area.

Pothole blasted with ammonium nitrate (ANFO) (Eldorado Wildlife Area).

Ammonium nitrate costs only about 1/10 as much as dynamite (42 cents/lb. for dynamite and 4 cents/lb. for ANFO) and is quite safe to handle and store. There is little doubt that if blasting of this type is to be done, ammonium nitrate is the best choice of explosives. Mathiak (1965) estimated that pond depths require 2 years to stabilize before accurate depth measurements can be made. A disadvantage of the blasted pond is that the edges are extremely steep, sometimes almost perpendicular. In loose soils this causes sloughing in and silting and is probably less attractive to waterfowl than is the dug pond which can be constructed with gradual slopes that provide shallow water for puddlers and an edge that may have good loafing spots.

When water levels drop a foot in a blasted pond with a conical bottom, the surface area of the pond shrinks appreciably and the decreased water area is then surrounded by a fairly steep bank. Since any bird using the pond would have its visibility obstructed by the steep pond edges because of the small confined water area, there is a strong possibility that the ponds would not receive much use during periods of low water level. However, Mathiak (1965:14) noted that a pair of teal were seen in a pond which had a water level that was 3 feet below the surface, so apparently birds do use them even under extreme conditions. Mathiak believed that in this instance the birds had established a territory before the water levels receded and they simply continued using it even though the water levels dropped.

Shearer (1960) found that in stock pond dugouts, waterfowl use increased as the ponds filled with water and cover increased. However, it appears that dug ponds do provide water areas that are usable for longer periods of time during low water conditions. During a dry fall, if jump shooting is expected, the blasted ponds may be completely unusable, while dug ponds, due to their flatter bottom contours and greater surface area, may still have usable water available for waterfowl.

If we consider blasted potholes strictly in relation to waterfowl breeding activity then their value greatly increases. In the spring and early summer, during a normal year, most potholes will be filled with water and there will be no problem with steep edges restricting visibility. There is little doubt that they will be used as territorial sites. In this case, their relatively small size should not be objectionable. Because of the low cost involved, areas of good waterfowl use could inexpensively be saturated with many small potholes that could conceivably increase waterfowl breeding use considerably. Mathiak (1965:19) reported excellent use by mallards and blue-winged teal of 44 blasted potholes in semidry portions of the Horicon Marsh Wildlife Area.

Blasted potholes in a variety of locations computed from measurements by Mathiak (1965:16) ranged from .0013 acres to .0025 acres for those constructed with 50 pounds charges of ANFO, and from .0015 acres to .0029 acres for the 100 pound charge. Blasted potholes constructed by Dreis (1963) were approximately .018 acre in surface area as computed from his dimensions, which was 9.4 times larger than the average pothole constructed by ANFO using a 50-pound charge, or 7.5 times larger than a hole constructed with 50 pounds of ANFO in wet peat, but at a cost that was 9.7 times larger. Labor costs for dynamiting are much larger than for ANFO because of setting multiple charges. According to Mathiak's (1965:16) table of averages there may be no advantage of using 100-pound charges of ANFO over 50-pound charges in wet peat. A gain of a few inches in depth was cancelled out by a decrease of 1 foot in diameter. From this it would appear that experimenting with various size charges at each general location would eliminate wasting ANFO through the use of unnecessarily large charges.

Blasting potholes on a per acre-foot basis may be more expensive than other forms of pothole construction, but when figured on a per pothole basis it is far cheaper than any other type of construction. If only limited funds are available for construction this may be the only way of putting water on an area. Since pothole volumes vary considerably with soil types and water content of the soil, it is difficult to predict exact costs on a per acre-foot basis.

Bulldozed Potholes

Bulldozed potholes ranged in cost from $77 per acre-foot to $721 per acre-foot. Spoil was spread and leveled as it was removed during bulldozing operations and final leveling was kept to a minimum. Conditions must be dry enough to allow efficient operation of the 'dozer. The high cost figure of $721 per acre-foot of water was caused principally by poor operating conditions. Extremely wet soil caused the 'dozer to become bogged down and cost figures went almost 4 times the average cost for this type of construction. Under such conditons a dragline would probably have been much more efficient. The cheapest bulldozed pond was a 1.44-acre pond costing $110 per acre-foot. A series of 10 ponds of varying size was bulldozed at an estimated cost of $87 per acre-foot, but these were constructed by cleaning out some natural depressions and are not really comparable since less spoil was removed than would have been if they were constructed in flat terrain.

Bulldozed pothole (Eldorado Wildlife Area).

On Crex Meadows Wildlife Area the objective was to re-establish natural potholes in the upland depressions which had silted in through the years and to again make them available for waterfowl use. The spoil was used to increase the amount of tillable acreage adjacent to them. About 5-1/4 acres of usable cropland were added by this process. Ten potholes ranging in size from .09 acres to 1.28 acres and totaling 3.55 acres were constructed with a D-7 bulldozer. They averaged 2 to 2-1/2 feet in depth. Loafing islands 15 to 20 feet in diameter were built into some of the larger potholes. Cost for the 10 potholes including leveling and seeding the edges was $310. Since pond contours may vary it is difficult to make a per acre-foot estimate but it probably was about $87.

Pothole constructed on the Crex Meadows Wildlife Area for breeding waterfowl.

The estimated useful life of these potholes is 25 years. Since the potholes are surrounded by cropland, waterfowl use was extremely heavy during migration. As many as 500 geese were seen at one time on or around the potholes. Heavy deer use was also noted. A good comparison between the size of the pond or pothole and its relationship to per acre-foot costs can be found in comparing costs for 19 fractional-acre potholes and those of a single 1.44-acre pond constructed on the same area during the same operation. The 1.44-acre pond cost only $110 per acre-foot of water constructed while collectively the fractional-acre potholes cost $279 per acre-foot of water. Per acre-foot costs increased 15 percent for the small potholes which had a collective surface area of only 1.16 acres.

Dragline Constructions

The average cost for dragline pothole constructions on state management areas where data were available was $435.33 per acre-foot of water constructed, although costs ranged from $222.22 to $750.00 per acre-foot of water. Cost figures were influenced considerably by weather and operating conditions. All costs were for actual construction. They did not include final spreading of the spoil or seeding of the banks. Under conditions of very wet soil there is no choice but to utilize a dragline or blast potholes since a bulldozer cannot operate efficiently. However, Hammond and Lacy (1959) found that 'dozer or tractor and scraper work could be half the cost of dragline work under favorable conditions.

It does not pay to move heavy equipment into an area for construction of only a few small potholes. Small potholes can be constructed more cheaply by blasting since moving time between potholes greatly influences the cost of constructing potholes with heavy equipment. This is especially true of dragline constructions. Larger ponds cost less on a per acre-foot basis with heavy equipment than do small ponds. Cheapest dragline pond construction recorded in this survey were two ponds, 1.6 acres and 2.0 acres. The cost was $222.22 per acre-foot of water.

Pothole Use

Allenton

On the Allenton Wildlife Area 27 potholes were constructed by dragline. They averaged 20 x 50 feet (.002 acres) in area and 4 feet in depth at a cost of $16 per pothole. Mathiak (1965) reported that duck use of the area greatly increased after pothole construction, since little or no open water was available prior to construction.

Horicon Marsh

Eleven potholes were dredged by dragline in semidry sedge-grass bog on the Horicon Marsh Wildlife Area at a cost of $22.72 per pothole. Pothole sizes varied from 15 feet by 60 feet (.02 acre) to 30 feet by 60 feet (.04 acre) in area. Average depth was 4 feet. Each was located on the edge of a low cattail swale, although the excavated portions were actually in sedge-grass bog. Surrounding sedge-grass meadow offered excellent nesting cover and the potholes provided open water. Lack of open water had limited use of this area by breeding waterfowl before pothole construction. An area of low utility was converted to one of high use.

Because the potholes were located on the edge of cattail swales, unlimited muskrat food was available and the 'rats responded by making fairly heavy use of the potholes. Water of insufficient depth in the swales had precluded much muskrat use of the area before pothole construction. However, in dry summers the potholes lost all their water and 'rats were forced to move out before winter unless fall rains restored water levels. This, of course, made for intermittent use by muskrats, but it did provide early spring and summer range and some muskrat litters were produced during normal years.

Checks made during spring and early summer of the first year after construction indicated that the 11 ponds were used by breeding pairs of blue-winged teal, mallards and shovellers. It was estimated that there was a minimum of 11 blue-winged teal pairs using the potholes. If each observed pair or lone bird represented a possible brood, then a minimum of 11 blue-winged teal and 2 mallard broods and 1 shoveller brood could have been produced on the potholes during their first year of existence. Some predation on duck nests was noted in the area, but there is nothing to indicate that predation should be any greater here than it is in any other waterfowl nesting habitat on this marsh.

Heavy deer use on the potholes increased as marsh water levels decreased leaving the potholes as the only source of open water in the vicinity. Raccoon sign around the pond edges was common so it is apparent that the ponds received multiple use by a variety of wildlife.

If we prorate construction costs over an estimated useful pothole life of 20 years, the cost per pothole per year would be $1.13. Hammond and Lacy (1959) estimated that this type of construction had a productive life of about 30 years. If we prorate costs over a 30-year period, this amounts to 75 cents per pothole per year. On the basis of 14 observed breeding pairs for the 11 potholes the costs per breeding pair per year would be 59 cents. Pair use was minimal in this check since the checks were begun after the peak of the mallard breeding activity. Include muskrat, deer and other forms of wildlife and the per unit cost for wildlife use becomes extremely low. In general, this pothole project can be considered highly successful. An area of very low waterfowl productivity was converted to good waterfowl breeding habitat and other wildlife use was increased.

Of course, this does not mean that all areas will respond in a similar fashion to pothole construction. Horicon Marsh is a highly productive area having a high potential for heavy use by breeding waterfowl. If bird use on a marsh is normally low it may take a relatively long time for birds to expand into this new habitat and fully utilize it, but if bird use is good this type of construction may encourage more of the temporary spring migrant population to stay and breed on the area. Broods produced on the area will be encouraged to return to breed because available habitat is expanded. Their tendency to spread out and use other areas will be minimized.

Other Areas

Detailed observations of waterfowl use on pothole constructions in other parts of the state are not available for comparison. The 35 potholes on Oconto Marsh were checked for one summer, but results are rather inconclusive. These potholes were constructed by dragline at a cost of about $30 per pothole. They were approximately 33 feet square (about .02 acre), 4 feet deep, and spaced 75 to 125 yards apart. They were constructed in a sedge-grass marsh. Oconto Marsh has Green Bay to draw on for breeding birds. However, during the first part of the breeding season relatively few birds were observed on adjacent water areas. There was a period when half of the breeding birds on the marsh appeared to be concentrated in the potholes, but these birds were in relatively small numbers. Peak counts on the potholes represented about 10 breeding pairs, and there was a possibility that some of these were reflushed birds. Since the breeding bird population on adjacent water areas was rather small and the total bird use of the potholes was low, the overall sample size is too small to properly evaluate. However, there is little doubt that these potholes did make a contribution to waterfowl production on the marsh since breeding birds were making use of semidry marsh which would have received little or no use without the potholes.

Weekly observations of breeding pair use were made on 12 potholes blasted along the semidry edge of the Eldorado dike. Peak use on one day was 16 pairs of birds on the 12 potholes. Of these, 14 pairs were blue-winged teal and 2 pairs were shovellers. Shoveller and blue-winged teal pairs often shared potholes. However, simultaneous use of the same pothole by 2 pairs of blue-winged teal showed rather surprising tolerance between pairs of the same species on such small potholes. Observations throughout the breeding season indicated that there was a minimum of 21 pairs of ducks using these 12 potholes during the season. They included 14 pairs of blue-winged teal, 2 pairs of shovellers, 3 pairs of mallards and 2 pairs of green-winged teal. Lone birds were considered as members of a pair.

Birds were first noticed using the potholes on April 27 and no birds were observed after June 29. Although water remained in the ponds throughout the summer, there was a conspicuous drop in water levels during July and August until fall rains again filled the potholes. Waterfowl used after the breeding season was minimal. However, it is obvious that potholes had filled a requirement in the breeding habitat and from this standpoint could be considered successful. It should not be inferred or expected that potholes of this type will be as heavily utilized in all parts of the state. Where breeding waterfowl populations are low it may require a number of years to build up a sufficiently high population to obtain 100 percent use on a dozen potholes. If other important requirements such as food and larger water areas for brooding are lacking this breeding habitat may never be completely used.

More evaluations of pothole projects in all types of areas are needed before the total contribution of potholes can be properly assessed. However, according to information presently available, this type of habitat manipulation does contribute to breeding bird use.

Runoff Ponds

These are essentially small impoundments but are usually located on upland sites. They are constructed by plugging natural drainage courses with short dikes or large gullies draining off upland slopes. The watershed must be large enough to supply and maintain levels of the resulting pond. Runoff pond dimensions will vary with the size and contour of the site, but for multiple acreage constructions they are cheaper to construct than other types of ponds since the principal part of the construction is the short dike and emergency spillway. If a water control structure is desired, construction costs will increase proportionately. Although a control structure is not a necessity, some means of drawing down the pond to remove undesirable fish or turtles, to make repairs, or to control vegetation is desirable. Since ponds of this type average an acre or more in size they usually can be developed into very satisfactory waterfowl brooding ponds. If the surrounding area is maintained in grass cover and scattered small potholes are added, a good waterfowl nesting and brooding unit can often be developed.

Runoff pond construction is essentially the same as that of the Soil Conservation Service farm pond with modifications to meet local needs. Bradley and Cook (1951:257) based small impoundment construction which depended on runoff water on the following criteria: (1) at least 20 acres of drainage area is required for each acre of water impounded; and (2) structural design is based on a water flow covering a 50-year frequency.

Addy and MacNamara (1948:62) pointed out that watershed requirements for runoff ponds are extremely variable and depend on rainfall, topography and land use. They say, "In some instances, 20 acres of pasture or cropland is sufficient for one acre of pond and in other cases 100 acres of woodland or brush land will be needed." Since watershed requirements vary with local conditions it is desirable to seek Soil Conservation Service assistance while still in the planning stage, before construction begins. A pond constructed on too small a watershed will fail to fill and may dry up during the middle of the summer, while a pond constructed on too large a watershed will require more expensive dikes and control structures to handle the peak flow, unless part of the flow can be diverted.

Two runoff ponds were constructed on the Eldorado Wildlife Area. A 2-1/2-acre pond with a maximum depth of 5 feet at the level of the emergency spillway was built with a D-11 bulldozer and a 12-yard carry-all. The watershed involved was 200 acres. Work was done by the Town of Eldorado road crew using their equipment at $14.50 per hour. Total cost including shaping of the dike was $550. No doubt equipment rental costs were below what could be obtained commercially. The average depth of this pond was 2 feet and it cost about $110 per acre-foot of water at full pool.

Another pond of this type also built on Eldorado had a total estimated area of 5 acres. It was constructed on a 450-acre watershed at a cost of $1,424 which included dike shaping. This pond had a maximum depth of 11 feet at emergency spillway level. Since the average depth was 3 feet it cost about $285 per acre-foot of water at full pool. A state-owned D-4 cat and a 9-yard carry-all was used for most of this construction with additional time and equipment furnished by the Town of Eldorado for the finishing. These ponds at the time of survey, although just completed and only partially filled with water, were already receiving use by ducks, geese, deer, raccoon and many shorebirds. They will undoubtedly have utility not only for aquatic wildlife, but also for upland birds and mammals as well.

Ott Pond, a runoff pond in the Eldorado Wildlife Area.

Brood Areas

In most wetland areas where potholes will be constructed, larger water areas or streams are usually close by which can serve as brooding areas for birds which breed and nest in the vicinity of the potholes. If a brooding area does not exist, one should be constructed. Just what constitutes a brooding area is a matter of opinion, but it should be large enough to supply food and escape cover for the duck broods until they are large enough to fly. Size, within reasonable limits, is probably not as important as the availability of food and escape cover and the permanence of the water. Evans and Black (1956:45) stated, "Once the eggs have been hatched the home range breaks down and the hen and brood, with a set of requirements and preferences different from those of the breeding pair, go off on a trek of their own."

The distance a brood will move to a brooding area may be considerable. Evans and Black (1956:41) recorded a 2-1/4-mile move for a blue-winged teal brood before they were 2 weeks old. They believed that movements of a mile are easily made. Brooding areas of 2 to 5 acres were more desirable to broods than larger areas. Cover in brooding areas was found to be of great importance for escape of the broods. They stated, "Observations of brood behavior have indicated that the selection of brood-rearing habitat depends on the availability of a means of escape from predators. This may be furnished by cover sufficient to conceal the brood but not so dense as to restrict the movements of the young. On the other hand, a means of escape may be provided by open water of sufficient size and depth that broods can dive to escape their enemies." They found that dabbler broods commonly used areas as small as 1 acre and as shallow as 5 inches provided good escape cover was also present. Areas without cover were used if they were at least 20 inches deep and 5 acres in size.

All Ackley Wildlife Area impoundments were drawn down completely during the summer of 1966 and the only water that remained was in two small disconnected pools near the structure of the Wicke Flowage. Their combined acreage was less than an acre. A blue-winged teal female maintained a brood of 5 young on one of these pools until they reached flight stage. They were observed only on the one pool and did not seem to move off until they were able to fly. When disturbed they disappeared into the dense stands of bulrush which covered the low areas adjacent to the pothole. Little or no water was present in the stands of bulrush. No submergents were present in these potholes and other food plants were not in evidence, although bulrush did fruit heavily later in the summer. What the ducks were eating was a matter of conjecture but it may have been principally invertebrates. Good crops of Daphnia were noted at various times. This would indicate that brooding needs can be quite minimal. However, ponds of an acre or more should provide sufficient edge and emergents encouraged in portions of the shallow edge waters will provide escape cover.

Pondweeds and other food plants should be planted or encouraged. Submergents not only provide food directly, but also increase the invertebrate population in the pond. Snails may increase greatly if good stands of submergents are present. Gurzeda (1964:31) found that submergents with the greatest leaf divisions or surface area harbor the largest crop of invertebrate animal life. In this respect muskgrass and water milfoil are of special significance.

Evans et al. (1952) noted that mallard broods may move up to 2 miles overland. However, the greater the distance a brood has to move to brood water the greater is the likelihood that mortality will occur. It therefore seems advisable to make provisions for a suitable brood area close to the potholes. Brooding areas can be provided by several different types of construction:

1. Blasting or dredging

2. Level ditching

3. Runoff ponds if topography of the land is suitable.

Multiple charges of 50 pounds of ANFO spaced at 15-foot intervals will make broad shallow ponds with only a slight ridge between the points where each charge had been located. (Mathiak 1965)

There are times when level ditching might be more advantageous than pond construction for providing brooding areas. Long ditches like streams and rivers can certainly provide brood area and at the same time serve as firebreaks so that controlled burning can be practiced to manage the cover adjacent to them for nesting habitat. Blue-joint and sedge meadows lend themselves very well to this type of management. The ditch is better constructed meandered or zig-zagged since it provides more concealment for birds than would a straight ditch which allows unlimited visibility from one end to the other. It also offers more territorial sites for breeding pairs if it is broken by curves. Mendall (1958) states that the greater the number of zig-zags in a ditch the greater the use.

If water tables are subject to large drops during the summer the ditch should probably be fairly wide (30 feet or more) to overcome the effects of exposed vertical edges of the ditch which may be unattractive to waterfowl. A wider ditch probably would provide greater security for the broods. If occasional depressions measuring about 10 feet in diameter and about a foot deep are carved in the bog so that they are continuous with the ditch the growth of emergent aquatics will provide escape cover for the broods. Bradley (1960:30) reported that "An individual small marsh can be made more productive when adjacent lowlands can be dug out or small draws blocked to give supplemental spring breeding units. The cost benefit ratio can be very favorable." This type of construction can be used for runoff ponds that, when properly constructed, can serve as brood areas.

Pothole Diversity

Where a number of ponds are being constructed on an area some thought should probably be given to diversifying their depth and edge cover. Addy and MacNamara (1948:12) stated, "Ponds of varying depths with a diversity of vegetation and open water will attract a greater variety of ducks." Puddlers desire water depths of 18 inches or less while the diving ducks prefer deep water ponds. Since most of the better marshes in the southern part of the state are too shallow to fully meet diving duck requirements, the construction of deeper multiple-acre runoff ponds in the vicinity of these marshes might increase breeding populations of divers such as redheads and ruddy ducks. These ducks already utilize some of these marshes to a limited extent.

In the larger brooding ponds, emergent escape cover for broods should be developed in the shallower areas which are best suited for such growths. Addy and MacNamara (1948:12) pointed out that, "With small ponds, vegetation is the principal escape cover, whereas with large ponds the open water serves also as an effective means of escape and is preferred by some species, particularly diving ducks."

Evans et al. (1952:45) concluded that managing waterfowl breeding habitat in regions of small water areas is dependent upon "the maintenance and proper interspersion of pothole types, each to serve its own function".

If we are attempting to duplicate prairie pothole conditions for breeding pairs through the construction of potholes and ponds, then we should also be striving for the right type of interspersion of cover and pothole types. Evans et al. (1952) also noted that breeding pair use was greatly influenced by pothole size. They stated that river duck pairs in the prairie pothole regions showed the greatest per acre use on areas of 0 to 0.5 acre while diving ducks preferred 2 to 3 acres of water. Most, if not all of the potholes constructed in Wisconsin so far are well within the optimum size range of the river or puddle ducks. Construction of more deep runoff ponds should certainly improve waterfowl use by providing a better interspersion of water types and cover.

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LEVEL DITCHING

Level ditching as a technique in wildlife management has been used in Wisconsin for a number of years. One of the first ditching projects on a state-owned area was the experimental level ditching at Horicon Marsh, which was set up to determine the value of this technique for muskrat management (Mathiak, 1953). Over 13,000 feet of ditch were dredged with a 3/4-yard dragline for this study. Most of the ditching done on state wildlife areas has been to improve semidry wetland habitats for waterfowl and furbearers.

Construction

On the New Auburn Wildlife Area a ditch was dug in the shape of a closed square so that it could also serve as a fire break during controlled burning operations. Spoil was placed along the inside edge of the square.

On the Jackson Marsh Wildlife Area a 3/4 mile ditch was put in by a gas company to bury a pipeline. The company agreed to construct the ditch 5 feet deep and 12 feet wide at the top with a 5-foot-wide bottom instead of constructing their standard ditch which is 3 feet wide and 3 feet deep. They further agreed to leave the ditch open after the pipeline was laid so that the ditch could fill with water and become useful for wildlife purposes. In return, the state gave the company easement rights for their pipeline. All spoil was placed along one side of the ditch so that it could be used as a dike if desired at a later date. This is the type of opportunity that game managers can watch for. Various commercial and public works constructions sometimes occur in or adjacent to state-owned wildlife areas which can sometimes be utilized for wildlife purposes at little or no cost to the Department of Natural Resources.

Two-and-one-half miles of shallow ditching were constructed on the Crex Meadow Wildlife Area when peat and top soil were removed for top dressing. In this case there were no spoilbanks and the ditch depths varied from 1 to 2-1/2 feet. Ditch width varied from 6-1/2 feet to 25 or 30 feet. Because of shallow depths and lack of spoilbanks, muskrat use was limited. However, ditches received very good use by breeding waterfowl for territorial and loafing sites. A 5/8-yard drag-line was used to remove the spoil. In this case the costs were written off as the cost of top dressing material since the resulting ditch was a by-product of this operation.

Ditching on the French Creek Wildlife Area has a zig-zag pattern. Segments of the zig-zag are in 70-foot lengths. Spoil is piled on alternate sides of the ditch for each segment.

Hammond and Lacy (1959) found that optimum ditch spacing for breeding waterfowl was 150 to 200 feet in Minnesota and the Dakotas. This gave maximum use per cubic yard of construction, and compares closely with optimum ditch spacing of 200 feet for muskrats in the Horicon Marsh studies (Mathiak and Linde, 1956). The maximum productive life of a ditching project for muskrats under conditions of maximum production is only about 6 years, for heavy muskrat tunneling in spoilbanks causes rapid silting. Hammond and Lacy (1959) estimated the productive life of ditches constructed for waterfowl to be 30 years. This figure would undoubtedly be reduced if heavy muskrat use was experienced. However, ditches should still be useful to waterfowl long after they have lost their utility for muskrats. Muskrats are unable to move about freely beneath the ice after the muck level becomes too high and use on these areas rapidly declines as a result. In northern areas with lower muskrat populations, ditch longevity can be expected to be considerably greater.

A zig-zag or meandered ditch is considered more desirable for furbearer trapping than a straight ditch on which it is harder to operate a light skiff in a strong wind (Mathiak and Linde, 1956). Mendall (1958) said that irregularly shaped ditches with meanders and zig-zag patterns are far more effective in building up waterfowl nesting densities than straight ditches. The principal species on this study area was the ringneck. Hammond and Lacy (1959) on the other hand, concerned more with puddle ducks, stated that zig-zagged or crooked ditching showed no greater use than straight ditching.

If the ditches are designed for both muskrat and waterfowl production, 200-foot spacing between ditches is probably optimum, but if the ditch is to serve as a fire break as well as for wildlife, it will necessarily have to take a shape which will serve as a boundary for the area to be burned. Spoilbanks in peat soil should be on the side of the ditch away from the controlled burn area to prevent peat fires from starting in the spoilbanks. Large sections of the bank may burn away completely if this occurs.

Spoilbanks are of importance if maximum muskrat production is to be attained, since in a semidry marsh nearly all muskrats will den in the spoilbanks. Because waterfowl often heavily use the banks for nesting, it is desirable to break the banks into short segments and alternate the segments on either side of the ditch if possible. This will tend to break up predator travel lanes and reduce nesting losses. If alternating the spoilbanks is impractical, a 10-foot break should be left in the bank at intervals. Reducing the marsh floor by about a foot between bank segments will produce surface water in these areas and encourage aquatic growths for muskrat use. It will also offer a further impediment to predator travel. Some of the ditching projects which are presently in existence are in grass-sedge areas which are almost devoid of good muskrat foods. Developing shallow water areas of this type for food production would be highly desirable.

Costs

Although a number of level ditching projects have been accomplished, construction figures comparable to the Horicon project are difficult to obtain and productivity observations are very meager. Draglines were used in all constructions and the equipment size varied from 1/2 yard to 1-1/2 yards. In order to be able to make meaningful comparisons, since figures for the various constructions were mostly in different terms, all figures were converted to a cost per foot of ditch. Costs varied from 18 cents per foot to $1.93 per foot (Table 14). Although depth and width of the ditches varied somewhat between constructions, the variation in costs seemed to be related mostly to the amount of ditching involved. More than 13,000 feet of ditching was dug for the experimental project at Horicon Marsh at a cost of 18 cents per foot while at the French Creek Wildlife Area, with only 800 feet of ditch, the cost was $1.93 per foot. No doubt part of this difference was due to variations in working conditions, differences in economic conditions, and the individual machine operators, but size of the operation is certainly the major factor. Moving costs are high for heavy equipment and if this can be prorated over a large amount of ditching, the unit costs can be reduced considerably.

Use

In a five-year period following construction, the experimental ditch area on Horicon Marsh yielded a harvest of 9.7 muskrats per acre as compared to only 1.5 muskrats per acre in the surrounding area (Mathiak and Linde, 1956). A nesting study on the experimental area in 1953 revealed 51 duck nests on the ditch spoilbanks or 1.5 nests per acre -- a higher concentration of nests than on any other known area of the marsh.

Muskrat use was noted and several duck nests have been found on ditchbanks at the French Creek Wildlife Area but like most of the other constructions no deliberate checks were made to determine wildlife use. On experimental ditches at Horicon Marsh, several waterfowl checks were made in July of the years 1952 through 1954 by walking the spoilbanks of each ditch (Table 15). Because of almost complete lack of cover in the first year and the newness of the ditches (constructed in the winter of 1952), no duck broods were observed. In 1953, however, 15 broods were observed on the 6 miles of ditch involved. The 1954 check produced slightly fewer broods, but this may have been due to high water which made more area in the surrounding bog available to broods and therefore made them harder to observe.

No further checks were made on these ditches until the spring of 1960 when I made some observations incidental to other work in this area. Flood conditions allowed access to the ditched area by skiff, as the surrounding bog was flooded. The first two ditches and the outer ends of the remainder were checked for duck nests. Five mallard nests and one blue-winged teal nest were located on the spoilbanks. Spoilbanks, although well covered by vegetation, were flattened and had very little freeboard above the surrounding water. High muskrat populations during the preceding 8 years had tunneled the banks, and when the tunnels collapsed, they caused a decrease in bank height. This type of degradation was accompanied by some bank erosion although bank cover was good. Muskrat excavating activities and erosion had heavily silted the ditches and severely reduced their depths. The ditches were of little value to muskrats at this time, but it was obvious that waterfowl still found them attractive.

TABLE 14

Level Ditching Projects on State-Owned Areas

Location	Length (Miles)	Ditch Dimensions*	Cost/Foot of Ditch	Size of Dragline (Yds.)
Crex Meadows Wildlife Area	2.5	Variable	No costs Available	5/8
New Auburn Wildlife Area	.35	14x6x6	$ 0.45	3/4
French Creek Wildlife Area	.17	13x5x5	1.93	3/4
Jackson Marsh Wildlife Area	.75	12x5x5	0.25**	3/4
Horicon Marsh Wildlife Area (Experimental Ditches)	2.5	13x5x5	0.18	3/4
Horicon Marsh Wildlife Area (post-experimental ditches)	6.0	13x5x5	Costs not comparable	1/2
Yellowstone Wildlife Area	.23	15x5x8	No costs Available	1-1/2

* Dimensions listed are: top width, bottom width, depth.
** Costs not paid by DNR.

TABLE 15

Observations Made on Horicon Ditches

Year	No. Duck Broods Observed	No. Rail Broods Observed	Spoilbank Cover
1952	-	1 coot	7 percent
1953	15	1 gallinule 2 coot	80 percent
1954	11	-	Very dense

Spoilbank Seeding

Cover should be established on the spoilbanks as soon as possible in new ditching projects if erosion and silting are to be kept to a minimum and the useful life of the ditch is to be prolonged. In some areas where residual seeds in the soil are plentiful, or when the surrounding vegetation is predominantly grasses, the spoil tends to seed naturally. This natural seeding is usually slow in most locations, but may be fairly rapid in others. However, to insure early establishment of vegetation banks should be seeded. Unless the spoil has been shaped, it is impractical to do more than broadcast the seed by hand. Ditching projects at Horicon indicated that sweet clover established itself early on peat soils and afforded some cover during the first two years. If this seeding is mixed with canary grass seed, permanent cover can be established within a few years which will provide excellent duck nesting cover and spring food for muskrats.

On some of the Horicon ditches a variety of grass seeds were used. Of these, only the clovers appeared to have much value in providing early cover. White sweet clover appeared to be the best species tried. Brome grass was mixed with this seeding but it was unsuccessful in establishing itself. No other grass seed was used, but a natural seeding of blue-joint became the dominant cover in the third year. On the experimental ditches at Horicon, white sweet clover was again found to be the best species for early establishment of cover, but in this instance a seeding of canary grass became the dominant cover in the third year.

Canary grass affords a heavier cover than blue-joint and seems to be a better soil binder. Dense sods of this species permit walking on the spoilbanks without breaking through into muskrat tunnels. An unprotected peat spoilbank invaded by a high muskrat population is extremely vulnerable to severe damage if it is subjected to even moderate foot travel. For every tunnel that is caved in, the muskrat may dig another one, thus putting that much more silt into the ditch. It is imperative that the seeding be accomplished early in the spring while soils are still saturated from the winter snows if maximum germination is to be expected on peat soils. Later, the top surface of the peat dries out and becomes powdery and germination will be very poor. Smartweeds and some of the other annuals seem to have little or no value in establishing cover as their stem density and root system are too small. On mineral soils and in northern regions, alsike and white clover seem to have considerable potential as spoilbank cover.

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APPENDIX

Scientific Names of Plants Used in the Text
(From Gray's Manual of Botany, by M.L. Fernald, 8th Edition Amer. Book Co., N.Y., 1950; and Manual of the Grasses of the United States by A.S. Hitchcock, USDA Misc. Pub. No. 200, 1950.)

Alder	Alnus spp.
Alta fescue	Festuca arundinacea
Aspen	Populus spp.
Birch	Betula spp.
Paper	B. papyrifera
Bird's foot trefore	Lotus corniculatus
Black spruce	Picea mariana
Bladderwort	Utricularia spp.
Blueberry	Vaccinium spp.
Blue-joint	Calamagrostis canadensis
Bromegrass (smooth)	Bromus inermis
Browntop millet	Panicum racemosum
Buckwheat	Fagopyrum sagittatum
Bulrush	Scirpus spp.
River	S. fluviatilis
Softstem	S. validus
Woolgrass	S. cyperinus
Burreed	Sparganium spp.
Giant	S. eurycarpum
Canary grass	Phalaris arundinacea
Cattail	Typha spp.
Clover - alsike	Trifolium hybridum
Red	T. pratense
White	T. repens
Cotton grass	Eriophorum spissum
Cranberry	Vaccinium spp.
Dock	Rumex spp.
Duckweed	Lemna spp.
Duckwheat	Fagopyrum tataricum
Elm	Ulmus sp.
German millet	Setaria italica
Jack pine	Pinus Banksiana
Japanese millet	Echinochloa crusgalli
Leatherleaf	Chamaedaphne calyculata
Muskgrass	Chara sp.
Mustard	Brassica sp.
Nettle	Urtica spp.
Nutgrasses (umbrella sedges)	Cyperus spp.
Oak	Quercus spp.
Oats	Avena spp.
Orchard grass	Dactylis glomerata
Panic grass	Panicum spp.
Pigweed	Chenopodium spp.

Pondweeds . . . . *Potamogeton* spp.
Sago . . . . *P. pectinatus*
Proso millet . . . . *Panicum miliaceum*
Quack grass . . . . *Agropyron repens*
Ragweed . . . . *Ambrosia* sp.
Giant . . . . *A. trifida*
Red maple . . . . *Acer rubrum*
Red-rooted nut grass . . . . *Cyperus erythrorhizos*
Redtop grass . . . . *Agrostis alba*
Rice cutgrass . . . . *Leersia oryzoides*
Rye . . . . *Secale cereale*
Ryegrass . . . . *Lolium* spp.
Sedge . . . . *Carex* spp.
Smartweed . . . . *Polygonum* spp.
Common . . . . *P. hydropiper*
Dock-leaved (nodding) . . . . *P. lapathifolium*
Water . . . . *P. amphibium*
Sphagnum moss . . . . *Sphagnum* sp.
Spiraea . . . . *Spiraea* spp.
Stick-tights . . . . *Bidens* spp.
Sweet clover . . . . *Melilotus* spp.
White . . . . *M. alba*
Yellow . . . . *M. officinalis*
Sweetflag . . . . *Acorus calamus*
Tartarian buckwheat . . . . *Fagopyrum tataricum*
Timothy . . . . *Phleum pratense*
Tufted loosestrife . . . . *Lysimachia thyrsiflora*
Umbrella-sedges (nutgrasses). . . . . *Cyperus* spp.
Walter's millet . . . . *Echinochloa walteri*
Water milfoil . . . . *Myriophyllum* spp.
Wheat . . . . *Triticum aestivum*
White water lily . . . . *Nymphaea odorata*
Wild rice . . . . *Zizania aquatica*
Willow . . . . *Salix* spp.