TOWARDS A SOCIALLY RELEVANT GEOMORPHOLOGY: A CASE STUDY FROM PRINCE EDWARD ISLAND

by

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ABSTRACT

Supervisor: Dr. Harold D. Foster

In 1969, the federal government of Canada and the provincial government of Prince Edward Island signed a joint Development Plan for Prince Edward Island, designed to reduce economic disparity between this province and the rest of Canada. An integral part of this Plan is the continued development of the Island's infrastructure, especially the highway system. The gravel from which these roads are to be constructed, is to be derived from open-cast quarries on the Island. As a result environmental quality will inevitably deteriorate. It is, however, one of the principal aims of the Development Plan to maintain the aesthetic quality of the province in an effort to stimulate tourism.

The gravel deposits, in southeastern Queens and southern Kings counties, on which this study focuses, were derived from the weathering of Permian conglomerates. A seismographic survey undertaken by the author revealed gravel reserves, in this area, in excess of 10,000,000 tons. Grain-size analyses and roundness studies of samples from available exposures indicate that, after suitable preparation, these deposits will probably reach the minimum standards, demanded by the provincial Department of Highways. It is estimated that 90,000 tons of gravel will be extracted, from the study area, for both asphalt manufacturing and concrete production, each year for the next five years.

During this period, planning programmes for agriculture, tourism, forestry and other economic activities will be initiated. In order to help avoid major conflicts of land use, this study evaluates the competition for land which will probably occur, as a result of both the road building programme and other proposals included in the Development Plan.

Various alternative sources of gravel supply were considered, including those at Folly Lake, and Malignant Cove, Nova Scotia. The economic and social costs of five distinct courses of action were then analysed using a least-cost equation and the consequences of each alternative are shown. The cheapest alternative, open to decision makers, is to continue using gravel from Island sources.

This study clearly demonstrates that the costs of land reclamation, after gravel extraction, resulting in the preservation of an aesthetically pleasing environment, are minimal if compared with the possible losses to future tourist trade. However, it is also argued that it is not necessary to establish the desirability of reclamation economically, but that it is simply an "inalienable right" of the population to demand that industry maintains environmental quality. It is fortunate that the least-cost solution to the land-use conflicts in southeastern Prince Edward Island satisfies commonly held aesthetic as well as economic criteria.

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Mr. D. R. Morrison, Mr. R. Perry, Mr. F. Miles and Mr. S. Frizzell. Many landholders allowed me access to their land and made helpful suggestions, among these in particular Mr. A. Whiteaway, Mr. G. Matheson, and Mr. H. Loans showed particular interest in my work.

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Finally, I owe a deep debt to my future wife, Yvonne, who helped in the writing and who suffered patiently many hours of boredom during the preparation of this thesis.

Whether you will or not

You are King, Tristram, for you are one

Of the time sifted few that leave the world,

When they are gone, not the same place as it was,

Mark what you leave.

E. A. Robinson

CHAPTER I

GRAVEL EXTRACTION AND PLANNING IN PRINCE EDWARD ISLAND

Introduction

As a result of economic expansion and associated construction, demands for gravel are growing and will continue to grow. Gravel is a location specific, non-renewable resource, the extraction of which results, all too frequently, in conflicts of interest with other land-orientated activities, especially recreation and agriculture. As a result of the landscape disruption, which must, of necessity, accompany gravel quarrying, environmental quality will deteriorate. Such conflicts of interest are particularly acute in areas where land is a scarce commodity but where demands for its use are growing, as a result of economic expansion and the increase in leisure time and income.

This thesis is essentially a case study of such land use conflicts and associated environmental deterioration in Prince Edward Island, the smallest of the Canadian provinces (see figure 1).[1] Within this province, the study focuses on the major area of gravel extraction, southern Kings and southeastern Queens counties, which lie in the east of Prince Edward Island.

The following analysis of the gravel industry of this Maritime province, and the concluding synthesis, differ markedly from the accepted geomorphological approach to the study of gravels. Such

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1. See p. 3.

studies are generally concerned with gravel morphology, genesis and chronology. In contrast, in this study, emphasis is placed throughout on the social significance of Prince Edward Island gravel deposits, and in so doing, a precedent is set which may perhaps be followed by other Canadian geomorphologists who are interested in contributing to the public good.

Prince Edward Island: A Summary of Problems and Prospects

Prince Edward Island which has an area of only 2,000 square miles, lies only 13 miles from the mainland of New Brunswick, in the south of the Gulf of St. Lawrence, as shown in figure 1.[1] The Permian sandstones, shales and conglomerates which form the bedrock over much of the Island have been modified by marine, glacial and fluvial erosion to form a gently rolling relief, no point of which reaches an altitude above 500 feet. Iron oxides in the Permian bedrock frequently provide the relatively fertile soils with a ferrous red colouration.[2] With the exception of gravel, this bedrock is not known to contain any minerals of economic significance.

Despite its location, Prince Edward Island has a climate with some continental characteristics, similar to that of the mid-western states of the United States of America. There are forty inches of precipitation each year, of which one third falls as snow. The average monthly temperature in February is 10 F. In contrast, however,

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1. See p. 3.

2. The soils are classified as "podzols, strongly leached of soluble salts, ... low in plant nutrients and strongly acid...(texturally) ...they are ... predominantly sand loams." G. B. Whiteside, Soil Survey of Prince Edward Island, Charlottetown, 1950.

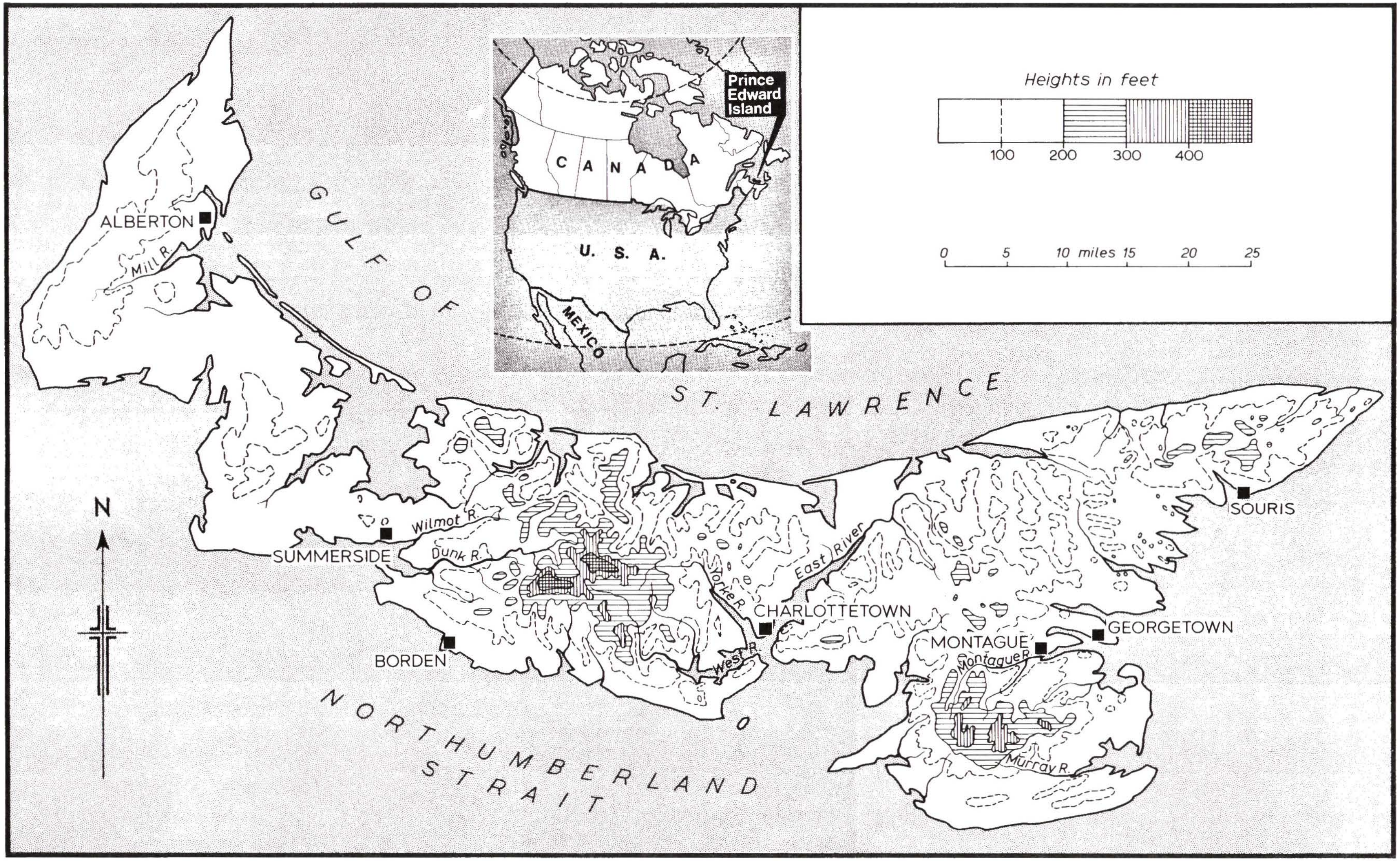

Figure 1 Location, Relief and Drainage of Prince Edward Island

the temperature of the warmest month, July, averages only 68 F., considerably lower than the summer maximum in the central United States of America. Soils on the Island vary in fertility. In the area between Charlottetown and Summerside, soil capability for agriculture is relatively good, in contrast to the less fertile soils elsewhere on the Island.[1]

In summary, when compared with the Maritimes as a whole, the area has a relatively advantageous resource base which is rivalled only by the Annapolis Valley of Nova Scotia.[2] Unfortunately, archaic, social and cultural attitudes are still prevalent in the Island, and have combined with external economic factors to prevent economic progress at a rate that compares with the rest of Canada.[3] For example, common features of the Island's agriculture, "the economic engine" of the economy are fragmented landholdings and lack of technical knowledge which reflect such attitudes. The availability of capital and transportation difficulties to national markets,[4] all combine to hamper the development of a viable agricultural system.

As a result, the resource base of the Island which strongly favours many agricultural activities, has not been well developed. The death of minerals in the province has hampered the growth of primary and secondary industry, which, in turn has retarded the deve-

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1. A.R.D.A, Soil Capability Map for Agriculture in Prince Edward Island, Ottawa, 1966.

2. P-Y Pepin, Life and Poverty in the Maritimes, A.R.D.A, Research Report No. RE-3, Ottawa, 1969, p. 196.

3. Ibid., p. 227.

4. Development Plan for Prince Edward Island, Schedule 'C', Charlottetown, 1969, p. 5.

lopment of a strong service structure. Consequently, rural depopulation has continued unabated since 1891 when the Island supported a population of 108,900. By 1931 the total provincial population had dropped to 88,000 but the urban population had expanded as had the rural non-agricultural sector.[1] Rural depopulation continued after 1931 and indeed is still occurring,

> "the rural population continues to dwindle away, Kings county is the hardest hit, in marked contrast with the prosperous centre of the Island".[2]

Although the major conclusions of this study are relevant to the province as a whole, the emphasis is placed on the most extensive gravel resources which occur in southern Kings and southeastern Queens counties, (see figure 2) where the social and economic problems also are more acute. In 1961 Kings county had a density of only 28 persons per square mile in contrast to 60 and 53 persons per square mile, respectively in Queens and Prince counties; both of which had significantly higher urban populations. In this year only 17 per cent of the total provincial population lived in Kings county, and of this proportion only 15 per cent were urban dwellers. Also, in 1961, the total labour force of Kings county numbered only 5,662. Forty-three per cent of the salaried workers earned less than $1,000 per annum and only 40 per cent of these salaried workers were employed for more than forty weeks in the year.[3]

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1. A. H. Clarke, Three Centuries and The Island, Toronto, 1959, pp. 128-131.

2. P-Y Pepin, op. cit., p. 48.

3. A. H. Clarke, op. cit., pp. 49-53.

In 1969, the current study indicated that gravel extraction and asphalt manufacturing employed five per cent of the total work force of Kings county, some 350 persons. These workers recieved average incomes of $2,500. In contrast, less than two per cent of the work force in the Island as a whole are employed in gravel extraction and asphalt manufacture. The social economic impact of these industries within the study area ~~are~~ is, therefore, of much greater significance than elsewhere in the Island.

The Development Plan and The Study

Faced with economic inequalities within the province, and economic disparity with the rest of Canada, the provincial and federal governments co-operated to produce a Development Plan for Prince Edward Island, which was signed in 1969. This Plan was designed to provide,

> "...full economic exploitation of the Island's large and potentially profitable resources for agriculture. Other main features of the strategy are: a considerable development of tourist facilities; better utilization of forest assets; rationalisation of fisheries; extension of education programmes ..."[1]

In order to achieve these ends the Plan provides for the reallocation of,

> "some 93,000 acres of poor agricultural land to forestry, tourist and wildlife use and to add, over time, approximately 270,000 acres of unused good agricultural land to the 550,000 acres presently being farmed. There will be zoning control and licensing to concentrate tourist developments in the most suitable areas, where they will not detract from the best use of farmland."[2]

The Plan places its major emphasis on agriculture and implies that the Island has a clear and substantial comparative advantage over the

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1. Development Plan for Prince Edward Island, op. cit., p. 1.

2. Ibid., p. 56.

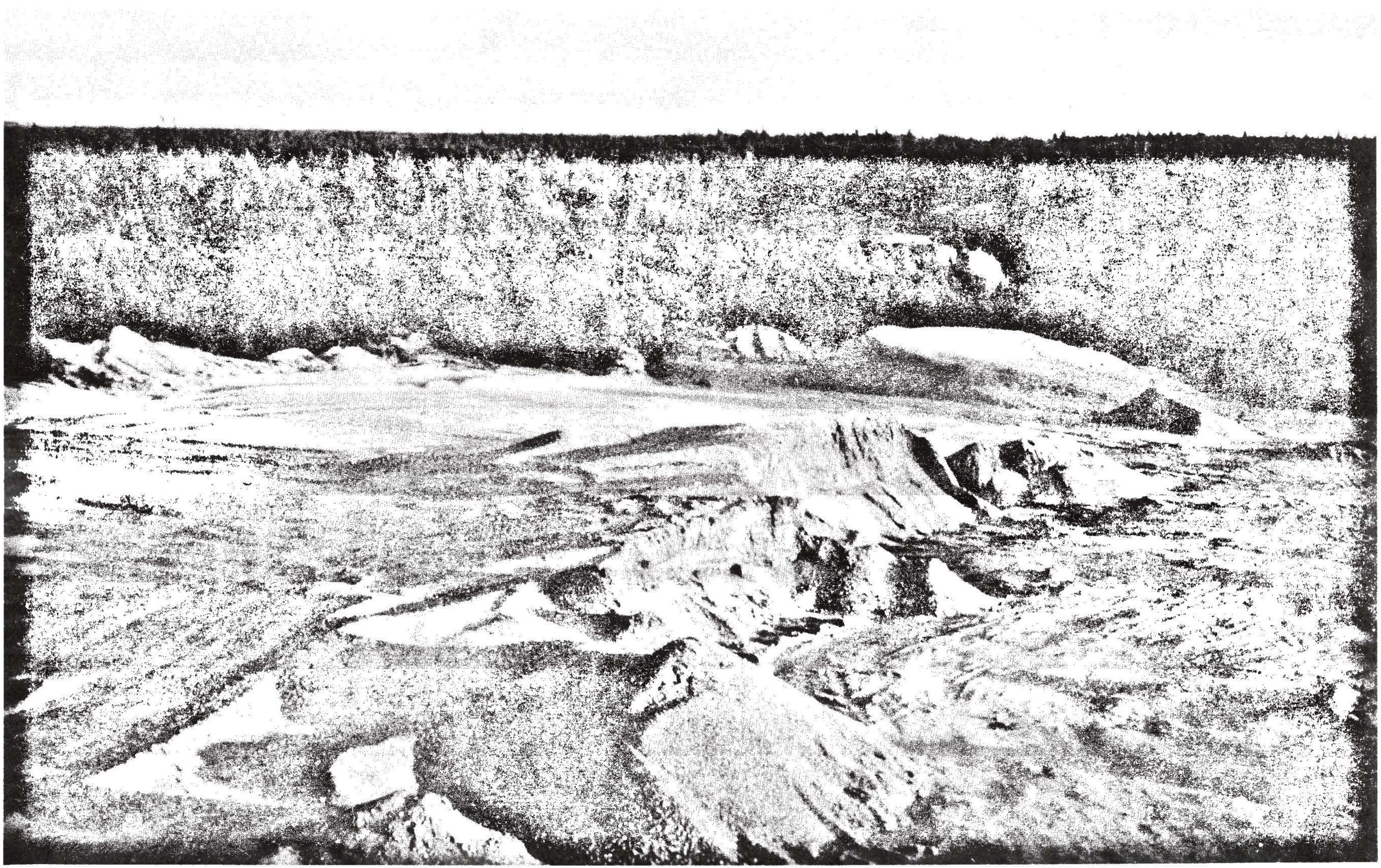

Plate 1 Excavation of Fluvio-Glacial Gravel Deposits, Conway River (MG3167)

rest of the Maritimes in this activity. Experiments with, and the introduction of, new crops are to be encouraged and it is stressed that tobacco has been a major success in the last decade. For example,

> "Commercial production of flue-cured tobacco began in 1959. Production has increased slowly but steadily to a peak of approximately 1600 acres in 1968."[1]

Unfortunately, the sites occupied by such tobacco farms are generally well drained, sandy, hilltops. These are particularly common in southern Kings and southeastern Queens counties, the study area. Subsurface gravel deposits generally provide these conditions and if tobacco farming continues to expand it is probable that the gravel extraction industry will eventually be in direct site competition with the most viable agricultural enterprise in eastern Prince Edward Island. The Plan recognises the importance of the tobacco industry to the provincial economy, an investment proposal of $1,200,000, and includes to provide a bulk kiln and associated equipment.[2]

Not all crop and livestock activities are viable within the context of the provincial economy. For example it has been shown that,

> "... the budget analyses indicated unsatisfactory incomes from the major land-using enterprises, i.e. dairy, beef and feed grain. Satisfactory labour incomes were indicated for those land-based enterprises which were physically adapted to the Maritimes, i.e., potatoes, tree fruits ... vegetables, strawberries and blueberries ... The budgets for non-land based enterprises (hogs, poultry, and greenhouses) indicated generally satisfactory labour incomes."[3]

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1. Atlantic Field Crops Committee, 1969 Field Crops Recommendations for the Atlantic Provinces, 1969, p. 33.

2. Development Plan for Prince Edward Island, op. cit., p. 56.

3. Atlantic Development Board, "Maritime Farm Enterprise Analysis," Ottawa 1969, p. 259.

The Plan suggests, therefore, the development of these agricultural activities which were considered to provide satisfactory labour incomes, within Prince Edward Island.

A further aim of the Planners is to increase tourist development. It is stressed that there must be, "regulation and control to prevent unsightly development," which would detract from the tourist trade.[1] It is also suggested that,

> "planning control to preserve the natural environment of the countryside would be executed by the Province; this control is considered to be equally as important to the successful implementation of the concept as the capital inputs."[2]

Such control should ensure that environmental quality is maintained. Indeed as the Plan states,

> "A large part of the continuing attractiveness of the Island to tourist will be the overall impression created by the environment."[3]

The successful expansion of tourism, as envisaged by the Planners depends, therefore, on the maintenance of environmental quality in both urban and rural areas, for the benefit of both the local inhabitants and the summer visitors.

Clearly if the economic expansion proposed in the Plan is to occur, a comprehensive road system is essential. For this reason,

> "the road needs over the next ten years have been carefully reviewed ... The highway plan provides for the construction, rebuilding and improvement of 570 miles of roads."[4]

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1. Development Plan for Prince Edward Island, op. cit., p. 21.
2. Ibid., p. 22.
3. Ibid., p. 47.
4. Ibid., p. 47.

It is also probable that the Province will continue with its own independent road paving programme.[1]

Gravel is necessary for highway construction, and for the manufacture of concrete, both of which will be required if the economic expansion envisaged takes place. It would be extremely unfortunate if the extraction of these gravels seriously affected the future development of agriculture and tourism in the province. A major aim of this study is to minimise the effects of such conflicts, Plate 1, on page 7, shows the typical effects of gravel quarrying.

This thesis reflects the concepts, priorities and strategies of the Development Plan for Prince Edward Island, which provided the stimulus for its initiation. The basic philosophy of the study is succintly summarized in the following extract from a press release noting the signing of the Prince Edward Island Development Plan, March 7th, 1969, which stated that,

> "Programmes for renewable resources such as agriculture, forestry and recreation are based on land use adjustment as indicated by land capabilities and market demands, and on policies and measures to promote development ... Involved is the use of land in a manner calculated to produce the best economic returns, and the reallocation of land for its most effective use is the fundamental factor involved ... Arising out of these basic programmes are requirements for roads..."[2]

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1. R. G. White, Deputy Minister of Highways, Prince Edward Island, personal oral communication.

2. Background Notes on Prince Edward Island Development Plan, pp. 2-3.

CHAPTER II

THE ORIGIN, NATURE AND WEATHERING OF UNIT C CONGLOMERATE, SOUTHEASTERN PRINCE EDWARD ISLAND

Introduction

The bedrock of Prince Edward Island consists of a series of red to brown sandstones and shales, and includes occasional limestones and conglomerates, which have been folded into very gentle, open synclines and anticlines.[1] These lithologies are probably Permian in age,[2] and have been subjected to only local faulting and minor igneous activity. Although the Island was subjected to extensive pre-Pleistocene erosion, much of the topography reflects the effects of continental glaciation which occurred during the Pleistocene epoch. The major drainage systems, for example Morrell River, Montague River and Dunk River, although probably of pre-Pleistocene origin have been modified by glacial erosion and deposition. Indeed glacial and glacio-fluvial deposition, has mantled much of the bedrock of the Island with a veneer of sediment.[3] It has also been suggested that Prince Edward Island rebounded at least seventy-five feet isostatically, following the retreat of the continental ice sheet. Marine and possibly glacio-

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1. G. C. Milligan, Geological Survey of Prince Edward Island, Charlottetown, 1949, p. 5.

2. L. Frankel, Geology of Southeastern Prince Edward Island, Ottawa, 1966, p. 6.

3. Ibid., pp. 53-64.

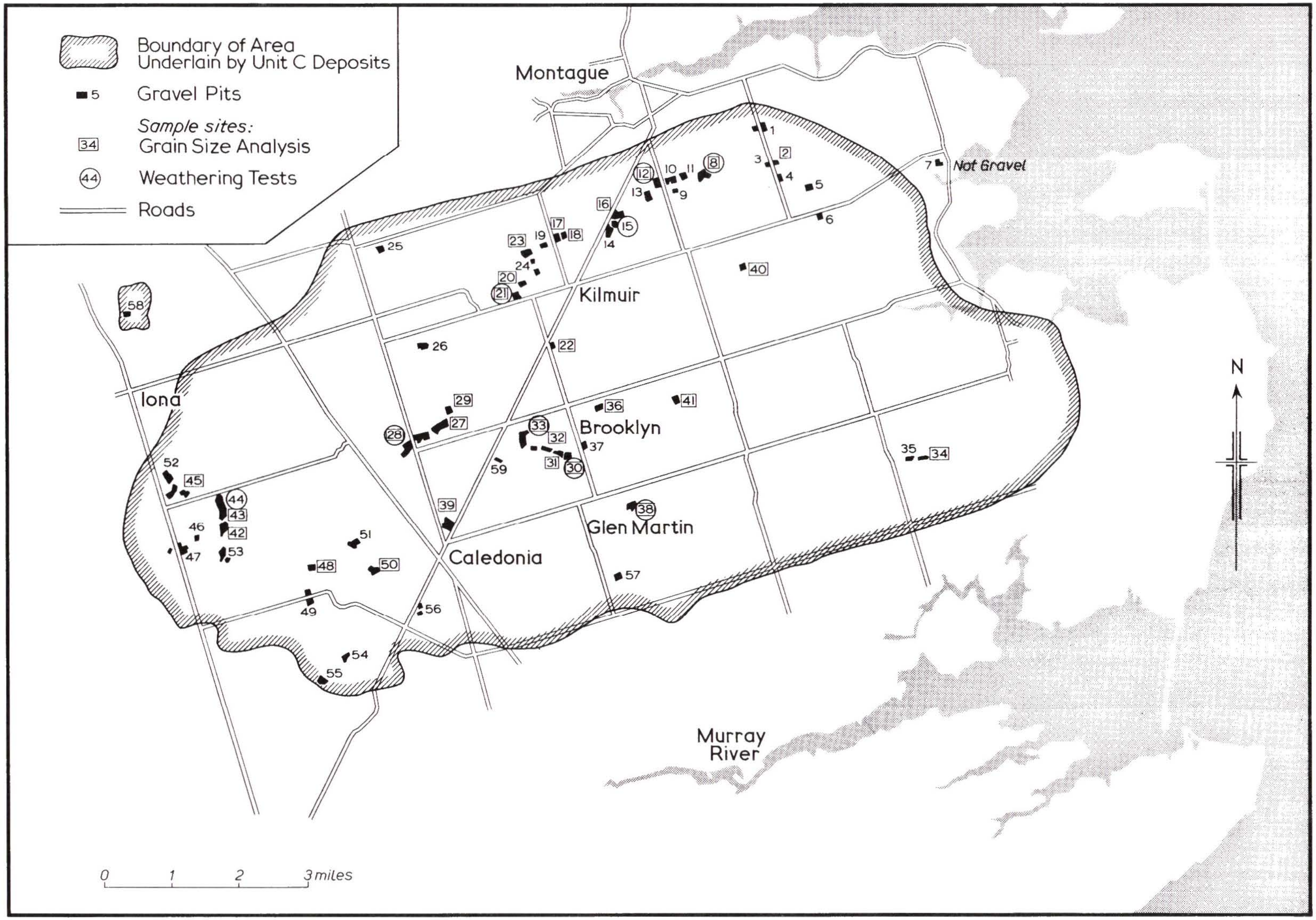

Figure 2 The Location of Gravel Pits and Sample Sites within the Unit C Outcrop South of Montague

marine gravels, sands and clays which were deposited during the transgression are found up to this altitude.[1]

During the Post-Glacial, marine erosion of sandstone bedrock and unconsolidated Quaternary deposits provided sediment for the formation of extensive sand spits, bay-mouth bars, tombolas and beaches, particularly along the northern coast of the Island. Post-glacial gravels, sands and silts are common in the larger river valleys. These river valleys have been submergedto form an extensive ria coast, which is especially well developed in the east, as shown in figure 1.[2] The unique relationship which exists between the structure, lithology, relief and the gravel industry of Prince Edward Island, are discussed elsewhere in this thesis.

The Lithology and Structure of Southeastern Prince Edward Island

The Permian deposits of the Island have been subdivided into three lithological units which are based on differences in grain-size distribution and shape of their particle content. For convenience, these subdivisions are termed units A, B and C. Unit A consists mainly of sandstone, mudstone and calcareous claystone breccia, while unit B, is mainly sandstone and conglomerate, with lithic components that are small and angular. Unit C includes more frequent conglomerates, the pebbles of which are larger and more rounded than those occurring in unit B.[3] The only one of these subdivisions, in the study area,

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1. L. Frankel, op. cit., p. 67.

2. See p. 3.

3. L. Frankel, op. cit., pp. 7-8.

to yield commercially exploitable gravels is unit C, the boundaries of which are illustrated in Figure 2.[1] This distribution naturally reflects both the geological structure and the erosional history of Prince Edward Island.

The geology of the province has been interpreted on several occasions, notably by G. C. Milligan,[2] and L. Frankel.[3] General agreement has been reached that a major syncline, the Kilmuir Syncline, exists to the south of Montague, the axis of which is inclined to the northeast, and is parallelled by bedrock outcrops, inclined at angles of less than five degrees.

Unit C occupies the axis of the Kilmuir Syncline, which is aligned approximately southwest-northeast with a slight plunge to the northeast.[4] Unit B deposits, outcrop to the north and south of the Kilmuir Syncline, in the limbs of the Gallows Point and Wood Islands anticlines. It is difficult to determine the inclination of sedimentary rocks with only rudimentary stratification especially when dips are low. Milligan states,

> "the maximum dips obtained in the area are less than 15 degrees. In general, the northern limb (of the Kilmuir Syncline) appears to dip to the south at about seven degrees, while the southern limb dips north at approximately 3-5 degrees."[5]

While this suggestion is generally accepted, his further contention that,"the synclinal axis appears to be lying horizontal, or with a slight plunge to the southwest" is disputed.[6] A consideration of the

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1. See p. 12.
2. G. C. Milligan, _op. cit._, pp. 1-83.
3. L. Frankel, _op. cit._, pp. 1-70.
4. _Ibid._, p. 27.
5. G. C. Milligan, _op. cit._, p. 43.
6. _Ibid._

relief, which falls progressively to the east from an elevation of 400 feet to a minimum of 50 feet, indicates that the axis is plunging in a similar direction, that is to the east.[1] There is, therefore, clearly a conflict of opinion among the geologists who have studied the structure of southeastern Prince Edward Island, which has yet to be completely resolved.

The Nature of Unit C Deposits

Gravel, of commercial value, is only obtained in southeastern Prince Edward Island from weathered unit C bedrock. However not all of this unit is commercially productive. Although there are local gravel beds over the full 225 feet of unit C, there appear to be only two horizons of commercially workable gravels.[2] G. C. Milligan, however, noted the presence of five conglomerate horizons within unit C, on the northern flank of the Kilmuir Syncline, and six on the southern flank.[3] Even within these weathered conglomerate horizons, sandstone beds and nodules of red clay may occur, rendering the deposit unsuitable for commercial use. The conglomerate beds have been described, in detail, by Frankel, who states that,

> "conglomerate commonly occurs in tabular and lenticular beds from one foot to more than 10 feet thick, with an average of 3 feet. The particles commonly exhibit a slightly imbricate structure. The conglomerate beds are separated by medium to coarse-grained conglomeratic and non-conglomeratic arkose and feldspathic sandstones ranging from one foot to more than 10 feet thick, ..."[4]

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1. L. Frankel, op. cit., p. 27.

2. V. K. Prest, personal oral communication.

3. G. C. Milligan, op. cit., p. 43.

4. Ibid., p. 22.

A study of the lithic composition of commercially exploited conglomerate, from unit C, demonstrated that 69-77 percent of the included pebbles are quartzites and 10-16 percent quartz.[1] Both lithologies possess considerable strength and are suitable for use in asphalt or concrete, but the pebbles are commonly well-rounded, necessitating crushing before use in asphalt.

The conglomerate matrices are composed of, "coarse-grained, angular to subangular sands, poorly cemented by iron oxides and minor amounts of carbonate."[2] Extreme variations occur in the chemical composition of the matrix which binds the conglomerate of unit C. In some cases, where the matrix is weak, the conglomerate is friable and disintegrates on impact, facilitating commercial extraction of gravel. The presence of stratification, within the weathered conglomerate, although not a common characteristic, is also commercially desirable. In contrast, the conglomerate matrix is frequently extremely durable, hindering gravel quarrying. Similarly, the presence of unweathered sandstones, intercalated with the conglomerate is a commercially undesirable characteristic which all too frequently occurs in the study area.

Weathering of Unit C Conglomerates

Bedrock conglomerates may be used for gravel production only after the matrix has been broken down by weathering and the pebble

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1. L. Frankel, op. cit. p. 22.

2. Ibid.

content released. In some areas for example at Brooklyn and Caledonia the weathering horizon has penetrated to a depth of 30 feet, while, elsewhere, as for example in the vicinity of Kilmuir, depths of only a few feet have been reached. The weathering processes involved are not fully understood. L. Frankel, however, suggested that although the cause of matrix disintegration was not known,

> "it may be the result of expansion and contraction of shale and claystone fragments upon wetting and drying; disruption because of freezing of contained water; or even the result of chemical removal of cement."[1]

It is possible, that the bulk of such weathering occurred under periglacial conditions, following the retreat of the continental ice sheet from the area. L. Frankel, however, considered that unit C conglomerates were, at present, undergoing rapid weathering.

Because commercially exploitable gravels are found only where weathering of bedrock has occurred, it is essential that such weathering processes should be examined in detail. For this reason, 36 samples of unweathered conglomerate were collected from the nine sites shown in figure 2.[2] Considerable difficulty was experienced in obtaining suitable samples, since totally unweathered conglomerate is inaccessible. Least weathered blocks of conglomerate exposed on the floors of quarries were therefore sampled. These samples were then subjected to freeze-thaw cycles and chemical tests, in a laboratory situation.[3]

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1. L. Frankel, _op. cit._, p. 19.

2. See p. 12.

3. This experiment was carried out with the aid of L. Bell, Materials Testing Division of the Department of Highways and his staff.

Two specimens from each sample site were subjected to ten, 24-hour freeze-thaw cycles. Each cycle included freezing to -10 F. and subsequent thawing, in a moist room, in order to simulate natural conditions as nearly as possible.[1] Two samples from each site were also placed in a saturated solution of magnesium sulphate, at room temperature, for five hours. After drying, they were replaced for a further five hours in the solution. This process was repeated five times.

The results of the experiments, to determine the effects of freeze-thaw action on the matrices of unit C conglomerate, proved inconclusive. The samples from pit 12 the location of which is shown in figure 2, partially disintegrated after six cycles.[2] The matrix breakdown was not complete, but had progressed sufficiently to free most of the particles. Conglomerates from other sample sites were not so seriously affected, although the matrix of sample 17 showed distinct breakdown, some of the pebbles being released. Indeed all the samples had been brushed clean of loose surface grains before being subjected to freeze-thaw action, but most showed a distinct loosening of the surface matrix, after ten cycles.

At the conclusion of chemical testing also, the matrix of every sample had begun to disintegrate. Some samples, notably those from pits 8, 30, 38 and 44, had broken down completely, the matrix having crumbled, releasing the lithic content. In all the other samples,

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1. Canadian Good Roads Association, American Standards Testing Manual, Test C-290, 63-T, p. 202.

2. See p. 12.

perceptible matrix breakdown had occurred only at the surface.

Although the tests outlined above are not strictly comparable to the natural weathering processes, to which the unit C conglomerates have been, or are being subjected, they clearly show that both physical and chemical weathering processes are potentially effective. A further conclusion drawn from these experiments was that no regional pattern exists in the response of unit C conglomerates to freeze-thaw and chemical action. This might be expected because of the rapid variation of matrix composition in unit C conglomerates.

Conclusions

The only commercially exploitable gravel deposits, in south-eastern Prince Edward Island, are the result of weathering of Permian conglomerates. The occurrence of these deposits is predictable, only if the structure of the area is fully understood. Although the structure of the Kilmuir Syncline has been established, the lithological variations within unit C have not. Different observers have suggested that either two, or six, commercially exploitable gravel horizons are present in 225 feet of unit C sediments.[1] Until the stratigraphy can be established with certainty, accurate prediction of the location of sub-surface unit C conglomerate will not be possible on the basis of structural knowledge alone.

Unless unit C conglomerates have been weathered, they are unsuitable for gravel production. While it is clear from the experiments described that both physical and chemical weathering affect the rate of disintegration of the conglomerate matrix, the relative importance of

1. G. C. Milligan, op. cit., and V. Prest, op. cit.

each process is not known. It is suspected that active weathering is continuing at the present time, but it is also possible that much of the depth of weathering occurred earlier, possibly during the Pleistocene. Whatever the processes involved, they are fundamental to the formation of exploitable gravel deposits.

CHAPTER III

THE LOCATION AND QUALITY OF GRAVEL RESERVES

Introduction

When making rational decisions concerning the management of any non-renewable resource, it is essential to have a detailed knowledge of its distribution and quality. It is clear from the preceeding synopsis of available information, concerning the distribution of gravel deposits in south-eastern Prince Edward Island, that although the distribution of Unit C has been established, there is insufficient information available about its stratigraphy. This hiatus renders accurate predictions concerning the occurence of economically significant gravels, especially where these are masked by glacial deposits, virtually impossible. It was, therefore, necessary to obtain more precise information about the location of weathered unit C conglomerates, before estimates of gravel reserves could be made, or future land use conflicts evaluated.

The great variation in distribution, depth and quality of gravel deposits, within the study area, makes it impossible to determine their location and composition without a comprehensive programme of test drilling, a very expensive proposition. Although some steps have been taken to implement a programme of drilling, this has not, as yet, been put into operation.[1] The only information, therefore, avail-

1. E. Matheson (Matheson & McMillan Ltd., personal oral communication)

able on the Island, concerning potential gravel reserves has been gathered from numerous test pits which are common throughout the study area and which are dug either manually or with a back-hoe. A study of the gravels of Prince Edward Island, prepared in 1949 by G. C. Milligan,[1] synthesized the available information from such pits as shown in figure 3.[2]

Although inexpensive to dig, test pits have a major disadvantage. Weathered conglomerate is very compact and it is impossible to penetrate using such techniques. The depth of gravel, exposed by a successful test pit, remains, therefore, unknown until commercial extraction begins. Test pits, therefore, although showing the distribution of gravels, do not give any indication of their depths. Because of the lack of reliable information concerning the distribution and depths of gravel reserves, in southeastern Prince Edward Island, a seismographic survey was undertaken. The results obtained provide a more valid overview of the distribution of this resource, although it is emphasized that they are less accurate than those which could have been provided by a programme of drilling, a more time consuming and expensive process.

Not all gravels, in the study area, are suitable for commercial exploitation. A variety of physical standards have been set by the provincial Department of Highways[3] and the concrete manufacturing

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1. G. C. Milligan, op. cit., pp. 21-48.

2. See p. 23.

3. Department of Highways, Prince Edward Island, Specimen Contracts, Division 2, section 8.

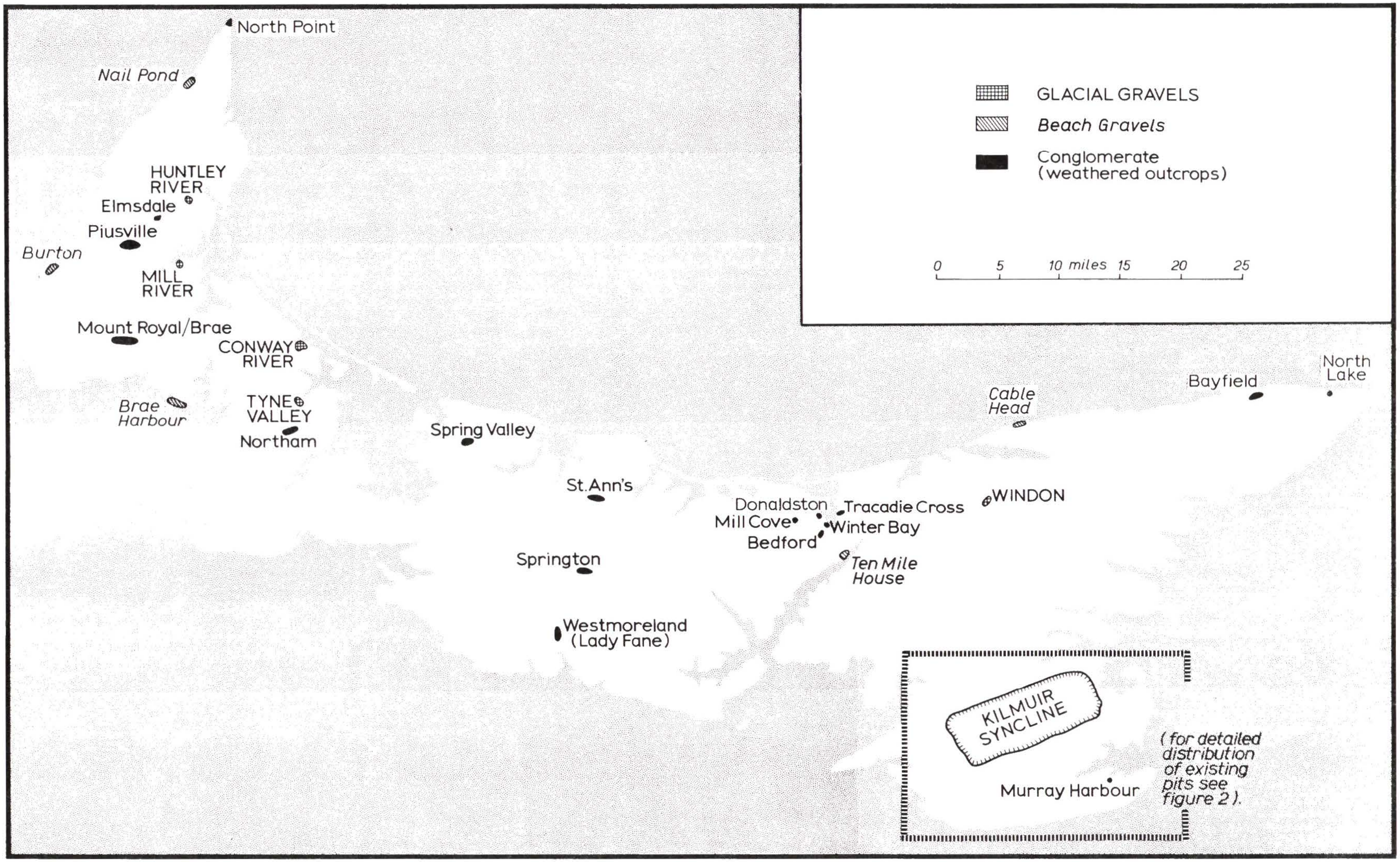

Figure 3   Location of Gravel Reserves, Prince Edward Island, (after G. C. Milligan)

industry,[1] which must be met before gravels will be used by these industries. In order to determine whether or not the gravels in the study area met these specifications, a series of samples were collected from existing exposures, the location of which is shown in figure 2.[2] These samples were then subjected to grain-size and roundness analyses, in an attempt to determine where gravel reserves are of commercial quality. Also by examining the physical characteristics of gravel from existing pits, it was hoped that regional patterns of these physical characteristics could be established. This would allow an assessment to be made about the commercial suitability of subsurface gravels, revealed by the seismographic survey and not yet quarried.

Techniques Employed during the Seismographic Survey

There are two related geophysical techniques; seismic and resistivity techniques, which are commonly used to locate and determine the depth of sands and gravels. Ideally these should be complementary tests, since their results are a reflection of differing physical properties of the bedrock.

> "The Resistivity meter responds to variations in resistivity of earth materials, which is largely dependent upon the amount and salinity of the contained water ... A seismograph responds to variations in seismic velocity of earth materials which is largely dependent upon hardness and degree of consolidation."[3]

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1. Portland Cement Association, Design and Control of Concrete Mixtures, 10th edition.

2. See page 12.

3. Soiltest Inc., Earth Resistivity Manual, Evanston, Illinois, p. 42.

Further comparisons between the techniques indicate that a seismograph gives more reliable depth information, usually with only a 5-10 per cent error, but is more time consuming to use. Unfortunately, this instrument may also result in errors of identification when used to identify certain combinations of rock type. Ideally, the two methods of identifying strata should be applied together, particularly when gravel beds are under consideration, however,

> "both gravel and bedrock show high resistivity, but the seismic velocity of bedrock is usually greater than that of gravel. A resistivity survey could therefore be used to outline areas of potential gravel deposits and ... seismic readings could separate the gravel from the bedrock."[1]

Since it was essential that this study was completed in a single field season, it was decided that a seismographic survey would be of more value than a resistivity survey, as it would allow the depth, as well as the location, of gravel deposits to be established.

Survey sites were selected, after an examination, on the ground and on aerial photographs, of worked and abandoned gravel pits. Before the selection was made, the structure and morphology of the study area was examined in detail. It was assumed that the Permian bedrock, of the Kilmuir Syncline, consists of a series of concentric open-ended ovals,[2] and it was hoped that, by extrapolating from the position of known gravel exposures, the location of sub-surface unit C conglomerate deposits could be predicted. Conglomerates are more resistant to erosion than sandstones and, therefore, hill summit sites were selected

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1. Soiltest Inc., op. cit., p. 43.

2. V. K. Prest, personal written communication, (with W. Phillips).

in preference to valley floor sites. On the basis of these assumptions, the twenty-four survey sites, the locations of which are shown in Table 1, were selected.[1]

The Terra-Scout Refraction Seismograph, used in the geophysical survey of southeastern Prince Edward Island, operates on the principle of wave refractions which is illustrated diagrammatically in figure 4.[2] Shock waves, artificially induced at given points,

> "have the property of being refracted (hence seismic refraction) back to the surface when there is a high velocity (very compacted) material beneath a low velocity material. This property enables depth computations of different strata to be made."[3]

A geophone receives the refracted shock wave, induced by hammer blows made at regular intervals, while a cathode ray tube measures the interval between impact and reception, allowing the speed with which the shock wave has travelled, through the deposits, to be measured. This velocity varies, as a result of the physical properties of the material through which the wave has travelled and the velocity is, therefore, a reliable indicator of the nature of this material. In order to interpret the results, a distance-time graph is plotted, from which the velocity of the shock waves can be established. Distinct changes of velocity show the break points between various materials, from which the depth of the break point and of the strata responsible for it may be calculated.

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1. See p. 28.

2. See p. 27.

3. Soiltest Inc., Terra-Scout, R-150, Refraction Seismograph, p. 2.

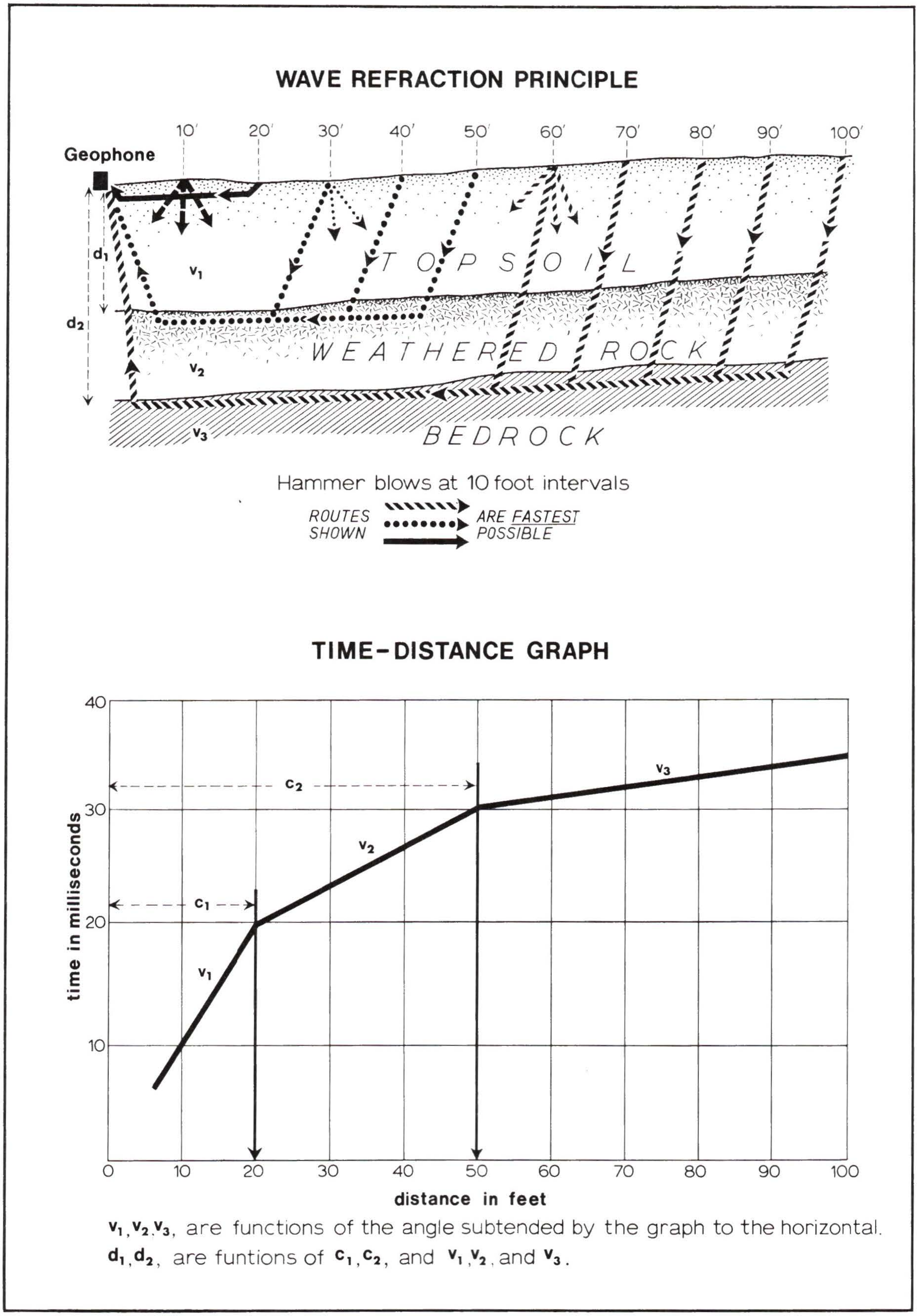

Figure 4 Function and Application of the Refraction Seismograph

TABLE 1

SEISMOGRAPHIC SURVEY SITES

Survey Number[1]	Nearest Pit (refer to figure 2, p. 12)	Altitude (feet)	Class[2]	Map Reference
1	58	275	2	150066
2	26	250	2	220058
3	25	175	2	210080
4	12	125	2	276093
5	24	150	1	250075
6	20	150	2	240075
7	-	200	3	255047
7	33	200	1	249035
7	30	250	2	255032
8	27	250	1	220039
8	-	250	3	231033
9	-	300	3	213027
9	-	250	3	213027
10	40	200	2	239029
11	33	200	1	249029
12	38	275	2	274020
13	34	125	2	339033
14	-	275	3	262018
15	45	300	2	162042
16	-	250	3	198041
17	-	350	3	157016
17	47	350	2	162008
18	48	350	2	175005
18	51	300	2	200009
18	48	200	2	193003
18	50	375	2	208003
18	39	350	3	223006
19	-	350	3	166991
20	54	300	2	195984
21	-	350	3	214996
22	55	300	2	195977
23	39	350	3	226015
24	18	125	1	253084

1. This number refers to the surveys shown in figures 5 and 6, p. 29 and p. 30.

2. Class Divisions:
   1. Extention of a Pit Presently in Operation.
   2. Extention of an Abandoned Pit.
   3. New areas selected on Structural or Morphological Criteria.

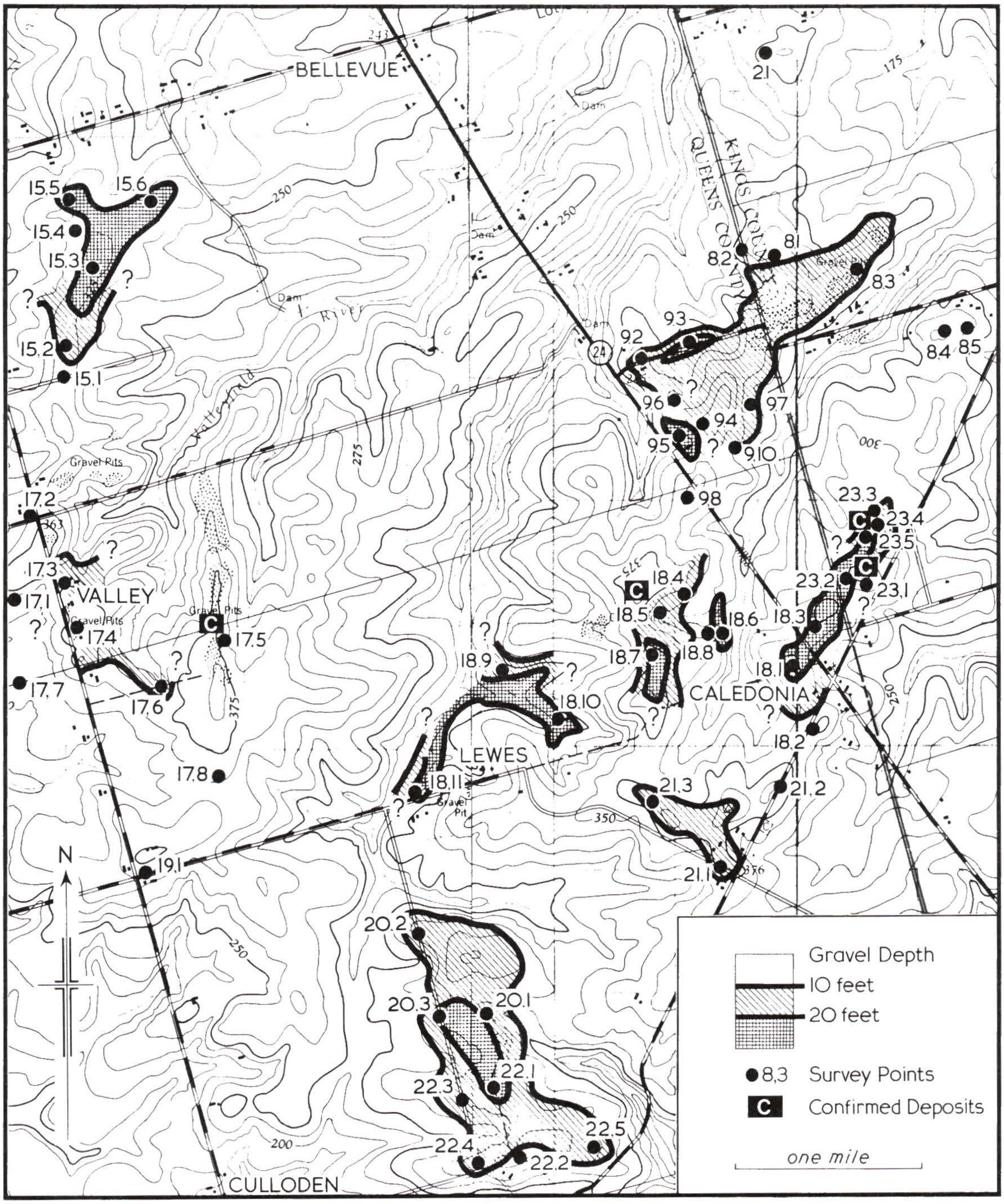

Figure 5 Seismograph Survey, Survey sites and Gravel Deposits within the Iona-Caledonia District

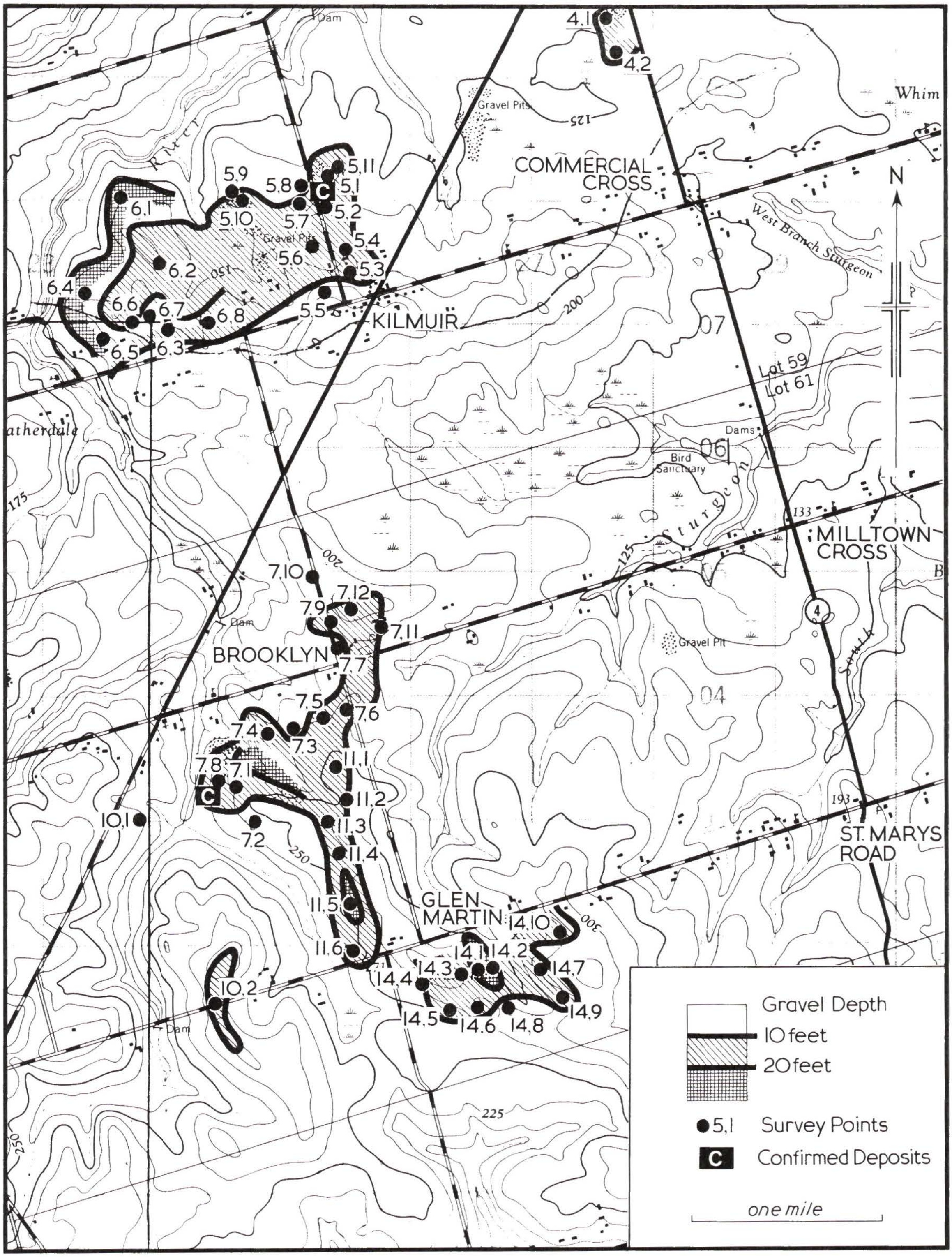

Figure 6 Seismograph Survey, Survey Sites and Gravel Deposits within the Kilmuir-Glenmartin District

Results

During the seismographic survey, soil, till, glacio-fluvial gravel, weathered sandstone, sandstone, conglomerate and weathered conglomerates (gravels), were encountered. Some of these deposits are, unfortunately (because this reduces the reliability of the survey), frequently interbedded. It has been suggested that, the velocity of shock waves through sandstone may vary from 3,000 feet per second to 9,000 feet per second, while those passing through gravel reach velocities of only 1,600-2,000 feet per second.[1] These figures were not confirmed, within the study area, where tests carried out in the vicinity of existing gravel exposures indicated that weathered unit C conglomerate, (gravel), has a shock wave velocity of approximately 3,000 feet per second, although variations which reached 3,750 and 1,600 feet per second were recorded. Unweathered conglomerates invariably underly the weathered beds, and allow shock wave velocities which always exceed 4,000 feet per second, reaching a maximum of 8,500 feet per second.

Sandstones, which usually occur as unweathered blocks within the gravel beds, allowed shock waves to pass through them at approximately 2,000 feet per second or at even slower velocities. Tests carried out on continuous sandstone outcrops, immediately south of Kilmuir (NG 2507), and at the unit A type locality, Eldon Wharf (NG 0905),[2] indicated that the velocity of shock waves passing through thick beds of sandstone

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1. Soiltest Inc., op. cit., p. 10.

2. L. Frankel, op. cit., p. 15.

could reach some 3,400 to 4,500 feet per second.

The similarity with which shock waves pass through unweathered sandstones and weathered conglomerates of unit C is unfortunate. However, at both of the localities described above, the shock waves maintained the same velocity when penetrating a depth of sandstone exceeding 40 feet. In contrast, gravel beds are invariably thinner than this and are underlain by unweathered conglomerates, which allow only shock waves with much higher velocities to penetrate. It is, therefore, usually a simple task to establish whether or not an horizon consists of weathered conglomerate (gravel) or unweathered sandstone. There is unfortunately, no method of determining, by seismographic survey alone, the proportion of unweathered blocks of sandstone associated with subsurface gravel reserves.

Gravel Deposits Located by Seismographic Survey

The information, on gravel location and depth, obtained by the seismographic survey is shown in map form in figures 5 and 6[1] and is summarized in Appendix 2.[2] As can be seen from these illustrations, gravel deposits in the southern Kings and southeastern Queens Counties are common and widely dispersed. Although the presence of large concentrations of gravels have been established in the vicinities of Kilmuir, Brooklyn and Iona, several smaller deposits are also located

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1. See pp. 29-30. Three other surveys not illustrated were made. In the vicinity of Valleyfield (NG 2107), five plots revealed gravel deposits, averaging 20 feet in depth; the outlier of conglomerate south of Grandview Station (NG 1508) had developed only very shallow gravel deposits, while north of Peters Road (NG 3402), only sandstone with a water table at 25-30 feet, was discovered.

2. See p. 29, p. 30 and pp. 135-139.

in intermediate areas. Both Island Construction Company and Warren Maritimes Ltd. currently obtain gravel from the considerable deposits south of Iona. However, because of the information already locally available about these deposits, few surveys were carried out in this area.

At present Matheson & MacMillan Ltd. are excavating to the north and west of Kilmuir. The survey demonstrated considerable reserves in this area, and as a result of the information obtained during seismographic survey, excavation of one further deposit was begun in 1969. The Iona-Wood Islands road appears to mark the western boundary of the unit C gravel deposits, approximately 15 feet of gravel occurring to the east of this road but only isolated, shallow pockets of gravel occur to the west.[1] The survey indicated that there are also further gravel deposits in the vicinity of Lewes and to the southeast of Iona. To the east of Lewes a series of deep gravel deposits occur, which have, as yet, not be exploited. This land has, however, already been contracted to Island Construction Company.[2] Also to the south of Lewes, deep and probably extensive gravel deposits occur.[3] Considerable gravel reserves were also discovered in the vicinity of the washing plant at Brooklyn and it is probable that the weathering horizon has penetrated deeper here than elsewhere in the unit C conglomerate.

Deeply weathered conglomerates, which cap the hills in the vicinity of Caledonia, are, as yet, little exploited. Similarly, two

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1. See figure 2, p. 12.

2. R. Perry, Island Construction Co., personal oral communication.

3. See figure 5, p. 29.

miles north of Caledonia, astride the county line road, considerable reserves of already well-known and commercially exploited gravel deposits are thought to occur.[1]

A number of suspected gravel reserves were discovered that are a considerable distance from any exposure. In such cases, confirmation of the presence of such gravel reserves by test pits is essential. Such deposits are suspected between St. Marys Road and Caledonia, and also to the southwest of Caledonia.[2] It is also suspected that, in the vicinity of Glenmartin, gravel deposits exceeding 20 feet in depth, probably underlie a wide area. Similarly, one mile west of Glenmartin suspected gravel, 15 feet in depth and of unknown areal extent were indicated by the survey. Similarly, south of Caledonia the seismographic survey demonstrated the presence of gravel, varying in depth from 18 to 13 feet.

It is stressed that the gravel deposits, outlined on Figures 5 and 6[3] should not be considered proven, until test holes have been dug and have established their presence beyond doubt. This is because, as previously stated, certain sandstone horizons cannot reliably be distinguished from gravel on seismic evidence alone. However, since this survey was completed, five excavations have taken place in areas where gravels were predicted from seismographic evidence. Four such excavations have confirmed the presence of suspected gravel deposits. As a

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1. Figure 5, p. 29.

2. Figures 5 and 6, see p. 29 and p. 30.

3. See pp. 29-30.

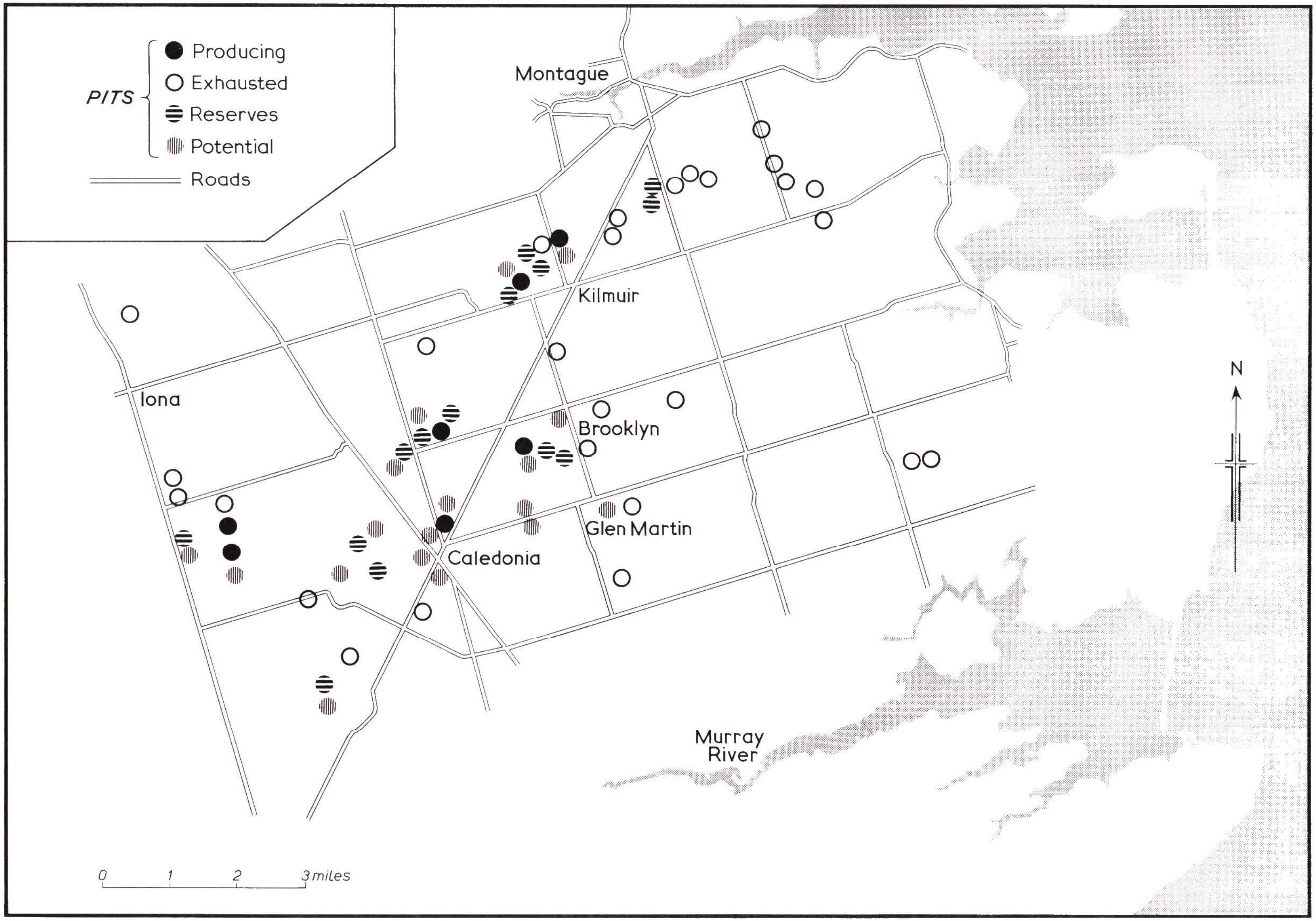

Figure 7 Distribution of Active, Inactive, Exhausted and Potential Gravel Quarries in Southern Kings and Southeastern Queens Counties, Prince Edward Island

result of the seismographic survey, total reserves of gravel in the southern Kings and southeastern Queens Counties are estimated to be at least 10,000,000 cubic yards, a figure which contrasts markedly with a previous under-estimate of 1,040,000 cubic yards.[1]

The results of the seismographic survey provide a suitable physical basis upon which to assess present and potential gravel management policies. It has been established that, gravel reserves are far more extensive than suggested by G. C. Milligan[2] and further extensive reserves have been shown to exist in the vicinity of each of the major commercial gravel pits. The proliferation of small pits illustrated by figure 7,[3] is, therefore, not a result of the distribution of an extremely fragmented resource, but rather a reflection of social, economic and political considerations. Clearly, fewer, but larger pits could satisfy current demands (and it will be shown, future demands) for gravel, and could, of course, be more easily controlled so as to reduce land use conflicts.

The Physical Characteristics of Commercial Gravel

Although it is essential to know the distribution of gravel reserves, in southeastern Prince Edward Island, this, in itself, is insufficient information upon which to base suggestions concerning resource management. A detailed knowledge of the physical characteristics of the gravel deposits is also required.

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1. G. C. Milligan, op. cit., pp. 47-8.

2. Ibid.

3. See p. 35.

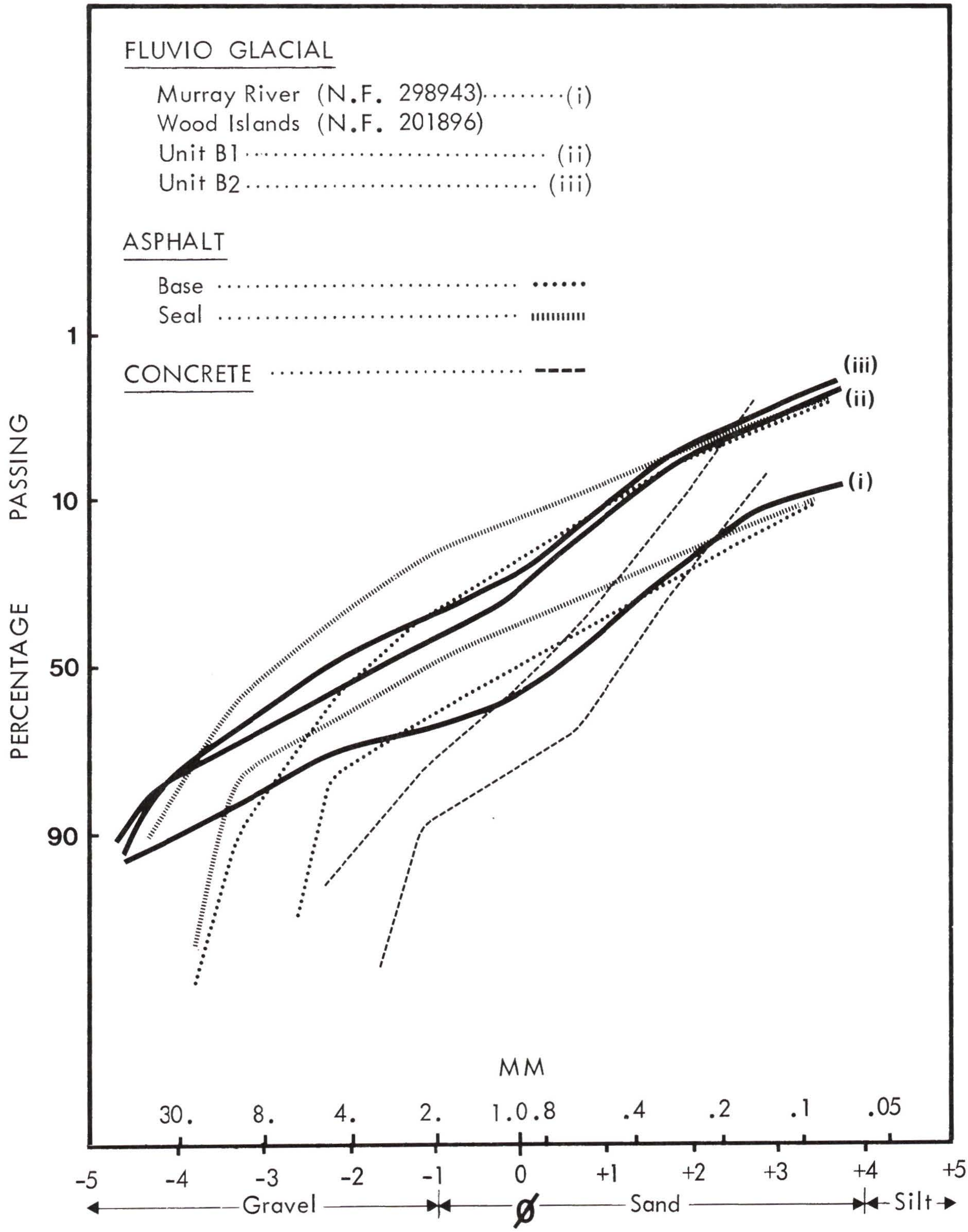

Figure 8 Grain-Size Analysis of Glacio-Fluvial and Unit B Deposits and their Comparison with Specifications for Asphalt and Concrete Aggregates

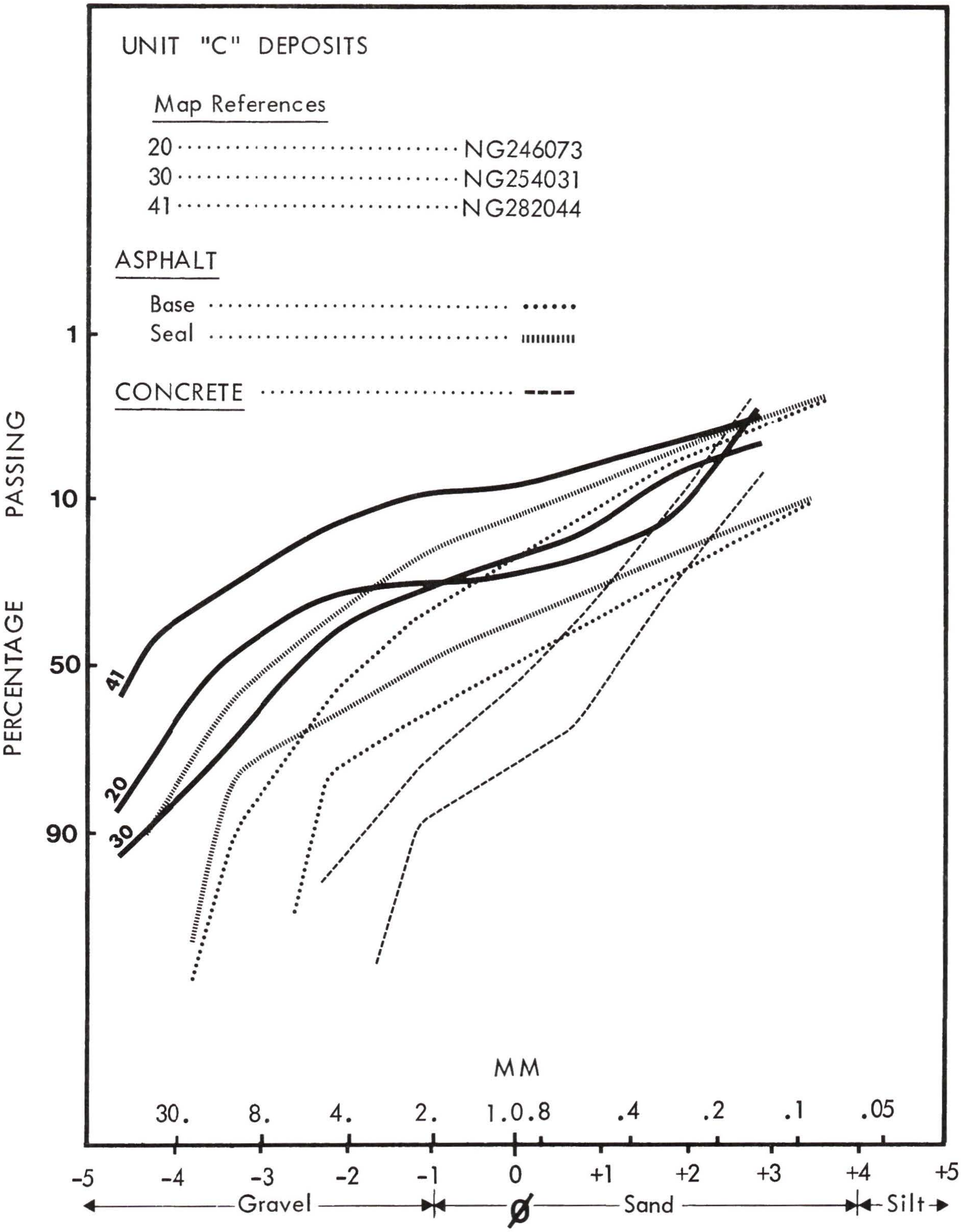

Figure 9 Grain-Size Analysis of Gravels Derived from the Weathering of Unit C Outcrops and their Comparison with Specifications for Asphalt and Concrete Aggregates

In some provinces, gravels occur which can be used in concrete or asphalt manufacture without further preparation. It is also possible to process certain rock types and so meet asphalt and concrete manufacturing specification for aggregate. Three basic physical requirements must be met by gravel, used in such industries: grain-size distributions, soundness standards (durability) and shape characteristics, must reach certain minimum standards. Grain-size distribution is determined by sieve analysis. If the material is too coarse for use in any particular manufacturing process, crushing may reduce particle size. Gravels which contain too much fine grained material can be wet sieved, and the fines removed, although this is an expensive and so frequently impractical process.

The grain-size specifications which must be met by gravels, used for both concrete and asphalt manufacture on Prince Edward Island, are illustrated in figures 8 and 9.[1] In figure 8, unit B and fluvioglacial gravels are compared with the Prince Edward Island specifications for aggregates used in asphalt and concrete manufacture.[2] The lack of large material in these deposits makes them unsuitable, after crushing, for use in asphalt or concrete, since the proportion of material passing the No. 200 (0.074 mm.) sieve exceeds ten per cent. In the latter diagram, samples of gravels derived from weathered unit C conglomerate are compared with these standards. It is clear from the data shown in Appendix 1,[3] that the excess of large material

1. See p. 37 and p. 38.

2. See p. 37.

3. See p. 133.

and the lack of fine particles present in weathered unit C conglomerate, renders it suitable for crushing.

The ideal grain-size distribution of uncrushed gravel lacks particles of intermediate and fine size but includes many larger particles. After crushing, the larger particles are naturally reduced in number and the fine particle content increased. This type of grain-size distribution is found in many unit C gravel deposits, but, unfortunately such deposits may contain an appreciable amount of silt and clay. The proportion of any sample, passing the No. 200 (0.074 mm.) sieve, may reach as high as three or four per cent or even higher.[1] Ideally in prepared (crushed) gravel, such fine grained material should not exceed six percent, but on Prince Edward Island, up to ten per cent has been allowed, in asphalt production.[2]

In concrete manufacture, two types of grain-size distribution are commonly utilised, fine aggregate and coarse aggregate. Fine aggregate is material retained by the No. 4 (4.76 mm.) and No. 100 (0.148 mm.) sieves while coarse aggregate falls between six inch (152 mm.) and No. 4 (4.76 mm.) sieves. Specification for fine aggregate are most critical; at a minimum, 15 per cent of particles must pass the No. 50 (0.297 mm.) sieve and, at least, three per cent must pass the No. 100 (0.148 mm.) sieve. As in asphalt, a maximum is set for the amount of fine material allowed. Further physical specifications are also set by both the asphalt and concrete manufacturing

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1. Sieve numbers refer to United States Standard Sieve Series.

2. Department of Highways, Prince Edward Island.

industries. Gravels used in asphalt must meet certain durability and roundness criteria.

Grain-Size Analysis: Methods

It is clear that the physical characteristics of the gravels of southeastern Prince Edward Island are of immense significance in determining their suitability for commercial exploitation. For this reason, detailed grain-size analysis was undertaken. The results obtained allowed an attempt to identify regional patterns of variation, if any, in the grain-size distribution of gravels derived from unit C deposits.

The sampling of the unit C weathered conglomerates presented some difficulties since it proved impossible to employ systematic sampling as this would require the digging of pits, four to five feet in depth, through extremely compacted overburden. Twenty-eight samples were, therefore, collected from previously existing exposures, in gravel or borrow pits, the locations of which are shown in Figure 2.[1] Clearly the distribution of these sample sites was not random. Sandstone outcrops, in Prince Edward Island, are never commercially exploited and, therefore, in keeping with the aims of this study, they were not sampled.

A statistically acceptable sample is one in which, "the characteristics of the sample show no systematic variations from the characteristics of the deposit at the sampling locality."[2] As stratified gravel deposits are not common, in the study area, the materials from which

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1. See p. 12.

2. W. C. Krumbein and F. J. Pettijohn, Manual of Sedimentary Petrology, New York, 1938, p. 39.

samples were taken were commonly homogenous. If variation occurred, an attempt was made, at each site, to subjectively choose a representative sample. However, samples were taken, when possible, at a depth of four to five feet below the surface, to avoid the inclusion of excessively weathered material. Although very large cobbles, with diameters in excess of three inches could not be included in a sample, these occurred only infrequently but at almost every locality. Samples generally weighed 5,000-6,000 grammes, the largest particles sampled weighed no more than 100 grammes.

Grain-size analysis of the samples was achieved using a Fisher-Wheeler Sieve Shaker. The sieve sizes demanded in specifications for concrete and asphalt manufacture, in Prince Edward Island, were used throughout. For this reason mesh sizes of 25.4, 19.05, 12.7, 9.5, 4.76 (No. 4), 2.38 (No. 8), 1.19 (No. 16), 0.595 (No. 30), 0.297 (No.50), 0.148 (No. 100), 0.074 (No. 200) millimetres respectively were used. Thirty minutes of automatic shaking were allowed for each sample because weathering of the matrix was frequently incomplete, and this length of time was required to ensure adequate sample disintegration.[1] In each case, thirty minutes proved sufficient to allow all the particles to become separated. In all cases, less than five per cent of the sample passed the No. 200 (0.074 mm.) sieve and, as a result no further grain-size analysis was considered necessary.

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1. The normal time is 10 minutes specified by Krumbein and Pettijohn, op. cit., p. 140.

After each sample had been sieved, the material retained on each sieve was weighed. The percentage of material passing each sieve was then calculated and plotted on logarithonic graph paper. Graphical plotting of the results enabled the mean, standard deviation and skewness of each sample to be calculated. Phi values were used as a measure of the sieve openings ($\emptyset = -\log_2$ of the diameter in millimeters),[1] these were derived from the tables, which allow the conversion of millimetres to phi units.[2]

It was possible to calculate numerous parameters from the information concerning the grain-size distribution of the samples available from these graphs. However, the accuracy and significance of such indices of grain size distribution has aroused much controversy. The median, for example, is not considered to be a very reliable guide to the central tendency of a sample. The simplest valid alternative is given by the formula $M\emptyset = \frac{1}{2}(\emptyset 16 + \emptyset 84)$.[3] As the units used are logarithmic, the mean is arithmetic and not geometric, as it would have been if the millimetre scale had been used. A more sophisticated formula for establishing the central tendency $Mz = \frac{\emptyset 16 + \emptyset 50 + \emptyset 84}{3}$ has been suggested,[4] and was used in this analysis. Appendix 1 provides data which indicates that, in the unit C samples, mean values ranged from -3.8 Ø to -1.4 Ø (14 mm. to 2.75 mm.), most values falling

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1. C. A. M. King, <u>op. cit</u>., p. 278.

2. D. L. Inman, "Measures for Describing the Size Distribution of Sediments, "<u>Journal of Sedimentary Petrology</u>, 1952, Vol. 22, pp. 126-45.

3. <u>Ibid</u>.

4. R. L. Folk and W. C. Ward, "Brazos River Bar: a study in the significance of grain size parameters," <u>Journal of Sedimentary Petrology</u>, 1957, Vol. 27, pp. 3-26.

in the 2.0 Ø to 2.5 Ø range.[1] An ideal figure for asphalt manufacture is 2.85 mm., or approximately -1.5 Ø. It is clear, from these grain-size analyses, that, provided the percentage of fine material does not greatly increase during crushing, gravels from the study area have a grain size distribution that allows them to be used in asphalt manufacture.

The degree of sorting in a sample can be established by the use of the formula $\sigma\phi = \frac{1}{2}(\phi 84 - \phi 16)$, suggested by Inman.[2] The samples were found to have sorting values which ranged from 3.2 Ø to 1.1 Ø, values characteristic of poorly and very poorly sorted material.[3]

It was also, of considerable value to establish the skewness, or the amount of deviation of the mean from the median, of the samples. This value is given by Inman's formula,[4] $\alpha\phi = \frac{M\phi - Md\,\phi}{\sigma\phi}$ which was applied to the data. The resulting values ranged from + 0.21 Ø to + 0.87 Ø, indicating a preponderance of coarse grains in the samples, most skewness values varied between 0.30 Ø and 0.40 Ø.

Grain Size Analysis: Results

The chief objective this mechanical analysis was to establish whether the gravels are suitable for commercial production. Figures 8 and 9 illustrate the grain-size specifications which must be met by gravel used in asphalt and concrete manufacture, and demonstrate the

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1. See pp. 133-134.

2. D. L. Inman, op. cit.

3. R. L. Folk, and W. C. Ward, op. cit.

4. D. L. Inman, op. cit., pp. 125-45.

relationships between the twenty-eight samples and these standards.[1] The analysis established that only three samples were of doubtful commercial value; samples 16, 30 and 42, collected from Kilmuir, Brooklyn and Iona respectively. These samples demonstrated very low mean values, -1.4 Ø, -1.9 Ø, and -1.6 Ø. The proportion of large grains in these samples exceeding -3.0 Ø, to small grains, less than -1.0 Ø, is much less than normal.

It must be remembered, however, that during crushing, most large grains are reduced in size, so that the proportion of small grains in any gravel deposit is increased. Figure 9 compares one of these samples, that for sample site 30, with the asphalt specifications.[2] From this figure it is clear that crushing will probably increase the amount of fine material in the sample to the point where it contains an excess of fines. This is also true of samples 16 and 42. The remainder of the samples all appear capable of meeting the minimum grain-size specifications required for asphalt manufacture, after crushing.

The second purpose of grain-size analysis was to determine whether there was any significant areal variation in the lithic size composition of unit C gravels. Several graphical and statistical techniques were used to analyse the data, to achieve this end. It was hoped that, if regional grain-size patterns were discovered, an estimate of the physical characteristics of sub-surface deposits discovered by seismographic survey could be made.

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1. See pp. 37-38.

2. See p. 38.

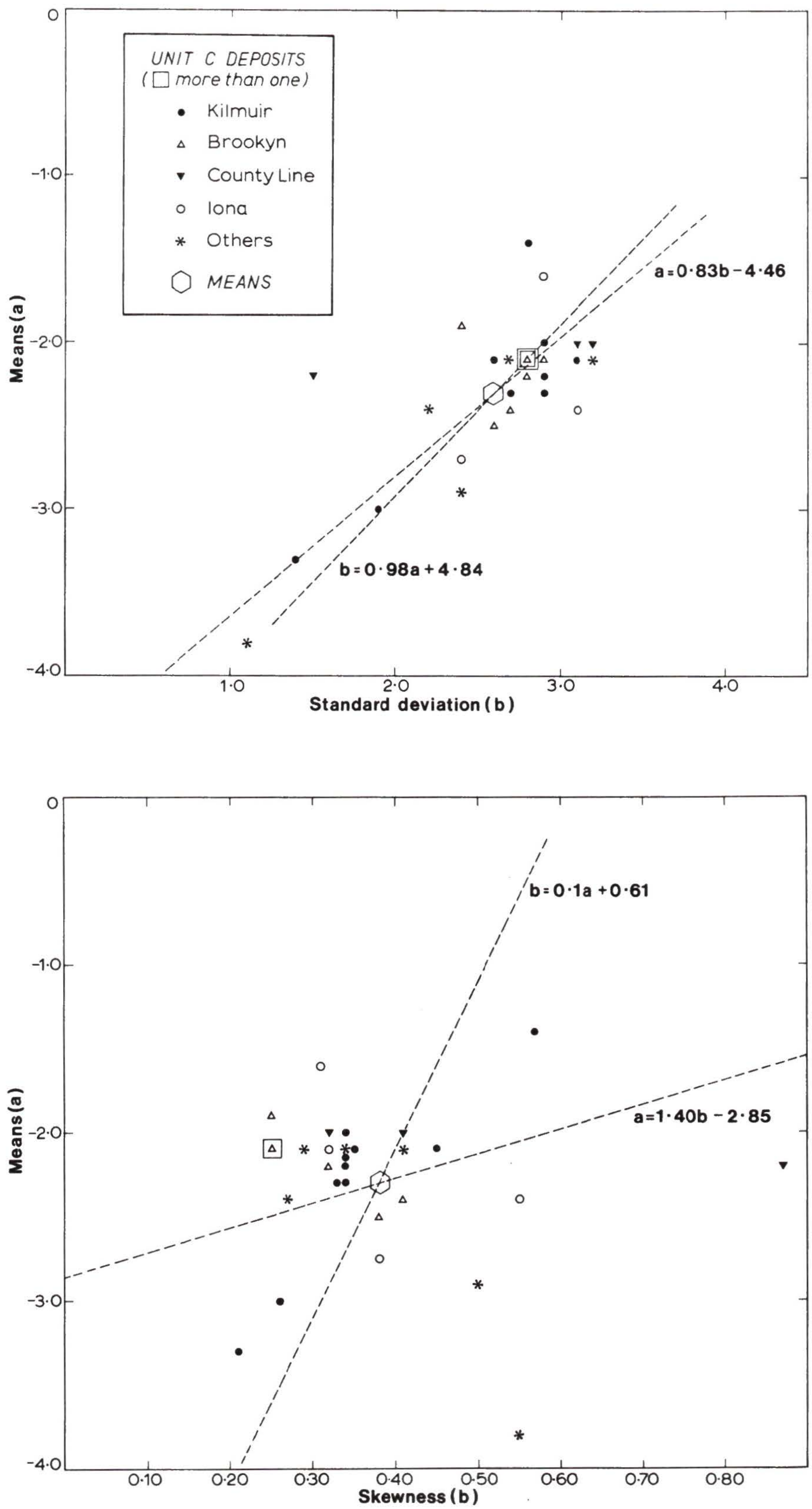

Figure 10

Grain-Size Analysis: Graphical Representation of Standard Deviations and Skewness

Sample means were plotted to visually discover any obvious concentration. Figure 10 clearly indicates that the means tend to cluster about -2.2 Ø.[1] Only six samples have mean grain-size distributions which occur outside the range -2.0 Ø to -2.9 Ø. The most valid conclusion again would appear to be that remarkably little variety occurs in the grain-size distribution of gravels from the conglomerate outcrop.

When plotted in a similar manner, the standard deviations showed a lesser concentration. The two lowest values, derived from samples 2 and 41 (with standard deviations of 1.4 Ø and 1.1 Ø respectively) are both from sites which occur in the east of the unit C outcrop. However, samples 34 and 40 were also taken from the eastern part of the study area and have standard deviations of 2.8 Ø and 2.7 Ø respectively. Once again no regional grain-size distribution pattern is evident. Previous studies have shown the relationship between mean values and dispersion values to be a linear regression.[2] This proved to be the case with samples from unit C gravels; as the mean diameter decreases so the degree of dispersion increases. However a strong clustering effect is still evident.[3]

When the skewness values of the samples are plotted as shown in Figure 10 some regional patterns appear visible.[4] For example, samples 30, 34, 36, and 50 have values of 0.3 Ø or less and all were

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1. See p. 46.

2. R. L. Folk and W. C. Ward, <u>op. cit</u>., pp. 3-26.

3. See Figure 10, p. 46.

4. See p. 46.

derived from the area south of Brooklyn. However samples 2, 8 and 22 are similarly skewed, but were collected at sites to the north of Brooklyn. Samples 16, 38, and 45, all of which have values of 0.5 Ø or greater, are from sites which occur around the periphery of the unit C outcrop. Most skewness values lie between 0.41 Ø and 0.31 Ø, a clustering effect similar to that of both the means and the standard deviations, as shown in figure 10.[1] It is clear that there is insufficient differentiation between the samples to confirm the previously suggested structure which was thought to consist of a series of concentric open ended ovals.

One further analysis was carried out in an attempt to distinguish any regional variation in grain-size characteristics. A correlation matrix was constructed, correlating the amounts retained on the various sieves. This is given in full in Appendix 5.[2] To demonstrate the areal association of these correlations, a six figure coordinate system was used and the altitude of the sample site given to the nearest foot. Analysis demonstrated that the sample points were lying almost perfectly on an inclined plane. It was established that the only other significant factors were the correlations of large numbers of particles on both 25.4 mm and 19.05 mm sieves, an inverse relationship between the material retained by the 9.5 mm and 4.76 mm sieves, correlation of the sample amounts on sieve sizes No. 8 (2.38), No. 16 (1.19) and No. 30 (0.595 mm) and an inverse relationship between particles on the No. 50 (0.297 mm) and No. 100 (0.148 mm) sieves. Such correla-

1. See p. 46.

2. R. Lycan, University of Victoria, personal oral communication. See Appendix 5, p. 151.

tions are always to be expected in sieve analysis; no further relationships were deduced.

Visual comparisons of means, standard deviations and skewness values, regression analyses and the use of a correlation matrix to discover related variables, all lead to the conclusion that there is no regional variation in gravel grain-size distributions, of the samples collected. If such a relationship exists, it has presumably been obscured in this analysis by bias arising from the manner in which the sample sites were selected.

The implication of these analyses is that all gravels, occurring as a result of the weathering of unit C conglomerate horizons, meet the minimum requirements for asphalt and concrete manufacture before crushing. However, after crushing, some of the gravels probably do not meet the specified standards, generally because they contain too many fines. The regulating agency, however, at its discretion, may allow some of these marginal materials to be used.[1]

These analyses do not preclude the possibility that, within the unit C outcrop, there occur deposits of conglomerate which, upon weathering, form gravels which are unsuitable for asphalt or concrete manufacture, although this possibility would appear unlikely. It may, therefore, be assumed that all gravels revealed by the seismographic survey will be within the specified grain-size range, and hence suitable for commercial exploitation. Clearly, there is no regional pattern of grain-size variation, although local variations do certainly occur. It is, therefore, impossible to predict where, in the study

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1. L. Bell, Materials Testing Engineer, Department of Highways, Prince Edward Island, personal oral communication.

area, gravel deposits with the optimum grain-size attributes for asphalt and concrete production will occur.

Durability

The durability of gravels is determined by two tests, the Los Angeles Abrasion Test,[1] which consists of corroding the sample in a drum and measuring the weight loss; and the sodium sulphate soundness test,[2] which establishes the resistance of the material to chemical weathering. These tests have been applied to samples from the study area, by the provincial Department of Highways and have revealed that, "gravel from the Iona area has a Los Angeles Abrasion test loss of 20-25 per cent."[3] This value is greater than the maximum that the Department of Highway's specifies for surface course aggregate, which is 18 per cent, although it is well within the specification of 30 per cent for base course aggregate. The provincial authorities have no specification dealing with the resistance of gravels to chemical weathering and hence no such tests have been carried out on gravels from the study area, by the Department of Highways or the author.[4]

Pebble Shape

Shape specification for gravel constituents, used in the road paving programme of Prince Edward Island establish that at least 50

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1. American Standards Testing Manual, op. cit., C-131-66.

2. Ibid., C-88-63.

3. L. Bell, op. cit., written oral communication.

4. Ibid.

per cent of the particles used must be angular.[1] This can be achieved by crushing, and is often produced as a coincidental effect of crushing undertaken to meet grain size specifications. Particle shape analyses, of the samples shown in figure 9,[2] revealed that none had more than 15 per cent of their particles with angular faces. It is clear therefore that, to meet the Shape Specifications for asphalt manufacture gravels from the study area must be crushed. Similarly in concrete production specifications for particle shape are laid down. Both rounded and angular particles may be used in concrete, "excellent concrete is made by using crushed stone and other crushed materials but the particles should be more or less cubical in shape. Stones which break up into long slivery pieces should be avoided."[3] A roundness index, derived by Cailleux and Tricart, which measures the ratio of the length to the least radius of curvature in the principal plane, and which is given by the formula $\frac{2r \times 1000}{l}$ was used.[4] This was used to demonstrate that the roundness index of all samples fell in the 275-350 range, indicating a high degree of rounding, equivalent to that usually found in fluvial environments.

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1. Department of Highways, Prince Edward Island, op. cit., Division 2, Section 8, 2-3.

2. See p. 38.

3. Portland Cement Association, op. cit.

4. C. A. M. King, Techniques in Geomorphology, London, 1966, pp. 291-3.

CHAPTER IV

PAST, PRESENT AND FUTURE DEMANDS OF THE GRAVEL USING INDUSTRIES

Introduction

Gravel used by the road construction industry has traditionally been supplied from within Prince Edward Island. Two attempts have been made to satisfy this demand by importing material from Nova Scotia, but both proved to be economically unfeasible. Gravel was used to provide the bases for asphalt roads, until the recent introduction of the soil stabilisation process. Since this innovation, the demand for gravel has decreased, although it is still essential for the manufacture of asphalt for both base and seal courses on roads, approximately 94 per cent (by weight) of asphalt consists of gravel. Gravel is also required in concrete manufacture, much of this however is supplied from Nova Scotia.

This chapter attempts to predict the demand for gravel during the next five years and, with less certainty, to predict such demand beyond this time period. It is generally accepted that any projection should follow four basic steps.[1] Initially a study must be made of the economic base, so that the general situation and background are known. In the present study this information includes details of the Development Plan, the need for road paving and concrete production. As a second step, factors which affect demand, such as technological changes and

1. W.R.D. Sewell and B.T. Bower, et al., Forecasting the Demands for Water, Ottawa, 1968, pp. 18-43.

public policies must be assessed. Thirdly, all possible alternative methods of meeting the demand must be reviewed, as the cost of supply may have a profound effect on demand. The final phase is to recheck the initial demand projections in view of the added knowledge concerning possible supply conditions.

The economic background, the future modification of which is discussed in the Development Plan, has already been reviewed in this study.[1] The assessment of present and future demands for gravel is the focus of this chapter, alternative sources of supply are considered elsewhere.[2] It should be realised that no reassessment of demand conditions can be made until the source of supply, and hence the cost of gravel to the gravel consuming industries, has been established. Therefore, it is possible that, if for any reason the cost of supply increases, the demand for gravel will probably decrease.

The immediate problem is to predict the demands for gravel required by the asphalt and concrete manufacturing industries during the next five, ten and fifteen years.

Future Demand of Gravel for (i) Asphalt Production

Since the asphalt used in highway construction contains 94 per cent gravel, the demand for gravel is directly related to the mileage of highways built. An accurate projection of the road building programme is, therefore, critical to any forecast of future demands for gravel on Prince Edward Island.

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1. See pp.6-10.

2. See pp. 101-118.

There is no long range plan for provincial road construction, however, two funding agencies are responsible for highways on the Island; the provincial Department of Highways and the Fund for Rural Economic Development (F.R.E.D.). While the latter has a five year plan, which was announced in September 1969, the provincial government has no plan. Indeed the budget for any given year's provincial road construction is not usually voted by the legislature until May 1st of that year, causing one contractor to exclaim, "roads in Prince Edward Island are usually planned two weeks after construction."[1] The absence of a provincial highway plan has a profound effect on all land use and economic planning in the Island. The need for such highway planning is felt acutely in all sectors of the provincial economy, especially amongst those asphalt manufacturing companies which supply the Department of Highways.

At present, it is only possible to predict future provincially funded highway construction from past trends, in Prince Edward Island. For this reason, road construction programmes for the years 1959-68 are shown in Table 2.[2]

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1. Anon.

2. L. McEwan, Department of Highways, Prince Edward Island, personal written communication. See p. 55.

TABLE 2

ROAD PAVING PROGRAMME, PRINCE EDWARD ISLAND, 1959-1968

Years	Total Paved Roads (Miles)	Increase in Paved Roads (Miles)	Total of Paved and Unpaved Roads (Miles)
1959-60	635.6		3,212.8
1961	860.4	224.8	3,211.2
1962	962.0	101.6	3,211.2
1963	1,044.4	82.4	3,213.3
1964	1,114.3	69.9	3,214.4
1965	1,184.8	70.5	3,217.4
1966	1,309.6	124.8	3,217.4
1967	1,368.3	68.7	3,217.4
1968	1,442.1	73.8	3,217.4

The median annual construction is some 80 miles, approximately 45 miles of which have been financed by the Fund for Rural Economic Development, or other federal government agencies. Approximately 35 miles of paved roads therefore, have been constructed annually by the provincial authorities, a figure which is unlikely to increase greatly in the near future, but which may possibly decrease, as the majority of significant roads, on the Island, are paved.[1]

In September 1969, the federal authorities, in conjunction with the provincial government, announced a five year road construction plan. A total of 210.2 miles of highway are to be financed by the Fund for Rural Economic Development between 1970 and 1974, of which 92.7 miles are to be rural roads, 63.0 miles collector highways and 54.5 miles paving shoulders. Assuming this plan will be successfully implemented,

1. R. G. White, Deputy Minister of Highways, Prince Edward Island, personal oral communication.

an average of 42 miles of roads will be paved annually under this programme. This projection, in part, supports the aims of the Development Plan.

Although highway improvements are recognized as important by the Development Plan, it merely states that 570 miles of roads will be constructed, re-built or improved.[1] Of these, it is anticipated that 375 miles will be of service to agriculture, 34 miles to recreation and 70 miles to fisheries. A further 66 miles of the collector highway will be improved.[2] It is estimated that this will cost both provincial and federal governments approximately $7.5 million during the first seven year period. As the annual provincial budget for the Department of Highways has approached $12 million in recent years, of which at least $4 million has been spent on construction, it is clear that the Plan requires much less road mileage to be constructed during this seven year period than is likely.

In order to determine how much gravel will be required to supply the projected highway construction programme precise figures have been provided by the Department of Highways, and are shown in Table 3.[3]

However, when these figures are checked against the total gravel actually used in constructing the roads, during 1968, a serious error is revealed. Some 235,000 tons of gravel were used in asphalt manufacture while 43.5 miles of highway were constructed with the assistance of the Atlantic Development Board and 30.3 miles by the provincial

1. Development Plan for Prince Edward Island, <u>op. cit</u>., pp. 47-8.

2. It should be noted that these figures do not total 570 miles.

3. See p.57.

TABLE 3

ROAD PAVING PROGRAMME, PRINCE EDWARD ISLAND, 1970-1974

1. Federal Rural Economic Development Plan

Specification	Mileage	Gravel Requirements per mile (tons)[1]	Total Gravel Requirements (tons)	
Rural roads	92.7	1,194.0	110,683.8	
Collector Highways	63.0	4,124.0	259,812.0	
Paving shoulders	54.5	1,390.2	70,315.9	
				440,811.7

2. Provincial Roads, Projection

Specification	Mileage	Gravel Requirements per mile (tons)	Total Gravel Requirements (tons)	
Rural roads	175.0	1,194.0	208,950.0	
				208,950.0

Total gravel requirements, by Road Paving Programme, on Prince Edward Island, 1970-1974 .... 649,761.7

Average annual gravel requirements, by Road Paving Programme, on Prince Edward Island, 1970-1974 .... 129,952.1

1. L. Bell, op. cit.

authorities. Calculation from the specifications given indicates that this mileage should have required only 147,500 tons of gravel, when in fact 235,000 tons were used. If similar discrepancies occur in the future, the projected annual gravel demand for asphalt manufacture, will in fact be 190,000 tons, not the 130,000 tons shown in Table 3.[1]

Projections are generally based upon the fundamental assumption of technological constancy. In the field of road construction technological advances occur frequently. For instance, it is now possible to lay asphalt in below freezing conditions; a 9 inch asphalt strip is laid which retains its internal heat for a sufficient time to allow rolling. With thicker strips of asphalt, larger cobbles may be used, thus dramatically altering the grain-size specification. It is also considered that the seal coat traditionally applied may not significantly lengthen the life expectancy of the road, although it does give a smoother finish. If this seal coat was to be dispensed with, much of the problem of suitable gravel supply in Prince Edward Island would disappear.[2] In this projection, it is assumed that neither these nor any other innovations will be introduced into the road construction programme during the next 15 years.

Future Demand of Gravel for (ii) Concrete Production

Concrete production is neither easier nor more reliable to predict than asphalt production. In recent years the demand on Prince Edward Island has not increased substantially, nor is it expected to

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1. See Appendix 3, p. 140.

2. L. Bell op. cit.

do so in the near future.[1] There is a further complication in this case, in that a large proportion of the gravel used by the industry is already 'imported' from Nova Scotia. It is possible that this proportion will increase in the near future.. The current annual demand of gravel for concrete manufacture is approximately 75,000 tons, of which a maximum of only 30,000 tons is supplied from Island sources. While neither has an appreciable price advantage, as prepared gravels from both sources cost approximately $3.75 per ton, it is unlikely that Island sources will ever supply a larger amount of gravel than at present. A decline in local gravel production for this industry, may occur as much of the processing equipment used on Prince Edward Island is unreliable. However, the annual total of 30,000 tons derived from Island pits will be used in the projection of future demand.

Total Provincial Gravel Demand: Its Relation to Supply from the Study Area

The total annual projected demand for gravel during the next five years, 160,000 tons, will be derived from sources throughout Prince Edward Island.[2] A considerable proportion of the required gravel, however, will be derived from within the study area, specifically from weathered unit C deposits. The amount of gravel supplied, from these deposits, will depend upon highway construction in the area and the demands of concrete manufacturing firms.

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1. F. Miles, Schurman Construction Co., Charlottetown, personal oral communication.

2. See Figure 3, p.23.

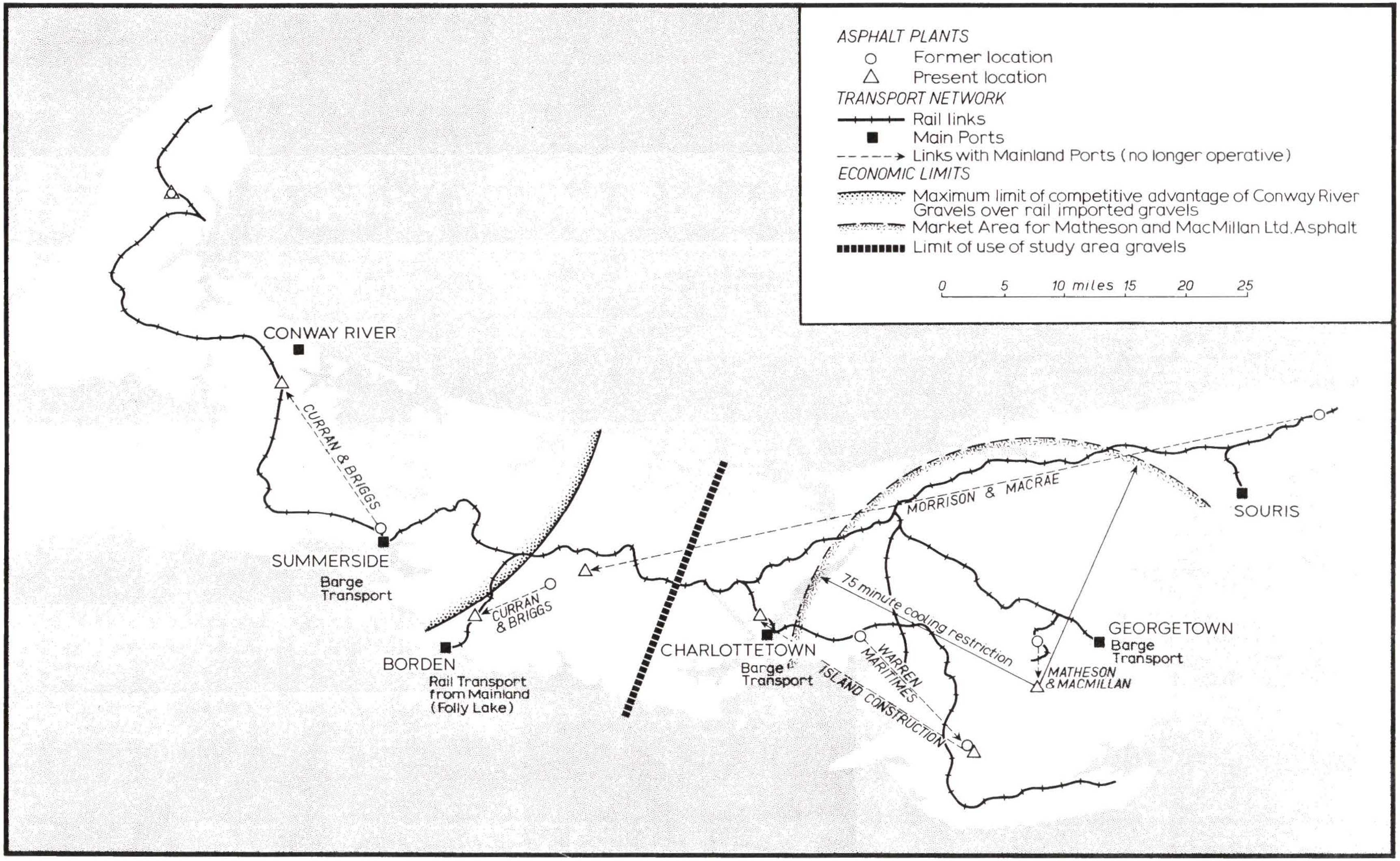

Figure 11 Market Areas of Asphalt Manufacturing Plants and their Relation to Transport Facilities

All paved roads in Charlottetown and to the east of this city, with the exception of the northeastern segment of the Island around Bayfield, are built with gravel derived from unit C outcrops to the south of Montague. The boundary between the market areas of Springton and study area gravels lies between Charlottetown and Hunter River as shown in figure 11.[1] Over 50 per cent of the Island's paved highways presently occur in this area. This percentage will be maintained if the Fund for Rural Economic Development five year programme is fulfilled, since 63.7 of the 92.7 miles of planned Resource Roads are located within the area served by unit C gravel reserves from the study area, while 31.5 miles of the 63.0 miles of Collector Highways and 20.0 miles of the 54.5 miles of Paving Shoulders, are also planned for this area. A total of 227,500 tons of gravel from the study area will be required by this programme which represents 52 per cent of the Island total.[2] Table 4 shows the total amounts of gravel used by asphalt producers from within the study area and those on the remainder of the Island, indicating that 53 per cent was derived from the area south of Montague, in 1968.[3]

Schurman Construction Company which dominates the concrete industry, on the Island, requires approximately 60,000 tons of gravel per annum, of which 75 per cent is imported from Nova Scotia by rail.[4] The remaining 10,000 to 15,000 tons is extracted and washed in the study area. A further 5,000 tons of gravel is utilised by McLean's

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1. See p. 60.

2. Some projects are included which could be supplied by gravel from Bayfield.

3. See p. 62.

4. F. Miles, op. cit.

TABLE 4

CONSUMPTION OF GRAVEL BY ASPHALT PRODUCERS,

PRINCE EDWARD ISLAND, 1968

1. Asphalt Producers Using Gravel from the Study Area

Firm	Plant Location	Consumption of Gravel (tons)	
Matheson and MacMillan	Kilmuir	55,836	
Island Construction	Sherwood	29,328	
	Iona (now closed)		
Warren Maritimes	Mt. Albion	16,910	
			123,412

2. Asphalt Producers Using Gravel from Sources Outside the Study Area

Firm	Plant Location	Consumption of Gravel (tons)	
Morrison and McRae	E. Bideford	29,046	
	Sprinton	18,612	
Curran and Briggs	Rose Valley	15,134	
	Albany	752	
	Ellerslie	9,494	
	St. Eleanors	9,024	
Hayes Paving	Alma	26,320	
			108,382
Total Gravel Consumption by Asphalt Producers on Prince Edward Island			231,794

of Montague, a small concrete manufacturing company.[1] Together the two firms utilise some 15,000 to 20,000 tons of gravel from the study area. A total of approximately 140,000 tons of gravel was extracted in southern Kings and southeastern Queens counties during 1968.

It may, therefore, be assumed that approximately 50 per cent of the Island's internal gravel supply will originate in the study area during the next five years. Several assumptions are implicit in this prediction:

(i) that no significant technological advances will be implemented in the highway construction programme;

(ii) that the proportion of imported material will not radically increase;

(iii) and that the provincial government will maintain its previous rate of highway construction.

Given these assumptions it is predicted, that of the 160,000 tons of gravel derived annually from the Island, some 90,000 tons will originate in the study area. Of this total, some 70,000 tons will be used for asphalt manufacture and 20,000 tons for concrete production.[2]

Future Gravel Extraction in the Study Area

During the summer of 1969, seven gravel pits were in production in the study area, as shown in figure 7.[3] Two of these were located at Kilmuir and supplied the nearby asphalt manufacturing plant of Matheson and MacMillan Ltd. Of the two pits near Iona, one supplied Warren Maritimes Ltd. asphalt plant, situated at the pit, while the other provided gravel for the asphalt plant of Island Construction Co.

1. J. McLean, personal oral communication.

2. If the figures in Appendix 3 are used this figure becomes 125,000 tons; 105,000 tons for asphalt and 20,000 tons for concrete.

3. See p. 35.

in Sherwood. This plant also derived some material from a pit two miles north of Caledonia, owned by A. Whiteaway. This same pit and two others, one at Caledonia and the other at Brooklyn, supplied the only operational gravel washing plant, S. Frizzell Co. at Brooklyn. The location of all these asphalt manufacturing plants is shown in figure 11,[1] and their consumption of gravel in Table 4.[2]

Any land use plan must establish the location of the pits which will supply future gravel demands in this area. Large reserves were demonstrated by the seismographic survey, in the vicinity of Kilmuir. These will probably be leased to Matheson and MacMillan by the landowner, H. Loans.[3] Both pits at Iona are associated with some reserves. Such deposits are particularly extensive in the area owned by Warren Maritimes Ltd., although the other pit, operated and owned by Island Construction Co., may have limited gravel reserves. This latter company, however, also owns land west of Caledonia, which has large reserves, already confirmed by test pits. Both pits leased by S. Frizzell Co. at Caledonia and Brooklyn have very large reserves, which are more than ample to satisfy the demands made for gravel by the washing plant at Brooklyn. Therefore, some supplies are sold by this company to the asphalt manufacturers of the area. The pit owned by A. Whiteaway (north of Caledonia) is usually exploited by S. Frizzell Co., but also supplies other companies when the demand for gravel is high.

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1. See p. 60.

2. See p. 62.

3. H. Loans, Kilmuir, personal oral communication.

Assuming that highway construction will continue to be equitably divided among the electoral districts (a seemingly essential political strategy on Prince Edward Island) there is no reason to predict the relocation of any of the asphalt paving plants within the near future. Past movements are shown in figure 11.[1] Assuming such stability, there is only one additional pit which needs to be opened in the next five years. Extentions of the gravel and workings at Kilmuir, Iona, Brooklyn and Caledonia will provide ample material for all companies except Island Construction Co. While this company could obtain material from existing pits at Caledonia and Brooklyn it may well prefer to exploit gravel from land owned by the company west of Caledonia.

Probable gravel reserves of approximately 10 million tons have been demonstrated in the study area, sufficient to supply the entire province for nearly 50 years,[2] at the present rate of demand. Gravel demand, however, will quite probably change, as, at the present rate of progress, the entire Island network of roads will be paved in some 22 years. With a probable lessening of demand for gravel, the next five years will be crucial for the industry. It is likely that as demand slackens, competition will become more intense, so that new pits may be opened at frequent intervals in the attempt to cut costs. It has been clearly shown that there are ample reserves, in the existing areas of extraction, to supply all the firms dependent on

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1. See p. 60.

2. Calculated from the seismographic survey and assuming consumption of only 200,000 tons per annum.

unit C gravel for the next five years. Any further proliferation of gravel pits is, therefore, quite unnecessary. However, economic pressures may lead to such proliferation unless checked by planning authorities.

Conclusions

Although the demand for gravel reached 300,000 tons in Prince Edward Island during 1968, the projected future annual demands are much lower. It is predicted that a maximum of 30,000 tons of gravel for concrete will be supplied per annum, and 130,000 tons of gravel per annum for asphalt in the near future. Of this total, of 160,000 tons of gravel, some 90,000 tons will probably be supplied from unit C gravels in the study area. This contrasts with the 1968 gravel production figures of 232,000 tons for asphalt manufacture, and 30,000 tons for concrete production, of which, 160,000 tons originated in the study area. The proportion of prepared material 'imported' for concrete production from Nova Scotia will probably remain constant at 45,000 tons per annum.

Possible depletion of gravel reserves in central Queens and Prince counties could alter this situation, for it has been predicted that gravel reserves, outside the study area may be low.[1] There are undoubtedly large reserves, of gravel at Conway River and also at Springton, but the remainder of the central and western sections of the Island may experience a shortage. Whether or not the demand for gravel in these areas could be met by Kings county gravels is doubtful,

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1. D.R. Morrison, Morrison and MacRae Ltd., personal oral communication.

because of high transport costs. Aggregate from Nova Scotia might prove to be economically competitive in these areas.

The presence of ample gravel reserves has been demonstrated in the study area and it has been shown that pits adjacent to manufacturing plants are quite capable of supplying these plants for the duration of the first phase of the Development Plan, which ends in 1976. However, the asphalt manufacturing plants are mobile, being relocated according to the dictates of economic competition. As plants move, gravel pits are abandoned and others opened. The result is a series of pits, many with gravel reserves left unworked, as shown in figure 7.[1] It is stressed that there is no reason for this continued proliferation. The three asphalt plants served by the gravels of the study area need only three pits to supply them, while the single washing plant requires only one pit. If the number of production pits were kept at a minimum, land use conflicts, which are accentuated by the overabundance of quarries could be more easily resolved.

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1. See p. 35.

CHAPTER V

THE EFFECTS OF GRAVEL EXTRACTION ON OTHER LAND USE ACTIVITIES

Introduction

Extractive industries have a twofold effect on the environment. The site on which extraction actually occurs is, of course, radically affected, precluding any other activity. A much larger area, in the immediate vicinity of the pit is indirectly affected. In this area, land use activities such as fishing and tourism may be adversely influenced. Manufacturing industries, associated with the gravel extraction process, have similar adverse affects on the landscape, plate 2.[1] Indeed, these may be more marked than those of gravel pits themselves.

A consideration of land use conflicts must take into account, not only the present state of the economy, but also anticipated future trends. In this way, potential conflicts may be perceived and action taken to ensure that the optimum land use is realised. A review of such present conflicts of interest in the study area, is presented but emphasis is placed on potential conflicts during the next 15 years.

As shown in figure 2[2] and table 5[3], by 1968, some 276 acres of land, in the study area, were occupied by gravel quarries, most of which had been abandoned. The projected demand of gravel, from this

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1. See pp. 69.

2. See p. 12.

3. See p. 70.

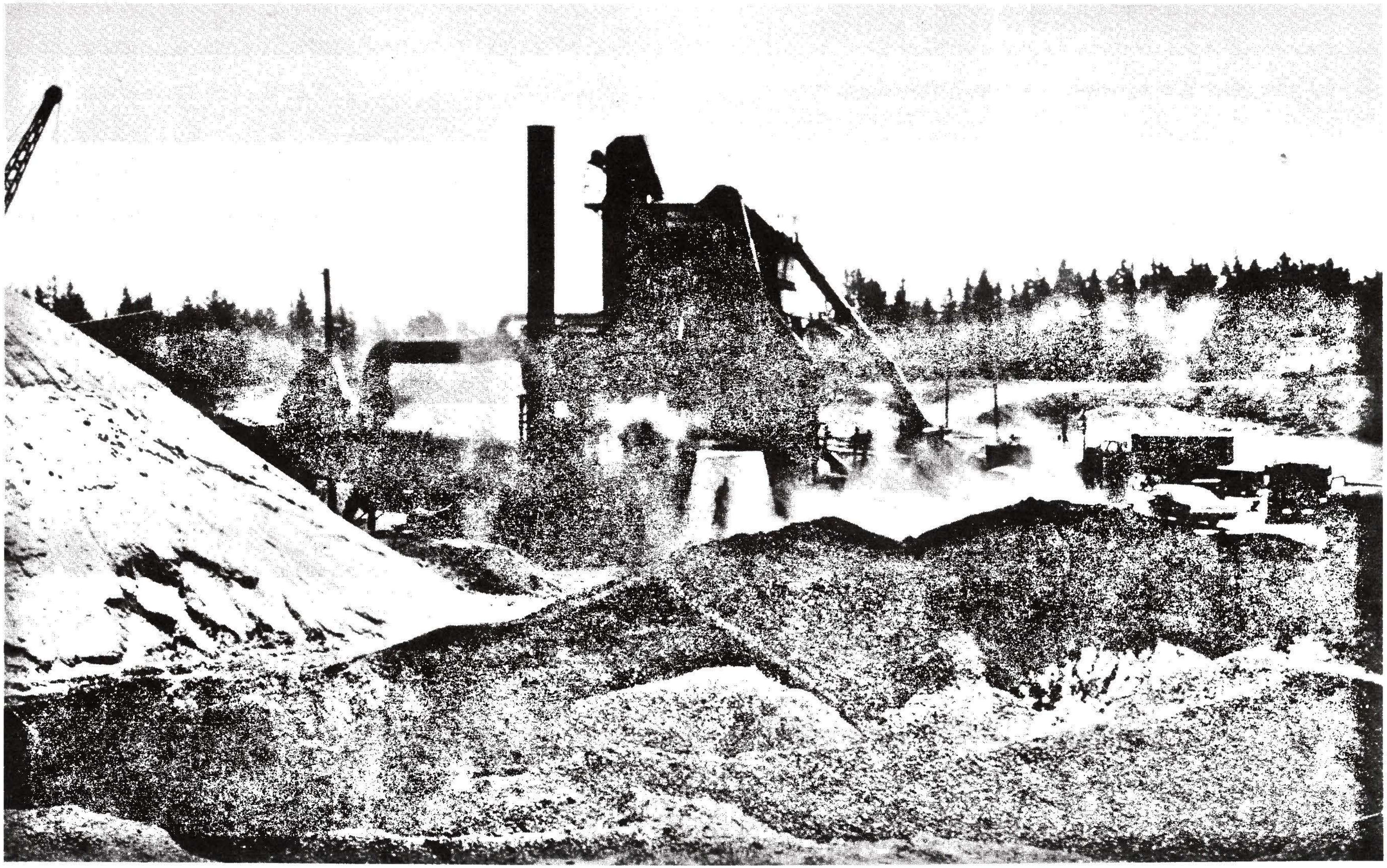


Plate 2 Matheson and McMillan's Asphalt Plant, Kilmuir (NG2608)

TABLE 5

AREA OF PITS IN THE STUDY AREA[1]

Pit[2]	Area (acres)	Pit	Area (acres)	Pit	Area (acres)
1	1	21	7	41	8½
2	½	22	1	42	8
3	½	23	5½	43*	10
4	½	24	8½	44	12
5	½	25	1	45	15
6	½	26	3	46	3½
7	-	27*	10	47	1
8	8	28	20	48	½
9	1½	29	2½	49	6½
10	9	30	8	50	1½
11	2	31	2½	51	5½
12	4	32	10	52	8½
13	5	33*	11	53*	4
14	4	34	3	54	1
15	5	35	2½	55	2
16	6½	36	2	56	½
17	5	37	2	57	½
18*	5	38	5	58	3
19	1½	39*	13	59	½
20*	3½	40	3		
				Total Area	276

1. Measured from Aerial Photographs taken April 1968 - pits excavated during 1968 have been included, but not those excavated during 1969. * - this symbol denotes pits being excavated in 1968.

2. Pit Numbers refer to figure 2, p. 12.

area, is approximately 90,000 tons each year, which theoretically represents about 40 acre-feet of gravel. As all gravel quarries in southern Kings and southeastern Queens counties contain some unuseable sandstones, a greater area may actually be involved. This figure is therefore an absolute minimum. If the average depth of commercial deposits is six feet, as indicated by the seismographic survey, approximately seven acres will be needed for such gravel extraction each year. Financial returns, to the owner of the land from which gravel is extracted, are $165 per acre-foot. As gravel is not usually quarried unless it is at least five feet deep, the minimum net profit per acre to the landowner, is $825, while returns may rise to $ 650.

The extraction of gravel affects at least four sectors of the economy; agriculture, tourism, forestry, fishing and other wildlife. The preservation and growth of each of these sectors of Prince Edward Island's economy are important aims of the Development Plan, as, of course, is the road building programme. It would indeed be unfortunate if the provision of a system of paved highways prevented the accomplishment of many of the associated goals, set out in the Development Plan.

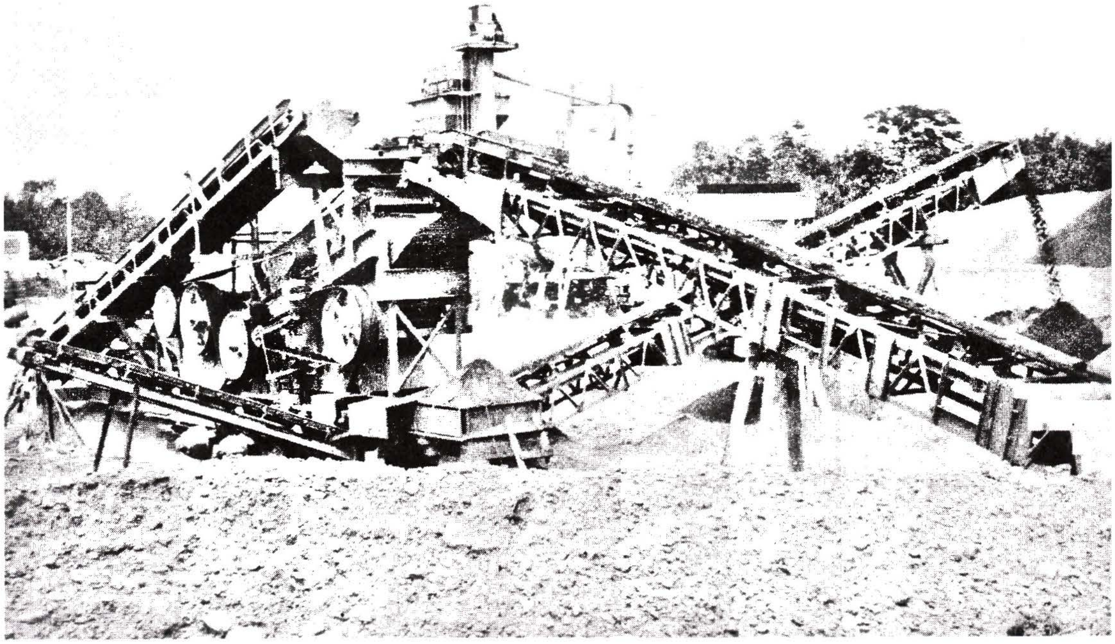
Appropriate alternative courses of action, open to decision makers, can be assessed only after a detailed examination of present and future economic and social conflicts, in the study area.

Gravel Extraction

The manner in which gravel is extracted, and the resulting ecological effects has important implications for other economic activities. Surface mining is invariably used to obtain gravel. In most cases, little planning precedes the initial removal of overburden. It is quite common to find, as in the pits excavated by S. Frizzell, that stripped overburden is frequently redeposited on top of gravel reserves. The same overburden may, in fact, be moved several times during the expansion of a pit. Generally, after some initial extraction of gravel, when the bedrock floor of the pit has been exposed, overburden is deposited in the depression leaving space only for the access of excavating machinery and transport vehicles. Other techniques have, however, been employed, for instance, on the farm of A. Whiteaway (NG 2203), the gravel is removed in a strip, the resulting depression was then filled with overburden leaving a series of five parallel strips of tip. This technique was used on the insistance of the owner of the surrounding land. It would be a comparatively simple matter to level these spoil heaps. The most antisocial method of removing overburden is to push it into adjacent productive land, on either side of the working face.

Most abandoned pits vary in depth from five to thirty feet deep, and are generally occupied by spoil heaps and pools of standing water. The removal of overburden and underlying gravel usually leaves the floors of such pits and surrounding areas low in nutrient levels and highly acidic.[1] Most abandoned gravel quarries are very infertile and

1. S. Vass, op. cit.



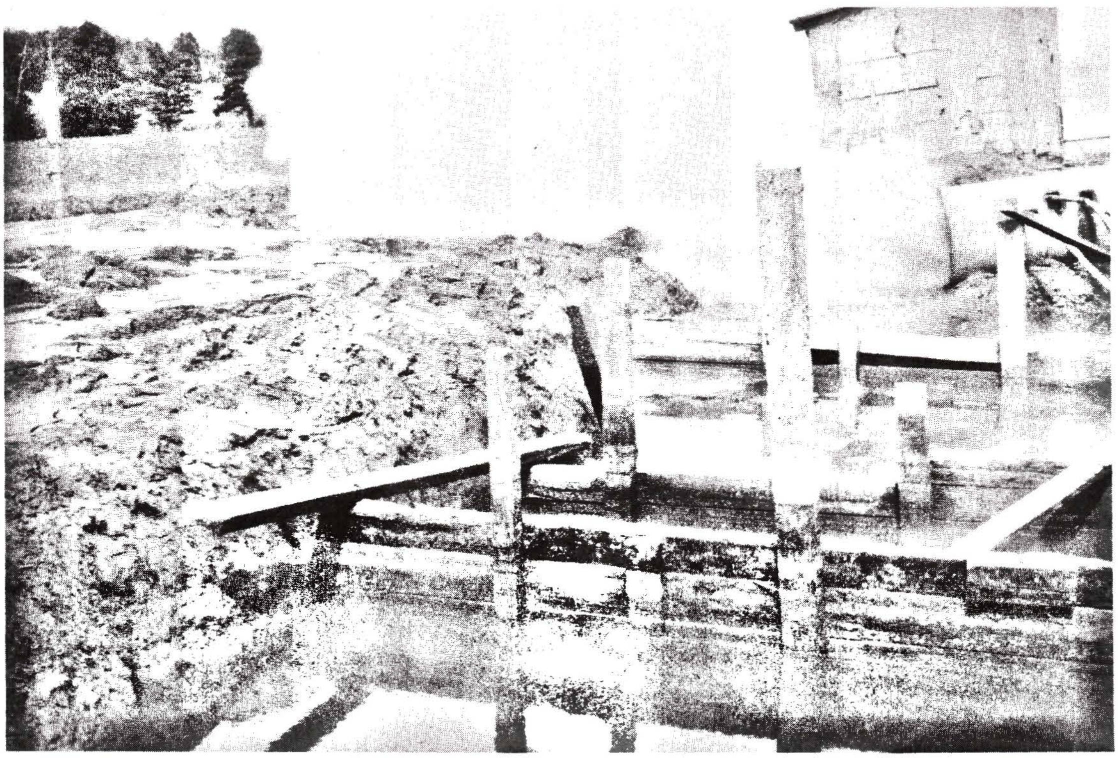


Plate 3 (i) Crusher and Asphalt Plant, Warren Maritimes Ltd, Iona(NG1700)
(ii) Dust Extractor, Island Construction Co., Sherwood (M98925)

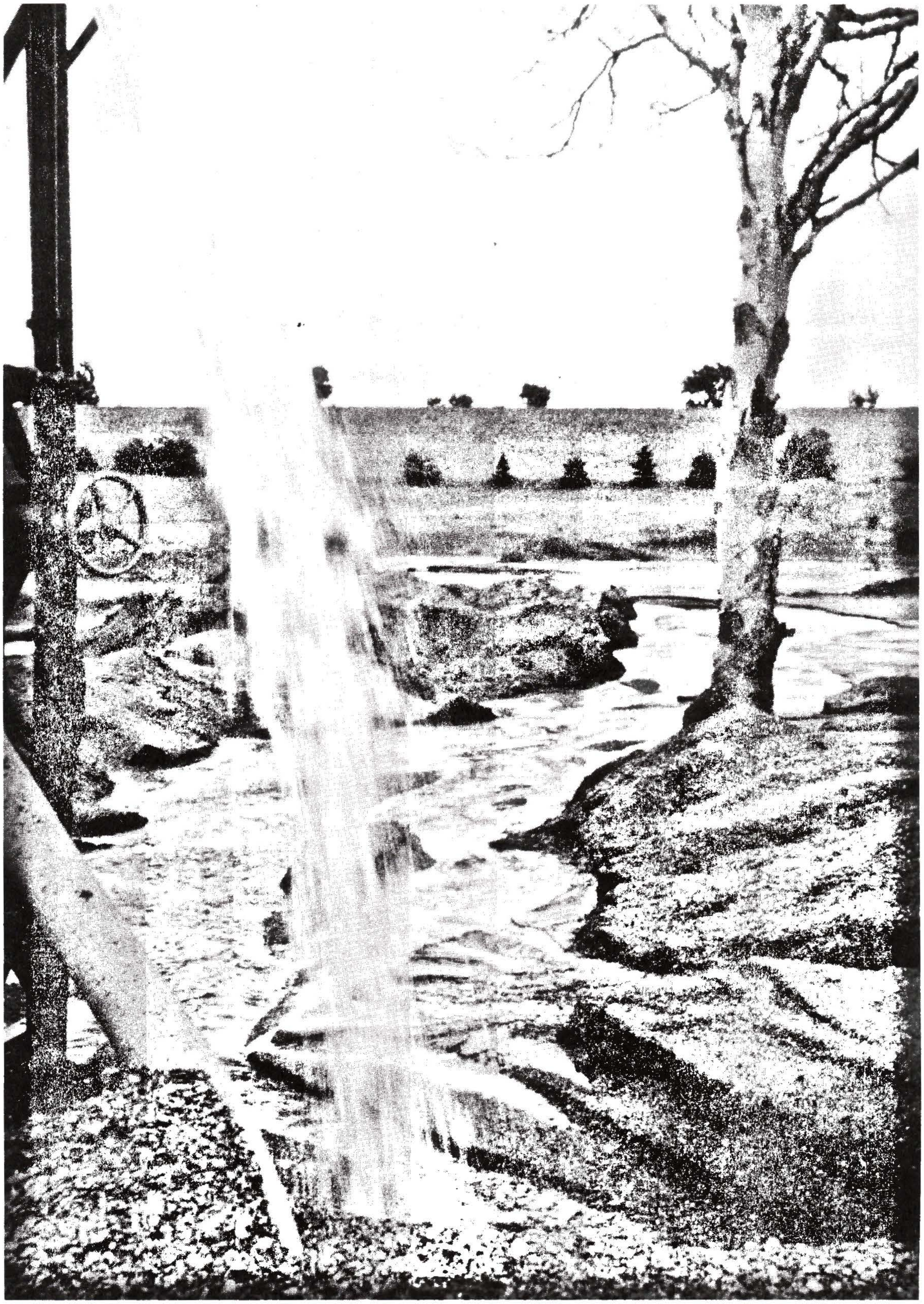


Plate 4 Gravel Washing Plant and Associated Sedimentation
S. Frizzell Co., Brooklyn (NG2403)

are only slowly recolonized by plants. Associated industries may also adversely affect the landscape. Concrete washing plants, for example, may release an excessive amount of sediment into streams, (plate 4)[1]; some asphalt manufacturing plants emit large amounts of dust into the atmosphere (plate 8)[2] and pollute the site with oil spillage. The presence of heavy gravel and asphalt trucking traffic, also has an adverse effect on the tourist trade.

Assessing Land Use Conflicts

An elementary type of benefit-cost analysis was employed to evaluate the impact of the conflicts outlined above. As much of the required quantitative data is either unavailable or incommensurate, the following analysis, therefore, provides only an incomplete basis for assessing these conflicts. An attempt is made to measure the benefits and costs of various land use activities to the entire community. It is extremely difficult to evaluate aesthetic aspects of the landscape and recreational benefits. Such variables are assessed in qualitative statements. Certain trends in public opinion are, however, becoming evident,

> "cultural and aesthetic values ... cannot ... be put directly into the cost minimizing calculation ... (but)... the public seems to be opting for beauty, or at least for the absence of ugliness."[3]

It is clearly erroneous to assume that those factors which cannot be measured are valueless. The author has, therefore, attempted

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1. See p. 74.

2. See p. 99.

3. D.B. Brooks, 1966, "Strip Mine Reclamation and Economic Analysis" Natural Resources Journal, Vol. 6, p. 43.

to evaluate, even if necessarily in a subjective manner, those factors which add to, or detract from, the quality of the environment. Amongst these factors are the adverse visual effects of gravel quarrying on the landscape, even though there may be some who value such physical manifestations of industrial progress.

Industrial activity is essential if the mode of life which Western society demands is to continue. Unfortunately such activity frequently detracts from the quality of life, giving rise to the dilemma of optimising industrial output with the least possible disruption of the natural environment. Such dilemmas can only be solved by detailed study and positive action. Unnecessary disruption of the landscape of Prince Edward Island has occurred and will continue to occur, unless land-use planning is instituted and enforced in the province.

Agriculture

There are, at present, within the study area, numerous small farms producing beef and fluid milk, a variety of cereals (including barley, oats and wheat), tobacco and potatoes. Much of the land, however, is out of agricultural production and in various stages of reversions to bush. The most important reasons for the decline of agriculture in this area are the small size and irregular shape of the holdings, their distance from large national markets, the frequency of slopes exceeding 10 degrees, and the infertility and low water-holding capabilities of the soils. The most serious of these disadvantages is perhaps, the adverse soil characteristics. Both the Culloden and Dunstaffnage soils, which are dominant in much of the study area, have both low water-holding capability and low fertility.[1] Their low water-holding capabilities can be reduced somewhat by increasing the amounts of organic matter in the soils, while the addition of fertilisers can overcome entirely the low fertility.[2]

> "It is the low water-holding capabilities that will be the cause of the relatively poor response of these soils to new technology in agriculture."[3]

It seems that, despite the activities of the Land Development Corporation, (which will soon provide assistance for the enlargement of holdings), dairying and the production of potatoes will continue to decline. It is predicted, by agricultural experts, that within the next fifteen years, tobacco may become the most important crop within the study area.[4] It has been estimated that this crop can be expanded on Prince Edward Island to occupy 10 times its present area, without adversely affecting national price levels.[5]

Although the cereals, grown in rotation with the tobacco, provide a basis for beef and hog-production, such operations can only be successful if additional capital and skilled farm operators are available. Similarly, the limited production of fluid milk for the local

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1. It is of interest to note that the Soil Capability Map for Agriculture Prince Edward Island, prepared by G.B.Whiteside, Experimental Farm, Charlottetown, under a project of ARDA, Canada Department of Forestry, 1966, shows much of the study area to be occupied by Soil Classes 3 and 4, which place moderately severe and severe limitations that restrict the range of crops or require special conservation practices, or both.

2. J. Lovering, Director, Farm Economics, Economic Improvement Corporation Prince Edward Island (personal communication).

3. Ibid.

4. L.B. Macleod, Canada Department of Agriculture Research Station, Charlottetown, and J. Lovering (personal communication).

5. J. Lovering op. cit.

market may also be a viable proposition. Other types of agriculture are less financially rewarding, and may disappear from southern Kings and southeastern Queens counties. Without the predicted expansion in the tobacco industry, it is possible that much of the study area could revert to bush. "It may well be, therefore, that the future of the entire area rests with tobacco."[1]

Farm enterprise analyses undertaken in 1969, by the Atlantic Development Board, reveals that returns to labour both in milk dairying, and in beef are especially poor, and are occasionally negative.[2] Annual net returns to agricultural land use in the study area are also very low. Further enterprise analyses studies, reveal that even with large, intensively managed herds, net returns to land from dairying might reach only 80¢ per acre.[3] Under ideal conditions sow and sow-weaner production might yield a maximum of $34.00 per acre. In contrast, tobacco production, under efficient management, is estimated to yield net returns of $170.00 per acre. All of the figures quoted above, with the exception of tobacco, bear little relation to present productivity and are projections of future maximum potential. They are specifically calculated returns to land which assume certain fixed expenses, including equipment, building depreciation and labour, which, depending on the particular operation, range from $8,121 to $3,599. The expenditure on livestock and crop inputs vary in these calculations as do fertiliser levels, but only

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1. J. Lovering, op. cit.

2. Atlantic Development Board, "Maritime Farm Enterprise Analysis", Ottawa, 1969, p. 261.

3. J. Lovering, op. cit. and Appendix iv pp.141-150.

the optimum operations are quoted above.[1]

Production of tobacco which first began in the province in 1959 occupied 1600 acres by 1968.[2] Most of Prince Edward Island is able to grow tobacco although the climate, soil and slope all provide controls on production of the crop, indeed it is now grown from Montague to Alberton. The only major concentration, which occurs in the Brooklyn, Glenmartin and Greenfield (2014) areas of Kings County, accounted for most of the 1600 acres in production in 1968. Site requirements for successful tobacco production are very specific; light sandy soils with rapid drainage and low nitrogen levels, are necessary and are provided by both the Dunstaffnage and Culloden soil series, in the study area. The frost-free period must extend well into September to permit harvesting, (cold air drainage extends the harvesting season), however, slopes must not be steep or the use of mechanised implements may be prevented.[3] These requirements are most frequently met by hill top sites, in Kings county, which are almost invariably underlain by gravel reserves as shown by the seismographic survey undertaken during this study.

Figures 5 and 6 show the location of gravel reserves, in the study area.[4] Together with the gravel deposits at Bayfield (on the north west of Kings County), these gravels constitute the only major

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1. The details of these farm enterprise analyses are given in Appendix 4, p.

2. Atlantic Field Crops Committee, <u>1969 Field Crop Recommendations</u>, Charlottetown, 1969, p. 33.

3. J. Lovering, <u>op. cit</u>.

4. See p. 29-30.

reserves east of Charlottetown. Tobacco farms already occupy a considerable acreage on soils developed on gravel deposits at Glenmartin (14) and Brooklyn (7).[1] Other gravel deposits in this area underlie potential tobacco growing sites (8, 9, 15, 18 and 21).

The availability of tobacco growing sites appears to be limited, and there is an increasing demand for such land. Farmers to the north of Iona (NG 1497) whose land probably overlies gravel reserves have received offers to buy their farms and convert them to tobacco production. They refused, however, in the hope that land values, which have already risen from approximately $50 per acre to $300 per acre, will rise even higher as suitable available sites for tobacco growth decline in number. It is most likely that tobacco production will continue to expand, and provided gravel continues to be exploited, conflicts of interest between the two activities will increase. However, tobacco is now grown on the south shore of the Brudenell River (2915) at Greenfield, on flat land, and also near Alberton, near the north coast of the Island. Should a serious shortage of suitable sites for tobacco production occur, in Kings County, as a result of gravel exploitation, there are a considerable number of possible alternative sites. It seems that perhaps the site factor is less critical, to tobacco farming, than many farmers in the study area realize. Therefore, direct site conflicts between gravel extraction and tobacco cultivation may be less significant than a cursory examination of the problem might suggest. In fact, many farmers, in

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1. These site numbers refer to the seismographic survey shown in Figures 5 and 6, see p. 29-30.

less profitable enterprises than tobacco production, welcome the opportunity to augment their incomes through gravel production. It is, however, extremely unlikely that any tobacco farmer would allow gravel to be excavated from his land as net returns per acre are only marginally higher. Table 6 provides a comparison of net returns to gravel extraction and tobacco production.

TABLE 6

COMPARISON OF NET RETURNS PER ACRE FROM GRAVEL AND TOBACCO

1. Gravel (acre feet)		2. Tobacco	@ 10% discount		@ 5% discount	
	Total $		$	Total $	$	Total $
1	165	1st year	170.00		170	
2	330	2nd year	153	323.00	161.5	331.5
3	495	3rd	138	461	153.5	485.0
4	660	4th	124	585	146.0	631.0
5	825	5	112	697	139.0	770.0
6	990	6	101	798	132.0	902.0
7	1155	7	90	888	125.5	1027.5
8	1320	8	81	969	119.0	1146.5
9	1485	9	72	1041	113.0	1259.5
10	1650	10	65	1106	107.5	1366.0
11	1815	11	59	1165	101.5	1468.5
12	1980	12	53	1218	96.5	1504.0
13	2145	13	48	1266	91.5	1656.5
14	2310	14	43	1309	87.0	1743.5
15	2475	15	39	1348	82.5	1826.0

As can be seen from the table, at low rates of discount, tobacco competes favourably with gravel extraction. This is quite exceptional since no other agricultural enterprise, found in the study area (even when the returns are discounted at low rates of interest over long time periods), competes with the returns from gravel extraction.

The problem of equating the returns to agriculture and extractive industry depends not only on the discount rate adopted, but also on the principle of equating the two time streams. Generally,

> "the present value of time streams of private net returns as a result of strip mining ... is usually considerably greater than the market price of land for any other use ... the present value is not greatly diminished by discounting the future."[1]

In this case, the gravel is usually extracted in one year, giving a maximum net income of $2,500 per acre,[2] while returns from tobacco over a 10 year period, if discounted at 5 percent, over a 15 year period, total $1,826 per acre.

Other disadvantages, encountered with gravel extraction on agricultural land, which are not included in this table include, unuseable and unsightly land often visible over much of the farm, noise and danger to farm animals. However, the owner is financially compensated for these inconveniences because he performs no work for his returns. In contrast the tobacco farmer, at the end of the period of comparison still has a productive farm and fertile fields but has had to work for his money. The cost of the farmer's labour is included in the analysis, since net returns from tobacco and are calculated only after an allowance of $3,750 has been made for the farm operator's time and effort. While it is impossible to place a cost on any of these factors, it is probable that they will greatly affect the decisions of a farmer. Only under exceptional circumstances would

1. H.R.Moore and R.C. Headington, Agricultural Land Use as Affected by Strip Mining of Coal in Eastern Ohio, Bulletin 135, Ohio State University Agricultural Experimental Station, 1940, p. 22.

2. This assumes that the gravel does not exceed 15 feet in depth.

such an agriculturalist permit gravel to be extracted from his land.

Tourism and Recreation

Of the 600,000 visitors to Prince Edward Island in 1968, only some 10 per cent visited Montague or the surrounding district.[1] Over 80 per cent, on the other hand, visited the well advertised National Park on the North Shore. "The areas west of Summerside and east of Charlottetown together accounted for about 30 per cent of the tourist days, but only 20 per cent of the tourists."[2] Figure 12 illustrates many of the factors affecting tourism within the study area.[3] The growth of tourist facilities in this area, is likely to increase both the numbers and proportion of visitors to Montague, considerably. The proposed development of a new National Park at East Point and the new recreation centre at Brudenell (NG 3016), will probably become the recreational foci of the area, as shown in figure 12.[4] The road paving programme will also allow easier access to these areas. Already the road to Montague, from the Trans Canada Highway at Cherry Valley (0514), reaches the standards of that highway, while by the end of 1970 the road paving programme will provide a direct link between the Wood Islands Ferry Terminal (NF 1988) and Montague. As a result, many more visitors will undoubtedly traverse Kings County from south to north, despite the attraction of

1. D.Darlington, Department of Industry, and Natural Resources, Prince Edward Island, Personal communication.

2. Acres Research Ltd., op. cit. pp. VII 5-6.

3. See p. 84.

4. See p. 84.

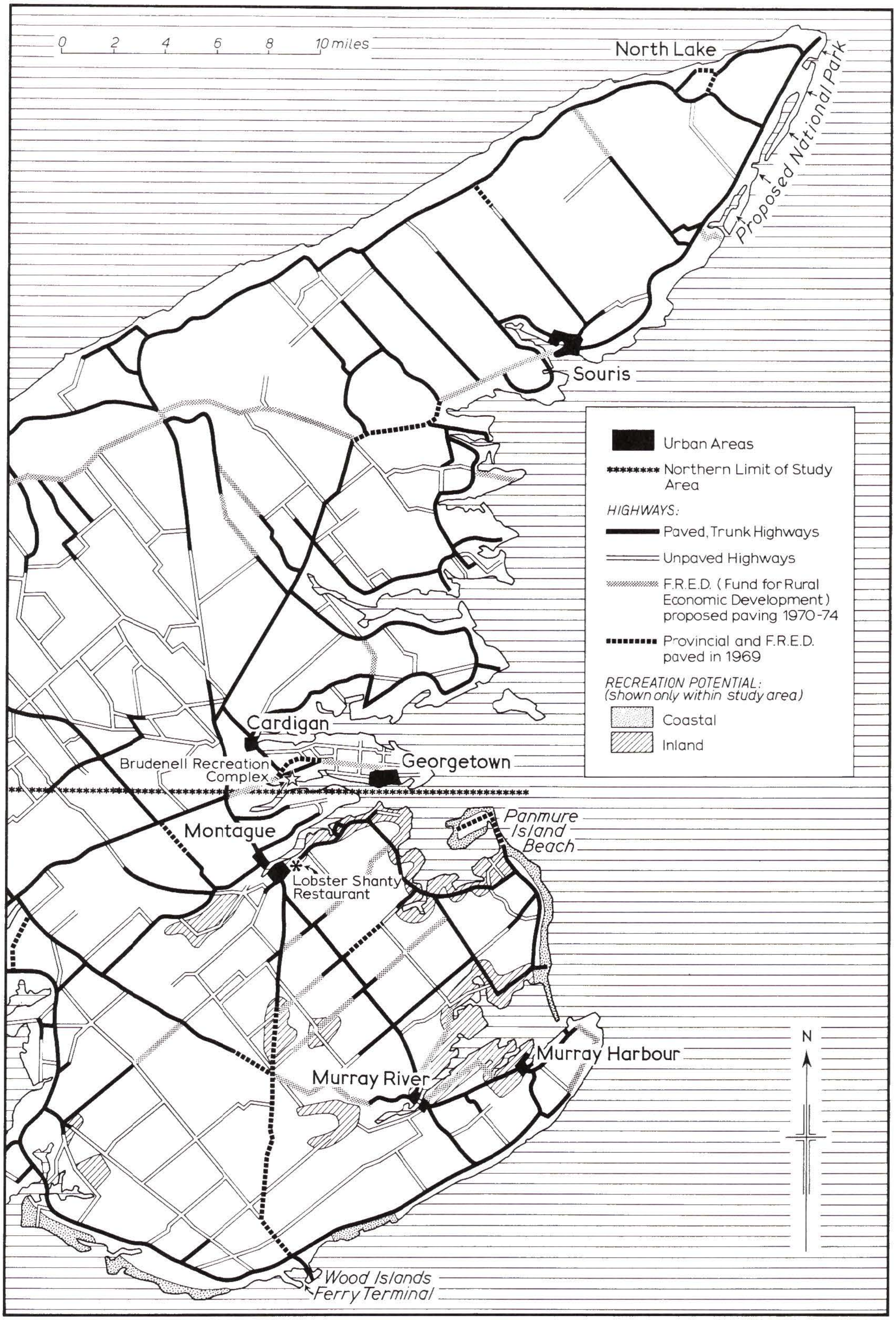

Figure 12 Recreation Potential and Highway Programme (1969-1974) in Eastern Prince Edward Island

the Kings Byway scenic route. This direct route will take tourists past the gravel pits at Caledonia (where the presence of large gravel reserves have been demonstrated by the seismic survey), the settling pond at Brooklyn (NG 2404) and the asphalt manufacturing plant at Kilmuir (NG 2608) shown in plate 2.[1] It is probable that some visitors will deviate from this direct route, not only to follow the Kings Byway and to visit Murray River, but also simply to travel rural roads. Some tourists will no doubt find fascination in gravel pits and accept them as part of the rural landscape or even view them as "illustrations of the cost of economic progress."[2] To most, however, they will appear disharmonious, and detract from the aesthetic experience of the rural landscape.

Usually the object of such travel will be to reach an attractive overnight stopping place, such as Brudenell or the National Park. The value of the travel experience is difficult to estimate,

> "some persons or groups may enjoy the travel itself ... on the other hand many travellers seem to regard the trip itself as a necessary nuisance ... we know little about how to go about measuring their satisfactions and dissatisfactions from travel."[3]

Nevertheless, it is estimated that, on Prince Edward Island, tourists spend on average 60 per cent of their available leisure time in their cars,[4] so that even if travel is not the prime reason for the holiday, it is certainly an important element. Subjective impressions resulting

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1. See p. 69.
2. W.R.D.Sewell, University of Victoria, personal written communication.
3. M. Clawson and J. Kretsch, Economics of Outdoor Recreation, Johns Hopkins, 1966, pp. 33-34.
4. T. Morrison, Economic Improvement Corporation, personal oral communication.

from the travel experience may well influence whether or not the visitor returns to an area and also colour the recommendations made to friends. An estimate of the importance of tourism to the Island's economy may be made if it is assumed that a $10.00 expenditure per day is incurred for facilities provided.[1] If each tourist were to spend only two days in the Montague district (including Brudenell), some $1,200,000 would be spent in the area.[2] Of course, not all this income is a direct benefit to the area, or even the province, nevertheless, many inhabitants of the Island depend upon it for their livelihood. It is estimated that 40 per cent of the income derived from tourism, is retained within the local area, even if none of the goods sold are locally manufactured.[3] In this case some $480,000 spent by tourists would still be retained within the area.

Visitors frequently explain the reasons for their visit to Prince Edward Island in terms of its 'rural charm' and 'atmosphere'.[4] One of the principal aims of the Department of Tourist Development is to prevent the loss of this 'charm' and 'atmosphere', an example of which is shown in plate 5.[5] It is clear that if the development of gravel pits, the provision of settling ponds and the siting of

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1. M. Clawson and J. Kretsch, p. 236, op. cit.
2. This figure is derived from figures supplied on ferry traffic by D.Darlington, op. cit. It reflects a rise from the 230,000 visitors in 1965 to 600,000 in 1969.
3. Ibid., p. 238
4. Acres Research Ltd. op. cit., (Their survey suggested that, "the landscapes, seascapes and general environment ... were repeatedly stressed by visitors as the Island's greatest attraction".) p.VII-16.
5. See p. 87.

Plate 5   An Example of "Rural Charm", Prince Edward Island; New Glasgow (MG7339)

plants detract from the features which attract tourist to the area, the revenue lost from tourism must be weighed against the cost of relocating the industries concerned.

The cost of relocating an asphalt manufacturing plant is approximately $7,000; this figure includes both the cost of moving and the loss of production, although the cost of the new site is not included.[1] In order to reclaim the settling pond at Brooklyn, the washing plant owned by S. Frizzell Company would have to be relocated and another settling pond constructed elsewhere. This would probably incur a similar cost. One of the most elementary precautions against atmospheric pollution, the provision of a dust extractor, has not been taken on any asphalt plant except that of Island Construction Co. at Sherwood. Contrast in this respect plates 3 and 8.[2] The gravel pits at Caledonia do not cover an extensive area and further development could be prohibited by new legislation.

Only the relationship between the primary tourist route in the area and the gravel industry has been considered; other conflicts are much less significant to the development of the Island's tourist industry. It is clear that a total investment, not exceeding $15,000, would retain much of the natural beauty of the landscape bordering the highway between Wood Islands and Montague.

An increase is clearly expected in tourism in the study area. This increase will be accentuated by publicly financed road improve-

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1. E. Matheson, Matheson and MacMillan Ltd., personal oral communication.

2. See pp. 73 and 99.

ments. Unfortunately certain industrial features in the rural landscape detract from its beauty, one of the main tourist attractions. The cost of relocation of these industries is very small ($15,000) compared with tourist expenditure in the area ($1,200,000), a percentage of which may be lost if such relocation is not carried out.

Fish and Wildlife

Gravel quarries create new habitats which may, or may not, bring advantages for wildlife.

> "In an area of uniform soil and plant conditions the interspersion of quarries creates 'edge' and habitat variety. Given adequate nutrients in the residual soils of the quarry, it would support plants of an earlier successional stage than that of its surroundings, and consequently different animals. Unfortunately, most gravel quarries are infertile and are very slowly colonized by invading plants."[1]

Open depressions containing standing water are common in abandoned pits, the vegetation is removed, steep slopes created and run-off increased. But the quality of the resulting wetland is usually very low. This is caused by a combination of low nutrient levels, inadequate water exchange and sometimes the introduction of toxic wastes. Fish ponds are usually only established through management techniques, only very rarely do they occur, spontaneously.[2]

These changes are illustrated by two examples, martins, whose nesting habits require a steep sandy slope, into which they tunnel horizontally, were in the past, confined to seashore cliffs. With the exploitation of gravel, numerous inland areas have been opened

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1. S. Vass, Division of Fish and Wildlife, Department of Fisheries, Prince Edward Island, personal written communication.

2. Ibid.

up to these birds. Herons, too, are generally confined to the seashore or streams. Any lake or pond occurring, as a result of gravel extraction, may become stocked with fish and thus extend the heron's range. Gravel pits are, therefore, some advantage to wildlife, extending the range of certain species.

It is, as yet, impossible to place any dollar value on wildlife, except perhaps in the case of sports fisheries,[1] hunting (both animals and birds) and exotic species which attract visitors to an area. The impact of animals or birds which damage property may also be measured in monetary terms. Changes in fauna, resulting directly from gravel pit development, are not thought to have any significant impact on the economy, unless they have been specifically developed to attract tourists, as is the case with Moore's Bird Sanctuary (NG 2805).

The indirect effects of gravel production on drainage have been extremely deleterious. Since the beginning of the road paving programme, accelerated sedimentation of stream beds has contributed to the loss of over 50 per cent of the trout habitat on Prince Edward Island.[2] This has occurred despite specific legislation to the contrary which states that,

> "no person shall put or permit to escape into any island water of the province, frequented by trout or salmon, any clay, sand, silt residue from washing gravel or other deleterious substance or thing."[3]

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1. W.R.D. Sewell, personal communication

2. S.Vass, op. cit.

3. Laws of Prince Edward Island, Statutes,"Fish and Game Protection Act," 1959 (amended to 1966), p. 18.

Although it is possible to legally defend the right of the Department of Highways to act in this manner, (as the sedimentation can be regarded as the result of natural process), the spirit of the law is certainly transgressed.

> "If one were evaluating the government's responsibility for maintaining environmental quality (the regulation quoted) would seem quite appropriate."[1]

The greater part of this sedimentation has resulted from the construction of embankments as part of the road building programme. These embankments suffer considerable erosion during rain storms, both directly from rainfall on the embankment and runoff from the highway. Large quantities of silt are, as a result, deposited in adjacent water courses. Elementary precautions to reduce erosion and prevent sedimentation have not been taken, although the seeding of embankments and the cutting of oblique lateral drainage ditches would probably solve much of this problem.[2] Indirectly, therefore, the gravel industry has had a very profound effect on fisheries, an effect which is now thought to be also affecting lobster fishing at the mouths of some streams.

Gravel washing plants may also contribute to excessive sedimentation in trout streams, (plate 4).[3] The recent threat of legal action has apparently influenced one company to clean out its settling pond, and so reduce siltation problems downstream.[4] Figure 13 illustrates

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1. S. Vass, <u>op. cit.</u>, personal written communication.

2. <u>Ibid.</u>

3. See p. 74

4. S. Vass <u>op. cit.</u>

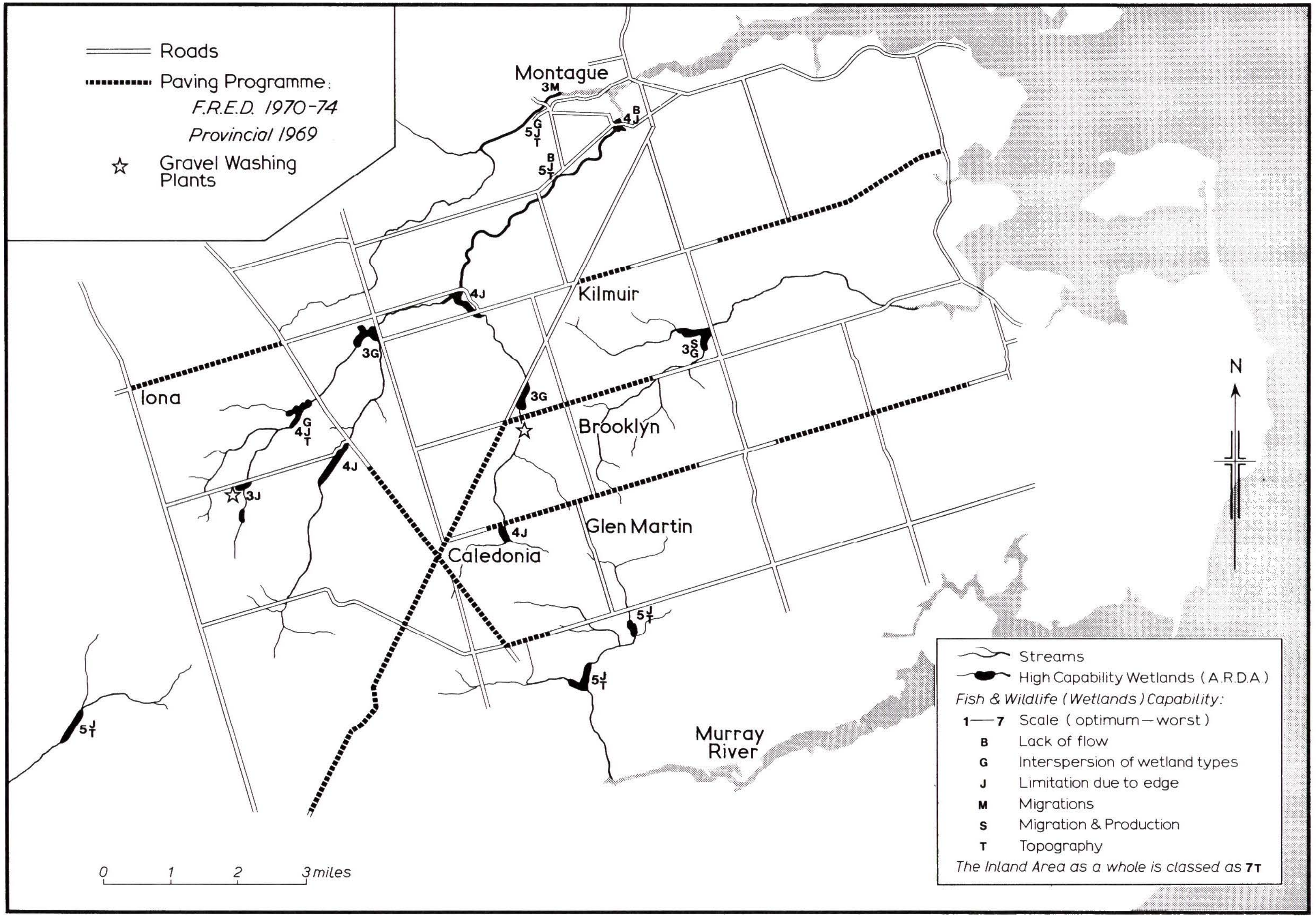

Figure 13 Gravel Washing Plants and Highway Construction (1969-1974) and its Relationship to Fish and Wildlife Potential, Southeastern Prince Edward Island

that 17 miles of high capability trout streams, below the two washing plants in the study area, are vulnerable to such sedimentation.[1] Already, one instance of the destruction of trout breeding grounds on the Valleyfield River, as far downstream as Knox's dam (NG 2509), has occurred. Projected highway construction projects, in the study area will also threaten a further 15 miles of trout streams within the next five years.

It has been suggested that, should agricultural production continue to decline in the study area, deer could possibly be introduced for hunting purposes.[2] This is unlikely to occur in the immediate future, but indicates that fish and wildlife could become economically significant. Indeed, it has been suggested that, "the streams and ponds of the area are among the finest water on this continent for trout production."[3] It is possible that the concept of a "semi-wilderness", which, "provides a refuge from mechanised recreation, but permits some logging and other uses," may be applicable in the future of eastern Prince Edward Island.[4]

Forestry

Both hard and softwoods grow in the study area, although the former are now much rarer than at the time when the land was first

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1. See p. 92.

2. J. Lovering, op. cit.

3. Acres Research Ltd., op. cit., VII-28.

4. R.C. Lucas, "Wilderness Perception and Use: The Example of the Boundary Waters Canoe Area", Natural Resources Journal, 1964, Vol. 3, p. 396.

cleared. The original forest cover consisted of,

> "quality timber with beech, sugar maple and yellow birch predominant among the deciduous trees, and cedar, spruce, fir and tamarack characterising the conifers. The second growth is of very inferior quality, the main varieties being spruce, Canada balsam and silver birch."[1]

The poor quality of this forest is reflected in the returns per acre. Pulpwood (produced from the softwoods) is worth only $9.00 per acre, while hardwoods produce $12.00 per acre. Growth rates are only 3-4 per cent of half a cord per acre per annum.[2] These returns do not compare with the use of the land for the more profitable agricultural activities nor for gravel exploitation.

However, forestry is associated with many other benefits which include recreation, agriculture, wildlife and the reduction of surface run-off and related soil erosion. Woods not only serve these functions, but also are responsible for part of the "peaceful atmosphere" of the Island.[3] An analysis of landscape harmony is extremely difficult, but while some physical changes are compatible with the environment as a whole others are not.[4] It is probably "in the best interests of the recreation-tourism business to maintain to the greatest extent possible the present relationship of cropland, pasture and woodlot."[5]

It is clearly important to consider both the primary and secondary benefits associated with forestry. Although forestry

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1. P-Y Pepin, op. cit., pp. 48-9.
2. I.Miller, Forestry Division, Department of Agriculture, Prince Edward Island, personal oral communication.
3. Acres Research Ltd., op. cit., p. VII-3.
4. R.H.Twiss and R. Burton, 1966 "Resource Use in the Regional Landscape," Natural Resources Journal, Vol. 3, p.70.
5. Acres Research Ltd., op. cit., P.VII-18

Plate 6 Overburden Removal into Woodland, Caledonia (NG2201)

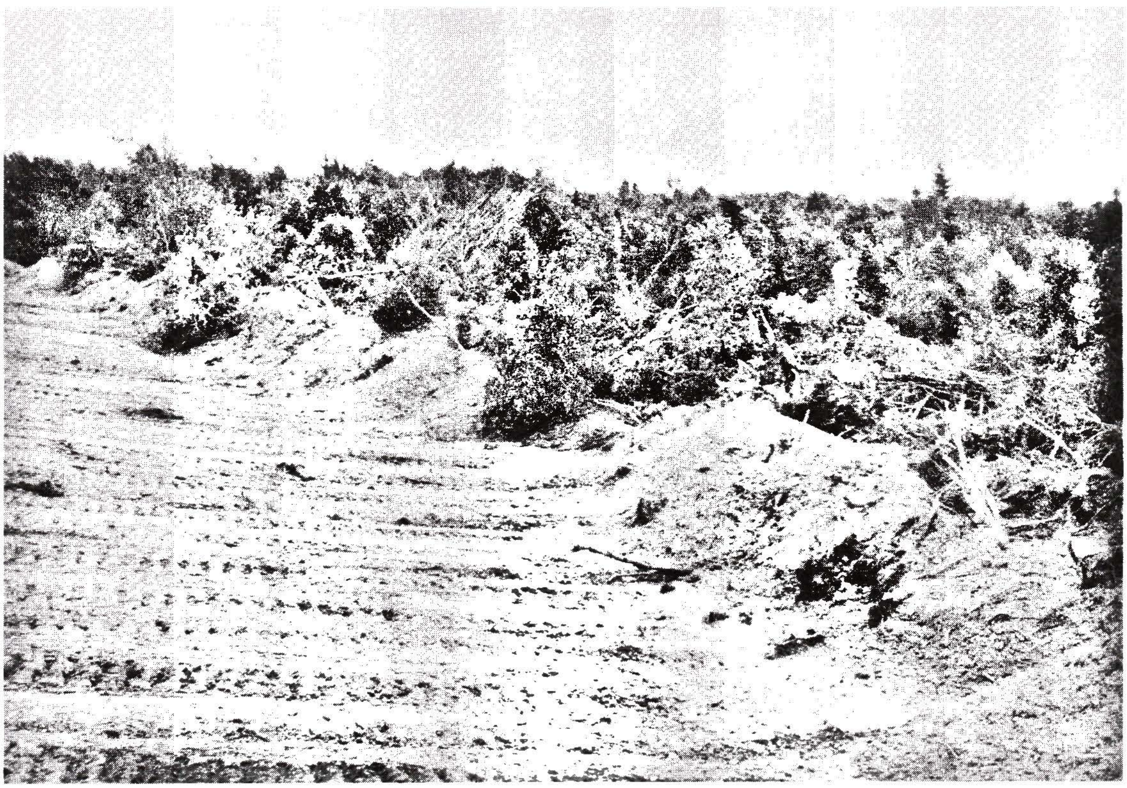

Plate 7 (i) Stripping of Woodland before Extraction of Gravel, near Iona

(ii) Impact of Overburden Removal on Forestry, Iona (NG1700) is being rationalised by the Economic Improvement Corporation, the returns from this activity will never be sufficiently high to compete with these from other major land uses. As tourism increases, so any decision which affects those factors attracting tourists to the Island has to be more carefully considered. This is especially true in the case of forestry activities, which may produce strong visual impressions. Twiss and Burton have developed the concept of 'imageability' and have suggested that some symbols such as tree stumps, evoke very strong negative images, unless these are obviously part of a cycle of growth and harvest.[1] Local examples of such evocative imagery are shown in plates 6 and 7.[2]

Conclusion

It is becoming increasingly widely recognised that there are conflicts between industrial, agricultural and recreational activities which cannot be resolved to the satisfaction of the majority, without recourse to planning control. The study area is no exception. Gravel is needed for road construction and the demand for this resource will continue into the foreseeable future. Economic considerations alone may prohibit the access of the extraction industry to gravel reserves, if the tobacco industry expands very rapidly. On the other hand, the continued exploitation of gravel will adversely effect the aesthetically harmonious relationship which exists between woodland and farmland, which has been achieved over many years, in the

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1. R. H. Twiss and R. Burton, op. cit., p. 80

2. See pp. 95-96.

Island. Other industrial activities may mar the tourist experience, adversely affect fishing and destroy small, but widely dispersed patches of vegetation.

It is usually agreed that, "The potential returns in alternative uses must be assessed and the use that pays the highest net return must be allowed to use the land." However, in some cases the social cost of this land is so high that other uses are to be prefered.[1] "Society must decide how much it is willing to pay for reclamation."[2] As Brooks points out, "private standards are not sufficient to define social efficiency..", but also, "strip mine reclamation can be socially, but not privately profitable."[3] He thus suggests that, if the public demand forces the individual to recognise more costly standards, then the public should also be required to bear the cost.

The site of a gravel quarry cannot simply be evaluated, in isolation from the economy in which it occurs. For instance, it has been pointed out that, "while arable land has been lost to pits, it is admitted that poor farming paractices resulted in greater losses."[4] Again when the wider context must be considered, the impact of any type of land use depends on "the viewer's predisposition and the way in which the environment is presented."[5] Consideration should be given to both of these factors, the former because of the great

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1. W.R.D. Sewell, University of Victoria, personal written communication.
2. Ibid.
3. D.B.Brooks, 1966, op. cit., pp. 23-29.
4. H.R.Moore and R.C. Headington, 1940, op. cit., p.21.
5. R. H. Twiss and R. Burton, 1966 op. cit., p. 79.

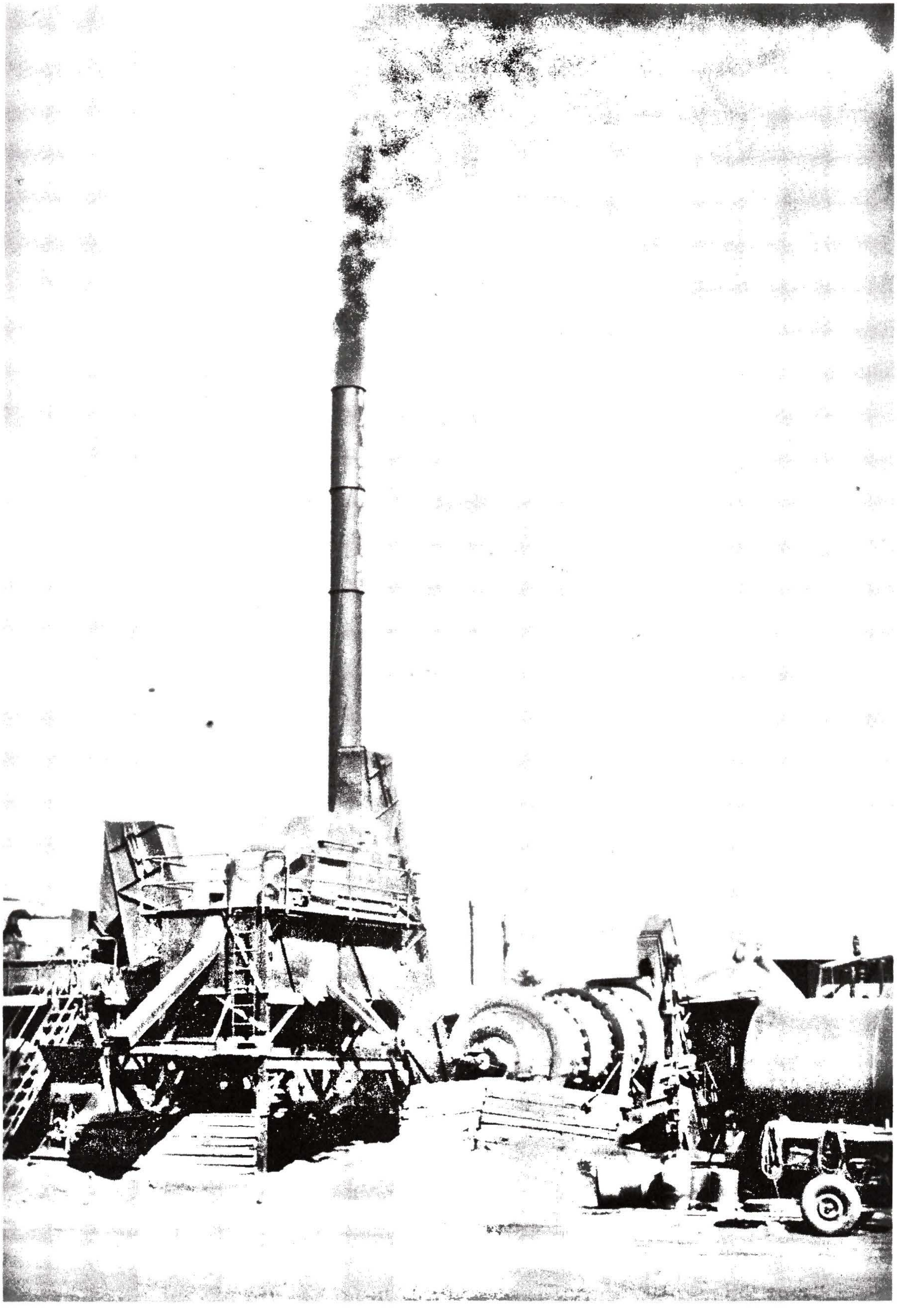

Plate 8 Hayes Paving Ltd., Alma, (MG1590), note dust emission

current public concern with environmental quality and the latter because the public is said to be impressed if concern is demonstrated, even though little may ever be accomplished. Although it may not be considered necessary because of economic criteria, to pursue reclamation policies, it may be decided that the physical appearance of the landscape must be assigned some value. This value is manifested in the scale of reclamation considered desirable, and reflects a series of intangible variables. Above all, the attitudes of the resident population toward their environment, manifested in the legislation of the province, "depend upon an inter-action between people and the regional resources base..."[1] "The concern of conservation is not with nature alone, but with the total relationship between Man and the world around him."[2]

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1. _Ibid._, p. 77

2. L.B.Johnson (President of the United States, 1965), quoted by _Ibid._, p. 76.

CHAPTER VI

THE RESOLUTION: A CONSIDERATION OF ALTERNATIVE SOURCES OF SUPPLY

Introduction

Quarrying operations, wherever they occur, invariably disturb some members of society. In Prince Edward Island, especially in southern Kings and southeastern Queens counties, the proliferation of relatively small gravel pits has given rise to concern about deteriorating landscape quality. A major object of this study has been to establish means by which such proliferation might be contained. Various hypotheses are therefore proposed, with the object of finding a solution to this problem which would maximise the total economic benefits to the province, while at the same time preserve the aesthetic qualities of the landscape. This implies a certain prejudgement of the situation as landscape quality is, of course, assessed subjectively.

There are approximately 10 million tons of gravel reserves within the area underlain by unit C in the study area, most of which are probably of commercial quality. Future demands have been examined and it is suggested that at least 90,000 tons of gravel will be extracted from the study area, each year, for the next 5 years. The excavation of these deposits will directly disrupt at least seven acres each year, possibly more. This land loss will probably adversely affect tobacco production and other agricultural enterprises, such as forestry, fishing, and tourism. Although some quantitative guide to the value of these activities has been given, the overall loss to the community, in terms of environmental quality, can never be completely measured. It is essential that decisions regarding the future of the study area are taken on a rational basis. In the past, too often, a complete lack of planning has resulted, in Prince Edward Island, in unnecessary land use conflicts.

A number of alternative sources of gravel supply lying outside the study area, are available to the highway construction and concrete manufacturing industries of Prince Edward Island. In this concluding section, these principal alternative sources of gravel supply are assessed and their social and economic impacts evaluated. The value of local gravel to the concrete industry is relatively small, and for the purpose of this study, is omitted, since a large proportion of material for this industry is imported from Folly Lake, Nova Scotia. In this study, the road programme was assumed to be a fixed objective, the benefits of which have been predetermined, and are to be achieved within a fixed budget.[1] Therefore, it is the costs of various alternative methods of achieving this objective that are considered in detail. Variations in these costs principally arise from the type of raw materials used, the quality of paved roads produced (and hence the cost of repairing these roads), employment and the number and nature of land use conflicts. Reclamation is also included as a variable affecting final costs. Other losses result from less tangible processes, for example continued depopulation of the province because of the loss of employment, and the reduction in aesthetically

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1. See p. 56

pleasing scenery. Although such intangible values cannot be included in a quantitative assessment, they must be qualitatively assessed. Such qualitative judgement may even prove to be the deciding factor between various alternatives, in the final analysis.

Private standards are not sufficient to define social efficiency, and for this reason any analysis must be made from the viewpoint of the regional interest of Prince Edward Island and not from the viewpoint of an individual entrepreneur or government agency.[1] Although the Department of Highways is the agency most directly concerned with gravel use, its aim is, naturally, to maximise the highway paving programme, within a given budget, and as a result, other factors, for example the level of local unemployment, disruptions of tourism and perhaps even the future maintenance cost of highways has been ignored or at least underestimated. Environmental management must be comprehensive and planned on a longterm basis; no organisation working solely for economic profit, or within a limited and inflexible budget, will produce optimum solutions to regional problems.

The cost-minimising equation used, in this study, is nothing more than a rudimentary attempt to include both social and economic costs in an evaluation. As long as it is not regarded as anything more than, "a useful means of weighing the implications of alternative courses of action", its use will not result in definitive statements of policy.[2] Many intangible costs cannot be quantified in the analysis and this

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1. W.R.D. Sewell et. al., A Guide to Benefit Cost Analysis, Ottawa, 1965.

2. Ibid.

limitation is inherent in any solution proposed. Such analyses, despite such limitations do indicate problem areas and allow the suggestion of optimum solutions to problems facing the province. However, it cannot be stressed too greatly, that, "not merely is benefit-cost analysis, conducted with ever so much refinement and sophistication, unable to replace judgement in the making of decisions, but it depends at every point on judgement in the choice of assumptions."[1]

The Alternatives

The gravels which develop as a result of weathering of unit C conglomerates meet only some of the standards set by the Province for pavement design, and are expensive to prepare for concrete manufacture.[2] Many exploited deposits, therefore, are of inferior quality and are also shallow. The use of such deposits results in high maintenance costs for highways, and is one of the basic causes of the proliferation of pits.

The nearest source of suitable quality rock, which could be crushed for aggregate was found to be Malignant Cove, Nova Scotia, but this is not at present being exploited.[3] The nearest source of high quality aggregate, presently being quarried, is Folly Lake, Nova Scotia, from which over 60 per cent of supplies for concrete

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1. R. J. Hammond, 1966, "Benefit-Cost Analysis", Natural Resources Journal, Vol. 6, p. 218.

2. See pp. 58-59.

3. W.S. Shaw, St. Francis Xavier University, personal oral communication.

production are already derived. High quality, glacio-fluvial gravels are currently being extracted on a small scale on the north coast of the Island, at Conway River (see figure 3).[1]

These alternative sources of gravel present a series of alternative courses of action:

(i) the continued use of existing land supplies including those in the study area,

(ii) the use of higher quality Island gravels, possibly from Conway river,

(iii) the use of gravel from Malignant Cove,

(iv) the use of both mainland gravel and local gravel.

The benefits and costs associated with these various alternatives are now examined in detail.

Assessing the Variables: (i) Cost of Supply

It is estimated that crushed gravels from the study area currently cost approximately $2.00-$2.50 per ton as they enter the asphalt plant. It has been estimated that the asphalt manufacturing industry of the Island will require some 130,000 tons of crushed gravel per annum for the next five years. At $2.00 per ton, the cost of this supply will be approximately $260,000 per annum, assuming that technological advances do not radically affect the demand, and that prices remain fairly constant.[2]

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1. See p. 23

2. Minimum values were used in order not to overstate the case.

If gravels were obtained from the Conway River glacio-fluvial deposits, which are thought to be more suited for asphalt manufacture, (an assumption that must be established by exhaustive testing), a price increase would occur throughout most of the Island, as a result of higher transportation costs. This increase would be approximately \$3.50 per ton, giving a total price of \$5.50 per ton. Clearly, this is prohibitively high. If only a proportion of the Conway River gravel were used, for example in the seal coat only, some 22½ per cent of the total gravel demand would be met, and the cost of supplying the road-building programme of Prince Edward Island would rise to approximately \$360,000 tons per annum. Aggregate from Folly Lake, used by the Island's concrete industry, is supplied by rail transport at a standard rate of \$3.75 per ton at the plant gate. If this material was used throughout the Island in the road building program little increase in this cost per ton would be expected under the present pricing policy.[1] The total cost of supplying gravel, obtained from Folly Lake, Nova Scotia would probably amount to \$480,000.

In the past, crushed rock from Malignant Cove, Nova Scotia, was used in an import operation based on self-loading barge transport. Gravel was taken directly to Charlottetown, Summerside and Georgetown. Some 5,000 tons were carried per load and a landing was made on the Island once every twenty-four hours, enabling 250,000 tons of main-

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1. Canadian National Railways policy as it existed in July 1969.

land gravel to reach Prince Edward Island in a single summer season.[1] This gravel cost approximately $1.80 per ton at its source; but added costs of $1.00 per ton for transport by barge, 15¢ per ton for dockside distribution in Prince Edward Island and an average of $1.00 per ton haulage charge on the Island (representing a 12 mile haul) were incurred giving a total cost of approximately $4.00 per ton. Although these prices applied in 1964, it is thought that subsequent technological advances and organisational efficiency might possibly lower this cost per ton, if such an operation were reestablished. For the purposes of this analysis, the figure of $4.00 per ton for gravel from Malignant Cove will be assumed. It would therefore cost $520,000 to meet a demand for gravel of 130,000 tons per annum using crushed rock from Malignant Cove. However, this material shows a weight loss of 37 per cent when tested for durability in a Los Angeles Abrasion test. Department of Highways specifications allow maximum weight losses of only 30 per cent and 18 per cent in the base and seal courses respectively, although gravels derived from Iona, in the study area, (already used in asphalt manufacture) show a weight loss of 20-25 per cent.[2] Malignant Cove aggregates, however, have more suitable grain-size distributions and roundness characteristics.

It is possible that a combination of mainland gravel and local gravel could be used for highway paving. Mainland gravels might perhaps be used for the seal coat, while the cheaper local gravels,

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1. D. R. Morrison, Morrison and MacRae Ltd., personal oral communication.

2. L. Bell, op. cit.

used exclusively in the base course. Provincial road construction projects employ 1½ inch base and ½ inch seal courses while other projects, that is joint federal-provincial projects, usually require a 3 inch base and 1 inch seal.[1] Of the total gravel required by the road building industry during the next five years, it is estimated that 22½ per cent will be used in the seal, and 77½ per cent of total gravel requirements will be employed in the base course.[2] If the suggested combination of Island and mainland gravel were used, 101,000 tons of Island gravel would still be required during the next five years costing some $202,000, together with 29,000 tons of imported gravel, costing $109,000, a total of approximately $310,000 per annum.

Assessing the Variables (ii) Quality of the Pavement

The strength of the pavement and hence the costs incurred in its repair, is partially dependent upon the grain-size distribution, roundness, and durability of the gravels used in the asphalt employed in construction. Provincial Department of Highway specifications state that particles must be, "free from coatings of clay, silt or other objectionable material".[3] It has already been established that local, study area gravels are not ideal for highway construction, and are often unsuitable in their natural state for use as either coarse or fine aggregate.[4] Crushed rock, from which mainland aggregates are composed, is manufactured to meet the grain-size and shape specifica-

1. L. McEwen, op. cit.

2. Estimate from information supplied by L. Bell, Prince Edward Island, Department of Highways, personal oral communication.

3. Department of Highways, Prince Edward Island, Specimen Contracts, Division 2, section 8, 2-3.

4. See pp. 36-51.

tions laid down by the Department of Highways and is, therefore, only likely to fail to meet soundness specifications.

During 1964-5, a series of experiments were carried out comparing the suitability of mainland gravels, from Folly Lake, and Island gravels for use in highway construction. These tests were conducted by Mr. J. A.A. Lefebvre on behalf of Mr. O. B. Berringer.[1] The object of the experiments was, to make maximum use of the local crushed gravel fines and sand, and minimum use of Folly Lake chips. It was found that when Prince Edward Island gravels were used,

> "the values for voids in the mineral aggegate (V.M.A.) are unusually high, 23.0 and 26.8 per cent. The Marshall stability values are very low, being in the range of only 200 to 400 pounds. The reason for the high VMA and high air voids' values, and low Marshall stabilities is shown to be the concave downward shape of the grading curves. This concave downward shape indicates that there is far too much of some of the finer size fractions to fit into the void spaces between the larger particles. Consequently the whole aggregate structure is forced apart, and ... pavement stability is seriously diminished."[2]

The report also states that, "the trial mixes improve as the percentage of Folly Lake chips increases and as the per cent of native sand decreases," and concludes that,

> "the cost of producing Mix No. 2 (the mix with higher percentage of Folly Lake chips) will be higher than that of Mix No. 1 (the mix with predominantly local material). Consequently someone has to decide whether or not the apparently higher quality of Mix No. 2 for surface course which should result in longer life, lower maintenance and better service performance, is worth its higher initial cost."

As the analyses of the physical characteristics of local gravels, undertaken by the author, show these to vary, so the mix used to

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1. The result of these tests were described in two letters given to the author by L. Bell, op. cit.

2. N.W. Mcleod, Memorandum on Hot-Mix Designs for Prince Edward Island, Department of Highways, 1965.

produce seal coat at each manufacturing plant varies. The best results are produced with the use of 75 per cent of Folly Lake chips at St. Eleanors (Curran & Briggs), 70 per cent at Bayfield (Morrison & MacRae), and 83 per cent at Crapaud (Morrison & MacRae)[1] For this reason, it can only be estimated that 22½ per cent of total aggregate requirements would need to be met by Folly Lake chips.

The only method of assessing the decrease in the costs, if Folly Lake chips are used in the seal coat, is to consider the costs of repairs to road pavement. At present, maintenance costs average $200,000 per year, on pavement manufactured exclusively using Island gravels. It is estimated that the few roads constructed during the period when all gravel was imported from Malignant Cove, require maintenance which cost 75 per cent less than similarly travelled roads built with Island gravels.[2] If all roads were constructed using such mainland gravel, total maintenance costs would therefore be only some $50,000 per annum, a saving of some $150,000 annually. If the seal coat only on proposed highways, were composed of better quality aggregate, whether it originated from Folly Lake or Conway River, a saving in maintenance costs of perhaps $100,000 per annum would be achieved.

Assessing The Variables (iii) Employment

Approximately two per cent of the total labour force of the province are employed, during some period of the year, by the asphalt

1. N.W. McLeod, Imperial Oil Ltd., letter to Mr. O.B.Berringer, Nov. 11, 1964.

2. L. Bell, op. cit.

3. Based on interviews with representatives of all Island asphalt manufacturing firms.

manufacturing industry. Of these 650 persons, approximately 65 are employed in excavating and crushing gravel.[1]

Should either of the alternatives requiring the import of all road construction aggregates be adopted, all 65 employment opportunities would be lost. The average wage of these employees, in extraction and crushing, is approximately $2,500 per annum. There would therefore be a total loss of $162,500 in wages if all became unemployed, and $32,500 if 22½ per cent became unemployed.

A number of truckers would also be affected by the adoption of any of the alternatives outline above. If gravels for use in the seal coat were trucked from Conway River, an increase in the distance of haul of some 45-50 miles would occur. This would add $100,000 to the cost of gravel used in seal coat throughout the Island, in a single year, and could theoretically provide an additional 40 jobs for truckers. Should Folly Lake materials be used for all highway construction, asphalt plants would be relocated on rail facilities, so that the present employment of truckers in moving gravel from the pit to the present locations of the plants would be lost. Such transport would probably involve the movement of 130,000 tons per annum which is carried at 8¢ per ton, per mile, an average of six miles (11¢ per ton is charged for the first mile), a total cost of approximately $65,000 or some 26 jobs.

However, if only 22½ per cent of the gravel used in road construction was imported, relocation of the plants would probably not occur

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1. Based on interviews with representatives of all Island asphalt manufacturing firms.

and aggregates would be transported, by truck, from rail terminals to asphalt plants. Truckers would, therefore, be required for this operation and no unemployment would occur. If mainland gravel from Malignant Cove or elsewhere were used and reached the Island by barge, truck transport from the dockside at Charlottetown, Summerside and Georgetown would be required. This would probably cost $1.00 per ton, an increase in 50¢ over present average cost because of the greater distances involved, and would result in an increased investment of $65,000 in trucking, which again represents 26 jobs. Table 7 shows the possible effects of all these alternatives on employment.[1]

Assessing the Variables (iv) Land Use Costs

It is difficult to assess the losses to agriculture, which result from gravel extraction, but the maximum possible losses would occur only if all ten acres excavated had previously been in tobacco production. In this unlikely case, losses up to $1600 per acre would occur. In fact, the losses per annum to agriculture will probably be much fewer than this. Although some ten acres per annum will be lost to gravel extraction on Prince Edward Island during the next decade, the effects of that extraction will be felt over a much wider area.

The most important losses to the economy would be manifested by a drop in tourist traffic. If only one per cent of the tourists visiting

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1. See p. 113

TABLE 7[1]

THE EFFECTS OF VARIOUS ALTERNATIVE COURSES OF ACTION ON EMPLOYMENT

Alternative Courses of Action	Extraction & Crushing		Truckers		Total	
	Dollars	Employment	Dollars	Employment	Dollars	Employment
1. 100 per cent from P.E.I.	nil	nil	nil	nil	nil	nil
2. 22½ per cent from Conway River	nil	nil	+100,000	+40	+67,500	+27
3. 100 per cent from Folly Lake	-162,500	-65	-65,000	-26	-227,500	-91
4. 22½ per cent from Folly Lake	-32,500	-13	nil	nil	-32,500	-13
5. 100 per cent from Malignant Cove	-162,500	-65	+65,000	+26	-97,500	-39

1. Source: interviews with D.R. Morrison, Morrison & MacRae Ltd. and E. Matheson, Matheson & MacMillan Ltd.

the Island were deterred from making a subsequent visit, by gravel extraction and assoiated industrial activity, a gross revenue of $168,000 would be lost (assuming that each visitor spends $10 per day[1] and remains on the Island for seven days).[2] Probably less tourist revenue would be lost if land reclamation took place after a pit were no longer required.

Losses to forestry are minimal (only $9 per acre) compared with tourism and agriculture. All other losses, to fishing, wildlife, and landscape quality, are intangible, but nevertheless, important. Sacrificing the standard of life for increases in the standard of living, has been an error too frequently made elsewhere to be repeated on Prince Edward Island.

<u>Reclamation</u>

> "In the end, society must decide how much it is willing to pay for reclamation:
> (a) either in terms of reduced income to farmers and other land owners because they bear the costs of pushing back the top soil.
> (b) or in terms of a subsidy that the government would be willing to pay to keep the land attractive to tourists."[3]

An abandoned gravel pit may remain simply this, or it may be filled and the land restored to its former use. It may however, be cheaper to reclaim for some alternative purpose. In the study area, it is undoubtedly cheapest to plant trees in abandoned gravel pits. Perhaps

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1. M. Clawson and A. Kretsch, <u>op. cit</u>. p. 236.
2. T. Morrison, <u>op. cit</u>.
3. W.R.D.Sewell, <u>op. cit</u>.

more logically the highest possible land use value on the site occupied by the quarry may be determined so that reclamation may achieve this end.

The desirability of reclamation, can, in part, be judged by the amount of it which has occurred in the past. In the United States of America, 3.2 million acres have been surface mined, of which, approximately 33 per cent has been reclaimed. Of this, 46 per cent is classed as natural reclamation, 51 per cent reclaimed by the industry and three per cent by government agencies.[1] For example, the National Sand and Gravel Association stated that, of land surface mined by its members in 1965, more than 50 per cent was reclaimed, whereas in 1963 only 25 per cent was reclaimed; (it should be noted that this is a voluntary United States organisation).[2] Clearly there would appear to be an increase in the value of reclamation occurring in North America, probably as a result of public pressure. If no action were taken, within twenty-five years, most of the excavations made in Prince Edward Island would be vegetated by secondary growth, probably poor quality trees. However the land would be of little, if any value, as shown in plate 9.[3]

There are a number of precedents which may be followed if it is decided to adopt land conservation policies in the area. For example,

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1. U.S. Department of the Interior, Fish and Wildlife Service, Surface Mining and Our Environment, Washington 1964, p. 74.

2. Quoted by D.L.Reimer, Surface Mining: A Geographical Study with a Focus on British Columbia, unpublished B.A.Thesis, University of Victoria, 1969.

3. See p. 125

in British Columbia the Mines Regulation Act, 1967, governing surface mining states that,

> "during the entire period of production from a surface mine, the owner agent or manager,
> (a) shall continually and progressively reclaim the surface of the land affected by the mining operation; or
> (b) deposit as security in a manner satisfactory to the minister in each year, a sum of money that, together with the deposit made in compliance with subsection (b) and calculated over the estimated life of the mine, will provide the funds necessary to properly perform and carry out
> (i) all the requirements of the approved programme at the proper time; and
> (ii) all the orders and directions of the chief inspector or an inspector respecting execution of the approved programme."[1]

In addition, before the mine is opened a complete file on the site; past, present and future, must be presented to the appointed minister. Enforcing this legislation depends upon the minister, who may apply these provisions at his discretion. This government intervention appears justified since the maximisation of profits from extraction and the maintenance of other resource values are mutually exclusive.[2]

The main problems existing in the study area concern the storage of overburden, the removal of waste products (for example, trees, derelict equipment) from the pit, the grading of slopes and replacement of overburden after the cessation of operations. It is also unclear to what use the land should be restored. Forest plantations represent the cheapest form of reclamation. For example it has cost as little as $12 per acre for reclamation of coal pits at Minto, New Brunswick, while in Prince Edward a figure of some $30 per acre is probably more reali-

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1. British Columbia, Statutes, British Columbia Mines Regulation Act, 1967, Ch. 25, section 8.

2. D. L. Reimer, *op. cit.*, p. 77.

stic. It should be stressed that financial returns are also very low.[1] Agricultural returns may, after reclamation, be higher, but so are the initial costs of this process and these cannot be borne by most Prince Edward Island farmers who have insufficient capital to support them.

Existing legislation in the province requires that every excavator obtain a license. While it was stated, by a representative of the provincial Department of Municipal Affairs, that no such licenses had ever been issued, the author was shown one such license by a representative of an asphalt manufacturing company.[2] Proposed legislation is being considered by the Department of Municipal Affairs which, at present has only planning jurisdiction over municipal urban areas and a strip of land extending 540 feet either side of the centre of paved roads.[3] It is considered administratively impossible for this Department to control planning, throughout the Island, for at least five years.[4] However it will be during this period that major demands will be made on gravel reserves and serious damage may occur if gravel extraction is not controlled. If a reclamation policy is adopted, but delayed five years, its value may be negligible. Another alternative is that in the interim period, control could be exercised under the provincial 'Unsightly Premises Act'.[5]

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1. I. Miller op. cit.
2. D.R.Morrison, op. cit.
3. S. Bishop Department of Municipal Affairs, Prince Edward Island, personal oral communication.
4. Ibid.
5. Ibid.

The responsibility for the formulation of reclamation policy lies with the provincial departments concerned; the Departments of Highways, Mines and Natural Resources, Municipal Affairs, Tourist Development and Agriculture. Any decision should have the full cooperation of all these bodies and should be in accord with the spirit of the Development Plan for Prince Edward Island. If a reclamation policy is adopted, the timing, the amount of planning control, and finance should be mutually satisfactory.

Cost of Reclamation

It is estimated that a maximum of $500 per acre is required to enable the replacement of the overburden in a pit, allow the clearance of the site and finance planting of trees.[1] Necessary resiting or landscaping of industrial sites and the inclusion of dust control devices on asphalt manufacturing plants could be achieved, within the study area, for a cost of approximately $15,000. It is therefore reasonable to assume that in the entire province a figure of $30,000 would cover these costs. If ten acres of gravel bearing land are to be reclaimed annually, the cost for this alone would reach $5,000 per year. Spread over a five year period industrial landscaping would cost $6,000 per year, giving a total annual investment of $11,000 per year for reclamation covering current industrial operations. In contrast, the application of alternative solutions to the problem of supply would lower this reclamation figure. If all materials were imported, reclamation costs would only apply to the industrial sites; a cost of $6,000 per year, over a five year period.

1. E. Matheson, op. cit.

CHAPTER VII

RESOLUTION AND CONCLUSIONS

Conclusions

Within the study area, some 10,000,000 tons of gravel reserves have been shown to exist over a wide area. Most of which will probably be acceptable for both asphalt and concrete production, although some specifications are not met. Other sources of gravel, in particular, Folly Lake, Malignant Cove and perhaps Conway River are more suitable. Accordingly an analysis was made of the costs of utilising gravel from these various sources, taking into account conflicts of land use on the Island between gravel extraction and various other land based activities.

There are four significant costs which will vary, depending upon which alternative method of satisfying the demand for gravels is adopted. These are; the cost of supply, the cost of highway maintenance, the cost of lost employment and the loss of revenue to other land orientated industries. This latter cost is associated with the cost of reclamation. Table 8 summarises these costs.[1]

Source of Supply

The cost-minimising equation used in this study demonstrates that the cheapest alternative course of action open to the province is to use Island gravel, with special emphasis on the Conway River

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1. See p. 120.

TABLE 8

THE COST MINIMISING SOLUTION
(all figures in $,000)

Alternative Sources of Gravel for Road Construction	Supply	Repairs	Employment	Land Use Agriculture (Maximum)	Land Use Reclamation	Total
1. 100 per cent gravel from Prince Edward Island the _status quo_	260	200	nil	16	11	487
2. 22½ per cent gravel from Conway River, remainder from other Island sources.	360	100	+67.5	12.5	11	416
3. 100 per cent gravel from Folly Lake, Nova Scotia	480	50	227	nil	6	563
4. 22½ per cent gravel from Folly Lake, remainder from Island sources	310	100	32.5	12.5	10	465
5. 100 per cent gravel from Malignant Cove, Nova Scotia	520	50	97.5	nil	6	673.5

deposits. If the Conway River gravels prove, after detailed examination to be any more suitable to the grain-size distribution and roundness specifications, than other Island gravels, they should be used in the seal coat. This course of action would also result in additional employment opportunities on the Island.

Should the Conway River gravels not meet the specifications of the Department of Highways there appears to be no other alternative source of high quality material on the Island. In this case two alternatives should be considered. Gravel extraction may simply continue within the province from the areas currently exploited, although legislation is necessary to ensure that reclamation is carried out. If not, the losses to tourism will probably make up for the added costs which would be incurred if all gravels were imported by rail from Folly Lake, Nova Scotia. The other alternative is to import 22½ per cent of gravel from the high quality reserves of Folly Lake which will result in an improvement of highway quality. The choice of these alternatives depends on the relative importance attached to road quality as opposed to employment opportunity and the cost of gravel in the equation presented as Table 8.[1] Both these alternatives depend on the implementation of reclamation to minimise losses to tourism and the quality of the environment. If this is not done it would be cheaper for the province to obtain all its gravel supplies by rail from Folly Lake.

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1. See p. 120.

Reclamation

Land reclamation is essential in Prince Edward Island. Two systems are possible, these may be used either independently, or in conjunction one with another. The first is the bonding system, developed and applied to much of the strip mining activity in the United States, while alternatively zoning regulation, which give governments total control over all developments in the zoned area can be applied. Either of these methods may be comprehensive or selective, although zoning is, in practical terms probably the only method of selective reclamation. An important effect of such control, might be the obtaining of leases and land by firms which do not intend to exploit the deposits but simply prevent others from using them. There is a fear in Kings county, that despite the large reserves, leases and land will be obtained by individuals, who could prevent the most economic use of the Island's gravel resources.[1] Possibly a survey of the ownership of reserves, in the remainder of the Island, is required and some consideration must be given to the rights under which the gravel is exploited. One suggestion is that leaseholders be obliged to extract a minimum amount of gravel each year, say 20,000 tons; however a large problem still remains as much of the gravel is on land owned by the companies. Although this might also lead to a proliferation of unnecessary pits. The physical appearance of the landscape has some value, which is manifested in the scale of reclamation considered desirable, and reflects a series

1. E. Matheson, op. cit.

of subjective judgements by tourists, and inhabitants. Above all, the attitudes of the resident population toward their environment, manifested in the legislation of the province, "depend upon an interaction between people and the regional resources base ..."[1] "The concern of conservation is not with nature alone, but with the total relationship between Man and the world around him."[2]

Reclamation of Borrow Pits and Abandoned Gravel Quarries

Reclamation of pits is certain to be criticised since abandoned gravel quarries are only a part of landscape deterioration occurring in Prince Edward Island. Other major causes for concern are the "borrow pits" from which sandstones and other materials are excavated to form both road embankments and driveway exits.[3] Abandoned farms, the buildings of which are decaying and the fields overrun with spruce and other tree species, are also adding to the degeneration of "rural charm". The latter problem is beyond the scope of this study, but the former should be examined if any reclamation policy is to be successful. Although no study was made of 'borrow' pits by the author, several examples of "borrow pit" reclamation were noted, as the sandstone bedrock is easily weathered, the only reclamation necessary is the replacement of some top soil after levelling, in one instance farm operations were resumed within one year of the cessation of excavations. However many landholders, desiring extra

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1. R.H. Twiss and R. Burton, 1966, op.cit.

2. L.B.Johnson, President of the United States 1965, quoted by Ibid., p. 76.

3. Dominion Bureau of Statistics figures indicate that almost 500,000 tons of sandstones, etc. were excavated in 1966 for these purposes.

income, prefer to keep a pit open so that they may make future sales, at some future date.[1] As a result often, despite offers from the extractor to reclaim the pits, they are left open. Clearly a provincial government policy governing the reclamation of gravel and "borrow pits" is required.

Within the study area, some 276 acres are presently occuppied by gravel pits over which little control has been exercised. Approximately $140,000 would be required to grade and afforest these pits. Many of these pits are, however, unobtrusive and, as such, do not form a serious threat to environmental quality. Some pits do however detract from aesthetic qualities. Should the reclamation of these pits be undertaken by the government, priorities should be established which take into consideration, not only gravel pits, but also borrow pits. Those excavations on major tourist routes should probably receive priority together with those adjacent to towns or villages. Some ten per cent of the abandoned pits in the study area are of this type, and could be reclaimed for some $14,000. If this cost were absorbed over five years, only $3,000 per annum need be spent, sufficient for reclamation of six acres each year.

Abandoned pits, for which neither the landholder nor the exploiter can probably be held responsible are poor in soil and vegetation even after a considerable time period, and remain open to public view. It seems likely that only the provincial government will assume responsibility for reclaiming these pits, no other organisation can be expected to bear the cost of returning this land to production.

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1. L. McEwen, op. cit.

Plate 9 Constrasting abandoned Gravel Pits

(i) Bayfield, North of Souris (NG6448)

(ii) Montague (NG2809)

It is possible that more imaginative projects than afforestation might be carried out, and some abandoned pits could provide recreational opportunities not found elsewhere in the Island.

Normally any project requiring high investment must be accompanied by an adjacent concentration of population, in order to provide the consumer demand for the projects' benefits. No such concentration exists in the study area, and hence projects, unless designed to attract tourists would have to be achieved at a very low cost. The most obvious functional use for abandoned gravel pits is their use as garbage or car dumps. After filling, under controlled conditions, the top soil may be replaced and many other land use activities re-established. At Murray River, garbage disposal takes place in pits dug especially for this purpose, while gravel pits lie abandoned nearby.

Plate 9 shows the most attractive abandoned pit in the study area.[1] The high water table has allowed the establishment of a permanent aquatic habitat, probably already stocked with fish. The other pit shown in plate 9 is however more typical of abandoned pits in Prince Edward Island.

Other, more exotic uses for abandoned pits, might include motorbike scrambling areas or bird sanctuaries. In the United States of America, wildlife sanctuaries have land values estimated at $1300, per acre much higher than any present land values in the study area.[2]

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1. See p. 125

2. C. Davies, Land Evaluation Officer, Economic Improvement Corporation. personal oral communication.

Unfortunately, the great depth of the water table below the surface, in many areas, precludes the establishment of aquatic parks which, scenically, are very attractive. Outside the study area, tourist homes have been built within old pits near Mill River (southeast of Alberton), in what is now an exceptionally beautiful setting. The possibilities offered by each individual pit should be considered before general reclamation procedures are carried out, Naturally, however, all proposed development must help to achieve the overall goals set by the Development Plan for Prince Edward Island.

Conclusion

In the smallest province in Canada, as elsewhere in North America, 'progress' is contributing to a decline in landscape quality. Gravel quarrying, and its associated works, are a major contributor to this decline, especially in the southeastern part of the Island. Gravel is, however an essential raw material for road paving and concrete production. This study has attempted to demonstrate that a compromise can be achieved here, as in most other areas of conflict, which reflects the aims of conservation and the dictates of economic competition.

Geographers not only give rational advice, they also make value judgements, so in this study the results of a geomorphological inquiry are utilised in the resolution of a particular geographical problem. The solutions suggested do take into account value-judgements, for the geographer does have viewpoints, he is opinionated and as these opinions arise from his training as a geographer they properly belong in a geographical study. As Carl Sauer says, "We need not say that it is not for us to cross the threshold of value judgements . . . As we study how men have used the resources available to them, we do distinguish between good and bad husbandry, between economical or conservative and wasteful or destructive use . . . we do not like soil erosion, forest devastation, stream pollution. We do not like them because they bring ugliness as well as poverty. . . we also think that misconduct is more than a matter of profit and loss . . . and we are aware that what we do will determine for good or evil the life of those who will come after us."[1]

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1. C. O. Sauer, "The Education of a Geographer", 1956, AAAG, Vol. 46 p. 299.

BIBLIOGRAPHY

Acres Research Ltd. Development Planning for Prince Edward Island. Charlottetown, 1967.

A.R.D.A. Soil Capability Map for Agriculture in Prince Edward Island. Ottawa, 1966.

Atlantic Development Board. Maritime Farm Enterprise Analysis. Ottawa, 1969.

Atlantic Field Crops Committee. 1969 Field Crops Recommendations for the Atlantic Provinces. Charlottetown, 1969.

British Columbia, Statutes. British Columbia Mines Regulation Act. 1967.

British Columbia Revised Statutes. "An Act to Amend the Mines Regulation Act, 1969". 1969.

Brooks, D. B. "Strip Mine Reclamation and Economic Analysis". Natural Resources Journal. Vol. 6, 1966.

Bryan, K. "Geomorphology in Geographic Sciences." AAAG. Vol. 40, 1950, 196-208.

Canada and Prince Edward Island, Development Plan for Prince Edward Island. Charlottetown, 1969.

Canadian Good Roads Association. American Standards Testing Manual.

Chorley, R. J. Geomorphology and General Systems Theory. U. S. Geological Survey Professional Paper, 500-B. Washington, 1962.

Clark, A. H. Three Centuries and The Island. Toronto, 1965.

Clawson, M. and Kretsch, J. Economics of Outdoor Recreation. Johns Hopkins. 1966.

Folk, F. L. and Ward, W. C. "Brazos River Bar: a Study in the Significance of Grain-Size Parameters." Journal of Sedimentary Petrology. Vol. 27. 1957. 3-26.

Foster, H. D. Alternative Sources of Gravel for Prince Edward Island; A Preliminary Review of Physical and Economic Factors. University of Victoria. 1969.

Foster, H. D. "Geomorphology: Academic Exercise or Social Necessity." Geographica 1969, 283-8.

Frankel, L. Geology of Southeastern Prince Edward Island. Geological Survey of Canada. Bull. 145, Ottawa, 1966.

Goulston, B. Communication with Mr. O.B. Berringer. Unpublished, 1964.

Hammond, R. J. "Benefit - Cost Analysis". Natural Resources Journal, Vol. 6. 1966.

Inman, D. L. "Measures for Describing the Size Distribution of Sediments". Journal of Sedimentary Petrology. Vol 22. 1952. 125-45.

Johnson, L. B. quoted by R. H. Twiss and R. Burton in, "Resource Use In the Regional Landscape." Natural Resources Journal. Vol. 6 1966, p. 76.

Kikolski, B. "Contemporary Research in Physical Geography in the Chinese Peoples Republic". AAAG. Vol. 1964, 181-9.

King, C.A.M. Techniques in Geomorphology. London. 1966.

Krumbein, W. A. and Pettijohn, F. J. Manual of Sedimentary Petrology New York, 1938.

Lucas, R. C. "Wilderness Perception and Use: The Example of the Boundary Waters Canoe Area". Natural Resources Journal. Vol. 3 1964, 394-411

Mcleod, N. W. Memorandum on Hot-Mix Designs for Prince Edward Island Department of Highways. unpublished, 1965.

Milligan, G. C. Geological Survey of Prince Edward Island. Department of Industry and Natural Resources, Prince Edward Island, Charlottetown. 1949.

Moore, H. R. and Headington, R. C. Agricultural Land Use as Affected by Stip Mining of Coal in Eastern Ohio. Bulletin 135. Ohio State University Agricultural Experimental Station. 1940.

Pepin, P. Y. Life and Poverty in The Maritimes. ARDA Research Report No. RE - 3. Ottawa. 1968.

Portland Cement Association. Design and Control of Concrete Mixtures. 10th Edition.

Prince Edward Island, Department of Highways. Specimen Contracts.

Prince Edward Island, Statutes. Fish and Game Protection Act. (amended to 1966) 1959.

Reimer, D. L. Surface Mining: A Geographical Study with a Focus on British Columbia. University of Victoria. 1969.

Russell, R. J. "Geographical Geomorphology". AAAG. Vol. 39. 1949. 1-11

Sauer, C. O. "The Education of a Geographer". AAAG. Vol. 46, 1956.

Sewell, W.R.D. et al. Guide to Benefit - Cost Analysis. Ottawa, 1965.

Sewell, W.R.D. and B. T. Bower, et. al, Forecasting the Demands for Water. Ottawa. 1968

Soiltest Inc. Earth Resistivity Manual. Evanston, Illinois.

Soiltest Inc. Terra-Scout R-150 Refraction Seismograph. Evanston, Illinois.

Strahler, A.N. "Statistical Analysis in Geomorphic Research." Journal Geology. Vol 62. 1954. 1-25.

Twiss. R. H. and Burton, R. "Resource Use in the Regional Landscape". Natural Resources Journal, Vol. 3, 1966, 76-81.

U.S. Department of the Interior, Fish and Wildlife Service. Surface Mining and Our Environment. Washington, 1964.

Vining, R. Quoted by P. Haggett, in Locational Analysis in Human Geography. London, 1965, p. 13.

Wentworth, C. K. Quoted by C.A.M. King in Techniques in Geomorphology. London, 1966, p. 276.

Whiteside, G. B. Soil Survey of Prince Edward Island. Charlottetown, 1950

Wooldridge, S.W. "The Trend of Geomorphology." Inst. Brit. Geog. Vol.25, 1958, 29-36.

Young, M. Forecasting and the Social Sciences, London, 1968.

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APPENDIX I

GRAIN-SIZE ANALYSIS

1. Unit C

Sample Number	Mean ∅	Standard Deviation ∅	Skewness ∅
2	-3.3	+1.4	+0.21
8	-3.0	+1.9	+0.26
12	-2.3	+2.7	+0.33
16	-1.4	+2.8	+0.57
17	-2.0	+2.9	+0.34
18	-2.3	+2.9	+0.34
20	-2.1	+3.1	+0.45
21	-2.2	+2.9	+0.34
22	-2.1	+2.8	+0.29
23	-2.1	+2.6	+0.35
27	-2.2	+1.5	+0.87
28	-2.0	+3.1	+0.32
29	-2.0	+3.2	+0.41
30	-1.9	+2.4	+0.25
31	-2.2	+2.8	+0.32
32	-2.5	+2.6	+0.38
33	-2.4	+2.7	+0.41
34	-2.1	+2.8	+0.25
36	-2.1	+2.9	+0.25
38	-2.9	+2.4	+0.50
39	-2.1	+3.2	+0.41
40	-2.1	+2.7	+0.33
41	-3.8	+1.1	+0.55
42	-1.6	+2.9	+0.31
43	-2.1	+2.8	+0.32
45	-2.4	+3.1	+0.55
48	-2.7	+2.4	+0.38
50	-2.4	+2.2	+0.27

2. Unit B

Sample Number	Mean Ø	Standard Deviation Ø	Skewness Ø
1	-0.1	+2.8	+0.21
2	-2.0	+2.5	-0.08

3. Fluvio-Glacial

1	-1.7	+2.6	+0.04

Calculation of Regression Equations shown in figure 10.

Variable	Mean	xy	x^2	
Means	-2.3	157.35	154.07	0.48
Standard Deviations	+2.6	23.65	197.1	0.52
Skewness	+0.38		4.47	0.13

Product Moment Correlation Coefficient

Mean and Standard Deviation $r=0.90$

Mean and Skewness $r=0.36$

Regression Equations:

1. Mean and Standard Deviation $a=0.83b-4.46$; $b=0.98a+4.84$
2. Mean and Skewness $a=1.40b-2.85$; $b=0.10a+0.61$

Where 'a' represents the mean, and 'b' the standard deviation and skewness respectfully.

APPENDIX II

SEISMOGRAPHIC SURVEY

Survey Number and Location			Velocities (feet per second) top soil	weathered layer	bedrock	Depth (feet) top soil/ weathered layer	weathered layer/ bedrock
1.*	1	NG151071		2800	5500		11.6
	2	150074		2600	3750		8.7
2.	1			2200	3600		7.5
3.*	1	NG215078	2800	3600	5200		14.5
	2	218076		1900	4500		18.6
	3	216080		1800	8500		20.5
	4	216083	1600	3200	6500	9.3	28.1
	5	209071	2000	3500	4500	5.0	18.0
4.	1		1900	4500	6200	13.3	25.6
	2			4400	6500		10.5
5.	1			5000	6000		13.6
	2			1750	7000		19.9
	3			4200	8000		17.4
	4		1700		8500		10.3
	5			3400			
	6		1550	6000	10,000	5.25	19.6
	7			4000	6500		16.8
	8		3000	6000		6.4	
	9			3750	4500		13.0
	10			1600	4000		12.9
	11			4000	8000		17.4
6.	1		1800	4100	5900	8.7	24.3
	2			2300	4500		14.2
	3			2300	3600		10.8

Survey Number and Location		Velocities (feet per second)			Depth (feet)	
		top soil	weathered layer	bedrock	top soil/ weathered layer	weathered layer/ bedrock
	4		2000	6250		22.3
	5		3400	7000		25.2
	6		2500	5000		10.2
	7		2000	5000		16.8
	8	1150	3500	7000	3.0	19.0
8.	1		1950	4000		24.1
	2		1700			
	3	1200		4500	7.6	
	4					
	5		2100	6000		15.8
	6	1200	2750	4000		17.6
	7	1350		5000	9.6	
	8		2100	8000		32.0
	9		2000	5300		11.9
	10	1200		3900	7.2	
	11	1000		4000	10.5	
	12		3300	5000		16.0
9.	1		1550	3550		8.4
	2		2000	3500		8.6
	3		3000	4700		9.2
	4		1600	4250		7.9
	5		2000	5500		22.5
	2	1900	4500	6500		12.6
	3		2400	6000		29.7
	4			2300		
	5		2100	13000		34.4
	6			4800		

Survey Number and Location		Velocities (feet per second)			Depth (feet)	
		top soil	weathered layer	bedrock	top soil/ weathered layer	weathered layer/ bedrock
	7		1800	5000		13.6
	8			2200		
10.	1			2000		
	2	2000	3400	6000		16.1
11.	1		1900			17.4
	2	1200	2400	3500		10.5
	3	1100	2200	3500		15.6
	4	1500	2300	4600		18.6
	5	1200	2400	8000		24.1
	6	1300	3100	5000		13.2
13.	1 NG340023		1700	3500		16.8
	2 349020		1850	8000		31.2
	3 338033		2200	7000		18.7
14.	1		2000	5500		20.5
	2	1550	2400	9500		24.6
	3	2000	4700		7.4	
	4	1400		5200	8.4	
	5		2400	5800		15.7
	6		1800	5500		12.9
	7		3000	5200		9.5
	8		2300			
	9		2000	5000		18.5
	10		1900	9000		16.4
15.	1		2000			
	2		2500	3800		16.6
	3		2000	5600		23.8
	4		2000			

Survey Number and Location			Velocities (feet per second)			Depth (feet)	
			top soil	weathered layer	bedrock	top soil/ weathered layer	weathered layer/ bedrock
	5			1900	8000		25.7
	6			1900	5600		21.4
17.	1		1500	3500	4600		13.0
	2			2300	4000		5.25
	3		1500	2400	5000		13.5
	4			1400	4500		12.6
	5		2000	3000	9500		28.4
	6			2200	4000		15.3
	7			3000	5500		16.7
	8			1700	5200		8.36
18.	1			1900	5000		24.8
	2			1800	4800		8.9
	3			2000	4900		23.7
	4			1900	5000		10.9
	5			2600	5000		16.2
	6			2400	7900		37.6
	7		1800	2800	10000		20.7
	8		1300		4000	7.2	
	9			1800	9800		18.0
	10		1850	4800	8000	16.5	32.9
	11			1700	7000		22.2
19.*	1	NF166990		2900	4500		
20.	1			2400	4700		17.7
	2			2300	5500		15.0
	3						
21.	1		1400	2100	7000		18.5
	2			2500	3700		7.3
	3			2300	4800		13.2

Survey Number and Location		Velocities (feet per second)			Depth (feet)	
		top soil	weathered layer	bedrock	top soil/ weathered layer	weathered layer/ bedrock
22.	1		2400	5500		23.2
	2		2250			
	3		1850	4300		18.6
	4		1800	5800		16.2
	5		1800	6250		19.9
23.	1		2100			
	2	1000	2800		9.8	
	3	1600	2800	8000	10.4	34.6
	4		2250	3400		17.6
	5		2000	5000		27.7

* Surveys sites which are not shown in figures 5 and 6.

APPENDIX III

HIGHWAY ESTIMATES

The estimate of 130,000 tons demand for asphalt on Prince Edward Island is based on the average road mileage paved in the last ten years, by all agencies, and figures supplied by the Department of Highways showing the amount of aggregate required for pavement at various specifications.[1] These specifications show the following requirements:

Base Course: 614 tons of aggregate at 20 ft. width in tons/inch/mile.
Sand Seal Course: 546 tons of aggregate at 20 ft. width in tons/inch/mile.

Further it is stated that in 1968[2] Provincial Projects were 18 feet in width, 1½ inches base, and ½ inch seal. Other Projects were 22 feet in width, 3 inches base, and 1 inch seal.

During 1968, the Atlantic Development Board paved 43.5 miles, while the provincial authorities paved 30.3 miles. A further 20,200 tons of asphalt were laid on the Trans Canada Highway at Wood Islands.[3] It is stated that 247,000 tons of asphalt were laid, of which approximately 94% consisted of aggregate- 235.000 tons. Calculation from the above specifications shows that only 147,500 tons of asphalt should theoretically have been required, which, with the additional 20,200 tons included, leaves 65,300 tons unaccounted. Further calculation shows that to utilize this quantity of gravel, the base course would need a further 280 tons and the sand seal course would require a further 250 tons per 20 feet width per inch per mile. If these revised figures are, in fact correct, the original demand estimates of 130,000 tons per annum is grossly underestimated by approximately 45% or 60,000 tons.

[1] L. Bell, Prince Edward Island, Dept. of Highways, personal written communication.
[2] L. McEwen, Prince Edward Island, Dept. of Highways, personal written communication.
[3] Ibid.

APPENDIX IV

FARM ENTERPRISE ANALYSIS

1. # 32, Dairy; 54 Animals.

200 Acre Farm A L.O.P. Except For Crop And Fertilizer At D Level

Return above Current Expenses:			$ 14,879
Fixed Expenses:			
	Telephone & Electricity	$ 400	
	Equipment Depreciation	1,838	
	Building Depreciation	1,350	
	Real Estate Taxes	503	
	Insurance	165	
	Building Repairs	540	
	Labor	3,325	
		$8,121	
Inventory:			
	Equipment	$18,375	
	Livestock	16,578	
	Feed & Supplies	3,764	
		$38,717 x 6%	$ 2,323
Return to Real Estate Ownership Labor & Management:			$ 4,435
Charge for Operator's Labor & Management: (3000 + 5% TR)			$ 4,595
Return to Real Estate Ownership:			$ - 160
Return to Real Estate Ownership/Cultivated Acre			$ - .80
Mean Value of Buildings:			$ 13,500

2. # 39, 170 Holstein Calves raised to 1145 lbs.

200 Acre Farm A L.O.P. Except For Crop And Fertilizer At D

Return above Current Expenses:		$ 9,468
Fixed Expenses:		
Telephone & Electricity	$ 400	
Equipment Depreciation	1,579	
Building Depreciation	425	
Real Estate Taxes	364	
Insurance	101	
Building Repairs	85	
Labor	420	
	$3,374	
Inventory:		
Equipment	$15,785	
Livestock	5,100	
Feed & Supplies	2,118	
	$23,003 x 6%	$ 1,380
Return to Real Estate Ownership Labor and Management:		$ 4,714
Charge for Operator's Labor & Management: (3000 + 5% TR)		$ 3,969
Return to Real Estate Ownership:		$ 745
Return to Real Estate Ownership/Cultivated Acre:		$ 3.73
Mean Value of Buildings:		$ 4,250

3. # 40, 155 Holstein Calves raised to 1175 lbs.

200 Acre Farm At A L.O.P. Except for Crop & Fertilizer At D

Return above Current Expenses:		$ 8,337
Fixed Expenses:		
Telephone & Electricity	$ 400	
Equipment Depreciation	1,838	
Building Depreciation	388	
Real Estate Taxes	358	
Insurance	100	
Building Expenses	78	
Labor	960	
	$4,122	
Inventory:		
Equipment	$18,380	
Livestock	4,650	
Feed & Supplies	2,491	
	$25,521 x 6%	$ 1,531
Return to Real Estate Ownership Labor and Management:		$ 2,684
Charge for Operator's Labor & Management: (3000 + 5% TR)		$ 3,915
Return to Real Estate Ownership:		$ 1,231
Return to Real Estate Ownership/Cultivated Acre		$ 6.16
Mean Value of Buildings		$ 3,880

4. # 41, 188 Holstein Calves to 990 lbs.

200 Acre Farm A L.O.P. Except For Crop & Fertilizer At D Level

Return above Current Expenses:			$ 11,683
Fixed Expenses:			
	Telephone & Electricity	$ 400	
	Equipment Depreciation	1,974	
	Building Depreciation	470	
	Real Estate Taxes	371	
	Insurance	109	
	Building Repairs	199	
	Labor	806	
		$4,320	
Inventory:			
	Equipment	$19,740	
	Livestock	6,580	
	Feed & Supplies	2,937	
		$29,257 x 6%	$ 1,755
Return to Real Estate Ownership Labor & Management:			$ 5,599
Charge for Operator's Labor and Management: (3000 + 5% TR)			$ 4,316
Return to Real Estate Ownership:			$ 1,283
Return to Real Estate Ownership/Cultivated Acre:			$ 6.42
Mean Value of Buildings:			$ 4,700

5. # 42, 134 Holstein Calves raised to 900 lbs.

200 Acre Farm A L.O.P. Except For Crop And Fertilizer At D

Return above Current Expenses:			$ 10,697
Fixed Expenses:			
	Telephone & Electricity	$ 400	
	Equipment Depreciation	1,974	
	Building Depreciation	335	
	Real Estate Taxes	350	
	Insurance	98	
	Building Repairs	67	
	Labor	741	
		$3,965	
Inventory:			
	Equipment	$19,740	
	Livestock	4,690	
	Feed & Supplies	5,442	
		$29,872 x 6%	$ 1,792
Return to Real Estate Ownership Labor & Management:			$ 4,940
Charge for Operator's Labor & Management: (3000 + 5% TR)			$ 4,286
Return to Real Estate Ownership:			$ 654
Return to Real Estate Ownership/Cultivated Acre:			$ 3.27
Mean Value of Buildings:			$ 3,350

6. # 42A, 136 Beef Calves.

200 Acre Farm A L.O.P. Except Crop And Fertilizer At D

Return Above Current Expenses:		$ 5,908
Fixed Expenses:		
Telephone & Electricity	$ 400	
Equipment Depreciation	1,838	
Building Depreciation	340	
Real Estate Taxes	351	
Insurance	131	
Building Repairs	68	
Labor	843	
	$3,971	
Inventory:		
Equipment	$18,380	
Livestock	17,680	
Feed & Supplies	3,078	
	$39,138 x 6%	$ 2,348
Return to Real Estate Ownership Labor & Management:		$ - 411
Charge for Operator's Labor & Management: (3000 + 5% TR)		$ 4,632
Return to Real Estate Ownership:		$ -5,043
Return to Real Estate Ownership/Cultivated Acre:		$ -25.21
Mean Value of Buildings:		$ 3,400

7. # 43 and 44, 42 sows raised to 210 lbs.

200 Acre Farm At A L.O.P. Except Crop And Fertilizer At D

Return above Current Expenses: $ 19,623

Fixed Expenses:

Telephone & Electricity	$ 400
Equipment Depreciation	1,700
Building Depreciation	1,470
Real Estate Taxes	521
Insurance	155
Building Repairs	294
Labor	1,528
	$6,068

Inventory:

Equipment	$17,000	
Livestock	11,550	
Feed & Supplies	5,528	
	$34,078 x 6%	$ 2,045

Return to Real Estate Ownership
Labor and Management: $ 11,510

Charge for Operator's Labor & Management:
(3000 + 5% TR) $ 4,661

Return to Real Estate Ownership: $ 6,849

Return to Real Estate Ownership/Cultivated Acre: $ 34.25

Mean Value of Buildings: $ 14,700

8. # 43 and 45, 188 sow-weaners raised to 30 lbs.

200 Acres A L.O.P. Except Crop And Fertilizer at D.

Return above Current Expenses:		$ 22,868
Fixed Expenses:		
Telephone & Electricity	$ 400	
Equipment Depreciation	1,700	
Building Depreciation	3,760	
Real Estate Taxes	864	
Insurance	246	
Building Repairs	752	
Labor	6,211	
	$13,933	
Inventory:		
Equipment	$17,000	
Livestock	15,604	
Feed & Supplies	5,695	
	$38,299 x 6%	$ 2,298
Return to Real Estate Ownership Land & Management:		$ 6,637
Charge for Operator's Labor & Management (3000 + 5% TR)		$ 5,040
Return to Real Estate Ownership		$ 1,597
Return to Real Estate Ownership/Cultivated Acre:		$ 7.99
Mean Value of Buildings:		$ 37,600

9. # 44 and 46, 51 hogs raised to various weights between 30 and 210 lbs.

200 Acre Farm A L.O.P. Except Crop And Fertilizer At D Level

Return above Current Expenses:		$ 17,210
Fixed Expenses:		
Telephone & Electricity	$ 400	
Equipment Depreciation	1,700	
Building Depreciation	765	
Real Estate Taxes	415	
Insurance	126	
Building Repairs	153	
Labor	40	
	$3,599	
Inventory:		
Equipment	$17,000	
Livestock	9,792	
Feed & Supplies	4,914	
	$31,706 x 6%	$ 1,902
Return to Real Estate Ownership Labor & Management:		$ 11,709
Charge for Operator's Labor & Management: (3000 + 5% TR)		$ 4,953
Return to Real Estate Ownership:		$ 6,756
Return to Real Estate Ownership/Cultivated Acre:		$ 33.78
Mean Value of Buildings:		$ 7,650

10. Tobacco

100 Acres Tobacco)
100 Acres Barley) 200 Acre Farm

Gross Receipts:

Tobacco	$ 98,000
Barley	6,600
	$104,600

Return above Current and Labor Cost:

Tobacco	$ 48,000
Barley	3,865
	$ 51,865

Fixed Expenses:

Electricity & Telephone	$ 400
Building Depreciation	2,000
Equipment Depreciation	3,470
Real Estate Taxes	900
Insurance	140
Building Repairs	400
	$7,310

Inventory:

Equipment	$34,700 x 6%	$ 2,082

Return to Real Estate Ownership
Labor and Management: $ 42,473

Charge to Labor and Management:
(3000 + 5% TR) $ 8,278

Return to Real Estate Ownership: $ 34,195

Return to Real Estate Ownership/Cultivated Acre: $ 170.97

Mean Value of Buildings: $ 20,000

APPENDIX 5

CORRELATION MATRIX OF GRAIN-SIZE ANALYSIS

	1	2	3	4	5	6	7	8	9	10	11	12	13
1.	1.00	0.54	-0.15	-0.44	-0.63	-0.53	-0.40	-0.40	-0.46	-0.23	-0.23	-0.31	0.20
2.		1.00	0.22	-0.51	-0.80	-0.65	-0.51	-0.32	-0.19	0.09	-0.15	-0.06	-0.21
3.			1.00	0.13	-0.17	-0.26	-0.23	-0.21	-0.15	0.04	-0.25	-0.26	0.03
4.				1.00	0.49	0.23	-0.11	-0.16	-0.13	0.05	0.37	0.06	-0.04
5.					1.00	0.73	0.43	0.10	-0.08	-0.18	0.10	0.11	0.11
6.						1.00	0.73	0.43	-0.03	-0.51	0.15	0.29	0.13
7.							1.00	0.70	0.16	-0.50	0.08	0.19	0.06
8.								1.00	0.47	-0.19	0.12	0.11	0.17
9.									1.00	0.51	-0.07	0.16	-0.12
10.										1.00	-0.01	-0.11	-0.35
11.											1.00	0.65	-0.38
12.												1.00	-0.46
13.													1.00

Sieve Sizes (mm.)	19.05	12.7	9.5	4.76 (No. 4)	2.38 (No. 8)	1.19 (No. 16)	0.595 (No. 30)
Equivalents in the Matrix	1	2	3	4	5	6	7

	0.297 (No. 50)	0.148 (No. 100)	0.074 (No. 200)
	8	9	10

11, 12 are the X, Y coordinates of each location
13 is the altitude, in feet, above sea level

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