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University
Landscape reclamation

LANDSCAPE RECLAMATION

ort on research into problems of reclaiming derelict land
research team of the University of Newcastle upon Tyne

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Volume 1

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Contents

Foreword

by the Right Honourable Peter Walker, M.B.E., M.P., Secretary of State for the Environment

I welcome the opportunity afforded by this Foreword of stressing the importance which I attach to the clearance of derelict land.

The scars left behind by industrial development of the past, the abandoned waste heaps, disused excavations and derelict installations and buildings no longer needed by industry, are an affront to our concept of an acceptable environment in the 1970s. The clearance of this dereliction can play a significant role in improving the environment in both a rural and an urban setting.

More reclamation than ever is now being undertaken; local authorities are being asked for an all-out effort and there are good prospects that the greater part of the derelict land will be cleared away within the decade.

But, of course, reclamation is not only a matter of allocating the necessary resources. We need to know how to make the best use of our resources, to examine techniques and to improve on them.

I am therefore grateful for the growing volume and variety of research, of which this Report forms part, which will have great practical benefits for the work of reclamation.

Peter Walker

Introduction

The problem of derelict landscape is an important issue facing the nation. Britain, already short of land, will be in a worse situation as the population increases; it is therefore a matter of necessity, and many would say of urgency, for the majority of the 37,490 ha (93,920 acres) of land now officially classed as derelict, to be restored to a state of good health and service in the total landscape and for the community. Because of the large area of derelict land and vast tracts which escape the official classification, the cost of reclamation will be considerable. If the reclamation work is allowed to proceed without a sure basis of research into the design and planning concepts, into the fundamental problems of soil formation and plant survival, and into the many techniques which will need to be worked out, this cost will be excessive.

There are, of course, many kinds of landscape dereliction, such as derelict coal mines, gravel excavations and old industrial buildings. Each kind of dereliction is likely to require certain techniques in reclamation which are peculiar to its own particular problems. No single research programme can hope to provide all the answers, but an extensive one will be of general use in that it can establish principles as well as techniques. In the Landscape Reclamation Research Project of the University of Newcastle upon Tyne, we have sought to avoid going over ground already covered in previous studies, and this can be seen both in the work relating to the design principles and, at the other end of the scale, in the work on techniques for specific operations and circumstances.

Important work has been undertaken in the period since the Second World War by some planning authorities faced with derelict land in their areas, and also by specialists working on problems like the establishment of trees on waste heaps. Among several problems which have been studied in the University Research Project was the central one of the design of landscape reclamation schemes in such a manner that the natural processes, which will eventually bring about a balance between drainage, erosion and vegetation cover, can be speeded up. Also, the objective was to achieve a new and healthy landscape without tying the planning authorities' hands to a particular land use.

The University was particularly fortunate in having the opportunity to carry out much of the research work in what may be termed 'outdoor laboratories'. These were eight selected areas with varying kinds of dereliction, and it was possible to plan the reclamation works for these areas with the additional advantages of including experimental techniques in specific places. In the chapters that follow, these techniques are described with the results achieved up to the present time. The work of assessment will, however, continue for many years and will form a part of a related research project into the problems of husbanding reclaimed landscapes beyond the initial stage. This latter project has been made possible by a generous grant to the University from the Natural Environment Research Council, and the results will be published in a second volume.

The University's interest is in the whole problem of changing derelict landscapes into healthy landscapes, although, within this major interest, the numerous special aspects also claimed appropriate attention. Consequently, the task of setting-up the research framework fell to the Landscape Design staff but the Departments of Botany and Soil Science have been essential to the work and have been most closely involved at all stages. Quite apart from the objectives of the research, a clear demonstration has been given that several disciplines in a University can make a contribution far outweighing that which would have been given by a single discipline.

Those of us who have worked on the project readily acknowledge the guidelines that have been given by many persons and sources of reference in various countries. In particular, the study tours made by some of the research staff to the excellent landscape reclamation work in the Ruhr, and to some of the earlier work carried out by the County Planning Department of Lancashire, proved extremely valuable. In all of these contacts, examples of failures were given as readily as the demonstration of success. We would wish to make a special point of the important work of the Department of Botany who carried out the survey and analysis of both naturally occurring and artificially planted vegetation. This basic line of approach has always been associated with the discipline of Landscape Design in the University of Newcastle upon Tyne as an aid to deciding upon the types of vegetation cover and the particular tree, shrub, and grass species to be used. The survey, and in fact most of the work described in the ensuing chapters, has been written up at much greater length in the series of interim reports which have followed one another in quick succession during the course of the research work.

A particular feature of the project has been the work of its Steering Committee, which met at monthly intervals for the first three years, and every other month subsequently. The membership is listed in detail elsewhere, but the Committee certainly gained much of its skill in guidance, advice and criticism from those members outside the University, including in the later stages persons concerned in the River Tyne Steep Slopes Research Project. The Steering Committee also served in some measure in place of a Director of the Project, this being a more appropriate arrangement in view of the involvement of several Departments of the University. The responsibility for the various parts of the research and for the material and views expressed in the several Chapters thus rests with the Authors, although in most cases, each Author has necessarily drawn upon the work and experience of his fellows in the Project.

The scale of work can in part be measured by the fact that six research workers have been involved on a full time basis, five members of the teaching staff have given much time voluntarily, and valuable assistance came from the employment of students during some vacations. Again, the names of all concerned are listed elsewhere.

The importance of landscape reclamation as a national objective, and of the need for it to be studied from all points of view, was discussed in a meeting called together in 1963 by the then Vice Chancellor of the University, Dr. C.I.C. Bosanquet, supported by a representative of the Ministry of Housing & Local Government and by the County Planning Officers of Durham and Northumberland and the Planning Officer of the City of Newcastle upon Tyne. Also present were representatives of University Departments likely to be concerned. Subsequently, the financial side of the work was made possible by the ready cooperation of the Ministry and the planning authorities, who were able to make available funds within the grant structure for the reclamation of derelict land.

Finally, every credit is due to the members of the research team, including several members of the University Teaching Staff who contributed a great deal in a directive capacity. To Miss Jennifer Ffennell, a member of the Research Staff who also undertook the initial task of gathering together the Authors' manuscripts for publication, Miss Jill Pagan who completed it and to Miss Anne Stokoe, who from 1965 to 1970 served as Secretary to the project, all of those concerned owe a special debt.

Steering Committee

I.S.Clark, Messrs. Douglas Macara/Groves/Associates, Quantity Surveyors, Newcastle upon Tyne.

The County Planning Officer for Durham represented by R.Briggs, Reclamation Officer.

The Engineer & Surveyor, Easington Rural District Council, represented by the late E.Crompton, Senior Assistant Engineer, W.McCrickard, Reclamation Officer, and W.Scanlan, Planning Officer.

The Borough Planner and Engineer, Gateshead, represented by A.F.Barber.

S.Hall (since retired), Surveyor, Crook & Willington Urban District Council.

W.T.Kailofer, Engineer & Surveyor, Newburn Urban District Council, also represented by J.Grant.

J.A.Mann, Director of Parks & Cemeteries Department, Newcastle upon Tyne.

Ministry of Housing and Local Government, represented by R.U.Harper until 1968, and subsequently by J.W.Dickson.

R.Morton, Surveyor, Felling Urban District Council, also represented by R.Whyte.

The City Planning Officer for Newcastle upon Tyne, represented by Miss E.L.Elliott, Landscape Architect.

The County Planning Officer for Northumberland, represented by F.E.Kerry, Reclamation Officer, and S.Manchee.

The Borough Engineer & Surveyor, County Borough of South Shields, represented by K.Smith.

The Borough Surveyor, County Borough of Tynemouth, represented by W.A.Charlton and M.Preston.

Also certain other people who have attended from time to time, and the following members of the University Staff:

B.Hackett: Professor of Landscape Architecture.
M.F.Downing: Lecturer in Landscape Design.
Miss J.Ffennell: Research Associate in Landscape Design.
C.J.Vyle: Senior Research Associate in Landscape Design, assisted by J.Fuchs for one year.
Miss J.Pagan: Research Associate in Landscape Design.

P.W.Arnold: Professor of Soil Science.
G.P.Doubleday: Senior Research Associate in Soil Science.
Patricia Hill: Technician in Soil Science.
Angela Bruce: Technician in Soil Science.

Dr.J.A.Richardson: Senior Lecturer in Botany.
Dr.A.W.Davison: Lecturer in Botany.
Dr.O.L.Gilbert: Senior Demonstrator in Botany.
R.Dicker: Research Associate

Students working during Vacation

Miss S.Lewis (Botany)
Miss S.McDonald (Botany)
D.F.Hardy (Botany)
B.Shenton (Botany)
D.J.Moffatt (Soil Science)
A.H.Cosens (Zoology)
C.Hindmarch (Landscape Design)
P.H.Goodchild (Landscape Design)
Miss A.Stokoe: Secretary (to October 1970)
Mrs H.Cox: Secretary (from October 1970)

Note: in connection with further work to be published in Volume 2, the following have been involved in the Project:

University Staff

Dr.M.L.Luff (Agricultural Zoology)
Dr.B.J.Selman (Agricultural Zoology)

Students working during Vacation

B.R.Hutson (Agricultural Zoology)
M.I.Hinke (Agricultural Zoology)

Chapter 1 Landscape reclamation and the region

1.1 Introduction

Preliminary investigations into the problems of landscape reclamation revealed the fact that the selection of sites on earlier programmes had been made in most cases on an *ad hoc* basis, and the evidence was that this situation still prevailed. The reasons included the availability of derelict land for purchase, the low cost likely to be involved on a project, and the demand for a particular land use in the area. Whilst the immediacy of these reasons must be acknowledged, the element of convenience which attaches to them is hardly appropriate to the vast expenditure now forecast over the next ten years or so. Thus, a study was made of the way a landscape reclamation policy could be related to the landscape pattern of the region in which derelict land occurs. It was not considered that a study of land use and derelict land from a regional point of view was part of the brief, although such a study is very proper to the work of a planning authority.

The study which was undertaken brought out the need for reclamation schemes to be so designed that they fit into the ecology of the regional landscape - in other words they should restore the continuity of the landscape, and once again should become an integral part of the surface drainage and the soil and vegetation patterns, instead of constituting a landscape in isolation.

1.2 Regional landscape plans

Among those policies reviewed under which the objective of landscape continuity might be achieved, the establishment of a landscape planning framework was considered to be the most appropriate. This conclusion was tested by a study made by members of the research team on landscape reclamation on the Continent which had been carried out under landscape planning policies; reference is made to this study later. As a result of our findings, and bearing in mind the mediocre results in the past of many schemes prepared in isolation, it is recommended that analyses of the physiology and ecology of the regional landscape in which dereliction occurs, should be made available to individual authorities and designers of projects in order that these projects may accord with the basic landscape pattern disclosed by the analyses. These analyses could be made on a regional basis through the appropriate Ministry, or on a county basis through the planning authorities.

1.2.1 Planning framework

The importance of the above recommendation is brought out by some definitions of landscape planning, of which three examples are given.

(a) "The substitution of the term landscape-planning for land planning makes a deliberate widening of the conception of planning to include appearance as well as use, pleasure as well as fertility, and the whole complex organic fabric of life, as well as man's immediate needs" (Crowe in I.U.C.N. 1967).

(b) "Within the concept of these landscape plans (for the Dutch countryside), the different aspects of landscape planning are taken into account. This involves *preservation* of valuable landscape features as well as the *creation* of new elements and the integration of a consciously designed new landscape in the process of a multi-purpose land reconstruction" (Benthem in I.U.C.N. 1967)

(c) "The objective of landscape planning is to ensure that landscape changes continue to provide habitat conditions that will accommodate the various forms of life, either in the existing pattern or, if the habitat conditions are changed, in a new pattern. Its definition embraces the need to reconcile and incorporate competing land uses in the landscape" (Hackett in I.U.C.N. 1967).

1.2.2 Investigations

Among several detailed investigations made in the study of the relationship of a landscape reclamation policy to the landscape pattern of the region, three examples are summarised as follows:

(a) *International resolutions* Several international resolutions concerned with the environment supported the regional approach of landscape planning. The Green Charter of Mainau of 1961 stated that the creation of a sound landscape, which could support residential and recreational area and could sustain agriculture and industry, was indispensable. The UNESCO resolution of 1962 saw landscapes and sites as important factors in the economic and social life of countries. The Council of Europe in 1964 passed a resolution on regional planning and the conservation of nature and landscape.

(b) *Dutch landscape planning* The fact that over 50% of the land of Holland is subject to planned landscape development clearly indicated that enquiries should be made whether this had led to better results socially, economically and aesthetically than under other systems of development control elsewhere. Also, the fact that some parts of the area were lands newly-won from the sea was of particular interest to our research into newly-won landscape from derelict land. The answers to enquiries and the research team's own observation of several areas in Holland confirmed the generally held view that the new and the modified landscapes based upon landscape plans have been successful.

(c) *West Germany* The reclamation of industrial dereliction in the Cologne brown coalfield and in the Ruhr has been widely praised. An investigation was made by the research team of the particular techniques used (see Chapter 2). Also examined was the manner in which the proposals of the mining companies must be related to regional plans which, in turn, must be worked out in association with landscape plans. An important point is that these landscape plans are based upon the structure of the landscape and its ecology. In the results observed by the research team, the value of planning in this way was abundantly clear in the upgraded environment of new open spaces, forest areas, and the riparian landscape.

1.3 The situation in Britain

It will have been noted that considerable emphasis is placed upon the need for landscape reclamation taking place in accordance with regional plans which have a strong landscape planning component. It is not surprising, therefore, that the situation in Britain, where no provision comparable with the Dutch and West German examples is made, should be the subject for comment and recommendations.

The latest figures available for the extent of dereliction (which does not include areas which many people would consider derelict) are given in the following table:

Derelict land - England and Wales in hectares (acres)

	Derelict land	Reclaimed land	Reclamation planned
1964	39,636 (99,091)	992 (2,481)	
1965	43,006 (107,515)	957 (2,393)	1,579 (3,947)
1966	44,435 (111,088)	737 (1,842)	2,117 (5,293)
1967	44,971 (112,428)	747 (1,867)	2,010 (5,026)
1968	45,184 (112,961)	1,078 (2,695)	2,332 (5,829)

No official figures are available for Scotland, but one estimate rates the figure at about 6,800 ha (17,000 acres) of derelict land.

A significant point is that to date, completed reclamation projects are not bringing down the total area of dereliction, because new dereliction is outpacing reclamation. In view of the Government's declared policy to clear dereliction within ten years, the programme at all levels from the National Government, through local Government, to the design team, and the contractors (who translate policy into projects) must be speeded up. As a first step, it is recommended that a study should be made, on the one hand, of the number of design and supervising staff, and supporting experts and, on the other hand, of the number of Ministry (now Department of the Environment) officials for approval and advisory purposes, who would be needed to make a substantial annual reduction to the total area of dereliction. Also, that ways and means of speeding up land acquisition should be studied, as this was found to constitute a particular difficulty in holding up projects. The experience gained from the several sites used for the research showed no lack of interest from contractors willing to undertake projects.

The recent setting up by the Ministry of a derelict land reclamation group to provide central advice and information and to take a continuous overall view of the dereliction problem is welcome. But it is stressed most strongly that the gap will not be filled without establishing a sufficient number of designers, quantity surveyors, experts in Soil Science and other disciplines at the local level, backed by Ministry officials who recommend approval of suitable schemes.

1.4 Industrial waste and dereliction

During the course of the research a great deal of evidence was collected and studied on the restoration of landscape health and fertility under landscape planning policies in areas of dereliction in other countries. In addition to the particular matter of reclaiming derelict sites, the possibility of controlling and perhaps preventing, future dereliction was examined. It was concluded that if the planning for, and the control of, industry took place within landscape planning considerations grafted on to the existing statutory planning provisions, the problem of derelict land would be diminished for future generations.

A particular problem is that if the planning conditions on the formation of new waste heaps or coal mines are too stringent, this may lead to the closure of a coal mine which is operating close to the margin of profit and loss. Nevertheless, when it is realised that the cost of subsequent reclamation of a waste heap involving earthmoving was in 1970 in excess of £3,000 per hectare (£1,250 per acre), it is not unrealistic to take steps in the first place against the need for a subsequent expensive reclamation scheme. One possibility is to ensure that, when tipping, the less toxic materials are placed on the surface; such a scheme may then require a less intensive use of ameliorants in after management.

A landscape plan for the dereliction problems of a region could include proposals for the economic use of materials. Forexample, colliery waste heaps could be assessed for:

(a) Those minerals which, if removed, would reduce the fire risk.

(b) The coal content which, if over 15%, can often be economically salvaged.

(c) The red shale content which is often a suitable source of foundation material for nearby road projects (some black shale is also accepted for this purpose).

(d) Other materials, like brick rubble, slurry and coke, may have a salvage value if present in sufficient quantity and adequate quality.

However, in order for the above proposals to be effective, it would be necessary to bring them under planning control.

1.5 Definitions

In the course of the research work, the difficulty arising from the definition of derelict land which is acceptable for grant purposes became clear. The official definition used by the Ministry for grant award is "land which is so damaged by industrial or other development that it is incapable of beneficial use without treatment". It has been widely suggested that this definition should be studied afresh, clarified and broadened because it does not appear to cover all the categories mentioned in the Acts, that is derelict, neglected and unsightly land. As an example of the difficulty, it can be argued that some sites, conforming with the definition, would make excellent adventure playgrounds with very little cost, and thus would be capable of fulfilling a "beneficial use"; such a site would not rank as derelict and no grant would be awarded for its visual improvement.

Another example is the vast area of derelict landscape lying in small lots which once had some agricultural or other use, doubtless too small or badly located to attract the normal developer. (Collins and Bush, 1969)

The wisdom of the Ministry decision allowing land adjoining derelict land to be incorporated into a reclamation scheme in order to achieve a better functional and visual solution was fully supported by the preliminary design studies made for the Roddymoor experimental site. Without this admissible extension of the narrow interpretation of derelict land, the overall result on many sites could be diminished. A convincing case however must be made for the inclusion of adjoining land.

A difficulty that became evident in discussion with Ministry officials was the degree to which the reclamation works can be taken and how far they can provide for the use of the land after reclamation. The present basis for decisions is contained in the explanatory memorandum on grants (MOHLG 1967) as follows:

(a) expenditure incurred in the acquisition of approved land, including legal and professional expenses properly payable in connection with the acquisition of the land, and the expenses of investigation or survey fees to determine its suitability for reclamation, and,

(b) expenditure, including professional fees and administration expenses properly chargeable to loan, incurred in carrying out approved works of reclamation. The works which will be approved will depend on the scheme. Provided that the Minister is satisfied that they are required primarily for the purpose of reclamation the following works undertaken on approved land will be eligible:

(i) demolition and removal of unwanted buildings and works;
(ii) earth moving for the purpose of levelling, filling, spreading and grading;
(iii) land drainage essential to the works of reclamation;
(iv) the importing and spreading of top soil and grassing for amenity schemes;
(v) tree or shrub planting where required for the purpose of soil conservation, or consolidation, or where planting is satisfactory and more economical than other methods of treatment.

The reference to tree or shrub planting ((b) (v) above) supports experience on the first two experimental sites set up for research purposes - Northbourne Park and Egerton Gardens. On both these sites, extensive shrub planting on steep banks was recommended as providing the best solution under the conditions prevailing, but some months of discussion, supported by visual evidence, took place before this solution was accepted for grant purposes. The strict interpretation of works eligible for grant under (b) (v) above has been widened to include tree planting where there is a lack of trees in the locality or where it would upgrade a poor environment.

Although many local authorities would welcome the extension of the works eligible for grant to include additional works related to a use of the land, the first task is to restore the health and fertility of the landscape over large areas of derelict land, instead of spending the same amount of money on a lesser number of projects taken to a state suitable for uses like public parks and fully-developed agricultural land. Some preliminary uses, like silage cropping and grazing are, of course, part of the works for restoring the health and fertility of the landscape.

1.6 Regional considerations

The eight derelict sites in the North East made available for research (two further sites were studied in some detail) were necessarily selected as far as possible to provide the greatest diversity of research problems. Also, wherever possible, the part that a reclaimed site could play in the region or locality was considered. In the early days of the research work, representatives of regional sport and recreational interests, of mineral salvage concerns, and of conservation bodies attended meetings of the Steering Committee and each scheme was commented upon in the light of these wider interests. It will be noted in Chapter 10 that a survey of over 200 sites was made in the North East to discern any significant pattern of naturally occuring vegetation on derelict sites. At the Big Waters site, in particular, the wildlife, boating and fishing interests were studied to find ways of providing for them on the same area as a result of strong demand from all three. Finally, for each of the sites, the proposals and experiments took account of the physiology and ecology of the surrounding landscape.

1.7 Conclusions

In the light of the brief for the research concentrating on the design and technical problems of landscape reclamation, the conclusions on the investigations made into the wider aspects must necessarily be few and general in character. Nevertheless, the solution of the broader planning decisions may well be the solution of the nation's dereliction problems:

(a) There is a need for reclamation schemes to relate specifically to the landscape of the region and locality, and this can best be achieved through incorporating landscape planning into statutory planning.

(b) Despite international resolutions and the Continental examples, there is little real evidence of landscape planning in Britain - if there was, the dereliction problem could be tackled more satisfactorily.

(c) The weak link in the nation's reclamation programme is the failure to set up an adequate establishment of design teams to initiate and carry through the technical and legal aspects of landscape reclamation schemes. The need for expanding education facilities must be pointed out in this respect.

(d) The definition of derelict land requires amendment and extension to damaged and disfigured landscape in all parts of the country, with emphasis on the restoration of health and fertility to the landscape rather than on immediate uses.

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Chapter 2 Previous techniques of reclamation

based on the work of C.J.Vyle

2.1 The study by Knabe of reclamation in various countries

An important review of completed reclamation projects in various countries was made by Knabe for the period 1950 to 1964, and covered the following matters:

2.1.1 Types of waste land

These can result from:

(a) Change by earthmoving equipment.
(b) Cover by waste materials.
(c) Disturbance in relation to ground water and drainage.
(d) Effects of air pollution.
(e) Dereliction as a result of an industrial neighbourhood.

2.1.2 Reasons for the absence of vegetation or the development of an adequate cover

Fresh disturbance by machines, lack of soil, stony soils, rate of weathering, absence of humus, value of other organic materials, nutrient deficiency, extreme soil reaction, toxic ingredients, adverse physical properties of waste, rising ground water table, erosion and air pollution.

2.1.3 Aims of reclamation

(a) Return to economic use by agriculture and forestry.
(b) Development of facilities for outdoor recreation.
(c) Protection against wind and water erosion.
(d) Increased amenity of the area.
(e) Housing developments.
(f) Planning of new industry.
(g) Road building etc.

2.1.4 Lines of approach

(a) After the waste land has been left by industry, some authorities accepted the site conditions as they were and planted the area with pioneer plants of low requirements.
(b) Some improved poor sites by reshaping the contours and by adding soil amending substances before or after planting.
(c) Others planned the future land use before disposing of the waste, and followed this by restoring fertility to the site.

2.1.5 Examples of reclamation

The principle examples cited by Knabe were: afforestation in the coal regions of USA; the Danish 'Desert Arboretum' on lignite spoil banks; planting trials on tin and gold mine waste and on pulverised fuel ash; topsoil management; reclamation schemes in Lancashire, United Kingdom; land reclamation in Germany; amelioration of toxic carbonaceous shale; advanced planning of land use in the brown coal area of Cologne; and others.

2.2 Grass establishment on colliery shale in Lancashire

Three members of the University research team - Doubleday, Downing and Vyle - undertook a study tour in 1966 of some representative reclamation schemes in Lancashire. The Project is indebted to the Lancashire County Planning Department for putting at its disposal their early experience, and enabling others to benefit from the examples of success and failure that were met in the course of the work. The sites visited were Bickershaw Reservoir, Whalley's Basin, Pennington Green, Bryn Hall and Bamfurlong and Marsh Houses, and the report (Downing 1966) is summarised below with respect to grading and grassing, and gives conclusions on alternative treatments.

2.2.1 Bickershaw Reservoir Site, Abram

A detailed description of this site and the work undertaken is given as an example of the study made by the team. This is the oldest reclamation site undertaken by Lancashire County Council incorporating grading of the surface to achieve a useable piece of land (Fig. 2.1), and contrasts with earlier schemes which were concerned with planting unaltered pit heaps (Fig. 2.2). It has also been carefully documented by Coates (1960). The site is 4.05 ha (10 acres) and comprised low heaps, mostly black shale with some clinker and ash. The shale was derived from a colliery which closed in the mid 1920's. The initial reclamation was carried out in 1954.

(a) *Earthmoving.* A D6 tractor with dozer blade and a $4.6m^3$ ($6\ yd^3$) scraper attached was used for the main work, together with a D4 tractor with dozer blade for final grading. Depth of fill of colliery shale was from 0.3m-6.1m (1ft-20ft). For the ground and

Fig 2.1 An early example of reclamation with grading to produce a useable piece of land at the Bickershaw Reservoir site in Lancashire (Courtesy of Lancashire County Planning Department).

...e preparation a 1.5m (5ft) rotavator set to work at a depth of 100mm (4in) was found to be the best implement for major cultivation. One chain harrowing was carried out before seeding and two after, and a flat roll was also used.

(b) *Grass seeding.* The seed was hand broadcast at 50kg/ha (45lb per acre) and contained:
12% S.22 Italian Ryegrass
14% S.23 Perennial Ryegrass
50% S.143 Cocksfoot
8% S.48 Timothy
10% S.59 Creeping Red Fescue
6% S.151 Early Red Clover
It was suggested by Coates (1960) that the lowest rate on shale should be 45kg/ha (40lb per acre), that 56kgha (50lb per acre) would give better cover, and the optimum cover on bare shale of a level nature would be around 72 kg/ha (65lb per acre).

2.2.2 Vegetation on colliery shale

As a result of their experience on a number of sites, the Lancashire County Planning Department suggested various principles and methods for establishing vegetation on colliery shale (Coates 1960). These are summarised:

(a) *Chemical testing.* Prior to site work, the site should be tested for toxic elements using indicator plants and laboratory tests. Chemical analysis should also be undertaken to ascertain whether the amount of sulphate would in due course reach toxic levels.

(b) *Cultivation.* The best implements were found to be:
(i) Rotovator, 2-3 passes at 75mm-100mm (3in-4in) setting.
(ii) Subsoiler. Very useful to aerate the shale and break up hard impervious layers formed naturally or through the use of heavy earth moving equipment. 450mm (18in) was found to be a satisfactory depth.
(iii) Chain Harrows. Effectively create a top tilth to receive the seed and the covering of the seed.

Fig 2.2 The Woodshaw Pit spoil heap in Lancashire is an early example of a reclamation technique involving planting on unaltered pit heaps (Courtesy of Lancashire County Planning Department).

(c) *Seeding.* The optimum seeding rate appeared to be in the region of 73kg/ha (65lb per acre), but this varied according to the fertility of the spoil. The grasses and clovers giving the best results (and which were agriculturally useful) were in order of preference:

Grasses	Clover
S.143 Cocksfoot	S.151 Early Red Clover
S.53 Meadow Fescue	S.100 White Clover
S.59 Creeping Red Fescue	
S.23 Perennial Rye Grass	
S.48 Timothy	

The best cover had been obtained by hand sowing or 'fiddle', making two passes, the second at right angles to the first. If the area was large, then a seed barrow would have to be used; sowing was again made as described above.

(d) *Manuring.* The application of an organic fertiliser prior to cultivation should be looked upon as a prime requirement. Any non toxic organic matter would be useful, and the fact that it might be low in available plant foods was very much a secondary consideration. The important factor was to choose a substance which, by physically improving the spoil, would make it more suitable for the promotion of growth.

The main attributes of organic matter in the spoil were considered to be:
(i) Better control of air and water.
(ii) Improvement in physical structure through the creation of adhesion between particles resulting in the binding together of the spoil.
(iii) Introduction of soil bacteria.
(iv) Plant foods.

The rate of application should be as high as economically feasible and would depend on the substance chosen, for instance sewage sludge should be applied at a heavier rate than farm-yard manure as the latter had a more pronounced physical effect. No application should be at a rate lower than 25 tonnes/ha (10 tons per acre), 50 tonnes/ha (20 tons per acre) being a more suitable dressing. It should be applied to the land before cultivations are begun.

(e) *Fertilisers.* During the period up to the publication of the results of the Lancashire County Planning Department's experience, it was considered that most plants grown on shale suffered from potash deficiency to some extent. A compound fertiliser was therefore used which had a fairly high potash content. A dressing of nitrochalk was made at the same time and the following rates were suggested:

Compound (high potash)	376 kg/ha (3 cwt/acre) i.e. 10:10:18 units/cwt
Nitrochalk	188 kg/ha (1½ cwt/acre) i.e. 21%N.

These should be applied together immediately prior to seeding.

(f) *Lime.* It was indicated that as colliery waste weathered it became gradually acidic, and toxic reactions had been obtained on the surface of heaps which had been exposed to the elements for over thirty years. Newly dug spoils might be neutral, but this condition did not last long. When the pH reaction is not lower than 4.5, 7.5 tonnes/ha (3 tons/acre) of ground limestone will usually remedy the acidity. The lime should be applied prior to the organic matter.

2.2.3 Development of techniques in Lancashire since 1960

Since 1960 a standard form of specification has been evolved in Lancashire for the ground and surface preparation and seeding. Also, the incorporation of a twelve month maintenance fertiliser and cutting period helps to establish the sward.

At Bryn Hall, for example, which was reclaimed over the period 1961-5, the following specification was used

(a) *Ground and surface preparation* - This is described in the Bill of Quantities thus
- (i) Lime spreading (see under lime).
- (ii) Remove all brick stones, wood and metal and other materials likely to obstruct cultivations
- (iii) Cultivate (Heavy) i.e. 150mm (6in)
- (iv) Disc (Heavy).
- (v) Disc (Light).
- (vi) Distribute fertiliser (Spinner Broadcaster)
- (vii) Cambridge roll.
- (viii) Broadcast grass seed at 39.5 kg/ha (35lb per acre).
- (ix) Harrow roll.

(b) *12 month maintenance period*
- (x) Cut grass with forage harvester (twice).
- (xi) Broadcast fertiliser.

(c) *Lime and fertiliser treatment.* Lime. Deliver and spread 10 tonnes/ha (4 tons/acre) of ground limestone 47% CaO

(d) *Fertiliser.* Seedbed 628 kg/ha (5 cwt/acre) of a 13:13:20 units/cwt fertiliser. Maintenance period 376 kg/ha (3 cwt/acre) of a 13:13:20 units/cwt fertiliser.
The units given in the text are percentage N, percentage P_2O_5 and K_2O

(e) *Grass seed.* Supply and deliver the following mixture

kg/ha	(lb/acre)	
7.0	6	NZ Certified Mother Perennial Ryegrass
7.0	6	S23 Perennial Ryegrass
4.6	4	S43 Cocksfoot
4.6	4	S48 Timothy
2.3	2	S50 Timothy
4.6	4	S215 Meadow Fescue
7.0	6	S53 Meadow Fescue
0.6	½	S59 Red Fescue
0.6	½	Alsike Clover
0.6	½	Altaswede Late flowering red clover
1.2	1	S184 Wild White Clover
0.6	½	S100 White Clover
40.7	35	

2.2.4 The situation in 1966 on the Lancashire sites

Following reclamation, site management is of the greatest importance. One of the sites visited in 1966, Marsh Houses, which showed excellent sward development, according to reports from Lancashire County

Fig 2.3 Bryn Hall in Lancashire. A reclaimed site returned to agriculture with provision for shelter belts

Council has since failed to live up to expectations because less effective management has been carried out. Bryn Hall, which showed less promise in sward development in 1966, has since become superior to Marsh Houses because of more effective management. At Pennington Green, failure to provide field drainage as part of the farm management has meant waterlogging and invasion by rushes; steeper gradients could possibly have overcome this problem.

At Bickershaw, since 1964, the land has received 25 tonnes/ha (10 tons/acre) of farm-yard manure every other year and up to 502 kg/ha (4cwt/acre) of a high phosphate (12:18:12 units/cwt) fertiliser every year. Hay yield is reported to be approximately 4 tonnes/ha (1.6 tons/acre) with good aftermath grazing.

(a) *Nutrient status of shale spoil.* The members of the Project who visited the Lancashire sites undertook a sample investigation of the nutrient status of the shale spoil and their observations were as follows (the Project is especially indebted to the Lancashire County Planning Department for their willingness to allow studies to be made on the various methods used):

(i) pH and lime requirement. The surface materials on these sites presented a very wide range of pH values (2.2 - 7.9) whereas most agricultural crops can grow well only over a smaller range. For example, at Bryn Hall there was a very small area which had been covered with a boulder clay subsoil. Usually this material is slightly calcareous and therefore would not require the 10 tonnes/ha (4 tons/acre) of limestone it received. The pH of a sample taken from this area was 7.9. There was also on the same site a small area where black shale was exposed at the surface. A sample taken from this area was found to have a pH of 2.2 and a lime requirement of 30 tonnes/ha (12 tons/acre). Probably this sample missed the dressing of limestone, but even if it had been limed, the application was only a third of what it should have received. It is understood that a spillage of diesel oil occurred during the contract on this area; this would interfere with the growth of vegetation under normal soil conditions.

(ii) Potassium. Analysis indicated that generally potassium was available to plants in quantities such that in future only light applications of potash fertilisers would be required.

(iii) Phosphate. Though no analysis was successful at that time in determining the phosphate status of the soils, indications in the field suggested that there was frequently a severe deficiency of this nutrient. It was considered likely, and it has since been confirmed, that this was caused by the soil fixing the phosphate so that little of the applied fertiliser was available to plant roots. More frequent and higher applications of phosphate would therefore have been required.

(b) *Fertilisers.* The fertiliser used on these sites contained 13:13:20 units/cwt, but it did not seem to be appropriate to shale soils. A fertiliser high in nitrogen and phosphate and lower in potash would have been better suited to the requirements of these soils.

(c) *Profile developments.* Four profiles were obtained of the Lancashire soils. Bickershaw and Whalley's Basin showed soils from the early reclamations and Bryn Hall and Marsh Houses from more recent sites (Fig. 2.4).

The profile at Bickershaw showed a deep, well structured soil, with root penetration down to at least 200mm (8in). Organic matter was well incorporated, the abundance of earth-worms and small animals making a real contribution to this. The humus form was of a mull type and the whole profile reflected the high quality of reclamation and after-management.

The profile from Whalley's Basin, though of similar age, contrasted well with that of Bickershaw, the profile showing an impoverished and wet soil. Organic matter had accumulated on the surface, and the roots were confined to the upper 50mm (2in) of the soil. No sign of soil fauna activity was found in the sample. Generally the profile showed poor reclamation, and the vegetation a deficiency of phosphate. Installation of an efficient drainage system and careful management of the soil would be required to bring this soil up to the standard of Bickershaw.

Over part of the Bryn Hall site, the surface material was boulder clay subsoil. The profile showed a structureless surface horizon with sparse vegetation and small restricted root systems. To improve this area, attention should have been given to the drainage of the soil and to improving plant growth. More vigorous root systems would themselves help to improve structure, and thus increase drainage through the profile. High levels of nitrogen in a balanced fertiliser programme would have helped, but other factors such as the conditions of grazing by farm animals would also be important. Profile development can be a self accelerating process if started correctly and followed with careful after-management.

At Marsh Houses a well drained profile of a red shale soil was exposed. Vegetation was dense and had root systems which penetrated deep into the shale. Reclamation here and surface treatment of the soil had produced a material on which an excellent sward had developed. This profile showed that no additional cover of imported soil had been spread and gave an interesting comparison with Bryn Hall. It is also interesting to compare it with the profile from Whalley's Basin. Although strict comparisons were not entirely valid, the soil from Marsh Houses indicated that drainage was most important and also that red shale might be a more suitable material for plant growth than black shale. Investigations have been continued to give more information on this point.

2.2.5 Soil problems encountered on the Study Tour of the Lancashire sites

It is necessary to point out that at the time the early work was done in Lancashire, various techniques of assessment now available had not been evolved (the techniques arising out of our work are referred to in Chapter 8). The most obvious conclusion to be drawn from the Lancashire sites

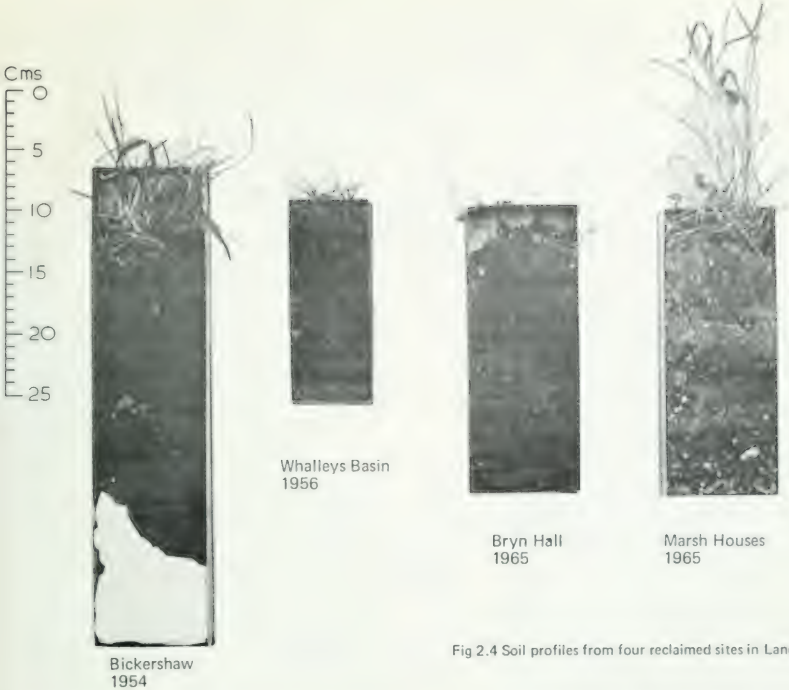

Fig 2.4 Soil profiles from four reclaimed sites in Lancashire.

is that the material forming these sites had a high potential for crop growth. The three difficulties most frequently encountered were waterlogging, nutrient starvation, and acidity and its associated toxicities.

(a) *Waterlogging.* This was generally caused by insufficient surface run off, together with low permeability of the 'soil'. Drastic compaction occurred as a result of the movement of heavy machinery over the site. This can be alleviated by thorough subsoiling before surface cultivations start. Slopes of between 1 in 20 and 1 in 30 seemed to be well suited to this material for accommodating run off without serious erosion.

(b) *Nutrient starvation.* This was common on reclaimed sites where the reclaimed shales cannot be expected to be initially as fertile as a soil. Regular attention needs to be paid to the fertility status of shale soils, as they require high levels of nitrogen and phosphate, but may need only small quantities of potash. Should a deficiency develop in any of these, it is likely that the sward will immediately deteriorate and severe erosion will occur on all but the gentlest slopes.

(c) *Acidity and associated toxicities.* Falling pH was also common on these sites, and justifies a lime requirement test each season in the initial stages of reclamation. Red shale, in its immediate period after reclamation, seems frequently to be superior to black shale in supporting plant growth.

Vigorously growing swards seemed to have the greatest beneficial effect on the soil which, at Bickershaw, showed rapid development when fertility was maintained. On this site, earthworms were abundant twelve years after the initial reclamation. It was also evident from our investigations of the Lancashire sites that ploughing the sward should be avoided until a stable structure has developed in the soil. No top soil or subsoil applications seemed to be required although large dressings of a bulky organic material are desirable.

The seed mixture used, and its seeding rate, seemed adequate on the Lancashire sites, though one may question the dependence on clover for nitrogen. In the initial stages, nitrogen supplied artificially may be better.

It should be stressed that the condition of sites transferred to other owners following reclamation is entirely dependent on the efficiency of the subsequent management, and this is reflected in the condition of a site at a particular time. Examples have been cited under Table 2.1

Table 2.1 Summary of Soil Findings encountered on Study Tour

Sites	Water-logging	Compaction	Slope gradient	Nutrient starvation	Vegetation	Management deficiency	Acidity & associated toxicities	Management improvement factor	Landscape or land use
Whalley's Basin	Yes	Not ripped	Shallow, association with playing field use	N + P	Root mat being formed. Impoverished soil. No faunal activity	Land drainage not installed. Soil fertility not maintained	pH 6.4		Housing/ Recreational open space
Bryn Hall	Small localised areas	Near shale road		N.P.K. Localised area on black shale	Bare	Lime requirement test. Extra fertility required	pH 2.2 possibly aggravated by contractor's refuelling point	Careful grazing by animals has greatly improved the quality of the sward.	Agriculture/ Shelter Belts
				N Small area of clay over black	Structureless surface horizon with sparse vegetation and small restricted root system	Lime not required. High N in a balanced fertiliser programme	pH 7.9	Balanced fert. programme has also helped	
Marsh Houses	None		1:20 - 1:30	None seen	Good vigorous deep rooting sward	Lime requirement. Quality of initial sward has dropped due to less effective management	pH 4.8		Agriculture
Bickershaw	None			None seen	Excellent vigorous sward. Deep well structured soil. Abundance of earthworms and animals. Mull humus form	Nil	pH 6.4	High quality of management has given rise to excellent sward	Agriculture
Pennington Green	Yes	Yes	Slope shallow at 1:50		Invasion by rushes	Land drainage not installed. Soil fertility not maintained. Poaching by cattle			Agriculture

Table 2.2 Financial implications. General breakdown of the five sites visited (Costs/unit area)

Site	Area		Acquisition		Earthworks		Cultivations		Total	
	ha	acres	ha	acre	ha	acre	ha	acre	ha	acre
Whalley's Basin	13	32	£295	£118	£859.5	£343	£132.5	£53	£1285	£514
Bryn Hall	17	180			£485	£194	£96	£38		
Pennington Green	14	34.25			£372.5	£149	£92.5	£37		
Bickershaw	4	10	£25	£10	£100	£40	£65	£26	£190	£96
Marsh Houses	18	45	£83.25	£33.3	£435	£174	£82.5	£33	£600	£240.3

2.3 Afforestation in Germany

A second study tour was undertaken by members of the research team (Doubleday and Vyle) to the Brown Coal and Ruhr areas of Germany in 1966. The species which have grown successfully are listed below, and the use of soil additives to help plant growth in areas of high pollution described.

2.3.1 Brown Coal area

Knabe (1964) described the species used in detail, and indicated that the best soil improving pioneer plants for afforestation were *Alnus glutinosa* and *A. incana*, *Robinia pseudoacacia* and perennial lupins. Hybrid poplars brought the highest yields on some but not all sites. *Populus* × *euramericana* and hybrids between European and American species e.g. *P. nigra* × *P. angulata* or × *P. deltoides*, were the main species used. Interest was then being shown in balsam poplars (*P. tacamahaca*) and the different hybrids between *P. alba*, *P. tremula*, and *P. tremuloides*, as well as new clones of tree willows.

2.3.2 Techniques of afforestation in the Ruhr District

The planting of conifers has been ruled out because of high levels of pollution. For example, the dust in the Ruhr contains fluorine, arsenic lead, zinc, beryllium seleniumphosphorus, vanadium and cadmium, and levels of 2-3 kg/100m^2 each month are obtained. Barnard (1967) also reports that the sulphur dioxide content of the air is between 0.2 and 0.3 mg/cbm. The depth of dust accumulation in Essen has been measured at 10cm. These pollution levels may be compared with the legal limits for dust levels suggested by the Union of German Engineers (V.D.I.) at a maximum of + 2 kg/100m^2/month.

It has been found that plant growth is related to an adequate depth of soil in areas of high pollution. 0.3m (1ft) of soil was given as an average figure for obtaining reasonable growth in such areas. The deciduous species of tree used were *Acer pseudoplatanus*, *Alnus glutinosa*, *Populus* spp., *Quercus borealis maxima*, *Crataegus* spp., *Robinia pseudoacacia* and *Tilia* spp. Twelve year old trees were up to 7.5m (25ft) high; growth rates, however, 50-80% slower than normal, have been recorded on the exposed slopes of heaps. *A. incana* and *A. glutinosa* 60% with *Quercus borealis maxima*, *Robinia* spp., *Tilia* spp., *Fraxinus excelsior* and *Betula* spp. was another successful mixture. *Sorbus* spp., *Prunus spinosa* and *Rosa* spp. were amongst the species used at the edges of plantations as part of the policy for landscape protection. Tree species planted elsewhere in the Ruhr district were *Crataegus prunifolia*, *Populus tremula*, *P.* × *berolinensis*, *Pyrus communis*, *Salix alba* 'Liempde', and shrubs included *Sarothamnus scoparius*, *Hippophae rhamnoides* and *Lycium* sp. An important matter in the success of the tree planting was the employment of forestry officers by some mining companies who carried out species trials.

The following conclusions were drawn from the policy and work of planting in landscape reclamation projects carried out under the Ruhr Regional Planning authority.

(a) The use of top soil in areas of high pollution should be considered.
(b) The use of deciduous species of trees and shrubs to encourage the development of soil fertility should be a prime consideration.
(c) Berrying trees and shrubs should be used as part of the overall policy for protecting the landscape by helping to provide winter food for birds.
(d) Species trials of trees and shrubs should be undertaken to extend the range of suitable species, native species and their improved forms, with smaller quantities of exotics being included for investigation.

2.4 Afforestation on colliery shale in Britain

The history of planting on shale heaps goes back, at least, to the 18th century (e.g. Seaton Delaval in Northumberland), and a considerable body of experience is available from the work of some Planning Departments (e.g. Co. Durham).

2.4.1 Observations by Wood and Thirgood (1955)

The investigations carried out by Wood and Thirgood indicated that some colliery spoils are capable of producing quality class I growth e.g. Hawkwell Inclosure, Dean Forest, Gloucestershire. They also made some general observations relating to the species which could be grown on spoil and these are given below. Reporting on the conifers, it was noted that those preferring, or at best tolerating, near neutral conditions seem to have been most successful. *Larix decidua* and *L. leptolepis*, *Pinus nigra* var *calabrica* and *Pinus nigra* had all done well. *Pinus sylvestris*, an adaptable species, had been widely used with some success, but it had compared unfavourably with *P. nigra* var *calabrica* and *P. nigra* when occurring on the same heap. *Alnus glutinosa, Acer pseudoplatanus, Fraxinus excelsior* and *Populus* spp. had all grown satisfactorily, *Ulmus* spp. and *Tilia* spp. had also performed well. *Alnus incana* had done well and it seemed likely that *Alnus cordata* would do well on spoil heaps. Many other species, including *Salix* spp, *Robinia pseudoacacia, Sorbus aucuparia* and *Crataegus* spp., had been recorded.

Recommendations included the use of a high proportion of *Alnus* spp. on heaps weathering to clayey material, and on lighter burned materials a higher proportion of *Betula*. *Alnus* and *Betula* were regarded as the safest pioneers, and with them *Acer pseudoplatanus* might be used on all sites. *Populus* spp. could be planted where there was adequate moisture; they should not be carried high on the slopes, and might best be confined to screens round the base. Care should be taken to choose canker resistant varieties; reliable clones of *Populus* × *serotina, gelrica, robusta* and *eugenii* were available.

2.4.2 Planting in Lancashire - early conclusions by Casson and King

Lancashire was among the pioneers of tree planting of colliery spoil, and an extensive investigation was commissioned by the Planning Department and carried out by Rees and Warwick of Birmingham University. This enabled some of the practical conclusions to be rationalised, and Casson and King (1960) reported on these investigations:

(a) Colliery spoil heaps appear to be sufficiently fertile to maintain tree growth.

(b) Sufficient moisture is usually available after establishment, although losses can be high in prolonged dry summers in the early stages. The choice of species must be governed by site factors, but atmospheric pollution does not rule out certain conifers.

(c) Where pollution and exposure is severe, it is essential that a nurse species be extensively used, and where the site is bare, the main function of the nurse is to improve site conditions (i.e. shelter, stabilisation of the surface, shade and surface moisture, build-up of humus). Alder has been found to be the first choice in Lancashire.

(d) Plants used should have a well developed fibrous root system and should be fairly small and sturdy.

(e) *Species.*
Alder is the first choice as it is the most successful, even where pollution and exposure are most severe or soil conditions detrimental. Common alder (*Alnus glutinosa*) is most satisfactory as a nurse because it develops a bushy habit which soon affords shelter and shade, although the height development is somewhat limited. Where alder is planted in mixture, grey alder (*Alnus incana*) should be utilised or used for beating up, because its foliage is not so heavy and it will continue to afford shade and shelter to a greater height.

Birch (*Betula*) is difficult to establish on unburnt shale, but is more readily established and thrives well on burnt shale.

White poplar (*Populus alba*) has been successful and thrives best when planted in loose material and is excellent for checking erosion.

Corsican pine (*Pinus nigra* var *calabrica*) has given excellent results where there has been sufficient shelter, although it has also done well in more exposed situations, especially where planted in mixture with a vigorous nurse. Recent work carried out by the Nature Conservancy at Merlewood shows that Corsican pine has exceptional qualities in building up soil nitrogen.

Lodgepole Pine (*Pinus contorta*) has been used more recently than Corsican pine, and the indications are that it may be as good.

Sycamore (*Acer pseudoplatanus*) suffers considerably from dieback. Only after there is considerable shelter from the nurse species does it throw up a leading shoot, and it appears that it should not be used in the early stages of establishment.

Beech (*Fagus sylvatica*), when planted at the same time as the nurse species, stands still for years, although odd trees have thrived on unexpected sites when there is some shelter. It may be that beech and sycamore, being rather demanding, suffer not only from exposure, but from soil conditions which are in the course of modification by the nurse.

Japanese Larch (*Larix leptolepis*) has shown vigorous growth when planted in sheltered positions, but has shown a fairly high rate of failure during severe drought.

Ash (*Fraxinus excelsior*) has failed on all sites and positions. Sitka spruce (*Picea sitchensis*) had only been planted on two sites, but results are encouraging.

Common Osier (*Salix viminalis*) is the most useful species of willow, showing vigorous growth. Grey willow (*Salix cinerea*) on the other hand, has shown only slow growth.

Certain species, notably Spanish Chestnut (*Castanea sativa*) as well as the ash, beech and sycamore, appeared to be establishing themselves satisfactorily in the first year, but showed severe die-back each year subsequently. From evidence obtained on some grass seeding experiments on shale elsewhere, it may be that shale breakdown has caused acidity and other chemical changes, creating soil conditions which may hold these species in check.

2.4.3 Later conclusions on tree planting in Lancashire by Casson and King

The following conclusions are based on the findings of Casson and King (1967), expanding upon and supplementing their findings of 1960.

(a) *Size of plants.* Plants must be selected. Small sturdy trees 0.3 - 0.45m (12in - 18in) high should be used to minimize the effect of wind damage.

(b) *Planting method.* The technique adopted in the early stages was to blanket the area under normal forestry practice using a nurse species of *Alnus incana* or *A. glutinosa, Betula* and *Salix caprea.*

(c) *Application of fertiliser.* Although composts and artificial manures to encourage growth had been experimented with at various times, no concrete conclusions had been reached. However, if fertiliser was used, it was recommended it should be mixed with a little soil and put in the planting hole, rather than spread on the heap with subsequent loss by wind and rain. The use of smaller quantities would save expense.

(d) *Range of species planted.* Many species had been planted, these included *Alnus glutinosa* and *A. incana*, *Acer pseudoplatanus*, *Betula* spp., *Fagus sylvatica*, *Populus alba*, *Castanea sativa*, *Pinus mugo*, *Larix decidua* and *L. leptolepis*, *Fraxinus excelsior*, *Acer platanoides*, *Picea sitchensis*, *Ulmus* spp., *Quercus cerris*, *Pinus nigra* var. *calabrica* and *P. contorta* var. *latifolia*.

(e) *Observations on blanket planting.* It was noted that on some sites the growth of the nurse species had been insufficient to offer protection to the chosen final crop species, and this had resulted in the dying back of leading shoots and the death of many of the plants. On one particular spoil heap, the nurse species chosen had reached a stage after five growing seasons where it was offering a definite protection to the *Pinus nigra* var. *calabrica*, and if this protection had been there when the pine was planted, it is quite certain a lot of beating up could have been avoided. To overcome this on more difficult sites where it was known that protection would be a definite benefit, *Alnus* spp., *Betula* and *Salix caprea* were planted in groups or narrow belts. As and when these species became established and offered protection (which could be from 3-5 years), the remainder of the area was then planted up with the final crop species. The advantage of this is that a large area can be planted each year, and the cost of beating up and weeding is reduced considerably.

(f) *Notes on the performance of individual species.* *Alnus glutinosa* was most satisfactory as it develops a bushy habit which soon affords shelter and shade. It was observed that after the first few years of rapid growth a considerable amount of die back occurred and many shoots then sprang from the base. On investigation, holes were dug to ascertain what was actually happening to the root growth, and it was apparent that whilethe roots had gone down to a depth of 1.5 - 1.8m (5ft - 6ft) they were very few in number with very little fibrous roots and most of the root system was now dead or dying. However, while this was occurring a mat of fibrous roots was developing from the base of the tree to about 0.3m (1ft) in depth and vigorous new shoots were now showing and forming a very effective windbreak. Within ten years Alder had reached a height of 4.5 - 6m (15ft - 20ft).

Betula species can be seen growing from natural regeneration on many spoil heaps. It is found to be a most difficult species to establish from transplants. It no doubt requires more careful siting and should only be used on shales that retain the moisture much longer and where, if possible, other vegetation has become established.

Populus alba is a good species particularly where the site is dry and subject to erosion. It promotes root suckers which run many feet and form a retentive root mat.

Acer pseudoplatanus, when planted at the same time as the *Alnus glutinosa* had shown only small growth each year. However, as soon as the *Alnus* provided some shelter, the *Acer* began to thrive, as did *Fagus sylvatica*. *Pinus nigra* var. *calabrica* and *P. contorta* had been most successful on all sites, even in areas of atmospheric pollution. Of the two, *P. nigra* var. *calabrica* showed the better growth, reaching a height of 3.6 - 4.5m (12ft - 15ft) within 10 years and again this species benefited from the shelter provided by the *Alnus*. At this stage the *Alnus* needed cutting back to relieve the *Pinus*.

Larix leptolepis, while showing considerable growth in the first three to four years, did show a tendency to fail during severe drought and many also seemed to check and grow only 50 - 75mm (2in - 3in) for a couple of years. Once out of check, growth became normal again showing some 0.3 - 0.45mm (12in - 18in) growth annually.

It is interesting to note that Casson and King's investigation of planted and naturally regenerated sites in the West Riding confirms the importance of considering rainfall and soil toxicity in the initial phases of planting and maintenence. However, while establishment may be more difficult there are indications that the prospects of producing effective timber crops may be better east of the Pennines.

In 1966 the planting at Bryn Hall contained no coniferous species, the main species being *Acer pseudoplatanus* (36%), *Alnus glutinosa* (25%), and hybrid balsam poplars *P. tacamahaca* × *trichocarpa*, 32 hybrid poplars *P* × *Serotina*, and *P* × *Robusta*, *Salix Caprea*, the remainder being made up of *Salix alba vitellina*, *S. purpurea*, *Quercus borealis maxima*, and *Acer platanoides*. An example of a simpler planting plan is shown in Fig. 2.5.

Fig 2.5 An example of a simple planting plan for a spoil heap in Lancashire, using only deciduous species (Courtesy of the Lancashire County Planning Department).

2.4.4 Planting in Durham

Richardson et al describe the early success of planting in Durham. The post war planting has also been examined by them and is reported in Chapter 9.

Up to 1954 a number of pit heaps and other waste heaps were acquired and afforested by various authorities and associations in the northern Region. It is thought that between 40 - 81 ha (100 - 200 acres) were dealt with, mainly in County Durham. From 1954 - 1960 Durham County Council itself undertook such planting and some 43 ha (108 acres) of trees were planted on twenty four sites. Of these, four sites have since been graded out. Of the remainder which may be considered to be establishing successfully, there are 21 ha (53 acres) mainly on seven sites. Since 1960, with improved grants, the tendency has been to undertake grading and grassing, and of 6.8 ha (17 acres) planted only 1.6 ha (4 acres) remain. However, because trees are capable of making a valuable contribution to the landscape, the Botany Department undertook a survey as described in Chapter 9. The grading out of slopes to 1:8 allows for agricultural management and may allow for the incorporation of tree planting for shelter purposes. Where slopes must be steeper, afforestation techniques may be used but suitable access should be provided for possible liming and fertiliser maintenance.

2.4.5 Financial implications

Each site must be treated on its own merits, and costs may vary considerably, taking into consideration the cost of forest transplants as against larger stock. However, larger stock may soon over-top weeds and, provided competition is not too severe from the weeds, the cost of weeding may be much less than with forest transplants. It may be necessary to look after forest transplants for up to twenty years. Larger plant stock used in Lancashire such as *Betula* spp. and *Salix caprea* at 0.3m (10in) and *Alnus* spp. at 1.4m (4ft 6in) can thus make a contribution in reducing weeding and establishment costs.

Neustein (1970) reports on small scale trials using the relatively simple method of pot planting, and concludes that satisfactory survival and early growth (and fair prospects of continuing health, assuming further fertilisation) can be obtained on some types of parts of colliery spoil heaps. The main diagnostic factor appears to be the presence of natural vegetation - even in quite sparse amounts. It is presumed that natural vegetation reflects the age (degree of leaching), stability, and exposure of the site. Hence, as far as possible colonised spoil heaps should be planted undisturbed. Although the small scale of the trials precluded realistic costing, a reasonable estimate could be made in costs/unit area, based upon the 1970 figures.

		acre	ha
Cost of transplants	1500 at £10 per 1000 =	£15	£37.5
Cost of pots	£9 per 1000 =	£14	£35.0
Cost of potting	£12 per 1000 =	£20	£50.0
Cost of planting	£20-£40 per 1000 =	£30-£60	£75-£150
Fertiliser-material and application	£10 per acre =	£10	£25
		£90-£120	£225-£375

Fencing, supervisory overheads and transport are additional charges, but are not included because they vary in accordance with the particular layout, shape of planted areas etc. Figures given by Lancashire indicate planting costs to be of a similar order, with the observation that fencing may be up to half the cost of the scheme.

2.5 Allied research projects

Early work has been undertaken by a number of Government Bodies such as the Commonwealth Agricultural Bureau, the Forestry Commission and the N.A.A.S. Individuals associated for many years with derelict land have made notable contributions, Stamp, Beaver, James and Oxenham to name but a few. The County Planning Departments of Durham, Lancashire, and West Riding of Yorkshire have laid down trials and have also been responsible for the physical action needed to remove derelict land in their areas. Different Departments in a number of Universities have been co-operating with County Councils, County Borough Councils and other authorities to investigate certain problems.

2.5.1 Past and present research projects

Bibliographies have been prepared by Whyte and Sisam (1949), the Ministry of Town and Country Planning (1949) and Knabe (1957-8); other contributions to the bibliography on reclamation are set down at the end of this chapter. The Forestry Commission in their Research Branch Paper No. 17 (1955) described the characteristics of colliery spoil heaps, and make recommendations on the type of plant material, and method of planting. The N.A.A.S. have co-operated in the Swansea Valley Project. Regional Offices of the N.A.A.S. in the West Riding and the Midlands have made valuable contributions with regard to grassing recommendations and shrub collections. More details of these will be given in Chapter 10.

Botanical studies have been undertaken by Birmingham University, particularly in relation to Pulverised Fuel Ash. Ph.D theses relating to this topic were by Sidrak (1955), Jones (1958) and Lewis (1961). Reed directed the project which was done at the instigation of the C.E.G.B. The University of Leeds, Department of Agriculture, has also conducted experiments on P.F.A. (1964). At Newcastle, work has been undertaken in the Botany Department over a number of years by Richardson, Greenwood, Shenton and Dicker, to mention a few, on various aspects of the problems of growing vegetation on colliery shale. Warwick (1958) of Birmingham University undertook a study of 'Plant nutrition on Colliery Waste' for a Ph.D thesis. The Lower Swansea Valley Project has been in the forefront of interdepartmental research projects with a wide range of discipline participating and co-operating with the Swansea C.B.C. The Report was first published in 1967, based on information available in the Autumn of 1966. The Department of Biology of the University of York is co-operating with the West Riding County Council and advising on particularly different vegetational problems. Studies are also being undertaken on the chemical nature of the colliery shales and nutrient cycling.

The Department of Civil Engineering at the University of Leeds is also collaborating with the West Riding County Planning Authority as previously indicated.

2.6 Setting the guide lines for the project

The Landscape Reclamation Research Project at the University of Newcastle started in 1964 with preliminary site selection, two sites each being selected from C. Durham, Newcastle upon Tyne, and Northumberland. The Landscape Design Section in the Department of Town and Country Planning drew up plans for six sites from 1965-1968, but because of difficulties two sites were withdrawn and have since been replaced with three further sites. Site descriptions are given in Chapter 3, and were based on engineering and soils assessments and upon landscape survey techniques described in Chapter 5. The plans, along with approximate estimates of costs prepared by a firm of chartered Quantity Surveyors, Douglas Macara/Groves/Associates, were submitted to the Ministry of Housing and Local Government. Following final approval, the Drawings were sent out to tender along with a Bill of Quantities and Specification. Tenders having been accepted by the respective Councils, work started on the sites and was supervised by the Landscape Design Staff of the University. Physical and other problems encountered on the sites are described in Chapter 6. Grass establishment on sites is an important aspect of visual improvement and for after-use of the sites, and to this end the Departments of Soil Science and Botany have co-operated actively and have been intimately involved over the period; their contributions are described in Chapters 8 and 9 respectively. The situation on the sites as at 30th April, 1970 is shown in Table 2.3.

Grass mixtures, seeding rates and seeding techniques for agriculture, public open space, erosion protection and prior to forestry planting are described in Chapters 9 and 10. Species, size of planting stock, methods of planting and fertiliser treatments are also included in Chapters 9 and 10. Financial and contractural aspects are given in Chapters 11 and 12.

2.7 Conclusions

(a) Good management after the initial contract work is essential, and studies of previous reclamation projects revealed examples where good grass coverage initially had failed to maintain quality because of poor management.

Table 2 3 Landscape reclamation research project. The situation as proposed at 14th October 1966 and the real situation as at 1st March 1971

Site	Revised brief	Sketch. Approximate estimate. Approval by L.A.	Ministry provisional approval	Working dwgs, bill of Qtys.	Final Ministry approval	Final L.A. approval	Out to tender	Contract start	Contract complete	Defects liability period 12 months from issue of substantial completion cert.
Egerton Gardens		Feb '66	Mar '66	July '66 July '66	21.11.66	Dec '66	Jan '67 Dec '66	Feb '67 Mar '67	Dec '67 Dec '68	Jan '70
Roddymoor		31.10.66	30.11.66	26.2.67	Mar '67	April '67	May '67 Sept '67	June '67 1.1.68	April/May '68 30.4.69	30.4.70
Haswell Colliery	Nov '65	30.11.66 8.12.66	31.12.66 2 Decision deferred	6.2.67	Mar '67 Public inquiry into extraction of Red Shale Site withdrawn Mar. '68	April '67	May '67	June '67	April/May '68	
Northbourne Park	21.10.66	31.12 66	28.2.67 10.10.66	31.3.67 Mar '67	April '67 Not necessary	May '67	June '67 April '67	July '67 Mar '68	May '68 Jan '69	Jan '70
Percy Pit	1.11.66	31.1.67 April '66	28.2.67 From June '66	30.4.67 Private firm investigation into extraction of coal site Site withdrawn July '69	May '67	June '67	July '67	Aug '67	June '68	
Big Waters		31.1.67	28.2.67	May '67	June '67	July '67	Aug '67 Mar '69	Sept '67 May '69	Aug '68 May '70	May '71
Replacement Sites										
Felling				May '70 Nov '70	Oct '70	June '70	Nov '70	1.2.71	31.3.72	31.3.73
Maria Colliery		Oct '68		Dec '68 Jan '69	Dec '68	Dec '68	Jan '69	Sept '69	?	?

(b) Land drainage problems are likely to arise from the compaction by heavy machines. Slopes of 1 in 20 to 30 often accommodated run-off of surface water without causing erosion, and are an insurance against subsequent failure to install land drainage systems and against subsequent failure of such systems due to the 'settling down' of regraded land.

(c) The new developing 'soils' of reclaimed sites should be analysed at frequent intervals to identify fertiliser ingredient deficiencies.

(d) Coniferous planting should be avoided in heavily polluted areas. Above normal topsoil depths encourage growth in polluted areas.

(e) The experience gathered from the study of sites elsewhere constitutes an important aid in clutivation, fertilising, seeding and planting decisions. For example, the alders stand out as trees with a high degree of success in growing in the particular conditions of reclaimed sites.

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Chapter 3 Research sites

by M.F. Downing

3.1 Historical background

The history of coalmining in the north east of England dates back to the Romans and even during the middle ages coal was shipped to London and other places. By Tudor times shortages of timber had resulted in renewed efforts at exploitation of the mineral. As early as the seventeenth century mining at a depth of 400 ft was not uncommon, and by the nineteenth century depths of several thousands of feet were commonplace. The history of mining was one of hardship and degradation, punctuated by unspeakable disasters. The sites on which the project has operated are no exception and it is salutary to remember that the legacy of dereliction represents an age and an industry careless not only of land and aesthetics, but also of human life and dignity. It would be fitting if some way of commemorating those who in past years have suffered and died so ignominiously in the cause of human progress could be incorporated in the new reclaimed landscapes.

Not all of the research project sites have been associated with coal mining, but six of the nine were the sites of working deep mine pits. The earliest of these is Heworth Colliery where boring to the high main seam commenced in 1763. This mine ceased operations so recently that the pit head winding gear was still standing in 1970. At Percy Pit, Newburn (Fig.3.1), the site was an operative coal mine but also served as a centre for the operations of the Walbottle Colliery Company which worked a number of other pits, inter-connected wagon ways, and pit railways. The nearby Duke Pit was sunk to the Brockwell seam in the late 18th Century and it is recorded that coal was being worked from the Beaumont seam in 1787. The Coronation, Wellington, Blucher and King Pits followed the Duke Pit, the Blucher Pit being opened in 1815. The lease on the Royalty was held until 1867 by Messrs. Lamb but in that year the colliery closed down. Stevenson & Co. who opened the nearby Isobella Pit in 1869 leased the Royalty in 1877 having sunk the Derwentwater shaft in 1876. The Blucher Pit was re-opened in 1901 and operated by the Throckley Coal Company. The Percy Pit site was the centre of a web of wagon ways, tramways and mineral railways linking the outlying pits to the public railway. Wagonways extended to Maria Colliery, apparently opened in the last quarter of the nineteenth century, North Walbottle Colliery and Throckley Colliery. The North Walbottle Wagonway was laid with iron rail to the Coronation Pit in 1794.

Haswell Colliery also has considerable historic interest, being the site of one of the many great tragedies of northeast mining. It is recorded as one of the first sites where sinkings were undertaken to prove coal below the magnesian limestone. This was undertaken in 1811 by Dr. William Smith. Twenty years later on 28th February 1931, the Engine Pit commenced. After excavating 54ft, this was abandoned because of running sand and the New Engine Pit was begun in the same year. This shaft was sunk first to the Hutton Seam, and on to the Beaumont seam by 1840. The first recorded shipment of coal was on 2nd July 1936.

Location of possible and actual research sites
(a) in the area of Newcastle upon Tyne
(b) in the area of Durham

In 1844 on 28th September at 3 p.m. there occurred what was described in Fordyce's History of Durham as "one of the most fatal cases of explosion on record". This was described as taking place in the Little Pit at a point called Meadows Flat 1400 yd from the shaft. This tragic explosion resulted in the loss of 95 lives and this was attributed by Professor Faraday, who carried out an enquiry after the event, to suffocation by chokedamp. The winding engine house which still stands at the southern end of the site is regarded as a very fine early example of its kind. The walls are 8ft thick at the base and this has led to the suggestion that it dates from the very early years of the nineteenth century. If this is accepted it must be assumed that it was built in connection with Dr. Smith's original borings.

The pit was evidently worked for some years after the tragedy, as a reference to the pit with ventilation maps of the upcast and downcast pits occurs in the Proceedings of the North of England Institute of Mining Engineers for 1859. The same Proceedings include a paper given on 8th December 1883 on "The Haswell mechanical coal getter, an invention for working coal without the need for gunpowder or explosive" by W.F. Hall. It is believed that the pit ceased operations around the turn of the century.

Roddymoor also has some claims to historic interest, notably for the coke oven plant which used to stand on part of the site. The Victoria County History of Durham records that borings in the Roddymoor Royalty were in progress at Old Roddymoor in 1836 and that in 1844 a sinking was put down by Mr. R.A. Heslop to work the Brockwell or Main Coal Seam in what was known as the New Colliery. The coke ovens, now removed, bore a plaque with the following text:

'These coke ovens are part of the first by-product coke oven plant erected in Great Britain. The original battery of 25 ovens was built for Pease and Partners Ltd. by Henry Simpson founder of Simon Garves Ltd., in 1882 and worked continuously for more than seventy years'.

It is hoped that the original battery may be re-erected at the Industrial Museum at Beamish Hall

At Big Waters, the influence of the Pits surrounding and undercutting the whole of this part of Northumberland has resulted in the subsidence of a large area creating a 'mining flash' a lake on the deadwaters of the Ouseburn.

St Anthony's Point at Walker has been renamed Northbourne Park after the Northbourne family which had estates in this neighbourhood for many years. It was the site of ballast dumping from ships coming up the Tyne, probably for many hundreds of years. St Anthony's Point was at one time the site of a mansion and garden belonging to one Henry Ibbetson Esq. The house which had a farmhouse, cottage and outbuildings was probably built in the early eighteenth century and the walls of the original garden still remain on site, having been incorporated into the walls of a car park. From contemporary sources it appears that the mansion was a handsome and elaborate structure. Another house standing on the south east corner of the site was reputed to date from the fifteenth century. This was standing when reclamation began, but being in a very poor state of repair was subsequently demolished. A large area was occupied in the nineteenth century by a lead works. At the western end of the site can be seen the remains of a slipway at which small trading ships used to transport millstone grit for milling. The river walls were constructed in 1842.

Egerton Gardens is located in a part of South Benwell known as Paradise; part of the site was occupied by steep rows of terrace housing dating from the early nineteenth century. There is evidence also of industrial operations contemporary with the housing including a waste heap from a foundry.

3.2 Site descriptions

The tables included with this chapter give brief notes on the location, size, and climatic and pedological conditions of each site. The visual description and end use are also presented in these tables. This information is included to serve only as a broad introduction to the site. Detailed information on specific aspects of the individual sites is found in the appropriate succeeding Chapter.

Fig. 3.1 Percy Pit: Newburn conical heap dominating miners' terraced housing, now demolished.

3.3 Selection of sites

3.3.1 Original basis of project

As indicated in Chapter 2, initial discussions on the setting up of a project began in 1963. The financial arrangements at that time proposed and those subsequently adopted, are also discussed in that chapter. From the outset the local authorities co-operated very fully and enabled the University to select six sites from a number offered, to give a useful range of research activities.

The passing of time during negotiations and the changing nature of the project resulted in changes of the sites selected, as well as the University personnel involved. Originally the Departments of Botany, Civil Engineering, Soil Science, Surveying, and Town and Country Planning were to have been fully participating members of the project. Circumstances forced Civil Engineering to withdraw, and Surveying was unable to participate as fully as at first envisaged although the continued and valuable support this Department has given should be recorded.

3.3.2 Original sites and research interest

It is interesting to record the six sites originally selected and the research interests on which the selection was based. They were as follows:

(a) *Trimdon Grange, Trimdon, Co. Durham.* This was described as a ridge shaped pit heap with mostly recently tipped black shale.

Problems and lines of research listed were:

- (i) Reshaping with consequent erosion slip and vegetation establishment problems.
- (ii) Investigation of possible coppicing, stool shooting, and other "unconventional" economic forestry practices.
- (iii) Concentrated examination of various approaches to limited areas for first phase treatment. (sic)
- (iv) Comparison of costs of reshaping and spreading approaches.
- (v) Drainage problems in relation to slip and vegetation establishment.
- (vi) Soil building processes.

(b) *Chester Moor, Co. Durham* described as derelict areas in a village.

- (i) Study of immediate problem of improving appearance.
- (ii) Study of costs of alternative solutions e.g. removing remains of demolition, creating contoured surface using different materials.
- (iii) Soil development from different materials.
- (iv) Natural succession of plants and processes to speed this process on areas of demolished housing.
- (v) Future use of land.
- (vi) Comparison of costs for terracing and contouring.
- (vii) Surface drainage.
- (viii) Vegetation, the contribution of different species to the development of soil fertility.
- (ix) Establishment of grass sites after demolition of buildings.

(c) *Montague Colliery, West Denton, Newcastle upon Tyne.* A medium sized pit heap in a restricted area amidst extensive urban housing development. This site offered the opportunity to investigate:

- (i) Operating plant on a restricted site, with the problems and potential nuisances to neighbouring properties which these would represent.
- (ii) Drainage of compacted hard surfaces which could not economically be removed.
- (iii) Selection of species and techniques to establish vegetation which will not be subject to severe damage particularly by children.

(d) *Egerton Gardens.* Derelict land south of Egerton Street, Scotswood, Newcastle. This site was thought to offer the possibility of:

- (i) Investigation of the minimum level of information (drawings and specifications) to enable competitive tenders to be obtained and submitted for grant.
- (ii) Studies of the establishment of vegetation on derelict sites in active industrial areas.
- (iii) Species and techniques of planting for urban open spaces in the conditions of (b) above.
- (iv) Use of derelict material to form play and other surfaces.
- (v) Maintenance of soil fertility in active industrial areas.

(e) *Big Waters, Seaton Burn, Northumberland.* The site as originally defined included 78 acres, and research problems were listed as:

- (i) Planting of reclaimed land to create wildlife habitat.
- (ii) Stabilization of flood waters to control lake level.
- (iii) Development of soil in areas of high watertable.
- (iv) Planning problems of providing active recreation facilities within a wildlife habitat.

(f) *Spoil Heap, Walbottle, Newburn, Percy Pit.* This site was said to give the opportunity for investigations as follows:

- (i) Reshaping a heap that was a prominent shape in the wide landscape and which could not be totally removed.
- (ii) The establishment of vegetation on steep shale slopes where some pollution occurs.
- (iii) The development of soil in the same conditions.

3.3.3 Final selection of sites and works

Three of these sites (d,e and f) still form part of the project. However, by the time the financial basis of the research had been decided, nearly two years had elapsed and the first three sites selected were, for one reason or another, no longer available. These were replaced by Roddymoor at Crook, Haswell Colliery, and St Anthony's Point. After the preparation of sketch plans, problems of acquisition resulted in Percy Pit and Haswell Colliery being replaced by the sites at Maria Colliery, Copperas Lane and Felling. These omissions and introductions resulted in some changes in the direction of enquiries, notably by the omission of the village improvement scheme at Chester Moor. This, with hindsight, is seen to be an advantage since, had this topic remained, it would have resulted in an undesirable broadening of the basis of research. The final selection has channelled the development of research into a number of clearly defined topics, with each site providing a different insight into a topic and its problems, rather than introducing new topics. Some sites have special features of interest and thus may be thought to give the lie to this generalisation. It is, in the main however, correct, and as the layout of chapters of this book indicates, the organisation of research into the general topics which are most significant represents a more coherent approach than the first tentative proposals.

3.4 General research interests

The subjects covered by the succeeding chapter titles and subheadings, for example, landform design, methodology of landform design, land drainage, soil-forming materials and botanical studies of natural and planted vegetation on colliery shale, can be studied on all the sites and the variations in site conditions make it possible to see each problem more fully. Special problems which require particular treatment can also be seen in the context of the total pattern of reclamation procedures.

3.5 Research interests associated with individual sites

It is nevertheless possible to pick out subjects and aspects of the major research topics which are particularly associated with, or specially suitable for study on individual sites because of situation, topography or land use requirements. These special lines of study and any specific trials related to them are listed site by site below.

3.5.1 Northbourne Park, St Anthony's, Newcastle upon Tyne

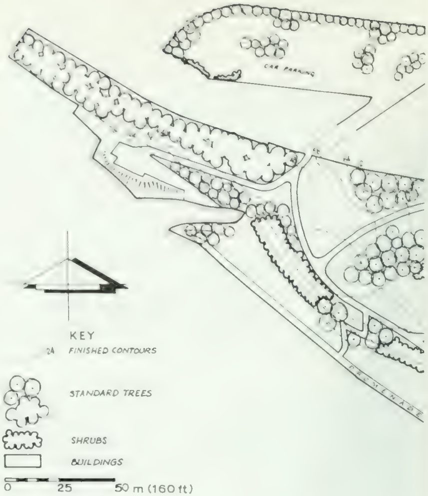
This site (Fig.3.2) has provided the opportunity to investigate the development of soils on areas affected by industry and development other than coal mining. The aim of this work has been to raise sub-optimum soil conditions by contrasting methods, including the application of sewage sludge (3 in cover) to allow adequate plant growth and to compare the methods used. Field trials to test a range of plants and soil treatments in site conditions have been included on this site. The investigation of steep slope stabilization was originally envisaged as a major feature of this site but the establishment of the separate, but closely linked steep slopes research project, resulted in this aspect being omitted. An evaluation has yet to be made of the application of agricultural grass seeding rates to recreation uses as attempted on this site.

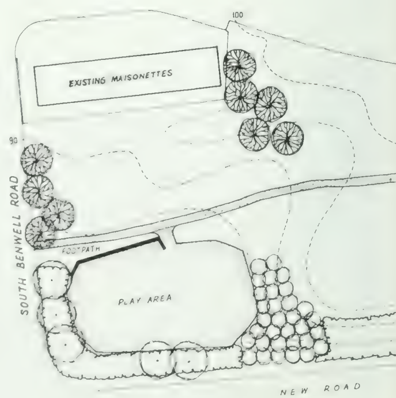
3.5.2 Egerton Gardens

The problems of extreme hard wear and vandalism as an influence on the design approach have been well illustrated on this site (Fig.3.3) and to a less marked extent at Northbourne Park. An experiment involving stooled plants to provide dense growth on embankments is in the course of assessment, though the comparative trials of three methods of grass stabilization by mechanical means were invalidated by a contractors error. Four methods of seeding were adopted.

(a) Hydromulching
(b) Seeding bitumen spray
(c) Seeding and P.V.A.
(d) Seeding alone (control)

Unfortunately the hydromulching sub-contractor sprayed the entire embankment, including an area which had been





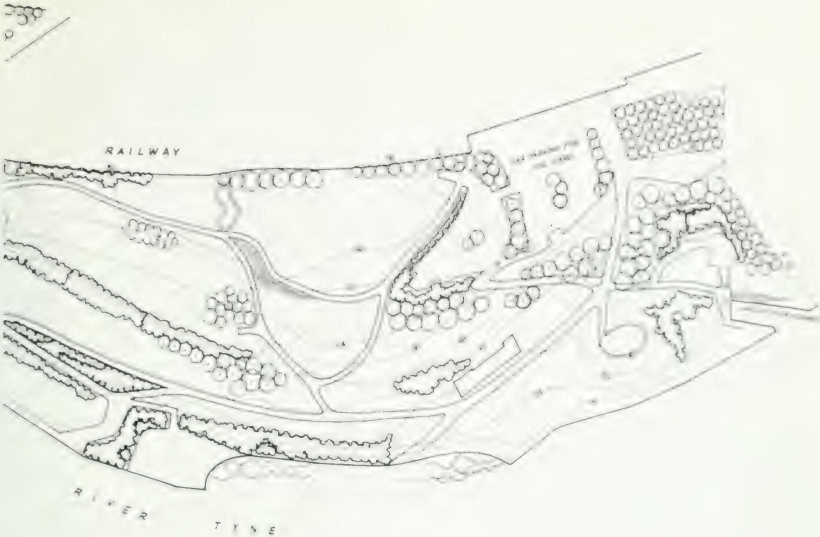


Fig 3.2 Northbourne Park: plan of reclamation proposals

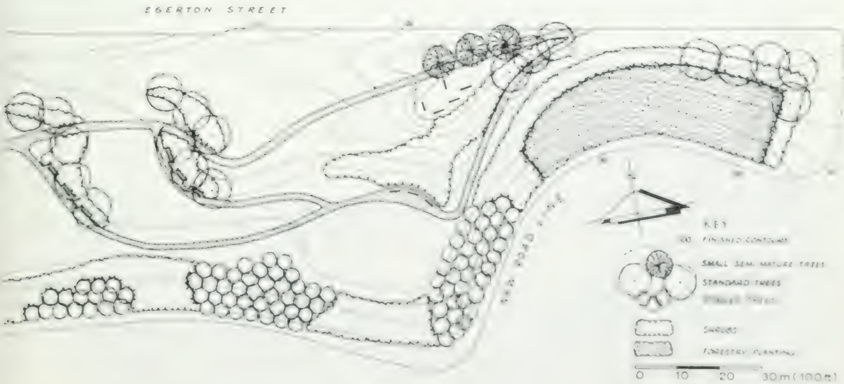


Fig 3.3 Egerton Gardens: plan of reclamation involving a series of terraces

seeded and sprayed with bitumen emulsion exceeding the area he was contracted, or indeed paid to do. The experiment was abandoned. Some parts of the site have been sown with experimental mixtures of grass and herbs to see if areas of interest requiring little maintenance could be created. The assessment of these mixtures is as yet incomplete.

3.5.3 Roddymoor, Crook, Co. Durham

Extensive species trials have been laid out on this site and investigations into the waterholding capacity, nutrient retention, the development of organic content and crumb structure as a result of maintenance techniques are under way. The results of this work are reported in the appropriate chapters of this volume The uses of topsoil, subsoil and drift material as well as farmyard manure as spoil additives are being compared. Spoils left as surface materials include grey, black and red shales, hot shale, slurry and red shale mix, coke breeze and ash. This sort of experiment is central to the work of the project and is repeated on most sites, as are studies of vegetation (e.g. grass/legume) covers. The species trials have been laid down for trees and shrubs and include unrooted cutting trials.

3.5.4 Percy Pit, Newburn

A range of investigations on vegetation, soil development and stability would have been undertaken on this site had the work proceeded on the ground. One aspect which was studied carefully in the design stage was a special approach to the drainage of steeply sloping sites involving the creation of low surface water channels, collecting water to prevent the build up of large volume flows down the slopes, holding the water to prevent excessive flooding at the lowest point due to rapid concentration and releasing it to the main drainage system at a rate which the system could accept. The investigation, at the design stage, of the influence of the heap in the broader landscape and approaches to its remodelling, are design research topics dealt with at some length elsewhere in this volume.

3.5.5 Haswell Colliery, Easington, Co. Durham

The development of this site, curtailed by acquisition difficulties, would have afforded practical testing proposals for optimum slope and aspect for agriculture. The site would have provided a particular opportunity for the study of the creation of heath type, *Nardus stricta Erica* flora on areas to be used for picnicking and casual recreation. This flora had developed over a number of years on certain parts of the site. Both the speed of natural and artificially stimulated development and the suitability of the naturally developing flora would have provided information of value.

3.5.6 Big Waters, Seaton Burn, Northumberland

As originally proposed, this site has offered the chance to plant a number of field trials of species suitable for wild life habitat. This is the only particular line of research within the compass of the project's main objectives which is specific to this one site. A large number of unrooted cuttings have been included in these trials. The techniques of working areas of burning shale and preventing the spread of burning has been a particular practical problem.

3.5.7 Windynook, Whitehills, Felling, Co. Durham

This site (Fig.3.4) has provided particular difficulties of acidity and salinity of the parent material. In addition to the scientific interest, and the administrative difficulties which this condition introduces, the study of earthmoving calculation techniques has been particularly significant on this site where a large volume of material has been regraded on what is a relatively small area in compliance with certain criteria for slopes and angles for use and maintenance. The problems of surface water and deep under drainage, stability and erosion can also be examined in detail.

The problems of toxic shales and their treatment at this site and at Big Waters are dealt with at some length in Chapter 6, and will be the subject of continuing research over a number of years.

Fig 3.4 Felling, the main heap

3.5.8 Maria Colliery, Newburn, Northumberland

This small site, in the process of reclamation at the time of writing, is to be returned to industry. Methods of providing temporary grass cover at low cost on the varied spoils is included though this work is not yet complete. Otherwise no particular topics for research other than those common to all sites, have been defined for this site.

3.5.9 Copperas Lane, Northumberland

At the time of writing, only preliminary investigations and sketch plans have so far been undertaken. It is not anticipated that any particular problems will be encountered on this small site, which is to be developed for casual recreation and open space.

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Name of site	Location	Climate	Area	Visual description	Soils	Proposals
1. 'Northbourne Park' St. Anthony's Site 'B' Newcastle upon Tyne, Northumberland	St. Anthony's Point, Walker Newcastle upon Tyne	Open and exposed to local prevailing wind westerly along river valley also to cold east wind in winter.	6.07 ha (15.0 acres)	The northern boundary feature, the railway, acts for a large part of its length as a visual limit to the site, which slopes southward to the Tyne in a formation consisting broadly of four terraces linked by embankments.	Surface material underlain by glacial drift. Consists of a mixture of natural soils and soils dominated by introduced material - loamy clay.	Developed as a river oriented park, allowing for more intensive use if this is subsequently felt to be desirable.
2. 'Egerton Gardens' Newcastle upon Tyne, Northumberland	Whitehouse Road, Paradise, Newcastle upon Tyne	A prominent position in the Tyne Valley on a favourable south facing slope. Comparatively exposed to prevailing winds down the valley.	1.17 ha (2.9 acres)	A small area of open space in a part of Newcastle undergoing extensive change. Good views across the Tyne Valley and up the Derwent Valley.	Clay, overlain by building rubble, chemical waste and other debris. Virtually no topsoil.	To provide a robust design by the development of strong land forms with a linear feeling created by the arrangement of contours and artificial platforms.

Name of site	Location	Climate	Area	Visual description	Soils	Proposals
3. Roddymoor Colliery, Crook, Co. Durham	One mile north west of Crook	Relatively high altitude of 183m (600 ft) and more above sea level. Generally exposed though the main west-east valley is comparatively sheltered.	56 ha (140 acres)	Before reclamation the site consisted of the massive pit heap, a dominant element in the whole valley landscape, and the associated colliery and coke plant working areas, creating a degenerate and depressing area.	Soils derived from boulder clay overlaying coal measures. Slurry ponds occupied a large area of the site. Burnt and unburnt shale, coke and ash.	Agricultural land, with grazing of stock, woodland on steep slopes and shelter belts along the watercourse in the flatter area.
4. Percy Pit, Newburn, Northumberland	West of Lemington	Position and aspect favourable, sheltered from north east winds. No danger of frost pocketting.	12.95 ha (32 acres)	A conical heap within an old dry gravel working at west end of site, and some low tips and a flat area of colliery yard at eastern end. There is also an area of allotments.	Gravel workings at western end, into which the pit heap material was tipped, indicate the presence of a bed of river gravel and a resulting light soil.	Western end incidental open space, possible development of an artificial ski slope on the retained pit heap material. Eastern end industrial development.
5. Haswell Colliery, Easington, Co. Durham	South of Haswell Village	Comparatively exposed, occupying a north/south saddle in open country. 143m (470 ft) above sea level at highest point.	31.02 ha (76.66 acres)	Much of the worst visual disturbance is created by the opening up of vertical shale faces by red shale operators. Established areas of vegetation, where undisturbed, attractive and extremely interesting botanically.	Some areas of natural soil remain at northern end of site where tipping did not occur.	Sketch plans only prepared. Agricultural use either as a single small holding or attached to existing holdings.
6. Big Waters, Seaton Burn, Northumberland	West of A.1 at Six Mile Bridge between Seaton Burn and Wideopen	Occupies a shallow depression in the South East Northumberland Plain. Liable to drainage of cold air and frosting in still conditions.	45.32 ha (112 acres)	Picturesque but much of the land is without vegetation and the lake water and Seaton Burn are frequently discoloured; in particular the burn has nasty deposits on the banks.	Derives from boulder clay overlaying coal measure rocks. Spread mixed burnt and unburnt shale appears not particularly hospitable to plant growth.	Nature reserve and field study facilities for the Northumberland and Durham Naturalists Trust.

Name of site	Location	Climate	Area	Visual description	Soils	Proposals
7. Whitehills/ Heworth/Windynook Felling	South and east of Windynook and Felling	High up and very exposed from its north and east aspect. It can be assumed this high elevation mitigates the effects of air pollution found elsewhere in this area.	56 ha (140 acres)	Five distinct areas of dereliction (with a characteristically typical appearance adjoining them). Views to south and west are restricted, but to the north and east a complete panorama of Tyneside from the west side of Newcastle to Tynemouth in the east is visible from numerous places on the site.	Limited natural soils derived from sandstone. In some parts a capping of boulder clay occurs. Burnt and unburnt shale, slurry, washery waste and domestic refuse in the quarry. Extensive areas of fused shale.	Playing fields and interesting open space for casual recreation.
8. Maria Colliery Throckley, Newburn on Tyne, Northumberland	West of Throckley/ Westerhope Road, a quarter of a mile north of Throckley	Open and exposed to all winds. Cold air drainage free, little evidence of serious atmospheric pollution.	4.45 ha (11 acres)	Small conical heap containing about 57,000m^3 (75,000yd^3) of unburned shale amongst low heaps of indeterminate age now largely vegetated. Overlooking open country of gently undulating nature.	Gravelly loam, textured brown earth, and unburnt shale.	Industrial development.
9. Copperas Lane Scotswood, Newburn on Tyne, Northumberland	At the southern end of Denton Dene, west of Newcastle City boundary	Exposed to valley winds in the Tyne Valley, and heavy atmospheric pollution.	16 ha (40 acres)	An uneven and badly drained area of uncontrolled tipping and brick waste to the north with steep banks of colliery waste tip overlooking the river to the south and old clay pit to the west. Extensive views across the river and towards Stella Power Station and Percy Pit to the west.	Limited natural soils. Soils developing on tipped material are of high clay content.	Casual recreation and public open space.

Chapter 4 Landform design

by M.F. Downing

While future land use is perhaps the dominant factor which must be considered in the design of earth shaping on reclamation sites, it is by no means the only constraint which requires consideration. Some reclamation may in fact take place when the future land use is as yet undetermined, in which case the design must incorporate positive features permitting the widest range of options for the future development of the site. Where specific requirements are the result of particular end uses, they should only be carried out when they either do not preclude other end uses or there is no possibility of a change of plans.

When discussing earth moving, the factors governing the design approach can be classified broadly under four headings.

(a) Economics
(b) Aesthetics
(c) Topographical factors, including surface drainage and aspect etc.
(d) Functional requirements of land use.

It is unlikely that a given solution will be directed by only one of these factors. On the other hand, the different factors may frequently suggest contradictory solutions. However, this classification method can be used to establish some order in the setting down of the factors which limit the design.

4.1 Economics

The influence of economic factors is felt at every stage of the design process. A preliminary assessment of the possibilities of a site will include careful attention to the comparative costs of alternative methods of treatment. In general terms, the selection of special solutions, when these involve particularly expensive measures, will only be undertaken when a clearly defined demand exists. It is sometimes necessary to carry out simple exercises to test the strength of such demands. For example at Percy Pit, Newburn, there was a need for land industrial development. It became obvious very quickly that to develop the whole site for industrial purposes was likely to result in excessive costs. A simple study sufficed to show that the topography of the western portion of the site was such that, after regrading, only half could be made available as a flat area suitable for industrial development; the remaining area consisted of steep banks, which would be entirely non-productive and difficult to maintain. The need for space for industry was not strong enough to justify such extravagant use of land at the time and place of the enquiry. That is not to say that such a step might not be considered justified in other circumstances.

Except in specific cases where particularly strong demands exist, economic factors play a significant role, not so much in determining the overall form of the reclamation, but in refining the effects of decisions based on aesthetics, topography, and land use requirements, so that the solution can be achieved at least cost. Again, no designer can consider these other factors without appreciating their cost implications, so cost consciousness may be said to influence all aspects of the design approach, sometimes at an almost subconscious level. At every design decision stage the answer to two questions must be sought. The first is 'what is the cost of the solution proposed?' The second is, 'is this the optimum return for the money outlaid or will any increase in expenditure result in significant improvements in the overall results?' or conversely, 'will further financial reductions result in limiting the potential of the site?' The design solution should always keep open as many of the development options for the site as possible.

4.2 Aesthetics

The aesthetic factor is the next to be considered, and the point must immediately be made that this is closely linked to the other factors listed. Although the functional and topographical requirements of a site design may result in compromise with the original aesthetic purpose, it is the visual aspect of landscape work which causes, in the majority of cases, the most significant impact on the greatest number of people. If this is a somewhat limited reason for the development of subtle designs it is a more than adequate justification for the avoidance of ill proportioned and unsightly compositions.

4.2.1 Natural or geometric forms

The basic aesthetic decision which must be taken on each site concerns the aesthetic 'idiom' which will govern the design. The choice is between a design adopting naturalistic forms which will blend into the natural topography of the surrounding landscape and a consciously dominant geometric or architectural form. This must depend largely on the site and its environs. Hackett (1960) has suggested that the natural landscape should be the dominant influence in the design of new landforms, and arrives at the conclusion that artificial or architectural forms are acceptable only in the context of environment in which man made forms dominate. A contradiction to this statement is provided by the many historic examples of landform design, showing most patently the hand of man, which are to be found in settings of natural topography. A number of such examples can be found in England alone, notable among them being Silbury Hill and Maiden Castle. Hackett later (1964) suggests three principles governing the appearance of such artificial earthworks which make them visually acceptable. These may be summarised as:

(a) Containment within the topographical framework
(b) The use of simple forms resulting from primitive methods.

(c) The relationship of earthworks to another humanised feature, eg defensive earthworks following the form of the city around which they were built. The form of the city will of course be set out with some regard to the topographical advantage to be gained from its site.

Of these, the first two principles accept the dominance of natural forms in a rural situation, the third offers a justification for architectural or formal design elements being acceptable in the context of an architectural background. Perhaps a fourth principle should be added to the three previously quoted when attempting to explain the success of many obviously artificial earthworks which are acceptable in natural surroundings. This is the relationship of objects of similar scale.

4.2.2 Scale

For example while the form of a feature such as Silbury Hill is totally foreign in the rural environment of Wiltshire, the rightness of its scale within the surrounding landscape makes it completely acceptable.

4.2.3 Antiquarianism

The acceptability of some historic examples such as the Cerne Giant of Dorset or the White Horse of Uffington, Wilts is enhanced because they have a readily comprehensible shape and an obvious historic significance, certainly for the amateur of landscape. Both these man made features keep clearly within the topographical framework, but both display an excellent scale relationship with their respective, and similar, landscapes. Antiquarianism as it affects the way in which people look at landscape is one of the aspects dealt with in an amusing article by Lowenthal and Price (1965), which also makes clear that landscape tastes are not static for all time but subject to subtle fluctuations of emphasis.

Two examples of the successful creation of landform designs related to dominant artefacts are for the Oldbury Power Station in Gloucestershire, and the nuclear research stations at Harwell in Berkshire, both by Geoffrey Jellicoe. The former the designer describes as geometric and the latter organic (Jellicoe 1966). At Oldbury the landform design achieved a compromise between the pattern of the existing landscape, a humanised but traditional pattern of the past, and the vast scale of the geometry of the age of technology. In so doing it has taken some of its form and its scale from each of these elements. At Harwell, nature dominates in the flow of the Berkshire downs, and the shaping of the land forms is based on the conscious study of the natural forms. These entirely different solutions by the same designer are both acceptable because the eighteenth century picturesque tradition, which is still the aesthetic criterion by which landscape is judged today, demanded the acceptance of the genius of the place.

4.2.4 Design aspirations

Jellicoe reminds the reader of the aspirations towards the creation of a self sufficient art form which must be the landscape architect's ideal, over and above the functional requirements of good craftsmanship. This is related to the effect on human beings which is, he says the ultimate objective of all landscape design. He quotes observations made by Barbara Hepworth (1952) who, speaking of the response of visitors to the design and proportions of the Piazza San Marco in Venice, said people "grouped themselves in unconscious recognition of their importance in relation to each other as human beings." This spiritual stimulation is the ultimate achievement of design and one which is most poignantly desirable in areas of industrial depression where landscape reclamation works are predominantly carried out.

4.2.5 Application to research sites

The project has been concerned with three sites where artificial forms have been positively accepted as the correct idiom for landscape reclamation. These were Northbourne Park (Newcastle), Egerton Gardens (Newcastle) and Percy Pit (Newburn). Of the other sites, the proposals for Roddymoor, Haswell Colliery and Big Waters involved regrading to contours compatible with the natural topography, while at Felling the design departs to some extent from its naturalistic basis as a result of the requirements for playing fields which result in terracing. Maria Colliery site is designed so that it and the adjoining land are returned to the natural contours of the land before both tipping and excavation for clay occurred, as nearly as these can be ascertained.

The acceptance of geometric forms on the three sites first mentioned, arises in each case from a different cause. At Northbourne Park, the form of the site was dictated by the existing strong terrace pattern resulting from residential and industrial uses in the eighteenth and nineteenth century, and from the tipping of ballast from ships arriving in the Tyne. This was an established and accepted part of the Tyne landscape and was retained with only minor modifications where function or stability factors made it necessary.

At Egerton Gardens, the urban setting, in an area where care for the landscape could not be expected to be of a high order, called for a design based on an artificial arrangement of planes and embankments (Fig.4.1). Such a design would reflect the vigour of the human environment and at the same time resist the worst depredations of vandalism.

Fig 4.1 Egerton Gardens: cardboard model prepared as a design check.

The problem at Percy Pit was one in which the aesthetic [illegible] was complicated by social factors. The site [illegible] regraded to natural contours, or it could [illegible] as it was as a conical pit heap. In the [illegible] Report (1965) the latter course was [illegible]. Planting was suggested, but 'there should be [illegible] height with consequent reduction of scale [illegible] which is so magnificently in key with [illegible] quality of the power station and the [illegible] and chimneys, the breadth of the Valley, and [illegible] of the surrounding hills.'

[illegible] not find universal support and, particularly, [illegible] residents were strongly opposed to the retention of something which, to those who lived in its shadow, had a physically overbearing presence and provided a permanent reminder of past social evils. The design [illegible] proposed by the project involved the remodelling of the heap to provide a feature which was significant in the valley landscape without overdominating its immediate surrounds. A series of south-facing viewing platforms were to be created commanding the valley (Fig.4.2). It was possible to arrange the design in such a way that the new artificial shape dominates only from the valley bottom where, Laurie has suggested, it would be in keeping with other large scale industrial objects. From some positions outside the immediate river valley, the conical heap had appeared totally out of place and the proposed regrading would have resulted in the creation of apparently natural contours well matched to the large scale of topography revealed in distant views along the higher slopes of the Tyne valley in this area. The early studies made into the influence of the heap in the Tyne valley and the neighbourhood are discussed in greater detail in Chapter 13.

4.3 Topographical factors

Aside from the influence that topography exercises on the design aesthetic, which has already been discussed, it plays

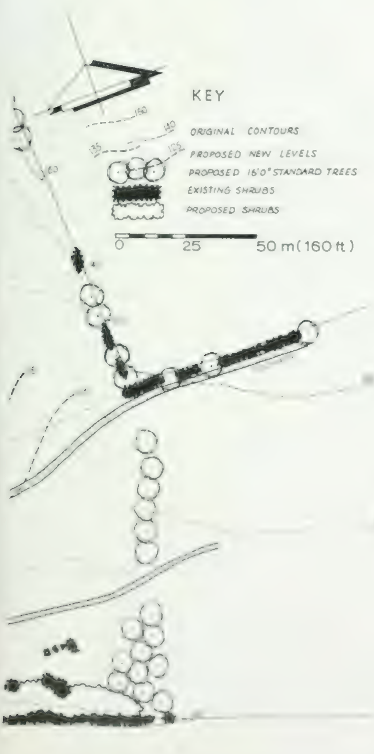
Fig 4.2 Percy Pit: plan of reclamation proposals.

a significant part in deciding the disposition of regraded material. It is essential to establish a healthy new landscape over the reclaimed area and this must be done so that the ecological balance of adjoining and otherwise interdependent areas is not disturbed.

4.3.1 Drainage

The designer must therefore pay attention to the watershed characteristics of the area to be reclaimed, and this should include detailed drainage considerations.

It is also necessary to consider the interior measures for the safeguarding of such areas in the event of adverse weather conditions during the operations period and while the site is becoming established. Many of the problems which Curtis (1969) has shown to result from strip mining in Kentucky, U.S.A., are commonly found on disturbed land particularly when reclamation of mining waste is in progress. Thus, operational land and land awaiting revegetational cover is subject to accelerated runoff and erosion with resultant turbidity in natural water-courses, silting up of basins, and in extreme cases gully erosion in existing stream beds.



4.3.2 Water quality effects on adjoining land

In addition to the effect of quantities of water, the quality of water emanating from reclamation areas is an aspect that should be carefully considered when natural drainage systems are involved. Downstream sections of water catchment areas can be seriously affected by the drainage of polluted water from strip mining or the deposition of spoil. In this country, the majority of this kind of dereliction occurs in close proximity to centres of population and industry, and either the effluent is taken into piped sewage systems or it is discharged into water-courses already heavily polluted by other industrial effluents. Where water quality is politically considered important, often the only solution available is to pipe the effluent away from the locality to prevent it from entering the natural drainage system.

4.3.3 Free drainage

The foregoing assumes attention to details of topography which ensures that the reclaimed landscape will drain adequately and that there are no areas where water will stand in storm conditions, unless this is by design, and no parts of the site are excessively damp. This involves ensuring that the design allows the free passage of water down and through or away from the site into the drainage system of the area, whether it be a natural stream and river drainage pattern or a piped sewer system.

4.3.4 'Water table'

The behaviour of a soil 'water table' is dependent on a number of factors - the topography, the type of soil, and the volume and intensity of precipitation according to the time of year. The regrading of pit heap areas is liable to have an effect on the watertable of the adjoining land and this can be particularly significant where the natural watertable of the area is high in relation to the surface of the ground. Any such possible alteration to the watertable and its consequences must be carefully studied before any regrading takes place. This is particularly important in relation to standing timber of any size. The conditions at the surface of regraded material will also be significant since the porosity of the ground surface will affect the percolation of water into the soil, affecting both water table level and subsequently the water availability in times of comparative drought.

4.3.5 Ground water movement

There are circumstances in which it is possible that a reduction in natural ground levels to form an even grade with opencast mine waste may result in the creation of a new springline, where the watertable has been artificially held up by an impervious stratum. Similar conditions can occur when waste material is laid down on impervious strata. The flow of water will follow the falls of the natural ground and a spring line is likely to develop along the lowest part of the deposited material. A situation such as this is one requiring extremely careful investigation and a sound knowledge of the engineering principles of the design of earth structures to ensure that a stable situation is created (Tschebotarioff 1951, Krynine & Judd 1957, Capper & Cassie 1954). The same careful attention is necessary for the treatment of natural spring lines or even water courses likely to be covered over by fill material. It can hardly be necessary, after the lesson of Aberfan, to underline the dangers of flow slides resulting where deposition occurs on sloping sites undermined by ground water.

4.3.6 Frost drainage

The consideration of drainage extends to ensuring, as far as possible, the unimpeded drainage of cold air on the site, regardless of the afteruse. Thus undrained hollows or the placing of vegetation screens where cold air flows might be impeded must be avoided.

4.3.7 Shelter

Consideration, and the solution, of this problem will depend to some extent on the specific afteruse intended. Also affected by the afteruse will be the consideration of shelter provision, though this is also determined to a large extent by the dominant surrounding topography (Caborn 1965). Shelter belts can be used to diminish the effect of wind on soil, both in its cooling effect and by wind erosion of soil particles in ploughed arable land, with a resultant improvement in the microclimate of the area of the shelter belt. In addition we now have a reasonable understanding of the effects of shelter belts on snow in terms of shelter and drifting (Caborn 1967), and the possibilities of planting to divert frost and cold air drainage from areas requiring special protection. The creation of new landforms offers unique possibilities of combining favourable arrangements of ground formation with shelter planting to create ideal climate situations. This design work is influenced by the framework of the existing topography and its consequent local climatic variations.

4.3.8 Engineering requirements

The critical structural requirements of earth banks and similar structures only enter the scope of topographical or functional factors as here defined when either aesthetic decisions, or the functional requirements of land use dictate the creation of steep banks and sharp angles. It is nevertheless important that the construction of new features out of deposited material must be structurally stable, and this involves investigation of the substrata and its relationship to ground water as previously indicated. It also involves ensuring that the surfaces of materials are stable which means that the angle of repose of the material must not be exceeded; on those sites where there is a large clay fragment in the shale, care must be taken to guard against rotational slip conditions developing (BSI Earthworks 1959). In fact the design usually formulated for regrading according to natural contours results in slopes very well below the structurally acceptable limits. The steepness of slopes is more usually dictated by other factors, the establishment of vegetation and minimising of slope erosion for example, or the economic maintenance of embankments which require slopes well below the critical structural level.

4.3.9 Application to research sites

The interaction of the dominant topography and the land use requirements of sites is demonstrated in section 5.4.7 where the application of both aspects to the research site is discussed.

4.4 Functional requirements of land use

The design of areas of regraded colliery waste material may be undertaken with any one of a number of end uses in mind. The most desirable end use for a site within a particular area may not have been determined. The possibility must be allowed for changing circumstances between the time of reclamation and subsequent site development resulting in changed land use requirements.

This presents two alternative possibilities as design approaches. The first as previously discussed is the creation of a site which has characteristics enabling it to be used for a number of purposes with a reasonably high degree of efficiency and convenience, while the second tailors the new landform and design details to one particular use, with the likely result that its adaptability is reduced. Before these extremes are reached there are a number of factors general to many, if not all, likely afteruses which need to be taken into consideration. It should be underlined here that the discussion refers to the climatic situation of the north east of England, and the range of afteruses which are possible in this climate and in the soils to be found here. Some limitations are also imposed as a result of human tradition and economics which dictate the choice of afteruse to conform with the pattern of development of an area. Investigation of nonconforming uses might well suggest that these could be established satisfactorily and such investigations should perhaps be encouraged. Except in those cases where an industrial, housing, or similar high density use is proposed for a site, it can be assumed that what is required is to create the best possible conditions to support plant growth, as this both indicates and is conducive to the development of landscape health. Buckman and Brady (1960) list 6 factors influencing plant growth as:

(a) Light
(b) Mechanical Support
(c) Heat
(d) Air
(e) Water
(f) Nutrients

It is therefore desirable to attain in all site developments the best conditions possible for plant growth under the listed headings.

The study of these factors supports the general conclusion that better, and particularly earlier, growth is achieved from plants growing on south facing slopes as a result of longer and more intensive exposure to sunlight. The advantages of this improved growth are most likely to be found with land in agricultural use, either pasture or arable, and particularly with horticultural crops. Soils which, because of favourable aspect, offer 'early bite' are much favoured by farmers, and standard recommendations for the siting of orchards emphasise the advantage of a south and south west aspect. In addition the increased warmth of such an aspect improves the environment for human occupation for both industry and habitation.

In the case of forestry on shale, on the contrary, experience has shown that with young trees better growth occurs on north facing slopes, for reasons thought to be connected with soil moisture tension (Richardson 1967).

Attention to aspect is particularly important when dealing with areas intended for sitting, walking and picnicking where the landform is frequently used to provide suitable sites in full sun and out of the wind for casual family and social gatherings. Other more specialist landforms can be developed for theatrical and musical presentations and arenas for sport where the raised sides can be used to accommodate the audience. The development of this type of feature in the north east of England calls for attention to the maximum provision of shelter and the optimum use of sunlight which implies careful consideration of aspect in the design.

4.4.5 Angle of slope

Detailed land form design is governed by slope angles and direction which are dictated by the nature of the spoil material and by the way the site is to be used. A theoretical optimum angle of slope is that angle at which adequate surface drainage occurs without any erosion of soil particles. This occurs at an angle of between 1:40 to 1:50 dependent on soil or spoil type. At angles above this erosion begins to assume significant proportions, while below it natural drainage does not take place. In field conditions the requirements of end uses usually dictate that this slope should be varied, necessitating the employment of either artificial drainage or measures to combat excessive erosion. Where reclaimed land is to be used for pasture, giving a comparatively low return on capital expenditure, the expense of providing field drainage is frequently considered unjustified and slopes of between 1:30 and 1:40 are usually employed. These have been successful on the research project. Even at these slopes, without careful management, there is a danger that cattle will poach the ground, which can cause particular problems in the poorly structured 'soil' of reclaimed land. Where land is to be used for playing fields a shallower slope must be achieved to provide a surface which is sufficiently flat for ball games. This means that an artificial drainage pattern must be installed to ensure that excess water is taken away from the surface so that there is a good growth of grass and the playing surface is in a suitable condition for use in the wintertime, when the heaviest use is generally to be expected.

On the majority of sites the large volume of material to be disposed necessitates the construction of some embankments. In open spaces for casual recreation, picnicking and nature study, the design may incorporate small hills.

The design of such features must be undertaken within certain limitations of slope. Experience in Durham has suggested that an angle of slope greater than 1:5 to 1:6 should not normally be adopted, as anything greater than this will not easily merge into the natural topography and will create problems of surface water drainage. Where a downward slope of this high angle approaches the boundary of a site, it has been the practice to reduce it to 1:20 so that the rate of flow of surface water is reduced. This helps the cut off ditches and drains to work efficiently and prevents flooding of the adjoining land. These points are discussed further in Chapter 7.

In certain cases it may be desirable to create slopes steeper than 1:5 to 1:6, and this may be possible in certain circumstances by the use of special techniques, some of which are discussed in Chapter 6. Although there are many examples of the satisfactory establishment of steep slopes on roadsides and in similar situations, it must be remembered that shales have their own particular problems of stability and chemical content. In general steep slopes need to be planted to maintain stability and tree planting undertaken to provide shelter and to eliminate or rather reduce the maintenance liability. It is important that species are selected with a light canopy which will not smother the shrub and ground cover layers necessary to maintain the surface stability of the slope. For certain special uses, notably artificial ski slopes, steeper slopes up to 1:2½ are required, and these can be adopted in the knowledge that the artificial cover afforded by the skiing surface will provide some stabilization of the soil.

The operating capabilities of machinery may be a more realistic limiting factor than the visual requirements on agricultural land. Where agricultural machines are to operate efficiently an angle of slope not greater than 1:10 should be adopted. It is possible to make use of grass maintenance equipment which will operate on short slopes as steep as 1:1. The machine which can do this is a flail which can cut up or down a short slope from a tractor with a long arm standing on flat or near flat ground. The situations in which this type of equipment can be operated are obviously limited, and their use is only warranted where amenity overrides economic considerations. The use of grass cutters operating on the 'hovercraft' principle are affected by the same limitations. They can be operated on slopes of 1:2. The steepest slope acceptable for reasonably efficient operation of standard grass cutting equipments is 1:3½, well below the angle of repose of engineering soils other than organic soils or soils in an exceptionally wet condition (BS C.P. 2003 1959 Table 3). This will be reasonably stable so long as the surface is held by some means, though this sort of slope can only be justified for small areas and where costly maintenance can be accepted. Even where forestry is to be undertaken on these slopes they may need special stabilising techniques and should in general be kept to a minimum. Particular precautions in the form of cut off drains need to be taken to prevent the flooding or silting of land at the bottom of slopes, but the expenditure and trouble involved is frequently well repaid by the greater area of land with favourable aspect which can consequently be developed.

4.4.6 Nature of material

Reference has been made to the nature of materials met on areas of colliery waste and their effects on the adjoining land, and on the watershed in which they exert their influence. The very varied chemical and physical properties of shale found on all coal sites may have a critical effect on decisions relating to the finished formations and the land use of individual sites. Some assessment of the material and its potential must be made at an early planning stage, before any proposals for land use or final landform. Details of the behaviour of various materials in relation to plant growth are given in Chapter 8. In addition to these limitations the liability to combustion in the material, dependent on combustible content, sulphides and air, will affect the suitability of the material, and thus the site, for certain uses.

Development of colliery land for industrial or housing purposes should in general be undertaken only on heaps of material derived from newer and more efficient washery plant. The difficulties of assessing the contents of heaps, the use of temperature measurements, and special precautions required to prevent combustion are discussed at greater length in Chapter 6. It must however be said here that until further research can be undertaken into this aspect of the behaviour of colliery waste material, the most stringent precautions should be observed.

The way in which the nature of the shale may dictate the final landform design has already been mentioned. Some material may need to be buried and other material used as a topdressing. The nature of some spoils may be so [illegible] to plant life, as to make their exposure undesirable and this must be ascertained by investigations before any designing is undertaken. Similarly the presence of large areas of fused material, in which single blocks can be many cubic metres in volume, presents problems of design (Fig.4.3). It is often not possible to break this material down, it is not susceptible to explosives, and it is frequently difficult to move by reason of its size. Consequently the design has to be manipulated to leave such material in place, with the limitations this imposes.

The nature of material on site also affects the cost of earth moving operations, and this may be significant in determining in some cases the final landform of any design. Simple operations which can be undertaken with one machine, e.g. a scraper, working homogeneous material varying from loam to gravel particle size, are the ideal processes for efficient low cost reclamation works. The presence of wet material, slurry, fused material, or hot material, all of which are common in pit refuse, introduce complexities which slow down the operational cycle or involve additional machinery and handling, and increase costs. Often economics can dictate that such difficult materials should be left undisturbed.

4.4.7 Economic operation of plant

Wherever possible the cost factor also enters into the detailed design of new land form. A design which can be completely carried out using a scraper, without any ancillary equipment, to form embankments for example, will be cheaper to carry out than one in which additional machinery is required to complete the final shaping and placing of material. Hackett (1964) suggested that designs involving undulating landform are less expensive to carry out than designs consisting of geometric terracing, and that on any site over 0.1 ha (¼ acre) the cost differential of different design approaches is significant. Landform designs should therefore take account of the maximum operational angles, the turning circle, and performance data of the type of machine which, from its method of operation and size, is thought to be the most appropriate for the site to be developed.

It is evident that any aspect of the design which causes any check in the free operational flow of the earthmoving process, or causes the introduction of special apparatus or a special process, must have a particular significance in the final design concept for it to be allowed to remain on economic grounds alone.

4.4.8 Application to research sites

The sites under treatment by the project offer a number of examples of the way in which the topographical framework of the site, and the proposed land use, control the design of earth shaping. Northbourne Park, Newcastle, can be quickly dismissed, as the earth shaping was a minor feature in an already strongly defined landform which suited admirably the recreational purposes related to river activities, for which the park is intended to cater. The site was one of the early schemes undertaken within the Project and did not involve any colliery waste. The proposal to leave the landform as existing and use trees and shrubs to further stabilise the banks (1:1½ gradient), was not at first received kindly by the Ministry of Housing and Local Government, and at one stage in the proceedings, the Inspector suggested regrading over the whole area. An exercise was carried out and this showed an average gradient of 1:4 would result and hence the area would be difficult to use for its intended purpose of public open space and also be difficult to maintain. It was finally agreed that by leaving the terraces and slopes in their present landform, areas of useable open space would be left. The use of trees and shrubs as acceptable reclamation elements for the stabilisation of steep slopes was eventually accepted for this site.

Fig 4.3 Felling: conical heap and lumps of fused burned shale.

At Egerton Gardens, the general topography of the area enabled the development of the site to the best functional advantages. The north slopes of the Tyne Valley at this point rise at an angle of approximately 1:10. Topography, function and aesthetics all combined to suggest a design with a series of platforms separated by steep banks. South facing sitting areas, with views across the valley are sheltered by being tucked into the banks. The site is free draining, discharging into the municipal sewers, and there were no problems of inhospitable parent material. The bank along the southern part of the site is at an angle of about 1:2. It has been thickly planted, and seeded with rough grass. An experiment to compare the merits of bitumen spraying and hydromulch techniques was unfortunately invalidated as a result of a contractor's error, as previously indicated, but the establishment of vegetation on slopes has been successful, except where limited human interference has occurred. An experiment making use of P.V.A. (poly vinyl acetate) as a method of covering a section of slope after seeding resulted in poor germination and growth which it has not been possible to explain satisfactorily, though it has been used successfully elsewhere. The angle of slope of the platforms is 1:50 to 1:60 and this appears to drain freely over the limited areas though it is assisted by the presence of some cut off drains at the base of embankments.

Percy Pit site (Fig.4.3) involved a design which for the heap area combined one artificial aspect with a naturalistic one, as has already been shown in Chapter 3. The use of this part of the site for open space providing sheltered viewing platforms overlooking the Tyne valley, dictated the form of the design. Drainage of the site introduced some problems discussed further in Chapter 7, but as the site was drained into the main sewer system, no dangers of watercourse pollution arose. The angles of slope adopted in the design were well below those critical for slope stability, though sufficiently steep to necessitate the provision of special open channel cut off drains to collect and hold storm water in severe cases until it could be carried away at the capacity of the sewers. The average slope was in the region of 1:7 to 1:9, while in one sector the provision of an artificial ski slope resulted in steeper angles, approximately 1:5 being proposed (Downing 1968).

The eastern sector of the site, subject to comparatively minor regrading to provide two almost flat terraces for industrial development, was entirely dominated by functional requirements. Industrialists generally require flat sites for the development of factories and regrading for this purpose should obey these demands. Where some delay may occur between reclamation and development it may be necessary to grade to a slope of the order of 1:70 so that some drainage of surface water will occur naturally. This was carried out in the Percy Pit designs; obviously temporary tile drainage was unjustified, but some way of limiting standing water was also called for. It was also important to minimise the excavation required for later development. Hence the slope was selected to give run off of surface water without excessive regrading at the industrial development stage.

At Haswell Colliery, the design was dictated by the functional requirements of agricultural pasture, but this has to be carefully combined with the topography of the site and neighbourhood. The site is in a watershed position, between streams draining to the west and east. The shale has been deposited for many years and there was little to suggest that surface water leaching through the site would result in watercourse pollution. Detailed investigations of this aspect were not completed due to the cessation of design work for the site. The position of the main bulk of material enabled the development of a small low hill with a long southerly slope at an angle of 1:30 suitable for grazing land without underdrainage (Figs 4.4a and 4.4b). This would have enabled the site to be drained naturally into the two existing watercourses and resulted in a steep northerly slope on which shelter belt treeplanting would have been established. The higher areas, being more freely drained, were expected to provide good pasture throughout the year. Some parts more nearly at the surrounding ground level were expected to provide more lush summer pasture, but to be less suitable for winter use. Some form of mulch to maintain surface moisture and prevent excessive temperatures during the establishment of grass would have been included on southerly slopes.

At Roddymoor the design proposals were predominantly influenced by the topography of the area: the major glacial valley divided into a series of small stream valleys, and a north-south and a west-east valley system united within the site area. The maintenance of this natural drainage pattern was a prime consideration in the design work and this has been extended into the adjoining National Coal Board opencast area whose restoration will maintain this feature, returning the whole area to a simulation of the natural drainage pattern. The proposed use of the land was for agriculture, and this involved obtaining the best southerly aspect for the largest possible area, leaving northern slopes of 1:3 to 1:4 for shelter belt planting. The angle of slope on areas of pasture has varied between 1:30 to 1:10 resulting from the grading down of the main heap to a gentle rounded hill formation. The drainage of the site is into the natural stream pattern of the area and though some pollution downstream has developed, no serious complaints have been received. Some of the damage may be attributable to the excavation of material on the opencast site which has not been so long exposed to weathering as that of the reclaimed area. One example of the influence of site material on the course of the design was the case of the slurry material which had to be dug out and spread in thin layers. This involved using light machines, constructing a red shale haul road and covering the spread slurry with 0.75 m (2 ft 6 in) red shale.

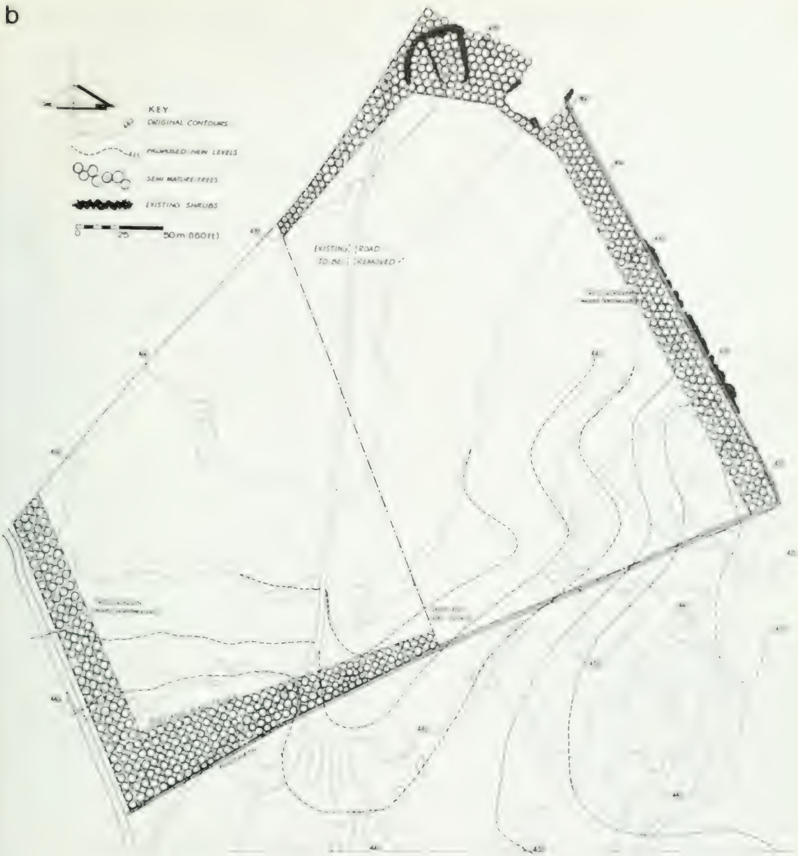
It is interesting to note that at Roddymoor the farmer has selected the land with a south westerly aspect in the face of the prevailing wind in this locality as the most suitable part of the site on which to dry a crop of hay. Other aspects of the site are apparently suitable for grass silage, except where the uneven settlement of the ground, due principally to burning material below the surface, makes the use of machinery impractical. On some parts of the land till erosion has resulted in an uneven surface which inconveniences the operation of machinery.

The Seaton Burn, Big Waters site developed from a mining flash in the typically flat glacial plain of south-east Northumberland. The site is enclosed by shallow ridge lines to north and south. The Hartley Burn flows from the south west into the flash area pond. The watertable is high and this, coupled with the extremely shallow gradients a

Fig. 4.4 (a and b) Haswell Colliery: plans for reclamation proposals.

on site, makes it very wet. The site generally falls towards the burn and the pond at gradients between 1:36 and 1:250. The conditions prevailing before reclamation had resulted in the development of a fauna population of considerable interest, and the high watertable related to the lake level is being maintained so that the site develops as an area of interest to naturalists. The regrading of the eastern part of the site to form a low hill with shallow slopes rising 6 m (20 ft) above the level of the lake, fits in with the gentle contours of the area and provides well drained pasture land. The lake glimpsed behind this new hill will provide an interesting scenic incident on the new Wideopen By-Pass motorway. A portion of reclaimed land on the eastern side of the motorway will be devoted to forestry planting to screen the backyards of Wideopen.

The Windynook site at Felling comprises several separate and distinct areas. As previously stated the attempt here has been to echo the natural character of the landscape of the area, though in some parts the development of areas suitable for playing fields has resulted in some dilution of the design ideal. Drainage of the site is entirely to the b



existing piped mains and the elevated position of the site means that surface water is easily and rapidly dispersed. Minor damp areas of low lying ground have been identified but these can be drained without difficulty. Some attempts have been made to create shelter for parts of the Windynook Quarry and Whitehouse Farm areas by mounding of spoil on the north sides of these sites. This will be reinforced by treeplanting on the northern slopes. The Windynook Quarry area is to provide open space for casual recreation and this involves sheltered south facing areas of gently sloping land at an angle (1:30 approx.) which will drain freely over the surface. The adjoining washery material area is to be reduced to original ground level for speculative housing development. The northerly aspect and the angle of slope (1:10 to 1:12) however render it somewhat short of the ideal for housing development. Both the Heworth Colliery Site and the Whitehouse Farm area are required as future playing field areas. In the former case, the topography prevents the achievement of a southerly aspect, though this is attained on the latter site. The National Playing Fields Association's recommendations for the slopes of winter playing surfaces include ideal gradients of 1:60 to 1:80 with the steepest maximum desirable slope in any direction given at 1:60 (Gooch 1963). On the Felling site the lateral falls have been designed at 1:10 which, with underdrainage on reasonably permeable shale, should result in a serviceable surface in most conditions.

At Maria Colliery the functional requirements of the use of the main site for industrial purposes, and the regrading of the pit material to a reconstruction of the original ground level of the clay pit, combine the functional and topographical aspects once more. The site is one where drainage is simple and there were no problems of aspect or steep slopes.

The design for Copperas Lane is not yet sufficiently far advanced for comments to be made on the proposals.

4.5 Conclusion

The general conclusion suggested at the beginning of this chapter was that besides afteruse, both aesthetic idioms and topographical features must play a part in governing the design of the site. Beyond this it is difficult to draw out any general conclusions other than the truisms that

(a) Landform and runoff are inseparable in design problems.

(b) Landform design is a major influence in the development of the pattern of vegetation on a site.

(c) The nature of the material is an important factor in design.

Some sites can be reclaimed with a multi purpose potential, others have their dominant use ineradicably stamped upon them. The process of design is different in every case. The common denominator is the need to work with the site rather than against it, either suppressing undesirable characteristics where this is possible, or emphasising its strong features. The new topography should not limit the aesthetic or functional development of the site, neither should afteruse or aesthetics impose on topography. J.O. Simonds'(1961) statement that "for every site there is an ideal use. For every use there is an ideal site" indicates the need to study the qualities of each site and make one's decision on landuse only after gaining information from site or landscape surveys. Following this course will result in designs which are visually acceptable, simply and economically executed, and functionally efficient.

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Chapter 5 Earthworks: outline of methods used within the project

by M.F. Downing

5.1 Introduction

The foregoing chapter has attempted to indicate the factors which influence the design of earth work operations in the creation of a new landform design. It is now necessary to look at some of the techniques adopted in the project in the preparation of schemes for design, and at some methods used by others. There is considerable divergence in the methods adopted in the field of landscape reclamation. This extends to the degree of accuracy and detail considered desirable for survey and for design, for calculation of quantities, and even to the scale at which design work is to be undertaken. Some general discussion on this aspect may well be appropriate here as an introduction to the more detailed information in subsequent sections. The degree of accuracy and detail adopted for the survey and calculation should be the highest possible taking into consideration the inherent limitations in precision of site operations. If operations on site are to be undertaken by earthmoving machinery which is vertically accurate only to 0.1 m, there is obviously no advantage in calculating everything to 0.01 m. Additionally, it is well known that the calculation of very precise quantities and very accurate measurements of height and area in plan often involves a greatly increased outlay in terms of man power, and therefore cost, than a survey to less rigorous standards. The limitations of machinery operating on site are not the only factors apart from increased survey costs, which limit the degree of accuracy and detail at which it is necessary to operate for design purposes. Everyone experienced in the commonly used methods of plan reproduction is aware of the limited reliability that can be placed on the accuracy of these documents. Whyte (1969) suggests that since it is difficult to plot on paper actual measurements smaller than 0.2 mm it is pointless to measure more accurately in scale on the ground. At scale 1:500, 0.2 mm represents 0.1 m so this may be adopted as the appropriate level of accuracy providing this is applied to any dimension and no cumulative error ensues. This, of course, does not allow for errors arising from shrinkage, expansion etc. of paper, negatives, and copy negatives.

5.2 Survey

The gathering of survey information for derelict land reclamation follows the common pattern adopted before major designs can be undertaken. It includes the topography of the site and its adjoining area, the significant landscape features on and off site including vegetation, geology, soil types or types of deposited materials, drainage - in short all the factors which have already been outlined in Chapter 4 as influencing landform design. In addition to this, the presence of services, rights of way, or easements over the site obviously must be established and recorded. The future use of a site is determined to a large degree by its existing features, but these are not the only factors, nor in the case of derelict pit heap landscapes when a complete revision of the topography is due to take place, are these as important as they would be on a more normal site. A great number of social or economic planning considerations also dictate the land use decisions, and these can outweigh the landscape factors with the result that the proposed land use may be less than ideal from a landscape point of view.

5.2.1 Topographical survey

The delineation of the topographical features of a site is the most important basic requirement for the carrying out of a design. This information may be obtained either from a team of surveyors working on the ground or by photogrammetric methods of aerial survey. Both methods are liable to some inaccuracy. Ground methods of surveying are based on selecting average readings, whether in triangulation or in the mapping of contours through a grid of levels, whilst photogrammetry is subject to scale inaccuracy in the plan preparation stage. But a very high degree of accuracy is not necessary since this would exceed the operating accuracy of the contract works. For further discussion of the "needless refinements of figures" see Clark (1949). It will be obvious that for small sites, or those with low rates of topographical variation, surveying can be undertaken by a team of field surveyors using triangulation, or more rarely plane table methods and grids of spot levels. The use of a grid with the individual spot level on the grid representing an average height of the area of land surrounding it introduces the element of averaging already mentioned. The accuracy of this method obviously depends on the size of the grid selected and this is influenced by the rate of change in topography and minor irregularities of the land surface. Where there are very large changes in gradient and the surface is extremely broken, a close grid will be necessary to achieve even an approximation of the topography. This will involve many changes of station and tedious operating over steeply sloping terrain. The smallest grid likely to be adopted on limited sites with complex surface characteristics is 10 m square (imperial measure used 25 ft). For one hectare (2.47 acres) this would involve taking 1000 spot levels, and even then the accuracy of interpolated contours, or of the average height assumption, is highly questionable. There are many derelict sites where the changes in level which may occur in a distance of 10 m (33 ft) could make the spot level chosen totally unrepresentative. Where this situation occurs only locally, it is possible to take intermediate levels, but this is plainly not conceivable all over a site where a reduction to a 5 m square grid would quadruple the number of readings while only marginally increasing the accuracy of the survey. These limitations apply no matter what method of assessing levels is chosen, since there is an inherent plus or minus error in photogrammetry, and because of this extreme sophistication of calculation is invalid.

On larger sites, 50 ha (125 acres) or more, a grid of 50 m squares (equated with 150 ft) may be adopted, this being the maximum acceptable grid size even on land with little topographical variation, and would involve over 300 grid point spot levels. If a grid of 25 m (82.5 ft) is used (which is a useful mean for grids on all but the largest sites, but seeFig.5.3) this will involve taking over 650 individual readings on a site of 50 ha (125 acres). The marginal advantage in accuracy of a 20 m (66 ft) grid is outweighed by the additional readings necessary; for a 50 ha (125 acres) site the total number would be in excess of 1000. Under normal ground conditions it is estimated that for small sites ground survey methods are cheaper than photogrammetric methods; Whyte (1969) quotes 5 ha as beingthe point at which aerial survey may start to be cheaper than field survey work. Calculations of aerial survey quotations made in the early years of this project suggest that the breaking point is considerably higher than 5 ha (12.5 acres). In the case of highly contorted derelict land, however, the figure may be well below this amount for a ground survey involving a great deal of time to obtain the required number of levels. There are however so many variables that these together with changing costs for labour and machine operations make it extremely difficult to make any firm general statement of comparative costs which would have any meaning.

Aerial survey methods are now being adopted in this country by the Ordnance Survey for the revision of some features of its existing maps, the scale for the work being 1:1250. This scale has been found convenient for many reclamation sites particularly where the land is to be returned to agricultural use. For small sites, and where closer attention to detail is required, a scale of 1:500 may be adopted and gives a more accurate delineation of the site. The following table is based on information set down by Whyte in a table on vertical photography for planning and engineering works. It shows the relation of scale of finished plan to photography commonly used, the vertical and hoizontal accuracy and the minimum possible contour interval which can be depicted.

Table 5.1 Levels of accuracy and detail for aerial survey plan reproduction (after Whyte 1969)

Plan scale	Photo scale	Flying height (above ground) (m)	Accuracy plan (m)	Spot-height (m)	Minimum possible contour interval (m)
1:500	1:3000	450	±0·15	±0·09	0·5
1:1000	1:4000	600	±0·20	±0·12	0·5
1:1250	1:5000	750	±0·25	±0·15	0·75
1:2500	1:10000	1500	±0·51	±0·30	1·5

This represents the best conditions of reproduction; semi dry copying will undoubtedly reduce the accuracy of scaled distances. The theoretical minimum possible contour interval is seldom reached except on even sites, and in many cases it is often desirable when complex topography results from deposition and subsequent shale extraction to select contour intervals sufficiently far apart to give a legible expression of the topography. Thus, for clarity, it is frequently desirable to select 5 ft intervals for contours at 1:500 scale rather than 1 ft or even 2 ft intervals (Figs 5.1 and 5.2). S.I. equivalents would be 2 m and ½ m for the two latter closer intervals. Where subtle changes in levels, or very accurate land forming is needed, for example adjoining existing property, it may be necessary at this scale to introduce ½ m contours, although this can only be done for a limited area.

At 1:1250 scale a vertical interval of 2 ft (0.6 m) is normally adopted. Here again the complexity of some sites may lead to the adoption of a 5 ft (2 m) interval (Fig.5.3).The same contours can be used at 1:2500 scale (Fig.5.4).

The majority of sites with which the project has been concerned were designed at 1:500 scale using 5 ft contour intervals (the nearest S.I. equivalent being 2 m) based on photogrammetric surveys. On some smaller sites, notably Maria Colliery, 2 ft (0.6 m) contour intervals

Fig. 5.1 1 ft contours at scale 1:500 are often difficult to read when abrupt changes in topography are to be delineated, and less detailed contour plans may give a clearer overall picture.

Fig. 5.2 This shows a plan at 1:500 scale with 2 ft contours. Even this degree of detail may be too great for some purposes and a 5 ft contour distance accepted.

Fig 5.3 Plan scale 1:1250, contour interval 2 ft produces a mass of barely legible detail.

Fig. 5.4 Rough plan at 1:2500 scale with 5 ft contours.

were used. At Roddymoor, where the site was to be returned to agricultural pasture land, the scale chosen was 1:1250. At Big Waters, survey information was compiled from enlargements of the Ordnance Survey with the contour information obtained by means of a field survey conducted by the University Department of Surveying.

5.2.2 Landscape survey

A limited form of landscape survey is of value in the preparation of earthworks drawings, and at this stage use is frequently made of the information collected for the final design stage. In reality it is difficult to separate the parts of the design process into watertight compartments, and it is readily accepted that all the principles of the design must be established before the details of one aspect, such as earthmoving, can be investigated. In many cases the design of a new landform is so much the major part of a reclamation scheme as to comprise virtually the whole design. The landscape survey must include the information already mentioned on the topographical features of the landscape surrounding the site, the drainage pattern of the area, and the soils and geology of the district. It must also include, for example, climatic factors such as shelter, freedom from frost, and air drainage, and liability to pollution from atmospheric sources. Techniques of landscape survey are set out in a number of standard works and have been the subject of papers by Barnard (1965) Vyle (1967) and discussion (Riddell and Downing 1967).

The landscape survey should also include an assessment of existing vegetation on site, the positions of which will have been noted in the topographic survey. This information will provide a most useful guide to the status of material in the heap and in its vicinity.

Derelict sites frequently call for particularly careful attention to discover the presence of unsuspected objects. Many sites date from the era of the private coal operator, and while the National Coal Board provides the most accurate information it has available about pit shafts in particular, and old buildings, foundations and other structures, it is always advisable to proceed cautiously on site, since the accuracy of old maps and surveys cannot be guaranteed. In addition to knowledge of the exact location of shafts, details of the method of capping or filling of the shaft and the level at which this has been carried out, may be vague and require some site investigation. Additionally, close investigation of the structures and foundations on site may reveal problems of demolition and removal not readily detected during superficial inspection. Some allowance must be made for this sort of unforeseen contingency in costing projects. Such a contingency occurred at Maria Colliery where an extra payment was granted for the demolition of a foundation, the extent and complexity of which were impossible to foresee.

At Haswell Colliery information regarding the presence of shafts was obtained from the Estates Branch of the National Coal Board, who were able to indicate the position of shafts including balance weight staples, all of which had been filled by the N.C.B. in 1952.

At Roddymoor, while some of the coke ovens on the site were visible and had in fact been carefully dismantled, another rank buried under the shale of the heap was only discovered during operations.

These notes show that the landscape survey needs to be extended to a careful investigation on site and by searches with the appropriate authorities to establish the position of any features which are not obviously visible and can lead to additional work or danger.

5.2.3 Services and easements

On all sites in the project involving spoil movement it has obviously been necessary to plot services, particularly those which lie underground, as accurately as possible. Not only is there a danger of disrupting services during excavation with the dangers this presents, but there is also a very real maintenance problem when the services are to be buried more deeply than originally laid. The accuracy of information from statutory undertakers needs always to be regarded with some caution. Where any doubt exists the authority should be asked to mark the line of the service on site. Statutory undertakers usually stipulate very precise depths of cover to be maintained over services and this can act as a limiting factor in regrading since re-routing major services is prohibitively expensive. The profile of an extensive area of the site at Copperas Lane has been closely controlled by the line and elevation of a 30 in water supply main crossing the site.

5.2.4 General information

Other information has to be gathered to build up a complete picture of the site and its surroundings, both at the time of the survey and later during development. The local planning authority's preference for the development of an area is usually expressed in local development plans in which appropriate forms of development for the site to be reclaimed are indicated if not specifically, then by general development proposals for the area. Experience on the project has shown that it is unwise to embark on design projects on land which has not already been acquired by the local authority. It is, of course, possible for a local authority to undertake work on land it does not own and which is to remain in private hands, but this is eligible for grant only under very special circumstances. Difficulties of acquiring land for reclamation work have been experienced on two project sites: Percy Pit and Haswell Colliery. On the first site difficulties arising from a leasehold agreement led to a stalemate over agreement for compensation, whilst on the second, local authority compulsory purchase was opposed by the lessees, who were shale extractors. The Ministry agreed that the Local Authority's intention to reclaim the land was not sufficiently urgent to override the need to extract the mineral.

When ownership is established, the presence of any public footpaths, rights of way or easements, whether public or private, needs to be ascertained. The presence of squatters on derelict land is quite common, and it is possible that by virtue of length of establishment on a site some rights will have been acquired by the squatter. Agricultural tenancies may also present problems in relation to the progress of reclamation of the land. It is as well that the presence of tenants and squatters is clearly established at an early stage, so that the appropriate action may be taken. At St. Anthony's (Northbourne Park) there was a tenant with an unexpired lease who had to be given adequate notice to quit. The contractor co-operated by working around the area of the tenancy, completing the works when the tenant was finally evicted. This is not, however, a happy situation and relies heavily on the goodwill of the contractor.

Where parts of sites adjoin public highways, it is clearly desirable to obtain information from the local highway authority so as to take account of any proposals for present or future road widening, highway control lines and where appropriate, lines of sight. With the development of the design proposals, the information may be extended to cover enquiries as to suitable sites for depositing material from the site to be reclaimed, or sources of covering material. At Maria Colliery the design problem was solved by removing the heaps into an adjoining clay pit. At Felling, it initially appeared that a satisfactory design could not be achieved without exporting considerable quantities of the shale. It was necessary to investigate the possible sites for deposition, and their distance from the reclamation site together with methods of transportation and the costs. Methods such as rail, road and even hydraulic pipeline were investigated in relation to the need for fill for a riverside area about eight miles from the site at Jarrow Slake. The proposed alternatives were all prohibitively expensive and this investigation was discontinued. Subsequently investigations into the importation of material to act as a top dressing for the very acid shale were put in hand. This involved clay and topsoil from existing road and building works near to the site where the material could be obtained and transported reasonably economically.

The economic use of material from derelict sites should not be entirely ignored. In most cases, sites with recognised or suspected economic value are not made available by the owners or lessees without protest and one can generally assume that a site released by the National Coal Board has no economic worth. Nevertheless the possibility that some economic return may be obtained to offset the high costs of reclamation should always be borne in mind, particularly in a world in which demand and economic circumstances can change so rapidly.

5.3 Geochemical investigations

The variation in shale materials, both physical and chemical, is dealt with in detail in Chapter 8 of this volume. It is sufficient to mention here that standard procedures have now been evolved whereby the chemical and physical properties of the shale can be assessed for its potential to support plant growth and form soil. This is important since the quality of shale in different sectors of a site may affect the regrading proposals. Some materials may need to be deeply buried because they are toxic or have a high coal content; others because they are composed of lumps of fused material which cannot be broken down either mechanically or by erosion. Some red shales, on the other hand, appear to have excellent soil forming and plant supporting qualities, and can be used as a top dressing over other less suitable materials.

It has become common practice to employ specialists to undertake a specific series of tests on the materials on site to establish its likely future behaviour and potential and this practice has been followed on the research project. This is not so much from the point of view of its soil forming potential, which is established by a series of soil science tests discussed in Chapter 8 and carried out by a soil scientist, but to establish its stability, combustibility, sulphur content, and the presence of gases. This is usually undertaken by the setting out of a grid to give surface samples which can provide a representative picture of the material covering the site. Deep bore hole samples are also taken at varying depths at selected points on the site. These are chosen where the

Table 5.2 Check list of survey information used for design of earthworks for reclaimed landscape, particularly oriented to colliery spoil areas.

Information	Source
1. **Contours**	Aerial survey,
either	OS plan or ground survey plus ground spot level survey.
2. **Landscape survey**	
a) Existing vegetation species age and condition.	Site observations
b) Shale types (visual classification)	" "
c) Vegetational cover of shales.	" "
d) Natural soil types (Where present)	N.A.A.S. or simple classification.
e) Geology	Geological survey.
f) Surface water drainage pattern	Site observation (see also 4)
g) Aspect, shelter exposure, etc.	" "
h) Visual aspects, views, areas of containment, ridges, dominant features	" "
i) Structures and foundations on site	" "
3. **Features on site not readily visible**	
a) Pit shafts	National Coal Board Area Chief Surveyor
b) Counter balance weight staples	" "
c) Coke ovens	" "
d) Structures	" "
e) Foundations	" "
4. **Services**	
a) Electricity Underground	C.E.G.B. &
" Overhead	Area Board
b) Gas Underground	Area Board
c) Water Underground	Local Water Authority
d) Telephone Underground	Post Office
" Overhead	
e) T.V./Radio Underground	Rediffusion
f) Main sewers	Local Authority
g) Other underground pipelines (oil etc.)	Local Planning Authority
h) Surface water culverts	National Coal Board, Area Chief Surveyor. Local Authority (see also 2)
5. **Landownership etc.**	
a) Land ownership	Local Authority Ministry of Agriculture Land Registry
b) Tenancies	Landowner
c) Public Rights of Way	Local Planning Authority
d) Easements	Landowner
e) Highway control lines of adjoining roads	Local Highway Authority
6. **General Information** County or District planning proposals for area of sites	Local Planning Authority
7. **Geochemical Site Investigation**	Specialist consultants
8. **'Soil' condition Investigations**	Soil Science Department of University.

material is thickest or where some particular problem may be encountered. For surface samples, a site of some 16 ha (40 acres) might be adequately covered by 100 samples, as was the case at Felling area 3. This, it will be appreciated, is a figure which can be greatly varied to suit different sites. Generally, it is possible to detect superficially the major changes in the composition of material, and the grid will be constructed so that each change is adequately represented in the samples. Deep boring is an expensive operation and so the number of samples that can be taken in this way is very limited. This introduces a large element of chance into the sampling due to the heterogeneous nature of the contents of most shale heaps. Unless large sums of money are to be expended initially this has to be accepted, and if problems are revealed it may be necessary to undertake further boring to get a clearer picture of the inside of the heap.

5.3.1 Heat

One of the first questions for investigation in the survey of a pit heap is the temperature within the heap. The presence of hot material in a pit heap will clearly direct the method of working to avoid aggravating the condition, and mean that additional work may be involved to cut out the heating area and render the heap relatively harmless after regrading, which would not be the case were any hot pockets allowed to remain. The presence of severe heating can be detected by the use of a surface probing thermometer with a probe approximately 1 m in length which can be plunged into the surface of the material. This may, however, only indicate surface heating, as was experienced in a series of small heaps at Big Waters. In this case, the surface of the heap reached high temperatures, and smoke and flames were frequently to be seen, whereas the centre of the heap was known to be almost completely unaffected by heating. Use can be made of the boreholes drilled to provide core samples to give temperature readings of the interior of the heap at different levels. This is done using a thermocouple lowered into the borehole which is then plugged. Some time is allowed to elapse for the temperature reading to become steady, as it is liable to be affected by the drilling operation and the passage of air into the heap, and the temperature is read at 15 minute intervals until stable. From the readings taken it is sometimes possible to build up a reasonably comprehensive picture of the temperature regime inside a heap. The presence of serious heating problems may call for prolonged investigation and the retention of thermocouples in the heap to detect trends, such as serious rises in temperature or spread of the areas of heating. Methods of dealing with hot areas are discussed in Chapter 6.

5.3.2 Gas analysis

It has been found desirable to carry out additional tests in some circumstances, particularly where heating is occurring, to determine the presence of toxic gases such as carbon monoxide and dioxide, sulphur dioxide, and hydrogen sulphide, all of which could be dangerous to operatives working on the heap. It is likely that gas analysis will need to be carried out on all sites; early investigations of pit heaps have established which gases are likely to be encountered, and it may only be necessary to undertake tests where a specific hazard is anticipated. Even then the gases likely to be responsible for these dangers are, with the exception of carbon monoxide, to be easily detected. Carbon monoxide can be guarded against by the wearing of sensitive discs by operatives where its presence is suspected.

5.3.3 Materials

The physical nature of materials found on site has been determined by the standard procedures of the grading analysis (by sieving), the index classification test, and the sedimentation analysis using the pipette sampling method (BS 1377 test 12), all of which are described in standard textbooks of Engineering Soil Mechanics (BS 1377:1967). These provide information on the strength and stability of spoil materials which may not be immediately relevant except where construction is proposed on site or where the material is to be shaped into steep banks or considered for load bearing bases. They may also provide valuable records for future reference, particularly where a change to some more intensive use is proposed. It is also desirable to test samples for moisture content.

5.3.4 Combustibles

Tests have also been applied to samples to establish the presence of combustible materials, either by determination of free coal as on earlier sites, or by total combustibles from loss of weight on ignition at 800°C.

5.3.5 Sulphates

Simple tests have been used to determine the free sulphur content and the sulphur trioxide content of shale soils. The value of these tests is questionable in the light of the very complex chemical regime of coal shales. At present work in a number of centres on the status of pyrites is aimed at arriving at more conclusive understanding of the availability of sulphur in various forms under differing conditions of spoil. The simple tests may, however, be adequate for the assessment of the effect of the materials on concrete and bricks used in drainage and building construction. Further discussion of this topic is found in Chapter 8.

5.3.6 pH

Experiments on the project and on other shale sites have shown that it is necessary for pH tests to be undertaken, using pH meters with glass electrodes, to obtain accurate readings of the low pH commonly discovered on shales. The use of the British Standard method of pH test involving a colorimetric technique which does not give a reading below pH 4 is of no value except at the initial field testing stage, and should be specifically excluded from the required works.

5.4 Earthwork computations

Clark (1953) classifies the methods of calculation of volumes according to whether the solid to be measured is defined by (a) cross sections, (b) spot levels or (c) contour lines. Writing before the development of computers, he favoured the cross section method and suggested that using spot levels is useful occasionally where large excavations are concerned, but that the method of contours is suitable only for rough calculation. This argument will be well known to engineers and surveyors.

Roberts and Stothard (1968) have shown how recent work with computers at the Road Research Laboratory, and studies of alternative road design calculation methods, have suggested that a grid of levels may be the most appropriate method for calculating earth movement for highway design. It is well within the required scale of accuracy for this work, and has the advantage that regular grids may be transferred direct from the original aerial survey to the computer data bank (Craig and Burns 1967). The application of this type of system to reclamation calculations is at present under study. The degree of accuracy which is obtainable from a grid of levels on exceptionally broken ground, such as is frequently met on reclamation sites, may not favour the use of this approach on such sites, a point already made in relation to field surveys of sites. Different sites within the project have made use of different methods of earthworks calculation depending on the size and topography.

5.4.1 Grid method

The use of the grid method, despite the limitations in relation to existing ground which have already been expressed, has been adopted at several project sites particularly for preliminary design calculations, with the final calculations being undertaken by another method. Where the existing topography was sufficiently even to enable the method to provide the final design quantities, as at the Big Waters site, a grid interval of 100 ft (30 m) was adopted. The calculation of the major earthworks was, in this case, achieved with a grid of 108 spot levels. This scale of grid is adopted by the National Coal Board for its opencast works and it may well be that while potential error is satisfactory in relation to the very large volumes of material moved in open cast operations, a greater degree of accuracy is required where the depth of material moved is small and the potential margin of error is large in proportion to the volume of excavation and deposition. The steepness of the sides of the heap and the changes of gradient of the material at Roddymoor meant that, even with careful centring of the grid, the use of the 100 ft (30 m) interval resulted in considerable errors.

At Maria Colliery and Haswell Colliery, a 30 ft (9 m) grid was adopted. In the first of these sites this appears, from the finished levels and comparison of the contractor's spoil movement records with the calculated quantities, to have given a reasonable degree of accuracy. Haswell Colliery, however, was a case where shale extraction operations had taken place, and the ground surface was exceedingly uneven with the result that the volumetric result obtained has to be considered with some caution. Despite the problem of accuracy, this method is a very useful design system enabling the designer to obtain a quick approximation of the volumetric consequences of new grading proposals. Even if this has subsequently to be checked by other methods and final amendments made, it is still worth doing to reduce calculation complexity in the formulation of the design. At Maria Colliery, the quantity surveyor undertook an independent check by means of cross sections of the volumetric calculations obtained by the grid method and reached a close enough agreement for the volumes to be accepted for contract purposes. At Percy Pit, where the pattern and areas of movement of material were very clear and simple, with a conical pit heap to be reduced and large specific areas of cut and fill, a grid of 30 ft (9 m approx.) was adopted as being reasonably representative of the changes in topography on site. This meant reading over 900 spot heights, and possibly a larger grid could have been used without significant loss of accuracy. The simple shape of the heap on site enabled the use of the contour method for balancing the cut and fill, as it was possible to balance the fill quantities required against a cut of varying thickness of the cone until a reasonable balance was achieved.

5.4.2 Computer application of the grid method

Indications have already been given in this chapter of the application of computers to the calculation of earth work volumes in the design of highways in which a grid of levels is the basis of the method. The accuracy obtainable with a rigid grid, which may not reflect detailed changes in level, is a limiting factor to its use on reclamation sites, which as already indicated, may have very broken topography. Set against this is the fact that the square grid has great advantages in ease of recording, storing and recalling data. Craig and Burns (1967) indicate that the accuracy of this type of grid is a function of the spacing adopted, and recommend a method involving variable spacing according to the topographical requirements. Work on grid accuracies is still in progress at the Road Research Laboratory, but from Craig and Burns' work, Roberts and Stothard were able to suggest relationships between grid point spacing and contour and ground shape which give an acceptable accuracy. This may be used as a guide in both computer and manual operations of the grid method of volume calculations.

Table 5.3 Grid point spacing related to ground & contour shape (after Roberts & Stothard).

	General ground shape (average slopes)			
Contour shape	1:100	1:50	1:25	1:10
Regular	150 (50)	100 (35)	75 (25)	50 (20)
Uneven	100 (35)	75 (25)	50 (20)	25 (10)
Very irregular	75 (25)	50 (20)	25 (10)	25 (10)

Table originally published in feet, S.I. equivalents (m) in brackets.

The fact that the requirement for accuracy of finished levels on reclamation sites is so much less critical than on highways may make the system acceptable, in spite of the inherent inaccuracies, because of the ease of use. A series of exercises to compare the acceptable levels of accuracy with those actually achieved with different methods of computation would provide a valuable insight into the methods available, and might even suggest those most suitable for general application.

Craig and Burns (1967) indicated the value of investigating a columnar method of calculating earth volumes in highway work and particularly at traffic interchanges. An interesting adaptation of this use of a regular grid on a reclamation site was that used by Messrs. Costain Mining Ltd., for the Acorn Bank open cast site at Bedlington, Northumberland. Here the land was to be restored to agriculture after the extraction of the coal. Rigorous requirements in relation to the level of the adjoining land, angles of slope, and drainage were in force, and the firm's operational research department were able to make use of computer operations to provide a series of solutions giving finished levels in which the relationship of adjoining and adjacent grid points satisfied a mathematical relationship. Concurrently it was possible to select the solution giving the minimum oversite transportation of material. The computer programmes used have not been published but the method was described in a paper given at the Operational Research Society's annual conference, Sept. 1966 (Caruthers and Canvin 1966). It should be noted, however, that such areas are usually less complex topographically than are colliery spoil areas, and therefore do not involve the calculator with a multiplicity of measurement.

5.4.3 Contour method

It is widely accepted that this method is suitable only on certain sites where the existing topography is reasonably simple and clearly defined. The system, depending on measurement with a planimeter and defining areas of cut and fill, will be familiar to all surveyors. The ease of design manipulation afforded by this method commends it on those sites where the topography permits easy identification of cut and fill sectors and measurements of areas. Its limited application needs little emphasis and it has not been suitable for computer use.

5.4.4 Cross section method

This method is as well known as the others previously mentioned and requires no description.

A good example of the way in which this method is used is provided by notes prepared by the planning department of Lancashire County Council. Two systems are in use, the second being strongly based on a physically defined centre line or base line from which measurements can be taken at all times on site. The following notes prepared by Lancashire County Planning Department describe the method very clearly. Original measurements in fact are retained throughout.

Reclamation work

Notes on the preparation of contract documents with particular reference to the balancing of cut and fill

Methods adopted in preparation of Bryn Road and Careless Lane schemes

1. Survey of site-contours at one foot vertical interval plotted to 1/500 scale.

2. Sections at 50 ft intervals - directly from contours on a print of site surveys to indicate existing ground levels. These sections are drawn to scale one inch to 10 ft vertically and 1/500 horizontally.

3. After giving consideration to existing ground levels immediately outside the site boundary and the invert levels of any culverts, drains or watercourses which may exist, tentative new ground levels are fixed and proposed contours are also drawn on the print of the site survey referred to in item 1.

4. Sections through the proposed ground level are projected directly from the print of the site survey (referred to in items 2 and 3) which now indicates existing and proposed ground levels on to the section referred to in item 2.

5. Quantities of cut and fill are obtained from the sections, referred to in item 4, by means of planimeter. A suitable allowance is made for bulking or compaction dependent upon the type of material and a trial balance is made.

6. If a balance is not achieved within an acceptable limit (being the equivalent of 1½ in over the area of the site, or 200 yd^3 per acre) then some adjustment of the proposed level of the whole area is effected by drawing a new contour line on the print of the site survey at such a fraction of the distance that will raise or lower the level of the surface as is necessary in multiples of $1\frac{1}{2}$ in, i.e. $1\frac{1}{2}$ in equals $\frac{1}{8}$ of a foot, therefore a new contour is easily positioned within $\frac{1}{3}$, $\frac{1}{4}$, $\frac{2}{3}$, or $\frac{1}{2}$ the distance between any two of the tentative ground level contours.

7. The sections in item 2 are now redrawn and fresh quantities of C (cut) and F (fill) computed. If at this stage an unacceptable difference exists, then a minor adjustment of levels over a small area of the site may give a balance.

Present method now undergoing trial

Stoney Land site (1968)

1. The boundary of the site and any features thereon are surveyed and plotted to 1/500 scale.

2. A base line is set out across the site by instrument in such a position that all or most of it is accessible. The position of the line is fixed at boundaries and other convenient positions by ⅔ in dia. steel bars set in concrete. The line provides the base from which subsequent levelling operations, setting out, and checking of actual contract operations may be controlled. The position of the base line is then recorded on the outline survey, item 1.

3. At intervals of 50 ft along the base line, instrument stations are established and by means of theodolite lines at right angles to the base line, i.e. section lines, are established and ground levels are taken thereon at all changes of level or gradient. The levels are reduced and their values are plotted directly along section lines which are drawn in their true position on the outline survey.

4. A print of the information now recorded is obtained and rough contours of the existing ground at 5 ft intervals are now pencilled in to show the humps or hollows. This is intended as a guide only to the ground configuration, and may be dispensed with if a careful visual inspection of the site is made from all possible vantage points. After giving consideration to the factors referred to in item 3 under heading Bryn Road/ Careless Lane tentative new ground levels are drawn.

5. Sections are drawn by direct projection from the print referred to in item 4 which now contains both existing and proposed ground levels. Cut and fill quantities are obtained from these sections and the trial balance effected with any necessary allowances for compaction.

6. If a balance is not achieved see methods of obtaining an acceptable limit in item 6.

The operation of these methods obviously depends on the ease of surveying and availability of staff to do the subsequent drawings and calculations. Under circumstances where staff are available, and where surveying on site is an appropriate method of gaining survey information, it appears from the Lancashire experience that the method gives satisfactory results economically and it therefore deserves consideration when the method of operations is to be chosen.

Cross sections have been used in this project as a check method on a number of sites, with measurements based on scaled drawings and planimeter reading. This method is obviously subject to errors resulting from the difficulties of drawing sections accurately but has proved adequate for a number of small contracts, notably Egerton Gardens, where it was the only method used, and Maria Colliery.

5.4.5 Computer applications of cross section method

The selection of a particular method when using the computer to carry out the calculations will depend upon the aspects previously discussed. It will also depend on the availability of a suitable computer programme, assuming that there is not the volume of work to justify the composition of a new programme. At the time that the volumetric calculations were beginning on sites of this project, inquiries were made as to the practicability of various methods and it was concluded that for ease, convenience and economic reasons the use of the road programme devised by Sir Robert MacAlpine & Sons Ltd was the most suitable available method. In this case the work required of the computer is not the solution of the design, which is undertaken in some computer operations, but the comparatively simple, arithmetical calculation of the volume of cut and fill and their relative balance over the site. Even for such an apparently simple task the computer has advantages. Human calculators would be involved in tedious arithmetic, and the expenditure of skilled man power in this way should be avoided whenever possible. As indicated, calculations are based on end areas obtained by the delineation of cross sections at selected intervals along a centre line which represents the centre line of road. When this system, embodied in the computer programme chosen is used on a reclamation site, the limitations of the programme may make it necessary to divide the site into two or more parts each with its own centre line. This is because the computer, designed to measure a linear feature is only programmed to accept 18 measurement points or ground points at a maximum offset of 999.99 linear units on each section for either existing ground level or for the regraded surface. It is in selecting the placement of the centre line, and establishing the best and most representative position for the cross sections that time and skill are required; this is true irrespective of the use of a computer or human agents. Indeed, where some degree of simplification of calculations is desired the section lines are commonly set at equal intervals, making the selection of representative positions more difficult. Where end areas are to be measured without computer aid, it is desirable that existing and proposed ground points should coincide.

Alternatively the method of drawing sections and measuring the area by planimeter is adopted. Both of these methods involve time, and both are liable to a degree of inaccuracy. In the first case this is due to the use of simplified formulae and compromise in the selection of ground points when the error is endemic and in the second case to the liability to error in the reproduction of section drawings in which case care can minimise error. The computer method suffers from neither of these specific limitations. No formula within the capacity of the programme is too time consuming. The accuracy of the result still, however, depends on the selection of the most representative sections and points and on the survey itself. Were the method not dependent on the errors of reproduction of the survey drawing, a greater degree of accuracy could be obtained: thus a data sheet prepared using original ground survey readings made on site or a direct reading of aerial survey material would show the highest possible degree of accuracy of calculation. A number of computer systems now are dependent on photogrammetry making use of a stereo plotter working direct on the original survey photographs. The co-ordinates produced by the stereo plotter are recorded and stored in the computer in the form of a digital ground model and any complexity of ground form can be calculated. By the introduction of these techniques some people believe that the need for contour plans is completely eliminated in highway work, and this might well be the case for existing contour plans in reclamation projects; however, the cost and availability of computer time and the possibility of the need for re-runs must not be discounted.

Present experiments within the project, however, have been limited to the measurement of ground points from the aerial survey plans prepared from the original flight material. Once the centre line has been selected, sections at random intervals to give the best and most accurate approximation of topographical changes are taken. Section points are then selected to reflect most accurately, within the limitations of the numbers of points available, the changes in topography. It is then necessary to translate this information from the plan to the data sheet, recording the height of the point and the offset distance from the centre line. This work can be done relatively speedily, and it has been estimated that one section, comprising 36 height and 36 offset measurements can be completed in 20 minutes. Ground point data is recorded on one sheet, and regraded level points data (in the road programme referred to as 'Road Formation Points Data') on another, as will be seen from the examples (Figs 5.5, 5.6).

It will also be seen that while the section lines are the same for each series the section points bear no relationship to each other but are recorded quite independently.

When the information is fed into the computer the print-out information includes:

(a) The co-ordinates of the points of intersection of the side slopes with the original ground at each specified cross-section.

(b) The cut and/or fill areas at each cross-section.

(c) The cut and/or fill volumes between adjacent cross-sections, using the "end area" method. It also accumulates those volumes to the end of the roadway.

(d) The topsoil volume between adjacent cross-sections, keeping topsoil in cut areas separate from topsoil in fill areas. It also accumulates these volumes to the end of the roadway.

SIR R. McALPINE & SONS LTD. AND ASSOCIATED COMPANIES

COMPUTER ROADWORKS SYSTEM

SHEET No

GROUND POINTS DATA

CONTRACT

SECTION	OFFSET	LEVEL	OFFSET	LEVEL	OFFSET	LEVEL	OFFSET	LEVEL	OFFSET	LEVEL	OFFSET	LEVEL		SOIL DEPTH FEET

Fig. 5.5 (By courtesy of Sir Robert McAlpine and Sons Ltd.)

SIR R. McALPINE & SONS LTD. AND ASSOCIATED COMPANIES

COMPUTER ROADWORKS SYSTEM

SHEET No 1

ROAD FORMATION POINTS DATA

CONTRACT Haswell Colliery

SECTION	OFFSET	LEVEL	OFFSET	LEVEL	OFFSET	LEVEL	OFFSET	LEVEL	OFFSET	LEVEL	OFFSET	LEVEL	CUT SLOPE 1 in	FILL SLOPE 1 in
75			224 17	432 17	215 00	435 00	200 00	440 00	163 00	445 00	79 00	450 00	1·0	1·0
	[illegible]	[illegible]	00 00	445 00	133 00	445 00	169 00	440 00	210 00	435 00	389 13	430 00		
	389 13	[illegible]												
150			288 22	430 22	273 00	430 00	258 00	435 00	244 00	440 00	214 00	445 00		
	[illegible]	450 00	143 00	455 00	58 00	460 00	00 00	462 50	87 00	460 00	165 00	455 00		
	217 00	450 00	250 00	445 00	289 00	440 00	335 00	435 00	388 11	432 00	388 11	419 11		
225			290 63	434 37	274 00	440 00	238 00	445 00	206 00	450 00	172 00	455 00		
	[illegible]	460 00	70 00	465 00	00 00	468 00 470 00	106 00	468 00 470 00	175 00	464 00 465 00	213 00	460 00		
	245 00	455 00	274 00	450 00	310 00	445 00	342 00	440 00	388 21	435 00	388 21	423 79		
300			291 22	444 22	250 00	445 00	216 00	450 00	187 00	455 00	145 00	460 00		
	[illegible]	465 00	34 00	469 00 470 00	00 00	470 00 472 50	35 00	471 00 475 00	141 00	470 50 475 00	187 00	468 00 470 00		
	229 00	[illegible]	254 00	460 00	284 00	455 00	309 00	450 00	387 14	440 00	387 14	428 86		
375			304 46	449 46	294 00	440 00	265 00	445 00	230 00	450 00	207 00	455 00		
	[illegible]	460 00	128 00	465 00	60 00	468 00 470 00	00 00	470 50 475 00	182 00	479 50 475 00	226 00	468 00 470 00		
	263 00	[illegible]	294 00	460 00	323 00	455 00	345 00	450 00	387 05	444 00	387 05	425 92		
450			309 30	441 30	289 00	445 00	268 00	450 00	233 00	455 00	198 00	460 00		
	[illegible]	465 00	[illegible]	468 00 470 00	[illegible]	470 50 475 00	00 00	470 50 475 00	214 00	471 00 475 00	260 00	468 00 470 00		
	298 00	465 00	[illegible]	460 00	356 00	455 00	386 04	450 00	386 04	433 96				
525			362 94	[illegible]	333 00	445 00	304 00	450 00	269 00	455 00	223 00	460 00		
	178 00	461 00 465 00	107 00	468 00 470 00	38 00	470 50 475 00	00 00	470 50 475 00	254 00	470 50 475 00	292 00	467 00 470 00		
	326 00	465 00	354 00	460 00	385 04	455 00	385 04	437 04						

Fig. 5.6 (By courtesy of Sir Robert McAlpine and Sons Ltd.)

(e) The area of side slopes on both sides of the roadway between adjacent cross-sections, and accumulates these areas to the end of the roadway (McMillan 1965).

The information is printed out in two reports, only one of which is relevant to the regrading of reclaimed land. This contains the information indicated under items 1, 2 and 3 (Fig.5.7). The separate recording of cut and fill between sections, as well as the accumulated total, makes it possible, when a balance has been achieved, to apportion the excess material in one section to appropriate adjacent sections and present this material in a table in the bill of quantities for the guidance of tenderers (Fig.5.8). This is related to a plan on which lettered sections are shown.

In the case of Haswell Colliery site, for which the first exercise was carried out, the total was twenty-seven sections on the plan. The balance was not achieved on the first attempt, and a redesign which achieved a balance involved revising and rerunning seventeen of these sections, the total cost of the calculation being £44. This method has been used on the Windynook/Whitehills site at Felling where the ratio of surface area to spoil resulted in critical slope angles and volumes and created the need for a high degree of accuracy, while at Maria Colliery simple cross-sections with end area calculations have provided a sufficient degree of accuracy.

A more sophisticated computer programme offering 50 ground points is under trial with Northumberland County Council. This will undoubtedly allow of a more flexible approach and result in greater accuracy in assessment of the volumes. Additionally it is intended ultimately to provide alternative design solutions as well as calculating volumes of material moved.

5.4.6 Comparison of calculation methods

The use of a particular method of calculation clearly must depend on the type of site, and the availability of staff. On small sites with simple topography, a grid of levels will give an adequate result; alternatively a series of cross-sections may be taken and the volumes measured with a planimeter. In some circumstances, notably when the areas of cut and of fill are large and easily defined, not necessarily simply shaped but with bold gradient changes, the use of contour methods for the measurements may be adopted. As already indicated this could well be suitable in a case like Percy Pit where a conical heap was to be reduced and the surrounding area raised, and cut and fill are clearly defined. More complex and larger sites require the use of sections and the end area formula. The question is then whether this is to be undertaken by computer method or by hand. The investigations carried out originally for the project suggested that the expense of writing a special programme for a limited amount of work was not justified, but where a suitable programme was available its use could result in time saving in a busy office as well as the possibility of some economic advantage. It is difficult on the information available to make any straight comparison of the economics of the manual and the computer approach, but work which would involve measurement and calculation manually for periods of five to six weeks can be completed in the same number of days when the computer is employed. Making use of an existing programme the cost is £1 per section to obtain the information previously listed. In the case of amendments to the contours to obtain a cut and fill balance it is possible to rerun as few or as many sections as desired, and so no excessive costs are entailed. The computer cross-section method then appears to be certainly as cheap as hand methods, undoubtedly more accurate, and to allow of simple checking in the event of any query. Other methods are in process of investigation and refinement, but at present this system is probably the best approach available, without the expense of writing a programme for special use. It is hoped that the current Highway Construction approach using digital ground models direct from the original aerial survey, and

Station	Cut Vol	Fill Vol	Acc. Cut	Acc. Fill	Cut Area	Fill Area	Intersection Points			
							Left		Right	
	(yd^3) X	(yd^3) X	(yd^3) X	(yd^3) X	(ft^2)	(ft^2)	X	Y	X	Y
0.	312.	7366.	312.	7366.	89.12	535.39	121.00	425.00	183.38	422.62
75.	2236.	13618.	2548.	20984.	135.58	4768.10	224.17	432.17	389.13	418.13
150.	4783.	12230.	7331.	33214.	474.59	5037.13	288.22	430.22	388.11	419.11
225.	8891.	12844.	16223.	46058.	1969.26	3768.52	290.63	434.37	388.21	423.79
300.	23882.	13538.	40104.	59596.	4432.41	5479.44	291.22	444.22	387.14	425.86
375.	24788.	14553.	64893.	74149.	12762.31	4267.81	304.46	449.46	387.08	425.95
450.	13649.	16496.	78542.	90645.	5085.36	6210.45	309.30	441.30	386.05	433.97
525.	12904.	16667.	91446.	107312.	4741.99	5666.45	362.95	440.93	385.04	437.04
600.	14147.	19674.	105593.	126986.	4548.94	6333.96	380.28	447.28	385.11	448.11
700.	10528.	11413.	116121.	138399.	3090.62	4290.11	559.02	444.98	384.07	451.07
800.	11268.	6108.	127389.	144507.	2594.47	1872.79	467.02	449.98	383.06	454.94
900.	12926.	20021.	140315.	164538.	3490.06	1425.64	457.07	454.07	383.12	441.12
1100.	3578.	21193.	143893.	185721.	0.00	3980.04	431.00	460.00	381.02	444.98
1300.	3901.	5179.	147794.	190900.	966.05	1742.05	375.00	450.00	383.04	436.04
1400.	6741.	2670.	154534.	193570.	1140.28	1054.48	321.03	467.97	352.03	435.03
1500.	4629.	4689.	159163.	198269.	2499.62	387.14	225.00	460.00	326.52	434.48
1600.	21.	4808.	159184.	203067.	0.00	2145.05	166.18	455.84	295.47	432.53
1700.	182.	4903.	159366.	207970.	11.09	451.30	92.06	454.94	257.33	435.33
2000.			72,17	77946	21.72	431.32	41.00	454.00	91.06	446.06
			231474	285916						

Fig. 5.7 The cut and fill volumes for individual cross sections and the accumulated totals are the significant figures for earthworks.

No	Description				Quantity	Rate	Amount
	CUT and FILL TABLE all quantities shown are in cubic yards						
	TOTAL CUT	apportionment	apportionment	TOTAL FILL			
	Sections BB/Embankment						
30	NIL		from BB/CC	535			
			from CC/DD	3,258			
				3,793	3793		
	Sections BB/CC						
	535 -	535 to BB/Emb.	from CC/DD	1,047			
			from DD/EE	11,344			
				12,391	12391		
	Sections CC/DD						
	4,305 -	3,258 to BB/Emb.	from DD/EE	984			
		1,047 to BB/CC	from EE/FF	6,429			
				7,413	7413		
	Sections DD/EE						
	12,328 -	11,344 to BB/CC	from EE/FF	7,956	7956		
		984 to CC/DD					
	Sections EE/FF						
	39,363 -	6,429 to CC/DD	from EE/FF	12,513	12513		
		7,956 to DD/EE					
		12,513 to EE/FF					
		8,615 to FF/GG					
		3,850 to GG/HH					
	Sections FF/GG						
	74,227 -	2,673 to GG/HH	from EE/FF	8,615	8615		
		4,867 to HH/JJ					
		3,445 to JJ/KK					
		2,428 to KK/LL					
		8,186 to LL/MM					
		11,364 to MM/NN					
		18,921 to NN/OO					
		20,214 to OO/PP					
		2,129 to PP/QQ					
	Sections GG/HH						
	22,445 -	13,666 to PP/QQ	from EE/FF	3,850			
		8,779 to QQ/RR	from FF/GG	2,673			
				6,523	6523		
	Sections HH/JJ						
	3,158 -	3,158 to QQ/RR	from FF/GG	4,867	4867		
	Sections JJ/KK						
	10,816 -	10,816 to QQ/RR	from FF/GG	3,445	3445		
	Sections KK/LL						
	22,533 -	2,383 to QQ/RR	from FF/GG	2,428	2428		
		20,150 to RR/SS					

Fig. 5.8 Table showing the movement of volumes from section to section.

subsequently to draw a new contour plan or a series of plans based on requirements of topography and aspect by computer, will ultimately be adapted to land reclamation. The perfecting of such a programme may well need to be undertaken as an academic study because the costs of this sort of research may be beyond the means of designers or may not seem to be economically advantageous, but it should be available for use by all where it is considered an advantage.

Additionally, comparative tests could be made on a site or sites where earthworking has been undertaken, where the values for compaction or bulking can be accurately assessed. Photographs from before and after reclamation are available for a number of sites; the actual volume changes can be determined accurately by the use of digital ground models and against this various methods of calculations of volume could be tested. These should be preferably assessed not only for accuracy but also for the time taken and level of skill needed to operate them. The assessments could also be compared with any contractor's records of material movement.

5.5 Machinery for regrading

5.5.1 Scrapers and the other machines

It is accepted that the ideal machine for the regrading of pit heap material is the wheeled scraper which comes in a variety of shapes and sizes and may carry from 10 to 45 yd^3 ($7{\cdot}5$ - $33\ m^3$) of material. On small sites, or sites where space is restricted, smaller scrapers towed by crawler tractors may be substituted, and this may be the case where other difficulties such as high temperatures and wet conditions prevail. The advantage of the scraper is that it can handle the complete cycle of material movement by itself, and when the cost of machines has to be borne in mind, smooth operation and quick handling are a major consideration. The use of face shovels or draglines may be necessary in certain circumstances where particular difficulties prevail, but this immediately involves additional machinery to transport the material and regrade it at its destination, and adds considerably to both the complexity of the operation and its cost. The use of this type of equipment is thus clearly limited to those occasions where there is a long haul off the site, or possibly for handling slurry materials or burning shale. Experience at Roddymoor in the handling of hot shale with temperatures of up to 450°C showed that burning pockets could be opened up with a bulldozer blade and the material spread over the adjoining surface where it quickly cooled to a temperature at which it could be handled by the scrapers. Exceptionally large hot pockets might require some special treatment devised to suit the circumstances but the degree of combustion to be encountered would be ascertained by the specialised survey undertaken before the commencement of works.

When scrapers are employed it has been found advisable to follow normal civil and highway engineering practice and ensure that the grade is kept even and smooth by running over the operational area with a blade grader.

At Maria Colliery, the contractor operated with a front bucket loader with ¼ yd^3 capacity which he used with four lorries of approximately 6 yd^3 capacity. A small site, Maria Colliery involved earthmovement of 80,000 yd^3 over a round trip of about a quarter mile, and this proved to be an economic proposition. The use of scrapers would have involved the construction of a special haul road which crossed a brook at one point. With a length of haul in excess of approximately 100 yd, scrapers towed by tracked vehicles are inappropriate except for special conditions such as handling hot material, slurry or possibly for breaking up fused material. The use of the bucket loader and four lorries at Maria involved a throughput of up to 1500 yd^3 a day. The ease of operation in this case has depended on the original method of deposition. Excavation from the base of the heap starting with the newest material working back to the oldest meant that the material fell easily towards the loader. One complication introduced by using the tipping method at the point of deposition is that compaction is much less and the volume of fill is much greater. In the case of Maria this was, fortunately, not critical.

In terms of cost, one significant advantage usually encountered in colliery waste sites is the open condition and easy drainage of the material. This has meant that operations can be undertaken in conditions when the normal clay soils which predominate in the British Isles would make plant operations totally impossible. A great deal of shale regrading work provides employment at a time of year when machinery would otherwise be standing idle, and this is advantageous to both client and contractor. Contract timing should be considered with this factor very much in mind.

5.5.2 Compaction and bulking

Calculations of material regrading to be done by scrapers must make allowances for loss of volume resulting from compaction on respreading. This rather variable factor, which depends on the types of machine in use, the nature of the material, and the way in which it was deposited, has generally been assumed to be about 12½%. In County Durham it has been found that with the smaller and lower heaps, compaction may be up to 25%, while in larger heaps the figure will be between 10 and 15%.

Where other methods of deposition are adopted, for example a dragline with only the surface graded by bulldozer, the compaction factor will be quite different, and indeed in certain conditions the regraded material could be left bulked. This occurs for example where land is regraded after highwall coalmining in Pennsylvania, where the spoil is excavated and thrown back by dragline and the surface subsequently regraded with bulldozers. The increase in height immediately after restoration is often from 5 - 10% of the depth of the excavation.

5.6 Summary

The chapter includes a suggested checklist for landscape survey for derelict landscapes, and observations on suitable scales and contour intervals for different sites and conditions based on the experience of the research project. Some general conclusions from the various sections of the chapter can be made as follows.

(a) Survey. The aerial method of survey, which is continually improving, is likely to be best for derelict landscapes which are topographically complex to obtain the desired degree of accuracy and detail. By the simultaneous flying of a number of sites the cost per hectare can be brought down to a level which might be competitive with ground survey in average conditions.

(b) There is particular reason to investigate underground and overhead services as these may limit the extent of regrading. The presence of old colliery workings and other unmapped objects needs special attention.

(c) Particular emphasis is laid on the need for careful study of geochemical conditions, and the early employment of geotechnical and soil science consultants in reclamation projects is strongly recommended.

(d) Except on small sites with simple problems, calculation of regrading is most efficiently undertaken using a cross-section method adapted to computer use. The application of other methods to the computer and its extension into the field of design is under study in a number of centres.

(e) The most appropriate machine for regrading colliery shale is the rubber tyred motorised scraper, different sizes being selected according to the site.

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Chapter 6 Special problems

based on the work of M.F. Downing and C.J. Vyle

The largest part of the research effort by the University team was directed to the problems likely to be met on many sites in spoil movement, the development of a soil cover, and to surface drainage and vegetational cover. These are the subject of other chapters in this Volume. Nevertheless, several special problems came to light which, although not common to all sites as with the aforementioned, were considered to be sufficiently important to justify including them in the research programme.

6.1 Spoil materials

6.1.1 Fused materials

Much colliery waste has high levels of combustible and pyritic material giving rise to high temperatures and subsequent ignition of the waste heaps to form red shale. Where this shale contains quantities of siliceous material, the intense heat of burning may result in the formation of large volumes of material fused together (Fig.6.1). The problems of dealing with hot and burning material are dealt with in section 6.4.

Fused material is extremely difficult to handle by machine, and laborious to break down by hand. In the sites allocated for research purposes, such material exists at Haswell Colliery and Windy Nook. The former site had to be withdrawn from the research programme because of administrative difficulties, and work had not progressed to grading stage on the latter site at the time of writing. At the other sites, the fused material, when present, was in sizes which could be handled or broken down by machines. It is expected that it will be possible to report further at a later date when the work at Windy Nook is in progress.

The investigations that were made on sites elsewhere indicated that fused material cannot easily be broken down by earth moving machines, the blades rebounding from the material. Where explosives have been used, the explosion has been absorbed in the material without much effect upon it. One method that has been successful is to saturate the fused material with water prior to anticipated frosts, leaving frost action to do the work. Bearing these difficulties in mind, it is recommended that, where possible, the design for the reclaimed landscape should be such that the fused areas are covered with other material, perhaps to form high places in the new topography and thus obviating the need for the saturation technique.

At the Windy Nook site, there is evidence that some of the fused material is in the form of independent masses or 'boulders', and may be dislodged in the course of grading operations, and thus endanger men and machines. The solution to this problem lies in adequate precautions on the part of the contractor when handling the material. The grading of the majority of sites is likely to be such that small changes of level and easy gradients are achieved. If special land form effects are required, it would be necessary to take precautions regarding the dislodgement of large masses of fused material.

6.1.2 Sandy materials and slurry

A well known hazard in earth moving operations is the presence of running sand or material consisting of particles with a low absorbency rating, either because of its unstable characteristics when excavated or deposited, or because of the difficulty of transporting non-cohesive material. At the Roddymoor site, this type of material was met in excavating a watercourse, and movement by dragline, instead of the pushing action of a bulldozer, was found to be successful.

Slurry, a very fine material with a coal dust content which settles in slurry ponds with the recirculation of water in coal washing plants, is difficult to handle because of its clay-like properties; its presence would normally suggest that the basic rates for earth moving should be increased unless it can be kept dry. An experiment was carried out at the Roddymoor site using red shale, deposited 0.75m (2ft 6in) in thickness, to form a haul road around the perimeter of the slurry area; the machines were then operated without undue difficulty from the haul road inwards, scraping the shale into the slurry area.

6.1.3 Materials from demolition

Materials from derelict buildings and engineering plant are likely to be dealt with in accordance with normal demolition practice. But two special problems occurred on some of the research sites, for which experiments were instituted to find solutions. First, during the expected lowering of new water-course beds as they performed the task of collecting and taking surface water away, foundations or bulldozed sections of walls came to light beneath the spoil and altered the flow of water so that erosion started in the sides of the water-course (Fig. 6.3).The situation was aggravated by flash floods arising from open-cast coal operations on an adjoining site. The recommendations for dealing with this sort of problem are given in Chapter 7. Second, several tunnels formerly carrying surface water, and no doubt pumped water from the mine, were encountered in the course of grading and cultivation operations at the Roddymoor site. The best machine for dealing with this problem was found to be a bladed bulldozer with subsequent tamping (Fig. 6.2).This was followed by scraping and grading spoil material over the tamped brickwork of the tunnels to a depth which is recommended at 0.3m (1ft 0in) minimum and a preferred depth of 1.0m (3ft 0in).

Fig 6.1 Fused material lying in a dangerous position at the Windy Nook site. The dislodgement of large masses needs to be handled with particular care in grading operations.

Fig 6.2 Bulldozer spreading thin layer of coke breeze over consolidated brick tunnels Foreground shows sections of tunnel still requiring to be broken and covered.

Fig 6.3 An example of the exposure of old foundations during the erosion process of a new watercourse. Recommendations for dealing with this problem are given in Chapter 7.

6.1.4 Conveyance of materials

There will be occasions when the removal of some spoil material from the site may be a solution to a regrading problem, especially when the material is of greater use elsewhere. At the Windy Nook experimental site, one possible design solution depended upon the removal of some material to fill a riverside dock some 12.8 kilometres (8 miles) away. This idea was eventually abandoned, but as a result of investigations, the following matters arose:

(a) Transport of large quantities by road may meet with objection from residents, the local authority and the police. Even the transportation of 1000 yd^3 of material is likely to generate 200 return journeys with their attendant noise, dirt and danger.

(b) The transportation of spoil material by pit railway is likely to be cheap, but only if there is an existing direct link between point of loading and point of deposition.

(c) The transporting of spoil material in water by pipeline is an economic proposition compared with removal by other methods, if land can be made available for the pipeline, and the material is sufficiently fine. If the spoil has to be crushed before passing into the pipeline, the cost is likely to render this method of transportation too costly. The economics of the method depend on having a relatively valuable material in sufficient quantity. A coal plant in Ohio operates a pipeline of this nature transporting fine coal in suspension over 60 miles.

6.2 Topsoil preservation

Topsoil and subsoil preservation, although a simple technical problem on conventional sites, is difficult and tedious on most derelict sites. Frequently, the topsoil has been masked with other debris and is not easily recognisable, but proper soil surveys should overcome this problem. When good soil is available, it is often in small areas and laden with debris. Also, in areas where colliery spoil has lain undisturbed for a number of years, it is probably beginning to develop qualities associated with conventional soils. Thus, the specification should identify separately these various areas in order to ensure the soils are not lost in the mêlée of operations and should make it clear that small machines are to be used, possibly with some handwork, although the latter can be costly. The importance of retaining every cubic metre of spoil material which has some degree of soil fertility cannot be over emphasised; even 25mm (1 in) thickness of such material can in theory assist the development of a sward. The spreading of such a small thickness however, would require expensive distribution techniques, such as the initial preparation of a smoothly graded surface and the careful planning of the use of plant to avoid mixing the fertile material with the spoil material to a depth where its benefit is lost.

6.2.1 Topsoil stripping and spreading

In the various handling operations for topsoil stripping and spreading that were observed at the various research sites, the following difficulties were met and the manner in which they were overcome is also described:

(a) At the Roddymoor site, the starting date in the winter gave low tender prices because of the difficulty of working elsewhere on normal sites, but as a result the topsoil was stripped and stacked when in a frozen condition. Thus, when spreading took place, the material was extremely wet and difficult to handle. To avoid this problem, particular care needs to be taken to avoid stripping during frosts, although, as at Roddymoor, it is not always practicable to arrange the phasing to avoid likely frost months.

(b) Enquiries made into the particular circumstances arising from the working conditions on reclamation contracts over large areas indicated that, even if the frost conditions referred to could be avoided, it is unlikely that the various operations can be phased to bring topsoil stripping and spreading within fine weather periods. Thus, material may often be wet and heavy to handle. If the timing of a project is such that topsoil stripping must take place in the summer and remain in a heap all winter, the temporary covering of the heap with a grass and clover crop would improve the handling qualities of the soil, and incidentally reduce weedgrowth.

    The assessment made of the use of different machines showed that the use of tractor-drawn scrapers gave an even distribution of topsoil. At the Big Waters site, stripping and spreading took place during May to July; even so, it was found that the wheeled tractors had a 'bouncing' action when distributing the topsoil in thin layers. In some places this led to smearing and compaction with a damaging effect on soil structure, requiring a ripping operation to break up the resultant pan.

(c) Over one part of the Roddymoor site, the nature of the spoil material left at the surface after grading was considered unlikely to produce conditions suitable for plant growth after the various treatments resulting from the experimental work described in Chapter 8. It was possible to arrange for some boulder clay drift to be imported from an adjoining opencast site for use as a top layer which provided a suitable medium after fertiliser and cultivation treatments.

6.3 Dust blow

Wind, rain and the physical nature of the spoil material are variants upon which the likelihood of dust clouds will depend (Fig 6.4). For example, whereas difficulties were anticipated at Roddymoor because some of the material (especially the red shale) was fine enough to give rise to dust, the damp winter months when the earth moving was carried out contributed to the fact that the fine material did not blow away. A combination of both wind and rain is likely to assist working when there is a potential dust hazard coupled with steaming from hot areas. The greater problem on the Roddymoor site was the steaming effect due to the damp atmosphere upon the warm spots as they were exposed (Fig 6.5).

Some spoil materials are also prone to produce dust during cultivation, but this was found to be lessened by selecting weather conditions of light rain and little wind. On sites which are very close to densely built-up areas, the dust problem can be reduced by lightly spraying a mist of water from a mounted container in front of the path of the cultivation equipment.

The effect of dust blow on adjoining areas can be lessened by attention to the design of the reclaimed landscape; for example, by mounds at the perimeter or by locating the spread of available topsoil in areas from which dust would be carried to adjoining areas. Design limitations of this nature will, however, require careful consideration in case they lead eventually to a less satisfactory landscape.

It is recommended that provisional items should be put in the Contract to cover (a) restricting operations up to an agreed limit while dust blow conditions are unfavourable (b) withdrawing machines from one part of a site to open up another part until conditions are more favourable and (c) providing mobile water spray vehicles.

6.4 Hot areas and combustion

A study of the literature revealed that while a great deal is known about the conditions leading to spontaneous combustion in coal mines, there is little documentation on spontaneous ignition in waste heaps. Most heaps associated with coal mining contain carbonaceous shale, and coal in the form of dust and small lumps, as well as hard stone. The most likely situation for spontaneous ignition occurs in pockets of loosely-packed material with a substantial coal content along with iron pyrites and/or organic residues.

6.4.1 Investigations

The necessity for investigating and making available knowledge about this particular problem is evident in the danger to men working on reclamation contracts, in the possibility of fires breaking out after the work is complete, and in the effect of fumes upon people, animals and vegetation in the surrounding areas.

The surveys of existing conditions at the experimental sites were supplemented by investigations specifically concerned with heating in heaps, made by Consulting Engineers. These included:

(a) Observations of heating and ignition by studying the conditions over the surface.

(b) Temperature readings at the surface, and taken in shallow boreholes 1m (3ft 3in) deep at regular distances.

(c) Deep bore holes to ascertain temperatures within the waste material. These should be carefully back-filled and consolidated after taking the temperature readings to avoid creating a chimney effect, allowing air to increase heating or start ignition.

(d) An analysis of exuding gases.

Fig. 6.5 A dramatic example of the steam clouds which can arise from hot areas as they become exposed during damp atmospheric conditions.

Fig. 6.4 A temporary problem with grading operations in some reclamation projects is the raising of dust clouds by earth moving machines. This illustration indicates the considerable distances over which the nuisance may occur.

(e) The content of the waste heaps as revealed by the material from the boreholes.

(f) Moisture content, loss of weight on ignition, total free sulphur, and sulphur trioxide tests.

In the case of (b) it was found that the prevailing weather conditions had a marked effect upon the temperature readings due to very great fluctuations at the surface, and this fact must be taken into account in assessing the ignition problem. The temperatures varied considerably in different places and at different depths on the sites investigated, the highest being 410°C at a depth of 1.8m (6ft 0in).

6.4.2 Ignition

It is advisable to regard all waste heaps arising from the coal industry as having the potential for ignition. Some unburned heaps may have rising internal temperatures over several decades before ignition becomes apparent externally. At Tanfield Lea, near Stanley, Co. Durham, a low heap ignited after 40 years lying dormant, apparently as a result of slow heating to ignition temperature. Other heaps may not ignite until after spoil moving operations have taken place when pockets of a high coal content may be the sources for ignition to occur. Nor should it be assumed that an apparently burnt heap - to all intents and purposes red shale or other burnt material - is free of pockets of coal or carbonaceous shale.

Attention is also drawn to the potential danger of levelled spoil heaps which provide what appears to be a flat area suitable for housing or industry. The following examples explain the latent danger.

(a) In a housing area on a levelled spoil heap at Barlow, between Winlaton and Blaydon, Co. Durham, an occupier lit a bonfire which led to a general conflagration of the ground in his garden.

(b) Paint waste burnt on a paint factory site adjoining Ouston East heap at Birtley, Co. Durham, set the heap on fire.

(c) On the Big Waters Experimental site, surface fires which broke out from time to time were attributed to children lighting small fires for camp cooking. These had to be extinguished by the Fire Brigade.

The information produced by the investigations referred to is essential at the design stage in order that provisions may be made in the design to reduce the fire risk to a minimum, and to aid contractors in assessing to what extent the fire risk must be taken into account in their methods of working.

6.4.3 Precautions to reduce fire risk

The first problem likely to be met in landscape reclamation when fire risk is present is that of disturbing the status quo. In some situations, it may be anticipated that a spoil heap will burn slowly over a long period of time, as was the case near Stanley where the heap has burned for over 30 years, despite determined attempts to prevent this by quenching with water by the N.C.B. Once disturbance takes place, the process can be aggravated to an extent where earth moving operations may have to be suspended before atmospheric conditions for those living in the district became intolerable, or excessive dangers to the plant operators are incurred. When excavating hot or burning heaps it is inadvisable to work over the top of underground fires; besides the dangers of fumes, including those of gas explosions and restriction of visibility, there is the likelihood that cavities may be created as the result of combustion of the carbonaceous material. On the other hand, excavation at the base of the heap may result in permitting the updraught of currents through it, in such a way that heating and ignition is stimulated. Nevertheless, this may be the safer way of excavation provided falls of material can be avoided. Lateral excavation at different levels, preferably at the side sheltered from the seasonal prevailing wind at the time of operation, may be a satisfactory solution.

6.4.4 State of spoil heaps

If, as a result of temperature borings, it is established that the spoil heap is at a temperature below the ignition stage, then any re-distribution of the spoil is best handled from the top of the heap downwards, thus avoiding the creation of draught effects. If there is a likelihood of ignition, the temperature may be kept down by pumping water on to the surface as the work proceeds, though this often gives rise to steam, making conditions uncomfortable to work in and reducing visibility. Water pumped on to hot heaps may also give rise to steam explosions, when an accumulation of steam takes place below the surface.

The physical condition of spoil heaps alters with the stage of burning. First, before ignition, they are more or less physically stable, depending on the method of deposition and degree of compaction. Second, during and soon after ignition, voids may develop. Third, some years after burning has ceased, the voids may have filled through settlement and the heap becomes comparatively stable. In the second condition, the normal method of operating machines from the top downwards can be particularly dangerous, as there is the possibility, already indicated, of men and machines falling into the voids, coupled with danger from fumes. Burning material should be quenched and distributed in 300mm (1ft) thick layers with 300mm (1ft) thick sealing layers of lime, chalk or clay between. It is stressed that sand is not sufficiently impermeable to be used as a sealing material.

6.4.5 Roddymoor

At the Roddymoor site, investigations into the spontaneous ignition situation forecasted that temperatures of about 200°C would be experienced in a small part of the waste heap, and of about 150°C generally over large volumes of material - mainly between boreholes 2 and 4. Also, that this hot material would cool rapidly after exposure. It was, therefore, considered advisable to use a long-boomed dragline or face shovel, though with care a tracked machine could be used. Machines with rubber tyres were not recommended. In fact, it was possible to use a tracked bulldozer to push out the hot material and spread it to cool. Within only a few minutes of spreading, it was cool enough to be transported by tractor-towed scrapers.

6.4.6 Percy Pit

Unless the precaution is taken of layering combustible material the potential danger that fires may break out in the newly-contoured landscape is likely to remain. One solution is to remove the combustible material by screening and washing, but this is expensive unless the contractor can be certain that the coal content is sufficient and can be disposed of quickly at a price giving a reasonable return for his outlay, taking account of the delay to the reclamation contract. This possibility was investigated at the Percy Pit site and was found to be uneconomic as a separate operation, largely because it would have been necessary to move the greater proportion of the material twice in order to achieve a satisfactory land form due to the restricted nature of the site.

6.4.7 Big Waters

Another method for overcoming the problem of spontaneous ignition was investigated at the Big Waters site. The experiment consisted in the isolation of a burning area by means of a ditch 2.4m (8ft) wide dug down to the original ground level. The ditch was filled with clay, and a cover of a similar inert material laid over the isolated area to a minimum depth of 1.8m (6ft). This experiment has proved successful. An interesting small point is that a small amount of hot material from another part of the site was removed to the experimental area and spread on the larger burning areas, before the clay cover, thus restricting the need for remedial work to one location.

6.4.8 Safety measures

On the results of various trials in regard to the procedure for grading in hot areas, we recommend that the following safety measures be taken:

(a) A contractor experienced in the movement of burning heaps should, if possible, be employed.

(b) High temperature reading thermometers should be kept on site.

(c) Warning disc badges should be worn by plant operatives to detect carbon monoxide, a further disc being mounted on the instrument panel in the operating cabin. Badges should also be worn by site personnel who are liable to go near areas of hot material. The badges are similar in style to the types worn by personnel in the nuclear industry and are inexpensive.

(d) Care should be observed with fuel on machines operating in hot areas, and in the use of rubber tyred vehicles. Manufacturers' recommendations indicate that most scraper tyres can be used where temperatures do not exceed 200°C. Few contractors will need to be reminded of the need for care with scraper tyres in view of their high cost - of the order of £1000 each for larger scrapers.

(e) Operators and personnel should have a basic knowledge of the hazards of toxic gases as well as the symptoms and initial treatment when affected, no matter how remote the likelihood may appear.

(f) Special care should be exercised in warm still weather when working hot areas.

(g) Thermocouples should be inserted into the area when it is reduced to its designed level, if any particular dangers are anticipated, to a depth of about 1.2m (4ft). The number would depend on the site condition. Daily readings should be taken and recorded as the scheme proceeds.

(h) On completion of the scheme an experienced observer should visit the site monthly for a period of a year, and thereafter at longer intervals for a period of up to five years. The presence of heating is often shown by damage to the herbage, which may become discoloured and quickly die off; this is usually the result of the release of gases.

6.5 Toxic gases

Associated with the problem of spontaneous combustion is that of the toxic gases which are often generated in waste heaps. The main gases occurring on the experimental sites were:

(a) Carbon dioxide, which is dangerous in concentration since it dilutes the available oxygen supply to the lungs, and has no smell. In the open, however, little hazard is presented.

(b) Sulphur dioxide and trioxide, which in diluted quantities will irritate the lungs and are liable to cause pneumonia; however, because of the irritant character, the gases are self advertising when inhaled.

(c) Hydrogen sulphide, even in diluted concentrations, is characterised by its smell of rotten eggs, and therefore makes its presence self-evident. It is almost as toxic as hydrogen cyanide (prussic acid gas). In very diluted concentrations over a period of time it can cause headaches and various other symptoms.

(d) Carbon monoxide, which is described as a toxic gas capable of destroying the red blood cells; its effect is more lasting than the dioxide. In diluted concentrations, it produces the symptoms as hydrogen sulphide. It has the disadvantage of having no smell and a cumulative effect.

There is likely to be a considerable dilution of the gases on sites, but plant operators should be warned about the dangers, and a strict watch kept on the situation and a strict control on the periods of working.

6.6 Pollution

Although such sources of pollution as burning from spontaneous ignition and chemical action may be controlled or physically contained, there is always the possibility that the water draining from a site may be polluted through the seepage of water down through the waste material and eventually to the water-courses draining the site. It has been found, for example, that polluted water from a waste heap material can upset the biological balance of sewage treatment plants and the chemicals leaking out can, if in sufficient concentration, kill off the bacteria which break down the sewage. The best way of preventing this type of pollution is through careful design of the reclaimed landscape. The slopes and disposition of materials should be such that surface water is unlikely to reach a source of pollution and then be able to surface again without a long journey through virgin subsoil or strata which act as filters. This problem was particularly important at the Big Waters site where one objective was to produce and maintain conditions to support fish and other types of wildlife. To date, the design of levels and layers of inert material have proved successful, and the only observable pollutant comes from a nearby project which drains into a stream entering the site.

6.7 Procedural problems

During the course of setting up the experimental sites, a number of procedural problems arose. These are not directly relevant to the design and technical problems of the research, but are listed for information:

(a) Services and other undergound elements may be encountered for which no record exists.

(b) The contractor may take risks by departure without permission from a precaution adequately covered in the specification. The contractor is clearly responsible for the risk but frequently this involves protracted discussion and extra work by the 'engineer', the client and other affected bodies.

(c) The procedures for giving notice of works to be carried out to all the many persons and authorities concerned are involved. To obviate omissions a check list similar to that of the Reclamation Section of the Durham County Planning Department is a wise provision to ensure that all likely persons and authorities are notified.

6.8 Conclusions

(a) The materials likely to found are so variable that site surveys including a large number of boreholes may not give a representative picture of the contents of heaps.

(b) Appropriate design of reclaimed landscape can often reduce the problems caused by difficult materials.

(c) If it were possible to disclose by survey every underground hazard, the cost would be prohibitive. If extra expenditure is incurred in the contract work on some sites through the presence of objects undetected at the survey stage, it should be recognized that even the most exhaustive surveys may fail to bring all potential hazards to light.

(d) The preservation and spreading of topsoil, even if only small quantities are available, is of paramount value in the creation of a medium for plant growth.

(e) The unpleasant effects of noise and dust during reclamation operations can often be mitigated by the design and by operational techniques.

(f) Further research is needed into the problems of controlling ignition in waste material, and into forecasting the likelihood of ignition.

(g) Safety measures at the highest standards should be adopted for operatives using plant on waste material.

(h) Pollution arising from within reclaimed sites can often be minimised or even eliminated by suitable design measures.

Chapter 7 Land drainage

by M.F. Downing

7.1 Introduction

It has needed comparatively little investigation of other reclamation schemes and experience on research project contracts to establish that attention to the adequate drainage of reclamation sites is a primary requirement of any design for returning the land to a fertile state. The final drainage pattern of sites is, however, not the only drainage problem which needs to be considered. The characteristics of the material and drainage of the site must be foreseen and catered for at all times, from the inception of operations to the consolidation of a mature landscape, and this involves a changing or phased drainage plan.

Surface water and subsoil drainage requirements in normal ground conditions are set out in principle in the British Standard Code of Practice No. 303 (1952).

Engineers will be aware of the seven subheadings set out in Paragraph 103 of the code, entitled 'exchange of information', enumerating the basic information necessary before drainage work is carried out.

7.1.1 Adaptation of standard information requirements to reclamation sites

The relevance of some of the information as listed in the code may not initially appear to be so direct and important in the case of reclamation sites. For example, the water table of derelict mounds and valleys of deposited material may bear no relation to the natural ground watertables or to the future water status of the regraded site. Also, the nature of the strata of natural ground underlying the site may appear to have little relevance to the regrading. This however, is not the case, and although the factors may vary in importance on reclaimed sites it is just as necessary to take account of them all as when dealing with the drainage of natural forms. The effects of regrading and perhaps covering impervious strata can result in the development of spring line conditions, or of wet and unstable areas. The movement of water within the material can result in erosion and internal collapses, and this will happen where lateral water movement is induced as a result of the influence of the underlying strata. It is not necessary to underline the need to deal adequately with known streams or watercourses which may be affected by the regrading, though the fact that some of them may be seasonal and therefore not immediately apparent during initial site inspection should be emphasised.

The watertable of adjoining land and of the land in question is a matter which needs particular attention. The regrading of material will inevitably have some effect on the water table around the site, and this must be studied for its effect on soil and water status, particularly its indirect effect on existing trees which could be adversely affected by either raising or lowering the watertable.

7.1.2 Phases of reclamation site drainage

Site drainage on reclaimed land can be considered within three distinct phases as follows:

(a) Drainage during contract operations.

(b) Special provisions to ensure simultaneous maintenance of stability and free drainage during site establishment.

(c) Terminal drainage.

If the framework of the terminal drainage system of a site can be so designed that it provides adequately for the maintenance of good site conditions in the intervening contract and establishment periods, this is an ideal solution. Initial drainage provision will consist of open ditches, easily cleared of silt and these may be left as such in the final state of the design, or may be filled with rubble or additionally piped.

7.1.3 Instability of colliery waste

Sir John Russell (1950) has enunciated the principle that 'the success of drainage operations depends on the stability of the soil'. This statement has particular relevance when dealing with regraded land involving waste material. Natural land forms in the majority of Great Britain, and certainly with minor exceptions in the north east of England, have achieved a reasonable degree of geological stability and may be described as being predominantly in the compaction stage of the denudation and deposition cycle described by geomorphologists (Bundred 1969). The processes of weathering and denudation effected by wind, water and extremes of temperature are well described in standard textbooks of geology. The principle that erosion will continue towards the creation of a flat plane, in any situation where the downward flow of water or the effect of gravity can overcome the stability of the surface material, is commonly understood. The fact that colliery waste is evidently highly subject to erosion may be due to its being inherently less stable than natural soils or to the high degree of impermeability of material when compacted by contractors heavy plant causing a high percentage run off. It follows, however, that in any situation where work with colliery waste is involved, a particularly careful watch must be kept on the design of slopes and situations which are especially liable to erosion. These will be dealt with in some detail in the following paragraphs.

7.1.4 Impermeability of colliery waste

In the operational stage the amount of percolation is very low and run-off is high. A surface covered with vegetation such as grass is generally regarded for drainage calculation purposes as having a run off of approximately 10% of the total rainfall. In many cases, however, during operations, the run off from shale will be more nearly comparable with the theoretical percentage impermeability of footpaths, namely between 50 and 75%. Indeed many designers prefer to base their calculations on the assumption of 100% run off as allowed for buildings. Apart from the characteristics of impermeability or run off arising from the nature of the soil and the vegetational cover, the ratio of run off to percolation depends on the rate of precipitation, and the angle of slope. It is therefore necessary to ensure that the angles of slope provided are satisfactory both in the long and short term.

7.1.5 Calculations of run off

It is important to emphasise that calculations of drainage provision should be based on the worst conditions anticipated on the site during the operating and subsequent establishment period involving a greater provision than would be required for the established site. This over provision is greatly preferable to the damage which can follow inadequate initial drainage measures. A number of formulae exist for the calculation of run off from areas of land, and here again engineers are familiar with problems of run off, rainfall intensity and storm duration, and will select their methods to suit their purposes. It may be useful to draw attention to the precise run off values given by the American writer Seelye (1951) which differentiate between clay, loam and sand, dependent on the vegetation cover.

Related experience on reclamation sites has emphasised the need to calculate using a high coefficient of run off approaching that of buildings as indicated in the previous section, and certainly not less than that for roads and pavements if trouble is not to be experienced in the initial establishment period.

7.2 Drainage during contract operation

Attention to drainage conditions on the site during the operation of the contract is important from two points of view, first the protection of works and second the protection of adjoining property.

7.2.1 Protection of works

The efficient operation of the works can be badly impeded by poor drainage, standing water, the formation of erosion gulleys, and the deposition of silt in low lying areas. Failure to take adequate precautions during the operational period when the site is likely to be completely devoid of vegetation, and run off potential is at its highest anticipated level, can result in this type of damage, as has been stressed. Where excavation of material results in temporary steep slopes or sheer faces, sudden high volume precipitation can result in flow slides or slips. Most of the precautions necessary for this type of work are well known to those concerned with earthworks. Experience in Durham County indicates that the worst period for run off and erosion is after grading and spreading of top soil and before the establishment of vegetation.

The dangers of soil creep, slides of fragmental detritus and rock, and deep rotational shear slips, and methods to prevent their occurrence and rectify their effects, are set out in the British Standard Code of Practice for Earthworks. All these or very similar phenomena may occur in the artificial conditions of deposition of colliery waste, and may indeed be aggravated by its peculiar liability to erosion.

7.2.2 The protection of adjoining property

During the operational period damage by run off can be caused to adjoining land. It is advisable to consider what would be the likely effect of the worst possible rainfall conditions, based on a 1 year cycle of records, and to plan the site operations accordingly. A higher degree of safety would be achieved by the use of a longer cycle but such a counsel of perfection is not always possible and some element of calculated risk is acceptable.

On very large sites, for example those exceeding several hundred hectares, it may be desirable to adopt a higher standard of safety based on a longer cycle of rainfall records, say 7 to 10 years. In practical terms, on urban sites where the drainage is into main sewers, the capacity of these will strongly influence the design of the site drainage. A limited surcharging of the main surface water sewage system may be accepted, provided that the anticipated discharge does not exceed the capacity of the system by too great an amount; the risk to adjoining property is comparatively remote and the provision of on-site stilling ponds permits the temporary retention of water on site. A high degree of care is needed where, on reclamation sites adjoining urban areas, steep slopes make for a high potential rate of run off.

Consideration of the duration of the operation, and the time of year, from which anticipated rainfall can be gauged, are further factors which help to give a balanced picture of the precautions which are required to be taken. Other risks which might occur in special situations, and must be foreseen and assessed, are: the washing of heavy metal or toxic water into water catchment areas, or on to agricultural land; the silting up of agricultural drainage channels and even the flooding of excavations into adjoining opencast coal workings.

Prevention of damage and flooding on adjoining land can usually be achieved by the temporary provision of bunds which operate in the same way as the stilling ponds and behind which storm water can be stored or diverted to drain away slowly depending on the flow capacity of the available drainage outflows. Frequently this requires no more than the limited operation of a bulldozer blade to create a shallow v-shaped ridge and furrow to cut off the flow of surface water from high ground to outfall. On such large sites or extensive slopes it may be necessary to construct several such ditches. The permanent protection of adjoining property often calls for the digging of cut off ditches along the boundary line of a reclamation site and this work can generally be carried out as an early item in the reclamation works so that some protection is given by it during operations. This is possible because it is desirable in practically all cases to grade reclaimed areas to merge with existing ground levels on adjoining land. The presence of such a ditch, and open ditches across the site does not obviate the necessity for stilling ponds and may in severe storm conditions make such holding devices even more essential. The ditches will tend to speed up the movement of water from the far corners of the site to the outfalls causing greater concentration than there would be without them.

The necessity for protection during the contract operations is underlined by the experience recorded at Brancepeth heap near Crook, Co. Durham, where high rainfall occurred at a time when the top-soiled areas of the site had just been seeded. Conditions were such that very high run off occurred and this was discharged into the local drainage system.

Due to a combination of local circumstances, the volume was too great for the system and the water flowed over the lower parts of the site temporarily flooding the village street.

7.2.3 Application to research sites

The maintenance of satisfactory site conditions during the operation of a contract is principally the responsibility of the contractor. This is clearly set out in the conditions of contract in so far as any loss, damage, or injury is concerned, whether to persons or to property. Any specific protective measures required both during the period of the contract or while the site is becoming established should be fully explained to the contractor particularly when adjoining property is concerned.

As far as the operation of the contract is concerned the contractor will naturally adopt what he regards as the most efficient and workmanlike procedures necessary to ensure unimpaired working. This may involve the digging of temporary diversion channels and ditches if the site becomes very wet, and, of course, ensuring that as far as possible no areas of low lying land capable of temporary flooding are allowed to remain any longer than operationally necessary. No major problems of this nature have been encountered on research sites during the earth moving operation periods of the various contracts. Some problems were met at Roddymoor due to the presence of slurry material which when wet is difficult to handle and this points to the need to make special drainage provision for slurry ponds during contract operation.

7.3 Special provisions during establishment

The drainage characteristics of both immature and mature sites are dependent on the earthshaping design and to a lesser degree on the physical properties of the material being regraded. In the establishment period, i.e. the period immediately after operations when the grass sward and other vegetation is neither dense nor robust enough to ensure the stability of the site under all but exceptional conditions, the damage which cna result from steep slopes and high run off conditions is more extreme than will be the case in the mature landscape as has already been stressed. The site and the soil are both less stable than they will be when the landscape matures, but the problem is basically the same in both situations. It has never been considered desirable to construct final tile underdrainage systems until regraded land is completely settled, and in any case closed systems of underdrainage, which rely on the percolation of water through the soil, do not adequately control the conditions of high run off and consequent erosion which occur at this stage. It has also been found that rubble drains, if completed before vegetation cover is established, are subject to severe silting. It is, however, essential to ensure that surface water run off does not result in excessive volumes or high flow speeds over the surface. This means that drainage by temporary open ditches is employed to reduce the area of local catchment and prevent the build up of surface water flows. (Fig.7.1). The ratio of percolation to run off discussed earlier is the significant factor which changes from the operational stage through the stage of establishment to the developed conditions of the site. Mention has been made in Chapter 4 of the theoretical optimum slope below which no drainage takes place and above which erosion occurs, and it has been indicated that land use requirements make the attainment of such slopes which theoretically ensure perfect drainage, most uncommon in practice. On all but steep embankments the rate of percolation can be assisted during the establishment period by opening up the surface with deep-tined equipment, and this should be considered even though the effect may be of limited duration as has been suggested by some workers. This is almost invariably necessary where the surface has been laid down using the types of heavy earth-moving machinery now available and commonly employed.

7.3.1 Temporary drainage to conform to the permanent pattern

The creation of open channels or similar devices to control run off of water during the establishment period has already been discussed, the layout of this work ideally being such that the channels will ultimately form the submains of the underdrainage system. Open channels can also be used in association with the piped system to act as a check on the water flow and can be constructed with check dams along their length where the falls and flow potential make this necessary. Where check dams are used some special construction may additionally be necessary to prevent scour of the banks or bed of the channel.

7.3.2 Protection of channels

It is particularly important when designing temporary or permanent open channels that the instability of shale materials is taken into account. It is frequently necessary to take special precautions to ensure that erosion does not take place in the channels. Where this has not been done, storm water has cut deeply into the shale in a very few days (see 7.3.4).

The placing of selected materials such as brick rubble, breeze blocks, stone or concrete in the channel to form a hard solid bottom not subject to erosion can overcome this problem and such material is often available on site either from demolished buildings or from colliery waste heaps. This method has been adopted in the design of channels at Percy Pit in particular, and similarly used for remedial works at Roddymoor as discussed in section 7.3.4.

It is sometimes desirable to open up temporary channels to counter flash flooding in positions where they are not subsequently to be incorporated into the final under-drainage pattern. In this case it is probably adequate to create shallow v-shaped trenches or make a furrow with a single furrow plough, with the furrow on the uphill side of the field, to check and direct the flow of water, though this may be difficult where there is a high stone content in the shale. These temporary features will be kept open for only one year and allowance should be made in the contract bill for them to be filled and grassed over during or towards the end of the maintenance period. There may also be a need to make similar arrangements for permanent drains which it is felt desirable to leave open as ditches during the establishment period, and to complete these after one or two growing seasons.

7.3.3 Tile drainage and plastic drains

As already indicated it is not generally regarded as desirable to lay permanent drains on regraded land, for example, after opencast mining, until it has settled, and this often means waiting for five years or more from the time of regrading. Without very careful control the compaction of material on regraded sites is not of guaranteed uniformity such as would be acceptable for structural engineering purposes. The use of heavy machinery, so common nowadays, achieves a degree of consolidation which exceeds that on much natural ground, and it may well be that with a minimal improvement of supervision a reasonable uniformity of compaction can be achieved to allow drains to be laid without delays for settlement. This possibility may be assisted by the use of plastic drain pipes in long lengths in place of traditional tile drains.

7.3.4 Research sites

It has been necessary to carry out a number of remedial activities on site to assist the establishment of vegetation and to counter erosion. In particular on the Roddymoor site, the erosion of channels formed in shale has proved to be severe in places. This was particularly so where a large discharge of water had been received from higher ground being worked for the extraction of opencast coal. In the main channel, deep erosion had been experienced (Fig. 7.3).

Fig.7.1 Roddymoor, Crook: Temporary open ditches to check surface water run off N.C.B. (Opencast) Site.

Fig.7.2. Roddymoor: Matting laid on bank of main channel to prevent erosion.

Fig. 7.3. Roddymoor reclamation site: Severe erosion on main drainage channel.

and the channel which was excavated at 1.2m wide x 0.9m deep (4ft wide x 3ft deep) has now eroded in places to a depth of 3.3m (11ft) below original ground level with an increase in width varying from 0.6m to 4.8m (2ft to 16ft). The channel has now been lined with large rocks in places and sand bags, and gabions filled with whinstone have been used to prevent further erosion in the most seriously affected lengths of the stream. The use of polypropylene matting has proved successful in controlling erosion on embankments, stream banks (Fig.7.2) and, in the case of small channels with intermittent flows, on the actual stream bed. This material is laid in sheets secured by galvanised pins and has a wearing life of several seasons. As it rots, the intention is that the vegetation will grow through it to act as the permanent stabilising medium. Further experiments in the use of this material are continuing. Experience at Roddymoor had underlined the need to counter scour at points where flow is impeded by isolated large objects in the stream or channel bed. In these circumstances silting occurs above the object and scouring takes place immediately down stream of it. Alternatively, scouring may act laterally into the stream bank if there is any weakness at a point where flow is impeded.

7.4 Permanent drains

The permanent drainage system of a reclaimed site must ensure that no damage occurs in the event of a sudden storm. It must also be adequate to the task of removing excessive soil water from the site so that the soil may remain open and healthy, capable of supporting good plant growth and human and animal use as required. The degree of underdrainage provision will depend on the use, angle of slope and elevation in relation to surrounding ground of the site in question. For forestry no underdrainage is required, any problems of damp low lying land are usually adequately dealt with where it is possible to regrade land to a slope which enables water to run into ditches at field boundaries. This it is suggested is a gradient of not less than 1:30 or 1:40. Open ditches may be cut when planting is undertaken, at suitable intervals of, say, 30 to 50 m, and can be left open permanently.

7.4.1 Use of tile drains

It is only where playing fields are to be constructed that it is necessary to lay tile drains extensively, because of the need to achieve relatively flat surfaces which do not allow for easy surface water run off. Where a long term future use is to be agricultural arable land then some tile drainage may be contemplated for a later date.

A good case has been made out by Doubleday (1968-9) for the inclusion of underdrainage in the early stages of reclamation where a high degree of salinity is encountered in red shales as occurred at Felling. The provision of underdrainage will allow leaching to take place at an enhanced rate. When this occurs it is necessary to delay sowing for a season or more by which time salinity levels should have dropped to an acceptable level. The status of the material should, however, be tested continuously. In areas where there is to be development for casual recreation, nature reserves, forest and woodland planting, and special uses such as ski slopes, variations in topography may call for special drainage measures.

7.4.2 Embankment drainage

Where terraces are separated by embankments it is desirable to protect the head of the embankment, introducing hill grips on the actual slopes, and ensuring that the foot is adequately drained. At the head of embankments and on steeply sloping terraced sites, the device of a wide shallow channel acting as a storm bund and collecting water from the terrace to convey it into the underdrainage system, may be adopted. These channels may be designed with tile drains back filled with rubble in the base or with gulleys at their lowest point. The hill grips consist of rubble drains, generally without tiles, not less than 450mm deep (18in), dug at forty five degrees to the line of maximum slope. These are connected to a collecting tile drain at the base of the slope. Experience so far at Roddymoor suggests that when the slopes are 1:5 or less there is no need for hill grips, though there may be some advantages in including some connected to cut off drains at the base where the slope is particularly long (Fig.7.4). Even with these gradients some danger exists during the establishment period. At the base of embankments, tile drains with rubble back fill should be provided to prevent the development of damp spots. On some banks the use of flumes to channel water from the higher level to the lower level may be adopted (Fig.7.5). This involves careful attention to the detail of the collecting area at the top of the flume or the system may otherwise be rendered useless by erosion channels which bypass the flume.

Subsequent proposals for Felling have introduced a series of drains parallel to the contours and connected with closed pipe drains at selected points down extensive slopes, in place of 45^{o} angled hill grips. These, left open at the early stage of the contract, and then back filled with rubble and a pipe are now thought to be more efficient.

Where the frequency of field boundaries permits, the drainage of a site can be achieved with open ditches. In this case it is only at the outfall, if it is into a main sewage system, that any major construction will occur with the need for a cross wall with a final piped length and a silt trap.

On many sites a new topography consisting of terraces and embankments will make the laying of drains to a consistent or near consistent fall a difficult matter though care for this aspect must be a major consideration in the landscape design.

7.4.3 Silt traps

The problem of silting is particularly prevalent in reclaimed colliery waste and there is a need to make complete provision for silt trap inspection chambers. Additional traps may be desirable where changes in the rate of flow occur from fast to slow, and where silt may be deposited. The need for continual and frequent inspection and clearance of silt traps especially during the early part of the site development is discussed in Chapter 6.

7.4.4 Legal requirements

The legal requirements of surface water drainage schemes are set out briefly in the B.S.C.P. 301 (1952). The powers of local authorities and rights of owners and occupiers of property are derived from the Public Health Act 1936. Where no publicly-owned sewers exist, drains may be discharged into streams or soakaways, provided no nuisance is caused and no pollution of any watercourse occurs. In such

Fig.7.4 Roddymoor: Main drainage channel.

Fig.7.5 Roddymoor: Concrete flume built on steep slope.

circumstances, and, in fact, in every case where discharge of water from reclaimed land is concerned the precise details of the problem should always be discussed with the Local Authority and the Water Authority concerned.

7.4.5 Research sites

It is as yet too early to provide any conclusion based on the permanent drainage characteristics of the research sites. It is hoped that more useful data may have been obtained by the time of publication of the second research volume. More work is, however, still required as indicated in the conclusion.

7.5 Conclusions

Among the important findings of the project are those concerned with the very significant part played by drainage operations in the development of any site. Not only must the site be designed with its ultimate drainage needs in mind but ample provision must be made for the short term or development stage of the landscape. This will frequently result in the inclusion of drainage measures considerably in excess of those needed for the permanent drainage of the site, simply to ensure its satisfactory establishment. These will range from temporary ditches to more substantial tile drains. In particular, the provision of silt traps to prevent silting of main drainage systems and watercourses is required, again principally during the short term development period of any site. Drainage channels too, must be capable of being easily cleared in the event of silting.

More work is required by hydrologists into the problems of pollution emanating from pit heap materials and its effect on watercourse flora and fauna. The possible dangers of the discharge of serious pollution on the anaerobic bacteria of sewage works should not be ignored. Similarly, additional detailed studies of the erosion of shales under site conditions would be a valuable contribution to knowledge on landscape reclamation. Measurements to assess the relationship between precipitation and run off, under different conditions on shales in unvegetated, partially vegetated, and completely vegetated conditions would provide useful information for future drainage calculations. Information could be gained by survey and observation of the gradients of drainage channels related to volumetric capacity and degree of compaction of the material, also affected by related catchment and rainfall intensity and applied to the design of channels which will not erode seriously.

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Chapter 8 Soil forming materials: their nature and assessment

by G.P. Doubleday

8.1 Introduction

On many derelict sites, especially those concerned with colliery waste, there may be some difficulty in establishing and maintaining vegetation. This problem can be overcome either by making the plants 'fit' the soil or by making the soil 'fit' the plants. In the former method the choice of plants may be narrowed down to a few species or even to a specially selected ecotype; in the latter approach, as outlined in this chapter, a diagnosis of the underlying soil problems is made, coupled with management practices which encourage the normal healthy growth of a wide range of plant species.

On most colliery waste the development of a useful soil only begins at reclamation and unless the process is controlled in the succeeding years, the site will tend to revert to its original condition.

8.2 Materials found on derelict sites

Once a site becomes derelict it is frequently used as a dumping ground for refuse, most of which is totally unsuitable as a soil forming material. Items such as broken foundations, scrap iron and timber, domestic waste etc. should be removed or buried at a depth so that normal cultivation practices may proceed without unduly risking machinery.

This chapter will be confined to the reclamation of stored soil and shale, these being the most important plant growth media on sites examined in the project. Of these two materials, the reclamation of shale is considered more fully as the problems of reclaiming stored and poor condition soils have already received considerable attention in open-cast restoration research.

8.3 Problems associated with the use of stored soil

Many reclamation schemes aimed at returning a derelict pit heap site to agricultural land follow the same basic pattern, see Fig. 8.1. The top and sub soils from areas adjacent to the pit heap may be stripped and then stacked for periods of several months. After the tip has been graded out over the stripped areas the soil is returned to cover as much of the new shale surface as possible. When top and sub soils are stacked in compact heaps, they undergo changes which normally involve some deterioration in their physical condition. Hunter and Currie (1956) examined these changes in fine textured soils and observed that when the material was respread it would:

(a) poach badly under cattle and machinery
(b) give a poor or unstable tilth
(c) be subject to erosion
(d) allow only shallow rooting of plants
(e) be subject to cracking in dry weather
(f) resist the introduction of earthworms
(g) require a starter application of 3cwt/acre single superphosphate per acre (i.e. 54 units P_2O_5) in the first year
(h) require no potash and little nitrogen in the first year but heavy applications subsequently.

In order to minimize the physical damage, a soil should be kept stored in a heap for the shortest possible time. When the material is respread it will require special management and cannot be expected to behave as if it had never been disturbed.

8.4 Colliery shale as a soil-forming material

8.4.1 The formation of pit heap materials

The commercially valuable Coal Measures were formed during the latter part of the Carboniferous System, some 220–280 million years ago. At that time what is now Northern England was a generally subsiding area periodically covered by the sea. Although submergence was by a sea, probably not more that "a few tens of feet deep" (Westoll, 1968), conditions led to the deposition of calcareous material which later formed limestone strata.

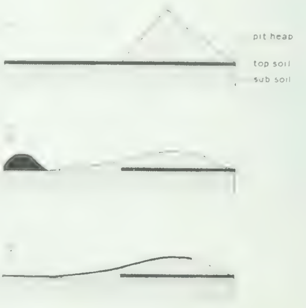

Fig. 8.1 Stages of regrading showing the distribution of top soil. (Not to scale.)

With the generally south westerly advance of a delta complex served by rivers from land blocks to the North and East (Wills, 1951), much argillaceous sediment was subsequently deposited over the calcareous sea floor. Pons and Zonneveld (1965) point to the ubiquitous association of organic material with argillaceous sediments. In stagnant waters this led to reducing conditions favouring the formation of finely disseminated iron sulphides. The organic material and sulphides gave the sediment the grey or black colour so familiar in pit heap shales.

With the seaward advance of the delta front the marine cover became shallower, reducing conditions changed to oxidising conditions, and the argillaceous sediments gave way to sandy material. As the delta formed, deposits became more heterogeneous, ranging from muddy banks to pebble and sand filled channels. No doubt the paths of the distributaries changed from time to time producing interbedded and reworked material.

Vegetation grew wherever possible, roots and rhizomes being incorporated into the primitive soil. Aerial growth was occasionally preserved as peat deposits but was frequently removed by shifting watercourses or during inundation by the sea, and incorporated into a new deposit elsewhere. The frequent reworking of the delta surface and incorporation of the organic debris gave rise to the material which subsequently formed the seatearths often found below coal seams, Moore (1968).

The surface pH of the material would have been 4.5 to 5.5, being conducive to a high rate of biological activity for which the necessary mineral nutrients would still have been present. Continued fresh water leaching, especially in the presence of organic complexing agents, led to the removal of many cations and to changes in the mineralogy involving a relative increase in the percentage of kaolinitic clay minerals. With time, deltaic conditions became stabilized with only the occasional brief inundation by the sea.

As the process of leaching and base removal continued, the pH fell and at a level of 3.5 to 4.0 microbiological activity became very sluggish. Organic material accumulated, later becoming coal. These areas were often slowly subsiding basins so that acid swampy conditions developed in which dead organic material only partially decomposed.

Several times the whole delta area and coal swamp became submerged below the sea again so that the sequence of limestone, shale, sandstone and coal was repeated. This sequence is called the Yoredale cyclothem. If submergence was not sufficient to allow the limestone to form as with the near shore sequence, the Millstone Grit cyclothem (shale–sandstone–coal) evolved. The complete system of deposition, from near shore to open sea is shown in Fig. 8.2.

The Yoredale cyclothem was first described explicitly by Miller (1887) and latterly in an idealised but much more detailed form by Johnson (1959).

The full Yoredale cyclothem according to Johnson (1959) is:

COAL
(x) Coal, ganister or seatearth, and some of: sandstone, flags, shales, limestones or marine shales
SANDSTONE
(ix) Sandstone, often current bedded
(viii) Thin bedded sandstones, flags, shales and siltstones
SHALE
(vii) Relatively unfossiliferous ferruginous shale
(vi) Dark pyritic shale
(v) Fossiliferous calcareous shale
(iv) Dark blue fragmental limestone, marl bands and partings
LIMESTONE
(iii) Light grey bioclastic limestone
(ii) Dark blue-grey muddy limestone
(i) Fossiliferous marine shale and sandy shale

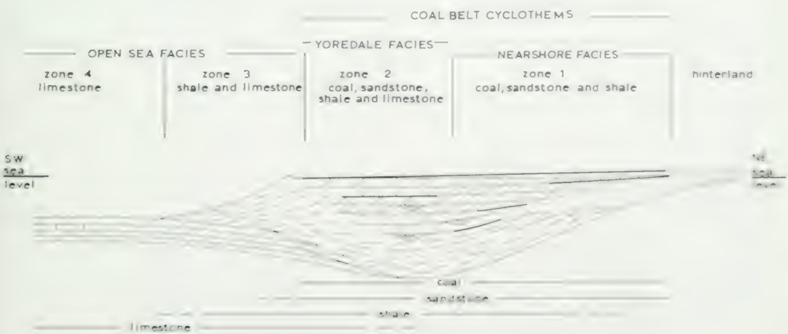

Fig. 8.2 Schematic section indicating some of the features of variation of sedimentary succession in a single Yoredale Cyclothem. (After Johnson, 1961; Westoll, 1968.)

A wide range of post-Carboniferous rocks will be excavated during the sinking of a mine shaft, but even during the subsequent mining solely within the Coal Measures, a wide variety of rocks will be encountered. Though any material within the Yordalian cyclothem may be included, most colliery waste will come from strata neighbouring the coal seams. As Johnson showed, these neighbouring seams are heterogeneous consisting of "seatearth, and some of: sandstone, flags, shales, limestones or marine shales."

8.4.2 Mineralogy of pit heap materials

The majority of pit heap material is composed of the following minerals:

Clay minerals	aluminosilicates such as illite, muscovite, kaolinite
Muscovite	
Quartz	SiO_2
Felspar	e.g. orthoclase $KAlSi_3O_8$
Hematite, magnetite	Fe_2O_3, Fe_3O_4
Goethite	$Fe(OH)O$
Iron pyrite	FeS_2

Other minerals in small amounts have been identified, e.g.:

Tourmaline	borosilicate of aluminium containing alkali metals or iron and magnesium
Siderite	$FeCO_3$
Jarosite	$KFe_3(SO_4)_2(OH)_6$

(a) *The clay minerals* The principal clay minerals in pit heap materials are of kaolinitic and micaceous types. A fireclay seatearth will contain a high percentage of kaolinite but shale deposited in marine conditions will contain illite and muscovite as well as kaolinite.

(b) *The formation of iron sulphides* A common feature in the formation of Coal Measure shales was the association of high levels of organic material with the fine grained mineral sediments. Though the marine fauna would have made some contribution, probably most of the organic material came from the lush vegetation in the neighbouring delta region.

With the onset of bacterial decay of the organic component in the waterlogged or submerged muddy sediments, a highly reducing environment was established. Under these conditions bacteria such as *Desulphovibrio desulphuricans* (Kuznetsov *et al.*, 1963) reduced sulphate ions from the sea water in contact with the sediment (Kaplan *et al.*, 1963).

In essence the following reaction took place:

$$\underset{\text{seawater}}{SO_4^{2-}} + \underset{\text{organic matter}}{2CH_2O} \longrightarrow H_2S + 2HCO_3^-$$

Either the bicarbonate ions were lost from the sediment or they partially decomposed and precipitated out as carbonates. The sulphide ions reacted with a variety of iron minerals initially forming the extremely insoluble iron sulphide, mackinawite, FeS (Berner, 1967a).

$$\text{At pH 6–9}\quad \underset{\text{goethite}}{2HFeO_2} + 3H_2S \longrightarrow \underset{\text{mackinawite}}{2FeS} + S^0 + 4H_2O$$

Mackinawite would combine with further quantities of sulphur forming greigite Fe_3S_4 and eventually pyrite (Berner, 1967b)

$$\underset{\text{mackinawite}}{FeS} + S^0 \longrightarrow \underset{\text{greigite}}{Fe_3S_4}$$

$$\underset{\text{greigite}}{Fe_3S_4} + 2S^0 \longrightarrow \underset{\text{pyrite}}{3FeS_2}$$

Where there was insufficient sulphur to complete the conversion to pyrite, sulphides of composition intermediate between FeS and FeS_2 would have existed in the sediment but would have slowly formed pyrite and another iron mineral (Goldschmit, 1958).

$$\underset{\text{greigite}}{Fe_3S_4} \longrightarrow \underset{\text{mackinawite}}{2FeS} + \underset{\text{pyrite}}{FeS_2}$$

followed by

$$\underset{\text{mackinawite}}{2FeS} + CO_3 \longrightarrow \underset{\text{siderite}}{FeCO_3} + \underset{\text{pyrite}}{FeS_2} + 2e$$

Because of their instability it is most unlikely that either mackinawite or greigite could now be found in black shale.

Pyrite is therefore by far the most common iron sulphide found in Coal Measure shales, but marcasite FeS_2 may also have been formed. In addition there is some evidence of the presence of pyrrhotite FeS in these shales.

(c) *The weathering of iron sulphides* The weathering of iron sulphides may proceed along any of several multistage pathways. According to Mapstone (1954) the following products can be formed: ferrous mono-sulphide, ferrous sulphate, sulphuric acid, sulphur dioxide, hydrogen sulphide and elemental sulphur. Ferrous mono-sulphide is unstable and is not likely to persist as such in a pit heap. Ferrous sulphate is found in the ground water of a shale tip and also as efflorescences on the weathered veins of iron pyrites. The very low pH of many shales indicates the presence of sulphuric acid. The gases sulphur dioxide and hydrogen sulphide are given off in readily identifiable quantities when a pit heap burns, and in the same circumstances crystalline elemental sulphur is frequently found condensed on the relatively cool shale surface.

Temple and Delchamps (1953) pointed to the role of autotrophic bacteria in the weathering of sulphides. *Thiobacillus ferrooxidans* oxidises ferrous sulphate to ferric sulphate while *Thiobacillus thiooxidans* oxidises sulphur to sulphuric acid. Russian workers (Kuznetsov *et al.*, 1963) have reviewed the physiology and ecology of these and other autotrophic bacteria.

Ferric sulphate hydrolyses rapidly and if allowed to go to completion, forms a ferric hydroxide gel. If hydrolysis is incomplete basic ferric sulphate results (van Beers, 1962).

The ferric hydroxide gel is not stable as such and crystallises out at geothite or lepidocrocite which forms crusts or stains on shale fragments. Sometimes in an acid, potash rich environment, jarosite, $KFe_3(SO_4)_2(OH)_6$, is formed as a lemon yellow powder or stain found within cleavages, or on the surface of shale fragments. Possibly natrojarosite $NaFe_3(SO_4)_2(OH)_6$, and alunite $KAl_3(SO_4)_2(OH)_6$ could also be formed.

The weathering of iron sulphides gives rise to two problems of importance in plant/soil relationships; firstly the development of extreme acidity and secondly the fixation of phosphate.

The abundance of hydrogen ions in the shale proto-soil causes a high proportion of hydrogen on the exchange site; this leads to the very rapid loss of bases when the material is leached, followed by the breakdown of illitic clay minerals. Muscovite, chlorite and kaolinite are more stable in acid conditions. As the illitic material disintegrates large quantities of aluminium are liberated into the soil solution. At these low pH values manganese is also released from manganese containing minerals. Plant growth is inhibited on these very acid shale soils largely as a result of the toxic levels of manganese and aluminium.

Though many shale soils are acidic, fortunately not all are. Fig. 8.3 shows the percentage frequency of samples falling within pH units from 2.0 to 9.0. Taking pH 6.5 as ideal, just over 25% of the samples were above that value.

Hall (1957) reported that shales are neutral or alkaline when tipped but after 100 years become very acid, burned shales showing an accelerated trend. This is a very simplified view as some shales are already acid when tipped (Moffatt, 1966) whereas other shales have relatively stable high pH values. A burned shale, exposed to weathering for twenty years at Donnington Colliery, Northumberland, was found to contain free carbonate and to have a pH of 8.6. This variability of soil reaction is to be expected from geochemical considerations.

The physiological aspects of plant survival on acid soils are reviewed by Jackson (1967). Liming usually corrects the direct and indirect effects of acidity or at least makes their solution much easier.

The other main problem arising from the weathering of iron sulphides is phosphate fixation. When phosphorus is added to a shale much of the nutrient reacts with the iron to form a highly insoluble precipitate, the solubility product of ferric phosphate being $pK_{sp}33-35$ (Chang and Jackson, 1957). In acid soils the greatly increased amounts of labile aluminium also fix phosphate, aluminium phosphate having a solubility product of $pK_{sp}28-32$ (Chang and Jackson, 1957). Reviews of phosphate fixation are given by Russell (1961) and Kardos (1964).

Preliminary results with shales indicate that phosphate requirement is closely correlated with pH, low pH values being associated with high phosphate requirements.

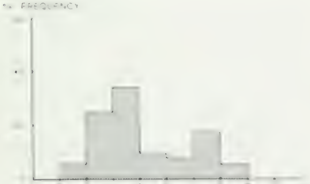

Fig. 8.3 The % frequency of pH values of shale. (The information was based on 168 measurements made on shale from 44 sites which were mostly in the northern coalfields.)

Theoretically, raising the pH should increase the availability of phosphate in iron and aluminium compounds but in practice an increase of 10% or less is achieved. Phosphate added after the pH of the shale is raised is fixed to a smaller extent so it is important that a site is first limed, then fertilized and not vice versa.

8.4.3 Salinity in shales

Salinity in the coal forming delta and the prodelta was likely to have been heterogeneous. Some material will have been leached with fresh water, while depressions in the delta were likely to be inundated periodically with sea water leaving rich deposits of salt after evaporation.

In an intermediate position would be vast areas of poorly drained sediments frequently inundated with brackish water giving the resulting shale a substantial salt content. As well as the sediments formed in deltaic conditions, there were considerable quantities of fine textured submarine deposits whose present salt content must reflect their environment during formation.

The salts contained in shales will be those left by sea water plus other salts originating from processes occurring at the time of deposition or later. The major salts formed during evaporation are sodium chloride, potassium chloride, magnesium chloride, magnesium sulphate and calcium sulphate. Whittig and Janitsky (1963) outlined a system operating in deltaic and estuarine environments whereby calcium, magnesium and sodium carbonates are formed together with iron sulphides. It is likely that this system would also operate in coal forming environments.

As soon as a fragment of a saline shale is exposed to weathering the soluble salts are rapidly released. High levels of salts in the soil solution adversely affect the vegetation in the following ways:

(a) Salinity increases the minimum soil moisture content at which plants are able to extract sufficient moisture (Wadleigh and Ayers, 1945).
(b) High sodium levels cause dispersion of the soil and a most difficult physical soil condition develops.
(c) Certain ions precipitate other specific ions and reduce their availability in the soil, e.g. high levels of bicarbonate precipitate calcium and magnesium ions as carbonates to such an extent that there is an unfavourable balance of sodium and potassium in the soil solution. Phosphate can be precipitated by calcium, iron or aluminium, depending on pH, leading to phosphate deficiency symptoms.
(d) High levels of one cation cause an imbalance in the uptake of other cations by ionic competition e.g. high levels of potassium suppress the uptake of magnesium.
(e) Direct injury to vegetation follows from excess of certain ions, e.g. boron at 2 ppm in the soil solution will inhibit plant growth (Reeve and Fireman, 1967).

Soil salinity can be estimated in a number of ways, but the normal method is by measuring the electrical conductivity of the saturated moisture extract (see section 8.5.6). The units of measurement are milli mhos per centimetre and an interpretative scale is given (U.S.S.S.S., 1954).

Salinity problems have been encountered on a number of reclamation sites in the Northumberland and Durham coalfield. Where a saline pit heap is regraded the new surface will have come from well inside the pit heap where the shale has the highest salinity.

At the Roddymoor site, Co.Durham, electrical conductivity values for the saturated moisture extract of surface samples immediately after regrading ranged from 1 to 25 m.mho/cm. On much of the site, test germination of S24 ryegrass was as low as 5%.

Salinity values at Roddymoor immediately after regrading

Salinity level	m.mho/cm 25°C	% of total shale surface
non saline	0 – 2	4
very slightly saline	2 – 4	13
moderately saline	4 – 8	35
strongly saline	8 – 16	36
very strongly saline	16+	12

In such a situation a period of leaching by rainwater is essential before sowing is undertaken. In the summer months evaporation from the soil often exceeds the rainfall so there is a net upward movement of salts which may be left as efflorescences at the surface. The only times of the year when there will be effective leaching are late autumn, winter and early spring.

Fig. 8.4 shows the variation in salinity for three areas of the Roddymoor site from early March 1968 (when regrading was completed) to November 1968. Coupled with this is a histogram for net water movement based on rainfall figures for the City of Durham and evapotranspiration figures for N.W. Durham. The estimated net moisture movement is not entirely accurate as the rainfall figures were measured 13.5 km (8.5 miles) from the site and at 150m (500ft) lower altitude. Also the evapotranspiration data assumes a vegetation cover. The data does not take into

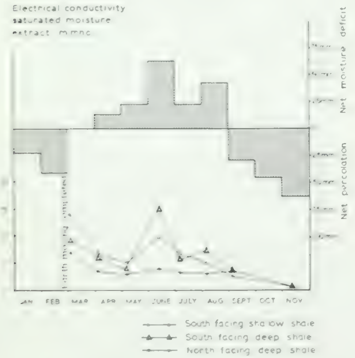

Fig. 8.4 Variation of salinity with water movement at Roddymoor. March – November 1968.

account any difference between the microclimate and the average for the district on which the figures are based. For each month Fig. 8.4 probably underestimates net percolation by about 18mm and overestimates the net moisture deficit by the same amount.

The figure indicates the strong link between net percolation and a lowering of salinity and vice versa. When the electrical conductivity values fell to 4 m.mho/cm sowing was undertaken.

When a saline tip has been regraded it is important for the material to be thoroughly ripped to depth especially on the 'fill' areas. An effective drainage system should be employed to encourage efficient leaching and removal of saline ground water especially along potential spring lines.

8.4.4 General nutrient status of colliery shales

(a) *Nitrogen* To a large extent nitrogen governs the level of plant growth. Shales can supply little or no nitrogen so that all requirements of non nitrogen-fixing species of vegetation must be met by additions of fertiliser. Most plant residues rotting down on the soil surface use up nitrogen and unless plenty is available for both residues and living plants, the vegetation will suffer from nitrogen starvation. In the initial stage of reclamation high levels of this nutrient should be applied to allow both adequate crop growth and rapid humification of dead plant material. High levels of nitrogen tend to kill out the clover content of a sward, largely by shading out the shorter species. Frequent cutting of the sward helps to preserve the clover and also encourages greater tillering of the grass.

Nitrogen should be split over several applications, but given at a low level at the end of the growing season as it reduces the potential winter hardiness of the crop.

(b) *Phosphorus* There is little or no available phosphorus in colliery shales, and much of the added phosphorus is fixed in an unavailable form. Phosphate should be applied at a rate that allows for both fixation and plant requirements. Data from a limited number of analyses indicate that phosphate requirements can be as high as 2500 units P_2O_5/acre for the $<$2mm material (this figure, worked out on the $<$2mm fraction, should be proportionally decreased to allow for the coarser, less reactive component of the total sample).

A deficiency of phosphate leads to stunted growth and loss of vigour. Ryegrass grown on phosphate deficient shale takes on a growth habit similar to that of *Festuca ovina*.

The effect of phosphate deficiency may be seen by comparing P_0K_0 with P_1K_0 and P_0K_1 with P_1K_1 in Fig. 8.5. Not only is the aerial growth stunted but the root systems are restricted, this being significant because shale has a poor water holding capacity and roots must penetrate to depth to obtain sufficient moisture. Rooting will be confined largely to the shale which has received an application of phosphate so depth of application is important. Deep cultivation after phosphate is applied is important but it is even better on 'fill' areas to have several broadcast applications during placement of the last 18 inches of shale.

PK factorial trial NFS/2. Black shale; first harvest

PK factorial trial BRU. Red shale; first harvest

PK factorial trial BRS. Red shale; first harvest

PK factorial trial BBS. Black shale; first harvest

Fig. 8.5 Response of S24 Ryegrass to potash and phosphate fertilisers in a factorial trial on black and red (burned) colliery shale soils.
P_0 no phosphate applied
P_1 phosphate applied (150 units P_2O_5/acre)
K_0 no potash applied
K_1 potash applied (100 units K_2O/acre)
All soils limed to pH 6.5 and given optimum nitrogen.

On acid sites either rock phosphate or basic slag may be applied though they are only slowly soluble and may not supply phosphate at a sufficient rate for fast growing vegetation. On neutral sites the efficiency of these cheaper fertilisers is greatly reduced and superphosphate should be used (Cooke, 1967)

(c) *Potassium* Together with nitrogen and phosphorus, potash completes the group of major nutrients most often deficient in soils. Greenhouse trials with shale soils have indicated that there is seldom any great lack of available potash and additions occasionally depress plant growth. Comparison of P_0K_0 with P_0K_1, P_1K_0 with P_1K_1 indicate the effect of added potash on a sward (Fig 8.5)

Recommendations of potassic fertiliser for shales are based on potassium removed by crops. For example, a hay crop of 35 cwt/acre dry matter containing 2% K_2O removes 88 units K_2O/acre. This figure represents the approximate level of potash required where one hay crop per year is removed. The total amount of potash to be applied should be split over two or more applications. Total annual applications should not exceed 120 units K_2O/acre

(d) *Calcium* Calcium is unlikely to be in short supply on neutral or alkaline shales but might be deficient on very acid material. As liming would be undertaken anyway, a calcium deficiency would be rectified

(e) *Magnesium* Extensive factorial greenhouse trials with magnesium and potassium showed no response to magnesium even when high levels of potash were applied. It is possible that a strongly weathered acid shale limed with a pure calcium limestone and given high levels of potash and ammonium nitrogen might show magnesium deficiency. The use of a limestone containing a little magnesium would avoid this situation

(f) *The trace elements* As far as is known, there are no published analyses of the trace elements in colliery shales of North East England. Namurian shales similar to those in the Northumberland Durham coalfield outcrop in other parts of the British Isles and have been examined in places. High levels of molybdenum and selenium have been reported in the Namurian shales of Co. Limerick, Eire (Webb and Atkinson, 1965; Thornton *et al*, 1966). Similar results have been found with the Namurian shales outcropping in the Southern Pennine area (Webb *et al.*, 1968).

Samples of a grass/clover sward grown on colliery shale at the Roddymoor (Co. Durham) site have been analysed* for the following elements; cobalt, nickel, molybdenum, iron, lead, tin, zinc, vanadium, titanium, chromium, copper, manganese, barium, strontium, aluminium, boron and silicon. None of these elements was present in the herbage at levels likely to cause either toxicity or deficiency symptoms in farm animals (Scott, 1970).

The reclamation of extremely acid shales necessitates the use of high levels of lime and phosphate. It is possible for these treatments to induce deficiencies of various trace elements which, though present in the shale, become unavailable to plants. An induced deficiency of iron has been encountered under these circumstances and it seems possible that deficiencies of zinc and copper could also occur.

Sewage sludge, which is frequently advocated as bulky organic fertilizer, sometimes contains toxic levels of zinc, especially where the sludge comes from highly industrialised areas.

8.5 The assessment of soils and shales and the treatment necessary for their reclamation

8.5.1 Sampling methods for soils and shales

The most skilful laboratory analysis is of little value in advisory work unless the conclusions drawn from the operation can be applied to a volume of soil in the field. This step from laboratory data to field recommendations is possible only when the sample analysed accurately represents the field soil or has a known and measured bias from it. Jackson (1958) outlines the theory and practice of soil sampling and the normal procedure for handling samples.

The procedure for sampling is as follows: a number of samples are taken from the volume of soil in the field (field subsamples), and these are bulked together and thoroughly mixed (bulked samples), laboratory analyses are performed on appropriately sized subsamples (lab. subsamples) withdrawn from the bulked sample.

There are three possible stages where errors can be introduced making a laboratory figure misrepresentative.

(a) Misrepresentation of the field by poor field sampling
(b) Misrepresentation of the bulked field sample by poor subsampling
(c) Variation of analytical figures for the laboratory subsample

Any errors involved in (b) and (c) are usually relatively small compared with (a) so that very careful attention should be given to obtaining representative field samples. Each bulk sample should represent one volume of soil thought to be homogeneous for the purposes of the intended analyses. Sufficient core samples should be taken, and from properly distributed locations over the whole soil volume i.e. at random or on a strict grid system. Reed and Rigney (1947) suggest that normally 20 to 30 subsamples from one area, when bulked together, reduce the field sampling error to the same order as that of (b) and (c). Each core of soil should have uniform cross-sectional dimensions.

The bulked field sample is usually air dried before analyses are undertaken though some determinations such as pH and available potash are best done on the moist sample. Drying should be slow and at a temperature not exceeding 35°C. Once the soil is dry enough to handle conveniently further drying is unnecessary unless long term storage is envisaged.

Atterberg (1912) proposed a system for classifying soil texture which is accepted by the International Society of Soil Science.

Coarse sand	2.0 – 0.2 mm dia.
Fine sand	0.2 – 0.02 mm dia.
Silt	0.02 – 0.002 mm dia.
Clay	below 0.002 mm dia.

Soil particles exceeding 2.0 mm diameter are classed as gravel or stones according to size (British Soil Survey Staff, 1960; U.S. Soil Survey Staff, 1951) and being comparatively inert can be regarded as diluents. After drying the bulked field sample, the material is sieved through a mesh having 2 mm apertures. The finer fraction is retained for analysis and its proportion of the total sample is calculated. With soils, gentle grinding may be necessary to break up soil aggregates which would otherwise be retained in the stone fractions.

The bulked and sieved field sample should weigh several kilos but individual analyses are usually on 5 to 25 g subsamples. A system of quartering ensures that laboratory subsamples are representative of the bulked sample, see Fig. 8.6.

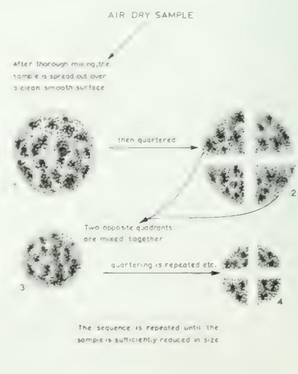

Fig. 8.6 A system of quartering for reduction in sample size.

* *Analyses kindly carried out by Dr R.O. Scott, Macaulay Institute for Soil Research*

The diagnosis and treatment of shale material must be based on the detailed inspection of all materials on each site. Coal bearing strata vary considerably along their length as well as vertically up the geological column (Hemingway, 1968), so that generalisations cannot be made even for one particular stratum of shale. Varying lengths of weathering on inherently variable material makes each colliery tip individual, requiring individual assessment and treatment.

8.5.2 Measurement of pH applicable to soils and shales

(a) *Special apparatus and chemicals* Laboratory pH meter with combination glass-reference electrode and temperature compensating probe e.g. Pye universal pH meter and millivoltmeter Gallenkamp Cat. no. 11067.

Buffer solution tablets for pH 4.0, 7.0 and 9.15.

(b) *Procedure* Although there are many procedures for determining pH the following method is in common use and is suggested. 10 g of air dry soil (<2mm material) is placed in a 50 ml beaker and 25 ml of distilled water added. The suspension is periodically stirred for half an hour and the pH of the agitated suspension is then measured. The figure obtained must be labelled as for a 1:2:5 aqueous suspension.

8.5.3 Lime requirement

Modified from Shoemaker *et al.* (1961). Applicable to soils and shales.

(a) **Chemicals**
Paranitrophenol
Triethanolamine
Potassium chromate
Calcium acetate
Calcium choloride dihydrate
Sodium hydroxide solution 1.0 N approx.
Hydrochloric acid 1.0 N approx.

(b) **Procedure**

(i) *Preparation of the buffer* 1.8 g paranitrophenol, 2.5 ml triethanolamine, 3.0 g potassium chromate, 2.0 g calcium acetate, and 53.1 g calcium chloride dihydrate are placed in approximately 800 ml distilled water contained in a 1000 ml beaker, and stirred until dissolved. The solution is made up to about 950 ml with distilled water and the pH adjusted to exactly 7.5 with sodium hydroxide solution or hydrochloric acid as appropriate. The buffer solution is transferred to a 1000 ml volumetric flask and made up to the mark with distilled water.

(ii) *Measurement of lime requirement* 10.0 g air dry soil (<2mm fraction) is placed in a 100 ml beaker and 25 ml distilled water added, the suspension is stirred periodically for half an hour when the pH of the agitated solution is measured. If the pH is below 6.0 a lime requirement test is used, the procedure being as follows.

The soil suspension is transferred to a shaking bottle and 15.0 ml of the buffer solution is added by pipette. The bottle is stoppered and shaken overnight (17 hours at room temperature) and the pH is measured. By referring the soil/buffer pH to the standard curve in Fig. 8.7 the appropriate lime requirement can be estimated. If the soil/buffer pH is below 5.5 the procedure should be repeated with half the quantity of soil.

Values obtained from the standard curve are for the <2mm fraction and in terms of pure calcium carbonate, and adjustments should be made for these factors. Normally not more than six tons per acre of limestone should be applied at one time.

(iii) *Specimen calculation*
10.0g<2mm soil (87.50% oven dry matter) used in test
<2mm fraction constitutes 95.3% total sample
pH of soil/buffer suspension = 5.9
Limestone to be applied has a calcium carbonate equivalence of 91%

From the standard curve, lime requirement =

$$= 2.8 \text{ T/A pure } CaCO_3$$

adjusted for true weight of sample =

$$= 2.8 \times \frac{100}{87.5} \text{ T/A pure } CaCO_3$$

adjusted for % >2mm material, regarded as a diluent =

$$= 2.8 \times \frac{100}{87.5} \times \frac{95.3}{100} \text{ T/A pure } CaCO_3$$

Lime requirement = 3.4 tons/acre ground limestone

8.5.4 The determination of available phosphate and potassium

The determination of available potassium is appropriate for both soils and shales but the available phosphate technique can be applied only to the soils. Phosphate and potassium are extracted by shaking the soil with 0.5 N ammonium acetate in 0.5 N acetic acid solution for half an hour. Phosphate in the extract is determined using the molybdate blue method of Murphy and Riley (1962), and potassium by flame photometry.

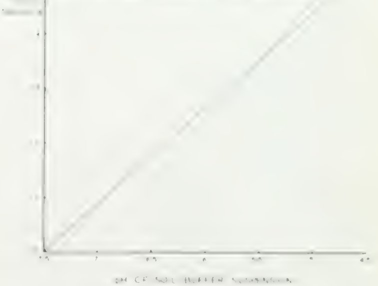

Fig. 8.7 Lime requirement of pH values of soil/buffer suspension.

Extraction of available nutrients (N.A.A.S. 1966)

(a) Chemicals, 1

Glacial acetic acid (analar)
Ammonia solution S. gr. 0.880 (analar)
2.0 N sodium hydroxide solution
1.0 N hydrochloric acid
Phenolphthalein indicator solution

Methyl red indicator solution

(b) Procedure, 1

(i) Preparation of extracting agent A 2 N acetic acid solution is prepared by standardising it against 2.0 N sodium hydroxide using phenolphthalein as an indicator. A 1.0 N ammonia solution is prepared by standardization against 1.0 N hydrochloric acid with methyl red as an indicator. Equal volumes of the 2.0 N acetic acid solution and the 1.0 N ammonia solution are mixed; this is the extracting agent.

(ii) Extraction of available nutrients 10.0 g of air dry<2 mm fraction material of known oven dry matter content is transferred to a shaking bottle and 50.0 ml of the extracting solution is added by pipette. The bottle is stoppered and shaken briefly, the stopper removed to release any pressure developed, replaced and shaking continued for 30 minutes on a reciprocating shaker. At the end of this period the suspension is filtered through a 12.5 cm Whatman No. 2 paper in a 6.5 o.d. funnel. The clear filtrate is used for available phosphate and potassium determinations.

Determination of phosphate in the extract (Murphy and Riley, 1962)

(c) Chemicals and equipment, 2

Ammonium molybdate (analar)
Antimony potassium tartrate (analar)
Sulphuric acid, specific gravity 1.84 (analar)
Ascorbic acid

Spectrophotometer e.g. Unicam SP 600

(d) Procedure, 2

Preparation of the standard curve 12 g of ammonium molybdate is dissolved in 250 ml of distilled water. Both dissolved reagents are added to 1000 ml of 5N sulphuric acid (148 ml concentrated sulphuric acid per litre), mixed thoroughly and made up to two litres. This solution is designated 'Reagent A' and should be stored in a Pyrex container in a cool dark place.

1.056 g of ascorbic acid is dissolved in 200 ml of 'Reagent A'. This solution is 'Reagent B'. As this reagent deteriorates rapidly after 24 hours it should be prepared as and when required.

About 2 g of potassium dihydrogen orthophosphate is dried in an oven at 110°C for an hour, then allowed to cool in a desiccator. 1.7576 g of this salt is placed in a 200 ml volumetric flask and dissolved in distilled water. 5 ml of 2N hydrochloric acid is added and the solution made to volume with distilled water. One drop of toluene is added and the solution which contains 2000 ppm P and 2525 ppm K is then stable for up to six months. This solution is designated 'Solution C'. 10 ml of 'Solution C' is diluted to 2 litres with distilled water. 0.0, 1.0, 2.0, 3.0, 4.0, 5.0 ml of this solution are placed in six 50 ml volumetric flasks and diluted to about 40 ml with distilled water. 8 ml of 'Reagent B' is added to each flask, made to volume with distilled water and mixed thoroughly. The flasks contain 0.0, 0.2, 0.4, 0.6, 0.8, 1.0 ppm P solutions respectively. After allowing ten minutes for full colour development the optical density of each solution is read in a 1 cm cell using light of 880 μm wavelength. The colour is stable for at least one day. Distilled water is used in the blank cell of the spectrophotometer and optical density of the zero phosphorus concentration solution is deducted from all other density readings. A standard graph of corrected density readings is drawn against phosphorus concentration.

Measurement of phosphorus in the extract

(e) Procedure, 3

An appropriate volume of the soil extract is placed in a 50 ml volumetric flask and diluted to about 40 ml with distilled water, 8 ml of 'Reagent B' is added. The solution is made to volume with distilled water and the optical density determined in a 1 cm cell at 880 μm after at least 10 minutes. The standard graph is used to calculate the phosphorus content of the 50 ml aliquot.

This procedure is repeated for a similar aliquot of the original extracting solution and any phosphorus detected is deducted from the phosphorus level in the soil extract.

(f) Specimen calculation

Optical density of phosphorus solution	0.311
Optical density of unused extracting solution	0.002
Volume soil extract made up to 50 ml	2.5 ml
Total volume of extract	50.0 ml
Weight soil used	10.0 g

Corrected optical density = 0.311 – 0.002 = 0.309

From standard curve optical density of 0.309 = 0.2 ppm P

Weight of phosphorus in total soil extract = $\frac{0.2 \times 50 \times 50}{2.5}$

Available P as μgP/g soil $= \frac{200}{10.0} = 20$

Available phosphorus (P) = 20 ppm

(g) Interpretation of results Interpretation of results will vary from region to region; the following system has been found satisfactory for N.E. England (Hunter, 1967).

Available P ppm	Category	Phosphorus application required
0 – 5	low	2 x standard P application
6 – 12	medium	1 x standard P application
13 – 20	good	
above 20	high	little response expected

Determination of potassium in the extract

(h) Chemicals and equipment, 4

2N Hydrochloric acid
Potassium dihydrogen orthophosphate (analar)
Toluene

Flame analyser e.g. Gallenkamp Cat. No. FH-500
Air compressor e.g. Gallenkamp Cat. No. AF-510

(i) Procedure, 4

(i) Preparation of a standard curve 100 ml of 'Solution C' (see prep. of standard curve – available phosphorus) is diluted to 252.5 ml. This solution now contains 1000 ppm K. 0, 2.0, 4.0, 6.0, 8.0, 10.0 ml of this solution is diluted to 100 ml aliquots, which will contain 0, 20, 40, 60, 80, 100 ppm K respectively. A series of flame photometer readings for these solutions are obtained and plotted on a graph of photometer reading versus concentration of potassium.

(ii) Measurement of potassium The original extracting reagent is tested for potassium and any found is deducted from levels in the soil extracts. The soil extract is tested for potassium and by relating the photometer reading to the standard curve the potassium content of the soil extract may be calculated.

(j) Specimen calculation

Weight soil = 10.0 g
oven dry matter content = 96.3%
<2 mm fraction = 88.1% total fraction
Photometer reading 40.5

From standard curve the photometer reading of 40.5 corresponds to 23 ppm K therefore the 50 ml extract contained 1150 μg K

Weight soil = $10.0 \times \frac{96.3}{100} = 9.63$ g

Available K = 1150 μgK/9.63 g sample
= 119.4 μgK/g (or ppm)

Available K for total fraction = $119.4 \times \frac{88.1}{100}$
(Where >2 mm material regarded as a diluent)
= 105.2 ppm

(k) Interpretation of results Interpretation of results will vary from region to region. The following system has been found satisfactory for North East England (Hunter, 1967).

Available K ppm	Category	K application required
0 – 35	low	2 x standard K application
36 – 83	medium	1 x standard K application
84 – 104	good	1 x standard K application
above 104	high	No K response

8.5.5 Phosphate requirement of shales (Modified from Ozanne and Shaw, 1968; Murphy and Riley, 1962)

As there is little or no available phosphate in colliery shales, extraction techniques are unsuitable. A more appropriate method for assessing phosphate requirement is the one Ozanne and Shaw (1968) advocated. It measures how much phosphate must be applied to the shale to increase the available phosphate to an acceptable level.

(a) Chemicals

Calcium chloride (analar)
Calcium tetrahydrogen diorthophosphate
Sulphuric acid specific gravity 1.84 (analar)
Ascorbic acid
Ammonium molybdate (analar)
Antimony potassium tartrate (analar)

(b) Procedure

(i) Standard curve (Phosphate measurement by the method of Murphy and Riley, 1962) 12 g of ammonium molybdate is dissolved in 250 ml of distilled water. 0.2908 g of antimony potassium tartrate is dissolved in 100 ml of distilled water. Both dissolved reagents are added to 1000 ml of 5N sulphuric acid (148 ml concentrated sulphuric acid per litre) mixed thoroughly and made to 2 litres. This solution is 'Reagent A' and should be stored in a Pyrex container in a dark, cool place. 1.056 g of ascorbic acid is dissolved in 200 ml of 'Reagent A' mixed, and is designated 'Reagent B'. This reagent should be freshly prepared when required as it is unstable after 24 hours

1.0170 g of dried (80°C) analar calcium tetrahydrogen diorthophosphate is dissolved in distilled water and made to 500 ml; 10.0 ml of this solution are transferred to a litre volumetric flask and diluted to volume with distilled water. This solution contains 5 ppm P. 0.0, 2.0, 4.0, 6.0, 8.0, 10.0 ml of the solution are placed in six 50 ml volumetric flasks respectively, distilled water added to make up to the mark.

The six flasks contain P at 0.0, 0.2, 0.4, 0.6, 0.8, 1.0 ppm concentrations respectively. 8 ml of 'Reagent B' is placed in each of the six 50 ml flasks and made up to the mark with the 0.0, 0.2, 0.4, 0.6, 0.8, 1.0 ppm P solutions in turn. After allowing 10 minutes for colour development the optical density of the solutions is read in a 1 cm cell at a wavelength of 880 μm. A graph is plotted optical density against phosphorus concentration (i.e. corresponding to 0, 0.2, 0.4, 0.6, 0.8, 1.0 ppm P).

(ii) Measurement of phosphate requirement Four or five portions of the air dry <2 mm fraction material are weighed out, each sample containing exactly 6.0 g oven dry material. The samples are transferred to 125 ml shaking bottles and 60.0 ml of the $Ca(H_2PO_4)_2.H_2O$ in 0.01 N $CaCl_2$ solution added. The phosphate contents of the 60.0 ml aliquots are chosen so that after equilibrium with the shales they cover the range 0.1 – 1.0 ppm P in solution. One drop of toluene is added to each bottle which is then stoppered and shaken for two half hour periods each day for twenty days. The suspensions are then filtered through a Whatman No. 2 paper into a 50 ml volumetric flask which contains 8 ml of 'Reagent B'. Enough filtrate is added to bring the volume up to the mark. The optical density is measured as detailed above and by reference to the standard curve the phosphorus concentration in the suspension filtrate is calculated. By subtracting phosphorus in solution from phosphorus added, the level of sorbed phosphorus as µgP/g shale can be estimated. This is done simultaneously for the four or five suspensions and a graph of phosphorus sorbed (units P_2O_5/acre) against phosphorus (ppm) in the liquid phase is drawn up. 1 µg P sorbed/g shale is approximately equivalent to 4.1 units P_2O_5 sorbed per acre to plough depth.

Ozanne and Shaw (1968) showed that for pasture plants, phosphate required = phosphate sorbed (at the 0.3 ppm P level in solution) with a correlation coefficient of $r = +0.96$. Various authors use different phosphate levels in the supernatant liquid; Beckwith (1965) used 0.2 ppm P as a basis for phosphate requirement as did Fox *et al.* (1968). As far as is known, no work has yet been undertaken with pasture plants growing on colliery shale in a temperate maritime climate. Until this data is available Ozanne and Shaw's level of 0.3 ppm is favoured.

Phosphate required =

$$= \frac{\text{phosphate sorbed}}{(0.3 \text{ ppm level})} \times \frac{\% < 2\text{mm in total fraction}}{100}$$

8.5.6 Measurement of salinity Applicable to soils and shales Jackson (1958)

The salt level in shale soils is frequently high enough to inhibit plant growth. Estimates of salinity are made on the saturated moisture extracts by measuring the electrical conductivity of the extracted solutions. The salinity hazard can be directly interpreted from electrical conductivity measurements.

(a) Chemicals and special apparatus

Potassium chloride
2, 11cm Hartley 3 section Buchner funnels
11cm Whatman No. 50 filter papers

Filtration tube with side arm (i.d. 30–35mm, length 100–110mm)
Specimen tubes (i.d. 25mm, length 75mm) and polythene closures
Conductivity cell e.g. Mullard type E.7591/A
Conductivity bridge

(b) Procedure

(i) Saturated moisture extract

About 100ml of the <2mm fraction air dry material is placed in a 250 ml Pyrex beaker, and saturated with deionised water. Saturation moisture content is defined as the maximum amount of water held in the puddled soil without free water collecting in a depression in the soil mass (Scofield, 1932). Preferably the water should be added in spaced increments so the soil colloids can imbibe moisture before further water is added. Should too much water be applied a little extra soil may be added to soak up the excess. As many shales contain slowly soluble salts, an equilibrium time of two hours is required before the soil mass is transferred to an 11cm Buchner funnel fitted with a Whatman No. 50 filter paper, see Fig. 8.8. A vacuum is applied to the system and the clear extract is collected and used for salinity and pH measurements.

(ii) Measurement of electrical conductivity

Standardisation of the conductivity cell The specific conductivity at 25°C of a 0.020 N KCl solution is 2.39 m.mho/cm. The conductivity cell is placed in a 0.020 N KCl solution at 25°C and the conductivity, E.C. is measured. The cell constant, k, is given by

$$k = \frac{2.39}{\text{E.C.}_{25°C}}$$

Conductivity measurements will vary with temperature and must be adjusted to the standard temperature of 25°C by using the correction factor f_t, see Fig. 8.9

$$\text{E.C.}_{25°C} = \text{E.C.}_t \times f_t$$

where E.C.$_{25°C}$ is the electrical conductivity at 25°C
E.C.$_t$ is the measured electrical conductivity at t°C
f_t is the correction factor see Fig. 8.9.

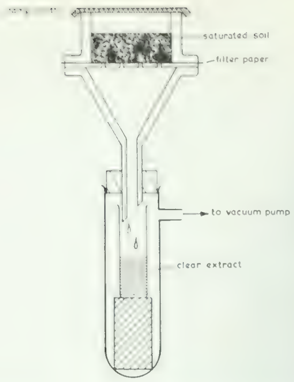

Fig. 8.8 Apparatus used for saturation moisture extraction and the determination of moisture equivalent.

Measurement of specific conductance of a standard moisture extract The conductivity cell (cell constant k) is placed in the saturated extract at temperature t, and the conductivity E.C.$_t$ measured.
Specific conductance = E.C.$_t \times k \times f_t$.

(c) Interpretation of results

Specific conductance (25°C) of saturated moisture extract m.mho/cm	Salinity level	Effect on vegetation
0 – 2	non saline	negligible damage
2 – 4	very slightly saline	yield of very sensitive crops reduced
4 – 8	moderately saline	
8–16	strongly saline	yield of many crops restricted only tolerant crops yield satisfactorily germination seriously affected
16+	very strongly saline	only few very tolerant crops yield satisfactorily

(d) Osmotic pressure and salinity

Moisture is available to a plant while at tensions between 0 and approximately 15 atmospheres. At about 15 atmospheres soil moisture tension, plants wilt as they are not able to extract any more water from the soil (Baver, 1961). Salts dissolved in solution give the solution an osmotic pressure which reduces the range of tensions over which plant roots can extract moisture.

The salts likely to be derived from shales e.g. Na_2SO_4, $CaSO_4$, $FeSO_4$ have similar effects on the osmotic pressure i.e. approximately 0.3 atm. per m.mho/cm electrical conductivity (U.S. Salinity Laboratory Staff, 1954). For example if the specific conductance of the saturated moisture extract is 10.0 m.mho/cm the maximum moisture tension at which the plant can still remove water from shale soil will be 12 atmospheres. At such a reduced moisture content the osmotic pressure will probably exceed the 3 atmospheres to further reduce the available moisture range in the material.

8.5.7 Percentage<2mm fraction Application to shales and stony soils

The %<2mm material in the total sample is an indication of the degree of weathering and to a large extent the value of the shale as a growth medium. Extremely low values are given by materials that can retain neither moisture nor nutrients. Extremely high values may suggest that although moisture and nutrient holding capacities are good there may be tilth problems involving an impermeable material which roots cannot easily penetrate. Agronomic values cannot be assigned to %<2mm figures with any certainty until considerable field work has been completed but for the initial stages of reclamation values of 40 – 60% are probably optimal. Fig. 8.10 shows the frequency of occurrence of values for %<2mm material.

Many analytical figures for the<2mm fraction must be readjusted when estimates are made for the complete soils.

Procedure

About 8 – 10 kg of air dry material is sieved through a mesh with 2mm apertures and the % by weight of the<2mm material in the total sample is calculated.

8.5.8 Moisture equivalent, Bouyoucos (1935) Applicable to soils and shales

The moisture equivalent of a soil is the % moisture held by the soil when under a tension of one-third atmosphere; this moisture content approximates to field capacity. Its determination can be conveniently linked with the saturated moisture extraction procedure as used in shale salinity testing.

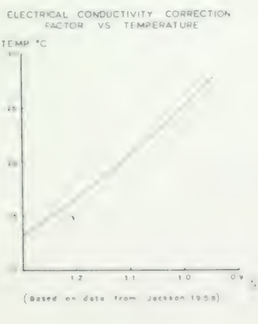

Fig. 8.9 Electrical conductivity correction factor vs. temperature.

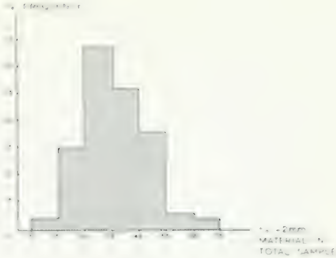

Fig. 8.10 Distribution of % 2mm material in 92 samples. (From 30 sites mostly in N.E. England.)

(a) Procedure

The method is the same as for saturated moisture content except that the tension applied must be controlled. A tension of 610mm (25in) of mercury is applied to the soil in the Buchner funnel for 15 minutes. At the end of this period a small amount of the moist sample is removed, weighed and dried in an oven at 105°C for 24 hours. The moisture content of the moist sample is calculated, this being approximately equal to the moisture equivalent of the<2mm material. This figure is used as the basis of the moisture equivalent of the total fraction, the following adjustments being made:

(i) A reduction to allow for the>2mm fraction which holds little moisture under tension.

(ii) An allowance for the moisture held within the >2mm particles. An average figure of 4.6% moisture is assumed for wet shale particles.

(iii) An allowance for moisture held between the <2mm and>2mm particles. An average figure of 0.069% moisture per %>2mm fraction in the total sample.

(b) Specimen calculation

Moisture equivalent of<2mm fraction = 13.8 g water contained by 100 g moist soil
<2mm fraction = 33.4% total fraction
apparent density = 1.10 g/cm³

Moisture content of a saturated shale fragment = 4.6% – adjustment (ii)

Moisture held between >2mm and <2mm shale particles = 0.069% moisture per % > 2mm material – adjustment (iii)

Reduction for effect of >2mm material
adjustment (i) $13.8 \times \frac{33.4}{100} = 4.6\%$ w/w

Moisture held in >2mm material
adjustment (ii) $4.6 \times \frac{100-33.4}{100} = 3.1\%$ w/w

Moisture held by pore spaces between >2mm and < 2mm material
adjustment (iii) $0.069 \times (100-33.4) = 4.6\%$ w/w

Moisture equivalent w/w = (i)+(ii)+(iii)= 12.3% w/w
On v/v basis = 12.3 x 1.10= 13.5%

Moisture equivalent of total soil = 13.5% v/v

(c) Interpretation of results

Average values (Pringle, 1969) are sandy soils 15%

sandy soils	15%
loams	30%
clay soils	45%

The figures represent the moisture content, once gravitational water has moved out of the previously saturated material and approximate to field capacity. Values for shales are generally low indicating a small reserve of water available for plants.

8.6 Summary

The surface of a regraded colliery site usually consists of freshly exposed shale with or without a thin covering of soil. The special problems associated with soil that has been stored in heaps for any length of time before being respread are listed in section 8.3. The methods of soil testing as given in section 8.5 can be used to determine the nature of treatments necessary to improve the fertility of the soil.

Section 8.4 deals with the nature and origin of colliery waste materials. Acidity and its associated effects, phosphate fixation, salinity and nitrogen deficiency are the major chemical problems likely to be encountered in reclamation schemes in Northern coalfields. Methods for both the diagnosis of these problems and the selection of ameliorative treatments are given. Low water holding capacity, excessive stoniness and over compaction of the shale by heavy earth moving machinery are the physical problems most frequently occurring during the reclamation of colliery tips. Methods for identifying these problems are given in section 8.5.

Volume 2 of this report will include examples of site investigations together with an evaluation of the success of the ameliorative treatments used.

Fig. 8.2 is reproduced by courtesy of Dr G.A.L. Johnson and acknowledgements are given to the publishers of his article (1961) in which the figure originally appeared — Geologisch Bureau voor het Mijngebied; to the publishers Oliver & Boyd Limited and editors Dr Murchison and Professor Westoll of the article 'Coal and Coal-Bearing Strata' in which the figure also appeared.

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Chapter 9 Botanical studies of natural and planted vegetation on colliery spoil heaps

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9.1 Introduction

In Britain most waste ground which is not contaminated by toxic material is quickly invaded by plants from the surrounding countryside. It is well known that some form of plant cover is often developed in under a decade on such places as derelict building sites, deserted fields and footpaths, disused ship-yards, abandoned railroads, brick fields, quarries and other neglected sites. For pit heaps on the other hand, it may take seven times as long before the colonizing vegetation is sufficiently well grown to mask the ugliness, and this is due mainly to their shape and height and to the physical and chemical properties of the surface layers.

From time to time, believing that those who extract the nation's coal supplies should not be forced to live permanently amongst the depressing spoil heaps, men have tried to retrieve the former beauty of the landscape by planting spoil heaps with trees and shrubs. Notable success was achieved in County Durham at Lambton in the early 1850's, at St. Helens Auckland in the 1920's, and at Houghall in the 1930's where trees were planted on pit heaps for the sake of amenity. Whyte and Sisam (1949), Wood and Thirgood (1955), have written reports of work done elsewhere in Britain and abroad. Three main advantages accrue from establishing a vegetative cover on a pit heap. First, there is the improvement of the landscape by planting with suitable quick growing plants (and fenced in the first instance, and then, later, perhaps opened as a natural playground, or given special treatment to make it into a park). Secondly, there may be the possibility of some financial return from the growing of trees for timber, or the sowing of grass for grazing stock. Thirdly, and possibly the most important advantage for some villages would be the elimination of a constant source of dust and grit which, in a dry summer, fill the air and make life miserable. Nevertheless, the amount of derelict ground on which vegetation has been established by artificial means is negligible, and the presence of trees and grasses on disused spoil heaps is mostly due to natural immigration from adjacent areas.

A principal aim of investigations into the physiology and ecology of plants growing in waste places, which started in Newcastle in 1952 and continued in the present Project, was to provide information useful to those people concerned with reclaiming the landscape. The account which follows summarizes relevant results.

9.2 Natural vegetation

9.2.1 Colonization

Some of the propagules (fruits, seeds and spores) produced by mature plants in the neighbourhood are transported by the agency of wind and animals to the surfaces of spoil heaps. Under favourable conditions they may germinate and produce adult plants from which a plant population may develop.

Weathering of the pit heap material

Newly tipped colliery waste often consists of a mixture of large rocks (500mm dia.), which forms the bulk of the material, together with smaller fragments (2mm dia.) and very fine material (0.002mm dia.). The breakdown of the shale by physical and chemical weathering into small particles has been described by Richardson (1957), who pointed out that whereas some pit heap surfaces produce a layer of small hard plate-like shales, on others a surface layer rich in clay particles is developed. The latter type of surface tends to puddle when wet, leading to poor penetration, much run-off and erosion; the former has no cohesion, penetration of rainfall is high and water holding capacity is low. Neither of these surfaces encourages the growth of plants and it was shown that those heaps which produce an intermediate surface, with a mixture of small shales and clay particles, are the ones on which plants spread most rapidly. In the early stages of weathering when fine particles are easily dispersed by wind or rainfall, and there is no protection from vegetation, even the smallest run-off of water will cause loss of soil-forming particles. Until sufficient particles have accumulated within a range 2.0mm to 0.002mm it is unlikely that plants will succeed because it is in the pores (capillaries) that exist between small soil particles that water available for plant growth can be held. Greenwood (1963) performed mechanical analyses on samples of surface material and found that when the fine fraction, i.e. that which passed through a 20 B.S. sieve (100mm^2 holes), exceeded about 43% of the sample the 'receptive stage' had been reached and colonization occurred; on surfaces with less than 35% of fine material seeds germinated but the seedlings did not survive. Brierley (1956) for pit heaps in Derbyshire, Nottinghamshire and Yorkshire and Pickersgill (1971) in Durham found that pit heaps were devoid of vegetation when most of the surface was composed of fine clay particles. Vegetation appeared on these clay surfaces when they included sufficient fragments which were retained on a 20 B.S. sieve. Beneath the surface layer of pit heaps (say 60 mm) the coarse material may show little change from the time of tipping except to contain some finer material carried down from the surface. It was commonly found (Greenwood, 1963) that while the surface 60 mm had 55% the next 120 mm had a coarse fraction of 94%.

Clearly these observations made under natural field conditions are relevant to artificial planting and they were drawn on when artificial planting procedures were planned (see section 9.3.1).

Density of incoming fruits and seeds
The natural vegetation of pit heaps (and other derelict places) is related to the local flora; Richardson (1956) has described plant communities which can develop on pit heaps in Durham, e.g. a heather moorland at Haswell (NZ 375448), a *Deschampsia* grassland at Springwell (NZ 287588), a birch woodland at Urpeth (NZ 248555) and many grass–herb communities elsewhere. There was a good correlation between the pit heap communities and the presence of seeding species in the vicinity, their distance and compass bearing, their numbers and abundance of seeds, their seed dispersal mechanisms and the weight of each seed.

The density of incoming seeds is critical because of the heavy losses which occur amongst those seeds which are deposited on pit heaps. Brierley (1956) reported that, for a four week period when seed dispersal was high, about 2,000,000 seeds per ha (800,000 seeds per acre) arrived on the south west slope of a pit heap. Accepting this as a typical figure, Greenwood (1963) collected samples of surface material from a comparable pit heap at Ravensworth (NZ 260582) and spread them thinly on sterilized soil in the greenhouse under ideal conditions for germination. He found that the seeds which germinated represented a seed density of about 272,000 per ha (110,000 per acre) or one-seventh of the amount of seeds reaching the heap from the local countryside. Greenwood further found that although the greenhouse figure corresponded to about 24 seeds per m^2 (20 seeds per yd^2) on the pit heap, the plants were not more frequent than one per m^2 (one per yd^2) when the observations were made.

Clearly, there is a high casualty rate amongst the incoming seeds for which high temperature and drought could be important causes –see section 9.2.1(b) and (c). Also important are high winds which lift seeds off the slopes of pit heaps, and an open texture which allows the small airborne seeds to be carried to considerable depths in the heap.

Experiments using *Agrostis tenuis* and *Dactylis glomerata* were carried out in 1961 on north east facing slopes at Ravensworth which were largely protected from high winds, high temperature and drought (see Richardson and Greenwood, 1967). The ground was fairly compact and the seeds were either spread over the surface of the plots, or spread lightly, covered with small shales, and then firmly pressed down. Briefly, the results showed that with a seed rate of 34.0 g per m^2 (1 oz per yd^2) the survival was 94% on raked and firm plots and only 10% on unraked plots. When the seed rate was reduced to 3.0 g per m^2 (1/12 oz per yd^2), i.e. to the agricultural rate for grass seed mixtures, the survival was reduced to 14% on raked-firm plots and to 1% on unraked plots. Greenwood gave details of the damage caused to surface germinated seedlings during the first winter and he has compared the heavy losses with the light losses sustained by seedlings developed from seeds well established just below the surface. These results confirmed the earlier findings (Richardson, 1956) that the 'receptive stage' on a pit heap, i.e. when the immature soil is suitable for the germination of incoming seeds and for the development of seedlings, depends on the conjunction of a suitable soil texture, adequate rainfall, and suitable seed density. Up to a point it appears that a deficiency in one condition can be compensated for by an excess in one or both of the others. For example, a coarse textured soil with a low water holding capacity will lose seeds carried downwards in drainage water, and will lose seedlings in summer owing to drought – see section 9.2.1(c). A high seed rate plus a high rainfall in any given year could compensate.

The rate of growth is important in the first season; if it is high the young plants could be sufficiently well rooted to survive summer drought. In the artificial planting of grasses and herbs steps must be taken to make the spoil heaps receptive and to allow for the compensation mentioned to be applied; reference to how this was done is made in section 9.3.1.

Factors affecting germination and survival
(a) pH values, toxic substances and essential minerals The characteristics which develop during the growth of plants are not determined solely by the factors of inheritance contained in the protoplasm but are also controlled by the conditions of the environment, e.g. by temperature, light intensity, acidity, water content, oxygen content, etc. For many years it has been known that pH is a factor almost as important as temperature in many plant processes. Growth of plants is only maintained between certain limits of pH; for example, good growth may occur between pH 5 and 8, but outside this range, in pronounced acid or alkaline soils, plant growth is at first retarded and finally arrested (see Richardson 1964 for details).

On many pit heaps when weathering processes have been acting for 4 – 5 years and the receptive stage has been reached, the soil reaction is neutral or even slightly alkaline. It appears that in midland and south country coal fields (Hall, 1957) newly tipped shales tend to have higher pH values, e.g. pH 8.8 in Somerset and pH 8.7 in North Staffordshire, than those for northern coalfields, e.g. 6.9 for Durham and Northumberland (Richardson, 1956). As the plant cover develops from the pioneer herb–grass stage to a grassland, heather moorland, scrub or woodland, there is a marked fall in the pH of the surface material and most surface layers become distinctly acid after about 80 years. Likely changes of pH in this period have been reported as follows: pH 7.0 – 3.5 (Richardson, 1956); pH 8.8 – 3.4 (Hall, 1957); pH 8.0 – 3.5 (Greenwood, 1963). Shenton (1967) examined 237 sites and found that naturally occurring and planted species grew and flourished on pit heaps where the pH values were between pH 7.0 and 3.0; the distribution of sites and pH values was as follows:

pH	7.0	6.0	5.0	4.0	3.0
% of sites	0.8	9.1	25.0	40.6	24.5

The pH varies with depth below the surface as well as with age. In a 100 year old heap at Birtley (NZ 279554) on which a mixed deciduous woodland had developed the values down the profile were as follows:

Depth (mm)	Organic content (%)	pH
0 – 50	17.6	5.3
50 – 100	6.4	5.8
100 – 200	2.3	6.1
200 – 300	1.5	6.1

Here the pH change (0.8 units) with depth was small compared with differences of 2.0 units (pH 4.4 – 6.4) reported elsewhere.

The changes in the pH of spoil heap material are influenced by burning (see below), by erosion and by the type of vegetation but they also depend very much on the sulphur content of the shale's waste coal. Pit heap spoil contains three forms of sulphur: pyrites, sulphates and organic pyrites (or marcasites) and in shale large amounts of sulphur may be present as sulphates or in the pyritic form. In the north of England the total sulphur content of waste coal and shales varies from zero to about 12% and there are wide differences from heap to heap and between places on the same heap.

During weathering and as a result of moist oxidation of the sulphur bearing rocks, quantities of free sulphuric acid, iron sulphates and ferric hydroxide appear in the surface layers of spoil heaps. Briefly, the presence of these substances in toxic quantities, together with the low pH values produces a medium in which growth of plants is often impossible (for some details of the effect of sulphur on colonization of eight pit heaps see Richardson, 1957). pH values in the region of pH 2 are common on pit heaps with pyrites bearing rocks at the surface and this condition may persist for over 40 years. Vegetation gains a foothold on these pit heaps when the toxic products of oxidation are leached out of the surface layers and cease to accumulate.

When there are large amounts of sulphur (e.g. 6%) in surface layers which also possess either very high or very low permeability to water (see: 'Weathering of the pit heap material'), conditions exist which may permanently prevent natural colonization or the success of artificial planting of trees and grasses. Clearly special problems attach to reclamation of pit heaps containing pyritiferous waste, and experiments are in progress to discover how ameliorating procedures can be practised on a large scale; these include liming, sealing with subsoil and turf, and burning.

It has been argued (Richardson, 1956) that the presence of large amounts of pyrites encourages the heating processes which lead to burning of pit heaps. Whether or not this is the case, it is true to say that when burning occurs much sulphur is removed from the heap and hard masses of clinker are produced below the surface. At the surface there are, characteristically, either layers of small, brittle, brick-red platey shales or light brown (or apricot) coloured material which weathers rapidly to a fine powder.

Physically, the range of surface material is as wide on burnt as on unburnt heaps. Immediately after burning the surface contains the products of oxidation of pyrites and these leach out rapidly (and are not replaced as happens in unburnt heaps, see above) to provide a less toxic medium than unburnt shale.

Shales and the young soils which develop from them are not normally rich in essential mineral elements compared with arable land or permanent pasture. Nevertheless most pit heaps in Durham support some vegetation after 40 years (section 9.2.2) and many of them have closed communities after 60 years. In some experiments surface material was removed from young heaps to the Botany Experimental garden and sown with seeds of recognised pit heap grasses. Provided the material was watered to bring the moisture content to near field capacity (section 9.2.1c) the seeds germinated and mature seeding plants were supported by over 90% of the samples. Added nitrogen, phosphorus and potash increased the yield.

(b) *Temperature* Pit heaps often have slopes of up to 43° and with all possible aspects. The amount of solar radiation reaching a surface is proportional to the cosine of the angle between the incident rays and a perpendicular to the surface, and, therefore, it is not surprising to find that on many summer days southern slopes of pit heaps may receive up to ten times the energy falling on north facing slopes. It is also well known that black surfaces are better absorbers of solar radiation than light coloured ones, and consequently one might expect that black shales would have higher daylight temperatures than lighter ones. It was shown (Richardson, 1953, 1958) that the combined effect of spoil colour, slope and aspect, could result in very high temperatures on south facing slopes in summer.

In autumn and spring, southern slopes of pit heaps were found to be covered with germinating seeds and seedlings of grasses and herbs. This is because the south facing slopes, even in winter, have equable temperatures when the northern slopes are little above freezing point (Greenwood, 1963). However, in the summer on bare southern slopes, temperatures as high as 57°C were recorded and the young plants withered and died. It was common to find surface temperatures exceeding 50°C lasting for several hours around mid-day in June, July and August. Below the surface, at 75mm (3in) the maximum temperatures reached were about 32°C, and at 150mm (6in) not more than 25°C. Protoplasm only maintains its normal powers within a certain temperature range; and it is not only temperature but also its duration which determines whether fatal results will follow. It follows that the absence of plants from the bare south facing slopes might be attributed to the quantity of heat (temperature and duration of exposure combined) acting directly on the shoot and root tissues at surface level, causing desiccation and subsequent death. Alternatively it can be argued that the heat caused sufficient loss of water in the surface layers to reduce the amount of water available for absorption by roots – see this section (c). When this available water is less than that lost in transpiration, loss of turgor and death of the plant follows.

It is well known that a plant cover, or a dry mulch at the soil surface, reduces the daily temperature fluctuations in the layers below the surface. The extent of this ameliorating effect of *Agrostis tenuis*, *Holcus mollis* and *Calluna vulgaris* was investigated on several pit-heaps near Chester-le-Street. When adjoining bare shale had daily temperature ranges of 45°C (8°C to 53°C) at the surface, a grass–herb cover reduced the range to about 12°C (12°C to 24°C).

Similar insulating properties were possessed by the layers of moss and lichen, about 15mm thick, which occasionally form an important part of the pit heap flora. When surface temperatures were over 50°C, the temperatures directly underneath were nearer 25°C; in other words the heat exchanges were concentrated in the thin boundary layer of moss and lichen which served to keep the shale at a reasonable temperature in summer and to conserve the water present. The successful colonization of the pit heap at Custon (NZ 267548) by *Holcus mollis* was attributed to the presence of the moss–lichen layer.

(c) *Available water* For successful growth in any habitat, plants must possess properties which meet the demands of transpiration as well as the limitations of soil water supply without incurring harmful water deficits. There are generally recognised limits to the water content of a soil profile in which plants will grow. The upper limit, called the field capacity, is the amount of water held in fine capillaries of a soil after rainfall when drainage from the soil reaches zero; the lower limit, the wilting point, is the water content at which turgor cannot be maintained and permanent wilting occurs. At the wilting point water is held by the soil with great tenacity; the moisture tension is about 15 atmospheres, or pF 4.2 on the logarithmic scale of tenacity. At field capacity water is less tenaciously held than at the wilting point and on the pF scale moisture tension is pF 2.5. The water held in soil between field capacity and wilting point is available to the plant for growth. Greenwood (1963) followed for over a year the changes in the moisture tension which occured at three depths on four aspects of a large conical pit heap at Custon (NZ 267548). There was little difference with aspect in the percentage of values above pF 4.2 which occurred on the surface or 25mm (1in) below the surface. However at 75mm (3in) depth there was clear evidence that the S.E., S. and S.W. slopes were generally about half as moist as the N.E. and N. slopes. (Parts of the graphs showing pF variations recorded between February 1961 and February 1962 are given in Richardson and Greenwood, 1967.) These results were in harmony with the distribution of plants on the heap where the south, south east and south west remained bare compared with the vigorous growth that occurred on the north and north east slopes. It appears that in their first year seedlings on spoil heaps may be subject to long periods of high soil moisture tension. Their duration and frequency will be the controlling factors in determining the success of invading species. A succession of dry summers with high soil temperatures and high pF values would retard colonization just as several wet summers, with low pF values, would favour the process. It is also clear from the results that any species with high rates of root elongation, which takes the extremities quickly down to depths greater than 75mm (3in) (see above) will have increased chance of survival on pit heaps. Slow growing herbs and grasses sown in spring would be at a disadvantage compared with comparable seeds sown in autumn. On the other hand trees and shrubs with long roots can be artificially planted, say, down to 230mm (9in) at which depth even in very dry weather the moisture content does not fall below wilting point. Information is accumulating for many mesophytic species indicating that, provided the roots are in moist soil, the leafy shoots can endure mid-day temperatures of up to 60°C.

9.2.2 Plant succession

Pioneer, intermediate stage and climax species In order to trace probable stages in plant succession one can investigate the flora of heaps of three or more age groups. Early stage plants may be studied on heaps up to about 20 years old, later stages on heaps from 25 to 50 years old and probable climax vegetation on heaps of 80 years and over. It is an advantage if observations are made on neighbouring heaps which are in two or three of these arbitrary classes. In general, the most sheltered positions, and therefore the last to dry out (section 9.2.1(c)) after rainfall, were colonised first. Hollows and gullies which faced north-east were such positions and from them plants spread out slowly over the heap. All previous work suggested that pit heap communities contained plants found in the immediate vicinity e.g. plants of woodland, moorland, pasture and hedgerow, together with an assemblage of 'waste place' species. The physical and chemical properties of the heap limits the number of species which can initially act as colonists. Later, as edaphic conditions are modified, other species invade the still open communities. In the west of Durham the climax of the vegetation is often a heather moorland with some birch, while in the east of the county deciduous woodland is likely to occur.

In order to examine more closely the distribution of species primary data (see below) was collected from 54 collieries in County Durham. Any one pit heap complex composed say of several ridges might be arbitrarily divided in 5 or 6 distinct areas based on age, aspect, slope or nature of the shale. There were 237 such areas and they were spread over the coal field from the western upland, around the 240m (800ft) contour, eastwards into the Wear Tyne lowlands and finally to the coastal strip where the Coal Measures are overlaid by Magnesian Limestone. Equal numbers of areas were examined in each of the three divisions of the county (see Fig. 9.1). In each case the species were recorded and an assessment of quantity was given using the following scale: (p) present – 1–20% cover; (f) frequent – 21–40% cover; (a) abundant – 41–60% cover; (d) dominant – 61–100% cover. Tables 9.1, 9.2, 9.3 summarise the occurrence of grasses, herbs, shrubs and trees in the 237 areas.

Fig. 9.1 Map showing position of heaps examined and the position of these heaps in three physical areas of Durham.

Table 9.1 Occurrence of grasses on 237 pit heap areas in County Durham

Species		Occurrence (%)
Agropyron repens		5
Agrostis canina	(p)	25
Agrostis stolonifera	(p)	1
Agrostis tenuis	(p)	34
Agrostis tenuis	(f)	28
Agrostis tenuis	(a)	14
Agrostis tenuis	(d)	6
Aira caryophyllea	(p)	1
Aira praecox	(p)	1
Alopecuris pratensis	(p)	2
Ammophila arenaria	(p)	1
Anthoxanthum odoratum	(p)	1
Arrhenatherum elatius	(p)	44
Avena fatua	(p)	1
Brachypodium sylvaticum	(p)	1
Dactylis glomerata	(p)	38
Dactylis glomerata	(f)	17
Dactylis glomerata	(a)	7
Dactylis glomerata	(d)	2
Deschampsia caespitosa	(p)	1
Deschampsia flexuosa	(p)	48
Festuca ovina	(p)	6
Festuca rubra	(p)	4
Holcus lanatus	(p)	21
Holcus lanatus	(f)	9
Holcus lanatus	(a)	3
Holcus mollis	(p)	1
Lolium perenne	(p)	4
Molinia caerulea	(p)	7
Nardus stricta	(p)	4
Poa annua	(p)	1
Poa pratensis	(p)	2
Vulpia bromiodes	(p)	1

The chief grasses found on pit heaps in County Durham are *Agrostis canina*, *A. tenuis*, *Arrhenatherum elatius*, *Dactylis glomerata*, *Deschampsia flexuosa*, *Holcus lanatus*. *Arrhenatherum elatius*, 44%, and *Deschampsia flexuosa*, 48%, are widely distributed but are only rarely the dominant species. *Holcus lanatus* is abundant on 3% and is present on 33% of the areas. *Agrostis tenuis* is either abundant or dominant on 20% of the areas and altogether it occurs on 82% of them. For *Dactylis glomerata* the corresponding figures are 9% and 64%.

Table 9.2 Occurrence of herbs on the 237 pit heap areas in County Durham (all species rated (p))

Species	Occurrence(%)
Achillea millefolium	1
Artemisia vulgaris	8
Calluna vulgaris	6
Carlina vulgaris	22
Centaurea nigra	40
Cerastium arvense	1
Chamaenerion angustifolim	76
Chrysanthemum leucanthemum	7
Cirsium vulgare	12
Digitalis purpurea	2
Empetrum nigrum	1
Equisetum arvense	1
Galium saxatile	2
Heracleum sphondylium	1
Hieracium pilosella	68
Hieracium umbellatum	40
Hieracium perproprinquum	43
Hypochaeris radicata	1
Lathyrus pratensis	1
Linaria vulgaris	3
Lotus corniculatus	1
Luzula campestris	1
Melandrium album	1
Myostis arvensis	1
Plantago lanceolata	27
Potentilla reptans	3
Potentilla erecta	1
Pteridium aquilinum	6
Ranunculus acris	1
Ranunculus repens	1
Reseda lutea	7
Reseda luteola	11
Rumex acetosa	5
Rumex crispus	7
Rumex acetosella	16
Senecio jacobaea	16
Silene vulgaris	3
Tanacetum vulgaris	3
Taraxacum officinale	1
Trifolium repens	1
Trifolium pratense	1
Tussilago farfara	61
Urtica dioica	4
Vaccinium myrtillus	1
Vicia cracca	1

The main herbs were *Centaurea nigra*, *Chamaenerion angustifolium*, *Hieracium* spp. (*H. pilosella*, *H. perpropinquum*, *H. umbellatum*) *Plantago lanceolata* and *Tussilago farfara*, all of which occurred on more than a third of the 237 sites.

Table 9.3 Occurrence of trees and shrubs on the 237 pit heap areas in County Durham

Species	Occurrence(%)
Acer pseudoplatanus	2
Alnus glutinosa	2
Betula (B. pubescens, B. verrucosa)	22
Crataegus monogyna	18
Ligustrum vulgare	1
Pinus sylvestris	4
Populus nigra	1
Pyrus aria	1
Rosa spp.	15
Rubus spp.	50
Salix spp.	8
Sambucus nigra	3
Sarothamnus scoparius	17
Sorbus aucuparia	1
Ulex europaeus	12
Ulmus montana	2

The principle trees and shrubs found commonly on the pit heaps (Table 9.3) were: *Betula, Crataegus, Rosa, Rubus, Salix, Sarothamnus* and *Ulex*.

The primary data for each area was entered first on a pro forma and then the information was transferred to a punched card. Thus a total of 237 cards was used in the analysis of the vegetation and each card contained the following information:

(a) species occurring on the heap
(b) altitude in 6 categories between 0 and 275 m (900 ft)
(c) aspect in 5 categories: N, S, E, W or flat
(d) slope in 4 categories: level, 0–10°, 10–20°, 20–35°
(e) nature of surface in 5 categories: black shale, red, cinders, humus present or absent
(f) surrounding vegetation in 4 categories
(g) age of area in 3 categories: 0–25 yr, 25–80 yr, over 80 yr
(h) amount of plant cover in 6 categories; 0, 0–20%, 20–40%, 40–60%, 60–80%, 80–100%.

In addition, the occurrence of grasses *Agrostis tenuis, Dactylis glomerata* and *Holcus lanatus* was recorded on a 4 point scale, present, frequent, abundant, dominant and the number of legume and umbellifer species on a 5 point scale.

Having selected a particular species, e.g. *Dactylis glomerata* (f), cards containing this plant were removed from the pack of 237 in the approved manner. Out of the 237 cards 39 (or 16.5%) were removed i.e. *D. glomerata* (f), occurred in 39 areas. Further selections were then made from the 39 cards for all the variables listed above. The chi-squared test was used to determine whether or not the observed values varied from those expected if the distribution of *D. glomerata* (f) was random and the calculations were performed by a KDF9 English Electric computer (Shenton, 1967 for details). Initially 25 of the most commonly occurring species were selected from Tables 9.1, 9.2, 9.3 for analysis; each species occurred on ten or more areas. Eleven species (out of the 25) showed some apparent dependence on *altitude* and these were: *Agrostis canina, A. tenuis* (p), *Arrhenatherum elatius, Calluna vulgaris, Centaurea nigra, Hieracium perpropinquum, Holcus lanatus, Plantago lanceolata, Rubus* spp., *Rumex acetosella, Tussilago farfara.*

It is not proposed to describe and account for each of these species, but to consider two examples:

(a) *Agrostis tenuis* is related to altitude when it occurs as a 'present' species and it appears to grow at lower altitudes 30m to 100m (100 – 400ft) rather than at 150m to 275m (500 – 900ft). However, in contrast, there was no correlation between *A. tenuis* with 'frequent' occurrence and altitude. One could conclude that colonization by *A. tenuis* is more likely to be favoured by low than by high altitudes, but that once it is established there is no variation with altitude.

(b) The case of *Calluna vulgaris* is interesting because the analysis showed it was favoured by habitats at 150m (500ft) but not by lower ones; it was significantly absent from any of the 237 areas at 30, 60 and 120m (100, 200 and 400ft) above sea level. However, at Plawsworth 90m (300ft), Haswell 100m (350ft) and at other places under 120m (400ft) not included in the 237 areas, *C. vulgaris* is found on pit heaps. Heather moorlands in Durham are largely found above the 140m (450ft) contour, and the open spaces of newly formed shale heaps, being in the vicinity of large quantities of seeds, offer suitable habitats for young plants. Below 140m (450ft) *C. vulgaris* is absent except for a few isolated places and most pit heaps are outside the range of its seeds. However, when a pit heap is formed near to a small piece of moorland, as at Washington and at Haswell, not only *C. vulgaris* but also other moorland species (Richardson, 1956) take on the role of colonists.

Example (b) may be used in support of the view that the local seeding plants are probably more important than other environmental factors in determining the flora of pit heaps.

This notion was supported by the analysis of the distribution of 35 of the commonly occurring species from Tables 9.1, 9.2, 9.3 with respect to aspect. Not one of the sets of data showed any correlation with aspect (N, S, E, W or flat, see above); nor was there any uniform correlation with age. *Betula* was found as a colonist on some heaps and as a late-comer on others. The same applies to *Chamaenerion angustifolium, Centaurea nigra, Hieracium* spp., *Linaria vulgaris, Reseda luteola* and *Ulex*. In contrast the following species appear later in the succession, after about 25 years when there is some humus in the surface layers: *Carduus nutans, Plantago lanceolata, Rosa* spp., *Rubus* spp., *Senecio jacobaea, Acer* and *Crataegus.*

9.2.3 Conclusions which relate to artificial planting

The results emphasize that pit heaps are often extremely unfavourable habitats because of their physical and chemical properties, their slope and their aspect. Nevertheless, very few shale tips are completely sterile, and, given time, closed plant communities usually develop. The main conclusions are:

(a) Clearly the list of naturally occurring species detailed in Tables 9.1, 9.2, 9.3 (together with their frequency of occurrence and the stage in the succession when they appear) is a basis for any planting programme, whether this takes place on existing heaps, or on partially or fully reclaimed heaps.

(b) The surface of the heap must be neither too compact nor too loose and it must contain both sand-sized (2mm) and clay-sized (0.002mm) particles.

(c) The pH value must not be too low -nor the amount of toxic substances too high.

(d) The seed rate must be high to allow for casualties, especially on south-facing slopes.

(e) Again, mainly with respect to southern slopes, precautions should be taken to insulate the surface of the heap from the heating and drying power of the sun.

9.3 Planted vegetation

9.3.1 Grass and herb planting experiments

Plants growing on bare but non-toxic flat surfaces on pit heaps are not subject to the same stresses as those growing on the slopes, particularly on south facing slopes, and it is relatively easier to establish a grass–herb community on flat areas. Except for control plants most of the experiments reported here were performed on 30–40° slopes. Given moist conditions in spring or autumn, seeds sown either on the surface or just below the surface (by light raking) germinate well. If conditions in the following summer are moist and cool the seedlings generally grow into substantial well-rooted plants.

Small scale planting

(a) *Kibblesworth* (NZ 242563) The surface on the slopes of the bare heap was composed of a mixture of loose, unburnt shales and small coal, with little clay content. Rainfall scarcely penetrated and ran off rapidly so that after rain the pF of the surface layers quickly approached pF 4.2 (wilting point). Furthermore, the pH was low (pH 4.0 – 2.5) and pyritiferous material was present. Briefly, only those plots which were heavily limed beforehand, given a layer of clay or peat, and seeded at 34.0 – 65.0g per m^2 (1–2oz per yd^2), supported a reasonable sward. *Agrostis tenuis* was the most successful colonist and it responded well to light dressings 16.0g per m^2 (½oz per yd^2) of bone meal and of hoof and horn.

(b) *Ravensworth* (NZ260582) In contrast to Kibblesworth the bare south slopes at Ravensworth had good water holding properties, the pH was around pH 6.8 and the total sulphur only amounted to about 0.2%. Seeds were sown in plots and lightly raked and rolled. *Agrostis tenuis* did well, closely followed in abundance by *Dactylis glomerata* and *Deschampsia flexuosa*. *Festuca rubra* did moderately well. Seed rates as low as 8.0g/m^2 (¼oz/yd^2) produced good results and all grasses responded to light dressing with fertilizer (see above).

(c) *South Moor* (NZ 193516) The bare slopes did not have the low water holding capacity of the Kibblesworth slopes, but also they did not contain appreciable amounts of sulphur. Seeds of *A. tenuis*, *D. glomerata* and *D. flexuosa* were sown at rates from 8.0g to 15.0g per m^2 (¼–1½oz per yd^2) and raked in. The ground was made as firm as possible. Following autumn sowing, germination and growth of the seedlings was encouraging. However, in the following spring and summer, drought conditions caused excessive water loss from the top 50mm (2in) and heavy casualties occurred. Once again plants of *A. tenuis* and to a less extent *D. glomerata*, did well in adverse conditions but generally their root growth was insufficient to carry the extremities down to moist levels in the heap. The herbs *Lupinis alba*, *Medicago sativa*, and *Melilotus alba* were also sown together with seeds of *Ulex*, but all of these never gained more than a foothold as colonists. Finally, four years after the original planting, all the species (herbs and grasses) were reduced to a few representative plants. Control plants grown on shale in the Botany Experimental Garden and well-watered produced massive growth.

The plants on the slopes of South Moor did not survive because there was excessive drying from the loose, unprotected surface. At Ravensworth the surface texture helped the conserve moisture, and at Kibblesworth the layer of clay or peat performed the same function. These experiments emphasize that unless it is possible to water young herbs and grasses on newly planted slopes in dry conditions, special care should be taken to protect the surface against drying out. Further experiments showed that water could be conserved by covering the surface with dry mulches of peat, straw and wood cellulose after the seeds were sown. As the observations with *Holcus mollis* had shown (section 9.2.1(b)) a thin layer (e.g. 10mm) was sufficient to insulate the soil against the sun's radiation and to keep moist the roots of seedlings. Dry materials applied to the surface have the disadvantage of being blown about in even slight winds and therefore experiments were carried out to find a method of holding the mulch in position. Fine-mesh hemp nets were ideal for the purpose and were suitable for fairly large areas as well as for small plots. Experience suggested that, whereas dry mulches were suitable for small trial areas, they would be costly if applied to large reclamation areas. Liquid mulches such as Unisol 91 and various wood cellulose pastes were compared with controls on the pit heap at Ravensworth and were found to increase the survival of seedlings by up to 100%. The wet mulch was applied to the heap surface by means of a coarse type of 'stirrup-pump' and although this was satisfactory for small plots it was evident that more powerful apparatus would be required for steep slopes of large area. One possibility was to employ the 'hydromulching' method in which a soft paste of the selected mulch is sprayed from a water-cannon mounted on a lorry tanker. This method was adopted at Roddymoor (see below).

Large scale planting

Roddymoor (NZ 155364) The north and north east slopes were levelled and compressed by bulldozer to give a firm surface in which there were adequate amounts of small clay and silt particles. The texture closely resembled that at Ravensworth (see above) and further rolling was not considered necessary. Water holding capacity was generally good and there was no evidence of waterlogging. The material was mainly neutral having pH values between pH6.5 and 7.2. For ease of application and to provide a surface insulating layer the seed mixtures were sown in a paste of wood cellulose to which fertilizers were added (see below).

The north and north-east banks of the heap were divided into fourteen plots of about 0.2 hectares (half an acre) each which were seeded with a mixture of grass seeds at various rates of application (see Fig. 9.2). Two

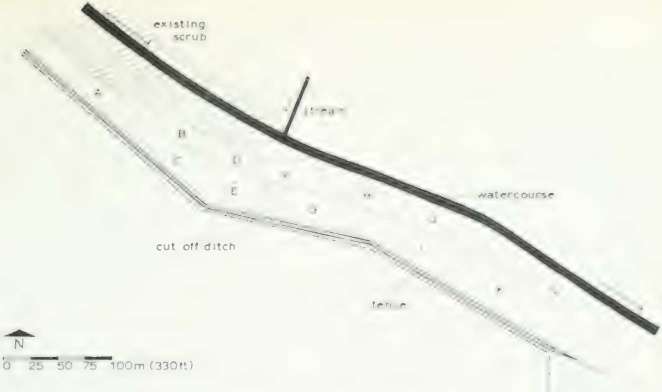

Fig. 9.2 Plan of north and north east slopes at Roddymoor.

methods of application were used to apply seeds to the bank.

Referring to the plan of the different seeding plots on the bank, plots C to N were seeded by the 'hydromulching' method and only plots A and B were seeded by the 'glob' seeding method. Plot A unlike plots B to N, which were seeded with a mixture containing only grass species, contained only one grass species, the rest of the mixture consisting of tree and herb species. All seeding was on the bare shale which had had no topsoil added to the surface.

The seed mixture for plot A consisted of the following species and its rate of application is given below.

	kg /ha	(lb/acre)
Festuca rubra	16.8	(15)
Trifolium repens	9.0	(8)
Alnus glutinosa	2.2	(2)
Fraxinus excelsior	1.1	(1)
Acer pseudoplatanus	1.1	(1)
Betula pubescens	1.1	(1)
Total	31.3	(28)

Plots B to N were all seeded with the same type of seed mixture using three rates of seed application of 84, 112, 168 kg/ha (75, 100 and 150 lb/acre). At these three rates the grasses making up the total seed mixtures were as shown in Table 9.4.

The thirteen plots (B–N) shown in Fig. 9.2 were seeded as in Table 9.5.

Table 9.5 Seed rates employed on the plots at Roddymoor

Plot	Method	Rate of application kg/ha	(lb/acre)
B	Glob	85	(75)
C	Hydromulching	170	(150)
D	"	85	(75)
E	"	112	(100)
F	"	112	(100)
G	"	112	(100)
H	"	85	(75)
I	"	170	(150)
J	"	85	(75)
K	"	112	(100)
L	"	85	(75)
M	"	85	(75)
N	"	85	(75)

Table 9.4 Composition of seed mixtures used at Roddymoor

Species		Rate of application kg/ha (lb/acre) 84 (75)	112 (100)	168 (150)
Agrostis tenuis		4.2 (3.75)	5.6 (5)	8.4 (7.5)
Dactylis glomerata	S.137	4.2 (3.75)	5.6 (5)	8.4 (7.5)
	S.143	4.2 (3.75)	5.6 (5)	8.4 (7.5)
	S.26	4.2 (3.75)	5.6 (5)	8.4 (7.5)
Festuca rubra	S.59	38 (33.75)	50.4 (45)	84.6 (75.6)
F. rubra communtata		15.3 (13.125)	19.6 (17.5	29.4 (26.25)
F. tenuifolia		15.3 (13.125)	19.6 (17.5)	29.4 (26.25)

The grass seeds, fertiliser, and mulch were mixed and sprayed from the top of the spoil heap down on to the slopes of the north bank. The mulch consisted of wood cellulose applied at 760 kg/ha (681 lb/acre) giving a theoretical depth of 1.6mm (one sixteenth of an inch). This application of a mulch with the seeds was to afford some conservation of water and insulation against the sun's rays to the surface of the spoil heap on the slope. The seeds on the north and north-east banks were sown on 23–26 August 1968 with 500 kg/ha (4 cwt/acre) of Fisons 53 fertiliser (N12-P24-K0), except plot M which did not have any fertiliser applied at the time of sowing. A further application of fertiliser, Fisons low nitrogen 55 (8–20–16), was applied to the north slope, but not to plots M and N, at a rate of 250 kg/ha (2 cwt/acre) during May 1969.

Samples of shale taken from various sites on the north bank were air dried and sieved through a size 6 mesh, and then subjected to close examination to see whether the shale contained any remains of the cellulose mulch used for hydromulching. None of the shales appeared to have any remains of the mulch as could be expected if micro-organisms were present in the soil which were active in breaking down the cellulose to its basic constituents. This indicated that the shale was in some respects fertile or was becoming fertile.

A number of sites 1m × 1m were chosen at random; the species of plants and their approximate distribution were recorded. These sites were marked by means of labels fixed on posts placed in the shale in order that the sites could be revisited occasionally to record the performance of the different grasses. Observations were made on 14 July 1969, and these are given in Table 9.6.

From the table it can be seen that the species list, both herbs and grasses, is much longer than the planted species list. The most obvious species not expected to be in the seed sown in August 1968, but growing strongly on the north bank in July 1969 was *Lolium multiflorum*. It can be seen in the photograph (Fig. 9.3) that the tall dense Italian rye grass growing on the right of the picture finishes in line with the seeding plot post at the top left of the photograph. Although the rye grass occurs on all the north bank in different frequencies, the greatest cover is at the west end of the slope. This grass flowered during the summer of 1969 and set seed which was viable; at the end of August the seeds germinated on large areas of shale which previously had little or no grass cover, as well as in the grass sward already present. This grass *L. multiflorum* was the most prolific seed-setting grass on the whole heap, and may prove to be a successful plant on spoil heaps during the first years of growth of a grass sward.

Table 9.6 Occurrence of grasses and herbs at Roddymoor 1 year after sowing

Species	Site number 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Agropyron repens	–	–	p	–	–	–	–	–	–	–	–	–	–	–
Agrostis tenuis	p	p	p	p	p	p	p	f	f	p	p	p	p	p
Dactylis glomerata (flowering)	–	–	–	–	r	p	–	–	r	p	p	–	–	–
D. glomerata (non-flowering)	p	p	p	f	p	f	f	p	f	p	f	–	p	–
Deschampsia flexuosa	–	–	–	r	–	–	–	–	–	–	–	–	–	–
Festuca rubra commutata	–	–	–	–	–	–	–	p	p	p	p	–	–	–
F. rubra rubra	d	d	d	–	–	d	f	p	p	f	f	d	d	d
F. tenuifolia	p	–	–	–	–	p	p	–	–	–	–	–	–	–
Holcus lanatus	–	f	p	p	p	p	p	f	p	p	p	–	p	–
Lolium multiflorum	f	–	–	p	f	p	f	f	f	p	f	d	d	d
Phleum bertolonii		–	–	–	–	–	–	–	–	p	p	–	·	p
Poa annua		p	–	–	–	–	–	–	–	–	–	–	–	–
Capsella bursa-pastoris	–	p	–	–	–	–	–	–	–	–	–	–	–	–
Ranunculus acris	–	–	–	–	–	–	–	–	–	–	r	–	–	–
Reseda luteola	–	–	–	p	–	–	–	–	–	–	–	–	–	–
Rumex obtusifolium	–	p	–	–	–	–	–	–	–	–	–	–	–	–
Trifolium repens	–	–	r	–	–	–	–	–	–	–	–	p	p	p

Fig. 9.3 Growth of *Lolium multiflorum* on a steep slope at Roddymoor.

Agrostis tenuis, one of the first natural colonisers of pit heaps, and one of the most commonly found grasses on heaps also proved itself to be a successful plant when seeded on to spoil, at least during the first year of growth observed at Roddymoor. It set seed quite profusely but no observations were made to see whether or not this seed was viable.

Dactylis glomerata during the summer was observed to be varying in performance in different localities on the north bank. Some plants were seen to be flowering and some were not. The non flowering plants seemed to have poorer growth than the flowering plants (see Table 9.6). This could show that the grass was not as suitable as *A. tenuis* for spoil heap colonisation, at least, in the first few years of the production of a grass sward.

On nine of the sites chosen for the observation of the performance of the grasses, *Festuca rubra commutata* seemed to be absent; in contrast *F. rubra rubra* had taken well and was growing strongly on eleven out of fourteen sites; *F. tenuifolia* was only found on three of the sites.

Several additional species of grass (which were not in the original mixtures) were observed; they were probably being introduced by the action of wind from neighbouring areas and this was also true of several herb species (see Table 9.6).

The glob seeded plot (plot A) which was seeded with only one grass species and the rest of the mixture consisting of tree and shrub species was observed during the whole of the spring, summer and autumn, but no tree seedlings were observed to have successfully germinated during 1969. This plot, as mentioned above, was covered with a tall vigorous growth of *Lolium multiflorum*.

9.3.2 Tree and shrub planting

Small scale experiments Early records of trees andshrubs growing on pit heaps in Durham (e.g. Harrison, 1937, Richardson, 1956) showed that *Betula, Crataegus, Rosa, Rubus* occurred most frequently and this was confirmed by Shenton's extensive researches (see Table 9.3). Detailed examination of sites showed that on most *Betula* was a pioneer plant on both burnt and unburnt heaps and, where there was a nearby source of seeds e.g. at Urpeth (NZ 248555), there was rapid spread of this tree to form an almost pure stand of birch. Furthermore, *Betula* was able to survive in exposed positions and often reached the tops of high slopes. *Acer* was frequent in very old heaps which were low mounds, and in sheltered places on unburnt heaps. The position of *Alnus* as a pit heap plant is important. *Alnus glutinosa Gaertn.* is described by Harrison and Temperley (1939) as a native in north-east England, occurring by stream sides and in wet places and low country. There is no example known to the present writers of this plant acting as a natural colonist of pit heaps in County Durham. Nevertheless, it has long been recognised here that this plant (as its introduced cogenor *A. incana* was later recognised) could do well on poor soils, and indeed it was one of the species used in 1928 on the old pit heap at Houghall (section 9.1) and elsewhere (see Whyte and Sisam, 1949).

Small scale experiments were set up on pit heap slopes at Ravensworth (NZ 260582) Kibblesworth (NZ 242563) Ouston (NZ 267548) Harraton (NZ 291539) and Urpeth (NZ 248555). Plots were laid out on 30° to 40° slopes which were (a) bare and about 8–16 years old, (b) with a plant cover of about 50% and 25–30 years old. The following conclusions were made:

(a) The ground vegetation must be well established before a 'slit' method of planting can be usefully employed. Deep hold planting (using spades) was more satisfactory and three variations were employed. Most heaps contain enough moisture to support colonising or planted species provided the roots penetrate to the appropriate depth (section 9.2.1(c)). To improve the water-holding capacity of the shale a spadeful of loam soil was placed in the hole below the roots and another spadeful above the roots before the soil was firmed around the stem. This procedure stimulated root growth in the first year and treated plants made increased growth compared with those placed directly on to the shale.

    It was time-taking, awkward, and wasteful of soil to apply soil from buckets or sacks carried along steep., unstable slopes. The following procedure was therefore adopted. The tree roots were surrounded by soil contained in hessian sandbags tied at the neck. This operation was performed at convenient points along the top or bottom of the steep slopes and the bagged trees were then easily transported e.g. by sledge, to the prepared holes.

(b) As a result of the small scale tree planting experiments carried out at the 5 sites listed, it was possible to classify the performance of the species used as follows:

(i)	good growth	*Alnus, Betula;*
(ii)	moderate growth	*Crataegus, Sorbus aucuparia;*
(iii)	poor growth	*Acer, Populus, Sambucus, Ulex.*

    It was not uncommon to find that all the *Acer* and *Populus* had died back after a few years in which time *Alnus* and *Betula* had grown on strongly.

    The experiment demonstrated the importance of selecting the best possible specimens for planting on pit heap slopes. The ideal sapling is probably one which is about three feet tall and possesses a well developed root system. On these difficult sites the planting of 'whips' and 'wolves' could be inviting a heavy beating-up programme.

(c) In the first years after planting there was often damage to the stems of trees due to friction caused by movement in the wind. Also there could be high transpiration losses from leafy shoots at a time when new root growth was just beginning and this could lead to wilting which, if prolonged, resulted in the death of the sapling. Much benefit was derived from cutting back the young trees to a height of under two feet; this produced a better balance between root and shoot, and eliminated the causes of damage as indicated above.

(d) Much benefit accrued from the quick transfer of trees from the nursery to their permanent places on the pit heap. It was clear that in a large scale planting scheme small batches of trees taken direct from nursery to site, eliminating any temporary 'heelingin', would assist quick establishment and also eliminate the delay and cost of beating-up. Pit heap slopes are usually very exacting habitats and it should be strongly emphasized that extra special care (even at some additional cost) should be given initially along the lines suggested in the sections above. This will lead to better tree growth, early establishment of a green cover, and will probably save time and money in the long run.

Large scale planting The Durham County Council made a notable contribution to landscape improvement when it acquired a number of abandoned pit heaps, and, largely between 1956 and 1959, planted them with trees. In 1966 it was decided to examine a number of these heaps and to report on the growth and development of the planted species with some reference also to the naturally occurring species. Some attempt was made to correlate the observed growth with the chief environmental factors. An ideal analysis would involve a comparison between past and present plant species, but unfortunately no records were made of the vegetation present before tree planting commenced or of detailed beating-up. The following nine sites were selected for inspection from a total of thirty because they provided a wide range of geographical position, parent material, and surrounding species (map references and areas planted, in hectares and acres, are given):

(1) Littleburn	(NZ 257397)	5.366 ha	(13.26 acres)
(2) Croxdale	(NZ 263374)	5.554 ha	(13.70 acres)
(3) South Moor	(NZ 192516)	2.303 ha	(5.69 acres)
(4) Tursdale	(NZ 302363)	3.568 ha	(8.57 acres)
(5) Twizell	(NZ 223523)	1.465 ha	(3.62 acres)
(6) East Tanfield	(NZ 196550)	1.578 ha	(3.90 acres)
(7) Gloucester Road	(NZ 115507)	3.845 ha	(9.50 acres)
(8) High Spen	(NZ 138597)	1.457 ha	(3.60 acres)
(9) South Pelaw	(NZ 270527)	3.841 ha	(9.49 acres)

Establishment of plantations When the trees were planted strict precautions were taken. The bundles of trees were loosened and heeled into good soil at the base of the spoil heap, and steps were taken to prevent damage by vermin. Unplanted trees were carried in sacks in order to prevent wind damage to the roots. Trees were kept out of the ground for the shortest possible time and were planted when the ground was not frozen. Pits were dug in the heap and the tree roots were spread outwards and downwards before they were firmed in. All trees were planted to the depth of the root collar. The heights of the principal trees were as follows:

Conifers 0.45m (18in) *Acer pseudoplatanus* 0.9–1.5m (3–5ft) *Betula* 0.45–0.76m (18–30in) *Alnus incana* 0.45–0.76m (18–30in) *Quercus robur* 0.30–0.45m (12–18in).

Except where otherwise stated all of the softwoods were grown for two years in one soil then a further year in another (i.e. 2 + 1). The trees were planted 1.22 X 1.22m (4 x 4ft) apart, at approximately 6660/ha (2700/acre). As a general rule mixtures of hardwoods and softwoods were planted in groups of nine or sixteen in alternate lines. All natural tree seedlings and saplings were retained and preserved, but occasionally top growth was cut back to allow satisfactory tree planting. More trees were planted on some areas of the heap than on others as the number of existing trees varied. Not only were the trees carefully planted but at intervals of time replacement of failures was carried out (beating-up). The same 1.22 X 1.22m (4 X 4ft) distance of planting was used in beating up as in the original planting. Because the species used in beating up operations occasionally varied from those in the initial planting, the final pattern of trees on the heap varied considerably in some cases from that first designed.

In order to prevent death of planted trees by intense competition from existing species many of the heaps were periodically weeded and this involved cutting back to ground level all herbaceous and shrubby growth along the rows of trees, and particularly over a radius of 0.45m (18in) around each tree.

Observations were made at all of the selected sites in August 1966 and the primary data were filed with the Landscape Reclamation Project Office and the Durham County Council. In order to illustrate the type of pit heap planting carried out, one site, Littleburn, was selected for detailed description.

Table 9.7 Species planted and areas covered at Littleburn

Area	Size ha	(acres)	Species
A_1	1.17	(2.89)	*Populus x robusta* } inter-spersed with scrub
A_2	0.61	(1.50)	*Populus x euramericana* *P. 'Serotina'* *P. 'Celrica'* } inter-spersed with scrub
A_3	0.08	(0.20)	*P. 'Eugenei'*
B	0.32	(0.78)	*Pinus contorata* (1+1)
C	0.17	(0.41)	*Pinus nigra* var. *calabrica* 3 rows *Quercus borealis* fringe
D	0.16	(0.39)	*Acer pseudoplatanus* 25% *Pinus nigra* var. *calabrica* 75%
E	0.25	(0.61)	*Pinus nigra* var. 50% *Larix leptolepis* 50%
F	0.21	(0.52)	*Larix leptolepis* *Pinus contorta*
G	0.13	(0.32)	*Pinus contorta*
H_1	0.09	(0.22)	*Pinus contorta*
H_2	0.06	(0.16)	*Pinus contorta*
H_3	0.01	(0.02)	*Pinus contorta*
H_4	0.012	(0.03)	*Pinus contorta*
J	0.19	(0.48)	*Pinus contorta* 33$\frac{1}{3}$% *Quercus* 33$\frac{1}{3}$% *Acer pseudoplatanus* 33$\frac{1}{3}$%
K	0.4	(1.00)	*P. contorta* (1+1)
L	0.09	(0.24)	*Betula pendula*
M	0.11	(0.27)	*Betula pendula*
N1	0.34	(0.83)	*Pinus nigra* var.
N2	0.13	(0.32)	*Pinus nigra* var.
P	0.112	(0.28)	*Alnus* 50% *Betula* 50%
Q	0.32	(0.80)	*P. contorta* 10% *Quercus* 10% *Acer* 10% *Betula* 70%
R	0.15	(0.36)	*Betula* 25% *P. nigra* var. *calabrica* 75%
S	0.25	(0.63)	*Acer* 50% *Betula* 50%
X	0.14	(0.35)	Planted in 1964 with a mixture of *P. nigra, P. contorta, P. sylvestris, Laris, Picea abies, Alnus, Betula*

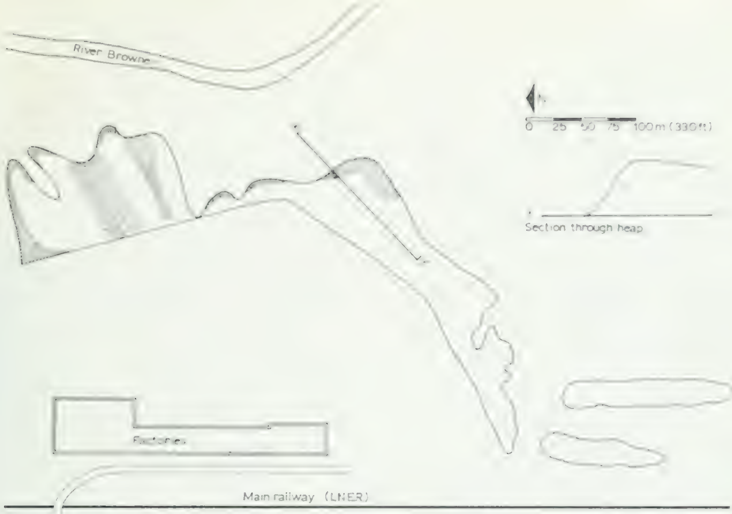

Fig. 9.4 Sketch plan of the pit heap at Littleburn.

Fig. 9.5 The pattern of planting at Littleburn in 1956.

Littleburn heap This complex heap lies between the main Newcastle – London railway line and the River Browney at Meadowfield. The heap is situated on ground which falls steeply from west to east and is composed of a number of flat-topped ridges with sides which slope at angles of between 30–45°. Generally the ridges are only a few feet above the surrounding land at their western ends but, because of the contours of the land, the spurs at their eastern ends tower up to a hundred feet above the flat river banks (Fig. 9.4). The long west and north west end of the heap complex was flattened for factory building and much building rubble lies marginally around this part of the site.

The pattern of planting for the Littleburn heap is shown in Fig 9.5 and Table 9.7 gives the species and the area in 1956.

An account of the subsequent beating-up and weeding can be summarised from the record as follows:

Date	Record
May 1957	Survival of *Pinus* fair; *Acer and Alnus* satisfactory; *Quercus* and *Populus* poor; smaller sized *P. contorta* doing remarkably well. No *Larix* seen.
Nov – Dec 1957	30% beating up of original species (*Populus* inadvertently omitted). *P. contorta*, 1300; *Salix daphnoides*, 275; *Acer*, 250; *Betula*, 100; *Quercus*, 100.
January 1960	Beaten up with *P. contorta*, 1200; *P. nigra*, 1300; *Alnus incana*, 3000; *Acer*, 2800; *Betula*, 700; Area beaten up includes 0.4 ha (1 acre) burned in August and 1.6 ha (4 acre) originally planted with *Populus* which has completely failed.
December 1961	Beaten up with *Alnus incana*, 2000; *Acer*, 800.

Weeding was carried out in 1957, 1958, 1959, 1961, 1963, 1964 and 1965.

General conclusions from the survey at Littleburn

(a) *Pinus nigra* var.*calabrica* was the most successful conifer planted on the heap. It tolerated not only strong south-westerly winds but also steep south facing slopes. Indeed this tree did better on steep slopes (areas N1, E and F), reaching 3–3.6m (10–12ft) in ten years, than it did on the flatter areas (e.g. area N2).

(b) *Pinus contorta* was less tolerant of exposure and was not well developed on areas B, H1 and H2. It was also sensitive to shading, and if planted where there is a good tree cover, as a 'beating-up' plant, it did not fully develop.

(c) *Pinus sylvestris* and *Picea abies*,recently planted on areas X and Y showed moderate growth, seemed to be well established and about to enter a period of more rapid growth. *Larix leptolepis* was the least successful of all the conifers and flourished only on the sheltered east side of area F at the bottom of the slope; *Larix* was also very poor on areas X and Y.

(d) *Alnus incana* and *Betula pendula* showed the best growth amongst the hardwoods with the former not quite achieving the high yearly increment of *Betula*. *Salix*, *Populus* and *Acer* did badly on the actual spoil heaps (although they did fairly well on the scrubland at the base of the heap, e.g. *Acer* and *Salix* attained satisfactory growth in area J). *Quercus robur* was largely unsuccessful but *Q. borealis*, planted on shale in area C, showed good growth.

Vandalism had occurred along part of area F with some *Larix* uprooted and others chopped down – the initial failure of *Populus* in area A1 may have been due to this. Nevertheless, as Fig 9.6 shows, there was not much damage by vandals when the trees were well established. Littleburn heap being remote from the village, coupled with diligent beating-up, are probably the main factors responsible for the excellent result. There was no evidence in favour of weeding for hardwoods whichwere 0.6 – 0.9m (2–3ft) at the time of planting. However, for the conifers, much less in height at planting, weeding in a circle around each plant was beneficial. If the colonising herbs and grasses are otherwise left undisturbed they help to bind the soil and increase its fertility.

In common with conditions on many sites the 'soil' varied greatly from place to place on the site at Littleburn. In some places the shale was red and burnt, in others grey/black and unburnt. Within these two groups the soil varied from raw shale to shale mixed to a depth of 76mm (3in) with dead and decaying organic matter. Similarly the pH ranged from values of 3.2 to 6.0, and the soil water available to plants for their growth varied from 8% to 24%. Furthermore, the aspect and slope of the heap changed from place to place, e.g. area N1 faced south east with a steep slope of 35°–40°; area B faced west with a gentle slope of 10°. Clearly with a uniform soil throughout the site some firm conclusions relating, say to the effect of slope and aspect on the growth of the different planted trees might have been made. However, with the large and random varieties which existed only very broad conclusions may be drawn. In some ways the position was clarified when all the nine sites listed above were considered collectively and this is done in the discussion below. All the sites were examined in the same way as Littleburn and the results were similarly recorded.

9.3.3 Conclusions on tree planting

There are only eight tree and shrub species which occur commonly and naturally as early colonists on pit heaps in Durham, and these are *Betula, Salix, Crataegus, Quercus, Rosa, Rubus, Ulex* and *Sarothamnus.* In the tree-planting experiment on nine sites now reported, eighteen species were employed, of which only four (*Betula, Salix, Quercus* and *Rosa*) are in the list of colonists. The remaining fourteen 'introduced' species are listed in Table 9.8.

Each of the nine sites listed above was divided into smaller areas for planting out. For example, at Littleburn there were 25 areas (A to Y, seeTable 9.7) making up the whole site of 5.5 ha (13.6 acres) and at Gloucester Road the site of 3.84 ha (9.5 acres) was divided into 5 areas. Altogether the 9 sites contained 38.0 ha (94 acres) and, in

Fig. 9.6 Growth of planted trees at Littleburn.

round figures, 203,000 trees were planted on the nine sites either at the main planting or in the later beating-up operations. The total number of each species planted was between 100 for *Rosa* and 86,000 for *P. contorta* (see Table 9.8) and clearly the large variation in numbers will have to be taken into consideration when conclusions are drawn about the degree of success.

Classification of the growth made by the trees was done by means of the following arbitrary categories and was based on ten years growth on the pit heaps

(i) height greater than 2.1m (7ft) – good (G)
(ii) between 2.1m and 1.4m (7ft and 4.5ft) – moderate (M)
(iii) between 1.4m and 0.9m (4.5ft and 3ft) – fair (F)
(iv) less than 0.9m (3ft) - poor (P)

Measurements of twenth-five trees of each species in an area were used to give the information contained in Table 9.9. Where there was less than 20% survival the plantation was described as sparse

The most successful hardwoods were *Alnus* and *Betula*, both of which were planted in large quantities (25,000 and 15,000). The percentage survival was good and the growth rate satisfactory. *Populus, Acer, Fagus, Prunus, Quercus robur* must be considered as failures both in numbers which survived and in growth rate of individual trees. *Salix* and *Robinia* had low survival rates but individual plants, once established, did fairly well. *Quercus borealis* (3350) planted) survived in encouraging numbers, and, after slow initial growth, formed a useful addition to the list of successes. *Rosa* (100 planted) was not used in large enough numbers to allow any conclusions to be made

An important experiment was carried out at Tursdale where the following species were planted in 10 lines running across the heap from west to east, a distance of 137m (150 yd): *Larix leptolepis, Pinus contorta, P. nigra* var. *calabrica, P. sylvestris, Acer pseudoplatanus, Alnus incana, Betula pendula, Fagus sylvatica, Quercus borealis, Robinia pseudoacacia.* There were 100 trees in each line and the pattern was repeated five times to give a total area planted of 1.18 ha (2.92 acres). 500 each of the 10 species were planted. The trees were examined in 1966, 6½ years after planting. *Fagus* and *Acer* were represented by a few plants showing poor growth but no *Robinia* survived. On the other hand *Alnus* and *Betula* survived in staisfactory numbers and the average height attained in 6½ years was 1.8m (6ft). The best specimens had grown to between 3.7m and 4.6m (12 and 15ft). *Quercus borealis* survived in small numbers and showed a low growth rate. A similar picture was presented at South Moor where *Pinus contorta* (1600), *P. sylvestris* (400), *Betula* (150), *Acer* (500) and *Robinia*

Table 9.8 Tree planting at nine sites in County Durham

Species	Total Numbers	Littleburn	Croxdale	South Moor	Tursdale	Twizell	East Tan.	Glou Rd.	High Spen	Sth Pelaw
Pinus contorta	86,882	p	p	p	p	p	p	p	p	p
P. nigra var. *calabrica*	22,635	p	p	p	p	x	x	p	p	x
P. sylvestris	6600	p	x	x	p	p	x	x	x	x
Larix decidua	4106	p	x	p	p	p	x	p	p	x
Picea abies	406	p	x	x	x	x	x	x	x	x
P. sitchensis	135	x	p	x	x	x	x	x	x	x
Acer pseudoplatanus	21,012	p	p	p	p	p	p	p	p	p
Populus spp.	13,093	x	x	x	x	x	x	x	p	x
Salix daphnoides	375	p	x	x	x	p	x	x	x	x
Betula pendula	16,651	p	p	p	p	x	x	p	p	p
Alnus incana	24,459	p	p	x	p	p	p	p	p	p
Quercus borealis	2350	p	p	p	p	x	x	x	p	p
Q. robraa	2066	p	p	x	x	p	x	x	p	x
Fagus sylvatica	8800	x	p	p	p	p	x	x	p	x
Prunus avium	850	x	p		p	p	x	p	x	x
Robinia pseudoacacia	750	x	p	p	p	p	x	x	x	x
Fraxinus excelsior	1500	x	x	x	x	p	p	p	x	x
Rosa spp.	100	x	x	x	x	x	p	x	x	x

Table 9.9. Growth of trees classified by height and frequency (see text)

Species	Number of areas planted	Areas in each class G	M	F	P	Areas designated sparse
Pinus contorta	38	10	11	12	5	0
P. nigra var. *calabrica*	23	7	8	3	4	1
P. sylvestris	7	1	3	1	2	1
Larix decidua	4	–	1	1	2	3
Picea abies	2	–	2	–	–	0
P. sitchensis	1	–	–	–	1	1
Acer pseudoplatanus	26	1	1	4	20	10
Populus spp.	1	–	–	–	1	1
Salix daphnoides	5	2	1	1	1	2
Betula pendula	31	17	9	2	3	2
Alnus incana	28	17	4	6	1	1
Quercus borealis	20	2	2	8	8	5
Q. robur	8	2	2	2	2	4
Fagus sylvatica	5	–	–	–	5	3
Prunus avium	7	–	–	–	5	3
Robinia	3				3	3
pseudoacacia	3	–	–	–	3	3
Fraxinus excelsior	2	–	–	1	1	1
Rosa spp.	1	–	–	–	1	1

(150) were planted in rows across the top of the flat heap running from North to South. After eight years *Acer* and *Robinia* were total failures whereas *Betula* and the two species of *Prunus* were surviving well and had reached a height of between 0.9m and 1.5m (3ft and 5ft).

The most successful softwoods were *Pinus nigra* and *P. contorta.* They were equally at home on both north and south facing slopes where they showed better growth at the base and mid points of slopes than at the flat tops of heaps, e.g. an average height of 3.0m (10ft) in 10 years, on the lower slopes compared with 1.5m (5ft) on the tops. Both species required seven or eight years before they began to show a high growth rate. For example, in 1965, the growth rate of *Pinus nigra* growing on slopes had increased from about 0.08m to 0.46m (3 to 18in) per year, and for trees on the tops to 0.2m (8in) per year. Similar results were obtained for *Pinus contorta* and for this species there was some evidence that, in situations exposed to the prevailing wind, its growth rate was less than that of *P. nigra. Pinus sylvestris* which was not planted in such quantity (and then sometimes only in beating-up) showed it could become established fairly quickly, for example, in areas X, Y at Littleburn, the east slope at South Pelaw and at South Moor.

The amount of damage to the trees by vandals varied from site to site. It appeared to be slight at Croxdale and Littleburn where the pit heaps were some distance 1.6km and 3.2km (1 mile and 2 miles) from the nearest village. In contrast, at places like High Spen and South Pelaw, where the pit heaps were beside the houses, vandalism was severe and notices warning off maurauders were largely ignored. At South Pelaw an area of approximately 44m by 22m (40 yd by 20yd) on the south facing slope nearest the houses was protected by means of 1.5m (5ft) chestnut fencing. This precaution produced noteworthy results (see Fig. 9.7) and it suggests that simple fencing carefully sited could be effective in urban areas.

Fig. 9.7 The fenced and unfenced parts of the pit heap at South Pelaw.

9.4 General conclusion

Pit heaps are often intransigent habitats where a number of environmental factors act to retard plant growth. Some of the main obstacles to the development of vegetation on the steep slopes of pit heaps have been investigated using physiological and ecological procedures and ways have been suggested for ameliorating the conditions. The main conclusion from the work reported here must be that each pit heap (or derelict site) scheduled for full reclamation should be first investigated thoroughly by a person competent to advise on living plants. It is unlikely that all sites will be identical or that they should be given the same treatment to encourage plant growth. The suggestion is that each reclamation site should be treated separately, its physical and chemical properties studied and the species available for planting considered.

Some heaps will require considerable treatment, others much less, but all should be treated as special cases. The deeper the investigation leading to the formulation of the final treatment the heap is to receive, the greater will be the chances of success.

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Chapter 10 Practical techniques for establishing vegetation on derelict land

by C.J. Vyle

10.1 The suitability of materials to sustain plant growth

In the light of experience in this project, the reasons for the absence or sparsity of vegetation on derelict land are listed as the dominance of rock material or stones, impermeability of the soil to air or water, high water table, exposure to extreme climate, atmospheric pollution, lack of plant nutrients, inability to hold nutrients in soil, inability to retain moisture in soil, toxic levels of chemicals, and salinity. Some of these problem conditions can be overcome through the design of a modified landscape, for example, to offset inability to retain moisture by new landform design which retards run-off. It is also possible to plant vegetation of low nutrient requirement, e.g. certain grass–legume mixtures and trees with 'pioneer' characteristics, and to ameliorate the site conditions with lime and fertilisers so that agricultural and other 'advanced' species may be grown.

The conditions prevailing around the experimental sites provided a range of experience of problems often found in areas in which derelict sites are located. Atmospheric pollution is one of the most frequent of these. At Roddymoor, however, no problem of this kind occurred and to a degree this site served as a control. At Big Waters, local sources of pollution in the form of burning pit heaps are in the process of being removed. At Northbourne Park, the nearby coal by-products plant emits fumes which have given a tarry deposit on trees at the eastern end of the site.

Exposure is a problem on the top of the Roddymoor heap, which lies in open country at an altitude of 182–212m (600–700ft) above sea level, and at Windynook, Felling which is 91–167m (300–550ft) above sea level. The Big Waters site, at only 61m (200ft) o.d., is nevertheless also exposed to strong winds crossing the fairly open country to the west.

10.1.1 Lime requirements

(a) Roddymoor The shales encountered at Roddymoor were black, grey, red, and mixtures of red and black; other materials were slurry, coke breeze, building foundations and stacked drift, subsoil and topsoil. The shales were stony and had been heavily compacted by earthmoving machines. Only a small amount of lime was considered necessary for the Roddymoor site as the pH levels of different parcels at the seeding time were generally reasonable for grass establishment for agricultural use.

(b) *Big Waters* The surface materials at Big Waters were ash which had been used for agriculture, black shale with a high coal content overlain with soil, black shale with mixed shale and soil, and black mixed shale with red mixed shale. These shales were stony, but impermeability to air and water was not a problem over most of the site. Areas of high water table were present because of the levels at the boundaries of the site in relation to the water level in the subsidence flash.

At Big Waters, the pH of the shales before regrading varied between 2.8 and 3.8, and during regrading these rose to 3.5–4.4. The agricultural ash area had a pH of 6.7 which rose to 7.1 on regrading. The imported Dinnington shale had a pH of 8.0 to 8.5 with free calcium carbonate present. Lime was applied to the north area west of the road prior to the placing of the Dinnington shale, and 2 ha (5 acres) to the south was similarly treated.

Salinity has not been a problem on Big Waters and has never exceeded the designated safe limit of 4 m.mho/cm.

At Big Waters, lime was applied at the appropriate rate to achieve optimum conditions for plant growth at the surface and part neutralisation of the sub-surface. The pH of the black shale surface after liming was 7.0, and the pH levels of the Dinnington shales after placement were 7.7, 7.3 and 6.9 (parcels 3,4,5). The incorporation of lime to neutralize or part neutralize the subsurface may help to prevent deep rooted species from going into check when their roots meet the less favourable medium.

(c) *Maria Colliery* Soil tests relating to lime and nutrient requirements were made, and it was recommended that shales with a low pH would be best buried under material which would be less of a problem from the point of view of management of the vegetation established on it. Provided that the more favourable shales were used, no lime would be required.

(d) *Northbourne Park* The soil tests at Northbourne Park revealed impoverished parent materials, including some areas with a pH of 3.5.

10.1.2 Fertilizer requirements

(a) *Roddymoor* The shales were found to require nitrogen and phosphate, but potassium was present at an adequate level to sustain plant growth. The fertilizer to meet the situation was applied at 500 kg/ha (4 cwt/acre), yielding 48 units nitrogen (N)–96 units phosphorus (P_2O_5)—0 Potassium (K_2O) units/acre in 1968 to the seed bed. The first application was not planned to meet the full deficiency, and further applications (e.g. 80 units/acre and 100/220 units/acre P_2O_5) in 1969 and 1970 respectively) were made.

(b) *Big Waters* In two areas there was a severe lack of phosphorus (427/470 units P_2O_5/acre), possibly owing to the particular fixing properties of the acid parent materials.

Those areas on shale which were sown with grass in the Autumn of 1969 received 112 units P_2O_5/acre as basic slag, and in addition 440 kg/ha (3½ cwt/acre) of a complete compound fertiliser yielding 35–70–70 units/acre, bringing the total units in the seed beds to 35–182–70/acre.

The area previously used for agriculture had 35–70–70 units/acre applied.

Other areas which included subsequent tree planting had 355 kg (7 cwt) of basic slag, yielding 112 units P_2O_5; this was ripped into the 610 mm (2ft) surface dressing of mixed red shale.

It is becoming apparent with increasing experience of shale soils that phosphorus is a limiting factor, and may help to explain why trees planted on some heaps have remained in check.

(c) *Maria Colliery* The after use of the site for industry will mean that the vegetational cover will be temporary, and fertiliser treatments have been designed to ensure that the sward is maintained until the time the site is required for its intended use. In the seed bed 500 kg/ha (4cwt/acre) yielding 48–96–0 units/acre was suggested, with two applications each of 500 kg/ha (4cwt/acre) yielding 160–80–80 units/acre for the establishment period.

(d) *Northbourne Park* The main aim at Northbourne Park was to re-establish a self-perpetuating soil fertility cycle on existing grass areas by applying a high level of a complete compound fertiliser. 1000 kg/ha (8 cwt/acre) were applied to the existing cover, yielding 80–120–80 units/acre. On areas with less requirement 500 kg/ha (4 cwt/acre) were applied, yielding 32–80–66 units/acre. On newly exposed ash surfaces with little mechanism for fertiliser retention, treatment with sewage sludge was undertaken and this was followed by a fertiliser at a higher rate. Where the material was particularly impoverished an additional application of a PK fertiliser was made at 376 kg/ha (3cwt/acre) yielding 0–60–60 units/acre. The limed area was covered with soil in depths between 100 mm (4in) and 305 mm (12in) and the soil fertilised at the high rate.

(e) *Egerton Gardens* At Egerton Gardens 880 kg/ha (7 cwt/acre) of a complete compound fertiliser, yielding 105–105–105 units/acre was used. The aim in the case of fertilising for recreational uses was to give a boost to the existing grass cover and a good start to new grass. During the course of maintenance, the grass cuttings left on site will help to re-establish or establish a soil fertility cycle, and minimal application of complete compound fertiliser was made during the establishment period.

10.1.3 Fertilisers – general comments

Where tree planting was the aim following autumn grass establishment, no extra fertiliser was applied until the spring of the following year, the intention being to maintain grass cover but not to cause undue competition with the trees. Particularly on newly reclaimed sites, plans for fertiliser applications should be flexible. Bearing in mind the widely differing characteristics of shale soils and other materials found on derelict sites, soil testing is imperative and lime requirement tests should be included, especially on those materials where there is a likelihood of increasing acidity. In these circumstances such a test should be undertaken as a matter of routine at least over the first five year period. Nutrient requirement tests are also vital, adjustments being made according to the type of management which is to be adopted.

10.1.4 Fertilisers for trees and shrubs

On Roddymoor, apart from the fertiliser referred to in 10.1.2(a), all blocks received 57 g (2oz) per plant of basic slag, except for the D planting. Block B received four treatments, three of which were superimposed on the initial treatment of 57 g i.e.

treatment 1
57 g (2 oz) basic slag
treatment 2
57 g + 57 g — i.e. 114 g (4 oz) basic slag
treatment 3
57 g + 170 g (6 oz) — i.e. 227 g (8 oz) basic slag
treatment 4
57 g + 283 g (10 oz) — i.e. 340 g (12 oz) basic slag

D planting on the north slope and on the north east slope received:

Autumn (1969)
57 g (2 oz) + 113 g (4 oz) bone meal

Spring (1970)
57 g + 113 g hoof and horn

On Big Waters, basic slag was ripped into the surface prior to seeding. Phosphorus deficits are to be made up with applications of triple super phosphate and basic slag. Recommended site preparation on sites showing severe phosphate deficiency and at suitable gradients e.g. 400 units deficiency might include 1250 kg/ha (10 cwt/acre) high grade slag ripped to a depth of 460 mm (18in), followed later by an application of 375 kg/ha (3 cwt/acre) triple super phosphate cultivated to 225 mm (9in) depth and finally finishing up with a complete compound fertiliser harrowed into the seed bed prior to grass sowing.

At Northbourne Park, no fertiliser dressing has been used on the vegetated banks. Basic slag at 57 g (2oz) and 113 g (4oz) could help to encourage more vigorous growth of plants. Other trees were planted in grass areas which had received varying levels of fertiliser in the seed bed or for upgrading existing cover, but no additional fertiliser to the trees has been applied.

10.2 Cultivation, preparation and grass establishment

10.2.1 Seed bed preparation

(a) *Ripping* The most effective operation used in the research for relieving compaction of existing and re-graded surfaces was found to be ripping. This was to be carried out at 915 mm (3ft) centres × 610 mm (2ft) depth. At Roddymoor under this specification, the ripper tended to rise out of the ground, while at Big

Waters the same phenomenon occurred, leaving a depth at which ripping was effective of only 305 mm (1ft) deep. Durham County Council have suggested that this specification does not provide adequate cones of shattering which meet, and they now specify ripping at 610 mm (2ft) centres X 610 mm (2ft) deep. It was found, however, on the research sites that if the machine operator drove slowly, using a Drott with its three tines set at 915 mm (3ft) apart, adequate depths of ripping were achieved

(b) *Stone picking* The removal of firstly, large stones, and then smaller stones was undertaken. The tracking of loaded trailers on damp soil and shale was a problem as it led to wheel compaction, which in turn led to water running down the tracks and eventually opening up small gulleys (Fig. 10.1).

(c) *Removal of hollows* The hollows left by the removal of the larger stones were smoothed out and filled in by scrubbing. Spring tine and fixed tine cultivators have also been used with success in removing hollows.

(d) *Cultivation* The normal processes of discing, harrowing liming and fertilising were used on the research sites. The application of lime before ripping had the advantage of achieving a better distribution through the profile, and thus helped to neutralize acid formed in the top 610 mm (2ft). Basic slag incorporated in this way is also beneficial for deep rooting species, and, in this respect, cultivating with fixed or spring tine cultivators can help to incorporate basic slag to between 150 and 225 mm (6 in and 9 in) depth.

Whilst accepting the normal practice of avoiding fertiliser and seed distribution at one and the same time, one

Fig. 10.1 Wheel track damage by stone picking trailers may lead to small gulley formation which may be hazardous later to tractor drivers and stock if not treated.

Fig. 10.2 Hydroseeding without mulch of a shallow gradient area on ash over building foundations. CP2 mixture was used. This method may have application where conventional seeding cannot be undertaken because underlying foundations would prevent cultivation by normal agricultural implements.

Fig. 10.3 Eroding surface on the north facing slope at Roddymoor. Rills were in evidence prior to seeding. Mulch held the slope surface until the grass became established.

area seeded in the cooler Autumn had a low nitrogen fertiliser application preceding it on the same day, and no subsequent damage occurred to the young seedlings.

10.2.2 Grass seed broadcasting

The conventional broadcasting machinery was used on Roddymoor and Northbourne Park, i.e. a tractor-drawn, spinner type. On Big Waters, distribution was made by a hand-cranked broadcaster from the back of a tractor-drawn trailer on areas where the seeding rate was very low. With regard to rolling operations after seeding, flat rolling was carried out with seed sown in May 1969 at Roddymoor, and was found to give better contact between the seed and the soil than with harrowing alone. Flat rolling was not, however, used after sowing in the Autumn.

10.2.3 Grass hydroseeding with mulch

At Roddymoor, a wood cellulose mulch, mixed with water fertiliser and seeds, was distributed via extension pipes to the least accessible parts of the north slope The mulch helped to bind the eroding surface (Fig. 10.3) and provided a favourable environment for seed germination. High seeding rates and special seed mixtures were used (see section 10.4. for details of seeding rates and mixtures).

10.2.4 Grass hydroseeding without mulch

The application of seed and fertiliser, using water as the medium for application, was also undertaken on flatter areas where the slopes were not less than 1:15. The machine used is shown in Fig. 10.2. Problems were experienced because of ground conditions and the weight of the machine (14 tonnes) leading to bogging-down and rutting up to 305 mm (12in) depth in some places. In these circumstances, harrowing of the agricultural areas to cover the seed was undertaken.

10.2.5 Turf laying and herbaceous plants

Although the use of turves for establishing a grass cover is unlikely to occur in reclamation projects, except in special circumstances, an experiment was set up at the west end of the north slope at Roddymoor. Erosion in this position had acted against the establishment of a seeded grass cover. It was also decided to assess the ability of various grass and herbaceous species, growing originally under conditions of high altitude or extreme exposure in Scotland, to establish in colliery shale. The turves were 460 mm (18in) $\times$ 305 mm (12in) $\times$ 100 mm (4in) deep, the shale being excavated and the bottom of the hole forked over prior to receiving the turves, which were laid so that they were level with the surrounding shale (see section 10.6).

Experimental plantings of vigorous herbaceous plants were undertaken on the stream banks at Big Waters, although as in the case of turves, the occasions when such plants are likely to be used in reclamation projects are limited.

10.3 Planting trees and shrubs

Several types of tree and shrub nursery stock were planted on the sites, including forestry transplants, oversized forestry stock, whips, 'coppiced' or stooled seedlings, standards and semi-mature trees.

10.3.1 Trees

The different planting techniques used for experimental and comparative purposes were the standard forestry practice: mattock planting on areas with 'natural' soils; pit planting for the oversized forestry stock; the poplars at Roddymoor and Big Waters; and the standards. The semi-mature trees at Egerton Gardens were planted in accordance with B.S. 4043:1966.

10.3.2 Shrubs

Shrubs were planted at Northbourne Park into the existing vegetational cover, at Egerton Gardens into shale, at Roddymoor into the shale surface, and at Big Waters into shale or existing grass cover. The method used was the conventional hole, large enough for the roots to be spread. As anticipated, the shale 'soils' were particularly subject to frost heave, and frequent attention to firming in is recommended.

10.3.3 Cuttings

Considerable experimental work in planting was carried out at the sites with cuttings, some being collected in the countryside by local conservation bodies and by the research staff, and some being obtained from the experimental station at Long Ashton. Both kinds of cutting were planted at Roddymoor and Big Waters into existing vegetated shale or spoil, and directly into shale. A 460 mm x 12 mm dia. (15in x ½in dia.) spike was driven into the different materials to depths between 225 mm and 305 mm (9 in–12in) and the cutting inserted to the appropriate depth using a hormone dip of naphthalene acetic acid with fungicide, Captan. At Roddymoor the hormone was applied to both *Populus* spp. and *Salix*, but at Big Waters in half of the plot areas cuttings were untreated. *Salix* spp. have rooted satisfactorily without hormone, but standard practice with *Populus* spp. is to use a dip.

10.4 Selection of species for grassland

10.4.1 Seed mixtures used and rates of application

Rates of seeding:

(a) Very low (V.L.) represents a low agricultural rate associated with fertile soils. Up to 20 kg/ha (18 lb/acre).
(b) Low (L) represents a generous agricultural rate. Up to 35 kg/ha (32 lb/acre).
(c) Medium (M) represents approximately twice the agricultural rate. Up to 75 kg/ha (66 lb/acre).
(d) Heavy (H) represents three times the agricultural rate. Up to 105 kg/ha (96 lb/acre).
(e) Very heavy (V.H.) represents five times the agricultural rate. Up to 175 kg/ha (160 lb/acre).

The seed mixtures used are coded as G. (grass mixture) or G.L. (grass legume mixture). H indicates that the mixture was applied by hydroseeding.

G.L.1 Recreational use on building debris covered with 100mm N 300mm (4in N 12in) soil

Species	Rate (M)	
	kg/ha	lb/acre
Lolium perenne N.Z.	13.3	12.0
Phleum pratense S.50	6.7	6.0
Festuca pratensis S.53	11.1	10.0
Festuca rubra S.59	5.0	4.5
Trifolium repens S.100	1.1	1.0
Trifolium hybridum	1.8	1.5
	39.0	35.0

G.L.2 Parkland, recreation and forestry cover on shale

Species	Rate 1 (M)		Rate 2 (H)	
	kg/ha	lb/acre	kg/ha	lb/acre
Lolium perenne S.24	13.3	12.0	27.0	24.0
Phleum pratense S.48	6.7	6.0	13.3	12.0
Festuca pratensis S.215	11.1	10.0	22.0	20.0
Festuca rubra S.59	5.0	4.5	10.0	9.0
Trifolium repens S.123	1.8	1.5	3.4	3.0
Trifolium pratense S.184	1.1	1.0	2.3	2.0
	39.0	35.0	78.0	70.0

G.L.5 H.5 Plant cover, prior to tree planting on mixed coke breeze; shale with 100mm subsoil over building foundations; shale (low maintenance)

Species	Rate (M)	
	kg/ha	lb/acre
Agrostis tenuis	5.6	5.0
Festuca rubra commutata	19.7	17.5
Festuca tenuifolia	19.7	17.5
Trifolium repens S.100	3.4	3.0
Trifolium pratense S.123	5.6	5.0
	54.0	48.0

G.L.6 H.6 Plant cover prior to tree planting on shale (low maintenance)

Species	Rate (M)	
	kg/ha	lb/acre
Agrostis tenuis	5.6	5.0
Festuca rubra S.59	19.6	17.5
Festuca tenuifolia	19.6	17.5
Trifolium pratense S.123	13.2	12.0
	58.0	52.0

G. H.4 (with mulch) Plant cover prior to tree planting, on mixed shales — erosion protection

Species	Rate 1 (H)		Rate 2 (V.H.)		Rate 3 (V.H.)	
	kg/ ha	lb/ acre	kg/ ha	lb/ acre	kg/ ha	lb/ acre
Agrostis tenuis	4.2	3.75	5.6	5.0	8.4	7.5
Dactylis glomerata S.37	4.2	3.75	5.6	5.0	8.4	7.5
Dactylis glomerata S.3143	4.2	3.75	5.6	5.0	8.4	7.5
Dactylis glomerata S.26	4.2	3.75	5.6	5.0	8.4	7.5
Festuca rubra S.59	37.8	33.75	50.4	45.0	75.6	67.5
Festuca rubra commuta	14.7	13.125	19.6	17.5	29.4	26.25
Festuca tenuifolia	14.7	13.125	19.6	17.5	29.4	26.25
	84.0	75.000	112.0	100.0	168.0	150.0

G.L.7 H.1 Plant cover on coke breeze, to prevent erosion (low maintenance)

Species	Rate (L)	
	kg/ha	lb/acre
Festuca rubra S.59	16.8	15.0
Medicago lupulina (substituted for:	9.0	8.0
Lotus corniculatus)	(9.0)	(8.0)
	25.8	23.0

G.L.10 Parkland, low maintenance on imported Dinnington shale

Species	Rate 1 (V.L.)		Rate 2 (V.L.)	
	kg/ha	lb/acre	kg/ha	lb/acre
Phleum pratense S.50	9.0	8.0	13.3	12.0
White Clover S.100	2.3	2.0	3.4	3.0
	11.3	10.0	16.7	15.0

G.L.18 Agricultural pasture on shale. A Lancashire C.C. (L.C.T.) mixture

Species	Rate (M)	
	kg/ha	lb/acre
Lolium perenne S.24	11.1	10.0
Lolium perenne N.Z.	11.1	10.0
Dactylis glomerata S.341	7.9	7.0
Dactylis glomerata S.37	5.6	5.0
Phleum pratense S.48	3.8	3.5
Phleum pratense S.51	7.9	7.5
Festuca pratensis S.215	5.6	5.5
Festuca pratensis S.53	7.9	7.5
Trifolium repens S.100	2.3	2.5
Trifolium pratense S.123	3.8	3.5
	67.0	60.0

G.L.11 Agricultural mixture – Northumberland

Species	Rate (L)	
	kg/ha	lb/acre
Lolium perenne S.23	22.0	20.0
Festuca rubra S.59	5.6	5.0
Agrostis tenuis	2.3	2.0
Trifolium repens S.100	1.1	1.0
Trifolium repens Wild white	1.1	1.0
Trifolium hybridum	1.1	1.0
	33.2	30.0

G.L.9 Cockle Park (C.P.) mixture. Agricultural pasture on stored soil (Rate 1) and shale (Rate 2)

Species	Rate 1 (M)		Rate 2 (M)	
	kg/ha	lb/acre	kg/ha	lb/acre
Lolium perenne S.24	15.7	14.0	31.2	28.0
Dactylis glomerata S.37	7.9	7.0	15.6	14.0
Phleum pratense S.51	4.5	4.0	9.0	8.0
Trifolium repens S.100	2.3	2.0	4.5	4.0
Trifolium pratense S.123	3.4	3.0	6.7	6.0
	33.8	30.0	67.0	60.0

G.L.12 Plant cover prior to tree planting

Species	Rate (L)	
	kg/ha	lb/acre
Lolium multiflorum Westerwolds	10.1	9.0
Dactylis glomerata S.143	13.3	12.0
Poa trivialis	3.4	3.0
Festuca rubra	3.4	3.0
Trifolium repens S.100	1.1	1.0
Trifolium repens Wild white	1.1	1.0
Trifolium hybridum	1.1	1.0
	33.5	30.0

G.L.13 Agricultural mixture — Derbyshire, on shale

Species	Rate (M) kg/ha	Rate (M) lb/acre
Lolium multiflorum Danish	22.0	20.0
Lolium perenne S.23	33.0	30.0
Trifolium repens N.Z.	3.4	3.0
Trifolium repens Kentish wild	1.1	1.0
	59.5	54.0

G.L.14 Temporary use on mixed topsoil and shale area

Species	Rate (M) kg/ha	Rate (M) lb/acre
Festuca rubra S.59	11.2	10.0
Lolium perenne S.23	16.8	15.0
Phleum pratense S.48	3.4	3.0
Trifolium repens S.100	2.2	2.0
Poa pratensis	3.4	3.0
Agrostis tenuis	5.6	5.0
	42.6	38.0

10.4.2 List of grass and legume species

Latin name	English name	Strains
Lolium perenne	Perennial Rye-grass	S23, S24, N.A. Mother
Lolium multiflorum	Italian Rye-grass	Westerwolds, Danish
Dactylis glomerata	Cocksfoot	S37, S341, S143, S26
Festuca rubra rubra	Creeping Red Fescue	S59
F. rubra commutata	Chewings Fescue	
F. Tenuifolia	Hard Fescue	
F. pratensis	Meadow Fescue	S215, S53
Agrostis tenuis	Bent	
Phleum pratense	Timothy	S48, S51
P. bertolonii	Small Timothy	S50
Poa pratensis	Rough Stalked Meadow Grass	
Trifolium repens	White clover	Kentish wild, N.Z., S100, S184, wild
T. pratense	Red clover	S123
T. hybridum	Alsike clover	
Lotus corniculatus	Birdsfoot Trefoil	
Medicago lupulina	Black Medock	

10.4.3 Performance of seed mixtures after 12 months

(a) G.L.1

Origin	Based on a Lancashire mix (cocksfoot element omitted).
Site	Northbourne Park
Use	Recreation
Comment	Successful at medium rate
Dominant species	Rye-grass

(b) G.L.2

Origin	As above
(i)	
Site	Northbourne Park
Use	Recreation
Comment	Successful at medium rate
Dominant species	Rye-grass, some patches of white clover
(ii)	
Site	Big Waters
Use	Parkland
Comment	Successful at medium and high rate
Dominant species	To be assessed

(c) G.L.5, H.5

Origin	Based on suitability of individual species
Site	(i) Roddymoor (ii) Big Waters
Use	Cover prior to forestry planting
Comment	Successful at medium rates for cover
Dominant species	Part Red clover dominant

N.B. Part red clover dominant, may suppress trees below 450mm (1½ft). 600mm (2ft) transplants and larger unaffected. Suggest red clover removed from low maintenance mixtures to be cut, or where small transplants to be used.

(d) G.L.6, H.6

Origin	As above
Site	As above
Use	As above
Comment	As above
Dominant species	Suggest red clover substituted with white clover

(e) G.L.7, H.1

Origin	As above
Site	Roddymoor
Use	Erosion control
Comment	Successful at low rate
Dominant species	Fescue mainly dominant some areas Medick dominant

(f) G.H.4

Origin	As above
Site	Roddymoor
Use	Erosion control on steep slope
Comment	Successful at heavy to very heavy rates. Excellent cover over majority of site. Cover disappears from area with pH 3.5
Dominant species	*Agrostis tenuis*

(g) G.L.8, L.C.T.

Origin	Based on experience of Lancashire County Planning Department on performance of seeds in mixtures
Site	Roddymoor
Use	Agriculture
Comment	Problems were met due to inadequate ripping depth, late sowings and under surface heating (350° C at 1.5m depth). Eventually successful at medium rates.
Dominant species	In parts Timothy, and white clover on areas of under surface heating

(h) G.L.9, C.P.

Origin	As above
Site	(i) Roddymoor (ii) Big Waters
Use	Agriculture. Cover prior to forestry planting
Comment	Grass successful at medium rate
Dominant species	Rye-grass under agriculture. Clover in forestry areas at Roddymoor

(i) G.L.10

Origin	Based on species used in a horticultural ley for sowing down orchard
Site	Big Waters
Use	Minimum maintenance
Comment	Mixture successful at very low rate associated with good horticultural soil
Dominant species	Timothy. White clover

(j) G.L.11

Origin	N.A.A.S. (Newcastle)
Site	Northumberland C.C. sites
Use	Agriculture
Comment	Low rate recommended

(k) G.L.12

Origin	As above
Site	As above
Use	Cover prior to forestry planting
Comment	Low rate recommended

(l) G.L.13

Origin	N.A.A.S. (Derbyshire)
Site	Derbyshire sites
Use	Agricultural
Comment	Successful at medium rate

(m) G.L.14

Origin	Based on suitability of individual species
Site	Maria Colliery
Use	Cover prior to industrial use
Comment	Apart from a small area on good top soil, weed growth has severely limited the growth of grass

10.4.4 Comments on seed mixture performance

(a) *Roddymoor* Whilst areas with a natural soil cover were seeded with G.L.9 at a normal agricultural rate (C.P.1), the shale areas were seeded at double the standard agricultural rate with two mixture (C.P. Rate 2 and LCT). The results on areas of red shales plus mixed shales, and which were also exposed, suggested that a seed mixture with a wide range of species would be more appropriate.

The grass seed mixture G (H4) and seed mixtures hydroseeded together with tree seed mixture (H2 and H3) were sown at various rates to provide protection against erosion on slopes, and as a cover to assist in the subsequent establishment of trees. The success of individual species in the seed mixture G, at different sowing rates, is recorded in Chapter 9.

Seeding at Roddymoor was undertaken during the last week in August, and during September 1968, the last sowing being made on October 4 on the exposed Parcel 10. (Fig 10.4) Although there was no sign of heating detectable by thermometer, steaming became obvious during the winter months, showing a high state of oxidation. Surface temperature readings ranging between 50°C and C and ambient were recorded with an air temperature of 0°C. A white clover sward now

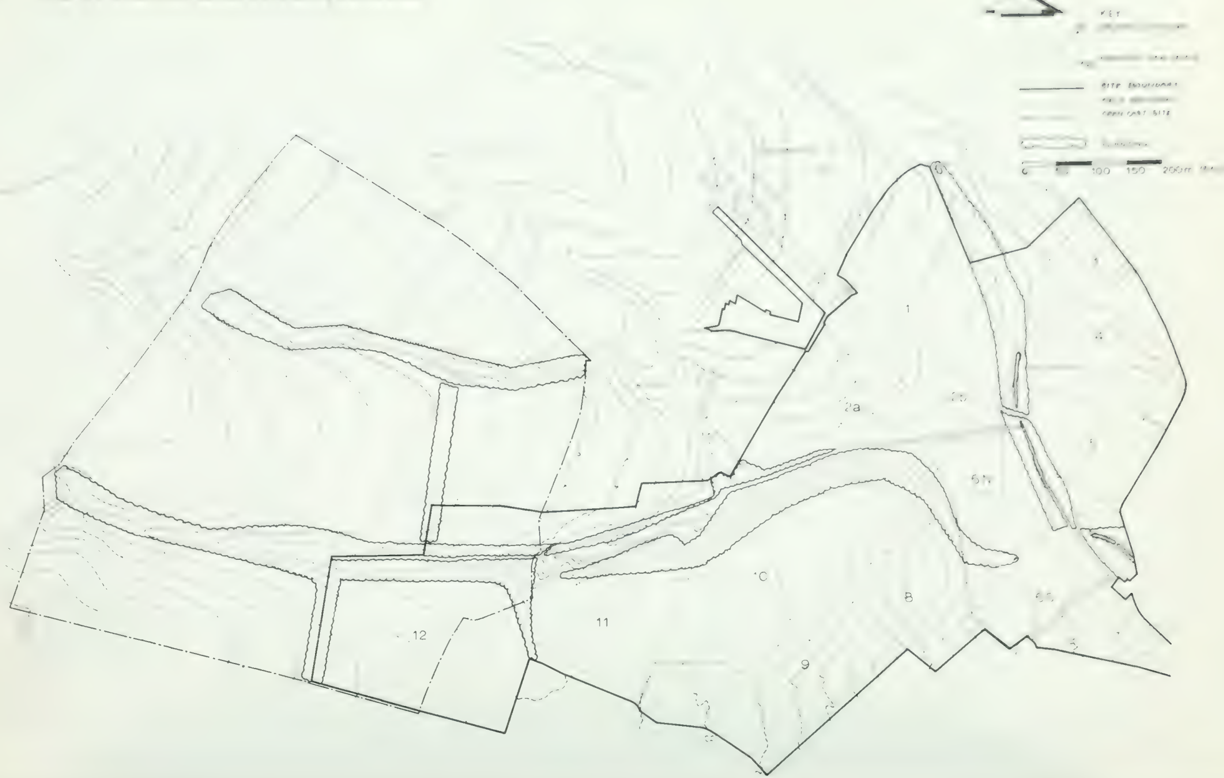

Fig. 10.3 Roddymoor. Layout plan showing planted areas.

dominates some of these areas of high activity. Over the rest of the site the clover content of the sward is markedly reduced from what it should be.
6S (Fig 10.4) was sown in May 1969 and the incorporation of farmyard manure in the seed bed may have helped the seedlings over a difficult moisture stress period. Elsewhere, seedlings on shale suffered from drought, many of the seedlings being killed; some seed remained dormant until Autumn and helped to infill some of the bare areas.

(b) *Big Waters* Areas which were to be agriculturally useful were sown with standard agricultural mixtures at a generous rate (C.P. Rate 1) and at double rate (C.P. Rate 2).

Areas to be planted with trees were sown with an agricultural mixture (C.P. Rate 1). The mixture was found to be difficult to maintain around the trees and is not recommended for cover prior to planting unless wide spacings allow for, say, hay cropping as a maintenance procedure.

(c) *Maria Colliery* The use of the site after grass development will be of a temporary nature, pending permanent uses, thus it was decided that soil differences need not be meticulously observed in the selection of a seed mixture.

(d) *Northbourne Park* The areas for open space used on Northbourne Park were sown at agricultural rates (LCT). The rate was a generous agricultural application but at about a third of the usual rate for open space sowings. Species liable to form tufts (cocksfoot) were omitted from the mixture (G.L.1 and G.L.2). Areas sown for later tree planting had a mixture of fine-leaved species sown at low rates, but sufficient to give a good plant cover.
For areas to be planted later with trees or shrubs, a fescue/bent mixture was used to give minimum competition.

The May 1968 seeding of G.L.1 and G.L.2 germinated very rapidly and gave excellent cover within six weeks. Areas sown in November 1968 did not germinate until Spring 1969. Spring sowings were made in 1969, again in May, on two ash areas; one took and the other failed.

10.5 Selection of tree and shrub species

The factors taken into account in species selection were soil type, aspect, water table, use of the area planted, ecological and visual appropriateness, availability, and the need to include a wide range for experimental purposes.

In the course of the experimental work, a considerable number of species was planted, and records kept of the materials into which the planting was carried out, and into the subsequent performance. Because of the complexity of this information, the major findings are summarised; these inevitably include damage by vandalism etc., as well as 'natural' failures.

10.5.1 Species used

Latin name	English name	Average percentage success after 12 months on all sites
(a). Standard trees (planted at between 0.9 and 3.0 m (3ft – 10ft) high)		
Alnus glutinosa	Common alder	71
Alnus incana	Grey alder	90
Alnus cordata	Italian alder	90
Alnus rubra		90
Acer platanoides	Norway maple	62
Acer pseudo-platanus	Sycamore	64
Betula pendula	Silver birch	98
Crataegus monogyna	Hawthorn	83
Fraxinus excelsior	Common ash	60
Populus alba	White poplar	90
Populus canescens	Grey poplar	90
Populus trichocarpa	Western balsam poplar	90
Salix alba	White willow	90
Salix vitellina	Golden willow	80
Sorbus aria	Whitebeam	90
Sorbus aucuparia	Mountain ash	90
Sorbus domestica	Service tree	80
Sorbus intermedia	Swedish whitebeam	90
Tilia platyphyllos	Lime	90
(b) Semi mature trees (planted 6m – 7m (20ft – 24ft) high)		
Acer pseudo-platanus	Sycamore	0
Betula pendula	Silver birch	0
Sorbus aucuparia	Mountain ash	0
(c) Forestry transplants or tree seedlings (planted 0.4m – 1.2m (1ft 4in – 4ft) high for 1 year + 1 year; 0.6m – 1.4m (2ft – 4ft 8in) high for 2 years + 1 year)		
Alnus glutinosa	Common alder	75
Alnus incana	Grey alder	68
Betula pendula	Silver birch	60
Crataegus monogyna	Hawthorn	80
Fagus sylvatica	Beech	[illegible]
Pinus nigra var. austriaca	Austrian pine	75
Pinus nigra var. calabrica	Corsican pine	75
Pinus sylvestris	Scots pine	75
Populus alba	White poplar	90
Pinus × berolinensis		[illegible]
Populus canescens	Grey poplar	90
Populus tacamahaca × tuchocupa	Balsam poplar	[illegible]
Prunus avium	Gean	78
Prunus padus	Bird cherry	83

Salix alba	White willow	80
Salix alba 'Liempole'	–	80
Sorbus aria	Whitebeam	90
Sorbus aucuparia	Mountain ash	83

(d) Stooled trees (planted cut back to 0.15m – 0.46m (6in – 1ft 6in) high)

Betula pendula	Silver birch	39
Fraxinus excelsior	Common ash	86
Fraxinus ornus	Manna ash	60
Populus alba	White poplar	77
Sorbus aucuparia	Mountain ash	60
Salix vitellina	Golden willow	30

(e) Shrubs – pot grown (planted 0.2m – 0.9m (8in – 3ft) high)

Cotoneaster simonsii	–	75
Hedera hibernica	Irish ivy	75
Hypernicum calycinum	St. John's Wort	90

(f) Shrubs – transplants (planted 0.4m – 1.4m (1ft 4in – 4ft 8in) high)

Berberis vulgaris	–	0
Cornus stolonifera var. *flaviramea*	Yellow-bark dogwood	73
Cornus mas	Cornelian cherry	60
Cornus alba sibirica	Red-bark dogwood	90
Cotoneaster simonsii	–	54
Hypericum calycinum	St. John's Wort	20
Mahonia aquifolium	–	
Malus sylvestris	Applestock	76
Ligustrum vulgare	Privet	100
Polygonum baldschuanicum	Russian vine	10
Rosa moschata	–	66
Rosa canina	–	60
Rosa wichuriana	–	N/A
Rosa rubiginosa	Sweet Briar	N/A
Rosa spinossissima	Scotch rose	52
Rosa rugosa	–	46
Rosa multiflora Japonica	–	65
Rubus 'Malling Promise'	–	84
Rubus deliciosus	–	N/A
Rubus fruticosus	Common blackberry	N/A
Rubus spectabilis	–	N/A
Salix purpurea	Purple osier	8
Salix cinerea	Grey willow	36
Salix caprea	Goat willow	32
Salix viminalis	Common osier	41
Sambucus nigra	Common elder	73
Sambucus racemosa	Red elder	90
Sorbus aucuparia	Mountain ash	95
Prunus cerasifera	Myrobalan plum	85
Robinia pseudoacacia	Common acacia	100

(g) Shrubs – stooled (planted 0.46m – 1.2m (1ft 8in – 4ft) high)

Corylus avellana	Hazel	0
Cornus alba sibirica	Red-bark dogwood	54
Salix caprea	Goat willow	70

N/A signifies that an assessment has not been possible to date.

10.5.2 Performance of various species

(a) *Standard trees* In general over all sites, trees planted as standards survived and made growth. Alder spp., poplars and *Sorbus* spp. being particularly successful, while the most doubtful species were ash and birch, although vandalism was a factor in this respect. A special point is made in respect of the Big Waters site where very dry weather conditions prevailed during the Spring and early Summer after planting, but after an initial check, the survival rate was very high, due no doubt to the high standard of planting carried out by the forestry staff of the Northumberland County Council.

(b) *Semi mature trees* These were used experimentally on one urban site Egerton Gardens, and the total loss was due entirely to vandalism. It is unfortunate that on urban sites, where trees planted initially at a large size are desirable, failures due to external circumstances are most likely to occur.

(c) *Forestry transplants* Despite the likelihood of more failures than with the 'individually' planted standard trees, the results from the species selected were encouraging. Although the percentage of success over all the sites for alder was lower than for some other species, *Alnus glutinosa* was very successful. Willows and poplars proved their usefulness on reclaimed sites, and Scots pine was noted as a successful conifer. Birch again proved an uncertain species.

(d) *Stooled trees* Site conditions produced considerable variation in the performance figures, but mountain ash and white poplar were generally regarded as successful. Despite the low figure for willow, this genus is likely to perform well under the stooling technique.

(e) *Shrubs — pot grown* The results were variable. For example, the first planting of *Hypericum* had a poor survival rate, but a second attempt in the following year was successful.

(f) *Shrubs — transplants* Dogwood proved the most reliable shrub, whilst *Rosa* spp. also proved useful and gave visual interest at an early stage.

(g) *Shrubs — stooled* The results were achieved on a site subject to much vandalism and atmospheric pollution, and were sufficiently good to justify this technique as worthwhile.

10.5.3 Cuttings

Several experimental plantings were made with tree and shrub cuttings planted directly into the soil material. This is a cheap and useful method of developing a tree and shrub cover, and the following summarises our experience to date.
Cuttings planted in a meadow habitat at Big Waters suffered from grass competition, vandalism and trespass by cows.

The *Populus* cuttings suffered from grass competition, high water table and waterlogging during the growing season. Areas where grass cover was sparse helped cuttings of *Salix* and also cuttings of *Cornus sanguinea* by making them less visible to vandals and by shading, providing a more favourable microclimate for the establishment of cuttings during the hot spell in June.

Populus cuttings at Roddymoor on the shale gave a 40% take. Where they were planted in meadow the grass overtopped them and killed them. *Salix* cuttings from Witton-le-Wear Nature Reserve were successful giving an overall take of 66% with some plots giving 100%, the worst performance being 20%. The Gosforth Park Willows especially the *S. cinerea* type performed poorly, giving complete failure in some cases and in no case was the take above 48%.
S. Fragilis gave a 92% take. The *Salix* from Long Ashton were in the poorest material, ash over building foundations, and performance was varied.
S. cinerea failed completely, *S. purpurea* 'Iretto' gave a 58% take, *S. daphnoides* 'Oxford Violet' 52%, *S. viminalis* 'Mealy Tops' 52%, *S. viminalis* 'Gigantea' 30%, *S. purpurea* 'Dicky Meadows' 32%, *S. daphnoides* 'French Purple', *S. triandra* and *S. daphnoides* × *caprea* all gave takes under 15%. The best performance was from a 19mm (0.75in) by 380mm (1ft 3in) *viminalis* type cutting from Witton-le-Wear which put out two leaders, one growing to 1525mm (5ft) and the other to 1170mm (3½ft) in the season of planting.

10.6 Experimental turf plantings (see 10.2.5)

A number of turves from high altitude sites in the north of Scotland were laid on an area at the Roddymoor site.

(a) *The western part of the area* Here the surface material was bare or sparsely vegetated shale, and the dominant species in each turf and the place and altitude of origin were as follows (reading from east to west):

Nardus stricta (Slochd (S) 390m (1300ft)), *Poa trivialis* (Corrischullie 330m (1100ft)), *Festuca tenuifolia* (S), *Holcus lanatus* (S), *Phleum pratense* (S), *H. mollis* (S), *Festuca ovina* (Dalmagerry 271m (904ft)), *Festuca rubra* (S), *Galium saxatile* (S), *Poa pratensis* (S), *Agrostis tenuis* (Tomdhu 195m 650ft), *Agrostis canina* Carrbridge (a) 330m (1100ft)), *Deschampsia flexuosa* (Ca), *Anthoxanthum odoratum* (S), *Trifolium repens*, *Vaccinium vitis-idaea*, *Luzula spicata* (S).

The results of this experiment were generally successful. The dominant species in each turf now varies from being 'present' on the turf to being 'dominant'. For example *Nardus stricta* and *Festuca tenuifolia* were found to be frequent on their respective turves, but *Vaccinium vitis-idaea* was found to be only present on its turf.

(b) *The eastern* turves were laid on a bare slope from which the sown grass had died out. This bare area was found to have a pH of 3.4 and a phosphorus deficit of 400 units at the end of 1969, thus the turf species have been subjected to severe conditions. Six rows of turves were planted across the slope, two thirds down the slope to help prevent erosion. The number of turves in each row varied from four to eleven.

The rows are numbered from the top of the slope (south) to the bottom of the slope (north) and the dominant species in each turf are listed reading from east to west across each row.

(i) *Rubus chamaemorus* 2, *Salix herbacea* 4 (Dunnet Head, Pentland Firth 120m (400ft))
(ii) *Vaccinium vitis-idaea* 3 (S), *Trifolium repens* 2 (S), *Betula nana* Hills of N.W. of Rogart, Sutherland 360m (1200ft) *Vaccinium myrtillus* 3 (S)
(iii) *Lathyrus montanus* 4 (Nethy Bridge (N.B.) 210 m (700ft)), *Veronica officinalis* 2 (Lecht Mt. Tomintour 422m (1405ft))
(iv) *Trifolium pratense* 2, N.B., *Ranunculus flammula* 2, N.B., *Lotus corniculatus* 2, N.B. and Tulloch. *Potentilla erecta* 3 (Boat of Garten (B.G.) Tulloch 240m (800ft)), *Polygala vulgaris* 2, B.G.
(v) *Galium saxatile*, 2, B.G., *Luzula campestris*, 3 (Bridge of Brown Tomintour 427m (1424ft)), *P. erecta* 2, B.G. *Polygala vulgaris* 1, B.G.
(vi) *Rubus chamaemorus*, 4.

The results of this experiment as regards the dominant species were similar to the turves referred to in (a) above. Only one species had, after two years, started to colonise the shale around, this being *Trifolium pratense*. *Betula nana*, *Vaccinium myrtillus*, *Rubus chamaemorus*, and *Vaccinium vitis-idaea* survived and show slight signs of growth. *Galium saxatile*, *Polygala vulgaris* and *Ranunculus flammula* appeared to be dying off.

Turfing is an expensive operation and on the large scale would be impracticable; however, for small areas with specific erosion problems it is possible to use turves as has already been described. The western turves at Roddymoor closed the foot gap between them in a season and trapped wind-blown and water-washed seed uphill and downhill giving visual continuity in the small scale within three months. The eastern turves have not closed the gaps, presumably due to low pH (3.4) and severe nutrient deficiency. They have, however, remained intact and formed a useful barrier to rill erosion.

10.7 Experimental herbaceous plantings (see 10.2.5)

These were planted at the Big Waters site in a neutral shale with relatively good nutrient characteristics in April 1970. The initial impact was minimal. However, after a dry summer until August, the results by the end of August were good, both as to survival and appearance. The species were as follows and 45 plants of each were planted in groups:

Species	Performance
Alchemilla mollis	All species survived well into the first year after planting, despite a dry initial Summer. Many of them have already put on growth
Artemisia palmeri	
Baptisia australis exaltata	
Brunnera macrophylla	
Centaurea steenbergii	
Cynoglossum sp. X	
Epimedium perralderianum	
Festuca glauca	
Geranium armenum	
G. 'Claridge Druce'	
G. grandiflorum alpinum	
G. ibericum	
G. sylvaticum album	
G. wallichianum	
Hosta fortunei	
H. undulate erromena	
Inula hookeri	
Lamium galegobdolon florentinum	
Lysimachia punctata	
Polygonum reynoutria	
Salvia superba	
Spartina pectinate aurea	
Stachys byzantinus	
Stipa gigantea	
Symphtum caucasicum	
Tellima grandiflora purpurea	
Tradescantia subaspera montana	

10.8 Conclusions

The most important aspect in vegetating derelict sites is to treat each site on its own merits. The following general principles are put forward:

(a) The first essential is to assess the waste material as a soil forming agent, and to undertake lime and major nutrient requirement tests, particularly phosphorus and potassium.

(b) The preparation of the site must ensure adequate relief from compaction by heavy ripping. If the site has a history of industry, then the foundations or other waste should be covered with at least a 915mm (3ft) depth of suitable material so that ripping could provide a reasonable medium for plant growth. If possible at the design stage the incorporation of slopes no greater than 1:8 will ensure maintenance problems are reduced to a minimum by allowing agriculture to take place. If steeper slopes are designed, then access to allow for mechanical fertilizer spreading should be built into the design.

(c) Removal of stones and preparing the seed bed so that a favourable environment for plant growth is created is an essential part of the process. Deep ripping with lime and basic slag, deep cultivation with triple superphosphate, and harrowing-in of a combined complete fertiliser in a phosphorus deficient material should help to reduce the possibilities of plants going into check.

(d) Having assessed the soil forming capabilities of the material and made good any deficiencies of the major nutrients, suitable seed mixtures can be selected and applied at the appropriate rates. The more fertile the material, the nearer to an agricultural rate of sowing. One and a half times should be adequate, but under adverse physical conditions twice the rate would be more appropriate. Three times the agricultural rate should be sufficient for the most rapid cover on slopes prone to erosion or for general use.

(e) *Grass and legume species performing successfully for different uses on the project sites*

(i)	Agriculture	
	S24 Perennial Rye Grass	*Lolium perenne*
	S51 Timothy	*Phleum pratense*
	S100 White clover	*Trifolium repens*
(ii)	Forestry and woodland areas	
	S59 Red Fescue	*Festuca rubra*
	Black Medock	*Medicago lupulina*
	Creeping Bent	*Agrostis tenuis*
	S100 White clover	*Trifolium repens*
	S123 Red clover	*T. pratense* (seed heads overwintering give brown effect apart from vigour which may tend to swamp small transplants)
(iii)	Recreational areas	
	S.24 P.R.G.	*Lolium perenne*
	E.Z. Mother P.R.G.	*L. perenne*
	S.59 Red Fescue	*F. rubra*
	S.184 White clover	*T. repens*
(iv)	Parkland	
	S.50 Timothy	*Phleum bertolonii*
	S.100 White clover	*T. repens*

(f) *Shrub species which have performed successfully*

(i) Flowers, fruit, erosion protection
Rosa and *Rubus* spp.

(ii) Spring colour, erosion protection
Salix spp.

(iii) Erosion protection, winter colour
Cornus spp.

(g) *Hedgerow species. Crataegus monogyna, Prunus padus, P. avium* and *Sorbus aucuparia* all performed well.

(h) *Standard trees. Sorbus aria* made the best contribution. *Sorbus aucuparia* and *Crataegus monogyna* did well. *Acer pseudoplatanus,* used to replace dead species which had not be vandalised, did not suffer as badly from vandalism as the *Populus tacamahaca* substituted for the *P. canescana* at Northbourne Park. *Alnus glutinosa* also did well.

(i) *Stooled trees. Sorbus aucuparia* made the best contribution, but *Populus alba* and *Betula pendula* also did reasonably well.

(j) *Forest transplants. Alnus glutinosa* established the best. *Sorbus aucuparia* established satisfactorily and *Salix alba* established well in some parts of Roddymoor. *Pinus sylvestris* did well, *Betula* could be regarded as failed.

(k) *Nursery stock. Sorbus aucuparia* established the best and *Robinid pseudoacacia, Crataegus oxycantha, Prunus padus, P. cerasifera* and *Malus communis* (Apple stock) all did well.

(l) *Cuttings. Salix* spp. established well, *Populus* less well. *Alnus* apical cuttings 460mm (18in) rooted in a shaded silty area.

It should be emphasised that the tree and shrub species selected should take account of the individual site conditions, such as the physical nature of material, exposure, local climate etc., and also note should be taken of the local hedgerow and tree species so that the vegetational cover produced relates to or extends the range of species in a harmonious manner. This approach will help to integrate the reclaimed landscape with the surrounding landscape.

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Chapter 11 Contract procedure

by I.S. Clark

11.1 Introduction

This chapter examines and considers the various aspects of contracts for land reclamation including forms of contract, the competitive element, modifications to standard conditions, specification, bills of quantities and administration of contracts.

All the schemes executed as part of the research project were carried out for local authorities receiving government grant but the procedures examined in this chapter are considered in broad terms and not restricted to local authority reclamation schemes.

11.2 Contracts generally

It is as well at the outset to consider the types of contract procedure and their application to reclamation before proceeding to examine the specific details of a land reclamation contract document.

11.2.1 Types of contract

It is convenient to consider contracts under two heads:
(a) *Incentive and risk bearing contracts* in which the contractor is awarded the contract either by competition or negotiation, estimated against the background of market prices ruling at the time. In this case the contractor has a high incentive to lower his costs and thereby increase his profit.

(b) *Cost reimbursement contracts* in which the contractor is paid his prime cost plus either a percentage or a fixed fee for site management, overheads and profit. Incentive and risk is low in this procedure. A contractor has no incentive to decrease cost, indeed quite the reverse with a percentage fee.

A method which falls between the incentive risk-bearing contract and cost reimbursement contract is the target cost contract where the contractor is given a partial incentive for any cost reduction he can make by sharing this in an agreed proportion with the employer.

The ideal procedure from the point of view of the employer is one where the contractor has a low element of risk, together with a financial incentive to reduce cost and is given the maximum opportunity to do so without detriment to the standard of workmanship. There is, of course, a limit to the amount of incentive which can be provided and the degree to which risk can be eliminated.

11.2.2 Competition

Excluding pure cost reimbursement contracts, all other types relate to the competitive market for their basis of pricing. It follows therefore that it is necessary to test market conditions. In competitive tender contracts the market is tested for each individual contract, whilst in negotiated contracts there is a tendency for a degeneration into a cost reimbursement situation unless recourse is made from time to time to the competitive market. This does not preclude negotiation of a string of serial or continuation contracts but it does suggest that running concurrently with these there should be similar contracts based on competitive tenders to provide comparisons of negotiated price with market trends.

11.2.3 Application to reclamation

Having examined the types of procedure and their relationship in respect of competition generally they can now be considered specifically in relation to their application to land reclamation.

Whilst land reclamation has been carried out in this country for many years, such as restoration of land as part of open cast mining operations, reclamation as the prime intention of a contract is relatively new. Simply stated, it is a combination of landscape and civil engineering contracting and yet the earthworks encountered are generally of a magnitude beyond the normal scope of a landscape contractor and the constructional work in the sense normally associated with civil engineering contracts does not exist. It is not surprising therefore that a number of rates and prices will differ greatly from those normally encountered in landscape or civil engineering contracts, and it follows that it is highly desirable to carry out a thorough test of market conditions by 'open' or 'selective' tendering prior to the introduction of other procedures.

Open and selective tender contracts
The 'open' tenders, or more properly tenders sought by public advertisement, have the advantage of providing in a short time a good indication of the scope, nature and price range of the market. In the long term they have the distinct disadvantage of the lack of selectivity and a tendency to make the market stale by attracting the cut-price firms, who often execute one contract and disappear, and discourage more reputable firms.

During the course of the research project it was found that tenders sought by the 'open' procedure usually resulted in keener tenders than those by the 'selective' procedure; however, it was evident that some of the firms submitting the lowest tender in the 'open' procedure were not ideally equipped either administratively or with suitable plant to execute the work satisfactorily. This was not so in those contracts using the 'selective' procedure where careful consideration could be given to the capabilities of the firms chosen to tender.

To some extent the 'select' tender also provides indications of market conditions. An indication of the scope and the nature of the market can be achieved by public advertisement seeking firms interested in this type of project, but since only a select number will be invited to tender for each project the price range of the market will not be evident immediately. Two essential factors emerge from this: firstly, that a list of competent firms must be made, with details of their capabilities in terms of size and nature of project that each can handle, and secondly, that a comprehensive list of price levels and market trends must be kept up to date. In respect of the latter there is possibly scope for the employment of the central agency to collect, analyse, and publish such cost information relating to reclamation schemes.

The adoption of a selected list of approved contractors from open tender experience does not preclude the addition of new firms to the list. In fact this is essential to maintain a healthy and competitive market.

The list of firms so compiled should be in categories related to plant and management capabilities, or, more simply stated, in terms of cost. At first sight it might appear that three categories could be usefully employed, namely small, medium and large. However, considerable difficulty has been experienced in the classification of firms in each category and it is submitted that for reclamation schemes two categories suffice to meet normal requirements:

Contracts up to £25,000 in value
Contracts over £25,000 in value

Up to £25,000 suggests the smaller landscape scheme with more emphasis on minor grading work using relatively small machines rather than heavy earth moving equipment. Over £25,000 usually involves the use of these heavier machines and firms with the organisation and the type of machines necessary to carry out such works are invariably capable of executing contracts ranging from tens to hundreds of thousands of pounds in value.

Within each category the number of firms listed should be of sufficient number to avoid the necessity of inviting the same firm to tender for several schemes which could give one firm more than its fair share. There is also the danger of price rigging between tenderers if the list is small.

Great care is required in selecting tenderers from the list to ensure genuine interest, that they have operatives, plant and management facilities available for such a project, that the value and nature of the work is within the price range and scale of works they normally undertake and that a sufficient number of firms are invited to provide an adequate element of competition. This does not necessarily guarantee the lowest possible tender, but providing care is taken in selecting the tenderers it does ensure a competitive and reasonable tender from a firm known to have the required capabilities and standards of workmanship. It is suggested that a useful guide to the number of tenderers can be obtained from the codes of procedure for selective tendering for the building and civil engineering industries and for most schemes six or at the most eight selected firms should provide an adequate degree of competition.

The lists of approved firms in each category will require constant revision to take account of new firms entering the market, existing firms withdrawing or changing from one category of work to another. The maximum number of firms in each category need not be fixed but the minimum should be related to the average number of schemes in each category sent out to tender each year to ensure the availability of a different list of firms for each project in a category during any one year.

It is evident that a three-phase procedure could usefully be adopted by an organisation contemplating reclamation on a large scale. The first to establish market conditions by 'open' tender; the second to introduce 'selective' tendering once market conditions have been satisfactorily tested and established; and third to introduce serial or continuation contracts to reduce contract risk and promote incentive cost reductions by planned capital investments in plant.

An employer with a major reclamation programme could well adopt a series of continuation contracts with a number of selected contractors based on the following procedure:

(a) *Selection of contractors* The contractors invited to participate would have to be selected from a carefully compiled list. Experience of individual contractor's performances gained from the open and selective procedures would greatly assist in this selection.

(b) *Scope* The number and value of the schemes offered would have to be sufficient in monetary value and period of time over which they are to be executed, to provide the contractor with the necessary incentive. The attractions must be for the purchase of plant almost specifically for the schemes and its use over a period of time would greatly reduce the risk element of the investment in expensive machinery. This in turn would have a marked effect on unit rates because plant rates for normal contracting work contain a large element for lost-working or non-working time and are therefore inflated to cover this element.

(c) *Tender procedure* The tender procedure would require careful consideration. Essentially an element of competition should be introduced for each series of contracts, either by inviting selected contractors to submit a schedule of rates and percentage addition for on-costs and profits expressed against a specified lump sum, or alternatively tender for a specific project split into (a) lump sum for the works (b) lump sum for on-costs, preliminaries and site management and (c) a lump sum for head office charges and profit. The sums for (b) and (c) can then be expressed as a percentage for following contracts in the series.

(d) *Safeguards* Safeguards in the form of penalties for termination of the series would be required in the event of the chosen contractor not providing an acceptable standard of performance, in effect the provision of a 'break' clause between each contract in a series.

(e) *Fluctuations* Provision would be required for fluctuations in rates of wages, cost of materials and all other costs, taxes etc., varying between contracts in a series.

(f) *Form of contract* The form of contract would not differ greatly from a normal lump sum contract and existing forms would be readily adaptable.

The above is possibly an over simplified statement of a possible procedure and other factors would require consideration, these include: careful programming of future projects to guarantee contract continuation in the series; early employment of the contractor's expertise in design and methods of working, thereby increasing his incentive to reduce cost; whether limitations are to be put on the scope of each contract in a series, that is whether certain sections of the work such as surface treatments and planting etc., are to be included or excluded from the contract.

'Package deal' contracts
All the above procedures are based upon the employer retaining control of the design either himself or through professional consultants.

'Package deal' contracts, that is where the contractor assumes responsibility for part or the whole of the design as well as the construction have been usefully employed in the building and civil engineering industry where the employer appoints the contractor to execute a scheme involving work for which the contractor has designed and developed a system to perform a given function. An example of this is industrial building where the contractor's design service is an essential part of his employment. At the present time little if anything would appear to be gained by adopting such a procedure for reclamation. Certainly in the case of serial or continuation contracts the contractor's expertise from the design point of view is a factor to be considered but even in these circumstances loss of the employer's design control would be a disadvantage.

11.2.4 Form of contract

The form of contract used for any scheme, whether of a building or civil engineering nature, has little bearing on the tender procedures used.

Choice of the form to use on a particular scheme depends largely on the nature of the work involved. Most of the contracts executed as part of the research project were of a civil engineering nature and were eminently suitable for execution under the I.C.E. Form of Contract. Generally, schemes predominantly of a bulk earthmoving nature with associated drainage etc. are best catered for by the I.C.E. form, since these schemes fall basically into a civil engineering category and attract civil engineering contractors. This form of contract, whilst complex and obscure to a degree that has produced judicial conflict in court actions, does in practice work reasonably satisfactorily and preserves a fair balance between employer and contractor. There is reason to believe that in the not too distant future a new form of contract will emerge which will, it is hoped, improve interpretation rather than policy. The tender documents for one scheme in the project (Egerton Gardens) were based on the I.L.A. Form of Contract. This was a small scheme with only minor grading and more emphasis on soft landscaping. No difficulties were encountered in the administration of this contract but no particular advantages were found in the use of the I.L.A. form.

11.3 Conditions of contract

Since the I.C.E. Contract is applicable to most reclamation schemes, only amendments relating to the conditions of this contract are considered below, although similar modifications will apply to other forms of contract. Further, only amendments relating specifically to reclamation are considered since other amendments vary extensively, depending on the individual organisations or authority's normal practice.

It should be noted that in keeping with the normal usage of terms in the I.C.E. Contract, the word 'engineer' is used to describe the person responsible for the design, direction and supervision of the works. This function was performed by a Landscape Architect on schemes executed as part of the Research Project.

11.3.1 Amendments to conditions of I.C.E. Contract

Clause 24 - Accident or injury to workmen
It is incumbent upon the contractor to indemnify the employer against all claims for injury to persons other than arising by an act or default of the employer, his servant or agent (this incidentally can be construed as applying to the engineer as agent of the employer).

To draw the contractor's attention to the specific hazards in respect of reclamation of pit heaps, it is of assistance to a contractor when assessing his responsibility to add a sub clause headed 'unusual hazards' in which specific reference is made to damages from concealed fire or cavities and explosion risk, abandoned shafts etc. and the contractor's obligation to indemnify the employer against all claims, demands, proceedings, damages, costs etc. arising from such hazards. It is doubtful whether this in any way increases the contractor's responsibility under clause 24 but it does serve to draw his specific attention to the dangers.

Clause 29 - Interference with traffic and adjoining property
The wording of this clause to some extent conflicts with clause 22 (c) which limits the liability of the contractor. It is normal in civil engineering contracts to expand and develop this clause but in addition, for reclamation schemes, it is advisable to require the contractor to take all reasonable steps by watering or otherwise to abate nuisance which may arise through wind action blowing dry materials from the working plant in dry ground conditions.

This nuisance has been experienced in those projects close to residential areas, resulting in complaints from inhabitants. It is doubtful however whether the above wording is sufficiently specific since there might be circumstances in which damage to an adjoining owner's property or trade could be severe. In such circumstances more stringent wording could be adopted, if necessary to a point of requiring the contractor to suspend work in certain weather conditions.

Clause 41 - Commencement of work
Unlike many other forms of contract the time for commencement is not to be found in the form of tender or form of agreement but is notified to the contractor after the contract has been let. This is not a satisfactory arrangement in days of rising prices, particularly in contracts where weather or seasonal considerations may affect price. More consideration is given to this question in section 11.5. A further matter relating to this clause is that the wording 'an order in writing' can be construed under clause 15, as being effected if served on the site agent, since it is unlikely that the site agent would be installed at this time the intention is not clear. An amendment of wording changing 'an order' to a 'notice' would appear to correct this anomaly as a notice under clause 68 (1) 'shall be served at the contractor's principal place of business'. This applies to any civil engineering contract where a contractor is not permitted to enter the site until he receives instructions to proceed.

Clause 42 - Sub-clause (2) wayleaves etc.
Access to a site is of prime importance to the economics of engineering contracts but the emphasis in this sub-clause must be on the word 'special' which indicates other than normal access. In fairness to tenderers the access of the

site and any restrictions should be fully described in the specification section of the document.

The effect of this clause is therefore to place upon the contractor financial responsibility for negotiating private wayleaves. In respect of reclamation schemes this invariably relates to adjoining land (very often agricultural) which the contractor might wish to use for soil dumps. It has been normal practice in these projects to impose a responsibility upon the contractor to properly reinstate such areas outside the site to 'the satisfaction of the Engineer', unless the landowner or his agent issues instructions to the contrary. It is doubtful whether this clause has any legal validity unless the employer is the Local Planning Officer who has jurisdiction over such temporary works. In other cases the decision will be by private arrangement between contractor and landowner (as a third party) who in turn might be controlled by local planning, but in any event would be outside the authority of the employer or his engineer.

Clause 49 - Definition of 'period' of maintenance
This clause defines the 'period' as being the period of maintenance, named in the tender from the date of completion of the works. The I.C.E. condition is obscure in its meaning of completion but in this chapter it undoubtedly means 'substantial completion', when under clause 60 (2) half of the retention monies are released. This is important since at this stage the risk of damage to the works passes from the contractor to the employer, always excluding damage to the works occasioned by the contractor during the maintenance period whilst fulfilling his obligation to repair defects.

Bearing in mind that it is the intention that the major works in reclamation contracts will be carried out by civil engineering contractors fully conversant and competent in their field, it is also highly desirable that the specialised work in respect of surface treatments and planting should be carried out by a firm fully conversant with the problems relating thereto and competent in their field. To ensure that the employer has the necessary control over this part of the work it is advantageous either to make it the subject of a PC sum in the bills of quantities or exclude it completely from the main contract. In either case special provisions must be made in respect of maintenance.

Firstly, in the case of a PC sum for surface treatment seeding and planting, since the execution of this work is closely related to seasons it naturally follows that maintenance of the completed works should commence from the completion of these works. A typical addition to sub-clause 49 (1) as used on some schemes is as follows:

'The contractor shall be responsible in respect of maintenance of the earthworks, drainage seeding and fencing for a period of 12 months from completion of seeding and in respect of planting for a period of 12 months from completion of the planting.'

It must be admitted that certain confusion has been created by the word 'completion' in this clause by reason of the obscurity of its meaning in other clauses. The intention here is 'the completion of the whole' of the seeding or planting as the case may be, rather than substantial completion, that is nearly but not wholly complete. It is suggested that the wording of this clause should be amended to clarify this point. It should be remembered that it does not preclude nine out of ten fields being accepted as complete for purposes of the maintenance period. The period for the tenth field will then commence from its seeding completion. Provision is made for partial completion in clause 48. Maintenance in the context of this clause is again not correctly used but this will be examined later.

Secondly in the case of complete exclusion of the seeding and/or planting work an amendment on the following lines has been used:

'The Contractor shall be responsible for the maintenance of the site for a period of 12 months from the date of completion of the sowing except that this period shall be deemed to be completed in the areas of woodland at the date of commencement of the Council's tree planting contract, should this occur before the expiration of this period.'

The comments above in respect of completion apply also to this clause but in addition it should be noted that the employer is relinquishing his right to order repair of defects under clause 49. This again hinges on the use of the word maintenance. It is suggested that this word is used incorrectly in this context since the contractor should remain liable for latent defects, such as subsidence due to insufficient or incorrect compaction during the earthworks. The intention should be to relieve the contractor of his 'additional works' liability, that is responsibility for grass cutting, fertilising and other works relating to establishment of the sward.

In the opening remarks under this clause it was stated that the risk of damage to the works passes from contractor to employer; this has an important bearing in relation to maintenance.

After completion (that is substantial completion) has been certified, by the engineer, the contractor's responsibility, subject to outstanding works, is reduced to responsibility for defects only. However it is essential on reclamation schemes to ensure adequate establishment of the grass and plants, such as cutting, further fertiliser applications and weeding. In addition it will be necessary to ensure the drainage works function correctly by clearing silt from grit chambers, ditches etc. These are not maintenance works in relation to defects, but additional works resulting out of the execution of the contract. It would appear possible therefore to hold a contractor liable for de-silting ditches etc. as part of his general obligations before substantial completion, but thereafter such work can be construed as being 'additional works', or 'outstanding works' depending on whether they are referred to in the specification or bills of quantities. The contingencies of both outstanding and additional work are provided for in clause 48 and 49(3) respectively. The methods of incorporating these items in the tender document are examined in section 11.4.

Clause 55 and 56 - Quantities and works to be measured
The crucial fact emerging from clause 55 is that the actual and correct quantities are not those shown in the bills. It follows therefore that there can be a departure from the bills of quantities without there being a departure from the 'actual and correct quantities of the Works' that is, such a departure is not necessarily a variation under clause 51. Further it is submitted that inclusion of provisional quantities in the bills serves no more than to emphasise even more strongly that such quantities are not the 'actual and

correct' quantities. They are used in bills for work which is not reasonably predictable in quantity, for example an item for breaking up hidden foundation. The wording of clause 56 implies that it is at the engineer's discretion alone whether any section of the work should be remeasured, but by reason of the wording of clause 66 which expressly gives an arbitrator the power to 'open up, review and revise any decision of the Engineer', it is submitted that this gives the right to either party to demand recalculation if it is thought a mistake has been made. However, it must also be pointed out that the engineer's position is protected where a contractor fails to present himself upon invitation to agree calculations by the words 'should the contractor not attend'. This would appear to extend protection even to arbitration or the courts where power to open up and review would be limited to valuation and not measurement. This is essential since alleged quantities of work covered up cannot be re-checked.

The above, whilst not exclusively pertaining to reclamation, is important when considering the following matter under clause 57. Before proceeding to examine these matters it is of interest to note under clause 56 the wording '. . . give notice to the contractor. . .' (meaning to the contractor's principal place of business) illustrates the point made in respect of 'order' and 'notice' in the examination of clause 41 above. This serves to illustrate the unaccountable differences and obscurities of wording in the I.C.E. form and the care required in drafting amendments.

Clause 57 - Method of measurement
It has been the practice to add the following to this clause:

'Except that the quantities in the appropriate Bills against the item referring to the bulk excavation of material from the waste heap have been calculated from the existing and the proposed contours shown on the Contract Drawings, with no allowance made for bulking or compaction. It is not proposed to re-survey the heaps and the Contractor shall before tendering satisfy himself as to the adequacy of the quantities listed against these items.

'He shall then price and extend this item and the resultant sum shall constitute a Lump Sum Tender not subject to measurement and this sum shall not be varied unless the Engineer instructs a departure from the proposed contours shown on the Contract Drawings. Even though a Lump Sum Tender is to be submitted for the bulk excavation work the Contractor is also required to indicate his unit price against this item.

'In the event of any departure as aforesaid the revised quantity will be agreed and the Sum revised according to the tendered rate. Such revised sum shall also stand as a Lump Sum and not be subjected to measurement.'

The intention behind this amendment is self evident although there is some doubt as to whether the phrase 'lump sum' is used correctly in this context. It might be argued that this clause runs against the intention of the I.C.E. conditions in that the quantities are not to be taken as 'actual and correct quantities of the Works'. However the tenderer is given the opportunity and all the necessary information to check and satisfy himself as to the accuracy of the quantities at tender stage and should he consider the quantities incorrect he is at liberty to insert a sum based upon his own calculations. The disadvantage in such circumstances is that the unit rate would be derived from his sum and the billed quantities thereby indicating a false unit rate; for example if a tenderer considers the quantity in the bills to be high compared with his own, the rate so derived would be set at an artificially low level.

Should the engineer then find it necessary to order additional excavation under the terms of the second paragraph of the amendment the contractor would then find himself at a distinct and possibly considerable disadvantage depending on the difference between the correct and artificial rate. It can be seen therefore that all possible care should be exercised in the preparation of such quantities and in the event of a large error being discovered then serious consideration should be given to the withdrawal and correction of the tender documents.

Assuming the calculations are correct another complication can arise in respect of errors in the proposed or original contour drawings and indeed there is always the imponderable question of the amount of bulking or compaction likely to be experienced. In any event the unit rate will represent an average price for all the bulk excavation, that is an average of long and short hauls. Circumstances could easily arise where it was necessary for the engineer to order additional excavation and deposition at the point of the longest haul. It is submitted under such circumstances and notwithstanding the third paragraph of the amendment that a contractor could justify a claim under clause 52 (2) for additional remuneration over and above tender rate. This could also apply where the additional quantity is of such a magnitude that the contractor is entitled to an extension of the contract under clause 44.

In the past it has been found that the schemes executed with the amendment to clause 57 incorporated operated satisfactorily providing all possible care was exercised in the preparation and checking of the bulk earthworks quantity, and fair consideration was given to the possibility of rate amendment in the event of a variation materially affecting the basis upon which the rate was calculated.

It should be noted that in adopting this amendment reference should also be made under clause 55 to this amendment and that certain quantities are deemed to be 'actual and correct'.

The main disadvantage of leaving the clause unamended is the physical task of recalculating from site measurement in the event of the contractor challenging the accuracy of the quantities and/or drawings. This could mean a re-survey of the site before and after the earthwork operations with attendant disadvantages of delays in commencement whilst the former survey is carried out.

Experience on a number of recent projects, however, has tended to weigh favour toward deletion of the 'Lump Sum' amendment to clause 57. This has arisen mainly through the problems created by varying compaction factors, necessitating variations in bulk earthwork quantities.

Additional clauses
It is common practice to include additional clauses in relation to allowances for travelling expenses, overtime, fluctuations, site offices and welfare facilities. These are not essential but they do serve to set out more explicitly the sometimes oblique references to such matters in the other conditions of contract.

In relation to care of the works the following clause again serves to draw the contractor's attention to more specific problems which might arise in respect of reclamation:

'The Contractor shall allow for keeping the trenches, excavations and works free from water, mud or slop arising from any source whatsoever during the progress of the works by pumping, baling or other means of providing all requisite appliances, etc.

'During the course of stripping and stacking top and sub-soil the mass excavation of the materials in the waste heap and the spreading and regrading of this waste on to adjoining land, the Contractor shall construct and operate, until the permanent drainage framework has been completed, a temporary drainage system of adequate dimensions as may be necessary to prevent the accumulation of standing water in ponds and flooding and damage from taking place in the surrounding communities and to the contract site itself or other surrounding areas, from the effects of heavy rainfall or water run off from snow or spring water.'

The phrases 'standing water in ponds' and 'flooding and damage from taking place in surrounding communities' have special significance in relation to local authority's schemes, where in addition to the contractor's responsibility to take all adequate steps to prevent damage and pay compensation in event of his failure, the local authority owes a duty to the public at large to take all adequate steps to prevent damage. This therefore is pertinent in respect of the potential dangers of such a site because of its attractions to small children and also flooding dangers to nearby properties or lands.

11.4 Specification and bill of quantities

The specification and bill of quantities are complementary and are therefore best considered together. The specification should be a comprehensive description of materials and workmanship without unnecessary or lengthy detailed descriptions of location or quantities which are self evident from the drawings and bills of quantities. The bill descriptions should be concise with sufficient detail to make the intention clear without repeating information contained in the specification. All too often too much reliance is put upon clause 12 (1) 'sufficiency of tender' that all the works described in the specification are included in the bill rates and sums. The drafting of both specifications and bills should be such that it makes it clear to tenderers which items are deemed to be covered in his rates and which are specifically subject to measured items or provisional sums. The judicious use of the phrase 'the Contractor is to allow in his rates for compliance with the foregoing' is often a useful tool where the intention is obscure.

11.4.1 Format of specification and bills of quantities for reclamation schemes

For most reclamation projects the specification and bills will require sections for demolition, earthworks, drainage, surface treatment and fences. In addition the specifications should contain a 'description of works'. This section which lists the drawings as required by clause 1(3) and describes the scope of the works and access thereto, has an important function in that both scope and access should be precisely defined to give full contractual effect to clause 22 (damage to persons and property) and clause 42 (possession of the site). Any information regarding land acquisition should be included in this section, as this will have a bearing on the programming of the works, and possession of the site under clause 42 in respect of delays and expenses incurred from failure of the employer to give possession. This is examined in more detail under section 11.5.

The first section of the bills contains the preliminaries, and provides the contractor with the facility to price separately, if he should so desire, the cost of complying with the provisions of the conditions of contract.

It has been the practice in a number of schemes to include an item in the preliminaries for 'maintenance' works in respect of de-silting ditches etc. As suggested in section 11.3 (clause 49) the use of the word maintenance in this context is incorrect. In any event it is now considered that such 'works' should be contained in the section to which they relate.

11.4.2 Sections of work in specifications and bills of quantities

It is not proposed to examine each section in detail but to consider those aspects which relate to reclamation in particular.

Demolitions and site clearance 'Foundations shall be broken up to a depth of 0.9 m below the finished surface.'

This clause is essential to ensure the finished surface is free of obstructions to cultivations. It is impossible to assess the quantity for this item before work commences. 'Provisional' quantities in the bills for breaking up brick, plain and reinforced concrete indicate to the contractor that there could be a substantial difference between the quantities stated and the actual quantities. The actual quantity will be measured and agreed as work proceeds but this will not constitute a variation under clause 51.

A problem sometimes arises in respect of hidden foundations within 0.9 m of the surface that do not become apparent until after substantial completion has been certified. This invariably means that the contractor has not carried out the ripping of the surface in accordance with the specification contained in the surface conditioning and seeding section and in such cases the additional works required can be construed as defects under clause 49 (3), payment for which will be at the rates inserted in the bills against the provisional quantities. Claims for additional reimbursement, such as the cost of returning plant to site, are not admissible because the work arose from the failure of the contractor to carry out his contractual obligations.

Excavations and earthworks The following general clause is inserted:

'The Contractor is deemed to have satisfied himself by inspection, tests or otherwise as to the exact nature of the materials to be encountered in the parts of the site where excavation is to take place and shall include in his price for excavating any materials likely to be found there such as shale, stone, bricks, clay, soil, earth, sand, gravel, or other substances likely to have been associated with coal mining. . .'

This, on the face of it, would appear to be in conflict with:

'Notwithstanding the general description given previously for the type of material to be excavated, if hard material is encountered during these operations in ledges or solid masses or large detached pieces exceeding 1 m^3 normally or 0.5 m^3 in trenches, all of which can only be removed by compressed air tools or similar means this work will be paid for separately as an extra over item for that given for normal excavation.'

This is however a valid clause because in any event the contractor has recourse to clause 12 (2) in respect of 'physical conditions . . . not reasonably foreseen' and the above clause assists in defining the nature of the 'condition'. It should be noted the above is entirely separate from the provision in 'demolition' for breaking up foundations for which no size limits are mentioned. It would appear unnecessary to apply limits in respect of foundations as by definition they indicate a mass of brick or concrete rather than small isolated pieces of rubble. This is not to imply that the latter is not a problem. Indeed brick and concrete rubble can at times be a greater problem than large isolated foundation bases. It is difficult to suggest a simple solution in terms of specification and quantities to this particular problem as the solution will vary depending on the quantity of rubble encountered and availability of a blanketting material.

It is of course always within the power of the engineer to order such work as is warranted in any particular case.

It is customary to insert the following clause in respect of red shale encountered in the course of earthworks:

'Should red burnt colliery shale be encountered in the mass excavation of the waste heap, which in the opinion of the Engineer is of sufficient quantity and satisfactory quality for use during the operations for the final covering of the respread and regraded black shale, then it shall be separately excavated as directed, stacked in suitable positions for use as may be required for the roads or the working of this material as a top covering to the regraded black shale.'

This as it stands is a perfectly good clause but it does leave the contractor in doubt as to whether he is to allow in his rates for excavating an indefinite quantity of shale hauling and stacking an indefinite distance. This clause is improved by the addition of the following:

'This work will be paid for separately as extra over that for the mass earthworks.'

Provisional quantities can then be included in the bills of schedules of additional rates to enable the contractor to price this item.

It has been practice on these schemes to specify compactions as follows:

'The materials in the filling areas shall be deposited in layers not to exceed 0.3 m in thickness and shall be well compacted and consolidated by the passage of the earth moving plant and equipment over the site.'

To a large extent this clause has been framed around the assumption that the machines used will be tyred scrapers but it has been found that lack of compaction has occurred on sites where tracked vehicles alone have been used. There is no doubt that in the majority of cases the tyred box scraper is the efficient earthmoving machine for most reclamation projects, but one hesitates to be too categoric in a specification on the basis of the maxim 'specify what but not how the work is to be done'. Limiting the contractor to a particular type of machine could possibly saddle the engineer with a burden of responsibility which in the strict terms of the contract belongs to the contractor alone.

However, a possible solution to this problem is presented by the addition of the wording '. . . equivalent to that achieved by a tyred box scraper'. This defines the degree of compaction without limiting the contractor to the use of a particular machine.

Drainage The specification and bill items follow those normally found in civil engineering contracts, but special mention should be made in respect of works to be carried out in the maintenance period. These apply generally to two items, the provision for filling temporary ditches formed to cope with the initial run-off problems until vegetation is established and the provision for the proper management of the ditch and piped drainage system to ensure efficient working during the maintenance period. An item in the specification describing the nature of filling to the temporary ditches and the time when such filling should take place, usually as directed by the engineer, and supported by a measured quantity in the bills would appear to adequately cover the first item above.

As previously indicated it is preferable to include items in relation to management of the drainage system in the drainage section rather than in the preliminaries. The specification should specifically state the contractor's responsibility on the following lines:

'The Contractor shall undertake during the maintenance period all necessary work in respect of the clearance of silt and other obstructions from streams, ditches, pipes, flumes, chambers and outfalls to maintain the efficient working of the system.

'In fulfilling this responsibility he shall at regular intervals (a particular interval could be specified) inspect the system and organise such work as is necessary.

'Prices shall include for any additional insurances, use and maintenance of plant and tools, superintendence and inspector's time, overhead charges and profit unless included elsewhere.'

Alternatively, a provisional sum can be included for this work to be ordered by the engineer at such times he considers necessary, and paid for on a daywork basis.

The last paragraph is possibly superfluous in that clause 12 (1) requires the contractor to satisfy himself that 'rates and prices . . . cover all obligations . . . for proper maintenance and completion'. However, it does serve to remind the contractor that these are additional works rather than maintenance of defects.

Whilst considering work during the maintenance period, it is well to mention that it is often necessary to carry out additional drainage works, that is additional ditches, drains etc. to ensure the efficient drainage of the site. Requirements of this nature can of course extend for a time far beyond the main contract and final completion, but in respect of the maintenance period it is submitted that the engineer has power to order such additional essential works.

However such work must be essential to the proper completion and functioning of the works and, if thought likely, is best included as provisional quantities or a provisional sum in the bills.

Major additional works should be made subject to a separate contract as works done during the maintenance period do not extend the said period and therefore the employer has little protection against defects.

Surface treatments, seeding and planting This is possibly the most difficult section to specify precisely since the cultivation, lime and fertiliser requirements will depend on the nature of the surface material. It is necessary to provide a concise framework for the contractor to price, drawn up in a form that gives the engineer latitude to amend the specification to suit site conditions. A loosely worded specification such as 'cultivate to a tilth approved by the engineer' does little to indicate to the contractor the precise requirement or give the engineer a basis for amending the specification. It is preferable to schedule the engineer's requirements on the following lines:

'Upon completion of liming and spreading topsoil where applicable the Contractor shall undertake the following operations over the shale areas in the order shown unless amended by the Engineer in writing:

1 Cultivate (heavy 150 mm)
2 Disc (heavy)
3 Remove all bricks, stones, wood, metal or other materials larger than 50 mm diameter brought to the surface during cultivation
4 'Scrub' to remove hollows left after 3 above
5 Disc (light)
6 Distribute fertiliser (spinner broadcaster) at prescribed rate (500 kg/ha on red shale, 750 kg/ha on black shale)
7 Broadcast seed at prescribed rate
8 Harrow roll

The above is not intended as a recommended treatment for any particular material since each must be considered individually for the cultivation likely to provide the required surface, but it does serve to illustrate a framework for a contractor to assess accurately the cost of the operations necessary. It further provides the engineer with the facility to add, omit or rearrange cultivation operations as site conditions dictate. The inclusion of a single cultivation operation in the schedule of rates provides the necessary framework in assessing the values of such variations.

Item 3, stone picking, whilst perfectly clear in its intent for the cultivation of normal soils, does create problems on reclamation sites. The nature of material encountered, varying from hard stony shales to fine friable shales, will have a marked effect on the amount of stone picking required, and therefore cost. The specification calls for materials brought to the surface during cultivations to be removed. This, however, does not include material brought up to the surface by weather action and erosion.

It is impossible to frame a specification to cover all these possibilities without imposing an unfair burden upon the contractor, yet it would be unstaisfactory to cover all such work by a daywork provision. It is submitted that whilst this specification is inadequate in scope there is provision within the conditions of contract clause 52 (2) for an engineer to vary the rate for additional work, and under clause 52 (3) to order additional work on a daywork basis. Further, there is protection for the contractor under clause 12 (2) against adverse physical conditions.

In practice it has been found that conditions of excess stony material in isolated areas on a site are best overcome by a blanket layer of more suitable material.

Since lime and fertiliser requirements are not known until after soil analysis, a provisional sum for the supply of these materials is inserted in the bills. In schemes where part or all the land is to be reclaimed for agriculture it has been customary to include a clause in the specification requiring the contractor or his supplier to claim lime and fertiliser subsidies, the net cost of such materials then being charged to the contract. It appears however that this procedure is incorrect since under the Agricultural Lime Scheme 1966 and Fertilisers (United Kingdom) Scheme 1969 claims can only be accepted from occupiers of agricultural land. The Ministry of Agriculture, Fisheries and Food have stated the view that under the terms of the Acts, derelict land is not agricultural until it is restored and as such does not rank for subsidy.

As for drainage, it is preferable to include items for management during the maintenance period. The full description of the requirements for cutting, fertilising etc. are included in the specification and measured in the bills of quantities. It has been the practice to describe the bill item as, 'Cut and maintain seeded areas all as described during the maintenance period'. Whilst the intention is clear the use of the word 'maintain' is unfortunate and in fact incorrect in the context used. This work is not maintenance as defined in the conditions of contract but is additional work. It is suggested therefore that the following wording is preferable:

'Cut grass and carry out establishment work as described during the maintenance period.'

The problems in respect of maintenance liability created by the letting of separate contracts for planting and seeding has been examined in section 11.3, (clause 49) but from the experience gained on the larger schemes of this project there is little doubt that the cultivation, seeding and planting work are so foreign to the main earthworks and drainage contract that they are best executed as a completely separate contract. To avoid overlapping of maintenance responsibilities, cultivations are best commenced after completion of the main contractor's defects period. This divides the work into neat compartments but does create a difficulty in respect of the possibility of severe surface erosion during the main contractor's twelve month maintenance period. However, if adequate precautions are taken to reduce erosion by the provision of temporary cut-off ditches, and it is accepted that a modicum of erosion repair will be required, there is a great deal to commend this arrangement. It is also submitted that the adoption of separate contracts removes the need for a twelve month maintenance period for the main contract. Six months would appear to be reasonably adequate to show up defects in the bulk earthworks and drainage works.

Fences No special provisions are required in the specification or bills of quantities for this work but some difficulty has been experienced in respect of obstructions in post holes. It is impossible to cater for such obstructions in the specification and should their occurence appear likely they are best covered by provisional quantities similar to those included for hidden foundations in the demolitions and site clearance section

Schedule of rates These fulfill the normal function of giving the engineer additional pricing information on composite items in the bills of quantities which the engineer might require at some time during the period of the contract

The main use in reclamation is to provide a breakdown of the composite items for cultivation in the 'surface treatment' section. This intention should be made clear in the documents since the rates inserted in this section on a number of schemes have borne little relationship to the composite items. It has been found that the insertion of unrealistic rates can be avoided by providing 'provisional quantities' against these items for the contractor to price, extend and carry forward to the main summary. The work thereby forms part of the tender and as such requires proper consideration by tenderers.

11.5 Administration

The management of reclamation contracts differs little from other civil engineering contracts, but certain aspects are worthy of comment.

11.5.1 Post-contract obligations

Under the I.C.E. Form of Contract obligations, in respect of production of a programme, securing bond and insurances are post-contractual obligations of the contractor and not a condition of the contract coming into being. Further under this form no date for commencement of the work is prescribed by the Form of Tender or Form of Agreement.

Programme of works Clause 14 provides for submission of a programme at the request of the engineer. This clause is admirable in that it recognises the much higher degree of interest and control an employer has in engineering as against building contracts, but unfortunately there is no sanction or machinery provided for its enforcement other than in a very serious case, the drastic remedy of determination under clause 63.

Difficulty in obtaining a programme has been experienced on a number of the schemes, and has been an impediment to the engineer in exercising his control and planning function.

It is submitted that a sufficient sanction could be applied if the programme had to be supplied, either at tender stage or before entering the site, or interim payments could be witheld until the programme is furnished. The first method has pitfalls in that the contractor is not likely to consider a detailed programme seriously at this stage; in any event such a programme would tend to be optimistic because it is considered at tender stage.

It might appear that the second method is the most suitable and the programme could be made enforceable by its inclusion in the form of tender, as an undertaking on the part of the contractor. However, a severe disadvantage occurs in the possible delay in commencement since the employer, by witholding entry, delays commencement, which could work against his interest as well as that of the contractor.

The third method has distinct advantages in that a delay in answering the engineer's request brings monetary repercussions. A sub-clause to this effect could be added to clause 41 of the conditions of contract. The engineer can request the submission of a programme before ordering commencement in the normal way but he then has the necessary machinery to enforce compliance with his request should the contractor be dilatory.

Guarantee bond The acquisition of an approved bond has proved to be a problem on a number of the schemes. The provision of a bond is not a condition precedent to commencement and the methods suggested above to expedite the production of a programme can also be applied to the bond. In many cases, however, the problem is not the failure by the contractor in attempting to secure a bond, but his failure to find a bondsman. This mostly arises in 'open tender' when there is a large number of tenders and a big margin between lowest and highest tender. The position is further aggravated if the lowest tender is submitted by a relatively small firm with limited financial resources. This aspect of the problem is largely removed by adoption of 'selective tendering', and is a further argument in favour of its adoption.

Insurances In the case of insurance, in particular third party insurance, clause 23 (1) clearly defines this obligation as a condition subsequent to the execution of a contract, and it is sensible for the employer, or the engineer, on the employer's behalf, to satisfy himself that such insurances are adequate, before work commences.

The provision of insurances has not created any major problems on schemes in the project, but unlike programme and bond, it is advisable to ascertain that the type and terms of the contractor's insurances are adequate before work commences. Application of a monetary sanction to the provision of a programme and bond, is, it is submitted, adequate to enforce the provision, but in respect of insurance the risk of damage or injury starts with the contractor's first moment on the site. It would appear prudent therefore to ensure that the contractor's insurances, particularly third party insurances, are adequate before entry is permitted. This should be made clear in the tender document by a suitable amendment to the insurance clauses.

Commencement and possession of site As commented in section 11.4, clause 41 of the conditions of contract provides for notification of time for commencement after the contract is let. Unfortunately all too often this clause is used unfairly by the employer in delaying the issue of the instruction to proceed.

It has been the practice in the project to endeavour to indicate the likely starting date, but this has purposely been loosely worded and more emphasis is placed on an instruction that 'tenders are to remain open for acceptance for a period of three months . . .'. This is not satisfactory because the only reliable information that the contractor can deduce from this is that commencement could be any time between the date for submission of tender and three months plus fourteen days from that date. This is not satisfactory on a scheme where weather and seasonal considerations play such a big part and when the cost to a contractor of reserving plant whilst awaiting this instruction can be considerable. It must be understood that what is unsatisfactory is not the length of period, so much as the uncertainty of a starting date. It would be infinitely better to state a definite date for commencement, for example, 'two months from the date for submission of tenders'. This would not in any way affect normal processes of consideration and acceptance of a tender but it would provide the successful tenderer with information to plan his plant, staff and management requirements prior to commencement, and greatly reduce the risk of plant standing idle.

Clearly the adoption of such a procedure imposes a responsibility upon the employer to ensure that the site becomes available for entry at the date specified, and failure on his part renders him liable under clause 42 (1) for the contractor's loss and expenses incurred. This additional responsibility would not be acceptable to some employers, but it is suggested that it is fair and reasonable to accept in the light of the imposed responsibility upon the contractor to commence within fourteen days and complete within the time specified. After all, failure on the contractor's part in these respects brings forfeiture or monetary sanctions by way of liquidated damages; should not the employer have similar responsibilities?

Depending upon the amendments made to enforce the provision of programme, bond and insurances, any specified commencement date will be subject to the requirements of such amendments

11.5.2 Supervision

The supervision of reclamation schemes follows the normal pattern for any civil engineering project, but it is worthy of note that these schemes need more site supervision throughout the contract than most civil schemes of a comparable size. It has been found that the services of a clerk of works can be usefully employed under the provision of clause 1 (d) to carry out day to day site inspections, tests and examine materials used and workmanship. However, it must always be remembered that the use of a clerk of works in no way relieves the engineer of his duties.

The clerk of works' duties should, therefore, be clearly stated and undertsood by all parties at the outset, and it is suggested that these duties be restricted to the terms stated in clause 2, that is 'watch and supervise' thus ensuring that the requirements of the specification are fulfilled and that materials and workmanship conform to description, and that plant returns, dayworks, site works etc. are properly recorded and certified.

11.5.3 Financial control

The financial control in respect of remeasurement, variations and valuation differ little from any other civil engineering contract. However special care was exercised on all the project schemes to ensure that the employer was kept informed of variations in cost and the overall effect on the contract sum, by submitting financial statements at regular intervals.

Since the early schemes were executed as pilots for the many schemes to follow, a careful watch was kept on price trends to assist in more accurate estimating. The application of this cost information in estimating cost planning, and cost control, is examined in detail in Chapter 12.

Chapter 12 Estimating and cost control

by I.S. Clark

12.1 The relation of estimate to cost plan

Estimating is an essential part of the pre-contract work. It is upon the proposed design and estimated cost that the decision is made to proceed to the tender stage of a project and it is the estimate which provides the basis of cost control. Comparative cost exercises for alternative designs or solutions to the design brief form the basis of the cost plan, culminating in an estimate of cost.

Cost planning is a system which relates design to cost, so that the solution to the design brief not only provides the answer in terms of function and appearance but also an economic solution within a pre-determined cost limit. It is unrealistic to attempt to set exact pre-determined cost limits on reclamation schemes since rarely do two projects have the same problems, but the principles still apply in terms of reaching an economic solution.

12.2 Estimates for reclamation projects

Estimates for reclamation projects are readily broken down into the main elemental sections of work to be carried out on site. These sections also conveniently provide the basic sub-divisions of the bills of quantities in the tender document and thereby provide quick comparison of cost when tenders are received.

12.2.1 Preliminaries

These we best covered as a proportion of the total estimated amount, 5% on the smaller projects (£20,000 to £50,000) down to 2% or less on the larger projects (£100,000 and over). In most instances, preliminaries, works, site supervision, plant etc. are included in the unit rates. The provision of huts,off site management, notice boards, welfare facilities for the men are usually adequately covered by the above percentage additions.

12.2.2 Demolition and site clearance

There is always a certain amount of demolition and site clearance associated with these projects since the derelict area usually contains industrial buildings of one sort or another in various stages of dilapidation. There are no criteria to apply, each site being taken on its own merits, but generally the cost of this section is small in comparison with the total. In addition, it is found that contract rates for this work are generally at a low level as most of the material arising from the demolition can be accommodated on site. The large earthmoving equipment used on these schemes disposes of the buildings, debris etc. very quickly.

A problem found on the majority of the sites is hidden concrete and brick foundations. On many schemes, there is little or no information available to give positions of bases, culverts, foundations and the like. The first knowledge of the existence of such items comes when the Contractor commences work in the area. The breaking up of these foundations is invariably the only solution, albeit costly if discovered at this stage of the works. It has become increasingly apparent that every effort should be made to ascertain the nature of the ground conditions where filling is not contemplated or where filling is no more than a few feet thick, and if possible make provision for adequate fill cover of any areas suspect, also ensure cultivation and drainage works are not impeded by such items.

Prior knowledge of a difficult area at the estimate stage enables consideration to be given to alternatives; that is, the cost of breaking up as against the cost of a design change to provide a blanket of shale or similar material of a sufficient depth to obviate the necessity of breaking up. This is an example of cost planning in relation to design to arrive at a practical as well as an economic solution.

12.2.3 Earthworks

This section forms the largest part of most reclamation projects. It comprises stripping and stacking available top soil and subsequent respreading, bulk earth movement and grading to proposed contours. From the point of view of cost this section usually accounts for 50% to 80% of the total and is, therefore, extremely critical.

Stripping, stacking and replacement of top soil is relatively easily assessed from the proposal drawings. In practice, it is found that the depth and location of the respread material within reasonable limits has only a marginal effect on cost; quantities are, therefore, assessed on a cubic metre basis.

The bulk earthworks quantity and costing is by far the most critical. Generally one million cubic metres or more are to be expected on sites of forty hectares or over (total value of scheme around £100,000). It is essential on schemes of this size to carry out accurate earthworks calculations to ascertain firstly that balance of cut and fill can be achieved within reasonable limits, without drastically amending the proposed design, and secondly to provide an excavation quantity for pricing; a 10% error on a million cubic metre scheme could represent £5,000 in cost (methods of earthwork calculation are discussed in Chapter 5). Having achieved a satisfactory result in the bulk earthwork calculations, it is then necessary to apply a suitable unit rate to ascertain the cost. In practice, a tendering contractor would assess his plant requirements with due regard to site conditions, type of material, topography of the site and plant availability. This, together with his calculated average time for haulage distance enables him to assess the number of machines and time required which, computed against his known costs and overheads, results in his total cost. This is possibly a simplified statement of the Contractor's pricing process, but it serves to illustrate the particular difficulty at the estimating stage when the type of machine to be used is not known, although one might make an intelligent assumption. The state of the market whether busy or slack is also an important factor. This factor has detectable trends, the seasonal trend being the most obvious. Contractors' plant can be kept fully employed on remunerative work during the drier seasons, such work as motorways, bridges, dams and civil engineering projects generally. Winter working on these projects can result in a 50% loss of output or more.

The nature of the material often encountered on reclamation schemes is such that all weather working is possible. They offer, therefore, attractive winter working for a Contractor, where his machines can earn their keep over a period which he would normally expect to be unremunerative. For this reason contracts let in late autumn reflect this trend and the likely date for commencement of a contract must be taken into account when preparing the estimate.

A further, more subtle, trend occurs through "Contract experience". Contractors adjust their pricing in the light of experience on similar previous projects. Hitherto few contractors in this country have had previous knowledge or experience on the specific difficulties of reclamation work. The basic advantage to contractors on reclamation schemes, other than the all weather aspect mentioned above, is quick turnover. The bulk earthworks on a million cubic metre scheme - if properly programmed, with suitable machines - can be executed in six months or less. Any unforeseen contingency delaying this programme can have an adverse effect on profitability where rates are keen and profit margins are small. A price difference is often noticeable in the comparison of tenders obtained by way of open and selective procedures. The former procedure provides the opportunity for new firms to enter the field and prices on the whole tend to be keener. Whether the tender is to be 'open' or 'selective' must be borne in mind when preparing the estimate.

12.2.4 Drainage and services

Each project has its own particular difficulties associated with the particular land form and requirements for drainage, water supply and diversion of public services. Costs of public service diversions can usually be obtained for estimating purposes from the public undertaking concerned. Drainage for these schemes usually follows a conventional pattern of ditching, tile and piped drains with associated catch pits and manholes.

The proposed land form will have a considerable bearing on drainage requirements. The cost implication of alternative landforms with attendant drainage requirements should be considered early in the design proposals to arrive at the most economic solution. In this respect care must be exercised when considering an open ditch construction against a piped drain alternative. The open ditch is not necessarily the cheapest solution when consideration has to be given to lining the ditch with a concrete flume, gabion mattress or similar lining to prevent erosion and scour.

Maintenance after completion is essential to keep the drainage system in sound working order. Work involved in desilting drains and chambers can be considerable in the twelve months after completion of the scheme during which time the drainage system requires regular checking and attention. An allowance of 1% - 2% of the total estimated drainage cost has generally been found to be adequate.

12.2.5 Surface treatments, seeding and planting

This section comprises cultivation, fertilisation and seeding of the reclaimed areas and associated land affected, soil stabilisation treatment of slopes, tree and shrub planting.

The cost level of general cultivations and seeding is much higher than for normal agricultural work, as would be expected considering the nature of the soil. A cost allowance of £150 - £175 per hectare plus £50 - £60 for ripping and removing rubbish has been generally found to be adequate for agricultural cultivations and seeding. The rate for cultivating and seeding areas covered with a good depth of top and sub-soil will be at the lower figure, working up to the higher for bare shale areas. Allowance must be made on slopes of 1:6 or 1:5 for heavier seed rates and over 1:5 (i.e. going up to 1:3) hydromatic seeding and mulching treatments are often used. The cost of the latter can be anything from £250 to £750 per hectare depending on the area involved and seed application rates.

Lime and fertiliser treatments vary depending on the chemical nature of the material. Preliminary analyses of surface and bore hole samples by the University Soils Department were a very useful guide at the estimating stage to assess the likely requirements. The costs of these treatments are best expressed as a provisional sum in the estimate.

Careful consideration should be given to the landform and surface treatment requirements since the cost of surface treatment tends to rise as the gradient of slope increases. Other factors such as drainage and land use requirements also affect the issue, but it is of interest to note that whilst a steeper slope increases surface treatment cost, reducing the slope, however, can produce a disproportionate increase in excavation cost. In a 'cut' situation (that is all excavation without fill) a finished slope of 1:3, mulched, hydromatically seeded, and forestry planted, will generally show a saving on a 1:5 slope covered with 0.3m (12in) of soil and seeded for agricultural use. This saving will increase almost directly in proportion to the height of the slope; thus in the above example if the saving on a 5m high slope amounts to £500 per hectare then the saving on a 10m high slope would be £1,000 per hectare. No account, of course, has been taken of the establishment and maintenance costs and also the after value of the land. The maintenance costs on steeper slopes are bound to be higher and the monetary return from the agricultural land could easily make the extra capital expenditure worthwhile; however, the sums used in the above example are indicative of the savings which can be achieved.

Planting varies from forestry planting (for slope stabilisation and shelter belts on the larger agricultural schemes) to shrub and tree planting (on smaller parks or public open spaces). The costing for estimating purposes is much the same for any landscape project, but special provision is normally made for 'establishment' and after care costs beyond the normal maintenance period. A sum to the value of 100% of the total planting cost is inserted for a five year establishment period, although there is no information available as yet as to whether this amount is representative of the actual cost.

12.2.6 Fencing

These follow conventional lines of estimating for the types required, commonly post and wire or post and rail agricultural. Difficulty has been experienced in driving posts in very stony ground or where remains of foundations are a few feet below surface. Generally the extra cost of fences erected on such ground is insignificant for estimating purposes unless a large proportion of the fencing is so affected.

12.2.7 Roads and paths

These usually fall into the categories of 'farm roads' or public footpath diversions. They are usually of a hardcore base and gravel or shale surfacing. They present little difficulty from the estimating point of view. The basic materials are generally available on site and costs are low.

12.2.8 Other miscellaneous items

Other items such as contingencies, professional fees, land acquisitions, administrative costs, aerial and other surveys etc are included as required.

12.3 Cost control

To exercise the control of cost, it is essential to have a measure of cost planning from the outset.

12.3.1 Pre-contract cost control

The most important tool of estimating is cost levels and trends. In the building industry there are large volumes of information published by the R.I.C.S., other professional bodies, building and allied trade organisations. This information is up-dated monthly or quarterly and takes account of market trends, labour availability and material cost variations, and gives information on changes from detailed, itemised units to complete buildings of all types. Such information is essential for accurate cost forecasting, planning and estimating.

From the mass of information available, it is possible to produce reasonably accurate estimates for all types of building on a square metre or square foot basis, relating type, design, locality and other factors to known cost analysis, up dating the information to take account of increased costs and latest market trends (i.e. if the market is busy, prices will tend to be high and vice versa).

In the landscape contracting field, and in particular reclamation, the amount of cost information available as yet is very limited. The Ministry of Agriculture and Fisheries and the National Association of Agricultural Contractors do publish, from time to time, cost information and broad trends in the industry for cultivation, seeding etc. These, however, have limited application in the reclamation field. Cost information compiled from reclamation projects, completed or at present being executed, has enabled us to build up a limited cost information guide. This, however, can only be taken as a very rough guide unless extreme care is exercised in assessing the effects of the quantity comparisons of such items as the bulk earthworks, drainage, treatment and general site conditions. In view of the limited amount of information available it is doubtful whether this approach at present warrants the effort involved as a far more reliable guide is obtained from approximate quantities measured from the preliminary scheme drawings and costed out, using prices extracted and compounded from the cost analysis of previous schemes.

Ideally cost control commences at the same time as the design work when a cost limit is set according to the client's brief requirements. This is rarely possible for reclamation schemes. Preliminary or outline design proposals must be carried out initially to provide a basis for an outline estimate. From this estimate more detailed work can proceed, analysing alternative proposals to arrive at the final design proposals and estimate.

12.3.2 Post-contract cost control

A properly cost planned project should present little difficulty in the tender and post-contract stage in terms of costing.

The control of cost during the progress of the work is equally, if not more, important than the pre-contract planning to keep the Engineer and employer fully abreast of the financial state of the project at all times. Ideally a running account of all variations should be kept together with an estimated valuation of other changes and works remeasured. Collation of these records enables cost forecasts to be made at regular intervals.

Chapter 13 Visual assessment of reclaimed landscape

based on the work of J.J. Ffennell and others

13.1 Appreciation of landscape

Clearly one objective of a policy for the reclamation of derelict land is to improve its appearance, and this objective has been supported by the level of grants made for reclamation in areas designated for economic growth, the improvement being held to be a factor in attracting new industries. On the other hand, it is true to say that there are examples of dereliction for which claims are made about their aesthetic interest. In fact, it is very difficult, if not impossible, to measure visual improvement with any accuracy or in a manner which is universally acceptable. Response to landscape varies, for example, with the cultural and economic background of the observer. The middle classes in the 19th century were attracted by the picturesque aspect of squalor and poverty when portrayed in a painting, but no such response was made by those who lived and worked in these conditions. Similarly, persons brought up in areas of landscape dereliction find it difficult to accept a pit heap as a form in the landscape, and to dissociate it from all it represents in social and economic history. An example of this conflict in response to the appearance of a pit heap,.is referred to later in this chapter.

Fines (1968) write thus of the many factors that relate to visual assessment:

"in its relationship to the observer landscape is multi-dimensional. The total experience whether pleasant or unpleasant obtained by the observer is not dependent solely - or even mainly - upon the response to visual beauty in the purest sense of the harmony of form, colour and texture in a single three dimensional pictorial composition, but upon interplay of sensory, psychological and sequential experiences".

Those responsible for the design of the reclaimed landscape of the various sites of the research project took into account the generally accepted principles of relating the proposals to the surrounding landscape and of the location and arrangement of the different elements with care and sensitivity. But, in particular, it was considered important to investigate the results at an early stage in order to ascertain what particular elements, and arrangements of them, made the greatest impact upon the observer in the way of early visual improvement.

13.2 Methods of analysis

Great interest is now being shown in methods of analysis of landscape in visual terms, and some references are given at the end of the Chapter. In general, however, the greater part of the work of visual analysis has been on the analysis and classification of large areas of rural landscape, whereas the various sites of the project, and perhaps the majority of derelict sites, lie in landscapes which are commonly accepted as of no more than average quality.

13.3 Government policy towards the environment of the North East

In the paper *The North East* published in 1963, the Government stated the problem of the area to be principally one of adjustment, and recognised there was a clear need for special help to shorten the period of adjustment and ease its difficulties. It was stated that the aim should be to promote a steady rise in economic activity as the basis for the continued growth of employment in the region and that "this action would be directed over a period of years towards an increase in the level of activity throughout the region as a whole rather than towards the relief of unemployment in particular localities". The reclamation of derelict land and the reduction of pollution were included in the Government's programme.

The Northern Economic Planning Council (1966) followed this up by pointing out that the reclamation of derelict land is an important part of rehabilitating the whole environment in the region's old industrial areas. Unemployment cannot easily be relieved without a new environment, as new industries are unlikely to move into the old one, and a new environment cannot be provided without the reclamation of derelict land.

13.4 Visual results of landscape reclamation

In May 1970, members of the Steering Committee of the research project looked at four sites which had either been reclaimed or were in the process of reclamation by the University. These were Northbourne Park, Big Waters, Roddymoor and Egerton Gardens. From the observations made by the members certain conclusions can be drawn. The surroundings of any site were particularly prominent in the observations of the members because, if there is disorganised clutter around a reclamation scheme, the smoother surfaces of a newly reclaimed site have a strong impact by contrast (Fig 13.1). In addition, panoramas are often exposed by the regrading, and these usually constitute the main visual change and must be taken into consideration.

13.5 Questionnaire on visual analysis

In January 1970, a simple questionnaire was sent out to forty-three people living adjacent to the Roddymoor, Northbourne Park and Egerton Gardens reclamation sites. In order to eliminate any risk of suggesting answers, the questionnaire was a postal one; replies were received from twenty-one people who either lived or worked in these areas.

13.5.1 Attitudes to the sites before reclamation

All except one person disliked the sites before reclamation, and the one exception felt indifferent. Everyone disliked the sordid appearance, and about a third also disliked the dirt, smell, danger and unavailability for productive use. It had been wondered if people would have a sentimental association for the sites through having used them as an adventure playground during their youth, but this was not so.

13.5.2 Attitudes to the sites during reclamation

Despite the noise of night working, all twenty-one thought the reclamation worthwhile, even if there was some inconvenience. There were requests, however, for a cessation of work between midnight and five in the morning. In about a quarter of the cases, inconvenience was suffered from dust and to a lesser degree from dirt, smell, noise and, in one case only, traffic.

13.5.3 Attitudes to the sites since reclamation

Everyone felt the reclamation was worthwhile and there was satisfaction that the sites were at last being used for some worthwhile purpose. The improved appearance was a strong factor and, to a considerably lesser degree, lack of dirt, lack of smell, reduction in danger and availability for use for walking, sitting and playing.

Nine people considered the change in the shape of the land and heap to be the more important, while nine others considered the new cover of grass and trees to be the more important. The remainder said both were equally important.

13.5.4 Suggestions for improvement

People at Roddymoor wanted more footpaths. They said there had been a few before reclamation which had been lost, and they felt that now the site was in a condition to be more available for public use, then more footpaths should be provided.

The questionnaire explained that there was intensive tree planting on all three sites and that in most cases the trees were small and would take some considerable time to make a show, but eleven people felt there should be even more trees. In one case, more grass was wanted, while in another case less grass was wanted.

The new views made a great impact, and nineteen people felt there was a significant improvement, while one respondent at Roddymoor felt the increase in sunlight to be a stronger point (Fig 13.2). One said the improvements were of equal value, but it was interesting to note how very strongly people preferred the visual improvement to the overall environmental one.

13.5.5 Questionnaire on visual analysis

1. Did you like or dislike the site before reclamation?

like	nil
dislike	20
indifferent	1

2. What did you most dislike about the site before reclamation?

dirt	8
smell	5
danger	8
appearance	20
unavailability for use	5
other reasons (please specify)	none given

3. Did you like the site before reclamation because:
   of its sentimental association
   of its use as a children's playground
   it was a large area of no activity e.g. industry, farming
   you thought it looked pleasant
   (nil return, see '1')

4. Do you, on balance, prefer the site since reclamation?

yes	21
no	nil
indifferent	nil

5. What do you like most about the site since reclamation?

lack of dirt	6
lack of smell	4
reduction in danger	5
appearance	21
availability for use (walking, etc.)	6

   other factor mentioned: that the site is being used

6. What do you dislike about the site since reclamation?

the use of land after reclamation	nil
you are no longer allowed to use it	1
its appearance	1

7. Which do you consider to be more important?

the change in the shape of the land (heap)	9
the new cover of grass and trees	9
equal	2

8. Would you like to see:

more trees (the trees are at present very small and will grow much larger)	11
fewer trees	nil
more grass area	1
less grass area	1
any other improvement - please state	
more footpaths	2

9. Do you consider there to have been any significant improvement in:

the view	19
direct sunlight	1
both	1

10. Did you suffer any inconvenience during the work from

dust	6
dirt	4
smell	3
traffic	1
noise	5

11. Do you think this could have been lessened in any way, and if so how?
    less work between midnight and 5.0 a.m. (night work is usually excluded from contracts, unless there are special circumstances)

12. In spite of temporary nuisance do you now think that the reclamation was worth while?

yes	21
no	nil

13.6 Assessment of individual sites

The observations of members of the Steering Committee and the answers to the questionnaire have enabled us to make

13.1

13.2 a

b

Fig.13.1 This photograph taken soon after the completion of the Northbourne Park site illustrates the extent to which the contrast between poor quality or untidy development adjacent to a reclaimed landscape emphasises by contrast the visual impact of the smooth grades of the latter.

Fig 13.2 (a & b) Photographs taken before and after reclamation at the Roddymoor site. The comparison demonstrates the increase in sunlight and view, which were improvements favourably commented upon by persons answering the questionnaire on visual improvement.

the following generalised assessment of individual sites, bearing in mind that either the Contracts had only been completed a few months previously or were still in progress.

13.6.1 Roddymoor, Crook, Co. Durham

Roddymoor is now an example of a soothing rural landscape (Fig 13.3). The harsh points of the pit heap have gone, the whole site having been moulded gracefully into the rolling countryside, and it is now virtually impossible to pick out Roddymoor from the surrounding environment. The 'feeling' of the pit heap has also been removed, for example the houses previously shielded from the low winter sun now enjoy improved daylight conditions all the year round

The site has now been returned to agricultural land for stock-grazing, with woodland on the steeper slopes. The agricultural area has been orientated towards the south where practicable to give a more favourable aspect. The steeper northerly slope forms one side of the valley and this asymmetrical form of a 'one-sided' valley is a feature commonly found in this part of Durham.

The planting has not been designed in the block formations usually used for research purposes, which would be unsightly when overlooked from the surrounding hills. Instead the trees have been planted in long lines, following the contours of the land.

Points to be learned from this scheme are that steep banks are very prominent in the period immediately following reclamation and that fencing should be in sympathy with the surrounding countryside as it forms an important element in the early stages. Harsh fencing lines with neither trees nor shrubs can spoil the desired natural look, although their effect can be slightly softened by having a road or other 'line' weaving through the scheme. Also, the design of the new land form must take into account the possible screening of surrounding areas of low visual value in the landscape, and conversely the exposure to view of elements like overhead wires that were previously hidden, which may occur.

13.6.2 Egerton Gardens, Newcastle upon Tyne

The result of the reclamation was described by one observer as an example of 'stimulating sequential urban landscape' (Fig 13.4). Bold earth moulding was designed to give something decisive which stands out from its surroundings, even if vandalism is so bad that planting and other elements are partially destroyed.

The southerly aspect provides views over the Tyne valley and also gives shelter. Planting on the lower slopes when growth has increased will screen nearer industrial sites in the valley bottom, and help to stabilise the steep banks. The site stands out well from Whickham across the valley.

It was noted that the experience on this site indicated the need for adequate topsoil cover in an urban setting in order to produce a hard wearing green cover, incidentally needing a higher standard of maintenance than in a rural area.

13.6.3 Big Waters, Seaton Burn, Northumberland

The site is to be a nature reserve and provide study facilities for the Northumberland and Durham Naturalists' Trust. The mass planting of the trees even at this early stage of growth is beginning to give the area a feeling of enclosure, and contrast in scale is emphasised between what can be seen up to the ridge and the surrounding landscape beyond. This emphasises the improvement that has been made. The fact that the scheme includes a large body of water and a stream is a great visual asset in the early stages of reclamation.

13.6.4 Northbourne Park, Walker, Newcastle upon Tyne

The site has been developed as a river-orientated park with space for strolling, informal recreation, and watching, as well as provision for boats, fishing etc. The design allows for more intensive use if this is subsequently felt desirable.

The scheme shows that care must be taken in running hard footpaths and roads along existing terraces or sloping up between them, as the result can be harsh and aesthetically unsatisfactory until the planting develops. Such roadways may be more sympathetic if they are varied in width and perhaps have bays to take seats here and there.

Care must also be taken not to use too much paving in prominent positions as this can look out of place if the reclaimed landscape is not on formal lines.

13.6.5 Percy Pit, Newburn, Newcastle upon Tyne

Plans were drawn up on the basis of a study done by Hackett and Vyle in 1966, but it has not been possible to carry them out. The spoil heap on the site had been recommended for retention as a landscape and industrial archaeological feature in the Survey of the Tyne Landscape (Laurie, 1965), but the local inhabitants were not in favour of retention. The University research team was asked to appraise the two recommendations, and the findings are reproduced in full:

Fig.13.3 Part of the reclaimed landscape at the Roddymoor site, which now constitutes a soothing rural landscape merging into the surrounding countryside.

Fig.13.4 The Egerton Gardens site after reclamation. This was referred to by one observer as constituting a 'stimulating sequential urban landscape', standing out from its surroundings. Such a design policy can be described as 'improvement by means of contrast'.

13.6.6 A Report on the alternative schemes for the redemption of Percy Pit, Lemington, in the urban district of Newburn, incorporating recommendations relating to the redemption of the heap

(a) *Terms of reference* An appraisal of the schemes has been requested; they are briefly:

(i) the leaving of the shape of the heap as it is, as envisaged in Mr. Laurie's Survey of the Tyne Landscape.
(ii) the removal of the top third of the heap and tying into the existing land form as a spur.

Other possible schemes are:

(iii) minor landform alternatives.
(iv) drastic re-shaping of the heap and surroundings.

The following is an abstract from the Survey

"Large scale tree planting and grassing is required to cover partially the unsightly surface of the main conical waste heap of Percy Pit and the Copperas Lane Site, but there should be no lowering of height with consequent reduction of scale in the waste heap which is so magnificently in key with the monumental quality of the power station and the cooling towers and chimneys, the breadth of the valley and the height of the surrounding hills. The crests of both waste heaps and existing hills should be laid out as 'viewing areas'."

(b) *Visual appraisal of the heap* - and possible effects of various land form alterations and different types of revegetation. Key viewing points at various distances from the heap were selected, and an assessment of the impact of the heap was made. The possible effects of various land form alterations and different types of revegetation were also considered.

Viewing Point 1

DUNSTON (ROAD - A6081)
Approximate distance from heap: 6.4 km (4 miles)

(i) *Comments - visual appraisal*
The colour of the heap was such that it merged completely into the landscape.

(ii) *The effects of various land form alterations*
Land form alterations would have little impact from this distance.

(iii) *Effects of different types of vegetation*
Grassing and tree planting would have little impact from this distance.

Viewing Point 2

WHICKHAM THORNS (SWALWELL ROAD) (A6081)
PHOTOGRAPH No. 1 (Fig. 13.5)
Approximate distance from heap: 5.23 km (3.25 miles)

(i) *Comments - visual appraisal*
The heap fitted into the landscape well, forming a visual stop to the gradually sloping hills, the background green fields forming a prominent feature. The heap itself contrasted well with the cooling towers, partially blackened at their tops.

Fig. 13.5

(ii) *The effects of various land form alterations*
The present shape of the heap forms a pleasant feature. However, in order that it might be laid out as a viewing area and for it to be more readily accessible, a certain amount of rounding off might be acceptable. By removing the top third of the heap, the line of the surrounding hills would be uninterrupted and the interesting feature lost.

(iii) *Effects of different types of vegetation*
Grassing the heap might emphasise its present shape in an unfortunate way, bearing in mind the almost luminescent quality of the background fields.
Tree planting would merge with the existing tree planting of the background.

Viewing Point 3

STELLA STAITHS
PHOTOGRAPH No. 2 (Fig.13.6)
Approximate distance from heap: 1.45 km (0.9 miles)

(i) *Comments - visual appraisal*
The heap does not make as great an impact as from the previous viewing point, both chimneys and cooling towers tend to diminish the visual importance of the heap.

Fig. 13.6

(ii) *The effects of various land form alterations*
By removing the top third, a spur could be formed which would merge with the surrounding hills. Slight rounding off would leave the heap as an interesting feature as envisaged in Mr. Laurie's report.

(iii) *Effects of different types of vegetation tree planting*
Tree planting in front of the heap would merge into existing tree planting and hedgerow systems.

Viewing Point 4

SWALWELL - RYTON ROAD (A695)

(i) *Comments - visual appraisal*
Glimpses of the heap through the trees gave the appearance of it fitting in with the landscape.

Viewing Point 5

NEAR WYLAM
PHOTOGRAPH No. 3 (Fig.13.7)
Approximate distance from heap: 5.23 km (3.25 miles)

(i) *Comments - visual appraisal*
The heap is situated reasonably well in the bowl of the valley. The distance is such that it almost merges with the landscape even in its present form.

(ii) *The effects of various land form alterations*
There is no strong case for the retention of the heap in its present form or for its reduction in height by one third to give a spur.

(iii) *Effects of different types of vegetation*
Tree grouping on the heap might give rise to an untidy appearance.

Viewing Point 6

NEAR HEDDON (ROAD - A69)
PHOTOGRAPH No. 4 (Fig.13.8)
Approximate distance from heap: 4.7 km (2.9 miles)

(i) *Comments - visual appraisal*
This is probably the most significant distant view point, the heap forming a visual stop to the sloping land.

Fig. 13.7

Fig. 13.8

(ii) *The effects of various land form alterations*
By removing the top third and tying the heap in as a spur, an interesting feature would be lost.

(iii) *Effects of different types of vegetation*
Tree planting would merge into existing tree planting and tend to reduce the height of the heap.

Viewing Point 7

NEWBURN ROAD (A6085)
Approximate distance from heap: 1.2 km - 0.8 km (0.75 - 0.5 miles)

(i) *Comments - visual appraisal*
Viewed as one journeys along this road, the heap 'sank' into the landscape and made its 're-appearance' at intervals.

Viewing Point 8

NEAR TERRITORIAL HALL' NEWBURN
PHOTOGRAPH No. 5 (Fig.13.9)
Approximate distance from heap: 0.8 km (0.5 miles)

(i) *Comments - visual appraisal*
From this view point the heap is not too dominant

(ii) *The effects of various land form alterations*
Removal of the top third would reduce its impact.

Fig. 13.9

Fig. 13.10

(iii) *Effects of different types of vegetation*
Tree planting at the base of the heap would have little impact from this view. Tree planting on the open space opposite the school adjacent to the Territorial Hall would reduce the dominance of the pit heap from this view point.

Viewing Point 9

NEWBURN ROAD (NEAR CHURCH)
PHOTOGRAPH No. 6 (Fig.13.10)
Approximate distance from heap: 0.72 km (0.45 miles)

(i) *Comments - visual appraisal*
The pit heap is a dominant element in the landscape; derelict houses appear at the left of the picture and, in the middle-ground , industrial concerns contribute as much to the air of dereliction as does the heap itself. Cleaning-up round the base of the heap would help, but equally as important is the cleaning-up of dereliction outside the boundary of the site.

(ii) *The effects of various land form alterations*
A certain amount of removal and rounding of the top of the heap would make the heap more acceptable from close to.

(iii) *Effects of different .ypes of vegetation*
Tree planting at the base of the heap and on adjacent industrial sites would diminish the impact of the heap from fairly close to.

Viewing Point 10

NEWBURN (HIGH STREET)
PHOTOGRAPH No. 7 (Fig.13.11)
Approximate distance from heap: 0.48 km (0.3 miles)

(i) *Comments - visual appraisal*
The heap again dominates the view.

(ii) *The effects of various land form alterations*
Slight reduction in height and rounding of the heap should reduce its overwhelming impact on the residents to an acceptable degree

(iii) *Effects of different types of vegetation*
Tree planting at the base would also reduce the

Fig. 13.11

impact of the heap. Screening of the Walker buildings would reduce the heap's impact still further.

Viewing Point 11

NEWBURN (TYNE VIEW)
PHOTOGRAPH No. 8 (Fig.13.12)
Approximate distance from heap: 0.96 km (0.6 miles)

(i) *Comments - visual appraisal*
The view is dominated by the heap and part of the Tyne Valley is obscured by it.

(ii) *The effects of various land form alterations*
Removal of the top third and tying in with the surrounding land form is a solution which would reduce the impact of the heap from this view point, but at the same time would remove a feature of a wider landscape setting. Rounding of the heap keeping the original form would help to reduce the impact.

(iii) *Effects of different types of vegetation*
Tree planting at the base of the heap would also help to reduce the heap's dominance.

Viewing Point 12

NEWBURN (LLOYD STREET)
PHOTOGRAPH No. 9 (Fig.13.13)
Approximate distance from heap: 0.32 km (0.2 miles)

Fig. 13.13

Fig. 13.12

(i) *Comments - visual appraisal*
The heap, although a dominant feature, appears to be more acceptable in its setting than from the previous view point.

(ii) *Effects of different types of vegetation*
Tree planting round the base of the heap would help to reduce its impact.

Viewing Point 13

LEMINGTON (UNION HALL ROAD)
Approximate distance from heap: 0.96 km (0.6 miles)

(i) *Comments - visual appraisal*
The impact of the heap was not too overpowering.

(ii) *The effects of various land form alterations*
The retention of the heap in its present form would be acceptable from this view point. Reduction in height by one third and tying into the surrounding land form as a spur would be equally acceptable.

Summary recommendations: Bearing in mind the several matters considered in the above, our recommendation is that the heap should be :

(i) rounded off at the top (as shown in Scheme 3)
(ii) kept largely unplanted and ungrassed, particularly on the upper slopes,
(iii) tree planting around the base and if possible outside the site boundary.
(iv) ancillary earthworks around the base towards the site boundary.

We make one qualification to the above recommendation that we will wish to investigate methods of holding fine dust particles where the heap is not to be grassed.

13.7 Conclusions

Landscape can be contrived or uncontrived, and contrived landscape can fall into two classes - soothing or stimulating. The experience which relates from landscape depends upon the sensory, sequential and psychological experience, and the latter need not always be constant.

An environmental image, or landscape, is not experienced on its own, but in relation to the context in which it appears, whatever has happened immediately before, and even in relation to past memories. This was particularly important at all the sites, and Roddymoor and Egerton Gardens are good examples of it.

The replies to the questionnaire showed the interest taken in the reclamation of landscape by people either living or working in the vicinity, and their deep appreciation of their environment is shown in the satisfaction they have indicated that the land is now being used for something worthwhile. The continuing Government policy of adjustment to a better environment is appreciated, but people frequently express the wish that the programme would move quicker.

13.7.1 Elements and effects giving visual impact

(a) In the early stages of a project, maintenance of clearly defined and closely mown areas, e.g. the flat terraces at St. Anthony's with other areas uncut, gives emphasis to the land form of a reclamation scheme.

(b) Footpaths are especially important as their appearance is very dominant, particularly when the reclaimed landscape is young and with little vegetation.

(c) Terracing effects give visual interest to slopes which may otherwise be reticent in a view.

(d) Low walls help in the early stages to give interest.

(e) If there is disorganised clutter around a reclamation scheme, smooth surfaces of a newly reclaimed site have a strong impact by virtue of contrast.

(f) Terraces built on a curve emphasise the terrace effect.

(g) Standard trees of large size (as at Big Waters) show up quite prominently against the bare shale soil, but might be 'lost' against grass.

(h) Deep cut streams are prominent and add much interest to the early barren stages of reclamation - as the landscape develops, their impact will be less.

(i) One large level platform (cf. Egerton Gardens) does help to emphasise the modelled landforms elsewhere on the site.

(j) The sharp angle between the slope and the plateau (Roddymoor) clarifies the modelling, particularly when the site is in a young state.

(k) A dense growth of clover adds variety to the usual cover of grass over a project.

(l) The surrounding countryside can be dramatised by the new landform design.

(m) The exposure of panoramic views constitutes the main visual change on many sites, and the effect of regrading to achieve this, with the screening of undesirable views, should be taken into consideration.

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5-3