Derivation of Appropriate Traffic & Loading Data, and Parameters for Road Asset Management

Transfund New Zealand Research Report No. 266

Derivation of Appropriate Traffic & Loading Data, and Parameters for Road Asset Management

D. Petrie, Traffic Design Group, Lower Hutt

P. Davis, Traffic Systems and Surveys Ltd, Kapiti

K. Mara, MKM, Wellington

Transfund New Zealand Research Report No. 266

ISBN 0-478-25377-X
ISSN 1174-0574

P O Box 2331, Lambton Quay, Wellington, New Zealand
Telephone 64-4-473 0220; Facsimile 64-4-499 0733

Petrie, D.[1], Davis, P.[2], Mara, K.[3] 2005. Derivation of Appropriate Traffic and Loading Data, and Parameters for Road Asset Management. *Transfund New Zealand Research Report No. 266.* pp. 244.

[1] Traffic Design Group, Lower Hutt, New Zealand.
[2] Traffic Systems and Surveys Ltd, Kapiti, New Zealand.
[3] MKM, Wellington, New Zealand.

Keywords: arterial, asset management systems, A-Train, B-Train, commercial, equivalent standard axle, fringe, heavy commercial vehicle, industrial, light commercial vehicle, medium commercial vehicle, residential, rural, strategic, temporary classifier, urban, weigh-in-motion.

An Important Note For The Reader

The research detailed in this report was commissioned by Transfund New Zealand. Transfund New Zealand is a Crown entity established under the Transit New Zealand Act 1989. Its principle objective is to allocate resources to achieve a safe and efficient roading system. Each year, Transfund New Zealand invests a portion of its funds on research that contributes to this objective.

While this report is believed to be correct at the time of preparation, Transfund New Zealand, and its employees and agents involved in its preparation and publication, cannot accept any liability for its contents or for any consequences arising from its use. People using the contents of the document, whether directly or indirectly, should apply and rely on their own skill and judgement. If necessary, they should seek appropriate legal or other expert advice in relation to their own circumstances, and to the use of this report.

The material contained in this report is the output of research and should not be construed in any way as policy adopted by Transfund New Zealand but may form the basis of future policy.

Abbreviations and Acronyms

Austroads	Association of Australian and New Zealand Road Transport and Traffic Authorities
A-Train	Semi-trailer towing a trailer
B-Train	Two semi-trailers connected together
Commodity Survey	A survey of the type of load, or commodity carried by each heavy vehicle
dTIMS	Deighton's Total Infrastructure Management System
ESA	Equivalent single axle, is the laden truck weight measured as a proportion of a reference axle group as defined by the Austroads Pavement Design Guide
HCVI	Heavy Commercial Vehicle I, i.e. rigid trucks with or without trailer, or articulated vehicle, with three or four axles in total
HCVII	Heavy Commercial Vehicle II, i.e. trucks and trailers and articulated vehicles with or without trailers with five or more axles in total
Interpeak	Refers to that period of the day between the commuter peaks, typically between 0900 hours and 1600 hours
LCV	Light Commercial Vehicle
LTSA	Land Transport Safety Authority
MCV	Medium Commercial Vehicle, i.e. two axle trucks without trailers
MOT	Ministry of Transport
NIWA	National Institute of Water and Atmosphere Research
NTD	National Traffic Database
Peak Hour	Refers to the hour(s) with the highest traffic volumes, typically quoted for each of the morning and afternoon commuter periods
PEM	Transfund Project Evaluation Manual
PMS	Pavement Management Systems (e.g. RAMM, dTIMS)
Psion Organiser	A hand-held item of equipment for recording and storing data, that can be down-loaded to a computer file
RAMM	Road Assessment and Maintenance Management system (developed in NZ for application by road controlling authorities)
SADT	Single axle, dual tyre
SAST	Single axle, single tyre
Semi-Trailer	A trailer, designed with rear axle(s) only, that can be joined to the prime mover via an articulated unit
TADT	Tandem axle, dual tyre
Telemetry Site	In the context of this report, the term relates solely to the continuous traffic count stations from which the data is conveniently able to be downloaded by Transit by means of telemetry. There are currently 69 such sites administered by Transit on State Highway sites across New Zealand, as follows: • 62 of the sites collect length classification data • 4 of the sites are 'weigh in motion'. These sites collect weight data on every vehicle weighing more than 3.5 tonnes as well as TNZ (1999) axle configuration data • 2 sites collect counts only (Auckland Harbour Bridge and Panama Road) • 1 site (Pukerua Bay) collects TNZ (1999) axle classification data
Transfund	Transfund New Zealand (Land Transport New Zealand)
Transit	Transit New Zealand
TRDT	Triaxle, dual tyre
Wheelbase	Distance between the front and rear axle of a vehicle or vehicle combination
WIM	Weigh-in-Motion, refers to equipment that weighs each individual vehicle passing over a measuring plate

Contents

Acknowledgments

The researchers acknowledge with appreciation the co-operation of Transit New Zealand in making available the extensive records of traffic loading data from their various count stations throughout New Zealand.

Executive Summary

Project Objectives

The main purpose of this project is to identify appropriate traffic and loading data for use in RAMM, other pavement management systems (PMS) with treatment selection algorithms and for pavement deterioration models (e.g. dTIMS)[1]. Also to meet the needs of pavement designers in the estimation of pavement loading over the life of a project, by establishing ESA[2] relationships from a variety of commonly used survey approaches and continuous data sources currently available in New Zealand.

The specific objectives for this research project were as follows:

1. To derive typical relationships between the Transit New Zealand standard telemetry outputs (four Vehicle Length Categories) and other commonly used classification systems in New Zealand such as that adopted by the Transfund Project Evaluation Manual (PEM), i.e. car, LCV, MCV, HCVI, and HCVII.
2. To derive typical percentages of PEM Vehicle Classes for different types of local and State Highway roads, based on a recent survey by LTSA of the vehicle composition across 2,350 roads of all types throughout New Zealand.
3. To derive typical ESA (equivalent standard axle) for the different Vehicle Classes, and determine whether there are any differences on the basis of region, road use, or traffic volume/percentage of heavy vehicles relationship.
4. To derive relationships enabling the ESA determined from short-term surveys to be factored to a week and a year based on the four 'weigh-in-motion' (WIM) sites.

Summary of Outcomes

The outcomes are considered in the order of the objectives listed above.

Objective 1

Relatively poor correlation was found between the four Vehicle Length Categories comprising Transit's standard telemetry outputs and other commonly used classification systems. As a broad generalisation, and in the absence of any other data, the percentage of vehicles from each Transit Vehicle Class (1-13) which can be allocated to each Vehicle Length Category is as follows (ignoring any representation of less than 5%):

Vehicle Length Category 1 (0.0 m -5.5 m)	includes	100% of Vehicle Class 1
Vehicle Length Category 2 (5.5 m - 11.0 m)	includes	100% of Class 2; 75% of Class 3; 70% of Class 4; 40% of Class 5; 70% of Class 6; and 9% of Class 7
Vehicle Length Category 3 (11.0 m - 17.0 m)	includes	8% of Class 3; 30% of Class 4; 40% of Class 5; 25% of Class 6; 70% of Class 7; 70% of Class 8; 25% of Class 9; 30% of Class 10; and 7% of Class 13
Vehicle Length Category 4 (>17 m)	includes	17% of Class 5; 5% of Class 6; 18% of Class 7; 30% of Class 8; 25% of Class 9; 20% of Class 10; 100% of Class 11; and 100% of Class 12

---

1 Traffic data required as inputs to dTIMS include AADT, %Cars, %LCV, %MCV, %HCVI, %HCVII and %Bus. NZdTIMS does not have the ability to accept individual axle or axle-group data. Inputs are in ESA/vehicle for each of the vehicle categories.

2 ESA as defined by the Austroads Pavement Design Guide = $\frac{\text{(Load on Axle Group)}}{\text{Reference Axle Group Load}}$

Accordingly, there is no simple relationship between Transit's Vehicle Class and its Vehicle Length Category. Similarly, there is no useful relationship between Transfund's PEM Classes (i.e. car, LCV, MCV, HCVI and HCVII) and Transit's four Vehicle Length Categories.

Objective 2
Typical percentages of PEM Vehicle Classes for different road types were accurately determined for the weekday interpeak period (09 00 - 16 00) across a wide range of road types throughout New Zealand. Accordingly updated factors are recommended for adoption by Transfund in the PEM manual.

Objective 3
For the convenience of pavement designers, typical ESAs for different Vehicle Classes were established, and reported as ESA4, ESA5, ESA7, and ESA12, for each of the weigh-in-motion sites. As this ESA data is based on a substantially larger sample than previously published data, the new values should be adopted in future. The research identified some differences on State Highways at a regional level, but was unable to identify whether there were any differences in ESA between different road types or between roads carrying different proportions of heavy vehicles.

Objective 4
Relationships were derived from the WIM sites that enable ESA to be calculated from short-term surveys and to be corrected by application of a week factor. However, as the level of accuracy is less than generally accepted, it is recommended that at least 3 years of data from each WIM station be evaluated before confirming whether week and day factors can usefully be used to adjust short-term counts.

Research Stages
The research was undertaken in a series of separate stages, independently addressing various of the objectives. In assessing the manner in which the objectives were met, it is important to understand that the individual stages did not address the various objectives in the order outlined above.

Specifically,
- Stage 1 addressed Objective 2 and part of 1,
- Stages 2 and 3 addressed Objective 1,
- Stage 4 addressed Objective 4, and
- Stage 5 addressed Objective 3

Stage 1 : Analysis of LTSA Composition Data
The data from 2,350 roads, randomly selected by LTSA from throughout New Zealand, was analysed in terms of vehicle class and road category, then compared with currently adopted relationships.

Stage 2 : Analysis of Transit Weigh-in-Motion Data
Surveys undertaken at the four Transit New Zealand WIM sites in February/March 2000 were analysed with a view to establishing a relationship between Vehicle Length Category, wheelbase and Vehicle Class for application to the Transit continuous telemetry traffic counting sites. The currently adopted Transit relationships between Vehicle Class and the four standard Length Categories, measured at the telemetry, sites are to be reviewed alongside the relationships derived in this research.

It was also intended to review the survey data with a view to identifying, if possible, axle spacing criteria which could be used to distinguish between the main heavy vehicle types classified by routine equipment survey; as opposed to specific visual or commodity surveys. This component produced disappointing results because the commodities were impossible to verify visually. However, the survey did establish a strong correlation between visually recorded truck types and those recorded with the WIM equipment. It was, therefore, decided that a larger sample of WIM data could be reliably used, and would produce more accurate and statistically reliable results.

Stage 3 : Analysis of Comparative Surveys at Selected Telemetry Sites

The data collected by manual means was examined and compared with portable equipment surveys and the telemetry outputs from the count stations at Ohau, Manawatu, and Clareville. Classifiers were used, capable of recording individual vehicles over three-hour periods, analogous to the LTSA survey periods reported in Stage 1. The relationships obtained from these surveys were compared with those derived in Stages 1 and 2.

Stage 4 : Deriving Factors for 3-4 and 8 Hour Visual Surveys

Detailed analysis was carried out of the data from three of the WIM sites over a full 12-month period. The objective was to develop the multipliers to be used for estimating annual ESA values from short-term surveys of vehicle types.

Stage 5 : Derivation Typical ESA for different Vehicle Classes

Undertaken in parallel with Stage 4, detailed analysis was carried out of the data from the four WIM sites, for the most recent 14-month period up to and including August 2002. The objective being to identify the ESA values for a range of different vehicle classifications, separately for each WIM site. Then, if practicable, to identify variations between different sites with different vehicle characteristics. Also to determine more reliable ESA values for site specific situations that can be related to:

1. Vehicle Length Categories, for which continuous data is collected by Transit NZ from telemetry sites throughout the country, and
2. TNZ Vehicle Classes (1-13), which can be measured by temporary classification equipment (as used in Stage 3).

Results

Stage 1

The results from the analysis of the LTSA survey data generally closely correlated with the relationships adopted by the Project Evaluation Manual and the National Traffic Database. They represent an improved level of accuracy of these relationships, given the large number of roads on which the vehicle classes were sampled and the use of a consistent survey procedure.

Stage 2

The results from Stage 2 give the following outcomes:

- Close correlation between overall vehicle length and wheelbase length.
- No direct relationship between Vehicle Length Category and Vehicle Class; i.e. for any particular Vehicle Class, there is a range of vehicle lengths.
- Some variation in the proportions of the various Vehicle Classes between sites.

Note that the research identified a problem with the Tokoroa WIM site. The data from this site was, therefore, discounted.

Stage 3

The results of Stage 3 showed:

- Close correlation (between 0.996 and 0.998) between overall vehicle length (as recorded at the telemetry stations), and wheelbase (as measured by the temporary classifier) for the heavy vehicle component of the traffic stream.
- Transit Vehicle Classes 2, 3 & 4 generally lie within the same vehicle length band (i.e. 5.5 m – 11 m).
- Transit Vehicle Classes 5-13 show more distinct length ranges, although with considerable overlap.
- Buses cannot be identified separately from other heavy vehicles by either type of classification equipment; they can only be identified visually.
- The PEM HCVII class correlates reasonably well with the Transit Vehicle Classes 8-13, as measured by the temporary classifier.

Stage 4

Interrogation of the data from each of the four WIM sites showed that a full year's reliable data was only obtainable from two of the sites; Drury (on SH1 south of Auckland – 'rural fringe') and Waipara (on SH1 north of Christchurch – 'rural strategic'). Any effects of temperature on the WIM equipment at each of the WIM sites was discounted. Also Vehicle Class (Transit Classes 1 to 13) and site were found to be the key variables with respect to vehicle weights and, by extension, ESA value.

The ESA4 relationships were examined in detail, since they are most commonly used in NZ (i.e. for the design of unbound granular flexible pavements).

The combination of data from the Drury and Waipara WIM sites was used to develop 'Weekly Multipliers' to estimate annual ESA4 from the classified vehicle counts converted to axle groups.

Part Day-of-Week Multipliers were developed for shorter count periods than a full week (3 hours and 8 hours respectively, on any weekday). However, when the relative errors of these ESA4 values were determined, the relative errors varied between about 10% (for the week multiplier) and 18% to 33% (for the three-hour multiplier). The error terms were specifically applicable to the Waipara and Drury sites, and are probably understated for other sites. Accordingly, 3-hour or 8-hour counts are considered to be <u>unsuitable</u> for estimating ESA.

Stage 5

The same data from each of the 4 WIM sites was interrogated with a view to establishing reliable ESA values (raised to the various powers commonly used for mechanistic pavement design - ESA4, ESA5, ESA7 and ESA12), using <u>large</u> continuous samples at each site. For convenience, the 2001 (June-December) and 2002 (January-August) samples were analysed separately, to enable a year to year comparison.

As identified by the detailed statistical analysis in Stage 4, there were some problems with the data collections at the Te Puke and Tokoroa WIM sites. Transit will be addressing these in the future.

Overall ESA values were determined for each site, together with:

- axle group
- TNZ Vehicle Class (3-13), and
- TNZ Vehicle Length Category.

Ignoring the values obtained from the suspect WIM sites, the ESA values for the other two sites are recommended for adoption by pavement designers.

Conclusions

- It is inappropriate to attempt to develop precise relationships between vehicle length and Transit Vehicle Classes, since the variation within and between sites is greater than expected (Stage 2).
- Although it may ultimately be possible to develop an algorithm to predict the detailed composition and ESAs from Length Categories, the usefulness of such an algorithm is considered marginal in relation to the required accuracy needed for current pavement design inputs.
- While the distributions of first axle spacings are not statistically different, a nominal threshold of 3.8 m has been found to differentiate between non-twin-steer truck and trailers (> 3.8 m) and B-trains and semi-trailers (< 3.8 m).
- A-trains cannot be distinguished from truck and trailers based on first axle spacing. Rather, they can be distinguished by their number of axle sets (typically five) as compared with the four axle sets of other 7 and 8 axle vehicles.
- A nominal threshold of 2.2 m has been found to distinguish twin-steer trucks (< 2.2 m) from non-twin-steer trucks (> 2.2 m).
- Commodity surveys cannot be usefully undertaken without stopping the traffic and interviewing each driver as to type and status of load (Stage 2). Visual inspections of moving vehicles are no longer a satisfactory method of commodity survey, and the stopping of vehicles to determine the commodities carried is often impracticable particularly on busy State Highways.
- Manual surveys (person or video) can be used to classify trucks, but are only practicable at sites with overall traffic volumes up to a threshold of around 7,000 vpd (Stage 3).
- Temporary classifier equipment (e.g. Peak ADR used in Stage 3 of this research) is able to identify a more comprehensive range of vehicle types (e.g. Transit Vehicle Classes 1-13) than current telemetry equipment, and accordingly is likely to be more useful for obtaining the necessary ESA values for pavement design purposes.
- Telemetry data is currently limited in its usefulness since the sites are almost all restricted to State Highways, and therefore to 'rural strategic' and 'rural fringe' road categories.
- The surveys (Stage 3) showed that the variability between survey types (visual, axle groups and length category) within sites was reasonable (with some noted exceptions), but the vehicle class patterns between sites was greater than anticipated. Although an important finding, because the road use category for each site was the same (rural strategic), this outcome contrasts with the findings from Stage 1. Such an outcome is likely a result of the small sample size (3 sites), the duration of surveys (3 hours), and the survey precision.
- It is difficult to determine whether a true seasonal variation or even daily variation exists as the precision of the monitoring equipment could mask any such variability.
- The Stage 4 and 5 results provide useful site specific ESA data by Transit Vehicle Class and Vehicle Length Category. These results are at some variance with previous ESA data published by Transfund that were based on much smaller samples of data. Again, greater accuracy is likely to be obtained if data is available for one or more full calendar years at each site.

Recommendations

- The default values of vehicle composition used by the PEM be updated based on the more extensive survey data now available, as reported in Stage 1.
- The nominal thresholds for axle spacings noted above will be helpful in using machine counts to differentiate between different types of heavy vehicle.
- For pavement design purposes, it may be appropriate to separately redefine road categories based on heavy traffic patterns only, as these are found to be different for the same road categories based on overall (light plus heavy) vehicle traffic patterns.
- Based on the knowledge gained from the detailed statistical analysis undertaken in Stage 4, it is now considered that a minimum of three years continuous and verifiably reliable data for all four WIM sites (preferably more if possible) are necessary to produce meaningful week factors or 3-hour factors. Accordingly, it is recommended that the week factors be reviewed and updated as necessary, once a full 12 months WIM data is available, and subject to rectification of the WIM equipment at the Te Puke and Tokoroa sites.
- It is further recommended that a sensitivity analysis be undertaken to determine the level of accuracy of ESA data required by way of design inputs into current design methods, for a typical range of New Zealand roads.
- That the ESA data developed in this research be publicised to NZ pavement designers (Stage 5).

Abstract

In order to identify appropriate traffic and loading data for use in Road Asset Maintenance Management, other pavement management systems, and for pavement deterioration models, data were collected between 2000 and 2002 from 2,350 randomly selected sites throughout New Zealand and from the four Transit New Zealand weigh-in-motion sites.

The data collection and analysis was undertaken in five stages:

1. Typical vehicle composition proportions were obtained for different road categories and compared with previously adopted relationships.

2. Relationships were determined between the various methods of categorizing vehicles and quantified to determine the validity of using such relationships to derive Equivalent Standard Axle (ESA) values.

3. Relationships were established between the commonly used Transfund Project Evaluation Manual vehicle classes, length categories and axle groups.

4. Data from short term surveys was used to develop multipliers for use in estimating annual ESA values.

5. ESA values were identified from different vehicle classifications, which can be related to data obtained by continuous collection or by continuous collection equipment.

1. Analysis of LTSA 3-Hour Vehicle Composition Data for all Road Categories

1.1 Introduction

In June 2000, vehicle composition data from 2,350 randomly selected sites throughout New Zealand, were collected by Traffic Design Group for the Land Transport Safety Authority (LTSA). The large volume of data recorded for this project was subsequently analysed to obtain typical vehicle composition proportions for different road categories.

1.2 Objectives

The principal objective of the first stage of the research project was to identify representative samples of vehicle types, particularly for roads other than State Highways and to obtain a series of default values for:

- State Highways, for all road categories
- Non-State Highways, for all road categories
- Urban arterial roads, by region
- Urban residential/other roads, by region
- Rural strategic/other roads, by region

Then to compare these with previous default values recorded from other sources. Depending on the results, the need for changing and/or expanding the default values in Transfund's Project Evaluation Manual could be assessed.

A second objective was to identify any inconsistencies in the National Traffic Database so that these can be corrected.

1.3 Methodology

The LTSA vehicle composition survey results form the basis of this Stage of the research. The survey results were obtained from a representative sample of 2,350 sites selected from all the roads located within the 73 Territorial Local Authorities throughout New Zealand. Surveyors recorded the vehicle composition data for a period of three hours (either 0900 to 1200 or 1300 to 1600) at each site, on a regular weekday.

The data obtained from the surveys were used to derive typical percentages of vehicle classes for different types of state and non-State Highway routes were derived, the results of which are presented within the report of this Stage.

Eleven separate road categories were identified within the data, based on the categories provided in the National Traffic Database, as follows:

- Urban Arterial 1a
- Urban Arterial 1b
- Urban Commercial
- Urban Industrial
- Urban Residential
- Urban Other
- Rural Urban Fringe
- Rural Strategic
- Rural Recreational (Summer)
- Rural Recreational (Winter)
- Rural Feeder

The criteria for each of the categories were defined by the following two traffic characteristics:

- the ratio of the 1200 – 1300 flow to the peak hour flow, and
- the Sunday peak hour as a percentage of the AADT as set out in Transit's "Guide to Estimating AADT and Traffic Growth".

During the course of the analysis, a further three categories were identified; these were nominated as 'Logging', 'Low-Flow' and 'One-Way' roads as appropriate. Analysis of all the data was undertaken separately for State Highways and local roads.

A number of inconsistencies were identified between the road categories as given by the National Traffic Database and the traffic volumes surveyed. In a number of cases the road categories were amended as appropriate.

For each of the road categories, the two-way volume of traffic using the particular roads was further separated into the following eight vehicle classes:

- Motorcycles
- Light vehicles (including utilities, vans, taxis and taxi shuttle vans)
- Buses or coaches
- Single unit trucks (2 axles)
- Single unit trucks (3 or 4 axles)
- Articulated trucks
- Trucks with 1 or more trailers
- Other

1.4 Results

Seven separate analyses were undertaken.

1.4.1 Vehicle Classes and Road Categories

The first and second analyses involved obtaining percentages of vehicle classes for each road category over New Zealand's 14 local government regions, further broken down by local roads and State Highways. The averages of the site percentages are summarised in Tables 1.1 and 1.2.

Table 1.1 illustrates that, as expected on the local roads, the highest percentages of heavy vehicles were observed on the urban industrial, rural strategic and rural feeder routes, varying between 11% and 19%. Logging routes recorded approximately 30% heavy vehicles.

Table 1.2 shows that, generally for the State Highways, heavy vehicle percentages were around the 7% to 10% level for urban highways and 8% to 13% for rural highways.

1.4.2 Urban Arterial Road Categories

The third and fourth analyses combined the Urban Arterial 1a and 1b road categories and assessed the typical percentages of vehicle classes in the majority of the local government regions. The results are shown in Tables 1.3 and 1.4.

It can be seen from Table 1.3 that there was little variation in non-State Highway route vehicle class percentages for urban arterials amongst the local government regions in which the surveys were undertaken, with heavy vehicle percentages of around 4% to 7%. Nationwide, on the non-State Highway roads, the vehicle percentages were around 0.5% motorcycles, 93.8% light vehicles, 0.7% buses or coaches, 3.0% two-axle single unit trucks, 0.7% three or four axle single unit trucks, 0.4% articulated trucks, 0.8% trucks with trailers and 0.1% other vehicles.

Table 1.4 lists the limited numbers of State Highway sites surveyed in this road category. The vehicle class percentages obtained closely matched the percentages obtained for the non-State Highway roads, with heavy vehicle percentages ranging between 5% and 11%. On the State Highway routes, the vehicle percentages were around 0.4% motorcycles, 92.1% light vehicles, 0.6% buses or coaches, 3.5% two-axle single unit trucks, 1.2% three or four axle single unit trucks, 0.9% articulated trucks, 1.2% trucks with trailers and 0.1% other vehicles.

1.4.3 Urban Residential and Urban Other Road Categories

The fifth analysis involved combining the urban residential and urban other road categories to determine the variation in vehicle class percentages over all the 14 local government regions. This analysis was only carried out for non-State Highway roads as there were few roads of this category on State Highway routes. The results are shown in Table 1.5.

Table 1.1 Vehicle percentages for all road categories (all regions - local roads).

Road Category	Numbers of Sites	Vehicle Classes							
		Motor-cycle %	Light Vehicle %	Bus or Coach %	2 axle SU Truck %	3-4 axle SU Truck %	Articulated Truck %	Truck with one or more trailers %	Other %
Urban Arterial 1a	121	0.4	93.8	0.7	3.2	0.7	0.5	0.6	0.1
Urban Arterial 1b	254	0.4	93.9	0.8	3.5	0.7	0.3	0.4	0.0
Urban Commercial	91	0.4	95.3	0.6	2.7	0.5	0.2	0.3	0.0
Urban Industrial	38	0.5	80.5	0.6	9.2	2.6	2.8	3.1	0.7
Urban Residential	309	0.4	94.7	0.7	2.9	0.6	0.2	0.4	0.1
Urban Other	247	0.5	93.5	0.7	3.4	0.7	0.3	0.7	0.2
Rural Urban Fringe	8	1.0	91.2	0.9	4.2	1.1	0.6	0.9	0.1
Rural Strategic	94	0.5	85.8	0.8	5.1	2.6	1.1	3.7	0.4
Rural Rec (Summer)	9	0.1	91.3	0.8	3.5	1.9	0.7	1.4	0.3
Rural Rec (Winter)	2	0.9	92.9	0.0	4.0	1.4	0.4	0.4	0.0
Rural Feeder	66	1.6	86.3	0.9	4.8	2.1	0.9	2.5	0.9
Logging	6	4.3	63.2	1.9	10.2	4.9	3.9	8.6	3.0
One-Way Roads	5	0.4	96.0	1.2	1.9	0.2	0.2	0.1	0.0
Low Flow	245	1.9	87.1	0.8	4.5	2.3	0.4	1.7	1.3

Table 1.2 Typical vehicle percentages for all road categories (all regions - State Highways).

Road Category	Numbers of Sites	Vehicle Classes							
		Motor-cycle %	Light Vehicle %	Bus or Coach %	2 axle SU Truck %	3-4 axle SU Truck %	Articulated Truck %	Truck with one or more trailers %	Other %
Urban Arterial 1a	27	0.3	92.9	0.5	3.4	0.9	0.8	1.2	0.0
Urban Arterial 1b	37	0.5	90.7	0.7	3.8	1.2	1.5	1.5	0.1
Urban Commercial	11	0.4	90.8	0.5	3.2	1.3	1.1	2.6	0.1
Urban Industrial	3	0.2	91.6	0.6	4.3	0.9	0.4	1.9	0.1
Urban Residential	0								
Urban Other	4	0.3	89.2	1.4	2.8	0.9	2.0	3.4	0.0
Rural Urban Fringe	40	0.5	91.7	0.5	4.4	0.9	0.7	1.3	0.0
Rural Strategic	620	0.7	86.6	1.0	4.1	1.7	1.6	4.2	0.1
Rural Rec (Summer)	56	0.9	87.8	1.0	4.2	1.5	0.9	3.5	0.2
Rural Rec (Winter)	43	0.6	88.5	1.8	3.0	1.0	1.3	3.7	0.1
Rural Feeder	1	1.5	95.6	2.9	0.0	0.0	0.0	0.0	0.0
Logging	1	0.1	76.6	0.6	2.0	6.0	3.0	11.6	0.1
One-Way Roads	2	0.4	94.8	0.4	3.1	0.7	0.1	0.3	0.2
Low Flow	7	2.0	81.5	1.8	7.1	3.6	0.4	1.8	1.8

Table 1.3 Vehicle percentages for urban arterials 1a and 1b by region (local roads).

Local Government Region	Numbers of Sites	Vehicle Classes							
		Motor-cycle %	Light Vehicle %	Bus or Coach %	2 axle SU Truck %	3-4 axle SU Truck %	Articulated Truck %	Truck with one or more trailers %	Other %
Northland	13	0.4	93.9	0.4	3.3	0.9	0.3	0.7	0.1
Auckland	83	0.3	93.0	0.8	4.4	0.8	0.3	0.4	0.0
Waikato	21	0.3	95.4	0.5	2.4	0.7	0.3	0.4	0.0
Bay of Plenty	19	0.4	94.4	0.4	2.8	0.7	0.6	0.5	0.2
Gisborne	0								
Hawkes Bay	26	0.2	93.0	0.3	3.4	0.8	0.9	1.1	0.3
Taranaki	12	0.6	95.3	0.6	2.7	0.3	0.3	0.2	0.0
Manawatu/Wanganui	30	0.5	94.9	0.5	2.6	0.7	0.5	0.3	0.0
Wellington	68	0.3	93.6	1.0	4.0	0.6	0.3	0.2	0.0
Nelson/Marlborough	33	1.0	94.9	0.2	2.9	0.4	0.2	0.3	0.1
West Coast	0								
Canterbury	31	0.5	93.9	1.0	3.1	0.5	0.3	0.7	0.0
Otago	36	0.4	93.7	1.3	3.0	0.8	0.3	0.4	0.1
Southland	3	0.6	89.6	1.5	1.8	1.6	0.7	4.0	0.2
OVERALL	375	0.5	93.8	0.7	3.0	0.7	0.4	0.8	0.1

Table 1.4 Vehicle percentages for urban arterials 1a and 1b by region (State Highways).

Local Government Region	Numbers of Sites	Vehicle Classes							
		Motor-cycle %	Light Vehicle %	Bus or Coach %	2 axle SU Truck %	3-4 axle SU Truck %	Articulated Truck %	Truck with one or more trailers %	Other %
Northland	0								
Auckland	0								
Waikato	5	0.4	90.9	0.5	3.5	1.9	0.8	1.9	0.1
Bay of Plenty	1	0.3	92.6	0.6	3.6	1.5	0.4	0.8	0.2
Gisborne	4	0.0	92.6	1.0	3.6	1.3	0.6	0.8	0.1
Hawkes Bay	10	0.4	91.7	0.4	3.3	1.2	1.4	1.6	0.0
Taranaki	0								
Manawatu/Wanganui	0								
Wellington	10	0.4	91.7	0.4	4.7	1.1	0.8	0.9	0.0
Nelson/Marlborough	2	0.8	92.4	0.9	3.0	1.0	0.5	1.1	0.3
West Coast	0								
Canterbury	13	0.4	88.9	0.6	4.4	1.2	2.8	1.7	0.0
Otago	15	0.5	92.9	0.9	2.7	0.6	0.8	1.5	0.1
Southland	4	0.5	94.8	0.5	2.4	0.7	0.3	0.8	0.0
OVERALL	64	0.4	92.1	0.6	3.5	1.2	0.9	1.2	0.1

Table 1.5 shows that, for urban residential/urban other type streets, there was little variation between the regions in terms of percentages of vehicle classes. The percentage of heavy vehicles varied between 3% and 9% over the 14 regions. The vehicle percentages were around 0.6% motorcycles, 94.3% light vehicles, 0.6% buses or coaches, 3.0% two-axle single unit trucks, 0.7% three or four axle single unit trucks, 0.2% articulated trucks, 0.4% trucks with trailers and 0.2% other vehicles. This closely resembled the percentages obtained for urban arterials, apart from the lower percentage of the combination heavy vehicles (trucks with semi-trailers or trailers attached).

1.4.4 Rural Strategic/Other and Rural Feeder Road Categories

The sixth and seventh analyses combined the rural strategic/other with the rural feeder roads to see if there was any variation in vehicle class percentages over the 14 local government regions. Analysis was undertaken for both the local roads and State Highways surveyed. The results of these analyses are listed in Tables 1.6 and 1.7.

Generally, the results show little variation in vehicle class percentages over the 14 regions notwithstanding the fact that in several regions the numbers of sites surveyed were low. Heavy vehicle percentages ranged between 8% and 17% over all the regions. Vehicle percentages were around 1.4% motorcycles, 85.8% light vehicles, 0.8% buses or coaches, 4.8% two-axle single unit trucks, 2.4% three or four axle single unit trucks, 0.9% articulated trucks, 3.1% trucks with trailers and 0.8% other vehicles.

The local authority road (Table 1.6) and State Highway (Table 1.7) results are closely similar. As with the non-State Highway routes, the results for State Highway routes show little variation in vehicle percentages on rural strategic/other and rural feeder roads across the 14 local government regions, with the percentage of heavy vehicles varying between 10% and 17%. The State Highway rural strategic/other and rural feeder roads vehicle percentages were around 0.8% motorcycles, 86.6% light vehicles, 1.0% buses or coaches, 4.2% two-axle single unit trucks, 1.7% three or four axle single unit trucks, 1.4% articulated trucks, 4.2% trucks with trailers and 0.1% other vehicles.

1.4.5 Time Periods

In all the preceding analyses, it needs to be understood that the data collected from the 2,350 randomly selected sites were collected only during a three hour time-slot during the 'inter-peak' period. As heavy truck percentages are likely to vary across a 24 hour, 7 day period, as well as the possibility of seasonal variations, the three hour time-slot represents a limitation to the usefulness of the data. However, it does provide a relatively accurate picture of the 'inter-peak' period, given the very wide spread of the surveys across all road types and geographical spread throughout New Zealand.

Table 1.5 Vehicle percentages for urban residential/other streets by region (local roads).

Local Government Region	Total Sites	Vehicle Classes							
		Motor-cycle %	Light Vehicle %	Bus or Coach %	2 axle SU Truck %	3-4 axle SU Truck %	Articulated Truck %	Truck with one or more trailers %	Other %
Northland	18	0.6	94.3	1.0	2.0	1.7	0.0	0.1	0.3
Auckland	48	0.4	92.5	0.6	4.8	0.7	0.3	0.5	0.2
Waikato	75	0.4	93.2	0.5	3.1	0.9	0.5	1.2	0.2
Bay of Plenty	45	0.4	94.5	0.6	2.9	0.7	0.4	0.3	0.2
Gisborne	18	0.3	96.6	0.4	2.3	0.1	0.1	0.1	0.1
Hawkes Bay	23	0.4	95.3	0.4	2.8	0.5	0.2	0.3	0.1
Taranaki	19	0.4	95.8	0.6	2.5	0.3	0.1	0.2	0.1
Manawatu/Wanganui	54	0.4	94.9	0.8	2.6	0.6	0.2	0.4	0.1
Wellington	72	0.3	94.8	0.8	3.3	0.4	0.1	0.2	0.1
Nelson/Marlborough	10	2.2	94.7	0.2	2.4	0.2	0.0	0.0	0.3
West Coast	27	0.8	91.3	0.3	4.2	1.3	0.8	1.1	0.2
Canterbury	70	0.3	94.4	0.6	3.1	0.5	0.2	0.7	0.2
Otago	37	0.5	93.8	1.0	3.3	0.9	0.1	0.3	0.1
Southland	40	0.6	94.7	0.5	2.8	0.5	0.2	0.5	0.2
OVERALL	556	0.6	94.3	0.6	3.0	0.7	0.2	0.4	0.2

Table 1.6 Vehicle percentages for rural strategic/other and rural feeder roads by region (local roads).

Local Government Region	Total Sites	Vehicle Classes							
		Motor-cycle %	Light Vehicle %	Bus or Coach %	2 axle SU Truck %	3-4 axle SU Truck %	Articulated Truck %	Truck with one or more trailers %	Other %
Northland	17	1.4	87.4	1.4	3.6	1.7	0.6	3.5	0.4
Auckland	27	0.7	87.2	0.4	6.6	2.2	0.7	1.7	0.5
Waikato	23	1.0	82.0	1.3	5.5	3.5	1.8	4.5	0.4
Bay of Plenty	12	0.5	84.9	0.3	4.8	4.5	0.7	3.7	0.6
Gisborne	1	4.3	78.5	0.0	7.6	4.7	0.7	2.8	1.4
Hawkes Bay	11	0.5	85.9	0.7	4.5	1.7	2.3	3.7	0.7
Taranaki	5	0.2	88.3	0.4	6.4	2.1	0.4	1.1	1.1
Manawatu/Wanganui	9	1.0	89.5	0.3	3.0	1.4	0.9	3.7	0.2
Wellington	9	0.5	86.5	0.7	5.3	2.4	1.5	2.4	0.7
Nelson/Marlborough	11	0.7	89.3	1.0	4.3	1.3	0.6	2.5	0.3
West Coast	4	5.4	84.2	1.4	4.7	0.8	0.0	3.1	0.4
Canterbury	18	0.4	86.0	0.9	5.4	2.4	0.8	3.6	0.5
Otago	5	1.1	87.8	1.7	3.0	1.3	0.0	1.7	3.4
Southland	8	1.7	84.5	0.5	3.0	3.0	1.4	5.3	0.6
OVERALL	160	1.4	85.8	0.8	4.8	2.4	0.9	3.1	0.8

Table 1.7 Vehicle percentages for rural strategic/other and rural feeder roads by region (State Highways).

Local Government Region	Total Sites	Vehicle Classes							
		Motor-cycle %	Light Vehicle %	Bus or Coach %	2 axle SU Truck %	3-4 axle SU Truck %	Articulated Truck %	Truck with one or more trailers %	Other %
Northland	41	0.7	86.6	0.8	4.4	2.1	1.1	4.2	0.1
Auckland	22	0.4	87.5	0.6	6.2	1.8	1.1	2.4	0.0
Waikato	117	0.5	85.1	0.9	4.1	1.9	2.3	5.0	0.2
Bay of Plenty	91	0.5	87.6	0.7	4.4	1.3	1.3	4.0	0.2
Gisborne	14	1.0	82.0	0.7	4.6	2.3	1.4	7.7	0.3
Hawkes Bay	26	0.6	84.4	1.0	3.7	1.8	2.2	6.1	0.2
Taranaki	31	0.7	87.1	0.6	4.7	1.5	1.2	4.0	0.2
Manawatu/Wanganui	66	0.8	86.7	0.8	4.0	1.8	1.8	4.0	0.1
Wellington	24	0.6	89.6	0.7	4.7	1.4	1.1	1.8	0.1
Nelson/Marlborough	27	1.1	86.2	1.2	4.3	1.5	1.5	4.1	0.1
West Coast	33	1.0	87.2	1.9	3.1	1.4	1.4	3.8	0.2
Canterbury	53	1.0	85.4	1.4	4.0	1.8	1.9	4.4	0.1
Otago	51	0.8	88.1	1.7	3.1	1.2	1.0	4.0	0.1
Southland	24	0.9	88.2	1.1	3.2	1.8	1.0	3.6	0.2
OVERALL	620	0.8	86.6	1.0	4.2	1.7	1.4	4.2	0.1

1.5 Comparison with other Sources

The vehicle percentages obtained from the visual surveys were compared with the percentages provided by other sources such as the Project Evaluation Manual (PEM), National Traffic Database (NTD) and earlier research work undertaken by Mr Dave Wanty of Traffic Design Group in 1998. In order for valid comparisons to be made, the various vehicle classifications have to be consistent over specific road categories. These comparisons are shown in Table 1.8.

Table 1.8 Comparison of vehicle class percentages from various sources.

Road Category	Source	Time Period	Vehicle Classes			
			Light Vehicle %	MCV %	HCVI %	HCVII %
Urban Arterial	Project Evaluation Manual[3]	Daytime interpeak	95.0	2.0	1.0	2.0
	National Traffic Database	24 hour	95.5	2.5	1.5	0.5
	Dave Wanty Compilation	Not specified	94.5	3.0	1.5	1.0
	LTSA Visual Surveys	Daytime interpeak	94.3	3.7	0.7	1.3
Urban Other	Project Evaluation Manual[3]	Weekday	94.0	3.0	2.0	1.0
	National Traffic Database	24 hour	94.9	2.8	1.5	0.8
	Dave Wanty Compilation	Weekday	85.2	11.4	3.0	0.4
	LTSA Visual Surveys	Daytime interpeak	94.9	3.6	0.7	0.8
Rural Strategic/ Other	Project Evaluation Manual[3]	Weekday	88.0	3.5	4.0	4.5
	National Traffic Database	24 hour	91.0	3.6	2.3	3.1
	Dave Wanty Compilation	Weekday	88.8	3.8	3.2	4.2
	LTSA Visual Surveys	Daytime interpeak	87.2	5.6	2.4	4.8

Table 1.8 generally shows consistent results over the various road categories from the four sources. However the following differences are noted:

- For the 'Urban Arterial' category, the PEM is underestimating the proportion of MCV's and slightly over-estimating the proportion of HCVIIs.
- For the 'Urban Other' category there is relatively close consistency apart from the Dave Wanty compilation which is only a very small sample of two sites in the Seaview, Wellington, industrial area and is therefore not representative. The proportion of HCVIs reported by the PEM is high in relation to the LTSA surveys.
- For the 'Rural Strategic/Other' category, the NTD for Light Vehicles and HCVIIs differs most from the other three sources for which there are a number of potential reasons, including that the NTD summary results incorporated 24 hour surveys undertaken during the weekend periods as well.

[3] Table A2.1 – Traffic Composition (%), Transfund Project Evaluation Manual

1.6 Summary & Recommendation

The analysis of the LTSA visual surveys has provided reasonable and consistent estimates of the typical weekday inter-peak vehicle composition for different types of roads. It is suggested that the resulting values can be used as a check on the validity of future surveys.

It is recommended that the PEM (Table A2.1) be updated to reflect the LTSA results reported by this research. The following revised table is suggested.

Table A2.1 Traffic Composition (%)

Road Category and Time Period	Vehicle Class				
	Car %	LCV %	MCV %	HCI %	HCVII %
Urban Arterial					
Morning Commuter Peak	85	10	3	1	1
Daytime Inter-Peak	84	11	4	0.7	1.3
Afternoon Commuter Peak	84	11	2	2	1
Evening/Night-time	85	9	2	1	3
Weekday All Periods	85	10	2	1	2
Weekday/Holiday	87	8	3	1	1
All periods	85	10	3	1	1
Urban Other					
Weekday	87	8	3.5	0.7	0.8
Weekend/Holiday	87	9	2	1	1
All Periods	87	8	3	1	1
Rural Strategic					
Weekday	75	12	5	3	5
Weekend/Holiday	83	5	5	4	3
All Periods	78	10	5	3	4
Rural Other					
Weekday	76	11	6	3	4
Weekend/Holiday	84	6	4	4	2
All Periods	80	9	5	3	3

2. The Classification of Vehicles from Surveys at Weigh-in-Motion Sites

2.1 Objective

The objective of Stage 2 of this research was to examine and quantify (if possible) the relationships between the various methods of classifying vehicles, in order to determine the validity of using such identified relationships to derive ESAs in a later stage of this research.

An additional objective was to establish axle spacing criteria which could distinguish between the main vehicle types. A particular focus was how to distinguish between articulated vehicles and truck and trailer units.

2.2 Methodology

Initially, the data from the four Transit New Zealand WIM sites (at Te Puke, Tokoroa, Waipara and Drury) and the corresponding visual survey data was analysed for the three-hour period of the visual survey. The visual surveys were undertaken at each of the WIM sites, to record all heavy vehicles by type, in each direction, together with a visual assessment of the commodities carried. The surveys were undertaken during February 2000.

The following three vehicle classification methods were used for the comparisons:

- TNZ Length (4 Categories: 0.0 m - 5.5 m, 5.5 m - 11.0 m, 11.0 m - 17.0 m, > 17.0 m)
- TNZ Standard (13 Classes, refer to the table in Appendix A)
- PEM (the heavy vehicle classes as defined by the Transfund Project Evaluation Manual, i.e. MCV, HCVI & HCVII)

A table showing the relationships between these classification methods has been supplied by Transit New Zealand and is appended as Appendix A.

TNZ Length Category data is collected continuously at 65 telemetry sites distributed across the State Highway network, under the management of Transit NZ. Accordingly, small samples of these data were used as the prime variable.

2.3 Analysis

2.3.1 Correlation of Visual Surveys with Machine Counts

A comparison was made between the visual surveys and the data collected by the WIM equipment at each of the four sites.

The results showed the following successful matches between the two survey methods at the respective sites:

Te Puke	89%
Tokoroa	94%
Waipara	76%
Drury	65%

Similar surveys undertaken for Bartley Consultants Ltd (2000), reported 98% correlation.

2.3.2 Commodity Survey

The commodity survey component produced disappointing results. The main problems were the difficulty in visually assessing many of the commodities carried, and the difficulty of determining the load status (empty, part, or full).

Open trucks such as logging and stock trucks were easy, as were tankers such as milk or fuel tankers (except for load status), and, for these obvious types, much valuable data were collected. For the most part however, the details of the remainder of the truck fleet could not be assessed with any certainty. Accordingly, subsequent analysis excluded the visual survey data because of the lack of representation.

A strong correlation was established between the vehicle types identified in the visual survey and those recorded by the weigh-in-motion equipment, i.e. that the WIM equipment provided reliable output. Accordingly, it was decided that the three hour visual surveys would limit the available data for statistical analysis, and that a larger sample of WIM data might be more useful.

2.3.3 Correlation of Vehicle Length with Wheelbase and Vehicle Class

Initially, one complete day's data of all vehicles with a gross weight of $\geq$ 3.5 tonnes for the same day (13th March 2002) from each of the four WIM sites, was randomly selected and examined.

However, in view of the limited number of vehicles associated with some of the vehicle types, and to establish a more accurate comparison between sites, a further six months continuous data for the period 1 January 2002 - 30 June 2002 were analysed. The site at Tokoroa was excluded because of known site (and therefore data) problems.

2.3.4 Axle Spacing Analysis

A consistency check was introduced for the first axle spacing, as at least one observer was coding B-trains differently, and occasionally short 4-axle articulated A122 vehicles were not picked up but were coded as twin steer T22 trucks, and vice-versa.

Table 2.1 Vehicle analysis codes.

Code	Description	Examples
T2	2 axle trucks	T11, R11
B2	2 axle buses	B11
X2	Excluded 2 axle vehicles	
B3	3 axle coaches (non-twin steer)	B12
TR	3,4 axle trucks, non-twin steer	T12
TS	4 axle twin steer truck without trailer	T22
	3 axle twin steer truck with single axle trailer	T21-1
TL	2 axle truck with 1 or 2 axle trailer	T11-2
	3 axle non-twin steer truck with single axle trailer	T12-1
AR	Non-twin steer tractor with single semi-trailer	A123, A122
AT	Non-twin steer tractor with semi-trailer and trailer	A122-12
BT	Non-twin steer tractor with two semi-trailers	B1232, B1222
TT	Non-twin steer truck with trailer, 5-8 axles altogether	T12-22
TH	Twin steer truck with trailer, 5-8 axles altogether	T22-22
XX	Excluded vehicles	A222

2.4 Results

2.4.1 Sample Size

The sample sizes for each site (full day) are shown in Table 2.2, for vehicles ≥ 3.5 t:

Table 2.2 Sample sizes per lane.

Lane	Number of Vehicles
Drury Lane 1 (southbound, slow)	2,164
Drury Lane 2 (southbound, fast)`	175
Drury Lane 3 (northbound, fast)	146
Drury Lane 4 (northbound, slow)	2,116
Te Puke Lane 1 (southbound)	1,088
Te Puke Lane 2 (northbound)	965
Tokoroa Lane 1 (southbound)	888
Tokoroa Lane 2 (northbound)	960
Waipara Lane 1 (southbound)	467
Waipara Lane 2 (northbound)	454

Generally, a close similarity between lanes within individual sites was observed. An exception was Drury (Auckland Southern motorway) where the following two problems were encountered:

- Only about 10% of heavy vehicles use the 'fast lanes', so they have been excluded from any further analysis. The graphs are included only for completeness.

- The observation of a significant difference between the vehicle lengths recorded in lanes 1 and 4. Lane 4 recorded longer lengths at the higher end of the heavy vehicle fleet. It is considered that a minor problem with the calibration of the equipment caused this.

2.4.2 Relationship between Vehicle Length and Wheelbase

A comparison of the vehicle length versus vehicle wheelbase shows three distinct clusters at all sites.

These clusters typically occur around the 5.5 m – 11 m, 15 m – 17 m, and 18 m – 22 m length points. Usefully, these clusters are consistent with the TNZ Length Categories, i.e. 11 metres being the maximum allowable length of a rigid truck, and 17 metres being the maximum allowable length of a truck/semi-trailer combination. Although some variability occurs in the data, it is considered to lie within the bounds of the equipment accuracy.

2.4.3 Comparative Relationships with TNZ Axle Classes

Graphs in Appendix B, resulting from analysis of the continuous 6 months data for all vehicles over 3.5 tonnes, show the following differences between sites:

- Graph 1 : Comparison between each site of the proportion of vehicles in each TNZ class.
- Graphs 2-12 : Comparison between sites of the relationship of each TNZ axle class (3-13) with vehicle length.
- Graphs 13-16 : Comparison between sites of the proportion of vehicle types in each of the four TNZ length categories.

The comparison of vehicle length with vehicle class between sites highlighted two outcomes, as follows:

i. the one-to-many relationship, or overlap between vehicle length and vehicles class,
ii. the slight variability between sites.

This is further illustrated in the Class Relationships tables in Appendix C.

2.4.3.1 The One-to-Many Relationship

It is assumed that this outcome results from the fact that there are many types of truck which carry light but bulky loads. An example is the car-transporter, which typically carries 6-8 cars. Therefore, this load only requires 3-5 axles. Another is the truck-and-trailer combination (4 axles total), which carries a commodity such as bread. This assumption is examined in Stage 4 when the axle loads (as ESAs) are examined in detail.

2.4.3.2 The Variability Between Sites

This outcome suggests some sort of site dependence which could be related to the limitations of the equipment calibration and/or to the assigned road use category. Again the more comprehensive data set used for the Stage 4 analysis clarifies this issue. It is also possible that there are 'local' variations in heavy vehicle traffic patterns within the road use categories that were developed from total daily traffic flow patterns on any road (i.e. for which light vehicles typically dominate). The current road use categories assume that the heavy vehicle use patterns are the same or similar within the same road use category. Although this research was predominantly on Rural Strategic roads, there was sufficient variation in heavy vehicle use patterns between sites to show that this assumption is invalid.

The following are the current road use categories for the respective WIM sites:

- Drury Rural/Urban fringe
- Te Puke Rural strategic
- Tokoroa Rural strategic
- Waipara Rural strategic

Although there is an obvious relationship between vehicle length and wheelbase, neither of these measures is a reliable predictor of number of axles. Since the PEM classes are based on number of axles, a potential problem exists in deriving PEM classes from length or wheelbase. Currently, it is assumed that the 11.0 - 17.0 m length category equates to PEM class HCVI, and the > 17.0 m length category equates to PEM class HCVII. This relationship between PEM classes and TNZ length category is therefore only a coarse approximation. There is also an element of site dependency which complicates the issue.

The analysis in Stage 3 provides additional information from which to draw more definitive conclusions.

2.4.4 Separate Identification of Articulated Trucks from Truck and Trailers

The primary focus of this analysis related to deriving a more objective threshold for the first axle spacing, which is used in distinguishing between articulated vehicles and truck and trailers.

A secondary focus was to determine the threshold for distinguishing between twin steer trucks and non-twin steer vehicles.

The result of the analysis is summarised below:

Table 2.3 Axle spacings for truck and trailers and articulated vehicles.

Vehicle	Number of Vehicles	Mean of 1st Axle Spacing (m)	Standard Deviation (m)
Non-Twin Steer Truck and Trailers	582	4.10	0.62
Semi-Trailers	496	3.63	0.44
B-Trains	248	3.66	0.38
A-Trains	24	3.82	0.51

On this basis, the distributions of the first axle spacings are not statistically different among non-twin steer truck and trailers, semi-trailers and B-trains. Given that a first axle spacing threshold is required, a nominal value of 3.8 m appears to be reasonable in distinguishing truck and trailers from semi-trailers and B-trains.

However, it is to be noted that this threshold value is inappropriate for distinguishing A-trains from truck and trailers. Generally though, A-trains are able to be distinguished as they typically have 5 axle sets compared to 4 axle sets on other 7 and 8 axle vehicles.

2.4.5 Identification of Twin Steer From non-Twin Steer Vehicles

With respect to the threshold for distinguishing twin steer vehicles, the minimum first axle spacing for rigid trucks was in the range 2.3 m to 2.4 m. Higher minima occurred for the semi-trailer, truck and trailer, A-train, and B-train vehicle codes (see above).

The figures from the manual surveys of twin steer vehicles and units in this analysis are as follows:

Table 2.4 Axle spacings for twin steer truck and trailers and twin steer trucks.

Vehicle	Number of Vehicles	Mean of 1st Axle Spacing (m)	Standard Deviation (m)	Typical Maximum (m)
Twin Steer Truck and Trailers	600	1.71	0.14	2.0
Twin Steer Truck	167	1.65	0.21	2.1

Accordingly, it would be reasonable to adopt a threshold of 2.2 m for distinguishing twin-steer vehicles from non-twin steer heavy vehicles.

2.4.6 Identification of Bus/Coach from Other Trucks

The results for non-twin steer single unit vehicles were also examined to determine if there potentially was a threshold to distinguish buses from trucks as follows;

Table 2.5 Axle spacings for bus/coaches and other trucks.

Vehicle	Number of Vehicles	Mean of 1st Axle Spacing (m)	Standard Deviation (m)
Two-axle buses	83	4.9	0.92
Three-axle buses	71	5.60	0.22
Two-axle trucks	808	4.02	0.89
Three- (or Four-) axle non-twin steer trucks	305	4.56	0.83

The results confirm the long held view that 2 axle buses in particular cannot be distinguished from trucks based solely on their first axle spacing (or wheelbase). However, a threshold of between 5.3 m and 5.4 m is potentially reasonable in distinguishing (with a certain degree of the likelihood of success) between 3 axle coaches and 3 axle trucks.

Where loops are used, vehicle length is likely to be a better discriminator. Precursory examination suggests a threshold of around 10.3 m is reasonable for the Drury southbound site, but a longer threshold of around 11.7 m is reasonable for the Drury northbound site. This indicates that the threshold is site dependent, consistent with research that has shown that the length of a vehicle as derived by loop sensors, is dependent on the sensitivity of the sensors and the approach speeds.

Alternatively, angled axle sensors might be able to identify the single-tyred/dual-tyred rear axles configuration invariably used by coaches in New Zealand but not by trucks.

2.5 Conclusion

The length categories, based on the legal lengths of rigid and combination truck types, are verifiable at the WIM sites.

Although it may ultimately be possible to develop an algorithm to predict the detailed vehicle composition and ESAs from the length categories, the usefulness of such an algorithm is considered marginal in relation to the current accuracy requirements of pavement design and modelling.

There are two complications:

- The 'one-to-many' relationship (length versus class).
- The variability in heavy vehicle patterns between sites belonging to the same road use categories.

Preliminary indications are that it would not be appropriate to attempt to develop relationships between vehicle length and TNZ vehicle classes, since the variability between sites is greater than expected.

It can be expected that the examination of a whole year's data from each of the WIM sites as proposed in Stage 4 of this research will assist in more clearly identifying the significance or otherwise of the one-to-many problem. At present, this phenomenon suggests that, although vehicle length is a useful indicator of heavy vehicles generally, it is not a good predictor of vehicle type, although Stage 4 of the research might demonstrate that this doesn't actually matter.

While the distributions of first axle spacings are not statistically different, a nominal threshold of 3.8 m has been found to differentiate between non-twin steer truck and trailers (> 3.8 m) and B-trains and semi-trailers (< 3.8 m).

A-trains cannot be distinguished from truck and trailers based on first axle spacing. Rather, they can be distinguished by their number of axle sets (typically 5) as compared with the 4 axle sets of other 7 and 8 axle vehicles.

A nominal threshold of 2.2 m has been found to distinguish twin steer trucks (< 2.2 m) from non-twin steer trucks, truck and trailers etc (> 2.2 m). Accordingly, these relationships will be helpful in differentiating between different types of heavy vehicle using machine counts, only.

3. Identification of Heavy Vehicle Composition from 3-Hour Counts

3.1 Introduction

Stage 3 comprises the derivation of relationships between the commonly adopted vehicle classification systems in New Zealand, using the data collected by different traffic counting devices. Each device counted the same vehicle stream over a three hour period at representative traffic count stations. A number of specific relationships are examined, including vehicle length and wheelbase, and vehicle length and vehicle type (class), in order to establish a relationship between the PEM vehicle classes, length categories, and axle classes.

3.2 Methodology

Three sites were chosen to compare the relationship between different count classifications. They were chosen on the basis of reliable telemetry equipment for recording a wide range of vehicle types, and restricted to sites where traffic volumes could be manually surveyed by an individual person (which, therefore, excluded higher volume sites). The most suitable sites were identified at Manawatu, Clareville, and Ohau. Each was noted to be in the most common State Highway 'rural strategic' category, providing a basis to compare results between roads of the same category. At each site, three different types of vehicle classification were used to record traffic movements. The different methods of measurement were all undertaken concurrently during a three-hour period:

- Telemetry measurements, as output from the permanent TNZ count station at the site.
- Recordings from a temporary classifier, supplied by Maverick Services ('Peak ADR' classifier).
- Manual observation, using either a hand-held Psion organiser or a video recording.

3.2.1 Permanent Telemetry

Each of the permanent telemetry sites is administered by Transit and continuously record vehicles by means of loops cut into the road, which record both the speed of the vehicle and the length of the wheelbase. All of the vehicles were then assigned to one of the following five 'length' categories:

CAR	=	Cars
LCV	=	Light Commercial Vehicles
MCV	=	Medium Commercial Vehicles
HCVI	=	Heavy Commercial Vehicles - Type I
HCVII	=	Heavy Commercial Vehicles - Type II

3.2.2 Temporary Classifier

The more detailed classified data was obtained using 'Peak ADR' equipment in conjunction with tubes across the roadway, as supplied and operated by Maverick Traffic Services for the duration of the survey. This equipment classified vehicles into the categories shown in Table 3.1.

Table 3.1 Relationship between peak ADR classification and axle configuration.

Class	Axles	Vehicle Types In Class
1	2	o-o (short vehicle)
2	3	o-o-o (short vehicle towing) o-o-oo (short vehicle towing)
3	2	o--o (long vehicle)
4	3	o--oo
5	3	o-o--o
6	4	oo--oo
7	4	o--o-o--o o-o--oo
8	5	o--oo-o--o o-oo--oo
9	6	o-oo--ooo
10	6	o-oo-o--oo
11	7	o-oo-oo-oo (B-train) o--oo-oo--oo (T & T) o-oo--oo-o--o (A-train)
12	6,7,8	oo--oo-o--o oo--oo-o--oo oo--oo-oo--oo
13	8,9	o-oo--ooo-oo (B-train) o-oo-ooo-o--o (B-train) o-oo-oo-o--oo (A-train) o-oo--ooo-ooo (B-train)
14		Everything else

3.2.3 Manual Observation

A hand-held Psion organiser was used to manually record each heavy vehicle in the traffic stream, by vehicle type, over the same three-hour period as the tube counts were undertaken. This relied on the observer correctly identifying each vehicle in the vehicle stream by type, and manually entering that vehicle type into the Psion register. The software automatically recorded the time of the data entry, which could subsequently be down-loaded for comparison with the timed records of each of the automatic classifiers.

Alternatively, a video camera was used to record the traffic stream in real time. The video had an inbuilt time setting, and all of the vehicles (other than light vehicles) were identified in time sequence as a desk-top exercise after the event. The benefit of the video was that it could be re-played, as necessary, to verify the identification of the type of vehicle/number of axles of any particular heavy vehicle. The manual records (Psion and video) identified all vehicles (other than motor cycles), by type, as follows:

Table 3.1 Classification of vehicles recorded manually.

Type	Vehicle
A	Car and Car with Trailer
B	Van and Van with Trailer
C	Bus and Bus with Trailer
D	Rigid Truck and Rigid Truck with Trailer
E	Rigid Truck with Heavy Trailer
F	Truck with Articulated Trailer
G	A and B Train
H	Other

The surveys were undertaken during the months of October and December 2000.

3.2.4 Additional Analyses

In order to obtain a more representative sample of the truck composition at each of the sites, the researchers also reviewed the detailed telemetry data for each site over the whole of the 24-hour period for which the three-hour counts were a part. These results were then compared for each site, as an extension to the research as initially envisaged.

3.3 Analysis

The output data for each classification system was incorporated into a single spreadsheet for each site. This data was then carefully examined to match the vehicles recorded over the three-hour period. The information so obtained was analysed graphically to investigate a range of relationships between the data recorded by the different classifiers at each site.

3.3.1 Classification

Table 3.2 Relationship between different classification systems.

Manual (Psion)	Telemetry*		Temporary Classifier (No. of Axles)
	Vehicle Type	Length (m)	
Psion 'B'	LCV	5.5 – 11	2,3,4
Psion 'C'	LCV/Bus	5.5 – 11 & 11 – 17	2,3
Psion 'D'	LCV/Bus	5.5 – 11 & 11 – 17	2,3,4,6,8
Psion 'E'	Bus/HCVII	11 – 17 & 17 – 35	3,4,5
Psion 'F'	LCV/Bus/HCVII	5.5 – 35	4,5,6,7,8
Psion 'G'	Bus/HCVII	11 – 35	5,6,7,8

(* Note that the telemetry equipment also output numerical 'vehicle code(s)', however these codes are meaningless in the New Zealand context.)

Comparison of data between one system and another was complicated by the overlap between the different systems in use.

3.4 Results

The results have been plotted separately for each of the three sites manually surveyed. There were problems with the data from both the Manawatu and Clareville sites in that satisfactory correlations between all three counting devices were not possible as a result of technical failures. The problems included possible interference caused by opposing traffic at the Manawatu site, requiring this survey to be repeated after the permanent station had been moved to a more appropriate location where accurate data could be recorded.

3.4.1 Clareville

There was good correlation among the three counting methods in the southbound direction. However the correlation was unsatisfactory for the northbound direction. Accordingly, more detailed analysis was only undertaken using the data for the southbound direction. The results are represented graphically in Figures 3.1 and 3.2.

Figure 3.1 shows the relationship between vehicle length (as measured by the telemetry) and wheelbase (as measured by the temporary classifier) for all heavy vehicles for which a match was obtained. It will be seen that there are essentially three clusters of data in relation to overall vehicle length, as follows:

- Vehicles between 5.5 and 11.0 metres.
- Vehicles between 11.0 and 17.0 metres.
- Vehicles between 17.0 and 21.0 metres.

Figure 3.2 shows the relationship between vehicle length (as measured by the permanent telemetry classifier) and vehicle class as reported by the Temporary Classifier. Considerable overlap is noted for classes 2, 3 and 4 in terms of length. There are too few vehicles in the sample from classes 5 and 6 to draw any conclusions, and classes 7 and 8 show length similarities. Again the data broadly fits into the three length categories 5.5 m – 11.0 m, 11.0 m – 17.0 m and above 17.0 m.

A total of 71 heavy vehicles were recorded during the 3-hour sample. It was particularly noted that neither the telemetry equipment nor the temporary classifier was able to correctly identify buses. In this instance, 11 buses were recorded manually.

An analysis of the data from the Clareville site for the three different measurement systems indicates that, for this site, the telemetry classifier produced significantly more errors than the temporary classifier or the manual count.

Figure 3.1 Clareville site - length comparisons.

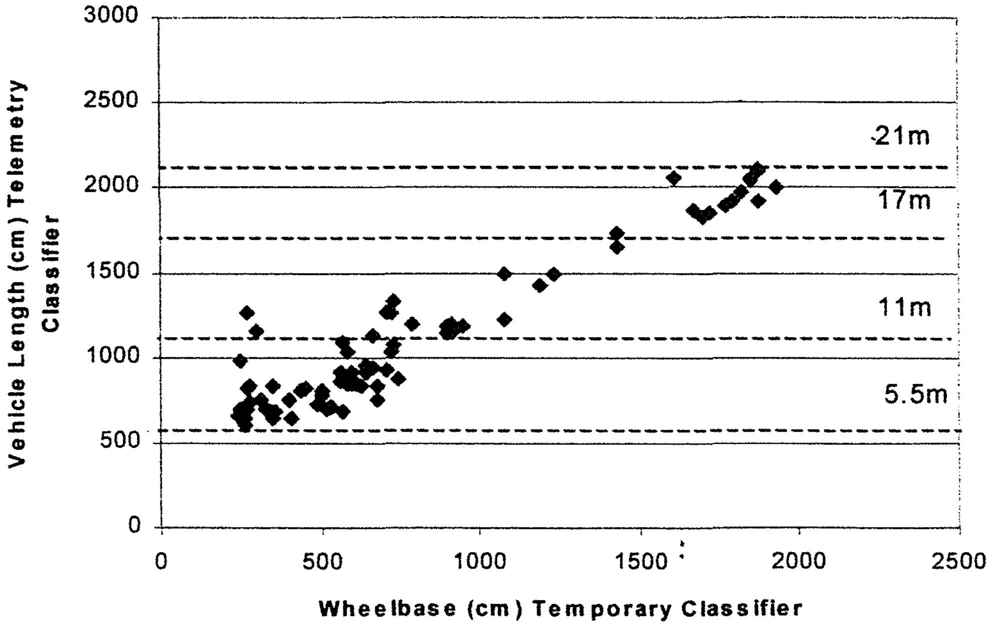
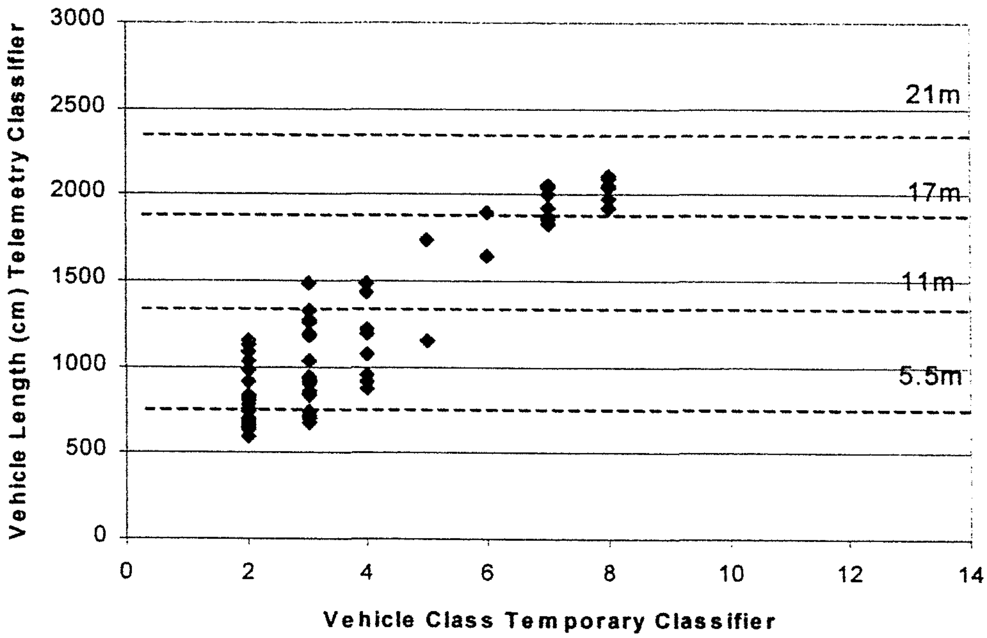


Figure 3.2 Clareville site - length versus class.



3.4.2 Ohau

Correlation of the three classification methods was relatively successful at the Ohau site, with only around 3% of data unable to be used. This was the best of the three survey sites and provided relatively close matches between all three classification systems for the northbound direction, with very little missing data.

For the Ohau site, the telemetry and manual surveys missed fewer vehicles than the temporary classifier for both directions. The southbound direction showed good matches between the manual and telemetry classifications, although fewer matches with the data from the temporary classifier. The data for both increasing and northbound directions has been tabulated and combined for the Ohau site to provide a usefully larger sample, as shown in Figures 3.3 and 3.4.

Figure 3.3 shows the comparison between vehicle length (as measured by the telemetry classifiers) and wheelbase (as measured by the temporary classifiers). Clustering is again evident for the commercial vehicle length classes 5.5 m – 11.0 m and above 17.0 m.

Figure 3.3 Ohau site - length comparisons.

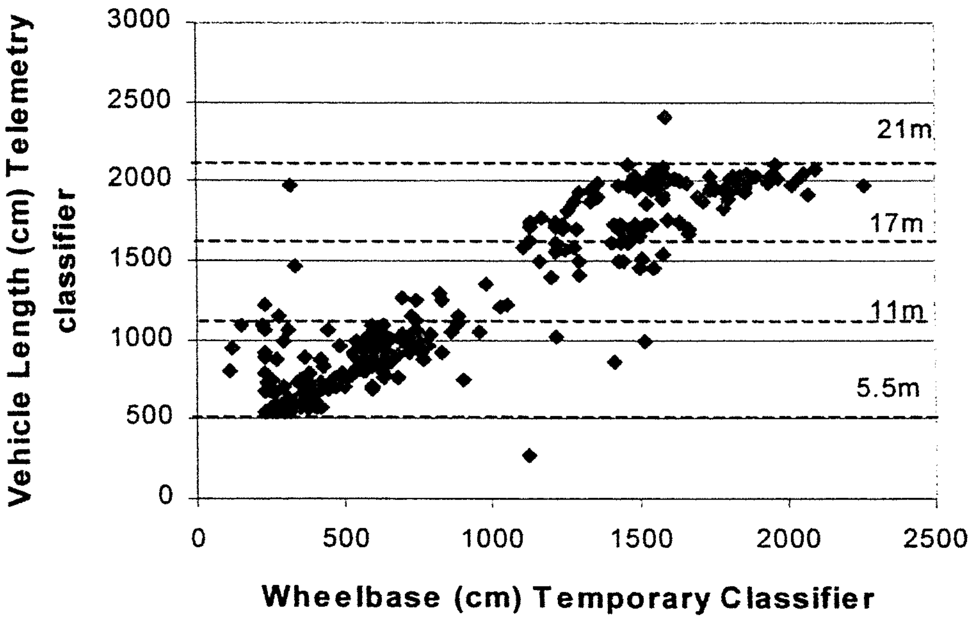
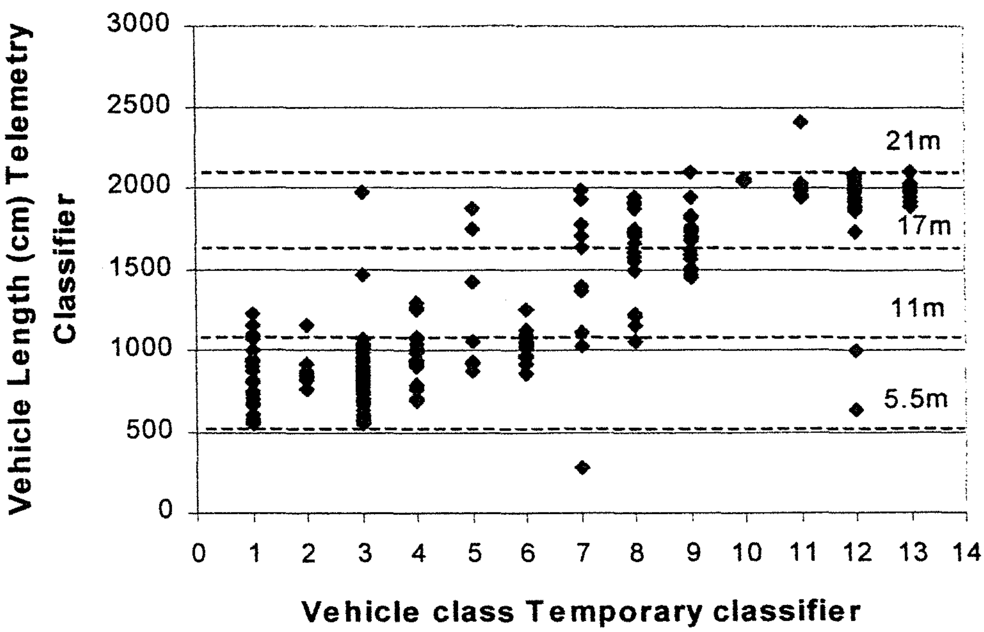


Figure 3.4 shows the comparison between the temporary classifier 'class' with the telemetry classifier length. It is evident classes 2, 3 and 4 show similar length ranges as do classes 7, 8 and 9. Classes 12 and 13 exhibit a more distinct cluster around the 20 metre mark.

As with the Clareville data, the telemetry counter erroneously classified a number of 6 axle HCVs and 4 axle LCVs as buses.

Figure 3.4 Ohau site - length versus class.



3.4.3 Manawatu

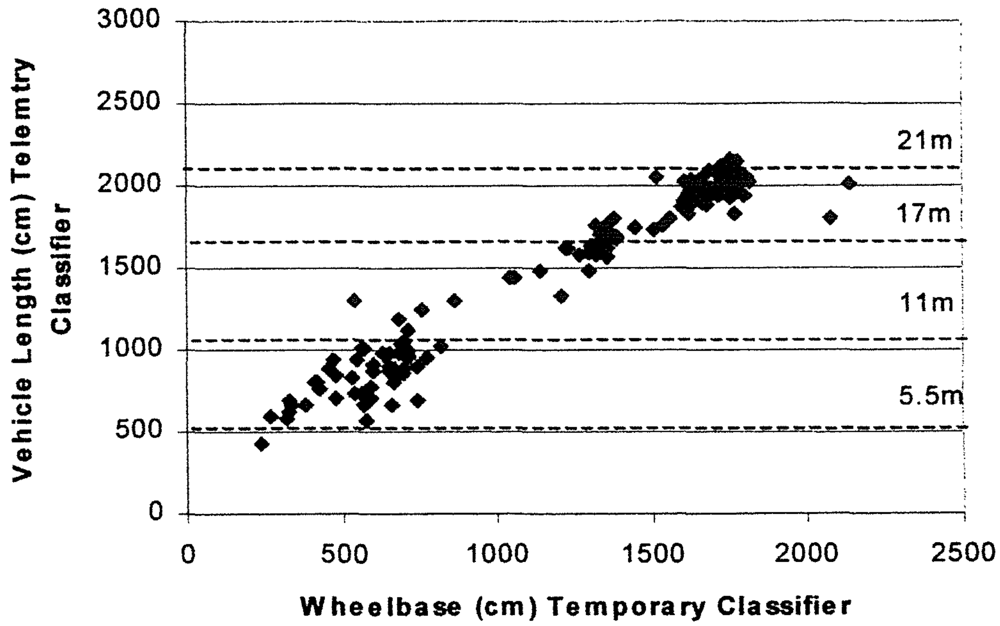
At the Manawatu count station, there was evidence of inconsistencies in the telemetry data during the initial survey. For the northbound direction there was relatively good correlation between the manual and temporary classification count data throughout the full period of the survey, but no matches with the telemetry data. A close examination of this data indicated that some vehicles were missing from the manual classified record, i.e. the surveyor recording the vehicles with the Psion machine occasionally missed a vehicle.

The southbound direction showed no clear matches between any of the three different counting systems.

Due to the problems encountered at this site, the survey was repeated at a later date. For the repeat survey, the duration of the survey was again three hours, and a video camera was used to provide a continuous record that could be interrogated at a later date.

The relationship between vehicle length and wheelbase for all of the matched vehicles from the telemetry and temporary classifiers was plotted as shown in Figures 3.5 and 3.6.

Figure 3.5 Manawatu site - length comparisons.



As seen in the Clareville and Ohau results, in Figure 3.5 there is evidence of clustering, more particularly in relation to the two length categories of 5.5 m– 11.0 m and over 17.0 m.

Figure 3.6 Manawatu site - length versus class.

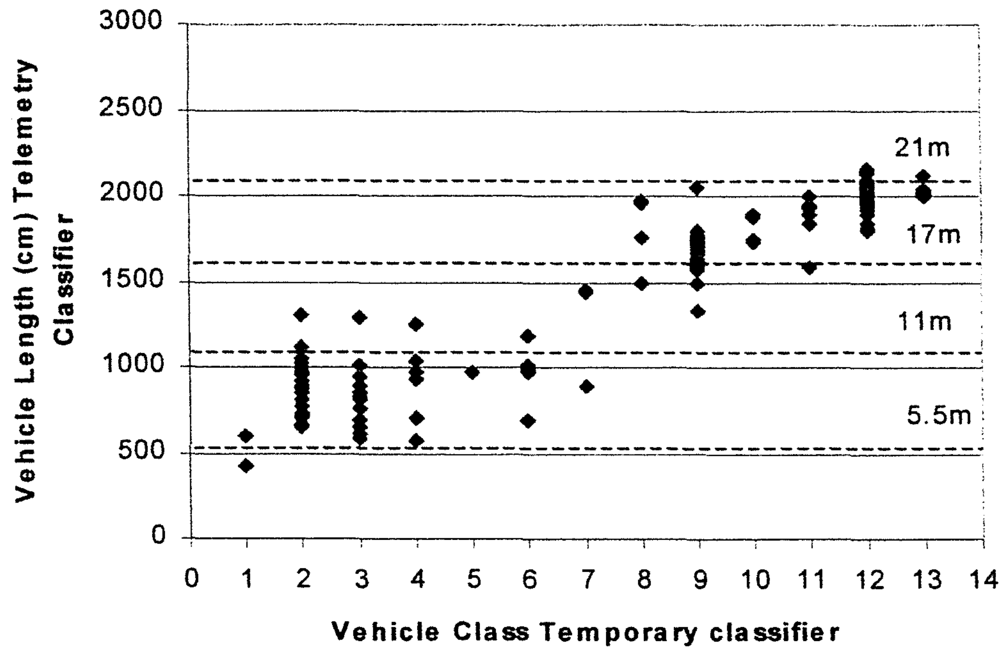


Figure 3.6 illustrates the relationship between the temporary classifier 'class' with the telemetry classifier length. Again, as at the Clareville and Ohau sites, classes 2, 3 and 4 all exhibit closely similar length ranges measured by the telemetry classifier. Vehicles recorded as class 5 to 13 show more distinct length ranges, although some overlap is still evident.

3.4.4 All Sites

The figures collected during each survey were examined in order to derive relationships between the temporary classifier, telemetry classifier and the manual or video record. Of particular interest were the differences in vehicle length and number of axles recorded by the two automatic classifiers.

3.4.4.1 Vehicle Classes

Matching of the data was carried out by matching the time records on all of the three devices used in the survey. Once the data were matched, relationships between the different classifications, number of axles, and vehicle length were developed. The correlation between the output from the temporary classifier and the telemetry classifier at the Manawatu site (repeat survey) are shown in Table 3.4 for the eastbound and westbound directions combined.

Table 3.4 Manawatu site temporary and telemetry classification matching.

Westbound & eastbound combined				
Temporary classifier	**Continuous (Telemetry) classifier**			
TNZ Class	**1, 2 (CAR & LCV)**	**3 (MCV*)**	**4 (HCVI)****	**5 (HCVII)**
1	**972**	7		
2	5	**252**	2	
3	11	1	1	
4		5	1	
5		1		
6	2		1	
7	2		2	
8	1		1	3
9	2		**15**	**12**
10				4
11	2		1	7
12	4			**47**
13				5
Total	1,006	266	24	78

*Telemetry equipment refers to as 'LGV'
**Telemetry equipment refers to as 'BUS'

As can be seen in Table 3.4, there is a relatively good correlation between Class 2 (short vehicles with three or four axles) and MCVs as recorded by telemetry. Similarly, there is some correlation between Class 9 and the HCVI class recorded by telemetry.

The HCVII class correlates well with the respective classification of the temporary counter (classes 8 to 13 inclusive), the majority of these vehicles being identified as 12, i.e. four axle trucks with two, three, or four axle trailers.

3.4.4.2 Length Recordings

Also derived from the Manawatu survey was the comparison of the length recordings between the permanent telemetry and the temporary classifiers. While the permanent telemetry classified by length in accordance with 4 standard length categories (i.e. 0.0 m – 5.5 m, 5.5 m – 11.0 m, 11.0 m – 17.0 m, 17.0 m – 35.0 m), the temporary classifier reported length in terms of axle spacing and wheelbase. The wheelbase lengths of each vehicle were accordingly somewhat shorter than the actual lengths as reported by telemetry. These results are illustrated in Table 3.5 for each of the Eastbound and Westbound directions.

As can be seen from this table, the differences between the telemetry site average vehicle length and the temporary classifier average vehicle wheelbase are highly correlated for both westbound and eastbound directions. This suggests that reliable data is gathered from both classifying systems for length measurements. Also evident is that the continuous (telemetry) equipment successfully classifies vehicles by length, noting that the length classes are reasonable approximations to the PEM classes.

3.5 Further Classifier Analysis

Additional data was analysed for each of the telemetry sites over the course of a typical week.

Figures 3.7, 3.8 and 3.9 illustrate a range of relationships for each of the sites Ohau, Clareville and Manawatu respectively.

All three sites showed similar proportions of vehicles across a typical week, i.e. where length bin '1' = 0.0 m – 5.5 m, '2' = 5.5 m – 11.0 m, '3' = 11.0 m – 17.0 m and '4' = over 17.0 m.

Figures 3.7, 3.8 and 3.9 also show, for each site, the percentage spread over a full day for each length class. Both the Manawatu and Ohau sites exhibited similar trends. However, for the over 17 m length class, the highest percentage (8%) occurred at 1200 at Manawatu, whereas at Ohau the highest percentage (7%) of these longest vehicles was recorded between 0600 and 0700. Similarly, 5% of the daily total of these large vehicles were recorded at the Manawatu site over the same hour. Both Manawatu and Ohau showed completely different trends to the Clareville site, which recorded consistent percentages throughout the day, and for each length class.

In addition, the Figures illustrate the percentage of each 'length class' for each hour of the day. Again, the Ohau and Manawatu sites showed similar trends of decreased car proportions and increased heavy vehicle proportions during the early hours of the day. By contrast Clareville again showed very little variation throughout the day, with constant percentages for each hour and length class.

Table 3.5 Correlation of overall length with wheelbase length.

Direction	Westbound			Eastbound		
Class (length)	MCV (5.5 m – 11 m)	HCVI (11 m – 17 m)	HCVII (17 m – 35 m)	MCV (5.5 m – 11 m)	HCVI (11 m – 17 m)	HCVII (17 m – 35 m)
Continuous classifier site average vehicle length (m)	8.26	15.49	19.63	8.55	14.43	19.36
Temporary classifier average wheelbase length (m)	5.71	12.03	16.41	5.71	10.93	16.82
Sample size	22	14	43	27	10	34
Difference	2.55	3.46	3.22	2.84	2.84	3.50
Correlation between continuous and temporary classifier	99.85%			99.65%		

3.6 Observations and Conclusions

A number of general observations can be drawn from the analysis of the 3-hour count records at the various sites and are summarised, as follows:

- Provided that an appropriate site is chosen for the location of recording equipment, i.e. away from bends or other factors that would affect the ability of the equipment to accurately measure the length/wheelbase/axle spacing of individual vehicles by direction, there is relatively good correlation between length data recorded by either telemetry or traffic classifier over a 3-hour period.

- Manual surveys (Psion or video) can be usefully classified, but are not suitable for measuring length (and are restricted to traffic volumes less than about 7,000 vpd).

- Temporary classifiers provide a comprehensive range of vehicle types, likely to be more useful for obtaining the necessary parameters for pavement design.

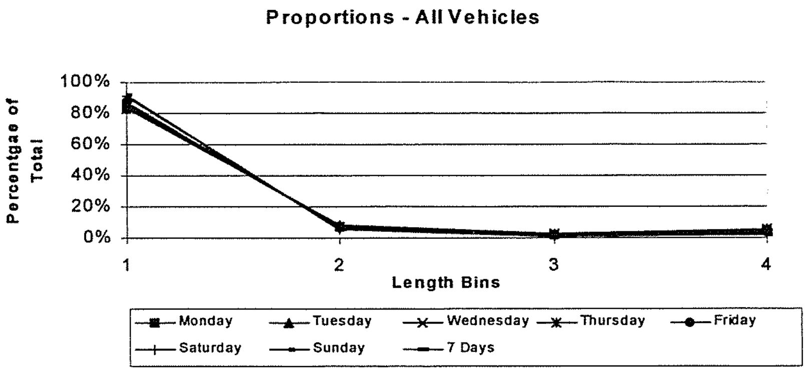
- Telemetry data is limited in its usefulness, since the sites are almost all restricted to State Highways - and therefore principally to 'rural strategic' and 'rural fringe' road categories.

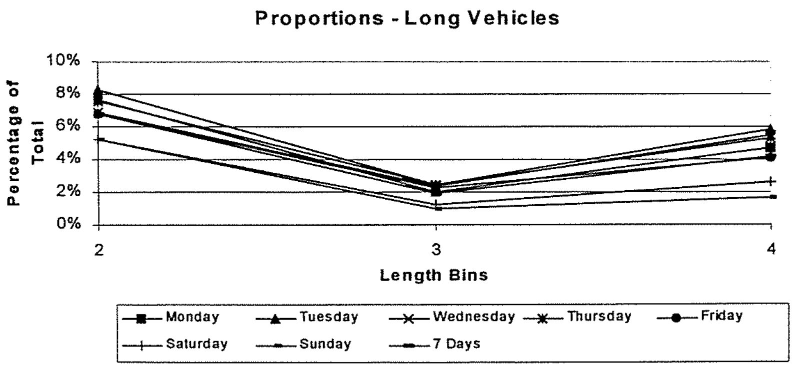
- The 3-hour count data is not necessarily representative of the day or week. This is further explored in the next stage of this research project. However, it is evident that there is variation between sites of the same road category. In this regard, it is to be noted that the road category types have been identified on the basis of overall traffic flow patterns (i.e. of the whole traffic stream inclusive of cars and other light vehicles). Therefore, if useful relationships are to be developed between vehicle length and road categories for pavement design purposes, then 'specific heavy vehicle road categories' may have to be defined.

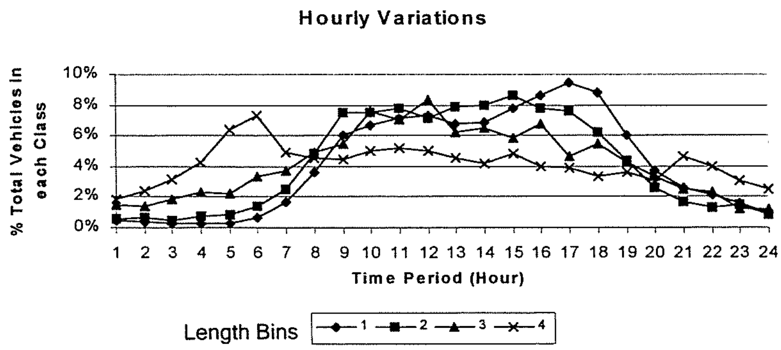
- While a very good correlation is found between the overall length and wheelbase length for any given vehicle (> 99% correlation), there is generally a wide variation of length for each 'Vehicle Class'. However, the vehicles in any specific class (TNZ Class 1 to 13) generally fall within either one or two particular length bins, e.g.

Vehicle Classes 2 - 6	:	Length bin 5.5 m - 11.0 m
Vehicle Class 7	:	Length bins 5.5 m - 11.0 m and 11.0 m - 17.0 m
Vehicle Classes 8 & 9	:	Length bins 11.0 m - 17.0 m and >17.0 m
Vehicle Classes 10-13	:	Length bin > 17.0 m

Figure 3.7 Relationships for the Ohau site.







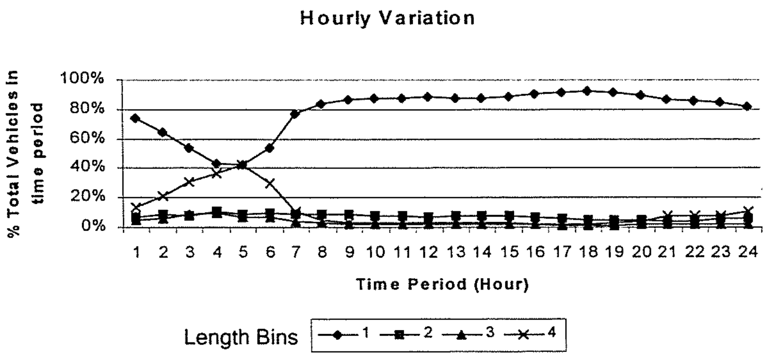
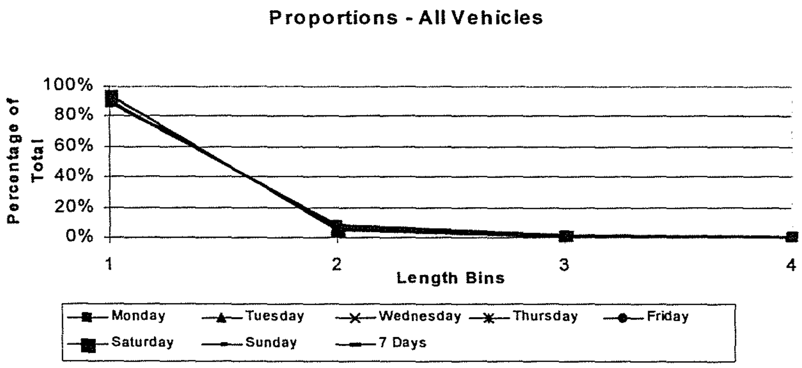
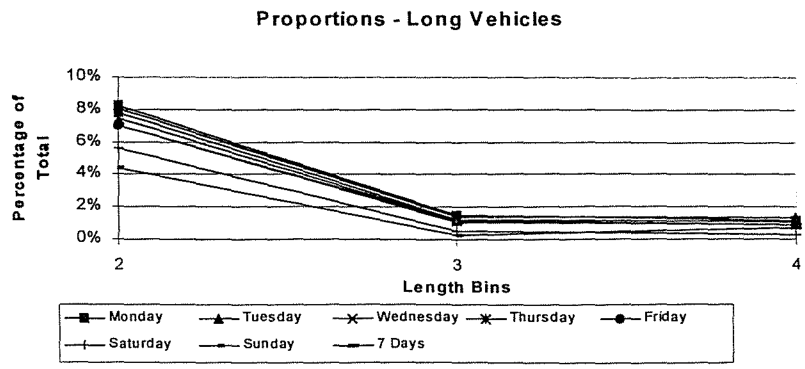
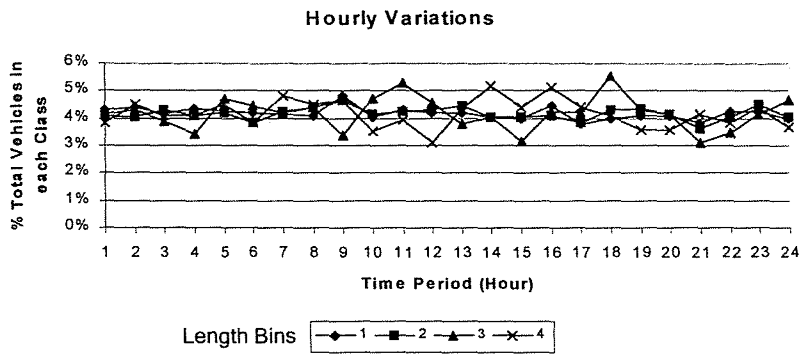


Figure 3.8 Relationships for the Clareville site.







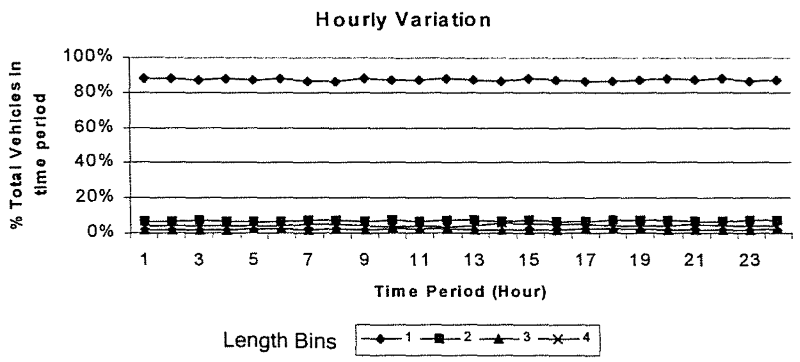
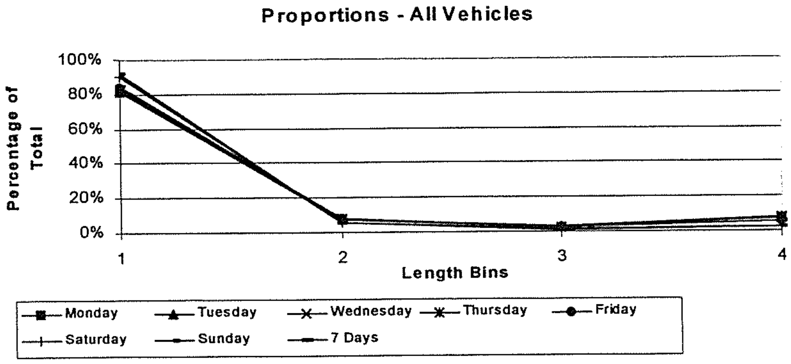
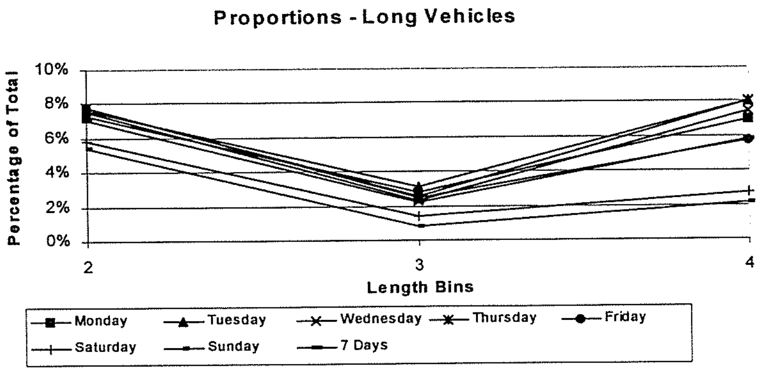
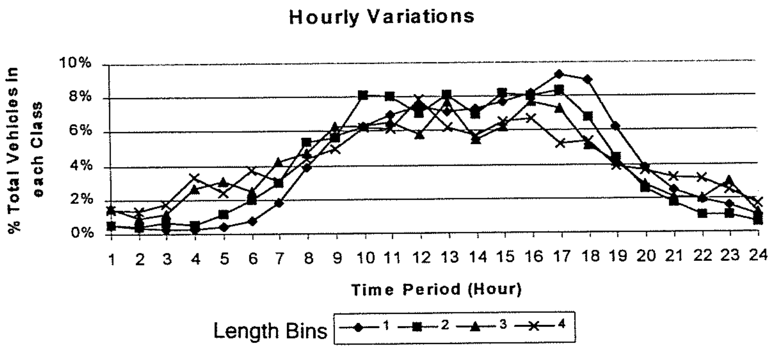
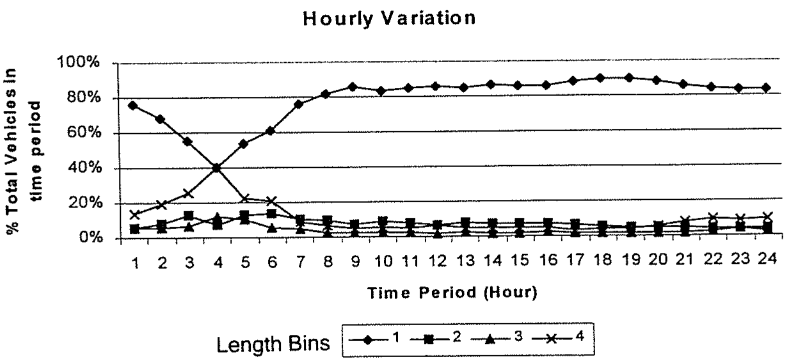


Figure 3.9 Relationships for the Manawatu site.









Before 3-hour temporary classifier or telemetry (continuous) classifier data can be considered useful, it will be necessary to identify the relationship of the length data from 3-hour count on any one day with the same data across a day, week, and year. It will also be more useful if the length data can be correlated with weight data, particularly if it is to be used as an input into pavement design. These relationships are explored in detail in Stage 4.

4. Deriving Factors for 3 to 4-Hour and 8-Hour Visual Surveys

4.1 Introduction

This Stage 4 report outlines the process used in developing the multipliers to be used for estimating annual ESA values from short-term surveys of vehicle types.

The current method relies on an estimation or measurement of annual heavy vehicles, converting these to axle group totals and multiplying by the annual average ESA for each of the axle groups. A full week survey is currently the recommended minimum survey period from which to estimate the annual ESA.

In developing the annual average ESAs, the current method ignores the possibility of any seasonal variations with loads being carried, also of either seasonal or time of day variations in vehicle types.

As reported in Stage 2, it is difficult to obtain reliable data by carrying out commodity surveys unless vehicles can be stopped for a driver interview. Accordingly, they were excluded from analysis in this phase of the research. These types of detailed surveys are seldom practical and simpler methods are sought in this research.

The analysis behind this report has examined a very large sample of heavy vehicle weight data from a continuous twelve-month period from each of the four WIM sites, administered by Transit NZ, i.e.:

- Drury
- Waipara
- Te Puke
- Tokoroa

The data from the Tokoroa site were considered insufficiently complete to be useful for generating reliable week or other short-term multipliers. Consequently, all of the analysis in this Stage 4 research is based on the first three sites, i.e. two in the North Island (Drury, Te Puke) and one in the South Island (Waipara).

4.2 Methodology

The data for analysis of the multipliers consisted of, in the first instance, all the daily weights and vehicle counts for all vehicles other than light vehicles, as measured at the three WIM sites over a full 12-month period. The vehicles were classified according to the following three major divisions:

- **Axle Groups 1-4:**
  SAST: Single Axle, Single Tyre
  SADT: Single Axle, Dual Tyre
  TADT: Twin (Tandem) Axle, Dual Tyre
  TRDT: Tri-Axle, Dual Tyre

- **Length Bins 2-4:**
  5.5 m – 11.0 m
  11.0 m – 17.0 m
  > 17.0 m

- **Transit Classes 3-13 – see Appendix A**

The 12- month period across which useful records were available included two part calendar years as follows:

- Days 1-170: 1 January, 2002 to 19 June, 2002
- Days 171-365: 20 June, 2001 to 31 December, 2001

Weight summaries for each day were available from each WIM site.

4.3 Analysis and Results

Technical difficulties at the WIM sites caused a delay until 20 June 2001 in order that an accurate continuous or near-continuous 12-month record of data could be obtained from each of the sites. A July to June year was adopted for analysis purposes so that the research was not further delayed. Accordingly, so that the report could be related to a 'calendar year' (January – December), the last six months of 2001 were combined with the first six months of 2002. The holiday periods for this 2001/2002 period were as follows:

- 20 June - 15 July 2001: Term 2 school holidays
- 22 September - 7 October 2001: Term 3 school holidays
- 22 October 2001: Labour Day
- 19 Dec 2001 - 27 Jan 2002: Christmas school holidays
- 6 February 2002: Waitangi Day
- 29 March - 14 April 2002: Term 1 school holidays (includes Easter)

4.3.1 Temperature Effects

The WIM equipment used strain gauges attached to steel plates mounted in the roadway. The researchers, therefore, considered there was a real possibility that temperature change could have affected the load readings and masked any possible seasonal variations.

Before examining the data for possible seasonal patterns, a statistical evaluation was undertaken to determine the relationship, if any, between the average daily weight at a site and the recorded daily temperature over the twelve-month period. Temperature data was obtained from NIWA for their recording sites nearest to the WIM stations. In particular, the daily minimum and maximum temperatures were obtained for:

- Pukekohe/Drury
- Waipara
- Rangiora
- Te Puke

Many temperature values were missing for the Waipara site, so the temperature measurements recorded at Rangiora were used. For the purpose of analysis, the daily mid-range temperature was used as the relevant daily measure.

Appendix D contains the time series plots for both of the average daily weights and temperatures recorded at the Drury site, for each of the eleven Transit classes (heavy vehicles only). Further plots are available, but the general result is similar.

Linear regressions were produced for each weight class at the three sites. Since the regressions examined were all linear and for the most part insignificant, the results can be summarised by the linear correlations. Table 4.1 provides the results of Pearson correlation tests of the relationship between temperature and weights for each of the three WIM sites and for each of the Transit classes. In almost all cases, the computed correlations are not significant (the P-Value indicates the level of significance – any test with a P-Value over 0.05 is regarded as not significant), and a non-significant result is obtained. Those seen as significant are marked with an *. The exceptional cases where a result appears significant cannot be explained as other than exceptional examples. Details can be found in Appendix E.

Given the overall lack of a clear relationship between temperature and average weight, temperature was not used in further analysis. Note that only for Transit Class 7 (four axle truck with single steer axle), was a significant result obtained at all three sites. However, there were relatively few vehicles in this class (compared with many other classes). The practical significance of the correlation may be questionable, and has therefore been discounted for the purpose of this analysis.

4.3.2 Vehicle Weights (Variation between Sites, Days of Year, and TNZ Classes)

In order to determine the major contributions to weight variance, a full regression was conducted using All Weights versus. Day of Year, Site, and Vehicle Class. (The result presented in the following Table 4.2 covers the heavy vehicle classes (3-13) as established by the Transit classification of Appendix A. Regressions conducted for the other classification methods (Axle Group or Length Bin), produced similar results.)

Table 4.1 Results of Pearson correlation tests of temperature versus weight.

Site	TNZ Class	Correlation Temp vs. Weight	P-Value	Significance
Drury	3	0.0025	0.1643	n
Drury	4	0.0000	0.4292	n
Drury	5	0.0000	-0.2583	n
Drury	6	0.0001	0.2131	n
Drury	7	0.8286	-0.0118	*
Drury	8	0.0000	0.2525	n
Drury	9	0.0001	0.2099	n
Drury	10	0.3362	-0.0526	n
Drury	11	0.1859	0.0721	n
Drury	12	0.1779	0.0735	n
Drury	13	0.0000	0.2978	n
Waipara	3	0.5989	-0.0283	*
Waipara	4	0.0000	0.3599	n
Waipara	5	0.0380	-0.1111	n
Waipara	6	0.0000	0.3686	n
Waipara	7	0.4231	-0.0430	*
Waipara	8	0.0000	0.2905	n
Waipara	9	0.0000	0.4562	n
Waipara	10	0.0009	0.1959	n
Waipara	11	0.0004	0.1886	n
Waipara	12	0.0046	0.1513	n
Waipara	13	0.0000	0.4389	n
Te Puke	3	0.0095	0.1410	n
Te Puke	4	0.0000	0.4313	n
Te Puke	5	0.0000	-0.2880	n
Te Puke	6	0.0002	0.2045	n
Te Puke	7	0.6437	-0.0253	*
Te Puke	8	0.0001	0.2095	n
Te Puke	9	0.0010	0.1781	n
Te Puke	10	0.1547	-0.0778	n
Te Puke	11	0.5007	0.0368	*
Te Puke	12	0.5435	0.0332	*
Te Puke	13	0.0000	0.2384	n

Table 4.2 Regression of weight versus day of year, site, TNZ class - all measurements.

Coefficients	Value	Std. Error	t value	Pr(>|t|)
Intercept	-4233.41	180.30	-23.48	0.0000
day	-0.296	0.402	-0.74	0.4612
site	-261.76	58.50	-4.47	0.0000
t class	3332.21	13.98	238.42	0.0000

[where: day = day of year; site = WIM site; t class = vehicle class (in this case Transit Class)]

Residual standard error: 4380 on 9716 degrees of freedom
Multiple R-Squared: 0.8541
F-statistic: 18950 on 3 and 9716 degrees of freedom, the p-value is 0
2325 observations deleted due to missing values

The major items of variation are the (Transit) vehicle class and the site. The day of the year contributes a non-significant amount when the contribution of the two main factors is accounted for. Appendix F provides the residual plots for the regression. Not unexpectedly, they reflect the numerical analysis that the vehicle class is a dominant factor. The consequence of this result is that all further analysis of weights (or resulting ESA) should be performed separately for each site and for each vehicle classification.

In view of this result, regressions were conducted for each vehicle class (3-13), to determine if day of year contributed a significant amount when the vehicle classes were considered separately. The residual plots (fitted versus actual) in Appendix G indicate otherwise. For classes 7, 8, 9 and 11, the residuals reflect the contribution of the three sites. For other vehicle classes, the distinction is less evident.

Similar analyses were conducted for the other two vehicle classification schemes (axle grouping and length bins). In both cases the dominant effects in the total regression were site and vehicle class. The effect on the analysis is the same, namely that examination of time-based multipliers should be conducted by both vehicle class and measurement site.

4.3.3 Computed ESA Values

An analysis, similar to that described above for vehicle weights, was conducted for the computed ESA4 values that are typically used for the design of flexible pavements. As before, the dominant factor was the weight or vehicle class, with site also contributing. (Note that a similar analysis was conducted for ESA5, ESA7 and ESA12 values, with similar results. For the purposes of further examination and analysis, only ESA4 values are considered.)

Appendix H lists the summarised ESA4 values for each classification and for each of the three WIM sites. For completeness, Appendix I lists the residual plots of ESA4 versus vehicle classification category, day of year, and site. As before, the dominant effect is that of vehicle classification.

4.3.4 Week Multipliers for ESA4 by Vehicle Class

The purpose of the Week Multipliers for each WIM site was to permit legitimate estimation of annual ESA4 loading, based on a one-week count and accounting for the time of the year at which the count was made. This required estimation of both the multiplier for each week and the variability inherent in estimating each weekly multiplier. Since the computed values relied upon computation of hourly ESA4, some standardisation to the computation was required. That is, the computation of an ESA4 for any week had to rely upon:

- A minimum number of hours in the week to be used for calculating an average.
- A clear definition of the start and finish of a week.

The following parameters were adopted throughout the evaluation process:

a. Each week is considered as starting on Monday, ending on Sunday.

b. A minimum of four daily counts within a week was required before a particular week at any site was included. This was because including a week which had, for example, only a single day of counts, could heavily bias the weekly-daily average count. Although the use of a minimum of four days was itself open to producing some bias, the overall effect was judged to be quite small given the number of site-years being examined. Since the process used hourly data, the threshold for computation was 96 hours for the week.

c. All analysis dealt with weeks 2 to 52 inclusive. However, given the likelihood of unusual patterns for many sites around the Christmas/New Year period, week multipliers for the extreme weeks were inherently highly variable. Consequently, the multipliers for weeks 2-51 were the most useful.

d. Week 2 started on the Monday after the first Sunday of the year. That is, the first few days of the year, up to a maximum of seven, were discarded from the analysis.

Each week multiplier for ESA4 required computation of the average ESA4 for the chosen week as a proportion of the overall annual hourly average ESA4. The count used was the average hourly, classified vehicle count. That is, every computation was conducted at an **hourly** level. This was done in order to allow for consistency in use of the multipliers, whether for the full week or for part of the week.

There are two major sets of tables for converting week data into annual ESA4 estimates. These are described in sections 4.3.5 and 4.3.6.

4.3.5 Using ESA4 Multipliers for Estimation of ESA4

The annual ESA4 hourly average can be estimated by multiplying the weekly average ESA4 by a multiplier. Since the 'annual average' and the 'weekly average' vary according to the site and the year of measurement, the multiplier will also vary. In this case, only one year of measurement has been used. This means that the nature of the variation of the computed multipliers is a reflection of only the hour-to-hour variation.

Appendix J contains the week plots of the average ESA4 multipliers for the week at each of the three WIM sites, Drury, Waipara, Te Puke. Note that these are <u>not</u> the final ESA4 factors. However, it is clear that, for at least two periods during the year, the Te Puke measurements exhibit peculiarities. As a consequence, it was decided that for the development of the week (and, later, part-day) multipliers, Drury and Waipara only were included.

4.3.6 Using Classified Vehicle Count Multipliers for Estimation of ESA4

Of more practical consequence is the estimation of Annual ESA from vehicle counts. Appendix J contains the plots of the average multipliers for the conversion of weekly counts to the annual average hourly ESA for each of the three WIM sites. (Note that Te Puke data is included in the appendix for completeness, since it was not excluded until after viewing the multipliers. It is excluded from the final multipliers.)

In order to make the process of using multipliers more useful in practice, a second table of multipliers for converting the week classified vehicle counts to the annual ESA for the vehicle class, is listed in Table 4.3 and the plotted values are given in Appendix K.

The annual ESA4 hourly average can then be estimated by multiplying the weekly average hourly vehicle count by a multiplier. In a similar manner to weekly ESA, any variation estimated for this multiplier reflects hour-to-hour variation within the week, not the overall variation for any such multiplier across either sites or years. Use of the multipliers is explained further in the following section.

4.3.6.1 Axle Group

Given that the numbers of vehicles in several of the Transit classes are relatively small, and that the 'Axle Group' is more useful for loading design purposes, it was decided that only axle groups would be used in the development of the multipliers.

The general methodology for using the week multipliers is as follows:

4.3.6.1.1 Estimate of the Week ESA4 Hourly Average

$$\text{Week ESA4 (i)} = \frac{\text{Total ESA4 in week (i)}}{\text{n(i)}} \qquad \text{for i = 2 to 52 inclusive}$$

Where n(i) is the number of hourly ESA4 values used in constructing the week total.

In a full week, n(i) = 168. The threshold for computation was set at 96 hours of ESA4 values for the week, at each of the Drury, Waipara and Te Puke sites. For some weeks, there were fewer than 96 hours of ESA values. Consequently, for those sites and weeks, computation of the weekly multiplier was not possible.

4.3.6.1.2 Estimate of the Weekly Multipliers for Site

The ESA4 for the site is obtained from the entire file of all hourly counts leading to the following multipliers:

$$K1_i = \frac{\text{Week ESA4 Hourly Average(i)}}{\text{(Annual Average Hourly ESA4)}} \qquad \text{for i = 2 to 52 inclusive}$$

Similarly, when converting from vehicle count to annual ESA:

$$K2_i = \frac{\text{Week Vehicle Numbers Hourly Average(i)}}{\text{(Annual Average Hourly ESA4)}} \quad \text{for i = 2 to 52 inclusive}$$

For the purposes of estimating variability measures of the multipliers, the extent of variation year by year is not obtainable. Any estimated variation is merely between hours. A separate table for each of the three sites, for estimating the purpose of annual hourly average ESA4 from the week average hourly ESA4 is provided in Appendix L.

Table 4.3 provides the 'week multipliers' for converting each of the four axle group counts (data from both the Drury and Waipara sites has been combined). This table is the set of $K2_i$ multipliers. Separate tables for each WIM site are listed in Appendix M. Table 4.3 is reproduced in Appendix N, which includes the combined weekly multipliers for the two sites, Drury and Waipara.

Note that the multipliers for the Te Puke site were very unusual for several weeks. Rather than attempting to second-guess the inclusion or exclusion of specific data from this site, it was removed from the combined analysis.

Appendix O includes the variabilities, expressed as the 95% relative errors in the mean estimates. (Specifically, 2 x standard error of the mean count per hour.) Error in this case refers only to hourly variation (within the week count by hour). Since there is only one week for each site, no estimate of variation between years is possible. The variabilities in the table are average variabilities across the two sites at Drury and Waipara. The use of such an error estimate for the mean value requires a full week of hourly vehicle counts.

4.3.6.1.3 Interpretation Example

If vehicles are counted and classified into axle groups for each hour of week 5 (or, at least 96 of the 168 hours in that week) for example, then:

The estimated Annual Hourly ESA4 for Vehicles in Axle Group 1 is:

$$ESA4_5 = \left(\begin{array}{c}\text{Hourly Average Number of Vehicles for Axle Group 1} \\ \text{for the Week 5 Count Period}\end{array}\right) \times 0.4425$$

The total Annual ESA4 for Axle Group 1 for the year is: $8760 \times ESA4_5$.

The result is similar for other weeks and for other axle groups.

It should be noted that the factors for weeks at the ends of the year (weeks 2 and 52) may not be useful due to the unusual nature of truck travel during those periods. Consequently, any counting should be conducted away from the holiday periods.

Table 4.3 Weekly multipliers to estimate annual ESA4 from classified vehicle counts.

Week	Axle Group 1	Axle Group 2	Axle Group 3	Axle Group 4
2	*0.4730*	*0.1664*	*0.4879*	*0.3881*
3	0.4458	0.1666	0.4633	0.3712
4	0.4423	0.1603	0.4563	0.3677
5	0.4425	0.1617	0.4529	0.3682
6	0.4649	0.1710	0.4669	0.3851
7	0.4225	0.1651	0.4174	0.3500
8	0.4078	0.1542	0.4043	0.3591
9	0.4068	0.1538	0.4015	0.3533
10	0.4112	0.1604	0.4038	0.3450
11	0.4042	0.1535	0.4017	0.3449
12	0.3975	0.1531	0.3937	0.3361
13	0.4565	0.1642	0.4718	0.3681
14	0.4551	0.1692	0.4570	0.3754
15	0.4155	0.1613	0.4005	0.3450
16	0.4131	0.1682	0.3948	0.3430
17	0.3444	0.1909	0.3938	0.3720
18	0.3446	0.2134	0.3934	0.3408
19	0.3133	0.1660	0.3620	0.3139
20	0.4618	0.1998	0.4330	0.3435
21	0.4649	0.1961	0.4290	0.3495
22	0.4764	0.2063	0.4465	0.3533
23	0.5115	0.2091	0.4835	0.3755
24	0.4797	0.2100	0.4580	0.3522
25	0.4649	0.1937	0.4405	0.3575
26	0.4812	0.1959	0.4576	0.3762
27	0.4806	0.1949	0.4591	0.3727
28	0.4877	0.1974	0.4690	0.3752
29	0.5070	0.2086	0.4821	0.3627
30	0.4944	0.2003	0.4872	0.3692
31	0.4894	0.1972	0.4862	0.3716
32	0.4891	0.1943	0.4823	0.3755
33	0.4929	0.2044	0.4902	0.3735
34	0.4884	0.1915	0.4884	0.3643
35	0.4926	0.1902	0.4841	0.3654
36	0.4806	0.1897	0.4706	0.3662
37	0.4616	0.1780	0.4611	0.3831
38	0.4487	0.1735	0.4454	0.3710
39	0.4416	0.1671	0.4417	0.3696
40	0.4413	0.1704	0.4396	0.3607
41	0.4457	0.1751	0.4382	0.3667
42	0.4514	0.1742	0.4510	0.3757
43	0.4813	0.1757	0.4907	0.4099
44	0.4362	0.1696	0.4311	0.3658
45	0.4190	0.1641	0.4179	0.3574
46	0.4361	0.1643	0.4411	0.3712
47	0.4279	0.1745	0.4155	0.3503
48	0.4179	0.1606	0.4153	0.3527
49	0.4078	0.1569	0.3993	0.3322
50	0.4090	0.1613	0.4021	0.3301
51	0.4155	0.1615	0.4179	0.3353
52	*0.8667*	*0.2686*	*1.0104*	*0.5630*

4.3.7 Part Day of Week Multipliers

The purpose of this element of the research was to determine multipliers for a shorter count period than a full week (i.e. 3 hours and 8 hours on any week day), and to establish whether or not such results are sufficiently reliable. It would be convenient if pavement designers could rely on the results from short-term surveys of heavy traffic using a particular roadway.

The periods chosen for evaluation were:

- 0900-1200 – Continuous count, over 3 hours;
- 0800-1600 – Continuous count, over 8 hours.

The general process was similar to estimation of the week multipliers. The first screen used in the calculation process was to assume that counting and classification was conducted on a weekday (Monday to Friday).

Multipliers were generated, as before, using the average hourly vehicle count during the period in question.

For the 3-hour tables, only those vehicles in the 0900-1200 Monday-Friday period were included. Multipliers were computed for only those weeks for which at least 6 (out of a maximum 15) hours of vehicle counts and classification were made.

For the 8-hour tables, only those vehicles in the 0800-1600 Monday-Friday period were included. Multipliers were computed for only those weeks for which at least 16 (out of a maximum 40) hours of vehicle counts and classification were made.

Other selection screens could be used. As for the week multipliers, the computation is performed at an hourly level.

4.3.7.1 Three-Hour Multipliers

Appendix P contains the tables of Week ESA multipliers based on a 3-hour count. Appendix Q lists the equivalent set of multipliers based on classified vehicle counts for each site. Appendix R contains the combination table (reproduced as Table 4.4) for Drury and Waipara.

Appendix S sets out the variabilities, expressed as the 95% relative errors in the mean estimates. (As above, 2 x standard error of the mean count per hour.) Error in this case refers only to hourly variation (within the week count by hour). The variabilities in the table are average variabilities across the two sites Drury and Waipara. The use of such an error estimate for the mean value thus requires a 3-hour count (0900-1200), by hour. The factor for the relevant week is applied to the average hourly count for the 3-hour period. As expected, with a short-term count, the standard error of the relative hourly count figure is quite high.

As for the weekly hourly averages, the calculation takes the 3-hour (hourly average), and multiplies by the relevant week factor to obtain the annual hour average ESA4.

Table 4.4 0900-1200 Multipliers to estimate annual ESA4 from classified vehicle counts.

Week	Axle Group 1	Axle Group 2	Axle Group 3	Axle Group 4
2	*0.2621*	*0.1016*	*0.2725*	*0.3909*
3	0.2517	0.0975	0.2678	0.3611
4	0.2569	0.0946	0.2736	0.3513
5	0.2588	0.0920	0.2683	0.3490
6	0.2665	0.1011	0.2770	0.3342
7	0.2338	0.0910	0.2327	0.2717
8	0.2232	0.0855	0.2242	0.3368
9	0.2276	0.0851	0.2277	0.3190
10	0.2269	0.0872	0.2240	0.2965
11	0.2213	0.0801	0.2216	0.3432
12	0.2105	0.0807	0.2104	0.3116
13	0.2378	0.0802	0.2576	0.3234
14	0.2407	0.0885	0.2518	0.3424
15	0.2289	0.0880	0.2313	0.3392
16	0.2195	0.0924	0.2082	0.3261
17	0.1981	0.1159	0.2352	0.4089
18	0.2181	0.1311	0.2516	0.3415
19	0.1715	0.0871	0.2043	0.3719
20	0.2319	0.1015	0.2241	0.2951
21	0.2465	0.1049	0.2398	0.3158
22	0.2578	0.1165	0.2454	0.3382
23	0.2803	0.1154	0.2780	0.3116
24	0.2528	0.1090	0.2461	0.3403
25	0.2559	0.1118	0.2425	0.3164
26	0.2656	0.1114	0.2538	0.3503
27	0.2634	0.1122	0.2499	0.3094
28	0.2669	0.1128	0.2668	0.3354
29	0.2810	0.1224	0.2886	0.3168
30	0.2807	0.1187	0.2832	0.3657
31	0.2771	0.1149	0.2827	0.3126
32	0.2654	0.1026	0.2679	0.3559
33	0.2731	0.1261	0.2675	0.3365
34	0.2666	0.1077	0.2701	0.2940
35	0.2651	0.1052	0.2618	0.3555
36	0.2645	0.1086	0.2742	0.3185
37	0.2644	0.1076	0.2777	0.3695
38	0.2452	0.0934	0.2575	0.3410
39	0.2295	0.0872	0.2336	0.3419
40	0.2398	0.0930	0.2521	0.3224
41	0.2484	0.0970	0.2493	0.3229
42	0.2521	0.0975	0.2566	0.3239
43	0.2883	0.1050	0.3243	0.3875
44	0.2388	0.0910	0.2553	0.3080
45	0.2379	0.0923	0.2390	0.3108
46	0.2523	0.0954	0.2653	0.3397
47	0.2398	0.0976	0.2424	0.3215
48	0.2408	0.0894	0.2429	0.3617
49	0.2245	0.0852	0.2261	0.3122
50	0.2388	0.0926	0.2385	0.3207
51	0.2298	0.0909	0.2255	0.2865
52	*0.5434*	*0.1729*	*0.6216*	

4.3.7.1.1 Interpretation Example
For week 5 (from Table 4.4)

The estimated Annual Hourly ESA4 for Vehicles in Axle Group 1 is:

$$ESA4_5 = \left(\begin{array}{c} \text{ESA4 Hourly Average for the 0900-1200 count period} \\ \text{in week 5} \end{array} \right) \times 0.2588$$

The total Annual ESA4 for Axle Group 1 for the year is: 8760 x $ESA4_5$.

4.3.7.2 Eight-Hour Multipliers
A similar result is evident for the 8-hour count period, for which the factors are listed in Appendices T (for ESA4 multipliers) and U (for classified vehicle count multipliers). Appendix V provides the combined multipliers for the Drury and Waipara sites. Table 4.6 is reproduced from Appendix V. However, the standard error estimates are based on an average hourly count of an 8-hour count. As expected, these will be smaller than those for the shorter 3-hour count based estimated errors, as outlined in Appendix W.

4.3.7.2.1 Interpretation Example
For week 5 (from Table 4.5)

The estimated Annual Hourly ESA4 for Vehicles in Axle Group 1 is:

$$ESA4_5 = \left(\begin{array}{c} \text{Vehicle Count Hourly Average for the 0800-1600} \\ \text{count period in week 5} \end{array} \right) \times 0.2555$$

The total Annual ESA4 for Axle Group 1 for the year is: 8760 x $ESA4_5$.

4.3.8 Use of the Multipliers and Estimated 'Error'
Since the multipliers are based on hourly figures, computed for either a full week or a part of the week, no estimation is made of the day-to-day variation. That is, each estimated standard error assumes that the computed multiplier (either a week, 3-hour or 8-hour) is made as an average of all hours within the week (or all hours 0900-1200, Monday-Friday; or all hours 0800-1600, Monday-Friday). Each computation is subject to the minimum required hours as previously described.

The average Relative Error (½ of 95% estimated Range) has been determined for the various 1 week, 3-hour, and 8-hour multipliers in Table 4.5.

Table 4.5 Average relative error of multiplier values.

Axle Group	Week Multiplier	3-Hour Multiplier	8-Hour Multiplier
1	0.097	0.1806	0.1210
2	0.108	0.2443	0.1547
3	0.099	0.2271	0.1539
4	0.076	0.3336	0.2337

Accordingly, when a full week classified count is conducted, the relative error for Axle Group 1 is ± 9.7%; for the 3-hour count, the error is ± 18.1%.

Table 4.6 0800-1600 Multipliers to estimate annual ESA4 from classified vehicle counts.

Week	Axle Group 1	Axle Group 2	Axle Group 3	Axle Group 4
2	*0.2584*	*0.0954*	*0.2803*	*0.3328*
3	0.2480	0.0934	0.2641	0.3142
4	0.2486	0.0904	0.2626	0.3253
5	0.2555	0.0921	0.2708	0.3138
6	0.2595	0.0961	0.2685	0.3334
7	0.2320	0.0898	0.2353	0.2814
8	0.2218	0.0843	0.2245	0.3096
9	0.2217	0.0817	0.2277	0.2928
10	0.2298	0.0863	0.2344	0.2788
11	0.2219	0.0838	0.2247	0.3011
12	0.2173	0.0832	0.2209	0.2796
13	0.2418	0.0849	0.2611	0.3173
14	0.2471	0.0890	0.2633	0.3009
15	0.2235	0.0860	0.2237	0.2911
16	0.2234	0.0907	0.2190	0.2944
17	0.1966	0.1223	0.2276	0.3619
18	0.2021	0.1239	0.2380	0.3363
19	0.1761	0.0936	0.2146	0.3204
20	0.2370	0.1033	0.2299	0.2765
21	0.2436	0.1053	0.2346	0.2956
22	0.2508	0.1110	0.2429	0.2893
23	0.2750	0.1150	0.2738	0.3234
24	0.2559	0.1116	0.2539	0.3185
25	0.2515	0.1058	0.2462	0.2957
26	0.2588	0.1093	0.2515	0.3054
27	0.2577	0.1068	0.2513	0.2999
28	0.2615	0.1050	0.2645	0.3245
29	0.2665	0.1150	0.2659	0.2981
30	0.2633	0.1126	0.2605	0.3074
31	0.2600	0.1065	0.2643	0.3026
32	0.2577	0.1020	0.2564	0.3178
33	0.2635	0.1133	0.2661	0.3232
34	0.2612	0.1030	0.2696	0.2878
35	0.2618	0.1043	0.2629	0.2952
36	0.2607	0.1055	0.2625	0.2924
37	0.2533	0.1003	0.2671	0.3143
38	0.2391	0.0927	0.2470	0.3049
39	0.2361	0.0901	0.2431	0.3094
40	0.2370	0.0930	0.2438	0.2982
41	0.2418	0.0924	0.2462	0.2913
42	0.2418	0.0905	0.2491	0.3076
43	0.2704	0.1012	0.2912	0.3402
44	0.2276	0.0867	0.2332	0.3113
45	0.2296	0.0877	0.2334	0.2997
46	0.2412	0.0913	0.2525	0.3127
47	0.2393	0.0973	0.2424	0.2961
48	0.2301	0.0861	0.2344	0.2998
49	0.2224	0.0842	0.2253	0.2848
50	0.2318	0.0917	0.2325	0.2774
51	0.2276	0.0851	0.2335	0.2900
52	*0.5465*	*0.1658*	*0.6673*	*0.4830*

Vehicle weight (and accordingly, ESA) data has been used for each hour for an entire year. For any given week, this produces only a single estimate of weekly multiplier. Consequently, each multiplier is, in effect, a single estimate of the relevant week factor. Accordingly, the 'error' term above is not adequate to describe the variation between multipliers when counting and classifying vehicles at any site other than those used for the computation (Waipara and Drury). Consequently, the relative 'error' for any other site is likely to be substantially understated. For this reason, it is considered that 3-hour and 8-hour counts are presently unsuitable for estimating ESA to other than a coarse level of precision.

4.4 Conclusions

4.4.1 Error Estimation

In order to determine a more robust estimate for error, it is essential that at least one, and preferably more, year of hourly vehicle counts and weights (from which ESAs are determined) should be collected and incorporated into the estimation process.

4.4.2 Reliability of Data Sample

To date, a sufficiently complete sample of reliable data has only been verified from two of the WIM sites, Drury and Waipara, from which 'multipliers' have been developed. In a pure technical sense, this can be used to provide site-based estimates of variability. However, this leaves only one degree of freedom for estimating site (spatial) variance, for each week. The variances produced would be almost useless, and the 95% range of error would greatly exceed the estimated multiplier.

4.4.3 Road Use Categories for Heavy Vehicles

Currently, there is no reliable means of applying the road use category for the WIM sites to other types of road. It could be considered that, in terms of total vehicle flow, the Drury site resembles a 'Rural-Urban Fringe' road-use type, while Waipara may be considered closer to 'Rural Strategic'. However, given the limited amount of data available for this task, the combination of both sites to give a composite set of week multipliers may be the most appropriate short-term resolution.

As a result, the multipliers developed here could be considerably enhanced by the inclusion of additional years of classified weight data, together with more complete data from the other WIM sites around the country. This would greatly enhance the applicability of the multipliers, at least for the 'Rural Strategic' and 'Rural Fringe' road-use types.

4.4.4 Classification Inputs

Axle Groups are the key input required, in terms of pavement loading for pavement design purposes, and are determined from the WIM data. The relationship between axle groups and the other two classifications discussed in this report, namely TNZ Class and TNZ Length Category, could also be examined. Given that there are many telemetry sites on New Zealand State Highways, extension of the tables of these alternate vehicle classification scheme multipliers, when more sites are added to the base data, would be highly appropriate.

However, Stages 2 & 3 demonstrated that, although the length classification was a useful indicator of heavy vehicles, the variability and accuracy in determining vehicle length renders this difficult for design purposes. Although the TNZ axle classification scheme provides a more detailed and accurate subdivision of heavy vehicle types, the net result is no different to using the current axle group methodology and so no additional benefits are derived.

4.4.5 Sensitivity

The sensitivity of the outcome of the pavement design process to the derived ESA4, or similar, can be expected to govern the usefulness of this methodology for the derivation of load factors from short surveys. Although the variability between the factors is not as large as anticipated, this could change in future with an increase in available reliable data. It is quite possible that this analysis exceeds the precision requirements for pavement design, and this needs to be tested.

Nevertheless, now that the methodology has been developed, it would be very desirable to include additional years of data and extra sites into the database, which would also increase the available sample sizes in the 3-hour analyses to allow inclusion of TNZ axle groups and length categories. The precision of the data collection methods could become important, but again, this needs to be governed by the level of precision necessary from which to obtain an efficient pavement design.

4.5 Recommendations

- Review the level of accuracy of ESA data required for pavement analysis.
- Update the week factors and their relative errors when a further 12 months' data is available from the WIM stations.

5. Derivation of Typical ESA Factors for Different Vehicle Classes

5.1 Objective

Stage 5 was undertaken in parallel with Stage 4 and involved the detailed analysis of the four WIM sites, in this case for the most recent 14-month period extending through to the end of August 2002. The objective was to identify the ESA values for a range of different vehicle classifications for each WIM site, and if practicable to identify any differences between sites with respect to different vehicle characteristics. This will result in more reliable ESA values for site-specific situations, that can be related to:

- the Transit length categories, for which continuous data is collected from 63 of the telemetry sites throughout the country, and
- the TNZ classes (1-13) which can be measured by temporary classification equipment (as used in Stage 3).

5.2 Methodology

The data records for every truck movement across each of the WIM sites were assembled, separately for years 2001 and 2002. For each site, the measured loads were then disaggregated and classified into:

- Axle groups (i.e. SAST, SADT, TADT, and TRDT).
- TNZ medium and heavy axle configuration classes (3-13, inclusive).
- TNZ length category.

The loading data for each of these classifications was averaged for all vehicle records, for each site and for each year.

The average ESA (ESA4, ESA5, ESA7, and ESA12) were then calculated by type, for all of the above classifications, and summarised in tabular form for each WIM site.

This data could then be compared for consistency between sites and between years 2001 and 2002. The overall ESA values were determined for each site and compared, for instance, with the previous ESA data reported in Transfund Research Report No. 185 ("Methods to Establish Design 'Traffic' Loading", Bartley Consultants Ltd 2000), based on much smaller (i.e. 8-hour) samples from each WIM site.

5.3 Results

For convenience, the results of the detailed analyses have been listed in Tables 5.1, 5.2, 5.3 and 5.4. The size of the vehicle sample at each site was very large, and accordingly, the average ESA results should be as accurate as the particular equipment could measure at each site.

Table 5.1 ESA values for State Highway 1 at Drury.

Year: 2001					
Class	**Sample Size**	**Average ESA4**	**Average ESA5**	**Average ESA7**	**Average ESA12**
SAST	327559	0.58	0.58	0.63	1.05
SADT	168333	0.18	0.16	0.15	0.26
TADT	411675	0.50	0.49	0.53	0.92
TRDT	81481	0.38	0.36	0.35	0.48
TNZ Class 3	90291	0.27	0.22	0.18	0.32
TNZ Class 4	32301	1.14	1.12	1.21	2.30
TNZ Class 5	6188	0.27	0.21	0.16	0.17
TNZ Class 6	14850	0.45	0.40	0.38	0.78
TNZ Class 7	9998	0.65	0.55	0.47	0.65
TNZ Class 8	7888	1.60	1.57	1.69	3.46
TNZ Class 9	51255	1.91	1.94	2.15	3.72
TNZ Class 10	9838	3.50	3.74	4.47	8.52
TNZ Class 11	28899	3.64	3.83	4.43	8.22
TNZ Class 12	45090	1.48	1.37	1.29	1.64
TNZ Class 13	30957	2.01	1.92	1.86	2.20
5.5 m-11.0 m	107075	0.38	0.34	0.33	0.63
11.0 m-17.0 m	65357	1.18	1.14	1.19	2.02
> 17.0 m	156947	2.16	2.17	2.34	3.87
TOTAL	**327559**	**454720**	**448754**	**477674**	**803415**
Average ESA		**1.39**	**0.99**	**1.06**	**1.68**

Year: 2002					
Class	**Sample Size**	**Average ESA4**	**Average ESA5**	**Average ESA7**	**Average ESA12**
SAST	308813	0.55	0.55	0.59	1.00
SADT	154043	0.17	0.15	0.14	0.23
TADT	390961	0.47	0.46	0.48	0.79
TRDT	76812	0.35	0.32	0.30	0.36
TNZ Class 3	84104	0.26	0.21	0.17	0.28
TNZ Class 4	30855	1.08	1.06	1.11	2.07
TNZ Class 5	5988	0.21	0.16	0.12	0.11
TNZ Class 6	13835	0.39	0.33	0.30	0.52
TNZ Class 7	10393	0.63	0.54	0.46	0.65
TNZ Class 8	7323	1.57	1.54	1.64	2.95
TNZ Class 9	48068	1.80	1.81	1.96	3.28
TNZ Class 10	8497	3.31	3.51	4.15	7.77
TNZ Class 11	27974	3.52	3.67	4.20	7.73
TNZ Class 12	42356	1.35	1.23	1.13	1.38
TNZ Class 13	29417	1.87	1.76	1.67	1.92
5.5 m-11.0 m	103917	0.38	0.33	0.31	0.55
11.0 m-17.0 m	67728	1.27	1.23	1.26	1.95
> 17.0 m	137168	2.04	2.03	2.16	3.57
TOTAL	**308813**	**405351**	**395805**	**414038**	**678193**
Average ESA		**1.31**	**0.98**	**1.05**	**1.64**

Table 5.2 ESA values for State Highway 2 at Te Puke.

Year: 2001					
Class	**Sample Size**	**Average ESA4**	**Average ESA5**	**Average ESA7**	**Average ESA12**
SAST	117105	0.51	0.60	1.34	60.33
SADT	70078	0.16	0.15	0.19	1.07
TADT	144634	0.42	0.40	0.41	0.89
TRDT	15762	0.36	0.33	0.33	0.96
TNZ Class 3	39237	0.57	0.81	2.64	152.21
TNZ Class 4	8536	0.87	0.88	1.21	31.17
TNZ Class 5	4159	0.52	0.71	2.15	136.10
TNZ Class 6	4822	0.30	0.25	0.26	1.45
TNZ Class 7	5863	0.60	0.69	1.38	33.28
TNZ Class 8	2363	1.27	1.33	1.89	19.29
TNZ Class 9	9483	1.55	1.52	1.57	4.40
TNZ Class 10	2075	2.24	2.33	2.85	20.27
TNZ Class 11	12911	2.61	2.67	2.98	7.84
TNZ Class 12	21532	1.47	1.34	1.22	1.40
TNZ Class 13	5956	2.10	1.97	1.84	1.94
5.5 m-11.0 m	45231	0.42	0.49	1.24	69.23
11.0 m-17.0 m	17444	1.02	1.06	1.63	40.40
> 17.0 m	54430	1.85	1.92	2.74	63.36
TOTAL	**117105**	**137344**	**145031**	**233643**	**7284844**
Average ESA		**1.17**	**1.06**	**1.61**	**31.18**

Year: 2002					
Class	**Sample Size**	**Average ESA4**	**Average ESA5**	**Average ESA7**	**Average ESA12**
SAST	146783	0.42	0.42	0.43	0.68
SADT	75907	0.14	0.12	0.11	0.15
TADT	211819	0.44	0.43	0.43	0.69
TRDT	22671	0.37	0.35	0.32	0.39
TNZ Class 3	39386	0.22	0.17	0.13	0.15
TNZ Class 4	12358	0.85	0.82	0.86	1.65
TNZ Class 5	3125	0.09	0.07	0.05	0.11
TNZ Class 6	6972	0.29	0.25	0.29	2.60
TNZ Class 7	4964	0.38	0.33	0.28	0.39
TNZ Class 8	2543	1.08	1.01	0.98	1.34
TNZ Class 9	13783	1.61	1.58	1.63	2.38
TNZ Class 10	2892	2.10	2.15	2.42	4.22
TNZ Class 11	18278	2.81	2.89	3.25	5.63
TNZ Class 12	33511	1.50	1.38	1.28	1.48
TNZ Class 13	8967	2.16	2.04	1.92	2.07
5.5 m-11. 0m	55153	0.32	0.28	0.26	0.53
11.0 m-17.0 m	21089	0.99	0.95	0.95	1.86
> 17.0 m	70541	1.94	1.89	1.93	2.81
TOTAL	**146783**	**175299**	**168409**	**170717**	**266282**
Average ESA		**1.19**	**0.96**	**1.01**	**1.56**

Table 5.3 ESA values for State Highway 1 at Tokoroa.

Year: 2001					
Class	**Sample Size**	**Average ESA4**	**Average ESA5**	**Average ESA7**	**Average ESA12**
SAST	90410	0.46	0.43	0.42	0.56
SADT	34878	0.20	0.17	0.14	0.24
TADT	145840	0.32	0.28	0.25	0.28
TRDT	20783	0.33	0.29	0.24	0.72
TNZ Class 3	10618	0.45	0.37	0.30	0.40
TNZ Class 4	9450	0.95	0.88	0.82	1.11
TNZ Class 5	1618	0.43	0.35	0.26	0.23
TNZ Class 6	7744	0.23	0.17	0.13	0.23
TNZ Class 7	2772	0.91	0.78	0.66	0.72
TNZ Class 8	5056	1.37	1.26	1.19	1.54
TNZ Class 9	9547	1.71	1.64	1.64	3.25
TNZ Class 10	2026	1.93	1.86	1.89	3.26
TNZ Class 11	10656	1.71	1.61	1.53	2.02
TNZ Class 12	19587	0.96	0.82	0.68	0.65
TNZ Class 13	11237	1.65	1.48	1.30	1.46
5.5 m-11.0 m	26383	0.54	0.47	0.41	0.57
11.0 m-17.0 m	18522	1.42	1.33	1.28	1.90
> 17.0 m	45505	1.34	1.21	1.09	1.43
TOTAL	**90410**	**101446**	**92007**	**84034**	**115068**
Average ESA		**1.12**	**0.91**	**0.91**	**1.37**

Year: 2002					
Class	**Sample Size**	**Average ESA4**	**Average ESA5**	**Average ESA7**	**Average ESA12**
SAST	128570	0.41	0.38	0.36	0.46
SADT	60394	0.16	0.13	0.11	0.16
TADT	198265	0.32	0.28	0.24	0.27
TRDT	27924	0.29	0.24	0.19	0.42
TNZ Class 3	23869	0.25	0.19	0.14	0.16
TNZ Class 4	10991	0.93	0.86	0.79	1.04
TNZ Class 5	2027	0.31	0.24	0.17	0.20
TNZ Class 6	9171	0.25	0.18	0.13	0.29
TNZ Class 7	3710	0.83	0.71	0.58	0.65
TNZ Class 8	5089	1.46	1.35	1.27	1.79
TNZ Class 9	12950	1.58	1.49	1.43	2.33
TNZ Class 10	2414	2.16	2.09	2.12	3.04
TNZ Class 11	13646	1.86	1.76	1.70	2.39
TNZ Class 12	29473	1.00	0.85	0.68	0.60
TNZ Class 13	15170	1.52	1.34	1.13	1.13
5.5 m-11.0 m	39602	0.41	0.34	0.29	0.37
11.0 m-17.0 m	20552	1.26	1.17	1.10	1.52
> 17.0m	68416	1.33	1.19	1.06	1.30
TOTAL	**128570**	**133361**	**119330**	**106152**	**134805**
Average ESA		**1.04**	**0.89**	**0.89**	**1.27**

Table 5.4 ESA values for State Highway 1 at Waipara.

Year: 2001					
Class	**Sample Size**	**Average ESA4**	**Average ESA5**	**Average ESA7**	**Average ESA12**
SAST	126989	0.34	0.31	0.29	0.66
SADT	59650	0.17	0.15	0.13	0.19
TADT	185910	0.40	0.38	0.39	0.70
TRDT	28240	0.35	0.30	0.25	0.23
TNZ Class 3	29449	0.24	0.19	0.16	1.57
TNZ Class 4	9184	0.88	0.83	0.84	1.70
TNZ Class 5	2955	0.18	0.14	0.10	0.11
TNZ Class 6	8034	0.40	0.36	0.38	1.71
TNZ Class 7	4544	0.44	0.37	0.30	0.42
TNZ Class 8	2422	1.35	1.27	1.24	1.81
TNZ Class 9	14041	1.76	1.70	1.70	2.37
TNZ Class 10	1519	2.06	2.07	2.30	4.43
TNZ Class 11	7643	2.37	2.37	2.59	5.04
TNZ Class 12	32827	1.34	1.24	1.20	1.73
TNZ Class 13	14368	1.63	1.44	1.21	1.04
5.5 m-11.0 m	41351	0.33	0.29	0.39	1.60
11.0 m-17.0 m	18959	0.98	0.92	0.89	1.47
> 17.0 m	66679	1.58	1.48	1.43	2.08
TOTAL	**126989**	**137242**	**127738**	**124257**	**232505**
Average ESA		**1.08**	**1.01**	**0.97**	**1.87**

Year: 2002					
Class	**Sample Size**	**Average ESA4**	**Average ESA5**	**Average ESA7**	**Average ESA12**
SAST	153576	0.32	0.30	0.27	0.32
SADT	69411	0.17	0.16	0.16	0.35
TADT	224594	0.38	0.37	0.37	0.73
TRDT	34350	0.33	0.29	0.23	0.22
TNZ Class 3	35592	0.23	0.18	0.14	0.20
TNZ Class 4	11709	0.86	0.81	0.81	1.64
TNZ Class 5	3775	0.17	0.13	0.10	0.10
TNZ Class 6	9441	0.38	0.34	0.35	1.06
TNZ Class 7	5499	0.41	0.33	0.26	0.24
TNZ Class 8	3101	1.26	1.17	1.12	1.69
TNZ Class 9	16771	1.69	1.62	1.60	2.27
TNZ Class 10	1478	1.99	2.01	2.28	4.85
TNZ Class 11	9677	2.21	2.20	2.43	5.37
TNZ Class 12	38823	1.31	1.23	1.24	2.22
TNZ Class 13	17710	1.53	1.34	1.11	0.97
5.5 m-11.0 m	50532	0.33	0.28	0.27	0.56
11.0 m-17.0 m	25263	0.99	0.92	0.88	1.28
> 17.0 m	77781	1.52	1.42	1.40	2.36
TOTAL	**153567**	**159423**	**148145**	**144592**	**243912**
Average ESA		**1.04**	**0.96**	**0.98**	**1.69**

Comparing each of Tables 5.1 to 5.4 across the WIM sites shows that there were considerable differences in ESA between the four sites by TNZ class and somewhat lesser differences in ESA between sites for the three TNZ length categories. In respect of the three length categories, the range in ESA4 across the sites is as shown in Table 5.5.

Table 5.5 Relationship of ESA4 to length category.

TNZ Length Category	ESA4 by Site and Year							
	Drury		Te Puke		Tokoroa		Waipara	
	2001	2002	2001	2002	2001	2002	2001	2002
5.5 - 11.0 m	0.38	0.38	0.32	0.32	0.54	0.41	0.33	0.33
11.0 - 17.0 m	1.18	1.27	1.02	0.99	1.42	1.26	0.98	0.99
>17.0 m	2.16	2.04	1.85	1.94	1.34	1.33	1.58	1.52

Accordingly, the ESA4 values vary across the four WIM sites between the different length classes as follows:

- 5.5 - 11.0 m : 0.32 - 0.54
- 11.0 - 17.0 m : 0.98 - 1.42
- >17.0 m : 1.33 - 2.16

Table 5.6 is a summary showing the number of 2001 (20 June–31 December) and 2002 (1 January–31 August) records available from each WIM site, together with the ESA results by site and by year.

Table 5.6 ESA data with respect to WIM site.

Site	Year	No of Records	Mean ESA4	Mean ESA5	Mean ESA7	Mean ESA12
Drury	2001	327,559	1.39	0.99	1.06	1.68
	2002	308,813	1.31	0.98	1.05	1.64
Te Puke	2001	117,105	1.17	1.06	1.61	1.61
	2002	146,783	1.19	0.96	1.01	1.56
Tokoroa	2001	90,410	1.12	0.91	0.91	1.37
	2002	128,570	1.04	0.89	0.89	1.27
Waipara	2001	126,989	1.08	1.01	0.97	1.87
	2002	153,576	1.04	0.96	0.98	1.69
Range			1.04-1.39	0.89-1.06	0.89-1.61	1.27-1.87

These results may be compared with the 1999 values in Table 3.3 of Transfund Report No. 185 in Table 5.7. Note the relatively large differences in the ESA results obtained from this current research as compared with the ESA values reported in Transfund Report 185. Reviewing the ESA4 results across all sites shows that the 2002 results at Drury were 9% higher, whereas at Te Puke and Waipara, the 2002 results were approximately 75% of the previously reported ESA4. At Tokoroa, the 2002 result was only 32% of the previously reported result. This is most likely attributable to previous technical problems at the Tokoroa site.

Table 5.7 ESA data with respect to WIM site.

Site	Year	No of Records	Mean ESA4	Mean ESA5	Mean ESA7	Mean ESA12
Drury	2002	308,813	1.31	0.98	1.05	1.64
	1999	3,504	1.20	1.16	1.20	2.00
Te Puke	2002	146,7835	1.19	0.96	1.01	1.56
	1999	1,958	1.65	1.74	2.13	5.42
Tokoroa	2002	128,570	1.04	0.89	0.89	1.27
	1999	1,294	3.22	4.07	7.80	81.67
Waipara	2002	153,576	1.04	0.96	0.98	1.69
	1999	821	1.38	1.38	1.58	4.08

5.4 Conclusions

A large sample of data is now available for each of the WIM sites, from which ESA values can be determined by Transit vehicle classes and length categories. The ESA values for this project have been derived from a relatively large sample (continuous 12-month record) as compared to the smaller sample size used in Transfund Research Report 185. While it is not possible to comment on the results of Transfund Research Report 185, it is considered that this current research has a relatively high level of precision, given the large sample size.

In reviewing the detailed ESA results that are available from the WIM sites, it needs to be recognised that the axle group configurations and their ESAs upon which pavement design is based, are currently only obtainable from the four WIM sites.

It is recommended that the values of ESA from this research be made available to pavement designers. However, in view of some problems with equipment that were identified at the Te Puke and Tokoroa WIM sites, the ESA data from these sites should be used with caution. Notably, the Drury site, which is on a 'Rural Fringe' type road, has a higher mean ESA than the other sites, which are all 'Rural Strategic' roads. However, the evidence is insufficient to indicate whether the different ESA is indicative of road type or traffic volumes. The results do, however, suggest that the TNZ class 10 and 11 vehicles have an ESA4 some 50% higher at the Drury site than at the other sites.

5.5 Recommendations

- That these ESA data be publicised to New Zealand pavement designers.
- That the analysis of the data be repeated for all sites, subject to rectification of the equipment at the Te Puke and Tokoroa sites, before using the results for these locations.

6. Conclusions and Recommendations

6.1 Summation

For completeness, this section contains a summation of all of the conclusions and recommendations that have been separately reported for the individual stages of this research.

6.2 Conclusions

- It is inappropriate to attempt to develop precise relationships between vehicle length and Transit Vehicle Classes, since the variation within and between sites is greater than expected (Stage 2).
- Although it may ultimately be possible to develop an algorithm to predict the detailed composition and ESAs from Length Categories, the usefulness of such an algorithm is considered marginal in relation to the required accuracy needed for current pavement design inputs.
- While the distributions of first axle spacings are not statistically different, a nominal threshold of 3.8 m has been found to differentiate between non-twin-steer truck and trailers (> 3.8 m) and B-trains and semi-trailers (< 3.8 m).
- A-trains cannot be distinguished from truck and trailers based on first axle spacing. Rather, they can be distinguished by their number of axle sets (typically five) as compared with the four axle sets of other 7 and 8 axle vehicles.
- In relation to the spacing between the first two axles, a nominal threshold of 2.2 m has been found to distinguish twin-steer rigid trucks (< 2.2 m) from non-twin-steer rigid trucks (> 2.2 m)
- Commodity surveys cannot be usefully undertaken without stopping the traffic and interviewing each driver as to type and status of load (Stage 2). Visual inspections of moving vehicles are no longer a satisfactory method of commodity survey, and the stopping of vehicles to determine the commodities carried is often impracticable, particularly on busy State Highways.
- Manual surveys (person or video) can be used to classify trucks, but are only practicable at sites with overall traffic volumes up to a threshold of around 7,000 vpd (Stage 3).
- Temporary classifier equipment (e.g. Peak ADR used in Stage 3 of this research) is able to identify a more comprehensive range of vehicle types (e.g. Transit Vehicle Classes 1-13) than current telemetry equipment, and accordingly is likely to be more useful for obtaining the necessary ESA values for pavement design purposes.
- Telemetry data is currently limited in its usefulness since the sites are almost all restricted to State Highways, and therefore to 'rural strategic' and 'rural fringe' road categories.
- The surveys (Stage 3) showed that the variability between survey types (visual, axle groups and length category) within sites was reasonable (with some noted exceptions), but difference in the vehicle class patterns between sites was greater than anticipated. Although an important finding, because the road use category for each site was the same (rural strategic), this outcome contrasts with

the findings from Stage 1. Such an outcome is likely a result of the small sample size (3 sites), the duration of surveys (3 hours), and the survey precision.

- It is difficult to determine whether a true seasonal variation or even daily variation exists, as the precision of the monitoring equipment could mask any such variability.
- The Stage 4 and 5 results provide useful site specific ESA data by Transit Vehicle Class and Vehicle Length Category. These results are at some variance with previous ESA data published by Transfund that were based on much smaller samples of data. Again, greater accuracy is likely to be obtained if data is available for one or more full calendar years at each site.

6.3 Recommendations

- The default values of vehicle composition used by the PEM be updated based on the more extensive survey data now available, as reported in Stage 1.
- The nominal thresholds for axle spacings identified in this research be used with machine counts to differentiate between different types of heavy vehicle.
- For pavement design purposes, it may be appropriate to separately redefine road categories based on heavy traffic patterns only, as these are found to be different for the same road categories based on overall (light plus heavy) vehicle traffic patterns.
- Based on the knowledge gained from the detailed statistical analysis undertaken in Stage 4, it is now considered that a minimum of three years continuous and verifiably reliable data for all four WIM sites (preferably more if possible) are necessary to produce meaningful week factors or 3-hour factors. Accordingly, it is recommended that the week factors be reviewed and updated as necessary, once a full 12 months WIM data is available, and subject to rectification of the WIM equipment at the Te Puke and Tokoroa sites.
- It is further recommended that a sensitivity analysis be undertaken to determine the level of accuracy of ESA data required by way of design inputs into current design methods, for a typical range of New Zealand roads.
- That the ESA data developed in this research be publicised to NZ pavement designers (Stage 5).

7. References

Bartley Consultants Ltd. 2000. Methods to establish design 'traffic' loading. *Transfund Research Report No. 185.* 89pp.

Traffic Design Group. 2001. Guide to estimation and monitoring of traffic counting and traffic growth. *Transfund Research Report No. 205.* 54pp.

Transfund New Zealand. 1997. *Project evaluation manual.* Transfund Manual PFM2. Transfund NZ. Wellington.

Transit New Zealand. 2000. New Zealand supplement to the document, *Pavement Design – A guide to the structural design of road pavement* (Austroads, 1992).20pp.

Appendices

A Comparison of Transit Vehicle Classification Scheme with Other Vehicle Classification Systems

B Comparisons between WIM Sites of:
- The Proportion of Vehicles in each TNZ Class
- The Relationship of each TNZ Axle Class with vehicle Length
- The Proportion of each Vehicle Type in each of the four TNZ Length Classes

C Class Relationships

D Average Weights and Temperatures

E Regression of Weights versus Temperatures

F. Regression of Weights versus Weight Class and Site

G. Regression of Weights versus Sites and Days of Year

H. ESA4 Computed Average Values per Vehicle Classification Scheme

I. Residual Plots for Regression of ESA4s versus Sites and Days of Year

J. Plots for Average Weekly Multipliers for Converting Week ESA4s to Annual ESA4

K. Plots for Average Weekly Multipliers for Converting Vehicle Counts to Annual ESA4

L. Average Weekly Multipliers for Converting Week ESA4s to Annual ESA4

M. Average Weekly Multipliers for Converting Vehicle Counts to Annual ESA4, each WIM site

N. Average Weekly Multipliers for Converting Vehicle Counts to Annual ESA4, combination of Drury and Waipara

O. 95% Margin of Error for Converting Vehicle Counts to Annual ESA4

P. Average Weekly Multipliers Three-Hour Counts for Converting Week ESA4s to Annual ESA4

Q. Average Weekly Multipliers Three-Hour Counts for Converting Vehicle Counts to Annual ESA4, each WIM Site

R. Average Weekly Multipliers Three-Hour Counts for Converting Vehicle Counts to Annual ESA4, combination of Drury and Waipara

S. 95% Margin of Error for Weekly Multipliers using Three-Hour Counts

T. Average Weekly Multipliers Eight-Hour Counts for Converting Weekly ESA4s to Annual ESA4 based on Weekly Average ESA4 per Hour

U. Average Weekly Multipliers Eight-Hour Counts for Converting Vehicle Counts to Annual ESA4, each WIM Site

V. Average Weekly Multipliers Eight-Hour Counts for Converting Vehicle Counts to Annual ESA4, combination of Drury and Waipara

W. 95% Margin of Error for Weekly Multipliers using Eight-Hour Counts

Appendix A

Comparison of Transit Vehicle Classification Scheme with other Vehicle Classification Systems

Transit New Zealand – Vehicle Classification Scheme (TNZ 1999)

Class	Axles	Distinguishing Features or Identification Algorithm	Vehicle Types in Class	% of Total HMV	Length Range (WIM Data)	RUC Class	TNZ Length Class	DKW Class	Austroads Class	Light or Heavy	Axle Groups (Pave. Des.)	PEM Class
1	2	No of axles & wb < 3.2m	o-o (short vehicle)				S		1	Light		Car & LCV
2	3	3 axles & sp ax1-ax2 < 3.2m or 4 axles & (sp ax1-ax2 < 3.2 & > 2.2) & sp ax3-ax4 <= 1.0m	o-o-o (short veh. towing) o-o-oo (short veh. towing)				S/M S/M		2 2	Light		Car & LCV
3	2	No of axles & wb>= 3.2m	o--o (long vehicle)	28	4m – 11m	2	M	3,4	3	Heavy	1s,1d	MCV
4	3	No. of axles & sp ax1-ax2 .=3.2m & sp ax2-ax3 <= 2.2m	o--oo	11	7m – 12m	6	M/L	5	4	Heavy	1s,2	HCV1
5	3	No. of axles & sp ax1-ax2 >= 3.2m & sp ax2-ax3 > 2.2m	o-o--o	3	6m – 15m	2,24	M/L	7	6	Heavy	1s,1d,1d	HCV1
6	4	No. of axles & sp ax1-ax2 <= 2.2m	oo--oo	4	8m -11m	14	M	6	5	Heavy	1s,1d,1d,1d	HCV1
7	4	No. of axles & sp ax1-ax2 >2.2m & sp ax3-ax4 > 1.0m	o--o-o--o o-o--oo	2 2	8m – 19m 10m – 17m	2,30 2,29	M/L M/L	8 8	7 7	Heavy	1s,1d,1d,1d	HCV1
8	5	No. of axles	o--oo-o--o o-oo--oo	1 3	16m – 19m 1m-17m	6,30 6,29	L/VL L	9 9	8 8	Heavy	1s,2,1d,1d 1s,2,2	HCV2
9	6	No. of axles & sp ax1-ax2 > 2.2m & sp ax4 – ax5 <= 1.4m	o-oo--ooo	14	15m – 18m	6,33	L/VL	10	9	Heavy	1s,2,3	HCV2
10	6	No. of axles & sp ax1-ax2 > 2.2m & sp ax4-ax5 > 1.4m	o-oo-o--oo	2	16m – 20m	6,37	L/VL	11	9	Heavy	1s,2,1d,2	HCV2

Transit New Zealand – Vehicle Classification Scheme (TNZ 1999) - Continued

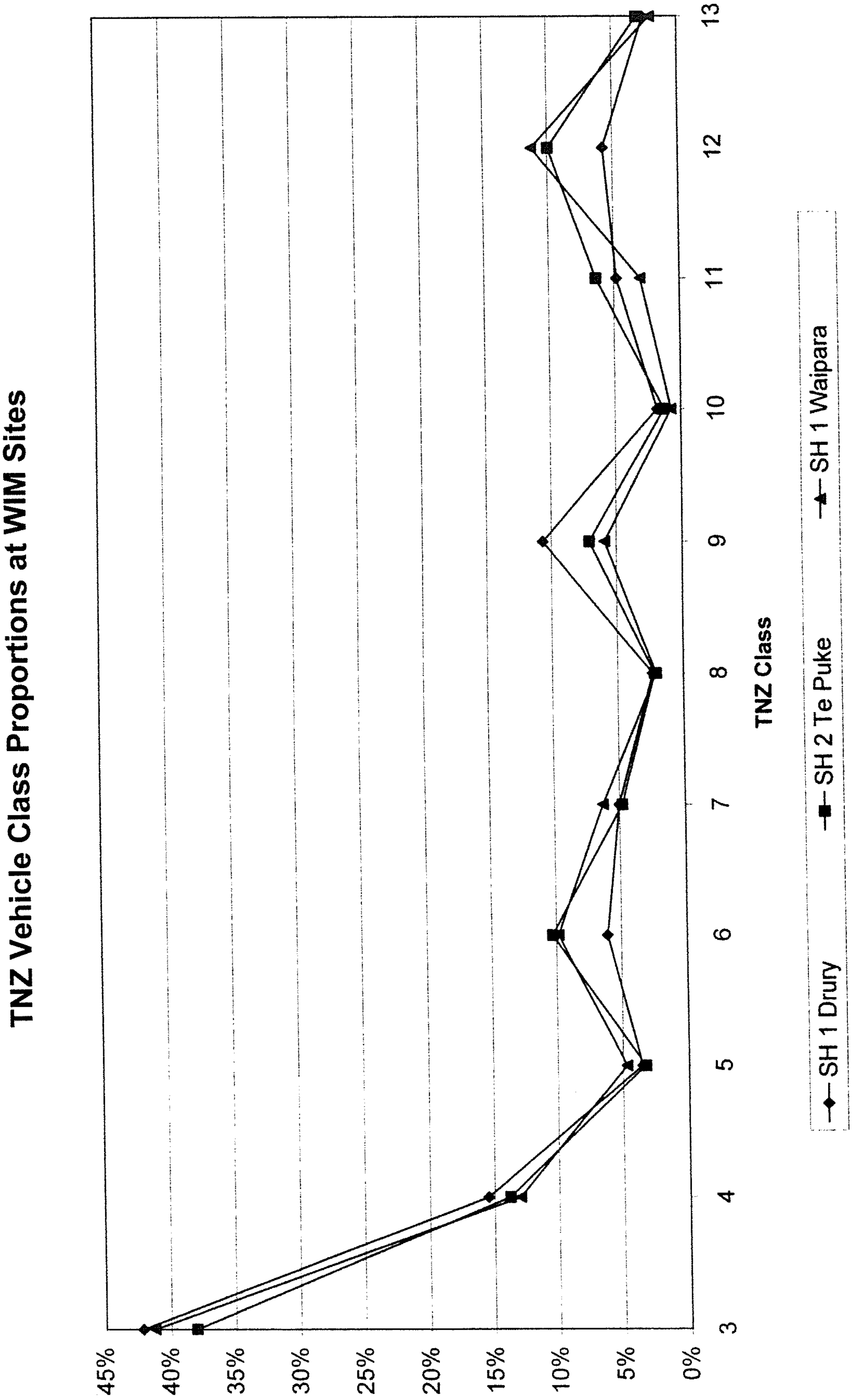
Class	Axles	Distinguishing Features or Identification Algorithm	Vehicle Types in Class	% of Total HMV	Length Range (WIM Data)	RUC Class	TNZ Length Class	DKW Class	Austroads Class	Light or Heavy	Axle Groups (Pave. Des.)	PEM Class
11	7	No. of axles & sp ax1-ax2 > 2.2m	o-oo--oo--oo (B-train)	4	18m – 21m	6,29,29	VL	12	10	Heavy	1s,2,2,2	HCV2
			o--oo-oo--oo (T & T)	4	18m – 21m	6,43	VL	13	10		1s,2,2,2	
			o-oo--oo-o--o (A-train)		18m – 21m	6,29,30	VL	14	10		1s,2,2,1d,1d	
12	6, 7, 8	No. of axles (6, 7, 0r 8) & sp ax1-1x2 <= 2.2m	oo--oo-o--o		15m – 20m	14,30	L/VL	13	9	Heavy	1s,1s,2,1d,1d	HCV2
			oo--oo-o--oo		17m – 21m	14,37	VL	13	10		1s,1s,2,1d,2	
			oo--oo-oo--oo	9	18m – 21m	14,43	VL	13	10			
13	8,9	No. of axles & sp ax1-ax2 > 2.2m	o-oo--ooo-o (B-train)	8	19m – 21m	6,33,29	VL	15	10	Heavy	1s,2,3,2	HCV2
			o-oo-ooo-o--o (A-train)		19m – 21m	6,33,30	VL	15	10		1s,2,3,1d,1d	
			o-oo-oo-o--oo (A-train)		19m – 21m	6,29,37	VL	15	10		1s,2,2,1d,2	
			o-oo--ooo--ooo (B-train)		19m – 21m	6,33,33	VL		10		1s,2,3,3	
14			Everything else									
							S 0.0 - 5.5m **M** 5.5 - 11.0m **L** 11.0 – 17.0m **VL** > 17.0m		Classes 11 & 12 not relevant in New Zealand		**1s** = SAST **1d** = SADT **2** = TADT **3b** =TRDT	

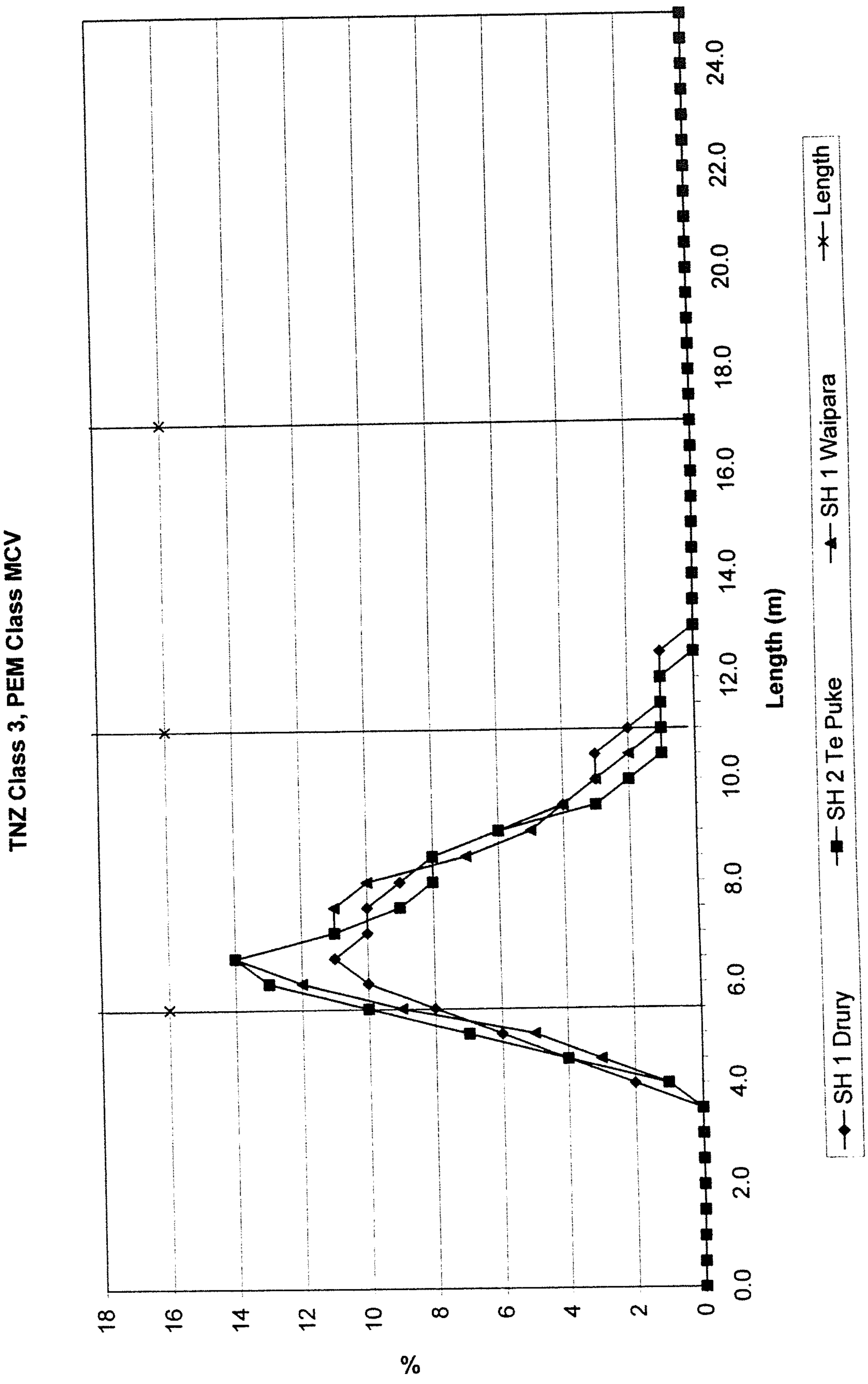
The current length scheme will remain in the meantime. The foundation it is based on is reasonably sound i.e. 5.5m is the approximate length of the longest common car on the road (Falcon station wagon). Eleven metres is the maximum allowable length of a rigid truck, and 17m is the maximum allowable length of a truck-semi trailer combination. The length classes approximate the PEM classes (with some minor adjustment at the low end).

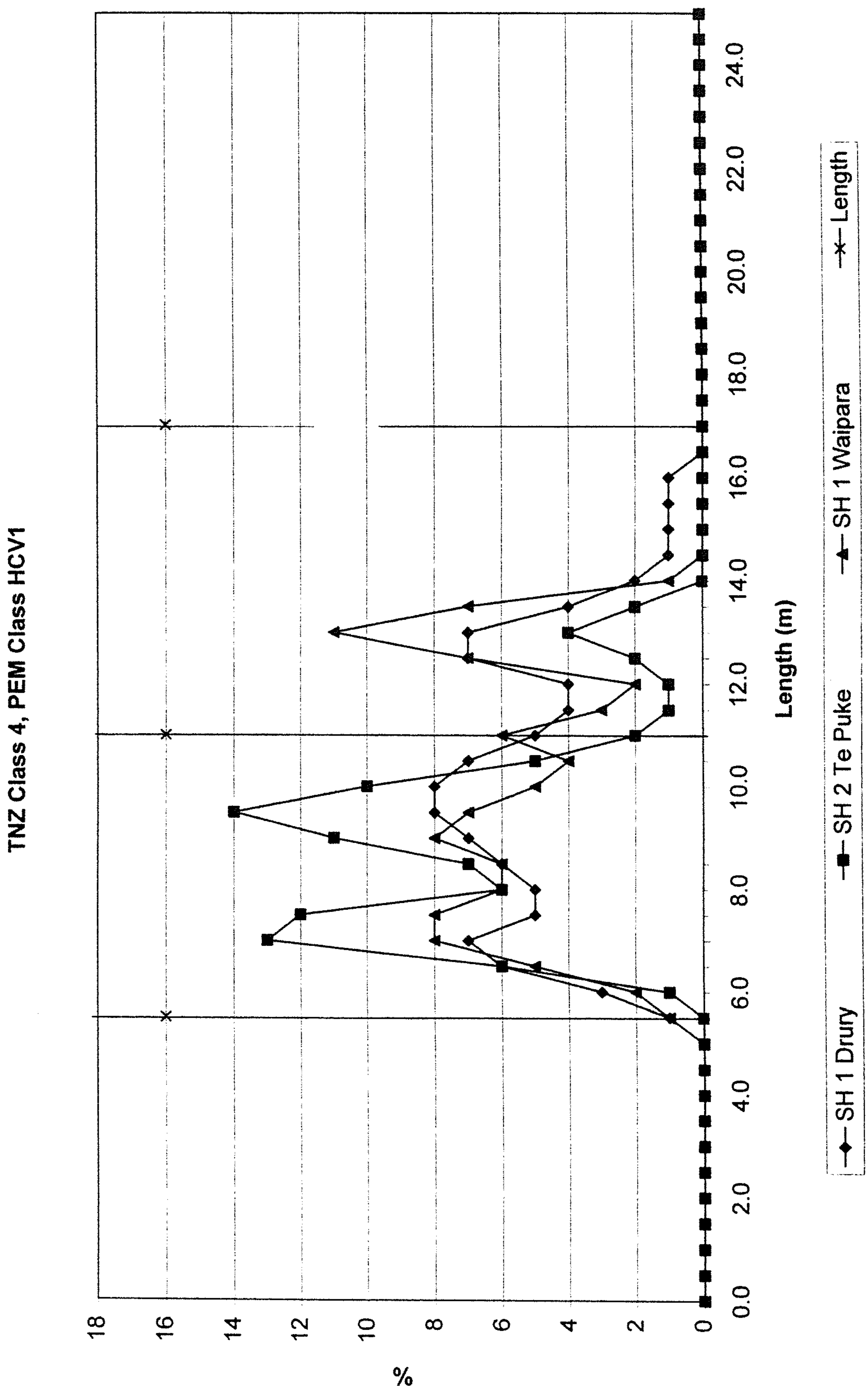
Appendix B

Comparisons between WIM Sites of:

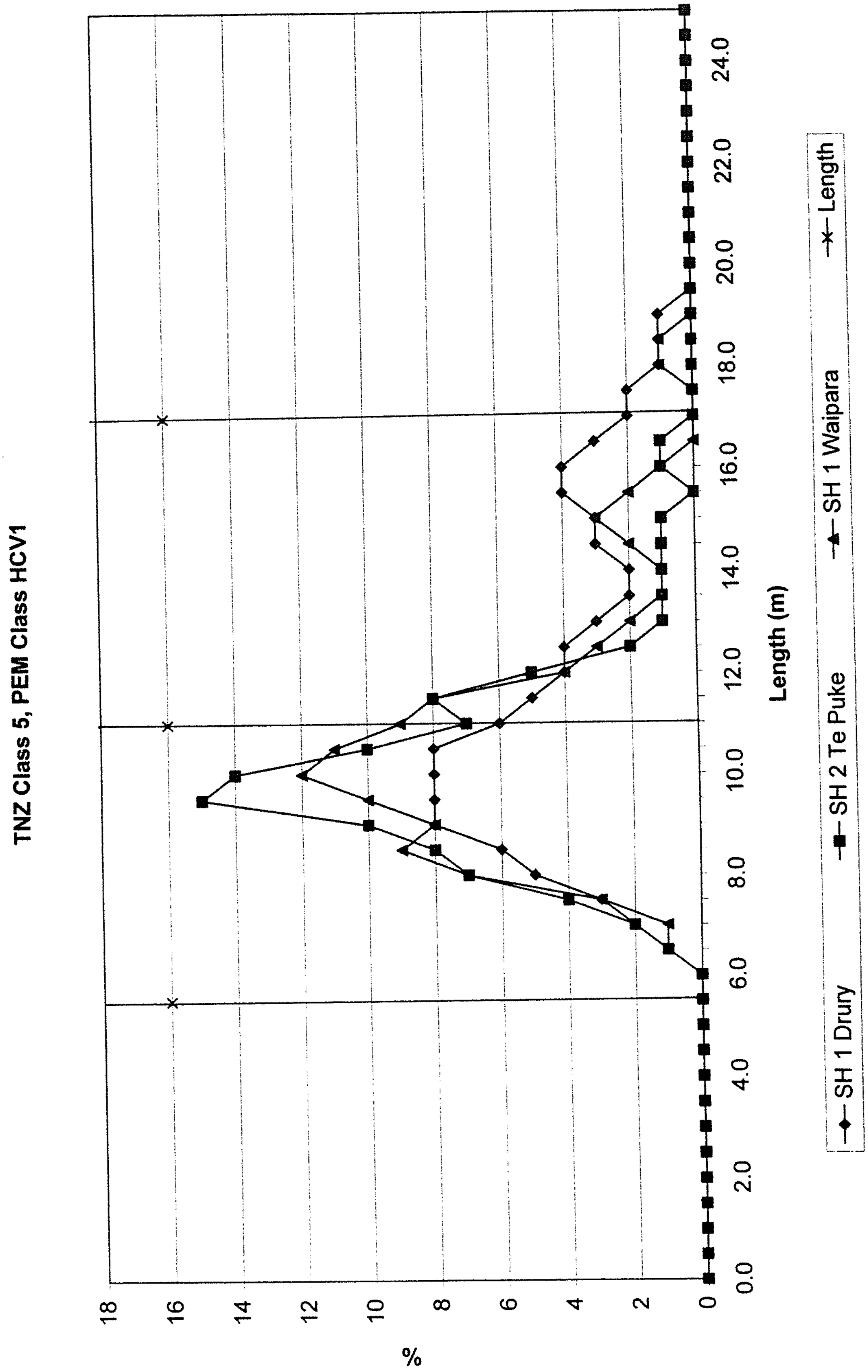
- **The Proportion of Vehicles in each TNZ Class**
- **The Relationship of each TNZ Axle Class (3-13) with Vehicle Length**
- **The Proportion of each Vehicle Type in each of the four TNZ Length Classes**

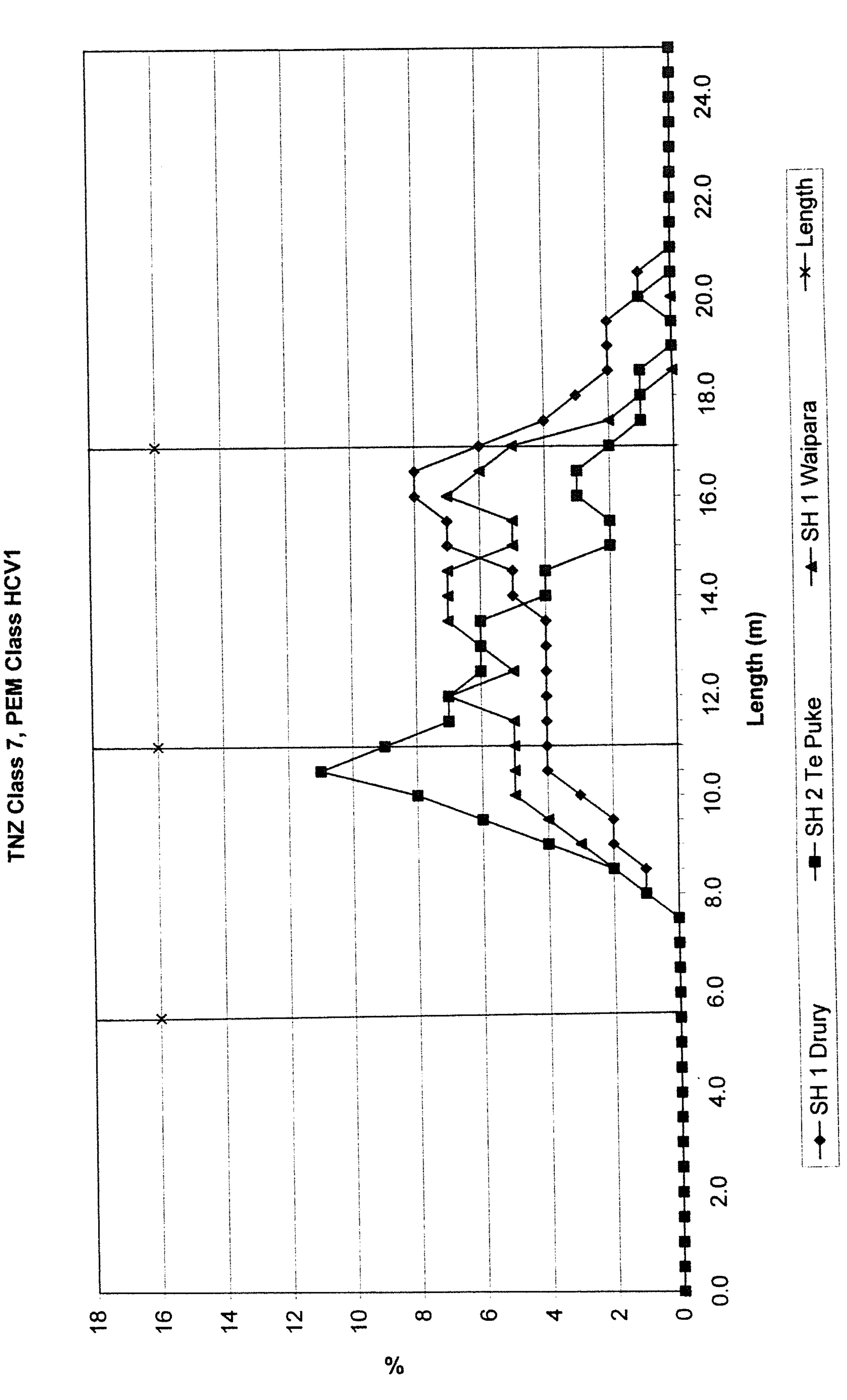

TNZ Vehicle Class Proportions at WIM Sites
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
3
4
5
6
7
8
9
10
11
12
13
TNZ Class
SH 1 Drury
SH 2 Te Puke
SH 1 Waipara


TNZ Class 3, PEM Class MCV
%
18
16
14
12
10
8
6
4
2
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
Length (m)
SH 1 Drury
SH 2 Te Puke
SH 1 Waipara
Length

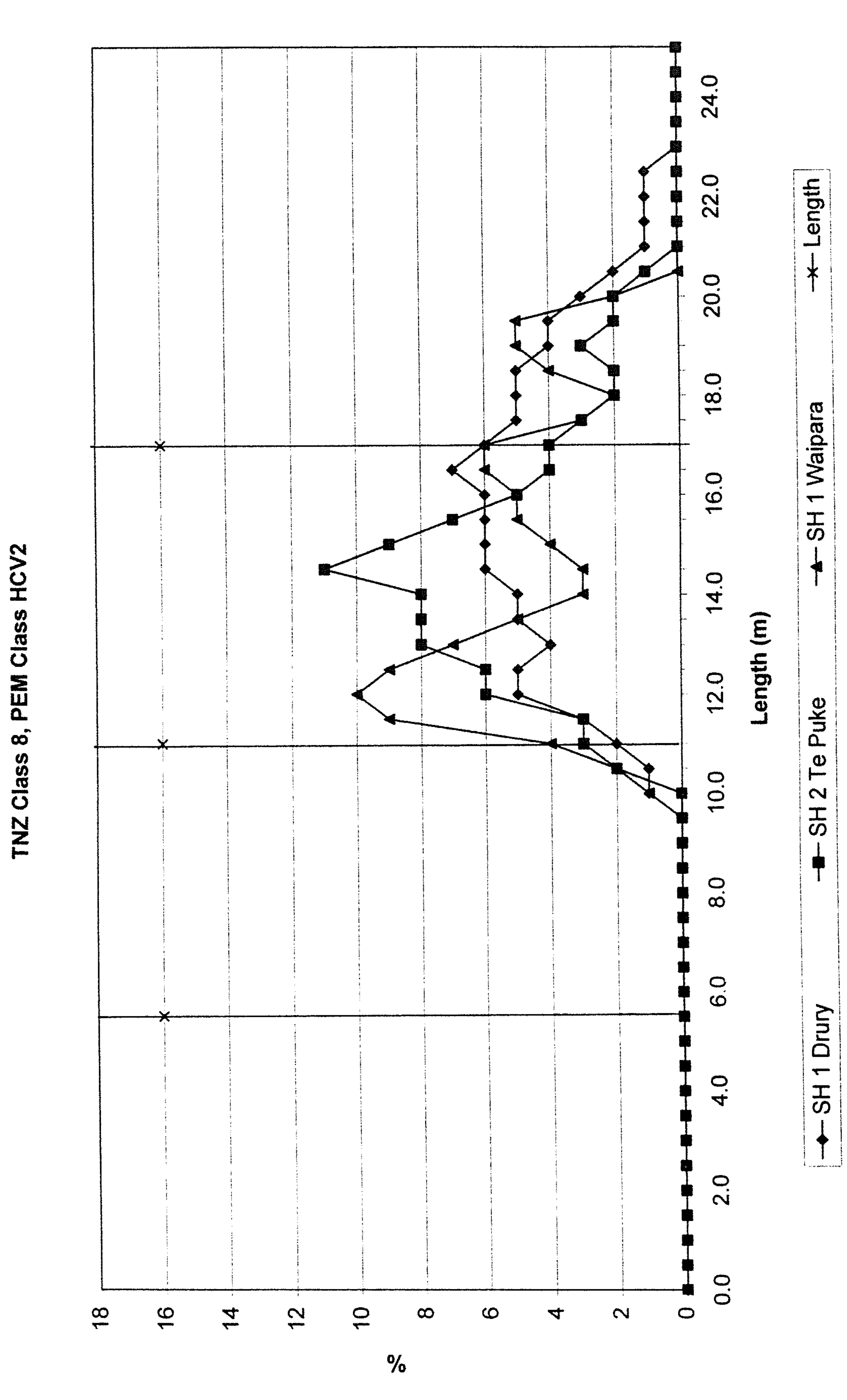


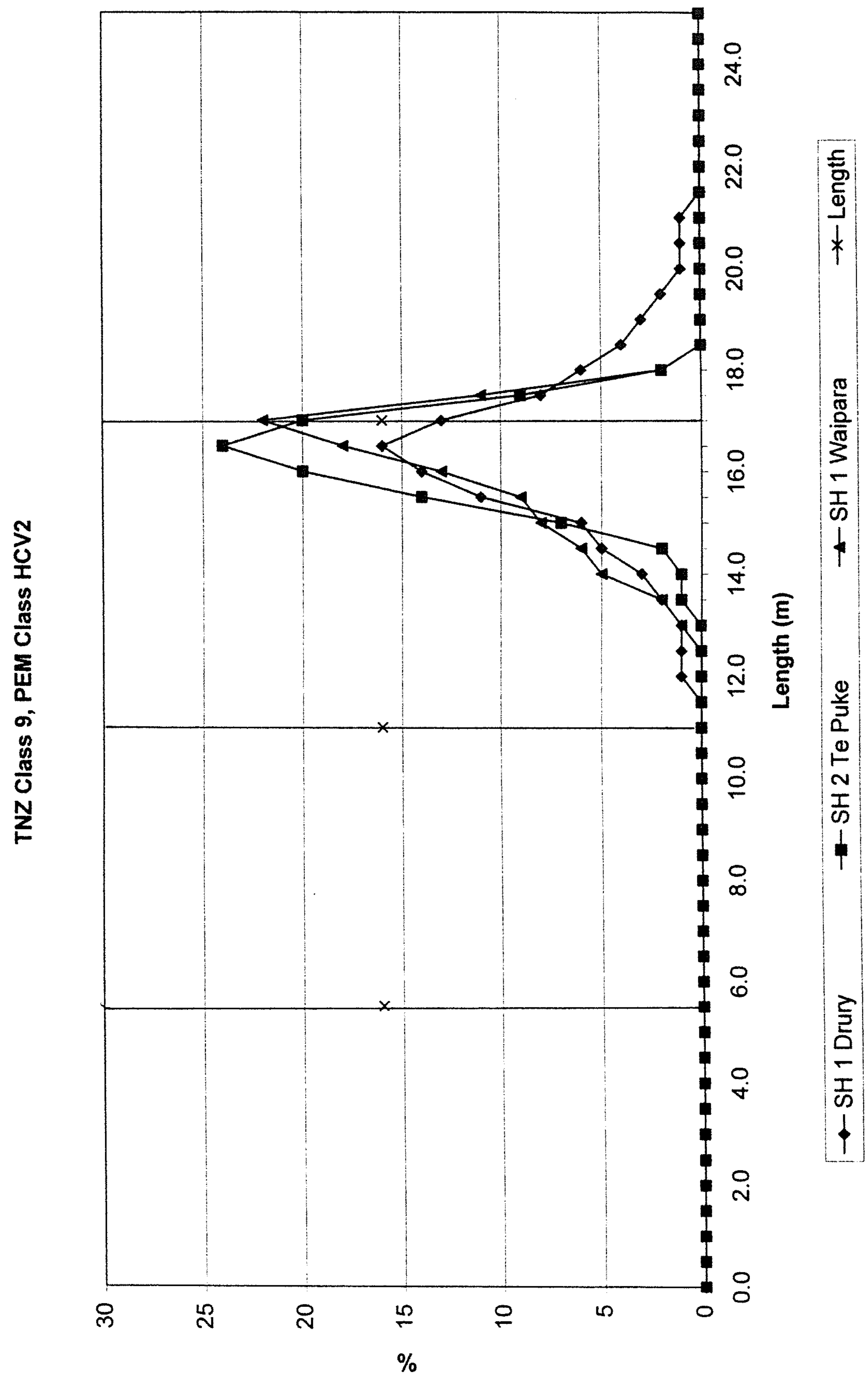
TNZ Class 4, PEM Class HCV1
%
18
16
14
12
10
8
6
4
2
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
Length (m)
SH 1 Drury
SH 2 Te Puke
SH 1 Waipara
Length

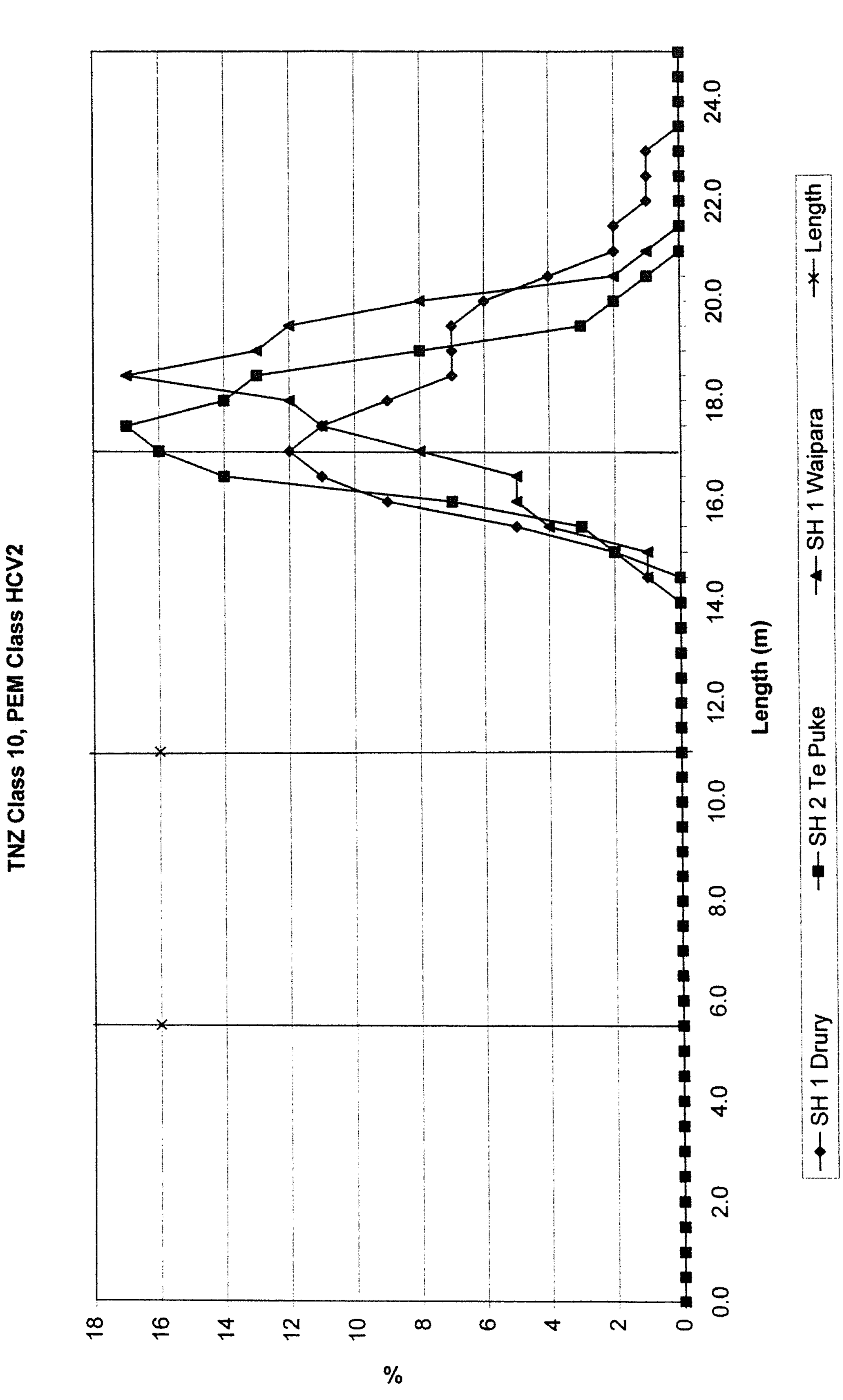

TNZ Class 5, PEM Class HCV1
%
18
16
14
12
10
8
6
4
2
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
Length (m)
SH 1 Drury
SH 2 Te Puke
SH 1 Waipara
Length

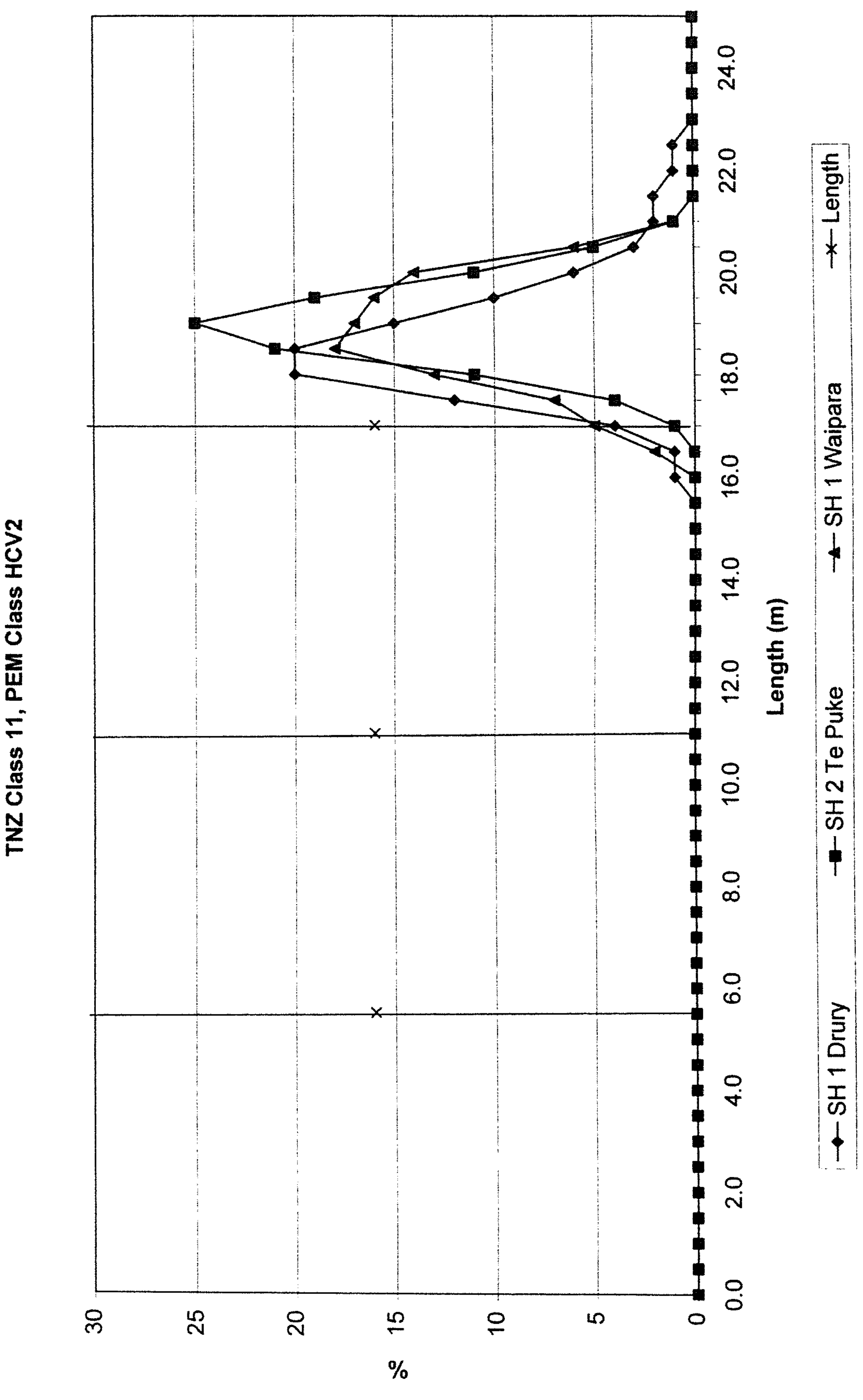


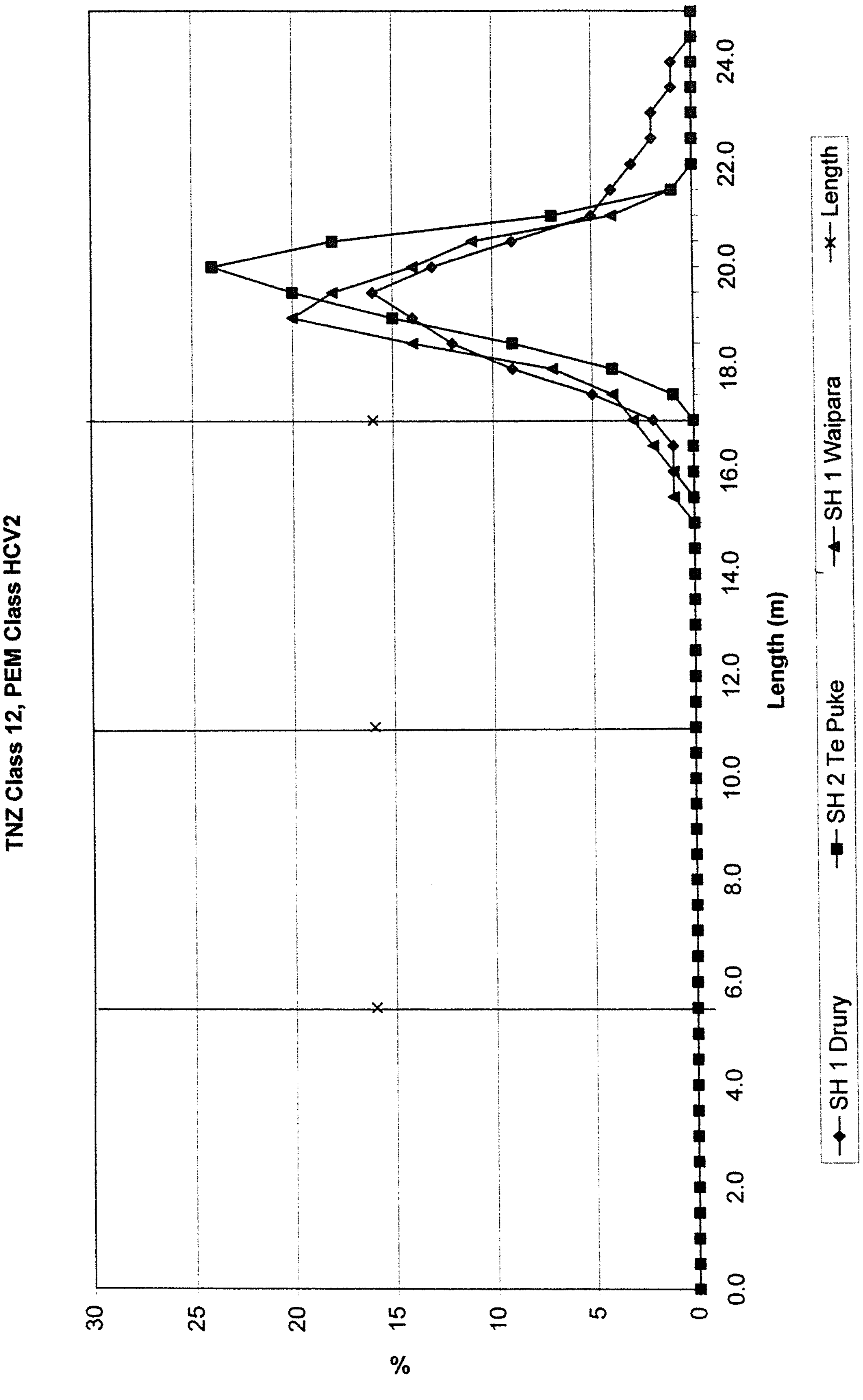
TNZ Class 7, PEM Class HCV1
%
18
16
14
12
10
8
6
4
2
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
Length (m)
SH 1 Drury
SH 2 Te Puke
SH 1 Waipara
Length

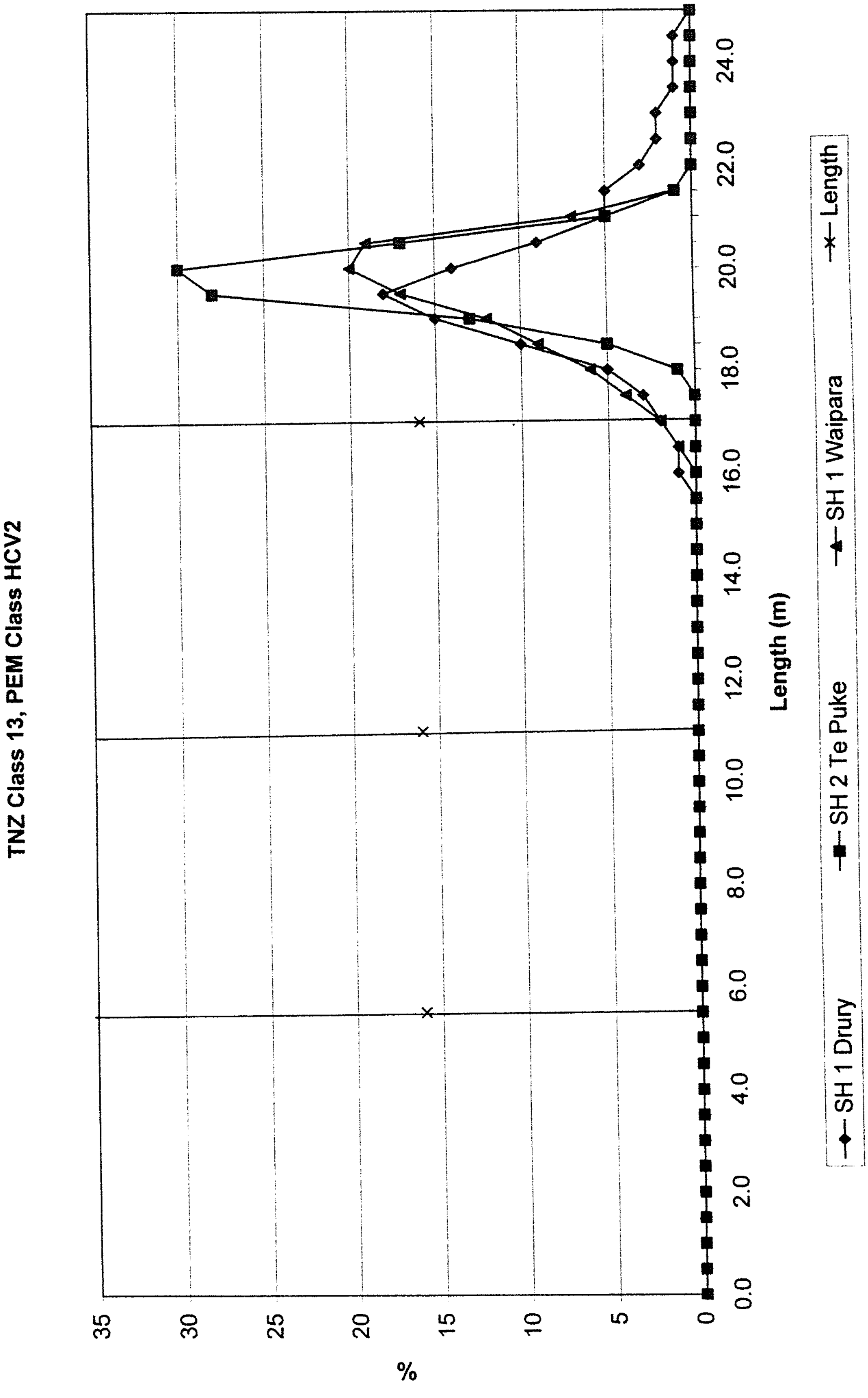

TNZ Class 8, PEM Class HCV2
%
0
2
4
6
8
10
12
14
16
18
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
Length (m)
SH 1 Drury
SH 2 Te Puke
SH 1 Waipara
Length

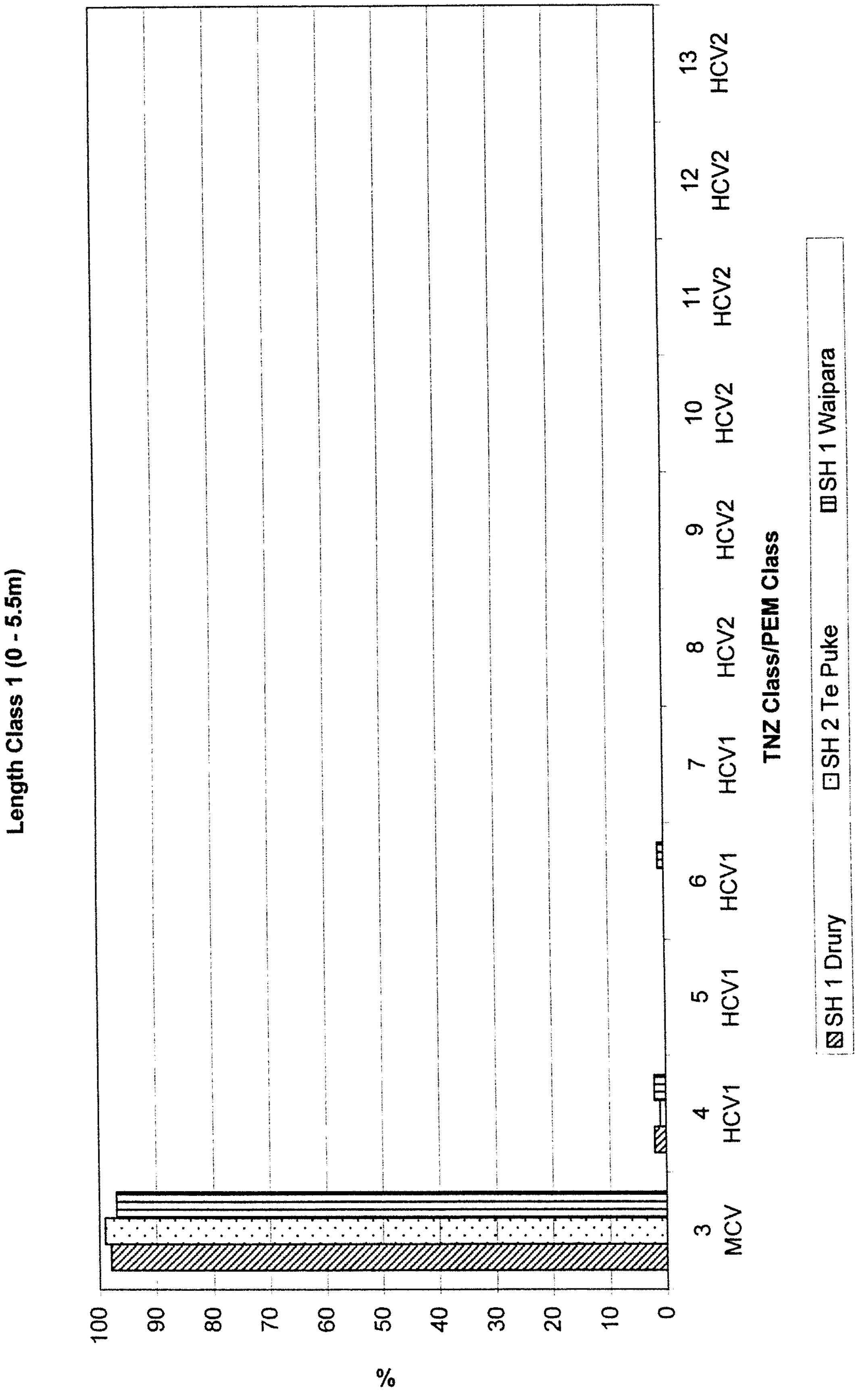

TNZ Class 9, PEM Class HCV2
%
30
25
20
15
10
5
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
Length (m)
SH 1 Drury
SH 2 Te Puke
SH 1 Waipara
Length

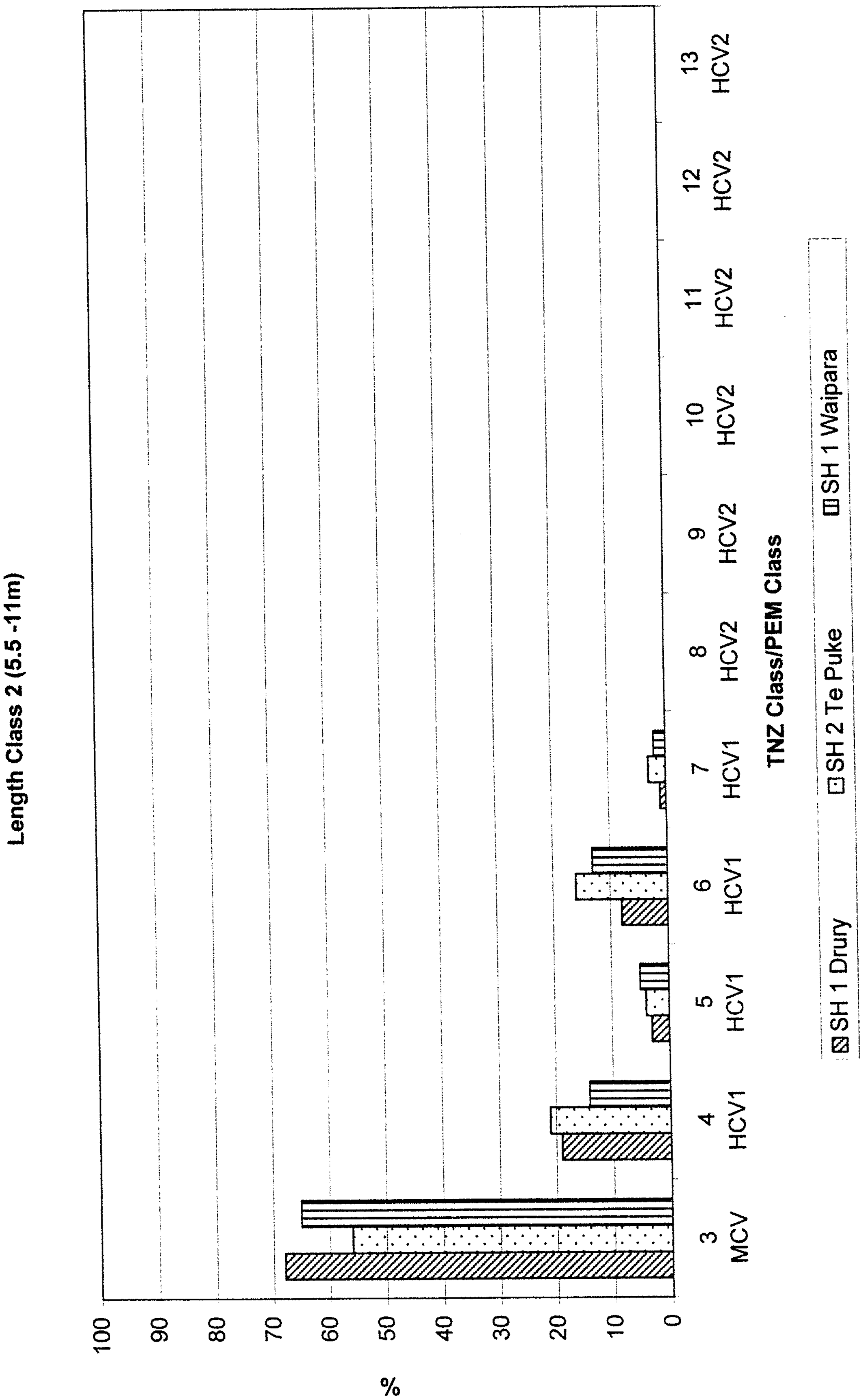

TNZ Class 10, PEM Class HCV2
%
18
16
14
12
10
8
6
4
2
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
Length (m)
SH 1 Drury
SH 2 Te Puke
SH 1 Waipara
Length


TNZ Class 11, PEM Class HCV2
%
30
25
20
15
10
5
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
Length (m)
SH 1 Drury
SH 2 Te Puke
SH 1 Waipara
Length

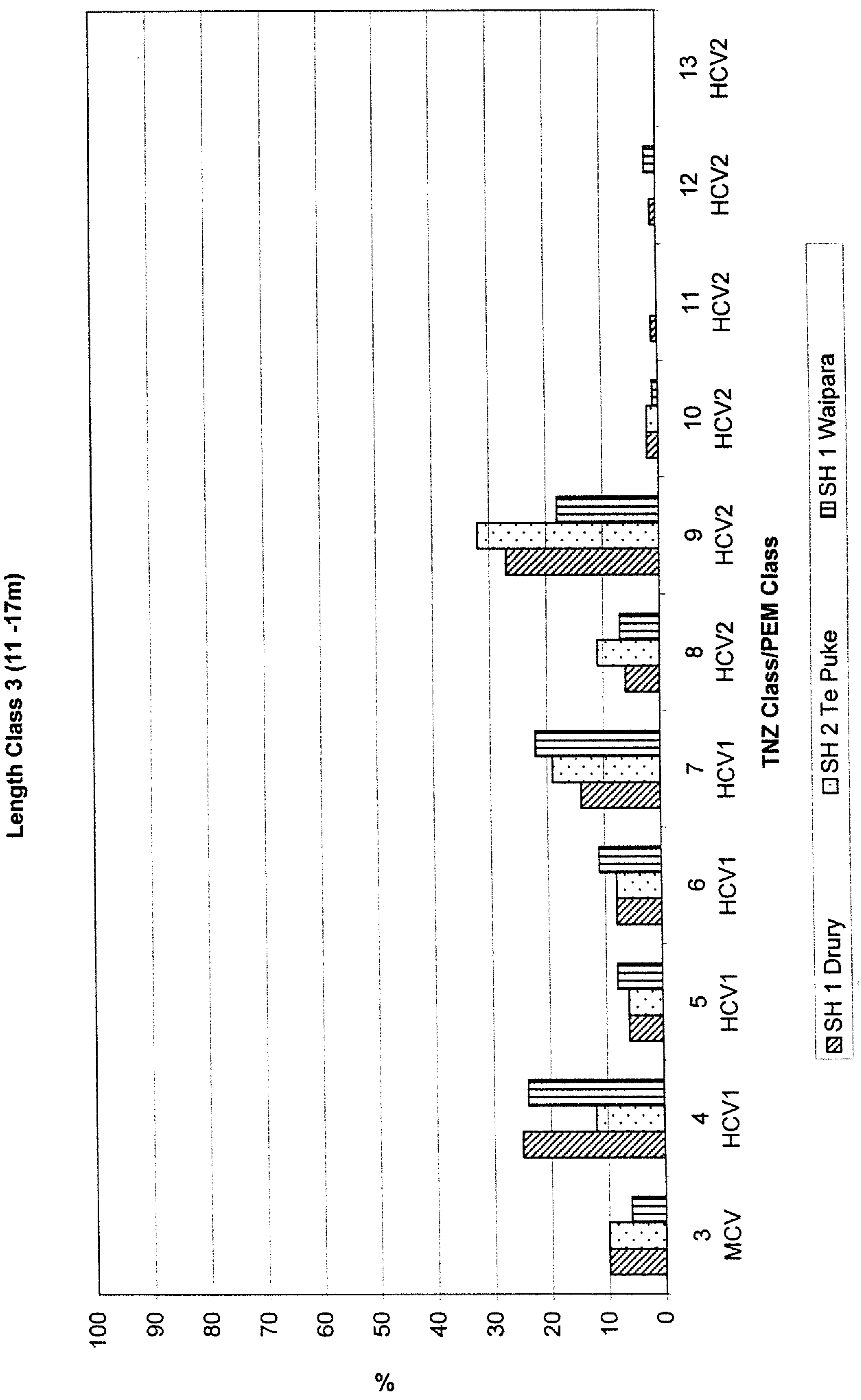

TNZ Class 12, PEM Class HCV2
%
30
25
20
15
10
5
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
Length (m)
SH 1 Drury
SH 2 Te Puke
SH 1 Waipara
Length

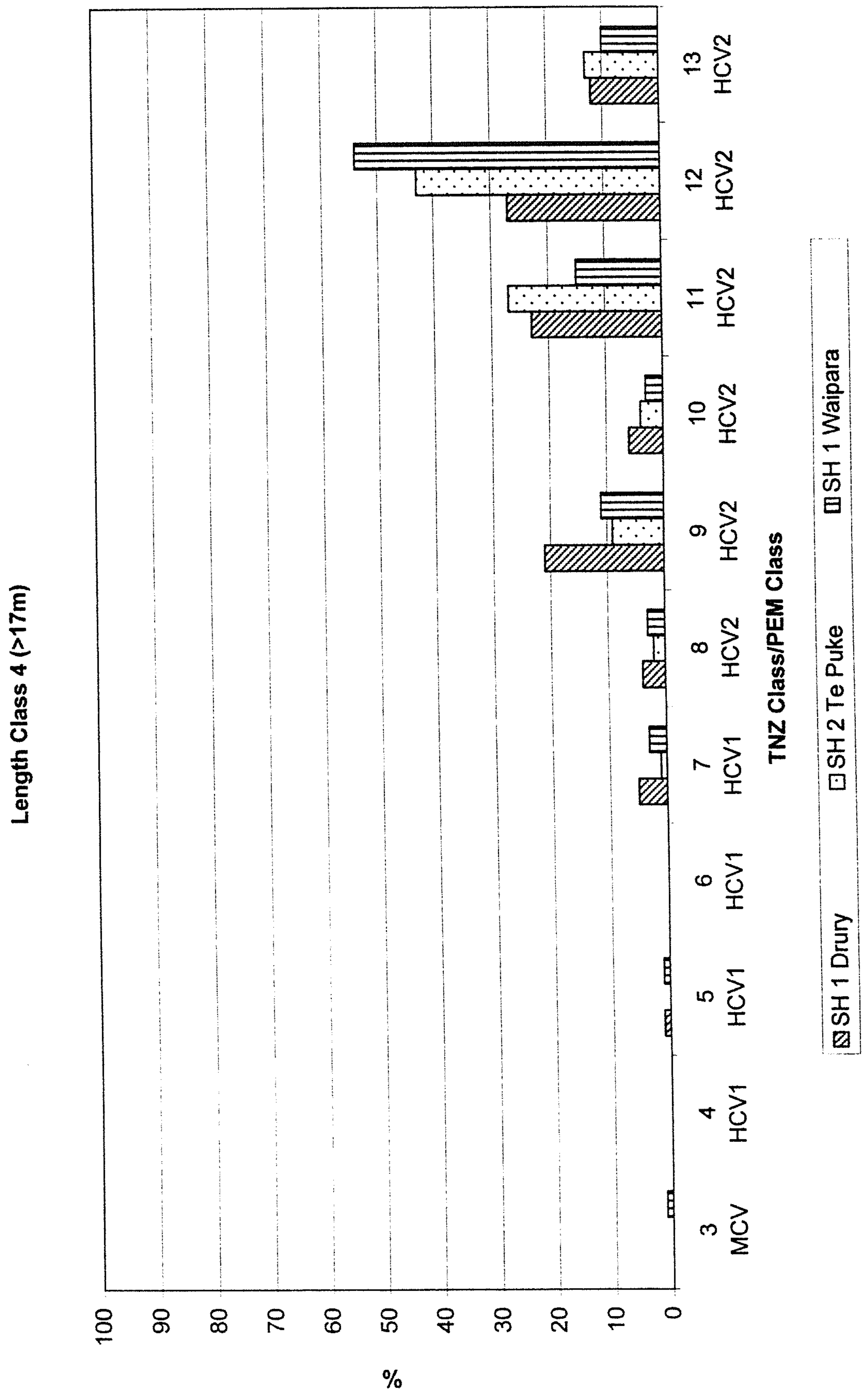

TNZ Class 13, PEM Class HCV2
%
35
30
25
20
15
10
5
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
Length (m)
SH 1 Drury
SH 2 Te Puke
SH 1 Waipara
Length


Length Class 1 (0 - 5.5m)
%
100
90
80
70
60
50
40
30
20
10
0
3 MCV
4 HCV1
5 HCV1
6 HCV1
7 HCV1
8 HCV2
9 HCV2
10 HCV2
11 HCV2
12 HCV2
13 HCV2
TNZ Class/PEM Class
SH 1 Drury
SH 2 Te Puke
SH 1 Waipara



Length Class 2 (5.5 -11m)
%
100
90
80
70
60
50
40
30
20
10
0
3 MCV
4 HCV1
5 HCV1
6 HCV1
7 HCV1
8 HCV2
9 HCV2
10 HCV2
11 HCV2
12 HCV2
13 HCV2
TNZ Class/PEM Class
SH 1 Drury
SH 2 Te Puke
SH 1 Waipara


Length Class 3 (11 -17m)
%
100
90
80
70
60
50
40
30
20
10
0
3 MCV
4 HCV1
5 HCV1
6 HCV1
7 HCV1
8 HCV2
9 HCV2
10 HCV2
11 HCV2
12 HCV2
13 HCV2
TNZ Class/PEM Class
SH 1 Drury
SH 2 Te Puke
SH 1 Waipara


Length Class 4 (>17m)
%
100
90
80
70
60
50
40
30
20
10
0
3 MCV
4 HCV1
5 HCV1
6 HCV1
7 HCV1
8 HCV2
9 HCV2
10 HCV2
11 HCV2
12 HCV2
13 HCV2
TNZ Class/PEM Class
SH 1 Drury
SH 2 Te Puke
SH 1 Waipara

Appendix C

Class Relationships

The first part of each table shows the proportions of each Vehicle Length Class in each TNZ Vehicle Class., For example, at Drury (below), of the vehicle in TNZ Class 3, 17.1% are 0.0 - 5.5 metres, 75% are 5.5-11.0 metres, 7.9% are 11.0-17.0 metres and there are no TNZ Class 3 vehicles longer than 17.0 metres.

The second part of each table shows the proportions of each TNZ Vehicle Class in each Vehicle Length Class. For example, at Drury (below), of the vehicles of length 5.5-11.0 metres, none are TNZ Class 1 vehicles, 31.2% are TNZ Class 2, 44.8% are TNZ Class 3, 14.1% are TNZ Class 4, 1.9% are TNZ Class 5, 6.5% are TNZ Class 6, and so on.

DRURY, Lanes 1 & 2 combined

Percentage of each Vehicle Length Class in each TNZ Vehicle Class													
Vehicle Length (metres)	TNZ Vehicle Class												
	1	2	3	4	5	6	7	8	9	10	11	12	13
0.0 - 5.5m	100.0%	0.0%	17.1%	0.0%	0.0%	0.3%	0.9%	2.1%	0.0%	0.0%	0.0%	0.0%	0.0%
5.5 – 11.0m	0.0%	100.0%	75.0%	70.7%	42.7%	71.1%	9.0%	1.6%	0.3%	0.0%	0.0%	0.0%	0.0%
11.0 – 17.0m	0.0%	0.0%	7.9%	27.8%	40.3%	22.6%	72.1%	67.7%	75.2%	28.3%	2.8%	1.5%	0.7%
> 17.0m	0.0%	0.0%	0.0%	1.5%	17.0%	6.0%	18.0%	28.6%	24.5%	71.7%	97.2%	98.5%	99.3%
Percentage of each TNZ Vehicle Class in each Vehicle Length Class													
0.0 - 5.5m	99.5%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.5 – 11.0m	0.0%	31.2%	44.8%	14.1%	1.9%	6.5%	0.6%	0.1%	0.8%	0.0%	0.0%	0.0%	0.0%
11.0 – 17.0m	0.0%	0.0%	9.9%	11.7%	3.8%	4.3%	10.7%	7.7%	44.4%	2.9%	1.1%	0.8%	2.7%
> 17.0m	0.0%	0.0%	0.0%	0.4%	1.0%	0.7%	1.6%	2.0%	9.1%	4.7%	23.7%	33.1%	23.7%

TE PUKE, Lanes 1 & 2 combined

Percentage of each Vehicle Length Class in each TNZ Vehicle Class													
Vehicle Length (metres)	TNZ Vehicle Class												
	1	2	3	4	5	6	7	8	9	10	11	12	13
0 - 5.5m	100.0%	0.0%	10.6%	0.3%	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.5 – 11.0m	0.0%	100.0%	85.0%	88.3%	59.6%	88.7%	13.9%	3.3%	0.0%	0.0%	0.0%	0.0%	0.0%
11.0 – 17.0m	0.0%	0.0%	4.4%	11.4%	38.6%	11.3%	81.0%	82.5%	64.1%	21.4%	0.2%	0.7%	0.1%
> 17.0m	0.0%	0.0%	0.0%	0.0%	1.2%	0.0%	5.1%	14.2%	35.9%	78.6%	99.8%	99.3%	99.9%
Percentage of each TNZ Vehicle Class in each Vehicle Length Class													
0 - 5.5m	99.6%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.5 – 11.0m	0.0%	31.0%	42.5%	14.3%	1.6%	9.9%	0.6%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
11.0 – 17.0m	0.0%	0.0%	9.9%	8.4%	4.6%	5.7%	15.8%	13.3%	38.1%	3.0%	0.2%	1.0%	0.0%
> 17.0m	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.7%	6.7%	3.5%	30.5%	46.3%	12.0%

WAIPARA, Lanes 1 & 2 combined

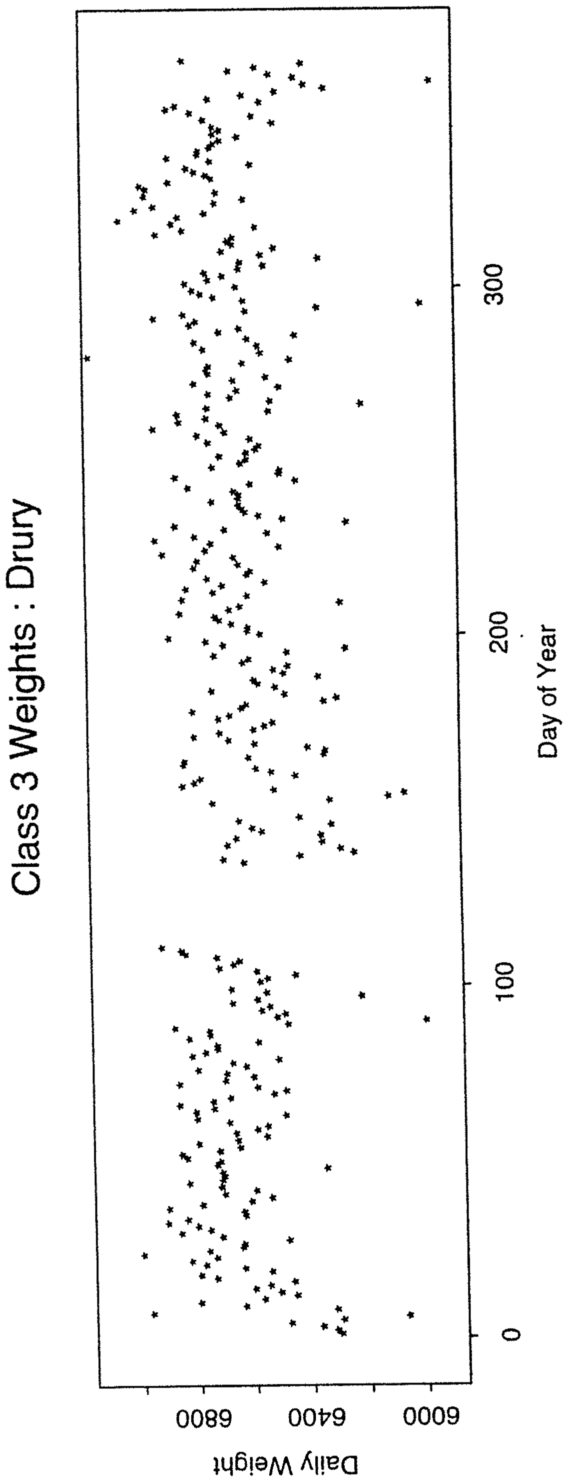
Percentage of each Vehicle Length Class in each TNZ Vehicle Class													
Vehicle Length (metres)	TNZ Vehicle Class												
	1	2	3	4	5	6	7	8	9	10	11	12	13
0 - 5.5m	100.0%	0.0%	12.6%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.5 – 11.0m	0.0%	100.0%	82.1%	64.1%	65.0%	76.5%	21.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
11.0 – 17.0m	0.0%	0.0%	5.3%	35.7%	30.9%	23.1%	69.0%	73.4%	64.4%	31.5%	3.4%	2.8%	0.9%
> 17.0m	0.0%	0.0%	0.0%	0.2%	4.1%	0.4%	9.4%	26.6%	35.6%	68.5%	96.6%	97.2%	99.1%

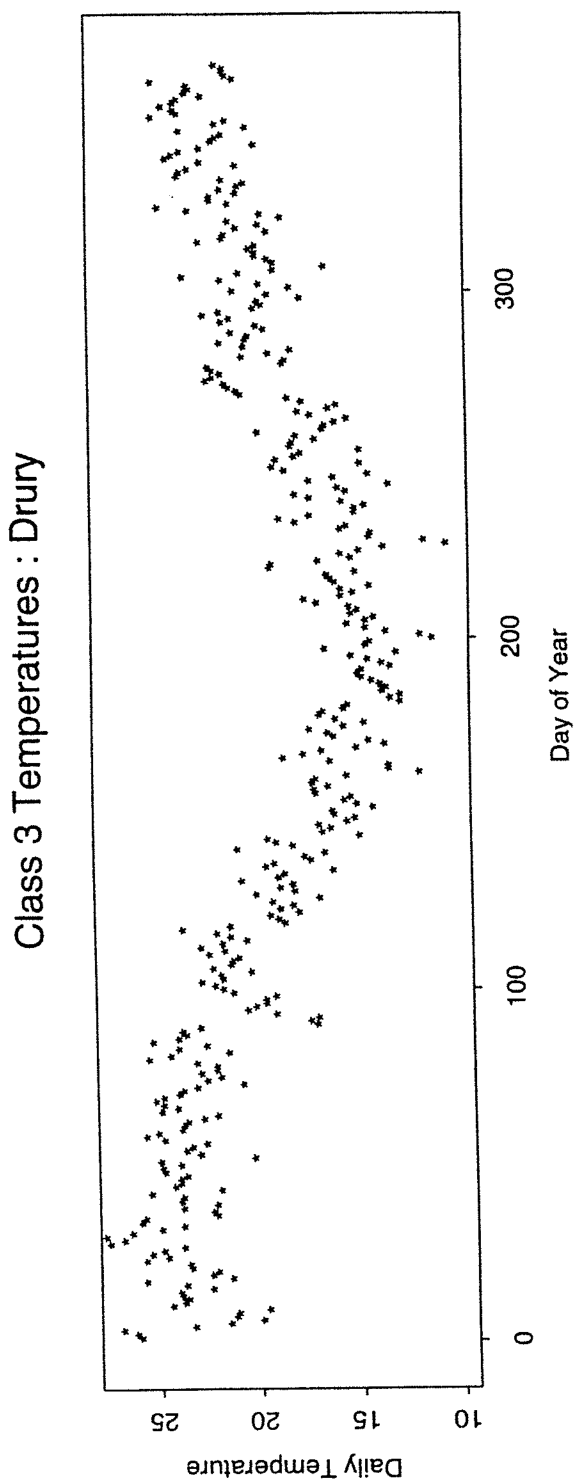
Percentage of each TNZ Vehicle Class in each Vehicle Length Class													
0 - 5.5m	99.5%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.5 – 11.0m	0.0%	49.0%	33.4%	8.7%	2.6%	5.1%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
11.0 – 17.0m	0.0%	0.0%	7.5%	17.7	4.6%	5.7%	14.1%	5.9%	36.6%	1.9%	1.5%	4.0%	0.5%
> 17.0m	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.8%	0.8%	7.4%	1.5%	16.1%	51.2%	22.0%

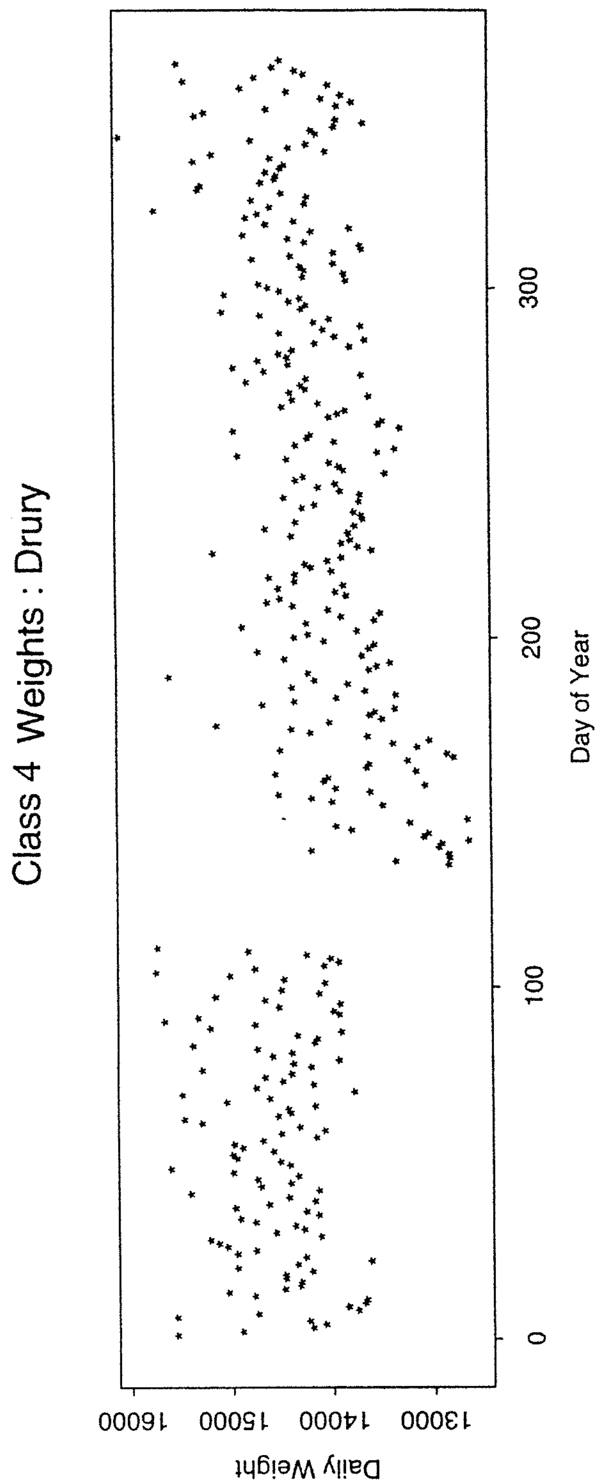
Appendix D

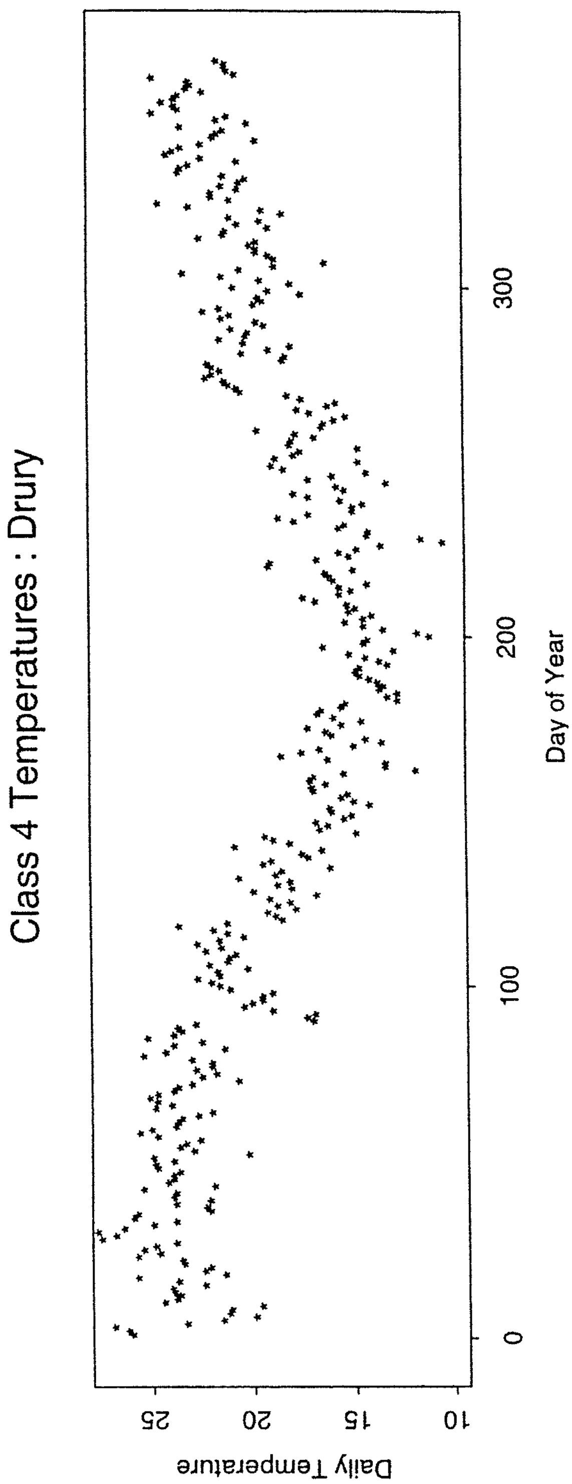
Average Weights and Temperatures for Transit Vehicle Classes

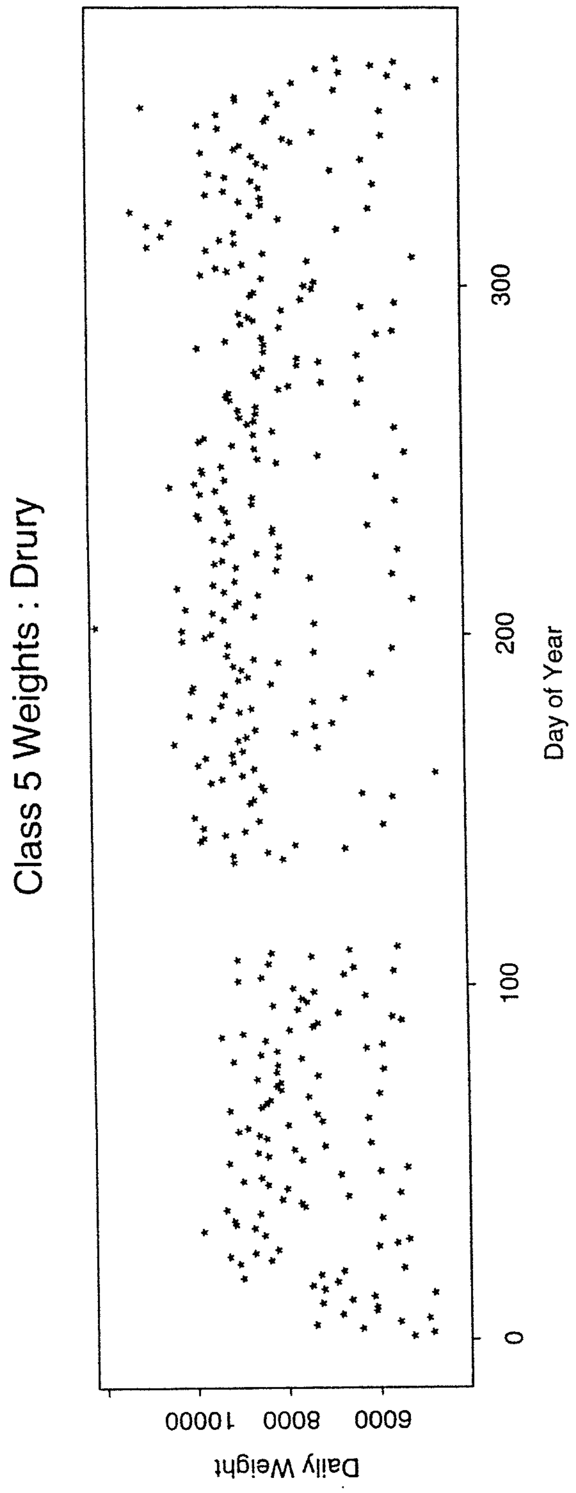
Site : Drury


Class 3 Weights : Drury
Daily Weight
6000
6400
6800
Day of Year
0
100
200
300

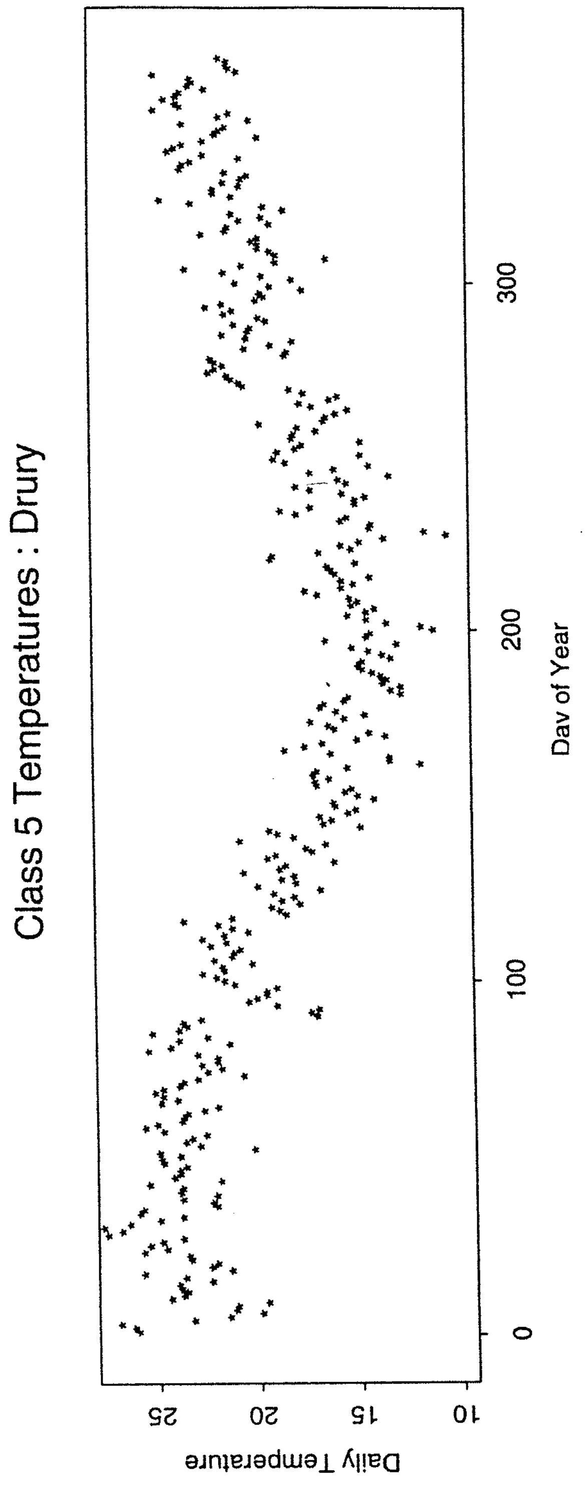

Class 3 Temperatures : Drury
Daily Temperature
10
15
20
25
Day of Year
0
100
200
300


Class 4 Weights : Drury
Daily Weight
13000
14000
15000
16000
Day of Year
0
100
200
300

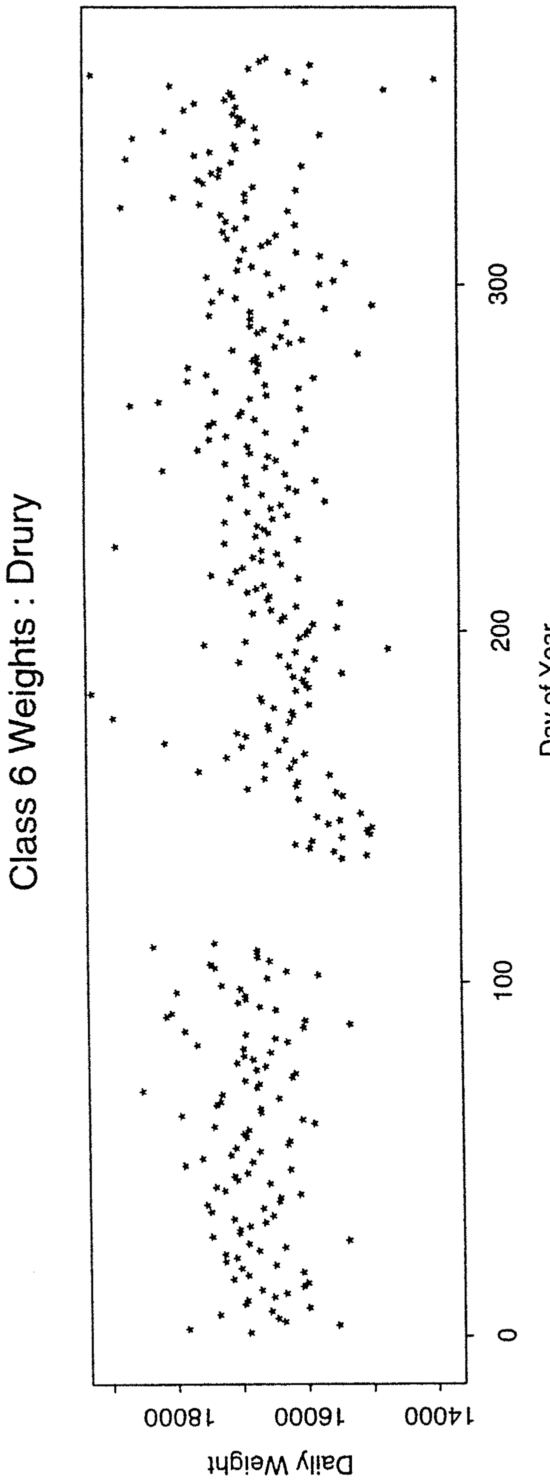

Class 4 Temperatures : Drury
Daily Temperature
10
15
20
25
Day of Year
0
100
200
300

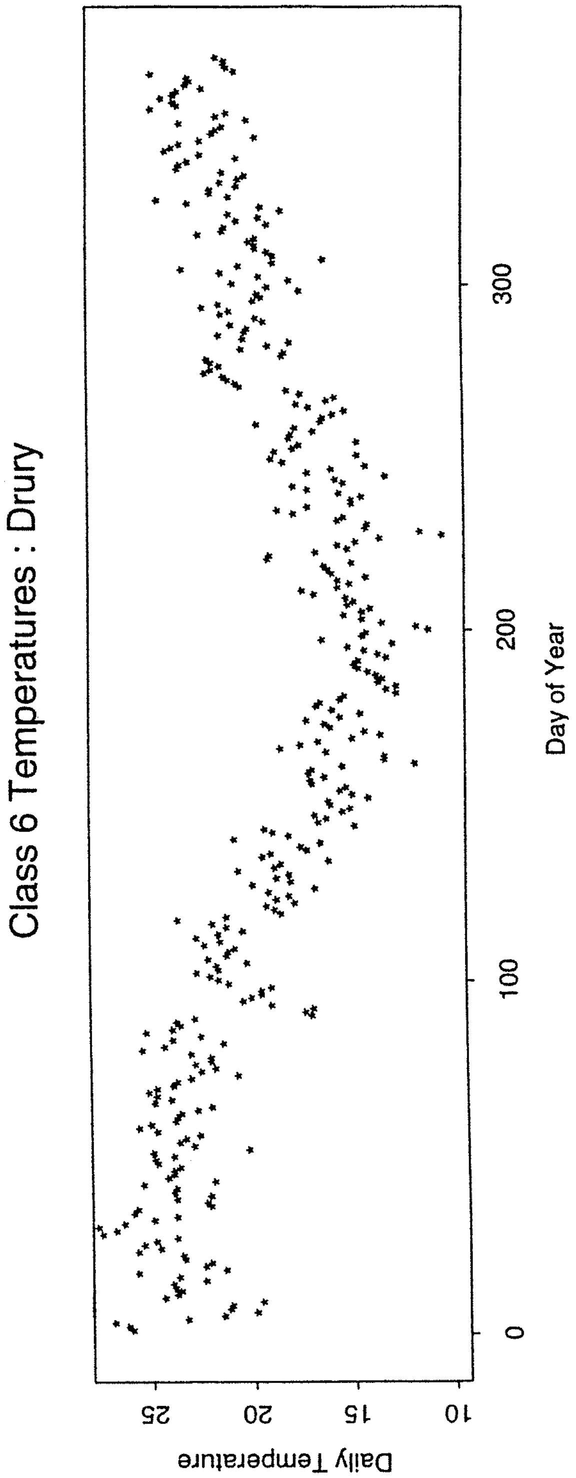


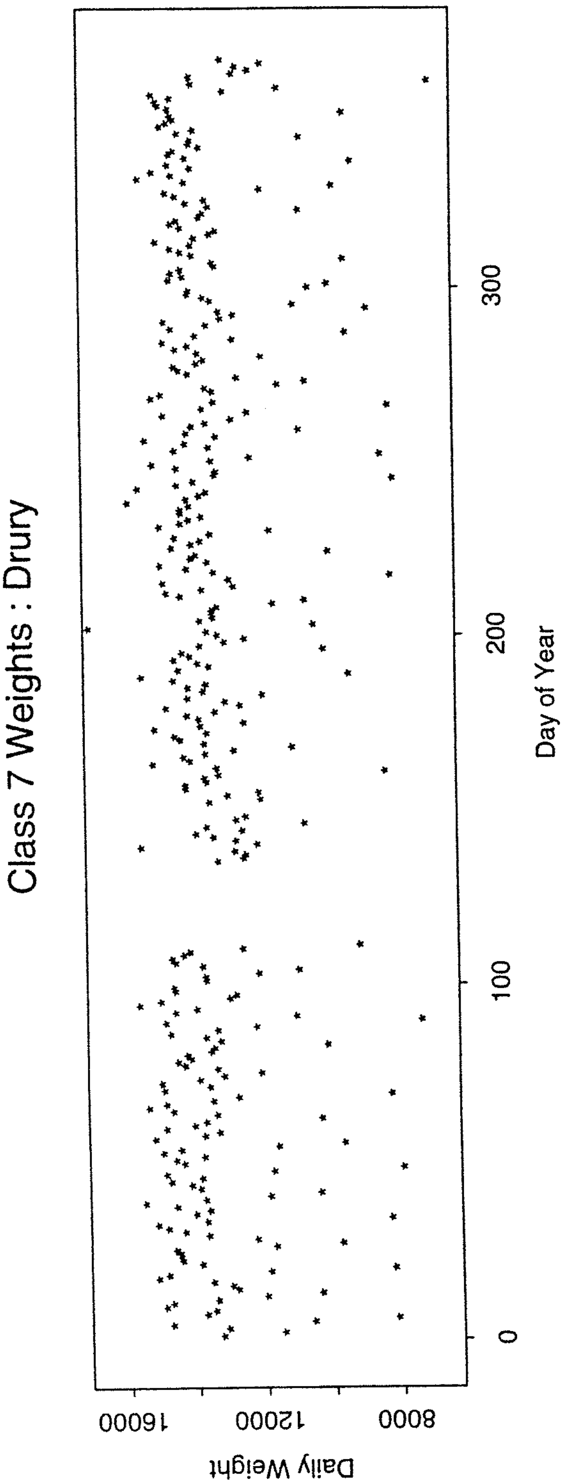
Class 5 Weights : Drury
Daily Weight
6000
8000
10000
0
100
200
300
Day of Year



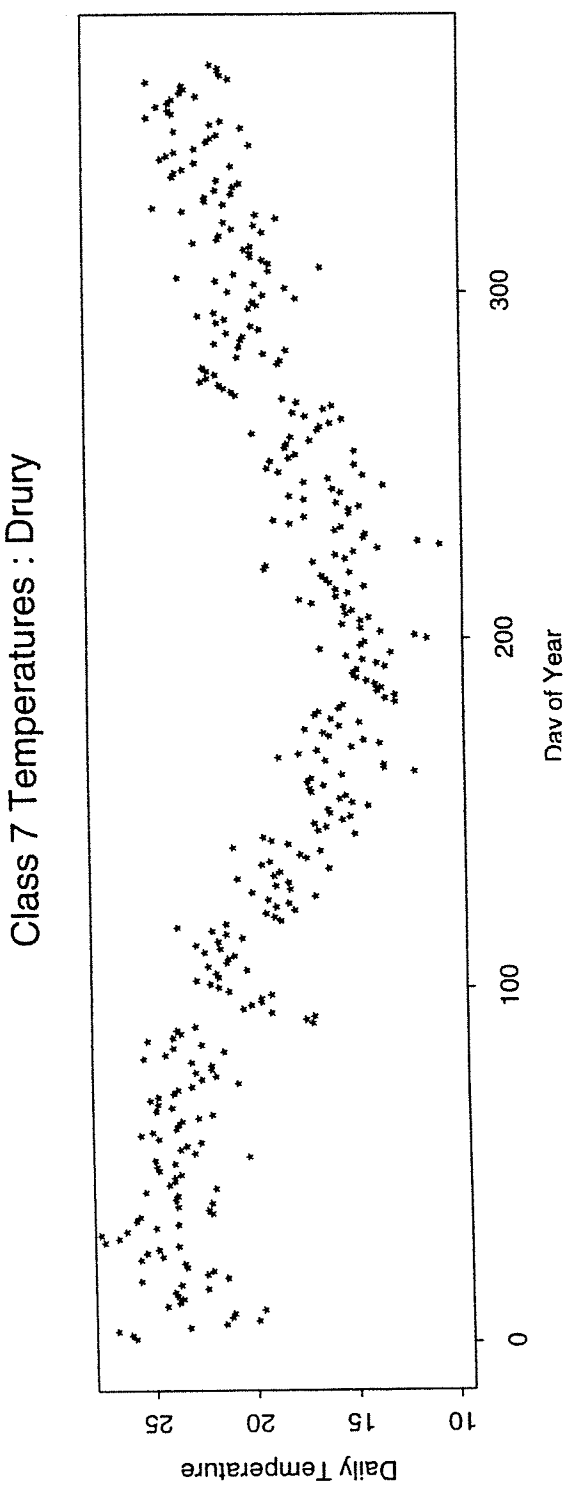
Class 5 Temperatures : Drury
Daily Temperature
10
15
20
25
0
100
200
300
Dav of Year


Class 6 Weights : Drury
Daily Weight
14000
16000
18000
0
100
200
300
Day of Year

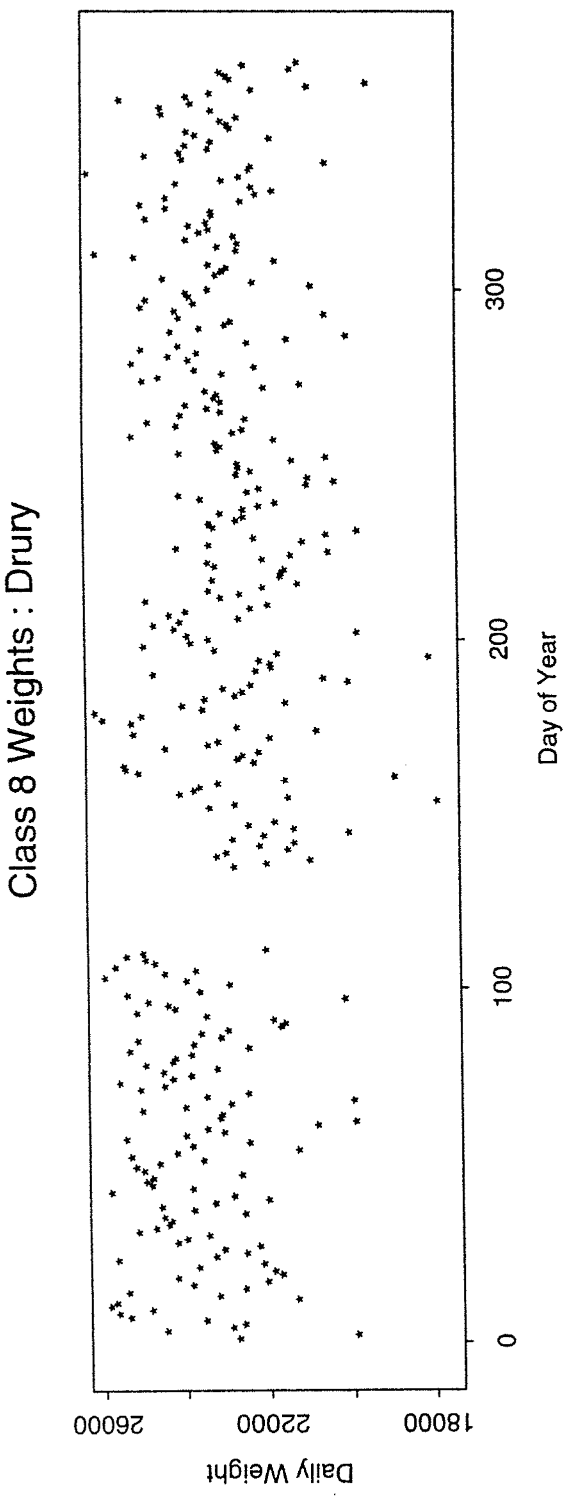

Class 6 Temperatures : Drury
Daily Temperature
10
15
20
25
0
100
200
300
Day of Year

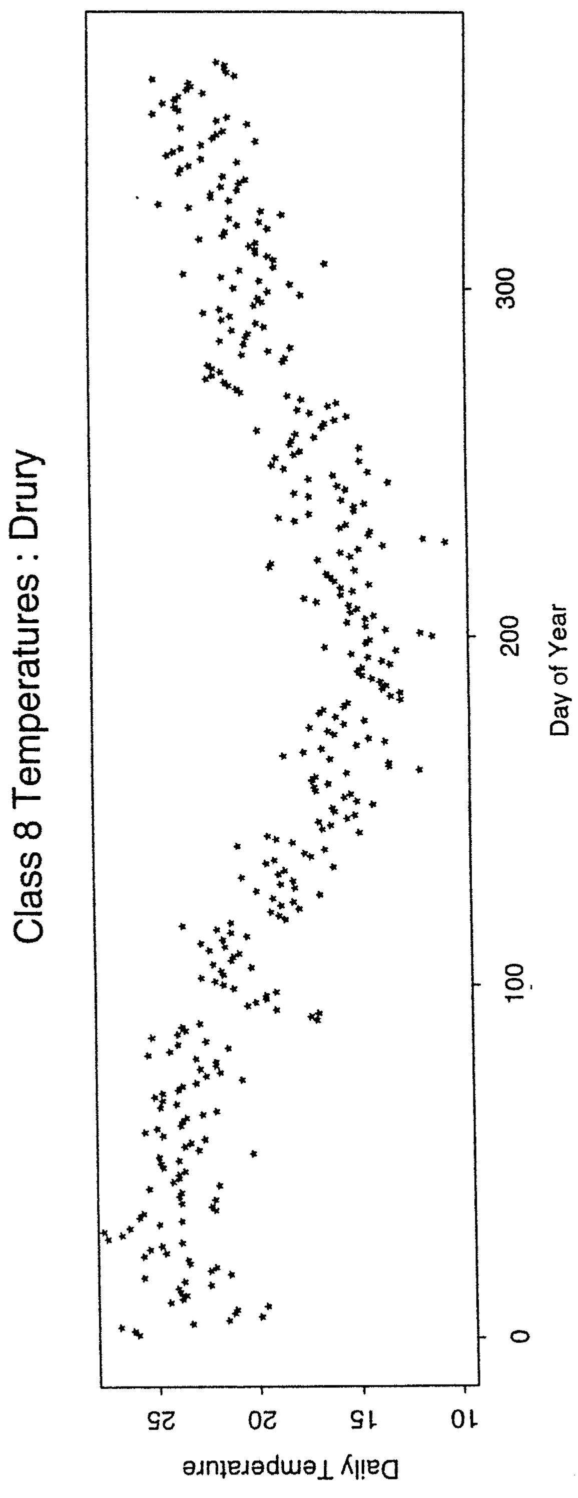


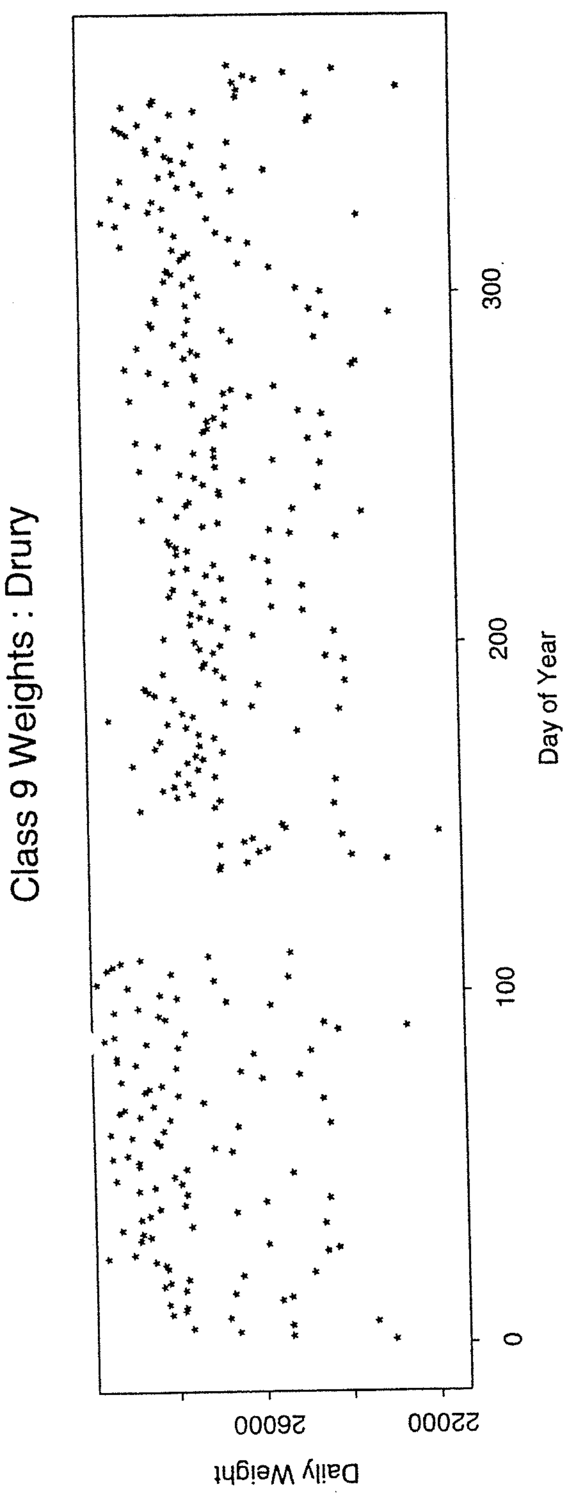
Class 7 Weights : Drury
Daily Weight
8000
12000
16000
0
100
200
300
Day of Year

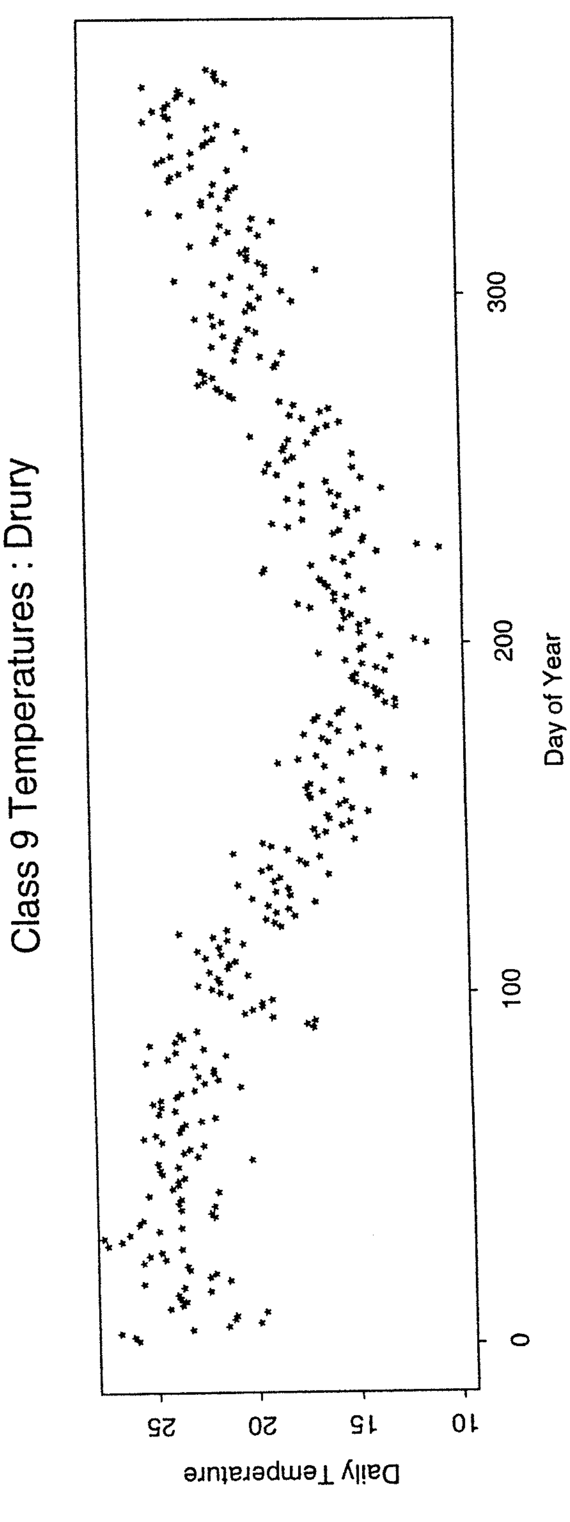


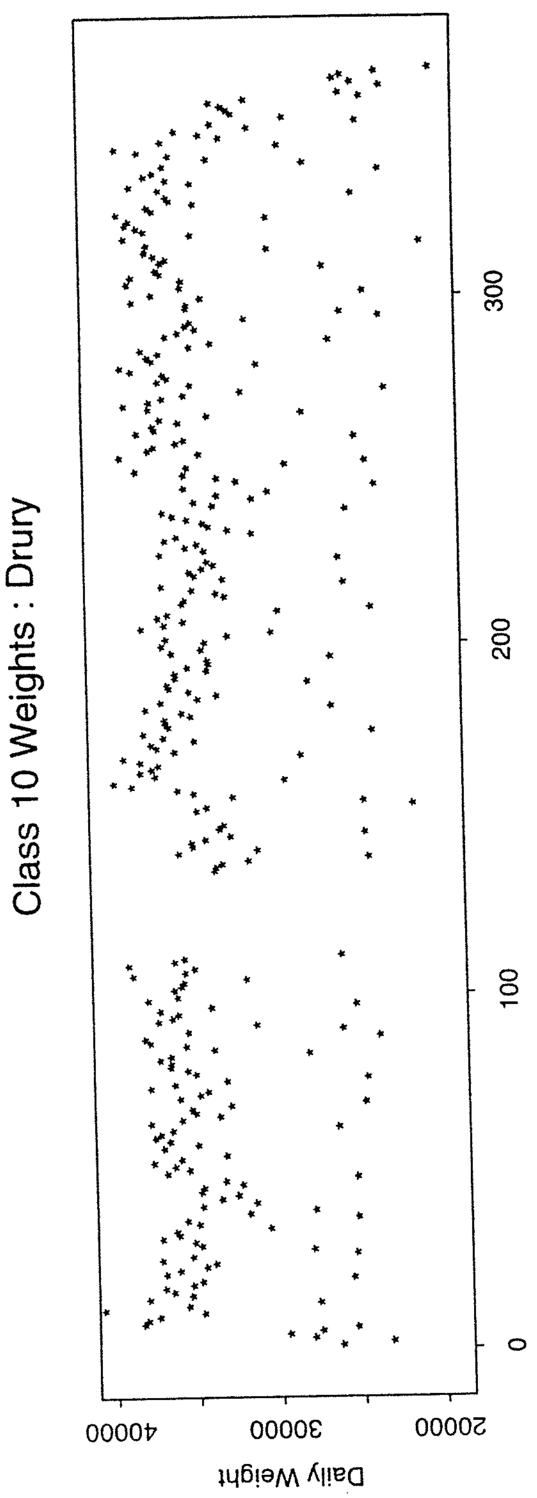
Class 7 Temperatures : Drury
Daily Temperature
10
15
20
25
0
100
200
300
Day of Year

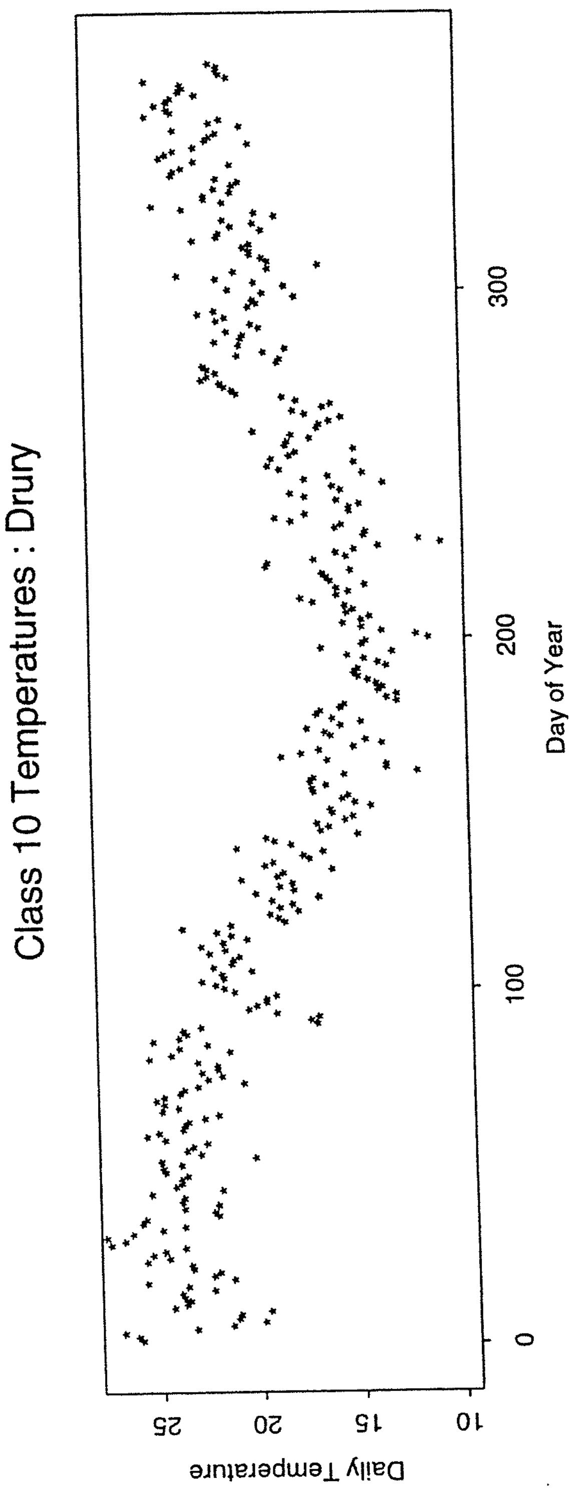

Class 8 Weights : Drury
Day of Year
0
100
200
300
Daily Weight
18000
22000
26000

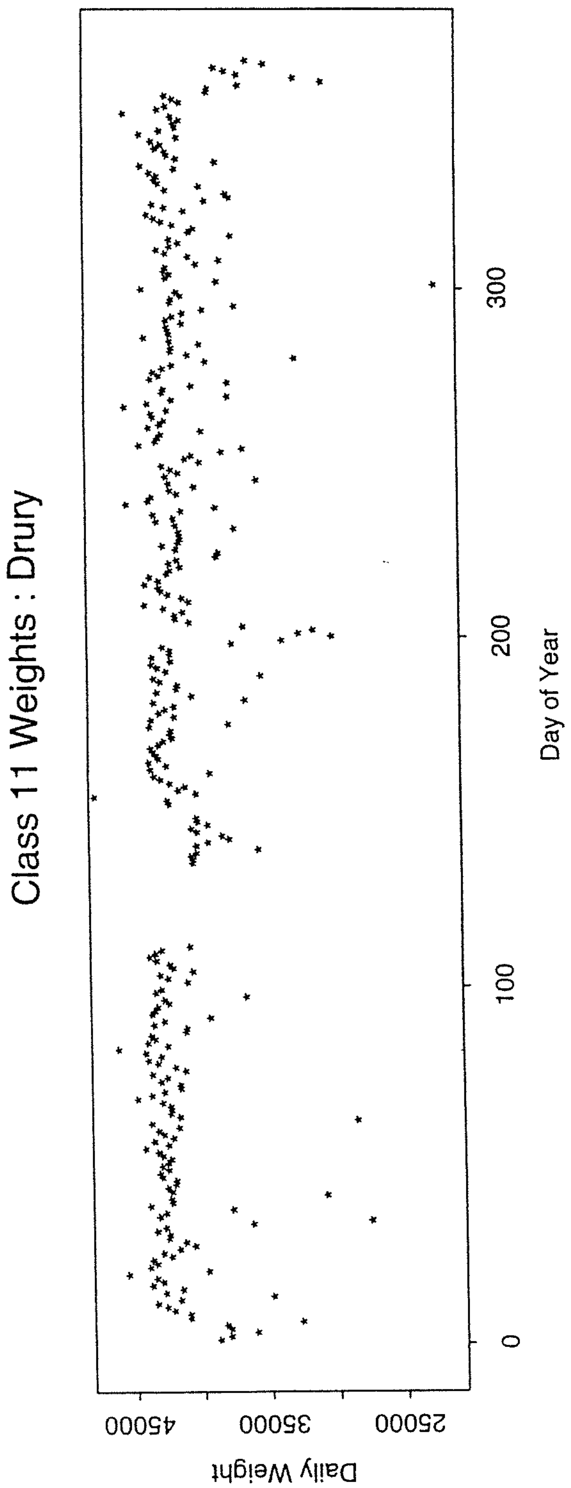

Class 8 Temperatures : Drury
Day of Year
0
100
200
300
Daily Temperature
10
15
20
25

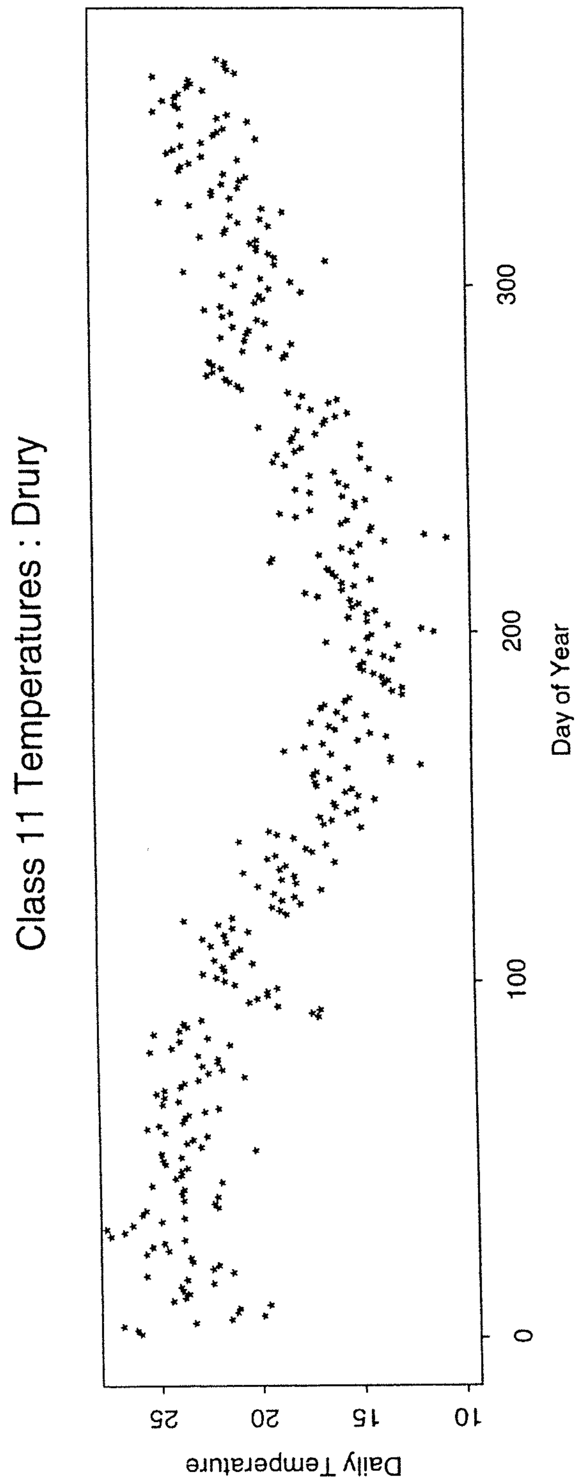

Class 9 Weights : Drury
Daily Weight
22000
26000
Day of Year
0
100
200
300

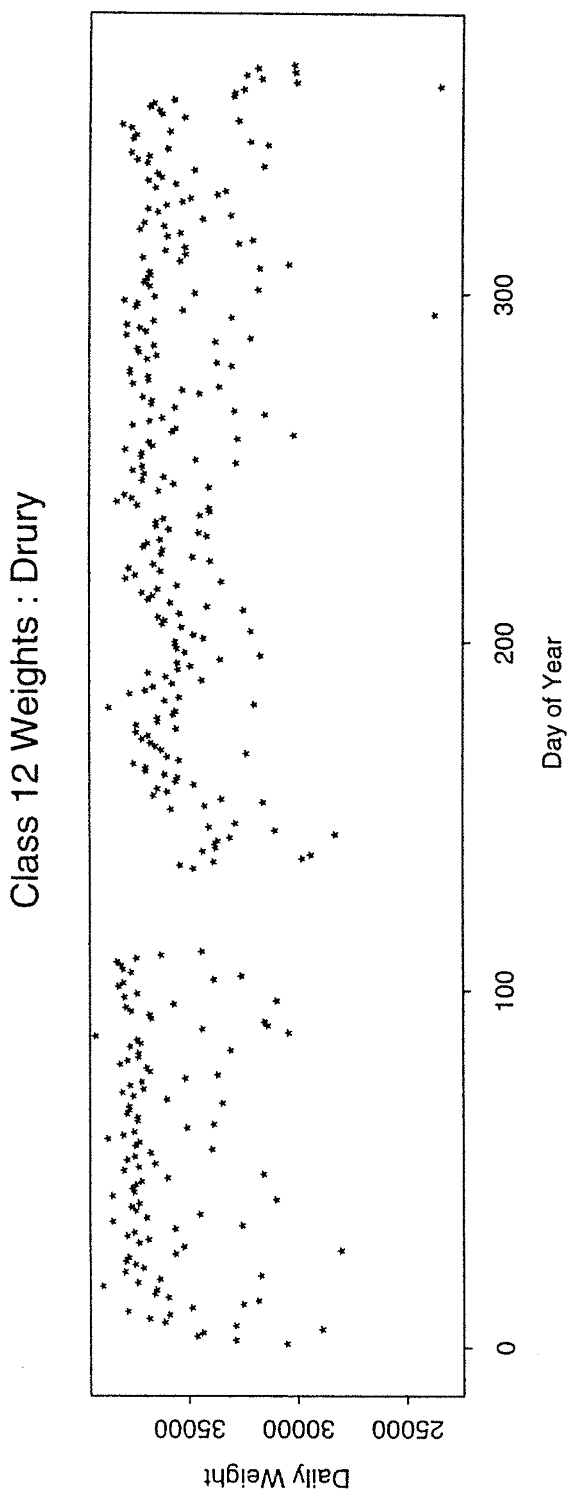

Class 9 Temperatures : Drury
Daily Temperature
10
15
20
25
Day of Year
0
100
200
300

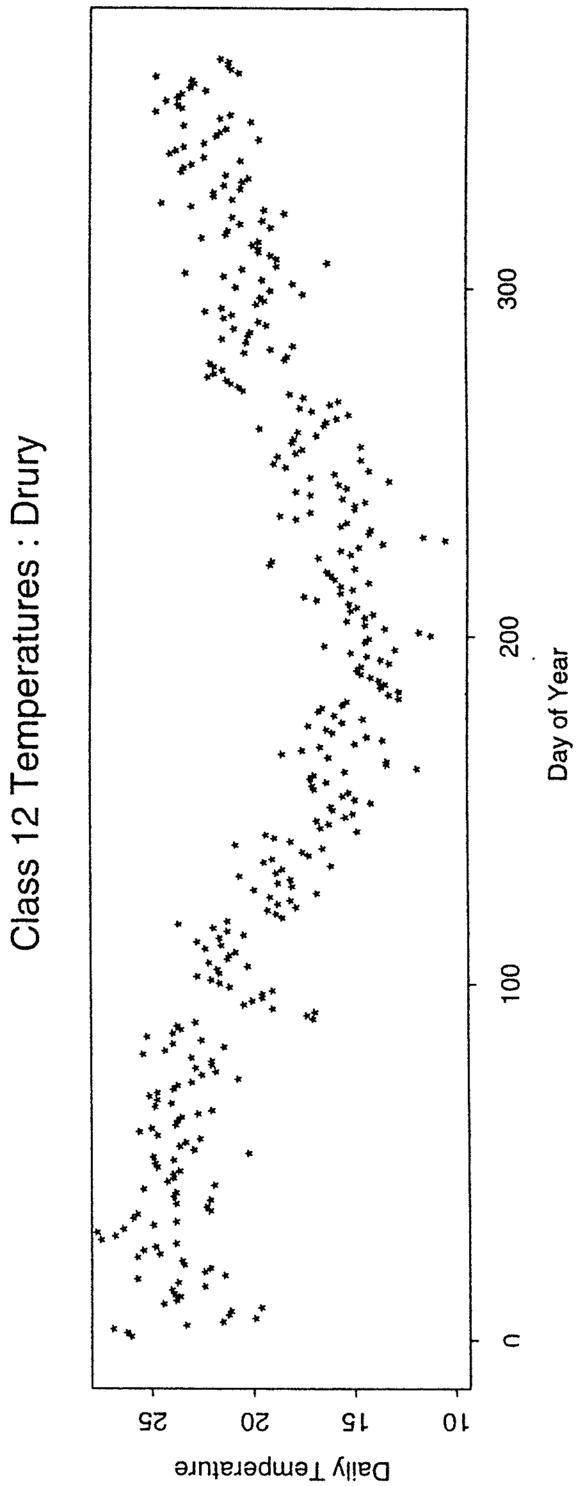

Class 10 Weights : Drury
Daily Weight
40000
30000
20000
Day of Year
0
100
200
300

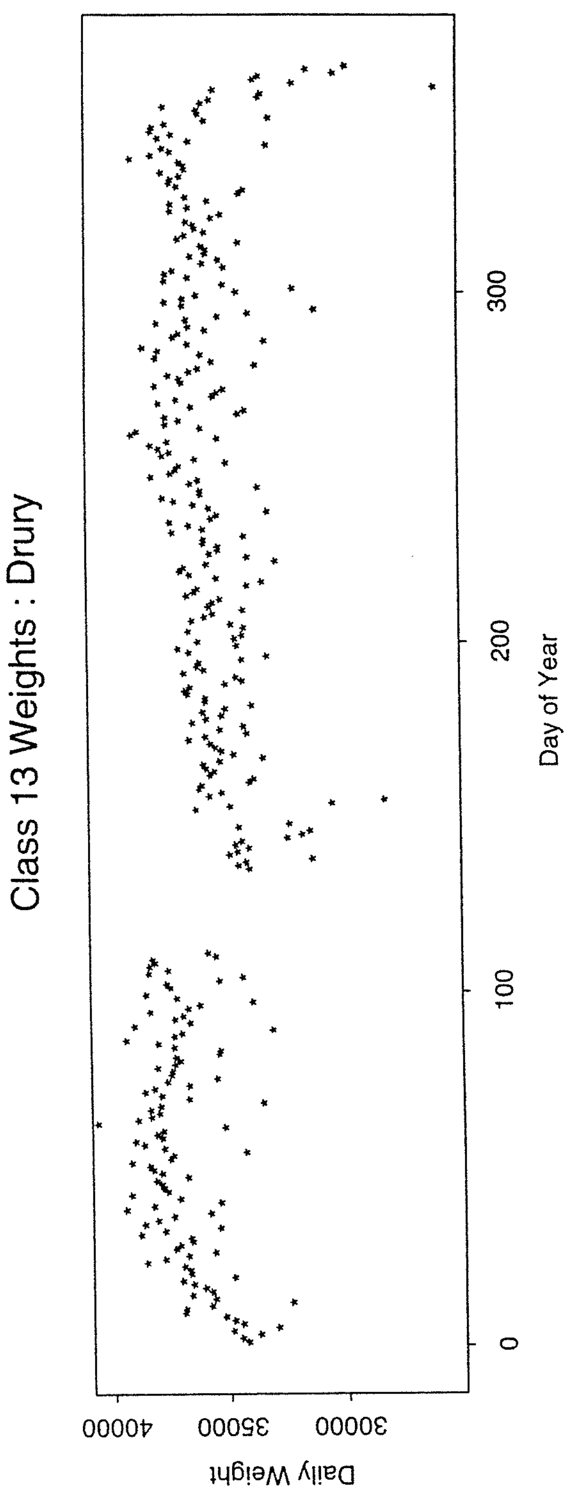

Class 10 Temperatures : Drury
Daily Temperature
25
20
15
10
Day of Year
0
100
200
300


Class 11 Weights : Drury
Daily Weight
45000
35000
25000
Day of Year
0
100
200
300

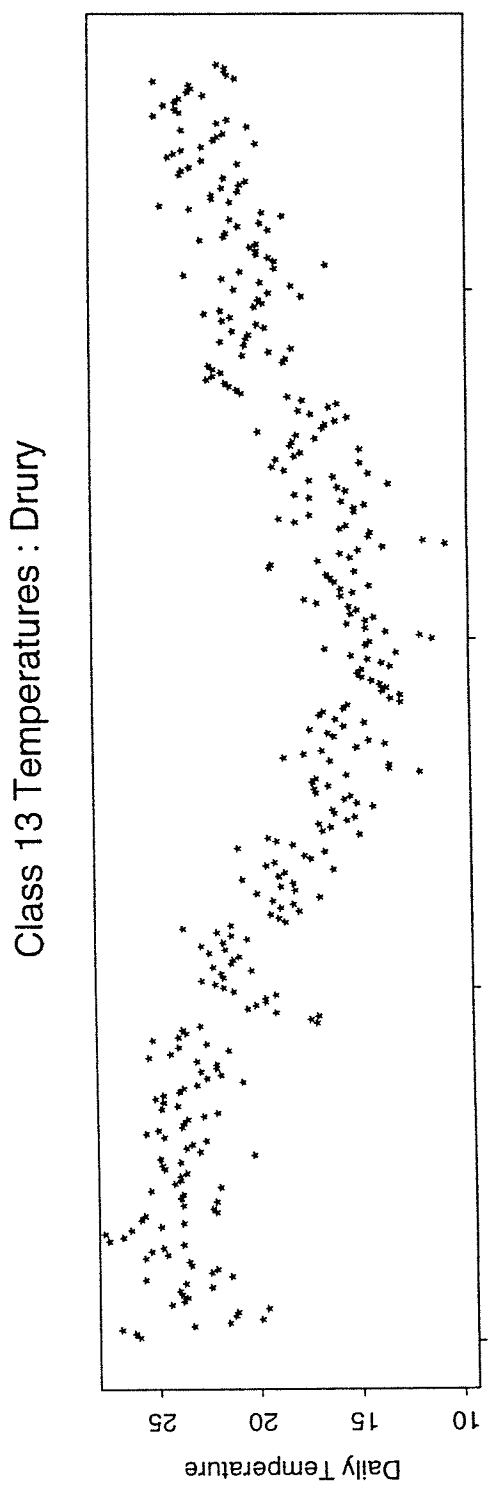

Class 11 Temperatures : Drury
Daily Temperature
25
20
15
10
Day of Year
0
100
200
300


Class 12 Weights : Drury
Daily Weight
25000
30000
35000
Day of Year
0
100
200
300


Class 12 Temperatures : Drury
Daily Temperature
10
15
20
25
Day of Year
0
100
200
300



Class 13 Weights : Drury
Daily Weight
30000
35000
40000
0
100
200
300
Day of Year

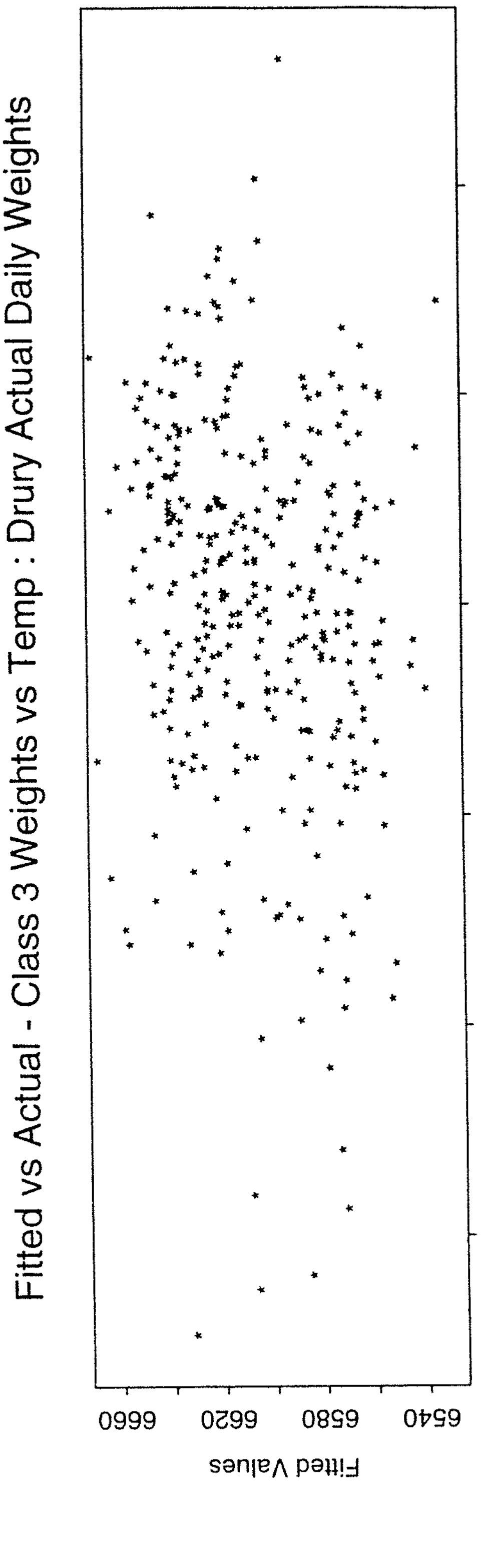


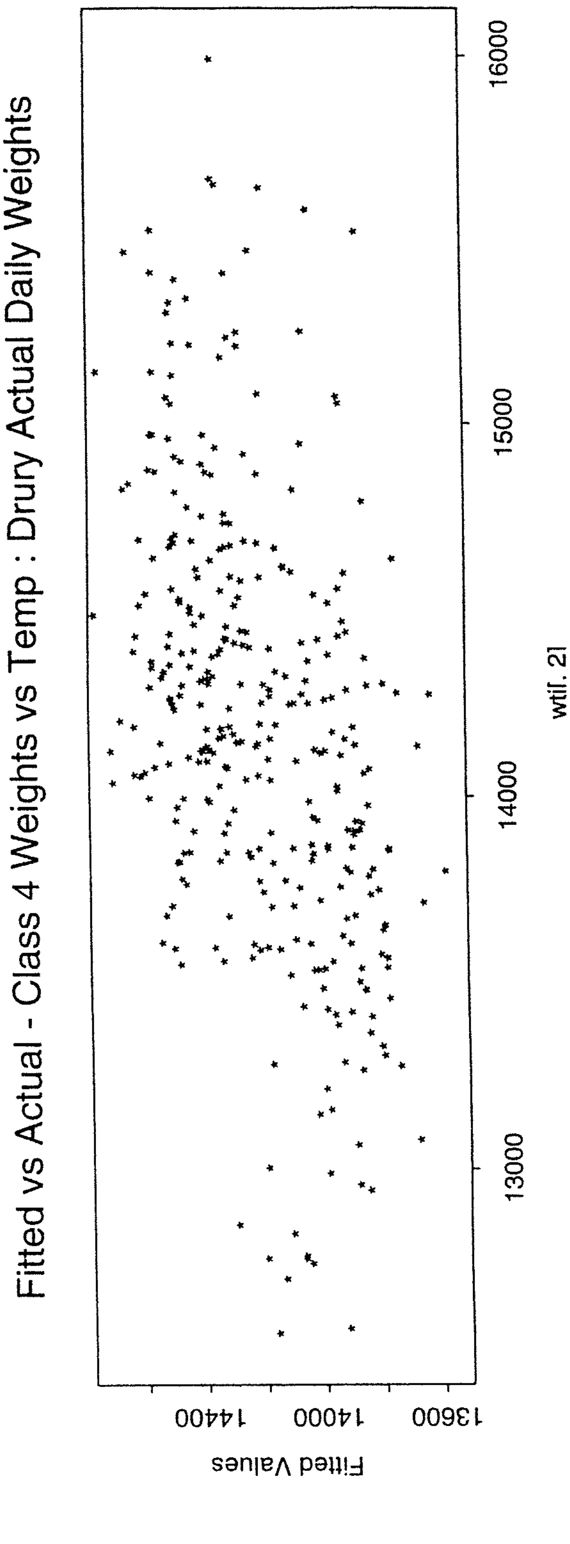
Class 13 Temperatures : Drury
Daily Temperature
10
15
20
25
0
100
200
300

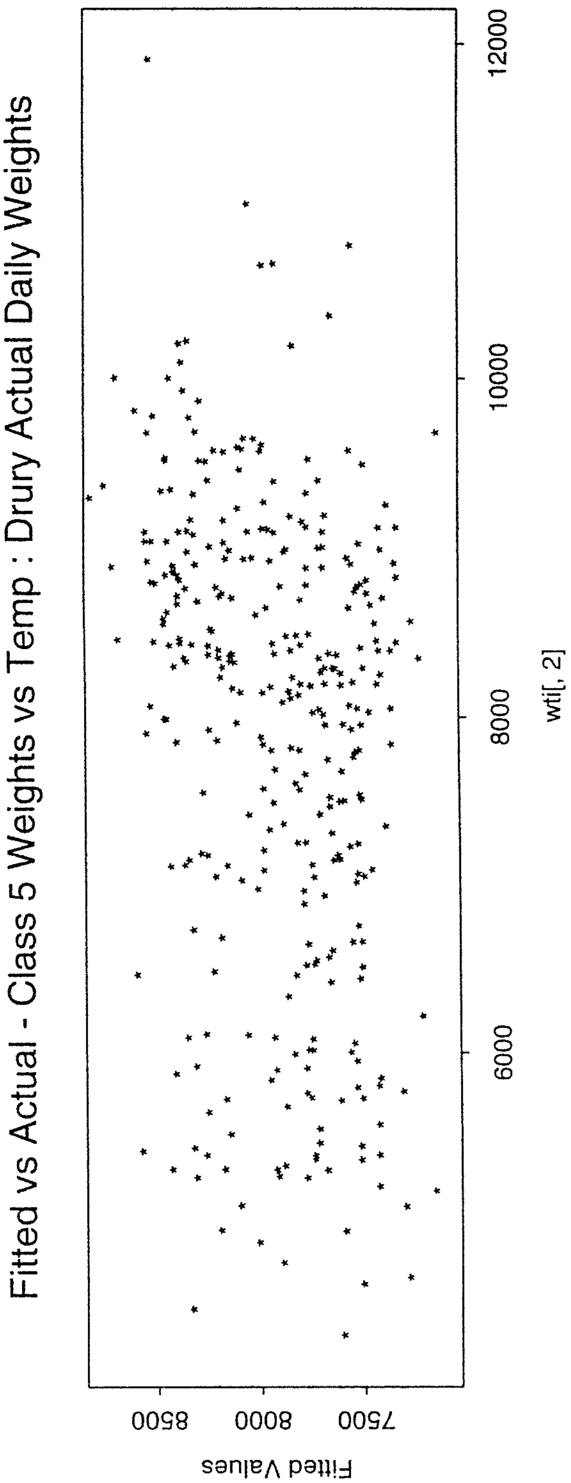
Appendix E

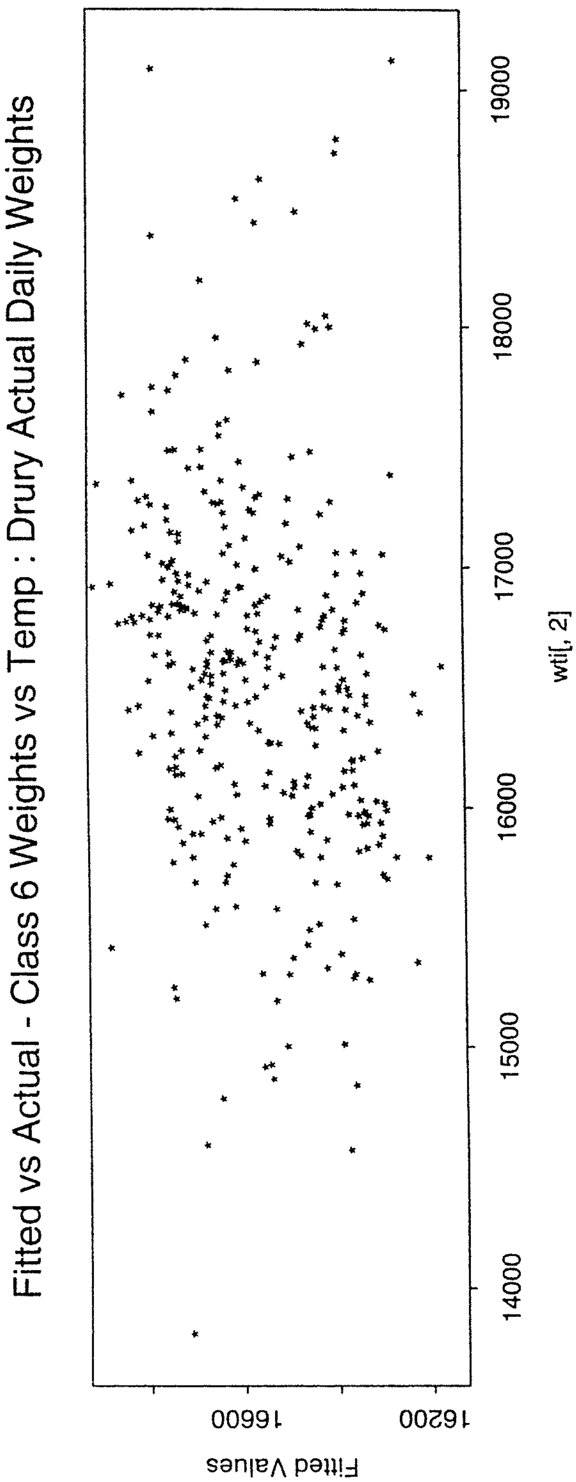
Residual Plots for Regression of Weights versus Temperatures over Days of Year for Transit Vehicle Classes 3-13

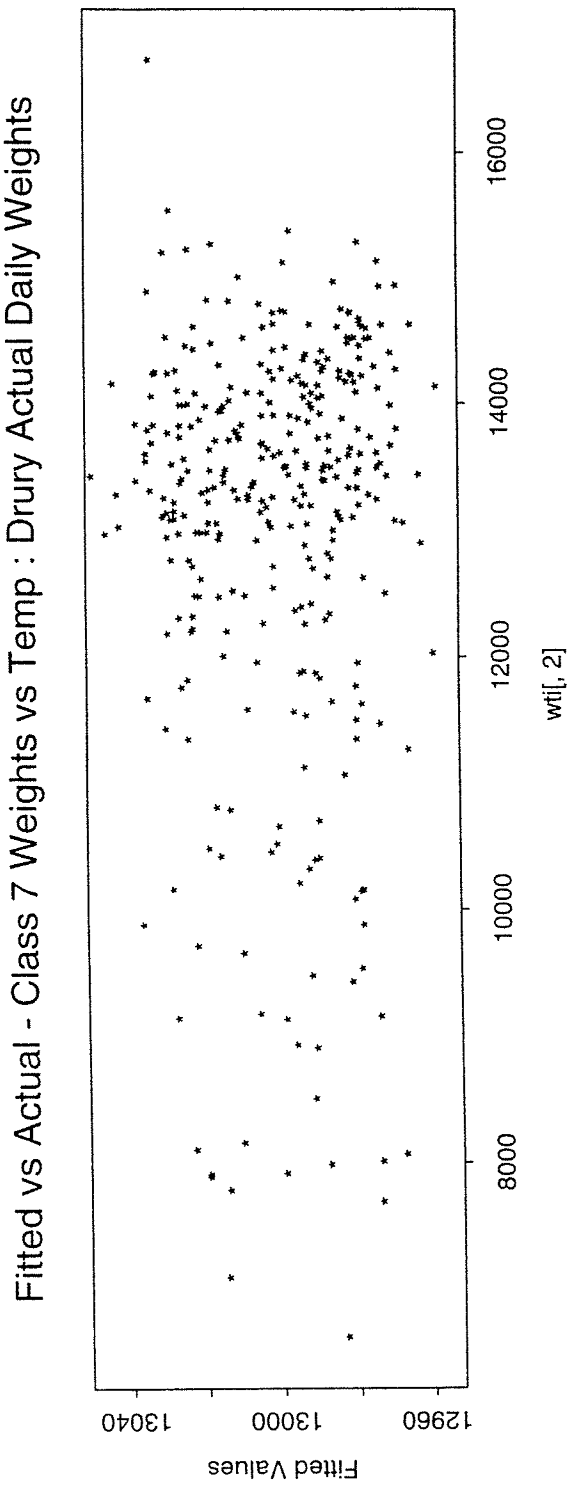
Three WIM Sites

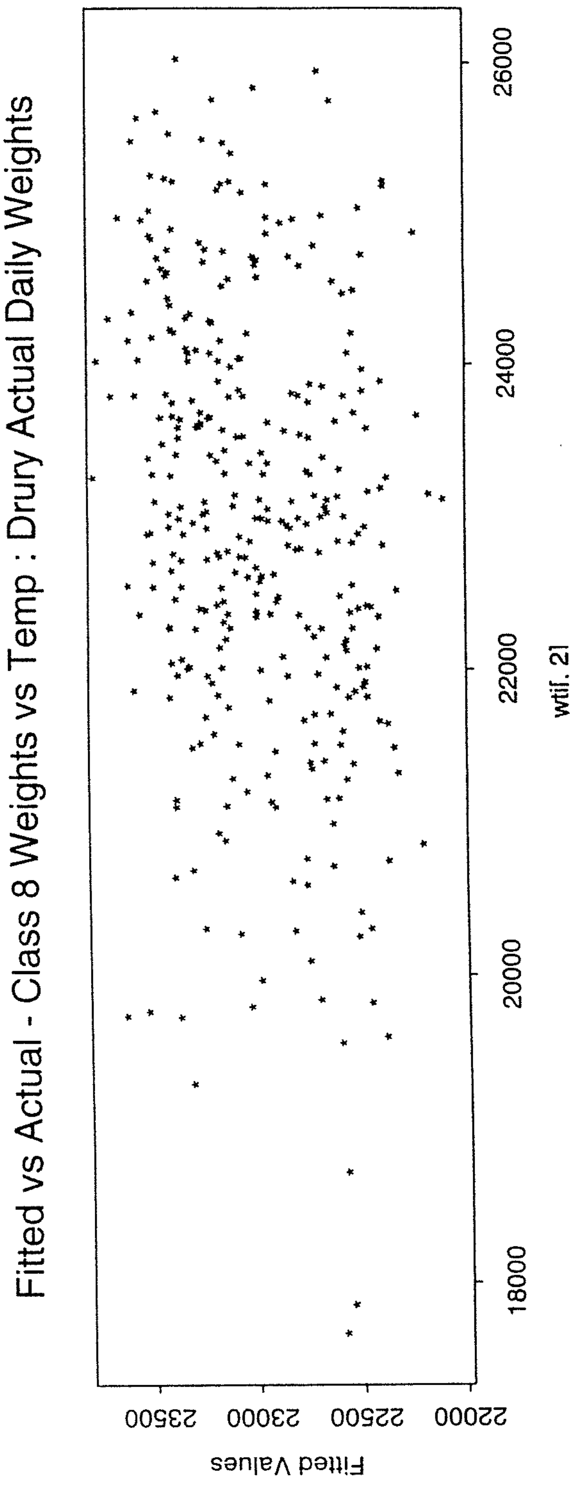

Fitted vs Actual - Class 3 Weights vs Temp : Drury Actual Daily Weights
Fitted Values
6540
6580
6620
6660
wti[, 2]
6000
6200
6400
6600
6800
7000

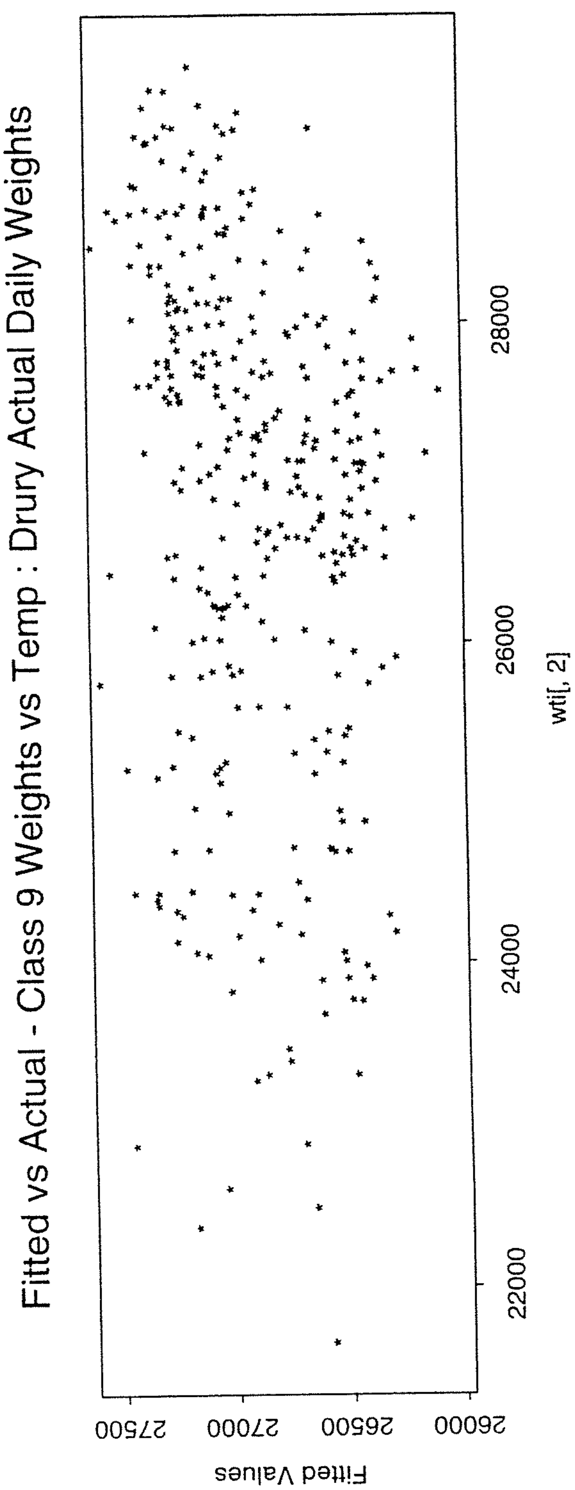

Fitted vs Actual - Class 4 Weights vs Temp : Drury Actual Daily Weights
Fitted Values
13600
14000
14400
wti[, 2]
13000
14000
15000
16000

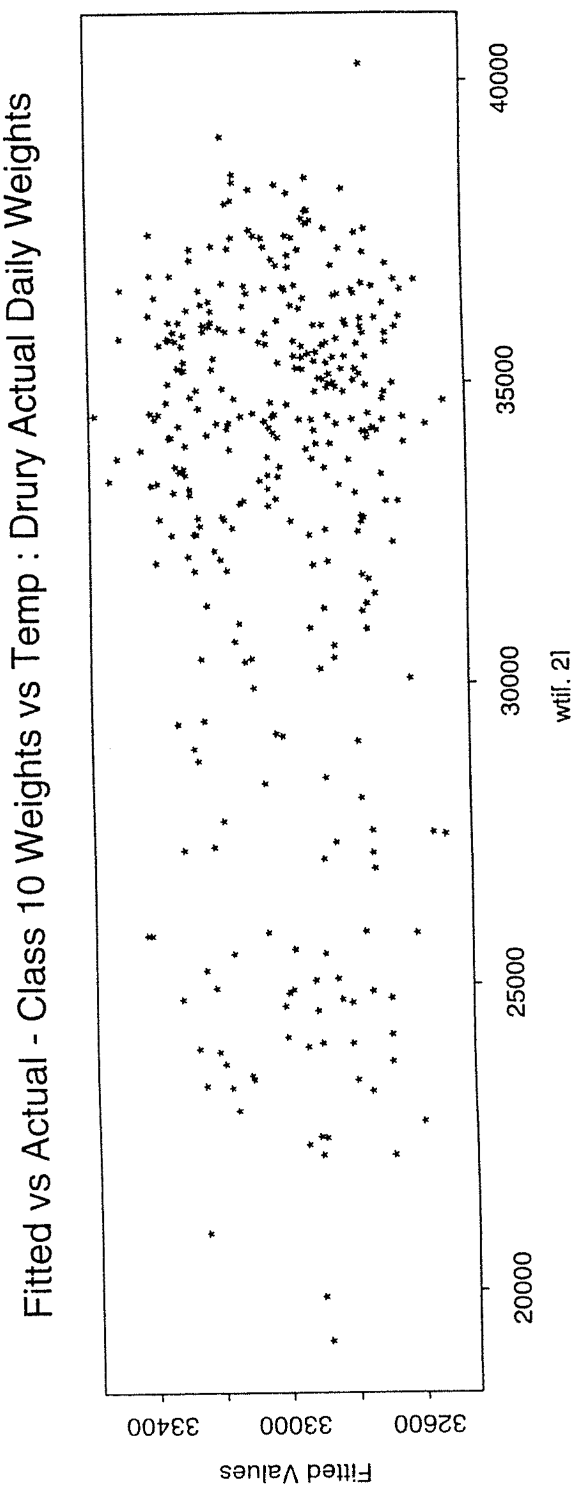

Fitted vs Actual - Class 5 Weights vs Temp : Drury Actual Daily Weights
Fitted Values
8500
8000
7500
6000
8000
10000
12000
wti[, 2]

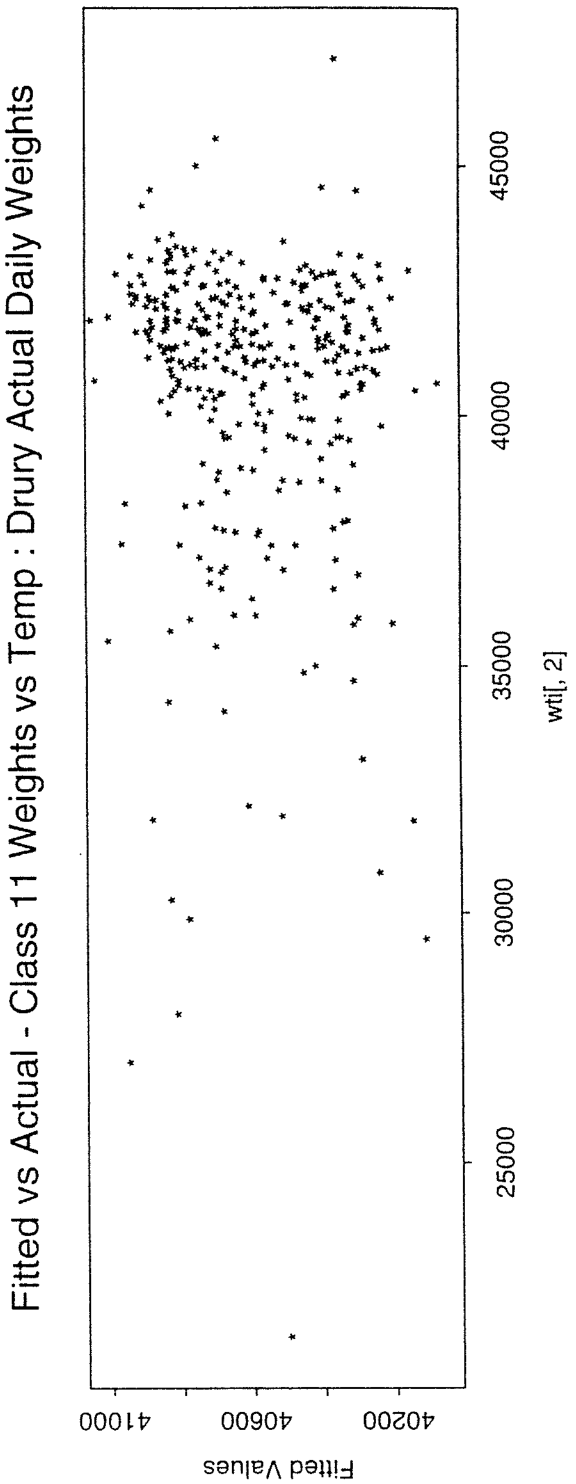

Fitted vs Actual - Class 6 Weights vs Temp : Drury Actual Daily Weights
Fitted Values
16600
16200
14000
15000
16000
17000
18000
19000
wti[, 2]

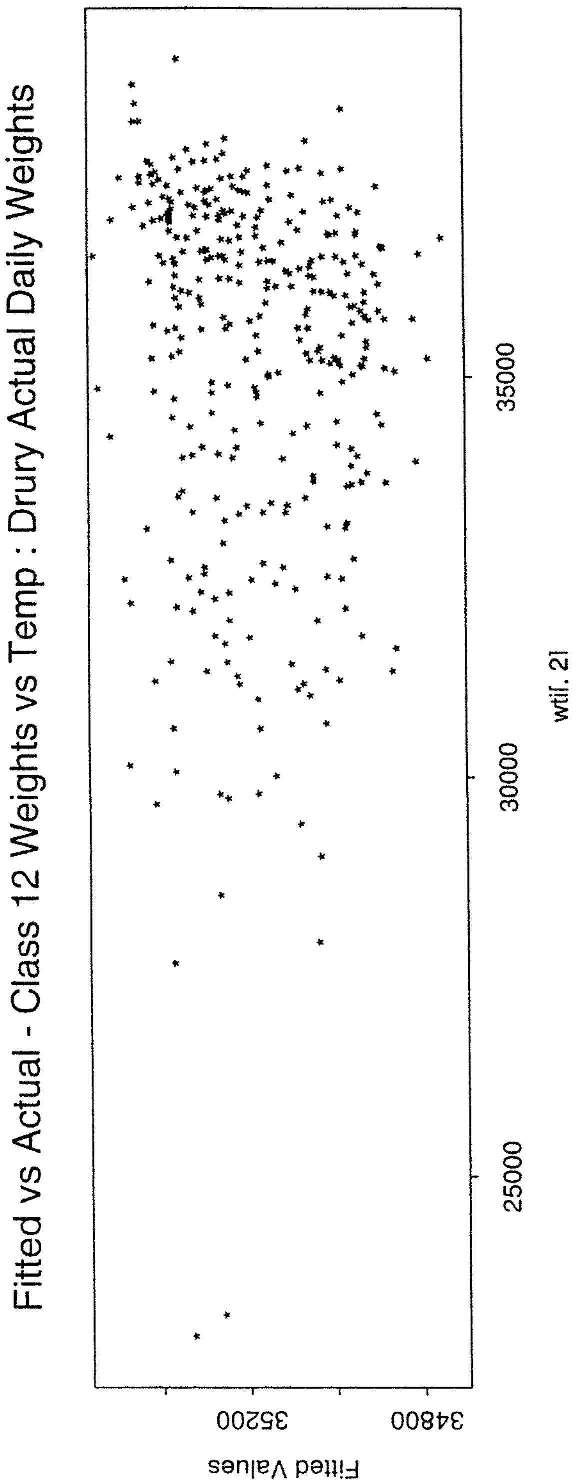

Fitted vs Actual - Class 7 Weights vs Temp : Drury Actual Daily Weights
8000
10000
12000
14000
16000
wti[, 2]
13040
13000
12960
Fitted Values

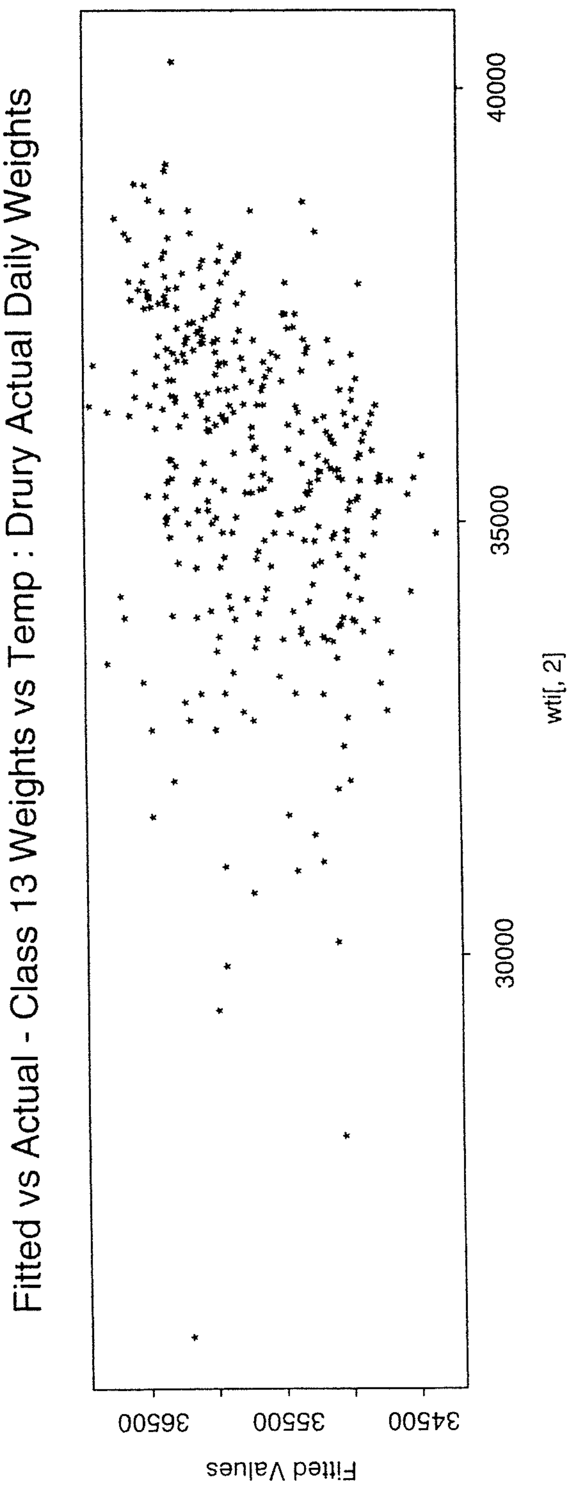

Fitted vs Actual - Class 8 Weights vs Temp : Drury Actual Daily Weights
18000
20000
22000
24000
26000
wti[, 2]
23500
23000
22500
22000
Fitted Values

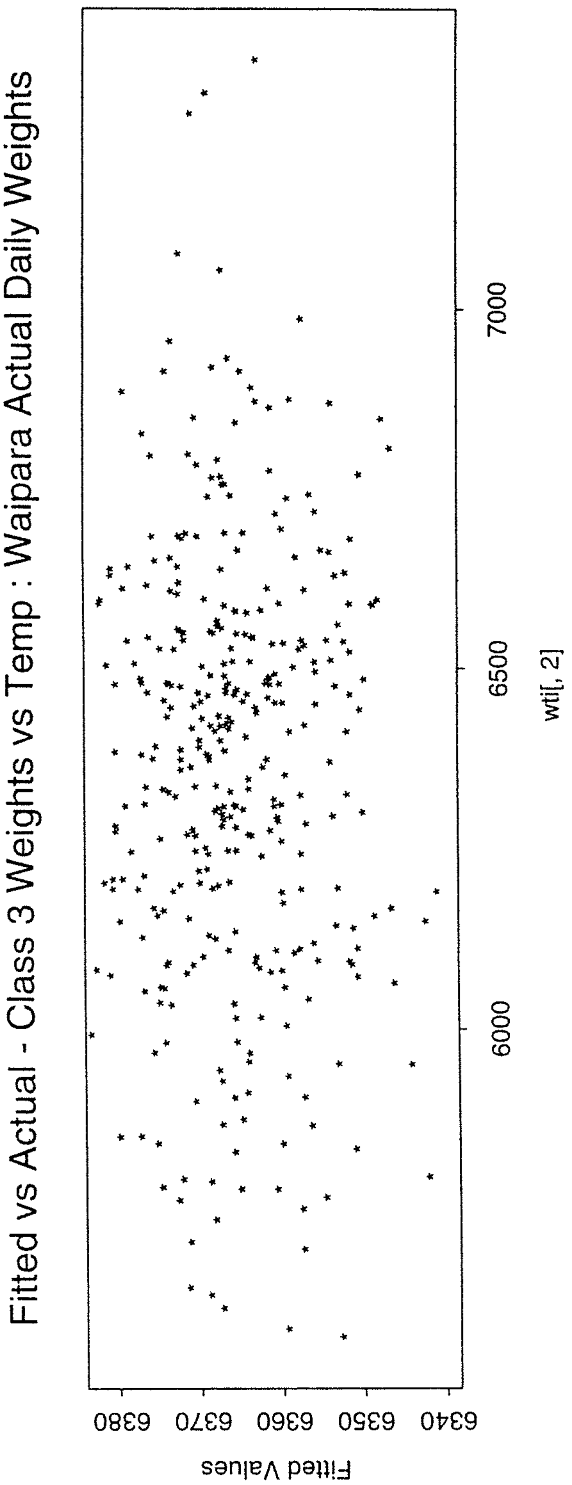

Fitted vs Actual - Class 9 Weights vs Temp : Drury Actual Daily Weights
wtl[, 2]
22000
24000
26000
28000
Fitted Values
26000
26500
27000
27500

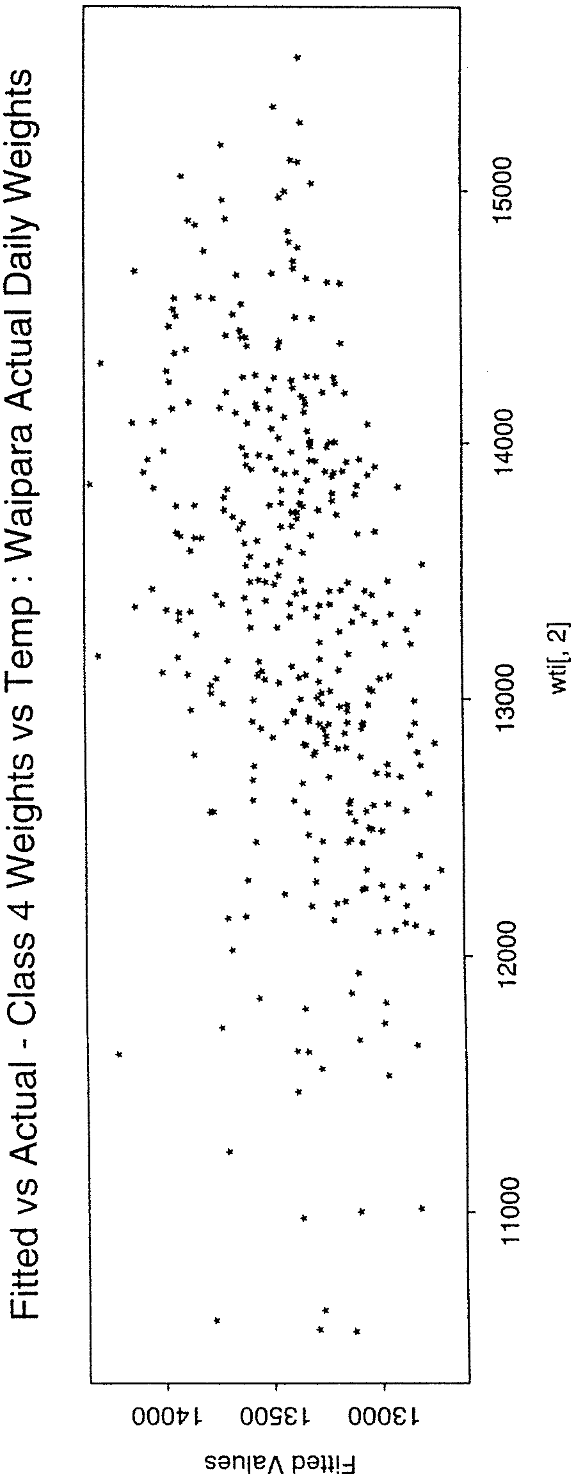

Fitted vs Actual - Class 10 Weights vs Temp : Drury Actual Daily Weights
wtl[, 2]
20000
25000
30000
35000
40000
Fitted Values
32600
33000
33400

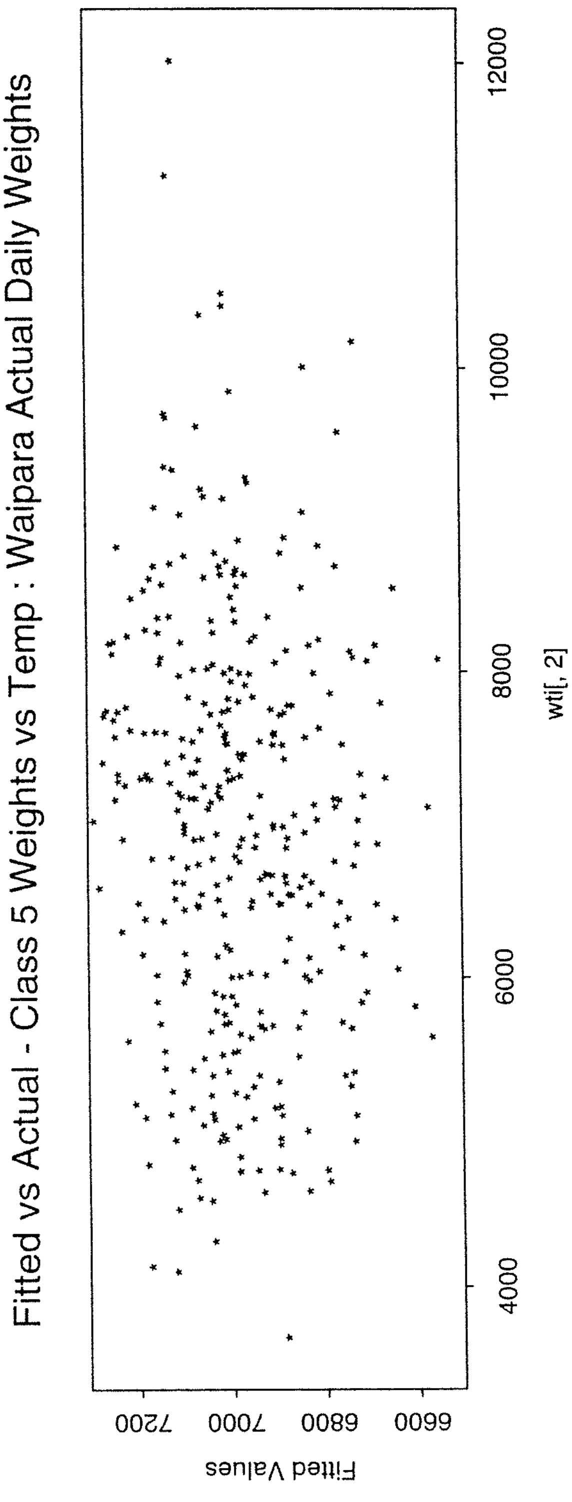

Fitted vs Actual - Class 11 Weights vs Temp : Drury Actual Daily Weights
Fitted Values
41000
40600
40200
wt[, 2]
25000
30000
35000
40000
45000

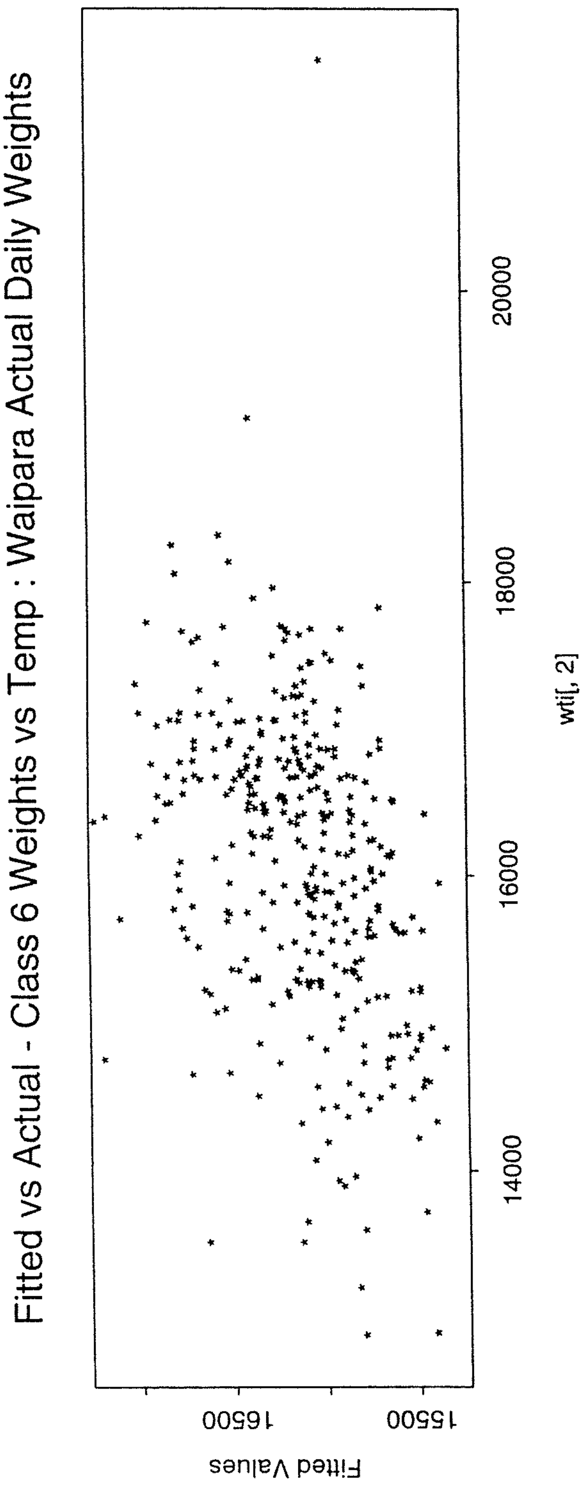

Fitted vs Actual - Class 12 Weights vs Temp : Drury Actual Daily Weights
Fitted Values
35200
34800
wt[, 2]
25000
30000
35000

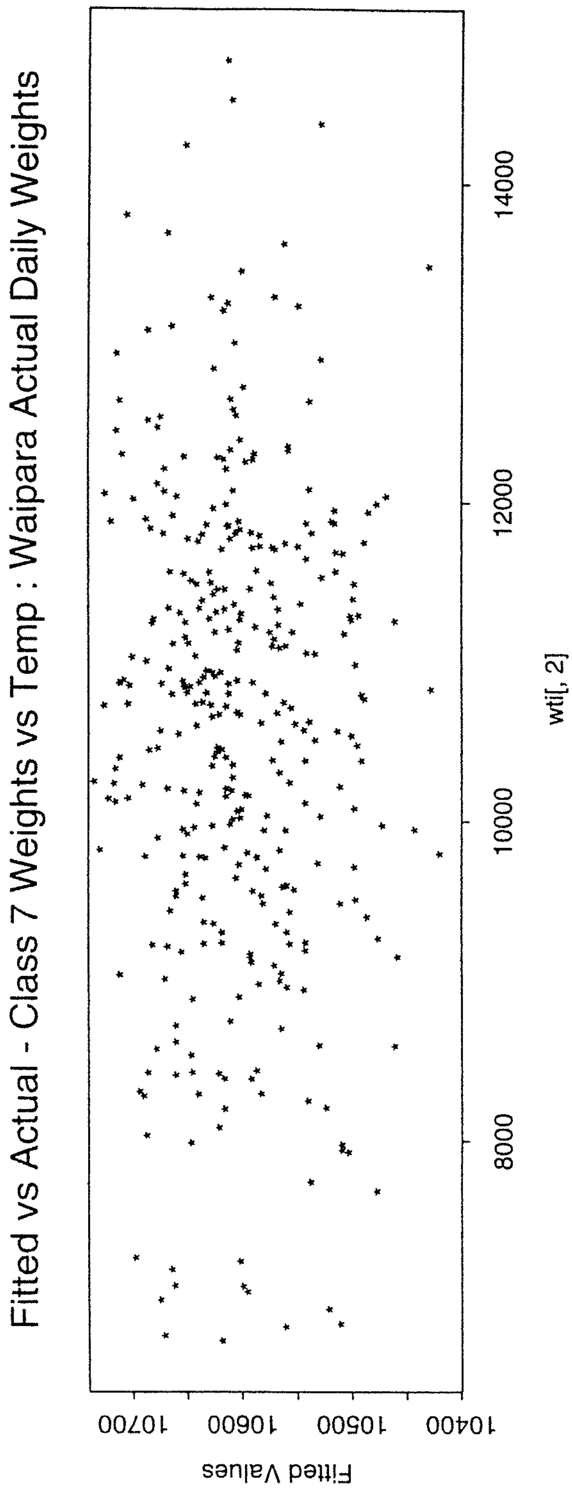

Fitted vs Actual - Class 13 Weights vs Temp : Drury Actual Daily Weights
30000
35000
40000
wti[, 2]
34500
35500
36500
Fitted Values

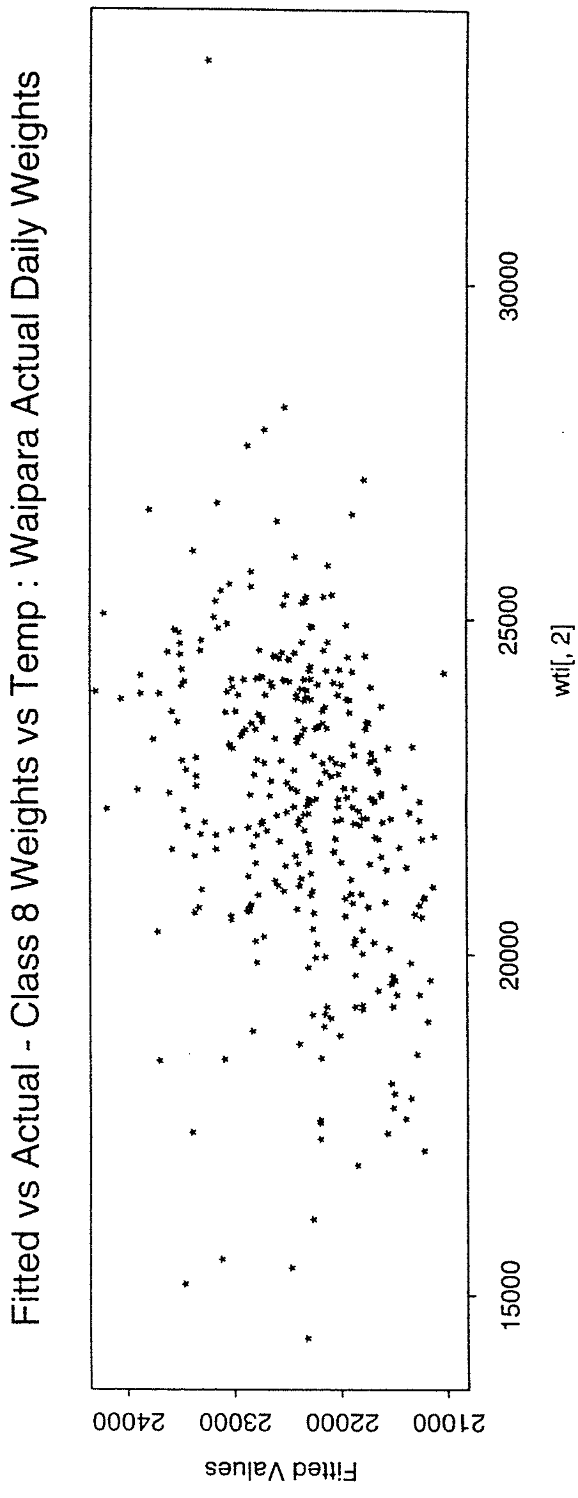

Fitted vs Actual - Class 3 Weights vs Temp : Waipara Actual Daily Weights
6000
6500
7000
wt[, 2]
6340
6350
6360
6370
6380
Fitted Values

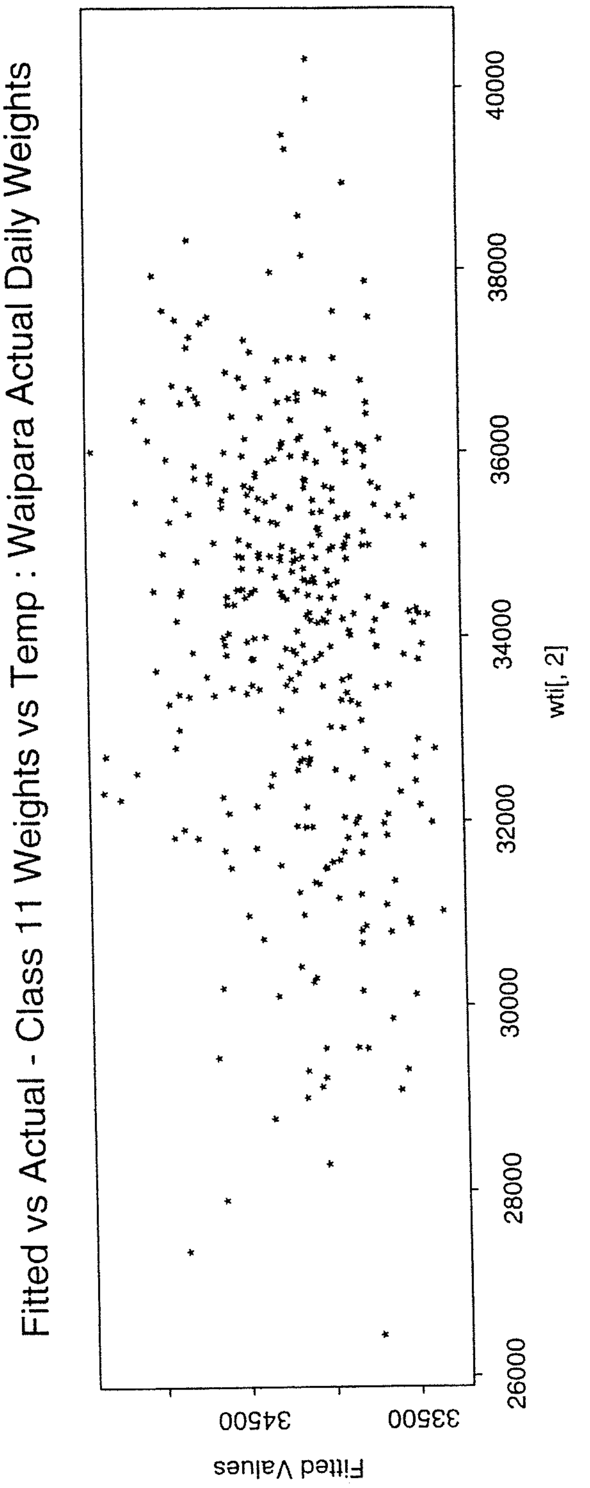

Fitted vs Actual - Class 4 Weights vs Temp : Waipara Actual Daily Weights
11000
12000
13000
14000
15000
wt[, 2]
13000
13500
14000
Fitted Values

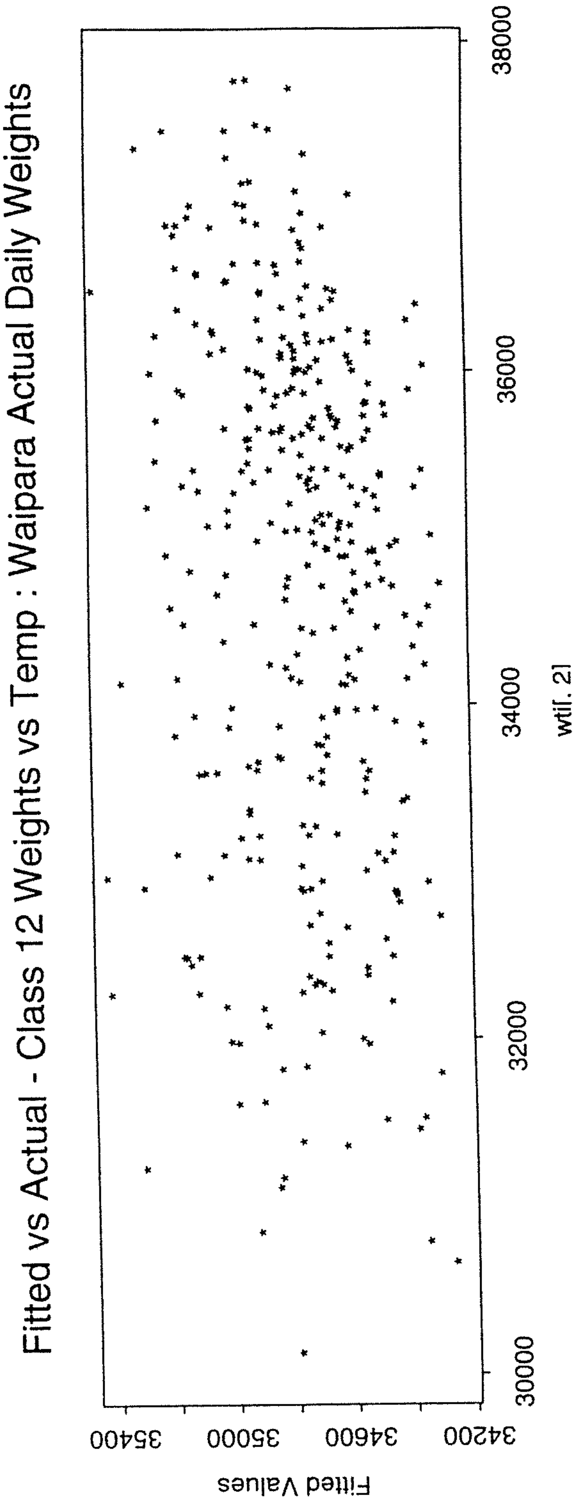

Fitted vs Actual - Class 5 Weights vs Temp : Waipara Actual Daily Weights
Fitted Values
wti[, 2]
4000
6000
8000
10000
12000
6600
6800
7000
7200

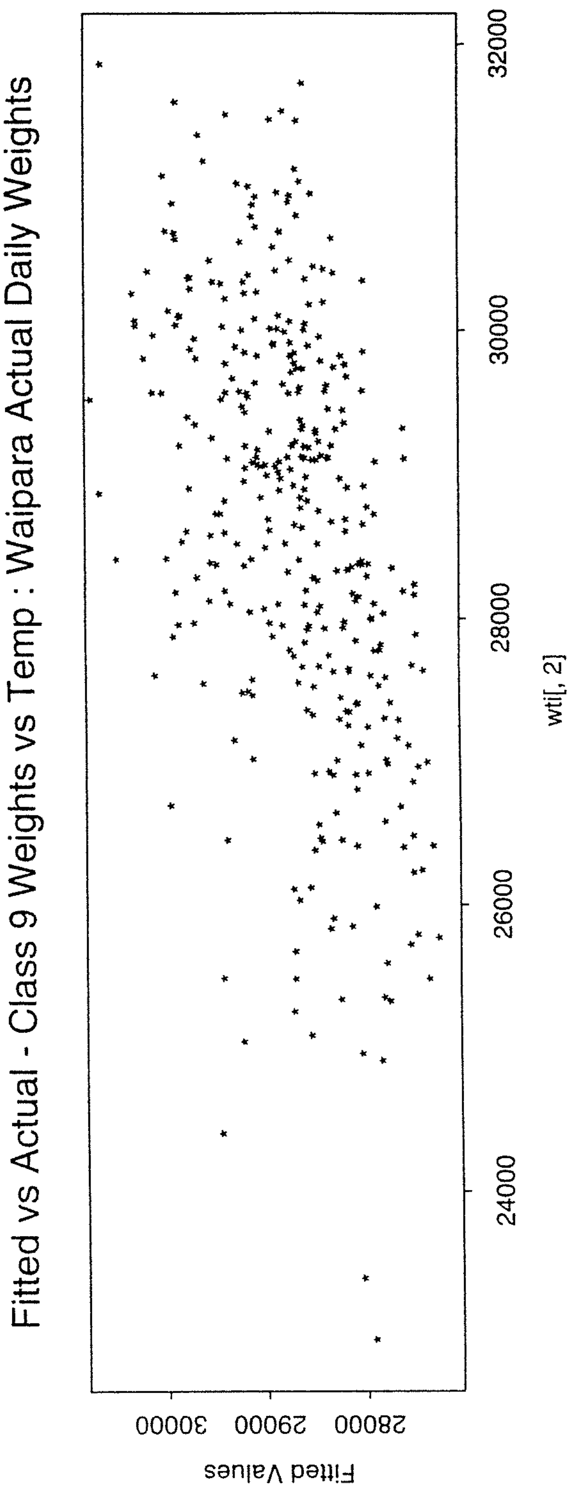

Fitted vs Actual - Class 6 Weights vs Temp : Waipara Actual Daily Weights
Fitted Values
wti[, 2]
14000
16000
18000
20000
15500
16500

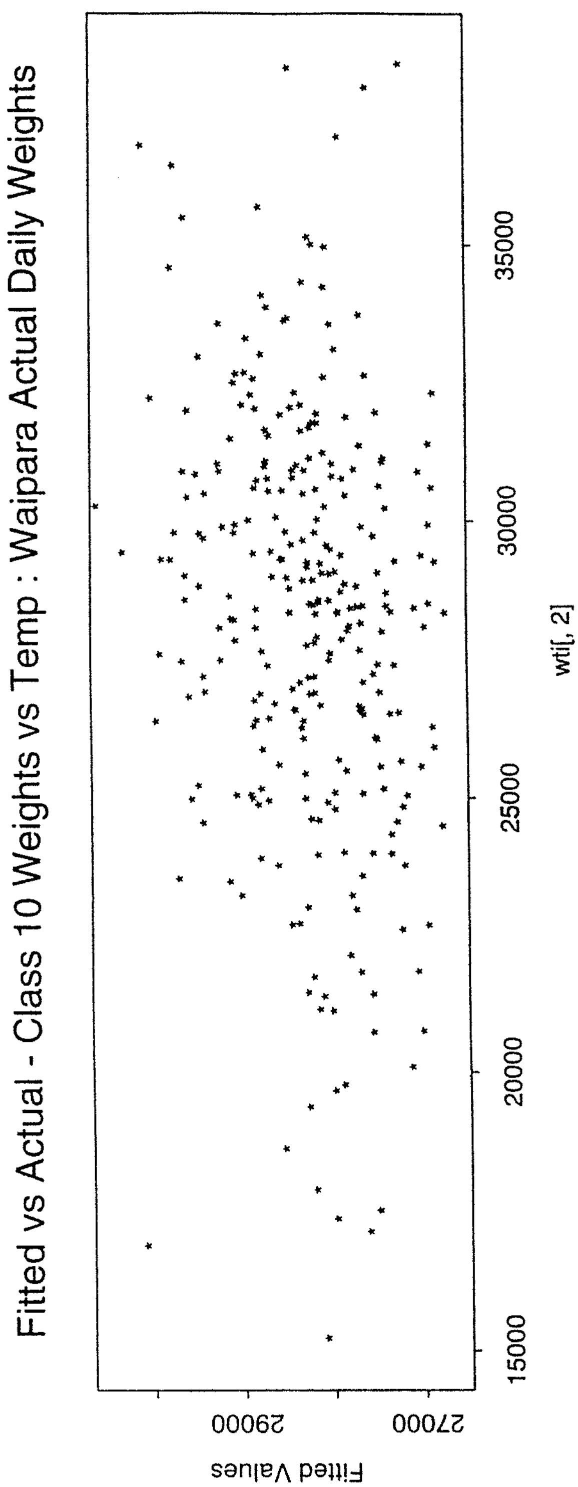

Fitted vs Actual - Class 7 Weights vs Temp : Waipara Actual Daily Weights
Fitted Values
10400
10500
10600
10700
wti[, 2]
8000
10000
12000
14000

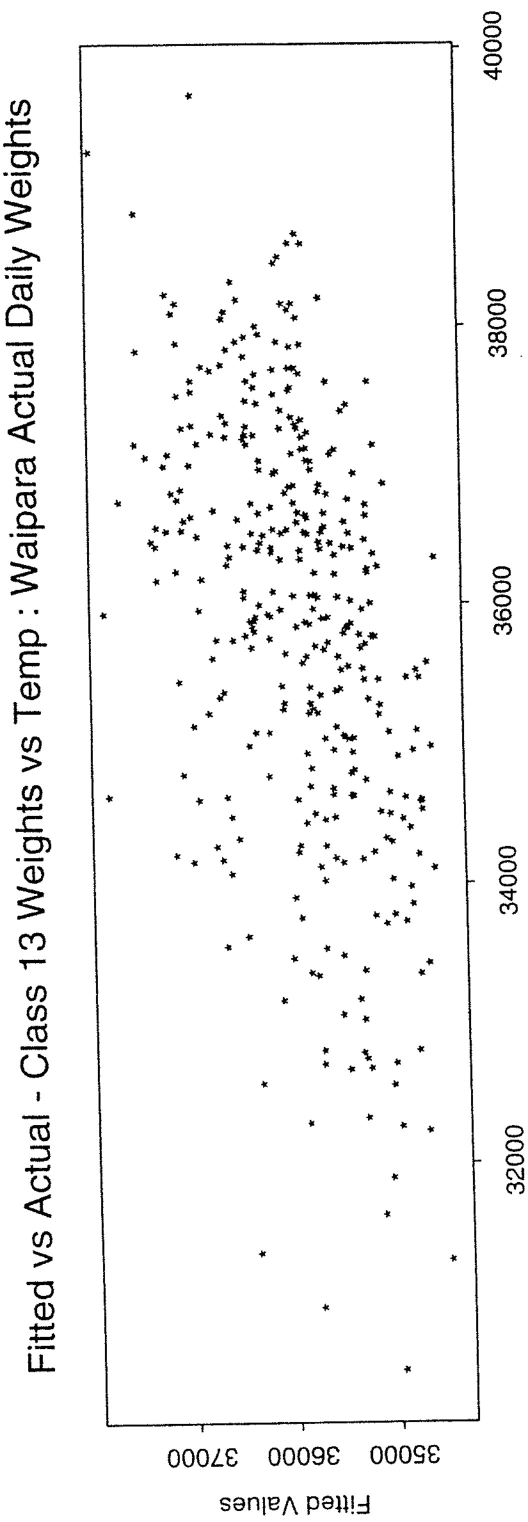

Fitted vs Actual - Class 8 Weights vs Temp : Waipara Actual Daily Weights
Fitted Values
21000
22000
23000
24000
wti[, 2]
15000
20000
25000
30000


Fitted vs Actual - Class 11 Weights vs Temp : Waipara Actual Daily Weights
Fitted Values
34500
33500
wti[, 2]
26000
28000
30000
32000
34000
36000
38000
40000

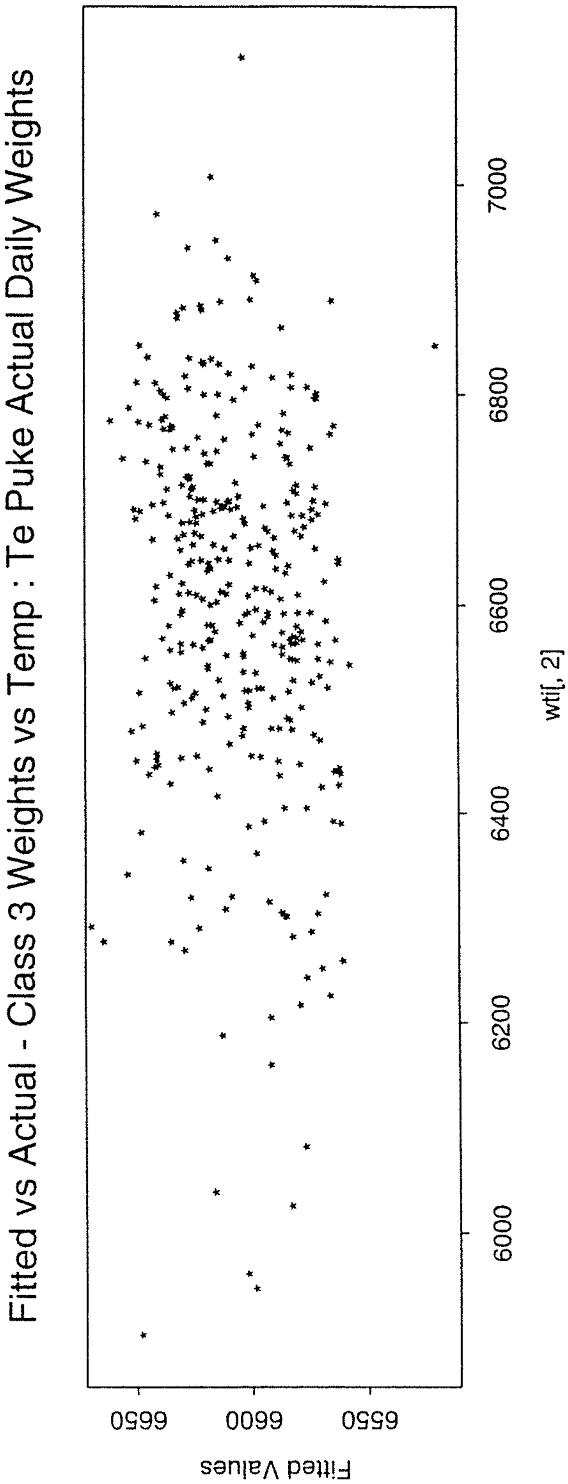

Fitted vs Actual - Class 12 Weights vs Temp : Waipara Actual Daily Weights
Fitted Values
35400
35000
34600
34200
wti[, 2]
30000
32000
34000
36000
38000

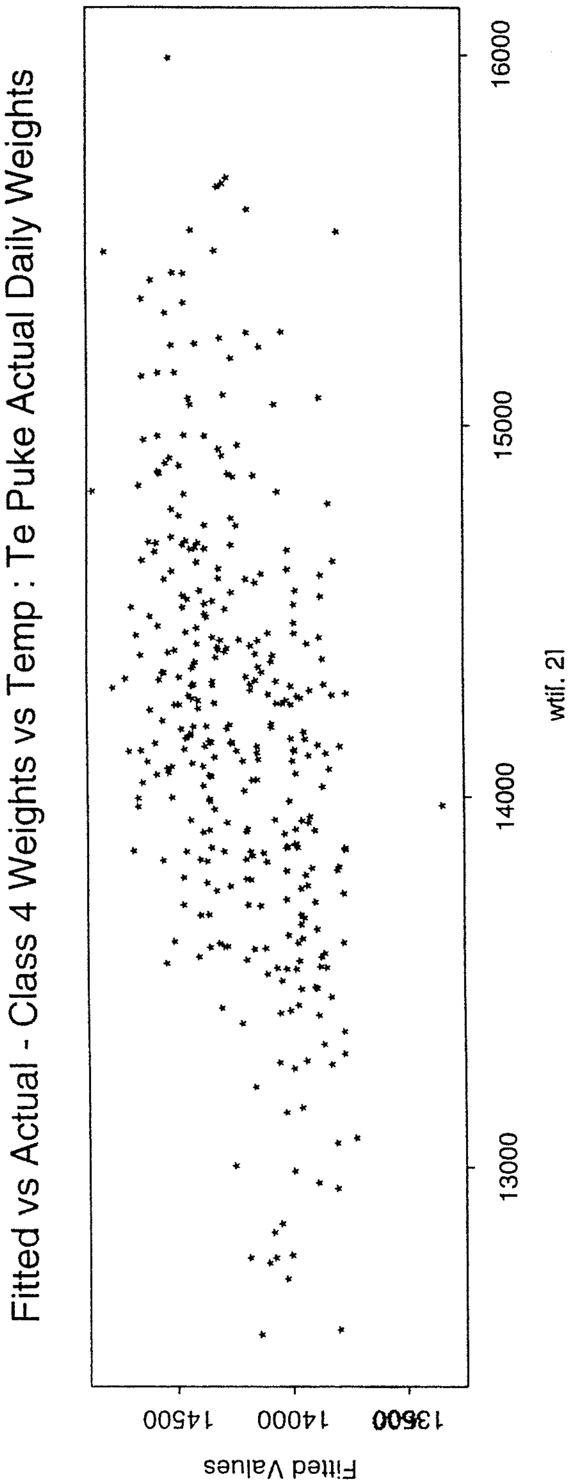

Fitted vs Actual - Class 9 Weights vs Temp : Waipara Actual Daily Weights
24000
26000
28000
30000
32000
wti[, 2]
28000
29000
30000
Fitted Values

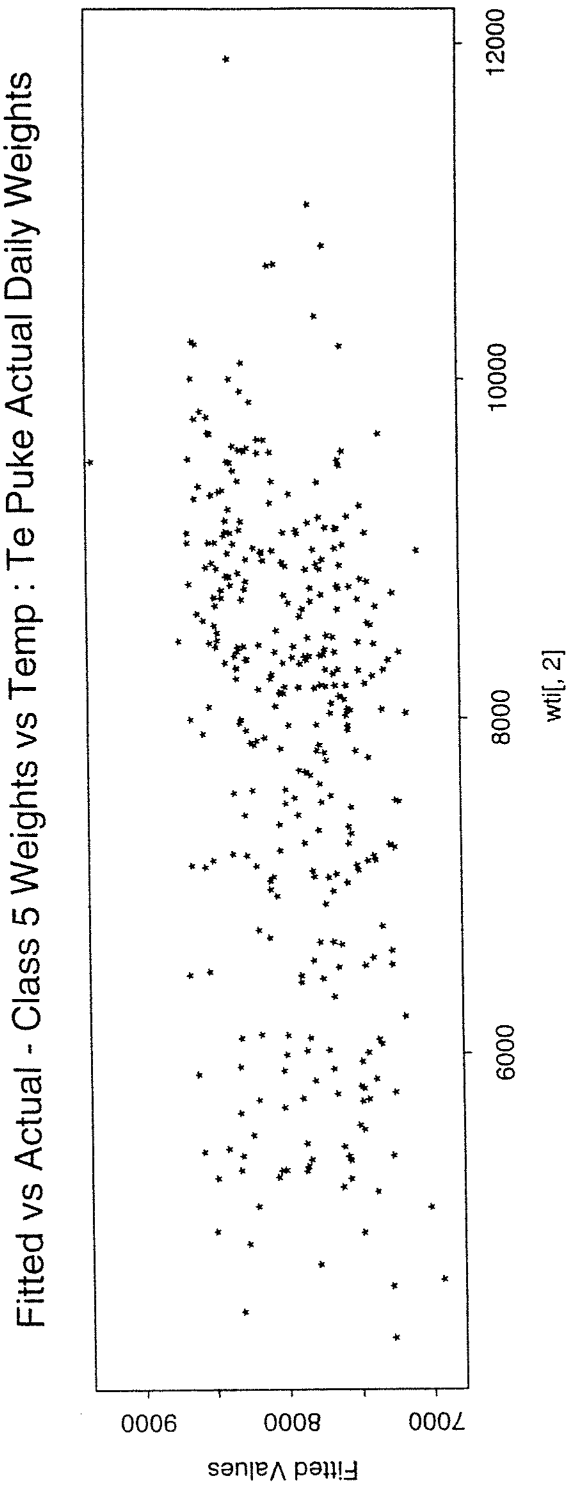

Fitted vs Actual - Class 10 Weights vs Temp : Waipara Actual Daily Weights
15000
20000
25000
30000
35000
wti[, 2]
27000
29000
Fitted Values

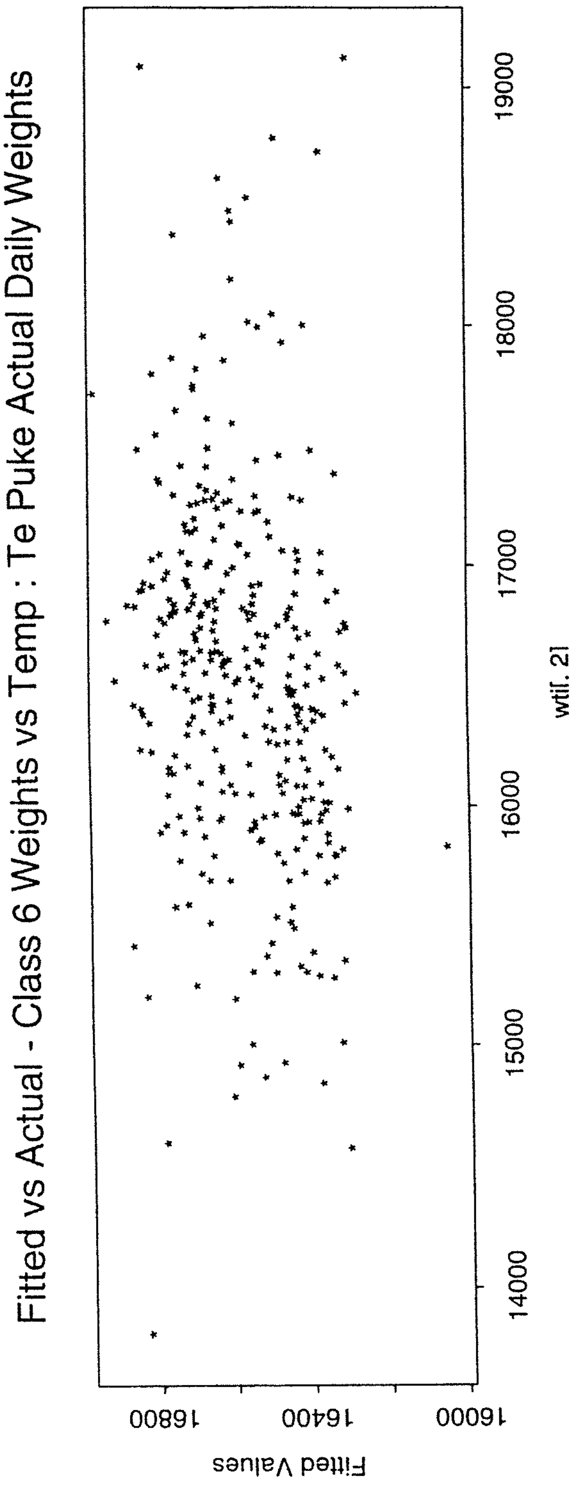


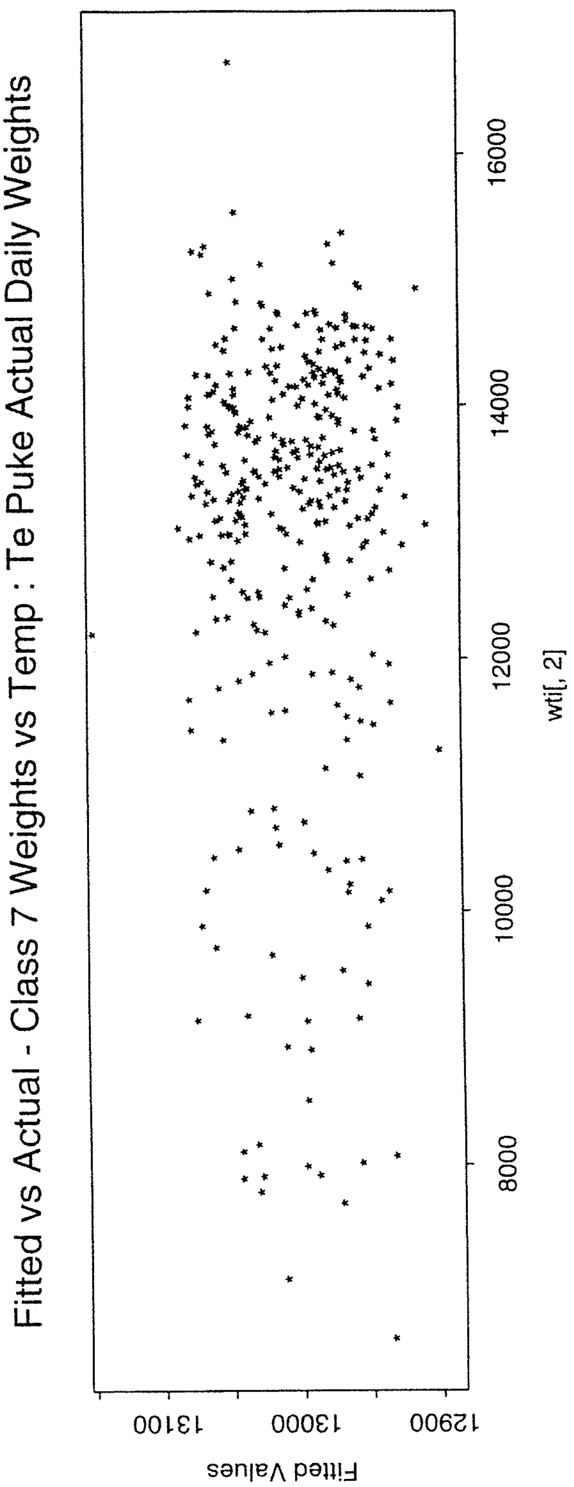
Fitted vs Actual - Class 13 Weights vs Temp : Waipara Actual Daily Weights
Fitted Values
35000
36000
37000
wti[, 2]
32000
34000
36000
38000
40000

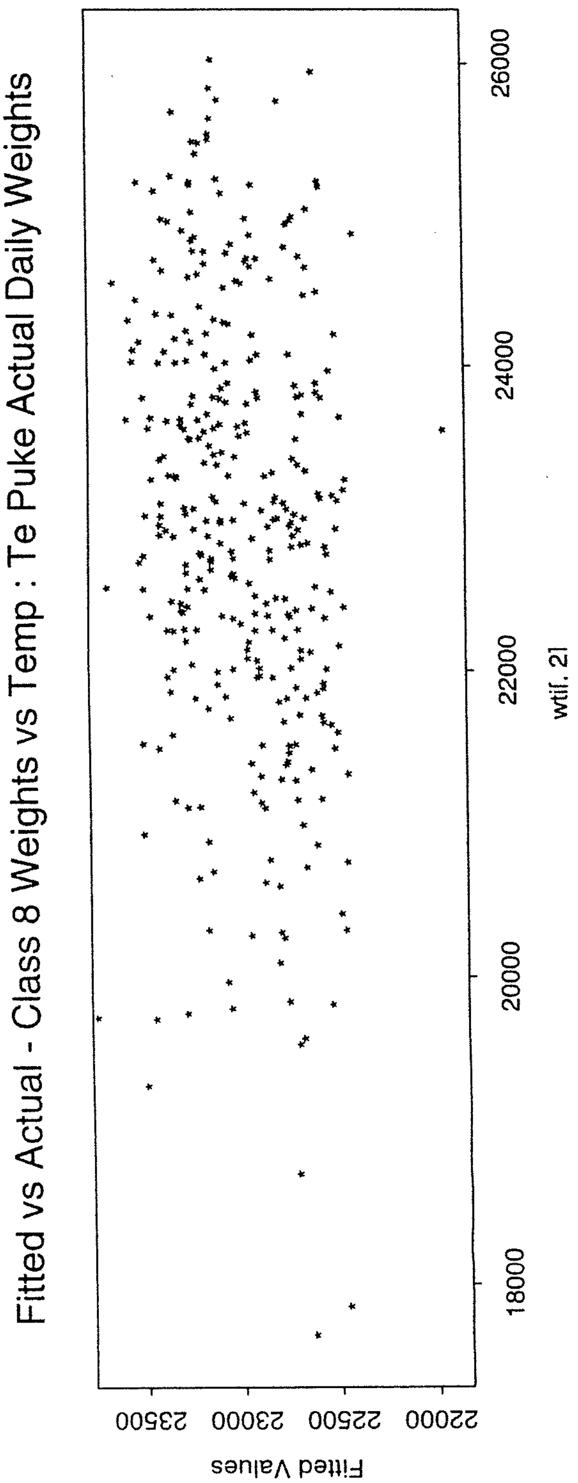

Fitted vs Actual - Class 3 Weights vs Temp : Te Puke Actual Daily Weights
Fitted Values
wti[, 2]
6000
6200
6400
6600
6800
7000
6550
6600
6650

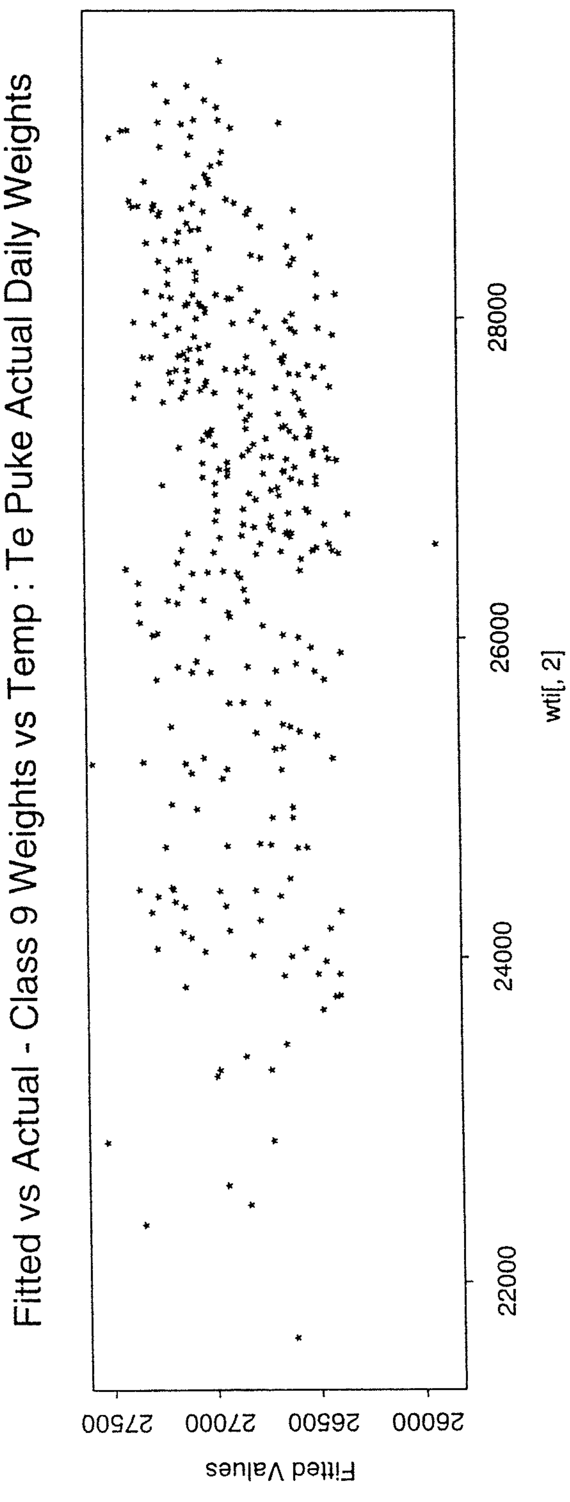

Fitted vs Actual - Class 4 Weights vs Temp : Te Puke Actual Daily Weights
Fitted Values
wti[, 2]
13000
14000
15000
16000
13500
14000
14500

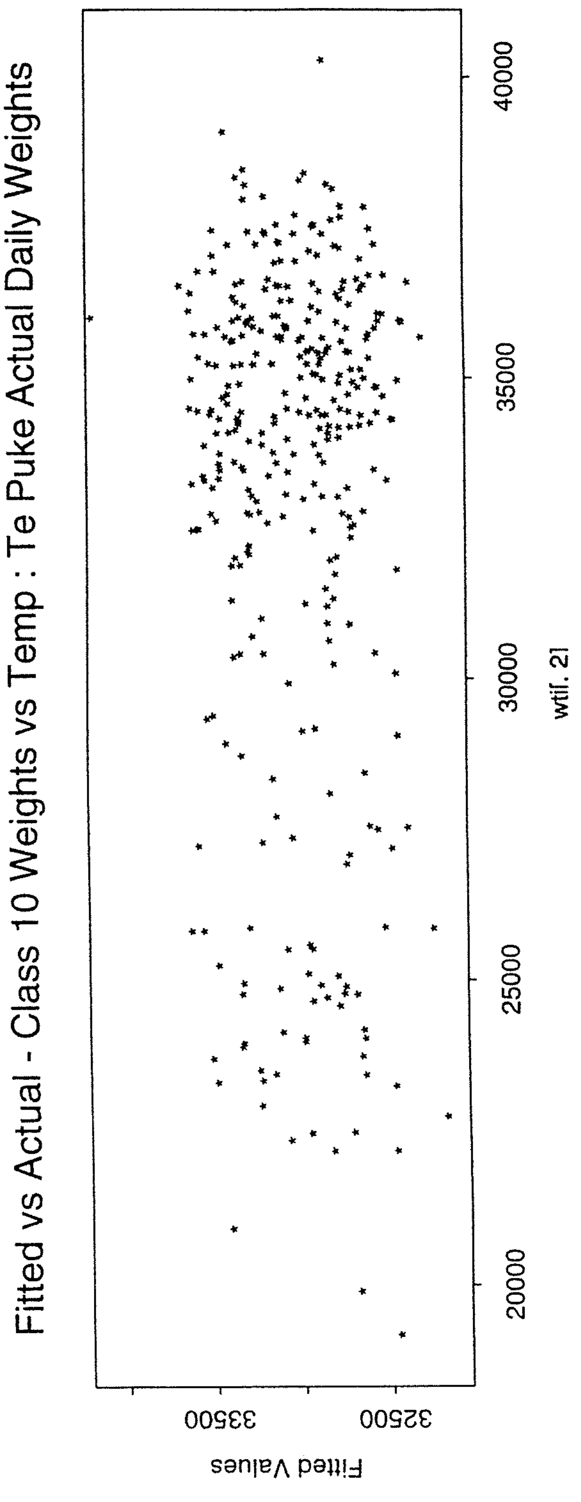

Fitted vs Actual - Class 5 Weights vs Temp : Te Puke Actual Daily Weights
Fitted Values
7000
8000
9000
wti[, 2]
6000
8000
10000
12000

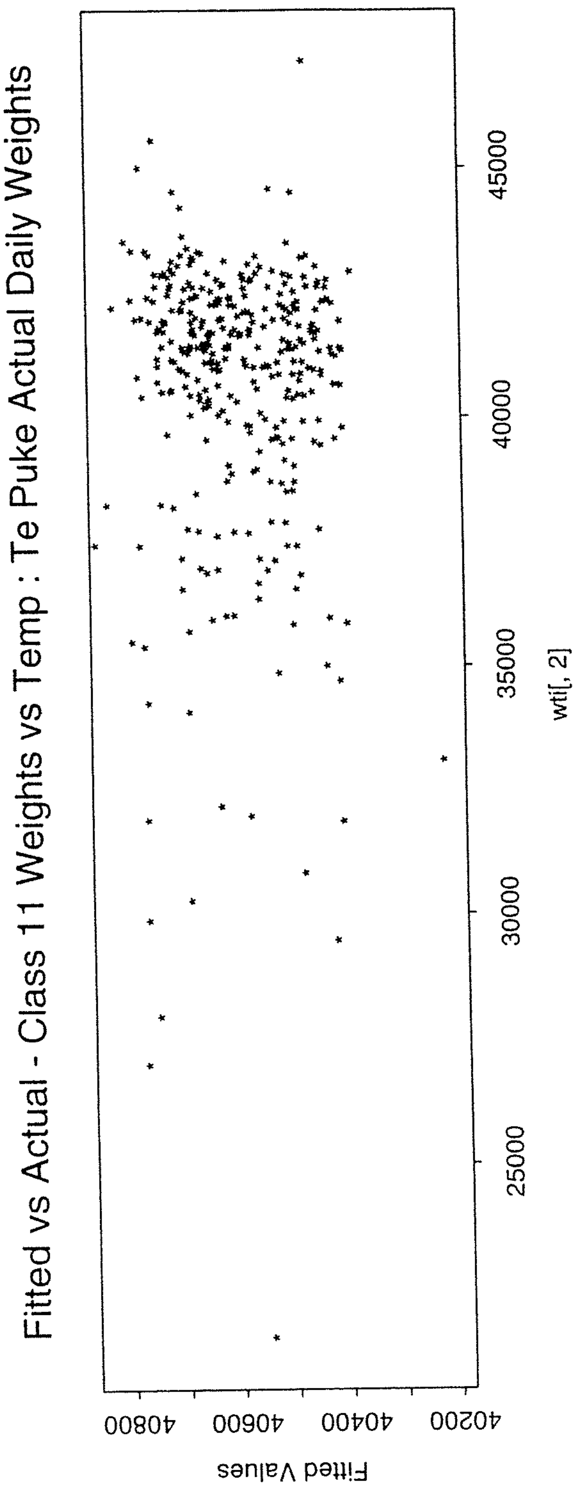

Fitted vs Actual - Class 6 Weights vs Temp : Te Puke Actual Daily Weights
Fitted Values
16000
16400
16800
wti[, 2]
14000
15000
16000
17000
18000
19000

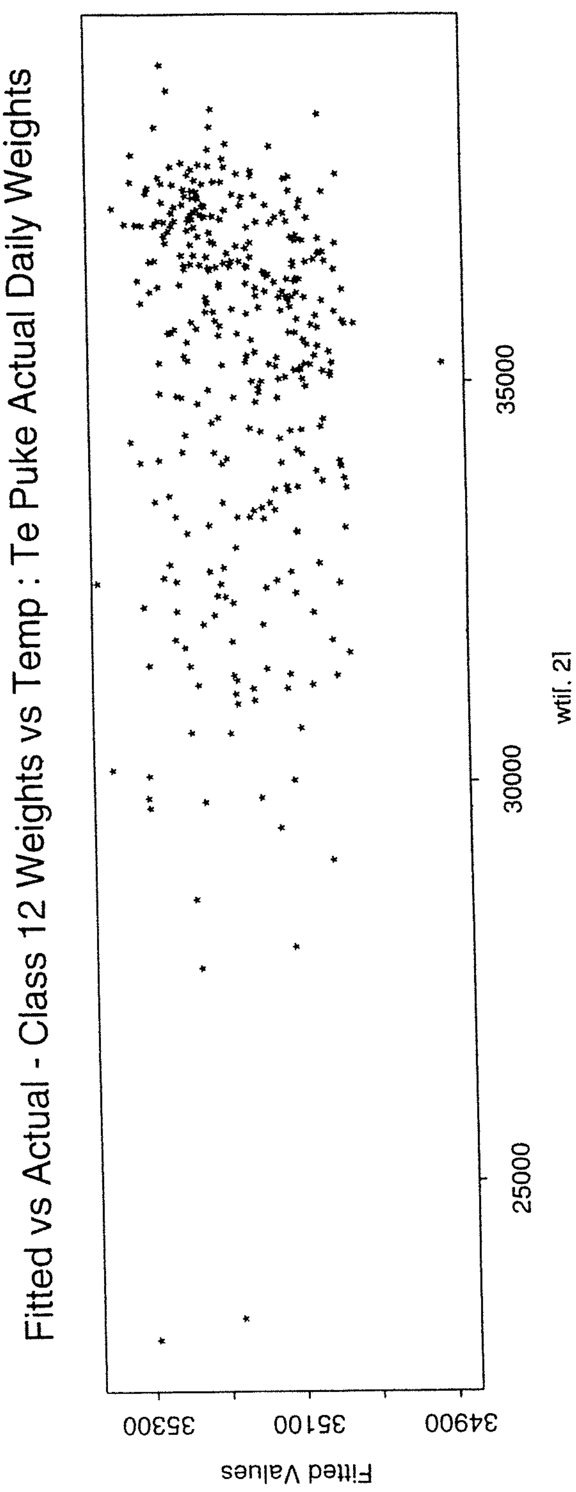

Fitted vs Actual - Class 7 Weights vs Temp : Te Puke Actual Daily Weights
Fitted Values
13100
13000
12900
wti[, 2]
8000
10000
12000
14000
16000

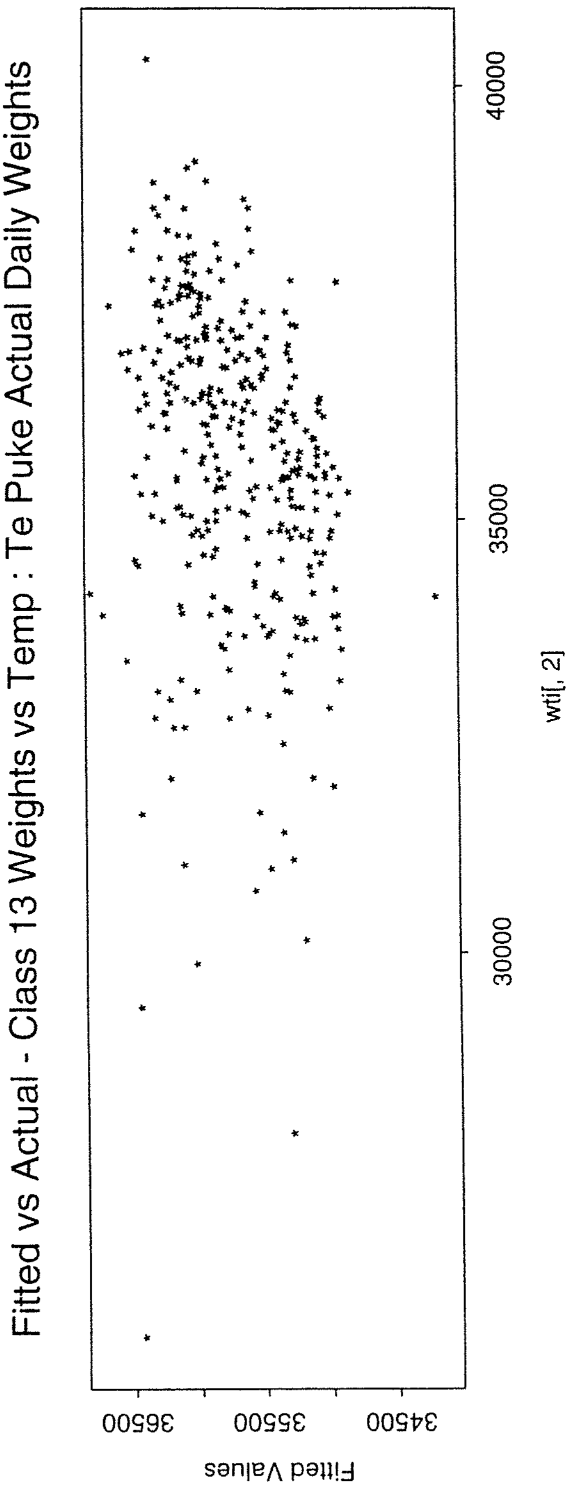

Fitted vs Actual - Class 8 Weights vs Temp : Te Puke Actual Daily Weights
Fitted Values
23500
23000
22500
22000
wti[, 2]
18000
20000
22000
24000
26000


Fitted vs Actual - Class 9 Weights vs Temp : Te Puke Actual Daily Weights
Fitted Values
26000
26500
27000
27500
wti[, 2]
22000
24000
26000
28000


Fitted vs Actual - Class 10 Weights vs Temp : Te Puke Actual Daily Weights
Fitted Values
32500
33500
wti[, 2]
20000
25000
30000
35000
40000


Fitted vs Actual - Class 11 Weights vs Temp : Te Puke Actual Daily Weights
wti[, 2]
Fitted Values
25000
30000
35000
40000
45000
40200
40400
40600
40800

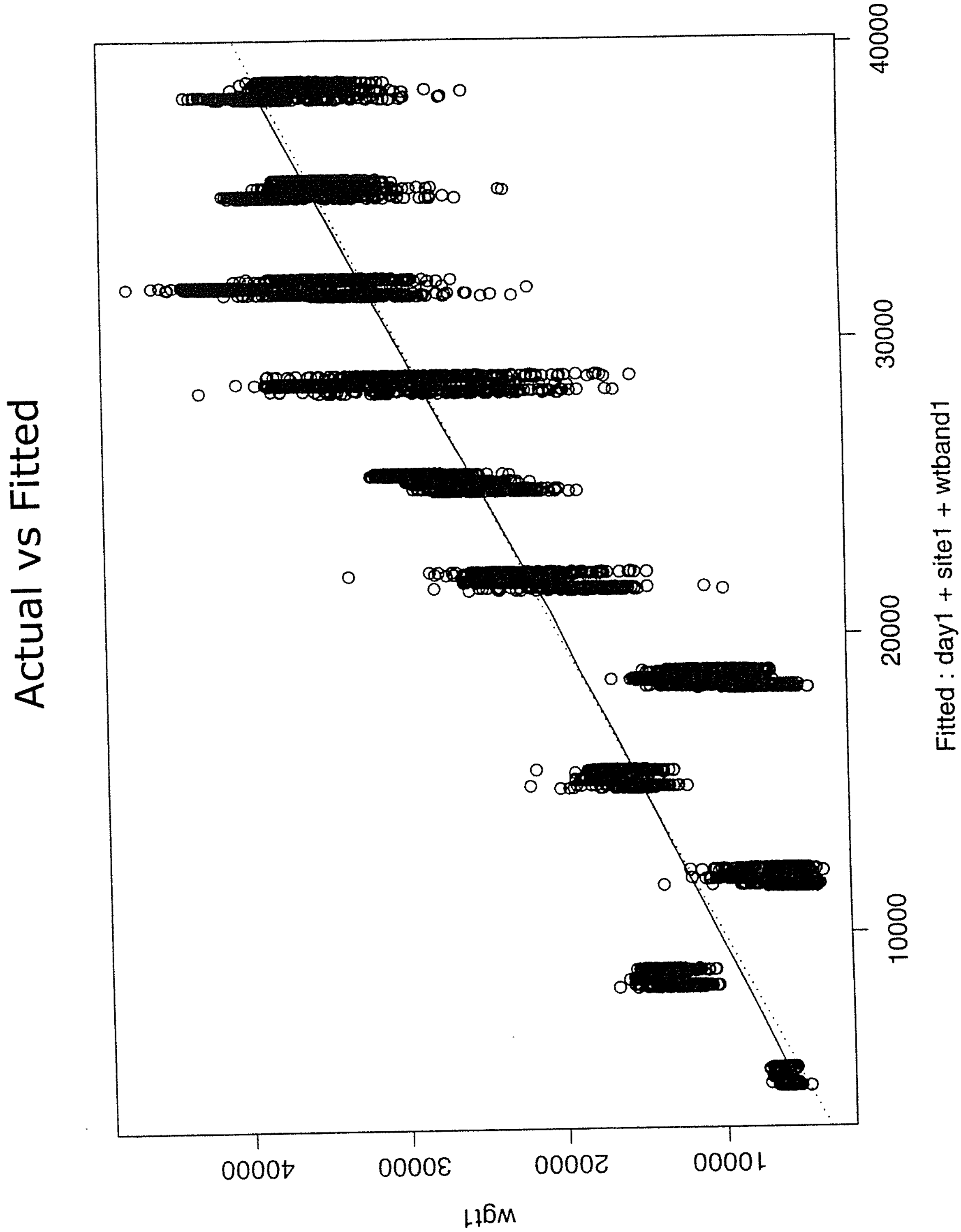

Fitted vs Actual - Class 12 Weights vs Temp : Te Puke Actual Daily Weights
wtl[, 2]
Fitted Values
25000
30000
35000
34900
35100
35300


Fitted vs Actual - Class 13 Weights vs Temp : Te Puke Actual Daily Weights
Fitted Values
34500
35500
36500
wt[, 2]
30000
35000
40000

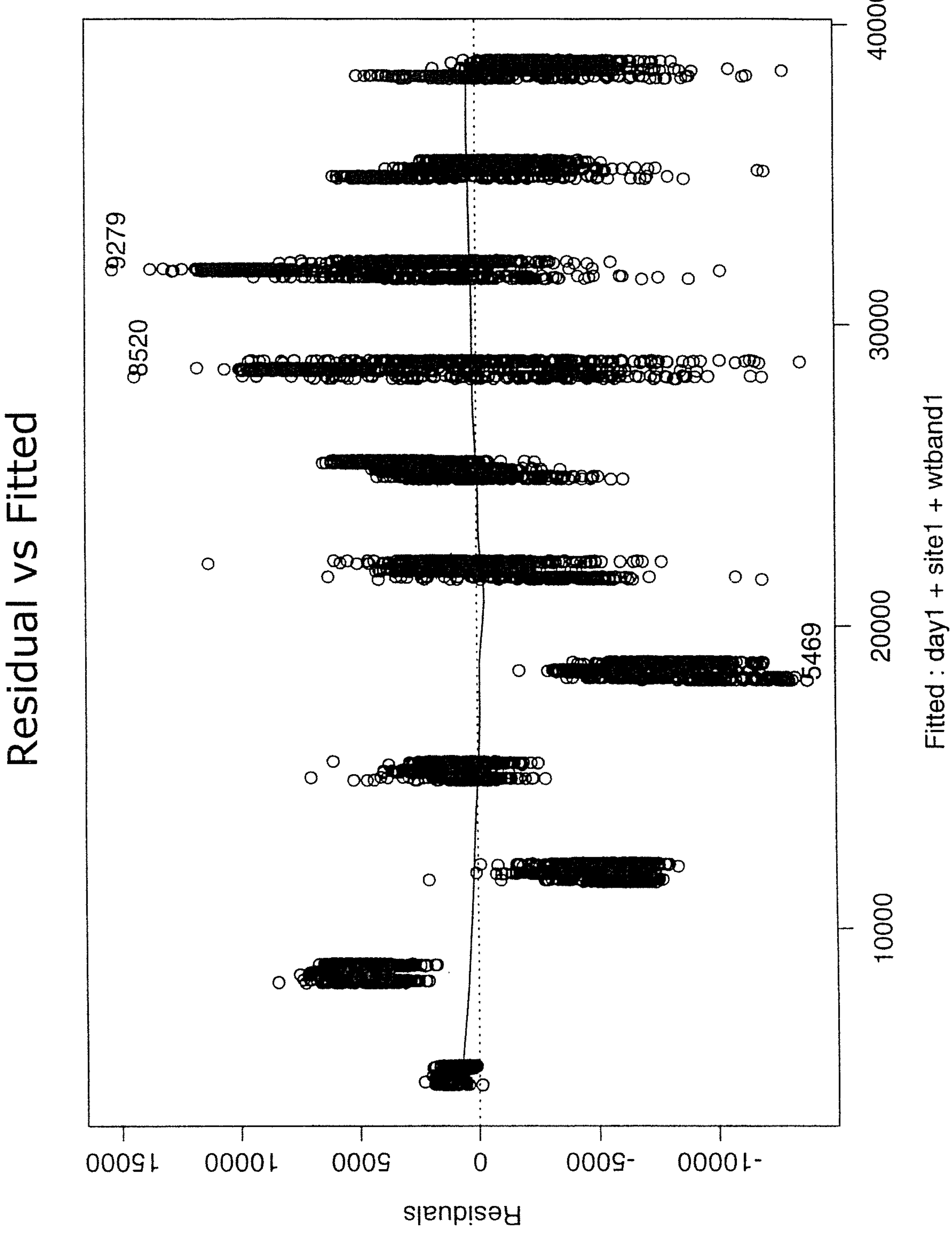
Appendix F

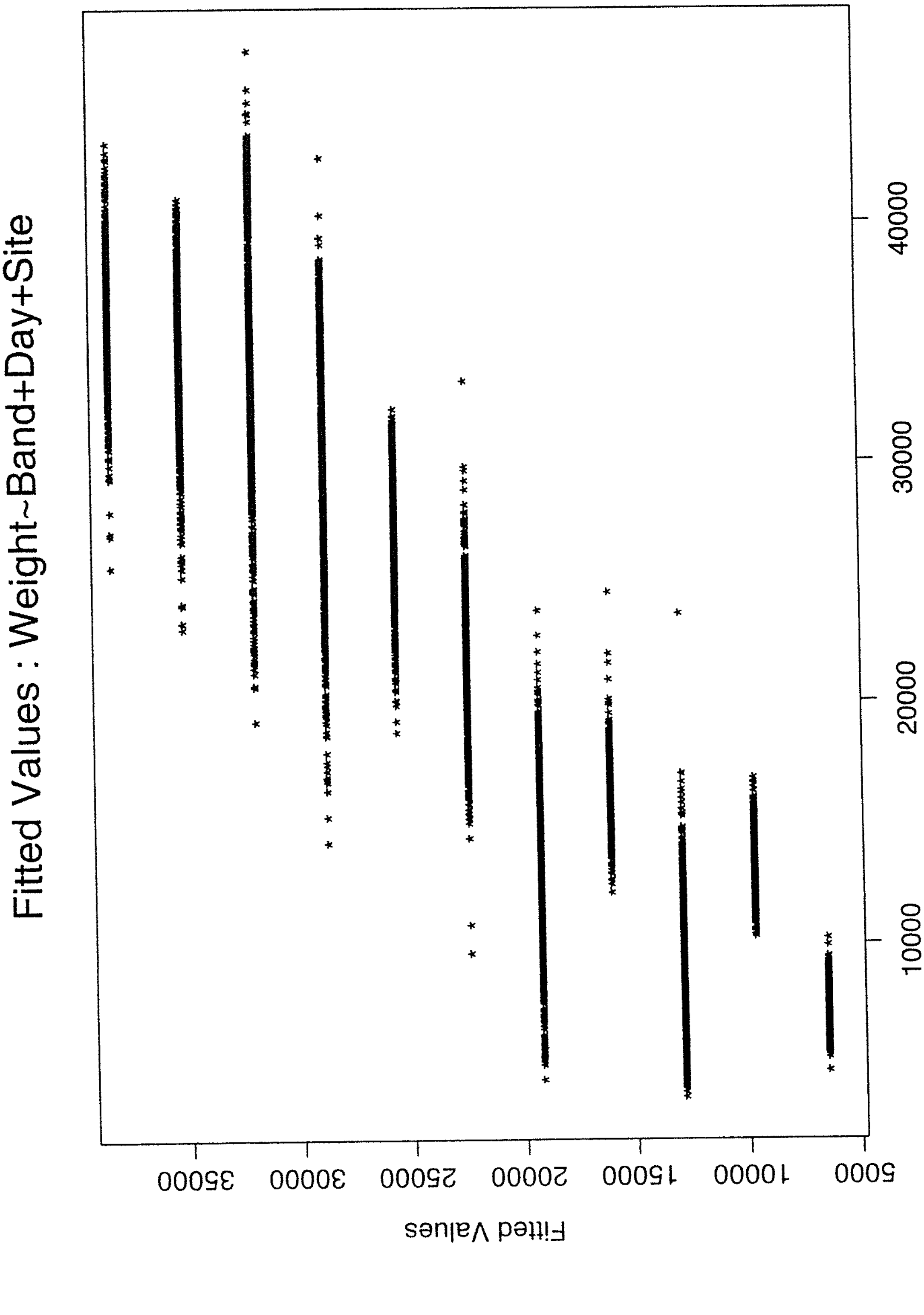
Regression of Weights versus Weight Class and Site over Days of Year, for All Vehicles

Three WIM Sites



Actual vs Fitted
wgt1
Fitted : day1 + site1 + wtband1
10000
20000
30000
40000

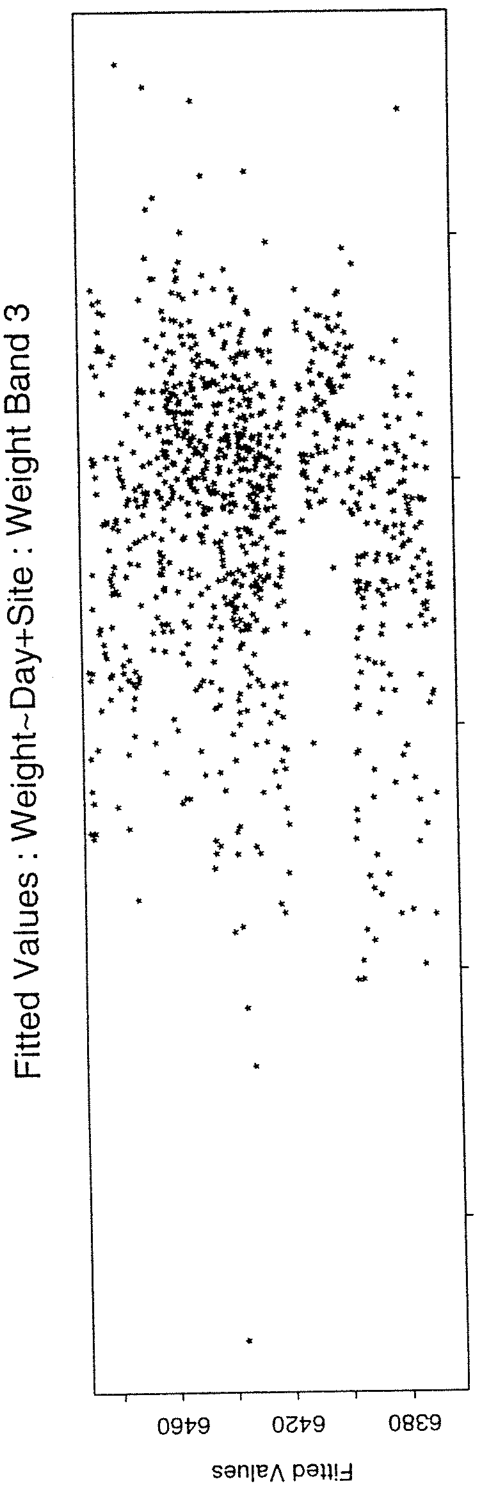

Residual vs Fitted
Residuals
15000
10000
5000
0
-5000
-10000
Fitted : day1 + site1 + wtband1
10000
20000
30000
40000
9279
8520
5469

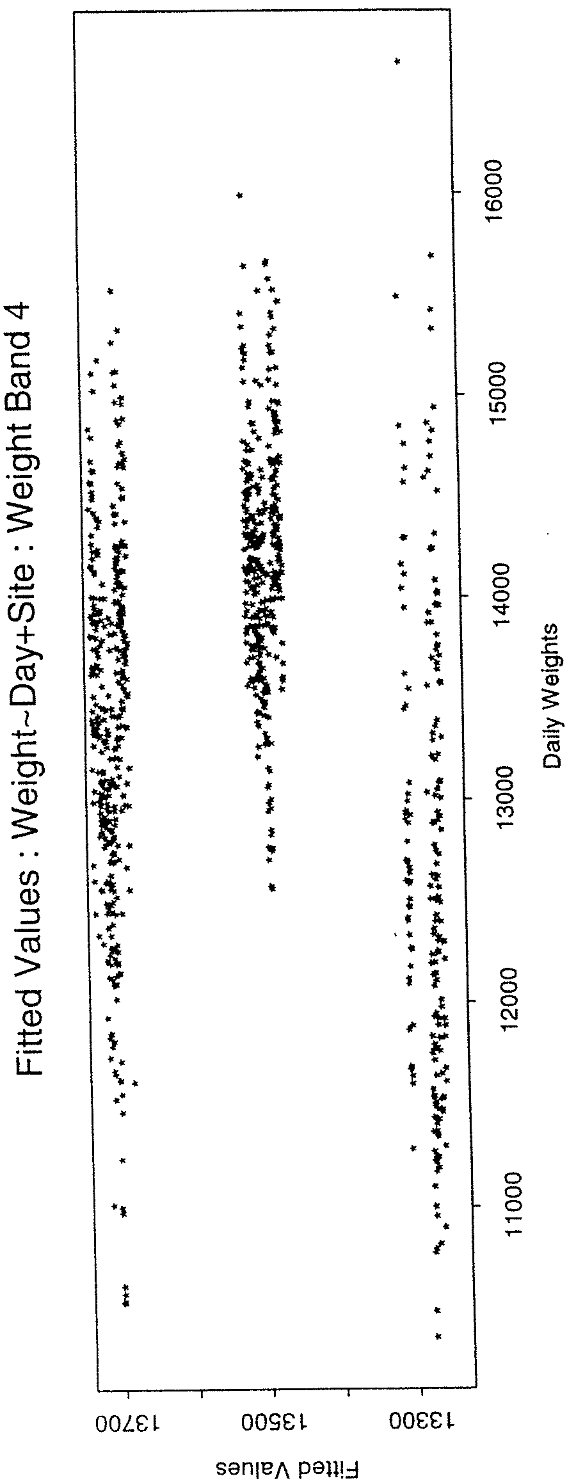

Fitted Values : Weight~Band+Day+Site
Daily Weights
10000
20000
30000
40000
Fitted Values
5000
10000
15000
20000
25000
30000
35000

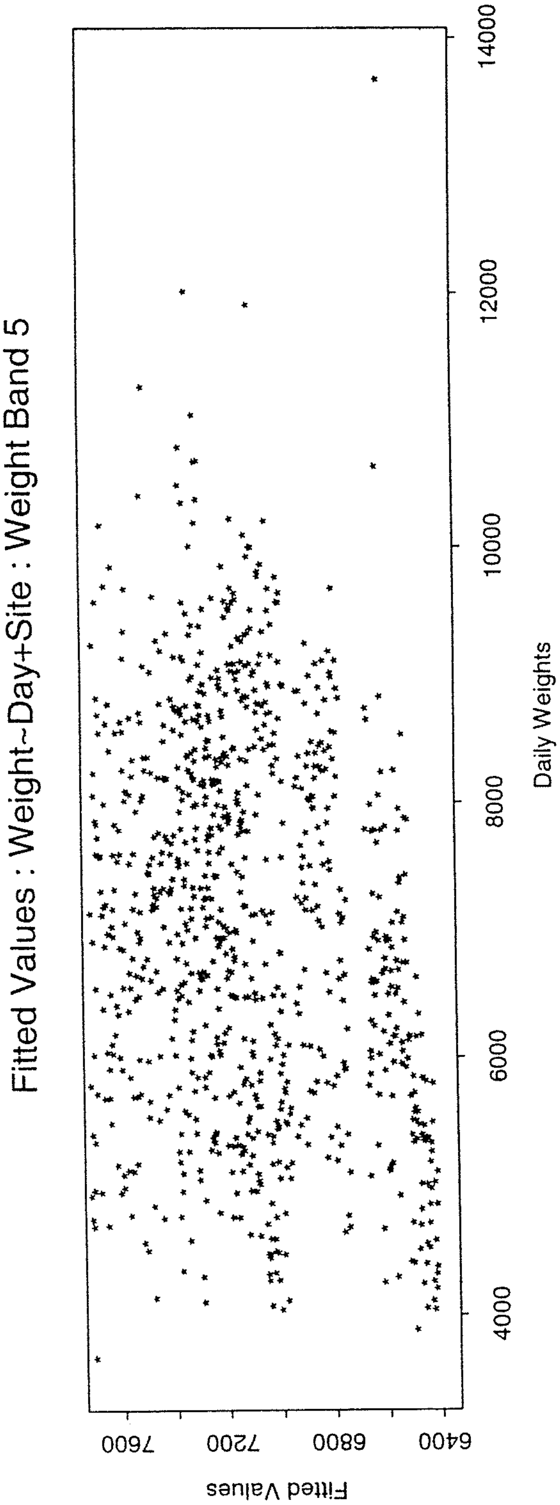
Appendix G

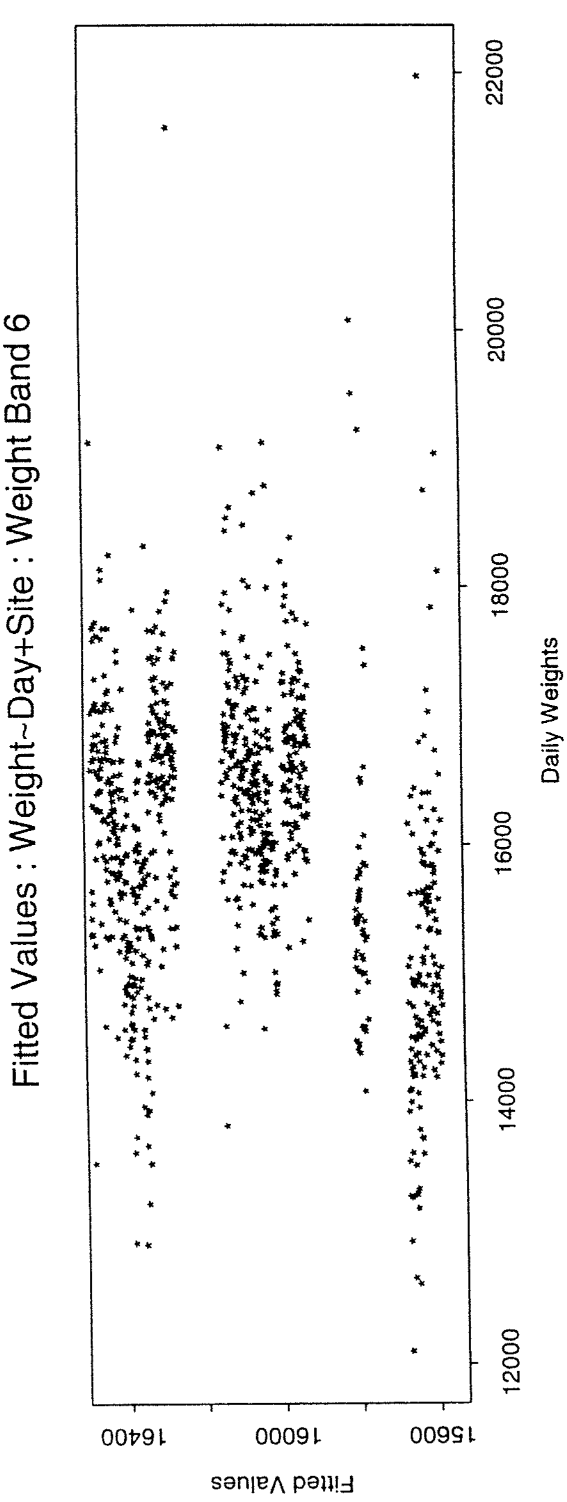
Residual Plots for Regression of Weights versus Sites and Days of Year, for Transit Vehicle Classes 3-13

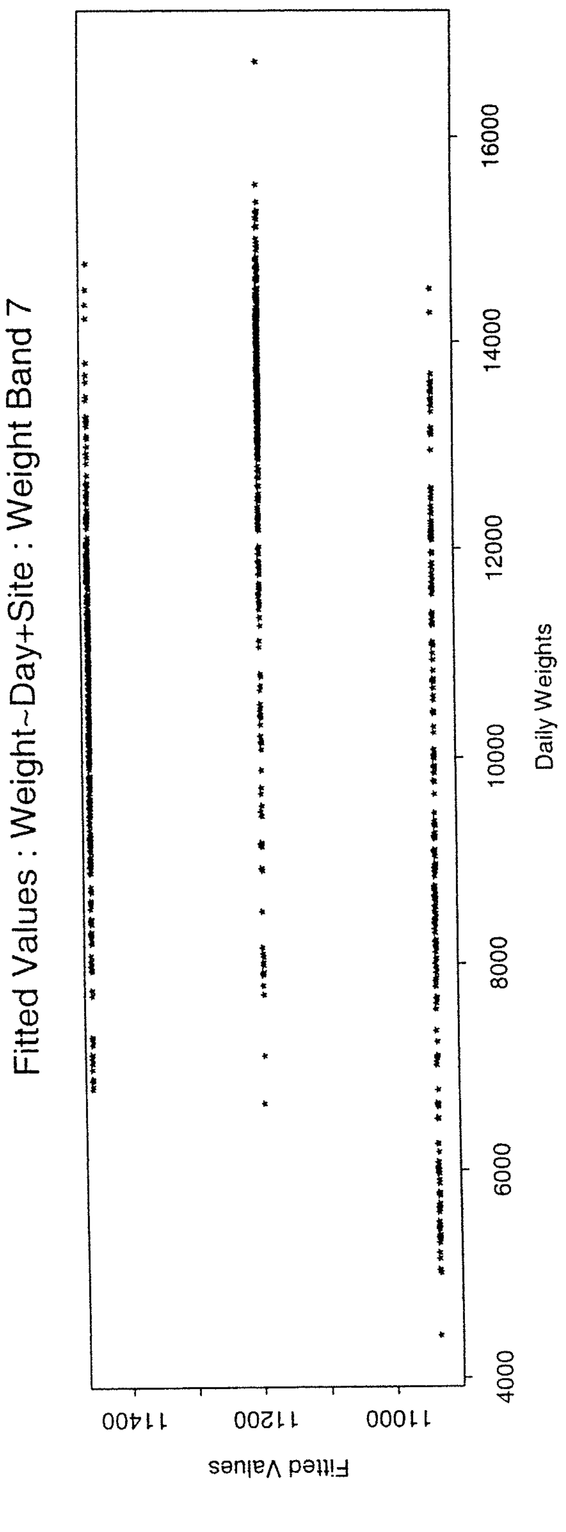
Three WIM Sites

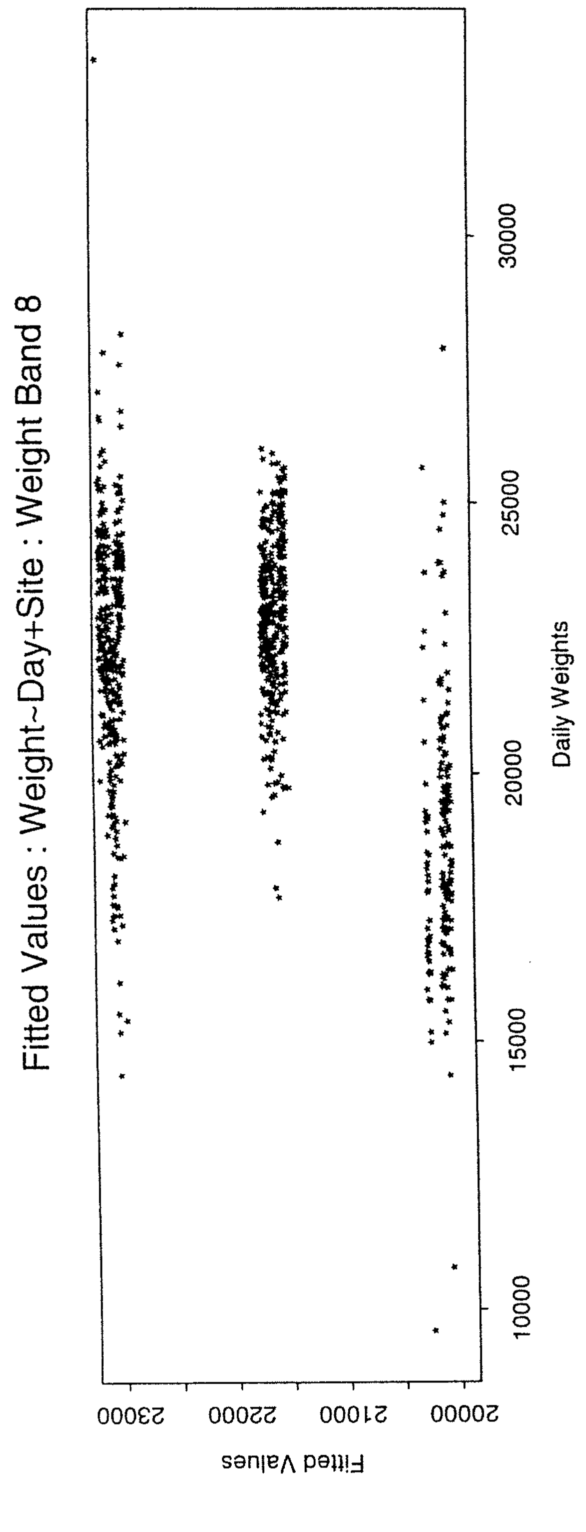

Fitted Values : Weight~Day+Site : Weight Band 3
Daily Weights
5000
5500
6000
6500
7000
Fitted Values
6380
6420
6460

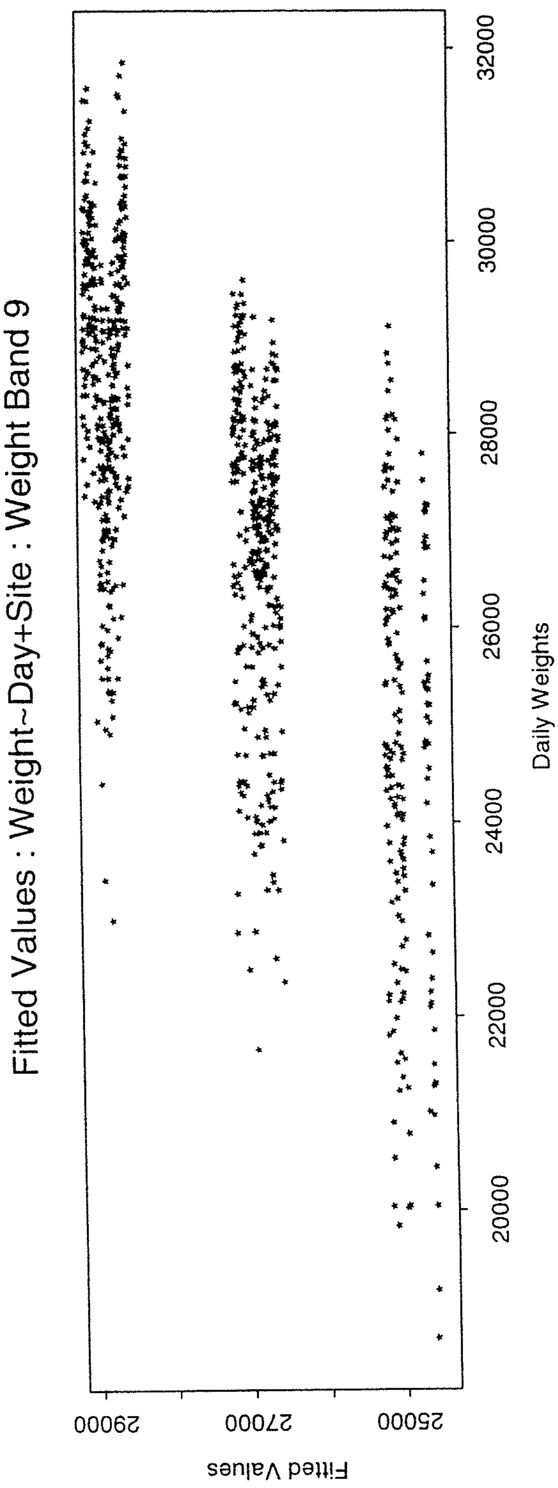

Fitted Values : Weight~Day+Site : Weight Band 4
Daily Weights
11000
12000
13000
14000
15000
16000
Fitted Values
13300
13500
13700

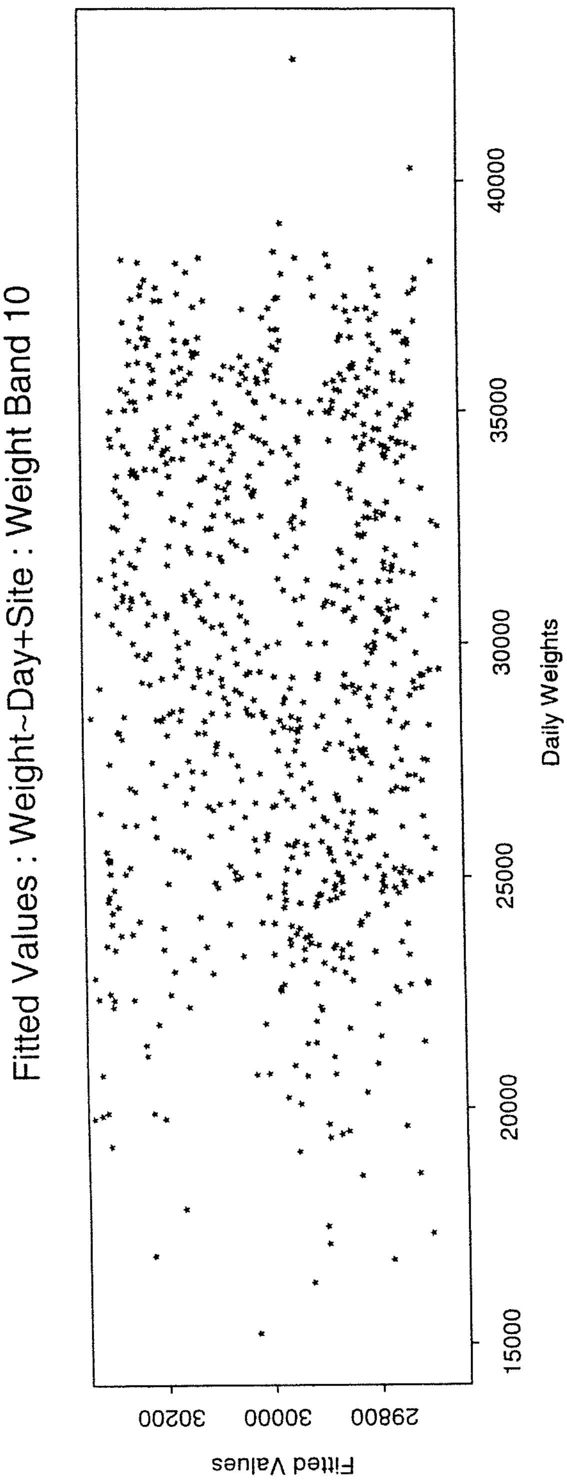

Fitted Values : Weight~Day+Site : Weight Band 5
Daily Weights
Fitted Values
4000
6000
8000
10000
12000
14000
6400
6800
7200
7600

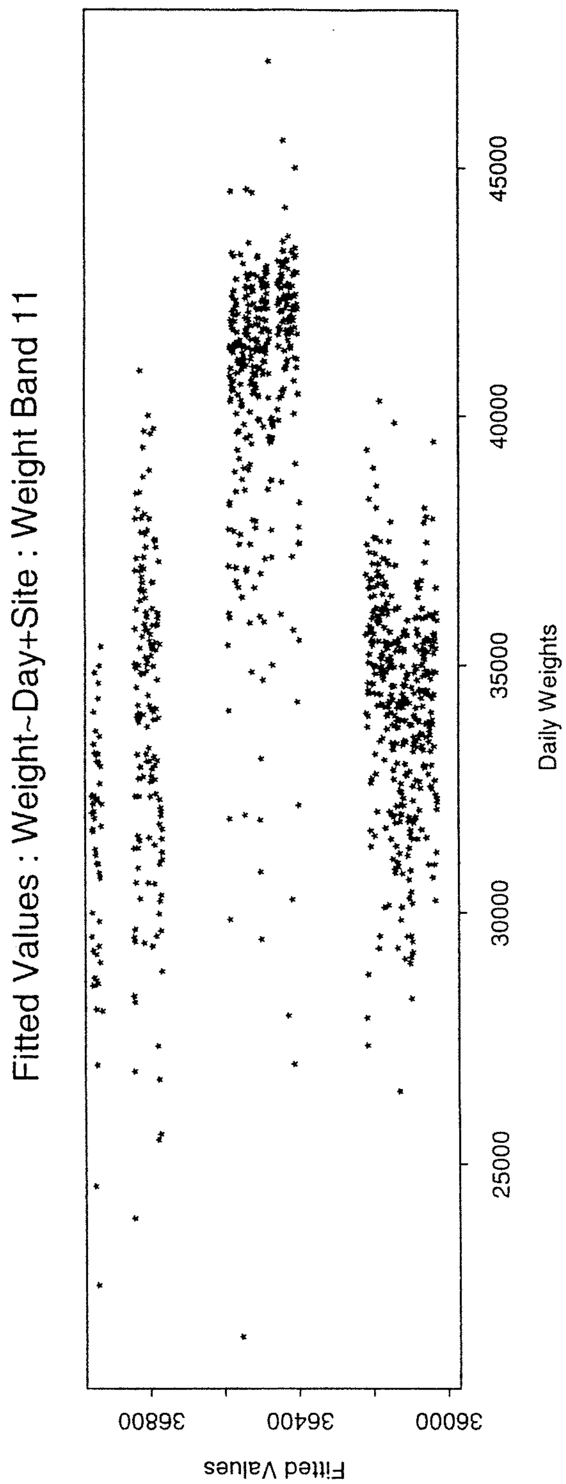

Fitted Values : Weight~Day+Site : Weight Band 6
Daily Weights
Fitted Values
12000
14000
16000
18000
20000
22000
15600
16000
16400

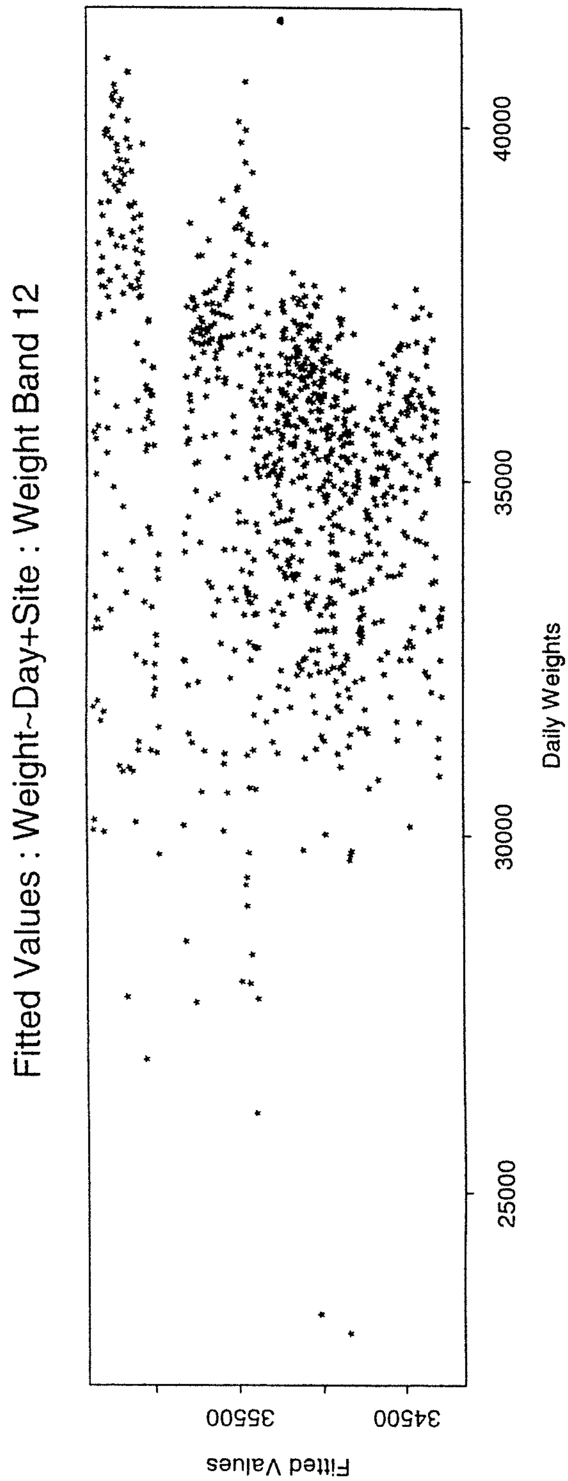

Fitted Values : Weight~Day+Site : Weight Band 7
Fitted Values
11400
11200
11000
Daily Weights
4000
6000
8000
10000
12000
14000
16000

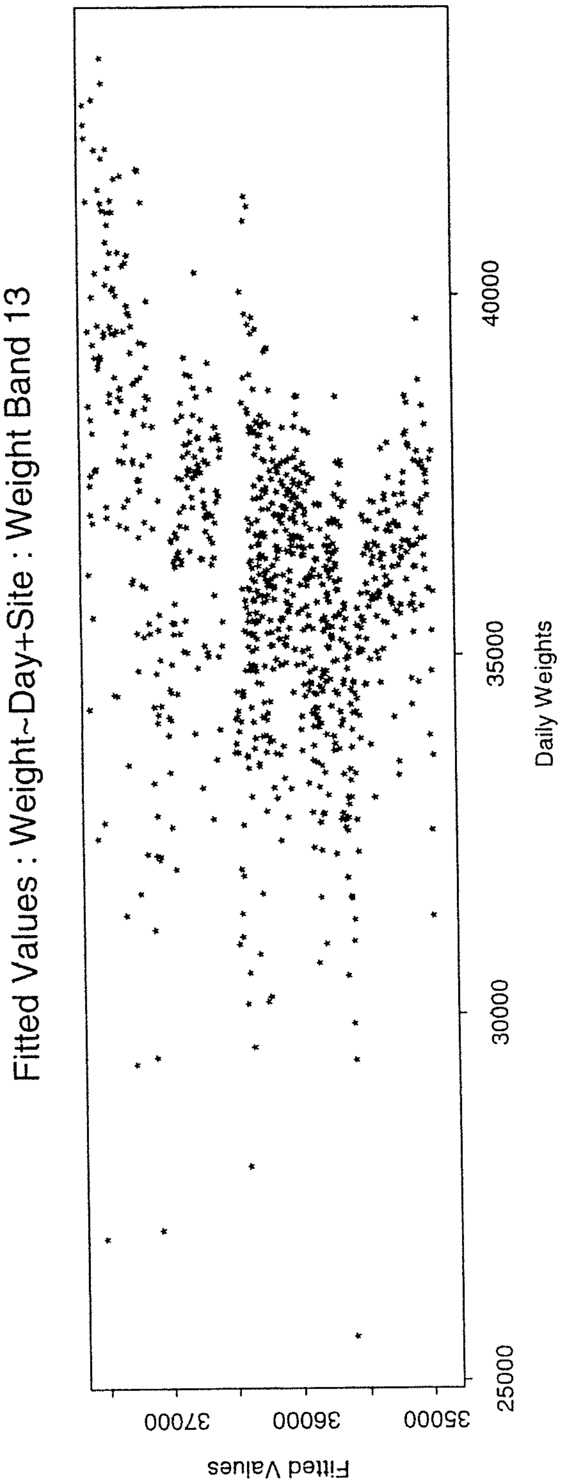

Fitted Values : Weight~Day+Site : Weight Band 8
Fitted Values
23000
22000
21000
20000
Daily Weights
10000
15000
20000
25000
30000


Fitted Values : Weight~Day+Site : Weight Band 9
Daily Weights
20000
22000
24000
26000
28000
30000
32000
Fitted Values
25000
27000
29000


Fitted Values : Weight~Day+Site : Weight Band 10
Daily Weights
15000
20000
25000
30000
35000
40000
Fitted Values
29800
30000
30200


Fitted Values : Weight~Day+Site : Weight Band 11
Daily Weights
25000
30000
35000
40000
45000
Fitted Values
36000
36400
36800


Fitted Values : Weight~Day+Site : Weight Band 12
Daily Weights
25000
30000
35000
40000
Fitted Values
34500
35500


Fitted Values : Weight~Day+Site : Weight Band 13
Daily Weights
25000
30000
35000
40000
Fitted Values
35000
36000
37000

Appendix H

ESA4 Computed Average Values per Vehicle Classification Scheme

Axle Group
Transit Class
Telemetry Length Bin

ESA4 COMPUTED VALUES PER VEHICLE CLASSIFCATION SCHEME

ESA4 Summaries by Axle Group

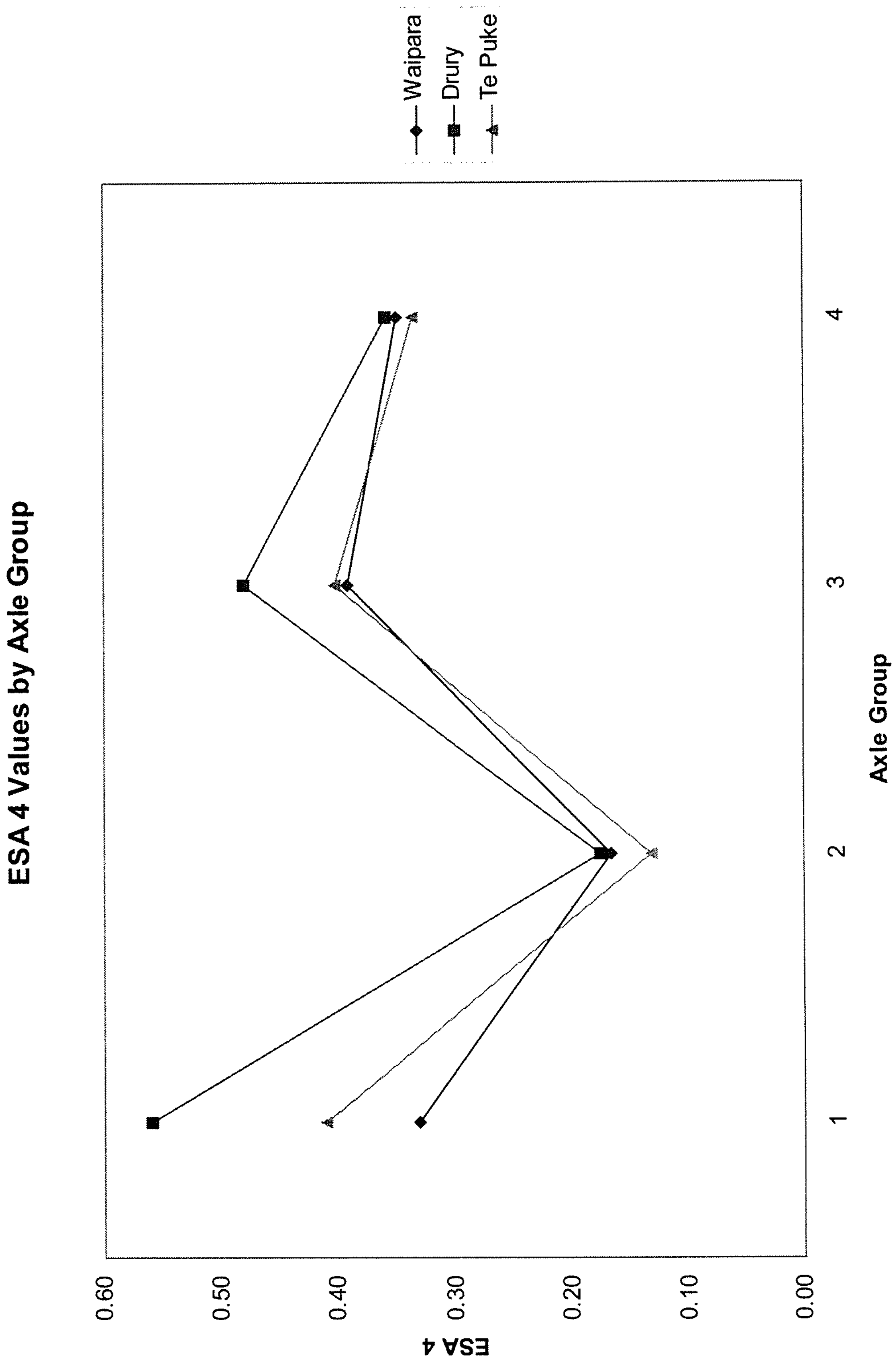
Axle Group	Mean Annual ESA4		
	Waipara	Drury	Te Puke
1	0.3309	0.5592	0.4097
2	0.1646	0.1743	0.1308
3	0.3917	0.4805	0.4016
4	0.3490	0.3585	0.3353
Axle Group	**Median Annual ESA4**		
	Waipara	**Drury**	**Te Puke**
1	0.336	0.582	0.421
2	0.163	0.181	0.134
3	0.398	0.504	0.411
4	0.355	0.374	0.348

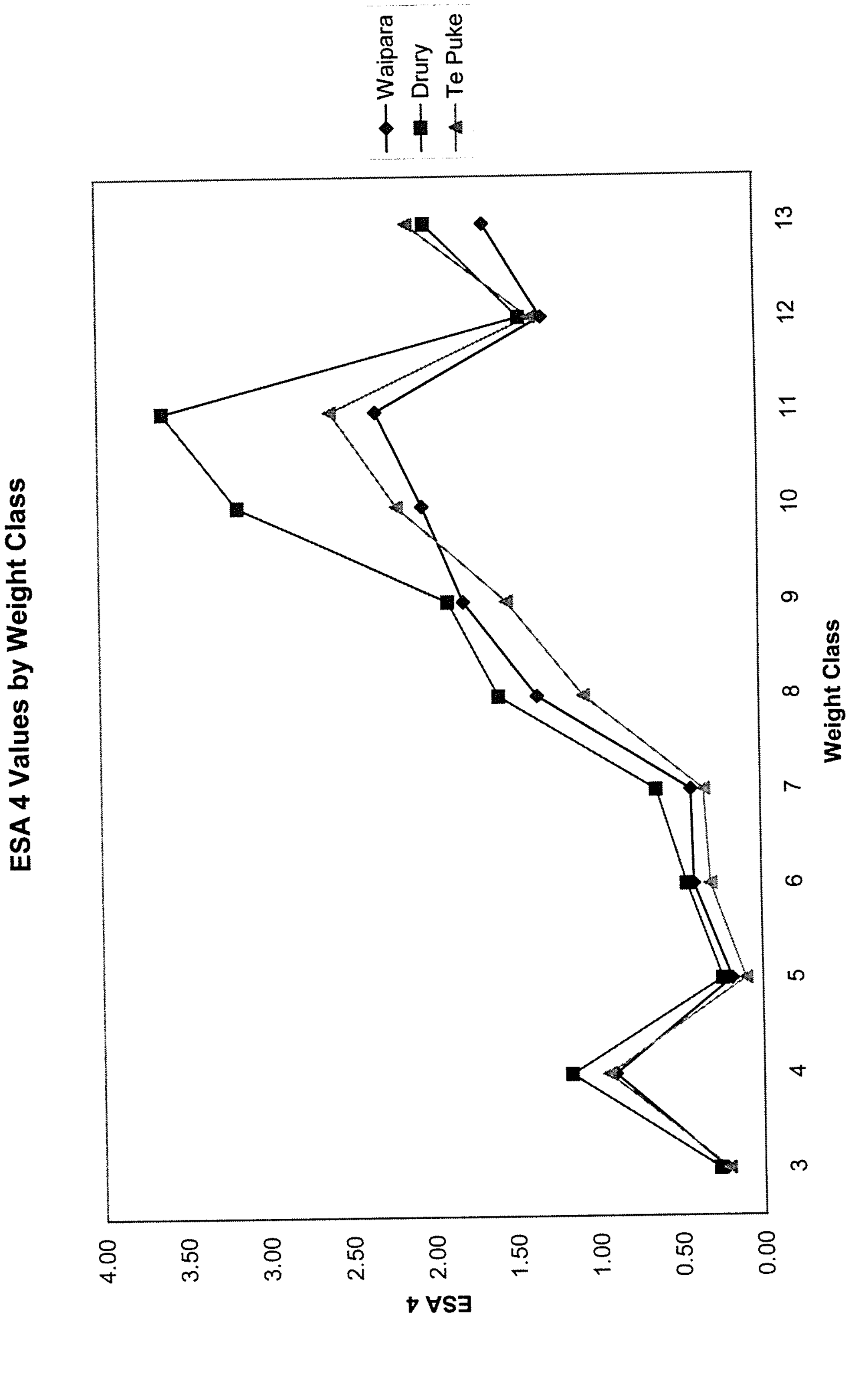
ESA4 Summary by Weight Class

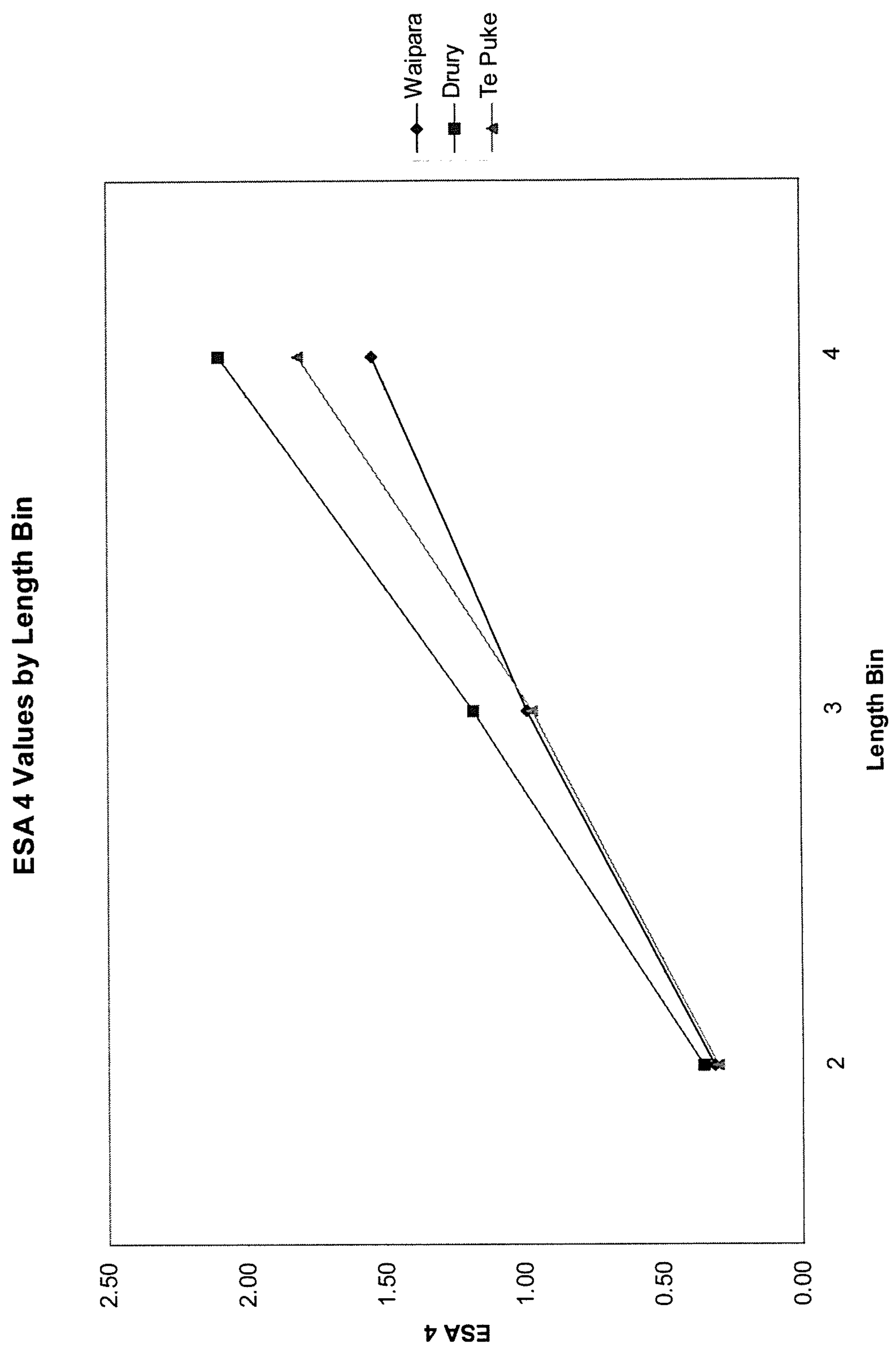
Weight Class	Mean Annual ESA4		
	Waipara	Drury	Te Puke
3	0.2315	0.2678	0.2157
4	0.8996	1.1638	0.9412
5	0.1867	0.2418	0.1026
6	0.4097	0.4523	0.3086
7	0.4194	0.6294	0.3445
8	1.3414	1.5743	1.0610
9	1.7873	1.8801	1.5228
10	2.0344	3.1522	2.1900
11	2.3137	3.6017	2.5864
12	1.2966	1.4295	1.3680
13	1.6433	2.0007	2.1100

ESA4 Summaries by Length Bin

Length Bin	Mean Annual ESA4		
	Waipara	Drury	Te Puke
2	0.3180	0.3590	0.3060
3	0.9885	1.1850	0.9656
4	1.5450	2.0945	1.8145
Length Bin	**Median Annual ESA4**		
	Waipara	**Drury**	**Te Puke**
2	0.319	0.378	0.312
3	0.985	1.198	0.979
4	1.567	2.192	1.836


ESA 4 Values by Axle Group
Waipara
Drury
Te Puke
ESA 4
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1
2
3
4
Axle Group


ESA 4 Values by Weight Class
ESA 4
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
3
4
5
6
7
8
9
10
11
12
13
Weight Class
Waipara
Drury
Te Puke

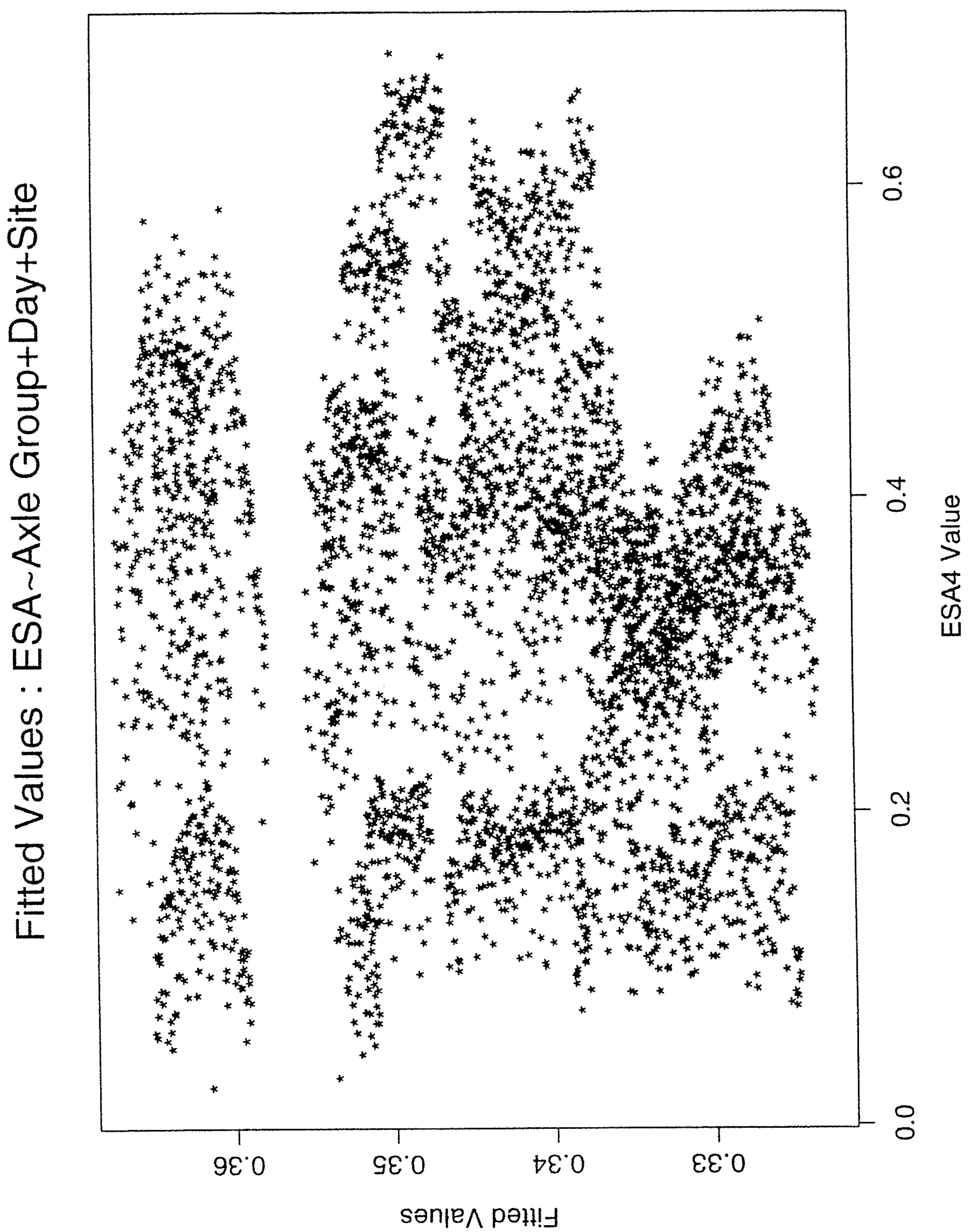

ESA 4 Values by Length Bin
ESA 4
2.50
2.00
1.50
1.00
0.50
0.00
2
3
4
Length Bin
Waipara
Drury
Te Puke

Appendix I

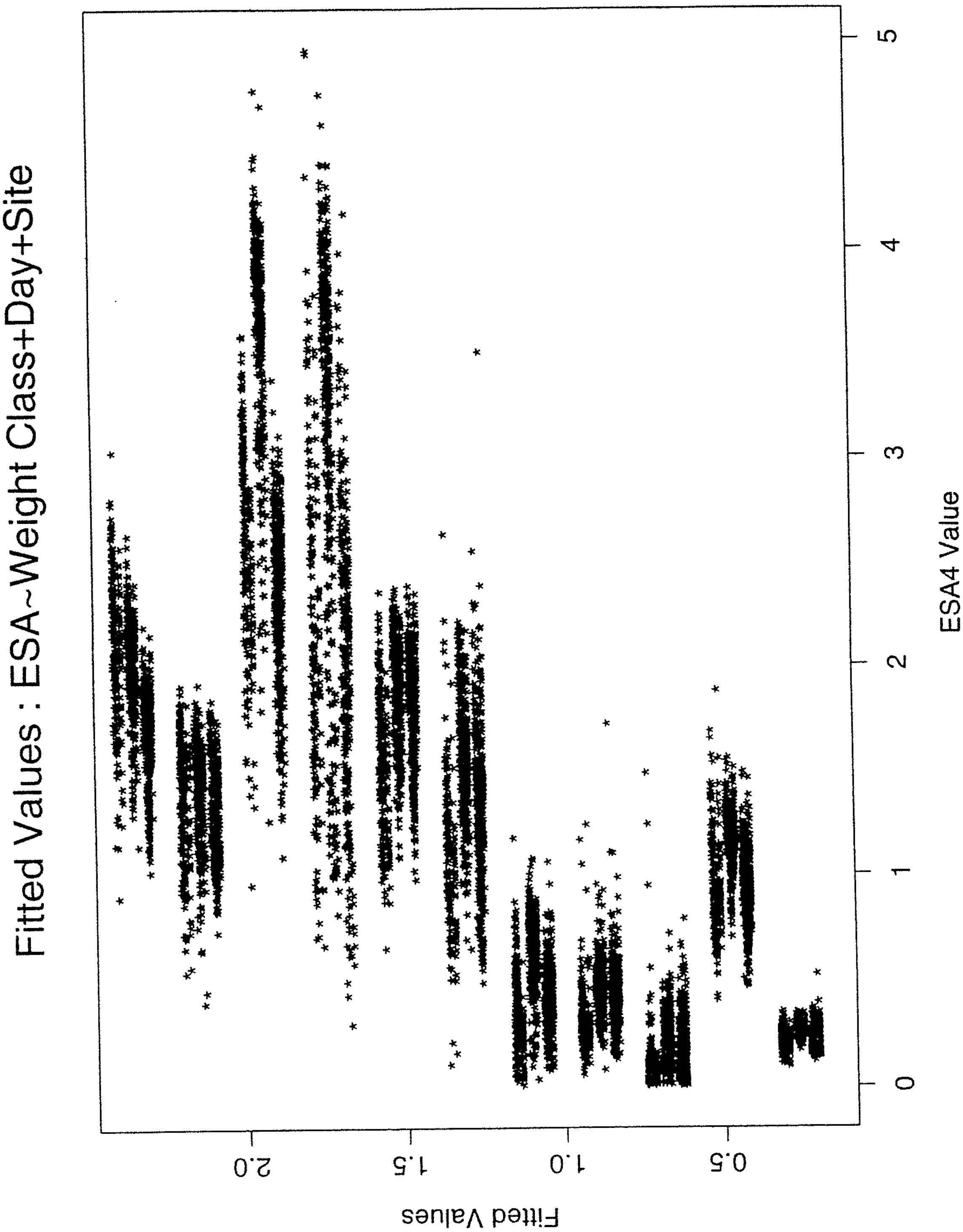
Residual Plots for Regression of ESA4s versus Sites and Days of Year

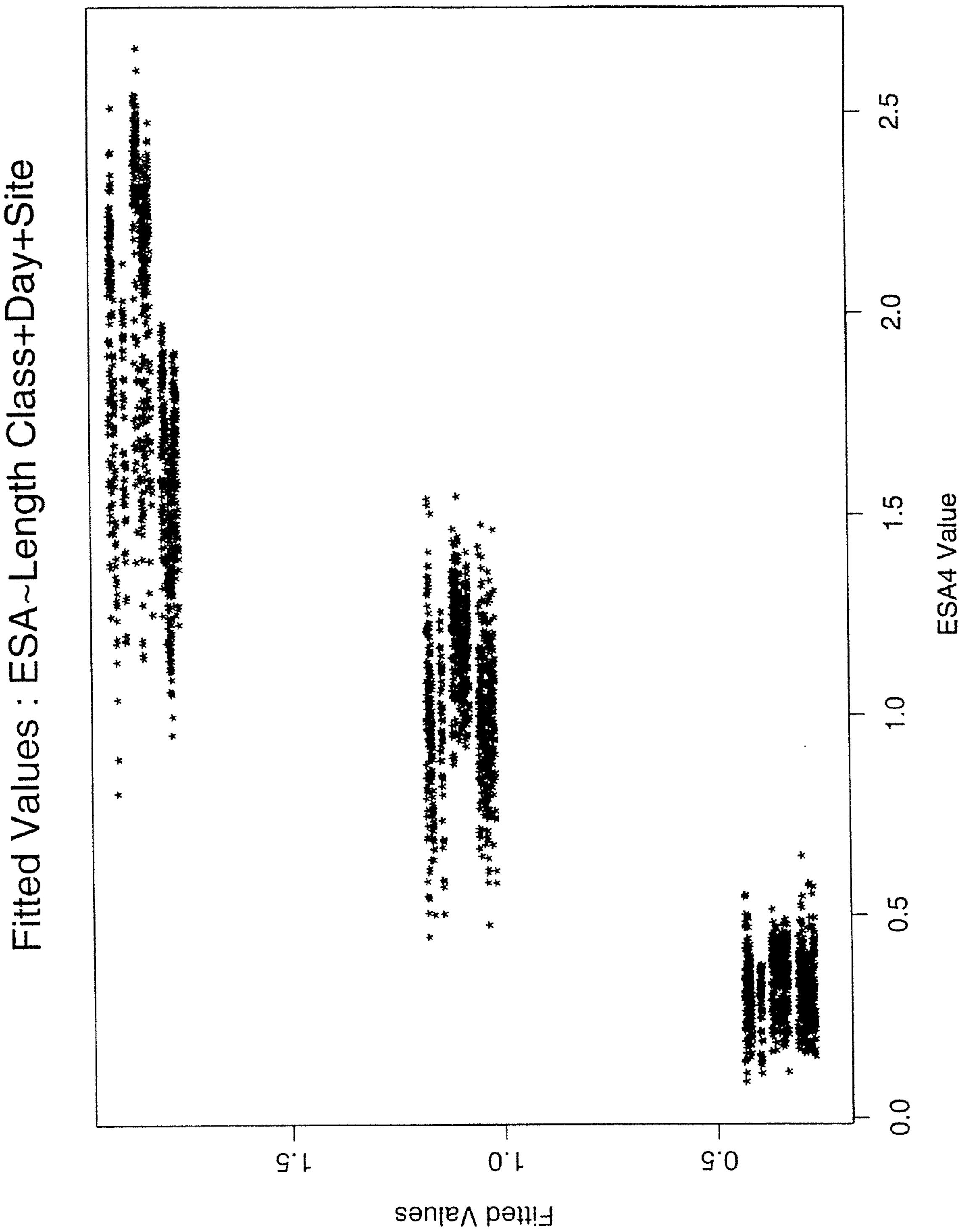
Axle Groups 1-4
Transit Vehicle Classes 3-13
Length Bins 2-4

Three WIM Sites



Fitted Values : ESA~Axle Group+Day+Site
ESA4 Value
0.0
0.2
0.4
0.6
Fitted Values
0.33
0.34
0.35
0.36

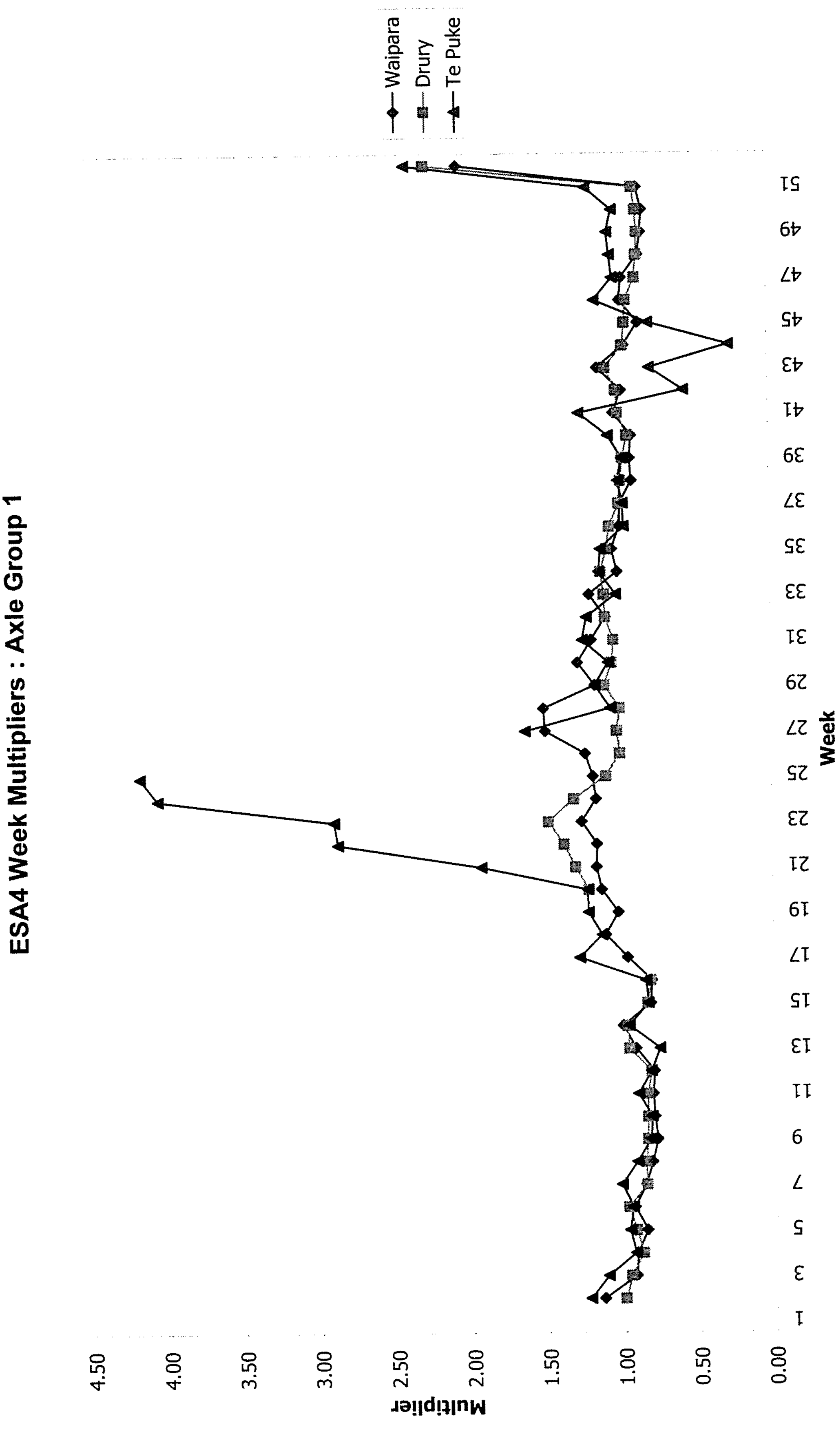

Fitted Values : ESA~Weight Class+Day+Site
ESA4 Value
0
1
2
3
4
5
Fitted Values
0.5
1.0
1.5
2.0

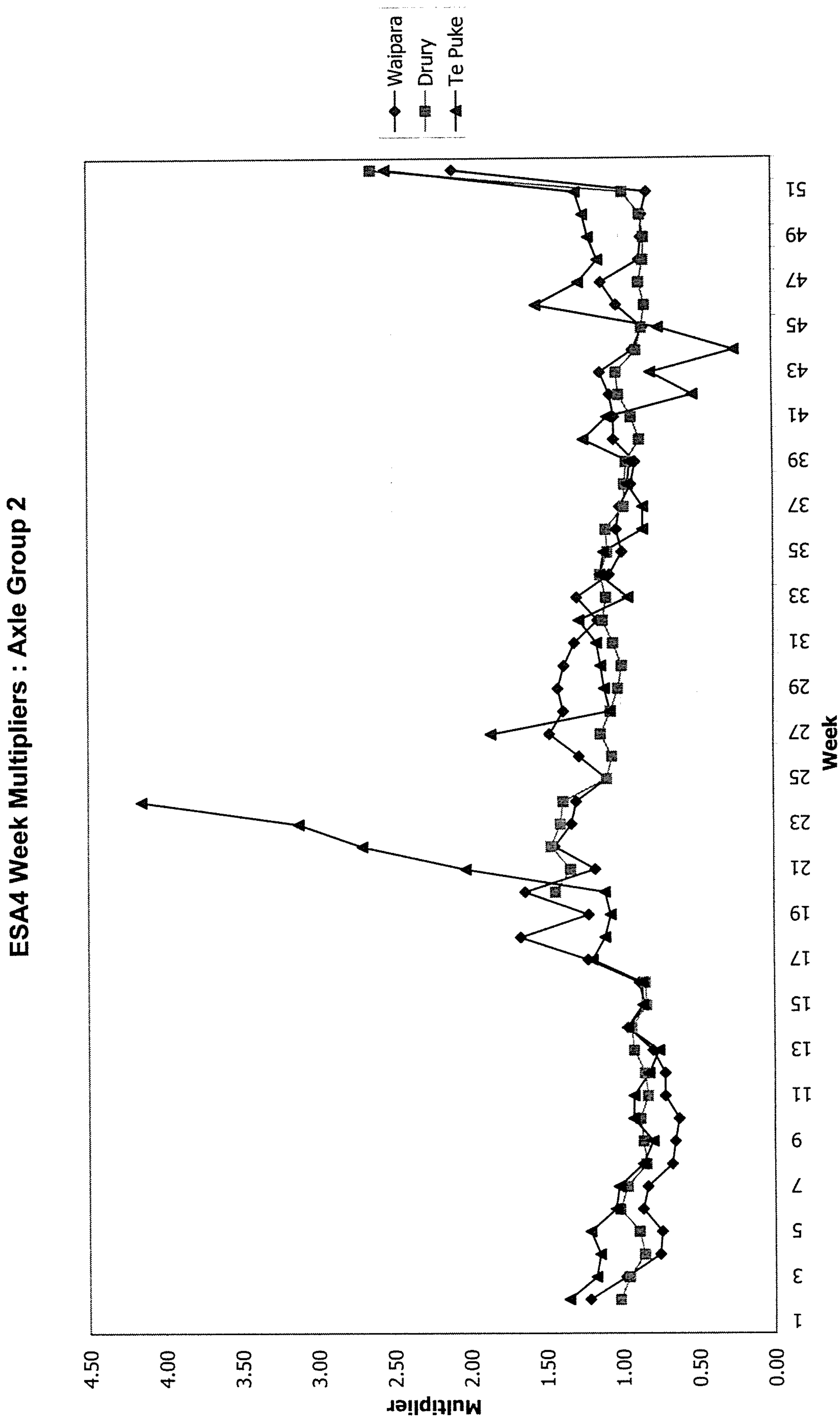

Fitted Values : ESA~Length Class+Day+Site
ESA4 Value
Fitted Values
0.0
0.5
1.0
1.5
2.0
2.5
0.5
1.0
1.5

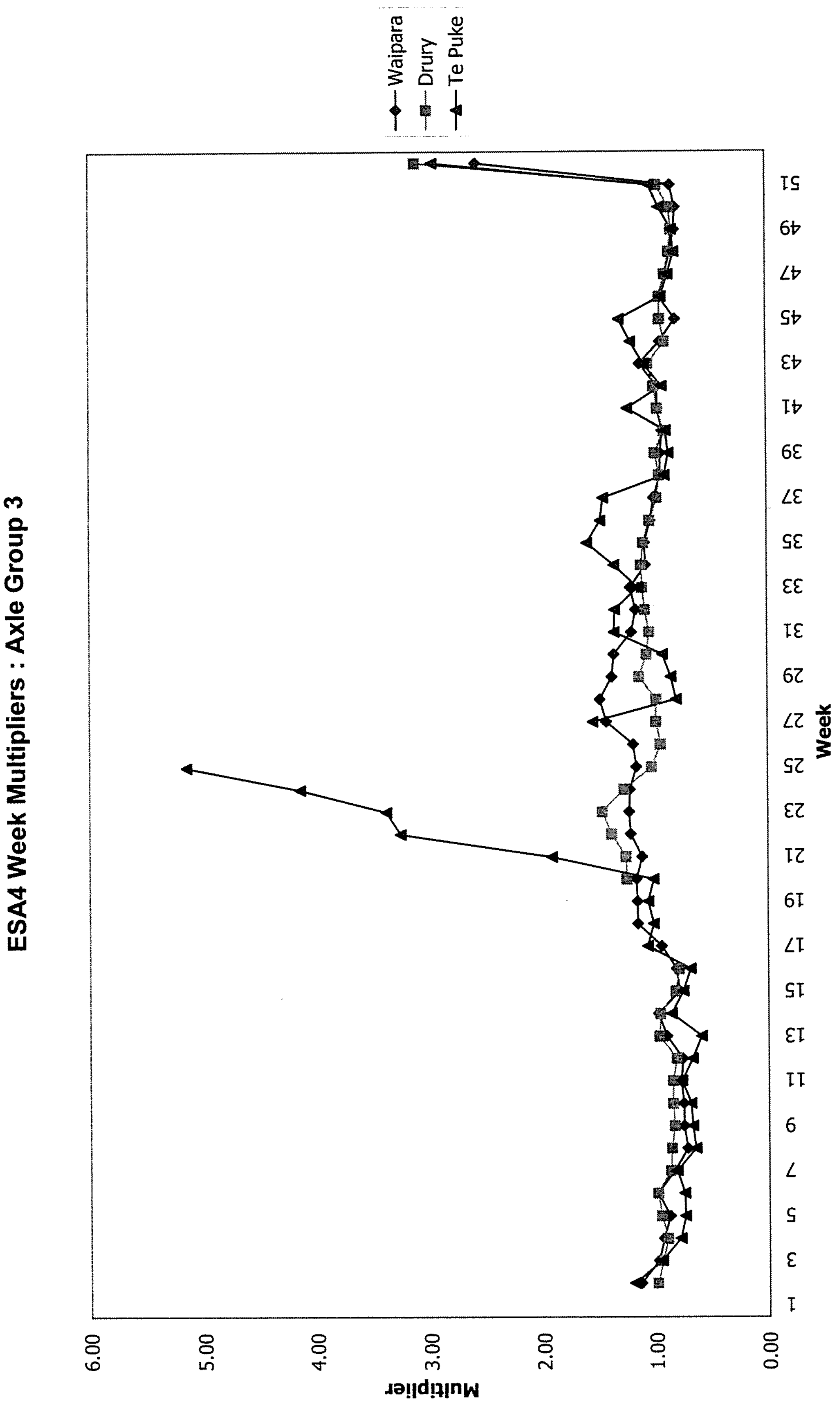
Appendix J

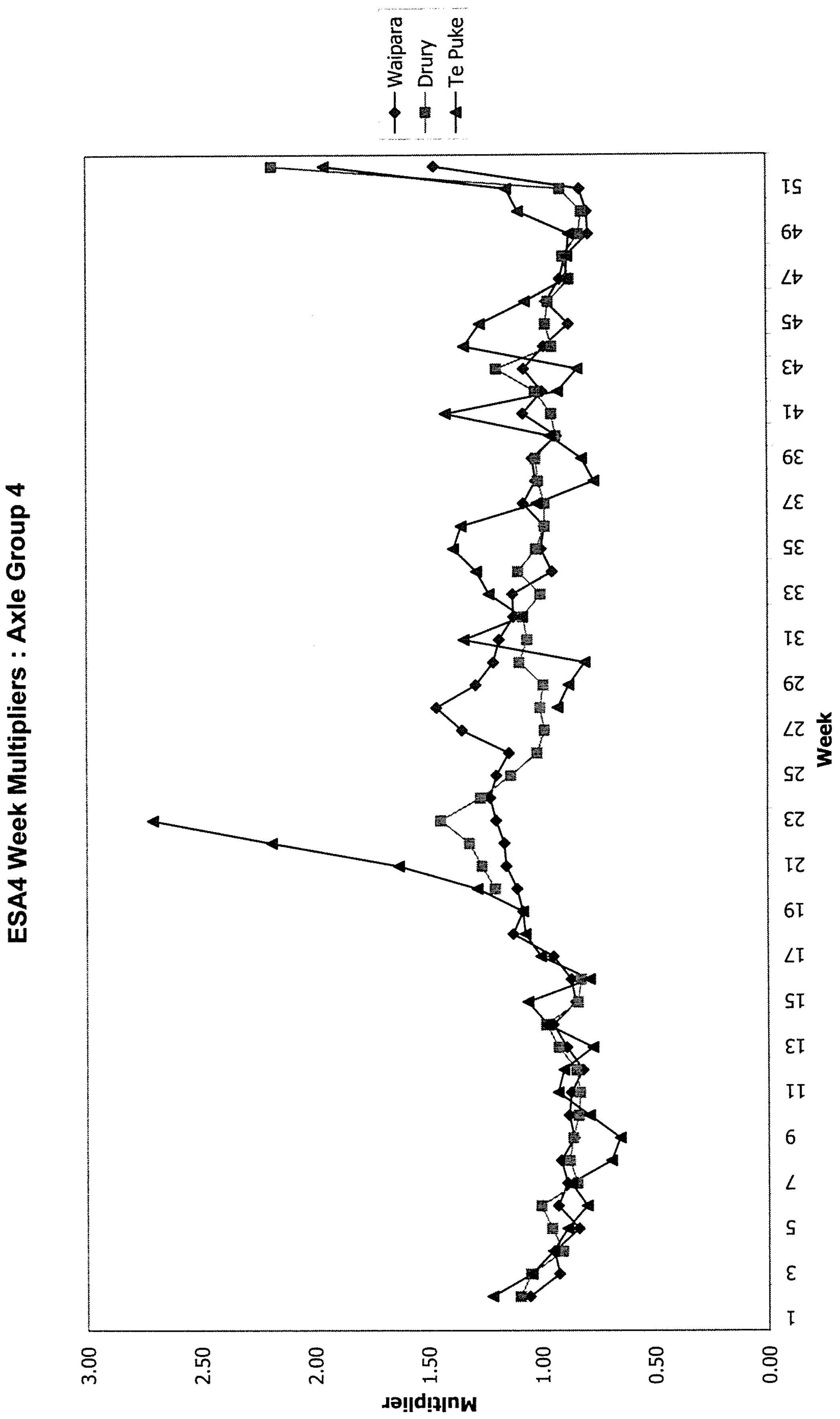
Plots for Average Weekly Multipliers for converting Week ESA4s to Annual ESA4s, based on Weekly Average ESA4 per Hour

Each WIM Site


ESA4 Week Multipliers : Axle Group 1
Waipara
Drury
Te Puke
Multiplier
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
Week
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
49
51


ESA4 Week Multipliers : Axle Group 2
Waipara
Drury
Te Puke
Multiplier
Week
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
49
51

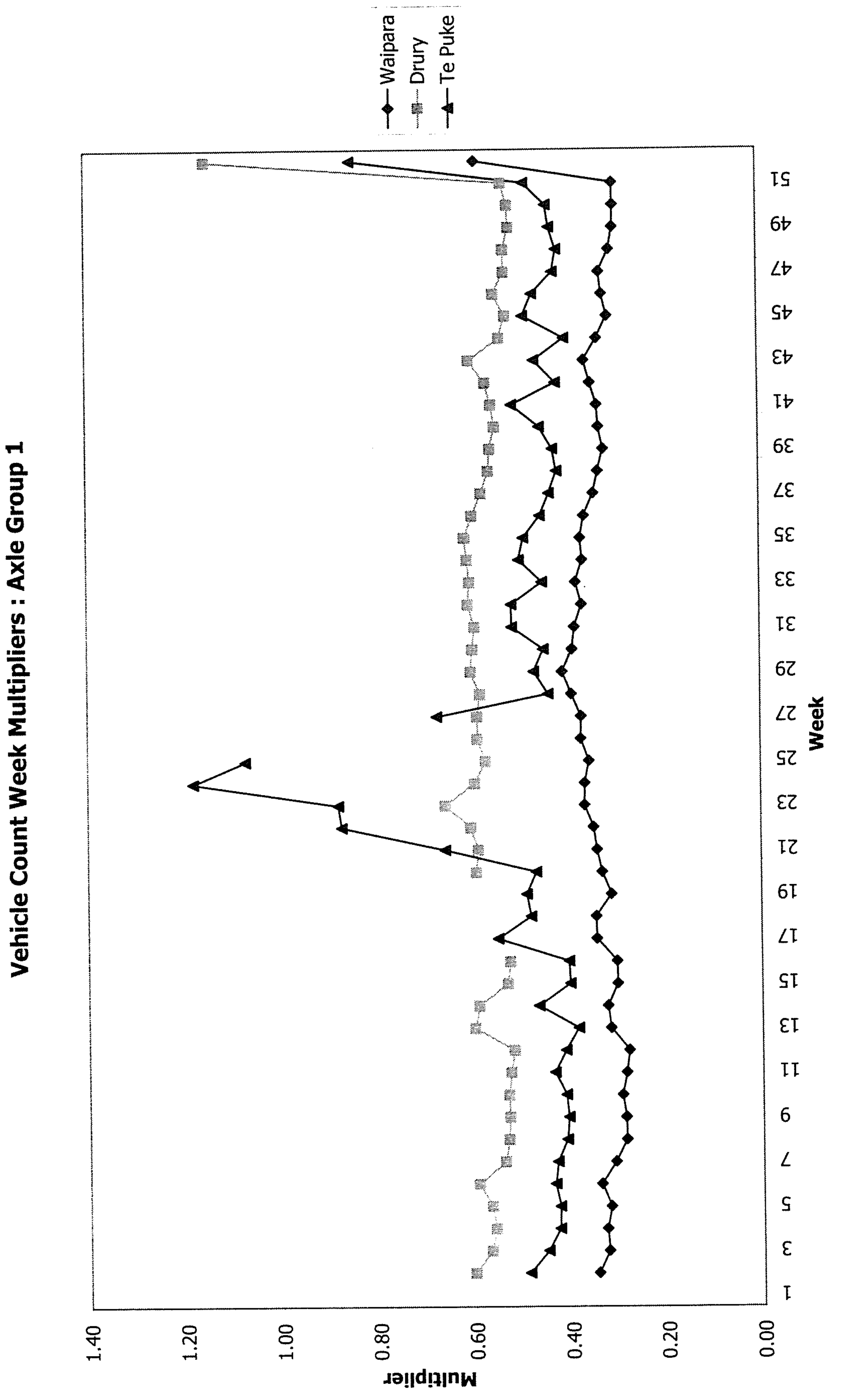

ESA4 Week Multipliers : Axle Group 3
Waipara
Drury
Te Puke
Multiplier
Week
0.00
1.00
2.00
3.00
4.00
5.00
6.00
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
49
51

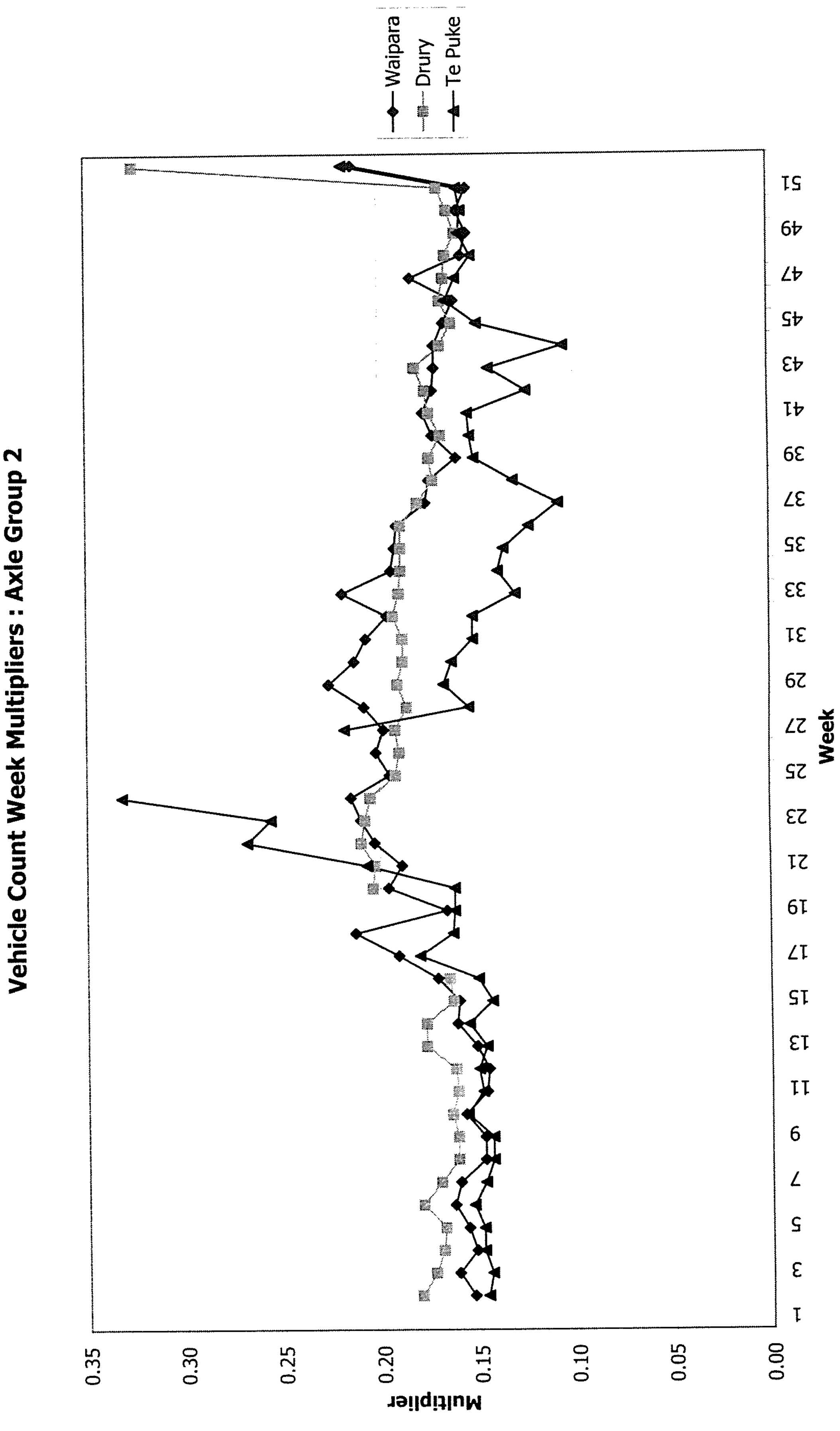

ESA4 Week Multipliers : Axle Group 4
Waipara
Drury
Te Puke
Multiplier
Week
0.00
0.50
1.00
1.50
2.00
2.50
3.00
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
49
51

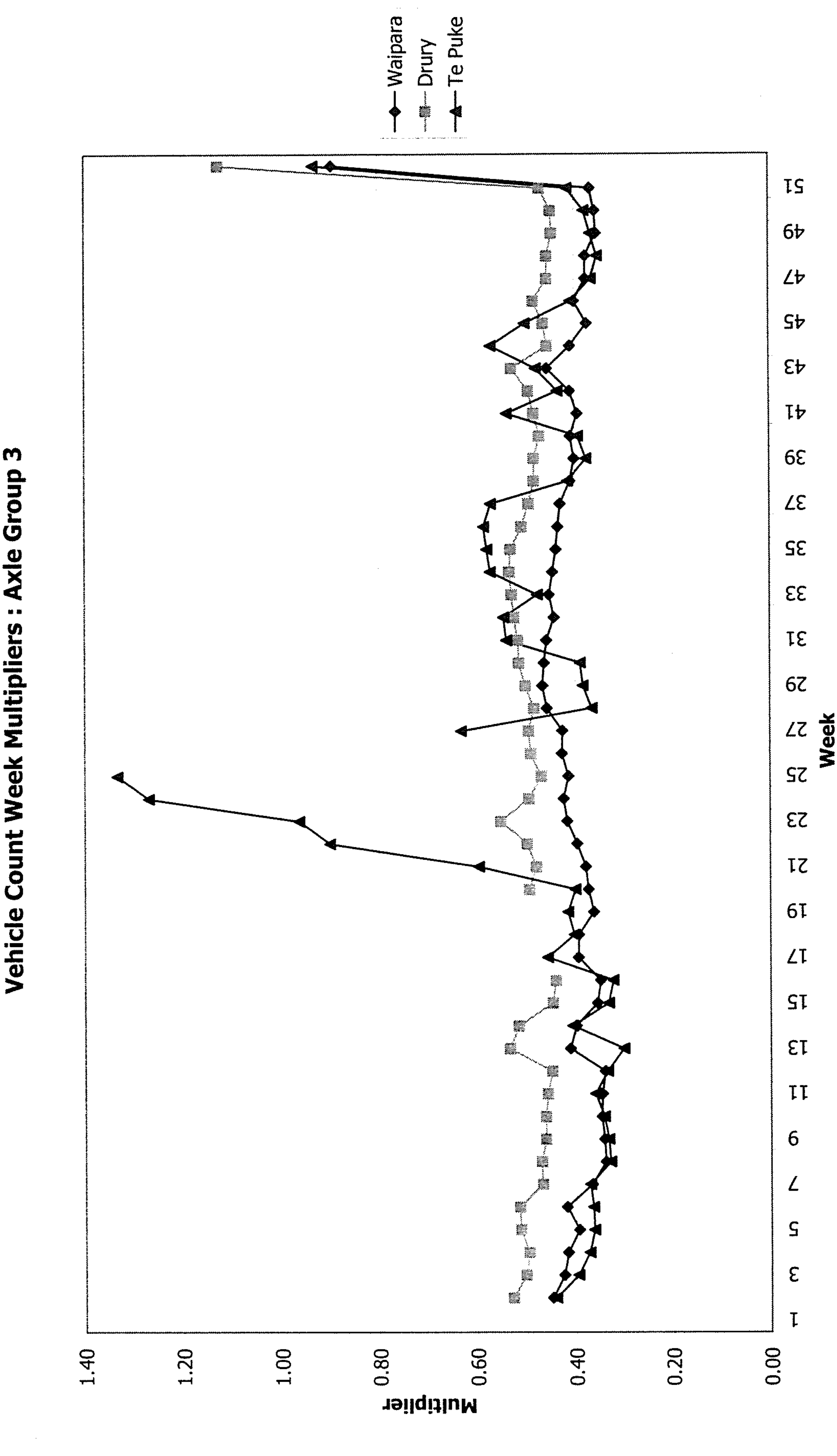
Appendix K

Plots for Average Weekly Multipliers for converting Vehicle Counts to Annual ESA4, based on Weekly Average Vehicle Count per Hour

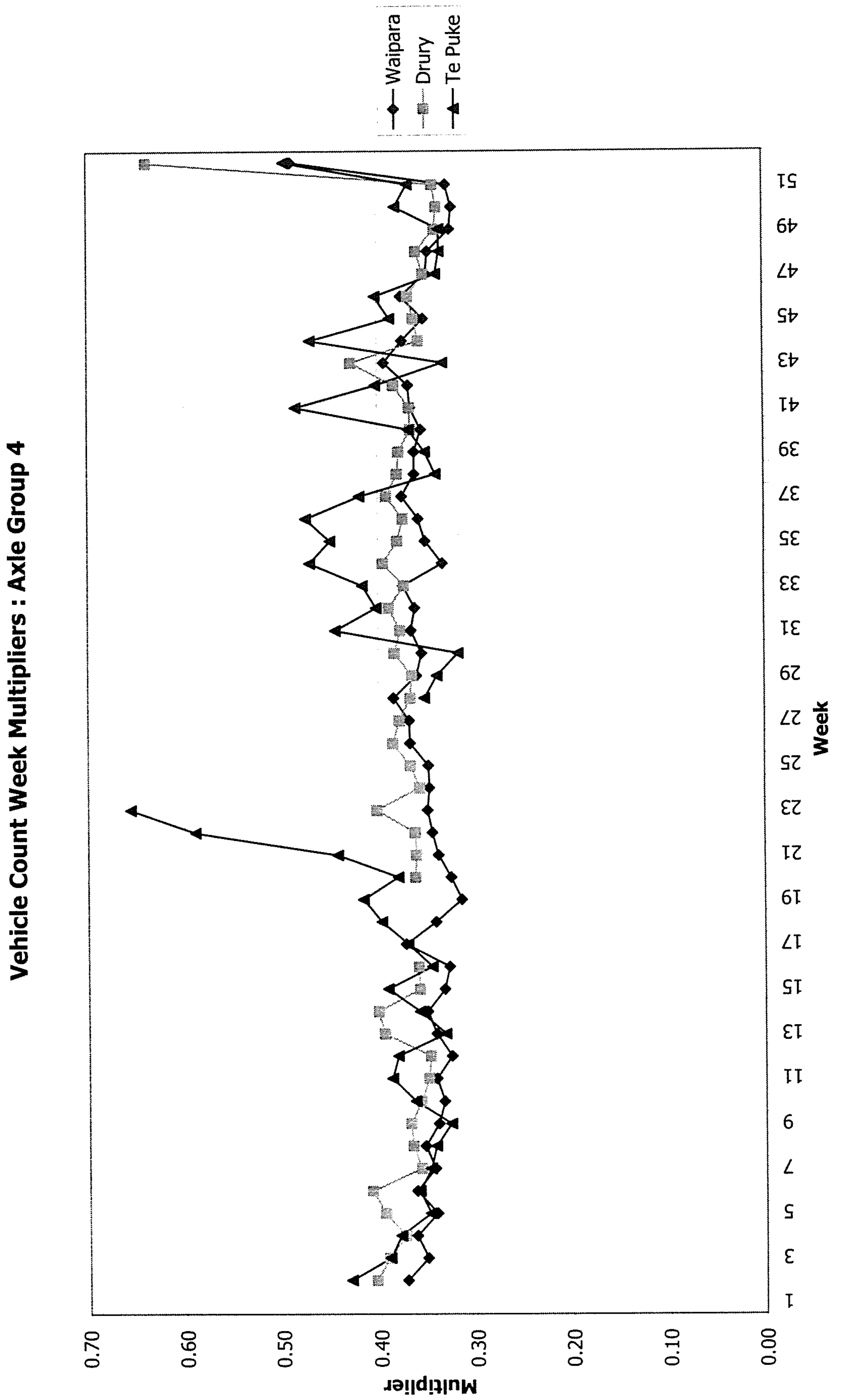
Each WIM Site

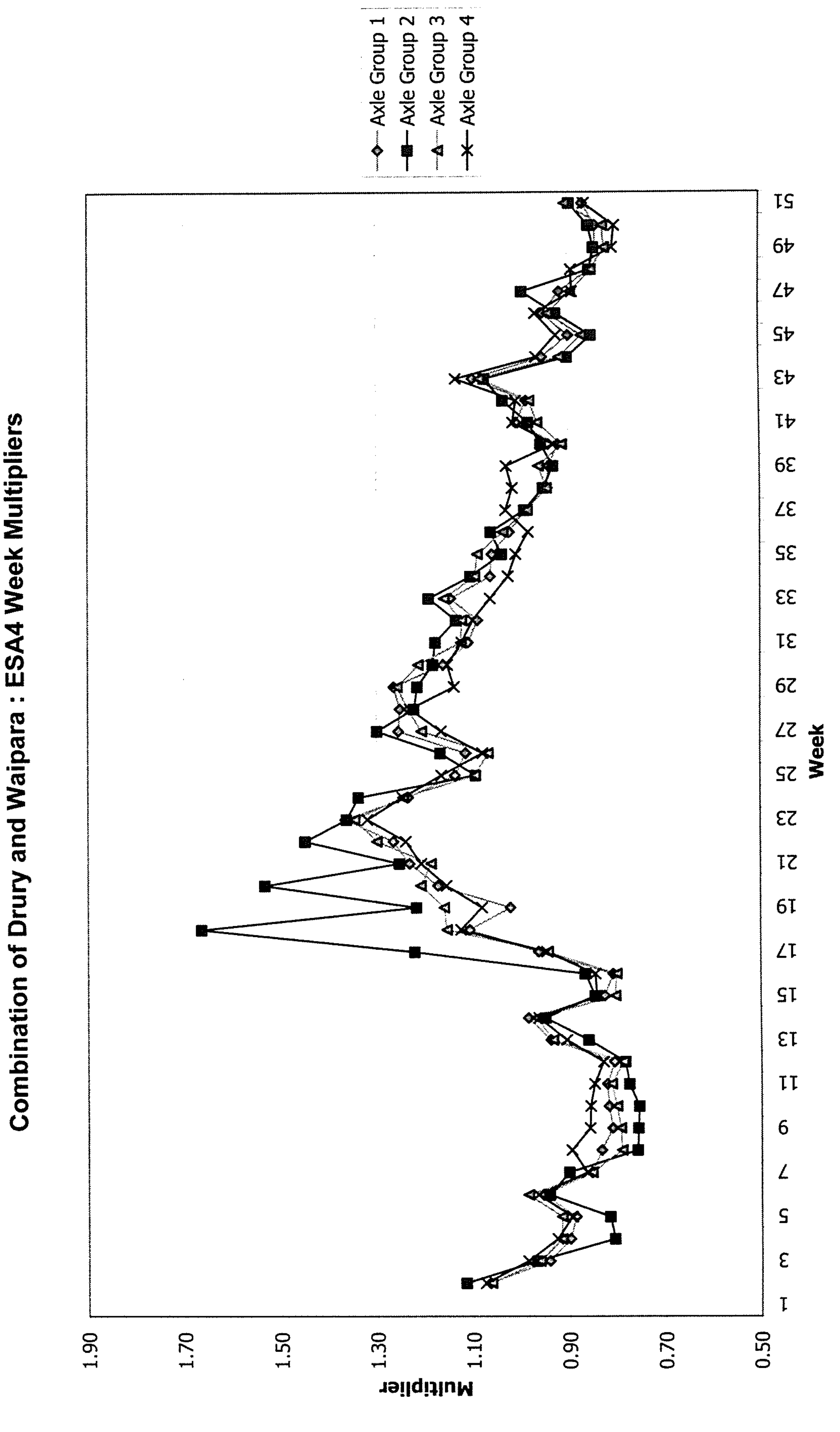

Vehicle Count Week Multipliers : Axle Group 1
Waipara
Drury
Te Puke
Multiplier
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
Week
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
49
51


Vehicle Count Week Multipliers : Axle Group 2
Waipara
Drury
Te Puke
Multiplier
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Week
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
49
51



Vehicle Count Week Multipliers : Axle Group 3
Waipara
Drury
Te Puke
Multiplier
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
Week
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
49
51


Vehicle Count Week Multipliers : Axle Group 4
Waipara
Drury
Te Puke
Multiplier
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
Week
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
49
51


Combination of Drury and Waipara : ESA4 Week Multipliers
Axle Group 1
Axle Group 2
Axle Group 3
Axle Group 4
Multiplier
1.90
1.70
1.50
1.30
1.10
0.90
0.70
0.50
Week
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
49
51

Appendix L

Average Weekly Multipliers for converting Week ESA4s to Annual ESA4, based on Weekly Average ESA4 per Hour

Each WIM Site

ESA4 Week Multipliers : Each WIM Site

Axle Group 1

Week of Year	Waipara Week Factor	Drury Week Factor	Te Puke Week Factor
2	1.135	0.997	1.227
3	0.927	0.957	1.111
4	0.919	0.880	0.929
5	0.851	0.925	0.967
6	0.935	0.973	0.945
7	0.858	0.852	1.016
8	0.814	0.855	0.915
9	0.778	0.845	0.824
10	0.796	0.842	0.816
11	0.805	0.840	0.904
12	0.797	0.817	0.816
13	0.917	0.960	0.758
14	0.997	0.973	0.958
15	0.816	0.838	0.831
16	0.806	0.813	0.845
17	0.964		1.278
18	1.106		1.129
19	1.021		1.218
20	1.130	1.213	1.222
21	1.161	1.301	1.921
22	1.157	1.373	2.866
23	1.257	1.475	2.890
24	1.159	1.307	4.056
25	1.179	1.093	4.172
26	1.228	0.999	
27	1.489	1.018	1.622
28	1.501	1.000	1.058
29	1.429	1.098	1.161
30	1.273	1.048	1.070
31	1.182	1.036	1.242
32	1.088	1.090	1.213
33	1.194	1.096	1.019
34	1.008	1.116	1.127
35	1.042	1.076	1.117
36	0.989	1.056	0.963
37	0.985	0.993	0.967
38	0.908	0.980	0.997
39	0.918	0.964	0.971
40	0.908	0.935	1.060
41	1.022	0.994	1.252
42	0.969	1.004	0.556
43	1.124	1.072	0.782
44	0.949	0.957	0.253
45	0.854	0.942	0.790
46	0.972	0.933	1.141
47	0.960	0.873	1.019
48	0.848	0.859	1.035
49	0.830	0.854	1.051
50	0.821	0.864	1.020
51	0.855	0.884	1.192
52	2.043	2.258	2.389

ESA4 Week Multipliers : Each WIM Site

Axle Group 2

Week of Year	Waipara Week Factor	Drury Week Factor	Te Puke Week Factor
2	1.215	1.016	1.353
3	0.979	0.958	1.174
4	0.756	0.858	1.149
5	0.744	0.891	1.213
6	0.868	1.017	1.045
7	0.836	0.968	1.025
8	0.675	0.845	0.867
9	0.654	0.862	0.800
10	0.629	0.883	0.928
11	0.720	0.834	0.925
12	0.720	0.850	0.826
13	0.799	0.922	0.760
14	0.961	0.939	0.966
15	0.854	0.840	0.863
16	0.886	0.848	0.869
17	1.220		1.191
18	1.664		1.107
19	1.216		1.070
20	1.633	1.432	1.109
21	1.171	1.333	2.024
22	1.437	1.461	2.701
23	1.325	1.400	3.120
24	1.294	1.381	4.150
25	1.092	1.093	
26	1.275	1.057	
27	1.467	1.130	1.854
28	1.376	1.066	1.067
29	1.412	1.017	1.107
30	1.372	0.992	1.130
31	1.304	1.049	1.158
32	1.150	1.116	1.274
33	1.287	1.094	0.952
34	1.072	1.134	1.134
35	0.991	1.085	1.110
36	1.026	1.096	0.854
37	1.004	0.978	0.854
38	0.931	0.973	0.953
39	0.902	0.961	0.938
40	1.041	0.872	1.240
41	1.040	0.926	1.084
42	1.064	1.006	0.522
43	1.127	1.020	0.797
44	0.912	0.890	0.248
45	0.848	0.854	0.745
46	1.017	0.831	1.548
47	1.118	0.870	1.268
48	0.868	0.841	1.140
49	0.854	0.837	1.201
50	0.851	0.861	1.237
51	0.817	0.975	1.286
52	2.098	2.631	2.538

ESA4 Week Multipliers : Each WIM Site

Axle Group 3

Week of Year	Waipara Week Factor	Drury Week Factor	Te Puke Week Factor
2	1.137	0.990	1.196
3	0.981	0.945	0.955
4	0.935	0.900	0.788
5	0.880	0.954	0.747
6	0.986	0.986	0.753
7	0.838	0.872	0.818
8	0.723	0.861	0.649
9	0.755	0.836	0.677
10	0.757	0.849	0.692
11	0.778	0.849	0.772
12	0.764	0.815	0.677
13	0.902	0.968	0.595
14	0.976	0.959	0.859
15	0.788	0.822	0.756
16	0.815	0.790	0.692
17	0.944		1.068
18	1.154		1.014
19	1.159		1.062
20	1.164	1.251	1.014
21	1.115	1.258	1.913
22	1.215	1.384	3.251
23	1.228	1.463	3.374
24	1.219	1.270	4.135
25	1.162	1.025	5.146
26	1.190	0.944	
27	1.426	0.985	1.548
28	1.484	0.984	0.808
29	1.376	1.136	0.853
30	1.358	1.067	0.928
31	1.203	1.044	1.357
32	1.164	1.081	1.349
33	1.211	1.106	1.143
34	1.074	1.115	1.355
35	1.083	1.096	1.595
36	1.033	1.039	1.475
37	0.999	0.972	1.451
38	0.941	0.950	0.903
39	0.939	0.985	0.869
40	0.920	0.908	0.891
41	0.963	0.965	1.232
42	0.965	0.995	0.922
43	1.121	1.044	1.084
44	0.938	0.897	1.200
45	0.803	0.939	1.302
46	0.941	0.939	0.927
47	0.894	0.893	0.866
48	0.846	0.855	0.814
49	0.810	0.837	0.832
50	0.801	0.854	0.943
51	0.843	0.968	1.032
52	2.569	3.107	2.957

ESA4 Week Multipliers : Each WIM Site

Axle Group 4

Week of Year	Waipara Week Factor	Drury Week Factor	Te Puke Week Factor
2	1.054	1.095	1.219
3	0.924	1.050	1.046
4	0.946	0.907	0.952
5	0.836	0.956	0.887
6	0.928	1.004	0.801
7	0.887	0.843	0.870
8	0.915	0.877	0.693
9	0.857	0.861	0.653
10	0.879	0.836	0.789
11	0.869	0.830	0.927
12	0.816	0.845	0.902
13	0.888	0.924	0.773
14	0.947	0.979	0.974
15	0.848	0.838	1.060
16	0.868	0.825	0.787
17	0.946		1.002
18	1.124		1.070
19	1.081		1.081
20	1.106	1.202	1.281
21	1.154	1.260	1.626
22	1.162	1.315	2.186
23	1.198	1.441	2.708
24	1.224	1.266	
25	1.196	1.133	
26	1.140	1.016	
27	1.346	0.983	
28	1.458	1.002	0.924
29	1.286	0.989	0.876
30	1.209	1.094	0.805
31	1.183	1.060	1.338
32	1.120	1.079	1.082
33	1.124	1.001	1.228
34	0.950	1.100	1.283
35	0.998	1.020	1.383
36	0.985	0.982	1.349
37	1.077	0.982	1.016
38	1.021	1.011	0.764
39	1.036	1.021	0.817
40	0.928	0.933	0.957
41	1.077	0.951	1.417
42	0.992	1.023	0.922
43	1.072	1.193	0.834
44	0.983	0.947	1.334
45	0.872	0.976	1.265
46	0.971	0.963	1.066
47	0.911	0.869	0.884
48	0.886	0.898	0.878
49	0.785	0.828	0.870
50	0.791	0.814	1.096
51	0.823	0.909	1.147
52	1.465	2.180	1.950

Appendix M

Average Weekly Multipliers for converting Vehicle Counts to Annual ESA4, based on Vehicle Counts per Hour

Each WIM Site

Vehicle Count Week Multipliers to Annual ESA4

Axle Group 1

Week of Year	Waipara Week Factor	Drury Week Factor	Te Puke Week Factor
2	0.345	0.601	0.488
3	0.324	0.567	0.450
4	0.327	0.558	0.426
5	0.319	0.566	0.425
6	0.338	0.592	0.434
7	0.308	0.537	0.429
8	0.285	0.530	0.409
9	0.286	0.528	0.405
10	0.293	0.529	0.410
11	0.284	0.524	0.433
12	0.278	0.517	0.410
13	0.316	0.597	0.383
14	0.322	0.588	0.465
15	0.301	0.530	0.400
16	0.302	0.524	0.402
17	0.344		0.549
18	0.345		0.480
19	0.313		0.489
20	0.331	0.593	0.469
21	0.342	0.588	0.657
22	0.349	0.604	0.872
23	0.367	0.656	0.879
24	0.366	0.594	1.180
25	0.357	0.572	1.072
26	0.374	0.588	
27	0.373	0.588	0.672
28	0.393	0.583	0.441
29	0.412	0.602	0.471
30	0.391	0.598	0.451
31	0.386	0.593	0.516
32	0.371	0.607	0.517
33	0.383	0.603	0.453
34	0.369	0.608	0.501
35	0.373	0.613	0.491
36	0.365	0.597	0.456
37	0.345	0.578	0.437
38	0.335	0.562	0.421
39	0.324	0.559	0.429
40	0.333	0.549	0.456
41	0.336	0.556	0.513
42	0.335	0.568	0.422
43	0.362	0.601	0.466
44	0.335	0.538	0.403
45	0.313	0.525	0.488
46	0.324	0.549	0.469
47	0.329	0.527	0.426
48	0.308	0.528	0.418
49	0.300	0.516	0.432
50	0.299	0.519	0.439
51	0.300	0.531	0.485
52	0.586	1.148	0.846

Vehicle Count Week Multipliers to Annual ESA4

Axle Group 2

Week of Year	Waipara Week Factor	Drury Week Factor	Te Puke Week Factor
2	0.153	0.180	0.146
3	0.161	0.173	0.144
4	0.152	0.169	0.148
5	0.156	0.168	0.148
6	0.163	0.179	0.153
7	0.160	0.170	0.147
8	0.147	0.161	0.143
9	0.147	0.161	0.143
10	0.157	0.164	0.156
11	0.146	0.161	0.148
12	0.145	0.162	0.150
13	0.151	0.177	0.146
14	0.161	0.177	0.155
15	0.160	0.163	0.143
16	0.171	0.165	0.150
17	0.191		0.180
18	0.213		0.163
19	0.166		0.162
20	0.196	0.204	0.162
21	0.189	0.203	0.207
22	0.203	0.210	0.268
23	0.210	0.208	0.256
24	0.215	0.205	0.332
25	0.195	0.192	
26	0.202	0.190	
27	0.198	0.192	0.218
28	0.208	0.186	0.154
29	0.226	0.191	0.167
30	0.213	0.188	0.163
31	0.207	0.188	0.152
32	0.196	0.193	0.152
33	0.219	0.190	0.130
34	0.194	0.189	0.139
35	0.192	0.189	0.136
36	0.191	0.189	0.123
37	0.176	0.180	0.108
38	0.174	0.172	0.131
39	0.160	0.174	0.151
40	0.172	0.168	0.153
41	0.177	0.174	0.148
42	0.172	0.176	0.124
43	0.171	0.181	0.143
44	0.171	0.168	0.105
45	0.166	0.162	0.149
46	0.161	0.168	0.165
47	0.183	0.166	0.160
48	0.157	0.165	0.152
49	0.154	0.160	0.158
50	0.159	0.164	0.157
51	0.154	0.169	0.159
52	0.213	0.325	0.218

Vehicle Count Week Multipliers to Annual ESA4

Axle Group 3

Week of Year	Waipara Week Factor	Drury Week Factor	Te Puke Week Factor
2	0.448	0.528	0.441
3	0.425	0.502	0.396
4	0.417	0.496	0.373
5	0.394	0.512	0.363
6	0.419	0.514	0.365
7	0.367	0.468	0.371
8	0.339	0.470	0.329
9	0.342	0.461	0.333
10	0.347	0.461	0.342
11	0.346	0.457	0.360
12	0.340	0.448	0.335
13	0.411	0.533	0.301
14	0.399	0.515	0.406
15	0.355	0.446	0.332
16	0.349	0.440	0.323
17	0.394		0.456
18	0.393		0.402
19	0.362		0.415
20	0.373	0.493	0.400
21	0.378	0.479	0.595
22	0.396	0.497	0.900
23	0.416	0.550	0.963
24	0.423	0.493	1.269
25	0.413	0.468	1.333
26	0.426	0.489	
27	0.425	0.493	0.630
28	0.456	0.482	0.365
29	0.465	0.500	0.383
30	0.462	0.513	0.389
31	0.457	0.515	0.538
32	0.442	0.523	0.544
33	0.452	0.528	0.476
34	0.445	0.532	0.571
35	0.438	0.530	0.578
36	0.434	0.507	0.584
37	0.429	0.493	0.570
38	0.409	0.482	0.414
39	0.401	0.482	0.376
40	0.408	0.471	0.393
41	0.394	0.482	0.537
42	0.409	0.493	0.434
43	0.455	0.527	0.478
44	0.408	0.454	0.569
45	0.374	0.462	0.500
46	0.400	0.482	0.407
47	0.376	0.455	0.365
48	0.376	0.454	0.352
49	0.354	0.445	0.366
50	0.357	0.447	0.379
51	0.367	0.469	0.414
52	0.895	1.126	0.933

Vehicle Count Week Multipliers to Annual ESA4

Axle Group 4

Week of Year	Waipara Week Factor	Drury Week Factor	Te Puke Week Factor
2	0.372	0.404	0.430
3	0.351	0.391	0.390
4	0.362	0.374	0.379
5	0.341	0.395	0.348
6	0.362	0.408	0.359
7	0.343	0.357	0.347
8	0.353	0.366	0.342
9	0.339	0.368	0.326
10	0.333	0.357	0.363
11	0.341	0.349	0.387
12	0.325	0.347	0.381
13	0.341	0.395	0.331
14	0.350	0.401	0.358
15	0.332	0.358	0.391
16	0.327	0.359	0.345
17	0.372		0.370
18	0.341		0.397
19	0.314		0.416
20	0.325	0.362	0.380
21	0.338	0.361	0.442
22	0.344	0.362	0.589
23	0.349	0.402	0.656
24	0.347	0.357	
25	0.348	0.367	
26	0.367	0.385	
27	0.368	0.378	
28	0.384	0.367	0.352
29	0.360	0.365	0.339
30	0.355	0.383	0.317
31	0.366	0.377	0.444
32	0.362	0.389	0.402
33	0.374	0.373	0.416
34	0.333	0.395	0.470
35	0.351	0.380	0.449
36	0.358	0.374	0.474
37	0.375	0.391	0.419
38	0.362	0.380	0.340
39	0.362	0.378	0.351
40	0.355	0.366	0.368
41	0.366	0.367	0.484
42	0.368	0.383	0.402
43	0.393	0.427	0.332
44	0.374	0.357	0.469
45	0.352	0.362	0.387
46	0.375	0.368	0.402
47	0.349	0.352	0.339
48	0.347	0.359	0.335
49	0.324	0.340	0.335
50	0.322	0.338	0.381
51	0.328	0.342	0.368
52	0.488	0.638	0.495

Weekly ESA4 Multipliers to Annual ESA4

Combination of Drury and Waipara

Week	Axle Group 1	Axle Group 2	Axle Group 3	Axle Group 4
2	1.0662	1.1152	1.0633	1.0749
3	0.9420	0.9682	0.9631	0.9870
4	0.8996	0.8073	0.9175	0.9264
5	0.8880	0.8175	0.9170	0.8956
6	0.9541	0.9423	0.9861	0.9659
7	0.8549	0.9018	0.8546	0.8646
8	0.8347	0.7598	0.7919	0.8961
9	0.8118	0.7580	0.7953	0.8589
10	0.8195	0.7560	0.8031	0.8577
11	0.8225	0.7769	0.8139	0.8496
12	0.8072	0.7849	0.7896	0.8305
13	0.9385	0.8607	0.9348	0.9060
14	0.9850	0.9497	0.9678	0.9629
15	0.8271	0.8470	0.8049	0.8430
16	0.8092	0.8670	0.8023	0.8462
17	0.9636	1.2205	0.9442	0.9461
18	1.1061	1.6639	1.1535	1.1243
19	1.0209	1.2163	1.1590	1.0805
20	1.1717	1.5326	1.2075	1.1539
21	1.2309	1.2519	1.1861	1.2069
22	1.2645	1.4488	1.2992	1.2385
23	1.3658	1.3626	1.3458	1.3192
24	1.2331	1.3375	1.2444	1.2451
25	1.1356	1.0926	1.0939	1.1643
26	1.1135	1.1662	1.0672	1.0782
27	1.2534	1.2986	1.2057	1.1649
28	1.2507	1.2210	1.2339	1.2296
29	1.2633	1.2143	1.2559	1.1374
30	1.1604	1.1818	1.2124	1.1513
31	1.1086	1.1766	1.1234	1.1217
32	1.0888	1.1330	1.1220	1.0991
33	1.1451	1.1904	1.1585	1.0625
34	1.0620	1.1032	1.0943	1.0249
35	1.0589	1.0383	1.0891	1.0094
36	1.0223	1.0611	1.0361	0.9838
37	0.9893	0.9910	0.9854	1.0298
38	0.9438	0.9522	0.9454	1.0163
39	0.9407	0.9311	0.9621	1.0284
40	0.9214	0.9564	0.9138	0.9307
41	1.0078	0.9828	0.9639	1.0143
42	0.9865	1.0348	0.9800	1.0076
43	1.0977	1.0733	1.0827	1.1329
44	0.9525	0.9007	0.9176	0.9654
45	0.8981	0.8511	0.8711	0.9240
46	0.9527	0.9240	0.9404	0.9668
47	0.9165	0.9940	0.8936	0.8898
48	0.8533	0.8545	0.8507	0.8919
49	0.8419	0.8453	0.8232	0.8067
50	0.8427	0.8561	0.8275	0.8025
51	0.8691	0.8965	0.9056	0.8658
52	2.1504	2.3645	2.8383	1.8225

Appendix N

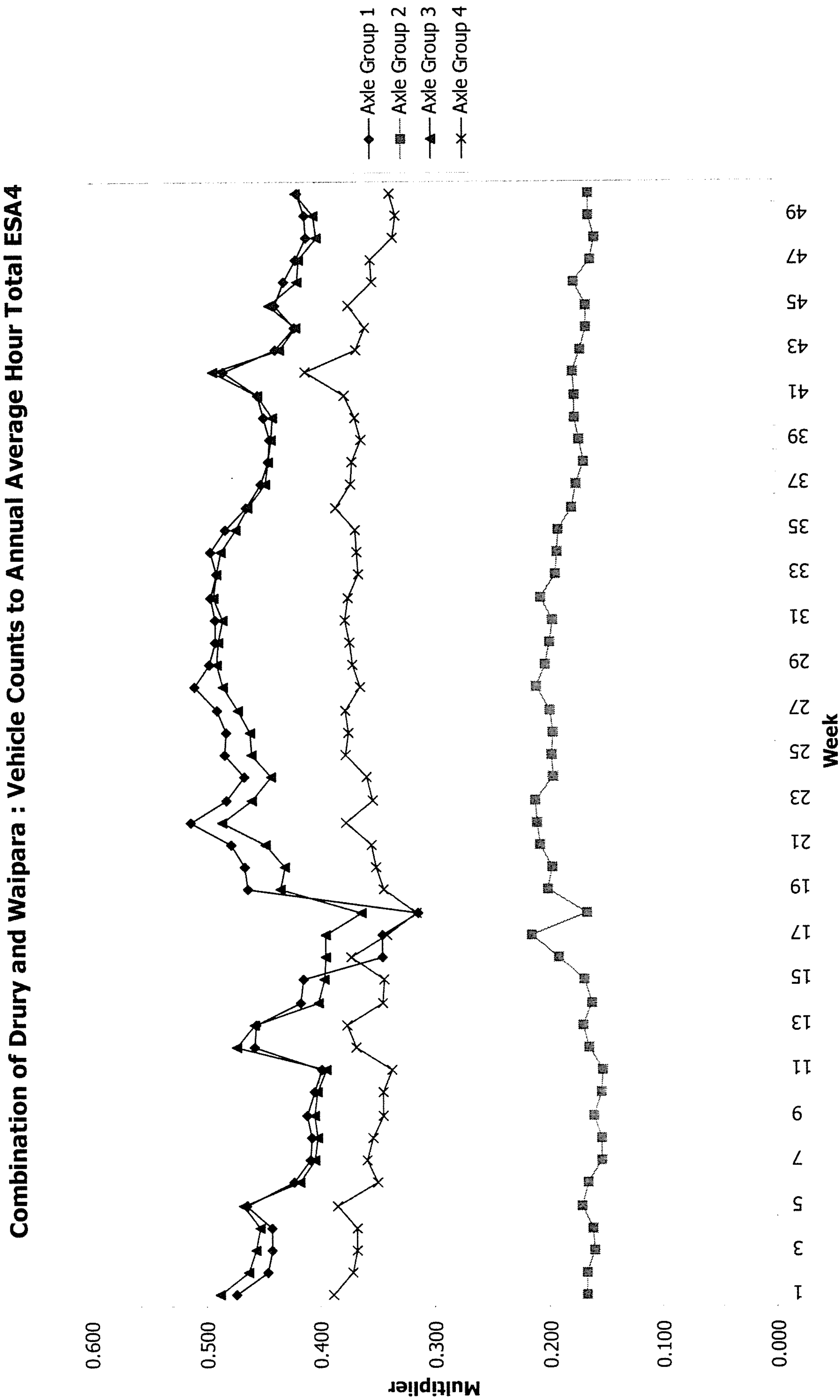
Average Weekly Multipliers for converting Vehicle Counts to Annual ESA4, based on Vehicle Counts per Hour

Combination of Drury and Waipara

Vehicle Counts Week Multipliers to Annual ESA4

Combination of Drury and Waipara

Week	Axle Group 1	Axle Group 2	Axle Group 3	Axle Group 4
2	0.4730	0.1664	0.4879	0.3881
3	0.4458	0.1666	0.4633	0.3712
4	0.4423	0.1603	0.4563	0.3677
5	0.4425	0.1617	0.4529	0.3682
6	0.4649	0.1710	0.4669	0.3851
7	0.4225	0.1651	0.4174	0.3500
8	0.4078	0.1542	0.4043	0.3591
9	0.4068	0.1538	0.4015	0.3533
10	0.4112	0.1604	0.4038	0.3450
11	0.4042	0.1535	0.4017	0.3449
12	0.3975	0.1531	0.3937	0.3361
13	0.4565	0.1642	0.4718	0.3681
14	0.4551	0.1692	0.4570	0.3754
15	0.4155	0.1613	0.4005	0.3450
16	0.4131	0.1682	0.3948	0.3430
17	0.3444	0.1909	0.3938	0.3720
18	0.3446	0.2134	0.3934	0.3408
19	0.3133	0.1660	0.3620	0.3139
20	0.4618	0.1998	0.4330	0.3435
21	0.4649	0.1961	0.4290	0.3495
22	0.4764	0.2063	0.4465	0.3533
23	0.5115	0.2091	0.4835	0.3755
24	0.4797	0.2100	0.4580	0.3522
25	0.4649	0.1937	0.4405	0.3575
26	0.4812	0.1959	0.4576	0.3762
27	0.4806	0.1949	0.4591	0.3727
28	0.4877	0.1974	0.4690	0.3752
29	0.5070	0.2086	0.4821	0.3627
30	0.4944	0.2003	0.4872	0.3692
31	0.4894	0.1972	0.4862	0.3716
32	0.4891	0.1943	0.4823	0.3755
33	0.4929	0.2044	0.4902	0.3735
34	0.4884	0.1915	0.4884	0.3643
35	0.4926	0.1902	0.4841	0.3654
36	0.4806	0.1897	0.4706	0.3662
37	0.4616	0.1780	0.4611	0.3831
38	0.4487	0.1735	0.4454	0.3710
39	0.4416	0.1671	0.4417	0.3696
40	0.4413	0.1704	0.4396	0.3607
41	0.4457	0.1751	0.4382	0.3667
42	0.4514	0.1742	0.4510	0.3757
43	0.4813	0.1757	0.4907	0.4099
44	0.4362	0.1696	0.4311	0.3658
45	0.4190	0.1641	0.4179	0.3574
46	0.4361	0.1643	0.4411	0.3712
47	0.4279	0.1745	0.4155	0.3503
48	0.4179	0.1606	0.4153	0.3527
49	0.4078	0.1569	0.3993	0.3322
50	0.4090	0.1613	0.4021	0.3301
51	0.4155	0.1615	0.4179	0.3353
52	0.8667	0.2686	1.0104	0.5630


Combination of Drury and Waipara : Vehicle Counts to Annual Average Hour Total ESA4
Axle Group 1
Axle Group 2
Axle Group 3
Axle Group 4
Multiplier
0.600
0.500
0.400
0.300
0.200
0.100
0.000
Week
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
49

Appendix O

95% Margin of Error for converting Vehicle Counts to Annual ESA4, based on Vehicle Counts per Hour

Combination of Drury and Waipara

Hourly Variation Only

Vehicle Count to ESA4 Week Multipliers Hourly Standard Errors

Combination of Drury and Waipara

Week	Axle Group 1	Axle Group 2	Axle Group 3	Axle Group 4
2	0.0964	0.1061	0.0978	0.0739
3	0.0926	0.1055	0.0958	0.0736
4	0.0952	0.1075	0.0992	0.0772
5	0.0939	0.1042	0.0986	0.0781
6	0.0986	0.1084	0.1011	0.0778
7	0.0945	0.1063	0.0970	0.0759
8	0.0957	0.1043	0.0980	0.0752
9	0.0948	0.1084	0.0948	0.0758
10	0.0918	0.1056	0.0929	0.0718
11	0.0924	0.1049	0.0953	0.0702
12	0.0944	0.1077	0.0960	0.0742
13	0.1144	0.1202	0.1196	0.0831
14	0.1053	0.1159	0.1075	0.0853
15	0.0979	0.1078	0.0989	0.0790
16	0.0973	0.1086	0.0966	0.0718
17	0.0918	0.0941	0.0927	0.0755
18	0.0871	0.0964	0.0878	0.0740
19	0.0924	0.1011	0.0896	0.0622
20	0.1003	0.1134	0.1033	0.0795
21	0.0996	0.1067	0.1004	0.0799
22	0.1016	0.1099	0.1038	0.0755
23	0.1050	0.1082	0.1086	0.0857
24	0.0975	0.1095	0.1009	0.0751
25	0.0973	0.1101	0.0997	0.0707
26	0.0955	0.1050	0.1005	0.0743
27	0.1005	0.1081	0.1042	0.0754
28	0.0985	0.1104	0.1004	0.0718
29	0.0991	0.1088	0.0977	0.0745
30	0.0998	0.1074	0.1040	0.0738
31	0.0984	0.1088	0.1023	0.0806
32	0.0986	0.1120	0.1027	0.0765
33	0.0970	0.1073	0.0999	0.0767
34	0.0971	0.1100	0.0987	0.0717
35	0.0993	0.1142	0.0999	0.0749
36	0.0946	0.1057	0.0967	0.0741
37	0.0950	0.1030	0.0984	0.0750
38	0.0983	0.1099	0.1003	0.0725
39	0.0969	0.1079	0.0988	0.0766
40	0.0956	0.1058	0.0988	0.0712
41	0.0943	0.1092	0.0947	0.0768
42	0.0988	0.1139	0.1020	0.0731
43	0.1024	0.1090	0.1054	0.0806
44	0.1007	0.1116	0.1003	0.0748
45	0.0941	0.1074	0.0983	0.0745
46	0.0956	0.1074	0.1000	0.0777
47	0.0932	0.1066	0.0948	0.0740
48	0.0942	0.1068	0.0965	0.0784
49	0.0962	0.1086	0.0972	0.0761
50	0.0936	0.1045	0.0965	0.0788
51	0.0928	0.1068	0.0969	0.0757
52	0.1074	0.1107	0.1059	0.0754

Appendix P

Average Weekly Multipliers Three-Hour Counts for converting Weekly ESA4 to Annual ESA4, based on Weekly Average ESA4 per Hour

Each WIM site

ESA4 3 Hour Factors : Each WIM Site

Axle Group 1

Week	Waipara	Drury	Te Puke
2	0.908	0.491	0.634
3	0.685	0.485	0.580
4	0.675	0.435	0.495
5	0.606	0.540	0.488
6	0.653	0.526	0.548
7	0.577	0.454	0.555
8	0.515	0.447	0.495
9	0.526	0.462	0.433
10	0.521	0.475	0.518
11	0.538	0.450	0.468
12	0.562	0.436	0.451
13	0.602	0.505	0.404
14	0.653	0.495	0.530
15	0.567	0.433	0.446
16	0.466	0.420	0.407
17	0.648		0.646
18	0.813		0.700
19	0.742		0.747
20	0.898	0.551	0.690
21	0.815	0.626	1.060
22	0.754	0.678	2.077
23	0.843	0.758	2.258
24	0.768	0.659	3.926
25	0.807	0.572	
26	0.842	0.468	
27	1.029	0.508	
28	1.089	0.482	0.512
29	1.050	0.555	0.603
30	0.934	0.565	0.529
31	0.969	0.517	0.701
32	0.816	0.528	0.642
33	0.833	0.519	0.618
34	0.767	0.560	0.592
35	0.704	0.532	0.596
36	0.718	0.516	0.668
37	0.741	0.493	0.502
38	0.657	0.491	0.582
39	0.543	0.447	0.594
40	0.643	0.454	0.574
41	0.698	0.514	0.663
42	0.655	0.527	0.275
43	0.921	0.563	0.421
44	0.663	0.501	0.359
45	0.567	0.497	0.495
46	0.697	0.495	0.492
47	0.667	0.459	0.529
48	0.556	0.480	0.521
49	0.602	0.453	0.555
50	0.590	0.494	0.545
51	0.601	0.471	0.583
52	1.789	1.409	1.420

ESA4 3 Hour Factors : Each WIM Site

Axle Group 2

Week	Waipara	Drury	Te Puke
2	0.762	0.490	0.786
3	0.497	0.433	0.701
4	0.423	0.403	0.735
5	0.443	0.478	0.862
6	0.604	0.580	0.768
7	0.456	0.466	0.615
8	0.476	0.388	0.683
9	0.399	0.449	0.489
10	0.351	0.514	0.700
11	0.348	0.469	0.611
12	0.436	0.387	0.669
13	0.385	0.484	0.460
14	0.567	0.430	0.633
15	0.468	0.400	0.484
16	0.495	0.467	0.525
17	0.665		0.765
18	1.346		0.788
19	0.942		0.645
20	1.156	0.649	0.685
21	0.701	0.615	1.439
22	1.062	0.626	2.822
23	0.950	0.680	2.227
24	0.746	0.678	3.806
25	0.787	0.582	
26	0.760	0.421	
27	0.789	0.521	
28	0.836	0.463	0.570
29	0.931	0.440	0.840
30	0.918	0.433	0.616
31	0.960	0.526	0.751
32	0.638	0.499	0.779
33	0.940	0.503	0.661
34	0.568	0.507	0.778
35	0.566	0.499	0.697
36	0.646	0.474	0.829
37	0.709	0.446	0.638
38	0.485	0.431	0.578
39	0.472	0.405	0.986
40	0.645	0.432	0.922
41	0.735	0.415	0.683
42	0.573	0.513	0.266
43	0.778	0.483	0.488
44	0.519	0.373	0.312
45	0.518	0.416	0.439
46	0.483	0.449	0.888
47	0.720	0.414	0.781
48	0.447	0.406	0.968
49	0.417	0.380	0.709
50	0.499	0.410	0.809
51	0.434	0.537	0.748
52	1.234	1.642	2.388

ESA4 3 Hour Factors : Each WIM Site

Axle Group 3

Week	Waipara	Drury	Te Puke
2	0.667	0.427	0.593
3	0.653	0.406	0.497
4	0.710	0.377	0.417
5	0.513	0.479	0.374
6	0.665	0.477	0.436
7	0.492	0.411	0.502
8	0.436	0.414	0.378
9	0.434	0.412	0.374
10	0.397	0.435	0.472
11	0.438	0.416	0.443
12	0.434	0.393	0.403
13	0.490	0.461	0.356
14	0.578	0.434	0.486
15	0.444	0.389	0.442
16	0.392	0.369	0.352
17	0.510		0.574
18	0.652		0.731
19	0.768		0.707
20	0.811	0.502	0.660
21	0.757	0.581	1.249
22	0.780	0.604	3.396
23	0.738	0.679	3.307
24	0.699	0.575	6.257
25	0.719	0.498	
26	0.793	0.401	
27	0.858	0.432	
28	1.003	0.412	0.412
29	0.968	0.534	0.445
30	0.916	0.498	0.455
31	0.888	0.467	0.836
32	0.755	0.459	0.716
33	0.741	0.468	0.734
34	0.650	0.493	0.832
35	0.620	0.468	0.978
36	0.682	0.444	1.277
37	0.586	0.414	1.273
38	0.531	0.414	0.712
39	0.517	0.409	0.653
40	0.597	0.376	0.559
41	0.641	0.435	0.833
42	0.609	0.449	0.825
43	0.936	0.474	0.787
44	0.642	0.420	0.998
45	0.458	0.436	0.952
46	0.626	0.416	0.411
47	0.526	0.419	0.468
48	0.494	0.408	0.446
49	0.496	0.392	0.475
50	0.500	0.408	0.517
51	0.470	0.450	0.529
52	1.903	1.437	1.737

ESA4 3 Hour Factors : Each WIM Site

Axle Group 4

Week	Waipara	Drury	Te Puke
2	1.678	0.603	0.676
3	1.551	0.582	0.738
4	1.127	0.489	0.586
5	1.028	0.585	0.773
6	1.337	0.580	0.578
7	0.990	0.509	0.810
8	1.336	0.645	0.524
9	0.844	0.549	0.478
10	1.036	0.566	0.647
11	1.067	0.550	0.645
12	1.109	0.561	0.733
13	0.894	0.520	0.474
14	1.285	0.533	0.679
15	1.270	0.475	0.827
16	1.043	0.473	0.515
17	1.305		0.711
18	1.106		0.769
19	1.651		1.195
20	1.804	0.590	1.189
21	1.487	0.678	1.798
22	1.509	0.864	2.187
23	1.327	0.877	3.435
24	2.073	0.915	3.706
25	1.337	0.831	
26	1.430	0.625	
27	1.390	0.548	
28	1.743	0.573	0.540
29	1.580	0.556	0.667
30	1.719	0.676	0.463
31	1.692	0.561	1.271
32	1.462	0.680	0.965
33	1.503	0.577	1.417
34	1.088	0.607	0.978
35	1.287	0.483	0.820
36	1.064	0.538	1.263
37	1.426	0.521	0.729
38	1.282	0.565	0.738
39	1.490	0.544	0.593
40	1.175	0.488	0.828
41	1.205	0.517	1.113
42	1.659	0.649	0.922
43	1.609	0.664	0.836
44	0.894	0.590	1.674
45	1.106	0.578	1.135
46	1.080	0.678	0.695
47	1.076	0.591	0.558
48	0.990	0.564	0.571
49	0.936	0.555	0.601
50	1.164	0.512	0.758
51	0.989	0.532	0.700
52	2.836	1.202	0.999

Appendix Q

Average Weekly Multipliers Three-Hour Counts for converting Vehicle Counts to Annual ESA4, based on Vehicle Counts per Hour

Each WIM site

Vehicle Count to ESA4 3 Hour Week Multipliers

Vehicle Counts

Axle Group 1

Week	Waipara	Drury	Te Puke
2	0.209	0.315	0.239
3	0.212	0.291	0.226
4	0.226	0.288	0.220
5	0.196	0.321	0.236
6	0.216	0.317	0.246
7	0.177	0.290	0.242
8	0.164	0.282	0.217
9	0.166	0.289	0.205
10	0.169	0.285	0.240
11	0.159	0.284	0.225
12	0.155	0.266	0.217
13	0.164	0.312	0.214
14	0.183	0.299	0.238
15	0.177	0.281	0.211
16	0.165	0.274	0.199
17	0.198		0.268
18	0.218		0.276
19	0.172		0.277
20	0.200	0.264	0.273
21	0.205	0.288	0.389
22	0.218	0.298	0.613
23	0.221	0.339	0.565
24	0.209	0.297	0.994
25	0.218	0.294	1.066
26	0.243	0.289	
27	0.231	0.296	
28	0.243	0.291	0.217
29	0.265	0.298	0.240
30	0.255	0.306	0.224
31	0.261	0.293	0.307
32	0.232	0.298	0.276
33	0.244	0.302	0.252
34	0.229	0.304	0.263
35	0.229	0.301	0.253
36	0.234	0.295	0.273
37	0.228	0.301	0.247
38	0.212	0.278	0.269
39	0.182	0.277	0.242
40	0.205	0.275	0.249
41	0.206	0.291	0.281
42	0.204	0.300	0.258
43	0.250	0.326	0.264
44	0.200	0.277	0.254
45	0.190	0.286	0.269
46	0.212	0.292	
47	0.211	0.269	0.225
48	0.191	0.290	0.220
49	0.183	0.266	0.229
50	0.194	0.284	0.229
51	0.177	0.282	0.247
52	0.413	0.674	0.509

Vehicle Count to ESA4 3 Hour Week Multipliers

Vehicle Counts

Axle Group 2

Week	Waipara	Drury	Te Puke
2	0.102	0.101	0.091
3	0.105	0.090	0.086
4	0.103	0.086	0.093
5	0.091	0.093	0.103
6	0.106	0.096	0.107
7	0.089	0.093	0.102
8	0.085	0.086	0.100
9	0.086	0.084	0.085
10	0.087	0.087	0.103
11	0.074	0.086	0.099
12	0.081	0.080	0.103
13	0.074	0.087	0.094
14	0.093	0.084	0.093
15	0.093	0.083	0.089
16	0.101	0.084	0.086
17	0.116		0.108
18	0.131		0.105
19	0.087		0.115
20	0.116	0.087	0.107
21	0.112	0.097	0.164
22	0.137	0.096	0.249
23	0.121	0.110	0.194
24	0.117	0.101	0.337
25	0.127	0.096	0.385
26	0.136	0.087	
27	0.130	0.095	
28	0.134	0.091	0.089
29	0.153	0.092	0.117
30	0.146	0.091	0.100
31	0.137	0.092	0.112
32	0.114	0.091	0.105
33	0.154	0.098	0.083
34	0.123	0.092	0.084
35	0.117	0.093	0.075
36	0.130	0.087	0.078
37	0.124	0.091	0.066
38	0.102	0.085	0.089
39	0.089	0.085	0.098
40	0.101	0.085	0.104
41	0.104	0.090	0.092
42	0.102	0.093	0.075
43	0.112	0.098	0.094
44	0.100	0.082	0.066
45	0.098	0.087	0.088
46	0.104	0.087	
47	0.114	0.081	0.099
48	0.092	0.086	0.098
49	0.094	0.077	0.100
50	0.100	0.085	0.093
51	0.091	0.091	0.103
52	0.151	0.195	0.176

Vehicle Count to ESA4 3 Hour Week Multipliers

Vehicle Counts

Axle Group 3

Week	Waipara	Drury	Te Puke
2	0.283	0.262	0.218
3	0.290	0.246	0.203
4	0.306	0.241	0.199
5	0.246	0.291	0.201
6	0.286	0.268	0.217
7	0.220	0.245	0.204
8	0.202	0.247	0.183
9	0.203	0.253	0.178
10	0.199	0.249	0.206
11	0.200	0.243	0.193
12	0.190	0.230	0.186
13	0.235	0.281	0.179
14	0.241	0.262	0.212
15	0.219	0.243	0.177
16	0.190	0.226	0.161
17	0.235		0.231
18	0.252		0.249
19	0.204		0.228
20	0.226	0.222	0.232
21	0.238	0.242	0.338
22	0.240	0.251	0.692
23	0.269	0.287	0.661
24	0.247	0.245	1.376
25	0.243	0.242	1.362
26	0.272	0.236	
27	0.260	0.239	
28	0.298	0.236	0.185
29	0.320	0.257	0.191
30	0.305	0.262	0.189
31	0.313	0.252	0.322
32	0.284	0.252	0.270
33	0.280	0.255	0.284
34	0.283	0.257	0.345
35	0.267	0.256	0.357
36	0.295	0.253	0.447
37	0.300	0.255	0.443
38	0.285	0.230	0.305
39	0.239	0.228	0.236
40	0.277	0.227	0.226
41	0.253	0.245	0.324
42	0.265	0.248	0.358
43	0.368	0.280	0.280
44	0.270	0.240	0.428
45	0.234	0.244	0.309
46	0.276	0.255	
47	0.248	0.237	0.195
48	0.237	0.249	0.191
49	0.222	0.230	0.194
50	0.235	0.242	0.206
51	0.208	0.243	0.213
52	0.660	0.583	0.578

Vehicle Count to ESA4 3 Hour Week Multipliers

Vehicle Counts

Axle Group 4

Week	Waipara	Drury	Te Puke
2	0.536	0.246	0.276
3	0.478	0.244	0.261
4	0.460	0.243	0.274
5	0.452	0.246	0.266
6	0.408	0.260	0.268
7	0.311	0.233	0.251
8	0.424	0.250	0.238
9	0.385	0.253	0.228
10	0.338	0.255	0.276
11	0.440	0.246	0.289
12	0.385	0.239	0.286
13	0.379	0.268	0.237
14	0.413	0.272	0.266
15	0.440	0.238	0.307
16	0.418	0.234	0.234
17	0.409		0.278
18	0.341		0.305
19	0.372		0.413
20	0.372	0.218	0.307
21	0.414	0.217	0.392
22	0.429	0.247	0.490
23	0.377	0.246	0.602
24	0.443	0.238	0.689
25	0.377	0.255	
26	0.461	0.239	
27	0.388	0.230	
28	0.435	0.236	0.226
29	0.417	0.216	0.254
30	0.488	0.244	0.192
31	0.406	0.219	0.394
32	0.471	0.241	0.325
33	0.454	0.219	0.396
34	0.354	0.234	0.376
35	0.485	0.226	0.355
36	0.398	0.239	0.462
37	0.498	0.241	0.327
38	0.435	0.247	0.347
39	0.454	0.230	0.256
40	0.420	0.225	0.284
41	0.417	0.229	0.373
42	0.394	0.254	0.454
43	0.506	0.269	0.290
44	0.398	0.218	0.594
45	0.377	0.244	0.312
46	0.416	0.264	
47	0.393	0.250	0.214
48	0.464	0.260	0.223
49	0.381	0.243	0.235
50	0.398	0.243	0.295
51	0.341	0.232	0.234
52		0.380	0.329

Appendix R

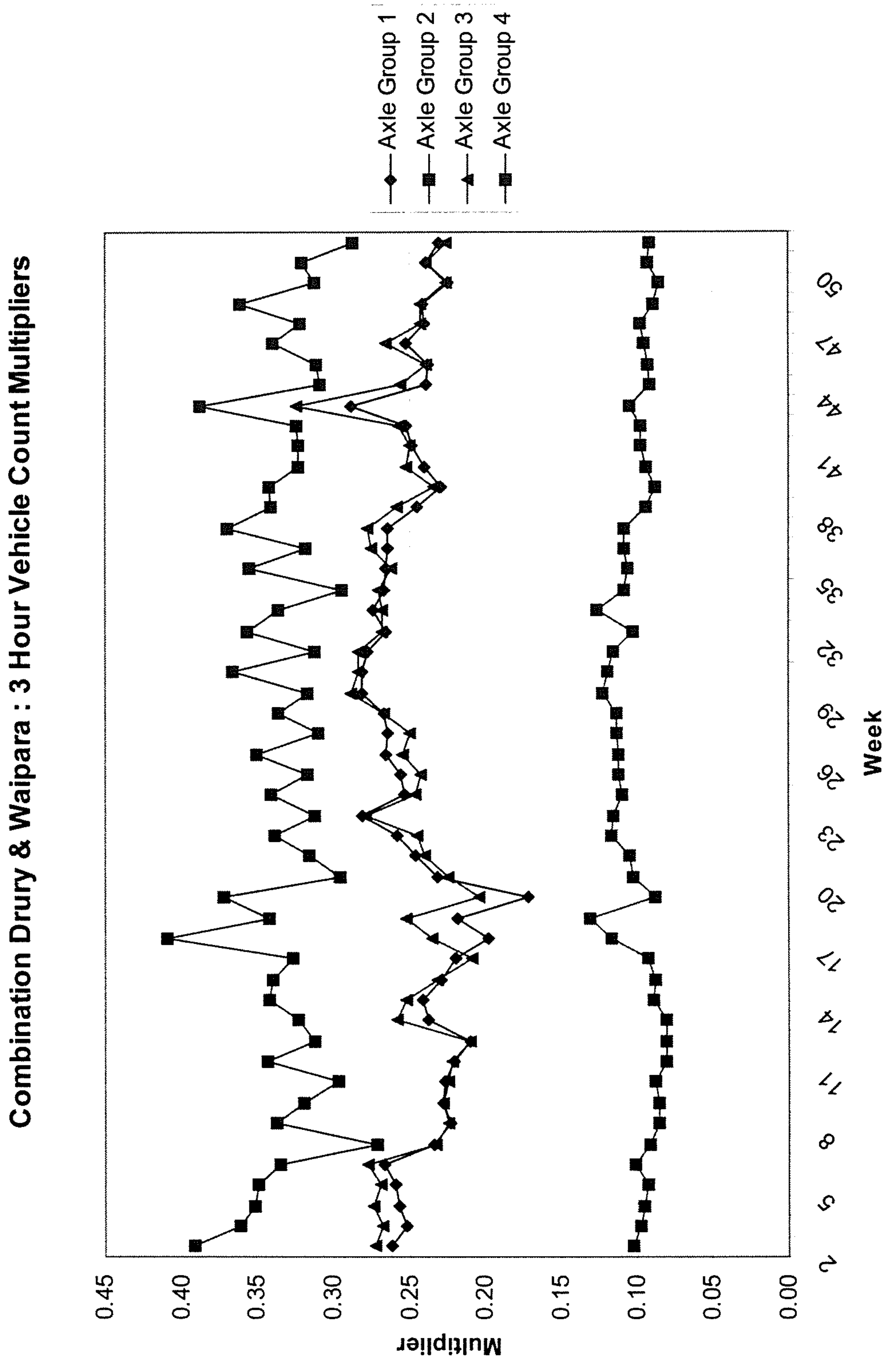
Average Weekly Multipliers Three-Hour Counts for converting Vehicle Counts to Annual ESA4, based on Vehicle Counts per Hour

Combination of Drury and Waipara

Vehicle Count to ESA4 3 Hour Week Multipliers

Combination : Drury and Waipara

Week	Axle Group 1	Axle Group 2	Axle Group 3	Axle Group 4
2	0.2621	0.1016	0.2725	0.3909
3	0.2517	0.0975	0.2678	0.3611
4	0.2569	0.0946	0.2736	0.3513
5	0.2588	0.0920	0.2683	0.3490
6	0.2665	0.1011	0.2770	0.3342
7	0.2338	0.0910	0.2327	0.2717
8	0.2232	0.0855	0.2242	0.3368
9	0.2276	0.0851	0.2277	0.3190
10	0.2269	0.0872	0.2240	0.2965
11	0.2213	0.0801	0.2216	0.3432
12	0.2105	0.0807	0.2104	0.3116
13	0.2378	0.0802	0.2576	0.3234
14	0.2407	0.0885	0.2518	0.3424
15	0.2289	0.0880	0.2313	0.3392
16	0.2195	0.0924	0.2082	0.3261
17	0.1981	0.1159	0.2352	0.4089
18	0.2181	0.1311	0.2516	0.3415
19	0.1715	0.0871	0.2043	0.3719
20	0.2319	0.1015	0.2241	0.2951
21	0.2465	0.1049	0.2398	0.3158
22	0.2578	0.1165	0.2454	0.3382
23	0.2803	0.1154	0.2780	0.3116
24	0.2528	0.1090	0.2461	0.3403
25	0.2559	0.1118	0.2425	0.3164
26	0.2656	0.1114	0.2538	0.3503
27	0.2634	0.1122	0.2499	0.3094
28	0.2669	0.1128	0.2668	0.3354
29	0.2810	0.1224	0.2886	0.3168
30	0.2807	0.1187	0.2832	0.3657
31	0.2771	0.1149	0.2827	0.3126
32	0.2654	0.1026	0.2679	0.3559
33	0.2731	0.1261	0.2675	0.3365
34	0.2666	0.1077	0.2701	0.2940
35	0.2651	0.1052	0.2618	0.3555
36	0.2645	0.1086	0.2742	0.3185
37	0.2644	0.1076	0.2777	0.3695
38	0.2452	0.0934	0.2575	0.3410
39	0.2295	0.0872	0.2336	0.3419
40	0.2398	0.0930	0.2521	0.3224
41	0.2484	0.0970	0.2493	0.3229
42	0.2521	0.0975	0.2566	0.3239
43	0.2883	0.1050	0.3243	0.3875
44	0.2388	0.0910	0.2553	0.3080
45	0.2379	0.0923	0.2390	0.3108
46	0.2523	0.0954	0.2653	0.3397
47	0.2398	0.0976	0.2424	0.3215
48	0.2408	0.0894	0.2429	0.3617
49	0.2245	0.0852	0.2261	0.3122
50	0.2388	0.0926	0.2385	0.3207
51	0.2298	0.0909	0.2255	0.2865
52	0.5434	0.1729	0.6216	


Combination Drury & Waipara : 3 Hour Vehicle Count Multipliers
Multiplier
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Week
2
5
8
11
14
17
20
23
26
29
32
35
38
41
44
47
50
Axle Group 1
Axle Group 2
Axle Group 3
Axle Group 4

Appendix S

95% Margin of Error for Weekly Multipliers using Three-Hour Counts, based on Vehicle Counts per Hour

Combination of Drury and Waipara

Hourly Variation Only

Vehicle Count to ESA4 - 3 Hour Week Multipliers Standard Errors

Combination : Drury and Waipara

Week	Axle Group 1	Axle Group 2	Axle Group 3	Axle Group 4
2	0.1504	0.2617	0.1955	0.2366
3	0.1779	0.3060	0.1947	0.2327
4	0.1811	0.2238	0.2160	0.3184
5	0.3192	0.3123	0.3787	0.3643
6	0.2784	0.3374	0.3127	0.3671
7	0.1335	0.1756	0.1738	0.2846
8	0.1197	0.1792	0.1312	0.2840
9	0.1567	0.2179	0.1800	0.3278
10	0.1478	0.1538	0.2054	0.3216
11	0.1325	0.1907	0.2046	0.3107
12	0.2210	0.2725	0.2400	0.3051
13	0.3447	0.3231	0.4568	0.4924
14	0.2984	0.3135	0.4215	0.4976
15	0.1465	0.2217	0.1875	0.3227
16	0.2024	0.2350	0.2124	0.3214
17	0.2488	0.3220	0.3400	0.4621
18	0.1931	0.3522	0.1862	0.3627
19	0.1166	0.1943	0.1625	0.4210
20	0.1493	0.2289	0.2122	0.2927
21	0.1606	0.2020	0.2262	0.2868
22	0.1715	0.2607	0.1887	0.3596
23	0.3225	0.3242	0.4545	0.4838
24	0.1501	0.2813	0.1975	0.2555
25	0.1546	0.3057	0.2219	0.3014
26	0.1594	0.2401	0.2342	0.3555
27	0.1598	0.2237	0.2042	0.3199
28	0.1903	0.2712	0.2276	0.2989
29	0.2119	0.3244	0.2386	0.3287
30	0.1399	0.1945	0.1871	0.2358
31	0.1506	0.2386	0.1937	0.3942
32	0.1569	0.2153	0.2142	0.2935
33	0.1338	0.2098	0.2132	0.3183
34	0.1229	0.2128	0.2055	0.3802
35	0.1449	0.3010	0.1658	0.2920
36	0.1851	0.2156	0.2231	0.4440
37	0.1766	0.2403	0.1965	0.2509
38	0.1504	0.2291	0.2045	0.3271
39	0.1850	0.2067	0.1959	0.4105
40	0.1372	0.1782	0.2025	0.3241
41	0.1374	0.1875	0.1678	0.3236
42	0.1581	0.2309	0.1891	0.2526
43	0.3943	0.3921	0.4854	0.4638
44	0.1684	0.2363	0.1955	0.2712
45	0.1564	0.2242	0.2171	0.3374
46	0.1981	0.2396	0.2905	0.3270
47	0.1998	0.2586	0.1939	0.3417
48	0.1591	0.2029	0.1745	0.3576
49	0.1618	0.2552	0.1902	0.4051
50	0.1331	0.2173	0.1344	0.3250
51	0.1238	0.2053	0.1713	0.3366
52	0.5737	0.5115	0.5412	

Appendix T

Average Weekly Multipliers Eight-Hour Counts for converting Weekly ESA4 to Annual ESA4, based on Weekly Average ESA4 per Hour

Each WIM Site

Weekly ESA4 to Annual ESA4 - 8 Hour Factors : Each WIM Site

ESA4 Only

Axle Group 1

Week	Waipara	Drury	Te Puke
2	0.809	0.504	0.579
3	0.601	0.497	0.519
4	0.639	0.453	0.431
5	0.598	0.508	0.454
6	0.641	0.530	0.471
7	0.548	0.449	0.514
8	0.511	0.454	0.439
9	0.501	0.449	0.386
10	0.508	0.463	0.432
11	0.505	0.442	0.423
12	0.543	0.428	0.379
13	0.563	0.499	0.401
14	0.641	0.515	0.465
15	0.510	0.437	0.387
16	0.478	0.435	0.384
17	0.604		0.635
18	0.711		0.564
19	0.665		0.600
20	0.783	0.555	0.609
21	0.702	0.638	1.036
22	0.662	0.674	2.082
23	0.769	0.763	2.138
24	0.719	0.669	2.816
25	0.734	0.584	3.799
26	0.807	0.492	
27	0.883	0.511	
28	0.935	0.488	0.523
29	0.902	0.554	0.549
30	0.791	0.536	0.494
31	0.770	0.522	0.603
32	0.670	0.537	0.569
33	0.783	0.548	0.489
34	0.656	0.566	0.556
35	0.643	0.540	0.604
36	0.628	0.528	0.592
37	0.642	0.493	0.522
38	0.557	0.500	0.499
39	0.566	0.486	0.502
40	0.570	0.463	0.531
41	0.650	0.513	0.614
42	0.605	0.517	0.370
43	0.766	0.560	0.455
44	0.579	0.482	0.298
45	0.523	0.488	0.470
46	0.661	0.487	0.452
47	0.651	0.461	0.490
48	0.536	0.445	0.492
49	0.557	0.445	0.506
50	0.554	0.473	0.504
51	0.567	0.478	0.588
52	1.583	1.492	1.386

Weekly ESA4 to Annual ESA4 - 8 Hour Factors : Each WIM Site

ESA4 Only
Axle Group 2

Week	Waipara	Drury	Te Puke
2	0.733	0.464	0.780
3	0.501	0.458	0.630
4	0.356	0.431	0.641
5	0.434	0.469	0.671
6	0.481	0.528	0.627
7	0.410	0.472	0.569
8	0.371	0.418	0.514
9	0.294	0.445	0.433
10	0.288	0.438	0.541
11	0.362	0.425	0.479
12	0.365	0.397	0.458
13	0.377	0.450	0.429
14	0.515	0.433	0.595
15	0.444	0.398	0.497
16	0.431	0.418	0.466
17	0.765		0.694
18	0.976		0.664
19	0.852		0.575
20	1.144	0.634	0.609
21	0.731	0.622	1.367
22	0.901	0.638	2.188
23	0.780	0.677	2.322
24	0.689	0.674	2.668
25	0.635	0.517	4.809
26	0.807	0.471	
27	0.760	0.508	
28	0.710	0.452	0.565
29	0.833	0.458	0.626
30	0.862	0.422	0.582
31	0.775	0.483	0.728
32	0.629	0.494	0.660
33	0.756	0.501	0.540
34	0.601	0.514	0.678
35	0.534	0.516	0.690
36	0.582	0.478	0.681
37	0.628	0.467	0.606
38	0.521	0.453	0.547
39	0.517	0.453	0.582
40	0.587	0.425	0.737
41	0.592	0.406	0.571
42	0.551	0.451	0.365
43	0.686	0.492	0.497
44	0.426	0.398	0.299
45	0.426	0.385	0.455
46	0.520	0.400	0.610
47	0.712	0.403	0.636
48	0.452	0.391	0.648
49	0.453	0.380	0.656
50	0.443	0.402	0.705
51	0.412	0.472	0.814
52	1.417	1.593	1.844

Weekly ESA4 to Annual ESA4 - 8 Hour Factors : Each WIM Site

ESA4 Only

Axle Group 3

Week	Waipara	Drury	Te Puke
2	0.685	0.443	0.556
3	0.578	0.442	0.443
4	0.557	0.414	0.349
5	0.539	0.475	0.361
6	0.582	0.480	0.390
7	0.471	0.413	0.447
8	0.376	0.412	0.328
9	0.395	0.406	0.327
10	0.406	0.437	0.379
11	0.419	0.410	0.385
12	0.427	0.396	0.337
13	0.491	0.473	0.331
14	0.583	0.458	0.419
15	0.424	0.398	0.374
16	0.431	0.388	0.327
17	0.506		0.556
18	0.638		0.540
19	0.737		0.527
20	0.760	0.540	0.520
21	0.622	0.583	1.135
22	0.661	0.626	2.490
23	0.713	0.705	2.812
24	0.677	0.597	3.549
25	0.671	0.507	5.171
26	0.738	0.427	
27	0.748	0.451	
28	0.820	0.436	0.405
29	0.758	0.533	0.407
30	0.746	0.489	0.411
31	0.693	0.490	0.688
32	0.628	0.485	0.661
33	0.667	0.491	0.560
34	0.618	0.519	0.870
35	0.601	0.509	0.901
36	0.611	0.474	0.915
37	0.595	0.431	0.793
38	0.513	0.443	0.481
39	0.513	0.446	0.461
40	0.509	0.405	0.465
41	0.549	0.448	0.706
42	0.526	0.447	0.503
43	0.684	0.487	0.572
44	0.493	0.400	0.658
45	0.430	0.429	0.722
46	0.556	0.434	0.383
47	0.532	0.417	0.420
48	0.459	0.398	0.409
49	0.476	0.388	0.433
50	0.470	0.407	0.470
51	0.463	0.465	0.532
52	1.880	1.800	1.681

Weekly ESA4 to Annual ESA4 - 8 Hour Factors : Each WIM Site

ESA4 Only

Axle Group 4

Week	Waipara	Drury	Te Puke
2	1.113	0.636	0.730
3	0.914	0.622	0.697
4	1.006	0.525	0.535
5	0.839	0.572	0.573
6	0.980	0.585	0.492
7	0.828	0.485	0.619
8	0.896	0.560	0.445
9	0.799	0.506	0.425
10	0.825	0.493	0.516
11	0.791	0.521	0.591
12	0.758	0.515	0.589
13	0.869	0.602	0.524
14	0.958	0.561	0.623
15	0.830	0.494	0.725
16	0.882	0.495	0.475
17	0.900		0.755
18	0.957		0.690
19	1.156		0.782
20	1.249	0.625	0.875
21	1.123	0.715	1.275
22	0.984	0.771	2.131
23	1.211	0.879	2.912
24	1.354	0.794	3.224
25	1.113	0.786	
26	1.116	0.591	
27	1.091	0.583	
28	1.227	0.574	0.572
29	1.169	0.576	0.655
30	1.204	0.643	0.488
31	1.213	0.611	0.991
32	1.123	0.675	0.868
33	1.264	0.602	1.044
34	0.945	0.647	1.000
35	0.968	0.559	1.030
36	0.954	0.564	1.246
37	1.044	0.505	0.770
38	1.012	0.585	0.578
39	0.975	0.615	0.590
40	0.972	0.532	0.737
41	0.954	0.567	1.099
42	1.003	0.603	0.727
43	1.205	0.667	0.610
44	0.856	0.587	1.182
45	0.841	0.586	1.000
46	0.837	0.594	0.565
47	0.819	0.545	0.584
48	0.800	0.561	0.572
49	0.769	0.508	0.621
50	0.697	0.484	0.657
51	0.802	0.546	0.749
52	1.589	1.335	1.303

Appendix U

Average Weekly Multipliers Eight-Hour Counts for converting Vehicle Counts to Annual ESA4, based on Vehicle Counts per Hour

Each WIM Site

Vehicle Count to ESA4 - 8 Hour Factors : Each WIM Site

Vehicle Counts

Axle Group 1

Week	Waipara	Drury	Te Puke
2	0.207	0.309	0.229
3	0.194	0.302	0.214
4	0.197	0.300	0.205
5	0.197	0.314	0.217
6	0.199	0.320	0.223
7	0.176	0.288	0.221
8	0.160	0.283	0.199
9	0.165	0.279	0.192
10	0.172	0.288	0.214
11	0.166	0.278	0.206
12	0.163	0.272	0.195
13	0.170	0.314	0.199
14	0.182	0.312	0.227
15	0.168	0.279	0.190
16	0.168	0.279	0.185
17	0.197		0.269
18	0.202		0.231
19	0.176		0.238
20	0.197	0.277	0.231
21	0.196	0.292	0.345
22	0.200	0.301	0.555
23	0.214	0.336	0.531
24	0.209	0.303	0.713
25	0.206	0.297	0.838
26	0.222	0.296	
27	0.220	0.296	
28	0.230	0.293	0.212
29	0.233	0.300	0.217
30	0.228	0.299	0.201
31	0.225	0.295	0.254
32	0.214	0.302	0.240
33	0.223	0.304	0.219
34	0.211	0.311	0.253
35	0.215	0.309	0.241
36	0.217	0.304	0.256
37	0.210	0.297	0.233
38	0.193	0.286	0.218
39	0.183	0.289	0.214
40	0.193	0.281	0.227
41	0.191	0.292	0.264
42	0.189	0.295	0.223
43	0.221	0.319	0.237
44	0.180	0.276	0.231
45	0.179	0.280	0.246
46	0.194	0.289	0.196
47	0.202	0.277	0.210
48	0.182	0.278	0.204
49	0.179	0.266	0.219
50	0.186	0.277	0.224
51	0.173	0.282	0.245
52	0.387	0.706	0.489

Vehicle Count to ESA4 - 8 Hour Factors : Each WIM Site

Vehicle Counts
Axle Group 2

Week	Waipara	Drury	Te Puke
2	0.099	0.092	0.086
3	0.097	0.090	0.082
4	0.090	0.090	0.086
5	0.095	0.090	0.089
6	0.097	0.096	0.094
7	0.090	0.090	0.089
8	0.084	0.084	0.086
9	0.083	0.081	0.080
10	0.088	0.085	0.093
11	0.085	0.082	0.083
12	0.085	0.081	0.087
13	0.080	0.090	0.086
14	0.089	0.089	0.091
15	0.089	0.083	0.079
16	0.097	0.085	0.082
17	0.122		0.111
18	0.124		0.090
19	0.094		0.095
20	0.117	0.090	0.089
21	0.113	0.098	0.134
22	0.122	0.100	0.209
23	0.123	0.107	0.184
24	0.121	0.102	0.235
25	0.116	0.095	0.305
26	0.126	0.092	
27	0.121	0.092	
28	0.121	0.089	0.086
29	0.138	0.092	0.093
30	0.137	0.088	0.085
31	0.123	0.090	0.091
32	0.112	0.092	0.085
33	0.132	0.094	0.075
34	0.114	0.092	0.078
35	0.114	0.094	0.075
36	0.121	0.090	0.080
37	0.112	0.089	0.070
38	0.100	0.086	0.082
39	0.091	0.089	0.086
40	0.101	0.085	0.088
41	0.098	0.087	0.085
42	0.094	0.087	0.076
43	0.108	0.094	0.085
44	0.092	0.082	0.069
45	0.093	0.082	0.084
46	0.098	0.085	0.080
47	0.111	0.083	0.086
48	0.090	0.083	0.083
49	0.091	0.077	0.090
50	0.100	0.083	0.096
51	0.085	0.085	0.105
52	0.140	0.191	0.161

Vehicle Count to ESA4 - 8 Hour Factors : Each WIM Site

Vehicle Counts
Axle Group 3

Week	Waipara	Drury	Te Puke
2	0.289	0.272	0.207
3	0.266	0.262	0.189
4	0.266	0.260	0.179
5	0.252	0.290	0.188
6	0.258	0.279	0.194
7	0.221	0.249	0.194
8	0.197	0.252	0.167
9	0.207	0.249	0.162
10	0.214	0.255	0.183
11	0.208	0.242	0.182
12	0.205	0.237	0.163
13	0.240	0.282	0.165
14	0.251	0.275	0.198
15	0.207	0.240	0.160
16	0.201	0.237	0.151
17	0.228		0.233
18	0.238		0.203
19	0.215		0.203
20	0.226	0.234	0.201
21	0.226	0.243	0.326
22	0.231	0.255	0.609
23	0.256	0.291	0.623
24	0.251	0.257	0.933
25	0.241	0.251	1.044
26	0.256	0.247	
27	0.253	0.250	
28	0.281	0.248	0.179
29	0.272	0.260	0.177
30	0.262	0.259	0.172
31	0.268	0.260	0.255
32	0.252	0.261	0.250
33	0.268	0.264	0.228
34	0.265	0.274	0.340
35	0.257	0.269	0.309
36	0.263	0.262	0.329
37	0.278	0.256	0.297
38	0.248	0.246	0.210
39	0.237	0.249	0.189
40	0.248	0.239	0.204
41	0.237	0.256	0.293
42	0.242	0.256	0.232
43	0.296	0.286	0.240
44	0.231	0.235	0.301
45	0.223	0.244	0.259
46	0.250	0.256	0.173
47	0.242	0.243	0.183
48	0.229	0.240	0.180
49	0.220	0.230	0.190
50	0.226	0.239	0.197
51	0.214	0.253	0.209
52	0.646	0.688	0.543

Vehicle Count to ESA4 - 8 Hour Factors : Each WIM Site

Vehicle Counts
Axle Group 4

Week	Waipara	Drury	Te Puke
2	0.402	0.263	0.305
3	0.371	0.258	0.289
4	0.393	0.257	0.255
5	0.362	0.266	0.258
6	0.392	0.274	0.251
7	0.326	0.236	0.258
8	0.366	0.254	0.240
9	0.339	0.247	0.235
10	0.315	0.243	0.254
11	0.357	0.245	0.280
12	0.322	0.237	0.269
13	0.357	0.278	0.241
14	0.332	0.270	0.262
15	0.343	0.239	0.291
16	0.344	0.245	0.226
17	0.362		0.290
18	0.336		0.281
19	0.320		0.321
20	0.330	0.223	0.284
21	0.361	0.230	0.359
22	0.346	0.233	0.532
23	0.381	0.265	0.631
24	0.395	0.242	0.630
25	0.333	0.259	
26	0.365	0.246	
27	0.360	0.240	
28	0.404	0.245	0.247
29	0.368	0.228	0.260
30	0.369	0.246	0.215
31	0.374	0.231	0.379
32	0.381	0.254	0.314
33	0.404	0.243	0.350
34	0.320	0.255	0.412
35	0.350	0.240	0.379
36	0.344	0.241	0.415
37	0.388	0.241	0.353
38	0.354	0.256	0.275
39	0.366	0.253	0.260
40	0.358	0.238	0.294
41	0.339	0.244	0.392
42	0.354	0.261	0.333
43	0.398	0.282	0.248
44	0.390	0.233	0.457
45	0.353	0.246	0.305
46	0.373	0.252	0.250
47	0.350	0.242	0.240
48	0.357	0.243	0.245
49	0.340	0.229	0.257
50	0.322	0.232	0.280
51	0.341	0.238	0.270
52	0.496	0.470	0.409

Appendix V

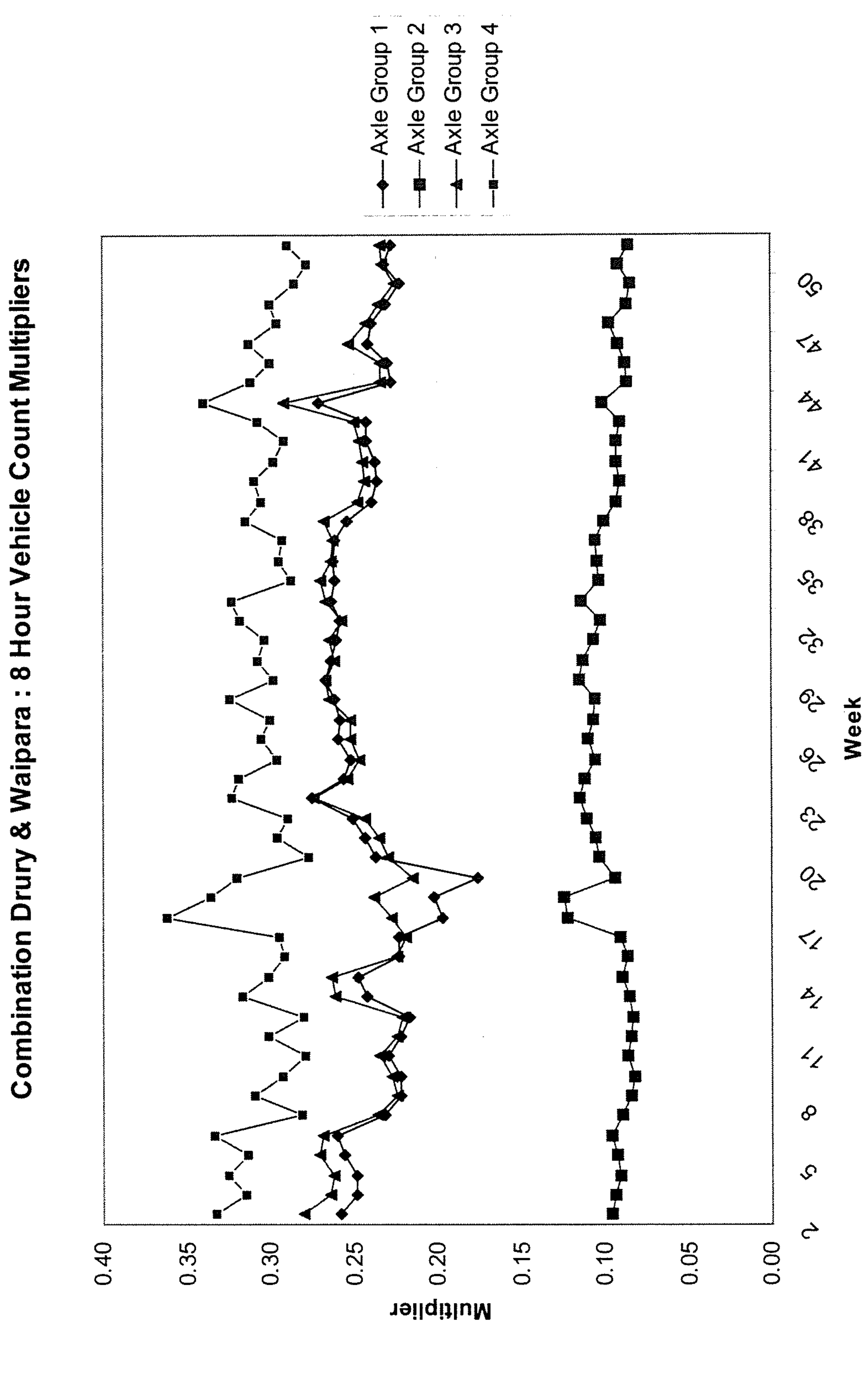
Average Weekly Multipliers Eight-Hour Counts for converting Vehicle Counts to Annual ESA4, based on Vehicle Counts per Hour

Combination of Drury and Waipara

Vehicle Count to ESA4 - 8 Hour Factors : Each WIM Site

Combination : Drury and Waipara

Week	Axle Group 1	Axle Group 2	Axle Group 3	Axle Group 4
2	0.2584	0.0954	0.2803	0.3328
3	0.2480	0.0934	0.2641	0.3142
4	0.2486	0.0904	0.2626	0.3253
5	0.2555	0.0921	0.2708	0.3138
6	0.2595	0.0961	0.2685	0.3334
7	0.2320	0.0898	0.2353	0.2814
8	0.2218	0.0843	0.2245	0.3096
9	0.2217	0.0817	0.2277	0.2928
10	0.2298	0.0863	0.2344	0.2788
11	0.2219	0.0838	0.2247	0.3011
12	0.2173	0.0832	0.2209	0.2796
13	0.2418	0.0849	0.2611	0.3173
14	0.2471	0.0890	0.2633	0.3009
15	0.2235	0.0860	0.2237	0.2911
16	0.2234	0.0907	0.2190	0.2944
17	0.1966	0.1223	0.2276	0.3619
18	0.2021	0.1239	0.2380	0.3363
19	0.1761	0.0936	0.2146	0.3204
20	0.2370	0.1033	0.2299	0.2765
21	0.2436	0.1053	0.2346	0.2956
22	0.2508	0.1110	0.2429	0.2893
23	0.2750	0.1150	0.2738	0.3234
24	0.2559	0.1116	0.2539	0.3185
25	0.2515	0.1058	0.2462	0.2957
26	0.2588	0.1093	0.2515	0.3054
27	0.2577	0.1068	0.2513	0.2999
28	0.2615	0.1050	0.2645	0.3245
29	0.2665	0.1150	0.2659	0.2981
30	0.2633	0.1126	0.2605	0.3074
31	0.2600	0.1065	0.2643	0.3026
32	0.2577	0.1020	0.2564	0.3178
33	0.2635	0.1133	0.2661	0.3232
34	0.2612	0.1030	0.2696	0.2878
35	0.2618	0.1043	0.2629	0.2952
36	0.2607	0.1055	0.2625	0.2924
37	0.2533	0.1003	0.2671	0.3143
38	0.2391	0.0927	0.2470	0.3049
39	0.2361	0.0901	0.2431	0.3094
40	0.2370	0.0930	0.2438	0.2982
41	0.2418	0.0924	0.2462	0.2913
42	0.2418	0.0905	0.2491	0.3076
43	0.2704	0.1012	0.2912	0.3402
44	0.2276	0.0867	0.2332	0.3113
45	0.2296	0.0877	0.2334	0.2997
46	0.2412	0.0913	0.2525	0.3127
47	0.2393	0.0973	0.2424	0.2961
48	0.2301	0.0861	0.2344	0.2998
49	0.2224	0.0842	0.2253	0.2848
50	0.2318	0.0917	0.2325	0.2774
51	0.2276	0.0851	0.2335	0.2900
52	0.5465	0.1658	0.6673	0.4830



Combination Drury & Waipara : 8 Hour Vehicle Count Multipliers
Axle Group 1
Axle Group 2
Axle Group 3
Axle Group 4
Multiplier
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Week
2
5
8
11
14
17
20
23
26
29
32
35
38
41
44
47
50

Appendix W

95% Margin of Error for Weekly Multipliers using Eight-Hour Counts, based on Vehicle Counts per Hour

Combination of Drury and Waipara

Hourly Variation Only

Vehicle Count to ESA4 - 8 Hour Week Multipliers Standard Errors

Combination : Drury and Waipara

Week	Axle Group 1	Axle Group 2	Axle Group 3	Axle Group 4
2	0.1017	0.1602	0.1217	0.2255
3	0.1174	0.1651	0.1421	0.2329
4	0.1281	0.1573	0.1592	0.2623
5	0.1761	0.1759	0.2367	0.2778
6	0.1848	0.2151	0.2158	0.2745
7	0.0936	0.1429	0.1194	0.2015
8	0.1028	0.1406	0.1236	0.2132
9	0.1011	0.1275	0.1173	0.2453
10	0.0986	0.1325	0.1329	0.1948
11	0.0941	0.1506	0.1233	0.2097
12	0.1205	0.1461	0.1499	0.2345
13	0.2234	0.2085	0.2876	0.2753
14	0.2043	0.2140	0.2663	0.3396
15	0.1023	0.1282	0.1380	0.2301
16	0.1091	0.1228	0.1388	0.2197
17	0.1614	0.2175	0.2089	0.3436
18	0.1482	0.1998	0.1871	0.3064
19	0.0998	0.1487	0.1583	0.2661
20	0.1162	0.1573	0.1485	0.2195
21	0.1070	0.1414	0.1334	0.2270
22	0.1266	0.1535	0.1530	0.2288
23	0.2006	0.1991	0.2670	0.2972
24	0.1076	0.1608	0.1364	0.2012
25	0.1045	0.1771	0.1432	0.2034
26	0.1054	0.1566	0.1402	0.2102
27	0.1228	0.1602	0.1441	0.2476
28	0.1147	0.1641	0.1536	0.1896
29	0.1298	0.1761	0.1517	0.2134
30	0.1245	0.1350	0.1606	0.2114
31	0.1235	0.1699	0.1613	0.2452
32	0.1027	0.1372	0.1339	0.2307
33	0.1030	0.1535	0.1371	0.2389
34	0.0992	0.1425	0.1228	0.2077
35	0.0899	0.1669	0.1107	0.2240
36	0.1009	0.1357	0.1274	0.2304
37	0.1144	0.1447	0.1402	0.2326
38	0.0950	0.1307	0.1294	0.1866
39	0.1063	0.1317	0.1438	0.2509
40	0.0959	0.1214	0.1330	0.1994
41	0.1019	0.1392	0.1221	0.2386
42	0.1183	0.1564	0.1491	0.2050
43	0.2125	0.2208	0.2749	0.3066
44	0.1029	0.1287	0.1282	0.1923
45	0.1109	0.1444	0.1503	0.2596
46	0.1466	0.1724	0.1888	0.2267
47	0.1148	0.1490	0.1356	0.2079
48	0.1061	0.1286	0.1320	0.2656
49	0.1106	0.1461	0.1271	0.2503
50	0.1094	0.1301	0.1379	0.2567
51	0.1037	0.1384	0.1371	0.2315
52	0.3919	0.3398	0.4207	