EXPERIMENTAL LEVEL DITCHING FOR MUSKRAT MANAGEMENT

TECHNICAL WILDLIFE BULLETIN NUMBER 5

Game Management Division
WISCONSIN CONSERVATION DEPARTMENT
Madison 2, Wisconsin
1953

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by

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Pittman–Robertson Project 15-R

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ACKNOWLEDGMENTS

I wish to thank Wallace Anderson of the Soil Conservation Service, and Harry Klemme of Kiel, Wisconsin, for advice and help in organizing and promoting the ditching study; Robert S. Dorney, Richard Mihalek, Harold D. Hettrick, and Arlyn F. Linde for assistance with the field work; and Cyril Kabat for very helpful advice and suggestions during the preparation of the manuscript.

Photographs were taken by Staber Reese (aerial photos) and by the author.

Compiled and Edited by Ruth L. Hine

(Submitted for publication 1952.)

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ABSTRACT

In order to determine what level ditch spacings result in the maximum production of muskrats, four series of experimental level ditches were dredged in a "dry marsh" portion of the Horicon Marsh Wildlife Area. The benefits to muskrats of level ditches are many. In this portion of the marsh, there often is not enough water to allow muskrats to obtain food throughout the critical winter period. The deep water of the ditches makes it possible for muskrats to obtain food such as submerged aquatics or fish despite thick ice, and the high spoilbanks offer more protection from freeze-outs than the average-size muskrat house. During summer drouth periods when other surface water is not available, the depth of the water in the ditches holds muskrats in a marsh. Furthermore, during flood periods spoilbanks hold muskrats in the ditched area by offering resting sites, feeding places, and shelter.

Dredging was superior to blasting as a method of ditch construction, for it was far more economical and produced a more desirable type of ditch. Over the three-year period during which the ditches have been in existence, deterioration of the ditches themselves and of the spoilbanks has been so slow that good fur harvests can be expected for years after the original investment is recovered.

The muskrat population has been high in the ditched area. Live-trapping and ear-tagging studies revealed an estimated population of 18 muskrats per acre in the ditched plots in 1951. The harvest of muskrats from the ditches clearly reflects the high population despite the often detrimental effects of weather on trapping. In 1951, approximately two animals per acre were harvested in the surrounding marsh, and six per acre from the ditches. Although the harvest from the ditches was considerably higher than that from the unditched area, it represented only 35 per cent of the total population in the ditches because of unfavorable trapping conditions during the fall season in 1951.

There was a marked effect of different ditch spacings on muskrat productivity and on the costs involved. The greatest number of musk-

Experimental level ditches at Horicon Marsh.

rats harvested were associated with the closer ditch spacings. The 200-foot spacing, however, provided the greatest return per $100 invested, and this is a more important consideration than actual muskrat productivity per acre when pelt prices are low. Even with low fur prices the high production in the ditch with the 200-foot spacing should result in the recovery of the initial investment in the fourth year, if the muskrat crop is fully harvested.

Muskrat movement away from the ditches was relatively slight except during periods of high density. The inadequate harvest of muskrats from the ditches in the fall of 1951 resulted in a higher residual population in the spring of 1952, and this in turn resulted in greater movement away from the ditches at this time. One of the important factors in the management of the ditches for muskrat production will be to regulate trapping pressure so that a large enough proportion of the population (approximately 75 per cent) is harvested.

Along with providing more stable water levels for muskrats, level ditches were also beneficial to waterfowl during the nesting season, fish and other furbearers. Twenty-four mallard and blue-winged teal nests were found on the spoilbanks in 1952.

Perhaps the greatest value of level ditching, however, is its influence in promoting the management of semi-dry marshes for wildlife production, rather than their drainage for relatively unproductive cropland or pasture.

INTRODUCTION

The muskrat is an important fur resource to Wisconsin. In 1950–51, over 296,000 muskrats were harvested, bringing in an estimated $442,000. Fur farmers and game managers, therefore, are interested in gaining further knowledge of ways to increase fur production. Whereas some muskrats will be produced annually by letting these animals care for themselves, management is often needed to insure a harvestable surplus each year. This is particularly true in "dry marsh" areas, where there is not enough water to allow muskrats to obtain food throughout the critical winter period. In winter, a large number of houses built in shallow water may freeze up (Aldous 1947). Errington (1939) believed that there is heavy mortality from intraspecific strife, predation, and random wandering in habitats which are drying out. The dry marshes are also in most danger of being drained under present agricultural land-use policies.

Many investigators have recognized that water control is one of the important features of marsh management (Gashwiler 1948, Williams 1950, and others). Many fur farmers have constructed dikes and ditches and have even put water pumping systems into operation to maintain water levels for wildlife. Knowledge of ways to improve marshes for fur production may be most widely used in states where liberal laws allow fur farmers almost complete control of their fur harvest. Licensed fur farmers in Wisconsin, for example, are not dependent upon a general trapping season to harvest their crop. They may take their muskrats under permit even if the home county has a closed season on furbearers. Under our fur farm laws the licensee purchases the muskrats from the state, and the muskrats then become his personal property. The Wisconsin fur farm laws have, therefore, encouraged a very large number of habitat improvement projects for furbearers by private individuals.

Level ditching is one of the more practical means of improving a marsh for muskrats where flooding by means of dikes or dams is not feasible because of physical conditions (soil types or water supply), financial limitations, or legal restrictions (rights of adjoining landowners). Level ditches are dug in a marsh to create deep water areas.

No drainage occurs because there are no outlets to a drainage system, or, if there is a connection to such a system, bulkheads are used to prevent drainage.

In a study of three Wisconsin marshes where level ditching had been installed, Anderson (1948) found that the catch of muskrats on these lands was increased by the ditching operations. Level ditches held water of sufficient depth in the winter to prevent "freeze-outs" and the subsequent loss of runner muskrats. They also provided muskrats with good cover on the spoilbanks, and food in the ditches themselves.

Anderson's report opened the way for a comprehensive analysis of ditching in relation to muskrat production where studies could be started at the time ditches were created. There was also a need for information on the most practical types of ditches and the best spacing of them for raising muskrats. The present study was set up on a five-year basis to investigate the productivity of ditches with four different spacing designs for muskrats, the economics involved, and the benefits of level ditching to other species of wildlife. This report presents findings of the first three years of study. The final analysis will appear in two years when the project has been completed.

Facts and figures are needed in order to sell a program of level ditching to increase the value of marshes for wildlife production. Many marshes which have been drained are poorly suited for agricultural crops. Others may already be dedicated to wildlife production but actually are poor producers of wildlife due to density of cover or lack of water.

STUDY AREA

In order to evaluate the productivity of different ditch spacings, a dry marsh area of submarginal muskrat habitat was chosen in which to carry on the ditching study. The experiment was set up in 1948 in Unit 26 of the state-owned portion of the Horicon Marsh Wildlife Area, Dodge county. This unit embraces about 500 acres of semi-dry marsh, with a water level below the minimum level requisite for muskrat survival. Clark's ditch forms the southern boundary. Peat is mostly over five feet in depth in this area. The vegetation of this section of the marsh at the beginning of the experiment was predominately sedge (*Carex* sp.) and bluejoint (*Calamagrostis canadensis*). At the time the state conservation department began to manage the muskrat harvest in 1943, practically no muskrats were taken from this area except from Clark's ditch. The limited number of muskrat houses found in the dry bog away from the ditch were so widely scattered that they were not worth trapping.

The area in which the ditches are located characteristically dries out in late summer, and muskrats are frozen out in most winters because of the lack of water. Only when heavy snows are present to insulate the bog during the coldest periods are the muskrats able to survive the winter. Ideal snow conditions existed in the winter of 1950–51, and to a lesser degree in 1951. Water levels in the marsh have gradually been raised since the ditching project was initiated, followed by an improvement of the whole area for muskrats. By the summer of 1951, many of the bluejoint stands disappeared, usually being replaced by sedge. Sedge stands were thinned out and invaded by cattail (*Typha latifolia*), burreed (*Sparganium* sp.) and bulrushes (*Scirpus* sp.). Although the combination of high water and excellent food plants has resulted in greatly improved conditions for muskrats, and consequently an increased population in the summer, there is little chance for survival in the winter without continuous snow cover. Ordinarily when there is no snow on the marsh, only one week of zero weather is needed to freeze-out most of the bog muskrats.

THE DITCHES

Construction

In December of 1948 and January of 1949 four series of ditches were dredged with spacings of 50, 100, 200, and 400 feet. The 50-foot series consisted of eight ditches in a five-acre plot. The other ditches were located in 10-acre plots 544.5 feet by 800 feet. The shape of the ditches and their location in relation to Clark's ditch are shown in Figure 1. All ditches were made 13 feet wide at the top and five feet deep. For convenience of travel by boat, the ends of the ditches

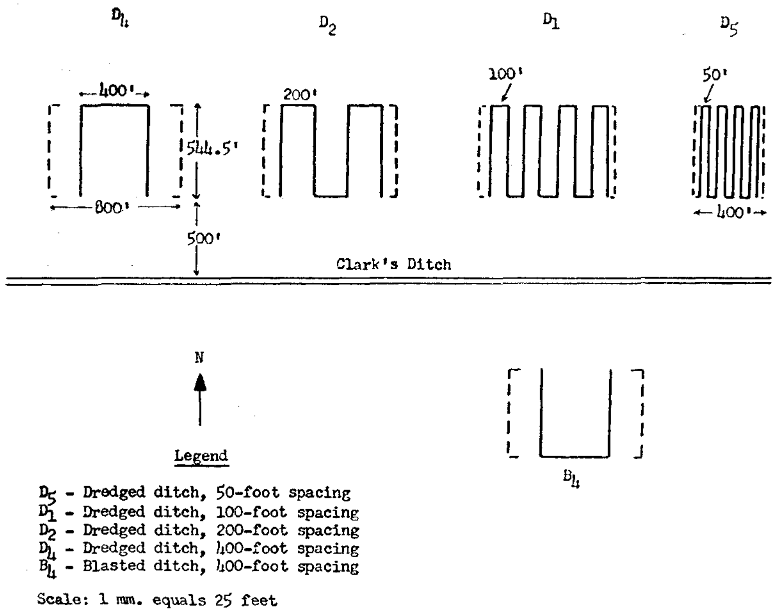


Figure 1. Experimental ditches, Horicon Marsh, Wisconsin.

were connected so as to form one continuous ditch within each plot. The excavated material was deposited on the north and west sides of the ditches creating spoilbanks. Gaps were created in the banks at 100-foot intervals by placing a few buckets of peat on the opposite side of the ditch. Numbered signposts were erected at 200-foot intervals along each ditch to facilitate accurate record-keeping.

The ditches were dredged by a local dragline operator at a contract price of 10 cents per cubic yard. A three-quarter yard dragline with a one-cubic-yard perforated bucket was used for the dredging.

Aerial view of the experimental ditches with 100- and 50-foot spacings, showing the design of the ditches and the placement of the spoilbanks.

Although the frost was thick enough to support the machine when moving from plot to plot, mats were needed during the actual dredging operations. It was not necessary to use an iron ball to break the frost at any time. The costs of each series of ditches are presented in Table 4, and will be discussed later in this report.

It was the original intention to dynamite a companion series of four ditches in order to compare dynamiting versus dredging as a means of ditch construction. Two ditches 400 feet apart were blasted in December of 1949. Four sticks of standard 50 per cent ditching dynamite placed every two feet appeared to give the best results. The location of the blasted ditch in relation to the dredged ditches is shown in Figure 1.

Biologists and engineers agreed that the ditch produced by blasting was far inferior to the dredged ditches. The blasted ditch was at least a foot shallower than the dredged ditch. Large amounts of loosened muck along the edges of the ditch proved to be highly susceptible to wave and rain erosion before protective vegetation developed. The lack of high spoilbanks desired for dens and rapid siltation drastically reduced the value of the ditch as furbearer habitat in the winter—the limiting period for muskrats in this area. Material blown from the ditch was deposited along both sides, mostly within a 50-foot space and in sufficient amount to materially raise the level of the bog. This raising of the bog favored the growth of plants of little value to muskrats. Furthermore, the cost of the dynamite and labor was more than twice as much as the total costs of dredging a ditch of the same length. The cost of dynamite alone at four sticks every two feet was $337.00. The entire cost of dredging the same length of ditch, however, totaled only $252.00.

Provost (1948) wrote that blasting in a marsh to create an interspersion of cover and water greatly improved the habitat for muskrats. His Iowa studies showed, however, that blasted holes were of much greater value in the deep-water emergent vegetation than in shallow-water areas.

Due to the excessive cost of blasting and the undesirable type of ditch produced in the Wisconsin study, plans to dynamite the other ditches were abandoned. Productivity studies of the dynamited ditch were dropped since it is difficult to see where, under present economic conditions, dynamiting could be justified for muskrat management. The comparative value of various ditch spacings will be determined from the four dredged ditches.

Survival

At the time of dredging, the ditches averaged five feet in depth. Three years later, the dredged ditches were approximately four feet deep which is sufficient for both summer and winter muskrat requirements. An uncontrolled fire in the ditched area in December of 1949 consumed most of the emergent vegetation. Sizeable waves could be produced during flood time as a result of the loss of the windbreaking action of the plant cover. Spoilbanks not protected by patches of unburned vegetation were undercut by the waves and the general elevation was lowered as the soil settled to form new slopes. Despite high flood waters during the spring of 1951, very little bank erosion took place. Present vegetative cover will afford excellent protection to the banks as long as fire is kept out of the ditched area.

A combination of muskrat and human activities can further contribute to the erosion of the spoilbanks. Tunnelling muskrats remove a considerable volume of material from the banks which is mainly deposited in the ditches or sometimes on the bog side of the spoilbanks. Also, dens may be caved in easily by walking on the banks. This results in lower spoilbanks, and renewed digging by muskrats to form new dens. Research personnel worked mainly from boats while conducting field studies of the ditches, and snowshoes were used in the duck nesting survey in order not to collapse the muskrat dens. The spoilbanks have been "protected" from the deleterious effects of large numbers of hunters roaming over the banks in search of game, since waterfowl hunters are restricted from that portion of the marsh, and there are no pheasants or rabbits in the ditched area to attract hunters.

Vegetation

Vegetation on the spoilbanks is of vital importance. It creates favorable habitat conditions for the wintering of muskrats in shallow water areas by retarding freezing, minimizing erosion, and delaying the filling of the ditches. After dredging was completed, and before the frost was out of the ground, the spoilbanks were seeded to yellow sweet clover (*Melilotus officinalis*), canary grass (*Phalaris arundinacea*), and smartweed (*Polygonum* sp.). The rough nature of the spoilbanks made it uneconomical to prepare the seed bed, so that the seeds had to germinate without any special effort to cover them. Sweet clover made good growth the first summer and matured the second summer. Its rapid growth helped prevent bank erosion, furnished food for muskrats and good nesting cover for waterfowl. The planting was considered worthwhile even though the clover was replaced by other plants in the third year. Canary grass was not conspicuous the first summer, but has been increasing every year. It is a favorite spring and early summer muskrat food. Canary grass was not found in this portion of the marsh before the banks were seeded. Bluejoint is also increasing on the banks every year. These grasses are especially desirable because they are soil binders and sod builders which are the best means of preserving the spoilbanks. The smartweed seeding proved valueless, for the thick patches and scattered individual plants of smartweed which appeared are believed to have developed mostly as volunteer growths. This is indicated by the fact that there was as much smartweed on the unplanted ditch-bank as on the planted sections.

In the third year of the life of the ditches, bluejoint, canary grass, and sedge (lower portions) have become dominant. Jewelweed *(Impatiens biflora)*, thistles (*Circium* sp.), smartweeds (*Polygonum* sp.), mints (*Mentha* sp.), nettles (*Urtica* sp.) and other species are present in lesser numbers. With the canary grass and bluejoint well established good waterfowl nesting cover and protection against erosion is assured.

Manual seeding of banks is not necessary in all marshes. Many times new spoilbanks are thickly covered by volunteer growths the first summer. There apparently was little residual seed in the peat of the experimental ditch area, however, probably because the area was too wet for the type of plants capable of growing on the drier spoilbanks. Better volunteer growths were found on spoilbanks of other ditches nearer the hard shore of Horicon Marsh.

Spot plantings of aquatics were made in alternate ditches in the latter part of July 1949. Coontail (*Ceratophyllum demersum*), waterweed (*Elodea anacharis*), bladderwort (*Utricularia* sp.), and milfoil (*Myriophyllum* sp.) were taken from Clark's ditch and distributed so as to plant 50 per cent of the total length of each ditch. These plantings of leaves and stems were moved back and forth by the wind, and eventually were distributed over the unplanted portions. Some duckweeds (*Lemna* sp.) were transplanted to the ditches, but a few were already present, as was bladderwort which had spread from the surrounding bog. Generally in the first summer plant growth was not conspicuous, but submerged aquatics are now well established and are especially important as a winter and early spring food supply.

THE MUSKRAT POPULATION

Methods of Study

As a first step in obtaining information on the size of the muskrat population, the harvest, and movements between the experimental ditches and other portions of the marsh, a considerable number of muskrats were live-trapped in the ditches in September and October. National live-traps baited with sliced carrots were placed on cedar floats anchored at 200-foot intervals in the ditches. These floats are used commonly by muskrats even when not baited, and muskrats were caught with relative ease during these two months. Live-trapping on the spoilbanks proved more difficult because mice tended to remove the bait before the muskrats arrived and frogs often snapped the traps as they hopped on the treadles. Individual muskrats were tagged with numbered fingerling ear-tags fastened to the right ears (Aldous 1946).

Steel-trapping, which ordinarily starts on November 1, provides a follow-up to the live-trapping and tagging operations. Steel-trapping on Horicon Marsh is conducted on a 50-50 share-trapping arrangement. Trappers known to be very cooperative were assigned to harvest the experimental ditches. By looking for ear-tags and recording the points of recovery, much valuable information on populations and movement was obtained. Most of the steel-trapping was conducted on the cedar floats on which the muskrats were accustomed to feeding. All muskrats were examined daily for ear tags when they were brought into the headquarter's checking station. Muskrats taken on the experimental ditches, however, were examined immediately in order to record the exact point of capture of ear-tagged muskrats.

Harvest

The harvest of muskrats in deep water ditches is greatly influenced by weather conditions. Dozier *et al.* (1948) and Dozier (1950) have pointed out that trapping success is to a very great extent dependent upon weather. Heavy ice formation and deep snows seriously hamper trapping operations.

Steel-trapping conditions appeared to be good in 1949, somewhat poorer in 1950, and decidedly unfavorable in 1951. Ordinarily the survival of muskrats from the time of live-trapping in September and October up to November 1 when steel-trapping begins should be very similar from year to year. However, the difference in the number of tagged muskrats recovered while steel-trapping the experimental ditches from 1949 to 1951 varied greatly, reflecting the effect of weather on the harvest (Table 1). The increased number of animals ear-tagged in 1951, as shown in Table 1, was due to the larger total muskrat population rather than new techniques or more intensive live-trapping. There was only a 31 per cent return of ear-tagged muskrats in 1951, compared with a 50 per cent return in 1950, and a 66 per cent return in 1949. Many more muskrats could have been taken in 1951 if the freeze-up had been delayed a few days. Just prior to the opening of the 1951 season, the muskrat activity on the floats was so heavy that we thought the trapper would not be able to haul the first night's catch in his boat. Ice formation on October 31, 1951, however, made trapping so difficult that less than 50 per cent of the potential crop was taken. The ditches and floats were coated with some ice almost every night until the complete freeze-up occurred.

Table 1

Muskrats Tagged and Recovered in Experimental Ditches, Fall 1949–1951

Ditch Number	*No. Ear-tagged Muskrats*			*No. Recovered First Year*			*Per Cent Returns*		
	1949	*1950*	*1951*	*1949*	*1950*	*1951*	*1949*	*1950*	*1951*
D_5	10	17	44	8	8	14	80	47	33
D_1	16	15	55	12	9	20	75	60	36
D_2	15	19	39	11	9	9	73	47	24
D_4	9	6	14	2	3	4	22	50	29
Total	50	57	152	33	29	47	66	50	31

Thirty-three muskrats were live-trapped after the spring break-up in 1950, and nine of these were later recovered by steel-trapping in the ditches (Table 2). None were retaken in other sections of the marsh. This is a relatively low recovery when compared to fall trapping returns (Table 1). Natural mortality probably accounted for the low rate of return. Spring live-trapping was not feasible in other years.

Table 2

Spring Live-Trapping of Muskrats in Experimental Ditches, 1950

Ditch Number	*No. Muskrats Ear-tagged*	*No. Recoveries**	*Per Cent Return*
D_5	7	3	43
D_1	12	3	25
D_2	13	3	23
D_4	1	0	0
Total	33	9	27

*All muskrats taken in 1950 except for two animals recovered in 1951 from D_1.

The muskrat harvest from Unit 26 is shown in Table 3 for a six-year period. Very few muskrats were taken in the bog area prior to 1951, for about one-half of the harvest from the bog surrounding the ditches came from Clark's ditch. The greatly increased harvest from the bog in 1951 was due both to higher water levels in this area and to the favorable wintering conditions during the winter of 1950.

Table 3

Muskrat Harvest from Unit 26, Horicon Marsh

Year	*Experimental Ditches*	*Surrounding Bog*	*Tota*
1946	---	---	42
1947	---	---	26
1948	---	---	190
1949	121	188	309
1950	225	109	234
1951	218	623	841

In 1951, approximately two muskrats per acre were taken from the bog portion of Unit 26 and six muskrats per acre from the ditched plots. Muskrats taken in the special 1952 spring season are not included in Table 3 since the ditch plots were not trapped at all during this period. Both areas were under-trapped during the winter season of 1951, but the ditched plots would still have had a much higher production per acre even if a complete harvest had been possible.

The application of the Lincoln Index, as will be explained later, showed a total population of 622 muskrats in the ditches in 1951. With a harvest of 218, this means that only 35 per cent of the population was taken. Under good management practices, approximately 75 per cent of the population should have been harvested.

Balance Sheet

A summary of the muskrat harvest from the different experimental ditch designs from 1949 to 1951 compared with the money invested appears in Table 4. An attempt was made to subject each ditch to the same trapping pressure by allotting two traps for each station spaced at 200-foot intervals. However, after ice conditions had terminated trapping in the ditches in December of 1951, the trapper was able to take an additional 67 muskrats from the smaller houses in plots D_2 and D_4. Because many more muskrats could have been taken also from D_1 and D_5 if equal trapping pressure had been applied to all plots, these 67 muskrats have been omitted from the productivity-cost analy-

Table 4

Evaluation of Four Ditch Spacings

Ditch Spacing in Feet	Size of Ditched Plots (Acres)	Actual Length of Ditches in Feet	Feet of Ditch/Acre	Total Cost	Cost/Acre	Muskrat Harvest				Yearly Harvest Per Acre*	Yearly Muskrat Harvest per $100 Invested in Ditching*
						1949	1950	1951	Total		
50 (D_5)	5	4433	887	$ 779.25	$156.00	20	37	63	120	8.0	5.1
100 (D_1)	10	4783	478	840.98	84.00	53	77	74	204	6.8	8.1
200 (D_2)	10	2647	265	465.00	47.00	36	76	51	163	5.4	11.7
400 (D_4)	10	1435	144	252.27	25.00	12	35	30	77	2.6	10.2
Totals				$2,338.00		121	225	218	564		

*Based on the average harvest per year for the three-year period.

sis. A truer comparison of the values of the four spacings is better shown when only the harvest figures from November 1 to December 12 are used (Table 4). During this period the ditches were subjected to approximately equal trapping pressure. Fifteen muskrats taken in early spring from D_5 are likewise disregarded in the harvest figures.

What are the dollars and cents values of the different ditch spacings? The facts and figures concerning the cost of the ditches and the muskrat harvest from them during the first three years of the study are presented in Table 4. The economics of the ditching technique may be evaluated by considering (1) the cost of ditching, (2) the harvest of muskrats per acre, and (3) the return per $100 invested.

The cost of a unit of ditch length is the same regardless of the spacing of the ditches. The costs per acre, however, increase with closer ditch spacings, since there is more dredging required per unit area. On any particular parcel of marsh, then, the closer the ditches, the higher the initial investment. The cost per acre figures in Table 4 will vary with the size of the ditching operation, but will serve here to indicate relative costs of the different ditch spacings.

The harvest of muskrats per acre also increases with closer ditch spacings, for on a given unit of land, more ditches provide more favorable habitat and consequently more muskrats. In other words, the closer the ditches, the more muskrats produced. True values cannot be determined in this respect, however, since the muskrats range beyond the boundaries of the ditch plots. Much larger blocks would have to be ditched with the various spacings in order to minimize the variable of feeding outside the plots. There is probably the most error in connection with the 50-foot spacing where much of the marsh vegetation within the plot is covered by spoilbanks. Actually the 50-foot spacing (D_5) is not a practical one, for there is too little vegetation left between the ditches. Muskrats would have to range outside the ditched area for food, and if there is no marshland surrounding the ditches, the animals might be lost.

In addition, the harvest of muskrats per $100 invested is greater in the ditches with the wider spacing, since the cost of dredging is less in these plots. The 200-foot spacing gives the greatest return per $100 invested. This is also an expression of the relative harvest per unit of ditch length, since dredging costs are based on the actual length of the ditches in feet.

Theoretically, if length of ditch were the only limiting factor on muskrat production, the harvest per unit length of ditch (or per $100 invested) should be the same for any ditch. Actually, however, with ditches spaced closely together (e.g. 50 feet), fewer muskrats are found along the length of any one ditch due to less food present, overcrowding, etc.

In a consideration of level ditching for muskrats by fur farmers, game managers, or by private individuals who might buy a marsh for hunting and trapping if they could improve the area by ditching, both the return for the money invested and the return per unit area will be important. Together they give an idea of the total production of a ditched area. For example, according to the results of this study (Table 4), the ditches with the 200- and 400-foot spacing both gave a high return per $100 invested, but the production per acre (or gross income from any marsh) was about twice as great with the 200-foot spacing.

The significance of the relationship between the cost of the operation and the return on the investment for the different ditch spacings is best illustrated by an example. Let us assume that muskrat pelts are worth $2.00 apiece. The following is a comparison of the economics of a 100-foot (D_1) and 200-foot (D_2) spacing:

	Yearly Muskrat Harvest/Acre	*Yearly Return/Acre*	*Ditching Cost/Acre*
D_1	6.8	$13.60	$84.00
D_2	5.4	10.80	47.00
Difference	1.4	$ 2.80	$37.00 (over a ten-year period = $3.70/acre/year)

For the harvest of 1.4 more muskrats per acre from D_1 than from D_2, the landowner is receiving $2.80 more per acre. However, his initial investment for dredging D_1 is $37.00 higher than that for D_2. Over a ten-year period (estimated minimum life of the ditches), he is paying $3.70 more annually for ditching per acre for D_1, and is receiving an annual return of only $2.80 more per acre in fur on his investment. Thus, although ditches with a 100-foot spacing produce more muskrats per acre, they are not as worthwhile an investment as ditches with a 200-foot spacing (until the average price of muskrat pelts reaches $2.64).

The total cost of a ditching operation by a private marsh owner will depend upon several factors, such as the size and value of the land unit, and whether or not the money for dredging is borrowed. The above discussion presents a cost analysis in its simplest form for purposes of comparing the relative costs of two different ditch spacings.

Anyone comtemplating ditching may extend the calculations, taking into consideration such items as interest payments, etc.

The return per $100 invested is a more vital consideration than the productivity per acre when pelt prices are low, for the added income resulting from ditching must pay the interest and liquidate the investment before the ditches lose their value for muskrats. If pelt prices remain high over a period of many years, it might be possible to dredge with the idea of getting the higher returns per acre associated with closer ditch spacings. Probably few dredging projects accomplished solely for muskrat production could be justified if pelt prices continued to be depressed. However, the periods of relatively low pelt values have always been followed by a rising market in the past. Fortunately the dredging field is in such a competitive position that dredging costs have not risen in recent years comparable to the rise in cost of most other goods and services. Low cost dredging is most easily obtained during the winter months when there is a slack in construction work and dredge operators are willing to work at a low margin of profit.

Actual monetary returns are not given in Table 4 because of the variation in pelt values in different years and also in different habitats in the same year. Production in the ditch with the 200-foot spacing was so high that even with relatively low pelt prices, the capital invested should be recovered in the fourth year if the next crop of muskrats is fully harvested. Ditch trapping by boat is so easy during open water periods that only a few days are required to harvest the crop if there is no limit on the number of traps. This is an extremely important economic feature of ditch trapping.

Population Estimates

Of interest to game managers and fur farmers is the length of time required for muskrats to move into newly-established ditches and the rate of population increase. In the first few weeks following construction several runner muskrats moved quickly into the new ditches, and fresh muskrat sign appeared in all parts of the ditches as soon as the ice was gone in the spring of 1949. This was not unexpected since there is a general invasion of all shallow water areas every spring when flood waters cover the marsh at Horicon, and many houses are completely submerged. Muskrat sign was well distributed throughout the ditches all summer. Feeding activities in the ditches, however, became much more noticeable in late August and September when the surrounding bog became dry.

An estimate of the population of muskrats using the ditches in 1951 was calculated using the Lincoln Index formula:

$$\frac{\text{No. returns}}{\text{Total tagged}} = \frac{\text{Total harvest}}{\text{Total population}}$$

There were 49 returns of the ear-tagged muskrats during the trapping season; five more animals had notched right ears which were believed to represent lost tags, thus increasing the total to 54 returns. The total number of animals tagged was 154, including two tagged muskrats found in the harvest which had not been handled during live-trapping in 1951. The total harvest from the ditches in 1951 was 218. The formula then reads:

$$\frac{54}{154} = \frac{218}{\text{T.P.}} = 622$$

The total population of 622 muskrats represents nearly 18 muskrats per acre in the ditched area of 35 acres. The ditched area is therefore as productive as the very best deeper water areas on the marsh, which produce about 13 muskrats per acre, and decidedly more productive than nearby unditched marsh.

Movements

Movement studies were made in order to determine the amount of movement within and away from the ditches. The possibility of the loss of muskrats from ditches due to natural dispersal and conditions causing such egress are important points to be considered in an evaluation of the ditching technique.

Ear-tagging provided some definite information on muskrat movements. The distances moved during 1949 to 1951 are presented in Table 5. When a muskrat was rehandled several times through live-trapping, the distance moved was calculated from the point of previous capture, and was figured for the most likely route of travel. A few muskrats travelled between the experimental ditches and Clark's ditch, but in general most of the movements seemed to be about 400 feet or less. Greater movements were recorded for muskrats in the ditches with the closer spacing.

There was surprisingly little movement shown by the 1951 fall-tagged muskrats. Of 49 recoveries during winter trapping, 27 animals (55 per cent) were taken on the same cedar float on which they had been previously live-trapped. Apparently most of the muskrats tagged in the ditches were residents of the ditches, because many of the houses lying between the experimental ditches and Clark's ditch were trapped without finding a single ear-tagged muskrat. However, of one litter of muskrats tagged in a house between two of the experimental ditch plots, three recoveries were made over a mile to the west while none of the litter was recovered in the experimental ditches themselves.

Table 5

Movements of Muskrats Tagged in Experimental Ditches 1949–1951

Movement in Feet	D_5	D_1	D_2	D_4	*Total*
0– 100	9	17	22	6	54
100– 200	16	20	13	2	51
210– 300	7	2	3	4	16
310– 400	4	4	4	--	12
410– 500	3	1	--	--	4
510– 600	7	1	1	--	9
610– 700	--	1	--	2	3
710– 800	1	2	--	--	3
810– 900	2	--	--	--	2
910–1000	1	--	--	--	1
1010–1100	--	--	--	--	0
1110–1200	--	--	--	--	0
1210–1300	1	--	--	--	1
1310–1400	--	1	--	--	1
1410–1500	1	--	--	--	1
1510–1600	--	--	--	--	0
1610–1700	--	--	--	--	0
1710–1800	1	--	--	--	1
1810–1900	--	--	--	--	0
Total	53	49	43	14	159

During 1949 and 1950, when the density of muskrats was relatively lower than in 1952, little movement away from the ditches is believed to have occurred. In the spring of 1952, however, there was a high residual population in the ditches and greater movement away from the ditches took place. During the April 1–15, 1952 trapping season, five muskrats ear-tagged in the ditches were recovered far away from the ditches. These returns suggest a rather heavy exodus of muskrats from the ditches. Two of the muskrats were known to have been trapped at least 1¼ miles to the southeast. The other three were taken at least ¼ mile from the ditches, but probably a mile in an easterly direction. Adequate trapping is the best insurance to keep muskrats from moving during the breeding season and being lost to some other trapper or perhaps to natural enemies. Since winter survival of the ditch muskrats apparently has been satisfactory, the movement noted in spring was due to the muskrats' intolerance to crowding during the early part of the breeding season.

Other authors have also found that muskrats normally cover a relatively small area in their wanderings. Aldous (1947) reported that 171 recaptures of tagged animals showed that 54.4 per cent did not move from the place where they were last released, and that only 15.2 per cent moved more than 31 rods. In an Idaho study, 75 per cent of 84 tagged muskrats were recovered within 50 yards of where they were first tagged (Williams 1950).

As has been shown in this study and by Errington (1943) and other investigators, drouth or freeze-up conditions or intraspecific strife resulting from overpopulation may cause rather extensive movement. This often subjects muskrats to the hazards of weather and predation.

Muskrats in favorable habitat, such as that created by level ditches, then, will not suffer large losses from movement, since these animals tend to live in a relatively small home range. But overcrowding, caused for example by undertrapping, will force muskrats to move out.

OTHER WILDLIFE VALUES

Waterfowl

Several duck nests were found on the spoilbanks the first spring after dredging. The only cover on the banks at that time consisted of clumps of sedge or bluejoint which had landed rightside up and were not covered with peat and muck. A thorough search for nests was made only in 1952 in order to protect the spoilbanks as much as possible. Arlyn Linde made a periodic search for new duck nests and rechecked previously located nests. He used snowshoes when walking the banks to prevent the caving in of muskrat dens. Nests of two species of ducks were found as shown in Table 6.

Table 6

Waterfowl Nesting Along the Experimental Ditches, 1952

	Mallard		*Blue-winged Teal*	
Ditch	*Number Nests Found*	*Number Hatched*	*Number Nests Found*	*Number Hatched*
D_5	6	2	2	0
D_1	4	1	2	2
D_2	4	2	4	3
D_4	2	1	0	0
Total	16	6	8	5

Twenty-four nests were found, 11 of which were successful. Of the 13 unsuccessful nests, nine apparently were destroyed by raccoon, one by mink, and three were deserted or destroyed by undetermined means.

Mallard nest on a ditch spoilbank, located next to a muskrat live trap.

The causes of nest destruction were determined by methods recommended by Rearden (1951). One-half of the nests found occurred on the small islands along the ditches which were opposite the gaps at 100-foot intervals in the main spoilbanks. The other nests were all located at the ends of the main spoilbanks, each of which is approximately 100 feet long. Definite selection of nesting sites was obvious. All of the nests were near the top of the bank. The ends of the main spoilbanks are essentially the same as the small islands. For future ditching operations, it would seem safe to recommend the staggering of spoilbanks with 50-foot sections of bank being placed on alternating sides of the ditch. Where it is necessary to have all the bank on one side of the ditch, numerous gaps could still be created in the bank by making the spoilbank higher and wider in places.

The Horicon experimental ditches are of chief importance to ducks during the nesting season. In late summer and fall, only small numbers of ducks are found in the ditches, even though the area is closed to waterfowl hunting. The ditching will prove valuable for waterfowl long after the banks are too low and the water too shallow to be of material value to wintering muskrats.

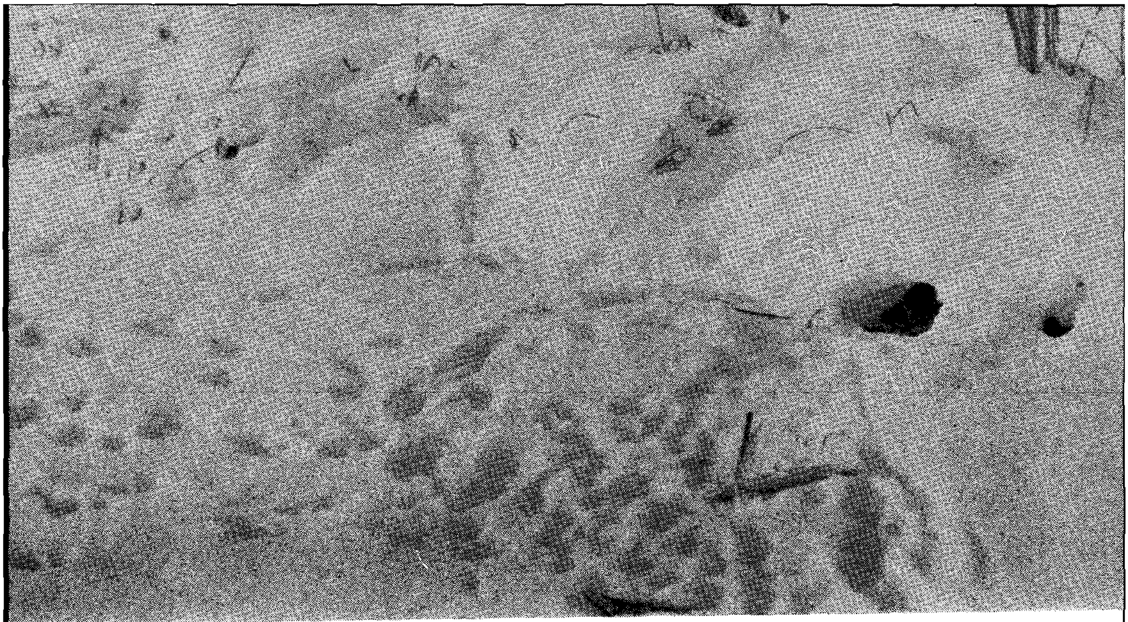
The 24 duck nests found in the 35 acres of ditched plots is necessarily a minimum figure. Undoubtedly some nests escaped detection as the vegetation became progressively denser. There is no other comparable concentration of duck nests known on Horicon Marsh. Approximately 3,000 acres of dry marsh on state lands at Horicon could be made more productive of wildlife by level ditching. To ditch all of this semi-dry marsh at 200-foot intervals, almost 150 miles of additional ditches would be needed. The additional production of muskrats would pay for this dredging, but if it is assumed that the spoilbanks will provide excellent nesting opportunities for 25 years, much of the original dredging costs could be justified on the basis of waterfowl production alone. Ditching to produce islands for nesting waterfowl is likely to cost much less per duck nest than the sometimes-advocated policy of clearing woody growth from existing islands or mainland adjacent to water areas where high initial clearing costs and a rapid woody regrowth can be expected.

Fish

Annual flooding of the bog in spring, and sometimes at other times of the year, prohibits the study of fish production in the ditches. Free movement of fish from one ditch to another or to other portions of the marsh is possible during the high water period. Northern pike frequently spawn in shallow water areas of the marsh that become dry during the summer. Undoubtedly many pike find their way into the ditches where they are secure until flood waters again cover the bog next spring. Fingerling pike have been observed in the ditches, and have been found on the ice in the winters, killed by mink. Large numbers of mud minnows have also been seen in the ditches. Ditches not subject to annual flooding might well be used for the commercial production of minnows or other fish under license in Wisconsin. Initial improvement costs can be justified more easily when multiple commercial uses are involved, especially in the case of private lands.

Furbearers

Due to the short period of trapping in the ditches very few mink and raccoon have been taken and they cannot be considered in the economic evaluation of the ditches. Mink and raccoon were commonly found in the area before the construction of the ditches. The cruising ranges of these animals are so great that 10-acre plots are inadequate for productivity studies. Nevertheless ditching undoubtedly makes the area more suitable for other furbearers by increasing their food supply and providing denning opportunities. More mink and raccoon activity

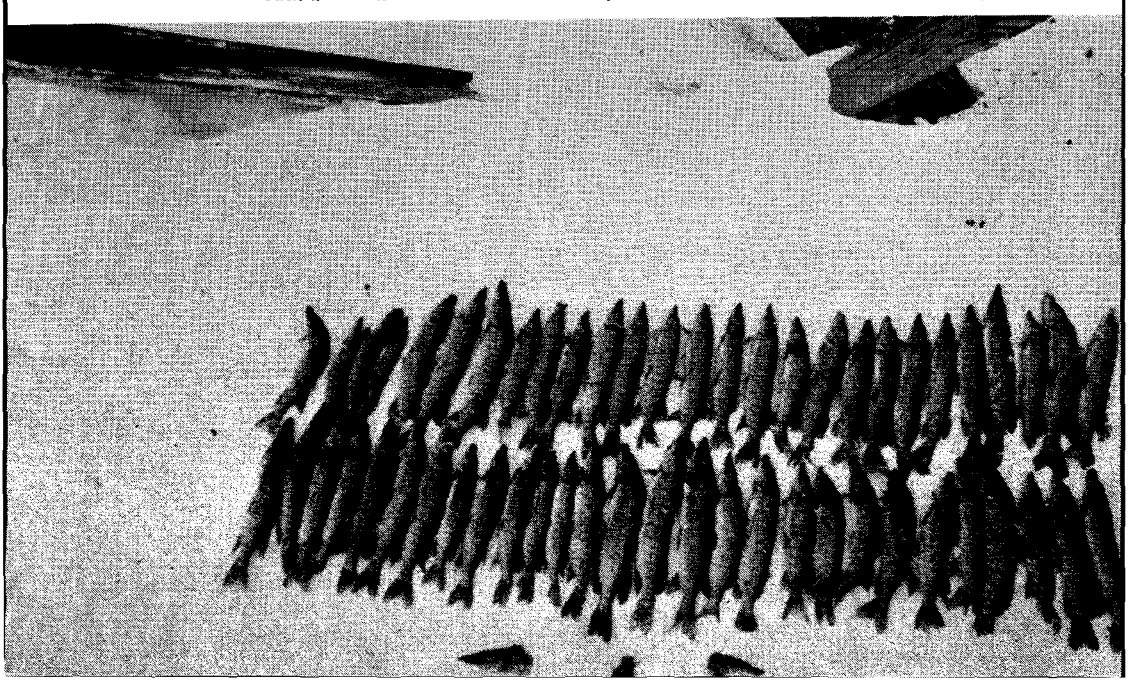


There was a heavy concentration of mink sign near the ditches as long as a few holes remained unfrozen . . .

was found near the ditches than in the adjacent marsh. Skunk have been observed denning in the spoilbanks on several occasions.

In December of 1949, mink were feeding extensively on northern pike fingerlings. Fifty-eight young pike were found dead on the ice, each bitten in back of the head by mink. There was a heavy concentration of mink sign near the ditches as long as a few holes remained unfrozen and the mink could get at the fish.

. . . and the mink could get at fish. Here are young pike found dead on the ice, *each bitten in the back of the head by mink* (December 1949).



Upland Game

Since the ditches are located over one-half mile from the nearest occupied upland game habitat, upland game species have not utilized the food and cover resources of the spoilbanks. Extensive use of the banks could be expected if the ditches were adjacent to good pheasant or rabbit cover.

SUGGESTED MODIFICATIONS OF THE DITCHING DESIGN

Experience gained so far from the experimental ditching project has pointed to several modifications of the design used in this study which will further increase the value of the ditches for muskrats and other wildlife. A new design, with ditches spaced at 200-foot intervals, is shown in Figure 2. Some of the modifications are:

1. There should be not more than 300 feet of ditch in a straight line in order to make boat travel safer and easier during high winds.

2. Place extra spoilbanks at the ends of each straight section of ditch to provide a windbreak, as shown in Figure 2.

3. Where a broken spoilbank is possible, cut a short channel into the bog at the breaks in the spoilbanks. This will encourage muskrat utilization of the bog on the side away from the banks, and discourage humans from walking on the banks.

4. Place spoilbanks 50 feet long on alternate sides of the ditch (Figure 2, right-hand ditch). This method would be more favorable to ducks and muskrats and would tend to eliminate the danger of the whole spoilbank burning. The need to have spoilbanks on the north and west sides of the ditch to create snowdrifts in winter is not considered too important.

5. When ditching in semi-dry marsh where the vegetation consists largely of sedges and grasses, it would be wise to excavate a strip six feet wide and one foot deep adjacent to the ditch to encourage the growth of muskrat food plants such as cattail, bulrushes, and burreed.

6. In peat marshes, place spoilbanks so that alternate areas can be control-burned without endangering the banks or having peat fires get out of control (Figure 2). Repeated burning of dry marsh may lower the marsh level enough to permit the growth of cattails, burreed, and other aquatics desired for muskrat production.

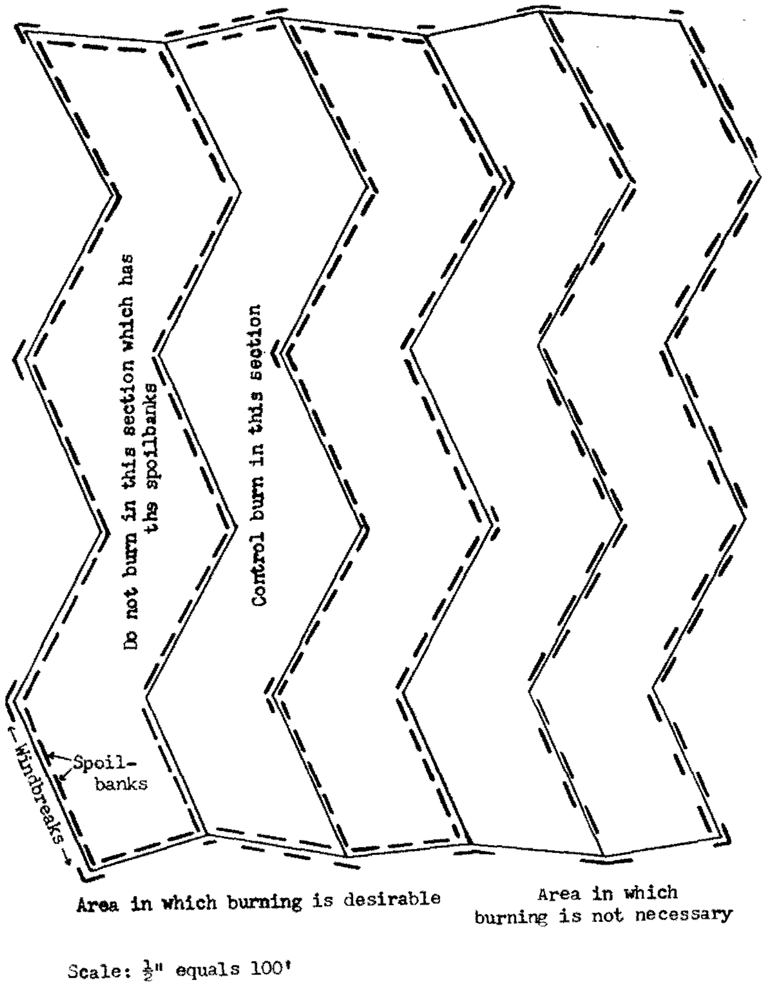


Figure 2. Proposed ditching lay-outs and spoilbank placement.

7. Water control structures, such as drop inlet culverts, can often be utilized to regulate the flow of water into or out of a ditching system.

8. Where a small amount of ditching is planned for a large marsh, it is advisable to ditch one section with a 200-foot spacing rather than put the same amount of ditch on this entire area and have a distance of 500 feet or more between ditches. Concentration of the muskrat population in one section of the marsh will tend to stabilize production from year to year and permit orderly development of the remainder of the marsh in future years.

MANAGEMENT PRINCIPLES

Numerous questions will arise in the minds of fur farmers, game managers and other individuals who are interested in using the ditching technique. The findings of the experimental ditching study will therefore be summarized in the form of questions and answers, with the hope that these will point up some of the more important aspects of level ditching as a management tool.

When is level ditching useful in the management of a marsh for fur production?

Level ditches provide deep water areas in a "dry marsh" when flooding by means of dikes or dams is not possible or practical. Ditching provides insurance against a "bad year." The deep water and high spoilbanks are a protection against freeze-outs, make food available during the winter period, and may hold muskrats during a dry period.

Level ditching is most practical where the water table is near the surface of the marsh.

What are some of the main advantages of level ditches?

Ditches increase the production of not only muskrats, but also of waterfowl, fish, and other furbearers.

The concentration of muskrats in the ditched area and the relative ease of boat travel make trapping conditions less difficult. The trapper can also get into the ditches sooner to trap. In an unditched marsh, for example, walking may be too difficult until the marsh freezes; by that time, however, the trapper runs the risk of too much snow.

What creates the better type of ditch, dredging or blasting?

The dredging cost was much less than dynamiting, hence it was a much more practical method of ditch construction. Even if the costs of the two methods were comparable, it would be better to dredge from the muskrat's point of view. The high spoilbanks and the less rapid filling in observed in the dredged ditch in the Horicon experiment made dredging far superior to blasting as a means of creating furbearer habitat.

What are some of the more important considerations in dredging a ditch?

Ditches should not be dredged in a straight line. Boat travel will be safer and easier during high winds if not more than 300 feet of ditch are dredged in a straight line.

Spoilbanks should be about 50 feet long and staggered on alternating sides of the ditch. This will reduce the chances of a fire sweeping down the length of the spoilbank, discourage walking on the banks, and create better conditions for duck nesting.

Optimum dimensions seem to be five feet in depth and 13 to 15 feet in width.

How long do level ditches last?

The rate of filling in is slow and the ditches can be expected to remain adequate for muskrats for at least ten years. The erosion of the spoilbanks is the main threat to the life of a ditch. The best prevention against erosion is the maintenance of good vegetative cover on the spoilbanks, and the protection of the banks against human disturbance.

When can controlled burning be used in the ditched area?

Strips of vegetation between ditches may be burned as long as the plant cover on the spoilbanks is not endangered. Repeated burning of "dry marsh" vegetation may lower the marsh floor enough to permit the growth of aquatic plants desired for muskrat food.

What are the pros and cons of close ditch spacings?

More muskrats were harvested per acre in the plots with ditches more closely spaced (50 and 100 feet) than in those with wider-spaced ditches (200 and 400 feet). However, the closer the ditches, the greater the cost of construction per acre and the lower the fur return per $100 invested.

What are the pros and cons of wide ditch spacings?

Fewer muskrats were produced per acre in the ditches with wide spacing (200 and 400 feet). However, since the cost per acre of these ditches was much less, the harvest of muskrats per $100 invested was greater than in the more closely-spaced ditches. This is an important consideration particularly during a period of low fur prices.

Which ditch spacing provides the greatest return for the money invested?

In the Horicon experiment a 200-foot spacing produced the most muskrats per unit area for the money invested.

How soon can the capital which has been invested in ditching be recovered?

In the Horicon Marsh experiment, production in the ditch with the 200-foot spacing was so high that even with the current low fur prices, the capital invested should be recovered in the fourth year if the next crop of muskrats is fully harvested. If the ditch muskrat crop had been fully harvested in 1951, the ditches would have returned the original investment in three years.

The value of ditches to waterfowl, fish, and other furbearers further tips the scales in favor of the initial investment.

How does the muskrat population in ditched marsh compare with that in unditched marsh?

About 18 muskrats per acre inhabited the ditched area. This is almost as many as are produced in the best deep water areas of Horicon Marsh, and many more than were found in the adjacent unditched marsh.

How far do muskrats move from the ditches?

Muskrats in favorable habitat, such as that created by level ditches, generally will not move far, since these animals tend to live in a relatively small home range. Most of the muskrats moved about 400 feet or less.

What are some of the conditions causing muskrats to move?

Unusual drouth or freeze-up conditions or overcrowding may force muskrats out of their home territory, even in good habitat, and subject them to the hazards of weather and predation.

Overcrowding may result from undertrapping a high population.

How can a large marsh be best developed for muskrats and other wildlife?

It is better to develop one end of a large marsh with ditches spaced at 200-foot intervals, rather than to spread a few ditches throughout the entire area. In this way the muskrat population will be concentrated as a unit in one part of the marsh. It will be easier to trap, and if overtrapped, the blank will be quickly filled in. The remainder of the marsh then may be ditched in an orderly fashion in future years.

A ditch around the outer edge of the marsh may provide both fire and trespass control.

What other species of wildlife are benefited by ditches?

The spoilbanks provide excellent nesting sites for waterfowl. Twenty-four mallard and blue-winged teal nests were found at Horicon in 1952, mostly near the ends of the ditch spoilbanks. There is no other comparable concentration of duck nests on Horicon Marsh.

Ditches not subject to annual flooding might well be used for the commercial production of minnows or other fish under license in Wisconsin.

The ditches and spoilbanks also improve habitat for mink, raccoon, and skunks.

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APPENDIX I

PROGRESS OF THE 1952 TRAPPING SEASON

Harvest figures for the uncompleted 1952 trapping season indicate that the total harvest will be very large by the time the freeze-up terminates trapping on the experimental ditches. Muskrats trapped in the dredged ditches from October 29 to November 10, 1952 are shown in Table i.

Table i

1952 Muskrat Harvest from Experimental Ditches, October 29 to November 10, 1952

Ditch	*No. Muskrats Taken*
D_5	177
D_1	172
D_2	200
D_4	111
Total	660

Analysis of the data for the entire 1952 trapping season cannot be completed in time to be included in this report. Efficiency of trapping in open water is indicated by the fact that over 80 per cent returns have been made of the muskrats ear-tagged in the experimental ditches in the fall of 1952. A provisional four–year evaluation of the ditches is given in Table ii which can be compared with the three-year summary in Table 4 of the text. A complete analysis of the 1952 trapping data will be published later as a supplement to the present report.

Table ii

Four-year Summary of Muskrat Harvest

(1952 figures not complete)

Ditch	*Total Harvest*	*Average Yearly Harvest per Acre*	*Yearly Muskrat Harvest per $100 Invested in Ditching*
D_5	297	14.8	9.5
D_1	376	9.4	11.1
D_2	363	9.1	19.5
D_4	188	4.7	18.6

The successful 1952 harvest greatly brightens the economic picture of the ditches; the values would appear still higher if an adequate harvest had been obtained in 1951. The relatively poor harvest in 1951 due to unfavorable trapping conditions and the apparently excellent take in 1952 clearly show that fluctuations in the harvest from the ditches will occur over a period of years. These fluctuations may be caused by variations in weather conditions and water levels, and may not be directly proportional to changes in the actual productivity of the ditches.

RES Wis Doc Nat.3: T4/5

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EXI ERIMENTAL LEVEL DITCHING FOR MUSKRAT MANAGEMENT.

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RES Wis Doc Nat.3: