Performance check of water pipelines in flood defences in the Rotterdam area

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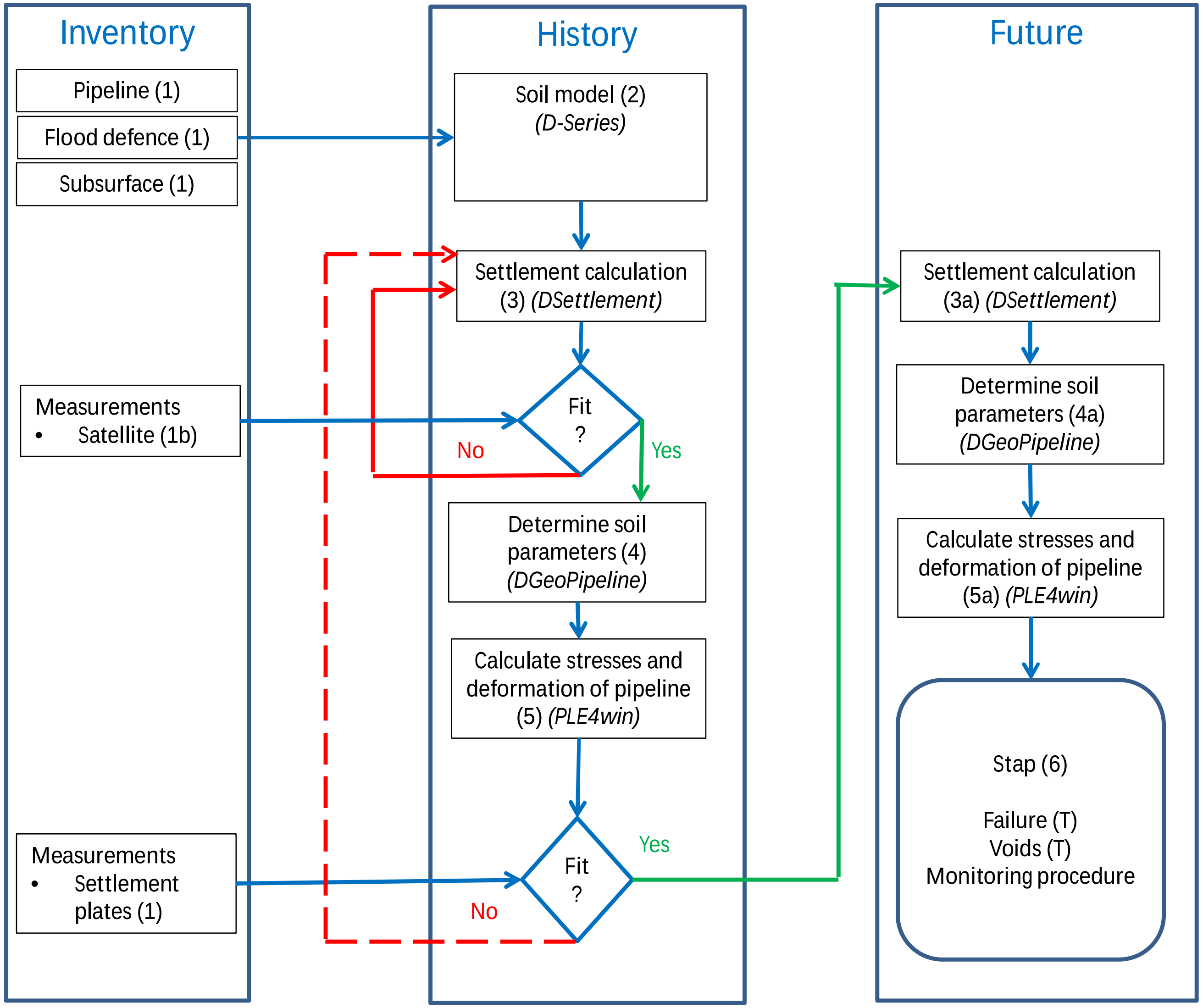
Project – objectives

Client: Evides

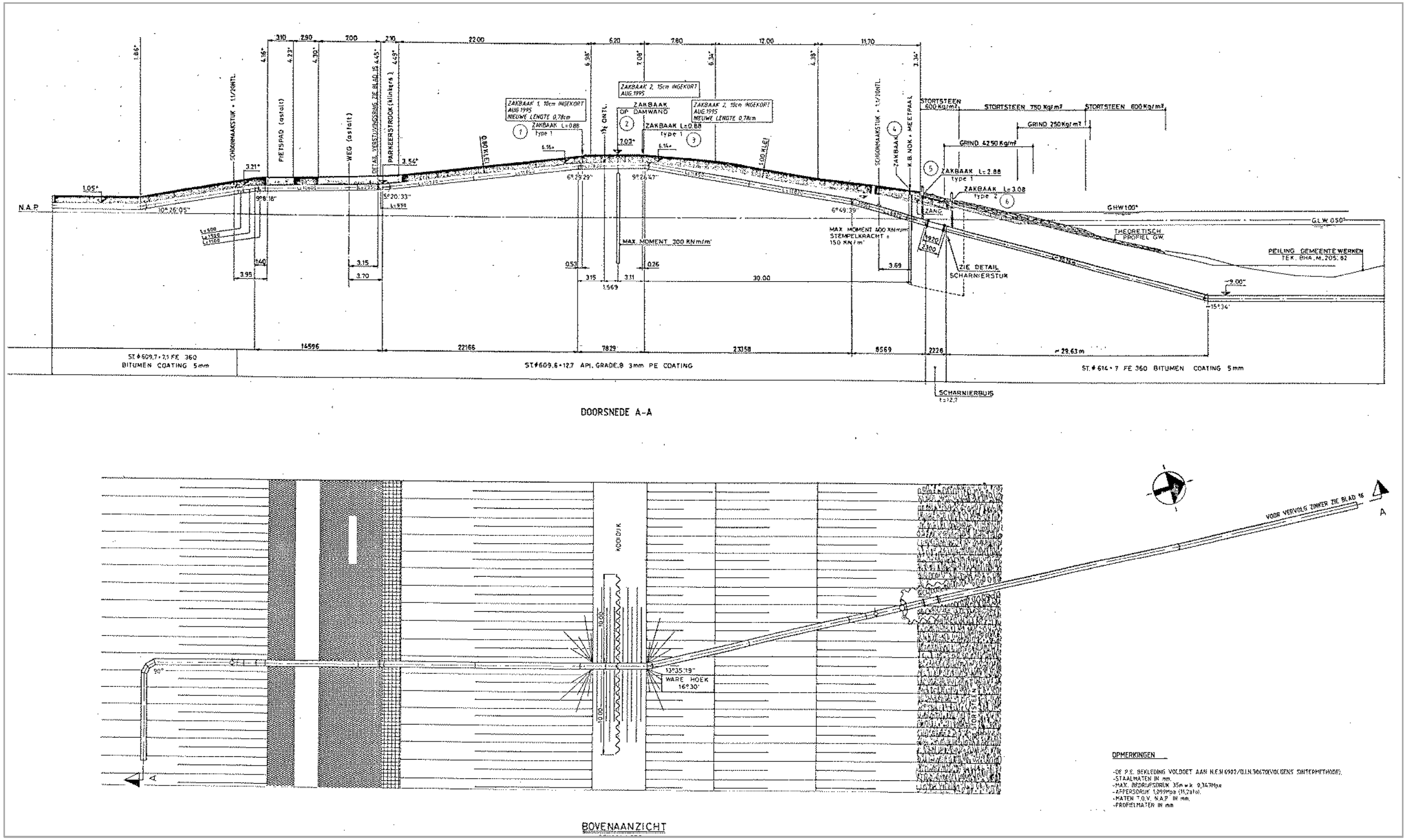
- Water supply in the Rotterdam area
- Asset Management of water supply network

1. Support Asset Management
    - Stresses and safety of pipeline
    - Voids developing under the pipeline
    - Monitoring process
2. Evaluate our new assessment method
    - Reliability, uncertainty
    - INSAR satellite measurements in stead of terrestrial settlement plates

Project – flow chart



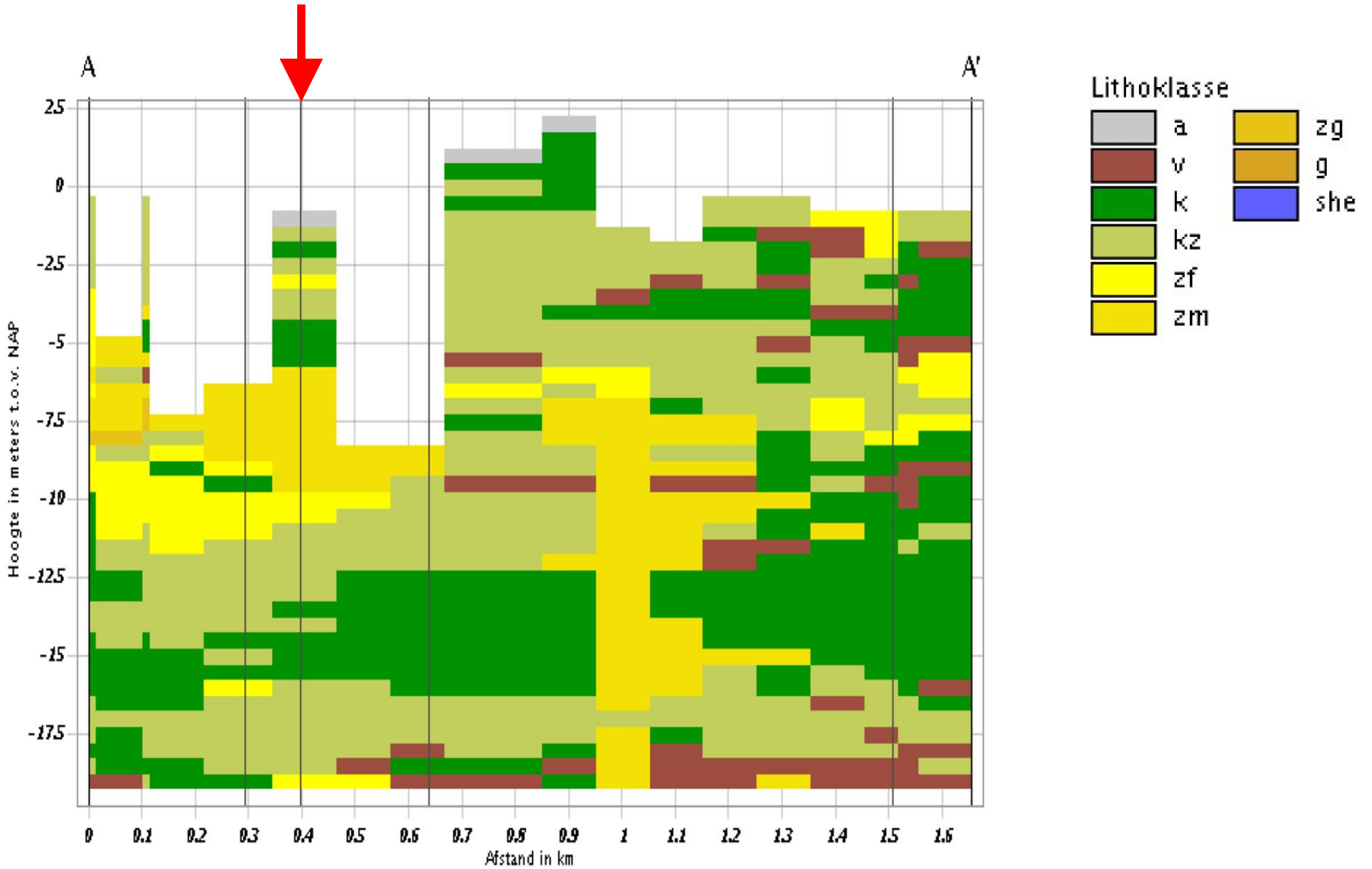
Inventory – Case 1



Steel pipeline 610 mm x 12.7 mm (1982)

Deltares

Inventory – Case 1



Deltares

Inventory – Case 1

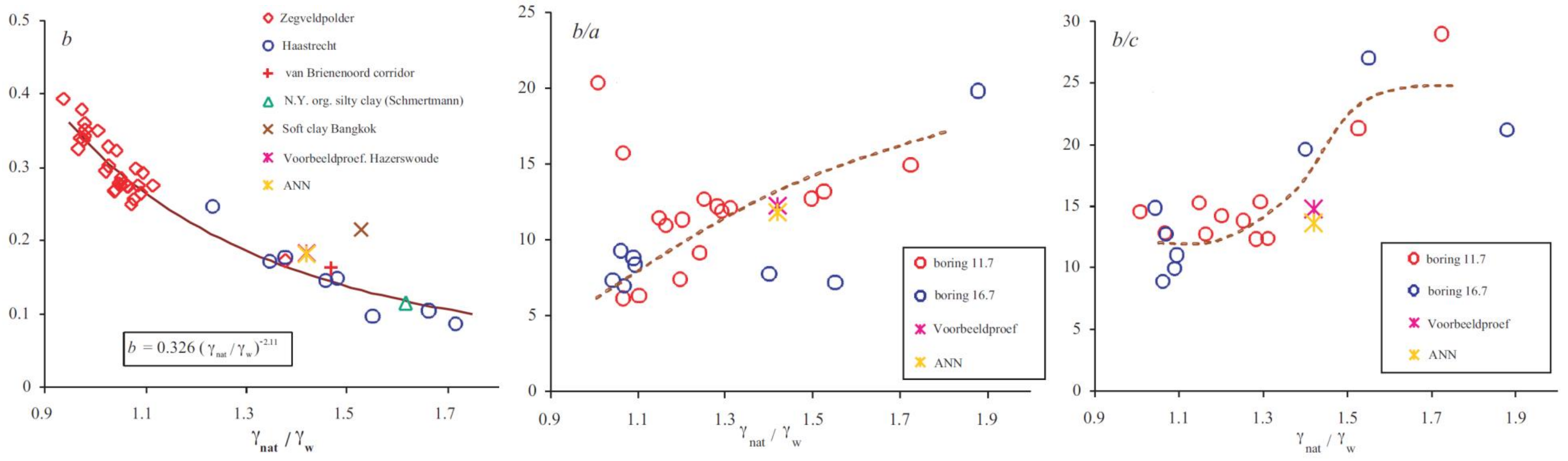
NEN 9997-1+C1:2012
2.4.5.2

Tabel 2.b — Karakteristieke waarden van grondeigenschappen

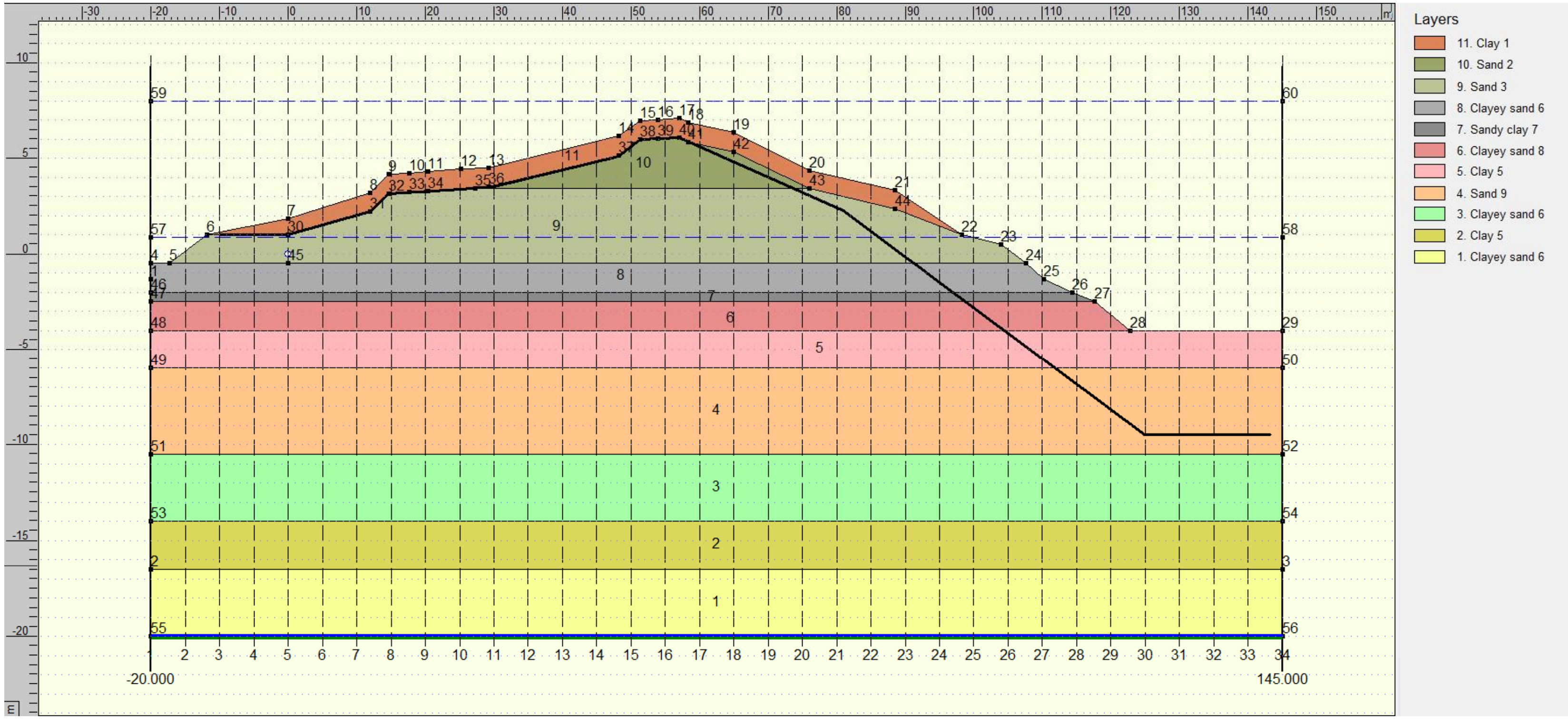
Grondsoort			Karakteristieke waarde[a] van grondeigenschap											
Hoofd-naam	Bijmengsel	Consis-tentie[b]	γ[c] kN/m³	γ_{sat} kN/m³	q_c[d g] MPa	C'_p[g]	C'_s	$C_c/(1+e_0)$[g] [-]	C_α[f] [-]	$C_{sw}/(1+e_0)$[g] [-]	E_{100}[g h] MPa	φ'[g] Graden	c' kPa	c_u kPa
Grind	Zwak siltig	Los	17	19	15	500	∞	0,0046	0	0,0015	45	32,5	0	
		Matig	18	20	25	1000	∞	0,0023	0	0,0008	75	35,0	0	n.v.t.
		Vast	19 20	21 22	30	1200 1400	∞	0,0019 0,0016	0	0,0006 0,0005	90 105	37,5 40,0	0	
	Sterk siltig	Los	18	20	10	400	∞	0,0058	0	0,0019	30	30,0	0	
		Matig	19	21	15	600	∞	0,0038	0	0,0013	45	32,5	0	n.v.t.
		Vast	20 21	22 22,5	25	1000 1500	∞	0,0023 0,0015	0	0,0008 0,0005	75 110	35,0 40,0	0	
Zand	Schoon	Los	17	19	5	200	∞	0,0115	0	0,0038	15	30,0	0	
		Matig	18	20	15	600	∞	0,0038	0	0,0013	45	32,5	0	n.v.t.
		Vast	19 20	21 22	25	1000 1500	∞	0,0023 0,0015	0	0,0008 0,0005	75 110	35,0 40,0	0	
	Zwak siltig, kleiig		18 19	20 21	12	450 650	∞	0,0051 0,0035	0	0,0017 0,0012	35 50	27,0 32,5	0	n.v.t.
	Sterk siltig, kleiig		18 19	20 21	8	200 400	∞	0,0115 0,0058	0	0,0038 0,0019	15 30	25,0 30,0	0	n.v.t.
Leem[e]	Zwak zandig	Slap	19	19	1	25	650	0,0920	0,0037	0,0307	2	27,5 30,0	0	50
		Matig	20	20	2	45	1300	0,0511	0,0020	0,0170	3	27,5 32,5	1	100
		Vast	21 22	21 22	3	70 100	1900 2500	0,0329 0,0230	0,0013 0,0009	0,0110 0,0077	5 7	27,5 35,0	2,5 3,8	200 300
	Sterk zandig		19 20	19 20	2	45 70	1300 2000	0,0511 0,0329	0,0020 0,0013	0,0170 0,0110	3 5	27,5 35,0	0 1	50 100
Klei	Schoon	Slap	14	14	0,5	7	80	0,3286	0,0131	0,1095	1	17,5	0	25
		Matig	17	17	1,0	15	160	0,1533	0,0061	0,0511	2	17,5	5	50
		Vast	19 20	19 20	2,0	25 30	320 500	0,0920 0,0767	0,0037 0,0031	0,0307 0,0256	4 10	17,5 25,0	13 15	100 200
	Zwak zandig	Slap	15	15	0,7	10	110	0,2300	0,0092	0,0767	1,5	22,5	0	40
		Matig	18	18	1,5	20	240	0,1150	0,0046	0,0383	3	22,5	5	80
		Vast	20 21	20 21	2,5	30 50	400 600	0,0767 0,0460	0,0031 0,0018	0,0256 0,0153	5 10	22,5 27,5	13 15	120 170
	Sterk zandig	-	18 20	18 20	1,0	25 140	320 1680	0,0920 0,0164	0,0037 0,0007	0,0307 0,0055	2 5	27,5 32,5	0 1	0 10
	Organisch	Slap	13	13	0,2	7,5	30	0,3067	0,0153	0,1022	0,5	15,0	0 1	10
		Matig	15 16	15 16	0,5	10 15	40 60	0,2300 0,1533	0,0115 0,0077	0,0767 0,0511	1,0 2,0	15,0	0 1	25 30
Veen	Niet voorbelast	Slap	10 12	10 12	0,1	5 7,5	20 30	0,4600 0,3067	0,0230 0,0153	0,1533 0,1022	0,2 0,5	15,0	1 2,5	10 20
	Matig voorbelast	Matig	12 13	12 13	0,2	7,5 10	30 40	0,3067 0,2300	0,0153 0,0115	0,1022 0,0767	0,5 1,0	15,0	2,5 5	20 30
Variatiecoëfficiënt v			0,05		–	0,25					0,10		0,20	

Zie vervolg

Inventory – Case 1



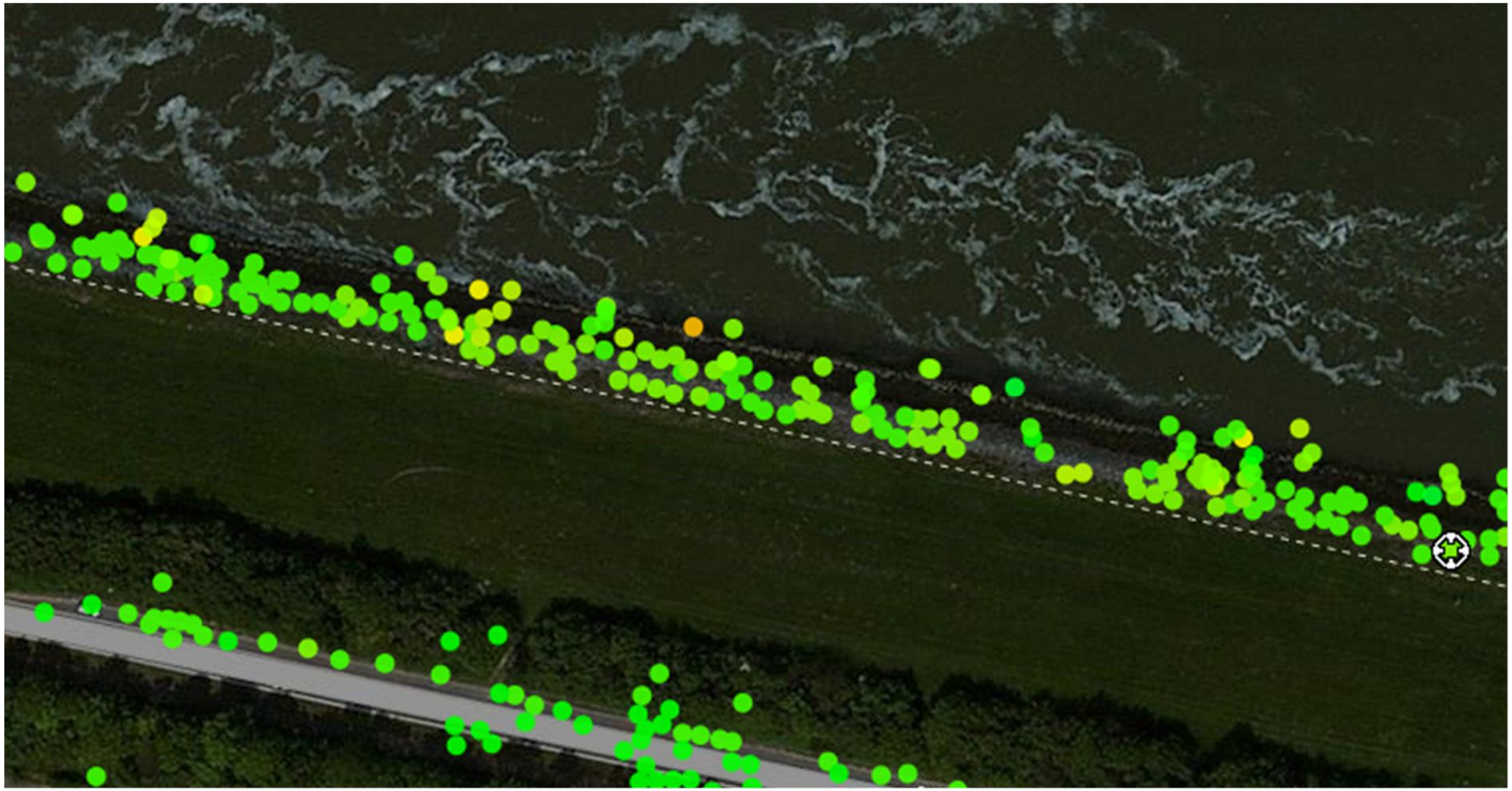
Inventory – Case 1



Measurements – Case 1

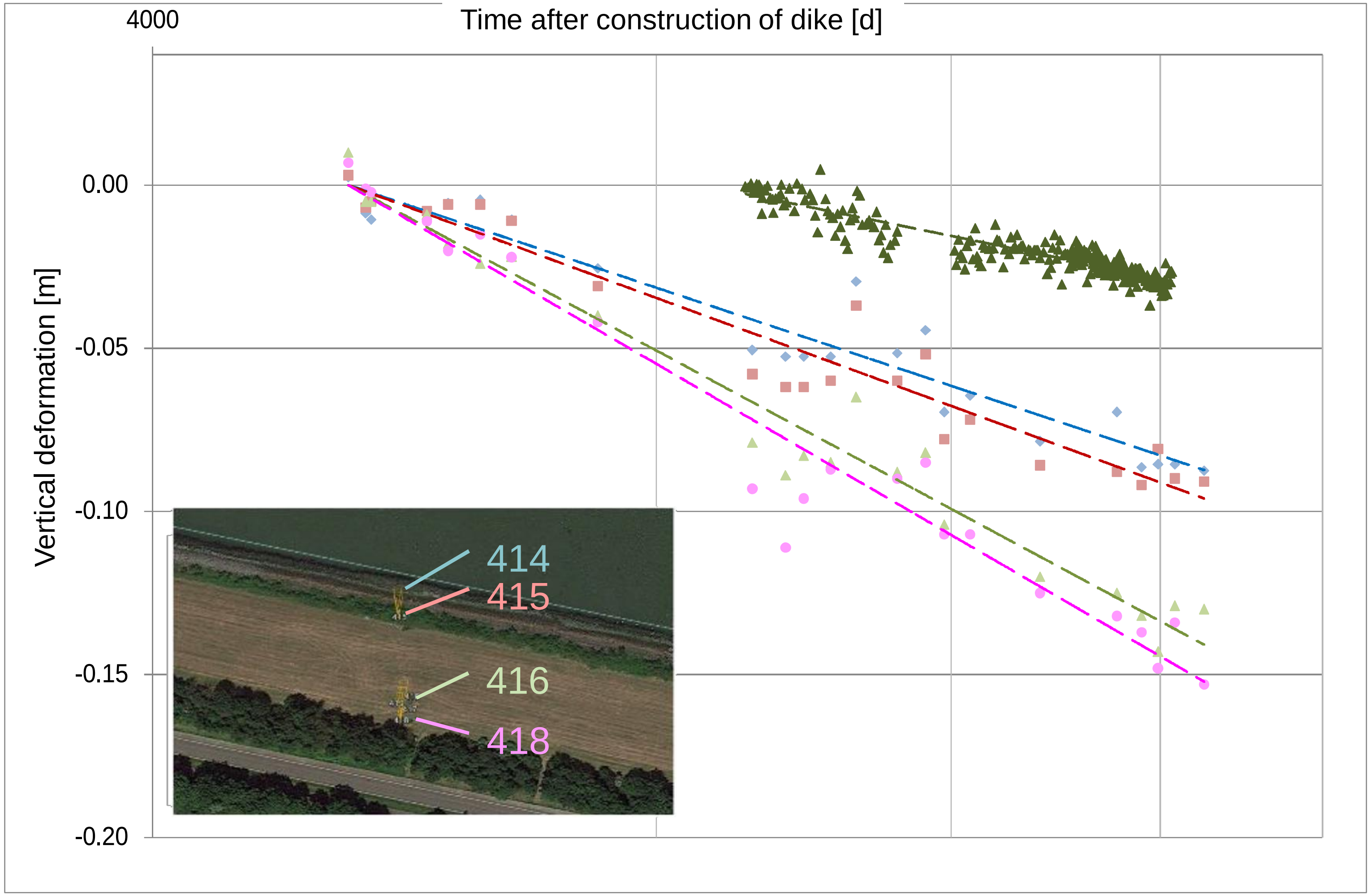
Deltares

Measurements – Case 1



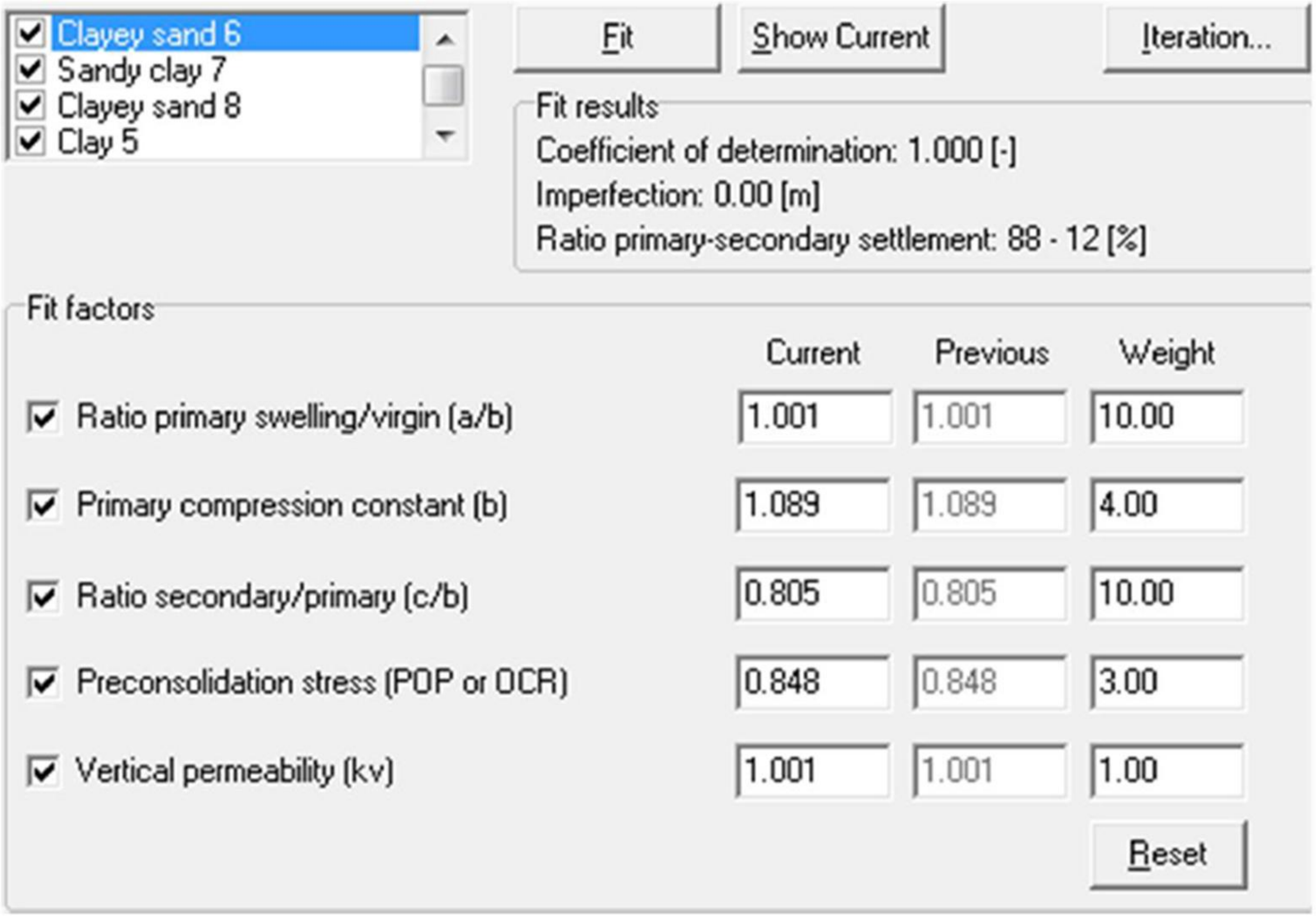
Deltares

Measurements – Case 1



Deltares

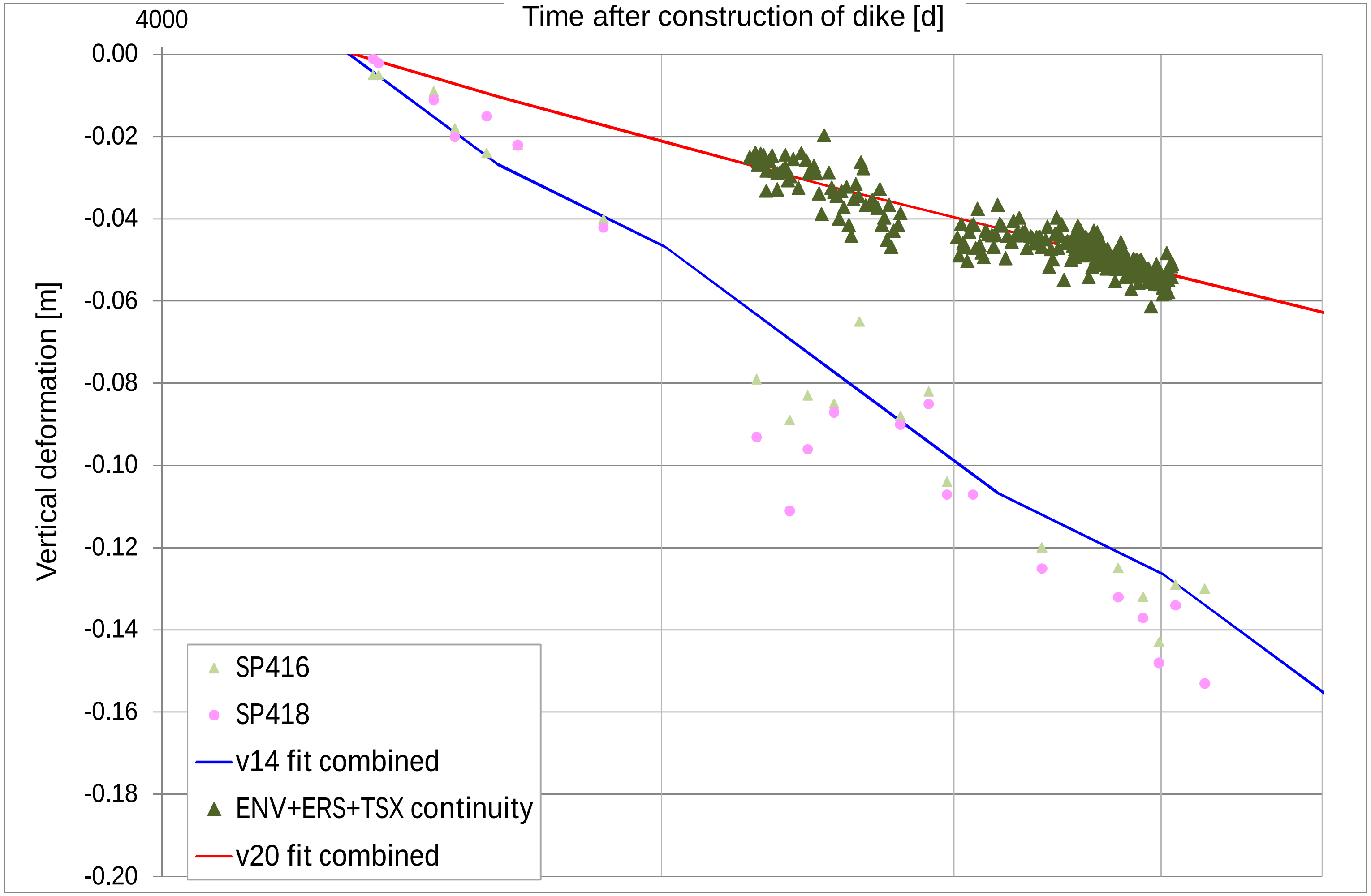
Results – Case 1



Fit factors for settlement calculation

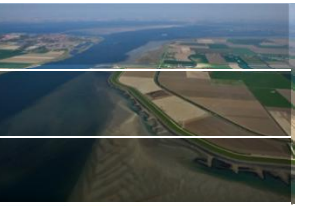
Deltares

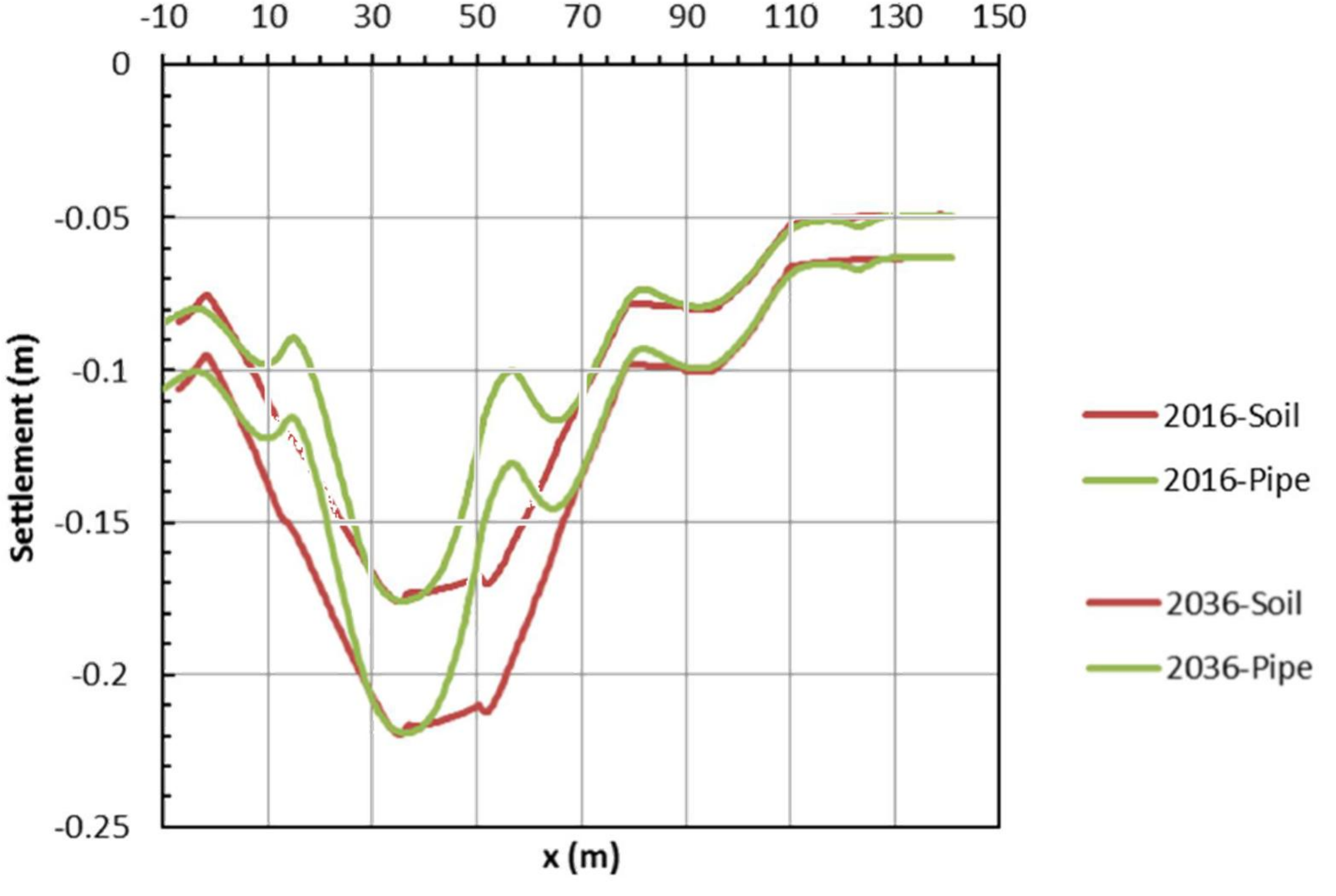
Results – Case 1



Deltares

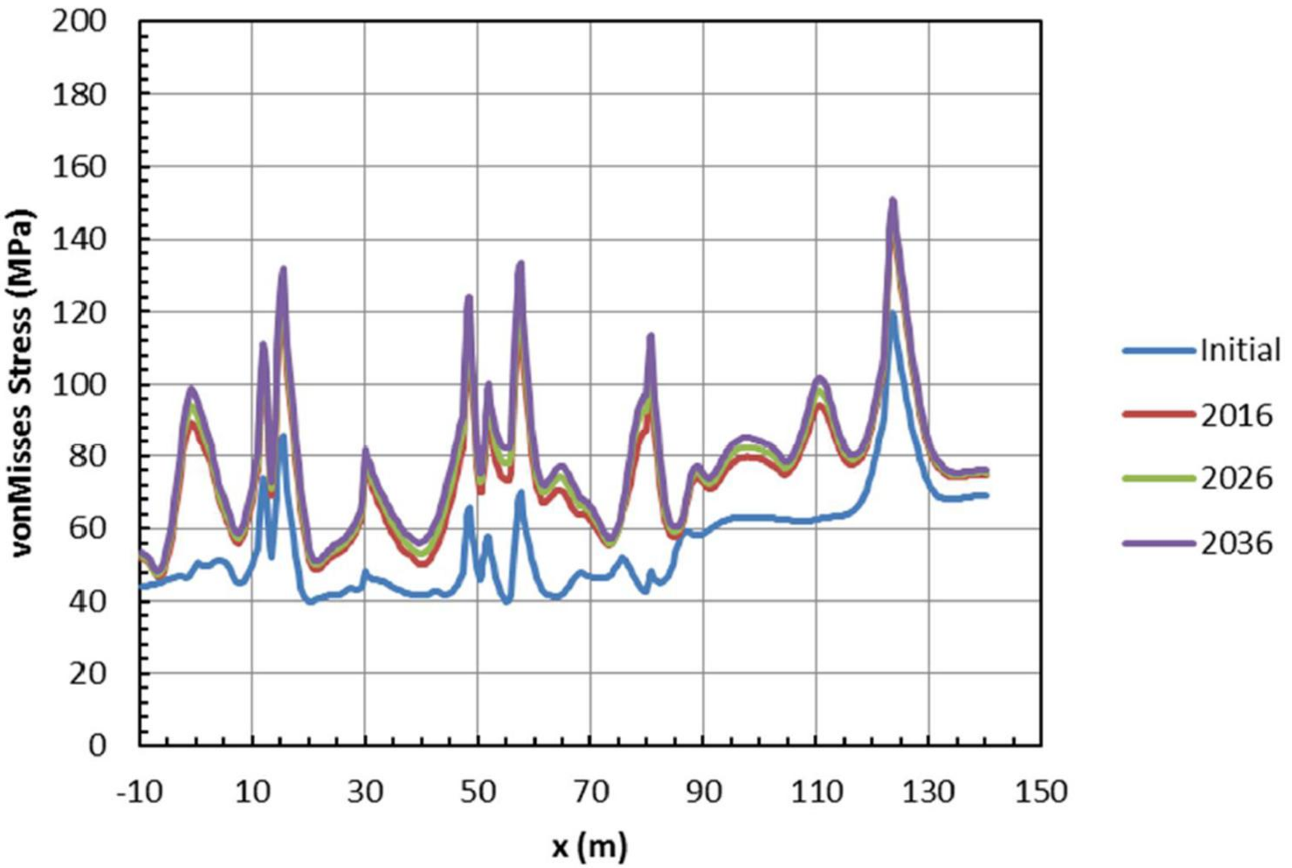
Results – Case 1



Deltares

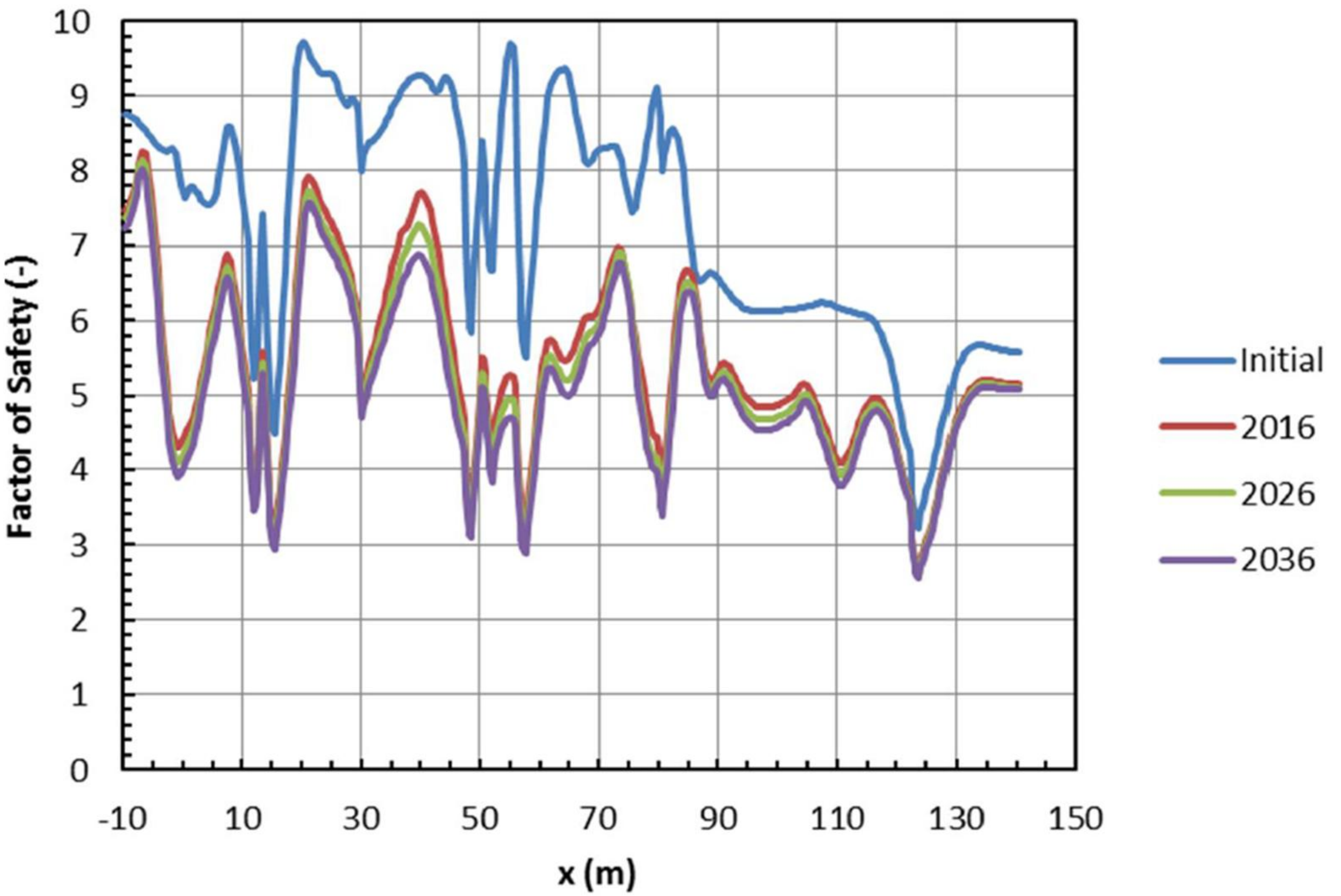
Results – Case 1



Increase approx. 5% / 10 years

Deltares

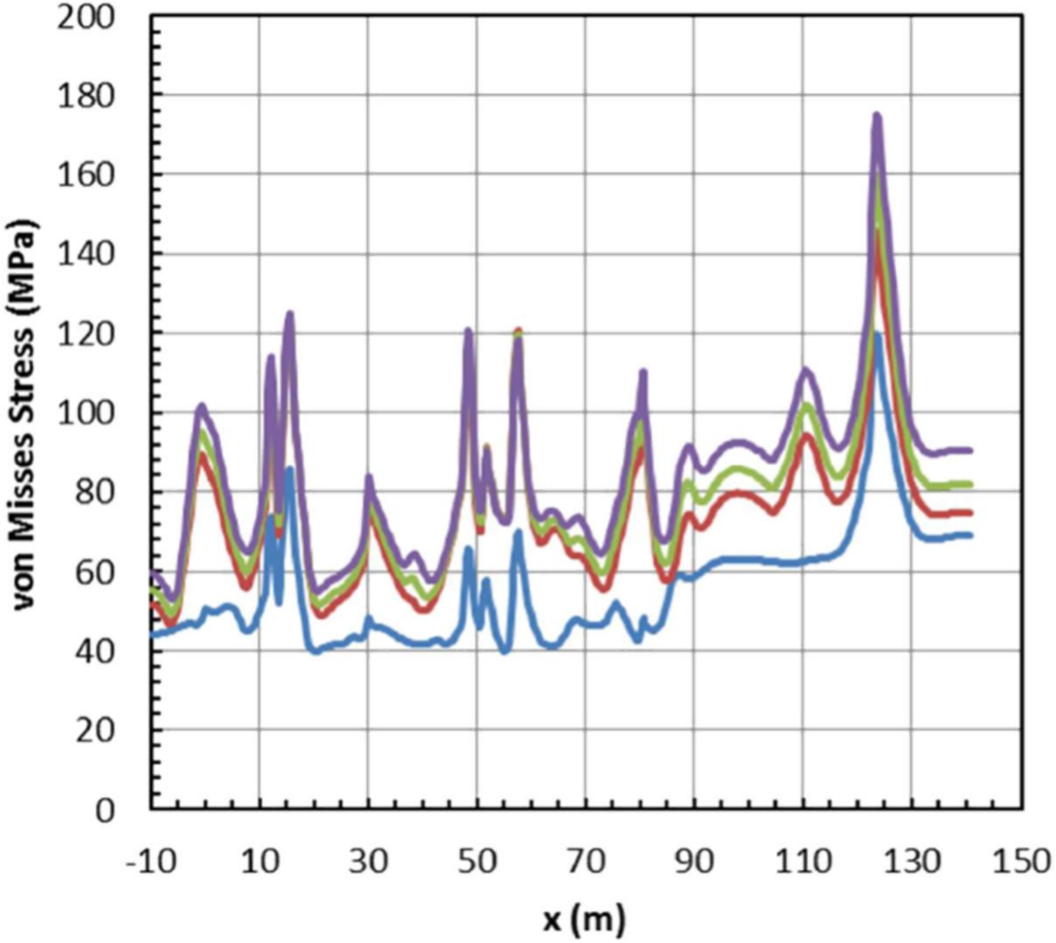
Results – Case 1



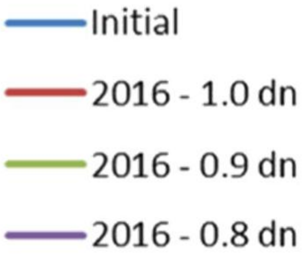
Allowable stress = 368 MPa

Deltares

Results – Case 1



Effect of wall thickness



Deltares

Conclusions – Case 1

Stresses and safety of pipeline

- Sufficient factor of safety, now and in the future

Voids under the pipeline

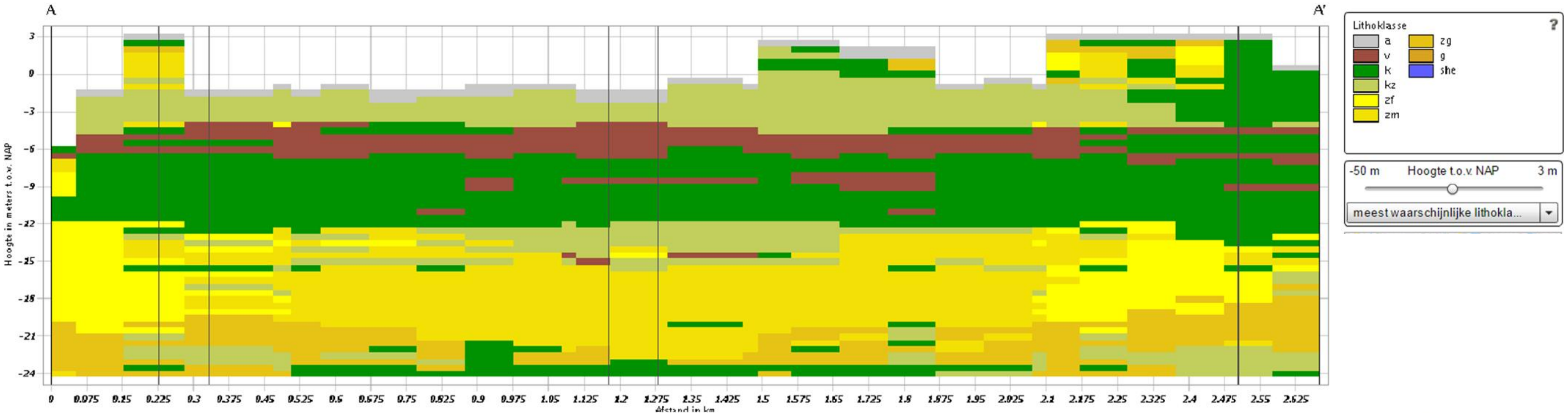
- High probability of voids under the pipeline, developing further

Monitoring

- Less frequent monitoring is possible
- INSAR only (available for toe), using historical data from settlement plates
- Discontinue measurements with settlement plates

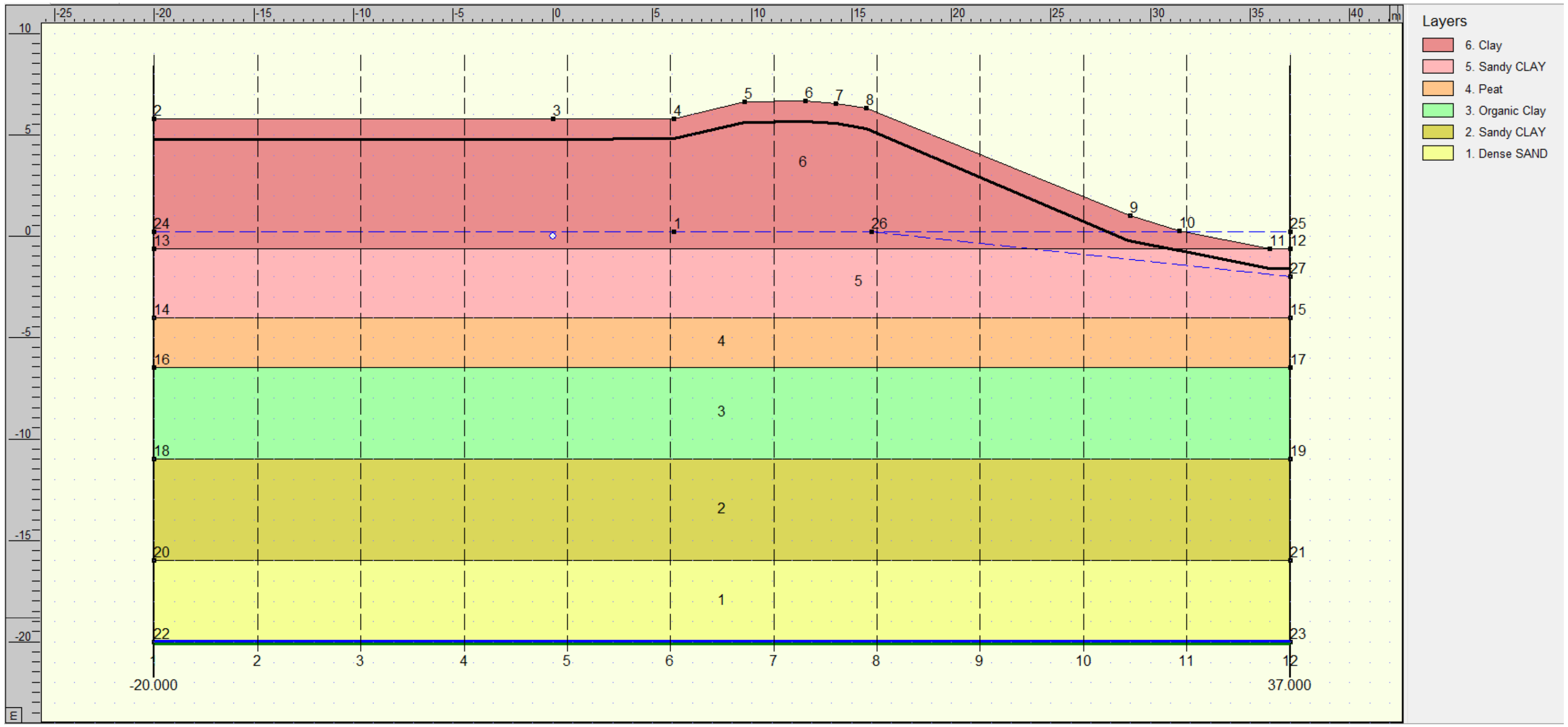
Deltares

Inventory – Case 2



Deltares

Inventory – Case 2

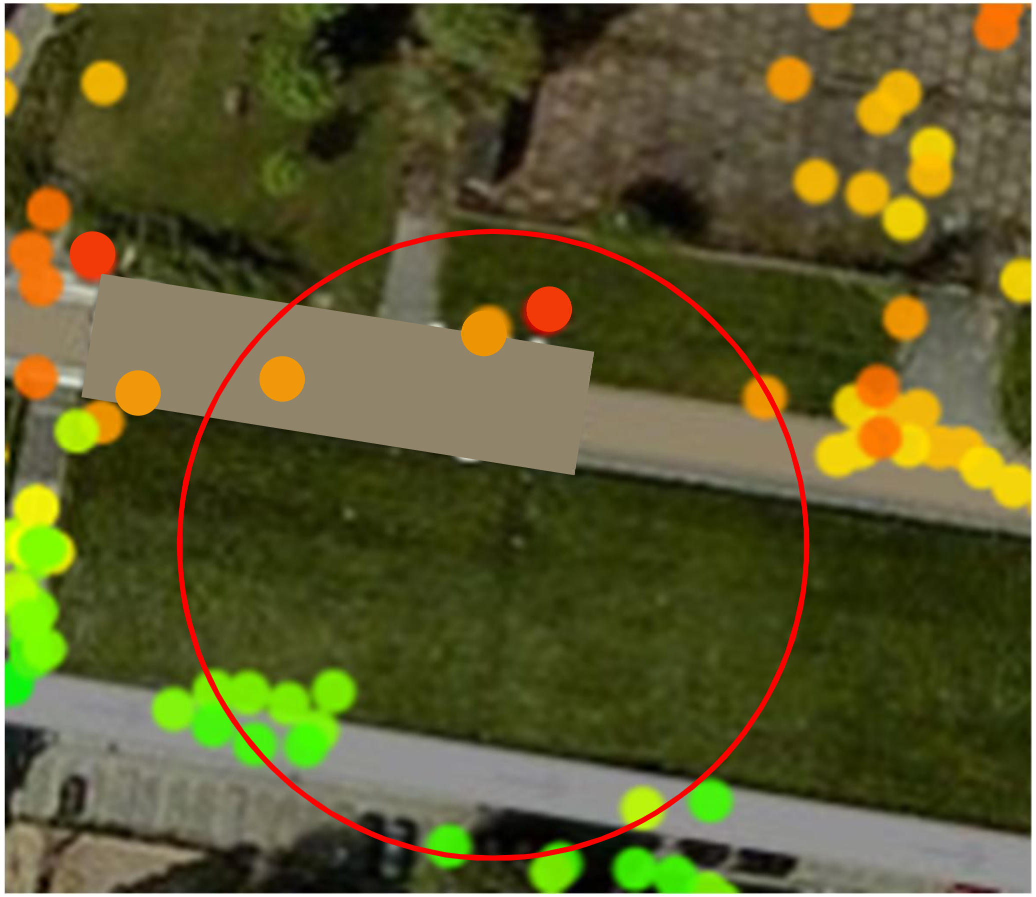


HDPE pipeline 160 mm x 17.8 mm (1989)

Deltares

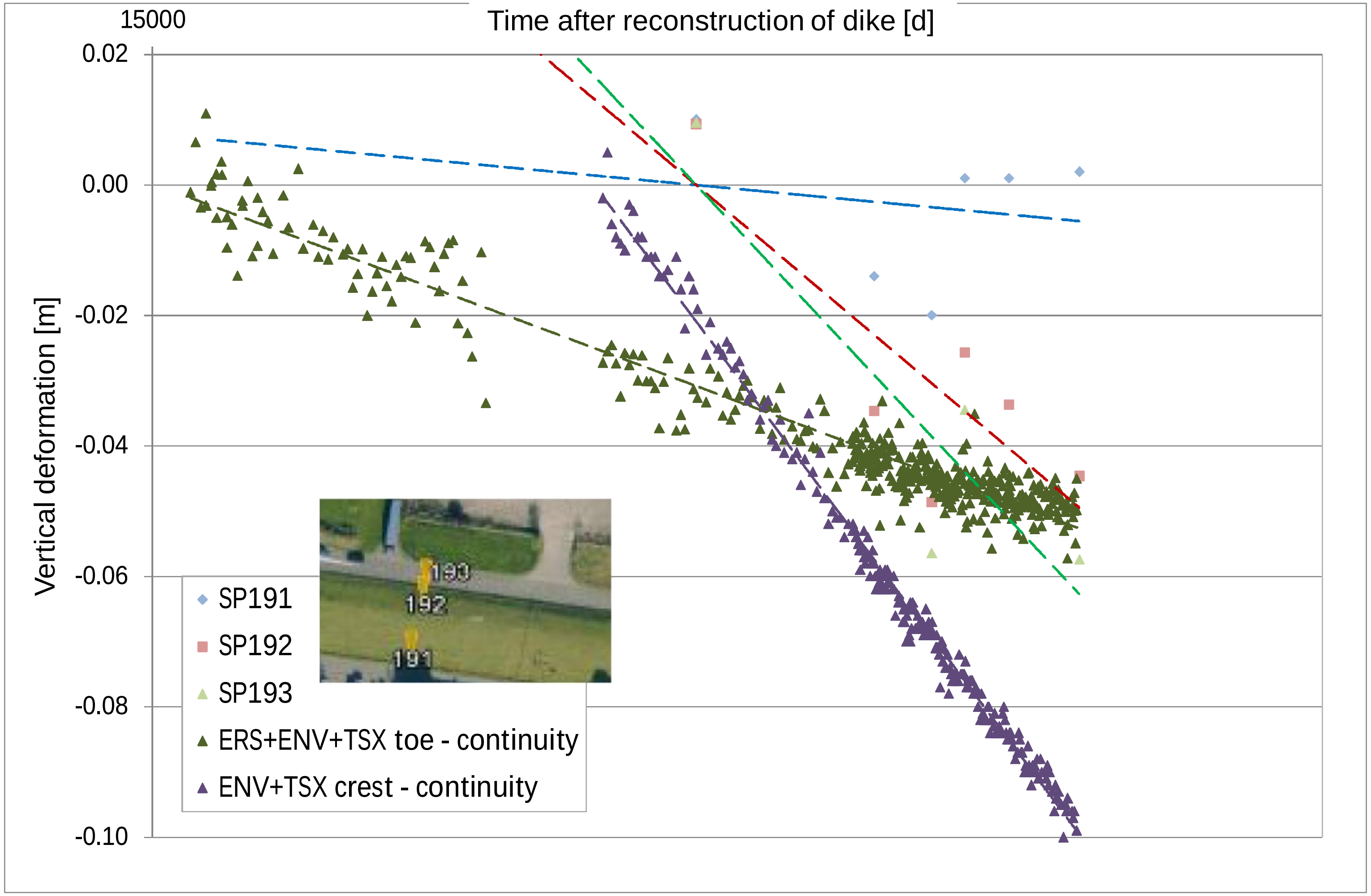
Measurements – Case 2

Measurements – Case 2



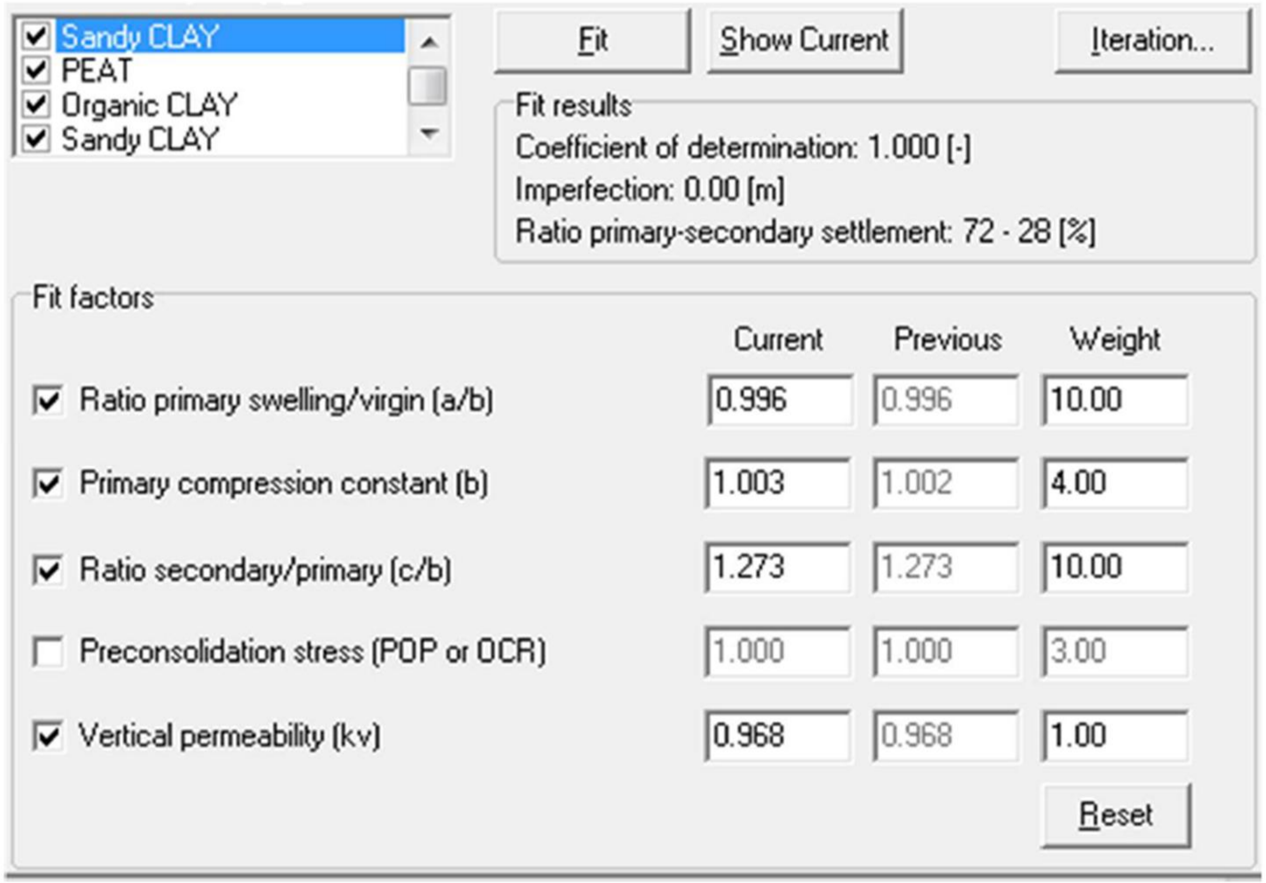
Deltares

Measurements – Case 2



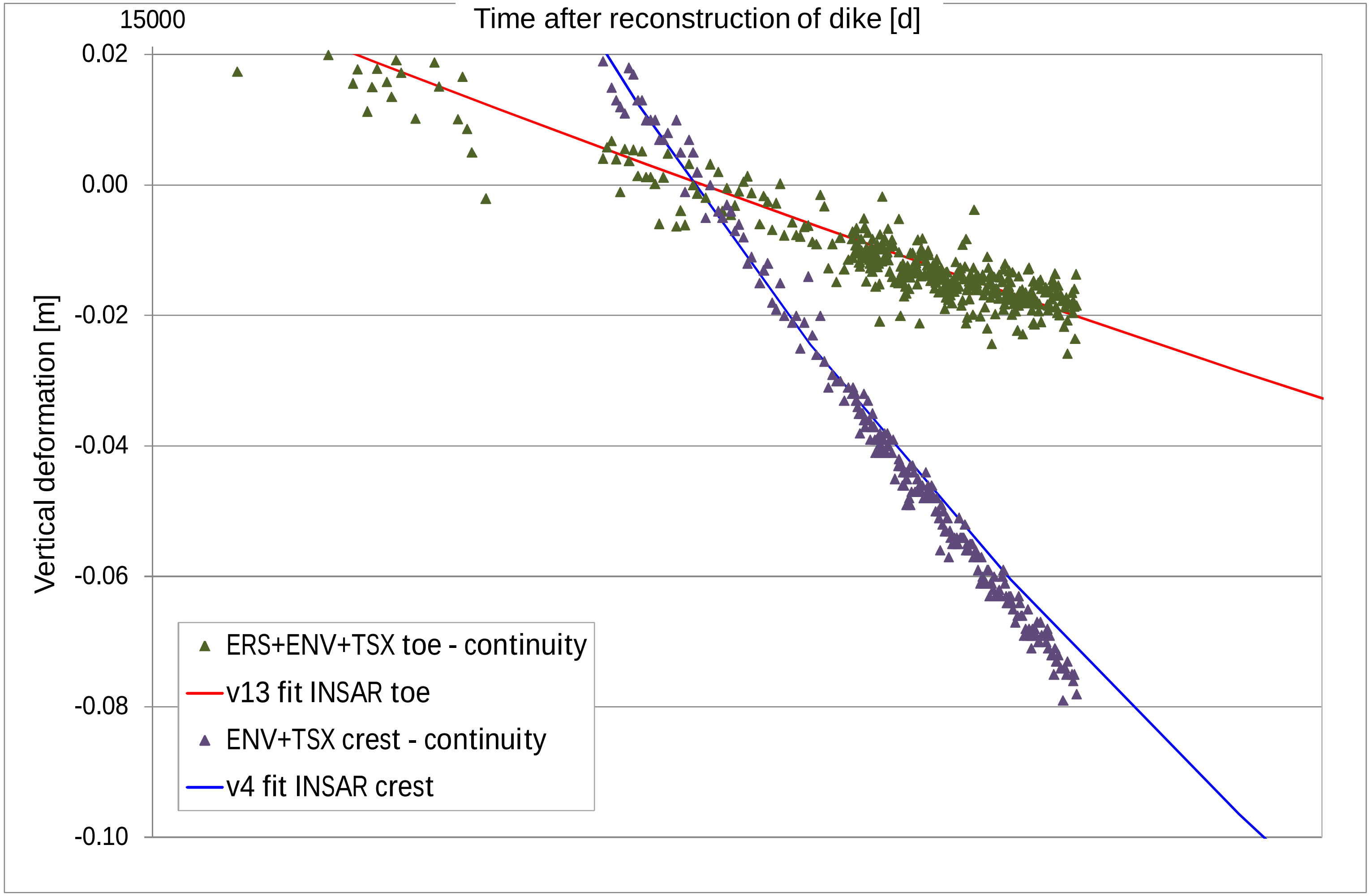
Deltares

Results – Case 2



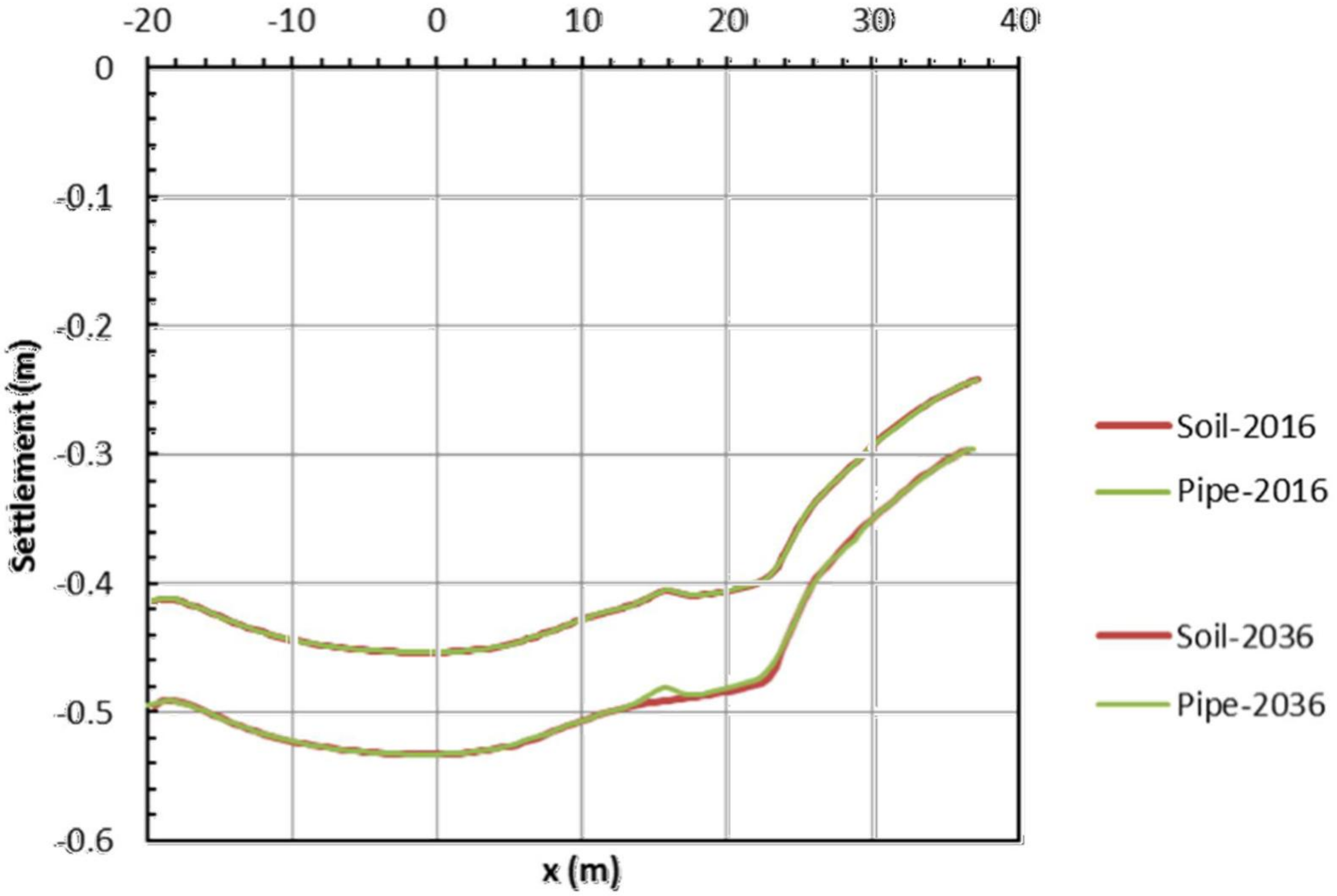
Fit factors for settlement calculation

Results – Case 2



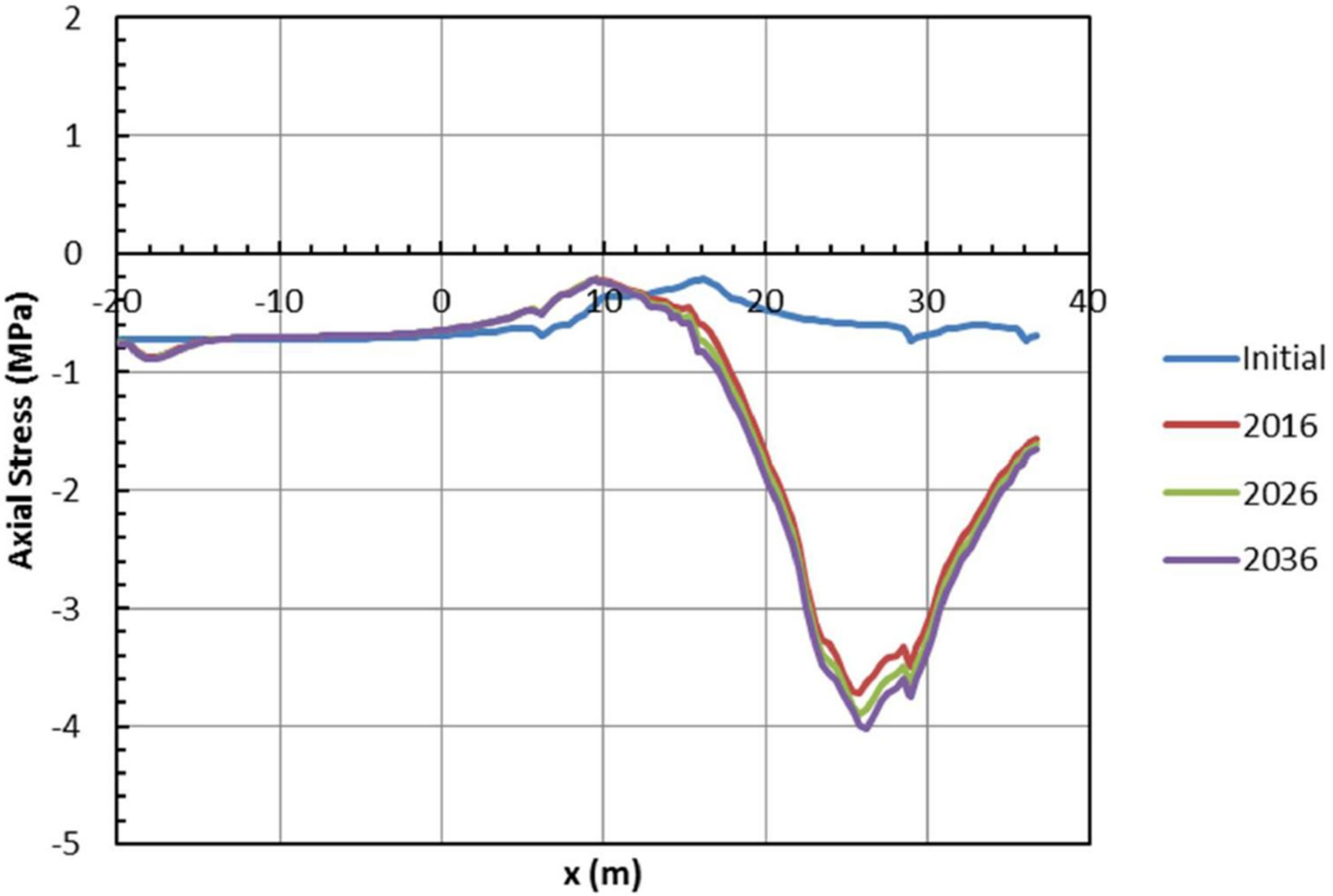
Deltares

Results – Case 2



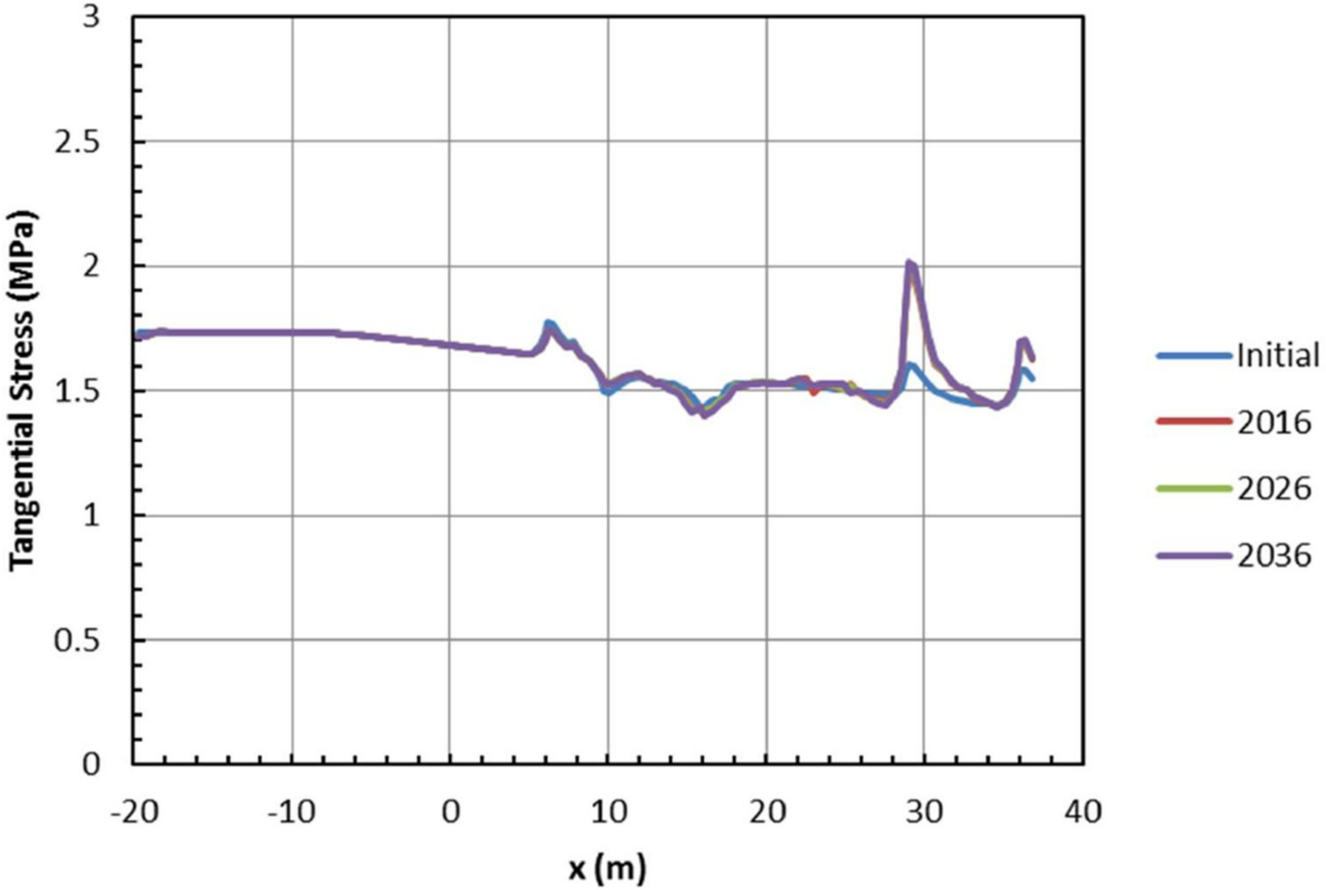
Deltares

Results – Case 2



Increase max. 5% / 10 years

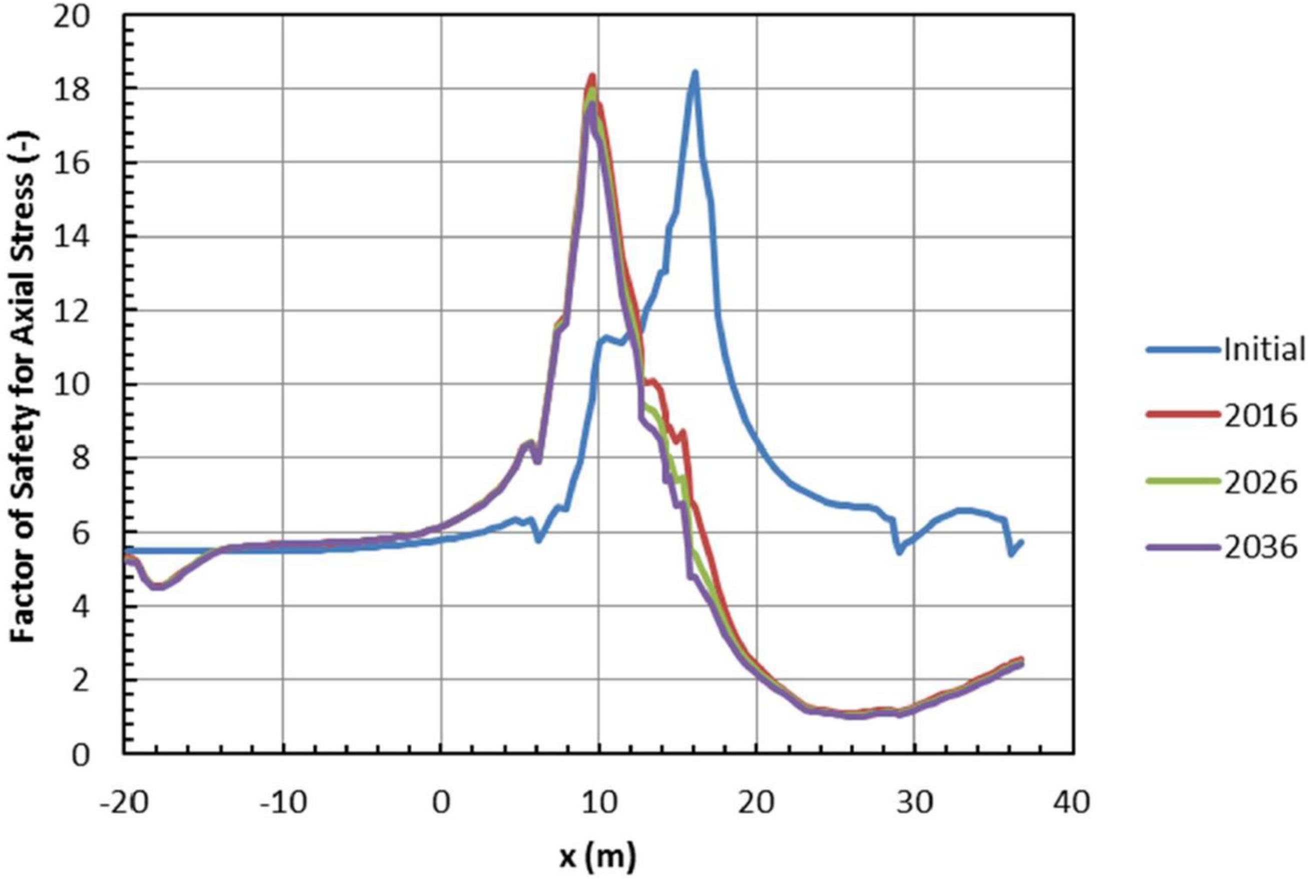
Results – Case 2



Increase max. 5% / 10 years

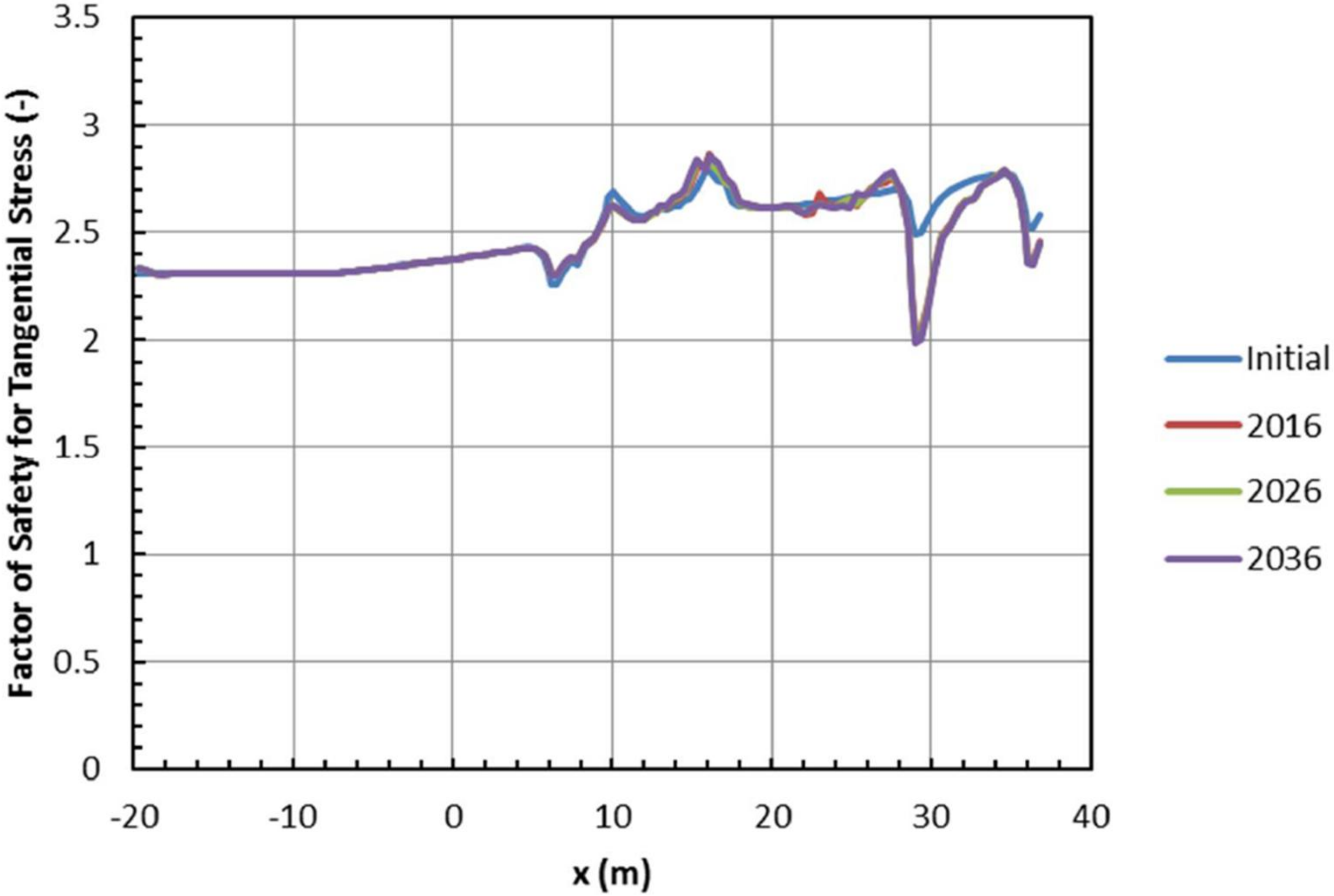
Deltares

Results – Case 2



Allowable stress = 4 MPa

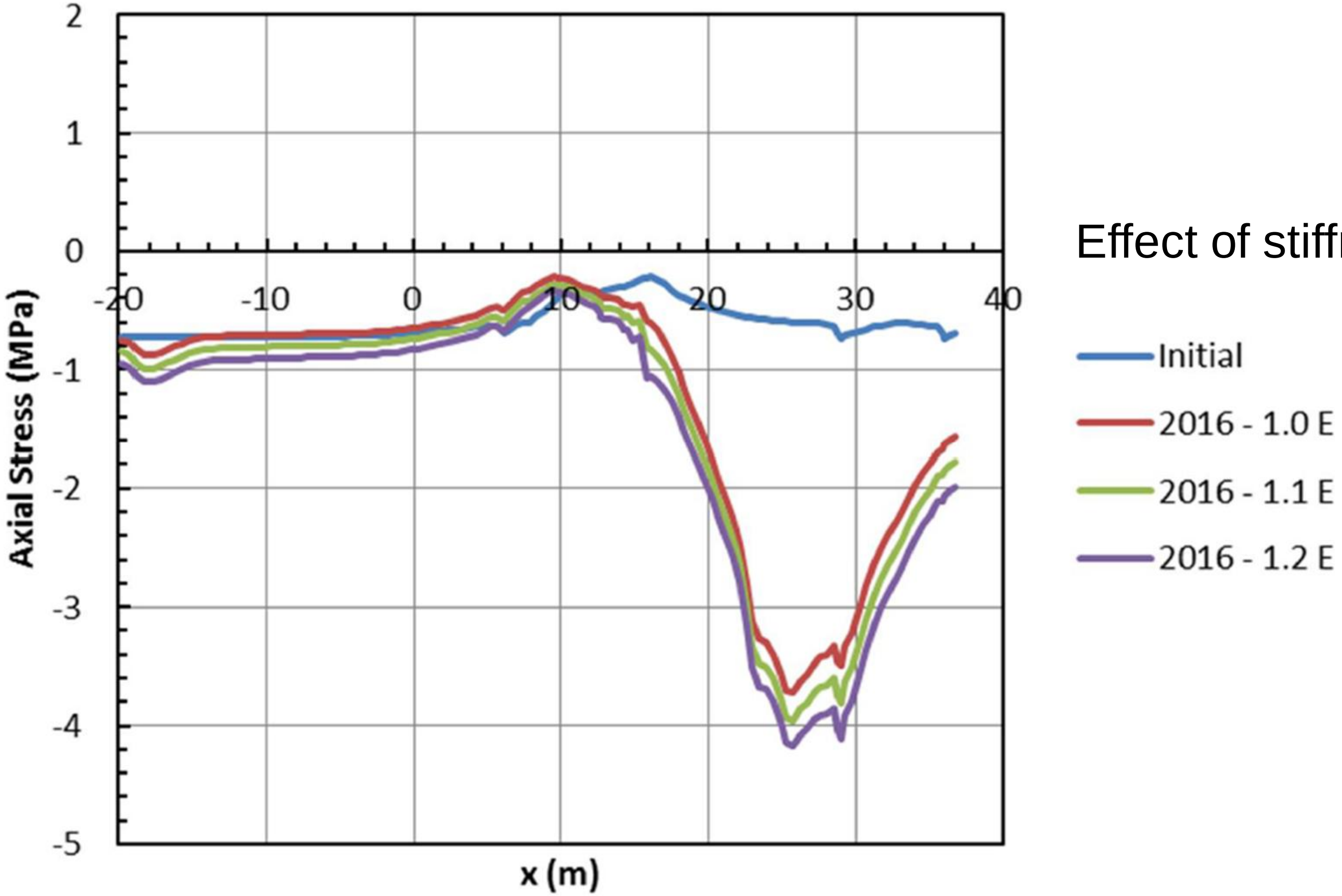
Results – Case 2



Allowable stress = 4 MPa

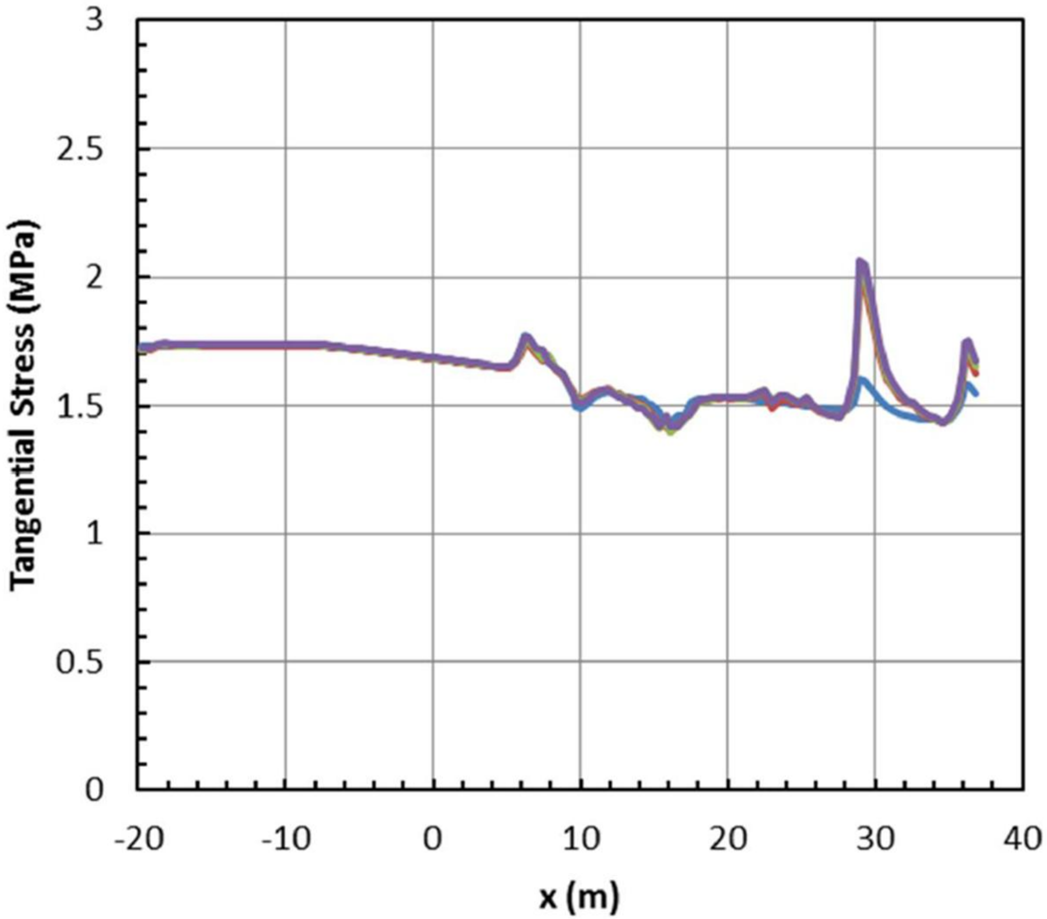
Deltares

Results – Case 2



Effect of stiffness

Results – Case 2



Effect of stiffness

Deltares

Conclusions – Case 2

Stresses and safety of pipeline

- Factor of safety is critical at present, failure in the future

Voids under the pipeline

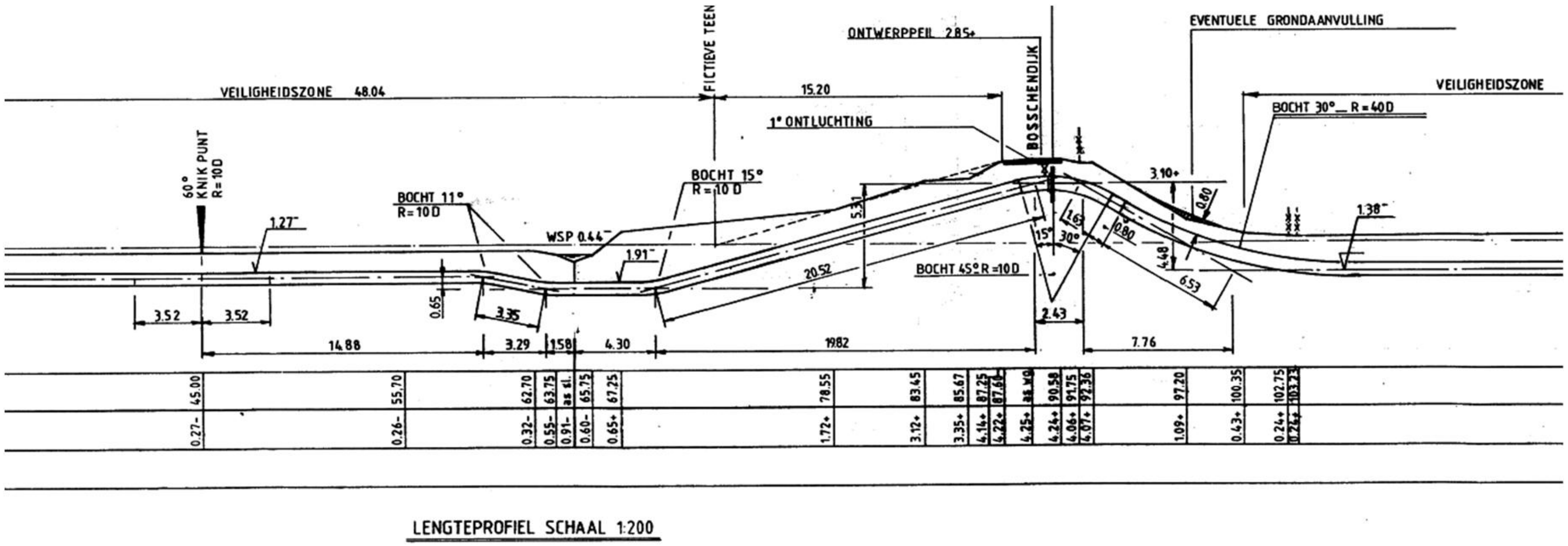
- Low probability of voids under the pipeline

Monitoring

- Frequent monitoring required
- INSAR only (available for crest and toe)
- Discontinue measurements with settlement plates

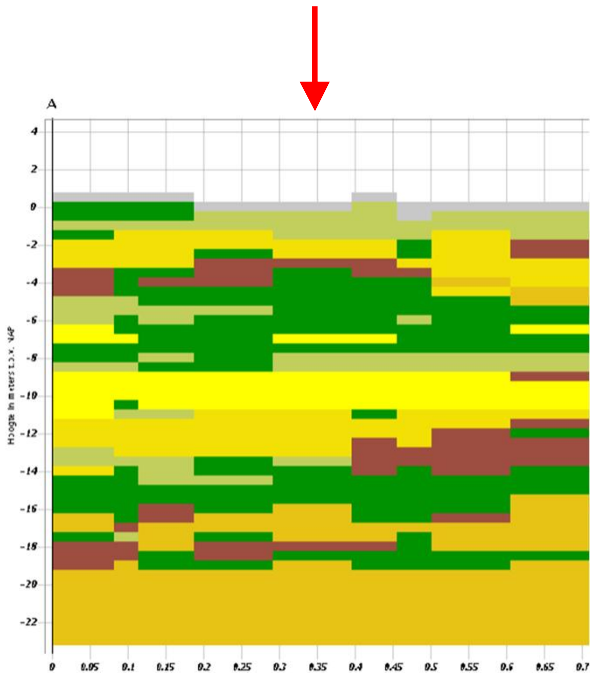
Deltares

Inventory – Case 3



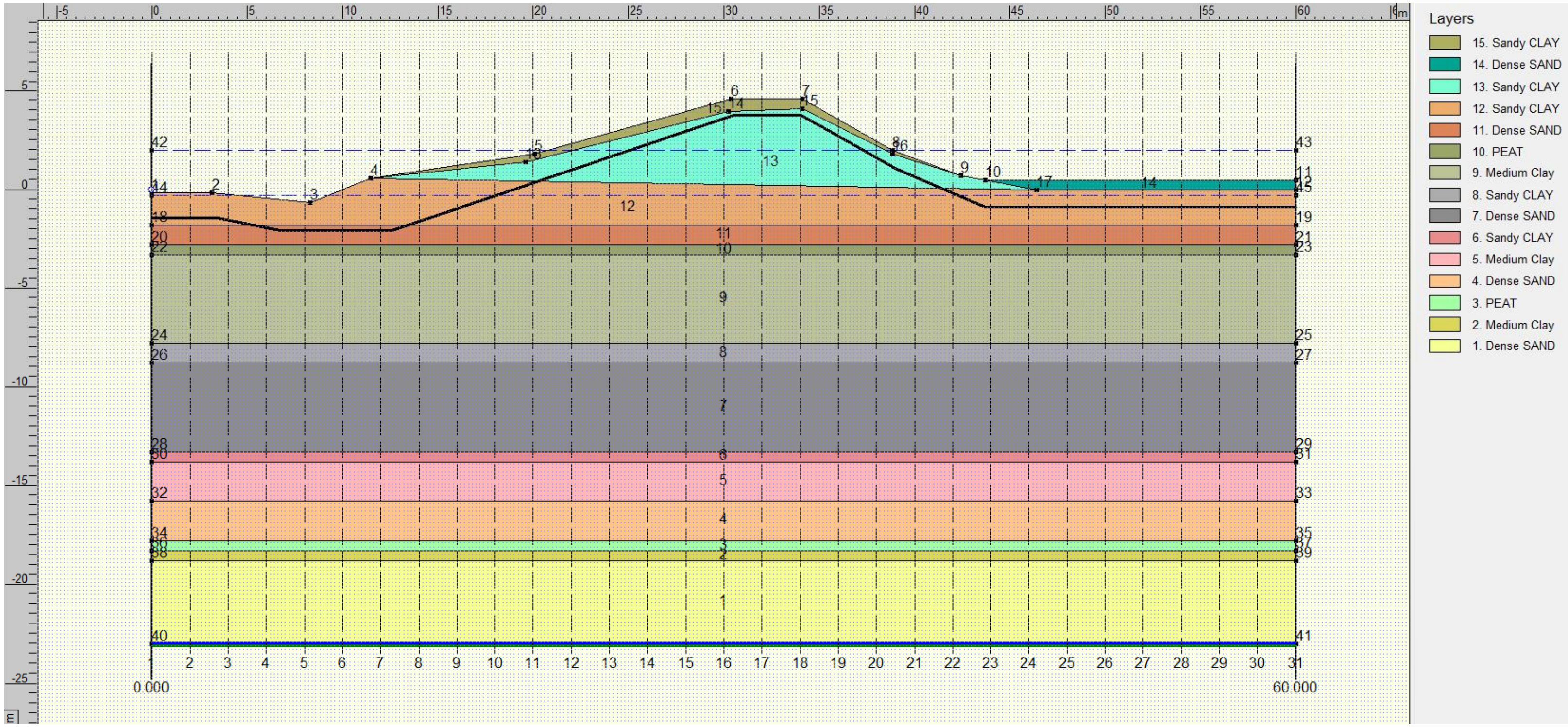
Steel pipeline 610 mm x 12.5 mm (1987)

Inventory – Case 3



Deltares

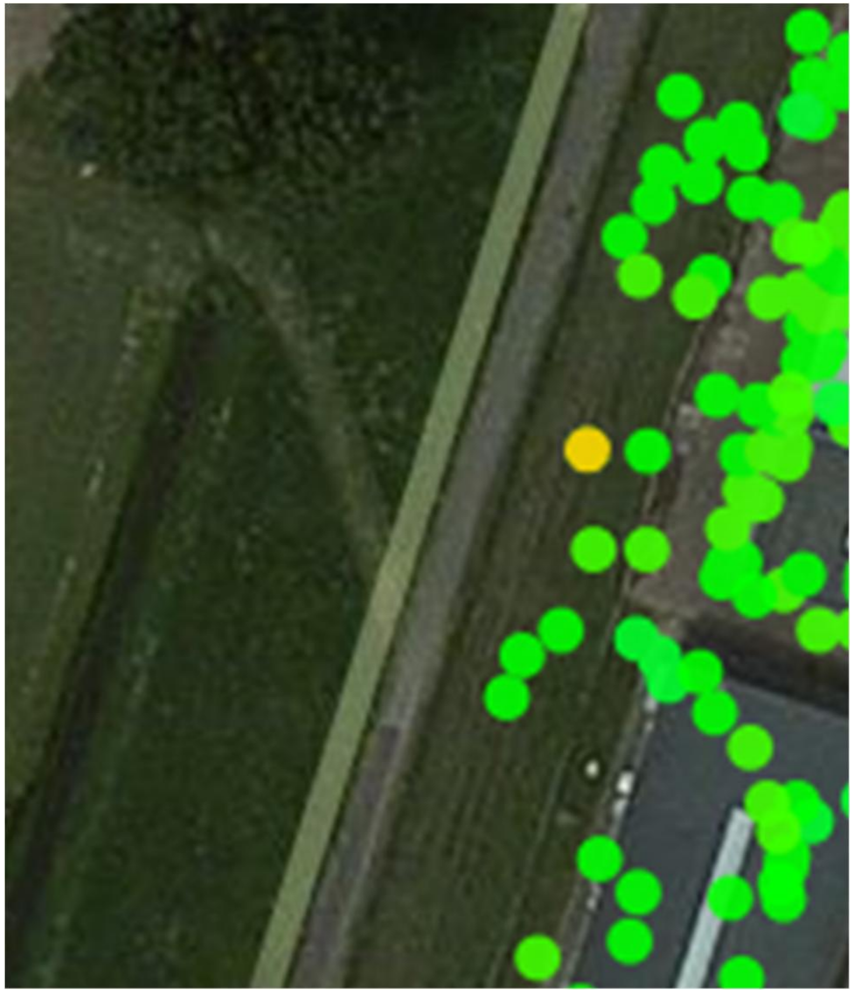
Inventory – Case 3



Deltares

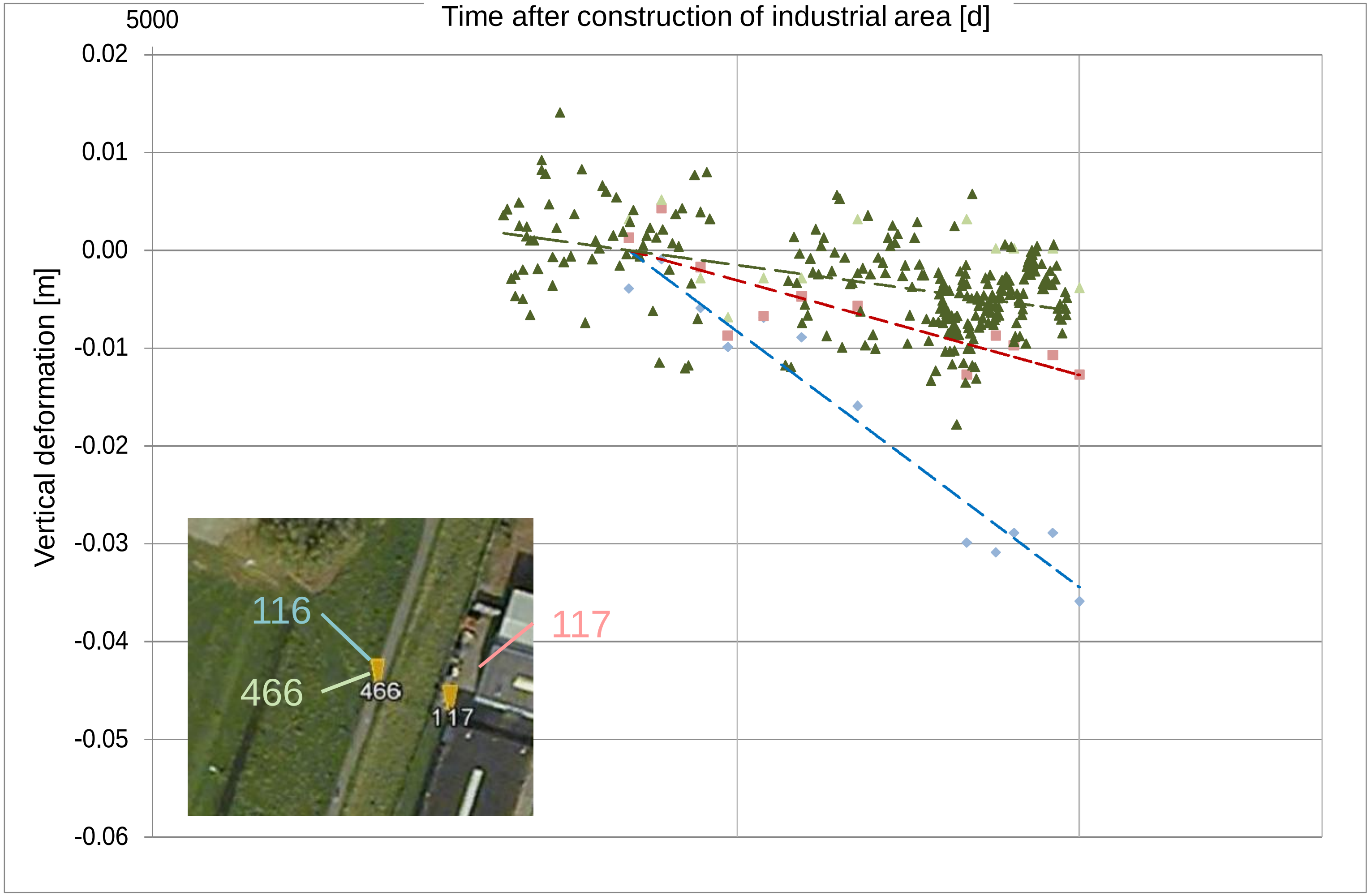
Measurements – Case 3

Measurements – Case 3



Deltares

Measurements – Case 3



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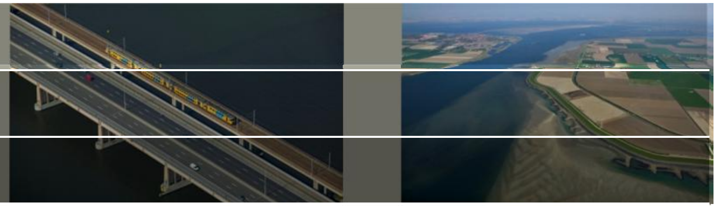
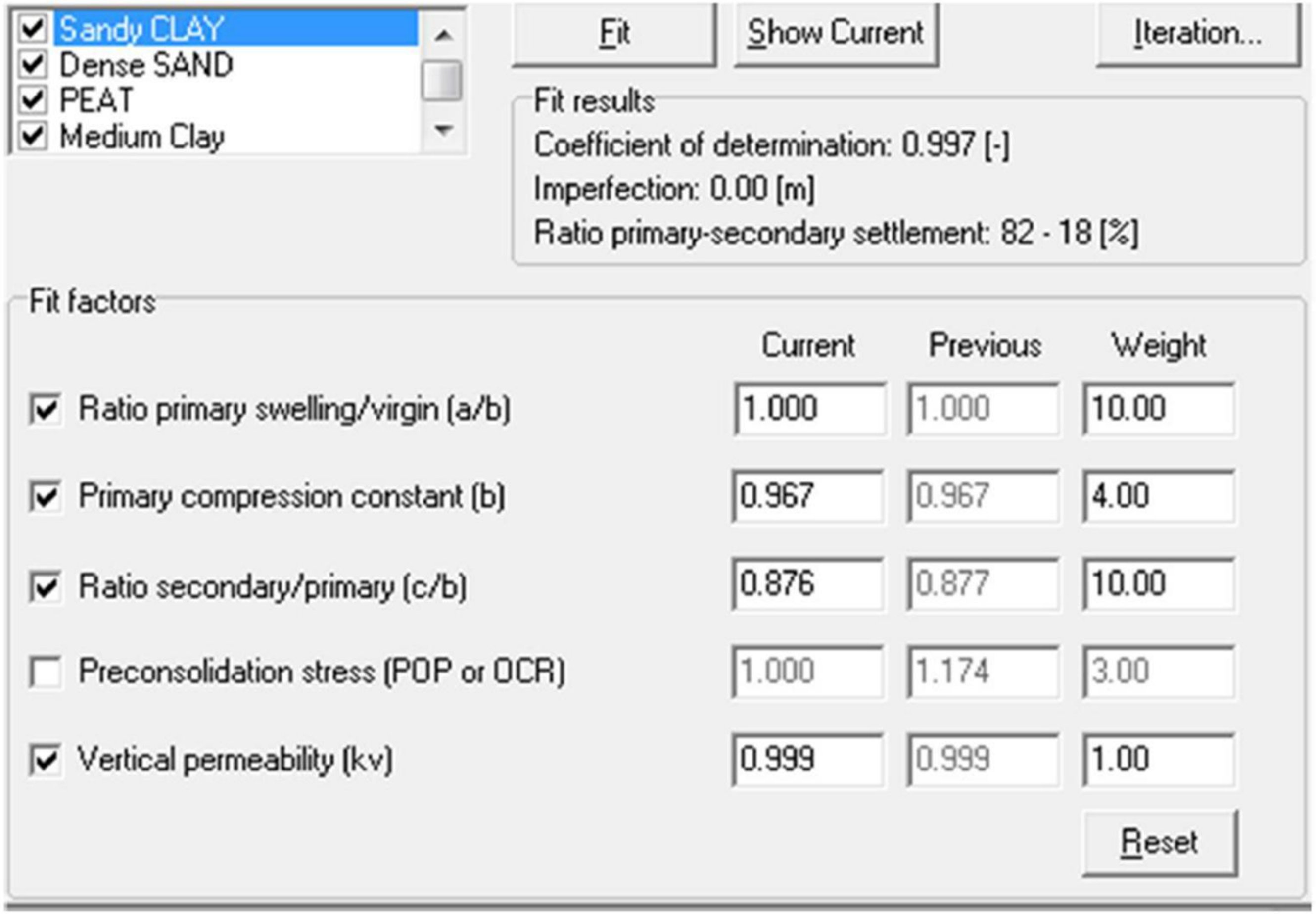
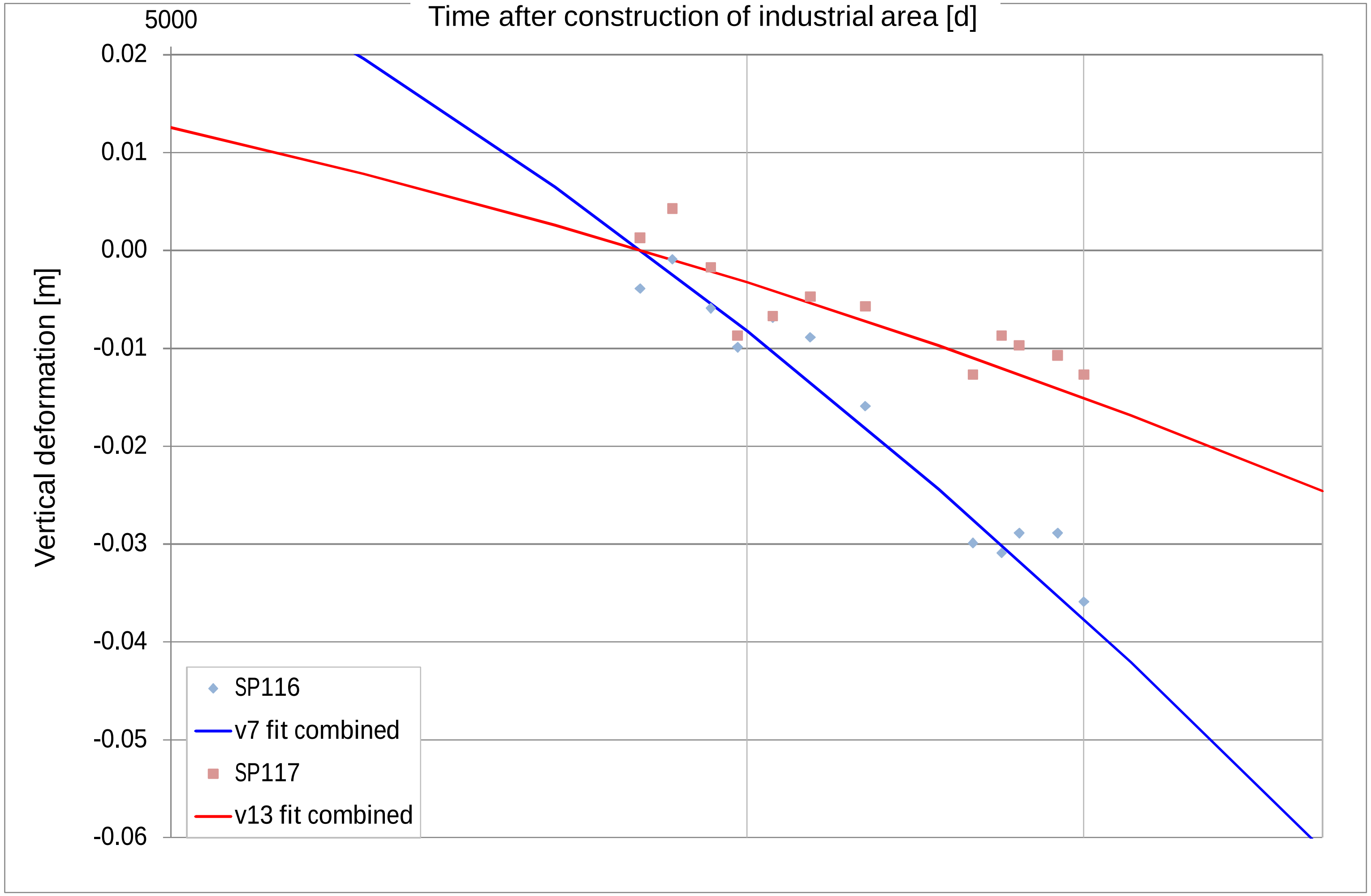
Results – Case 3





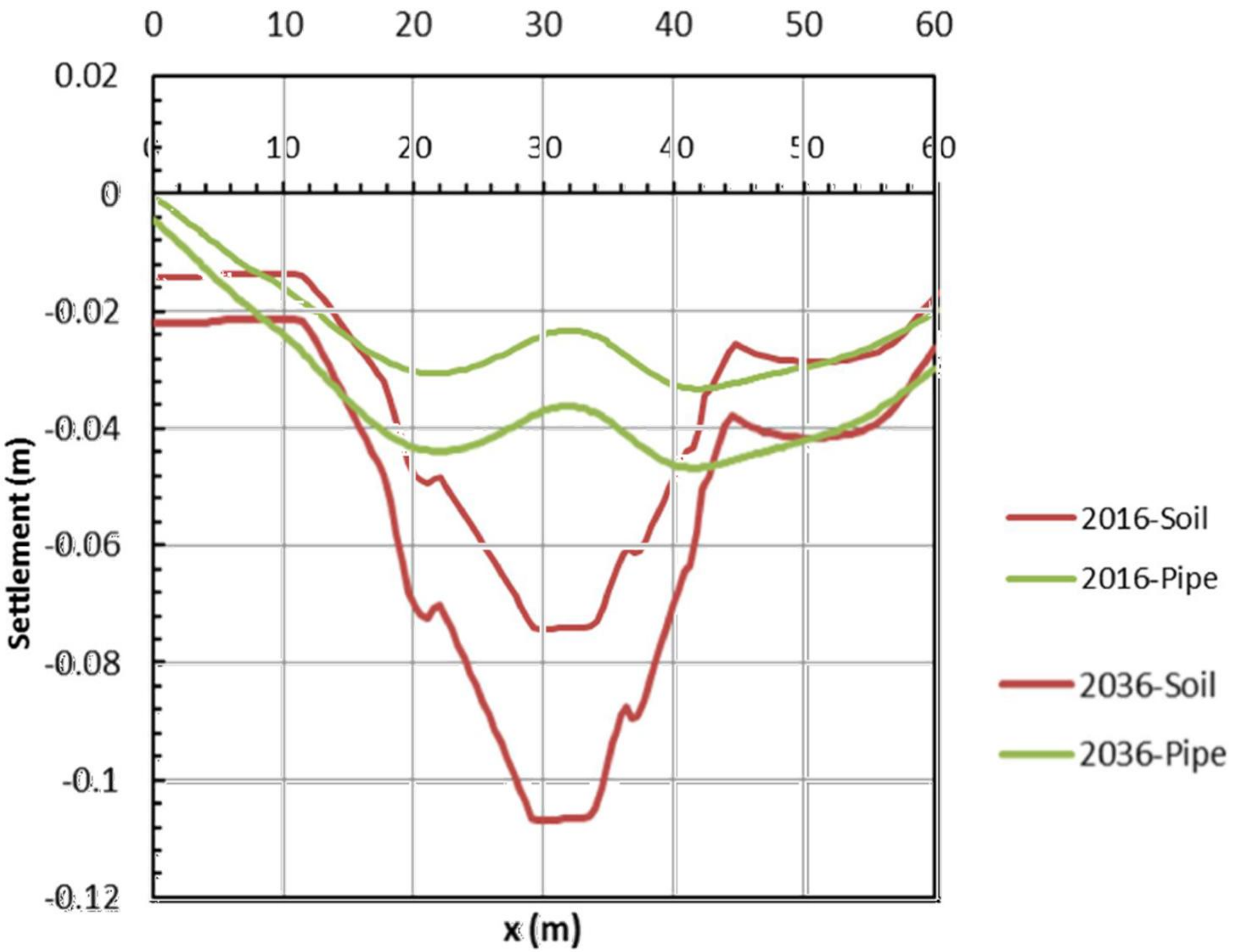
Fit factors for settlement calculation

Results – Case 3



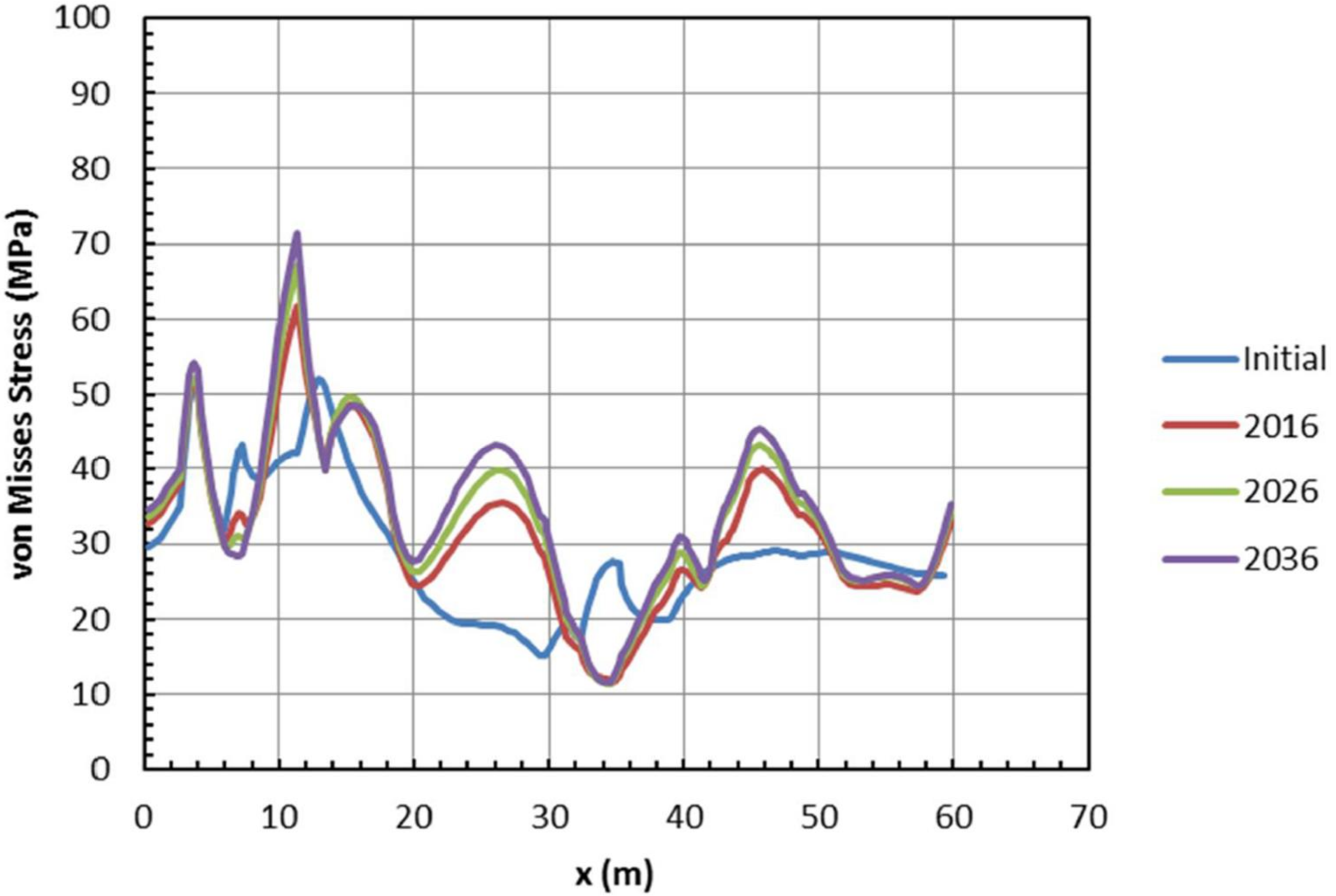
Deltares

Results – Case 3



Deltares

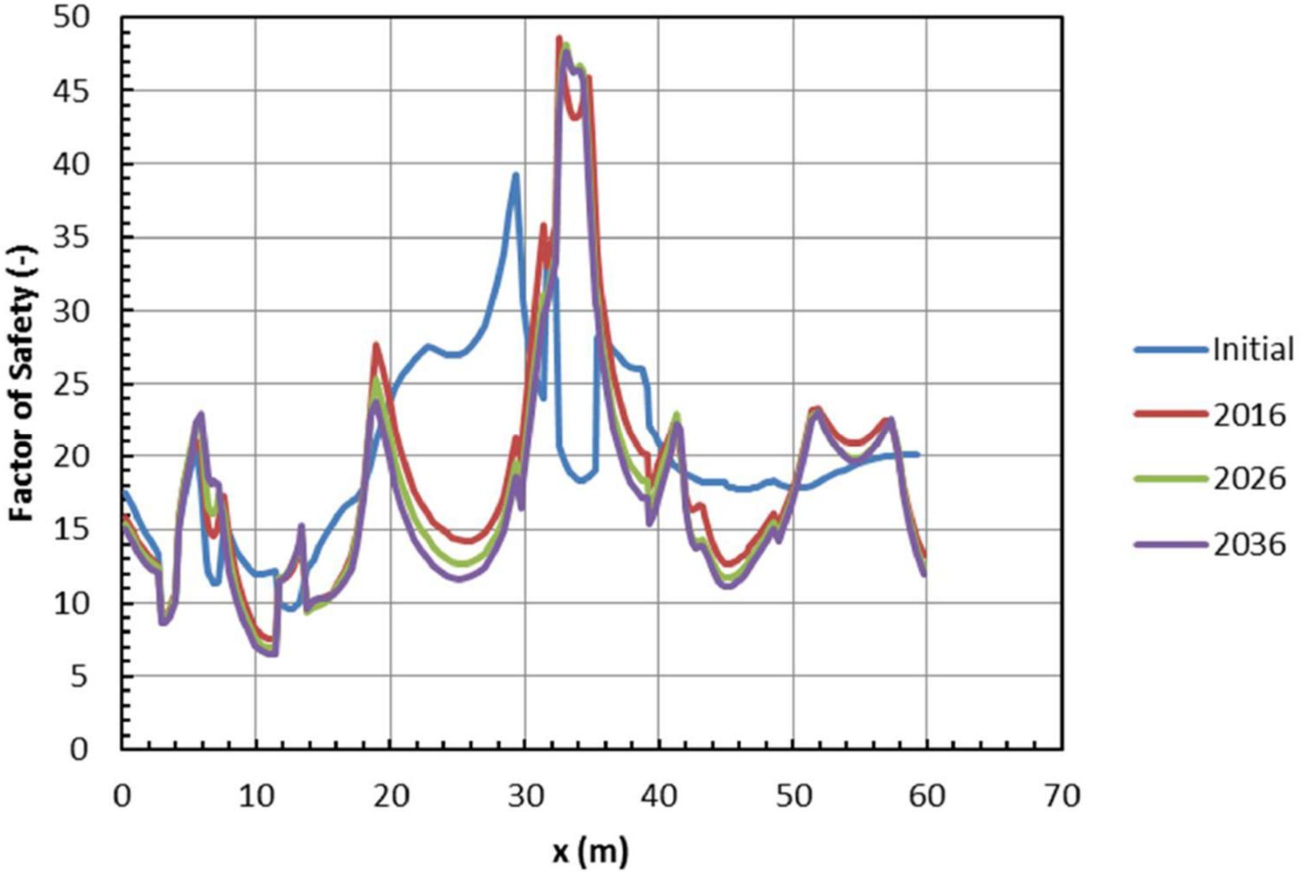
Results – Case 3



Increase approx. 10% / 10 years

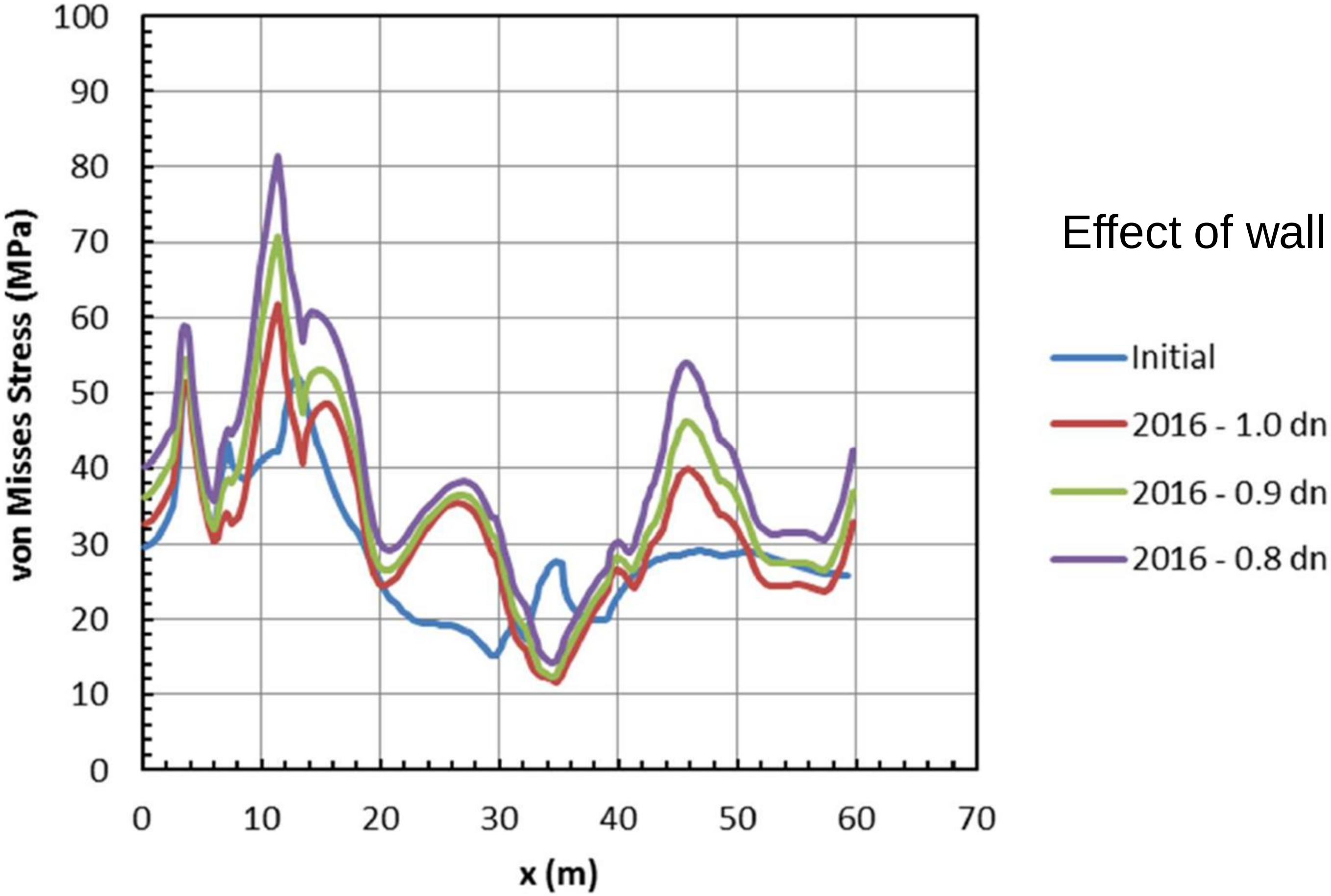
Deltares

Results – Case 3



Allowable stress = 517 MPa

Results – Case 3



Effect of wall thickness

Conclusions – Case 3

Stresses and safety of pipeline

- Sufficient factor of safety, now and in the future

Voids under the pipeline

- High probability of voids under the pipeline, developing further

Monitoring

- Less frequent monitoring is possible
- INSAR only (available for toe), using historical data from settlement plates
- Discontinue measurements with settlement plates

Deltares

Conclusions - method

New assessment method

- Works in pilot studies
- GeoDelft archive data usually not available / sufficient
- Fit of settlement calculations on measurements is OK
- Uncertainty (settlement, wall thickness / stiffness) in SF is less than 1.3%
- Loading history / cause of settlements is critical

Deltares

Conclusions - method

INSAR measurements vs. settlement plates

- Reliable measurements needed for crest and toe
- Settlement plates not reliable for settlements < 30 mm / 10 years
- INSAR measurements not available for locations with ‘soft’ surface
- If reliable INSAR measurements → use INSAR and historical measurements from settlement plates, discontinue settlement plates
- If no reliable INSAR measurements → maintain settlement plates

Future work

- Match presentation of results to information need of Evides Asset Managers
- Integrate the method in the Evides Asset Management process
- Apply the method to the other Evides pipelines in flood defences
- Include loading history in future analyses
- Develop criteria to assess reliability of settlement measurements
- Develop criteria for reducing monitoring frequency
- Develop procedure for checking data validity and consistency

Other

- Use WTI-SOS as subsoil model