

A Guide To Comprehensive Rehabilitation Planning For Pit Mining Regions

by

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Each generation has only a temporary rendezvous with the land; despite fee titles and documents of ownership we are no more than brief tenants on this planet. By exercise of choice, or by careless default, we shape the land legacy of our descendants. We can either abuse the land and squander its boundary with physical and spiritual loss to ourselves and to them, or we can strive for an economy in which physical affluence and richness of spirit go hand in hand.

Stewart Udall

United States, Secretary of the Interior,
1967

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1. Introduction

INTRODUCTION

1.1 PURPOSE:

During the past decade in Canada there has been a remarkable increase in public concern regarding the exploitation of our non-renewable resources. Much of the controversy is focused on the sand and gravel mining industry due to its enormous scale and high visual profile.

Issues of dwindling mineral reserves and offensive environmental impact have provoked the enactment of controls by many provincial and municipal levels of government. While the details of such controls vary with the specific circumstances, they can be broadly classified as either minimum standards for mine operation and ultimate landscape restoration, or requirements to produce evidence of planning for sequential excavation and progressive restoration of the mine environment.¹ In both instances the party held responsible is the individual mine operator.

The need for such government controls is unquestionable, given the highly competitive nature of the mining industry. However, there is also a need for planning of resource extraction and landscape transformation at a broader level, beyond the limits of a single property.

Gravel deposits are rarely owned and controlled by one mining company. The geologic processes from which sand and gravel deposits are derived acted over vast areas of land and it is common to find a large number of operators working one deposit simultaneously. While the preparation of individual

¹Doug Hogan, Pits and Quarries: Government Involvement in Their Planning, Operation and After-Use. (Toronto: Intergovernmental Committee on Urban and Regional Research, 1978), p. 8.

site plans for mining and rehabilitation of each property is essential, public authorities must have some rational and equitable basis:

- i) to evaluate the adequacy and appropriateness of each plan,
- ii) to provide direction and guidance to operators preparing such plans, through central co-ordination; and
- iii) to exercise controls on the extent and direction of future mining of the deposit, particularly where it will be a source of undue environmental degradation.

To achieve these purposes, the responsible public agency (or a consortium of private operators) should examine each deposit as a whole, and develop an overall planning program as a context for the preparation of individual site plans. The advantages of such comprehensive planning may be summarized as follows:

1. Environmental problems can be readily foreseen and resolved, precluding environmental calamity.
2. The mining and rehabilitation programs of individual operators can be co-ordinated to ensure efficient utilization of the resource and development of appropriate environmental conditions in the post mining landscape.
3. A rational basis can be identified for sequential excavation and rehabilitation of the deposit, minimizing the overall environmental impact while maximizing the efficiency of resource exploitation.
4. The development of post mining land use activities on individual properties can be directed to ensure compatibility with adjoining uses, and with the local community.
5. The planning program can provide a forum in which the participation of mine operators, environmentalists, local politicians, government regulatory agencies and the public at large may be accommodated. The issues can be presented in their proper context for informed debate, and necessary trade offs can be made prior to confrontations.



Photo #1 and #2

The cumulative impact on the landscape of adjoining mine operations can be enormous.

The central purpose of this practicum is to promote such comprehensive mining and rehabilitation programs. It is recognized that the agencies and individuals who are in the best position to undertake such programs may not be readily familiar with the issues and problems involved. Consequently, this study has been structured as an information manual, which outlines the full scope of the problem, defines a problem solving process, and synthesizes pertinent technical information. The advantages of such comprehensive mining and rehabilitation programs are demonstrated through a case study.

1.2 REPORT FORMAT

The report has been organized into two parts; one dealing with the overall context of the problem, and the second directed specifically at development of a comprehensive mining and rehabilitation planning program.

In Part I, (Sections 2.0 and 3.0) the aggregate dilemma of resource utilization versus environmental degradation is introduced, both in the national and provincial setting. The intent and detail of Manitoba's legislative requirements for rehabilitation are then reviewed, and objectives are defined for both directing and evaluating rehabilitation programs.

Since this report is directed to individuals who may have had only limited experience with the mining industry, a brief description of the aggregate resource and its use has been included. Reference is made to operation procedures and patterns.

Part II of the report (Sections 4.0, 5.0 and 6.0) outlines a comprehensive mining and rehabilitation planning process. Using a case study as an example, the important stages of such a program are described. Pertinent technical information and environmental management criteria are provided, in conjunction with reference sources for further investigations. The advantages of establishing such a planning program are pointed out generally, and specifically in relation to the study area.

2. The Aggregate Dilemma

2.1 THE INDUSTRY AND THE ISSUES

Sand and gravel is an essential component of all construction projects, by virtue of its inherent characteristics as a stable backfill, or as an ingredient in cement and asphalt. The growth and functioning of our towns and cities, and the transportation linkages between them, demands large quantities of sand and gravel at relatively low cost. A proportional breakdown of sand and gravel used in Canada is illustrated in Table 1. Substitute materials such as crushed stone, slag and lightweight aggregates are simply not available in sufficient volume to meet all needs.

Aggregate has historically been a leading mineral commodity in terms of both tonnage produced and value, and the industry remains among the largest and fastest growing in the primary sector of the Canadian economy.¹ In 1978, the value of sand and gravel produced in Canada increased 26.7% from the year before to an estimated \$375.4 million.² This was based on a small increase in production of 1.2% with total output at 293.2 million tons.

In Manitoba for the same year, the value of sand and gravel was \$30.2 million dollars. The Province sustains about twenty major commercial operations, employing approximately 225 people. In addition, a large number of smaller contracting businesses produce sand and gravel, but not on a regular basis. Total reported production in 1978 amounted to 14,969,000 tonnes.

¹A.G. McLellan, "The Aggregate Dilemma", The Conservation Council of Ontario Bulletin, (October 1975), pp. 12.

²The Mining Association of Canada, Mining in Canada: Facts and Figures (Ottawa: The Mining Association of Canada, 1979), p. 10.

³Peggy Large, Sand and Gravel in Manitoba, (Winnipeg: Manitoba Department of Mines, Resources and Environmental Management, 1978), p. 4.

TABLE 1: PRODUCTION OF SAND AND GRAVEL BY PROVINCE 1976-1978

	1976		1977		1978	
	(000 tonnes)	(\$000)	(000 tonnes)	(\$000)	(000 tonnes)	(\$000)
Newfoundland	4,964	8,687	4,468	7,023	4,627	7,650
Prince Edward Island	789	1,687	865	1,864	885	1,901
Nova Scotia	8,408	15,727	9,012	18,214	9,067	18,491
New Brunswick	5,672	5,403	5,378	6,141	5,443	6,600
Quebec	77,156	68,852	74,423	69,586	71,776	64,398
Ontario	68,802	106,093	75,400	121,776	79,832	132,000
Manitoba	16,126	25,395	14,535	29,363	14,969	30,195
Saskatchewan	8,619	11,142	9,135	11,102	9,253	11,730
Alberta	24,520	43,659	23,900	45,658	24,313	46,900
British Columbia	34,103	47,772	45,789	54,154	45,813	55,550
Canada	249,159	334,414	262,905	364,881	265,978	375,415

Source: Stonehouse, 1979, Sand and Gravel, p. 2.

Figures on the volume of sand and gravel production provide an indirect indication of the impact mining has on the landscape. Manitoba's 1978 production converts to 17.1 million cubic metres, which may be graphically visualized as covering 18.74 square kilometres at a depth of one metre. These figures do not include the tremendous volumes of overburden moved for access to a deposit, or the volumes of tailings and reject material.

There are an estimated 5,000 gravel pits in Manitoba, many of them under 2.5 hectares in size.⁴ In contrast to hard rock mining, these excavations are usually shallow, rarely more than 15 metres in depth and often less than 6 metres. However, where demand is high, massive deposits may be sequentially mined out in a relatively short time, creating enormous scars on the landscape. Mining technology has advanced rapidly, permitting one operator with a single piece of equipment to remove large volumes of material, from both above and below the water table.

The legacy of past mining activity is a scattering of abandoned pits, left in a condition unsuitable for productive use. In the United States, some 823,000 acres of derelict land was created as a result of sand and gravel mining by 1965.⁵ More recent figures in the Canadian context are unavailable, but the dimensions are significant. One regional municipality in Ontario was surveyed in 1978 and found to have over 161 hectares of derelict land resulting from past gravel mining operations.⁶

⁴Personal Communication: Mr. R. Casson and Mr. L. Bilton, Mines Inspectors, Province of Manitoba, September 1979.

⁵U.S. Department of Agriculture, Restoring Surface Mined Land, Washington, U.S. Government Printing Office, Publication No. 1082, 1968), p. 2.

⁶A.G. McLellan, S.E. Yundt, and M.L. Dorfman, Abandoned Pits and Quarries in Ontario, (Toronto: Ontario Geologic Survey, Miscellaneous Paper 79, 1979).

The environmental impact of the aggregate industry is compounded by the high bulk/low value characteristic of the material. Distance from a market is generally the limiting factor determining the economic viability of a mineral reserve. In southern Ontario transportation charges have been found to represent from 35% to 58% of consumer costs, where the material is moved by truck.⁷ In Manitoba, it is estimated that transportation costs by truck are approximately 30% to 40% of the cost of a ton of aggregate produced in Birds Hill and delivered to Winnipeg, a distance of 19 kilometres.⁸ The longest regular hauling distance to Winnipeg is 96 kilometres.

This economic reality dictates that all gravel sources close to large urban centres must be heavily exploited. It brings mining operations into close contact with a large segment of the population, where they must compete successfully with a wide range of other land uses.

The growing sensitivity of society to environmental issues has created some difficulties for the sand and gravel industry. In recent years, there has been a tendency for municipal officials (responding to vocal lobby groups) to preclude mining through zoning regulations. In some instances, valuable aggregate deposits have been permanently lost as a result of residential or other development which was allowed to occur prior to excavation. The long term environmental problems of an ongoing sand and gravel operation, and the possibility of inheriting only a valueless open scar in the landscape, weighs heavily in the minds of many individuals.

⁷D.H. Stonehouse, "Sand and Gravel". Canadian Minerals Yearbook, 1978, (Ottawa: Canadian Government Publishing Centre, 1979), p. 2.

⁸The U.M.A. Group, Aggregate Resources of the Winnipeg Region. (Technical Study Prepared for the Manitoba Department of Mines, Resources and Environmental Management, Winnipeg, 1976), p. 49.

This, then, is the crux of the aggregate dilemma, common across Canada and throughout North America.⁹ On the one hand, sand and gravel is essential to our society, and there is a need to protect and efficiently utilize those reserves readily accessible to the urban market. On the other hand, high environmental impact and competing land uses create pressures which work to preclude mining activity where it is most needed, taking out of production valuable aggregate deposits. The challenge for those involved in the field is to effectively mitigate the ongoing environmental impact of sand and gravel operations and ensure that the potential of the post mining landscape is maximized.

2.2 REHABILITATION: PLANNED EXCAVATION AND PROGRESSIVE RECLAMATION

The most promising and frequently advocated solution to the aggregate dilemma is to require mine operators to adopt individual programs for 'planned excavation and progressive reclamation'. A wide range of definitions and explanations of this concept are found in the literature, and terminology is used interchangeably within the industry. As a result, any discussion of rehabilitation must be qualified at the outset by the writer's individual interpretation of terms.

Table 2 presents examples of how the key words, reclamation and rehabilitation, have been used in the literature. An even greater variation of 'meanings' is found in the day-to-day use of the terms, causing at least one reviewing agency to recommend standardization through legislative definition.¹⁰

⁹A.G. McLellan, The Aggregate Dilemma, p. 12, and D.H. Stonehouse, Sand and Gravel, p. 1.

¹⁰Ontario Mineral Aggregate Working Party, A Policy for Mineral Aggregate Resource Management in Ontario, (Toronto: Ontario Ministry of Natural Resources, 1977), p. 19.

TABLE 2: ALTERNATIVE DEFINITIONS OF RECLAMATION AND REHABILITATION

Reclamation:

"the popular understanding.....includes remedial earthwork and grading, smoothing out the biggest bumps, planting of grass in the wide open spaces, rows of trees lined up like soldiers around the property line and repair of the perimeter fence, complete with "No Trespassing" signs. Some periodic rubbish removal during the life of the operation would be included but for the most part this is a final clean up operation with practically no relation to the regular extraction operation."

(Bauer, 1979)

"either the physical condition of the site has been improved for aesthetic reasons alone without consideration of its use to fulfill some land use need, or the site is returned to usefulness even though the actual physical appearance does not change."

(McLellan, Yundt, Dorfman, 1979)

"prior land use planning, physical operation to achieve a suitable topography, and natural or assisted revegetation, directed to ensure that upon completion of mining, an aesthetically pleasing and ecologically balanced environment is established that will satisfy the final land use objectives."

(Thirgood, 1973)

Rehabilitation:

"planned mining and land shaping."

(Bauer, 1970)

"a planned method of returning mineral extracted land to a harmonious form with the surrounding landscape to a level of biological productivity approximately equal to the previous condition or to another productive use of social or economic value."

(Coates, Scott, 1979)

TABLE 2 ...continued...

"treatment of land to develop and improve it into a beneficial form.....both the appearance and the land use have been changed to an acceptable condition."

(McLellan, Yundt, Dorfman, 1979)

"as a minimum requirement (of rehabilitation) the land should be brought back to the level of productivity before extraction started, and should be in a useful form harmonious with the surrounding land use, or to some other use as specified in the site plan and agreed to by local council."

(Ontario Mineral Aggregate Working Party, 1976)

In this context, the following general explanation of the concept is provided, based on the most widely accepted and valid application of terminology.

'Reclamation' is the restoration of derelict land to some socially or economically useful condition. It refers to those activities undertaken specifically to achieve restoration - the grading of the land, establishment of vegetation, etc. When mining has discontinued, all efforts to transform a worked-out mine site to an alternative, non-derelict condition may be considered reclamation.

Although this term is commonly used today in reference to coal mines or metal mine tailings, it has fallen into disfavour within the aggregate industry. The central reason is the implication that the work of restoration is a totally separate operation, after mining is discontinued, and not necessarily a responsibility of the mine operator.

'Rehabilitation' is 'progressive reclamation', in that the restoration of the mine landscape is undertaken incrementally as a component of the mining process. The responsibility and cost of the work is assumed by the operator from the outset. There are two major advantages of rehabilitation, over non-progressive reclamation.

First, the cost of transforming the landscape to a desired condition is lower. By efficiently utilizing the available personnel and mining equipment to shape the land, there are enormous economies. Consequently, more ambitious restoration programs can be achieved. Movement of earth material is minimized, since the mining operation leaves fill where required, and graded at the correct slope. When not approached progressively, the cost of transformation to a certain condition may not be justified, and hence that potential is lost.

The second major advantage is that the environmental impact of a mining operation is reduced. The area exposed to mining is limited, as rehabilitated portions of the site become productive, aesthetically pleasing, and compatible with the non-mined landscape. This makes the mine operation more acceptable to local residents and the community at large. The public can begin to appreciate the transitional nature of mining, and the potential of the post mining landscape for productive use. This, in turn, will alleviate pressure to prohibit mining in the vicinity of our urban centres.

Intuitively, any rehabilitation program will require planning. The desired condition of the post mining landscape must be determined at the outset of mining in relation to the operation and the phasing of excavation. Such detailed planning of the mine operation offers certain other advantages, beyond those of efficiently restoring the landscape to a productive condition.

First, maximum utilization of the available mineral reserve is assured. For example, the location of stockpiles and processing plants can be determined to minimize interference with future excavation. Similarly, rehabilitation work will not interfere with future mining.

Major environmental problems can be identified and guarded against. This may be as simple as planting tree screens to cut off a particularly unattractive view of the operation, or as complex as avoiding disruption of a ground water aquifer.

Finally, the preparation of plans facilitates review of the mine operation by regulatory authorities, municipal officials and the public at large. Unjustified concerns which may delay or defeat approval of the mine operation can be quickly overcome. Those reviewing the plans, on the other hand, have a rational basis for raising any objections to the mine operation where it is clear that certain problems have not been addressed.

The concept which has been described here as 'planned excavation and progressive reclamation' has been promoted since the early 1960's. Different terminology has been used, and the explanation has been re-worded from time-to-time, depending on the proponent and the audience. It has been referred to as "rehabilitation" (Bauer, 1970), "progressive rehabilitation" (Johnson, 1965), "creative excavation" (Bauer, 1968), and even "industrial mineral site planning" (Baxter, 1969).

In all cases, however, the underlying objectives have remained essentially unchanged. They may be summarized as follows:

- i) To ensure the fullest possible exploitation of the available gravel reserve.
- ii) To optimize the potential for utilization of the landscape both during and after the mining operation.
- iii) To minimize the ongoing environmental impact, ensuring compatibility with adjoining land uses.
- iv) To efficiently utilize equipment and personnel in the shaping of the land by planning their disposition as part of the extraction operation.
- v) To minimize the movement of earth materials, while maximizing the use of excavation and backfill processes to reshape the land.
- vi) To create useable and attractive land forms as opposed to derelict land forms.

The advantages of a planned excavation and progressive reclamation program have been demonstrated in a wide range of circumstances, through applications across the United States and Canada. It has now been generally accepted as the single most effective means of resolving the aggregate dilemma.¹¹

2.3 THE PROVINCIAL RESPONSE

Under the British North America Act, Canada's mineral resources and the responsibilities for their management have been allocated to the individual provinces. The provincial response to the aggregate dilemma has not been uniform, since the pressures and circumstances vary.¹² Some provinces have enacted special legislation, others have included provisions in general mining or environmental legislation, while others have relied on regulations or guidelines. In all instances, however, the controls have taken the form of either minimum standards for mine operation and reclamation, or requirements to produce evidence of planning for sequential excavation and rehabilitation.

In Manitoba, the aggregate dilemma is being addressed on a number of different fronts. These are summarized as follows:

i) Resource Identification:

The Provincial Mineral Resources Division has initiated a survey program to identify and assess the quality of all sand and gravel deposits in the Province. In conjunction with these data, demand projections are being formulated to determine the future need for aggregate in any given locality. These two components are then used as a basis for evaluating the need to protect specific reserves from future development.

¹¹The Interdepartmental Task Force on Land Use Policy, Land Use in Canada, (Ottawa: Lands Directorate, Environment Canada, 1980), p. 21; and Ontario Mineral Aggregate Working Party, A Policy, p. 9; and K.L. Schellie, Ed., Sand and Gravel Operations - A Transitional Land Use, (Silver Springs, Maryland: National Sand and Gravel Association, 1977), pp. 36, 37.

¹²For a Review of Legislative Requirements, See Canada Centre for Mineral and Energy Technology, Environmental Planning: Pit Slope Manual, (Ministry of Supply and Services, Ottawa, 1976), pp. 55-67.

The information is made available to provincial and municipal planning officials for consideration in formulation of development plans and approval of land subdivisions.

ii) Rehabilitation Regulation under The Mines Act:

The regulation of surface mining in Manitoba is also the responsibility of the Provincial Mineral Resources Division. Specific reclamation requirements were enacted on January 1, 1977, in Manitoba Regulation 226/76.

Under this authority, every owner of a commercial quarry or a commercial quarry lease is required to submit a 'plan of rehabilitation', to be updated on a three-year basis. Upon depletion of the quarry, or prior to suspension of production for a period not exceeding twelve months, the owner must 'rehabilitate' the landscape in accordance with the submitted plan.

Unless otherwise approved, rehabilitation under the regulation must comprise:¹³

- (a) The removal of vegetative cover and overburden in advance of the working face at a minimum distance of twice the height of the working face;
- (b) Upon depletion, the sloping of the quarry walls no steeper than 45 degrees;
- (c) The distribution of overburden over the surface of the sloped quarry walls and the quarry floor;
- (d) Planting of vegetation appropriate to the environment of the commercial quarry on the surfaces covered by overburden;

¹³ Manitoba Quarry Minerals Regulation 226/76, Being a Regulation Under The Mines Act Governing the Disposition of Crown Minerals and the Rehabilitation of Commercial Quarries, p. 593.

- (e) The contouring of quarry walls standing below water level to minimize danger to the public;
- (f) Disposing of all debris, refuse, scrap or inflammable liquids in an approved manner;
- (g) Any other activities of a similar nature to any of those described in clauses (a) to (f).

The effectiveness of this regulation over its brief history has been disappointing. There is little evidence to indicate that mine operators have adopted programs of rehabilitation, or that they are living up to the intent of the legislation. The main reasons for this appear to be as follows:

- a) The definition of what constitutes rehabilitation is vague, and the few standards proposed are counter-productive. For example, the maximum slope of 45 degrees is steeper than the angle of repose of unconsolidated material, and certainly not safe.
- b) The timing of rehabilitation is left to the discretion of the operator, who defines when the mine site is 'depleted'. Most operators remain unconvinced of the merits of progressive rehabilitation, which would represent an immediate cash outlay for a less direct or somewhat intangible return. There is rarely an economic incentive for the operator to rehabilitate in terms of either increased property equity or subsequent landscape productivity. Given the highly competitive nature of the industry, minimization of mine operation costs is heavily favoured.

iii) Municipal Controls on Mining Activity:

The Planning Act and the Municipal Act of Manitoba allocate authority to local municipal levels of government.

for the control of surface mining operations. To provide guidance for the scope of such bylaws, the Province has established as an overall and binding land use policy that designated mineral reserves shall be protected from any non-compatible development. However, a municipal council may still prohibit mining or establish such conditions as it deems appropriate. The number of municipalities electing to exercise this authority is increasing rapidly.

In summary, the Province of Manitoba has undertaken a number of measures in recent years to address the aggregate dilemma. From the standpoint of the operator, the rationale underlying this move to increasing government involvement has proved somewhat unclear and frustrating. The process of preparing rehabilitation plans, and the expected scope and content of such plans is not always understood. Consequently, compliance with Manitoba Regulation 226/76 remains incomplete. Municipal and provincial officials charged with the responsibility of evaluating existing and proposed mining operations have also encountered difficulties in establishing assessment criteria which are universally equitable yet resolve individual site problems.

3. The Resource And Its Use

3.1 THE RESOURCE

3.1.1 Location of Aggregate Sources:

Sand and gravel are derived from land forms laid down by fluvio-glacial processes. The fast moving melt waters associated with the continental ice sheet carried large volumes of debris. As water velocity decreased, the large particles settled out while fine textured material was held in suspension. In other locations lakeshore beaches were subjected to the differentiating forces of moving water, which washed the silts and clays out to the lake bottom.

Our primary sources of aggregate are the eskers kame morraines, deltas, beach ridges, and outwash plains formed by these glacial rivers and lakes, which have long since vanished.¹

The textural quality of material in granular deposit varies widely. Where the velocity of water action was high, as in eskers or deltas, deposits tend to be well sorted by size and free of clay and organic material below the soil horizon. Moraines, on the other hand, may have had little sorting or removal of fines. This unsorted material can be used directly for some purposes (such as backfill), although some form of processing is usually required before use. Most sand and gravel operations encounter a range of particle size distributions, even within the same pit.

¹P. Large, Sand and Gravel in Manitoba, p. 1.

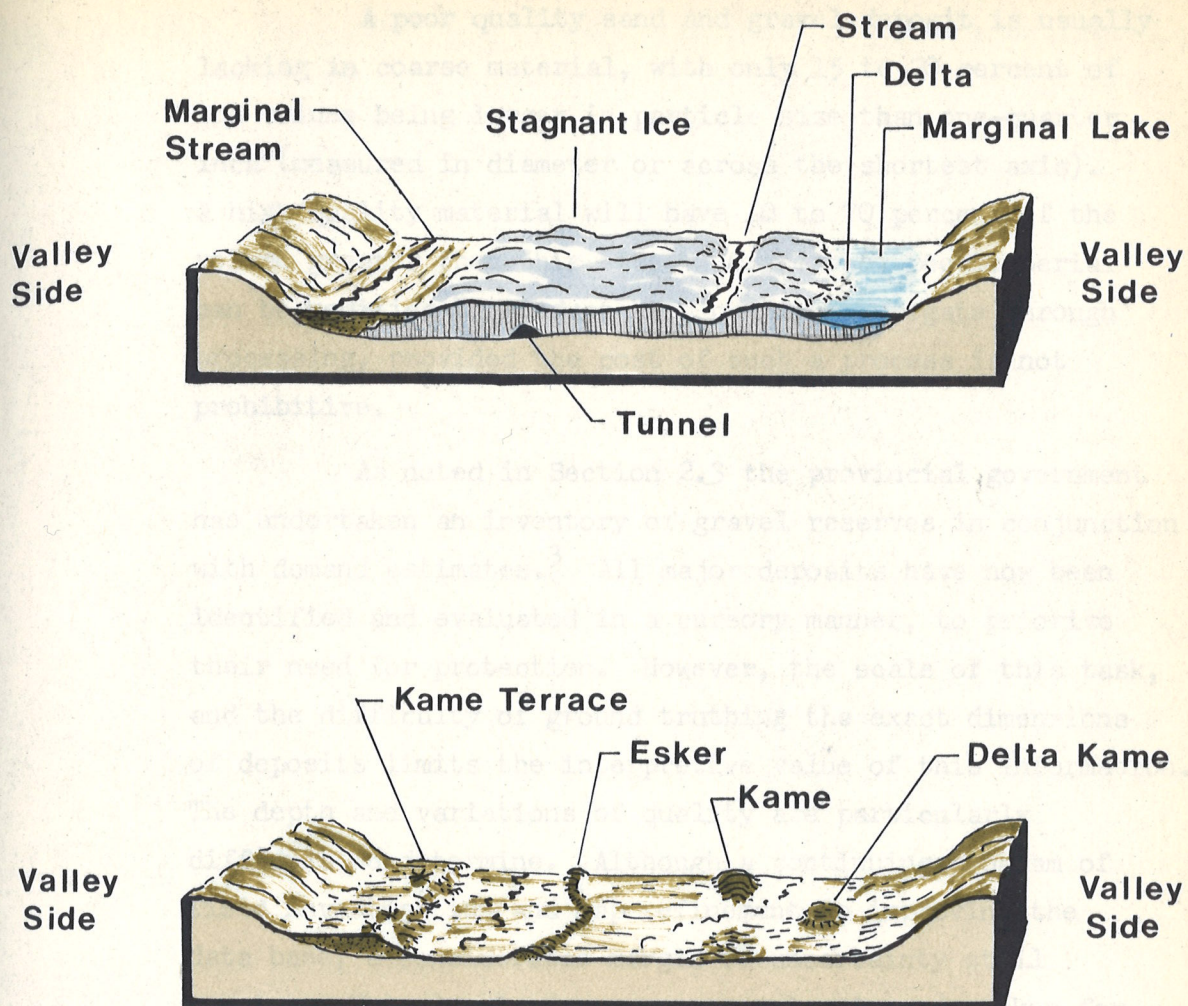


Fig.1: Glacial Features That Are Sources Of Aggregate

Source: Strahler, 1969, Physical Geography, P 519

A poor quality sand and gravel deposit is usually lacking in coarse material, with only 15 to 20 percent of the volume being larger in particle size than one-quarter inch (measured in diameter or across the shortest axis). A high quality material will have 40 to 70 percent of the volume greater than this size.² Of course, poor material can be modified to produce high quality aggregate through processing, provided the cost of such a process is not prohibitive.

As noted in Section 2.3 the provincial government has undertaken an inventory of gravel reserves in conjunction with demand estimates.³ All major deposits have now been identified and evaluated in a cursory manner, to prioritize their need for protection. However, the scale of this task, and the difficulty of ground truthing the exact dimensions of deposits limits the interpretive value of this information. The depth and variations of quality are particularly difficult to determine. Although a continuing program of field investigation and map refinement is improving the data base, a considerable margin of uncertainty still remains. This level of resource mapping is undertaken for the purposes of large scale planning, and cannot substitute for the level of detailed information required to undertake a specific program of planned excavation and rehabilitation.

²Underwood, McLellan & Associates Ltd., The Aggregate Resources of the Winnipeg Region, p. 3.

³For further information contact the Mineral Evaluation Section, Mineral Resources Division, Manitoba Department of Energy and Mines.

Demand projections up to the year 2026 are also being made by the provincial authorities, to prioritize the need for sand and gravel reserves. The inherent difficulties of this task must also be recognized. Demand is a function of changing economic conditions, notably regional and provincial construction projects, as well as changes in the economics of transportation due to economies of scale or alternative technology.⁴ Since these projections really represent only a "best guess", it would be ill-advised to squander existing reserves through misconception of our future need.

Sand and gravel are a non-renewable resource. The substitution of reprocessed materials is generally dismissed as an alternative, at this time since there is little likelihood that they could be available in sufficient quantity at a price less than five times the current cost of aggregate.⁵ However, it should be recognized that even with cautious management of existing reserves, we will eventually be forced to use of lower quality material, at a much higher cost to society.

3.1.2 Classification and Use of Aggregate:

A list of the uses of sand and gravel is provided in Figure 2, in conjunction with a breakdown of the proportional use in Manitoba.

⁴Ontario Mineral Aggregate Working Party, A Policy for Mineral Aggregate Resource Management in Ontario, p. 23.

⁵Ibid., p. 24.

FIGURE 2: USES OF SAND AND GRAVEL IN MANITOBA

Road Construction

sub-base
base
traffic (surface) gravel
shoulders
culvert fill
maintenance (pit run)
ice control

Concrete Aggregate

road surfaces
dams
foundations
buildings
ready mix
sidewalks
pre-cast blocks, tiles
mortar
grout
railway ties

Fill

sewer and water pipe
bedding
septic field
construction
rip-rap
dam construction

Railway Construction

sub-base
ballast

Mine Backfill

Silica Sand

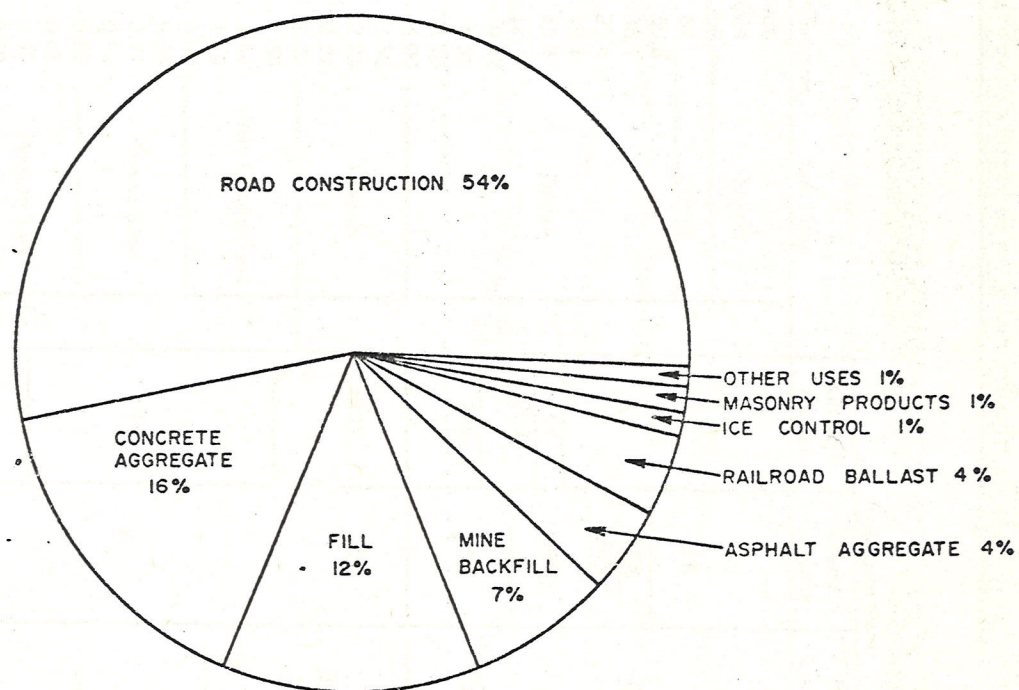
smelting flux
sand blasting
glass-making

Asphalt Aggregate

road surfacing
parking lots

Other Uses

Portland Cement
moulding sand



Source: Large, Sand and Gravel in Manitoba, p. 3.

TABLE 3: SIZE CLASSIFICATION OF GRANULAR MATERIAL

Inches/ Mesh	Millimetres	Size Class		Aggregate Sizes		
				Grade A Asphalt	Coarse Concrete	Fine Concrete
161"	4906		GRAVEL			
40	1024	Boulder				
10	256					
2½	64	Cobble				
2	50.8				0%	
1½	38.1			0%		
1	25.4				10%	0%
¾	19.1				30%	
½	15.9	Pebble		5%		
¼	12.7			20%	50%	
9.52						
6.35				20%		
#4 mesh	4.76				5%	10%
5	4.00					
6	3.36		SAND			
7	2.83					
8	2.38	Granule		20%	5%	
10	2.00					30%
12	1.68					
14	1.41	Very Coarse Sand				
16	1.19					
18	1.00					
20	0.84					
25	0.71	Coarse Sand		15%		
30	0.59					
35	0.50					
40	0.42					40%
45	0.35	Medium Sand				
50	0.30					
60	0.25					
70	0.210					
80	0.177	Fine Sand		15%		
100	0.149					
120	0.125					
140	0.105					
170	0.088	Very Fine Sand				20%
200	0.074					
230	0.0625					
270	0.053		MUD			
325	0.044	Silt		5%		
400	0.037					
	0.0039	Clay				

Source: Large, Sand and Gravel in Manitoba.

TABLE 4: EXAMPLES OF AGGREGATE USAGE BASED ON
SAND AND GRAVEL CONTENT

Size	Typical Uses
90-100 percent passing No. 4 sieve	Fine concrete, seal coat paving, plaster, masonry mortar.
40-90 percent, 70-80 percent or 40-70 percent passing No. 4 sieve	Concrete blocks, concrete culverts, railway sub-ballast, roadway base coarse, granular backfill.
less than 40 percent passing No. 4 sieve	Crushed and blended with other aggregates, coarse masonry grout, coarse culvert subdrain filter, coarse concrete aggregate.

Source: The U.M.A. Group, Aggregate Resources of the Winnipeg
Region, p. 2.

Due to its permeability and compacted stability, gravel is an essential base for most of our construction work, from roads to buildings. Processed granular material is used as aggregate that is mixed with cement to make concrete or with bitumen to make asphalt. Sand after it is screened to remove coarse material, is used in masonry produces such as concrete blocks, mortar, and grout; in the manufacture of Portland Cement; on winter streets for ice control; and in foundries for moulding. Sand that has a particularly high content of silica is used in sand blasting, as a flux in smelting processes, and may be used in glass making.⁶

Aggregate materials are classified and sold on the basis of particle size distribution. Quantities may be purchased containing one or more specific particle sizes, or graded to have either a minimum or maximum particle size. A system of sieve screening is used to sort out materials into size categories, as noted in Table 3. The size of the holes in each sieve is commonly expressed in terms of inches or as a mesh (one square inch of a 200 mesh screen, for example, has 200 equal sized holes in it).

Specifications for different products require that sand and gravel conform to certain sizes or proportionate mixtures. The typical requirements for asphalt, coarse concrete and fine concrete are illustrated in Table 3, while examples of other uses are outlined in Table 4. These are by no means the only combinations of sizes that might be used. Changing economic conditions associated with depletion of the mineral resource have necessitated modification for all specifications, and as a consequence, material which at one time was considered unuseable is constantly being reconsidered.

⁶P. Large, Sand and Gravel in Manitoba, p. 3.

3.2 THE MINING PROCESS

3.2.1 Pit Operation:

Although every extraction method and production site is unique in its own operation, there are a number of basic steps common to most sand and gravel surface mines. These are as follows:⁷

i) Clearing:

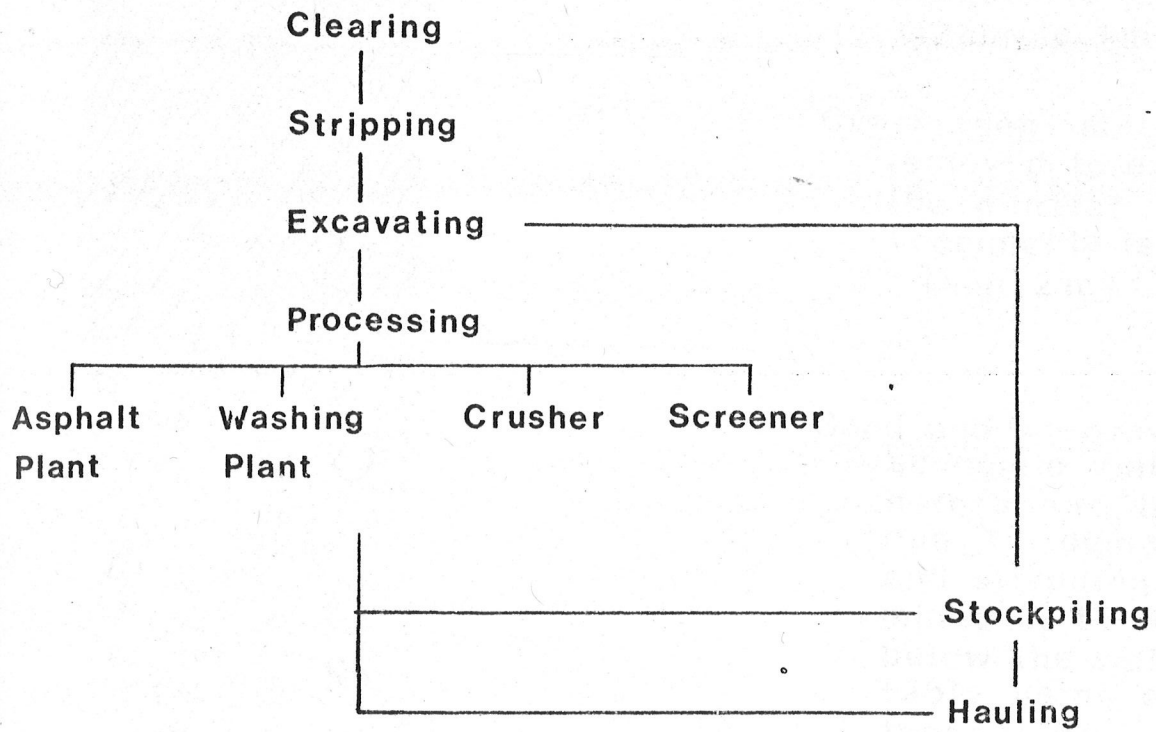
Trees, shrubs and other surface litter must be removed and disposed of prior to any earthwork. Where the lumber is of value, it is harvested through selective cutting or clear cutting. The terrain is subsequently grubbed by bulldozers or loaders to remove stumps and trash litter. This may be hauled away, burned, or more commonly, buried on site.

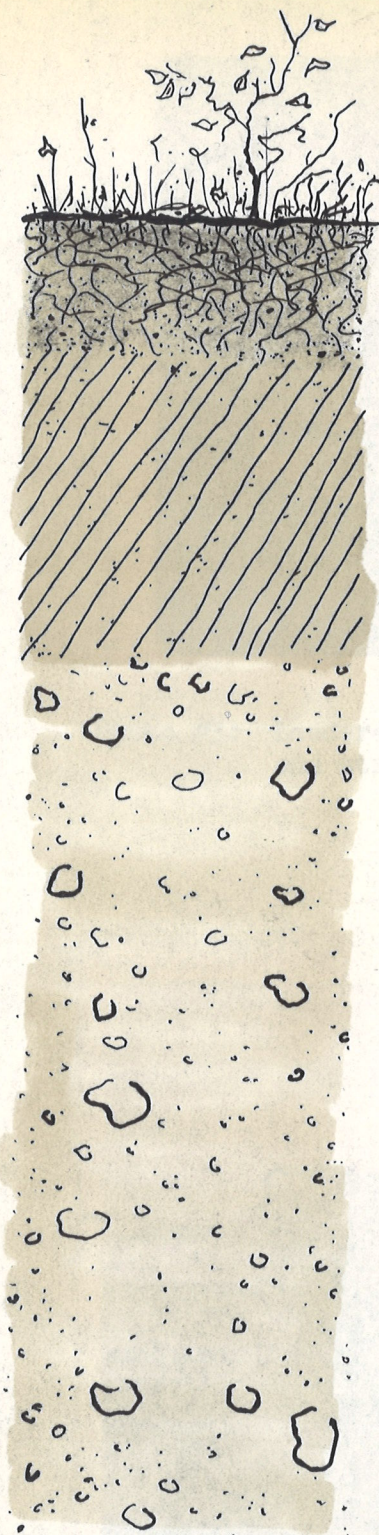
ii) Stripping:

A fresh mineral deposit will be overlain by a zone of topsoil, the surficial layer which has been subjected to active pedogenic processes. The accumulation of plant nutrients and organic material in this zone, may give it a sufficient value to warrant separate stripping and stockpiling. The practice of selling this topsoil has been common in the past, although regulations in some provinces and states now require that it be retained on site for use in rehabilitation.

⁷The U.M.A. Group, Aggregate Resources of the Winnipeg Region, p. 3; and Craig Johnson, Practical Operating Procedures for Progressive Rehabilitation of Sand and Gravel Sites, (Silver Springs, Maryland: National Sand and Gravel Association, 1969); and H.L. Nichols, Moving the Earth: The Workbook of Excavation, (Toronto: D. Van Nostrend Co., 1955), Chapter 10.

Fig.3 TYPICAL PIT OPERATING STAGES





Top soil: biologically
productive zone
(12 cm to 1 m)

Overburden: material
removed to expose
the mineral
(commonly less
than 2 m)

Sand and/or gravel:
- economic viability
determined by
quality, demand,
and stripping ratio
- mined up to 30 m
below the water
table using existing
technology

**Fig. 4 Typical Deposit
Stratigraphy**



Photo #3: Loaders are commonly used to simultaneously clear and strip, with unfortunate consequences.



Photo #4: Scrapers are the most effective machine for stripping large areas.

All overlying earth material which is not considered commercially valuable in itself as sand or gravel is referred to as overburden. This zone usually must be stripped off to prevent it from mixing in with the ore. Such stripping exposes the sand and gravel bearing strata, making it directly accessible to excavation and the operations that follow. Overburden commonly consists of fine lacustrine deposits or glacial till, with an excessively high proportion of fines. In some circumstances, it may be desirable to leave the overburden or at least a portion of it. For example, much run-of-bank gravel does not contain enough fines to bind it for road use. Overburden, if permitted to mix with the gravel by caving, may improve its quality. However, from a resource management standpoint, it would be desirable to select a site with lower grade gravel for such a purpose.

The stripping of overburden may be a very large part of the cost of mining. The ratio of the volume of overburden relative to the volume of quality ore which may subsequently be mined is one of the key factors in determining the viability of an operation. Occasionally, layers of overburden may also be encountered between zones of ore, and must be handled in a similar fashion.

Overburden is stripped in advance of the mining bank. Provincial regulations require that it be cleared for at least twice the height of the mining bank. This is a minimum requirement; it is often economically advantageous to strip large areas of overburden when equipment is available.

Since overburden cannot be sold, it presents a major storage problem in pits. The ideal solution is to stockpile it outside of the gravel deposit, or behind the excavation, in depleted areas. This way it does not have to be moved a second time to get access to the underlying ore. Other considerations include the cost of moving the material, which increases substantially with distance, and the need for backfill to achieve pit rehabilitation.

iii) Excavation:

These operations unearth the sand and gravel and convey it directly to the transporting vehicle, to a processing plant, or simply to stockpiles. Most primary pit excavation is in formations deep enough to load direct from a bank. Gravel is removed from a steeply sloped, vertical face. The height of this embankment is limited by provincial safety regulations, which specify that it must not exceed the reach of the equipment used.

Hill pits may be opened by a straight cut in or by benching. After reduction to the level of surrounding land they are dug as sunken pits. Sub-surface workings, called sunken pits or dig-down pits, may be opened with shovels and ramps, or by dragline or hoe work from the top. They may subsequently be worked down in a series of terraces, with one or more mining faces exposed at a time.

The operational pattern is largely dependent on the type of equipment used to perform the operations of stripping and excavating, as well as the requirements for processing and transportation. For example, a fixed processing plant requires large operating space

and a central location, relative to mining and transport patterns. Typical operating patterns include fan shapes, radiating forms, and linear shapes. Patterns become erratic if larger areas of unmineable deposits are present, and must be circumvented by the excavation equipment. Other factors affecting the phasing and direction of operation include the configuration of the deposit, restrictions of road access, as well as environmental and rehabilitation objectives.

Loading machinery for pit excavation can be roughly divided as follows: tractor loaders, which depend on traction on the pit floor for digging power; revolving shovels with dipper, clamshell or skimmer front ends, which stand on the floor while working; revolving shovels, with dragline, hoe or clamshell rigs which load from the top of the bank; scrappers and bulldozers which work down the bank slope; and remote cableway excavators. A description of the capabilities and production factors for each of these machines is found in Nichols (1955).

Occasionally, material is obtained by sinking a large area of the pit floor, in thin layers, without developing a bank. Scrappers and cable excavators are used for this purpose.

For detailed information regarding techniques, productive use of machinery, and optional excavation patterns, see Nichols (1955), Johnson (1965), and Ovenham (1966).



Photo #5: A front end loader, excavating from a gravel bank.

iv) Processing:

In Section 3.1.2, the requirement for various size classifications of aggregate was discussed. For some purposes, excavated gravel may be used directly, as the natural textural composition of material meets the contract specifications. This would be called 'pit-run', and is the least expensive form of aggregate. In many instances, however, the excavated gravel is screened, washed and/or crushed to meet certain requirements. Equipment for these operations varies widely in size and complexity, from small portable plants to enormous intricately connected systems fixed in a central location. The portable units allow a high degree of flexibility but are limited in size by highway transport requirements. The cost of hauling to a fixed plant is high and must be justified on the basis of increased capacity.

Screening plants separate the particle sizes, as the material is vibrated in a system of overhanging conveyors. When the total elimination of very fine silt/clay is called for, the gravel may be washed. Large volumes of discarded water is then directed to a settling basin.

Crushing machines are used for two purposes. First, the breakdown of the larger pieces of stone into sizes which are more marketable. Present day capability allows operators to crush boulders as large as 30 inches in diameter. In addition, the quality of crushed stone, which compacts to a greater strength than smooth stone, is commonly a requirement for construction.



Photo #6: A screening plant, sorting aggregate into stockpiles of various size categories.



Photo #7: A portable crusher, used to break rock into specified sizes.

Processing is by no means limited to these operations, although they are the most common in Manitoba. Asphalt and concrete mixing plants may also be established as a component of the processing within a mining area. Figure 5 shows a typical pit operation in the Province.

3.2.2 Wet Mining Operations:

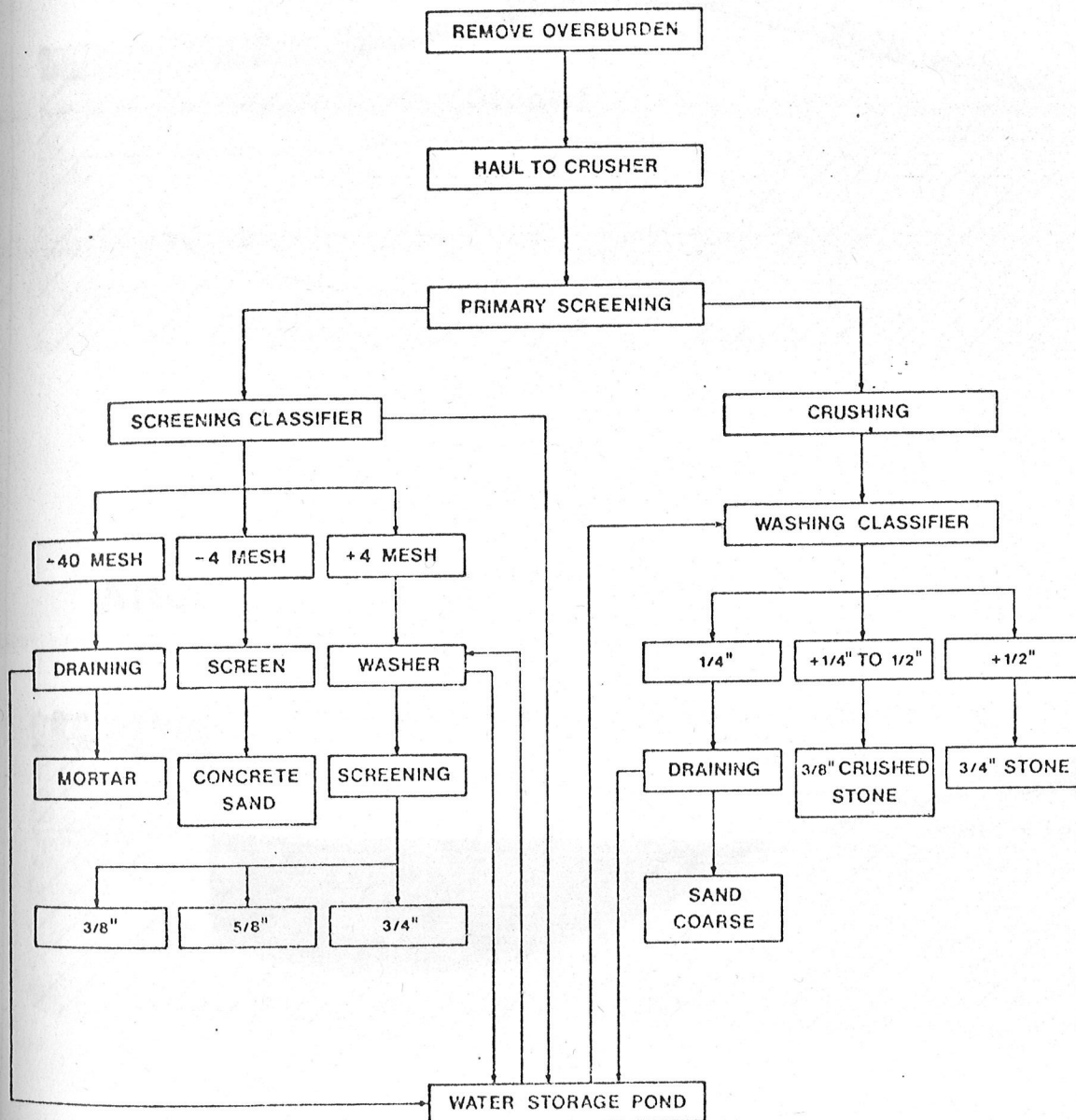
Sand and gravel can be mined below the water table, using such equipment as hydraulic dredges, clamshells, and cable excavators. The depressions created become lakes which are environmentally sensitive, but offer enormous potential for a wide range of uses following rehabilitation. The scale of excavation is massive - one piece of equipment currently used in the Province can excavate over 100 feet below the water level.

Wet mining operations are somewhat specialized, requiring high investment in equipment. Special problems include weaker penetration because of decreased bucket weight, inability to see the work, and less stable slopes. However, the principles of operation are essentially the same, with the added benefit of a washing process being inherent to the excavation.

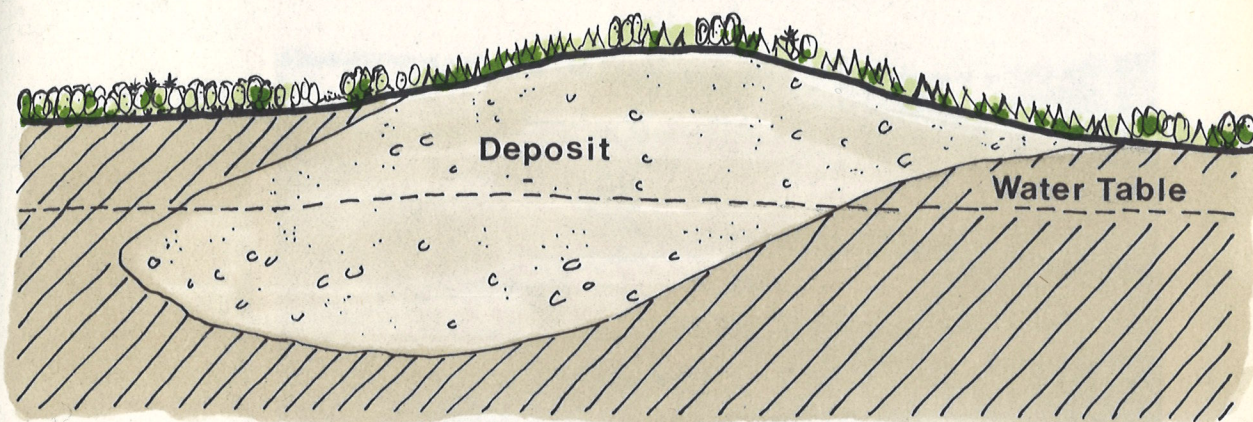
Due to its relative inavailability, the value of aggregate has now reached a level where the water table does not represent as prohibitive a constraint as it has in the past. While the enormous dry reserves of the Birds Hill complex are expected to be depleted by the mid 1980's, mining below the water table in this area will continue for many more years. In some locations, it may be economically viable to artificially lower the water table to gain access to more gravel. Such massive undertakings can have a significant environmental impact, both positive and negative, which must be carefully considered.

⁸The U.M.A. Group, Aggregate Resources in the Winnipeg Region, p. 40.

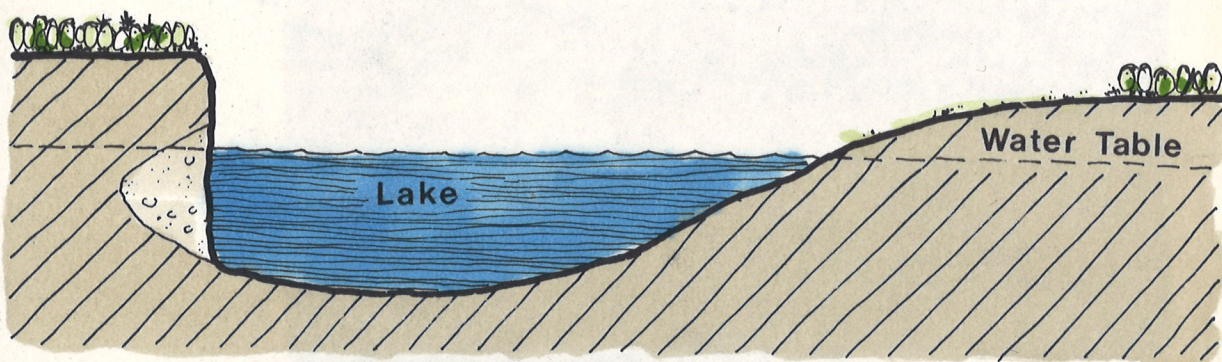
FIGURE 5: FLOW DIAGRAM FOR SAND AND GRAVEL OPERATION



Before :



After :



**Fig. 6 : Formation Of
Groundwater
Lakes**



Photo #8 and #9: Equipment used for wet mining operations vary from a simple clamshell (above) to a sophisticated hydraulic barge (below). The latter is capable of reach depths over 80 feet below water.

4. The Comprehensive Rehabilitation Planning Program

4.1 OBJECTIVES OF THE PROGRAM

Most of the major sand and gravel deposits in Manitoba are being mined simultaneously by a number of different operators. While each commercial operator is required under Manitoba Regulation 226/76 to submit a plan of rehabilitation for his site, it is unlikely that the sum of these individual efforts will properly address the many problems and conflicts which can arise. A comprehensive planning program is required, to provide a decision making framework and environmental management guidelines which will direct the efforts of all participants. Individual rehabilitation plans are a component of such a program, but they should be both prepared and evaluated in the context of an overall strategy.

The advantages of such comprehensive planning are as follows:

- i) Environmental problems can be readily foreseen and resolved, thereby precluding environmental calamity. The impact of a single operation may not seem significant, but when compounded by other operations and evaluated over the full time period, the consequences may be unacceptable.
- ii) The mining and progressive reclamation activities of individual operators can be co-ordinated to ensure efficient use of the resource and development of appropriate environmental conditions in the post mining landscape.
- iii) A rational basis can be indentified for sequential excavation and rehabilitation of the deposit, minimizing the overall environmental impact while maximizing the efficiency of resource utilization. The phasing and direction of excavation activity is particularly important on Crown land, where authorization of mining is the responsibility of a government agency.

- iv) The development of post mining land use activities on individual properties can be directed to ensure compatibility with adjoining land uses and with the local community.
- v) The planning program represents a forum in which the participation of mine operators, environmentalists, politicians, government regulatory agencies and the public at large may be accommodated. The issues can be presented in their proper context for informed debate, and necessary trade offs can be made prior to confrontations.

4.2 A MODEL PROCESS FOR COMPREHENSIVE REHABILITATION PLANNING

The flow chart in Figure 4 outlines the essential components of any comprehensive rehabilitation planning program. Three distinct phases may be identified.

The first phase addresses the mineral deposit as a whole. On the basis of a comprehensive inventory of site conditions, opportunities and constraints are identified and clear guidelines are established to direct site planning.

The second phase is that of individual site planning. Each operator prepares a plan of mine operation and progressive reclamation, within the context of the guidelines established in Phase I. These plans are reviewed by the Mines Branch and other regulatory agencies, also using the Phase I guidelines as criteria.

The final phase is actual implementation of the individual plans, and realization of the objectives.

Given the many variable factors and unknowns, it would be unrealistic to assume a simplistic linear planning program. The process must include intervals of reassessment, and accommodate changes over time resulting from refinement of the data base, shifts in goal priority and correction of inaccuracies. These may be

initiated at any point as indicated in Figure 6. If the program becomes too inflexible to accept change, it will quickly become self-defeating, frustrating all the parties involved.

The type of planning program proposed here has not been attempted elsewhere. The unique component is the initial phase of comprehensive assessment and strategy development. Consequently, it has been given the heaviest emphasis in this paper. Preparation of mining and reclamation plans for individual properties is a common requirement in both Canada and the United States. A number of worthwhile publications may be consulted for more information on this aspect.¹

The following sections illustrate the scope of a comprehensive rehabilitation planning program. A specific gravel deposit located in southern Manitoba is dealt with by way of example. The important components of the process are described and a typical strategy for rehabilitation is presented.

¹Bauer, 1970; Schellie and Rogier, 1963; Schellie, 1977; Jenson, 1967; Bauer, 1965; Johnson, 1965; Baxter, 1969; Gates, 1979.

PREPARATION OF SITE PLANS
BY INDIVIDUAL PROPERTY OWNERS

DETAILED SITE INVENTORY
AND ANALYSIS

DEVELOP MINING AND REHABILITATION
PLANS IN CONTEXT OF GUIDELINES

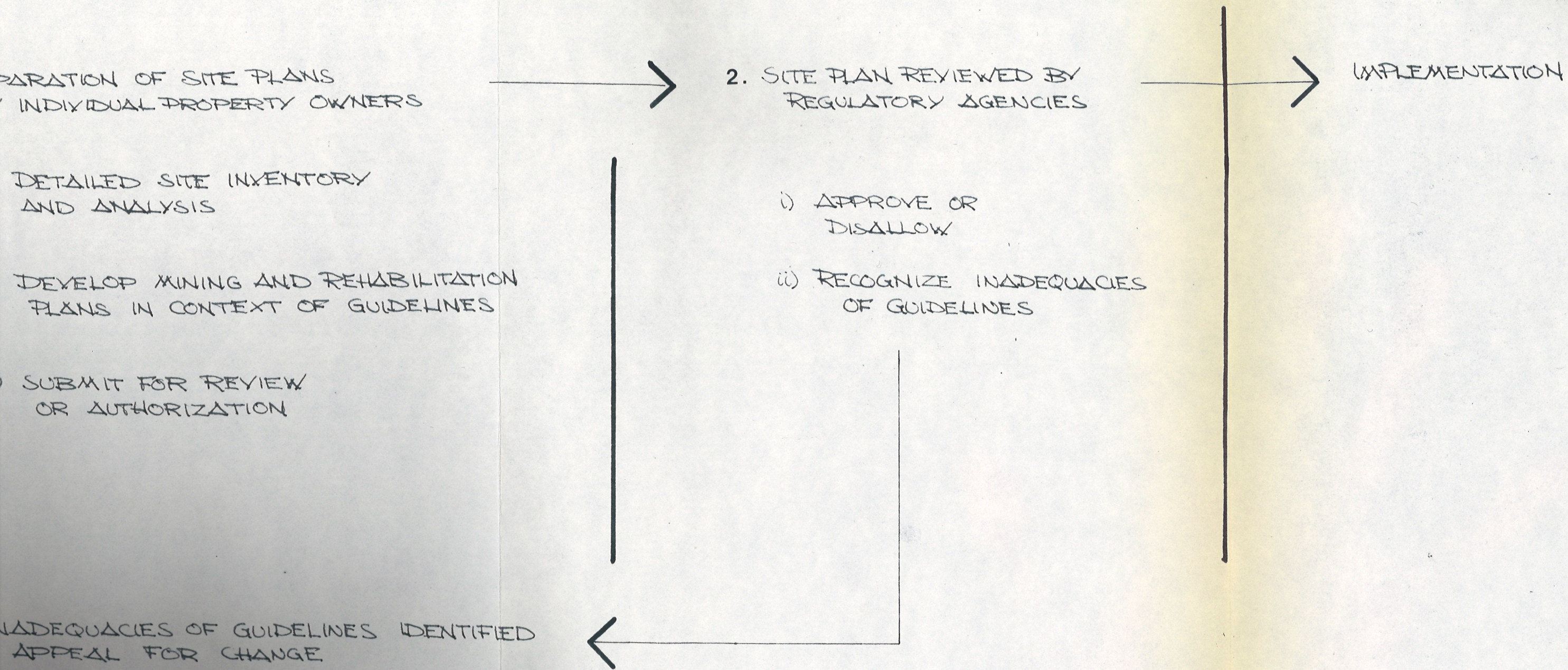
SUBMIT FOR REVIEW
OR AUTHORIZATION

INADEQUACIES OF GUIDELINES IDENTIFIED
APPEAL FOR CHANGE

2. SITE PLAN REVIEWED BY
REGULATORY AGENCIES

- i) APPROVE OR
DISALLOW
- ii) RECOGNIZE INADEQUACIES
OF GUIDELINES

IMPLEMENTATION



Phase 2

1. PREPARATION OF SITE PLANS BY INDIVIDUAL PROPERTY OWNERS

- i) DETAILED SITE INVENTORY
AND ANALYSIS
- ii) DEVELOP MINING AND REHABILITATION
PLANS IN CONTEXT OF GUIDELINES
- iii) SUBMIT FOR REVIEW
OR AUTHORIZATION

2. SITE PLAN REVIEWED BY REGULATORY AGENCIES

- i) APPROVE OR
DISALLOW
- ii) RECOGNIZE INADEQUA
CY OF GUIDELINES

INADEQUACIES OF GUIDELINES IDENTIFIED
APPEAL FOR CHANGE

Rehabilitation Planning Process

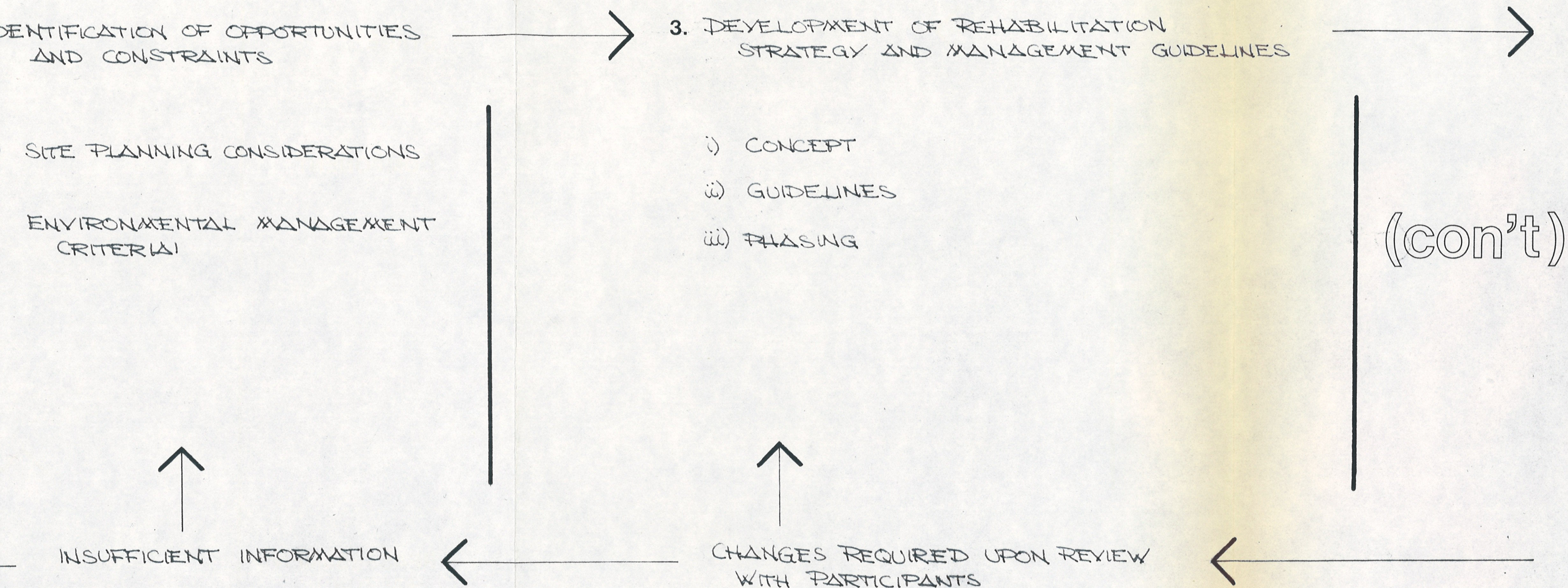
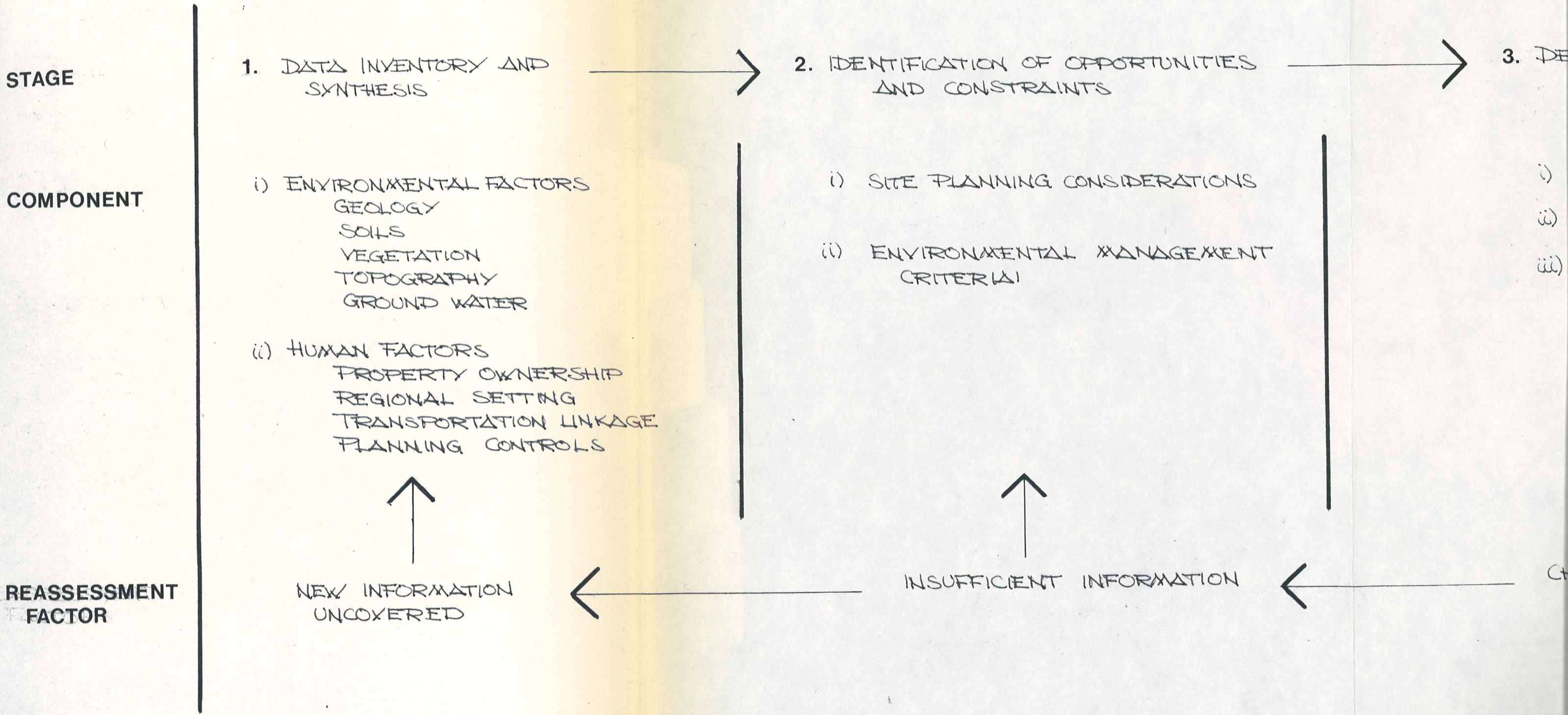


fig 7: A Comprehensive Rehabilitation Planning Process

Phase 1



5. Inventory Of Human Factors

5.1 REGIONAL SETTING:

The identification of constraints and opportunities for future development of any landscape requires an understanding of regional context. This should comprise an inventory of the existing structure as well as the potential for change.

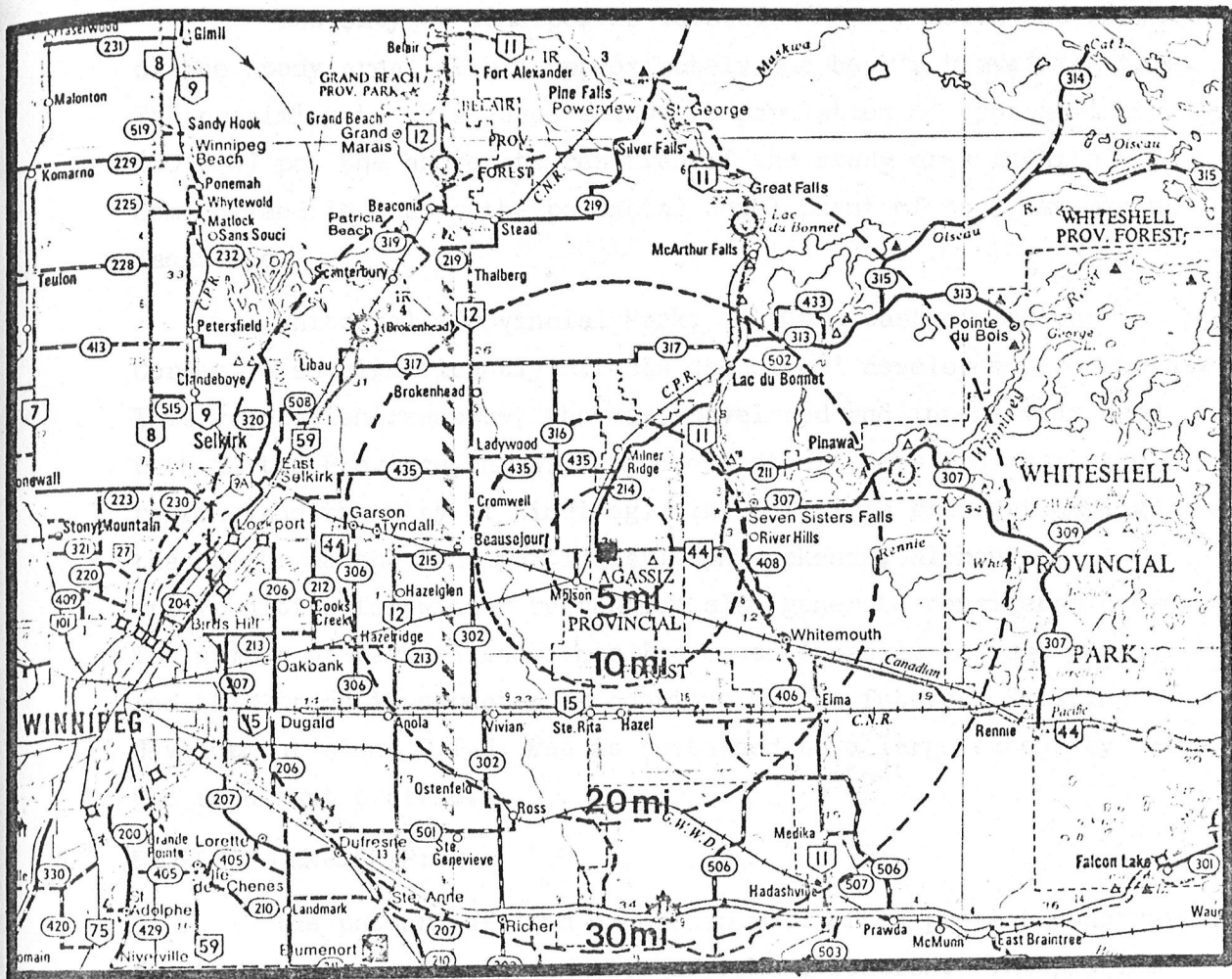
The study area includes approximately ten square kilometres, within the Agassiz Provincial Forest, located at Sections 34 and 35, Township 12, Range 9E, and Sections 2 and 3, Township 13, Range 9E. (See Regional Setting Map). This gravel complex is part of a major north-south ridge which rises immediately to the east of the Seddons Corner highway junction.

The closest centre of population is the Town of Beausejour, 16 kms. west of the site. This community offers a wide range of shopping and social services, and serves as an important retirement centre for the region. It supports a population of over 2700, a level which has remained fairly constant over the last eight years. A recent report by the Manitoba Department of Industry and Commerce projects a 1981 population of 2812, (based on the 1971 to 1976 migration trend estimate), with an increasing proportion of elderly residents.¹

Many of the residents of Beausejour currently use the Agassiz Forest in the vicinity of the study area for recreation activities such as ski-dooing, cross-country skiing and hunting.² There is a lack of day-use recreation facilities in the area.

¹Community Planning Program and Regional Planning, A Community Planning Profile of Beausejour and the Surrounding Area, (Winnipeg: Manitoba Department of Industry and Tourism, 1977).

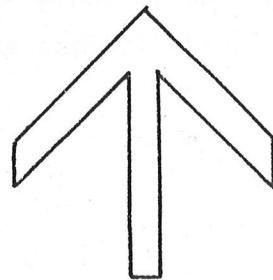
²Personal communication with Mr. D. Houghton, District Planner, June 8, 1978.



Regional Setting Map

----- Miles In Radius From
Study Area

Scale: 1 inch = 14 miles



The City of Winnipeg is located 67 kms. south and west of the study area, within approximately one hour's travelling time. The proximity to this large centre (a population of approximately 600,000) put the aggregate reserves of the study area in high demand, and increases the potential development of the post mining landscape.

Whiteshell Provincial Park, 32 kms. east of Seddons Corner, also significantly affects the sites' development potential. This recreation resource, the most developed and intensively used park in the Province, draws large volumes of users from both the region, and the City of Winnipeg. The influx is greatest during the summer months, and particularly on weekends, although opportunities for winter recreation also generate considerable use. The number of park visitors has increased steadily in past years, and this trend is expected to continue in the future. Existing development along P.T.H. #44 is sustained to a large extent by the resultant traffic.

5.2 PROPERTY OWNERSHIP:

The pattern of land ownership will often present constraints for the phasing and co-ordination of rehabilitation. The problem becomes increasingly complex where many owners with different aspirations are involved. It is not politically feasible to prohibit one operator from mining until another has depleted his reserves. On the other hand, it is not possible to force an operator to mine his property, where he chooses to hold it in speculation. Although such controls would greatly simplify the problem, they could probably not be established in the existing capitalistic political system.

Property ownership in the study area is indicated on the Land Title Map. The quarter sections abutting Seddons Corner on the east, both north and north and south of P.T.H. #44 are privately owned. The remainder of the gravel complex lies on Crown land, within the Agassiz Forest Region. Under Sections 10 and 11 of the Forest Act, the provincial government has the authority to control land sales and hold such land in forestry production.

A number of Mining Leases have been issued, as indicated on the Land Title Map. In most instances, aggregate is now being excavated within these areas. Mining also occurs in two Crown pits, on the basis of Casual Permits. The Provincial Department of Highways operates a major pit in subdivision 15 of Section 35, and owns a small easement in subdivision 14 of Section 34. Any phasing of future mine operations and rehabilitation, must work within the context of this established pattern.

5.3 LAND USE:

The existing land use pattern in the vicinity of the mineral reserve should be inventoried for two purposes. Those land use activities which would clearly be sensitive to the impact of mining activity must be protected. This may involve establishment of special buffer zones in which future mining is prohibited, or development of attractive berms or tree screens which will mitigate any negative impact. Secondly, the appraisal of existing land use provides evidence of the development potential of the post mining landscape, as either an extension of the pattern or complement to it.

The study area, as a consequence of environmental constraints and crown ownership, has been restricted in the past to forest production with ancillary recreation. To the west of Seddons Corner most of the land is in agriculture, including both crops and pasture. Development of Seddons Corner includes a general store, restaurant, service station and a dozen houses.

A private campground is being operated on the Brokenhead River just outside Beausejour. Close by, on the south side of P.T.H. #44, the Provincial Parks Branch currently runs a youth camp facility in Sherwood Forest, which it leases to various interest groups. A wayside picnic area has been developed by the Parks Branch 16 kms. to the east of the study area. These recreation sites suggest a similar potential for the study area.

5.4 TRANSPORTATION LINKAGES:

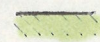
The network of roads and patterns of movement in the study area may also be of significance for the following reasons:

- i) hauling large volumes of aggregate from a site to market will severely impact any sensitive land uses adjoining the road, and the physical condition of the road itself. Truck routes must be selected carefully.
- ii) access to the post mining landscape will be an important factor affecting development potential.
- iii) road right-of-ways frequently intersect aggregate deposits. It may be feasible, with proper planning, to re-route highways in a manner which frees up the underlying deposit for mining.

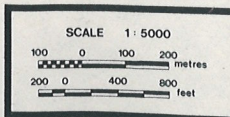
The study area is presently divided by P.T.H. #44, a two-lane highway with a 76 metre right-of-way. Also within this right-of-way is the unused remnant of a forerunner of this highway. Modification of other highways in the area has disrupted traffic patterns, so statistics on the vehicle use of P.T.H. #44 are not available at present. Generally, this highway has high volumes of traffic on the weekends, related to use of Whiteshell Provincial Park. It is an important regional trucking route, and since the study area accesses onto it directly, land use conflicts are not anticipated.



LAND TITLE

-  QUARRY LEASE ISSUED
-  LIMITS OF CROWN LAND

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& ENVIRONMENTAL MANAGEMENT
MINERAL RESOURCES DIVISION



SEDDONS CORNER REHABILITATION PLAN



SOURCE OF INFORMATION: MINING RECORDING OFFICE
JULY, 1978

P.T.H. #44 transects the study area, thereby precluding any mining of underlying aggregate. It is highly probable that at some point in the future the highway will be expanded to four lanes in order to accommodate greater volumes of traffic, including truck traffic from the study area. Realignment of the right-of-way on to a mined out portion of the property or off the deposit would be feasible at that time. This opportunity should be exploited in the rehabilitation planning program, and co-ordinated with planners in the Department of Highways.

5.5 LAND DEVELOPMENT CONTROL:

The rehabilitation planning program must work within the context of other planning controls. In most instances the central authority directing such activity is the local municipality. Through policies and zoning bylaws they prohibit or allow property subdivisions, and land use development. Their involvement in the rehabilitation planning process is critical to ensure that there is no conflict between the mining/post mining activities and those adjoining the area.

More than one planning agency will frequently become involved, since mining is of regional importance. The objectives of urban centres, rural municipalities, as well as provincial government departments must be co-ordinated.

The study area technically falls under provincial jurisdiction, as it is located in Agassiz Provincial Forest. The Mineral Resources Division is directly responsible for rehabilitation planning. Depending on the post mining activity, Forestry Branch, Parks Branch, and/or Municipal Planning will be involved.

²Personal communication with Mr. Don Lam, Planning Projects Engineer, Manitoba Department of Highways, July 7, 1978.

Local municipalities are consulted regarding any Crown land use development. Since the study area also abutts private land, the role of local municipalities is particularly important. Highway #44, which splits the study area, represents the boundary between the two local Government Districts - Lac du Bonnet and Reynolds. Neither municipality has enacted any zoning restrictions. Lac du Bonnet classifies the portion of the site in their jurisdiction under an "agriculture policy", controlling residential development. Reynolds has no planning controls or strategy for future development at present.

No development has occurred at Seddons Corner in recent years, although there has been rural residential development on the road to Lac du Bonnet, and on Highway #44 towards Beausejour.

6. Inventory Of Environmental Factors

6.1 GEOLOGY:

The most fundamental information to any program of planned excavation and progressive reclamation is geologic. It is necessary to have firm data concerning the dimensions of the mineral deposit. This includes both its lateral extent and its depth.

Knowledge of variations in the quality of ore is also valuable. Low quality aggregate specifications can then be provided by mining low quality areas of the deposit, making most efficient use of the resource. Information concerning anticipated volumes of overburden may be used by planners as an index to the size of overburden and tailing stockpiles which must be accommodated, and which may be available for regrading in the subsequent rehabilitation.

The size and configuration of the deposit obviously has profound implication for the phasing of excavation, as well as the opportunities and constraints for rehabilitation. Will mining drastically alter the natural topography? Will new lakes be created? Over what time span will excavation be done?

Unfortunately, the level of information required concerning the geology is rarely available. Many operators in the Province work without any real pre-inventory of the extent of the deposit for long term use. They test for ore in advance of mining, to ensure that short term needs are met, but in the longer run more or less follow wherever the deposit leads.



Photo #10 and #11: Geological information is fundamental to any planning of mine operation or rehabilitation.

As noted in Section 2.3 the Province has undertaken a comprehensive inventory program. However, the central objective of this program is to flag available reserves for protection, and the level of detail required for this task is much less than that needed for the development of a mine rehabilitation strategy.

Finally, the science of such geologic investigations is not exact - there must be a great deal of interpretation and there is a considerable margin of error, even for experts. Power auger test holes and resistivity surveys are essential tools, complemented by sound geologic interpretation. Judgement becomes increasingly unreliable when the number of site tests is low in relation to the extent of the deposit, and where the deposit extends deeper than the range of testing equipment.

To overcome this constraint, the rehabilitation planning program must have a high level of flexibility which will allow continuous modification. As geologists gather more data through new field investigations and observation of excavations, the planning strategy can be refined.

In the case of the Seddons Corner site, relatively detailed geologic information is available as a result of research and field investigations by the provincial government.¹ The Seddons Corner gravel deposit is part of the Milner Ridge end moraine complex. The Quarternary history of this feature was incorporated into a thesis by R.A. McPherson (1970)², who postulated that the ridge was deposited during a major retreat stage of the Labrador ice lobe, in the Wisconsin period. A subsequent glacial advance (from the northeast) deposited an upper till layer which was then modified as a result of wave action during the early, high level stages of Lake Agassiz.

¹Personal communication with Dr. Susan Ringrose, Pleistocene Geologist, Manitoba Department of Mines, Resources and Environmental Management, July 1978.

²R.A. McPherson, Pleistocene Geology of the Beausejour Area, Manitoba, (Unpublished Ph.D., dissertation, University of Manitoba, 1970).

At Seddons Corner, (see Geology Map), the moraine complex included a large outwash delta. Glacial melt waters apparently flowed from the north or northwest into standing water, probably during an early stage of Lake Agassiz. (McPherson, 1970). The associated esker type channel features are thought to be sub-glacial feeder channels through which sediment was transported into the pro-glacial basin.

The best available information regarding the quantity and quality of aggregate in the study area is indicated on the Geology Map. Portions of the deposit are known to extend twenty feet below the water table, possibly much more. The total proven reserve is estimated to be 12.4 million cubic yards (9.5 million cubic metres), constituting one of the best quality and largest aggregate deposits in the Winnipeg Region.

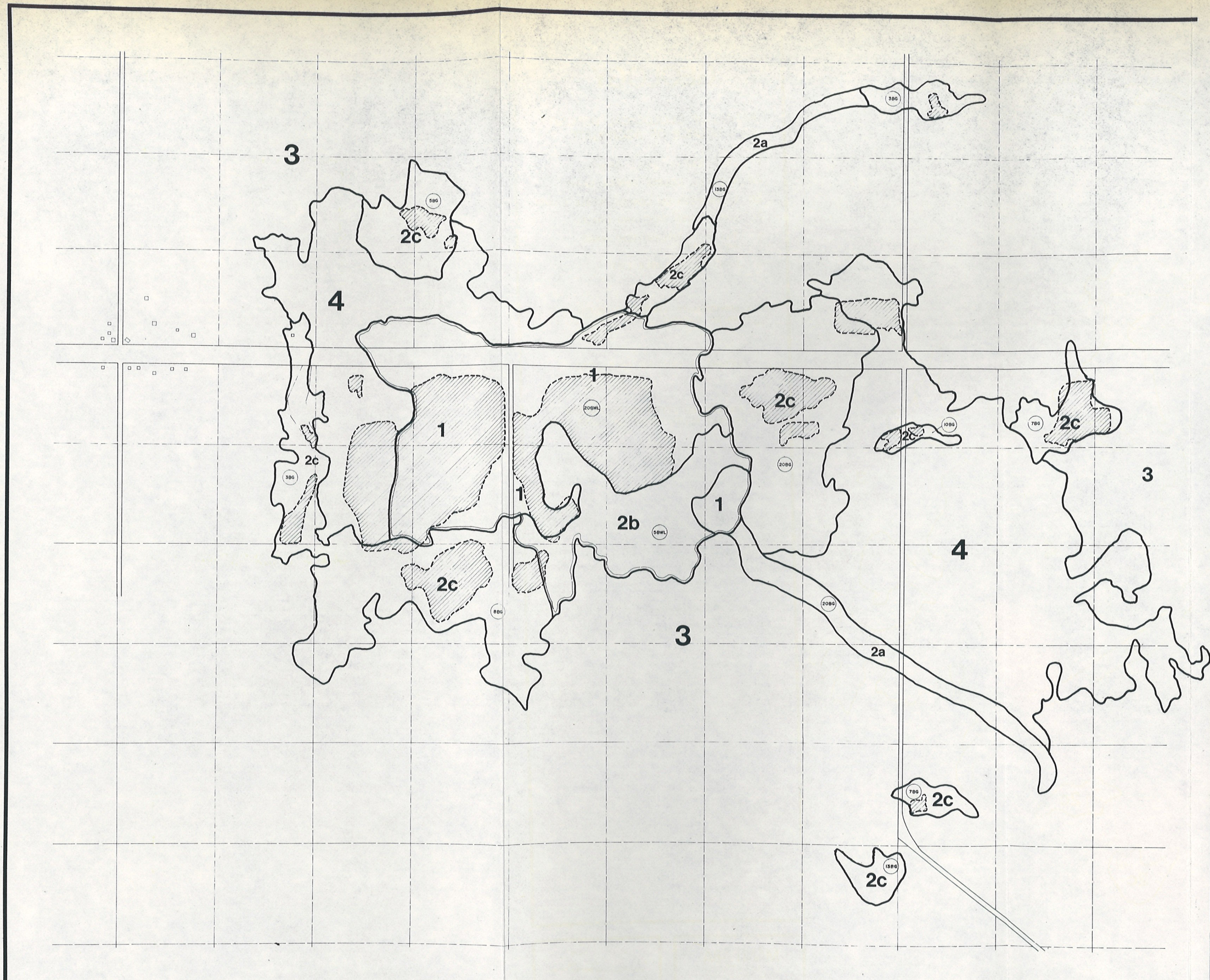
Detailed information concerning the texture classification, as well as the relationship of aggregate to overburden and unuseable material, will become available through future field studies. While it is anticipated that the Geology Map and development strategy will have to be adjusted to accommodate detailed findings, the fundamental components should remain unchanged.

6.2 GROUNDWATER:

The importance of the groundwater level for surface mining operations was commented on in Section 3.2.2. Excavations below ground water level are now highly feasible, but require specialized equipment. The relationship of the deposit to the groundwater level (as shown on the Geology Map) indicates the potential size of the resultant lake.



Photo #12 and #13: The aggregate reserves at Seddons Corner are considered to be the largest volume and best quality remaining in the Winnipeg region.



GEOLOGY

RATING OF GEOLOGICAL DEPOSITS AS A SOURCE OF AGGREGATE

- 1 DEEP COARSE PEBBLE GRAVEL
- 2a SURFICIAL COARSE PEBBLE GRAVEL
- 2b OVERBURDEN ON COARSE PEBBLE GRAVEL
- 2c INTERBEDDED SAND AND GRAVEL
- 3 TILL WITH INTERMITTENT SAND AND GRAVEL
- 4 SAND WITH PEBBLE LAG

○ APPROXIMATE LIMITS OF BELOW WATER EXCAVATION

⊗ EXTENT OF EXISTING OPERATIONS

○ ANTICIPATED DEPTH OF EXCAVATION IN FEET BELOW GRADE OR WATER LEVEL

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SCALE 1:5000
100 0 100 200 metres
200 0 400 800 feet

SEDDONS CORNER REHABILITATION PLAN



SOURCE OF INFORMATION: MINERAL EVALUATION AND ADMINISTRATION BRANCH
1978

Although little information is available concerning groundwater conditions in the study area, it is assumed that the level of the existing lake (913 feet A.M.S.L.) marks the normal water table. This has been extrapolated east and west, as shown on the cross sections. A piezometric water surface probably occurs at the bottom of the slope.

The morainic feature is obviously a major groundwater recharge zone. Underground flow follows the slope of the surface contours, and seepage discharge occurs on the slope in an almost uninterrupted ring surrounding the plateau. This pattern may be discerned from the Soils Map, which indicates the gradient of drainage conditions. The level of the groundwater would probably not vary more than two feet from the assumed mean elevation.³

6.3 TOPOGRAPHY:

The scale of many aggregate operations is such that the end topography bears no resemblance to the original landscape. However, the excavated area must still fit within a natural system, and the interface between the two is a highly critical zone. The greater the difference between the final excavated grade and the grade of the adjoining undisturbed land, the more extensive the rehabilitation problem.

Information concerning elevation change within the study area is presented on the Topography Photo Mosaic and on the Cross Sections Plan.⁴ The site falls within the Brokenhead River watershed and drains regionally to the north and west. Due to the coarse soil texture and extensive tree cover, surface run off is negligible. Internal (below ground) drainage conditions are indicated on the Soils Map.

³Personal communication with Mr. Frank Render, Groundwater Geologist, Water Resources Division, Manitoba Department of Renewable Resources and Transportation, June 12, 1978.

⁴Information Source: Surveys Branch, Manitoba Department of Mines, Resources and Environmental Management, 1:50000 NTS Sheets and field investigations by the author.

Although the moraine ridge rises less than 27 metres above the surrounding lacustine plain, it represents a major visual component in the landscape. As indicated on the cross sections, the land slopes gently (approximately 1.3%) for over one mile, then levels off at an elevation of about 950 feet (A.M.S.L.). To the southwest, the gradient of the slope is much steeper, rising from a wetland. The plateau dips north of the highway, then rises to the 950 foot elevation at two small knolls.

The most striking topographic feature in the area is a high stockpile of sand built up on the west side of the old B.A.C.M. pit, on legal subdivision 10 of Section 34. It is highly visible when approaching the site on P.T.H. #44, since it extends well above the existing tree tops.

The relationship between the natural contour of the land, the assumed groundwater level and the anticipated excavation, is illustrated in the Cross Section Plan. These sections have been taken along the lines of legal subdivision, as noted on the Topography Map.

The mineral deposit has been extrapolated in cross section as a straight vertical extension, which emphasizes the differential between the natural and excavated grades. In reality, the deposit could feather out to a shallow surface lense. Excavation would leave a sloping condition at this interface, minimizing reclamation costs. Alternatively, the limiting factor at the edge of the deposit may be an uneconomic stripping ratio where the mineral strata dips under a till bed. In this circumstance, the vertical face graphically presented in the section drawings would be the condition encountered upon discontinuation of mining.

The shore condition of any excavated groundwater lake will be extremely important from both the aesthetic and functional standpoint. To address this problem, a sectional profile of the assumed lake is illustrated on the Rehabilitation Strategy Plan. The relationship between the existing grade, excavated grade, water level and lake bottom at any point along the lakeshore may be determined from this drawing.

The most difficult (and expensive) slope reclamation work may be anticipated where the difference between the off shore elevation and the water level is greatest.

An important problem which this sectional analysis reveals is the minimal difference in elevation between the lake level and the natural grade sloping downward in the northeast. Precautions will have to be taken to ensure that mine excavation does not break through the containing barrier, creating a permanent surface outflow to the lake. The environmental impact of the resultant water course would have to be assessed carefully. If such an outflow could be feasibly accommodated, this location may be of use during mining to temporarily de-water the lake and to facilitate deeper excavation.

At this stage, it is sufficient to recognize the problem, the potential, and the need for more detailed investigation.

6.4 SOILS:

Information concerning the local soil conditions is needed as a basis for decisions concerning the stripping, stockpiling and subsequent re-use of topsoil in rehabilitation. If the soil is unproductive, the cost of such special treatment may not be justified.

Internal and surficial drainage patterns can also be determined from soils data.



Photo #14: View eastward over the study area from the top of the stockpile.

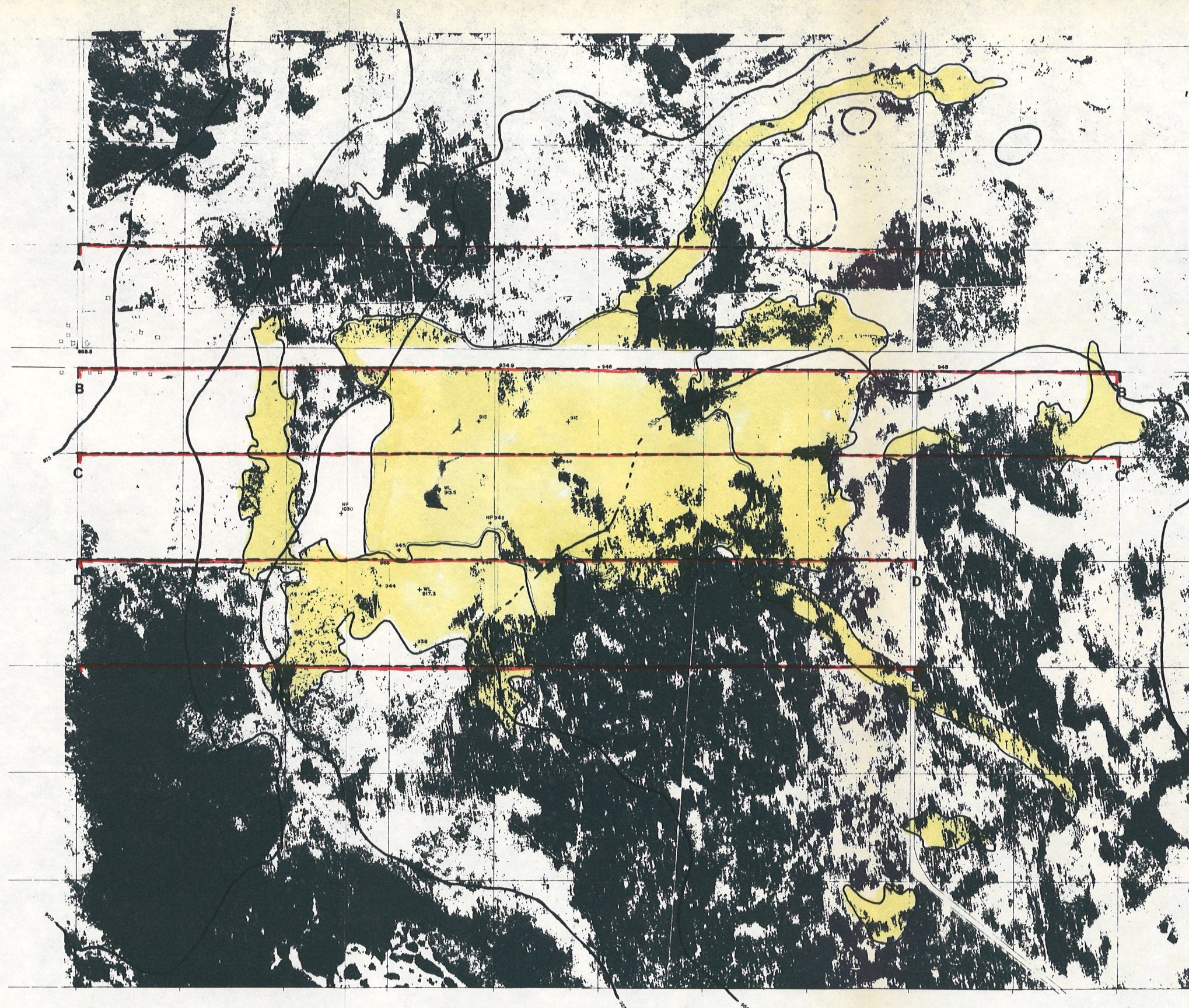


Photo #15: View of the existing lake formed by mining in the study area over a decade ago.

 CONTOUR INTERVAL (25 FT)

 CROSS SECTION LINE

 GRAVEL DEPOSIT



SEDDONS CORNER REHABILITATION PLAN



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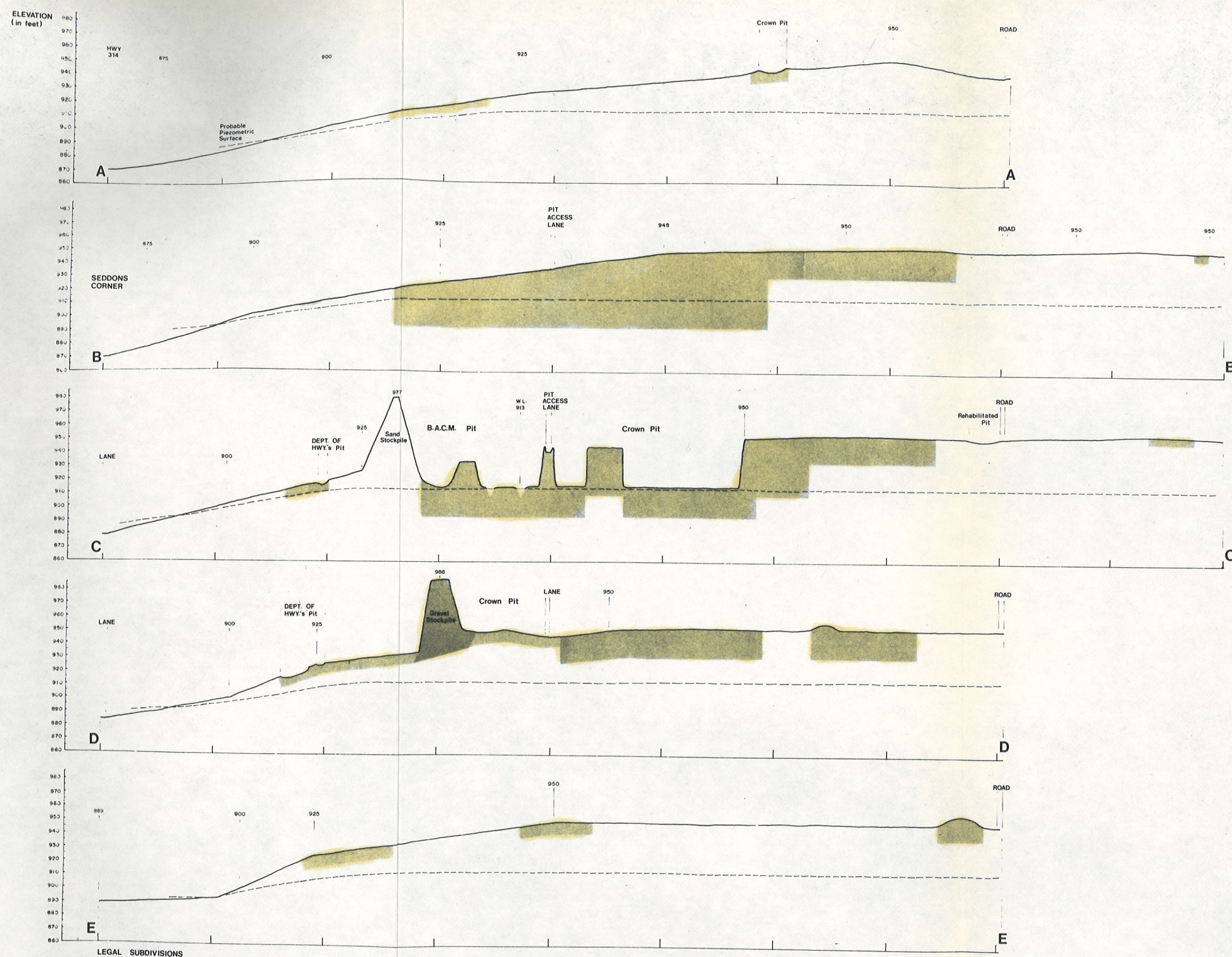
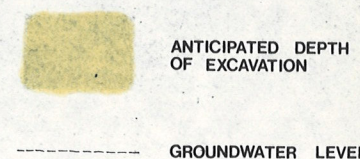
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100 0 100 200 met

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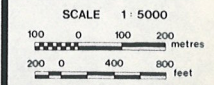
SOURCE OF INFORMATION: 1 TO 50,000 CONTOUR MAP
FIELD SURVEYS

CROSS SECTIONS



SEDDONS CORNER REHABILITATION PLAN

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SOURCE OF INFORMATION: MINERAL EVALUATION AND
ADMINISTRATION BRANCH
1978

Due to the complex physiography, the soil conditions of the Milner Ridge are highly variable. Twelve soil series may be identified within the study area, as indicated on the Soils Map. These soil types provide clues concerning local environmental conditions, suggesting opportunities or constraints for development. Information concerning the texture, drainage, and natural productivity of each soil type is summarized on the Tables in the map legend.

The areas where excavation is anticipated to occur are characterized by a rapidly to well drained Orthic Grey Wooded soil in the Woodridge Series. It generally consists of a thin organic surface layer ($0\frac{1}{2}$ inch), a deep, leached light greyish brown A horizon (6 to 20 inches) and a brown textural B horizon (32 to 41 inches). The zone of active pedagenic process thus extends some three to six feet below the surface.

The natural productivity of this soil type is relatively low, due to its coarse texture. Excessive internal drainage causes droughty conditions. The soil is also low in organic matter and natural fertility. These limitations are so serious that the application of normal agricultural improvement practices are impractical. (Opportunities which arise as a result of surface mining would be an exception).

From a potential agriculture productivity standpoint, this soil is in the second lowest of A.R.D.A.'s productive classes (Class 6), and considered suitable only for limited grazing where fire has removed the tree cover. The productivity of the soil for forestry use is limited by the periodic lack of soil moisture, as well as the high carbonate content. Although moderately good Jack Pine (Pinus banksiana) growth can be sustained, the soil is generally

⁵Soils of the Lac du Bonnet Region - Soil Survey Report 15, (Winnipeg: Manitoba Department of Agriculture, 1962).

rated as Class 5 in terms of forest productivity, generating a gross mean annual increment in merchantable volume of 31 to 50 cubic feet/acre. This is also based on the Canada Land Inventory System, in which Class 1 is most productive (110 cu.ft/acre) and Class 7 is least productive (less than 10 cu.ft/acre). Intensive recreation activity would also be limited by droughty soil conditions, since the vegetative cover is difficult to maintain.

6.5 VEGETATION:

The species composition and growth characteristics of vegetation are indicative of the environmental conditions in which they grow. Consequently, vegetation can be used as clues to natural relief, internal and surficial drainage patterns, as well as soil productivity, particularly where other data sources are unavailable.

Merchantable timber within a mining area should be harvested prior to clearing operations. In some circumstances, it may be appropriate to preserve certain tree stands for visual screening or aesthetic reasons. Relocation of specimen trees may also be warranted.

The extent and character of forest cover in the study area is illustrated on the Vegetation Photo Mosaic. The study area falls almost entirely within the Agassiz Provincial Forest, which is controlled for forest production. Timber from the plateau area is being selectively harvested, as indicated by the complex of lumber roads.

The dominant vegetation found on each soil type is indicated in Table 5. Those areas where excavation is anticipated generally support stands of Jack Pine, since this species is most tolerant to the coarse soil conditions.

TABLE 5: VEGETATION ASSOCIATIONS

<u>Soil Series</u>	<u>Dominant Vegetation</u>
Woodridge (W)	Jack Pine, Aspen.
Caliento (Co)	Aspen, Balsam Poplar.
St. Labre (Si)	Aspen, Birch, Jack Pine.
Sirko ($\frac{Si}{T}$)	Aspen, Balsam Poplar, White Spruce, Balsam Fir.
Carrick (C)	Aspen, Spruce.
Vasser (V)	Jack Pine, Aspen, Birch.
Carrick - St. Labre (C-Si)	Aspen, Spruce, Jack Pine, Birch.
Wintergreen (Wg)	Aspen, Balsam Poplar, Jack Pine, Balsam Fir.
Foley (Fo)	Sedge, Grass, Willow, Alder, Balsam Poplar.
Kerry (KY)	Alder, Willow, Swamp Birch, Sedges, Reeds.
Deep Peat (DP)	Sedge, Weeds, Moss, Shrubs, Tamarack, Black Spruce, Cedar.
Shallow Peat (SP)	Black Spruce, Tamarack, Cedar, Swamp Birch, Alder, Sedges, Reeds.

Source: Manitoba Soils Survey Report #15, 1967.



SOILS

	SERIES	TEXTURE	DRAINAGE
W	Woodridge	sand	excessive
Co	Caliente	fine sand	imperfect
Si	St Labre	fine sand	good
Si T	Sirko	coarse sand	imperfect
C	Carrick	fine sandy loam	good
V	Vasser	fine sand	good
C-Si	Carrick-St Labre	fine sandy loam	good
Wg	Wintergreen	fine sand	imperfect
Fo	Foley	very fine sandy loam	poor
Ky	Kerry	sand	poor
DP	Deep peat	organic	poor
SP	Shallow peat	organic	poor

SOIL CAPABILITY CLASSIFICATION*

	AGRICULTURE	FORESTRY
W	6	5
Co	4	3
Si	4	4
Si T	5	4
C	4	5
V	5	4
C-Si	4	4
Wg	5	4
Fo	3	5
Ky	6	5
DP	7	7
SP	7	6

* Based on the A.R.D.A. system in which Class 1 land is the most productive and Class 7 is the least productive.

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SCALE 1:5000
100 0 100 200 metres
200 0 400 800 feet

SEDDONS CORNER REHABILITATION PLAN



SOURCE OF INFORMATION: MANITOBA SOILS SURVEY
REPORT No. 15

7. Land Use Selection Guidelines



7.1 PURPOSE:

One of the main goals of any rehabilitation program is to optimize the potential for utilization of the landscape during and after the mining operation. This does not necessarily mean that the landscape should be returned to its original use. In some instances environmental constraints would prohibit this, while in other cases opportunities may arise for different yet more productive uses.

The potential of landscape modification during the course of mine operation is impressive. The cost normally incurred to make such large scale modifications to the terrain are prohibitive. We generally design our living and working environment on the basis of drainage constraints. Mining presents a chance to establish land use activities in a much more exciting aesthetic setting - houses overlooking panoramic valleys, golf courses winding around lakes, trail systems leading to spectacular summits.

This enormous potential may be wasted unless site planning for the end land use is incorporated into the mining process. The grading requirements of the landscape can be achieved as a component of excavation, making most efficient use of men, machinery and earth material. The cost of developing an environment appropriate to the end use is minimized and unnecessary grading costs can be avoided.

The same rationale for planning post mining land uses on a specific site apply at the macro-level, dealing with rehabilitation of the deposit as a whole. Although the decision to develop any land use on private property ultimately lies with the individual owner, it is in everyone's interest that such development is:

- i) compatible with adjoining land uses, existing and proposed, to form a harmonious community, and
- ii) appropriate to the local environmental conditions.

Land use planning must therefore be undertaken at a comprehensive level to guide and co-ordinate the efforts of the various mine operators working the deposit. Inappropriate land uses can be identified at the outset and prohibited.

Where the property is owned by the Crown, the mine operator working under lease or permit authorization has no personal incentive to maximize the post mining land use potential. Upon discontinuation of mining, the land is returned to the Crown, and the operator does not share in any equity increase. In these circumstances, there is additional justification for planning at the comprehensive level, where it can:

- i) provide guidance directing the operator's selection of a post mining land use, and
- ii) provide a basis for evaluation and approval of individual site plans submitted to the government in accordance with Manitoba Regulation 226/76.

7.2 THE PROCESS OF POST MINING LAND USE SELECTION:

While the advantages of jointly planning mining activity with post mining land use development are well recognized, a common misconception prevails regarding the actual process. It is often incorrect to assume that site planning at the outset of mining can be definitive, and exact. Unless the duration of the mining period is very short, such 'master plans' are usually outdated by the time they are printed, and may work to the detriment of rehabilitation objectives by locking into an inappropriate form.

The process of land use selection must be evolutionary, commencing with identification of a range of most probable uses and proceeding through constant re-evaluation and refinement over time to a final selection. Where decisions regarding site configuration are necessary during the early stages of mining they should be based on meeting the minimum requirements of the most probable range of land uses, as opposed to prematurely implementing a single assumed land use.

The reason for adopting such a flexible program is the time factor. Mining of major deposits typically occurs over a long period. For example, geologists anticipate that it will be some 30 years before the deposit at Seddons Corner is finally worked out. During this period, we may anticipate considerable changes in the regional setting, opening new opportunities for development and possibly precluding some uses which now seem reasonable. For example, there is no indication of a large demand for housing in the study area at present, but there may be by the year 2000.

As discussed in Section 6.1, the uncertainties are further compounded by inadequate information regarding environmental conditions. Layout of a housing development at the outset may be a waste of time if future geologic investigation or changes in mining technology allow an unforeseen extension of below water excavation. Individual mining plans are constantly reviewed and revised by the operator. Post mining land use selection and planning should respond accordingly.

7.3 PROGRESSIVE DEVELOPMENT OF POST MINING LAND USES:

The need for flexibility should not be confused to mean that no land use commitments are possible until the entire deposit is mined out. Certain portions of a mine site will be depleted prior to others, and certain mine properties may be depleted before mining is discontinued on adjoining properties. In these areas, detailed site

planning will have to be conducted in conjunction with mine excavation, to direct rehabilitation of the landscape to a final condition appropriate for the selected land use or range of land uses. The comprehensive rehabilitation program must provide a rational decision making forum ensuring these early developments will be compatible with those occurring subsequently. For example, if an auto race track is established, the resultant noise level may preclude housing on adjoining lands.

It may not be advantageous to fully implement a desired post mining land use during an interim stage. The land use may be sensitive to mining activity which will be continuing elsewhere on the site, or on adjoining property. In these circumstances, interim land uses which can be easily converted at a subsequent date should be implemented. For example, where housing is identified as the optimum end use, the land may be initially rehabilitated to agriculture or forestry, and then converted to housing at a later stage.

7.4 AGENCIES INVOLVED IN LAND USE DECISION MAKING:

Where property is privately owned, the selection of land use is ultimately in the hands of the owner, who will evaluate the advantages and disadvantages of alternatives largely on the basis of economic return. Provincial agencies and municipalities may limit the selection of land uses, through regulations and bylaws, to protect the environment and adjoining property.

In the case of the Seddons Corner deposit, and many other gravel deposits in the Province, the land is owned by the Crown. The decision making process to determine land use on Crown property is highly political, with input from many government agencies, municipal and provincial elected officials, as well as the public.

Although time consuming, this process is not necessarily restrictive. The land could be traded to private developers and developed for housing, in exchange for land more suitable for recreation, or further gravel extraction. It could be transferred to an Indian Band as part of a treaty settlement, then developed for commercial or industrial use. The Province is now actively involved in the development of parks and cottage subdivisions, as well as regenerating forests and leasing agricultural land. This provides a wide choice of potential activities.

7.5 EVALUATION OF ALTERNATIVE LAND USES:

The impact of gravel excavation at Seddons Corner will present opportunities for a wide range of land uses. The site is highly accessible, only one hour from Winnipeg and 12 minutes from Beausejour by highway. As noted in Section 5.4, the route is already a major recreation corridor leading to Whiteshell Provincial Park, and the volume of use is expected to increase. The natural resources of the site will be considerable. It is feasible that soil conditions can actually be improved, as will be discussed in Section 8.3.6. Agricultural as well as forestry uses may then be considered.

Even more significant, however, is the creation of an enormous lake on the site as a result of excavation. When mining is completed it will measure over 1.2 kilometres in length and 0.8 kms. in width, comprising some 96 hectares. The aesthetic and functional value of this element in the landscape opens the door for a wide range of land uses, from housing to recreation.

The task at the outset of a comprehensive rehabilitation planning program is to develop a scenario of land uses which are most feasible in the foreseeable future, and which are mutually compatible. The complexity of this problem is clearly dependant on the location of the mine within the Province. For example, some sites may offer only one potential after use - a return to forest production.

All conceivable land uses have been evaluated to determine the feasibility for development at Seddons Corner as summarized in Table 6. During the course of this study a number of specific activities have been discussed in meetings with various provincial agencies. (The government departments and individual representatives are noted in Appendix I). It was necessary to deal with each of these proposals in detail. However, since it is physically impossible to list every conceivable land use, Table 6 deals with broad categories as well as specific activities. (i.e. "commercial use", "industrial use", etc.).

7.6 FEASIBILITY CLASSIFICATION:

Each land use listed in Table 6 has been rated as having either a high, medium or low feasibility for development in the foreseeable future at Seddons Corner. This judgement is based upon discussions with representatives of various provincial agencies (see Appendix I) and accepted land use planning criteria. (Henson, 1967; Bauer, 1965; Schellie and Rogier, 1963; Schellie, 1977; Adhern, 1964; Bauer, 1970; Lynch, 1971; DeChiara, 1979; DeChiara and Koppelman, 1965; N.A.H.B., 1969; Goodman and Freund, 1968). The exact rationale for the classification varies with the circumstances of each particular use. There is a considerable margin of subjectivity involved since long range planning is a far from an exact science. For this reason, the ranking of feasibility in more precise, quantitative terms at this time would be of little value, and quite possibly misleading. This assessment is sufficient for the purpose at hand, which is to define a broad scenario of potential uses for which the mining landscape should be managed. In subsequent phases of the program, the analysis will be refined, based on increasingly precise and objective criteria.

Explanation of the specific criteria used to arrive at a feasibility rating is beyond the scope of this study. In general, however, each land use was judged against the following objectives:

1. The spacial and environmental requirements of the land use must be met by the physical resources of the Seddons Corner site, and the functioning of the land use should not result in severe deterioration of local environmental conditions.
2. There is or will be a demand for the land use above and beyond the facilities already provided, and consequently a need to accommodate it somewhere in the region.
3. There will be few if any alternative locations for such a land use in the region which are equally as advantageous as the Seddons Corner site.

The constraints to the development of each land use have been indexed in Table 5 under these broad objectives. Interpretation of this information should be based on the following:

i) Environmental Conditions:

When the physical requirements of a land use are weighed against the physical characteristics of the site it is apparent that some uses are much more appropriate than others. For example, we know that field crops in Manitoba require extensive acreage of highly productive soils. At Seddons Corner, the excavation will not result in the clearing of sufficient space for this use, and although soil conditions may be improved, it is doubtful that they could be transformed to ARDA's Class 1 productivity group. Consequently, environmental constraints for this land use are considered severe. To take another example, motor boating requires a large body of water, and the resultant wave action generated by this use would cause severe erosion along the shore. Again, these difficulties severely constrain the appropriateness of such a use at Seddons Corner.

ii) Regional Demand:

The anticipated regional demand for each of the various land use activities has been assessed, based on information provided by the government agencies listed in Appendix I. Where the need for more of any one type of land use is weak, this 'severely' constrains the appropriateness of such a use in the rehabilitation scenario. A strong demand, on the other hand, would mean that this is a relatively 'low' constraint.

iii) Alternative Location:

The physical suitability of the site for a particular land use, and the strength of anticipated demand, are not sufficient grounds to judge the feasibility of such a development. The central question remains - do other sites exist within the region which offer advantages as better locations? Where this is the case, it severely constrains the appropriateness of such a land use at Seddons Corner.

For example, there may be a demand for ice skating facilities, and this could physically be accommodated on the site. Nevertheless, this type of activity should be developed much closer to urban centres where it is more convenient for public use.

Where the Seddons Corner site offers clear advantages over other locations in the region for a particular use, it has been given a 'low' constraint designation. Where other locations are much more advantageous, the development of that land use at Seddons Corner is considered to be 'severely' constrained.

iv) Degree of Commitment:

Each land use has also been classified in Table 6 by its 'degree of commitment', as low, medium, or high. The importance of this characteristic has been pointed out in Section 7.2. Those activities which do not require long term commitment of the landscape may be considered as interim uses in the rehabilitated landscape. A use which has a 'low' rating may be converted into an alternative land use with relative ease and low cost. Pasture land is an obvious example of a low committing use. Where there is a 'high' degree of commitment by a land use, the relative cost and difficulty involved to transform the landscape to alternative uses is extensive. For example, a housing subdivision, once established, is a relatively permanent feature. Removal of houses to make space for alternatives such as industry or forestry would be difficult.

In summary, the analysis in Table 6 provides a land use scenario for the probable (high feasibility), the possible (medium feasibility), and the unlikely (low feasibility). It must be emphasized that this is merely an initial step in the planning program, and in no way a commitment to any one pattern. The end selection of land uses may be limited to only a few of the uses now most feasible, or alternatively, it may include a range of uses from all three feasibility classes. By way of example, a number of alternative development concepts have been suggested in Table 7.

What the scenario does not indicate in a systematic manner is the potential of the landscape for post mining uses. We are able to interpret from this the qualities of the landscape which will be important, and to define those areas in the mining landscape which can be most efficiently transformed to meet these requirements.

TABLE 7: LAND USE ALTERNATIVES

Concept I:

Low Key Rehabilitation

Pasture
Reforestation
Hunting/Wildlife
Onshore Fishing
Ice Fishing
Offshore Fishing/Boating
Boat Launch
Small Wayside Picnicing

Concept II:

Focus on Wayside Function

Reforestation (major)
Hunting/Wildlife
Hiking/Cross-country Trails (limited)
Onshore Fishing
Offshore Fishing/Boating
Beach/Swimming (limited)
Tent Camping
RV Camping
Toilets/Cooking House/BBQ Shelter
Boat Launch
Picnicing, Wayside Development
Ice Fishing
Ski-doo Trails

TABLE 7 ...continued...

Concept III:

Focus on Intense Day Use Recreation and Club House Development

Reforestation (minor)
Node for Hunting (club house)
Rifle/Archery Range
Hiking and Cross-country Skiing
Fishing (onshore)
Fishing (offshore)
Fishing (ice)
Boating
Swimming
Beach
Picnic
Play Field
Skating
Golf Driving Range
Camping (tent and recreation vehicles)
Toilets/Concession
Club House
Summer Camp
Skating
Skiing/Tobogganing
Ski-dooing/Trail bikes
Horseback Riding
Scuba Diving
Automobile/Motor Cycle Racetrack Node - club house
- concession
- stands for spectators
All Terrain Vehicle

TABLE 7 ...continued...

Concept IV:

Private Resort

Reforestation

Wildlife Reserve

Nature/Cross-country skiing

Fishing (onshore, offshore, ice)

Small Wayside Picnicing

Boating

Golf Course

Horseback Riding

Club

Seasonal Cottages

Permanent Residential

8. Environmental Management Guidelines

8.1 PURPOSE:

The identification of a post mining land use or uses will provide broad criteria for decisions concerning the optimum configuration of the landscape. However, these decisions must also be based on an understanding of environmental processes, which provide both constraints and opportunities.

The technology of site planning and development is generally documented, and it would be redundant to fully discuss it in this paper. This Section is directed only to those aspects of mine landscape restoration which are somewhat unique from other site development programs. Information on these aspects is generally sparse, and in some instances hypothetical. Systematic field investigation will often be required to provide answers.

The purpose of this Section is to outline the environmental issues which should be addressed in a comprehensive rehabilitation planning program, as a basis for development of an overall rehabilitation strategy. Such information should be presented to the operators as a guide for the preparation of their individual site plans.

8.2 GROUNDWATER LAKES:

8.2.1 Impact of Mining on Groundwater Levels:

Mining below the water table is becoming increasingly common in Manitoba, as the demand for aggregate near urban centres off sets the associated production costs. The anticipated environmental impact of such mining is frequently a matter of controversy for local citizens, municipal officials and regulatory authorities. Riparian rights of all citizens are established both in common law and through the provincial Water Rights Act. Any major change to natural water flows



Photo #16: Enormous lakes may be created by mining below the water table. The potential for ground water disruption or contamination is high.

requires prior approval and careful monitoring by the provincial regulatory agency.

Mining below the water table may affect groundwater levels in a number of ways, depending on local conditions.¹ The immediate consequence of removing earth material is to create a void. In accordance with the basic principles of hydrology, groundwater flows in to fill this void, establishing over the long term a lake with a surface level at the elevation of the water table. The impact of mining on ground water levels will be a function of the rate of movement in the aquifer, the size of the aquifer and excavation, and the relationship of the excavation to surface and subsurface flows.

i) Rate of Water Movement through the Aquifer:

The porosity of the subsurface material will determine the rate of lateral water movement, and consequently the amount of time required to establish a lake level in balance with the local water table. The permeability of various soil types is indicated in Table 8. The immediate effect of mining is to cause a local drawdown of the water table. Recovery may be so fast that this drawdown is insignificant. Alternatively, a subsoil of low permeability such as clay may cause a larger recovery time. The area affected by any drawdown is also related to subsurface porosity. Coarse material has a much broader area of impact, although recovery is faster.

The drawdown resulting from excavation will eventually disappear, unless some factor continues to cause an outflow from the area of excavation. One factor may be the rate of evaporation from the lake surface.

¹Personal communication with Mr. Frank Render, Groundwater Geologist, Water Resources Division, Manitoba Department of Renewable Resources and Transportation, July 1978.

TABLE 8: PERMEABILITY OF VARIOUS SOIL TYPES

<u>Soil</u>	<u>Permeability Feet Per Day</u>
Coarse Sand	394
Sand	39
Fine Sand	16
Very Fine Sand	8
Loamy Sand	4
Sandy Loam	0.79
Very Fine Sandy Loam	0.39
Loam	0.16
Silt Loam	0.079
Silty Clay Loam	0.039
Silty Clay	0.0079
Clay	0.0039

Source: K.L. Schellie, Sand and Gravel Operations - A Transitional Land Use, p. 172.

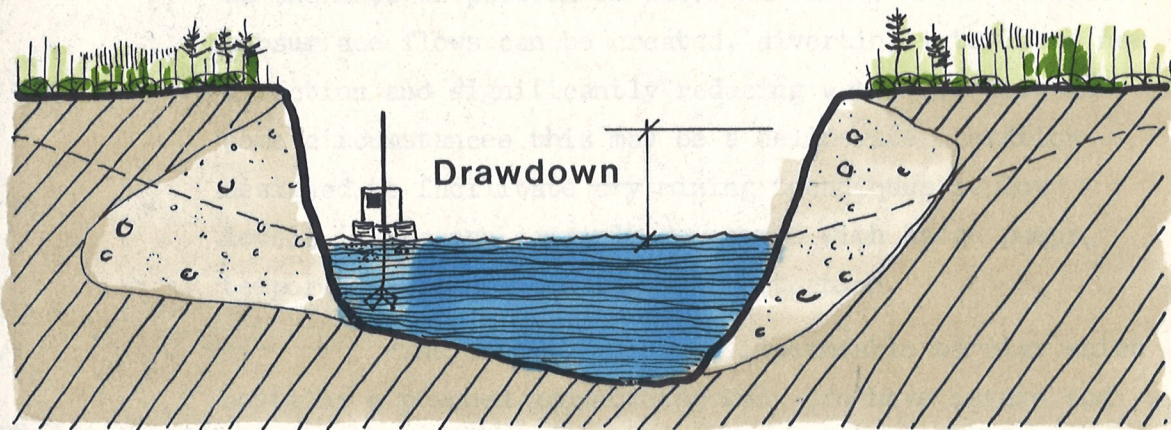
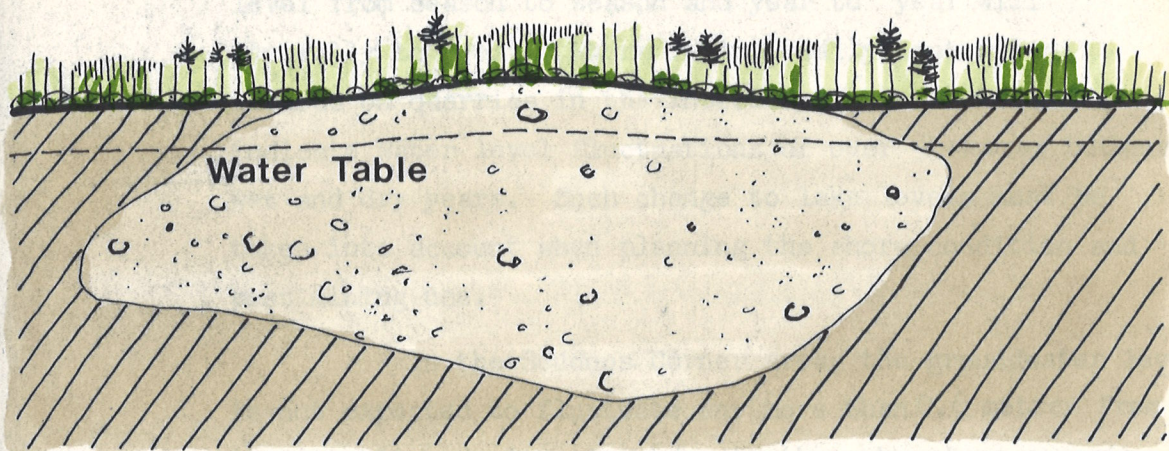
A large area of excavation associated with a low sub-surface porosity could in this way cause a permanent or seasonal impact on local groundwater levels.

The common concern expressed in regard to below water table excavations is that such short or long term drawdowns will affect neighbouring wells or water bodies. Another factor to consider is the possibility of damage caused by a raising of the water table. The fine sediment associated with excavations may in some circumstances be carried laterally out of the lake by groundwater flows, and deposited in the walls of the lake, which act as a filter. Over time, such deposition could build up, reducing porosity and outflow. Where the excavated lake extends across the aquifer feature, as it may in an esker, or beach ridge, such 'damming' could cause the water table to rise.

At Seddons Corner, the subsurface water movement is considered to be relatively fast, as a result of the coarse texture of the Milner Ridge aquifer. The proposed excavation will probably not have any significant or long term impact on the groundwater level in the area.

ii) Size of the Groundwater System:

The groundwater encountered when excavating may be part of a regional aquifer extending many square miles in area, or it may be a very local system occurring as a 'perched' condition. In the latter instance, the excavation of a proportionately large volume of material can cause a lowering of the groundwater level over the entire area, and fluctuations in the water level as a result of excavation may be significant.



**Fig 8: Local Drawdown Of
The Groundwater Table
Due To Mining**

The natural fluctuation of the groundwater level from season to season and year to year will generally be greater where it is locally controlled. Records on quarries in the Interlake area of Manitoba indicate water level fluctuations of over 3 metres between wet and dry years. Such change to lake levels must be taken into account when planning the shore condition and post mining use.

In the Seddons Corner area, the groundwater level is not expected to fluctuate any more than 0.6 metres from its established elevation, due to the subsurface porosity and the catchment size of the Milner Ridge aquifer.

iii) Relationship of Excavation to Surface and Subsurface Flows:

Excavation below the water table may have a major environmental impact where it results in a change to the natural pattern of water movement. Both surface and subsurface flows can be created, diverting water to a new direction and significantly reducing water levels. In some circumstances this may be a deliberate operation designed to facilitate dry mining techniques at low levels. Pits are commonly dewatered with large pumps, temporarily creating a drawdown situation.

The disruption of an impermeable barrier which contains a perched groundwater body can have severe and permanent implications. Not only would local groundwater levels drop, but associated lakes and ponds could also be drained.

At Seddons Corner, the anticipated area of excavation will intersect a hillside presently containing the head of water. If this is allowed, there is a high probability that surface drainage of the excavated lake will occur. A water course would develop where none had previously existed. The potential negative impact is sufficient to warrant detailed study and consideration before any approval of such excavation is granted.

In addition to providing for a safeguard against environmental calamity, the identification of such a hydrologic situation at this early stage allows scope for controlling or even manipulating conditions to facilitate mining. The area has now been designated as a major stockpiling zone for overburden and reject material, which may subsequently be graded to form a levee. (See Concept Plan). A control structure could be introduced in the levee to regulate the outflow of water.

The situation also offers potential for dewatering the mine site, thereby facilitating less expensive dry excavation techniques. This warrants more detailed investigation to define clearly the associated cost and benefits.

8.2.2 Sensitivity to Pollution:

The groundwater lakes formed by mine excavations may be comparable in scale to naturally occurring waterbodies, but they should not be equated for management purposes. The potential for post mining uses may be quickly destroyed if adequate controls are not imposed to maintain water quality.²

²D.A. Rickert and A.M. Spieker, Real Estate Lakes: Water in the Urban Environment, Geological Survey Circular 601-G (Washington: U.S. Department of the Interior, 1971), p. 4.

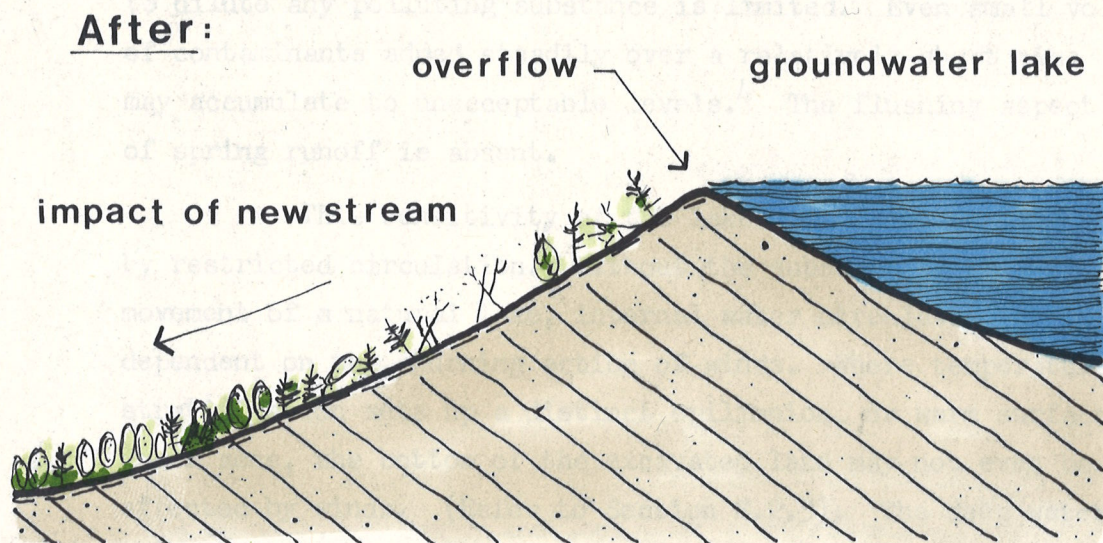
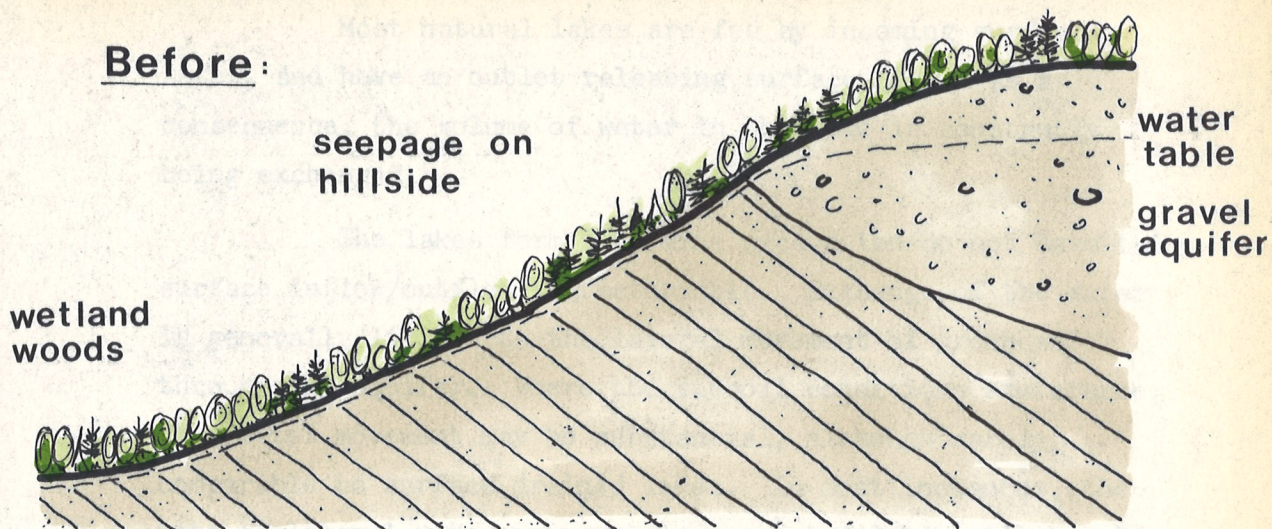


Fig. 9: Environmental Conditions Where Mining Creates A New Water Course

Most natural lakes are fed by incoming surface water, and have an outlet releasing surface flow. As a consequence, the volume of water in the lake is constantly being exchanged.

The lakes formed by mine excavation do not have this surface inflow/outflow characteristic. Exchange of the water is generally limited to the lateral movement of groundwater through the aquifer. Where the subsoil conditions are coarse, this water movement may be substantial, although rarely comparable to surface drained lakes. In most instances, the rate of lateral water movement in excavated lakes will be slow, since any coarse subsoil will have been mined for aggregate.³

A consequence of the slow water movement is increased sensitivity to pollution. The capacity of the lake to dilute any polluting substance is limited. Even small volumes of contaminants added steadily over a relatively short time may accumulate to unacceptable levels.⁴ The flushing aspect of spring runoff is absent.

This sensitivity of the lakes is often compounded by restricted circulation. Without the substantial inflow/outflow movement of a natural lake, internal water circulation is dependent on the churning action of winds. Where temperature stratification sets up a distinct epilimnion, or warm surface water zone, the bottom of the excavated lake may not even be affected by winds. (Refer to Section 8.2.3). The deep water

³George Mulamoottil and Robert Farvolden, "Planning for Rehabilitation of Gravel Pits", Water Resources Bulletin, Volume 11, No. 3, (June 1975), pp. 599-604.

⁴Personal communication with Mr. Ted Parant, P. Eng., Wardrop and Associates Ltd., Consulting Engineers, October 24, 1978.

of the lake can become oxygen depleted by ongoing decomposition of organic matter. As a consequence, minor sources of pollution may cause contamination to reach unacceptable levels in localities, although the volume of lake water is normally sufficient for dilution. By way of example, water testing in an excavated lake near Winnipeg which was used for public swimming revealed a substantial layer of concentrated urine accumulated on the lake bottom.⁵

Lakes newly formed by excavation below the water table are comparable to the glacier fed lakes of alpine regions. They are usually cold, deep and low in nutrients per unit volume. Littoral plant growth is sparse and plankton production is low. Such lakes are termed oligotrophic, and are highly regarded as a recreation and aesthetic resource.

Over time the natural accumulation of organic material in a lake will change the biology and chemistry through the process of 'eutrophication'.⁶ When the level of available nutrients rises too high, the lake becomes subject to excessive vegetation growth and algae blooms. Decomposition depletes the oxygen supply in the water, killing fish and causing unpleasant anaerobic gases.

The introduction of large volumes of organic matter, phosphates, nitrates, or other substances by man accelerates the process of eutrophication.⁷ In a relatively closed system such as the excavated lakes, input of nutrients leached from inadequate sewage systems may quickly cause a deterioration of water quality, transforming the lake from an asset to a liability.

⁵Personal communication with Mr. R. Casson, Mines Inspector, December 28, 1980.

⁶W.H. Amos, Limnology - An Introduction to the Fresh Water Environment, (Chestertown, Maryland: La Motte Products Company, 1969).

⁷R.H. Wagner, Environment and Man, (New York: W.W. Norton and Co. Inc., 1971), pp. 127-128.



Photo #17 and #18: The mining operation itself poses a serious threat of ground water contamination, since it involves large volumes of petroleum products. The abandoned gas truck and oil spill point to an ongoing problem.

In addition to stimulating the eutrophication process, raw sewage is a source of harmful bacteria. The swimming potential and aesthetic appeal of a new lake is lost where the water develops into a health hazard.

Sewage is not the only source of contamination warranting careful control. Gasoline, road salt, or other chemicals can have disastrous consequences if emitted into the lake.⁸ Since the excavated lake water constitutes a direct, unfiltered component of the groundwater system, its contamination may have a local or even regional impact, detrimentally affecting well water sources.

8.2.3 Water Temperature:

One of the limiting factors for recreational use of groundwater lakes is considered to be water temperature.⁹ Although some swimmers enjoy the refreshing quality of cold water, it is a deterrent for most and can represent a safety hazard. The surface layer, perhaps the top 2 metres are of major interest to swimmers and waterskiers. The temperature of bottom water affects skin and scuba divers and where upwelling occurs, will also concern those participating in surface water sports.

Groundwater typically reflects the average annual temperature, and in the study area this would be around 5°C. The distribution of the heat energy of the sun received at the lake surface depends on a number of factors including wind velocity, turbidity, currents, rate of groundwater movement, and basin contour configuration.¹⁰

⁸ Ontario Ministry of the Environment, Guidelines and Criteria for Water Quality Management in Ontario, (Toronto: Ministry of the Environment, 1975).

⁹ Personal communication with Mr. Doug Mazur, Parks Planner, Eastern Section, Parks Branch, Manitoba Department of Natural Resources, June 14, 1978.

¹⁰ J.M. Masterton, R.B. Crowe, and W.M. Baker, The Tourism and Outdoor Recreation Climate of the Prairie Provinces, (Ottawa: Atmosphere Environment Service, Environment Canada, 1976), p. 171.

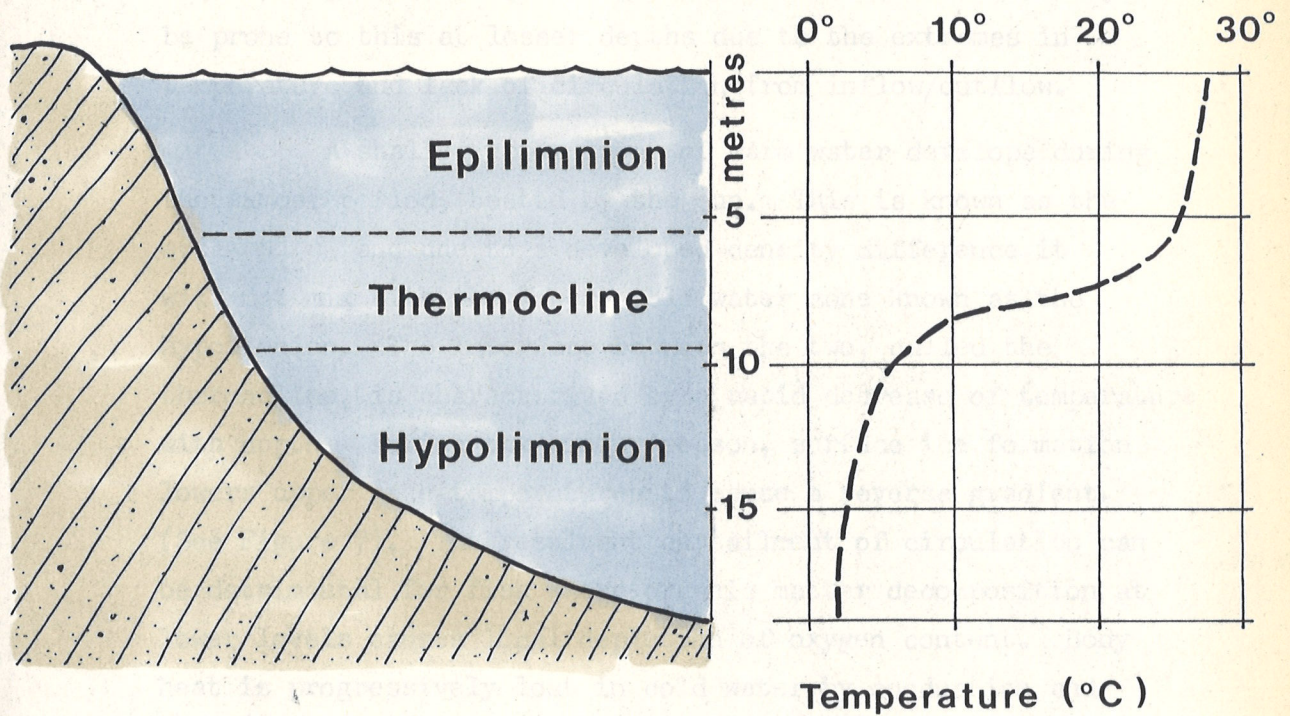


Fig. 10: Typical Thermal Stratification Of A Lake In Summer

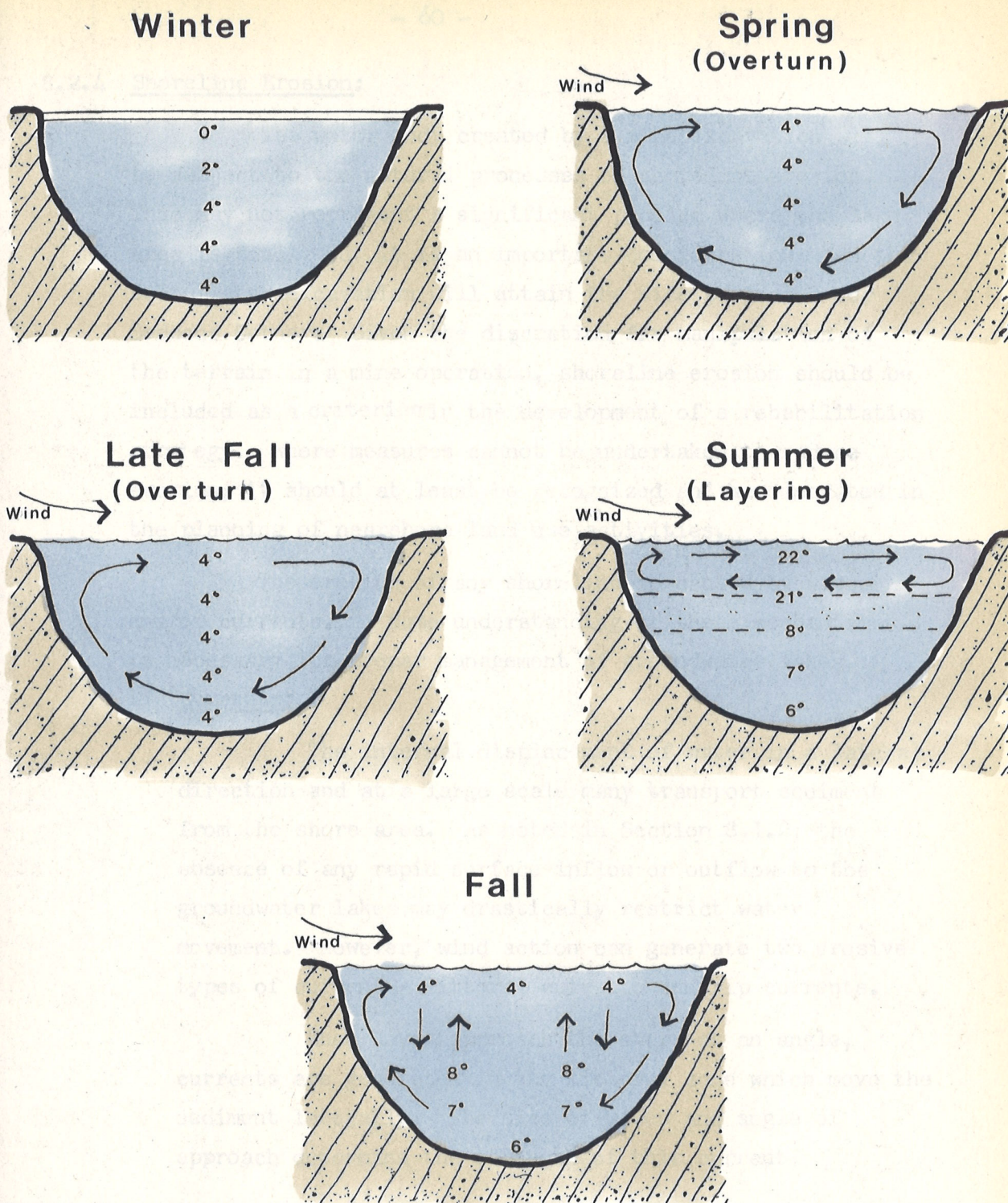
Where water depths exceed approximately 10 metres, most lakes become thermally stratified during the summer and winter seasons.¹¹ Water layers of different temperatures become established, and due to density differences, little intermixing occurs. (See Figure 5). Groundwater lakes may be prone to this at lesser depths due to the extremes in temperature and lack of circulation from inflow/outflow.

A shallow upper layer of warm water develops during the summer period, heated by the sun. This is known as the epilimnion and due to a developed density difference it will not mix with the lower, cold water zone known as the hypolimnion. The interface between the two, called the thermocline, is characterized by a rapid decrease of temperature with depth. During the winter season, surface ice formation lowers upper lake temperatures to cause a reverse gradient. (See Figure 7). The resultant curtailment of circulation can be detrimental for fish where organic matter decomposition at lower levels causes local depletion of oxygen content. Body heat is progressively lost in cold water by conduction and exercise increases the rate of loss. Lowering of the body temperature to 25°C is usually lethal. Most people find swimming comfortable only with a water temperature above 18°C.¹²

Attractive swimming areas can be created in ground water lakes by taking fullest advantage of the epilimnion zone when establishing lake basin contours. Such swimming areas should be located in the shallowest portion of the lake and where possible should be sheltered from any open fetch. A sand bar feature can be developed to surround the swimming area, and prevent the influx of cold water from deep portions of the lake. The bar does not extend to the surface, thereby facilitating circulation of the warm epilimnion water.

¹¹ W.H. Amos, Limnology - An Introduction to the Fresh Water Environment, p. 26.

¹² Masterton, Crowe, and Baker, The Tourism Climate, p. 174.



**Fig. 6: Temperature Cycles
In Lakes (°C)**

8.2.4 Shoreline Erosion:

The water body created by a mine excavation will be subject to the natural processes of shoreline erosion. This may not represent a significant problem where the lake area is small, but it is an important consideration when the below water excavation will attain the size projected for Seddons Corner. Given the discretion for manipulation of the terrain in a mine operation, shoreline erosion should be included as a criterion in the development of a rehabilitation strategy. Where measures cannot be undertaken to reduce erosion, it should at least be recognized and accommodated in the planning of nearshore land use activities.

The erosion of any shoreline is caused by waves and/or currents.¹³ Some understanding of these mechanisms is necessary for proper management of groundwater lakes.

i) Currents:

The internal displacement of water in a lateral direction and at a large scale may transport sediment from the shore area. As noted in Section 8.1.2, the absence of any rapid surface inflow or outflow to the groundwater lakes may drastically restrict water movement. However, wind action can generate two erosive types of current - littoral currents and rip currents.

When waves approach the shore at an angle, currents are generated in the littoral zone which move the sediment laterally. The size of waves and angle of approach determine the strength of this current.

¹³K.M. East, Shoreline Erosion Point Pelee National Park, (Ottawa: Parks Canada, National Parks Branch, 1976), pp. 19-23.

Rip currents occur under storm conditions causing very localized return flow patterns for water driven onshore by surface wind. Although they are usually no more than five to ten metres wide, they may achieve high velocity.

ii) Wave Action:

Waves themselves provide a mechanism whereby energy is transmitted by water from the drag of wind over the surface. An orbital motion of water particles is set up in planes adjacent to the surface. The motion is most pronounced at the surface, but is transmitted to adjacent layers below, with a rapid loss in the magnitude of the orbital radius at increasing depth.

Three factors influence the size of wind waves:¹⁴

- 1) the wind velocity.
- 2) the duration of time the wind blows.
- 3) the extent of open water across which it blows (the fetch).

East (1976) describes what happens to waves when they encounter a land body:

"As waves reach the coastal zone, bottom friction retards the lower portion of the wave so that the upper portion, moving more rapidly, ultimately overturns. Energy is then dissipated in turbulence and the consequent shearing stress on the bottom throws sediment into suspension. The remaining energy is utilized moving the water up the beach slope. In general, storm conditions result in erosion with the effects of backwash and high subsurface water pressure combining to provide a balance of lakeward sediment transfer in the littoral zone."¹⁵

¹⁴W. Bascom, Waves and Beaches, (New York: Anchor Books Double Day and Company, Inc., 1964), p. 44.

¹⁵K.M. East, Shoreline Erosion: Point Pelee National Park, A History and Policy Analysis, p. 19.

The point at which waves 'feel' the lake bottom is at a water depth less than one-half the distance between successive wave crests. When the depth of water becomes less than 1.3 times the wave height, they become unstable and begin to break. The slope of the shore is therefore an important aspect of wave dynamics. The distance the wave will run up a shore sloping at less than three horizontal to one vertical is about equal to the incident wave height. As the slope approaches near vertical wave run up is approximately twice as great.¹⁶

The only combined action of currents and waves will, over time, develop a shoreline configuration which is in balance with the hydrologic forces. This equilibrium shore slope will be greatly affected by the size of sediment involved and will typically be as follows:

fine sand - 30 horizontal to 1 vertical;
coarse sand - 10 horizontal to 1 vertical;
gravel - 4 horizontal to 1 vertical.

The main factors influencing the depth to which erosion occurs are the wave heights and size of soil particles. Examination of shore profiles of the southern basin of Lake Winnipeg indicate that erosion is confined to water depths less than 3.6 metres.¹⁷

By creating comparable slopes as a component of the mine site rehabilitation, stabilization of the shoreline can be greatly accelerated. Four to one slopes in the near shore zone are recommended as a maximum in any substantial water body created by mining. Steeper slopes, up to the

¹⁶M. Young, F. Penner, The Lake Winnipeg Shoreline Handbook, (Winnipeg: Manitoba Department of Mines, Resources and Environmental Management, 1977), pp. 4-5.

¹⁷Ibid., p. 5.



Photo #19 and #20: The condition of the shore zone is often a major limitation for biological development in mine excavated lakes.

material's angle of repose, may be allowed where shore erosion will not be a problem, or where alternate protection measures are proposed (rip rap slopes, gabion slopes, walls, or cribs). A vegetated buffer zone extending 7 to 14 metres on shore is an effective means of stabilizing this zone to prevent undue sedimentation.

The greater the distance over which the wind 'drags', known as fetch, the greater the wave energy to be dissipated on the shore. The same wind velocity from different directions may have a markedly different impact on wave generation, depending on the configuration of the lake.

For this reason, it may be advantageous to minimize the effective fetch lengths, particularly in relation to the prevailing winds. Within the study area this has been accomplished by designating stockpile areas for overburden and reject material where they will subsequently form an island and a peninsula feature. The open span of lake surface is thereby interrupted.

In summary, the configuration of the lake and the shore can be manipulated to minimize shoreline erosion. From the standpoint of the rehabilitation strategy, it is most important that areas where shore erosion may be a problem are identified, so they may be properly addressed in this manner.

8.2.5 Biological Development:

The lakes newly created by mine excavation below the water table are biologically sterile - devoid of any flora or fauna that we would typically find in a natural feature. The normal mine operation pattern leaves steep shores, often dropped off at slopes of 1.5:1. Exposed subsoil may be coarse and infertile, and although there is adequate depth of water for fish, the system is landlocked.

Photo #19 and #20: The condition of the shore zone is often a major limitation for biological development in mine excavated lakes.

These 'bathtub' features should not be accepted as rehabilitated, even though the water may hide the impact of mining. For aesthetic and recreational reasons, the development of conditions which promote biological activity should be mandatory.

The key to promoting biological productivity is the creation of diverse habitat conditions,¹⁸ particularly by the enhancement of the littoral zone.¹⁹ The littoral zone of a lake is the shallow water area, generally defined as the area where light penetrates to the bottom. It can be occupied by rooted vegetation - both emergent and submergent, and consequently represents a complex feeding zone for a wide variety of insects, fish, water, fowl and mammals.

Where the shore slopes steeply into deep water, the area of littoral zone is minimal, comprised of a narrow margin within a few feet of land. It is generally preferable therefore to create gentle shore slopes, or to actually create shallow water zones (less than four feet) through additional excavation or backfill. With the invasion of reeds, sedges, grasses, cattails, and associated plant communities, these areas can become marshes, an ecological community which supports rich and abundant animal life.²⁰

In addition to manipulating depth of water, consideration should be given to development of a satisfactory rooting medium in the littoral zone. Coarse or compacted material, low in nutrient status, will impede establishment of emergent and submergent vegetation. A fine textured and

¹⁸ A.C. Martin, H.S. Zim, and A.L. Nelson, American Wildlife and Plants - A Guide to Wildlife Food Habits, (New York: Dover Publications Inc., 1961), p. 3.

¹⁹ Personal communication with Dr. Joel O'Connor, Sport Fish Biologist, Fisheries Branch, Manitoba Department of Mines, Resources and Environment, August 12, 1978.

²⁰ R.L. Smith, Ecology and Field Biology, (New York: Harper and Row, 1966), p. 186.

penetratable soil, such as backfilled silty-clay overburden, is recommended. Although there is no published data to support such a proposal, incorporation of a slow release fertilizer in the littoral zone soil would undoubtedly accelerate the establishment of marsh vegetation.²¹ Actual planting of the desired species in strategic locations is also recommended to ensure availability of a seed source. There are a number of references regarding selection of appropriate plant species.²²

Although a marsh area in association with the lake will increase the level of apparent biological activity, it is not necessarily desirable to surround the entire lake with a marshy littoral zone. The more abrupt land water interfaces can be valuable as fish spawning zones, particularly in coarse textured material. It will also be advantageous to have alternative shore configurations from the standpoint of human use (fishing, swimming, etc.).

In some circumstances, the mine excavation below water is shallow. Rehabilitation should be directed to form a lake of at least one acre, with 25% of the surface area at least 5 metres deep, where a fish population is to be sustained.²³ Water depths of less than one metre are subject to the invasion of aquatic vegetation, which may be undesirable when out of proportion to the open water area. Disadvantages include mosquito production and oxygen depletion during organic decomposition.

²¹Personal communication with Dr. Joel O'Connor, Sport Fish Biologist, August 12, 1978.

²²Martin, Zim, and Nelson, American Wildlife and Plants.

²³J.S. Allen, and A.C. Lopinot, Small Lakes and Ponds - Their Construction and Care, Fishery Bulletin No. 3, State of Illinois Department of Conservation.

A number of mine excavated lakes in the Province have been stocked with fish. The recommended species is usually trout. This species prefers the cold water temperature, and the absence of predators such as northern pike, pickerel, and perch, is advantageous for development of trout populations. Furthermore, this species, particularly the rainbow trout, is a favoured sport fish, prized by the gourmet and trophy hunter alike.²⁴ Opportunities to fish for trout in the immediate vicinity of our towns and cities are rare, so the Provincial Fisheries Branch strongly promotes a stocking program.²⁵

The main limiting factor to establishment of a fish population is the availability of food. Development of a diverse littoral zone, with a complexity of plant and insect populations is essential. Biologists have found that at least five years are generally required before sufficient natural vegetation is established in new dug-outs to permit stocking.²⁶ This time period may be eliminated where direct seeding is initiated and proper conditions are established.

The minimum depth of water to sustain a fish population over winter in this region is 4.5 metres. Where depth is less than this there is a degree of winter kill as a result of freezing and oxygen depletion. (up to 1.2 metres of ice may be expected).

Deep areas in association with extensive littoral zones are a desirable habitat combination for many fish species which cannot tolerate the warm water temperature of summer. The fish will move into these areas during the day, then rise to the shallow littoral zone in the evenings to feed.

²⁴H.R. MacCrimmon, B.L. Gots, Rainbow Trout in the Great Lakes, (Toronto: Ontario Ministry of Natural Resources, 1972), p. 23.

²⁵Personal communication with Dr. Joel O'Connor, Sport Fish Biologist, August 12, 1978.

²⁶Ibid.

The usual recommendation is to stock at a rate of about 300 one lb. fish per hectare. This would provide a sufficient population to attract serious trout fishermen from Winnipeg.²⁷ The recreation aspect can be greatly enhanced by development of ancillary onshore facilities. Steep shore slopes in certain areas would provide greater opportunity for shore fishing, and boat launching sites would be necessary.

Trout farming in Manitoba is a new concept which originated in 1968 and is still in experimental and developmental stages. Many small mine excavations would be well suited to this business, under proper management. A lake area of 2 to 4 hectares, and depth of 1.5 metres would be minimum requirements.²⁸ The lake at Seddons Corner will be of such a magnitude that harvesting of the stock would be difficult.

Ducks and geese are highly visible elements of the marsh community, prized for both aesthetic and recreational reasons. Their habitat requirements include both emergent vegetation and open water areas, preferably in about a 50:50 ratio.²⁹ Dabbler ducks browse in shallow water (approximately 0.3 metre) while diving ducks feed in water depths of about 1.5 metre. Island features provide excellent nesting and gathering locations protected from intrusion by predators. At Oak Hammock marsh they have been constructed specifically for this purpose (minimum dimensions of 25m x 50m). Nesting commonly occurs among the grasses and emergent macrophytes where shore slopes are less than five or six horizontal to one vertical.

²⁷Ibid.

²⁸W. Hayden, Trout Farming in Manitoba, (Winnipeg: Fish and Wildlife Division, Manitoba Department of Mines, Resources and Environment, 1976), p. 6.

²⁹Personal communication from Mr. Chuck Dickson, Regional Biologist, Ducks Unlimited, October 1979.

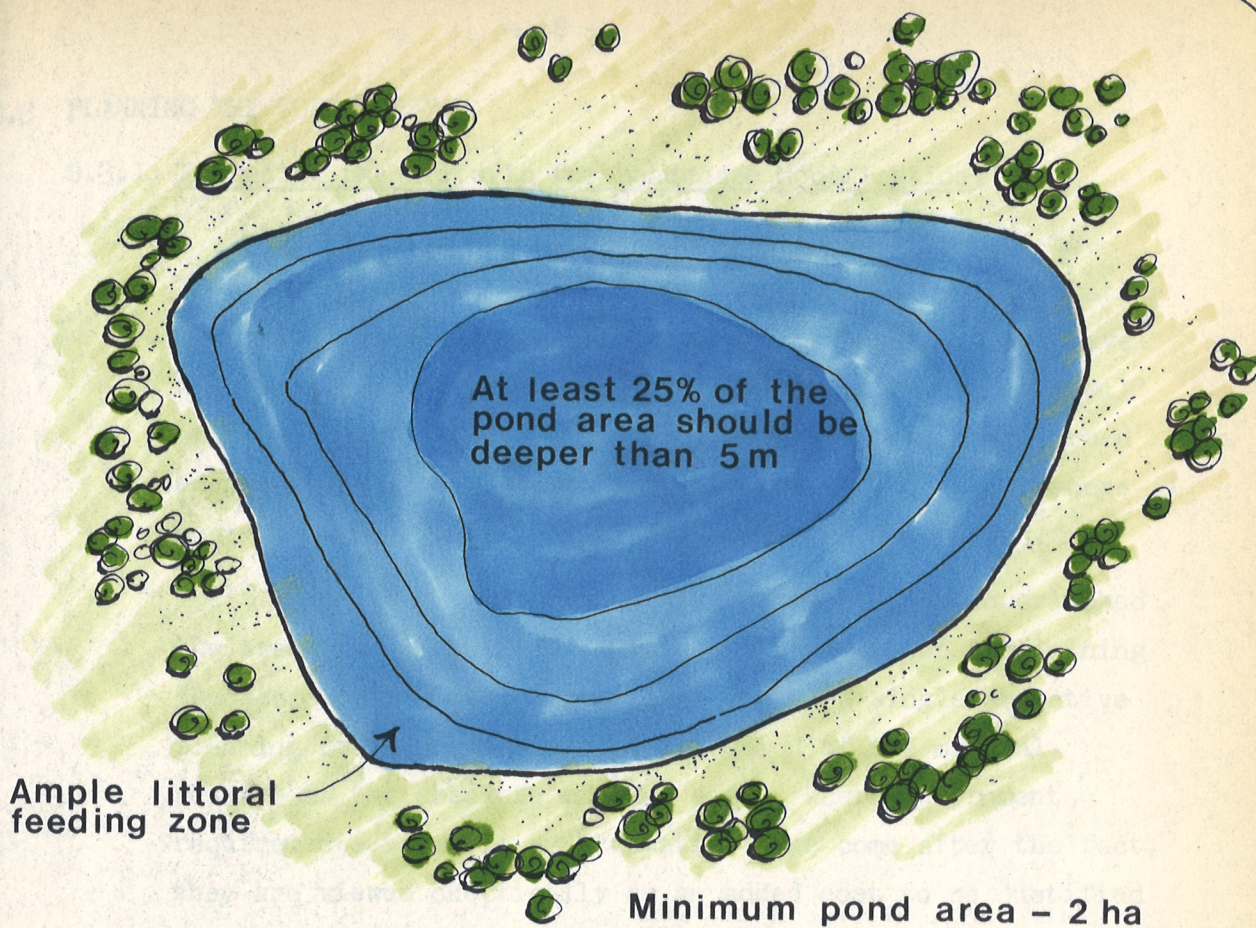


Fig.12: Criteria For Fish Stocking

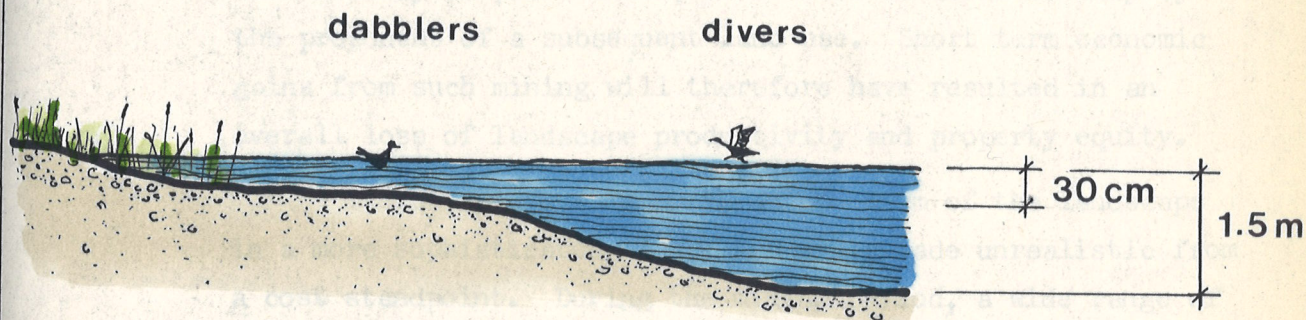


Fig.13: Optimum Depths For Duck Habitat

8.3 PLANNING THE TOPOGRAPHY:

8.3.1 Expanding the Criteria for Landscape Modification:

Section 6.0 was directed to an appraisal of the anticipated post mining landscape at Seddons Corner, relative to the existing environment. Removal of the sand and gravel will leave an enormous void, and the most critical zone will be the interface between the excavation and the undisturbed environment. It is here that major topographic differences must be accommodated in some acceptable configuration.

Mining practice in the past has usually overlooked the tremendous capacity to mould the form of the post mining landscape. This has largely been due to a single objective planning program - maximum exploitation of the mineral reserve at the absolute minimum cost. Where government requirements to slope an excavation have come after the fact, they are viewed skeptically as an added cost to be justified only on the basis of public safety.

As a consequence of this short-sighted approach, the end form of a mining landscape will have little aesthetic value or potential for future land use development. The cost of modifying the landscape when mining is completed will usually be prohibitive, if it must be borne totally by the proponent of a subsequent land use. Short term economic gains from such mining will therefore have resulted in an overall loss of landscape productivity and property equity.

The opportunity to mould the form of the landscape in a more sophisticated manner is rarely made unrealistic from a cost standpoint. During the mining period, a wide range of earthmoving equipment is available at the property and the mining company has the expertise to efficiently utilize such equipment. Overburden usually has to be moved to get access to the mineral. It therefore can become an excellent medium for backfilling mining embankments to desired slopes, as

opposed to a liability requiring sloping itself. Finally, consideration should be given to the cost/benefit of total excavation of the mineral. The economic return from the mineral may not be justification for its excavation where subsequent sloping costs are raised excessively. Leaving a small proportion to the aggregate to obtain a desirable landscape configuration should be a last resort, but should not be overlooked entirely.

These three factors underlie the potential for more creative, imaginative and functional handling of the topography as a component of mining. The guiding criteria for shaping the landscape should be extended beyond simple mining economics and resource exploitation to properly include the following:

- i) stabilization.
- ii) public safety.
- iii) post mining land use development.
- iv) visual aesthetics.

8.3.2 Stabilizing the Landscape:

The immediate visual impression of any mining landscape is generally a reaction to its dynamics. It appears as an open wound, stripped of the protective vegetation and rapidly changing in configuration. Even when mining is discontinued, the unrehabilitated landscape is highly susceptible to the erosive forces of nature - weathering, mass wasting, gullyng and rillwash from overland water flow, and wind erosion.

The configuration of the landscape will be a major factor affecting surface stability. However, a common misconception which has become institutionalized in legislation is that slope is the key to surface stability. The problem is actually much more complex and involves many inter-related factors, as follows:

i) Steepness of Slope:

Mine operations typically work from a near vertical embankment cut into the deposit. Legislation in both Manitoba and Ontario require sloping to the 'angle of repose' of the earth material. This is the slope which the material will naturally assume when it falls in a pile under the force of gravity. For example, if you pour a pail of sand onto the floor, it will consistently form a pile with side slopes angled 34° from the horizontal plane. Table 9 indicates the angle of repose for a variety of materials.

The angle of repose is not necessarily a stable slope. It does not take into consideration important factors of erosion or surface disturbance. Furthermore, a cut slope (carved from undisturbed material) will stand at much steeper slopes due to its inherent compaction.

The steepness of a slope is clearly a factor in stability. While steep slopes may expose a smaller area to the impact of rainfall, this advantage is offset by the increased velocity of overland runoff. Slopes exceeding a ratio of two horizontal to one vertical are generally regarded as unacceptable from the standpoint of surface stabilization.^{1, 2}

Where the slope exceeds the angle of repose, material loosened by weathering will also move under gravity. There is always potential then for mass wasting in the form of a slow creeping action or a rapid landslide.³

¹Hough, Stansbury and Associates, Design Guidelines for Forest Management, (Toronto: Ontario Ministry of Natural Resources, 1974), p. 15.

²Lynch, Site Planning, p. 49.

³A.N. Strahler, Physical Geography, (New York: John Wiley and Sons, Inc., 1969), pp. 402-408.



Photo #21: This recently formed slope, at 41 degrees, is virtually untraversable. It is highly susceptible to erosion and visually incongruent with the adjoining landscape.

TABLE 9: ANGLE OF REPOSE OF VARIOUS MATERIALS

Material	Angle Between Horizontal and Slope of Heaped Pile	
	Ratio	Degrees
Coal, industrial	1.4:1-1.3:1	35-38
Common earth, Dry	2.8:1-1.0:1	20-45
Moist	2.1:1-1.0:1	25-45
Wet	2.1:1-1.7:1	25-30
Gravel, Round to angular	1.7:1-0.9:1	30-50
Sand and clay	2.8:1-1.4:1	20-35
Sand, Dry	2.8:1-1.7:1	20-30
Moist	1.8:1-1.0:1	30-45
Wet	2.8:1-1.0:1	20-45

Source: Peel, Mining Engineers Handbook.

Internal changes as a result of subsurface water movement can also reduce stability.

This unpredictability, and the associated safety problem, is the sole rationale for requiring slopes no steeper than the angle of repose. However, where these factors can be controlled, near vertical embankments may be safely retained as an exciting feature in the landscape.

ii) Surface Drainage:

Overland flow of water in the form of surface runoff, is the major cause of instability in post mining landscapes. It results in the formation of rills and gullies in slopes, and drastically impairs development of a vegetation cover through both erosion and deposition.

The impact of surface runoff on the landscape is a function of its velocity, which in turn is a function of the water depth, the steepness of the slope, and the roughness of the terrain. Given information on the depth of water and slope, the force acting on the ground surface can be calculated.⁴

A number of factors may be manipulated to reduce overland flows. The length of uninterrupted slope can be reduced by side slope swales. Surface water should never be directed over a mining embankment from a catchment basin. Since the volume of surface water can be reduced by increasing soil infiltration, permeable material is preferable on slopes. While some consolidation is desirable, care should be taken not to overly compact the surface and create a hardpan.

⁴E.W. Lane, "Design of Stable Channels" in American Society of Civil Engineers Transactions, 120:1234-1279.



Photo #22: This slope was graded to an angle of about 18 degrees (30%) four years prior to the picture, but no vegetation cover was established. Erosion has exposed rocks on the surface and formed gullies measuring 18 to 24 inches deep.

Finally, the prompt establishment of a vegetation cover is essential. Roots consolidate the soil while above ground portions of plants reduce surface flows and the impact of raindrops. Techniques of establishing vegetation will be addressed in Section 8.3.6.

8.3.3 Public Safety:

The concern for public safety in most programs of mine reclamation has been a dominant factor. It underlies all government regulations, as a universally accepted goal, and it has been most readily addressed by mine operators who recognize problems of legal liability.

There is no question that it must be considered as a criterion of landscape development. However, elimination of all possible conditions which could pose a danger will inevitably result in a sterile and unexciting environment. Excessive concern with safety can destroy the aesthetic and functional potential of a post mining landscape.

Where people encounter a natural feature which has an inherent hazard, it is assumed that they are responsible for their own safety. The same level of hazard is rarely accepted in a manmade environment. For example, the City of Winnipeg prohibits shore slopes of storm water retention lakes to less than seven horizontal to one vertical, even though the slopes of the Red and Assiniboine Rivers far exceed this at many locations in the City.

The design criteria for landscape development should be directed toward preventing inadvertent encounters with potentially dangerous situations, as opposed to elimination of all hazards. Steep slopes are quite acceptable where they can be approached with normal caution, and the edge is clearly visible.

⁵City of Winnipeg, Stormwater Management, p. 6.



Photo #23: Sand material is particularly susceptible to erosion when exposed during a mining operation. In this picture, a property boundary fence is almost covered over.



**Fig. 14: Danger Of
Inadvertant Access**

Dangerous conditions which are not obvious must be eliminated. This would include any unstable slopes, and treacherous footing on the edge of embankments. Similarly, shore slopes where public access is focused can be less than four horizontal to one vertical, to ensure that anyone falling in can climb back out. These precautions would still allow the development of an exciting landscape on the mine property.

8.3.4 Land Use:

Every land use activity is subject to certain slope limitations which must be carefully considered in the development of a site plan. (Jenson, 1967; Bauer, 1970; Schellie and Rogier, 1963; Schellie, 1977). Information regarding the range of slopes acceptable for a variety of activities is provided in Table 10.

Knowledge of these slope limitations may be applied in two ways to the problem of rehabilitation. First, where it is evident that relatively steep slopes must be accommodated in the post mining landscape, a wide number of alternative uses will not be feasible. Slope information can be used in this manner to refine our understanding of land use potential as outlined in Section 7.0.

On the other hand, where specific uses have been identified as desirable post mining activities on the basis of the regional analysis, rehabilitation can be directed to creating appropriate slopes. The importance of detailed site planning and the capacity to form the landscape has been discussed in previous sections.



Photo #24: Abandoned or unused pits seem to attract abuse as convenient garbage disposal sites. This type of post mining land use is often the least desirable since it may lead to ground water contamination.

As demonstrated in Table 10, the large proportion of land use activities require slopes of less than 15%. Consideration must also be given to the maintenance of a minimum slope of at least 2% for positive surface drainage. Most gravel excavations create a 'bowl' effect, and unless subsoil conditions permit rapid infiltration, specific areas should be designed as either temporary or permanent collection ponds.

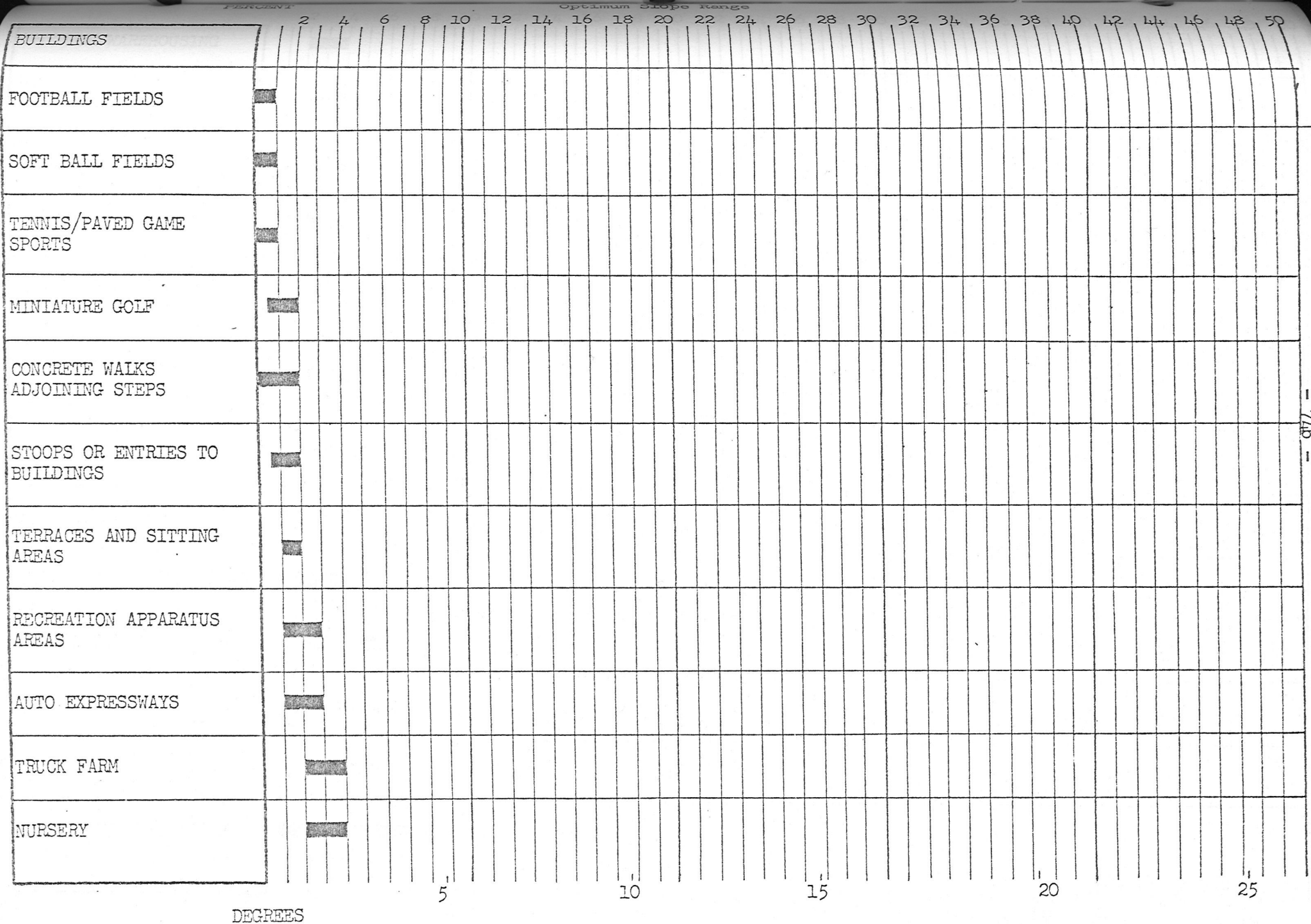
A number of other critical slopes warranting special consideration are as follows:

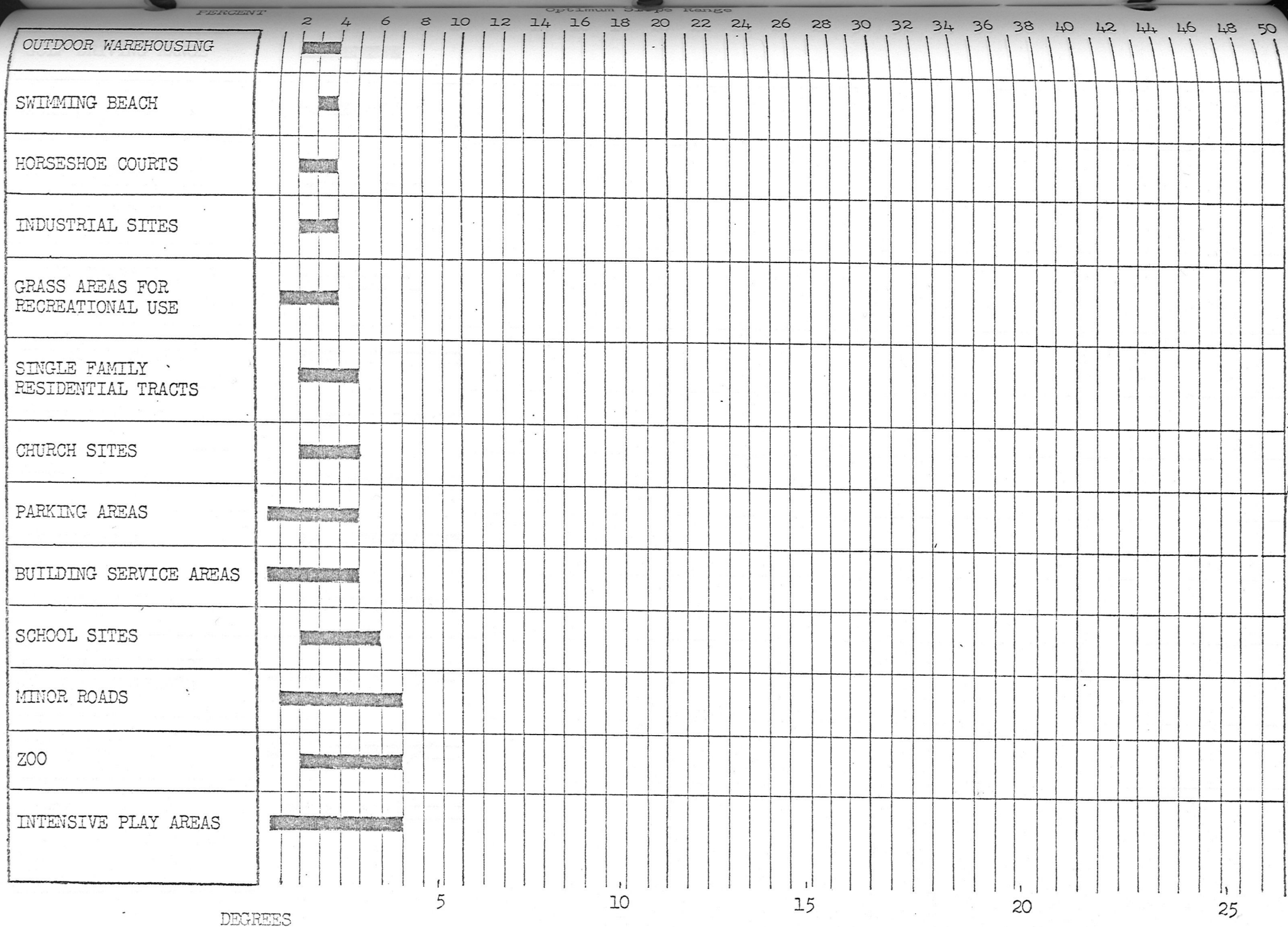
- 50% (27°) - slopes steeper than this are considered very difficult to stabilize.
- 30% (18°) - this is the maximum slope on which conventional seeding equipment can be used, and which can be mowed by tractor.
- 18% (10°) - this is generally the maximum slope on which agricultural equipment can function economically.
- 15% (9°) - the limit traversable by a loaded vehicle over a sustained run.
- 10% (6°) - the preferred maximum slope of any road used by conventional automobiles.

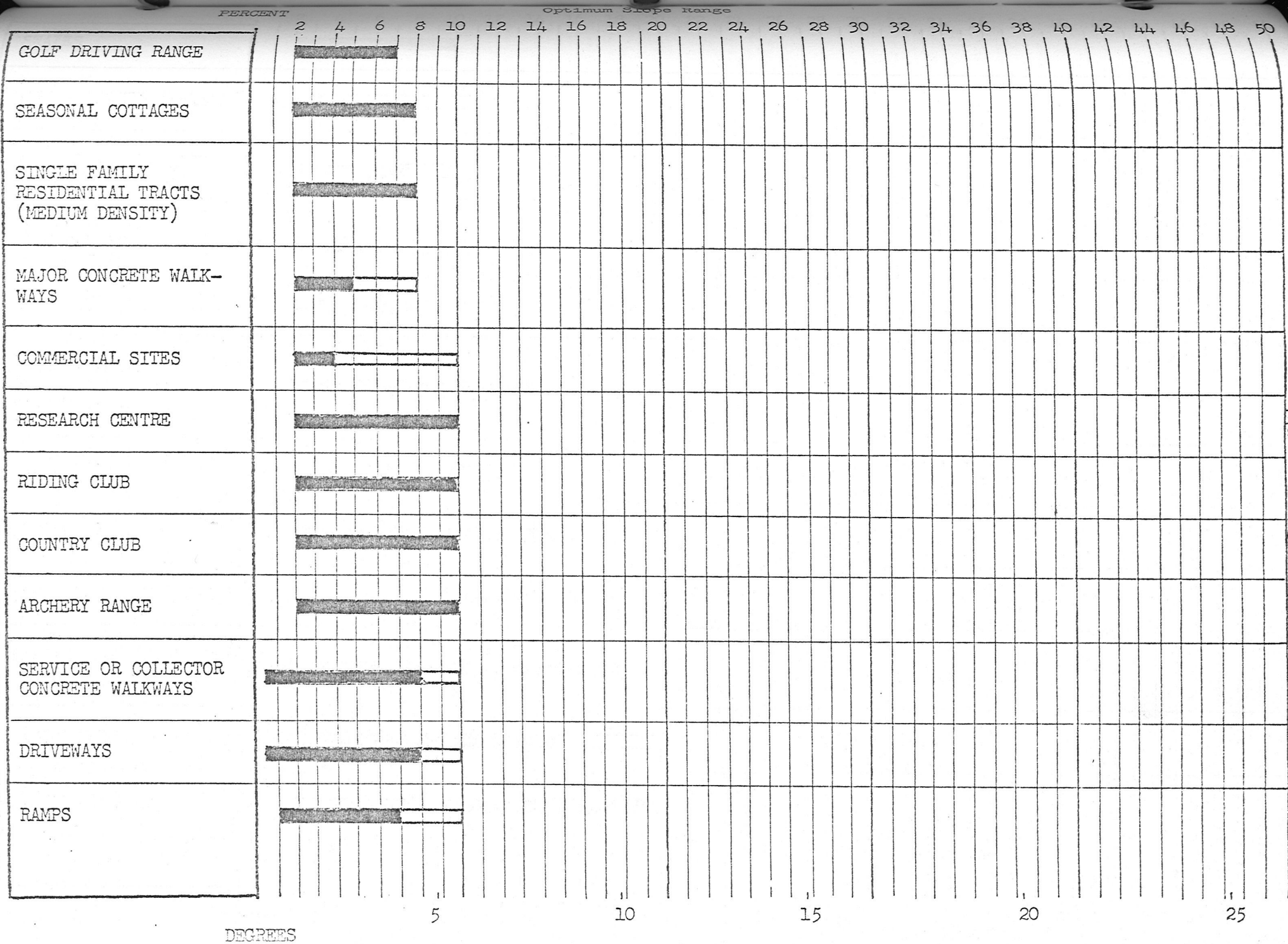
8.3.5. Visual Aesthetics:

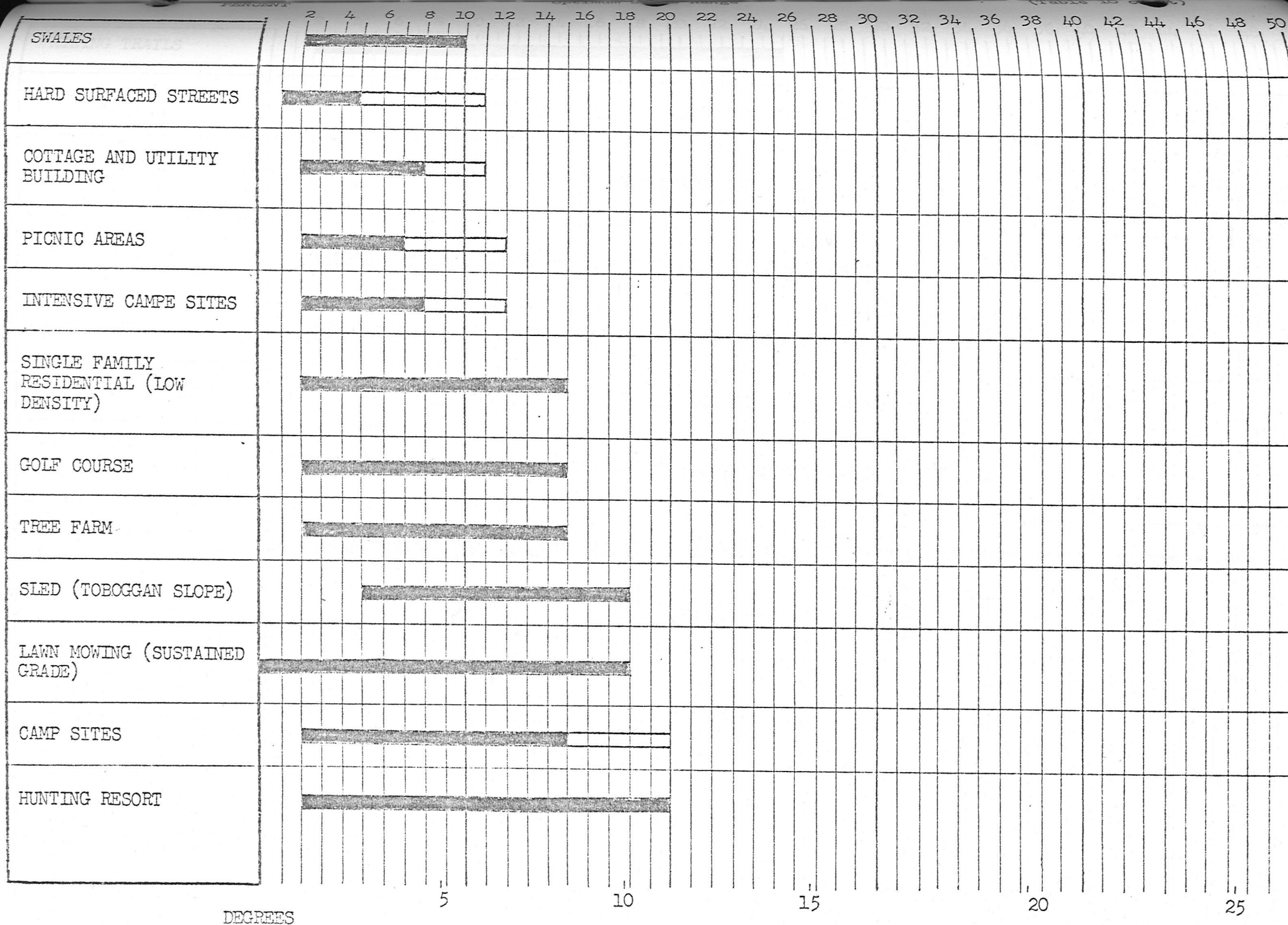
This aspect of rehabilitation is often overlooked yet will in the final analysis be the true measure of success or failure. It is a summation of the spacial form and arrangement of the landscape.

TABLE 10: Grading Requirements
For Land Use Activities





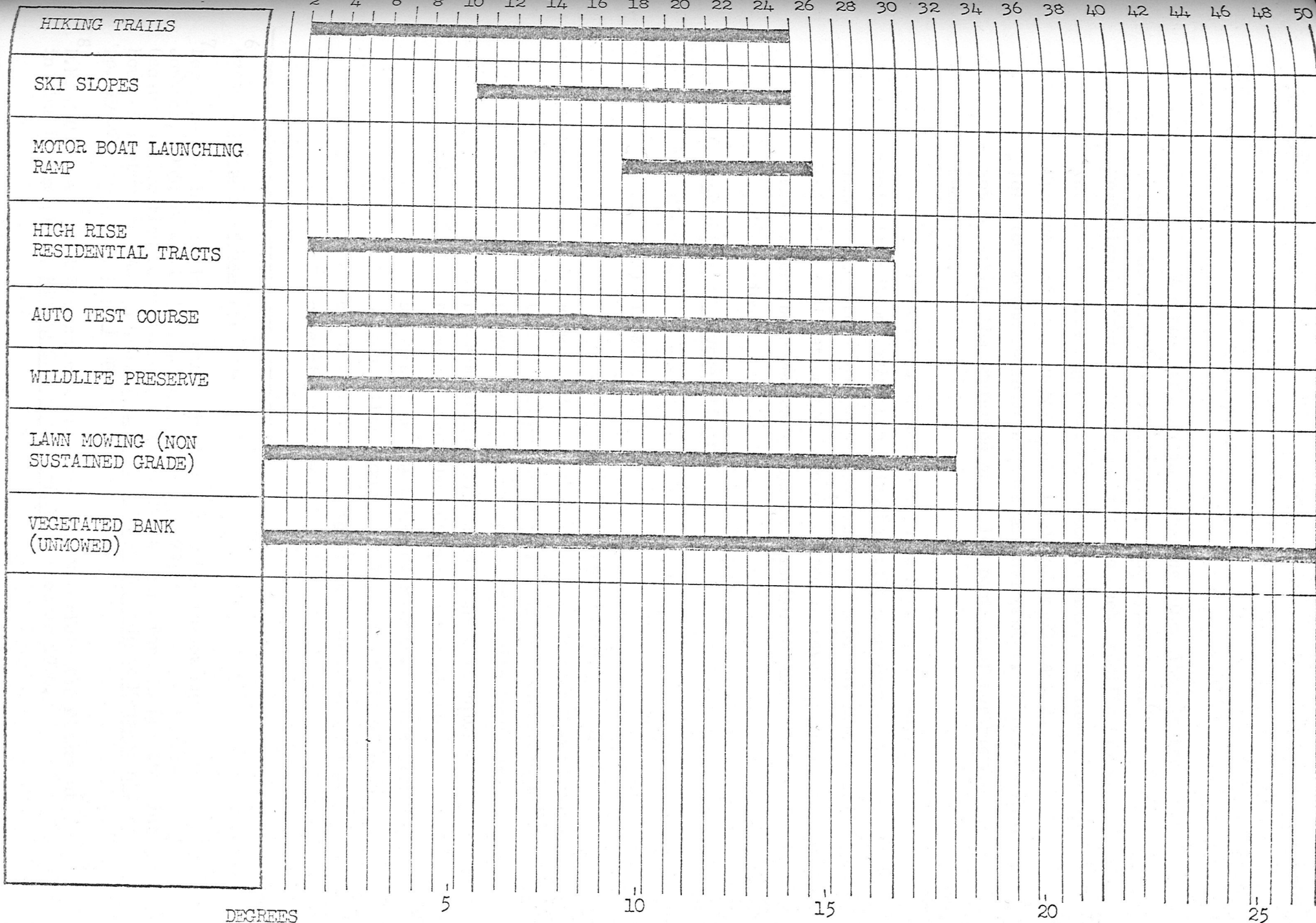




PERCENT

Optimum Slope Range

(Table con't)



DEGREES

5

10

15

20

25

A common problem in reshaping mine sites is the failure to hide the artificial, man-made appearance.⁶ Mechanically formed slopes may rigidly meet specifications, yet fail to flow together. As a consequence, the landscape appears obviously incongruent, both internally and in relation to the undisturbed natural environment. Forms should not be set by the preferred operation pattern of earthmoving machinery.

Principles of design such as rhythm, harmony, balance and continuity must also be applied in forming the landscape. These are proper considerations of any site plan and their application has been discussed in several other publications both generally and in relation to mine rehabilitation.⁷

8.3.6 Techniques of Revegetation:

8.3.6.1 Soil Preparation:

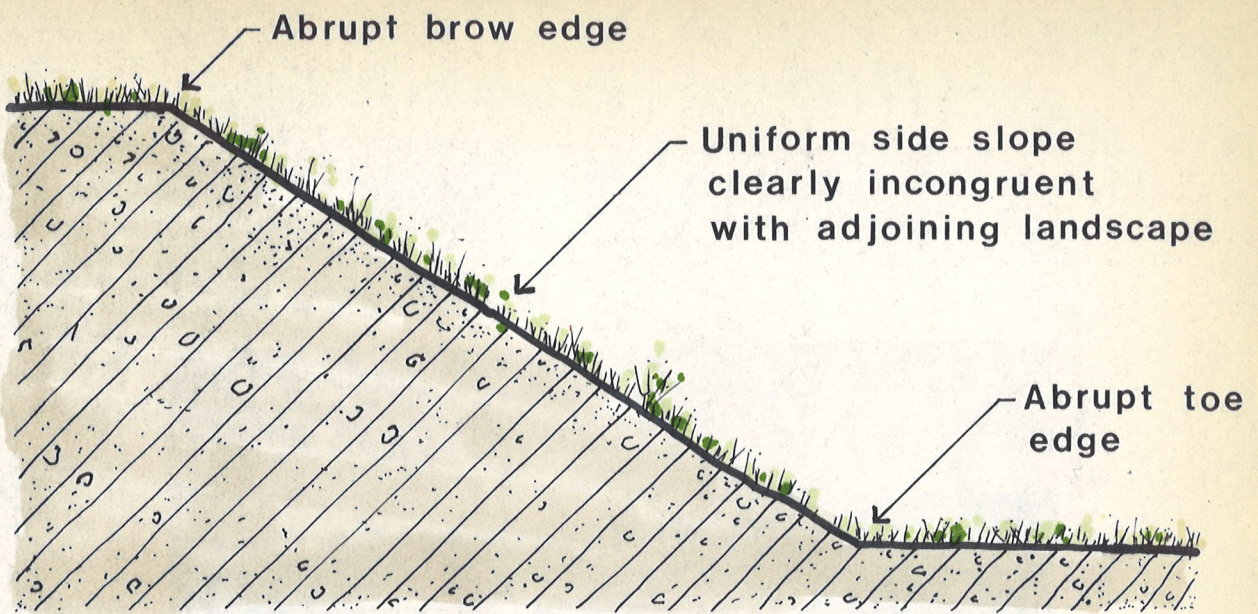
i) Topsoil:

The nature of the soil conditions left after surface mining is of far greater importance than any other factor for a successful revegetation program.⁸ Where the pre-mining site inventory reveals good topsoil conditions this valuable resource should be stripped and stockpiled separate from any other overburden. McRae (1979) suggests that agricultural productivity of pits can be restored to high levels where topsoil is carefully handled.

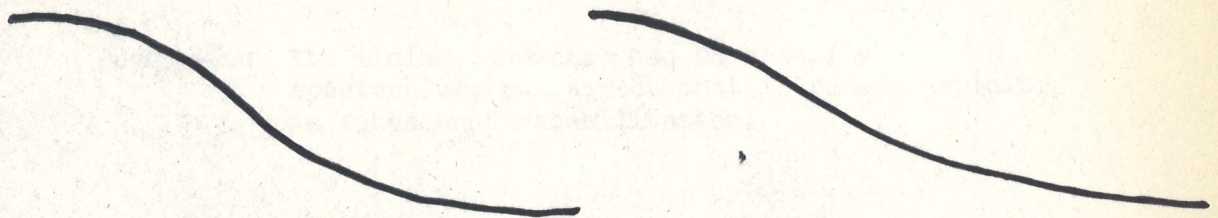
⁶Coates, Rehabilitation, pp. 1-3.

⁷For specific information on this aspect refer to the following: Johnson, 1965; Schellie (ed.), 1977; Coates, 1979; General information concerning aesthetics of landscape form is provided in: Hough Stansbury and Associates, Design Guidelines for Forest Management, pp. 19-28; and Lynch, Site Planning, pp. 189-228.

⁸D.E. McCormack, "Soil Reconstruction: Selecting Materials for Placement in Mine Reclamation", Mining Congress Journal, September 1976.



"Artificial" Slope



"Natural" Slope

Transitional curves and variations in gradient

Fig. 15: Slope Form



Photo #26: The mining landscape can be visually spectacular, an aspect that is rarely exploited in subsequent rehabilitation.



Photo #25: The bulldozer is commonly used in Manitoba for final grading of depleted pits, in compliance with government regulations. The resultant slopes, as seen in the background, reflect the machines performance in their gradient (usually 18 degrees) and form.

A commonly recommended practice in North America is to strip to a standard depth of 23 cm and stockpile in mounds less than 2.4 metres in height.⁹ However, the 'A' horizon of most soils ranges from 10 cm to 60 cm thick and represents the most enriched portion of the soil. Although the 'B' horizon is inferior in quality it may also be worth preserving. The judgement regarding stripping depth should be made individually on the basis of soil structure, tilth, accumulated nutrients, organic matter, and living organisms present.

Lengthy or improper storage of topsoil can have a detrimental effect on soil quality. The living component of the soil, the bacteria and micro-organisms will perish if the soil is compacted in huge stockpiles for a long period. Serious leaching of nutrients can also occur even within a one year period. For these reasons, it is commonly recommended that topsoil be stored in small piles, and revegetated during the interim period.¹⁰ It is highly desirable to utilize topsoil as quickly as possible through an ongoing rehabilitation program.

⁹J. Tourbier, R. Westmacott, Water Resources Protection Measures in Land Development - A Handbook, (Delaware: New Castle County Planning Department, 1974).

¹⁰Ontario Ministry of Natural Resources, Vegetation for the Rehabilitation of Pits and Quarries, (Toronto: Queen's Printer, 1975), p. 9.

The application of topsoil to a site also requires special care. Due to its friable nature, it is extremely susceptible to erosion. Consequently, it should be applied as part of the seed bed preparation. The quick establishment of these plants will minimize erosion and at the same time, prevent an invasion of noxious weeds.¹¹

Depth of topsoil application is an important consideration. Although deep topsoil is favourable to growth, it may discourage plants from rooting into the subsoil; at the same time, it may absorb too much water causing it to slide during rains. For this reason, and for economy, the common practice in North America has been to limit topsoiling of steep slopes to a depth of 5 cm to 10 cm.¹² This is the minimum required for a successful, self-maintaining stand of grass.¹³ Where shrubs and small or shallow rooted trees are to be planted, 60 cm to 76 cm of topsoil is recommended.^{14,15} If a site is severely disturbed and topsoil is scarce, pockets or trenches may be filled with topsoil and planted to create seeding areas and visual barriers.

¹¹R.L. Hodder, "Montana Reclamation Problems and Remedial Techniques" in Problems and Practices of Land Reclamation in Western North America, ed. Wali, M., (Grand Forkes: University of North Dakota Press, 1975), p. 102.

¹²Nichols, Moving the Earth, pp. 10-18.

¹³Ontario Ministry of Natural Resources, Vegetation, p. 9.

¹⁴Ibid., p. 10.

¹⁵G.T. Goodman, "Ecological Aspects of the Reclamation of Derelict Land" in Conservation in Practice, ed. Warren, A., (London: John Wiley and Sons Ltd., 1974).

ii) Soil Reconstruction:

The site inventory at Seddons Corner revealed that soil conditions are poor, due largely to a coarse texture. (See Section 6.4). This is commonly the case in sand and gravel mining, as economics require the deposit to be near surface.

Under such circumstances, the cost associated with separate stripping and storage is not justified. It is more appropriate to use other geologic strata which are better suited to plant growth. Although we cannot 'manufacture' topsoil, the availability of earthmoving equipment provides considerable latitude for re-construction. Fine material can be mixed with coarse to obtain good aggregation. Considerable success has been achieved on sandy soils by adding organic matter from peat bags (Logan, 1978). A sequence of horizons may be established, chosen from the best available soils and geologic strata. Where these techniques have been applied, crop land is productive within two years and yields are as good or better than before mining.

¹⁶McCormack, "Soil Reconstruction", p. 3.

¹⁷Ibid., p. 5.

At Seddons Corner large volumes of heavy textured till overburden will be encountered during the course of mining. Sand tailings derived during the operation or obtained from the existing stockpile may be mixed to improve tilth and structure, where this can be accomplished economically.

In other locations, there may not be an opportunity for such on-site modification. Experiments have shown that it is possible to establish vegetation on relatively harsh subsoil conditions.¹⁸ This necessitates careful management, including application of fertilizers and mulch material with seeding.

An effective mulch will hold the surface against erosion, allow water infiltration and promote seed germination. The most common is straw or hay, which must be disced into the soil. Different mulches and stabilizers have been evaluated by Murray (1973) and are compared in Table 11. The mulch should be applied uniformly, but excessive mulching is detrimental to seed germination and establishment. At least 10% to 20% of the soil surface should remain exposed for satisfactory results.¹⁹

¹⁸R.L. Gros, R.M. Blanchard, and W.R. Melton, The Establishment of Vegetation on Non-Topsoiled Highway Slopes in Washington, (Washington: Pullmore Agricultural Research Centre, 1970).

¹⁹D.R. Murray, Vegetation of Mine Waste Embankments in Canada, (Ottawa: Mining Research Centre, 1973), p. 14.

TABLE 11: THE INFLUENCE OF VARIOUS MULCHES ON GRASS SEEDLING EMERGENCE AND SURVIVAL

Mulch	Mulch Rates Per Acre	Plant Emergence ^a 6-28-62	Plant Survival ^a		
			10-9-62	5-22-63	7-1-64
Asphalt emulsion ^b	200 gal.	P	P	P	N
Asphalt cutback ^b	200 gal.	P	P	N	N
Elastomeric polymer emulsion ^c	700 lbs.	P	P	P	N
Polyvinyl acetate copolymer ^d and ammonium sulfate	69 gal.	E	E	G	G
	55 lbs.				
Polyvinyl alcohol solution	300 gal.	G	G	G	G
Sodium silicate and ammonium sulfate	66 gal.	E	E	G	G
	200 lbs.				
Gelatin	1000 lbs.	P	P	N	N
Hay	2000 lbs.	P	P	N	N
Heavy jute mesh ^e	3/4" opening				
Check no mulch		E	E	G	G
^a E - Excellent, G - Good, F - Fair, P - Poor, N - Nothing. ^b Asphalt emulsion (Agricultural mulch E.A.P. 2005) and the asphalt cutback were supplied by Esso Research and Engineering Company, Linden, New Jersey. ^c Elastomeric polymer emulsion (Soil Set) Product of Alco Oil and Chemical Corporation, Philadelphia, Pennsylvania. ^d Polyvinyl acetate copolymer (Gelva Emulsion T.S. 70) and Polyvinyl alcohol (Gelvatol 1-60) are products of Shawinigan Resin Corporation of Springfield, Massachusetts. ^e Heavy jute mesh supplied by Ludlow Textile, Ludlow, Massachusetts.					

A wide variety of fertilizers and fertilizer rates have been reported in the literature,²⁰ but these generally apply to metal mine tailings and cannot be correlated with gravel quarries. General recommendations for forage plants are published by the Manitoba Department of Agriculture (Table 12). The most accurate determination requires specific soil testing and correlation with selected plant species.

The degree of effort and associated cost, which goes into developing soil conditions should be related to the objectives of the revegetation program. Where prompt stabilization of a steep slope or development of an agricultural after use is desired, heavy emphasis should be placed on creating adequate soil conditions. On the other hand, less critical areas to be revegetated over a long term largely for aesthetic reasons may receive less attention, providing only the minimum necessary for plant establishment. Time and effort expended on soil preparation should be viewed as an insurance for protection of subsequent investments in a revegetation program.

8.3.6.2 Species Selection for Revegetation:

Very little scientific research has been directed toward identification of optimum plant species for rehabilitation of mine sites in the prairie region. The main selection criteria have been identified by Wheeler and Vaartnov (1975) as follows:²¹

²⁰Ibid., pp. 30-40.

²¹G.W. Wheeler, H. Vaartnov, Establishment and Survival of Ground Cover Plantings on Disturbed Areas in Alberta, Progress Report, (Edmonton: Alberta Agriculture, 1974), p. 9.

TABLE 12: GENERAL FERTILIZER RECOMMENDATIONS
- MANITOBA DEPARTMENT OF AGRICULTURE

Annual Rate of Nutrient

1. Legume or legume/grass mixture:
 - i) new stands
 - ii) established stands
2. Grass
 - i) new stands
 - ii) established stands

N Kg/ha	P ₂ O ₅ Kg/ha	K ₂ O Kg/ha	S Kg/ha
0	60-80	65-170	30
0	45-60	45-110	30
0-2	30-50	50-100	-
100-120	20-35	35-70	-

Source: Department of Agriculture, Field Crop Recommendations, p. 63, 68.
(These are general guidelines, soil testing is recommended to determine exact rates).

1. The use of the area in which the species is to be planted and degree of maintenance anticipated are important considerations (i.e. cropland, pasture, wildlife, forestry, recreation, etc.).
2. The resistance of the species and the particular variety to local diseases is necessary for long term survival.
3. A variety of root systems among the species planted will help to optimize the use of nutrients at various levels in the soil. Species with thick rooting systems, such as red top, bentgrass, and bluegrass, are good sod formers. Long lived perennials with strong rhizome growth serve to hold the surface stable. As noted in Section 4.2.1, deep rooted plants such as alfalfa and trefoils have been used to break up a compacted subsoil.
4. The plant should be adaptable to the range of soil conditions found on the site - nutrient levels, pH, salt content, conductivity, and texture.
5. The growth habits of a plant will determine the degree of ground cover protection which the plant can provide, which in turn affects its success at soil erosion control and at water conservation. This includes not only the physical form, but also the growth rate, life span, and the reproductive capability.
6. Adaptability to local microclimatic conditions is desirable. As noted in Section 2.2, abandoned quarries often display extreme conditions.

7. Finally, the species must have a strong competitive ability if it is to survive and reproduce within a plant community. In this regard, caution should be exercised when using a combination of different species, since inter-competition could hamper the establishment of the desired species. The bio-competitive ability is in many ways a cumulative effect of all other selection factors.

i) Agricultural Species:

In most reported revegetation programs, agricultural varieties of grasses and legumes have been seeded together in mixtures developed to satisfy local conditions.²² This may be attributed to their effectiveness, but also to the availability of seed and planting technology.

Nitrogen assimilation of the legume boosts the growth of grass, facilitating the use of this combination on nutrient poor sites. The effectiveness of the legume can be increased by inoculating the seed with the nitrogen-fixing bacteria before planting.²³ For minimum maintenance, the legume/grass mixture is regarded by some authors to be superior to grasses, trees, or legumes alone.²⁴

²²Canada Centre for Mineral and Energy Technology, Pit Slope Manual, (Ottawa: Ministry of Supply and Services, 1976), p. 24.

²³Ibid., p. 22.

²⁴Murray, Vegetation, p. 36.

Fine textured grasses have been used to increase organic deposition for soil development.²⁵ Another common practice is to plant grasses and legumes together with companion crops such as oats, wheat, rye or barley.²⁶ Companion crops are used only in the initial year when a fast growing rough cover is needed to provide protection against soil erosion. Such species also produce stubble that will catch snow and reduce winter kill. The Ontario Ministry of Transportation and Communications in Ontario also uses a companion crop in conjunction with their standard grass mixture for fresh sites. (See Table 13).²⁷

For dry sites, the Ontario Ministry of Natural Resources recommends only legumes - Birdsfoot Trefoil, Crown Vetch, Reed Canarygrass - to be accompanied later by trees and shrubs.²⁸ However, Massey (1973) found that grasses and legumes (see Table 14) could be established on fine sand tailings, with proper site preparation. Lesko (1974) recommended the use of a number of grass species (see Table 15) following tests on a similar site.

²⁵Ibid., p. 125.

²⁶Canada Centre for Mineral and Energy Technology, Pit Slope Manual, p. 22.

²⁷Ontario Ministry of Natural Resources, Vegetation, p. 17.

²⁸Ibid., p. 13.

TABLE 13: ONTARIO MINISTRY OF TRANSPORTATION AND
COMMUNICATIONS STANDARD SEED MIXTURE

The following standard grass mixture should be sown at 80 pounds per acre.

Creeping Red Fescue (<u>Festuca rubra</u> L.)	55%	Permanent Grass.
Kentucky Blue Grass (<u>Poa pratensis</u> L.)	25%	Permanent Grass.
Red Top (<u>Agrostis alba</u> L.)	5%	Short lived interim grass germinates quickly, will reseed itself.
Companion Crop	12%	May be increased if hydroseeded.
White Dutch Clover (<u>Trifolium repens</u> L.)	3%	May be increased for heavier soils

Source: Ontario Ministry of Natural Resources, Vegetation, p. 17.

TABLE 14: SPECIES SUCCESSFULLY PLANTED ON SAND TAILINGS
MODIFIED BY SURFACE MIXTURE OF CLAY OR PEAT
(FORT McMURRAY, ALBERTA)

<u>Bromus inermis</u>	<u>A. cristatum</u>
<u>Agropyron trichophorum</u>	<u>Trifolium hybridum</u>
<u>A. riparium</u>	<u>Melilotus alba</u>

Source: Massey, Tailings Sand to Trees, p. 7.

TABLE 15: SPECIES RECOMMENDED FOR REVEGETATION OF
TAR SAND TAILINGS, FORT McMURRAY, ALBERTA

<u>Agropyron cristatum</u>	<u>Agropyron latiglume</u>
<u>A. trichophorum</u>	<u>A. riparium</u>
<u>Bromus inermis</u>	<u>Dactylis glomerata</u>
<u>Agrostis alba</u>	<u>Phleum pratense</u>

Source: Lesko, Preliminary Revegetation Trials, p. 11.

TABLE 16: SEED MIXTURE TESTED TO PROMOTE RANGE RECOVERY
FROM THE IMPACT OF MILITARY OPERATIONS, SHILO,
MANITOBA.

<u>MIX</u>	<u>SEEDING RATE</u> (lbs/acre)	<u>MIX</u>	<u>SEEDING RATE</u> (lbs/acre)
<u>ONE:</u>		<u>FOUR:</u>	
Agropyron intermedium	10	Agropyron cristatum	6
Agropyron cristatum	6	Mymus junceus	6
Agropyron trachycaulum	4	Medicago sativa	3
Bromus inermis	8		
Mymus junceus	6	Mix rate	= 15
Festuca rubra	5		
Medicago sativa	3	<u>FIVE:</u>	
Melilotus officinalis	6	Agropyron intermedium	10
Mix rate	= 48	Mililotus officinalis	6
		Agropyron trachycaulum	4
<u>TWO:</u>		Mix rate	= 20
Agropyron cristatum	6		
Bromus inermis	8	<u>SIX:</u>	
Medicago sativa	3	Agropyron intermedium	10
Mix rate	= 17	Elymus junceus	8
		Melilotus officinalis	6
<u>THREE:</u>		Mix rate	= 24
Elymus junceus	6		
Festuca rubra	5		
Medicago sativa	3		
Mix rate	= 14		

Source: J.M. McKerna, Range Ecology Report, Bio/Tech Incorporated,
March 1981, p. 28.

Lesko (1974) also experimented with sand dune reclamation, at Lesser Slave Lake, Alberta.²⁹ There he found that the species most successful in germinating, out of 14 grasses and 5 legumes, were Russian Wild Rye (Elymus junceus), Nordan Wheatgrass (Agropyron desertorum), Pubescent Wheatgrass (A. trichophorum), Alberta Fescue (Festuca arundinacea), Fairway Wheatgrass (Agropyron cristantum), Perennial Ryegrass (Lolium perenne), and Sainfoin (Onobrychis corniculatus).

The Manitoba Department of Agriculture recommends equal portions of the following mixture for reclamation of droughty sites.³⁰ Crest Wheatgrass (Agropyron cristatum), Alfalfa (Medicago sp.), Creeping Red Fescue (Festuca rubra), and Bromegrass (Bromus sp.). The mixture should be seeded at a rate of 10 lbs. to 12 lbs. per acre. The department's recommendations for less disturbed sites are outlined in Table 16.

Where rapid establishment is not a factor, and where subsequent harvesting for forage is not anticipated, application of fertilizer may not be critical. The Manitoba Department of Highways often seeds roadsides without fertilizer. However, those portions of a mine site characterized by poor soil conditions or steep slopes should be fertilized at the rates prescribed in Table 17.

²⁹G.L. Lesko, Species Suitability for Sand Dune Reclamation at Lesser Slave Lake, (Edmonton: Northern Forest Research Information Report NOR-X-86, 1974).

³⁰Personal communication with Mr. David Campbell, Grassland Specialist, Manitoba Department of Agriculture, July 1980.

TABLE 17: FORAGE MIXTURES RECOMMENDED BY THE
MANITOBA DEPARTMENT OF AGRICULTURE

<u>Mixture</u>	<u>Seedling Rate</u> <u>Kg/ha</u>
A. All Soils Except Where Drainage is Poor	
Bromegrass	7
and Alfalfa	3
Intermediate Wheatgrass	7
and Alfalfa	3
B. Soils With Ample Moisture, Good Drainage	
Orchardgrass	7
and Timothy	2
Timothy	2
and Alfalfa	3
Orchardgrass,	7
Timothy	2
and Alfalfa	2
Timothy and	2
Birdsfoot Trefoil	2
C. Poorly Drained Areas Subject to Temporary Flooding	
Reed Canarygrass,	9
Timothy and	2
Birdsfoot Trefoil	2
Reed Canarygrass,	9
Timothy and	2
Alsike Clover	4
D. Light Soils and Areas Deficient in Moisture	
Crested Wheat and	8
Alfalfa	
E. Saline (White Alkali) Soils	
Tall Wheat,	5
Slender Wheat	5
Alfalfa and	3
Sweet Clover	3

Source: Manitoba Department of Agriculture, Field Crop Recommendations,
p. 67.

General characteristics of agricultural species are described in the "Pit Slope Manual", as follows:

"Grasses are more tolerant of adverse soil pH and moisture than legumes, and are therefore easier to establish. They do, however, require more fertilizer.

Species with a high nutrient requirement include Bentgrass and Bromegrass; those with medium nutrient requirement are Reed Canary grass, Timothy, Wheatgrass, Red Clover, and Alfalfa. Red Top, Ryegrass, Fescues, Birdsfoot Trefoil, Crownvetch and Sweet Clover have low nutrient requirements. Many species cannot tolerate very wet conditions, however, grass species such as Reed Canary grass, Timothy, Bromegrass, Red Top, Bentgrass, Bluegrass and Fescues will tolerate some flooding. Legumes cannot tolerate more than about 14 days of flooded conditions."³¹

ii) Use of Tree Species:

The efficiency of a herbaceous layer for erosion control is inferior to trees, once a good canopy is established.³² However, research has demonstrated that new forest plantings, even though the trees are spaced three feet on centre, do not effectively control erosion on slopes. The small tree affords little protection until the stand has closed and a leaf mulch forms on the ground. In addition, the environmental requirements of trees, which are generally more

³¹Canada Centre for Mineral and Energy Technology, Op. cit., p. 22.

³²R.F. Finn, Ten Years of Strip Mine Reforestation in Ohio, (U.S. Forest Service: Cent. States Forest Expt. Sta. Tech. Paper #153, 1958), p. 37.

specific than grasses and legumes, restrict establishment under the harsh conditions of a highly disturbed site.³³ For this reason, a ground cover should be established to develop soil structure, before tree plantings are made, or at least in conjunction with plantings.³⁴

Although grass mixtures contribute greatly to humus formation, water retention and improved structure, most grasses have a detrimental effect on tree development.³⁵ Knabe (1964) recommends the use of legumes such as Crown vetch, Korean lespedeza, or Blue perennial lupine to build up humus, supply nitrogen, and offer little competition to the tree. In Canada, sweet clover is often used in combination with trees or shrubs.³⁶ However, dense plantings of sweet clover have been found to cause high initial mortality of newly planted trees.³⁷

Trees are often selected for planting in rough areas not fit for agriculture.³⁸ Hybrid poplars have been particularly successful where soil conditions are corrected.³⁹ These trees grew 30 inches in a season while natural volunteer

³³Lesko, Preliminary Revegetation Trials, p. 10.

³⁴Ibid., p. 11.

³⁵W. Knabe, "Methods and Results of Strip Mine Reclamation in Germany" in The Ohio Journal of Science 64(2): 75.

³⁶Canada Centre for Mineral and Energy Technology, Op. cit., p. 22.

³⁷Knabe, Methods and Results, p. 10.

³⁸Murray, Vegetation of Mine Waste, p. 24.

³⁹Ibid., p. 24.

found trembling aspen to have a very high potential for reclamation planting in Alberta. It displayed moderate drought tolerance, and could readily spread through established grasses.

Commercial nurseries are the best source of trees and shrubs in that they offer a variety of species and sizes, all cultivated for the purpose of transplantation. Manitoba Publication #271, Recommended List of Ornamental Trees, Shrubs, Climbers and Ground Covers for Manitoba should be referred to in consultation with a professional nursery man. For re-forestation purposes, large volumes of coniferous seedlings can be obtained from the provincial government of Pineland Forest Nursery.

iii) Natural Vegetation:

Use of native species in landscape reclamation has not received a great deal of attention in the past. Emphasis has been on agricultural plants, due to the availability of seed and a well tested technology.

However, in some instances the objective of rehabilitation may be "a return to some stable productive state in which the hand of man may be visible but is not necessary to the maintenance of the stability and productivity of the landscape".⁴⁰

⁴⁰R.R. Curry "Biochemical Limitation on Western Reclamation" in Problems and Practices of Land Reclamation ed. M. Wali, (Grand Forks: University of North Dakota Press, 1975), p. 19.



Photo #27: The balsam poplar (Populus balsamifera) is commonly a pioneer species found invading the harsh environment of non-rehabilitated gravel pits in southern Manitoba.

Stable soil/vegetation relationships imply a vegetation which has adapted to the range of extremes, not the means of climatic and hydrologic conditions. In this context, we should strive for the best combination of plants for long term success, not necessarily the most rapid growth or most vigorous green. For example, Dabbs (1974) compared commercial and native grass species in the Northwest Territories. Although Arctagrostis latifolia and Calamagrostis canadensis were slower to establish, after three years they were found to have a productivity two to eight times that of Arctared Creeping Red Rescue and Nugget Kentucky Bluegrass.⁴¹

The resilience of agricultural species over time is not known - in fact there is a general lack of research on long term performances and natural successional changes.⁴² In the absence of hard data, it is logical to assume that native species could fulfill this objective much more readily, since they have survived the environmental stresses for centuries.

Perhaps the most comprehensive research in western Canada on the establishment and survival of ground cover plantings on disturbed areas was undertaken in Alberta.⁴³ The aim of this study was to provide a stable self-supporting plant

⁴¹D.L. Dabbs, "Rationale and Problems in the Use of Native Pioneer Species in Land Reclamation" in Proceedings of a Workshop... ed. D. Hockings, (Edmonton: Alberta Environment, 1974).

⁴²Goodman, "Ecological Aspects of Reclamation", p. 10.

⁴³Wheeler and Vaartnov, Final Report of Phase I, 1974.

community for revegetation areas. Vegetation along roadsides, pipeline and powerline rights-of-way, and some strip mining areas was inventoried and analysed in conjunction with soil studies, and some growth chamber tests. On this basis, the species listed in Table 17 were recommended as potentially useful plants for revegetation purposes. Although the Seddons Corner site is classified in a different boreal region, it is quite similar in character.⁴⁴ This data should be used as a baseline from which more specific site research and experimentation may be directed.

8.3.6.3 Planting Methods:

Three types of seeding methods have been successfully employed for revegetation of mining landscapes.

The most effective method is to use a conventional seed drill or billion seeder, which requires the lowest seeding rate and gives the best germination.⁴⁵ The seed is placed directly in the ground and covered with soil, eliminating the need for a mulch. In order to use this equipment, however, a slope of 30% (18°) or less is recommended. In fact, such conventional equipment can only be reasonably and economically used on slopes flatter than 15% (9°), a consideration where agricultural activity is to be sustained.

⁴⁴J.S. Rowe, Forest Regions of Canada, (Ottawa: Canadian Forestry Service Publication No. 1300, 1972), pp. 31 and 36.

⁴⁵Ontario Ministry of Natural Resources, Vegetation, p. 11.

TABLE 18: SPECIES FOR RECLAMATION AND REVEGETATION
OF A BOREAL MIXED-WOOD REGION

Agropyron dasystachyum	Northern Wheat grass
A. smithii	Western Wheat grass
A. trachycaulum	Slender Wheat grass
Agrostis gigantea	Red Top
A. scabra	Tickle grass
Alopecurus pratensis	Meadow foxtail
Arctagrostis arundinaceae	Arctagrostis
Arctostaphylos rubra	Alpine bearberry
A. uva-ursi	Bearberry
Astragalus agrostis	Purple Milk Vetch
A. cicer	Cicer Milk Vetch
Bromus inermis	Smooth Brome
B. pumpellianus	Northern awnless brome
Calamagrostis canadensis	Marsh reed grass
C. inexpansa	Northern reed grass
Deschampsia caespitosa	Tufted hair grass
Elaeagnus commutata	Silverberry
Elymus innovatus	Hairy wild rye
Festuca rubra	Red Fescue
Glyceria pulchella	Manna grass
Hedysarum alpinum	Alpine hedysarum
Hierochloe odorata	Sweet grass
Lathyrus ochroleucus	Pea vine

...con't...

TABLE 18 ...continued...

<i>L. venosus</i>	Pea vine
<i>Medicago falcata</i>	Alfalfa
<i>M. sativa</i>	Alfalfa
<i>Phalaris arundinaceae</i>	Reed canary grass
<i>Phleum pratense</i>	Timothy
<i>Poa compressa</i>	Canada bluegrass
<i>P. interior</i>	Interior bluegrass
<i>P. palustris</i>	Fowl bluegrass
<i>P. pratensis</i>	Kentucky bluegrass
<i>Puccinellia distans</i>	Weeping alkali grass
<i>Rosa acicularis</i>	Wild rose
<i>R. woodsii</i>	Wild rose
<i>Symphoricarpus albus</i>	Snowberry
<i>Trifolium hybridum</i>	Alskie clover
<i>T. medium</i>	Zig-sag clover
<i>Vaccinium myrtillloides</i>	Blueberry
<i>V. vitis-idaea</i>	Bog cranberry
<i>Vicia americana</i>	Wild vetch

Source: G. Wheeler, H. Vaartnov, Establishment and Survival of Ground Cover Plantings on Disturbed Sites in Alberta, Final Report of Phase I, (Edmonton, Alberta Agriculture, 1974), pp. 38-44.

The broadcast method applies seed and fertilizer to the soil surface, without cultivating it into the soil. Consequently, a mulch is needed to protect the seed and to prevent soil drifting. In some cases a binder will be required to stabilize the mulch.

Hydroseeding, where seed, fertilizer and a commercial soil stabilizer or mulch are applied to the surface in a emulsion, is an expensive seeding method. It is recommended for difficult sites where such conditions as steep terrain, low moisture retention or poor soil preclude other methods.⁴⁶ Although results are often not as good as normal agricultural methods, vegetation can be effectively established. The critical factor in this method is apparently the quality of humus or mulch.⁴⁷

Trees and shrubs are generally planted by hand although bare rooted seedlings can be planted in large quantities (5000 or more) by a tractor-pulled machine. Planting techniques are described in detail in a number of publications. (Ontario Ministry of Natural Resources, 1975; Lowe, 1979; Hough, Stansbury and Associate, 1974; Coates, 1979; Coates and Mooney, 1979; Cole, 1979).

Time of planting is also important to the success rate. Grasses and legumes should be planted as early as possible in spring, when the soil has become firm. It is also possible to 'dormant' seed in late

⁴⁶Ibid., p. 11.

⁴⁷Murray, Vegetation of Mine Waste Embankments, p. 26.

October, immediately prior to freeze up, when there is no risk of germination before winter. This practice should only be considered for sites which are difficult to gain access to in early spring, as there is greater potential for erosion of the seed bed.

Deciduous and evergreen trees and shrubs can be planted in either spring or fall when the plants are dormant.

Deciduous plants can be moved in the spring as soon as the frost is out of the ground, or at any time until the new foliage is partly unfurled. In the fall they can be planted from the time the leaves start to turn colour until the soil freezes.

Evergreens should only be planted when the soil is warm (above 10°C). The optimum period is generally from late May to early June and late August to early September. They can be planted in the spring up to four weeks after deciduous trees have opened their leaves, provided they receive adequate water. In the fall a minimum of six weeks before freeze up should be allowed for establishment of new roots.

Trees and shrubs can be planted during the growing season, provided they are properly handled. This may include water, cool storage and spraying with antidesiccants. Professional advice should be obtained if summer planting is considered.

⁴⁸Cole, Planting of Trees and Shrubs, (Ottawa: Agriculture Canada Publication 1679, 1979), p. 2.

Maintenance of established vegetation should also be considered, particularly during the initial years. The cost of a maintenance program can generally be justified as a protection of the investment already made in site preparation and planting. The most important procedures include watering, refertilizing, eliminating herbaceous competition around trees and shrubs, and replacement of dead plants.⁴⁹

⁴⁹ S.B. Lowe, Trees and Shrubs for the Improvement and Rehabilitation of Pits and Quarries in Ontario, (Toronto: Ontario Ministry of Natural Resources, 1979), p. 26.

9. Development Of A Rehabilitation Strategy

9.1 PURPOSE:

Following the completion of a site inventory and analysis of land use potential, it is possible to prepare an overall concept of physical development. The central purpose of this undertaking is as follows:

- i) To establish critical grade elevations, slopes, and requirement for terrain regularity (or roughness) directed to the implementation of a post mining land use development concept.
- ii) To identify major zones for the stockpiling of overburden, tailings and topsoil, based on a strategy for maximizing their usefulness in rehabilitation.
- iii) To outline a rational phasing for excavation and rehabilitation of the site, based on the overall objectives of the planning program.

The level of detail in this physical development strategy should be dictated by the information upon which it is based. In the case of the Seddons Corner deposit, we anticipate that modifications will be required over time as more detailed information becomes available concerning the extent of economically exploitable gravel, the groundwater regime, and the ultimate after use of the landscape.

This constraint does not reduce the need for an overall physical development concepts at the outset of mining, or for specific site plans where mining is ongoing and depletion is expected in the near future. It does limit the usefulness of detailed site plans in areas where mining has not even commenced, since these would not be sufficiently flexible to accommodate the inevitable changes over time.

The rehabilitation strategy for Seddons Corner has been designed to the level of detail required and possible at this time. (See Rehabilitation Strategy Plan).

The ultimate configuration of the lake feature has been identified, based on the extent of the gravel deposit now found below the water table. A cross-section has been taken along the entire shoreline of this lake, illustrating the relationship between:

- the existing grade;
- the onshore excavated grade;
- the lake water level; and
- the lake bottom (or off shore excavated grade).

The sections and plan may be correlated by the reference points (A to G).

9.2 SUMMARY OF REHABILITATION STRATEGY:

9.2.1 Reforested Areas:

A) Land Use Potential:

Many of the areas which have been or will be excavated lack potential for uses other than reforestation. This is due to the following factors:

- i) The relatively small land area.
- ii) Separation from the lake feature by undisturbed forest.
- iii) Lack of spectacular change in elevation resulting from excavation.
- iv) Proximity to competing sites which are much more amenable to the development of land use requirements.

B) Management Criteria:

- The maximum slope should be no steeper than three horizontal to one vertical.
- The areas should be graded to provide positive drainage to designated collection areas and to create an even surface condition congruent with the adjoining landscape.
- Fine textured overburden or peat should be distributed over and worked onto the surface to promote revegetation and tree growth.

9.2.2 Development Areas:

Three discrete development areas have been identified around the lake shore, where the potential for post mining land use activities other than forestry is high. Due to the physical separation of these sites, it would be possible to develop each one independently.

A) Development Area #1:

i) Description:

This landscape unit, comprising some 8 hectares, lies immediately south of the highway on the west shore of the lake. Unlike the other designated areas, it is largely outside of the excavation zone. The only portions of this site which will be severely impacted will be the shoreline, where the development of a levee and creation of useable slopes will necessitate extensive regrading. The gravel deposit west of the site is very shallow (1 metre) and therefore will not present a significant mining bank. The area is presently well treed, with the exception of a small clay borrow pit. (See Vegetation Map).

Immediately adjoining this area to the south is the old stockpile of reject material. Although largely unvegetated, it provides a striking landmark in the region and hikers are treated to panoramic views from the summit.

ii) Potential Uses:

The proximity of this area to the highway makes it an ideal site for the future development of wayside picnic facilities. By retaining the existing vegetation cover over most of the site, rehabilitation will be greatly accelerated. It is possible that the area may be used for recreation purposes at an early phase of lake excavation, when the mining operation would constitute a visually interesting feature.

The shoreline of this area is sheltered from the prevailing winds (because it is on the lee side of the Lake) and drops into deep water. Due to these characteristics, it would be a good location for any boat launch facilities. Sailing and canoeing are feasible uses, particularly in association with fishing. Motor boats should not be allowed on the lake, however since they can cause extensive shoreline erosion.

The existing hill feature could be developed as a hiking area complementing the wayside picnic function.



Photo #28 and #29: The existing stockpile could be landscaped to improve its appearance, and used as a viewing point.

iii) Management Criteria:

- This area should be developed as a wayside picnic facility, under the authority of the Provincial Parks Branch.
- Such a development should be initiated as early as possible, but not until below water mining has advanced to a point that any conflicts are minimal.
- The existing vegetation on the site should be carefully protected from any impact of mine operation and preserved as an amenity for future development.
- The mining and subsequent rehabilitation should be the focus of displays, signage and viewpoints at this recreation site since it can be both interesting and educational.
- The shore zone should generally be sloped no steeper than four horizontal to one vertical, providing for public safety and the development of a biologically rich littoral zone. Special sloping consideration should be given to develop a boat launch, on shore fishing points, and nesting areas for water fowl.
- The existing hill feature should be stabilized and aesthetically enhanced through slope modification and plantings. A hiking trail with scenic lookouts should be developed, with displays explaining the processes of mining and rehabilitation that will be evident below.

B) Development Area #2:

i) Description:

This area comprising some 26 hectares, abuts the southwest corner of the lake. As noted on the cross-sections and plan, the backshore area will be excavated for approximately 0.4 kilometres to a depth of about 2.4 metres below the natural grade. The site is isolated from other development areas by the lake, the hill, and the undisturbed forest land, although a physical connection to Area #1 could be easily strengthened.

ii) Potential Uses:

Due to its location, the potential for the development of rehabilitated uses on this site are unlimited, as noted in Section 7.0. However, certain environmental opportunities should be noted. Large portions of the shore are in a sheltered position from prevailing winds. The proposed island will provide further shelter for the zone between Section Points D and E on the plan. In addition, the depth of excavation abutting this shoreline is relatively shallow (see Geology Map) resulting in potentially warmer water temperatures. As a result of these characteristics, the opportunities for intensive shoreline recreation, including beaches and swimming, are greatest in this area.

iii) Management Criteria:

- The shore zone in this area, particularly between Section points E and D, should be developed as a public beach. This would necessitate grading to a shallow slope, and distribution of sand (reject material of mine operations).
- An off shore sand bar should be developed to ensure the warmest possible water temperatures (refer to Section 8.2.3).
- Development of the back shore should be compatible with the public beach function. A wide range of uses may be feasible (see Table 7, Section 7), although at this point in time the development of a campground facility seems most appropriate. Any land use must be regulated carefully to prevent contamination of the groundwater and lake.
- Appropriate topsoil conditions should be developed to cover the area to a depth of at least 10 centimetres.
- Slopes in this area should generally not exceed three horizontal to one vertical and several expanses of flat plains (sloped no less than 2%) should be developed to accommodate intensive uses. The terrain should generally be left with an even surface form, congruent with the surrounding landscape.

C) Development Area #3:

i) Description:

The portion of the study area lying east of the lake comprises over 400 hectares of developable land after excavation. It is recommended that the northern part of this area be returned to forest production during an early phase of the operation, creating a buffer zone between the highway and any future uses. The remainder of the site, shown as Development Area #3, can have access from the secondary road through the mined out esker feature.

ii) Potential Uses:

This site is physically separated from Area #2 by one-half mile of undisturbed crown land. The shoreline zone may be used to provide a pedestrian connection between the two sites.

The creation of intensive shoreline activities is possible, although constrained by deep excavation and open exposure to prevailing winds.

Considering its isolation, and separate access, the land uses developed on this site need not be compatible with those of the other two development areas.

iii) Management Criteria:

- Uses which would not be compatible with the public recreation concept implemented in Area #2 should be considered in Area #3. These might include private cottage and residential development, or commercial recreational ventures, (i.e. resort, raceway, golf course, etc.).
- The shore zone should generally be sloped no steeper than four horizontal to one vertical providing for public safety and development of a biologically rich littoral zone. A variety of shallower slopes would be preferable to create a diverse shoreline.
- Until such time as detailed site plans are submitted to achieve a specific after use, no slope should exceed a gradient of three horizontal to one vertical, and the terrain should be left with an even surface form congruent with the adjoining landscape. Steeper slopes may be considered in relation to specific landscape development proposals.
- Appropriate topsoil conditions should be developed to cover the area to a depth of at least 10 centimetres.

9.2.3 Road Relocation:

P.T.H. #44 presently cuts across the main gravel deposit, bisecting the site and effectively eliminating a large volume of aggregate. It is anticipated that at some point in the future (although probably not within the next ten years) this highway will need to be upgraded and possibly expanded to a four lane capacity. When this investment is to be made, it will probably be economically advantageous to relocate the highway to the north, thereby allowing the excavation of over a mile of deep gravel deposit now underlying the right-of-way.

The proposed configuration of the highway is somewhat conceptual of this point, in the absence of more detailed engineering investigations. The curve approaching Seddons Corner is based on an assumed speed of 50 miles per hour, with a maximum super elevation of 0.08 and a maximum co-efficient of side friction of 0.14. Using these criteria, the need for expropriation of private land is minimized.

Elsewhere, the road is designed to be close to the lake, allowing panoramic views, yet providing sufficient space for development of stable and safe shore line slopes. Uncontrolled public use of the north shore should not be encouraged. Instead, future uses should be focused into one of the development areas, where they can be safely accommodated. In this context, a steep gradient from the highway right-of-way to the shore is desirable. This slope may be as high as 50% (two horizontal to one vertical) provided it is stabilized with vegetation.

However, for safety purposes a margin of land, extending 3 metres above the high water level should have a maximum gradient of 12% (8:1). The slope below the high water mark should not exceed 25% (4:1) for a distance of 7 metres from shore.

9.2.4 Major Stockpiling Zones:

The stockpiling locations for overburden and reject material have been selected to achieve certain objectives of the rehabilitation strategy. At this point in time it is difficult to estimate the quantity of reject material which will be available for use, and the configurations illustrated in the rehabilitation strategy are somewhat conceptual. However, this does not reduce the need to identify future stockpile sites where the requirements for backfill material have highest priority.

Five major stockpile locations have been identified in the rehabilitation strategy as follows:

- i) A levee
- ii) An island
- iii) A peninsula
- iv) North marsh
- v) South marsh.

A) The Levee:

The most important stockpile area is the levee, at the northwest corner of the lake. At this point there will be very little difference between the existing grade of the land and the anticipated water level of the lake. The terrain slopes down to the northwest. Consequently, there is danger of unexpected surface overflow causing severe erosion problems.

This problem was pointed out in Sections 6.3 and 8.2.1. Detailed hydrogeologic studies are recommended. The purpose of any stockpiled material in this area would be to bank up the shore adequately to contain the lake water. It may be advantageous to include an overflow structure within the levee to regulate changes in lake level.

Hydrogeologic studies and monitoring programs should be initiated promptly, since the area should be built up to a safe level prior to the highway relocation.

B) The Island:

The eventual slope of the lake formed by excavations below the water table has been assumed on the basis of geological data. The long axis of this configuration extends east and west, almost parallel to the prevailing northwest winds. It would be desirable to break up the expanse of water, minimizing the effective fetch length and thereby reducing wave erosion problems along the shoreline.

This is the main function of the proposed island feature. Ancillary functions include visual aesthetics and development of environmental amenities. By closely sheltering the shallow southwest shore, warmer water temperatures may be developed, facilitating a wide range of recreation activities. Visually, the island breaks the lake into a number of contrasting zones, adding interest and variety. Since you cannot see the entire lake from any one point, it has the illusion of being much larger in size.

At this time, the volume of waste material and unneeded overburden is not known. It is recommended that such stockpiles be placed in the shallow water area, where it can be used most efficiently to create an island. The size and ultimate shape of the island is shown conceptually, but may be changed depending upon the availability of material.

Although the topography of the island will also be a function of the availability of fill, the effectiveness will increase if the land rises well above the water surface. Slopes should not exceed three horizontal to one vertical, and the land form should appear natural, since it will be a focal point of all views from the shore.

C) Peninsula:

The proposed peninsula feature is designed to serve the same function as the island, breaking up the open expanse of water and pinching off the long fetch axis. It should be a lower priority for stockpiling.

The peninsula would be an appropriate location for development of low land vegetation associations and fen conditions. Views from the highway would look over this land form, in contrast to the areas east and west where the view is over a water dominated landscape. To achieve this, the terrain should not be built up more than a few feet above the lake level, and should be given a gently rolling character. Native vegetation may be strategically planted as a seed source to promote rapid establishment.

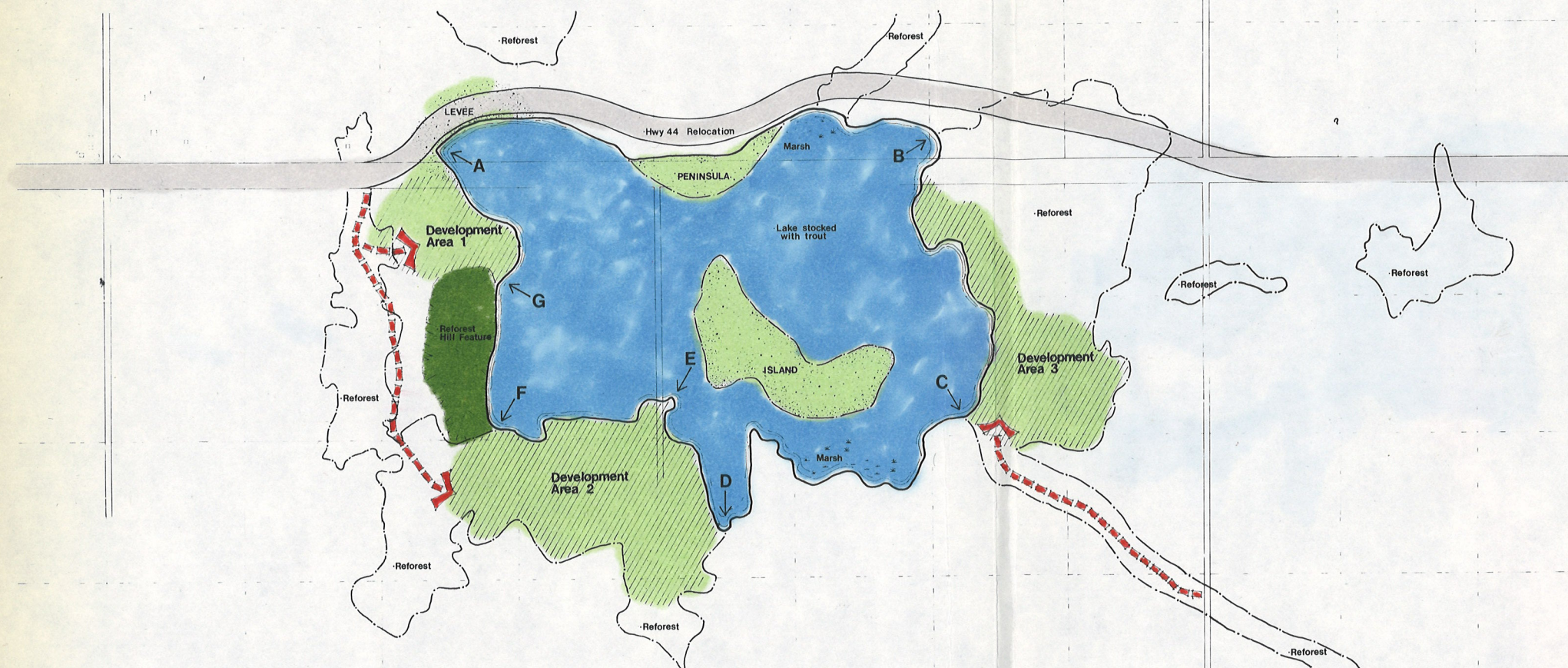
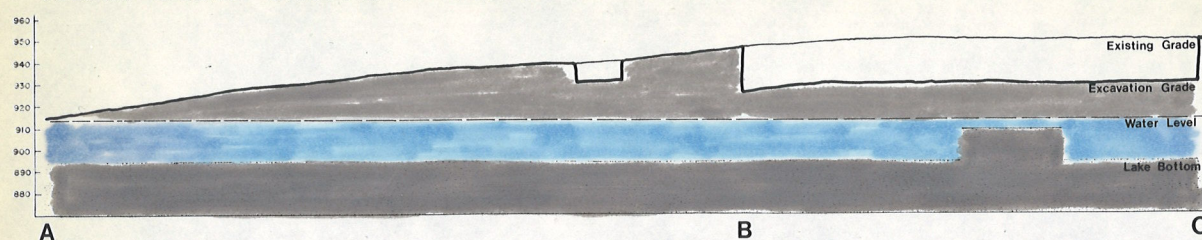
D) The Marshes:

The importance of a rich and diverse littoral zone was discussed in Section 8.2.5. Although the lake has adequate deep water for stocked trout, the plant and animal communities of shallow water are needed as a food source. Steep shores comprised of coarse soil material severely limit the biological productivity of most excavated groundwater lakes.

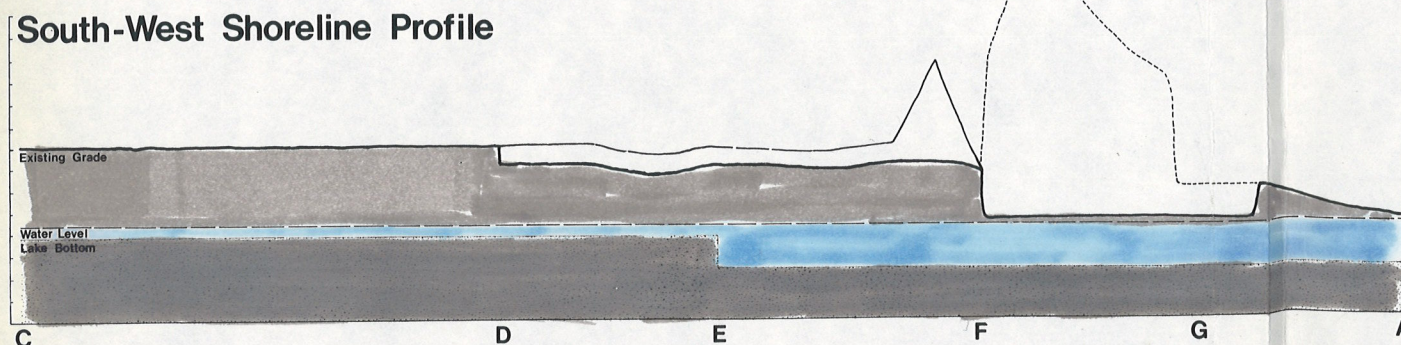
To overcome this constraint, it is recommended that most of the shore slopes be moderate, no more than four horizontal to one vertical. (Other activities such as boat launches, public beach areas, onshore fishing sites, and water fowl nesting habitat will dictate special slopes and shore conditions). In addition, two major marsh areas are proposed to introduce a high level of biological activity.

The north marsh is located in the lee of the peninsula, while the south marsh is sheltered by the island. Both should be developed initially as a shallow water area (one to two metres deep). Fine textured overburden should be used to establish a mucky soil condition appropriate to macrophytes and other aquatic vegetation. Planting of desired species as a seed source would greatly accelerate establishment of marsh habitat. Experiments in controlled release of fertilizers might also be undertaken.

North-South Shoreline Profile



South-West Shoreline Profile



REHABILITATION STRATEGY

Major Stockpile Zone

Development Zone

Future Access Route

Outline of Deposits

Lakeshore Outline

Section Points

MANITIBA
DEPARTMENT OF MINES, RESOURCES
& ENVIRONMENTAL MANAGEMENT
MINERAL RESOURCES DIVISION

SCALE 1:5000
100 0 100 200 metres
200 0 400 800 feet

SEDDONS CORNER REHABILITATION PLAN



9.3 PHASING OF EXCAVATION:

9.3.1 Objectives:

The development of a detailed long term phasing plan is restricted by a number of variables. Foremost of these is the uncertainty of future demand for aggregate from this area, and the resultant economics of operation. At what point, for instance, will it be viable to commence below water excavation? This problem, compounded by the presence of a wide number of operators working simultaneously, prohibits any quantitative measures of future extraction in relation to specific years.

To overcome these difficulties, the phasing strategy has been approached on the basis of a priority system. It is advantageous to mine in certain areas before others, regardless of when excavation occurs. The objectives of this phasing strategy are as follows:

- i) The ongoing environmental impact of the mining operation should be minimized. A corollary of this is that the proportion of land exposed by surface mining should be minimized through ongoing rehabilitation.
- ii) The movement of earth material should be minimized, making efficient use of men and machinery.
- iii) The phasing plan should facilitate implementation of the development strategy and the ultimate use of the landscape.

These objectives form the basis of the proposed Phasing Strategy. Since a wet mining operation can commence at any time, depending on economics, a separate system of prioritization is used for areas of deep (below water) deposits, as opposed to deposits above the water table.

The two types of operation may occur simultaneously. However, it would be inefficient to mine all the above water portion of the deep deposit prior to the commencement of below water excavation. Stockpiles would have to be moved later to get at the material underneath then. A huge area of mine operation would be exposed, with an extensive environmental impact. Any interim rehabilitation efforts would be wasted, since the site would have to be cleared for subsequent excavation when it became economically advantageous to mine below the water table. Consequently, it is recommended that priority be given to mining the shallow areas, which can then be either permanently rehabilitated, or used as long term stockpile sites.

Given the uncertainties of aggregate supply vs demand, and the established pattern of lease ownership and mine development, at Seddons Corner it would be politically impossible to follow any single phasing pattern directed exclusively to the above objectives. The priorities will have to be applied in this context. For example, where we must accept mining in a third priority area, only the direction of mining can be controlled by the phasing strategy. Mining in a fifth priority area is not catastrophic, it may simply delay implementation of the rehabilitation plan.

9.3.2 Rational for the Phasing Zones:

A) Shallow (Above Water) Deposits:

First Priority (1):

It would be desirable to have the aggregate under the Highway's future right-of-way extracted prior to the actual relocation.

Second Priority (2):

The levee should be built-up before the relocation of the highway. Any overburden or unneeded material resulting from extraction in this area could be put to this use.

Third Priority (3):

When excavation begins on the deep (below water) deposit, space will be required for stockpiling. By completing excavation along the margins of the deep deposit at this time, a permanent stockpile zone can be created. Unneeded material may subsequently be used to rehabilitate the shore zone. Excavation along the old highway right-of-way should be completed as quickly as possible, then rehabilitated to forestry, providing a buffer zone between future work and the public road.

Fourth Priority (4):

Since excavation has already commenced in these areas, there is justification for working here as opposed to Zone 5.

Fifth Priority (5):

There would be no apparent advantage to mining these areas prior to any others in the vicinity. Similarly, those areas which are geographically separate from the main deposit can be mined at any point in time without detrimentally affecting the implementation of the plan or the program objectives.

B) Deep (Below Water) Deposits:

First Priority (1):

Excavation should be completed in this shallow zone, providing space for future stockpiling and the development of an island.

Second Priority (2):

Excavation should be completed over the remaining shallow water area. This provides additional space to accommodate future stockpiling, and allows final rehabilitation of an extensive shoreline area. At the same time, it would be advantageous to complete the excavation of material in the northwest corner of the lake (assuming the road has been relocated). The levee construction could be completed, and the landscape rehabilitated allowing early development of Area #1.

Third Priority (3):

Excavation can be completed in this designated stockpile zone, freeing it for future use.

Fourth Priority (4):

By completing the mine operation in this zone, and rehabilitating the shoreline, both the Development Area #1 and Development Area #2 could be used.

Fifth Priority (5):

There is no apparent advantage to mining in these zones prior to the others.

PHASING OF EXCAVATION

Priority of Zone



Deposit Above Water



Deposit Below Water



SEDDONS CORNER REHABILITATION PLAN



MANIT^{BA}
DEPARTMENT OF MINES, RESOURCES
& ENVIRONMENTAL MANAGEMENT
MINERAL RESOURCES DIVISION

SCALE 1:5000
100 0 100 200 metres
200 0 400 800 feet

10. Summary and Conclusion

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It has become increasingly apparent to those proponents of aggregate resource extraction that the industry must work within limits established to protect the quality of the environment. Over the last decade, rapid urbanization throughout North America has brought the industry into a high public profile situation. This was inevitable, since the relative inavailability of sand and gravel and the economics of bulk transportation necessitate a close proximity to the market place. In this setting, any industry seen to degrade environmental quality risks being subjected to public criticisms, political controversy, and harsh restrictions on growth.

Great strides have been made in recent years to mitigate the impact of mining. While certain immediate consequences of this industry are inevitable, case studies have demonstrated that sound planning of the extraction and progressive rehabilitation of the landscape can protect and occasionally improve environmental quality. Such site planning has therefore become widely accepted by the industry and regulatory agencies as a necessary component of the mining process. In Manitoba, as in many other provinces and states, site rehabilitation planning is compulsory under government regulation.

While the merits of planning for excavation and rehabilitation at the site level are recognized, the work cannot be seen as an end in itself. Sand and gravel deposits are commonly regional in scale, and worked by a large number of individual operators over a long time period. The responsible regulatory agency must have a rational and equitable basis to evaluate the appropriateness of each individual site plan. It must also be concerned with:

- i) the cummulative impact of the various operations on the environment; and
- ii) the relationship of mining and proposed post mining activity with other existing and planned land use development in the region.

To achieve these purposes, it is necessary for the responsible public agencies (or consortium of private operators) to develop a comprehensive rehabilitation planning program for the mining region as a whole. A model for such a program is outlined in Figure 7, and has been tested in application to a mining region in southeastern Manitoba.

In this model, individual mine site planning is preceded by a more comprehensive examination of the region. At this broad level, environmental and human factors are inventoried, constraints and opportunities are identified, and a general mine rehabilitation strategy is drafted. It includes a concept of post-mining land use and landscape form development, guidelines for protection of the environment, and phasing policies to direct the sequence of mining.

The comprehensive rehabilitation strategy and management guidelines may then be used by the individual operators in the region as a context for the preparation of their site specific mining and rehabilitation plans. For the regulatory authorities, it provides a rational basis for the review of these individual submissions. It facilitates decisions to approve or disallow proposed activities or to require certain modifications of mining/rehabilitation proposals.

Perhaps the most critical component of any such model is its dynamics. It must not be viewed as a sequence of steps leading to a single end product, but as a continuing process, with opportunities at every stage for re-assessment. Over time, new environmental information may become available, objectives may change, and priorities may shift. The program must be sufficiently flexible to accommodate these changes and follow through the implications. It must also be sensitive to input from all the participants, including the industry and the public at large.

The application of this model to the Seddons Corner region of southeastern Manitoba has demonstrated the advantages of comprehensive rehabilitation planning. These may be summarized as follows:

1. Environmental problems can be readily foreseen and resolved, precluding environmental calamity. In the study area, for example, it was determined that uncontrolled mining could upset a delicate balance between the water table and the natural topography creating a new overland flow with a substantial environmental impact.
2. The mining and rehabilitation program of individual operators can be co-ordinated to ensure efficient utilization of the resource and development of appropriate environmental conditions in the post mining landscape. For example, maximum slopes in the study area have been recommended on the basis of potential end land uses - less than 5% where beaches are possible, but up to 30% where only forest regeneration will occur.
3. A rational basis can be identified for sequential excavation and rehabilitation of the deposit, minimizing the overall environmental impact while maximizing the efficiency of resource exploitation.
4. The development of post mining land use activities on individual properties can be directed to ensure compatibility with adjoining uses, and with the local community.
5. The planning program can provide a forum in which the participation of mine operators, environmentalists, local politicians, government regulatory agencies and the public at large may be accommodated. The issues can be presented in their proper context for informed debate, and necessary trade offs can be made prior to confrontations.

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