# PAVEMENT DESIGN & PERFORMANCE

W.W.Yardley BE(Hons) MIPENZ, MNZIF

## Synopsis

This paper describes the development and history of a design system for upgrading flexible pavement strengths by the application of an overlay.

The design system proposed can suitably accommodate axle loads expected and I believe is adaptable to local conditions such as varying overlay materials.

By using Benkelman Beam testing before overlaying, immediately after overlaying and following loading with time I believe it is possible to determine:

(a) the thickness of overlay required
(b) the effect of the overlay applied
(c) how the strengthened pavement responds with changing use

With further loading, time and testing a more complete picture of Access Road's pavement performance will be developed. However, at this stage it is ascertained that the overlay considerably reduced deflections due to load and the coefficient of variance of the deflections. It is also evident that with loading and time the load deflections of the pavement are increasing.

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N.Z. Forest Products Limited
Forest Engineering Department

This system would also have an application in testing existing pavements to determine their suitability to a proposed loading.

Acknowledgements

Appreciation is expressed to Mr.G.S.Vatasan for the early development work, and Mr.A.P.Stevens for recent testing and the computer plots.

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## 1.0 INTRODUCTION

In the early '70's Access Road, a straight 3 km sealed arterial road leading into the Kinleith Mill site was showing considerable signs of distress. Evidence of plastic deformation existed over its entire length and the annual repair bills resulting from excavations, basecourse replacement and patch sealing were increasing as the road was deteriorating.

Originally sealed in the mid 50's for its early life, it carried logging trucks loaded to public highway limits. The linking of large areas of forest to the end of this road by a concrete crossing and extended 'off highway' roading system in the mid 60's burdened the road with 'off highway' traffic.

Other roads forming part of the Kinleith forest 'off highway' system were also beginning to show signs of distress in the mid 70's, having been sealed and heavily trafficked for around 10 years.

At this stage we required a system for upgrading the strength carrying capacities of these roads. The desire was to maximise the use of the remaining strength in the existing pavements with the final surface being a conventional chip seal surface as all asphaltic concrete sections on these highways showed marked cracking.

## 2.0 INITIAL TESTING

Following an examination of testing procedures we decided that Benkelman Beam testing would provide us with a simple system for directly measuring the remaining strength in a pavement.

It was simple to use (i.e. no sample collections, no testing laboratories were required) and had the advantage to us that it was measuring directly the response of a pavement to an applied wheel load.

Initial testing in the field confirmed that areas showing large deflections were considerably cracked and misshapened. Areas with low deflections showed no signs of stress. Typically on well used pavements areas with deflections in excess of 1.5 mm for a 10 tonne axle were distressed. This agreed with others' findings, (1), and therefore became our desired resultant deflection.

A special testing trailer was constructed so that axle loadings in the order of 10 tonnes could be achieved, for literature (2) and a desire to as far as possible measure what was happening under typical field loading conditions, suggested that tests should be conducted under axle weights experienced in the normal duty of the pavement.

## 3.0 DEVELOPMENT OF DESIGN PROCEDURE

It was now required to determine what additional strength need be applied to a pavement to achieve the desired deflection.

A small test section of approximately 200 m was chosen. Benkelman Beam readings were taken before and after a 100 mm overlay was applied. These readings were compared. They indicated that the 100 mm section had resulted in a 25% reduction in the initial deflections.

From this we postulated that every 100 mm thick overlay would reduce the deflection at a particular point by 25%.

## 4.0 DEVELOPMENT OF DESIGN FORMULA

Assume that every 100 mm of overlay reduced beam deflections by 25%.

Let n = number of 100 mm overlays

Let deflection = dn

Then $dn_0$ = initial deflection

$dn_1$ = deflection resulting after 1st 100 mm overlay

$dn_2$ = deflection resulting after 2nd 100 mm overlay

$dn_n$ = deflection resulting after nth 100 mm overlay

From the assumption

$$dn_1 = 0.75\ dn_0$$

$$dn_2 = 0.75\ dn_1 = 0.75\ (0.75\ dn_0)$$

$$\therefore\ dn_n = 0.75^n\ dn_0$$

$$\therefore\ \log dn_n = n(\log 0.75) + \log dn_0$$

$$\therefore\ n = \frac{\log dn_n - \log dn_0}{\log (0.75)}$$

Now as the desired deflection = 1.5 mm under the heaviest typical axle then

$$\log dn_n = \log 1.5 = 0.176$$

Also $\log (0.75) = -0.125$

Substituting then

$$n = \frac{0.176 - \log dn_0}{-\ 0.125}$$

The overlay design depth then = n x 100 mm

## 4.1 Example

Let the average top 10% deflections

$$dn_0 = 2.2\text{ mm}$$

Determine the overlay depth

$$n = \frac{0.176 - \log (2.2)}{-\ 0.125}$$

$$= 1.328 \quad \therefore \text{ Overlay depth} = 133\text{ mm}$$

## 5.0 APPLICATION TO ACCESS ROAD

### 5.1 Description of Procedure

Benkelmen Beam readings were taken under a design axle of approximately 10 tonnes, 2 per lane every 20 m, during winter.

These deflections were plotted. This road deflection plot was divided into sections of similar readings.

Isolated locations where deflections exceed 5 mm and outliers were investigated in the field and excavated if considered necessary.

The top 10% of deflections (neglecting re-excavated sites) of a section were then averaged and the overlay depth required was determined using the design formula in 4.0.

### 5.2 Deflection of Original Pavement

A deflection survey was conducted in the winter of 1976.

Graphed deflections are shown in Appendix A.

The loaded side plot refers to the left hand side of the road when travelling towards the mill. This particular road receives loaded trucks on both sides significantly more on the loaded road side.

These graphs are divided into 3 sections and the overlay depths determined are added.

## 5.3 Deflection Following Overlay

Following overlay to the depths indicated in Appendix A and a one coat seal, deflection readings were taken in the following winter - 1977.

These graphed deflections form Appendix B.

From these plots it is evident that the design deflection of 1.5 mm (0.060 in) was largely met.

## 5.4 Deflections - Winter 1979

Between June 1977 and July 1979 a void filling coat and a second coat seal were applied.

Graphs of the deflections are shown in Appendix C.

Little variation is evident from Appendix B.

## 5.5 Deflections Winter 1985

Since 1979 depressions in the wheel tracks had formed in some areas. These were 'filled' with another chip seal coat. Also one shaded section between 1320 and 1500 m received severe frost damage and was relaid.

Otherwise the 3 km road has not required maintenance work and is not showing signs of distress.

Graphs of these deflections form Appendix D.

Note that the axle load on the testing trailer weighed in at 11.08 t cf 9.53 t for all previous testing.

## 5.6 Loading of Road

During this period (i.e. since overlay) the loaded side of the road has carried some 112,000 "off highway" logging trucks with maximum axle loads of around 10 t and an E.D.A. (Equivalent Design Axle) loading/truck of approximately 6.5.

The road loading for the 9 year period is approximately 5 million tonnes or 1 million EDA's.

## 5.7 Comparison of Deflection Plot

These deflection plots are compared statistically in Appendix E.

Visually from the deflection plots it can be verified that:

(a) the design desired deflection was achieved by the overlay

(b) deterioration of the pavement in terms of increased deflections is occurring slowly

(c) following the overlay the deflections recorded were much more uniform.

Uniformity of deflections is indicated also by the coefficient of variance as graphed in Appendix E.

## 5.8 Comparison of Deflection Statistics

Statistical parameters were taken from the Benkelmen Beam plots, corrected for varying text axle load weights (See Appendix F) and plotted against time for the three sections.

From these graphs it can be seen that

(a) the design desired deflection of the average top 10% deflections ($0.\overline{1N}$) was achieved i.e. less than 1.5 mm (0.060 in).

(b) Average deflection $\overline{x}$ and the average of the top 10% deflections are increasing gradually with time and at a faster rate on the loaded side of the road.

## 6.0 CONCLUSIONS

Owing to the performance of the overlay on Access Road we have now overlaid other failed sealed road sections. Because the design procedure outlined in this paper predicted the deflections resulting from various overlay depths we continue to use this design method.

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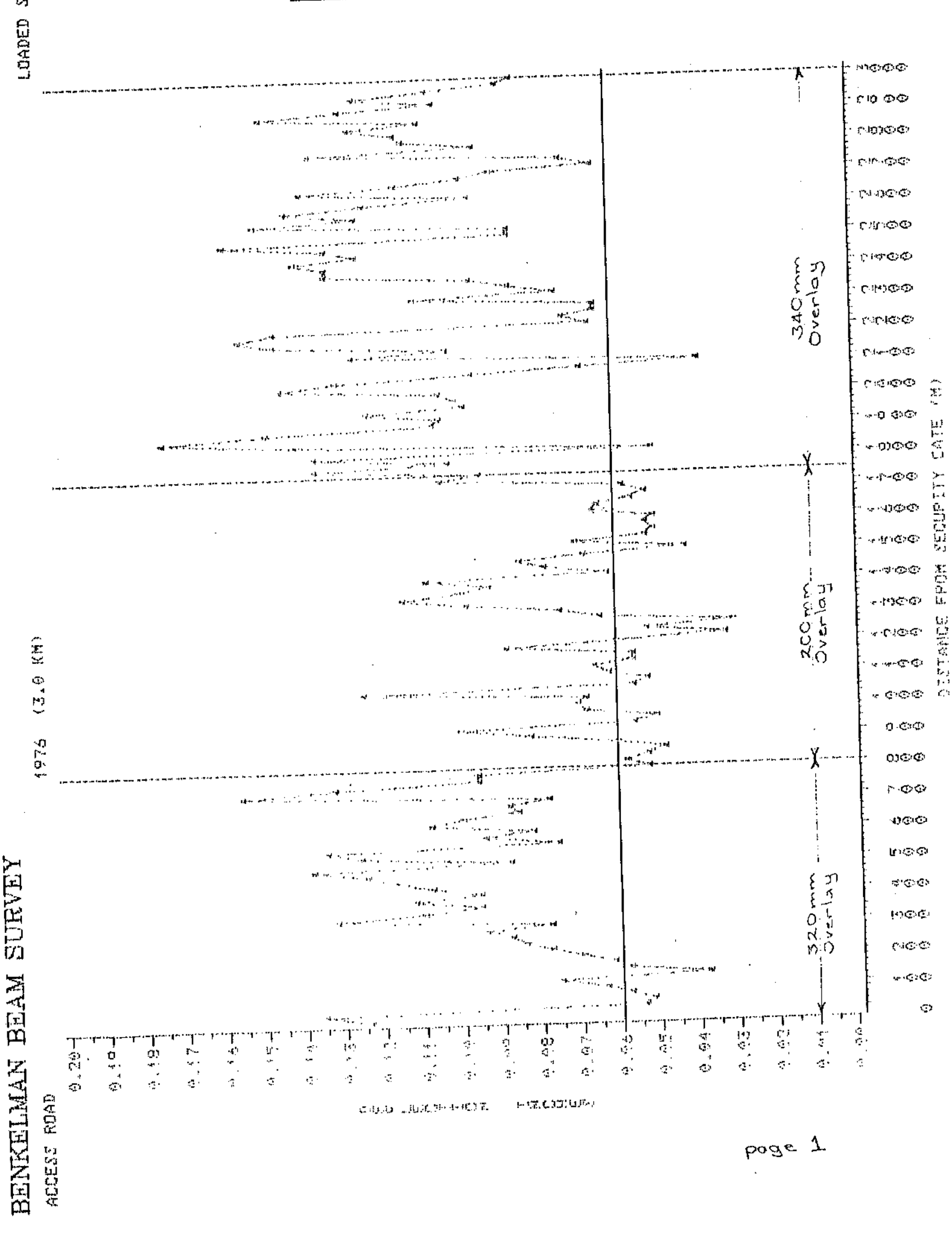
## References

(1) BELSHAW, T Some Uses of the Benkelmen Beam in Road Testing

(2) McFARLANE, H.W., PATERSON W.G. and DOHANEY W.J. (1973) Use of Benkelmen Beam on Forest Roads, Can.LRR/49

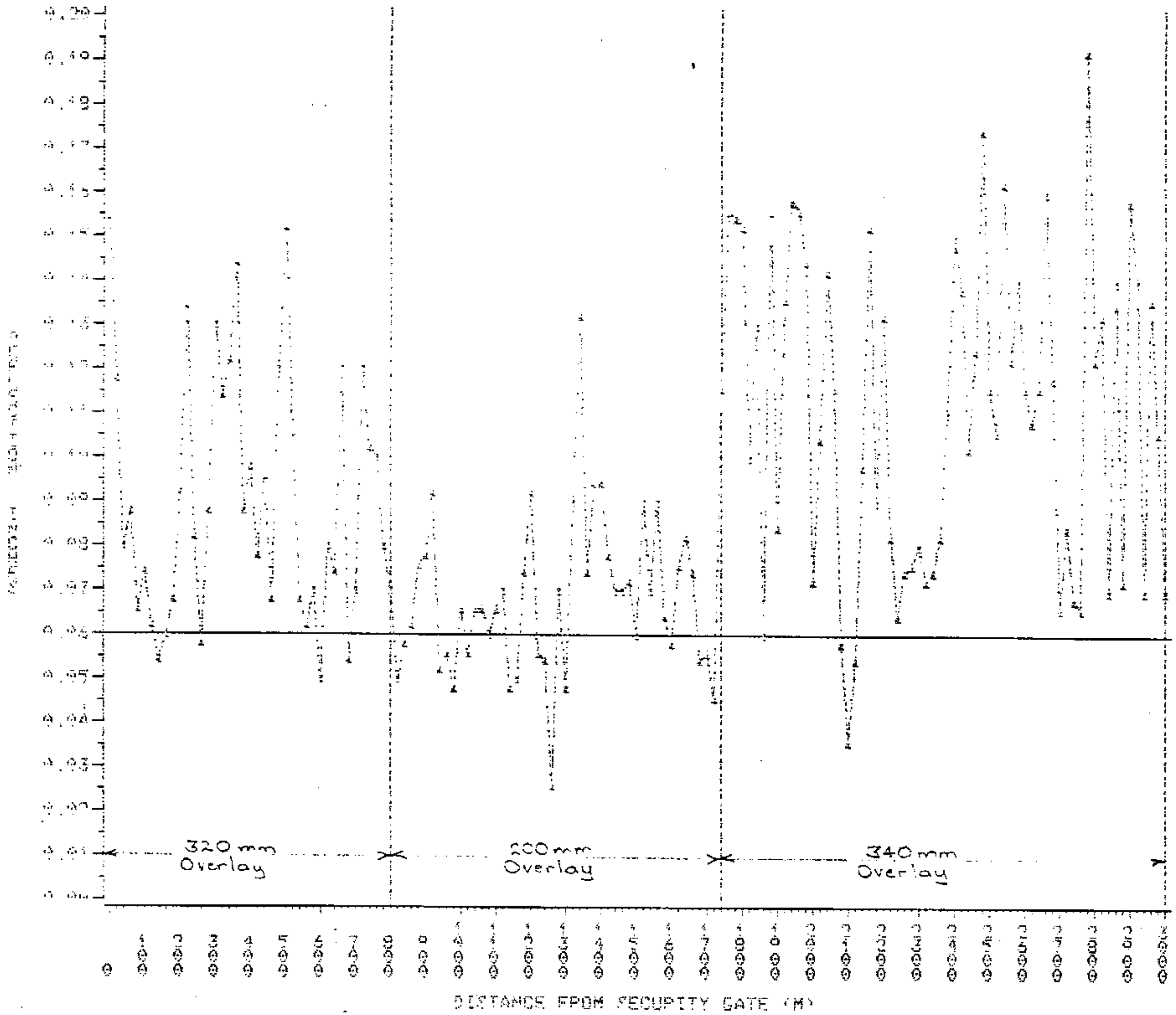
## APPENDIX A


BENKELMAN BEAM SURVEY
ACCESS ROAD
1976 (3.0 KM)
LOADED SIDE
DISTANCE FROM SECURITY GATE (M)
320mm Overlay
200mm Overlay
340mm Overlay
page 1

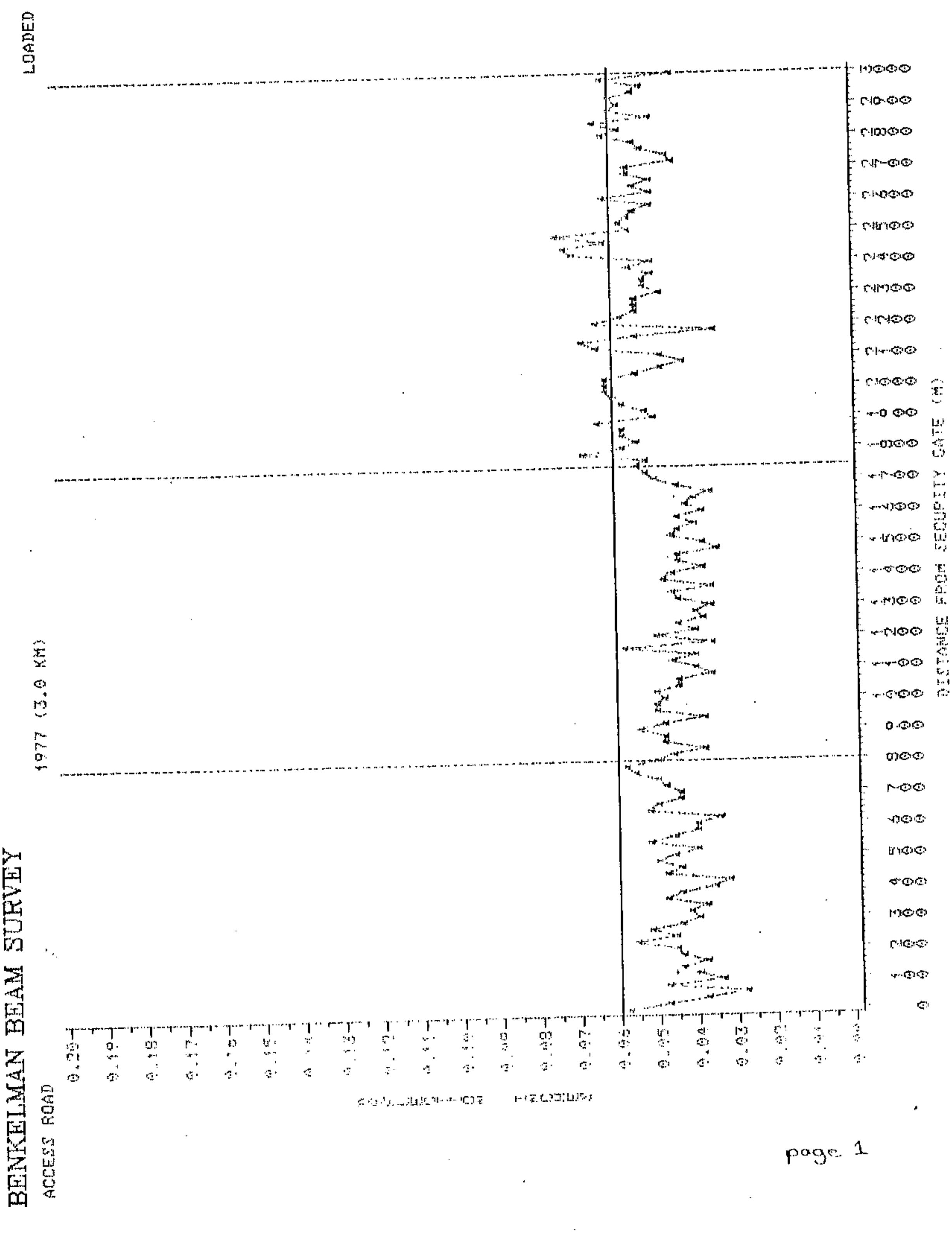
APPENDIX A

# BENKELMAN BEAM SURVEY

ACCESS ROAD 1976 (3.0 KM) UNLOADED SIDE



APPENDIX B

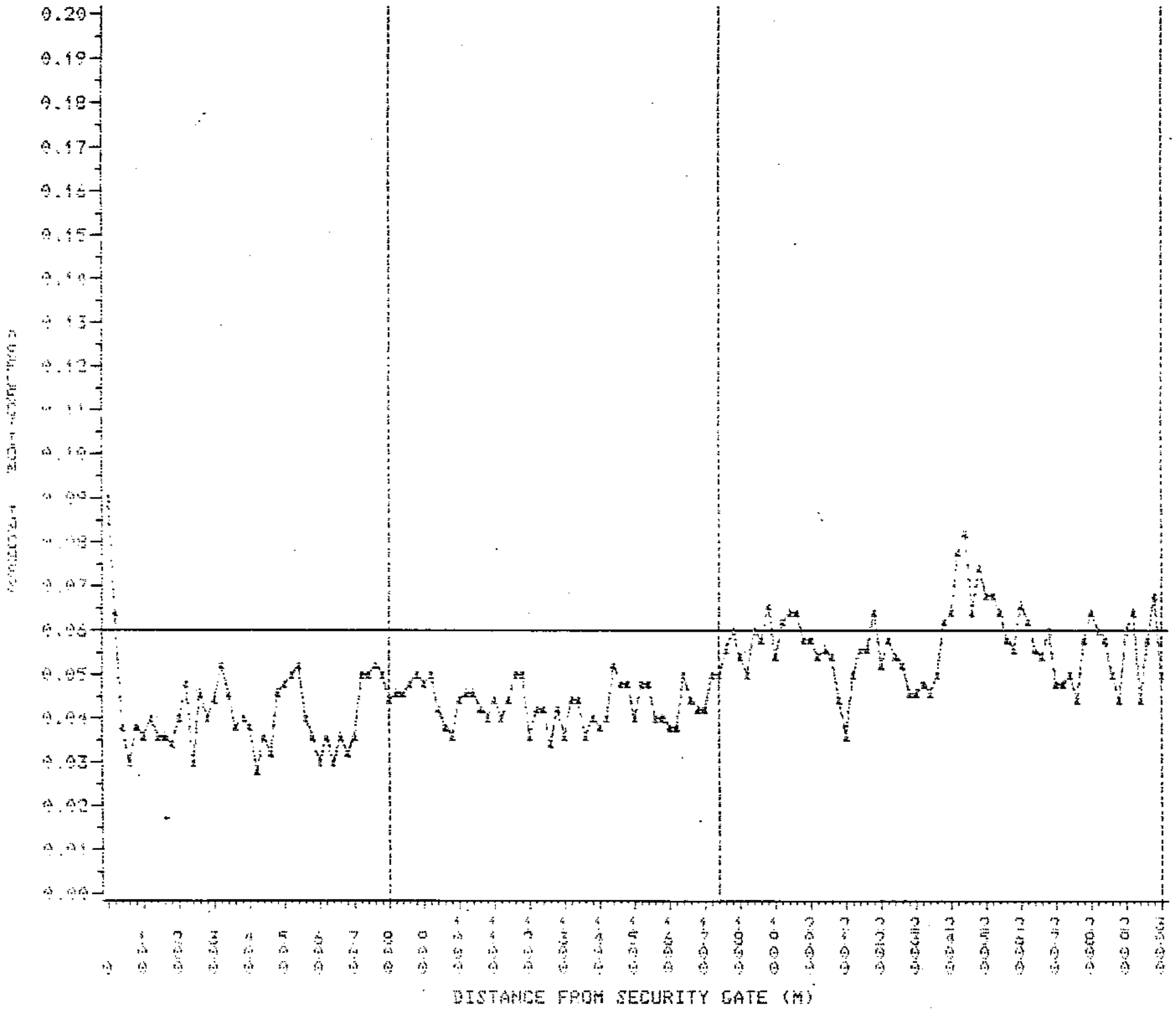



page 1

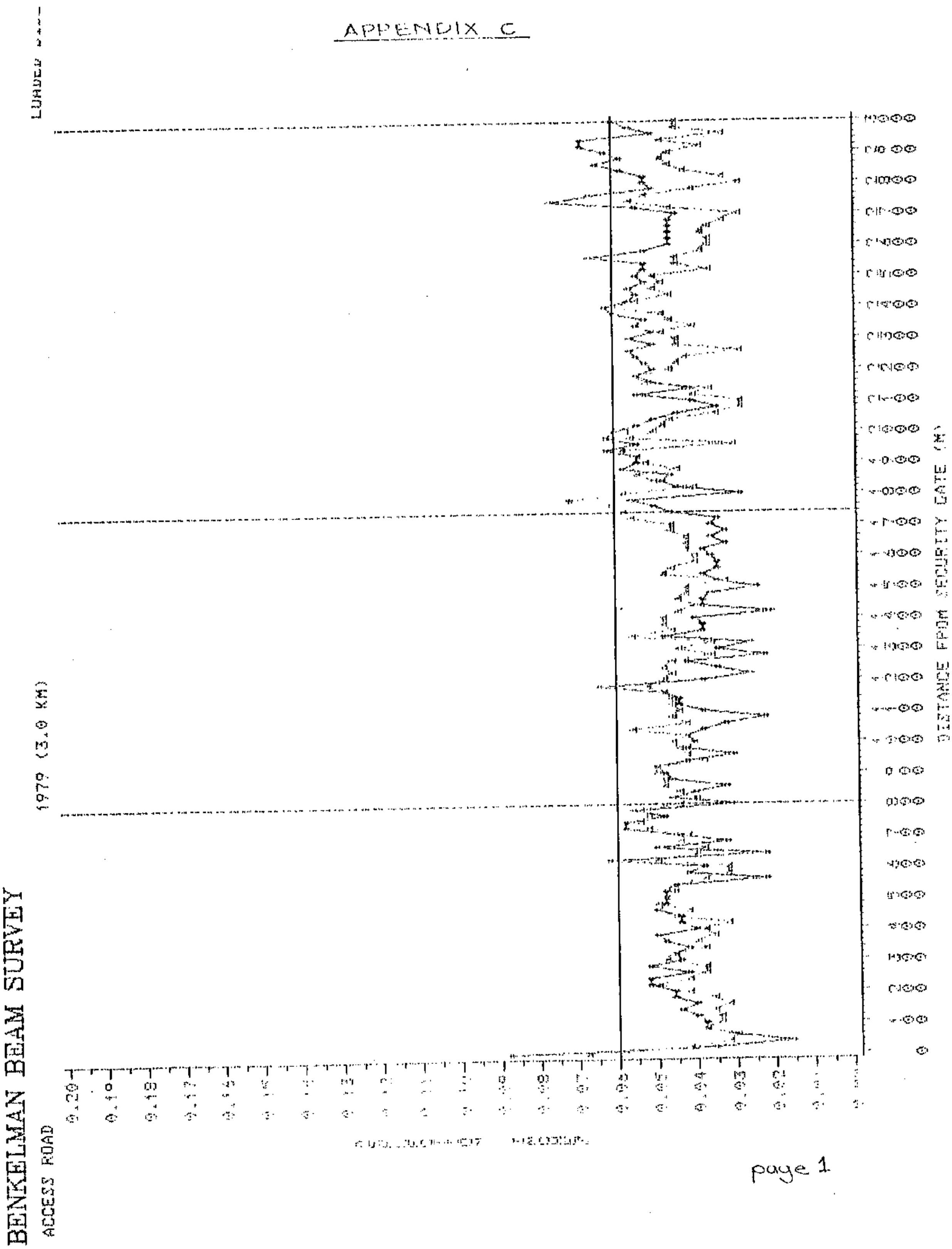
APPENDIX B

# BENKELMAN BEAM SURVEY

ACCESS ROAD 1977 (3.0 KM) UNLOADED SIDE



APPENDIX C

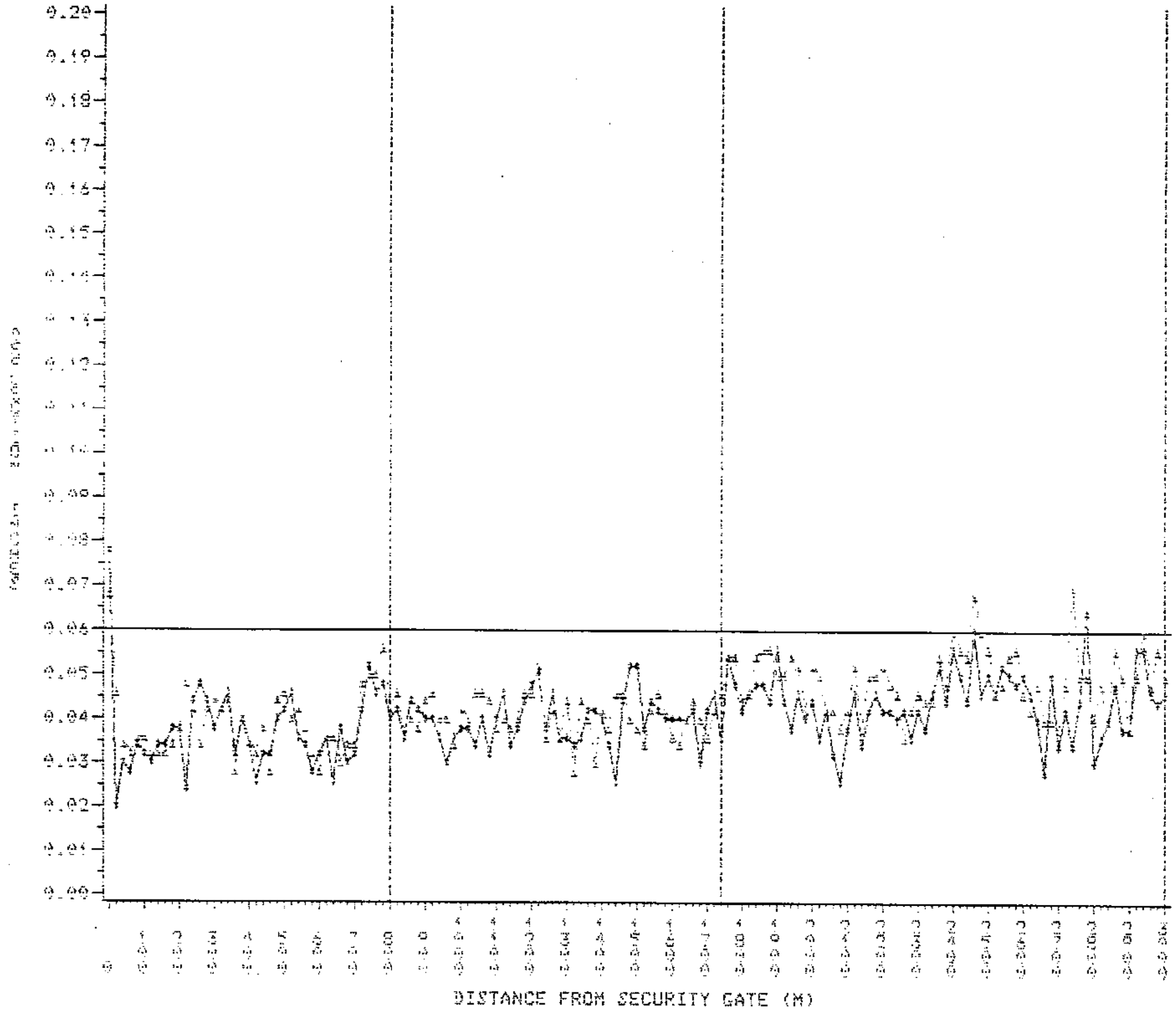



page 1

APPENDIX C

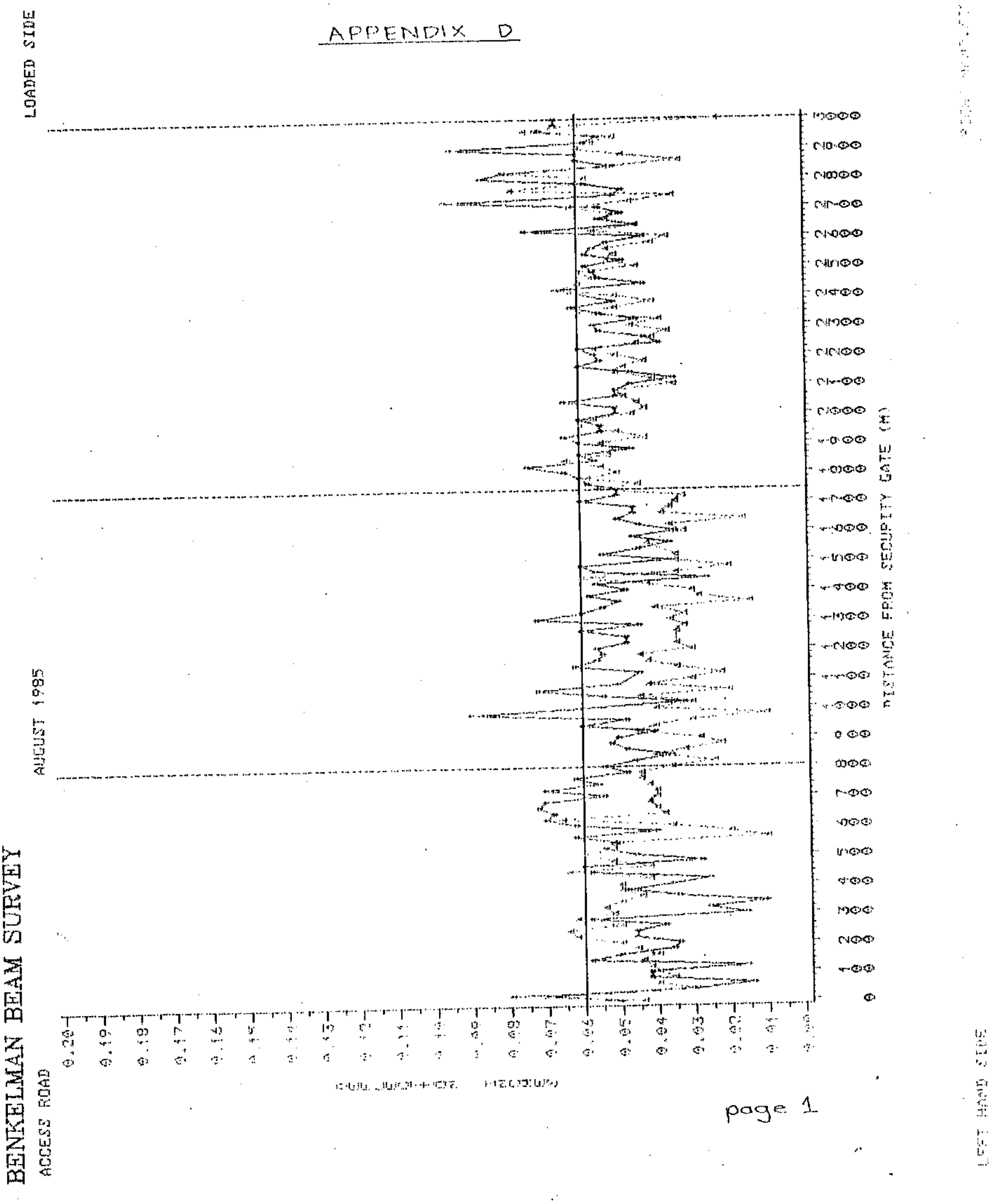
# BENKELMAN BEAM SURVEY

ACCESS ROAD 1979 (3.0 KM) UNLOADED SIDE

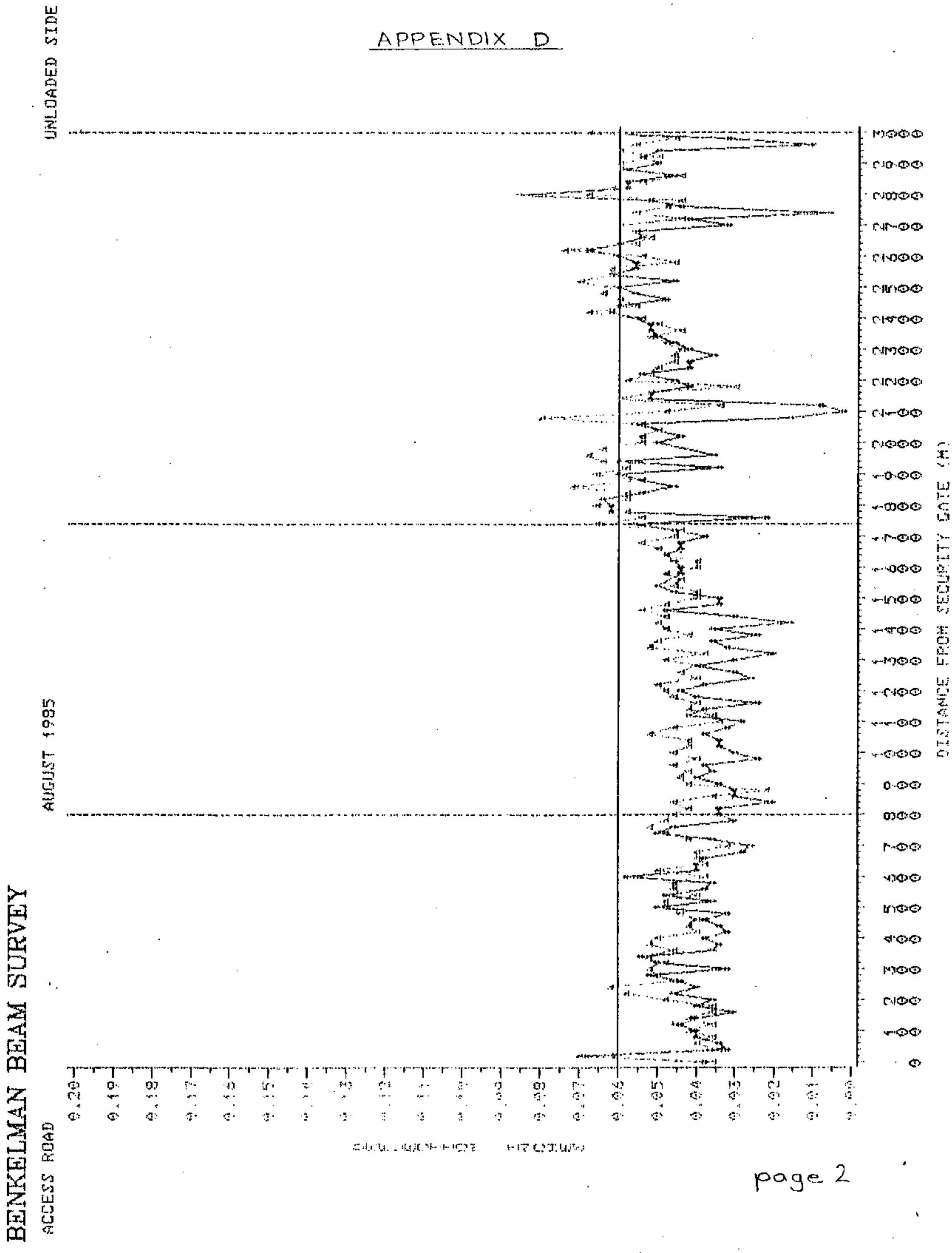



LEFT HAND SIDE

APPENDIX D

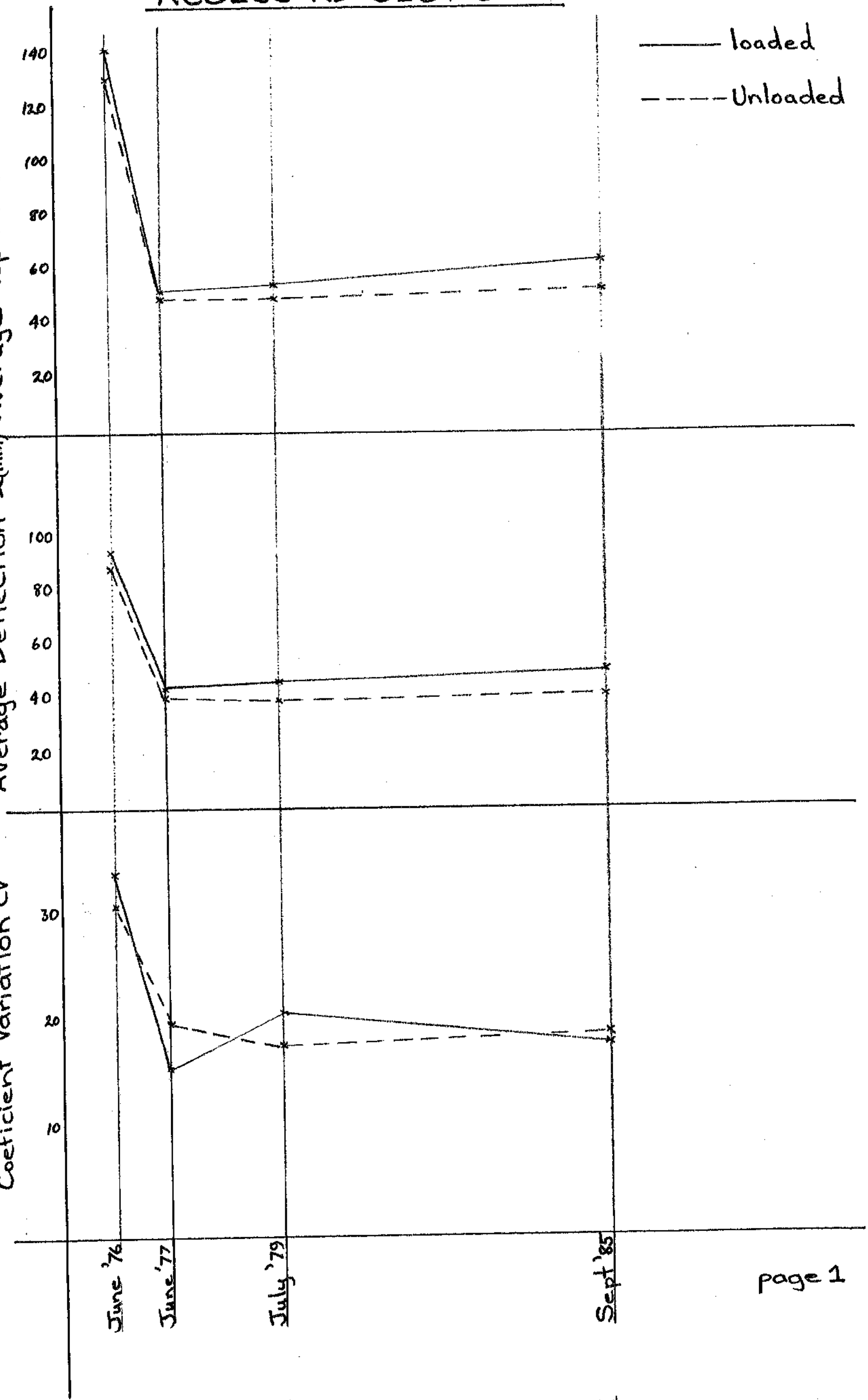

BENKELMAN BEAM SURVEY
ACCESS ROAD
AUGUST 1995
LOADED SIDE
DISTANCE FROM SECURITY GATE (M)
LEFT HAND SIDE
page 1

APPENDIX D


BENKELMAN BEAM SURVEY
ACCESS ROAD
AUGUST 1995
UNLOADED SIDE
DISTANCE FROM SECURITY GATE (M)

# APPENDIX E

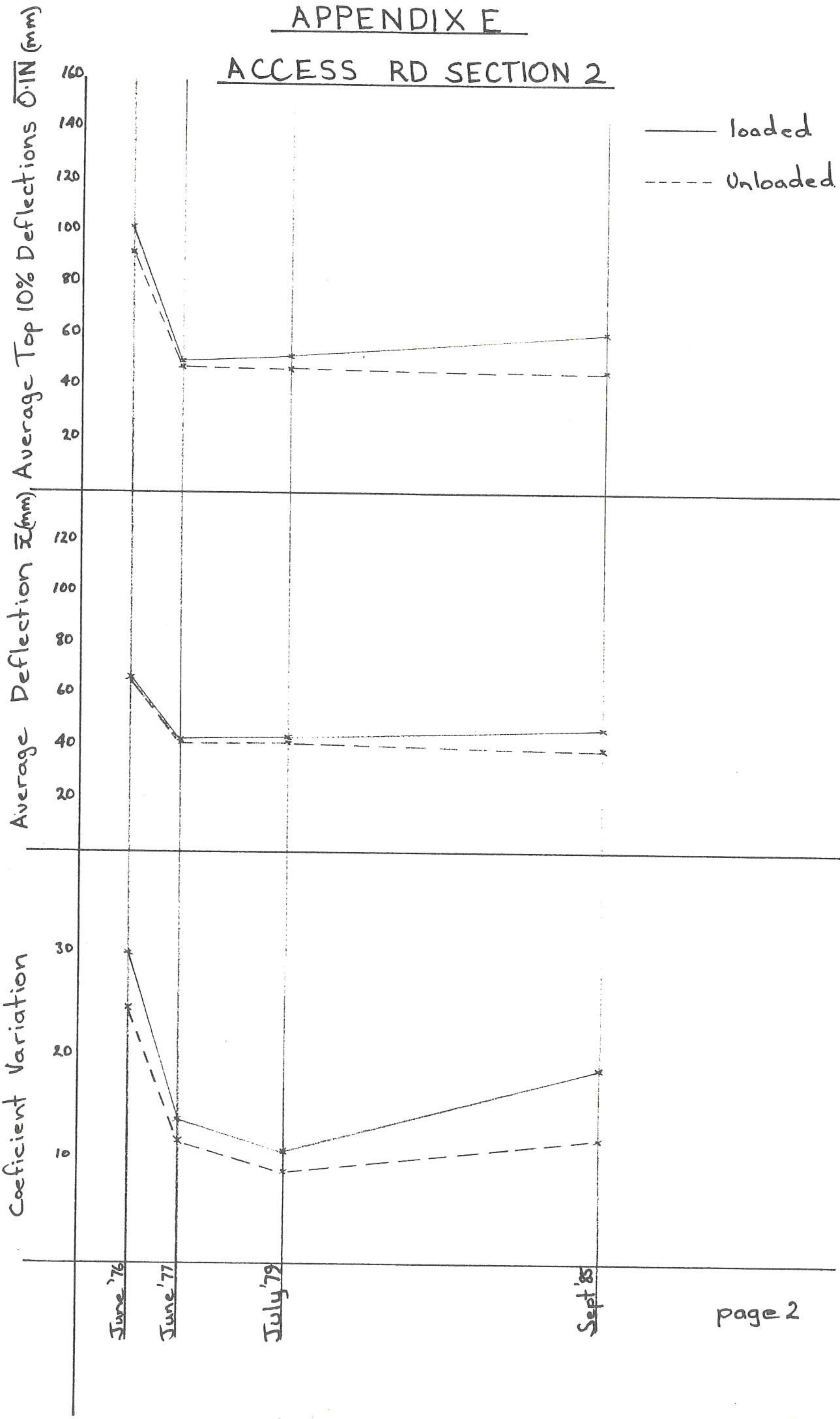
## ACCESS RD SECTION 1




page 1

# APPENDIX E

## ACCESS RD SECTION 2

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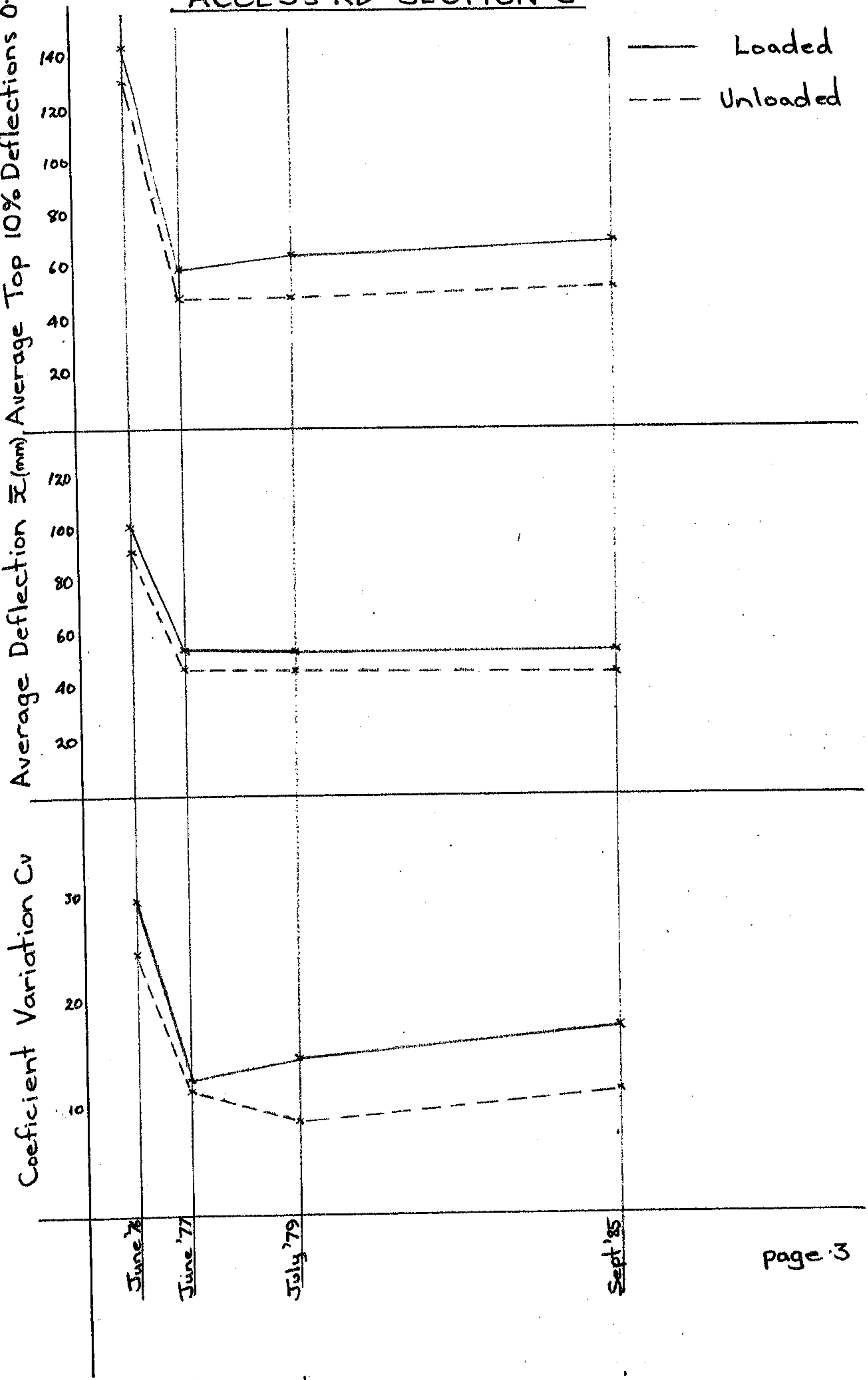
# APPENDIX E

## ACCESS RD SECTION 3



# APPENDIX F

To determine the change in the statistical parameters of:

(a) the average of the top 10% deflections $0.\overline{IN}$

(b) the average deflection $\overline{x}$

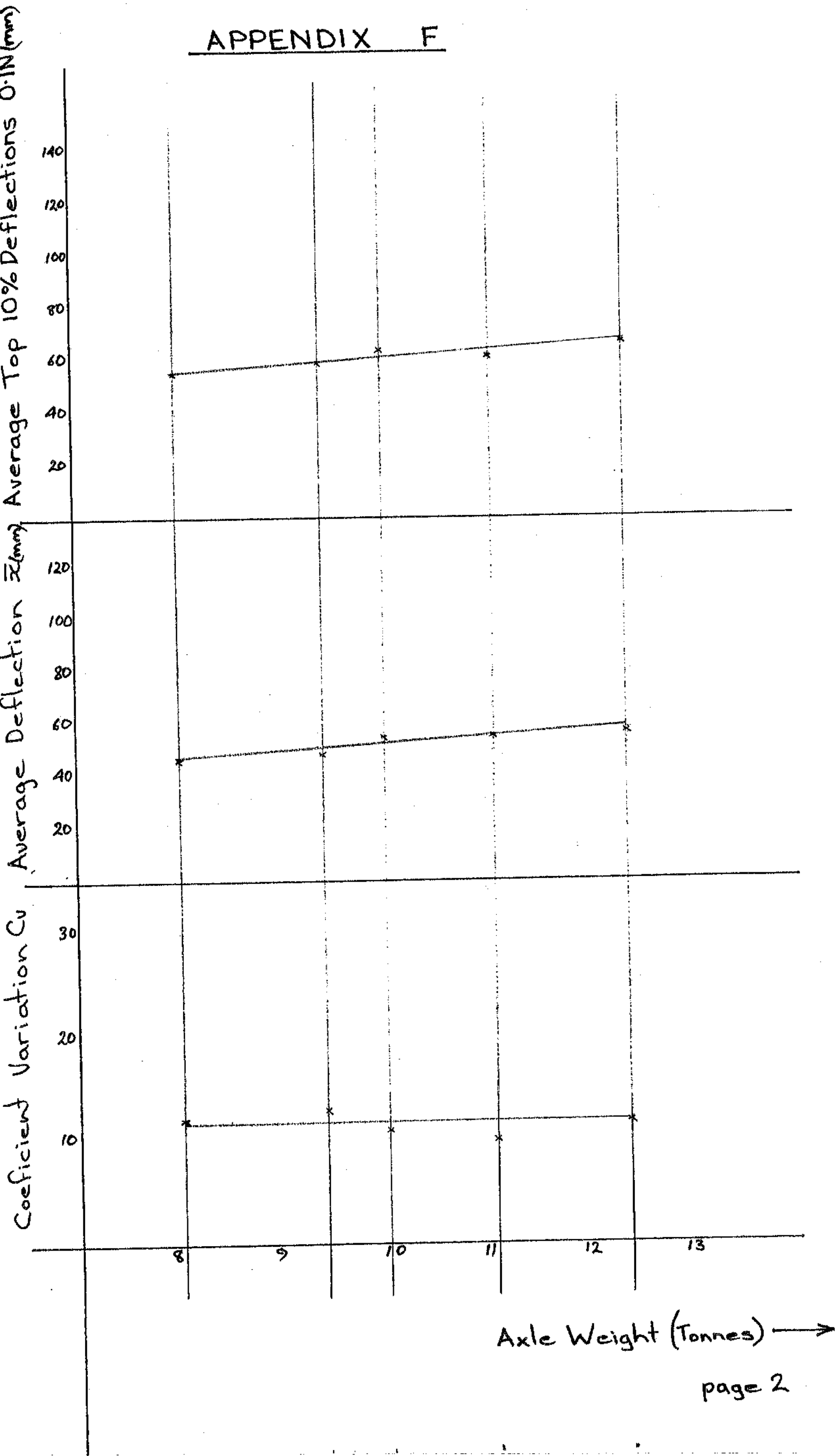
(c) the coefficient of variation Cv

with change in axle weight, a trial section of Access Road, 400 m long was tested with axle weights varying between 8 tonnes and 12.3 tonnes.

The above statistical parameters were calculated for the varying test axle weights and plotted as attached.

From these graphs it can be determined that for every 1 tonne increase in axle weight in this range a 0.07 mm increase in $0.\overline{IN}$ and $\overline{x}$ can be expected.

# APPENDIX F


Average Top 10% Deflections $\overline{0 \cdot 1N}$ (mm)
140
120
100
80
60
40
20
Average Deflection $\bar{x}$(mm)
120
100
80
60
40
20
Coeficient Variation Cv
30
20
10
8
9
10
11
12
13
Axle Weight (Tonnes)