University of Southern Queensland
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An Assessment of the Deceleration on Horizontal Curve Component of the Austroads Operating Speed Estimation Model

A disertation submitted by

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With Supervision from

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ABSTRACT

This dissertation builds on earlier work by the Australian Road Research Board (AARB) and Austroads. Speed data was obtained for the Golden Highway in NSW and the 85th percentile speed was derived at the approach, start, middle and end of 96 horizontal curves sites in the Westbound direction.

The calculated curve design speed was plotted against the 85th percentile speed. The results support earlier work by (Mclean, 1979) and showed that drivers are still willing to tolerate higher values of side friction when travelling at speeds less than 100km/hr and that on horizontal curves suitable for 100km/hr or more that drivers tend to travel at a more uniform speed.

The potential variables affecting a vehicle’s operating speed were recorded at each of these horizontal curve sites. Multivariable regression analysis was undertaken to determine what variables were statistically significant to a vehicles operating speed as it traverses a horizontal curve. These variables were found to be longitudinal grade (+3% or more and -4% or less), horizontal curve length (700m or more), vertical geometry (crests) and whether stopping sight distance was achieved. Sites with variables exceeding these values were excluded.

The remaining factors contributing to a vehicle’s speed as it traverses a horizontal curve were approach speed and horizontal curve radius. The radius of the remaining data was plotted against 85th percentile vehicle speed at the start, middle and end of each of the remaining horizontal curve sites and confirmed that the maximum deceleration occurs at the middle of the horizontal curve.

Sites that experienced an increase in 85th percentile vehicle speed at the midpoint of the horizontal curve (relative to the approach speed) were removed and the radius of the remaining data was plotted against curve midpoint speed for each separate banded approach speed and compared to earlier prediction models. Similarly to recent research by Austroads it was found that that the current Austroads deceleration on horizontal curves model provided a conservative representation of the operating

speeds of vehicles. It is recommended that further research be done into the effects of these roadway characteristics on operating speed with the aim of developing correction tables. A new deceleration on horizontal curve speed prediction relationship was produced for 100km/hr approach speed. This relationship could potentially be used to help update the current Austroads deceleration on horizontal curves graph.

LIMITATIONS OF USE

CERTIFICATION

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

GLOSSARY

Table 1 – Glossary of terms (Austroads, 2010b)

advisory speed	The recommended maximum speed at which a section of roadway should be negotiated for comfort and safety.
advisory speed sign	Advisory speed signs are a category of warning sign. They are therefore yellow and diamond shaped with black writing displaying the advisory speed for an upcoming section of roadway.
alignment	The geometric form of the centreline (or other reference line) of a carriageway in both the horizontal and vertical directions.
alignment coordination	A road design technique that considers the relationship of the horizontal and vertical alignments and its influence on safety and the three-dimensional aspect of the finished carriageway.
annual average daily traffic (AADT)	The total volume of traffic passing a roadside observation point over the period of a calendar year, divided by the number of days in that year (365 or 366 days).
camber	The transverse convexity given to the surface of a carriageway or footway.
CAMs	Chevron alignment markers
carriageway	That portion of a road or bridge devoted particularly to the use of vehicles, inclusive of shoulders and auxiliary lanes.

centreline	The line which defines the axis or alignment of the centre of a road or other work. It may be defined by pavement markings on a road delineating opposing traffic flows.
chainage	The distance of a point along a control line, measured from a datum point.
crest curve	A convex vertical curve in a longitudinal profile of the road.
crossfall	The slope, measured at right angles to the alignment, of the surface of any part of a carriageway.
cross-section	A vertical section, generally at right angles to the centreline showing the ground. On drawings it commonly shows the road to be constructed, or as constructed.
crown	The highest point on the cross-section of a carriageway with two-way crossfall.
cutting	That portion of the road where the finished road surface is below the natural surface level.
delineation	Treatments that enhance the selection of the appropriate path and speed, or position, to allow a manoeuvre to be carried out safely and efficiently, e.g. linemarking, raised pavement markers, traffic cones and flaps and post-mounted reflectors.
design speed	A speed fixed for the design and correlation of those geometric features of a carriageway that influence vehicle operation. Design speed should not be less than the intended 85th percentile speed.
design standard	Identifies particular standards used in the design, e.g. standard lane width.

desired speed	The speed over a section of a road adopted by a driver or drivers as influenced by the road geometry and other environmental factors.
divided road	A highway or road with separated carriageways for traffic travelling in opposite directions.
dividing line	A road marking formed by a line, or two parallel lines, whether broken or continuous, designed to indicate the parts of the road to be used by vehicles travelling in opposite directions.
edge line	A line marking to indicate the outer edge of the vehicle traffic lane on the carriageway.
fill	That portion of road where the formation is above the natural surface.
grade	A length of carriageway sloping longitudinally.
guide post	A post used to indicate the edge of a carriageway.
head wall	A retaining wall at the end of a culvert.
heavy vehicle	A two-axle vehicle with the minimum axle spacing greater than 3.2 m, or a three- or more-axle vehicle configured at least with two axle groups.
highway	A road where traffic has the right to pass and owners of abutting property have access.
hinge point	The point in the cross-section of a road at which the extended batter line would intersect the extended verge line.
horizontal	The bringing together of the straights and curves in the plan view

alignment	of a carriageway.
horizontal curve	A curve in the plan or horizontal alignment of a carriageway.
intersection	The place at which two or more roads meet or cross.
k value	The length required for a 1% change of grade on a parabolic vertical curve.
lane	A portion of the paved carriageway marked out by kerbs, painted lines or barriers, which carries a single line of vehicles in one direction. A lane is generally between 3.0 and 3.5 m wide. A single carriageway road normally has at least one lane in each direction.
lane line	A line (usually painted), other than the centreline, that divides adjacent traffic lanes.
linemarking	Lines, painted or otherwise applied, that delineate lane boundaries and guide traffic with respect to overtaking and the like.
longitudinal profile	The shape of a pavement surface measured as the vertical distance from a datum horizontal plane along the direction of traffic flow.
longitudinal section	A vertical section, usually with an exaggerated vertical scale, showing the existing surface levels along a road or bridge centreline, or other specified line. It commonly shows also the levels to which the road or bridge is to be constructed or reconstructed.

median A strip of road, not normally intended for use by traffic, which separates carriageways for traffic in opposite directions. Usually formed by painted lines, kerbed and paved areas, grassed areas, etc.

operating speed The 85th percentile speed of cars at a time when traffic volumes are low and which allows a free choice of speed within the road alignment. NZ: The highest overall speed, exclusive of stops, at which a driver can safely travel on a given section of road under the prevailing traffic conditions.

pavement That portion of a road designed for the support of, and to form the running surface for, vehicular traffic.

pavement marker A discrete retroreflective device, bonded to the pavement, which is of sufficiently small size as to be effectively a point source of light when viewed by vehicle drivers at normal night-time viewing distances; a non-retroreflective pavement marker is applicable for daytime.

percentile speed Speed at or below which the nominated percentage (e.g. 15, 50, 85) of vehicles are observed to travel under free flow conditions.

road furniture A general term covering all signs, streetlights and protective devices for the control, guidance and safety of traffic, and the convenience of road users.

safety barrier A physical barrier separating roadside hazards or opposing traffic and the travelled way, designed to resist penetration by an out-of-control vehicle and as far as practicable, to stop or redirect colliding vehicles.

sag curve	A concave vertical curve in the longitudinal profile of a road.
shoulder	The portion of formed carriageway that is adjacent to the traffic lane and flush with the surface of the pavement.
side friction	Friction force acting on a vehicle during cornering.
stopping sight distance (SSD)	The sight distance required by an average driver or rider, travelling at a given speed, to react and stop before striking an object on the road.
speed (85th percentile)	The speed at or below which 85% of vehicles travel.
speed environment	A basic design parameter for a section of road, representing the uniform desired speed of the 85th percentile driver. It can be measured on existing roads as the 85th percentile of the speed distribution on the longer straights or large radius curves over the section.
speed zone	A length of road subject to legally enforceable speed limits.
spot speed	Speed of individual vehicles as they pass a given point on the road.
superelevati-on	A slope on a curved pavement selected so as to enhance forces assisting a vehicle to maintain a circular path.
terrain	Topography of the land.
through lane	A lane provided for the use of vehicles proceeding straight ahead.

traffic volume	The number of vehicles or pedestrians passing a given point on a lane or carriageway during a specified period of time
V85 (85th percentile speed)	The speed at or below which 85% of vehicles are observed to travel under free flowing conditions past a nominated point.
vertical alignment	The longitudinal profile along the design line of a road.
vertical curve	A curve (generally parabolic) in the longitudinal profile of a carriageway to provide for a change of grade at a specified vertical acceleration.

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1. INTRODUCTION

The early principals of road design were initially adapted from railways. Historically a road was given a design speed and curves were designed for safe operation at this speed. As vehicles increased in power they began operating at higher speeds resulting in an increased number of high severity accidents. One of the earliest definitions of design speed defines it as “the maximum reasonably uniform speed which would be adopted by the faster driving group of vehicle operations, once clear of urban areas” (Barnett, 1937). During the mid-20th century researchers started questioning the design process and particularly the use of one specific design speed for a road. Research AARB in the 1970’s found that in instances where a design speed of less than 100km/hr was assumed a motorist’s actual operating speed was quite different from this theoretical design speed. It was concluded that the use of a constant design speed does not ensure consistency between design elements, drivers have no concept of design speed and drive at whatever speed they feel comfortable (VicRoads, 1993). This research was used to produce the Speed Environment Model that was adopted by the National Association of Australian State Road Authorities (NAASRA) in the 1980’s. Limited use of the Speed Environment Model led to AARB being contracted by VicRoads in 1994 to validate the model which resulted in the development of the Operating Speed Model. The Operating Speed Model was incorporated in the *Rural Road Design, Guide to the Geometric Design of Rural Roads* (Austroads, 2003), and has remained unchanged in the current *Guide to Road Design Part 3: Geometric Design* (Austroads, 2010a). These changes have resulted in current definition of design speed which is defined as “a speed fixed for the design and correlation of those geometric features of a carriageway that influence vehicle operation. Design speed should not be less than the intended 85th percentile speed” (Austroads, 2010a).

The geometry of a road should coincide with the way the road is driven. This is more easily achievable on high standard, high speed roads, such as multi lane highways and therefore a uniform design speed can be adopted. However, on lower standard rural roads motorists are more likely to accelerate on straight sections and then slow down when they reach horizontal curves. This results in a varying design speed for different geometric elements in order to cater for the way the road is driven. Establishing the appropriate design speed is one of the first tasks required when undertaking a new geometric design or improving an existing geometric design. The adopted design speed should be conservative against the sign posted speed. The design speed is directly related to the key components of road design including:

- Stopping sight distance/vertical curves
- Horizontal curves/superelevation
- Lane width/lane widening

Austroads currently specifies the use of the Operating Speed Model on rural roads with operating speeds less than 100km/hr in order to determine the 85th percentile and obtain a design speed. Research from (Cox, 2008) suggests that the Operating Speed Model also suffers from limited use similarly to its predecessor the Speed Environment Model. In many cases there is no operating speed data available and it has become common design practice to take the operating speed as 10km/hr higher than the sign posted speed and then accepting this as the design speed. It is also widely recognised that there is very limited guidance provided about the impact of roadway characteristics such as longitudinal grade, cross section and surface condition on the 85th percentile operating speed. Adopting an unsuitable operating speed has the potential to result in a design that is either one of two extremes:

- Geometrically incorrect and unsafe
- Exceedingly conservative and costly

One of the major components of the Austroads Operating Speed Model is the car deceleration on horizontal curve graph. This graph is used by designers to predict the speed that a vehicle will decelerate to when traversing a horizontal curve of a given radius knowing the approach speed. A recent technical report titled *Expanded Operating Speed Model* (Austroads, 2013) was initiated to update and expand road design operating speed models in Australia. The first part of this report aimed to assess the validity of the current Austroads deceleration on horizontal curve graph and it was concluded that the current Austroads deceleration on horizontal curves model provided a conservative representation of the operating speeds of vehicles, most notably for horizontal curves of medium radii. This revised deceleration for horizontal curves model for cars on rural roads has been presented for consideration in updating the existing Austroads model. However before updating the existing model the report has called for further research that considers "investigating curve radii greater than 250m to confirm the results of the project, as the greatest differences in model predictions occurred in this range of curve radii" (Austroads, 2013).

2. LITREATURE REVIEW

2.1 Timeline of the Definition of Design Speed

Table 2 – Design speed definition timeline

<table>
<tr><th>Source</th><th>Definition</th></tr>
<tr><td>(Barnett, 1937)</td><td>Assumed Design Speed is the maximum reasonably uniform speed which would be adopted by the faster driving group of vehicle operations, once clear of urban areas.</td></tr>
<tr><td>(AASHO, 1938)</td><td>Design Speed is the maximum approximately uniform speed which probably will be adopted by the faster group of drivers but not, necessarily, by the small percentage of reckless ones.</td></tr>
<tr><td>(AASHO, 1941)</td><td>Assumed Design Speed is the maximum approximately uniform speed which probably will be adopted by the faster group of drivers but not, necessarily, by the small percentage of reckless ones. The approved speed classifications are 30, 40, 50, 60 and 70 mph. The assumed design speed for a section of highway will be based principally upon the character of the terrain though a road of greater traffic density will justify choosing a higher design speed than one of lighter traffic in the same terrain.</td></tr>
<tr><td>(AASHO, 1945)</td><td>Design Speed:<table><tr><td>Topography</td><td>Minimum (mph)</td><td>Desirable (mph)</td></tr><tr><td>Flat</td><td>60</td><td>70</td></tr><tr><td>Rolling</td><td>50</td><td>60</td></tr><tr><td>Mountainous</td><td>40</td><td>50</td></tr></table></td></tr>
<tr><td>(AASHO, 1954)
(AASHO, 1965)</td><td>Design Speed is a speed determined for design and correlation of the physical features of a highway that influence vehicle operation. It is the maximum safe speed that can be maintained over a specified section of highway when conditions are so favorable that the design features of the highway govern.</td></tr>
<tr><td>(AASHO, 1984)
(AASHO, 1990)</td><td>Design Speed is the maximum safe speed that can be maintained over a specified section of highway when conditions are so</td></tr>
</table>

(AASHO, 1994)	favourable that the design features of the highway govern. The assumed design speed should be a logical one with respect to the topography, the adjacent land use, and the functional classification of highway.
(AASHO, 2001) (AASHO, 2004) (AASHO, 2011)	The Design Speed is a selected speed used to determine the various geometric design features of the roadway.
(NAASRA, 1973)	Design Speed is the speed at which a vehicle can travel without being exposed to hazards arising from curtailed sight distance, inappropriately superelevated curves, severe grades or pavements too narrow to accommodate the design volume.
(NAASRA, 1980) (Austroads, 1989) (Mclean, 1988)	85th percentile driver speed on a particular geometric element, chosen to co-ordinate the geometric design features.
(RTA, 1991)	Design Speed is the speed adopted for the design of individual geometric elements of an existing or selected speed environment. It should be no less than the observed or selected 85th percentile desired speed for the section of road.
(Austroads, 2003) (Austroads, 2010a)	A speed fixed for the design and correlation of those geometric features of a carriageway that influence vehicle operation. Design speed should not be less than the intended 85th percentile speed

2.2 Design Speed Concept

2.2.1 Evolution of the Design Speed Concept

In the early 20th century there was no consistency in curve design and very little though was given to the speed that a vehicle would negotiate a curve. Roads were generally positioned on long straight sections and were linked by curves with a radii size governed by the topography and funding available. As the 1930’s came along more though was given to the correlation between radius, superelevation, vehicle speed and centripetal force (Mclean, 1979).

(Barnett, 1937) provided the first formal definition of design speed which was given as ‘the maximum reasonably uniform speed which would be adopted by the faster driving groups of vehicle operators, once clear of urban areas’. This concept of design speed was endorsed by the American Association of State Highway Officials 1938 guide ‘A Policy on Highway Classification’ and defined it as ‘the maximum approximately uniform speed which probably would be adopted by the faster group of drivers but not, necessarily, by the small group of reckless ones’ (AASHO, 1938). The definition of design speed changed again with the release of the American Association of State Highway Officials guide; *A Policy on Geometric Design of Rural Highways* and defined it as ‘a speed used for the design and correlation of the physical features of a highway that influences vehicle operation’ (AASHO, 1954). This definition was further refined with the release of an updated version of this guide to ‘the maximum safe speed that can be maintained over a specified section of highway when conditions are so favorable that the design features of the highway govern’ (AASHO, 1965).

Australian road authorities typically tended to follow the geometric practices employed in the United States and this was evident in the National Association of Australian State Road Authorities guide ‘Policy for the Geometric Design of Rural Roads’ (NAASRA, 1973) which defined design speed as ‘the speed at which a vehicle can travel without being exposed to hazards arising from curtailed sight distance, inappropriately superelevated curves, severe grades or pavements too narrow to accommodate the design volume’.

The publications outlined above and their evolution of the design speed definition resulted in a shift of the interpretation of design speed away from the behavioral measures and resulted in a set of minimum design standards for all design elements that were related to the selected design speed. (Mclean, 1979) described design speed as no longer being the speed adopted by the faster driving group of vehicle operators, but as a design procedural value used for the design and correlation of design elements which is also a maximum safe speed.

2.2.2 Criticisms of the Design Speed Approach

During the 1970's and early 1980's most road authorities in Australia were employing the design speed as the basis for alignment design. It was not uncommon to find roads where the vertical alignment was more constrained than the horizontal alignment as it was a misconception that the vertical geometry was the governing factor of a vehicles speed. A growing suspicion emerged in the industry that deficiencies existed with the design speed concept once it was applied in a literal sense. (Mclean, 1979) listed the criticisms of the design speed concept as:

- A design speed only specifies minimum values. Above minimum values were recommended wherever terrain and available funds permitted. This resulted in roads that were designed with a constant design speed as regarded by the designer yet they had a considerable difference in speed standard to a driver which resulted in the appearance of a wide variance in design standard.
- When elements adopt minimum values the level of safety provided varies if depending if the elements occur in isolation or occur in combination.
- Free vehicle operating speed and design speed are not necessarily the same. Design reference guides around this time argued that on rural highways most drivers aimed to travel at the same speed. (Mclean, 1979) discovered that while this was likely to be true for higher standard alignments it was becoming more credible that on lower standard alignments drivers adjust their speed according to their desired speed of travel and the perceived hazards.

2.2.3 An Alternative Approach (ARRB Research)

ARRB was set up by NAASRA in 1960. Due to the criticisms of the traditional design speed approach outlined above ARRB undertook a study of driver speed behavior on horizontal curves. Speed data was measured at 120 different horizontal curve sites on two lane rural highways. A minimum of 100 measurements were taken at each of the sites. Vehicle speed was measured at the tangent point upon entering the curve.

From this study (Mclean, 1979) found that when the design speed was 90km/h or less, the 85th percentile driver would be travelling along all sections of the road with a free speed in excess of the design speed. It was identified that the classical design speed concept was not a realistic design procedure to accommodate the higher percentile speeds within the criteria for safe operation. It was though that increasing the overall standard of the alignment would only result in increasing the operating speed on the individual elements of the alignment. It was suggested by (Mclean, 1979) to maintain current design procedures for alignments based on design speeds in excess of 100km/h as curve speeds exhibited by drivers were examined to be conservative relative to the design standards. The observed 85th percentile free speeds were plotted against the curve speed standard as shown below:

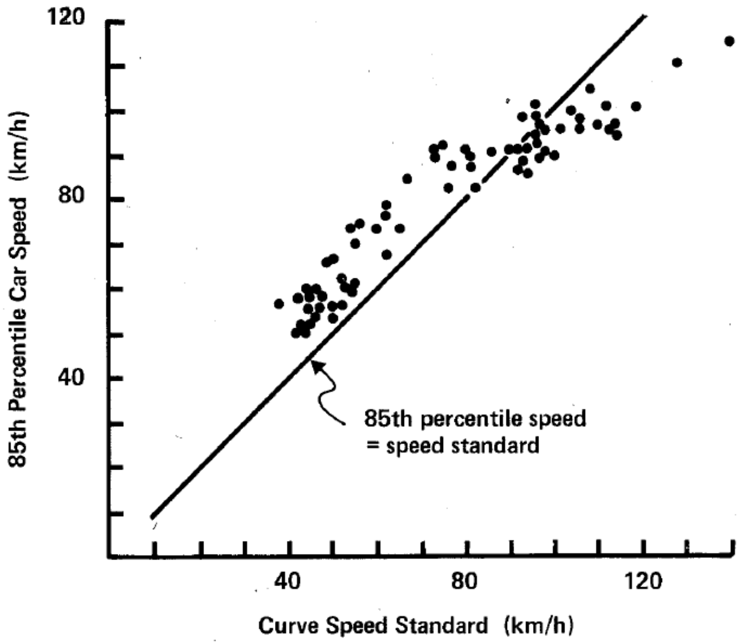


Figure 1 – Relaionship between observed 85th percentile car speeds and curve speeed standard (Mclean, 1979)

Regression analysis determined that the 85th percentile car speeds were heavily influenced by the desired speed relating to that section of road and curvature. Even though sight distance was found to have a statistically significant effect on the curve speeds it embodied only one percent of the variability. It was found that other traffic and geometry parameters did not have a statistically significant effect on the curve speeds. A regression of the desired speed in relation to first and second order terms of curvature depiction the empirical data well with all terms significant at $p < 0.1$. This equation can be found in Appendix B. The equation worked well for explaining the inconsistencies in the observed curve speeds. However it was found to produce unreliable results for the ends of the data range which was due to the non-linear nature of the relation between the observed desired speed and the curvature. The data was separated into four groups relating to the desired speed and regressions were applied to each group producing four linear speed curvature equations. The regression coefficients were iterated or extrapolated against the desired speed value to produce the curve speed prediction relationships which can be found in Appendix B. The original data was used to validate these relationships and the results were rounded up to the nearest 5km/h. These relations were plotted against radius and the results can be seen in the figure below:

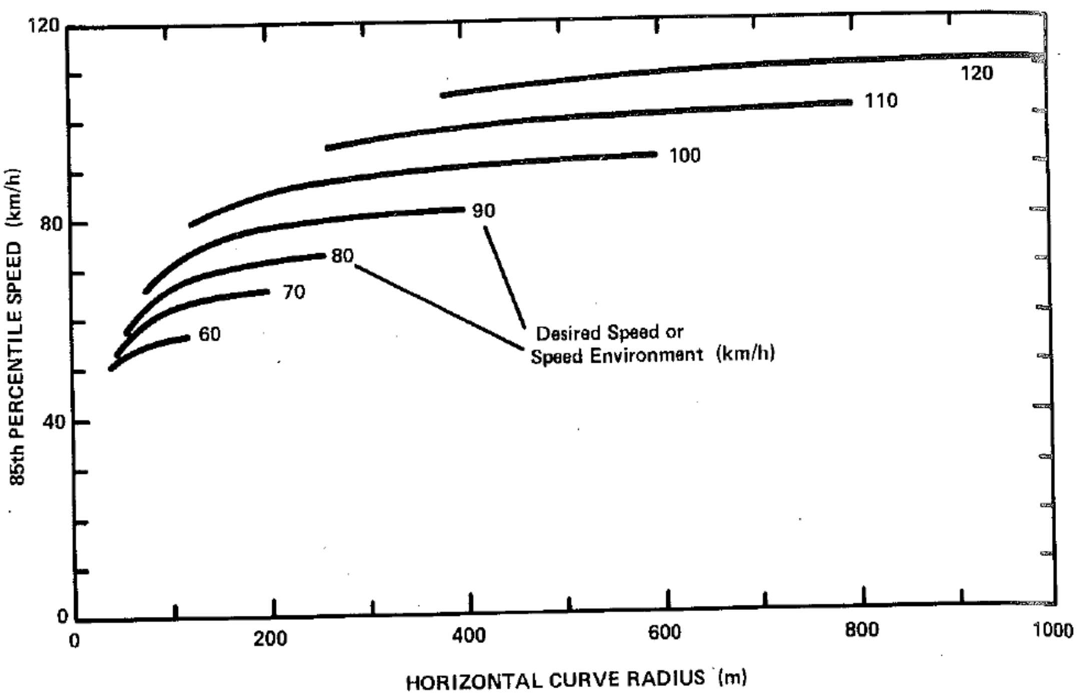


Figure 2 – Curve Speed Prediction Relationships (Mclean, 1979)

The main advantage of this alternative approach is that it places a larger emphasis on producing alignments that are more in line with the expectancies of drivers.
This research undertaken by ARRB led to the introduction of the operating speed concept in the “Interim Guide to the Geometric Design of Rural Roads” (NAASRA, 1980) as well as subsequent issues of the “Rural Road Design Guide” (Austroads, 1989, Austroads, 2003) and the current “Guide to Road Design” (Austroads, 2010a).

2.3 Australian Approach

2.3.1 (NAASRA, 1980, Austroads, 1989)

In 1934 the first Conference of State Road Authorities (COSRA) was held. In 1959 the conference renamed to the National Association of Australian State Road

Authorities (NAASRA) to reflect its growth as an organisation. Austroads superseded NAASRA in 1989 and still remains today. Austroads is an association of various road transport and traffic authorities from across the Australasian region (Australia and New Zealand). Research from McLean and ARRB led to a review in 1978. Four different speed parameters are needed in order to determine a logical speed for geometric design:

- Desired Speed: It was specified that on a section of road with mostly uniform geometry there is a maximum speed that a driver will travel at which was known as the desired speed. This desired speed was likely to be adopted on long straight sections and was determined by the driver's perception of the road and was related to the horizontal curvature and terrain of the road.
- Speed Environment: The desired speed of the 85th percentile of a driver was termed the speed environment of the road. It is important to remember that the speed environment applies to a section of road rather than just an individual element. A table was provided listing speed environment values as a function of the overall geometric standard and terrain type for single carriageway rural roads when geometrics are constrained and can be found in Appendix B.
- Design Speed: The design speed applies to individual geometric elements and should not be less than the 85th percentile that will result from a particular geometric element with a given speed environment.
- Limiting Curve Speed: The maximum speed at which a vehicle can traverse a curve of given radius and superelevation while adopting the maximum side friction demand value. The limiting curve speed must never be less than the design speed.

It was specified that there was three speed standard ranges for which different philosophies should be used for each. High speed alignments with speed environments of 100km/hr or more provide drivers with an expectation of uniform high speed travel and a single design speed is selected. On intermediate and low speed alignments the speed environment is less than 100km/hr and is influenced by the characteristics of the road and its surroundings. Iteration of the alignment is required to achieve consistency as the curve geometry of the individual elements is determined by but also helps determine the 85th percentile travel speed. A flowchart of this procedure can be found in Appendix B.

A straight or large radius curve would have to be at least 250m long before the 85th percentile speed could be assumed for a 70km/hr speed environment and 1km and 3km long for a 90km/hr and 110mk/hr speed environment respectively. The design speed for a curve at the end of a long straight was specified to not be more than 10km/hr and definitely no more than 15km/hr below the design speed of the straight and can be determined from the figure below which utilises the same speed predictions equations as (Mclean, 1979).

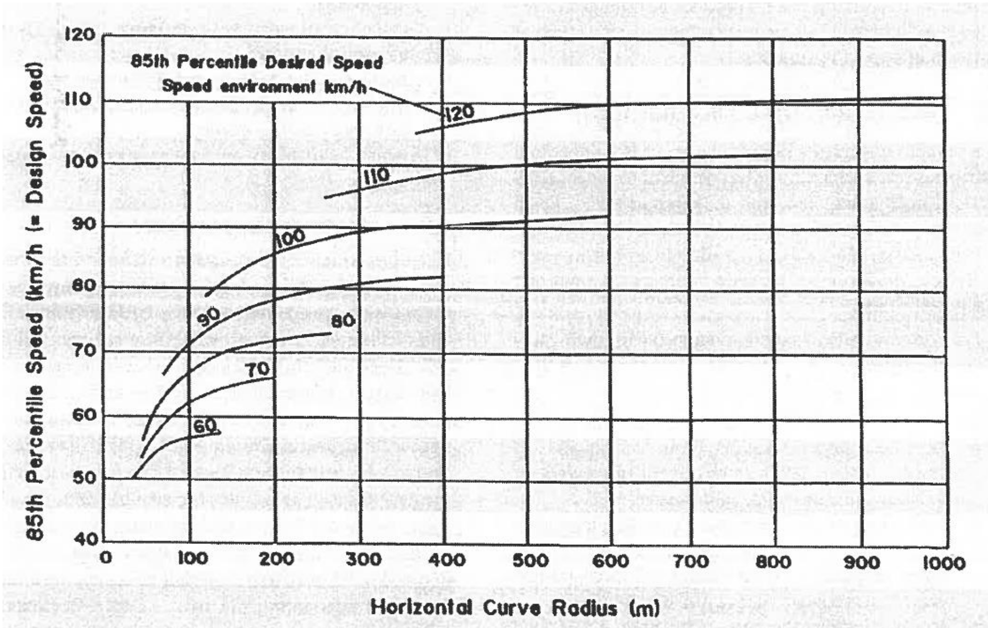


Figure 3 – Derivation of Design Speed for Horizontal Curves (NAASRA, 1980, Austroads, 1989)

2.3.2 Validation (VicRoads, 1994)

ARRB was contracted by VicRoads to validate and potentially improve the key features of the operating speed model in regards to driver behavior on linked curve sections of rural roads. Data was obtained by monitoring drivers travelling along test courses in instrumented vehicles and were calibrated against large population samples. One of the features to be examined was the speed on curve graph and the aim was to produce a more accurate equation to express the relationship between desired speed, the horizontal radius and the curve departure speed. The graphs developed by (Mclean, 1979) were individual equations with different coefficients for different desired speeds and limited applicability. VicRoads redrew these equations to provide a more realistic behavior, especially with larger radii. Numerous avenues were investigated including:

- Alternate forms (additive/multiplicative models, radii/angular velocity and quadratics)
- Alternate variables (breakpoint velocity, standard/measured radii and operating speed/mean speed)

The combination that was found to provide the best results was the linear angular velocity equation using measured radii and significant speed difference data that was split above and below 85km/hr. This equation can be found in Appendix C and was used to produce best result speed on curves graph shown below:

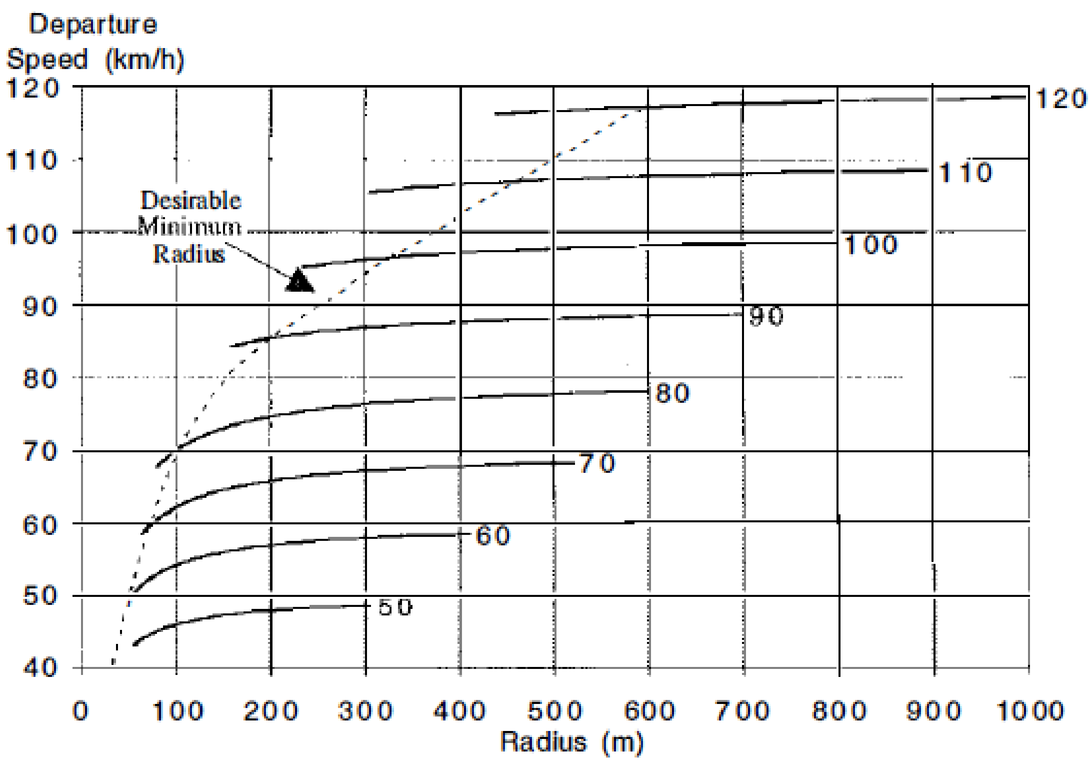


Figure 4 – Speed on curves graph – best result (VicRoads, 1994)

2.3.3 (Austroads, 2003, Austroads, 2010a)

Various uncertainties arose from (NAASRA, 1980, Austroads, 1989) which included:

- Different interpretations associated with speed environment
- Designers were reluctant to accept predicted speeds on small radii curves
- Instructions were not clear on the use of design curves

- Results frequently varied between different designers
- Long straights were required for vehicles to reach speed environment

Although the procedure resulted in appropriate outcomes it was thought that a more transparent procedure was needed with a more specific method to determine vehicle speeds on both straights and horizontal curves. This is the 85^{th} percentile speed of cars when they are unaffected by other traffic and are free to choose whatever speed they wish to travel and will cater for the majority of drivers. The design speed should not be less than the operating (85^{th} percentile) speed. If the operating speed varies along the road the design speed must also vary to suit accordingly. Rural roads can be classified by their general operating characteristics regardless of their functional classification. There are three different speed standards for rural roads, each with a different philosophy that should be employed. All have the fundamental objective to provide a road which aligns with the expectation of the driver:

- High Speed Rural Roads: These are designed to have an operating speed in excess of 90km/hr. The operating speed is not constrained by the geometry which is largely consistent and supports a high desired speed and allows for a uniform operating speed.
- Intermediate Speed Rural Roads: Geometry on these roads constrains the operating speed to between 70-90km/hr on curves. Drivers will accelerate on straights and large curves and can reach up to 110km/hr. Horizontal curve radii on these roads are generally in excess of 160. Typical desired speeds for rural roads influenced by the horizontal alignment are shown in Appendix C.
- Low Speed Rural Roads: Geometry on these roads constrains the operating speed to between 50-70km/hr on curves usually due to difficult terrain. These roads will have numerous curves with radii less than 150. These alignments prompt alertness from the driver and accompanied by a reduced speed limit help lower the desired speed. Similar to intermediate speed rural roads drivers will slow down for horizontal curves and accelerate when the opportunity arises.

The Austroads operating speed model allows designers to determine the 85^{th} percentile operating speed of cars in both directions along a road where typically the varying speed is dictated by the horizontal curvature. The design speed for every geometrical element is required to be greater than or equal to the 85th percentile of the operating speed. The operating speed should be concluded by obtaining data measurements or estimation using the Operating Speed Model. The approach speed of a vehicle is estimated for a vehicle travelling in the direction being examined. This approach speed is applied to the first curve to determine an operating speed which is read from a graph. This operating speed then becomes the approach speed for the next curve or straight and so on. The operating speed model consists of three main components:

- Section Operating Speeds: As a driver is travelling along a series of similarly sized radii curves they eventually reach a comfortable constant speed which is known as the section operating speed. It is necessary to break down the alignment being examined into sections of approximately 1 -1.5km in length. Section operating speeds are required for the start of each of these sections and can be determined from the table in Appendix C. Similarly sized curves separated by small straights or spirals can be classified as a single element and drivers can be assumed to travel along these sections with a uniform section operating speed. Sometimes a single curve cannot be group with other curves due to irregularities in the size of the radii. A 200m straight is the minimum length of straight that may be classified as a section and any straights less than 200m will have no impact on the operating speed. Acceleration will occur whenever the speed drops below the section operating speed. If the section operating speed for a range of curves is larger than the desired speed then the desired speed should be adopted as the section operating speed.
- Car Acceleration on Straights Graph: This graph estimates the speed a vehicle can accelerate to over a given length. Large radius curves are considered straights. Generally an increase of 1km/hr per 5m is adopted. This graph can be seen in Appendix C.
- Car Deceleration on Curves Graph: This graph estimates the speed a vehicle decelerates to when traversing a curve of a known radius. The graph also highlights if the curve is not appropriate for the operating speed by specifying desirable minimum and absolute minimum curve radii for a range of approach speeds and supereleveations.

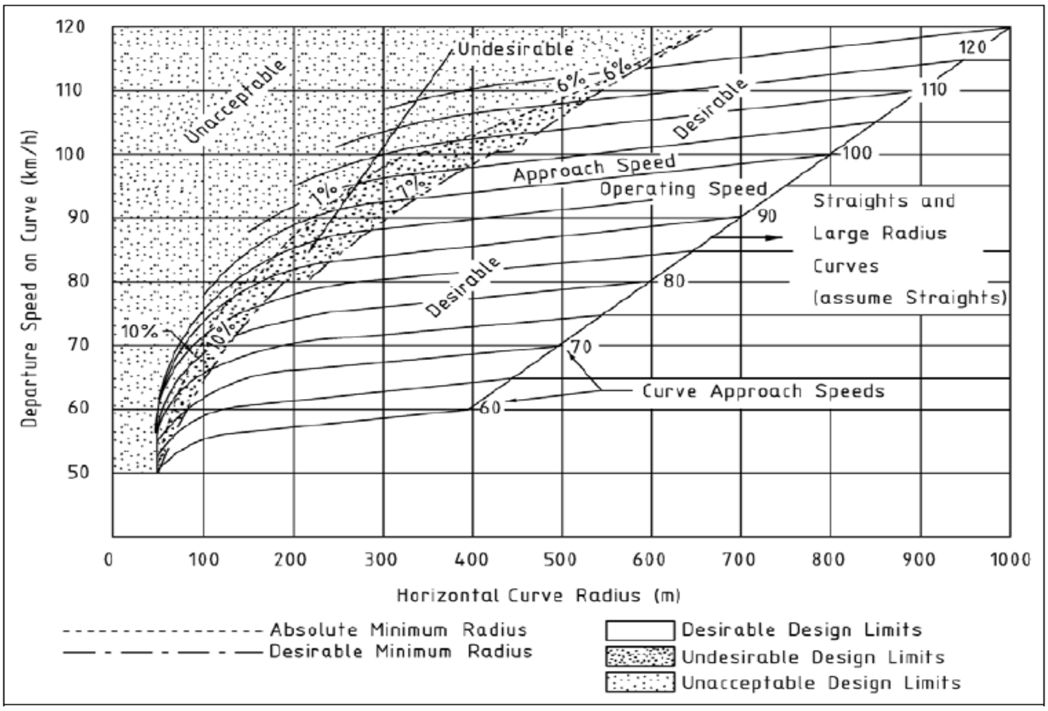


Figure 5 – Deceleration on Curves (Austroads, 2003, Austroads, 2010a)

2.4 Expanded Operating Speed Model (Hammonds et al., 2013)

A recent technical report by Austroads titled "Expanded Operating Speed Model" was initiated 'to update and expand road design operating speed models in Australia' (Hammonds et al., 2013). The project focused on small and medium radii curves totaling nine sites. Banding the speed data resulted in 57 combinations of approach speed and curve radii. The first part of this report analysed this data to assess the validity of the current Austroads deceleration on horizontal curve graph. The various speeds measured on the horizontal curves were compared to the speed reductions predicted by the current Austroads deceleration on horizontal curve graph and regression models were produced. The multiplicative-origin model shown in Appendix D was used to produce an updated deceleration on horizontal curve model. A comparison of the existing deceleration on horizontal curves model and the revised model developed in this report can be seen below:

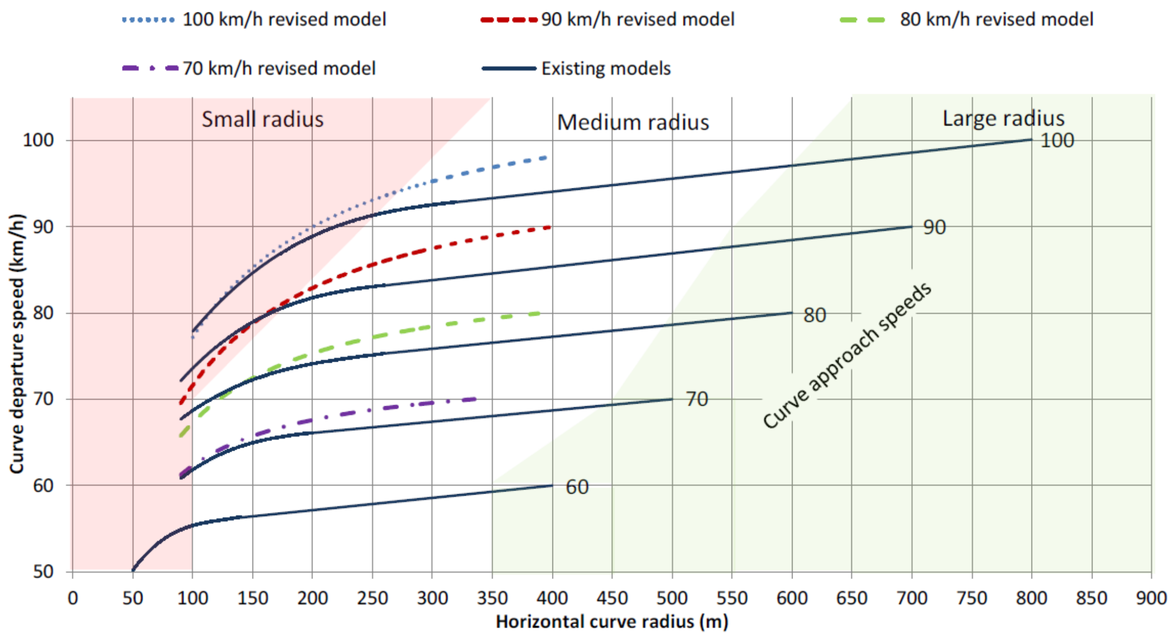


Figure 6 – Comparison of existing and revised deceleration on curves model for cars (Hammonds et al., 2013)

The study concluded that the current Austroads deceleration on horizontal curves model provided a conservative representation of the operating speeds of vehicles, most notably for horizontal curves of medium radii. This revised deceleration for horizontal curves model for cars on rural roads has been presented for consideration in updating the existing Austroads model. However before updating the existing model the report has called for further research that considers 'investigating curve radii greater than 250m to confirm the results of the project, as the greatest differences in model predictions occurred in the range of curve radii'.

2.5 International Approaches

2.5.1 United States

The United States use the classical design speed concept that was outlined earlier. This concept specifies only minimum values for design elements relating to design speed and invites the use of design elements which exceed these minimum values. The statement "Above minimum design values should be used, where practical" from (AASHO, 2004) was amended to "Above minimum design values should be used, where practical, particularly on high speed facilities" in (AASHO, 2011). Also the statement “On lower speed facilities, use of above minimum design criteria may encourage travel speeds higher than the design speed” was added to (AASHO, 2011) and did not appear in any earlier releases. (Polus et al., 1998) suggests that research has shown that AASHTO’s recommended minimum design speeds underestimate the desired speeds of current drivers.

2.5.2 Canada

Canada has adopted the use of the AASHTO Design Policy and as a result implemented the design speed concept the same way as the United States.

2.5.3 United Kingdom

In the United Kingdom the operating speed concept is not explicitly used and the decisive parameter for speed on rural highways is the design speed.

2.5.4 Germany

In Germany operating speed is referred to as the 85th percentile free flow speed. As appose to reviewing individual features in trying to ensure design consistency the curvature change rate (CCR) is used as a measure of the highway’s homogeneity. A regression equation based on CCR is then used to estimate the 85th percentile speed along the alignment. The 85th percentile speed cannot exceed the design speed on any given section by more than 20 km/hr and the 85th percentile speed between successive sections cannot exceed a10 km/hr difference.

2.5.5 Switzerland

In Switzerland operating speed is referred to as project speed. Speed differentials between successive geometric features are identified by preparing a speed profile which utilises the estimates the 85th percentile speed on horizontal curves, the maximum speed on straights and the acceleration rates entering or exiting horizontal curves. The 85th percentile speed between a horizontal curve and the preceding straight or large curve cannot exceed 5 km/hr. The difference in 85th percentile speeds between successive horizontal curves cannot exceed 10km/hr and the 85th percentile speed cannot exceed the design speed by more than 20km/hr

2.5.6 France

In France operating speed is referred to as the conventional 85th percentile free flow speed. Operating speed values can be determined with the use of equations that consider curve radii and longitudinal grade and are grouped depending on the carriageway width.

2.6 Factors Affecting Operating Speed

2.6.1 Terrain

When the terrain is flat and undulating drivers have an expectation that they can at travel faster speeds compared to if the terrain is rugged and steep and as a result are less likely to accept lower standards of geometry if there appears to be no physical limitations.

2.6.2 Volume of Traffic

When a road carries a large volume of traffic drivers believe that the geometry will allow them to travel at higher speeds. Drivers are less likely to accept lower standards on roads that they perceive to be more and important.

2.6.3 Road Characteristics

It is hard to accurately understand the impact of characteristics such as longitudinal grade, cross section and surface condition as there has been very little research however they should always be given some consideration. (Austroads, 2010a) provides the following guidance.

- Longitudinal Grade: The operating speed for cars is thought to be unaffected by downhill grades less than 9% and shorter than 200m whereas the operating speed can be assumed to be around 5-10km/hr less on downhill grades steeper than 9%. The operating speed of cars can be reduced on uphill grades steeper than 8% and longer than 200m.
- Cross Section: The operating speed model assumes that the traffic lanes are 3.5m wide and as a result speeds can be reduced by 3km/hr when traffic lane widths are 3.0m or less.

Surface Condition: The operating speed model assumes that the pavement is in a good condition and as a result speeds can be reduced by 5-10km/hr when the pavement is in a rough or broken condition.

2.6.4 Other Factors

The operating speed selected by a driver is not only relative to the geometry of the road and the volume of traffic, there are other factors which can affect the operating speed chosen by the driver, such as:

- The amount of risk a driver is prepared to take
- The level of enforcement of speed limits
- Performance of vehicles

2.7 Horizontal Alignment

(Mclean, 1974) determined that drivers do not respond to superelevation and the associated friction factor when selecting the speed at which they will negotiate a curve. The curvature of the road appeared to be the underlying factor affecting speed selection.

2.7.1 Horizontal Curve Equation

The principal of horizontal curve design was developed from railway engineering practice and is derived from the kinematics equation. The equation is based on the side friction required for a vehicle to transverse a constant radius curve at the design speed.

$$R = \frac{V^2}{127(e + f)}$$

Where:

R = curve radius (m)

V = vehicle speed (km/h)

e = pavement superelevation (m/m)

f = side friction factor (between tyre and pavement)

2.7.2 Side Friction Factors

When a vehicle is traversing a horizontal curve a force known as a friction factor exists between the tyres and the road surface which results in a change of direction and a centripetal acceleration. If this force is insufficient the vehicle will continue in motion tangentially to the horizontal curve. The side friction values for cars adopted in Australia over the years as well as the current values employed by AASHTO are listed in the table below:

Table 3 – Side friction factor value timeline

Operating Speed (km/hr)	(DMR, 1978)	(NAASRA, 1980)	(Austroads, 1989)	(RTA, 1991)	(Austroads, 2003)		(Austroads, 2010a)		(AASHO, 2011)	RMS, 2015)
					des max	abs max	des max	abs max		
20										
30	0.20									
40	0.19						0.30	0.35	0.18	0.30
50	0.17	0.35	0.35	0.30	0.30	0.35	0.30	0.35	0.17	0.30
60	0.16	0.33	0.33	0.24	0.24	0.33	0.24	0.33	0.17	0.24
70	0.15	0.31	0.31	0.19	0.19	0.31	0.19	0.31	0.16	0.19
80	0.14	0.26	0.26	0.16	0.16	0.26	0.16	0.26	0.15	0.16
90	0.13	0.18	0.18	0.13	0.13	0.20	0.13	0.20	0.14	0.13
100	0.12	0.12	0.12	0.12	0.12	0.16	0.12	0.16	0.14	0.12
110	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.12
120	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.12	0.11
130	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11

3. METHODOLOGY

3.1 Aims, Objectives, Scope and Benefits

The aim this project is to:

- Assess the validity of the current Austroads operating speed estimation model in relation to deceleration on horizontal curves.

The objectives of this project are:

- Research the history of the design speed concept and its involvement in road design in Australia. Compare this to approaches adopted by various road authorities around the world.
- Determine the key factors affecting the deceleration of vehicles around horizontal curves and develop a methodology to allow the collection of data relating to these key factors.
- Establish a suitable quantity of horizontal curve sites required in order to achieve meaningful results. Identify site locations and detail the conditions of each site that may influence the speed at which a vehicle transverses a horizontal curve.
- Analyse the data collected and identify which and compare the measured speed reductions with theoretical speed reductions.
- Produce revised design models that are more applicable to the circumstances of today. Recommend potential amendments to current design standards that consider the evolution of driver speed behaviour and vehicle performance.
- Report on the findings of the research in the required oral and written formats.

The scope of this project will be limited to:

- Cars only with no consideration given to trucks
- Two lane, two way rural roads

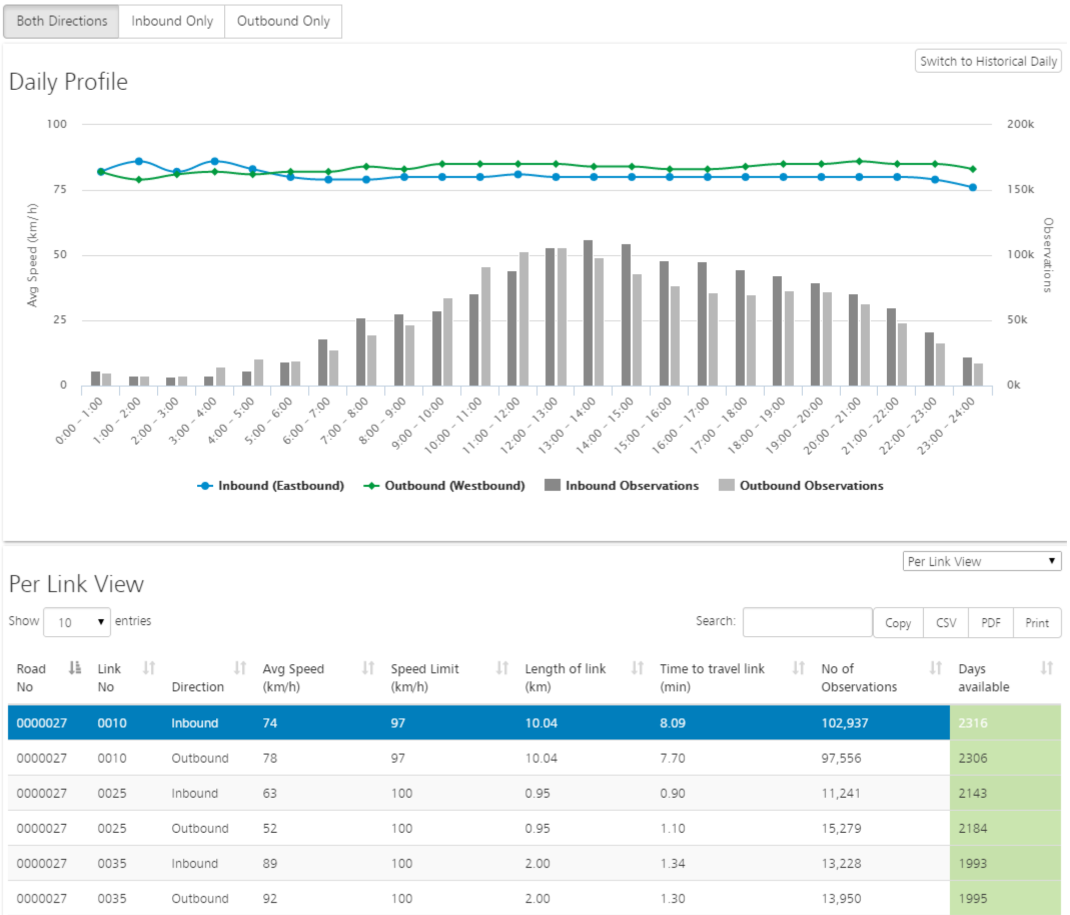
This project is likely to result in the following benefits:

- The prediction of a more accurate operating speed which will reduce the potential for designs that are either geometrically incorrect and unsafe or exceedingly conservative and costly.

- Improved safety for road users.

3.2 Data Identification

I initially proposed to collect operating speed data myself manually using a radar gun however I realized that this would involve considerably more fieldwork than I initially anticipated in order to achieve meaningful results. In search of obtaining some existing from within the RMS data I contacted the Network and Safety (Hunter) section of the RMS. This proved unsuccessful and I was advised to approach the Network Optimisation (Hunter) section of the RMS. This too proved unsuccessful as all of their speed data is obtained from tube surveys which are limited to straight sections of road as appose to horizontal curves. I was then advised to contact the Journey Management section (Sydney) and was informed of the new RMS Travel Time Analyser (RMS, 2016)which can be accessed online. The Travel Time Analyser is comprised of spot speeds of fleet vehicles that are every 60 seconds with the use of GPS technology. This data encompasses all state roads in NSW and includes data from 2008 onwards at various times of the day and days of the week. I was informed that it would be possible to obtain the data behind this tool. A screen shot below provides an example of an output produced by this tool.



Road No	Link No	Direction	Avg Speed (km/h)	Speed Limit (km/h)	Length of link (km)	Time to travel link (min)	No of Observations	Days available
0000027	0010	Inbound	74	97	10.04	8.09	102,937	2316
0000027	0010	Outbound	78	97	10.04	7.70	97,556	2306
0000027	0025	Inbound	63	100	0.95	0.90	11,241	2143
0000027	0025	Outbound	52	100	0.95	1.10	15,279	2184
0000027	0035	Inbound	89	100	2.00	1.34	13,228	1993
0000027	0035	Outbound	92	100	2.00	1.30	13,950	1995

Figure 7 – Travel Time Analyser Screenshot (RMS, 2016)

3.3 Site Selection

The RMS travel time tool outlined above produces better results as the number of observations increases. I decided to aim for a minimum data density (length of link divided by number of observations) of 0.5. The Golden Highway (HW27) was selected due to its rural nature, consistent traffic volumes and generally flat to undulating terrain. The Golden Highway provides a vital East- West connection between Newcastle and the Central West of NSW with a fairly low crossing of the Great Dividing Range. The Golden Highway connects the New England Highway at Belford with the Newell Highway at Dubbo, as well as numerous towns along its length (Mount Thorley, Jerrys Plains, Denman, Sandy Hollow, Merriwa, Cassilis, Dunedoo, Elong Elong and Ballimore). An overview of the Golden Highway is shown below.

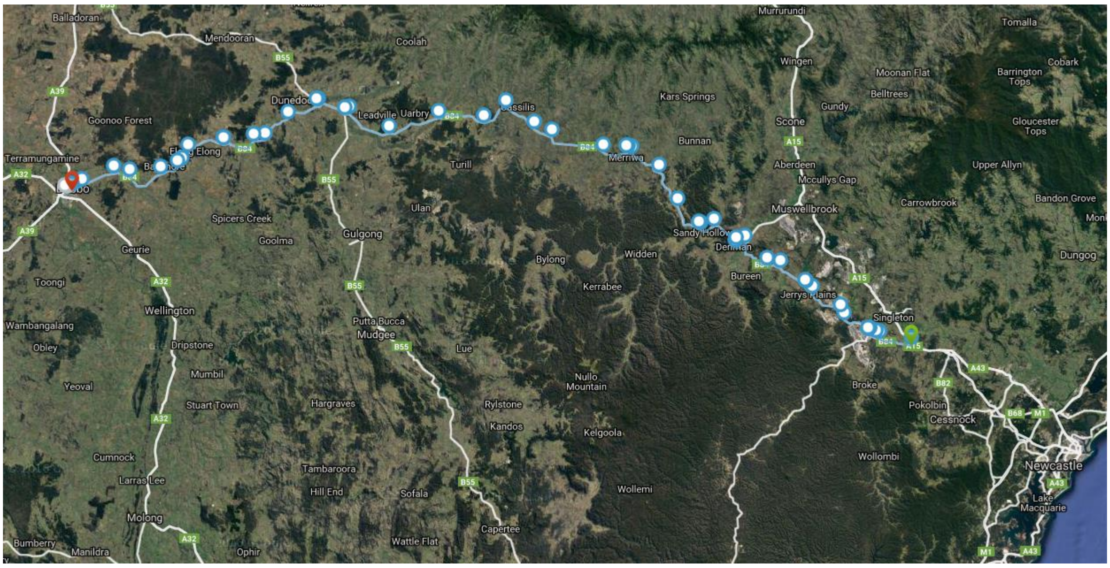


Figure 8 – General Site Overview (RMS, 2016)

Using MX Road I referenced in the aerial photography and was able to use the CAD drawings tools to trace the existing horizontal alignment of the Golden Highway and convert it to a Master Control string which contained chainage and alignment information.

3.4 Data Preparation

3.4.1 Received Data

I contacted the Journey Management section of the RMS and requested all the raw speed data available for the Golden Highway (all years, all times of day, both directions of travel, etc.) along with geographic coordinates. The data that I received was extracted from the RMS travel time tool and was in Microsoft excel format as shown in Appendix E. Due to time restraints I decided to only consider the Westbound direction of travel. As per the conditions outlined in Appendix A of AS1742.2 (SA, 2009) I removed all data that didn't occur between:

- Monday – Friday (Weekdays)
- 6:00am – 6:00pm (Daytime)

3.4.2 Conversion

The geographic coordinates from the spreadsheet above were in latitude and longitude and I required the coordinates to be MGA56. The RMS has a program called Gridloc which is capable of converting these coordinates and requires the data to be saved in .csv file. A screenshot is provided in Appendix F.

3.4.3 Alignment Report

Using the dynamic point report tool in MX Road I was able to determine the X any Y coordinates of the master control alignment at 10m chainage intervals. A screenshot is provided in Appendix F.

3.4.4 Cartesian Report

Using the coordinates obtained alignment report outlined above I was able to undertake a Cartesian analysis in excel and identify which 10m chainage interval each data point was closest to. A visual basic macro was developed to assist with this process due to the large number of data point and screenshot is provided in Appendix F. I was then able to remove all data that was outside start and end chainage ranges of the alignment.

3.4.5 Identify Outliers

In order to identify any outliers in the data set I calculated the inter quartile range of the data and then used the following equations:

$$Q_1 - (1.5 \times IQR)$$

$$Q_3 + (1.5 \times IQR)$$

A frequency distribution plot and cumulative frequency distribution plot of the remaining data are provided in Appendix F.

3.4.6 Determining the 85th Percentile

All remaining data points were then grouped into 50m intervals and the 85th percentile was calculated for each of these individual 50m section using the percentile function in excel.

3.5 Site Analysis

3.5.1 Identifying Horizontal Curve Sites

Using the geometry string point reporting tool in MX Road I was able to identify the chainage of the start and end tangent points of each curve and the associated radius for the entire alignment. Taking this information back to excel I was able to use basic arithmetic formulas to calculate the chainage at the middle of the curve, the approach (100m before the starting tangent point) and the length of the curve. I was then able to sort the horizontal curve sites by length and radius to remove all sites that:

- Were less than 140m in length (minimum horizontal curve length for 70km/hr)
- Had a radius greater than 1000m (assumed to be a straight)

This resulted in 115 potential horizontal curves sites.

3.5.2 Speed Differential

A RL was assigned to the Master Control string at each 50m interval corresponding to the calculated 85th percentile speed value. With the use of input files in MX Road I was able to produce a profile for the entire length of the Golden Highway with 85th percentile speed plotted against chainage and horizontal geometry which is shown in Appendix F.

Special chainages were added to the Master Control string at the middle of the curve and the approach to accompany the tangent points of each curve. Again using the dynamic point report tool in MX Road I was able to produce a report of the RL (85th percentile speed) at the approach, start, middle and end of each of the identified horizontal curve sites as per the diagram below.

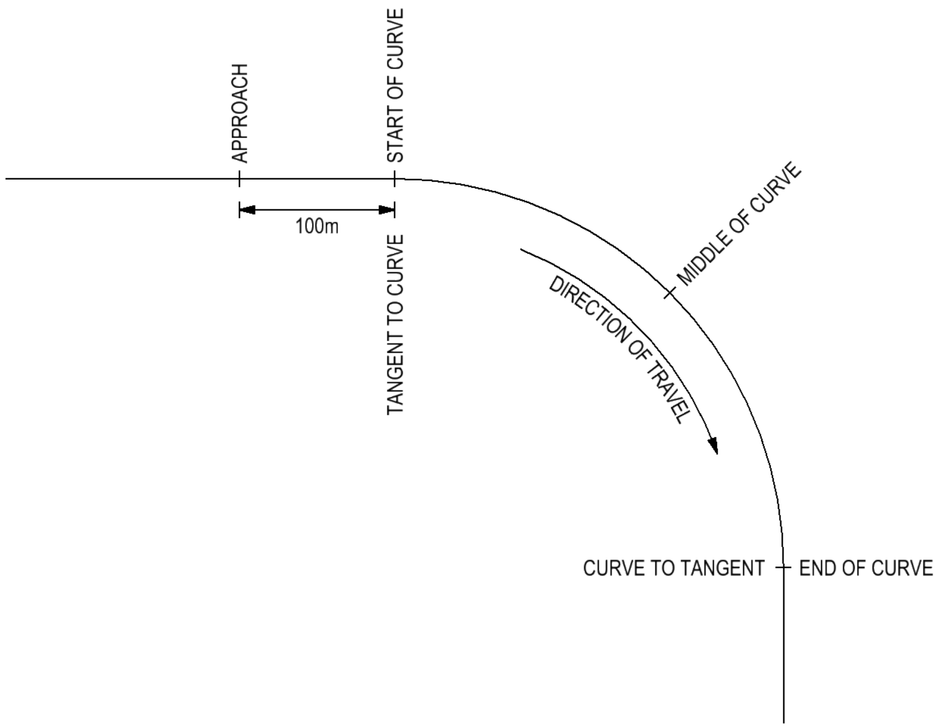


Figure 9 – Speed measurement points along curve

3.5.3 Site Conditions

GIPSICAM Road Asset Viewer was used to approximately determine the conditions for each of the potential horizontal curve sites. The recorded conditions included:

- Superelevation
- Longitudinal grade
- Vertical geometry (downgrade, upgrade, crest, sag)
- Environment (signposted speed, stopping sight distance, shoulder width)
- Signage (symbolic curve, speed advisory, CAM’s)

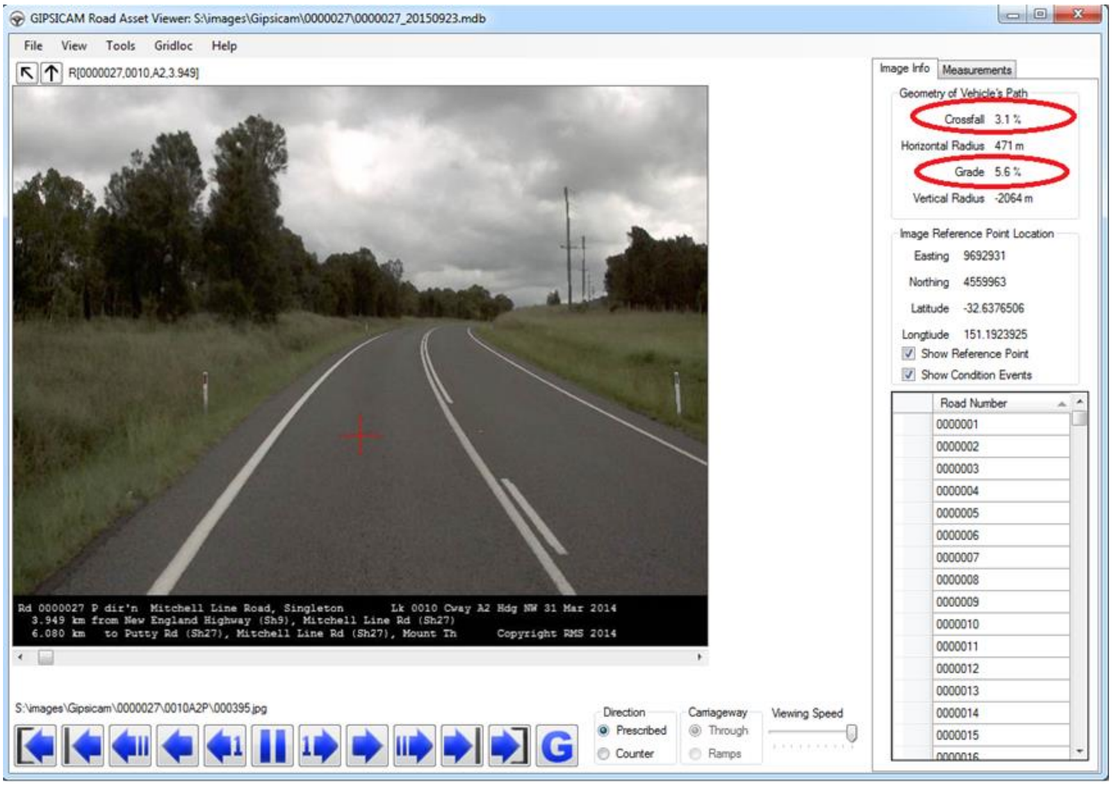


Figure 10 – GIPSICAM Screenshot (RMS, 2014-15)

Sites that were observed to have more than one lane in each direction, such as an overtaking lane were removed. Sites that were observed to be close to a speed zone change or were entering/exiting a town were removed. There were a small number of curves sites with approach speeds less than 75km/hr. These were considered outliers and were removed. This resulted in 96 remaining sites.

3.6 Data Analysis

3.6.1 Design Speed

Using the friction factors associated with the signposted speed and the superelevation values measured above I was able to calculate the design speed for each of the horizontal curve sites of varying radii.

3.6.2 Speed Drop Percentage

The speed drop percentage was calculated relative to the approach speed at start, middle and end of each curve.

3.6.3 Banded Approach Speed

Sites were grouped into their closest correspond approach speed band and the percentage factor was applied to the calculated 85th percentile speed at the start, middle and end of each curve.

3.7 Results and Analysis

3.7.1 Curve Design Speed vs 85th Percentile Speed

The curve design speed will be plotted against the 85th percentile speed for each horizontal curve sites and the results will be compared to research by (Mclean, 1979).

3.7.2 Factors Effecting Operating Speed

Multivariable regression analysis will be undertaken to determine what variables are significant at $p < 0.1$. The following variables will be examined against the speed drop percentage (relative to the approach speed) at the start, middle and end of each horizontal curve site and line fit plots will be produced.

- Longitudinal grade
- Vertical geometry (crest)
- Curve length
- Shoulder width
- Signage

3.7.3 Location of Maximum Deceleration

Data that is significantly affected by the variables highlighted above will be removed. The radius of the remaining data will be plotted against 85th percentile vehicle speed at the start, middle and end of each of the remaining horizontal curve sites for each approach speed band to confirm that the maximum declaration occurs at the middle of the horizontal curve.

3.7.4 85th Percentile (Curve Midpoint) vs Radius

Sites that experience an increase in 85th percentile vehicle speed at the midpoint of the horizontal curve (relative to the approach speed) will be removed. The remaining 85th percentile midpoint curve speeds will be plotted against their associated horizontal curve radius and compared to other earlier models.

3.8 Recommendations

3.8.1 Roadway Characteristics and Operating Speed

Recommendations will be made about the effect of roadway characteristic such as longitudinal grade and cross sectional width that could potentially be used to help update the guidance given in sections C.2.4 and C.2.5 of Austroads *Guide to Road Design Part 3: Geometric Design*. Any issues that may have influenced the results that I obtain will also be noted.

3.8.2 Update to Existing Austroads Deceleration on Horizontal Curve Graph

New deceleration on horizontal curve speed prediction relationships will be produced that could potentially be used to help update the current graph that appears in section 3.5.7 of Austroads *Guide to Road Design Part 3: Geometric Design*.

4. RESULTS AND ANALYSIS

4.1 Horizontal Curve Summary

A summary of the 96 horizontal curves sites is provided below for each separate banded approach speed. It includes the number of horizontal curves and the radius range.

Table 4 – Horizontal Curve Summary

Banded Approach Speed	Number of Curves	Radius Range (m)
75-85	15	220-980
85-95	12	250-990
95-105	54	245-1000
105-115	15	390-820

4.2 Curve Design Speed vs 85th Percentile Speed

Work by (Mclean, 1979) not only resulted in the development of the Speed Environment Model but also played an important role in contributing to the refinement of new side friction factors. It was found that in previous design guides such as (DMR, 1978) conservatively low side friction values were implemented in order to provide drivers with a high margin of safety. (Mclean, 1979) determined that drivers were willing to tolerate higher values of side friction when traveling at speeds less than 100km/hr as was shown earlier in Figure 1. The calculated curve design speed (X) has been plotted against the 85th percentile speed (Y) at the start, middle and end of each of the 96 horizontal curve sites and a similar graph to Figure 1 has been produced below. The results of this graph support earlier work by (Mclean, 1979) and shows that drivers are still willing to tolerate higher values of side friction when traveling at speeds less than 100km/hr. It can be seen that on horizontal curves suitable for 100km/hr or more that drivers tend to travel at a more uniform speed.

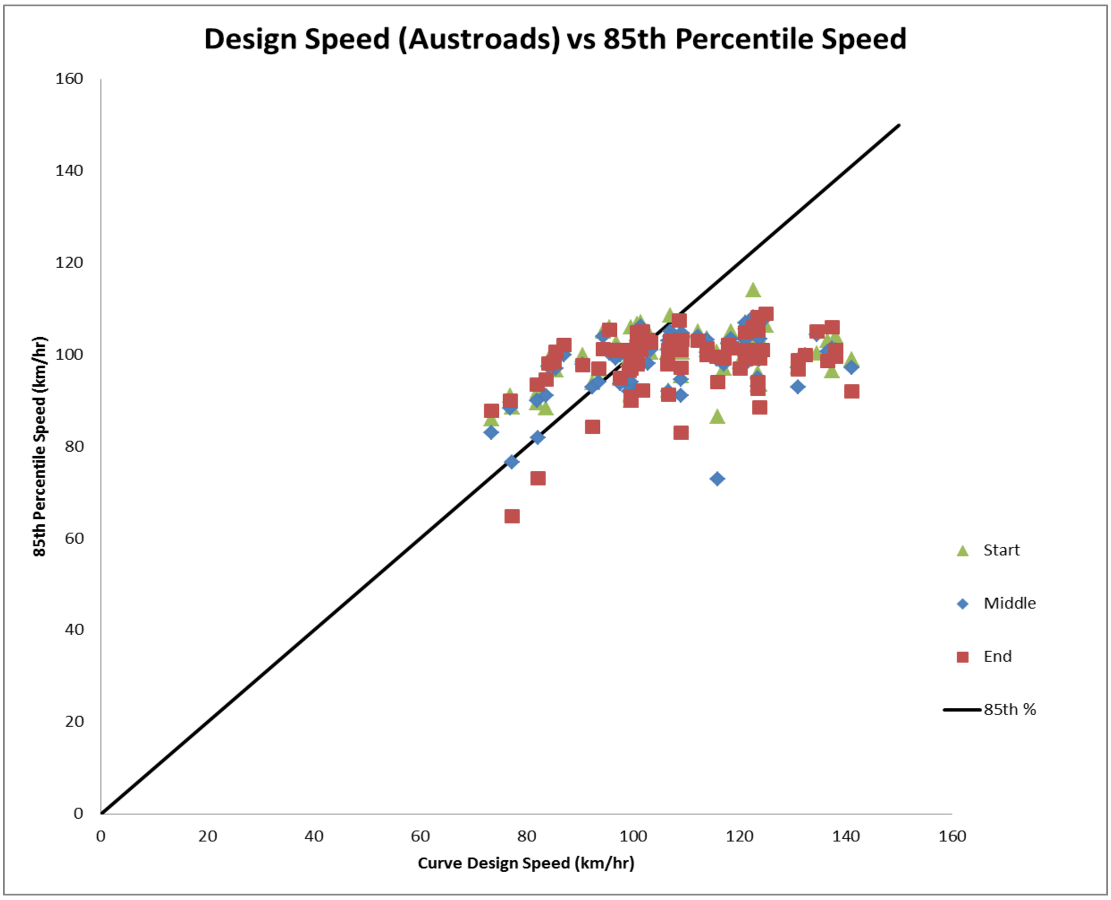


Figure 11 – Relaionship between observed 85th percentile car speeds and curve speeed standard

4.3 Factors Effecting Operating Speed

Multivariable regression analysis was undertaken to determine what variables are significant at $p < 0.1$. The following variables will be examined against the speed drop percentage (relative to the approach speed) at the start, middle and end of each horizontal curve site and line fit plots were produced.

4.3.1 Longitudinal grade

The longitudinal grade (X) was plotted against the speed drop percentage (Y) at the start, middle and end of each horizontal curve.

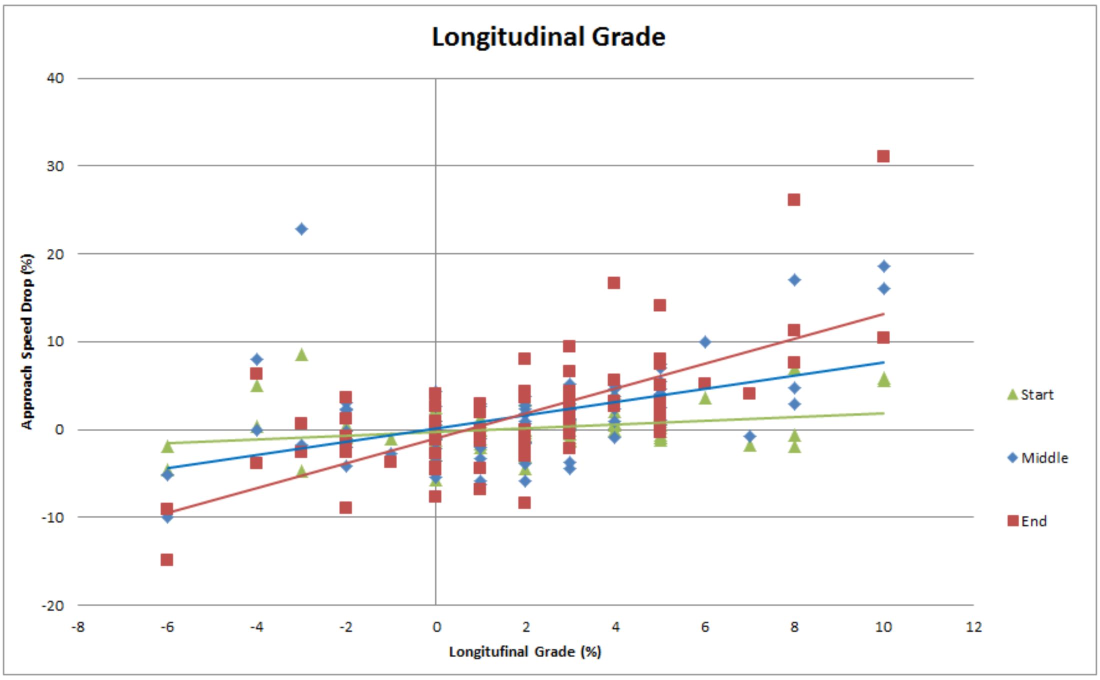


Figure 12 – Effect of Longitudinal Grade

It was found that longitudinal grade has a significant effect on a vehicles speed as it transverses a horizontal curve. A vehicles speed was shown to progressively decrease (relative to their approach speed) as longitudinal grade increased and vice versa.

4.3.2 Vertical Geometry (Crests)

Whether or not there was a crest (X) was plotted against the speed drop percentage (Y) at the start, middle and end of each horizontal curve.

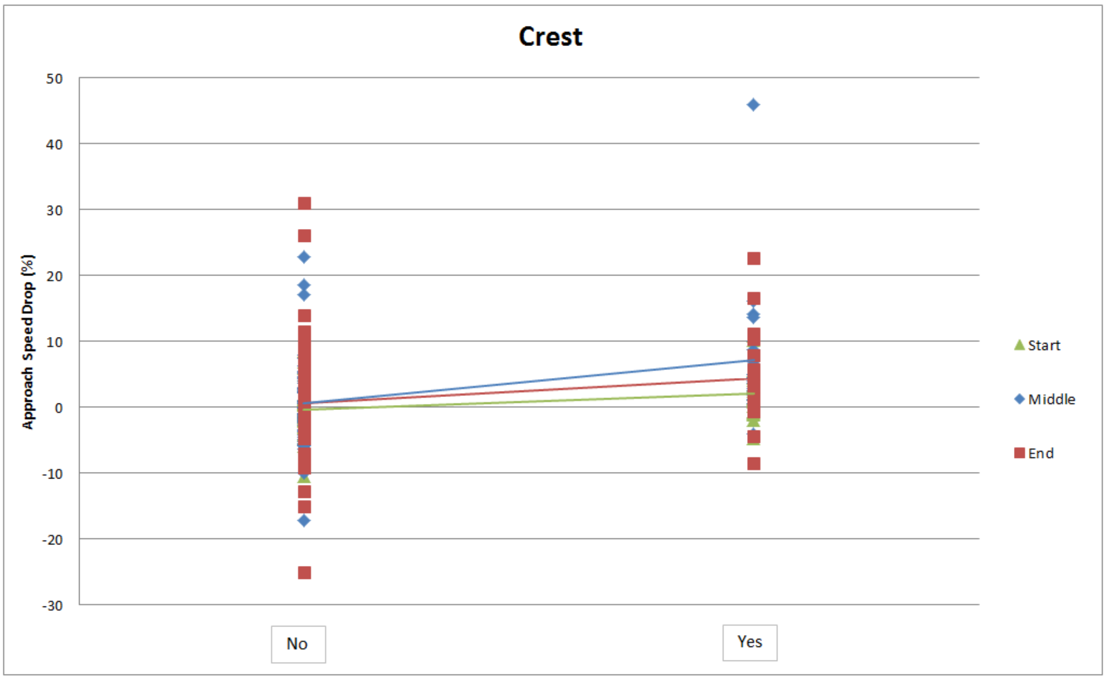


Figure 13 – Effect of Vertical Geometry (Crest)

It was found that the vertical geometry (crest) has a significant effect on vehicles speed as it transverses a horizontal curve. A vehicles speed was shown to decrease the most (relative to their approach speed) as the vehicle travelled through the middle of the horizontal curve.

4.3.3 Stopping Sight Distance

Whether or not stopping sight distance was achieved (X) was plotted against the speed drop percentage (Y) at the start, middle and end of each horizontal curve.

Figure 14 – Effect of Stopping Sight Distance

It was found that whether stopping sight distance was achieved has a significant effect on vehicles speed as it transverses a horizontal curve. A vehicles speed was shown to decrease the most (relative to their approach speed) as the vehicle travelled through the middle of the horizontal curve. This is similar to the vertical geometry (crest) as these two parameters are related.

4.3.4 Curve length

The curve length (X) was plotted against the speed drop percentage (Y) at the start, middle and end of each horizontal curve.

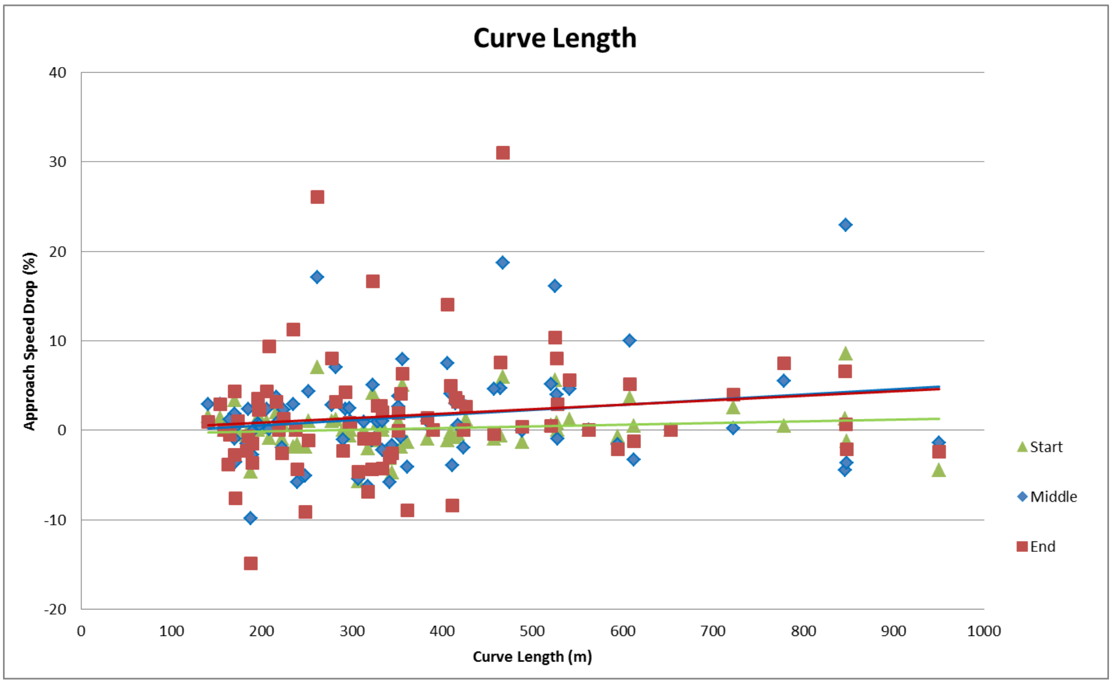


Figure 15 – Effect of Curve Length

It was found that curve length has a significant effect on a vehicles speed as it transverses a horizontal curve. A vehicles speed was shown to decrease (relative to their approach speed) in the first half of the horizontal curve as the length of the horizontal curve increased and remain constant for the remaining half of the horizontal curve.

4.3.5 Shoulder width

The shoulder width (X) was plotted against the speed drop percentage (Y) at the start, middle and end of each horizontal curve.

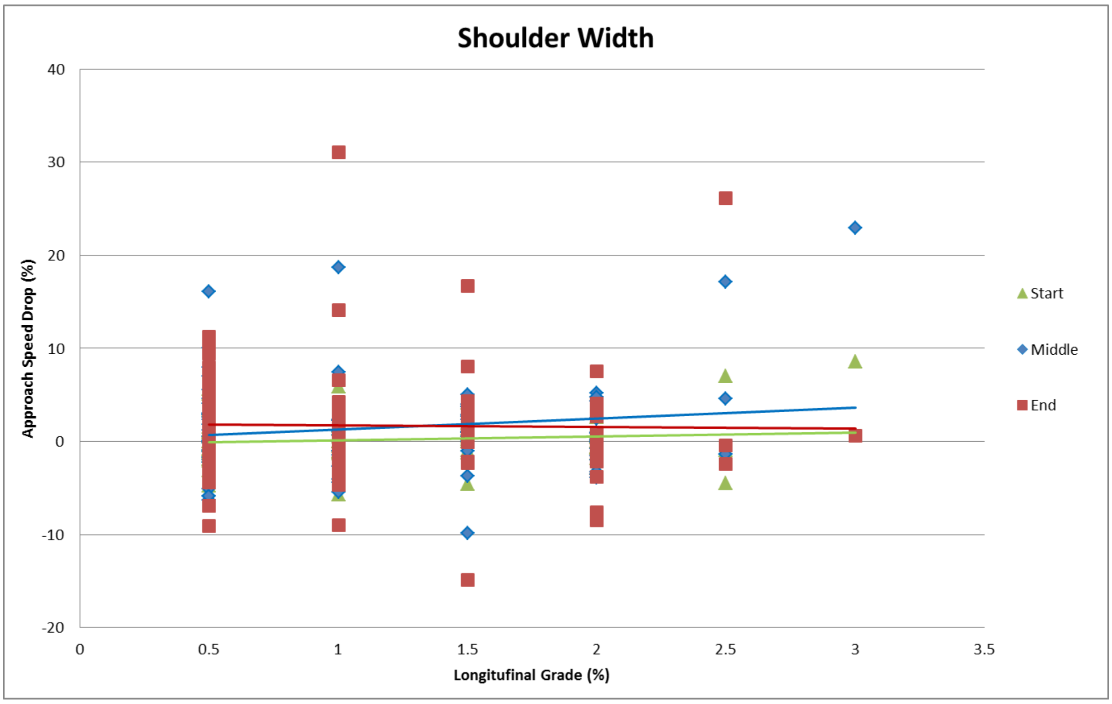


Figure 16 – Effect of Shoulder Width

It was found that shoulder width did not have a significant effect on a vehicles speed as it transverses a horizontal curve.

4.3.6 Signage

Whether or not there was a symbolic curve sign on the approach to the curve (X) was plotted against the speed drop percentage (Y) at the start, middle and end of each horizontal curve.

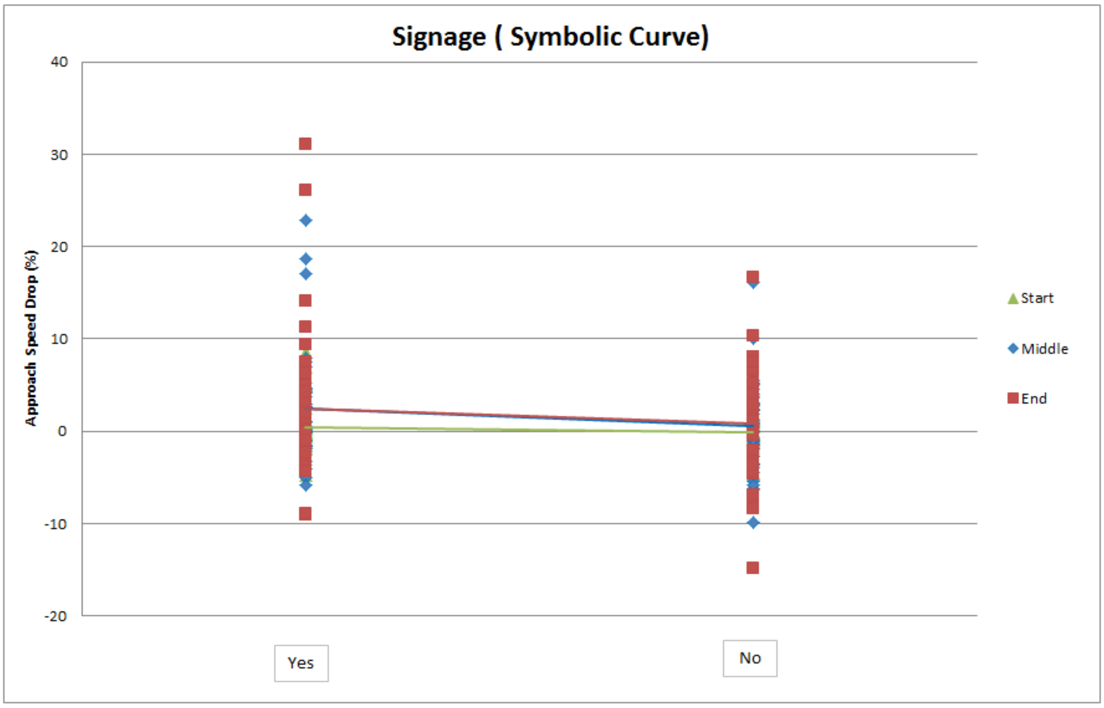


Figure 17 – Effect of Signage (Symbolic Curve)

It was found that symbolic curve signage did not have a significant effect on a vehicles speed as it transverses a horizontal curve.

Whether or not there was a speed advisory sign on the approach to the curve (X) was plotted against the speed drop percentage (Y) at the start, middle and end of each horizontal curve.

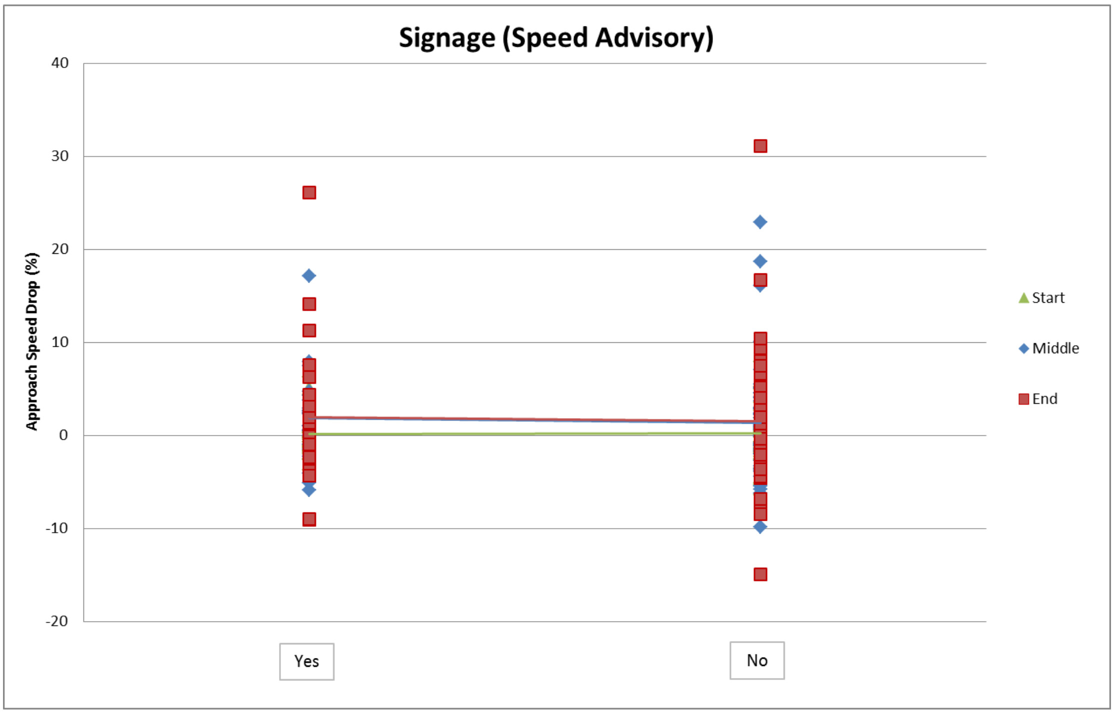


Figure 18 – Effect of Signage (Speed Advisory)

It was found that speed advisory signage did not have a significant effect on a vehicles speed as it transverses a horizontal curve.

Whether or not there were chevron alignment markers around horizontal curve (X) was plotted against the speed drop percentage (Y) at the start, middle and end of each horizontal curve.

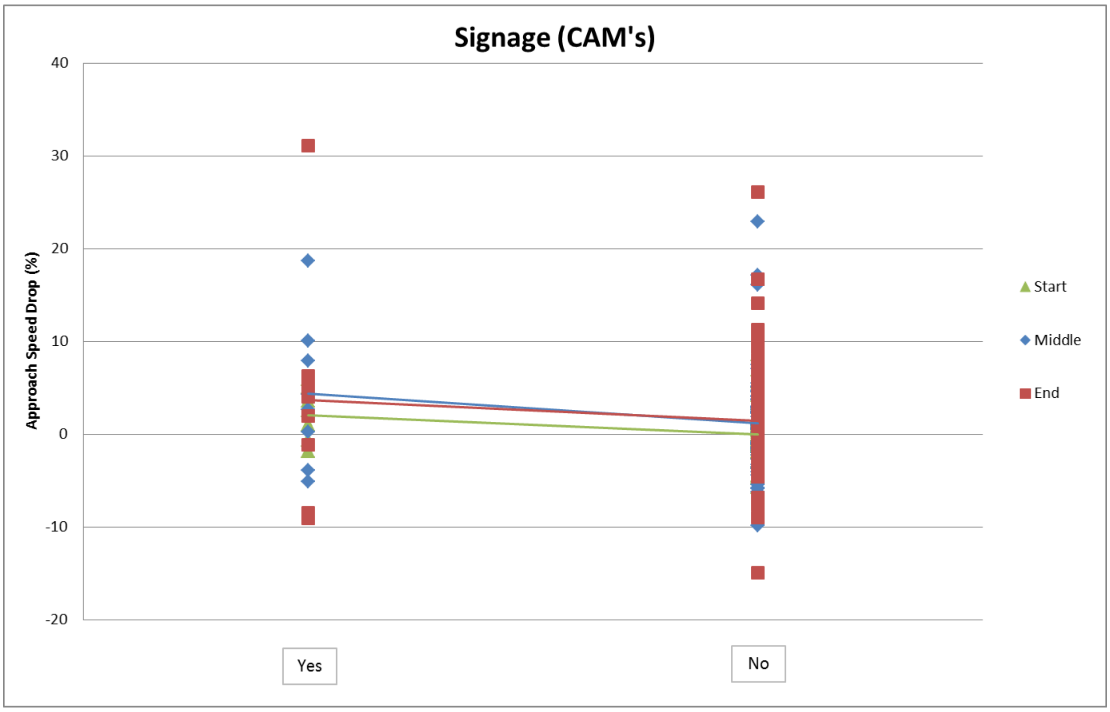


Figure 19 – Effect of Signage (CAM’s)

It was found that chevron alignment markers did not have a significant effect on a vehicles speed as it transverses a horizontal curve.

4.4 Location of Maximum Deceleration

It was determined that longitudinal grade, horizontal curve length, vertical geometry (crest) and whether stopping sight distance was achieved had a significant effect on a vehicles speed as it transverses a horizontal curve. All other factors were found not have a significant impact. This resulted in all data being removed that:

- Had a longitudinal grade of -4% or less and a longitudinal grade of +3% or more.
- Had a curve length of 700m or more.
- Was on a crest
- Didn’t achieve stopping sight distance.

The remaining factors contributing to a vehicles speed as it traverses a horizontal curve are approach speed and horizontal radius. The radius of the remaining data was plotted against 85th percentile vehicle speed at the start, middle and end of each of the remaining horizontal curve sites to confirm that the maximum declaration occurs at the middle of the horizontal curve. It was originally planned to produce a plot for each of the separate banded approach speeds, however only the 100km/hr banded approach speed had enough data points to show meaningful results.

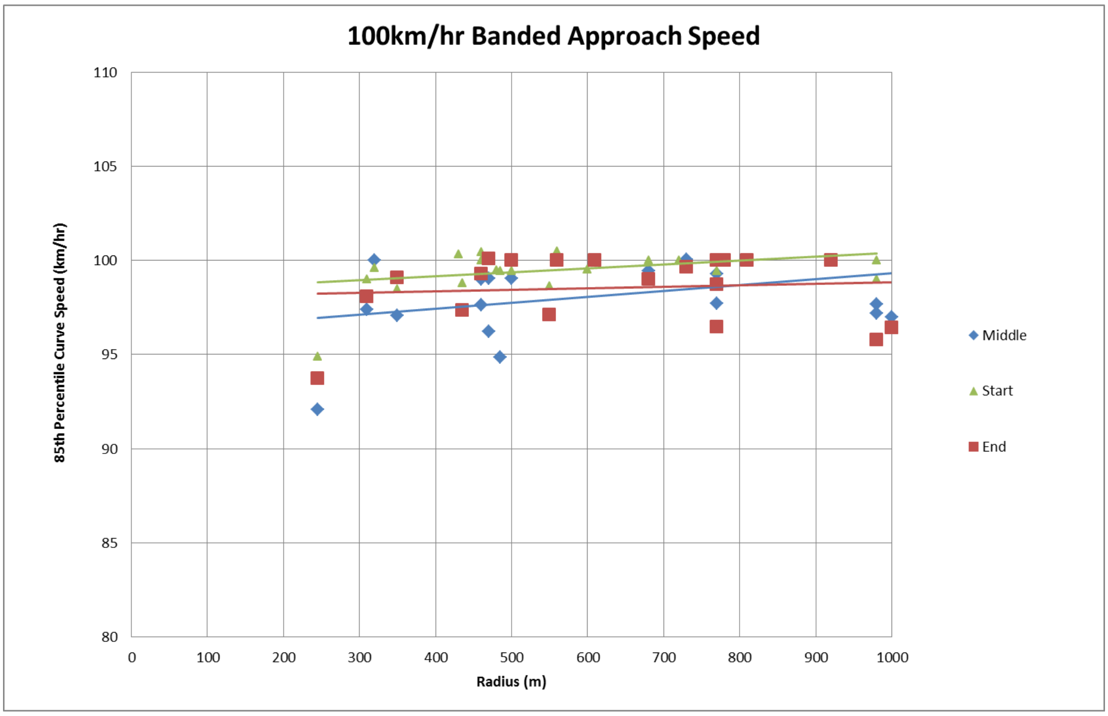


Figure 20 – Location of maximum deceleration (100km/hr)

It can be seen from the plot above that the maximum deceleration occurs at the middle of the curve (shown in blue) and that the deceleration increases with as the radius decreases.

4.5 85th Percentile (Curve Midpoint) vs Radius

Sites that experienced an increase in 85th percentile vehicle speed at the midpoint of the horizontal curve (relative to the approach speed) were removed. The remaining 85th percentile midpoint curve speeds were plotted against their associated horizontal curve radius. It was originally planned to produce a plot for each of the separate banded approach speeds, however only the 100km/hr banded approach speed had enough data points to show meaningful results. Plots for the other banded approach speeds can be found in Appendix F. The results were compared to similar prediction models by (Mclean, 1979), (VicRoads, 1994), (Austroads, 2003)/(Austroads, 2010a), (Austroads, 2013).

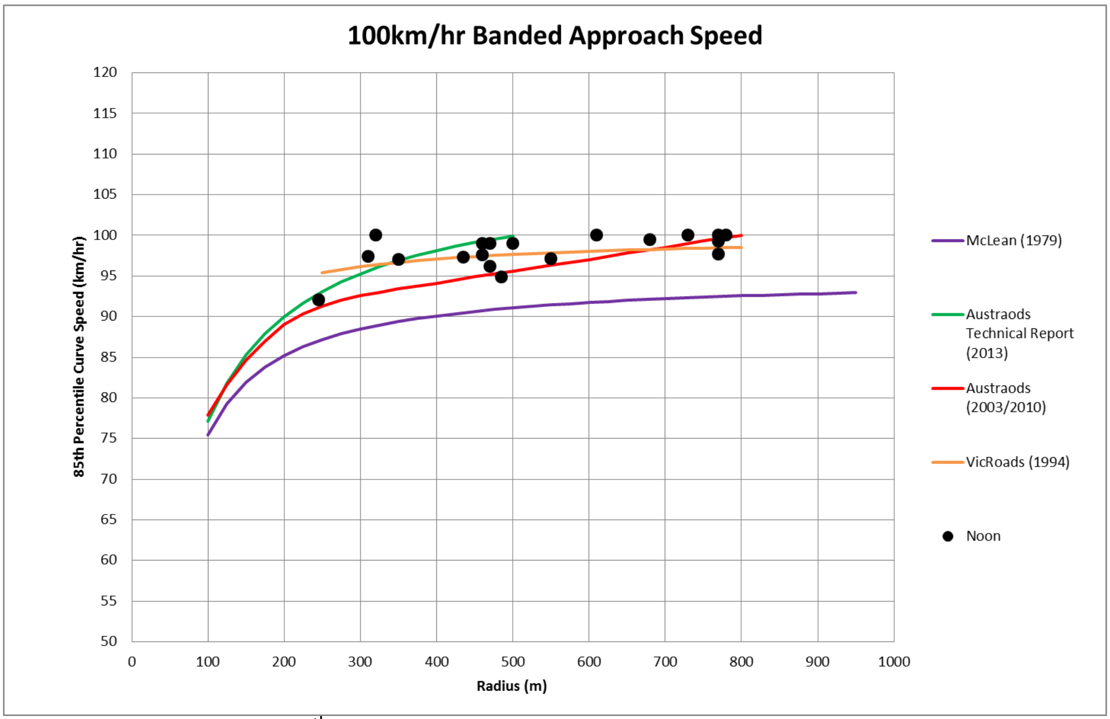


Figure 21 – 85th Percentile (Curve Midpoint) vs Radius (100km/hr)

From the plot above it can be seen that my results (shown in black) are mostly above the red line (Austroads, 2010a) and seem to be more accurately represented by the orange line (VicRoads, 1994).

5. RECOMMENDATIONS

5.1 Roadway Characteristics and Operating Speed

5.1.1 Longitudinal Grade

Section C.2.4 of Austroads Guide to Road Design Part 3: Geometric Design assumes the operating speed of cars is unaffected by downhill grades less than 9% and is assumed to be around 5-10km/hr less once this grade is exceeded. Uphill grades steeper than 8% are assumed to affect the operating speed however no values are specified. My research showed that longitudinal grade had a significant effect ($p < 0.1$) on a vehicles speed as it traverses a horizontal curve when the longitudinal grade was -4% or less and +3% or more. It is recommended that the effect of longitudinal grade on operating speed be further investigated with the aim of developing a correction table for varying grades.

5.1.2 Curve Length

Austroads does not include any guidance in relation to horizontal curve length and its effect on operating speed. My research showed that horizontal curve length had a significant effect ($p < 0.1$) on a vehicles speed as it traverses a horizontal curve when the curve length was 700m or more. It is recommended that the effect of horizontal curve length on operating speed be further investigated with the aim of developing a correction table for varying horizontal curve lengths.

5.1.3 Vertical Geometry and Stopping Sight Distance

Austroads does not include any guidance in relation to crests and stopping sight distance and its effect on operating speed. My research showed that the vertical geometry and whether stopping sight distance was achieved had a significant effect ($p < 0.1$) on a vehicles speed as it traverses a horizontal curve when a crest existed and stopping sight distance wasn't achieved. It is recommended that the effect of vertical geometry and whether stopping sight distance is achieved be further investigated with the aim of developing a correction table.

5.2 Update to Existing Austroads Deceleration on Horizontal Curve Graph

Using my results a new deceleration on horizontal curve speed prediction relationship was able to be produced for a 100km/hr approach speed (shown in black). This relationship could potentially be used to help update the current graph (shown in red) that appears in section 3.5.7 of Austroads Guide to Road Design Part 3: Geometric Design.

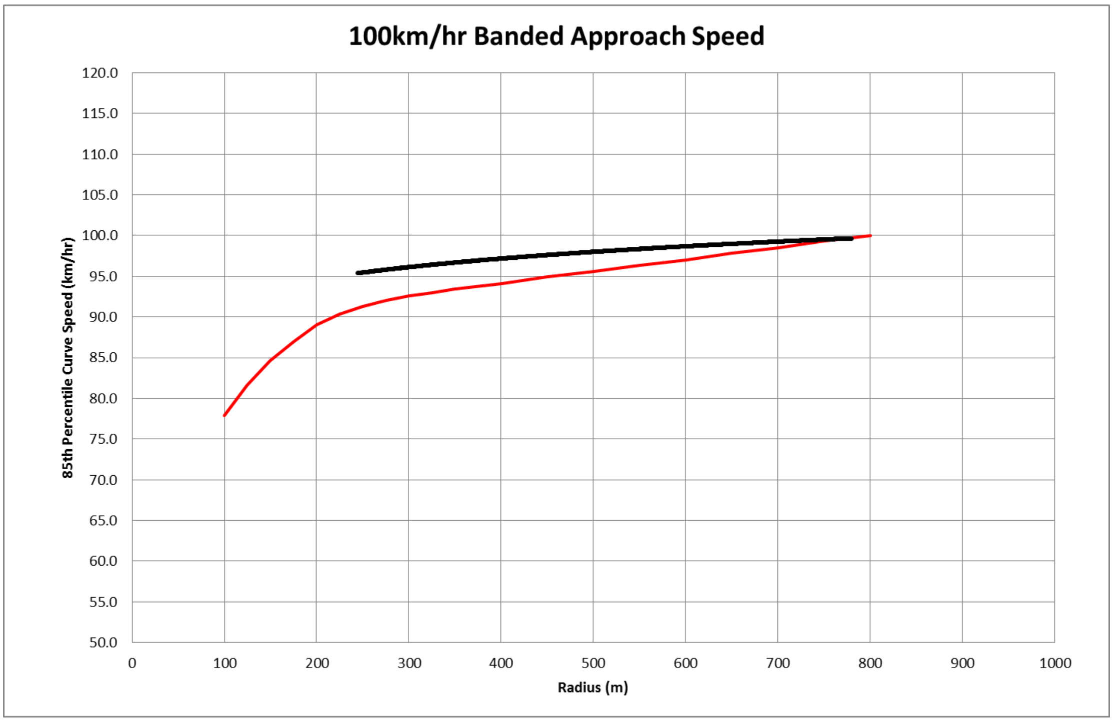


Figure 22 – Potential amendment to existing Austroads deceleration on horizontal curve graph (100km/hr approach speed)

It is important to note the following issues as they may have had an influence on my results:

- Data was from state fleet vehicles only. Drivers may have known that their vehicles were recording their speed and this may have altered driver behavior.
- RMS travel time analysis tool provided GPS coordinates when a vehicles speed was measured. It is unknown how accurate these GPS coordinates are.
- Gipsicam was used to obtain values for superelevation, longitudinal grades, shoulder width, and whether stopping sight distance was achieved. This program is only an estimation.

- The existing horizontal alignment of the Golden Highway was traced over the top of aerial photography. This is only an estimation.
- It is known that the Golden Highway is a significant freight route with an estimated 15% heavy vehicles. A motorist's speed could have been altered by being stuck behind a heavy vehicle (especially on steep upgrades).
- Data extracted from the RMS travel time analysis tool spanned over many years. It is unknown if the environment of the road had changed over time (such as shoulder widening and the installation of safety barriers).

6. AREAS OF FURTHER RESEARCH

Some potential areas of further research that I have identified include:

- There has been very little research done into the effects of roadway characteristics on operating speed and limited guidance is given to designers. I have recommended further research in regards to the roadway characteristics of longitudinal grade, horizontal curve length, vertical geometry and whether stopping sight distance is achieved with the aim of developing correction tables.
- Examining the effects of the roadway characteristics on heavy vehicles when traversing horizontal curves.
- For my research I only analysed the Westbound direction of the Golden Highway due to time restraints. There is potential for further research to analyse the Eastbound direction of the Golden Highway and compare the results.

7. CONCLUSION

Results supported earlier work by (Mclean, 1979) and showed that drivers are still willing to tolerate higher values of side friction when travelling at speeds less than 100km/hr and that on horizontal curves suitable for 100km/hr or more that drivers tend to travel at a more uniform speed.

These variables that had statistically significant effect on vehicles operating speed as it traverses a horizontal curve were found to be longitudinal grade (+3% or more and -4% or less), horizontal curve length (700m or more), vertical geometry (crests) and whether stopping sight distance was achieved.

It was confirmed that the maximum deceleration occurs at the middle of the horizontal curve. Similarly to recent research by Austroads it was found that that the current Austroads deceleration on horizontal curves model provided a conservative representation of the operating speeds of vehicles.

It is recommended that further research be done into the effects of these roadway characteristics on operating speed with the aim of developing correction tables. A new deceleration on horizontal curve speed prediction relationship was produced for 100km/hr approach speed. This relationship could potentially be used to help update the current Austroads deceleration on horizontal curves graph.

8. REFERENCES

AASHO 1938. A Policy on Highway Classification. AASHO, Washington.

AASHO 1941. A Policy on Design Standards. AASHO, Washington.

AASHO 1945. A Policy on Design Standards. AASHO, Washington.

AASHO 1954. A Policy on Geometric Design of Rural Highways. AASHO, Washington.

AASHO 1965. A Policy on Geometric Design of Rural Highways. AASHO, Washington.

AASHO 1984. A Policy on Geometric Design of Highways and Streets. AASHO, Washington.

AASHO 1990. A Policy on Geometric Design of Highways and Streets. AASHO, Washington.

AASHO 1994. A Policy on Geometric Design of Highways and Streets. AASHO, Washington.

AASHO 2001. A Policy on Geometric Design of Highways and Streets. AASHO, Washington.

AASHO 2004. A Policy on Geometric Design of Highways and Streets. AASHO, Washington.

AASHO 2011. A Policy on Geometric Design of Highways and Streets. AASHO, Washington.

AUSTROADS 1989. Rural Road Design, Guide to the Geometric Design of Rural Roads. Sydney, Australia: National Association of Road and Traffic Authorities in Australia.

AUSTROADS 2003. Rural Road Design, Guide to the Geometric Design of Rural Roads. Sydney, Australia: National Association of Road and Traffic Authorities in Australia.

AUSTROADS 2010a. Guide to road design – part 3: geometric design, by Barton, AGRD03/10. Sydney, NSW.

AUSTROADS 2010b. Austroads Glossary of Terms, by P Milne, K Sharp & B Ungers, report no. AP-C87/10, 4th Edition. Sydney, NSW.

AUSTROADS 2013. Austroads Technical Report - Expanded Operating Speed Model. Austroads.

BARNETT, J. 1937. Safe side friction values and superelevation design. *Highway Research Board Proceedings,* 16**,** 69-80.

BENTLEY 2015. MX Road V8i ed.

COX, R. 2008. Using the Austroads Operating Speed Model (Maybe We Will Get it Right This Time!). *23rd ARRB Conferance.* Adelaide, Australia: ARRB.

DMR 1978. Training Manual for Road Design Draftsmen.

HAMMONDS, B., LEVASSEUR, M. & MITCHELL, B. 2013. Austroads Technical Report - Expanded Operating Speed Model.

MCLEAN, J. 1974. Driver behaviour on curves - A review. *Australian Road Research Board*

proceedings, 7**,** 129-147.

MCLEAN, J. 1979. An alternative to the design speed concept for low speed alinement design. *Transportation research record,* 702**,** 55-63.

MCLEAN, J. 1988. Driver speed behaviour and rural road alignment design. *Australian Road Research Board,* Research Report ARR 154.

NAASRA 1973. Policy for the Geometric Design of Rural Highways (Metric Units). Sydney.

NAASRA 1980. Interim Guide to the Geometric Design of Rural Roads. Sydney, Australia: National Association of Road and Traffic Authorities in Australia.

POLUS, A., POE, C. M. & MASON, J. M. REVIEW OF INTERNATIONAL DESIGN SPEED PRACTICES IN ROADWAY GEOMETRIC DESIGN. 1998. Transportation Research Board, p. 5:1-8.

RMS 2014-15. GIPSICAM Road Asset Viewer. 1.1.0 ed.

RMS 2016. Travel Time Analyser. v1.0 ed.

RTA 1991. Road Design Guide. Parramatta, NSW.

RTA 2000. GridLoc. 2.05 ed.

SA 2009. AS1742.2. *Appendix A - A Guide to the Determination of 85th Percentile Speed.*

VICROADS. 1993. New Road Design Procedures Affecting Saftey. *Part 1 changes to design speed*.

VICROADS 1994. Validation of Operating Speed Model. Australian Road Research Board.

APPENDIX A - PROJECT SPECIFICATION

For: Jarred Noon (0061005226)

Title: **An Assessment of the Deceleration on Horizontal Curve Component of the Austroads Operating Speed Estimation Model**

Major: Civil Engineering

Supervisor: Ron Ayers

Sponsorship: NSW Roads and Maritime Services

Enrolment: ENG4111 – EXT S1, 2016
ENG4112 – EXTS2, 2016

Project Aim: To assess the validity of the current Austroads operating speed estimation model in relation to deceleration on horizontal curves.

Programme: Issue B, 30th March 2016

1. Research the history of the design speed concept and its involvement in road design in Australia. Compare this to approaches adopted by various road authorities around the world.
2. Determine the key parameters affecting the deceleration of vehicles around horizontal curves. Develop a methodology to allow the collection of data relating to these key parameters.
3. Establish a suitable quantity of horizontal curve sites required in order to achieve meaningful results. Identify site locations with specific neutral controls. Detail the conditions of each site that may influence the speed at which a vehicle transverses a horizontal curve.
4. Analyse the data collected and compare the measured speed reductions with theoretical speed reductions.
5. Produce revised design models that are more applicable to the circumstances of today. Recommend potential amendments to current design standards that consider the evolution of driver speed behaviour and vehicle performance.
6. Report on the findings of the research in the required oral and written formats.

7. (If time permits) Consider the economic implications of proposed changes to the design standards.

Agreed:

Student: J. Noon Date: 30/3/16
(Jarred Noon)

Supervisor: ____________ Date: __/__/__
(Ron Ayers)

APPENDIX B – SPEED ENVIRONMENT MODEL

$$V_c(85) = 53{\cdot}8 + {\cdot}464\,V_F - \frac{3{\cdot}26 \times 10^3}{R} + \frac{8{\cdot}5 \times 10^4}{R^2}$$

$$r^2 = {\cdot}92$$

where

$V_c(85)$ = 85th percentile car curve speed (km/h)

V_F = desired speed of the 85th percentile car (km/h)

R = curve radius (m)

r_2 = proportion of variance of the dependent variable explained by the regression.

Figure 23 – Speed environment model (Mclean, 1979)

Table 6 – Speed prediction relationships (Mclean, 1979)

Desired speed (km/h)	Speed prediction relation
60	60–380/R
70	69–715/R
80	77–1 050/R
90	85–1 410/R
100	95–1 960/R
110	105–2 920/R
120	115–3 940/R

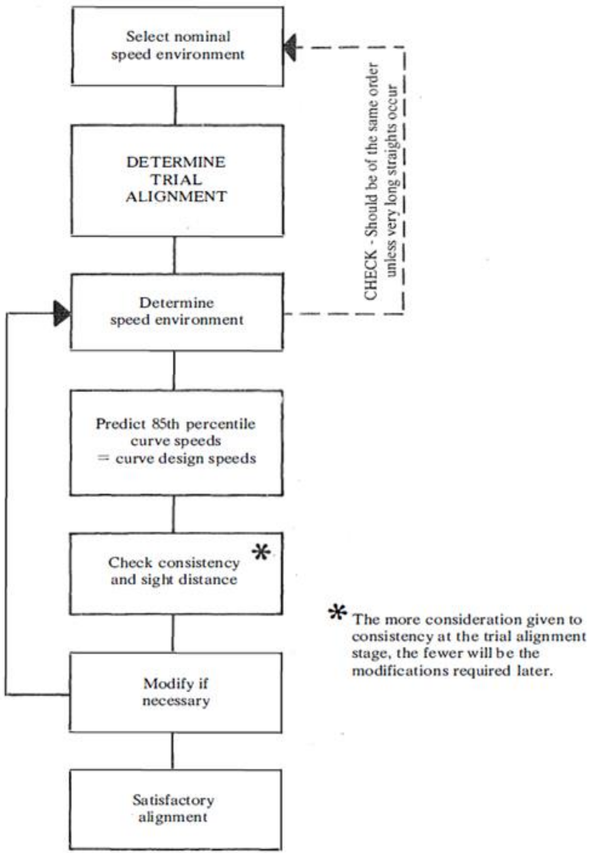


Figure 24 – Alignment selection procedure (NAASRA, 1980)

Table 5 – Speed environment values (NAASRA, 1980)

Approximate Range of Horizontal Curve Radii (b) (m)	Speed Environment km/h (c)			
	Terrain Type			
	Flat	Undulating	Hilly	Mountainous
Less than 75			75	70
75 - 300		90 (d)	85	(e)
150 - 500		100	95	
over 300 - 500	115 (d)	110	(e)	
over 600 - 700	120	(e)		

(a) Use also for one way carriageways of divided roads where geometrics are constrained.

(b) Value selected as representative of the road sections general geometric standard.

(c) The speed regarded as acceptable to most drivers in the particular environment, and represented by the 85th percentile speed on unconstrained sections, e.g. straights, curves with radii well above those listed.

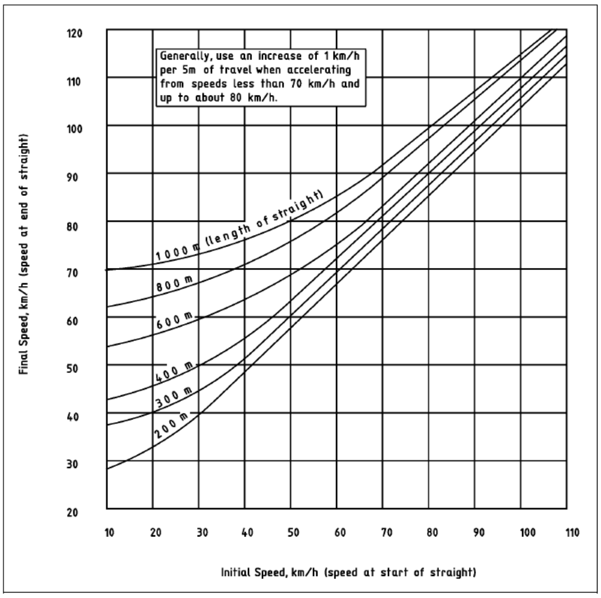
(d) Overall horizontal geometry below about R300 m (flat) or R100 m (undulating) will not be normal, so that speed environments below about 115 km/h and 90 km/h respectively should not be used. Should low design speed curves be necessary in such cases, see para 2.4.2.3.

(e) When economically justified, it may be that more liberal geometry than listed in undulating and mountainous terrain will be considered. In such cases, use the speed environment for the next less severe terrain type.

APPENDIX C – OPERATING SPEED MODEL

Table 7 – Section operating speeds (Austroads, 2010a)

Range of Radii In Section (m)	Single Curve Section Radius (m)	Section Operating Speed (km/h)
45-65	55	50
50-70	60	52
55-75	65	54
60-85	70	56
70-90	80	58
75-100	85	60
80-105	95	62
85-115	100	64
90-125	110	66
100-140	120	68
105-150	130	71
110-170	140	73
120-190	160	75
130-215	175	77
145-240	190	79
180-285	235	84
200-310	260	86
225-335	280	89
245-360	305	91
270-390	330	93
295-415	355	96
320-445	385	98
350-475	410	100
370-500	440	103
400-530	465	105
425-560	490	106
450-585	520	107
480-610	545	108
500-640	570	109
530+	600	110



Note: To use graph, enter the base of the graph at the initial speed of the vehicle, project vertically up to the line representing the length of the straight, then project horizontally left to read the speed at the end of the straight.

Figure 25 – Car acceleration on straights graph (Austroads, 2010a)

Table 8 – Typical desired speeds (Austroads, 2010a)

Approximate range of horizontal curve radii (m)[1]	Desired speed (km/h)[2, 3] terrain type			
	Flat	Undulating	Hilly	Mountainous
Less than 75	–	–	75	70
75 – 300	–	90	85	80
150 – 500	110	100 – 110	95	90
over 300 – 500	110	110	–	–
over 600 – 700	110 – 120	–	–	–

1. Value selected as representative of the road section's general geometric standard. These are not to be used as design values.
2. Desired speed as a function of overall geometric standard and terrain type. It is the speed regarded as acceptable to most drivers in the particular environment, and represented by the 85th percentile speed on unconstrained sections, e.g. straights, curves with radii well above those listed.
3. On roads with a speed limit < 100 km/h, the desired speed is typically equal to the speed limit + 10 km/h.

APPENDIX D – EXPANDED OPERATING SPEED MODEL

$$V = \frac{B \times V_d}{\left(1 + \frac{C}{r}\right)}$$

where

V	=	Speed on curve (km/h)
r	=	Radius of curve (m)
V_d	=	Approach speed (i.e. desired speed, km/h)
B and C	=	Coefficients specific to a curve approach speed (V_d), refer to Table F 1 and Table F 2

Figure 26 – Expanded operating speed model (Austroads, 2013)

Table 9 – Coefficients for best cases (Austroads, 2013)

Curve approach speed (km/h)	Curve sites	Curve radii range included	Coefficient values		Coefficient +/- errors		Adjusted r^2
			B	C	B	C	
100	12	90–400	1.079	39.861	0.026	4.899	0.937
90	12	90–400	1.093	37.385	0.020	3.747	0.939
80	11	90–320	1.069	27.086	0.019	3.119	0.922
70	11	90–320	1.056	18.627	0.018	2.899	0.856

APPENDIX E – METHODOLOGY

Table 10 – Conditions for speed data collection (SA, 2009)

Factor	Recommended criteria
Day of week	Monday to Friday
Time of day	6.00 am to 6.00 pm, but avoiding times of traffic congestion
Environmental conditions	Good weather, dry pavement
Sample vehicle selection	Vehicles travelling under free-flowing conditions only (see Note 1)
Sample vehicle type	All types to be included (see Note 2)
Site conditions	Site to be clear of permanent or transient features that may cause drivers to temporarily adjust speed
Position of measuring equipment	Equipment to be hidden or disguised so that measurements are taken without drivers being aware

NOTES:

1 A vehicle is considered to be operating under free-flowing conditions when the preceding vehicle has at least 4 s headway and there is no apparent attempt to overtake the vehicle ahead.

2 It is normal to aggregate the speed measurements of **all** vehicles for the purposes of assessing the statistical characteristics of a speed distribution. As far as practicable the major vehicle types should be sampled in proportion to their relative numbers in the stream.

	A	B	C	D	E	F	G	H	I	J	K	L
87345	27	10	-32.63150024	151.1692963	20120118	08:13.0	1	100	96	A	201201	Wednesday
87346	27	10	-32.63150024	151.1692963	20120119	02:35.0	1	100	100	A	201201	Thursday
87347	27	10	-32.63150024	151.1692963	20120328	06:48.0	1	100	83	A	201203	Wednesday
87348	27	10	-32.63150024	151.1692963	20120402	40:20.0	1	100	79	A	201204	Monday
87349	27	10	-32.63150024	151.1692963	20120427	16:02.0	1	100	90	A	201204	Friday
87350	27	10	-32.63150024	151.1692963	20121230	37:53.0	1	100	88	A	201212	Sunday
87351	27	10	-32.63150024	151.1692963	20130509	02:50.0	1	100	83	A	201305	Thursday
87352	27	10	-32.63150024	151.1692963	20130814	43:19.0	1	100	90	A	201308	Wednesday
87353	27	10	-32.63150024	151.1692963	20150530	22:29.0	1	100	101	A	201505	Saturday
87354	27	10	-32.63150024	151.1692963	20150909	26:15.0	1	100	90	A	201509	Wednesday
87355	27	10	-32.63150024	151.1692963	20160504	25:22.0	1	100	99	A	201605	Wednesday
87356	27	10	-32.63150024	151.1694031	20081203	47:03.0	0	100	96	A	200812	Wednesday
87357	27	10	-32.63150024	151.1694031	20090625	00:07.0	1	100	103	A	200906	Thursday
87358	27	10	-32.63150024	151.1694031	20090907	05:15.0	0	100	94	A	200909	Monday
87359	27	10	-32.63150024	151.1694031	20100415	27:50.0	0	100	93	A	201004	Thursday
87360	27	10	-32.63150024	151.1694031	20100420	54:25.0	0	100	97	A	201004	Tuesday
87361	27	10	-32.63150024	151.1694031	20130205	29:02.0	1	100	93	A	201302	Tuesday
87362	27	10	-32.63150024	151.1694031	20130219	36:35.0	1	100	85	A	201302	Tuesday
87363	27	10	-32.63150024	151.1694031	20130813	52:19.0	1	100	88	A	201308	Tuesday
87364	27	10	-32.63150024	151.1694031	20141216	46:20.0	1	100	98	A	201412	Tuesday
87365	27	10	-32.63150024	151.1694031	20150127	36:49.0	1	100	92	A	201501	Tuesday
87366	27	10	-32.63150024	151.1694031	20150914	43:42.0	1	100	97	A	201509	Monday
87367	27	10	-32.63150024	151.1694946	20120208	11:22.0	1	100	93	A	201202	Wednesday
87368	27	10	-32.63150024	151.1694946	20120402	40:15.0	1	100	100	A	201204	Monday
87369	27	10	-32.63150024	151.1694946	20130316	56:15.0	1	100	86	A	201303	Saturday
87370	27	10	-32.63150024	151.1694946	20130826	52:13.0	1	100	76	A	201308	Monday
87371	27	10	-32.63150024	151.1696014	20100501	29:12.0	0	100	97	A	201005	Saturday
87372	27	10	-32.63150024	151.1743011	20111214	13:15.0	1	100	0	A	201112	Wednesday
87373	27	10	-32.63150024	151.1744995	20091119	12:00.0	1	100	72	A	200911	Thursday
87374	27	10	-32.63150024	151.1746979	20090530	31:00.0	1	100	97	A	200905	Saturday
87375	27	10	-32.63150024	151.1748047	20090609	06:49.0	1	100	86	A	200906	Tuesday
87376	27	10	-32.63150024	151.1748047	20090904	42:12.0	1	100	79	A	200909	Friday
87377	27	10	-32.63150024	151.1748047	20130514	42:07.0	1	100	88	A	201305	Tuesday
87378	27	10	-32.63150024	151.1748047	20150217	37:15.0	1	100	91	A	201502	Tuesday
87379	27	10	-32.63150024	151.1748047	20151006	35:19.0	1	100	90	A	201510	Tuesday
87380	27	10	-32.63150024	151.1748962	20090522	41:19.0	1	100	104	A	200905	Friday
87381	27	10	-32.63150024	151.1748962	20090924	06:37.0	1	100	91	A	200909	Thursday

Figure 27 – Raw data screenshot

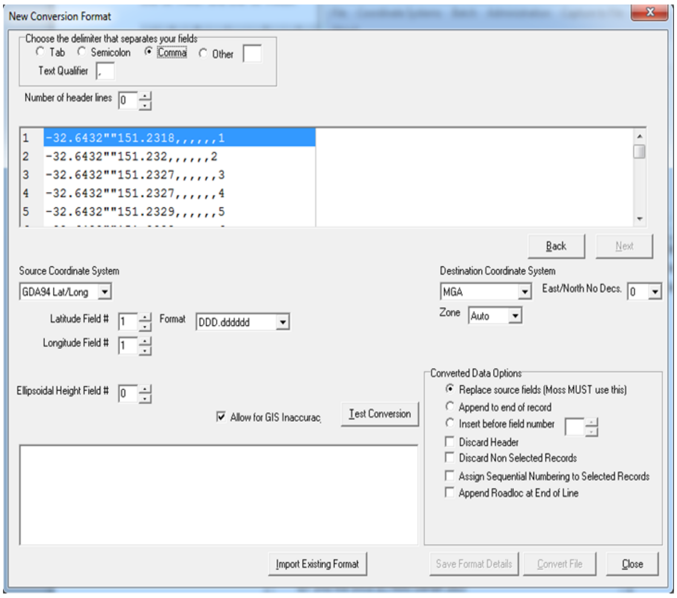


Figure 28 – Gridloc conversion screenshot (RTA, 2000)

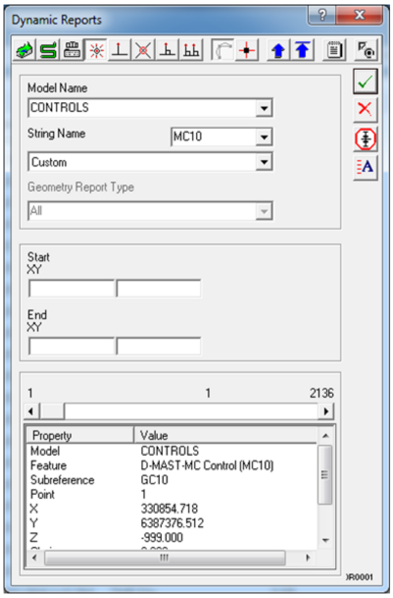


Figure 29 – MX Road dynamic report screenshot (Bentley, 2015)

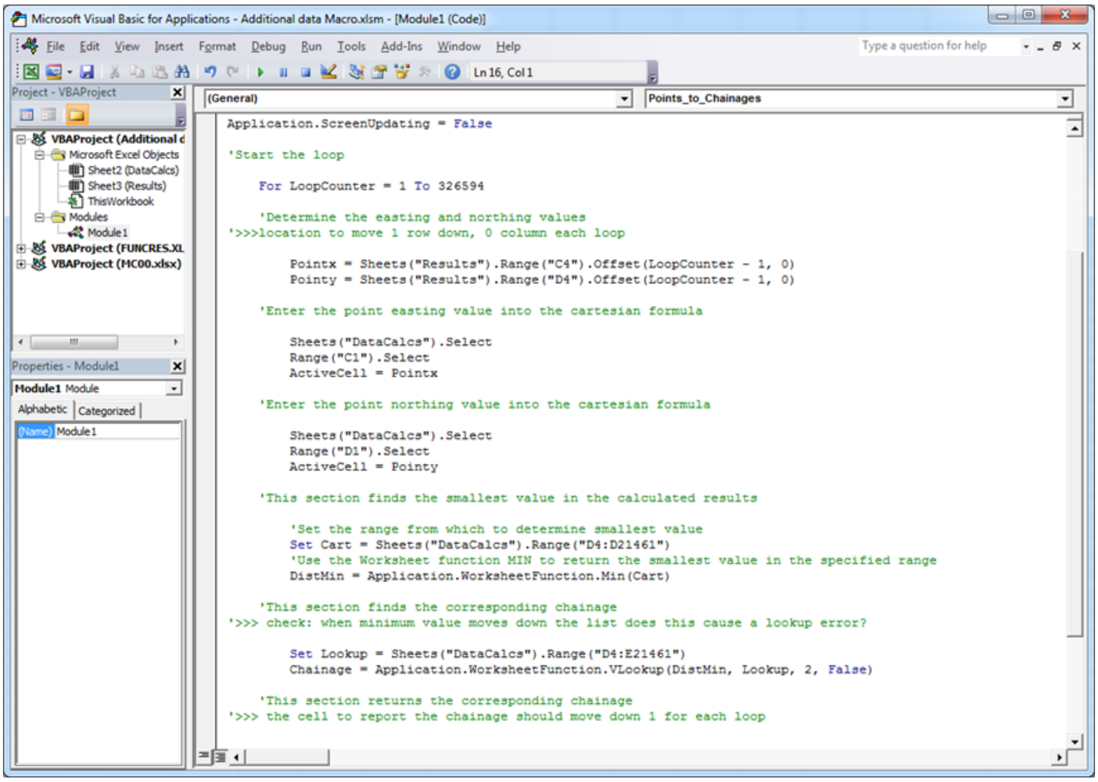


Figure 30 – Cartesian analysis – visual basic macro screenshot

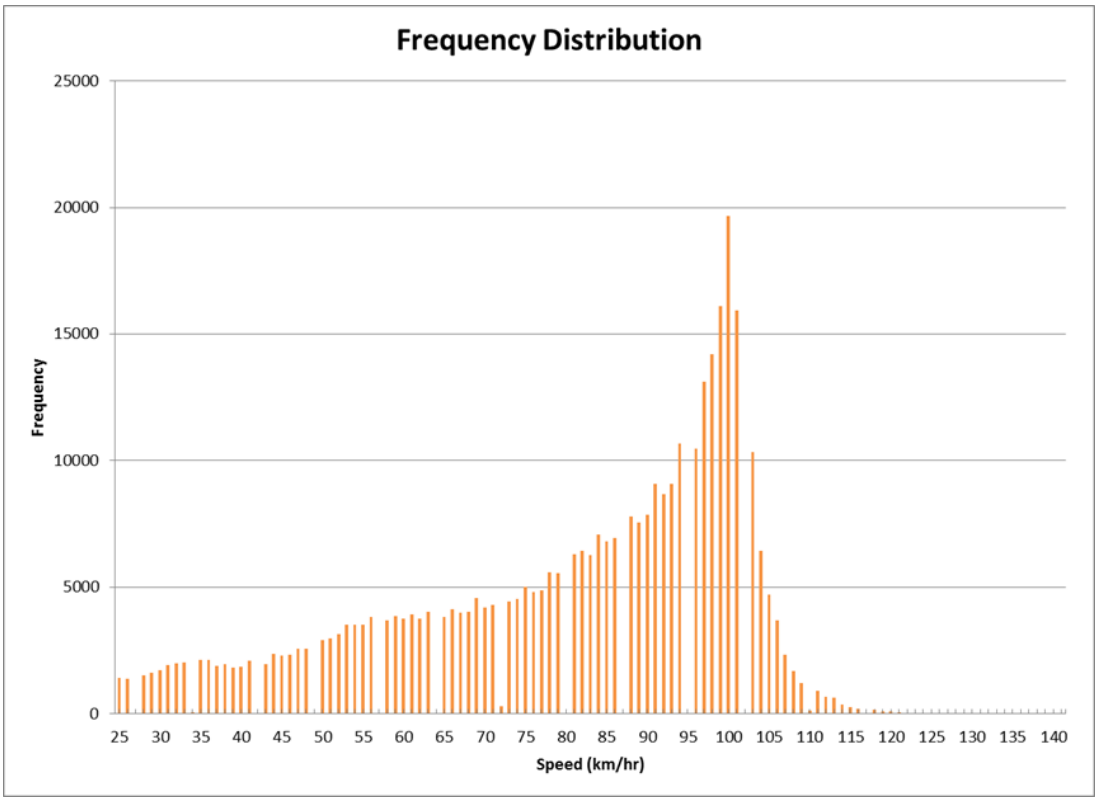


Figure 31 – Frequency distribution plot

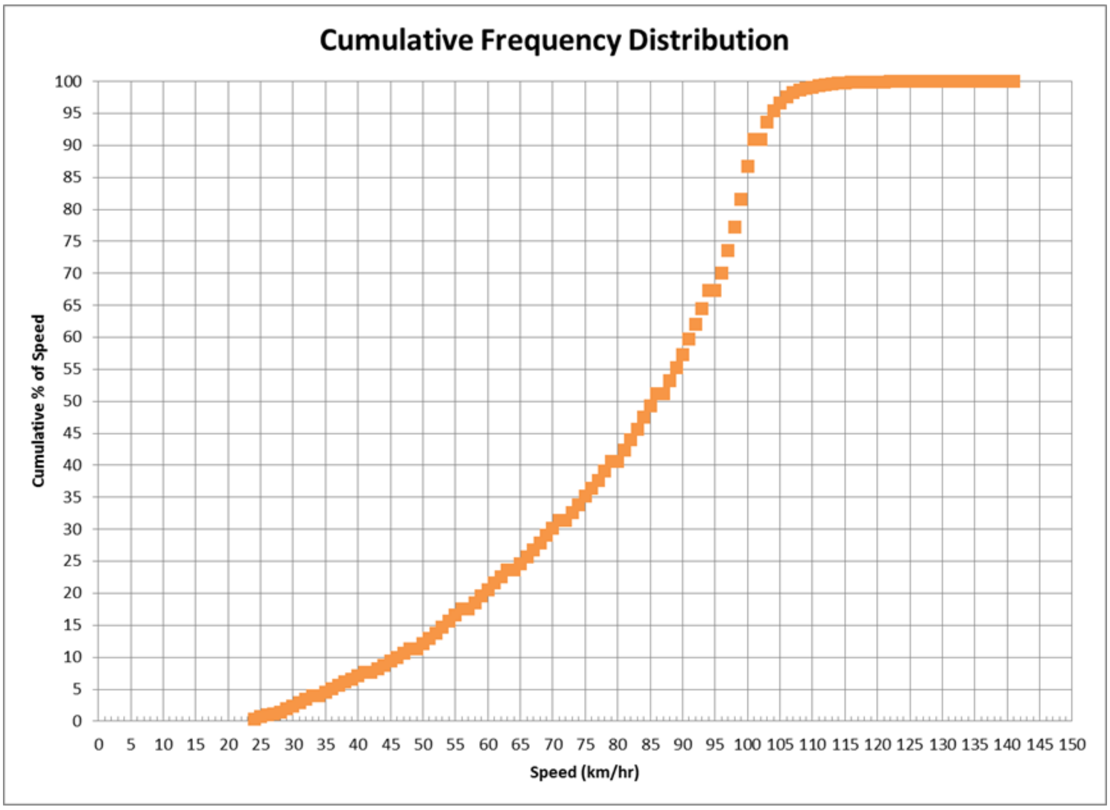
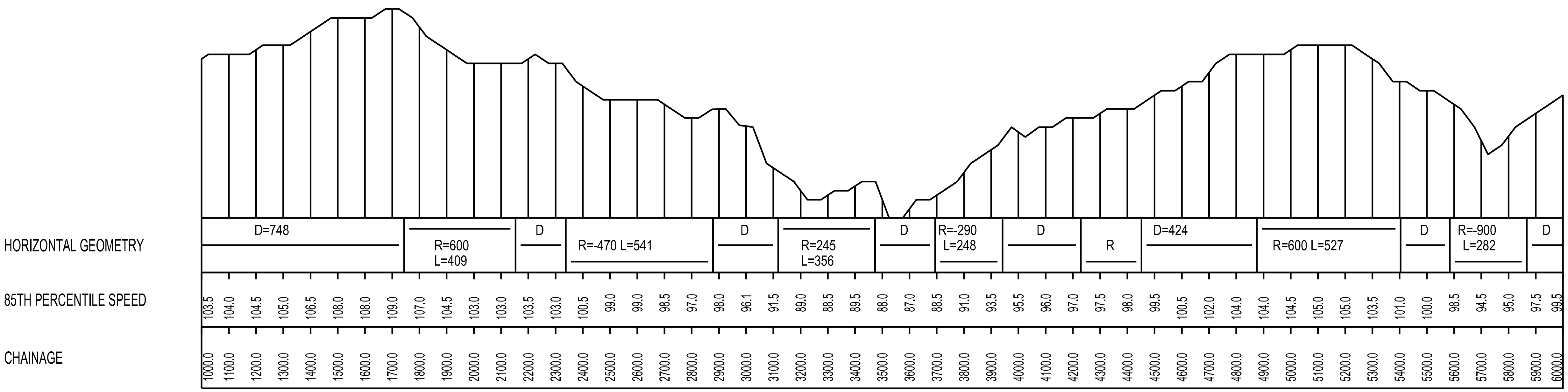
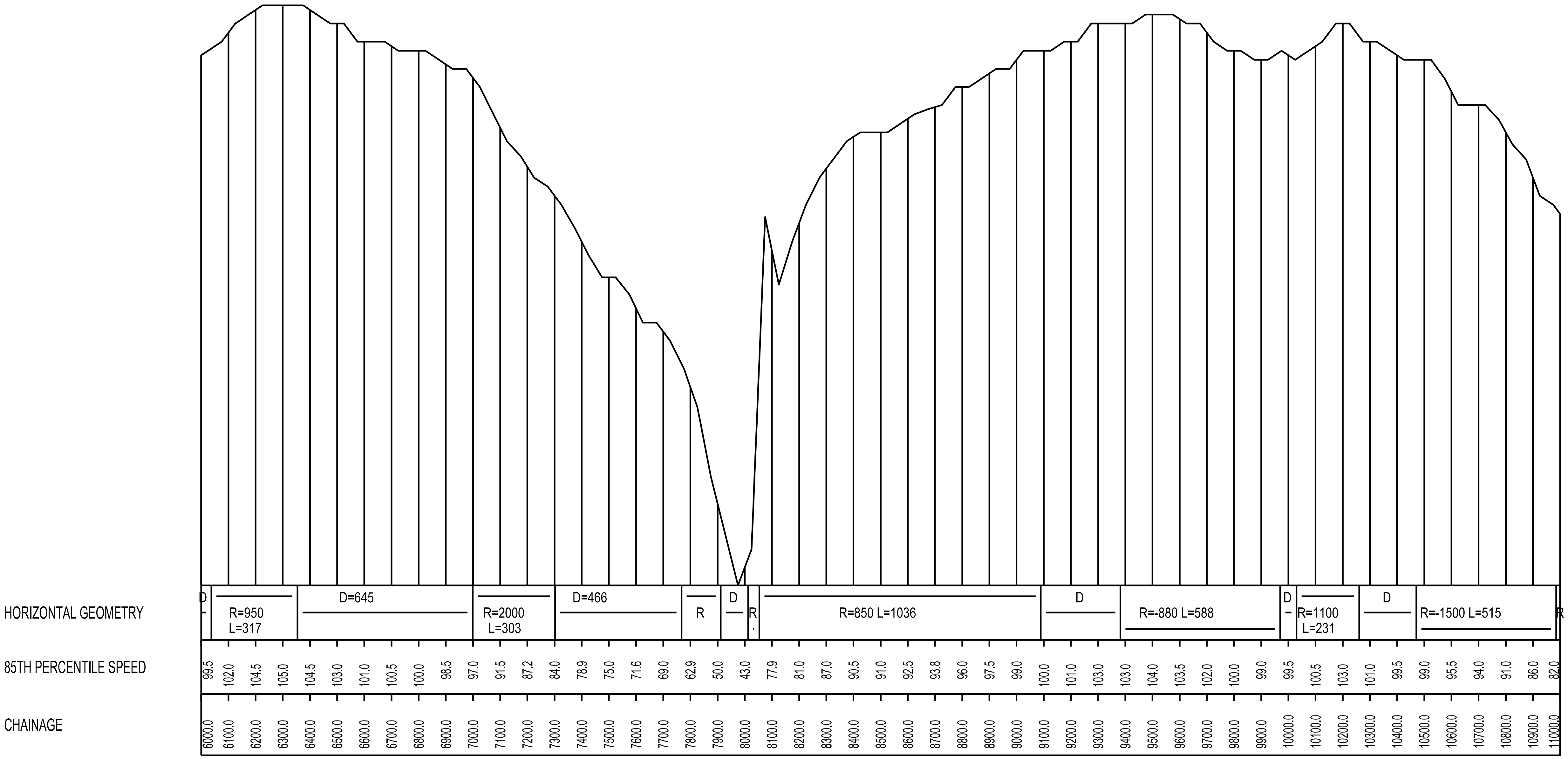


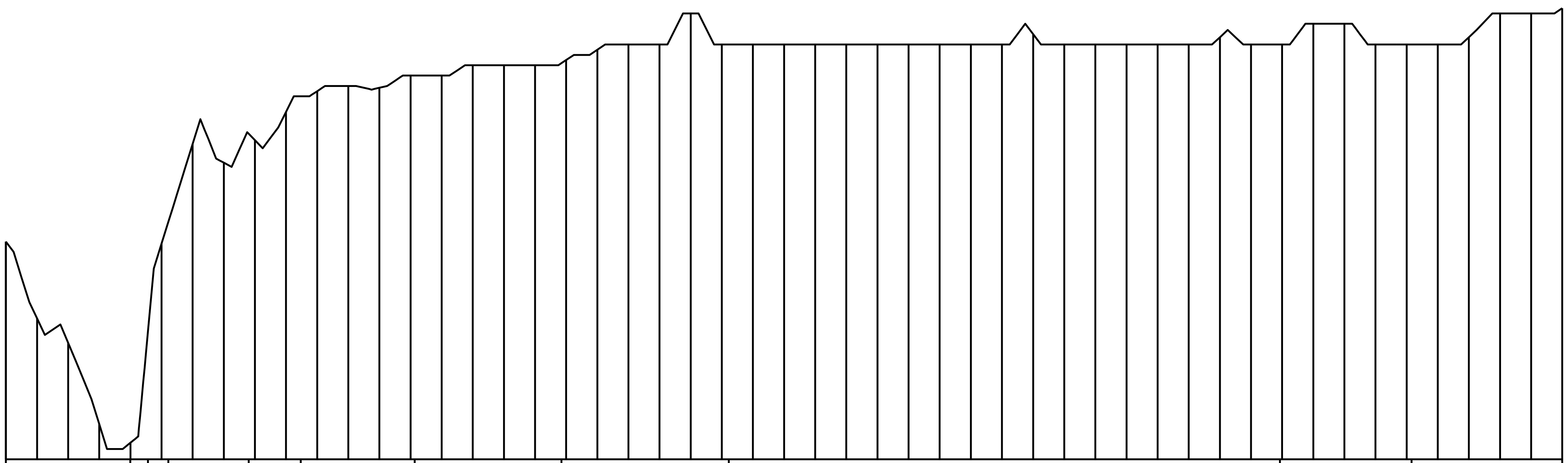
Figure 32 – Cumulative frequency distribution plot

APPENDIX F – 85th PERCENTILE SPEED PROFILE



HORIZONTAL GEOMETRY
85TH PERCENTILE SPEED
CHAINAGE
D=748
R=600 L=409
D
R=-470 L=541
D
R=245 L=356
D
R=-290 L=248
D
R
D=424
R=600 L=527
D
R=-900 L=282
D
103.5 104.0 104.5 105.0 106.5 108.0 108.0 109.0 107.0 104.5 103.0 103.0 103.5 103.0 100.5 99.0 99.0 98.5 97.0 98.0 96.1 91.5 89.0 88.5 89.5 88.0 87.0 88.5 91.0 93.5 95.5 96.0 97.0 97.5 98.0 99.5 100.5 102.0 104.0 104.0 104.5 105.0 105.0 103.5 101.0 100.0 98.5 94.5 95.0 97.5 99.5
1000.0 1100.0 1200.0 1300.0 1400.0 1500.0 1600.0 1700.0 1800.0 1900.0 2000.0 2100.0 2200.0 2300.0 2400.0 2500.0 2600.0 2700.0 2800.0 2900.0 3000.0 3100.0 3200.0 3300.0 3400.0 3500.0 3600.0 3700.0 3800.0 3900.0 4000.0 4100.0 4200.0 4300.0 4400.0 4500.0 4600.0 4700.0 4800.0 4900.0 5000.0 5100.0 5200.0 5300.0 5400.0 5500.0 5600.0 5700.0 5800.0 5900.0 6000.0

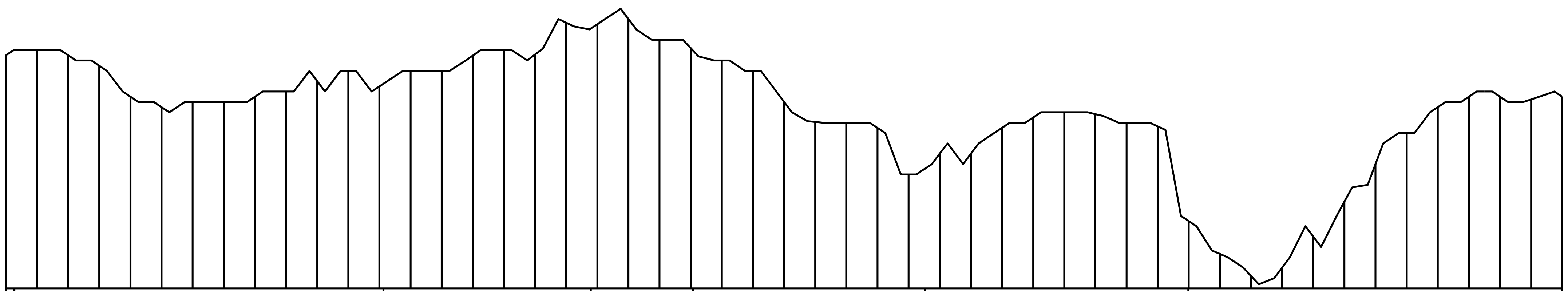

HORIZONTAL GEOMETRY
D
R=950 L=317
D=645
R=2000 L=303
D=466
R
D
R
R=850 L=1036
D
R=-880 L=588
D
R=1100 L=231
D
R=-1500 L=515
R
85TH PERCENTILE SPEED
99.5 102.0 104.5 105.0 104.5 103.0 101.0 100.5 100.0 98.5 97.0 91.5 87.2 84.0 78.9 75.0 71.6 69.0 62.9 50.0 43.0 77.9 81.0 87.0 90.5 91.0 92.5 93.8 96.0 97.5 99.0 100.0 101.0 103.0 103.0 104.0 103.5 102.0 100.0 99.0 99.5 100.5 103.0 101.0 99.5 99.0 95.5 94.0 91.0 86.0 82.0
CHAINAGE
6000.0 6100.0 6200.0 6300.0 6400.0 6500.0 6600.0 6700.0 6800.0 6900.0 7000.0 7100.0 7200.0 7300.0 7400.0 7500.0 7600.0 7700.0 7800.0 7900.0 8000.0 8100.0 8200.0 8300.0 8400.0 8500.0 8600.0 8700.0 8800.0 8900.0 9000.0 9100.0 9200.0 9300.0 9400.0 9500.0 9600.0 9700.0 9800.0 9900.0 10000.0 10100.0 10200.0 10300.0 10400.0 10500.0 10600.0 10700.0 10800.0 10900.0 11000.0



HORIZONTAL GEOMETRY

R=-2000 L=414	- R
D -	R=-300 L=258
D	R=490 L=366
D=472	R=-1100 L=537
D=1771	R=-560 L=423
D=511	

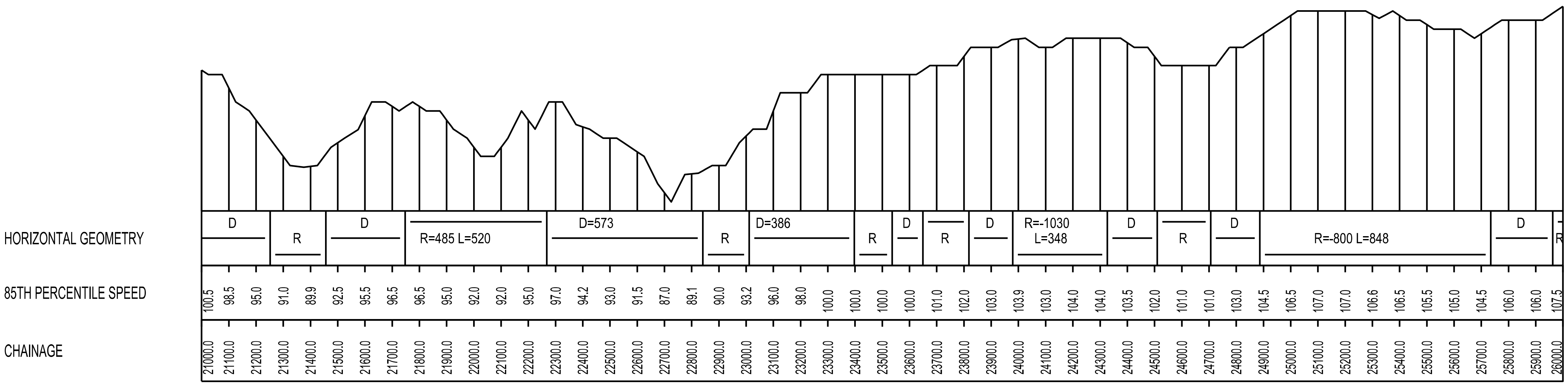
CHAINAGE	85TH PERCENTILE SPEED
11000.0	82.0
11100.0	74.6
11200.0	72.2
11300.0	64.4
11400.0	62.6
11500.0	81.8
11600.0	91.4
11700.0	89.6
11800.0	91.8
11900.0	94.5
12000.0	96.5
12100.0	97.0
12200.0	96.8
12300.0	98.0
12400.0	98.0
12500.0	99.0
12600.0	99.0
12700.0	99.0
12800.0	99.5
12900.0	100.5
13000.0	101.0
13100.0	101.0
13200.0	104.0
13300.0	101.0
13400.0	101.0
13500.0	101.0
13600.0	101.0
13700.0	101.0
13800.0	101.0
13900.0	101.0
14000.0	101.0
14100.0	101.0
14200.0	101.0
14300.0	102.0
14400.0	101.0
14500.0	101.0
14600.0	101.0
14700.0	101.0
14800.0	101.0
14900.0	101.7
15000.0	101.0
15100.0	101.0
15200.0	103.0
15300.0	103.0
15400.0	101.0
15500.0	101.0
15600.0	101.0
15700.0	101.7
15800.0	104.0
15900.0	104.0
16000.0	104.5



HORIZONTAL GEOMETRY

D | R=-3650 L=1185 | D=666 | R=-770 L=328 | D=746 | R=805 L=846 | D=1453

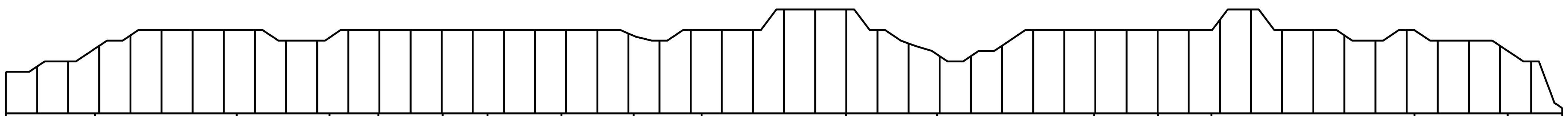
CHAINAGE	85TH PERCENTILE SPEED
16000.0	104.5
16100.0	105.0
16200.0	104.5
16300.0	103.5
16400.0	100.5
16500.0	99.5
16600.0	100.0
16700.0	100.0
16800.0	100.5
16900.0	101.0
17000.0	102.0
17100.0	103.0
17200.0	101.5
17300.0	103.0
17400.0	103.0
17500.0	104.5
17600.0	105.0
17700.0	104.6
17800.0	107.6
17900.0	107.5
18000.0	108.0
18100.0	106.0
18200.0	105.2
18300.0	104.0
18400.0	103.0
18500.0	100.0
18600.0	98.1
18700.0	98.0
18800.0	97.5
18900.0	93.0
19000.0	95.0
19100.0	95.0
19200.0	97.5
19300.0	98.5
19400.0	99.0
19500.0	98.8
19600.0	98.0
19700.0	97.6
19800.0	88.5
19900.0	85.3
20000.0	83.2
20100.0	84.0
20200.0	87.0
20300.0	90.4
20400.0	94.0
20500.0	97.0
20600.0	99.5
20700.0	100.5
20800.0	100.5
20900.0	100.2
21000.0	100.5


HORIZONTAL GEOMETRY
85TH PERCENTILE SPEED
CHAINAGE
D
R
D
R=485 L=520
D=573
R
D=386
R
D
R
D
R=-1030
L=348
D
R
D
R=-800 L=848
D
R
100.5
98.5
95.0
91.0
89.9
92.5
95.5
96.5
96.5
95.0
92.0
92.0
95.0
97.0
94.2
93.0
91.5
87.0
89.1
90.0
93.2
96.0
98.0
100.0
100.0
100.0
100.0
101.0
102.0
103.0
103.9
103.0
104.0
104.0
103.5
102.0
101.0
101.0
103.0
104.5
106.5
107.0
107.0
106.6
106.5
105.5
105.0
104.5
106.0
106.0
107.5
21000.0
21100.0
21200.0
21300.0
21400.0
21500.0
21600.0
21700.0
21800.0
21900.0
22000.0
22100.0
22200.0
22300.0
22400.0
22500.0
22600.0
22700.0
22800.0
22900.0
23000.0
23100.0
23200.0
23300.0
23400.0
23500.0
23600.0
23700.0
23800.0
23900.0
24000.0
24100.0
24200.0
24300.0
24400.0
24500.0
24600.0
24700.0
24800.0
24900.0
25000.0
25100.0
25200.0
25300.0
25400.0
25500.0
25600.0
25700.0
25800.0
25900.0
26000.0

HORIZONTAL GEOMETRY

R=800 L=594 | D | R=-805 L=526 | D=2518 | R=705 L=847 | D=345 | R

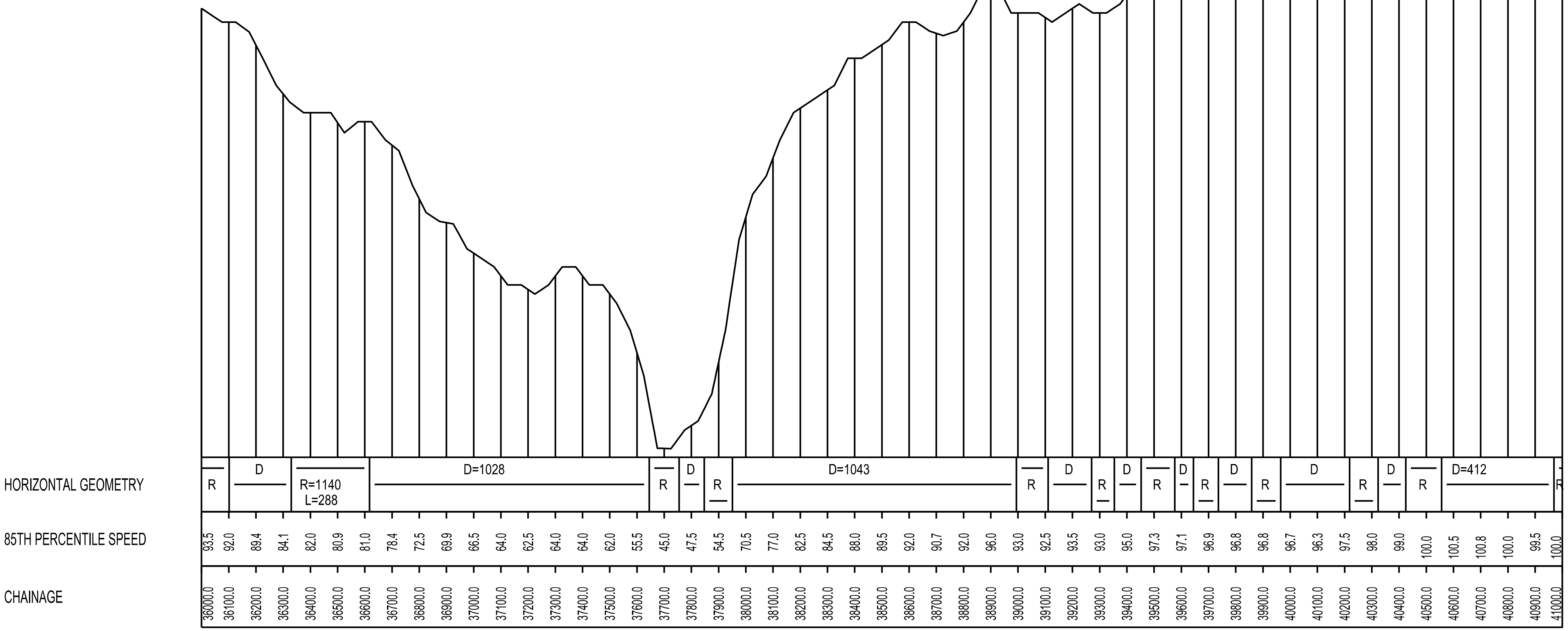
CHAINAGE	85TH PERCENTILE SPEED
26000.0	107.5
26100.0	108.0
26200.0	107.5
26300.0	108.0
26400.0	107.5
26500.0	107.0
26600.0	109.0
26700.0	106.9
26800.0	106.5
26900.0	105.0
27000.0	103.5
27100.0	101.5
27200.0	99.5
27300.0	99.4
27400.0	100.0
27500.0	100.0
27600.0	100.0
27700.0	101.0
27800.0	102.0
27900.0	103.0
28000.0	103.0
28100.0	103.0
28200.0	103.0
28300.0	103.0
28400.0	102.0
28500.0	99.5
28600.0	95.0
28700.0	94.0
28800.0	93.2
28900.0	89.1
29000.0	89.0
29100.0	92.0
29200.0	97.5
29300.0	97.5
29400.0	95.5
29500.0	93.7
29600.0	86.6
29700.0	94.9
29800.0	86.1
29900.0	89.0
30000.0	90.7
30100.0	80.5
30200.0	73.5
30300.0	80.5
30400.0	90.5
30500.0	86.1
30600.0	91.0
30700.0	94.0
30800.0	94.5
30900.0	97.0
31000.0	97.0

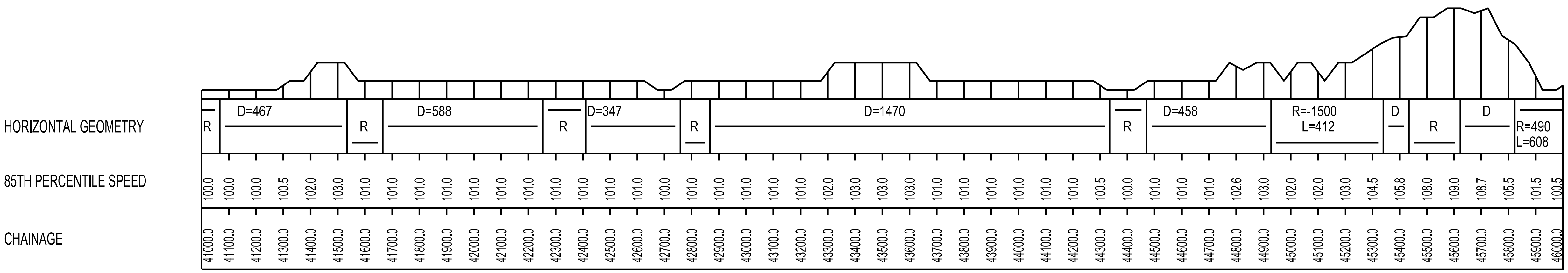


HORIZONTAL GEOMETRY

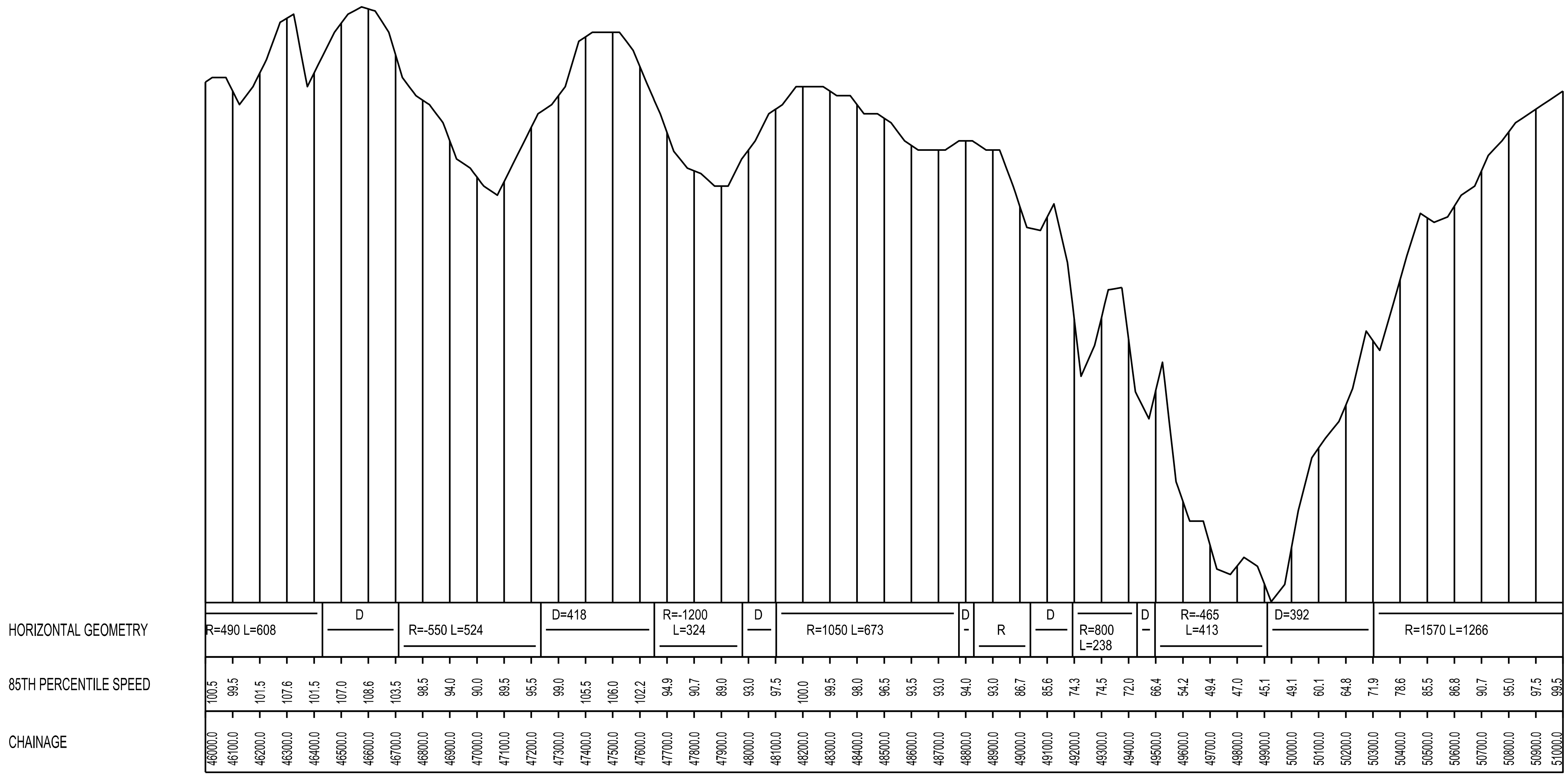
R=-720 L=289	D=455
R=-460 L=298	D
R	D
R=610 L=238	D
R=500 L=218	D=464
R=980 L=293	D=505
R	D
R=-810 L=653	D
R=980 L=277	

CHAINAGE	85TH PERCENTILE SPEED
31000.0	97.0
31100.0	97.5
31200.0	98.0
31300.0	99.5
31400.0	100.5
31500.0	101.0
31600.0	101.0
31700.0	101.0
31800.0	101.0
31900.0	100.0
32000.0	100.0
32100.0	101.0
32200.0	101.0
32300.0	101.0
32400.0	101.0
32500.0	101.0
32600.0	101.0
32700.0	101.0
32800.0	101.0
32900.0	101.0
33000.0	100.7
33100.0	100.0
33200.0	101.0
33300.0	101.0
33400.0	101.0
33500.0	103.0
33600.0	103.0
33700.0	103.0
33800.0	101.0
33900.0	99.7
34000.0	98.5
34100.0	98.5
34200.0	99.5
34300.0	101.0
34400.0	101.0
34500.0	101.0
34600.0	101.0
34700.0	101.0
34800.0	101.0
34900.0	102.0
35000.0	103.0
35100.0	101.0
35200.0	101.0
35300.0	100.5
35400.0	100.0
35500.0	101.0
35600.0	100.0
35700.0	100.0
35800.0	99.5
35900.0	98.0
36000.0	93.5

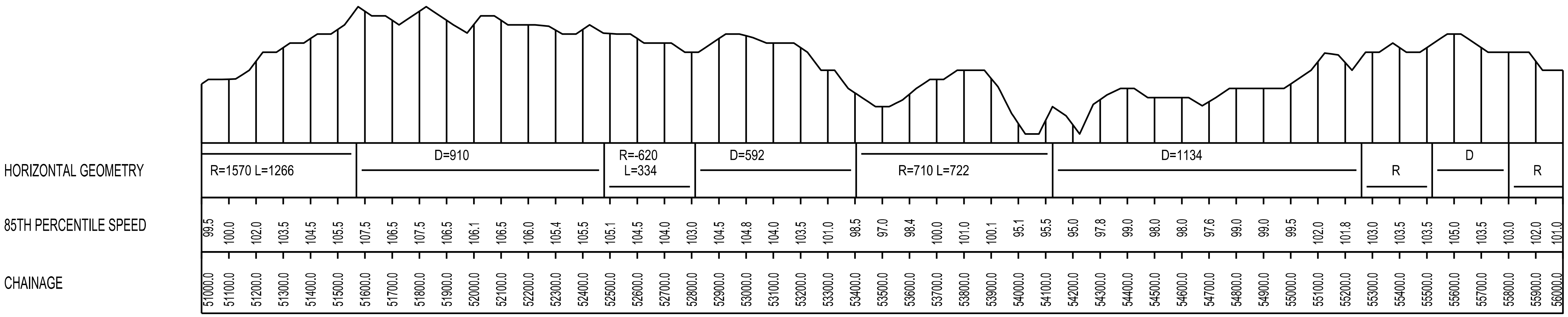

HORIZONTAL GEOMETRY
R D R=1140 L=288 D=1028 R D R D=1043 R D R D R D R D R D R D R D=412 R
85TH PERCENTILE SPEED
93.5 92.0 89.4 84.1 82.0 80.9 81.0 78.4 72.5 69.9 66.5 64.0 62.5 64.0 64.0 62.0 55.5 45.0 47.5 54.5 70.5 77.0 82.5 84.5 88.0 89.5 92.0 90.7 92.0 96.0 93.0 92.5 93.5 93.0 95.0 97.3 97.1 96.9 96.8 96.8 96.7 96.3 97.5 98.0 99.0 100.0 100.5 100.8 100.0 99.5 100.0
CHAINAGE
36000.0 36100.0 36200.0 36300.0 36400.0 36500.0 36600.0 36700.0 36800.0 36900.0 37000.0 37100.0 37200.0 37300.0 37400.0 37500.0 37600.0 37700.0 37800.0 37900.0 38000.0 38100.0 38200.0 38300.0 38400.0 38500.0 38600.0 38700.0 38800.0 38900.0 39000.0 39100.0 39200.0 39300.0 39400.0 39500.0 39600.0 39700.0 39800.0 39900.0 40000.0 40100.0 40200.0 40300.0 40400.0 40500.0 40600.0 40700.0 40800.0 40900.0 41000.0

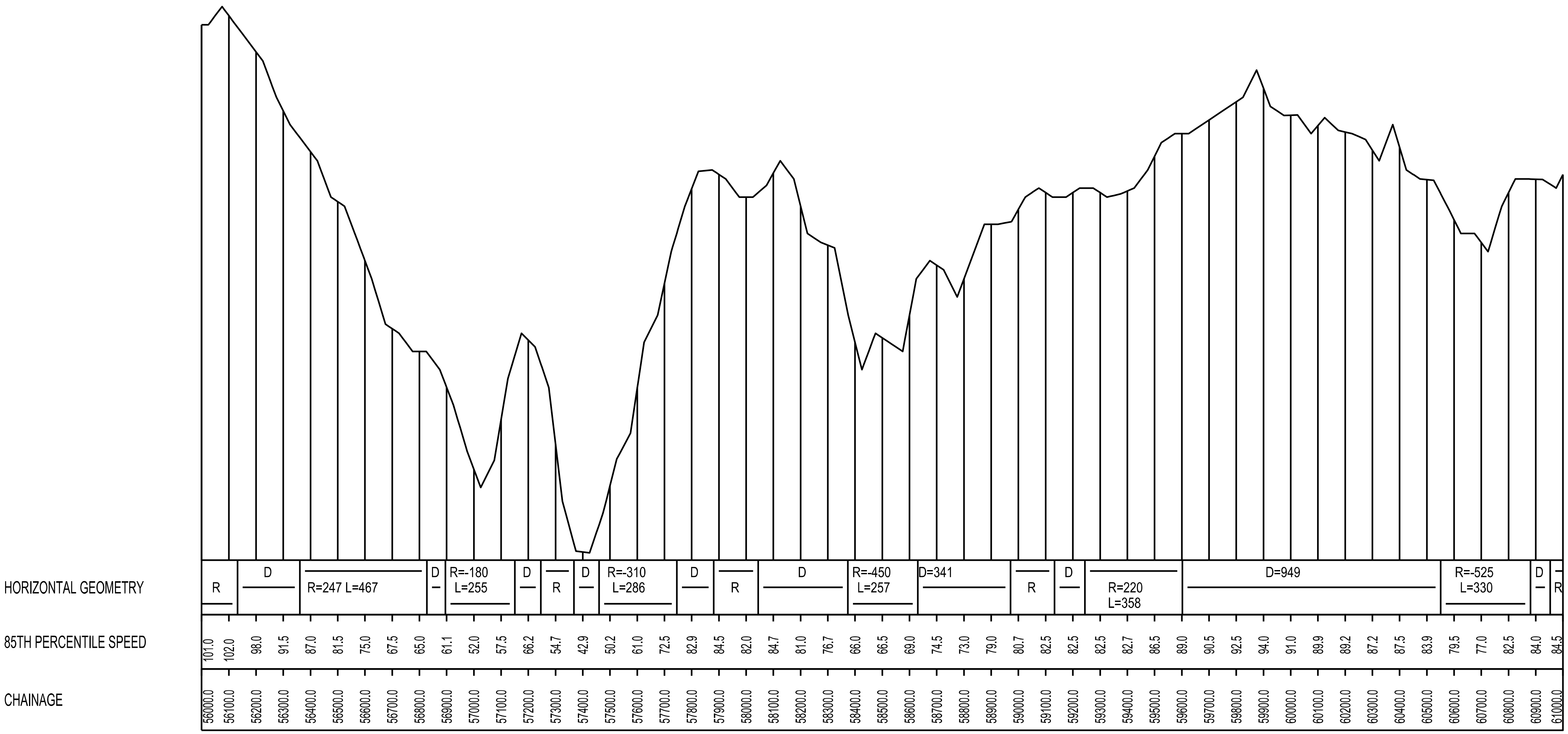


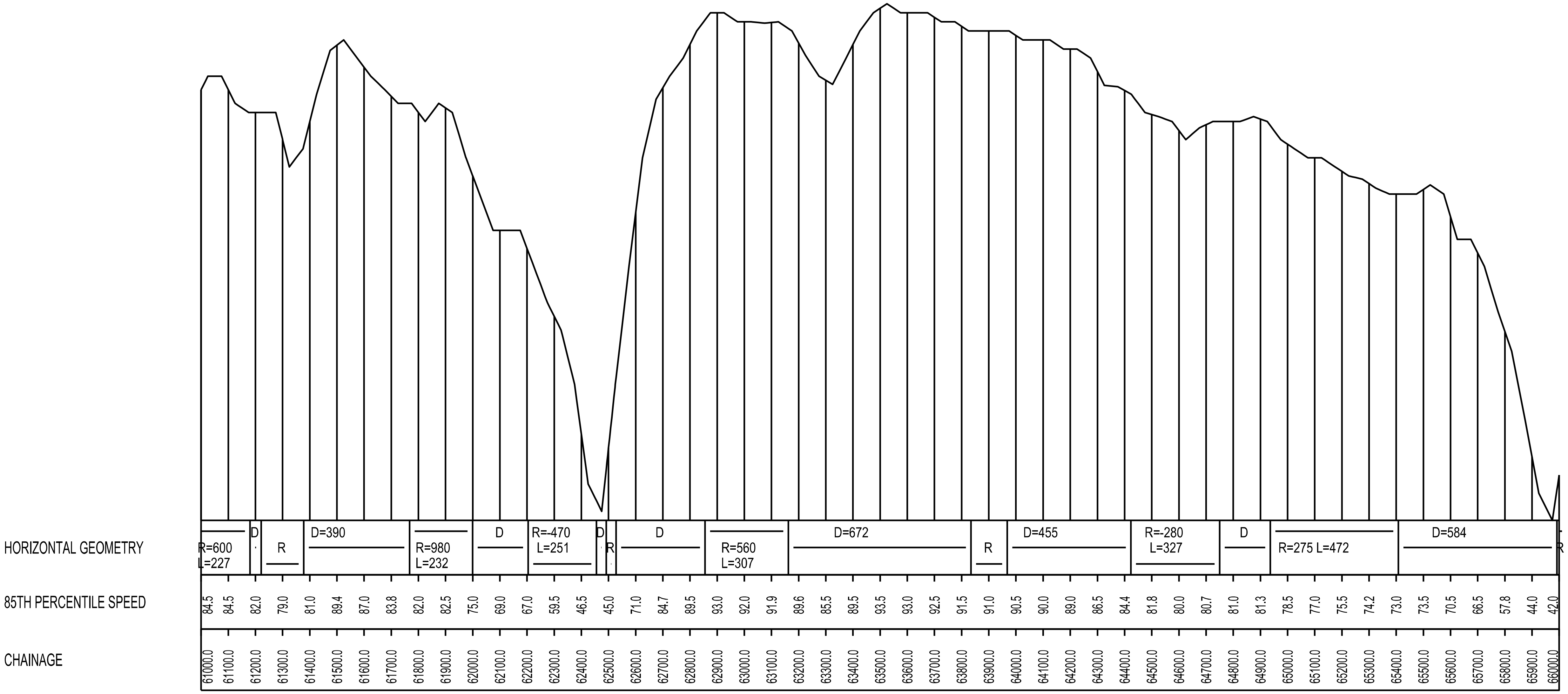
HORIZONTAL GEOMETRY
R
D=467
R
D=588
R
D=347
R
D=1470
R
D=458
R=-1500
L=412
D
R
D
R=490
L=608
85TH PERCENTILE SPEED
100.0 100.0 100.0 100.5 102.0 103.0 101.0 101.0 101.0 101.0 101.0 101.0 101.0 101.0 101.0 101.0 101.0 100.0 101.0 101.0 101.0 101.0 101.0 102.0 103.0 103.0 103.0 101.0 101.0 101.0 101.0 101.0 101.0 100.5 100.0 101.0 101.0 101.0 102.6 103.0 102.0 102.0 103.0 104.5 105.8 108.0 109.0 108.7 105.5 101.5 100.5
CHAINAGE
41000.0 41100.0 41200.0 41300.0 41400.0 41500.0 41600.0 41700.0 41800.0 41900.0 42000.0 42100.0 42200.0 42300.0 42400.0 42500.0 42600.0 42700.0 42800.0 42900.0 43000.0 43100.0 43200.0 43300.0 43400.0 43500.0 43600.0 43700.0 43800.0 43900.0 44000.0 44100.0 44200.0 44300.0 44400.0 44500.0 44600.0 44700.0 44800.0 44900.0 45000.0 45100.0 45200.0 45300.0 45400.0 45500.0 45600.0 45700.0 45800.0 45900.0 46000.0

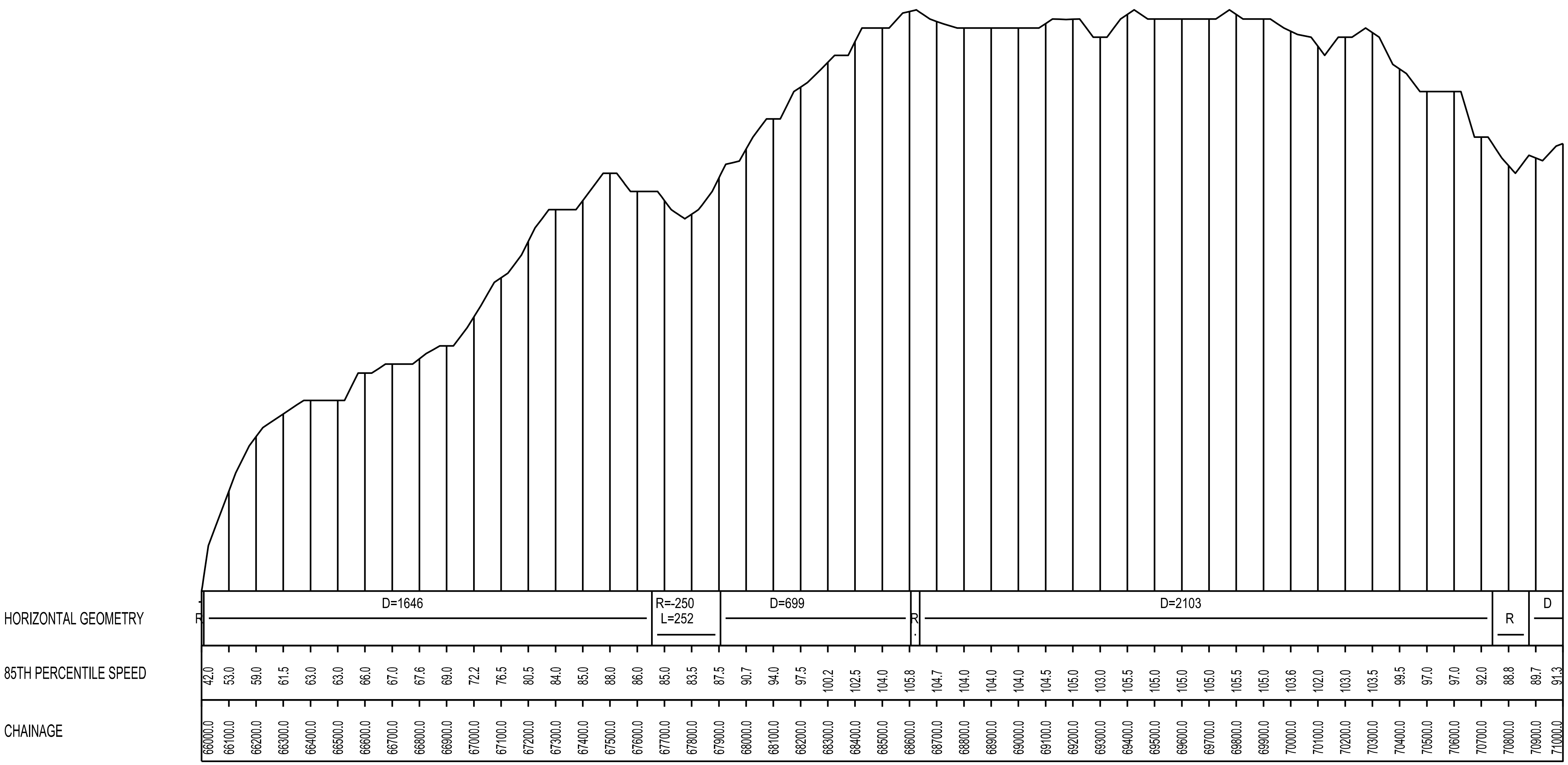


HORIZONTAL GEOMETRY
R=490 L=608
D
R=-550 L=524
D=418
R=-1200 L=324
D
R=1050 L=673
D
R
D
R=800 L=238
D
R=-465 L=413
D=392
R=1570 L=1266
85TH PERCENTILE SPEED
100.5 99.5 101.5 107.6 101.5 107.0 108.6 103.5 98.5 94.0 90.0 89.5 95.5 99.0 105.5 106.0 102.2 94.9 90.7 89.0 93.0 97.5 100.0 99.5 98.0 96.5 93.5 93.0 94.0 93.0 86.7 85.6 74.3 74.5 72.0 66.4 54.2 49.4 47.0 45.1 49.1 60.1 64.8 71.9 78.6 85.5 86.8 90.7 95.0 97.5 99.5
CHAINAGE
46000.0 46100.0 46200.0 46300.0 46400.0 46500.0 46600.0 46700.0 46800.0 46900.0 47000.0 47100.0 47200.0 47300.0 47400.0 47500.0 47600.0 47700.0 47800.0 47900.0 48000.0 48100.0 48200.0 48300.0 48400.0 48500.0 48600.0 48700.0 48800.0 48900.0 49000.0 49100.0 49200.0 49300.0 49400.0 49500.0 49600.0 49700.0 49800.0 49900.0 50000.0 50100.0 50200.0 50300.0 50400.0 50500.0 50600.0 50700.0 50800.0 50900.0 51000.0

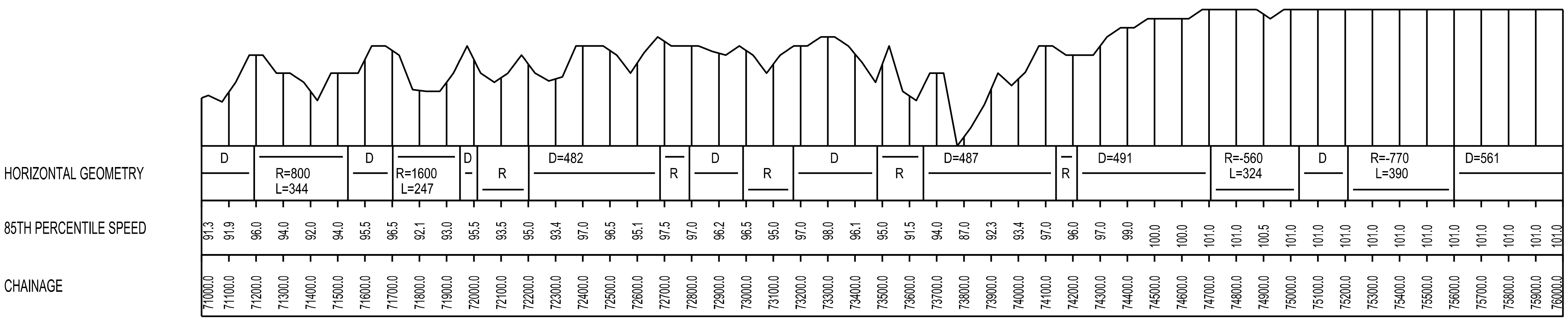

HORIZONTAL GEOMETRY
R=1570 L=1266
D=910
R=-620
L=334
D=592
R=710 L=722
D=1134
R
D
R
85TH PERCENTILE SPEED
99.5 100.0 102.0 103.5 104.5 105.5 107.5 106.5 107.5 106.5 106.1 106.5 106.0 105.4 105.5 105.1 104.5 104.0 103.0 104.5 104.8 104.0 103.5 101.0 98.5 97.0 98.4 100.0 101.0 100.1 95.1 95.5 95.0 97.8 99.0 98.0 98.0 97.6 99.0 99.0 99.5 102.0 101.8 103.0 103.5 103.5 105.0 103.5 103.0 102.0 101.0
CHAINAGE
51000.0 51100.0 51200.0 51300.0 51400.0 51500.0 51600.0 51700.0 51800.0 51900.0 52000.0 52100.0 52200.0 52300.0 52400.0 52500.0 52600.0 52700.0 52800.0 52900.0 53000.0 53100.0 53200.0 53300.0 53400.0 53500.0 53600.0 53700.0 53800.0 53900.0 54000.0 54100.0 54200.0 54300.0 54400.0 54500.0 54600.0 54700.0 54800.0 54900.0 55000.0 55100.0 55200.0 55300.0 55400.0 55500.0 55600.0 55700.0 55800.0 55900.0 56000.0

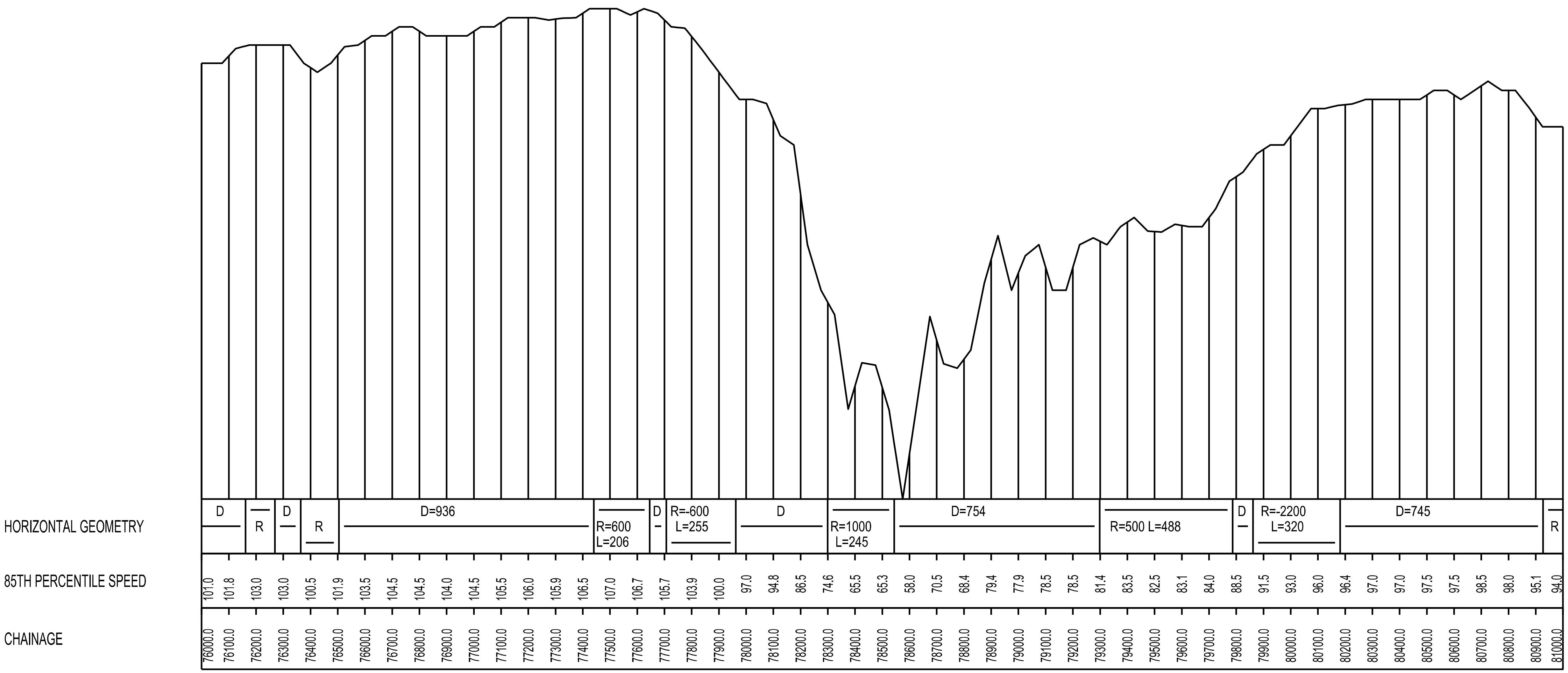

HORIZONTAL GEOMETRY
R
D
R=247 L=467
D
R=-180 L=255
D
R
D
R=-310 L=286
D
R
D
R=-450 L=257
D=341
R
D
R=220 L=358
D=949
R=-525 L=330
D
R
85TH PERCENTILE SPEED
101.0 102.0 98.0 91.5 87.0 81.5 75.0 67.5 65.0 61.1 52.0 57.5 66.2 54.7 42.9 50.2 61.0 72.5 82.9 84.5 82.0 84.7 81.0 76.7 66.0 66.5 69.0 74.5 73.0 79.0 80.7 82.5 82.5 82.5 82.7 86.5 89.0 90.5 92.5 94.0 91.0 89.9 89.2 87.2 87.5 83.9 79.5 77.0 82.5 84.0 84.5
CHAINAGE
56000.0 56100.0 56200.0 56300.0 56400.0 56500.0 56600.0 56700.0 56800.0 56900.0 57000.0 57100.0 57200.0 57300.0 57400.0 57500.0 57600.0 57700.0 57800.0 57900.0 58000.0 58100.0 58200.0 58300.0 58400.0 58500.0 58600.0 58700.0 58800.0 58900.0 59000.0 59100.0 59200.0 59300.0 59400.0 59500.0 59600.0 59700.0 59800.0 59900.0 60000.0 60100.0 60200.0 60300.0 60400.0 60500.0 60600.0 60700.0 60800.0 60900.0 61000.0


HORIZONTAL GEOMETRY
85TH PERCENTILE SPEED
CHAINAGE
R=600 L=227
D
R
D=390
R=980 L=232
D
R=-470 L=251
D
R
D
R=560 L=307
D=672
R
D=455
R=-280 L=327
D
R=275 L=472
D=584
R
84.5 84.5 82.0 79.0 81.0 89.4 87.0 83.8 82.0 82.5 75.0 69.0 67.0 59.5 46.5 45.0 71.0 84.7 89.5 93.0 92.0 91.9 89.6 85.5 89.5 93.5 93.0 92.5 91.5 91.0 90.5 90.0 89.0 86.5 84.4 81.8 80.0 80.7 81.0 81.3 78.5 77.0 75.5 74.2 73.0 73.5 70.5 66.5 57.8 44.0 42.0
61000.0 61100.0 61200.0 61300.0 61400.0 61500.0 61600.0 61700.0 61800.0 61900.0 62000.0 62100.0 62200.0 62300.0 62400.0 62500.0 62600.0 62700.0 62800.0 62900.0 63000.0 63100.0 63200.0 63300.0 63400.0 63500.0 63600.0 63700.0 63800.0 63900.0 64000.0 64100.0 64200.0 64300.0 64400.0 64500.0 64600.0 64700.0 64800.0 64900.0 65000.0 65100.0 65200.0 65300.0 65400.0 65500.0 65600.0 65700.0 65800.0 65900.0 66000.0



HORIZONTAL GEOMETRY
R
D=1646
R=-250
L=252
D=699
R
D=2103
R
D
85TH PERCENTILE SPEED
42.0 53.0 59.0 61.5 63.0 63.0 66.0 67.0 67.6 69.0 72.2 76.5 80.5 84.0 85.0 88.0 86.0 85.0 83.5 87.5 90.7 94.0 97.5 100.2 102.5 104.0 105.8 104.7 104.0 104.0 104.0 104.5 105.0 103.0 105.5 105.0 105.0 105.0 105.5 105.0 103.6 102.0 103.0 103.5 99.5 97.0 97.0 92.0 88.8 89.7 91.3
CHAINAGE
66000.0 66100.0 66200.0 66300.0 66400.0 66500.0 66600.0 66700.0 66800.0 66900.0 67000.0 67100.0 67200.0 67300.0 67400.0 67500.0 67600.0 67700.0 67800.0 67900.0 68000.0 68100.0 68200.0 68300.0 68400.0 68500.0 68600.0 68700.0 68800.0 68900.0 69000.0 69100.0 69200.0 69300.0 69400.0 69500.0 69600.0 69700.0 69800.0 69900.0 70000.0 70100.0 70200.0 70300.0 70400.0 70500.0 70600.0 70700.0 70800.0 70900.0 71000.0


HORIZONTAL GEOMETRY
D
R=800
L=344
D
R=1600
L=247
D
R
D=482
R
D
R
D
R
D=487
R
D=491
R=-560
L=324
D
R=-770
L=390
D=561
85TH PERCENTILE SPEED
91.3 91.9 96.0 94.0 92.0 94.0 95.5 96.5 92.1 93.0 95.5 93.5 95.0 93.4 97.0 96.5 95.1 97.5 97.0 96.2 96.5 95.0 97.0 98.0 96.1 95.0 91.5 94.0 87.0 92.3 93.4 97.0 96.0 97.0 99.0 100.0 100.0 101.0 101.0 100.5 101.0 101.0 101.0 101.0 101.0 101.0 101.0 101.0 101.0 101.0 101.0
CHAINAGE
71000.0 71100.0 71200.0 71300.0 71400.0 71500.0 71600.0 71700.0 71800.0 71900.0 72000.0 72100.0 72200.0 72300.0 72400.0 72500.0 72600.0 72700.0 72800.0 72900.0 73000.0 73100.0 73200.0 73300.0 73400.0 73500.0 73600.0 73700.0 73800.0 73900.0 74000.0 74100.0 74200.0 74300.0 74400.0 74500.0 74600.0 74700.0 74800.0 74900.0 75000.0 75100.0 75200.0 75300.0 75400.0 75500.0 75600.0 75700.0 75800.0 75900.0 76000.0


HORIZONTAL GEOMETRY
D
R
D
R
D=936
R=600
L=206
D
R=-600
L=255
D
R=1000
L=245
D=754
R=500 L=488
D
R=-2200
L=320
D=745
R
85TH PERCENTILE SPEED
101.0
101.8
103.0
103.0
100.5
101.9
103.5
104.5
104.5
104.0
104.5
105.5
106.0
105.9
106.5
107.0
106.7
105.7
103.9
100.0
97.0
94.8
86.5
74.6
65.5
65.3
58.0
70.5
68.4
79.4
77.9
78.5
78.5
81.4
83.5
82.5
83.1
84.0
88.5
91.5
93.0
96.0
96.4
97.0
97.0
97.5
97.5
98.5
98.0
95.1
94.0
CHAINAGE
76000.0
76100.0
76200.0
76300.0
76400.0
76500.0
76600.0
76700.0
76800.0
76900.0
77000.0
77100.0
77200.0
77300.0
77400.0
77500.0
77600.0
77700.0
77800.0
77900.0
78000.0
78100.0
78200.0
78300.0
78400.0
78500.0
78600.0
78700.0
78800.0
78900.0
79000.0
79100.0
79200.0
79300.0
79400.0
79500.0
79600.0
79700.0
79800.0
79900.0
80000.0
80100.0
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80700.0
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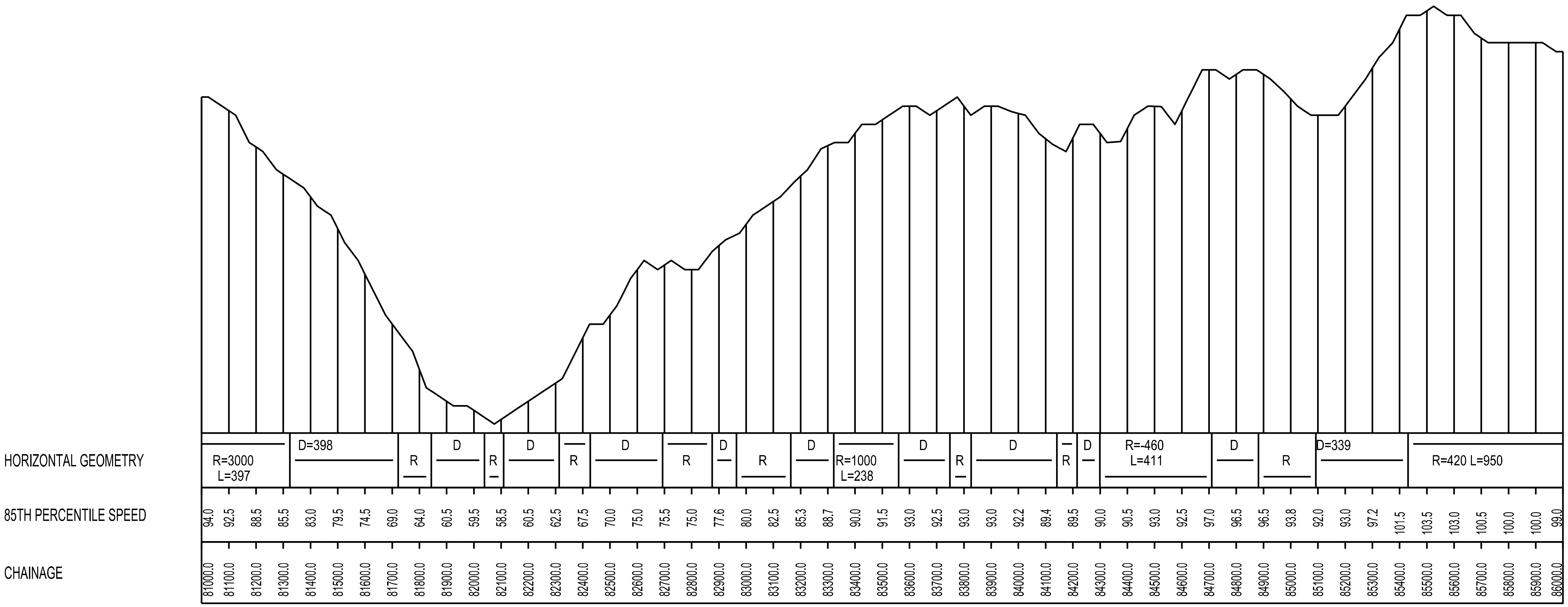
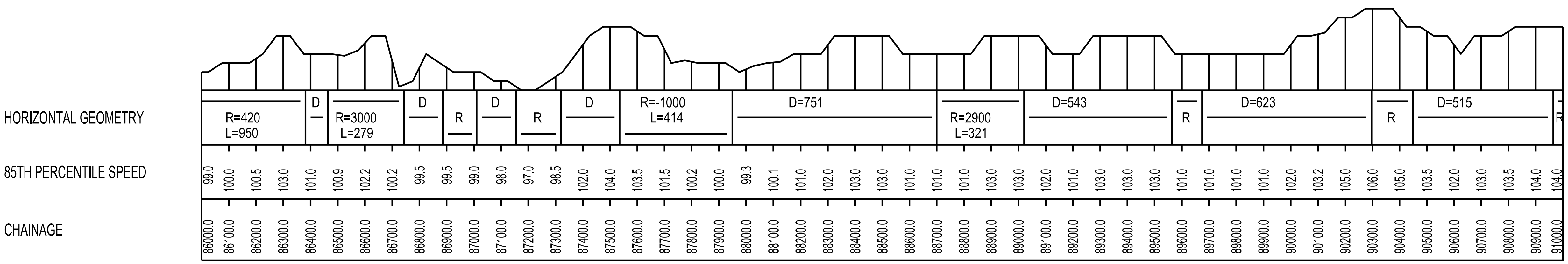
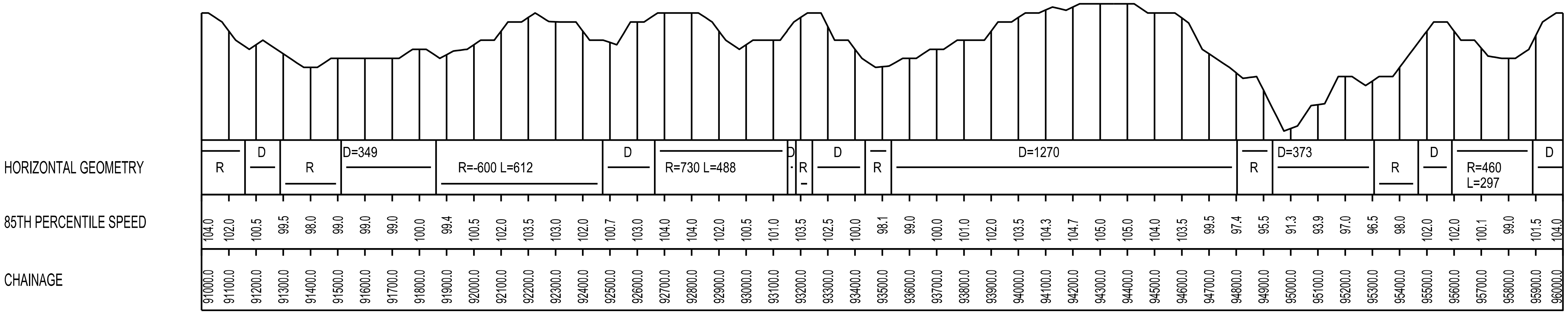
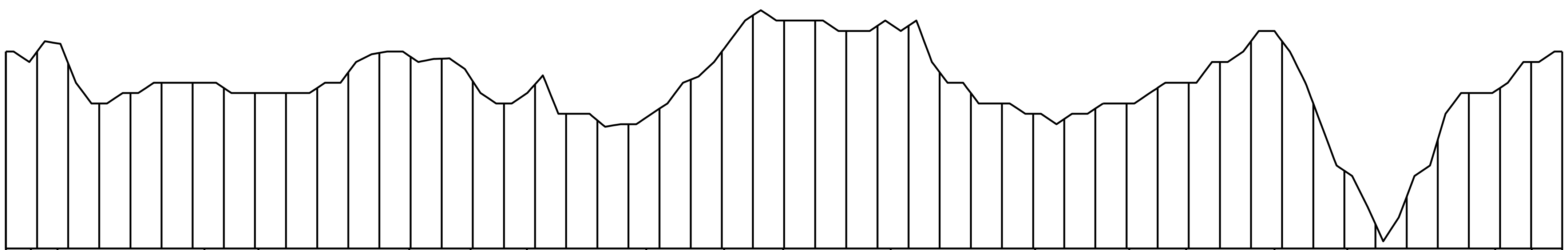
80900.0
81000.0


HORIZONTAL GEOMETRY
R=3000
L=397
D=398
R
D
R
D
R
D
R
D
R
D
R=1000
L=238
D
R
D
R
D
R=-460
L=411
D
R
D=339
R=420 L=950
85TH PERCENTILE SPEED
94.0 92.5 88.5 85.5 83.0 79.5 74.5 69.0 64.0 60.5 59.5 58.5 60.5 62.5 67.5 70.0 75.0 75.5 75.0 77.6 80.0 82.5 85.3 88.7 90.0 91.5 93.0 92.5 93.0 93.0 92.2 89.4 89.5 90.0 90.5 93.0 92.5 97.0 96.5 96.5 93.8 92.0 93.0 97.2 101.5 103.5 103.0 100.5 100.0 100.0 99.0
CHAINAGE
81000.0 81100.0 81200.0 81300.0 81400.0 81500.0 81600.0 81700.0 81800.0 81900.0 82000.0 82100.0 82200.0 82300.0 82400.0 82500.0 82600.0 82700.0 82800.0 82900.0 83000.0 83100.0 83200.0 83300.0 83400.0 83500.0 83600.0 83700.0 83800.0 83900.0 84000.0 84100.0 84200.0 84300.0 84400.0 84500.0 84600.0 84700.0 84800.0 84900.0 85000.0 85100.0 85200.0 85300.0 85400.0 85500.0 85600.0 85700.0 85800.0 85900.0 86000.0


HORIZONTAL GEOMETRY
R=420
L=950
D
R=3000
L=279
D
R
D
R
D
R=-1000
L=414
D=751
R=2900
L=321
D=543
R
D=623
R
D=515
R
85TH PERCENTILE SPEED
99.0 100.0 100.5 103.0 101.0 100.9 102.2 100.2 99.5 99.5 99.0 98.0 97.0 98.5 102.0 104.0 103.5 101.5 100.2 100.0 99.3 100.1 101.0 102.0 103.0 103.0 101.0 101.0 101.0 103.0 103.0 102.0 101.0 103.0 103.0 103.0 101.0 101.0 101.0 101.0 102.0 103.2 105.0 106.0 105.0 103.5 102.0 103.0 103.5 104.0 104.0
CHAINAGE
86000.0 86100.0 86200.0 86300.0 86400.0 86500.0 86600.0 86700.0 86800.0 86900.0 87000.0 87100.0 87200.0 87300.0 87400.0 87500.0 87600.0 87700.0 87800.0 87900.0 88000.0 88100.0 88200.0 88300.0 88400.0 88500.0 88600.0 88700.0 88800.0 88900.0 89000.0 89100.0 89200.0 89300.0 89400.0 89500.0 89600.0 89700.0 89800.0 89900.0 90000.0 90100.0 90200.0 90300.0 90400.0 90500.0 90600.0 90700.0 90800.0 90900.0 91000.0



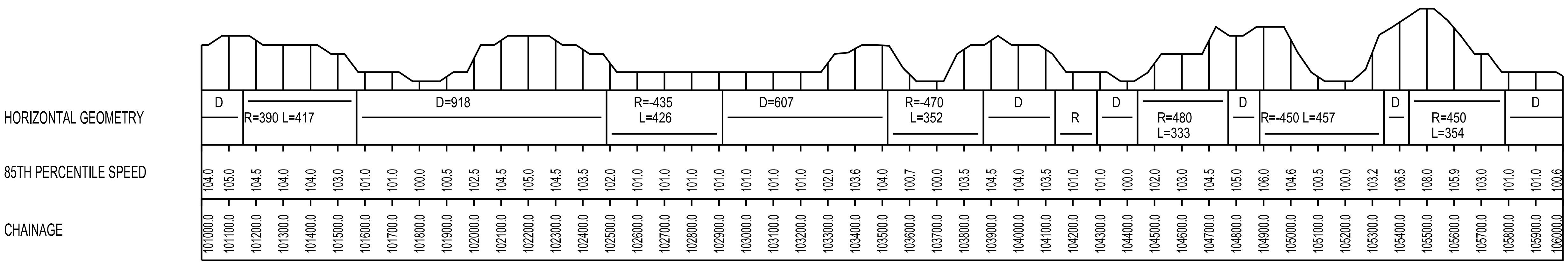
HORIZONTAL GEOMETRY
85TH PERCENTILE SPEED
CHAINAGE
R
D
R
D=349
R=-600 L=612
D
R=730 L=488
D
R
D
R
D=1270
R
D=373
R
D
R=460
L=297
D
104.0 102.0 100.5 99.5 98.0 99.0 99.0 99.0 100.0 99.4 100.5 102.0 103.5 103.0 102.0 100.7 103.0 104.0 104.0 102.0 100.5 101.0 103.5 102.5 100.0 98.1 99.0 100.0 101.0 102.0 103.5 104.3 104.7 105.0 105.0 104.0 103.5 99.5 97.4 95.5 91.3 93.9 97.0 96.5 98.0 102.0 102.0 100.1 99.0 101.5 104.0
91000.0 91100.0 91200.0 91300.0 91400.0 91500.0 91600.0 91700.0 91800.0 91900.0 92000.0 92100.0 92200.0 92300.0 92400.0 92500.0 92600.0 92700.0 92800.0 92900.0 93000.0 93100.0 93200.0 93300.0 93400.0 93500.0 93600.0 93700.0 93800.0 93900.0 94000.0 94100.0 94200.0 94300.0 94400.0 94500.0 94600.0 94700.0 94800.0 94900.0 95000.0 95100.0 95200.0 95300.0 95400.0 95500.0 95600.0 95700.0 95800.0 95900.0 96000.0

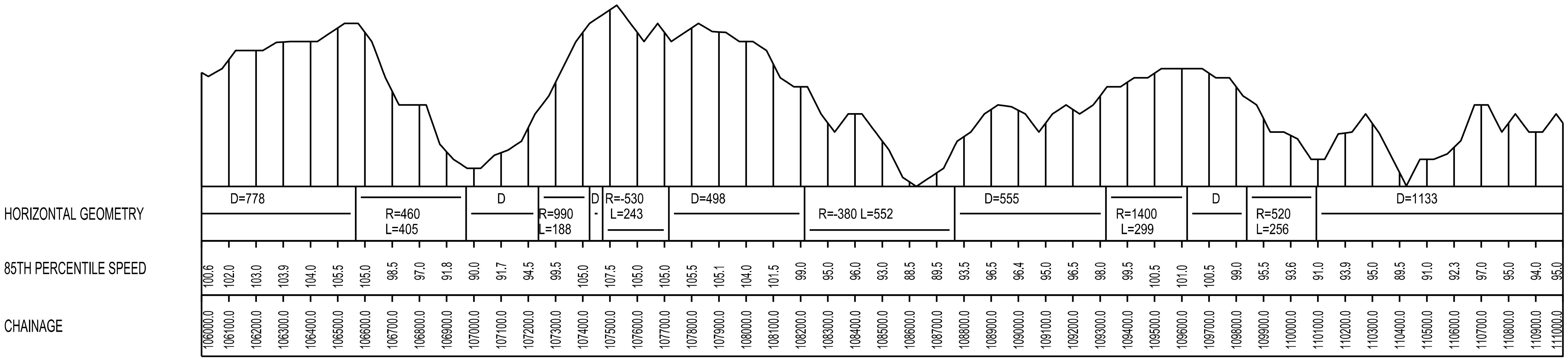


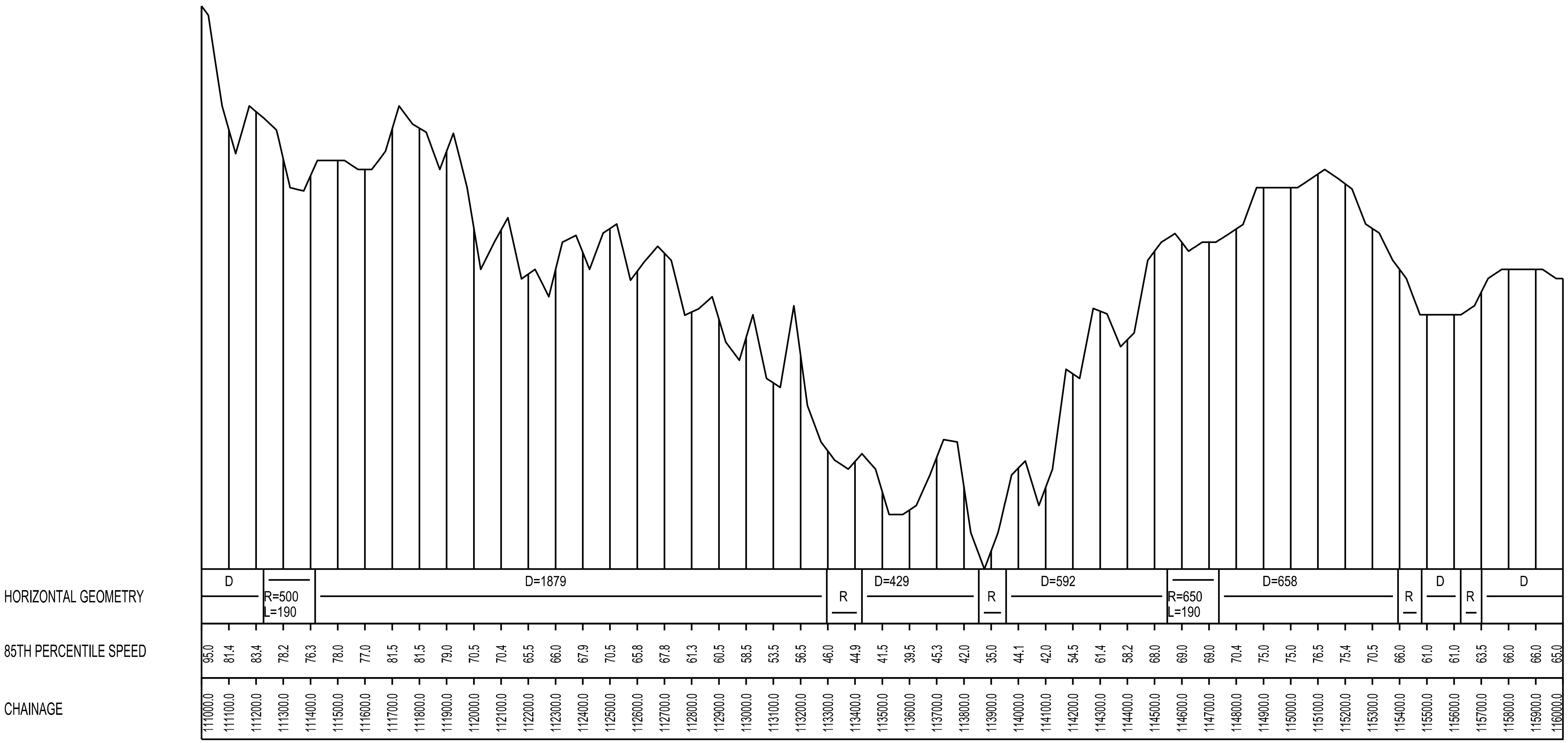
CHAINAGE	85TH PERCENTILE SPEED
96000.0	104.0
96100.0	104.0
96200.0	102.9
96300.0	99.0
96400.0	100.0
96500.0	101.0
96600.0	101.0
96700.0	100.5
96800.0	100.0
96900.0	100.0
97000.0	100.5
97100.0	102.0
97200.0	103.9
97300.0	103.5
97400.0	103.3
97500.0	101.2
97600.0	99.0
97700.0	100.9
97800.0	98.0
97900.0	97.4
98000.0	97.0
98100.0	98.5
98200.0	101.3
98300.0	104.0
98400.0	107.5
98500.0	107.0
98600.0	107.0
98700.0	106.0
98800.0	106.5
98900.0	106.5
99000.0	102.0
99100.0	100.0
99200.0	99.0
99300.0	98.0
99400.0	97.5
99500.0	98.5
99600.0	99.0
99700.0	100.5
99800.0	101.0
99900.0	103.0
100000.0	105.0
100100.0	105.0
100200.0	99.0
100300.0	92.5
100400.0	87.4
100500.0	90.0
100600.0	95.5
100700.0	100.0
100800.0	100.5
100900.0	103.0
101000.0	104.0

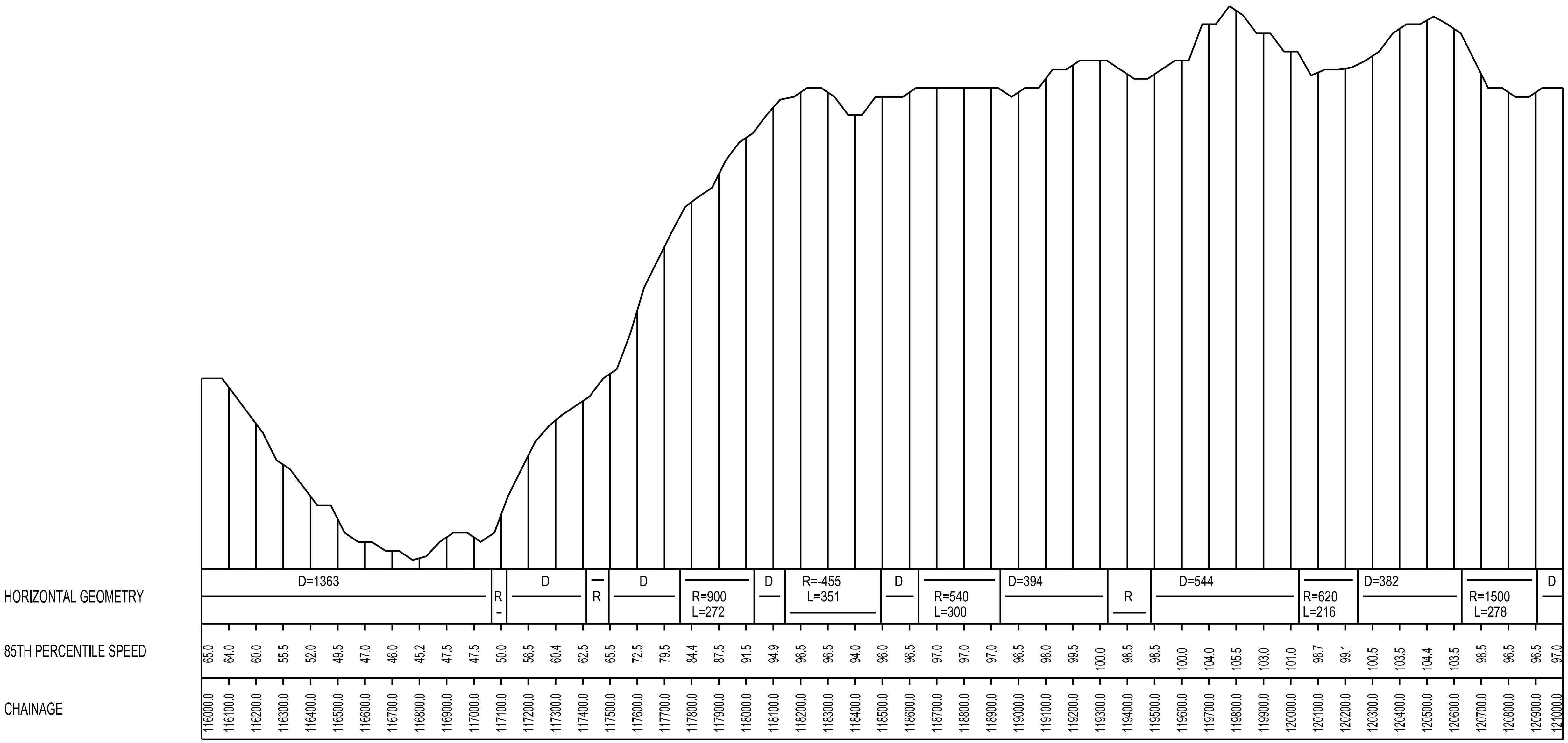
HORIZONTAL GEOMETRY

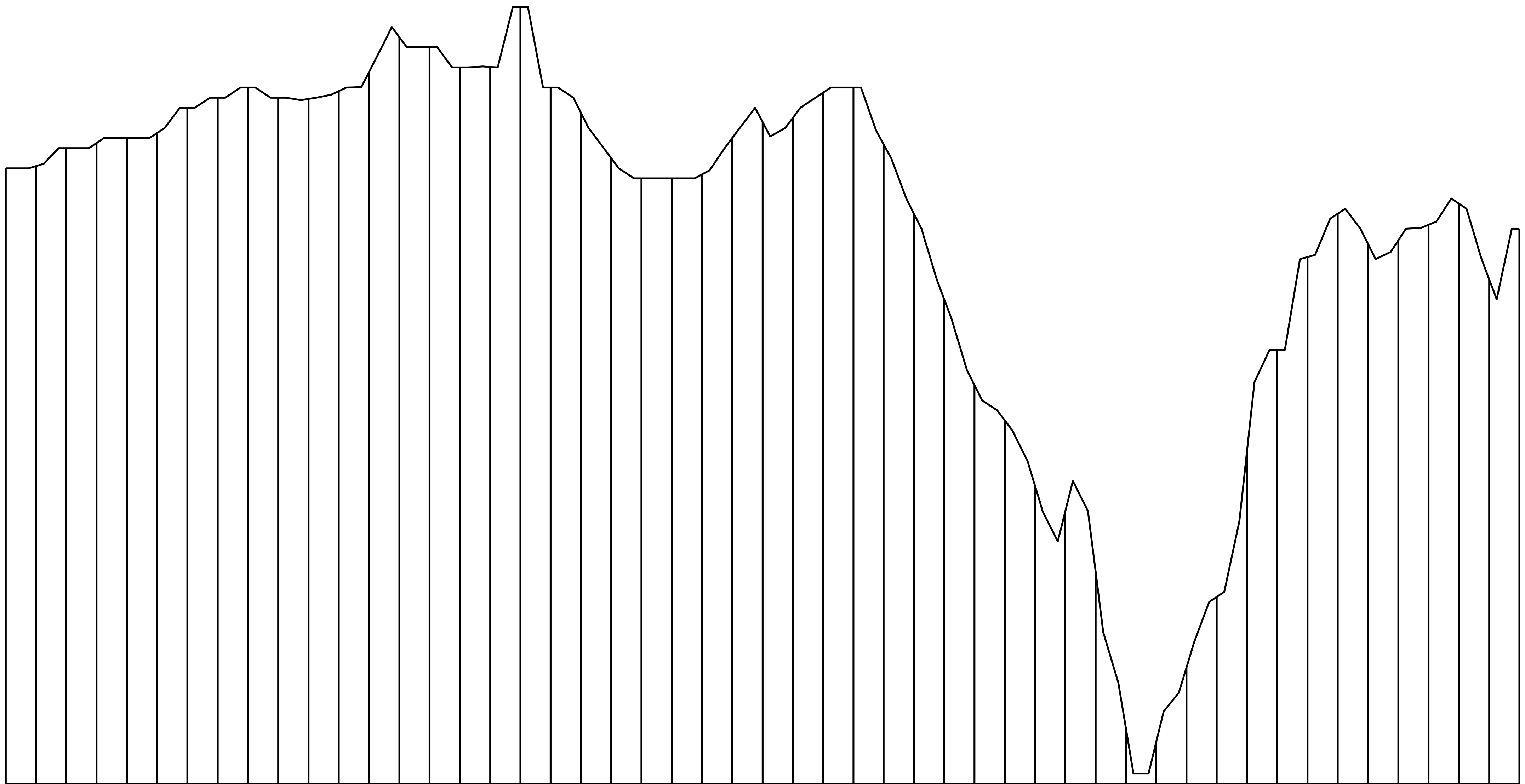
D	R	D=472	R	D=484	R	D	R=-380 L=384	D	R	D=345	R=470 L=464	D	R	D	R=510 L=234	D=475	R	D


HORIZONTAL GEOMETRY
85TH PERCENTILE SPEED
CHAINAGE
D
R=390 L=417
D=918
R=-435
L=426
D=607
R=-470
L=352
D
R
D
R=480
L=333
D
R=-450 L=457
D
R=450
L=354
D
104.0 105.0 104.5 104.0 104.0 103.0 101.0 101.0 100.0 100.5 102.5 104.5 105.0 104.5 103.5 102.0 101.0 101.0 101.0 101.0 101.0 101.0 101.0 102.0 103.6 104.0 100.7 100.0 103.5 104.5 104.0 103.5 101.0 101.0 100.0 102.0 103.0 104.5 105.0 106.0 104.6 100.5 100.0 103.2 106.5 108.0 105.9 103.0 101.0 101.0 100.6
101000.0 101100.0 101200.0 101300.0 101400.0 101500.0 101600.0 101700.0 101800.0 101900.0 102000.0 102100.0 102200.0 102300.0 102400.0 102500.0 102600.0 102700.0 102800.0 102900.0 103000.0 103100.0 103200.0 103300.0 103400.0 103500.0 103600.0 103700.0 103800.0 103900.0 104000.0 104100.0 104200.0 104300.0 104400.0 104500.0 104600.0 104700.0 104800.0 104900.0 105000.0 105100.0 105200.0 105300.0 105400.0 105500.0 105600.0 105700.0 105800.0 105900.0 106000.0


HORIZONTAL GEOMETRY
85TH PERCENTILE SPEED
CHAINAGE
D=778
R=460
L=405
D
R=990
L=188
D
-
R=-530
L=243
D=498
R=-380 L=552
D=555
R=1400
L=299
D
R=520
L=256
D=1133
100.6
102.0
103.0
103.9
104.0
105.5
105.0
98.5
97.0
91.8
90.0
91.7
94.5
99.5
105.0
107.5
105.0
105.0
105.5
105.1
104.0
101.5
99.0
95.0
96.0
93.0
88.5
89.5
93.5
96.5
96.4
95.0
96.5
98.0
99.5
100.5
101.0
100.5
99.0
95.5
93.6
91.0
93.9
95.0
89.5
91.0
92.3
97.0
95.0
94.0
95.0
106000.0
106100.0
106200.0
106300.0
106400.0
106500.0
106600.0
106700.0
106800.0
106900.0
107000.0
107100.0
107200.0
107300.0
107400.0
107500.0
107600.0
107700.0
107800.0
107900.0
108000.0
108100.0
108200.0
108300.0
108400.0
108500.0
108600.0
108700.0
108800.0
108900.0
109000.0
109100.0
109200.0
109300.0
109400.0
109500.0
109600.0
109700.0
109800.0
109900.0
110000.0
110100.0
110200.0
110300.0
110400.0
110500.0
110600.0
110700.0
110800.0
110900.0
111000.0


HORIZONTAL GEOMETRY
D
R=500
L=190
D=1879
R
D=429
R
D=592
R=650
L=190
D=658
R
D
R
D
85TH PERCENTILE SPEED
95.0 81.4 83.4 78.2 76.3 78.0 77.0 81.5 81.5 79.0 70.5 70.4 65.5 66.0 67.9 70.5 65.8 67.8 61.3 60.5 58.5 53.5 56.5 46.0 44.9 41.5 39.5 45.3 42.0 35.0 44.1 42.0 54.5 61.4 58.2 68.0 69.0 69.0 70.4 75.0 75.0 76.5 75.4 70.5 66.0 61.0 61.0 63.5 66.0 66.0 65.0
CHAINAGE
111000.0 111100.0 111200.0 111300.0 111400.0 111500.0 111600.0 111700.0 111800.0 111900.0 112000.0 112100.0 112200.0 112300.0 112400.0 112500.0 112600.0 112700.0 112800.0 112900.0 113000.0 113100.0 113200.0 113300.0 113400.0 113500.0 113600.0 113700.0 113800.0 113900.0 114000.0 114100.0 114200.0 114300.0 114400.0 114500.0 114600.0 114700.0 114800.0 114900.0 115000.0 115100.0 115200.0 115300.0 115400.0 115500.0 115600.0 115700.0 115800.0 115900.0 116000.0

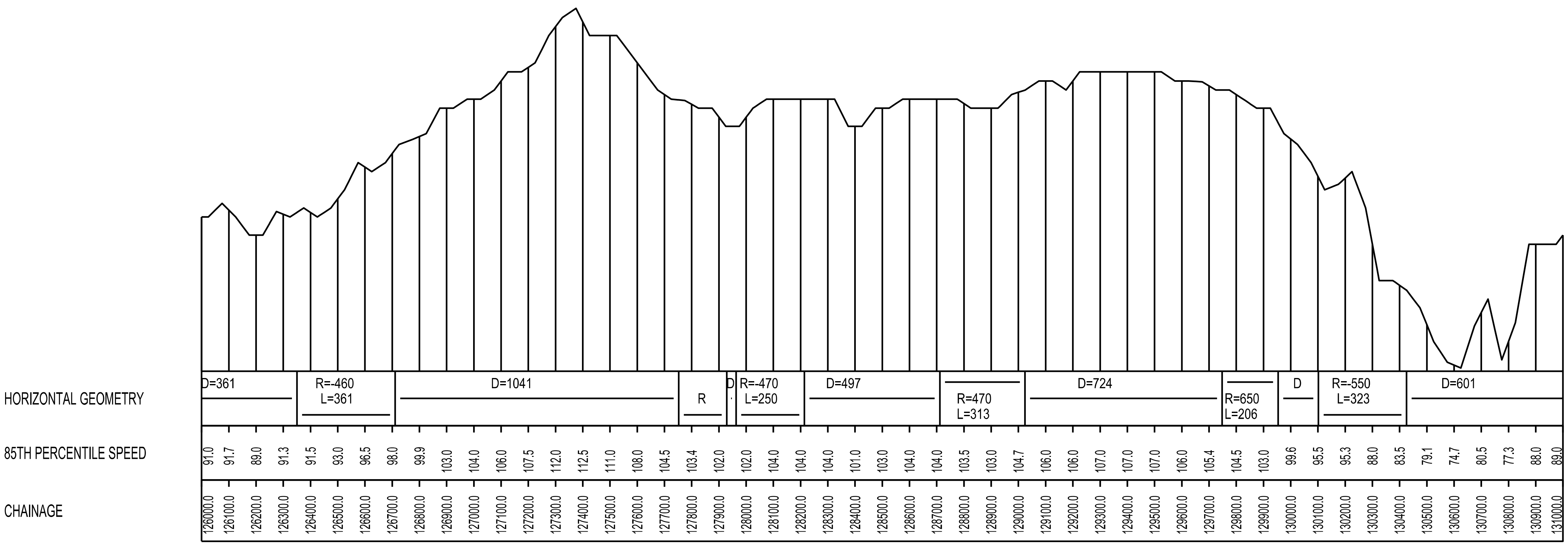

HORIZONTAL GEOMETRY
85TH PERCENTILE SPEED
CHAINAGE
D=1363
R
D
R
D
R=900
L=272
D
R=-455
L=351
D
R=540
L=300
D=394
R
D=544
R=620
L=216
D=382
R=1500
L=278
D
65.0 64.0 60.0 55.5 52.0 49.5 47.0 46.0 45.2 47.5 47.5 50.0 56.5 60.4 62.5 65.5 72.5 79.5 84.4 87.5 91.5 94.9 96.5 96.5 94.0 96.0 96.5 97.0 97.0 97.0 96.5 98.0 99.5 100.0 98.5 98.5 100.0 104.0 105.5 103.0 101.0 98.7 99.1 100.5 103.5 104.4 103.5 98.5 96.5 96.5 97.0
116000.0 116100.0 116200.0 116300.0 116400.0 116500.0 116600.0 116700.0 116800.0 116900.0 117000.0 117100.0 117200.0 117300.0 117400.0 117500.0 117600.0 117700.0 117800.0 117900.0 118000.0 118100.0 118200.0 118300.0 118400.0 118500.0 118600.0 118700.0 118800.0 118900.0 119000.0 119100.0 119200.0 119300.0 119400.0 119500.0 119600.0 119700.0 119800.0 119900.0 120000.0 120100.0 120200.0 120300.0 120400.0 120500.0 120600.0 120700.0 120800.0 120900.0 121000.0

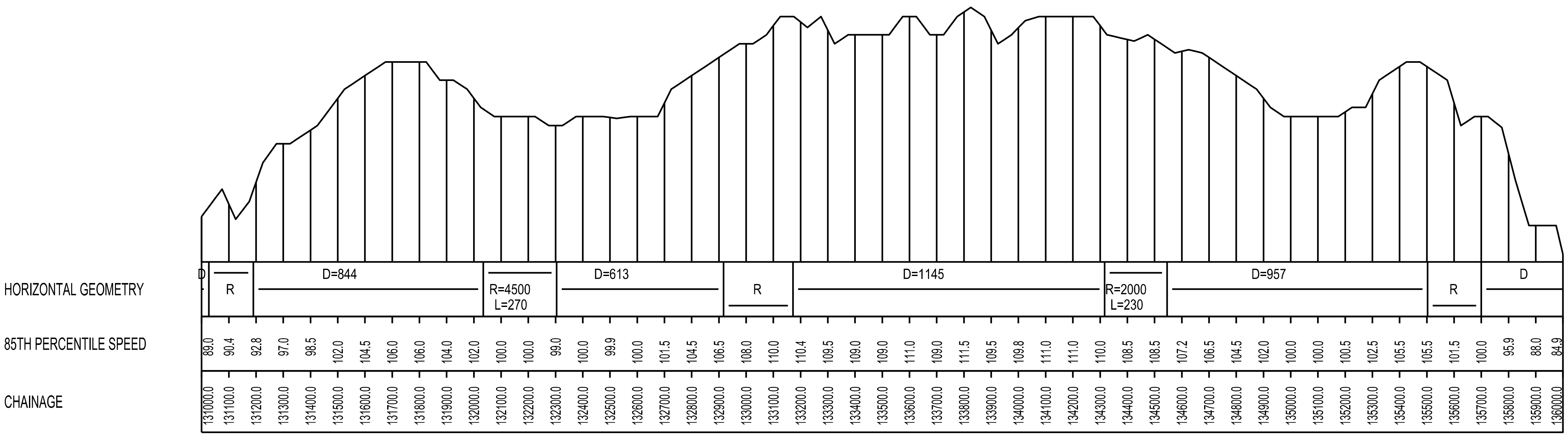


HORIZONTAL GEOMETRY

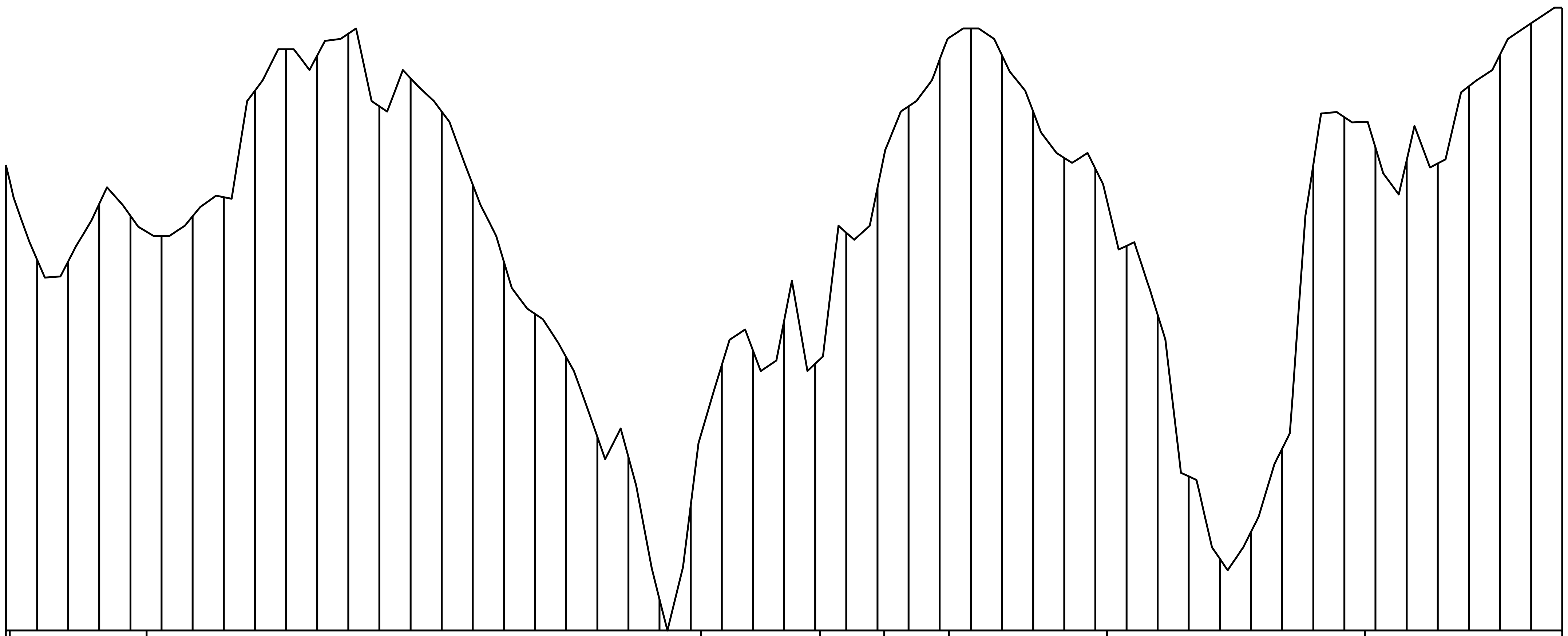
D=786	R	D=401	R	D=492	R	D	R	D	R=-1400 L=455	D	R=280 L=261	D	R	D=390	R=-1100 L=629	D	R=460 L=341	D

CHAINAGE	85TH PERCENTILE SPEED
121000.0	97.0
121100.0	97.2
121200.0	99.0
121300.0	99.5
121400.0	100.0
121500.0	100.5
121600.0	103.0
121700.0	104.0
121800.0	105.0
121900.0	104.0
122000.0	103.9
122100.0	104.7
122200.0	106.5
122300.0	110.0
122400.0	109.0
122500.0	107.0
122600.0	107.1
122700.0	113.0
122800.0	105.0
122900.0	102.5
123000.0	98.0
123100.0	96.0
123200.0	96.0
123300.0	96.4
123400.0	100.0
123500.0	101.6
123600.0	102.0
123700.0	104.5
123800.0	105.0
123900.0	99.4
124000.0	92.5
124100.0	84.0
124200.0	75.5
124300.0	72.0
124400.0	65.5
124500.0	63.0
124600.0	57.0
124700.0	41.5
124800.0	40.1
124900.0	47.5
125000.0	54.5
125100.0	68.9
125200.0	79.0
125300.0	88.2
125400.0	92.5
125500.0	89.5
125600.0	89.8
125700.0	91.4
125800.0	93.5
125900.0	86.0
126000.0	91.0


HORIZONTAL GEOMETRY
D=361
R=-460
L=361
D=1041
R
D
R=-470
L=250
D=497
R=470
L=313
D=724
R=650
L=206
D
R=-550
L=323
D=601
85TH PERCENTILE SPEED
91.0 91.7 89.0 91.3 91.5 93.0 96.5 98.0 99.9 103.0 104.0 106.0 107.5 112.0 112.5 111.0 108.0 104.5 103.4 102.0 102.0 104.0 104.0 104.0 101.0 103.0 104.0 104.0 103.5 103.0 104.7 106.0 106.0 107.0 107.0 107.0 106.0 105.4 104.5 103.0 99.6 95.5 95.3 88.0 83.5 79.1 74.7 80.5 77.3 88.0 89.0
CHAINAGE
126000.0 126100.0 126200.0 126300.0 126400.0 126500.0 126600.0 126700.0 126800.0 126900.0 127000.0 127100.0 127200.0 127300.0 127400.0 127500.0 127600.0 127700.0 127800.0 127900.0 128000.0 128100.0 128200.0 128300.0 128400.0 128500.0 128600.0 128700.0 128800.0 128900.0 129000.0 129100.0 129200.0 129300.0 129400.0 129500.0 129600.0 129700.0 129800.0 129900.0 130000.0 130100.0 130200.0 130300.0 130400.0 130500.0 130600.0 130700.0 130800.0 130900.0 131000.0



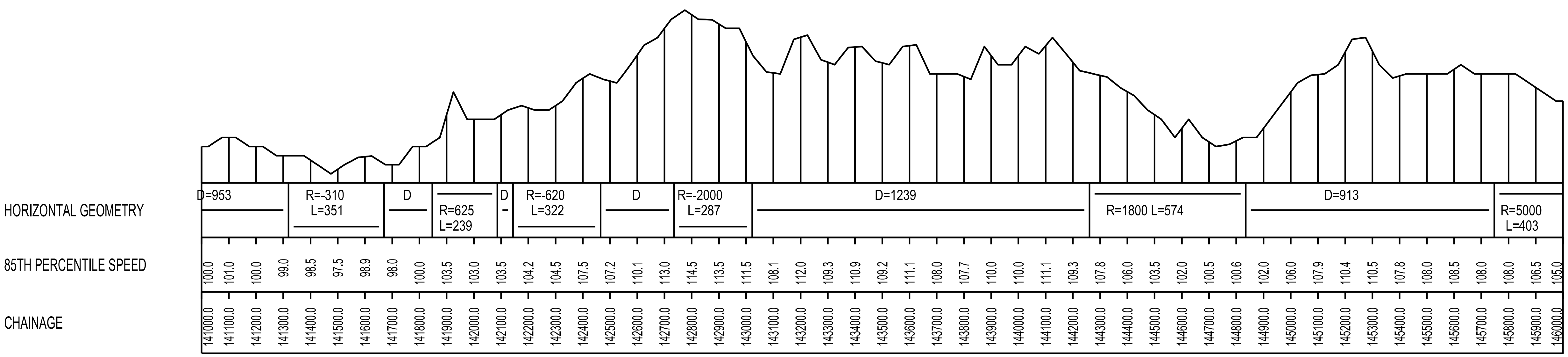
HORIZONTAL GEOMETRY
D
R
D=844
R=4500
L=270
D=613
R
D=1145
R=2000
L=230
D=957
R
D
85TH PERCENTILE SPEED
89.0 90.4 92.8 97.0 98.5 102.0 104.5 106.0 106.0 104.0 102.0 100.0 100.0 99.0 100.0 99.9 100.0 101.5 104.5 106.5 108.0 110.0 110.4 109.5 109.0 109.0 111.0 109.0 111.5 109.5 109.8 111.0 111.0 110.0 108.5 108.5 107.2 106.5 104.5 102.0 100.0 100.0 100.5 102.5 105.5 105.5 101.5 100.0 95.9 88.0 84.9
CHAINAGE
131000.0 131100.0 131200.0 131300.0 131400.0 131500.0 131600.0 131700.0 131800.0 131900.0 132000.0 132100.0 132200.0 132300.0 132400.0 132500.0 132600.0 132700.0 132800.0 132900.0 133000.0 133100.0 133200.0 133300.0 133400.0 133500.0 133600.0 133700.0 133800.0 133900.0 134000.0 134100.0 134200.0 134300.0 134400.0 134500.0 134600.0 134700.0 134800.0 134900.0 135000.0 135100.0 135200.0 135300.0 135400.0 135500.0 135600.0 135700.0 135800.0 135900.0 136000.0



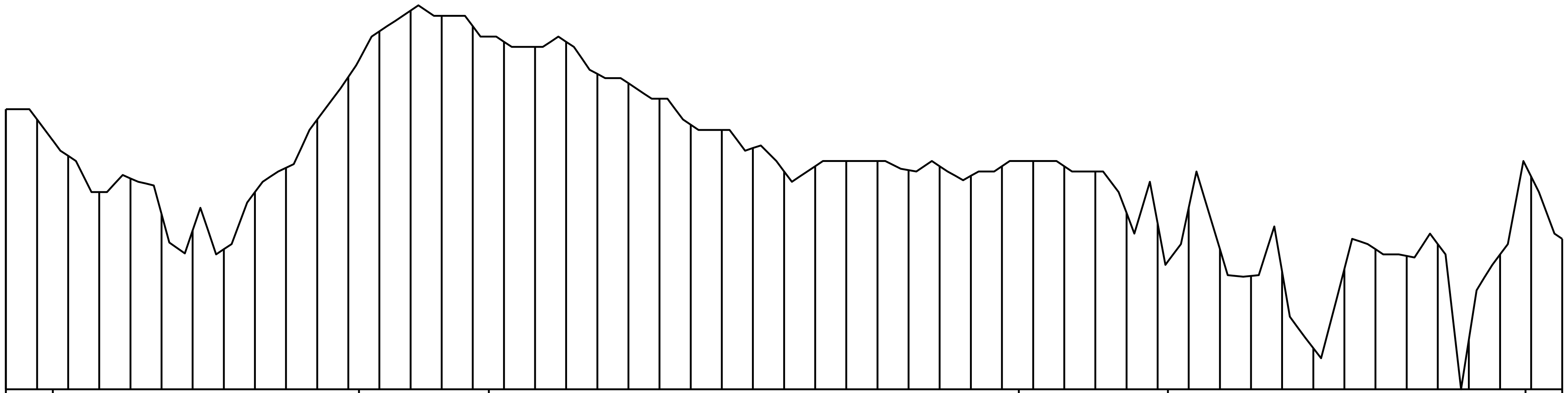
HORIZONTAL GEOMETRY

D	R=3100 L=440	D=1781	R=-900 L=382	D	R=600 L=208	D=508	R=555 L=829	D=953

CHAINAGE	85TH PERCENTILE SPEED
136000.0	84.9
136100.0	75.7
136200.0	75.6
136300.0	81.1
136400.0	80.0
136500.0	78.0
136600.0	79.9
136700.0	81.7
136800.0	92.0
136900.0	96.0
137000.0	95.4
137100.0	97.5
137200.0	90.5
137300.0	93.2
137400.0	90.0
137500.0	82.9
137600.0	75.5
137700.0	70.5
137800.0	66.3
137900.0	58.7
138000.0	56.7
138100.0	43.0
138200.0	52.1
138300.0	65.6
138400.0	67.0
138500.0	69.9
138600.0	65.7
138700.0	78.3
138800.0	82.6
138900.0	90.5
139000.0	95.0
139100.0	98.0
139200.0	95.4
139300.0	90.0
139400.0	85.5
139500.0	84.5
139600.0	77.1
139700.0	70.4
139800.0	54.8
139900.0	46.9
140000.0	49.5
140100.0	57.5
140200.0	84.9
140300.0	89.4
140400.0	86.5
140500.0	85.3
140600.0	85.0
140700.0	92.4
140800.0	95.5
140900.0	98.5
141000.0	100.0



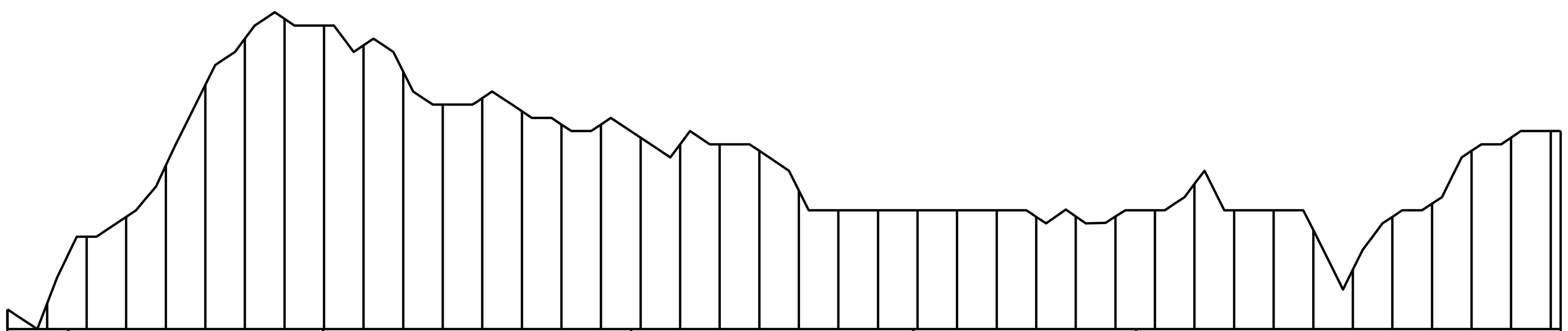
HORIZONTAL GEOMETRY
85TH PERCENTILE SPEED
CHAINAGE
D=953
R=-310
L=351
D
R=625
L=239
D
-
R=-620
L=322
D
R=-2000
L=287
D=1239
R=1800 L=574
D=913
R=5000
L=403
100.0 101.0 100.0 99.0 98.5 97.5 98.9 98.0 100.0 103.5 103.0 103.5 104.2 104.5 107.5 107.2 110.1 113.0 114.5 113.5 111.5 108.1 112.0 109.3 110.9 109.2 111.1 108.0 107.7 110.0 110.0 111.1 109.3 107.8 106.0 103.5 102.0 100.5 100.6 102.0 106.0 107.9 110.4 110.5 107.8 108.0 108.5 108.0 108.0 106.5 105.0
141000.0 141100.0 141200.0 141300.0 141400.0 141500.0 141600.0 141700.0 141800.0 141900.0 142000.0 142100.0 142200.0 142300.0 142400.0 142500.0 142600.0 142700.0 142800.0 142900.0 143000.0 143100.0 143200.0 143300.0 143400.0 143500.0 143600.0 143700.0 143800.0 143900.0 144000.0 144100.0 144200.0 144300.0 144400.0 144500.0 144600.0 144700.0 144800.0 144900.0 145000.0 145100.0 145200.0 145300.0 145400.0 145500.0 145600.0 145700.0 145800.0 145900.0 146000.0



HORIZONTAL GEOMETRY

R	D=984	R=2000 L=417	D=1703	R=4000 L=479	D=1148	R

CHAINAGE	85TH PERCENTILE SPEED
146000.0	105.0
146100.0	104.0
146200.0	100.5
146300.0	97.0
146400.0	98.3
146500.0	94.9
146600.0	93.3
146700.0	91.5
146800.0	97.0
146900.0	99.4
147000.0	104.0
147100.0	108.1
147200.0	112.5
147300.0	114.5
147400.0	114.0
147500.0	113.0
147600.0	111.5
147700.0	111.0
147800.0	111.5
147900.0	108.4
148000.0	107.5
148100.0	106.0
148200.0	103.5
148300.0	103.0
148400.0	101.2
148500.0	99.0
148600.0	99.5
148700.0	100.0
148800.0	100.0
148900.0	99.1
149000.0	99.5
149100.0	98.6
149200.0	99.5
149300.0	100.0
149400.0	99.5
149500.0	99.0
149600.0	95.0
149700.0	94.0
149800.0	95.5
149900.0	91.5
150000.0	88.9
150100.0	89.3
150200.0	82.0
150300.0	89.6
150400.0	91.5
150500.0	90.9
150600.0	92.0
150700.0	82.8
150800.0	91.0
150900.0	98.5
151000.0	92.5



HORIZONTAL GEOMETRY

R	D=644	R=-790 L=779	D=713	R=920 L=562	D=1108

CHAINAGE	85TH PERCENTILE SPEED
151000.0	92.5
151100.0	93.0
151200.0	98.0
151300.0	99.5
151400.0	103.4
151500.0	109.5
151600.0	113.0
151700.0	114.5
151800.0	114.0
151900.0	112.5
152000.0	110.5
152100.0	108.0
152200.0	108.5
152300.0	107.5
152400.0	106.5
152500.0	106.5
152600.0	105.5
152700.0	105.0
152800.0	105.0
152900.0	104.5
153000.0	101.5
153100.0	100.0
153200.0	100.0
153300.0	100.0
153400.0	100.0
153500.0	100.0
153600.0	99.5
153700.0	99.5
153800.0	99.5
153900.0	100.0
154000.0	102.0
154100.0	100.0
154200.0	100.0
154300.0	98.5
154400.0	95.5
154500.0	99.5
154600.0	100.5
154700.0	104.5
154800.0	105.5
154900.0	106.0

APPENDIX G – CURVE SPEED DATA

G.1 80km/hr Banded Approach Speed

Table 11 – Curve Speed Data – 80km/hr banded approach speed

Curve No.	Horizontal Alignment Chainages				85th Percentile Speed											Geometry					Environment				Signage		
	Approach	Start	Middle	End	Approach	Start	Middle	End	Drop % (Start)	Drop % (Middle)	Drop % (End)	Band (Approach)	Band (Start)	Band (Middle)	Band (End)	Radius (m)	Length	Super (%)	Design Speed	Grade (%)	Signposted Speed	Vertical	SSD Achieved	Shoulder Width	Symbolic Curve	Speed Advisory	CAM's
32	49093	49193	49312	49432	85	76	73	66	11	14	23	80	68	63	51	800	238	3	123	2	100	Crest	Yes	0.5	No	No	No
39	57781	57881	57963	58044	81	85	83	83	-4	-2	-1	80	88	85	84	330	163	7	89	3	100	Sag	No	0.5	Yes	Yes	Yes
40	58274	58374	58502	58631	77	69	66	73	10	14	5	80	62	57	70	450	257	4	96	2	100	Crest	No	0.5	No	No	No
41	58871	58971	59052	59132	79	79	83	82	-1	-5	-4	80	80	87	85	560	161	3	103	-3	100	Downgrade	Yes	0.5	Yes	No	No
42	59144	59244	59423	59602	82	83	83	89	-1	-1	-9	80	84	84	97	220	358	7	73	-2	100	Sag	Yes	2.5	Yes	Yes	Yes
43	60451	60551	60716	60880	84	82	77	84	2	9	1	80	80	70	84	525	330	4	103	2	100	Crest	No	0.5	Yes	Yes	No
44	60853	60953	61066	61180	84	83	86	82	1	-2	2	80	83	88	80	600	227	3	107	-1	100	Flat	Yes	1.0	No	No	No
45	61121	61221	61300	61378	83	82	79	78	1	5	6	80	81	75	74	980	156	3	137	-2	100	Crest	Yes	1.5	No	No	No
46	61667	61767	61883	62000	85	83	83	75	2	2	11	80	81	81	66	980	232	3	137	0	100	Flat	Yes	2.0	No	No	No
49	64323	64423	64586	64750	85	84	81	81	1	5	5	80	83	76	77	280	327	6	82	0	80	Flat	Yes	0.5	Yes	Yes	Yes
50	64836	64936	65172	65408	81	81	76	73	1	6	10	80	80	71	66	275	472	6	81	0	80	Flat	Yes	0.5	Yes	Yes	Yes
62	79198	79298	79542	79787	78	81	83	88	-4	-6	-13	80	85	87	99	500	488	3	98	-4	100	Downgrade	Yes	3.0	Yes	No	Yes
93	111127	111227	111322	111417	79	83	75	77	-5	5	2	80	87	72	76	500	190	5	104	2	100	Crest	Yes	1.0	Yes	Yes	No
109	138722	138822	138926	139030	78	86	91	97	-10	-17	-25	80	95	107	121	600	208	3	107	-7	100	Downgrade	Yes	0.5	Yes	Yes	No
110	139437	139537	139952	140366	85	81	46	89	5	46	-4	80	78	25	93	555	829	5	109	4	100	Crest	No	0.5	Yes	Yes	No

G.2 90km/hr Banded Approach Speed

Table 12 - Curve Speed Data – 90km/hr banded approach speed

Curve No.	Horizontal Alignment Chainages				85th Percentile Speed											Geometry					Environment				Signage		
	Approach	Start	Middle	End	Approach	Start	Middle	End	Drop % (Start)	Drop % (Middle)	Drop % (End)	Band (Approach)	Band (Start)	Band (Middle)	Band (End)	Radius (m)	Length	Super (%)	Design Speed	Grade (%)	Signposted Speed	Vertical	SSD Achieved	Shoulder Width	Symbolic Curve	Speed Advisory	CAM's
4	3594	3694	3818	3942	87	88	91	95	-2	-5	-9	90	90	96	103	290	248	7	84	-6	100	Downgrade	Yes	0.5	Yes	Yes	Yes
13	22741	22841	22926	23011	87	89	90	94	-3	-4	-8	90	92	93	101	330	170	3	82	0	80	Flat	Yes	2.0	No	No	No
31	48730	48830	48934	49038	93	94	93	84	-1	0	9	90	95	93	76	420	208	4	92	3	100	Upgrade	Yes	0.5	Yes	No	No
37	56261	56361	56594	56828	94	89	77	65	6	19	31	90	83	62	45	247	467	7	77	10	100	Upgrade	No	1.0	Yes	No	Yes
48	62755	62855	63009	63162	87	92	92	91	-6	-5	-5	90	98	97	95	560	307	4	107	0	100	Flat	Yes	1.0	No	No	No
51	67554	67654	67780	67906	87	86	83	88	1	4	-1	90	85	80	89	250	252	5	73	0	100	Flat	Yes	2.0	Yes	Yes	Yes
52	71093	71193	71365	71537	92	96	93	94	-5	-2	-3	90	101	95	96	800	344	3	123	-3	100	Upgrade	Yes	0.5	Yes	No	No
53	71913	72013	72107	72202	94	95	94	95	-1	0	-2	90	96	94	96	500	189	3	98	-2	100	Downgrade	Yes	0.5	Yes	No	No
65	84199	84299	84505	84710	89	90	93	97	-1	-4	-8	90	91	97	105	460	411	4	100	2	80	Crest	Yes	2.0	No	No	Yes
89	107137	107237	107331	107425	92	97	101	106	-5	-10	-15	90	101	111	122	990	188	3	137	-6	100	Downgrade	Yes	1.5	No	No	No
102	125548	125648	125819	125989	88	91	94	91	-3	-6	-3	90	94	99	94	460	341	5	100	2	100	Upgrade	Yes	0.5	Yes	Yes	No
103	126250	126350	126531	126711	90	92	94	98	-1	-4	-9	90	93	98	107	460	361	5	100	-2	100	Downgrade	Yes	1.0	Yes	Yes	No

G.3 100km/hr Banded Approach Speed

Table 13 – Curve Speed Data – 100km/hr banded approach speed

Curve No.	Horizontal Alignment Chainages				85th Percentile Speed												Geometry					Environment					Signage		
	Approach	Start	Middle	End	Approach	Start	Middle	End	Drop % (Start)	Drop % (Middle)	Drop % (End)	Band (Approach)	Band (Start)	Band (Middle)	Band (End)	Radius (m)	Length	Super (%)	Design Speed	Grade (%)	Signposted Speed	Vertical	SSD Achieved	Shoulder Width	Symbolic Curve	Speed Advisory	CAM's
2	2238	2338	2608	2878	104	102	99	98	1	5	6	100	101	94	92	470	541	7	106	4	100	Upgrade	Yes	0.5	Yes	No	No
3	3018	3118	3296	3473	96	91	88	90	5	8	6	100	87	81	84	245	356	7	77	-4	100	Downgrade	Yes	0.5	Yes	Yes	Yes
5	4130	4230	4341	4452	96	97	98	99	-1	-2	-3	100	98	100	101	300	222	7	85	-2	100	Downgrade	Yes	0.5	Yes	No	No
6	4776	4876	5140	5404	104	104	105	101	0	-1	3	100	104	106	98	600	527	3	107	4	100	Upgrade	Yes	0.5	Yes	No	No
7	5485	5585	5726	5867	100	99	93	97	1	7	3	100	98	86	94	900	282	3	131	5	100	Crest	No	0.5	Yes	No	No
8	5937	6037	6195	6354	98	100	104	105	-2	-6	-7	100	102	111	112	950	317	3	135	1	100	Flat	Yes	0.5	No	No	No
9	14993	15093	15305	15516	101	101	103	101	0	-2	0	100	101	105	101	560	423	4	107	1	100	Flat	Yes	2.0	No	No	No
11	18853	18953	19376	19799	95	94	99	89	1	-4	7	100	92	103	83	805	846	3	124	3	100	Sag	Yes	1.0	No	No	No
12	21648	21748	22008	22268	97	96	92	97	1	5	0	100	96	87	96	485	520	3	96	3	80	Upgrade	Yes	2.0	No	No	No
14	23549	23649	23734	23818	100	100	101	103	0	-1	-3	100	101	102	106	560	169	3	103	0	100	Flat	Yes	1.0	No	No	No
15	24410	24510	24608	24706	103	102	101	101	2	2	2	100	100	99	99	1000	197	3	138	3	100	Crest	Yes	1.0	No	No	No
16	24787	24887	25311	25735	103	104	107	105	-1	-4	-2	100	105	111	107	800	848	3	123	3	100	Upgrade	Yes	1.5	No	No	No
19	29705	29805	30228	30652	95	87	73	94	9	23	1	100	79	56	93	705	847	3	116	-3	100	Downgarde	Yes	3.0	Yes	No	No
20	30897	30997	31142	31286	97	97	98	99	0	-1	-2	100	97	99	102	720	289	3	117	-2	100	Downgrade	Yes	1.5	Yes	No	No
21	31641	31741	31890	32039	101	101	100	100	0	1	1	100	101	99	100	460	298	5	100	0	100	Flat	Yes	1.5	Yes	No	No
22	32447	32547	32666	32785	101	101	101	101	0	0	0	100	101	101	101	610	238	3	108	0	100	Flat	Yes	1.5	Yes	No	No
23	32917	33017	33126	33235	101	100	100	101	1	1	0	100	100	99	101	500	218	3	98	0	100	Flat	Yes	1.5	Yes	Yes	No
24	33599	33699	33845	33992	103	103	101	99	0	2	4	100	103	98	95	980	293	3	137	2	100	Upgrade	Yes	1.0	No	No	No
25	34773	34873	35199	35525	101	101	101	101	0	0	0	100	101	101	101	810	653	3	124	1	100	Upgrade	Yes	1.0	No	No	No
26	35724	35824	35963	36102	100	99	97	92	1	3	8	100	98	94	85	980	277	3	137	2	80	Upgrade	Yes	0.5	No	No	No
27	42153	42253	42332	42411	101	101	101	101	0	0	0	100	101	101	101	780	158	3	122	0	100	Flat	Yes	1.0	No	No	No
35	53304	53404	53765	54126	101	98	101	97	3	0	4	100	96	101	93	710	722	4	120	0	100	Crest and Sag	Yes	2.0	Yes	No	Yes
36	55701	55801	55967	56132	103	103	101	101	0	2	3	100	103	99	98	465	331	5	100	4	100	Upgrade	Yes	2.0	Yes	No	No
54	72889	72989	73081	73173	96	97	94	97	0	2	-1	100	97	92	98	460	184	3	94	-2	100	Downgrade	Yes	0.5	Yes	Yes	No
55	73381	73481	73566	73651	97	94	95	93	3	2	4	100	90	93	89	800	170	3	123	2	100	Crest	Yes	0.5	No	No	No
56	74606	74706	74868	75031	100	101	101	101	-1	-1	-1	100	102	102	102	560	324	4	107	1	100	Flat	Yes	1.0	Yes	Yes	No
57	75110	75210	75405	75600	101	101	101	101	0	0	0	100	101	101	101	770	390	3	121	1	100	Flat	Yes	0.5	No	No	No
58	76264	76364	76434	76505	103	101	100	102	2	3	1	100	100	97	101	350	141	5	87	3	100	Upgrade	Yes	0.5	Yes	No	No
66	85331	85431	85906	86381	99	103	100	101	-4	-1	-2	100	108	101	103	420	950	7	101	2	100	Upgrade	Yes	2.5	No	No	No
67	87055	87155	87237	87319	98	97	97	99	1	1	0	100	96	96	99	900	164	3	131	3	100	Crest	Yes	0.5	No	No	No
68	87435	87535	87742	87949	103	104	100	100	-1	3	4	100	105	97	96	1000	414	3	138	-2	100	Downgrade	Yes	0.5	No	No	No
69	90864	90964	91062	91159	104	104	103	100	0	1	4	100	104	103	97	770	195	3	121	2	100	Upgrade	Yes	1.0	No	No	No
70	91189	91289	91401	91512	100	100	98	99	1	2	1	100	99	96	98	770	224	3	121	-2	100	Flat	Yes	1.0	No	No	No
71	91761	91861	92167	92473	100	99	103	101	0	-3	-1	100	99	106	102	600	612	3	107	1	100	Upgrade	Yes	2.0	Yes	No	No
72	92565	92665	92908	93152	102	104	103	102	-1	0	0	100	105	103	102	730	488	3	118	3	100	Upgrade	Yes	2.0	No	No	No
73	95206	95306	95387	95468	97	97	97	101	0	0	-4	100	96	97	105	320	162	6	86	-4	100	Downgrade	Yes	2.0	Yes	Yes	No
74	95492	95592	95741	95889	102	102	99	101	-1	2	1	100	103	97	100	460	297	4	97	5	100	Crest	No	2.0	Yes	Yes	No
75	96538	96638	96725	96811	101	101	100	100	0	1	1	100	101	100	99	680	173	3	114	0	100	Flat	Yes	2.0	No	No	No

Table 14 – Curve Speed Data – 100km/hr banded approach speed (continued)

76	97196	97296	97394	97493	104	104	103	101	0	1	2	100	103	103	99	600	197	5	114	5	100	Crest	No	1.5	Yes	Yes	No
77	97574	97674	97866	98058	99	100	98	98	-1	1	1	100	101	97	96	380	384	5	91	5	100	Crest	No	1.5	Yes	Yes	No
79	99509	99609	99700	99792	99	99	100	101	0	-1	-2	100	99	102	103	430	183	6	99	2	100	Upgrade	Yes	1.0	Yes	Yes	No
80	99975	100075	100192	100310	104	106	101	92	-2	3	11	100	108	98	82	510	234	4	102	8	100	Crest	No	0.5	Yes	Yes	No
82	102387	102487	102700	102913	104	103	101	101	1	3	3	100	101	98	98	435	426	5	97	0	100	Flat	Yes	1.5	Yes	Yes	No
83	103420	103520	103695	103871	104	104	100	104	0	4	0	100	104	96	104	470	352	5	101	2	100	Upgrade	Yes	1.5	Yes	Yes	No
84	104035	104135	104212	104289	104	103	101	101	1	3	3	100	101	98	98	550	153	5	109	1	100	Upgrade	Yes	1.5	No	No	No
85	104337	104437	104604	104771	101	100	103	105	1	-2	-4	100	100	105	110	480	333	5	102	0	100	Flat	Yes	0.5	Yes	Yes	No
99	119930	120030	120138	120246	103	101	99	100	2	4	3	100	99	95	96	620	216	5	116	4	100	Crest	Yes	1.5	No	No	No
100	123908	124008	124139	124270	99	92	82	73	7	17	26	100	86	68	54	280	261	7	82	8	100	Upgrade	No	2.5	Yes	Yes	No
105	128611	128711	128868	129024	104	104	103	105	0	1	-1	100	104	102	106	470	313	5	101	2	100	Upgrade	Yes	2.0	Yes	Yes	No
107	130002	130102	130264	130425	100	95	95	83	4	5	17	100	91	90	69	550	323	5	109	4	100	Crest	Yes	1.5	No	No	No
111	141219	141319	141495	141670	100	99	97	98	1	3	2	100	98	95	96	310	351	6	84	1	100	Upgrade	Yes	0.5	Yes	Yes	Yes
112	141748	141848	141967	142086	99	100	105	103	-2	-6	-4	100	102	111	108	625	239	3	109	1	100	Flat	Yes	0.5	No	No	No
113	142044	142144	142304	142465	103	104	104	108	-1	-1	-4	100	105	105	112	620	322	3	109	0	100	Flat	Yes	0.5	No	No	No
115	153189	153289	153571	153852	100	100	100	100	0	0	0	100	100	100	100	920	562	3	132	1	100	Upgrade	Yes	0.5	No	No	No

G.4 110km/hr Banded Approach Speed

Table 15 – Curve Speed Data – 110km/hr banded approach speed

Curve No.	Horizontal Alignment Chainages				85th Percentile Speed											Geometry					Environment				Signage		
	Approach	Start	Middle	End	Approach	Start	Middle	End	Drop % (Start)	Drop % (Middle)	Drop % (End)	Band (Approach)	Band (Start)	Band (Middle)	Band (End)	Radius (m)	Length	Super (%)	Design Speed	Grade (%)	Signposted Speed	Vertical	SSD Achieved	Shoulder Width	Symbolic Curve	Speed Advisory	CAM's
1	1644	1744	1948	2153	108	109	104	103	0	4	5	110	109	100	98	600	409	3	107	5	100	Upgrade	Yes	0.5	Yes	No	No
10	17779	17879	18043	18207	108	107	107	105	1	1	3	110	106	106	102	770	328	3	121	4	100	Upgrade	Yes	2.0	No	No	No
17	25863	25963	26260	26556	106	107	108	108	-1	-2	-2	110	108	109	111	800	594	3	123	2	100	Upgrade	Yes	2.0	No	No	No
18	26660	26760	27023	27287	108	107	104	99	1	4	8	110	106	99	91	805	526	3	124	5	100	Crest	Yes	1.5	No	No	No
28	45334	45434	45529	45623	105	106	108	109	-1	-3	-4	110	107	111	113	820	189	3	125	-1	100	Downgrade	Yes	1.0	No	No	No
29	45723	45823	46127	46431	109	105	98	103	4	10	5	110	101	88	98	490	608	5	103	6	100	Crest	No	0.5	No	No	Yes
30	46611	46711	46973	47235	108	102	91	97	6	16	10	110	97	76	87	550	524	5	109	10	100	Crest	No	0.5	No	No	No
34	52379	52479	52646	52813	105	105	104	103	0	1	2	110	105	103	101	620	334	4	112	3	100	Upgrade	Yes	1.0	Yes	No	No
78	98742	98842	99074	99306	106	107	101	98	-1	5	8	110	107	96	91	470	464	5	101	8	100	Upgrade	Yes	2.0	Yes	Yes	No
81	101053	101153	101361	101569	105	105	104	101	0	1	3	110	105	103	98	390	417	6	94	3	100	Upgrade	Yes	0.5	Yes	Yes	No
86	104786	104886	105114	105343	105	106	100	105	-1	5	0	110	107	96	106	450	457	4	96	5	100	Crest	Yes	2.5	No	No	No
87	105334	105434	105611	105788	105	107	106	101	-2	-1	4	110	109	107	97	450	354	6	101	7	100	Upgrade	Yes	2.0	No	No	No
88	106466	106566	106769	106971	105	106	97	90	-1	7	14	110	107	90	77	460	405	5	100	5	100	Upgrade	Yes	1.0	Yes	Yes	No
106	129648	129748	129851	129954	106	105	103	101	1	2	4	110	104	101	97	650	206	5	118	3	100	Upgrade	Yes	1.5	Yes	Yes	No
114	151698	151798	152187	152576	115	114	108	106	0	6	7	110	113	102	98	790	779	3	123	5	100	Upgrade	Yes	0.5	No	No	No

APPENDIX H – MULITVARIABLE REGREESION OUTPUTS

H.1 Speed Drop Percentage (Start)

Regression Statistics	
Multiple R	0.411122884
R Square	0.169022026
Adjusted R Square	0.102921505
Standard Error	2.841941741
Observations	96

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	7	144.566213	20.65232	2.557045	0.019114597
Residual	88	710.7436916	8.076633		
Total	95	855.3099046			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-1.495779966	5.988040272	-0.24979	0.803328	-13.39575171	10.40419178
Length	0.000700063	0.001719473	0.407138	0.684895	-0.002717029	0.004117154
Grade (%)	0.186328293	0.111720659	1.667805	0.098909	-0.035693041	0.408349626
SSD Achieved	2.038215718	1.051807886	1.937821	0.055852	-0.052031434	4.128462871
Shoulder Width	-0.00492844	0.435346783	-0.01132	0.990993	-0.870088688	0.860231809
Symbolic Curve	0.097602222	0.776214106	0.125741	0.900223	-1.444960203	1.640164648
Speed Advisory	1.078439742	0.834618208	1.292135	0.199693	-0.580188563	2.737068047
CAM's	-0.885307425	0.909662941	-0.97323	0.333109	-2.693071369	0.922456518

Figure 33 – Multivariable regression output – speed drop percentage (start)

H.2 Speed Drop Percentage (Middle)

Regression Statistics	
Multiple R	0.580021957
R Square	0.336425471
Adjusted R Square	0.283641133
Standard Error	6.185257538
Observations	96

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	7	1706.858061	243.8369	6.373585	4.54592E-06
Residual	88	3366.652152	38.25741		
Total	95	5073.510212			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-9.945894072	13.03248786	-0.76316	0.447408	-35.8452251	15.95343696
Length	0.009693171	0.003742295	2.590167	0.011226	0.002256146	0.017130197
Grade (%)	0.426682497	0.243151025	1.754804	0.082773	-0.056529072	0.909894065
SSD Achieved	7.768036498	2.289175237	3.393378	0.001037	3.21878175	12.31729125
Shoulder Width	-0.266475826	0.947497244	-0.28124	0.779185	-2.149427497	1.616475845
Symbolic Curve	-0.950338736	1.689367548	-0.56254	0.575178	-4.307601742	2.406924269
Speed Advisory	-0.107191978	1.816479376	-0.05901	0.953077	-3.717063032	3.502679075
CAM's	0.198179512	1.979808201	0.1001	0.920492	-3.73627326	4.132632283

Figure 34 – Multivariable regression output – speed drop percentage (middle)

H.3 Speed Drop Percentage (End)

Regression Statistics	
Multiple R	0.666536909
R Square	0.444271451
Adjusted R Square	0.400065771
Standard Error	5.787770879
Observations	96

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	7	2356.62799	336.6611	10.0501	3.57035E-09
Residual	88	2947.849674	33.49829		
Total	95	5304.477664			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	14.53030184	12.19497381	1.191499	0.236661	-9.704646018	38.7652497
Length	-0.00420223	0.003501802	-1.20002	0.233353	-0.011161326	0.002756866
Grade (%)	1.651462186	0.227525275	7.258368	1.47E-10	1.199303513	2.10362086
SSD Achieved	-1.458001147	2.14206469	-0.68065	0.497879	-5.714904596	2.798902302
Shoulder Width	-0.733609728	0.8866077	-0.82743	0.410229	-2.495556224	1.028336768
Symbolic Curve	-1.094799823	1.580802778	-0.69256	0.49041	-4.236313161	2.046713515
Speed Advisory	2.038342021	1.699745948	1.199204	0.233668	-1.339545874	5.416229915
CAM's	-2.969513029	1.852578681	-1.60291	0.112538	-6.651123865	0.712097807

Figure 35 – Multivariable regression output – speed drop percentage (end)

APPENDIX I – CURVE SPEED PREDICTION RELATIONSHIPS

I.1 80km/hr Banded Approach Speed

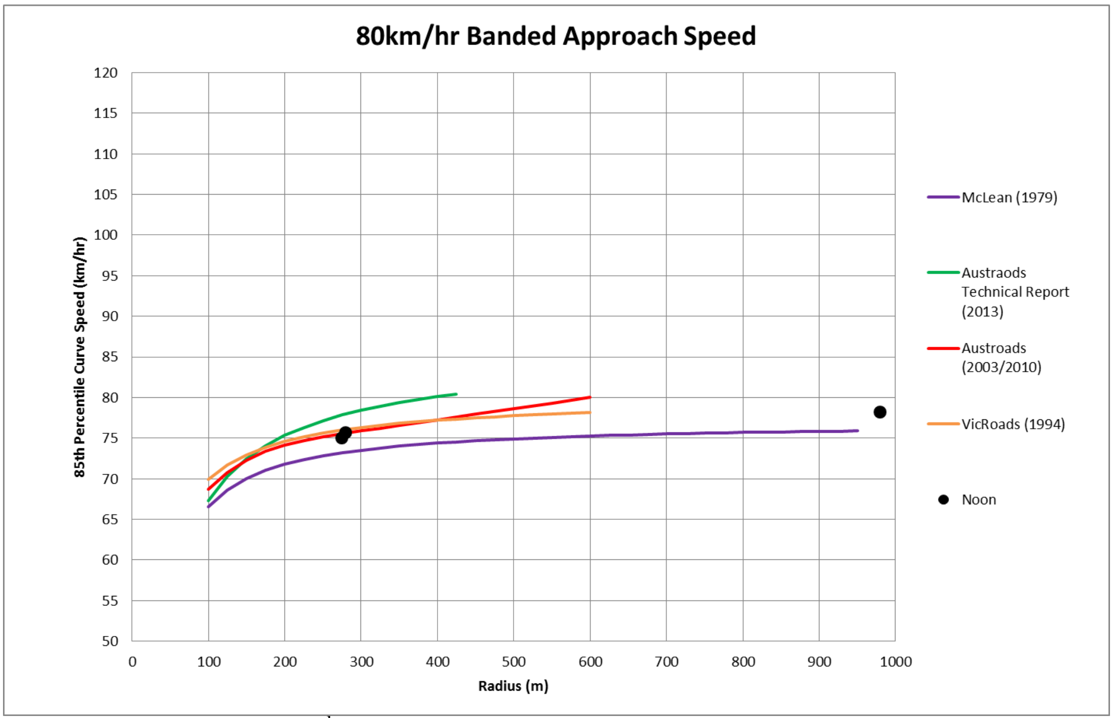


Figure 36 – 85th Percentile (Curve Midpoint) vs Radius (80km/hr)

I.2 90km/hr Banded Approach Speed

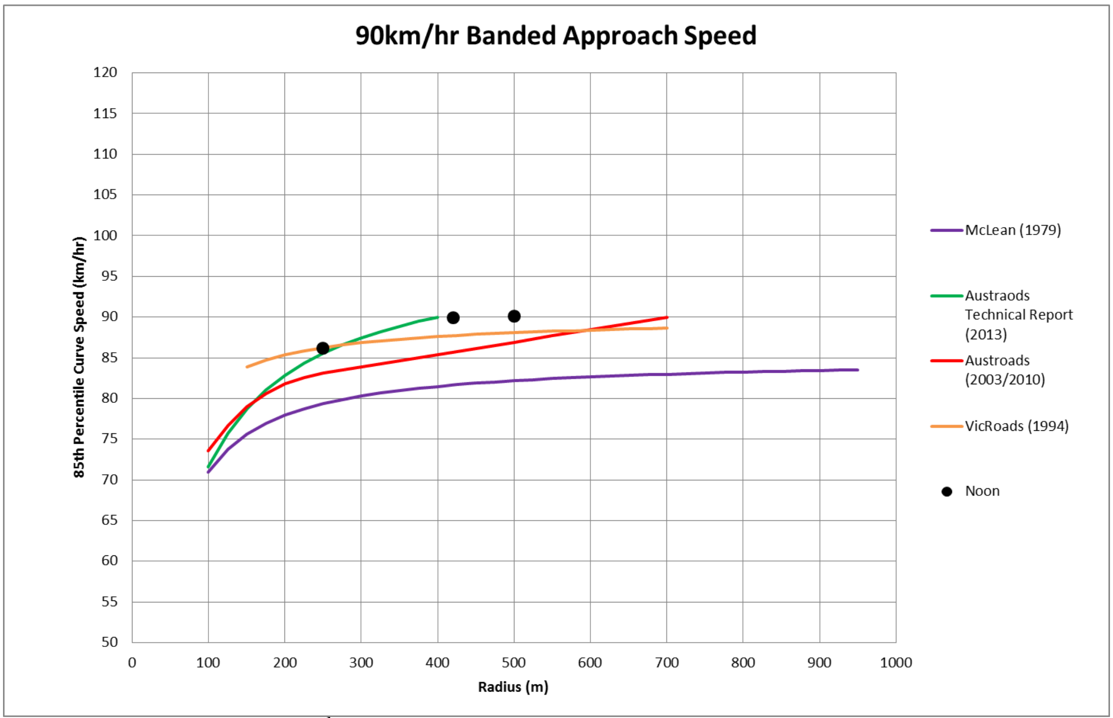


Figure 37 – 85th Percentile (Curve Midpoint) vs Radius (90km/hr)

I.3 110km/hr Banded Approach Speed

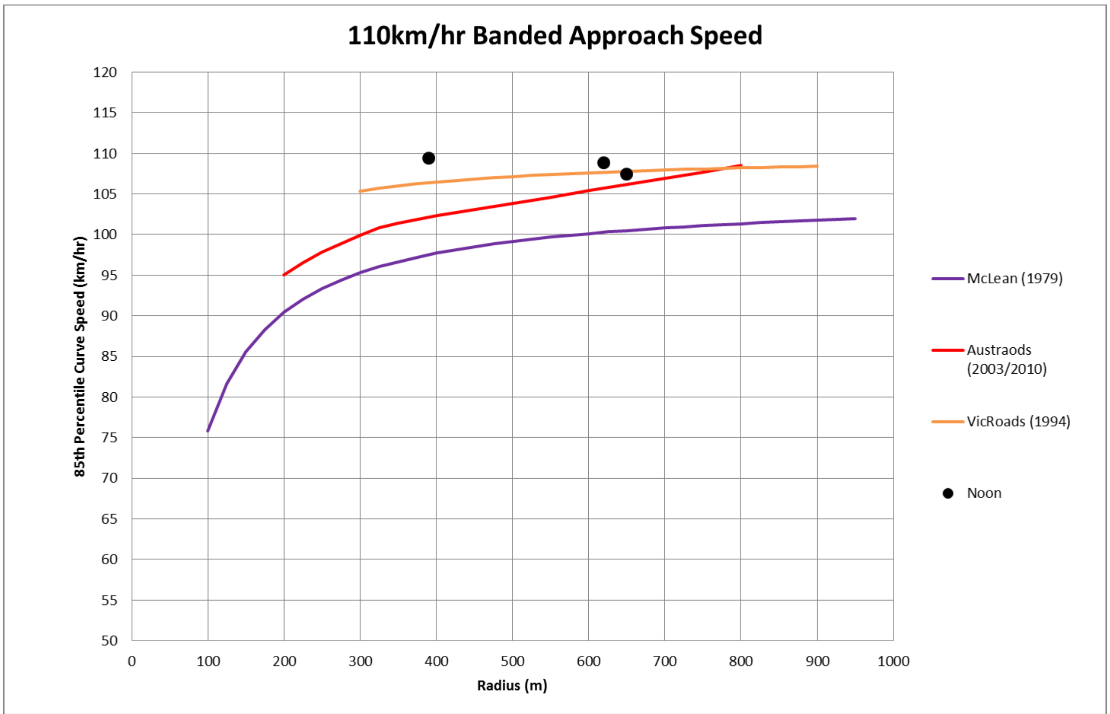


Figure 38 - 85th Percentile (Curve Midpoint) vs Radius (110km/hr)