A priority rating system for highway maintenance

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A PRIORITY RATING SYSTEM FOR HIGHWAY MAINTENANCE

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A COMPUTER BASED PRIORITY RATING SYSTEM FOR HIGHWAY MAINTENANCE

ABSTRACT

The purpose of the project was to design a system of computer programs to store and manipulate data concerning the physical characteristics and measurable defects of the roads in Durham County, based on the recommendations of the Marshall Committee on Highway Maintenance.

From the extent and severity of defects present, in conjunction with the physical characteristics of the section of road, remedial treatments and priority rating points can be assigned. Thus listings can be produced giving remedial treatments necessary for sections of road making up the highway network, in order of urgency. The system will eliminate from the listings those sections of road requiring no remedial work and indicate where a greater cost effectiveness is given by replacing remedial work by a minor improvement scheme (e.g. realignment of the road).

ACKNOWLEDGEMENTS

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To Gordon Craine who directed the project; to Howard Rose, the Marshall Engineer, who made sure that all the ideas incorporated in the system were practical; to all the members of the Highway Maintenance Section for their patience with my ignorance of the finer points of Maintenance Practice; to Mrs. Janis Wood who typed this thesis so efficiently; and to Miss Pauline Dobson who wrote some of the programs incorporated in the system, my grateful thanks.

Without their help and encouragement this project could not have been completed.

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INDEX

APPENDICES

1. Introduction

The report of the Marshall Committee on Highway Maintenance was published in 1970. It recommended that the approach to the problem of highway maintenance should be standardised at a national level; that a comprehensive, objective survey of highways be undertaken, and that a maintenance rating system be devised and applied. The Marshall Report classified roads according to their importance and the amount of traffic carried; and recommended that roads of a similar category should be maintained to a similar standard throughout the country.

The Committee found that the overall picture of highway maintenance was chaotic, with little standardisation of recording or expenditure, and wide variation in maintenance standards. The Road Research Laboratory collected data from a sample of 22 Maintenance Authorities (See Appendix F) and the Committee attempted, by analysis of available data, to quantify and explain the inconsistencies in terms of such variable factors as climate, traffic density, terrain etc. Only about half of the variation could be eliminated, suggesting that subjective judgements on the part of Maintenance Engineers and the varying efficiencies of the authorities were responsible for a large proportion of the discrepencies noted. Thus, if a comprehensive system of inspection and rating of highways were introduced on a national basis these variations could be greatly reduced, and the overall efficiency of the maintenance function increased.

Since there is usually more remedial work to be done than funds will finance, a maintenance rating system would enable the Maintenance Engineer to formulate policy based on verifiable facts, and allow the effects of various courses of action to be assessed. Long term plans could be made using the rating system and such machines as Deflectograph (for measuring the strength of the road), avoiding costly and disruptive emergency repairs caused by failure or near-failure of the fabric of the

Road, and giving the Maintenance function greater cost-effectiveness.

A data base containing maintenance information, probably computer based, would also provide easily accessed objective data on the state of the highways in the County area and obviate the necessity for "scouting" for information on receipt of queries. This advantage would be greater in the larger, less compact rural or semi-rural County Authorities.

This thesis describes the design and implementation of a Maintenance Rating System now installed by Durham County Council.

2. Previous Work

The Marshall Report put forward a rating system, described below, and several working parties have since described data collection and rating systems based on the recommendations of the Marshall Committee.

2.1 The Marshall Report does not give a detailed description of a data collection system but outlines a rating system. Each defect is assessed out of 100 points, such that maximum points would indicate a completely satisfactory condition and zero points complete unserviceability. These ratings are designed to be carried out over lengths of approx. 500 metres (Marshall Sections) and where defects are measured objectively tables giving the relationship between percentage defective and rating points would have to be devised. Adjustments are then made to the assessments to take into account the presence of patching, skidding resistance etc., and weighting factors applied to differentiate between the importance of the defects. The final adjustment is made to allow for the importance of the traffic flow, giving the final rating. Critical levels would be compared before the application of the weighting factors. The lowest final rating for each section would then be taken to determine absolute priorities between sections. This method of rating depends very heavily on weighting factors, if these are accurate then the system will, within its limitations, be reasonably good. It is a manual system basically which would be inappropriate if transferred to a computer, and the 500 metre sections are too rigid for a large scale system. Therefore this system would be reasonable for a small urban authority with few computer facilities. However for an authority with a large highway network there is too much manual work involved for a very basic and rigid system and this system as it stands would be uneconomic.

2.2 T.R.R.L. * produced Technical Note NOTE A which set out a comprehensive system of measurements and data collection, based on practical experimentation and experience, which could be used as a guide-line, in an objective survey of an authorities' highways. This Note elaborates on the Marshall Report standards and measurements (Appendix A), expanding and in some cases rationalising them. Measuring instruments and methods of inspection are all well described and the data collection system should be capable of adaptation to any Authorities needs. This report introduces a variable length Marshall Section of road, using highway features (road junctions or variations in road geometry) or administrative features (divisional or district boundaries) to divide these sections. In some cases a section could be several kilometres in length so 100 metre sub-sections are introduced to locate deterioration. This is an improvement on the Marshall system, which split all roads into 500 metre sections, since it gives logical start and end points for sections and also a finer location of deterioration within sections.

However the processing method shown is manual and uses running lengths of deterioration, with averaging of deterioration percentages, which could mask short lengths of bad deterioration. So although the methods of measurement and data collection are good, a better processing method giving greater definition of critical areas is needed. For most authorities computer processing of the highway data would be more economical in terms of cost and time.

2.3 Working parties representing the City Engineer's Group have developed a system based on the recommendations of the Marshall Report and on Technical Note NOTE A. A rating points system is used, similar to that suggested in the Marshall Report, where for a defect, a range of deterioration is given a certain points

* Transport and Road Research Laboratory.

rating. A road where a certain defect is absent would be given a rating of 10 points for that defect, and as the amount of deterioration for that defect increases, the rating given for the defect decreases in an inverse relationship. Weighting factors are used to differentiate between the importance of the various defects measured and also between the different categories of road. The roads are divided into maintenance lengths according to local environmental conditions and only one reading for each defect is taken along the maintenance section. This is reasonable for City streets where the sections will be very short, e.g. a section of street betwen two junctions, but in more rural areas, and on roads such as motorways and trunk roads, sections could be more than a kilometre long, where there are no administrative boundaries to subdivide the sections further, so that only one reading would give an inaccurate picture of the condition of the road. The actual percentages of deterioration are not recorded and as the percentage spread for a particular rating point can be 20% or more the accuracy of the assessment could be suspect. Further if the rating system were changed then the sections could need resurveying. The weighting factors are said to work well but the rating relationships they are based on are at times illogical giving a lower (and therefore more critical) rating to a less important defect. This system, like the Marshall system, is a basically manual system with the computer being used for storage and the production of the final priority lists. Thus the computer is not being used to its full advantage and this system would entail too much manual work to be economical to run for a large highway network. The computer system uses magnetic tapes for storage which are very slow compared to direct access disk files, thus increasing running time for the programs and therefore increasing computer costs. The printed output is also fairly difficult to follow where large volumes of output are envisaged.

2.4 Edinburgh Corporation, in association with the T.R.R.L. produced Technical Note NOTE B, which describes a comprehensive rating system differentiating between the importance of the various defects by assigning individual rating relationships to the defects. Thus a priority list can be compiled taking into account all defects present in the road and their relative importance, and the system allows for comparison between the conditions of different stretches of road. Certain minor modifications and rationalisations have been applied to the standards set out in the Marshall Report and in NOTE A for the critical levels of deterioration. NOTE A introduced the 100 metre sub-section, which is valuable in localising deterioration and preserving definition in the measurements, criticality being determined on a sub-section basis. However NOTE B splits these 100 metre sub-sections into 10 metre microsections and uses these microsections to calculate rating values. The microsections may be useful, in urban situations, for locating deterioration on a fine basis but as a basis for the calculation of rating values they are illogical. For continuous (chainage to chainage) recording the final rating gained over 100 m is identical whether the ratings are calculated on 10 metre microsections and totalled or the rating is calculated for the total deterioration, for that defect, over 100 metres. However the former method involves up to ten times as much calculation. Similarly for fixed interval recording at 20 metre intervals, as suggested by NOTE B, ratings calculated on the basis of the 20 metre reading will be identical to those calculated at 10 metres, but with half the calculation time. For fixed interval recording at 25 metres, as suggested by NOTE A, the ratings based on 10 metres will not only take 2½ times longer but will be inaccurate since the readings at

10 metres will be based on interpolated values. For a large highway network such inefficiency of calculation, without the mitigating circumstance of more useful information, since maintenance other than patching would not normally be carried out on a length of less than 100 metres, renders the system described by NOTE B uneconomic to run. The Edinburgh system uses sequential disk files as storage for the Marshall data base, which is reasonable for the initial creation run if all data is available at once. However where random access is envisaged, for updating or for interogation, a large proportion of the file could be read unproductively. This inefficiency of disk storage, in the context of a large road network (6000 records), could mean an average overhead to update one record of 500 times that for an equivalent direct access storage system. The printed output consists of histograms of rating points on 10 metre microsections. This is a very visual output and very easily assimilable; however for a large highway network such output is very voluminous and therefore individual lengths of road would be difficult to find without an efficient indexing system.

All the above rating systems are either manual systems or have been developed by City authorities with small compact highway networks. None are efficient enough to be applied to a large network in a County. Therefore it was decided that a series of programs should be written by the author to process the data collected and to implement a computerised maintenance rating system. The data collection system described in NOTE A, which is both simple to use and objective was adopted and has been proved satisfactory. The rating relationships proposed in NOTE B have been utilised as a basis for the rating system. However these require further study and adjustment as the results of the rating programs are compared with actual conditions. The program suite was written in PL/1 for and IBM 370/145 and uses direct access files (for a more detailed discussion of the computer aspects see Appendix E).

3. Extensions to the Rating System

All the above working parties have concentrated on providing Maintenance Rating Systems without fully exploring the interactions between the Maintenance function and the other departmental activities (Traffic, Planning, Land Use etc). To implement the Marshall Report a comprehensive data bank must be created. If this information is stored in such a way as to be easily cross-referenced with other data banks the effects of planning decisions, traffic policies etc. on the maintenance function could be assessed; allowing priorities to be changed or policies advanced which would allow for greater cost effectiveness. Where a section of highway requires reconstruction because the road is badly rutted or failing then other factors could indicate that a minor improvement such as realignment or widening of the road would give a greater cost benefit than costly and possibly ineffective remedial work. These factors would be increasing traffic, a bad accident record and a low free speed (See Appendix I). The Marshall data bank could provide useful information for planning and traffic functions since the condition of the road network could be taken into account when a factory or estate site is chosen or when a new road or by-pass is planned.

The County Forward Plan encompasses all of the various departmental functions and if the interaction between data banks is facilitated the Forward Plan forcasting should be improved. The implications of such policy decisions can be assessed more thoroughly since more data is available in compariable form.

The Programme of Work (see Fig. 1 below) for the highway network shows the allocation of work between Maintenance and Transportation.

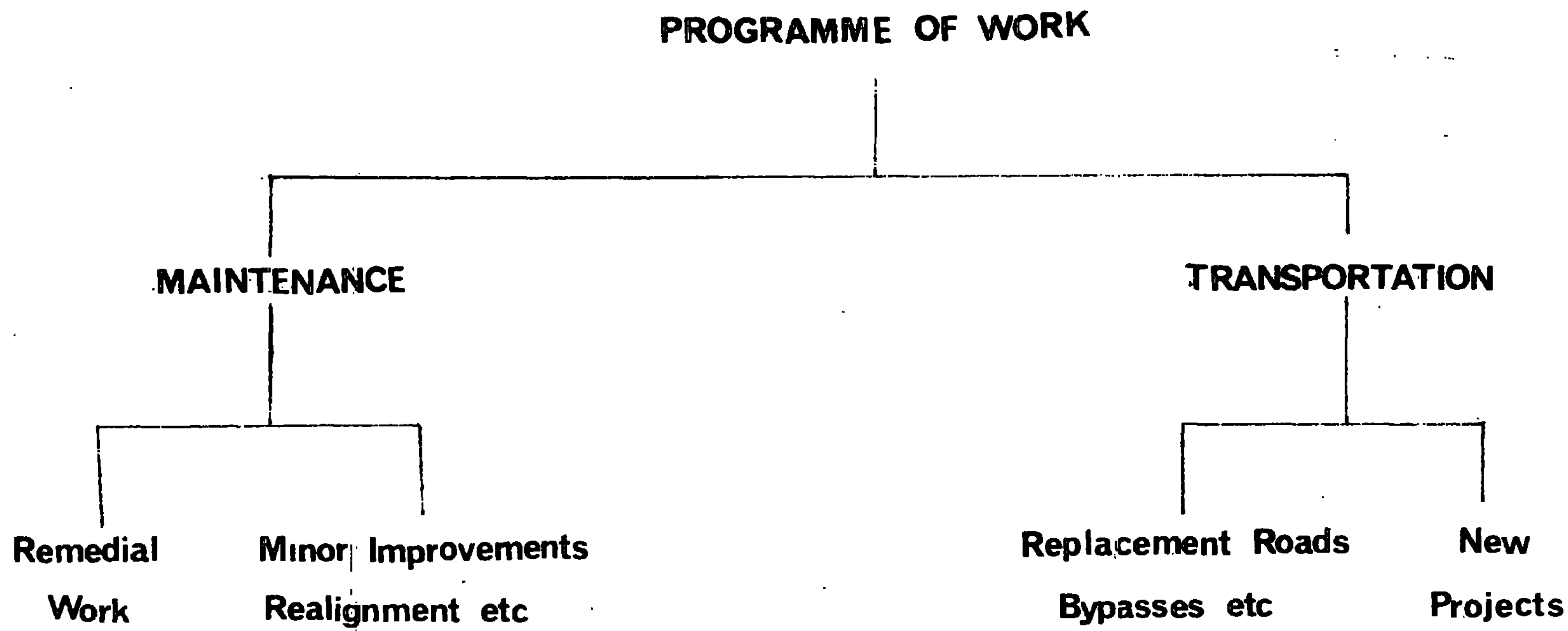

PROGRAMME OF WORK
MAINTENANCE
TRANSPORTATION
Remedial Work
Minor Improvements Realignment etc
Replacement Roads Bypasses etc
New Projects

Figure 1

4. Data Collection

4.1 Introduction

The object of the system is to give an objective and detailed view of the County highways, and to enable the Maintenance Engineer to allocate funds to the various maintenance projects on the basis of greatest need.

It will indicate to the engineer the treatment or treatments necessary, with any substitute treatments which could be carried out if a main treatment is ruled out due to lack of funds.

A computer based system has been used, since it will handle large masses of data efficiently and will perform complex manipulations on that data accurately. For a small road network, say in a city, this efficiency is not so imperative, but for a large road network, say a county, such efficiency is necessary for an economic system.

The system eliminates all sections of road requiring no treatment and allows the engineer to use his expertise to formulate an optimum program of work on the basis of verifiable data.

4.2 Defining Sections

The approximately 500 metre sections recommended in the Marshall Report were replaced in NOTE A by a more flexible method of defining sections, based on construction, traffic and important physical details. Each carriageway of a dual carriageway road, roundabouts, slip roads and very large junction areas would be separate sections. Junctions would normally define the end of a section, but where a major road crosses an unclassified road (an unclassified junction) only the minor road need be divided, unless other factors also change at this boundary. Changes in construction type will also define the end of a section as will changes in the width of the road (i.e. from 2 lanes to 3). Large changes in traffic volume will also signal the end of a section, as where an unclassified estate road loads a considerable volume of traffic on to a classified road.

Because of the interaction between departmental functions mentioned in 3 above, other factors will also define the end of a section; these are important nodes on the county traffic network, delegation limits and administrative boundaries (i.e. for divisions and districts).

4.3 Defects

The programs calculate ratings on 100m sub-sections for structural defects, of pavement and roadside. Such amenity maintenance as roadsweeping and snow clearing is not included in the priority rating system.

The defects measured are as follows :-

Roadside

1. Footway deterioration.
2. Verge deterioration.
3. Kerb deterioration.
4. Kerb upstand deficiency.
5. Provision of kerbs for the protection of pedestrians.

Pavement

1. Wheel track rutting.
2. Wheel track deterioration.
3. Whole carriageway deterioration major.
4. Whole carriageway deterioration minor.
5. Edge deterioration.
6. Inadequate drainage.
7. Existing patching.

Loss of skidding resistance is not measured at present. The SCRIM* machine (which is used for testing skidding resistance) is rather expensive and the question of the interpretation of results is not yet satisfactorily answered as yet (see Appendix H). However provision has been made to store the skidding resistance factors. These factors will not be incorporated into the priority rating system but will be used in conjunction with it to provide lists for remedial treatment.

Deflection readings, which are a measure of the strength of the pavement, are obtained by using the Deflectograph machine (See Appendix H). They are stored for each 100 metre sub-section for all Marshall Category 1, 2 and 3 roads (See Appendix A). They are incorporated into the Rating System to give road life data as a check against the visual inspection ratings.

Surface irregularity is measured by using the Bump Integrator machine. The output from this machine is stored for each Marshall Section as integrated inches per mile, and used as further information for the engineer without incorporation into the rating system.

Adverse camber is deemed to be impractical to measure objectively. However, where it occurs to a dangerous extent, usually on older roads, it could be noted by the inspection team and reported to the Maintenance Engineer. It is not stored and is not incorporated into the Rating System.

4.3 Recording

There are three methods of recording defects :

(a) Continuous : chainage to chainage recording. Most deterioration will be recorded in this way. Coded as start

* Sideways Force Coefficient Routine Inspection Machine.

chainage end chainage and value. (width, severity etc).

(b) Spot : deterioration too small to be recorded as continuous. Coded as chainage and area.

(c) Fixed Interval : Measurements taken at regular intervals (usually 20 or 25 metres) along a road. Rutting and kerb upstand are measured in this way, since the defect is deformation from a standard value rather than physical deterioration. Coded as continuous recording.

The measurements are recorded in the manner described by NOTE A onto sheet A (See Appendix B)

The readings are then transcribed onto Sheet 3 (See Appendix B) for punching. The recording and punching documents are separate since to design a document which is suitable for both purposes is extremely difficult. The detrimental effect of transcribing errors is felt to be more amenable to checking routines than those errors produced by a sheet which is perfect for neither of its functions and therefore produces errors in both.

4.4 Treatments

(a) Resurfacing, overlaying and reconstruction - correct general deterioration of the surface, rutting, surface irregularity, adverse camber and where surface dressing is inappropriate, sub-standard skidding resistance. Overlaying and Reconstruction will also strengthen the pavement where increased traffic loads threaten to cause structural failure and will prevent structural failure due to normal loadings. Reconstruction also corrects structural failure.

(b) Surface Dressing - seals porous surfaces against the entry of water, binds the surface of the pavement at the onset of deterioration and restores skidding resistance.

(c) Patching - repairs small isolated areas of serious rutting, deterioration, erosion and edge failure of carriageways and inadequate reinstatements of openings in the carriageway.

(d) Haunching and kerbing - repairs and protects the edges of the carriageway where overriding and potholing of the edge is severe.

(e) Drainage treatment - to ensure that water is not allowed to penetrate the road and is removed from the surface of the carriageway as quickly as possible. Inadequate drainage is sometimes due to rutting of the pavement especially on corners where the asphalt has been "squeezed" by the sideways force exerted by vehicles cornering, so that it forms a "wall" between the wheel track and the drainage channel. This situation is cured by treating the rutting rather than by drainage treatment.

The standards for the application of the above treatments are those given in the Marshall Report and amended by NOTE A and NOTE B and are set out in Appendix A.

The computerised system does not indicate where patching of the carriageway is necessary to cure potholes, small areas of very bad deterioration or bad reinstatements by statutory undertakers. These conditions would be reported by the inspection team and would be dealt with in the minor maintenance program, or within 24 hours if the condition is dangerous.

5. File Structure

In deciding the file structure and the storage devices to be used the ultimate aims of the system must be considered; otherwise a file structure could be chosen which, while suitable for the initial creation of the data base, would not be adaptable for further processing. This would make the system extremely rigid, inefficient and uneconomical to run.

The first choice is that of storage device; between magnetic tape and disk storage. The data base is large and access time must be small for efficient execution of the programs. Magnetic tape storage, although inexpensive, is extremely slow in comparison to disk storage and, therefore, for a large highway network would make the access time overhead too great for economical running of the programs. Thus disk storage would be more suitable for this application.

Having decided the storage device the file structure must be chosen. For this decision the content of the files must be examined. The data falls neatly into two classes, first, general data pertinent to each section and secondly, inspection data pertinent to each hundred metre sub-section. If only one file was envisaged, variable length records would have to be used since each section is of a different length. In certain circumstances such a record (for a section of maximum length, ten kilometres) could be over 6000 bytes long, which is an extremely unwieldy size. Also, editing of files would normally be carried out for one type of data (general or inspection) at a time; with only one file the whole record would have to be retrieved to edit possibly a small proportion of the data, implying large overheads and resultant inefficiencies. Thus for maximum utilisation of file space and minimum retrieval time two separate files would be indicated. This would allow the general and inspection data to be stored at different times without records having to be retrieved (as they would be if only one file was used), giving increased efficiency. Further, as the sections are of different lengths if variable length records are not to be used, a suitable sub-division should be found.

The average length of a Marshall Section in a semi-rural area such as Durham County is approximately one kilometre and storing the information pertaining to 1 kilometre of road (in 730 bytes, See Section 6) gives the best utilisation of disk space (least wasted space for 73 byte multiples) for a 3330 type disk pack. Thus each section of road is split into kilometre lengths for storage purposes. The file structure therefore is a general information file with one record per Marshall Section and an inspection data file with one record per kilometre of Marshall section.

Finally the access method must be decided upon. There are two types of access method :

(a) Sequential access, where the records are accessed in physical order, so that to read the n^{th} record of the disk file the (n - 1) records before it must also be read.

(b) direct access, where any record can be accessed in random order, so that the n^{th} record of the disk file can be read directly without any other records being read.

To decide between the two access methods the various functions of the suite of programs must be examined. The programs perform the following procedures :

(i) Creation of disk files: since the amount of data is large it may not be possible to create the entire file in one run.

(ii) Updating of disk files: possibly only a selection of data on file will be updated at any one time.

(iii) Priority Scan : this involves a sequential search of the inspection data file for continuous lengths of pavement requiring remedial treatment.

(iv) Calculation of the life expectancy of various roads in the network, for which deflectograph readings are available.

(v) Displays, in histogram form, of the condition of various roads in the network; these displays could be requested on a random basis.

For all functions apart from (iii) random access of the data files would be more efficient than sequential access. In the extreme case to update one record only in a file of 6000 records would take an average of 5 seconds for sequential access and 5 - 10 milliseconds for direct access, since sequential access requires that the file be read, unproductively, until the required record is reached.

For the Priority Rating scan direct access may give a marginally greater access time but the difference in time is negligible.

Therefore for greatest efficiency of access time for the functions envisaged, direct access files should be used.

However to use direct access files the location of data on the file must be known. For the inspection data file this is relatively easy since each general information record has an associated block of inspection data records. Thus a pointer (in this application the record number of the first inspection data record) can be stored with the general information for each section to give the location of the associated block of inspection data records. To find the location of data on the general information file an index is used. The index is a sequential file which is searched to find the location of the first general information record for a particular road. To make access quicker the index is split into six sections, one for each class of road, Motorway, Trunk, A, B, C and Unclassified. To access a section other than the first in a road the pointer can be incremented and the general information record for that section read directly. Similarly the second and subsequent kilometre records for a Marshall Section can be accessed directly by incrementing the pointer for the first inspection data record associated with that section.

The most efficient storage method for this application consists of a three tier system of files (an index, a general information file, with one record per section and an inspection data file with one record per kilometre of Marshall Section) stored on disk and using, for the general information file and the inspection data file, direct access methods. The structure of the files is shown in Fig. 2 below.

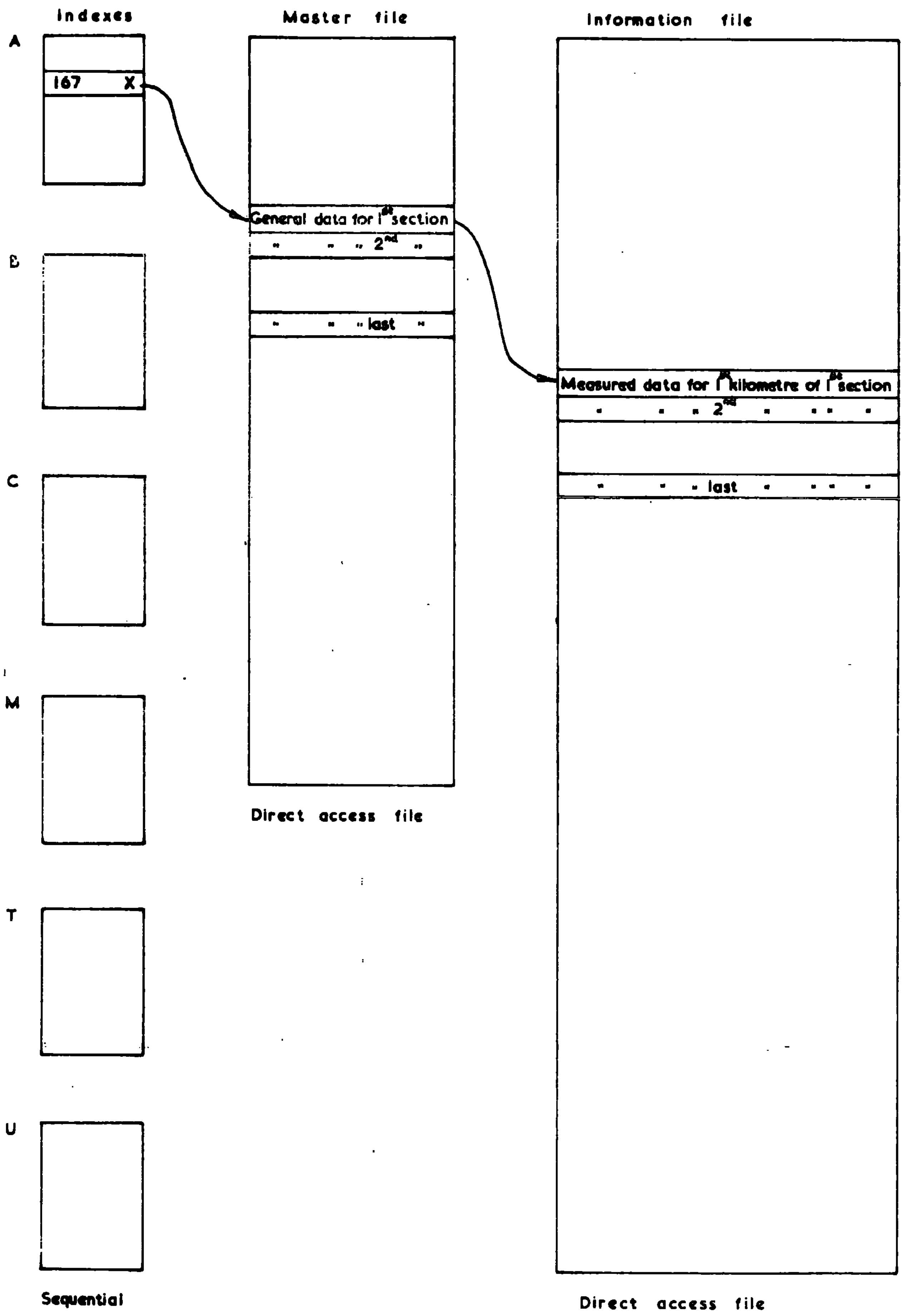

Indexes
Master file
Information file
A
167 X
General data for 1st section
" " " 2nd "
" " " last "
Measured data for 1st kilometre of 1st section
" " " 2nd " " "
" " " last " " "
B
C
M
T
U
Direct access file
Direct access file
Sequential files

Figure 2

6. File Contents

6.1 The General Information File

This file contains data split into four broad categories :

(i) Geophysical: giving information for use with the rating system on the general condition of the section of road, details of the physical location of the section of road etc.

(ii) Traffic: facilitating interface with the traffic information files to allow future trends in traffic flows (particularly numbers of heavy lorries) and their putative effects on the fabric of the roads to be assessed.

(iii) Location and Administrative: to allow sharing of work throughout the County and to enable information to be extracted for various sub-divisions of the highway network.

(iv) Historical data: giving an indication of the type, extent and timing of recent remedial work done.

This general information gives valuable background data to the rating system and allows future trends to be examined. The contents of the file are as follows :-

(i) Geophysical Data:

(a) Length.

(b) National grid co-ordinates of start point and end point of section.

(c) Restrictions on height and weight of vehicles using the section.

(d) Surface irregularity factor.

(ii) Traffic Data:

(a) Link number (for the link which contains this section)

(b) Node numbers for the above link.

(c) Speed limit information.

(d) Traffic flows.

(e) Percentage of heavy vehicles.

(f) Realistic travelling speed for the section.

(iii) Location and Administrative Data:

(a) Division.

(b) District.

(c) Ministry GPH Number.

(d) Delegation Limits.

(e) Marshall Category.

(f) Urban/Rural Classification.

(iv) Historical Data:

(a) Type of remedial work done.

(b) Extent in metres.

(c) Year work carried out.

(v) Pointer to the associated block of records in the inspection data file.

6.2 Inspection Data

There are three broad categories of inspection data:

(i) Data collected by inspection teams during routine inspections of the highway.

(ii) Data on gradients and radii of bends.

(iii) Data supplied by the Deflectograph and Scrim Machines (Appendix H)

The contents of the inspection data file is as follows :

(a) Footway width left and right.

(b) Verge width left and right.

(c) Left footway deterioration.

(d) Left verge deterioration.

(e) Left kerb deterioration and upstand.

(f) Right kerb deterioration and upstand.

(g) Right verge deterioration.

(h) Right footway deterioration.

(i) Left carriageway edge deterioration.

(j) Wheel track rutting.

(k) Wheel track cracking.

(l) Whole carriageway deterioration major.

(m) Whole carriageway deterioration minor.

(n) Right carriageway edge deterioration.

(o) Existing patching.

(p) Inadequate drainage.

(q) Carriageway width.

(r) Bend and Gradient Factors.

(s) Deflectograph records. (when available)

(t) SCRIM - skidding resistance records (when available)

6.3 The Index

This file contains the road number, the number of sections contained by the road and the pointer to the first general information record associated with the road.

7. Creating the General Information File

The general information (or master) file consists of one record per Marshall Section of road and contains data pertinent to the section as a whole (see 6.1).

Certain of the data items stored on this file are informative and are not essential to the initial running of the priority rating system. Therefore to facilitate the creation of the general information file only the following essential data items are stored at file creation time. Other data items will be added to the file as they become available.

Items initially stored are :-

(i) length.

(ii) link number - the link in the traffic network which contains the section.

(iii) node numbers - the nodes at the start and end of the above link.

(iv) National Grid Co-ordinates of the start and end points of the section.

(v) Division.

(vi) District.

(vii) Strategic Route Classification. (See Appendix A).

(viii) Marshall Category.

(ix) Delegation Classification.

(x) Urban/Rural Classification.

(xi) D.O.E.* G.P.H. Number (if known)

(xii) Speed Limit Data.

(xiii) Adjacent Marshall Section : for a short length of dual carriageway this is the Marshall Section adjacent to the section under consideration, as shown in Fig. 3 below.

* Department of the Environment.

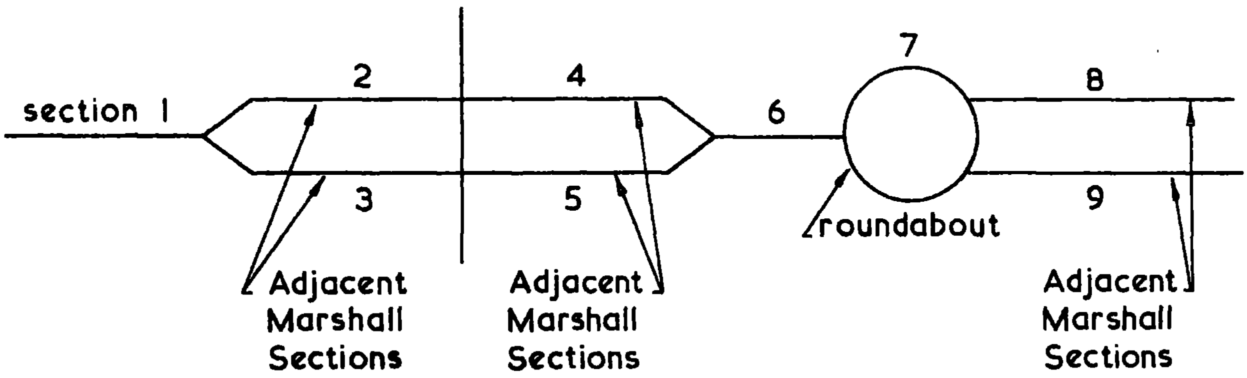


FIG. 3

(xiv) Delimiter : where a treatment length would end because of a discontinuity of the road, such as a roundabout or where a minor road crosses a major road, any treatment necessary on the minor road would not impinge on the major road.

To create the general information file the road identifier must be entered in the appropriate index, the position of the road in the general information file must be discovered and a pointer to the position of the rating data for each section of the road must be calculated.

The program decides the index relevant to the road; it then searches all indexes to find the general information file pointer with the highest value, giving the last road to be added to the general information file and increments this pointer by the number of sections present in that road, giving the position of the next "free" record in the general information file. Before the new road can be added to the index and therefore to the general information file the next "free" position on the rating file must be found. This is calculated using the last general information record of the last road to be stored, since this record gives the position of the rating information relevant to the first kilometre of the last Marshall

Section of the road. By incrementing this pointer by the smallest integer greater than the length of the section in kilometres the position of the next "free" record of the rating file can be found. The new road is then added to the appropriate index and the relevant data read from cards and stored in the general information file.

The road indentifier will normally be the road number, but provision has been made for alphameric notation to reduce ambiguity. For example, where the M1 and the A.1(M) are both present in a county area both would be entered in the Motorway index with road identifier '1' for the M1 and 'A1' for the A.1(M).

An updating program is used to correct data already stored or to add new data to the file. The program reads the road type and road identifier from the reader card. The road type identifies the index the program must search to find the information associated with that road identifier. The position of the general information record pertinent to the first Marshall Section of the road can be found from the index, and therefore the general information record for any section of the road can be updated directly by the program. The input data (sheets 2A and 2B in Appendix B) is checked for illegal characters and any valid data is entered in the appropriate position in the general information record and the whole record is displayed.

The general information records for a road or part of a road can be displayed on the line printer, with appropriate headings (See Appendix B).

8. General Information File Programs

There are four programs which manipulate the General Information File Data.

(i) MASTRF - which creates the file.

(ii) MFDISP - which displays the data on the file.

(iii) MFEDIT - which edits the data on the file.

(iv) SNAME - adds a section description or name to each general information record.

8.1 MASTRF

This program sets up the index files and the general information file. The first road to be entered on the general information file must have its data cards preceded by a card containing "CREATE" in the first six columns. This card sets all the keys to zero and initialises all the index files.

Data for all Marshall Sections of a road need not be entered in the same run since the program reads the section number from the card and accesses the relevant record directly.

8.1.1 Data Input

Card Type 1

Cols	
1	Road Type.
2 - 5	Road Identifier.
6 - 8	Number of Marshall Sections in the road.

Card Type 2

Cols.		
1 - 4	Node 1	Nodes on the traffic network.
5 - 8	Node 2	
9 - 12	Link Number from the traffic network.	
13 - 14	Indicator for sequence of roads, and direction, in a strategic route.	

Card Type 2 (Continued)

Cols.		
15 - 20	Easting	Start Co-ordinates.
21 - 26	Northing	
27 - 32	Easting	Finish Co-ordinates.
33 - 38	Northing	
39 - 41	Length.	
42	Division.	
43	District.	
44	Strategic Route Classification.	
45	Marshall Category.	
46	Delegation Status.	
47	Urban or Rural Status.	
48 - 52	G.P.H. Number for Trunk Roads.	
53 - 54	Speed	Speed Limit Information.
55 - 57	Start Chainage *	
58 - 60	End Chainage *	
61 - 62	Speed	Speed Limit Information.
63 - 65	Start Chainage *	
66 - 68	End Chainage *	
72 - 74	Adjacent Marshall Section for dual carriageway roads.	
78 - 80	Marshall Section Number.	

Card Type 3

Cols.	
1 - 3	"END" - delimiter Card.

* To nearest 10 metres.

If only one road is processed in a single run then no card Type 3 is necessary.

There will be as many cards Type 2 as there are Marshall Sections to be entered on the General Information File.

Several roads may be processed in a single run, the sequence of cards for such a multiple processing being as shown in Fig. 4 below.

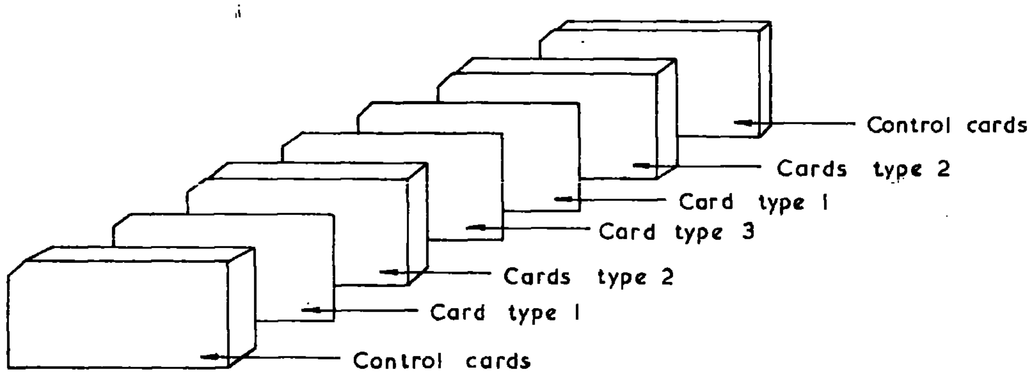


FIG. 4

8.1.2 Error Messages

The error messages produced by this program are self explanatory, as shown below :

(i) ILLEGAL CHARACTER ON CARD ----------

(ii) TOO MANY SECTIONS FOR ROAD ----------

(iii) NO SECTIONS ENTERED FOR ROAD ----------

8.1.3 Output

A disk record is entered in the appropriate index file.

As many general information records as there were cards Type 2, entered in the General Information File in the appropriate places.

The format of the printed output is shown below, in Fig

5. A more detailed example of the printed output is given in Appendix B.

8.2 MFDISP

This program displays records from the General Information File for a particular road. All Marshall Sections for a road can be displayed or a selection of sections can be made. If all sections are to be displayed no cards Type 2 are necessary.
The program reads the Card Type 1, finds the road in the appropriate index and uses the pointer contained in the index record to find the relevant General Information File Records to be printed out.

8.2.1 Data Input

Card Type 1

Cols.	
1	Road Type.
2 - 5	Road Identifier.
6 - 8	if all sections are to be printed out then this field should contain "ALL" otherwise it should contain the total number of sections to be printed.

Card Type 2

Cols.	
1 - 3	1st Section to be printed out.
4 - 6	2nd Section to be printed out.
7 - 9	3rd Section to be printed out.
10 - 12	4th Section to be printed out.
13 - 15	5th Section to be printed out.
16 - 18	6th Section to be printed out.

```
  ROAD NO A  67            SECTION NO   7           LENGTH 0.51         NO OF SECTIONS  45

 NODES    LINK IND START COORDS  FINISH COORDS D D S M U GPH NO D=STCH ENCH
 1    2    NO  R D    E      N      E      N    V S R C R        L

 0    0    0  0   404780 516370 405020 516300 3 6 P   U               0     0

        SPEED LIMITS          REAL       WORK DONE           TRAFFIC FLOWS
SPD STCH ENCH SPD STCH ENCH T.SP T YR LNTH T YR LNTH YR FLOW  YR FLOW  YR FLOW

 0    0    0   0    0    0    0  0  0    0 0  0    0  0    0  0    0  0    0

%   RESTRCTN SURF I WDTH DEG LIGHTING AMS
HV  HT    WT  YR RDG B.FR URB STD  NC

 0 0.00  0.0  0   0  0.0   0   0   0   0


  ROAD NO A  67            SECTION NO   8           LENGTH 0.05         NO OF SECTIONS  45

 NODES    LINK IND START COORDS  FINISH COORDS D D S M U GPH NO D=STCH ENCH
 1    2    NO  R D    E      N      E      N    V S R C R        L

 0    0    0  0   405020 516300 405030 516340 3 6 P   U               0     0

        SPEED LIMITS          REAL       WORK DONE           TRAFFIC FLOWS
SPD STCH ENCH SPD STCH ENCH T.SP T YR LNTH T YR LNTH YR FLOW  YR FLOW  YR FLOW

 0    0    0   0    0    0    0  0  0    0 0  0    0  0    0  0    0  0    0

%   RESTRCTN SURF I WDTH DEG LIGHTING AMS
HV  HT    WT  YR RDG B.FR URB STD  NC

 0 0.00  0.0  0   0  0.0   0   0   0   0
```

Figure 5

Card Type 2 (Continued)

Cols.

19 - 21	7th Section to be printed out.
22 - 24	8th Section to be printed out.
25 - 27	9th Section to be printed out.
28 - 30	10th Section to be printed out.
31 - 33	11th Section to be printed out.
34 - 36	12th Section to be printed out.
37 - 39	13th Section to be printed out.
40 - 42	14th Section to be printed out.
43 - 45	15th Section to be printed out.
46 - 48	16th Section to be printed out.
49 - 51	17th Section to be printed out.
52 - 54	18th Section to be printed out.
55 - 57	19th Section to be printed out.
58 - 60	20th Section to be printed out.
61 - 63	21st Section to be printed out.
64 - 66	22nd Section to be printed out.
67 - 69	23rd Section to be printed out.
70 - 72	24th Section to be printed out.
73 - 75	25th Section to be printed out.

There will be as many cards Type 2 as are needed to specify the sections to be printed.

Further roads may be displayed by submitting subsequent Type 1 and Type 2 cards.

8.2.2 Error Messages

The error messages produced by this program are self explanatory, as shown below :

(i) ILLEGAL CHARACTER IN CARD. ----------

(ii) ROAD NO. ----- DOES NOT EXIST IN INDEX.

(iii) SECTION NO. ---- DOES NOT EXIST FOR ROAD NO. ----

8.2.3 Output

The output is printed and is identical to the printed output produced by program MASTRF, as shown in Fig. 5.

8.3 MFEDIT

This program allows data to be added to the General Information File, or data present on the file to be edited.

The program finds the specified road in the relevant index, and uses the key contained in the index record to find the position of the records to be edited. The program then tests for non-blank fields in the data cards, and checks that these fields do not contain illegal characters(i.e. an alphabetic character in a field which should be numeric). The General Information File record is then updated with the new value. The entire record is then printed out.

8.3.1 Input Data

Card Type 1

Cols.	
1	Road Type.
2 - 5	Road Identifier.
6 - 8	Number of sections to be edited.

Card Type 2A

Cols.		
1	Card Identifier 'A'	
2 - 5	Node 1	Traffic Nodes.
6 - 9	Node 2	
10 - 13	Link Number.	
14 - 15	Indicator for Strategic Route.	
16 - 21	Easting	Start Co-ordinates.
22 - 27	Northing	

Card Type 2A (Continued)

Cols.		
28 - 33	Easting	Finish Co-ordinates.
34 - 39	Northing	
40 - 42	Length.	
43	Division.	
44	District.	
45	Strategic Route.	
46	Marshall Category.	
47	Urban or Rural Classification.	
48 - 52	Ministry G.P.H. Number.	
53 - 54	Speed.	Speed Limit Information
55 - 58	Start Chainage	
59 - 62	End Chainage	
63 - 64	Speed	Speed Limit Information
65 - 68	Start Chainage	
69 - 72	End Chainage	
73 - 75	Adjacent Marshall Section.	
78 - 80	Marshall Section.	

Card Type 2B

Cols.		
1	Card Identifier 'B'	
2	Delegation Factor.	
3 - 6	Delegation Start Chainage.	
7 - 10	Delegation End Chainage.	
11 - 12	Degree of Urbanisation.	
13 - 15	Hillyness Factor.	
16 - 18	Bendiness Factor.	
19 - 21	Realistic Travelling Speed.	
22 - 23	Year	Traffic Data
24 - 28	Flow	

Card Type 2B (Continued)

Cols.

29 - 30	Year	Traffic Data.
31 - 35	Flow	
36 - 37	Year	Traffic Data.
38 - 42	Flow	
43 - 44	Percentage of heavy vehicles.	
45	Treatment	Work Done.
46 - 47	Year	
48 - 51	Length	
52	Treatment	Work Done.
53 - 54	Year	
55 - 58	Length	
59 - 60	Year	Bump Integrator Data
61 - 63	Reading	
64 - 66	Height	Restrictions.
67 - 69	Weight	
78 - 80	Section Number.	

There will be as many cards Type 2A and 2B as are necessary to describe the data to be edited. Data for several roads may be submitted in a single run by using subsequent cards Type 1, 2A and 2B to describe the editing data.

8.3.2 Error Messages

The error messages produced by this program are self explanatory as shown below :-

(i) ILLEGAL CHARACTER ON CARD ---------------

(ii) ROAD NUMBER ------ DOES NOT EXIST

(iii) SECTION NO. ----- DOES NOT EXIST FOR ROAD NO.------

8.3.3 Output

The printed output from this program is identical to that produced by program MASTRF as shown in Fig. 5.

8.4 SNAME

This program adds a section identifier or name, 40 characters long, to the General Information File. This can be printed as a heading in other programs to aid identification of sections.

8.4.1 Data Input

Card Type 1

Cols.

1	Road Type.
2 - 5	Road Identifier.
6 - 8	Number of Sections following.

Card Type 2

Cols.

1 - 3	Section Number.
4 - 43	Section Identifier.

8.4.2 Error Messages

The error messages produced by this program are self explanatory and are shown below :

(i) ROAD NO. ----- DOES NOT EXIST

(ii) SECTION NO. ----- DOES NOT EXIST.

8.4.3 Output

The printed output from this program consists of a directory for each road showing the section number followed by a forty character description of the section (See Appendix B). This description is also stored in the General Information File record for each section.

9. Creating the Rating File

The rating file consists of one record for each kilometre (or part thereof) of a Marshall Section. Each record contains information recorded at 100 metre intervals; this information falls into three categories :-

(i) Inspection Data - recorded deformation and deterioration of the pavement and roadside.

(ii) SCRIM data - skidding resistance values.

(iii) Deflectograph data - data relating to the strength of the pavement.

The various types of data are collected separately and in different ways; the forms of the data are different and they require varying amounts of manipulation before they are stored. Thus a separate program is required for each type of data.

9.1 Inspection Data

The inspection data is collected as described in NOTE A and transcribed into data sheet 3 (see Appendix B) for punching. The data at this stage is in a fairly raw form and must be transformed into rating values and allocated to the relevant subsections. This manipulation is performed by a computer program obviating the necessity for tedious and error prone hand calculations.

The program has been written so that the input data is accepted in a flexible manner. If a defect is not present for a subsection then no data for that defect on that subsection is entered. Where fixed interval recording is used and a series of intervals have the same value associated with them then only one entry is made, similar to a continuously recorded defect. There is no fixed order of data input, but all data for a particular section must be entered together. If the input data for a defect overlaps onto a second or subsequent card these cards are not required to be entered consecutively. The program will recognise the 4 letter code associated with a particular defect and will calculate the total deterioration for each subsection from the data following this code. At the end of the data for each section a delimiter card is necessary. The rating points allocated to each subsection are calculated as shown below :

9.1.1 Pavement* Defects

For continuously recorded defects the program collects all deterioration for a particular defect pertaining to a hundred metre subsection. A rating relationship is then applied to this total value giving the rating points for that defect for that subsection. Certain defects require that the width of the pavement be known before the total deterioration can be calculated. This is done by storing the area of deterioration, and when all data for the section has been input, including the carriageway width, the total area of each subsection is calculated and the percentage deterioration can then be deduced for that defect, on each subsection affected. For defects recorded at fixed intervals the rating relationships are applied to the individual fixed interval recordings, where these are significant. The rating points so given are then averaged over the subsection.

9.1.2 Roadside Defects

Certain standards for roadside defects vary according to whether the subsection of highway is deemed to be urban or rural, and also with usage. Thus where a rural footpath is said to be well-used the standard of kerbing etc. will be higher than that for a little used rural footpath. A code

* Pavement - road surface between kerbs or verges.

is input in the cards giving this information. The program then decides which of several rating relationships is appropriate and then continues as for the pavement defects. There is one defect which is deduced rather than measured. This is the provision of kerbs for the protection of pedestrians. The program calculates the length of road per subsection, having a pavement nearer than a standard value but having no kerb. The rating relationship for urban or rural roads, depending on the situation of the particular subsection, is then applied giving the relative criticality for kerbing.

The program prints out all rating points collected for each defect for each subsection, indicating criticality where necessary, as shown in Appendix D. These values are then stored on the rating file.

9.2 SCRIM Data

This type of data is not at present being collected or stored. When a satisfactory method of interpreting results has been discovered a system of storage and manipulation will be devised. (See Appendix H).

9.3 Deflectograph Data

The Deflectograph Data is collected as described in TRRL Report LR 571. The output from the machine is in the form of a trace, or histogram. A punched paper tape output is envisaged in the future since the trace output must be digitised* producing paper tape output before it can be used in the volumes necessary for Durham's highway network. For each sub-section an 85 percentile ø

* using a base line as reference, accurate co-ordinates may be assigned to a point by the use of a digitising machine.

ø 85 percentile - the level below which 85% of the readings for the subsection will lie.

reading is calculated and this reading is adjusted for temperature. The construction materials of the road and the date of the construction or last major resurfacing of the road must be known. The present traffic flows and the percentage of heavy vehicles are determined, and the estimated growth factor of traffic in the years since the construction or last resurfacing of the road must be known so that the cumulative heavy traffic over that period can be calculated. From graphs (see Appendix H) the cumulative heavy traffic needed to cause failure of the road (on the basis of the above information) can be determined. Thus the life of the road can be calculated, since the present heavy vehicle flow is known and the growth factor can be estimated. This road life figure provides a check for the visual inspection data, and gives useful data on the strength of the roads in the county. For a detailed description of the working method of the above calculations see Appendix H and TRRL Report LR 571.

10. The Rating File Programs

10.1 RATE

This program stores the inspection data in the rating file, and requires that the inspection data recorded on data sheet A be transcribed onto data sheet 3 (See Appendix B for examples of data sheets).

A four letter code is used to identify the defect, as follows :

Code (Left)		(Right)	Description
LFWY		RFWY	Footway presence and width.
LFWD		RFWD	Footway deterioration.
LVRG		RVRG	Verge presence and width.
LVGD		RVGD	Verge deterioration.
LKBU		RKBU	Kerb presence and upstand.
LKBD		RKBD	Kerb deterioration.
	CWAY		Carriageway type and width.
LEDG		REDG	Edge deterioration.
LRUT		RRUT	Wheel track rutting.
LWTC		RWTC	Wheel track cracking.
	WCMA		Whole carriageway major deterioration.
	EXPT		Existing patching.
	WCMI		Whole carriageway minor deterioration.
RIDR		LIDR	Inadequate drainage.

The program treats the data associated with the various codes in different ways, since the recording and requirements of the defects differ.

10.1.1 Footway and verge presence and carriageway width

This data is recorded in a continuous manner, and the value given is assigned to the hundred metre subsections between the start chainage and the end chainage of the entry. If the footway or verge ends (or starts) in the middle of a hundred metre subsection then it is deemed to exist for the full subsection. If a footway, verge or carriageway changes width in the middle of a subsection the value assigned to that subsection is the average of the two widths present.

10.1.2 Footway, verge and whole carriageway major deterioration

This data is recorded as a width of deterioration, in the case of continuous recording or as an area of deterioration in the case of spot recording. The width of deterioration is converted to an area by multiplying it by the percentage length of the subsection affected by the deterioration, given by the start and end chainages. All such areas of deterioration are then totalled for a subsection. From the carriageway, footway, or verge width for the subsection, whichever is appropriate, and the length of the subsection, the total area of the subsection can be calculated. Therefore the percentage deterioration can be found. A rating relationship is applied to this percentage deterioration to determine the total rating points for the defect for that subsection.

10.1.3 Kerb upstand

This defect is recorded at fixed intervals, i.e. 25 metres, and the standard to be applied depends on whether the area is considered to be urban or rural, and if rural whether the footway, if present, is frequently or rarely used. Thus the appropriate target kerb upstand is determined and the corresponding rating relationship can be found. The recorded kerb upstand for a single 25 metre interval is then compared with the determined standard or target value. If the recorded value is higher than the target value no further action is taken since the reading is therefore not significant. If the recorded value is lower than the target value the difference between the recorded and target values, in millimetres, is used with the appropriate rating relationship to determine the rating points for the 25 metre interval. This process is repeated for all such 25 metre intervals, and the rating points awarded are averaged to give the corresponding rating points for the 100 metre subsections, that the 25 metre intervals are contained within.

10.1.4 <u>Kerb deterioration</u>

This defect is recorded in a continuous manner, and from the start and end chainages percentage deteriorations are ascertained and assigned to the relevant 100 metre subsections. A rating relationship is applied to these percentage deteriorations to determine the rating points assigned to the subsections.

10.1.5 <u>Edge Deterioration</u>

This defect has three severities associated with it, as below*

* From NOTE A p.16

(i) Severity 1 - edge erosion and need for patching present but little overriding of the verge is occuring.

(ii) Severity 2 - serious overriding of the verge with pot-holing of the edge and verge.

(iii) Severity 3 - serious overriding of the verge, potholing of the edge and verge and serious deformation of the carriageway in the vicinity of the edge.

Thus in a single subsection various amounts of the three severities may be present, contributing to the final rating points for that subsection and therefore to its possible criticality. Three rating relationships are necessary so that both the amount and severity of the defect may be considered when rating points are assigned. These relationships must be such that rating points allocated to the various severities must be additive and such that a single set of critical levels may be used to determine criticality, regardless of the varying proportions of rating points allocated from the different severities. Thus for each severity, the total percentage deterioration is calculated for the subsection and the requisite rating relationship for that severity applied; the resulting rating points are then totalled for all severities over the subsection.

10.1.6 Wheel track rutting

This defect is recorded at fixed intervals, i.e. 25 metres. The significant level of rutting has been taken as 10 millimetres; any rutting below this figure being ignored by this program. The rating relationship is applied to the individual measurements and the resultant rating points are averaged over the corresponding subsections. The side of the road collecting the most rating points for a particular subsection determines the rating points value assigned to that subsection.

10.1.7 Wheel track cracking

This defect can be present in one or both wheel tracks. The total length of cracking present over both wheel tracks is compared with twice the length of the subsection containing the cracking to give the percentage deterioration for the defect for the subsection. The rating relationship is then applied and the side of the road collecting the most rating points for the subsection is stored as the rating points value for that subsection.

10.1.8 Existing patching

This defect is recorded at fixed intervals, i.e. 25 metres. The estimated percentage deterioration is recorded by the inspection teams, and if this value is greater than the standard value then the program assigns ten rating points to the subsection containing the interval. If the recorded value is less than the standard value then no points are assigned. No criticality is tested for or assigned with respect to this defect.

10.1.9 Whole carriageway minor deterioration

This defect is recorded on the 25 metre fixed intervals as a presence or absence only. If present a rating value is assigned and these rating values are averaged over the section.

10.1.10 Inadequate drainage

This defect is not measured during the visual inspection. The road is inspected after rain, to find the areas where water is not being drained from the road. The defect is recorded in a continuous manner as a presence of inadequate drainage. The various amounts of the defect are totalled for each subsection and a rating relationship is applied to give rating point values. The side of the road having the greater rating point value for the subsection is taken as the rating point value for the subsection.

10.1.11 Data input

Card Type 1

Cols.	
1	Road Type.
2 - 5	Road Identifier.
6 - 8	No. of sections in the road.

Card Type 2

Cols.	
1 - 4	Code.
5 - 8	Start chainage.
9 - 10	Type.
11 - 13	Measure.
14 - 17	Finish chainage.
19 - 31	As for cols. 5 - 17
33 - 45	As for cols. 5 - 17
47 - 59	As for cols. 5 - 17
61 - 73	As for cols. 5 - 17
73 - 80	Sequence.

<u>Card Type 3</u>

<u>Cols</u>.

1 - 3 "END" - deliminter card.

There will be as many cards Type 2 as are necessary to describe all the inspection data pertaining to a section, followed by a card Type 3. Further blocks of cards Type 2 and Type 3 will follow until all sections for which inspection data is to be presented have been described.

A brief description of the data to be entered under the card Type 2 headings follows :-

(i) CODE - a four letter abbreviation identifying the type of data (defect, etc.) following, see section 10.1 above.

(ii) Start chainage - the chainage at which :

(a) an element (footway, verge, kerb etc.) of the road begins.

(b) an element of road changes type.

(c) an element of road changes width.

(d) a section of deterioration begins.

(e) a section of deterioration changes severity.

(f) a section of deterioration changes width.

(g) a kerb changes upstand.

(iii) Type - indicates the material of which the element of the road is constructed. It is indicated using approved abbreviations.

In the case of footway types only the first character identifies the material; the second character indicating the footway usage as follows :-

U - urban situation.

F - rural situation with frequent usage.

L - rural situation with little usage.

(iv) Measure - indicates :

(a) the width of carriageway, footway or verge (to 1 decimal place)

(b) the width of whole carriageway major, footway or verge deterioration (to 1 decimal place)

(c) the area of spot deterioration of carriageway, footway and verge.

(d) the severity of edge deterioration.

(e) the number of wheel tracks in which cracking occurs.

(f) the kerb upstand.

(g) the percentage of existing patching.

(h) the depth of rutting.

(v) Finish chainage - the chainage at which :

(a) an element of road finishes.

(b) a section of deterioration finishes.

(c) a spot deterioration occurs (for spot deterioration the start and finish chainages are equal).

(vi) Sequence - this indentifies the road, the section and the sequence of cards within the section. The section number must be present in Cols. 75 and 76 on the first card Type 2 for a section, to allow the program to identify the section the data describes.

10.1.12 Incomplete subsections

A Marshall Section will probably not end at a chainage which is a multiple of one hundred metres. Thus the last subsection of the Marshall Section will be incomplete. For the purposes of calculating percentage deteriorations the actual length of the incomplete subsection is used, this process giving a more accurate picture of the deterioration for that subsection, rather than taking the length of all subsections to be 100 metres for the purposes of calculation.

10.1.13 Error messages

The error messages for this program are self explanatory, as shown below :-

(i) ILLEGAL CHARACTER IN CARD -----------

(ii) ROAD NO. ----- DOES NOT EXIST.

(iii) SECTION NO. ----- DOES NOT EXIST.

10.1.14 Output

The output to disk consists of a matrix of rating point values and element widths. Each disk record contains data pertinent to one kilometre of Marshall Section, with values stored for the 100 metre subsections as shown in section 6.2 above.

The printed output is as shown in Figure 6 below and in Appendix B. A defect which is critical for treatment on a subsection is tagged with a code letter to show the treatment necessary. The codes used are as follows :-

(i) K - a kerb, footway or verge is critical for remedial treatment.

(ii) C - reconstruction of the road.

ROAD NO A 67 SECTION NO 15 LENGTH 0.58

FOOTWAY AND VERGE

	CHAINAGE	0	100	200	300	400	500	600	700	800	900
LEFT	FOOTWAY DETN	0	0	0	0	0	0				
	VERGE DETN	0 GR	0 GR	0 GR	0 GR	0 GR	0 GR				
	KERB DETN	0 CT	0 CT	0 CT	0 CT	0 CT	0 CT				
	KERB PROVIDE	0	0	0	0	0	0				
	KERB UPSTAND	0	0	0	0	0	0				
RIGHT	KERB UPSTAND	0	0	0	0	0	0				
	KERB PROVIDE	0	0	0	0	0	0				
	KERB DETN	0 CT	0 CT	0 CT	0 CT	0 CT	0 CT				
	VERGE DETN	0 GR	0 GR	0 GR	0 GR	0 GR	0 GR				
	FOOTWAY DETN	0 BF	0 BF	0 BF	0 BF	0 BF	0 BF				

ROAD NO A 67 SECTION NO 15 LENGTH 0.58

CARRIAGEWAY

CHAINAGE	0	100	200	300	400	500	600	700	800	900
EDGE LEFT	0	0	0	0	0	0				
WHEEL TR.RUTTING	25	0	0	25	185R	1440C				
WHEEL TR.CRACKING	666R	633R	333R	643R	576R	666R				
W.CWAY MAJOR	0	0	0	0	0	140R				
W.CWAY MINOR	0	0	0	0	0	0				
EDGE RIGHT	0	0	0	0	0	0				
EXISTING PATCHING	10	8	0	0	0	0				
INADEQUATE DRAINAGE	0	0	0	0	0	0				
WIDTH	9.3 HA	7.4 HA	7.4 HA	7.4 HA	7.4 HA	8.4 HA				

Figure 6

(iii) R - resurfacing of the road.

(iv) D - surface dressing of the road.

(v) H - haunch/kerb - reconstruction of the edge of a road.

(vi) P - patch the edge of the road.

(vii) T - drainage treatment.

If no data is input for a section, that section will not appear in the printout.

10.2 MDISP*

This program totals the rating points for each subsection along a road and prints a histogram showing the total rating points for the subsection and general data concerning the section and subsection.

10.2.1 Data input

Card Type 1

Cols.	
1	Road Type
2 - 5	Road Identifier.
6 - 8	No. of sections to be printed.

Card Type 2

Cols.	
1 - 3	1st section to be printed out.
4 - 6	2nd section to be printed out.
7 - 9	3rd section to be printed out.
10 - 12	4th section to be printed out.
13 - 15	5th section to be printed out.
----------	----------
70 - 72	24th section to be printed out.

* This program was written by Miss P. F. Dobson to specifications by the author.

If columns 6 - 8 of Card Type 1 are left blank all sections will be printed out and no cards Type 2 are needed.

There will be as many Cards Type 2 as are necessary to describe all sections to be printed out. Further blocks of cards Type 1 and 2 may be submitted if further roads are required to be printed out.

10.2.2 Error messages

The error messages for this program are self explanatory as shown below :

(i) ROAD NO. ----- DOES NOT EXIST.

(ii) SECTION NO. ----- DOES NOT EXIST.

(iii) ILLEGAL CHARACTER IN CARD -----

10.2.3 Output

There is no output to disk as this is purely a display program.

The printed output shows the total rating points for each subsection of the road in histogram form and displays various categories of information from the General Information file and from the Rating file, as shown in Appendix B and Figure 6A below.

==========

ROAD:A 67

==========

MS	MARSHALL SECTION	AR	ACCIDENT RECORD	RTS	REALISTIC TRAVELLING SPEED
CH	CHAINAGE	M	MARSHALL CATEGORY	I	IMPROVEMENT STATUS
LF	ROAD LIFE	R	ROAD STATUS	HT	HEIGHT RESTRICTION (METRES)
WDTH	WIDTH OF CARRIAGEWAY	TFLOW	TRAFFIC FLOW	WT	WEIGHT RESTRICTION (TONS)
B	BEND FACTOR	HV	PERCENTAGE OF HEAVIES	D	DIVISION
G	GRADIENT FACTOR	B.I	BUMP INTEGRATOR		

Figure 6A

```
MS  CH                 TOTAL CARRIAGEWAY RATING                                   RATE LF WDTH B G AR M R TFLOW HV B.I RTS I   HT WT D
--------------------------------------------------------------------------------------------------------------------------------------

  1500 ****************************************                                    7845  0  6.3 0 0  0 0 P  2500 10   0   0 0  0.0  0 3
  1600 ***************************************                                     7620  0  6.3 0 0  0 0 P  2500 10   0   0 0  0.0  0 3
  1700 ********                                                                    1515  0  6.3 0 0  0 0 P  2500 10   0   0 0  0.0  0 3
  1800 *                                                                             50  0  6.3 0 0  0 0 P  2500 10   0   0 0  0.0  0 3
  1900 *                                                                             36  0  6.3 0 0  0 0 P  2500 10   0   0 0  0.0  0 3
  2000 *                                                                              5  0  6.3 0 0  0 0 P  2500 10   0   0 0  0.0  0 3
  2100                                                                                0  0  6.3 0 0  0 0 P  2500 10   0   0 0  0.0  0 3
  2200 ********                                                                    1440  0  6.3 0 0  0 0 P  2500 10   0   0 0  0.0  0 3
  2300 ********                                                                    1460  0  6.3 0 0  0 0 P  2500 10   0   0 0  0.0  0 3
  2400 **************************************                                      7545  0  6.3 0 0  0 0 P  2500 10   0   0 0  0.0  0 3
  2500 ************************************************                            9541  0  6.3 0 0  0 0 P  2500 10   0   0 0  0.0  0 3
  2600 **                                                                           210  0  5.8 0 0  0 0 P  2500 10   0   0 0  0.0  0 3
  2700 **************                                                              2700  0  6.3 0 0  0 0 P  2500 10   0   0 0  0.0  0 3
  2800                                                                                0  0  0.0 0 0  0 0 P  2500 10   0   0 0  0.0  0 3
  2900                                                                                0  0  0.0 0 0  0 0 P  2500 10   0   0 0  0.0  0 3
4    0 **************************************                                      7530  0  7.3 0 0  0 0 P  2500 10   0   0 0  0.0  0 3
   100 ***************************************************************************** 15395  0  7.3 0 0  0 0 P  2500 10   0   0 0  0.0  0 3
5    0 ************************************************                            9558  0  7.1 0 0  0 0 P     0  0   0   0 0  0.0  0 3
   100 ***********************************************                             9330  0  7.4 0 0  0 0 P     0  0   0   0 0  0.0  0 3
6    0 *                                                                             65  0  5.7 0 0  0 0 P  3900  0   0   0 0  0.0  0 3
7    0 *                                                                            172  0  5.5 0 0  0 0 P  4700  0   0   0 0  0.0  0 3
   100                                                                                0  0  7.0 0 0  0 0 P  4700  0   0   0 0  0.0  0 3
   200 *                                                                             27  0  7.0 0 0  0 0 P  4700  0   0   0 0  0.0  0 3
   300                                                                                0  0  9.8 0 0  0 0 P  4700  0   0   0 0  0.0  0 3
   400                                                                                0  0 13.0 0 0  0 0 P  4700  0   0   0 0  0.0  0 3
```

Figure 6A (Continued)

11. The Priority Rating System

There will seldom, if ever, be sufficient funds available to the Maintenance Engineer to carry out all remedial work necessary to maintain all roads in the County network to a uniformly high standard. A priority system is therefore envisaged, allowing available funds to be allocated for maximum cost benefit. The purpose of this Priority Rating System is to provide the Maintenance Engineer with easily assimilable data; a precis of the objective inspection data highlighting those facts pertinent to his decisions. Thus the system is a useful tool for the engineer, and as such must be flexible enough to give both the general, overall picture of the County network and a detailed picture of a small section of a particular road. This flexibility is achieved by having several levels of reports, of varying design and degree of detail, some of which have been described above (Sections 8 and 10).

The scope and format of the reports are dictated by the information required by the Engineer to formulate his programme of work. Many factors must be considered; the information supplied by the Rating System is as follows :-

(i) the urgency of the work - given by the priority rating points allocated to a length of road on the basis of the visual inspection; and by consideration of the estimated residual life of the length of road given by the Deflectograph readings.

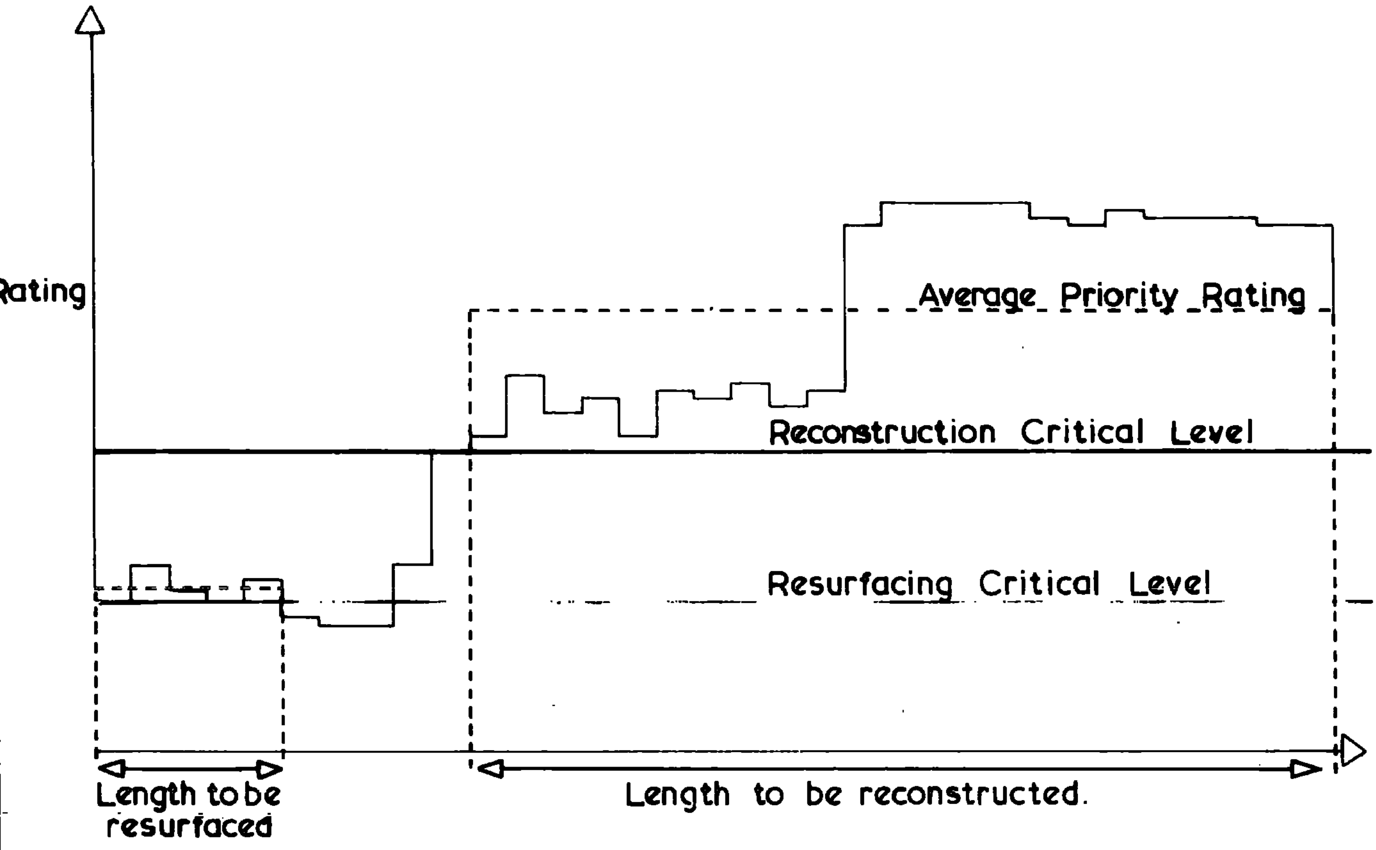
(ii) The importance of the road - given by its Marshall Category, its traffic and its economic effect as a through route or heavy vehicle route serving trading estates etc.

(iii) the future of the road - where redevelopment or improvement is scheduled or indicated costly maintenance would be avoided where possible.

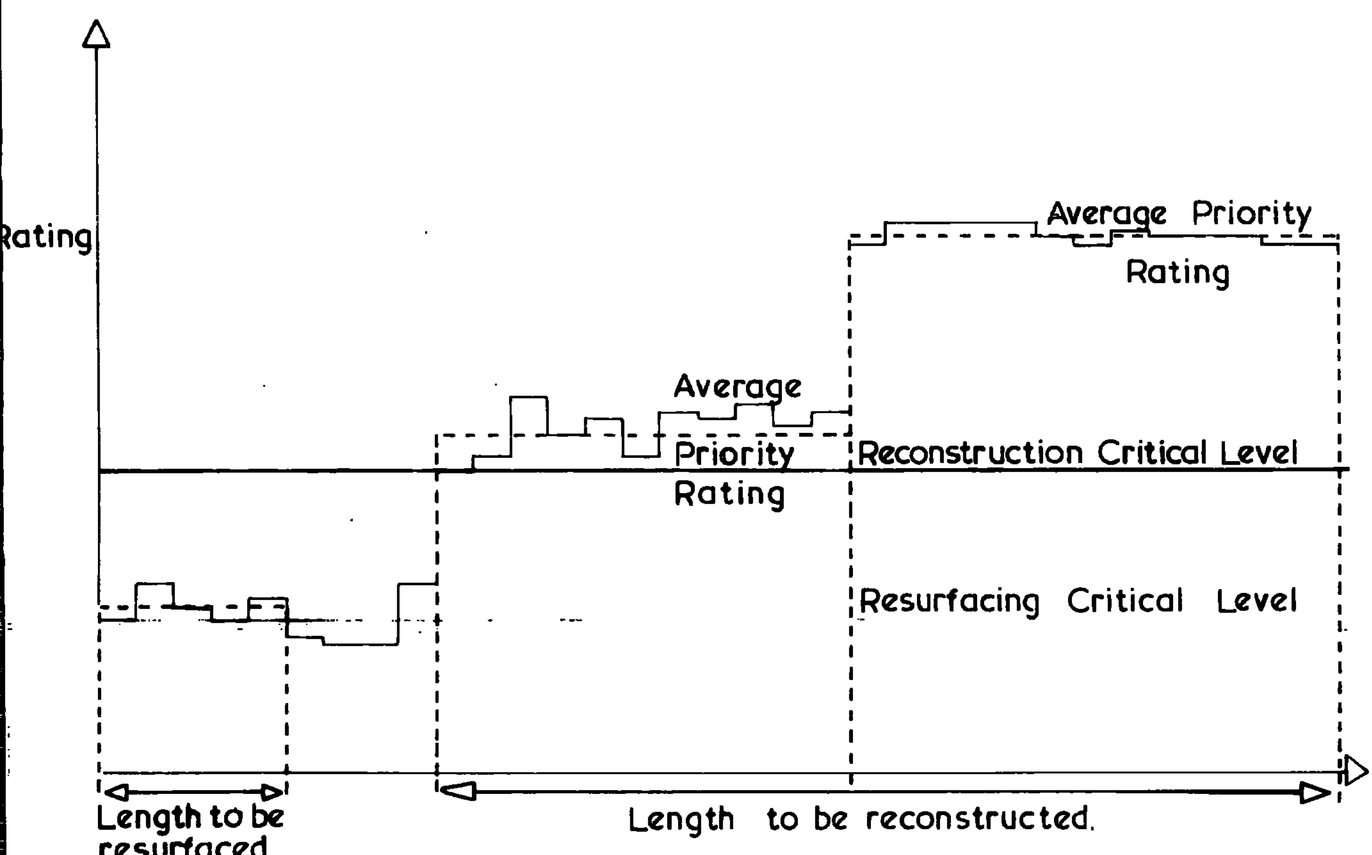
(iv) The position of the road - work must be shared between divisions within the County, such that one division is not idle whereas another is overburdened with work, otherwise demand for labour would be uneven or transferal of staff between divisions could involve long and tedious journeys to and from a site. This problem is not so severe in urban situations, where the road network tends to be more compact.

11.1 Treatment Lengths

Where several contiguous subsections require the same treatment with the same degree of urgency then it would be advantageous to the Engineer to group these subsections together to form treatment lengths. This allows the Engineer to assess the extent of the weakness of the fabric of the road, which is more difficult if each subsection is considered separately. The technique used to group the subsections in this way is Cluster Analysis (See Appendix G), which avoids most of the common pitfalls of the"running length" techniques. Where a situation exists as shown in Fig. 7 below, any averaging of priorities would result in a distortion of the results (a lowering of the high priority subsections and an enhancement of the lower priority subsections). Cluster Analysis by allowing only subsections with priorities of the same order of magnitude to be merged, preserves detail to a greater extent, whilst allowing acceptable generalisation of data.



TREATMENT LENGTHS USING AVERAGING



TREATMENT LENGTHS USING CLUSTERING

Figure 7.

11.2 Creating the Cluster File

Since several forms of printout are envisaged using treatment lengths as a basic unit a disk file is created by storing any clusters found to be critical for remedial treatment. This Clustering procedure is carried out only for carriageway defects, since roadside defects tend to be less expensive to remedy and relatively minor in nature. The cluster technique is used on the six major defects separately, the defects being :

(i) Wheel Track Rutting.

(ii) Wheel Track Cracking.

(iii) Whole Carriageway Major Deterioration.

(iv) Whole Carriageway Minor Deterioration.

(v) Edge Deterioration.

(vi) Inadequate drainage.

Each cluster has an average priority rating associated with it and this value is tested against the critical level or levels for that defect. If the defect has two critical levels associated with it, and the cluster is critical with respect to the higher level then the treatment corresponding to the lower level of criticality is a substitute treatment for that defect and an extra disk record will be output for that cluster with an indicator set to show that this is a substitute treatment. A total priority rating for the cluster is formed by adding together the rating points for each pavement defect which is cured by the treatment for which the cluster is critical.

The format of the file is as follows :-

(i) Road Type.

(ii) Road Identifier.

(iii) Marshall Category.

(iv) Division.

(v) District.

(vi) Total priority rating for the cluster for the treatment type below.

(vii) Treatment type.

(viii) Total length of the cluster.

(ix) The Marshall Sections contained by the cluster with start and end chainages.

(x) Indicator to be set where the treatment type in (vii) is a substitute treatment.

(xi) Strategic Route Category.

(xii) Average Width for costing purposes.

11.3 Priority Listings

The Cluster file must be presented to the Engineer in a useful and usable form, as information rather than as data. Thus the file must be sorted and printed out in one of several formats before it achieves the status of information. For this purpose the Engineer's requirements must be considered. The listings may be divided into two categories: those showing the overall picture in the County (or in some other category), and those showing in detail the condition of a particular road. For an overall picture the Engineer needs to know :

(i) the urgency of the work

(ii) the Marshall Category or Strategic Route Classification.

(iii) the Division and District.

(iv) details of the position and length of the cluster.

(v) the type of remedial work recommended.

(vi) the approximate cost of the work.

Thus several formats of listing are possible, and those most useful have been chosen as shown below.

In the Marshall Report the concept of roads of differing importance being maintained to different standards was introduced, so that most money would be spent on the roads carrying the most traffic as a general rule (i.e. Category 1 and 2 roads). Thus the cluster file is sorted into Marshall Category Order.

Within Marshall Categories it is useful to separate all treatment lengths requiring the same remedial treatment since each treatment type is given its own program of work. This allows resources in the form of men, machines and raw materials to be allocated optimally.

Within treatment types the clusters must be sorted on their priority ratings so that the most urgent jobs in each category may be identified.

Therefore one possible format has three levels of categorisation as shown in Appendix B.

A similar format is possible using the Division parameter rather than the Marshall Category as the primary level of categorisation, as shown in Fig. 8.

An example of this type of printout is shown in Appendix B.

	ROAD	M C	TREATMENT START	END	SECTIONS INCLUDED	PRIORITY RATING	TOTAL LENGTH	COST £
	A 181		8: 0	8: 100		7745	0.10	
	B6312		8: 500	8: 600		1731	0.10	
	A6127		6: 400	6: 500		1635	0.10	
	A6127		5: 0	5: 100		1460	0.10	
	A 181		2: 800	2: 900		1283	0.10	

DIVISION: 1 TREATMENT: RESURFACE

	ROAD	M C	TREATMENT START	END	SECTIONS INCLUDED	PRIORITY RATING	TOTAL LENGTH	COST £
*	A 181		8: 0	8: 100		7745	0.10	
*	B6312		8: 500	8: 600		1731	0.10	
*	A6127		6: 400	6: 500		1635	0.10	
*	A6127		5: 0	5: 100		1460	0.10	
*	A 181		2: 800	2: 900		1283	0.10	
	B6312		8: 100	9: 100		481	0.91	
	A6127		3: 0	3: 50		405	0.05	
	A 181		2: 400	2: 500		333	0.10	
	A 181		4: 100	4: 200		333	0.10	
	A 181		4: 0	4: 100		193	0.10	
	A6127		6: 500	6: 600		185	0.10	
	B6312		9: 100	9: 200		183	0.10	
	A6127		6: 800	6: 900		165	0.10	
	A6127		6: 100	6: 200		155	0.10	
	A 181		2: 300	2: 400		103	0.10	

DIVISION: 1 TREATMENT: SURFACE DRESS

	ROAD	M C	TREATMENT START	END	SECTIONS INCLUDED	PRIORITY RATING	TOTAL LENGTH	COST £
	B6312		8: 700	8: 800		406	0.10	
*	B6312		8: 100	9: 100		356	0.91	
*	A 181		2: 400	2: 500		333	0.10	
*	A 181		4: 100	4: 200		333	0.10	
*	A 181		4: 0	4: 100		193	0.10	
*	B6312		9: 100	9: 200		183	0.10	
*	A 181		2: 300	2: 400		103	0.10	
	A 181		4: 200	4: 300		83	0.10	
	A 181		8: 0	8: 100		70	0.10	
	A 181		2: 800	2: 900		37	0.10	
	A 181		2: 100	2: 200		20	0.10	

Figure 8

The approximate cost of the remedial work necessary may be included for each treatment length in either printout. The area of work is calculated from the average width of the road for the cluster and the total length of the cluster (or treatment length). A cost factor may be estimated for each treatment type, per square metre, which when multiplied by the area of remedial work necessary gives an estimate of the cost of the work. This cost is for the Engineer's information and is not intended for use in accurate budget calculations, since the cost factors are, necessarily, crude approximations.

These two printout formats give an overall picture of the condition of roads in the County network and should provide a reasonable basis, with the deflectograph road life information, for the programme of work. They allow the Engineer to identify those stretches of road requiring remedial treatment necessitating their inclusion in the programme of work and also those stretches of road where a cheaper substitute treatment may possibly be used. However, in order to make such a decision the Engineer requires further, more detailed information about the stretch of road in question. This is available, of course, in the output from the Rating programs and the Master file programs but to find such information from these printouts is a tedious exercise therefore a precis of this information is made available to the Engineer in an easily assimilable pictorial form, as shown in Fig. 9 below. The information is as follows :-

(i) the extent and type of remedial work necessary.

(ii) the "free speed" calculated from the geophysical characteristics of the road and the traffic flows.

(iii) the road life (in years) calculated from the deflectograph readings.

(iv) traffic flow.

(v) heavy vehicle flow.

(vi) width.

(vii) position of speed limits.

(viii) estimated realistic travelling speed.

Where possible the values are either shown in histogram form (i.e. road life) or their extent shown by asterisks, rather than numbers, giving a simplified printout which highlights any areas needing further investigation using the outputs from the Rating and Master file programs. Space is provided on the printout so that the Program of Improvements may be entered. This enables the Engineer to see where improvement work will make costly maintenance unnecessary and allow a cheaper alternative to be used. The "free speed" information gives a good indication of the necessity for an improvement scheme rather than remedial work, since where the free speed drops below acceptable levels the alignment or width of the road is usually substandard with respect to the traffic carried.

These three types of printout, with those produced by the Rating and Master file programs, form a reasonably comprehensive system of information for the Engineer, with varying degrees of detail and varying amounts of data produced according to the Engineer's need.

==========

ROAD:A 67

==========

KEY:

SECN NO	SECTION NUMBER
HEAVY VEHCL	NUMBER OF HEAVY VEHICLES
REAL T.SP	REALISTIC TRAVELLING SPEED

DEFECTS:

RC	RECONSTRUCT
RS	RESURFACE
SD	SURFACE DRESS
ET	EDGE TREATMENT
DR	DRAINAGE

Figure 9

1000				*	234					6.30	0
1100				*	140					6.30	0
1200	*	*	*	*	1831					6.30	0
1300	*	*		*	1715					6.30	0
1400		*	*	*	711					6.30	0
1500	*	*		*	7845					6.30	0
1600	*	*			7620					6.30	0
1700	*	*			1515					6.30	0
1800					50					6.30	0
1900					36					6.30	0
2000					5					6.30	0
2100					0					6.30	0
2200	*	*			1440	68				6.30	0
2300	*	*			1460	67				6.30	0
2400	*	*			7545	75				6.30	0
2500	*	*			9541	63				6.30	0
2600		*			210	62				5.80	0
2700	*	*			2700	67				6.30	0
4 B8A STARTFORTH - B6277 JUNCT (WEST)											
0	*	*			7530	48		2500	250	7.30	0
100	*	*	*		15395	-30	*			7.30	0
5 B6277 JUNCT (WEST) - B6277 JUNCT (EAST)											
0	*	*	*		9558	-47	*	0	0	7.10	0
100	*	*			9330	-81	*			7.38	0
6 B6277 JUNCT (EAST) - OLD DISTRICT BDY											
0					65	63		3900	0	5.70	0
7 OLD DISTRICT BDY - C44 R/BT											
0		*	*		172	-43	*	4700	517	5.50	0
100					0	57				7.00	0
200					27	22				7.00	0
300					0	-62	*			9.80	0
400					0	37				12.98	0
500					0					12.80	0
8 A67/C44 R/BT											
0					0			0	0	6.40	0
9 C44 R/BT - B6278 JUNCT											
0					37	69		6000	0	8.70	0
100					0	21				8.70	0
200		*	*		118	-57	*			8.70	0
300					0	62				8.70	0
400					0	67				8.70	0

Figure 9 (Continued)

12. The Priority Rating Programs

12.1 PRLIST

This program uses the data stored in the General Information File and the Rating data file to produce a file containing details of lengths of road critical for one (or more) of the five remedial treatments :

(i) Reconstruction.

(ii) Resurfacing.

(iii) Surface Dressing.

(iv) Edge Treatment.

(v) Drainage Treatment.

The program uses data from the Rating Disk file for the six pavement defects :

(i) Wheel Track Rutting.

(ii) Wheel Track Cracking.

(iii) Whole Carriageway Major Deterioration.

(iv) Whole Carriageway Minor Deterioration.

(v) Edge Deterioration.

(vi) Inadequate Drainage.

Where edge deterioration or inadequate drainage is present on both sides of the road the worst side is taken as being representative of that sub-section of road. A modified cluster technique (See Appendix G) is then applied to the data for each defect, forming clusters, which are tested against the standards for the particular defect considered. Any cluster found to be critical for remedial treatment on the basis of the critical levels given in Appendix D is written to a disk file, and is termed a treatment length. A treatment length may consist of a single sub-section or may span several adjacent sub-sections or even several adjacent Marshall Sections. In the latter case problems may arise where a treatment length spans a District or Divisional boundary; in this case the Division or District in which the treatment length begins is taken as the Division or District for the entire treatment length.

Short lengths of dual carriageway, as shown in Figure 10 below, also pose a problem to the treatment length concept.

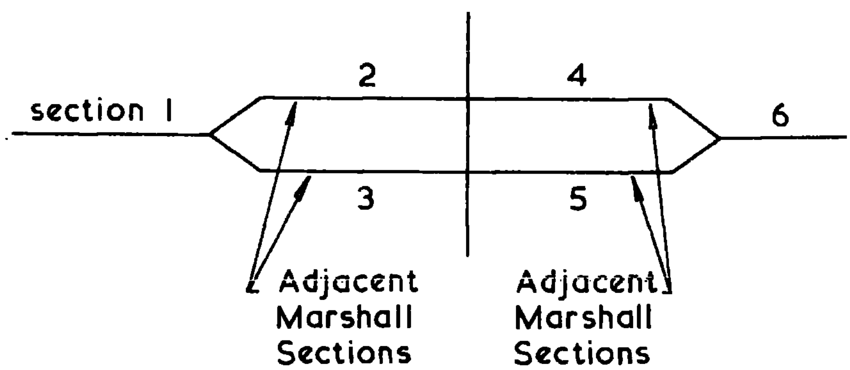


Figure 10

To carry out remedial work on Sections 1, 2, 3, 4, 5 and 6 in that order would obviously be inefficient. Therefore either the numbering system should be changed so that these short lengths of dual carriageway are isolated, or the computer must be able to recognise the correct sequence of section numbers. Any numbering sequence has inherent problems, and will create problems either during inspection or during processing. For, if the Section numbers are not in sequence, the inspectors may become confused and make mistakes; if they are, the computer must be programmed to recognise that sequentially numbered sections are not necessarily contiguous. The second course is preferred since it tends to lead to fewer mistakes. The program recognises the short lengths of dual carriageway by considering an adjacency array, containing each sub-section and the sub-section adjacent to it, if any, in a forward direction as an adjacent pair. Therefore for the situation in Figure

10 the relevant adjacent pairs are :-

(i) last sub-section of Section 1 and first sub-section of Section 2.

(ii) last sub-section of Section 2 and first sub-section of Section 4.

(iii) last sub-section of Section 4 and first sub-section of Section 6.

(iv) last sub-section of Section 3 and first sub-section of Section 5.

Intermediate sub-sections have been omitted to preserve clarity. This adjacency procedure results in more sensible treatment lengths being produced by the program.

The Marshall Standards themselves also pose problems, since in the case of Wheel Track Rutting an isolated high reading of 18 mm or more, in an otherwise satisfactory sub-section is sufficient to imply criticality for reconstruction for the whole sub-section.

A more practical approach would be to patch these areas, where such rutting is not widespread, rather than to reconstruct the whole sub-section. Eventually a new treatment type, Extensive Patching, may be introduced, however, for the present such lengths are included in the reconstruction list but the practical alternative treatment is indicated by the tag 'XP' after the priority rating. A similar state of affairs exists for the wheel track cracking defect. Under certain circumstances a section of surfacing would be cut out and a patch inserted, rather than the treatment of resurfacing suggested by the Marshall Standards. However, until satisfactory standards are introduced governing this situation the treatment of resurfacing will continue to be recommended.

Surface dressing treatment, as a cheaper substitute for resurfacing or as a treatment for less critical levels of Wheel Track Cracking and Whole Carriageway Deterioration is inappropriate for hot rolled asphalt surfacing. Therefore it will not be recommended as a substitute treatment for resurfacing on such surfaces and where a section of hot rolled asphalt is critical for surface dressing it will be tagged with the letters 'HA' to signify that an alternative treatment must be used.

A disk file is created by the program comprising all treatment lengths for all roads on the Durham County Road network. The format of this file, the Treatment Length File, is as follows :

(i) Road Type.

(ii) Road Identifier.

(iii) Division.

(iv) District.

(v) Strategic Route Classification.

(vi) Marshall Category.

(vii) Urban/Rural Classification.

(viii) Treatment Recommended.

(ix) Sections included in the treatment length.

(x) Start chainage of treatment length.

(xi) End chainage of treatment length.

(xii) Priority Rating of treatment length.

(xiii) Length requiring treatment.

(xiv) Average width of treatment length.

(xv) Counter signifying if the treatment recommended in (viii) is a substitute for a more expensive treatment.

The format of this file allows the sorting and selection of data to take place in future programs so that the Maintenance Engineer would receive only the information pertinent to his area, in the form most useful to him. This cuts down the amount of printout each Maintenance Engineer would receive. The printout from this program consists of a priority listing for each treatment type for each Division, or Marshall Category as shown in Figure 8.

12.2 <u>CLUDIS</u> *

This program displays the Treatment length file, created by program PRLIST, for a particular road. The Treatment Length File is sorted and the data, if any, pertinent to the road under consideration is accessed. The program uses data from the General Information File and the Rating File to make the data displayed more complete. The program gives a very visual output by using asterisks and histograms rather than figures for certain data. The extent and position of treatment lengths are shown by asterisks in the printed output which is displayed in Figure 9. The road life, given by the deflectograph results, is shown as a histogram composed of asterisks. A geometric assessment of the road is given so that sub-standard alignment is highlighted, and an explanation of this technique is given in Appendix I. Space is reserved on the printout for an indication (inserted manually) of any improvement schemes being carried out or in the planning stages so that maintenance will be kept to a minimum on those stretches of road which are to be re-aligned or widened, since such maintenance, other than short term measures would be wasted. Traffic figures, heavy vehicle flows and road widths are also given since the engineer will take these into account when deciding the remedial work to be carried out.

* This program was written by Miss P. F. Dobson to the Author's specifications.

12.2.1 Data Input

(a) From cards :

Card Type 1

Cols.

1	Road Type.
2 - 5	Road Identifier.
6 - 8	No. of Sections.

(b) From disk :

(i) Extent and type of treatment lengths.

(ii) Section Description.

(iii) Traffic Flow.

(iv) Heavy Vehicle Flow.

(v) Speed Limits.

(vi) Realistic Travelling Speed.

(vii) Total Rating for each sub-section.

(viii) Hilliness and Bendiness factors used in the Geometric Assessment.

(ix) Road Life, from the Deflectograph Data.

(x) Road width.

12.2.2 Output

There is no output to disk, since this is purely a display program. The printed output is as shown in Figure 9.

13. System Details

The programs comprising the system are written in PL/1 (Optimising Compiler) for an IBM 370 computer using the DOS/VS Operating System.

13.1 Storage Requirements

In the PL/1 Environment program sizes are difficult to estimate from the Linkage Editor map since the compiler uses dynamic storage for internal variables to save storage space. As control passes to a procedure (an invoked procedure) a dynamic storage area (D.S.A.) is allocated. When control passes back to the invoking procedure this D.S.A. is released as shown in Figure 11 below.

Main Procedure

```
MAIN: PROCEDURE;
      CALL A;
      CALL B;
      END;
```

Procedure A

```
A: PROCEDURE;
   CALL A1;
   END;
```

DSAs PRESENT

At entry to Procedure MAIN	:	DSA for MAIN
At entry to Procedure A	:	DSA for MAIN DSA for A
At entry to Procedure A1	:	DSA for MAIN DSA for A DSA for A1
At entry to Procedure B	:	DSA for MAIN DSA for B

Figure 11

The PL/1 compiler requires at least 44K (1K = 1024 bytes) of core storage, and allows the programmer to chose between optimising for minimum core storage or minimum execution time for a program. The computer in use at Durham has a virtual storage facility allowing up to 1 megabyte of virtual storage to be mapped onto the ½ megabyte of real storage as shown in Figure 12 below.

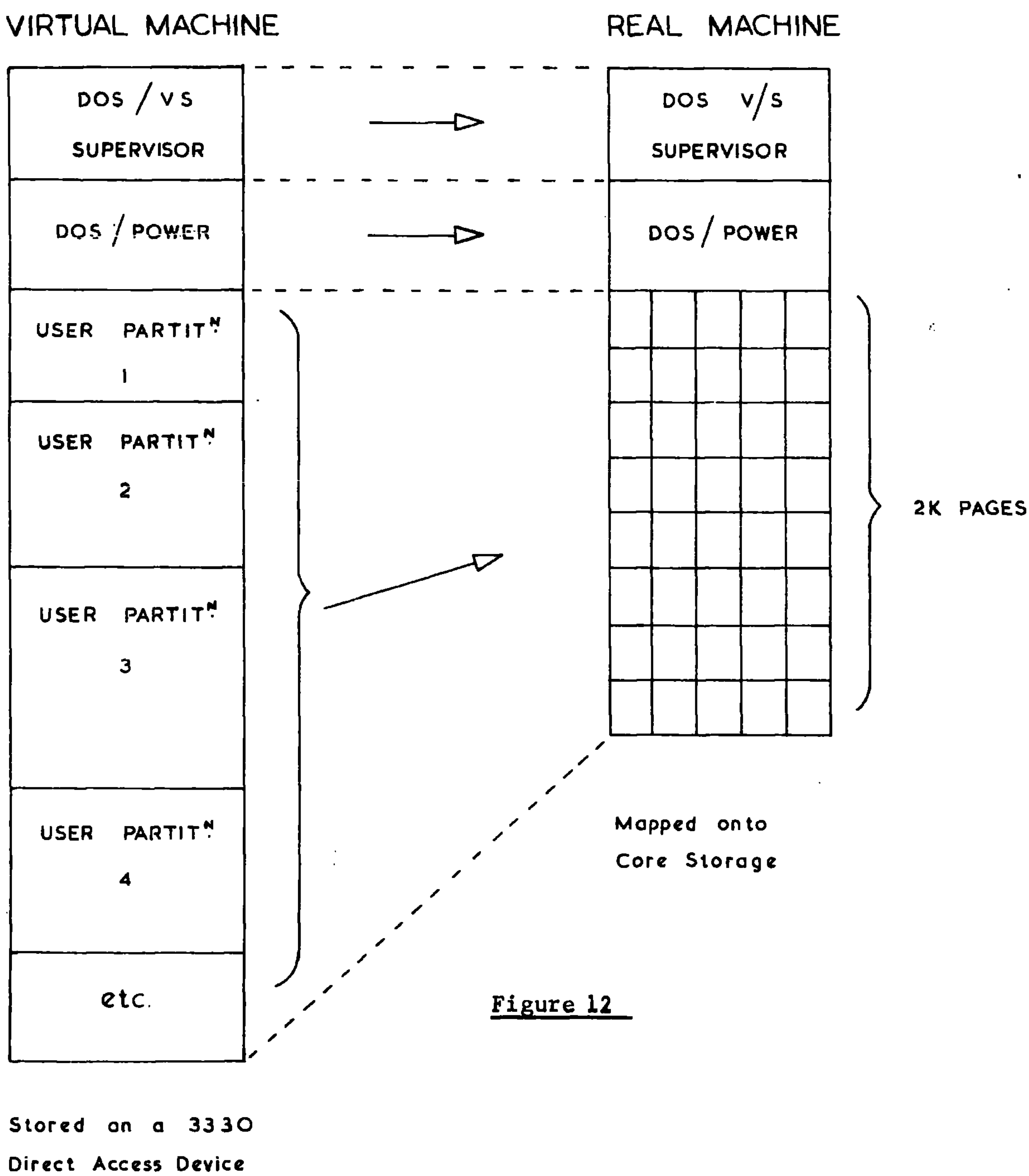


Figure 12

Theoretically several megabytes of virtual storage can be mapped onto the ½ megabyte of real storage but for optimum performance a 2 : 1 ratio of virtual to real storage is recommended. This mapping procedure is possible because when a procedure is processed sequentially only a portion of the procedure is actually being processed at any time, the rest of the procedure is using space without actually being processed. The virtual storage system splits a program into 2K segments and only holds in core those segments actually being accessed.

The normal virtual partition size is 150K allowing the programmer to optimise for execution time rather than core storage. The approximate sizes of the programs are shown below :-

(i)	MASTRF	60K
(ii)	MFEDIT	
(iii)	MFDISP	
(iv)	MDISP	
(v)	MFIPUT	90K
(vi)	PRLIST	
(vii)	CLUDIS	

13.2 Execution Times

All the programs in the system other than the Priority Listing program have been designed so that each road may be processed separately. This allows the files to be built up gradually, avoiding the inconvenience of long computer runs. The data files may be built up whilst the Inspection programme is in progress, spreading the burden on the computer over many weeks; and allowing printouts to be checked and filed. The only program requiring a single run is the

Priority Listing program, and whilst this has never been run on the full network an estimate has been made (on a section of the network) that the full 4,000 kilometres of road would take approximately 3 hours to run. However this is a once a year run, creating a Treatment Length file and any further printouts would access this file and therefore involve very short run times. The timings of all programs depend on the lengths of the individual sections and on the length of the road. Therefore it is difficult to give precise timings for a program. The timings given below are for one road, the A.67, which is approximately 42.5 kilometres long and has 45 sections.

(i)	MASTRF	:	19 sec.
(ii)	MFIPUT	:	1 min. 52 sec.
(iii)	MFEDIT	:	13 sec.
(iv)	MFDISP	:	12 sec.
(v)	MDISP	:	19 sec.
(vi)	CLUDIS	:	55 sec.

13.3 Disk Storage Requirements

The file structures are shown below :

(a) General Information File :

Information	Data Type	Storage (Bytes)
Length.	DEC.FIX.(3,2)	2
1st Node Number.	DEC.FIX (4)	3
2nd Node Number.	DEC.FIX (4)	3
Link Number.	DEC.FIX (4)	3
Indicators (2)	CHAR (1)	2
National Grid Co-ordinates (4)	DEC.FIX (6)	16
Division.	CHAR (1)	1
District.	CHAR (1)	1
Strategic Route Classification.	CHAR (1)	1
Marshall Category.	CHAR (1)	1
Urban/Rural Classification.	CHAR (1)	1
GPH Number.	CHAR (5)	5
Delegation Indicator.	CHAR (1)	1
Delegation Start and End Chainages.	DEC.FIX (4)	6
Speed Limit Data (2) : Speed	DEC.FIX (3)	4
Start & End Chainages.	DEC.FIX (4)	12
Realistic Travelling Speed.	DEC.FIX (3)	2
Remedial Work Done (2) : Type.	DEC.FIX (1)	2
Year.	DEC.FIX (2)	4
Length.	DEC.FIX (4)	6
Traffic Flows (3) : Year.	DEC.FIX (2)	6
Flow.	DEC.FIX (5)	9
Percentage Heavy Vehicles.	DEC.FIX (2)	2
Height Restriction.	DEC.FIX (3, 1)	2
Weight Restriction.	DEC.FIX (3, 1)	2
Bump Integrator : Year.	DEC.FIX (3)	2
Reading.	DEC.FIX (3)	2
Adjacent Marshall Section.	DEC.FIX (3)	2
Section Description.	CHAR (40)	40
Key to Rating File.	CHAR (8)	8

(b) Rating File

Information	Data Type	Storage (Bytes)
Rating Points, Footway & Carriageway Widths.	DEC.FIX (5)	630
Hilliness Factors.	DEC.FIX (3)	20
Bendiness Factors.	DEC.FIX (4)	30
Deflectograph Readings : Deflection.	DEC.FIX (3)	20
Life.	DEC.FIX (2)	20
Hot Rolled Asphalt Indicator.	CHAR (1)	10

(c) Treatment Length File

Information	Data Type	Storage (Bytes)
Road Type.	CHAR (1)	1
Road Identifier.	CHAR (4)	4
Division.	CHAR (1)	1
District.	CHAR (1)	1
Strategic Route Classification.	CHAR (1)	1
Marshall Category.	CHAR (1)	1
Urban/Rural Classification.	CHAR (1)	1
Treatment Recommended.	DEC.FIX (1)	1
Sections Included (5)	DEC.FIX (2)	10
Treatment Start & End Chainage.	DEC.FIX (4)	6
Priority Rating.	DEC.FIX (5)	3
Length.	DEC.FIX (4,2)	3
Average Width.	DEC.FIX (3,1)	2
Substitute Treatment Marker.	CHAR (1)	1

Where DEC. FIX = Decimal fixed and CHAR = Character.

The disk storage requirements are based on an expected 6000 records for the Rating File. The figure for the General Information File will be somewhat less than for the Rating File since sections less than or equal to 1 kilometre long will have one General Information File record and one Rating File record, but sections greater than 1 kilometre in length will have one General Information file record and two or more Rating File records. Thus we may take a value of 4000 records for the General Information file. The Treatment Length file (output by the program PRLIST) has been estimated to contain a maximum of 10,000 records. The estimates of disk storage are given below :-

(i) General Information File :

Record Size = 180 bytes = 35 records/track.

5000 records = $\frac{4000}{35}$ tracks = 115 tracks.

(ii) Rating File :

Record Size = 730 bytes = 14 records/track.

6000 records = $\frac{6000}{14}$ tracks = 429 tracks.

(iii) Treatment Length :

Record Size = 36 bytes, blocked in 20s. giving blocks of 20 x 36 = 720 bytes = 15 blocks/track = 300 records/track.

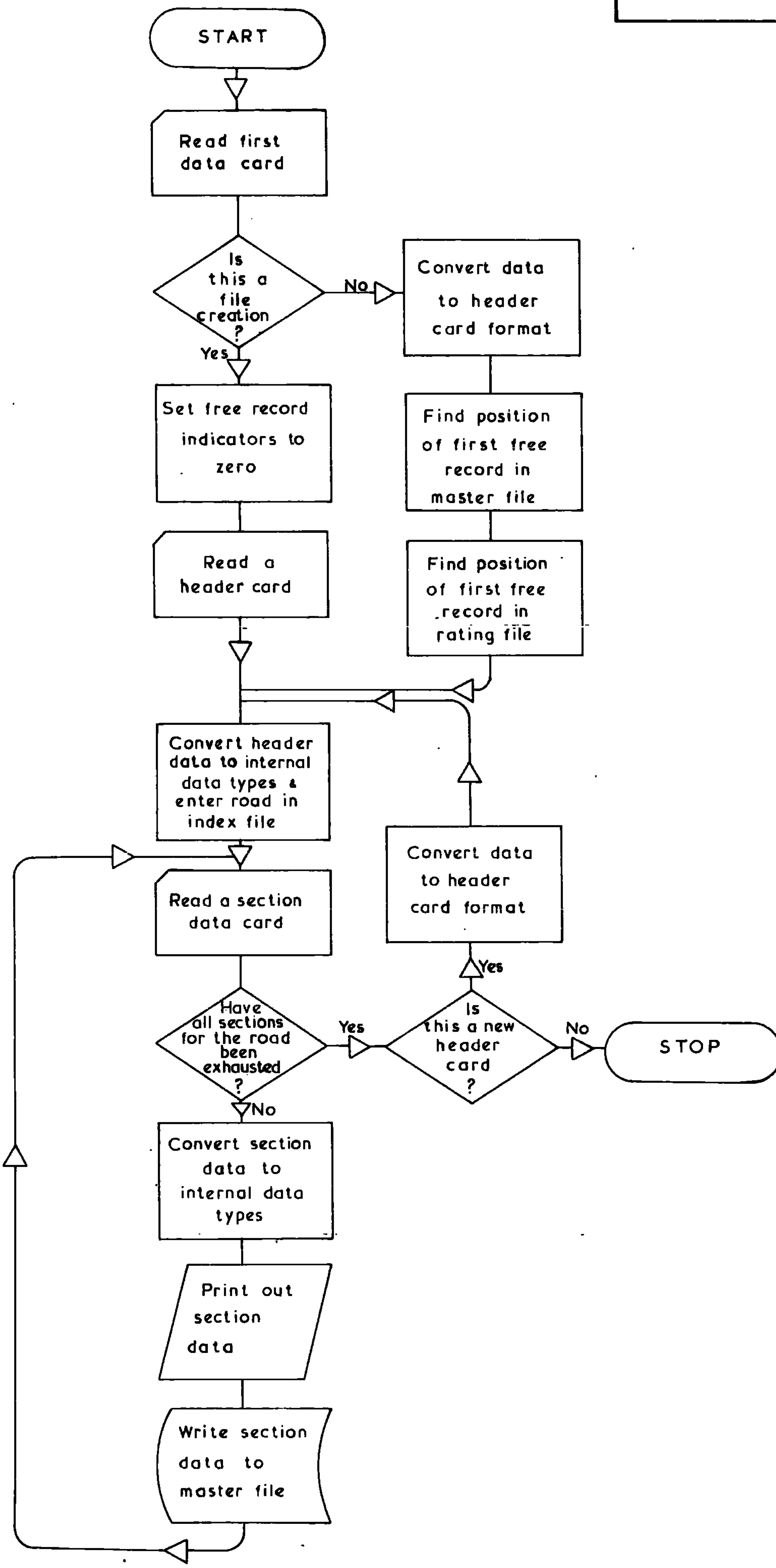
10000 records = $\frac{10000}{300}$ = 34 tracks.

Thus the total disk storage commitment is in the region of 575 tracks.

13.4 Flowcharts

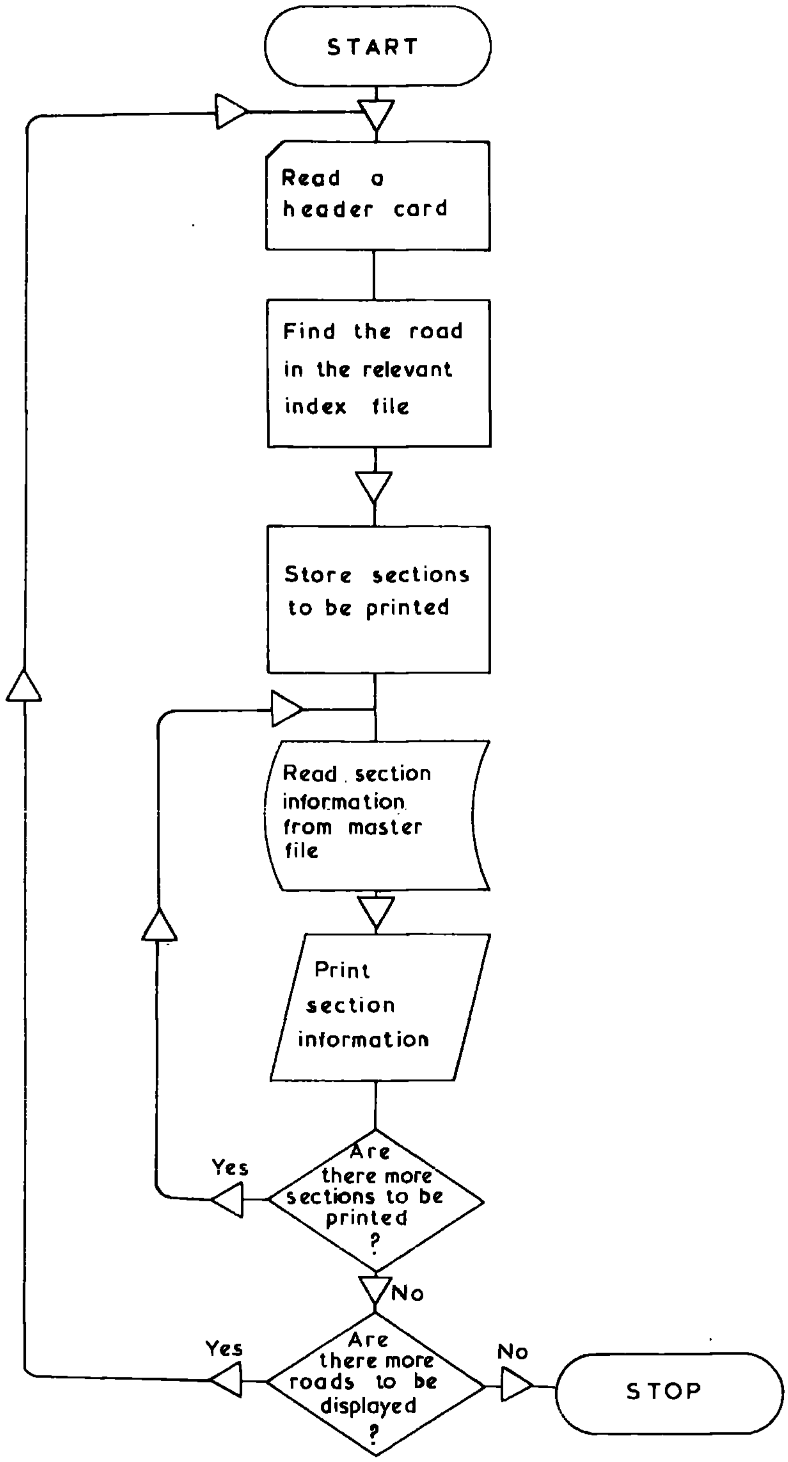
The following flowcharts show the basic logic of the programs in the suite.

MASTRF

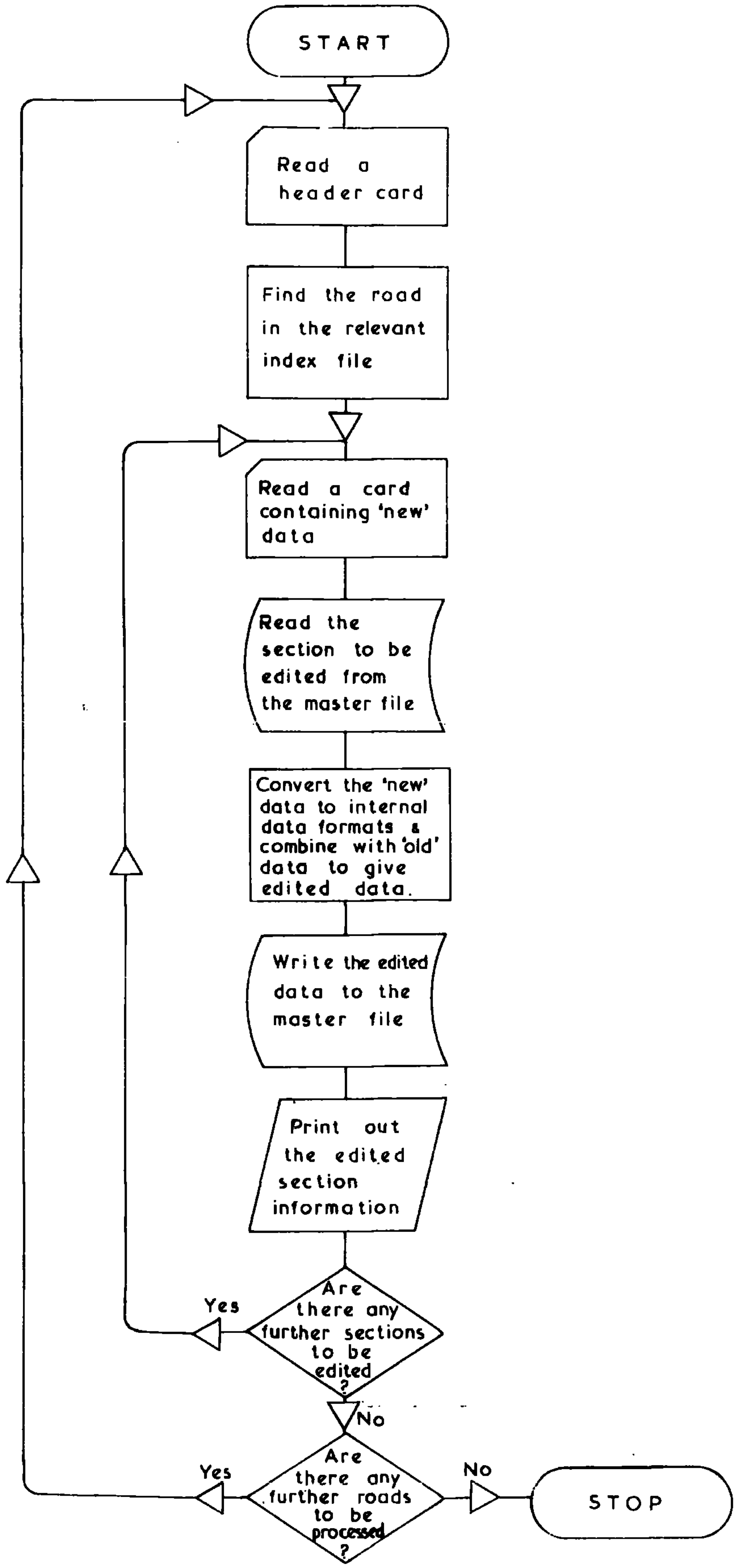


START
Read first data card
Is this a file creation ?
No
Yes
Convert data to header card format
Set free record indicators to zero
Find position of first free record in master file
Read a header card
Find position of first free record in rating file
Convert header data to internal data types & enter road in index file
Convert data to header card format
Read a section data card
Yes
Have all sections for the road been exhausted ?
Yes
Is this a new header card ?
No
STOP
No
Convert section data to internal data types
Print out section data
Write section data to master file

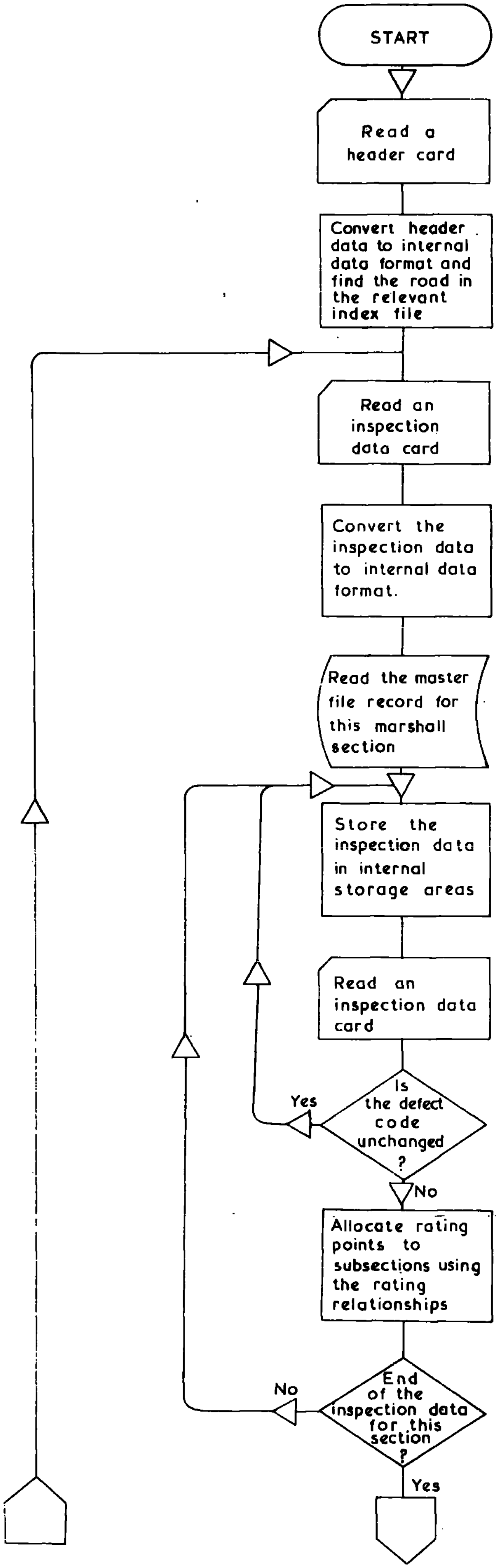
MFDISP


START
Read a header card
Find the road in the relevant index file
Store sections to be printed
Read section information from master file
Print section information
Are there more sections to be printed ?
Yes
No
Are there more roads to be displayed ?
Yes
No
STOP

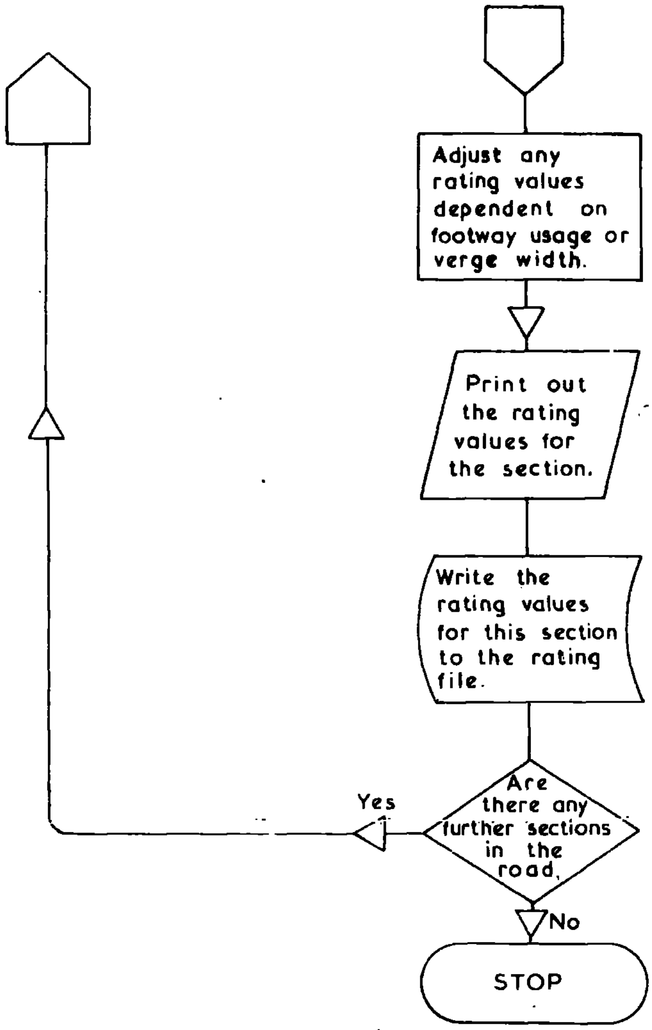
MFEDIT


START
Read a header card
Find the road in the relevant index file
Read a card containing 'new' data
Read the section to be edited from the master file
Convert the 'new' data to internal data formats & combine with 'old' data to give edited data.
Write the edited data to the master file
Print out the edited section information
Are there any further sections to be edited ?
Yes
No
Are there any further roads to be processed ?
Yes
No
STOP

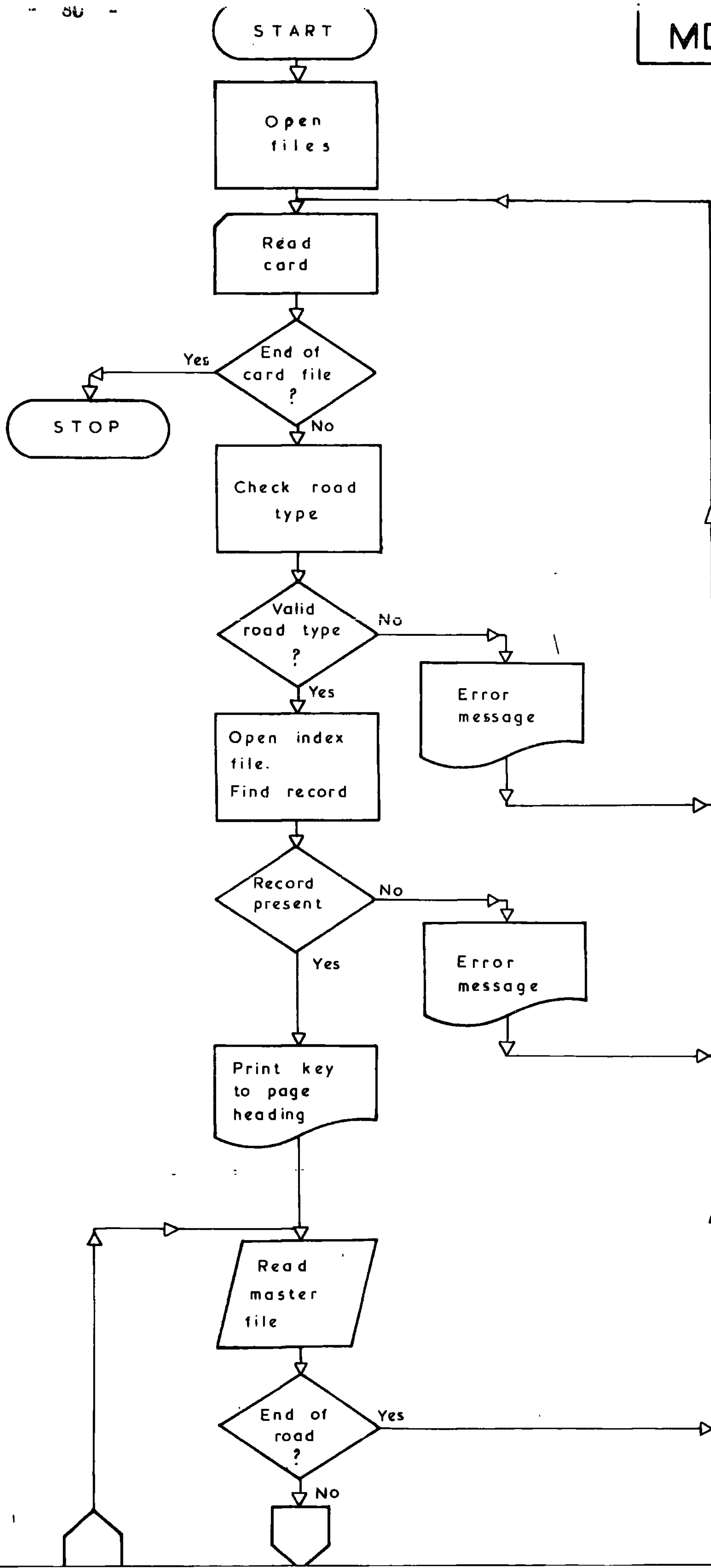
MFIPUT

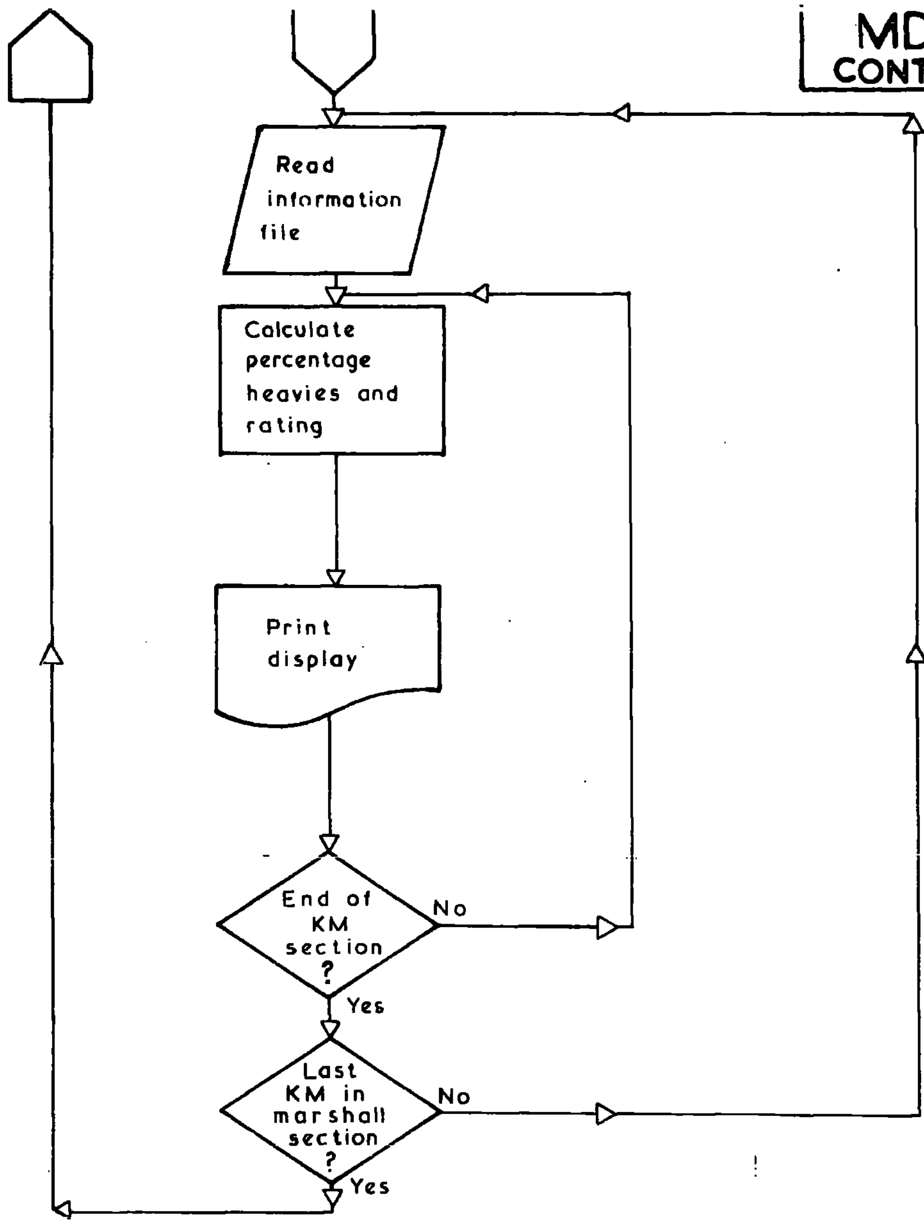

START
Read a header card
Convert header data to internal data format and find the road in the relevant index file
Read an inspection data card
Convert the inspection data to internal data format.
Read the master file record for this marshall section
Store the inspection data in internal storage areas
Read an inspection data card
Is the defect code unchanged ?
Yes
No
Allocate rating points to subsections using the rating relationships
End of the inspection data for this section ?
No
Yes

MFIPUT CONTINUED

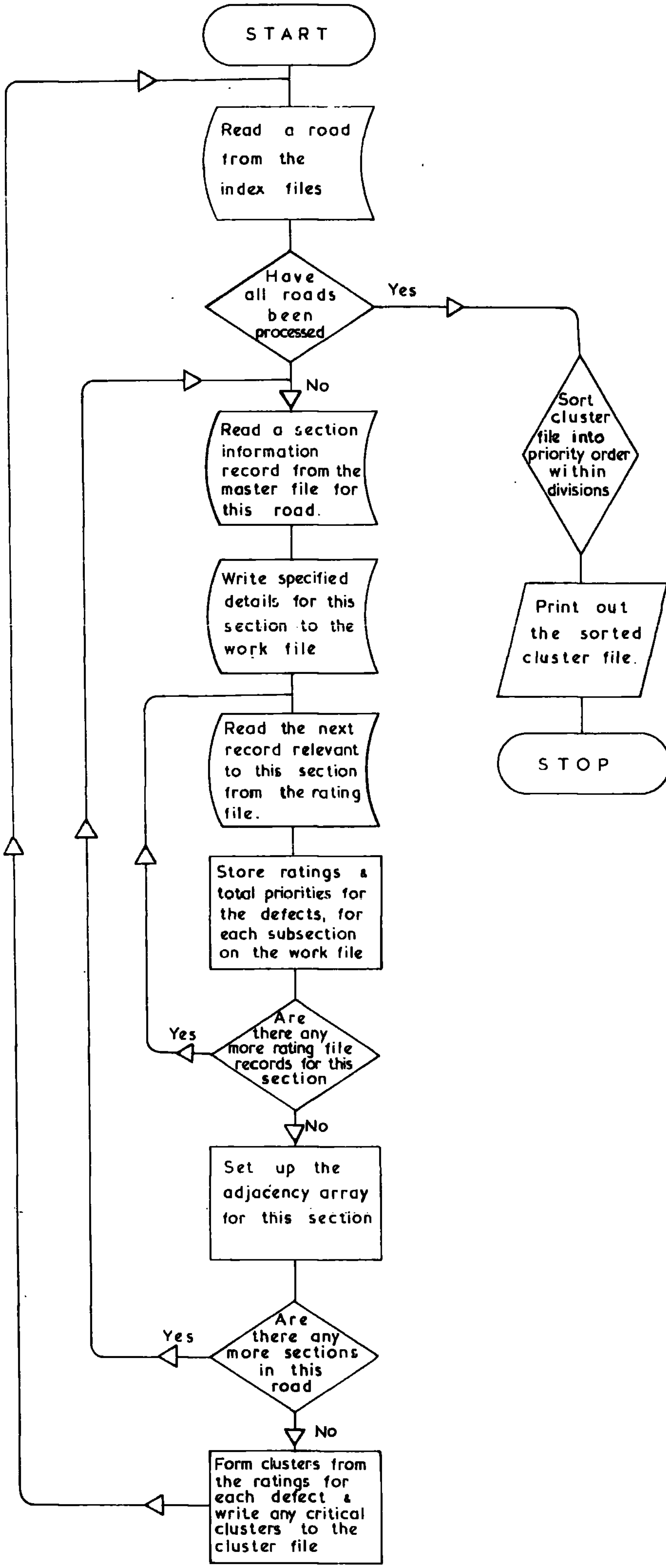


MDISP

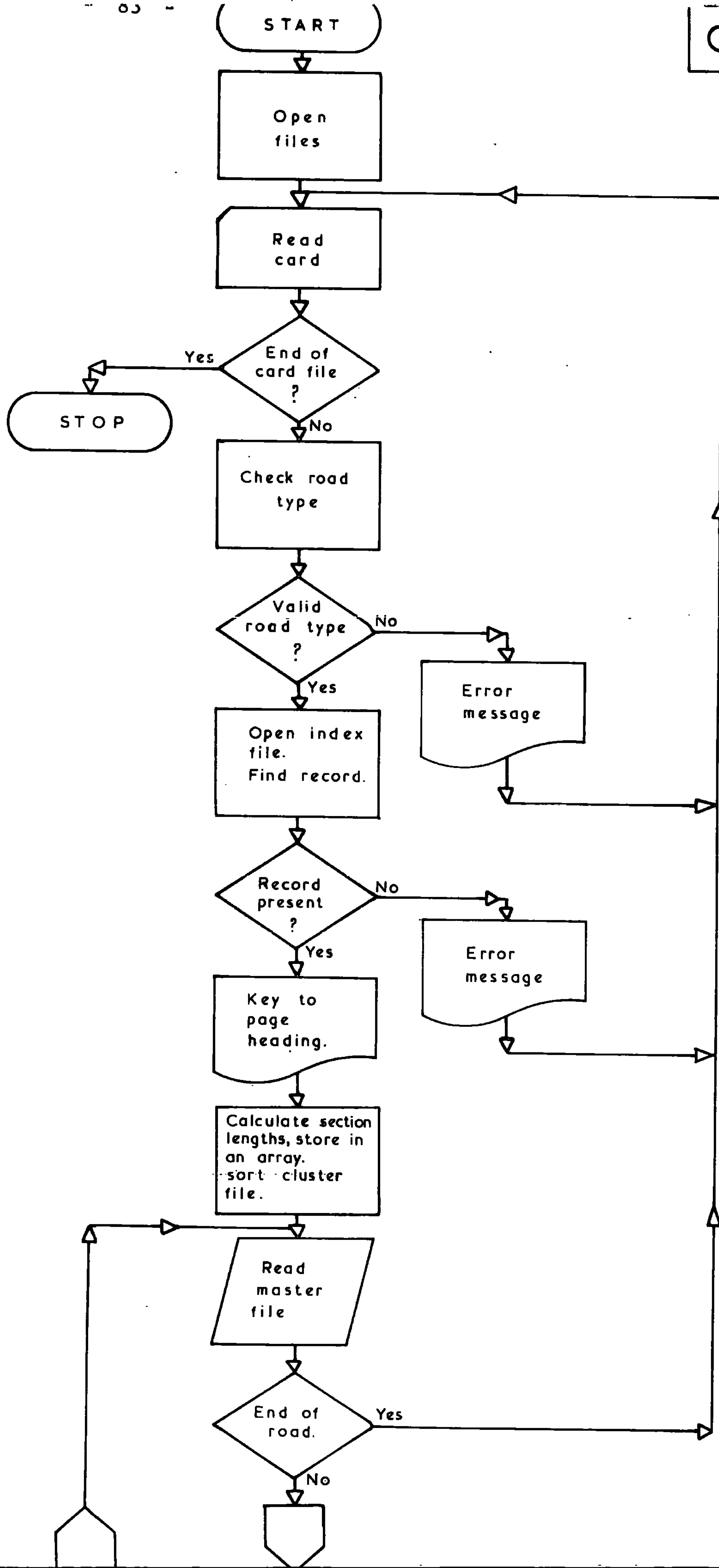

START
Open files
Read card
End of card file ?
Yes
STOP
No
Check road type
Valid road type ?
No
Error message
Yes
Open index file. Find record
Record present
No
Error message
Yes
Print key to page heading
Read master file
End of road ?
Yes
No


Read information file
Calculate percentage heavies and rating
Print display
End of KM section ?
No
Yes
Last KM in marshall section ?
No
Yes

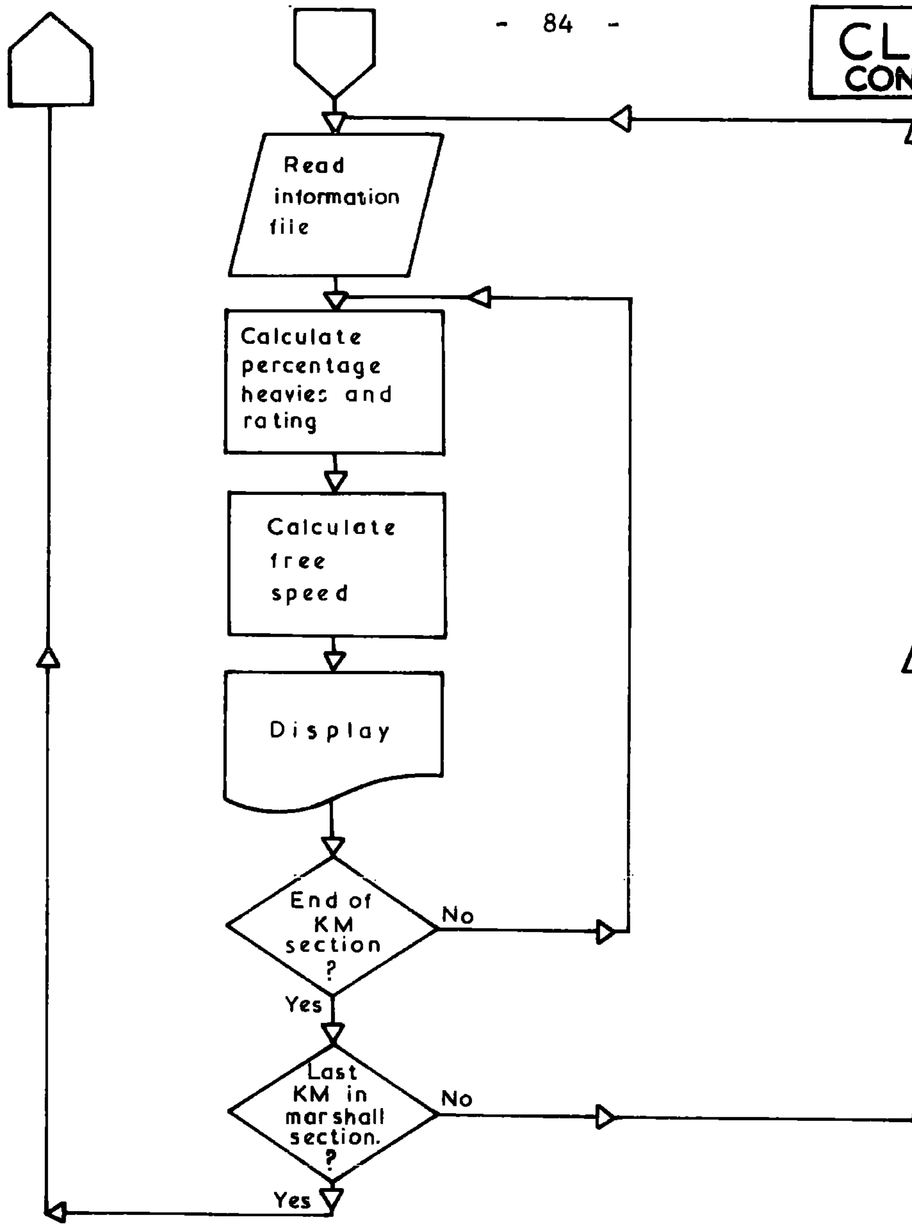
PRLIST


START
Read a road from the index files
Have all roads been processed
Yes
No
Read a section information record from the master file for this road.
Write specified details for this section to the work file
Read the next record relevant to this section from the rating file.
Store ratings & total priorities for the defects, for each subsection on the work file
Are there any more rating file records for this section
Yes
No
Set up the adjacency array for this section
Are there any more sections in this road
Yes
No
Form clusters from the ratings for each defect & write any critical clusters to the cluster file
Sort cluster file into priority order within divisions
Print out the sorted cluster file.
STOP

CLUDIS


START
Open files
Read card
End of card file ?
Yes
STOP
No
Check road type
Valid road type ?
No
Error message
Yes
Open index file. Find record.
Record present ?
No
Error message
Yes
Key to page heading.
Calculate section lengths, store in an array. sort cluster file.
Read master file
End of road.
Yes
No

CLUDIS
CONTINUED



14. Conclusions

The Priority Rating System implemented by Durham County Council has its roots in the Marshall Report and the TRRLs Technical Notes NOTE A and NOTE B. However, it has been tailored to suit Durham County's particular needs. This has been achieved by consultations between the Highway Maintenance Section and the Computer Section of the County Engineer's Department, to discover the most practical presentation of maintenance information. The volume of data collected for Durham County Council's 4000 kilometres of road is extremely large; thus the intention has been to present selections of pertinent information in forms acceptable to the engineer. This is done by introducing various levels of report, varying in content and degree of detail, so that in the extreme cases an engineer may have an overview of many roads or a section of a single road in precise detail.

The inspection data is collected as described in Technical Note NOTE A, since this was considered to be an eminently practical data collection system. However in view of the volume of data involved a computerised Priority Rating system was felt to be more appropriate than the manual method described in NOTE A. The computerised system described in NOTE B was then considered and was found to be impractical to implement for a large rural highway network, however useful it may be in a compact urban situation. The rating relationships given in NOTE B were accepted as a useful initial approximation, to be modified as experience dictates. The 10 metre microsection, also introduced by NOTE B, was felt to be less useful since its introduction increases the volume of printout to unacceptable levels, would be detrimental to the run-times of the programs in the system, and in a rural situation is less practical than the 100 metre sub-section introduced by NOTE A. Thus it was decided that a system modified to suit the special needs of Durham County Council's

Highway Maintenance Section would have to be designed.

The system is based on Marshall Sections, chosen according to rules given in NOTE A, which are divided into 100 metre sub-sections for storage and printout purposes. The general information, e.g. geophysical, traffic and administrative data, and inspection data concerning a Marshall Section must be stored in such a way as to give fast access and flexible processing. The files must therefore be held on disk and allow direct access methods to be used, otherwise access times could make the system uneconomic to run.

The most efficient storage method was considered to be a three tier system of files :

(i) Index files, one for each type of road: A, B, C, Motorway, Trunk and Unclassified.

(ii) A General Information File, with one data record per Marshall Section.

(iii) A Rating File, with one record per kilometre of Marshall Section.

These files are stored on disk and use, for the General Information and Rating Files, direct accessing methods. For direct access files the position of the record to be accessed must be known. Thus a system of keys has been introduced. The Index file record for a particular road contains a pointer to the position of the data record in the General Information file for the first Marshall Section of the road. Subsequent sections may be accessed directly by incrementing the pointer by a number one less than the required section number. The General Information file record for a Marshall Section contains a pointer to the position of the data record in the Rating file for the first kilometre of the Marshall Section. The second and subsequent kilometres, if the Marshall

Section is more than one kilometre long, may be accessed directly by incrementing the pointer by the number of kilometres preceding the kilometre in question. The file structure is shown in Figure 2 above.

The direct access files enable data to be stored as it becomes available without the unproductive reading of files implied in the use of sequential disk files. These files are the basis of the system; data stored on the files may be manipulated, selected and displayed in many ways to give the Maintenance Engineer the information he needs to formulate his Programme of Work. The levels of report available are described below :

(i) Priority Listing : treatment lengths (one or more contiguous sub-sections requiring the same treatment) for all roads or a selection of roads in priority order.
Various printout options allow selection of information and the categorisation of that information under pertinent headings. Any stretches of road not critical for remedial treatment will be omitted from the printout for clarity and brevity.

(ii) Treatment Length Display : for a single road this printout gives in pictorial form the extent and position of lengths requiring treatment. Relevant information from the General Information and Rating files concerning the road life, road width, traffic flows and travelling speeds is included in the printout.

(iii) Histogram Printout : a representation of the total rating points assigned to each sub-section of a road for carriageway defects, in the form of a histogram of asterisks, with relevant data from the General Information and Rating files included in the printout.

(iv) General Information File Display : a display of all information held on the General Information File.

(v) Rating file display : the rating points collected by each sub-section for each roadside and carriageway defect plus verge, footway and carriageway widths and types.

The Engineer would use the Priority Listing to identify the roads requiring treatment. After elimination of certain treatment lengths on practical or economic grounds the Engineer is left with a list of treatment lengths with recommended treatments. The Treatment Length Display program outputs for the roads in the list then locates the treatment lengths and supplies information about the strength and physical characteristics of the road. A tentative Programme of Work could be formulated at this point, and examples of weak roads with bad alignment possibly considered for minor improvement work rather than remedial treatment. Further information about a stretch of road may be obtained from the Rating and General Information file displays, and for difficult stretches of road and to finalise the Programme of Work the Divisional Surveyor may carry out a subjective appraisal of the stretch of road.

This tiered system prevents the Engineer being inundated by large volumes of data. Instead the system gives selections of information in as great or as little detail as the Engineer requires, so that time is not spent sorting out relevant information from large masses of irrelevant data.

APPENDIX A

A.1 Marshall Categories

The roads are divided into Marshall Categories on the basis of the type of road and the traffic carried. For convenience in costing remedial work all trunk roads are included in Category 1 since the financing of highway maintenance for Motorway and Trunk Roads is from central government; whereas maintenance for the other classes of road is financed from the rate fund. Otherwise the categories are as given in the Marshall Report (p.18), with traffic figures from NOTE A.

CATEGORY 1 : MOTORWAY AND TRUNK ROADS.

CATEGORY 2 : IMPORTANT PRINCIPAL ROADS : TRAFFIC FLOWS URBAN $>$ 18000 pcu *
RURAL $>$ 6000 pcu

CATEGORY 3 : OTHER PRINCIPAL ROADS AND IMPORTANT NON-PRINCIPAL ROADS :
TRAFFIC FLOWS URBAN $>$ 3600 pcu
RURAL $>$ 1200 pcu

CATEGORY 4 : OTHER ROADS : TRAFFIC FLOWS URBAN $<$ 3600 pcu
RURAL $<$ 1200 pcu

These pcu totals are a general guide and would differ with differing overall traffic.

Other factors could also influence the categorisation of a road; such as its strategic importance or local amenity value. A through route or a road servicing many isolated rural communities would have considerable local importance which may put it into a higher category than its traffic would indicate. The importance of such roads could be assessed by theoretically removing them and examining the impact their absence would make on the traffic network.

* passenger car unit.

The Marshall Report introduced the concept that roads of differing importance would be maintained to different standards. This could be implemented generally by considering a network of Category 1 and 2 roads covering the county area maintained to a high standard and having a high priority for maintenance funds. Category 3 roads covering the rest of the county would have the next call on maintenance funds with Category 4 roads receiving whatever funds were left. Thus most money would be spent on the most important roads and would therefore benefit the greatest number of motorists. Urgent maintenance for dangerous conditions is not covered by the above scheme, which is for general, planned maintenance; however, on a Category 4 road, where a cheaper alternative treatment is available giving, perhaps, a shorter life expectancy than reconstruction this alternative would be used. The idea of "minimum maintenance" (preserving the waterproof surface and preventing foundation failure) coupled with weight restriction orders to remove heavy traffic from certain Category 4 roads is being considered. The intention is to define a network of roads maintained to a reasonable standard and capable of carrying the volumes of commercial traffic found in the district, fed by local roads. These local roads would have weight restrictions imposed or would be physically cut (i.e. by a gate etc.) so that through traffic could not use them, but access to farms, quarries and villages in the catchment area would be allowed. These measures would stop "short cutting" by heavy lorries and confine them to roads able to withstand their damaging effect on the pavement. This network would have to be self-enforcing, since, unless the area involved is compact and easily patrolled, the policing involved in enforcing widespread weight restriction orders would be a difficult task for an already over-extended police force. A report is at present being prepared by Local Government on the feasibility of the above project and the advantages and problems it would bring.

A.2 The Standards

The standards shown below are taken from the Marshall Report and have been modified by NOTE A and NOTE B. Since the fixed interval inspections are taken over 25 metres rather than 20 metres as for NOTE B some critical percentages have been changed from 20% to 25%.

A.2.1 Pavement Defects

A.2.1.1 Wheel Track Rutting

(i) Reconstruct :

(a) where 25% or more of the subsection shows rutting of 18 mm or above.

(b) where 100% of the subsection shows rutting of 17 mm.

(ii) Resurface :

(a) where 25% or more of the subsection shows rutting of 13 mm or more.

(b) where 100% of the subsection shows rutting of 12 mm or more.

Thus a small amount of serious rutting will make a subsection critical for treatment, and a large amount of less serious rutting will give the same effect.

A.2.1.2 Wheel Track Cracking

(i) Resurface : where deterioration covers 30% of the wheel tracks for Category 1, 2 and 3 roads, or 50% of the wheel tracks for Category 4 roads.

(ii) Surface Dress : where deterioration covers 10% of the wheel tracks for Category 1, 2, 3 roads or 17% of the wheel tracks for Category 4 roads.

A.2.1.3 Whole Carriageway Major Deterioration

(i) Resurface : where 20% of the road surface shows deterioration.

(ii) Surface Dress : where 7% of the road surface shows deterioration.

A.2.1.4 Whole Carriageway Minor Deterioration

Surface Dress : where 25% of the road surface shows deterioration.

A.2.1.5 Edge Deterioration

(i) Haunch and kerb where :

(a) 50% of the edge shows Severity 1 deterioration.

(b) 30% of the edge shows Severity 2 deterioration.

(c) 20% of the edge shows Severity 3 deterioration.

(ii) Patch where :

(a) 17% of the edge shows Severity 1 deterioration.

(b) 10% of the edge shows Severity 2 deterioration.

(c) 7% of the edge shows Severity 3 deterioration.

A.2.1.6 Inadequate Drainage

Drainage Treatment : apply where 30% of the subsection is inadequately drained.

A.2.2 Roadside Defects

A.2.2.1 Footway and Verge Deterioration

(i) Inner Urban footways and verges repair when the footpath or verge shows 10% deterioration.

(ii) Outer Urban footways and verges, frequently used rural footways and verges - repair when the footpath or verge shows 20% deterioration.

A.2.2.2 Inadequate Kerb Upstand

(i) Urban Roads : where a footway is within 3 metres of the road and unprotected by a safety fence or embankment, the required upstand is 75 mm; otherwise the required upstand is 25 mm. Loss of upstand from these standards may be present in varying degrees and to varying extents. Thus criticality may be indicated by a small percentage showing total loss of upstand or by a large percentage showing a smaller loss of upstand. Thus a rating relationship is used and criticality is indicated when the subsection has collected rating points equivalent to 20% showing total loss of upstand.

(ii) Rural Roads : where a frequently used footway lies within 1.2 metres of the carriageway unprotected by a safety fence or embankment the required upstand is 75 mm; otherwise the required upstand is 25 mm. Criticality is indicated when the subsection has collected rating points equivalent to 30% showing total loss of upstand.

A.2.2.3 Kerb Deterioration

(i) Inner Urban Roads : repair when 10% of the kerb shows deterioration.

(ii) Other Roads : repair when 20% of the kerb shows deterioration.

A.2.2.4 Kerb Provision

Kerb provision is only required where a footpath is within a standard distance of the carriageway and unprotected by a safety fence or embankment.

(i) Urban roads with a footway within 3 metres of the carriageway provide kerbs where 20% of the sub-section is unkerbed.

(ii) Rural roads with a frequently used footway within 1.2 metres of the carriageway provide kerbs where 30% of the subsection is unkerbed.

A.3 Strategic Routes

The policy of dividing the roads into Strategic Routes is similar in intent to the division of roads into Marshall Categories. However a Strategic Route may consist of more than one road. The intention is to offer commercial traffic particular routes which have been improved to a higher standard than the remainder of the road network and so encourage this traffic to concentrate upon a limited number of roads. The removal of heavy commercial traffic from minor roads will result in increased life for these roads and reduce the need for maintenance and improvement. Three categories of route are envisaged : Primary, Secondary and Tertiary.

APPENDIX B

The data sheets and output lists, in the following orders.

1. Inspection Sheet.

2. General Information Coding Sheet.

3. Inspection Data Coding Sheet.

4. General Information Editing Sheets 2A and 2B.

5. Priority Listing.

6. Cluster Display.

7. Histogram Printout.

8. General Information File Display.

9. Rating File Display.

INSPECTION SHEET

Section No. ____ Sheet No. ____

Name of road ______ from ______ to ______

LEFT		0	50	00	50	00	50	00
Features								
Ditch distance								
FOOTWAY	Levels							
	Type							
	Width							
	Detn.							
VERGE	Type							
	Width							
	Detn.							
KERB	Type							
	Detn.							
	Upstand							
CARRIAGEWAY	Width							
	W/Course							
	Features							
	Edge L							
	WT defm. L							
	WT detn. L							
	WC Major							
	WT detn R							
	WT defm. R							
	Edge R							
	Exg. patch							
	WC Minor							
	Refl Crkg.							
KERB	Type							
	Detn.							
	Upstand							
VERGE	Type							
	Width							
	Detn.							
FOOTWAY	Levels							
	Type							
	Width							
	Detn.							
Ditch distance								
Features								
RIGHT		0	50	00	50	00	50	00

DURHAM COUNTY COUNCIL — ENGINEER AND SURVEYOR'S DEPT.

MARSHALL MASTER FILE - GENERAL INFORMATION

SHEET 1

CARD TYPE 1

	RD. No.				No. OF SECTS		
1	2	3	4	5	6	7	8

CARD TYPE 2

NODE 1	NODE 2	LINK No.	IND		START CO-ORDINATES		FINISH CO-ORDINATES		LENGTH	DIV	DIST	SR	MC	DEL	U/R	G.P.H. No.	SPEED LIMIT			SPEED LIMIT			WIDTH	ADJ. MARSH SECT.		SEQ.
			R	D	EASTING	NORTHING	EASTING	NORTHING									SPD	START	FINISH	SPD	START	FINISH				
1 2 3 4	5 6 7 8	9 10 11 12	13	14	15 16 17 18 19 20	21 22 23 24 25 26	27 28 29 30 31 32	33 34 35 36 37 38	39 40 41	42	43	44	45	46	47	48 49 50 51 52	53 54	55 56 57	58 59 60	61 62	63 64 65	66 67 68	69 70 71	72 73 74	75 76 77	78 79 80

DURHAM COUNTY COUNCIL

ENGINEER AND SURVEYOR'S DEPT.

MARSHALL MASTER FILE – EDITING

CARD TYPE 1

TYPE	ROAD IDENTIFIER	Nº OF SECTS
1	2 3 4 5	6 7 8

CARD TYPE 2B

SHEET 2B

TYPE	DEL ID	DELEGATION CHAINAGES		DEG OF URB	HILLYNS FACTOR	BENDYNS FACTOR	REAL TRAV. SPD.	TRAFFIC DATA						% HV	WORK DONE						BUMP I		RESTRICTN			SEC. No.
		START	FINISH					YR	FLOW	TR	FLOW	YR	FLOW		T	YR	LENGTH	T	YR	LENGTH	YR	RDNG	HT.	WT.		
1	2	3 4 5 6	7 8 9 10	11 12	13 14 15	16 17 18	19 20 21	22 23	24 25 26 27 28	29 30	31 32 33 34 35	36 37	38 39 40 41 42	43 44	45	46 47	48 49 50 51	52	53 54	55 56 57 58	59 60	61 62 63	64 65 66	67 68 69	70 71 72 73 74 75 76 77	78 79 80

DURHAM COUNTY COUNCIL ENGINEER AND SURVEYOR'S DEPT.

MARSHALL MASTER FILE – EDITING

SHEET 2A

CARD TYPE 1

STD TP	ROAD IDENTIFIER				No. OF SECTS		
1	2	3	4	5	6	7	8

CARD TYPE 2A

TYPE	TRAFFIC NETWORK			ID		START CO-ORDINATES		FINISH CO-ORDINATES		LENGTH	DIV	DIST	SR	MC	U/R	GPH. No.	SPEED LIMIT 1			SPEED LIMIT 2			AMS		SEC. No.
	NODE 1	NODE 2	LINK	R	D	EASTING	NORTHING	EASTING	NORTHING								SPD	START	END	SPD	START	END			
1	2 3 4 5	6 7 8 9	10 11 12 13	14	15	16 17 18 19 20 21	22 23 24 25 26 27	28 29 30 31 32 33	34 35 36 37 38 39	40 41 42	43	44	45	46	47	48 49 50 51 52	53 54	55 56 57 58	59 60 61 62	63 64	65 66 67 68	69 70 71 72	73 74 75	76 77	78 79 80

DURHAM COUNTY COUNCIL ENGINEER AND SURVEYOR'S DEPT.

CARD TYPE 1

TYPE	ROAD No.				MARS. SECTn		
1	2	3	4	5	6	7	8

MARSHALL INFORMATION FILE

CARD TYPE 2

SHEET 3

CODE	START CHAINAGE	TYPE	WIDTH OR SEVERITY	FINISH CHAINAGE		START CHAINAGE	TYPE	WIDTH OR SEVERITY	FINISH CHAINAGE		START CHAINAGE	TYPE	WIDTH OR SEVERITY	FINISH CHAINAGE		START CHAINAGE	TYPE	WIDTH OR SEVERITY	FINISH CHAINAGE		START CHAINAGE	TYPE	WIDTH OR SEVERITY	FINISH CHAINAGE		SEQUENCE
1 2 3 4	5 6 7 8	9 10	11 12 13	14 15 16 17	18	19 20 21 22	23 24	25 26 27	28 29 30 31	32	33 34 35 36	37 38	39 40 41	42 43 44 45	46	47 48 49 50	51 52	53 54 55	56 57 58 59	60	61 62 63 64	65 66	67 68 69	70 71 72 73	74	75 76 77 78 79 80

DIVISION: 1   TREATMENT: RECONSTRUCT

ROAD	M C	TREATMENT START	TREATMENT END	SECTIONS INCLUDED	PRIORITY RATING	TOTAL LENGTH	COST £
A 181		8: 0	8: 100		7745	0.10	
B6312		8: 500	8: 600		1731	0.10	
A6127		6: 400	6: 500		1635	0.10	
A6127		5: 0	5: 100		1460	0.10	
A 181		2: 800	2: 900		1283	0.10	

DIVISION: 1   TREATMENT: RESURFACE

	ROAD	M C	TREATMENT START	TREATMENT END	SECTIONS INCLUDED	PRIORITY RATING	TOTAL LENGTH	COST £
*	A 181		8: 0	8: 100		7745	0.10	
*	B6312		8: 500	8: 600		1731	0.10	
*	A6127		6: 400	6: 500		1635	0.10	
*	A6127		5: 0	5: 100		1460	0.10	
*	A 181		2: 800	2: 900		1283	0.10	
	B6312		8: 100	9: 100		481	0.91	
	A6127		3: 0	3: 50		405	0.05	
	A 181		2: 400	2: 500		333	0.10	
	A 181		4: 100	4: 200		333	0.10	
	A 181		4: 0	4: 100		193	0.10	
	A6127		6: 500	6: 600		185	0.10	
	B6312		9: 100	9: 200		183	0.10	
	A6127		6: 800	6: 900		165	0.10	
	A6127		6: 100	6: 200		155	0.10	
	A 181		2: 300	2: 400		103	0.10	

DIVISION: 1   TREATMENT: SURFACE DRESS

	ROAD	M C	TREATMENT START	TREATMENT END	SECTIONS INCLUDED	PRIORITY RATING	TOTAL LENGTH	COST £
	B6312		8: 700	8: 800		406	0.10	
*	B6312		8: 100	9: 100		356	0.91	
*	A 181		2: 400	2: 500		333	0.10	
*	A 181		4: 100	4: 200		333	0.10	
*	A 181		4: 0	4: 100		193	0.10	
*	B6312		9: 100	9: 200		183	0.10	
*	A 181		2: 300	2: 400		103	0.10	
	A 181		4: 200	4: 300		83	0.10	
	A 181		8: 0	8: 100		70	0.10	
	A 181		2: 800	2: 900		32	0.10	
	A 181		2: 100	2: 200		20	0.10	

==========

ROAD:A 67

==========

KEY:

SECN NO	SECTION NUMBER
HEAVY VEHCL	NUMBER OF HEAVY VEHICLES
REAL T.SP	REALISTIC TRAVELLING SPEED

DEFECTS:

RC	RECONSTRUCT
RS	RESURFACE
SD	SURFACE DRESS
ET	EDGE TREATMENT
DR	DRAINAGE

SECN NO	CHAINAGE (METRES)	MARSHALL DEFECTS RC	RS	SD	FT	DR	RATING	PROGRAM	GEOMETRIC ASSESSMENT	ROAD LIFE (IN YEARS)	TRAFFIC FLOW	HEAVY VEHCL	WIDTH	SPEED LIMITS	REAL T.SP
	1000				*		234						6.30		0
	1100				*		140						6.30		0
	1200	*	*	*	*		1831						6.30		0
	1300	*	*		*		1715						6.30		0
	1400		*	*	*		711						6.30		0
	1500	*	*		*		7845						6.30		0
	1600	*	*				7620						6.30		0
	1700	*	*				1515						6.30		0
	1800						50						6.30		0
	1900						36						6.30		0
	2000						5						6.30		0
	2100						0						6.30		0
	2200	*	*				1440		68				6.30		0
	2300	*	*				1460		67				6.30		0
	2400	*	*				7545		75				6.30		0
	2500	*	*				9541		63				6.30		0
	2600		*				210		62				5.80		0
	2700	*	*				2700		67				6.30		0
4	BBA STARTFORTH - B6277 JUNCT (WEST)														
	0	*	*				7530		48		2500	250	7.30		0
	100	*	*	*			15395		-30 *				7.30		0
5	B6277 JUNCT (WEST) - B6277 JUNCT (EAST)														
	0	*	*	*			9558		-47 *		0	0	7.10		0
	100	*	*				9330		-81 *				7.38		0
6	B6277 JUNCT (EAST) - OLD DISTRICT BDY														
	0						65		63		3900	0	5.70		0
7	OLD DISTRICT BDY - C44 R/BT														
	0		*	*			172		-43 *		4700	517	5.50		0
	100						0		57				7.00		0
	200						27		22				7.00		0
	300						0		-62 *				9.80		0
	400						0		37				12.98		0
	500						0						12.80		0
8	A67/C44 R/BT														
	0						0				0	0	6.40		0
9	C44 R/BT - B6278 JUNCT														
	0						37		69		6000	0	8.70		0
	100						0		21				8.70		0
	200		*	*			118		-57 *				8.70		0
	300						0		62				8.70		0
	400						0		67				8.70		0

==========

ROAD:A 67

==========

MS	MARSHALL SECTION	AR	ACCIDENT RECORD	RTS	REALISTIC TRAVELLING SPEED
CH	CHAINAGE	M	MARSHALL CATEGORY	I	IMPROVEMENT STATUS
LF	ROAD LIFE	R	ROAD STATUS	HT	HEIGHT RESTRICTION (METRES)
WDTH	WIDTH OF CARRIAGEWAY	TFLOW	TRAFFIC FLOW	WT	WEIGHT RESTRICTION (TONS)
B	BEND FACTOR	HV	PERCENTAGE OF HEAVIES	D	DIVISION
G	GRADIENT FACTOR	B.I	BUMP INTEGRATOR		

MS	CH	TOTAL CARRIAGEWAY RATING	RATE	LF	WDTH	B	G	AR	M	R	TFLOW	HV	B.I	RTS	I	HT	WT	D
	1500	***	7845	0	6.3	0	0	0	0	P	2500	10	0	0	0	0.0	0	3
	1600	**	7620	0	6.3	0	0	0	0	P	2500	10	0	0	0	0.0	0	3
	1700	********	1515	0	6.3	0	0	0	0	P	2500	10	0	0	0	0.0	0	3
	1800	*	50	0	6.3	0	0	0	0	P	2500	10	0	0	0	0.0	0	3
	1900	*	36	0	6.3	0	0	0	0	P	2500	10	0	0	0	0.0	0	3
	2000	*	5	0	6.3	0	0	0	0	P	2500	10	0	0	0	0.0	0	3
	2100		0	0	6.3	0	0	0	0	P	2500	10	0	0	0	0.0	0	3
	2200	********	1440	0	6.3	0	0	0	0	P	2500	10	0	0	0	0.0	0	3
	2300	********	1460	0	6.3	0	0	0	0	P	2500	10	0	0	0	0.0	0	3
	2400	***************************************	7545	0	6.3	0	0	0	0	P	2500	10	0	0	0	0.0	0	3
	2500	***	9541	0	6.3	0	0	0	0	P	2500	10	0	0	0	0.0	0	3
	2600	**	210	0	5.8	0	0	0	0	P	2500	10	0	0	0	0.0	0	3
	2700	**************	2700	0	6.3	0	0	0	0	P	2500	10	0	0	0	0.0	0	3
	2800		0	0	0.0	0	0	0	0	P	2500	10	0	0	0	0.0	0	3
	2900		0	0	0.0	0	0	0	0	P	2500	10	0	0	0	0.0	0	3
4	0	***************************************	7530	0	7.3	0	0	0	0	P	2500	10	0	0	0	0.0	0	3
	100	**	15395	0	7.3	0	0	0	0	P	2500	10	0	0	0	0.0	0	3
5	0	**	9558	0	7.1	0	0	0	0	P	0	0	0	0	0	0.0	0	3
	100	**	9330	0	7.4	0	0	0	0	P	0	0	0	0	0	0.0	0	3
6	0	*	65	0	5.7	0	0	0	0	P	3900	0	0	0	0	0.0	0	3
7	0	*	172	0	5.5	0	0	0	0	P	4700	0	0	0	0	0.0	0	3
	100		0	0	7.0	0	0	0	0	P	4700	0	0	0	0	0.0	0	3
	200	*	27	0	7.0	0	0	0	0	P	4700	0	0	0	0	0.0	0	3
	300		0	0	9.8	0	0	0	0	P	4700	0	0	0	0	0.0	0	3
	400		0	0	13.0	0	0	0	0	P	4700	0	0	0	0	0.0	0	3

```
   ROAD NO A  67            SECTION NO   7            LENGTH 0.51          NO OF SECTIONS  45

  NODES   LINK IND START COORDS  FINISH COORDS D D S M U GPH NO D=STCH ENCH
  1    2   NO  R D    E      N      E      N    V S R C R         L

  0    0    0  0   404780 516370 405020 516300 3 6 P   U               0    0

        SPEED LIMITS          REAL       WORK DONE           TRAFFIC FLOWS
SPD STCH ENCH SPD STCH ENCH T.SP T YR LNTH T YR LNTH YR FLOW  YR FLOW  YR FLOW

 0    0    0   0    0    0    0  0  0    0 0  0    0  0     0  0     0  0     0

%   RESTRCTN SURF I WDTH DEG LIGHTING AMS
HV  HT   WT  YR RDG B.FR URB STD  NC

 0 0.00  0.0  0   0  C.0   0   0   0   0


   ROAD NO A  67            SECTION NO   8            LENGTH 0.05          NO OF SECTIONS  45

  NODES   LINK IND START COORDS  FINISH COORDS D D S M U GPH NO D=STCH ENCH
  1    2   NO  R D    E      N      E      N    V S R C R         L

  C    0    0  0   405020 516300 409030 516340 3 6 P   U               0    0

        SPEED LIMITS          REAL       WORK DONE           TRAFFIC FLOWS
SPD STCH ENCH SPD STCH ENCH T.SP T YR LNTH T YR LNTH YR FLOW  YR FLOW  YR FLOW

 0    0    0   0    0    0    0  0  0    0 0  0    0  0     0  0     0  0     0

%   RESTRCTN SURF I WDTH DEG LIGHTING AMS
HV  HT   WT  YR RDG B.FR URB STD  NC

 C 0.00  0.0  0   0  0.0   0   0   0   0
```

ROAD NO A 67 SECTION NO 15 LENGTH 0.58

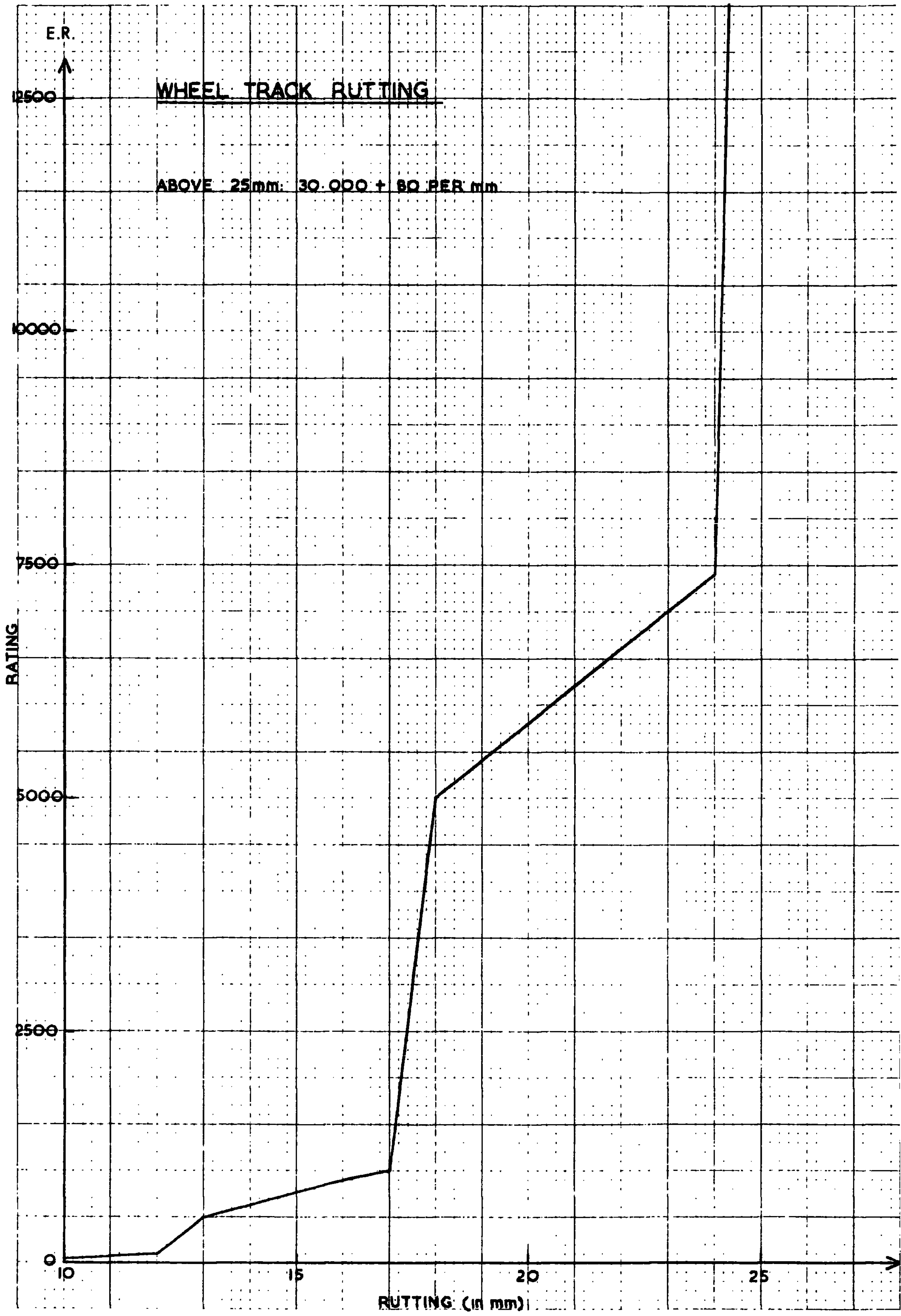
FOOTWAY AND VERGE CHAINAGE		0	100	200	300	400	500	600	700	800	900
LEFT	FOOTWAY DETN	0	0	0	0	0	0				
	VERGE DETN	0 GR	0 GR	0 GR	0 GR	0 GR	0 GR				
	KERB DETN	0 CT	0 CT	0 CT	0 CT	0 CT	0 CT				
	KERB PROVIDE	0	0	0	0	0	0				
	KERB UPSTAND	0	0	0	0	0	0				
RIGHT	KERB UPSTAND	0	0	0	0	0	0				
	KERB PROVIDE	0	0	0	0	0	0				
	KERB DETN	0 CT	0 CT	0 CT	0 CT	0 CT	0 CT				
	VERGE DETN	0 GR	0 GR	0 GR	0 GR	0 GR	0 GR				
	FOOTWAY DETN	0 BF	0 BF	0 BF	0 BF	0 BF	0 BF				

ROAD NO A 67 SECTION NO 15 LENGTH 0.58

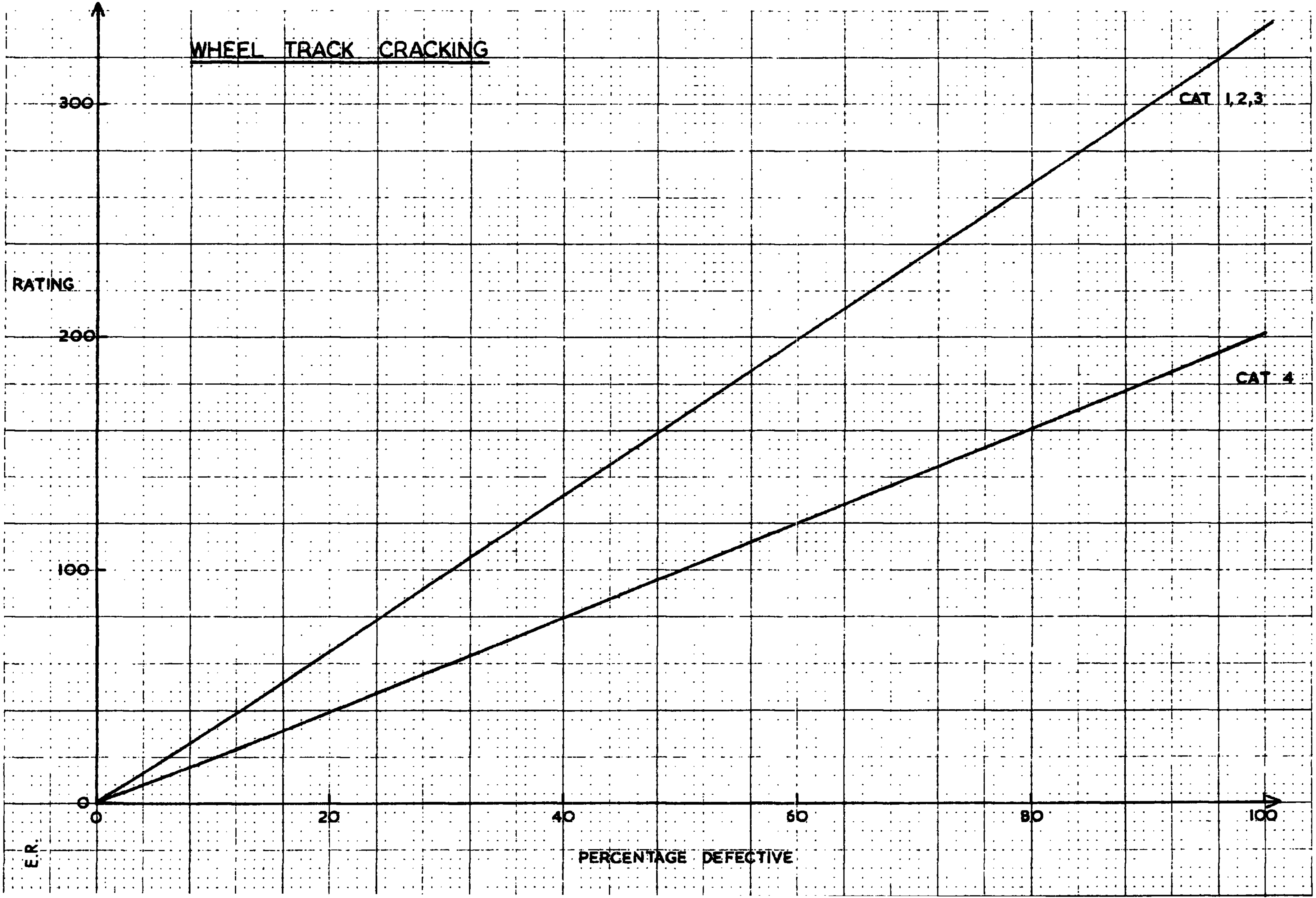
CARRIAGEWAY CHAINAGE	0	100	200	300	400	500	600	700	800	900
EDGE LEFT	0	0	0	0	0	0				
WHEEL TR.RUTTING	25	0	0	25	185R	1440C				
WHEEL TR.CRACKING	666R	633R	333R	643R	576R	666R				
W.CWAY MAJOR	0	0	0	0	0	140R				
W.CWAY MINOR	0	0	0	0	0	0				
EDGE RIGHT	0	0	0	0	0	0				
EXISTING PATCHING	10	8	0	0	C	0				
INADEQUATE DRAINAGE	0	0	0	0	0	0				
WIDTH	9.3 HA	7.4 HA	7.4 HA	7.4 HA	7.4 HA	8.4 HA				

APPENDIX C

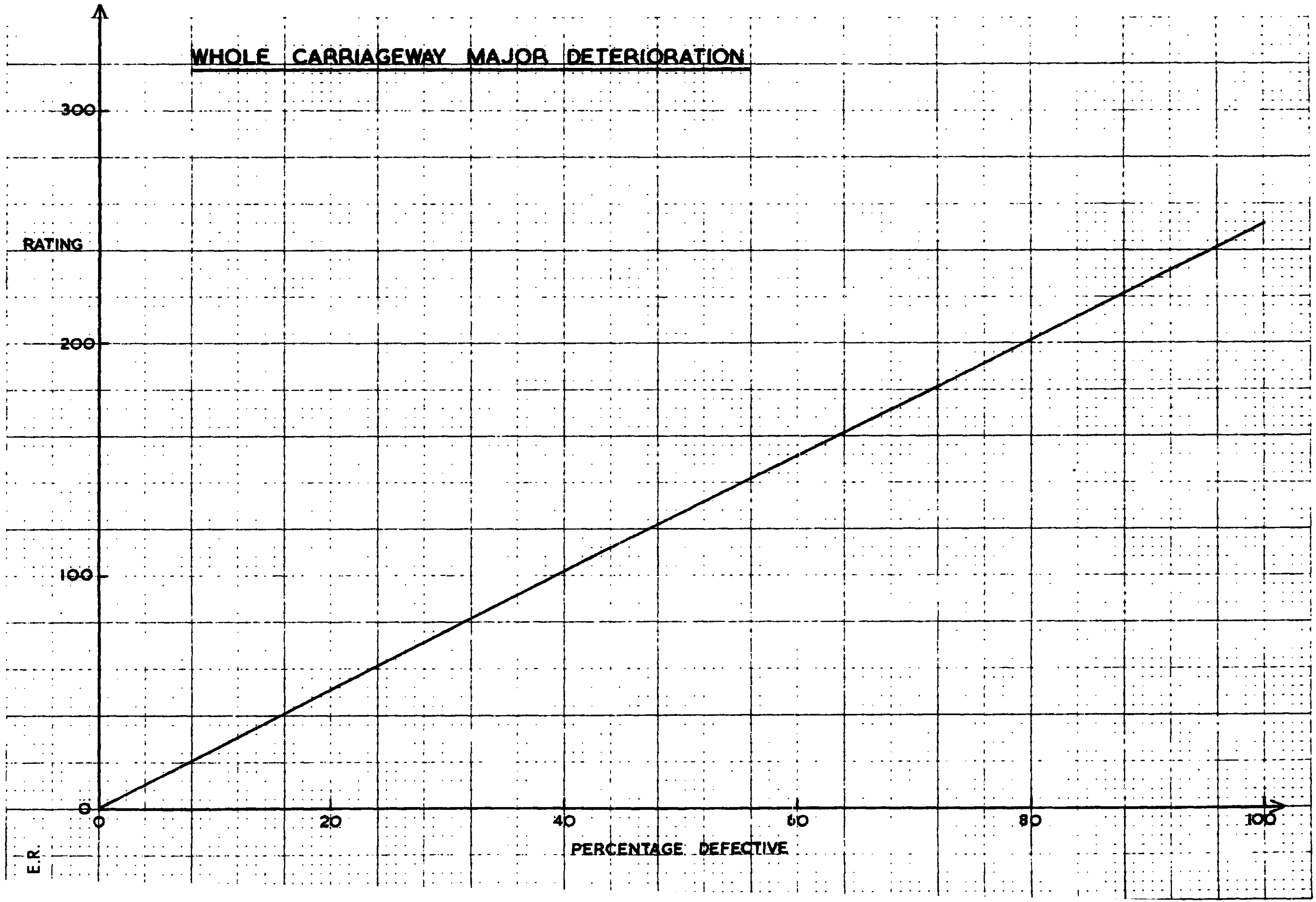
The Rating Relationships.



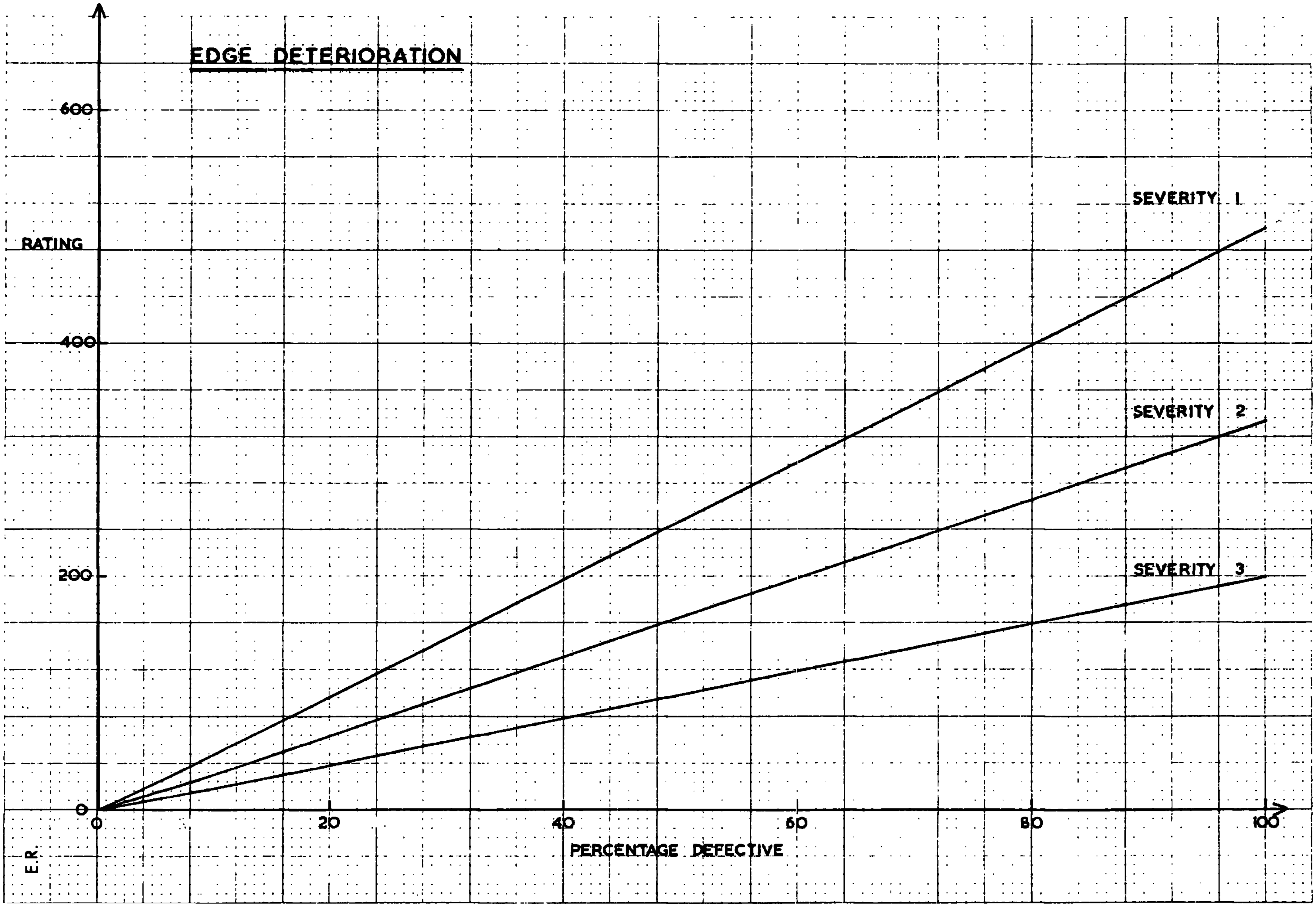
WHEEL TRACK RUTTING
ABOVE 25mm: 30.000 + 80 PER mm
E.R.
RATING
12500
10000
7500
5000
2500
0
10
15
20
25
RUTTING (in mm)

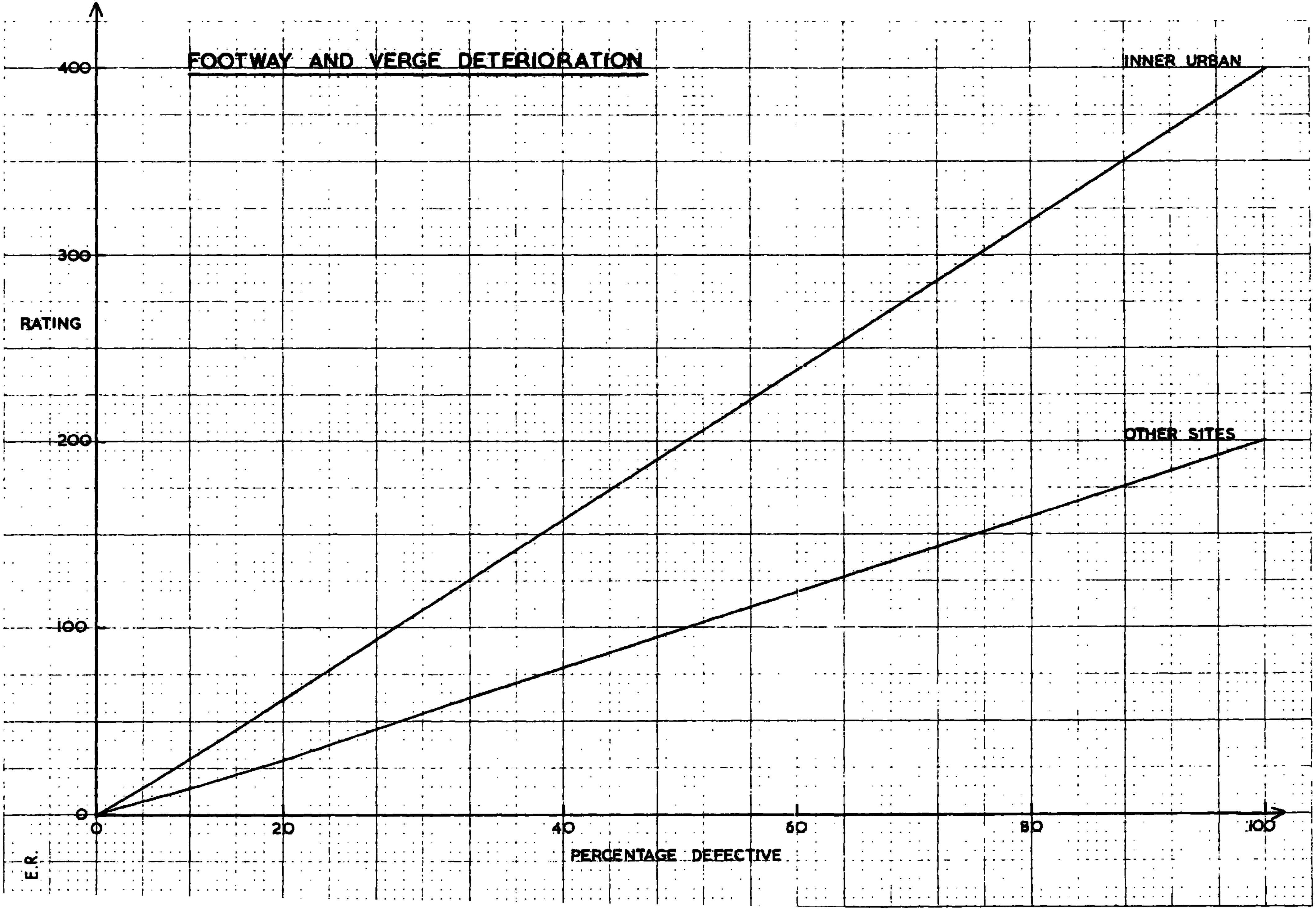


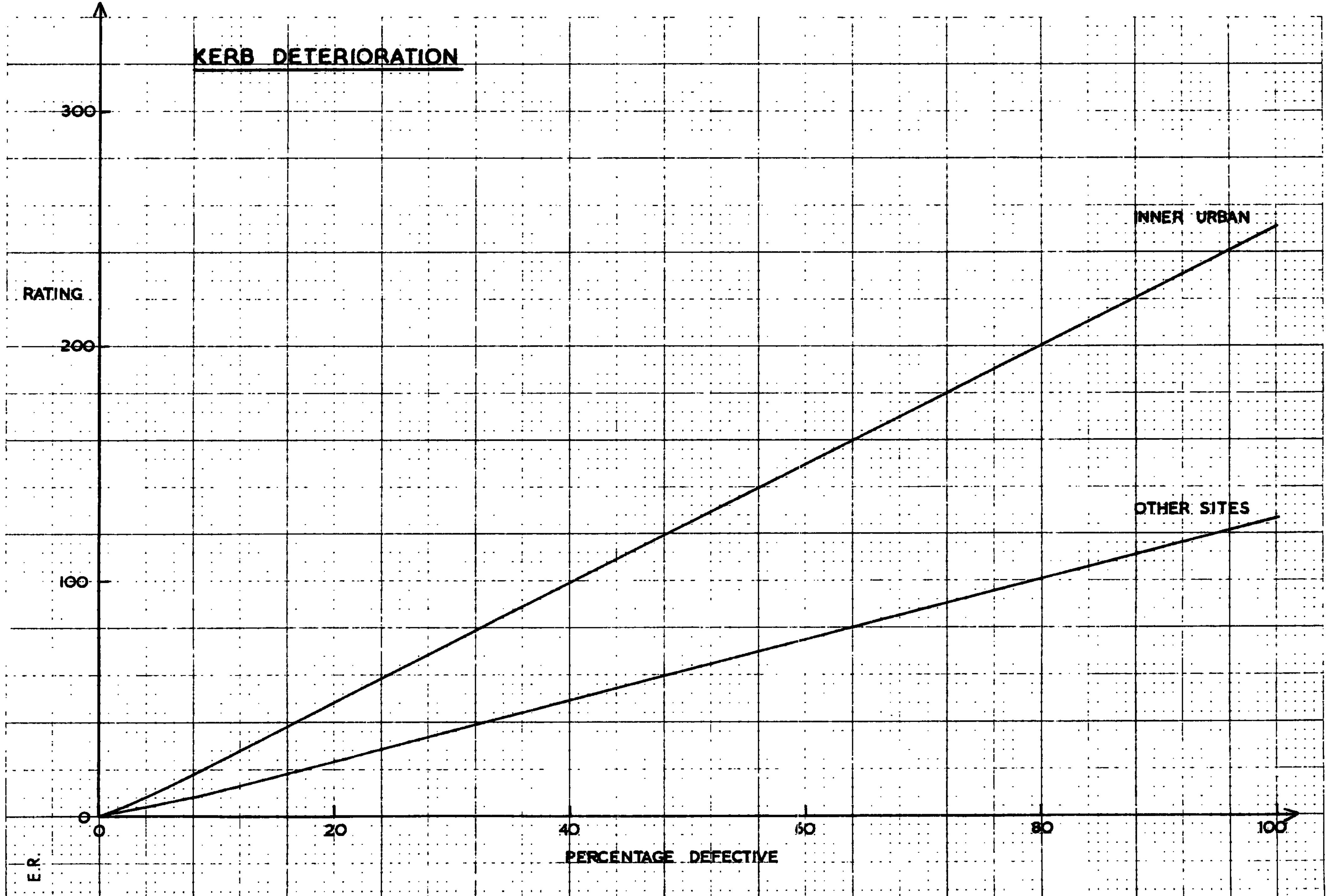
WHEEL TRACK CRACKING
RATING
300
200
100
0
CAT 1,2,3
CAT 4
0
20
40
60
80
100
PERCENTAGE DEFECTIVE
E.R.



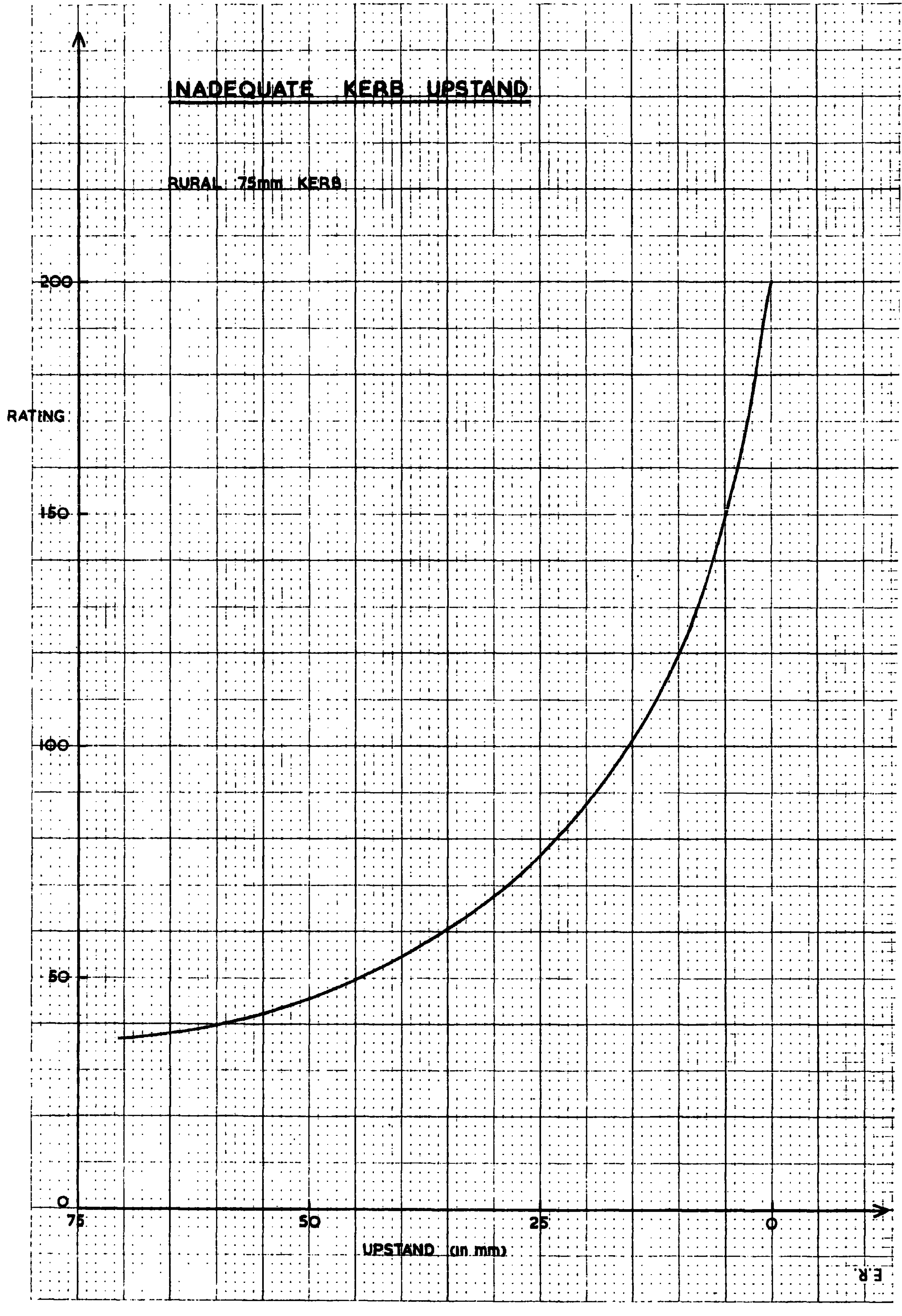
WHOLE CARRIAGEWAY MAJOR DETERIORATION
RATING
300
200
100
0
0
20
40
60
80
100
PERCENTAGE DEFECTIVE
E.R.

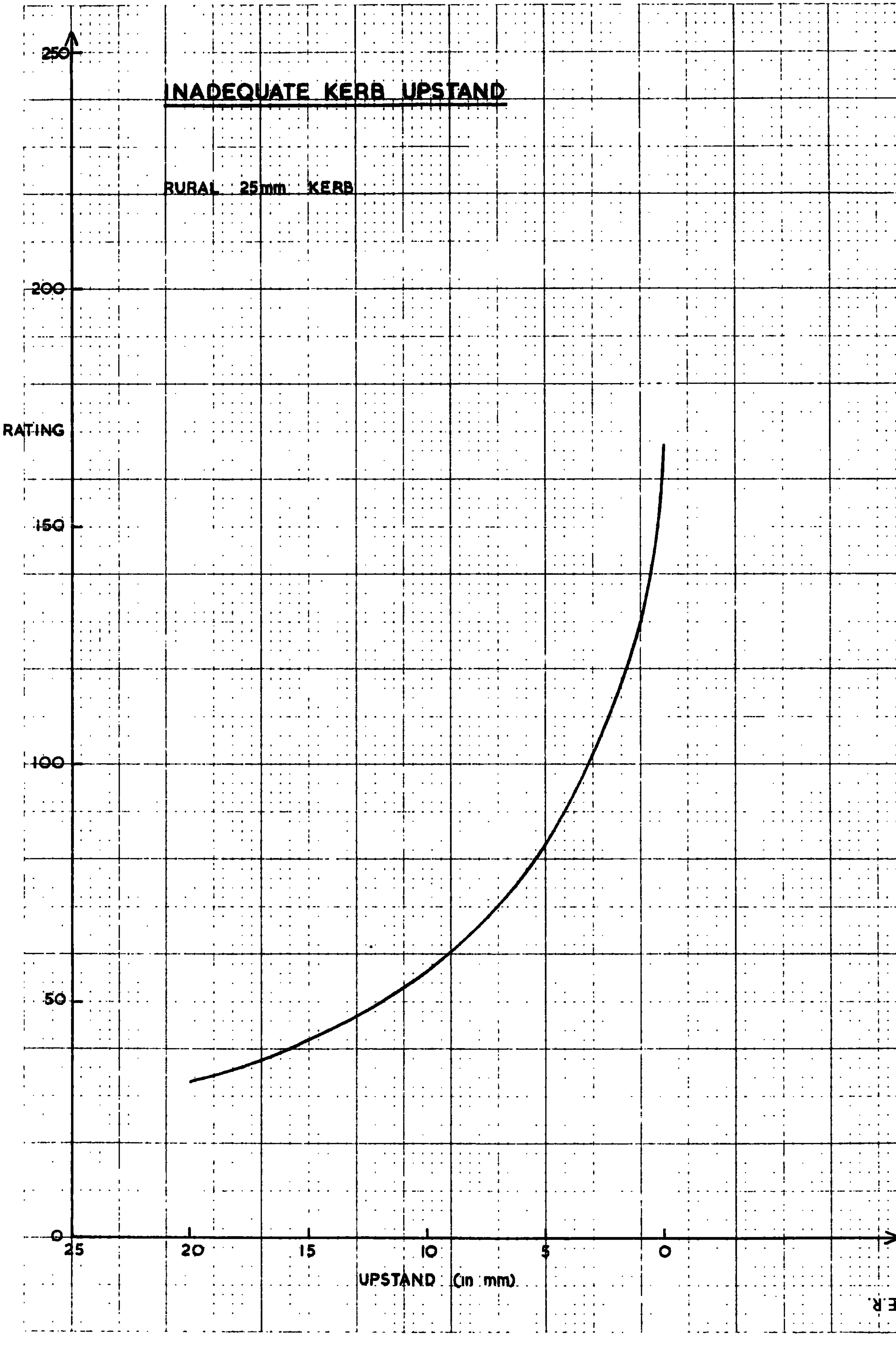

EDGE DETERIORATION
RATING
600
400
200
0
SEVERITY 1
SEVERITY 2
SEVERITY 3
0
20
40
60
80
100
PERCENTAGE DEFECTIVE
E.R.

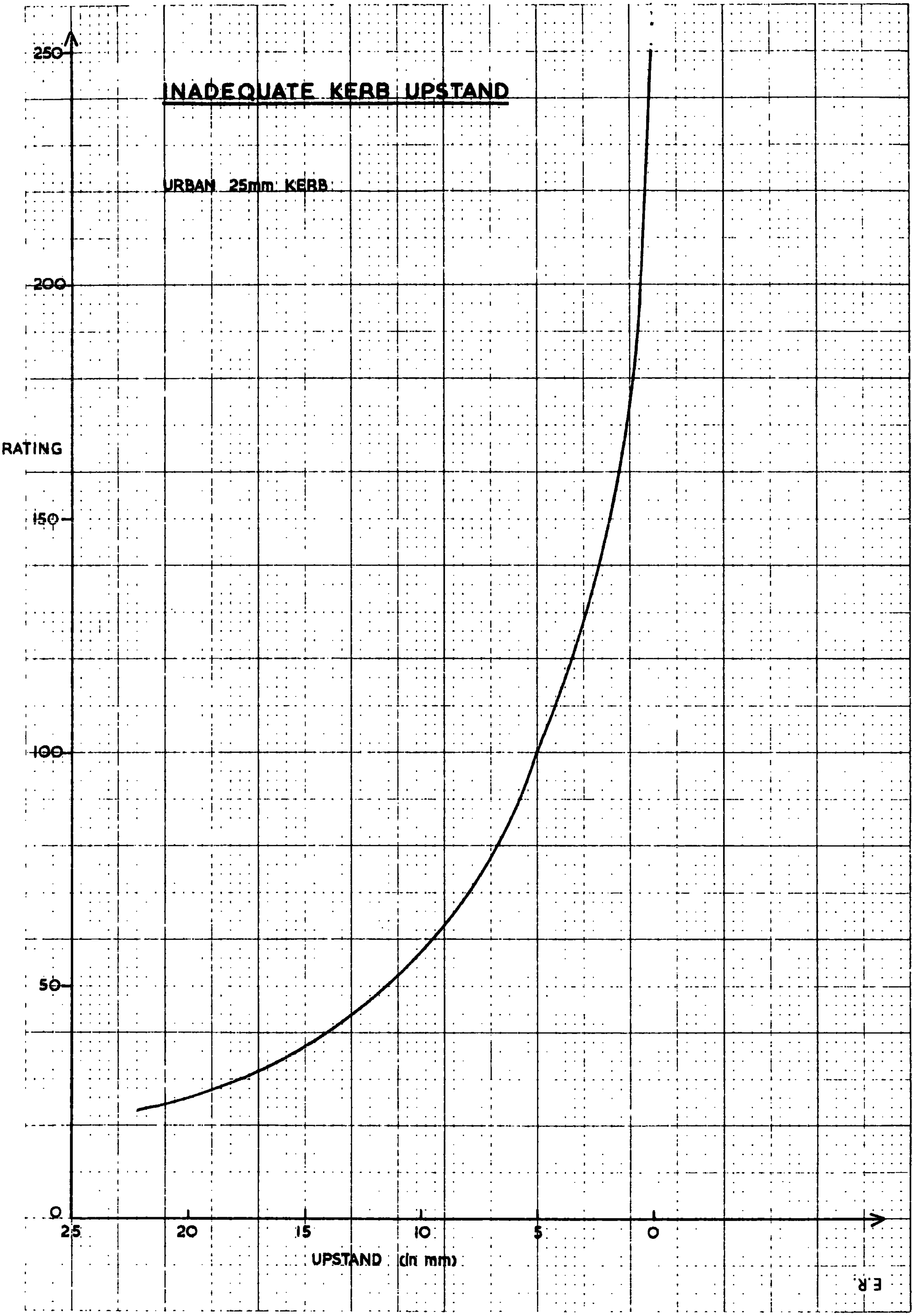

FOOTWAY AND VERGE DETERIORATION
INNER URBAN
OTHER SITES
RATING
400
300
200
100
0
PERCENTAGE DEFECTIVE
20
40
60
80
100
E.R.



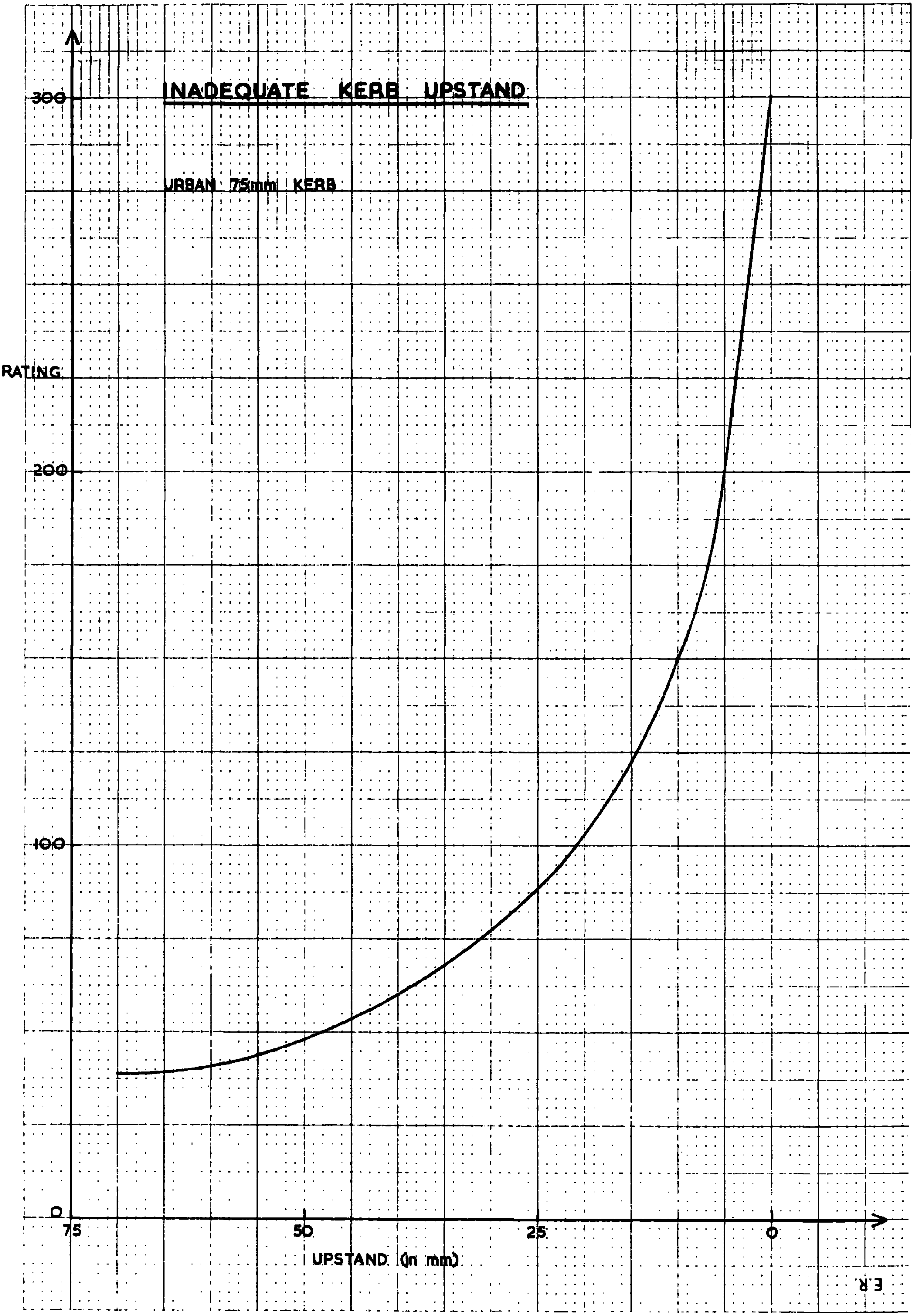
KERB DETERIORATION
RATING
300
200
100
0
20
40
60
80
100
PERCENTAGE DEFECTIVE
INNER URBAN
OTHER SITES
E.R.


INADEQUATE KERB UPSTAND
RURAL 75mm KERB
RATING
200
150
100
50
0
75
50
25
0
UPSTAND (in mm)
E.R.

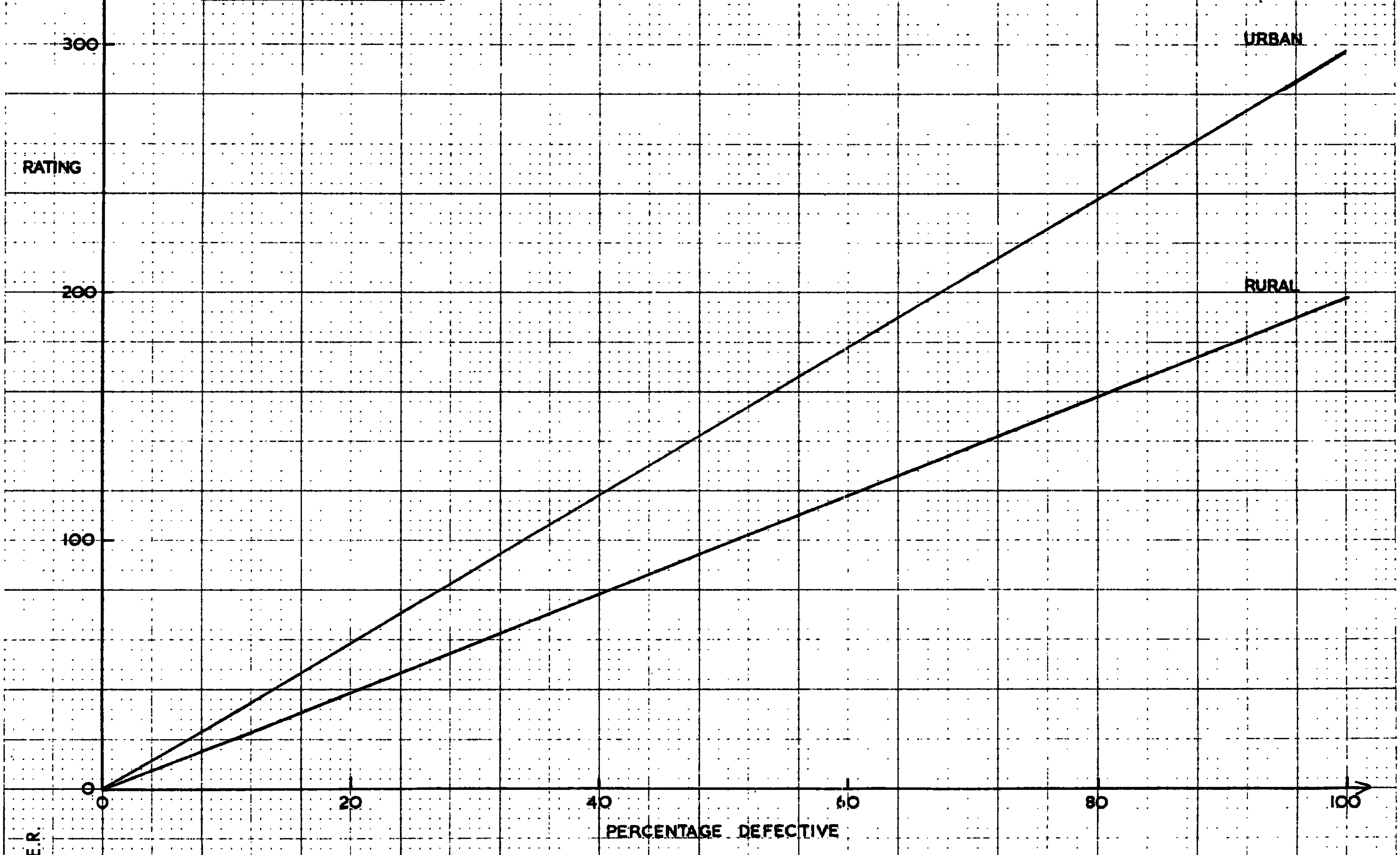

INADEQUATE KERB UPSTAND
RURAL 25mm KERB
RATING
250
200
150
100
50
0
25
20
15
10
5
0
UPSTAND (in mm)
E.R.



INADEQUATE KERB UPSTAND
URBAN 25mm KERB
RATING
250
200
150
100
50
0
25
20
15
10
5
0
UPSTAND (in mm)
E.R.


INADEQUATE KERB UPSTAND
URBAN 75mm KERB
RATING
300
200
100
0
75
50
25
0
UPSTAND (in mm)

NEED FOR KERBING



APPENDIX D

CRITICAL LEVELS: CARRIAGEWAY

Defect	Treatment	Critical Level
Wheel Track Rutting.	Reconstruct	1000
	Resurface	100
Wheel Track Cracking.	Resurface	100
	Surface Dress	34
Whole Carriageway Major Deterioration	Resurface	50
	Surface Dress	17
Whole Carriageway Minor Deterioration	Surface Dress	17
Edge Defects	Haunch/Kerb	100
	Patch	34
Inadequate Drainage.		30

CRITICAL LEVELS: ROADSIDE

Defect	Position	Critical Level
Footway Deterioration.	Inner Urban	40
	Other Sites	40
Verge Deterioration.	All Sites	40
Kerb Deterioration.	Inner Urban	25
	Other Sites	25
Kerb Provide.	Urban Sites	60
	Rural Sites	60
Inadequate Kerb Upstand	Urban (75 mm)	60
	Urban (25 mm)	50
	Rural (75 mm)	60
	Rural (25 mm)	50

APPENDIX E

Computer Considerations

The computer available to the author was an IBM 370/145, with IBM 3330 Direct Access disk packs. This machine was considered to be a suitable configuration to allow the program suite to run economically. The programming language was chosen after considering the type of program and the types of data to be used. The following requirements were found to be desirable :

(i) modular structuring of programs.

(ii) variety of data types.

(iii) easy debugging and error checking routines.

(iv) easy array handling.

(v) flexibility of input/output.

(vi) ability to read a data aggregate under several formats.

(vii) easy coding of programs and simple modifying of programs.

The programming language most suitable was found to be PL/1 which has the following characteristics :

(i) Program Structure : a PL/1 program consists of blocks of coding called procedures. A procedure may call other procedures which may be either internal or external to the calling procedure. An internal procedure is a discrete block of code nested within the calling procedure. An external procedure is one compiled separately from the calling procedure. These procedures are the building blocks of a program allowing a modular structure useful for testing, debugging and program modification, since each external procedure may be compiled, edited and tested separately.

(ii) Data Types : PL/1 allows a great variety of data types to be used. There are three main categories :

(a) Arithmetic Data - binary or decimal, fixed point or floating point, real or complex, with precision specified by the programmer.

(b) String Data - Bit or character of varying or constant length, specified by the programmer.

(c) Program Control Data - label variables, file variables, pointers etc.

The compiler allows arithmetic operations, comparison operations, string manipulation and assembling, scanning and subdividing of character strings.

Where a variable is not specified fully, or indeed at all, in a procedure default attributes are applied, either by context, by programmer supplied defaults or by computer supplied defaults.

The compiler also specifies every variable used in the program, giving its attributes, and showing the statements in which the variable is used and its position in the DSA* if the variable is internal to the procedure.

The data elements may be collected together in the form of arrays (where all aggregated variables have the same attributes) or structures (where the aggregated variables may have different attributes). This facility allows a set of data elements to be manipulated as a single data aggregate, cutting down on coding and reducing the possibility of errors.

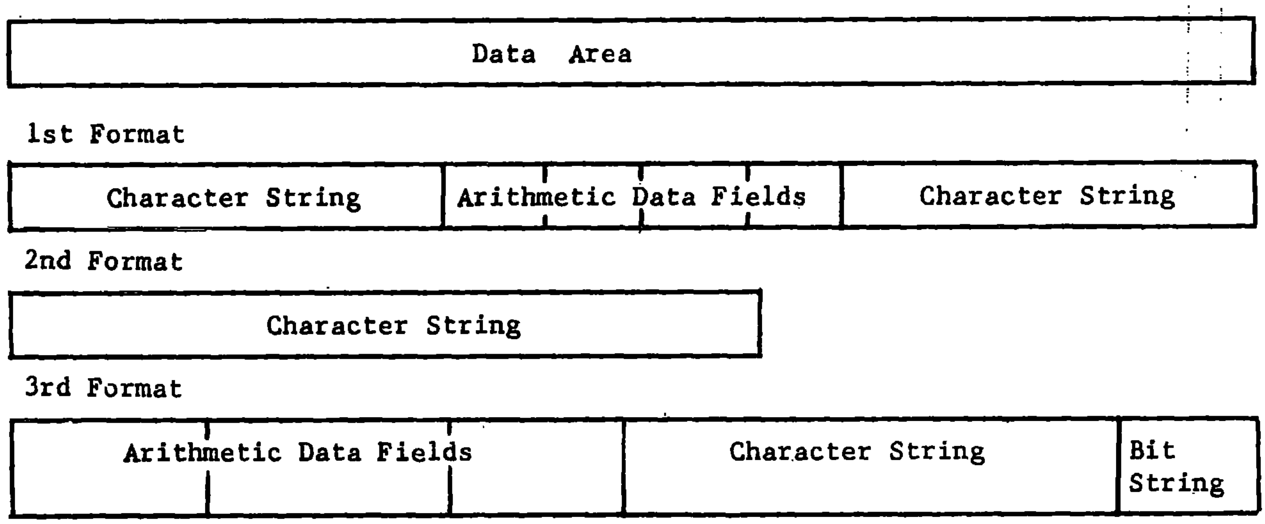
(iii) Debugging : the compiler has many debugging and error handling facilites. Suspect variables may be printed out whenever their value changes by enabling a CHECK condition for a procedure. Dumps of all or part of the program (file buffers, DSA's etc.) may be obtained dynamically and these are presented in an easily assimilable form which is extremely useful during debugging runs. Error conditions may be handled by the programmer so that appropriate action may be taken, i.e. transfer control to another part of the program, dump DSA's file buffers etc. set variables affected to acceptable values. A

* Dynamic Storage Area

range of checking conditions may be enabled for a procedure, such as a check for subscripts which fall outside the bounds of an array. These facilities plus the compiler data descriptions and cross-reference of variable usage greatly facilitate the testing and debugging of programs.

(iv) Storage

The use of the BASED attribute allows several variables or data aggregates to occupy the same block of storage. This facility allows a data area to be accessed under several formats or the format of a data aggregate to be chosen by the program where several formats are possible :



Variables internal to a procedure are stored in a Dynamic Storage Area. Only those procedures which are active will have a DSA present in core. When a procedure becomes inactive its DSA space is returned to the free storage area available to the program thus cutting down the storage required by the program.

(v) Input/Output : the input/output facilities of PL/1 are extremely flexible, allowing the programmer to optimise the use of storage space on disk or tape and to use data transferal methods appropriate to the application. Data may be printed out or read in under format control specified by the programmer or under free format recognised by the computer. The use of data aggregates in input/output statements reduces the amount of coding necessary.

For further details of the PL/1 Language refer to the PL/1 Language Reference Manual (Optimising Compiler) and PL/1 Programmers Guide.

APPENDIX F

The following figures are based on data collected by the TRRL from a sample of 22 authorities :

(i) the proportion of trunk road maintenance expenditure devoted to resurfacing varies :

- from under 20% to over 60% in rural areas
- from under 10% to over 55% in urban areas.

(ii) average annual resurfacing on Class I roads varies :

- from £170 to £1,670 per mile in rural areas
- from £80 to £2,680 per mile in urban areas.

(iii) on Class II roads annual maintenance expenditure varies :

- from £470 to £1,870 per mile in rural areas
- from £910 to £3,200 per mile in urban areas.

These figures, which are condensed from those given in the Marshall Report, suggest misapplication of resources. When the available data were analysed in detail no more than 50% of the variation between agent's expenditure could be explained by objective factors, the most important of which seemed to be the weather, traffic flow and road widths. The analysis suggests that there is a trend in expenditure amounting to a fixed increase each year which is in line with the Marshall Committee's conclusions on the traditional allocation methods for highway maintenance finance.

APPENDIX G

Cluster Analysis

If a series of points, each having a single value associated with it, is considered then a pair of contiguous points can be chosen such that the difference between the values associated with the two points is the minimum such difference for all pairs of contiguous points in the series. The two points thus chosen are merged to form a cluster of size two with associated value equal to the mean of the values associated with the two points. This cluster is then considered as a point with an associated value and the process is repeated until either the minimum difference for all pairs of contiguous points is greater than a set limit or there are no more contiguous clusters to be merged.

Treatment lengths are determined for each pavement defect which has a Marshall Standard (i.e. a critical level) associated with it. Each cluster as formed above is considered to be a treatment length and its associated value is tested for criticality. A cluster cannot span more than one road and a single road may be split into several lengths for clustering purposes.

For example, where a minor road crosses a major road and the minor road is critical for remedial treatment, this treatment would not be allowed to impinge on the major road; similarly a roundabout or other such obstacle would divide the road into clustering lengths.

This procedure gives a more accurate representation of the priorities allocated to the treatment lengths, than averaging over contiguous sub-sections the rating points for a defect which is critical on those sub-sections. Where the situation exists such that a length that is just critical for a certain treatment is followed immediately by a length which is highly critical for the same treatment; if the respective priorities of the two lengths are averaged, the criticality of the first length will be enhanced and that of the second length lowered. However where a clustering technique is used the respective priorities will be separate and a reasonable level of detail is preserved. Thus clustering gives a more accurate representation as shown in Fig. 7 above.

APPENDIX H

H.1. Measurement of Skidding Resistance

Loss of Skidding Resistance can be measured either by using SCRIM (Sideways Force Coefficient Routine Inspection Machine) or the Pendulum Skid Tester.

H.1.1. The Pendulum Skid Tester

This method is slow and requires that the part of the road under test must be cordoned off, causing delays to traffic. The rate of testing is about 2 km/day and therefore this method could only be used to measure specific sites, such as junctions, bad bends and roundabouts. The target values for various types of site are given in the Marshall Report page 110.

H.1.2. SCRIM

The SCRIM machine is rather expensive but has an inspection rate which would allow the entire Durham classified road network to be inspected in 4 - 5 months. However the question of interpretation of results both for SCRIM and the pendulum skid tester is not yet satisfactorily answered. The target standards given by the Marshall Report are sparse and therefore rather arbitrary. Only three standard target values are given to cover every possible situation, with the effect that whilst some roads would be brought to a higher standard than necessary in view of their accident record, the skidding resistance on some extremely difficult sites would not be high enough to prevent accidents. T.R.R.L. report LR. 510 gives target values based both on the type of site and the accident record of the site. This gives a more representative set of standards; pinpointing the sites where sub-standard skidding resistance is most dangerous. Since the object of assessing skidding resistance is to reduce the number of accidents, and thus reduce the cost to the county and to the community of these accidents, to assess sites on the basis of their accident records would allow funds to be allocated more efficiently, and give priority to those roads which are most dangerous. The allocation of target values on the basis of accident records and type of site will depend on the overall amount of traffic using the roads and the overall traffic accident figures for the county. No guidelines have yet been given covering these points, and the allocation of accidents to particular roads where an accident occurs at a junction is difficult because the format of the Police Traffic Accidents file is not conducive to the extraction of such data at present.

Thus until these points are classified and the Accident information is more readily available, the interpretation of the SCRIM results is difficult and the expense of a SCRIM is not readily justifiable.

H.2 Deflectograph

The Deflectograph machine measures the deflection of a road caused by a standard loading on the rear axles of the truck containing the equipment. Its working speed is approximately 2 km/hour and the points of measurement are about 3.8 metres apart on the road. The readings given by the Deflectograph must be corrected for temperature before being used to calculate the strength of the road.

The number of heavy vehicles using a road,multiplied by a factor depending on the type of road * gives an estimate of the number of standard axles ∅ the road carries per day.

For all practical purposes private cars do not damage the road and may therefore be ignored for the purposes of the deflection survey. The growth rate of traffic for the road may be estimated or measured and therefore the cumulative standard axles carried by the road since construction (or last major strengthening) may be computed. The deflection readings give the cumulative standard axles which must be carried by the road before it fails. Thus the remaining life of the road may be calculated.

This procedure is fully described in TRRL Report LR 571: "Pavement deflection measurements and their application to structural maintenance and overlay design".

* Heavier commercial vehicles tend to use Category 1 and 2 roads, therefore these roads have a higher standard axle factor.

∅ an axle loaded with 18,000 lb. (8160 kg).

APPENDIX I

GEOMETRIC ASSESSMENT OF CARRIAGEWAYS

1. Transport and Road Research Laboratory Leaflet LF170 gives four speed/flow formulae to cover a range of rural carriageway types. Each formula is a function of hilliness (i.e. rate of total level change in m/km), bendiness (i.e. rate of change of bearing in deg/km), vehicular flow (veh/hr) and percentage of heavy vehicles. Speeds are calculated relative to a speed under free flow conditions which is represented by a flow of 300 veh/hr. per standard lane of 3.5m width.

2. It seems reasonable to assume that under "free flow" conditions with a zero percentage of heavy vehicles the factor most affecting the vehicle speed is the geometrical alignment of the carriageway. By calculating the speed under "free flow" and "zero heavy vehicle" conditions for different sections of carriageway it should be possible to compare the alignments and make a judgement as to the need for realignment works.

3. There are four formulae given to cover a range of carriageway types. Since three of the types (three lane carriageways, dual carriageways and motorways) are of recent origin and have usually been designed to a reasonable standard only the formula for two lane single carriageway will be considered.

4. Since the object of this exercise is to compare carriageway alignments and not to calculate realistic speeds for traffic flow along carriageways, the formula for two lane single carriageways will be applied to three lane carriageways and to each carriageway of dual carriageway roads. It will also be applied to urban roads although the original formulae were specifically for rural situations.

5. The formula for "free speed" on a two lane carriageway is :-

$$\text{Speed} = .5 + \frac{(P - 15)}{10} - \frac{H}{7.5}\frac{(185 - P)}{200} - B\frac{(P - 215)}{200}$$

where H = hilliness, B = bendiness and P = % heavy vehicles.

In a zero heavy vehicle condition P = 0 and the formula is :-

$$\text{Speed} = 87 - \frac{(185H + 215B)}{1500}$$

The constant term in the equation is given for 1975 speeds and in genuine speed calculations would increase by 1½ k.p.h. per year to allow for the annual increase in vehicle speeds. In our application of the formula it can remain constant or indeed be removed from the equation since we are concerned only with relative values.

6. In its application to Durham County Council's Marshall assessments the formula is used to assess the alignment of 100m lengths of carriageway. Because the lengths considered are small the hilliness and bendiness when expressed as "per km" tend to appear exaggerated and to give distorted speed values derived from the formula and can therefore accept the distortion. Indeed since the distortion occurs in the regions of poor alignment it can be to our advantage in that it elongates the range.

7. Although the alignment of a carriageway is considered over 100m lengths there are some instances where the length examined is shorter than 100m. To allow geometrical factors to be calculated for these short lengths two empirical rules have been formulated.

(a) bendiness - for lengths shorter than 100m the bendiness per km is taken as the actual degrees of direction change x 10.

(b) hilliness - for lengths shorter than 100m the hilliness per km is taken as the actual level change x (1000/length of section considered).

8. Having established the means of calculating geometrical factors for 100 m lengths of carriageway (or whatever other lengths are considered convenient) it only remains to set levels of criticality for these factors. These critical levels will need to be related to the importance of the road in the network.

BIBLIOGRAPHY

1. REPORT OF THE COMMITTEE ON HIGHWAY MAINTENANCE - The Marshall Report H.M.S.O. 1970.

2. TRRL NOTE A - An Unpublished Report issued by the Transport and Road Research Laboratory, "Methods of Assessing Structural Maintenance Needs of Highways" June, 1972.

3. TRRL NOTE B - An Unpublished Report issued by the Transport and Road Research Laboratory, "Specification for a Maintenance Rating System using Histograms" March, 1973.

4. THE MARCH SYSTEM - A Highway Maintenance Priority Rating System produced by the City Engineers Group (Computer Applications) and updated April, 1975.

5. DOS PL/1 OPTIMISING COMPILER LANGUAGE REFERENCE MANUAL GC33-0005-3.

6. DOS PL/1 OPTIMISING COMPILER PROGRAMMER'S GUIDE SC33-0008.