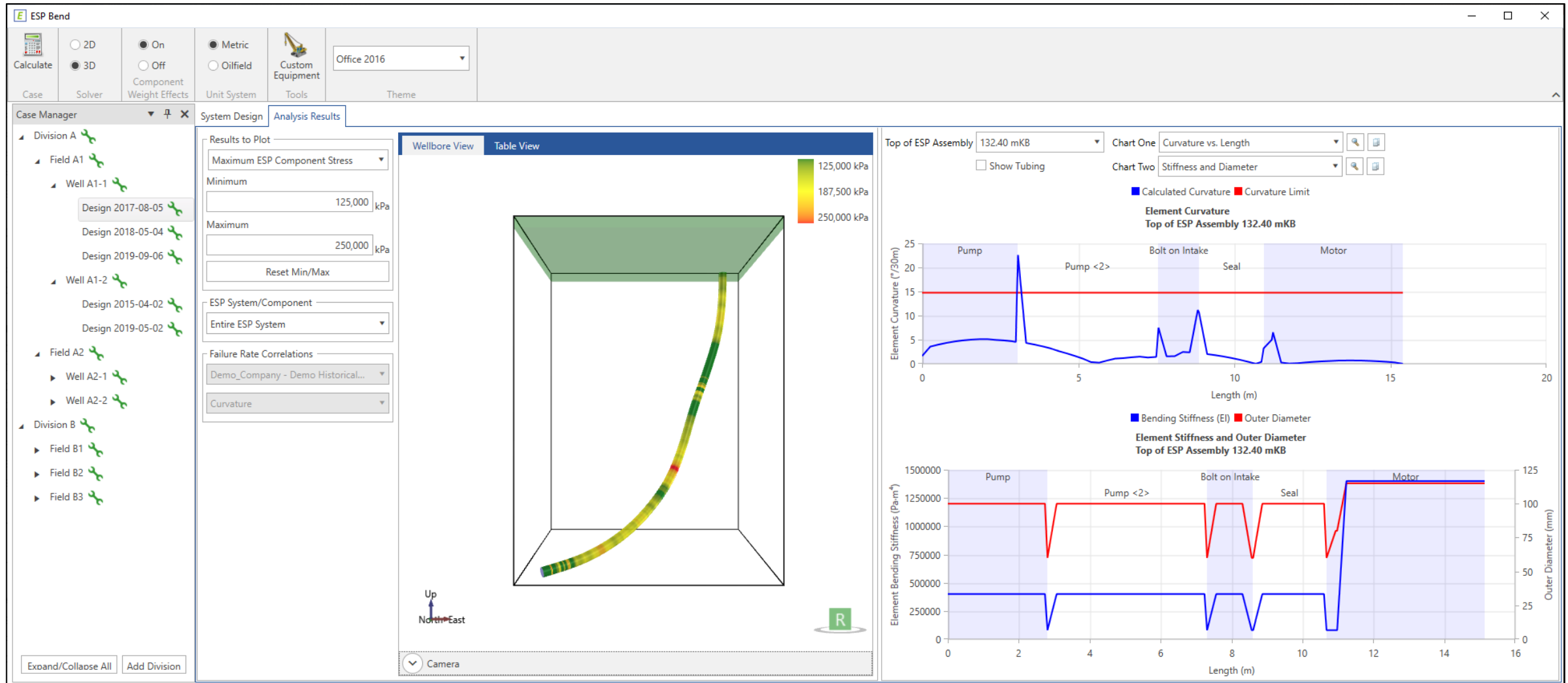


ESP Bend™

Key Capabilities and Workflow



- ESPBend is an engineering analysis tool that allows users to assess the deflection, stress, and reliability of ESP components at different intervals in a deviated well.
- ESPBend was designed to facilitate:



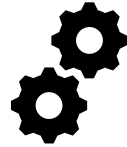
1. Detailed bending analysis and visualization



2. Transparent, vendor agnostic comparisons

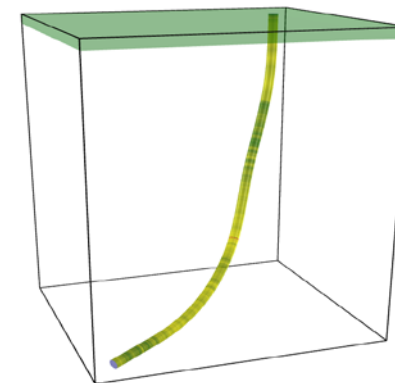
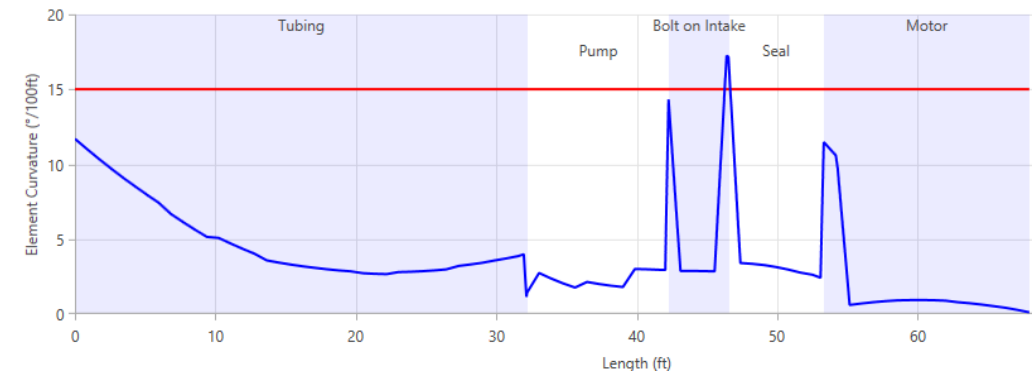
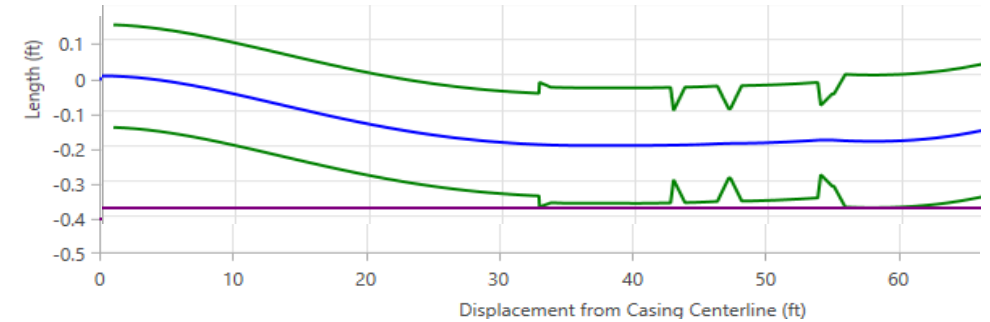


3. Reliability-based decisions



Detailed Bending Analysis and Visualization

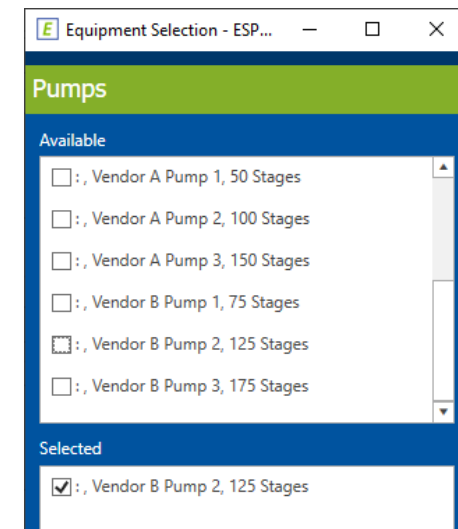
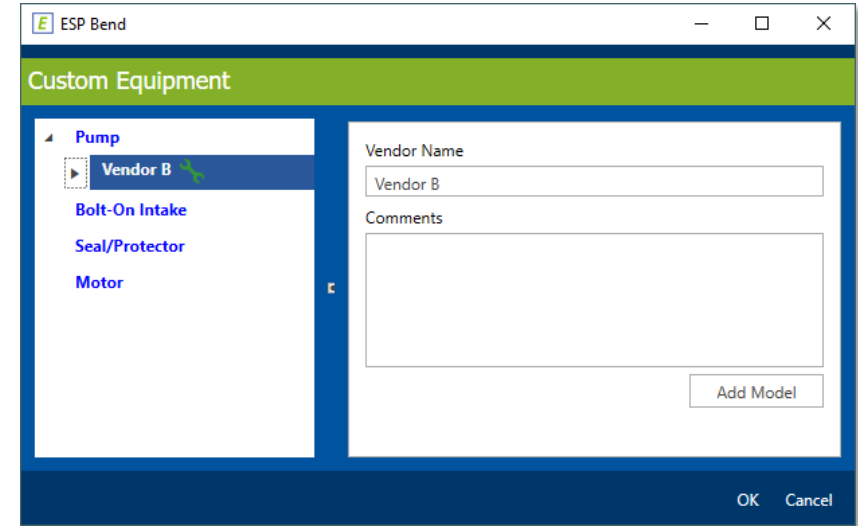
- ESPBend uses a 3D finite element analysis algorithm based on linear elastic, static beam deflection theory
- Can consider:
 - **Tortuous 3D well trajectories**
 - e.g. as characterized by gyro surveys
 - **Detailed equipment models** including dimensions, weights, and stiffness values
- Outputs include deflected shape, shear stress, bending moment, component curvature, and housing stress
- User can visualize the wellbore trajectory in 3D





Vendor Agnostic Comparisons and User Transparency

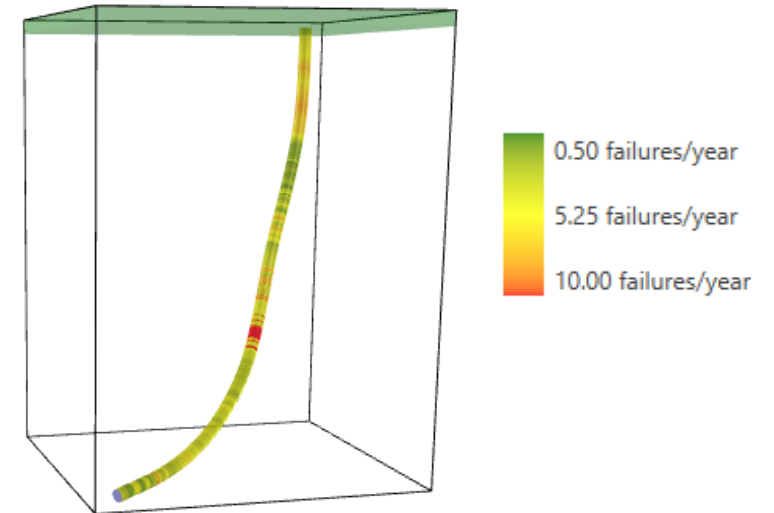
- ESPBend is vendor agnostic, allowing “apples-to-apples” comparisons between ESPs from different ESP manufacturers
- User can define properties for each section of the assembly:
 - Element weight
 - Element length and OD
 - Flexural stiffness
 - Bending stress/curvature limits



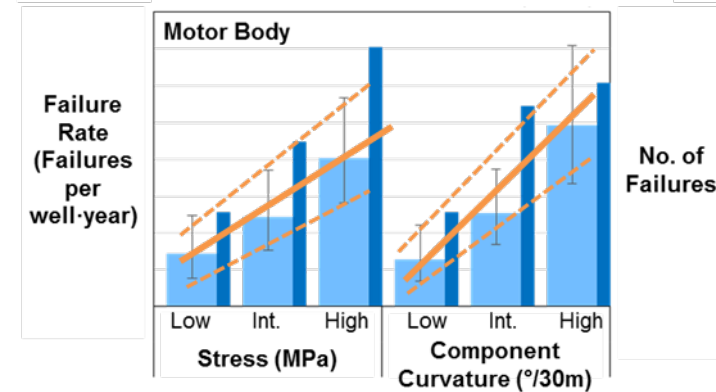


Reliability-Based Decisions

- ESPBend can generate an equipment reliability estimate for a given ESP system design, based on correlations from historical field data
- Allows users to assess the **economic tradeoffs** between reliability and other key driving factors (upfront costs, production rate, etc.)



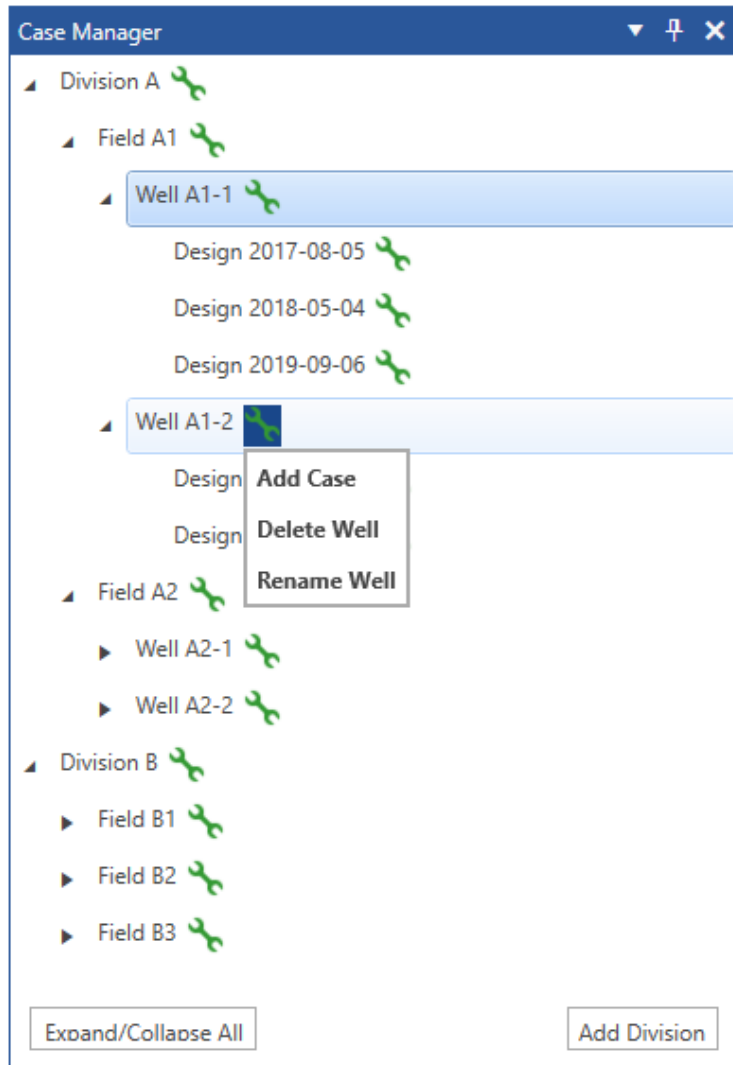
ESP Motors – One SAGD Operator



Wellbore View		Table View
	Top of ESP Assembly (mKB)	Estimated Failure Rate: Entire ESP System (failures/year)
>	10.00	2.64
	20.00	4.74
	30.00	5.18
	40.00	7.52
	50.00	5.74
	60.00	6.95
	70.00	8.05
	80.00	6.84

ESPBend Workflow

Manage Designs



- Create, edit, and organize designs company-wide using the case manager tree

Enter Wellbore Trajectory Data

Case Manager System Design Analysis Results

Directional Survey 3D View

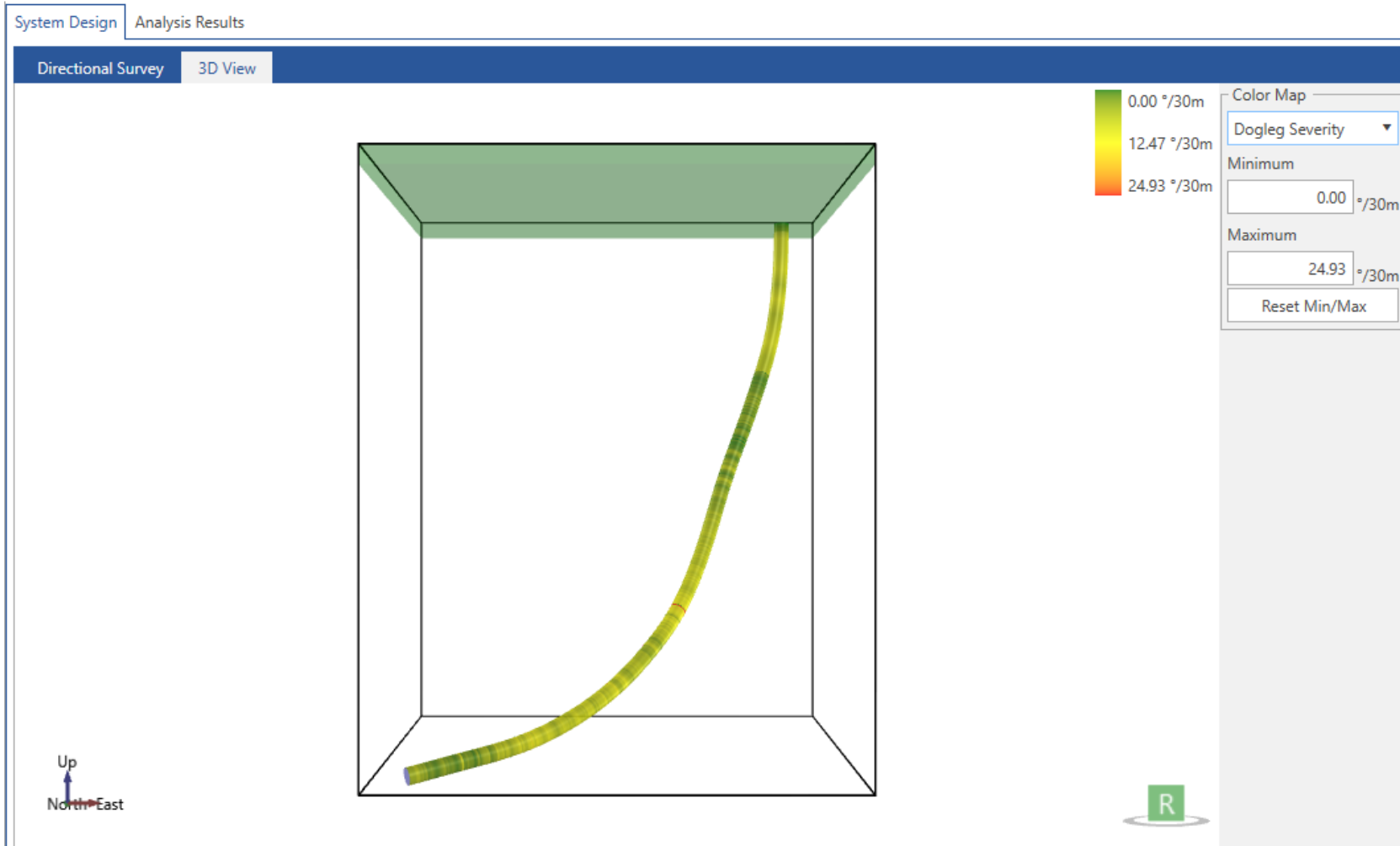
Kelly Bushing Offset: 0.00 m

Stn #	Measured Depth (mKB)	Hole Angle (°)	Azimuth (°)	Dogleg Severity			Hole Angle Change (°/30m)	Vertical Depth (m)	Horizontal Distance (m)	Latitude (m)	Departure (m)
				Overall (°/30m)	Vertical (°/30m)	Plan (°/30m)					
1	0.00	0.00	201.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	10.00	2.76	203.96	8.28	8.28	0.00	8.28	10.00	0.24	-0.22	-0.10
3	20.00	5.64	206.16	8.65	8.64	0.45	8.64	19.97	0.97	-0.88	-0.41
4	30.00	9.03	208.79	10.22	10.17	0.98	10.17	29.89	2.25	-2.01	-1.01
5	40.00	11.02	210.54	6.04	5.97	0.91	5.97	39.73	3.99	-3.52	-1.87
6	50.00	14.66	212.87	11.03	10.92	1.54	10.92	49.48	6.21	-5.41	-3.04
7	60.00	16.75	214.85	6.47	6.27	1.60	6.27	59.11	8.91	-7.65	-4.55
8	70.00	19.49	217.31	8.53	8.22	2.29	8.22	68.61	12.00	-10.16	-6.39
9	80.00	22.82	219.74	10.33	9.99	2.62	9.99	77.94	15.60	-12.98	-8.64
10	90.00	25.04	221.33	6.93	6.66	1.93	6.66	87.08	19.63	-16.06	-11.28
11	100.10	27.30	223.42	7.25	6.71	2.74	6.71	96.14	24.05	-19.35	-14.28
12	100.40	27.32	223.44	2.19	1.99	0.91	1.99	96.41	24.19	-19.45	-14.38
13	101.50	27.23	223.55	2.81	2.45	1.37	-2.45	97.38	24.69	-19.82	-14.72
14	102.40	27.18	223.63	2.07	1.67	1.22	-1.67	98.18	25.10	-20.11	-15.01
15	103.40	27.20	223.74	1.62	0.60	1.51	0.60	99.07	25.55	-20.45	-15.32
16	104.50	27.20	223.82	1.00	0.00	1.00	0.00	100.05	26.05	-20.81	-15.67
17	105.40	27.21	223.88	0.97	0.33	0.92	0.33	100.85	26.46	-21.10	-15.96

Expand/Collapse All Add Division

- Directional survey data can be copy/pasted directly into ESPBend

Visualize Wellbore



- Plot dogleg severity values on a 3D visualization of the wellbore

Create Equipment Models

The screenshot shows the 'Custom Equipment' tool in the software interface. The 'Specifications' section includes the following fields:

- Series: 400
- Resistance Type: Abrasion Resistant
- Part Number: PN1234
- Housing: [Empty]
- Weight: 103.50 kg
- Number of Stages: 75
- Comments: [Empty]
- Length: 10.11 m
- Number of Nodes: 0
- Impeller Type: F

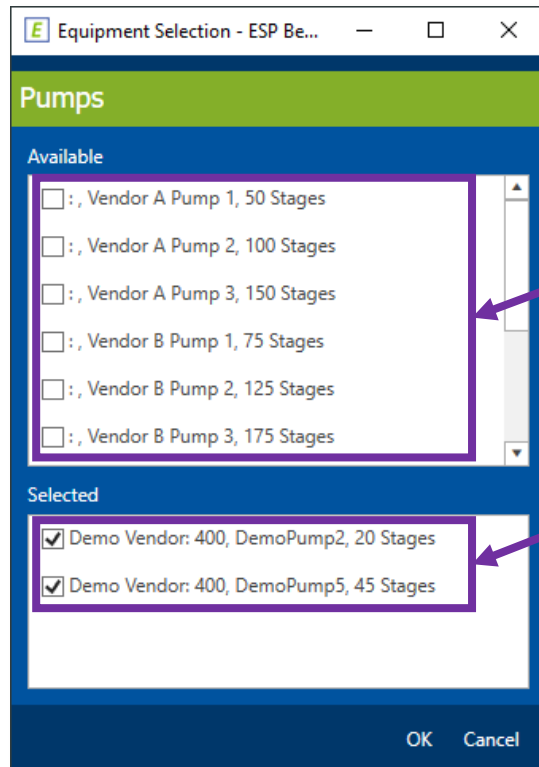
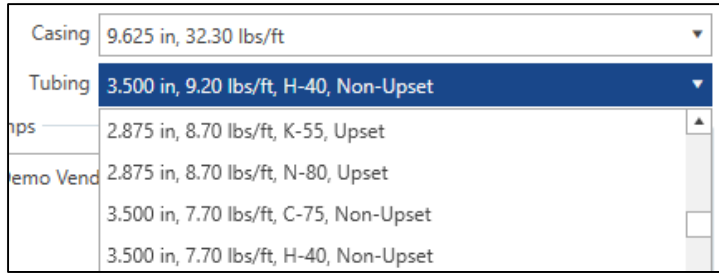
The 'Elements' section contains a table with the following data:

		Length (m)	Outer Diameter (mm)	Inner Diameter (mm)	Weight (kg)	Flexural Stiffness (Pa·m ⁴)	Axial Stiffness (Pa·m ²)	Torsional Stiffness (Pa·m ⁴)	Maximum Curvature (°/30m)	Maximum Stress (kPa)
>	✖	10	4	3.5	100	12345678	12345678	12345678	10	200000
	✖	0.08	3.5	3	2	123456	123456	123456	15	200000
	✖	0.03	4	2	1.5	12345678	12345678	12345678	5	200000

Below the table is a button: 'Click here to add new item'.

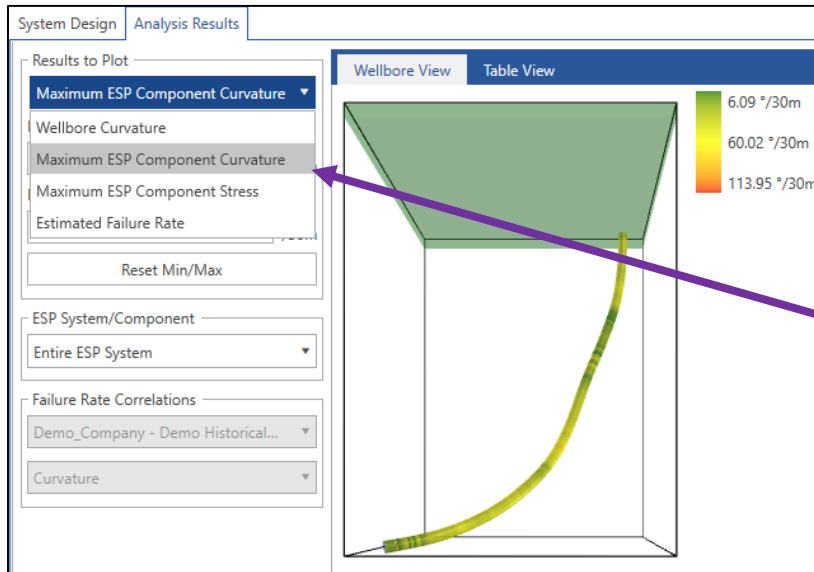
- User can create ESP component models, where each component consists of a series of cylindrical beam elements
- For each element, define:
 - Dimensions and weights
 - Stiffness values
 - Acceptable curvature and stress limits
- Custom components can then be added to assemblies (next slide)

Select Equipment



- For each case, the user selects casing, tubing and ESP equipment (pump, intake, seal, motor) from databases
 - Casing and tubing databases are built-in to ESPBend
 - Database of ESP components can be populated manually using the Custom Equipment tool (previous slide), or built-in to ESPBend if a batch of equipment data is provided to C-FER
 - Assemblies can include tandem equipment

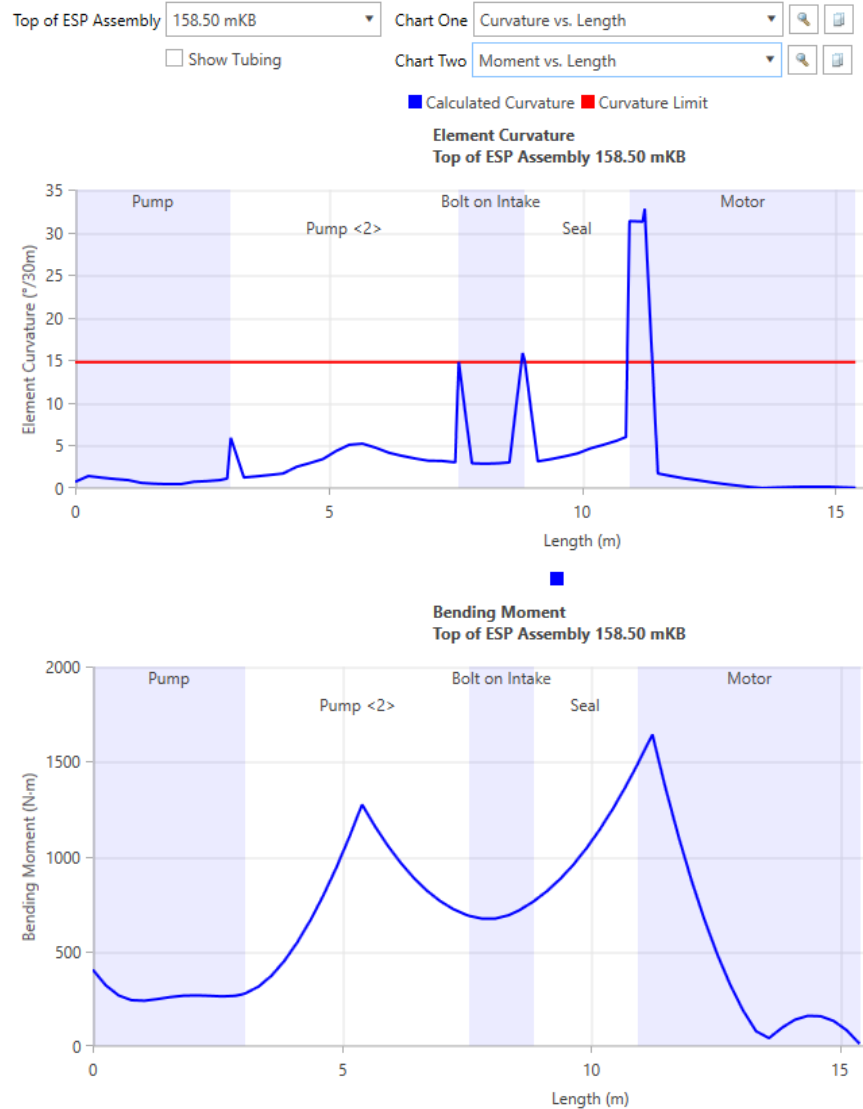
Analysis Results: Summary



Top of ESP Assembly (mKB)	Estimated Failure Rate: Entire ESP System (failures/year)
> 10.00	3.79
20.00	5.96
30.00	6.24
40.00	8.18
50.00	7.01
60.00	8.59
70.00	6.12
80.00	5.23
90.00	5.26
100.00	2.80
110.10	2.43

- Analysis results can be plotted on the 3D visualization of the wellbore, or viewed as a table
- The following results can be plotted vs. landing depth:
 - Maximum ESP Component Curvature
 - Maximum ESP Housing Stress
 - Estimated Failure Rate
 - Requires separate analysis of historical dataset
- Results can be plotted for entire system or for a component of interest

Analysis Results: Detailed



- Plot detailed results at any given landing depth, including:
 - Component housing curvature
 - Bending stress
 - Shear stress
 - Bending moment
- Charts can be expanded or exported as images

- For more information, please contact Craig Radke:

c.radke@cfertech.com

1-780-450-8989 x340

Contact Information

