12d® International Innovation Awards

Executive Summary

Name: Gary McLean
Company: SKM
Name of Project: Adelaide Hills Rail
Awards Result: Highly Commended

12d Model and the 12d Track module were used on the Adelaide Hills Rail Project. Gary devised an innovative method to have plotted cross sections showing rail design formation with the track infrastructure correctly displayed. This meant having the ballast, sleepers and rail profiles shown in all cross sections but, more importantly, on the correct cant at the horizontal curves.

He also managed to calculate the exact ballast depths under the sleepers at both (high and low) rail locations. This value is critical as all the loads of the train are directly bearing under the rail foot and the minimum designed depth should be maintained.

Rail Innovation – Ballast depth under Rail plus other benefits

Introduction

I have been involved in railway design using 12d software for a combination of 6 years in my 12 years of using the program. In recent years the 12d rail module was added and has helped many designers produce a better product. I went through the rail module finding many functions that were both simple and testing to use. This made me realise some alternative ways to achieving the most out of this module. I will show you how to input and edit the user interface with confidence and a greater understanding. A further benefit will be a superior output of quantities with the benefit of producing better cross section plots depicting the rails on correct cant (Wish No. 1). The important ballast depth directly beneath the rail is also measured using a combination of tools already at your fingertips within the 12d environment (Wish No. 2). These benefits were on my own wish list, which have become innovative and will be described further on page 5.

Use of Rail Module

After creating the super alignment consisting of horizontal and vertical geometry you then apply the Cant Panel macro. *Tip: This macro is always run prior to Plot Rails macro.*

There are 4 important inputs required in the Cant Design Tab before continuing.

1. Alignment speed (from design criteria)
2. Track Gauge (from design criteria)
3. Kec
4. Ksc

Items 3 & 4 need explaining. Both these values are constants, where item 4 in reality is variable in rail designing.

How it works: The designer produces a 'speed table' which calculates the cant (superelevation) required to accommodate the speed and radii of design curves. The mathematical formulae vary slightly depending on the rail size and gauge between inside rail faces.

The Kec constant is derived from the formula Kec = $S/g * (3.6)^2$

Where S is the centreline spacing of the rails, g is gravitational acceleration (taken as $9.8m/^2$) and 3.6 is the conversion factor to allow the use of V (km/h) instead of Vm (m/s)

So an example of heavy haul rail using 68kg rail with 75mm width of rail head on a standard gauge being 1435mm → $1435 + (2 * 37.5mm) / 9.8 * 3.6^2$ which = 11.89 Kec value

This 11.89 value is used in calculating the applied equilibrium cant allowed.

The formula is $Ee=11.89*V^2/R$ where V is speed and R is horizontal radius.

The item 4 value although being a constant does vary pending each curve on the design. The value is brought about by the curve requiring some deficiency in the calculated equilibrium cant. The idea of cant deficiency being a lower cant than calculated is to ‘drive’ the train with gravitational force into the rails thereby having a smoother continuous ride than any slack between the wheels and the rails where the ideal equilibrium was originally calculated. This value is generally two thirds (66%) of the chosen applied cant *Ea* to the equilibrium cant.

Therefore after all that to calculate item 4, simply 66% of Kec Value,

An example being 11.89 *0 .66 = 7.847 Ksec

A speed table is shown below; note column 8 is the recommended 66% ratio a designer aims for.

These figures I produced were ranging between 60% and 83%

75/45	kph

STANDARD GAUGE

DESIGN LIMITS	Exceptional	Recommended	
MIN RADIUS	450	1000	m
MAXIMUM CANT (Ea)		40	mm
MAXIMUM DEFICIENCY (D)		50	mm
RATE OF CHANGE OF CANT (Eroc)		35	mm/s
RATE OF CHANGE OF DEFICIENCY (Droc)		35	mm/s
CANT GRADIENT (Er)		1250	1 in _

HORIZONTAL ALIGNMENT

Design Speed	Geometry											Rates of Change		Cant Gradient
	Element ID No.	Element	Radius (m)	Ee (mm)	Ea (mm)	D=Ee-Ea (mm)	Ea/Ee Ratio Rec. 66 %	Min Trans (Method 1) (m)	Min Trans (Method 2) (m)	Min Trans (Method 3) (m)	Trans (m)	Eroc (mm/s)	Droc (mm/s)	Er (1 in _)
		Straight	0.000	0.00	0.00	0.00								
								17.857	8.683	37.500	50	0.00	0.00	1667
75	South 75-1	Curve	1500.000	44.59	30.00	14.59	67							
								17.857	8.683	37.500	50	12.50	6.08	1667
75		Straight	0.000	0.00	0.00	0.00								
								17.857	8.683	37.500	50	12.50	6.08	1667
75	South 75-2	Curve	1500.000	44.59	30.00	14.59	67							
								17.857	8.683	37.500	50	12.50	6.08	1667
75		Straight	0.000	0.00	0.00	0.00								
								17.857	8.683	37.500	50	12.50	6.08	1667
75	South 75-3	Curve	1500.000	44.59	30.00	14.59	67							
								17.857	8.683	37.500	50	12.50	6.08	1667
75		Straight	0.000	0.00	0.00	0.00								
								23.810	16.001	50.000	50	16.67	11.20	1250
75	South 75-4	Curve	1000.000	66.88	40.00	26.88	60							
								23.810	16.001	50.000	50	16.67	11.20	1250
75		Straight	0.000	0.00	0.00	0.00								
								5.952	1.234	12.500	50	4.17	0.86	5000
75	South 75-5	Curve	5540.000	12.07	10.00	2.07	83							
								23.810	16.001	50.000	50	16.67	11.20	1250
75		Straight	0.000	0.00	0.00	0.00								
								8.929	5.403	18.750	20	15.63	9.46	1333
45	South 75-6	Curve	1000.000	24.08	15.00	9.08	62							
								5.357	3.242	18.750	20	9.38	5.67	1333
45		Straight	0.000	0.00	0.00	0.00								

$$E_e = \frac{11.89 \times V^2}{R}$$

$$L_1 = V \times Ea/(3.6xEroc)$$

$$L_2 = V \times D/(3.6xDroc)$$

$$L_3 = 1.25 \times Ea$$

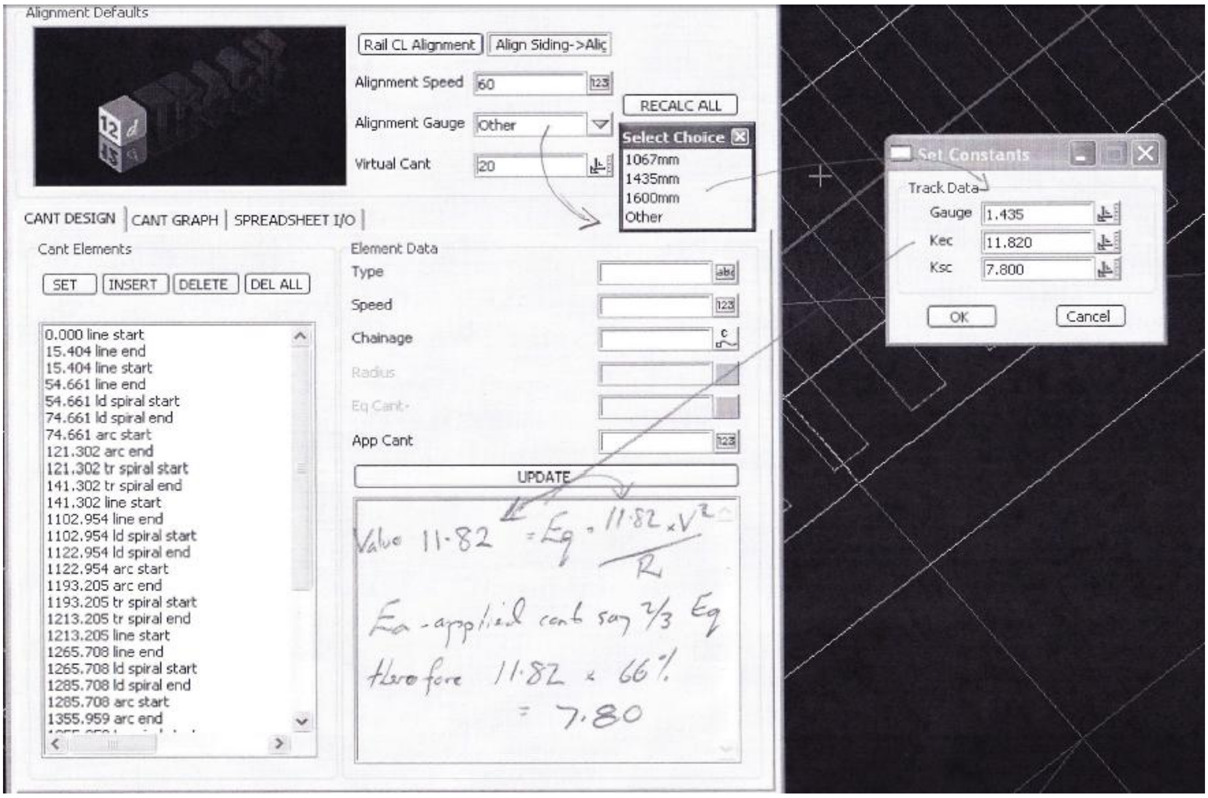
$$E_{roc} = \frac{\Delta E_a \times V}{3.6 \times L}$$

$$D_{roc} = \frac{\Delta D \times V}{3.6 \times L}$$

$$E_r = \frac{1000 \ * L}{\Delta E_a}$$

Note the 11.89 formula imbedded into my spreadsheet in the bottom left. This figure would change for broad gauge, (1600mm rail face to rail face) typically 13.1.

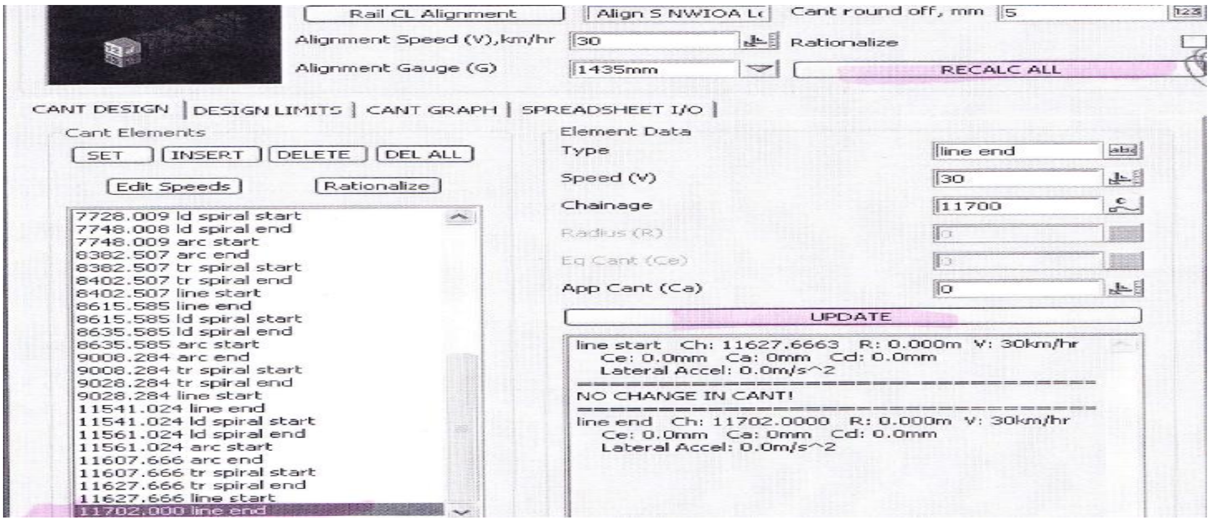
An example is shown below of 12d input into the Cant Panel. This is a different Ksec value supplied to me by ARTC (Australian Rail Track Corporation) as specified for a project in Adelaide on standard gauge.



The panel below has highlighted 2 buttons and also the last point in the alignment (line end).

The RECALC ALL button must be used if the alignment changes then the UPDATE button is necessary to follow.

The last point can be added or manipulated manually to avoid rail loop closure problems. This can occur when the loop comes back on itself and picks up the earlier chainage where it is about to join back onto, known as a rail turnout. So it is best to stop a fraction short of your intended turnout.

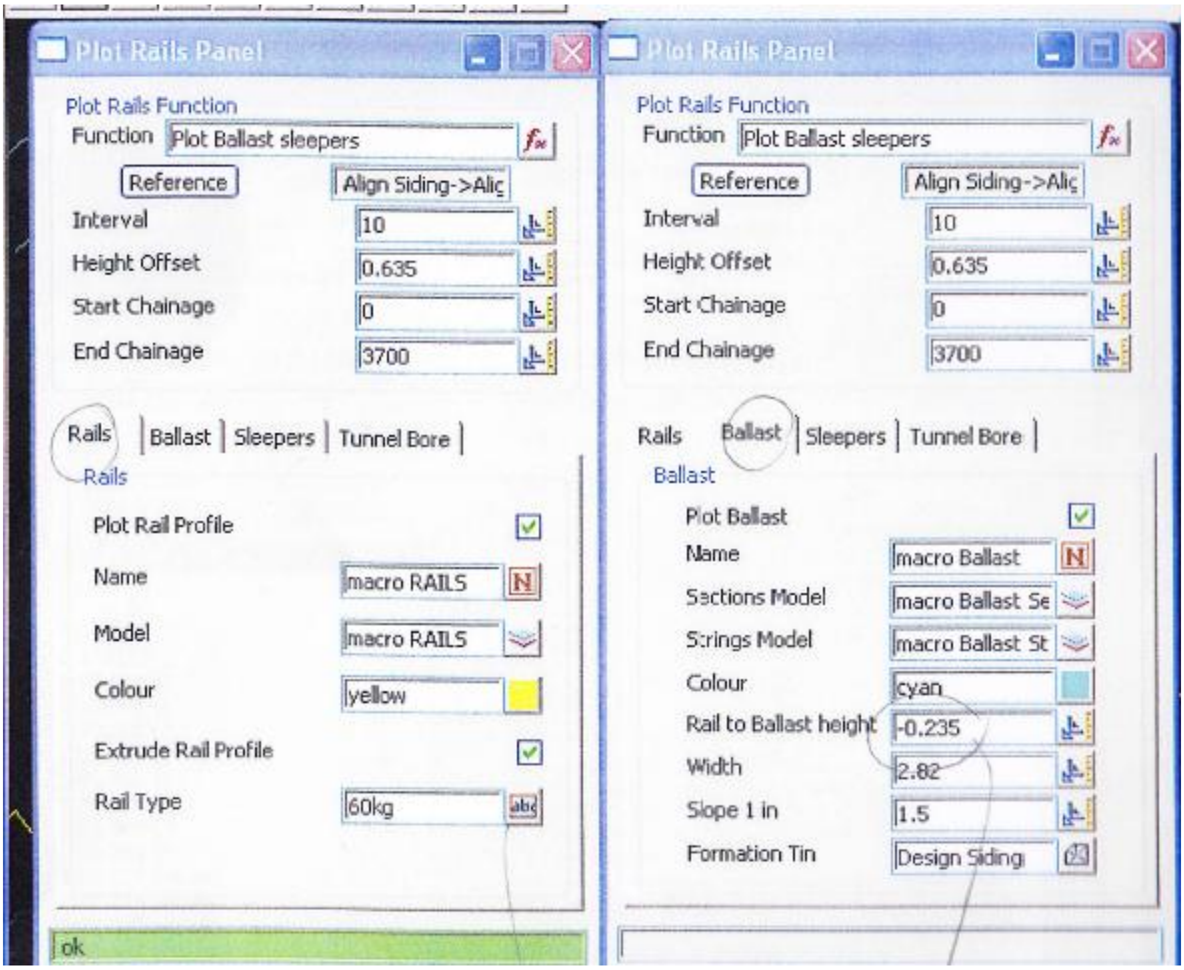


Next in the design process in to run the Plot Rails macro.

This macro will produce 12d models for rail strings, ballast string & sections and sleepers.

This case example has a sleeper depth of 200mm, minimum ballast depth under sleeper of 200mm and rail with seating pad is 235mm. Therefore this equates to 635mm above the designed rail formation. As can be seen in both Rails and Ballast tabs the height offset is 0.635. The other dimension Rail to Ballast height is 0.235. This is correct as the ballast come to the top of the sleeper level when there is no sleeper present, as sleepers spaced generally 600mm centre to centre. Also worth explaining is the width, which is the ballast shoulder edge to shoulder, in this case 150mm is used for the shoulder and sleeper width is 2520mm, therefore 2.82.

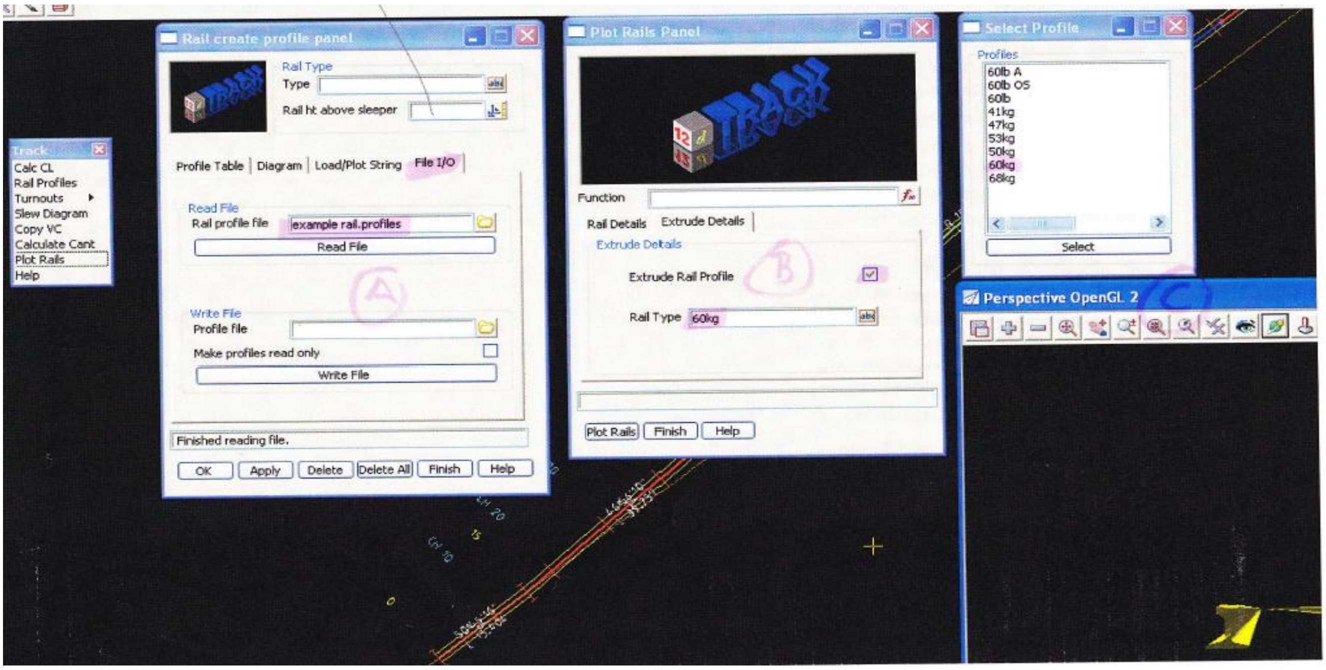
Below is the case in question.



The simple choice of selecting the correct Rail Type, (base of rails tab) is applied only after the using the Rail Profiles macro.

This allows importing previously profiled rails into your project. There is an 'examplerail.profile' supplied by 12d. Simply copy this file into your project then use the File I/O as shown on the example below where a 60kg rail is chosen.

Note, this can be extruded and displayed in a Perspective OpenGL view, but still is only a point in your typical cross section indicating top of rail. There is no rail profile.



So far I have explained some useful input for the 12d macro panels to help populate. What 12d produces is unique but we the designer can take it a bit further with some innovative ideas brought about a couple of wishes I had.

WISH No.1

To have plotted cross sections showing rail design formation with the track infrastructure correctly displayed. This means having the ballast, sleepers and rail profiles shown in all cross sections but importantly on the correct cant at the horizontal curves.

WISH No.2

To calculate the exact ballast depths under the sleepers at both (high and low) rail locations. This value is critical as all the loads of the train are directly bearing under the rail foot and the minimum designed depth should be maintained. Axle loads in the Pilbara, Western Australia on heavy haul rail are reaching up to 40 tonne limits.

TO ACCOMPLISH - WISH No.1

The first objective is to establish what 12d can already produce and then see if you can enhance this further. Using the Plot Rails panel produces the rail model strings at gauge centres (face to face) and the on the correct cant but can only be viewed as a point in your cross section view and plots. 12d does allows you to display the sleepers but sometimes randomly they will not display in the cross section and finally the ballast where 12d creates models of strings and sections but will also not be visible unless cross sections are taken at exact intervals in the Apply Many Function.

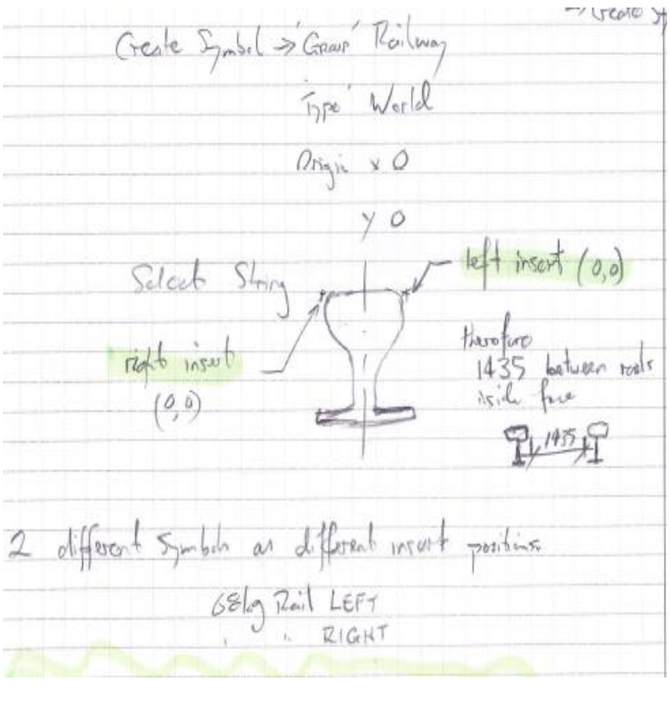
So to work from the bottom up, the ballast requires that a 'ballast.tin' be created from the models with the default 'nulling' values, this enables the tin to be viewed and cut giving the ballast shape at any point along the alignment.

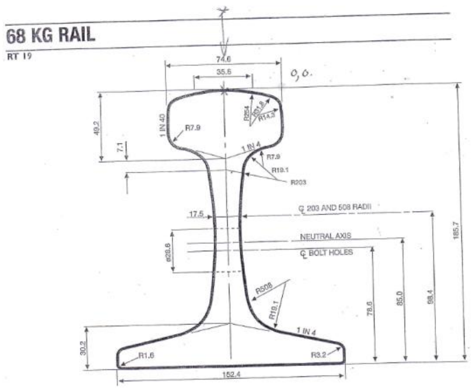
The next items are the sleepers that simply require a 'corridor overlap' in the cross section plot routine to include the sleepers. This overlap would be half the sleeper spacing, with sleepers designed at 600mm centres then 300mm or 0.3 would suffice, this value is often forgotten. The last item being the rails is where some innovation takes place.

The rail requires a symbol to be drawn that can be called up in the cross section plot routine. Yet, you must draw 2 symbols as the insertion point is on the face of the rail because 12d produced strings at rail gauge centres; standard gauge being 1435mm. (broad – 1600mm) (narrow-1000mm)

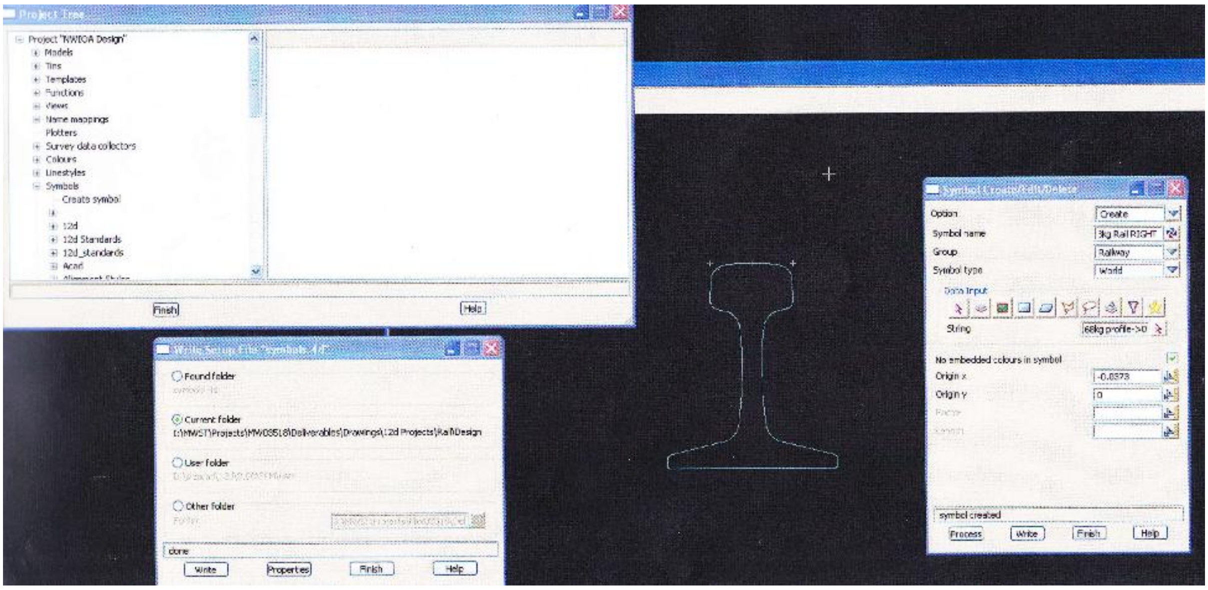
The origin of the symbol is critical to the correct placement on the rail model string. The rail model strings must be renamed to identify the left and right rail. I use increasing chainage direction to determine left and right. This is important when using the plot routine and will be explained ahead on pages 7 & 8.

A small hand sketch shows below followed by 12d screen capture.





The symbols will be stored in the 12d file, symbol.4d

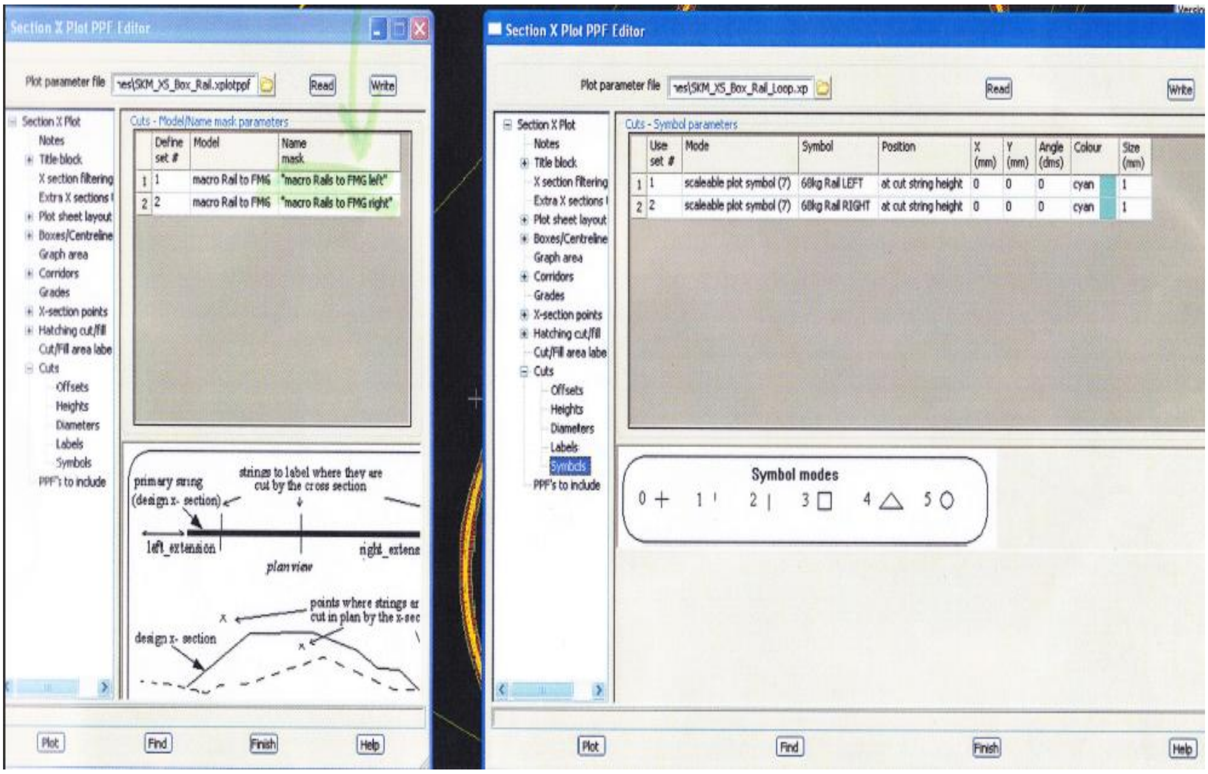


Above shows the project tree, symbol create and setup file 'symbols.4d' dialogue boxes.

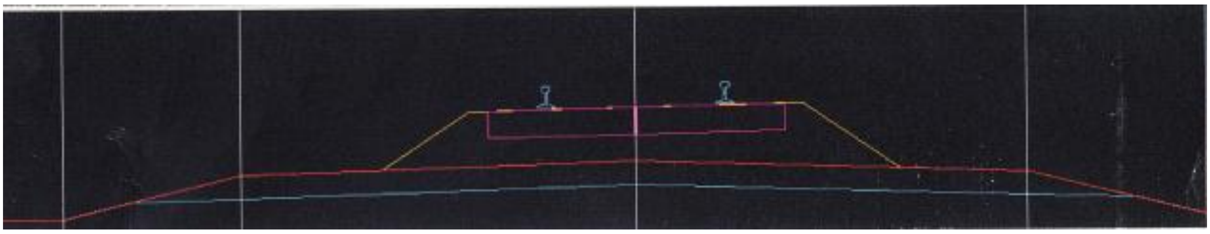
Now we have all the tools to start populating the cross section plot PPF editor. Since we want a left and right rail profile to appear with the correct symbol then we must ensure a separate name within the rail string model for left and right. The reason is that when you use 'Cuts' in the plot routine a defined set numbers are allocated and we can then use our newly created rail symbols to be positioned on the associated defined sets. The example below will explain graphically.

Note: The Name mask <u>MUST</u> be within inverted commas as shown "macro Rail to FMG left"

Note: The symbol name at 'cut string height location' is either ***68kg Rail Left*** or ***68kg Rail Right***



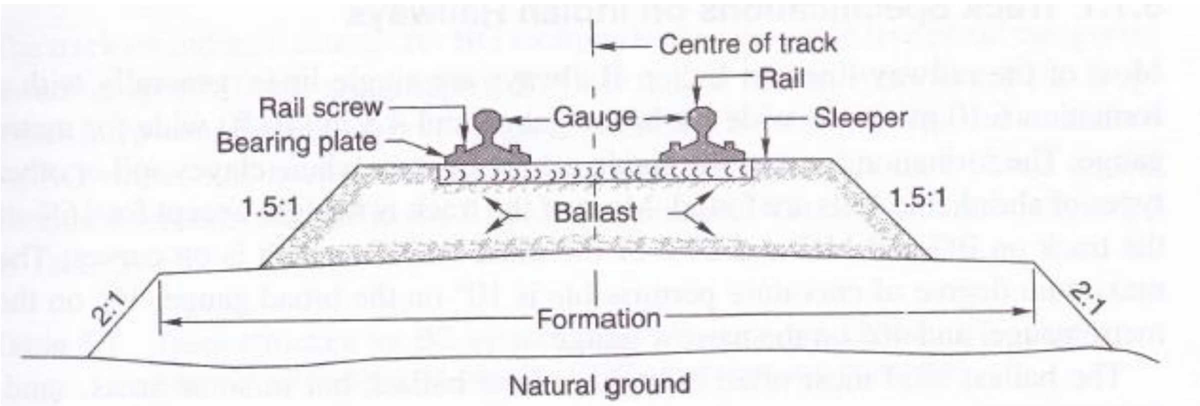
After running the plot routine a cross section as shown will develop and accomplish Wish No. 1



Also shown in this cross section is 200mm sub-ballast capping (blue) captured by my boxing routine.

The red line is the design formation, yellow the ballast, magenta the sleepers and cyan the rail.

This indicates a left hand bend in the horizontal alignment by the cant falling inside to the left, which is the low rail (on the left) in direction of increasing chainages.



The final output was exactly as wished for and further benefits flowed through. The quantity of the ballast becomes easier to calculate by applying a ballast tin to formation tin volume report and simply deducting sleeper cross sectional areas. Another great advantage is now 12d visualisation can be used to create different rendering and realistic drive through movie (*.avi) files.

A tip with the drive through movie files is that the 12d style contained within the Library Extrude called 'Train TRACK' gives a far smoother and quicker movie than creating your own group extrusions for rail and sleepers. The overall affect is important rather than exact sleeper dimensions.

TO ACCOMPLISH - WISH No.2

This task of establishing the exact ballast depth below the rail foot was a matter of applying some innovation to the data we have created. First we must understand why this can vary and how to rectify the issue if the minimum depth specified is encroached.

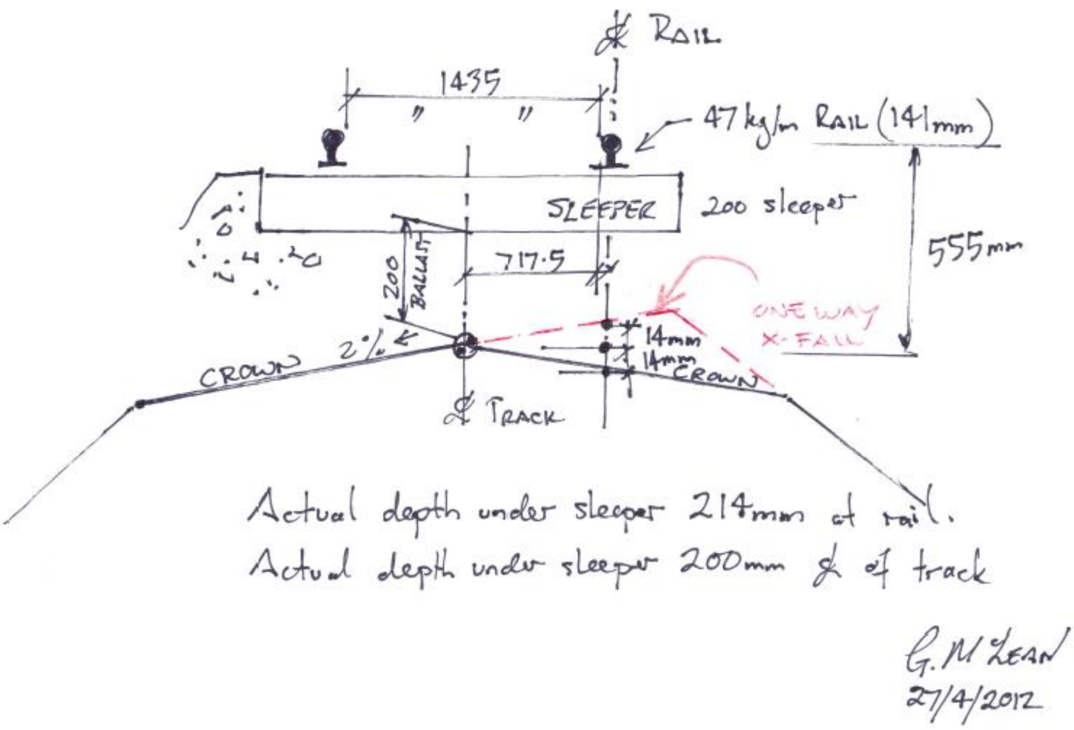
The area where this may happen is in horizontal curves only. This is where the cant or superelevation occurs and which puts the sleepers and rail on a one way cross fall. The designed formation below is generally crowned but can also have one way cross fall, normally for use in rail duplication projects which require drainage run off. This formation cross fall grade is about 2% either crowned or one way. Now this is how the dilemma happens, what if the cant designed for that particular horizontal bend is greater than the formation grade of 2%, then these two grades would eventually cross one another as the cant being steeper than the formation. The low rail is where the ballast depth encroachment will occur.

So we now know how it happens. We can start working with the 12d rail left and right strings created earlier by the Plot Rails macro. The example I will describe will be shown with further screen captures to follow.

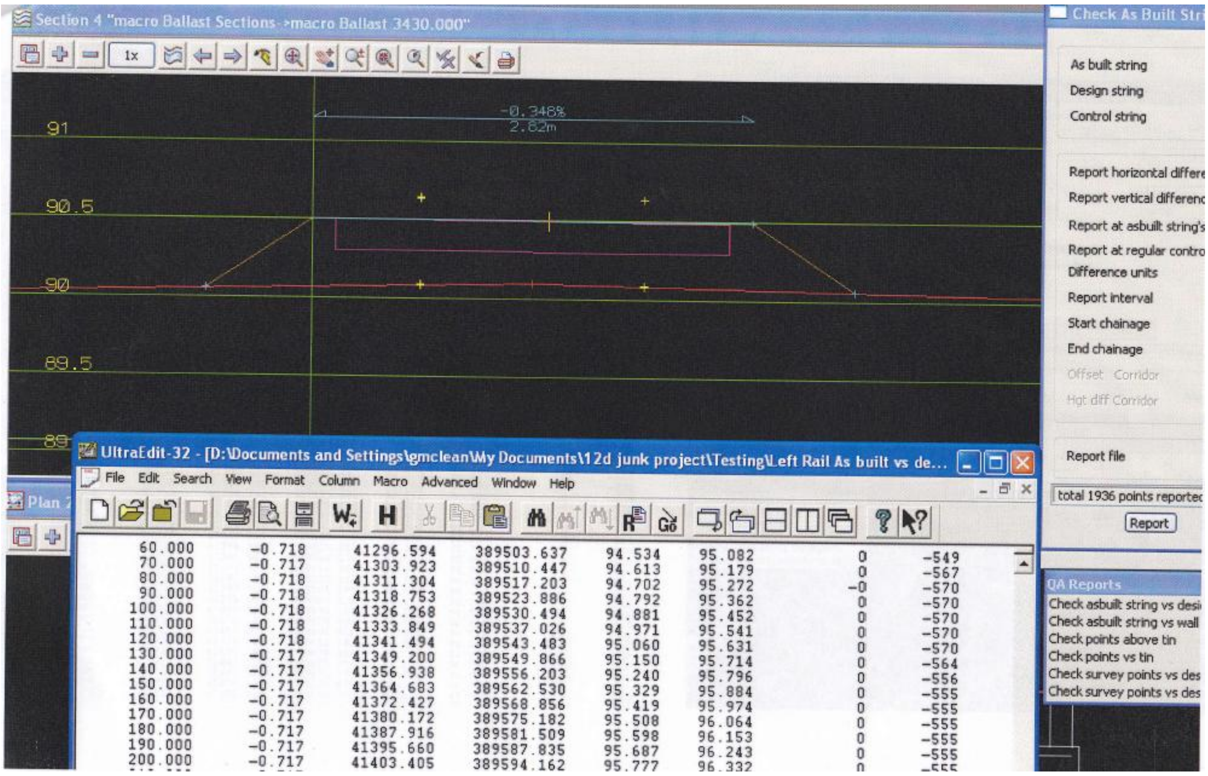
The track criteria example:

- 47 kg/m Rail inclusive of rail seat – 141mm
- Sleeper depth under rail seat – 200mm
- Ballast under sleeper at rail seat – 200mm
- Fall of formation by ½ rail gauge – 717.5mm * 2% = 14mm

As mentioned the ballast depth is an issue when there is one-way cross fall on the design formation and not a typically crowned formation. Some engineers will debate that having a reduced ballast at the centre of the track is not an issue considering the loads are somewhat reduced compared to directly over the rail. This means a reduced value in this example by 14mm, therefore 186mm ballast. This does contradict the design specification which dictates a minimum of 200mm ballast under the sleeper but the criteria generally do not indicate where along the sleeper. So by adding the 14mm this ensures the minimum is maintained at the crown work point under the sleeper and an additional 14mm (in this case) under the rail. Sketch below helps describe.



The combined dimensions total 555mm, this is the input value in the Height Offset panel described earlier on page 4. The next step is the 12d function of draping onto a tin. The created models of the left and right rail strings (yellow points above sleeper) are draped onto the design formation (red). This creates the yellow draped strings on the design formation (red) as shown below.



The next step is to create a QA Report within the 12d environment. I have used 'Check As Built Design String vs Design String' at 10m intervals. (also Xfall/Offset report can achieve results)

- As Built String = draped string
- Design String = Top of rail string (above sleeper)
- Control String = Alignment CL (shown at crown of red formation)

The report file shown as an output file with more chainages captured inclusive of 10m intervals.

File: D:\Documents and Settings\gmclean\My Documents\12d junk project\Testing\Left Rail As built vs design report.rpt 12/08/2010, 10:33:09AM

```
Macro                      Asbuilt_vs_design_h_z_dif_01
Report file name:          Left Rail As built vs design report.rpt

Check design string using as built string
    Design string       "macro RAILS->macro RAILS left"      compared to
    As built string     "Rail Left draped->macro RAILS left"

Control string             "Align Siding->Align Siding"

Date: Thu Aug 12 10:33:06 2010

Vertical difference is Asbuilt minus Design.
That is, vert diff is positive if Asbuilt is above the Design

At As Built String Vertices:
```

Anything less than (this case) -555 is ballast 200mm un

555 [200 ballast, 200 sleeper, 155 Rail]

Relative To CentreLine Chainage	Offset	Asbuilt Coordinates Easting	Northing	Asbuilt Level	Design Level	Horz-Diff (mm)	Vert-Diff (mm)
57.224	-0.717	41294.565	389501.741	94.513	95.056	5	-544
60.000	-0.718	41296.594	389503.637	94.534	95.082	0	-549
60.053	-0.717	41296.633	389503.673	94.534	95.083	0	-549
60.291	-0.717	41296.808	389503.835	94.536	95.085	0	-549
65.000	-0.711	41300.258	389507.042	94.572	95.131	5	-559
65.458	-0.711	41300.594	389507.354	94.576	95.135	5	-560
68.000	-0.713	41302.457	389509.085	94.595	95.160	3	-565
68.000	-0.713	41302.457	389509.085	94.595	95.160	3	-565
68.000	-0.713	41302.457	389509.085	94.595	95.160	3	-565
68.401	-0.714	41302.750	389509.358	94.598	95.164	3	-566
70.000	-0.717	41303.923	389510.447	94.613	95.179	-0	-567
70.049	-0.717	41303.959	389510.480	94.613	95.180	0	-567
73.716	-0.706	41306.665	389512.957	94.646	95.214	10	-568
74.661	-0.706	41307.363	389513.596	94.655	95.223	11	-568
74.932	-0.706	41307.563	389513.778	94.657	95.225	11	-568
75.000	-0.706	41307.613	389513.825	94.658	95.226	11	-568
76.014	-0.706	41308.362	389514.510	94.667	95.235	10	-569
80.000	-0.717	41311.304	389517.203	94.702	95.272	-0	-570
80.042	-0.717	41311.336	389517.231	94.703	95.273	-0	-570
83.986	-0.706	41314.273	389519.867	94.738	95.308	12	-570
85.000	-0.705	41315.028	389520.544	94.747	95.317	12	-570
86.014	-0.706	41315.784	389521.222	94.756	95.326	12	-570

The report above shows the first 4 chainages below the design 'governor' of 555mm by up to 11mm which would mean 189mm of ballast at the crown and 203mm under the rail.

The report below shows many chainages at 555mm which quickly indicates a straight section of track inclusive of the 0mm horizontal offset is also clear indicator that there is no horizontal difference between the strings directly below each other.

File: D:\Documents and Settings\gmclean\My Documents\12d junk project\Testing\Left Rail As built vs design report.rpt 12/08/2010, 10:33:09AM

93.986	-0.706	41321.748	389526.520	94.828	95.398	12	-570
95.000	-0.705	41322.510	389527.190	94.837	95.407	12	-570
96.014	-0.706	41323.272	389527.860	94.846	95.416	12	-570
100.000	-0.717	41326.268	389530.494	94.881	95.452	0	-570
100.028	-0.717	41326.289	389530.512	94.882	95.452	-0	-570
103.986	-0.706	41329.290	389533.098	94.917	95.487	12	-570
105.000	-0.705	41330.058	389533.760	94.926	95.496	12	-570
106.014	-0.706	41330.827	389534.422	94.935	95.505	12	-570
110.000	-0.717	41333.849	389537.026	94.971	95.541	0	-570
110.021	-0.717	41333.864	389537.040	94.971	95.541	0	-570
111.024	-0.713	41334.632	389537.688	94.980	95.550	5	-570
115.000	-0.705	41337.671	389540.255	95.016	95.586	12	-570
118.976	-0.713	41340.711	389542.822	95.051	95.622	5	-570
120.000	-0.717	41341.494	389543.483	95.060	95.631	0	-570
120.014	-0.717	41341.505	389543.492	95.061	95.631	-0	-570
120.267	-0.716	41341.700	389543.654	95.063	95.633	1	-570
121.302	-0.713	41342.498	389544.314	95.072	95.642	4	-569
122.055	-0.710	41343.078	389544.795	95.079	95.648	6	-569
125.000	-0.707	41345.347	389546.675	95.105	95.672	9	-567
126.015	-0.708	41346.130	389547.323	95.114	95.681	9	-566
130.000	-0.717	41349.200	389549.866	95.150	95.714	0	-564
130.000	-0.717	41349.200	389549.866	95.150	95.714	0	-564
130.000	-0.717	41349.200	389549.866	95.150	95.714	0	-564
130.008	-0.717	41349.206	389549.871	95.150	95.714	-0	-564
131.025	-0.716	41349.993	389550.516	95.159	95.722	1	-563
135.000	-0.714	41353.069	389553.035	95.195	95.755	1	-560
136.021	-0.714	41353.859	389553.682	95.204	95.763	1	-559
140.000	-0.717	41356.938	389556.203	95.240	95.796	0	-556
140.267	-0.717	41357.145	389556.372	95.242	95.798	0	-556
141.302	-0.717	41357.946	389557.027	95.251	95.807	0	-556
144.242	-0.717	41360.223	389558.887	95.278	95.833	-0	-556
145.000	-0.717	41360.810	389559.366	95.284	95.840	-0	-556
148.975	-0.717	41363.889	389561.881	95.320	95.875	-0	-555
150.000	-0.717	41364.683	389562.530	95.329	95.884	0	-555
151.025	-0.718	41365.476	389563.178	95.338	95.894	0	-555
155.000	-0.718	41368.555	389565.693	95.374	95.929	0	-555
158.975	-0.717	41371.633	389568.208	95.409	95.965	-0	-555
160.000	-0.717	41372.427	389568.856	95.419	95.974	0	-555
163.975	-0.717	41375.506	389571.371	95.454	96.010	-0	-555
165.000	-0.717	41376.299	389572.019	95.463	96.019	-0	-555
166.025	-0.717	41377.093	389572.668	95.473	96.028	-0	-555
170.000	-0.717	41380.172	389575.182	95.508	96.064	0	-555
173.975	-0.717	41383.250	389577.697	95.544	96.099	-0	-555
175.000	-0.717	41384.044	389578.346	95.553	96.108	0	-555

These results can be exported into Excel software and using 'if' statements can colour highlight 'cells' where less than 555mm. This final report is a great source for design considerations between the designer, engineer and the client.

The results can show some areas where ballast is less than desired. One must consider the depth change and over how many meters of the alignment where this reduction is occurring and may not warrant any work to the existing design. Yet, if there is significant distances where the ballast is far less than desired then the designer can increase the rail height locally in these areas of concern. This is easily written in a sentence but a difficult task. Heavy haul rail design has specific criteria for vertical intersection points (VIP's) which is commonly a distance of 1000m, yes that is 1km between VIP's. This can cause higher ballast volumes than necessary due to some local earthworks dipping which dictates the low point between VIP's. The cant can also be looked at by reducing the value thereby reducing the height variation between high and low rails, which in turn would increase the depth between the draped string on the formation and the new low rail position.

The other alternative, which I commonly used, is to steepen the formation locally by introducing a new VIP and maintain the rail 1km VIP's as this is the primary running surface of the train but the earthworks below can vary to accommodate design constraints. Best adopt a super alignment for rail and another for the design formation. This is common as the longitudinal plotted profile needs to show both alignments.

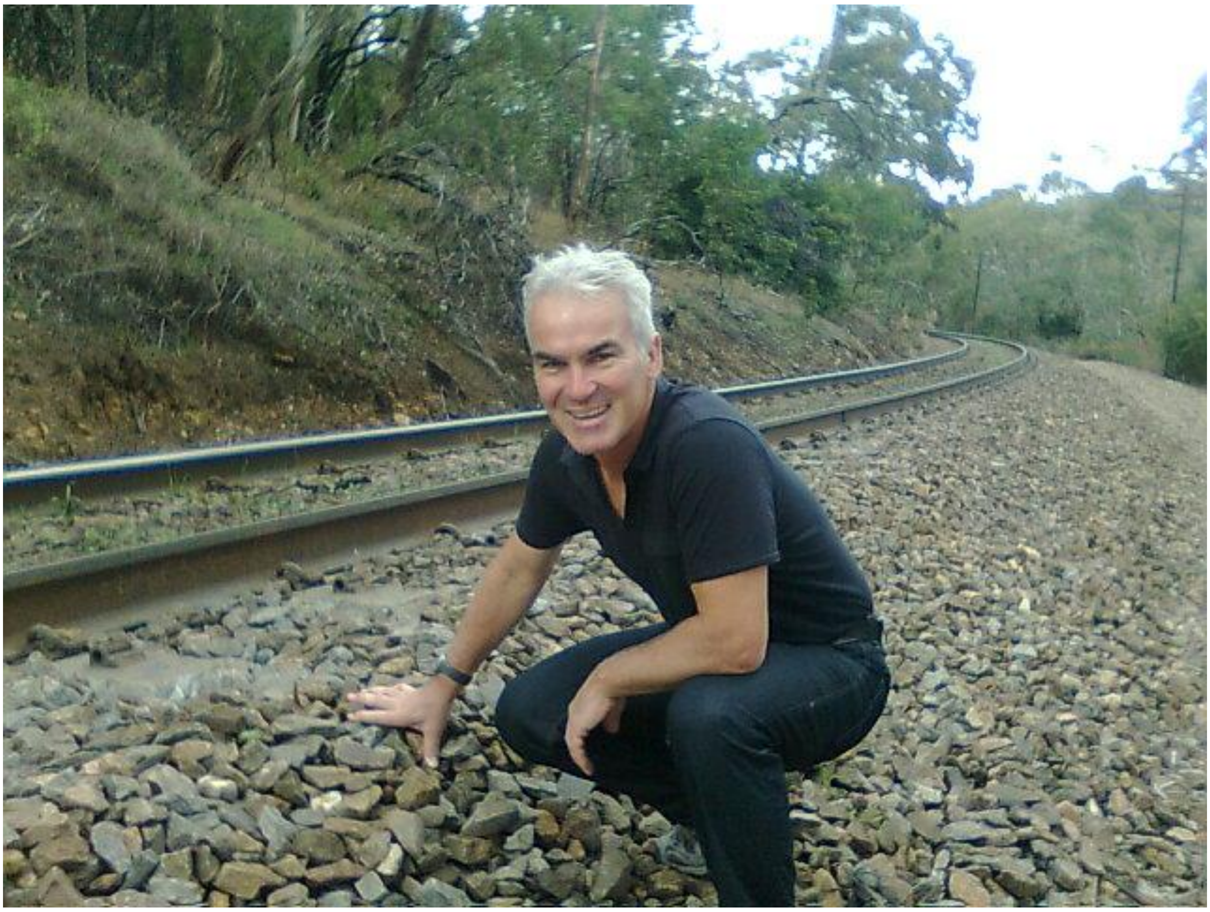
The combination of the existing rail macro's and 12d functions such as drape, followed by creating a report, validates the ballast depth which ensures the client the design criteria is validated and **more importantly accomplishes Wish No. 2.**

Closing Statement

In this submission I chose to highlight what can be manipulated with the 12d tools already at one's fingertips. There are no fabulous macros written in this submission that did not already exist within 12d. This showcases that with some intervention to seek one's wishes, that the outcome can become quite innovative without realising the initial potential when embarking on solving issues.

Fortunately I was doing some 'beta' testing of sorts by delving into the rail module. The company 12d were of great assistance in my probing questions. So a special mention must go to their employee Mike Jenson.

I hope my wishes are worthy of accreditation when adjudicating this submission.



The author beside Belair railway track Adelaide Hills.