Rehabilitation of Pits and Quarries for Fish and Wildlife

Ontario

Ministry of Natural Resources

Hon. Vincent G. Kerrio
Minister

Mary Mogford
Deputy Minister

Rehabilitation of Pits and Quarries for Fish and Wildlife

Prepared for the Aggregate Resources Section, Land Management Branch, Ontario Ministry of Natural Resources

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Part 1
Background

Introduction

The Pits and Quarries Control Act of 1971 first legislated the concept of pit and quarry rehabilitation in Ontario. The Act has since been gradually applied to most of the principal aggregate producing areas of the province. There has also been a gradual evolution from rehabilitation of pits and quarries for the sake of rehabilitation, to rehabilitation of each pit and quarry to useful and beneficial after uses most appropriate in each case. As part of this process, the Ministry of Natural Resources commissioned *A Study of Pit and Quarry Rehabilitation in Southern Ontario* (Coates and Scott 1979). Among the recommendations of this study were that the Ministry initiate research into rehabilitation of pits and quarries for agricultural and fish and wildlife purposes, leading to the development of practical rehabilitation guidelines. Two recent Ministry publications, *Agriculture and the Aggregate Industry* (Mackintosh and Mozuraitus 1982) and *Rehabilitation of Sand and Gravel Pits for Fruit Production in Ontario* (Mackintosh and Hoffman 1985), evaluate past agricultural rehabilitation efforts and outline procedures and techniques for rehabilitating extracted sites to viable farm lands.

In 1984, the Ministry commissioned the second research priority identified by Coates and Scott (1979), namely an assessment of fish and wildlife rehabilitation practices and potentials applicable to Ontario. This publication presents findings of that assessment useful to landowners and operators. It is designed to serve as a practical guidebook to selecting preferred fish and wildlife after uses and to implementing them successfully.

This publication is not intended to be a comprehensive guide to rehabilitation requirements or practices in Ontario. Persons interested in specific information on pit and quarry rehabilitation should contact their local Ministry of Natural Resources district office (see Appendix 1 for locations).

Part 1, Background, includes this introduction, plus a discussion of lessons learned from past rehabilitation efforts. The authors undertook an extensive review of North American and British literature on rehabilitation for fish and wildlife, and also contacted many rehabilitation workers and researchers in Canada, the United States, the United Kingdom, and West Germany. As well, 14 Ontario pits and quarries which have been, are being, or could be rehabilitated for fish and wildlife were selected for detailed investigation, designed to assess the strengths and shortcomings of rehabilitation efforts. These sites included various types and stages of operation and rehabilitation, types of fish and wildlife after uses, and types of ownership and management. Thirteen of the sites are in south central and southwestern Ontario south of the Canadian Shield, while one is on the Shield in eastern Ontario.

Part 2, Six Steps to Successful Rehabilitation, begins with a checklist of physical, operational, and economic factors which landowners and operators can use to help them identify which fish and wildlife uses or combinations of uses are appropriate to their specific site conditions and local circumstances. Guidelines are then provided to take owners/operators from after use identification, through resource analysis and site planning, to progressive and final rehabilitation and long term management. The guidelines are backed up by more detailed information in the appendices.

Seven major fish and wildlife after uses of rehabilitated pits and quarries are dealt with in this publication. These are:

- Waterfowl hunting area: a wetland producing or supporting waterfowl for hunting on site.
- Waterfowl protection area: a wetland area producing or supporting waterfowl for nonconsumptive uses on site. These uses can include

species protection (including for hunting elsewhere in the case of migratory waterfowl), viewing, interpretation, education, research, etc.

- Commercial game farm: a confined land area producing game harvested by the operator and for sale as food or stock. The sale may be to the general public or commercial end users in the case of food, or government agencies or other operators in the case of stock, and may occur on or off the site.
- Wildlife hunting area: a land area producing or supporting wildlife (waterfowl excepted) for hunting on site.
- Wildlife protection area: a land area producing or supporting wildlife (waterfowl excepted) for nonconsumptive uses on site. These uses can include species protection, viewing, interpretation, education, research, etc.
- Recreational fish pond: waters producing or supporting fish for sport fishing on site. Sport fishing includes all harvesting by the general public, including operations where harvested fish are paid for on a per fish or per unit of weight basis.
- Commercial fish farm: waters producing fish harvested by the operator and for sale as food or stock. The sale may be to the general public or commercial end users in the case of food, or government agencies, other operators, or the general public in the case of stock, and may occur on or off the site.

These descriptions of end uses are not meant to suggest that providing public use or deriving revenue are the only reasons for rehabilitating to fish and wildlife. Owners/operators will often rehabilitate to one or more of these uses for intangible reasons, such as public relations, private recreation, resource conservation, species protection, aesthetic satisfaction, or landscape creativity.

There are other potential fish and wildlife after uses of pits and quarries, including trapping of furbearers, fur farming, commercial fish farming using land-based systems, and commercial raising of fish for bait. This publication does not provide any detail on these uses, but this does not mean that they are being discouraged. Management for wildlife or waterfowl hunting or protection is in general consistent with management for furbearers. Fur farming and land-based aquaculture are highly specialized activities with their own requirements, but unlike the seven after uses dealt with here, are not significantly limited by natural habitat conditions.

It is possible for one site to support more than one fish and wildlife use, or to support fish and wildlife uses along with other after uses. Multiple use of sites is discussed in Part 2.

Lessons From Past Rehabilitation

Lessons learned from past efforts to rehabilitate pits and quarries for fish and wildlife after uses come from two sources: scientific literature, and field investigations of 14 southern Ontario sites.

Careful, Thorough Planning Essential

Writers on rehabilitation constantly stress that careful and thorough site assessment and planning before extraction are critical to successful rehabilitation. To realistically assess whether a site can support fish and wildlife populations, several key factors must be assessed in advance. These include deposit and overburden characteristics, water availability, adjacent land uses, and local planning policies.

Progressive Rehabilitation Benefits Wildlife

Progressive rehabilitation involves mining and rehabilitating a licensed area section by section (see Figure 1), rather than all at once at the end of the extraction process. While Ontario legislation and regulations encourage progressive rehabilitation of pits and quarries in general, this approach has particular benefits for wildlife, because it can produce a vegetation cover in varied stages of successional development. Birds in particular benefit from

Figure 1. *Example of progressive rehabilitation. The bank in the foreground has been regraded and seeded with knapweed; active extraction is continuing in the background.*

Figure 2. *Rehabilitated bass pond. Banks have been regraded and seeded. The stump offshore enhances fish habitat.*

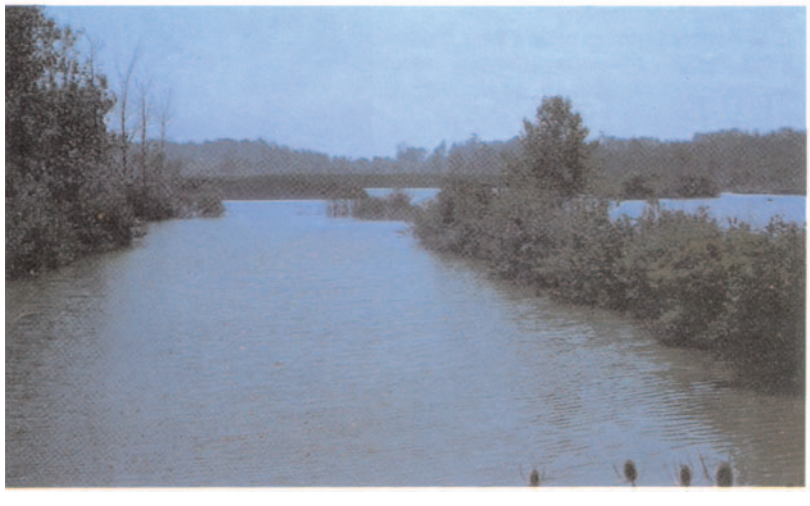
Figure 3. *Clay pit pond well suited for waterfowl. Shoreline is irregular, and plant cover dense and naturally regenerated. Willow and cat-tail are dominant.*

the vegetational diversity characteristic of complex successional patterns. Progressive rehabilitation also reduces the time and costs needed for desired wildlife populations to become established.

Pond Designs More Suitable for Fish than Waterfowl

Seven of the Ontario sites reviewed have at least one pond intended for fish and/or waterfowl production. Most are quite suitable for either self-sustaining or put and take fisheries. The pond in Figure 2 is well designed for the resident largemouth bass populations it sustains. Even with minimal management, this pond provides the owner with excellent angling as well as some revenue from the commercial sale of fingerlings.

However, most of the ponds are not as well suited for waterfowl. Average



depths are too great. Shorelines are very regular, with steep banks, narrow onshore zones, and minimal offshore shallows. Islands and peninsulas are rare or absent. As a result, the emergent aquatic plant communities needed for cover and nesting are very poorly developed. The clay pit ponds shown in Figure 3 are exceptions. These ponds are shallow and highly dissected, with abundant emergent plant growth. The waterfowl populations using this site provide significant hunting opportunities.

Artificial Structures Merit More Use

Writers on rehabilitation stress the value of reefs, shoals, logs, boulders, etc. to improve fish protection and nursery areas and overall aquatic habitat, and of nesting boxes, snags, brush piles, mounds, boulders, etc. to enhance wildlife habitat. However, these have been little used at the Ontario sites. Figure 2 shows one example of the use of a stump to improve fish habitat. For wildlife, nesting boxes have been put up at two sites only. As well, while there are scattered large boulders at some sites (see Figure 4), these have been deposited incidentally rather than out of any intention to develop wildlife habitat.

Pond Productivity for Fish Needs Improving

Most of the Ontario ponds depend on substantial groundwater inputs. The high pH typical of groundwater results in low levels of usable phosphorus and low fisheries productivity. High fish production in groundwater dependent ponds can only be maintained through various artificial enhancement techniques, none of which are currently practised in Ontario. In contrast, techniques to enhance pond productivity for waterfowl are commonly practised.

Varied Topography Important for Upland Wildlife

Upland wildlife hunting and/or protection were intended uses at several of the Ontario sites. In general, the sites which have been left alone appear to have at least as much value for upland wildlife as those which have been actively rehabilitated. For example at the abandoned site shown in Figure 5, small earth mounds dot the pit floor, providing modest cover for colonizing species. The varied vegetation now regenerating there reflects this microtopographic diversity. On the other hand, the pit floor in Figure 6 was totally regraded, eliminating microtopographic diversity and limiting its potential for upland wildlife.

Natural Regeneration versus Active Rehabilitation: Both Help Wildlife

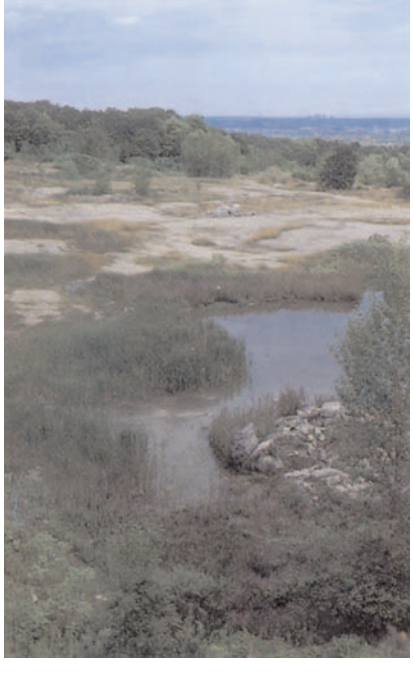
Some researchers feel that if wildlife habitat is desired, it is best to abandon a site following extraction, letting natural regeneration take its course. This approach not only provides good diversity, but is also inexpensive (see Figure 7).

Figure 4. *Abandoned pit. Large boulders and other materials scattered over the floor provide cover and perching sites for a wide variety of small mammals and birds.*

Figure 5. *Abandoned pit. Irregular, mounded topography results in greater diversity of plant cover. The small mounds in the right foreground are vegetationally as well as topographically distinct. Small depressions between the mounds collect water, allowing more luxuriant plant growth which provides denser cover for wildlife.*

Figure 6. *Totally regraded site. This is one of a series of pit openings in a forested area which have been graded and then seeded with clover and grasses for deer habitat enhancement. The site's topographical uniformity limits its wildlife value; as well, the seed mixtures failed.*

Figure 7. *Floor of abandoned quarry. Small wetland area in foreground, with bare limestone pavement behind. All vegetation has developed naturally.*



Others believe that a wildlife area cannot be made without spending money. The compacted pit floors and steep eroding banks at the abandoned site shown in Figure 8 have remained bare due to continued erosion. The poor habitat at this site calls for some active rehabilitation to produce good cover and food and water supplies. On the other hand, the regrading and seeding undertaken at the site shown in Figure 6 have reduced habitat diversity.

Often, the best habitat has been created when natural succession has been incorporated with deliberate plantings, as shown in Figure 9. At this site, plantings have significantly enhanced habitat diversity to provide excellent cover for upland wildlife.

On balance, whether to rely on natural regeneration or active rehabilitation to develop good wildlife habitat depends on the state of the site following extraction, and the character of the surrounding environment. However, there are other considerations involved. The Pits and Quarries Control Act and regulations set minimum standards of rehabilitation that must be complied with, either progressively or at the end of operations. In many cases, natural regeneration is not appropriate, because the length of time needed for successful rehabilitation will be environmentally and socially unacceptable.

Mixed Results from Wildlife Habitat Seeding

Plant seeding at the Ontario sites has had poor to moderate success. Seeded species are usually succeeded by invading plants. For example,

Figure 8. *Abandoned pit. Severe erosion problems could have been controlled by regrading, soil amendments, and plantings.*

Figure 9. *Example of integration of natural succession with deliberate plantings. Regraded banks have been seeded with grass and legume mixtures. Red pine in the foreground has also been planted. Shoreline is revegetating naturally with willow, bulrush, and cat-tail.*

Figure 10. *Example of natural revegetation of pit pond shorelines by old field species. Purple loosestrife is dominant here.*

the pond banks in Figure 10 have become densely vegetated with invading old field species. At the site shown in Figure 6, clover seed mixtures failed almost completely, and these are being slowly replaced by a wide variety of dry species typical of the area.

Ecological Relationships: A Concept to be Realized

Owner/operator consideration of fish and wildlife uses at the study sites has focused on individual species (such as rainbow trout), or on a group of similar species (such as waterfowl). Most owners/operators do not fully appreciate the ecological principles which underlie habitat development, especially the close relationships among the communities and organisms that compose the overall environment within which individual species exist. There are several reasons for this. Very few owners/operators are trained as biologists, and few employ any. Most operators interested in specific fish and wildlife after uses therefore think about management only in terms of the minimal requirements for the species most commonly associated with those uses.

More Site Use and Management Information Essential

Owners/operators of the Ontario sites have very little good information on site use and management relative to the after use objectives originally identified. Except for one site, there is almost no information on fish and wildlife populations (composition, numbers, nesting pairs, etc.), or on human use (harvest volumes, hunting occasions, success rates, etc.) This shortcoming may be due to lack of biological expertise, lack of perceived need for biological and use data, insufficient funds to conduct appropriate surveys, or too short a time period since implementation. The full potentials of most sites as fish and wildlife habitats have not been reached because most owners/operators have not tried to assess whether their sites are deficient in some respects. In a few cases, the owners plan to put in new facilities or plantings to enhance overall habitat potential. However, these decisions have been reached on the basis of general perceptions of need, rather than hard data.

Many Reasons for Fish and Wildlife Rehabilitation

At the Ontario sites, the intended fish and wildlife after uses, and the reasons for them, are varied.

- Recreational fish ponds are the most popular after use.
- Uses at public sector sites, all targeted to the general public, are dominated by waterfowl and wildlife hunting and recreational fishing.
- Uses at most privately owned sites are for the enjoyment of the operator and his/her/its family, friends, and employees. Recreational fishing is the dominant use, with waterfowl and wildlife hunting and protection accounting for the remainder.
- There are few examples of private site after uses targeted at public relations or expectations of revenue. The only revenue example is a commercial fish farm.
- Half of the after uses on private sites are associated with owner expectations of residential development in the long term, with fish and wildlife seen as providing amenities which will enhance property values. When these uses are deducted, the remaining long term fish and wildlife uses on private sites are a scattered mixture of hunting, angling, and protection for private enjoyment, and commercial fish farming for private enjoyment and nominal revenue.
- Government incentives to rehabilitate to fish and wildlife after uses are only one factor in what private landowners decide to rehabilitate their sites to. Economic considerations are only one other factor. If a landowner or operator likes fishing or hunting, or likes to protect animals, or likes to recreate natural habitat, or likes the creative aspect of trying to raise fish or game birds, then one or more of these intangible incentives may be the most important factor in deciding what to do after extraction. However, private enjoyment is usually significant only for smaller, individual operators; economics and public relations are the dominant factors for most larger corporate operators.

Part 2
Six Steps to Successful Rehabilitation

Introduction

Part 2 presents a series of practical guidelines for rehabilitating pits and quarries for fish and wildlife after uses. The guidelines are intended to lead the owner or operator through the steps he or she will have to take, from after use identification through site concept and plan development, extraction, rehabilitation, and finally long term management. We have identified six basic steps, and these are shown in Figure 11. The following sections describe these steps in detail, one section per step.

STEP 1: IDENTIFICATION OF PREFERRED AFTER USES

Choosing Uses: A Checklist

Table 1 provides a summary checklist of the key physical, operational, and economic factors involved in the seven fish and wildlife after uses identified for pits and quarries. The checklist is designed to help landowners and operators identify the fish and wildlife use or uses they wish to pursue, taking into account site conditions, local circumstances, and personal interests and desires. This is of course only a first step.

The information in Table 1 consists of highlights. For further information and explanation, the following sections of this publication should be consulted:

Checklist item in Table 1	See section
Physical:	
– key habitat requirements	Step 2
– extraction type	Step 2
– special rehabilitation	Steps 4, 5
– typical species	Step 2
– species propagation	Step 6
Operational:	
– user groups/markets	self explanatory
– resource management requirements	Step 6
– special regulations	Appendix 2
Economic:	
– revenue potential	Step 6
– special capital costs	Step 6
– operating costs	Step 6
– potential assistance programs	Appendix 3

As noted in Table 1, raising fish or game for food or stock is a form of animal husbandry, with highly specialized technical requirements. This report is not intended to serve as a handbook for successful commercial fish and game farming, and does not go into detail on the physical and operational requirements for these activities. Persons interested in commercial fish farming should consult *Aquaculture in Ontario* (Ontario Ministries of Natural Resources, Agriculture and Food, and the Environment 1986), and should contact the Ontario Trout Farmers Association, Box 1633, Guelph, Ontario, N1H 6R7. Persons interested in commercial game farming should contact the Ontario Game Bird Breeders and Hunting Preserve Association, through Mr. Fred Corbett, R.R. 1, Belwood, Ontario, N0B 1J0. This Association is a chapter of the North American Gamebird Association.

Figure 11. *Rehabilitation for fish and wildlife: six basic steps.*

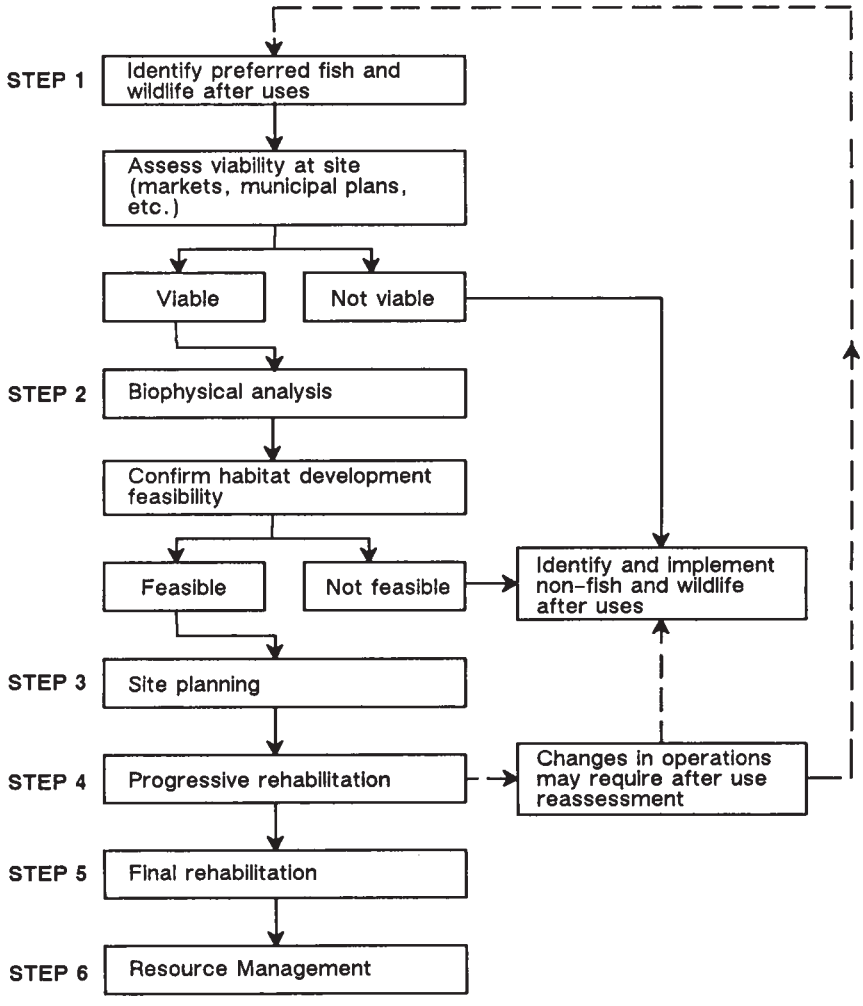


TABLE 1. REHABILITATION ALTERNATIVES CHECKLIST.

checklist item	AFTERUSE						
	waterfowl hunting area	**waterfowl protection area**	**commercial game farm**	**wildlife hunting area**	**wildlife protection area**	**recreational fish pond**	**commercial fish farm**
PHYSICAL:							
key habitat requirements	• shallow ponds with low banks and wide shorelines • stable water levels during breeding season • diverse habitat combining tall wetland and terrain vegetation, open water, bare shores, small islands, and irregular shorelines • rich feeding areas		• cultivated fields, pastures, old fields, and hedgerows, with scattered woodlots and moist to wet depressions • level to irregular topography • woodlot corridor links to off site and availability of habitat nearby			• cold water species require deep ponds, while warm water species can tolerate shallower ponds • ponds at least 0.1 ha for recreational fishing, and larger for commercial fish farming • good water quality • stable water levels	
extraction type	• limited extraction below water table • extraction area can be large • all overland drainage can be directed into pits • waste materials used for landform construction • topsoil and subsoil used for landforms and pond enrichment		• extraction mainly above water table • overland drainage directed to small depressions for retention of small, shallow ponds • topsoil and subsoil can be used in rehabilitation, especially where lure crops are required			• extraction below water table • deep extraction for cold water species, shallow extraction for warm water species	
special rehabilitation which may be required	• water level control structures • islands, floating and fixed • appropriate bottom substrate importation • aquatic vegetation introduction • nesting boxes • recreational and access support facilities		• specialized husbandry facilities	• artificial cover structures including brush piles, boulders, snags, logs, fence row piles, nesting boxes, etc. • shrub and evergreen plantings for food and protection • recreational and access support facilities		• water level control structures • artificial reefs, shoals, and shelves • islands, floating and fixed • bank overhangs, cribs, and other attractors • aquatic vegetation introduction • recreational access and support facilities	• water level control structures • supplemental aeration • specialized husbandry facilities

typical species	• mallard • wood duck • Canada goose • blue-winged teal	• mallard • wood duck • Canada goose • blue-winged teal • marsh wren • great blue heron • red-winged blackbird	• ring-necked pheasant • bobwhite quail • wild turkey • chukar partridge (domesticated)	• ring-necked pheasant • Hungarian partridge • ruffed grouse • bobwhite quail • woodcock • deer • rabbits, hares	• ring-necked pheasant • Hungarian partridge • ruffed grouse • bobwhite quail • woodcock • field sparrow • red-tailed hawk • cardinal • white-throated sparrow • catbird • deer • rabbits, hares • coyote • raccoon • fox	• cold water species: brook trout, rainbow trout • warm water species: bass, catfish, carp, panfish including sunfish, perch, rock bass	
species propagation	• natural colonization once habitat is established		• husbandry	• natural colonization once habitat is established • purchase or husbandry of game birds for release	• natural colonization once habitat is established	• initial stocking to establish resident populations, and as required thereafter • continuous put and take required for intensive use	• husbandry
OPERATIONAL:							
user groups/ markets	• individual hunters • hunting clubs	• naturalists • school groups • school boards • general public	• food • stock	• individual hunters • hunting clubs	• naturalists • school groups • school boards • general public	• individual anglers • fishing clubs	• food • stock
resource management requirements	• seeding of lure crops • vegetation management (fertilizing, mulching, pruning, culling) • access and recreational use management		• husbandry	• vegetation management (fertilizing, mulching, pruning, culling) • access and recreational use management		• aquatic vegetation management (pollution, weed growth, undesirable fish, turbidity, water levels, seepage, etc.) • access and recreational use management	• husbandry

TABLE 1. CONTINUED.

checklist item	AFTERUSE: waterfowl hunting area	waterfowl protection area	commercial game farm	wildlife hunting area	wildlife protection area	recreational fish pond	commercial fish farm
special regulations	—	—	• game bird propagation and sale	• game bird propagation and sale • game bird hunting preserve	—	• fishing preserve • Lakes and Rivers Improvement Act • water withdrawal and wastewater discharge approvals • aquatic nuisance control approvals	• fish propagation and sale • Lakes and Rivers Improvement Act • water withdrawal and wastewater discharge approvals • Fish Health Protection Regulations • aquatic nuisance control approvals
ECONOMIC:							
revenue potential	• minimal	• minimal	• low to medium	• minimal	• minimal	• low to medium	• medium to high
special capital costs (not claimable against security)	• low to medium	• low to medium	• medium	• low	• low	• low to medium	• medium to high
operating costs	• low	• low	• medium	• low	• low	• medium	• medium to high
potential assistance programs	• Community Wildlife Involvement Program (MNR) • Ducks Unlimited	• Community Wildlife Involvement Program (MNR) • Ducks Unlimited	• Farm Tax Reduction Program (MMA) •MAF assistance programs	• Community Wildlife Involvement Program (MNR) • Woodlands Improvement Program (MNR) • Managed Forest Tax Reduction Program (MMA)	• Community Wildlife Involvement Program (MNR) • Woodlands Improvement Program (MNR) • Managed Forest Tax Reduction Program (MMA)	• Community Fisheries Involvement Program (MNR)	• Farm Tax Reduction Program (MMA) •MAF assistance programs

Multiple Use

Fish and wildlife rehabilitation will often be viable only if more than one fish and wildlife use is implemented on the same property, or if fish and wildlife uses are mixed with other after uses. In most cases, dedication of a rehabilitated pit or quarry to a single fish or wildlife after use will be economically unrealistic, wasteful of site potential, or not in keeping with owner or user interests and desires.

This publication does not try to tell owners and operators how to decide between fish and wildlife and other uses. The information in this and other publications should permit each operator to make that decision in light of his or her own unique interests and circumstances. The following discussion of multiple use is intended only to provide some guidance as to what uses can and cannot go together.

Compatibility Among Fish and Wildlife Uses

In theory, there is no reason why the seven fish and wildlife uses we have identified cannot coexist in any combination within the same property or on adjacent properties, provided that the appropriate physical conditions are present for each, and that there is enough space available for all. However, site size and diversity will limit the numbers of uses which can coexist on most sites. As a rule, the smaller the site, the fewer uses can be accommodated. While two uses may be able to function side by side on adjacent tracts of land or portions of a water body, more often than not, they cannot coexist simultaneously on the same tract of land or section of water. This may be not only for physical reasons (waterfowl need shallow waters, while cold water fish require deep waters), but also for operational reasons (wildlife hunting and wildlife protection may not be consistent on the same tract of land).

If properties are large and physically diverse enough to accommodate several uses, the operator's decision as to whether to pursue all of these uses will likely be based on economics, markets, regulatory aspects, and individual preferences. From an economic point of view, if the markets are there, the more uses which can make more effective use of the site, the better. There are two pairs of uses which are especially complementary economically. These are wildlife hunting and commercial game farming, and recreational fishing and commercial fish farming. In both cases, the husbandry activity can be used to provide stock for the recreational activity. Also, existing regulations are designed to accommodate both pairs of uses on one property. There are already many examples in Ontario of both pairings, although not necessarily on rehabilitated pit and quarry sites.

Compatibility of Fish and Wildlife Uses with Other Uses

Table 2 shows the degree of compatibility that each fish and wildlife use has with five other major after uses of pits and quarries: residential development, commercial and industrial development, agriculture, recreation, and forestry. As would be expected, fish and wildlife uses are most likely to be able to coexist on the same land and water units with other active and passive recreational uses. The seasonal nature of fish and wildlife recreation and other recreational activities can allow several uses to be accommodated within a property, or even within the same land or water unit on that property: for example, car camping and swimming in summer, hunting in fall, cross country skiing in winter, and birdwatching in spring. Agriculture and forestry can often coexist side by side with any of the fish and wildlife uses, and can also coexist simultaneously or seasonally on the same land unit with some wildlife uses.

Assessing Viability at Site

Having identified a potential after use or uses, the owner/operator should then assess whether they are viable at the particular site. In most cases, there are two key questions to be answered for each use: is there a market for it, and is it permitted by the municipality's official plan and zoning by-

TABLE 2. COMPATIBILITY OF FISH AND WILDLIFE END USES WITH OTHER AFTER USES OF PITS AND QUARRIES.

fish and wildlife after use	OTHER AFTER USE				
	residential development	commercial, industrial development	agriculture	recreation	forestry
waterfowl hunting area	I	I	A	C	A
waterfowl protection area	A	A	A	S	A
commercial game farm	I	I	A	A	A
wildlife hunting area	I	I	C	C	S
wildlife protection area	A	A	S	S	S
recreational fish pond	A	A	A	S	A
commercial fish farm	A	A	A	A	A

NOTES: The letter in each cell refers to the maximum degree of compatibility of the fish and wildlife use at the left with the other use at the top. The explanation of the letters is:

S – the two uses can occur simultaneously on the same land or water unit.

C – the two uses can seasonally alternate on the same land or water unit (e.g., recreation in the summer, hunting in the fall).

A – the two uses can be complementary or compatible next to each within the same property if site size and conditions permit, or on adjacent properties.

I – the fish/wildlife use can operate on an interim basis until the other use is developed as the final use.

law? The question of markets will not be relevant to owners who have already decided that they want to pursue particular uses for their private enjoyment only.

A market evaluation at this stage does not require a detailed, sophisticated feasibility analysis. What is needed is a more general, common sense assessment of whether a specific concept has a reasonable chance of being a successful enterprise. For example, rehabilitation to put and take rainbow trout angling for the general public would likely be more successful close to major population centres than off the beaten track. This should be recognized early on, before proceeding into detailed site assessment and concept development. Also, this would be the time to consider the market aspects of situations where fish and wildlife may be appropriate as an interim use, to enhance a site's aesthetic and amenity value for final uses such as residential development. When might the final use come on stream? Would the interim use add to the value of the final use? Is the interim use therefore worthwhile in terms of the ultimate market objectives for the site?

The owner/operator should also at this stage check with the offices of his or her local municipality to ensure whether the intended use is compatible with the municipality's official plan and zoning bylaw. If not, the owner/operator will want to consider whether an amendment or variance will be difficult to obtain. As well, the owner/operator should contact the local offices of the Ministries of Natural Resources and the Environment if the intended use will involve provincial licences or approvals (see Table 1).

STEP 2: BIOPHYSICAL ANALYSIS

Habitat Requirements

Before an appropriate site plan can be prepared for fish and wildlife after uses, the biophysical characteristics of the licensed area and nearby lands must be identified and evaluated against the habitat requirements of the species desired. Regardless of owner preferences or market potentials, fish and wildlife after uses will not be feasible if critical habitat factors are not present, or cannot be reproduced or compensated for by management of the site. For example, wildlife requiring secluded environments may not tolerate certain land uses on or near the site, particularly if the site is small. As well, biophysical analysis may provide some idea of how much effort will be needed to make a site suitable for the desired species.

What might appear to be a good choice originally could turn out to be totally inappropriate on the basis of the habitat development potential actually identified for the site, or to be completely unrealistic because of the costs involved in trying to duplicate the needed habitat. On the other hand, biophysical analysis can reveal realistic opportunities not at first apparent, or confirm that the originally desired after uses are feasible. The specific baseline information which needs to be collected for biophysical assessment, the reasons for obtaining it, and its relevance to basic habitat requirements are presented in Appendices 4 (wildlife) and 5 (fisheries). Detailed physical and water quality requirements for key fish species are presented in Appendices 6 and 7. Further information on biophysical information sources and requirements is provided below.

Species Groups

Wildlife

Discussion of wildlife in this publication focuses on three groups of typical southern Ontario species. Each group is named after the type of habitat which the species favour. There is a much broader range of habitat types in Ontario than the three used here. However, many of these, for example, open lake and mature forest habitats, are not realistic options in pit and quarry rehabilitation.

Each group includes a mix of game animals, furbearers, and other animals. Many landowners may be interested mainly in the economic returns from the game species, while others may prefer nonconsumptive uses. In any case, the prime game species tend to have more stringent habitat requirements than do many other species such as songbirds, so management for game will ensure the presence of many other species. Development or maintenance of whatever habitat type is most suitable to an individual site will leave the owner/operator some scope to select the uses of that habitat most consistent with his or her interests and objectives.

Aquatic/shoreline group. Aquatic/shoreline habitat includes wetlands, and can be one of the most productive habitat types in southern Ontario. The habitat consists of the shoreline zones of ponds, including both shorelands and nearshore waters. Typical game and furbearer species include mallard, wood duck, Canada goose, blue-winged teal, muskrat, mink, and raccoon. Examples of the nongame birds which can be expected are marsh wren, red-winged blackbird, and great blue heron.

Agricultural/old field group. Agricultural/old field habitat is a typical southern Ontario agricultural environment, consisting of cultivated fields, pasture, old fields, and fencerows. It does not include extensive woodland areas. Typical game and furbearer species are ring- necked pheasant,

Hungarian partridge, cottontail rabbit, fox, and raccoon. Examples of the nongame birds which can be expected are field sparrow and red-tailed hawk.

Immature forest group. Immature forest habitat includes patches of naturally reforesting old fields and immature tree stands. The productivity of this habitat depends to a large degree on the "patchiness" of the site. Some of the species found in the agricultural/old field habitat type are also found here. Typical game and furbearer species are deer, coyote, ruffed grouse, and woodcock. Nongame birds include a mix of woodland and edge species, such as cardinal, white- throated sparrow, and catbird.

Fisheries

Fishery habitats created in pits and quarries tend to be more artificial, and usually depend on introduction rather than natural colonization for species propagation. Also, nonconsumptive interest in fish is considerably less than for wildlife, especially in pit and quarry aquatic environments. Therefore, the conventional breakdown of key game, bait, and food fish species into cold and warm water groups is adhered to, and other aquatic organisms are not taken into account. The key cold water species are brook and rainbow trout, while the key warm water species are smallmouth and largemouth bass, catfish, carp, and typical Ontario panfish.

Information Sources and Requirements

Subsurface Conditions

Surficial geology and county soil survey maps provide fairly reliable information on general surface characteristics. As well, a reasonable idea of groundwater availability can be secured from Ministry of the Environment water well records. In some cases, these records have been integrated into maps which show approximately how much groundwater is available from different types of aquifers. However, subsurface features are often complex, and detailed studies may be required to obtain a sound understanding of overburden characteristics, deposit stratigraphy, and groundwater conditions. These studies can involve groundwater pumping to estimate inflow rates and the potential area of influence, and subsurface sampling to estimate the composition, depth, and distribution of the deposit and the overburden. The information obtained from these investigations and any subsequent groundwater monitoring is useful in determining:

- the natural static groundwater elevation;
- expected fluctuations in groundwater levels;
- hydraulic gradients and rates of water movement during and following extraction;
- the depth, composition, and distribution of the deposit, all of which will determine the size and shape of a potential wetland or pond;
- the depth, composition, and distribution of the overburden, all of which will determine the types and extents of landforms which can be created.

Most ponds which use groundwater as their major source of supply will generally have temperatures suitable for cold water fish species such as brook or rainbow trout. Where it appears that surface waters will need to be combined with groundwater flows to provide sufficient water supply, an owner/operator desiring cold water species might want to estimate thermal inputs for the future pond. Once a thermal budget is determined using conventional hydrogeological models, the predicted temperatures can be compared to the preferred growth temperatures for cold water species given in Appendix 7.

Warm water species are generally more tolerant of water quality conditions. The key water management considerations are that there will be enough flushing to avoid stagnation, and that waters will be deep enough in both summer and winter. The minimum flushing rate needed to avoid stagnation depends very much on pond biology, as enriched ponds tend

to stagnate more quickly. However, as a rule, as long as water levels are stable through the summer, there should be sufficient turnover, as evaporation and seepage losses are compensated for by groundwater inflows, overland drainage, and rainfall.

Groundwater fluctuations generally follow the same cycles as surface waters, with highest levels in spring and fall. The degree of fluctuation depends on the characteristics of the aquifer, and on how much water pit operations and nearby users consume. Annual ranges of 2 m are not uncommon in porous sand and gravel aquifers with local recharge zones. The fluctuations are best determined from monitoring studies, and once estimated must be considered in relation to proposed pond bottom contours.

Surface Water

Ministry of Natural Resources approval is required to divert a watercourse to supply a pond, as is approval of the Ministry of the Environment if the quantity of water to be withdrawn or diverted is over 50,000 L/day. If it is felt that the withdrawal or diversion would have an adverse impact on downstream users or the natural environment, the application can be refused. Another possibility is that the amount of water to be withdrawn or diverted from a stream could be restricted to a percentage (usually not over one third) of the stream's estimated lowest flows during the year. Owners/operators considering using natural surface waters as a source of supply should consult officials of the two Ministries early on. The Ministry of the Environment sometimes has data on stream water qualityand actual long term flows, both important considerations in determining specific fisheries after uses.

If any facility such as a commercial fish farming operation is to discharge wastewater, a Certificate of Approval must be obtained in advance from the Ministry of the Environment. In reviewing the application, the Ministry considers the nature and quantity of pollutants, and the types of treatment needed to offset any downstream water quality problems which could result. *Aquaculture in Ontario* (Ontario Ministries of Natural Resources, Agriculture and Food, and the Environment 1986) provides an excellent review of the water pollution potential of fish farming operations.

Wildlife Populations

Information on existing local wildlife populations and their suitability for any specific rehabilitation proposal may be obtained from the Ministry of Natural Resources.

Land Use

Information on land use is available from the local municipality and the county or regional planning department. As well, aerial photographs are available from the Ministry of Natural Resources. These sources are very useful in identifying nearby agricultural, industrial, and residential developments which could disturb wildlife populations or affect water quantity and quality. Aerial photographs are also very helpful in identifying nearby wildlife habitat and travel corridors.

Confirming Habitat Development Feasibility

Once all the necessary information has been collected, it will have to be compared with the various habitat requirements in Appendices 4 through 7, to determine whether or not it is physically feasible to develop the habitat needed for the after uses desired. The biophysical analysis should indicate either that the site is not appropriate for the desired uses, in which case other types of fish or wildlife or non-fish and wildlife after uses should be investigated, or that the site can support the habitat types needed.

If fish and wildlife rehabilitation is physically feasible, the owner/operator will then want to consider the following before proceeding further:

- are the likely development costs involved, especially those which may not be claimable against rehabilitation security deposits, acceptable?
- are the likely operational and management costs involved acceptable?

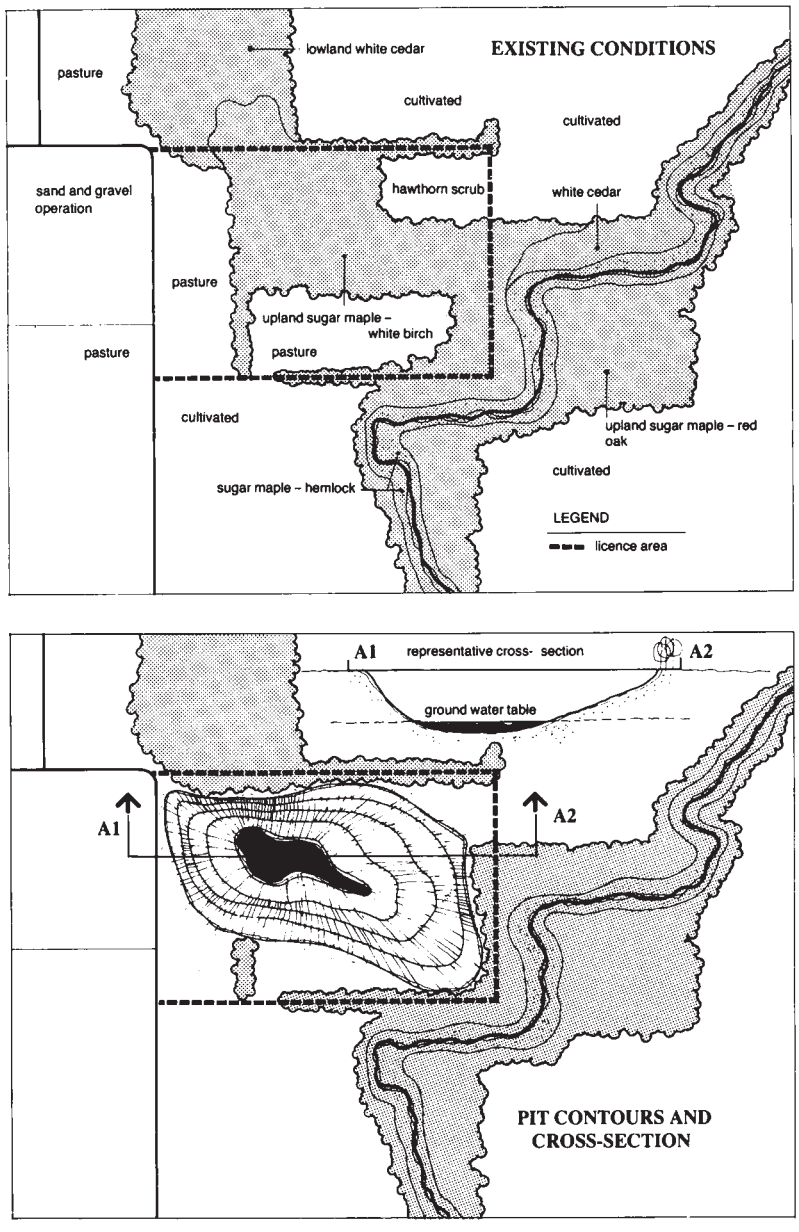


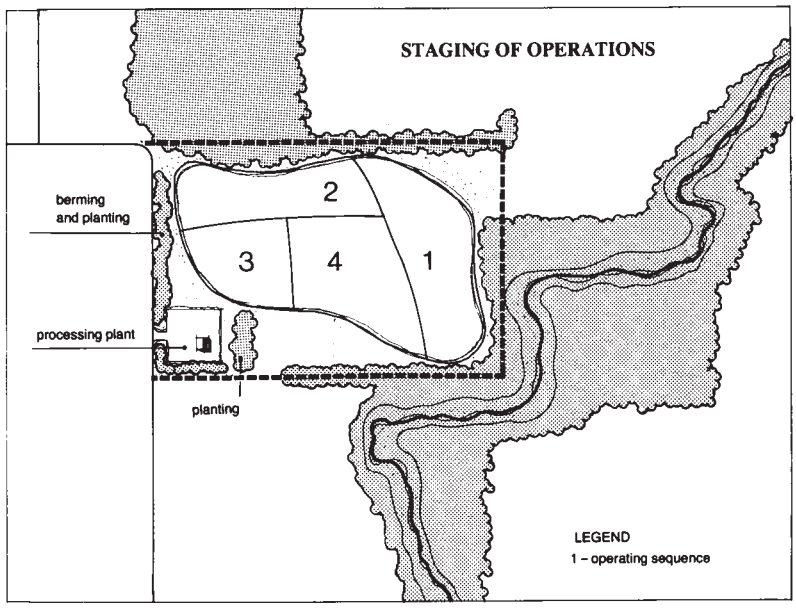
Figure 12. *Four stages of site planning.*

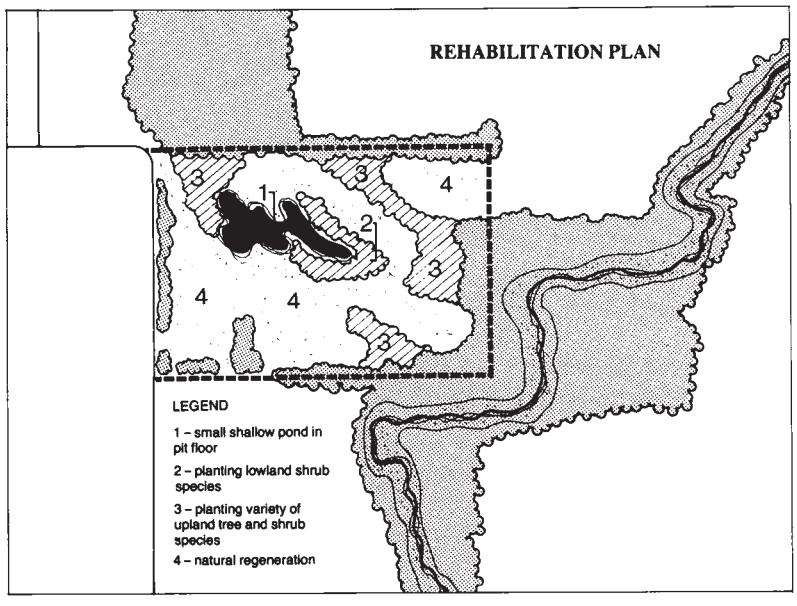
- are the revenues which can be expected acceptable in light of the costs and the owner/operator's objectives?
- will the development provide significant public relations benefits, if these are potentially valuable to the owner/operator?
- will there be any significant problems gaining the necessary government approvals?
- is the development as it now appears still consistent with the objectives, needs, and desires of the owner/operator?

STEP 3: SITE PLANNING

A site plan is not just a piece of paper required to obtain a pit or quarry licence in Ontario. Many examples here and elsewhere show that cost effective and productive rehabilitation begins with the preparation of a detailed site plan before extraction. The site plan allows the operator to balance three basic objectives: running an efficient mining operation, using the deposit effectively, and realizing the desired rehabilitation end product.

An Ontario site plan must describe existing site conditions, the planned extraction and rehabilitation sequence, and the proposed final form of the





site. At this point, two of the variables necessary to prepare a practical site plan for fish and wildlife rehabilitation should already be known from Step 2. These are site conditions (deposit and surface characteristics, water conditions and availability, wildlife populations and corridor linkages, and surrounding land uses), and fish and wildlife habitat requirements relevant to the desired after uses (see Appendices 4 through 7). The key, therefore, is to phase the mining operation so as to capitalize on the characteristics of the deposit, while using waste materials to advantage in rehabilitation.

The pattern and rate of extraction will likely vary according to market demand for aggregates. Accordingly, how much can the sizes and shapes of ponds, landforms, etc. be planned prior to mining? The character and distribution of these features will often have to evolve along with the mining operation.

To illustrate the general process of preparing a site plan, a four stage example based on a hypothetical site is shown in Figure 12.

- Existing conditions (a). This shows the land uses and vegetation communities in and near the licensed area. The area supports a local deer population and other upland game species, and would be appropriate for rehabilitation for wildlife protection or hunting.

- Pit contours and cross-sections (b). This shows the potential extent and depth of excavation, and a representative cross-section through the pit shows the position of the water table relative to the pit floor. Also shown are vegetation remnants left after initial clearing operations.
- Staging of operations (c). This shows the basic sequence of operating areas within the pit and the potential location of the processing plant. The plant is located as far as possible from natural and wooded areas to minimize disturbance to local wildlife populations. The operating sequence begins in remote parts of the pit so that progressive rehabilitation can return these areas to conditions suitable for wildlife as quickly as possible. Activity will then move towards the plant. Also shown are berms which can be constructed and planted to screen the plant.
- Rehabilitation plan (d). This shows the basic rehabilitation tactics that will be implemented to return the entire site to wildlife after uses, including appropriate slope and pond contouring, and a mixture of planting and natural regeneration.

STEP 4: PROGRESSIVE REHABILITATION

Progressive rehabilitation is undertaken over the lifetime of the pit or quarry as extraction of each portion is completed, rather than all at once after the entire deposit has been depleted (see Figure 1). This approach is a logical extension of effective site planning, especially on larger sites and in longer term operations. Integrating rehabilitation with the actual mining operation by using to advantage machinery and waste materials available on the site is the key to establishing productive fish and wildlife habitat quickly and inexpensively.

Progressive rehabilitation is especially valuable and effective when rehabilitating for wildlife, as most species require plant communities in varying stages of succession, a condition more or less ensured by extracting and rehabilitating sequentially. As well, progressive rehabilitation not only reduces the visual impact of the pit or quarry, but also minimizes the effect of operations on nearby wildlife populations. Finally, the natural colonization of newly rehabilitated areas by neighbouring wildlife will provide an early indication of habitat quality, and therefore rehabilitation success.

Specific tactics which should form part of progressive rehabilitation are as follows.

Clearing

Before any extraction can take place, well developed vegetation has to be cleared. Wherever possible, stands of natural vegetation in or near the operating area should be retained. Priority areas for retention would include mature groves over poor quality sections of the deposit, or natural connections to nearby wildlife habitat. Retaining these stands will preserve centres from which plants and soil microorganisms can spread back into extracted areas, and help minimize noise and other disturbances to wildlife populations within the licensed area and on nearby lands. Conserving select areas is of more value to some wildlife species than to others. Deer, for example, are sensitive to visual and noise impacts, and will therefore especially benefit from retained vegetation screens.

Stripping and Stockpiling

Soil and Overburden

Wherever possible, topsoil, subsoil, and overburden should be handled separately. First, topsoil is valuable for reestablishing natural vegetation communities, as it typically contains soil microorganisms and viable plant seed banks which enhance the potential for natural regeneration. Second, topsoil is not suitable as construction material. Third, in cases where topsoil is too thin to be removed separately, subsoil can provide an acceptable substitute, as it is generally weathered to some extent and is therefore far more appropriate for establishing vegetation than the underlying parent

material. If overburden is mixed with either topsoil or subsoil, the value of the soil will be greatly reduced.

Topsoil should be stripped during dry periods to minimize compaction. Heavy machinery used on wet ground compresses the soil, reducing pore spaces and creating a hard, impervious surface. Drainage and root development are inhibited as a result. Also, as stockpiled topsoil generally deteriorates with time, it should when possible be transferred directly to a new site rather than stored. When topsoil must be stored for a long period, it should be seeded to reduce the potential for deterioration.

The overburden, along with any excess fines, sands, and clay lenses within the deposit, will form the base for construction of appropriate landforms. To reduce the time and effort needed to move materials, land forming activities should be concentrated where the overburden to deposit ratio is high.

Organic Material

Large quantities of plant material (tree trunks, branches, leaf litter, etc.) often have to be cleared before excavation. This material should not be discarded; rather, it should be stored on site for later use in habitat development. For example, fine material such as leaf litter should be composted. Compost can be added to topsoil to enhance soil microorganism populations and plant reestablishment, or provide pond bottom material to promote aquatic invertebrate production. Coarser twigs and small branches are appropriate for mulch material, while large branches, trunks, stumps, and roots can provide excellent cover for small mammals and birds, and protection and forage areas for fish, when replaced on the site. During the extraction period, these plant materials can be stored in brush piles, which will help to maintain wildlife on site until rehabilitation.

Organic soils such as muck and peat also need to be cleared where present. Although these are unsuitable for landform construction, they are excellent for use in rehabilitation of wetlands, where they can provide nutrient bases, seed banks, etc.

Boulders and Clay

Large boulders and rocks are common in some deposits. Some of these should be retained for later distribution in ponds, along shorelines, and on pit floors, rather than discarded or buried under constructed landforms. These rocks can provide cover for insects, small mammals, etc., perching sites for birds, and protection and nursery areas for fish.

Clay lenses, like boulders, are unusable materials in sand and gravel operations. However, if site plans call for moist depressions or ponds, layers of clay spread on the bottoms can provide effective seals. The needed clay should be stockpiled.

Monitoring

Most operations continue for relatively long periods. After 10, 20, or 30 years, changes in land uses on adjacent properties may occur which can have direct impacts on local wildlife populations. These changes could affect the feasibility of the wildlife after uses originally identified. As well, market conditions may change, affecting the economic viability of the originally identified fish and wildlife uses and perhaps suggesting new ones. Operators should therefore periodically monitor markets, land uses, and other characteristics which may change over time, to detect any changes and amend rehabilitation plans as required.

Landform Construction

Throughout the operating period, overburden and waste materials can be redeposited and graded into a variety of landforms above and below the water line: varied pond bottoms, islands, peninsulas, spits, contoured banks, mounds, etc. Construction of some landforms can begin early on, greatly aiding the development of the site's supporting ecosystem. As Herricks (1982) pointed out, ". . . if conditions are optimized for development of

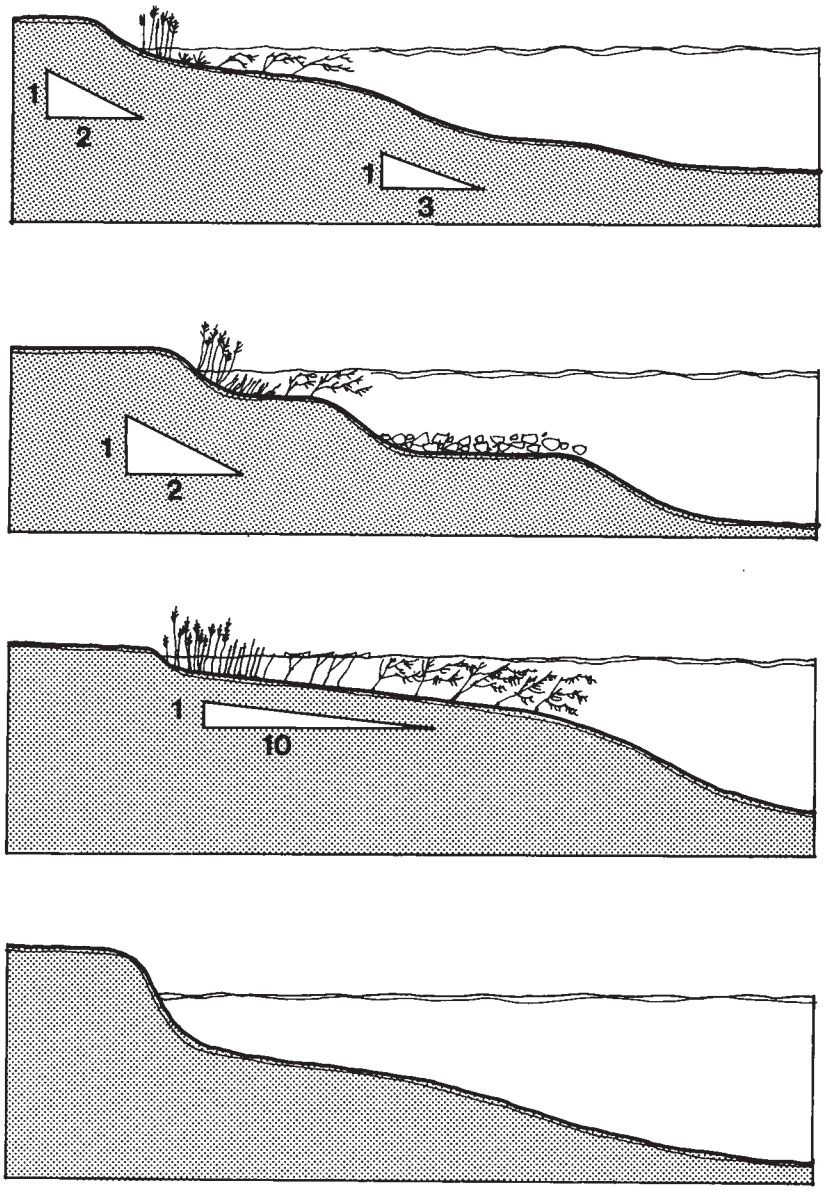


Figure 13. *Bank grading alternatives for fish and waterfowl. Side slopes should not exceed 2:1, especially in loose soil* ***(a)****. Aquatic vegetation provides fish nursery areas, and gravel spawning shoals on deeper shelves are appropriate for some fish species* ***(b)****. Extensive nearshore zones will evolve into good fish nursery and spawning areas and good waterfowl habitat* ***(c)****. For recreational angling, banks should be sloped as steeply as possible to a 1 m depth to minimize weed growth and optimize shoreline angling* ***(d)****.*

a healthy ecosystem, the management of a desired species is facilitated and maintenance costs are similarly minimized." Thus, an operator should first develop a stable and suitable land and water base, then permit the site to develop naturally, and finally enhance rehabilitation by selecting and applying appropriate techniques. Specific criteria for landforms that can be constructed during the operating period are as follows.

Pond depths. Maximum and mean depths are especially important to a pond's capacity to sustain fish year round. If a pond is too shallow, dissolved oxygen will likely be depleted under the ice. This may cause fish kills, and will limit the pond's potential to maintain self-sustaining populations. In general, unless a pond is spring fed, maximum water depths of 3 m or more are needed for trout to overwinter successfully. As well, a lake which is too shallow and whose productivity zone extends to its bottom can be a prime candidate for extensive weed growth, leading to possible fisheries problems. Accordingly, ponds created for both cold and warm water species should have variable depths, with a mixture of deep and shallow areas. Maximum depths should cover 25% or more of a pond's area (see Appendix 5 for more information).

Shallows. Nearshore zones of ponds, up to 1 m deep, provide habitat for emergent plant growth and insect colonization. These habitats provide essential protection and food for waterfowl and fish. For waterfowl in partic-

ular, large areas of water less than 1 m deep are essential. Conditions in these shallows favour high biological productivity. Sunlight can reach the bottom of the pond, thus allowing various plants and animals to develop there. Nearshore shallows should make up about 20% of a pond's total area. Both narrow and wide nearshore zones or shelves can be provided to enhance habitat diversity. Some fish species prefer areas where depths fall off rapidly, while waterfowl require more gentle slopes. Some typical nearshore grading schemes are shown in Figure 13.

Bottom topography. As noted in Street (no date), "The plants form the habitat and food for the freshwater animals that are the important food for most water birds in the breeding season. In shallow water these are available to the dabbling duck, while the deeper water, around 1.5 m deep, provides good feeding conditions for the diving duck and fish-eaters." Accordingly, instead of spreading available overburden uniformly over the bottom of a pond, it is better to concentrate the fill in selected sites, so that sufficient food production areas are created. An uneven pond bottom with a range of depths will provide diversified underwater habitat. Figure 14 shows the type of bottom topography which is most likely to yield diverse bottom fauna and fish populations. Variations should be as much as 1 to 1.5m.

Substrates. A variety of substrate types should be deposited in ponds, in both nearshore areas and deeper basins. This is because aquatic organisms are quite selective in the size of particles they use for spawning and support. By linking the substrate requirements of fish and other aquatic organisms to the structure of the excavated bottom and the character of the stockpiled material, it is possible to develop a mosaic of substrate types on a rehabilitated pond bottom. This mosaic will control and may enhance the stability of the pond ecosystem. One of the main problems in rehabilitating pits for waterfowl production is the immaturity and infertility of the excavated bottom. The bed is usually a sand-gravel-clay mixture, poor in nu-

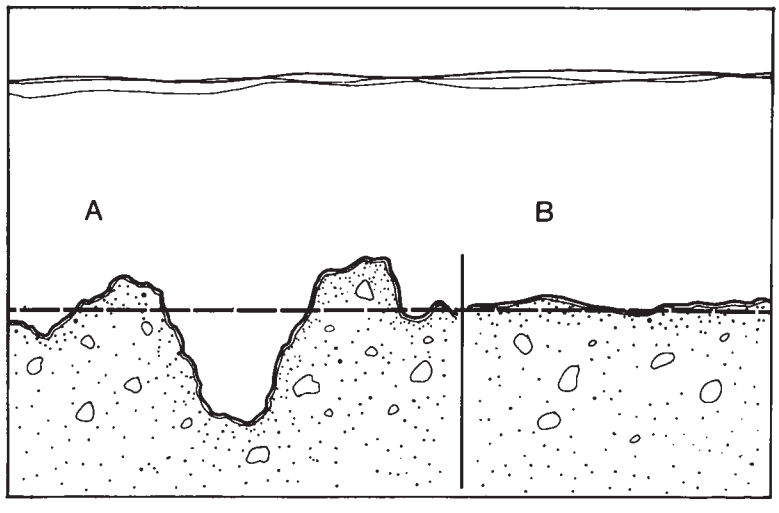


Figure 14. *The uneven bottom topography of* ***(A)*** *is more likely to yield diverse bottom fauna and fish populations than the even topography of* ***(B)****. (adapted from Herricks 1982)*

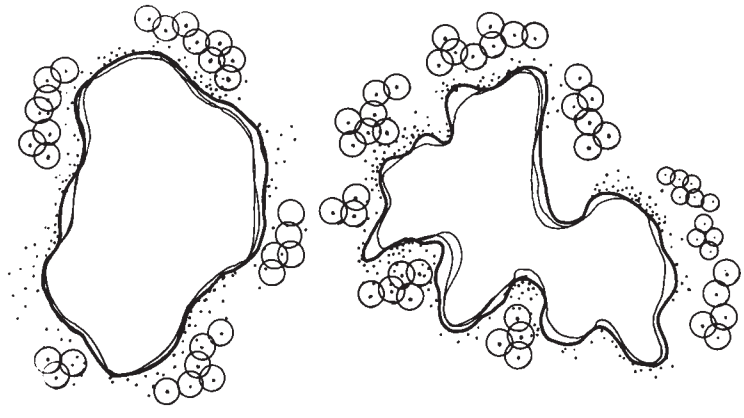


Figure 15. *Sculpturing of pond edges to lengthen the shoreline enhances diversity and productivity. The pond at right has significantly greater potential for waterfowl production.*

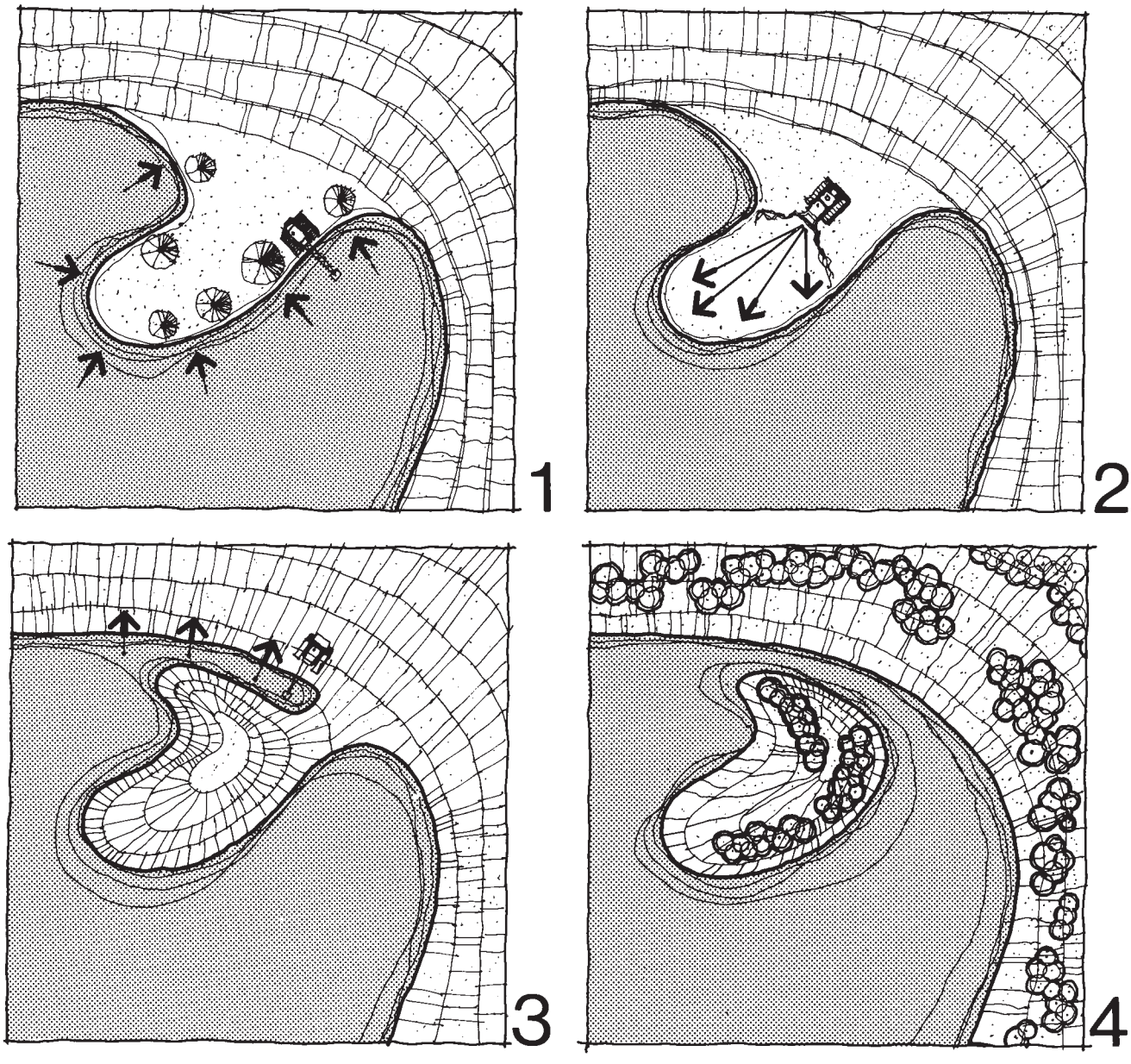


Figure 16. *Islands can be developed in undrained pits during operations. They start as peninsulas (1,2) which are then graded to provide the appropriate shapes and slopes (3). Channels are then dredged to separate them from the mainland (4). Steps 3 and 4 should not be undertaken until final water levels are known.*

trients and lacking the organic content essential for food production. Eventually, a pond will accumulate an organic layer from decomposition of plant and animal remains. However, this can take many years. To offset this problem, there are a number of management tactics which can be undertaken, and these are described in Step 5.

Shorelines. Ponds which are basically round or rectangular are not ideal for establishing diversified biological communities. Sculpturing the edges of the excavation can create a much longer shoreline area (see Figure 15). The longer the shoreline relative to surface area, the more productive the pond can be.

Islands. Islands serve the same purpose as irregular shorelines, that is, they increase shore length and therefore ecosystem diversity and productivity. In addition, they can provide vital refuges for waterfowl nesting and loafing. Where water is not pumped out of pits, islands can be created by removing material from around a spit and then cutting the connection to the shore, as shown in Figure 16. Where water is pumped out of pits, islands can be constructed in their final locations. However, where it is not possible to predict precise water levels after flooding, it is a good idea to leave islands connected to the shore. After water levels have stabilized, the islands

and their shorelines can then be finally shaped to achieve their optimum heights and profiles, and the connections removed.

Water Quality Control

During operations, pond water quality should be disturbed as little as possible, and any water used for processing should be treated if it is being discharged to the pond. Low cost settling ponds or lagoons offer the best solutions to treating waste processing water, mainly to reduce or eliminate suspended solids. The number, sizes, and retention times of settling ponds will depend on the size and character of the operation, and must also meet the requirements of the Ministry of the Environment, the key approval agency for wastewater discharges. The ponds can be arranged either in series or in parallel depending upon the scale of production and degree of operating flexibility desired. Depending on the number and sizes of settling ponds, and the length and configuration of channels between them, it may well be possible to integrate the settling pond system into the final rehabilitation plan, thus turning a possible constraint into a benefit.

Early Stocking

Considerable time is required for a stable ecosystem and a viable recreational resource based on that ecosystem to evolve in a newly extracted pit or quarry. The earlier that stocking and management for self-sustaining fish populations can begin, the better the resource will be when the mining operation is at an end.

STEP 5: FINAL REHABILITATION

Wetland Wildlife

While any permanent water body is likely to attract some waterfowl and other wildlife of the aquatic/shoreline group, productive ponds have a very specific set of characteristics which can be achieved through careful site preparation.

Pond Depths

The most productive dabbler ponds are shallow (1.0 to 1.5 m at the deepest), with extensive nearshore zones less than 50 cm deep. These depth characteristics allow the establishment of emergent aquatic plants necessary for cover, and provide shallow feeding zones, as described in Step 4.

Pond Bottoms

Pond bottoms should be uneven, and should consist of a layer of organic material or topsoil applied before flooding. The advantage of using some of the topsoil originally stockpiled is that it provides a good medium for plant rooting, excellent inorganic nutrients and organic food sources, and good habitat for aquatic invertebrates which burrow into the sediments and provide food for dabbling ducks.

One technique which can help in developing an enriched environment is to keep water out of the pond while seeds are allowed to germinate and grow. As suggested by Street (no date),

"It would be even better to seed the soil on the lake bed with a leafy green manure crop such as mustard, clover, alfalfa . . . . When the lake is allowed to fill, the plants decay and form an immediate source of food and energy material for the invertebrates, plus a supply of leached-out soluble salts to give the new lake ecosystem an initial boost. A root mat also binds the soils and reduces the amount of sediment which can become suspended in the water, thus making better conditions for the establishment of rooted aquatic plants."

If topsoil is not available, farm manure can be used instead as an enriching material. As well, wet sewage sludge can be sprayed into ponds from trucks, as long as heavy metal content is not a problem. However, the high levels of bacteria in these materials can decay rapidly and consume large

quantities of dissolved oxygen. This can harm fish and some invertebrates. Accordingly, manure or sludge must be used very carefully. Only small amounts should be added relative to pond size, and fish stocking should be delayed until enough time has passed to offset any ill effects. On the plus side, any low dissolved oxygen conditions which do develop may favour the production of large numbers of midge larvae, which are an important food for ducklings.

Shorelines

As noted in Step 4, ponds with irregular shorelines are significantly more productive. It appears that the number of duck pairs in a pond is directly related to shoreline length. Longer shorelines can be developed by using overburden, fines, etc. to create spits, peninsulas, and islands, and by grading pond sides to form numerous bays and inlets (Figure 15).

Bank Conditions

Waterfowl production, and wildlife diversity in general, are usually greatest in wide shoreline and nearshore zones with low grades. Bank grades should be no greater than 10:1, and ideally should be around 20:1. These grades allow the extensive food and cover areas typical of productive natural shorelines to develop. For example, a wide shoreline and nearshore zone will support a characteristic distribution of plant communities, from wet meadows, through emergent and floating aquatic zones, to the submerged plants of waters 1.5 m or more deep (Figure 17). On a 2:1 or steeper slope, the shoreline zone is very compressed, and only a limited range of plants will develop. Also, low grades are particularly important for ducklings, which cannot easily cope with steep banks.

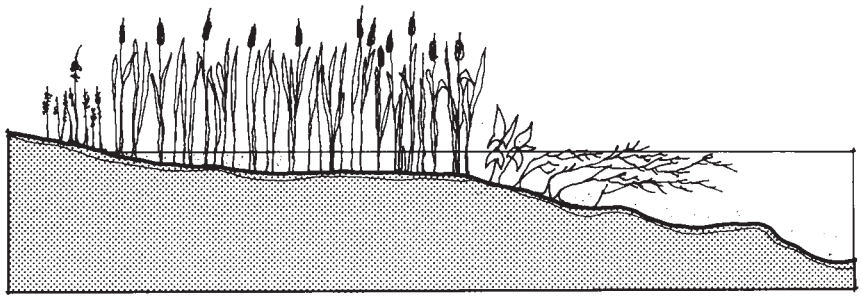
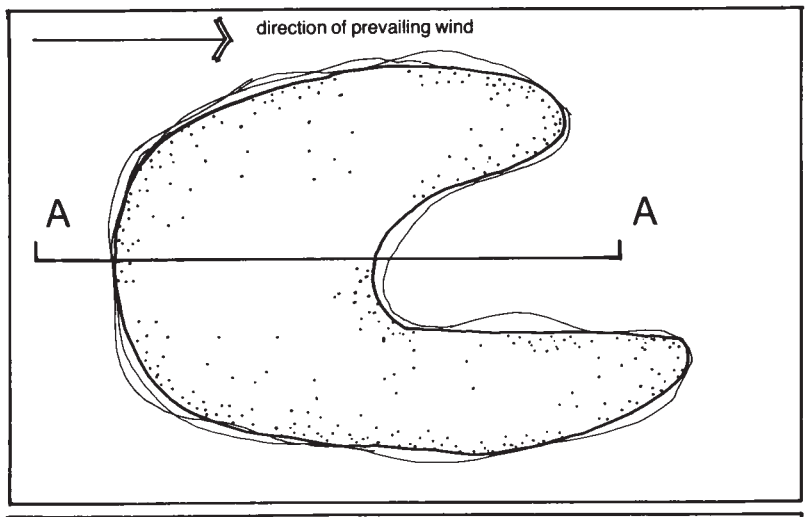


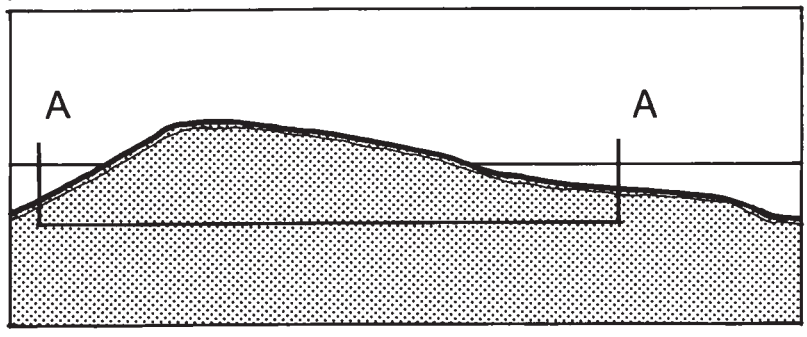
Figure 17. *Wide nearshore zones and gentle, sloping conditions encourage waterfowl production much more than narrow shore zones and steep banks do.*

Figure 18. *Islands suitable for waterfowl production should have low profile banks.*

Figure 19. *Horseshoe shaped islands are ideal for waterfowl. The mouth of the horseshoe should be in the lee of the prevailing wind. The inner banks should be more gently sloped than the outer banks to increase the sheltering effect.*

Figure 20. *Floating, anchored rafts can provide waterfowl nesting sites in deeper waters. (from Street, no date; courtesy ARC Limited, The Ridge, Chipping Sodbury, Avon, England)*





Islands

Islands not only increase shoreline length, but also protect waterfowl from most predators, particularly during nesting and moulting. To be effective, an island should have a low profile (Figure 18), and ideally should be either horseshoe shaped (Figure 19) with the open end facing away from prevailing winds, or designed as a small crowded cluster or atoll surrounding a sheltered lagoon. In either case, the sheltered zone should be shallow, with the adjacent banks graded gently to provide easy access for ducklings. As pointed out by Street (no date), such a shape and profile "... [provide] a

long productive water's edge in relation to the area of the island, and [enclose] a shallow, sheltered productive lagoon out in the security of a deeper lake, thus providing for several needs of waterfowl (nesting, loafing, feeding) on the one site."

As noted in Step 4, island final design and completion are probably best left until eventual water levels can be predicted. In particular, spring levels are critical to waterfowl, and final design should ensure that the islands are above spring high levels.

Islands can also be established in deep water by building floating, anchored rafts (Figure 20).

Vegetation

Vegetation cover in productive waterfowl ponds varies widely. Shallow nearshore zones are typically dominated by tall dense stands of emergent aquatic plants such as cat-tail, giant reed, and bulrushes, while deeper zones support floating and submerged aquatics such as lily pads and pondweeds. For dabblers, emergent plant communities providing nesting and cover should occupy at least 30% of a pond surface, while floating and submerged communities providing feeding should occupy at least 20%. On land, moist shore zones dominated by wetland grasses and rushes are most suitable. Ideally, there should be some areas bare of vegetation for loafing. A varied shoreline leads to diversified vegetation. This is why it is important to develop the right mix of landforms when constructing a pond.

As Street (no date) points out,

> "If a gravel pit is left to colonise naturally and is allowed to develop without control, the result is the establishment of a plant community which is dominated by only a few species . . . with a low floral diversity. It has been shown that the number of bird species at unmanaged gravel pits declines after 5 or 6 years due to the increase in uniformity of the vegetation as naturally vigorous plant species become dominant."

It is important to increase vegetation diversity, and therefore the richness, productivity, and stability of a potential waterfowl pond, by introducing appropriate plants at an early stage, before less desirable species can colonize the site.

While desirable species can spread into a site by natural colonization, sometimes quite quickly, revegetation can also be given a boost through transplanting. In introducing aquatic plants, care must be taken to locate the various species where they will be of greatest benefit as food sources, support for invertebrates, nest cover, shelter, etc. Further details on appropriate wetland plant species are provided in Appendix 8. Factors which need to be considered before introducing wetland plants include:

- a nearby source of natural stock should be available for transplanting;
- the stock should be transported to the new site relatively quickly;
- roots should be kept in water during transportation;
- plants should whenever possible be transplanted in spring and before they flower;
- submerged and floating plants should be planted in 50 cm to 1 m of water;
- top growth should be removed from shoreline plants, and the roots should be planted just above the water line;
- planting on exposed shores may require protection from wave action and soil erosion.

Water Level Control

Most waterfowl species prefer ponds with stable water levels. Major fluctuations can limit productivity and species diversity. However, periodic planned drawdowns are important. They aerate the sediments, and aid the release of essential plant nutrients when the pond is reflooded. Many pit and quarry ponds have no surface drainage, and cannot be drawn down using

standard dikes and weirs. Pumps may therefore be needed. Landlocked ponds can also be designed to receive supplemental water from surface runoff; the runoff can be diverted when a partial drawdown is desired.

Upland Wildlife

Progressive rehabilitation will provide a valuable initial boost, but additional site preparation after operations are finished is essential to productive habitat development and wildlife recolonization. The following site preparation measures will provide the most favourable conditions for wildlife of the agricultural/old field and immature forest groups.

Grading and Contouring

As shown in Appendix 4, preferred topographic characteristics differ among the typical upland wildlife species. Grouse prefer irregular topography; pheasant, irregular topography with local 1 to 3 m variations; and deer, rolling terrain or deep valley systems.

After extraction, steep slopes are regraded to minimize erosion. Dry pit floors are commonly dotted with mounds of various sizes, as well as moist depressions, and these are often graded as well to produce a more uniform surface. However, where wildlife habitat is desired, regrading over and above what is required by the regulations under the Pits and Quarries Control Act should be kept to a minimum, so that the rehabilitated topography will reflect the preferences of the desired species. Small ponded areas

Figure 21. *Abandoned pit with small, ponded areas on floor. These ponds should be retained wherever possible to increase overall site diversity.*

Figure 22. *These vertical pit faces provide nesting sites for swallows and other cliff-dwelling birds.*

should be retained wherever possible (Figure 21). Increased populations of not only the prime game species, but also many other species, particularly small mammals, can be expected when irregular topography is provided, as in Figure 4. Keeping low, open pit faces can provide nesting sites for swallows and other cliff-nesting birds (Figure 22).

Surface Preparation

Whatever the approach to site revegetation (see next section), plant establishment, growth, and succession will depend very much on how the ground is prepared beforehand. Large scale mining totally disrupts the surface, dramatically altering its structure, water retention capacity, chemistry, and microorganisms. The overburden newly exposed on pit floors and slopes is a raw, unweathered, undeveloped substrate, unsuited for all but the hardiest pioneer plant species. The floors of both pits and quarries are difficult to rehabilitate because they lack nutrients. Therefore, it is essential to reestablish a productive soil cover after grading and contouring are complete. Specific tactics include the following.

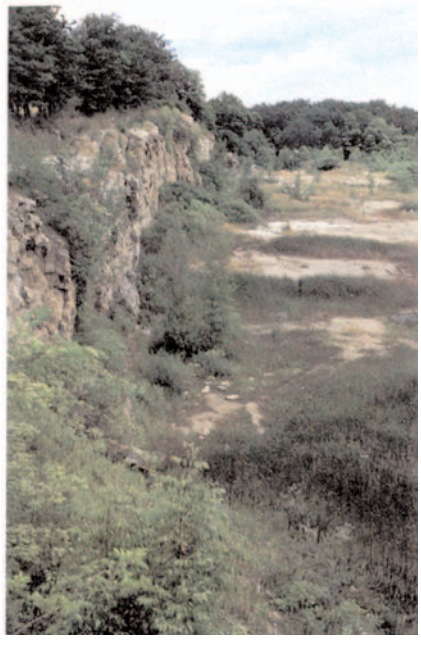
Scarification. The constant movement of heavy machinery throughout the operating period severely compacts pit floors. Compaction prevents plant root penetration, water penetration, and water circulation, and therefore makes vegetation establishment difficult. This problem can be dealt with by ploughing where compaction is shallow, or ripping where it is deep.

Topsoil distribution. As discussed in Step 4, topsoil should be preserved for later use during rehabilitation, basically to provide a medium for productive plant growth. However, in wildlife rehabilitation, unlike rehabilitation for agriculture, topsoil should not be evenly redistributed over the new landscape. Instead, the soil cover should vary in depth, from bare areas to deep topsoil layers. The deeper layers should be placed where trees and shrubs are to be planted. These variations will yield different rates of plant establishment, growth, and succession, and therefore produce a mosaic of plant communities.

Organic material. Incorporating organic matter into the soil will increase nutrient accumulation and cycling, water retention, and plant root penetration. As discussed in Step 4, this material may consist of composted leaves etc. or organic soils (mucks or peats) removed before excavation.

Mulches. Timber wastes and mulches derived from cleared vegetation material can be redistributed to promote soil invertebrate colonization and improve water retention capacity.

Fertilization. Stripping and stockpiling of topsoil and subsoil normally causes fertility and other values to deteriorate, especially if the soil is stored over long periods. Fertilizers containing nitrogen, phosphorus and potassium (NPK) should be applied to redistributed soil to compensate for nutrient losses. Rates and frequencies of application depend on the types of vegetation desired (for example, lure crops require considerably more fertilization than do shrubs or trees). Planting legumes in the initial years can also help restore fertility.



Vegetation

A combination of natural succession and deliberate planting is the most effective way to establish vegetation for wildlife in pits and quarries, and achieve a balance among speed of revegetation, wildlife production, and costs. Incorporating at least some natural regeneration should lead to greater wildlife diversity and production, as native and naturalized plant species adapted to harsh environments often succeed better than introduced agricultural or horticultural species (Figures 23 and 24). Naturally regenerated areas usually provide more reliable, longer term cover, and more nutritious food supplies. Introduced grass and legume seed mixtures, where they do survive, usually impede natural successional processes.

Most successful revegetation will start with planting or seeding of both native and introduced plants to establish the desired species and control erosion, followed by natural succession to reduce overall rehabilitation costs. Native species should be used as much as possible. How much planting is done will depend on the labour and materials available and the

Figure 24. *Rehabilitated pit. Here also, natural succession and colonization have yielded diverse vegetation valuable to wildlife.*

Figure 25. *Planting at a rehabilitated pit. Distinct plant groups such as this conifer population have been established. These can serve as core areas for vegetation dispersion and wildlife protection.*

priority placed on speed of revegetation. The specific planting pattern will depend on the preferences of the wildlife species and groups desired. Where planting materials or funds are scarce, efforts should be concentrated in small areas rather than spread over large areas or the entire site. This will allow recognizable plant groupings or communities to become established and to begin to be used by wildlife. From these centres of initial plantings, natural successional processes will spread across a suitably prepared site (Figure 25).

The species selected for planting or seeding should provide wildlife with food, cover, or preferably both. Plant site preferences and reproduction methods should also be taken into account. Appendix 9 provides a list of trees, shrubs, and herbaceous species recommended for upland wildlife rehabilitation.

Artificial Structures

Habitat can be made still more diverse by redistributing boulders, logs, stumps, and brush piles through the extracted area (Figure 26). These materials provide cover and perching sites, not only for grouse and pheasant, but also for many small mammals and birds. Nesting boxes can also be built and installed.

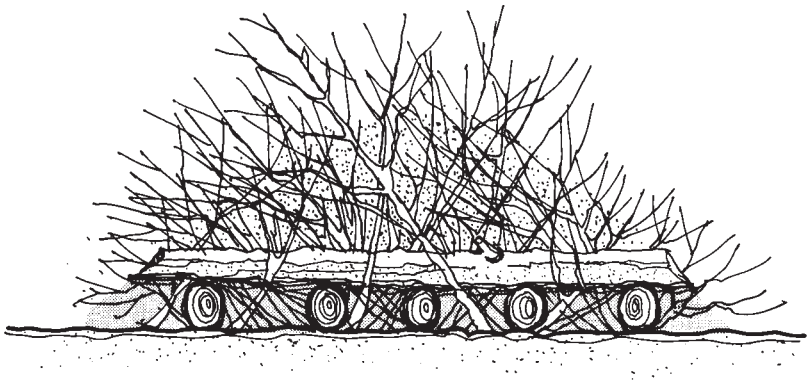


Figure 26. *Brush piles can provide cover for wildlife such as grouse, pheasants, and small mammals.*

Fisheries

Spawning Habitat

Rainbow and brook trout are mainly stream spawners, and usually only reproduce successfully in ponds that have gravel bottoms and inflowing springfed streams or upswelling spring waters. Sites without these characteristics are unlikely to support natural reproduction, and trout stocks will need to be maintained on a put and take basis instead.

For smallmouth bass, spawning habitat can be provided by placing gravel of the right size at the right depth. Shoals for reproduction and feeding can be constructed near shorelines and to a final depth of at least 50 cm. Where possible, shoals should be on the windward sides of ponds, so as to be kept clean by wave action. The shoals should be topped with a mixture of smooth stones ranging from pebble size to 10 cm in diameter, plus about 10% fine sand. This mixture should be at least 40 cm deep on average.

For largemouth bass, the best spawning substrates are marl or soft mud 50 to 150 cm below the surface. Where possible, emergent aquatic plants such as cat-tail, bulrushes, and water lily should be introduced.

Panfish generally have the least stringent requirements for spawning. For example, rock bass will spawn in areas ranging from swamps to gravel shoals. As well, good protected spawning and nursery habitat can be provided by laying tiles, culverts, crib structures, and rubble piles on pond bottoms (Figure 27).

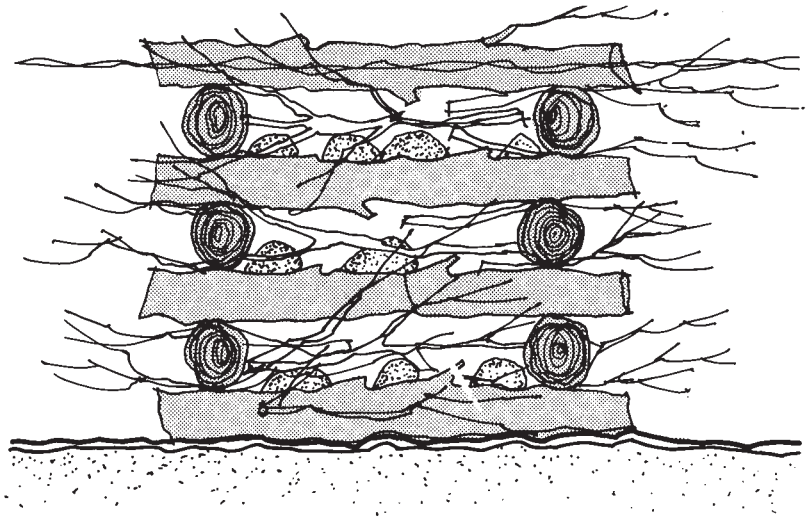


Figure 27. *Cribs can provide both feeding and cover areas for fish.*

Cover

Where rehabilitation cannot be started during operations, fish habitat can be quickly improved after extraction is complete by adding structures which duplicate the habitat requirements of the desired species as well as other aquatic organisms. Brush piles and submerged tree crowns provide excellent cover, and also serve as substrates for the growth of organisms

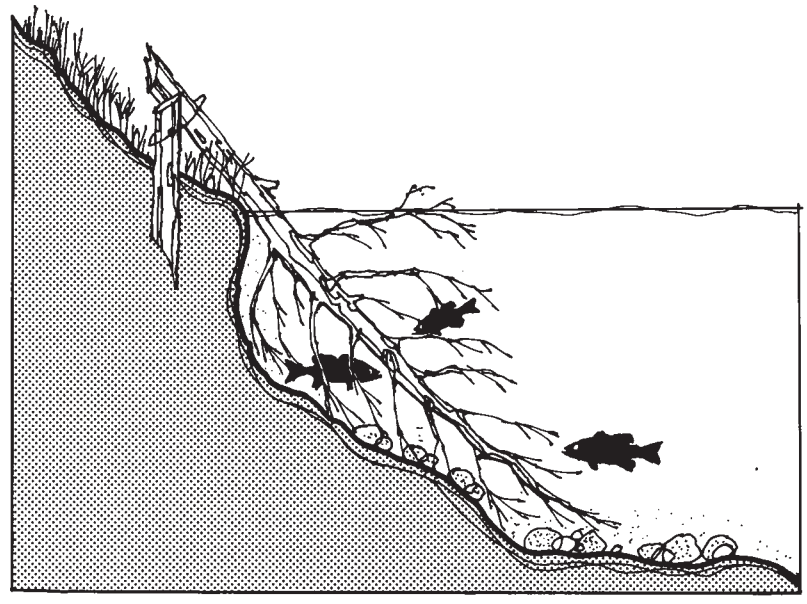
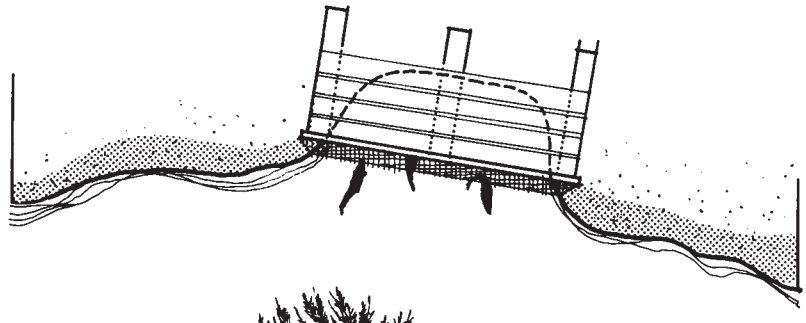


Figure 28. *Submerging tree crowns is an easy way of providing cover for fish where banks drop off steeply.*



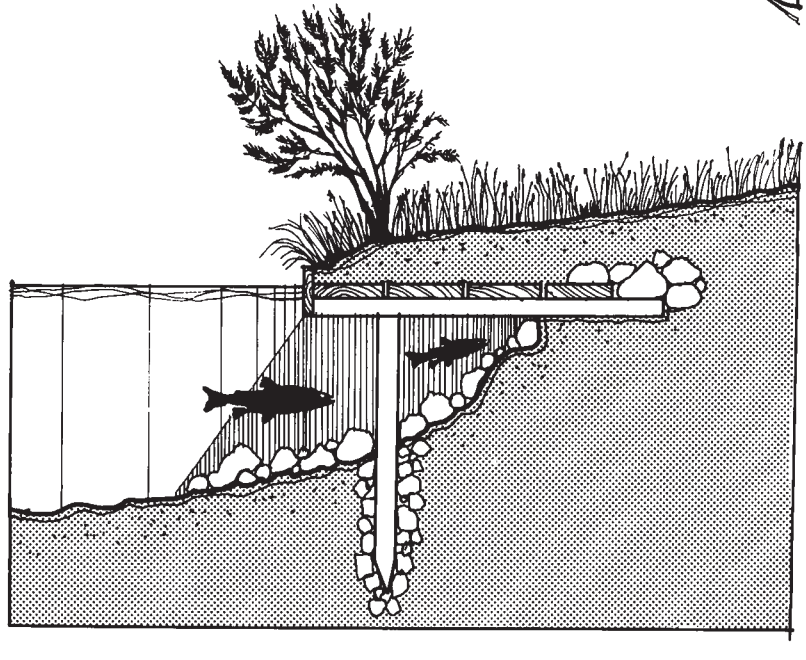


Figure 29. *This structure can be built out of scrap lumber to provide effective cover for fish. The upper sketch is an overhead view, without the earth and plant cover shown in the lower sketch.*

on which fish feed (Figure 28). Effective cover-providing structures can also be made from scrub timber, scrap lumber, old tires, etc. (Figure 29).

In shallow bays and other nearshore areas, rooted aquatic plants will provide protective cover for brook trout, rainbow trout, largemouth bass, and forage species, as well as a substrate for many invertebrates. These shallows should average about 1 m and not exceed 2 m deep. Bottom materials should consist of soils with significant organic content. Although a variety of aquatic plants will eventually establish themselves, the process can be accelerated by introducing the plants artificially. Appendix 8 identifies selected plant species appropriate to nearshore areas.

Shoreline Vegetation

Shade is important for some species, such as brook trout. Nearshore pools about 1.5 m deep provide excellent protection when overhung by vegetated banks. As well, insect populations associated with these sites are a prime food source. Although shade can be provided by all the habitat enhancement examples mentioned above, trees, brush, and other vegetation growing along or hanging over the banks of a pond can considerably enhance fisheries habitat, especially if there are deep pools within the shaded area (Figure 29). However, not too many deciduous trees should be planted near the shorelines of small ponds (1 ha or less) without either inlet or outlet. Decaying leaves which fall into the pond have high oxygen demands, which can reduce dissolved oxygen levels and impair fish habitat.

STEP 6: RESOURCE MANAGEMENT

Maintaining and Enhancing Wildlife Habitat

Owners/operators may do everything needed to develop suitable habitats for the wildlife species they desire, but will still need to manage those habitats carefully over the long term for the selected uses to remain viable.

One time applications of NPK fertilizers are usually not enough to ensure plant establishment on the poor substrates typical in pits and quarries. Additional fertilizer inputs are needed until a stable plant cover has developed. Application frequencies and rates will vary, depending upon soil fertility and vegetation cover stability.

Over long periods, vegetation composition and structure and plant community patterns may change to become less desirable or no longer suitable for the desired species. Selective control programs may be required to reintroduce appropriate successional stages. For example, maturing woods might be cut to promote suckering of trees and produce the coppice growth preferred by some species, or aquatic weeds might be cut when they impede pond use by waterfowl.

As noted in Step 5, water drawdowns are an important management practice in duck ponds. Drawdowns are normally done in early spring. Their frequency will vary with the needs of individual ponds.

Food and cover resources can be improved over time by installing additional nesting boxes, logs, stumps, boulders, etc., and by planting lure crops (such as corn for pheasant) or other food and cover plants. How much effort will be put into habitat enhancement will naturally depend on how much effort was put into initial rehabilitation, how well that effort succeeded in terms of colonization by local populations (see below), what food and cover are available nearby, and how much time and money the owner/operator wants to put into achieving the desired after uses.

Operating Wildlife Hunting Areas

Stocking

Only two wildlife species are commonly stocked for hunting: ring-necked pheasant and bobwhite quail. Pheasants account for most hunting preserve activity.

TABLE 3. ANNUAL YIELDS FOR SIX GAME SPECIES.

Species	Average annual mortality from hunting in Canada	Average density in good quality habitat (no./100 ha)	Average hunter success rate (no./day)	Annual yield (no./100 ha)	Hunting opportunities (days/ 100 ha/yr)
Deer	25%	6	0.08	2	18
Ruffed grouse	35%	50	1.8	18	10
Mallard	20%	150	1.5	30	20
Ringed-neck pheasant	40%	40	1.5	16	11
Woodcock	15%	50	2.2	8	3
Cottontail rabbit	40%	40	2.5	16	6

Most hunting preserve operations raise their pheasants in pens and release them just before hunting begins. Stocking rates are based not on habitat limitations, but on hunter expectations and the extent to which released birds escape from the hunting area. Publicly operated preserves release fixed numbers of birds daily based on historical trends in hunter numbers and acceptable success rates. For a private operator, stocking rates should be determined on the basis of the cost of stock versus the demand and fee charged for hunting opportunities.

Harvest Rates

Estimated annual natural yields per 100 ha for six common upland game species are shown in Table 3. These are calculated on the basis of typical population densities and kill rates. Hunter success rates and hunting opportunities per 100 ha are also shown. Quite large areas of good habitat are needed to sustain a hunting operation on the basis of natural reproduction. For example, a 100 ha property would sustain about six days of rabbit hunting and 18 days of deer hunting per year.

Revenue Sources

Game bird hunting preserves are run as either clubs or day use fee operations. Clubs charge initiation and annual fees, which can be quite high if top quality hunting and good club facilities are provided. Club members may also be charged a fee for each bird taken. Day use fee operations charge various mixtures of per head and per bird fees. Private day use preserves usually charge more than publicly operated game bird hunts, and provide higher quality, lower density hunting.

Landowners not interested in operating game bird hunting preserves may rent their lands to preserve operators and hunting clubs for their exclusive use, at least during hunting seasons. Prices will be determined by local conditions. Also, landowners often informally allow individuals or small groups to use their lands for hunting. Depending on the species sought, the quality of the habitat, local demand, and landowner attitudes, permission may be granted for nothing, for a nominal gift, or for a price. Prices are determined by local conditions, and, while still low, are probably greatest for quality deer and waterfowl hunting opportunities.

Managing and Monitoring Wildlife Areas

Some sites, such as game bird hunting preserves, waterfowl hunting areas, and protection areas near major population centres, may be relatively heavily used by the public. Specific user management programs may be needed to ensure that wildlife populations remain viable. These may include:

- control of access to the entire site, or to portions of the site at all times (refuge zones) or during critical seasons (nesting zones);
- depending on site objectives, prohibition of hunting or control of hunter numbers;
- in the case of a game bird hunting preserve, development and enforcement of appropriate rules in place of nonapplicable provincial regulations (seasons, bag limits, etc.).

Monitoring is another essential part of management. This is particularly important at heavily used hunting sites, but should not be ignored by anyone wanting to maintain wildlife uses over the long term. The following should be monitored:

- plant community development, to determine where vegetation control or replantings are required;
- wildlife population levels, to assess colonization rates, harvest impacts, habitat enhancement requirements, etc.;
- harvest characteristics (species, volumes, etc.), to assess stocking requirements, hunter management tactics, etc.;
- adjacent land use, to identify changes which will affect wildlife after uses and allow time to implement appropriate measures (buffer plantings, for example).

Operating Recreational Fish Ponds

Managing ponds to produce fish yields of consistent quality and quantity over the long term is more complex than managing wildlife habitats. Owners/operators needing more information than is provided here should consult local staff of the Ministries of Natural Resources, the Environment, or Agriculture and Food, depending on their particular needs.

There are two basic types of recreational fish ponds. The first provides private enjoyment for the owner/operator and his or her family, friends, employees, etc. (Figure 30). Angling pressure is relatively low, and management need not be intensive to provide a satisfactory recreational experience. Bass and panfish populations are often self-sustaining after initial stocking, while trout fisheries usually require additional stocking to maintain quality. The second type is a recreational facility open to the general public (Figure 31). Angling pressure is high, and intensive management and repeated stocking are essential. Public recreational ponds are usually licensed as fishing preserves and operate as entirely put and take fisheries.

Stocking

The species, number, and size of fish to be stocked are determined mainly by pond size, pond productivity (how much habitat and food are available, including opportunities for natural reproduction), water quality conditions, and the type, quality, and amount of angling desired. Where stocking is to be on a put and take basis, or where food supplements are to be provided, natural habitat and food availability are less important. However, water quality aspects, especially temperature and dissolved oxygen, and surface area must always be taken into account in deciding how to stock. A useful measure of angling quality is catch per unit effort, which for managed ponds is most commonly defined as numbers of fish taken per angler per hour. Catch per unit effort values average good and bad days, variable angler skills, and good and bad luck, all of which affect an angler's success rate on any given day. The total number of fish taken in a year will be a product of the number of anglers fishing, the hours each angler spends

Figure 30. *Rehabilitated private enjoyment recreational fish pond. The owner is providing supplemental food to enhance fish growth.*

Figure 31. *Rehabilitated public recreational fish pond. The shoreline and bank slope are designed to provide optimum shore angling. This pond is stocked annually with rainbow trout and has unlimited free access.*

fishing, and the catch per unit effort measured in fish per angler per hour. A change in any of these will require a change in stocking rates.

For private enjoyment trout ponds expected to provide between 250 and 500 hours of angling per year, the recommended initial stocking is 2,500 advanced fry or 750 to 1,250 fingerlings or 500 to 750 yearlings per hectare of surface water. Stocking with fry is cheaper than stocking with larger fish, but the fry are more vulnerable to predators such as other fish, water beetles, birds, etc. Trout stocked as yearlings should provide excellent angling if harvested in the same year. Stocking older fish on a put and take basis is acceptable, though expensive, if the owner/operator wants to be able to take larger fish immediately. However, older trout have short life expectancies, so stocking with older fish is not a good way of developing a self-sustaining population. If suckers, chub, bass, sunfish, etc. are already in the pond, they should be eliminated before stocking with trout fry or fingerlings, as these are vulnerable to predation and competition. However, other species do not need to be removed if larger fish are to be stocked on a put and take basis.

Largemouth and smallmouth bass can be initially stocked for private en-

joyment at 250 fingerlings or 60 yearlings or 25 adults per hectare, with variation for pond condition and anticipated angling quantity and quality. If fingerlings or yearlings are not available from a supplier, another way of developing a self-sustaining population is to stock about 50 7.5 to 15 cm long bass per hectare. Ayers et al. (1981) explain,

> "If parent fish are stocked, angling should be deferred until reproduction occurs with the successful production of progeny. While limited angling for the parent fish may then take place, care should be exercised to leave adequate brood stock for reproduction the next spring. In this way the initial parent stock will provide two-year classes of progeny. If fingerling bass are stocked, the first harvest will be delayed for one or two years, and caution must be observed to avoid over-exploitation of these fish until they have reached maturity and reproduced at least once and preferably twice.
>
> "The first appreciable harvest of bass can be made after the first progeny of the original parent stock reaches an age of two or three years and an acceptable size for angling. In each year thereafter a new class should appear in the fishery . . . ."

Stocking rates for public recreational ponds should be designed to maintain angler interest and stock turnover. The turnover, of course, provides the financial return to the operator. Some operators may stock fully grown catchable fish, usually about 25 to 30 cm long, while others may decide on a mixture of sizes and then provide food supplements to speed up growth. A public operation might begin by stocking 2,000 to 3,000 catchable size trout per hectare, and then restock as the initial supply is caught. Put and take stocking rates must assume that some fish will die and that others will be taken by predators. These losses can be as high as 15% to 25%.

According to Ayers et al. (1981),

> "Ponds should be stocked with trout of any size only at times when the pond water temperature approximates within a few degrees that of the hatchery from which the trout are procured. The problem of differences in water temperatures can be overcome most simply by restricting plantings to other than the warm summer months."

However, summer stocking cannot be avoided in well used public ponds. Smaller fish can be left in their oxygenated transport bags, and the bags placed in the pond until a temperature equilibrium is achieved. Larger fish, especially trout, can be stocked even if surface temperatures are high, as long as they have access to deeper, cooler waters.

Harvest Rates

Many people believe that self-sustaining bass or panfish pond fisheries are best maintained by taking only a few fish. However, the opposite is true. Harvesting as many fish as possible leads to maximum yields and enjoyment. Ponds used for private enjoyment and managed on a self-sustaining basis should be fished for at least 250 person hours per hectare each year. For maximum yields, angling should begin as soon as fish have reached an acceptable size, between about 13 and 18 cm. Fish should whenever possible be harvested before they are three years old. Once self-sustaining populations are established, they may reproduce quickly, and if not harvested, the result in a small pond will be large numbers of stunted fish. Heavy fishing pressure therefore keeps down losses from natural causes, prevents stunting, and helps ensure high angler success.

McCombie and Berst (1975) reported an average catch of 1.07 fish per angler hour at a 12 ha pond where a fishing club stocked 1,000 to 1,200 20 cm rainbow trout each year. The club members felt that the fishing was satisfactory. At a public day use pond, typical harvests per angler may be around 1.5 to 2.0 fish during a normal fishing period of one to two hours, or even half a day, though some anglers may take 10 or more fish in the same time period. Put and take ponds usually have higher success rates than ponds managed on a self-sustaining basis because stocking rates are also higher. The key to success in public recreational ponds is maintaining a high catch per unit effort. Obviously, anglers are not likely to come back unless they are satisfied with the pond's angling quality.

Maintenance Stocking

Trout ponds with good natural reproduction will usually provide harvests satisfactory for private enjoyment without maintenance stocking. However, not all pit and quarry ponds are ideal environments for trout reproduction, even with proper rehabilitation. In these cases, maintenance stocking may be needed to provide the angling desired over the long term.

According to Ayers et al. (1981),

> "Maintenance stockings should be based on a knowledge of the past performance of the fishery, whether or not there is natural reproduction in the pond. . . . accurate harvest records should be kept which will indicate trends in fishing quality and serve as a guide for stocking rates. . . . Under conditions of heavy fishing pressure and high harvest levels, stocking on a put-take basis may extend over the fishing season. If predation on newly stocked fish by larger resident trout is to be avoided, it is necessary to plant yearling or older trout. Stocking with trout of this size provides more or less immediate angling. An alternative is to stock larger quantities of fry or fingerling trout with the understanding that a portion of the planting will provide forage for larger resident trout. In most situations, there is adequate escapement and survival of young trout to maintain angling of the desired quality.
>
> "If based on a knowledge of the past fishing and future angling requirements, maintenance stocking with trout of any size is a satisfactory management procedure."

Private enjoyment ponds managed for warm water species such as largemouth bass also may or may not need maintenance stocking, depending on the quality of the environment for natural reproduction.

Maintaining natural populations is not an issue in put and take ponds. Continuing supplies of fish are provided just by replacing them as needed. To keep angling quality high, it may be necessary to restock often during the season, and follow specific strategies such as stocking before weekends, reducing supplemental feeding during peak use periods, etc.

Revenue Sources

Fishing preserves are run as either clubs or day use fee operations. Clubs charge initiation and annual fees, which can be quite high if top quality angling and good club facilities are provided. Public day use operations normally charge an admission fee per head, plus a fee per fish. Per fish charges may be based on numbers, weight, or length. On average, each visitor will take about two fish. To recover its operating costs, a typical fee operation will need to admit 5,000 to 10,000 anglers per season (usually late April to Labour Day). There are many promotional incentives which operators can use to attract business, including prizes for trophy fish, fishing derbies, and various angler awards.

Landowners not interested in operating fishing preserves may rent their ponds to fishing clubs for their exclusive use. Prices will be determined by local conditions. Landowners also often informally allow individuals or small groups to use their lands for angling. Depending on angling quality, local demand, and landowner attitudes, permission may be granted for nothing, for a nominal gift, or for a price. Prices are determined by local conditions, and are usually low.

Management and Monitoring

Fishing preserves are relatively heavily used by the public. Specific user management programs may be needed to ensure that fisheries and angling quality remain viable. These may include control of angler numbers, and development and enforcement of appropriate rules in place of nonapplicable provincial regulations (seasons, catch limits, etc.).

Monitoring is another essential part of management. This is particularly important for heavily used ponds, but should not be ignored by anyone wanting to maintain fisheries uses over the long term. The following should be monitored:

- harvest characteristics (volumes, species, lengths, weights), to assess

stocking requirements, reproductive success, and general fisheries health;

- water quality characteristics, in particular temperature and dissolved oxygen, to ensure continued suitable conditions for survival and reproduction.

Operating Commercial Fish Farms

Commercial fish farming in rehabilitated pit and quarry ponds can produce fish for food or stock, or bait fish, and can be carried out to whatever intensity the owner/operator desires. However, a serious commercial venture requires high intensity cultivation and management. The most common food and stock species is rainbow trout. Fish can be raised using an entire pond as habitat, or in cages suspended in the pond. The cages are made of wire or fibre mesh supported on wood frames, and can be floated in the middle of a pond (Figure 32) or tied to a dock. Wind and currents carry waste products away from the cages, and provide a continuous supply of fresh, oxygenated water. The cage technique can provide a low cost entry into the intensive commercial aquaculture market.

Stocking and Harvesting

Fish farming using entire ponds is common in Manitoba and Saskatchewan. There, about 750 to 1,000 8 to 10 cm rainbow trout fingerlings per hectare of surface water are stocked in spring, and can more than triple their weight by late fall when they are harvested. Most Ontario pit and quarry ponds are much less productive than the shallow sloughs used for fish farming on the Prairies. Fish farming using whole pit ponds can therefore only succeed in Ontario if productivity is artificially increased, the production cycle is lengthened beyond one season, or fewer fish are stocked.

Operators planning to overwinter fish in whole ponds should closely monitor dissolved oxygen to ensure that at least 2 mg/L is available between January and March. This value, although considerably less than ideal, will allow the fish to survive at low temperatures when their metabolic activity is low. Fingerlings should not be stocked in whole ponds in the spring of the second year, because the older fish will prey on them. Where pond productivity enhancements or supplementary feeding support fast enough growth, fish can be harvested in the fall or early winter. This will avoid problems of winter kill and spring predation.

Fish stocked in whole ponds are most efficiently harvested with nets. While gill nets are easier to handle in larger ponds, seine nets can be used in ponds of 0.5 ha or less. Gill nets can also be set under ice using a specialized ice jigger. Netting requires a permit from the Ministry of Natural Resources.

Figure 32. *Fish rearing in cages. (courtesy Ministry of Natural Resources, Espanola District)*

Two strategies are available for cage stocking. An operator can stock to a final density (expressed in kilograms of fish per cubic metre of water), and thin out his stock as the fish grow, or he can stock at a lower density, with the fish growing to reach a final density at harvest time. In either case, the stocking and mesh sizes must be chosen to ensure that the caged fish do not escape. Cage systems can support final densities of 15 to 30 kg/m^3; the high end of this range can be reached by skilled operators in especially suitable locations.

While overwintering fish in cages may be possible in some ponds, freeze-up prevents normal feeding practices. Accordingly, most cage operators harvest their entire stock in the late fall. If the fish are to be overwintered, the area around the cages should be kept ice free. This can be done using an aeration device. Supplemental aeration may also be required in the summer.

Monitoring

Water quality characteristics, especially temperature and dissolved oxygen, should be monitored regularly to ensure that conditions remain suitable for fish survival, particularly in cage areas.

Common Fisheries Problems

Groundwater Problems

Groundwater flows may change from time to time, especially if extraction operations and pit dewatering are continuing elsewhere on the site. If extraction is still continuing, care must be taken not to draw down groundwater to where designed fish ponds become too shallow or stagnant. Slow, continuous dewatering is better than a purge type drawdown, as it will not cause as great changes in levels. Groundwater flows may also be interrupted if storm or sanitary sewers are installed to serve nearby residential developments. Infiltration of groundwater into the new systems can lower the local water table.

Groundwater is seldom polluted, and its quality for fish pond purposes is usually good. The most common quality problem occurs when contaminated surface water, or runoff with high sediment concentrations from extraction operations, mixes with groundwater. This can be avoided by proper drainage and treatment of surface waters and operation discharges. Groundwater from deep wells, or from springs originating in soils high in organics, may be supersaturated with nitrogen or hydrogen sulphide. This can be offset by aerating the water, either with fountains or by allowing it to cascade over a series of baffles.

Most groundwater has low concentrations of the essential nutrients phosphorus and nitrogen, so ponds heavily dependent on groundwater inflows are usually not very productive. Nutrients can be added to improve productivity. Dosage rates will depend on the species desired and the pond's volume and flushing rate.

Surface Water Problems

All streams or overland drainage entering a rehabilitated fish pond should be as close to pollution free as possible. Drainage from agricultural, industrial, and urban sources should be treated or diverted around the pond. Drainage from these sources may contain fertilizing elements such as phosphorus and nitrogen which can cause excessive algae and weed growth. These growths can undermine a pond's aesthetic appeal and interfere with angling. Decomposing algae and weeds can also severely deplete dissolved oxygen in late summer and late winter, causing fish kills. As well, herbicides and pesticides are frequently applied to farm fields and road and utility rights of way. Many trout fisheries have been destroyed by toxic shock loads in waters flowing from these sources.

Seepage

Pond waters can be lost through seepage, often because underlying soils are too permeable or bottom sediments are not compacted enough. This type of seepage can be overcome by adding an impervious layer of compacted soil to a pond's bottom. Placing plastic sheets covered with earth on the bottom has also proven successful in ponds small enough that costs are not prohibitive.

Turbidity

Muddy water seldom kills fish, although it may slow growth, affect flesh taste, and impair pond aesthetics. However, high turbidity may prevent growth of desirable floating and submerged aquatic vegetation. Turbidity is best controlled by stabilizing banks or by diverting any turbid water draining into the pond. Where turbidity cannot be controlled by these methods, and particularly where clays form part of the pond bottom, 200 kg of natural gypsum or 50 kg of commercial aluminum sulphate can be added per 1,000 m^3 of water.

Excessive Aquatic Vegetation

Although aquatic plants are essential components of good fisheries habitat, excessive growths can use up dissolved oxygen, impair pond aesthetics, and interfere with angling and other recreational uses such as swimming and boating. There are three ways to control weeds in ponds.

Mechanical control. Weeds can be removed temporarily using rakes, chains dragged through the weeds, or small boat-mounted cutters. Whatever method is used, floating fragments will remain afterwards and have to be removed, usually manually. Large scale weed harvesters are available and operate successfully on larger lakes, but the costs of bringing these in to small ponds will usually be prohibitive.

Habitat manipulation. Water can be drawn down over the winter, so that aquatic plants will freeze and die. Obviously, this can only be done in ponds without self-sustaining fish populations. Weed barriers which can be lain over growths are now available. These continuous nylon sheets are heavier than water and are coloured with a black pigment to block the light. The manufacturers claim that heavily weeded areas can be cleared in about a month, and that the weeds will not return as long as the barriers stay in place and sedimentation is light.

Chemical control. Chemicals are most practical for short term weed control because they can be easily applied. It is important to ensure that an algicide or herbicide which kills nuisance plants does not at the same time affect fish or other desirable aquatic life. Anyone applying a pesticide directly to surface waters must obtain an aquatic nuisance control permit from the Ministry of the Environment.

Fish Kills

Oxygen depletion problems are most common in late winter, when decomposition of the previous year's vegetation uses up much of the oxygen that fish need. There can also be summer fish kills in shallow, very weedy ponds, at night when oxygen consumed by plant respiration counterbalances daytime oxygen produced by photosynthesis, and on calm, cloudy days when photosynthesis and aeration are low.

Summer and winter kills from inadequate oxygen can usually be avoided by deepening part of a pond to 3 m or more, or by controlling aquatic vegetation using the methods discussed above. Dissolved oxygen can be added directly to ponds with a surface aerator or a small compressor and air diffuser line. As well, winter dissolved oxygen levels can sometimes be increased, particularly on smaller ponds, by clearing the ice to allow light penetration and photosynthesis, but the benefits often may not be worth the considerable effort involved.

Fish can die from too high summer water temperatures. While this problem is not easy to overcome, some attached plants, in particular Chara, can

have a shading effect and provide a layer of cool water at the bottom of a pond.

Waste products and uneaten food can build up below commercial fish cages and lead to water quality problems, especially dissolved oxygen depletion, if ponds are too shallow, small, or stagnant. Cage culture is best suited to ponds over 5 ha with depths of at least 5 m and reasonably high flushing rates. Waste buildup below the cages can be kept down by moving the cages within the pond every year or two.

Undesirable Fish

Ayers et al. (1981) report that,

> "The problem may concern overpopulation by a preferred species (e.g. largemouth bass or bluegills), the presence of a few large predaceous fish (e.g. trout), or an abundance of coarse fish such as suckers, creek chub and bullheads. . . .
>
> "Ponds may be reclaimed by draining, poisoning with a fish toxicant, or a combination of both methods. In most cases it is impossible to eliminate a fish population merely by draining the pond and the use of a fish toxicant is necessary to ensure success. . . .
>
> "Rotenone derivatives . . . are usually recommended at an application rate of [2 mg/L] . . . .
>
> "Before any poisoning procedure is undertaken, it is essential that there is an absolute control of the water leaving the pond unless it is certain that there will be no harmful consequences in allowing the treated water to pass downstream. Where possible, the pond should be drained previous to poisoning. This has two advantages: first, the volume of water requiring treatment is considerably less and second, the chemical becomes diluted to a sub-lethal level as the pond refills. Rotenone deteriorates rapidly and the pond will usually be ready for restocking within five or six weeks."

If there is any possibility that rotenone might contaminate downstream fisheries, it would be safer to apply the chemical at 0.5 mg/L for four days, for example, than at 2 mg/L for one day. As with algicides and herbicides, a permit from the Ministry of the Environment is needed for any use of rotenone.

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Appendix 1 — Ministry of Natural Resources District Offices

ALGONQUIN PARK
P.O. Box 219
Whitney
K0J 2M0
(613) 637-2780

ATIKOKAN
108 Saturn Avenue
Atikokan
P0T 1C0
(807) 597-6971

AYLMER
353 Talbot St. West
Aylmer
N5H 2S8
(519) 773-9241

BANCROFT
Highway 28
Bancroft
K0L 1C0
(613) 332-3940

BLIND RIVER
62 Queen Street
Blind River
P0R 1B0
(705) 356-2234

BRACEBRIDGE
P.O. Box 1138
Bracebridge
P0B 1C0
(705) 645-8747

BROCKVILLE
Oxford Avenue
Brockville
K6V 5Y8
(613) 342-8524

CAMBRIDGE
Beaverdale Road
Cambridge
N3C 2W1
(519) 658-9355

CARLETON PLACE
10 Findlay Avenue
Carleton Place
K7C 3Z6
(613) 257-5735

CHAPLEAU
190-192 Cherry Street
Chapleau
P0M 1K0
(705) 864-1710

CHATHAM
435 Grand Ave. West
Chatham
N7M 5L8
(519) 354-7340

COCHRANE
2 Third Avenue
Cochrane
P0L 1C0
(705) 272-4365

CORNWALL
113 Amelia Street
Cornwall
K6H 5V7
(613) 933-1774

DRYDEN
479 Government Road
Dryden
P8N 2Z4
(807) 223-3341

ESPANOLA
148 Fleming Street
Espanola
P0P 1C0
(705) 869-1330

FORT FRANCES
922 Scott Street
Fort Frances
P9A 1J4
(807) 274-5337

GERALDTON
208 Beamish Ave. West
Geraldton
P0T 1M0
(807) 854-1030

GOGAMA
Low Avenue
Gogama
P0M 1W0
(705) 894-2000

HEARST
631 Front Street
Hearst
P0L 1N0
(705) 362-4346

HURONIA
Midhurst
L0L 1X0
(705) 728-2900

IGNACE
Highway 599
Ignace
P0T 1T0
(807) 934-2233

KAPUSKASING
6-8-10 Government Road
Kapuskasing
P5N 2W4
(705) 335-6191

KENORA
808 Robertson Street
Kenora
P9N 1X9
(807) 468-9841

KIRKLAND LAKE
P.O. Box 129
Swastika
P0K 1T0
(705) 642-3222

LINDSAY
322 Kent St. West
Lindsay
K9V 4T7
(705) 324-6121

MAPLE
10401 Dufferin Street
Maple
L0J 1E0
(416) 832-2761

MINDEN
Minden
K0M 2K0
(705) 286-1521

MOOSONEE
Revillon Road
Moosonee
P0L 1Y0
(705) 336-2987

NAPANEE
1 Richmond Boulevard
Napanee
K7R 3S3
(613) 354-2173

NIAGARA
Highway 20
Fonthill
L0S 1E0
(416) 892-2656

NIPIGON
Highway 17
Nipigon
P0T 2J0
(807) 887-2120

NORTH BAY
R.R. 3
Hwy. 63
North Bay
P1B 8K7
(705) 474-5550

OWEN SOUND
611 Ninth Ave. East
Owen Sound
N4K 3E4
(519) 376-3860

PARRY SOUND
4 Miller Street
Parry Sound
P2A 1S8
(705) 746-4201

PEMBROKE
Riverside Drive
Pembroke
K8A 6X4
(613) 732-3661

RED LAKE
Highway 105
Red Lake
P0V 2M0
(807) 727-2253

SAULT STE. MARIE
875 Queen St. East
Sault Ste. Marie
P6A 5L5
(705) 949-1231

SIMCOE
548 Queensway West
Simcoe
N3Y 4T2
(519) 426-7650

SIOUX LOOKOUT
Prince Street
Sioux Lookout
P0V 2T0
(807) 737-1140

SUDBURY
P.O. Box 3500
Sta. A
Sudbury
P3A 4S2
(705) 522-7823

TEMAGAMI
Lakeshore Drive
Temagami
P0H 2H0
(705) 569-3622

TERRACE BAY
P.O. Box 280
Terrace Bay
P0T 2W0
(807) 825-3205

THUNDER BAY
435 James St. South
Thunder Bay
P7E 6E3
(807) 475-1471

TIMMINS
896 Riverside Drive
Timmins
P4N 3W2
(705) 267-7951

TWEED
Metcalfe Street
Tweed
K0K 3J0
(613) 478-2330

WAWA
22 Mission Road
Wawa
P0S1K0
(705) 856-2396

WINGHAM
R.R. 5
Wingham
N0G 2W0
(519) 357-3131

Appendix 2 — Fish and Wildlife Regulations

The following summary is presented as a convenience for readers of this publication, and was current as of early 1986. Owners/operators should contact the responsible agencies directly for detailed, up to date information on applicable regulations.

Wildlife Areas

Use of areas rehabilitated to wildlife after uses is subject to the following regulations (all administered by the Ministry of Natural Resources):

- hunting is subject to standard provincial regulations for upland game (except on game bird hunting preserves), and standard federal regulations for waterfowl;
- trapping is subject to standard provincial regulations;
- raising and selling game birds requires a provincial licence;
- operating a game bird hunting preserve requires a provincial licence.

Game bird propagation and sale licences apply to bobwhite quail, wild turkey, and pheasant only. They simply permit operators to buy, raise, and sell these species, and are issued annually. Only pheasant can be sold for food; quail and turkey can only be sold to other holders of game bird propagation and sale licences, or holders of game bird hunting preserve licences. No other species of game bird may be bought, raised, or sold.

Game bird hunting preserve licences also apply to bobwhite quail, wild turkey, and pheasant only. They permit operators to own or operate preserves, and exempt the preserves from standard season, daylight, and kill/possession limits for those species under provincial hunting regulations. These licences are issued annually. A preserve must be at least 40 ha in size. No other species of game bird may be hunted on a game bird preserve except under standard provincial regulations.

Fisheries Areas

Use of areas rehabilitated to fisheries after uses is subject to the following regulations (administered by the Ministry of Natural Resources except where noted):

- sport fishing is subject to standard provincial regulations under the Fisheries Act (Canada) (except on fishing preserves);
- alteration of natural watercourses is subject to approval under the Lakes and Rivers Improvement Act (Ontario);
- withdrawal of large quantities of water (over 50,000 L per day) and discharge of waste water from a commercial facility are subject to Ministry of the Environment approval;
- raising fish for the purpose of sale, and selling raised fish, require a provincial licence or licences;
- operating a fishing preserve requires a provincial licence;
- interprovincial or international trade in fish eggs and cultured fish is subject to the Fish Health Protection Regulations (Canada), administered by the Ministry of Natural Resources and the Canada Department of Fisheries and Oceans;
- use of chemicals for control of aquatic nuisance organisms requires Ministry of the Environment approval.

Fish propagation and sale licences apply to smallmouth bass, largemouth bass, brook trout, and rainbow trout only. They permit operators to raise these species in artificial ponds which are not part of natural watercourses, or in natural ponds from which there is no outflow. While all four species may be sold for stocking purposes, only trout can be sold for food.

Current plans are for the list of eligible species to be broadened. At present, however, no other species of fish can be cultured for sale. The licences are issued annually.

Fishing preserve licences permit the operation of preserves in artificial ponds which are not part of natural watercourses. Fish which can be stocked are limited to those raised under fish propagation and sale licences, or those harvested commercially. Licences exempt fishing preserves from standard provincial angling season and catch/possession limits. The licences are issued annually.

Appendix 3 — Potential Assistance Programs

The following summary is presented as a convenience for readers of this publication, and was current as of early 1986. Owners/operators should contact the responsible agencies directly for detailed, up to date information on assistance programs.

The *Community Wildlife Involvement Program* and *Community Fisheries Involvement Program*, administered by the Ministry of Natural Resources, provide advice, equipment, and materials to volunteer groups undertaking projects to improve wildlife and fisheries habitats and populations. All labour must be voluntarily contributed by the interested group, and the project must provide conservation or recreation benefits to the general public rather than private individuals or groups alone. Projects under these programs may be carried out on private lands with landowner cooperation. Therefore pit and quarry owners/operators willing to work with local volunteer groups can utilize these programs to achieve fish and wildlife rehabilitation and management at little cost to themselves, provided that the rehabilitation is consistent with program objectives. Owners/operators may also realize significant public relations returns from working with community groups on conservation or recreation projects of public benefit. Field manuals outlining specific rehabilitation techniques are available for each program.

Ducks Unlimited assistance generally consists of payment for, installation of, and management of enhanced waterfowl habitat directly by the agency. The owner signs an agreement with Ducks Unlimited permitting the agency to carry out the work agreed to. The owner is not required to provide public access, as the agency's objective is to benefit hunters at large through enhanced migratory bird habitat. The decision as to whether a specific project would merit assistance is made on a case by case basis by Ducks Unlimited.

The *Farm Tax Reduction Program* administered by the Ministry of Municipal Affairs provides for a 60% reduction of property taxes on assessed farm lands which form part of productive farming enterprises. Qualifying farming enterprises must normally produce at least $8,000 worth of farm products per year ($5,000 in eastern and northern Ontario). Lands used for production of fish and game for sale as food or husbandry stock are assessable as farm lands. Assessors may split individual properties into farm and non-farm (commercial, residential, etc.) portions. Lands may be leased to hunting clubs while retaining a farm land status provided that they remain integral parts of a farm operation and that the hunting use is clearly subsidiary.

A wide range of *Ministry of Agriculture and Food assistance programs* are also available to food producers, including in some cases those producing fish and game for food. Among the programs for which fish and game producers are potentially eligible are the Beginning Farmer Program, Young Farmer Credit Program, and Soil Conservation and Environmental Protection Assistance Program. Each program has its own set of criteria.

The *Woodlands Improvement Program*, administered by the Ministry of Natural Resources, enables the Ministry to enter into agreements with landowners to provide reforestation and stand improvement assistance. The Ministry specifies and arranges for the work to be done, while the owner commits the land to forestry for a 15 year period and pays for any nursery stock planted. While reforestation and forest productivity improvement are the objectives of this program, the actions involved can often help develop or improve wildlife habitat.

The *Managed Forest Tax Reduction Program*, administered by the Ministry of Municipal Affairs, provides for a 60% property tax rebate for managed forest lands. These lands include those under a Woodlands Improvement Act agreement or other forest management plan, as well as larger woodlots which meet minimum standards of conservation.

Appendix 4 — Wildlife Groups: Habitat Requirements and Information Needs

		RELEVANCE TO WILDLIFE HABITAT REQUIREMENTS		
Baseline information	**Rationale**	**aquatic/shoreline group (a)**	**agricultural/old field group (b)**	**immature forest group (c)**
Geographic location	• determines whether site is within natural range of species	• throughout Ontario	• naturally sustaining populations restricted to southern Ontario	• throughout Ontario
Nature of the deposit (composition, depth, distribution), particularly relationship between pit floor and groundwater elevation	• determines eventual area, depth, and configuration of extracted portion of site, slopes and heights, and ratio of upland to lowland sites • indicates water availability for pond or wetland development, and pond size and morphometry	• prefer shallow (1 m) ponded areas over 1 ha, with low banks	• prefer protected south facing slopes in winter, associated with dry and moist sites	• prefer mixture of dry upland sites with moist habitats
Nature of overburden (composition, depth, distribution); volume of excess sands, clay lenses, fines	• estimates the amount of material available for creating landforms	• prefer irregular shoreline with peninsulas, and wide, low shoreline zones and offshore bars and islands • high overburden to deposit ratio is an advantage	• prefer irregular topography with 1-3 m local variation	• prefer rolling terrain or deep valley land systems
Nature of topsoil (texture depth, chemistry)	• indicates amount and quality of material available for vegetation (soil capability for establishing the appropriate food and cover plant species)	**Cover:** • prefer tall dense herbaceous wet shoreline vegetation (e.g., cattails, bur-reed, giant reed) • require herbaceous dry shoreline vegetation - grass species • need loafing areas including islands, logs and bare shorelines	**Cover:** • prefer tall seed producing annual or perennial herbaceous vegetation • also, conifer plantations (0.25-0.5 ha) may be used for roosting • shrubby valleys provide winter cover	**Cover:** • deer and grouse both require substantial conifer or dense shrub thickets in winter • deer require fairly extensive (minimum 20-25 ha) woodland system during winter for protection and escape • during other parts of year, deer may be found in open agricultural land with scattered woodlots • grouse favour early growth coppices and are highly associated with early successional forest communities

Food:
- prefer highly productive ponds
- introduction of aquatic vegetation is a good management tactic (e.g., pondweeds)
- areas of gravelly shore may be used for grit

Food:
- favour corn, grain and fruits
- also feed on weedy species associated with disturbed sites
- in winter, require food sources above the snow (uncut corn rows, persistent weed stalks, grapes, apples, and thorn apples)

Food:
- deer feed on herbaceous foliage and prefer productive agricultural land; will feed in wooded or open sites, and favour apples, thorn apples, acorns, corn and various agricultural crops
- winter food for grouse consists primarily of ironwood buds in Southern Ontario; will eat berries, grapes, fruits, herbaceous leaves (clover, strawberry), and grains if adjacent to suitable habitat

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NOTES: (a) Includes mallard, wood duck, Canada goose, blue-winged teal, muskrat, mink, raccoon, marsh wren, great blue heron, etc.

(b) Includes ring-necked pheasant, Hungarian partridge, cottontail rabbit, red fox, raccoon, field sparrow, red-tailed hawk, etc.

(c) Includes deer, ruffed grouse, woodcock, coyote, cardinal, white- throated sparrow, catbird, etc.

Appendix 5 — Fish Groups: Habitat Requirements and Information Needs

Baseline information	Rationale	RELEVANCE TO FISHERIES HABITAT REQUIREMENTS cold water species group	 warm water species group
Nature of the deposit (composition, depth, and distribution)	• determines lake geometry including maximum and mean depths, surface area, and shoreline configuration	• prefer deeper ponds (maximum depths >3 m) where bottom temperatures during midsummer will remain cool (<21°C) and dissolved oxygen concentrations will exceed 5 mg/L • ponds with continuous flows can be shallower; in ponds with low or intermittent flows, part of the pond should be at least 4.5 m deep • if good harvests are desired, surface area should be at least 0.1 ha; ponds 0.2-0.8 ha generally give the least management problems, although ponds 2-4 ha can be managed to provide excellent angling	• prefer shallow ponds (maximum depths <3 m) where bottom temperatures during midsummer will remain warm (>21°C) • water supply should be adequate to maintain water levels, and compensate for seepage and evaporation losses • management is easier in ponds 0.8-2.0 ha in area, although ponds as small as 0.1 ha and as large as 40 ha are satisfactory • average depth should be 2.0-2.5 m, with some areas of water >4 m, to minimize winter kill from dissolved oxygen depletion
Depth to groundwater table (relative to eventual pit floor elevation and topography)	• indicates water availability for pond development, size, and configuration	• require constant supply of cool, clear water; accordingly, groundwater is preferred source of supply	• groundwater can be used; however, if water temperatures between early May and late October are too cool (<21°C at bottom of pond), fish growth will be poor
Location of surface waters and overland drainage characteristics	• indicates water availability for pond development	• headwater streams are likely to provide satisfactory sources of cool water • ponds constructed on lower reaches of streams often may be managed for trout production, given satisfactory temperatures; however, management may be more difficult because of flow variability and extremes in water quality conditions	• stream water temperature is generally satisfactory; however, can be problems of water quality control and variable or extreme water quality conditions if site is in lower part of watershed
Flushing rate	• determines ability to maintain long term water quality conditions	• an outflow of 0.03-0.15 m^3/sec per hectare of surface area is a good flushing rate guideline, although higher and lower flows can provide excellent trout waters	• intermittent water flows are acceptable, as long as water levels are stable and losses owing to evaporation and seepage are adequately compensated for
Runoff quality	• determines ability to maintain healthy fish stocks	• runoff water must be retained, controlled, or treated to deal with contaminants from within the site (suspended solids and turbidity generated by mining operations) and outside (nutrients, herbicides, insecticides, and other chemical pollutants)	

Appendix 6 — Fish Species: Habitat Requirements

Species	Preferred habitat	Preferred food	Spawning habits	Nursery areas	Forage zones
Brook trout	permanently clear, cold springfed water; abundant cover from branch overhangs, logs, etc; sand and gravel bottom with occasional muck, marl, and clay	carnivorous on a wide range of organisms including terrestrial and aquatic insects and their larvae, snails, clams, crayfish, worms, leeches, and small fish	in fall, on gravel beds in shallow stream headwaters or on gravelly shallows of lakes where there is a spring upswelling and moderate current; low water temperatures; restocking often required	areas under cover along stream banks or shallow areas in lakes	nearshore zones or open lakes
Rainbow trout	similar to brook trout, but species is more adaptable to a wider range of conditions	various invertebrates including plankton, terrestrial and aquatic insects and their larvae, crustaceans, snails, leeches and other small fish; feed on bottom most often, but behaviour of rising to surface to take emerging or egg-laying insects is well known to anglers	in spring, on gravel or rubble substrates in riffle areas of streams; some fall spawning also occurs; water temperatures 10°to 15°C; can spawn in ponds with gravel bottoms and inflowing, springfed streams accessible during spawning; otherwise restocking is required for pond populations	streams or lakes	open lakes and nearshore areas
Smallmouth bass	waters clear and rocky enough to be suitable to trout, but with water temperatures too high for trout	insects, crustaceans, and small fish, taken from the surface, in the water off bottom	May to early July, on gravel or rocky substrate at least 50 cm deep, with rocks, logs, or vegetation nearby for protection; water temperature 12° to 20°C; does not generally spawn in ponds	shallow, weedy areas	nearshore and open water areas
Largemouth bass	adaptable to a large variety of habitats from smallmouth bass waters to shallow ponds; prefers muck bottom with an abundance of aquatic vegetation; can withstand higher temperatures than smallmouth bass, and quite low dissolved oxygen levels for short periods of time	largely fish eating predators, but also consume frogs, crayfish, leeches and insects; food taken at the surface (morning and evening), in the water (during day) and from bottom	late spring to mid summer, peaking in early June, on marl or soft mud or sometimes sand, 50 to 150 cm deep, among emergent vegetation such as reeds, bulrushes, water lilies; water temperature 16°to 18°C; usually self-sustaining after initial stocking	shallow, weedy areas	nearshore and open water areas, although most often found in mud-bottomed areas with extensive vegetation growths

Appendix 6 — Continued.

Species	Preferred habitat	Preferred food	Spawning habits	Nursery areas	Forage zones
Catfish	mud bottom, with or without plant life	wide variety of plant and animal material including bottom dwelling molluscs, crayfish and other insects, algae, some vascular aquatic plants, and small fish	spawn in late spring to early summer in secluded, semidark nests in holes, undercut banks, log jams, or rocks; usually self-sustaining after initial stocking	initially, on lake or stream beds, then near surface	cool, clear, deeper water with sand, gravel, or rubble bottoms
Carp	thrive in moderately warm shallow waters of lakes and rivers with abundant aquatic vegetation and deeper places for retreat; very adaptive to a wide range of water quality and bottom conditions, and can survive in drying ponds long after other fish have died because of their ability to take oxygen from the air	omnivorous, with many kinds of insects, crustaceans, worms, and molluscs common; plant material includes algae, weeds, plant seeds, wild rice, etc.	spring to early summer, in weedy or grassy shallow areas; eggs are adhesive and cling to plant material, roots, etc.; often detrimental to spawning success of other species	shallow, weedy areas	nearshore and deeper waters
Panfish (rock bass, pumpkinseed, bluegill, etc.)	clean flowing streams and weedy ponds with sand and gravel bottoms, and rocks, submerged logs, and other substrates to provide cover	small insects and their larvae, and small fish	early summer, in areas ranging from swamps to gravel shoals; water temperatures for rock bass 16°to 21°C; usually self-sustaining after initial stocking; can overpopulate if not angled	shallow nearshore zones	shallow nearshore zones

Sources: Scott and Crossman (1973) and Ontario Ministry of Natural Resources (1984).

Appendix 7 — Fish Species: Water Quality Criteria

Requirements	Rainbow trout	Brook trout	Smallmouth bass	Largemouth bass	Catfish	Carp	Panfish	Comments
Preferred temperature (°C)	18-22	16-18	19-31	29-32	n.a.	n.a.	n.a.	Preferred temperature ranges from the literature.
Dissolved oxygen (mg/L)	>5-6	>5-6	>3	>2	>2	>2	>3	Minimum requirements, providing maintenance conditions only.
Alkalinity	20-200 mg/L for all species							Low alkalinity can result in slow growth rates and poor conditions; soft and hard water means an alkalinity of less than and more than 100 mg/L respectively.
pH	6.5-8.6 acceptable, but 7.5-8.0 preferred for all species							Low pH increases susceptibility to disease, probably by decreasing protective capability of mucous coat.
Suspended solids (mg/L)	<80 normally, but higher values acceptable during periods of high rainfall and spring thaw events							High suspended solids may clog gill tissues, decrease growth rates, and increase susceptibility to bacterial gill diseases. Levels >80 mg/L are likely needed to affect warm water fish stocks.
Non-ionized ammonia (mg/L)	<0.005	<0.005	<0.02	<0.02	<0.02	<0.02	<0.02	Some water supplies may contain unacceptably high nitrogen levels. Nitrogen is also a major byproduct of fish metabolism, and exists in two forms, NH3 and NH4+, depending on pH and temperature. The non-ionized form is toxic and becomes more prevalent at higher pHs. Criteria for warm water species are slightly higher than values for cold water species.
Dissolved nitrogen	<102% saturation for nitrogen, or total gases if measuring total gas pressures							Groundwater can often be deficient in dissolved oxygen and supersaturated with dissolved nitrogen. Fish retained in water supersaturated with dissolved nitrogen develop gas bubble disease, as nitrogen is released from the blood.
Hydrogen sulphide (mg/L)	<0.002 preferred for all species							Hydrogen sulphide is often present in ground water and can be harmful to fish growth; criteria for warm water species are likely to be similar to values for cold water species.
Copper (mg/L)	<.03 preferred for all species							
Iron (mg/L)	<1.0 preferred for all species							

Sources: Ontario Ministry of the Environment (1984), Ontario Ministry of Natural Resources (1981 and 1984), Ayers et al. (1981), and McCauley and Casselman (1981).

Appendix 8 — Plant Selection Guide for Revegetating Wetlands

Species	Moist shorelines	Wet shorelines	Shallow nearshore zone (<0.5 m)	Deep nearshore zone (0.5-1.0 m)	Open water (>1 m)
Bent grasses (*Agrostis* spp, *Puccinellia* spp.)	X				
Cut grass (*Leersia oryzoides*)	X				
Reed bentgrass (*Calamagrostis canadensis*)	X	X			
Reed canary grass (*Phalaris arundinacea*)	X	X			
Manna grass (*Glyceria canadensis, G. grandis*)	X	X			
Wool bulrush (*Scirpus cyperinus*)	X	X			
Pickerel weed (*Pontedaria cordata*)			X		
Arrowhead (*Sagittaria latifolia*)			X		
Cat-tail (*Typha latifolia, T. angustifolia*)			X	X	
Giant reed (*Phragmites australis*)			X	X	
Great bulrush (*Scirpus validus, S. acutus*)			X	X	
Bur-reed (*Sparganium* spp.)			X	X	
Water lily (*Nymphaea odorata*)				X	X
Pond lily (*Nuphar variegatum*)				X	X
Pondweeds (*Potamogeton* spp., especially *P. pectinatus*)					X

Appendix 9 — Plant Selection Guide for Revegetating Uplands

Species	SITE REQUIREMENTS Moisture	Fertility	VALUE TO WILDLIFE SPECIES Food	Cover
TREES:				
red maple (*Acer rubrum*)	moist to wet	medium	young twigs, winter browse material	generally good for early growth coppice for grouse
balsam poplar (*Populus balsamifera*)	dry to wet	low to high		general cover in early succession phases; typical early colonizer of sand and gravel pits
trembling aspen (*Populus tremuloides*)	dry to moist	low to medium	winter browse material	general cover in early succession phases; spreads vegetatively to form groves; typical early colonizer of sand and gravel pits
pin cherry (*Prunus pensylvanica*)	dry	low to medium	berry production; winter browse material	good dense cover in early successional phases; spreads vegetatively to form thickets and groves
eastern red cedar (*Juniperus virginiana*)	dry	low to medium		general cover in open settings; good for forming glades
tamarack (*Larix laricina*)	moist to wet	medium to high		general conifer cover
white spruce (*Picea glauca*)	moist to wet	low to medium		general conifer cover
white pine (*Pinus strobus*)	dry to mesic	low to medium		general conifer cover; occasionally colonizes pits where there are adjacent seed sources
white cedar (*Thuja occidentalis*)	dry to wet	low to medium		excellent conifer cover on variety of sites; forms open glades to dense woods
apple (*Malus* spp.)	dry to mesic	medium to high	fruit production for variety of wildlife species; fruit valuable as winter food source	

Appendix 9 — Continued.

Species	SITE REQUIREMENTS Moisture	Fertility	VALUE TO WILDLIFE SPECIES Food	Cover
SHRUBS:				
grey dogwood (*Cornus racemosa*)	dry to mesic	medium	berry production; winter browse material	spreads vegetatively; excellent for forming dense thicket cover in uplands
red-osier dogwood (*Cornus stolonifera*)	moist to wet	low to high	berry production; winter browse	excellent for forming thickets in lowlands
common juniper (*Juniperus communis*)	dry	low to medium		general low cover in open, upland settings
choke cherry (*Prunus virginiana*)	dry to mesic	medium to high	berry production; winter browse	dense cover at forest edges; spreads vegetatively
nannyberry (*Viburnum lentago*)	moist to wet	medium	berry production; winter browse	typical component of lowland thickets
highbush cranberry (*Viburnum trilobum*)	moist to wet	medium to high	berry production; winter browse	typical component of lowland thickets
sumac (*Rhus typhina, R. glabra*)	dry	low to medium		spreads vegetatively; forms tall thickets on poor upland sites
hawthorns (*Crataegus* spp.)	dry to mesic	medium to high	fruit production; occasional winter browse	good for forming open to dense thickets on upland sites
raspberry (*Rubus* spp.)	dry to mesic	low to high	summer food (berry production)	spreads vegetatively; forms low dense thickets at forest edges and openings
currant (*Ribes americanum*)	mesic	medium to high	summer food (berry production)	
VINES:				
wild grape (*Vitis riparia*)	dry to moist	medium to high	fruit production	dense cover at forest edges and openings
Virginia creeper (*Parthenocissus inserta*)	dry to moist	medium to high	fruit production	dense cover at forest edges and openings

FORBS:				
clover (*Trifolium* spp.)	dry to mesic	low to medium	occasional leaf browse for grouse	early colonizer on poor sites; typical component of low upland meadow
strawberry (*Fragaria virginiana*)	dry to mesic	medium	berry production	typical colonizer and component of open upland meadows
medic (*Medicago lupulina, M. sativa*)	dry to mesic	low	occasional leaf browse material	early colonizer on poor sites; typical component of upland meadows
millet (*Setaria* sp.)	dry to mesic	low	seed production	common colonizer of poor sites
bent grasses (*Agostis* spp.)	dry to moist	low to medium	seed production	commomly colonizes abandoned sites; typical component of low meadow cover
wild rye (*Elymus* spp.)	dry to moist	low to high	seed production	
reed canary grass (*Phalaris arundinacea*)	mesic to wet	low to medium	high seed production	forms tall dense meadow cover in lowland sites; persistent stalks over winter
timothy (*Phleum pratense*)	dry to mesic	low to medium	seed production	typical colonizer in open sites forming moderately dense cover in upland meadows

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