Reference material

ATP Project Specifications – Gradient Simplification Design Guideline

This document is published as reference material to support the implementation of Automatic Train Protection as part of the roll out of the Advanced Train Control Migration System project.

The content described might be of assistance to individuals and organisations performing work on NSW Rail Assets.

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ATP PROJECT SPECIFICATIONS

GRADIENT SIMPLIFICATION DESIGN GUIDELINE

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Guidelines – Applicable to Transport Projects ATP Program

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0.1	30/05/2016	C. Chéreau	Initial draft
0.2	01/06/2016	C. Chéreau	Update after initial review
0.3	02/06/2016	C. Chéreau	Update after second review
0.4	03/06/2016	C. Chéreau	Minor Corrections added
0.5	18/07/2016	C. Chéreau	Removal of Shifting concept in Figure 5, 6 and 9.
1.0	21/07/2016	C. Chéreau	Correction of Typos Release Version
2.0	23/09/2016	C. Chéreau	Update Figure and new section for gradient output.
3.0	03/10/2018	L.LEE	Updated to CR #1360 Updated to review comments from ZK and PS #DS 6148998

Foreword

This guideline forms a part of the TfNSW suite of railway signalling guidelines which detail the requirements for the implementation of ATP on the TfNSW heavy rail network. This guideline specifically covers the use of gradient data for ATP, including within the ERA Braking Curve Tool.

To gain a complete overview of ATP signalling design requirements, this document should be read in conjunction with the ATP suite of signalling design principle modules.

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1. Introduction

1.1. ATP Background

The ATP program was previously deploying a European Train Control System (ETCS) Level 1 'Full Supervision' system over the Transport network through various approval package rollouts. In the Level 1 'Full Supervision' (FS) system all signals were to be fitted with an LEU and a balise group.

The ATP Program is now deploying an ETCS Level 1 'Limited Supervision' (LS) system with the intent of facilitating accelerated trackside deployment, the fitment of additional rolling stock and the realisation of earlier safety benefits. The system provides ceiling speed supervision and targeting high risk areas of the network e.g. signals without mechanical train stops, high risk junctions and buffer stops.

Speed supervision under ETCS is achieved through comparing the train speed and position to the various supervision limits. The Onboard equipment provides this relevant information to the Driver, and if the Driver does not react appropriately, the Onboard generates traction cut-off commands and braking commands. The information displayed to the Driver is selected according to the supervision status of the speed and distance monitoring function: Normal status, Indication status, over speed status, Warning status and Intervention status.

Under ATP, the following types of speed and distance monitoring (shown in Figure 1) are defined:

- Ceiling speed monitoring (CSM)
- Target speed monitoring (TSM)
- Release speed monitoring (RSM), only for Buffer Stop

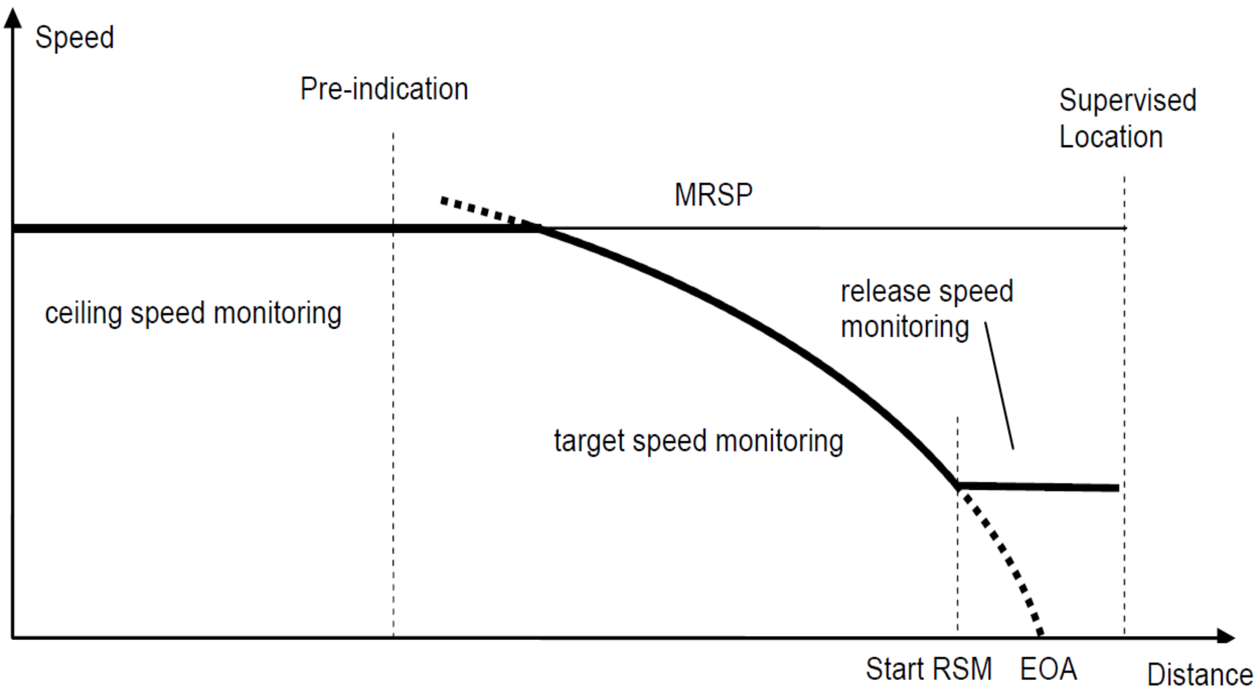


Figure 1 – Different types of speed and distance monitoring

Ceiling speed monitoring is general speed supervision in areas where no target speed monitoring for high risk locations is required.

Target speed monitoring is speed and distance supervision on the approach to a high risk location.

Release speed monitoring is speed supervision on the approach to an End of Authority.

For ATP, release speed monitoring (RSM) only applies to Buffer Stops supervision. For all other ATP fitments under ATP, only ceiling speed monitoring (CSM) and target speed monitoring (TSM) will be applied.

1.2. Purpose

This guideline describes how the ATP Project will use gradient data, and how it shall be transformed from a trusted source (VAD) to a simplified version for ATP use (Concept design, detailed design and data design).

1.3. Application

This document applies to AEOs engaged to carry out signal design and data design for new works.

2. Reference documents

The following documents are cited in the text. For dated references, only the cited edition applies. For undated references, the latest edition of the referenced document applies.

ATP Technical Issue Paper

AMS-TIP-007 - Geographic Data for ATP

Tools

ERA Braking Curve Tool configured for AMS

ATP Project Specifications

AMS Signal Design Principle

Balise Arrangement for High Risk Location Design Guideline

3. Terms and definitions

The following terms and definitions apply in this document:

AEO Authorised engineering organisation; means a legal entity (which may include a Transport Agency as applicable) to whom the ASA has issued an ASA Authorisation

AMS Advanced train control Migration System

ASA Asset Standards Authority

ATP Automatic Train Protection; a system which supervises train speed and target speed, alerts the driver of the braking requirement, and enforces braking when necessary. The system may be intermittent, semi-continuous or continuous according to its track-to-train transmission updating characteristics.

BG Balise Group

ETCS European Train Control System; a four level, unified, modular automatic train protection specification to enhance interoperability across Europe

ERA European Railway Agency

Gradient Iteration Number of separate gradient entries in a gradient Packet 21, as per ERA Subset 26.

Onboard Computer that processes train data and track data to calculate the required braking, speed, distance and intervention functions.

LEU Lineside Electronic Unit

LS Limited Supervision

TfNSW Transport for New South Wales

TSM Target Speed Monitoring

VAD Vertical Alignment Database, referring to gradient information

4. Concept

There are various functions defined in ATP which require TSM calculations, these are listed below:

- High Risk Speed Signs
- High Risk Turnouts
- High Risk Overlap Deficiencies
- End of lines / Buffer Stops
- Hazard Protection in the wrong running direction

For all ATP functions requiring TSM, an accurate gradient is required in order to determine where the train will be required to start braking. The ERA Braking Curve Tool, customised for ATP, is used to calculate the braking curves of an ETCS train, and hence to calculate the optimal location when needed for the TSM announcement BG.

5. Inputs

5.1. Gradient

This section describes the methodology to extract gradient data from the VAD (Vertical Alignment Database).

The source of the gradient is VAD, an extract of which is shown in Figure 2. For the purposes of ATP, only the columns “Metrage” and “Grade” are required. As onboard works with relative distance from the last reference point, the converted gradients shall be given in multiples of sections represented in the rolling distance format. The length of a gradient section between Intersection Points (IP) shall always be calculated based on the corresponding metrage with associated track length adjustment (circled in green).

The precision of the gradient value for the data design is 1‰ therefore the gradient value shall be rounded down to the next positive number in the case of a rising gradient, or rounded up to the next greatest negative value in the case of a falling gradient: e.g. 8.5‰ to +8‰ and –4.2‰ to –5.

When there are 3 different “Metrage” figures given for the same gradient change, the second one shall always be used (e.g. in Figure 2, in column Metrage, from the 3 values 7220, 7240 and 7260, only the value 7240 shall be used).

```
File: ILDM0070.VAD          Time: 12:56      Date: Tue 10-02-2015  #-Check PrpVC

IP                    Metrage        Level         Grade  Prp VC/Rd   Req VC/Rd   Cls Vel Dtm

3                 7000.000000     4.513000                0                       1XNo VC Req
                                                0.000000%
4                 7130.000000     4.513000                0                       1XNo VC Req
                                                0.037273%
                  7220.000000     4.546545
5                 7240.000000     4.554000                40/13323    40/5000     1XC 100 AHD
                  7260.000000     4.621500
                                                0.337500%
6                 7360.000000     4.959000                0                       1XNo VC Req
                                                0.525000%
                  7420.000000     5.274000
7                 7440.000000     5.379000                40/9412     40/5000     1XC 100 AHD
                  7460.000000     5.569000
                                                0.950000%
8                 7600.000000     6.899000                0                       1XNo VC Req
                                                1.091667%
                  7640.000000     7.335667
9                 7660.000000     7.554000                40/8980     40/5000     1XC 100 AHD
                  7680.000000     7.683250
                                                0.646250%
                  7720.000000     7.941750
10                7740.000000     8.071000                40/6413     40/5000     1XC 100 AHD
                  7760.000000     8.325003
                                                1.270013%
 Adj Start: 7760.000000      End: 7771.698000      Length: 12.405000
                  7880.000000     9.857997
11                7900.000000    10.112000                40/7767     40/5000     1XC 100 AHD
                  7920.000000    10.263000
                                                0.755000%
                  7960.000000    10.565000
12                8000.000000    10.867000                80/11679    #40/5000    1XC 100 AHD
                  8040.000000    11.443000
                                                1.440000%
```

Figure 2 – VAD file extract

From the data in Figure 2, a table of gradients can be extracted, as shown in Figure 3.

					Adjustment		
Position	Adj.	Rolling Distance	Gradient (‰) rounded	Gradient (‰)	start	end	length
7000	0	7000	0	0			
7130	0	7130	0	0.3			
7240	0	7240	3	3.3			
7360	0	7360	5	5.2			
7440	0	7440	9	9.5			
7600	0	7600	10	10.9			
7660	0	7660	6	6.4			
7740	0	7740	12	12.7			
7900	1	7901	7	7.5	7760	7771.7	12.405
8000	1	8001	14	14.4			

Figure 3 – Gradient table

From Figure 3, in order to help the designer, a graph can be extracted to visualize the gradient.

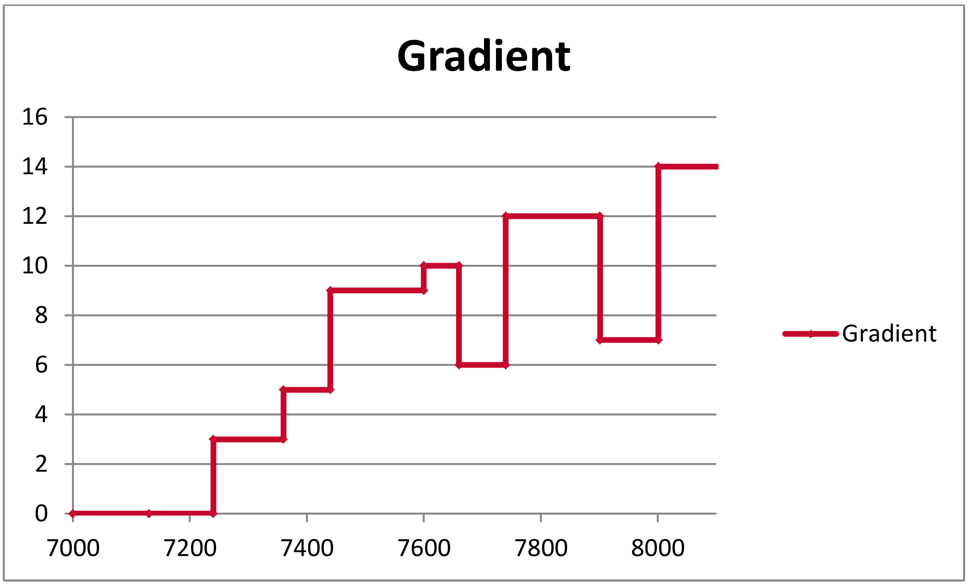


Figure 4 – Gradient graph

5.2. Signals and Points

The kilometrage (in ESC210KM format) of signals and point locations and the relative distance between each information point could be extracted from the GIS database, as this uses the same positional information as the VAD.

The information in the GIS database can also be found in WebGIS/WebGIS Network Viewer.

6. Simplification

6.1. Requirements

The gradient information required covers the distance called $D_{gradient}$, which is the distance based on the distance P (the distance from the start of the decrease of the Permitted Curve to the target location) plus an additional 20% of that distance (See Figure 5). The additional margin of 20% shall be extended if it is too short where the default grade begins to impact on the permitted distance as this is not the desired intent. This is due to the train length compensation where the default gradient could make the permitted distance more conservative for some cases.

There shall be no more than 10 separate gradient segments to cover the distance $D_{gradient}$. If there are less than 10 separate gradient segments within $D_{gradient}$, then those exact gradients can be used with no simplifications, however if there are more than 10 separate gradient segments within $D_{gradient}$, then a gradient simplification (or smoothing) is needed (see section 6.2).

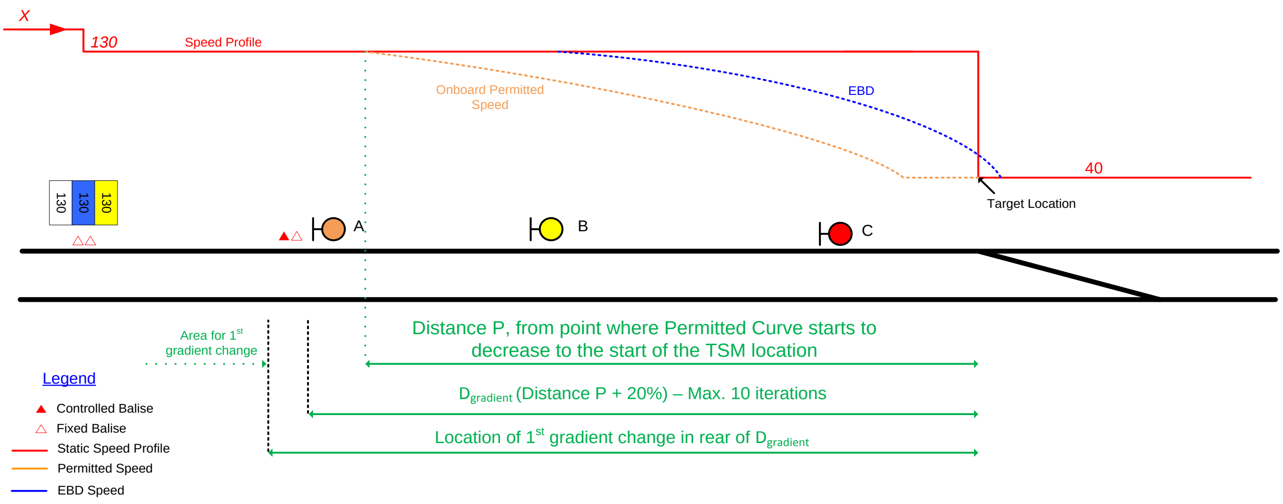


Figure 5 – Gradient coverage for TSM over a turnout

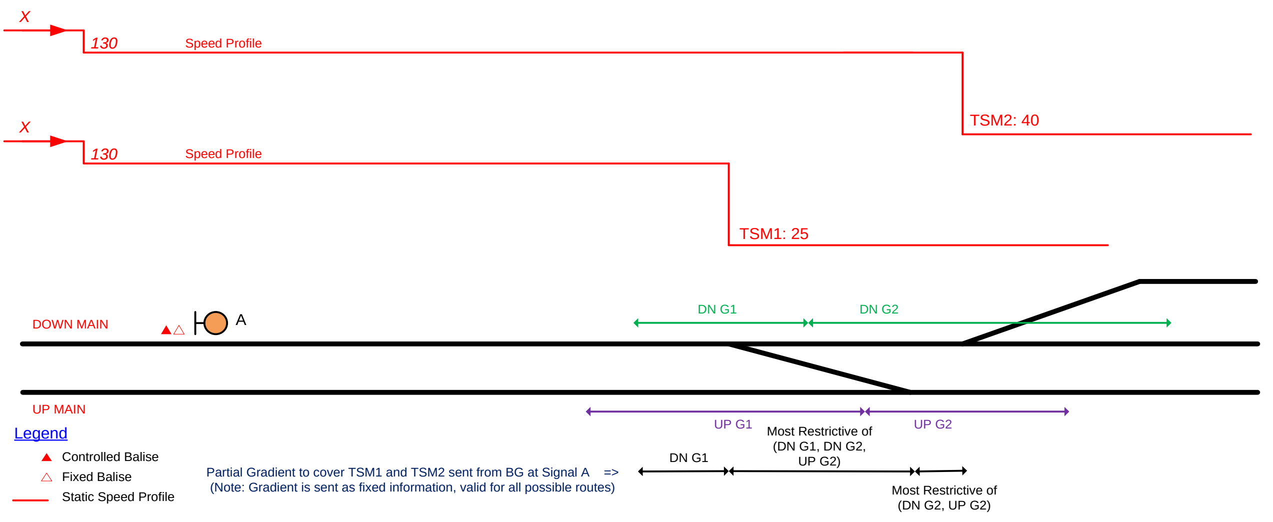


Figure 6 – Partial Gradient coverage for TSM over consecutive turnouts

If there are turnouts completely within the TSM (e.g. Existence of another high risk asset in series through the diverging route of a high risk turnout on adjacent track) and no gradient data exists for the turnout, the worst falling gradient either side of the turnout (Worst among DN G1, DN G2, UP G1 and UP G2) shall be used for the gradient of the crossover / turnout (See Figure 6).

If the turnouts are not completely within the TSM (e.g. Existence of another high risk asset in series through the straight route of a high risk turnout on down main shown in Figure 6) only the gradient from the original track (DN G1 and DN G2) shall be used.

In case of consecutives or cascaded cases, the gradient shall cover all the functions. This means that gradient tables of one or more targets may require to be combined as one table for the submission and simplification purposes under the following conditions,

1. If $D_{gradient}$ of a target impinges on the $D_{gradient}$ of the target in the rear or,
2. If a BG requires sending 1 gradient profile to multiple target locations (which could be independent targets with independent gradient tables)

In case of the 2nd condition, if the number of gradient iterations overruns (more than 10) the simplification is not straight forward. In order to maintain the technical consistency, the AEO shall propose the potential solution and shall seek TfNSW agreement through RFI.

The designers shall re-run the ERA Braking curves tool using the simplified gradient profile to identify any changes in the BG placements.

6.2. Smoothing rules

In case more than 10 separate gradient segments are required to cover $D_{gradient}$, some simplifications are necessary to lower this number. The simplification rules shall be applied in the order shown below until the number of gradient entries is 10 or less.

Simplification Rule SR1: If two consecutive gradient entries have the same value, then they should be combined and treated as one entry (see Figure 7). This rule could be re-applied after any of the rules that follows.

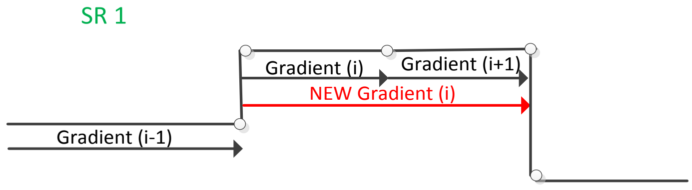


Figure 7 – Identical gradient restriction removal

Simplification Rules SR2 to SR5:

The 4 simplification rules in Figure 8 can be used to reduce the numbers of gradient segments. Each Rule shall be applied starting by simplifying with the gradient values furthest away from the target location.

Rules SR2, SR3 and SR4 shall be applied in order until the number of gradient entries is 10 or less, with a gradient minimum length of 150m (i.e. the rules apply to gradient sections less than 150m long). If there are still more than 10 gradient segments, SR5 can be applied, (with no gradient minimum length).

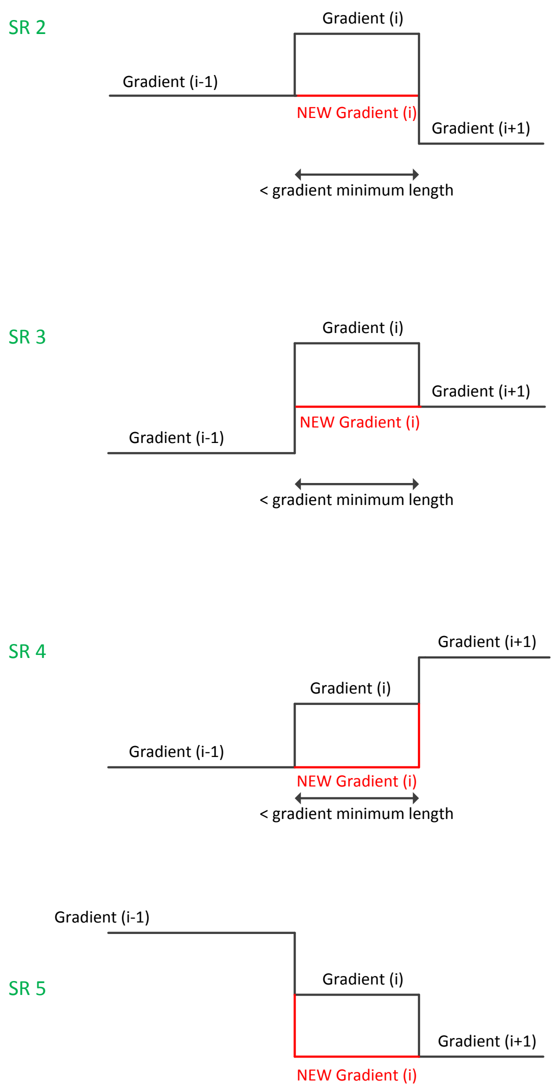


Figure 8 – Gradient minimum length – safe reduction of gradient iteration

<u>Simplification Rule SR6:</u> As per Figure 9 below, all complete gradient segments before the “Strict Minimum Gradient Coverage” (the EBD plus the train length) shall be simplified to only one gradient segment, with the gradient value being the worst falling gradient over that area.

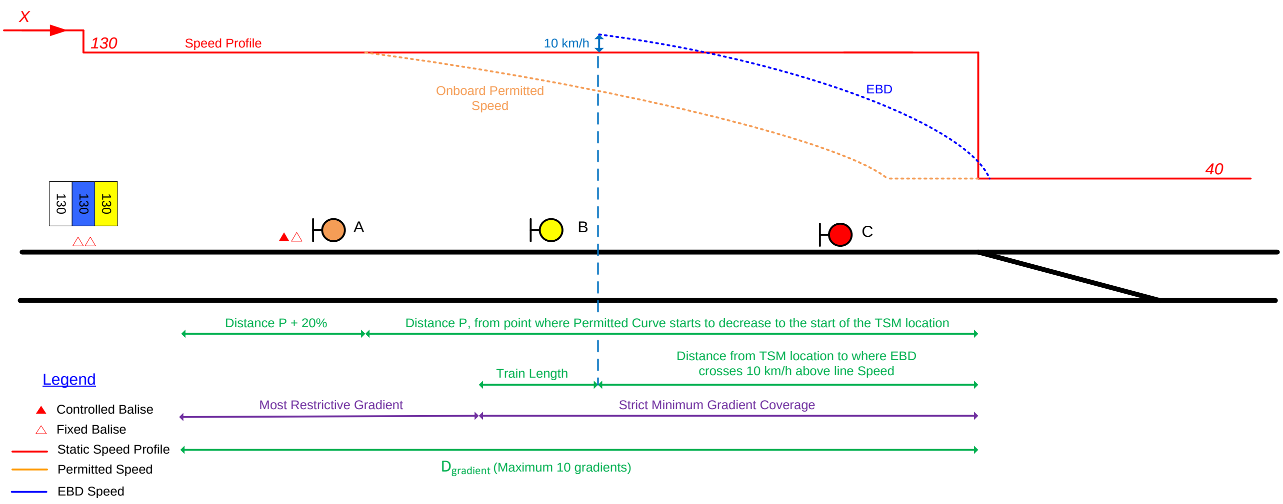


Figure 9 – Simplification gradient coverage for TSM

Simplification Rule SR7: If after applying the simplification rules SR1 to SR6, there are still more than 10 separate gradient segments, simplification Rule SR2 to SR4 shall be re-applied with no gradient minimum length (i.e. consider gradient sections more than 150m long) until the maximum of 10 gradient segments is achieved, starting with the gradient values furthest away from the target location.

7. Gradient Output

The gradient shall be exported into an excel table (see Table 2),

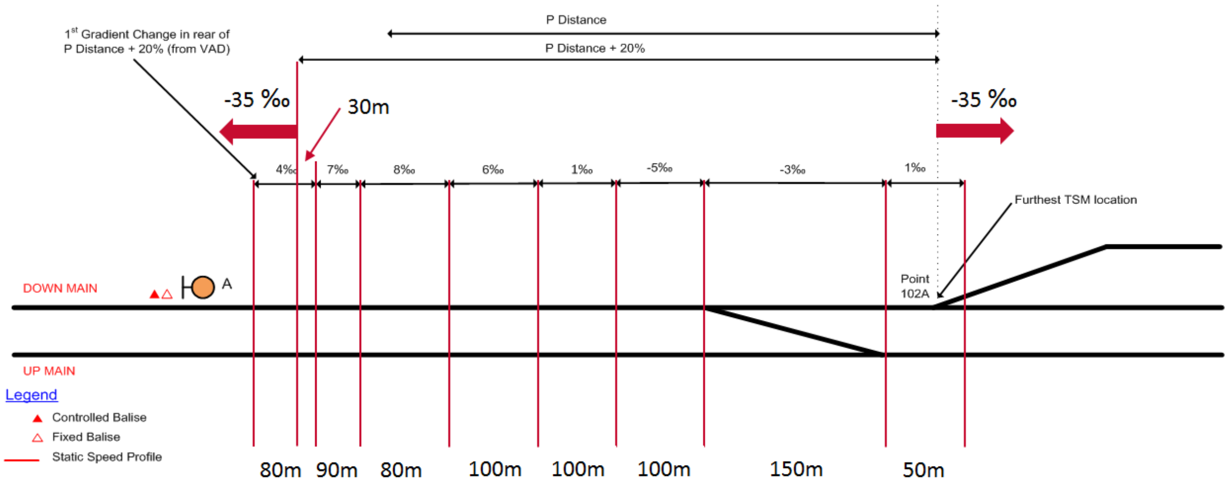


Figure 10 – Example of gradient iteration

The example in Figure 10 shows 8 iterations of gradient and Table 1 represents how they will be entered into the ERA Braking Curve tool.

Gradient profile		
ID	d (m)	Gradient G (‰)
	0	-35
	0	-35
	0	-35
	1300	-35
1	1300	4
	1330	4
2	1330	7
	1420	7
3	1420	8
	1500	8
4	1500	6
	1600	6
5	1600	1
	1700	1
6	1700	-5
	1800	-5
7	1800	-3
	1950	-3
8	1950	1
	2000	1

Table 1 – ERA Table for Figure 10 example

Table 2 shows the table (in excel format) that will be used as reference for the design and will be further used for data design.

The gradient prior to 1st Gradient Change in rear of P Distance + 20% does not need to be included in Table 2. Whenever not required to supervise a target location, the default gradient shall be set to -35‰ (note this is only of interest during the ETCS data design).

The output table should include the furthest target relative location and name, and the direction of the gradient table (Up or Down).

	d(m)	Gradient G (‰)
1	1300	4
2	1330	7

3	1420	8
4	1500	6
5	1600	1
6	1700	-5
7	1800	-3
8	1950	1
Furthest Target Location (point 102A): 2000m		
Direction: Down		

Table 2 – Gradient output table

8. ERA Braking Curve Tool Example

8.1. Simple Example

Using the simplified gradient table from Figure 3, an example of a high risk deficient overlap is shown below, with a signal located at position 8000 (referencing to gradient shown in Third Column of Figure 3). All information shall be offset so that signal is located at position 2000m (See Figure 11).

The curves calculated to supervise the target speed use the gradient profile with the train length compensation. The gradient not intervening in the braking distance can be set to a default value (set to level gradient in the example below).

Gradient profile	
d (m)	Gradient G (‰)
0	-35
999	-35
999	0
1129	0
1129	0
1239	0
1239	3
1359	3
1359	5
1439	5
1439	9
1599	9
1599	10
1659	10
1659	6
1739	6
1739	12
1900	12
1900	7
2000	7

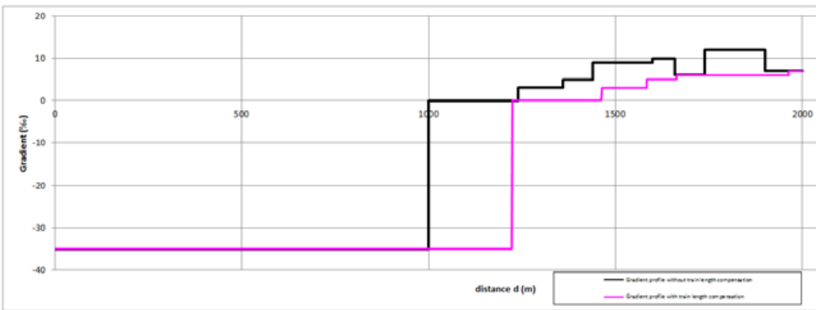
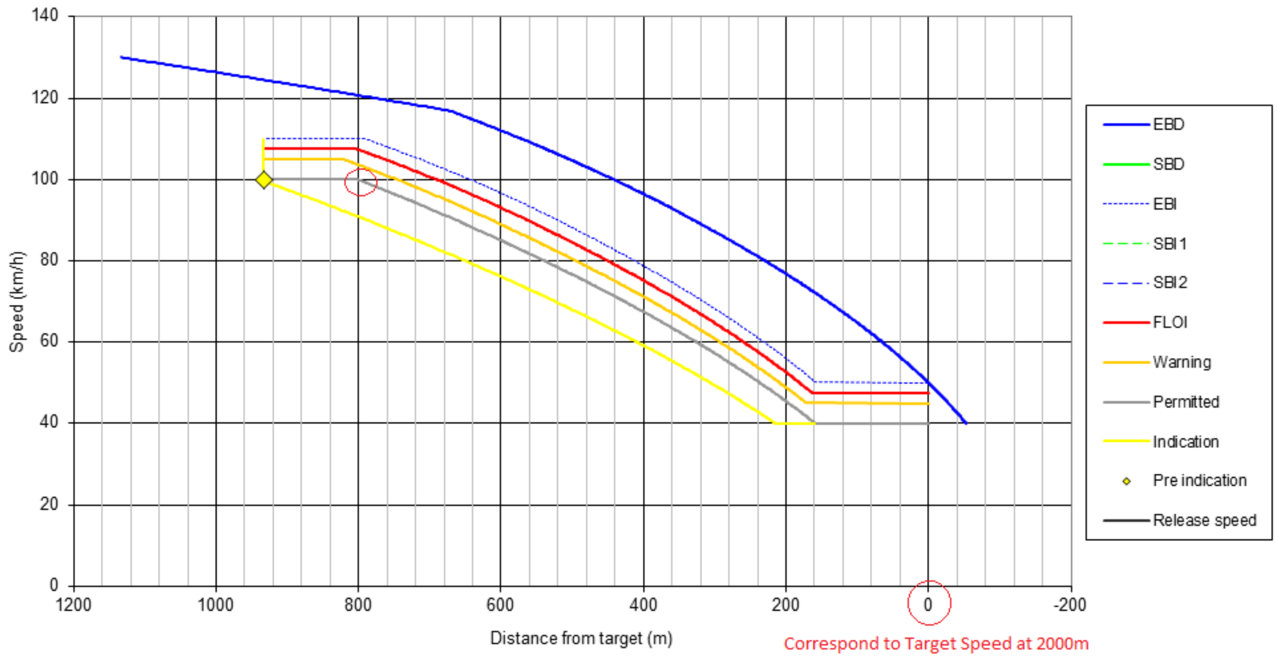


Figure 11 – Gradient table in ERA Braking Curve Tool

In Figure 12 is shown an example of the braking curves, with the Permitted curves starting to decrease at 801.01m from the target location.



Initial speed	Distance from target (m)							Release
(km/h)	Pre-indication	Indication	Permitted	Warning	FLOI	EBI	StartRSM	speed (km/h)
100.00	933.30	933.30	801.01	745.45	690.08	642.86	N/A	N/A

Figure 12 – Braking Curve Example with ERA Braking Curve Tool

8.2. Multiple TSM Management

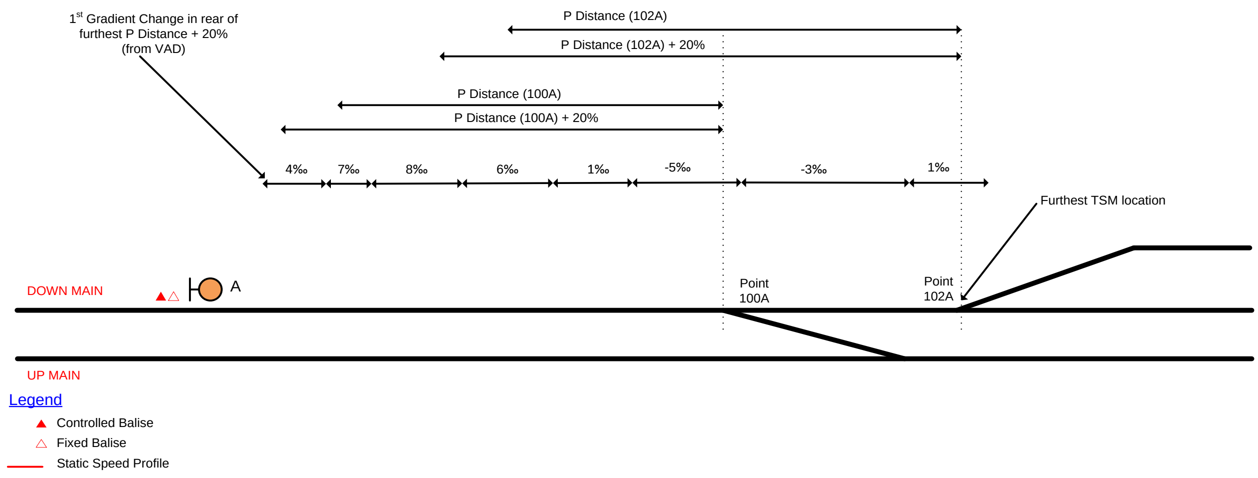


Figure 13 – Multiple TSM Management of gradient with ERA Braking Curve Tool

Figure 13 shows an example with two TSMs to be announced. There are at least 2 options to use the ERA Braking Curve tool.

Option 1: For each TSM, the gradient table is updated, so that for point 100A, the gradient goes from 4‰ to -5‰ and that for point 102A, the gradient goes from 4‰ to 1‰ and distances shall be updated accordingly.

Option 2: The gradient table is not updated and is valid for all TSM, as per this guideline. From Table 1 (section 7), the table is covering up to point 102A (reference 2000m in gradient table), so in order to calculate the braking curve for 100A (e.g. 200m before 102A), the “Dist. origin/target (m)” shall be modify to 1800m (2000m – 200m).

Therefore, for a calibration BG at 1500m from point 102A:

Target type	⦿ LOA/MRSP ○ EOA/SvL			Relocation balises (m)	Location accuracy (m)	Relocation balises Distance from target
Target speed (km/h)	25			0	5	2000
Dist. origin/target (m)	2000			500	5	1500
Initial speed (km/h)	100					

And for point 100A, the only change required is for “Dist. origin/target (m)”:

Target type	⦿ LOA/MRSP ○ EOA/SvL			Relocation balises (m)	Location accuracy (m)	Relocation balises Distance from target
Target speed (km/h)	25			0	5	1800
Dist. origin/target (m)	1800			500	5	1300
Initial speed (km/h)	100					

Appendix A – Working Examples

A.1. Gradient extraction – Single target (Down, KP Increasing direction)

This section describes in detail a sample process of formulating the gradient profile from the VAD data for a high risk turnout (HRTO). Figure 19 presents the layout where 418A in the facing direction is the HRTO in consideration. The ATP Onboard requires a sufficient number of gradient sections in approach to the HRTO for accurately estimating the safe deceleration rate for TSM.

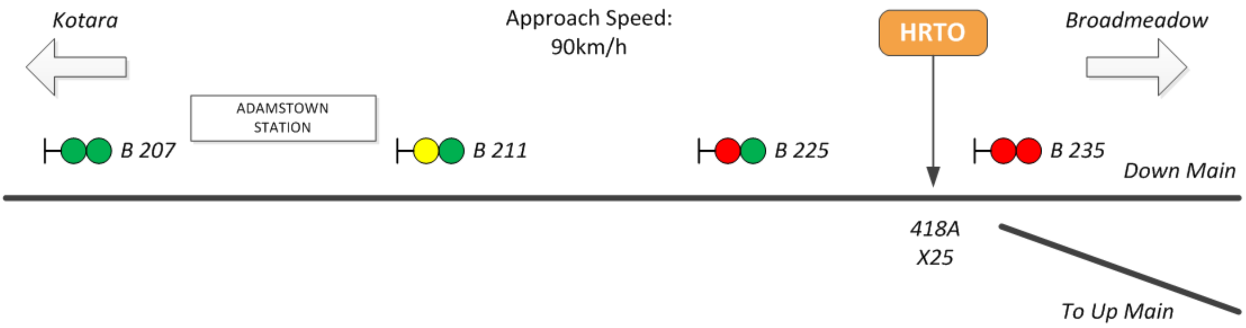
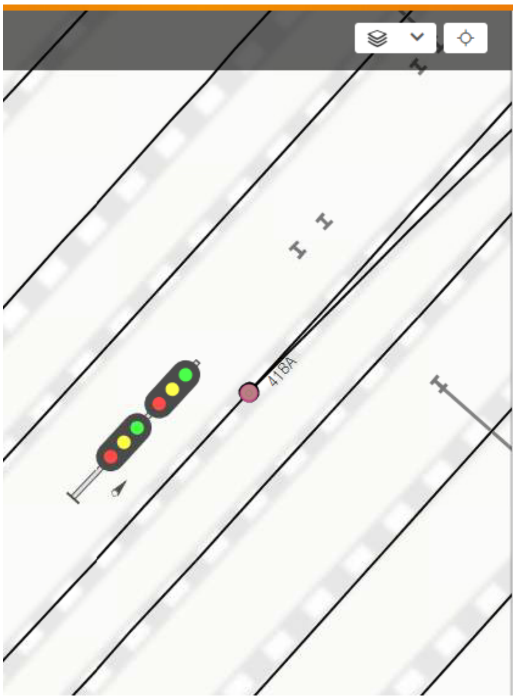


Figure 14 – 418A High risk turnout located on the city side of Broadmeadow

A.1.1 GIS KP Extraction

GIS KP of the target can be extracted from the client applications such as WebGIS or WebGIS NV. Alternatively, GIS flat file exported in Excel also provides the KP values. Using WebGIS NV, The GIS KP of the target in this example is,



Object Details

Track Node

Id	10141
Node ID (survey)	7703
Location	BMY Broadmeadow Down Yard
Kilometrage	Main North Down | 10002 | 162km457.482
Kilometrage References	588282 1170268
Name	418S Points
Status Code	active
Node reliability	other
Revision Date	21/07/08
Points Ends	90786
Ending Track Base Codes	13762
Ending Track Segments	424772041 461396694
Starting Track Segments	461390240

2 Kilometrage References

Figure 15 – 418A shown in WebGIS NV

- 418A has two KM references associated with different base codes.

Kilometrage Reference

Id	588282
Owner	Track Node:[7703] 418S Points
Track Base Code	10002 Main North Down
Kilometrage	162.457 km
ESC210 KM	162km457.482
LR	162.242 km
Corridor LR	162.242 km
Label	Track Node[[7703] 418S Points]
Derive	survey alignment
Auto G	true

Correct ESC210KM for the BC

Kilometrage Reference

Id	1170268
Owner	Track Node:[7703] 418S Points
Track Base Code	13762 Broadmeadow Yard Crossover 418 Points
Kilometrage	162.518 km
ESC210 KM	162km518.000
LR	162.518 km
Corridor LR	162.242 km
Label	Track Node[[7703] 418S Points]
Derived from	unknown
Auto Generated?	

- **GIS KM for 418A – 162457.482 (in metrage)**

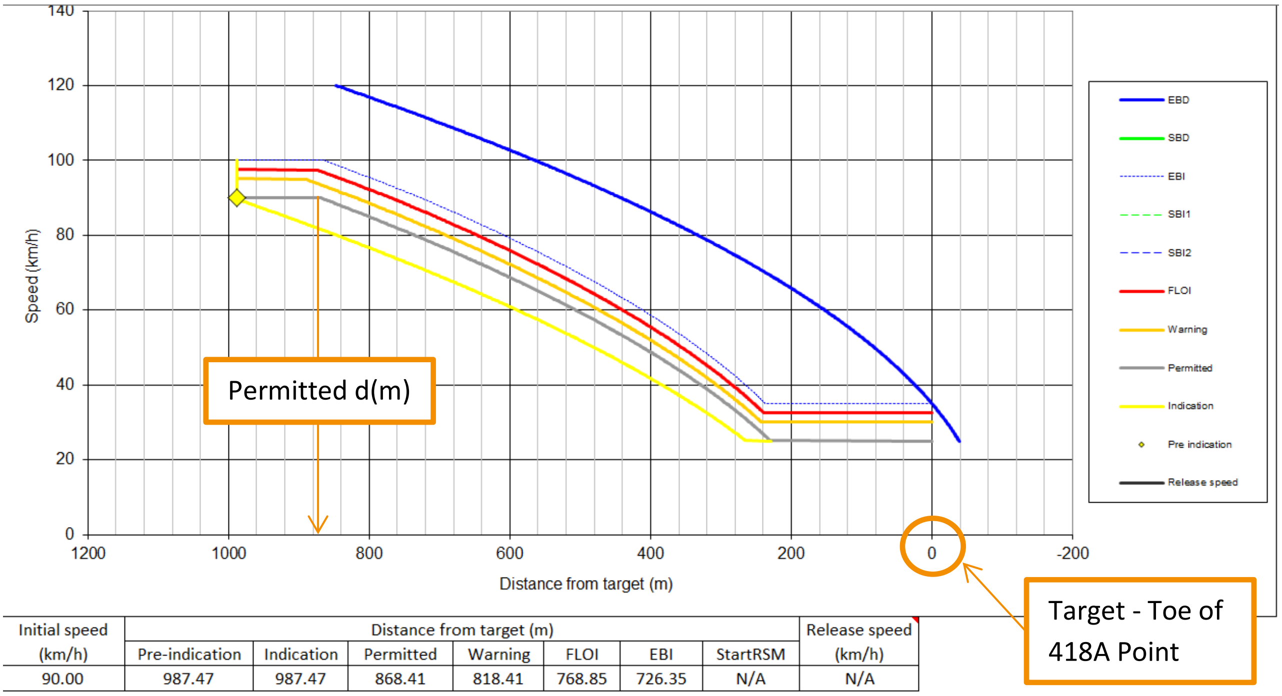
A.1.2 VAD Data Extraction

Initially, running the ERA Braking curves tool from 90 to 25 km/h over 2000m at a level gradient (Figure 21) shows an approximate permitted distance of 900m. Note that 2000m was chosen to simulate the potential location of the RDT BG, but this value should further be fine-tuned in subsequent iterations as the design progresses to reflect the BG placements accurately. (i.e., considering the calculated permitted distance, principles of placing the redundant BG for HRTO and other potentially overlapping BG placements, the estimated place for the RDT BG for 418A HRTO would be at signal B207).

Therefore, the following can be obtained using the same approach covered in A.1.1,

- **GIS KP for 418A** – 162457.482 (in metrage)
- **GIS KP for B207** – 160976.166 (in metrage)
- **Approx**. **RDT BG from the target** – 1482 m

The outcomes of the initial assessment indicate that extracting gradients over a minimum of 1500m from the target would be a good starting point as it covers both the RDT BG distance and the permitted distance from running the ERA Braking curves tool. Alternatively, the designer can also work out the $D_{gradient}$ and use this value directly for the extraction.



Initial speed (km/h)	Distance from target (m)							Release speed (km/h)
	Pre-indication	Indication	Permitted	Warning	FLOI	EBI	StartRSM	
90.00	987.47	987.47	868.41	818.41	768.85	726.35	N/A	N/A

Figure 16 – Initial ERA Braking distance simulation from 90km/h to 25km/h at level gradient

The relevant VAD Section is then extracted based on the target GIS KP (162457.482 Km), the initial lookup distance (1500 m) and the nominal direction of travel (Down or KP Increasing). The PDF extract in Figure 22 shows the range of applicable metrages (black), the range of applicable grades (red) and one adjustment (green).

```
File: 8 NMH_HMNJN_DM_ISG_10002.VAD Time: 14:43      Date: Thu 19-05-2016  #-Check PrpVC
 IP                      Metrage            Level         Grade  Prp VC/Rd  Req VC/Rd  Cls Vel Dtm
----  ------------------------  -----------  ----------  ---------  ---------- --- --- ---
599               160010.000000   27.450000              0                   1XNo VC Req
                                              -0.858333%
                  160110.000000   26.591667
600               160130.000000   26.420000              40/13489   40/5000   1XC 100 AHD
                  160150.000000   26.307640
                                              -0.561802%
                  160251.392000   25.738018
601               160271.509000   25.625000              40/12052   #40/5000  1XC 100 AHD
                  160291.626000   25.579143
                                              -0.227953%
                  160372.031000   25.395857
602               160392.148000   25.350000              40/8304    #40/5000  1XC 100 AHD
                  160412.265000   25.206676
                                              -0.712454%
                  160593.333000   23.916649
603               160633.567000   23.630000              80/10931   #40/5000  1XC 100 AHD
                  160673.801000   23.047177
                                              -1.448583%
                  160874.947000   20.133411
604               160895.064000   19.842000              40/15158   #40/5000  1XC 100 AHD
                  160915.181000   19.497193
                                              -1.714006%
    Adj Start: 161120.000000    End: 161130.000000    Length: 9.709883
                  161158.375000   15.333807
605               161178.492000   14.989000              40/17585   #40/5000  1XC 100 AHD
                  161198.609000   14.690221
                                              -1.485206%
606               161230.000000   14.224000              0                   1XNo VC Req
                                              -1.190909%
                  161275.000000   13.688091
607               161285.000000   13.569000              20/2635    #40/5000  1XC  90 AHD
                  161295.000000   13.525799
                                              -0.432009%
608               162125.260000    9.939000              0                   1XNo VC Req
                                              -0.313254%
609               162509.294000    8.736000              0                   1XNo VC Req
                                              -0.193099%
    Adj Start: 162580.000000    End: 162589.823973    Length: 9.782953
                  162669.954000    8.425846
610               162690.071000    8.387000              40/10866   #40/5000  1XC 100 AHD
                  162710.188000    8.273668
                                              -0.563365%
```

Figure 17 – VAD Extraction for 418A High risk turnout

Figure 23 shows the result of the extraction into an Excel table. Note the grades (highlighted in orange) are in ‰ (Per mil, 1 in 1000).

IP	Metrage	Level	Grade (%)	Grade (%)	Grade(‰)	Adj (m)	Adj. Start	Adj. End	Length
604	160895.064000	19.842000	-1.714006%	-1.714006%	-18	-0.290	161120	161130	9.710
605	161178.492000	14.989000	-1.485206%	-1.485206%	-15	0			
606	161230.000000	14.224000	-1.190909%	-1.190909%	-12	0			
607	161285.000000	13.569000	-0.432009%	-0.432009%	-5	0			
608	162125.260000	9.939000	-0.313254%	-0.313254%	-4	0			
609	162509.294000	8.736000	-0.193099%	-0.193099%	-2	0			

Figure 18 – VAD Extraction onto excel, stage1

The table in Figure 24 shows the final extraction, incorporating the target GIS KP and the RDT BG Distance. Having a table formulated in this manner enables relatively straightforward gradient output conversion for data preparation and provides the traceability.

IP	Metrage	Section (m)	Grade (‰)	Relative from Target (m)	Relative from Origin (m)	Adj (m)	Adj. Start	Adj. End	Length
604	160895.064000	283.137883	-18	1562.127883	-	-0.290	161120	161130	9.710
605	161178.492000	51.508000	-15	1278.990000	221	0			
606	161230.000000	55.000000	-12	1227.482000	273	0			
607	161285.000000	840.260000	-5	1172.482000	328	0			
608	162125.260000	-	-4	332.222000	1168	0			
609	162509.294000	-	-2	-	-	0			
				162457.482	1500				
				Target GIS KP(Km)	Origin to Target d(m)				

Figure 19 – VAD Extraction onto excel, stage2

Note that,

- Relative from target (m) distances show the start of the gradient change relative to the target. This is useful in working out the initial gradient section
- Relative from origin (m) distances show the start of the gradient change relative to the simulation origin which is useful in building the gradient profile in the ERA Braking curves tool
- Entries within the orange rectangle are likely candidates for 418A gradient profile. The relative distances are rounded to integers as the precision for data design application does not accept decimals.

The corresponding gradient profile derived from the table in Figure 24 is shown in Figure 25.

All unused sections can be populated with '0'. This should not have any impact on the simulation result

Gradient profile	
d (m)	Gradient G (‰)
0	-35
0	-35
0	-35
0	-35
0	-35
0	-35
0	-35
0	-35
0	-35
0	-35
0	-35
221	-35
221	-15
273	-15
273	-12
328	-12
328	-5
1168	-5
1168	-4
1500	-4

Default value of -35‰ shall be entered for all unused sections. This should not have any impact on the simulation result

Figure 20 – Gradient profile

A.1.3 Step 4 – Re-run the ERA Braking curves tool

The ERA Braking curves shall be re-calculated with the gradient profile in Figure 25 to provide a more accurate representation of the actual conditions. In this particular example, the re-calculated braking curves would be pushed further out from the target as the actual gradients are in negatives (falling gradient). However, the simulated distance from the origin to target is reduced from 4000 to 1500m. Hence, a slight performance gain is expected overall.

The updated track parameters in the ERA tool are shown in Figure 26, and the result of the simulation is shown in Figure 27.

Target type	◉ LOA/MRSP ○ EOA/SvL	
Target speed (km/h)	25	
Dist. origin/target (m)	1500	
Initial speed (km/h)	90	
Track condition brake inhibition profile		
Start of brake inhibition (m)		Brake inhibition area
End of brake inhibition (m)		
Reduced adhesion profile		
Start of reduced adhesion (m)		Reduced adhesion area
End of reduced adhesion (m)		

Recalculate the track values

Relocation balises (m)	Location accuracy (m)	Relocation balises Distance from target
0	5	1500

Gradient profile

d (m)	Gradient G (‰)
0	-35
0	-35
0	-35
0	-35
0	-35
0	-35
0	-35
0	-35
0	-35
0	-35
0	-35
221	-35
221	-15
273	-15
273	-12
328	-12
328	-5
1168	-5
1168	-4
1500	-4

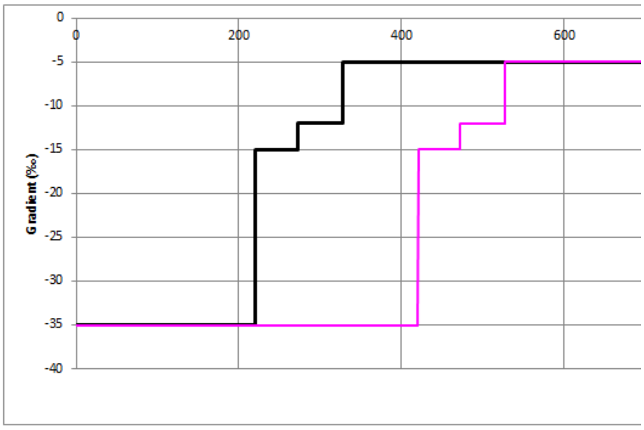
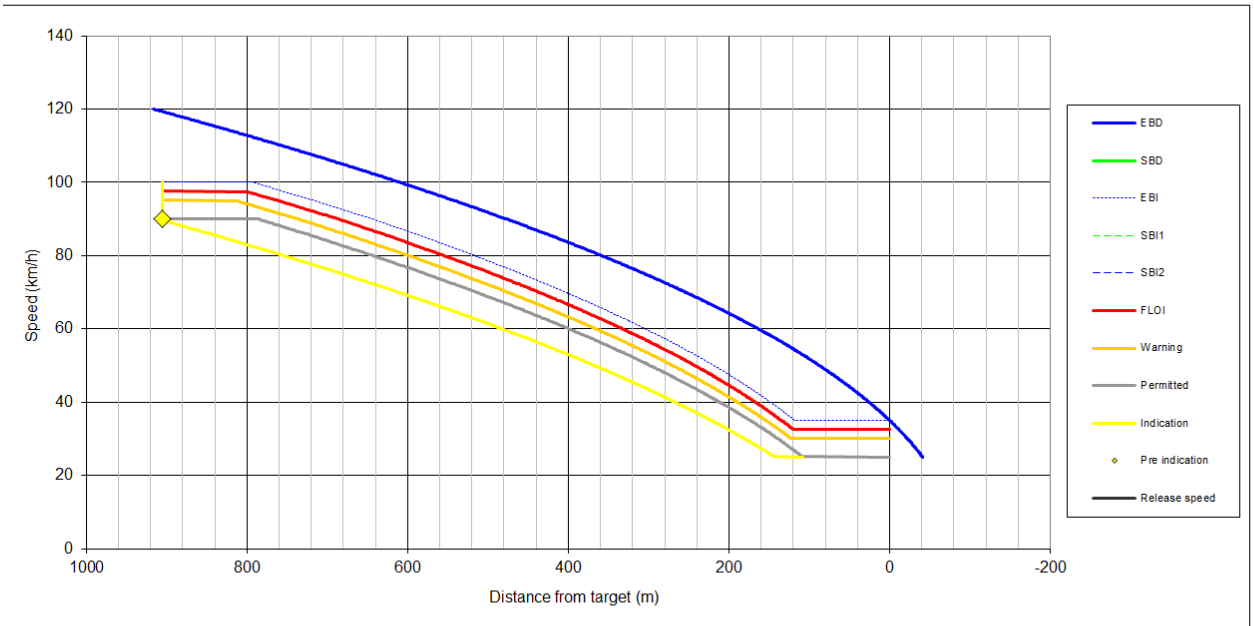


Figure 21 – Updated track parameters in the ERA Braking curve tool



Initial speed	Distance from target (m)							Release speed
(km/h)	Pre-indication	Indication	Permitted	Warning	FLOI	EBI	StartRSM	(km/h)
90.00	905.48	905.48	786.41	736.41	686.53	644.03	N/A	N/A

Figure 22 – Re-calculated ERA Braking curve for 418A

Note that the permitted distance is reduced from 868.41 to 786.41m as expected.

A.1.4 Step 5 – Prepare gradient output table

The coverage distance for the gradient output table is shown below,

$$\boldsymbol{D_{Gradient}} = Permitted\ d(m) * 1.2$$
$$= 786.41 * 1.2$$
$$= 944m\ (Rounded\ Up)$$

Table 1 – Gradient output table for 418A

944m from the target

	d(m)	Gradient G (‰)
1	556	-5
2	1168	-4
Furthest Target Location (Point 418A): 1500m		
Direction: Down, Down Main North		

Dist. origin to target (m) in the ERA Tool. For the single target output, this generally represents the distance of the RDT BG from the target location.

The ERA Calculation shall be updated to match the gradient output table shown in Table 6.

A.2. Gradient extraction – Single target (Up, KP Decreasing direction)

Majority of the extraction process is identical to the down direction example covered in A.1. However, designers should watch out for some common pitfalls.

A.2.1 Signs (+/-) of grade values shall be reversed

Independent of the nominal direction of a track, the grade values in VAD represent the down direction of travel (KP Increasing direction) by default. This means that the sign to indicate the rising or falling shall be reversed for extracting gradients in the up direction of travel (KP Decreasing direction).

Table 2 – Example showing grades values with flipped signs

		Gradient in VAD	Gradient for Up Dir (KP Dec.)
IP	Metrage	Grade (‰)	Grade (‰)
3	164100.000000	-0.500000	0.500000
4	164300.000000	-1.149920	1.149920
5	164492.187000	-1.434460	1.434460
6	164553.534000	0.000000	0.000000
7	164654.288000	-1.840000	1.840000
8	164734.723000	-2.774770	2.774770
9	165056.552000	-6.839910	6.839910
10	165277.900000	-4.029890	4.029890
11	165519.346000	-1.559960	1.559960
12	165800.123000	0.000000	0.000000

Represented Direction

A.2.2 Safe ‰ conversion shall be performed after reversing the sign

The safe ‰ conversion shall only be performed after reversing the sign. Otherwise, it can result in a different set of values as shown in the example below.

Table 3 – Example of the safe ‰ conversion performed before and after reversing the sign

A. Safe rounding performed before sign reversing

IP	Metrage	Grade (‰)	Safe Rounded Grade (‰)	Sign Reversed for Up Dir
3	164100.000000	-0.500000	-1	1
4	164300.000000	-1.149920	-2	2
5	164492.187000	-1.434460	-2	2
6	164553.534000	0.000000	0	0
7	164654.288000	-1.840000	-2	2
8	164734.723000	-2.774770	-3	3
9	165056.552000	-6.839910	-7	7
10	165277.900000	-4.029890	-5	5
11	165519.346000	-1.559960	-2	2
12	165800.123000	0.000000	0	0

Method. A (Before)	Method. B (After)
Grade for Up Dir	**Grade for Up Dir**
1	0
2	1
2	1
0	0
2	1
3	2
7	6
5	4
2	1
0	0

B. Safe rounding performed after sign reversing

IP	Metrage	Grade (‰)	Sign Reversed for Up Dir	Safe Rounded Grade (‰)
3	164100.000000	-0.500000	0.500000	0
4	164300.000000	-1.149920	1.149920	1
5	164492.187000	-1.434460	1.434460	1
6	164553.534000	0.000000	0.000000	0
7	164654.288000	-1.840000	1.840000	1
8	164734.723000	-2.774770	2.774770	2
9	165056.552000	-6.839910	6.839910	6
10	165277.900000	-4.029890	4.029890	4
11	165519.346000	-1.559960	1.559960	1
12	165800.123000	0.000000	0.000000	0

A.2.3 Metrage value represents the start of the section in rear

The metrage value typically indicates the start of a gradient change for the corresponding grade in the down direction of travel (KP Increasing). However, it now represents the end of the section for the up direction of travel (KP Decreasing). See Table 9 for clarification.

Table 4 – Metrage representing the end of a gradient section

IP	Metrage	Safe Rounded Grade (‰) - Direction adjusted
3	164100.000000	0
4	164300.000000	1
5	164492.187000	1
6	164553.534000	0
7	164654.288000	End 1
8	164734.723000	Start 2
9	165056.552000	6
10	165277.900000	4
11	165519.346000	1
12	165800.123000	0

Rising grade of 1‰ represents the section in the indicated direction.

A.3. Gradient extraction – Multiple targets (Overlapping gradients management)

All high risk targets shall be assessed against each other to determine if the $D_{Gradient}$ (1.2 * Permitted d(m)) of a target overlaps with the target in the rear. Due to some foreseen risks in the data design phase, a combined gradient output table shall be created covering for all overlapping targets.

Consider the following high risk assets for example,

Table 5 – Multiple high risk targets for consideration

Asset Name	Asset Type	Location	Line	KP DIR.
B207	Deficient Overlap	Broadmeadow	Down North Main	Increasing
B211	Deficient Overlap	Broadmeadow	Down North Main	Increasing
405S	High Risk Turnout	Broadmeadow	Down North Main	Increasing

Once the individual ERA Braking curves simulation is complete and permitted d(m) is available the overlapping status can be determined by comparing the $D_{Gradient}$ from the furthest target in the direction. This is shown in Table 11 and Figure 28.

Table 6 – Overlapping gradient analysis

Asset			Speed (km/h)		GIS KP (Km)			Distance to Target (m)					
Seq. ID	Name	Type	Approach	Target	RDT BG	Main BG	Target	RDT BG	Main BG	Permitted	1.2* Permitted (m)	1.2 Permitted (Km)	Overlap?
1	**B207**	DFOL	90	50	158498	159950.156	160976.166	1931.166	1029.91	713.83	857	160119.166	TRUE
2	**B211**	DFOL	90	10	158498	159950.156	161181.144	2136.144	1234.888	977.23	1173	160008.144	TRUE
3	**405S**	HRTO	90	25	158498	159950.156	161243.778	2198.778	1297.522	939.23	1128	160115.778	Furthest Target

Please advise if Main BG distance to target is rolling distance because I'm getting slightly different values to Main BG in "Distance to Target" 1236m

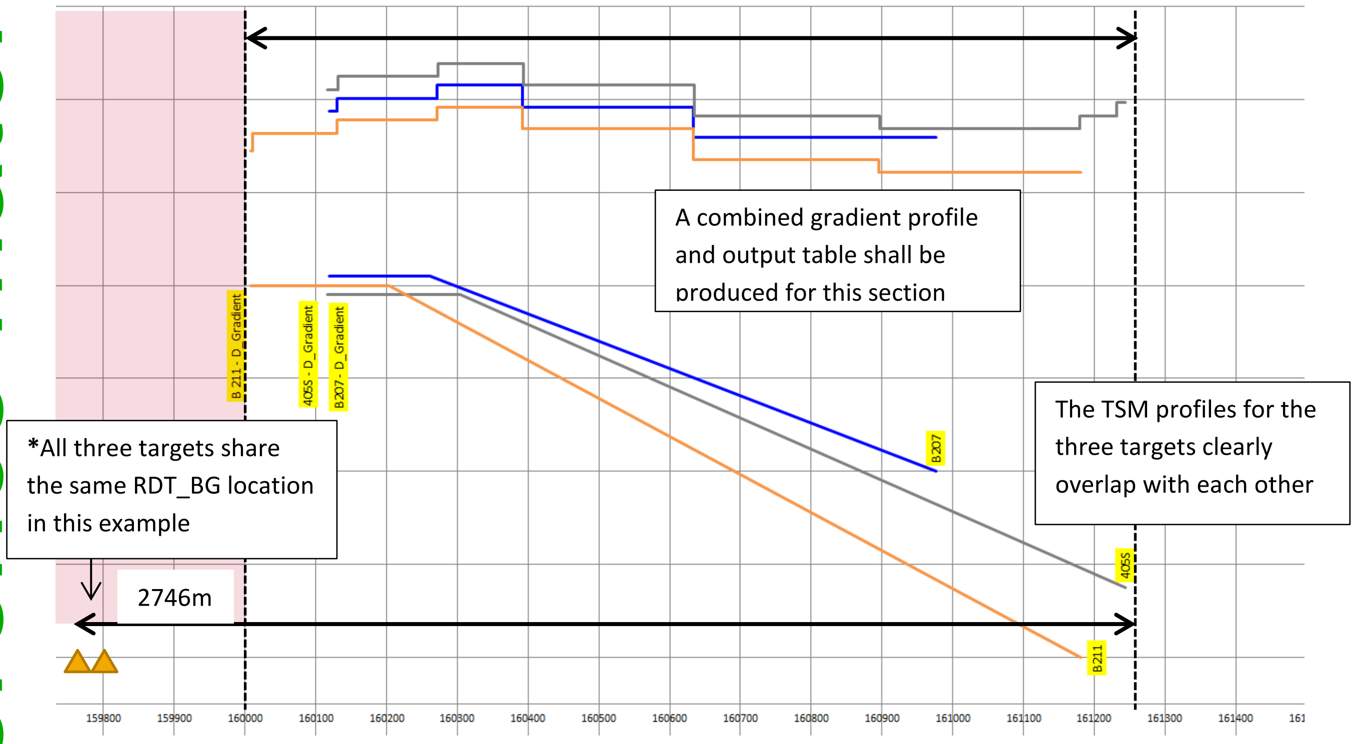


Figure 23 – Visualisation of the overlapping gradients

RDT BG is 2198.778m from furthest target in Table 11 but in figure 28 it is 2746m.

Extracting the gradients from the furthest target (Toe of 405S Point) to the $D_{Gradient}$ of signal B211 results in Table 12,

Table 7 – VAD Extraction result

IP	Metrage	Section (m)	Grade (‰)	Relative from Target (m)	Relative from Origin (m)	Adj (m)	Adj. Start	Adj. End	Length
598	159550	461	-13	1694	1052	0.638635	159640	159650	10.638635
599	160010	120	-9	1233	1513	0			
600	160130	142	-6	1113	1633	0			
601	160272	121	-3	972	1774	0			
602	160392	241	-8	851	1895	0			
603	160634	261	-15	610	2136	0			
604	160895	283	-18	348	2398	-0.290117	161120	161130	9.709883
605	161178	52	-15	65	2681	0			
606	161230	-	-12	14	2732	0			
607	161285	-	-5	-	-	0			
				161243.778	2746				
				Furthest Target	Simulated Distance				

Gradient profile

d (m)	Gradient G (‰)
0	-35
1510	-35
1510	-13
1513	-13
1513	-9
1633	-9
1633	-6
1774	-6
1774	-3
1895	-3
1895	-8
2136	-8
2136	-15
2398	-15
2398	-18
2681	-18
2681	-15
2732	-15
2732	-12
2746	-12

Combined Gradients for HRTO 405S, DFOL B207 and

	d(m)	Gradient G (‰)
1	1510	-13
2	1513	-9
3	1633	-6
4	1774	-3
5	1895	-8
6	2136	-15
7	2398	-18
8	2681	-15
9	2732	-12
Furthest Target Location (HRTO 405S): 2746m		
Direction: Down, Down North Main		

If the number of sections overrun (more than 10) and require smoothing, then the ERA Braking curves simulations shall be carried out again using the smoothed profile.

A.4. Gradient smoothing

Consider the VAD extract given in Figure 29 where every entry shall be considered for gradient extraction. The gradient simplification is required as there are more than ten sections.

IP	Metrage	Section (m)	Grade (%o)	Relative from Target (m)	Relative from Origin (m)	Adj (m)	Adj. Start	Adj. End	Length
599	160010	120	-9	2792	8	0			
600	160130	142	-6	2672	128	0			
601	160272	121	-3	2530	270	0			
602	160392	241	-8	2410	390	0			
603	160634	261	-15	2168	632	0			
604	160895	283	-18	1907	893	-0.290117	161120	161130	9.709883
605	161178	52	-15	1623	1177	0			
606	161230	55	-12	1572	1228	0			
607	161285	840	-5	1517	1283	0			
608	162125	384	-4	677	2123	0			
609	162509	181	-2	293	2507	-0.017047	162580	162590	9.782953
610	162690	-	-6	112	2688	0			
				162802	2800				
				Furthest Target KP	Dist. Origin/Target				

12 Sections in total, requires smoothing

Figure 24 – VAD Extract on Down North Main

By applying the smoothing rules in 6.2, the following sections can be smoothed out (highlighted in grey). s

IP	Metrage	Section (m)	Grade (%o)	Relative from Target (m)	Relative from Origin (m)	Adj (m)	Adj. Start	Adj. End	Length	
599	160010	120	-9	2792	8	0				
600	160130	142	-6	2672	128	0				
601	160272	121	-3	2530	270	0				Removed (Applied Rule: SR2)
602	160392	241	-8	2410	390	0				
603	160634	261	-15	2168	632	0				
604	160895	283	-18	1907	893	-0.290117	161120	161130	9.709883	
605	161178	52	-15	1623	1177	0				Removed (Applied Rule: SR4)
606	161230	55	-12	1572	1228	0				Removed (Applied Rule: SR4)
607	161285	840	-5	1517	1283	0				
608	162125	384	-4	677	2123	0				
609	162509	181	-2	293	2507	-0.017047	162580	162590	9.782953	
610	162690	-	-6	112	2688	0				
				162802	2800					
				Furthest Target KP	Dist. Origin/Target					

Figure 25 – Smoothing rules applied on the VAD Extract

Visualising the simplification,

- Section (IP: 601) – This section was smoothed as per the rule SR2. The train length compensation in calculating the safe deceleration rate means the Onboard would still consider the previous gradient of -6 as this is more restrictive then -3.
- Section (IP: 605, 606) - These sections were smoothed as per the rule SR4. (Same principle as above).

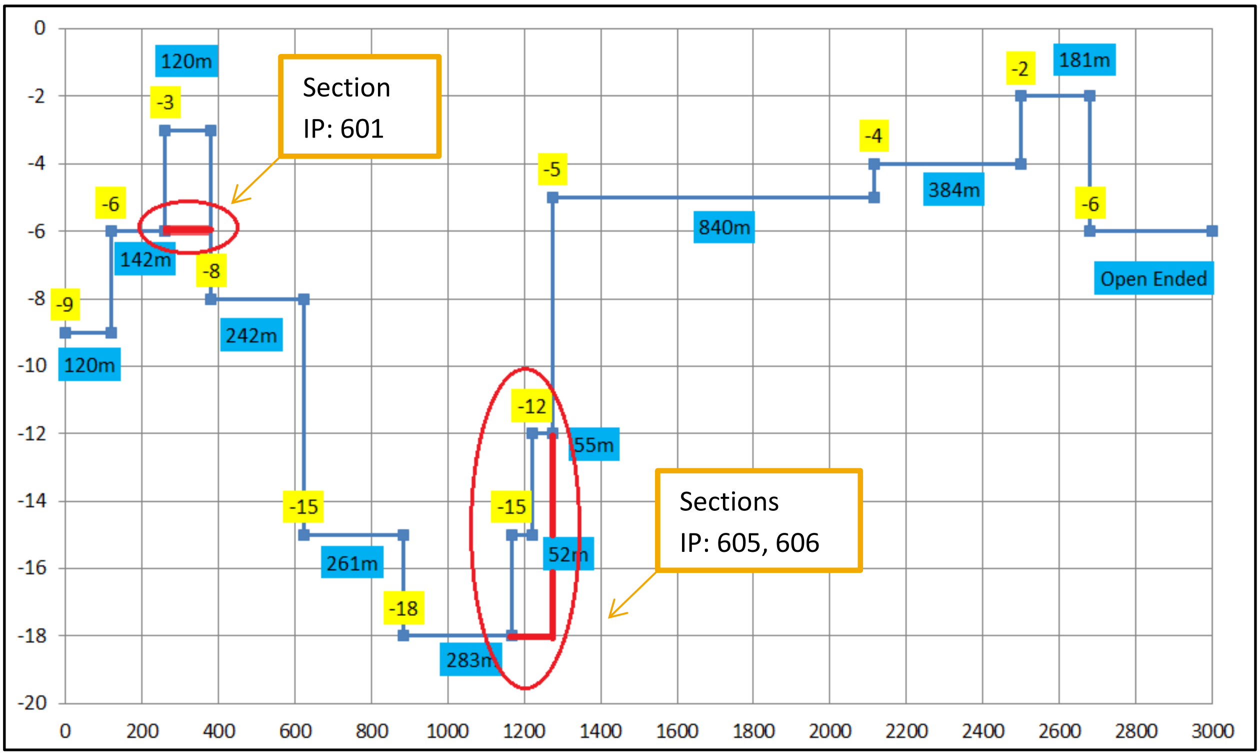


Figure 26 – Visualisation of the simplification