KellyDown Tips

Periodic tips to help you use KellyDown more effectively

Ellipsoid Separation - Expanding Ellipsoid Method

Question: I have heard so much about the Expanding Ellipsoid method of calculating Ellipsoid Separation Distance compared to the Pedal Curve method. The Expanding Ellipsoid method often computes a larger separation factor. My customers will ask for evidence that this method is more accurate than the Pedal Curve method. How do I prove to them that the Expanding Ellipsoid method is more accurate?

Answer: The Expanding Ellipsoid or Absolute method of calculating Ellipsoid Separation is being more readily adopted by many oil companies due to the need for more precise drilling scenarios through existing and already congested projects. With the advent of more accurate survey error models, it becomes more difficult to justify the use of less accurate ellipsoid separation calculation methods. Traditionally, this method has been too slow to accurately calculate the separation between ellipsoids because of computer processing power and the speed required, especially when performing anti-collision scans against many wells in highly congested fields.

A detailed explanation of the Expanding Ellipsoid method of calculating Ellipsoid Separation for directional surveying purposes is available from the Society of Petroleum Engineers – *SPE – 159840-PA - Explicit Calculation of Expansion Factors for Collision Avoidance Between Two Coplanar Survey Error Ellipses,* authored by S. J. Sawaryn, A. L. Jamieson and A. E. McGregor, March 2013. However, customers still require proof that the Expanding Ellipsoid method is more accurate than the current industry accepted Pedal Curve method especially when dealing with such a safety critical process that appears to produce less conservative results.

This document helps to prove that the Expanding Ellipsoid method used in KellyDown produces accurate ellipsoid separation results.

Theory: When an anti-collision scan is performed on a reference well against an offset well, at each station, the centre to centre distance and ellipsoid separation distance between the two wells is reported. Using the Pedal Curve method, it is often quite obvious that the actual separation is greater than the reported separation particularly in situations where the ellipsoids are oblique and diametrically opposed to each other.

To prove that the Expanding Ellipsoid method gives accurate results, two wellplans were created that are positioned side by side; a reference well that is vertical to 2,000m, builds at 2.7°/30m to 90° inclination along an azimuth of 0°and then remains horizontal to 5,000m measured depth.

No.	Measured Depth (m)	Course Length (m)	Inclination (°)	Azimuth (°)	Vertical Depth (m)	Northings (m)	Eastings (m)	Vertical Section (m)	Dogleg Rate (°/30m)	Toolface (°)
1	0.00		0.000	0.000	0.00	0.00 N	0.00 E	0.00		
2	2,000.00	2,000.00	0.000	0.000	2,000.00	0.00 N	0.00 E	0.00	0.000	0.000
3	3,000.00	1,000.00	90.000	0.000	2,636.62	636.62 N	0.00 E	636.62	2.700	0.000
4	5,000.00	2,000.00	90.000	0.000	2,636.62	2,636.62 N	0.00 E	2,636.62	0.000	0.000

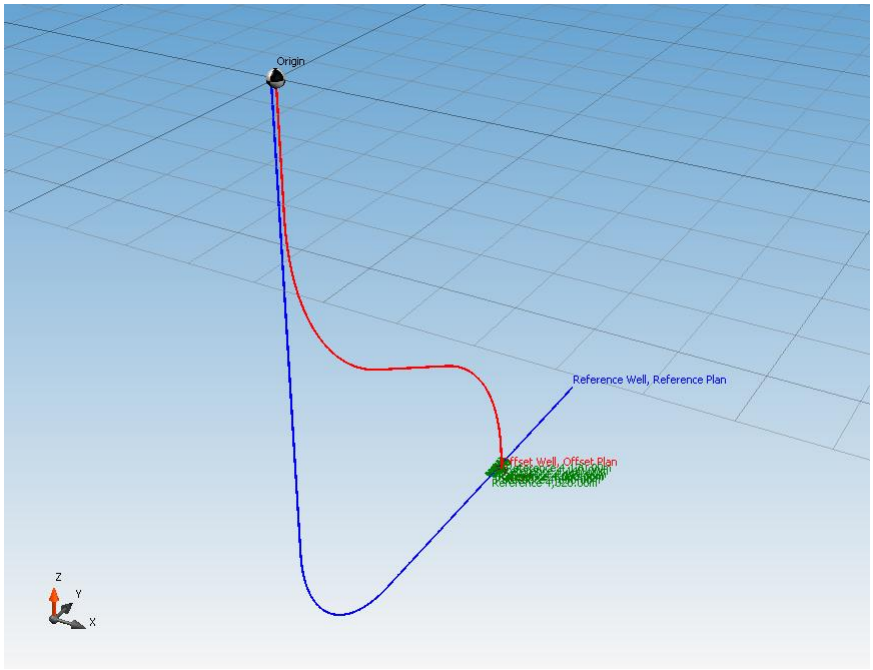
A survey program was added utilising a standard MWD tool down to 4,000m and then Zero Error from 4.000m to TD. The Zero Error model was used to maintain a constant ellipsoid size along the horizontal section of the well from 4,000m to TD.

A second offset wellplan located 20m East of the reference well was created. This well is vertical to 500m and then builds to 63.711° inclination along a 0° azimuth at a 1.7°/30m dogleg rate. It holds this angle for 641.88m and then drops back to 0° using a 1.7°/30m dogleg rate. The TD of this well is at a vertical depth of 2,636.62m and passes 20m to the east of the reference well in the middle of the reference well's horizontal section.

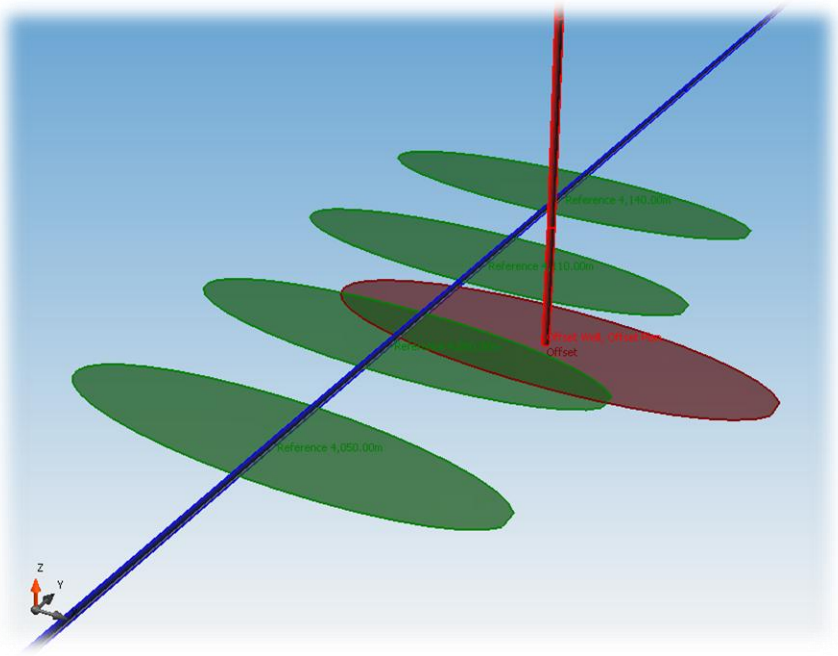
No.	Measured Depth (m)	Course Length (m)	Inclination (°)	Azimuth (°)	Vertical Depth (m)	Northings (m)	Eastings (m)	Vertical Section (m)	Dogleg Rate (°/30m)	Toolface (°)	
1	0.00		0.000	0.000	0.00	0.00 N	20.00 E	0.00			
2	500.00	500.00	0.000	0.000	500.00	0.00 N	20.00 E	0.00	0.000	0.000	
3	1,648.67	1,148.67	63.711	0.000	1,426.17	575.49 N	20.00 E	575.49	1.664	0.000	
4	2,290.56	641.88	63.711	0.000	1,710.45	1,150.99 N	20.00 E	1,150.99	0.000	0.000	
5T	3,439.23	1,148.67	0.000	0.000	2,636.62	1,726.48 N	20.00 E	1,726.48	1.664	180.000	Offset

A standard MWD tool survey was used from surface to TD.

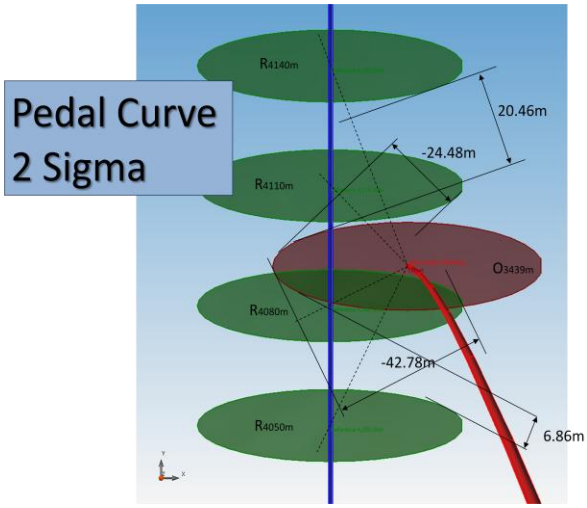
This configuration is designed such that a scan along the horizontal section of the Reference Well from 3,100m to 5,000m will always detect the TD of the Offset Well as the closest point, and all ellipsoids on the Reference Well have the same dimensions.

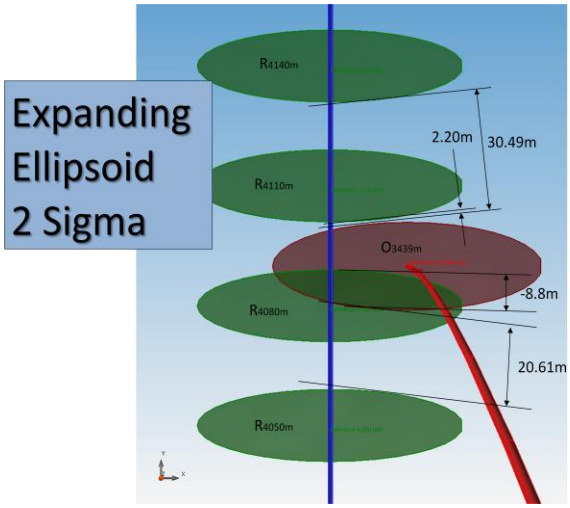


The Reference Well was scanned at regular intervals for proximity against the Offset Well and the measured depths of the four closest stations to the Offset Well were noted. Elliptical targets representing the four uncertainty ellipsoids on the Reference Well were created at each of the measured depths. An elliptical target was also created to represent the Error Ellipsoid at the bottom of the Offset Well.

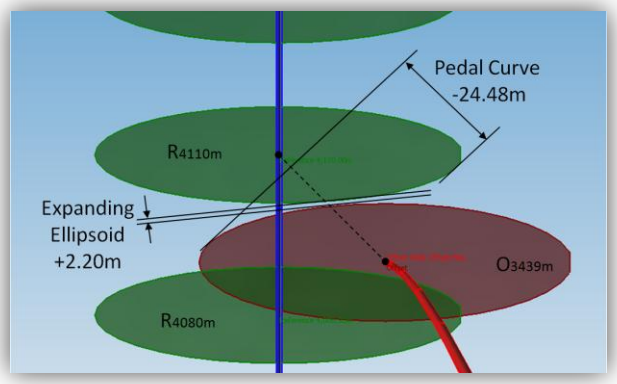


The following diagram shows the separation between each Reference Ellipsoid and the Offset Ellipsoid using the Pedal Curve method to calculate the separation. The report shows the separation between R_{4080m} and O_{3439m} is -42.78m. We can measure the distance using the measurement tool in the KellyDown Visualiser to see that the actual overlap is approximately -9m.





Similarly, the Pedal Curve method shows the separation between R_{4110m} and O_{3439m} is -24.48m, but we can see in the Visualiser that the ellipsoids are not overlapping and if we measure the distance in the KellyDown Visualiser, we see the separation is actually about +2m.



Offset Design Site #1 - Well #2 - Wellbore #1 - Design #1

Survey Program: 0-MWD

Offset Site Error:

Offset Well Error:

Reference Measured Depth (m)	Reference Vertical Depth (m)	Offset Measured Depth (m)	Offset Vertical Depth (m)	Semi Major Axis Reference (m)	Semi Major Axis Offset (m)	Highside Toolface (°)	Offset Wellbore Centre +N/-S (m)	Offset Wellbore Centre +E/-W (m)	Distance Between Centres (m)	Distance Between Ellipses (m)	Minimum Separation (m)	Separation Factor	Warning
3,810.00	2,636.62	3,439.19	2,636.61	31.35	36.41	89.97	1,726.46	20.00	280.55	258.40	22.15	12.666	
3,840.00	2,636.62	3,439.20	2,636.61	31.95	36.41	89.98	1,726.46	20.00	250.64	228.34	22.30	11.241	
3,870.00	2,636.62	3,439.20	2,636.61	32.56	36.41	89.98	1,726.46	20.00	220.75	198.25	22.50	9.811	
3,900.00	2,636.62	3,439.20	2,636.61	33.16	36.41	89.98	1,726.46	20.00	190.89	168.09	22.80	8.373	
3,930.00	2,636.62	3,439.20	2,636.62	33.77	36.41	89.99	1,726.46	20.00	161.09	137.82	23.26	6.924	
3,960.00	2,636.62	3,439.20	2,636.62	34.38	36.41	89.99	1,726.46	20.00	131.37	107.32	24.05	5.461	
3,990.00	2,636.62	3,439.20	2,636.62	34.99	36.41	89.99	1,726.46	20.00	101.82	76.27	25.55	3.985	
4,020.00	2,636.62	3,439.20	2,636.62	35.29	36.41	89.99	1,726.46	20.00	72.65	43.70	28.94	2.510	
4,050.00	2,636.62	3,439.20	2,636.62	35.29	36.41	90.00	1,726.46	20.00	44.58	6.86	37.72	1.182	Level 2
4,080.00	2,636.62	3,439.20	2,636.62	35.29	36.41	90.00	1,726.46	20.00	22.29	-42.78	65.07	0.343	Level 1
4,089.84	2,636.62	3,439.20	2,636.62	35.29	36.41	90.00	1,726.46	20.00	20.00	-51.70	71.70	0.279	Level 1, ES, SF
4,110.00	2,636.62	3,439.23	2,636.65	35.29	36.41	90.07	1,726.46	20.00	28.40	-24.48	52.88	0.537	Level 1
4,140.00	2,636.62	3,439.23	2,636.65	35.29	36.41	90.07	1,726.46	20.00	54.00	20.46	33.54	1.610	
4,170.00	2,636.62	3,439.23	2,636.65	35.29	36.41	90.07	1,726.46	20.00	82.62	55.08	27.54	3.000	
4,200.00	2,636.62	3,439.23	2,636.65	35.29	36.41	90.07	1,726.46	20.00	111.96	86.79	25.17	4.448	
4,230.00	2,636.62	3,439.23	2,636.65	35.29	36.41	90.07	1,726.46	20.00	141.58	117.55	24.03	5.891	

The Expanding Ellipsoid method of calculating the Ellipsoid Separation in KellyDown reports actual separation between R_{4110m} and O_{3439} as 2.20m. Clearly the Expanding Ellipsoid method produces a much better determination of the actual ellipsoid separation.

Comparison Wellplan: Test for Expanding Ellipsoid, Offset Well, Offset Plan

Uncertainty Data for Reference Wellplan: Measured Depth (m)	Vertical Depth (m)	Ellipse Centre Northings (m)	Ellipse Centre Eastings (m)	Ellipse Major Axis/2	Uncertainty Data for Comparison Wellplan: Measured Depth (m)	Vertical Depth (m)	Ellipse Centre Northings (m)	Ellipse Centre Eastings (m)	Ellipse Major Axis/2	Separation (Ref. > Comp.): Between Centres (m)	Between Ellipsoids (m)	Relative North Bearing	Clrnc. Factor
3,570.00	2,636.62	1,206.62 N	0.00 E	26.84	3,439.23	2,636.62	1,726.48 N	20.00 E	36.41	520.24	497.49	2.203	22.86
3,600.00	2,636.62	1,236.62 N	0.00 E	27.43	3,439.23	2,636.62	1,726.48 N	20.00 E	36.41	490.27	467.50	2.338	21.53
3,630.00	2,636.62	1,266.62 N	0.00 E	28.02	3,439.23	2,636.62	1,726.48 N	20.00 E	36.41	460.29	437.51	2.490	20.21
3,660.00	2,636.62	1,296.62 N	0.00 E	28.62	3,439.23	2,636.62	1,726.48 N	20.00 E	36.41	430.33	407.53	2.664	18.88
3,690.00	2,636.62	1,326.62 N	0.00 E	29.21	3,439.23	2,636.62	1,726.48 N	20.00 E	36.41	400.36	377.54	2.863	17.55
3,720.00	2,636.62	1,356.62 N	0.00 E	29.81	3,439.23	2,636.62	1,726.48 N	20.00 E	36.41	370.40	347.56	3.095	16.22
3,750.00	2,636.62	1,386.62 N	0.00 E	30.41	3,439.23	2,636.62	1,726.48 N	20.00 E	36.41	340.45	317.58	3.368	14.89
3,780.00	2,636.62	1,416.62 N	0.00 E	31.01	3,439.23	2,636.62	1,726.48 N	20.00 E	36.41	310.51	287.60	3.693	13.56
3,810.00	2,636.62	1,446.62 N	0.00 E	31.62	3,439.23	2,636.62	1,726.48 N	20.00 E	36.41	280.57	257.63	4.088	12.23
3,840.00	2,636.62	1,476.62 N	0.00 E	32.22	3,439.23	2,636.62	1,726.48 N	20.00 E	36.41	250.66	227.66	4.576	10.90
3,870.00	2,636.62	1,506.62 N	0.00 E	32.82	3,439.23	2,636.62	1,726.48 N	20.00 E	36.41	220.77	197.70	5.198	9.57
3,900.00	2,636.62	1,536.62 N	0.00 E	33.43	3,439.23	2,636.62	1,726.48 N	20.00 E	36.41	190.91	167.76	6.013	8.25
3,930.00	2,636.62	1,566.62 N	0.00 E	34.03	3,439.23	2,636.62	1,726.48 N	20.00 E	36.41	161.11	137.83	7.131	6.92
3,960.00	2,636.62	1,596.62 N	0.00 E	34.64	3,439.23	2,636.62	1,726.48 N	20.00 E	36.41	131.39	107.94	8.755	5.60
3,990.00	2,636.62	1,626.62 N	0.00 E	35.25	3,439.23	2,636.62	1,726.48 N	20.00 E	36.41	101.84	77.82	11.325	4.24
4,020.00	2,636.62	1,656.62 N	0.00 E	35.55	3,439.23	2,636.62	1,726.48 N	20.00 E	36.41	72.67	49.70	15.976	3.16
4,050.00	2,636.62	1,686.62 N	0.00 E	35.55	3,439.23	2,636.62	1,726.48 N	20.00 E	36.41	44.60	20.61	26.645	1.86
4,080.00	2,636.62	1,716.62 N	0.00 E	35.55	3,439.23	2,636.62	1,726.48 N	20.00 E	36.41	22.30	11%	63.756	0.89
4,089.86	2,636.62	1,726.48 N	0.00 E	35.55	3,439.23	2,636.62	1,726.48 N	20.00 E	36.41	20.00	57%	89.997	0.43
4,110.00	2,636.62	1,746.62 N	0.00 E	35.55	3,439.23	2,636.62	1,726.48 N	20.00 E	36.41	28.38	2.20	135.200	1.08
4,140.00	2,636.62	1,776.62 N	0.00 E	35.55	3,439.23	2,636.62	1,726.48 N	20.00 E	36.41	53.98	30.49	158.254	2.30
4,170.00	2,636.62	1,806.62 N	0.00 E	35.55	3,439.23	2,636.62	1,726.48 N	20.00 E	36.41	82.60	59.79	165.987	3.62
4,200.00	2,636.62	1,836.62 N	0.00 E	35.55	3,439.23	2,636.62	1,726.48 N	20.00 E	36.41	111.94	89.42	169.708	4.97
4,230.00	2,636.62	1,866.62 N	0.00 E	35.55	3,439.23	2,636.62	1,726.48 N	20.00 E	36.41	141.56	119.18	171.878	6.33
4,260.00	2,636.62	1,896.62 N	0.00 E	35.55	3,439.23	2,636.62	1,726.48 N	20.00 E	36.41	171.31	149.01	173.296	7.68

To further test the accuracy of the separation calculations, we can increase the Well Position Error for both the Reference Well and the Offset Well by half the reported separation. For example, if we enter 1.1m for the Well Position Error on both wells, the separation at 4,110m should be zero.

4,020.00	2,636.62	1,656.62 N	0.00 E	36.78	3,439.23	2,636.62	1,726.48 N	20.00 E	37.64	72.67	47.37	15.976	2.87
4,050.00	2,636.62	1,686.62 N	0.00 E	36.78	3,439.23	2,636.62	1,726.48 N	20.00 E	37.64	44.60	18.28	26.645	1.69
4,080.00	2,636.62	1,716.62 N	0.00 E	36.78	3,439.23	2,636.62	1,726.48 N	20.00 E	37.64	22.30	15%	63.756	0.85
4,089.86	2,636.62	1,726.48 N	0.00 E	36.78	3,439.23	2,636.62	1,726.48 N	20.00 E	37.64	20.00	59%	89.997	0.41
4,110.00	2,636.62	1,746.62 N	0.00 E	36.78	3,439.23	2,636.62	1,726.48 N	20.00 E	37.64	28.38	0.00	135.200	1.00
4,140.00	2,636.62	1,776.62 N	0.00 E	36.78	3,439.23	2,636.62	1,726.48 N	20.00 E	37.64	53.98	28.16	158.254	2.09

Change the Well Position Error for the Reference and Offset wells to 10.3m (half of 20.61m) and note that the separation at 4,050m is 0.00m.

4,020.00	2,636.62	1,656.62 N	0.00 E	46.55	3,439.23	2,636.62	1,726.48 N	20.00 E	47.41	72.67	28.40	15.976	1.64
4,050.00	2,636.62	1,686.62 N	0.00 E	46.55	3,439.23	2,636.62	1,726.48 N	20.00 E	47.41	44.60	0.00	26.645	1.00
4,080.00	2,636.62	1,716.62 N	0.00 E	46.55	3,439.23	2,636.62	1,726.48 N	20.00 E	47.41	22.30	52%	63.756	0.48
4,089.86	2,636.62	1,726.48 N	0.00 E	46.55	3,439.23	2,636.62	1,726.48 N	20.00 E	47.41	20.00	68%	89.997	0.32
4,110.00	2,636.62	1,746.62 N	0.00 E	46.55	3,439.23	2,636.62	1,726.48 N	20.00 E	47.41	28.38	16%	135.200	0.84
4,140.00	2,636.62	1,776.62 N	0.00 E	46.55	3,439.23	2,636.62	1,726.48 N	20.00 E	47.41	53.98	9.17	158.254	1.20

Note: In KellyDown, overlapping ellipsoids are reported by the percentage volume of the overlap rather than the negative separation distance and the Clearance Factor is based on the overlapping volume. I.e. ellipsoids that overlap by 25% have a Clearance Factor of 0.75, ellipsoids that overlap by 80% have Clearance Factor of 0.20.

Conclusion: Although the Pedal Curve method of calculating Ellipsoid Separation is a valid method and produces conservative and therefore safe results, the computing power of modern portable computers is easily capable of computing the actual separation between ellipsoids and the recent evolution of more accurate survey uncertainty error models makes the use of more accurate separation calculation methods much more attractive.
